Cohort 24-24 Team 206:

Melting of Thermo-BioPlastic for Rapid Prototypes

Team Members

Sebastian Gonzalez

Bryan Leao

Farhan Khan

Jason Pham

Dali Ramon

Paola Reyes

Faculty Advisor

Dr. Mathias Brieu

Agenda

1. Background, Problem, and Objective
2. System Overview
3. Tasks
4. Planetary Gear Design
5. Control System
6. Budget
7. Conclusion

Objective

The goal for this Cohort Spring 24- Fall 24 project, “Melting of Thermo-Bioplastics for Rapid Prototypes are:

Build a device that is able to

- Melt and mix plastic pellets into homogeneous mixtures

- Temperature control

Background

Research: Bio-Medical Research

Sustainability: Plastic Pollution

Problem/Situation

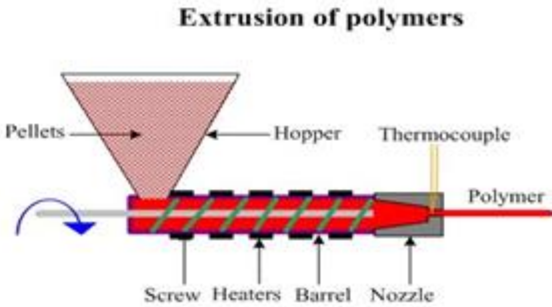
In this situation when creating a model, we shall consider:

- The function and position of the gears inside the Planetary Gear Design
- The controls of the gears rotation
- Observing peak temperatures in heating

Agenda

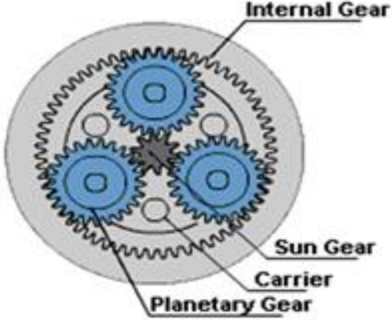
1. Background, Problem, and Objective
2. System Overview
3. Tasks
4. Planetary Gear Design
5. Control System
6. Budget
7. Conclusion

Trade Analysis: Single Screw Extruder



No.	Trade Parameter	Weighting	Functionality Score (1-5)	Total
1	Complexity	10%	3	0.3
2	Versatility	20%	4	0.8
3	Cost	30%	2	0.6
4	Size	20%	3	0.6
5	Stability	10%	5	0.5
6	Maintenance	10%	3	0.3
Total		100%	20	**3.1**

Trade Analysis: Gear Extruder

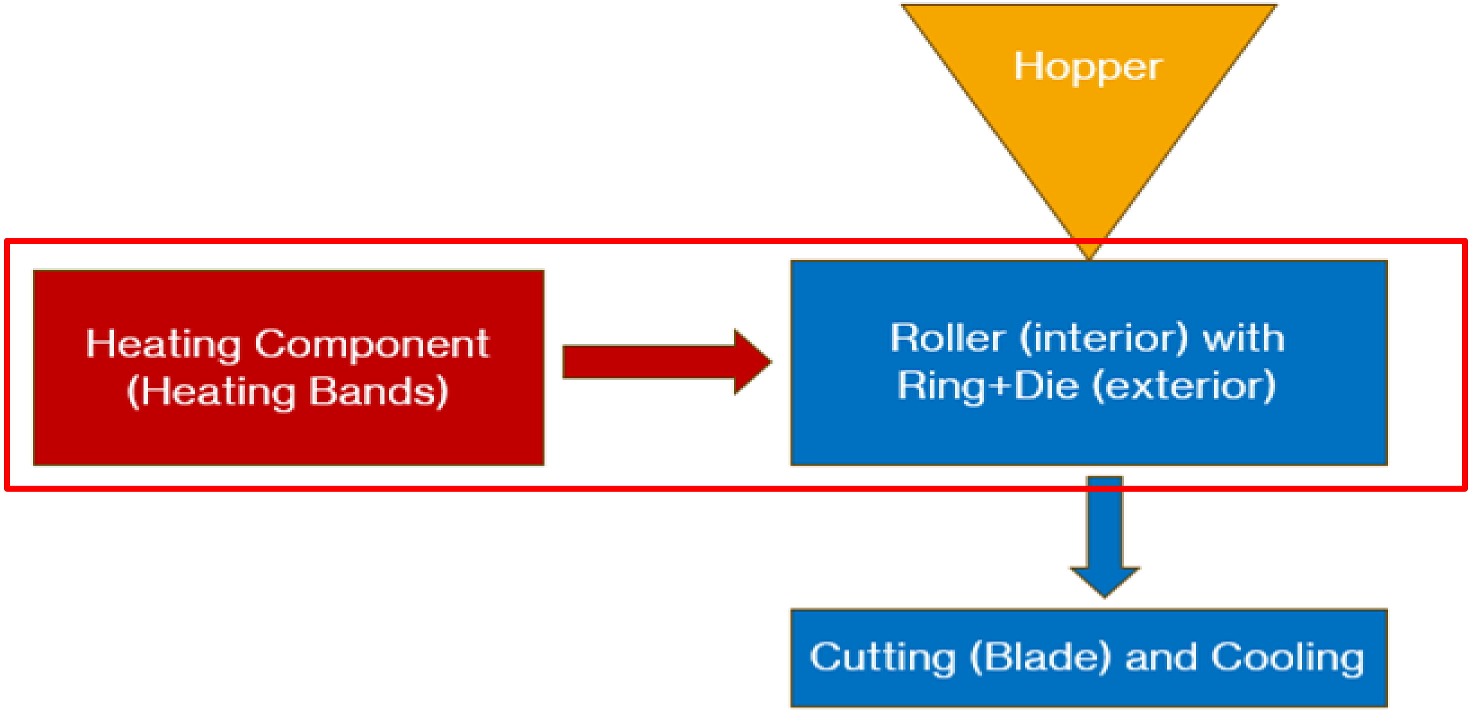


No.	Trade Parameter	Weighting	Functionality Score (1-5)	Total
1	Complexity	10%	4	0.4
2	Versatile	20%	3	0.6
3	Cost	30%	4	1.2
4	Size	20%	5	1
5	Stability	10%	3	0.3
6	Maintenance	10%	1	0.1
Total		100%	20	**3.6**

Material Properties of Plastic Pellets

Property	PLA	PGA	PCL
Glass Transition Temperature	60°C / 140°F	60 - 65°C / 140 - 149°F	30 – 35°C / 86 - 95°F
Melting Temperature	175°C / 347°F	220 - 240°C / 428 - 464°F	55 – 65°C / 131- 149°F
Degradation Temperature	320°C / 608°F	-	300 - 380°C / 572 - 716°F
Conduction Coefficient (W/mK)	0.13	0.35	0.5
Specific Heat Capacity (J/kg°C)	1,750	1,200	1,900
Viscosity(Pa*s)	-	15	25
Density(g/m^3)	1.27	1.6	1.14

System Layout



Agenda

1. Background, Problem, and Objective
2. System Overview
3. Tasks
4. Planetary Gear Design
5. Control System
6. Budget
7. Conclusion

Work Breakdown Structures: Tasks/Responsibilities

Mechanical Engineers

- Dali: Leadership, 3D Design, Simulations
- Farhan: Gears and Drum w/ SolidWorks
- Paola: Gears and Drum w/ SolidWorks

