SMART ASSISTED LIVING ENVIRONMENT

5.12.2025
SENIOR DESIGN ‘25 / FINAL DESIGN

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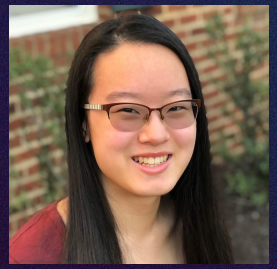
SALE

Our Team

Padmanabh K.



Priscilla W.

Nicholas S.

Calum M.

Hernan T.

Chris C.

Scott T.

What is SALE?

SALE

Trends in Smart Homes Solutions

- **Voice controlled Systems for Hands free interaction:** Voice assistants like Alexa, Siri and Google Assistant are widely used to enhance user experience
- **Environment Control Systems:** ECS allow users with mobility impairments to control their surroundings (lights, doors, beds) through interfaces adapted to their abilities, such as switches, eye-gaze systems, etc.
- **AI and Context Aware Automation for Cognitive Assistance:** For users with cognitive impairments, smart homes can offer context-aware prompts and reminders for daily routines, like medication reminders.
- **Wearable and Sensor-Based Monitoring for Safety and Health:** Smart homes often integrate health monitoring wearables and alert systems to track user wellbeing and notify caregivers or emergency services when needed.
- **Mobile and Web Interfaces for Customized Control:** Mobile apps tailored to user needs (e.g., large fonts, simple UI) allow people with visual, motor, or cognitive disabilities to manage their environment using smartphones or tablets, with personalized accessibility features.

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Smart Home Solution for people with disabilities

- Existing homes are inadequate since they tend to be very niche and only support a few individuals based on certain designs.

- Many smart home technologies are designed with the general population in mind, neglecting the unique requirements of users with disabilities. These can include but are not limited to:
  - Lack of personalization and adaptability for many users.
  - Inadequate user interfaces that fail to consider individuals with visual impairments, many of whom may struggle with interfaces that rely on visual cues and feedback.
  - Inefficient integrating assistive technologies, which can hinder the usability of these systems for users who rely on them for daily function.
  - High cost, which can be a prohibitive burden for many individuals.

Target Users

Our smart home design may cater to four categories of people:

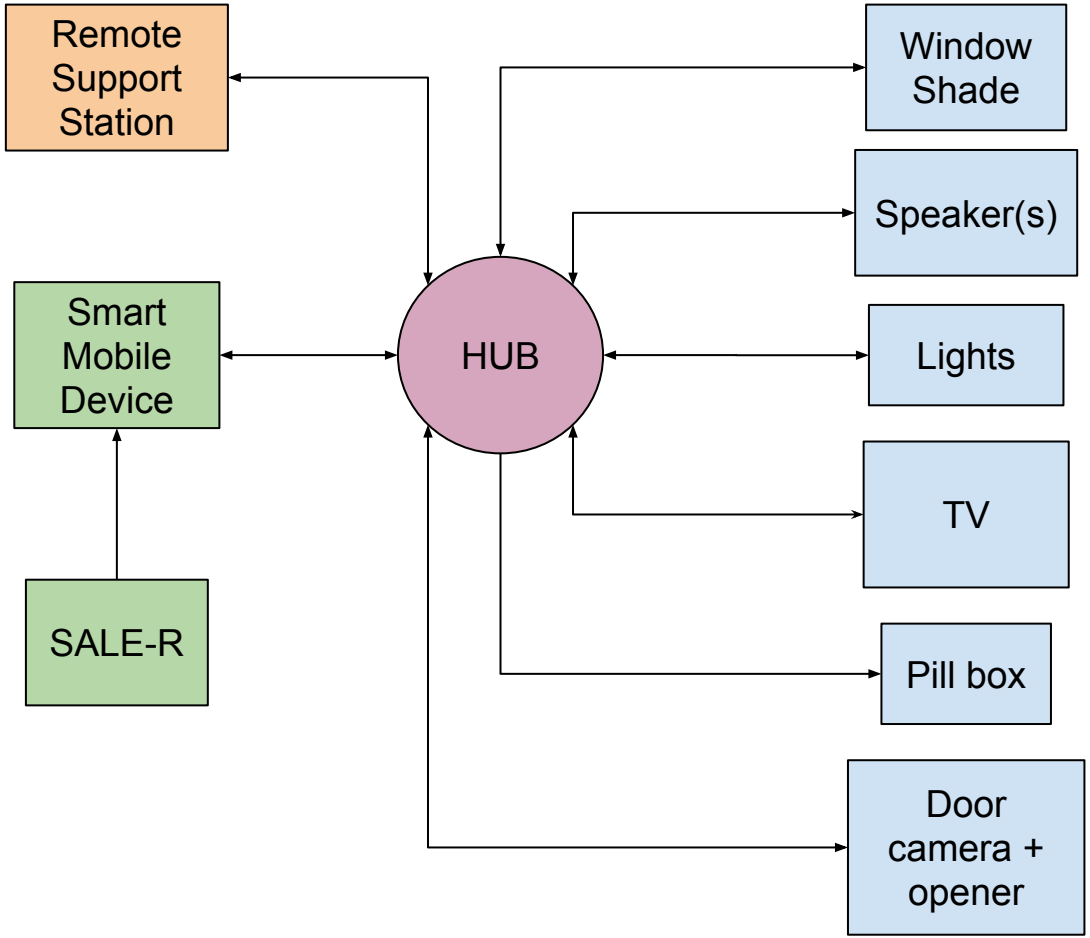
- **Ageing population**: The older people who have limited physical strength and mobility, and have difficulties managing their daily tasks like turning off appliances, managing medications, etc. They may manage the smart home through through the ***SALE android app***.
- **People with limited forelimb (hand) mobility**: Individuals who have congenital conditional, injuries, or neurological orders that limit the hand mobility and fine motor skills like using fingers to use a touch screen interface. Our adaptive device enables ***gross hand motions (fist pounding)*** to control the smart home.
- **People with no hand mobility, and hindlimb hobility**: People who are not able to use their hands due to paralysis, amputation, or serious neuromuscular diseases. Our adaptive control device can use ***leg motions (kicks)*** to control the smart home.
- **People with no limb mobility**: Individuals who have lost or were born without both upper and lower limbs face significant challenges in interacting with their environment. For them, our smart home system can provide comprehensive limbs-free control through ***voice recognition***

Target population: cerebral palsy, multiple sclerosis, spinal cord injuries, arthritis, or stroke-related paralysis, many of whom may have weakened hand control, limited dexterity, or loss of function in their legs.

Our devices

Include:

- Hub
- Smart Mobile Device (SMD)
  - SALE-R (SALE Remote)
- Remote Support Station
- Smart Devices
  - Lights
  - Speaker
  - Door Opener
  - Door Lock
  - TV
  - Window Shade
  - Pill Box



Proposed

- Smart HUB
- Smart Mobile Device
- Smart Pill Box
- Smart Speaker
- Smart Door Opener
- ~~Smart Door Lock~~
- SALE-R
- Remote Support Station
- Smart Window Shades
- Smart Light
- Remote Support Station
- Voice Assistant
- ~~Fully Secure~~ Interface

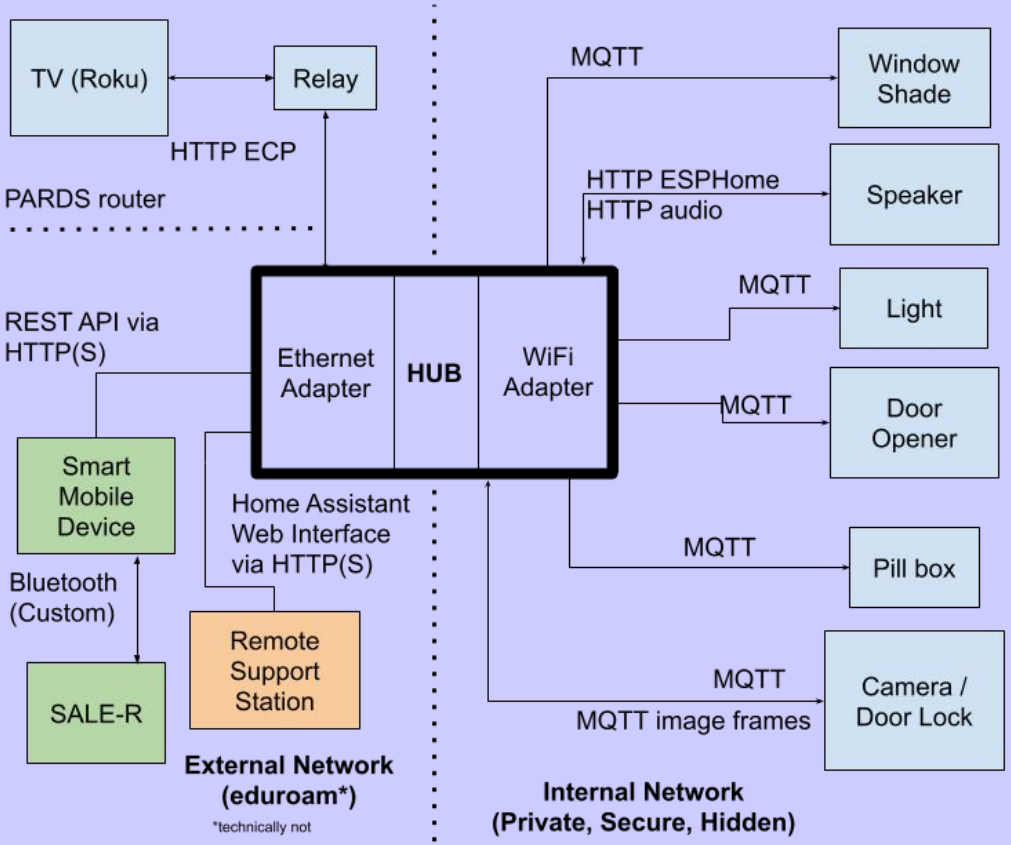
Implemented

- Smart HUB
- Smart Mobile Device
- Smart Pill Box
- Smart Speaker
- Smart Door Opener
- Camera
- SALE-R
- Remote Support Station
- Smart Window Shades
- Smart Light
- Remote Support Station
- Voice Assistant
- Home Assistant User Interface

Core Structure

Network Architecture

- Secure internal network
- Controlled external interfaces
  - Limited attack surface
- HTTPS implementation planned
  - Delayed by the existing Lafayette security that makes it redundant
- Largely MQTT-Based
  - Devices autoconfigure themselves via Home Assistant MQTT API
  - Control messages via MQTT
  - Last-will messages for status WIP



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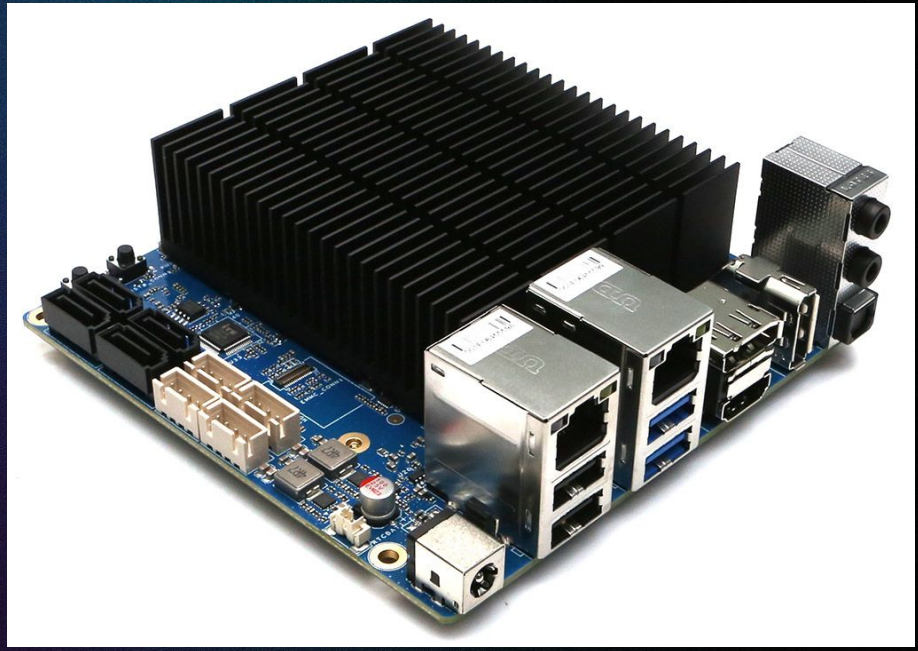
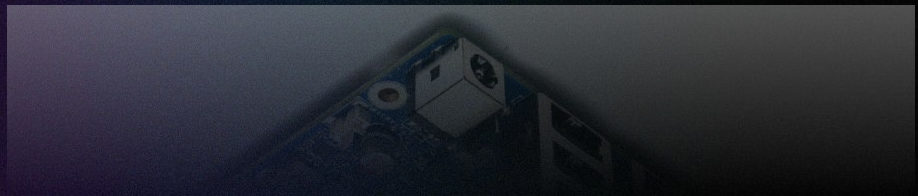
SMART HUB

- ODROID H4+ as the computer
- Debian Trixie (currently Testing) as the OS
- Home Assistant Software
  - Open source
  - Easily patched, well supported
  - Broad existing ecosystem
- Supports several other programs,
  - Local Voice assistant processing (TTS and STT)
  - Media hosting
  - Video Call Relay (Jitsi) (WIP)
- Handles automations, data logging, security
- Battery backup to be provided as a standard UPS





Home Assistant - Resident View

Lighting

Light Switch

Window Shades

Partly cloudy
Forecast Home
62 °F
62 °F / 55 °F

Sun	Mon	Tue	Wed	Thu
62° 55°	74° 47°	67° 59°	64° 61°	72° 61°

Audio

SmartSpeakerESP32 Media Player

Roku Express 4K+

May 11, 2025

SmartSpeakerESP32 Media Player changed to Paused
8:13:19 PM - 6 minutes ago

SmartSpeakerESP32 Media Player changed to Paused
8:11:46 PM - 8 minutes ago

SmartSpeakerESP32 Media Player changed to Playing
8:11:44 PM - 8 minutes ago

SmartSpeakerESP32 Media Player changed to Paused
8:10:53 PM - 9 minutes ago

SmartSpeakerESP32 Media Player

Smart Door

19 minutes ago

Open Door

Door Log

May 11, 2025

Pico W HA Starter Open changed to May 11, 2025 at 8:01 PM
8:13:19 PM - 6 minutes ago

