ECE 445
SENIOR DESIGN LABORATORY
PROJECT PROPOSAL

Automatic Door Conversion Kits

Team 83
Romeo Delgado (rdelg2)
Love Patel (lovep2)
Alexander Vega (avega40)

TA: Chi Zhang
Professor: Viktor Gruev

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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. So as citizens, we never have to think about how the systems got there and how they were paid for. However, installing similar accessibility systems in one's home for those with physical limitations is just as costly and difficult. Even for 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 a Bluetooth door opener, Bluetooth door handle, and Bluetooth remote. The door opener can be screwed onto both the door frame and the door, while the handle would be able to replace standard door handles. The Bluetooth door opener would be attached to the door you're converting and its frame, allowing it to be remotely close/opene with the Bluetooth remote. The door opener would have a box containing the electronics that run along the top of the door frame with the motor controlling the arm. The arm would be attached to the far sides of the door to allow the system to easily close/open the door. To allow the door to close/open remotely, its latch would also be replaced by a Bluetooth actuator that would close/open in sync with the door opener to allow it to swing freely. This latch would be stored within the handle, and would allow users to either turn the handle or press the close/open button on the remote to cause the latch to extend/retract. Lastly, the Bluetooth remote would be able to pair to multiple doors and have the capability to cycle between them. This would allow individuals to buy multiple sets and attach them to doors throughout the house if needed.

Since performing this demonstration on an actual door will prove to be difficult, we will scale down our design to work on a modeled door. The model version will have the same remote and door opener design. However, instead of modeling and installing a door handle, the electronics for the latch system will be placed on the door frame in another component box near where the handle would be on the door. The actuator would then simply protrude out in front of the door to represent the door being in the closed state, and then the actuator would retract the latch when the door is set to open.

