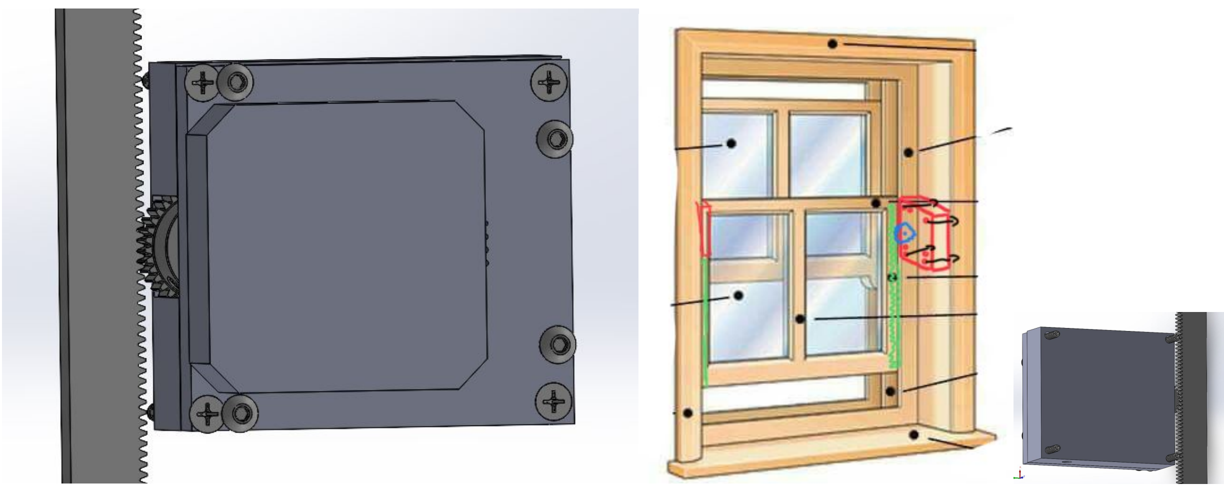
The Automatic Window Opener and Closer

By Zachary ElShaer

Motivation and Description for the Product:

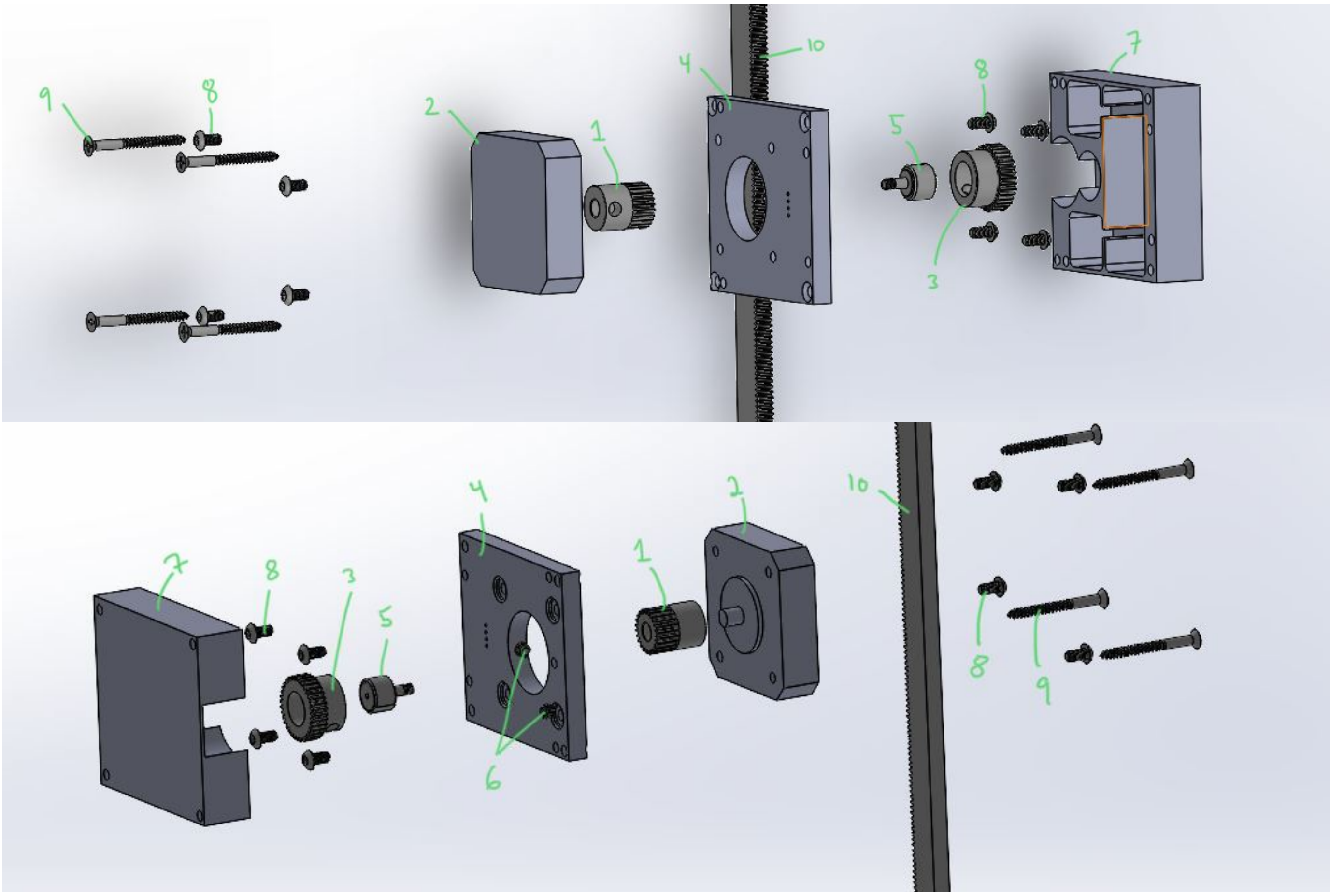
Over the course of the semester I encountered a need or desire to remotely open my windows in my house without calling and asking my sibling to do it for me. In one instance, I left my window open and it started raining and ended up soaking a bunch of my notes. I also noticed that (depending on where you live) there was a good period of the year where opening the windows would have allowed my room to cool off or warm up just as well as running the AC/Heat with the added bonus of bringing in fresh air and saving energy. So my goal was to develop something that would integrate with smart home thermostats (Nest, Honeywell etc.) that would allow home windows to open and close automatically. The functionality would allow it to open and close windows based on temperature differences between the inside and outside of the building, humidity differences, and presence rain. It would also allow the user to remotely open and close the window from a smart phone, and alert the user if the window was manually opened (perhaps for security purposes). I developed a CAD prototype of the product, which includes everything except the microcontroller, motor controller, sensors, wiring, and neutral switch (for manual opening). However, I planned for where they would mount in CAD.



Figure(s) 1: The front and back views of the entire enclosure. The rack (geared track) attaches vertically to the edge of the window, and the motor enclosure attaches to the side of the window frame.

This design is intended to be used with basic double hung or single hung sliding windows with wooden frames. It includes a pancake stepper motor, which was rated for being able to break the initial friction force to open older windows. It also very compact and allows for precise opening and closing movement. The motor is mounted to an enclosure which then mounts to the outer non moving frame of the window. Connected to the motor shaft is a gear, held on with a set screw. This gear drives an idler gear, which is mounted to a cam roller, which threads into the same plate as the motor. The idler gear then runs along a rack (as a pinion) that will be mounted to the window vertically, and cause the window to slide up and down when the motor rotates. The motor and gears are all enclosed by a backing plate, which also neatly houses an esp32 controller, a stepper motor driver, and internal sensors. There is an outlet hole for the motor power cable and external rain sensors. The goal of this design was to, keep it simple, keep it compact so that the motor is not an eyesore, and verify functionality. With the current design, two motors and racks will be needed on either side of the window.