Pico W HA Starter Open changed to May 11, 2025 at 8:01 PM
8:10:49 PM - 9 minutes ago

Medical

19 minutes ago

Dispense Pills

Help needed
Off

Smart Pillbox Log

May 11, 2025

Smart Pillbox Smart Pillbox changed to May 11, 2025 at 8:01 PM
8:13:19 PM - 6 minutes ago

Smart Pillbox Smart Pillbox changed to May 11, 2025 at 8:01 PM
8:10:49 PM - 9 minutes ago

Smart Pillbox Smart Pillbox changed to May 11, 2025 at 8:01 PM triggered by action Button: Press
8:01:10 PM - 18 minutes ago - Calum McConnell

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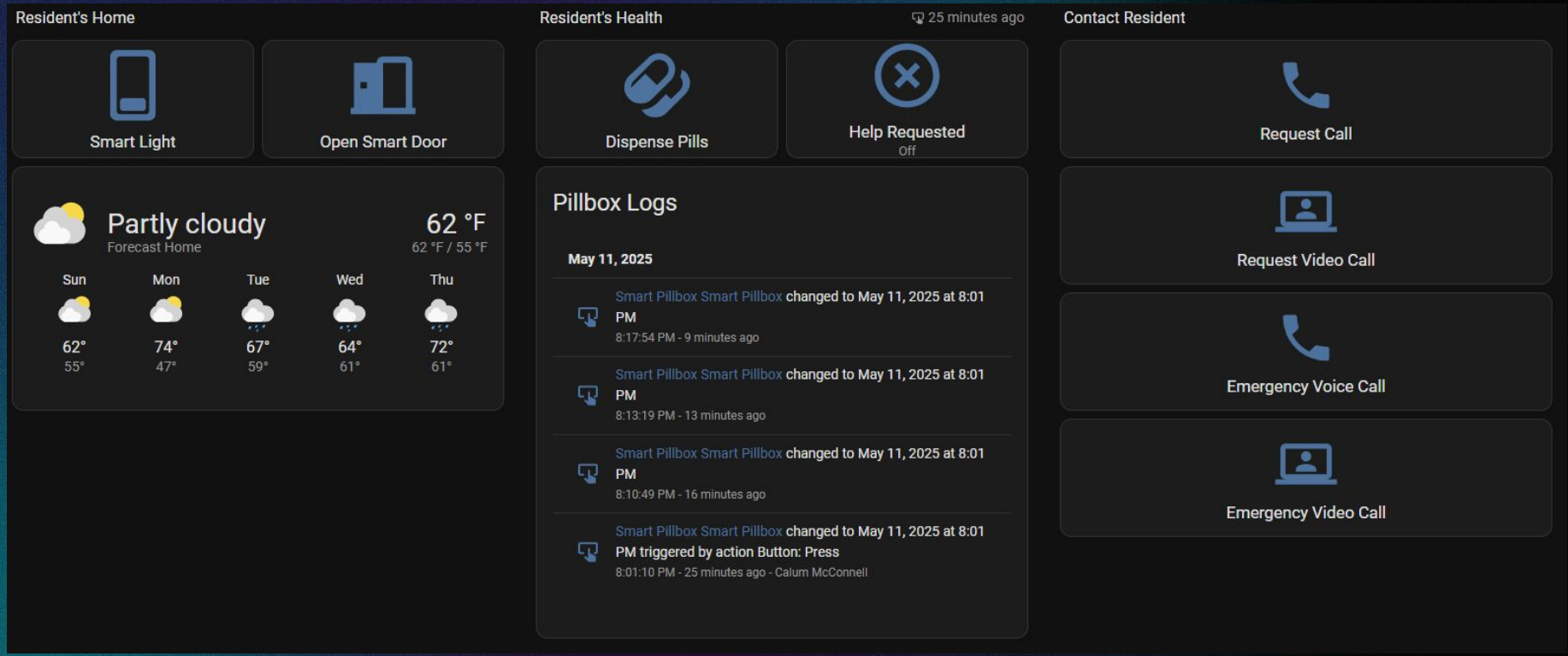
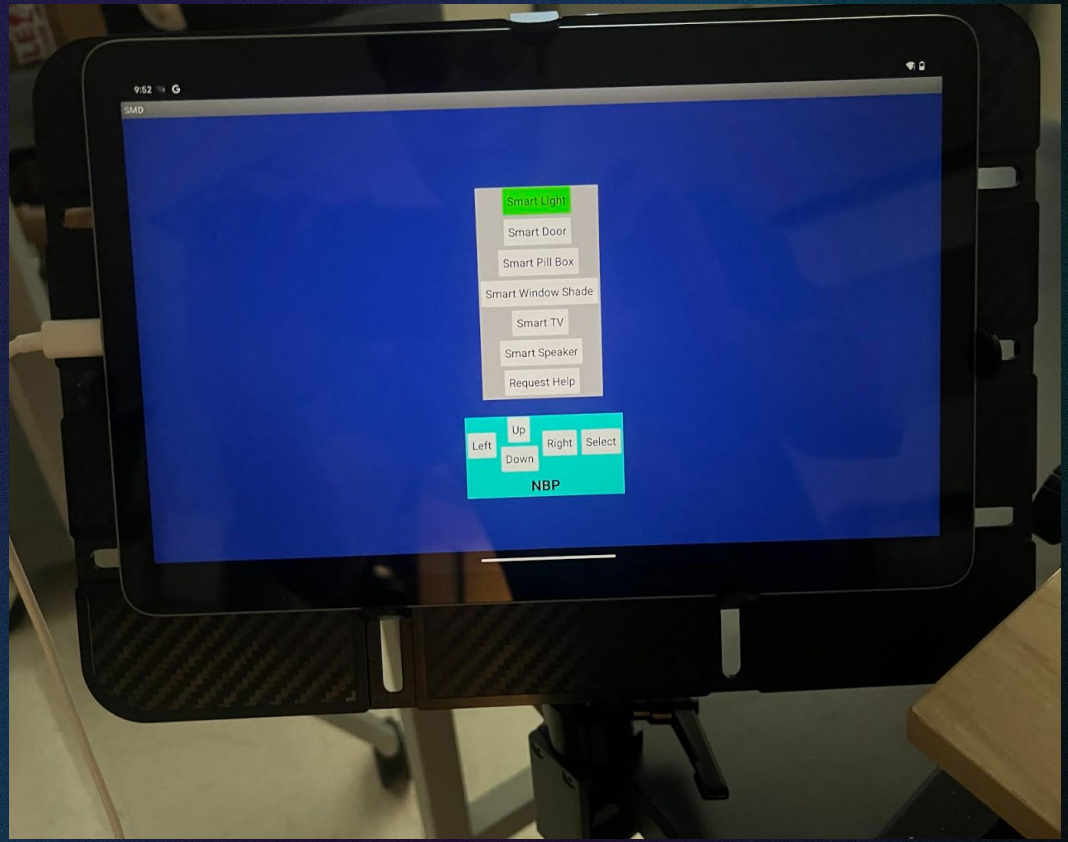
Remote Support Station

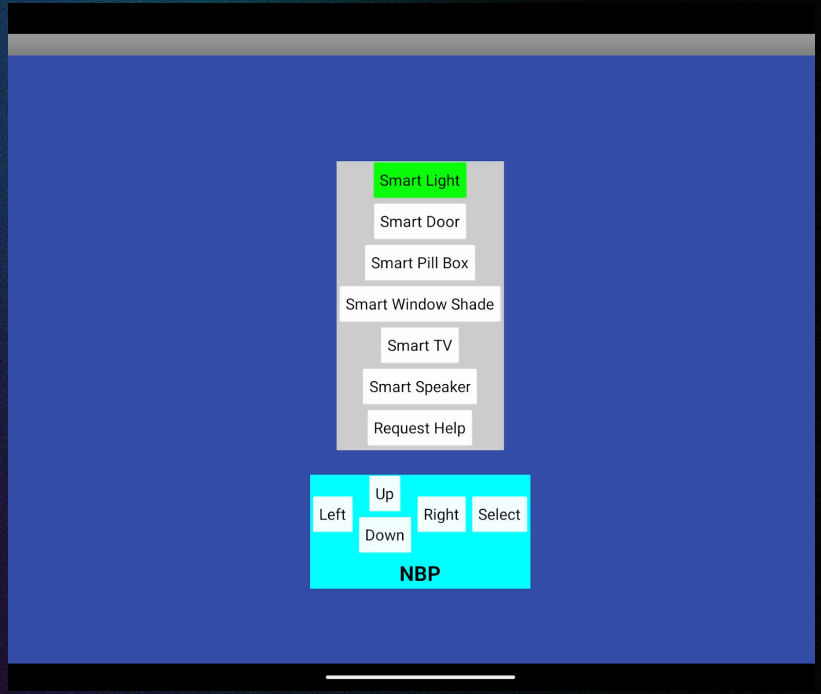


Smart Mobile Device



SMART Mobile Device

- A custom Android app that acts as the **main control panel** for our SALE users navigate it by tapping or using foot remotes
- Built using **MIT App Inventor** to quickly prototype a clean, accessible user interface and handle complex menu logic
- Connects to the SALE-R over **Bluetooth Low Energy (BLE)**, which uses low-power wireless signals to receive kick button input
- Sends commands to our smart hub using **REST API** calls, structured web requests that tell the system which action to perform



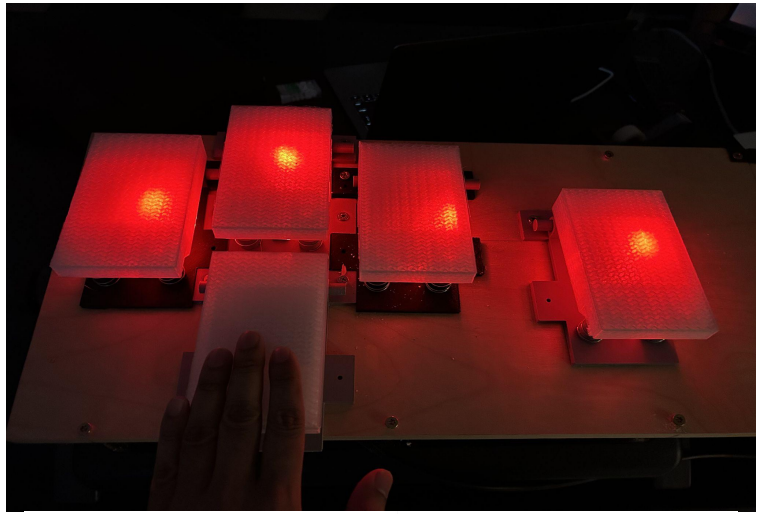
SALE-R

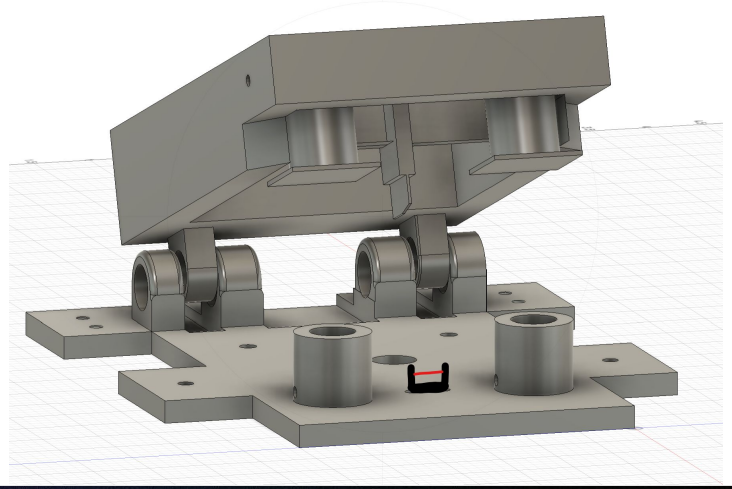
The SALE Remote is a set of 5 buttons, of which 4 are **directional** (Up, Down, Left, Right) and one is a **select** button.

Each of the individual buttons use an **optical sensor**, which gets goes low every time the button is pressed.

The Each button has an ***LED circuit***, which lights up red every time the kick button set is turned on. The operating voltage for the buttons is **12 V, 0.2 A**. Every time a button is pressed, the LEDs within it turn off.

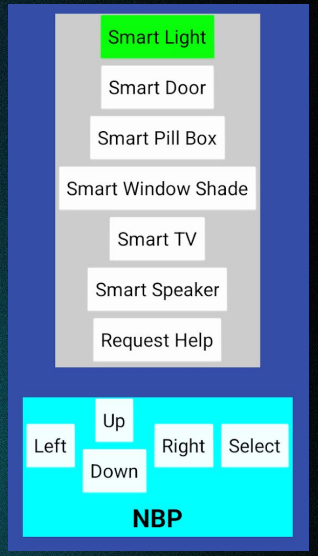
The kick buttons are supposed to be both ***assistive and rehabilitative.*** While these buttons help the user manage the whole smart home through the SMD, it also encourages them to keep their residual limb motion abilities active.

