Automatic Door Conversion Kits

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Abstract

This report is a focus on our design of the Automatic Door Opener Conversion Kit. We propose a solution to the necessity of having more affordable accessibility options within residential homes. We utilized KiCad to design our schematics and PCBs for the different subsystems, and we use Arduino IDE to implement the control of our different components. Our three main subsystems have been discussed that have led to the success of this project. We have built a remote control that sends a signal to an actuating latch to retract it so that a door motor can open the door without any obstruction. A smooth transition has been created between the press of a button to the automatically opening a door. Additionally, LEDs and buttons have been implemented to allow the user to visibly see the current state of any connected doors.

1. Introduction

1.1 Problem

With accessibility being considered more in modern infrastructure, more and more systems for accommodating people with physical disabilities are being installed every day. Most of these systems are installed in public locations and are paid for by the government. This makes it so that the general public never has to think about how the systems got there and how they were paid for. However, for those with physical limitations, installing similar accessibility systems in one's home is extremely costly and difficult. Even doors, something used many times each day by a single individual, will cost someone hundreds of dollars to make automatic. Cheaper and easier to install automatic doors meant for residential homes would alleviate this cost barrier and difficulty of installation for those that struggle to use standard, manual doors.

1.2 Solution

Our solution for the high barrier to entry for making one's home accessible is to make cost effective and quick to install automatic door conversion kits for interior, residential doors. These kits would include an actuating latch, a motorized opener, and a remote control. The motorized opener can be screwed onto both the door frame and the door, while the actuating latch would be able to replace standard door latch. The motorized opener would be able to be remotely activated with a Bluetooth signal from the remote control. The motorized opener would have a box containing the electronics that run along the top of the door frame with a motor controlling an arm that would swing the door open. To allow the door to close/open remotely without getting caught on the latch, the actuating latch that would close/open in sync with the motorized opener to allow the door to swing freely. Lastly, the Bluetooth remote would be able to pair to multiple motorized openers and have the capability to cycle between them. This would allow individuals to buy multiple kits and attach them to doors throughout their house as needed.

