UCF Senior Design 1 : Smart Mirror

Group 31

120 Page Final Submission

Group 31:

Tyler Newman	Computer Engineer
Jacob Williams-Moore	Computer Engineer
Axel Ortega	Computer Engineer
Jonathan Martin	Electrical Engineer

Contents

1. Executive Summary (Tyler)

In the modern world things that were previously “dumb”, or in other words not controlled by computers or connected to the internet, are becoming increasingly hard to find. Appliances that we interact with daily are slowly becoming more and more connected to the digital world. Things that were once simple analog devices such as a toaster now contain high-definition screens with touch functionality, custom user profiles with practically infinite options for how an individual likes their toast, and incredibly accurate temperature sensors.

Currently widely available and generally financially accessible to the general public are smart speakers, cameras, coffee makers, lights, security systems, alarm clocks, thermostats, air quality monitors, smoke detectors, and even fridges that can tell you when you are low on items. The list of smart home appliances could go on forever, however one item that people use daily that has not been widely brought to market is a mirror.

Current smart mirror options that are available for purchase can generally be placed into two categories. The first being cheap and simple without much real-world use, most in this category are simply mirrors that display the weather in the corner. The second category of options are at the multi thousand-dollar price point and contain great features, however given the cost it would not be worth it or cost feasible for an average person to own one.

The third option for a smart mirror is complete DIY. By purchasing all the parts and pieces and setting up a raspberry pi with a UI called Magic Mirror. The user can configure the Magic Mirror software to their liking. They can also make it to any size or shape they want. The issue with the DIY solution is that it isn’t accessible to most. In order for a person to DIY they need to be able to construct a frame and 2-way mirror, obtain a display, obtain a raspberry pi, load and configure the raspberry pi with all the required software/ OS, and then take care of any bugs or glitches that they may encounter. Many users don’t have the time or skill to do all of these things, leaving it as an option only for the biggest of tech and DIY enthusiasts.

Our team intends to fill the gap in between these two categories and create a smart mirror that provides an experience that aids the user in their daily routines and can be marketed at a mid-three figure price point. We are also hoping to be a superior option to DIY by providing a better and more in-depth user experience than can be reached with a simple garage job. Our Smart Mirror also aims to be a lot easier to setup and use than a DIY option, providing a bug free experience that just works.

The Smart Mirror will feature network connectivity and integration with many existing API’s that will make the users life easier. It will also be very power efficient, only using full power when the user is present. The team is hoping to deploy a range of custom and open-source solutions to give the user the best possible experience. We also intend to make the mirror as visually appealing as possible, so the user doesn’t have to sacrifice looks for functionality. Hopefully this project will serve as another steppingstone to bringing Smart Mirrors into mainstream use so they can become a standard part of the modern home.

2. Project Description

Contained in this section will be the team's motivation to pursue this specific project. It will also include the personal and team-wide goals hoped to be achieved by taking on this project. This section will also include the specific engineering specifications the team is targeting.

2.1 Project Motivation (Jacob)

Each invention related to "smart" technology usually brings some sort of convenience to the user. While brainstorming ideas within the group, one of our key motivations was developing a device that would provide convenience within the home. The idea of a "home" usually includes safety, comfort, and convenience. With smart technology, a home expands upon these principles while adding more amenities that are not necessarily required to have but are certainly useful. As smart technology progresses, the home seems to be a focal point to which devices are being used. Most consumers are familiar with some form of smart ecosystem. These smart ecosystems include Google Home, Amazon Alexa, Apple HomeKit, Samsung SmartThings, and more. With these ecosystems already in place, third parties are capable of developing compatible devices.

There are smart lightbulbs which can be turned on/off with voice commands and/or change colors, smart doorbells which allow the user to monitor their front door, and much more. Considering these smart devices are already in place and common within the home, we tried to focus on a device that isn't common but can still be useful when performing daily activities. Our idea is an attempt to bring together multiple smart features into one device. We considered a smart pet bowl which would be a great help for pet owners who either forget to refill or aren't home most of the day to do so. Based on a group vote, we ultimately decided to develop a smart mirror.

For our project a smart mirror provides the ability to start small and potentially expand with more intensive features. With smart devices, common features include voice recognition, touchscreen capabilities, and relevant information provided though APIs. Our smart mirror aims to integrate these features into a simple display for the user in the bathroom or any other location in the home a mirror would usually be. With the idea of most people encountering a mirror on a daily basis (usually at the start of the day in a bathroom), our intent is to develop a product that can fit to support daily activities within the home.

2.2 Project Goals (Jonathan)

Our main goal of this project is to improve on the concept of the smart mirror and at the same time Learn about different technologies to gain experience that can help us in our careers. To achieve this goal, we discussed the best way to build on the idea of the smart mirror. We talked about the main features we wanted the mirror to incorporate. Because of the potential and versatile nature of the mirror we are able to look up a wide range of technologies that were of interest to each individual of the team and see how we could apply it to the mirror. Being able to research and apply concepts that interest us allows everyone to enjoy the project and that is an important part of the project. Being able to research and find the best way to build the mirror by comparing and selecting components and building and testing circuits that will be used in the mirror is a good way to develop experience and engineering skills

Each member of the team will have their own goals the electrical engineer's goal is to power the device from the wall outlet and distribute the power to the different devices efficiently the Primary goal for the computer engineers is to integrate the most key features into the mirror

2.3 Related Work (Tyler)

The smart mirror is not a new concept. Many people have been DIY creating them since shortly after Alexa and other home automation controllers gained popularity. It has not gained much of a following from companies as a product, however some do exist. In this section will take a look at the DIY project platforms people use to create their own smart mirrors as well as the offerings companies have created to fill the consumer need for smart home electronics.

The DIY options are all fairly similar, most of them aim to provide similar functionality to an Alexa or Google Home with the added benefit of being able to serve content up visually not just with audio. The product options for smart mirrors differ greatly, some have been created with similar intentions to the DIY, others are made to be a TV for your bathroom, and there are also many options for smart mirrors centered around fitness.

2.3.1 Samsung ML55E

This smart mirror made by Samsung is marketed as a hybrid display mirror with digital signage functionality and retails for around 2,200 to 2,500 US dollars. The mirror comes in two different sizes, one is a 32 inch display and the other is a 55 inch display, both having a 1080p full HD panel. It has Wi-Fi and can be connected to a smart phone. The mirror uses a IR and proximity sensor to sense when a user approaches, when this happens the mirror will go from mirror mode to display mode, our group will most likely be deploying a similar sensor and strategy to give the user a better experience. The mirror also has an on-board speaker, which our group also intends to have. The mirror can also be used in a horizontal or vertical mode, giving the user options for how they want to place the mirror. Our group doesn't plan on having this feature but it is something to keep in mind. The mirror operates on a custom proprietary operating system based on VDLinux. This is area which our group believes can be improved on. The software features of this mirror are limited and could easily be expanded on, it mainly acts as a display/ mirror and doesn't have many uses as a "smart" home addition.

Figure 1 - Samsung ML55E Smart Mirror

2.3.2 Macvon Tough Fitness Mirror

This smart mirror is made by Macvon, an up and coming fitness tech company. They specialize in home gym equipment and workout classes. One of the products they offer is smart mirror focused around giving at home fitness classes to consumers which retails for around 750 US dollars. The smart mirror acts as a display for the classes and a mirror to watch yourself as you mimic the instructors movements. This smart mirror is not quiet what the group is going after in terms of end user base, but it has a lot of research and development put into it, something foreign in the current world of smart mirrors, making it a good product to look at as well as compare features with. The mirror uses a 43 inch touch screen display, something the group thought about implementing but chose to avoid due to the nature of getting finger prints on a mirror. It has Wi-fi and Bluetooth compatibility and can pair with certain smart Bluetooth fitness devices. Although our group is not targeting fitness connect ability to other smart devices is something the group hopes to achieve. The mirror also features 4 high quality 10-watt speakers, if the budget allows for it the group plans to also include high quality loud speakers on the smart mirror, as it will benefit the end user. The software on this smart mirror is all proprietary and not much information is given out on it. However our group is not planning to use the mirror for fitness, so not many software features on board this mirror are worth digging into.

Figure 2 - Macvon Tough Fitness Mirror

2.3.3 Integrity Savvy Electric Mirror

This smart mirror is made the company Integrity and claims to be the leader in smart mirror technology. The Savvy smart mirror comes in many sizes and prices, ranging from around 6,000 to 10,000 US dollars. All sizes are equipped with 21.5 inch 1080p touch screen display. The smart mirror also includes bright LED vanity lights going around the entire mirror, something our group plans to do with our Smart mirror as it is a feature many consumers enjoy and look for in a bathroom or bedroom mirror. This mirror also claims to be energy efficient, something users will want in a smart home appliance that will be plugged in constantly. Our group plans to include this as a feature as well. The Savvy smart mirror also includes 10-watt speakers like the other products in this section, many users will want to listen to music as they shower or get ready, making this feature a must. Along with the others on this list it has Wi-fi and Bluetooth compatibility, although the extent of this compatibility is not listed. The display on this mirror can serve up breaking news, play videos, display a calendar, and more. This is a more conventional smart mirror like our group will be developing and will be closely looked at to ensure our end users get the best.

Figure 3 - Integrity Savvy Electric Mirror

2.3.4 DIY Option 1: Magic Mirror

Magic mirror is not a built product but an open source software platform built for users to create their own smart mirrors from. It is primarily community driven with the overall platform being updated by and modules made by smart home enthusiasts via GitHub. It uses Node.js and CSS to serve up a tile based UI of modules to a connected display. It is by far the most supported and widely used smart mirror platform in existence and is the first thing the group found when starting to research smart mirror technology.

Due to its open source modular nature there is a module made for just about anything, and if something was not found in the pre-made list of thousands of modules the tools are there to create a new one. The possibilities of this platform are only limited to the amount of time the group would be able to spend developing software for it.

This platform was developed to run on a Raspberry Pi micro-computer as it is lightweight and simple. The group will most likely either use this as our user interface platform or create something similar too it, as it is about as good as it gets for smart mirror software.

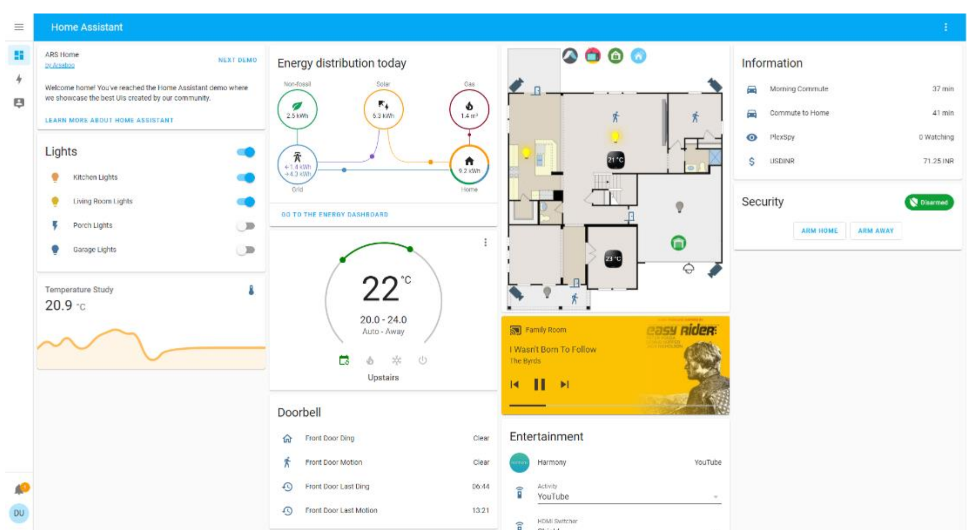
Figure 4 - Magic Mirror Example

2.3.5 DIY Option 2: Home Assistant

Home assistant is a lightweight piece of software made to be ran on a micro-computer. Its primary purpose is to provide easy centralized control of any smart home technology in existence. This would make hooking into all other smart home technology a breeze. Similar to Magic Mirror this software also has a tile based user interface called Lovelace, although not necessary to use the connectivity functions of the software, it could be used for our project.

It could also be used in conjunction with our own software and user interface to control smart home technology. Like the Magic Mirror project Home Assistant is also completely open source and community driven. Similarly it can be modified and added on too easily by any developer who wants to. Another benefit to Home Assistant is its vast API, almost everything developed on this platform is made to be interacted with using API calls, further making the software easier to use and interact with.

Figure 5 - Home Assistant Example



2.4 Engineering Specifications (Tyler, Axel)

This section shall lay out the requirements and intended functions of the project. These specifications should be met by the end of the course. The overall general specifications are broken down in the table below. Following this table is a more specific table detailing individual component specifications, all of these subsystems will be tested in future sections of the document. The engineering specifications that will be tested and showcased in senior design 2 will be identified using red text and summarized at the end of this section. Some of the things being demonstrated cover multiple specs or requirements so more than 3 things were highlighted. What will be demonstrated is summarized at the end of this section.

Table 1 - Overall Engineering Specifications

General Specifications	
Display Dimensions	18x24 inches
Mirror Total Weight	Less than 25 pounds
Mirror Power Input	AC 120V 60Hz
Mirror User Input	Speech recognition
Mirror User Detection	Facial Recognition and Proximity Sensing
Mirror Functionalities	The mirror will display the following: - Time - Date - Weather - Temperature - Breaking News - Social Media Feed - YouTube Videos

This next table details the specific specifications all the components must meet. The goal of setting these specifications early on is to ensure conformity across the entire project. Because this project will be developed in subsystems and only tested together towards the end of development the specifications are important to have one-hundred percent certainty that each subsystem can be connected together.

Table 2 - Subsystem Engineering Specifications

Microcomputer Requirements	
Connect Ability	Wi-Fi and Bluetooth
Voltage Requirement	Less than 5 VDC
Serial Standards	UART and I2C
Microcontroller Requirements	
Serial Standards	UART and I2C
Digital I/O Pin Requirement	At least 5 pins
Voltage Requirement	Less than 5 VDC
Power Requirements	
Input Cord	Single US Standard 3 prong power cord
Step Down Voltage	12VDC
Power Rails	The power system will provide a - 5VDC rail for the microcomputer, microcontroller, and sensors - 3.3VDC rail for the logic level converter between the microcomputer and microcontroller. - 12VDC rail for the LED vanity lighting
Efficiency	At least 60% efficient
Camera Requirements	
Resolution	1080p HD
Lighting Requirements	
Brightness Requirement	Light the users face from 2 feet away
Voltage Requirement	Less than 12VDC
Speaker Requirements	
Volume Requirement	The speaker will provide a minimum 100% volume output of 65dB from 2 feet away
Display Requirements	
Display Resolution	Greater than 720p HD
Motion Detection Requirements	
Detection Range	At least 5 feet away
Voltage Requirement	Maximum of 5 VDC
Microphone Requirements	
Pickup Distance	Pick up the users voice input from 2 feet away

During presentation in senior design 2 the group will demonstrate the following 3 features:

Facial Recognition – The mirror *should* be able to recognize the user's face from at least 2 feet away. This will be demonstrated by allowing the smart mirror to identify a group member during the presentation

Speech Control – The mirror *should* respond to the user's voice from at least 2 feet away. The smart mirrors primary source of input is voice. Therefor it is an important function to showcase. This feature will be demonstrated by showing that the mirror recognizes the users voice and performs commands as intended based on what the user says.

Presence detection – The mirror *should* be aware of the user's presence and respond to it. This will be showcased by vanity LED's on the front of the mirror that will power on once the user has been detected.

2.5 Project Block Diagram (Axel, Tyler)

The Block diagram below visualizes how administrative labor has been divided between the members of this group. Jonathan, the electrical engineer of the group will be in charge of ensuring a proper power distribution system between all of the components in the system is created. This task involves designing a custom PCB which will be purchased. The remaining computer engineers will divide the software and hardware integration between themselves.

Tyler will be tasked with overseeing the coding on a microcontroller, designing the micro-controller PCB, and making sure it will be able to properly communicate with the main microcomputer. This involves testing hardware using breadboards.

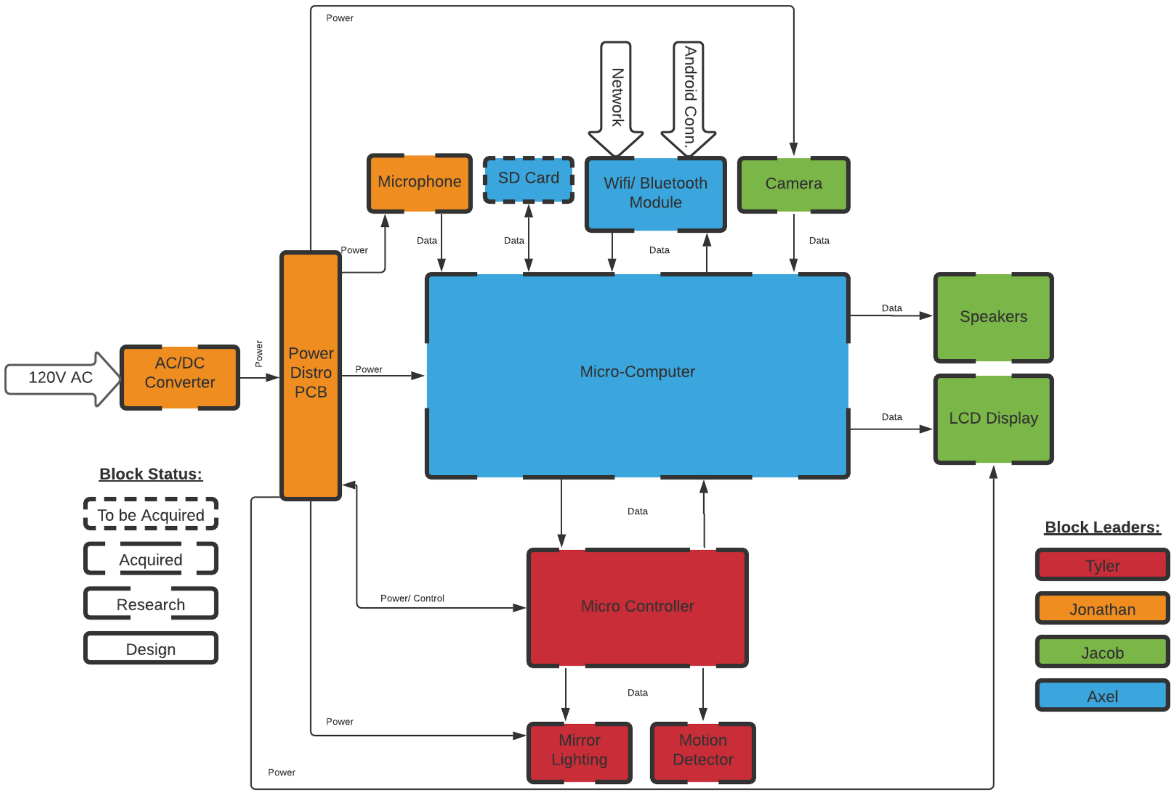
Axel will be involved in developing software to run the magic mirror interface on the microcomputer. This involves setting up necessary API's and testing wireless communication.

Jacob will be involved with overseeing the configuration necessary for hardware such as the display that will be used in this prototype as well as the cameras and speakers.

The block diagram was designed in a way where each person's block contains like elements. Each person will end up working on other group members blocks, the goal of the block diagram was not to divide labor, but to divide administrative responsibility over each section, this way administrative duties are distributed somewhat evenly, and each element of the project has a group member over it to ensure things proceed in a timely manner.

The group members assignments also carry over into the document, for example Tyler is responsible for hardware selection of the micro-controller, Axel the selection of the micro-computer, Jonathan the selection of the AC/DC conversion technology, and Jacob, the selection of the LCD display. With this each group member gets to make decisions all their own on what will be used in the project.

Figure 6 - Project Block Diagram



2.6 House of Quality Analysis (Tyler)

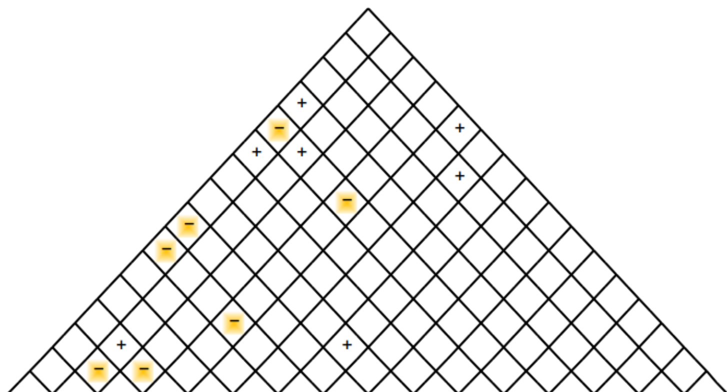
Figure 7 - House Of Quality Analysis

QFD: House of Quality
Project: SD Smart Mirror Group 31
Revision: 2.0
Date: 10/15/21

Correlations	
Positive	+
Negative	−
No Correlation	

Relationships	
Strong	●
Moderate	○
Weak	▽

Direction of Improvement	
Maximize	▲
Target	◇
Minimize	▼



Category	Weight	Column #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
		Direction of Improvement	▼	◇	▼	▼	▲	▲	▲	▲	▲	◇	◇	▲	▲	▲	▲	▲
		Customer Requirements (Explicit and Implicit) / Engineering Requirements	Power Consumption	Dimensions	Weight	Cost To Build	Wireless Connectivity Range	Camera Resolution	Vanity Light Lumens	Audio Output	Vanity Light Distance	Vanity Lighting Voltage	Display Voltage	Display Resolution	Motion Detector Range	Speech Recognition Distance	Facial Recognition Distance	Bluetooth Connectivity Range
Function	8	Phone Compatibility					○											●
Function	8	Ease of Use		▽	●		○	○	○		○			○		●	○	○
Function	5	Functions as a Bathroom Speaker	▽		○	○	▽			●								●
Function	10	Makes A Good Mirror		●					●		●							
Economic	5	Low Use Cost	●			▽			▽						●			
Economic	10	Low Entry Cost	○	○		●		▽	▽	▽		▽	▽	●	○			
Design	6	Looks Stylish		▽		○			○									
Design	8	Display Easy To See	▽	●		○								●				
Design	3	Durability		▽	○	○												
Software	10	Shows Time/ Date		○										○				
Software	8	Shows Weather/ Temperature		○										○				
Software	5	Shows Breaking News		○		○								○				
Software	7	Modern UI		○										○				
Software	3	Smart Home Integration		○										○		○		

The group's goal with this project is to build an affordable but feature packed smart mirror that is easy to use and stylish enough to fit in the modern home. As seen in the figure above our primary concerns were with the functionality of the mirror. For the mirror to be widely used it needs to provided good functionality to the user as a smart device as well as a mirror, without these two things the user will not have many reasons for having one.

Also included in functionality is the software features. These will define almost all of the user experience as it will be what the user is interacting with on a daily basis. The group intends to visually serve up all the primary information a user could want to easily access during something such as their morning routine. These items are things such as time and date, weather information, breaking news, etc.

The next area of importance is the economic impact. Many smart mirrors are available on the market currently but the cost of them prices out many users as the price to performance is just not there for average consumers. In order for the groups project to succeed in the ways intended the mirror must have a reasonable entry cost to make it attainable to average consumers, as well as have a low use cost.

The use cost can be represented by its energy efficiency. In today's world energy efficiency is important, and so is energy cost. If the mirror can be plugged in 24/7 365 days a year while having a low impact on the user's electric bill and providing a great feature filled experience the group will have succeeded in its primary goal.

The final area of importance is the design part. The smart mirror needs to fit into the modern home. This means that the design is also important. It needs to be durable and able to be mounted to a wall. It also needs to be stylish. A mirror is like a piece of art in many homes, so the smart mirror needs to be able to fit nicely into most of user's bedrooms or bathrooms.

3. Research

Before starting a project such as this one, it is important to understand how the technology involved in such a product works. For us its important to understand what kind of processes would be involved in a smart mirror. This includes an understanding on things such as facial recognition, or API connections, which will give the smart mirror its internet functionality. In addition to software, hardware is an important part of this project being successful. It is necessary to gather information on what kind of hardware must be used in order to accomplish this project, as well as the power requirements of each component. This will be useful for designing the power distribution boards that will be able to supply the power needs of each component.

3.1 Technology Comparison

This section will be used to compare/discuss the different technology options available for use in this project.

3.1.1 Serial Communication (Tyler, Axel)

For this project there will be a minimum of two different embedded devices and many different PCB's that all must communicate and share data with one another. To accomplish this, we will need a solid form of serial communication so all the different elements of the project work together as one. There are three main forms of serial communication used in embedded devices.

Logic Level Communication:

The first being simple logic level communication. Ones and Zeros, this method is the most simple and limited form of control, but also very easy to pull off. By simply sending bits on and off across devices simple actions can be accomplished. The issues of this form of communication are limited to two primary problems. The first being its simplicity, it cannot be used to communicate anything other than on/off or a change of state. The information being transferred across devices must be binary. The other issue with this is that different devices have different defined logic levels. Meaning some of our devices that we need to communicate may not easily be able to on a logic level, as they won't understand each other's ones and zeros.

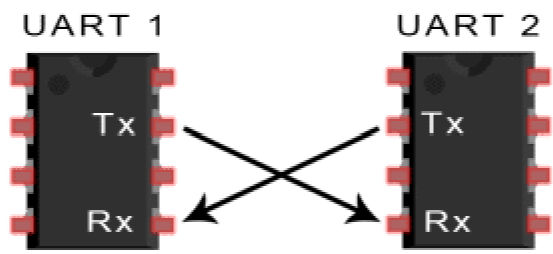
This technology will definitely be implemented on a device-by-device basis, as it is perfect for simple communication from sensors to MCU's. However, the use case of this technology for device-to-device communication is non-existent when other technologies can do the same job better. Not to mention the other more advanced forms of serial communication can transmit complex data too, something logic level cannot perform at all.

Universal Asynchronous Receiver-Transmitter (UART):

The second choice is probably one of the most widely supported and used forms of serial communication. UART serial communication relies on two signals connected together from each device, a transmission line, and a receiving line. The only thing required of the two devices is to have UART support, and a baud rate agreed upon for both UART modules used. This form of communication can be used for just about anything as long as it is strictly one device to one device communication. For multiple device communication a more complicated communication system is needed.

UART works by converting parallel data from a device, such as a CPU, into a serial form. That data is then transmitted to the receiving device. Once the serial data has been received, the device must then convert that information back into parallel data. Data flows through two wires in UART. TX, the transmission line, and RX, the receiving line.

Figure 8 - UART transmission pins



UART does not require a clock signal when transmitting data. This means data is sent asynchronously. Normally this is dangerous, because if two devices are not operating with the same clock frequency, data may not be sent or received properly. Fortunately, when sending data, UART transmits what are called start and stop bits. As those names suggest, these particular bits signify when the receiving device needs to begin reading the bits and when to stop reading them. This makes it so that a clock synchronization is unnecessary.

UART transmits data at a specific frequency. This frequency is commonly referred to as baud rate. Baud rate is essentially just how many bits are transferred per second. Both devices involved in the data exchange must be operating at the same baud rate. If not, the timing of bit reading may not allow for accurate data transfer. A standard baud rate used for most devices is 9600 baud. In most cases, UART can support baud rates of up to 115200.

Data transmission is done through packets. A typical data packet is divided into chunks. These chunks include: Start bit, data bits, parity bits, and stop bits. Data bits are bits that contain the message being transmitted. A parity bit is optional. Parity bits are used for error checking. If a parity bit is set to 0, that means that the total number of bits in the transmission should add up to an even number. If the parity bit is set to 1, this means the total should be odd. This allows the UART on the receiving device to verify whether or not the transmission had errors or not. Assuming the transmission was error free, the UART will discard the start, parity, and stop bits from the data packet, and wait for another packet to be received. A downside of using this technology is that the size of the data packets are not very large. However, in this project, UART would mainly be involved in sending small amounts of data between two devices anyway, making this issue mostly irrelevant.

Figure 9 - A typical UART data packet

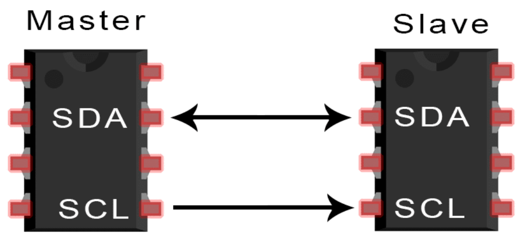
This technology is perfect for what we are trying to accomplish as both the chosen microcontroller and the chosen microcomputer both support UART communication.

Inter-Integrated Circuit Communication (I2C):

This form of communication is similar in capability to UART only more versatile. The I2C communication standard is capable of sending data from a single master device to several different slave devices all at the same time. The communication protocol works off two signal wires, one of which is a clock signal line from the master. This means that this standard is synchronous across the master and all slaves.

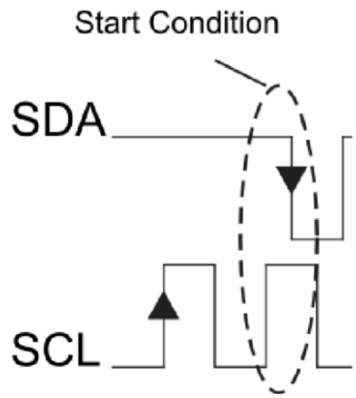
Similarly to UART, this method of communication only uses 2 wires. Serial Data(SDA) is the line where the data itself is transmitted. Serial Clock(SDL) is the line that carries the clock signal between the master and slave devices to ensure proper synchronization. The clock rate is set by the master. The master device is in charge of all communication that occurs in the I2C network. I2C scalable up to 112 total devices. In this communication protocol, devices are categorized by Slave or Master. There is only one Master in the system. Each slave device has its own unique address that the master is able to send messages to directly. The master can send messages to individual slave devices, or to the entire system. Slave devices are not able to start communication on their own without permission of the master. Slave devices generally only receive data and execute requests given to them by the master device.

Figure 10 - Communication lines between master and slave devices



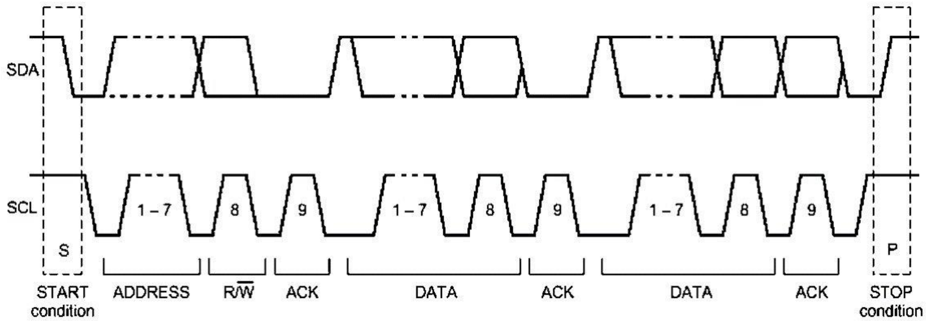
Similarly to UART, the master sends messages in packets of data, in this case they are called frames. The data frames in I2C are more complicated than in UART mainly due to the fact that a clock cycle is involved in the transfer process. A typical frame is divided into the following sections: Start condition, Stop condition, Address Frame, Read/Write bit, and an ACK/NACK bit. When the master device begins a transmission to a slave device, it must first transmit what is called a starting condition using both the SDA and SCL lines. This condition is signified by holding the SDA line to a negative voltage while the SCL line is at a positive voltage. It is important that the SDA line must switch before the SCL line switches its polarity. At this point, the slave device(s) know a message is incoming.

Figure 11 - Start condition of the I2C protocol



The address frame is a bit sequence that defines each device. The master will refer to this sequence when it intends to communicate with any particular slave device. This frame ranges from 7 to 10 bits in length. The read/write bit signifies whether or not the master wishes to send data, or receive data from the specified slave device(s). When data frames are sent between devices, they are followed by an acknowledge or no acknowledge bit. Before another message can be sent between two devices, an ACK/NACK bit must be sent in order to tell the sender whether or not the data has been received or not. A proper acknowledgement is done by pulling the SDA line to a low voltage. In the event that a data frame is not received, it is up to the master device to decide how to proceed. Assuming an ACK has been sent, this tells the master that the slave is ready for another data transmission. This process of sending data bits, and receiving acknowledgement bits may occur as long as it needs to for the entirety of the data to be transmitted between devices. When the sender is completed sending data, a stop condition must occur to inform the recipient that the transfer is going to terminate. This stop condition is the opposite process of the start condition. The SDA must be pull to a positive voltage while the SCL line is at a positive voltage. A visualization of an I2C transmission is shown below. Note the ACK bits that are sent in between the data frames.

