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Eastman Guide Rail Project

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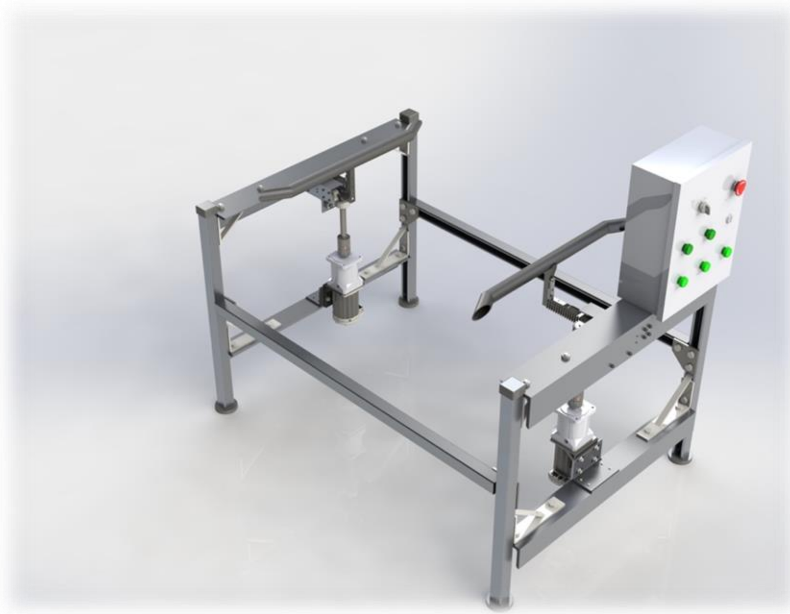
User Manual: Eastman Guide Rail System

Spring 2022: Senior Design Project



May 6, 2022

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Introduction

The system in the following manual was designed to correct an issue that The Eastman Chemical Company faces with a current guide rail system. A roll (undesignated) is experiencing tracking back and forth as it is being unrolled. The current system does not perform reliably. Our group was tasked with creating a system that would allow for a reliable guide rail system that has the capabilities of preventing tracking (roll movement), allowing for 2 inches of lateral movement on either of the sides of the rails, and being able to move the rails to preset positions. Each rail should have the ability to move independently of the other as well as move synchronously. The system should have a single operator interface.

For the project, the group proposed the use of either a hydraulic or electric actuator for the system. The use of hydraulics would allow for a user friendly, highly accurate system that could lift heavy loads, but had the possibility of being prone to leakage, maintenance, and cost concerns. Consequently, the use of an electrical system allowed for a low maintenance, cost friendly, system that did not require a large amount of space. This is also easier to implement in the current work environment where the rest of the assembly can be found.

For the electrically actuated system, the use of a rack and pinion, which is further explained in the system design, was used along with a motor, gear box, and shaft. After preforming the necessary torque calculations, creating a model and test assembly in solid works, and deciding the logic to produce the necessary code to be able to control the motors using digital inputs from multiple buttons, the group designed a system that had strong potential to be a solution to the problems that Eastman Chemical Company is currently facing with this specific assembly.

User Manual

Performance Requirements

For the project, a roll is being unrolled and a guide rail system was designed to prevent the roll from tracking. In this instance, the roll weighs 1,000 pounds, but the system only experiences around 200-300 pounds of force. Other design requirements are outlined below.

1. The guide rail system must allow for 2 inches of lateral movement on both sides of the system.
2. There must be an adjustable gap to change the set point of the rails.
3. The rails must be able to move synchronously and independently.
4. The rails must be fully open to allow for maintenance.
5. The rails must be controlled manually as an operator would be responsible for monitoring the rolls and tracking.

Motor, Control System, Buttons and Enclosures

Motors

For the project, two stepper motors were used to contribute to the mode in which the movement occurs. The two motors used in the designed guide rail system were the Teknic model, ClearPath Integrated Servo System, and SDSK model. These motors allow for precise control of the motor by using step and direction commands to ensure that the desired position is achieved. Although the SDSK motor in this project is utilized as a stepper motor, it can react similarly to servo motors due to the precision and smooth motion. The parts of a clear path motor can be seen in Figure 1.

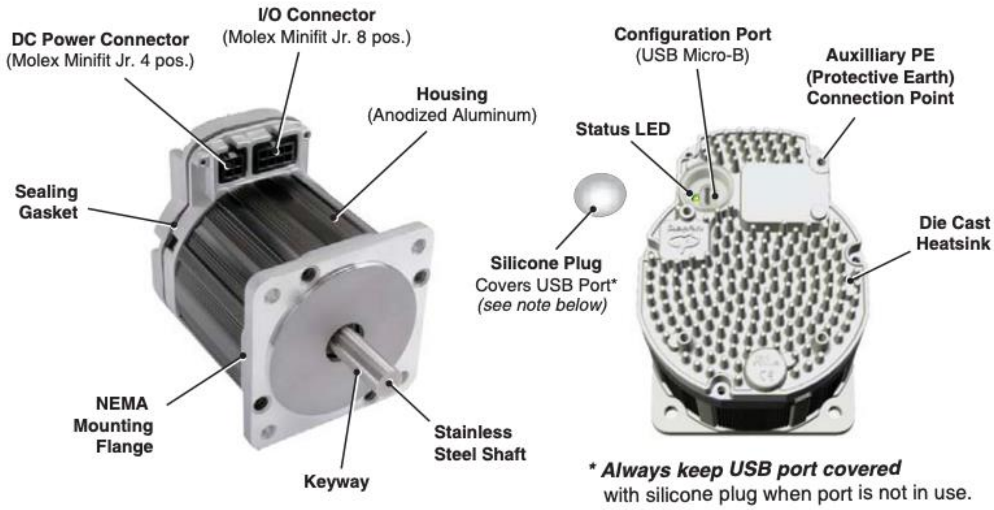

Figure 1. Parts of a ClearPath Motor

The motor frame size of is a NEMA 34, 3.24 inch with a length of 5.38 inches and shaft diameter of .500 inches. To supply power to the ClearPath SDSK motors, the use of a 24 Volt DC Power supply is utilized for both the motors and the control system. The one recommended by Teknic is shown in Figure 2.