2. Design

2.1 Block Diagram

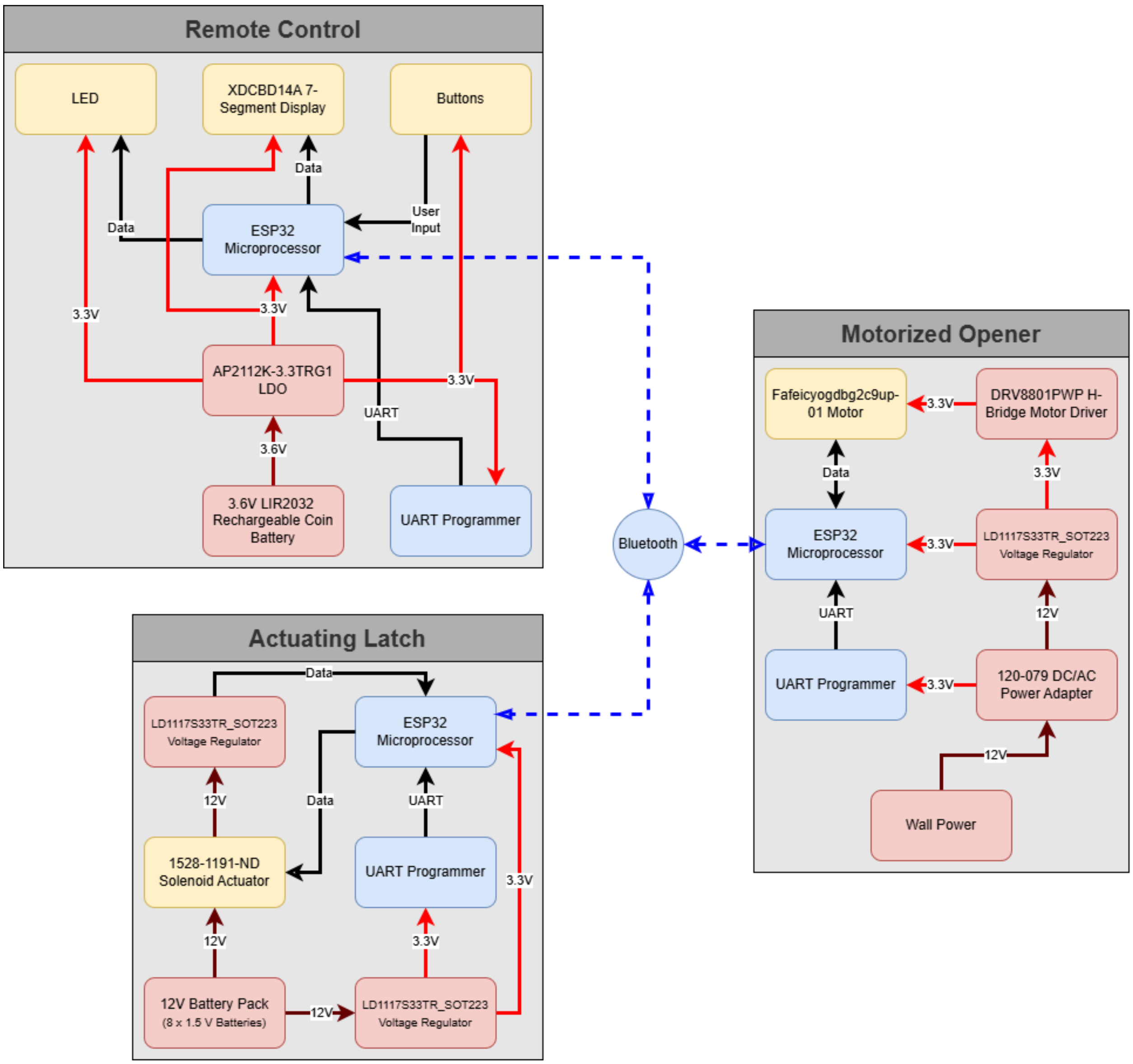

Figure 1. Automatic Door Conversion Kit System Block Diagram

2.2 Actuating Latch Subsystem

Figure 2: The final actuating latch subsystem.

The actuating latch subsystem is responsible for replacing the door's latch to allow the door to close/open upon receiving a bluetooth signal from the motorized opener. The actuator remains engaged and only disengages upon receiving an open signal from the remote control to allow the door to swing open with the help of the motorized opener without getting caught on the door's latch. The actuator's rod is shaped to allow the door to close without the actuator needing to disengage then reengage upon making contact with the door frame. The actuator also sends a bluetooth signal back to the motorized opener to confirm that it is disengaged/engaged.

2.3 Control Subsystem

The control subsystem is responsible for all of the Bluetooth signals sent between our three PCBs as well as all of the control logic for signals sent between the actuating latch, the motorized opener, and the remote control. The control logic includes pairing to available door systems and latch systems, the currently targeted door's number, the currently targeted door's closed/open state, and the timing of the close/open signals for the actuating latch and motorized opener. The user can use the pair button to initiate a search for door and latch servers by looking for specific UUIDs. When the remote finds these UUIDs, it will assign the door and latch to a specific number representing a pair based on their group characteristics. Assuming a pair has been made, the action button can now be used to send the close/open signal. When the remote control sends a close/open signal, the control subsystem will send the signal to the actuating latch. The actuating latch will then tell the latch to retract and receive a signal back from the latch that it has retracted. This subsystem can then tell the remote to ask the motorized opener to open the door. When the remote switches between which door is targeted, the control subsystem changes which latch and opener closes/opens with an activation signal. Additionally, the switching of which doors are targeted will update the hex display, changing the number displayed and the LED indicating if the door is closed or opened.

