ECE 491 – Senior Design I

Final Design Proposal

Smart Assistive Living Environment (SALE) Project

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Introduction

Smart homes and smart home devices are a growing sector in the electrical and computer engineering field. Lafayette College's Department of Electrical and Computer Engineering (ECE) requested the 2025 senior class to design and/or integrate user-friendly devices that create a cost-efficient smart living environment for older adults or people with disabilities. This project will allow the senior design team to better understand the Internet of Things (IoT) and gain experience doing research and development in a team setting.

The final product of the senior design process is a Smart Assistive Living Environment (SALE) system. The goal of the system is to help residents in the smart home manage daily tasks, stay connected with friends and caregivers, and live more independently. The system must have a way for residents with dysfunctional hands to interact with the system, necessitating an alternate input device (to replace the mouse or keyboard). The SALE system consists of four elements: a Hub, a Smart Mobile Device (SMD) with the SALE app installed, a set of smart devices, and a Remote Support Station (RSS). The Smart Mobile Device will accept input from Kick Buttons, which we've chosen as our alternate input device.

To ensure that the system works in the real world, the SALE system must be Matter-compatible. Matter is an industry-unifying protocol/standard that facilitates reliable, secure smart home connectivity. More information about Matter can be found in the Existing Standards section. In addition, the system shall be cost-efficient, and members must propose and work within a budget approved by the ECE Department.

High Level Design

System Block Diagram

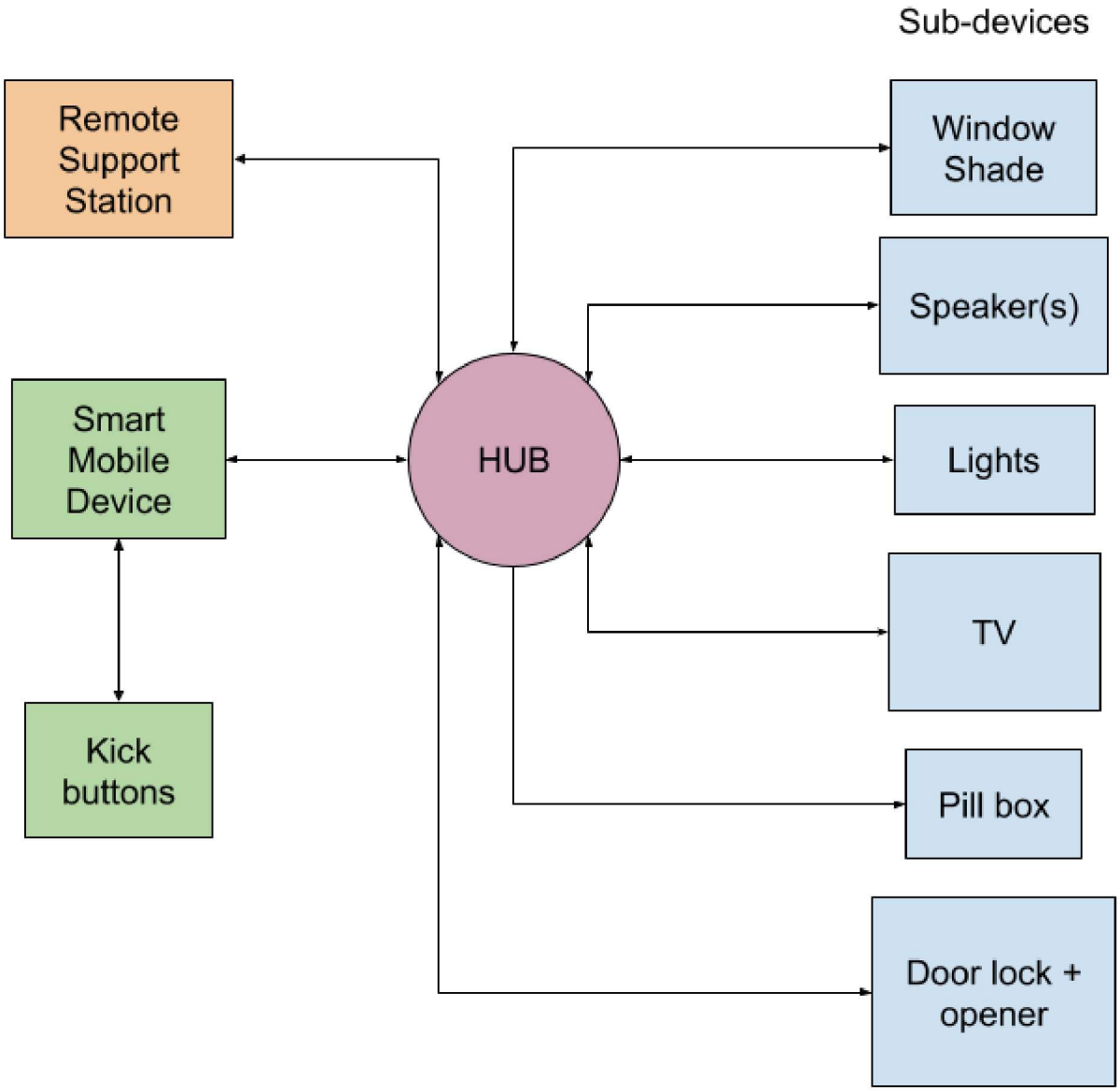

Figure 01: High-Level Device Overview

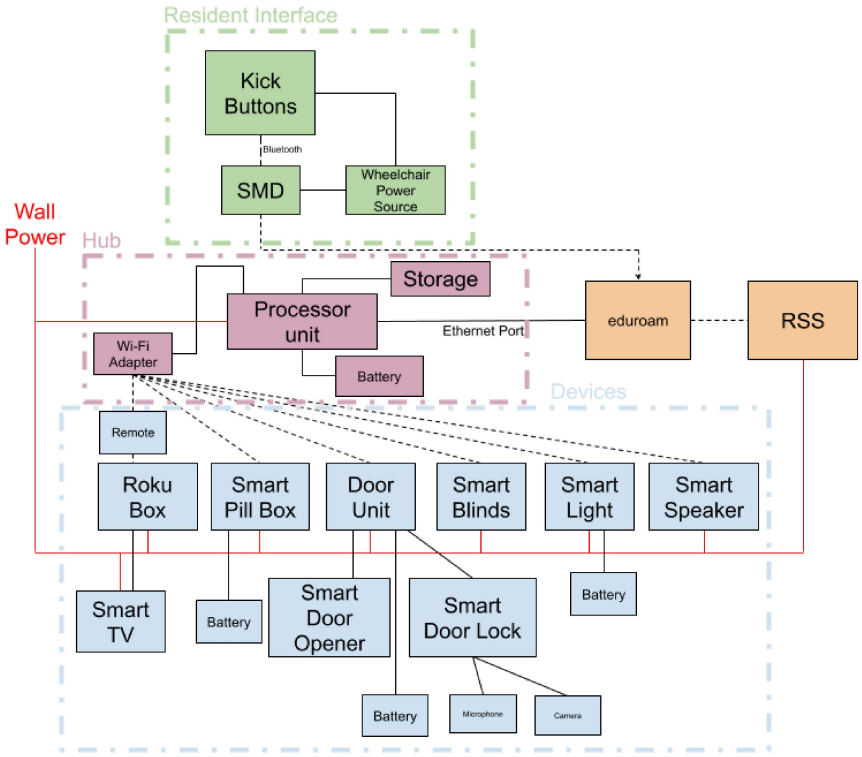

Figure 02: System Connection Diagram

System Test Plan

Note: all steps past step 1 can be completed in parallel

1. Set up the Home Assistant system on the Smart Hub and add the default companion app (provided by Home Assistant) to the SMD.
    a. Prerequisite step(s): none
2. Set up Tasker on the SMD to allow the Home Assistant system to control android tasks on the SMD.
    a. Prerequisite step(s): 1
    b. Note: this will allow for testing connections with the SMD when the SALE app has not completed testing.
3. Write a test code that allows the Smart Hub to control the LED on a Raspberry Pi Pico W, thus proving the Smart Hub can control individual sub-devices.
    a. Prerequisite step(s): 1
4. Repeat the step above (step 3) with multiple Raspberry Pi Pico W devices simultaneously.

    a. Prerequisite step(s): 3
5. Test individual sub-devices for connectivity to the Smart Hub.
    a. Prerequisite step(s): 3, individual tests from the various sub-devices
6. Make a user called “RSS user” on the Home Assistant System. Set up permissions with demo entities to ensure RSS user can only access the devices we want them to have access to.
    a. Prerequisite step(s): 1
7. Test the calling capabilities of the RSS and the SMD (see RSS Test Plan, T6 - T9)
    a. Prerequisite step(s): 2, 6
    b. Note: due to using Tasker on the SMD, the RSS does not require the SALE app.
8. Set up the SALE app with the Smart Hub. Test that the SALE app can control Picos connected to the Smart Hub.
    a. Prerequisite step(s): 1, 3
9. Test that the user inputs to the Kick Buttons can be used to navigate the SALE app.
    a. Prerequisite step(s): none
10. Test the whole system, and ensure that all device sub-device tests are complete.
    a. Prerequisite step(s): 5, 7, 9

Additional Inter-device Connections Test Plan

1. SMD can additionally interface (via voice call) directly with both RSS and with Door Lock.
2. Pill Box can send notifications to SMD, Smart Hub, and RSS.

Overall Schedule

Friday Due Date	Deliverable	Key
1/31/2025	*intermediary progression*	Connection Testing
2/7/2025	Microcontroller Matter API	Individual Functionality/Construction
	Smart Light (individual functionality)	Full Integration (RSS + SMD +Kick Button) Testing

2/14/2025	*intermediary progression*	
2/21/2025	Hub to Smart Light (Matter) Testing	
	Kick Button (fully assembled)	
	Smart Window Shade (individual functionality)	
2/28/2025	Hub to RSS Connection Testing	
	Kick Button to SMD Connection Testing	
3/7/2025	Fully Integrated Smart Light Testing	
	Hub to SMD Connection Testing	
3/14/2025	Fully Integrated Smart Window Shade Testing	
	Hub Video Streaming Testing	
	Smart Door Opener (individual functionality)	
	Smart Door Lock (individual functionality)	
	Smart Pill Box (individual functionality)	
SPRING BREAK	SPRING BREAK	
3/28/2025	Fully Integrated Smart Door (Opener + Lock) Testing	
4/4/2025	Fully Integrated Smart Pill Box Testing	
	Smart TV (individual functionality)	
4/11/2025	Fully Integrated Smart TV Testing	
	Smart Speaker (individual functionality)	
4/18/2025	Fully Integrated Smart Speaker Testing	
4/25/2025	**Overall Integration Testing**	
5/2/2025	**Medical Feasibility Testing (obtain feedback)**	

Table 01: Overall Schedule

Overall Budget

Device/Component	Estimated Cost
Smart Hub	$495.37
Smart Mobile Device (SMD)	$451.81
Kick Buttons	$612.34
Remote Support Station (RSS)	$0.00

Smart Light	$245.07
Smart Door Lock	$276.36
Smart Door Opener	$676.08
Smart Pill Box	$204.29
Smart Speaker	$428.60
Smart TV	$75.69
Smart Window Shade	$341.04
Sub-total	$3,806.65
10% Additional Buffer - shipping and redesigns	$380.67
Total	$4,187.32

Table 02: Overall Budget

Smart Hub

The Smart Hub will serve as the center of the SALE system. It will connect to every other device, and will coordinate all actions taken by the system. It will be made based on the Home Assistant software suite, which provides many of the basic features such as automations and matter compatibility. It will communicate with the sub-devices of the smart home via the Matter protocol; it shall support multiple of the different transport techniques under that protocol (such as WiFi, Zigbee, and Thread). The Smart Hub will also be responsible for data logging and voice processing, as well as maintaining configuration about the home's state. Lastly, due to its central role, the Smart Hub must have a battery backup, and maintain itself via software updates.

The Smart Hub will be implemented using the open-source Home Assistant software suite. This suite can be run on numerous host computers; however, there are some premade modules available. Research will need to be done to determine which pre-made module and configuration options shall be acquired, or if a custom design is needed. Voice assistant processing is also available via open-source software. By using open-source components, the team has the flexibility to modify and extend them as needed or necessary for the project, and can furthermore contribute those improvements back to the central repository.

Requirements:

1. The Smart Hub shall be able to record actions taken to files.
2. The Smart Hub shall be able to record data from various sensors/inputs to files.
3. The Smart Hub shall have enough storage for 30 days of files.
4. The Smart Hub shall be able to remove old data automatically as required by space.
5. The files on the Smart Hub shall be able to survive power loss
6. The Smart Hub shall be able to be connected with remote devices
7. The Smart Hub shall have password protection in order to access.
8. The Smart Hub shall have encrypted connections used for all signals.
9. The Smart Hub shall have Smart Mobile Device and Remote Support Station pairing.
10. The Smart Hub shall have backup battery power for at least 90 minutes.
11. The Smart Hub shall be able to track battery power from software
12. The Smart Hub shall have the Ability to unpair from devices
13. The Smart Hub shall pair to matter devices.
14. The Smart Hub shall utilize a Home Assistant to send matter commands.

15. The Smart Hub shall be powered via connection to an outlet.
16. The Smart Hub shall include a system status consisting of an RGB LED, where different colors indicate whether the system is functioning properly or not.
17. The Smart Hub shall have a physical on/off switch on the device.
18. The Smart Hub shall have the ability to connect a keyboard and screen to the system for debugging.
19. The Smart Hub shall provide a network for all devices to connect to
20. The Smart Hub shall isolate its network from the outside world
21. The Smart Hub shall provide audio/video streaming capabilities to and from certain devices
22. The Smart Hub shall perform local voice processing
23. The Smart Hub shall allow for voice control of smart devices
24. The Smart Hub shall automatically update its software
25. The Smart Hub shall automatically restart