Figure 12 - I2C Transmission



For our project this communication standard would work, as both the microcontroller and microcomputer support I2C serial communication. However, this method seems to be a slight overkill for this project. The main benefits to using I2C are its clock synchronization and its ability to send data from one device to multiple simultaneously. The first of which is only a real issue when communicating with devices with inaccurate clocks that can't hold a consistent baud rate, and the second is only a benefit when needed, which in the case of this project the only communication required is from a single device to another single device.

Given the above information logic level communication will be used in the project for any and all communication between simple sensors such as motion detection. Then given that this magic mirror project does not require transmission from one device to many, and both devices in use have accurate enough clocks to synchronize baud rates, UART communication will be used for all other applications where logic level would fail. In the event that I2C became necessary both microcontroller and microcomputer can be setup to accommodate the standard.

Table 3 - Serial Communication Comparison

	Logic Level	UART	I2C
Synchronization	N/A	Asynchronous	Synchronous
Wires Used	1	2	2
Connection Capability	2 Devices	2 Devices	112 Devices
Addressable	No	No	Yes
Data Bits Transferred	1 Bit	5 to 9 Bits	8 Bits
Total Bits In Packet	1 Bit	7 to 13 Bits	15 Bits

3.1.2 Power Distribution (Jonathan)

The mirror will be plugged into a common 120 wall outlet so it will need Ac to DC converter power supply from there the power will be stepped down and will go through power distribution circuit that will split the voltage into different rails to power the devices inside the mirror

Table 4 - Power Distribution Table

Device	Voltage (volts)	Current Amps	Power Max Watts
Raspberry Pi 4 Model B	5	3	15
ATMega328P	2.7 to 5.5	2mA	0.011
Monitor	12	2.5-3A	36
Led Lights	12	3	36
Total Power			87.011

The chart above is of the main components power consumption for the mirror. Totaling 87 WATTS. The power distribution circuit will have three rails at voltages of 3 volts, 12 volts, and 5 volts.

3.1.3 Wireless Communication(Axel)

Mirrors are not known for having buttons. That's why for this project we opted to make user interaction with the mirror wireless. The mirror will be equipped with several features such as voice recognition and facial recognition. The voice recognition will primarily be used for when the user wants the mirror to display certain media or information. For example, the user can say "Show me the weather forecast", and the mirror will focus on just the weather and nothing else. This could also be used to display just the time, or even a social media feed. Voice commands could also be used to adjust certain physical aspects of the mirror such as the current ambient lighting. Face recognition will be used to personalize certain aspects of the mirror. For example, what if a particular user is only interested in the weather in Seattle? The mirror given the voice prompt "Detect my face", will check to see which user is standing in front of the mirror. Once the analysis is successful, the mirror will adjust the information displayed depending on the preferences of the current user.

3.1.4 Facial Recognition(Axel)

Most humans are instantly able to recognize a face. This process happens in less than a second for humans. We have evolved to see faces and interpret faces and different facial expressions, even where there are none. Think of a cloud that looks like a face, or a rock that sort of looks like a human face. In fact, our human brains may be too good at detecting faces. Computers do not have millions of years of evolution to help them recognize faces, they must be taught in a very particular manner.

The facial recognition process typically starts with identifying "landmark" features of a particular face. These landmarks are used to distinguish one face from another. These features tend to be the eyes, eyebrows, and chin. This typically means that so long as a camera is able to clearly stream these features to the computer, the software should be able to identify what face its looking at regardless of lighting. This process starts by giving the computer a baseline image to work with. There are different algorithms that are used to parse through a sample image for data extraction. A popular algorithm is called "Histogram of Oriented Gradients", or HOG. Introduced as far back as 1986, the HOG algorithm starts with a baseline image in grayscale. The algorithm creates a grid of pixels in the image itself, often times each square in the grid is a size of 8x16 pixels, but this can vary depending on the resolution and size of the image. The center pixel in each point on the grid is compared to its neighboring pixels to calculate an overall gradient magnitude and direction. After applying this process to the training image, the computer now has a record of what patterns to look for when looking for a particular face. When the computer is introduced to a new face all it needs to do now is to apply the same exact process to this new face. If the new face contains the same gradient values as the training images, then the computer is able to determine the new face is a match.

Figure 13 - Example of a grid of gradients in the HOG algorithm

3.1.5 Speech Recognition (Axel)

Speech recognition has become an ever popular and expected feature of most smart devices. Users like the ability to control their devices easily and conveniently, with minimal effort. Being able to speak to a device in order to control it is not only a popular feature for the average consume. But it also increases the accessibility of the device. Speech commands allow disabled users a reasonable way to interface with a device.

It is important to highlight the difference between speech recognition and voice recognition before proceeding further. Voice recognition is the ability to recognize the voice of a particular speaker. Speech recognition is much simpler than that. Speech recognition is merely the ability to recognize the words being said by the speaker, not the inflection and cadence of one's speech.

For humans, detecting and understanding speech is a nearly instant and effortless process. The same cannot be said for computers. Computers must be taught how to not only recognize human speech, but interpret the words being said. The English language contains many homophones. Homophones are words that sound exactly the same, but are spelled differently. For example, the words “read and “red.” The way humans are able to understand the difference in everyday conversation is by recognizing the context in which a particular word is being used in. When a transcribes a sentence like “I love the color red,” they don’t transcribe it as “I love the color read,” because they are aware of the context. The same goes for words that have multiple ways of pronunciation. The key here is context. A good speech recognition software takes context of the sentence into account. This level of prowess and knowledge required to achieve this is above the ability of an undergraduate student. However, there exist tools freely available to programmers that can be used in order to develop software with decent speech recognition. A popular tool is the google speech recognition API.

Figure 14 - Speech Recognition will be powered by Google Cloud

Google Cloud

The Google Cloud platform is a service that allows private individuals and companies to use the same processing infrastructure that Google uses for its own products. This service allows users access to many google API’s. This is a paid service, however, google does offer free API’s for users to work with. One of them is the Google Speech API. This API allows users to send their own data to Google, which will then process their sound data and returns an approximation of what spoken in the audio file in the form of text. This text can then be used by our software for speech commands, provided that the returned speech is accurate.

3.1.5.1 Smart Assistant integration (Axel)

Smart Assistants are becoming increasingly common. Major tech companies are each in their own race to achieve what they believe to be the best assistant. Google has Google Assistant, Amazon has Alex, Apple has Siri, and Microsoft has Cortana. Smart assistant software aims to make life easier for users by making daily tasks simpler. A smart assistant works by responding to a particular "Wake Words”, such as “Okay Google”, or “Alexa.” At this point the smart assistant is activated and is waiting for a user to issue a command or ask a question. A user could ask something such as “How long will it take to get to work today?” The assistant will respond with an approximation of todays commute time. Implementing a voice assistant is more attractive than creating voice detection software from scratch. Software development kits (SDKs) for many of these assistants is made available online by these respective companies. It makes more sense to use the reliability of the speech recognition of these sophisticated technologies. The downside from this is that in order for these assistants to be able to respond to wake words at any moment, they must constantly listen to the environment. This may make some users uncomfortable. What happens to the information sent to these companies is out of the control of us, the designers of the smart mirror, and the user. Which means the user must decide for themselves if this product is worth the risk to their privacy. This is decision average consumers are used to making on a daily basis. Society as a whole, by adoption of this technology has generally decided it is willing to trust their personal information with these companies.

Figure 15 - Google Assistant Logo

Google Assistant

Google Assistant is Google's approach on smart assistance released in 2016. It was initially created to rival Apples own Siri technology. However, at this point, Google Assistant has expanded beyond mobile technology and into the realm of smart home devices. Google Assistant excels at allowing the user to make simple requests. It is quickly able to return information regarding weather, traffic, and even daily events marked on a user's google calendar. The google platform is widely used by many consumers worldwide. Implementation of Google Assistant would in turn connect the mirror itself to many of Google's services. Services such as Maps, Calendar, Hangouts, etc. The user would be able to ask account specific questions and get responses. For example, if the user wants to know the distance to a particular location. If the user has a "Home" set in google maps, the user can simply say something along the lines of "How far is X from Home?" Google Assistant will be able to give a precise answer by looking into the user's google maps account. This is one of the advantages of using Google Assistant. Google Assistant is also capable of voice recognition. This would allow for even more personalization and security.

Figure 16 - Amazon Alexa Logo

Amazon Alexa

Alexa is a titan in the world of smart home technology. Making its first debut in 2014 as part of Amazon Echo. Alexa has had a head start in the business. Alexa is an extremely popular Assistant in part to its ease of use. The name Alexa has become almost synonymous with Amazon's technology to the point where merely saying "Alexa" results in the collective unconscious immediately thinking of this technology. It is a testament to how widespread this product is. Alexa tends to give better results when asking trivia or for basic information on a wide variety of topics. A major advantage Alexa has over Google Assistant is integration with Amazon shopping. If a user is interested in buying a certain product for their household. Instead of searching online, the user can simply ask Alexa to buy the product for them. Alexa will automatically search through the Amazon marketplace, and if the user has an already set up payment method in their account, Alexa will go ahead and buy the product for the user. This is a frictionless process on Alexa. Although this is a convenient feature, the vision for this project is not to create a product through which users will buy goods. Alexa also has integration with other services provided by Amazon such as Amazon Prime Music. Alexa also has access to other, far more popular music streaming services such as Spotify, Pandora, and SiriusXM. It should be noted that Google Assistant also has access to these services as well, in addition to their own: Google Play Music. Alexa does not have any meaningful advantages over Google Assistant in terms of music streaming.

The goal of this project is to create a device that will deliver to the user all the information they need as they begin their day. Every person looks into a mirror in the morning. Generally, users would benefit more from a mirror that is capable of providing more personalized results, than a mirror capable of ordering things from the internet. That's why Google Assistant is the better choice for this product.

Table 5 - Comparison of both Google Assistant and Amazon Alexa

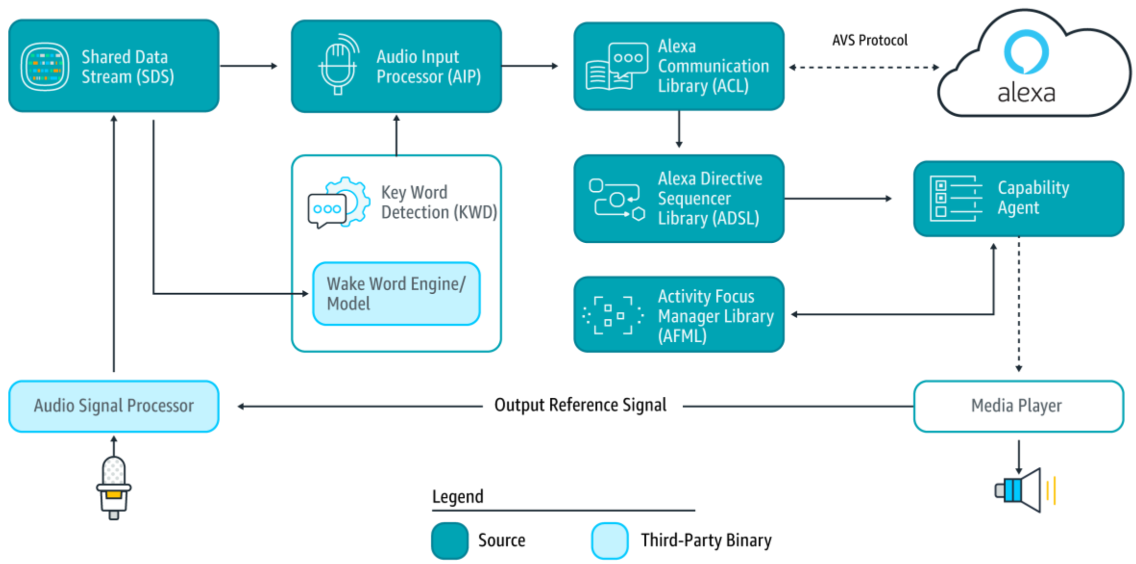
Assistant	Google Assistant	Amazon Alexa
Voice Recognition	Yes	No
Google Services Integration	Yes	No
Amazon Services Integration	No	Yes

3.1.6 Smart Home API Integration (Jacob)

There's a good chance that a consumer would already have some sort of smart device within the home. Common devices include smart light bulbs, smart appliances, or smart TVs. Each of these devices are usually compatible with some smart home environment such as Amazon Alexa or Google Home. Since our smart mirror aims to have a microphone and speaker for voice recognition, it's a good idea for our smart mirror to have the ability to control other devices within the home.

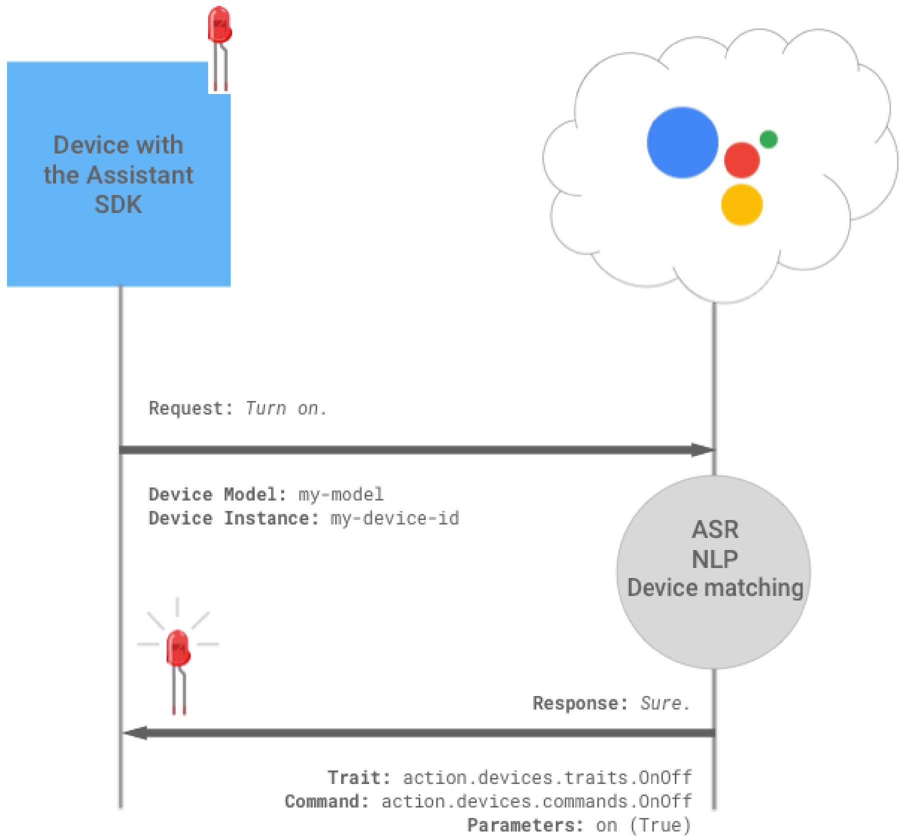
Two of the most popular smart home environments – Amazon Alexa and Google Home, both have voice assistants to aid with voice commands and control over other devices. Usually, one would have an Amazon Echo or Google Nest device placed in a convenient spot within the home to control each respective environment with voice commands. Thankfully, for our smart mirror both Amazon and Google have a software development toolkit (SDK) for their smart assistants. This would allow the integration of voice assistants in the mirror to which we could potentially control other smart devices within the home.

Figure 17 – An interactive model that gives an overview of the Alexa Voice Service (AVS) Device SDK



Either of the software development kits, Google Assistant Software Development Kit and Amazon Voice Service Device Development Kit, allow for their popular and powerful voice assistants to be used for development. As mentioned previously, a voice assistant can be integrated into devices to enhance its capabilities. Voice assistants would help take care of voice recognition and allow for common uses that any frequent user of smart technology may be familiar with. The way these voice assistants work is by user audio inputs being processed to trigger connections to their respective APIs for the command to be both interpreted and executed. Figure 17 gives a great overview of how this process works for the Alexa Voice Service Device software development kit. A brief outline of a device using Google's smart assistant can be found in the figure below.

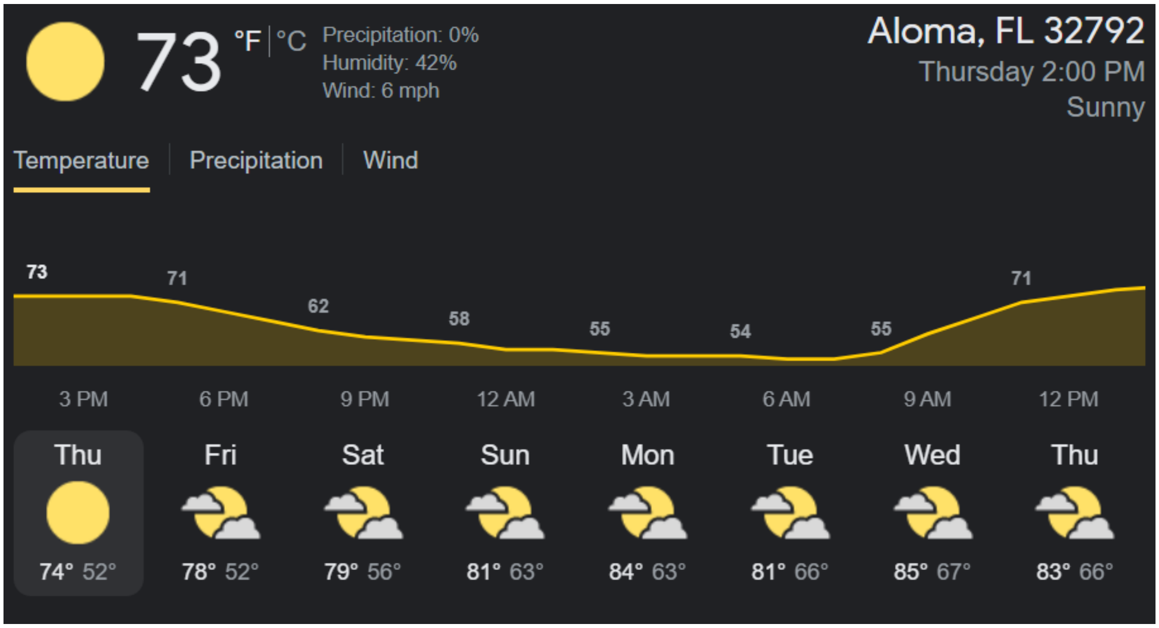
Figure 18 - A brief example of the Google Smart Assistant working with a device. Automatic speech recognition and natural language processing are used to understand the user's request - "Turn on." This ultimately works to turn on the desired LED on the device.



3.1.7 Weather Data (Jacob)

With the idea of the smart mirror being used on a daily basis, weather information is a key feature to include in its display. Local weather information can be obtained from many sources including news channels on cable TV, the radio, the internet, and even smartphones. An average person may check the weather just for the temperature or chance of rain but there's much more than that to be displayed. Weather data can also include humidity percentages, wind speeds, dew point, air pressure, UV index, visibility, sunset/sunrise times, and which phase the moon is currently in. Some of this information is not only available for the current day, but usually over a span of a week or more.

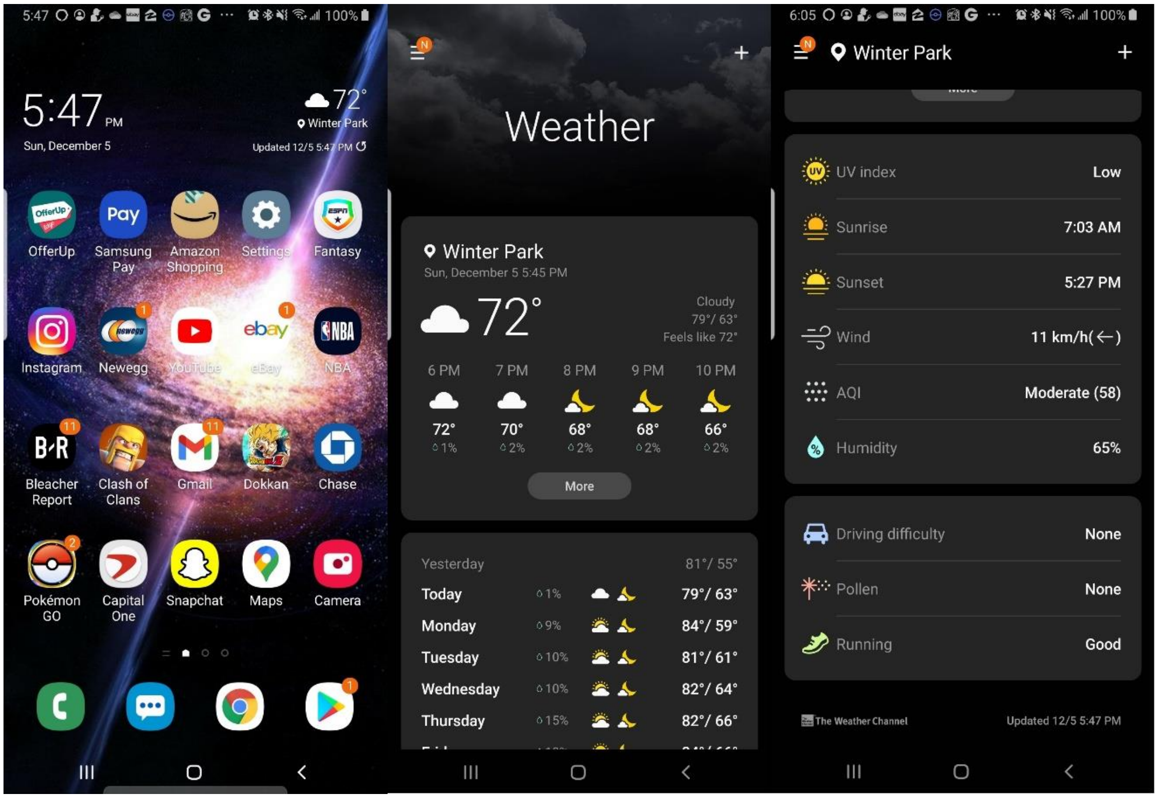
Figure 19 - A quick Google search of local weather. This weather information comes from Weather.com



Smart devices or appliances usually use some form of website or API to retrieve weather data. For instance, when simply searching for "weather" on Google, a summary of the weather is displayed on the screen. This isn't necessarily Google's own collected data being viewed, it is actually weather data pulled and displayed from Weather.com. This is the same for mobile devices as well. Widgets that display weather on your home screen or anywhere they've been placed has data pulled from popular weather websites. From a user interface standpoint, there may be similarities from a basic smart phone's display and our smart mirror. The idea would be to somewhat mimic this design of widgets to display the weather data. A good way of doing this would be using the modularity of Magic Mirror's user interface which will be discussed later.

Figure 20 - An example of how weather widgets are displayed on an Android smartphone device. This specific widget pulls its data from Weather.com as well. Along with other apps, the weather widget can be placed on the screen in different sizes. The example here shows a 5 x 1 size that displays both the time and current temperature in the current location. Tapping on the widget opens up a screen with more detailed information including the chance of precipitation, an hourly forecast, the high/low temperature for the day, a weekly forecast, UV

index, sunrise time, sunset time, wind speed, air quality index (AQI), humidity, driving difficulty level, and running level.



Directly Using an API

The OpenWeatherMap app has a simple API which allows for weather data for any city, geographic location, or zip code to be retrieved. After creating a free account, an API key is generated to access the API. A simple HTTP request can be made but alternatively, PyOWM is a great choice as a python wrapper library to access the OpenWeatherMap API. The following figure shows a small snippet of code to access the OpenWeatherMap API.

Figure 21 - Using the API key from the OpenWeatherMap, an HTTP request is made to find weather information of Orlando.

```
[ ]  import requests

     apiKey = "a9a6561219b1335464ff5956d6bbb90c"
     url = "http://api.openweathermap.org/data/2.5/weather?q=Orlando&appid=" + apiKey
     data = requests.get(url).json()

     data
```

In Figure 18 right above, we were able to find the weather information of Orlando using the OpenWeatherMap. The weather data retrieved was converted to a JSON format and output to the screen as shown in Figure 20 below. The retrieved data provides detailed weather information to which we can select what information we want displayed on the smart mirror's screen. This example shows retrieving weather information of a city but weather information in a specific geographical location (in latitude longitude format) or zip code can also be obtained.

Figure 22 - API Response Example

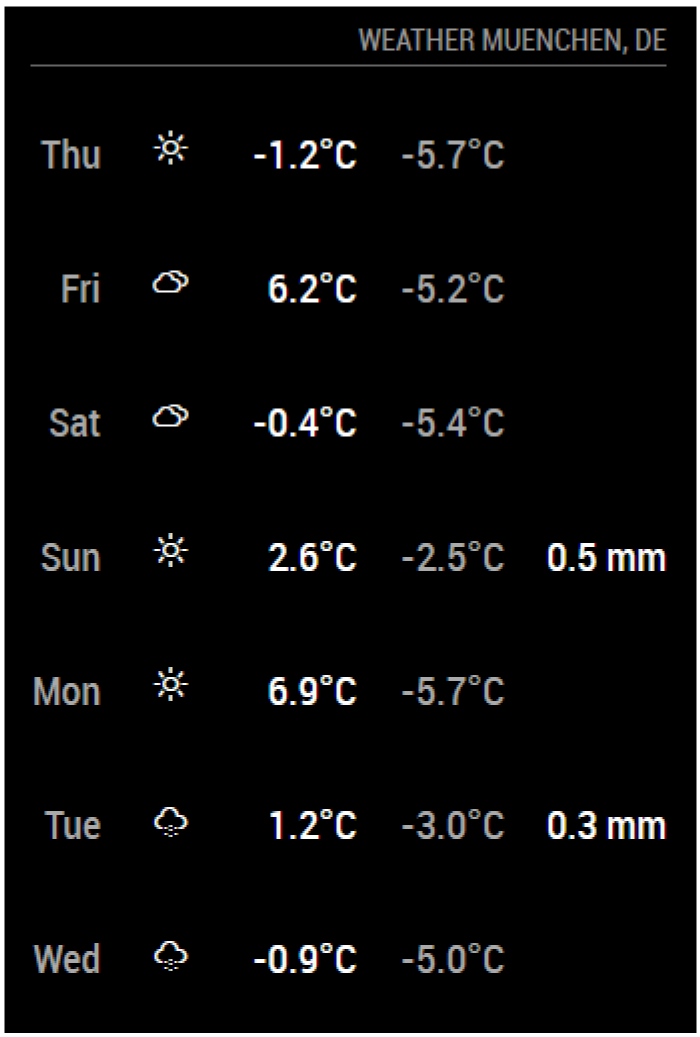

```
{'base': 'stations',
 'clouds': {'all': 1},
 'cod': 200,
 'coord': {'lat': 28.5383, 'lon': -81.3792},
 'dt': 1634656952,
 'id': 4167147,
 'main': {'feels_like': 299.48,
  'humidity': 54,
  'pressure': 1021,
  'temp': 299.48,
  'temp_max': 301.03,
  'temp_min': 297.66},
 'name': 'Orlando',
 'sys': {'country': 'US',
  'id': 5234,
  'sunrise': 1634642922,
  'sunset': 1634683909,
  'type': 1},
 'timezone': -14400,
 'visibility': 10000,
 'weather': [{'description': 'clear sky',
   'icon': '01d',
   'id': 800,
   'main': 'Clear'}],
 'wind': {'deg': 40, 'speed': 4.12}}
```


Magic Mirror Modules

With the modular design of the Magic Mirror UI, there's also the option of adding in a module that will display the weather. Due to Magic Mirror being open source there's community driven development to which a multitude of different modules are developed. Pertaining to weather, there are included modules in the documentation for the Magic Mirror which can be used for our display. The modular design also allows for us to attempt to build/develop our own modules to display the weather information to our liking. This idea would most likely include strategies from the previous section showing how to pull weather data from a desired API and displaying them in however fashion we desire.

Figure 23 – This portion of the weather module includes information from the desired city including the time, temperature, wind speed and direction, and weather condition.

Figure 24 – Weather Module Data



3.1.8 Social Media Integration (Jacob)

Consuming some form of media has become a common activity for most people in today's age. A large part of media consumption can be derived from the increasing popularity of social media. Chances are likely that if you are a user of technology, you have either used or come across some form of social media. Social media provides the ability to interact among people and share, create, or exchange media or information through the internet. Examples of popular social media platforms include Facebook, Twitter, Instagram, and Reddit. Information including weather, current events, articles, and much more can all be accessed using social media. This arguably makes using social media an all-in-one experience for accessing information without the need of other websites or applications.

Due to our hope to make this Smart Mirror something that's used on a daily basis (preferably to start the day), it makes sense to integrate social media. When it comes to actually implementing this on the mirror, there's multiple strategies and factors that needs to be considered. To start, we want to figure out which social media platforms to use, where/how the data is pulled from, and how we want the data presented. Thankfully, most of the popular social media platforms provide their own developer tools and APIs. Using these APIs, it's possible to pull information from different parts of each social media platform and control what data to keep and display.

Figure 25 - Popular Social Media platforms

Though some of these social media platforms have their own APIs, some are more restrictive of what content and information can be used and how frequently each can be pulled.

Twitter

Twitter is a popular social media platform to which users use "tweets" to post on their own or other feeds. These tweets are bite-sized posts including text to which media such as images and videos can be attached. Tweets can be liked or retweeted to your own feed. For the sake of integrating this well into the smart mirror, we will attempt to simply have the user's live feed displayed. This live feed will mimic twitter's home page which provides tweets from any twitter account the user follows.

Twitter's API is a great start when attempting to pull data from its social media platform. There's plenty of documentation and examples provided to show how to access Twitter's data. There are even in-depth tutorials which relate to integrating a live feed of tweets to possibly help for the smart mirror.

There are also open-source libraries in multiple programming languages that simplifies using Twitter's API. Reading through some of the documentation shows these tools and libraries. Python appears to be the language of choice when it comes to simplicity, so Tweepy's python library is suitable for accessing the Twitter API.

To start, you must have access to a Twitter developer account to use their API. After gaining access and creating a project app you will be given consumer keys and authentication tokens. These will be needed to connect to the respective twitter account to pull data. The following figure will display a snippet of code which tests using Tweepy to connect to Twitter's API.

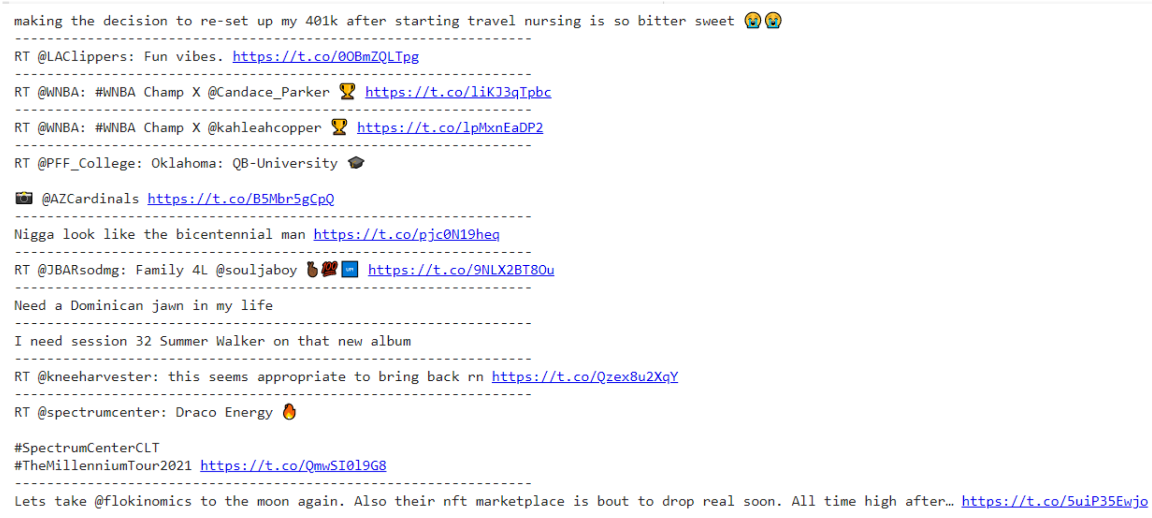
Here we can see the use of the Tweepy library to connect to Twitter's API. A consumer key, consumer secret key, access token, and secret access token are used with Tweepy's OAuthHandler function. Once the connection is made with the API, a few tweets are pulled from the home timeline and printed to the screen formatted to text.

