UNIVERSITY OF ILLINOIS URBANA-CHAMPAIGN

Group 83:

Automatic Door Conversion Kit

Electrical & Computer Engineering

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Introduction

So, what is an automatic door conversion kit?

Our Objective

The Problem

- Accessibility systems like automatic doors are commonly available in public spaces but not in homes.
- For individuals with physical disabilities, installing home automation systems is often prohibitively expensive and complex.
- There is a need for affordable, easy-to-install solutions that bring accessibility to residential interiors.

Our Solution

- A cost-effective, easy-to-install automatic door conversion kit designed for interior residential use.
- The kit includes:
  - Actuating latch to unlock/relock the door.
  - Motorized opener to swing the door open/closed.
  - Remote control to operate the system wirelessly through Bluetooth
- Designed to open doors safely in ~3 seconds with reliable syncing between subsystems.
- Supports pairing with multiple doors via a single remote.

Demonstration Limitations

- Since performing a demonstration for this project on an actual door wasn't possible, our project was designed and scaled down for a 21-inch tall, 13-inch wide, and 5lb door.
- The scaled down project has the same actuating latch, motorized opener, and remote-control design as the real project would.
- Since we couldn't modify the machine shop's door too much, all of our components were mounted on the door's frame external.

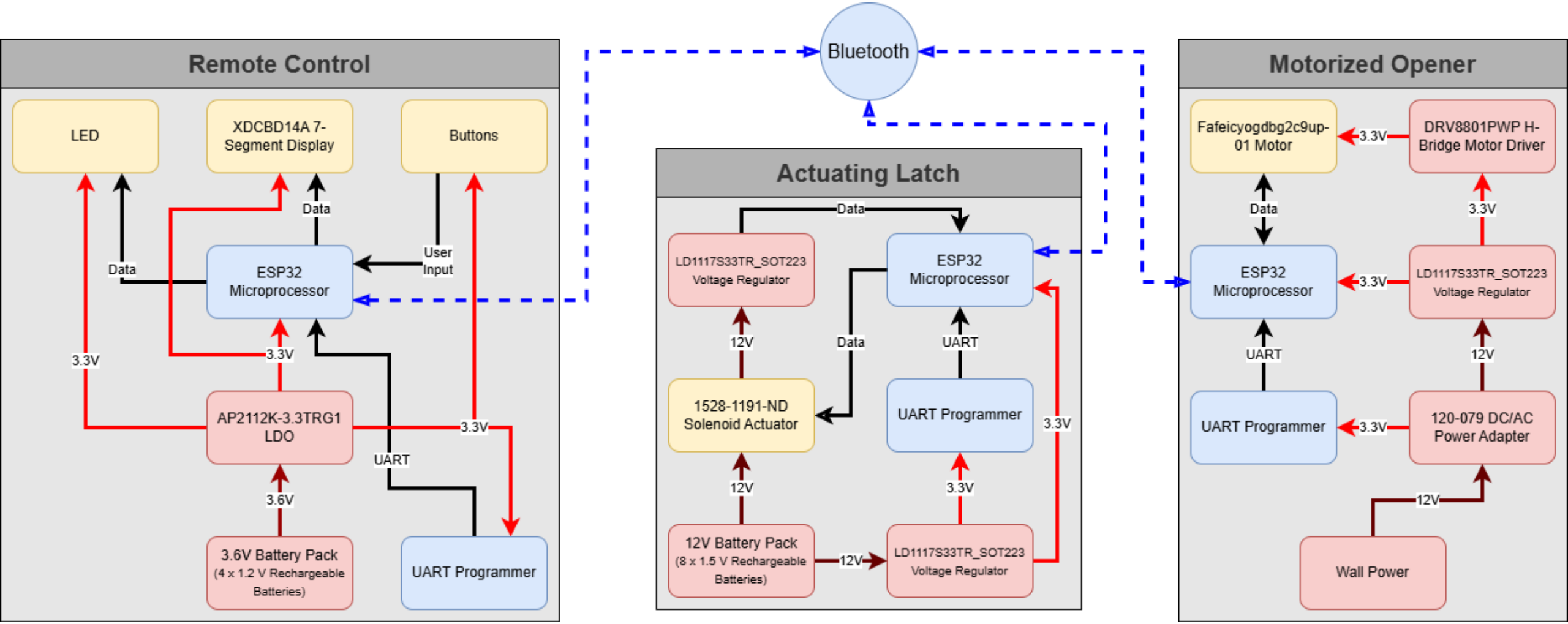
The Design

Now, how did we make it happen?

Design Considerations

- **Accessibility:** System must be operable by individuals with limited mobility or strength.
- **Feedback Mechanisms:** System must confirm states (open/closed, paired/unpaired) with visual indicators like LEDs and displays.
- **Responsiveness:** Bluetooth communication between remote, latch, and opener must occur within milliseconds to feel seamless.
- **Signal Synchronization:** Latch must disengage before the door begins to open—requires precise timing logic.
- **Scalability:** Remote can control multiple doors, allowing expansion throughout a home.
- **User Safety:** Ensure door opens/closes at a controlled speed (~3 seconds) to prevent injury.