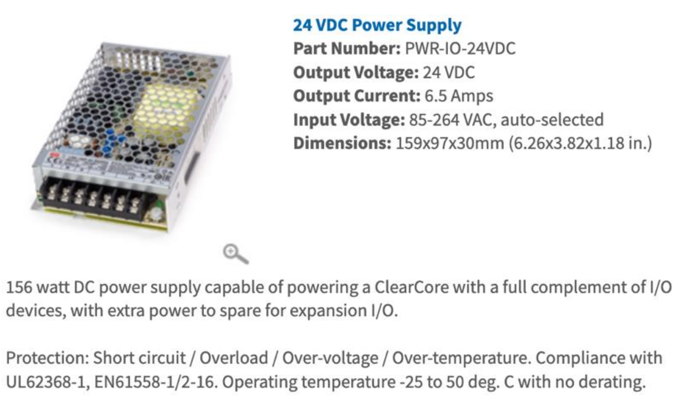

Figure 2. Recommended 24 VDC Power Supply

The power supply uses 156 Watts of DC power, which allows the capability of powering I/O devices as well. At 24 volts, the motor experienced specifications which can be found in Table 1.

Peak Torque	681 oz-in
Cont. (RMS) Torque	479 oz-in
Max Speed	270 RPM
Peak Power	38 W
Cont. (RMS) Power	38 W

Table 1. Motor Torque and Speed Specifications at 24 VDC

Specifications

Motor Frame Size	NEMA 34 - 3.42 in (86.87 mm) sq.
Length	5.38 in (136.65 mm)
Input (bus) Voltage Range	24-75 VDC (90 VDC max)
Peak Torque (@75 VDC)	1,844 oz-in (13.0 N-m)
Cont. (RMS) Torque (@75 VDC)	479 oz-in (3.4 N-m)
Max Speed (@75 VDC)	840 RPM
Achievable Resolution	0.450 degrees (0.057 deg. w/ Enhanced option)
Repeatability	0.03 degrees
Shaft Diameter	0.500 in (12.70 mm)
Weight	7.3 lb (3.3 kg)
Rotor Inertia	15.5 oz-in^2 (2.8 kg-cm^2)
Logic Input Voltage Range	4.0 to 28 VDC
Maximum Radial Load	50 lbf (222.4 N)
Maximum Thrust Load	10.0 lbf (44.5 N)
Ambient Temperature [1]	-40° to +70° C
Ambient Humidity	0-95%; non-condensing
Environmental Rating	Dust & water splash resistant
Regulatory Certifications	UL recognized; cUL recognized; CE; RoHS
Safety	Supports STO (IEC 60204-1) Safety Requirements [2]
Country of Origin	USA
Warranty	3 Years

Figure 3. Motor Specifications

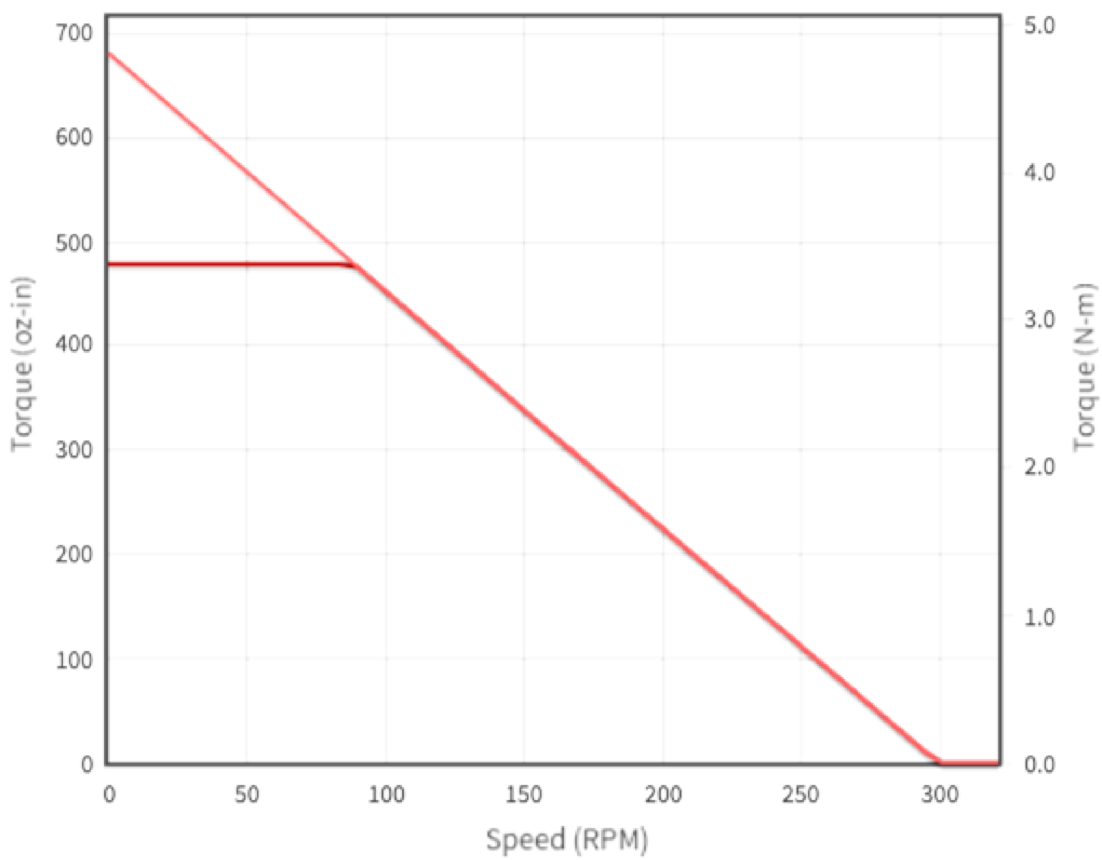

Figure 4. Torque Curve for the SDSK ClearPath Motor at 24VDC

Because the motors will not have to operate at high velocities during operation, higher torques are reached due to the RPM values being low. Since the system designed did not require high speed, the motors were set with an RPM limit of 80 RPM and utilized 50% of the torque at that designated RPM. The torque curve for the selected SDSK model can be seen in Figure 4.

