THE OHIO STATE UNIVERSITY

Manhattan 2 Active Window Team

Thermally Turning Windows Into Walls

Final Presentation

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Team Introduction

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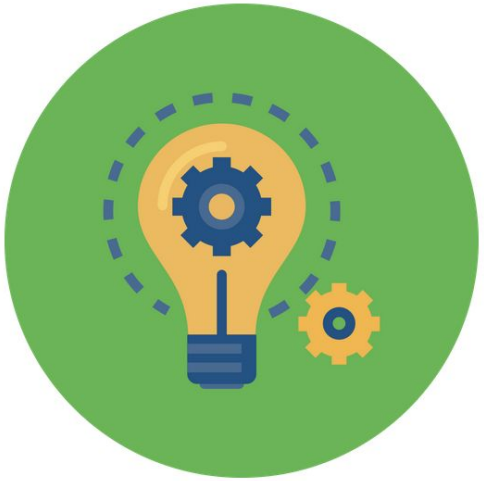
Agenda

- Problem Definition
- Project Motivation
- Preliminary Design
- Design Selection
- **Prototype Construction**
- **Results & Lessons Learned**
- **Next Steps -or- Recommendations**



Problem Definition

On average, buildings in America lose 25% of energy through windows which is causing typical household owners and renters to pay more in heating and cooling every year.

Project Motivation

- **10%** of total U.S. energy consumption is dedicated to heating and cooling homes
- Average household leads to **17,320 lbs of CO_2**
- Installing storm windows can reduce energy lost through windows by 25-50%

source: https://rpsc.energy.gov/energy-data-facts

Preliminary Mechanical Designs

- Car Window
- Trifold
- Lead Screw
- Venetian
- Counter Weights
- Belt Drive
- Linear Induction Motor
- Garage Door Style Linkages
- Servo + Actuators
- Piston
- Chain + Magnet

Mechanical Concept Screening

Categories of Selection Criteria

1. Affordable
2. Energy Efficient
3. Ability to be Concealed
4. Serviceable
5. Usability
6. Standard for Installation

Concept	Score
Car Window	7
Trifold	9
Lead Screw	13
Venetian	5
Counter Weights	7
Belt Drive	3
Linear Induction Motor	1
Garage Door Style Linkages	3
Servos + Actuators	5
Piston	5
Chain + Magnet	7