Block Diagram



Design Changes

Our Old Design

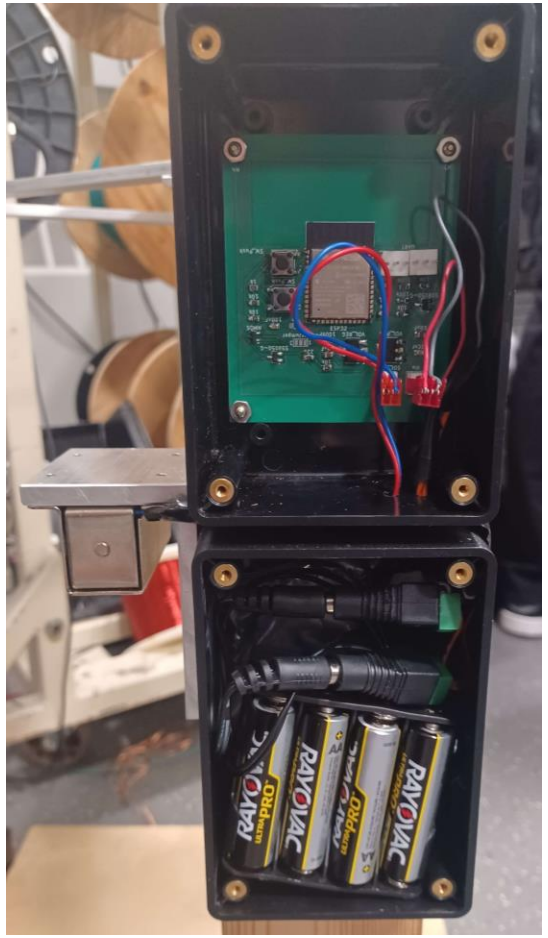
- 3D printed door handle encompassing the latch
- 3.6V coin battery for the remote
- 8 x 1.5V battery pack for the motor
- Door Subsystem acts as the central communicator between the Remote and Latch Subsystems

The Changes

- Exterior latch due to door limitation
- 4 x 1.5V battery pack for the remote
- Wall power for the motor
- Remote Subsystem acts as a client subscribing to Door and Latch Subsystems and their services

The Actuating Latch

- Actuator retracts to allow the door to open and re-engages to secure it shut.
- Operates via solenoid lock controlled through Bluetooth by an ESP32 microcontroller.
- Powered by an 8 x 1.5V battery pack stepped down to 3.3V for logic components.
- Sends feedback to confirm latch engagement/disengagement.



The Motorized Opener

- Ensures door fully opens to 90° within 3 ± 0.15 seconds using a motorized arm and joint system.
- Includes H-bridge motor driver circuit controlled by ESP32.
- Outputs status updates and engages/disengages in sync with latch subsystem.
- Powered via wall AC adapter converted to 12V and regulated to 3.3V for logic.
- Responds to Bluetooth signals from the remote control.

The Remote Control

- Allows user control of door systems using three onboard buttons (Activate, Down, and Up).
- Can switch between multiple door kits and send open/close signals.
- Displays door number and status using a 7-segment display.
- Powered by a 4 x 1.2V battery pack regulated to 3.3V for ESP32.
- Top-left LED indicates Bluetooth connection status (on = searching, off = paired).

Current Analysis

- Energy equation for current:
  - E = I x t, where I = Current output and t = Duration
- Using the 4 x 2.3 Ah battery pack and the 800 mA output voltage regulator from our remote control, we get a battery life of:
  - t = 11.5 hours
- ESP32 microprocessors draw close to 240 mA but each led draws 20 mA
  - 9 * 20 mA = 180 mA ≤ 240 mA
- Motor draws maximum of 600 mA, so 6A from AC/DC converter will be enough to operate the door opener system.
- Lastly, for the actuating latch, the 2.6 Ah battery pack and maximum 500 mAh draw of the ESP32 and solenoid will give us a battery life of:
  - t = 5.2 hours