Control System

The ClearCore, an additional Teknic product, was used as a control system for the motors. The ClearCore motion controller contains both digital and analog input and output ports, but in the case of our design, digital I/O is utilized. The ClearCore features 13 software I/O points, and each point contains separate ground and power pins. An ARM Cortex M4 processor is incorporated into the Clearcore system to allow for highly efficient signal processing. The system can control up to 4 axis of servo motion and is C++ programmable, but Teknic provides an Arduino wrapper that can be utilized to accommodate the potential of a learning curve. The ClearCore also allows for step and direction outputs that allow for the ClearPath SDSK servo systems to preform similarly to a stepper motor. The ClearCore and all its features are defined in Figure 3.

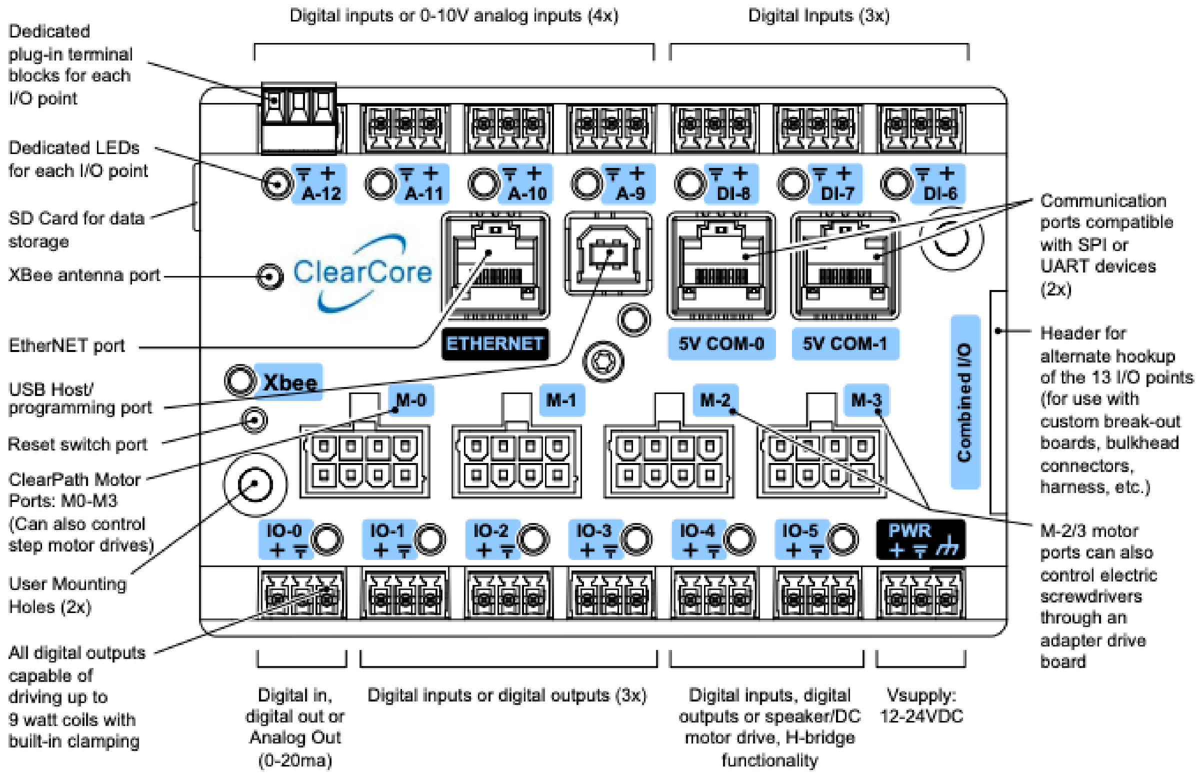

Figure 5. 3ClearCore Features4ClearCore Features

ClearCore Specifications

Mechanical	
Dimensions	5.0" x 3.5" x 1.0" (127mm x 88.9mm x 25.4mm)
Weight (with cover)	0.41 lbs (186 g)
Material	3mm thick polycarbonate cover, aluminum mount frame
Electrical	
Voltage Input	20-28 VDC (24VDC nominal)
Output Current Capability	I/O 0,1,2,3 - 375mA RMS, (750mA peak) I/O 4,5 - 750mA RMS, (1000mA peak)
Indicator LEDs for each input	yes
IP rating	IP20
Operating Temperature/Humidity	-20C to 50C, 0-90% non-condensing
Storage Temperature	-40C to 85C
Power Consumption	300mA@24V Adding an XBee will add as much as an additional 100mA@24V
Protection features	Overcurrent protection on all outputs Inductive clamping on all outputs Board master overvoltage and overcurrent protection ESD protection features on all I/O circuits
Capacitive load (max.)	Capacitance on I/O-0 through I/O-5 (and expansion port power pins) collectively may not to exceed 250uF.

Figure 6. 5ClearCore Specifications6ClearCore Specifications

The dimensions of the ClearCore are 5” x 3.5” x 1” and was powered using the same 24 VDC power supply as the SDSK motors. For placing the motors in a control box, there were specific specifications to follow. To avoid any overheating of the power supply or controller, we placed them spaced apart in a larger box than we initially planned on. The box is described below in the operator interface section. Some of the specifications for the ClearCore are listed in Figure 6. To mount the ClearCore to a control box, there must be a minimum of 1.5 inches of clearance around the entire Clearcore surface to allow for proper ventilation. The Clearcore dimensions for both mounting and clearance can be seen in Figure 7.