Design

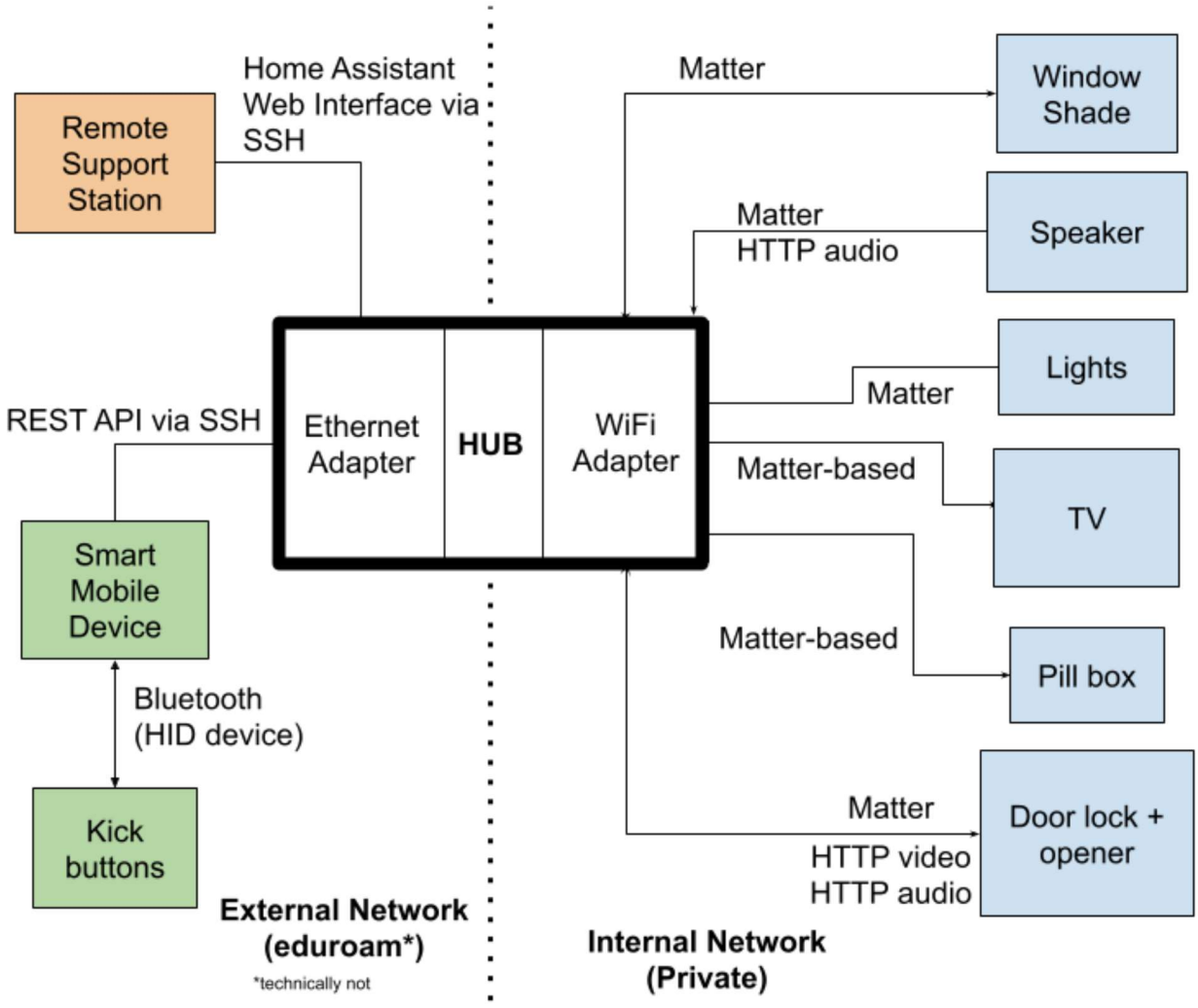

Figure 03: System Networking Diagram

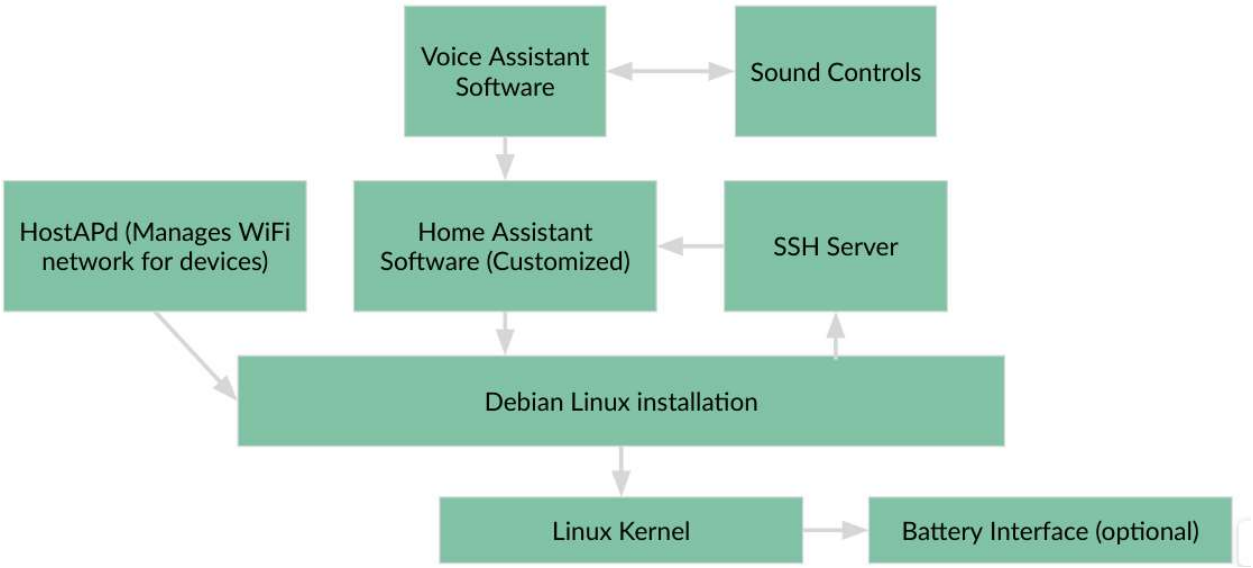

Figure 04: Software High-Level Design

Test Plan

Power Test

Requirements: 5, 10, 15, 17, 25

Test Method:

1. Connect power and a debug display.
2. When the hub has started, perform actions that will be recorded
3. Switch power off with switch, wait at least 10 seconds
4. Reconnect power

Acceptance:

- Hub starts immediately upon enabling power, both times
- Relevant files are still present on hub after power outage
- Switch causes system to shut down

Basic Networking Test

Requirements: 19,20

Test Method:

1. Connect a smart device to the hub network
2. Send a ping from the device to the hub
3. Send a ping from the hub to the device
4. Send a ping from the device to an external address

Acceptance:

- The network connection occurs
- The device receives a response ping
- The hub receives a response ping
- The external ping fails (NOTE: may want to permit external connections)

Remote Device Connection Test

Test Method:

1. Pair the Smart Mobile Device to the hub
2. Pair the Remote Support Station to the hub
3. Unpair Both

Matter Protocol Pairing Test

Test Method:

1. Pair matter devices to the hub
2. Confirm Matter communications
3. Unpair the devices

Acceptance:

1. Confirm the devices communicate successfully

Battery Test

Test Method:

1. Connect and charge the battery
2. Confirm battery is charged in hub monitoring software
3. Disconnect power
4. Confirm battery is discharging
5. Wait duration of required discharge
6. Confirm battery has remaining life

Acceptance Criteria

- Battery charges within 2 days
- Battery charge appears approximately correct in hub software throughout the test.
- System does not shut down before required duration

Budget

Qty	Description	Unit Price	Total Cost
1	ODROID-H4	$99.00	$99.00
1	Option : 15V/4A power supply US plug	$9.40	$9.40
1	8Gb DDR5 Ram Module	$18.99	$18.99
1	Western Digital NVME SSD	$32.99	$32.99
1	Panda Wireless USB Wifi Adapter	$24.99	$24.99
1	Battery and charging circuit	$100.00	$100.00
	PCB Costs		$60.00
	3D printing costs		$50.00
	Buffer		$100.00

Table 03: Estimated Costs for Smart Hub

Smart Mobile Device (SMD)

The Smart Mobile Device (SMD) shall allow the resident to use all the features of their home through various means of input to accommodate disability, including custom kick button inputs and voice commands. The device will be battery-powered and can attach to a wheelchair for mobile control.

The SMD will consist of a tablet with a mount. The screen will have a custom interface design to be easy to use for a person with disabilities. It will have a keyboard and microphone to allow the device to intake voice commands and make video calls via the Smart Hub. The tablet will have a biometric scanner to allow the resident to easily login while still being password protected.

Requirements

1. The SMD shall send audio from the internal microphone to the Smart Hub for voice assistant features.
2. The SMD shall handle commands from Kick Buttons.
3. The SMD shall use Linux/Android GUI tools to make a user-friendly GUI.
4. The SMD shall have a custom downloaded app from playstore/internet/website.
5. The SMD shall be protected by a password which will be entered through the Kick Buttons.
6. The SMD shall have a biometric alternative to log into the Smart Home app.
7. The SMD shall be battery-powered.
8. The SMD shall be easy to use.
9. The SMD shall have a camera.
10. The SMD will be able to be attached to a wheelchair.

Design

The SMD will be a Google Pixel Tablet with a custom-built Android Studio application. This application will allow the resident to operate with devices in the SALE ecosystem, and will accomplish this by sending user input information to the SMART HUB for processing. User inputs will be entered via swiping and tapping the tablet, or alternatively from the kick buttons, which will be connected via BLE (Bluetooth Low Energy).

The resident will first select their user profile, enter their password, and will then enter the main menu. The main menu consists of various squares stacked vertically that can be scrolled through in a pleasing-to-the-user way. The first stack will include the various subdevices in the SALE ecosystem, and when an option is selected its stack will dim and slide leftward (as pictured in the figure below), revealing the various and unique options available for each subdevice.

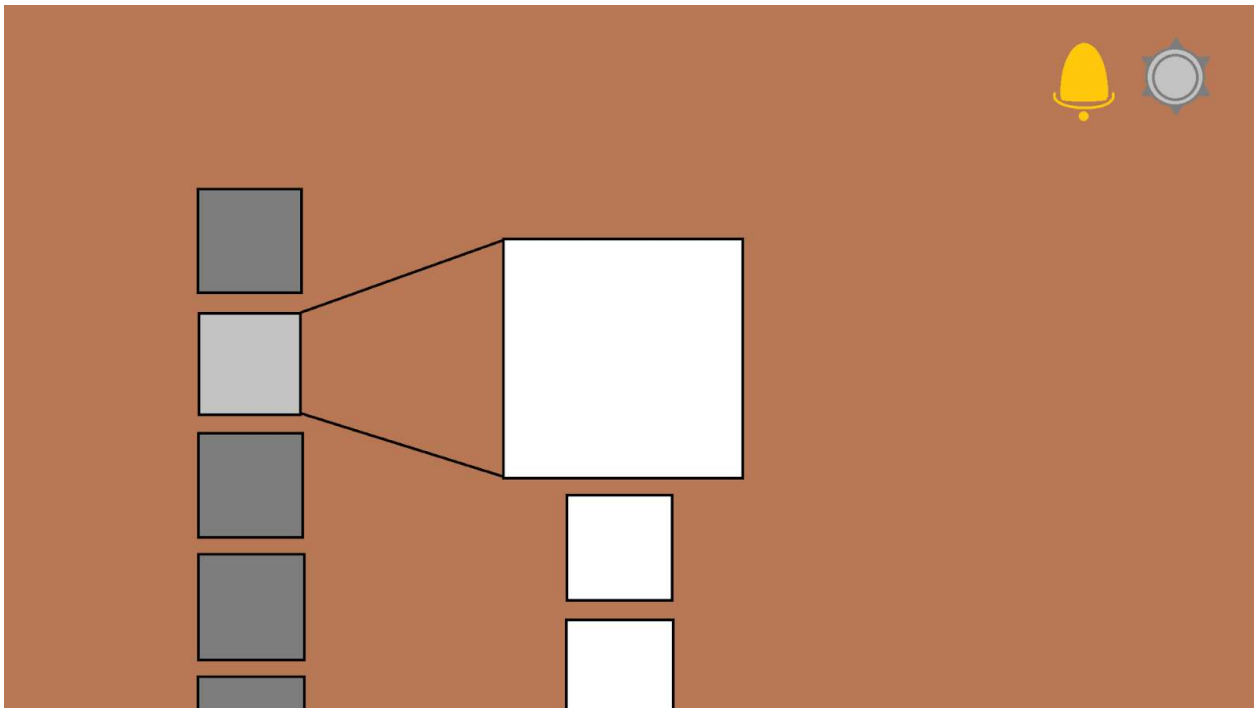

Figure 05: Sample

Test Plan

Test T1 - Audio Transmission Test:

Speak into the SMD microphone and check if the Smart Hub responds appropriately.

Pass/Fail Criteria: The test passes if the voice assistant on the Smart Hub correctly responds to commands received from the SMD microphone.

Cover Requirements: 1

Test T2 - Command Handling Test:

Send various commands from Kick Buttons and verify SMD's response.

Pass/Fail Criteria: The test passes if the SMD correctly executes each command received from the Kick Buttons.

Cover Requirements: 2

Test T3 - User-Friendly GUI Test:

Assess usability through a user experience review, focusing on ease of navigation and accessibility.

Pass/Fail Criteria: The test passes if the GUI is intuitive and easily navigable, as assessed by user feedback.

Cover Requirements: 3

Test T4 - Custom App Functionality Test:

Verify proper installation of the custom app on the SMD and its functionality.

Pass/Fail Criteria: The test passes if the app performs its intended functions.

Cover Requirements: 4

Test T5 - Password Protection Test:

Attempt to access the SMD and enter a password using Kick Buttons.

Pass/Fail Criteria: The test passes if incorrect passwords are denied and the correct password allows access.

Cover Requirements: 5

Test T6 - Biometric Login Test:

Test login functionality with the registered biometric input.

Pass/Fail Criteria: The test passes if the SMD grants access only when the correct biometric input is detected.

Cover Requirements: 6

Test T7 - Battery-Powered Operation Test:

Verify that the SMD operates normally when powered solely by its battery.

Pass/Fail Criteria: The test passes if the SMD operates without any power connection after being charged.

Cover Requirements: 7

Test T8 - Ease of Use Test:

Conduct a user experience assessment with test users and gather feedback on usability.

Pass/Fail Criteria: The test passes if a majority of test users (e.g., >80%) report that the SMD is easy to use.

Cover Requirements: 8

Test T9 - Camera Functionality Test:

Verify that the camera can capture and display images or video.

Pass/Fail Criteria: The test passes if the camera functions as expected, with clear image or video output.

Cover Requirements: 9

Test T10 - Wheelchair Attachment Test:

Attach the SMD to a standard wheelchair and verify stability and ease of attachment and detachment.

Pass/Fail Criteria: The test passes if the SMD securely attaches to a wheelchair and remains stable during movement.

Cover Requirements: 10

Budget

Component	Description	Quantity	Cost per unit	Total Cost
Tablet	Google Pixel Tablet	1	398.32	398.32
Tasker	Tablet Application	1	3.49	3.49
Total				**401.81**

Table 04: Estimated Costs for SMD

Kick Buttons

The *Kick Buttons* will be designed for residents who have partial mobility of their legs and can use their legs to kick objects. The kick button panel will have 5 kick buttons, allowing the resident to control the entire home automation system. We will be creating this kick-button system for a resident who uses a wheelchair and has limited leg motor control. The buttons will be designed so that the caretaker can shift their location (by sliding) to a position that is convenient for the resident.

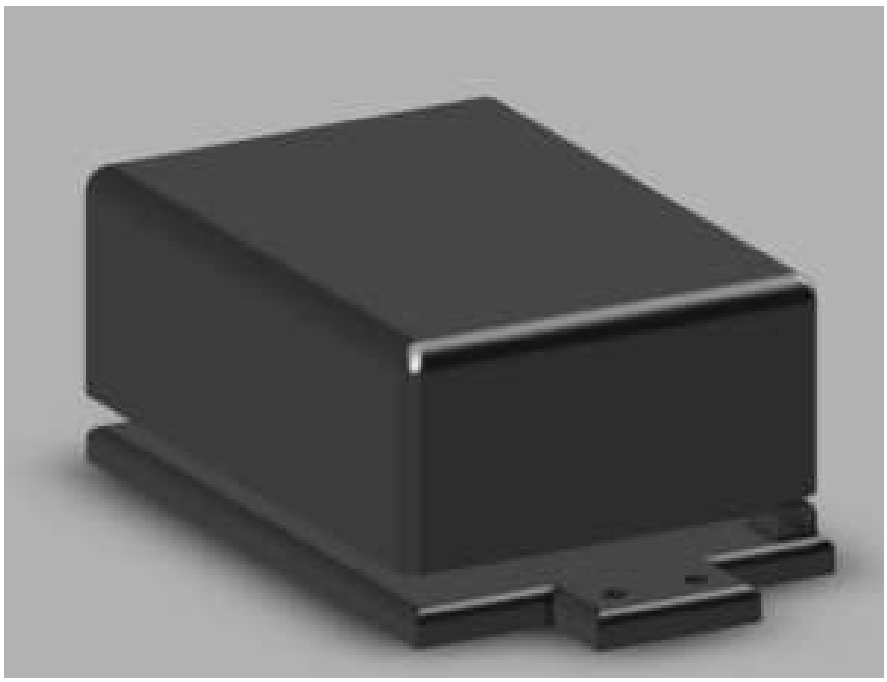

Figure 06: Kick Button enclosure

Requirements

Initial Design Requirements:

1. The kick buttons must be easy to activate, requiring minimal force to be kicked.
2. They should be mounted on a raised platform that can be positioned within easy-kicking distance from the resident's wheelchair.
3. The buttons need to light up whenever they are kicked.
4. The buttons must transmit data wirelessly to the connected smart mobile device.

5. The power usage for the button system should not exceed 12 V or 200 mA.
6. The button system should be powered with a 12 V input.