Threshing Results: Ranking Concepts

Version 1

1. Chain Drive
2. Counter Weight
3. Lead Screw

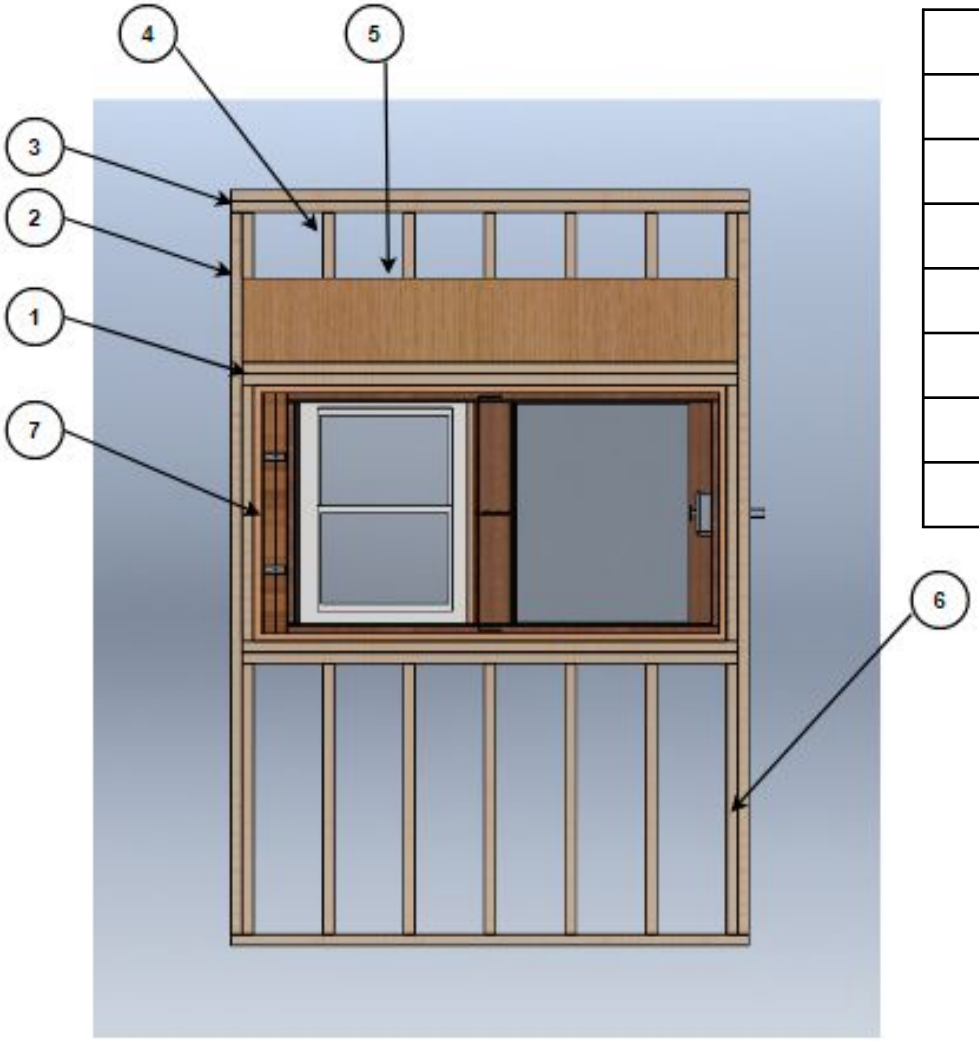
Version 2

1. Lead Screw
2. Chain Drive
3. Car Window

Version 3

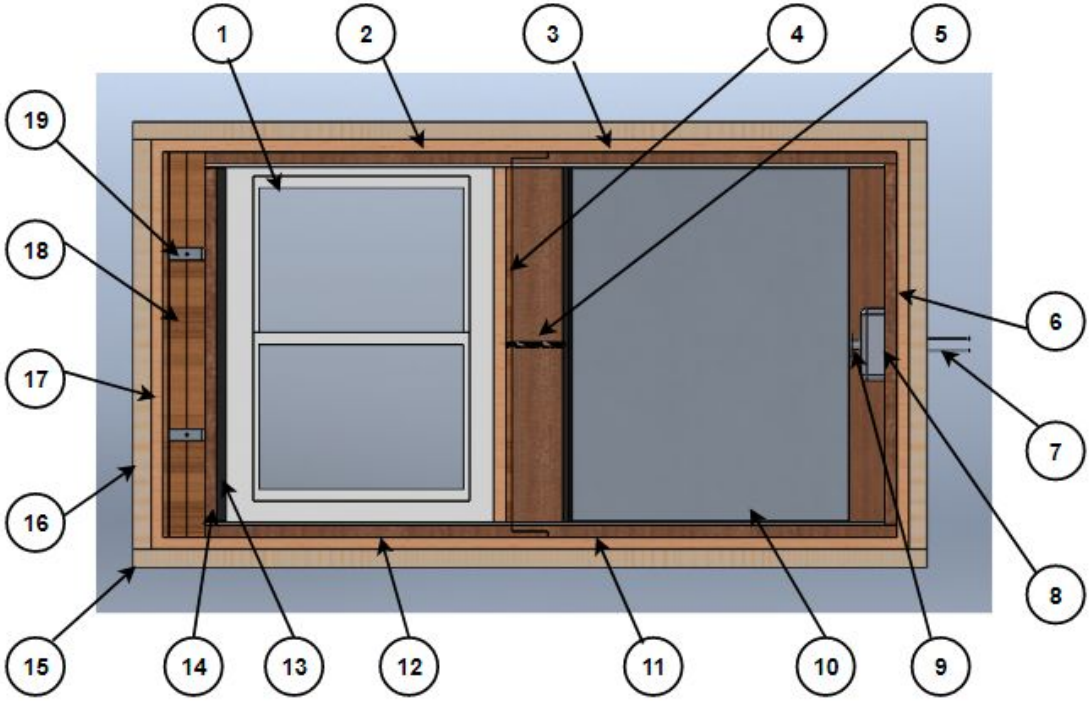
1. Chain Drive
2. Counter Weight
3. Lead Screw

Part Identification:



Identifier	Item	Quantity
1	Exterior Sill Plate	2
2	King Stud	2
3	Top-Bottom Boards	3
4	Cripples	7
5	Header	2
6	Jack Stud	7
7	Rough Opening	1

Part Identification 2:

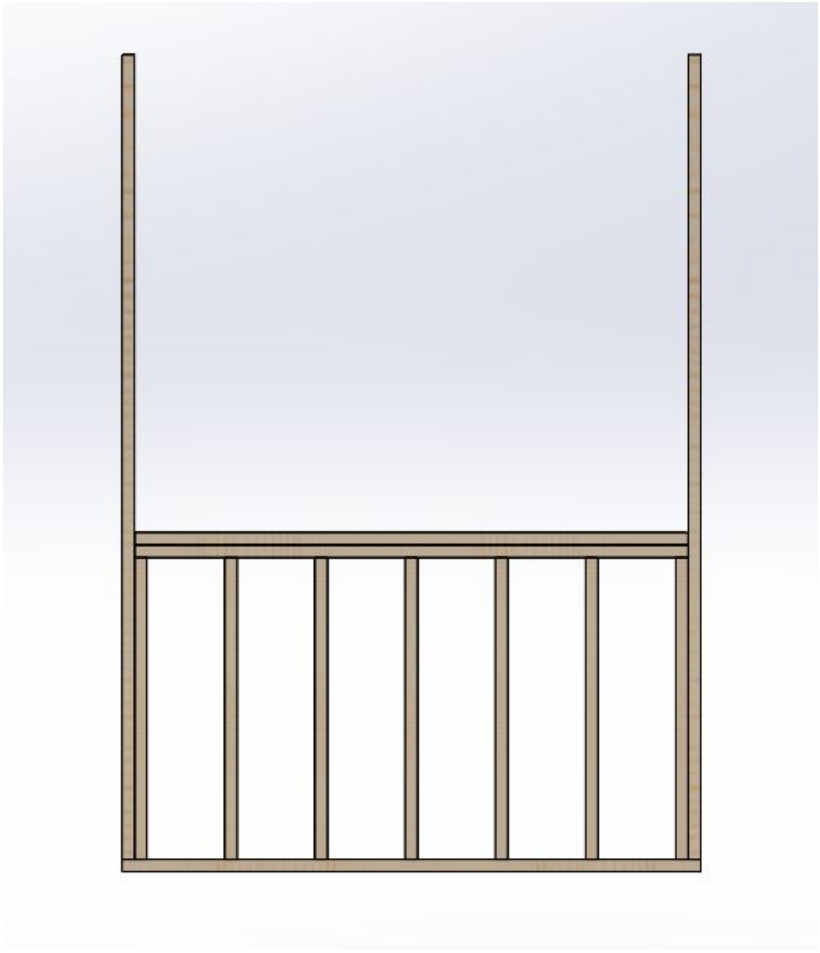


Identifier	Item	Quantity
1	Window	1
2	Top Left Box Leg	1
3	Top Right Box Leg	1
4	Window Casing	1
5	Lead Screw	1
6	Back Box Leg	1
7	Ribbon Connector	1
8	Electrical Box	1
9	Ball Nut	1
10	Cover	1
11	Bottom Right Box Leg	1
12	Bottom Left Box Leg	1
13	Cover Gasket	2
14	Front Box Leg	1
15	Sill Plate	2
16	Jamb	2
17	Box Casing	1
18	Added Supports	5
19	L Bracket	2

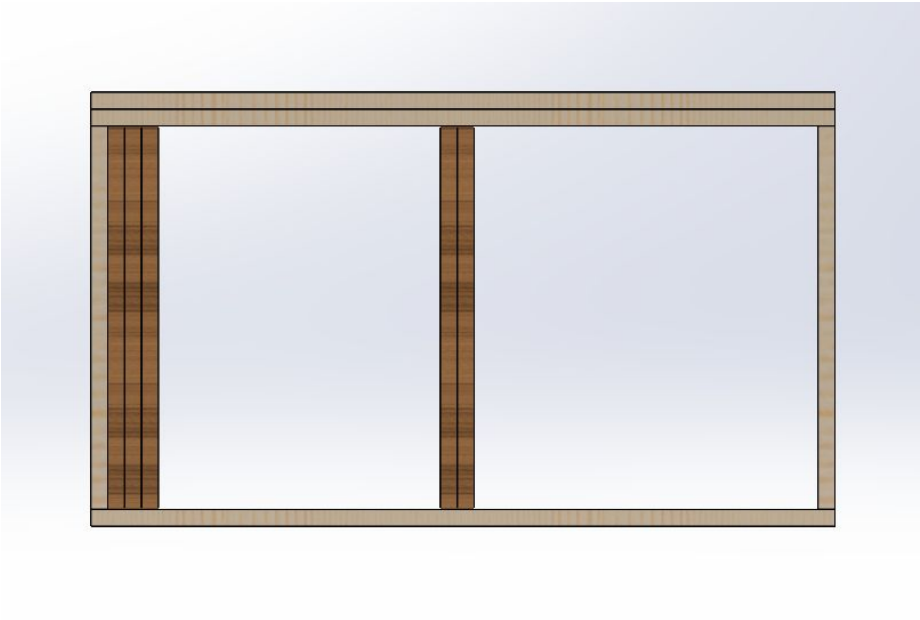
Construction Steps:

1. Construction of Main Wall
2. Construction of Casing and Supports
3. Construction of Box, Leveled
4. Construction of Window Cover Module, fit to Box
5. Integration of Sub Assemblies and Electrical Box

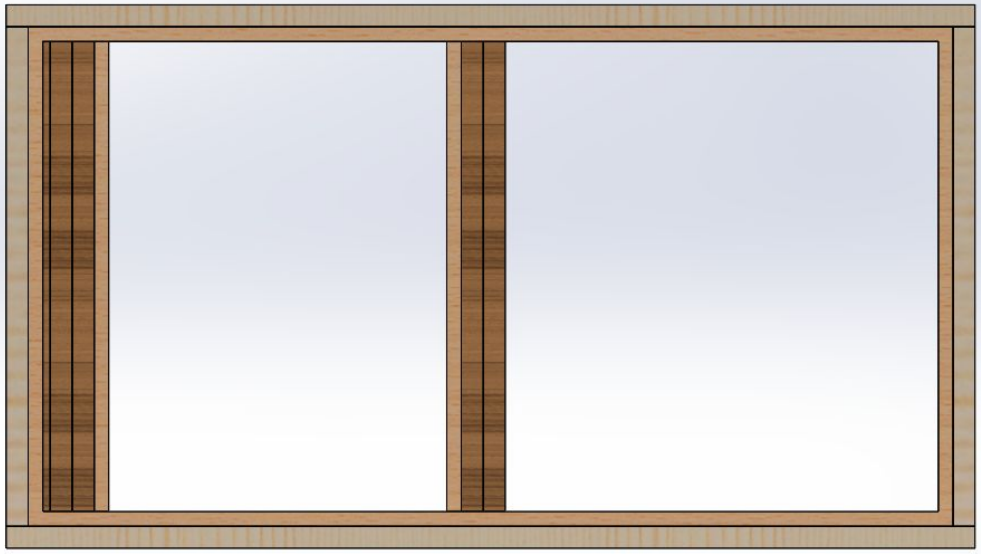
Construction Steps Wall Frame:

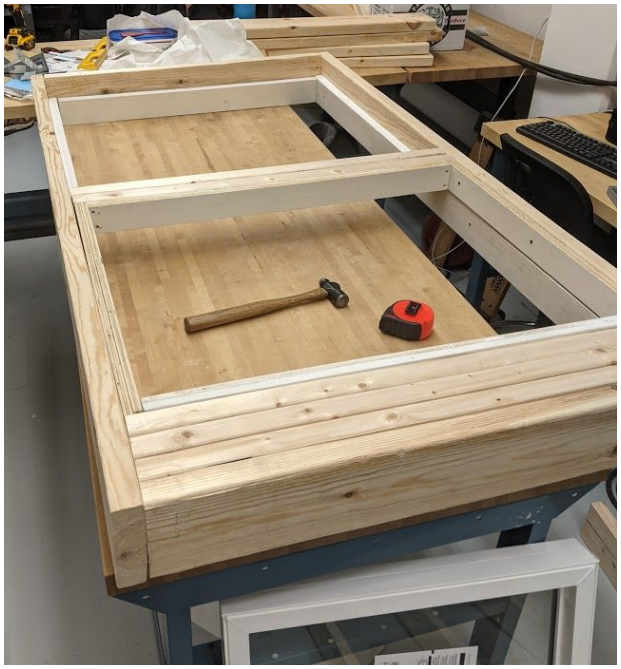


Construction Steps Rough Opening:

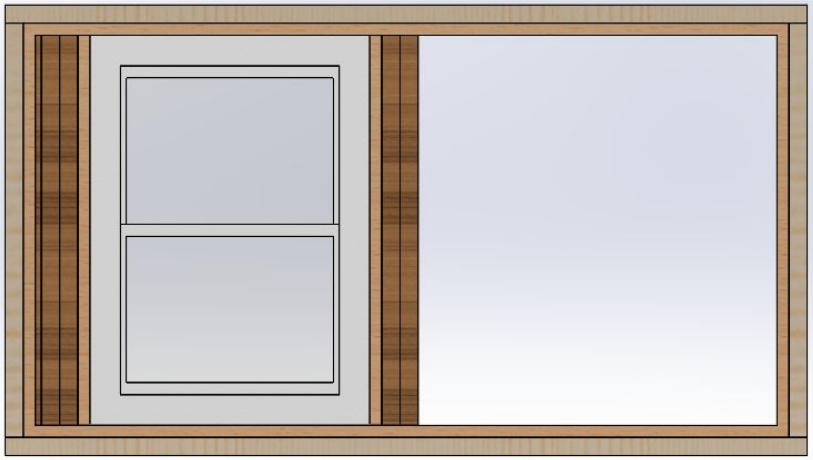


Construction Steps Rough Opening-Casing:

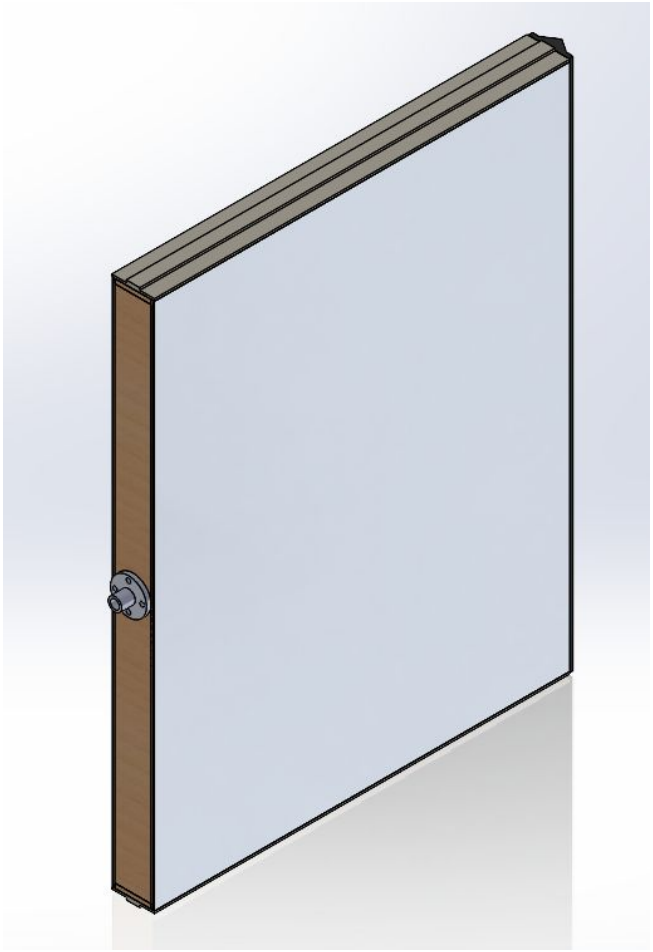


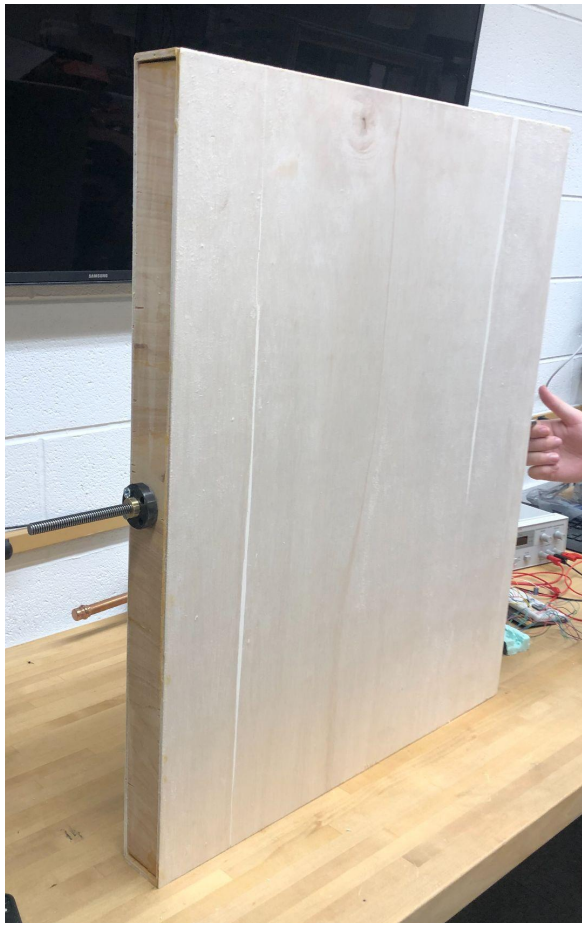


Construction Steps Window:

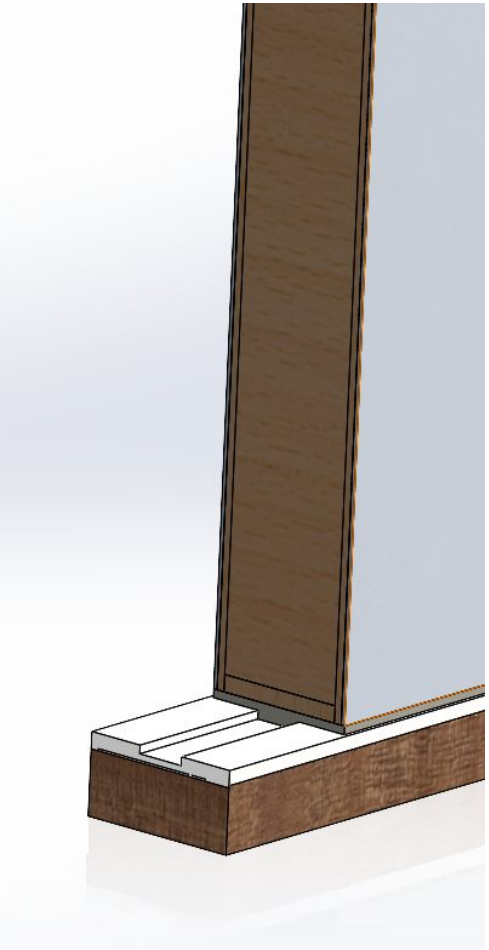


Construction Steps Cover:

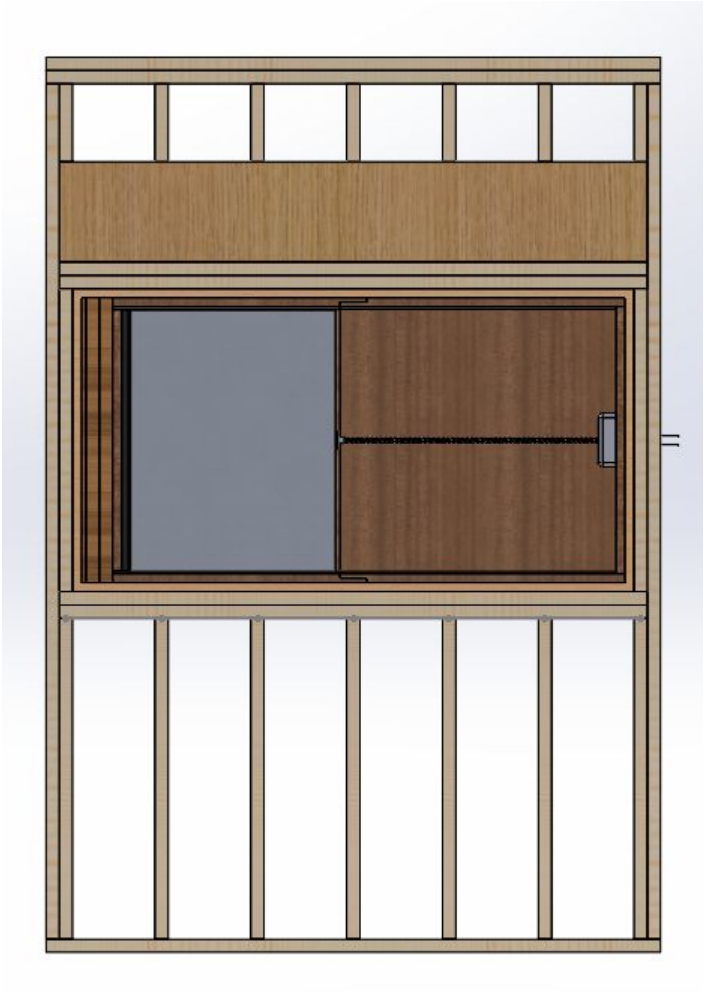




Construction Steps Track:



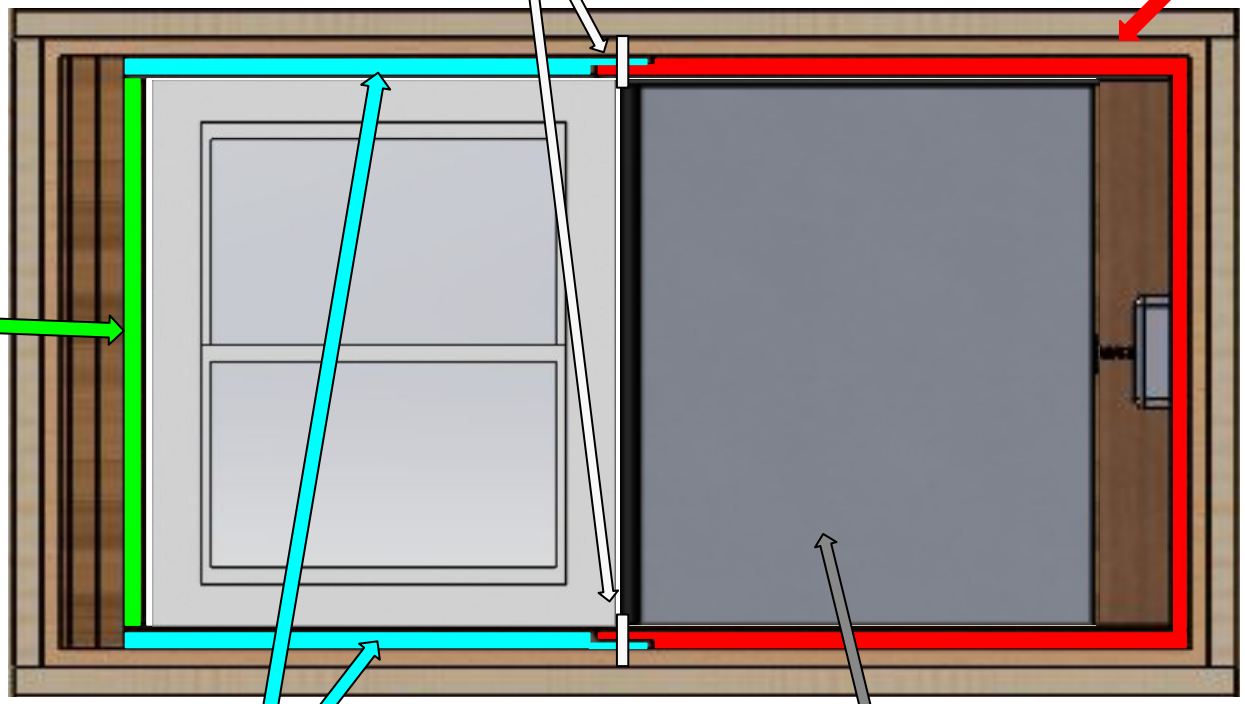
Construction Steps Full:



Install Guide

Step 4: Screw mating box pieces together and into the window casing

Step 1: Slide RHS box pieces into casing. These pieces are glued together.



Step 5: Slide leftmost box piece to align with the top piece edges (in blue)

Step 3: Align top and bottom left box pieces (in blue) with their respective mates (in red)

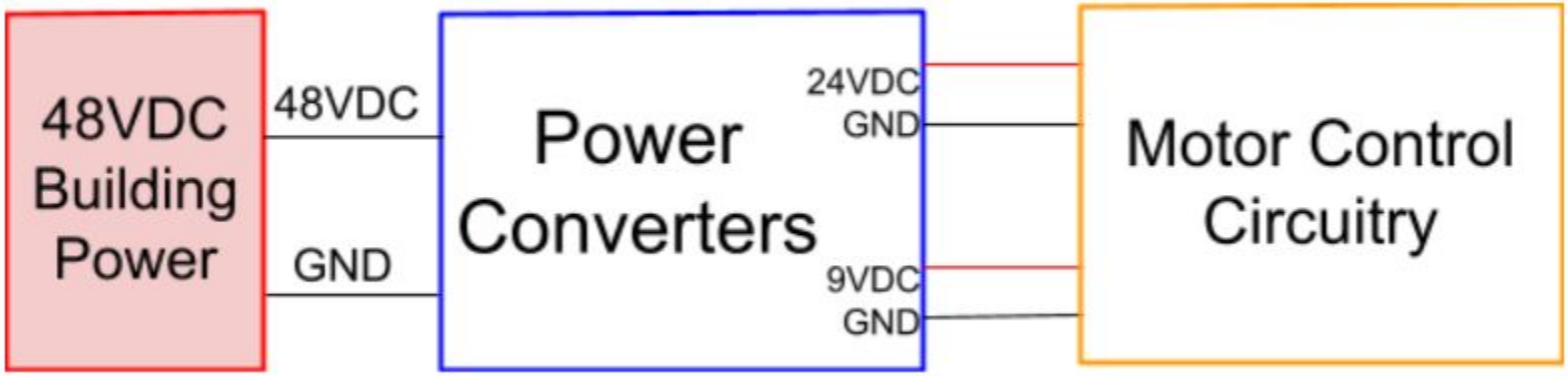
Step 2: Slide cover module into the RHS of box, securing the lead screw on the cover to the motor coupling accessible from the electrical boxing

Electrical System

1.) 48VDC Input Building Power

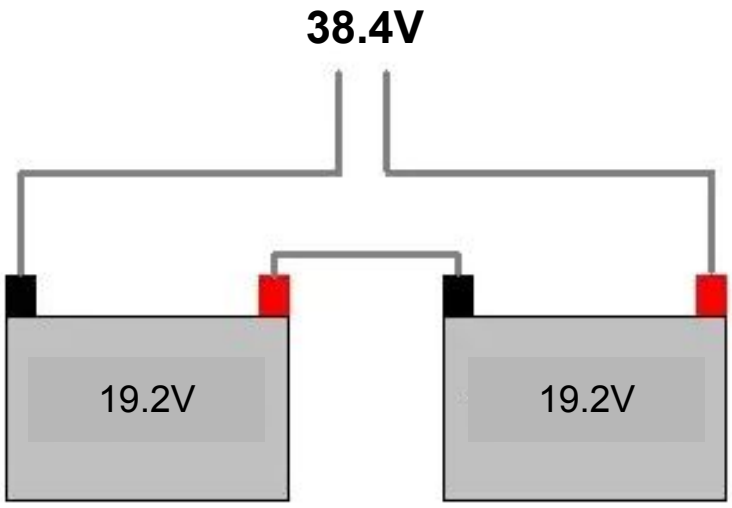
2.) Power Converters to convert the building power to usable 24V and 9V outputs for the motor and microprocessor

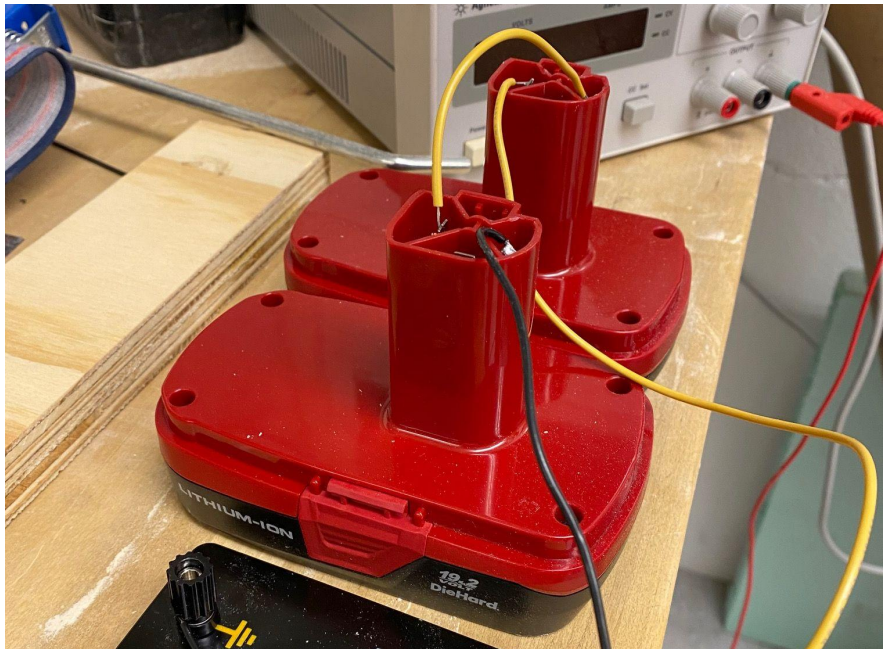
3.) Motor Control circuitry to control the movement of the thermal cover