2.4 Motorized Opener Subsystem

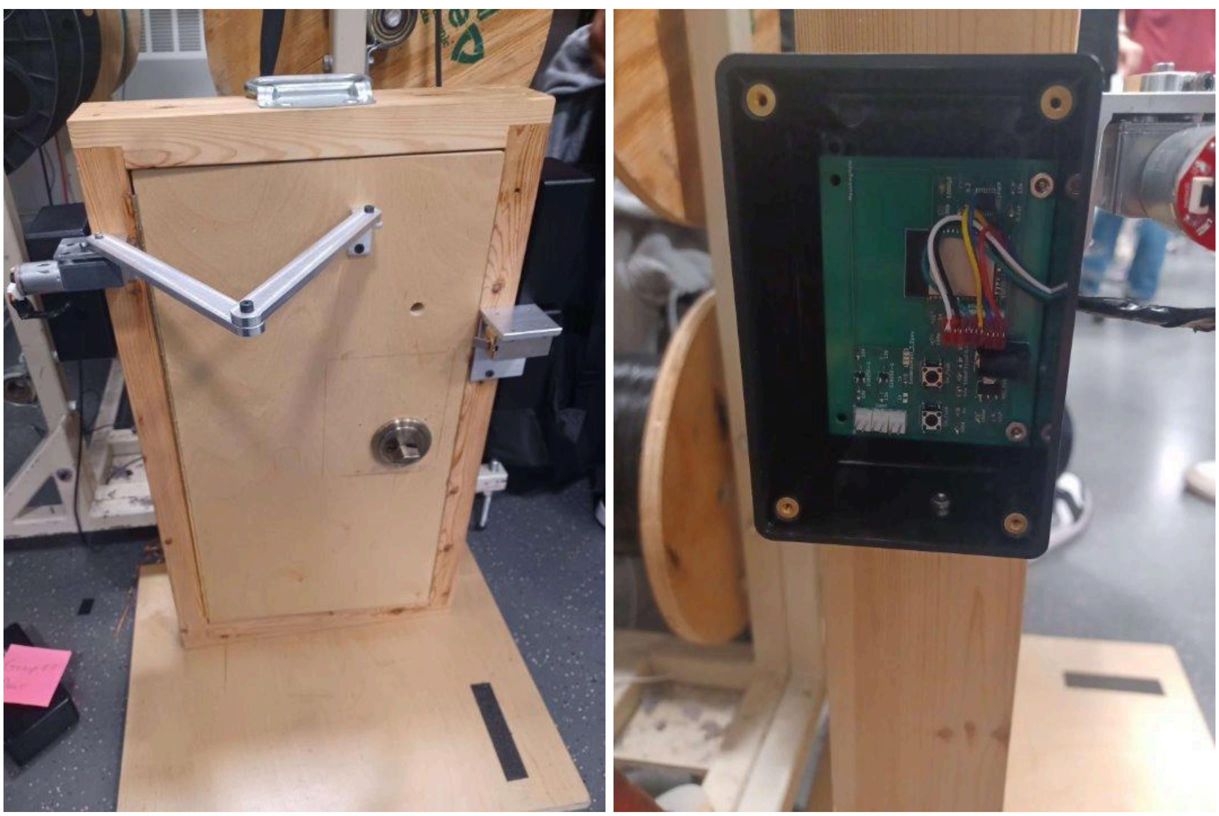

Figure 3: The final motorized opener subsystem.

The motorized opener subsystem is responsible for closing/opening the door upon receiving a close/open signal from the remote control. Upon receiving an open signal, the motorized opener swings open the door with a jointed arm. After fully opening with the expected RPM from the motor for the duration of the opening cycle, the motorized opener considers the door as having opened and changes the door's state to open, and vice versa for closing the door.

2.5 Power Subsystem

The power subsystem is responsible for powering the actuating latch, the motorized opener, and the remote control. For the actuating latch, power comes from a 4 x 1.5V battery pack through a voltage regulator to stabilize the 12V before running the power to the actuator and through a different voltage regulator to step down to 3.3V for the PCB. For the motorized opener, the power comes from the wall through an 12V AC/DC converter, then through a voltage regulator into the motor to stabilize the 12V, and also through a different voltage regulator to step down to 3.3V for the PCB. Lastly, for the remote control, power comes from a 4 x 1.2V battery pack run through a voltage regulator stepping it down to 3.3V for the buttons, hex display, LED, and PCB.

2.6 Remote Control Subsystem

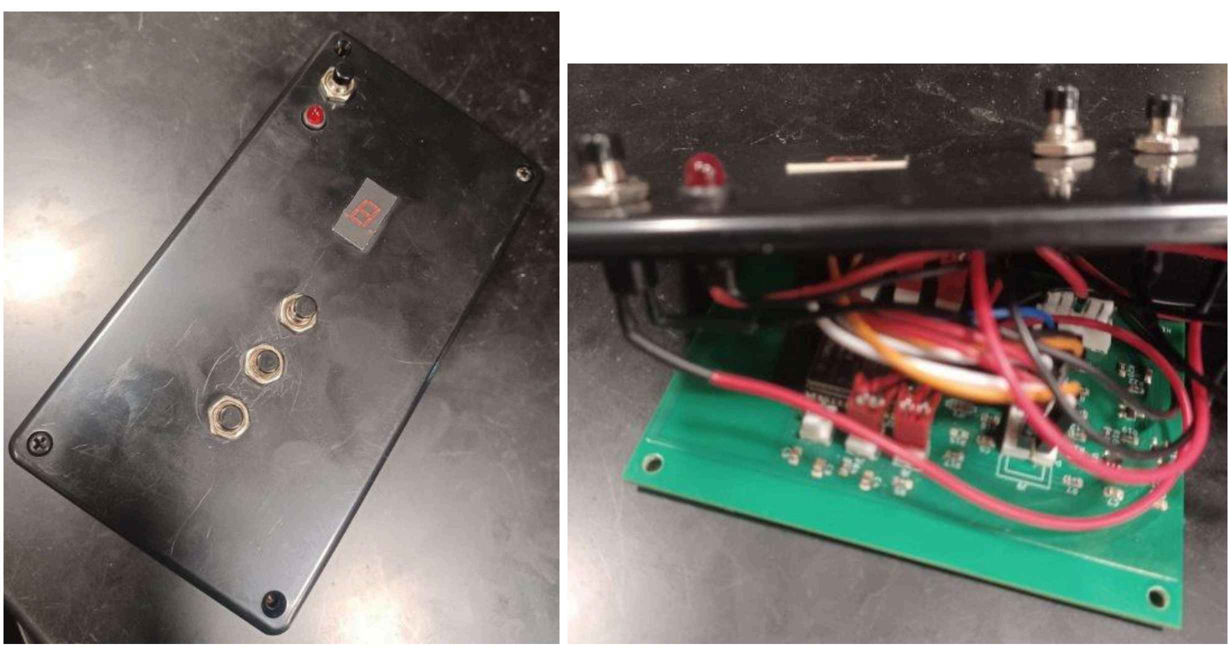

Figure 4: The final remote control subsystem.