Parts List:

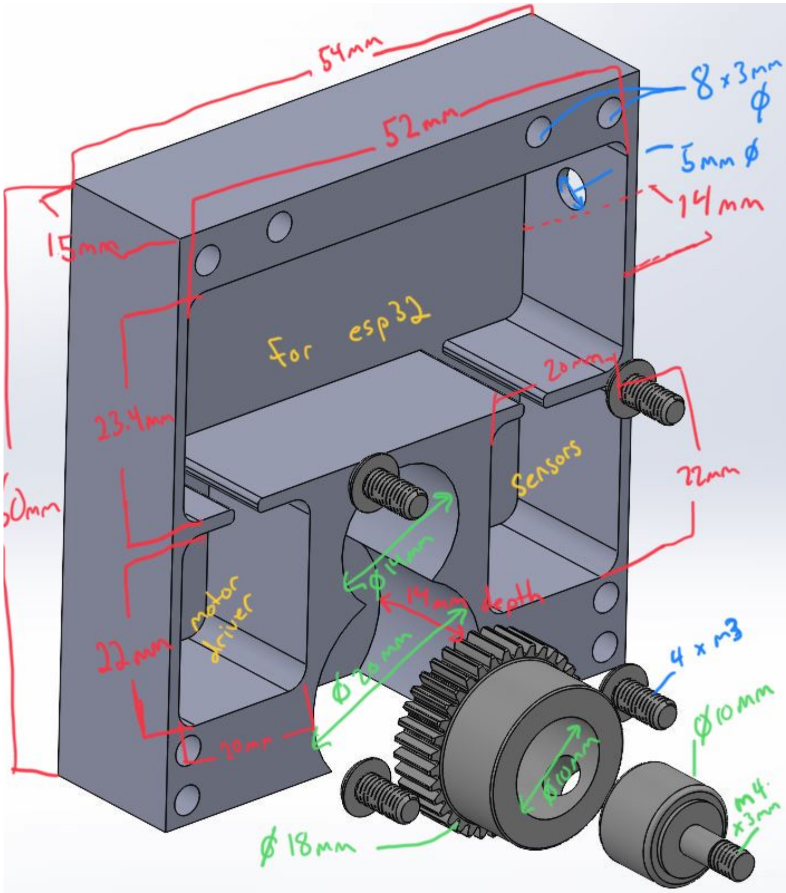


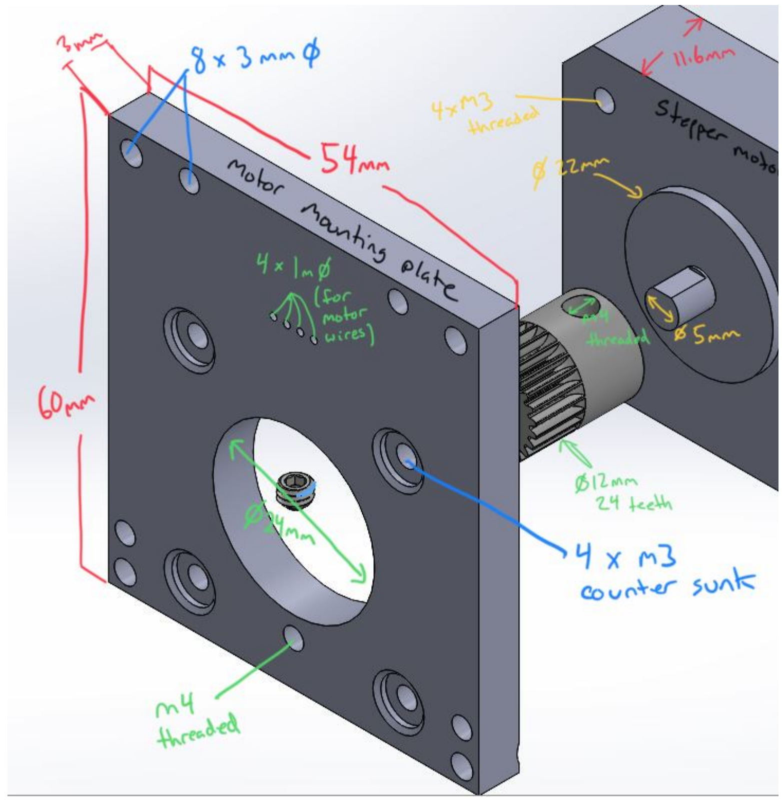
Figures 2 and 3: Exploded view with parts labeled by Item No.