Prototype Input Building Power

- Two 19.2V Li-Ion Batteries are connected in series to produce a voltage of 38.4V to use as an input voltage for our prototype



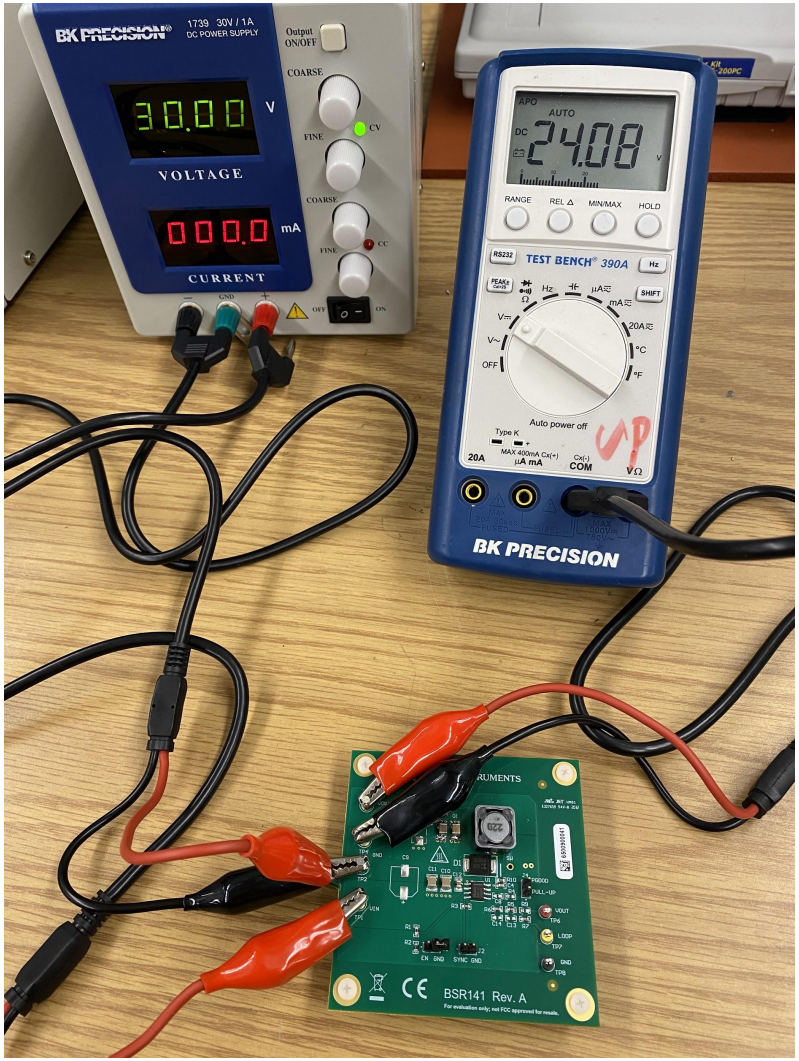


24V Power Converter

Input Voltage: 30VDC

- Will work for input voltages up to 60VDC
- Will work for our 38.4V input from the batteries

Output Voltage: 24VDC



Motor Control

Manual Control

- 3-position toggle switch for manual deployment, retraction, or automation of the thermal cover

Automation

- Indoor and outdoor temperature sensors to determine when the thermal cover should be deployed or retracted

Prototype Electronics

Inside Module Electronics

- Arduino, Motor Driver, and Motor are used to move the thermal cover

Outside Module Electronics

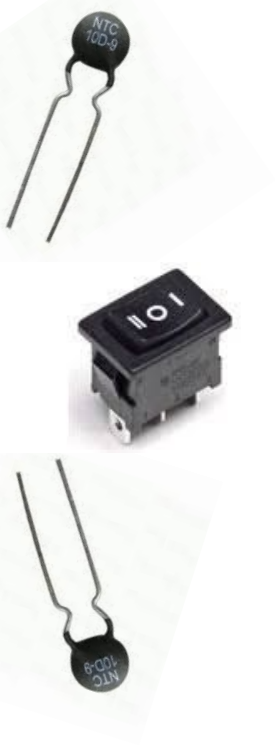
- Temperature Sensors and Toggle Switch are used to determine when the cover should move