The remote control subsystem is responsible for allowing the user to control the closing/opening of each automatic door conversion kit using input from the user to three buttons on the remote. Two of these buttons control which door is being targeted, and the third is used to send the close/open signal to the motorized opener. The remote control is also able to receive a bluetooth signal from each motorized opener to confirm it's closed/open state. A fourth button on the remote allows the user to control the syncing of the remote, which displays on an LED as on when not synced and off when synced to a door. The remote also displays the number of the currently targeted door as well as its closed/open state on a 7-segment display.

2.7 Tolerance Analysis

Energy equation for current:

$$E = I \times t, \text{ where } I = \text{Current output and } t = \text{Duration}$$

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:

$$t = 11.5 \text{ hours}$$

ESP32 microprocessors draw close to 240 mA but each led draws 20 mA.

$$9 * 20 \text{ mA} = 180 \text{ mA} \leq 240 \text{ mA}$$

The motor draws a maximum of 600 mA, so 6A from the AC/DC converter will be enough to operate the motorized 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:

$$t = 5.2 \text{ hours}$$

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.

Torque Equation for motor:

$$\tau = F \times r = I * \alpha$$, where F = force needed to move the door, r = distance from the hinge where the force is applied, α = angular acceleration, and I = moment of inertia = $(1/3) * m * L^2$, where m = mass of door and L = width of door

Angular acceleration equation:

$$\theta = w * t + (1/2) * \alpha * t^2 \rightarrow \alpha = 2 * \theta / t^2$$, where w = initial angular velocity and t = time to open door completely to 90°

So, the torque required to open the door 90° is:

$$\tau = 0.082401 * 0.3491 = 0.0288\ Nm$$

Angular velocity equation:

$$W = w + \alpha * t$$, 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:

$$P = \tau \times w$$, 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°.

3. Cost and Schedule

3.1 Cost Analysis

3.1.1 Labor Cost

All three members of our group are Computer Engineering students. Based on the ECE department website regarding average salaries, a post-graduate starting salary from the University of Illinois at Urbana-Champaign is approximately $109,176 and the average work hours per year is about 2,080 hours. This equates to approximately $52.49/hr. We approximately work for 12 hours on this project and estimate that it will take us 10 weeks to complete the entire project.

So the labor cost per person is:

$$\$52.49/hr * 2.5*12*10 = \$15,747 \ / \ person$$

So the total labor cost comes out to:

$$\$15,747 \ / \ person * 3 = \$47,241 \text{ of total labor cost}$$

3.1.2 Parts Cost

- 4 AA Battery Pack from the Electrical and Computer Engineering Lab
  - **Cost:** Free
- Door Arm from the Electrical and Computer Engineering Machine Shop
  - **Cost:** Free
- Rechargeable AA Batteries from Energizer
  - **Part #:** NH15-2000 (HR6)

- **Cost:** 4 x $2.80 for a total of $11.20
- Microcontroller from Expressif Systems
  - **Part #:** ESP32-S3-WROOM-1-N16
  - **Cost**: 4 x $5.92 for a total of $23.68
- 12 V DC Gear Motor with Encoder from Fafeicy
  - **Part #:** Fafeicyogdbg2c9up-01
  - **Cost**: 2 x $15.09 for a total of $30.18
- 12 V Solenoid Lock from Adafruit Industries LLC
  - **Part #:** 5012
  - **Cost**: 1 x $14.98 for a total of $14.98
- 7-Segment Hex Display from Broadcom Limited
  - **Part #:** 5082-7650
  - **Cost**: 1 x $2.97 for a total of $2.97
- Linear Voltage Regulator, 12V to 3.3V from STMicroelectronics
  - **Part #:** LD1117S33TR
  - **Cost**: 4 x $0.34 for a total of $1.36
- LDO, 3.6 V to 3.3 V, 12V to 3.3V from Diodes Incorporated
  - **Part #:** AP2112K-3.3TRG1
  - **Cost**: 3 x $0.56 for a total of $1.68
- 10 K Ohm Resistor from Stackpole Electronics Inc
  - **Part #:** RMCF0805JG10K0
  - **Cost**: 9 x $0.10 for a total of $0.90
- 1 K Ohm Resistor from Stackpole Electronics Inc
  - **Part #:** RMCF0805JT1K00
  - **Cost**: 5 x $0.10 for a total of $0.50
- 1 µF Capacitor from Samsung Electro-Mechanics
  - **Part #:** CL21B105KBFNNNG
  - **Cost**: 6 x $0.11 for a total of $0.66
- 220 Ohm Resistor from YAGEO
  - **Part #:** RC1206JR-10220RL
  - **Cost**: 9 x $0.10 for a total of $0.90

