Smart Package Delivery Box

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INTRODUCTION

Purpose

This report documents the creation and proof of concept of the Smart Package Delivery Box (SPDB). The intention behind this report is to outline the embedded system design, and electrical engineering design that was developed and ultimately led to the completion of the project. A secondary objective is to capture the critical elements of the project management aspect of the project.

Problem

In the last 5 years America has begun to see a progressive growth in online ordering due to more products being offered online for convenience, and corporate giants like Amazon quickly becoming a staple in society. In response, package theft has grown alongside this cultural shift so much that these criminals have been coined by the mass media as "Porch Pirates". The aim of the SPDB is to provide homeowners with a method to combat these thieves and provide them with a sense of security.

In addition to the physical aspect of security the SPDB will be used to provide the homeowner with accurate non-proprietary communication. Delivery communication information is an important aspect to combating this issue as it can be used to let the homeowner know when to remove the packages from outdoor exposure, thereby eliminating the problem entirely or in an effort to help narrow the timeframe of when the thefts are occurring; By extension this will also help law enforcement with their investigation into thefts that occur as well. The current atmosphere surrounding package delivery communication is quite difficult for the homeowner as each online store and courier service offers a proprietary form of communication which often is inaccurate and dependent on the delivery driver updating information on time of delivery.

Scope

This report is based on work completed between January 10, 2022 to April 22, 2022. The report will cover only key components and procedures used in the creation and development of the SPDB. All research and procedures attempted but not used in the final design of the project will not be included in this report unless the attempt resulted in the final solution. The SPDB will be created under the notion that because it will be located within close proximity to the homeowners home it will have internet connectivity via Wi-Fi. Therefore, it should be assumed that no process will in any way accommodate the circumstance where the homeowner's internet is not functional. As a result of the homeowner's internet being used the devices data security will therefore be the responsibility of the homeowner. Data in transit while not included in this report due to limited resources but is noted and would be one of the first topics to be addressed in the future development of the project.

The SPDB will by design accommodate small to medium size packages only and focus on the following three services: Fedex Ground, UPS Ground, and USPS First-Class. As this is a proof of concept and for the purpose of saving time all other services will be excluded from this report. The SPDB is to be considered as a theft deterrence mechanism as opposed to theft prevention. No form of security is impenetrable and likewise a threat actor with the appropriate tools and enough time will be able to access the contents of the box. However, the objective is to deter potential criminals while still providing a hassle-free solution for mail couriers.

BACKGROUND

Theory

A study conducted in 2020 revealed that 8 in 10 Americans currently shop online, of those 43% have been a victim of package theft, and the average cost of a stolen package is valued at $136 dollars (C+R Research, 2020). These numbers have been progressively growing over time alongside the increase in online shoppers with no indication of slowing down. For the above reasons, a smart device is needed to offset this growth and the answer is the Smart Package Delivery Box.

To develop the SPDB several tasks must be accomplished: (1) Procure all standard equipment and materials necessary to complete the project. (2) Design and build a physical box that will house the system. (3) Acquire or create a case to protect the Raspberry Pi camera. (4) Design and create a power circuit capable of powering the Raspberry Pi, the 12-volt electronic lock, and 12-volt composite display. (5) The system must be capable of scanning a package barcode and determining the courier and tracking number associated. (6) The system must be capable of verifying the address on the package and matching it against the homeowner's address prior to granting access to the box. (7) Upon a valid delivery, the system must notify the homeowner that a package has been delivered via Short Message System (SMS) or Multimedia Messaging

Service (MMS). (8) The system must provide the homeowner exclusive access to the box contents via membrane keypad. (9) Provide communication to SPDB users using BlinkM Smart LED and Composite display. (10) Program the ability to make the SPDB inaccessible outside of delivery hours with the exception of the homeowner. (11) Install the system into the physical box and complete testing.

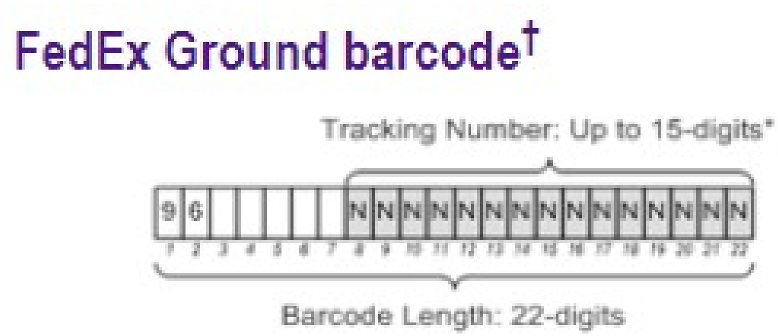
Research

Commercially Available Smart Package Delivery Boxes

At the projects start it was important to review what is commercially available to better understand where they fall short and where improvements can be made. Inquiries were made into the three most popular products: Yale, eufy Security, and Boxillion with the Yale being the most prominently advertised. All three claim to be hassle free which is likely the case for the homeowner but they in fact are not hassle free for the mail courier. They each require that the mail couriers that use the boxes know the pin in order to gain entry which is cumbersome for them and provides the release of sensitive information to the multiple parties involved. In the case of the eufy the homeowner has the ability to see a camera that is triggered when a delivery is made to view the courier which is noted as a nice feature however, if the courier does not have the pin the homeowner, then is required to unlock the box for them with their phone. This idea of user management goes against the concept of hassle free for the homeowner as well.

Package Barcodes

An in-depth knowledge of barcodes was required in order to understand how they can be used or not throughout the project. Each delivery package barcode is identified by the first 2-3 characters when decoded. While this varies from service to service it does provide a potential for courier classification. Additionally, through research it was discovered that the tracking number is also incorporated into each barcode typically near the end. See example below.



Short Message Service & Multimedia Messaging Service

The first text message was sent on Dec. 3 1992 by Papworth to his friend Richard Jarvas (Gayomali, 2012). Since then Short Message Service (SMS) has become one of the world's most used technologies for communication. While limited to 160 characters it is very ideal for sending delivery information to homeowners for a very low cost. The point where an SMS becomes a Multimedia message service communication is when a video or picture is transmitted.

The options available to send an SMS and MMS were to incorporate it on device requiring an antenna or to utilize a 3rd party service that would provide it. The main drawback of the incorporation of an on-device SMS/MMS capability is that signal similar to cell phone service will have low coverage areas making the device unable to send communications in certain locations. The utilization of a 3rd party service however would utilize the homeowner's internet connectivity avoiding the low coverage situation. The downside to a 3rd party service is that it comes at a long-term cost.

Inter-Integrated Circuit (I2C) in python

The project experts were familiar with I2C and using it in communication to the BlinkM smart LED in the C programming language from previous projects. However, using I2C in python is not exactly the same and some research was required to adapt. After investigation of the smbus2 library in python it became clear that an object containing the I2C bus needed to be created and specified. From there, data is written to the bus in blocks with smaller portions capable of being sent in bytes. In the case of the blocks each block must follow the format (address, register, data) and likewise with the byte (address, data). In C this process is much less intuitive and requires the programmer send data in the correct order and allow a proportionate amount of time to pass between each communication sequence.

Amazon Web Service (AWS) - S3 & Rekognition

Amazon S3 provides cloud storage for objects as a service (Cloud Object Storage, 2022). While it offers industry leading scalability, availability, security, and performance it also is free for the first 12 months which pairs great for prototype development. In addition to being free for the first 12 months it also offers up to 5000 image uploads per month which is well within the range of the amount of data being worked with for the SPDB project. For python the Boto3 Software Development Kit (SDK) is available for easy integration.

AWS S3 works well with the multitude of services hosted by the AWS platform. Most notable is AWS Rekognition which is a service that provides customizable computer vision and machine learning capabilities to extract data from images and videos at a high rate of speed (Machine Learning Image and Video Analysis, 2022). More importantly it is capable of object and text detection in images regardless of orientation which puts it at the top of its category when working with images.

Utilizing Analog Sensors with Digital Systems

Upon selection of the light sensor, the original idea was to use the formula T=RC where 'T' is equal to the time constant in seconds, 'R' the resistance in ohms, and 'C' the capacitance in Farads; to find the resistance of the photoresistor, and from the resistance the light conditions. The GPIO would output 3.3V for the time needed to fully charge the capacitor, and then be switched to input mode measuring the time it takes for the pin to go low. This cannot be done reliably since the pin will read low before the capacitor is done discharging. Another option would be to buy an analog-to-digital converter which is expensive and complicated to use. A comparator circuit was suggested as a solution, and upon further research was found to be a perfect low-cost solution for this application. An operational amplifier could be used as an inverting comparator that would saturate towards Vcc (5V) when the non-inverting pin voltage is greater than the voltage of the inverting pin. (Op-amp Comparator and the Op-amp Comparator Circuit, 2021) Using a Wheatstone Bridge to provide voltage to the operational amplifier's inverting and non-inverting pins, a resistance value can be chosen as a threshold to saturate the Op-amp toward Vcc. Meaning the resistance determined from a light level and anything over that threshold will saturate the Op-amp and output a high signal to the GPIO input pin connected to the circuit. The program can simply poll that pin to check if it's high. When high, the BlinkM LED can be used to output a flashing sequence that will help aid the mail courier in finding the box in dim or dark lighting conditions.