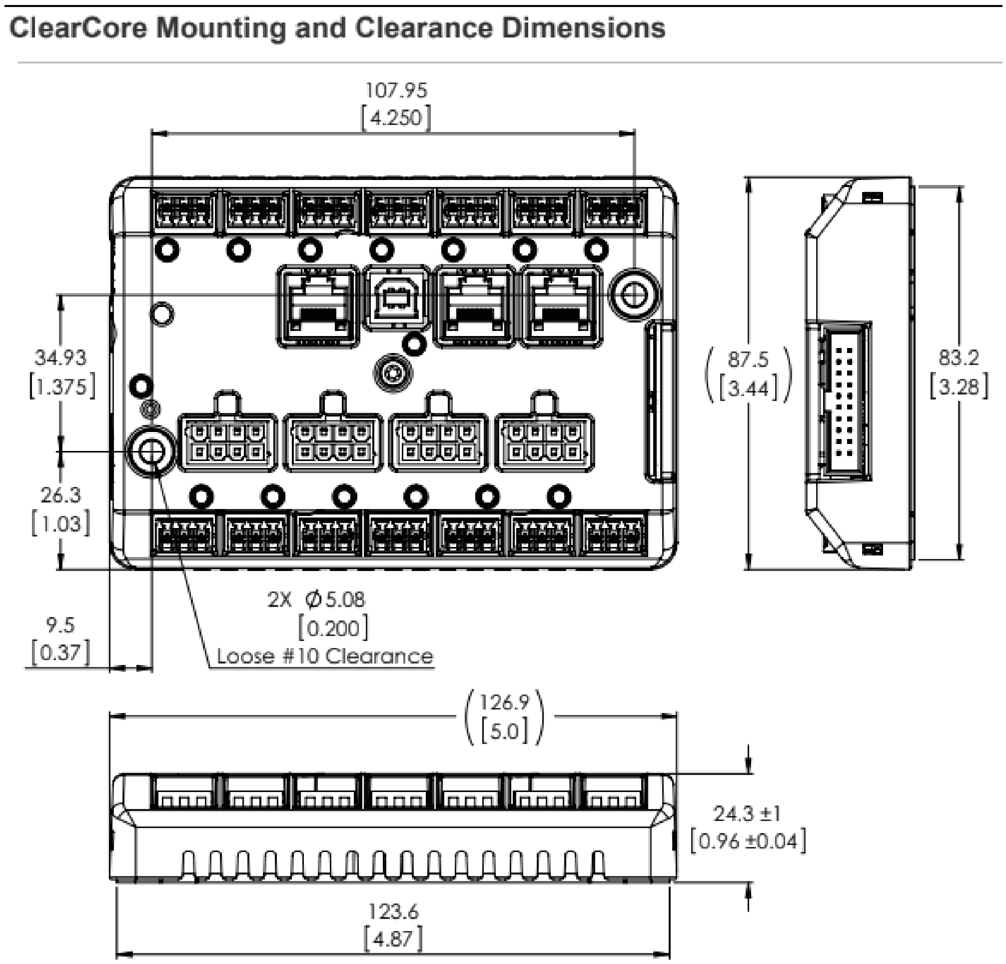

Figure 7. ClearCore Mounting and Clearance

To connect I/O to the Teknic ClearCore, the use of 3-position terminal block plugs are used to wire the power supply and I/O devices to the ClearCore controller. The wiring of schematic of these plugs in reference to the ClearCore can be found in the wiring and code section of the manual, but a general schematic of wiring the power supply to the motors for spinning and configuration can be seen in Figure 4.

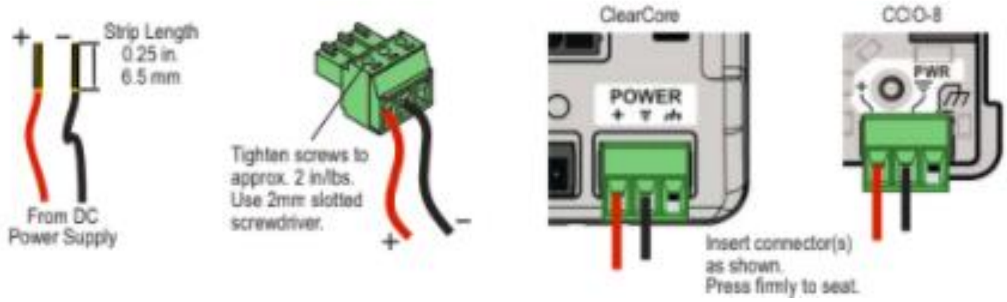

Figure 8. 8ClearCore connection to Power Supply Using Terminal Block Plugs9ClearCore connection to Power Supply Using Terminal Block Plugs

Motor Configuration

To configure a ClearPath SDSK motor, the MSP (Motor Setup Program) software, provided by Teknic, is utilized. The link to download the MSP software can be found at https://teknic.com/downloads/, under ClearPath.> software> ClearPath-MC and - SD Series Motor Setup Program (MSP). This is the first step in getting the motor to run to the desired parameters needed for the system. **It is imperative that the clear path motor is configured before being used in any application.** The steps needed to configure the motors for the designed system are outlined below.

1. Install the Clearpath MSP software to a Windows PC.
2. Wire the 24 VDC power supply to the motor. (Discussed in detail under the Wiring and Code Section)
3. Connect the ClearPath motor to a PC using any standard micro-USB cable.
4. Select a mode of operation of Step and Direction and set parameters to 50% torque and a velocity limit of 80 RPM's.
5. Set the steps per revolution count to 400 steps/rev.
6. Adjust settings to fine tune the system.

Once all settings are uploaded to the motor, no additional setup is needed unless the parameters need to be changed. All other motor control will be done using coding which is further discussed in the Wiring and Code section on the manual. The MSP software is used to set up the motor and ensure that it spins at desired parameters.