Design

For the purposes of technical design, the above requirements have been broken down into the following electrical, mechanical, and system-level requirements given below. All the inputs from the kick buttons shall be sensed by a Raspberry Pi Pico W, and transmitted to the Smart Mobile Device via BLE (Bluetooth Low Energy).

Technical Design Specifications:

Setup:

- The button system (5 buttons and the circuitry) shall be powered using a 12 V supply
- The 5 buttons shall be on a custom slanting mount/footrest.

Mechanical Design Requirements:

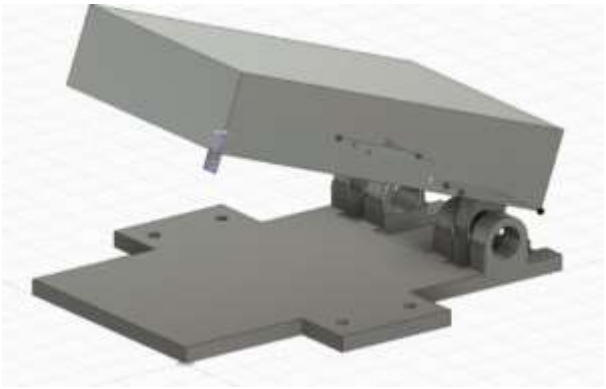

Figure 07: Kick Button internal structure

- The metal strap should not hit the surface of the optical switch.
- The metal strap shall cut the laser of the optical switch once the button is pushed
- In the equilibrium position, the metal strap should not be cutting the laser of the optical switch.
- After pressed, the button shall return to the equilibrium position
- The button shall be able to hold the LED driving circuitry.

Electrical functionality:

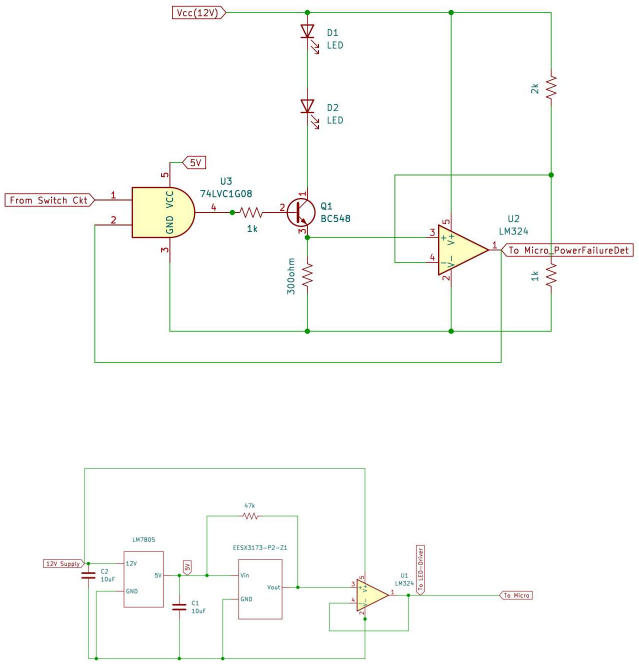

Figure 08: Electrical Setup of kick-button circuits

- The optical switch, whose voltage is regulated by LM 7805, shall not receive more than 5.5 V.
- The current in the LED driver circuit shall not exceed 40 mA.
- The GPIO input to the microcontroller shall not be more than 3.8 V.

Individual Button Functionality:

- On pressing the button, the microcontroller shall detect a logic high.
- On pressing the button, the LEDs on the button should light up.
- On pressing the button, the microcontroller should transmit the “ON_buttonNumber” message to the tablet via Bluetooth. The default message for each button on the tablet should be “OFF_buttonNumber”

Overall Requirements:

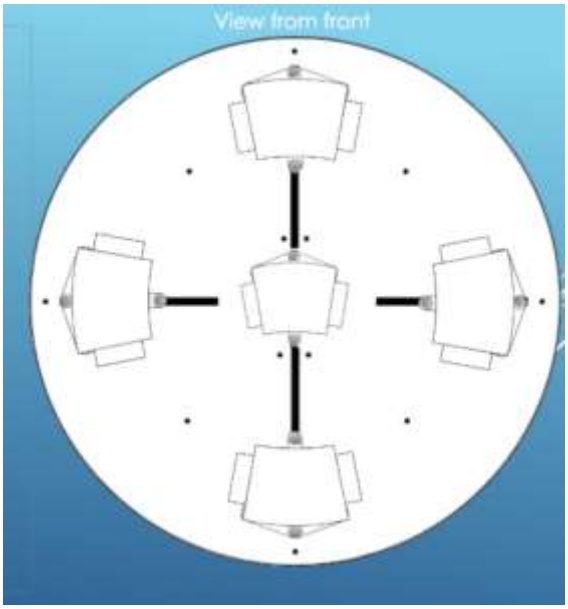

Figure 09: Figure title

- The microcontroller shall compile a complete string indicating the state of each button: ON_1 OFF_2 OFF_3 OFF_4 ON_1
- The microcontroller shall transmit a complete string (as defined in the above point) over Bluetooth to the tablet.
- The system shall be responsive to rapid button presses.

General Design Requirements:

- The kick buttons must be easy to activate, requiring minimal force to be kicked.
- The power usage for the button system should not exceed 12 V or 200 mA.

Test Plan

Mechanical Design Requirements

Test T1: Interaction with Optical Switch Surface

- **Equipment**: Caliper or other precision measurement tool.
- **Method**: Visually inspect and measure the clearance between the metal strap and the surface of the optical switch in all button positions.
- **Pass/Fail Criteria**: There should be a minimum clearance of 1 mm (to be defined as per design) between the metal strap and the optical switch surface in both pressed states.

Cover Requirements: The metal strap should not hit the surface of the optical switch.

Test T2: Laser Interruption upon Button Press (T2)

- **Test Equipment**: voltmeter.
- **Test Method**: Press the button and monitor the optical switch to confirm that the laser is interrupted by the metal strap.
- **Acceptance Criteria**: The laser of the optical switch should be interrupted once the button is fully pressed. (See change in output from the button)

Covered Requirements: The metal strap shall cut the laser of the optical switch once the button is pushed.

Test T3: Laser Continuity in Equilibrium Position

- **Test Equipment**: voltmeter.
- **Test Method**: Set the button in its equilibrium position and check if the laser beam of the optical switch remains unblocked.
- **Acceptance Criteria**: In the unpressed/equilibrium state, the laser of the optical switch should not be interrupted by the metal strap. (See that output from the button is unchanged)

Covered Requirements: In the equilibrium position, the metal strap should not be cutting the laser of the optical switch.

Test T4: Button Return to Equilibrium Position

- **Test Equipment**: Manual testing, caliper for measurement if needed.
- **Test Method**: Manually press the button multiple times and observe whether it reliably returns to the equilibrium position each time.
- **Acceptance Criteria**: The button should return to its original (equilibrium) position after release.

Covers Requirement: After being pressed, the button shall return to the equilibrium position.

Test T5: LED Circuitry Accommodation

- **Requirement**: The button shall be able to hold the LED driving circuitry.

- **Test Method**: Insert the LED driving circuitry into the designated compartment within the button. Check for proper fit, alignment, and secure positioning.
- **Acceptance Criteria**: The LED circuitry should fit securely within the button, with no movement or obstruction.
- **Test Equipment**: LED driving circuitry module.

Electrical functionality

Test T6: Optical Switch Voltage Regulation (T6)

- **Test Equipment**: Digital multimeter or oscilloscope.
- **Test Method**:
    - Measure the output voltage from the LM 7805 voltage regulator to the optical switch under both idle and active states.
    - Repeat the test under different load conditions and environmental variations (turning the system on or off).
- **Acceptance Criteria**: The voltage supplied to the optical switch should not exceed 5.5 V.

Covers Requirements: The optical switch, whose voltage is regulated by LM 7805, shall not receive more than 5.5 V.

Test T7: LED Driver Circuit Current Limitation

- **Test Equipment**: Digital multimeter
- **Test Method**:
    - Power the LED driver circuit and measure the current flowing through the circuit under standard and maximum operating conditions (maximize base current, i.e. i_b = 4 mA).
    - Measure the current in voltage across the 300-ohm source resistor and calculate the current.
- **Acceptance Criteria**: The current in the LED driver circuit should be ≤ 40 mA in all tested conditions.

Covers Requirements: The current in the LED driver circuit shall not exceed 40 mA.

Test T8: GPIO Input Voltage Limitation to Microcontroller

- **Test Equipment**: Digital multimeter or oscilloscope.
- **Test Method**:
    - Measure the voltage at the GPIO input pin on the microcontroller in both idle and active states.
    - Test under various input signal conditions to ensure stability.
- **Acceptance Criteria**: The voltage at the GPIO input should not exceed 3.8 V.

Covers Requirements: The GPIO input to the microcontroller shall not exceed 3.8 V.

Individual button Functionality:

Test T9: Microcontroller Readings

- **Test Equipment**: Oscilloscope.
- **Test Method**:
    - Monitor the GPIO input pin on the microcontroller while pressing the button.
    - Program the microcontroller to turn on the built-in LED if the button is pressed.
- **Acceptance Criteria**: The microcontroller should register a logic high signal when the button is pressed.

Covers Requirements: On pressing the button, the microcontroller shall detect a logic high.

Test T10: LED Illumination on Button Press (T10)

- **Test Equipment**: None. Only visual inspection is needed.
- **Test Method**:
    - Press the button and visually confirm that the LEDs in the button turn on.
- **Acceptance Criteria**: The LEDs should illuminate immediately upon pressing the button and remain on while pressed.

Covers Requirements: On pressing the button, the LEDs on the button should light up.

Test T11: Bluetooth Message Transmission on Button Press (T11)

- **Test Equipment**: Tablet or computer with Bluetooth receiving capability, terminal software for message logging.
- **Test Method**:
    - Pair the microcontroller with the tablet over Bluetooth.

    - Observe the message log on the tablet's receiving application or terminal to confirm that pressing the button sends an “ON_buttonNumber” message.
    - Verify that the default “OFF_buttonNumber” message is sent when no buttons are pressed.
- **Acceptance Criteria**:
    - Upon pressing the button, an “ON_buttonNumber” message is received by the tablet.
    - When no buttons are pressed, the default message “OFF_buttonNumber” is received.

Covered Requirements: On pressing the button, the microcontroller should transmit the “ON_buttonNumber” message to the tablet via Bluetooth. The default message from each button to the tablet should be “OFF_buttonNumber.”

System level integration (involves 5 buttons):

Setup:

- Power the button system (5 buttons and the circuitry) using a 12 V supply
- Place the 5 buttons on a custom mount/footrest that is comfortable to use when a person is in a wheelchair.

Test T12: Button State Detection and String Composition

- **Test Equipment**: USB cable for implementing serial print.
- **Test Method**:
    - Press each button individually and in combinations, then observe the microcontroller’s generated string by printing the result over a serial port.
    - Confirm that the microcontroller correctly updates the state for each button in the output string.
- **Acceptance Criteria**: The generated string accurately reflects the current state of each button in the format "ON_1 OFF_2… etc".

Covered Requirements: The microcontroller shall detect the state of each button and compose a complete string indicating whether each button is ON or OFF (e.g., "ON_1 OFF_2 OFF_3 OFF_4 ON_5").

Test T13: Bluetooth Transmission of Button States (T13)

- **Test Equipment**: Tablet or computer with Bluetooth receiving capability and logging application.
- **Test Method**:
    - Connect the tablet to the microcontroller via Bluetooth.
    - Press each button individually and in various combinations, then verify the string received on the tablet matches the current state of each button.
    - Test the system under rapid button presses to confirm accuracy.
- **Acceptance Criteria**:
    - The tablet consistently receives the correct button state string for every possible combination of button presses.
    - The format matches the specified pattern (e.g., "ON_1 OFF_2 OFF_3 OFF_4 ON_5").

Covered Requirements: The microcontroller shall transfer the complete string indicating the state of each button (e.g., "ON_1 OFF_2 OFF_3 OFF_4 ON_5") to a tablet via Bluetooth

Test T14: Stability and Responsiveness Testing (T14)

- **Test Equipment**: Logging software.
- **Test Method**:
    - Rapidly press buttons in various sequences and observe the transmitted string on the tablet.
    - Test responsiveness by pressing multiple buttons simultaneously and check for correct updates.
- **Acceptance Criteria**: The system should not miss any button press events or provide incorrect button states.

Covered Requirements: The system must accurately report button states in real-time under rapid button presses.

User Utility Requirements:

Test T15: Kick Button Activation Force

- **Test Equipment**: None
- **Test Method**:
    - Ask 5 participants if the kick buttons are easy to kick, given that each of the participants is in a wheelchair.
- **Acceptance Criteria**: More than 90% of the people should say that kick buttons can be easily activated.

Covered Requirements: The kick buttons must be easy to activate, requiring minimal force to be kicked. The experiments have to be done while the person is in a wheelchair.

Test T16: Power Usage Limitations

- **Test Equipment**: Adjustable power supply, digital multimeter.
- **Test Method**:
    - Connect the button system to a power supply set to a maximum of 12 V.
    - Measure the current draw of the system, (by using a multimeter) under idle conditions and while buttons are being activated.
- **Acceptance Criteria**:
    - The current draw should not exceed 200 mA under any operating condition, given that the input voltage is 12V

Covered Requirements: The power usage for the button system should not exceed 12 V or 200 mA.

Test Table

Requirement Type	Requirement No.	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12	T13	T14	T15	T16
Mechanical	1	X															
Mechanical	2		X														
Mechanical	3			X													
Mechanical	4				X												

Mechanical	5					X											
Electrical	6						X										
Electrical	7							X									
Electrical	8								X								
Individual Button	9									X							
Individual Button	10										X						
Individual Button	11											X					
System Integration	12												X				
System Integration	13													X			
System Integration	14														X		
User Utility	15															X	
User Utility	16																X

Budget

Component	Description	Quantity	Cost per unit	Total Cost
Optical Switch	Omron EESX3173	5	3.57	17.85
Switch Cable	EE-5002	5	5.61	28.05
Voltage Regulator	L7805	5	1.46	7.3
Op-amp	LM 324N	10	0.39	1.95
Micro	Pi Pico W	1	25	25
Protoboard	Prototype Kit	1	9.99	9.99
RGB LED	WP154A4SUREQBFZGC	10	1.91	19.1
Transistor (NPN)	BC 548	10	0.18	1.8
Foot stand	Foot stand (kick button mount)	1	200	200
AND Gate	74LVC1G08GV,	10	0.13	1.3
Sub Total				**312.34**
Buffer Budget for PCB				**100**
Cost for custom printing buttons				**200**

Total				**612.34**

Table 05: Estimated Costs for Kick Buttons

Note: The budget estimate includes the budget cost of printing kick-buttons externally and building a metal food stand, which may require metal cutting. However, we may not be using these custom-made parts and use something off the shelf, depending on how the prototype comes together. As such, the realistic budget for the kick button set should be around 300-400 USD.

Remote Support Station (RSS)

The Remote Support Station shall allow the caregivers or family members to communicate with senior and/or disabled residents and support them without affecting their privacy. The station will require the resident's permission to start a call but shall allow for emergency overrides in the case of an emergency call.

The Remote Support Station will consist of a specialized website integrated with the Smart Hub.

Requirements

1. The RSS shall require user authentication in order for the support staff to access the support options.
2. The support staff shall have ready access to a limited number of support options via the Smart Hub.
    a. The support staff shall be able to lock and unlock the door from the station.
    b. The support staff shall be able to set reminders for the resident.
    c. The support staff shall be able to access medication records logged by the pillbox.
3. The support staff shall be able to use the RSS to call the resident and vice versa.
    a. The support staff and resident shall both be able to start and end a call.
    b. The support staff and resident shall be able to select a video or voice call.
    c. The call shall require approval from the person receiving the call before the call starts to stream audio and/or video.
    d. The receiver shall be able to select whether or not to have their camera on.
    e. The support staff shall be able to initiate an emergency call that does not require resident approval.
        i. The emergency call shall announce itself on the resident's end as an emergency call.
    f. The RSS shall keep a record of call time and length and send it to the Smart Hub.