Figure 26 - Tweepy API Token

```
import tweepy

consumer_key = "[redacted]"
consumer_secret = "[redacted]"
access_token = "[redacted]"
access_token_secret = "[redacted]"

auth = tweepy.OAuthHandler(consumer_key, consumer_secret)
auth.set_access_token(access_token, access_token_secret)

api = tweepy.API(auth)

public_tweets = api.home_timeline()
for tweet in public_tweets:
    print(tweet.text)
```

In the following figure you can see the output from the code snippet from the figure above. In this figure the output from the code snippet in Figure x is shown. Each tweet is separated by a horizontal dashed line. Original tweets are shown and also retweets which are denoted by "RT." Tweets with images include a link.

Figure 27 - API Output



```
making the decision to re-set up my 401k after starting travel nursing is so bitter sweet 😭😭
----------------------------------------------------------------
RT @LAClippers: Fun vibes. https://t.co/0OBmZQLTpg
----------------------------------------------------------------
RT @WNBA: #WNBA Champ X @Candace_Parker 🏆 https://t.co/liKJ3qTpbc
----------------------------------------------------------------
RT @WNBA: #WNBA Champ X @kahleahcopper 🏆 https://t.co/lpMxnEaDP2
----------------------------------------------------------------
RT @PFF_College: Oklahoma: QB-University 🎓

📸 @AZCardinals https://t.co/B5Mbr5gCpQ
----------------------------------------------------------------
Nigga look like the bicentennial man https://t.co/pjc0N19heq
----------------------------------------------------------------
RT @JBARsodmg: Family 4L @souljaboy 🤞💯🆙 https://t.co/9NLX2BT8Ou
----------------------------------------------------------------
Need a Dominican jawn in my life
----------------------------------------------------------------
I need session 32 Summer Walker on that new album
----------------------------------------------------------------
RT @kneeharvester: this seems appropriate to bring back rn https://t.co/Qzex8u2XqY
----------------------------------------------------------------
RT @spectrumcenter: Draco Energy 🔥

#SpectrumCenterCLT
#TheMillenniumTour2021 https://t.co/QmwSI0l9G8
----------------------------------------------------------------
Lets take @flokinomics to the moon again. Also their nft marketplace is bout to drop real soon. All time high after… https://t.co/5uiP35Ewjo
----------------------------------------------------------------
```

The figure below will show a portion of a home timeline of tweets from the twitter account used to pull data from.

Figure 28 - The tweets displayed here correspond to the first two tweets shown in the output in Figure 25.

The previous example using Tweepy to access Twitter's API is only shows a small part of what data can be pulled. Tweepy will help tremendously with integrating Twitter with the Smart Mirror.

3.1.9 Breaking News Integration (Tyler)

One feature the group all agreed was necessary to include on a smart mirror was breaking news. Not only do people want to keep up with what's going on in the world, what better place to do so then on an object you stare at every single morning. There are two main technologies that can be deployed to show users a news feed. The first being the ancient but reliable RSS feed, although an old standard it would work well without much setup. The second option would be finding a decent breaking news REST API, many of these are out there and although take more setup they also provide a lot more customization.

Really Simple Syndication (RSS):

This technology is simple and light weight. It requires only an RSS reader be loaded on to the smart mirror. After that the reader just needs to be pointed to one of the many RSS Feeds available from most if not all major news networks, CNN, Fox News, NPR, ABC, and NBC to name a few. Anything from individual country news all the way to global news can be monitored.

The positives of this technology are its ease of use. There is also pre-loaded ready to use RSS Readers for just about any use case, so adapting it to our project would be simple. Because of its simplicity it is good and bad, simple means easy to use but also limited in functionality. What you see is what you get in an RSS feed, the customization is limited to the channels you follow and which RSS tags are provided by the feed creator. For a simple feed RSS would be perfect. If, however, we chose to go more complex by giving the user more freedom to read stories and easily customize their news feed this simplicity would not be a benefit.

REST API:

This option provides similar functionality to the RSS feed option only with way more customization and options. There are many breaking news REST API services out there. Being an API, it runs off HTTP requests which can be called in almost any programming language we decided to use, meaning it is very versatile. The results are returned in a JSON package that can be as simple or as complex as needed depending on how advanced the API is.

The main benefit of using a REST API over an RSS feed is that it is very dynamic. You can call for anything using the same API. One moment you could request a basic list of breaking news article titles and summaries, then you could request an entire article, or search for articles with specific key words. With the API option the customizability is really only limited to what API service you go with, but pretty much any and all will offer the services listed above.

As for the negatives, there is a cost to all those extra features, and the cost can be represented in dollars per month. Although the group won't incur any costs from using an API for the project since almost all API services have low tier free versions for testing, development, and personal projects. The cost of the service should still be taken into account, as it would be an expense if we were to produce these mirrors and bring them to market. Services like this can be found for as cheap as 50 dollars per month, or all the way up to multiple thousand dollars per month. The pricing is based on scale of operation and how many calls are needed. The only other negative other than cost is more development work. Unlike the easy to implement RSS Feed this solution would require a little more leg work to get working.

Table 6 - RSS vs REST API Comparison

	RSS Feed	REST API
Cost of Monthly Operation	**Free**	~50 to ~100 USD/Month
Setup Time	**~1 Day**	~2 Day plus troubleshooting time
Information content	• **Headlines** • **Article Links** • **Dates**	• Headlines • Article Links • Full Articles • Dates • And More Depending on the API Provider

After weighting the positives and negatives we have decided to go with Real Simple Syndication. Although it is simpler in comparison to using a REST API it sav

3.2 Hardware Part Selection

This section will be used to compare the different options for hardware to be included in the Smart Mirror.

3.2.1 Microcomputer Selection (Axel)

The Microcomputer is arguably the most important component of this product. This component will interface with all other components in the build, so it must be capable of doing so quickly and efficiently. The board must be able to accomplish the vision created for the magic mirror. It must be able to connect to the internet via Ethernet/Wi-Fi and be modular enough to support hardware such as a camera, speaker, and microphone. The board should be versatile enough so that it can handle the features that are required as well as extra features that may be required, but would be welcome additions, such as touch controls. Two candidates discussed for the microcomputer were the TI Beaglebone Black, and the Raspberry Pi 4.

TI Beaglebone Black

The TI Beaglebone Black is a Linux based microcomputer manufactured by Texas Instruments. The Beaglebone relies on TI's AM335x 1GHz ARM® Cortex-A8 processor. The processor runs at a 1Ghz clock speed, which is about standard for a microcomputer, and should be more than enough to handle the processes required in the magic mirror. The board also features USB connectivity and HDMI. This means any modern computer monitor can be used with this board, which is convenient. The USB port also means the board is capable of interfacing with third party products which means there is a broader selection of products that can be selected for this product in terms of speakers and cameras.

However, the Beaglebone falls short in some areas. The addition of a USB port is great, but there is only 1. This just means the board is a bit limiting on how many peripherals can be connected to it at a time. The board also does not have any option for expandable memory. Onboard flash memory is generally faster than external memory, but this still presents a design constraint on the amount of software and features than can be present on the magic mirror. The board also lacks Wi-fi integration. Which means if this board is chosen the mirror with have an additional wire that must be connected to it, which could make it less appealing to use and set up. A solution to this would be connected a Wi-fi USB adapter and configuring it, but that essentially negates the positive of having a USB in the first place, as it can no longer be used with third party hardware. Finally, the Beaglebone is not a particularly popular board. Which means there is much less open-source software and support for the board. Which would make running into difficulties with it much more cumbersome and time-consuming had another, more popular board been used instead.

Raspberry Pi 4 Model B

The Raspberry Pi 4 Model B is a Linux based microcomputer developed by the Raspberry Pi Foundation. The Raspberry Pi is a versatile all-purpose microcomputer that runs on a quadcore 64bit processor with a a clock speed of 1.5Ghz. This should be more than capable to keep up with the processes and tasks of the magic mirror. The Raspberry Pi 4 also comes in 3 different versions. The difference in these versions is the amount of on board ram. The options include 2 Gb, 4Gb, and 8 Gb. For this project, a 4 Gb option was considered mainly for redundancy. However, only 1Gb would likely be enough to suffice for the scope of the magic mirror. This board also includes 4 USB ports. This obviously beats the beaglebone black. The board includes onboard wifi integration, which means all 4 of these ports can be used as well. Unlike the Beaglebone, the pi does not have onboard memory. This is both a positive and a negative. The downside is that writing to memory will not be as fast as the Beaglebone, but the pi has support for micro SD. This means the total memory space to work with is much larger than what the Beaglebone can offer. This is a worthwhile trade off as modern SD cards have more than sufficient write/read speeds. The Raspberry Pi outperforms the beagleboard on almost every metric, which makes it an attractive board for this project. The popularity of the pi also means that there is no shortage of open source software and support that can be refered. Difficulties will be much easier to overcome with the raspberry pi than with the Beaglebone. Its for these reasons that the pi was selected for this project.

Table 7 - Microcomputer Spec comparison

Micro-Computer	~~Beaglebone Black~~	Raspberry Pi 4 Model B
Retail Price	$60.00	**$55.00(4GB)**
Processor	AM3358 ARM Cortex A8 @ 1GHz	**Broadcom BCM2711, Quad core Cortex-A72 (ARM v8) 64-bit SoC @ 1.5GHz**
Memory	512MB DDR3 RAM	**4GB LPDDR4-3200 SDRAM**
Connectivity	Ethernet	**Gigabit Ethernet/2.4 GHz and 5.0 GHz IEEE 802.11ac wireless, Bluetooth 5.0, BLE**
USB Ports	1	**2 USB 3.0, 2 USB 2.0**
Power Consumption	5v/2Amps(10 Watts)	**5v/3Amps(15 Watts)**
Operating System	Linux	**Linux**
Storage	4GB 8-bit eMMC on-board flash storage	**MicroSD Expandable(64 Gb)**

3.2.2 Microcontroller Selection (Tyler)

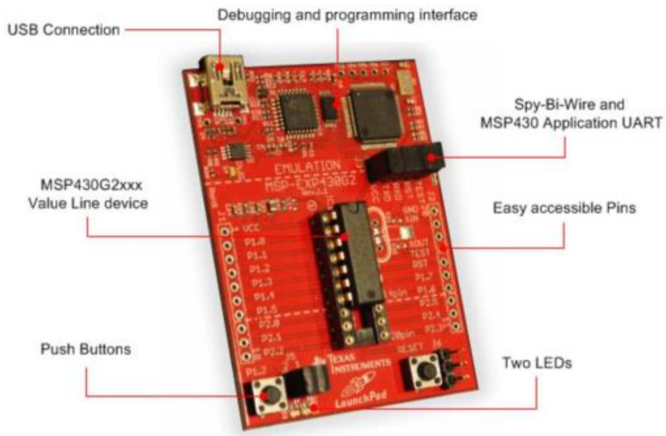
The primary role of the microcontroller in the design of the smart mirror will be dealing with the low power feature. In order to make the mirror environmentally friendly, as well as save the user money on their electric bill, the mirror will enter a power saving mode when not in use.

To accomplish this the MCU will need to have its own low power state, as well as be able to interface with a motion detector and our custom power distribution to control power flow to the other mirror electronics. The secondary role of the MCU will be to control the front facing LED vanity lights. Both of these roles give the group a huge number of options for microcontrollers.

The microcontroller should be affordable and easily programable so our group can all debug things if needed. It should also have a relatively low input voltage so providing power from the distribution board will be simple. To save money and time the group will be using a board that we already have access to. The 3 main options are the MSP430 G2, the MSP430 FR6989, and the Arduino Uno Rev3.

MSP-EXP430G2:

Figure 29 - MSP430G2 Dev Board

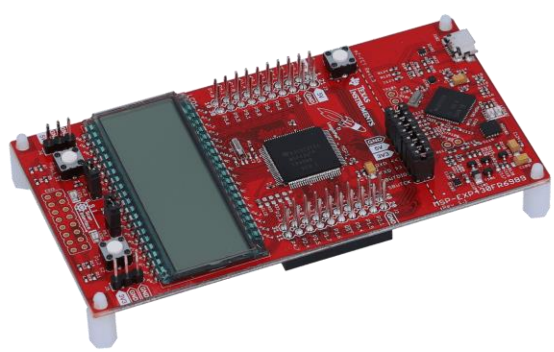


The MSP platform is an obvious choice for any project a UCF student takes on due to the amount of exposure we have had to them thanks to our classes. This board features the 16-bit Texas Instruments MSP430G2553 MCU. It's a great middle ground board between the two other options available to us for this project. The MCU has a very low supply voltage range of 1.8VDC to 3.6VDC which makes providing power to it easier. The MCU has pre-programmed power-saving modes which are very efficient, when active it consumes 230uA, 0.5uA in standby, and 0.1uA when sleeping. It also advertises having a less than 1us wake time from standby, which is helpful to our project because the faster the board can wake the faster our mirror can turn on when a user walks up to it. The MCU has a 16MHz clock speed, which is plenty enough for our project. It also includes a lot of different serial communication options built in and features 24 GPIO pins. The chip is also priced at under 2 dollars which is cheaper than both others.

The negatives of this chip verses the others are non-existent. It is cheap, familiar, and efficient. Before a side-by-side full comparison this chip seems to be the frontrunner and most certainly provides the group the best cost to performance bargain.

MSP-EXP430FR6989:

Figure 30 - MSP430FR6989 Dev Board



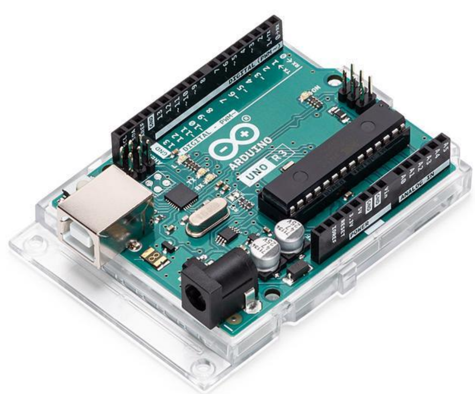
As with the MSP430G2 this platform is very familiar. Although this MCU is most definitely overkill for this application it is still good to analyze all available options. The board is powered by the 16-bit Texas Instruments MSP430FR6989 chip. It has a very low supply voltage range of 1.8VDC to 3.6VDC which makes providing power easy. The clock speed operates up to 16MHz.

It also boasts highly optimized ultra-low-power modes, 100uA/MHz active, 0.4uA standby, 0.02uA sleeping, and many options for serial communication. This package has 82 GPIO pins, which is way more than we could ever need, however many of the GPIO groupings have advanced features attached to them not available on the other chips.

This board only has one real downside, price. The chip costs around 6 to 7 dollars each, making it the most expensive of all the options. Other than that, it performs better and has more options than the other two. The gains performance and flashy extra options are most likely not worth the cost for this project, so most likely this will not be the chosen MCU.

Arduino Uno Rev3:

Figure 31 - Arduino Uno Revision 3 Dev Board



This board features the 8-bit ATMEL ATmega328P microcontroller. This board has a lot of positives for use in this project. It has a 2.7VDC to 5.5VDC operating voltage and a very efficient power consumption which is perfect, 1.5mA when active and 1uA when in a low power state.

The microprocessor speed is also fast enough for our application regardless of operating voltage, 8MHz at any voltage and 16MHz from 4.5VDC to 5.5VDC. It also supports wake-up from pin changes which is very helpful for optimizing our low-power state when the mirror is not in use. It also features 23 general purpose input and output pins, which is more than enough for the projects applications. The microcontroller chip can be had for less than 3 dollars, making it extremely affordable.

The negatives of this board are limited to experience. The board is not needed for anything complicated, so the specifications are plenty enough to perform the two tasks required. The only downside of this MCU is that none of the group members have a high level of experience with this particular chip or the Arduino platform as a whole. This would make debugging and sharing work more difficult than it needed to be verses the TI boards we have all had many classes worth of experience working with.

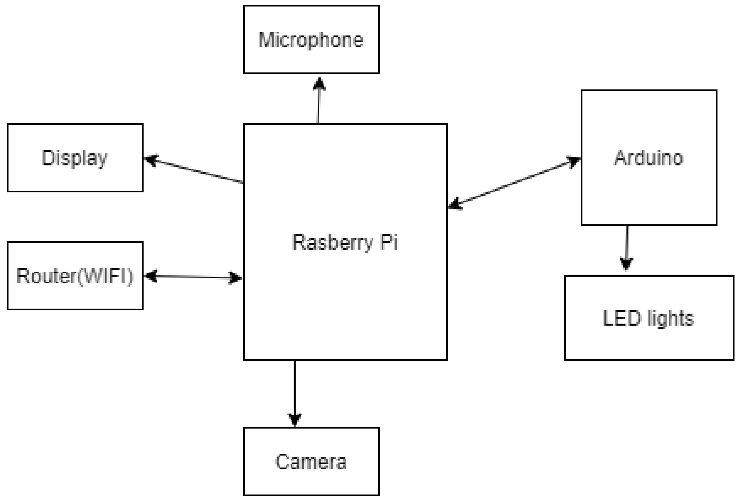
To easily compare the 3 options below is a table with their respective specifications.

Table 8 - Microcontroller Comparison

	~~MSP430G2553~~	~~MSP430FR6989~~	**ATMega328P**
Operating Voltage	1.8 to 3.6 VDC	1.8 to 3.6 VDC	**2.7 to 5.5 VDC**
Max Clock Frequency	16MHz	16MHz	**8MHz to 16MHz**
GPIO Pins	24 Pins	83 Pins	**23 Pins**
MCU Bits	16-bit	16-bit	**8-bit**
Sleep Power Consumption	0.1uA	0.02uA	**1uA**
Standby Power Consumption	0.5uA	0.4uA	**N/A**
Active Power Consumption	230uA	100uA/MHz	**1.5mA**
I2C/ UART	Both	2xBoth	**USART**
Programming Language	C	C	**Arduino**
Software	TI CCS	TI CCS	**Arduino IDE**
Non-volatile memory	16KB	128KB	**32KB**
RAM	0.5KB	2KB	**2KB**
Price	$1.929	$7.023	**$2.28**

Given the above table comparison as well as a practical comparison the group decided to go with the ATMega328P in the Arduino Uno. It is fast, efficient, and something that everyone in the group would like to get experience with, which makes it the perfect choice. Having all gone through UCFs curriculum the entire group has been exposed to TI's MSP430 platform many times and it would be more beneficial to add other experience to our resumes.

Figure 32 - Connections between Raspberry Pi and Arduino



The image above shows the connections between the Raspberry Pi and the Arduino. The Raspberry Pi will be in charge of most of the communication between components. All connection to the LED lights must first go through the Arduino.

3.2.3 Camera Selection (Jacob)

To implement any sort of facial recognition or capture features, a camera must be considered. Most cell phones and laptops come with built in cameras. There are also webcams that can be bought for desktops which can be attached to the screen. Each of these cameras vary in size, quality, and price. For the sake of the smart mirror being able to capture a detailed enough image for facial recognition and other features which need a camera, a higher resolution camera is preferred.

Logitech C920x

The Logitech C920x is a great choice and one of the best-selling web cameras. The camera provides Full HD (1080p) and recording at 30 fps. The camera provides good image quality for video conferences and recordings. The camera is able to attach to the top of most screen displays with an adjustable mount to fit in place properly. HD lighting adjustment and autofocus are useful features to have, especially in darker settings. Though the image quality is great, the price is a little high to be considered a budget friendly option.

Figure 33 - Logitech C920x

Logitech C615

The Logitech C615 is a 1080p web camera. The camera is able to record video at 1080p but when it comes to live video chat, the resolution is reduced to 720p. The C615 provides a more low-profile look compared to other web cameras. It also features a 360-degree swivel design. The camera quality is respectable but not as good as the Logitech C920x. However, in some cases the camera seems to have more realistic colors and skin tones. The price of the C615 is a bit more reasonable and could be consider budget friendly.

Figure 34 - Logitech C615

Amcrest 1080p Webcam

The Amcrest 1080p web camera is another web camera to consider. Along with the Raspberry Pi Camera Module 2 (which will be looked at in the next section), the Amcrest web camera are the most affordable options.

Figure 35 - Amcrest 1080p Webcam

Raspberry Pi Camera Module 2

The final camera for consideration is the Raspberry Pi Camera Module 2. Since we are considering to use a Raspberry Pi, this camera module is the most compatible choice. Smart phones and laptops usually have a small camera which is place behind the display. If we intend to have a cutout in the display of the smart mirror, this would be the camera to use. The Raspberry Pi Camera Module 2 provides exceptional quality for the price.

Figure 36 - Raspberry Pi Camera Module 2

Camera Summary

A more direct side-by-side comparison of each camera will be displayed in the following table (Table x). Key factors to consider are size, quality, and price. Our selection on which camera to use will be based on which has the best balance of the three key factors we're considering.

The camera to be selected is the Raspberry Pi Camera Module 2. Being the cheapest camera does not also translate to being the worst. Since we are already using a Raspberry Pi for our Smart Mirror, it makes sense to use this camera module. It is used for the sole purpose of providing the Raspberry Pi with general capabilities that comes with a camera. Picture quality would be clear enough for our use and video recording would be at 1080p. This camera would also be the only option that would allow for placement behind the display in a cutout.

Table 9 - Summary of camera specifications

Camera	Logitech C920x	Logitech C615	Amcrest 1080p Webcam	**Raspberry Pi Camera Module 2**
Retail Price	$59.99	$39.99	$27.99	**$25-29.95**
Image Resolution	15 megapixels	8 megapixels	megapixels	**8 megapixels**
Video Resolution	1080p video calling and recording	1080p video calling and recording	720p video calling, 1080p recording	**1080p**
Lens/Sensor	Glass	Glass	Glass, CMOS	**Glass, Sony IMX219**
Field of View (Diagonal)	78 degrees	78 degrees, 360 degrees swivel	70 degrees	**~79 degrees**
Microphone	2 omnidirectional	1 omnidirectional	Built-in “high sensitivity”	**None**
Connection Type	USB 2.0	USB 2.0	USB 2.0	**Ribbon connection to board**

3.2.4 Speaker Selection (Jacob)

Certain desired functionalities of our smart mirror would require output or feedback through audio. This would require the connection of some type of speaker. When it comes to what type of speaker to use, there are a few different options. Our first option is that sound could be passed through an HDMI connection from the Raspberry Pi to a display that has built-in speakers. Secondly, we could use separate speakers connected to the Raspberry Pi through either the 3.5 mm audio jack, USB, or Bluetooth. Other options may include soldering to which should be avoided for simplicity purposes. Choosing which option will depend on cost, size, sound quality, and complexity.

Display Speaker

A built-in speaker within a display would minimize complexity because, like mentioned earlier, the sound will be passed through an HDMI connection. This not only completely eliminates the need to purchase a separate speaker, but it also frees up a USB port for other possible uses. Though a built-in speaker is technically the cheapest option, built-in speakers tend to be weak or have poor sound quality.

Figure 37 - An example of a monitor with built-in speakers.

USB Powered Speaker

Our cheapest choice of an actual separate speaker would be a USB powered speaker. This would allow for a simple plug-and-play scenario to which the speaker is powered and can deliver sound from the Raspberry Pi to the user. Using a USB powered speaker would provide both low cost and complexity, but poorer sound quality compared to more expensive options is usually the key tradeoff. The USB powered speaker to be considered is the LIELONGREN USB Powered Computer Speaker. This is an inexpensive option that has dual 3W drivers for a total of 6W. It appears to provide some level of bass with a passive radiator. The frequency response for this speaker ranges from 140Hz to 20 kHz.

Figure 38 - USB Speaker Example

Another type of USB powered speaker would include an audio jack. This would require both a USB port and the Raspberry Pi's 3.5mm jack to be used.

Figure 39 - 3.5mm Speaker

Bluetooth Speaker

With advances in Bluetooth technology, Bluetooth speakers have become more common to use. Whether you're at home, at the beach, or at any form of social gathering, a Bluetooth speaker provides respectable sound quality while being wireless and battery powered. The Raspberry Pi has onboard Bluetooth capabilities which makes using a Bluetooth speaker a possible option. Some drawbacks with using a Bluetooth speaker include keeping it always powered and on to maintain a paired connection. Bluetooth speakers usually run on an internal battery which needs to be kept charged. For the smart mirror, this speaker would have to be on at all times requiring the need to use a micro-USB or type-C connection to some power source. Even with a steady power connection, most Bluetooth speakers time out and power off when no audio is present. Ideally, the speaker would be within the mirror's housing to which the user would not have to turn on the speaker each time it needs to be used. Due to this, using a Bluetooth speaker may not be a preferable option because a USB powered speaker would be powered at all times, draw less power, and cost less.

Figure 40 - Bluetooth Speaker Example

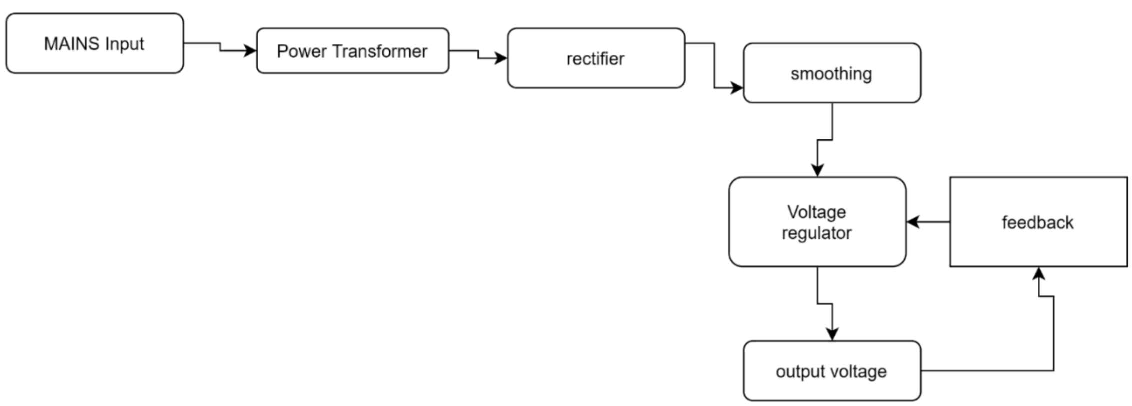
Table 10 - Speaker Comparison Table

Speaker	Display Built-In Speaker	LIELONGREN USB Powered Speaker	LENRUE Bluetooth Speaker
Retail Price	(included with monitor)	$17.98 - 21.98	$19.99
Connection Type	HDMI	USB 2.0	Bluetooth 5.0
Drivers	Variable	Two 3W + 2W	-
Total Output	Variable	8W	Battery Powered
Frequency Response	Variable	100Hz – 20kHz	-
Connection Length	Variable	3.8ft	Variable
Dimensions (W x H x D)	n/a	7.17" x 2.2" x 1.81"	6.9" x 1.8" x 2.8"

3.2.5 Power Supply Selection (Jonathan)

The way the smart mirror will receive power is through an AC to DC power supply. The reason for this choice is that the mirror will be mounted on the wall and should not be moved constantly so if Batteries were used the user would have to Dismount the mirror every few weeks to replace the batteries. Another reason to use the AC to DC converter is that most of the components in the mirror require a dc input to power them. First the 120 AC input from the wall will be stepped down to 12 volts using a step-down transformer then using a full bridge rectifier the AC voltage will be switched to DC to combat Rippling the capacitors will be added to smooth out the signal. unregulated power supplies don't have voltage controllers incorporated into them; they normally are intended to create a particular voltage at a particular greatest yield load current. These are typically chargers that transform AC into a little stream of DC and are often used to control gadgets like household devices They are the most widely recognized power connectors. A regulated power supply is the power supply design that is wished to be implemented in the smart mirror. What differs the regulated power supply from the unregulated power supply is that the regulated power supply has voltage regulators to control and have a more stable voltage. This would be beneficial for the mirror because the mirror will have many different components that require a very stable voltage such as the microcontroller. The regulated power supply does this by sampling the output voltage and the regulator adjusts the signal to be stable. there are three ways to implement voltage regulator Linear, switched and battery

Figure 41 - Regulated power supply flow chart



Linear Power Supply

Linear power supplies have commonly used for a long time and are widely used and preferred. They also attribute to less noise. Linear power sources have the disadvantage of requiring larger components and thus being larger and dissipating more heat than switching power supply. They are also less efficient than switched power supply and batteries, sometimes only achieving 50% efficiency.

Switched Power Supply

Switched mode power supplies (SMPS) are complex to construct but have more use in polarity they have an efficiency of 80% or more. It holds more components than the linear supply but are smaller and less expensive than linear power supplies.

Table 11 - Power Supply Comparison Table

SWITCHED	~~LINEAR~~	~~BATTERY~~
> 80% efficiency	50% efficiency.	Portable
small components	Large components	Doesn't require on-site power
Inexpensive	Expensive	Fixed voltage input
Higher noise	Less noise	Short life

The desired voltage regulator to be implemented in the regulated power supply is the switched regulator for its high efficiency. It also uses smaller components so it will not contribute to the weight it is also the cheapest option.

3.2.6 Display Selection (Jacob)

The display for our smart mirror is arguably one of the topmost important components. When deciding which display to choose, we must consider one that would be appropriate to fit our desired 18x24 inch display for the smart mirror. With an 18x24 inch display, the diagonal would be 30 inches. Displays of 30 inches exactly aren't common so displays that are less than 30 inches along the diagonal are appropriate to use. Common display sizes for monitors that can be considered are 24 inches and 27 inches. For televisions, it appears that there are options of 24 inches and 28 inches.

When selecting a display, certain specifications are necessary to compare for desired image quality. Refresh rate and response time should be considered though, the highest refresh rate possible isn't necessarily required but a monitor with a minimum of 60 Hz should be satisfactory. HDMI support is required to which we can consider using a TV or a monitor. Using a monitor or display that includes built-in speakers would eliminate the need to connect separate speakers for the smart mirror. When it comes to resolution, the accepted minimum is 720p for a decent picture. For modern technology, 720p appears to be a resolution of the past for current monitors. Monitors come in 1080p, 1440p, and even 4K. For this smart mirror project, we will pursue the minimum of 1080p for a display.

A key difference in different displays is the actual panel type. Three primary panel types are Twisted Nematic (TN), In-plane Switching (IPS), and Vertical Alignment (VA). Each panel type offers its advantages and disadvantages over the other. The differing panel types depend on how the molecules are aligned within the display. For the sake of this project, deciding on which panel isn't necessarily a huge factor to consider, but it's important to compare and decide which may be the best option.

TN panels are the oldest technology and usually fall short in viewing angles, color gamut, color reproduction, and contrast ratios. The only real noticeable advantage of a TN panel would be that the cost is less than an IPS or VA panel.

The choice between using a monitor or a television will be determined based on a few factors. These factors include price, image quality, and responsiveness. Based on researching products, it appears that televisions around the same screen size as monitors tend to be a bit cheaper. Though, choosing a television over a monitor has some drawbacks. Monitors are made to be much more responsive since they're primarily used for computers. Input lag is minimized due to lower response times. Lower response times helps reduce ghosting and blurring during pixel transitioning. Higher refresh rates help the image on display change faster and reduces screen tearing. For the sake of cost, refresh rates of 60 to 75 hertz will be considered. Anything higher than those refresh rates would cause an increase in price. A key difference between the target sizes of monitors and televisions is that it seems only a high definition (720p) resolution is available for televisions. The resolution of full high definition (1080p) is more commonly available for monitors.