Light Sensors

The following light sensors were compared during the research phase: photoresistors, photodiodes, and phototransistors. Photoresistors act as a resistor whose resistance varies from low resistance the brighter the lighting conditions, to high resistance when the lighting conditions are dark. These are commonly used to determine whether a light is on or off or compare lighting conditions to a set point. An example use of these would be in streetlights, where the light turns on in dim to dark lighting conditions. In photodiodes the light levels are determined by the electrical current across the photodiode. The brighter the lighting conditions, the higher the current. These are used in applications that require fast response time like smoke detectors. Phototransistors act as an amplified photodiode providing additional light sensitivity. (What is a light sensor? types, uses, Arduino Guide, 2020) In our project we are simply trying to determine dim to dark lighting conditions and turn on a light sequence to help the mail courier find the delivery box, very similar to streetlights. A photoresistor was found to be the best choice considering the use of the light sensor in this project.

Mosfet Switches

A switching circuit was determined to be needed during the early stages of development for this project that would energize the lock for a short interval of time. While researching it was found that N-channel Mosfets are good low-side switches, and P-channel Mosfets high-side. In low-side switches the load is connected to Vcc, where high-side switches are the opposite, with the load connected to ground. In this application, we want to isolate the lock from Vcc, because if connected to Vcc the lock will never close and would eventually burn out. That means in this case we need to use a P-channel Mosfet as a high-side switch so that the lock will only be energized when the Mosfet is on. In order to prevent the Mosfet from turning on unintentionally, it is important to add a resistor between the gate and source. (Simple MOSFET Switching Circuit – How to turn on / turn off N-channel and P-channel Mosfets, 2021)

Composite Video

Composite video was the analog video transmission used when the color TV was first introduced in 1954. It utilizes a single-channel analog video transmission format carrying standard-definition (SD) video at 480i or 576i resolution (Composite Video-NFI, 2022). Composite video is also called SD video or CVBS for composite video baseband signal. Composite video input standard is a 3.5mm jack with a yellow plug output leaving audio to be handled separately on its own channel denoted by white and red plugs.

TEST AND EVALUATION

Apparatus

Raspberry Pi 4 Model B – 8GB RAM, 32GB Micro SD, Raspbian OS

First released on June 24, 2019 the raspberry Pi 4 is a robust all-encompassing system. It uses the Broadcom BCM2711, Quad Core Cortex-A72 (ARM v8) 64-bit SoC @ 1.5GHz processor and has the speed of a minicomputer. It comes equipped with Raspbian Operating System (OS), Bluetooth, Gigabit Ethernet port, 2 USB 3.0 ports; 2 USB 2.0 ports, 4-pole stereo audio and composite video port, 40 GPIO pins, and the list goes on. Due to the robustness, speed, support for multiple programming languages, and affordability it has no equal when it comes to prototype development.

19.5VDC Power Supply by Hewlett-Packard

The power supply utilized in this project is a repurposed charger power adapter from a Hewlett-Packard OMEN 15 inch laptop. This power supply plugs into a 100-240VAC, 50-60Hz outlet, and converts the power from the outlet to a 19.5VDC power source that can handle 7.7A, for a total of 150 Watts. This was important for this project as it can comfortably provide enough power to power the Raspberry Pi which takes a total of 3.5A, the solenoid lock with 2A, and the analog display of 500mA with 1.7A unused. Some other benefits are in the power supply's size, cable length, and overcharge, temperature, short-circuit, and lightning protection. With its slim size it can fit into the small area allotted for the electronics, and the power cord has enough length to run from the electronics cabin to a power outlet on the wall of the user's home.

15W DC-DC Converter by PlusRoc

This DC-DC converter allows a voltage input range from 12-24VDC and outputs 5VDC 3A. The output is in the form of a USB-C adapter, which is the adapter type of the Raspberry Pi's power supply. This was the perfect converter for our project as a solution was needed that would convert 19.5VDC to 5VDC 3A with a USB-C adapter to power the Raspberry Pi.

IRF630 P-Channel Mosfet by STMicroelectronics

The IRF630 from STMicroelectronics is meant for switching applications, specifically for use as the primary switch in DC-DC converters. It is rated at 200V and 9A, with a flyback resistor between the drain and source, designed to reduce capacitance and charge at the gate.(IRF630 STMicroelectronics product datasheet Rev.10, 2018) As donated by Ferris State University, this Mosfet worked perfectly in this project as a high-side switch used to unlock the solenoid lock, as the lock is not meant to be powered for more than 200ms as outlined in the advertisement upon purchase. The lock draws 2A and requires 12VDC to unlock, in addition to accounting for flyback voltage upon the solenoid lock quickly turning on and off. Compared to the 200V and 9A this Mosfet it is seen that this Mosfet can very comfortably handle the switching of the solenoid lock in this project.

IR 5MP 1080p Pi Camera by Longrunner

This $20 camera is quite powerful offering clear images in 1080p with resolution that scales up to 2592 x 1944. It has the added benefit of having two attached IR lights on each side to aid in limited visibility and for taking photos at night. This camera does not have a data sheet available but was listed as being compatible with the Raspberry Pi Camera module in python. It uses the ribbon cable camera port on the Raspberry Pi though this does come with one disadvantage. After careful review of the Raspberry Pi hardware, it was discovered that the camera port on the Pi is tied directly to 3.3V power meaning the only way to turn the camera/IR lights off is by turning off the Pi. While this is not an issue for the purpose of a prototype it is worth noting an alternative solution would need to be found for extended use of the camera port. The IR lights on the side s of the camera do get incredibly hot after extended use and to address this issue small heat sinks were placed on the back of them to prevent overheating during preliminary testing of the device.

1D USB Barcode Scanner

The barcode scanner selected for the project was chosen for its cheap cost, Universal Serial Bus (USB) output, and because it is a one dimensional (1D) scanner. The cheapness of the device came with the drawback that there is no model information however, it was delivered with a booklet that allowed configuration of the device by scanning barcodes to adjust hardware settings. The USB output was a sought-after trait at the beginning of the project due to the question of how many GPIO pins would end up being used later throughout the project. The raspberry Pi has 4 USB ports therefore it made more sense to put an unused area of hardware to work. The 1D scanner was selected for its cost as previously mentioned but also because of the security component it adds. 1D scanners prevent barcodes on a phone or generated on a display screen and only allow real physical barcodes on paper to be scanned. This element allowed for the avoidance of a situation where a criminal might try to generate a tracking number barcode to gain entry into the SPDB using a phone.

12V DC Solenoid Lock by ATOPLEE

This lock is closed when unpowered, unlocks when given 12VDC and draws a total of 2A when powered. This is perfect in applications where the box needs to stay locked even if the system loses power. It is simple to use and is of small size making it perfect for hidden installations. The lock can hold a force up to 280kg and has heavy door bounce upon unlocking. Some other desirable features are its emergency unlock function, and energy saving due to it only being powered for short intervals up to 200ms. The lock has been heavily tested for durability, powered for ten second intervals 500,000 times according to the lock's online advertisement. This works well for our project as our 19.5VDC, 7.7A power supply can comfortably meet the current and voltage requirements. Its small size allows it to fit into the electronic compartment on the inside of the front of the box. The lock can hold far more force than the pressure on the lid being pushed by the struts and provides some bounce when unlocked, which aids the struts in opening the lid of the box. (ATOPLEE Electronic Cabinet Lock,1pcs DC 12V Power Control Door Lock for Cabinet Drawer Locker, 2022)

Membrane Keypad

This membrane from Parallax is ultra-thin with adhesive on the back for trouble-free mounting. It has a total of 16 buttons labeled as the numbers 0-9, letters, A-D, and the addition of a pound and star symbol. These interface with the Raspberry Pi using 8-pins that access the 16 buttons using a 4x4 matrix. Its maximum voltage and current is rated up to 24VDC at 30mA. (4x4 Matrix Membrane Keypad Parallax Incorporated product datasheet #27899 v1.2, 2011)

BlinkM Smart Light Emitting Diode (LED)

The BlinkM LED uses 5V standard TTL inputs capable of remote commanding via IC2 communication to set its 8000 mcd 140 degree full-color RGB LED (BLINKM V1 DATASHEET, 2007). It has the added function of stand-alone operation able to play back scripts and light sequences.

Composite Video Display

A repurposed composite video display with no model number information was scavenged out of an old military kit used to control robots designed to drop ordinance. After analyzing the device with the naked eye it became apparent that it was capable of a connection via radio frequency channels and composite video input and output via 3.5mm jacks.

161 Photoresistor by Adafruit

Commonly referred to as CdS Cells as they are made of Cadmium-Sulfide, photoresistors, photocells, or light-dependent resistors (LDRs). These are small, inexpensive, low-power analog devices that are used to detect light. They act as variable resistors whose resistance values change depending on the light shining on the metal surface. The resistance ranges from 100 ohms in direct sunlight to 600k ohms in complete darkness. This photoresistor responds to a range of wavelengths from 400nm(violet) to 600nm(orange), with a peak responsiveness of 520nm(green) wavelengths. It can also handle a wide range of input voltages of up to 100V and pulls about 1mA of current on average, which is approximately 100mW if used at the maximum operating voltage.(161 Adafruit product datasheet, 2021) Due to its inexpensive price and ability to detect general lighting conditions, this was the top choice for this application. The photoresistor also has long wire terminals which were long enough to allow the metal surface to peak out of a small, drilled hole on the front of the box while still reaching the comparator circuit on the inside of the electrical compartment.