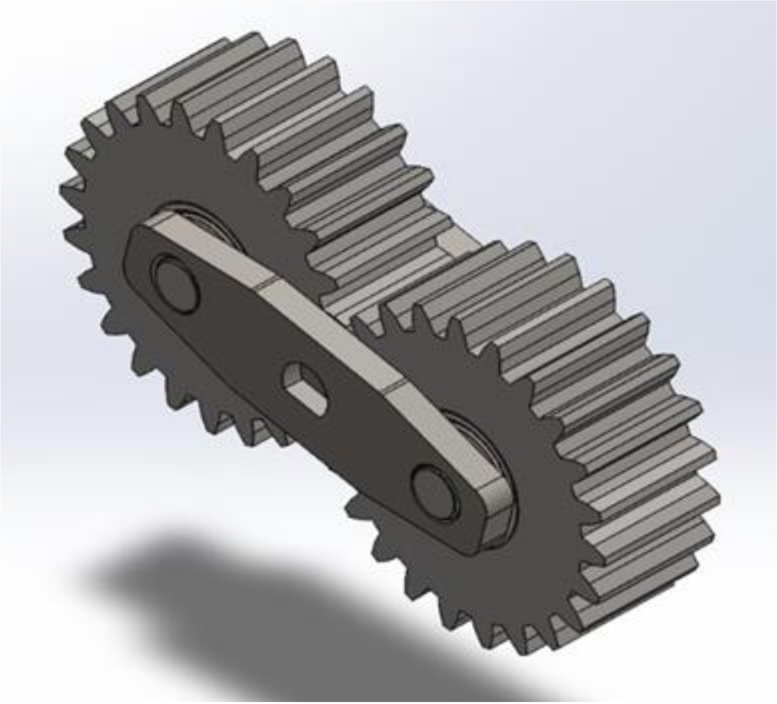
Electrical Engineers

- Bryan: Controlling and Measuring Using Thermocouples
- Jason: Controlling Motors
- Sebastian: Controlling Heating Bands

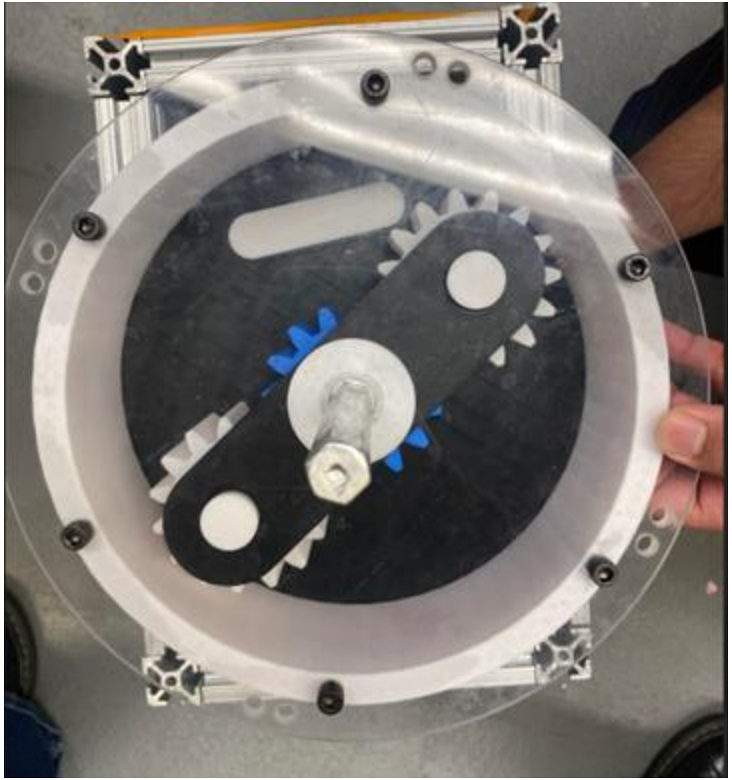
Agenda

1. Background, Problem, and Objective
2. System Overview
3. Tasks
4. Planetary Gear Design
5. Control System
6. Budget
7. Conclusion

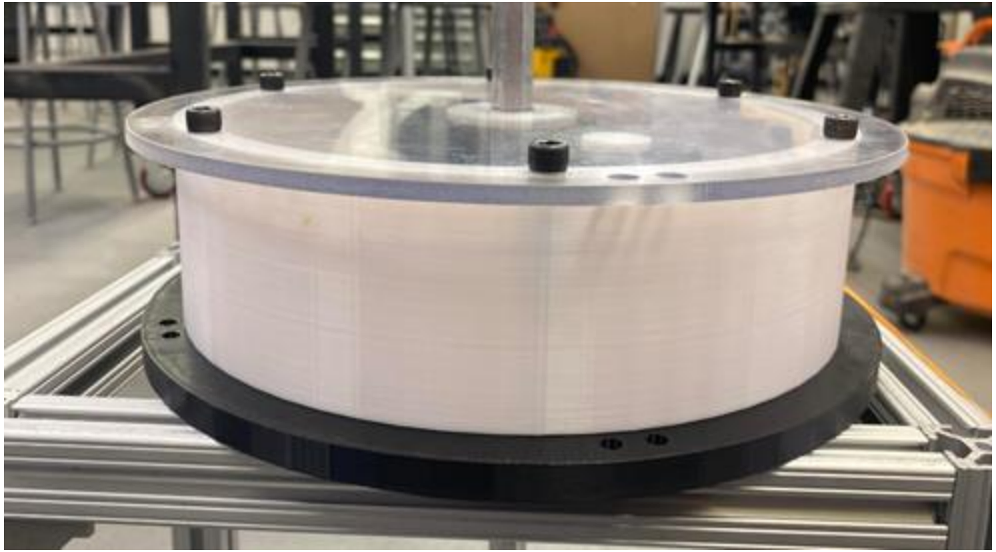
Planetary Gear System

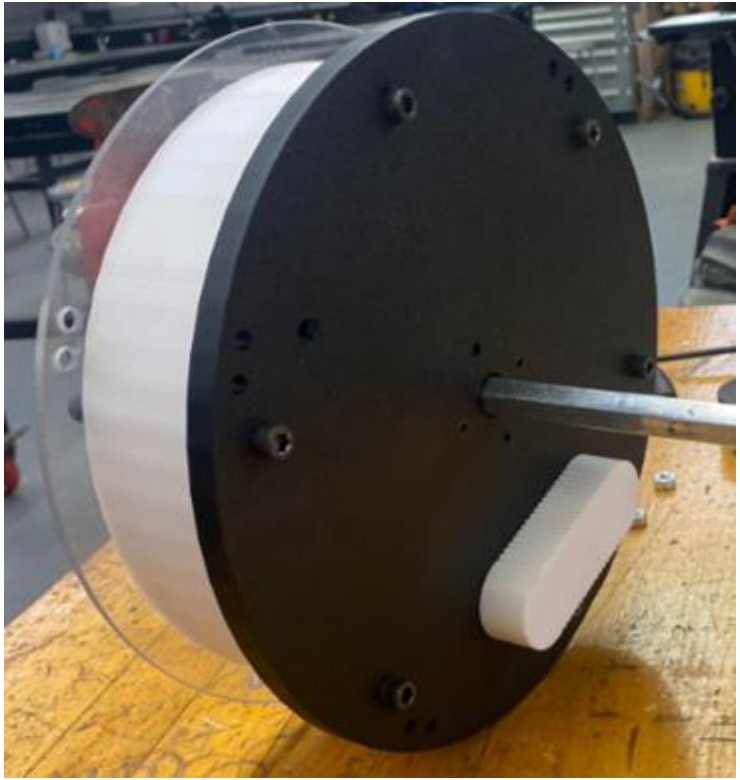


Prev.