1.3 Visual Aids

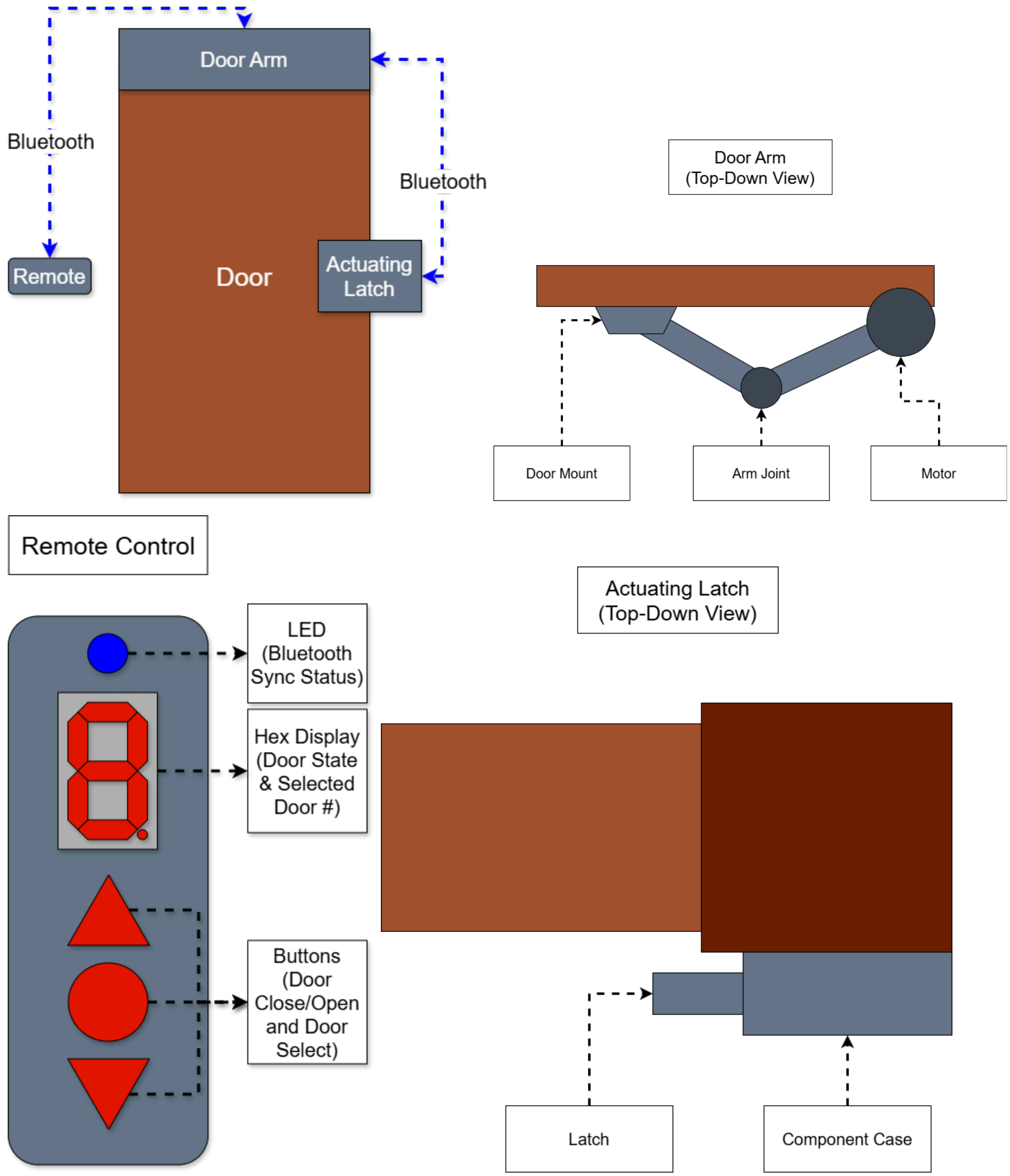

Figure 1. Automatic Door Conversion System Visual Diagram

1.4 High-level Requirements List

- For demonstrational purposes, the singular conversion kit will be placed on the door that should be able to fully swing open the 21 inch tall, 13 inch wide, and 5 lb door. The door should be able to fully swing close/open in approximately 3 seconds. A secondary kit will also be made that should still be able to fully extend or retract the arm in approximately 3 seconds. Each of these kits should be able to enter into a close/open state after receiving a Bluetooth signal. Since the system does not need to be extremely responsive, we require that either of the arms begin to contract/extend within ½ second.
- When the latch system is given a bluetooth signal to open, the actuated latch must retract within ¼ second to allow the door to swing freely. The latch system can then extend once again after 1 second. The latch system should retract long enough for the door to open once again.
- The bluetooth remote is able to pair with at least 2 automatic door conversion kits, as well as display and switch between which door is being targeted to close/open. The remote will be able to send close/open signals to the targeted door while also displaying each door's closed/open state.