NSDU45 NPN Bipolar Junction Transistor (BJT)

A NPN BJT was desired to drive the p-channel mosfet used to unlock the solenoid lock. Since the BJT is only used in cutoff and saturation modes, the only specifications taken into consideration were the maximum collector-base voltage(Vcb) and collector current (Ic). A collector-base voltage needed to be able to handle 19.5VDC, and a collector current of 2A in the case that the mosfet fails to protect the GPIO pins. This BJT was donated from Ferris State University and has a max Vcb of 50V and Ic of 2A which meets the current needs and far above the voltage needs of this application. (NSDU45 datasheet, Equivalent, cross reference search. Transistor catalog, n.d)

LM741 Operational Amplifier

This Op-amp has input and output overload protection, latch-up prevention when exceeding the common-mode range, and oscillation protection. The maximum voltage ratings are a supply voltage up to 22V, and differential input voltage of up to 30V. Example uses are as a comparator, DC amplifier, or active filter. Considering the Op-amps key features and voltage ratings this amplifier is a top choice general amplifier when working with voltages within its specifications. (LM741-MIL Texas Instruments Incorporated product datasheet, 2017)

Procedure

Physical Box Design and Creation

The physical box for the project was designed using a generic online cad software. The overall dimensions chosen were 30” long x 16.5” wide x 16.5” tall as these dimensions matched standard 2x6 material width and were practical. The width of the material was chosen to be 1 inch in thickness while originally thought to be too thick ended up becoming an incredible asset when it came to installing all of the components. The box itself was created by hand to specification using a drill, tape measure, carpenters square, hand tools, table saw, planer, circular saw, jig saw, palm sander, wood glue, and wood screws. An inlay was created near the front of the box using the table saw as a deido blade for a thin piece of material to be able to slip in and store components on. This small subsection acts as a separator to keep components away from users and as a troubleshooting mechanism to allow the system itself to be able to be withdrawn from the box for maintenance work. Gas struts were added to keep pressure up on the lid so packages could be placed inside without users having to hold it open. The box was then stained with a carbon grey wood stain to give it a neutral appeal. Components were installed on the front by tracing each component with a pencil, drilling a pilot hole big enough to get a jig saw blade in, and by cutting it out with the jig saw. The enclosure used for the BlinkM is a night light casing that was repurposed.

Mosfet Switching Circuit Design and Creation

A circuit was designed using the NSDU45 NPN BJT, IRF630 P-channel Mosfet, a 18k ohm resistor, and 6.8k ohm resistor that energizes the solenoid lock for a duration of 200ms. The circuit schematic can be seen in the Data section, beginning with the 3.3V power supply and switch representing the Raspberry Pi GPIO pin 27. When this pin outputs a high signal the current flowing to the base of the BJT allows current to begin flowing from the collector to the emitter. This current causes the voltage across the 18k ohm resistor to increase, which decreases the voltage at the gate of the Mosfet from Vcc to approximately 12.6V. This creates a negative voltage between the gate and source of the Mosfet, turning it on, energizing and unlocking the solenoid lock.

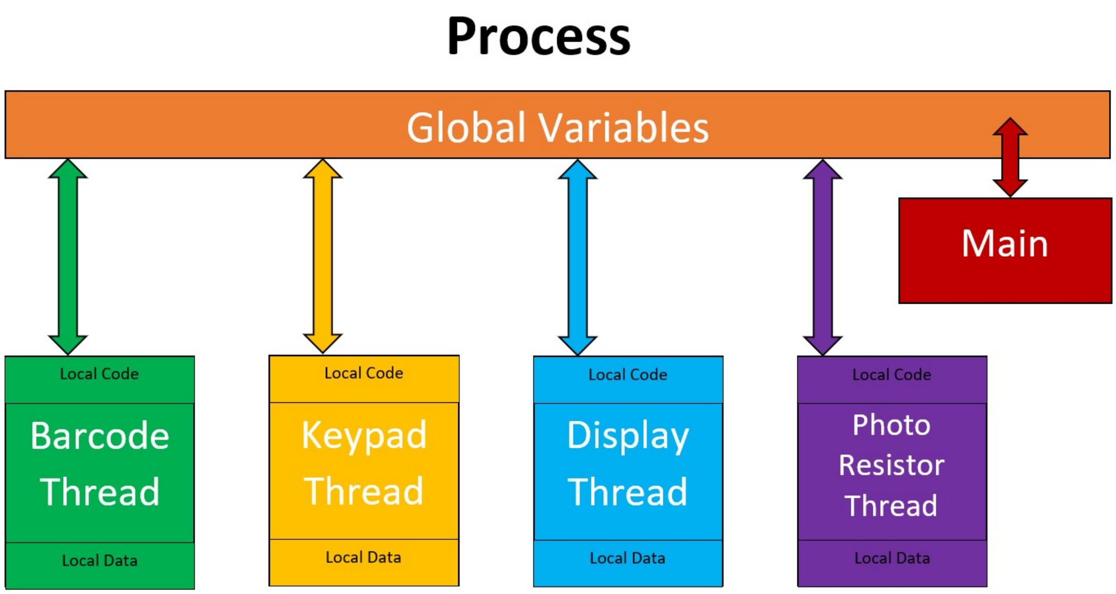
All of the circuits designed in this project are comprised of through-hole components soldered onto previously owned perforation board. The solder used in the making of this product is lead free solder made up of 97.3 percent copper/tin, and .7 percent flux. Temperatures of 350-375 degrees centigrade were required to melt the solder.

Photocell Comparator Circuit Design and Creation

A circuit had to be designed to fulfil the task of providing visibility aid in dim to dark lighting conditions. This circuit which can be seen in the data section will output a high signal to pin 25 of the Raspberry Pi GPIO. A Wheatstone Bridge is used to provide the comparator voltages of the inverting and non-inverting 741 Op-amp inputs. Connected to the inverting pin is a voltage divider that determines the voltage threshold of which the non-inverting pin needs to be greater than for the 741 to saturate to Vcc. When the photoresistor is greater than 10k which is the resistance at which the lighting conditions are that of a dim room, the voltage of the non-inverting pin becomes greater than the inverting pin, and the Op-amp saturates to the Vcc voltage of 5V. The final voltage divider brings the 5V out of the 741 down to 3.3V output to the GPIO pin which will read as a high input. The program uses a thread to poll this pin, checking to see if the pin is high. When high, a light flashing sequence begins outputting from the BlinkM LED to help the mail courier find the delivery box.

Program Approach via Multithreading

All of the primary components selected for the SPDB have one thing in common and its that they all need to be waiting for data at the same time. The solution to this problem was multithreading as it allowed the barcode scanner, membrane keypad, display, and photoresistor all to wait for data concurrently. In addition to concurrency multithreading allowed for shared resources between the main thread and each other. This was taken advantage of by using global variables as interrupt flags similar to how a processor utilizes its interrupt flags (see graphic below). Through this method for example, when data comes in on the barcode scanner thread it can process its data and when ready will raise its flag to notify the main thread (who has been checking it) that data has come in. The main thread then acknowledges the flag, processes the scanners data, and when finished will reset the scanners flag so new data can then be accepted by the barcode scanner thread. One issue experienced with having multiple threads/functions was that global variables in python require that they be redeclared inside each function. This was quite cumbersome given the number of global variables being used. This was overcome by placing all global variables inside a class. For example, “glb.scanner” is the flag for the barcode thread where the “glb” is reference to the class.



Barcode Extraction & Camera Implementation

The address verification objective was achieved using the barcode scanner and camera together. The barcode scanner utilized the serial module available in python. The code for this section was written so that when the user scans a barcode, data is then read in serially one byte at a time. Each byte was then decoded from UTF-8 until a carriage return is received at which point the data is then returned to the main thread (see function below). The program then filters the barcode to determine which courier the package is being delivered by and utilizes string splicing to acquire the tracking number for later use.

```
def serialScan():
    data = "" #initializes local variable as empty string
    item = "" #intializes local variable as empty string
    glb.ser.open() #open serial port
    while item != '\r': #while a cariage return is not read
            item = glb.ser.read().decode("utf-8")#read serial port one byte at a time and decode it
            data += item #store the decoded byte and concatonate the string
    data = data.strip("\r") #remove it from the string
    glb.ser.close() #close serial port now that were done with it
    return(data) #return the scanned barcode back to 'barcode thread'
```

The camera itself needed a case as no case was commercially available therefore one was 3D printed at the Ferris State University Makers Space (see data section for pictures of the results). The camera was implemented with the Picamera python module and more specifically the picamera class within the module. This allowed the camera to be used as an object with several traits such as the specification of the resolution which was set at 2592 x 1944 (maximum) and the use of an overlay. An overlay was added to the camera object so that each picture would include the timestamp, an invaluable function for the homeowner.

AWS & Twilio

The picture taken from the camera was then used in conjunction with AWS S3 & Recognition via pythons Boto3 SDK to correctly verify the address. It was uploaded to S3 for storage with the timestamp used as the file name for uniqueness. After being uploaded, the image was then analyzed using AWS Recognition with the results returned as a series of strings inside an object. The object was then extracted one line at a time and saved into a text file for filtering. The addresses of the couriers were inconsistent therefore to remedy this issue each text file was filtered to be case insensitive and contain no commas. From this point the text file was the parsed for each element of the address and if all elements are found the address variable named "glb.verified" was then set to a 1 (raised) for the main thread to process. This section was initially complicated and therefore each aspect was broken up into small portions and tested to determine how the data was behaving at each step.

Now that all important information had been extracted from the barcode and image this information needed to be shared with the homeowner. This was achieved using the third-party service Twilio via the twilio.rest module with the client class. Through Twilio a MMS and SMS was able to be sent to the homeowner containing the timestamp of the event, the picture captured the label, tracking number, and courier service information. A trial account was required to do this which was free up to $15 where each MMS cost only 2 pennies. An object containing the ID and authentication token was also needed and for the purpose of the prototype was input in plain text. It is acknowledged that this is likely a bad practice and for future development all credential information should be input using environmental variables for concealment. The only issue encountered with the Twilio service was that in order to send the picture stored in S3 to the homeowner it needed to be made publicly available which imposed a security risk. In essence anyone with the link would be able to access and view the image if the image was made public. To overcome this issue a pre-signed URL was used to make the picture publicly available for a very short period of time. To overcome this issue a pre-signed URL was used to make the picture publicly available for a very short period of time only. During this window of time Twilio will have access to grab it and send it to the homeowner after which it is then set back to private.