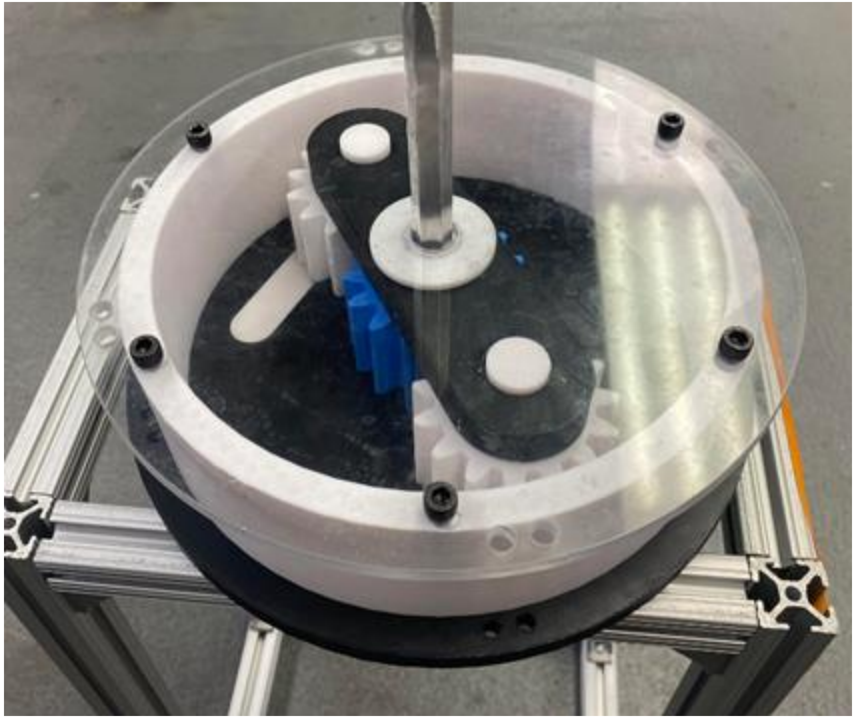


Drum Subsystem

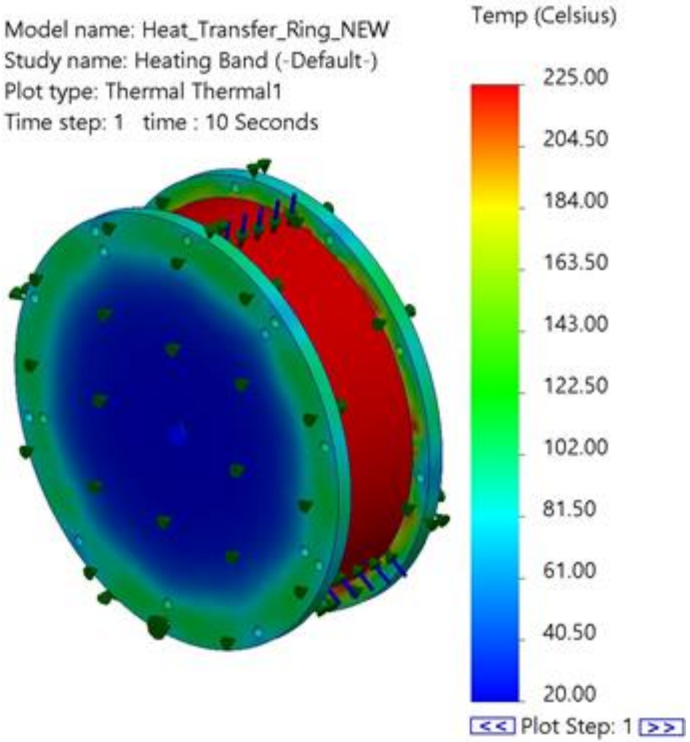


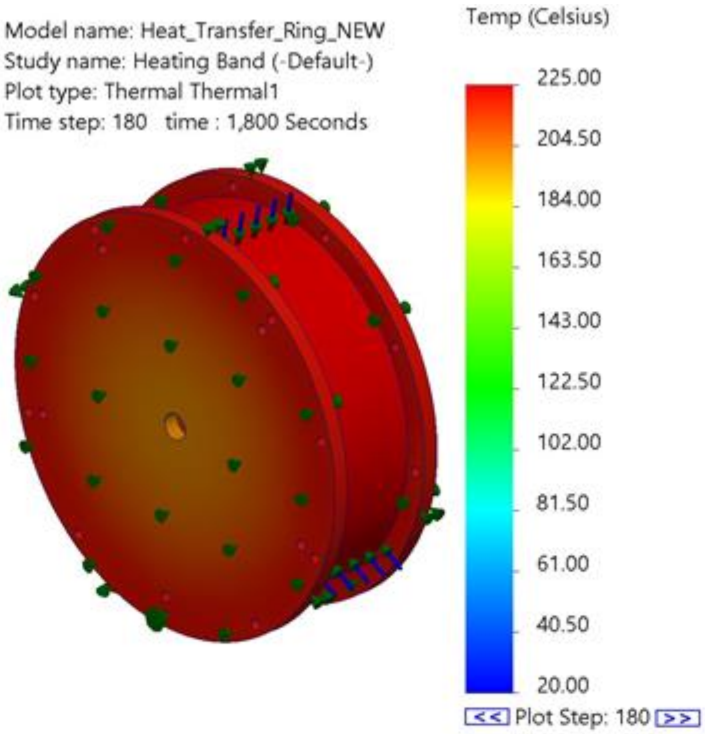


3D Printed Design



Heating Simulation

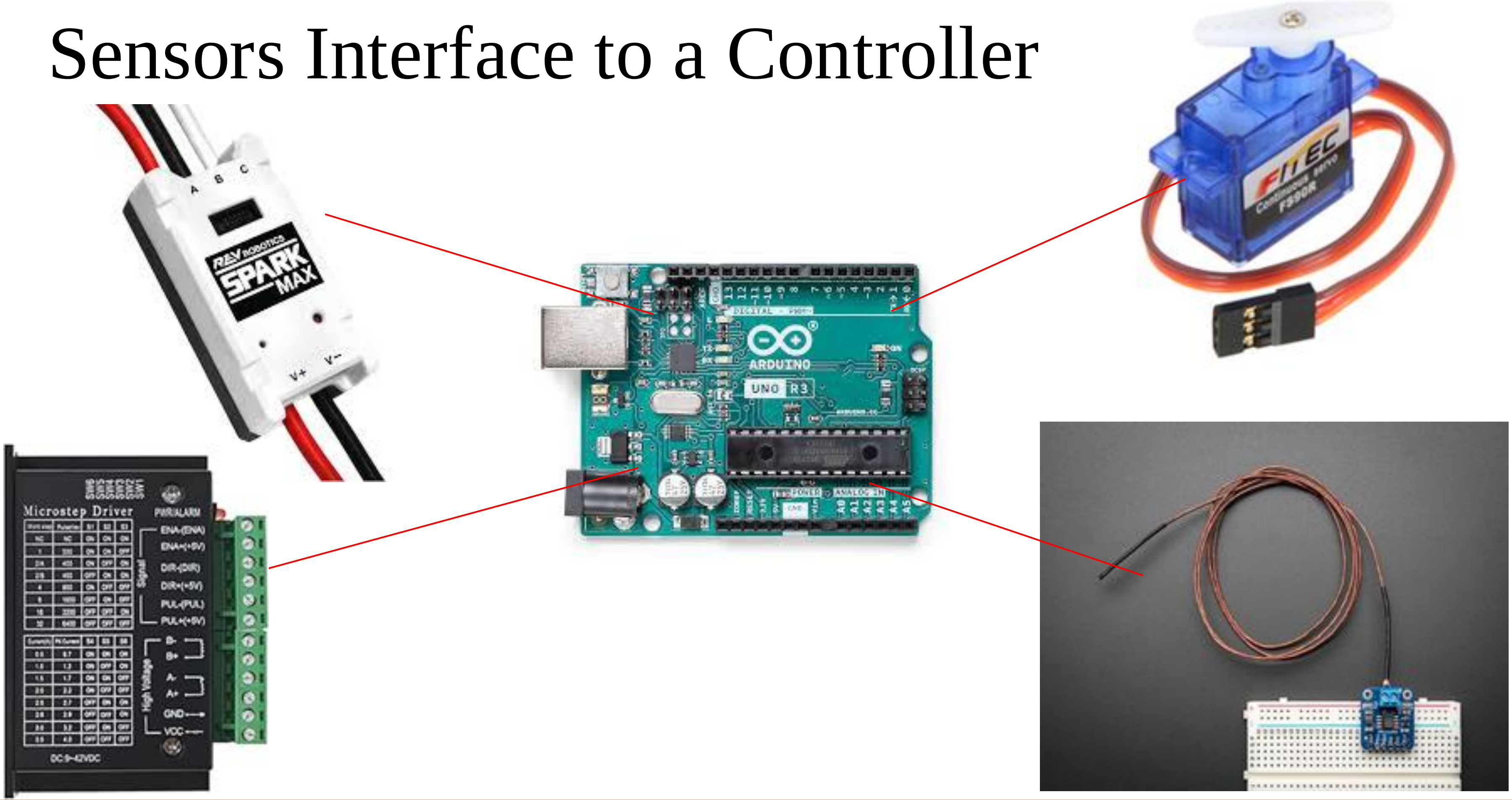




Agenda

1. Background, Problem, and Objective
2. System Overview
3. Tasks
4. Planetary Gear Design
5. Control System
6. Budget
7. Conclusion