Design

In the Home Assistant system, each person is a user in the system. Logging in as a specific user requires a user name and password, and the backend is built into the Home Assistant system. The first user made (during onboarding) is marked as the “owner.” The “owner” has administrative access and can manage other users and permissions.

In the Home Assistant documentation, it is unclear if permissions are enabled or enforced. If they are not currently enabled, “owners” can still modify the Home Assistant dashboard and configure the visibility of badges (which represent devices). To enable limited permissions, the RSS will use a combination of Home Assistant Permissions and Entity Badge configurations. Entity Badges are small widgets that are on the dashboard and control one or more devices.

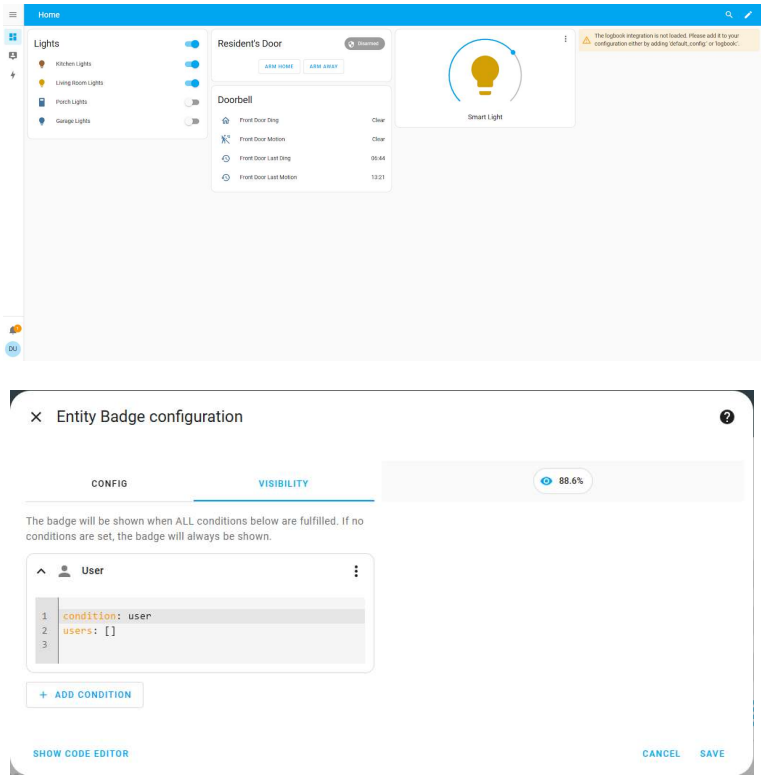

Figure 10: Sample Home Assistant Dashboard and the Entity Badge configuration

To interface more closely with the SMD, the RSS will use Tasker to trigger android tasks on the SMD. There are no costs associated with the RSS, as they are covered by other devices.

Test Plan

Test T1 - Authentication Test:

Try to log onto the website without having set up user authentication on that computer.

Pass/Fail criteria: The test passes if the user must provide user authentication to access the support options.

Cover Requirements: 1

Test T2 - Permissions Test:

Try to access unauthorized support options by adding unauthorized devices and automation onto the dashboard.

Pass/Fail criteria: This test passes if the user is not able to access unauthorized support options.

Cover Requirements: 2

Test T3 - Door Access Test:

Use the RSS to open/close the door.

Pass/Fail criteria: This test passes if the Smart Door Opener correctly responds to user input within 5 seconds.

Cover Requirements: 2a

Test T4 - Reminder Access Test:

Use the RSS to set reminders.

Pass/Fail criteria: This test passes if the SMD adds the reminders set by the support staff.

Cover Requirements: 2b

Test T5 - Pillbox Access Test:

Use the RSS to access medication records logged by the pillbox.

Pass/Fail criteria: This test passes if the RSS user is able to access medication records from the pillbox that are up to date as of 1 minute prior to the request.

Cover Requirements: 2c

Test T6 - Call Rejection Test:

On the RSS, select voice/video call, but not respond on the SMD. Repeat this with a call on the SMD but no response on the RSS.

Pass/Fail criteria: This test passes if the corresponding call shows up on the receiving end but does not go through.

Cover Requirements: 3a, 3b, 3c

Test T7 - Call Video Test:

Repeat Test T6, but respond to the call and select case 1) camera on or case 2) camera off.

Pass/Fail criteria: This test passes if the receiver is able to select whether or not to have their camera on.

Cover Requirements: 3d

Test T8 - Emergency Call Test:

Use the RSS to initiate an emergency call.

Pass/Fail criteria: This test passes if the call is announced as an emergency call on the SMD and goes through 0-2 seconds after the call is initiated by the RSS user.

Cover Requirements: 3e

Test T9 - Call Logging Test:

Initiate a call on the RSS and on a separate device, record when the call starts and how long it goes.

Pass/Fail criteria: This test passes if the RSS logs the call time and call length accurately and sends the information to the Smart Hub.

Cover Requirements: 3f

	Requirements

Tests	1	2	2a	2b	2c	3a	3b	3c	3d	3e	3f
T1	x										
T2		x									
T3			x								
T4				x							
T5					x						
T6						x	x	x			
T7									x		
T8										x	
T9											x

Smart Light

The Smart Light shall allow the resident and their caregiver to control the lighting of the smart home via a connection to the Smart Hub.

The Smart Light will consist of an LED light bulb socket connected to the Smart Hub wirelessly. The resident will be able to easily turn the light on and off from the Smart Mobile device using the kick button inputs. The caretaker shall be able to easily switch out the bulb in the event that it breaks. The light will be completely safe and not cause any overheating or fires.

Requirements

1. The Smart Light shall have limited heat output to avoid starting fires.
2. The Smart Light shall be wirelessly toggled through the Smart Hub.
3. The Smart Light shall have the ability to change bulbs without replacing the full smart device.
4. The Smart Light shall be able to be controlled through kick button inputs.
5. The light bulb shall not burn out.
6. The base shall be secure.
7. All electronic components shall be enclosed.

Design

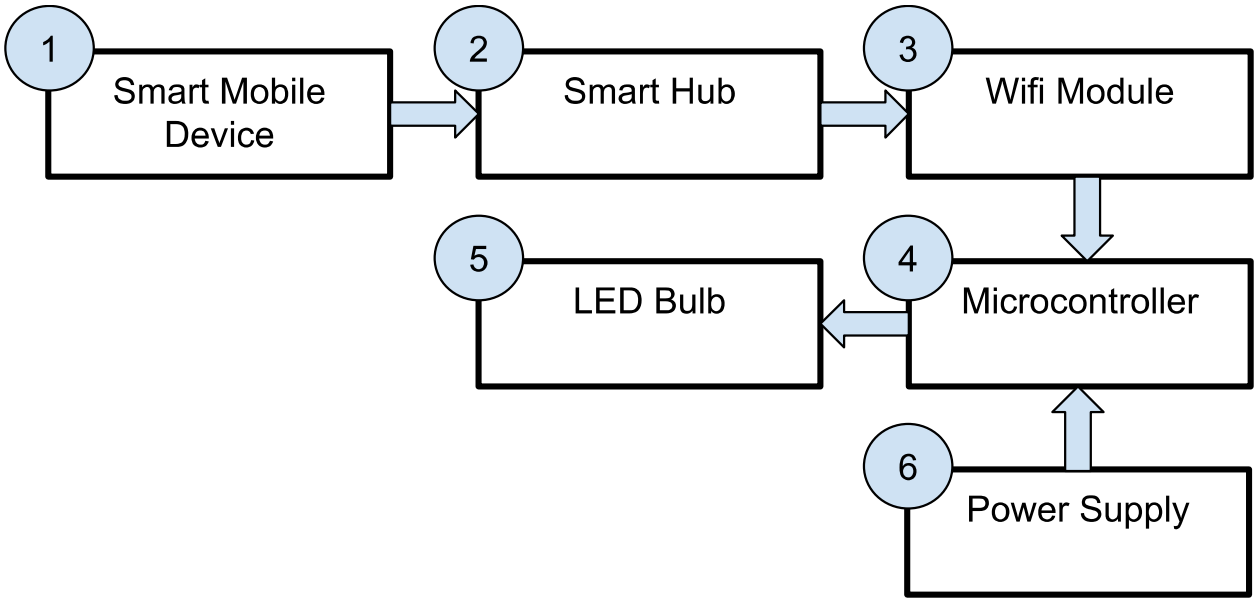

Figure 11: Block Diagram for Smart Light

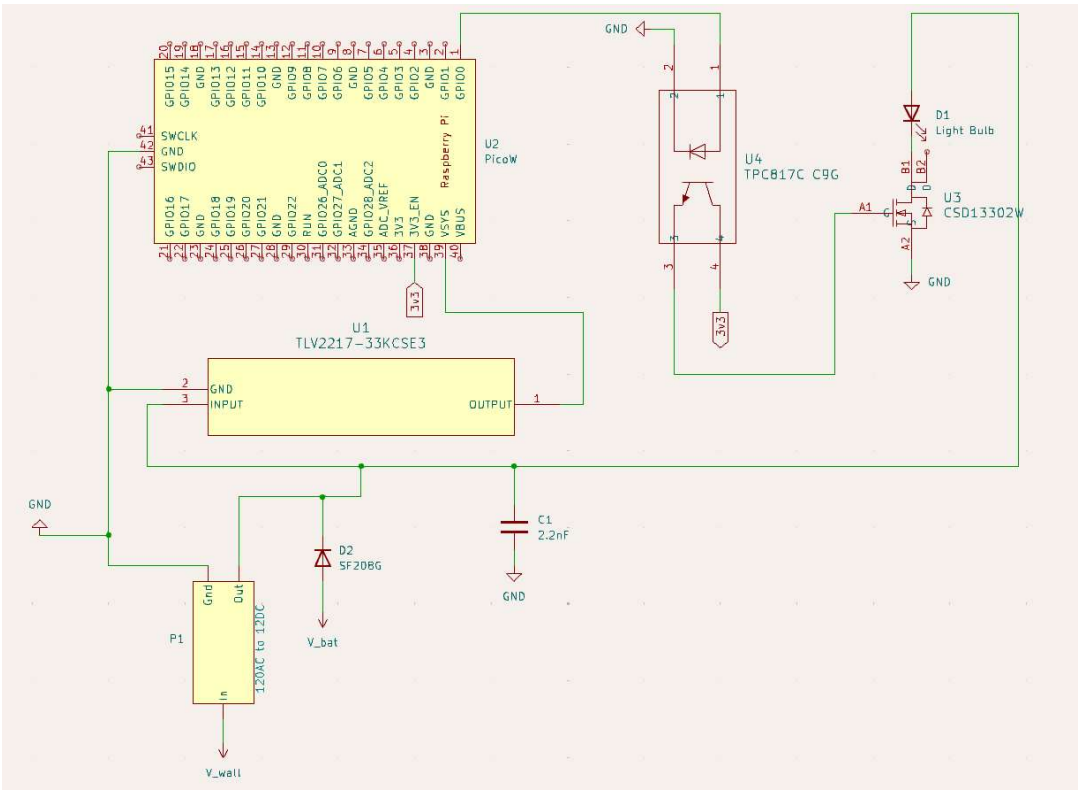

Figure 12: Circuit Diagram for Smart Light

In Figure 12, there is an AC to DC converter that takes power from the wall. A diode blocks the power from leaving the battery to go to the circuit if there is wall power. There is a capacitor stabilizing the circuit current for when the power source switches. A voltage converter steps the voltage of the system down to power the Pi Pico W. The Pi Pico W receives signals from the Smart Hub and uses those to send signals to the optocoupler to switch the transistor. The optocoupler is there to isolate the Pi Pico W from the transistor. The transistor switches to allow or disallow power to the light.

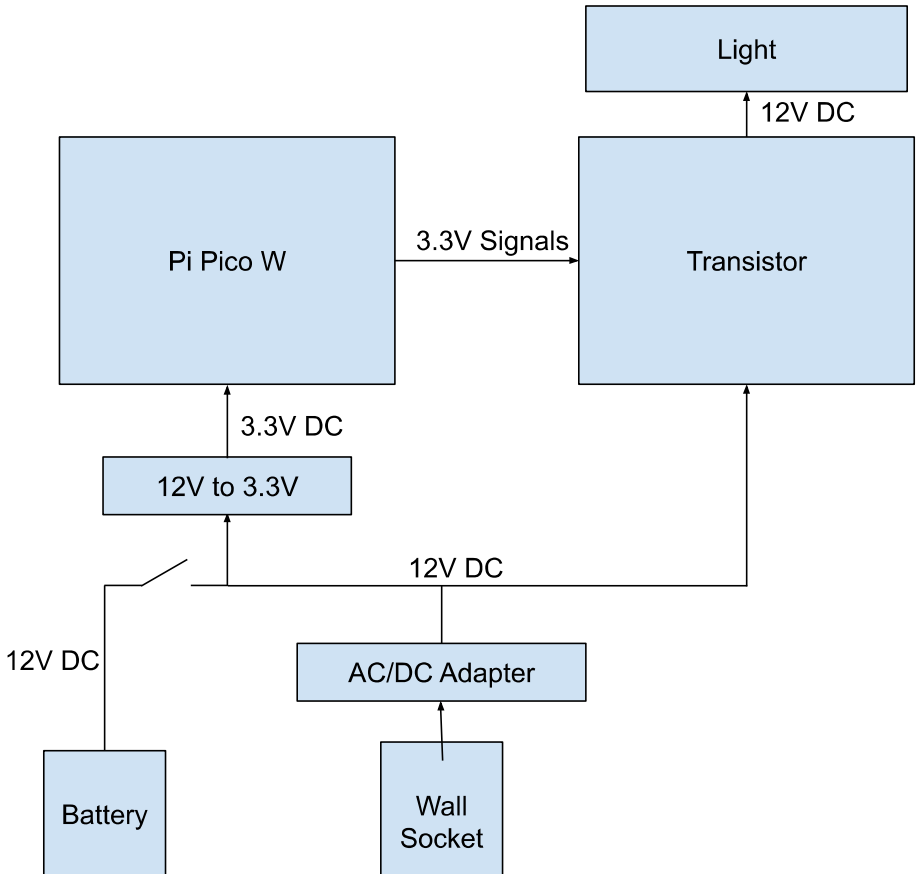

Figure 13: Power Diagram for Smart Light

Qty	Description	Unit Price	Total Cost
1	CSD13302W Mosfet	$0.27	$0.27
1	12V Low Voltage LED Light Bulbs - Daylight 7W(Only for 12-36V)	$5.00	$5.00
1	TLV2217-33KCSE3 Voltage Regulator	$1.05	$1.05
1	TWDRTDD Porcelain Lamp Holder Socket	$8.99	$8.99

1	KBT 12V 1200mAh Rechargeable Li-ion Battery Pack	$16.99	$16.99
1	2.2nF Capacitor	$1.06	$1.06
1	WSU120-0700 AC/DC Wall Adapter	$5.81	$5.81
1	SF208G Diode	$0.10	$0.10
1	PJ-063AH Power Jack	$1.98	$1.98
1	DIP-4 PC817C Octocoupler	$0.50	$0.50
1	PC604BR50 Surface Mount Adapter	$11	$11.47
1	PCB	$30	$30
1	Emergency PCB (Estimate)	$100.00	$100.00
1	Emergency Mechanical Design	$60	$60.00
		Total	$245.07

Table 06: Estimated Costs for Smart Light

Test Plan

Test T1 - Run Test:

Provide power to the Smart Light. Place a piece of paper on top of the light bulb. Turn on the light bulb. Time 30 minutes using a stopwatch.

Pass/Fail criteria: The paper is not burned and the light does not fall over.

Cover Requirements: 1, 5, 6

Test T2 - Connection:

Provide power to the Smart Light. Kick the Kick Buttons to wirelessly turn the Smart Light on. Kick the Kick Buttons to wirelessly turn the Smart Light off. Repeat five times.

Pass/Fail criteria: The light is responsive.

Cover Requirements: 2, 4

Test T3 - Replaceable:

Provide power to the Smart Light. Turn the Smart Light on. Turn the Smart Light off. Unscrew the light bulb from the socket. Screw a new light bulb into the socket. Turn on the Smart Light.