Through experimentation 5 seconds was the amount of time chosen as some pictures when sent with 1 second took too long to be processed by Twilio (errors viewed in Twilio’s logs).

Multiplexing

As mentioned in the Apparatus section, the membrane keypad allows the Raspberry Pi to use 8 GPIO pins to interface with 16 buttons using a 4x4 matrix. Without this matrix 16 GPIO pins would need to be used, which is more than half of the total GPIO pins available. Each row and column have an associated pin, and the software for the project continuously checks for key presses using the following technique. Each column in a queue is energized, followed by the checking of the rows for a high pin. If a pin is high the program knows that the button where that column and row meet has been pressed. This process happens very quickly so even though each column is being checked separately, it is much faster than a human is in interfacing with the hardware, so button presses will not be missed.

BlinkM Functions

BlinkM functions were created and stored in a separate file to be imported into the main program. The colors required to relay information in the program were preset as constants with the variables named their respective color. This allowed for the “SolidColor()” function to be simply passed a variable or the appropriate color in order to set the LED that color. Most notably in the BlinkM function file contains two custom scripts. The first called “LocationHelper” to be used with the photo-resister as previously described above. The second “FullHelper()” was created to be used when the SPDB is marked full as it will then play repeatedly without requiring management from the program.

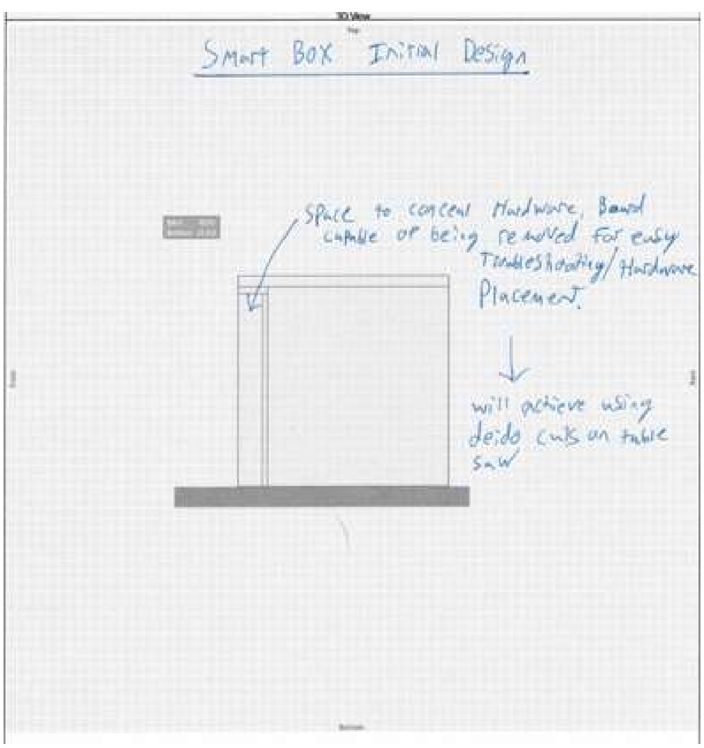
Composite Display Communication

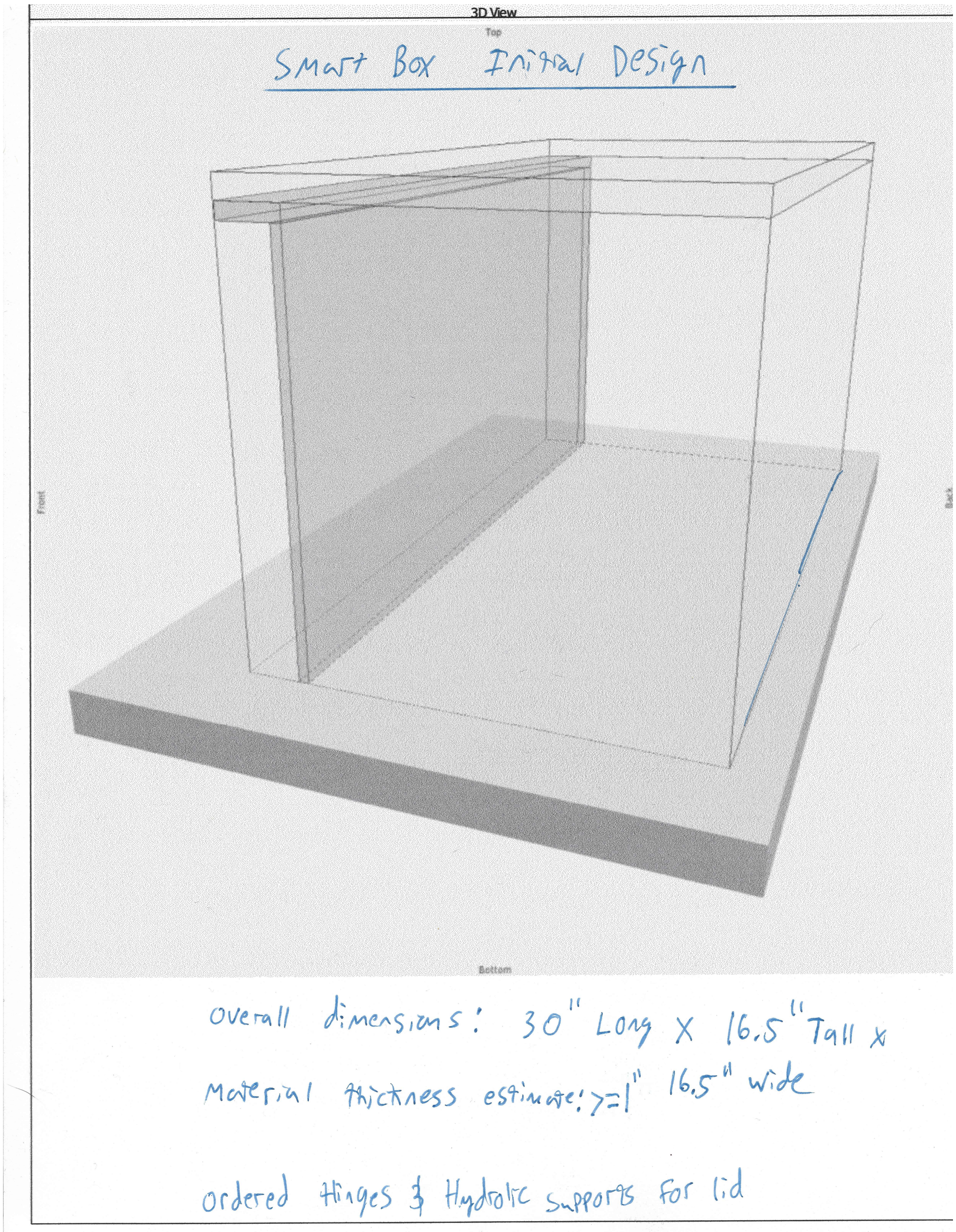
The display was placed in its own thread so that it could independently receive information from the main thread as well as the other threads in order to update based on data being received. The display portion of the program was achieved using the pySimpleGUI module for the various windows, and the VLC media player module for playing short video clips (see code listing for specifics). The main issue encountered with the display was that the Raspberry Pi's composite output placed the video on the sleeve of the 3.5mm jack while the display needed the video to be located on the second ring. After this was discovered, an adapter was used to make the correction which then allowed both audio and video to be transmitted from the Pi to the display.
This display requires 12VDC and pulls 500mA, so a solution had to be created to allow the 19.5VDC power supply to power this at the lower voltage. To drop the voltage to approximately 12V the display was put in series with three 10 Watt 50-ohm resistors in parallel.