- 100 nF Capacitor from Samsung Electro-Mechan
    - **Part #:** CL21F104ZAANNNC
    - **Cost**: 3 x $0.10 for a total of $0.30
- 10 µF Capacitor from Murata Electronics
    - **Part #:** GRM21BR61H106ME43L
    - **Cost**: 3 x $0.29 for a total of $0.87
- 12V DC Power Supply from Parts Express
    - **Part #:** 120-079
    - **Cost**: 1 x $17.989 for a total of $17.98

3.1.3 Total Cost

- Parts Cost: $108.16
- Labor Cost: $47,241

So, the total cost of our entire project comes out to be $47,349.16

3.2 Schedule

- March 2nd - March 8th: All members worked together
    - Finalize our design document
    - Determine/order what parts we will need in order to demo our project on the breadboard
    - Start putting together the breadboard demo by the end of the week
- March 9th - March 15th
    - Finish breadboard and demo it to the instructor and TA
    - Finalize our PDB designs for the second round of PCBway orders
    - Talk with the machine shop regarding the door they are providing us and finalize any design decisions by the end of the week
- March 16th - March 22nd
    - Have parts all ordered in so the following week we can start with soldering our parts onto the PCBs once they arrive
- March 23rd - March 29th

    - Start soldering parts onto the PCBs
    - Start working on the ESP32 firmware
    - Start testing the PCBs, ensuring that all the components are soldered on correctly and that they are receiving the correct voltages
    - Make amends for the third round of PCBway orders
- March 30th - April 5th
    - Send in our third round orders for PCBway orders
    - Start programming the PCBs that seem to be correct and ensure physical components are able to receive necessary signals
- April 6th - April 12th
    - Send in our fourth round orders for PCBway orders if needed
    - Complete BlueTooth configuration and make any amends to ESP32 software development
    - Start assembling the physical components such as the box that will house the remote, the box that will house the door subsystem and the box that will house the latch subsystem
- April 13th - April 19th
    - Prepare for the mock demo
    - Start testing the whole system, making any adjustments as needed for the project to work
- April 20th - April 26th
    - Demo with TA during weekly meeting to prepare for the final demo next week
    - Make any adjustments that the TA may have suggested
    - Start working on the final paper for the project
- April 27th - May 3rd
    - Present the project to the professor and TA
    - Do a mock presentation to prepare for final demo
- May 4th - May 10th
    - Finalize the final paper, ensuring that everything has been included
    - Do the final presentation with the professor and TA