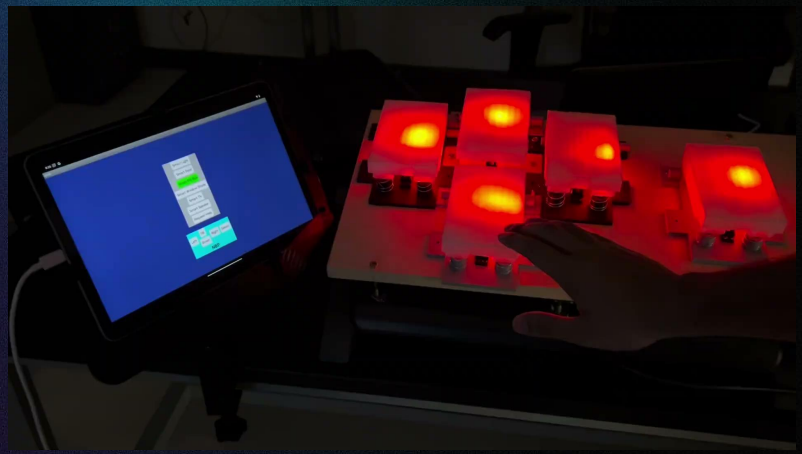




SALE-R

- The buttons on the remote communicate with the Smart Mobile Device using ***Bluetooth Low Energy***
- Every time a kick button is pressed, a message about which button is pressed in spent over the bluetooth. The communication is one way, where the kick-button behaves a peripheral device.
- In order to connect to the kick buttons, the user needs the ***UUID*** and the ***Bluetooth identifier name***.
- Every time a button is physically pressed, the bottom most window in the smart tablet app turns the UI button green.





Smart Devices

General Smart Device Structure

Overall: Based on “PicoW_HomeAssistant_Starter” by daniloc on github

- Raspberry Pi Pico W microcontroller
- Wireless communication with Home Assistant via MQTT Protocol
- Use Arduino-HA library for buttons, switches, and other device templates
- Code using C++

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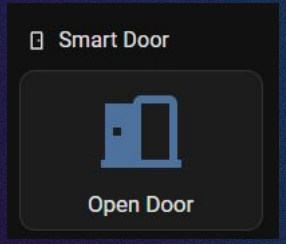
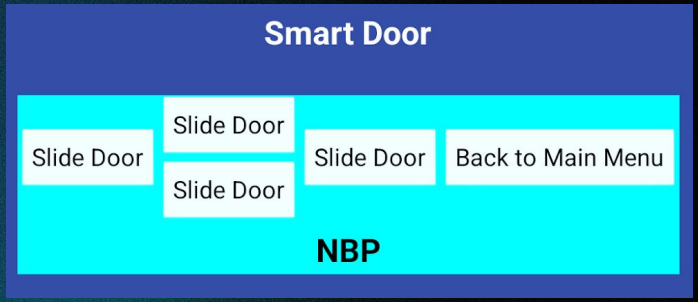
Smart Door

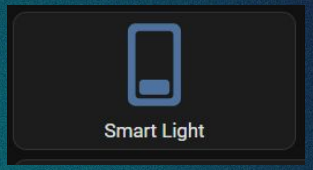




- Design
  - AutoSlide Sliding Door Opener
  - Relay cable ports for additional inputs
  - A simple circuit turns a relay on and off to open the door
- Properties
  - Collision sensing
  - Additional ports for more sensors and controllers
- Functionalities achieved
  - Original: Use switch to select open/close
  - Current: Opens and closes with one click of a button

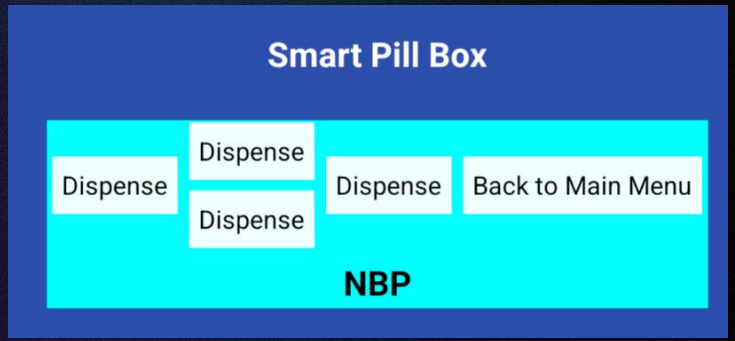
Smart Light

- Design (Technical and Mechanical)
  - 7W LED light bulb
  - Switched with transistor
  - Smart Lampshade
- Functionalities achieved
  - Remotely turned on and off



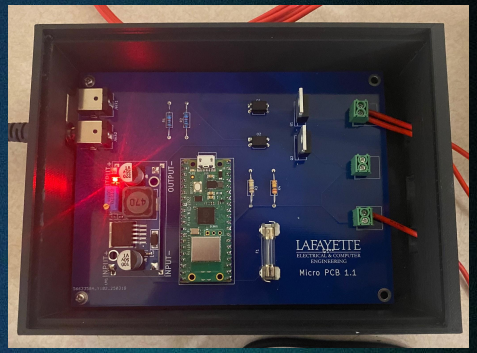
Smart Pill Box

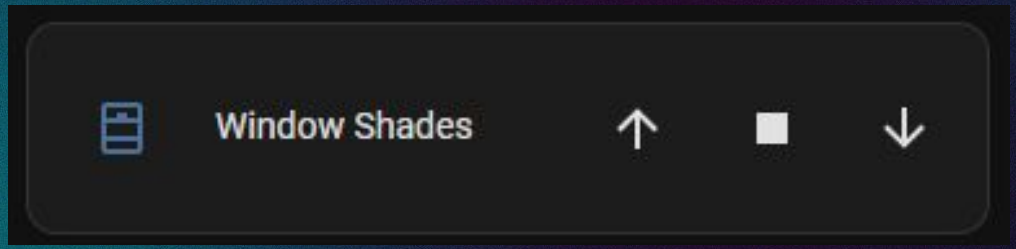
- Design
  - 7 chamber rotating spindle to dispense pills using gravity
  - 5V Stepper motor controlled with Accelstepper Arduino library
- Functionalities achieved
  - Remotely prompt pills to be dispensed
  - Remotely schedule times to dispense pills

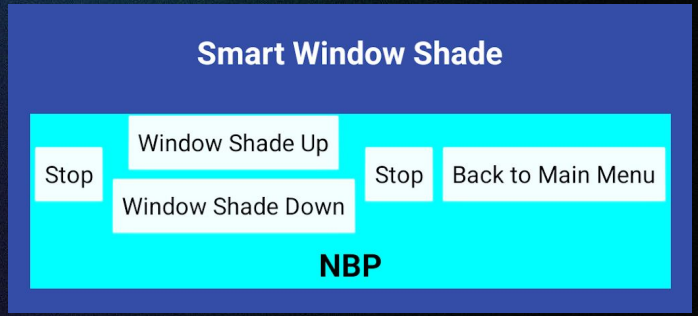


Smart Window Shades

- Design:
  - Motor.
  - Power PCB.
  - Microcontroller PCB.
- Functionalities achieved:
  - Remotely controls shades up and down in a steady motion based on user input.
  - Allows control of lighting without any significant physical requirements.

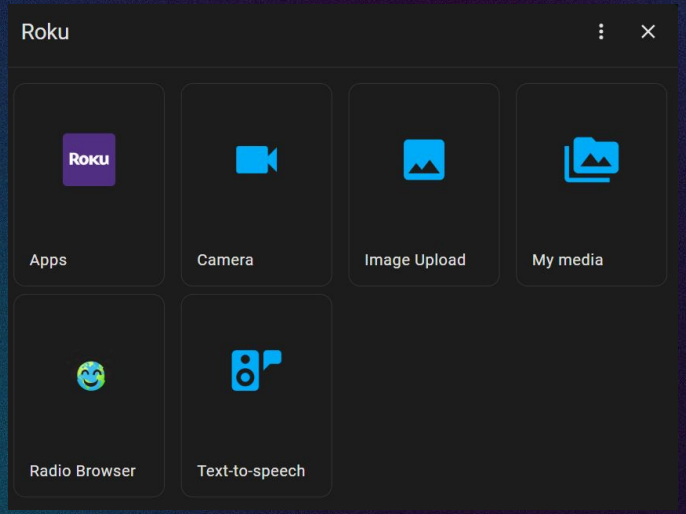


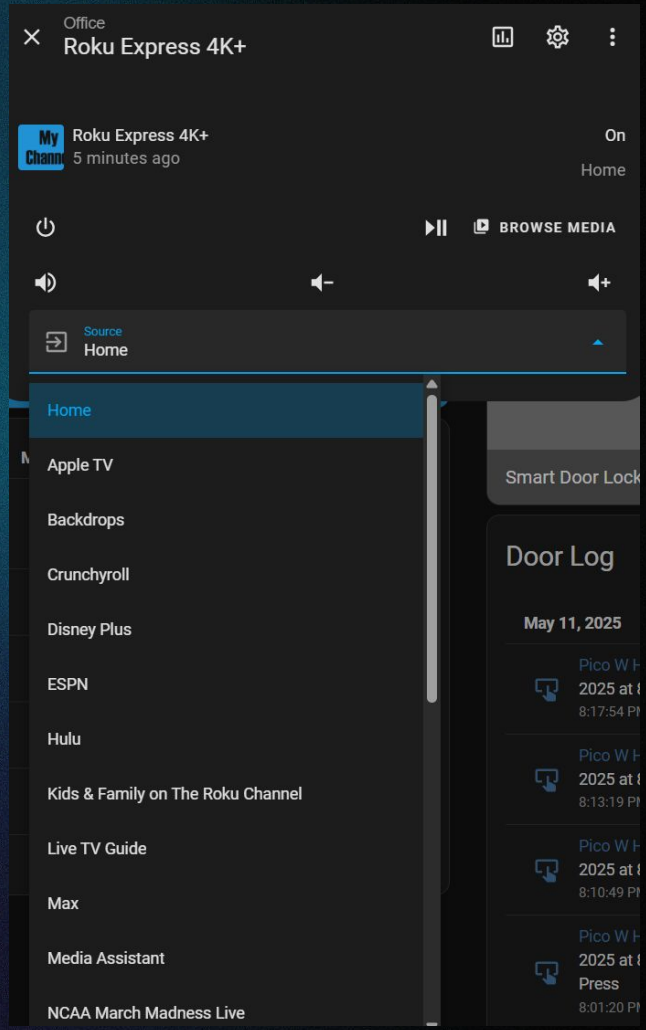




Smart TV

- Home Assistant has a Roku Integration that uses http commands
- For security reasons, the Hub cannot communicate directly to the Roku
- Pico W connects to both the Hub and the Roku, and serves as a courier of http requests/responses





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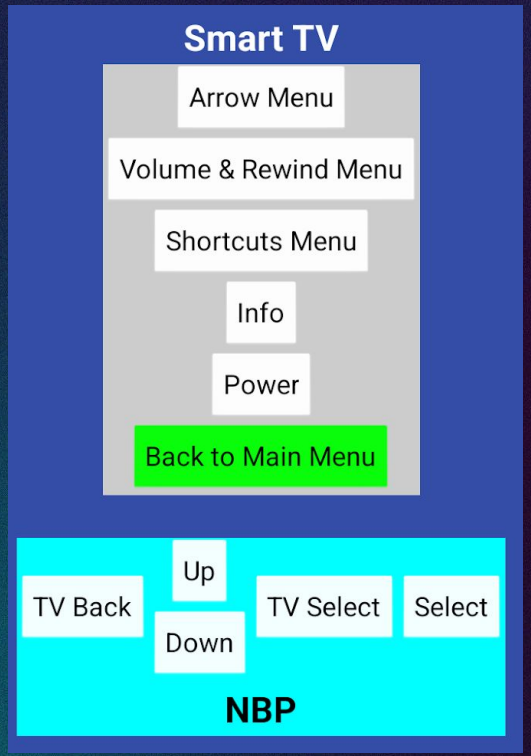
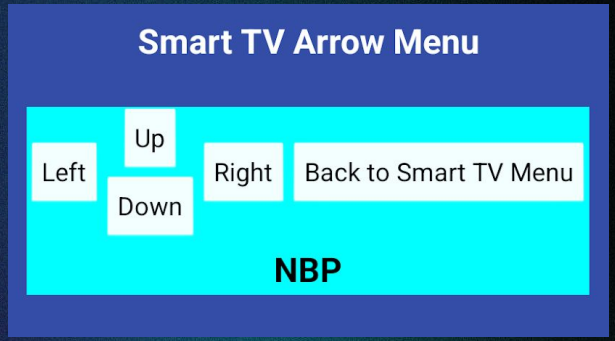
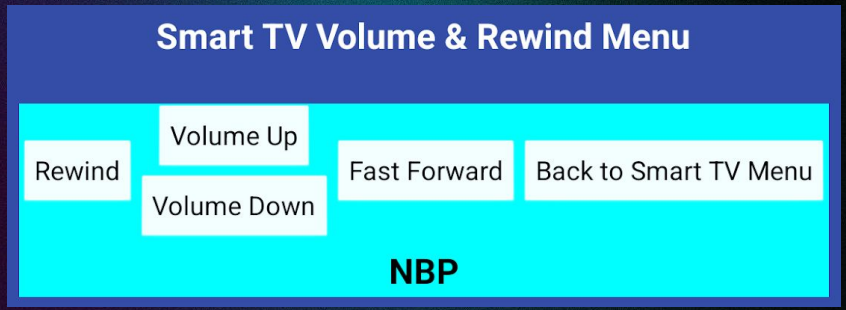
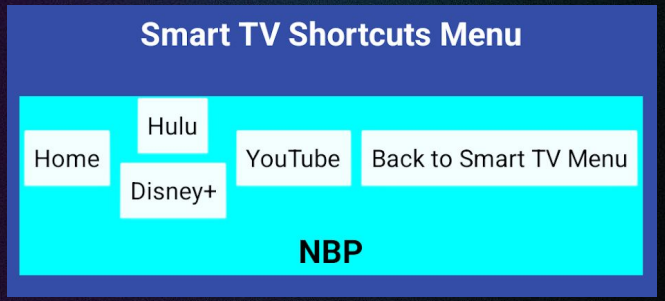
Smart TV