FINDINGS

Data

Physical Box Design and Creation

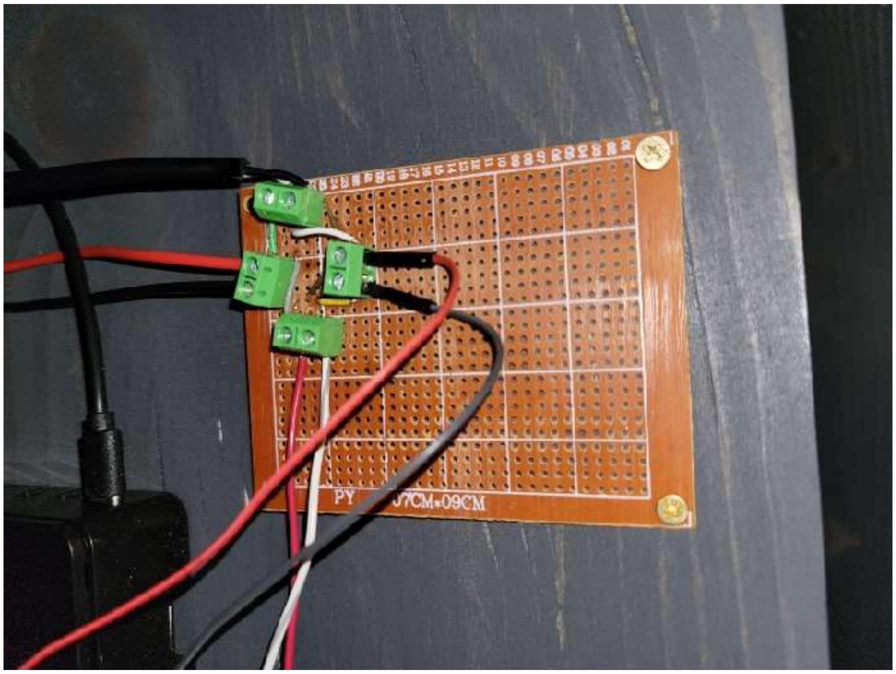




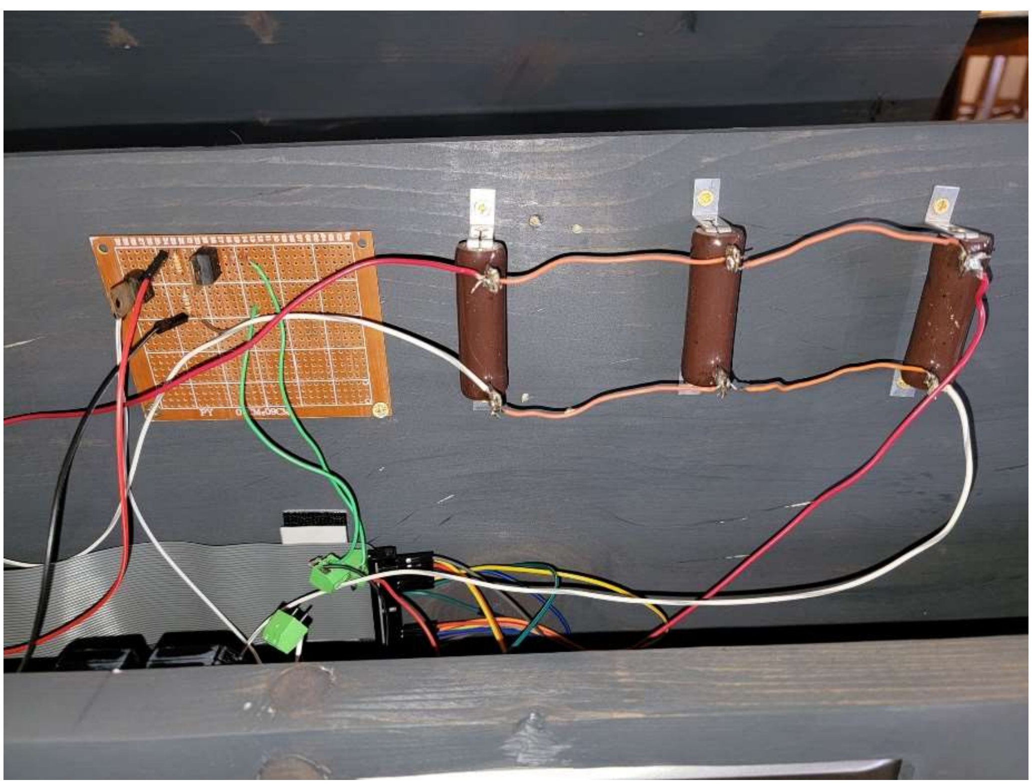
--CAD Designs of the concept for the box

--Timelapse of the box from start to finish

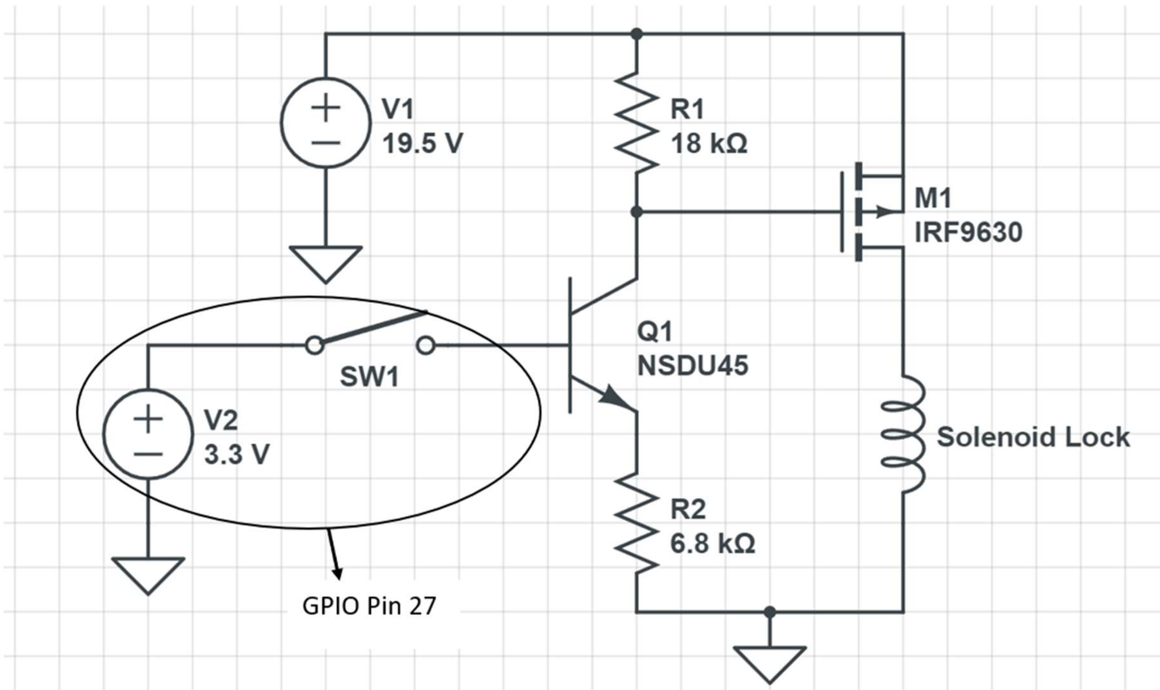
Headers Splitting the Power Supply into Parallel Branches