Buttons

To control the motors, various buttons were used as digital inputs. The buttons included 2 illuminated push buttons, 3 momentary push buttons, an emergency stop, and 1 three-way switch. The utilization of these buttons is further discussed in the Wiring and Code section of the manual. The three-way switch is used as the primary source of movement when controlling the motors on the guide rail system. This switch is 22mm, and uses a spring return, two-way operation to allow a choice when determining if the motor moves the rails to the left or to the right. The Illuminated push buttons are 22mm and operate maintained. These buttons are maintained as they are used as left and right buttons to control the guide rails. When these buttons are pressed, the designated guide rail motor (left, right, or both) will move when the three-way switch is turned to the left or right. When the buttons are not pressed, neither of the rails will move. The shape of these buttons is extended and require two normally open contacts. The 3 momentary push buttons are also 22 mm with extended buttons, but only require 1 normally open contact. These buttons are used for returning the system to set point, a new set point, or fully opening the rails. Fully opening the rails will allow for maintenance to be completed. The emergency stop is a 22mm push lock button that uses 1 normally open and 1 normally closed contact. A table consisting of the button names, sizes operation and contact is seen in Table 2. A manual consisting of all information regarding buttons can be found at https://www.lectrocomponents.com/content/PDFs/IDEC/Catalog/Switches/TWSeries.pdf .

Button	Operation	Size	Contacts	Part Number
3-Position Selector Switch	Spring Return Two-Way	22mm	4NO	ASW3340
Illuminated Extended Switch	Maintained	22mm	3NO	AOLW29920D-G-24V
Non-Illuminated Extended Switch	Momentary	22mm	1NO	ABW210-G
Emergency Stop	Push Lock Turn Reset	40mm	1NO- 1NC	AVW411-R

Table 2. *Button Information*

To install the buttons into the control box, they must be partially disassembled first. For the dial switch, the white covering must first be removed using a screwdriver. This reveals a notch where a screwdriver can then remove the black switch. After this, the metal bezel can be unscrewed. Then the switch can be placed and tightened in the opposite order on the control panel. As shown in Figure 9, the black and white inserts can be pressed in once the bezel is tightened.

Figure 9. 10 Breakdown of Switch Installment Breakdown of Switch Installment

For the illuminated switches, the bezel, and the light itself unscrew to be installed. For the non-illuminated buttons as well as the emergency stop a screwdriver must be inserted to pop the button off as shown in Figure 10. Once the button is popped off, the metal bezel can be unscrewed, and the buttons can be inserted and placed in the same way as the switch. For all the buttons, to obtain a secure fit, the adjustment ring that is next to the inside of the panel can be rotated until the desired fit and tightness is achieved.

Figure 10. 11Placement of Screwdriver Insert for Removal of Button Faces12Placement of Screwdriver Insert for Removal of Button Faces

The placement of the buttons can be changed as desired. The presented system’s button configuration is shown in Figure 11. The illuminated buttons are the east and west motors. The non-illuminated buttons are the “Return to Set Point”, “New Set Point”, and “Fully Open” buttons.

Figure 13. Button Placement

Control Box

The box we purchased was from Galco, and the part number is N1C121606S. It is a Wiegmann Wall Mount Enclosure, N1C Series. Its height is 16 inches, width is 12 inches, and depth is 6 inches. We machined holes in the box as shown in Figure 12 to place the buttons.

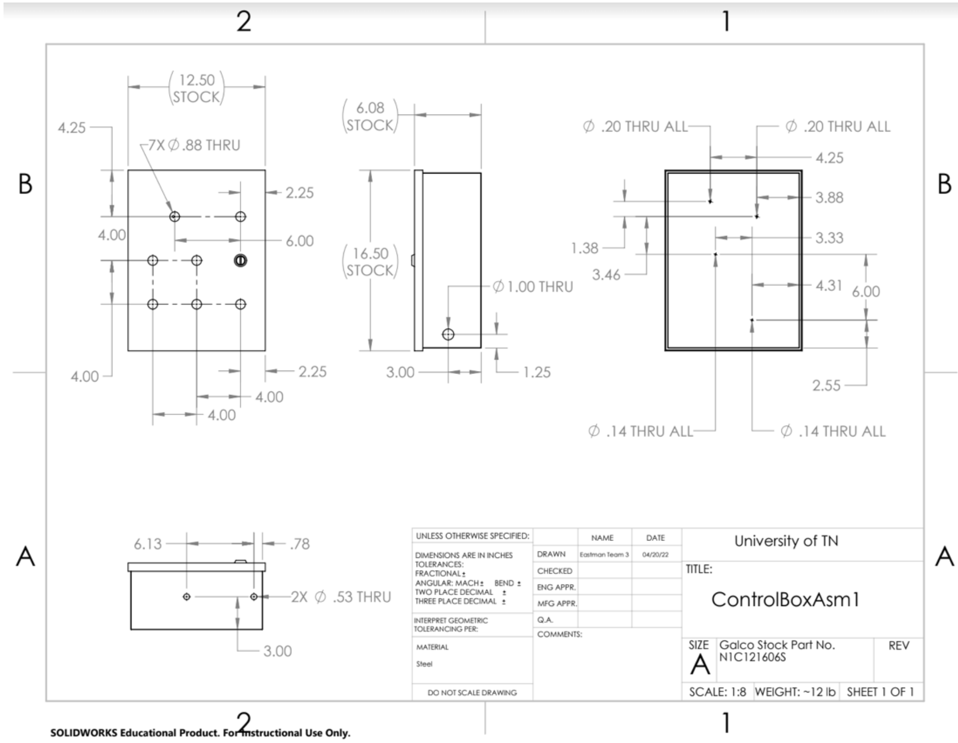

Figure 14. Hole Drawing

Operator Use

The presented system's operator interface is designed to be easily used and understood. Once the system is powered on, it is ready to use. Depending on which motor the operator wanted to activate, he will press the button and it will illuminate to show it is engaged. These buttons are labeled "East Motor" and "West Motor." If both buttons are engaged, both pusher bars are ready to move. Once the desired motors are selected and the buttons are pressed, the switch can be used. The switch is labeled "Motor Drive." Moving the switch toward the "East" label will move either or both selected pusher bars towards the East Motor. As expected, moving the switch toward the "West" label will move either or both selected pusher bars towards the West Motor.