Sensors Interface to a Controller

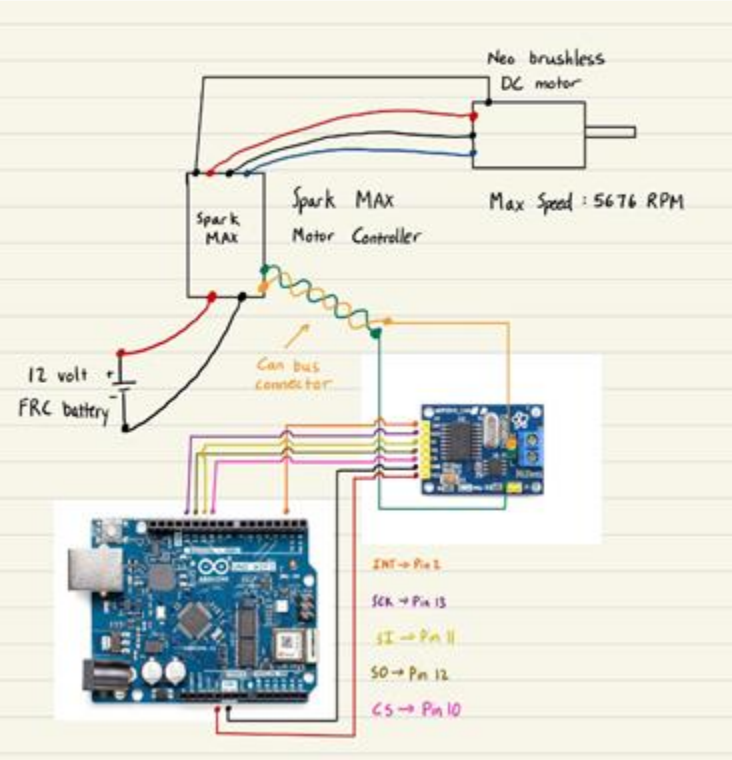


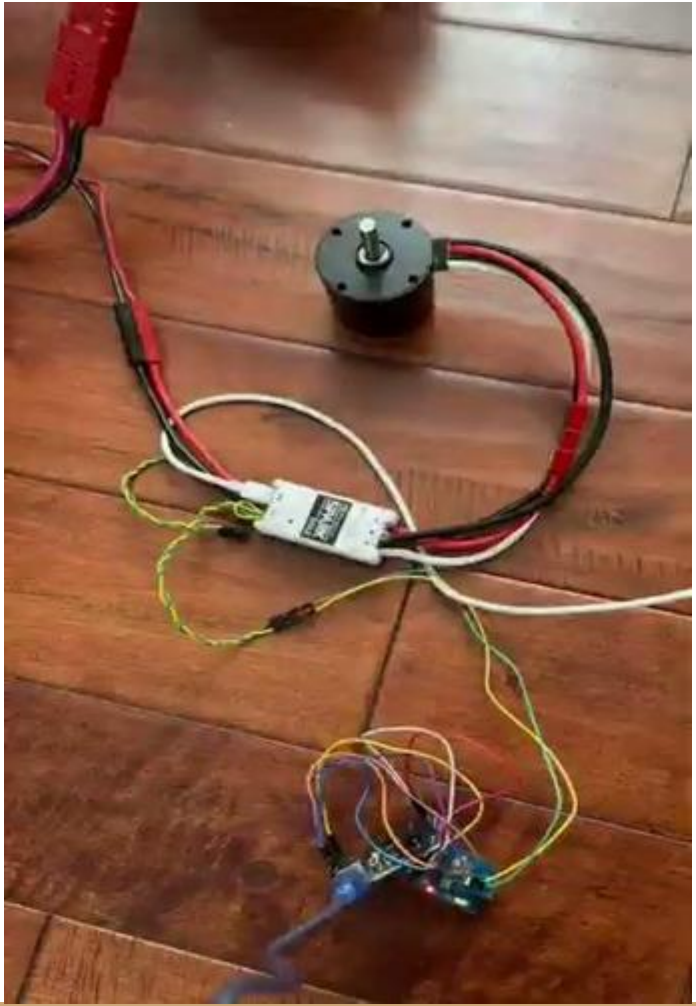
DC Motor

NEO Brushless Motor

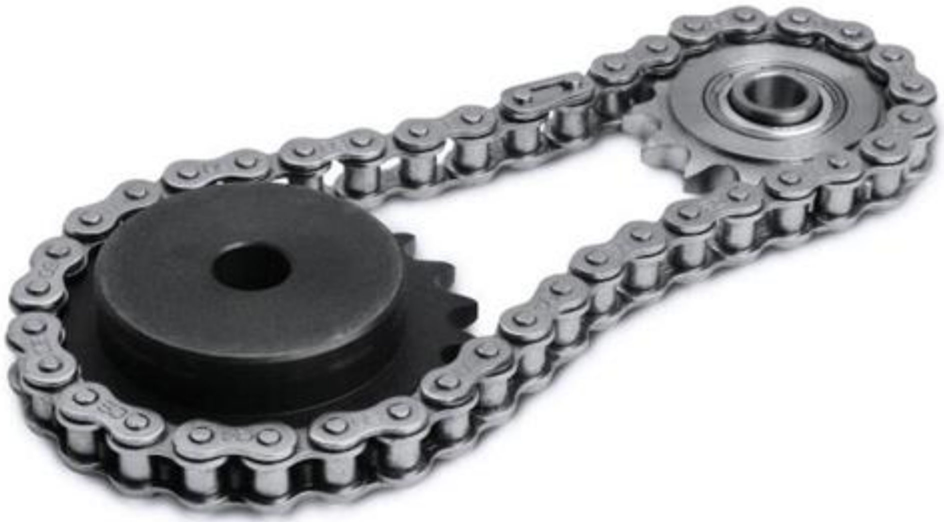
- Using Spark Max Motor Controller w/ CAN BUS connectors
- MCP2515 CAN BUS Module TJA1050 SPI Receiver
- **Program:** Arduino IDE and REV Hardware Client
- **Mechanism:** Planetary Gear Design