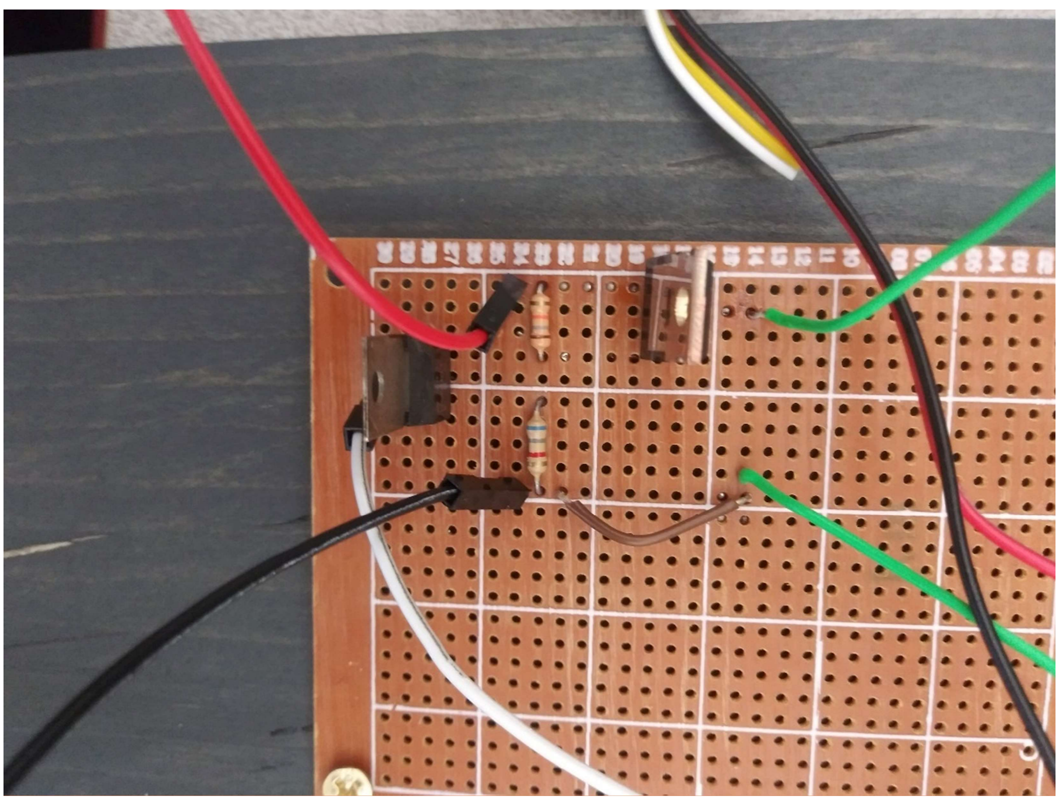


Mounted Resistors used to Power the Display

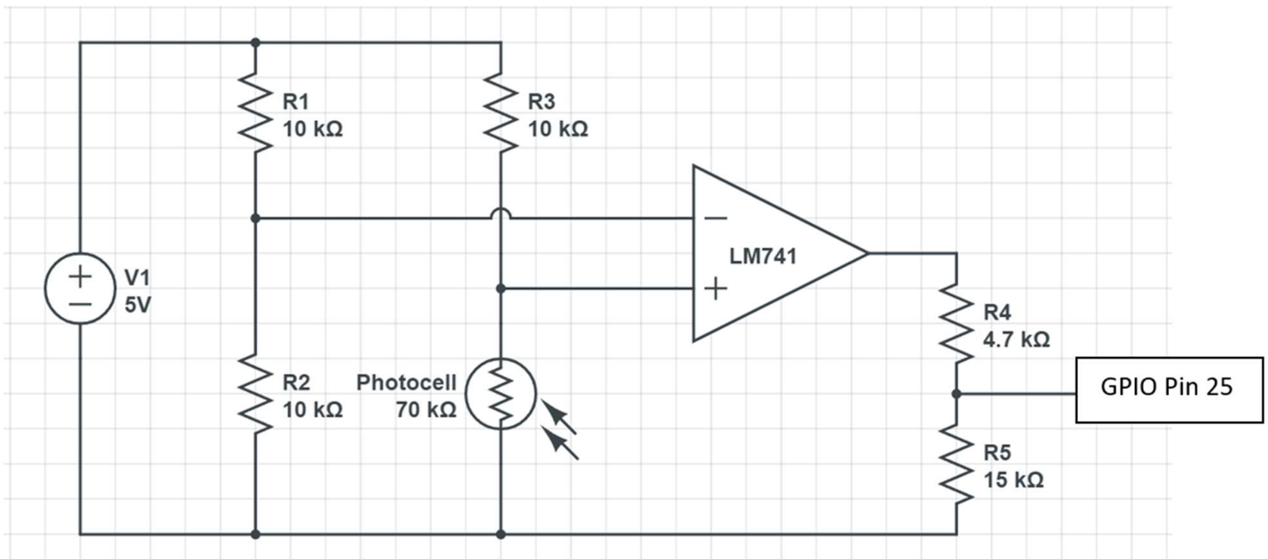


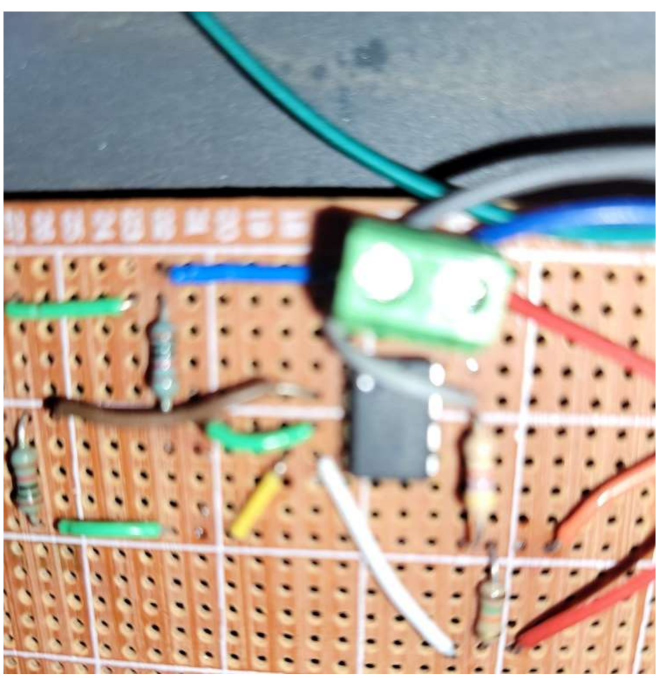
__Mosfet Switching Circuit__



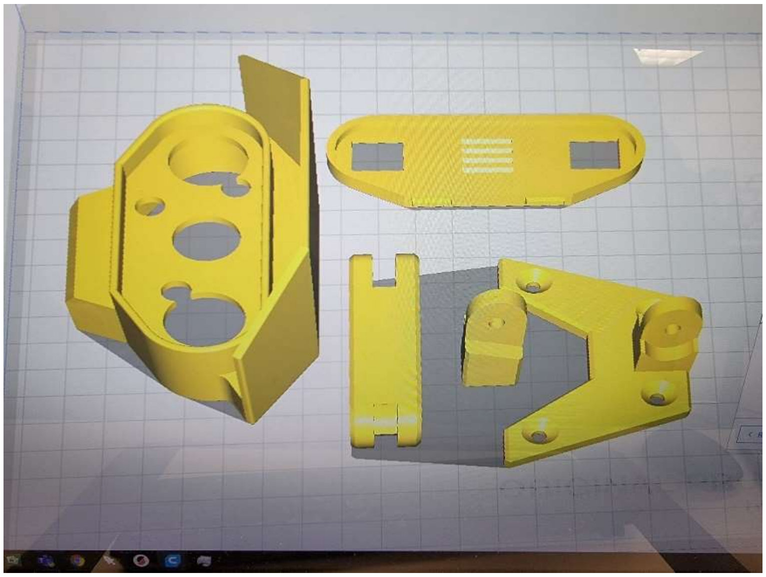


<u>Photocell Comparator Circuit</u>

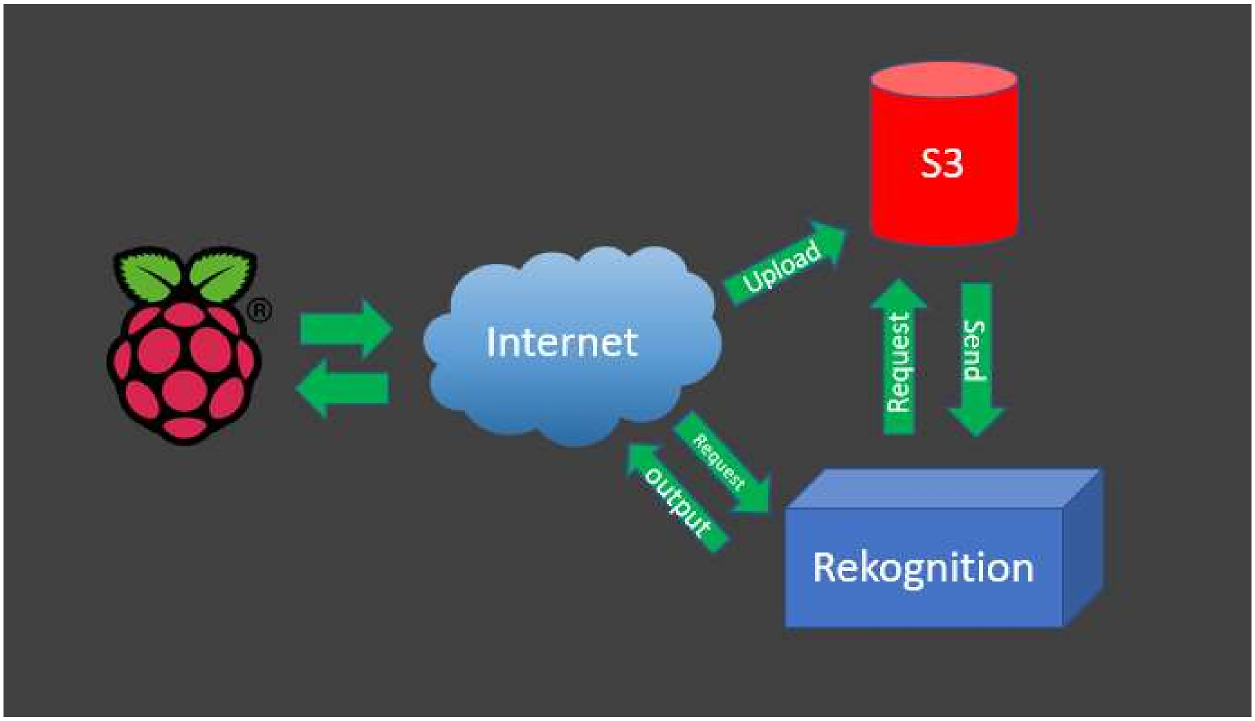


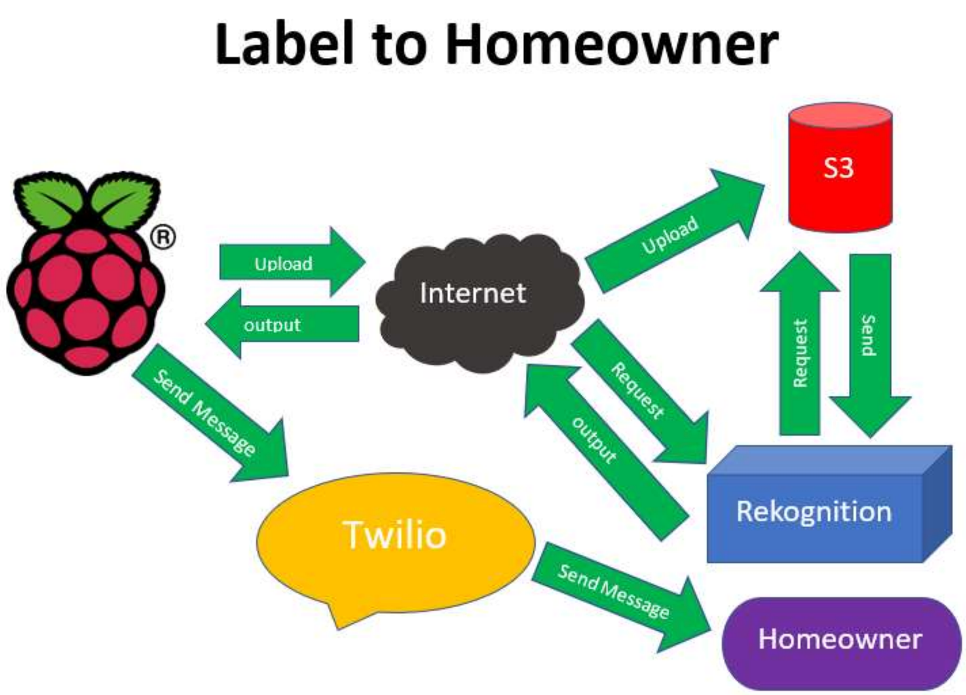


Camera Case 3D printed

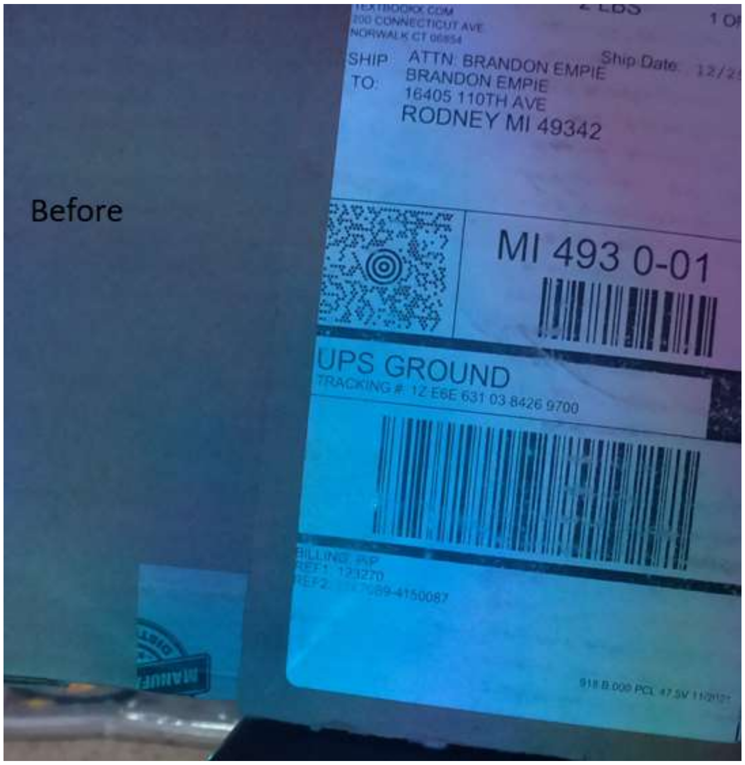


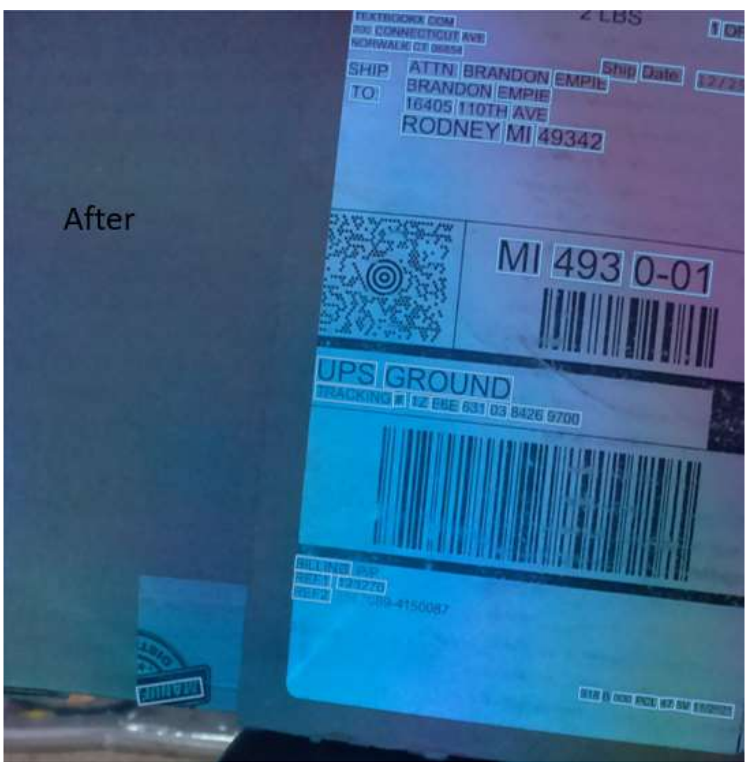
AWS Integration



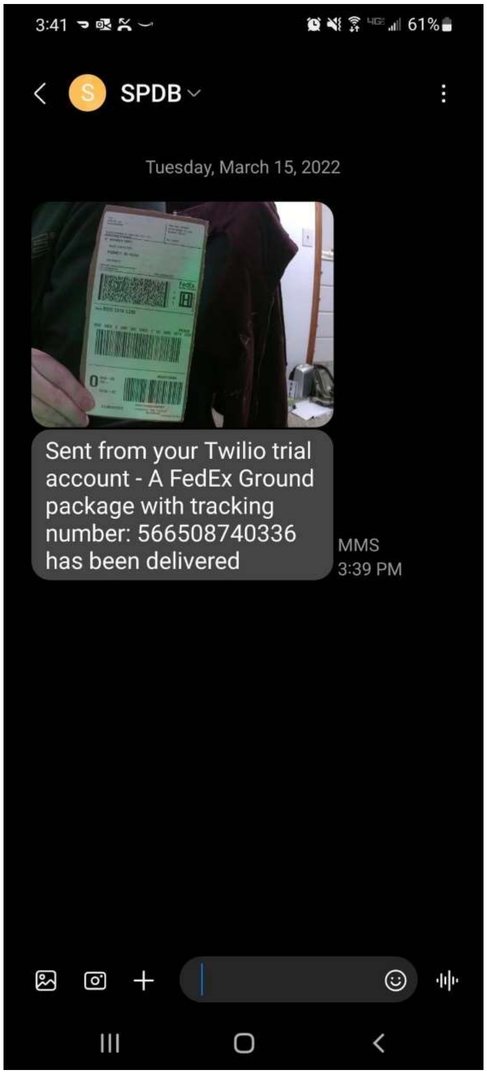


AWS Rekognition Analysis



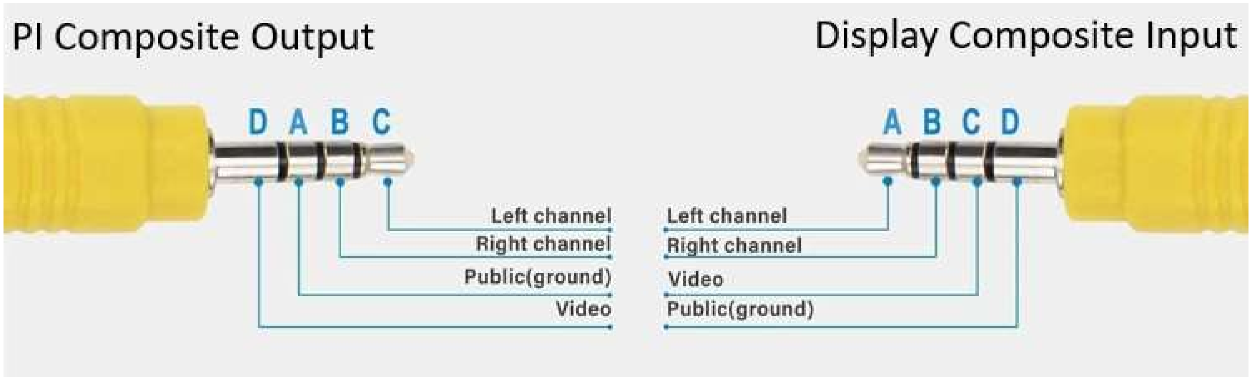


Twilio Integration



--Screenshot of homeowner's phone, showing MMS message upon delivery

Composite Video Input/Output



Budget

Objective: This spreadsheet is to serve as the budget for the senior project Smart Package Delivery Box (SPDB).			
*Items purchased for the project will be listed in no particular order.			
Item Number	**Name**	**Cost**	**Notes**
1	Raspberry Pi 4	$ -	Previously owned (x2)
2	Pi Camera	$ 22.00	
3	Membrane keypad	$ 3.50	
4	1M Camera Cable	$ 2.30	
5	1D USB barcode scanner	$ 20.00	
6	Camera Heat Sinks (x2)	$ 0.30	
7	GPIO Ribbon Cable	$ 8.00	
8	Dupont Wire kit	$ 7.00	