Sceptre E248W-19203R

The Sceptre E248W-19203R is a great option for the smart mirror's display. Measuring at 24 inches (23.8 inches to be exact), this will fit the planned housing for the smart mirror. This monitor is 1920x1080 in resolution and has a Vertical Alignment (VA) panel. Color accuracy is decent with a 95% sRGB rating for the color gamut. The refresh rate on this monitor is 75Hz. When it comes to ports, the monitor includes two HDMI 1.4, one VGA, an audio in, and an audio out. The response time is 8 ms (gray-to-gray). Depending on which speaker option is selected, this monitor is a good choice since it has built-in speakers. This will possibly eliminate the need for purchasing external speakers, but it depends on if the audio quality is adequate enough. The speakers are two 2W speakers which may provide decent sound. The exact dimensions for the monitor without the stand is 21.59 inches by 1.28 inches by 12.71. The measurements are Width by Height by Depth. The monitor weighs 5.77 lbs without the stand which is pretty light.

Figure 42 - Sceptre E248W-19203R

Sceptre E278W-FPT

The second monitor for consideration is the Sceptre E278W-FPT. At 27 inches, this monitor is a step up in size from the previous E248W-19203R. Being at 27 inches, this monitor size would be favorable to decrease the bezel size of the smart mirror's display. This would allow for a less bulky and more modern look to appeal the ocular senses. In contrast with the Sceptre E248W-19203R, the Sceptre E278W-FPT is an In-Plane Switching (IPS) panel type rather than Vertical Alignment (VA). This display provides up to 75Hz for the refresh rate and 5 ms for the response time. The color gamut is 99% in sRGB. The dynamic contrast ratio is 1,000,000: 1 and the contrast ratio is 3,000: 1. External speakers are also included in this monitor which, as mentioned prior, helps eliminate the need for purchasing and integrating an external speaker.

Figure 43 - Sceptre E278W-FPT

Insignia N10 Series (24-inch television)

As mentioned earlier, for our display we can also consider televisions. The purpose for possibly using a television over a monitor would be due to pricing and the availability of built-in speakers. The Insignia N10 Series is the first television to consider. It's a 24-inch HD LED TV. Though the cost is cheaper, there are definitely some drawbacks. To start, being only HD allows for this television to only support a maximum of 720p for resolution. This would cause for a sacrifice of image quality. The television also has a slower refresh rate at 60 Hertz compared to the previous monitors at 75 Hertz. This isn't too much of a difference but it's definitely worth noting. Since we're developing a smart device that would have touch inputs that would constantly change the display on the screen, response time is also important. Unfortunately, this television has what could be considered a slow response time of 14 milliseconds.

Figure 44 - Insignia N10 24-inch Television

LG 28" Class LED TV

The second television that we could potentially use is an LG 28-inch LED TV. This television is also high definition like the Insignia N10 Series but is larger in comparison. This would probably be our last option since the cost would be more than either monitor option but it's worth considering. This television has some of the same specifications as the smaller Insignia N10 Series at 24 inches. Only having support for high definition becomes a bigger problem with a larger screen. The refresh rate isn't as bad at 8 milliseconds, but it is still on the lower end.

Figure 45 - LG 28-inch Class Television

Display Summary

Based on specifications and our use case it may be favorable to choose a monitor instead of a television. Monitors have the edge with responsiveness and for our price range the resolutions are better. Below is a table summarizing each of the considered displays.

Table 12 - This table summarizes the specifications for each display.

Monitor/ Television	Sceptre E248W-19203R	Sceptre E278W-FPT	Insignia N10 Series	LG 28" Class LED TV
Retail Price	$139.97	$179.97	$109.99	$179.99
Screen Size	24 inches	27 inches	24 inches	28 inches
Panel Type	VA	IPS	Standard LED	Standard LED
Resolution	FHD	FHD	HD	HD
Refresh Rate	75Hz	75Hz	60Hz	60Hz
Response Time	8 ms	5 ms	14 ms	8 ms
Color Gamut	95% sRGB	99% sRGB	n/a	68% CIE1931
Power Specifications	Adapter: 100-240 VAC, 50/60 Hz, 1.0A (Max) Output: 12V DC, 2.5A	Adapter 12V 3A 100-240V, 0.8A, 50-60Hz	n/a	PSU: 55W Input: 100-240V
Dimensions (W x H x D)	21.59" x 1.28" x 12.71"	24.12" x 14.14" x 1.12"	21.7" x 13.1" x 2.7"	25" x 15.2" x 3.0"

3.2.7 Motion Detector Selection (Tyler)

The motion detector will be responsible for letting the mirror know that the user has walked up and therefor it needs to wake up from its low power state. This means the sensor needs to be fast reacting and not use a lot of power, the lower the better. The sensor used for motion detection will also need to be accurate for detection up to at least 5 feet. As with the rest of the components the sensor chosen should have less than a 12VDC operating voltage, the lower the better.

The first option is one that the group already has access to, an ultrasonic range sensor. The second option is a simple infrared motion sensor. The third option is a LIDAR sensor, and lastly a microwave radar sensor. After digging into the ultrasonic sensor, it became obvious that range sensors are overkill for what we are using them for, so the LIDAR sensor was removed from the running.

HC-SR04 Ultrasonic Range Sensor:

This sensor is good because the group has worked with it before. It has a 5V operating voltage, making power supply to it easy. It uses a pulse input and output for data and provides information on exactly how far away the user is. Its max range is 4 meters, 13.12ft, with a 15-degree measuring angle. These sensors are also very cheap and can be found for under 4 dollars.

The drawbacks to going with this sensor are firstly its size, because it uses sound the sensor needs to be fully exposed and it is not small, this could become an eyesore on something that is supposed to be an elegant mirror. The second drawback is that it is not exactly what we are looking for, we primarily need the sensor to determine presence. The actual distance of the user is not needed for anything and would be a wasted.

PIR SENSOR IR WIDE ANGLE PARALLAX 28032:

This sensor is a simple IR motion detector only it has a large 180-degree field of detection, making it a perfect option for our smart mirror. It can detect movement up to 30 feet away, which is plenty enough for any normal sized room. The sensor also boasts a night-time-mode for use in low light conditions. Unlike the previous option this sensor also won’t be an eyesore and could easily be flush mounted to the mirror frame. It requires an operating voltage of 3VDC to 6VDC and outputs a single-bit high or low signal to indicate motion.

The negative of this sensor is only the cost of it. The sensor retails for around 13 dollars, much more expensive than the others.

5.8GHz Doppler Radar Motion Sensor MW0582TR11:

This sensor uses microwaves to detect motion instead of infrared. This means that it could be mounted inside the frame and provide for the cleanest overall look, which is a huge plus. The sensor has a detection range of 10 meters, or 32.8ft, which is even more than the PIR sensor. It communicates using UART, which will work with the microcontroller. It also runs off an operating voltage of 5VDC, making it a perfect fit in our project. The cost is also good with options from around 7 dollars. Other models can also be found for around 10 to 12 dollars that have similar functionality.

The only negatives found with this sensor is limited documentation. There doesn’t appear to be a whole lot of information available on doppler radar sensors of this scale. This could be a potential issue in the future as no team member has dealt with this technology before. The only added benefit this sensor has over the PIR in the context of the smart mirror is a cleaner finished product.

Below is a comparison table containing the specifications of all sensor options.

Table 13 - Motion Detector Comparison

	~~Ultrasonic Range Sensor~~	Wide Angle Passive Infrared Sensor	~~5.8GHz Doppler Radar Sensor~~
Operating Voltage	5VDC	3VDC to 6VDC	5VDC
Max Detection Range	13.12ft	30ft	32.8ft
Sensor Angle	15 Degrees	180 Degrees	104/153 Degrees
Interface	High/Low	High/Low	UART
On Board MCU	No	No	Yes
Standby Current Consumption	N/A	150uA	40mA
Active Current Consumption	15mA	3mA	70mA
Can Pass Through Non-Metals	No	No	Yes
Low Light Operation	Yes	Yes	Yes
Pin Count	4-Pin	4-Pin	3-Pin
Price	$3.95	$12.99	$6.95

Although it is the most expensive at almost 13 dollars, the wide angle PIR sensor seems to be the best option for this project. It has very low power consumption, performs the exact task we need to it for this project, and is no more complicated than it needs to be. The Doppler Radar Sensor is a fantastic option, but the power consumption and complexity are not worth the small cost savings and elimination of any visual sensors on the front of the mirror. The Ultrasonic sensor on the other hand is just not at all what we are looking for in a sensor. This sensor is much more focused on overall detection, not range. So, the higher power consumption and low detection range/ angle mean that it did not make the cut. The best and most reliable option by far is the PIR sensor.

3.2.8 Vanity Light Selection (Tyler)

The purpose of the vanity lighting included on the smart mirror will be to enhance the users experience while using it as a mirror. Lighting facing the user will help light up the users face and make things like doing makeup, hair, or even trimming a beard much easier. The extra lighting provided by the vanity lights will allow the user to see things they would otherwise not be able to without performing a major upgrade to all the users current home lighting. Including these lights will make the users life easier as well as potentially save them money by including a feature that may not otherwise be included in their current home.

The lights themselves have a few requirements they need to meet. They must be bright, at least 300 lumens. They must have a white with a color temperature of at least 3000K. The must be LED so they are very power efficient. They should operate at a maximum of 12VDC so that powering them from our distribution board will be easy. Finally, they will be placed behind a light diffusing plastic for aesthetics, so they need to be small. Because of this led light strips will be the best option.

We don't need the flexibility of addressable lighting so simple LED strips will do fine. We also don't need RGB lighting, however it would be a good feature to have as it would allow full control of the vanity lights color temperature, allowing the user to select a more incandescent look or a modern LED white. This means that either purpose built "white" LED strips, 4 channel RGBW strips, 3+1 RGB+W strips, or a more complicated 5-pin RGB+CCT containing 2 whites a warm white and a cold white as separate diodes is what we are looking for. Dimming is also a feature we would like to implement, and this can be done on any of the below options, with the given remote of the tunable strip, or with a custom PWM module for the basic strips.

Lepro Tunable LED Strip Light Kit:

This purpose-built LED lighting kit comes in a 16.4 ft or 32.8ft length and can be cut. It operates off a 3-wire system. The LEDs can be set to a variety of color temperatures ranging from 3000K to 6000k and are dimmable. The lights come with 3M adhesive, so mounting is easy. They run off 12VDC, which works well for this project and will make powering them easy enough. They also have the ability to be controlled via an IR remote, which could be used in our project, or we could control the LED's using a home-made solution giving the group flexibility. It is also very cheap at 18.99 for the lights and controller.

The only con of using this kit is that it has a pre-made 3-pin control system. This means the group would have to work around whatever technology the company has implemented instead of building our own system from the ground up. This could make implementing the lights easier or harder in the future. For this reason, this kit is not as high up on the list of options but more as a comparison to other options or a backup in the even our custom solution did not pan out.

BTF-LIGHTING RGBCCT 5050 RGBCCT Light Strip:

This product is simply a large strip of RGBCCT lights. They can be cut to any length and easily soldiered to make any shape needed. They use a standard 5-pin connection so a custom control will need to be implemented, this is a good a bad thing because it gives the group infinite control over the LED's but requires a custom solution or a separate pre purchased LED controller we can interface with. These lights are RGBCCT which means they have separate red, green, blue, 6500K cool white, and 3000K warm white diodes. This allows for infinite lighting control. These lights are also silicone coated and IP65 waterproof, which although not a requirement for our project as they will be sealed in, it is a nice feature. Its operating voltage is 12VDC, which works great for the project and keeps everything at 12V and under.

The downsides of this choice are its price point. The 16.4ft strip comes in at around 52 dollars. It provides the most options, but many are un-needed for this project and it would eat up a large portion of our budget to provide a simple feature of lighting. If we went with a pre-built controller this would make the lighting portion cost even more.

BTF-LIGHTING 5050 RGBW/RGBWW White Light Strip:

This light strip is a good middle ground verses the other options. It is a 16.4ft long RGB-WW strip, meaning it has full RGB as well as 2700K to 3000K warm white diodes. This option would give us full RGB capability, which is not necessary but would give the user more options, while also providing a nice warm vanity light setting. The company also offers a RGBW version if we decided to go with a 6500K cool white color. The strips can be cut to any length and easily soldiered to make any shape needed. It uses a standard 5-pin connection so a custom control will need to be implemented as with the previous option. This strip is also IP65 rated which is a nice extra feature.

This strip is priced in between the others at around 27 dollars. The only draw back is we would need to choose between warm or cool white LED's. So, if RGB is a wanted feature and we want to be budget conscious this is the best option for the project.

YUNBO LED Strip Light:

Lastly, we have the cheapest and simplest option. This strip is a basic 3000K warm white or 6500K cool white strip. It has no RGB capability, and we would have to choose between the warm or cool white color temperature. The features on this strip are minimal and it is therefore the most budget conscious of all the options, coming at just under 13 dollars for a 16.4ft section. As with the others it can be cut to any length, runs off 12VDC.

This option is not IP65 rated, and its only real capability is dimming if we built a PWM circuit. This is cheapest and most bare bones option we have available, but it checks off any of the minimum requirements we have for the vanity lighting in the smart mirror.

To easily compare the options below is a table with their respective specifications.

Table 14 - Vanity Light Option Comparison

	~~Lepro~~	~~BTF RGBCCT~~	~~BTF RGBW~~	YUNBO
DC Op. Voltage	12V	12V	12V	12V
RGB	No	Yes	Yes	No
Warm White	Yes	Yes	Pick One	Pick One
Cool White	Yes	Yes		
Width	10mm	12mm	12mm	4mm
# Of Pins	3-Pin	5-Pin	5-Pin	2-Pin
Waterproof	No	IP67	IP67	No
Cuttable	Yes	Yes	Yes	Yes
Adhesive	3M	Knock-off	Knock-off	Knock-off
Max Power Draw	15W	150W	120W	36W
Control	Included	N/A	N/A	N/A
Length	16.4ft	16.4ft	16.4ft	16.4ft
LED Count	300	300	300	300
LED Type	2835	5050	5050	2835
Price	$18.99	$50.88	$26.88	$12.99

Given the above table and comparison we can quickly rule out the RGBCCT strip. Although it provides the most options and features it is not worth the investment for a smart mirror that has cost in mind. RGB is not a primary feature and would simply be an added benefit to the end user as a decorative piece. It also has a high max power draw for a simple feature such as vanity lights. The RBGW option also has a high-power draw, the only real negative to the strip, other than the power requirements it has the best price to performance ratio out of the four. As nice as they are I think it is best to eliminate them to save our overall power budget and opt for one of the less power-hungry options.

The remaining options are the Lepro and the YUNBO. Between these two the obvious choice is the YUNBO. It is cheaper, simpler, and doesn't use a proprietary controller we would need to work around. In the event that we run out of time developing our own controller, the Lepro would be a perfect back-up piece. Unless that ends up happening, we will be using the YUNBO and using the micro-controller to handle the lighting control.

3.2.9 SD Card Selection (Axel)

The board selected for this project does not contain any onboard flash storage. It does however feature support for MicroSD cards. This means that the card selected is an important choice because the operating itself must be installed on the SD card itself, or else the pi is functionally useless. The Raspberry Pi operating system image must be installed on the SD card using an imagining software. Raspberry Pi Foundation features its own first party imaging software on its own website, which can be used to make the process as simple as possible. The process is rather simple as all that needs to be done is flash the operating system image files onto the SD card through the program. However, it is important to note that Raspberry Pi OS requires at least 8 GB of storage for the OS itself. Which means the card selected for this project must be at least that amount. It is also noteworthy to mention that the Raspberry Pi itself has a max throughput of 25 Megabytes per second. Meaning it does not make the operating system run faster or more efficiently to use a microSD card with a higher data transfer rate. The pi is generally used with SD cards that have 32GB of memory storage. This is because cards of a higher capacity are formatted differently(exFAT) versus what the raspberry pi is design to be compatible with (FAT32). This means any card greater than 32GB must be reformatted to work with the Pi. In order to keep complications to a minimum, a compatible SD card size of 32GB will be selected instead.

Longevity

Generally, memory cards tend to outlast estimations for reliability. Meaning they tend to last much longer than the manufacturer claims they should. Longevity of storage devices in measured by something called Program/Erase Cycles. Memory cards available on the market today can last at least 100,000 Program/Erase Cycles. Based on current technology this means that the typical lifespan of an SD card is 10 years or more. It should be safe to say that no matter which SD card is chosen, it will not have been because of any concerns for longevity. This means most if any all SD cards available today could be considered for this project. This gives us more flexibility and options when it comes to deciding what to go with. A table comparing the specifications of 3 of the most popular MicroSD cards is shown below.

Table 15 - MicroSD Spec Comparison

Card	Samsung PRO Endurance MB-MJ32GA/AM	~~SanDisk Extreme PRO SDSQXCG-032G~~	~~Silicon Power 3D NAND~~
Price	$8.99	$13.37	$7.99
Capacity	32GB	32GB	32GB
Transfer Speed	100MB/s	100 MB/s	85MB/s

Based on this table, we believe that the Samsung PRO Endurance MB-MJ32GA/AM would be the best fit for this project. It has just as fast a transfer speed as the SanDisk Extreme PRO SDSQXCG-032G, but is almost half the cost. Samsung is a well-respected brand in the world of electronics as well, which makes the decision to trust this card a confident one.

3.2.10 Frame Material Selection (Jonathan)

The required material needed to build the frame of the mirror should be able to support all components of the mirror such as the monitor screen, the power supply and the micro controlled and microcomputer the material should be durable and lightweight to stay within the twenty-five-pound limit. the material should be able to withstand moisture created in bathroom environment

Wood

The main material the frame would be made from is wood because wood can be inexpensive and there is a variety to choose from with many different qualities. There is softwood and Hardwood. Softwood comes from gymnosperm trees. These trees usually grow at a faster rate and they usually have pinecones and needles. because of the faster growth rate of these trees. The wood of these trees is less dense than hardwood and are more malleable. Softwood is less expensive but has poor fire resistance. Softwood has many uses Including being used for doors and window frames and even being used to make paper. Hardwoods come from Angiosperms trees and they are usually deciduous trees which means they hibernate in the winter and lose all their leaves. These trees take longer to grow and the fact they must withstand the harsh cold environment is the cause of their denser and heavier wood. This wood is more fire resistant than the soft wood. Typical uses of the hardwood include construction of houses, high quality furniture, and flooring.

Pine wood is the better choice for the mirror frame because of the price and how light it is and still can be structurally sound even though pinewood is not as water resistant as the other hardwoods the wood can become more water resistant if it is finished in Polyurethane, varnish, and lacquer.

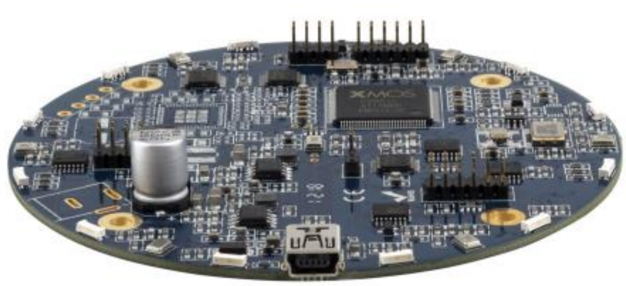
Table 16 - Wood Material Comparison

	Pinewood	~~Redwood~~	~~Teak~~	~~Oak~~
Price 2x4	$5.17	$14.98	15.20	$10.14
Density(lb/ft^3)	22-31	28	41-55	37-56
Type	Softwood	Softwood	Hardwood	Hardwood
Moisture resistant	No	Yes	Yes	Yes

3.2.11 Microphone Selection (Jonathan)

UMA-8

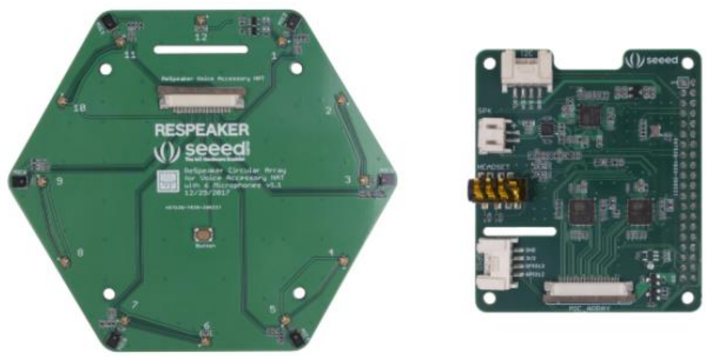
Figure 46 - UMA-8 USB mic array - V2.0



The UMA-8 is aUSB microphone array and is well suited for this project it has seven MEMS (micro-electromechanical systems) omnidirectional microphones for high quality voice capture this microphone array supports beamforming algorithms which is a signal processing technique used for spatial filtering signals it beamforming allows the device to hone onto one or multiple voices it also supports al algorithms for noise reduction and acoustic echo cancellation which is important if the device is placed in a bathroom setting this is the same microphone array used in the Amazon Dot/Echo so it is compatible with most voice assistant which is good for home API integration. This device also has compatibility with the raspberry pi which is being used in this project. It has USB API for direction of arrival, 8ch raw audio mode via USB Audio, PDM to I2S conversion

Respeaker

Figure 47 - ReSpeaker 6-Mic Circular Array kit for Raspberry Pi



The Respeaker is also a microphone array though it does not have as much capabilities and compatibility as the UMA-8 It is compatible and made for the raspberry pi it is Compatible with Raspberry Pi 40-pin headers which could make it easier to configure to. It has 6 x high performance Omnidirectional microphones it differs from the UMA-8 in that it has a speaker output so you can hear the virtual assistant respond back. The Speaker 6-Mic Circular Array is at a way better price point than the UMA-8 it contains3.5mm headset audio jack, Speaker jack,2 ADC chips and 1 DAC chip, and8 input and 8 output channels

Movo M1 USB Lavalier

Figure 48 - Lav Mic

The Movo M1 microphone is the microphone we will most likely use in the mirror although it does not come with as many features as the other two microphones, we have researched it does it meets all basic criteria for a microphone for this project. It is easier to use and more affordable than the other options we were considering. Another advantage it has over the other options is that the fact that it is on a wire can easily be placed in the best position in the mirror and can be easily moved unlike the other two options which are microphone array boards which will be more difficult to place on the mirror so the board can be in the best position but also be placed so you can not see it to remain aesthetically pleasing

Table 17 - Microphone Spec Comparison

Microphone Arrays	UMA-8 USB mic array - V2.0	ReSpeaker6-Mic Circular Array kit for Raspberry Pi	Movo M1 USB Lavalier Lapel Clip-on Omnidirectional
Price	$105	$39.90	$29.95
Microphones	7xKnowles SPH1668LM4H	6x MSM321A3729H9Cp	-
Sample rate	24bit11/16/32/44.1/48 kH	48Khz	18Khz
Compatibility	UAC2.0with WidowsASIOdriver, OS X driverless, Linux Alsa 2.0 Mac/Win GUI for real time control of DSP settings API for microphone control Raspberry Pi	Raspberry Pi Zero, Raspberry Pi 1 B+, Pi 2 B, Pi 3 B, Pi 3 B+,4	USB connection
Dimensions (diameter) mm	90 mm diameter / 20mm height	1mm x1mm x1mm	N/A
Sensitivity	-29dBFS (Omnidirectional)	-22dBFS (Omnidirectional)	N/A
Audio Channels	8	8	1

3.2.12 Two-Way Mirror (Axel)

This is arguably the most important component of the entire project. The project depends on the quality of this component for the best results. A two-way mirror is necessary. A two-way mirror allows for some light to pass through both sides. This is important because the goal is to have the user be able to see the display when it is turned on, as well as themselves, simultaneously. A standard mirror reflects nearly all of the light that hits it. The amount of light that passes through a pane of glass is measured in a percentage of “Visual Transmittance.(VT)” A higher percentage means that more light passes through. For this project, a lower VT is desired, this will allow enough light to pass through so that the user can see the screen behind the pane, but also reflect enough light so that the user may see their own reflection.

Figure 49 - Visual Transmission on a decimal scale

Mirrorview 50/50

There are several companies that specialize in creating custom two-way mirrors. One of these companies is Fab Glass and Mirror. This manufacturer creates mirrors capable of 43% VT. They call these mirrors Mirrorview 50/50. A VT of 43% is a rather high percentage for a two-way mirror. However, this is advantageous in the event that the user places the mirror in a room with high ambient lighting. If there is too much ambient light, it may become more difficult to see the display underneath the mirror. A similar effect can be experienced when watching television in a room with abundant sunlight. The sunlight almost drowns out the light coming from the television, making it more difficult to view properly. The mirrors manufactured by MirrorView capable of this much VT have reflect about 53% of light. This is enough for the user to see a reflection of themselves, although it will be a bit fainter than most are likely used to.

Mirrorpane

Mirrorpane is a brand of two-glass, that is a great deal more affordable than Mirorview’s specialized glass. Mirrorpane has a VT of 11%. On the lower end. This is not an ideal choice if a user prefers to put the mirror somewhere with good lighting. Mirrorpane has a reflectance of 68%, which means the user will be able to see themselves just fine.

Acryllic

Another option is to avoid glass altogether and go for an Acryllic panel. One of the greatest advantages of using Acryllic for the relfective surface is the fact that it is much more affordable than glass. However, Acryllic scratches very easily, which means the user must avoid touching the surface. However, this is not a real problem as the user only needs to use their voice to interface with the mirror, not touch. The only time the user is expected to touch the mirror is to clean any spit particles that may have landed on the surface from speaking. Another benefit of using Acryllic is that it does not crack in the same way glass does. Many Acryllics are flexible, which makes them resistant to forces that may shatter glass. The particular Acryllic panel being considered for this project has a VT of about 40%. This makes this panel a great option for the project. It has a good enough VT so that the mirror can be used in most indoor environments, durability, as well as affordability. Because it is also made of Acryllic, it will weigh less than glass, which makes this product easier to hang on a wall. It should be noted however that the vendor does not show the reflectivity percentage on their product page. However, based on photos from customers who have purchased this product for their homes, reflectivity should not be any issue.

The cost for the mirrors in the table below are for mirrors of dimensions 12”x24”

Table 18 - Two-Way mirror comparison

Mirror	Acryllic	Mirrorpane	Mirrorview 50/50
Visual Transmission	**40%**	11%	43%
Reflectivity	**Unknown**	68%	53%
Price	**$24.99**	$99	$251.08

4. Design Constraints and Standards

This section of the document will discuss constraints that must be taken into consideration during designing of the smart mirror. As well as certain standards that must be followed in order for a prototype like this to be safe to operate under normal conditions.

4.1.1 Time Constraints (Axel, Tyler)

The time allotted for research and development of the project is 2 full semesters: fall and spring. The fall semester is primarily devoted to brainstorming design and what kind of features the mirror will have. So realistically, most if not all the actual development of the mirror will occur in only 1 semester. Or approximately 4 months. It's because of this short time, that our mirror can only have only implement the most essential features.

To deal with this time constraint many features we initially intended to include had to be cut from the project to include more important things like demonstrating our ability to design things like power converters, supplies, and embedded circuits and then turn those things into PCBs.

In a perfect world the smart mirror would include a lot more features than currently included. To determine which features and things would be included in the final rendition of the smart mirror the house of quality diagram located in section 2.6 was used. This way we can demonstrate our skills, develop a cool product, and stay within the time constraints present for this course.

Another constraint involving time is present in senior design 2. It is not something constraining the group and the project currently, but it is a future constraint that must be considered. If the group designs more than can be handled next semester the overall project will turn into a failure. In order to avoid this negative outcome the group has attempted to design a project that can be assembled and programed in the given time frame during senior design 2.

4.1.2 Economic Constraints (Axel, Tyler)

This project has no sponsorship. So, funding presents an issue. Low cost, yet high quality parts are difficult to come by, which means that sacrifices might need to be made in certain areas. Audio and camera quality are essential to the proper functioning of the mirror. Which means costs must be cut in other areas.

The group came into this project with the intent to keep cost under or around 100 US dollars per group member, giving us and approximate budget of 400 US dollars. If the group intends to stay within this budget and now exceed it certain items of the project will need to be either cut entirely or lowered to quality to meet these economic constraints.

An example of the first economic constraint the group met was an initially intended feature. In the beginning of this semester, it was an intention of group members to make the smart mirror have a touch display. This would give users the option to interact with the mirror physically or through voice control. However, this feature was cut due to the immense cost of touch panels. A small IR touch panel can run as much as 100 US dollars.

A potential cost-saving measure would be making the frame of the mirror strictly out of wood. It would have to be custom made by hand. Wood is not necessarily an ideal material to make a smart mirror frame out of as it does not fit the overall aesthetic of a smart home device. But due to the face that the frame serves no function other than being a shell for the display and components, it’s a sacrifice that must be made.

Another cost saving measure is selecting an LCD display instead of OLED display. An OLED display would make the screen look better. This is because of the fact that OLED is capable of turning off individual pixels, this makes blacks look darker than LCD displays. However, this is again, another aesthetic feature that serves no real purpose.

Overall, the entire project has been looked at through the lens of cost savings. Throughout all comparisons and research in section 3 of the document cost was a primary factor in choosing technologies to use as well as hardware to deploy in the project. Found in the tables and explanations in section 3 it is noted that cost is a large decision making factor.

Another economic factor that constrains the project is the cost to the end consumer. In order to have a good smart mirror it needs to have a bearable cost initially and throughout the life of the smart mirror. The first thing there, the initial cost, is directly related to the previous economic constraints we have taken on as a group. The cheaper that we can produce the smart mirror the cheaper it can be offered to end users.

The second thing is the use cost of the mirror, many users today are very cost conscious when it comes to their electricity bill. If the smart mirror draws too much electricity and costs the user a large amount of money to keep plugged in at all times like it is designed, the user will not want to use the smart mirror, meaning it needs to be efficient with power usage to keep from being an economic strain on end users.

4.1.3 Environmental Constraints (Axel, Tyler)

Two different types of environmental constraints exist for this project, firstly being the environment that the smart mirror will exist in, which is important and the smart mirror will have to be designed to accommodate its surroundings. The other environmental constraints the group needs to take into account are the physical impacts to the earth's environment as a whole. We deal with many issues in the world today that need to be addressed.

Not only is it ethical to consider these things when designing a new product, but it is also valued by many consumers, and companies that take these issues seriously are elevated over the others. Both of these things are addressed below.

The environmental constraints of the mirror depend on where it will be placed knowing that mirrors are typically placed and used in two places in the bedroom or bathroom. We placed our constraints with these two environments in mind.

Knowing the bathroom will be an environment where water will be heavily present, we must make sure the mirror will have any exposed wire in case of any water contact also the bathroom is an environment with high humidity so the inside of the mirror should be properly sealed and insulated to avoid any damage from humidity. The material that the frame will be made out of should be resistant to humidity or not effected so no water damage can occur on the frame.

A bedroom environment is also an environment that the group must take into consideration. A bedroom is a place where an individual there can be stray noises from people or other devices and movement from other people or even animals the mirror should be able to differentiate between stray movement and sounds and purposeful commands.

In terms of environmental impact, the groups smart mirror will attempt to have as little impact as possible. The smart mirrors design components have been designed to use as little power as possible which will lower the amount of power pulled from the electrical grid while still giving the user a good experience. The components selected for this project have also been selected with power draw and efficiency in mind.

The project was also designed with the avoidance of batteries. Modern day batteries have a very large impact on the environment when created, and this impact would be multiplied with the usage of disposable batteries. Instead of deploying a battery-based solution the group will be creating their own efficient AC to DC converter and power supply that will operate on the homes already existing power grid.

The vanity lighting chosen for use in the project has been done with all LED lighting. LED lighting is far more efficient and better suited for the project. This will further assist with the groups mission to lower the power draw of the smart mirror to the lowest level possible.

In today's world we are dealing with a large amount of trash, much of this trash is electronic waste and it is rarely recycled. In order to reduce this impact new technology that is created should really be built with minimal materials that will end up as permanent. The smart mirror should also be built to last a long time.

Modern technology is built to be used for a year or two and then be replaced. The group hopes to make something more modern, something that can be upgraded via software remotely to extend the lifespan of the smart mirror as long as possible.