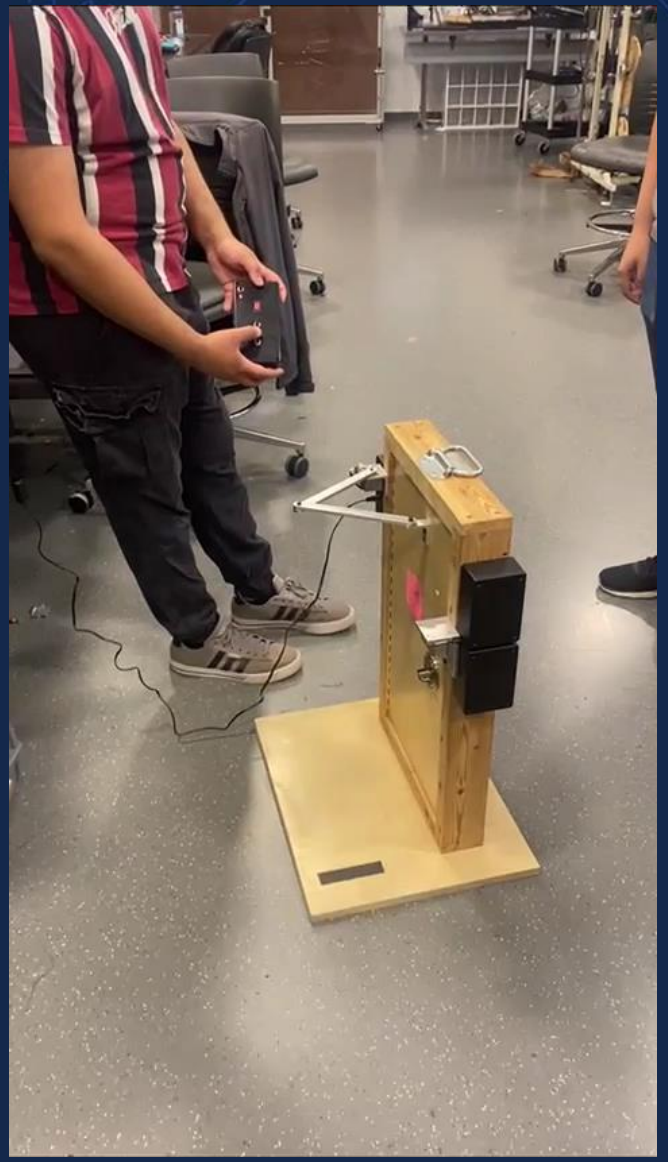
The 11.5-hour battery life of the remote control and 5.2-hour battery life of the actuating latch should be enough given their relatively short effective operational times.

Motor Analysis

- Torque Equation for motor:
  - τ = F x r = I * α, where F = force needed to move the door, r = distance from the hinge where the force is applied, I = moment of inertia, and α = angular acceleration
    - I = (1/3) * m * L^2, where m = mass of door and L = width of door
- Angular acceleration equation:
  - θ = w * t + (1/2) * α * t^2 -> α = 2 * θ / t^2, where w = initial angular velocity and t = time to open door completely to 90°
- So, the torque required to open the door 90° is:
  - **τ = 0.082401 * 0.3491 = 0.0288 Nm**
- Angular velocity equation:
  - W = w + α * t, where w = initial angular velocity, α = angular acceleration, and t = time to open door completely to 90 degrees
- Using our previous values, we get:
  - **W = 0 + 0.3491 * 3 = 1.0472 rad/s = 10.00 RPM**
- To determine the motor's required power, we used the following power equation:
  - P = τ x w, where τ = torque and w = angular velocity
- Using our previous values, we get:
  - **P = 0.3*1.047 = 0.3142 W**

Therefore, our motor should be able to produce 0.3 Nm of torque with 0.3142 W of power. So, the 12V DC gear motor that we are using will be able to produce 10 RPM with the required torque and power to open the door 90°.

The Final Result



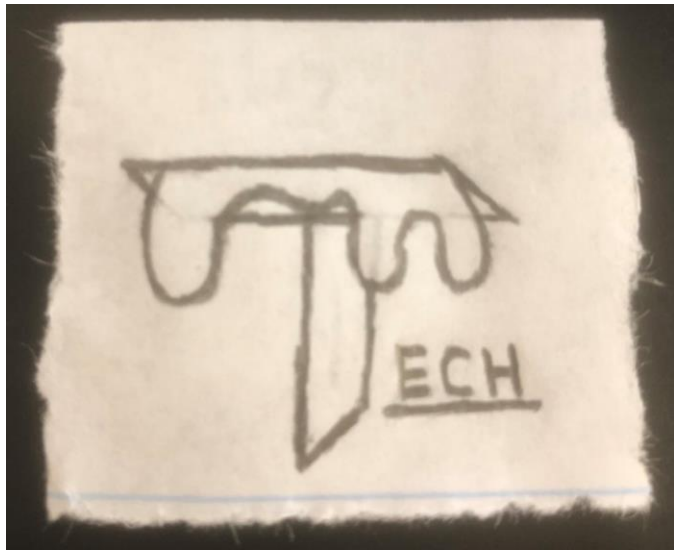
Conclusions

Our Takeaways

- Failures
  - Fried a battery pack
  - Fried our 2nd motor
  - Fried our 2nd motor PCB
  - Impact safety feature was not implemented
- Successes
  - Remote Control was successful in paring with motor and latch
  - Latch retracted in sync with the button press to open/close the door
  - Motor freely swinged open as the latch retracted
- What would we do differently?
  - Figure out how to use the motor's encoder to implement the safety features
  - Go back to using coin batteries for the remote, but use a more common and reliable battery
  - Use reliable, long-lasting batteries for the motorized opener
- What did we learn?
  - How to use flux and a soldering oven
  - How to hand solder
  - How to use KiCad

What comes next?

- Automatic Door Conversion Kits v2.0
  - Upscale the project to standard sized interior residential doors
  - Allow for functionality with exterior doors
  - Implement security features
  - Program an app instead of using a remote
- MUC Tech
  - Work on our technical pursuits together
  - Our original logo was drawn by Love Patel and our new logo was drawn by Eliza Perkovich



Thanks for listening!