Problem:

Many buildings and rooms still use traditional, non-smart light switches, requiring individuals to manually slide the knob up and down, to adjust the light level of the light bulb. Upgrading these switches to smart ones typically involves removing the existing switch and installing a smart light switch in its place. However, for people living in rented rooms or apartments, this option may not be feasible, as they do not own the property and are often restricted from making permanent changes to the electrical fixtures.

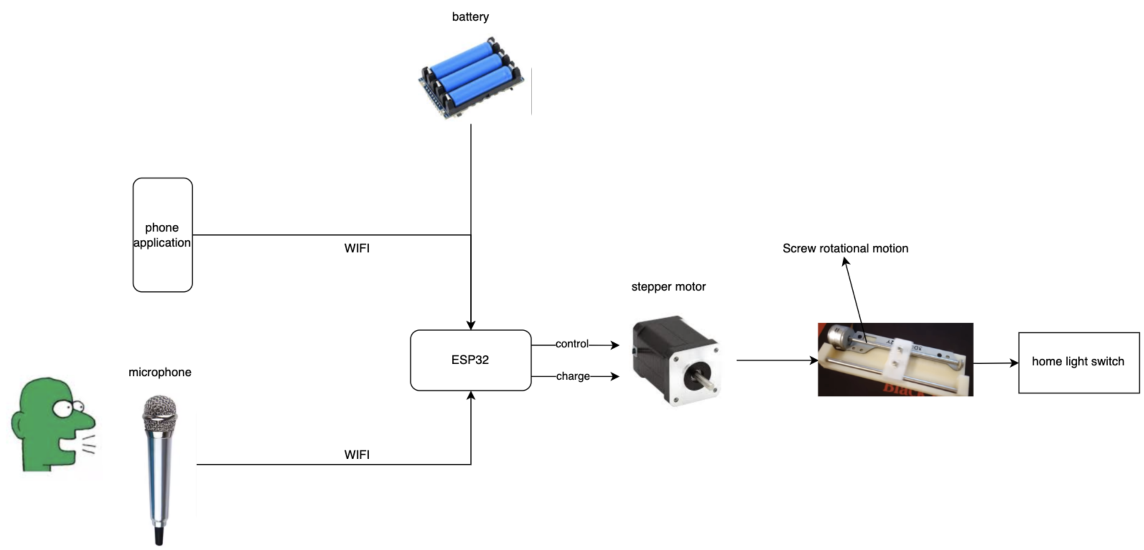
This limitation creates a challenge for renters or those in temporary living arrangements who want the convenience and energy-saving benefits of smart lighting systems without violating lease agreements or incurring high installation costs. Moreover, current solutions for retrofitting smart functionality are either limited in functionality, expensive, or complicated to install, making them inaccessible to the average tenant. As a result, there is a growing need for innovative, non-invasive solutions that enable smart functionality without requiring structural modifications to existing light switches or electrical wiring.

Solution:

The solution to this problem is to design a smart switch that can be easily mounted over the existing light switch without requiring any modifications to the electrical wiring or permanent changes to the property. This smart switch would fit seamlessly over the traditional switch, allowing users to control their lights both manually and remotely.

The light switch we would be focused on is the dimmable light switch. The user will have full control over the brightness of the light, either through voice commands or via the app. With voice control, users can simply state their desired light level, ranging from 10 (the brightest) to 0 (completely off). To enhance convenience, we will also develop a companion mobile app that allows users to control the smart switch wirelessly through WIFI. In the app, an intuitive slider allows for easy adjustment of the light level, offering the same range from 10 (brightest) to 0 (off) for precise customization.