The smart mirror will also contain minimal plastic components, with the bulk of the frame being built out of wood, which is a biodegradable. This means that even if the end user doesn't properly dispose of the smart mirror, as many people don't, and it ends up in a landfill the environmental impact will be minimal.

If the groups smart mirror was to be produced in future it would also be a fantastic idea to give users the proper information on how to recycle the smart mirror once it has reached the end of its life cycle. This is something many companies are doing now to help provide a positive environmental impact.

This could not only positively impact the environment but could also impact the future producer of the smart mirror in a positive way by providing good press, and maybe even providing recycled components at little to no cost that could be used in the next generation of smart mirrors.

4.1.4 Ethical and Safety Constraints (Axel, Tyler)

User privacy is a hot topic in the modern age of technology. Data collection is a common practice by post tech companies. User data is valuable to advertisers who seek to market their products to as relevant an audience as possible. As of now, this project involves recording user audio, and video. However, we believe that our implementation of these features is ethical.

Camera feed will only ever be used locally to identify the user, it has no function aside from that. It would be possible to implement a camera cover in the final design. Or even have the LEDs on the frame change color to red only when the camera is in use, so that the user is always aware of when the camera is on.

User audio, however, is sent to the google speech API in the cloud. What google decides to do with that audio file is out of our control. It is up to the user to decide if they believe it is worth it to use our product knowing that their audio information is being sent to Google’s cloud service. It is relevant to note however, that the average user trusts their data with google every single day, assuming they use their services and products regularly.

A safety constraint of this project is the use of the groups own power distribution system. In order to show that the group members have the knowledge and skills necessary to fully develop a product the group has elected to develop its own AC to DC power converter, as well as its own power distribution system.

With this in mind the group will be tapping into and using 120VAC and doing a lot of conversions into various DC voltages, meaning there is a risk involved. For our project to be safe for normal users to plug into their homes and leave plugged in at all times while home, away, or even sleeping these circuits need to be safe.

This means the power supply and converter, as well as any other circuits designed inside the smart mirror, must be thoroughly tested, and have proper safeguards in place to prevent hazards such as fire or electrocution of the user. These safeguards should also be in place to protect the users home electrical system, as the last thing we would want would be to damage a person’s home with our design.

4.2 Standards

This section details all the standards applicable to the groups smart mirror project. All of these standards have either been chosen by the group to ensure conformity with other devices and connections or are a requirement to be used because they are already on board components the group has chosen to use. For both of these cases the standards used have been explained below.

4.2.1 Wi-Fi Standard (Axel, Tyler)

IEEE 802.11, better known as WI-FI, is a standard set by the Institute of Electrical and Electronics Engineers (IEEE). This standard allows any device with a stable internet connection to wirelessly communicate with one another regardless of manufacturer. The standard has many designations, the designations are as follows 802.11a, 802.11b, 802.11d, 802.11g, 802.11n. These designations can also be combined to indicate the support of both standards on one radio.

Devices WIFI compatible must network through wireless access points in order to establish a connection. This Wireless Access Point (WAP) not only allows said device to interact with other WI-FI enabled devices, but also allows seamless transmission to devices connected to the internet via Ethernet. This technology is reliant on radio waves.

The micro-computer contains a wireless radio that follows the IEEE 802.11ac standard. This standard is commonly referred to as Wi-Fi 5 and was first introduced in the year 2012. This standard allows for multiple frequencies detailed below and can support up to 1300 Megabits per second on the multi stream, higher speed, and lower range 5 Gigahertz band. The maximum data rate for a single stream connection on 802.11ac is 450 Megabits per second, which is still plenty enough bandwidth for most usages.

The IEEE 802.11ac standard is more than enough to accommodate the connectivity requirements of the groups smart mirror. The only widely used standard faster than the Wi-Fi 5 802.11ac standard is the Wi-Fi 6 802.11ax, this standard is exceptionally faster when compared to Wi-Fi however it is only now coming into mass use and is far faster than required for the smart mirror as the only speed intensive applications that will be used will be streaming High Definition YouTube content.

The most common radio band rates for Wi-Fi are 2.4 Gigahertz and 5.0 Gigahertz. The Raspberry Pi 4 is equipped with a module that allows it to take advantage of either band rate. Which band rate is used is entirely dependent on the access point used at the time. WI-FI in this project will be used to connect to API's to collect data that will be displayed to the user on the mirror. This data includes weather information, and basic news headlines. Our project adheres to guidelines for WIFI set by the IEEE as the Raspberry Pi has been manufactured with a chip that is Compliant with these standards.

All of the different IEEE Wi-Fi standards are backwards compatible as well. So regardless of the new technologies present the smart mirror will always be able to connect to the user's wireless network as long as Wi-Fi continues to be the primary wireless internet connectivity standard present in people's homes. So when the Wi-Fi 15 standard comes out boasting Terabit per second data transfer speeds the groups smart mirror will still function just fine.

Figure 50 - One of The Many Wi-Fi standard indicators

4.2.2 Bluetooth Standard (Axel, Tyler)

Bluetooth is a standard created by IEEE initially defined under IEEE 802.15.1 but since taken over by another entity known as Bluetooth SIG. The standard is used as a short range low power data transmission. The transmission power of Bluetooth is limited to only 2.5 milliwatts, hence the short range it has. In order for a device to become listed as Bluetooth compatible it must meet the latest standard.

Figure 51 - Bluetooth Standard Identifier

Raspberry Pi 4 is equipped with Bluetooth 5.0 compatibility. This allows the group to meet the Bluetooth standard by default as the micro-computer has already been through the standard verification process. Bluetooth is a wireless technology that allows compatible devices to exchange data via UHF Radio Waves. This allows many different devices, from mobile phones, to speaker, to even refrigerators, the ability to communicate with one another wirelessly.

However, Bluetooth is a “very” short-range technology, operating at a maximum of 30 feet. This is not a problem for something like a smart mirror, that will at furthest will interface with something across a bedroom. The Bluetooth standard is maintained by Bluetooth Special Interest Group (BSIG). Any device marketed as a “Bluetooth Device” must meet standards established by BSIG. By our project being dependent on the Pi for its Bluetooth functionality, it must meet and abide by the standards set by BSIG.

The utilization of Bluetooth in this project would allow the Magic Mirror to act as somewhat of a smart home device. A more mature smart mirror would be able to connect to mobile phones to cast multimedia content onto the mirror. While also connected to a Bluetooth speaker the mirror could play the video content on itself and play any audio content through the connected Bluetooth speaker.

In theory the mirror could be used to control many popular smart home devices. If the API's are publicly available, the smart mirror could interface with devices such as smart light bulbs, to conveniently control the color or intensity of the light in one's bedroom with only a simple Speech command prompt given the smart mirror. Bluetooth with the smart mirror creates the opportunity to wirelessly connect and even automate parts of a person's day to day life.

Figure 52 - Example of a popular Bluetooth enabled speaker

Bluetooth itself as a communication standard consists of 4 different layers. It has an application layer that carries the applications and profiles for the standard. The middleware layer that contains things such as audio, control, discovery data, telephony data, RF data, and protocol data. The data link layer which contains the baseband information, and lastly the physical layer which has the physical radio information. All of this together forms the information passed between Bluetooth devices and is the actual protocol that is Bluetooth.

4.2.3 Three Prong Plug Standard (Tyler)

The plug options for this project are limited to the 2 120V plugs used in the United States. The first plug option is the Type A ungrounded two prong plug, governed by NEMA standard 1-15. This plug is polarized and is used in most applications that don't require a direct connection to an earth ground. Examples of this plug being used are most small device chargers, and other small electronics that rely on their own board ground more than a real earth ground.

The second plug option is the Type B grounded 3 prong plugs. This standard is governed by NEMA 5-15 and will be the one used for this project due to the advantage of the added earth ground. This will make our power supply cleaner and safer. The connector has 3 prongs, two blades and ground pin. One of the two blades, the taller of the blades is the neutral connection, and the short blade carries the hot AC current. The standardized plug is rated for up to 15A and 125V volts. For the smart mirrors application this works perfectly as we will be using it with standard US 120V 60Hz connections, and the smart mirror will require much less than 15A.

Figure 53 - NEMA 5-15 3 Prong Plug

If the group wanted to make the smart mirror available for use in other countries two things would be necessary. Firstly, the plug would have to be changed out for a plug standard used in the given country, this would be simple as plug standards exist for all countries with standardized power grids like the US.

The second thing that would have to happen would be the adaptation of the power converter and distribution board. This will be covered in a future section, but to put it simply a power converter would have to be used to change the input power to the US standard, which is not always possible. Or the power distribution board and converter would have to be totally redesigned with the new electrical standard in mind.

4.2.4 Universal Serial Bus Standard (Tyler)

USB stands for Universal Serial Bus and is an industry standard for connectors, cables, and communication developed and maintained by the USB Implementers Forum, a non-profit corporation dedicated to advancing and standardizing the USB standards. They can be found at usb.org.

The USB standard has many sub standards for cables and connector types, some of these are USB 1.0, USB 2.0, USB 3.0, and USB 3.1. The numbering standard on USB cables is dedicated to the data rate, with cables on the 1.0 standard being capable of transmitting 12 Megabits per second, and the 3.1 standard capable of an astounding 10 Gigabits per second.

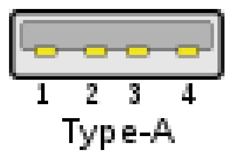
For this project the group does not need the large data rate of the newer and more complicated cables, therefor we will be using the USB 2.0 standard, which is capable of sending and receiving up to 480 Megabits per second. All of the new USB standards are backwards compatible, meaning a USB 2.0 cable can be plugged into a USB 3.0 port and operate just a it would if it was a USB 2.0 port. This means that the micro-computers 2 USB 3.0 and 2 USB 2.0 ports can all be used for our USB 2.0 devices.

The next level of standard in the USB library that must be decided on is the connector standard. This standard is determined using letters. Some of the available standard connectors are Type-A, Type-B, Type-C, as well as mini and micro versions of the aforementioned types. For our application the connector standard will be based on the equipment we are using, the micro-computer, speaker, camera, and microphone.

These components all support and use the USB 2.0 standard and deploy Type-A connectors. Therefor the USB 2.0 Type-A standard will be selected. This is a shielded 4-pin connector and cable carrying a power, ground, and two data connections that can transmit 480 Megabits per second using half-duplex communication. It uses a 5VDC signal and can transmit a maximum of 5.5VDC, at a maximum current of 0.5 amps. For the groups application of connecting speaker, camera, and microphone components to the micro-computer this standard is perfect.

Pictured below is a 4-pin USB 2.0 Type-A cable that will be used in connecting various components of the smart mirror.

Figure 54 - USB 2.0 Type-A Connector



4.2.5 US Voltage Standard (Tyler)

The United States and Canada have both standardized their power grids and what is delivered to individual homes. Power from the grid, generally found around 10000VAC to 20000VAC, most commonly in the US 15000VAC, at the nearest substation is delivered to homes in the form of 240VAC. The massive voltage from the substation goes into a local 240VAC center tapped transformer and from the transformer provides the individual home with 3 legs for usage.

The first leg is a 120VAC hot leg, the second is a 120VAC hot leg that is 180 degrees out of phase from the previous, and the third is a neutral leg. For normal applications one of the hot legs and the neutral are used to provide 120VAC to standard devices in the house such as the groups smart mirror. The other option provided in the home for heavier duty equipment such as an oven is 240VAC, this is provided by using the two 120VAC legs and the neutral.

For the smart mirror this level of voltage is not necessary. The other aspect of the standard is the cycle amount, otherwise known as the number of times the alternating current switches poles. The standard for much of the world is 50Hz or 50 cycles, the United States and Canada however utilize 60Hz or 60-cycle power.

This must be taken into account for our project and the AC to DC converter must be designed for use with 120VAC 60-cycle. If the smart mirror was to be used in another country this would have to be adjusted, or an AC-to-AC converter would have to be placed before the 120VAC 60-cycle input.

4.2.6 Display Cable Standard (Tyler)

For this project we are limited in what means we use to transmit data to the display. The micro-computer only has a single display output connector option, this connector option uses the HDMI standard, specifically the micro-HDMI port.

HDMI stands for High-Definition-Multimedia-Interface and was created by a group of 7 companies together and today is governed by the HDMI Forum, a group of 83+ companies. Like USB the HDMI standard has numeric versions which governs the cables data rate and alphabetic labels for connector types.

The cable versions range from version 1.0 through the latest which is version 2.1. The HDMI standard used by the micro-computer is version 2.0. This version is capable of transmitting 18 Gigabits per second, has support for four different color formats and depths, as well as 9 different color spaces.

The HDMI standard is also capable of simultaneously transmitting audio data. The audio sample rate for version 2.0 is capped at 192,000 Hertz per channel and can carry up to 32 different audio samples. This is not required for our usage as audio will be carried through USB and fidelity is not a requirement for the smart mirror's basic speaker, however it is impressive.

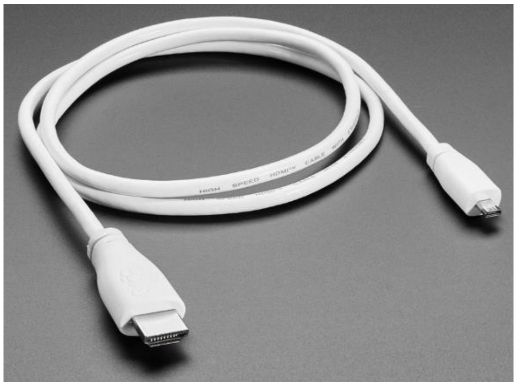
In terms of connectors the HDMI standard has five different options, the Type A, Type B, Type C, Type D, and Type E. For use with the smart mirror, we will be using 2 different types and deploying a conversion cable to connect the two types. Both of these types have the same standard 19-pins on them but have different pin assignments.

The first type being used is the Type D, otherwise known as Micro-HDMI. This connection is present on the micro-computer. The other connector type that will be used is the Type A connection. This is the connection most people think of when HDMI is mentioned and has been the most used display connector since the rise in popularity of HD video and displays. The Type-A will be used on the end of the display for the smart mirror, as almost any HD display found will support it.

Other display connector and cable standards exist however none are as versatile and widely used as HDMI. These other connectors also would have required some form of active adapter due to the fact that the only option on the micro-computer is micro-HDMI. Making HDMI the clear best choice for a display connector standard.

The only other real options are Display port, commonly found and available for computer monitors and supportive of high resolutions and refresh rates, a limit we will not reach using HDMI for this project. Another standard used is Digital DVI. This technology is much older and was not considered for use in this project. It is mainly found on computer monitors but is slowly being phased out in favor of Display port and HDMI standards.

Figure 55 - Micro-HDMI to HDMI Cable



In between these two devices will be male Type D Micro-HDMI to male Type A Standard HDMI cable. This cable can be seen in the figure above. Due to the nature of the two connector types the cable is one to one in terms of pins, the pin locations differ but nothing is required in between them to redirect signals.

4.2.7 Power supply standards (Jonathan)

It is important to understand and comply with the safety standards of the power supply. The reason is we are handling high ac voltage that is coming from the wall outlet. Following the safety standards help prevent harm to users, the environment and the device and all of its components. If the device were to be on the market it would have to follow the safety standards. Power supply circuits can be defined as

Hazardous Voltage

Is a circuit that has a voltage exceeding 42.2 Vac peak or 60 Vdc and does not have a limited current circuit.

Extra-Low Voltage (ELV)

Is a secondary circuit that has a voltage not surpassing 42.2 Vac peak or 60 Vdc and is separated from the primary hazardous voltage by at least basic insulation.

Safety Extra-Low Voltage (SELV) Circuit

A SELV is when a secondary circuit is at a low voltage that cannot be potentially lethal if one gets shocked the circuit must be separated from earth ground and isolated from the primary high voltage circuits by two layers of insulation SELV circuits cannot be greater than 42.4 Vac peak or 60 Vdc for longer than 200 ms. An absolute cap of 71 Vac peak or 120 Vdc must not be exceeded.

Limited Current Circuits

These circuits are defined by the same rules as the SELV circuit but the voltages surpass the limits of 42.2 Vac peak or 60 Vdc to keep it from becoming hazardous

Limits are placed on the current these limits are:

- Frequencies less than1 kHz the current drawn at steady state should not surpass .7 mA peak ac or 2 mA
- Frequencies more than1 kHz the current drawn at steady state the limit of 0.7 mA is multiplied by the frequency in kHz but will not exceed 70 mA
- Accessible parts of the circuit will not be surpassing 500 Vac peak or 1500 Vdc the maximum stored charge allowed is 45 µC and the available energy will not be above 350 mJ.

Limited Power Source (LPS)

LPS circuits are least likely to cause electrocution or a fire the reason for that are the limits being placed on the output current and voltage that will be delivered to the load the power supply can be limited by the components being used in the making of the power supply such as winding resistance of the transformer. The use of a linear or nonlinear impedance can help with power limiting. using a regulating network by using voltage regulators can also limit power. Power supplies certified as LPs must have these limits:

- DC voltage less than or equal to 30 Vdc or substantially sinusoidal ac voltage less than or equal to 30 VACrms
- Maximum short circuit current of 8 A
- Maximum VA of 100
- Maximum marked output power rating of 5 A * Voc
- Maximum marked output current rating of 5 A
- DC voltage with ripple greater than 10% of the peak or non-sinusoidal ac voltage
- Maximum peak voltage of 42.4 V
- Maximum short circuit current of 8 A
- Maximum VA of 100
- Maximum marked output power rating of 5 A * Voc
- Maximum marked output current rating of 5 A
- DC voltage greater than 30 Vdc and less than or equal to 60 Vdc
- Maximum short circuit current of 150 VA/Voc
- Maximum VA of 100
- Maximum marked output power rating of 100 VA
- Maximum marked output current rating of 100 VA/Voc

The Power supply that was designed for the mirror fall under the Safety Extra-Low Voltage (SELV) Circuit the maximum voltage output of the secondary circuit is 12 volts dc this meets the requirements of the supply not being over the 42.2 Vac peak or 60 Vdc limit the Power supply board is also isolated from the conductors of the systems on the board. The power supply will not have any earth connection and will be placed in the mirror with basic Power supply and will also be double insulated. It will be contained in the mirror in its own plastic casing and the power cord of the device will also be insulated.

IEC Power supply Standard

One of the main agencies that is responsible for electrical safety standards is The International Electrotechnical Commission (IEC) the standards they create help maintain quality and safety. These standards are a consensus of knowledge from thousands of technical experts across the globe them. Guidelines they provide are used to install, certify, design, manufacture, maintain and repair electronic devices and systems

IEC 62368-1

IEC 62368-1 is the hazard-based product-safety (HBSE)standard for ICT and AV equipment under the scope this also includes consumer electronics such as the mirror and also power supplies

4.2.8 PCB standards (Jonathan)

IPC PCB standards

The Institute for Interconnecting and Packaging Electronic Circuits (IPC) is a global trade association and their goal is to standardize the production and the requirements IPC standards are widely used across the electronics manufacturing industry.it is important to understand these standards the reason being is that the PCB is an integral part of the project and in the industry.

IPC-2221

The IPC-2221 covers the generic standard of PCB design; this standard specifies on certain design requirements of the PCB board; these requirements include thermal management of the board, how the design will manage and dissipate heat. The standard specifies on requirements regarding the material being used on the board such as plating and the substrate. It also specifies on conductor spacing values

IPC-2222

IPC-2222 specifies on the requirements for the design of rigid organic printed boards this standard applies multilayered boards the main components that IPC-2222 specifies on are

- Properties of Rigid Laminate
- Printed Board Assembly
- Holes/Interconnections
- Dielectric Spacing
- Lead-free Laminate Materials
- Routing Parameters
- Nonfunctional Lands
- Hole Aspect Ratios
- Clearance Areas in Planes
- PCB Thickness Parameters
- Tolerance of PCB Thickness

IPC-2223

IPC-2223 specifies on the requirements of flexible design on the PCB board this includes component mounting and there interconnecting structures the main components that IPC-2223 Specifies on are

- Control of impedance and capacitance
- Vias and micro vias filled with copper
- Selective plating
- Edge Conductors
- Minimum Bending Tolerance of Flexible Circuits with Coverlay

5. Project Design

This section will be dedicated to the design process of the smart mirror. Included in this section is all elements of hardware design including schematics and breadboard testing, as well as software design and testing.

5.1 Hardware Design

This section includes the design of each hardware element in the project. Included in this section are images of hardware elements and there individual schematics, as well as details on the inner-workings of all hardware pieces used in the groups smart mirror.

5.1.1 Vanity Lighting System (Tyler)

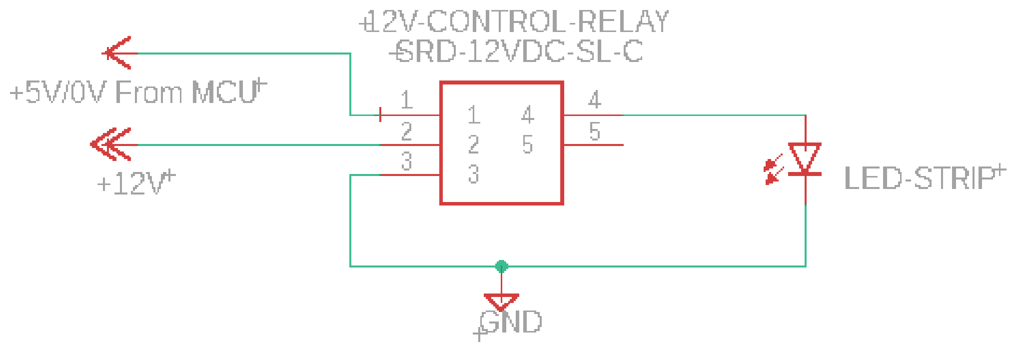
Figure 56 - LED Strip 12V Connection

The lighting system will need to be able to be turned on and off either by the user or in an automated fashion when the user approaches the mirror. This functionality will be primarily controlled by the MCU. When the user is sensed by the PIR sensor the lighting will be turned on. Each time the user is no longer sensed the lighting will wait for a minute and then turn off if the user isn't sensed again.

The micro-controller can output up to 5VDC on its GPIO pins. So, this won't be enough to power our 12VDC LED lights chosen for our vanity lighting. To make up for the low voltage output of the micro-controller this process will be accomplished using simple 5VDC high/low signals from the micro-controllers GPIO pins.

The high or low signal will be sent to a 5-pin 12V relay and will be used to actuate the relay. A 12VDC line will be provided for the micro-controller and LED's and be aloud to pass through the relay and into the LED strip.

Figure 57 - LED Control Design Schematic



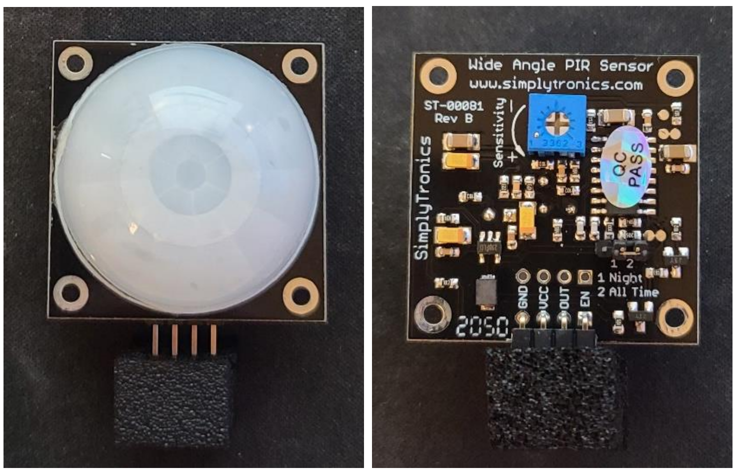
The on and off portion of the LEDS will be handled using a momentary push button switch like the one shown below located on the mirror frame. The micro-controller will store the current state of the user's lighting preference on or off, defaulting to on if rebooted. If the momentary switch is pressed the MCU will take in a high signal on one of its GPIO pins instructing it to update the current state to the next state.

The high or low signal mentioned in the previous paragraph will remain low if the user has selected the off state and will operate as normal turning on and off automatically based on the presence sensor if the saved state is on.

This concept was tested using a singular led and a 5V relay to ensure it could be done. Next it will be tested with a 12V source and relay with the entire led light strand to ensure the design will work in the project practically.

5.1.2 User Presence Circuit(Tyler)

Figure 58 - 180 Degree 4-pin PIR Sensor F/B



The presence circuit is simple physically, the real application of this part is mostly programming. The sensor has its own PCB with adjustable sensitivity and light settings. For this project we will be using the “All Time” light sensitivity setting and adjusting the overall sensitivity as needed come final assembly. The sensor has a 4-pin connector, a ground, a VCC in, a HIGH/LOW signal output to indicate motion detected, and an enable pin. This sensor is capable of detecting 180 degrees around it and can sense things over 30 feet away depending on the sensitivity adjustment. The sensor has been tested using some simple Arduino code shown below and functions as expected, quickly sending a HIGH signal whenever something comes into the sensor’s detection radius.

Figure 59 - 180 Degree PIR Sensor Test Code

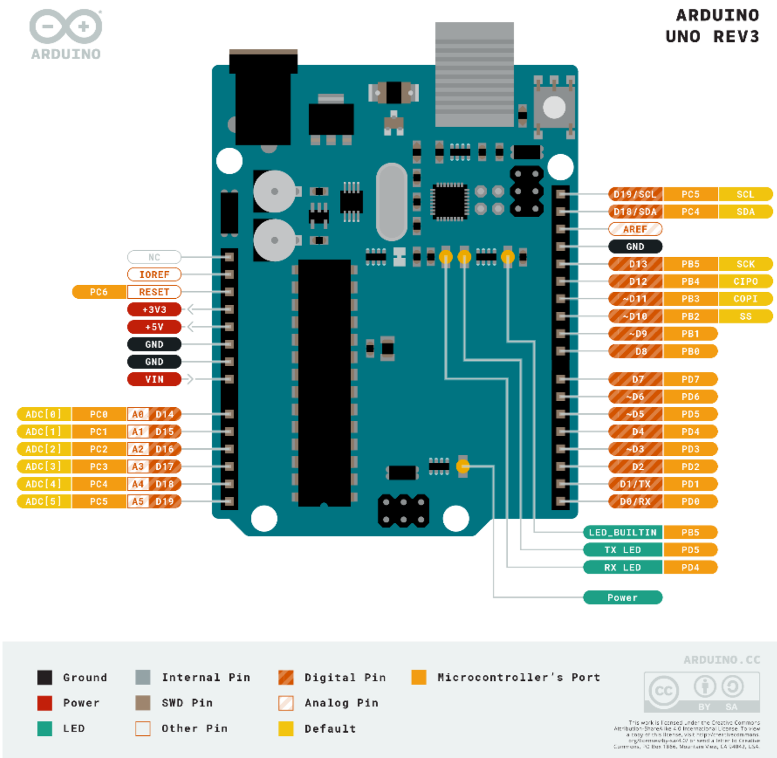
```
PIR_Sensor_Test
const byte ledPin = 7;
const byte motionPin = 3;

void setup()
{
  Serial.begin(9600);
  pinMode(ledPin, OUTPUT);
  digitalWrite(ledPin,LOW);
  pinMode(motionPin, INPUT);
}
void loop()
{
  if(digitalRead(motionPin)==HIGH){
      digitalWrite(ledPin, HIGH);
      Serial.println("motion detected");
      delay(1000)
      digitalWrite(ledPin, LOW);
      }
}
```

The test was a good proof of concept and shows that all the equipment is working as expected. The light went on and off each time the sensor was tripped.

5.1.3 ATMega328P (Tyler)

For this project we have chosen to go with the ATMega328P micro-controller, a low-power Arduino based chip that has all the capability we could possibly need. For prototyping purposes, we have chosen to go with the Arduino Uno Revision 3. The uno is one of the most popular and widely used development boards in the Arduino space. It has many libraries available and can be hooked up to just about anything in the micro-controller space due to its popularity. The board features 14 digital GPIO pins that can be setup for input or output for HIGH or LOW communication. It also features 6 pins that can be used for analog input, 4 of which can be configured to be 4 more digital GPIO pins. The board pinout is pictured below.

Figure 60 - Arduino Uno R3 Pinouts:



Featured on the Uno development board is the ATMega328P in its 28-Pin Narrow Dual In-line package (DIP-28N) format, identified as the ATMega328P-PU. For our project in the event, we moved from prototype and chose to develop a board the ATMega328P could be moved onto a custom PCB by simply including a standardized DIP-28N connector, with soldering required. In the event space was a concern the ATMega328P micro-controller comes in many different pin and package configurations. For our project it is not believed at this time that space, in this capacity, is something we are short on, the back of the mirror frame will provide ample space to mount and hide the various boards on this project, so currently the DIP-28N package will be chosen.

Figure 61 - ATMega328P-PU DIP-28N Schematic

To run the ATMega328P on its own board, which will be done for this project due to the design required as well as the large advantage in power savings, it will need to be bootloader and some external parts will need to be added.

For the boot loading the easiest solution is to program and load the ATMega328P using the Arduino Uno and it's on board solution, since the group has chosen to go with the dual in-line package variant of the micro-controller it can be loaded on the Uno and transferred to the new printed circuit board without requiring any extra connections on the printed circuit board. This will save space on the board, make things less cluttered and complicated, save design time, and save money on small board components.

Another element that is not required but could be added for stability is an external clock. The Arduino Uno deploys a 16 Mega-Hertz crystal oscillator and the ATMega328P can use an external clock of up to 20 Mega-Hertz. The main advantages of using an external clock are added stability, faster clock speeds, and better I2C communication. At this time the group doesn't expect to use I2C on the ATMega328P, but it wouldn't hurt to have. The only downside to using an external clock is increased power consumption. Given the above information the group has chosen to go with a 16 Mega-Hertz External clock. It could save time in the long run if I2C ended up being used and will make the micro-controller much more reliable.

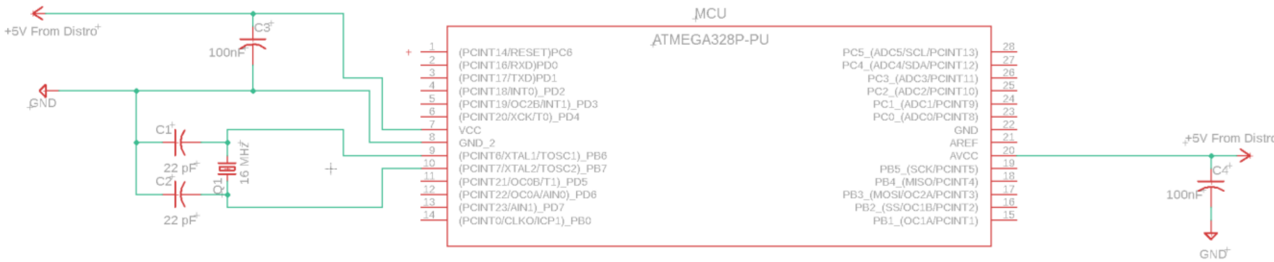
Adding an external clock to the ATMega328P a 16 Mega-Hertz crystal and 2 capacitors are used. It is recommended by Arduino to use an 18 picofarad to 22 picofarad ceramic capacitor. The crystal and capacitors are connected across pins 9 and 10 on the ATMega328P, pins 9 and 10 are also labeled as XTAL1 and XTAL2 when used this way.

Once the external clock has been connected the only other things necessary for the Micro-Controller to function standalone without the development board is the power and ground. The ground will be connected to ground and pin 7, the VCC pin gets connected to the 5V source. A 100 nano-farad de-coupling capacitor was added to make sure clean power gets to the micro-controller from the 5V railing coming from the power distro.

The AVCC pin, pin 20, is used to power the analog components of the micro-controller, for this project it is not necessary but will be powered from the 5V source with another 100 nano-farad de-coupling capacitor. Generally, an inductor would be used before the source voltage gets to the AVCC pin, however this is just for ADC accuracy and noise prevention. The ADC is not necessary for our application and is only being powered to prevent the parasitic power draw on the digital side that can occur when leaving the analog side unpowered.