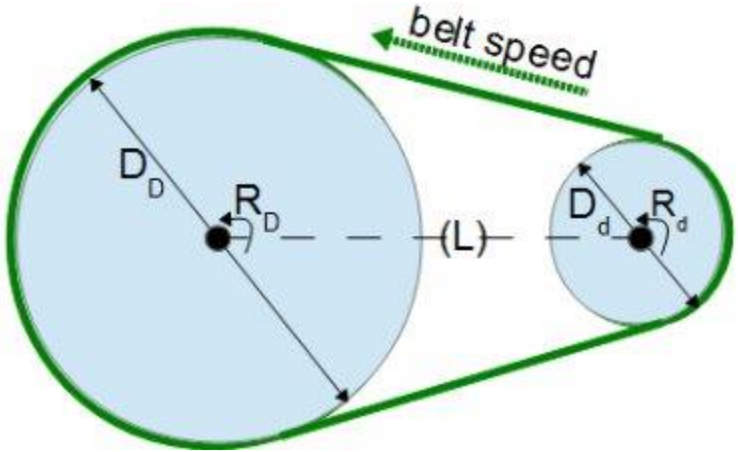
DC Motor Schematic





Pulley Mechanism



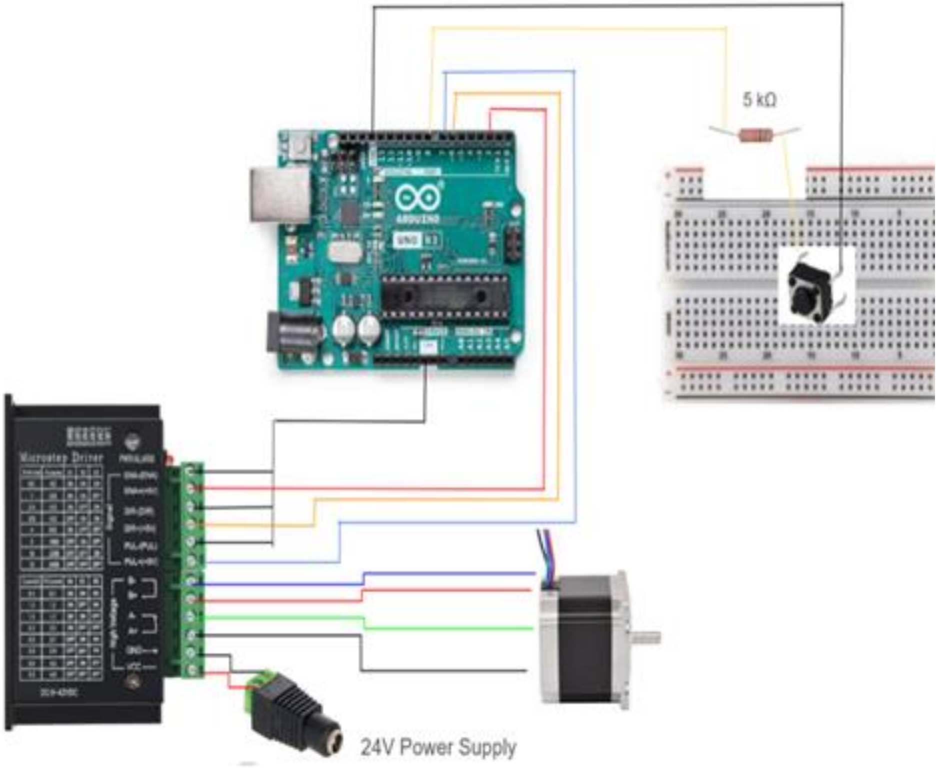


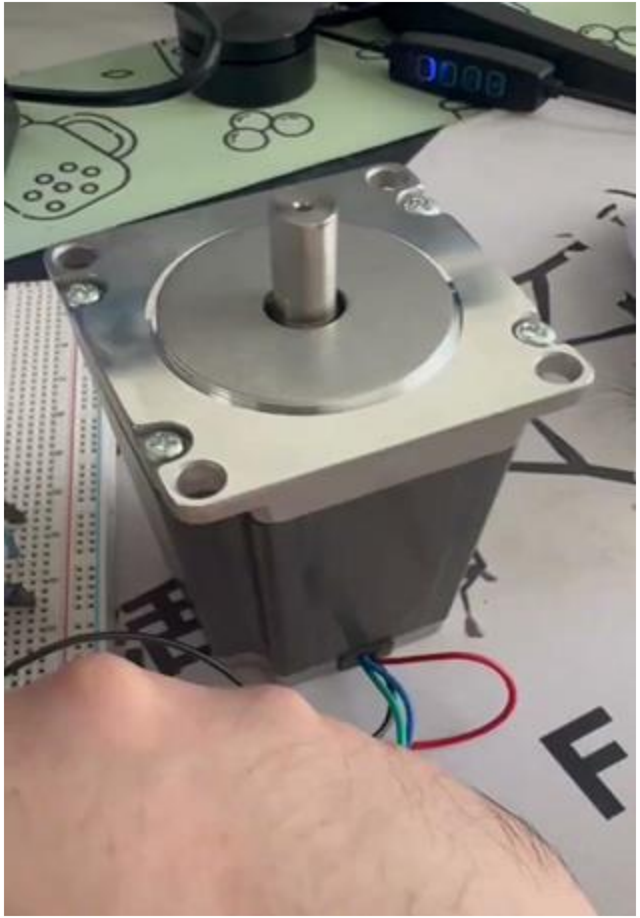
Stepper Motor

<u>Nema 23 Stepper Motor</u>

- TB6600 Stepper Motor Driver
- Push button (ON/OFF)
- **Program:** Arduino IDE (Changing Speed and Directions in 360° or 180°)
- **Mechanism:** Blade System