4. Conclusions

4.1 Accomplishments

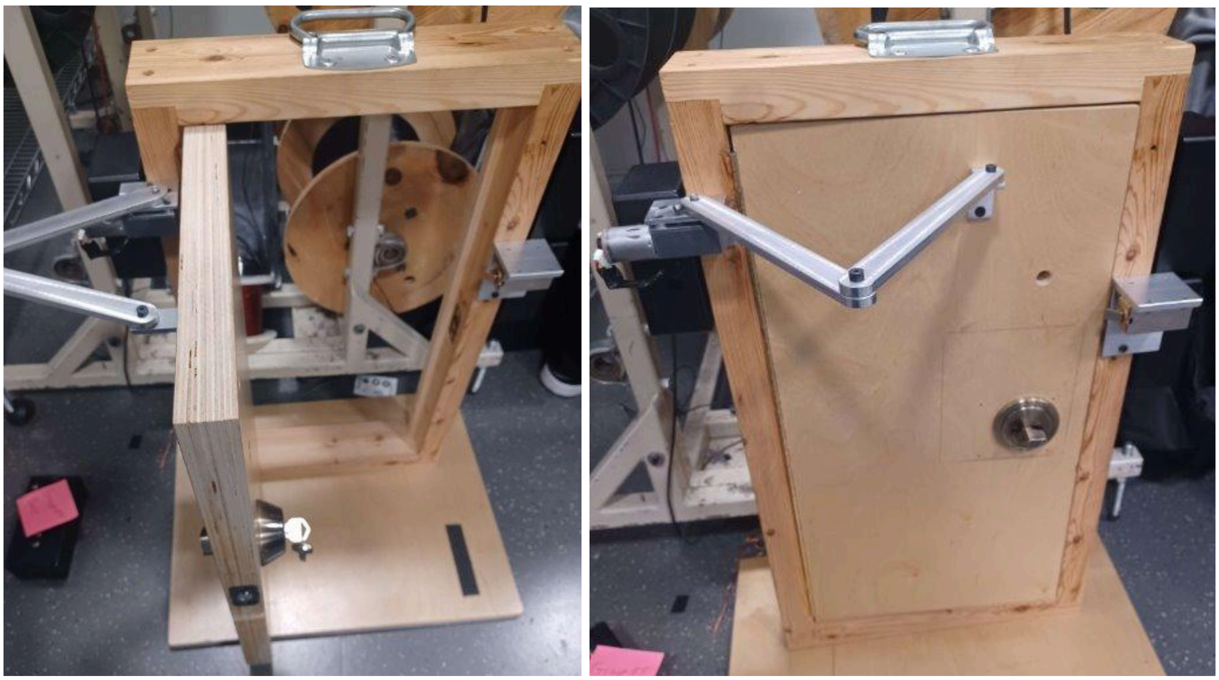

Figure 5: The final automatic door conversion kit project.

In the end, we achieved most of our goals set at the beginning of the semester. For our actuating latch, we achieved full functionality with the actuator retracting in sync with the door swinging open. For our motorized opener, we achieved full functionality with our door closing and opening fully to 90 degrees upon receiving an activate signal. Lastly, for our remote control, we also achieved full functionality with full Bluetooth connections to each system, proper display of the targeted door's number and closed/open state, and proper syncing to multiple doors. All three of these main systems worked in tandem to make the project work on our one full automatic door conversion kit.

4.2 Uncertainties

With all of our successes, there were also some failures and uncertainties. The first and biggest failure was our inability to complete a second automatic door conversion kit in time to demonstrate full functionality with two kits. Despite this, we were able to demonstrate targeting different doors by desyncing/syncing to our one functional kit and reassigning its door number to show proper door targeting.

The second main issue we had was not being able to implement the impact/jam detection safety feature that we originally intended. This was primarily due to the fact that we couldn't read data from our motor's encoder due to the motor not having a proper data sheet and documentation for us to figure out how to do so.

4.3 Ethical Considerations

4.3.1 Safety and Reliability of the Automatic Door Mechanism

This system is designed for people with physical disabilities therefore we will make sure to follow IEEE Code of Ethics section 1.1 to ensure the automatic door does not cause injury or malfunction. We will test this to an extent that will ensure that it does not malfunction and also make sure the opening and closing speed of the door is not too fast to ensure safety entering and leaving by the person with physical disabilities. To also ensure the safety of anyone or anything being crushed by the force outputted by the motor on the door, we will stop the motion of the door if the motor detects resistance in its rotational output. This will be done reading the rotational output from the motor's encoder.

4.3.2 Sustainability and Environmental Responsibility

Since we have considered using batteries that are disposable such as the 12V battery, this can lead to electronic waste. According to ACM Code of Ethics section 3.3, which states to ensure the public good, the team will consider using rechargeable ones to reduce the electronic waste and promote sustainability. In the Remote Control subsystem, the LiR2032 3.6V battery is rechargeable in an attempt to reduce waste.

4.3.3 Campus and Lab Policies

To make sure that there is proper handling of tools and materials, we will follow the University of Illinois at Urbana-Champaign laboratory safety guidelines. This will ensure that the team is making sure of being well organized and keeping the workspace free of potential problems. This includes keeping food and drinks out of the laboratory, and also never working alone inside the laboratory. Any equipment that we use will be returned to the state that we found them in, which includes shutting down the soldering iron.

4.4 Future Work

Going forward, we would like to continue work on improving our automatic door conversion kits. First, we'd like to scale the project up for full sized, interior residential doors. As part of that process, we'd also complete implementing the project on multiple doors as originally intended. A bit part of upscaling the project would also include finding a better motor with decent documentation so that we could figure out how to read from its encoder in order to successfully implement the impact/jam detection safety features we originally intended to implement on the scaled down model.

Once we successfully scale the project up, we'd also like to adapt the project to work for all types of doors, including exterior doors. As part of this expansion of scale, we feel that the implementation of security features would be necessary, especially for exterior doors. These security features would mainly be intended to prevent random people from syncing to and opening any door with a Bluetooth signal. We'd also like to implement functionality to allow our installed kits to work with standard lock and key to expand every day usability. Lastly, we'd like to program a phone app to allow users to use it instead of a remote control to expand the project's convenience and usability even further.