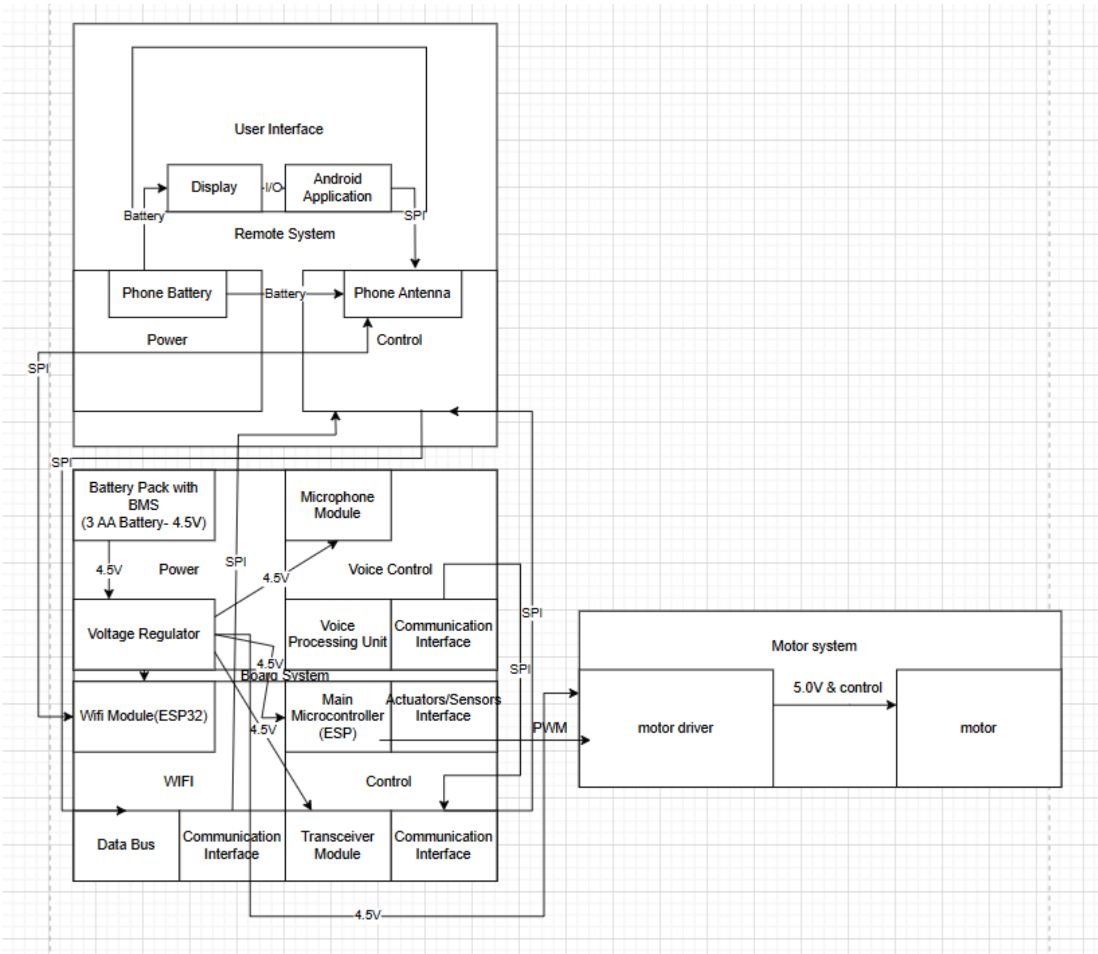
Visual Aid



High-level requirements list

1. The smart switch must maintain a stable and uninterrupted connection with the mobile app over a Wi-Fi range of at least 100 feet (30 meters) indoors, allowing users to conveniently control their lights from any room in the house, even through walls or obstacles.
2. The voice module must accurately recognize and respond to spoken numbers between 1 and 10, adjusting the light brightness to the corresponding level with precise control, ensuring that users can easily set their desired light intensity via voice command.
3. The smart switch must execute app or voice commands within 2 seconds, providing near-instantaneous adjustments to the light level, ensuring a seamless and responsive user experience without noticeable delays.