The pusher bars will stop moving if they get too close to the end of the rack. The movement of the bars is slow and constant any time the switch is turned.

The other buttons on the bottom of the panel represent special functions. The button to the far left is labeled “Return to Set Point.” Wherever the push bars are whenever the system is powered on is the set point. This will typically be set to a middle position that is a common place to have the rolls in between. If the pusher bars are moved at any point to other locations and the “Return to Set Point” button is pressed, the bars will return to their original location. If this set point needs to be changed, the pusher bars can be simultaneously or individually moved to their desired location and the middle button can be pressed. This button is labeled “New Set Point.” Once this button is pressed, no matter how much the bars change location, when the “Return to Set Point” button is pressed, the pusher bars will return to the new set point. The button to the far right is labeled “Fully Open.” When this button is pressed, both motors engage and the pusher bars both go toward their respective motor and the bars are as far apart as possible. This is convenient for maintenance purposes. All these buttons are not maintained and only need to be pressed, not held.

The last button of the panel is the button on the top right labeled “Emergency Stop.” When this button is pressed, both motors disengage. To release the E-Stop, the button must be turned. In the event of an emergency, since the motors are disengaged the pusher bars can be pushed back or pushed forward. This is an important feature given the condition of an operator’s safety during an emergency. For example, if their hand is stuck, he or she can push the bar away and remove their hand without fighting resistance from the motors. This is essential to the safety of this assembly.

Wiring Diagram and Electrical Information

Wiring

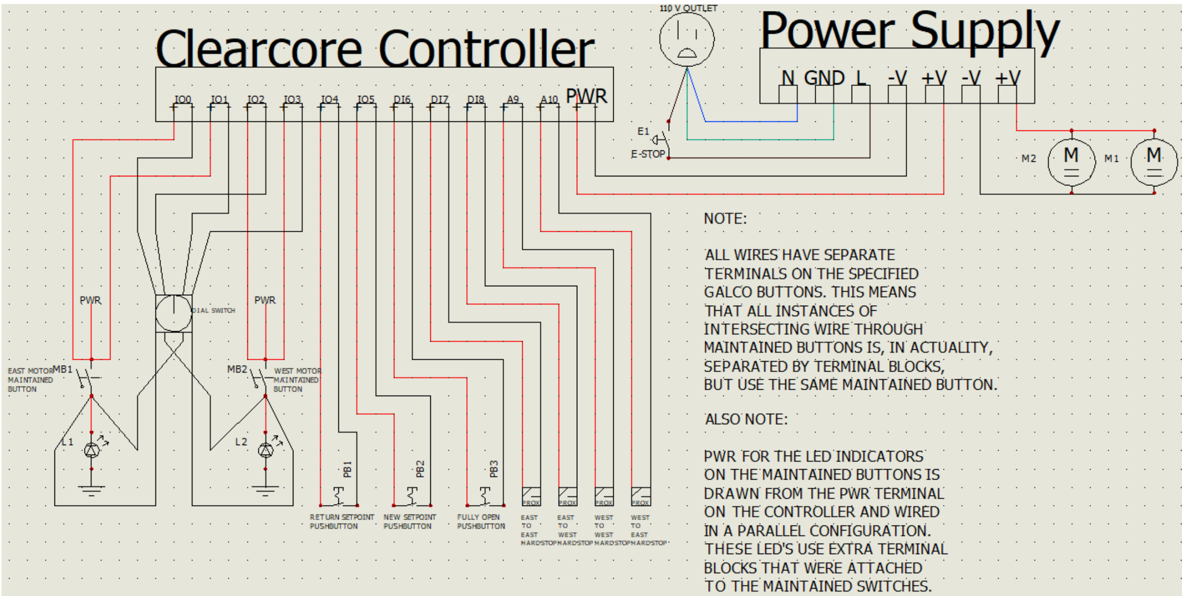

Figure 13. Wiring Schematic

This section will provide a brief overview of the wiring schematic, that can be seen above. The system consists of a Teknic Clearcore controller, a 24VDC power supply, two illuminating pushbuttons, a dial switch, 3 normally open pushbuttons, 4 magnetic switches, and an emergency stop twist mushroom button. To begin, the 110 VAC power cord is wired into the power supply and the emergency stop. The power supply is then wired into the controller's power terminal to power the controller. The three normally open pushbuttons are wired into IO4, IO5, and DI6 on one side and to ground on the other. The four magnetic switches are wired into DI7, DI8, A9, and A10 on one side and to ground on the other. The two illuminating pushbuttons and dial switch must work in tandem to operate the system. This is done by wiring one side of the illuminated pushbuttons into IO2, IO3 and IO0, IO1 respectively. The other side of the illuminated pushbutton contact block is wired into the dial switch and the dial switch is then wired to ground.

Power must be wired from the power supply through a terminal block attached to the maintained switch, then to the LED to illuminate one of the maintained switches. A wire is then utilized to jump the power to the other maintained switch so both buttons can be illuminated. This is done so that the buttons are only illuminated when they are maintained. This eases the task of determining which motor is designated for movement at the current time.

Finally, the motor communicator cables must be plugged into their respective ports on the controller. The communicator cable from the EAST MOTOR will go in CONNECTOR M0 on the controller. The communicator cable from the WEST MOTOR will go in CONNECTOR M1 on the controller.

Coding and Logic Information

In terms of background, this section outlines necessary software, downloads, and hardware for the control implementation of the machine assembly. The controller used in this project was the Clearcore controller. This controller is distributed by Teknic and specifically designed to be integrated with the Teknic Clearpath motors.