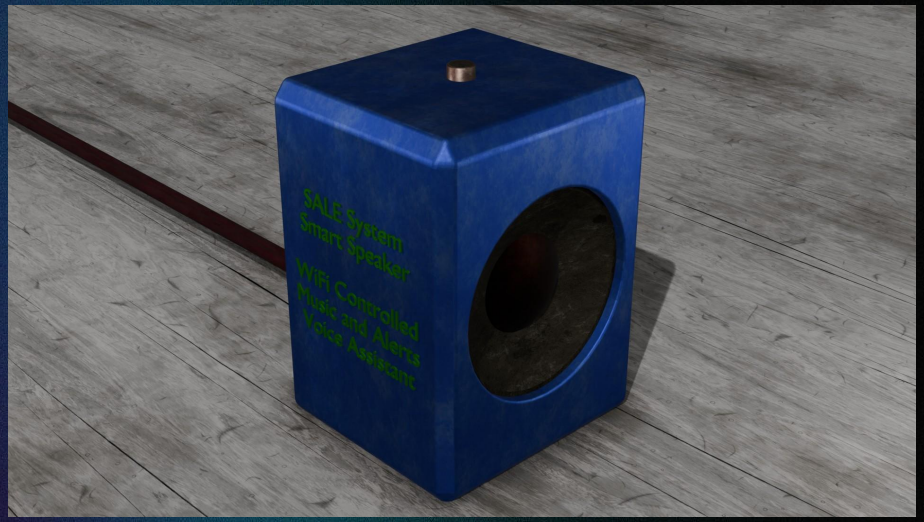


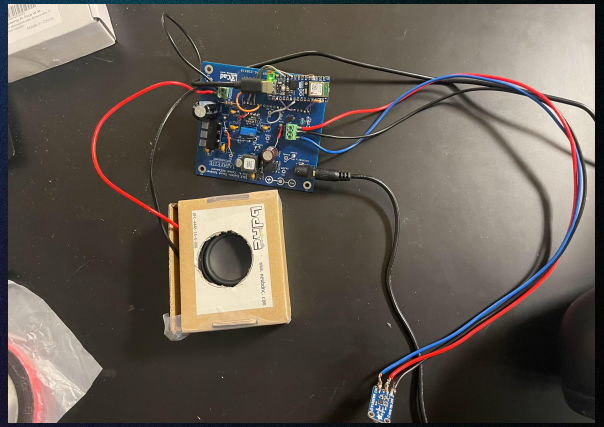




Smart Speaker

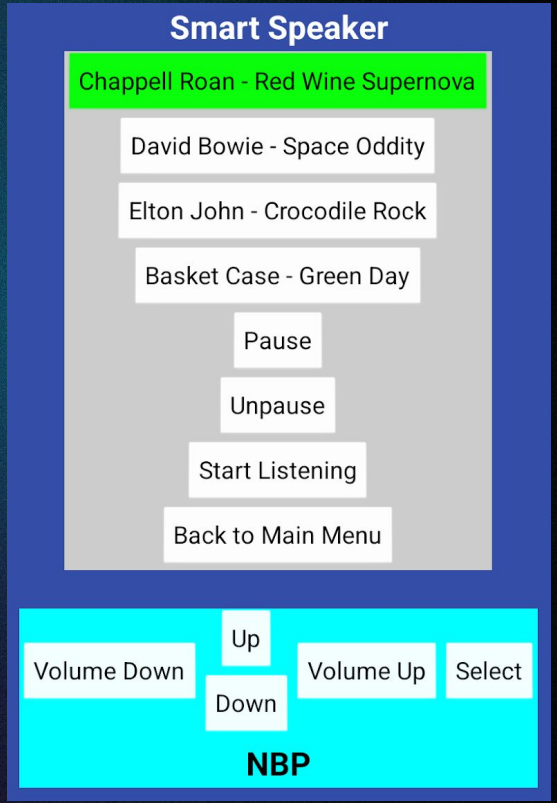
- Custom PCB that integrates power conversion, DAC, a microcontroller (with ADC), and audio amplifier,
- Exchanged Pi Pico with Arduino Nano ESP32, to allow for use of existing Voice Assistant libraries (via ESPHome)
- Wrote custom drivers to enable use of ESP32 ADC and convert I2S audio into SPI.
    - Code will be upstreamed
- Can stream audio (books and music)
- Provides a voice assistant satellite





Smart Speaker

- Provides a list of sound files to play
  - Currently limited to pre-selected files
  - Straightforward to interface with Spotify, Audible, etc
- Allows volume changes, pausing and unpausing
- Trigger the voice assistant manually
  - Always-on wake word detection also possible
- Custom wake word (Hey SALE-E) to be implemented
- Provides entertainment to user



Smart Security/Door Camera

Design Overview

- Arduino with ArduCAM Mini 5MP Plus captures JPEG frames and motion detection
- UART used to transmit frames to Raspberry Pi Pico W at 57200 baud, max rate before breakdown
- Pico W parses byte stream for valid JPEG headers/footers and encodes image for MQTT publishing

Core Properties

- Event-driven: notification triggered by PIR motion sensor (published as MOTION:1 or 0)
- Real-time image capture at 10 fps to continuously stream feed to remote device
- Low bandwidth: JPEGs base64-encoded and compressed before publish

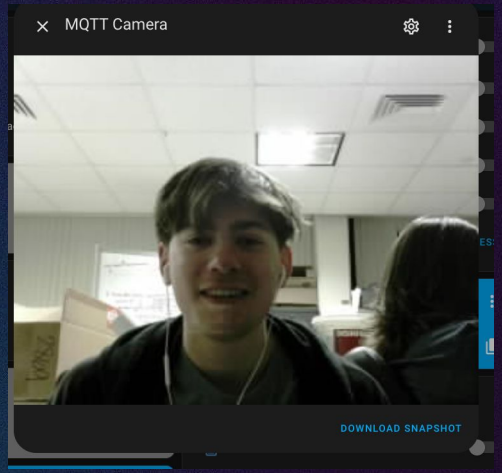
Functionalities Achieved

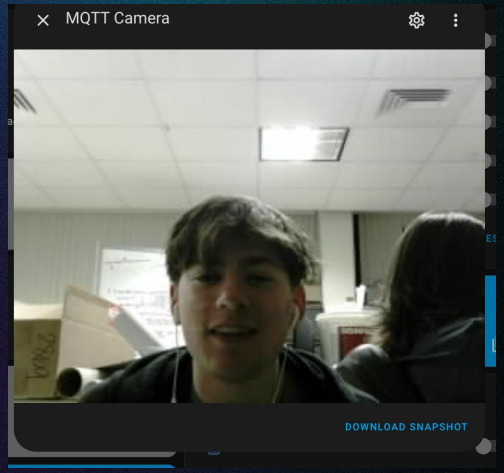
- Live camera integration with Home Assistant via MQTT (camera/frames/latest)
- Motion detection fully integrated with HA’s notification system
- Streamlined UART frame parser ensures reliable multi-frame capture

Smart Security/Door Camera

User Interface (In Progress)

- Tablet-based interface built using Scratch
- Tablet pulls latest image via HTTP (http://<HA_IP>:8123/api/camera_proxy/<camera entity_id>)
- Motion alert prompts user to open the feed viewer and inspect recent activity
- Tablet integration is nearly complete and final UI testing is underway





Testing and Budget

System Integration

Connecting to the HUB

- HUB generates a private Wifi Network. Each individual device's microcontroller (Pi Pico W) connects to the HUB network by adding credentials to the "Credentials.h" file in the PicoW_HomeAssistant_Starter repo (HUB IP, HUB network password, MQTT password, etc.).
- The Arduino Home Assistant starter pack helps declare the number of buttons/switches that each individual device has.
- The device connection is confirmed when the device shows up on the Home Assistant UI.
- On the HUB logs, a successful device connection can be converted with a Pairwise Key Handshake Completed "RSN Handshake Successful".
- Once connected to the HUB, devices have the capacity to automatically connect to the HUB network when plugged in.

System Integration

Operation Through Home Assistant

- After each individual was connected to the HUB, the devices were tested by operating with the buttons/switches that appeared on the Home Assistant website.

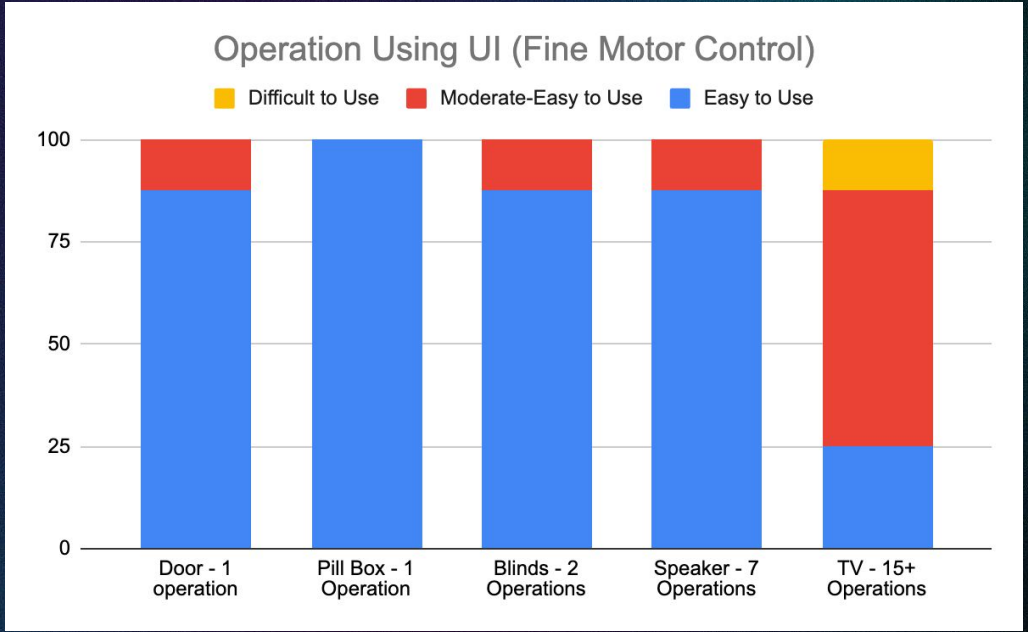
Operation Through the Smart Mobile Device

- The Smart Mobile device also connects to the private Wifi Network of the HUB (test123), using a user ID and password
- The Smart Mobile Device app makes HTTP calls to operate individual buttons/switches associated with different smart devices. After ensuring that smart devices were working properly with the Home Assistant website, it was ensured that they were working through the Smart Mobile Device UI.

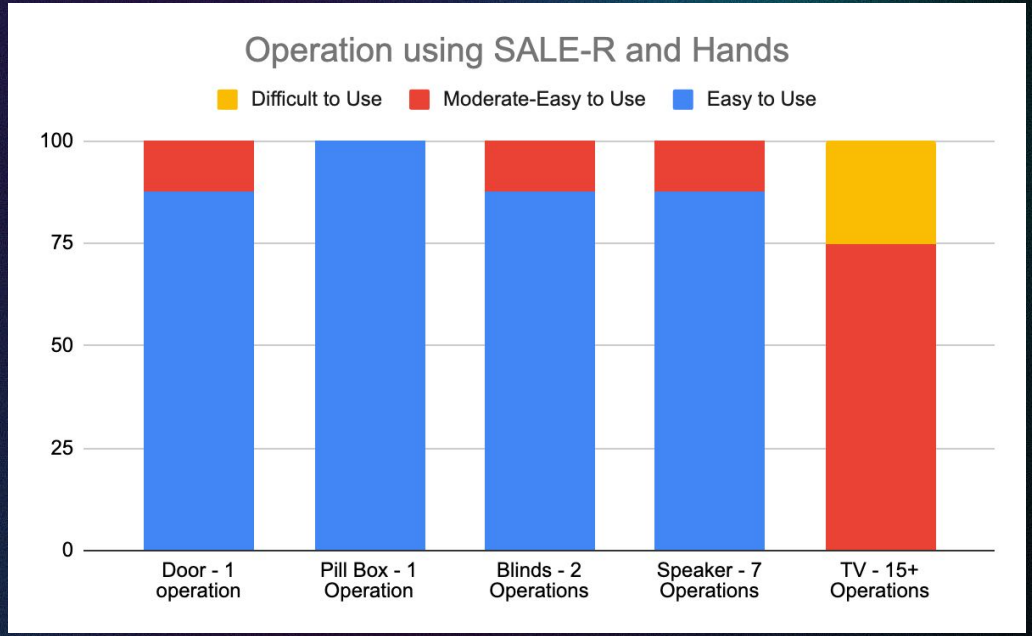
Operation Through The Kick Buttons

- In the last step of integration, the SALE-R was paired with the SMART mobile device using bluetooth low energy.
- The BLE-messages were used to control the Smart Tablet UI, using a serial-peripheral transfer of commands to the Central (Tablet)

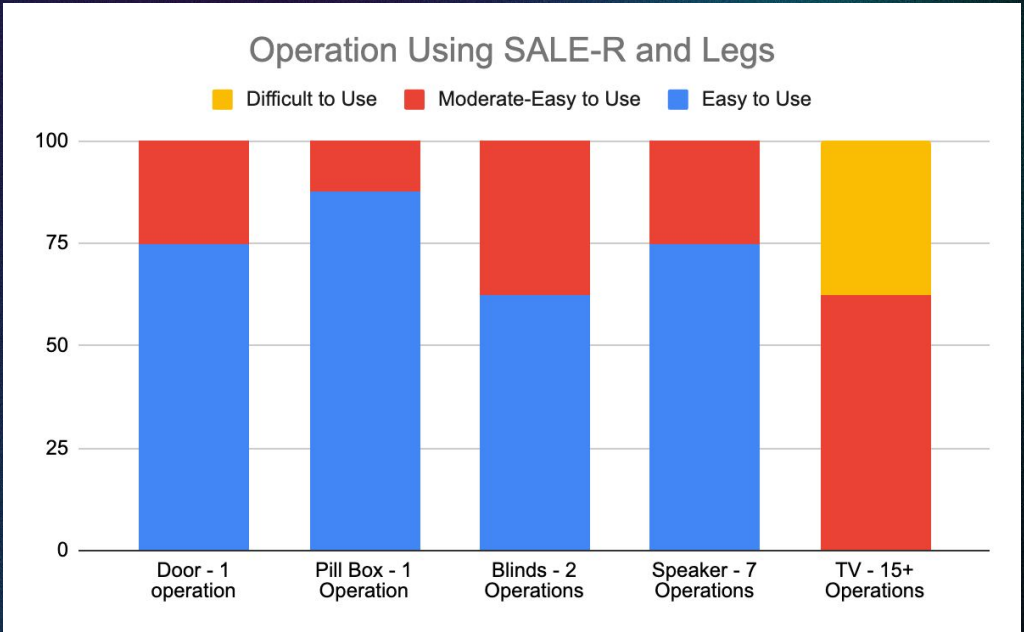
Results From Human Test - UI Operation



Results From Human Test - Hand Control Using SALE-R



Results From Human Test - Leg Control Using SALE-R



Budget

Proposed

Device/Component	Estimated Cost
Smart Hub	$495.37
Smart Mobile Device (SMD)	$451.81
Kick Buttons	$614.69
Remote Support Station (RSS)	$0.00
Smart Light	$375.07
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	$3,939.00
10% Additional Buffer - shipping and redesigns	$393.90
Total	$4,332.90