- Input Power comes in and is sent through ribbon cable

Inside Module Electronics

Ribbon Cable

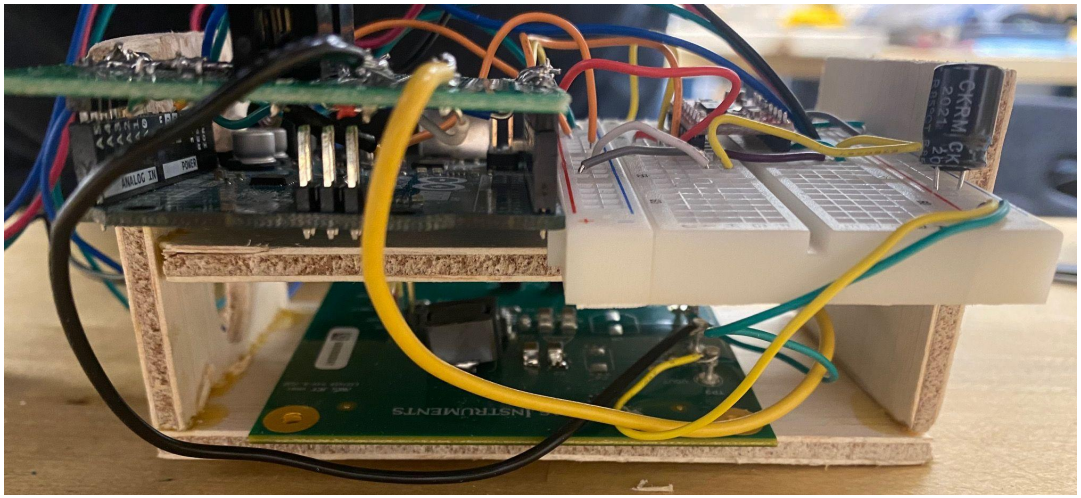
Temperature Sensors and Toggle Switch



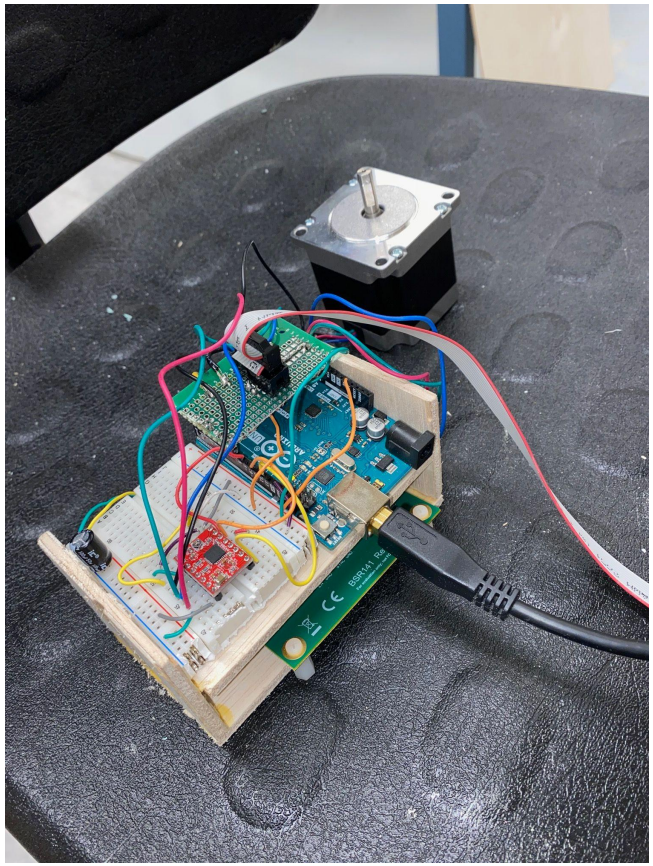
Outside Module Electronics

Inside Module Electronics

- Power Converter on the bottom of box
- Ribbon cable connection on top of Arduino
- Motor Driver connections on breadboard
- Motor wires fed through wooden box



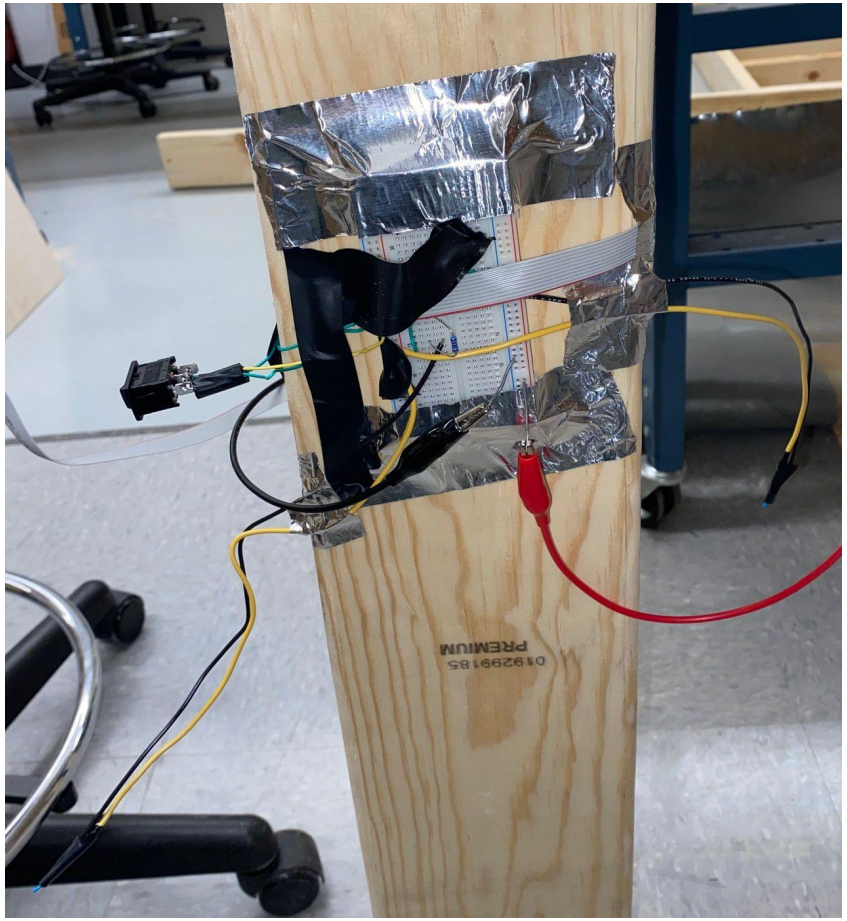
Side View of the Electrical Box inside the module



Top View with Ribbon Cable and USB-B Connected

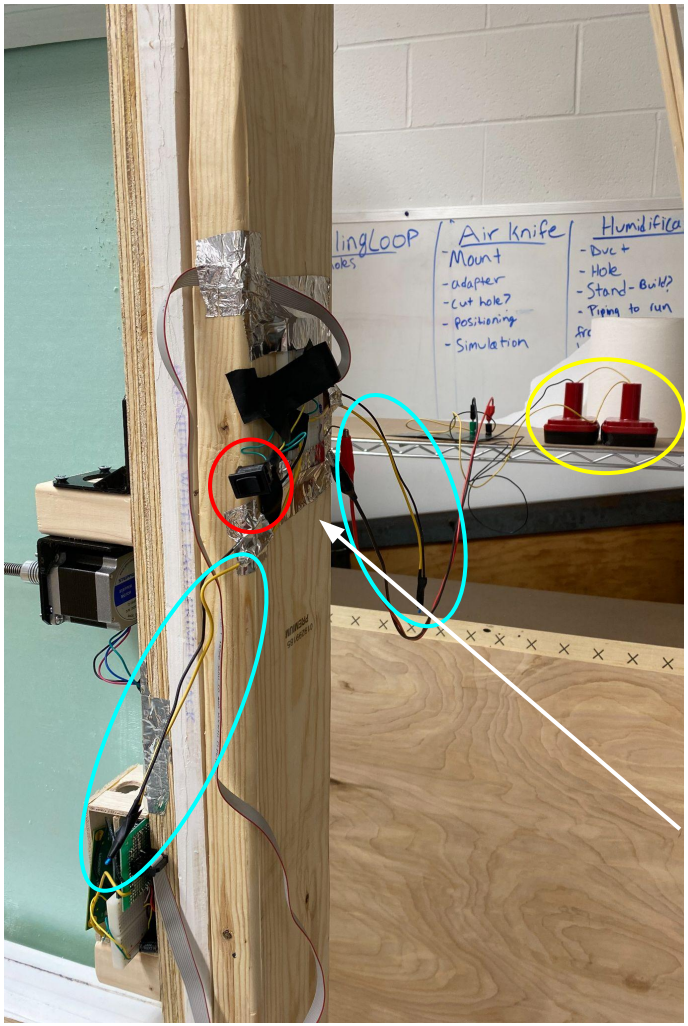
Outside Module Electronics

- Ribbon Cable connections covered with electrical tape to hold connections in place
- Input Power connected through the red and black alligator clips
- Indoor and outdoor temperature sensors on the left and right
- Indoor Toggle Switch on the left