Block Diagram



Subsystem Overview:

1. Voice Control Subsystem: Sense user voice commands using the ESP32 microcontroller and digital signal processing.
2. Application Subsystem: Create an application using Android Studio and connect to the ESP32 microcontroller to send signals and activate the light switch.
3. Power Subsystem: Provide the power supply for ESP32 and Motor Driver Module. Use
4. Mechanical subsystem: The motor rotates to drive the screw to rotate, and the screw rotates to move the rod up and down, realizing the up and down movement of the switch.
5. Wifi Subsystem: Using ESP 32 which has a built-in Wi-Fi module, it allows long-range (Up to 100m) communication between the app and the light switch.

Subsystem Requirements:

1. Voice Control Subsystem: The voice control subsystem must be reliant and consistent with voice recognition. We will use the ESP32 A1S Audio Kit for the voice processing unit. Once the microphone module senses user voice, the voice processing unit within ESP32 will determine whether the input voice is commanding to turn the switch on or off. The voice processing unit will use digital signal processing to organize input and output signals. If the signal is determined to be a command, the signal is sent to the control subsystem on the board system, then to the ESP microcontroller.
    a. Interfacing with the power subsystem: must be able to operate under a power supply of 3.3V ± 0.1V.
    b. Interfacing with the control subsystem: must be able to communicate with the main microcontroller via I2S.
    c. Requirements:
        i. Must be supplied with 3.3V ± 0.1V from the power subsystem.
        ii. Must be able to draw up to 200mA during data transmission.
        iii. Must have a minimum data rate of 16 kHz and a bit clock frequency of 512 kHz when communicating with I2S.
2. Application Subsystem: The application will be developed on Android Studio emulator using the programming languages Java and/or Kotlin. The application will consist of a slider that adjusts the intensity of the light for the users. The application will require access to an internet connection and will send signals to the WIFI module of ESP32. The application will connect to the HTTP server on ESP32 and send/receive signals through HTTP requests/responses.
    a. Interfacing with the WIFI subsystem: the application will require a HTTP server to send and receive signals to the WIFI module of ESP32
    b. Requirements:
        i. Must connect to 2.4 GHz Wi-Fi networks.
        ii. Must connect to the HTTP server created on the ESP32 module.
        iii. Must not exceed a delay of 500ms between the application and the HTTP server.
        iv. Must be able to connect to the HTTP server 30 meters within the ESP32.
3. Power Subsystem: The Power Subsystem is responsible for supplying stable and sufficient power to all other subsystems. It ensures that the ESP32 microcontroller, motor driver, and voice recognition module operate reliably. The power supply is a

lithium battery (3.7V) and utilizes the DC-DC converters (Buck and Boost module) to provide the appropriate voltages and current required for each subsystem.

   a. Interfacing with the control subsystem: must provide the appropriate voltage supply for ESP32 microcontroller through voltage regulator
   b. Interfacing with Voice Control Subsystem and WIFI Subsystem: must provide the appropriate voltage supply for Voice control module and WIFI module through voltage regulator
   c. Interfacing with motor driver: must provide the appropriate voltage supply for motor driver through voltage regulator
   d. Requirements:
      i. Must supply 3.3V ± 0.1 and provide greater than 250mA to ESP32 microcontroller through Buck module.
      ii. Must supply 5V ± 0.1V and provide greater than 1A to motor driver.
      iii. Must supply 5V ± 0.1V and provide greater than 1mA to voice recognition.
      iv. Must supply 5V ± 0.1V to the motor through motor driver.
      v. Must use battery power efficiently, lasting at least 7 days per charge.
      vi. Each subsystem shares common GND to ensure proper voltage referencing.

4. Mechanical Subsystem: The mechanical subsystem is responsible for physically interacting with the slide switch. It consists of a 3D-printed mechanical structure that grips the switch and moves it up and down to switch between different positions. This movement is controlled by a stepper motor that converts electronic commands into precise mechanical movements.
   The stepper motor and the lead screw form a linear drive system. The nut is fixed on the slider. When the lead screw rotates, the nut moves along the lead screw, causing the slider to slide up and down. Two clamping rods are fixed on both sides of the slider to form a stable clamping area.
   a. Interfacing with the Power Subsystem: it operates on a regulated 3.3V supply, derived from a battery-powered 3.7V system using boost module
   b. Interfacing with the Control Subsystem, it communicates with the ESP32 microcontroller via UART (115200 bps) for receiving movement commands.
   c. Interfacing with the ESP32 GPIOs to send control signals to the motor driver
   d. Requirements:
      i. Must securely clamp the switch and move it up and down without slipping.

ii. Must accurately position at each of the 10 levels within ±0.5 mm.
iii. Must move smoothly, avoiding sudden jerks or stalls.
iv. Must work reliably with the ESP32, ensuring accurate motion based on voice commands.