PART NUMBER & VENDOR	DESCRIPTION	QTY.	ITEM NO.
McMaster #2664N316	Metal Gear - 20 Degree Pressure Angle (24 teeth, 12 mm pitch diameter)	1	1
Pololu #2298	Sanyo Pancake Stepper Motor (42 mm x 11.6 mm)	1	2
McMaster #2664N321	Metal Gear - 20 Degree Pressure Angle (36 teeth, 18 mm pitch diameter)	1	3
In House #1	Motor Mounting Plate - Machined 6061 Aluminum	1	4
McMaster #6314K14	Threaded Cam Roller Bearing	1	5
McMaster #91390A403	M4 * 3mm Alloy Steel Cup Point Set Screw	2	6
In House #2	Enclosure Back Plate - Machined 6061 Aluminum	1	7
McMaster #92095A179	M3 * 8mm Button Head Hex Drive Machine Screw	8	8
McMaster #90031A117	Philips Flat Head Screw For Wood (1.25 inches)	4	9
McMaster #2485N241	Metal Gear Rack—20° Pressure Angle (0.5 Module)	1	10

Key Dimensions and Calculations:

The enclosure plate needed to be large enough to house both the gears and the electronics for the system.





Figures 4 and 5: Show the annotated dimensions of the enclosure (left) and mounting plate (right).

Using a simple spring scale to measure the initial force needed to open a window in my home, I found the force was about 20 N to initially get the window moving. So I know I need a motor that can exert at least 10 N of force since I plan to use two motors on each side of the window.

Pololu's stepper motors come in a vast amount of sizes. I backtracked and found the smallest pitch diameter gear on McMaster in order to maximize force given a motor torque. This gave me the equation:

Motor Torque / Pitch Radius of Output Gear = Force on Rack
Motor Torque / .006 m = 20N / 2

Motor Torque = .06 Nm

This allowed me to find the most compact motor with a holding torque of at least .06 Nm. The motor specified in the BOM I found to have a holding torque of .08 Nm and be extremely compact.

The only other crucial calculations were the specifications of the idler gear/pinion. I took the referenced output gear, which had 24 teeth and a pitch diameter of 12mm. This gave me a module of 0.5. With this module value, I just had to make sure the idler gear/pinion and the gear rack would have the same value of 0.5 and the same pressure angle of 20 degrees.

Manufacturing and Future Considerations:

The manufacturing of my design is very basic. First, we have all of the off the shelf parts. Of these parts, a flat needs to be cut on the motor output shaft and the cam roller bearing so that the gears' set screw can mount to them. The only things left to be manufactured is the motor mounting plate, and the enclosure. Both of these could easily be prototyped with 3d printing. However, assuming costs are low, the plate and enclosure would likely have to be machined aluminum on either a mill or in CNC. A few of the holes on these parts need to be tapped with an M3 or M4 thread size. Then the assembly of the system is very straightforward using the specified bolts and screws. An alternative to this, for mass production, would be to make the enclosure and plate using injection molded plastic and adhesive. This would eliminate the need for a lot of the screws and cut long-term cost, but would need to be verified and optimized for the given loads. Overall, this design has limitations. The first being that the motor requires power and windows aren't always near outlets. The second is that the cost of the motor alone is very high. The third is that it requires you to drill into your window. Going forward I would like to explore the electronic implementation and physical prototyping as well as potentially explore using a pulley system from the top of the window frame instead of mounting the motor on the side.