Underrun:
$1,487.50

Implemented

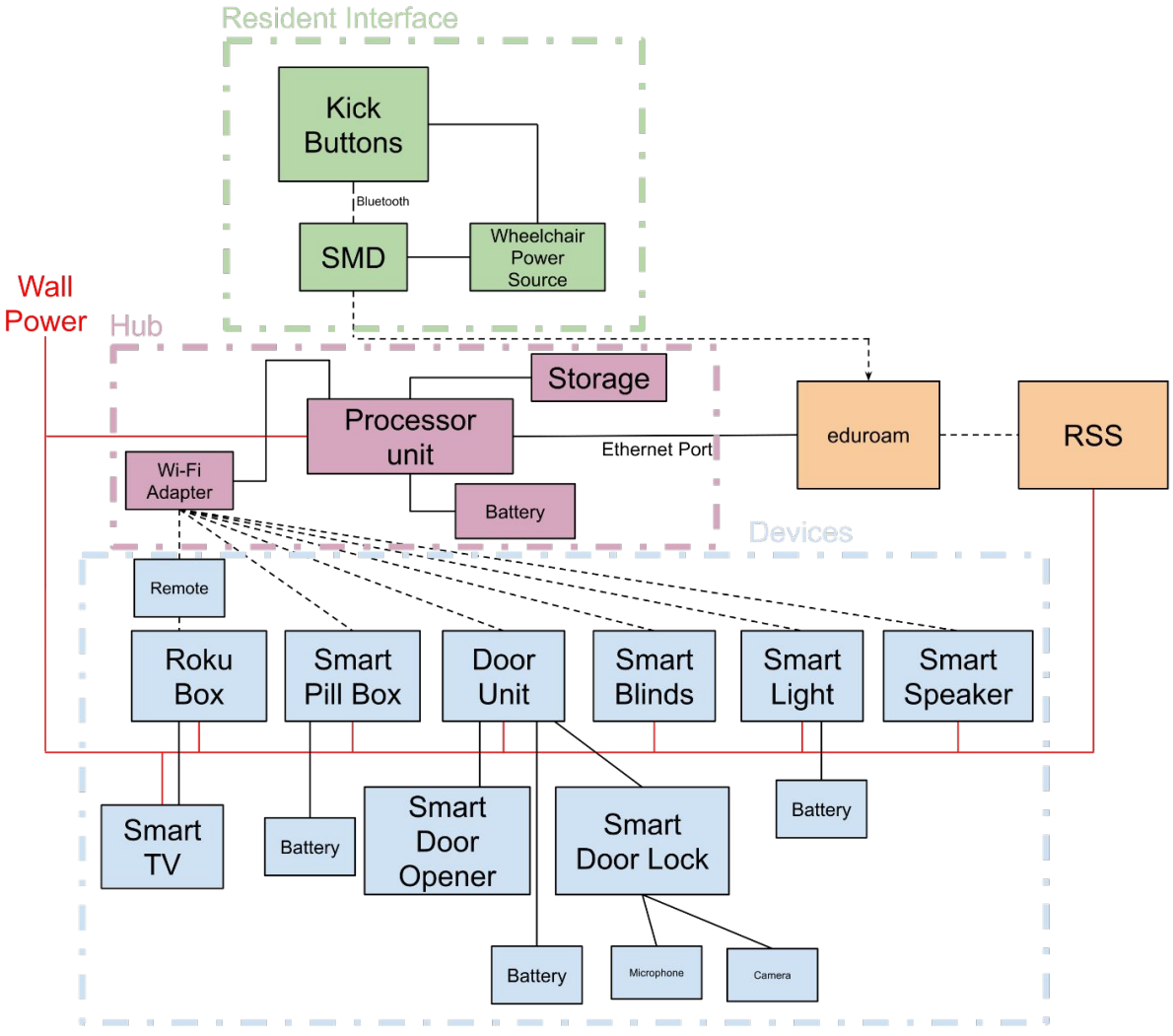
Device/Component	Estimated Cost
Smart Hub	$185.37
Smart Mobile Device (SMD)	$481.80
Kick Buttons	$244.73
Remote Support Station (RSS)	$0.00
Smart Light	$128.00
Smart Door Lock	$272.41
Smart Door Opener	$713.24
Smart Pill Box	$121.72
Smart Speaker	$239.93
Smart TV	$51.23
Smart Window Shade	$345.15
Sub-total	$2,783.58
Shared costs/components, shipping, etc	$61.92
Total	$2,845.50

THANK YOU

Backup Slides

SALE

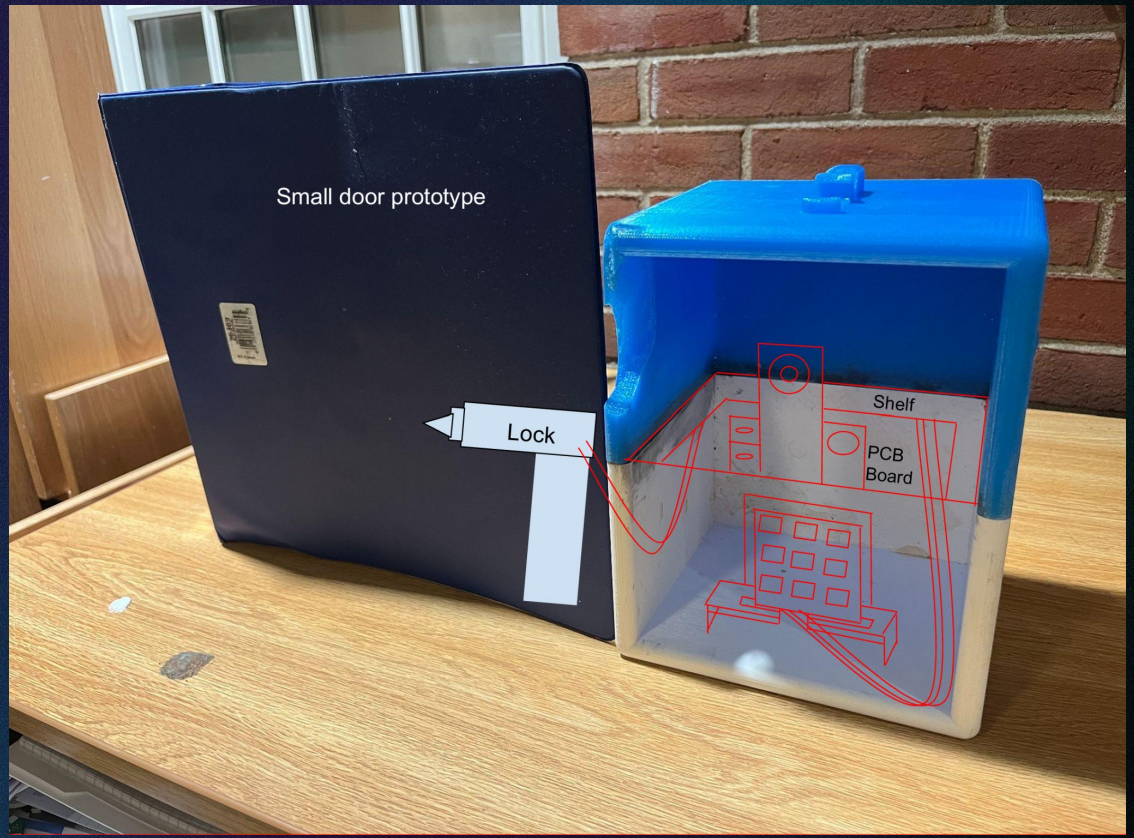
Concept



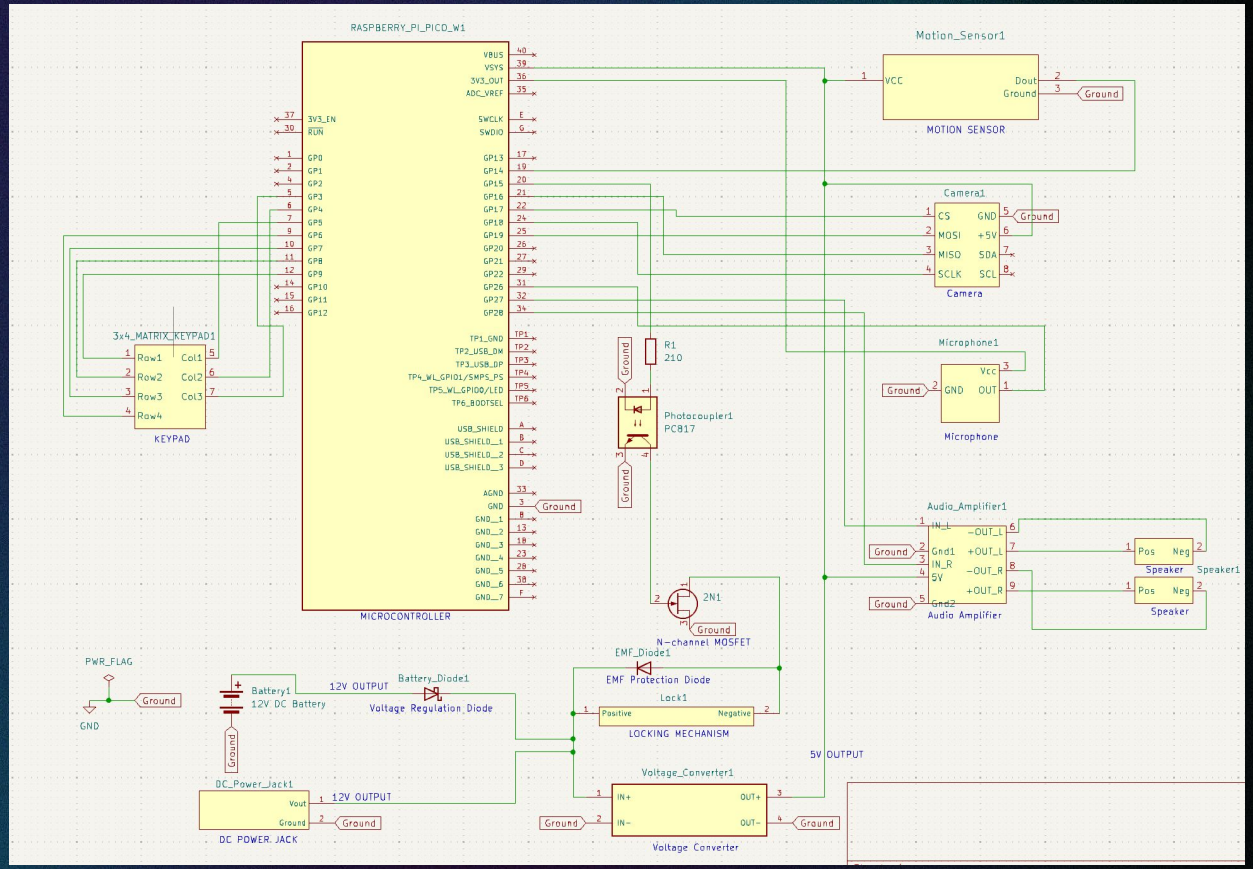
Why we chose our Smart Devices

- **Door Unit:** To enable our resident enable answer visitors at the door, and enter and exit the space without external assistance
- **Foot remote/kick buttons:** To enable residents with partially functional legs control the devices. Other methods like eye tracking, IMU sensors, and BCI might result in fatigue when used over prolonged time.
- **Smart pill box:** To enable the resident to manage their daily medications
- **Smart lights and smart blinds:** To enable independent living, especially for people with dysfunctional hands
- **Smart TV and Smart Speaker:** To have entertainment features