Stepper Motor Schematic





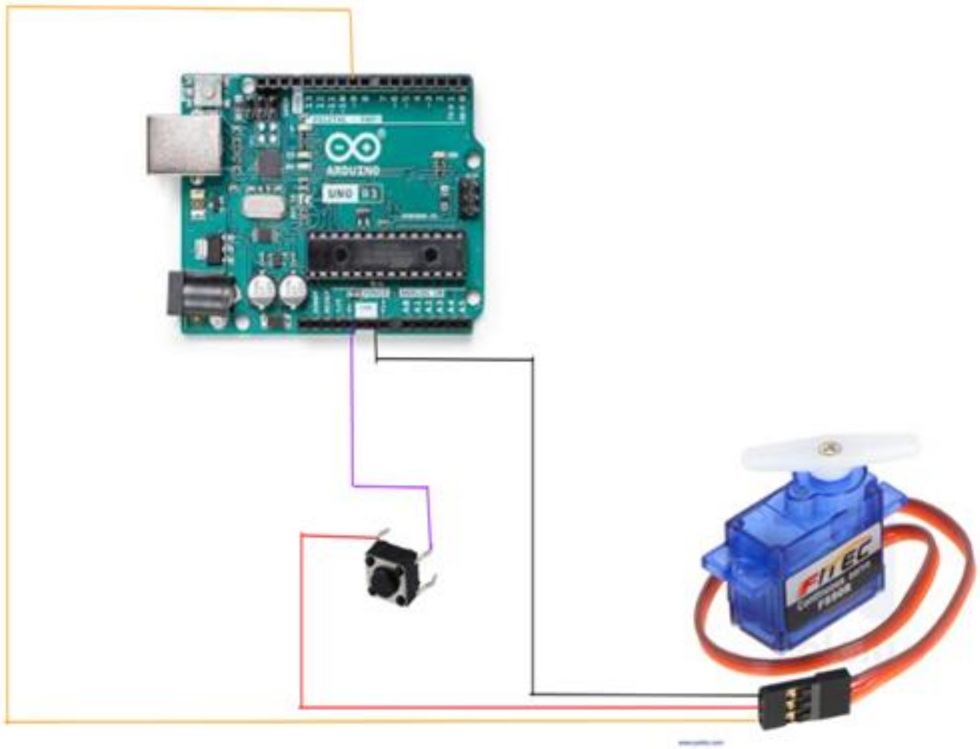
Stepper Motor in 180°

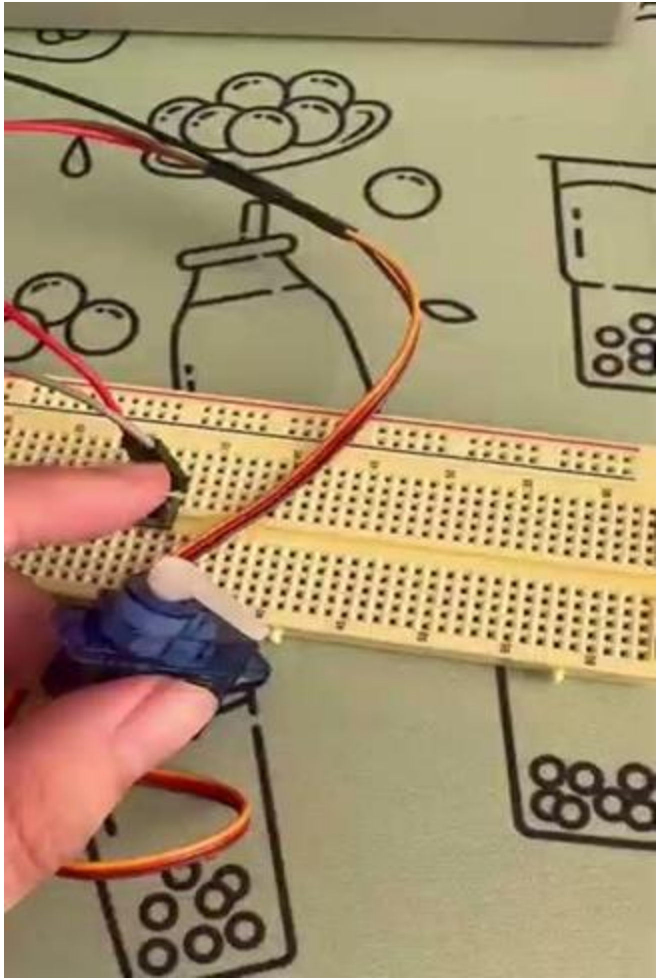
Servo Motor

Micro Servo Motor

- Uses push button for the lid
- **Program:** Arduino IDE
- **Mechanism:** Door System

Servo Motor Schematic





Heating Bands

What Are Heating Bands?

Heating bands, also known as band heaters, are devices used to apply heat to cylindrical objects such as pipes, barrels, or nozzles. They are made from a heating element encased in a durable material like mica, ceramic, and/or metal. The heating element generates heat when electricity passes through it, which is then transferred to the surface it surrounds.

Functions of Heating Bands

1. **Heat Transfer**: They provide uniform heat to the surface they are wrapped around, ensuring consistent temperature distribution.
2. **Process Control**: Heating bands help maintain specific temperatures required for industrial processes, avoiding thermal losses or overheating.
3. **Energy Efficiency**: Designed to minimize heat loss by directing heat into the target object and often insulated to save energy

Key Advantages of Heating Bands

- **Customizability**: They can be tailored to fit various diameters and power specifications.
- **Precision**: Ideal for applications requiring accurate temperature control.
- **Durability**: Constructed to withstand industrial conditions, including high temperatures and corrosive environments.

HEATING TAPE & THERMOCOUPLES

THERMOCOUPLES

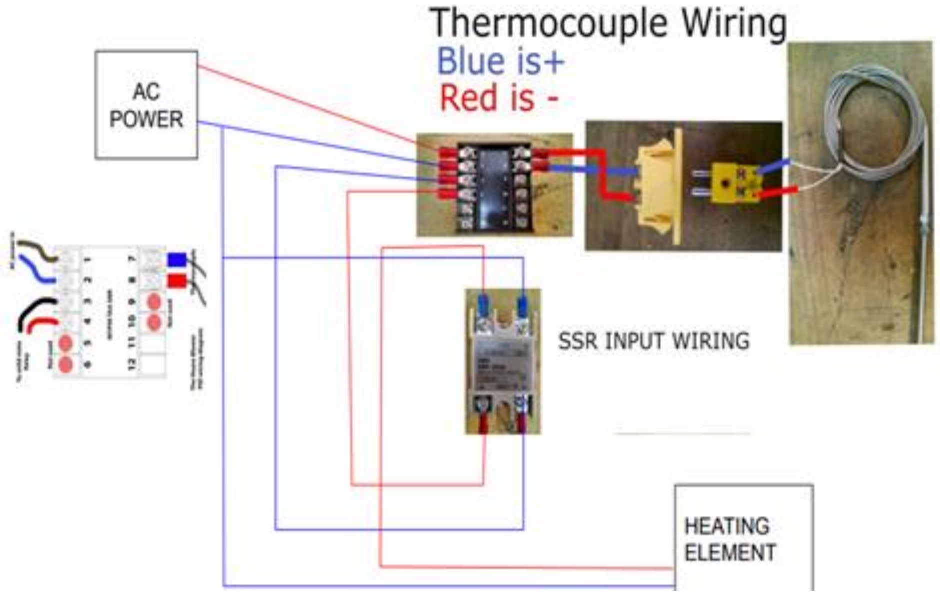
- **To Measure Temperature**: They provide real-time data to control systems like PID controllers.
- **Safety**: Detect overheating or system failures to trigger alarms or shut-offs.
- **Efficiency**: Ensure the system maintains the desired temperature for optimal performance.

HEATING TAPE

Heating bands is paired with **PID controllers** and **solid-state relay (SSR)** for precise temperature control. This setup ensures:

- Accurate heating.
- Energy efficiency.
- Safety and reliability in critical processes.

Heating Bands Schematic



PID CONTROLLER & STEADY STATE RELAY

PID Temperature Controller

1. **Setpoint Adjustment**: The desired target temperature can be set by the user.
2. **Sensor Input**: Compatible with thermocouples
3. **Output Control**: Sends signals to control devices such as heaters, cooling units, or solid-state relays (SSRs).
4. **Alarms**: Provide warnings if the temperature deviates significantly from the setpoint.