Pass/Fail criteria: The light illuminates using both light bulbs.

Cover Requirements: 3

Test T4 - Presentation:

Visually inspect the device.

Pass/Fail criteria: No wires or electronic components are visible.

Cover Requirements: 7

	Requirements						
Tests	1	2	3	4	5	6	7
T1 - Run Test	x				x	x	
T2 - Connection		x		x			
T3 - Replaceable			x				
T4 - Presentation							x

Smart Door Lock

The Smart Door Lock will secure exterior access to the home, with two access methods. The door may be remotely locked/unlocked through the SMD or RSS. There will also be a keypad located outside the door which can unlock the door. Caretakers assigned to this resident will have access to the password in case the remote unlocking is malfunctioning, or there is an emergency. Once the door closes, it will lock automatically.

Requirements

1. The door shall only unlock/lock with resident approval via the Smart Hub or from caretakers assigned to the resident.
2. The system shall be able to withstand constant usage of door opening and closing.
3. The system shall utilize an electronic keypad located on the outside of the door.
4. The system shall utilize remote locking and unlocking via the Smart Hub.
5. The keypad system shall contain a motion sensor, camera, microphone, and speaker so the resident can see and communicate with people outside the door.
6. The resident shall have the option to automatically lock after it is closed by implementing a 10 second delay.
7. The system shall incorporate a backup power system in case of power loss.
8. The system's primary source of power shall come from a power outlet.
9. The lock shall function as a proper lock so that it stays locked if repeated attempts are made to open the door incorrectly.

Design

See the visual diagram in the Smart Door Opener section to visualize the design conception. It will require a power connection to the same outlet which is located beneath the whiteboard. The Raspberry Pi Pico W will provide Wi-Fi capabilities for the resident to interface with the I/O components of the Smart Door Lock system via the Smart Mobile Device. The Pico will allow integration into the Home Assistant system and perform other functions such as storing the state of the door. It is important to note that only the locking system is matter compatible.

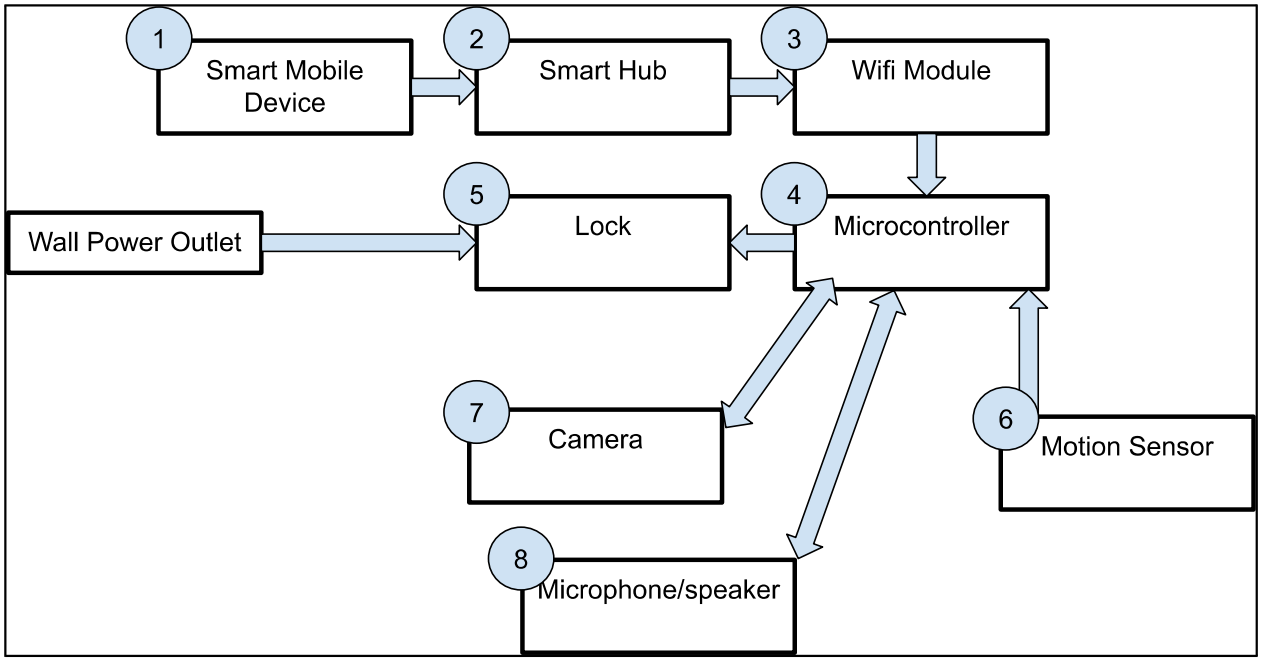

Figure 14: Block Diagram for Smart Door Lock

The Smart Mobile Device sends a signal to the Smart Hub. The Smart Hub sends the signal to the Wifi Module on the Raspberry Pi Pico W microcontroller. The microcontroller is programmed to facilitate the function of the user based on the signal that is read. The first function is the ability to unlock and lock the door. The second function is to view the video feed from the camera and interact with the individual outside the door through the microphone and speakers. When motion is detected, the I/O devices activate, and the microcontroller sends a notification to the SMD via the Smart Hub where the user can choose to interact with said I/O devices.

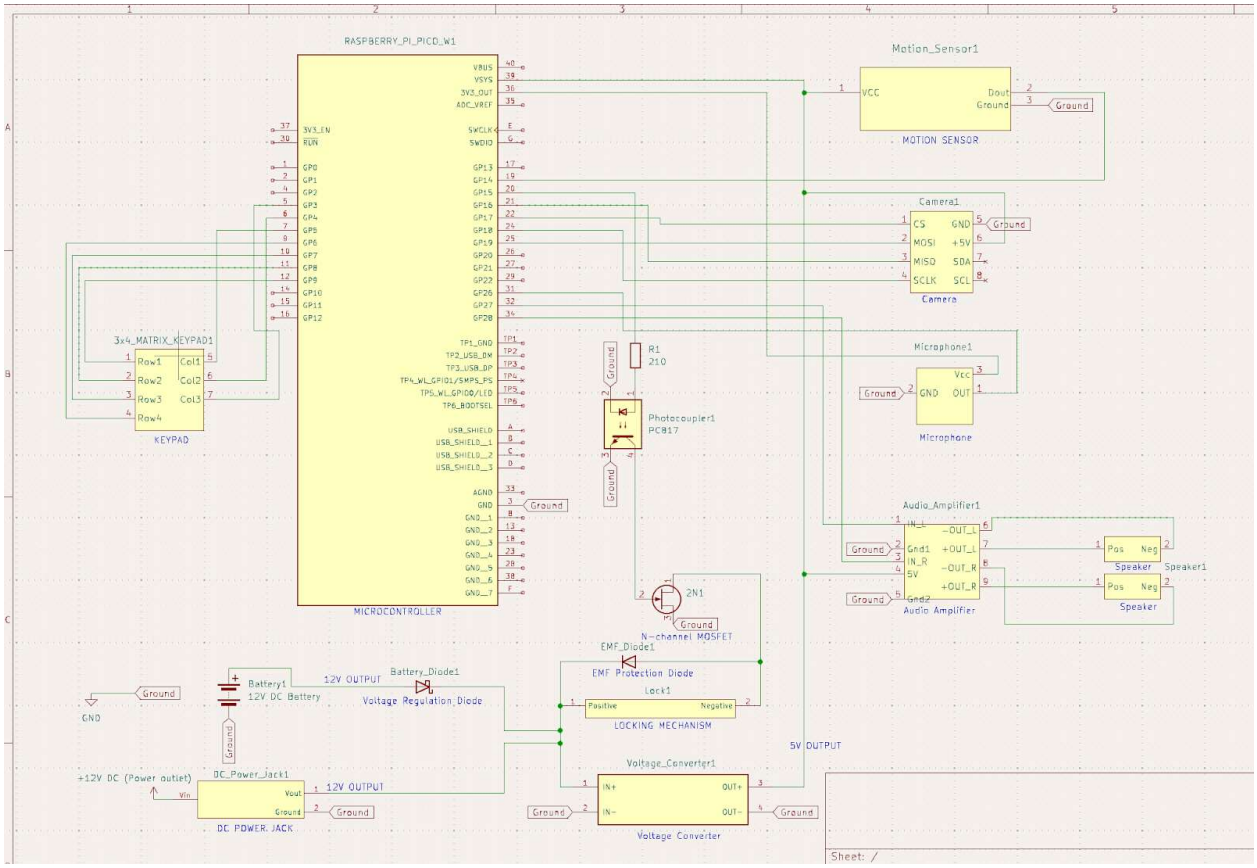

Figure 15: Schematic for Smart Door Lock

The schematic shows the inner workings of the smart door lock system. There are two power supplies which include 12V DC from the power outlet connection and 12V DC from the battery to serve as a backup power source. 12V is fed to the solenoid lock and voltage converter. The LM2596 steps the voltage down to 5V and sends that to the other devices that require it. An N-channel MOSFET is connected to the Raspberry Pi Pico W to control the solenoid lock operation. The signal from the Pico is sent using a photocoupler. The other I/O devices are also connected to the Pico based on their pin functions.

Qty	Description	Unit Price	Total Cost
1	Raspberry Pi Pico WH - Pico Wireless with Headers Soldered	$7.00	$7.00
1	Power Source: 12V 5A 60W DC Adapter	$13.90	$13.90
1	Power Source: 12V Battery	$5.79	$5.79
1	12v Battery Holder	$6.49	$6.49
1	Power Switching - Diode: 1N5822 (2)	$5.99	$5.99
1	Voltage Converter: LM2596 Module (12V-5V)	$9.99	$9.99
1	Motion Sensor: HC-SR501 PIR	$8.49	$8.49
1	Lock: 12V Linear Solenoid Lock	$15.99	$15.99
1	Solenoid Control - N-channel MOSFET: IRLZ44N	$9.99	$9.99
1	Solenoid EMF Protection - Diode: 1N5408	$6.99	$6.99
1	Camera: Arducam 5MP Plus OV5642 Mini Module Camera	$39.99	$39.99
1	Microphone: MAX4466 Microphone Preamp Module	$9.99	$9.99
1	Amplifier: PAM8403 Mini Audio Amplifier Module	$5.69	$5.69
1	Speaker: 3W 4 Ohm Micro Speaker (2)	$6.99	$6.99
1	Keypad: Adafruit 4x3 Matrix Keypad	$9.99	$9.99
1	PC817X Photocoupler	$4.99	$4.99
10	DC Power Jack: PJ-063AH	$1.51	$15.10
1	PCB	$100	$100
		Total	$276.36

Table 07: Estimated Costs for Smart Door Lock

Test Plan

Test T1 - Keypad:

Insert the incorrect code into the keypad. Then, insert the correct code into the keypad.

Pass/Fail criteria: The test passes if the lock remains closed when the incorrect code is entered, and the lock opens if the correct code is entered.

Cover Requirements: 1, 3, 8

Test T2 - Sustained Use Test:

Unlock the whiteboard, and slide the whiteboard. Then, slide the whiteboard back and lock it in place. Repeat 10 times. For every time the whiteboard is locked, with a reasonable amount of force equivalent to the average individual attempting to open a locked door, attempt to slide the whiteboard.

Pass/Fail criteria: The test passes if the locking system functions correctly after repeated uses, and the lock functions as a proper lock so that it stays locked if repeated attempts

Cover Requirements: 2, 9, 8

Test T3 - SMD Interface Test**:**

Press the unlock button on the smart mobile device, and wait 10 seconds. Then, select the lock button on the smart mobile device.

Pass/Fail criteria: The test passes if the lock completes the desired action when the resident uses the smart mobile device.

Cover Requirements: 4, 8

Test T4 - I/O Device Test:

Connect the camera, microphone, and speaker to a power source and the Raspberry Pi Pico W on a breadboard individually. Write simple code to interface with each component.

Pass/Fail criteria: The test passes if all components turn on. The camera shall display a video for 10 seconds, the motion sensor shall blink an LED when activated, a 10 second recording from the microphone shall be output, and the speaker shall output any sound that can be audibly heard.

Cover Requirements: 5, 8

Test T5 - Automatic Lock Test:

With the automatic door locking function enabled, unlock the door and wait 10 seconds.

Pass/Fail criteria: The test passes if the door locks automatically.

Cover Requirements: 6, 8

Test T6 - Backup Power Test:

Unplug the power cord and repeat test 1.

Pass/Fail criteria: The test passes if lock functions the same under the backup power supplied by the battery.

Cover Requirements: 7

	Requirements								
Tests	1	2	3	4	5	6	7	8	9
T1	X		X					X	
T2		X						X	X
T3				X				X	
T4					X			X	
T5						X		X	
T6							X		

Smart Door Opener

The resident will select the icon to open or close the door on the Smart Mobile Device (SMD) display. The Smart Hub will receive the signal and send it to the Pico microcontroller. The microcontroller will use the signal to control the Autoslide RF remote, which will in turn control the Autoslide Sliding Door Opener. The power supply will come from a wired connection to a power outlet.

Requirements

1. The Smart Door Opener shall be wirelessly operated by the Smart Hub.
    a. The Smart Door Opener shall accept commands via Wi-Fi.
    b. The resident shall have the option to select “open” or “close.”
    c. The Smart Door Opener shall communicate the current status of the door with the Smart Hub.
2. The Smart Door Opener shall be able to withstand constant usage of opening and closing.
3. The Smart Door Opener shall not inhibit manual door opening and closing if the system is not functioning properly.
4. The Smart Door Opener shall not cause any blockage for people entering or exiting.
5. Primary power for the Smart Door Opener shall be wired connection to a power outlet.
6. The Smart Door Opener shall detect collisions and automatically retract when a collision is detected to prevent injury.