The coding languages available for use with the Clearcore controller are both Arduino and C++. The coding environment used for the controller in this specific application was the Arduino IDE. The reason this environment was chosen is because of the familiarity of the language to our team. Teknic provides an “Arduino Wrapper” download on their website that installs an Arduino Library and other components that allow the Arduino language to be compiled and sent to the Clearcore controller.

The components that the logic is dependent upon include 2 maintained button switches, 1 dial switch, 4 external proximity switches, and 3 pushbuttons. The logic for this machine is best described using a logic diagram (provided below).

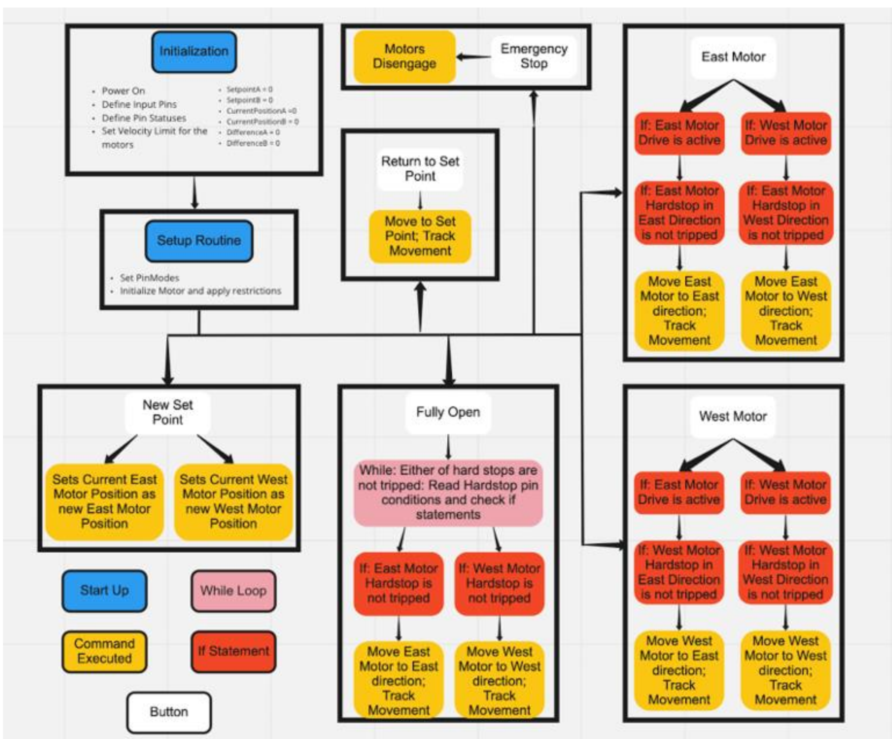

Figure 13. Logic Diagram

The system starts up when power is supplied to the controller. At this point, the motors will begin to initialize. This means that the current position of the motors will read as zero immediately after the startup sequence. The pin modes of all active pins on the controller are then set to input. The logic proceeds into a void loop that runs constantly.

The if statements within the void loop utilize a few specific commands provided by the Clearcore library. Each if statement for all control logic and motor movement contains conditions that correspond to different inputs and readouts from the controller and motors to ensure that no motor will push into hardware and break any of the mechanical components or portions of the machine assembly. It is important to note that these conditions do not surround the entirety of the void loop, but are called individually in each command, as to improve the efficiency and safety of the program. The state of motor movement completion is the first condition that is checked. If the last move commanded to the motor is completed, the condition is met. The state of the proximity switches is checked next. This is telling the system whether it is within its physical bound or not. If it is not, the condition is not met. The last condition that is checked is the “Alerts Present” bit on the motor readout. If there is an alert present, the condition is not met. All beginning conditions will stop a command if not met properly. This keeps the machine running smoothly, allows for tracking of position, and ensures safety in almost every malfunction (including wire severance, as the E-Stop and proximity switches are normally closed).

As the void loop begins, the first thing to be checked is the state of all digital inputs. The motor drive control is checked next. If one or both motors is/are active for driving and the dial switch is turned to either direction, the designated motor(s) will move, and the movement will be tracked using variables. The third condition to be checked is the fully open button. If this button is pressed and all other conditions are met, the motors will retract toward their respective sides and track the movement using variables until the proximity switches on the respective sides are activated. No other inputs will have any effect until the fully open condition is reached for both sides of the assembly. Subsequently, the new setpoint condition is checked. If this button is pressed, the new setpoint for the motors will be the position of the motors when the button is pressed. The final condition to be checked is the return to setpoint button. If this button is pressed and all other conditions are met, the motors will use the variables that have been tracking movement throughout the void loop to complete an absolute position move to the setpoint variables for the respective motors and set the current position of each motor to its respective setpoint.

Miscellaneous Items

Noise

There is no excessive noise in the system as it operates. If noise occurs, it could be caused by a misalignment, or the motor could be out of tune.

Safety and Product Reliability

The system should be able to safely move around and is safe for operators to be near. The area will not be heavily populated, but with heavy weight being moved, the operator interface is in a position where no one would be in danger. The fully open position allows for easy access for maintenance work. Lastly, in the event of an emergency and when the “Emergency Stop” button is pressed, the motors disengage so the pusher bar can be manually moved.

Environmental Considerations and Maintenance

Since the system designed does not require a fast output speed, the wear of the design will be minimal. This along with frequent maintenance would ensure that the system does not experience too much wear. Since the system will not be exposed to high temperatures or liquid, there is a small chance that the system will experience any corrosion so long as the system receives proper maintenance. The motors used in the system are both dust and water splash resistant. Since most of the set-up is composed of stainless steel, the system would not experience as much corrosion. The pusher bars, rack, and pinion gear used for the rack and pinion subassembly are all composed of steel for the consideration of strength and durability. This is because these components of the system will be experiencing a high amount of force. Lubrication would only be necessary for the linear bearing or the rack and pinion subassembly, but this would only have to be applied annually, if at all.