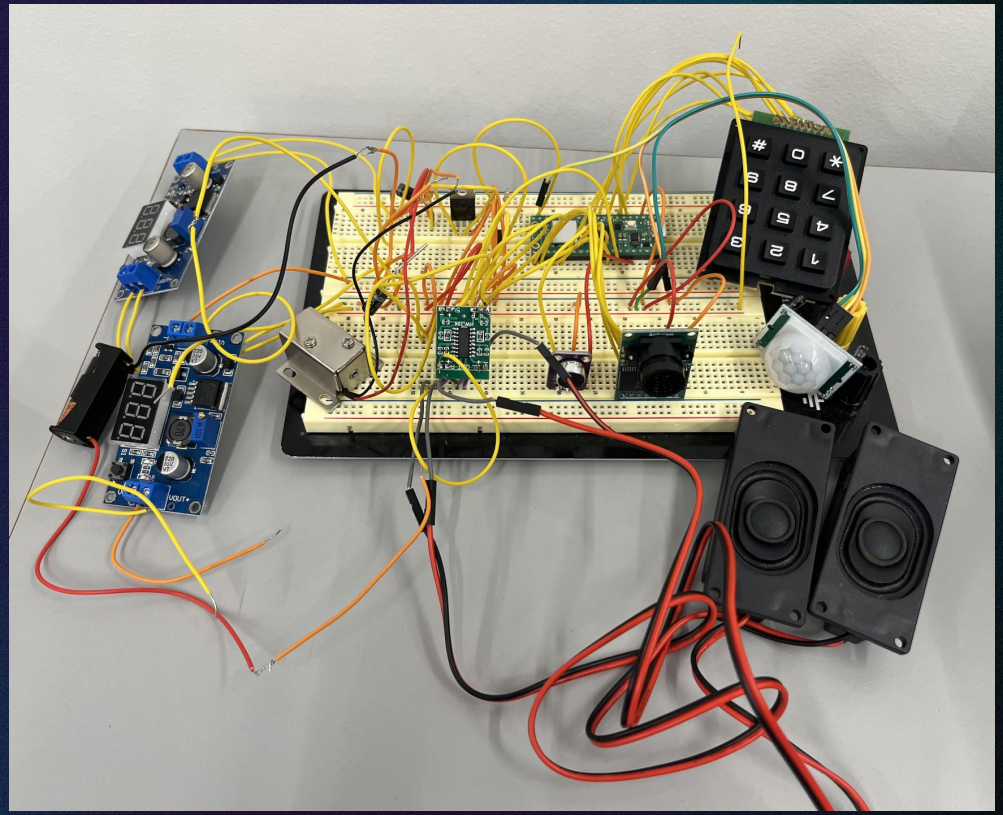
Smart Door Lock Initial Conception



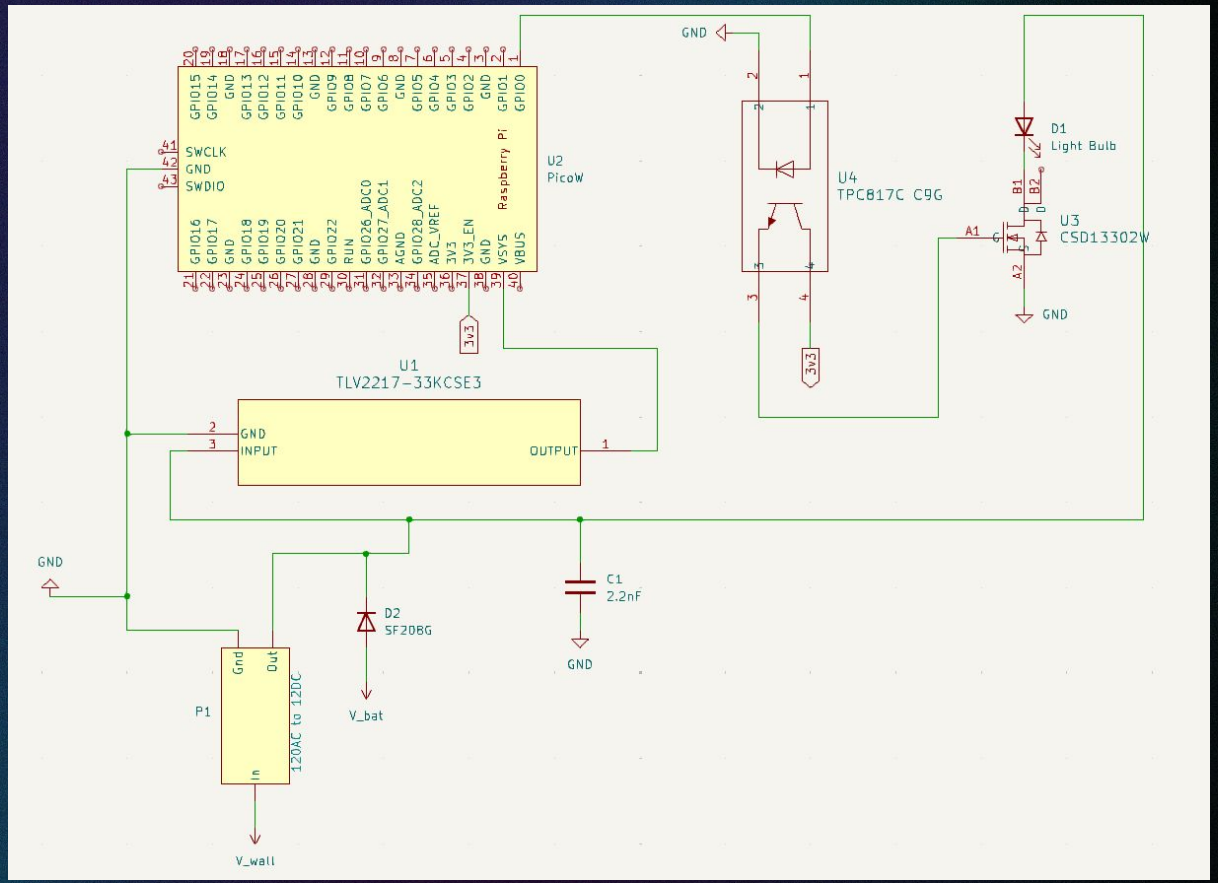
Smart Door Lock Schematic



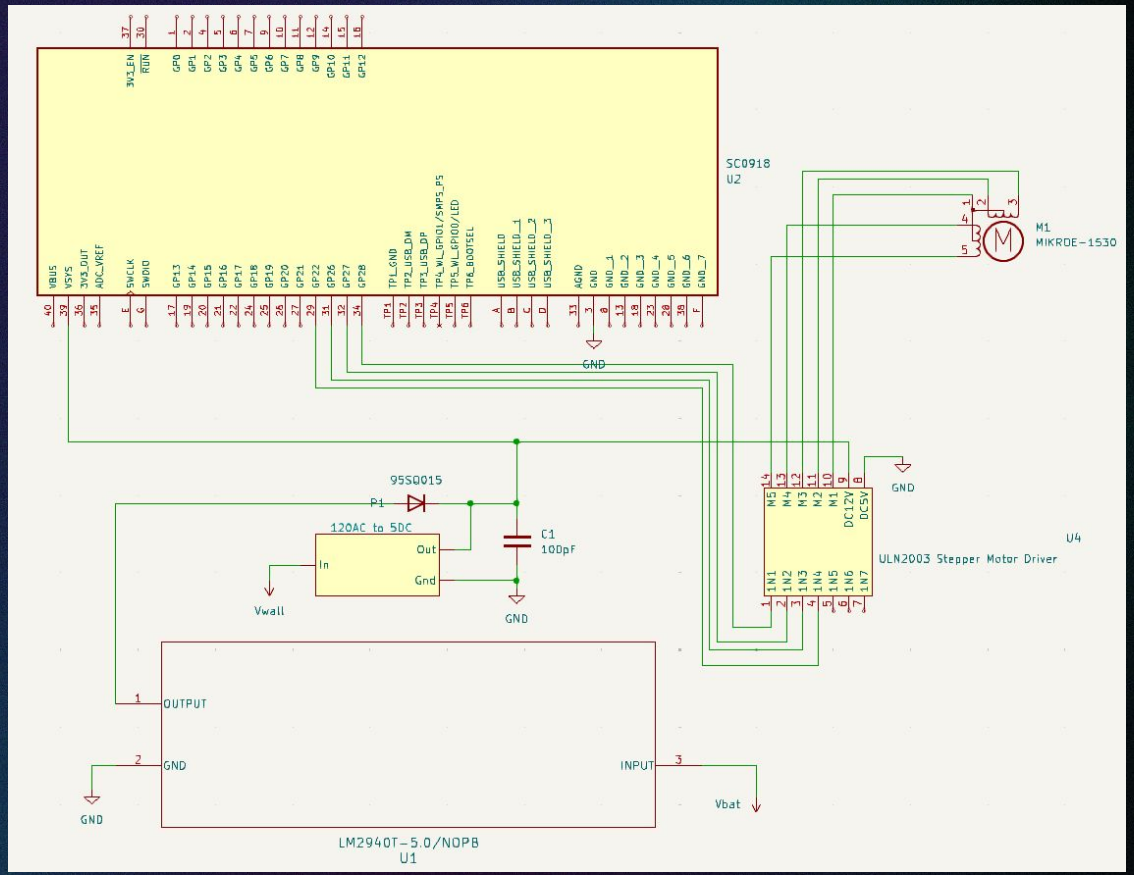
Smart Door Lock First Implementation



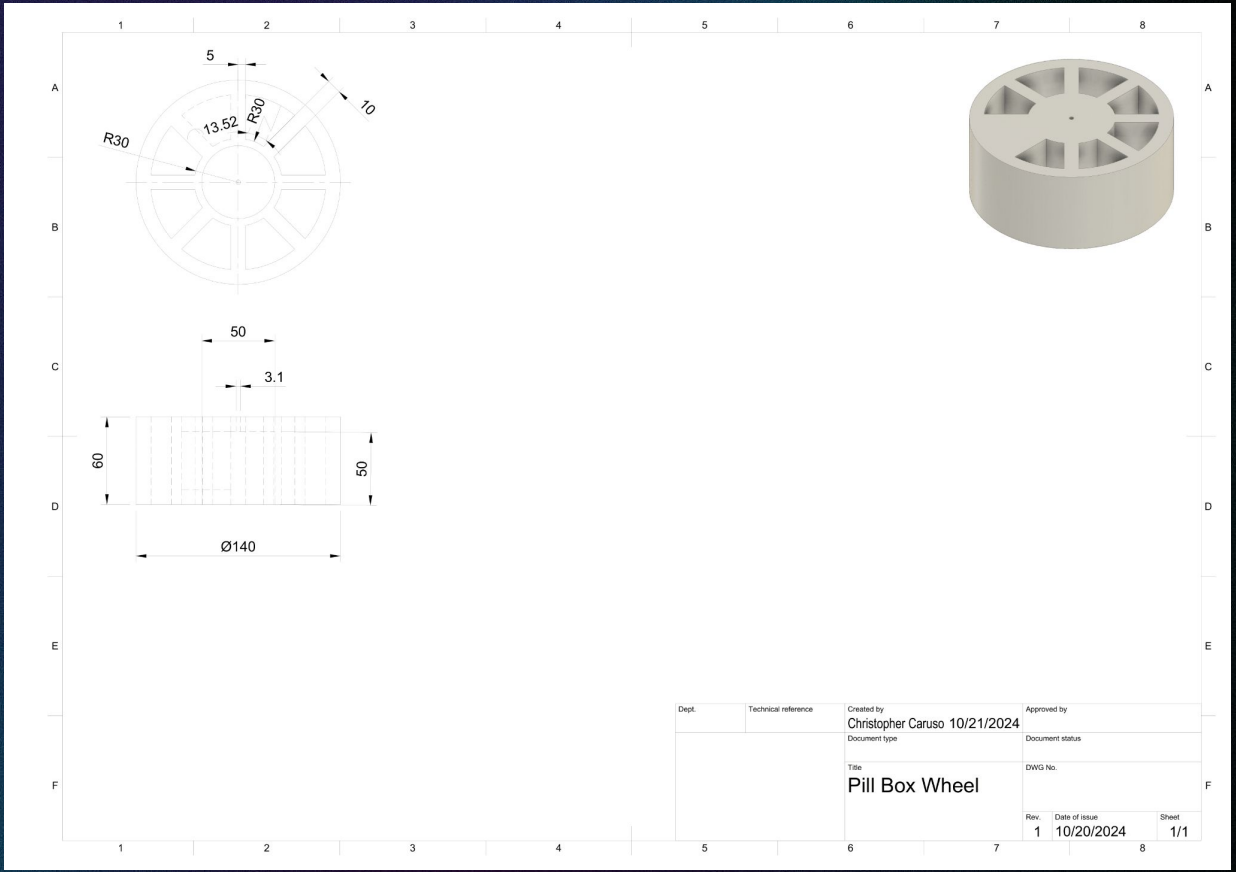
Smart Light Schematic