Design

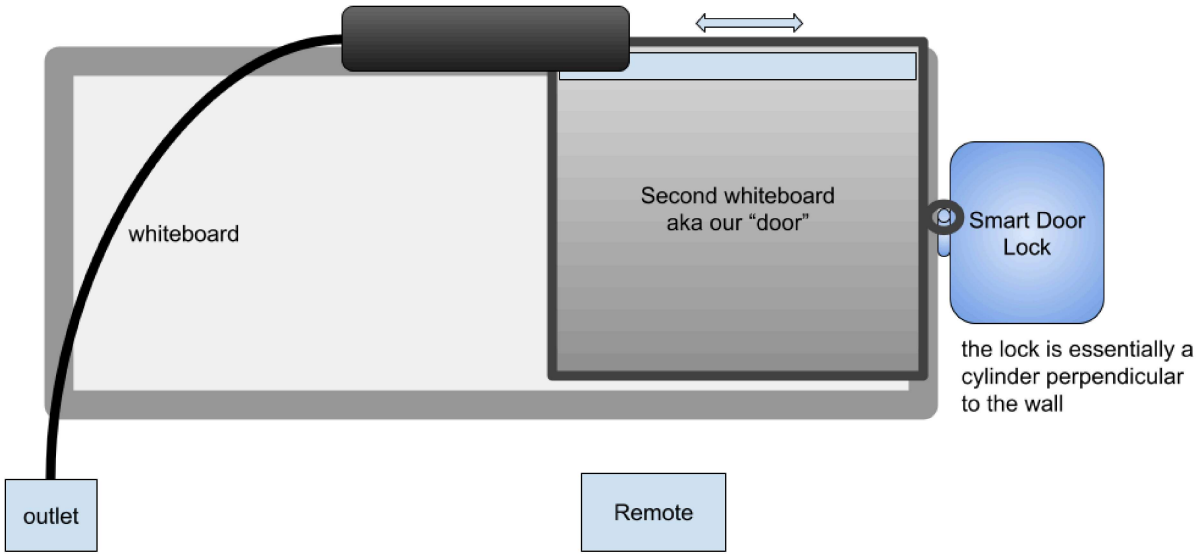

Figure 16: Visual Diagram for Smart Door Opener

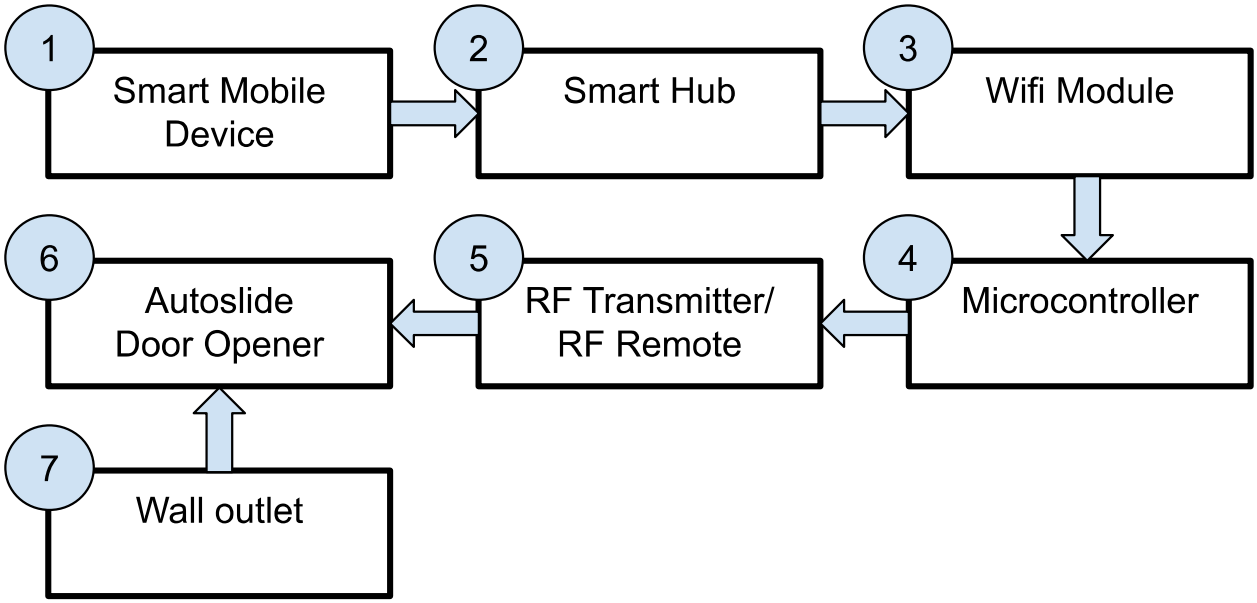

Figure 17: Block Diagram for Smart Door Opener

The Autoslide Sliding Door Opener is a commercial sliding door opener. It is operable by a remote control, but does not connect to the internet. The Smart Door Opener will connect the GPIO pins on a Raspberry Pi Pico W to the remote control’s buttons to operate the door opener.

The Pico W will allow wireless integration into the Home Assistant system and perform other functions such as storing the state of the door.

Estimated Cost

Qty	Description	Unit Price	Total Cost
1	Raspberry Pi Pico WH - Pico Wireless with Headers Soldered	$7.00	$7.00
1	Autoslide Mobility Kit	$590.00	$590.00
1	Barn Door conversion hardware	$29.00	$29.00
1	Amazon Basics Magnetic Dry Erase Whiteboard, 36 x 24-Inch	$30.08	$30.08
1	RF transmitter (estimate)	$20.00	$20.00
		Total	$676.08

Table 08: Estimated Costs for Smart Door Opener

Test Plan

Test T1 - Wi-Fi Connectivity Test:

Follow the set up in https://github.com/raspberrypi/pico-examples/tree/master/pico_w/wifi/blink

Pass/Fail criteria: The test passes if the light blinks when it receives a command over Wi-Fi.

Cover Requirements: 1a

Test T2 - :

Use the Smart Hub to send “open” and “close” commands to the Smart Door Opener

Pass/Fail criteria: This test passes if the door opener obeys the Smart Hub commands.

Cover Requirements: 1b

Test T3:

Use the Smart Hub to request the status of the door.

Pass/Fail criteria: This test passes if the Smart Door Opener responds with the correct state of the door.

Cover Requirements: 1c

Test T4:

Disconnect the Smart Door Opener from the outlet. Manually attempt to slide the door.

Pass/Fail criteria: This test passes if a student is able to open/close the door with only one hand and without excessive force.

Cover Requirements: 3

Test T3:

Place a hand in the path of the door and select open/close, and hold the hand firm.

Pass/Fail criteria: This test passes if the Smart Door Opener automatically stops and retracts after collision with the hand.

Cover Requirements: 6

Requirements 2, 4, and 5 are covered by the innate design of the Smart Door Opener

	Requirements				
Tests	1a	1b	1c	3	6
T1	x				
T2		x			
T3			x		
T4				x	
T5					x

Smart Pill Box

The Smart Pill Box will be designed to organize the resident's daily medications. Each time slot worth of medications will be combined in a single compartment and dispensed as a group. When it comes time for the resident to take their medication, the Smart Pill Box will send a voice notification through a smart speaker. The Smart Pill Box will dispense the pills into the dispense tray by spinning the spindle at the center of the device. Additionally, the Smart Pill Box will notify the caregiver whenever the pills have been dispensed and when the medications need to be refilled.

Requirements

1. The Smart Pill Box must activate the Smart Speaker (through the Smart Hub) at a set time, notifying the resident that it's time to take their medication and specifying what the medication is for.
2. It shall have the capacity to hold multiple types of medications.
3. The Smart Pill Box must send a notification to the caregiver once the medication has been dispensed.
4. It shall also communicate to the caregiver when it's time to refill the medications.
5. The caregiver shall be able to enter the medication data into the Remote Support Station to set up the Smart Pill Box.
6. Access to the Smart Pill Box medication data on the Remote Support Station/Hub must be password-protected.
7. The Smart Pill Box shall be able to be positioned at an appropriate location and height to dispense pills to the resident in the wheelchair.
8. The pill box wheel shall spin to the next slot at the designated time.
9. The device should dispense pills so they slide out from the dispenser without falling on the floor.
10. The Smart Pill Box must be manually openable by a caregiver in the event of a malfunction.

Design

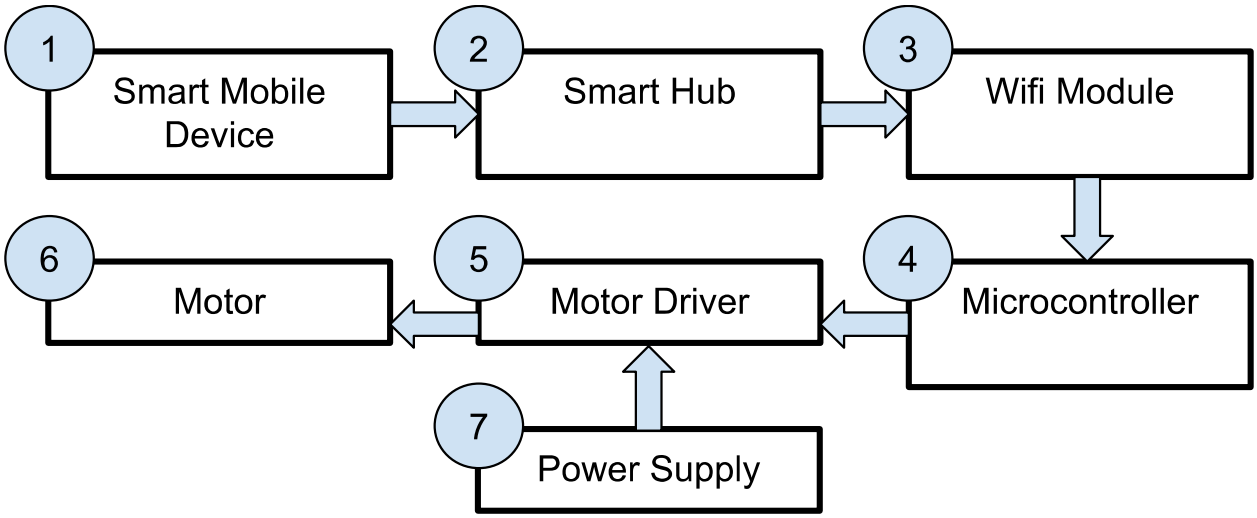

Figure 18: Block Diagram for Smart Pill Box

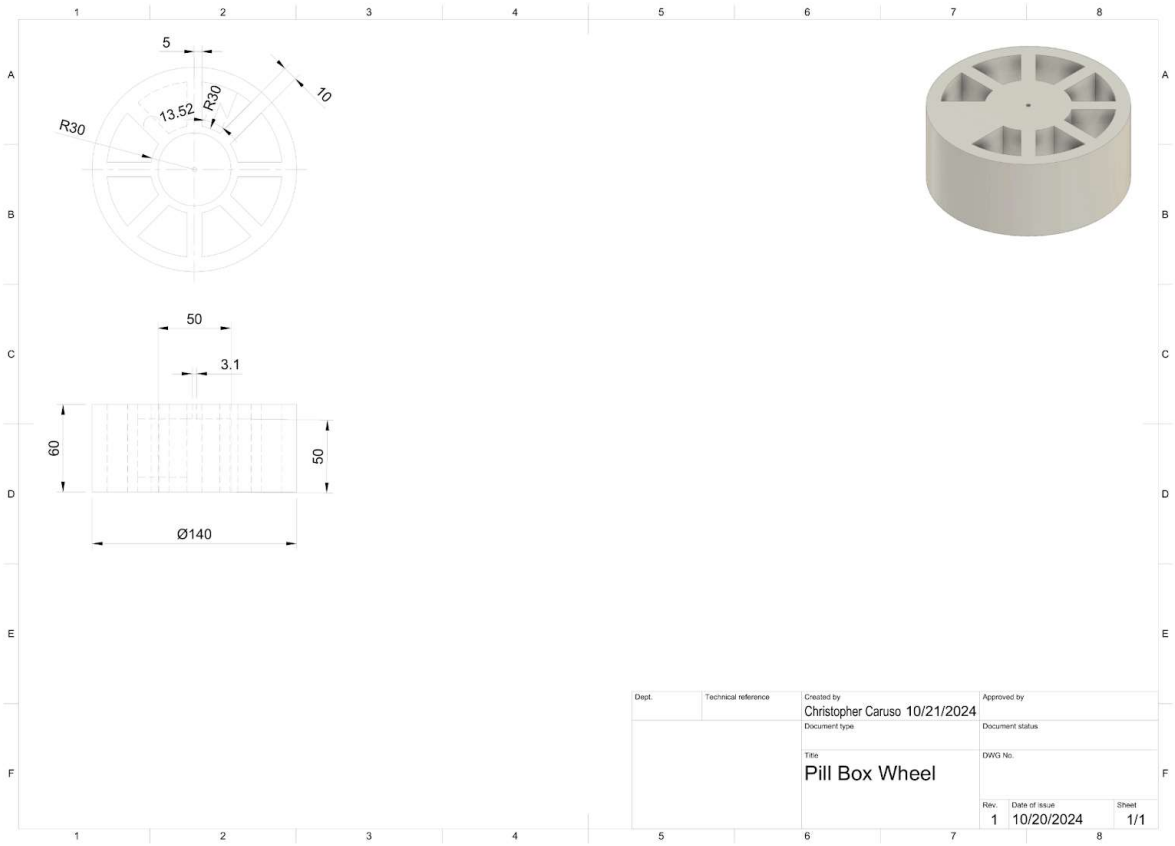

Figure 19: CAD Design for Pill Box Spindle

Figure 19 is the main device used in holding and dispensing pills. The blocked slot will act as the closed position, and the other slots will spin over an opening to dispense their contents.

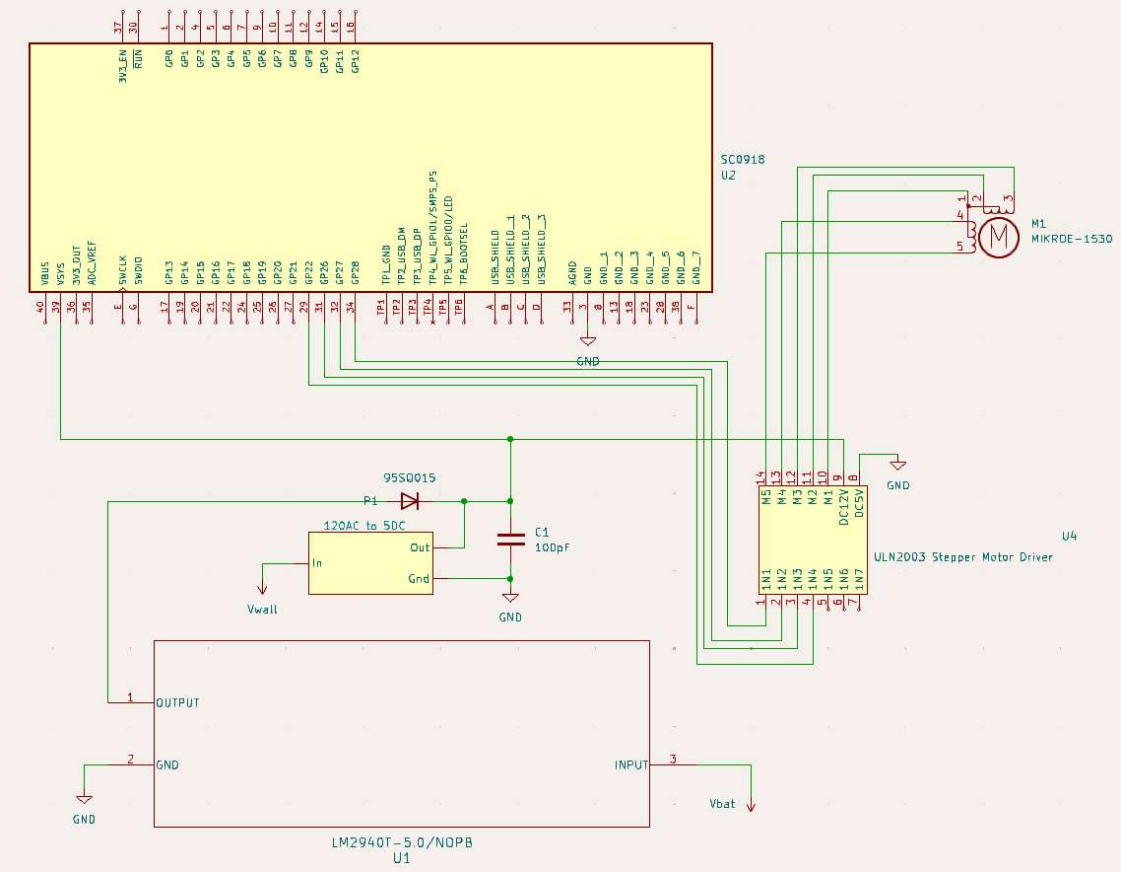

Figure 20: Circuit Schematic for Smart Pill Box

In Figure 20, there is an AC to DC converter that takes power from the wall. A voltage converter steps the voltage down from the battery to match the same voltage. A diode blocks the power from leaving the battery to go to the circuit if there is wall power. There is a capacitor stabilizing the circuit current for when the power source switches. The Pi Pico W receives signals from the Smart Hub and uses those to control the motor driver. The motor driver controls the motor so pills are dispensed when we want them to.

