Design of Automated Residential Window System

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***Abstract*—The Automated Window System enables users to raise and lower residential single-hung windows from any web enabled device capable of browsing the web. It allows for opening and closing the windows to five different levels, as well as automatically locking the window in the desired position. Additionally, it is designed to be user-friendly, allowing users to operate the window at a simple click of a digital button from anywhere in their homes. The design includes precision magnetic limit switches for accurate and consistent opening and closing to desired levels. All devices required to operate the system can be powered from a single electrical connection.**

I. Introduction

Homeowners often turn to electric cooling systems to regulate the temperature in their homes. Often this is done more so out of convenience than necessity. Navigating throughout a home to open windows to create airflow is a burden for some, and others may struggle to raise and lower windows. Utilizing electronic air conditioning to alleviate these issues increases power consumption considerably. Although this may seem minor, air conditioning systems alone account for 17% of the total residential electricity usage [1]. Utilizing this automated window system aims to not only add convenience to users, but also decrease overall residential power consumption by increasing the usage of home windows.

II. Methods and Materials

The goal of this project was to create a system that is extremely easy to use, remains quiet during operation, and creates results that are accurate and repeatable. This was accomplished utilizing high quality materials and controls. The result of this project is a highly functioning proof of concept.

A. Two 12VDC Worm Drive Gear Motors

The primary goal of the project was to raise and lower the window consistently with minor alterations to a standard residential single-hung window. Overcoming the natural friction of a window, as well as lifting the weight of the window, is a challenge for most small DC motors. This challenge was overcome by utilizing worm drive gearboxes in conjunction with the motors in order to reduce speed, but increase the torque tremendously. The result is smooth operation in a small package.

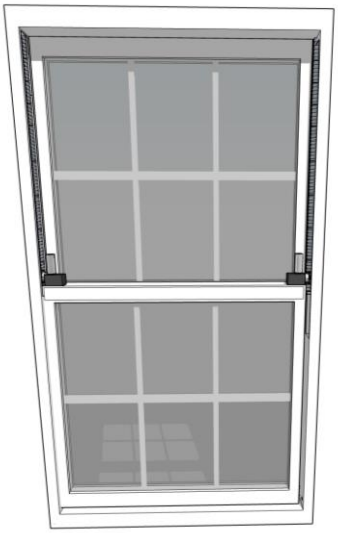

Figure 1: DC Motors Mounted on Window Ledge

B. Rack and Pinion System

In order for the motors to lift the window, a mechanical connection point is necessary. A 1018 carbon steel rack is mounted inside the window channels and hidden from view of the user. These racks span the entire length of the upper portion of the window. High precision machined pinions are mounted on each motor to engage the rack. The motors and pinion travel with the window during operation.

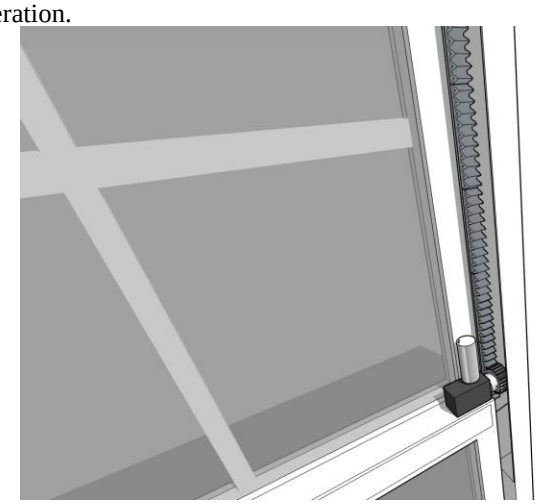

Figure 2: Rack and Pinion System

C. Raspberry Pi Zero W

To control the system and generate a web server for user input, a Raspberry Pi Zero W is utilized. Using a single-board-computer allows for seamless integration with the users existing wireless network, as well as motor controls that are fast and precise. Dedicated pulse-width-modulation GPIO pins allow for motor speed control to be tailored to each individual application of the system. Utilizing a board with 40 GPIO pins allows for the system to be expanded to multiple windows without the need of an additional control board.

D. 120VAC to 12VDC Transformer and 5VDC Converter

Another goal of this project was to produce a system that can be powered from a single electrical connection. This created a challenge due to the various voltages required for each design element. To accomplish this, a transformer is used to convert a standard residential power system to a 12VDC signal suitable for the motors used. Additionally, powering the Raspberry Pi through its GPIO pins requires a steady 5V, 1.2A signal. A transformer rated for 5A output current is used to provide sufficient current to both the computer, and the motors, even under load.

E. Motor Driver

In order to utilize the 3.3v GPIO output voltage to adequately operate the 12v motors, a motor driver H-bridge is used. When connected to 12v power from the transformer, no additional power sources are required to use the system.

F. Magnetic Limit Switch and Neodymium Disc Magnets

A limit switch is necessary within this design to safely turn off the motors when the window has raised or lowered to the user specified level. Due to space constraints within a standard window, a magnetic switch is used to eliminate the need for any physical contact. In conjunction with the magnetic switch, several neodymium disc magnets are mounted allowing the window to engage the switch at the various positions. This allows the window to raise and lower to exact positions consistently, with little to no maintenance required or excess friction created.

G. Pulley and Counterweight

This design requires motors to travel approximately two feet while the window is in motion. This creates complications due to the distance in which the wiring to the motors must travel. To create a higher level of aesthetic, pulleys are mounted on the outer framing of the window, and use a counter-weight to smoothly retract extra wire when the window is raised. This allows for all slack to be retracted away from view of the user, and eliminates the risk of damage to the wiring.

III. Results and Discussion

The prototype was designed to enable integration to existing windows in the user's home. To accomplish this, the design requires minimal alterations to the window itself, and all components are mounted on the exterior framing, with the exception of the lifting mechanisms. The prototype was fully developed and tested, and shown to create consistent and accurate results, well within design parameters. The user interface was developed to provide users exceptional ease of operation, as well as important information at their fingertips. This information includes current window position, as well as hourly and daily local weather.

IV. Conclusions

The prototype developed as a result of this project was largely successful. Due to the space limitations and variety of residential windows on the market, more alterations to the window were necessary for successful operations than originally anticipated. However, this remained within acceptable levels as determined by the development group. Overall goals of the project include consistent raising and lowering, ease of use, a single power source, an aesthetically pleasing design, and quiet operation. The use of high torque motors, and high-quality rack and pinion system allow for complete functionality with repeatable results that meet all design goals.

V. Acknowledgements

The success of this project was largely facilitated by the overall support and guidance of our faculty advisor Dr. Donald Zinger. Additional gratitude is extended to the team's graduate advisor German Ibarra. We would additionally like to thank Northern Illinois University College of Engineering for the organization and development of this program.

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[1] U.S. Energy Information Administration - EIA - Independent Statistics and Analysis. (2015). https://www.eia.gov/energyexplained/use-of-energy/electricity-use-in-homes.php)