9	Dupont Connector kit	$ 3.00	Full kit was $12
10	Lid Supports	$ 14.83	
11	Hinges	$ 8.99	
12	Lumber - 2x6 - 10 Feet (x6)	$ 24.00	Previously owned (x4)
13	BlinkM Smart LED	$ 13.12	
14	BlinkM Cover	$ 1.00	Ripped cover off night light
15	Composite Video Display	$ -	Repurposed/Salvaged
16	Solenoid Electronic Lock	$ 5.49	
17	Photoresistor	$ 0.95	
18	Perf board (x3)	$ 4.95	
19	Laptop Power Supply- 19V	$ -	Repurposed/Salvaged
20	Wood Screws	$ 4.99	
21	Wood Glue	$ 2.99	
22	Wood Stain	$ -	Previously owned
23	Camera Case	$ -	3D printed on campus
24	Picture Hangers- Velcro	$ -	Previously owned
25	Soldering Iron	$ -	Previously owned
26	Solder	$ -	Previously owned
27	Misc. Electrical Components	$ -	Donated by FSU
28	Composite Video Cable	$ 14.17	
	Total Cost:	**$ 161.58**	

Interpretation

In terms of functionality and general use of all the components in the project all tests returned excellent results. All testing on the Mosfet switching circuit and photocell comparator circuit was performed in a lab environment and based on mathematical calculation in comparison to real-time readings using a multimeter. The following testing result data demonstrates adequate expectations for the project.