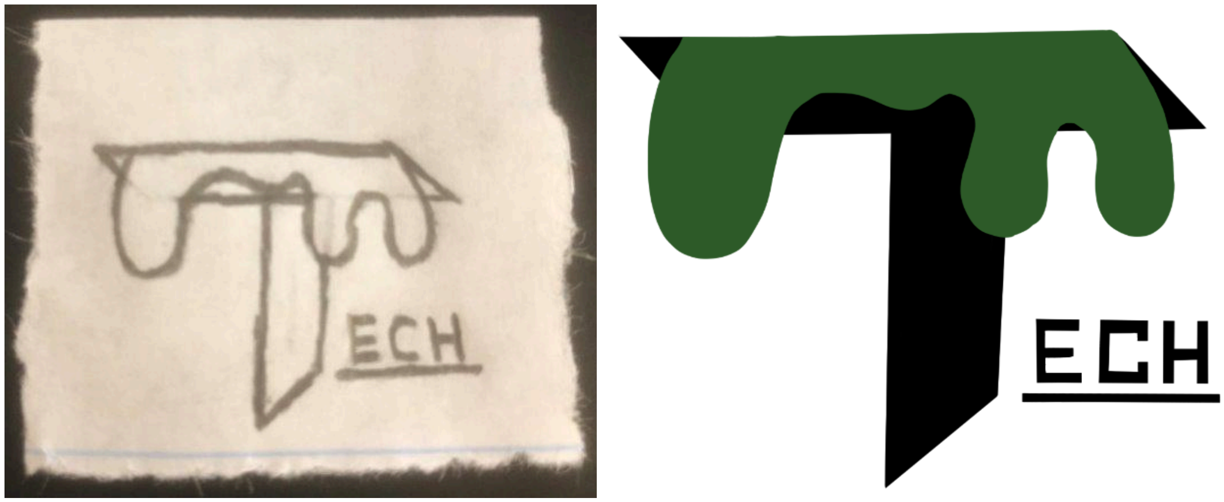

Figure 6: MUC Tech logos by Love Patel and Eliza Perkovich, respectively.

Upon implementing all of these future features, we see potential to commercialize this product. Our project has real potential to help physically disabled people make their homes and the world as a whole more accessible. The three of us have been friends for a long time and have spoken about following technical pursuits together under the name of MUC Tech. Our automatic door conversion kits could be one of the first products produced, distributed, and sold under this name.

5. References

[1] "ESP32WROOM32 Datasheet." *Espressif Systems*, datasheet, 2023, www.espressif.com/sites/default/files/documentation/esp32-wroom-32_datasheet_en.pdf.

[2] Grainger Engineering Office of Marketing and Communications. "Salary Averages." *Electrical & Computer Engineering | Illinois*, ece.illinois.edu/admissions/why-ece/salary-averages.

[3] IEEE. *IEEE Code of Ethics*. June 2020, www.ieee.org/content/dam/ieee-org/ieee/web/org/about/corporate/ieee-code-of-ethics.pdf.

[4[Payne, Michelle. "How Many Work Hours in a Year." *FreshBooks*, 6 Sept. 2024, www.freshbooks.com/hub/productivity/how-many-hours-do-people-work-in-a-year#:~:text=There%20are%208%2C670%20hours%20

[5] Same Sky. *TACTILE SWITCH*. 12 Sept. 2024, pp. 1–5. www.sameskydevices.com/product/resource/ts02.pdf.

[6] STMicroelectronics. *Adjustable and Fixed Low Drop Positive Voltage Regulator*. datasheet, 2025, www.st.com/content/ccc/resource/technical/document/datasheet/99/3b/7d/91/91/51/4b/be/CD00000544.pdf/files/CD00000544.pdf/jcr:content/translations/en.CD00000544.pdf.

[7] *The Code Affirms an Obligation of Computing Professionals to Use Their Skills for the Benefit of Society.* www.acm.org/code-of-ethics.

Appendix A: Requirement and Verification Table

Actuating Latch RV Table

Requirements	Verification
Remote sends a signal to the latch subsystem and allows the latch to open within ¼ second of the latch receiving the signal.	● Latch receives signal written via Bluetooth and writes to a pin to open the latch via NMOS gate. ● Latch will then receive a signal via a different pin as confirmation that the latch was properly opened. ● Have the program print statements of the time when the latch received signal from remote and when it sends confirmation signal back to the remote.
Solenoid latch receives 12V +/- 5% across when it is activated.	● Connect the 12V power supply to the door latch PCB. ● Use a multimeter with the negative probe on the PCB ground. ● Touch the positive probe to the positive end of the batteries and confirm it is outputting 12V first. ● Touch the positive end of the solenoid latch with the positive probe of the multimeter to confirm it is also receiving 12V.

	• Touch the negative end of the solenoid latch with the positive probe of the multimeter to confirm it is receiving 0V.
ESP32 receives an input voltage of about 0V from the solenoid latch when it is activated.	• Similar to before, power the door latch PCB with the power supply. • Use a multimeter with the negative probe on the PCB ground. • Touch the negative end of the solenoid latch with the positive probe of the multimeter to confirm it is receiving 0V. • Also confirm that the voltage regulator connected to the negative end of the solenoid latch is receiving and outputting nearly 0V. • Ensure GPIO1 receives 0V using the positive probe. • Lastly, confirm using digital reads and print statements that the pin is receiving a LOW voltage.