5. WIFI Subsystem: The subsystem uses the ESP32 Wi-Fi module, which operates at 3.3V and includes an integrated antenna for wireless communication over the 2.4 GHz frequency band. This module interfaces with the Control Subsystem via UART or SPI communication protocol. Enables wireless communication between the board system and external devices, such as mobile applications. It is important to the overall system as it facilitates control of the light switch over a network. The subsystem is designed to work seamlessly with the Control Subsystem, providing low-latency communication and ensuring stable data rates.
   a. Interfacing with the Power Subsystem, it requires a regulated 3.3V supply from the Power Subsystem.
   b. Interfacing with the Control Subsystem, the WIFI Subsystem Communicates with the main microcontroller via UART or SPI, configured at a baud rate of 115200 bps (UART) or data rate of up to 10 Mbps (SPI).
   c. Requirements:
      i. Must be supplied with 3.3V ± 0.1V from the Power Subsystem.
      ii. Must be able to draw up to 240mA peak current during data transmission.
      iii. Must support UART communication at a minimum baud rate of 115200 bps.
      iv. Latency between Wi-Fi Subsystem and Control Subsystem must not exceed 50ms for command execution.
      v. Since SPI is used, it must support data transfer rates of up to 10 Mbps.
      vi. Must connect to 2.4 GHz Wi-Fi networks.
      vii. Must support a minimum range of 30 meters in an indoor environment.
      viii. Must achieve a minimum data transfer rate of 1 Mbps for continuous data streaming.

Tolerance Analysis:

1. The designed gripper opening size is **10 mm**, but due to 3D printing accuracy, there may be a dimensional error. If printing tolerance is ±0.2 mm, the actual gripping range is 10 ± 0.2 mm

2: The internal clock frequency of ESP32 is 80 MHz, but due to the accuracy of the crystal oscillator, there may be an error of ±0.5%, which may cause a slight deviation in the actual speed of the stepper motor. If it is 2000HZ PWM, frequency error = 2000 * 0.005 = 10HZ, there may be an error of 10Hz, causing some minor problems in the rotation of the motor.

Ethics and Safety:

Our project consists of three main ethics and safety concerns, according to the ACM Code of Ethics.

1. Privacy and Data Security

- The application and microcontroller we are using require access to WiFi and Bluetooth, so there are security risks if the data transferred is misused
- Voice control, if recorded, can collect and store sensitive data, which imposes security risks to users

Potentially violates ACM Code of Ethics 1.6 (Respect privacy.) and 1.7 (Honor confidentiality.)

We will avoid these issues by making sure we don't record the data from users and release the development process to the public to ensure that data transferred through WIFI and Bluetooth are not sent to third parties.

2. Reliability and Safety

- If our system malfunctions, safety issues can occur in specific locations, such as hospitals, staircases, or emergency exits

Potentially violates ACM Code of Ethics 2.5 (Give comprehensive and thorough evaluations of computer systems and their impacts, including analysis of possible risks.) and 3.1 (Ensure that the public good is the central concern during all professional computing work.)

We will ensure reliability by testing voice control with various sounds, so that it doesn't malfunction in unwanted cases.

3. Misuse of Technology

- Unauthorized users having access to the light switch might turn the lights on/off without permission

Potentially violates ACM Code of Ethics 1.2 (Avoid harm.)

We will avoid this issue by allowing everyone to have access to the light switch, since voice recognition of specific users requires our system to record voices, and this goes against our first safety concern mentioned. This is not that big of an issue since using the light switch without permission does not lead to large safety concerns.