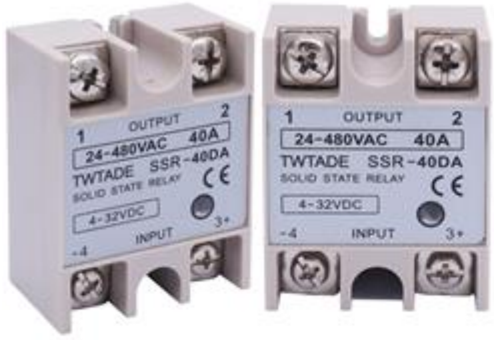
High-Speed Switching: Enables rapid ON/OFF cycles, which are essential for accurate PID control without mechanical wear and tear.

Durability: No moving parts mean it lasts longer compared to mechanical relays, especially in environments requiring frequent switching.

Safety:Handles high-power loads safely with minimal risk of sparking or mechanical failure.

STEADY STATE RELAY:

- Works in conjunction with a PID controller to switch the heating element on and off.
- Allows precise modulation of power to maintain a stable temperature.



Heating System w/ PID Controller

Heating System with PID Controller

A **PID controller** precisely regulates temperature in industrial heating systems by continuously adjusting the heating element:

- **Proportional (P):** Adjusts output based on the current error.
- **Integral (I):** Eliminates steady-state error over time.
- **Derivative (D):** Predicts future error to stabilize and reduce overshoot.

Set Temperature: Configured to maintain 250°C (or up to 750°C) for stable and consistent operation.

Solid State Relay (SSR): Rapidly and efficiently switches power to the heating element, ensuring precise control without mechanical

ear.4o**The Temperature Set**

The set temperature depends on the specific application. For example, in our case, we are using a heating tape to reach and maintain **250°C**, the PID controller is configured to this setpoint. It adjusts the heating element to maintain this temperature with minimal fluctuations, ensuring a stable and consistent process.

PID Controller: Precisely adjusts the heating element's power to reach and maintain the set temperature **250°C** with minimal fluctuations.

Set Temperature: Our heating system is designed for high temperatures like **250°C-750°C.**

Stress testing Heating Bands

Objective: The purpose of this test was to evaluate the performance, stability, and durability of the heating bands under various conditions to ensure they could reliably reach and maintain high temperatures, specifically up to 250°C.

Thermocouples:

- Multiple thermocouples were used to measure temperature at different points of the heating band and surrounding areas.
- This allowed for:
  - Monitoring temperature uniformity along the band.
  - Measuring internal temperature of drum.
  - Validating the accuracy of the primary thermocouple used for control.

Measurements:

- The key parameter measured was the **temperature** achieved and maintained by the heating band.
- Additional factors included:
  - Response time to reach the desired temperature.
  - Stability and fluctuations once the target temperature was achieved.
  - Behavior under prolonged operation to test durability.

Results:

- The heating band successfully reached the target temperature of **250°C**.
- **Temperature uniformity** was verified, with minimal variation (< ±5°C) across measured points.
- The system demonstrated stable operation, maintaining the target temperature for an extended period without failure.
- These results validated the effectiveness of the **PID control** system and thermocouple feedback for precise temperature regulation.

Thermocouples

2004 LCD Screen

MAX31855

Arduino UNO R3

Thermocouples Schematic

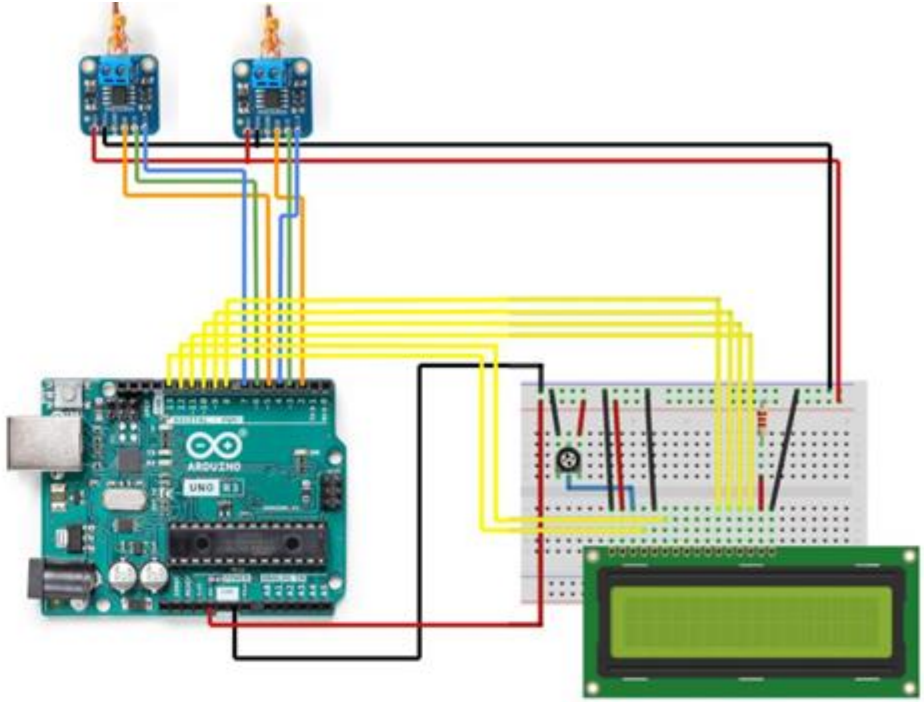
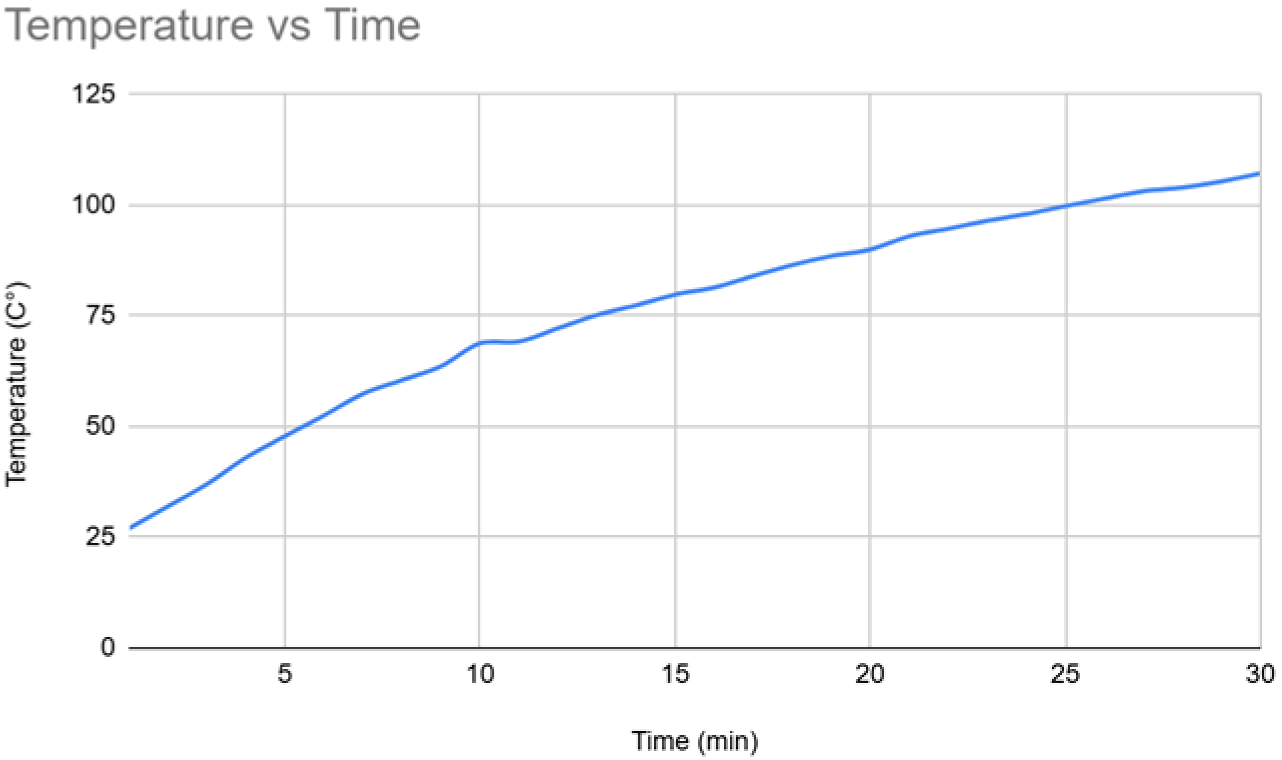