Control System RV Table

Requirements	**Verification**
Each microprocessor should be able to communicate with the rest of the system	• Set up two ESP32s as communication partners using BlueTooth Low Energy to send signals between them.

within 100 milliseconds of receiving and sending out signals.	● Have the program output print statements of time when an ESP32 receives a signal from another ESP32 and transmits it back .
We can check that all the inputs to the ESP32 are 3.3V +/- 5%.	● Connect the proper power supply to each of the PCBs. ● For each of the PCBs, use a multimeter with the negative probe on ground. ● Touch positive probe to each battery/wall power and confirm it is outputting the right voltage for the given PCB (latch-12V, door-12V, remote-3.6V). ● Touch the power pin of the ESP32s with the positive probe to ensure that they are receiving 3.3V +/- 5%.
The correct data must be transferred to the ESP32 when programming each of the devices.	● Firstly, to ensure any data transmission, we can use the positive probe of a multimeter at each of the RX and TX pins of the ESP32 as we send data through UART, which should read 3.3V when the programmer is connected. ● Secondly, proper data checks can be performed through software checks, which involve sending data through GPIO pins and then using another oscilloscope check at that said pin.

Motorized Opener RV Table

Requirements	**Verification**
Ensure that modeled door opens up to a full 90 degrees in 3 +/- 0.15 seconds	● Use a protractor once the door is opened to measure that it has opened to the full 90 degrees. ● Have the program print statements of time from when the motor started spinning to open the door to when it stopped spinning at the full 90 degrees to ensure that it was opened within 3 seconds.
The door automatically stops upon feeling a significant decrease in rotational speed (<5 RPM) and re-opens the door.	● When the door starts to close, give it some resistance by trying to stop it from closing. ● Will use encoder signal feedback received through the GPIO pins to track the doors position. ● Through the software, check if the change in position has significantly decreased (0.5x), and then send a signal to the pin and remote for the door to open.
We must check that the voltage across the motor is 12V +/- 5V.	● Connect 12V power supply to the door PCB. ● Use a multimeter with the negative probe on ground.

	● Touch the positive probe to the voltage regulator input and confirm it is outputting 12V +/- 5%.
The 12V DC gear motor should be able to produce 0.3142 W of power.	● Connect 12 V power supply to the door PCB. ● Use a multimeter with the negative probe on ground. ● Touch the positive probe to the output of the motor driver and receive the voltage and current. ● Use the equation, P= V*I, to calculate the power.

Power System RV Table

Requirements	**Verification**
8 AA batteries in series should be able to produce 12 +/- 0.3V in order to power the solenoid actuator.	● Connect 12V power supply to the door latch PCB. ● Use a multimeter with the negative probe on ground. ● Touch the positive probe to the positive end of the battery and confirm it is outputting 12V.
Wall power should be stepped down to 12V to power the 12V DC gear motor. This should also be stepped down to 3.3V by the regulator to power the microcontroller.	● Connect 12V power supply to the door PCB. ● Use a multimeter with the negative probe on ground.

	● Touch the input of the voltage regulator with the positive probe to ensure it is getting 12V, this shows that the power adapter is stepping down wall power to 12V. ● Touch the output of the voltage regulator with the positive probe to ensure it is reading 3.3V.
Battery pack used to power the remote control should be outputting > 3.3V and less than 6V to comply with the LDO regulator.	● Attach the batteries to the remote control PCB. ● Use a multimeter with the negative probe on ground. ● Touch the input of LDO with the positive probe to ensure it is receiving at least 3.3V, but less than 6V. ● Lastly, ensure the output of the LDO regulator is 3.3V so that the rest of the remote is receiving an appropriate voltage.

Remote Control RV Table

Requirements	**Verification**
The decimal point on hex display should be able to properly indicate whether a door is open or close within 100 milliseconds of receiving the Bluetooth signal from the Motorized Opener Subsystem. (on = door	● Have the remote control program output a print statement of the time when the signal is first received from the door subsystem. ● Output print statements of the time

open, off = door closed).	when the GPIO outputs the correct signal to turn on the hex display.
A LED should be functioning properly to signal if the pairing is currently occurring.	● Have the program output print statements of what is currently occurring when the LED is on. ● This should include other devices that the remote control is connecting to. ● Turn off the LED when the remote control has finished pairing.
The buttons on the remote should be properly functioning and providing input signals to the ESP32.	● We can check the voltage of the positive end of each button before pressing using the positive probe of the multimeter. ● Have the negative probe of the multimeter on ground. ● The voltage while the button is not pressed should read 3.3V, and the pressed voltage should read around 0V. ● Additionally, print statements can be included within the program to print text whenever a specific button is pressed.