Below is the schematic for the ATMega328P with all connections necessary to run it alone without the Arduino Uno development board.

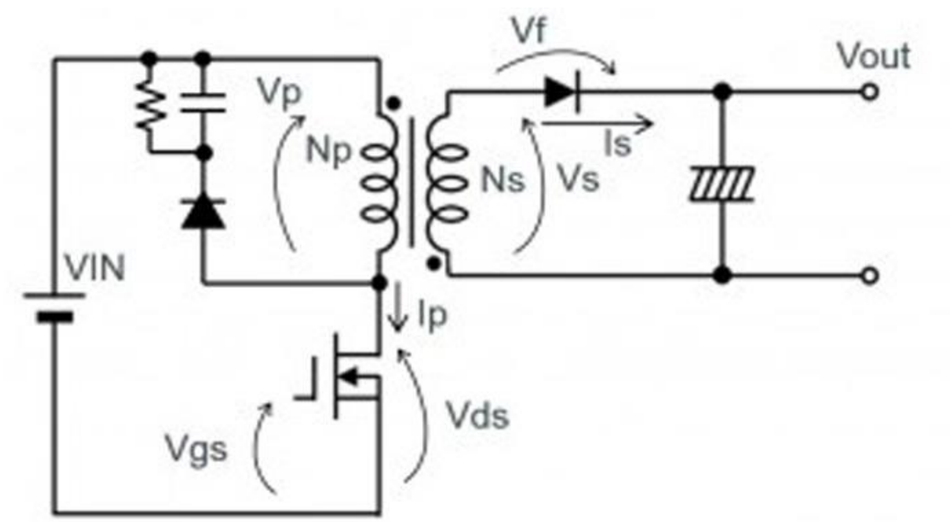
Figure 62 - Standalone ATMega328P Schematic



5.1.4 Power Supply Design (Jonathan)

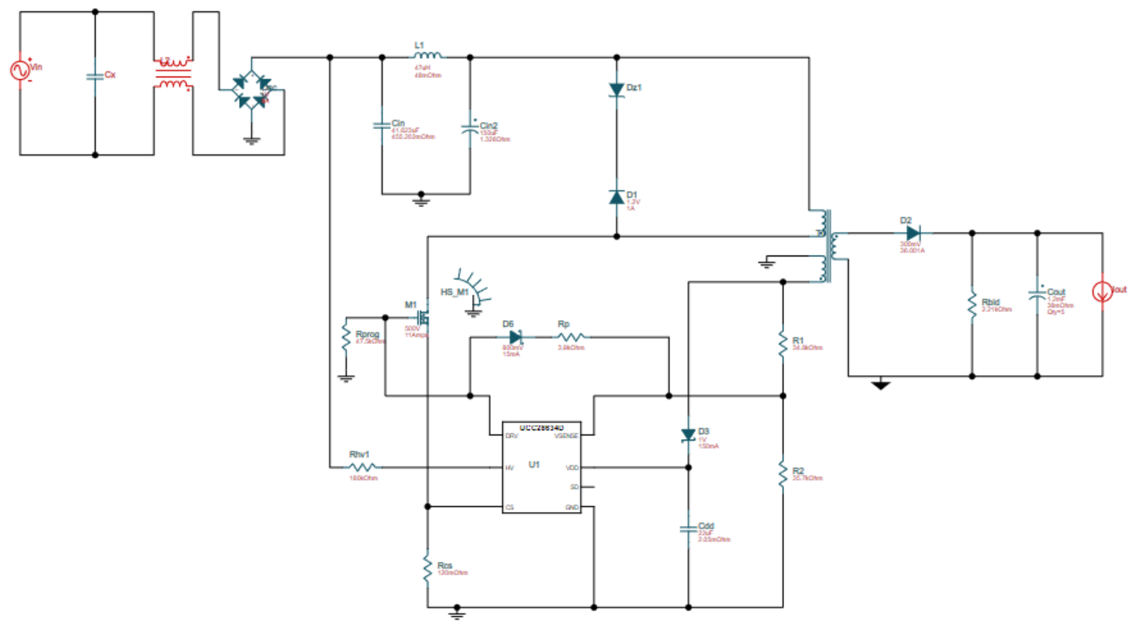
Flyback power supplies are a switch-mode power supply the way flyback supplies are designed. Power from the input is transferred to the output during the off-time of the switch. They are used for devices using around 100 watts which is in spec with our project the benefits of the flyback supply is that it has a low part count the main components of the flyback supply are input capacitor, a primary site switch, MOSFET, flyback transformer which is a coupled inductor, an output rectifier, and an output capacitor. The primary input is separated from the output which is beneficial for safety reasons: the supply can have high voltage isolated on one side of the supply and low vow voltage on the other. protecting components from damage. Because of the isolation of the primary this allows the flyback to also be able to supply multiple output voltages. The Flyback can function on a wide range of input voltages and can be regulated with a single control.

Figure 63 - Flyback Transformer



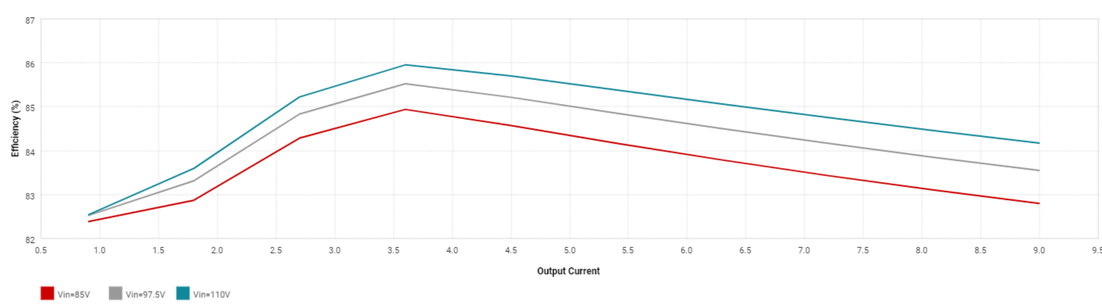
The flyback transformer shown in the image above acts as two coupled inductors. The flyback transformer is designed to store energy unlike the regular transformer; the core of the flyback transformer contains an air gap where energy is stored while

Figure 64 - Flyback Power Supply



This is the schematic shows the Flyback power supply that is going to be used to power all the components of the mirror. This power supply can take input of120 Ac volts and output 12 volts and 9 amps the main component of the power supply is the UCC28634, High-Power Flyback Controller with Primary-Side Regulation and Peak-Power Mode the UCC28634 sits in the primary side of the flyback converters. Which is usually the high-power side. The UCC28634 can work in two modes: the CCM (Constant-Current mode) and DCM (Discontinuous Conduction Mode). The system is 82.8% efficient

Figure 65 - Power Supply Simulation



Simulated Power Supply Testing:

Table 19 - Simulated Testing Data For PSU

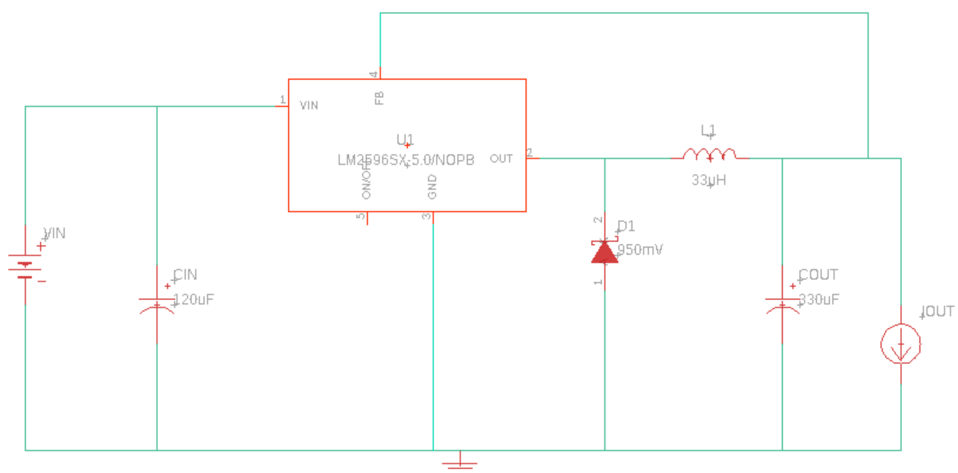
Name	Value	Category	Description
Vi Peak Rectified Vin	**120.21 V**	System Info	Peak voltage seen at rectified input
Min Rectified Vin	**72.12 V**	System Info	Minimum voltage seen at rectified input
Efficiency	**82.80%**	system Info	Steady state efficiency
Frequency	**60 kHz**	System Info	Switching frequency
Duty cycle	**63.13%**	System Info	Duty cycle
Vout p-p	**272.98mV**	System Info	Peak-to-peak output ripple voltage
Vout	**12V**	System Info	Operational Output Voltage
Total Pd	**22.44 W**	System Info	Total power disapation
Pout	**108W**	Power	Total output Power
Iout	**9A**	System Info	Iout operating point
Iocc	**16.91 A**	Systen Info	Constant Current Limit
BOM Count	**26**	System Info	Total Design BOM count

To create the 5 volt and 3-volt rails to power the devices in the mirror a Dc-to-Dc step down converter (Buck converter) will be used. Buck converters are a type of switched power supply usually containing a diode and a Transistor. For energy storage the Buck converter will have a capacitor or a resistor. Capacitors and resistors will also be used to filter out the excess noise reducing voltage ripple. The buck converter is more power efficient than regular linear regulators.

Linear regulators are less complex than Buck converters. Linear regulators are less efficient because the voltage is lowered by dissipation of heat. Buck converters have an efficiency of around 90%. In the Buck converter circuit, the switching transistor rapidly switches on and off at a high frequency to keep the output constantly flowing to the load without interruptions; a flywheel circuit is used.

The flywheel circuit consist of an inductor and a capacitor to store energy and a diode when the transistor is on the inductor is being charged with the current and the capacitor is also being charged also the load is being supplied power. The diode will not be in use at this point because the of the positive voltage acting on it the diode will be reverse biased. When the transistor is on its off state the e.m.f field of the inductor starts collapsing and reverses the polarity of the voltage across the diode is now forward biased completes the circuit and allows current to flow and prevents voltage spikes caused by the inductor. The capacitor and inductor supply current to the load while the transistor is off.

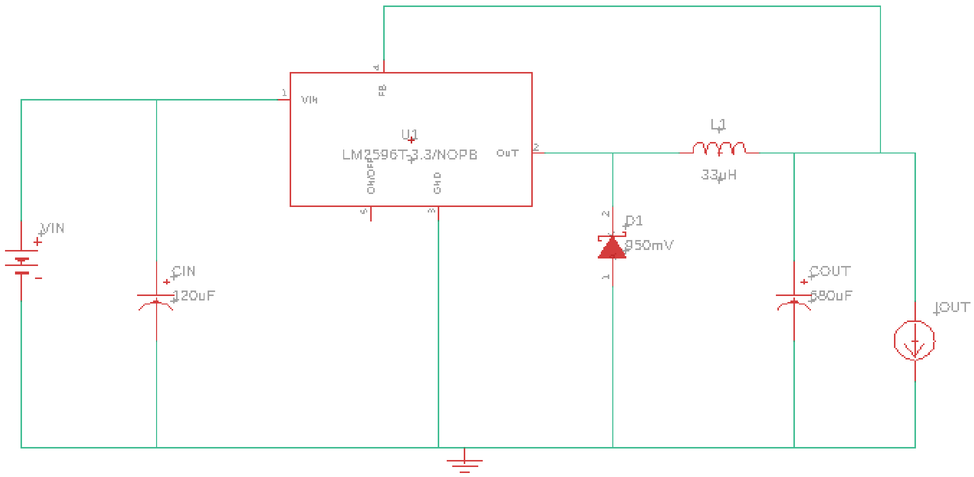
Figure 66 - 5-volt rail



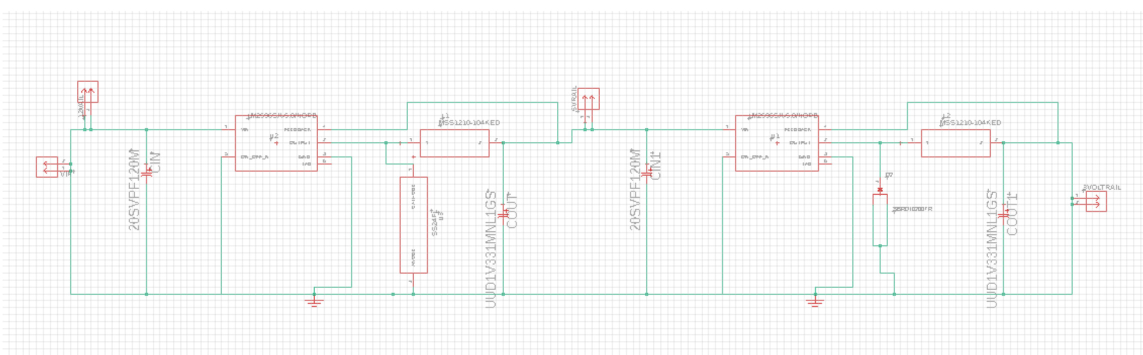
This circuit will be used to make the 5 volts rail this circuit will be placed at the end of the 12-volt power supply it drops down 12 volts to 5 volts using LM2596(5 volt) SIMPLE SWITCHER Power

Converter. The LM2596 is a buck converter this IC was chosen because it can handle an input voltage of 40 volts and outputs the 5 volts and 3 amps need to power devices in the mirror based on the data sheet this device requires four external components to function the 120 µF capacitor to smooth out he the input voltage signal and the output of the IC will contain a flywheel circuit consisting of a 33µH inductor, 330 µF capacitor, and a 950mV diode.

Figure 67 - 3-volt rail



This circuit will be used to make the 3 volts rail this circuit will be placed at the end of the 5-volt rail circuit it drops down 5 volts to 3.3volts using LM2596(3.3volt) SIMPLE SWITCHER Power Converter. The LM2596 is a buck converter; this IC was chosen because it can handle an input voltage of 40 volts and outputs the 3.3 volts and 3 amps needed to power devices in the mirror. based on the data sheet this device requires four external components to function the 120 µF capacitor to smooth out he the input voltage signal and the output of the IC will contain a flywheel circuit consisting of a 33µH inductor, 680 µF capacitor, and a 950mV diode.



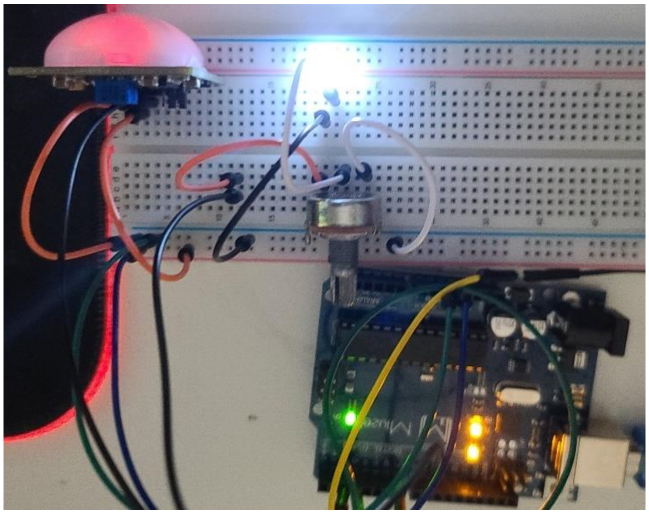
5.2 Breadboard Testing

This section is dedicated to documenting the physical testing of the circuits designed by the group. It will include images, explanations, and testing data.

5.2.1 Presence Subsystem Testing (Tyler)

In order to test the functionality of the presence sensor a circuit was setup prior to designing a printed circuit board. This was also necessary in order to test components in their individual subsystems prior to connecting them all together.

Figure 68 - Presence Sensor Breadboard Circuit



The presence sensor functionality was tested over a variety of angles and distances to ensure proper functionality once attached to the smart mirror. The table below details 20 separate tests performed using the above breadboard and the test code from section 5.1.2.

The tests cover all relevant angles and distances from the sensor that the group feels the mirror should be capable of sensing. If the attached LED Light turns on the test will be considered a pass as it indicates the presence sensor has sent a high signal to the Arduino Uno test board. If no light is shown the test has failed and will be labeled as such.

Table 20 - Presence Sensor Subsystem Tests

Degrees From Center	3 Foot	6 Feet	10 Feet	16 Feet
90 Degrees Left	Pass	Pass	Pass	Fail
	Pass	Pass	Pass	Pass
	Pass	Pass	Pass	Pass
90 Degrees Right	Pass	Pass	Pass	Pass
	Pass	Pass	Pass	Pass
	Pass	Pass	Pass	Pass
45 Degrees Left	Pass	Pass	Pass	Fail
	Pass	Pass	Pass	Pass
	Pass	Pass	Pass	Pass
45 Degrees Right	Pass	Pass	Pass	Pass
	Pass	Pass	Pass	Pass
	Pass	Pass	Pass	Pass
0 Degrees	Pass	Pass	Pass	Pass
	Pass	Pass	Pass	Pass
	Pass	Pass	Pass	Pass

In order to test different angles cardboard was used to block the portion of the sensor not being tested to ensure the sensor is not detecting from the other side. Each test was performed 3 times to ensure accuracy and recorded in the table above.

The Sensor Subsystem tests only resulted in 2 failures. Theses failures are acceptable due to the fact that the smart mirror does not require a sensor that can sense up to 16 feet, 10 feet is perfectly acceptable for this projects requirements.

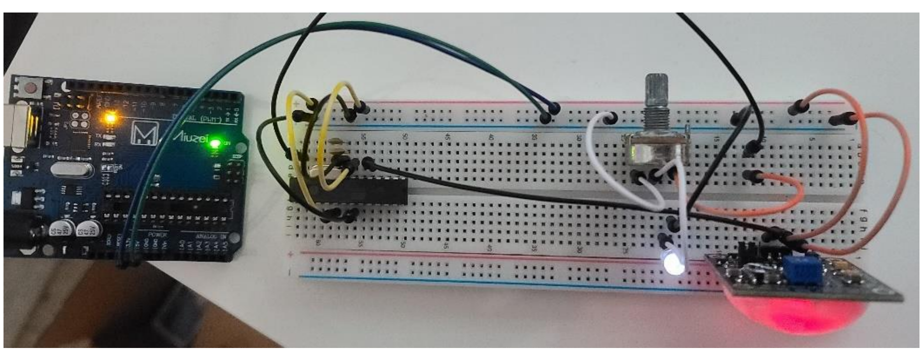
5.2.2 ATMega328P Standalone Testing and Design (Tyler)

In order to design a PCB for the micro-controller the design first needs to be mocked up on a breadboard. As discussed and schematic designed in section 5.1.3 the ATMega328P can be ran standalone on a breadboard with an external clock using a crystal and two capacitors. This will save power and make the overall micro-controller package much smaller compared to using a development kit like the Arduino Uno board.

The Arduino Uno board has an onboard bootloader which was used to load the test program from section 5.1.2 on the ATMega328P. Once loaded the micro-controller chip can be removed from the board and placed onto the breadboard, or in the future a custom PCB. This eliminates the need to have a bootloader circuit on board, which makes the board less complex, easier to design, and easier to use once printed.

The breadboard circuit shown in the figure below demonstrates that the designed circuit is working fully on its own, when the presence senor detects motion it sends a positive signal to the micro-controller which then sends power to the LED circuit to indicate it is functioning. The only thing the Arduino Uno development board was used for was its 5V and ground pins. These pins simulate the ground the board itself will have as well as the 5V DC connection that will be received from the mirrors power supply. Outside of these two connections the breadboard is operating independently.

Figure 69 - Independent MCU Breadboard Operation



Now that the concept has been tested on a breadboard and proved to work the micro-controller full schematic and PCB can be designed. Not included in the above design but will be present in the final are the de-coupling capacitors. These are not required for the breadboard design as they are included on board the Arduino Uno board that is supplying the 5V DC rail.

After testing this on the breadboard a schematic was created. The schematic pictured at the end of this section will be turned into a PCB in section 6 of this document. The ATMega328P is pictured in the bottom right of the schematic. The micro-controller is connected to a 16 Mega-Hertz external clock in the bottom left as tested on the breadboard with two 22pF capacitors.

Pin 13 otherwise identified as GPIO digital pin 7 is connected to actuation pin on the 12V relay pictured in the top right of the schematic. This will be used to control the on and off functionality of the 12V LED strip. Pin 5 otherwise identified as GPIO digital pin 3 will be used to take in the status of the PIR sensor.

As mentioned above the LED vanity lighting will be controlled using a 12V relay which can be actuated using a 5VDC signal from the micro-controller. This relay takes in the micro-controller signal on pin 1, a 12VDC line from the external power distro on pin 2, and a GND connection on pin 3. When pin 1 is turned on the 12VDC on pin 2 is passed through the relay to pin 4.

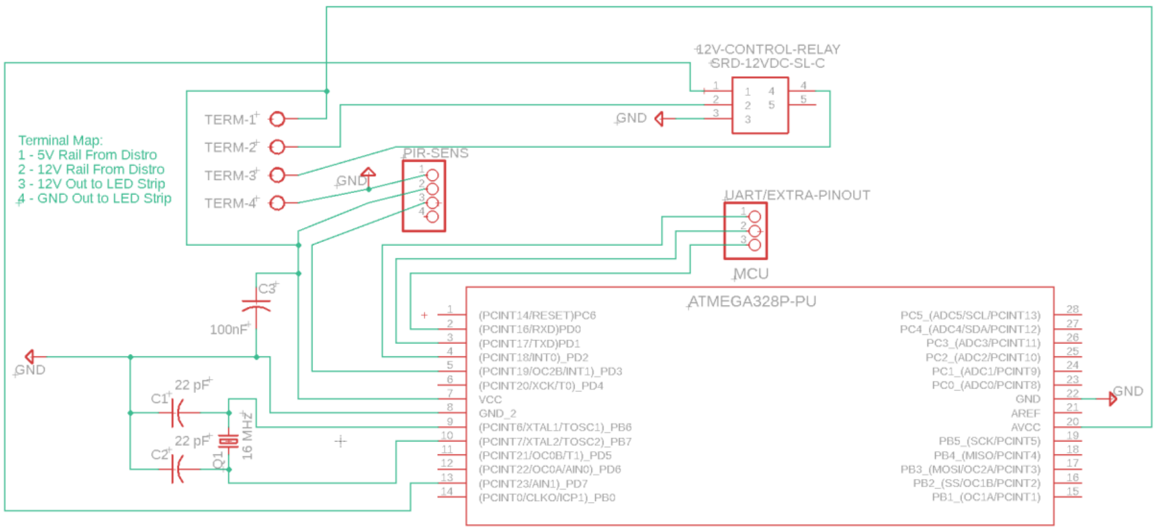
The PIR sensor for this project will be mounted to the frame of the smart mirror, due to this fact it cannot be mounted to the PCB. To accomplish this a four-pin header was used, labeled as PIR-SENS on the schematic. This header will be connected to a cable which will run along the frame and carry 5VDC and GND to the sensor, as well as return the sensors response back to the ATMega328P.

Another pin header mounted to the PCB is found in the middle right-hand side of the schematic, labeled as UART/EXTRA-PINOUT. This is a three-pin header designed to provide two functions. Firstly, it provides three extra connections to the GPIO digital pins on board the ATMega328P which provides some level of expansion if needed, the last thing the group wants is to purchase and construct a PCB only to find that we need one more input or output from the micro-controller. Secondly, two of the pins the header is mapped to are the UART communication lines, meaning if using logic level communication doesn't pan out between the micro-controller and micro-computer, the micro-controller can be configured and UART can be deployed instead. This also still leaves one open GPIO pin for expansion.

The last element of the schematic is the 4-pin screw terminal located on the top left of the schematic identified as TERM-1 through TERM-4. This terminal serves 2 purposes. The first purpose is 2 input terminals, TERM-1 takes in 5VDC from the power distro board and TERM-2 takes in 12VDC from the power distro board. The second purpose is 2 output terminals for connecting the LED Vanity lighting mounted externally on the frame. TERM-3 outputs the 12VDC to the LEDs from the relay and TERM-4 provides a ground for the LED vanity lights. The connector supports 33AWG to 16AWG wire and is rated for up to 300V and up to 13.5 amps, so it works perfectly for this application.

The design serves the necessary functions required of the smart mirrors micro-controller and is also slightly expandable in the event we need to add something to the design in the future. The design also deploys many different connectors for the external components which will keep the board design small and will not limit the layout of the smart mirror once built in the next semester.

Figure 70 - Micro-Controller PCB Schematic



5.3 Overall Schematic (Tyler)

Found in the figure below is a connection schematic of all components in the project connected as they will be in the final design of the smart mirror. The schematic includes everything beginning with the input of a 3-prong AC plug and connections can be followed throughout the overall system. This schematic details the way in which all the separate subsystems will be combined to form the functioning smart mirror.

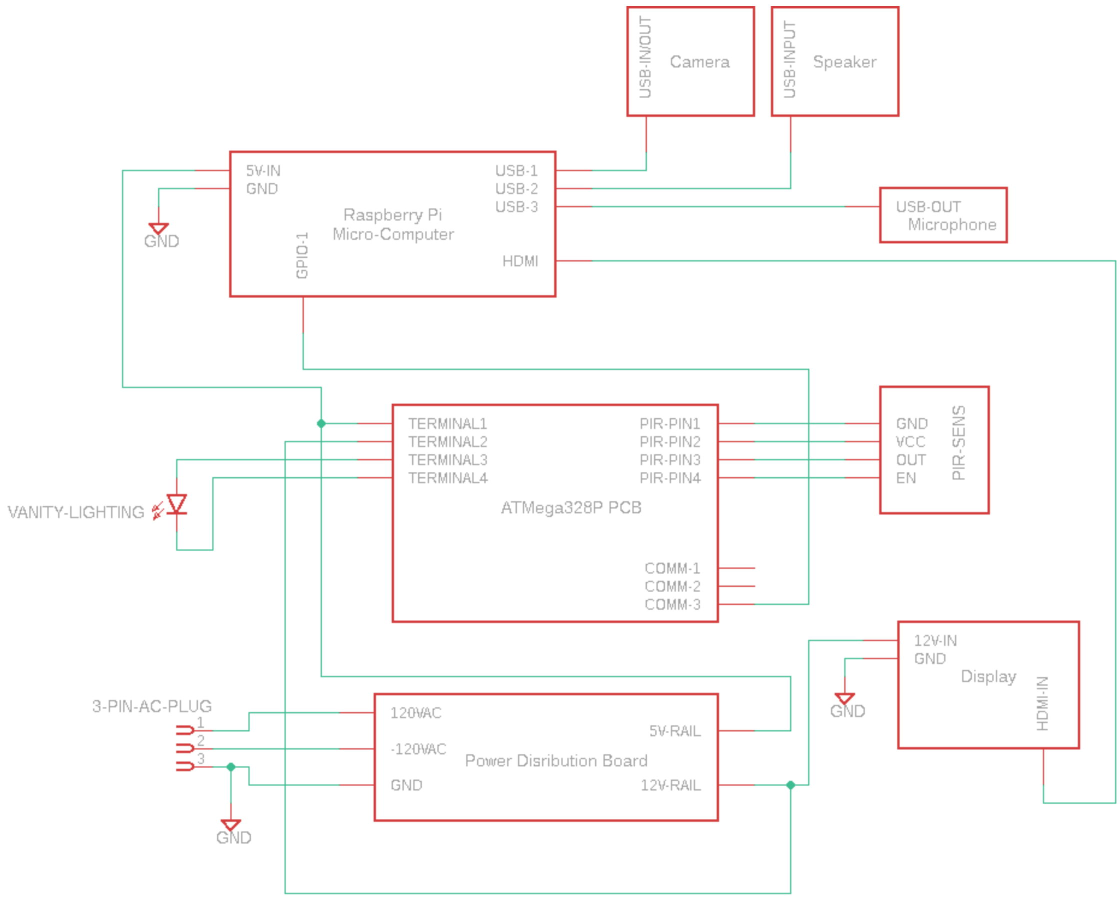
The Raspberry Pi micro-computer will be connected to the camera, speaker, and microphone via its onboard USB controller. It will also be connected to the display via an HDMI cable hooked to its onboard graphics processor. The micro-computer will receive its power and grounding from the power distros 5VDC power rail and earth ground from the NEMA grounded plug connection. The micro-computer will also be connected to the micro-controller to via GPIO pins on each respective board to receive data on user presence

The ATMega328P PCB will receive power via the power distribution boards 5VDC rail on “TERMINAL-1, just like the micro-computer. It will also receive a leg of the 12VDC rail on “TERMINAL-2” to pass through to the externally connected LED lights labeled “VANITY-LIGHTING” on the schematic hooked to “TERMINAL-3” and “TERMINAL-4”. The PIR sensor will be connected via the 4-pin header found on the PCB labeled as “PIR-PIN#”, and one of the COMM ports labeled as “COMM-3, hooked directly to GPIO pins, will be used to send presence data to the micro-computer. “COMM-1” and “COMM-2” ports are unused at the moment and present in case of additions.

Lastly the display will receive power and grounding from the power distribution board using the 12VDC rail. Its HDMI input will be received from the micro-computer.

Individual subsystem schematics can be found in their respective section's future up in the document, for example the "ATMega328P PCB" schematic is located above this section in section 5.2.2

Figure 71 - Final Overall Schematic (With All Subsystems Connected)



5.4 Software Design (Axel)

This section includes detailed information on how exactly the software of the device has been implemented. Featuring examples of code as well as outputs.

5.4.1 Face Recognition (Axel)

Our team opted to use one of the many already existing python libraries intended specifically for facial recognition. This library is called "face_recognition." Earlier in the document it was discussed how facial recognition tends to identify certain unique markers. These markers being called "landmarks". This library works in much the same way. First a training image must be supplied before any face can be recognized by this library. Otherwise, any face that appears before the camera will be marked as an "unknown" figure. After the training image is "encoded" and recorded in an array. It is now possible for the software to identify the face. This library makes face recognition quick and efficient. This is important because of the specs of the raspberry pi being used on this project. Most computers on the market today tend to run at speeds of at least 3Ghz, over several cores. However, the computer used on this project runs at roughly half that speed, so it is imperative that this software runs as quickly as possible or else we risk sacrificing the overall usability of this product. End users are impatient and want to do as little waiting as possible when interacting with any technology.

After the training images are encoded and saved, the software initializes the camera and prepares to capture a photo of the user. To accomplish this, another library called “OpenCV2” must be used. OpenCV2 is a python library developed by Intel. The library is intended to be used for real time computer vision software. It is freely available for all to use under the open source Apache 2 License. This library will be responsible with handling initialization of the video camera itself, as well as modifying video frames that have been recorded to prepare them for processing. To reduce the amount of time it takes to encode the recorded video frames, all video captured by the camera will be downscaled to one fourth of its original resolution, courtesy of the OpenCV2 library. This is done so that the computer has to iterate over as few pixels as possible, while still being able to make out the essential landmarks used to identify a face. At this point, the software encodes the modified image in the exact same was as the training images. Then the encoding is compared to each entry in the existing encodings array. If there is a match, then a face has been successfully recognized. The software library allows for a certain margin or error, such that even if a user is not in the exact same position as the training photo, their face will still be recognized. After several test, it has been determined that this margin does not lead to false positives.

Testing/Proof of Concept:

As mentioned earlier, a training image must be used to teach the software what to look for. A sample image must be provided in the same directory where the script is located. After the image is loaded all that must be done is call the method that will apply the HOG algorithm for facial recognition to the file.

Figure 72 - Code for encoding the training image

```
# Load a sample picture and learn how to recognize it.
obama_image = face_recognition.load_image_file("obama.jpg.")
obama_face_encoding = face_recognition.face_encodings(obama_image)[0]
```

The testing image used is shown below.

Figure 73 - Test Image for facial recognition

In order to test if whether or not the facial recognition is successful, a different image of the same face must be used. OpenCV2 is able to display recorded video, as well as mark key features on the video as well. That will be seen in the test image below.