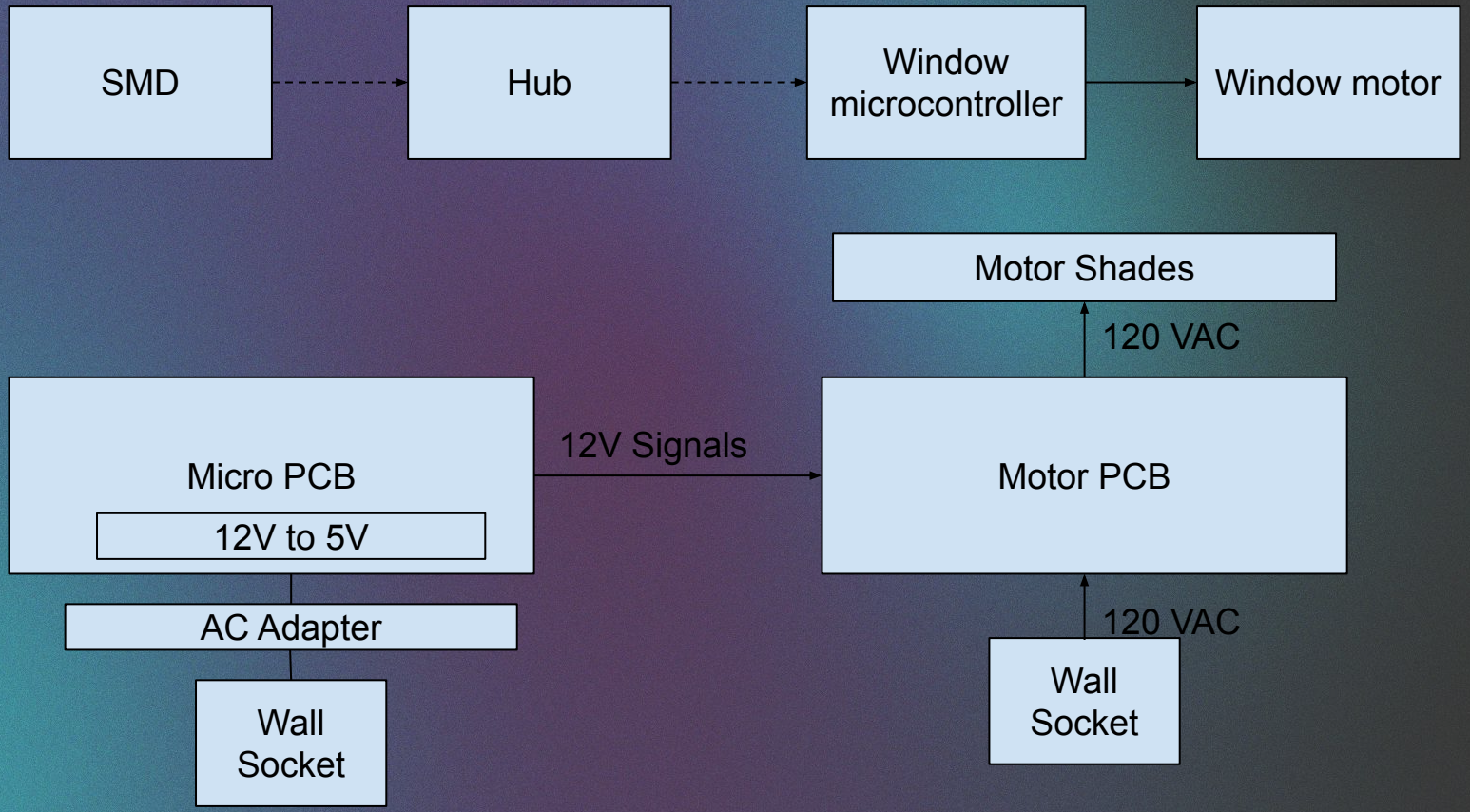
Smart Pill Box Schematic



Smart Pill Box CAD



Smart Window Shade



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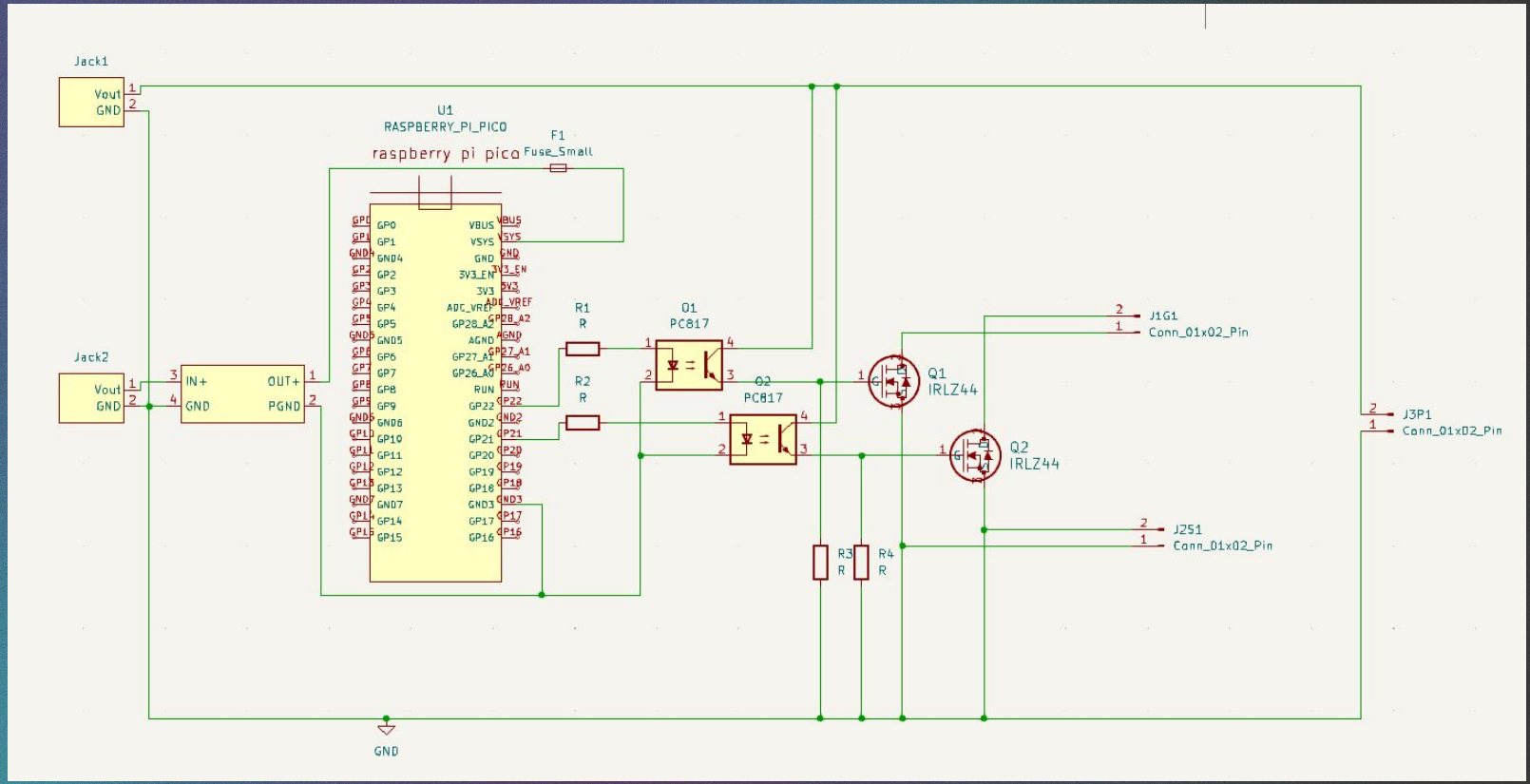
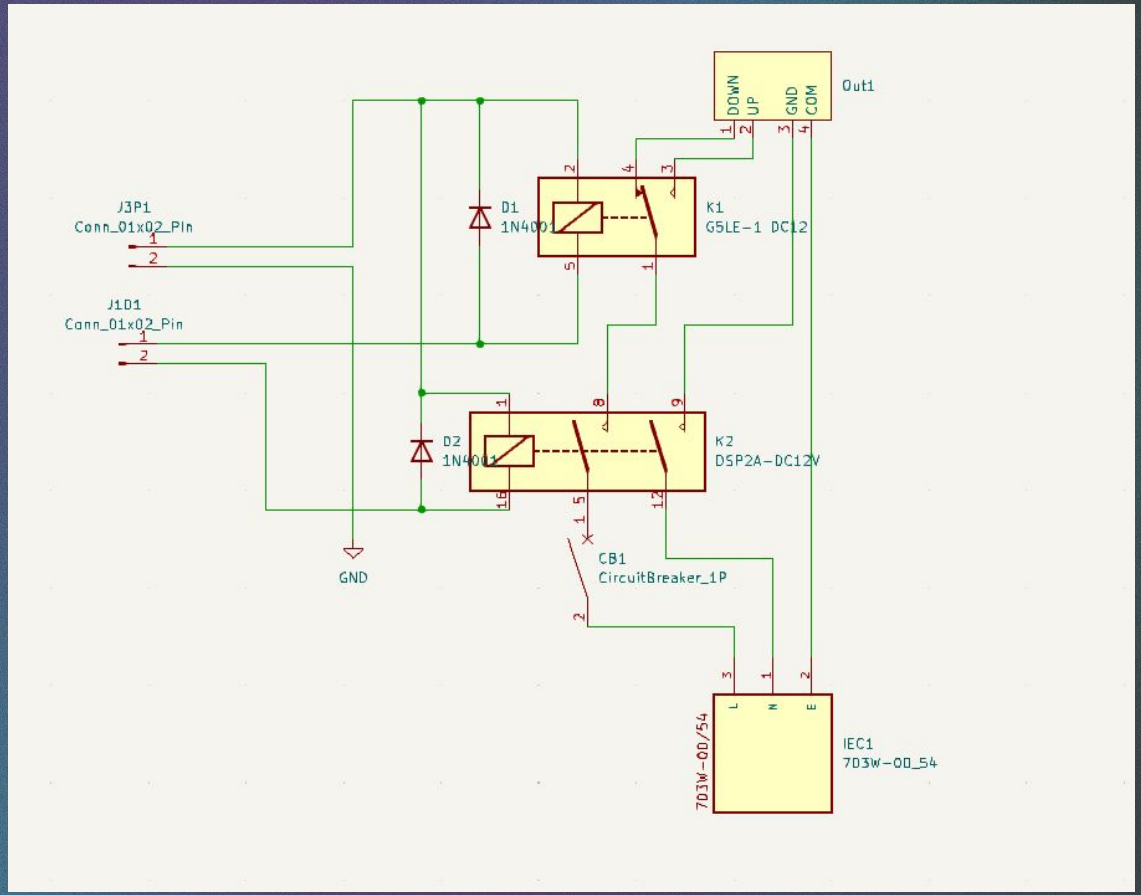
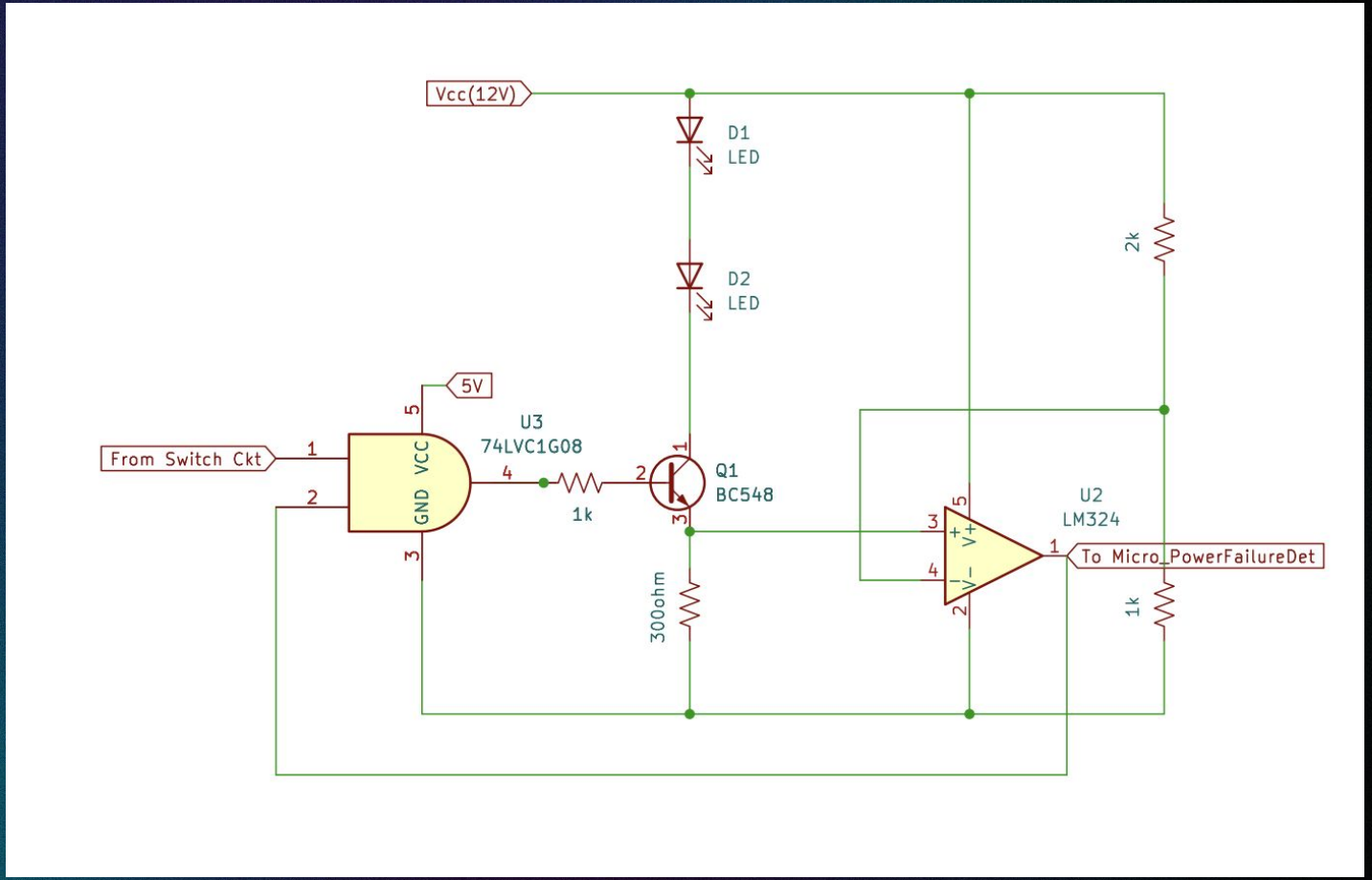