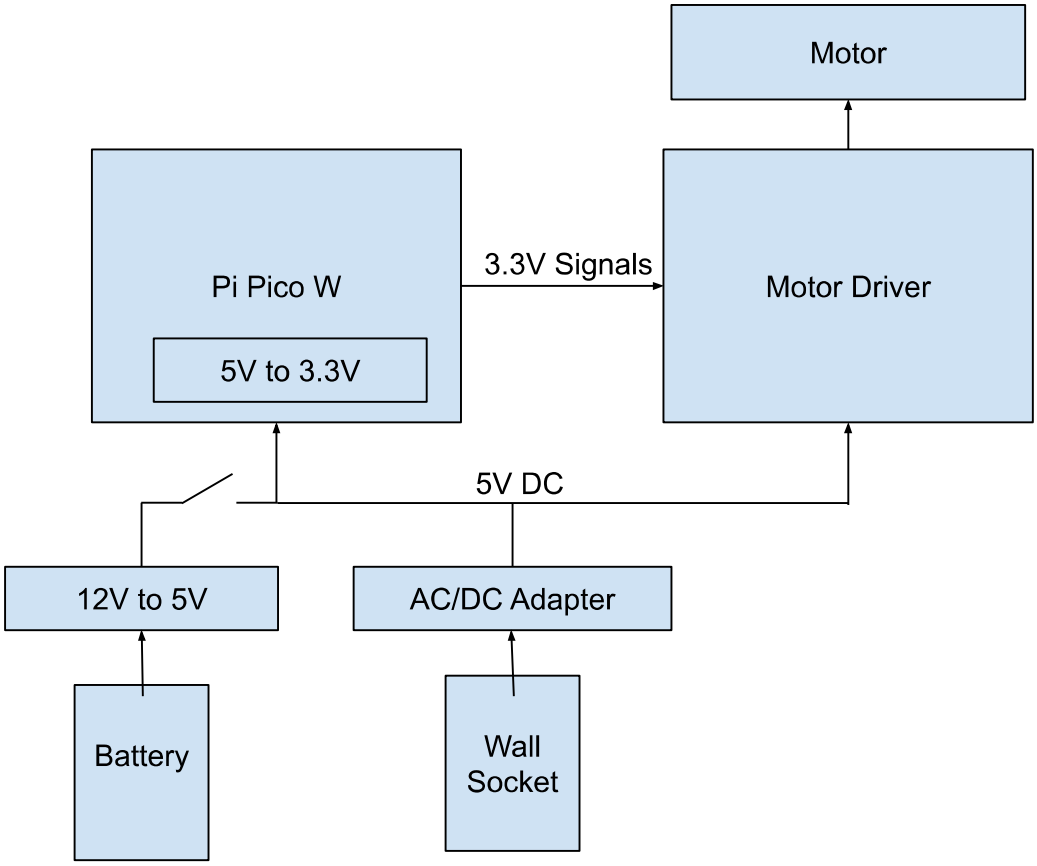

Figure 21: Power Diagram for Smart Pill Box

Qty	Description	Unit Price	Total Cost
1	MIKROE-1530 Motor	$9.60	$9.60
1	ULN2003 Stepper Motor Driver	$1.00	$1.00
1	Seasider 12V 2600mAh Rechargeable Li-ion Battery Pack	$20.99	$20.99
1	100pF Capacitor	$0.13	$0.13
1	16-00014 AC/DC Wall Adapter	$4.30	$4.30
1	PJ-063AH Power Jack	$1.98	$1.98
1	95SQ015 Diode	$0.51	$0.51
1	PCB	$30	$30
1	Emergency PCB (Estimate)	$100.00	$100.00
1	Emergency Mechanical Design	$60	$60.00
		Total	$204.29

Table 09: Estimated Costs for Smart Pill Box

Test Plan

Test T1 - Dispensing:

Provide power to the Smart Pill Box. Load up the spindle with pill substitutes. Set the pill box to dispense in 5 minutes. Set a timer on a stopwatch for 5 minutes.

Pass/Fail criteria: The pills are dispensed at the designated time and land in the tray.

Cover Requirements: 1, 2, 5, 8, 9

Test T2 - Emptying:

Provide power to the Smart Pill Box. Load up the spindle with pill substitutes. Connect the UART to the Pi Pico W. Send a command to trigger the pill box. Repeat six more times.

Pass/Fail criteria: The pill box sends a notification each time a pill is dispensed and one notification when the pillbox is empty.

Cover Requirements: 3, 4

Test T3 - Information:

Provide power to the Smart Pill Box. Connect the Smart Pill Box to the Smart Hub. Provide power to the Remote Support Station. Connect the Remote Support Station to the Smart Hub. Navigate the menu of the Remote Support Station to the Smart Pill Box menu. Set a pill to be dispensed in one minute. Go to the main menu and wait for the notification. After it is received, navigate back to the Smart Pill Box menu and look for the medical information.

Pass/Fail criteria: The health information can be accessed from the Remote Support Station.

Cover Requirements: 6

Test T4 - Access:

Provide power to the Smart Pill Box. Place the Smart Pill Box on a table. Place a pill substitute in the first slot of the spindle. Access the Remote Support Station and set a pill to be dispensed in three minutes. Bring a chair over and sit in it to simulate a wheelchair.

When the pill is dispensed, ball your fingers into fists and try to remove the pill without uncurling your fingers.

Pass/Fail criteria: The tester is able to remove the pill substitute from the tray.

Cover Requirements: 7

Test T5 - Openable:

Place two pill substitutes in the first two slots of the Smart Pill Box spindle. Close the lid of the pill box. Bring a third party product tester into the room. Instruct them to attempt to open the pill box. If they succeed, instruct them to remove the spindle. If they succeed in removing the spindle, instruct them to remove the pill substitutes.

Pass/Fail criteria: The pill substitutes are able to be removed without additional instruction.

Cover Requirements: 10

	Requirements									
Tests	1	2	3	4	5	6	7	8	9	10
T1 - Dispensing	x	x			x			x	x	
T2 - Emptying			x	x						
T3 - Information						x				
T4 - Access							x			
T5 - Openable										x

Smart Speaker

The Smart Speaker will be an essential component of our SALE home system, designed to stream audio from our Hub (including medicine notifications, doorbells, or music selected using the smart mobile device). It shall be easily configured by the resident, specifically the volume control, and will be the conduit through which our home system communicates with our resident. Additionally, the smart speaker shall listen to voice commands from the resident and send the audio to the Smart Hub for interpretation.

Requirements

1. The Smart Speaker shall be controlled by a Matter compatible control system.
2. The Smart Speaker shall connect wirelessly to the Smart Hub.
3. The Smart Speaker shall have a volume control system accessible through the smart mobile device.
4. The Smart Speaker shall send a notification to the Smart Hub when an error occurs.
5. The Smart Speaker shall be easily accessible/controlled using the Kick Buttons and voice control.
6. The case of the Smart Speaker shall be durable and good-looking.
7. The Smart Speaker shall be able to stream audio to and from the Smart Hub.
8. The Smart Speaker shall be sufficient enough for FM-quality sound.
9. The Smart Speaker shall be able stream from pandora/internet radio, and play audiobooks.
10. The Smart Speaker shall play error messages (if any). There shall be an option for the resident to disable the feedback messages.
11. The Smart Speaker shall play messages when actions are undertaken through the smart mobile device.
12. Speaker shall be loud enough to hear across the room.

Design

The smart speaker is based upon a Raspberry Pi Pico W microcontroller, using WiFi to communicate audio data with the hub. The speaker uses an external DAC chip to produce a high-quality analog waveform, which is amplified and played through a speaker. It also supports a microphone, using a premade PCB module that integrates a sensitive microphone with an amplifier, which allows for a high-quality but low-cost implementation.

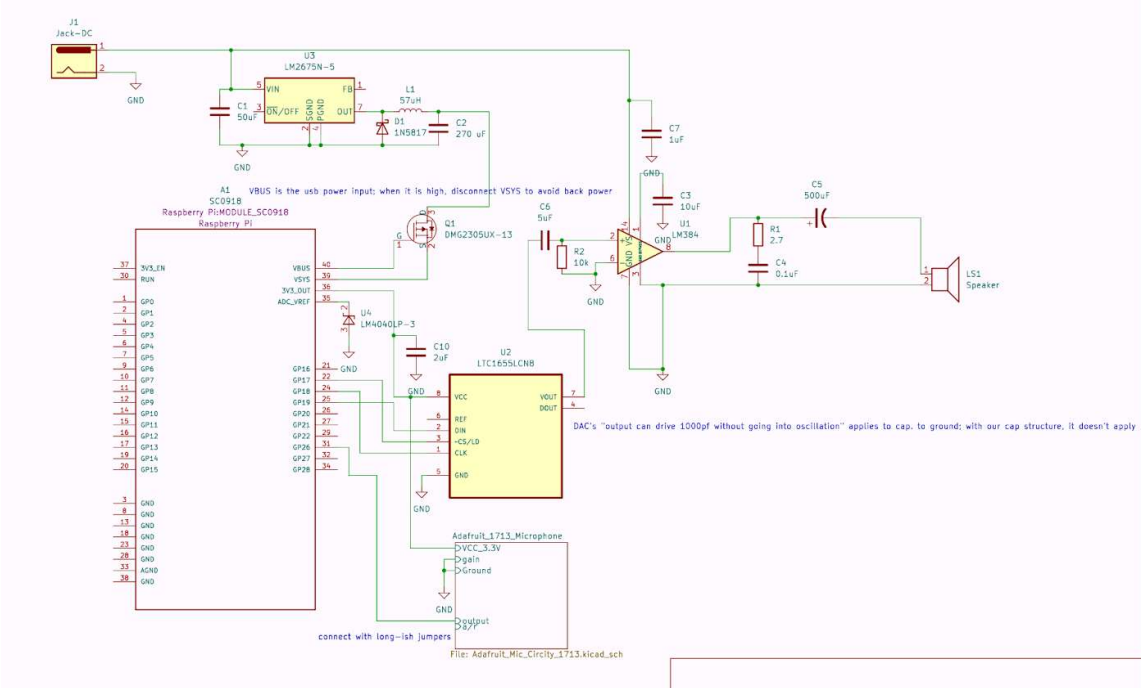

Figure 22: Schematic Diagram for Smart Speaker

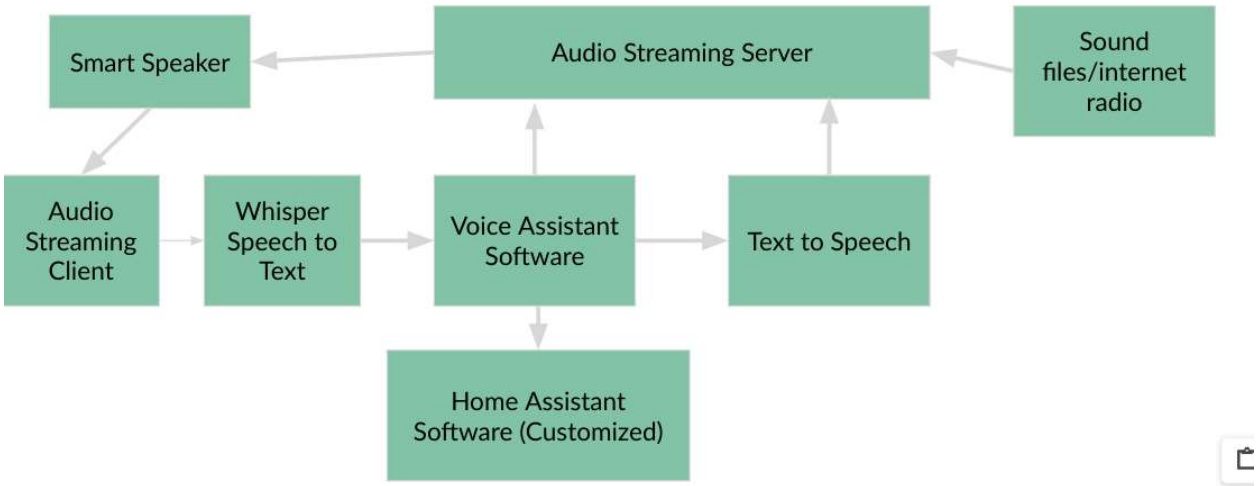

Figure 23: High-Level Software Design for Smart Speaker

Test Plan

Test T1 - Startup and Connect Test:

Start the speaker, and confirm it connects to the hub.

Pass/Fail criteria: The test passes if the connection is established, and the hub can send pings to the speaker

Cover Requirements: 1,2

Test T2 - Error Handling

An error is induced in the speaker, and it is confirmed that the speaker plays the error and notifies the smart mobile device.

Pass/Fail criteria: The test passes if the connection is established, and the hub can send pings to the speaker

Cover Requirements: 3,10

Test T3 - Basic Hub Streaming

Sound is streamed from the hub, from an arbitrary source; the sound is confirmed on the speaker

Pass/Fail criteria: The test passes if audio plays from the device

Cover Requirements: 7

Test T4 - Hub Stream Routing

An error message, an audiobook, a Pandora stream, and an action confirmation message are produced on the hub

Pass/Fail criteria: The test passes if audio plays from the device for all stimuli

Cover Requirements: 7,9,10,11

Test T5 - Audio Quality

A series of test audio files are played on the speaker

Pass/Fail criteria: The test passes if the sound is perceived to be of sufficient quality when heard from afar.

Cover Requirements: 8, 12

Budget

Qty	Unit	Part #	Description	Unit Price	Total Cost
10	each	1N5817	High-speed diode	$0.08	$0.83
10	each	LM2675N-5	Power Converter IC	$3.77	$37.69
10	each	67144080	Inductor - 67144080	$3.80	$37.95
10	each		Low ESR filtering capacitor	$0.51	$5.08
10	each		High voltage rating input capacitor	$0.25	$2.47
3	each	LM384N	Audio amplifier	$1.72	$5.16

2	each		Heatsink	$1.90	$3.80
2	each	LTC1655LCN8	High-quality DAC	$25.57	$51.14
2	each	Adafruit 1713	microphone w/ preamp	$7.95	$15.90
4	each	LM4040	voltage reference for ADC	$0.64	$2.56
10	each		PMOS to prevent current back-powering	$0.14	$1.37
1	each		Speaker	$11.55	$11.55
5	each		Barrel jack connector	$0.64	$3.20
2	each	Adafruit 1230	SMD to DIP adapter	$4.95	$9.90
			PCB Costs		$90.00
			3D printing costs		$50.00
			Buffer		$100.00
				Total	$428.60

Table 10: Smart Speaker Estimated Budget

Smart TV

The Smart TV will provide added convenience to the resident by providing functionality through the Smart Hub to control a home entertainment unit. In our project, the SALE home system will utilize a TV with a Roku player streaming box, and the Smart Hub will be able to control both the native TV settings and preferences as well as the Roku. The Smart TV control will be accomplished via an infrared home-built remote controller, which will emulate both the Roku and TV remotes.

Requirements

1. The resident shall be able to control the Smart TV via voice, Kick Buttons, and Smart Mobile Device. This might include the following:
    a. TV power on/off
    b. TV volume control
    c. HDMI Input
    d. Navigate TV native preferences and settings (e.g. picture quality)
    e. Roku control (seamlessly navigate to different Roku applications as well as operate within those applications)
2. The Smart TV shall send notifications to the Smart Hub when the following error occurs:
    a. Lost HDMI connection
    b. TV unexpectedly turns off
    c. Poor internet connection
3. The Smart TV shall be easy to control via voice control.
4. The Smart TV shall be powered via a standard room outlet, connected to the main power line.

Design

The Smart TV device consists of a Raspberry Pi Pico W being used to control a TV and Roku streaming box via an infrared LED which mimics the TV and Roku remotes. The design utilizes the Vishay TSAL6400 IR LED, chosen for its peak wavelength of 940 nm, which is compatible with most IR receivers. The circuit connects the GPIO pin of the Pico W to the infrared LED, a 100Ω resistor, and then to the ground. With the Pico W's GPIO operating at 3.3 Volts and supplying up to ~50 mA, the resistor ensures the LED operates at a safe 20 mA.
Infrared signals emitted by the LED replicate remote-control commands (IR codes) for both devices. These signals are triggered by inputs received by the Smart Hub, processed, and sent via Wi-Fi to the Pico W, which then relays those inputs as 38 kHz pulses to the LED. The infrared light emitted from the LED will thus reflect IR codes that can be interpreted by the TV and the Roku. This streamlined connection simplifies hardware design, which mostly consists of a 3D-printed rectangular case to house.

Component	Description	Quantity	Cost per unit	Total Cost
TV		1	$0	$0
Streaming Box	Roku Express	1	$30	$30
Casing		1	$30	$30
IR LED	TSAL6400	10	$5	$5
Proto Board		1	$10	$10
Microcontroller	Pi Pico W	1	$25	$25
Total				**$100**

Table 11: Estimated Costs for Smart TV

Test Plan

Test T1 - Voice-Controlled Smart TV Operation:

Test specific commands (e.g., "Turn on TV," "Increase volume," "Switch to HDMI 1") and verify the TV's response.