Table of Temperature Analysis

Time	Temperature in Drum (C)	Time	Temperature in Drum (C)	Time	Temperature in Drum (C)
0 min	25	9 min	63.6	18 min	86.5
1 min	27.9	10 min	68.8	19 min	88.5
2 min	32.3	11 min	69.2	20 min	90
3 min	37.4	12 min	72.2	21 min	93
4 min	43.6	13 min	75.2	22 min	94.7
5 min	47.8	14 min	77.4	23 min	96.5
6 min	52.5	15 min	79.8	24 min	98
7 min	57.4	16 min	81.4	25 min	99.8
8 min	60.5	17 min	84	26 min	101.5

Graph of Temperature in Celsius



Agenda

1. Background, Problem, and Objective
2. System Overview
3. Tasks
4. Planetary Gear Design
5. Control System
6. Budget
7. Conclusion

Pricing/Budget - ME

	Description	Quantity	Price
1	Printer Filament Rolls	2	$19.99
2	20x24x12mm Bearings (pack of 2)	1	$7.58
3	20x24x12mm Bearings	2	$23.99
		Total	**$95.54**

A portion of the items used were from the previous team and the rest has been source from various donors/supporters of the project.

Pricing/Budget - EE

Some of the budget for EE components was purchased this year and most were already purchased by first generation from last year.

	Component Desc.	Quantitative	Price
1	Heating Bands (120V / 3.9A) - 1400°F or 760°C	2	$165.32
2	Thermocouples	3	$27
3	NEO Brushless DC Motor	1	$48
4	Spark MAX Motor Controller	1	$90
5	MCP2515 Transmitter Module	1	$10
6	NEMA23 Stepper Motor w/ TB6600 Driver	1	$49.19
7	24V AC-DC Power Supply	1	$15
8	Micro Servo Motor	1	$8
9	Push Buttons	2	$6
10	PID Controller	2	$70
11	Solid State Relay	2	$29.76
12	Pack of Wires	1	$15
13	10kΩ Potentiometer	1	$8.66
14	Box of Resistors	1	$10
15	Breadboard	3	$9
16	LCD (20x4)	1	$10
17	Arduino UNO	3	$82.80
18	Arduino MEGA	1	$22
19	12V FRC Battery	1	$40
Total			**$715.73**

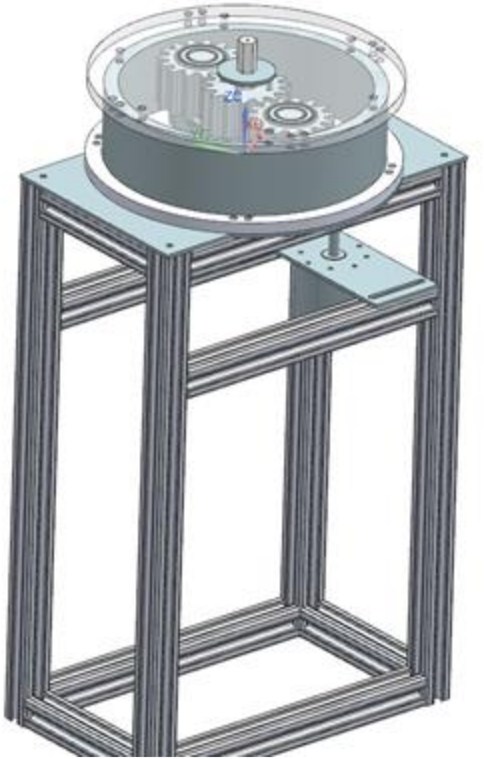
Agenda

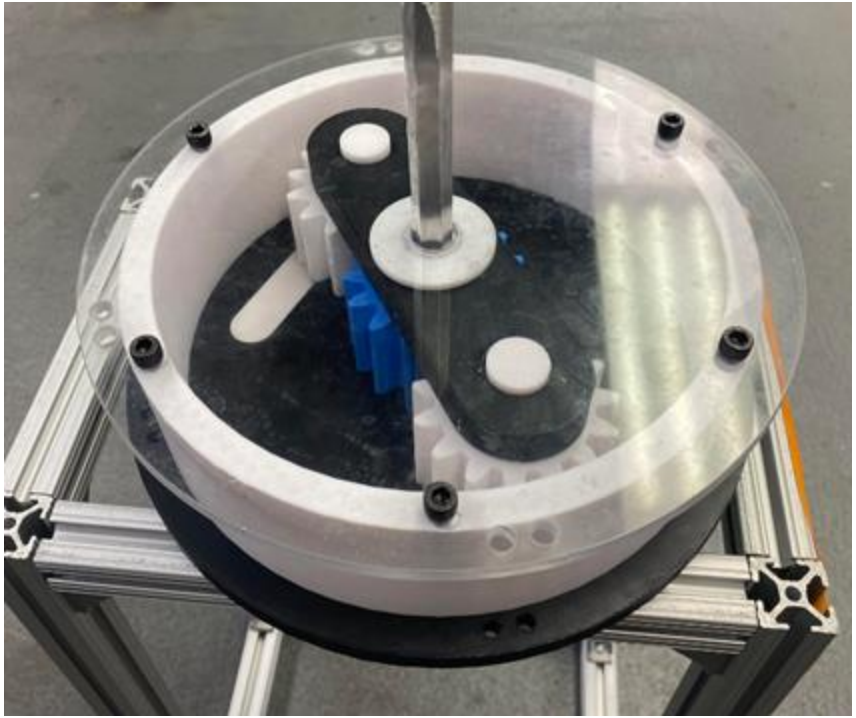
1. Background, Problem, and Objective
2. System Overview
3. Tasks
4. Planetary Gear Design
5. Control System
6. Budget
7. Conclusion

Melted BioPlastic Model Requirements Were Met

No.	Requirement Desc.	Requirements' Objective	Requirement Met
1	Homogeneous Mixtures	Mix PLA, PGA, and PCL into homogeneous pellets.	TBD
2	Heating Bands	To control the temperature with heating bands.	Yes
3	Motors	To control DC, stepper, and servo motors determining by each mechanisms.	Yes
4	Thermocouples	To check the temperature from the heating band to find dependent variables.	Yes
5	3D Design of Planetary Gear System	Using 3D printers to design a Planetary ring and gears.	Yes
6	Mounting	Mounting DC for pulley mechanism	Yes
7	Thermoplastic Material Test [First Generation]	Able to heat materials w/ safety procedures.	Yes

Conclusion





Improvement in the Future?

- Hopper
- Extrusion system
- Cooling system

Acknowledgements

- 3D Design the Planetary Gear System
- Controlling the motors
- Able to measure and check the temperature control w/ thermocouples
- Controlling heating bands
- Able to test the pulley system
- [Previous Generation] Able to test each pellets with minimum temperatures - PLA, PGA, and PCL for homogeneous mixtures

Questions?