2. Design

2.1 Block Diagram

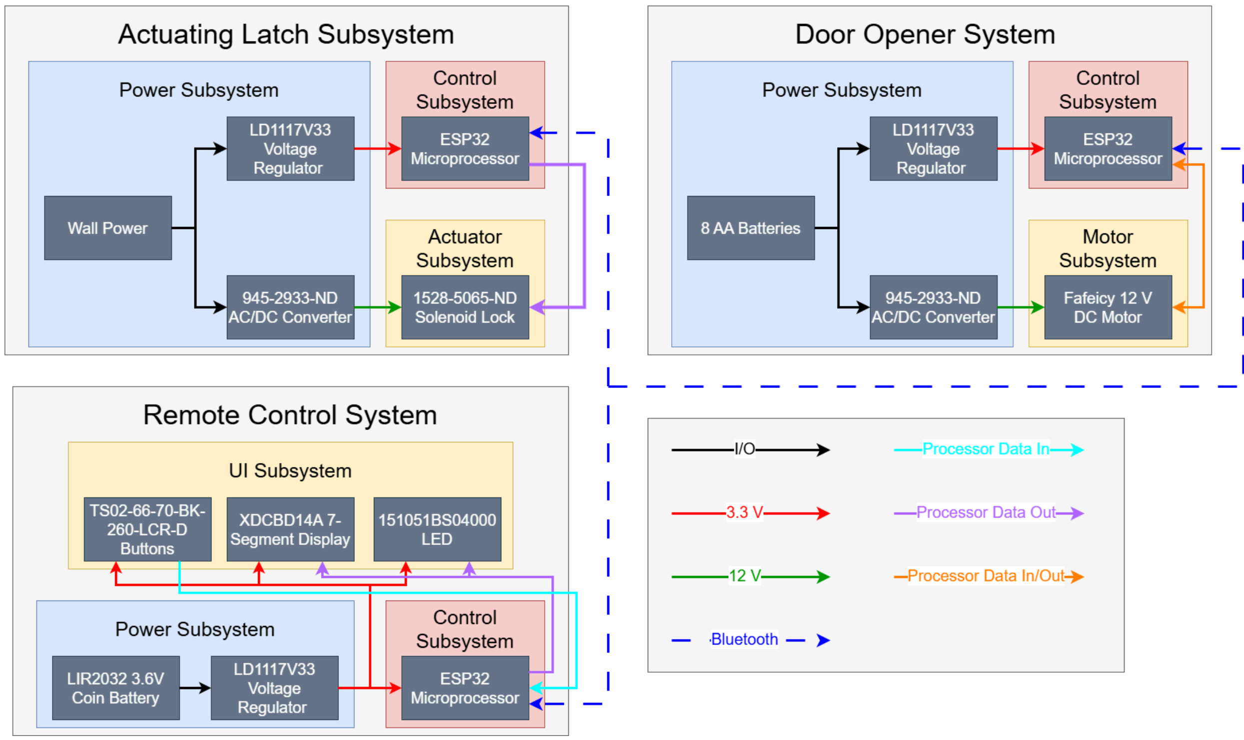

Figure 2. Automatic Door Conversion Kit System Block Diagram

2.2 Subsystem Overview

2.2.1 Actuating Door Latch Subsystem

- This subsystem receives a bluetooth signal from the main door microcontroller, indicating whether the door has been opened or closed. This communicates with a separate microcontroller, which communicates with the actuator to push or pull the latch back. The latch will be pushed out when the door has been closed, and it will be pulled in when the door has received the signal to open. As confirmation that the latch has been pushed or pulled, the bluetooth transceiver will send back a signal that the action has been completed. Everything will be powered by the batteries and the voltage will be regulated to comply with the actuator.
- Inputs: Bluetooth Signal (Door Opener Subsystem), 12V, and 3.3V
- Outputs: Bluetooth Signal (Door Opener Subsystem), Latch Extension/Retraction

2.2.2 Door Opener Subsystem

- A 10 RPM, 12V motor capable of producing 0.3 Nm of torque, allowing the closing/opening of residential doors through the jointed door arm. This subsystem receives bluetooth signals from the remote control, indicating that the door is to be closed/opened. The microcontroller in this subsystem will track the current state of the door. When a signal is received to open the door, the microcontroller will send a signal to the door latch subsystem to retract. Once a signal is received back from the door latch subsystem, the microcontroller will then open/close the door by signaling the motor to rotate. This will result in the motor closing/opening the door through the door arm. Once the door begins to close/open, a signal will be sent to the remote control, indicating that the state has changed.
- Inputs: Bluetooth Signal (Actuating Door Latch Subsystem and Remote Control UI Subsystem), 12V, and 3.3V
- Outputs: Bluetooth Signal (Actuating Door Latch Subsystem and Remote Control UI Subsystem), Arm Extension/Retraction, Door Closing/Opening

2.2.3 Power Subsystem

- The power system will have a few functionalities since there will be multiple systems that need to be powered with different batteries. The remote control will be powered by a 3.6V lithium-coin battery that will go to a voltage regulator, which will output 3.3V to the rest of the components in the battery. The DC gear motor with an encoder and microcontroller will be powered by wall power. This power will be converted into 12V for the motor and 3.3V for the microcontroller with the use of a voltage regulator. The actuating latch will be powered with 8 1.5V AA batteries and converted into 12V for the actuator. The 12V will be stepped down to 3.3V using a voltage regulator for the microcontroller in the latch subsystem.
- Inputs: Wall Power, 8x 1.5V AA Batteries, 3.6V Lithium Coin Battery
- Outputs: 3.3V (Remote), 12V (Motor and Actuator), and 3.3V (Rest of Door Opener and Latch Subsystem)

2.2.4 Remote Control UI Subsystem

- The remote control has UI elements including 3 buttons, a 7-segment display, and an LED. All three of the buttons connect directly to the processor, with 2 of them being used to select which door is currently being targeted, and the 3rd being used to sync the remote to a door and close/open the door that is currently being targeted. The 7-segment display will display the number associated with the door that is currently being targeted as well as whether that door is closed/opened on the DP dot of the display. Finally, the LED will be lit if the remote is currently on and paired to a door.
- Inputs: 3.3V, Microcontroller Signals, User Button Input
- Outputs: Button Outputs, Hex Display, LED Light

2.2.5 Control Subsystem

- All of the Microcontrollers will communicate with each other via Bluetooth. This includes the door communicating with the remote about door status and the door opener subsystem communicating with the door latch subsystem about latch status. This system handles any logic such as door status, motor RPM output, and determines when signals should be sent to motors, actuators, and displays.
- Inputs: 3.3V (All microcontrollers), Bluetooth signals
- Outputs: Bluetooth signals, Control Signals (Motor, Actuator, Display, etc.)