Figure 74 - Face detection successful

The software is successfully able to detect a face from a distance of at least 2 feet away, with very little error. This can reliably be used to keep a particular user's preferences and information stored on the mirror secure.

5.4.2 Speech Recognition (Axel)

Our project aims to use as many preexisting tools as possible. This allows us to be swift and efficient in our implementation of design. For this project it was decided to implement Google Assistant into the smart mirror. Using this would allow us to implement much more complex features by taking care of googles already existing services. It will also result in a faster program. Writing a speech recognition script from scratch would be less efficient and more error prone than using a tried and tested technology.

Implementation and Operation:

Google Assistant operates with the following states: Idle, Recognizing, Busy, Expecting Speech.

Idle State:

Before capturing the user's speech. The software must run in an idle state. You would not want the software to think every word spoken in the room is directed specifically to itself. This makes for an extremely intrusive and annoying device. The assistant will only respond to a particular word. This word the "Wake Word" as it is called, is what will be used to move the assistant from the idle state to the next state, the Recognizing state. In order for the software to be able to identify the wake work, it must be always listening in. This is posing a privacy concern, that has been discussed earlier in the document. All users assume all risks associated with using such software.

Recognizing State:

After a wake word is identified, the software transitions to the recognizing state. It is at this stage that the software actively listens to the user for input. The assistant will remain in this state until the user has finished speaking. After which, the software will transition to the next state, the Busy state.

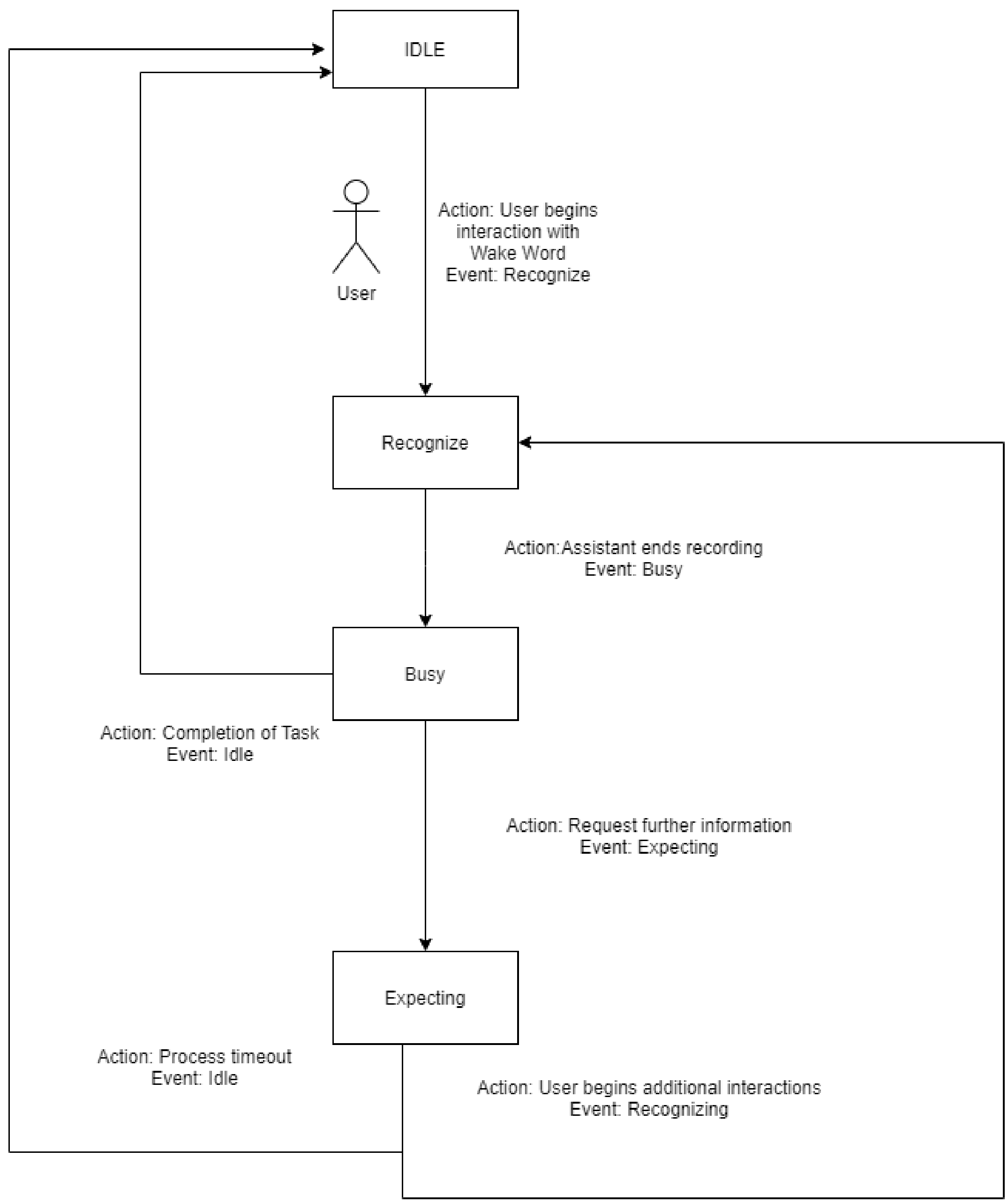
Busy State:

It is at this state that the software processes the information given by the user. It is impossible for the user to provide another prompt until this stage is completed. After the assistant has completed processing, it will then act on the prompt given by the user. If the user has asked for directions to a particular location, it will provide map information, including distance and estimate commute time. This is just one example of what may be produced by the end of a busy state.

Expecting State:

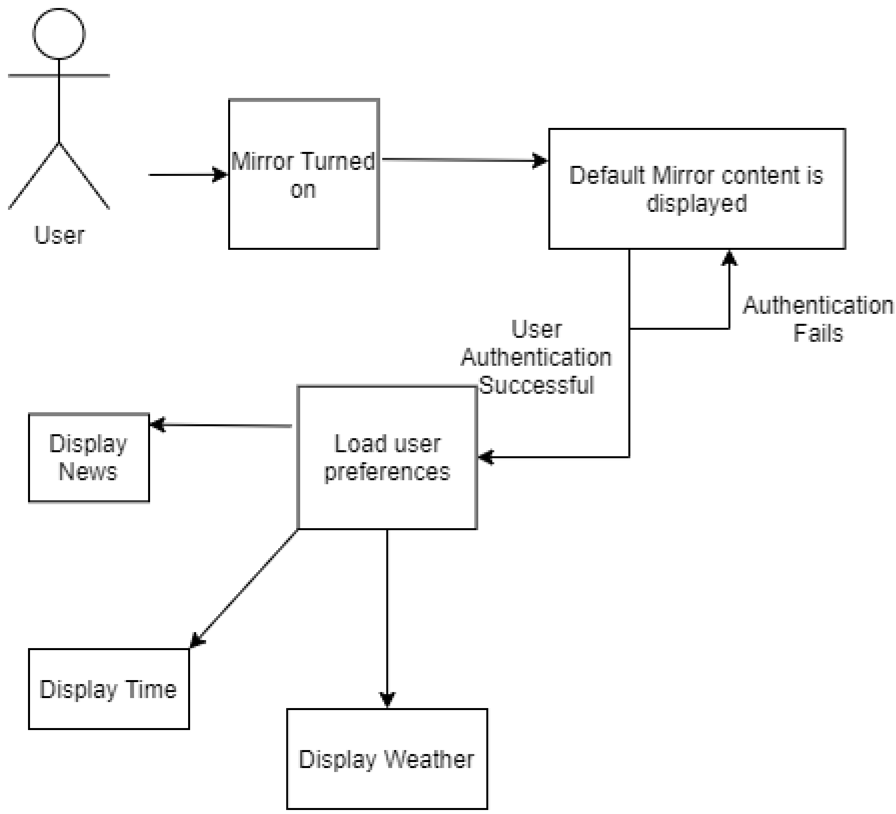
Depending on what the user tells the assistant, an additional state may be necessary. The assistant enters the expecting state from the busy state. This occurs when additional audio input is required from a user. A rudimentary example may be when asking the assistant to tell a joke. Many of these jokes told by Google Assistant require the user to say something in response to what it has to say. This is a case where the software would expect the user to say something in between its own responses. Another instance where the expected state will be reached is when performing more complex tasks. Google Assistant is capable of making restaurant reservations for the user. After requesting the assistant to make a reservation at a particular restaurant, the assistant will need to collect additional information from the user such as date and time. The assistant will expect the user to provide this information on request. If the user does not respond, the software will request that the user speak again. It will first assume that it could not understand what the user was saying. After enough time has passed, the assistant will time out and return to the idle state, ready to begin the process all over again.

Figure 75 - Different states of the assistant



5.5 Flow Chart (Axel)

Figure 76 - Device flow Chart



The flowchart above displays how the process by which the mirror will operate. The first step in this process at the moment is undetermined. Either the user will simply turn the mirror on, or the mirror will activate itself by detecting a prescence with an ultra-sonic range finder. For simplicity, the first option will be assumed.

At this point, the mirror is turned on and will automatically load the default user interface. This default interface will have preset preferences. The time displayed will default to UTC−05:00, otherwise known as eastern standard time. The newsfeed will default to news centered around the Orlando metropolitan area. Weather, will again default to weather in the central Florida/Orlando area.

If a user wants to see their personal preferences, then then must speak the phrase “Detect my face.” The device will always be listening to the user, waiting for this phrase to be spoken. Similar to how Amazon smart echo works. Smart Echo works by constantly listening in on the user at all times. It is activated when the user says “Alexa.” Our product works in a similar way. Alexa lights up the smart echo device when it is activated, so our device may also light up the LED’s on the device to make it clear that the mirror is actively waiting for a prompt.

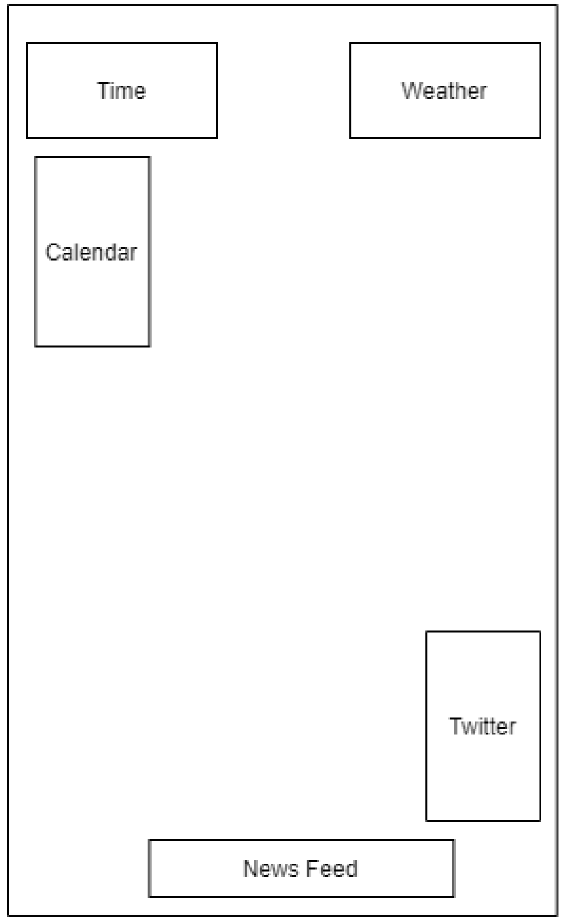
Assuming the device is able to pick up the user’s command with no issue, the mirror will go into face detection mode. The mirror will run the face detection software and decide if whether or not the user is in the registry of known faces. If this passes then at this point the interface will load the user's personalized mirror screen. If the face recognition fails, the, the user will be shown a prompt saying that their face was not recognized and that they should try again. It will also suggest that the user use better lighting and to get closer to the camera, as this typically fixes most errors with the facial recognition software.

A user's personal preferences are stored in memory. After authentication, those preferences are loaded. If for example, a user is only interested in weather in Seattle, their weather preferences will be loaded and they will be shown todays weather in Seattle, as well as a future forecast. This also goes for time, news, and even social media feed(twitter). It may take a moment to load everything. As the device will have to connect to all the API's again, request the information, and display it on the screen.

The prototype will have the ability to adjust certain preferences. The user will be able to speak a limited number of commands such as "Show the weather in New York City." After which the mirror will display the weather in said city. The user will also be able to do this with the time. Due to project time constraints however, the customization feature must be limited to only these two section as of now. The user will be able to do this, regardless of if they are an authenticated user.

5.6 Interface (Axel)

Figure 77 - Default Layout of smart mirror



The image above displays the overall layout of the basic software components of the smart mirror. Basic information regarding time and weather are located on the top of the mirror. Information regarding world news and social media is placed on the bottom. It is important for us to leave a sizeable amount of empty space in the middle of mirror for the user to look at themselves, because this is still a mirror after all, and it should not lose that utility. Otherwise, we would just be creating an oversized tablet.

5.6.1 Time (Axel)

This is by far the simplest part of the entire mirror. This portion will simply display the current time in a digital format. It is possible for a user profile to have the clock display time in their preferred time zone as one of the user preferences. If the user prefers a 24-hour clock instead, that option is also available to them. In addition to just showing the time, this clock also displays the current date.

5.6.2 Weather (Axel)

The weather portion will display today's weather information. This information includes temperature, windspeeds, chance of precipitation, and a small visual cue suggesting the current conditions outside. For example, if a day is cloudy, the weather will display a small cloud on the interface.

The weather widget will also be able to display a forecast to the user. The user will be able to request this feature with voice commands. After the command is made the weather widget will update to show the forecast for the next few days in addition to the current day's weather.

5.6.2 Calendar (Axel)

The calendar portion will show important upcoming dates and events to the user every time they use the mirror. It only makes sense to include this feature in a project such as this one. The aim is to make the mirror an informational hub the user will use every morning before going on with their lives. Its because of this goal that inclusion of a calendar was considered necessary

By default, the user will only be able to see basic holidays, Halloween, Presidents Day, Thanksgiving, and the like. This mirror widget operates on an ical link. Ical links are weblinks that lead to particular calendar files online. Think for example, google calendar. Any calendar made in google calendar may be accessed through a custom url produced when a new calendar is made. This means by default, when no user profile is loaded, a generic calendar file is loaded. However, if the user wishes to include their own personalized calendar, with events and dates they create for themselves, then they will be able to load their own ical link into the software under their profile and have their personal calendar loaded.

Due to the nature of how this process works, the user will not be able to use voice commands to update the default ical link to their own personal one. A user would have to know how to modify the configuration files in the software itself. This is not ideal for a product directed to the average user. But at the current moment, there is no other solution to this issue.

5.6.3 Social Media (Axel)

This section on the mirror would display user curated social media information. The platform chosen for this project to display is twitter. Twitter offers user friendly APIs that allows users to retrieve tweets specific to certain keywords or phrases. Tweets are also in essence, very simple to integrate as they are simply just lines of text with a username. Displaying something like this will be no issue.

The user will also be able to update what tweets to show with voice commands. Since the API returns tweets based on particular keywords, the user can provide these keywords and update the API itself and thus update the tweets that are shown.

5.6.4 News Headlines (Axel)

This widget shows current news headlines. The headlines will update every few seconds. The user will be able to get a general idea of the current state of the world in just a few seconds as the headlines fade in and out.

This widget operates in a similar way to the calendar. This widget can be connected to the API of any news website. The Api being accessible through a link unique to the website itself. However, unlike ical, the user will be able to update this newsfeed to a degree. If the user wishes to see news headlines from a different source, say from BBC to CNN, the user can change this with a voice command. The software will save different Api links, which the user will be able to select from. This is done to give the user the option to get their news headlines from news sources they personally deem trustworthy.

5.6.5 Additional Features (Axel)

Because of the inclusion of Google Assistant, the smart mirror will include additional functionality.

Google Maps

The user will be able to ask the assistant for information regarding their morning commute. The user can ask "How long is the drive to work?" After which google assistant will process the question and return this information to the user. Not only will the assistant deliver the information audibly, but google assistant will also display the fastest route to the user on the screen. This is a convenient feature for users who may be hearing impaired. Users will also be able to view traffic data as well as delays that might be encountered on the way to work. Most if not all features of Google Maps will be accessible through the assistant.

Timers/Reminders

Assistant has the capability of setting timers. This is useful for a variety of household tasks, from cooking to laundry. In order to start a timer, the user needs to give a prompt after the wake word. A prompt similar to "Start a timer." The assistant will then prompt the user for how long they want the timer to be, and then transition to the expecting state, waiting for the user to give it the information it needs. After that is done the timer will begin, and the user can return to their daily tasks. If at any point the user wants to know the status of the timer, the user can simply ask the assistant how much time is left on their timer.

The user may also set reminders with assistant. If a user wants to set a reminder, such as "lunch with jenny next Tuesday at 12pm", they can do so with Google Assistant. The assistant will automatically update the user's google calendar and add the event at the correct date. If the user profile uses an ical linked to the user's own google calendar, then they will be able to see their created event show up on the in the onscreen calendar.

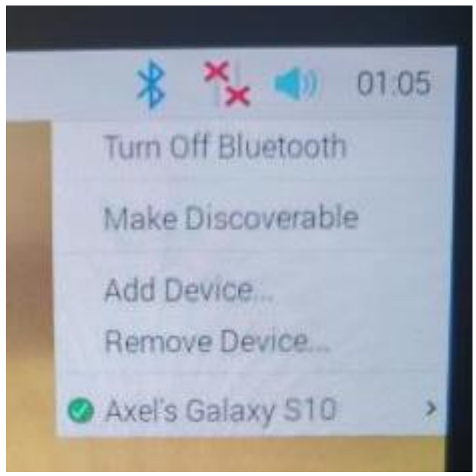
General Information

Users will be able to ask Google assistant broad questions on just about any topic and receive an answer to their question with supplemental information. This is a fun feature for those who enjoy trivia or are curious about something.

5.7 YouTube Casting (Axel)

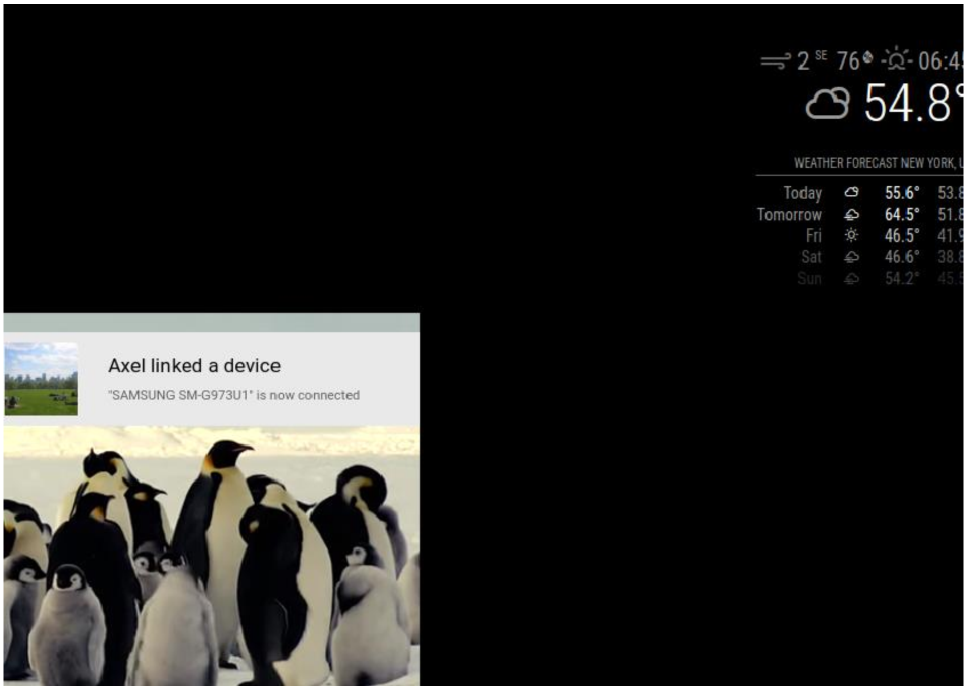
In addition to the aforementioned features above. The smart mirror will be able to simulcast YouTube content from a connected device with casting capabilities. This includes cellphones and tablets. In order for this to work, the device doing the casting must connect to the raspberry pi via Bluetooth. This involves navigating through Raspberry Pi OS and manually connecting to the device using the operating system's Bluetooth settings. For a final product marketed at consumers, Bluetooth pairing should be a frictionless process. However, for a prototype it will suffice.

Figure 78 - pairing mobile device to pi



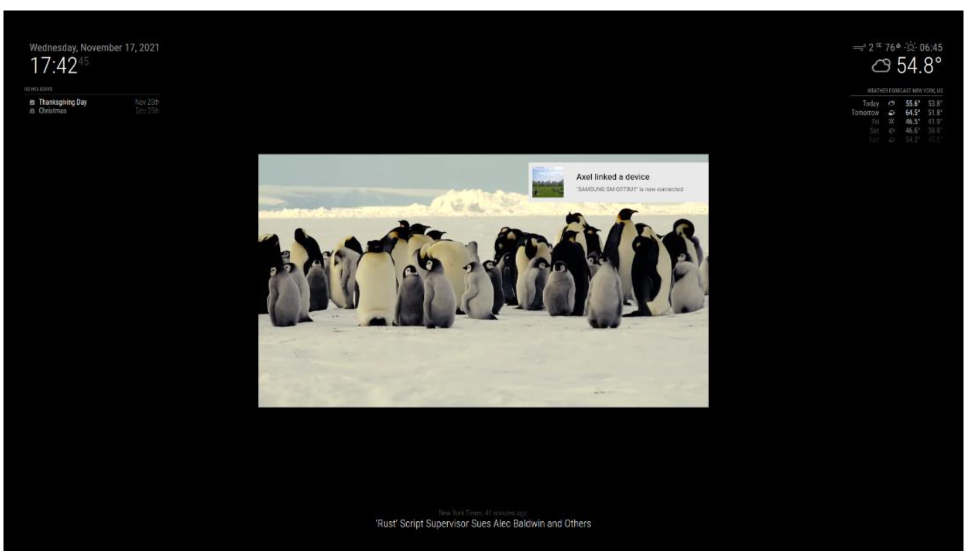
In order for YouTube casting to work properly, the raspberry pi must also have a stable internet connection, either through ethernet or Wi-Fi. After testing the Wi-Fi capabilities of the pi by connecting it to a mobile hot spot, it was determined that a weak internet connection is not sufficient. The raspberry pi needs a strong internet connection to mirror the YouTube content. This is due to the fact that the pi itself will be connecting to YouTube and playing the video at the same time as the device. Best results were found when the pi had a download speed of at least 20Mbps.

Figure 79 - YouTube casting on Mirror Software



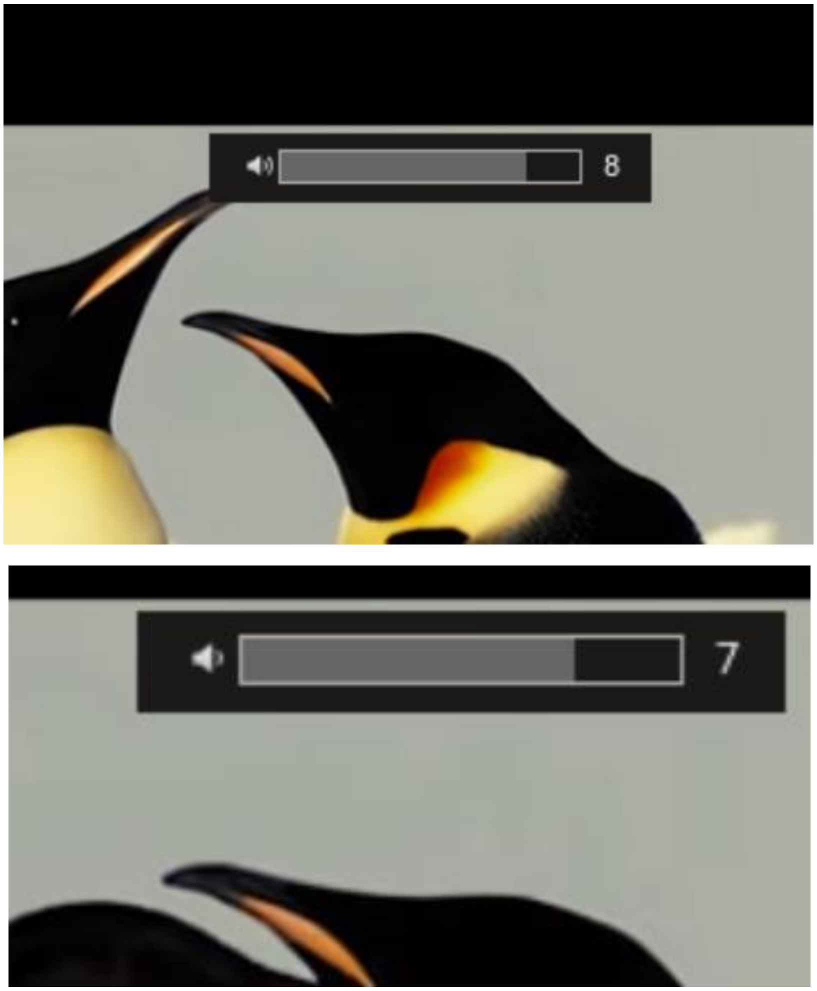
The image above shows what will happen once YouTube casting begins. The video will play in the very center of the smart mirror. A full image of the test display and the location of the video relative to the modules is shown in the figure below. In the final prototype the mirror will be in a vertical position:

Figure 80 - YouTube video relative to components



The user will have remote control of the video once it is casted. The YouTube app will allow the viewer to pause, scrub, and change stream quality of the video. It is also possible to create a video queue for the smart mirror. Most if not all YouTube casting features will be available to the user. While the video is being casted to the mirror, the mirror will play the audio as well. When the user adjusts the volume of the video, they will be able to adjust the output volume of the speakers on the smart mirror.

Figure 81 - User adjusting output volume from 8 to 7



The casted video will overlay on a layer above the smart mirror UI. This means modules below the video will be blocked by the video. If the user wishes to use Google Smart Assistant, they must end the simulcast with the mirror or else they may miss whatever content the Smart Assistant may display after processing the user's request.

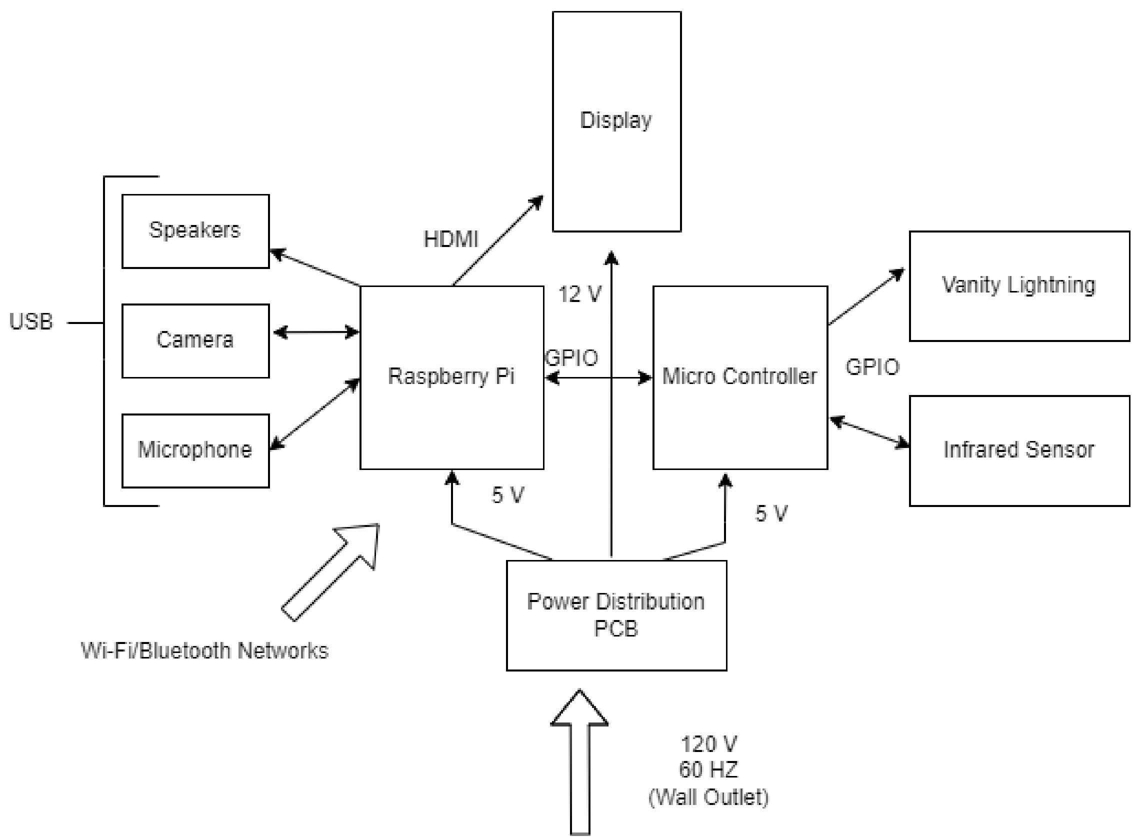
6. Project Prototyping

This section will be dedicated to the physical prototyping of the smart mirror project. In this section all elements shown in the previous sections will be connected together and tested together as one final product.

6.1 Overall Integration (Axel)

The Smart mirror will have it's components integrated in the manner below:

Figure 82 - Hardware Block Diagram



The power distribution is is the beginning of this pipeline. The power distribution will have 2 power rails. A 5v rail, for the Raspberry Pi and micro controller. As well as a 12 v rail for the monitor display. The pcb will be capable of adjusting the input voltage from a standard outlet into voltages acceptable for these devices. This is necessary for the product, because it will allow everything to be connected to one power source. Otherwise, this prototype would have several wires connected to it at a single time. This makes the device overall more user friendly.

The Raspberry Pi will interface with the speakers, camera, and microphone. All these connections are done through the Pi's USB ports. So long as the Raspberry Pi receives adequate voltage, it will be able to send power to these devices in the same way a traditional desktop computer can send power a keyboard and mouse. The microcontroller will be involved in continuous wireless connection with a paired mobile device and a Wi-Fi access point. The pi will constantly update data displayed to the user using API's, which makes Wi-Fi a crucial component of this system.

The Atmega based micro controller will interface with the infrared sensor and vanity lighting. It will be in charge of adjusting the lightning depending on the information retrieved from the infrared sensor. This connection is made through GPIO pins on the microcontroller itself. When a presence is detected by the infrared sensor, the controller will send a signal to the vanity LED's that will activate them. As soon as the prescence is gone, the board will send a turn off signal. The microcontroller will also be connected to the Raspberry Pi microcomputer via a single GPIO pin. This allows the controller to send data back and forth to the pi. This allows us to implement additional functionality such as a possible sleep mode for when the sensor does not detect any presence.

6.2 PCB Design

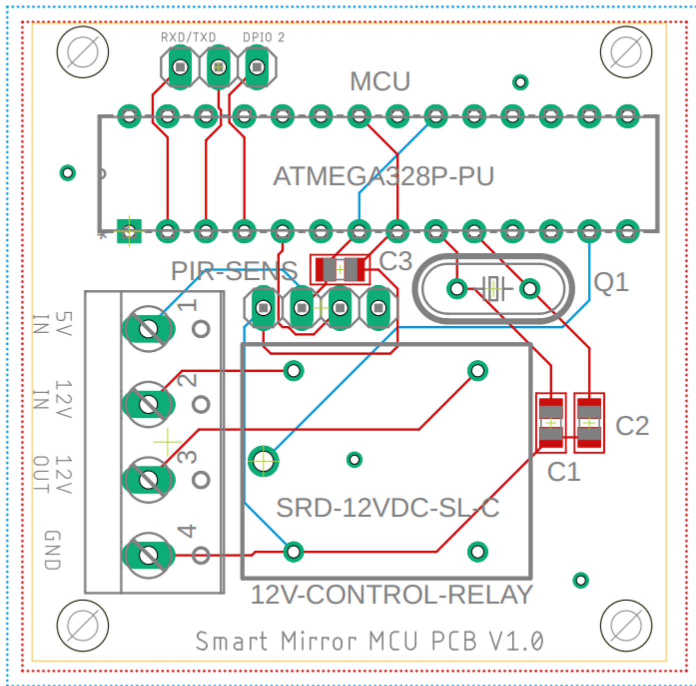
In this section all prototyped and tested circuits will be designed in AutoDesk Eagle and showcased here.