Pass/Fail Criteria: The test passes if the TV performs each command as spoken without lag or misinterpretation.

Cover Requirements: 1

Test T2 - Kick Button-Controlled Smart TV Operation:

Map each Kick Button to specific TV functions (e.g., power on/off, volume control) and test each function.

Pass/Fail Criteria: The test passes if each Kick Button correctly triggers the mapped TV function without delays.

Cover Requirements: 2

Test T3 - Mobile Device-Controlled TV Operation:

Pair the Smart Mobile Device with the TV and test control functions such as turning the TV on/off, adjusting volume, and switching inputs.

Pass/Fail Criteria: The test passes if each control function from the mobile device accurately performs the intended action on the TV.

Cover Requirements: 3

Test T4 - TV Power On/Off Control:

Use voice commands, Kick Buttons, and a Smart Mobile Device to turn the TV on and off.

Pass/Fail Criteria: The test passes if the TV powers on/off immediately after receiving each control input.

Cover Requirements: 4

Test T5 - TV Volume Control:

Adjust volume using voice commands, Kick Buttons, and a Smart Mobile Device.

Pass/Fail Criteria: The test passes if the volume level changes accurately with each control input.

Cover Requirements: 5

Test T6 - HDMI Input Control:

Switch between HDMI inputs on the TV using voice commands, Kick Buttons, and a Smart Mobile Device.

Pass/Fail Criteria: The test passes if the TV switches to the requested HDMI input as commanded.

Cover Requirements: 6

Test T7 - TV Preferences and Settings Navigation:

Attempt to navigate and adjust the TV's native settings, including picture quality, using all control methods.

Pass/Fail Criteria: The test passes if the resident can access and adjust settings and return to the main menu using any control method.

Cover Requirements: 7

Test T8 - Roku Control Integration:

Use each control method to navigate within the Roku interface and open/operate applications (e.g., Netflix, YouTube).

Pass/Fail Criteria: The test passes if the resident can navigate to and operate applications on the Roku platform using each control method.

Cover Requirements: 8

Test T9 - Voice Control Usability:

Conduct a user experience study with at least five participants to assess ease of use and responsiveness of voice commands.

Pass/Fail Criteria: The test passes if a majority (e.g., >80%) of participants find the voice control intuitive and responsive.

Cover Requirements: 9

Test T10 - Power Supply Test:

Plug the Smart TV into a standard 120V AC outlet and confirm functionality.

Pass/Fail Criteria: The test passes if the Smart TV powers on and remains stable when connected to a standard outlet.

Cover Requirements: 10

Smart Window Shade

The Smart Window Shades component of the SALE home system will essentially be integrated with controls intended to unburden the resident. The resident will be able to conveniently adjust their preferences for lighting with simple, straightforward controls. The shades will be sheets of translucent cloth that block out most of the light.

Requirements

1. Simple controls; with a push/touch shall open or close.
2. Smart Window Shades shall be connected with the Smart Hub wirelessly.
3. Smart Window Shades shall have manual mechanical control as an alternative.
4. Wired aspects shall be secured and out of reach/away from the resident.
5. The resident shall be able to raise/lower the Smart Window Shades by interfacing from the Smart Mobile Device.

Design

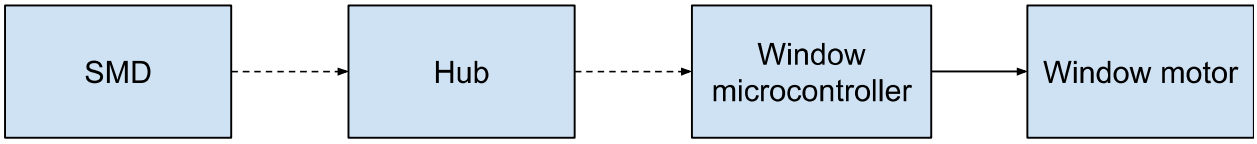

Figure 24: Higher Level body diagram

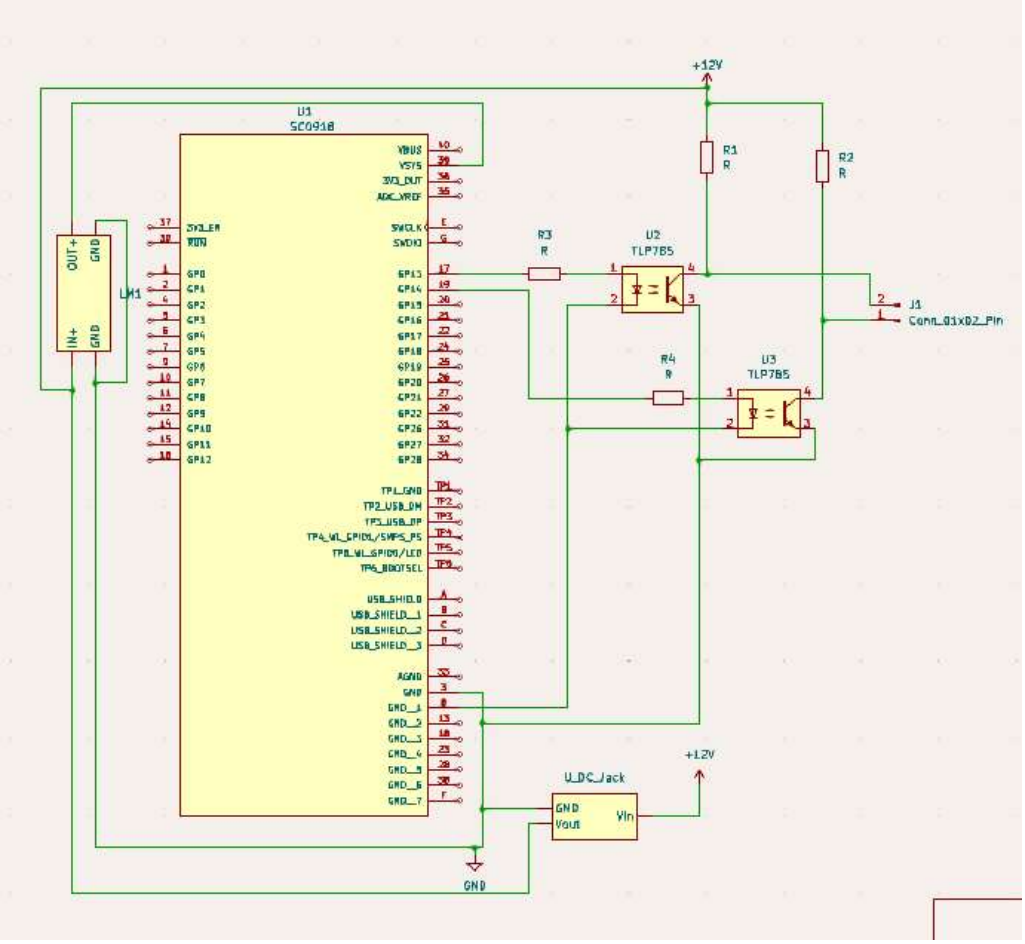

Figure 25: Microcontroller Schematic

The schematic in Figure 25 shows the layout of the PCB with the microcontroller. There is one power input supplied from a jack that is connected to an AC adapter from Line Voltage to 12V. 12V is fed to a voltage converter. The LM2596 steps the voltage down to 5V and sends it to the PICO-Microcontroller. The signal from the Pico is sent using a photocoupler. The other I/O junctions that include the signals that will be sent to the Motor PCB.

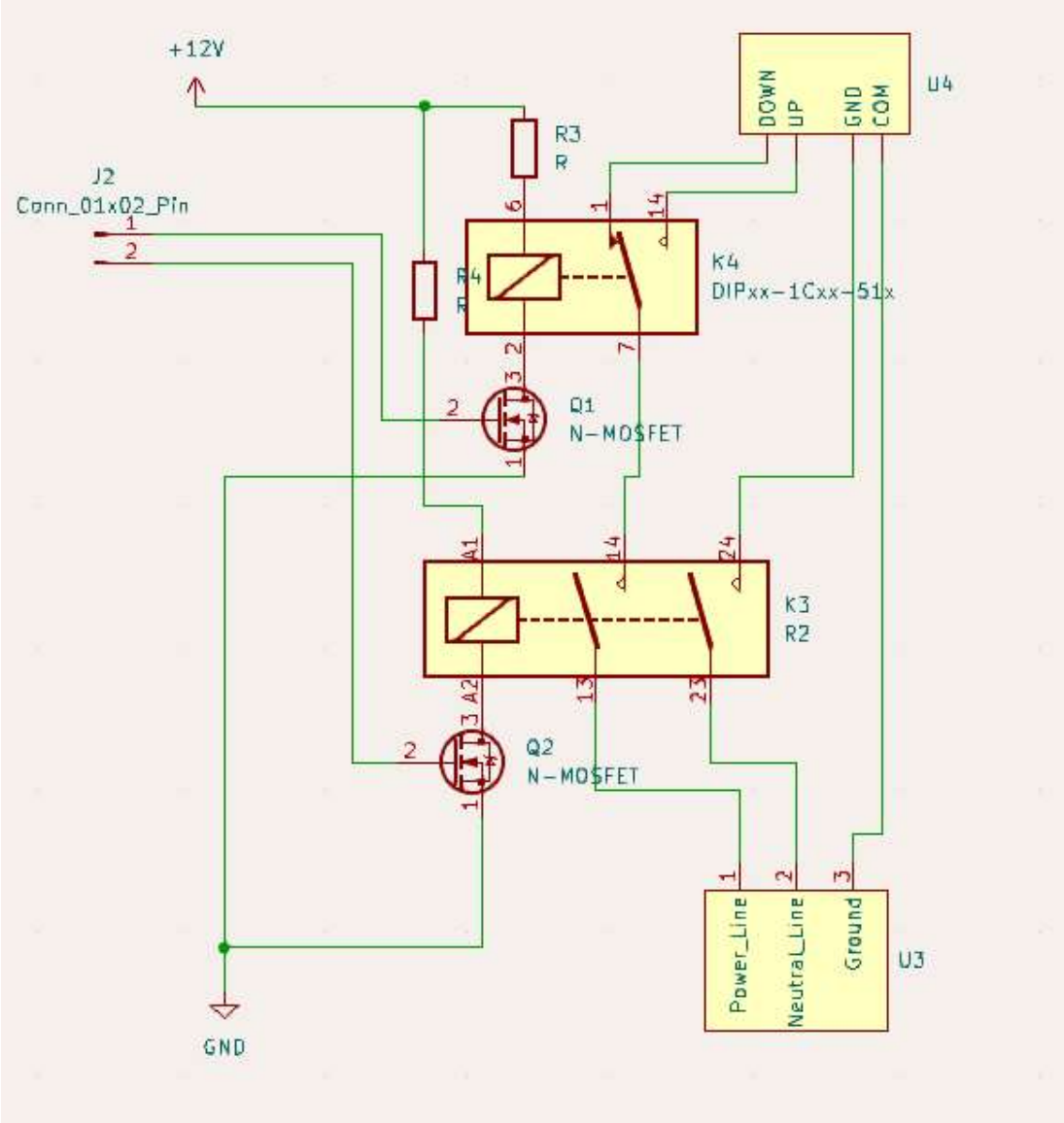

Figure 26: Power Motor Schematic(NMOS)

The schematic in Figure 26 shows the layout of the Motor PCB. The power in this schematic utilized will be an IEC power connector, and 12V signals coming from the Microcontroller PCB. The signals control N-type MOSFETs which switch relays on or off. These relays have the 12V as the primary side and the AC line voltage as the secondary side hedging towards the motor of the window shades.

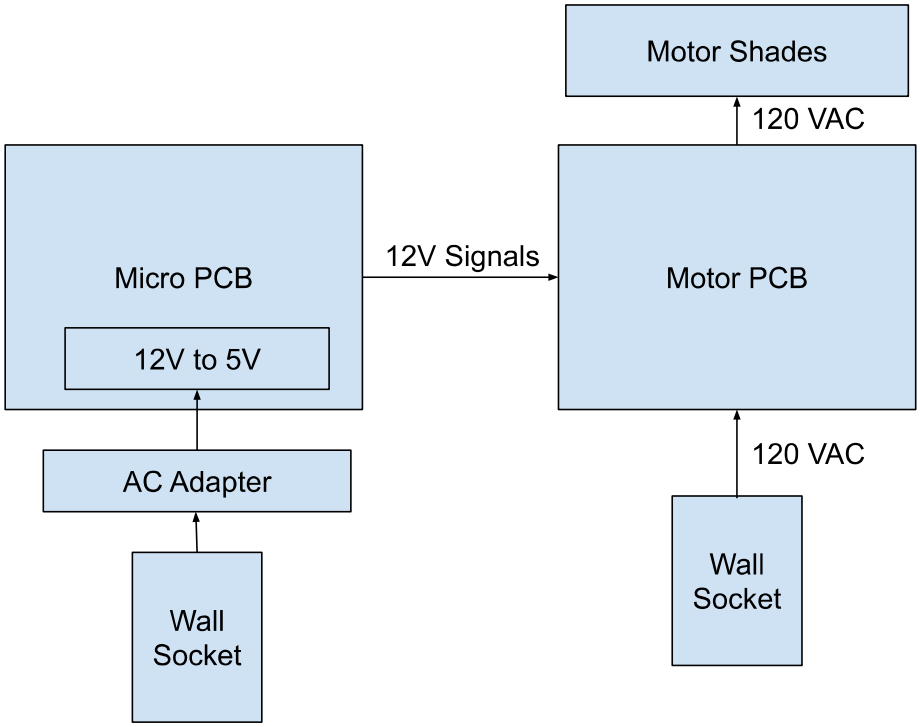

Figure 27: Power Diagram

Qty	Description	Unit Price	Total Cost
1	Raspberry Pi Pico W	$5.00	$5.00
1	Power Cord(Cable)	$6.86	$6.86
1	12V DC Adapter	$14.39	$14.39
1	DSP2A-DC5V	$5.29	$5.29
1	G5LE-1 DC5	$1.84	$1.84
1	DSP2A-DC12V	$6.28	$6.28
1	G5LE-1 DC12	$1.70	$1.70
1	Window shades motor	$165.68	$165.68
1	Tube 39"	$19.00	$19.00
1	LM2596 Buck Converter	$7.99	$7.99
1	DIP-4 PC817C PC817 opto isolator	$4.99	$4.99
1	AC Power Entry Modules PCB	$2.02	$2.02
1	PCB (Estimate)	$100.00	$100.00
		Total	$341.04

Table 12:Window Shade Budget

Test Plan

Test T1 - Simple controls

Utilize the test board with one touch or one press of a button.

Pass/Fail criteria: The test passes if one button/touch makes the test protoboard light up/motor move in intended direction.

Cover Requirements: 1

Test T2 - Wireless Connection

Be connected with the Smart Hub wirelessly, send signals via the hub and return a 'Hello' from the pico window shade microcontroller.

Pass/Fail criteria: The test passes if the microcontroller is able to be interfaced and test code operates with the hub via Wi-Fi.

Cover Requirements: 1, 2

Test T3 - Manual Mechanical Control

Using hands, twist or pull, depending on design, and the Smart Window Shades shall lower or raise via manual mechanical control.

Pass/Fail criteria: The test passes if the motor window shades is off and the user can manually move the shades up and down via rolling lever.

Cover Requirements: 3

Test T4 - Wiring Placement and Sturdiness

Wired aspects shall be secured and out of reach/away, walking next to the board and tugging on the motor PCB housing.

Pass/Fail criteria: The test passes if the wiring and electrical components are enclosed in a housing or out of reach in a general area. Fails if there is any misalignment or doesn't stay in place.

Cover Requirements: 4

Test T5 - Motor Shade Control via Smart Shade Device

Raise/lower the Smart Window Shades by interfacing from the Smart Mobile Device using commands that will be coded into the hub and SMD integration.

Pass/Fail criteria: The test passes if instructions from Smart Mobile Device interact with and move the smart window shades.

Cover Requirements: 1, 2, 5

	Requirements				
Tests	1	2	3	4	5
T1	X				
T2	X	X			
T3			X		
T4				X	
T5	X	X			X