Side View of the Electronics outside the module

Prototype Electrical System



Motor and Lead Screw

Inside Electronics

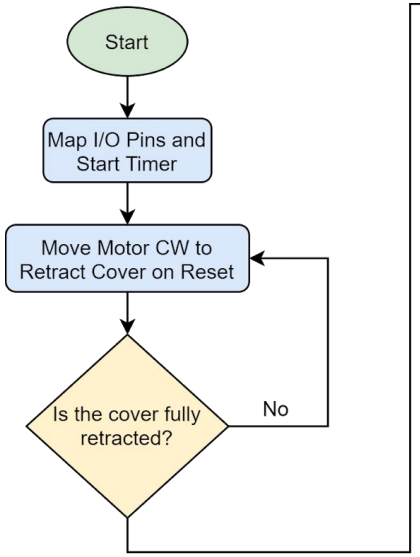
Input Power Source

Manual Switch

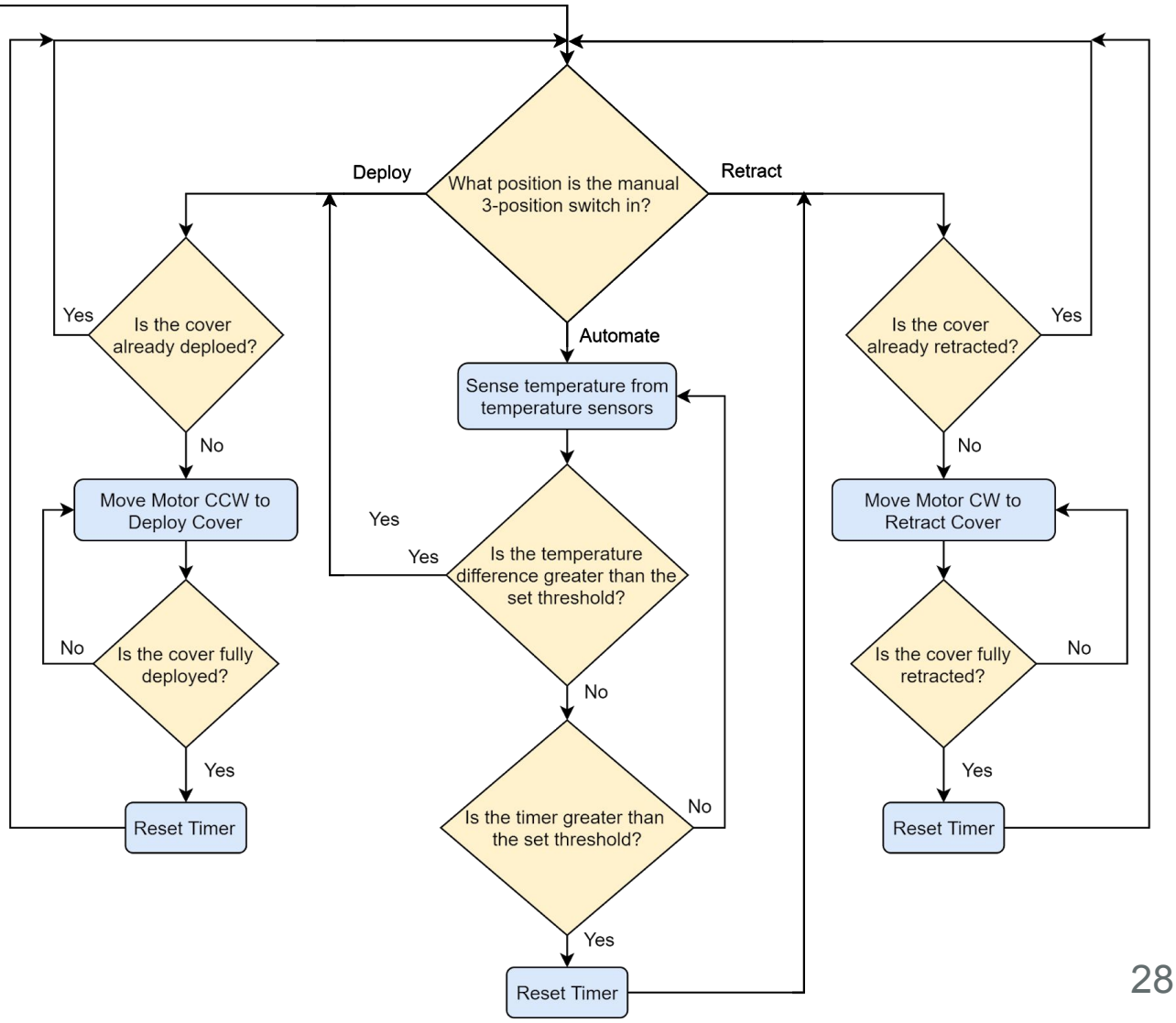
Temperature Sensors

Outside Electronics

Start-up Routine



Infinite Loop



Prototype Construction: Materials & Cost

Components	Cost
Lumber, Insulation, & Aluminum	$195.42
Window	$227.30
Mechanism & Fasteners	$129.25
Track & Sealing	$60.79
Electronics	$288.57
Total	**$901.33**

Prototype Construction: Obstacles

- Measurement Error
  - Recutting
  - Reassembly
- Glue Delays
- Managing Constructing Time with Zoom Communications
- Teammate COVID exposures

Demo: Deployment from Manual Switch

Demo: Retraction from Manual Switch

Demo: Deployment From Temperature Sensors

Prototype Future Improvements

Improve sliding/sealing abilities
- Increases thermal insulation

Prepare a more mobile prototype
- Current prototype is large and needs to be taken apart to move

Improve prototype presentation
- Add drywall, more insulation, moulding

Prototype Future Improvements

Step-down converter for the controller
- Able to power the controller from the 48V input

Op amp current feedback
- Sense the current drawn by the motor to efficiently stop motion

XMC4200 controller and CAN bus wired connections
- Ability to connect multiple Active Windows to the same network

Wireless manual control
- Ability to control the Active Window through a phone app

PCB layout for inside electronics
- Design a PCB layout for the controller, motor driver, and step-down converters

Final Product Comments:

- Device Movement
  - 102 seconds to close
  - Cover fully deploys and retracts into the wall
- Insulation Properties: The cover can insulate the window when deployed and can do so automatically
- Ease of Construction: With mass production of a standard system, the construction of the casing and cover can be streamlined easily
- Ease of Installation: Installation of the module is very easy, assuming the proper tools are available. With further prototype iterations, this will become even easier.
- Standardization: All of the materials used are common and available. With mass production, this will be an easy standard

Thank you!

Any Questions?