6.2.1 Micro-Controller PCB Design (Tyler)

The micro-controller schematic created, explained, and showcased in section 5.2.2 required the design of a printed circuit board. The goals in creating this PCB were to create a compact design of less than 50mm by 50mm and keep the design to under 2 layers. These goals not only keep the cost of the board down but also keep the board compact which will make it easier to mount and integrate in with the entire smart mirror.

Both of the above goals were met with the initial design of the smart mirrors micro-controller PCB. The PCB was designed at 2 layers and total size came in just over 46mm by 45mm. The board could have been made slightly smaller, however for ease of use it was decided to add easy to see labeling on all connections going in and out of the board to prevent board damage when hooking things up.

Figure 83 - Smart Mirror MCU PCB V1.0



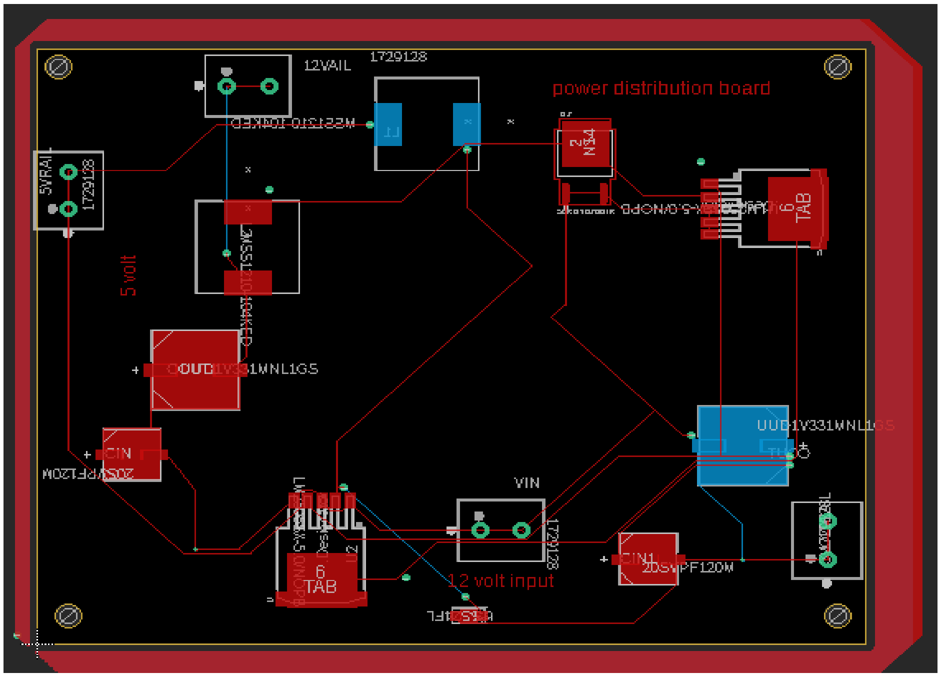
Pictured above is version 1.0 of the micro-controller. The two capacitors C1 and C2 are both C0805 ceramic SMD 22pF capacitors for use with the external clock. Q1 is a 2 prong through-hole 16 Mega-Hertz crystal in an HC49S package. C3 is a 100nF de-coupling capacitor used in between the incoming 5VDC rail and the various 5VDC components on and powered by the board, these things being the ATMega328P, the PIR Sensor, and the 12VDC relay actuation.

The board has 2 different pin-headers on board, the top 3-pin header contains labels and is a direct connection to the ATMega328P pins it represents, these pins being the UART RXD and TXD pins and the digital GPIO pin-2. The 4-pin header found in the center of the board under capacitor C3 to the lower right of the PIR-SENS label is an extension of the 4-pin header on board the PIR Sensor, it carries 5VDC, GND, and the data from the sensor all in the same order the sensor has making it impossible to plug in incorrectly. The sensor carries 4-pins for an optional enable and disable pin, the group has chosen to not utilize this pin, but has used a 4-pin header anyways to ensure no open connections are present anywhere.

The next element present on the board is the 4-pin wire to board terminal block. This block has been clearly labeled to prevent incorrect installation, which could potentially destroy our project. This element will be used to get 5VDC and 12VDC power into the board from the power distributor board. The remaining 2 block connections will be dedicated to powering the LED vanity lights. This block was used due to its ability to support wires as big as 16AWG, which will make getting power in and out of the board easier and safer.

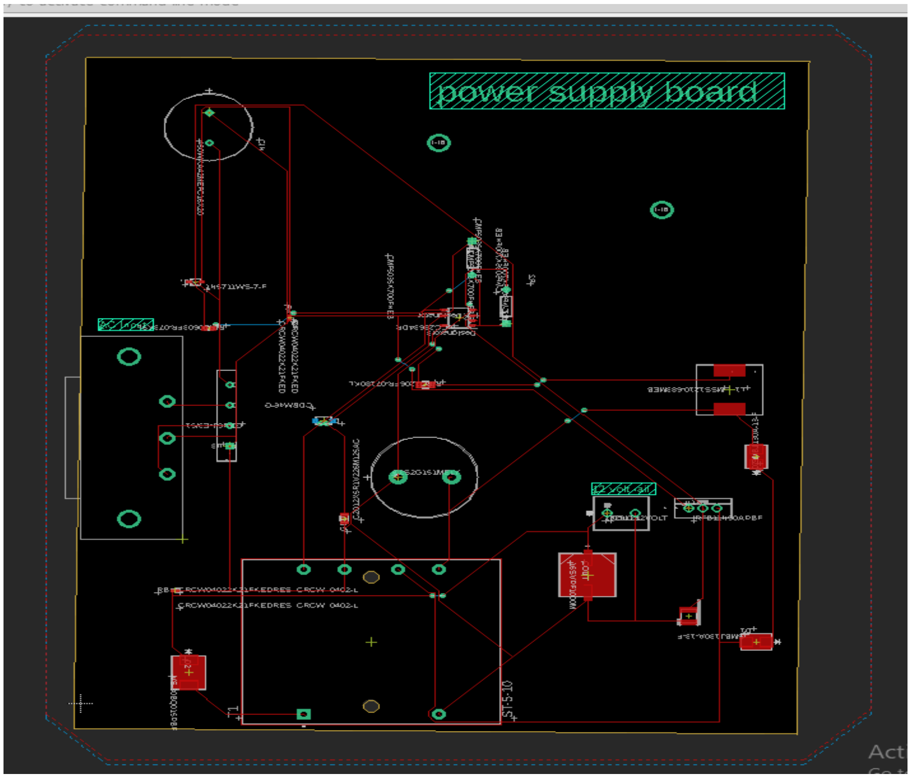
6.2.2 Power Distribution PCB Design (Jonathan)

Figure 84 - Power Distro PCB V1.0



Pictured above is version1.0 of the power distribution board It is a 2-layer copper board the area of the board 8000mm2 and is1.57mm thick there are 14 components on the top layer and 14 components on the bottom layer the trace width should be1.2mm to hold the 3-amp current for the rails of the power distribution board we are using 2 Position Wire to Board Terminal Block these terminal blocks are rated to withstand 300 volts and 10 amps theyalso can contain a wire Gauge of 14-30 AWG

Figure 85 - Power Supply PCB



The picture above is the PCB board design of the power supply being used This is a two layered board that is 1.57mm thick its area is 22663.08mm2 21 components are on the top layer and 2 components are traded on the bottom layer the trace width has to .25 in to handle the amount of current traveling through the board a heat sink will be added to manage temperature

The supply is being powered using a standard us three-pronged plug that will be plugged in a standard us wall outlet the Qualtec Screw Mount AC Receptacle was used in the design so the board can receive power the AC Receptacle is rated for 250 volts and 15 amps it is placed on the left side of the board from there the power goes through electromagnetic compatibility EMC/EMI filter this filter was is implemented to for the UCC2863x High-Power Flyback Controller. The UCC2863x uses magnetic sensing so the EMC/EMI filter is used to filter out electromagnetic noise reducing electromagnetic interference of the controller. The EMC filters reduce EMI By using capacitors and inductors the capacitors that are used in the filter are called shunting capacitors. The capacitors can put the current in a specific high frequency range and then send the current to the inductors that are placed in series. When the current passes through the inductors, the overall voltage is reduced. after the power is filtered it goes through the full bridge rectifier changing the AC signal to DC after that it goes through the UCC2863x fly back circuit from there it is step down to 12 volts by the transformer and it he signals is smoothed out by the capacitor before it is sent to the power distribution board

6.3 Systems Testing Plan (Axel)

This section is dedicated to the testing of all sub systems in the project individually as well as testing the overall project to ensure our specifications and requirements have been met. These tests will take place after the PCBs have been received and the components have come in.

6.3.1 Wi-Fi Testing (Axel)

This test involves use of the Raspberry Pi. The goal is to ensure that internet connectivity works correctly. After connecting the Pi to an appropriate power supply, it must first be connected to a nearby wireless access point. At this point we must navigate to any webpage, google.com for example. If the webpage is able to load with no issues, and within a reasonable amount of time, then this test is a pass.

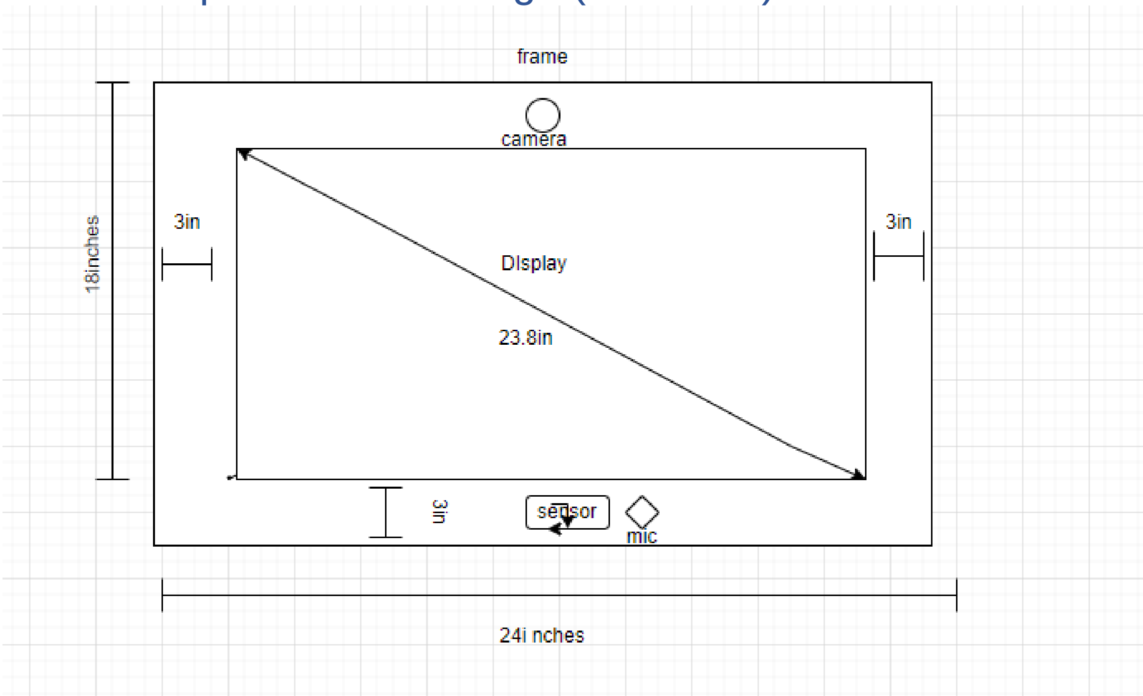
6.3.1 Bluetooth Testing (Axel)

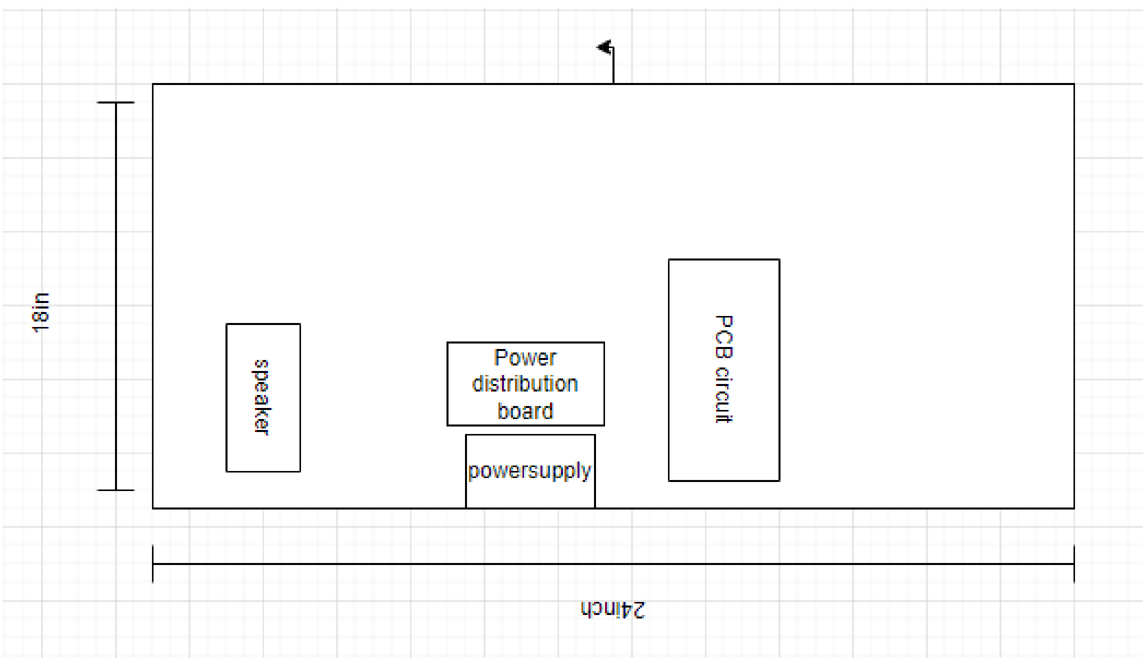
This test will ensure that the smart mirror will be able to interface with third party devices. This test in particular will simply involve a smartphone. All that needs to be done with this test is connect the smartphone to the micro computer. This is done within the computer's network settings. Assuming the phone is made visible to devices, the pi will need to pair with the phone. If the phone is recognized as a paired device on the pi, and vice versa, this test is a pass.

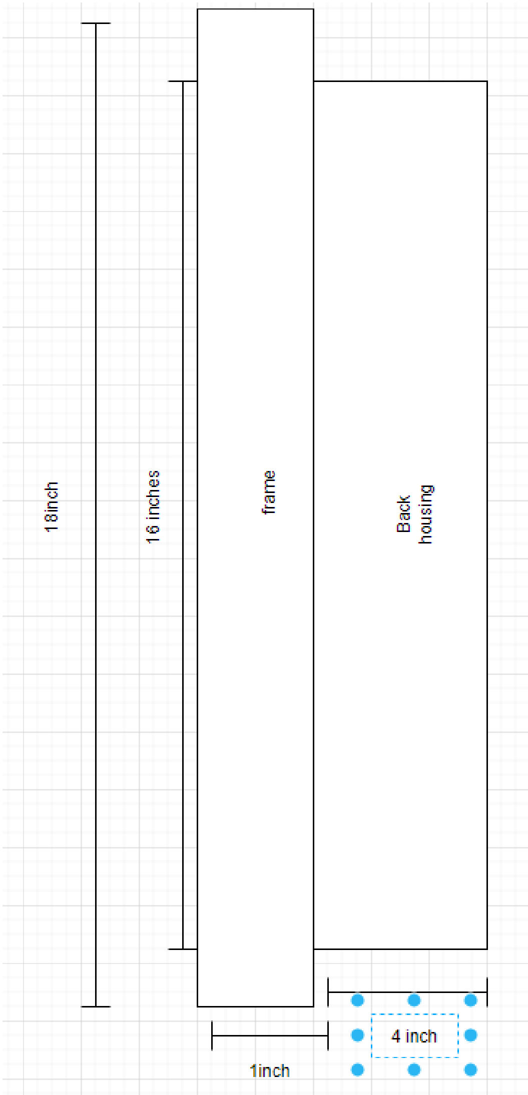
6.3.2 Power Distribution Testing (Axel)

The power distribution board must output the appropriate voltage in order for our devices to work properly. The power distribution board must have 2 rails that output voltages of 12v and 5v. This test will require the use of digital multimeters. To begin this test, the PCB must be connected to a standard 120 V wall outlet. Using the multimeter, both rails must first be measured to determine if the proper voltages are output. Assuming the proper voltages are being measured, it is then time to connect the devices to the rails. The Raspberry Pi should turn be able to turn on and stay on without overheating while connected to the distribution. The display should be able to connect to the 12v rail and power on with no issues as well. If this requirement is met, then this test is a pass.

6.3.3 Complete mirror Design (Jonathan)






18inch
16 inches
frame
Back
housing
4 inch
1inch

7. Administrative Sections

7.1 Team Description (Tyler)

Group 31 has come together to develop an inexpensive and easy to use Smart Mirror that will positively impact users lives. The group consists of three computer engineering students and one electrical engineering students. The hope for this project was to give each team member a way to showcase and further develop the skills and knowledge each person has developed on their journey at the University of Central Florida.

Tyler Newman, a computer engineering student at the University of Central Florida, is primarily interested in circuit and PCB design specifically in the field of embedded systems and IoT devices. Throughout his time at UCF he has been introduced to embedded systems programming, testing, and design in courses such as embedded systems, digital systems, junior design, and electronics. After this introduction from UCF he has pursued more knowledge of the subjects and pushed into the world of IoT devices, something that will soon be a massive thriving industry. This interest and experience in embedded computing will be beneficial in the development of the smart mirror and its embedded components. He will be designing many of the schematics present in the project as well as PCB components for certain project elements. He hopes that this project will be another steppingstone to the future and add highlight the skills he's acquired while studying at the University of Central Florida.

Axel Aristud Ortega is a computer engineering student attending the University of Central Florida. Axel has an interest in robotics and robotic vision. He is also interested in smart devices and the future of the industry. This interest has manifested itself into this smart mirror project. Axel plans to enter the industry and further develop his interests before returning to academia as a graduate student.

Jonathan Martin, an electrical engineering student, attending the University of Central Florida. His interest is in in renewable energy when entering the industry Jonathan plans on trying to develop new ways to produce renewable and sustainable energy and implement them across the globe Jonathan Currently works at a component testing facility where he is learning skills in test engineering. And also, Metrology where he learns about Industry standards

Jacob Williams-Moore, a computer engineering student at the University of Central Florida, developed his love for computers and technology at a young age. Having access to computers and video games consoles since he could remember, it was natural to become a key hobby of his. When starting college, Jacob wasn't too sure of which major to choose but ultimately decided upon Computer Science. Though his interests in computers were more on the hardware side, he progressed through the first two years of his degree and learned basic coding. During year three, Jacob switched majors from Computer Science to Computer Engineering in hopes of learning more about computer hardware instead of software. This decision may be seen as redundant after Jacob getting internships in the software engineering field. He has learned to appreciate computer software while keeping his initial interest in computer hardware as a personal hobby. Jacob's subject related and professional experience mostly consists of front-end development using common frameworks such as Angular and React for web-based applications. This experience helped extend into some of his interests, but he also continued to collect computer parts and build computers to fulfill his initial preference towards hardware

In order to ensure the project was completed in a timely manner and all elements were done to the best of the group's ability, responsibilities were given to each team member, some of them being solo responsibilities and others shared among group members.

7.2 Team Responsibilities (Tyler)

This section details the responsibilities each group member was tasked with during the duration of the Senior Design project.

7.2.1 Tyler Newman – Computer Engineering

- Micro-Controller Software Design
- Micro-Controller Integration
- Micro-Controller Circuit Design
- LED Vanity Light Circuit Design
- Presence Sensor Circuit Design
- PCB Design
- Power Saving
- API Integration
- Project Testing

7.2.2 Axel Ortega – Computer Engineering

- Micro-Computer Software Design
- Micro-Computer Integration
- UI Design
- Wi-fi and Bluetooth Integration
- Facial Recognition
- Voice Recognition
- API Integration
- Project Testing

7.2.3 Jonathan Martin – Electrical Engineering

- AC/DC Power Converter Design
- Power Distribution Design
- Power Distribution Integration
- Micro-Controller Integration
- Microphone Integration
- PCB Design
- Frame Design
- API Integration

- Project Testing

7.2.4 Jacob Williams-Moore – Computer Engineering

- Micro-Computer Software Design
- UI Design
- Camera Integration
- Speaker Integration
- Display Integration
- API Integration
- Project Testing

7.3 Project Milestones (Tyler)

In order for the team to keep good progress and ensure the project would be completed on time tasks were broken up and deadlines were set to ensure all members would consistently be on the same page.

Table 21 - Project Milestone Table

#	Task	Start	End	Status	Member(s)
Senior Design 1					
1	Ideas	8/30	9/3	Complete	All
2	Project Selection	9/6	9/10	Complete	All
	Project Report				
3	Initial Documentation	9/13	9/17	Complete	All
4	First Draft	9/27	10/8	Complete	All
5	Final 60 Page Initial Report	10/11	11/5	Complete	All
6	Final 100 Page Initial Report	11/8	11/19	In-Progress	All
	Research and Design				
7	Research Micro-Computer	9/20	9/24	Complete	Axel
8	Research Speakers	9/20	9/24	Complete	Jonathan
9	Research Display(s)/ Peripherals	9/20	9/24	Complete	Jacob
10	Research Power Delivery	9/27	10/8	Complete	Jonathan
11	Research Motion Detection	9/20	9/24	Complete	Tyler
12	Research Android Connectivity	9/27	10/1	Complete	Axel
13	Research Micro Controller	9/27	10/1	Complete	Tyler
14	Research Facial Recognition	10/4	10/8	Complete	Axel
15	Research External Info API's	10/4	10/8	Complete	Jacob
16	Draft Power Distro	10/11	10/29	Complete	Jonathan
17	Design Micro Controller Circuit	10/4	10/29	Complete	Tyler
18	Obtain Computer and Controller	10/4	10/29	Complete	All
19	Program/ Integrate Micro-Computer	11/1	11/12	Complete	Axel/ Jacob
20	Program/ Integrate Micro-Controller	11/1	11/12	Complete	Tyler/ Jonathan
21	Integrate Controller & Comp.	11/15	11/19	Complete	All
22	Design Final Power Distro	11/15	11/19	Complete	Jonathan
23	Design PCB's	11/22	11/26	Complete	
	Prepare For SD 2				
24	Final Preparation	11/26	12/3	Complete	All
25	Order Final Materials	11/29	12/3	Complete	All

7.4 Project Budget (Tyler)

For this project all group members agreed to a set maximum budget. Some elements of the project would be kept post-project and paid for by certain group members, all other expenses were to be added up and divided among members evenly. All members agree to a maximum contribution of 100 US dollars each, bringing the group's total budget to 400 US dollars. The group believed that this also fit perfectly with the mission of project, which was to develop a smart mirror that individuals could afford to own.

Table 22 - Project Budget Table

Part	#	Budgeted Cost	Actual Cost	Cost Diff.
Micro-Computer	1	$35	$61.95	+$26.95
Micro-Controller	1	$20	Free	-$20
HDMI 24 inch Display	1	$100	$	
Camera	1	$20	$25	-$5
32GB SD Card	1	$10	$8.99	-$1.01
IR Motion Detector	1	$5	$12.99	
Micro HDMI to HDMI Cable	1	$8	$6.38	-$1.62
White LED Vanity Lights	1	$15	$12.99	-$2.01
LED Light Diffuser	1	$15	$	
2x4x8 For Frame	2	$8	$	
Two Way Acrylic Panel	1	$40	$	
Wood Stain	1	$5	$	
AC/DC Power Converter	1	$30	$	
Power Distro PCB	1	$15	$	
Speaker(s)	1	$15	$	
Totals:				

8. Project Conclusion (Axel)

The goal of this project was to create a product that is not widely available on the market today. During the fall semester of 2021, group 31 has been able to show a thorough design of a potential smart mirror. This design process by first identifying products of this type that do exist in the market and learning from them. "What kind of features would users want in a product like this?", and "how would it help them become more productive", were necessary questions we had to ask ourselves before implementing any sort of interface or design.

At this point we began researching the technology that would need to be used in order to make our vision come to fruition. Methods of serial communication, face detection algorithms, popular voice recognition software, as well as diverse kinds of hardware options we had available to us. This research allows us to filter for the precise hardware and software development needed for this kind of project. Once proper research has been conducted, at this point testing and development can occur. Experimentation with the ordered hardware and development of the software needed is done to verify the feasibility of our design.

This process has exposed us to a real-world design scenario and allowed us to put our accumulated knowledge we developed over the past 4 to 5years to use. This project has allowed us to put the theory we learned in university into real practice. In the semester to come, our designs will mature and will be pieced together into one cohesive prototype. The struggles experienced and lessons learned in this semester will help us push forward in rapidly approaching spring 2021 semester and help guide us in our lifelong careers as engineers.

9. Appendices

9.1 Appendix A – References

ATMega328P. (2021, 10). Retrieved from Microchip: https://www.microchip.com/en-us/product/ATmega328p

Basics of UART Communication. (2021, 12). Retrieved from Circuit Basics: https://www.circuitbasics.com/basics-uart-communication/

Campbell, S. (n.d.). *BASICS OF THE I2C COMMUNICATION PROTOCOL*. Retrieved 12 2021

Document Library. (2021, 11). Retrieved from USB Org: https://www.usb.org/documents

HDMI Specifications and Programs. (2021, 11). Retrieved from HDMI Org: hdmi.org/spec/index

Matarneh, R. (2017). Speech Recognition Systems: A Comparative Review. *ELAr*, 9.

RSS, email, & table of contents alerts: Academic feeds & alerts. (2021, 10). Retrieved from MIT Libraries: https://libguides.mit.edu/c.php?g=175947&p=1158942

What Is the Difference Between Two- and Three-pronged Plugs? (2021, 12). Retrieved from How Stuff Works: https://electronics.howstuffworks.com/everyday-tech/question110.htm

Wikimedia Foundation. (2021, December 3). *Wi-Fi*. Wikipedia. Retrieved October 7, 2021, from https://en.wikipedia.org/wiki/Wi-Fi.

Raspberry Pi. (n.d.). Raspberry pi 4 model B specifications. Raspberry Pi. Retrieved September 30, 2021, from https://www.raspberrypi.com/products/raspberry-pi-4-model-b/specifications/.

Face-recognition. PyPI. (2020, February 20). Retrieved October 12, 2021, from https://pypi.org/project/face-recognition/.

Helmenstine, A., & Helmenstine, A. (2021, August 25). *How a two way Mirror Works*. Science Notes and Projects. Retrieved November 8, 2021, from https://sciencenotes.org/how-a-two-way-mirror-works/.

Crawford, S. (2011, October 17). *How secure digital memory cards work*. HowStuffWorks. Retrieved October 13, 2021, from https://computer.howstuffworks.com/secure-digital-memory-cards.htm.

Lamberterie, C. de. (n.d.). SpeechRecognizer 2.3. Amazon. Retrieved November 19, 2021, from https://developer.amazon.com/en-US/docs/alexa/alexa-voice-service/speechrecognizer.html#setwakewords.

Amazon. (n.d.). *AVS Device SDK*. Amazon. Retrieved December 7, 2021, from https://developer.amazon.com/en-US/alexa/devices/alexa-built-in/development-resources/sdk.

Google. (n.d.). *Device Actions Overview*. Google. Retrieved December 7, 2021, from https://developers.google.com/assistant/sdk/device-actions-overview.

Twitter. (n.d.). *Twitter API Documentation*. Twitter. Retrieved December 7, 2021, from https://developer.twitter.com/en/docs/twitter-api.

Tweepy. (n.d.). *Getting Started*. Tweepy. Retrieved December 7, 2021, from https://docs.tweepy.org/en/stable/getting_started.html.

Weather Module. MagicMirror² Documentation. (n.d.). Retrieved December 7, 2021, from https://docs.magicmirror.builders/modules/weather.html.

Amazon. (n.d.). *Logitech C920x HD Pro Webcam*. Amazon. Retrieved December 7, 2021, from https://www.amazon.com/Logitech-C920x-Pro-HD-Webcam/dp/B085TFF7M1.

Amazon. (n.d.). *Logitech HD Laptop Webcam C615*. Amazon. Retrieved December 7, 2021, from https://www.amazon.com/Logitech-Laptop-Webcam-Design-360-Degree/dp/B004YW7WCY.

Amazon. (n.d.). *Amcrest 1080p Webcam*. Amazon. Retrieved December 7, 2021, from https://www.amazon.com/Amcrest-Microphone-Computer-Streaming-Superior/dp/B085STB7FR.

Raspberry Pi. (n.d.). *Raspberry Pi Camera Module 2*. Raspberry Pi. Retrieved December 7, 2021, from https://www.raspberrypi.com/products/camera-module-v2/.

Amazon. (n.d.). *LIELONGREN [Newer] USB Computer Speaker*. Amazon. Retrieved December 7, 2021, from https://www.amazon.com/dp/B08QRYTPGH?ref=ppx_yo2_dt_b_product_details&th=1.

Amazon. (n.d.). *Lenrue Bluetooth Speaker*. Amazon. Retrieved December 7, 2021, from https://www.amazon.com/LENRUE-Bluetooth-Playtime-Portable-Wireless/dp/B07PJZRJ8X.

Amazon. (n.d.). *Sceptre 24" Professional Thin 75Hz 1080p LED Monitor*. Amazon. Retrieved December 7, 2021, from https://www.amazon.com/Sceptre-E248W-19203R-Monitor-Speakers-Metallic/dp/B0773ZY26F/ref=sr_1_3?keywords=Sceptre%2BE248W-19203R&qid=1638891787&s=electronics&sr=1-3&th=1.

Amazon. (n.d.). *Sceptre IPS 27" LED Gaming Monitor*. Amazon. Retrieved December 7, 2021, from https://www.amazon.com/Sceptre-Monitor-Speakers-Edgeless-E278W-FPT/dp/B098YKNVWR.

Best Buy. (n.d.). *Insignia™ 24" Class N10 Series LED HD TV*. Best Buy. Retrieved December 7, 2021, from https://www.bestbuy.com/site/insignia-24-class-n10-series-led-hd-tv/6394746.p?skuId=6394746.

Best Buy. (n.d.). *LG 28" Class LED HD TV*. Best Buy. Retrieved December 7, 2021, from https://www.bestbuy.com/site/lg-28-class-led-hd-tv/6337625.p?skuId=6337625.

9.2 Appendix B – Copyright Permissions

Texas Instruments: https://www.ti.com/legal/terms-conditions/copyright.html

Copyrights

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.

TI further grants permission to non-profit, educational institutions (specifically K-12, universities and community colleges) to download, reproduce, display and distribute the information on these pages solely for use in the classroom. This permission is conditioned on not modifying the information, retaining all copyright notices and including on all reproduced information the following credit line: "Courtesy of Texas Instruments". Please send us a note describing your use of this information under the permission granted in this paragraph. Send the note and describe the use according to the request for permission explained below.

Arduino: https://www.arduino.cc/en/trademark

You may

- Use the word Arduino (or any other wordmark being a trademark of Arduino) when referring to or describing an Arduino product.
- Use the word Arduino (or any other wordmark being a trademark of Arduino) to indicate that a third party product is compatible with or based on Arduino technology.
  - In these cases the Arduino trademark should follow a referential phrase such as “compatible with”, “for” or “with”.
- Use the Arduino logotype(s) in relation to sales of Arduino products.
- Use the Arduino logotype(s) when needed for descriptive or explanatory purposes, for instance in different kinds of publications.

Copyright Notice

Editorial contents of the arduino.cc website, such as texts and photos, are released as Creative Commons Attribution ShareAlike 3.0.

9.3 Appendix C – List of Tables

9.4 Appendix D – List of Figures