

### Introduction

Design and build a mechanical regenerative door opener with a built-in removable battery pack to operate independently of the building's electrical grid. Accessibility impaired and health-conscious individuals currently have a need for contactless doors. This project will improve accessibility by enabling door usage without any physical interface. The project scope includes model-based design and prototyping of a mechanical, electrical, electronic and software integrated system.

### Project Motives



#### Limitations of Current Products

- In-market products need to be connected to electric grid
- Battery powered door operation is a niche market
- Regenerative energy conversion not widely applied for door operation systems



### Design Specifications

#### Constraints

4:1 ratio of manual to automatic door operations while ensuring the device is independent of the electrical grid

Regenerative Battery Mechanism



The time taken to close the door from 90° to 12° should be greater than 5 seconds to prevent the door from operating too quickly

ANSI 117.1 & ADA Standards



Manufacturing cost of the system should be under \$800 CAD and ensure all standard safety requirements are met

Cost and Safety Considerations



#### Criteria

The battery pack should be removable in less than 12 minutes to ensure ease of replacement

Battery Training & Replacement



The maximum time the door remains open should be less than 15 seconds to avoid burnout/over-heating of the motor

Device Operating Conditions



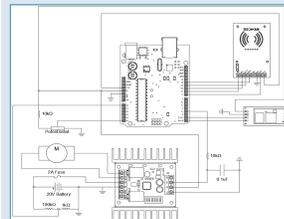
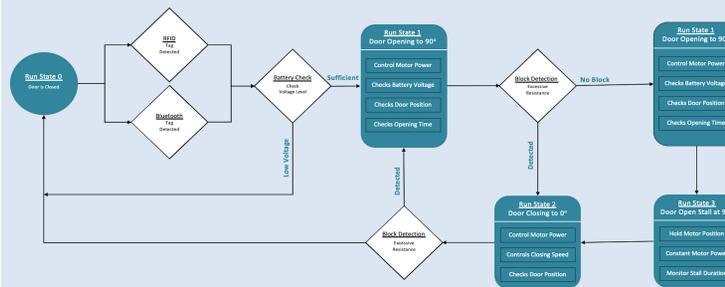
The total weight of the device should be <math>\leq 5\text{ kg}</math> and should be able to achieve 10 consecutive uses of automatic door operation without failure

Prototype Specifications

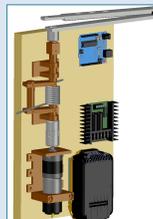


### Solution Analysis

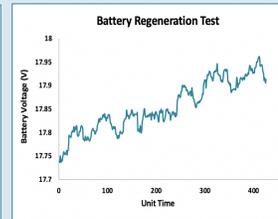
#### Process Flow Diagram



Electrical Circuit Diagram: Electrical CAD drawing including major components: Motor, Battery, Arduino UNO, RFID, Bluetooth, & Potentiostat. Necessary wiring connections, resistors, and capacitors to ensure proper device operation are shown as well.



System Design Model: 3-D model designed in Autodesk Inventor. The model holds all the components while optimizing space within the enclosure.



Battery Regeneration Trend: The figure displays the regeneration trend of the battery over a time period of manual door operations. The increasing trend indicates the battery being recharged.

### Product Impact

#### Health & Safety

- Product complies with ADA, AODA, ANSI 117.7 & ANSI 156
- Battery safety through restricted battery access
- Control systems to restrict current output and prevent high charge flow

#### Sustainability

- Reduced fossil fuel dependence through regenerative energy conversion
- Product complies with EPA standards

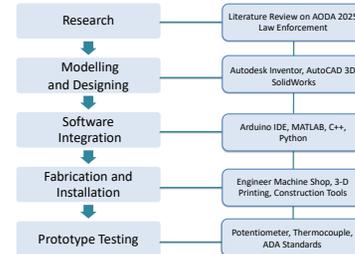
#### Economic

- Production upscaling will lower future potential BOM costs
- Improved vendor relationships for scaled production
- Low installation costs due to minimal electrical connections

#### Social & Cultural

- Product is geared towards serving persons with disabilities who require inclusive accessibility services.
- Touchless interface prevents spread of harmful germs and viruses

### Method of Analysis



### Selected Solutions

#### Motor Selection

- Geared DC motor 24 VDC 82 rpm 1.6 N-m
- Desired strength, application, and cost

#### Battery Selection

- 20V Lithium-ion battery, 5Ah
- Desired voltage, performance, and cost

#### Touchless Selection

- RFID Technology
- Ease of integration, applicability, and mass production

### Future Development

Introduce use of two speed gearbox to optimize power regeneration. Power generated from Electric DC Motor is proportional to angular velocity.

Refine selection of DC Motor to ensure its nominal operational RPM is near maximum efficiency. DC motors follow a RPM and efficiency curve.

Purchase higher power output motors to test device on heavier doors.

Introduce a left-wound torsional spring that has a greater spring constant value to generate a stronger push to close the door which will improve the regenerative mechanism.

### Acknowledgements

We would like to thank Dr. Michael Fowler for providing technical support and guidance in reaching our project objectives.

#### References

- George Ellis, in Control System Design Guide (Fourth Edition), 2012
- Yasar Demirel, in Comprehensive Energy Systems, 2018