Mosfet Switching Circuit Calculations:

- Mosfet Gate Voltage:

  V(BE) = 3.3V - 0.7V = 2.6V

  I(C) = 2.6V/6.8K ohms = 382.353uA

  V(C) = 382.353uA * 18K ohms = 6.88V

  V(G) = 19.5V - 6.88V = 12.62V

- Mosfet Vgs Voltage:

  V(GS) = 12.62V - 19.5V = -6.88V

Mosfet Switching Circuit Tested Values:

- Mosfet Gate Voltage:

  V(BE) = 2.6V

  I(C) = 384.7uA

  V(C) = 6.87V

  V(G) = 12.63V

- Mosfet Vgs Voltage:

V(GS) = -6.87V

Photocell Comparator Circuit Calculations:

- Inverting Input Voltage:

  V(-) = 5V * 10K ohms/(10K ohms + 10k ohms) = 2.5V

- Non-inverting Input Max Voltage:

  V(+) = 5V * 600K ohms/(10K ohms + 600k ohms) = 4.92V

- Voltage to GPIO pin:

  V(out) = 5V * 15K ohms/(15K ohms + 4.7K ohms) = 3.8V

Photocell Comparator Circuit Tested Values:

- Inverting Input Voltage:

  V(-) = 2.5V

- Non-inverting Input Max Voltage:

  V(+) = 4.91V

- Voltage to GPIO pin:

  V(out) = 3.68V

Composite Display Calculated Values:

- Voltage of Display:

  R(display) = 12V/500mA = 24 ohms

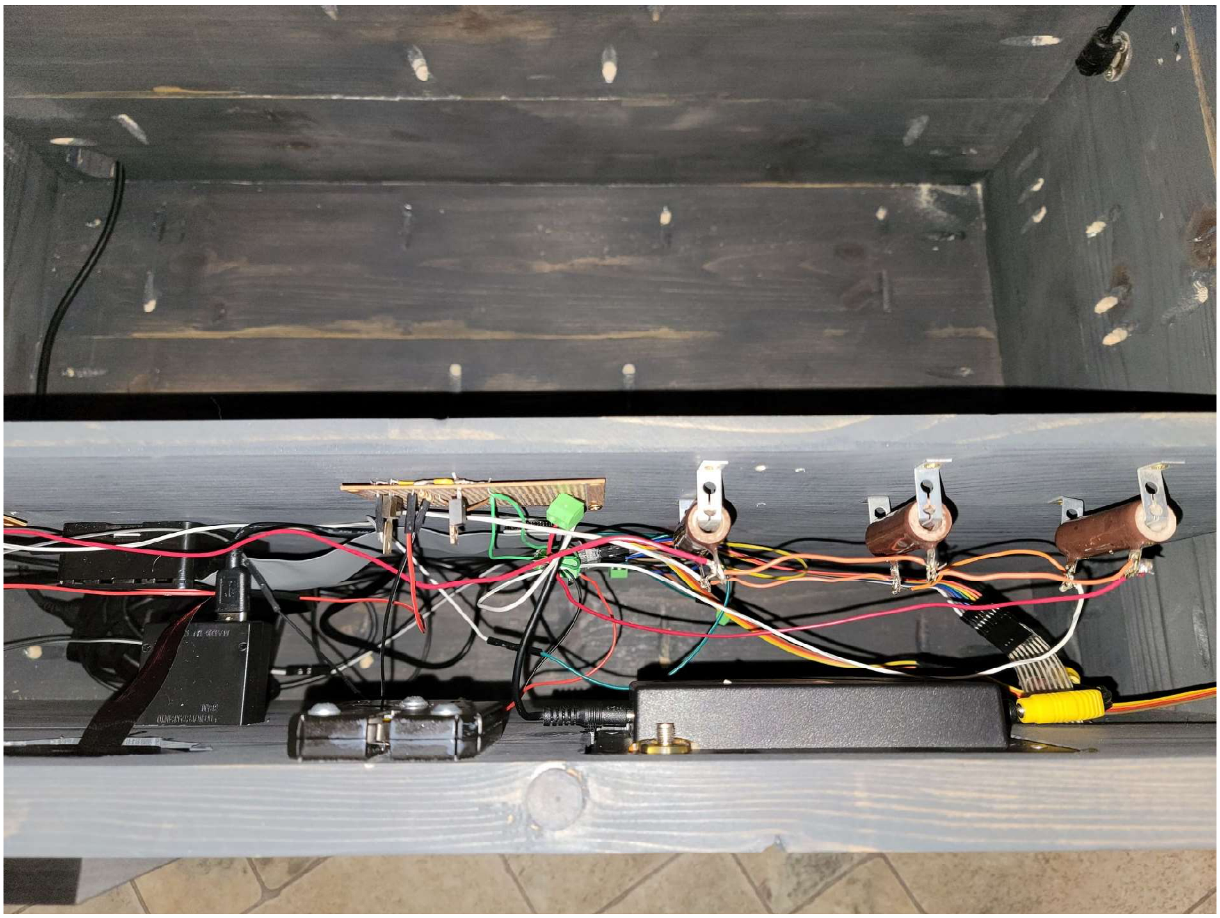
  V(display) = 19.5V * 24 ohms /(24 ohms + 1/((1/50) + (1/50) + (1/50))) = 11.5V

Composite Display Tested Values:

- Voltage of Display:

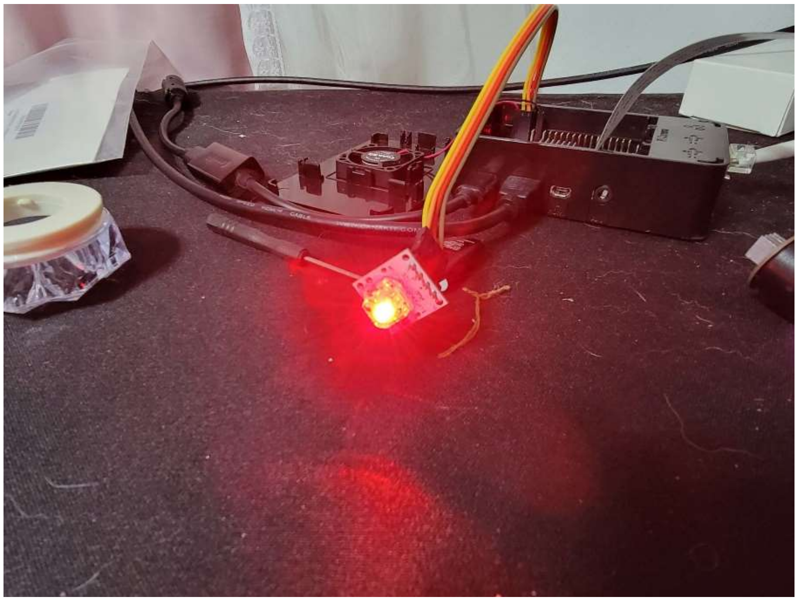
  V(display) = 11.7V

For general use from the homeowner's perspective all testing was conducted as if the product were to be used in real life scenarios. Testing was conducted using real package labels addressed to the homeowner's location. The following data demonstrates the cohesiveness of all components of the project working together at the same time.



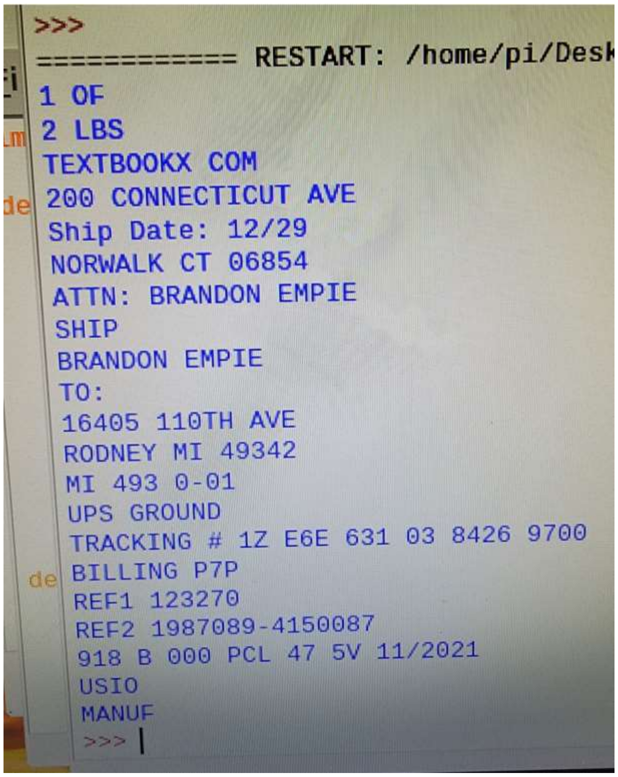
Testing Samples

Preliminary Testing – Camera, Scanner, BlinkM, Composite Display



--BlinkM initial testing

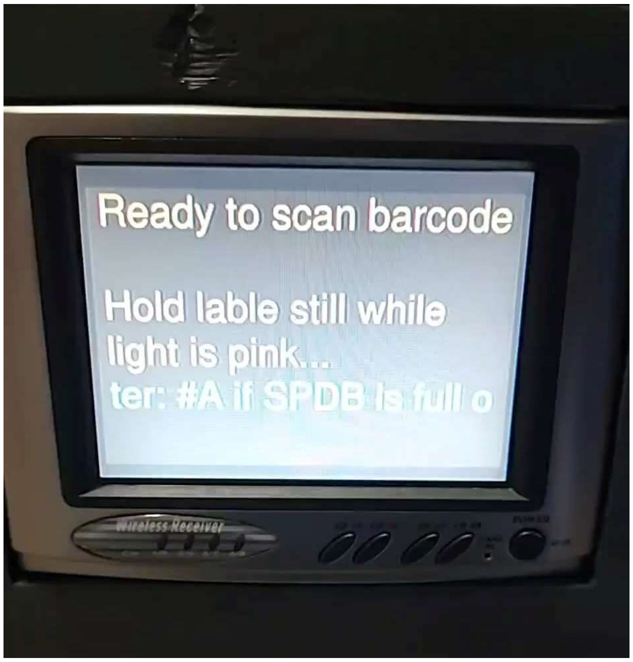
-Camera, barcode scanner, and BlinkM working together



--Initial AWS Results

--Composite Display Current Analysis/Power Consumption

Final Testing Results



-Running display with scrolled line

-- showing package delivery, successful address verification, and opening of the lock

-- showing an address that was not validated

--covering up the photoresistor during delivery hours, showing beacon activating

CONCLUSION

Assessment

In the Interpretations section above it can be seen that not only was the outlined scope completed successfully, but improvements outside of the scope as well. The project was under budget as our initial approximated budget was $250, and our actual total cost came to a total of $161.58. The final determining criteria for a successful project that was achieved is the project being completed by the end date set at the beginning of the project. Considering we went above and beyond what was outlined in the scope, ended under budget, and completed the project on time, this project is determined as more than a success.

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Appendix

Program high level overview