2.3 Subsystem Requirements

2.3.1 Actuating Door Latch Requirements

- Transceiver receives signal from sensor such that the solenoid latch can disengage within ¼ of a second
- Transceiver signals back to the door opener microcontroller within ¼ second

2.3.2 Door Opener Requirements

- Ensure that modeled door opens up to a full 90 degrees in 3 +/- 0.25 seconds
- Significant decrease in rotational speed (<9 RPM) results in door opening

2.3.3 Power Requirements

- 12V DC gear motor should be able to produce 0.3 Nm of torque and 0.3142 W of power
- 8 AA batteries should be able to produce 12 +/- 0.3V in order to power the solenoid actuator
- Wall power should be stepped down to 12V to power the 12V DC gear motor
    - Should also be stepped down to power the microcontroller
- LIR2032 should be used to be able to power the remote control
- Every other modules in the system will be powered by 3.3 +/- 0.3V
- We will use a voltmeter on the parts to ensure they are receiving the correct voltage

2.3.4 Remote Control UI Requirements

- A led should be able to properly indicate whether a door is open or close within 100 milliseconds of receiving the Bluetooth signal from the Door Opener Subsystem
- Another led should be functioning properly to signal if the paring of the device was successful or not also within 100 milliseconds of receiving the Bluetooth signal from the Door Opener Subsystem
- For high responsiveness, the display should display the correct door number within 150 milliseconds of pushing the cycle buttons

2.3.5 Control Requirements

- Each microprocessor should be able to communicate with the rest of the system within 100 milliseconds of receiving and sending out signals

2.4 Tolerance Analysis

In this analysis, we will be using the following equations to determine the torque and the power that our motor needs to produce.
The torque equation is the following:

$$\tau = F\,x\,r$$

F = force need to move the door
r = distance from the hinge where the force is applied

But since this will be rotational force, we will be using moment of inertia and angular acceleration:

$$\tau = I\alpha$$

I = inertia
$\alpha = angular\ acceleration$

The Inertia equation is the following for a door:

$$I = \frac{1}{3}mL^2$$

m = mass of door
L = width of door

The angular acceleration equation is the following

$$\theta = w_i t + \frac{1}{2}\alpha t^2 \ -> \ \alpha = \frac{\theta * 2}{t^2}$$

$w_i = initial\ angular\ velocity$, 0 since initially at rest
t = time to open door completely to 90 degrees

So,

$$I = \frac{1}{3} * 2.27 * 0.33^2 = 0.082401\, kg * m^2$$

and,

$$\alpha = \frac{\pi/2*2}{3^2} = 0.3491\, rad/s^2$$

So the torque is:

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

Now to determine RPM, we will find the angular velocity in rad/s and convert it to RPM:

$$w_f = w_i + \alpha t$$

$w_i = initial\ angular\ velocity$, 0 since initially at rest
$\alpha = angular\ acceleration$
t = time to open door completely to 90 degrees

So,

$$w_f = 0 + 0.3491 * 3 = 1.0472\, rad/s$$

$$\frac{1.0472 * 60}{2\pi} = 10.00\, RPM$$

The power equation is the following:.

$$P = \tau\, x\, w$$

$$\tau = torque$$

w = angular velocity

So,

$$P = 0.3 * 1.047 = 0.3142\, W$$

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

3. Ethics and Safety

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.

Sustainability and Environmental Responsibility: Since we have considered using batteries that are disposable such as the AA batteries, 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 UI subsystem, the LiR2032 3.6V battery is rechargeable in an attempt to reduce waste.

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. References

[1] Espressif Systems. *ESP32 Series Datasheet Version 4.8*. www.espressif.com/documentation/esp32_datasheet_en.pdf.

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

[4] 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.

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