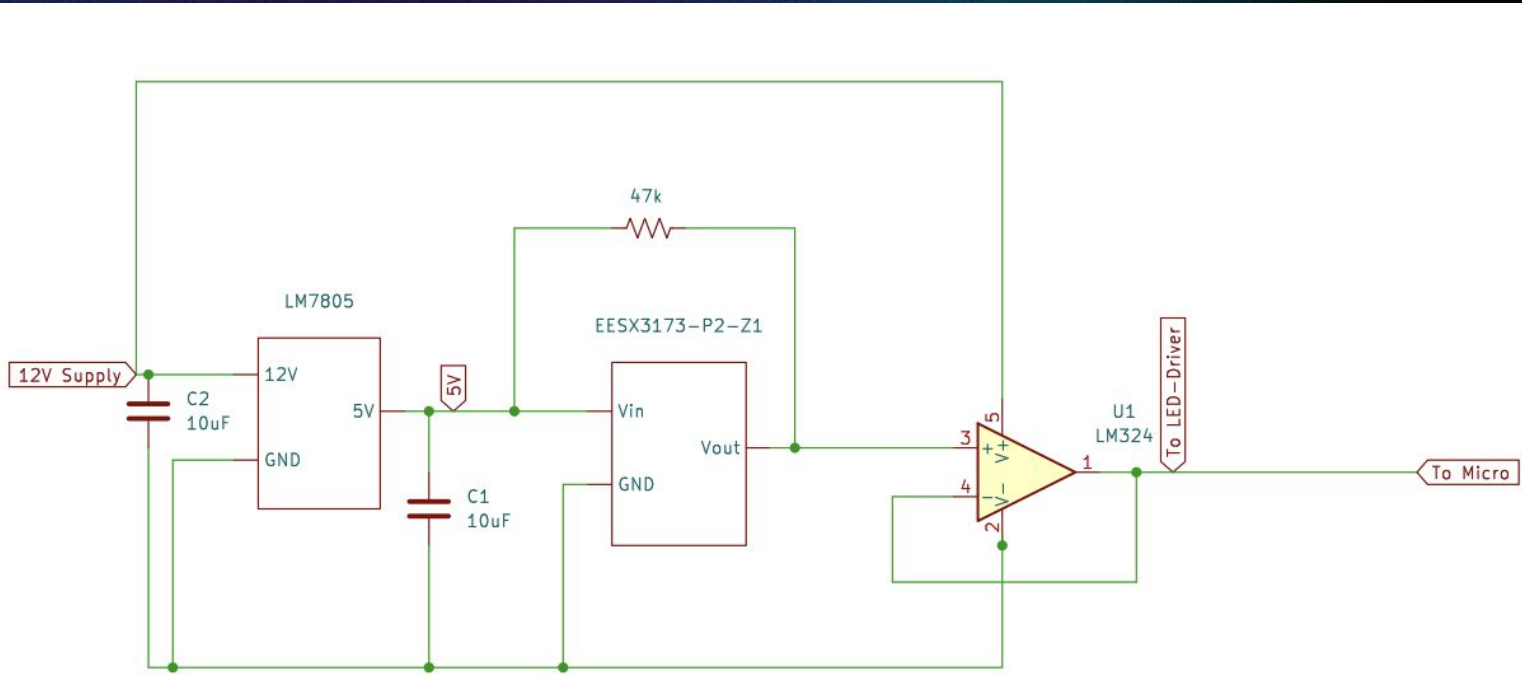
Smart Window Shade



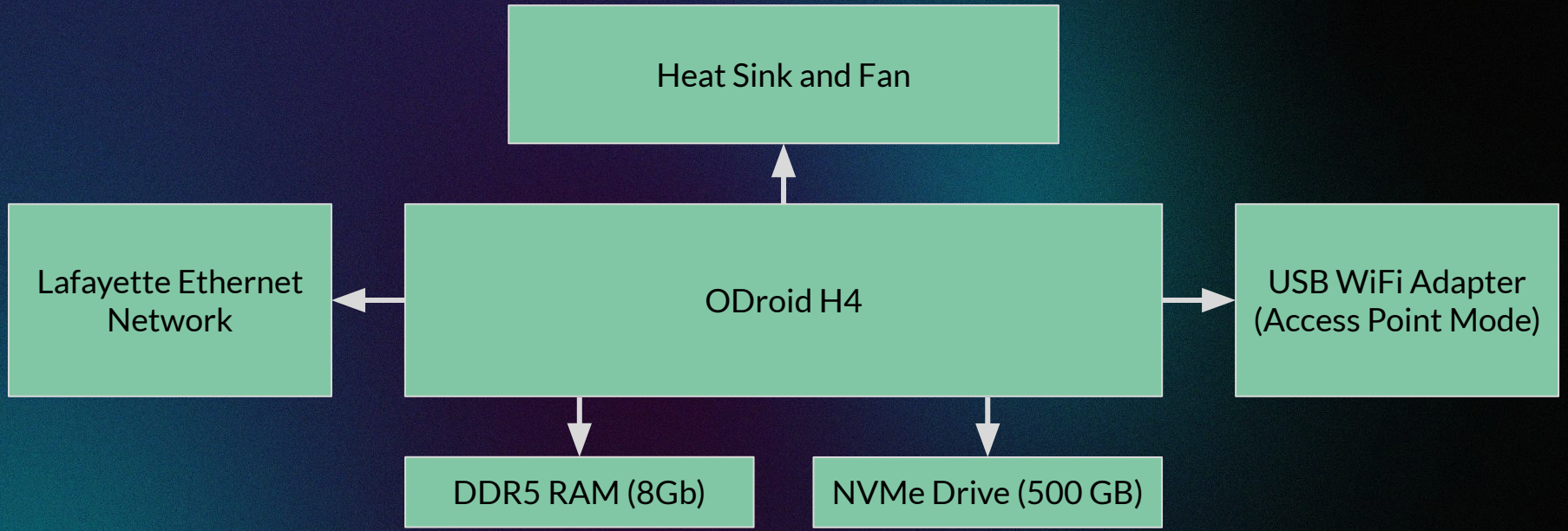
Smart Kick Buttons



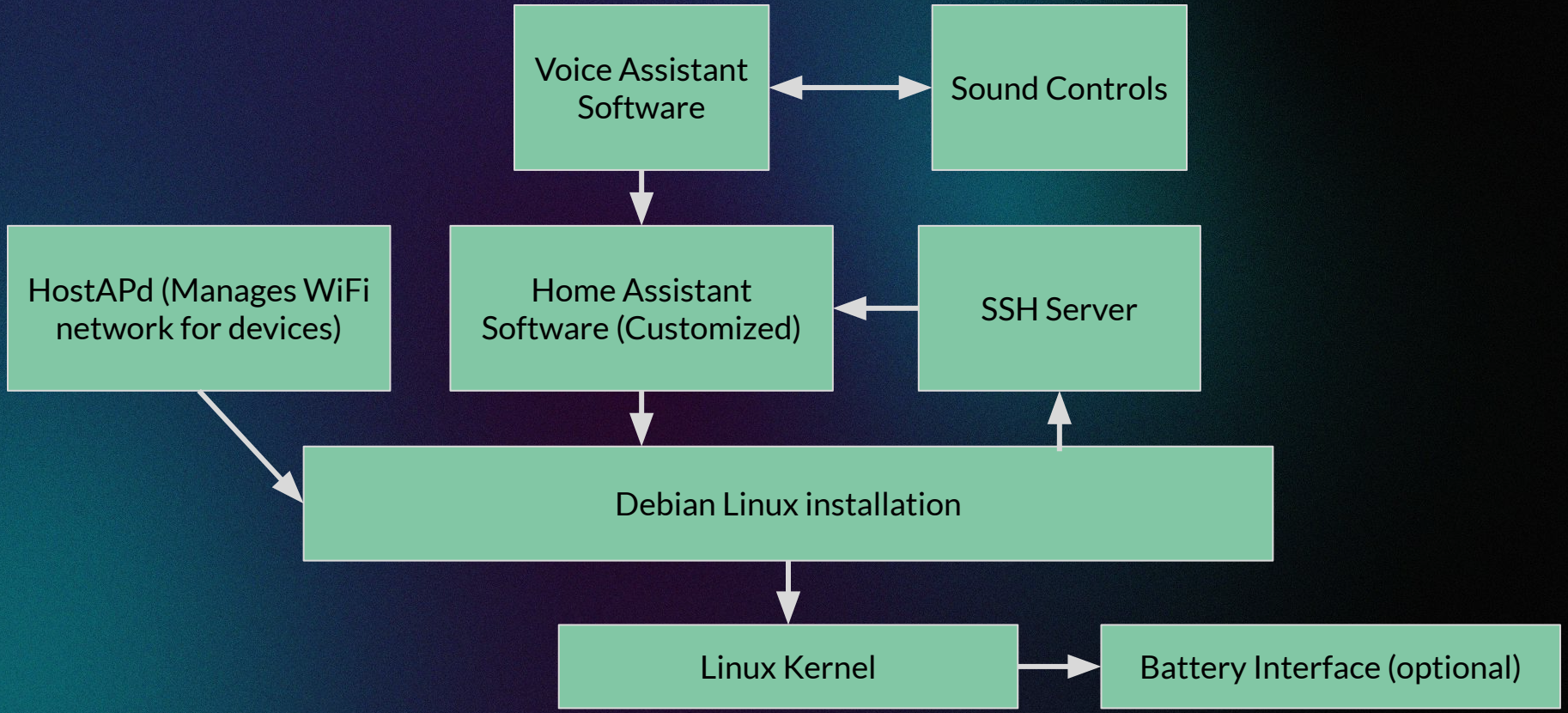
Smart Kick Buttons



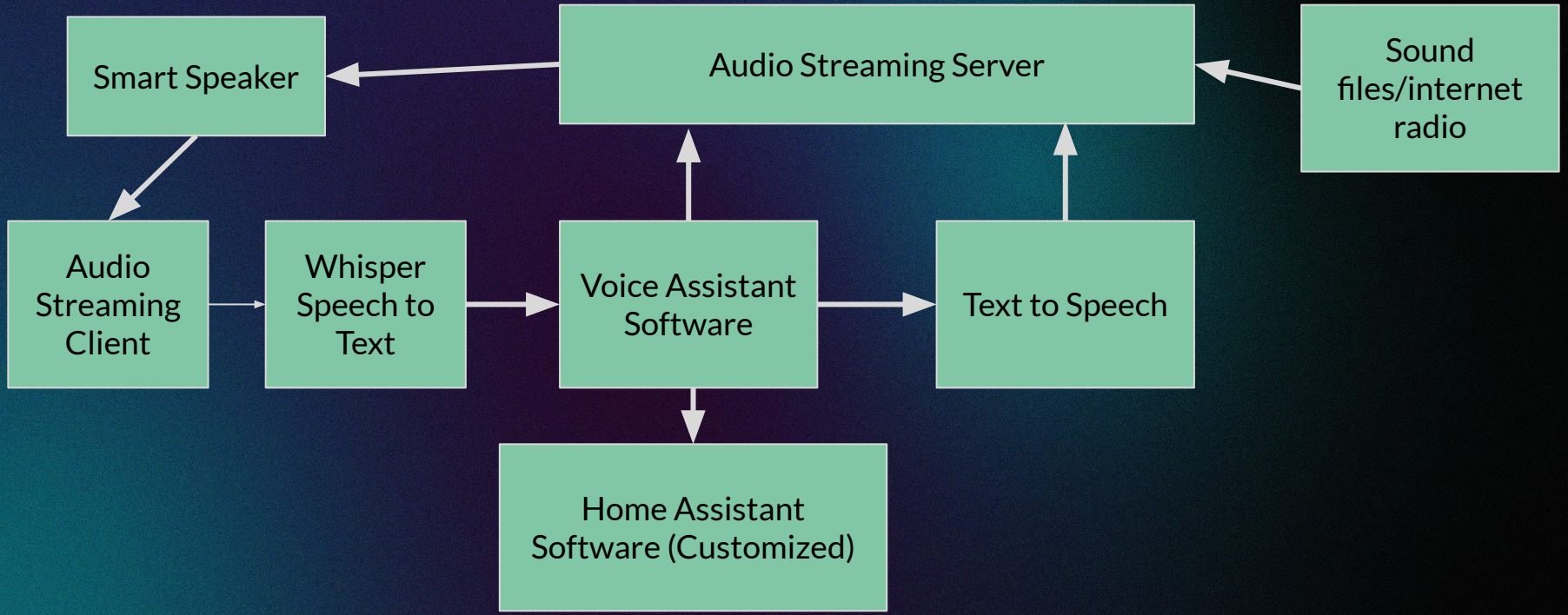
Hub Computer Module



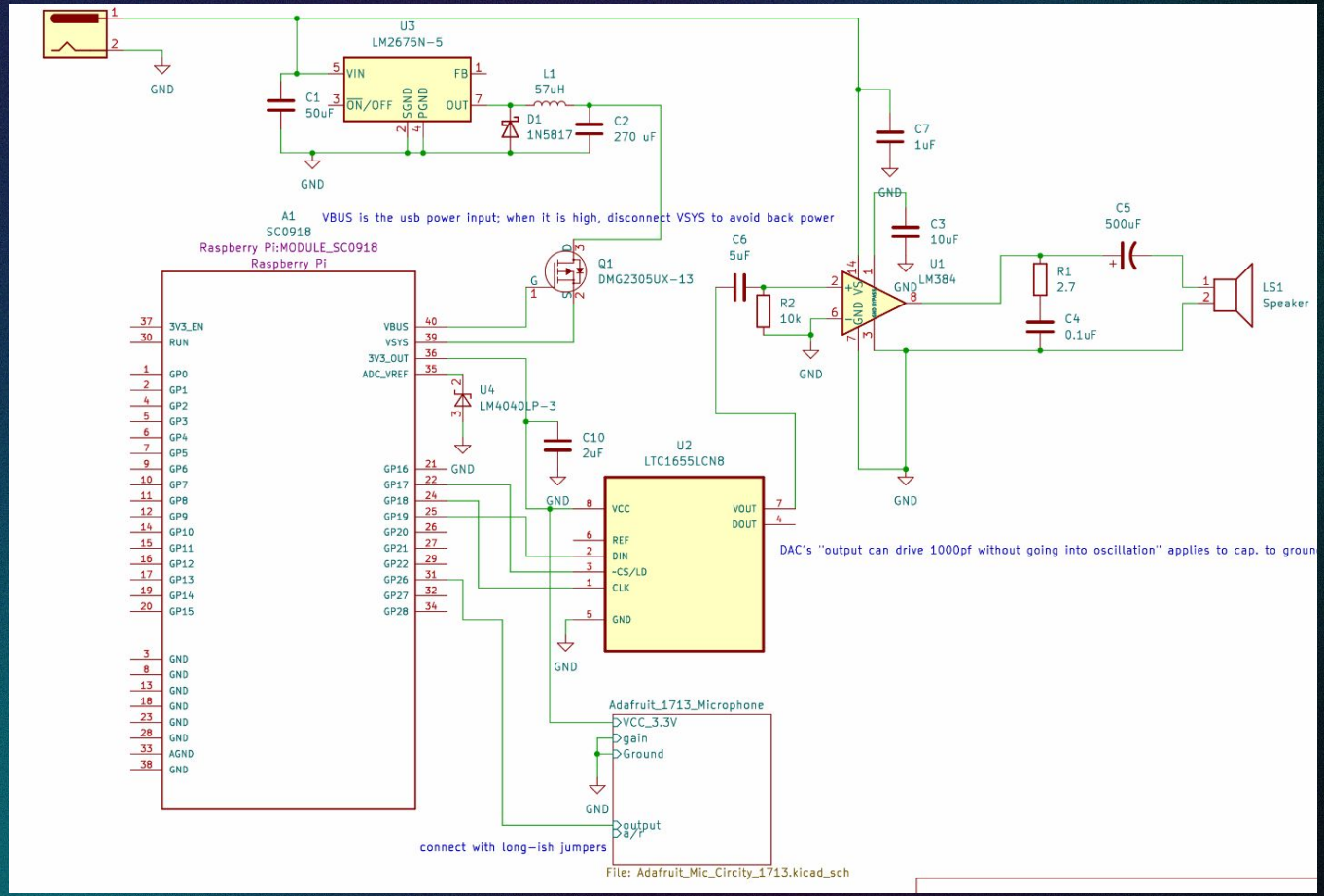
Software Architecture



Audio system



Audio system



Audio system