Design Package

Appendix A: Bill of Materials

	DESCRIPTION	QUANTITY	UNIT PRICE	AMOUNT
TEKNIC				
	Clear Path Servo Motor	2	$424.00	$848.00
	24 VDC Power Supply	1	$39.00	$39.00
	Digital I/O Expansion, 8 Point	1	$49.00	$49.00
	Clear Core Controller	1	$149.00	$149.00
	USB Cable	1	$9.00	$9.00
	Terminal Block Plugs, 3 Position (10/Pack)	1	$9.00	$9.00
	Cat5e Patch Cable	1	$9.00	$9.00
STEPPER ONLINE				
	10:1 Gearbox	2	$107.57	$215.14
	Gearbox Shaft Sleeve	2	$3.23	$6.46
	NEMA 34 Bracket for Motor	2	$5.68	$11.36
MCMASTER-CARR				
	Keyed Rotary Shaft	1	$90.48	$90.48
	Dry-Running Mounted Sleeve Bearing	2	$35.87	$71.74
	Metal Gear Rack	1	$49.31	$49.31
	Metal Gear	2	$49.94	$99.88
	Ball Bearing Carriage	2	$118.97	$237.94
	Guide Rail for Ball Bearing Carriage(160mm)	2	$51.20	$102.40
	Flexible Shaft Coupling Spider	2	$7.19	$14.38
	Flexible Shaft Coupling	4	$22.92	$91.68
	Corner Bracket	2	$35.56	$71.12
	Hex Head Screws with Phillips Drive(5/Pack)	2	$7.63	$15.26
	3/4'' Long Flanged Hex Head Screws (25/Pack)	1	$5.00	$5.00
	1'' Long Flanged Hex Head Screws (25/Pack)	1	$4.87	$4.87
	10.9 Steel Hex Head Screws (10/Pack)	1	$6.69	$6.69

18-8 Steel Hex Head Screws (100/Pack)	1	$11.75	$11.75
18-8 Steel Phillips Flat Head Screw (50/Pack)	1	$6.56	$6.56
3/4" Long 18-8 Steel Socket Head Screw (50/Pack)	1	$16.35	$16.35
1" Long 18-8 Steel Socket Head Screw (50/Pack)	1	$22.79	$22.79
Steel Flanged Hex Head Screws (100/Pack)	1	$16.03	$16.03
Serrated-Flange Hex Head Screwed (25/Pack)	1	$7.50	$7.50
High Strength Steel Flange Nuts (1/Pack)	4	$2.50	$10.00
High Strength Steel Serrated Flange Locknut (100/Pack)	1	$6.91	$6.91
Unistrut Brackets	8	$17.61	$140.88
Unistrut Member 5ft	2	$47.07	$94.14
Unistrut Meber 4ft	2	$39.64	$79.28
Plastic End Caps	4	$2.03	$8.12
Strut Channel Feet	4	$13.28	$53.12
Unistrut Nut (5/Pack)	4	$8.82	$35.28
Bolt for Unistrut (10/Pack)	2	$9.15	$18.30
Black-Oxide Alloy Steel Socket Head Screw (50/Pack)	1	$11.19	$11.19
Stainless Steel Hex Head Screw,1-1/8" Long 18-8 (10/Pack)	2	$9.15	$18.30
Strut Channel Bracket, 3-1/2" x 3-1/2"	4	$8.00	$32.00
Flanged Hex Head Grade 8 Steel Screws, 1" Long 10-32 (100/Pack)	1	$16.03	$16.03
Machine Key Stock, 305mm Long, 6mm x 6mm	1	$4.91	$4.91
Magnetically Actuated Switch with Wire Leads	4	$39.44	$157.76
Stainless Steel Hex Head Screws, 2-56 Thread Size 3/8" Long, 18-8 (50/Pack)	1	$7.58	$7.58
Zinc-Plated Alloy Steel Socket Head Screw, 2-56 Thread Size 3/4" Long (25/Pack)	1	$8.89	$8.89

	Multipurpose 6061 Aluminum ,1/16" Thick x 1" Wide, 1 Foot Long	1	$1.71	$1.71
	Multipurpose 6061 Aluminum, 1/4" Thick x 1" Wide, 1/2 Feet Long	1	$2.58	$2.58
	Easy-to-weld 5052 Aluminum Sheet, 0.1000" Thick, 6" Wide x 6" Long	1	$13.68	$13.68
	Zinc Plated Low-Strength Steel Hex Nut, 2-56 Thread Size (100/Pack)	1	$1.10	$1.10
	Black-Oxide Stainless Steel Thin Hex Nut, 1/2"-13 Thread Size (10/Pack)	2	$6.77	$13.54
	Strut Channel Solid, Aluminum, 5 Feet Length	1	$47.07	$47.07
GALCO				
	Wiegmann Wall Mount Enclosure, N1C Series	1	$151.04	$151.04
	IDEC Non-Illuminated Selector Switches TW Series, ASW3340	1	$37.20	$37.20
	IDEC Non-Illuminated Pushbuttons TW Series, AVW411-R	1	$40.60	$40.60
	IDEC Non-Illuminated Pushbuttons TW Series, ABW210-G	3	$12.93	$38.79
	IDEC Illuminated Pushbuttons TW Series, AOLW29920D-G-24V	2	$46.42	$92.84
	IDEC Contact Blocks, HW-U10	2	$5.88	$11.76
MERCURY ENGRAVING				
	Control Box Labels	-	-	$24.75
	Total	**$3,466.04**		
SOURCED MATERIAL				
	Description	**Material**	**Stock Type**	
	Pillow Block	Aluminum	Sheet	
	Bearing Angle plate	Aluminum	Angle	

Angle Plate for the NEMA 34 Bracket	Aluminum	Angle
Angle Plates for the Mounting Assembly	Aluminum	Angle
Square Bar (Pusher Bar)	Steel	Bar

Appendix B: MSP Software – Recommended Settings

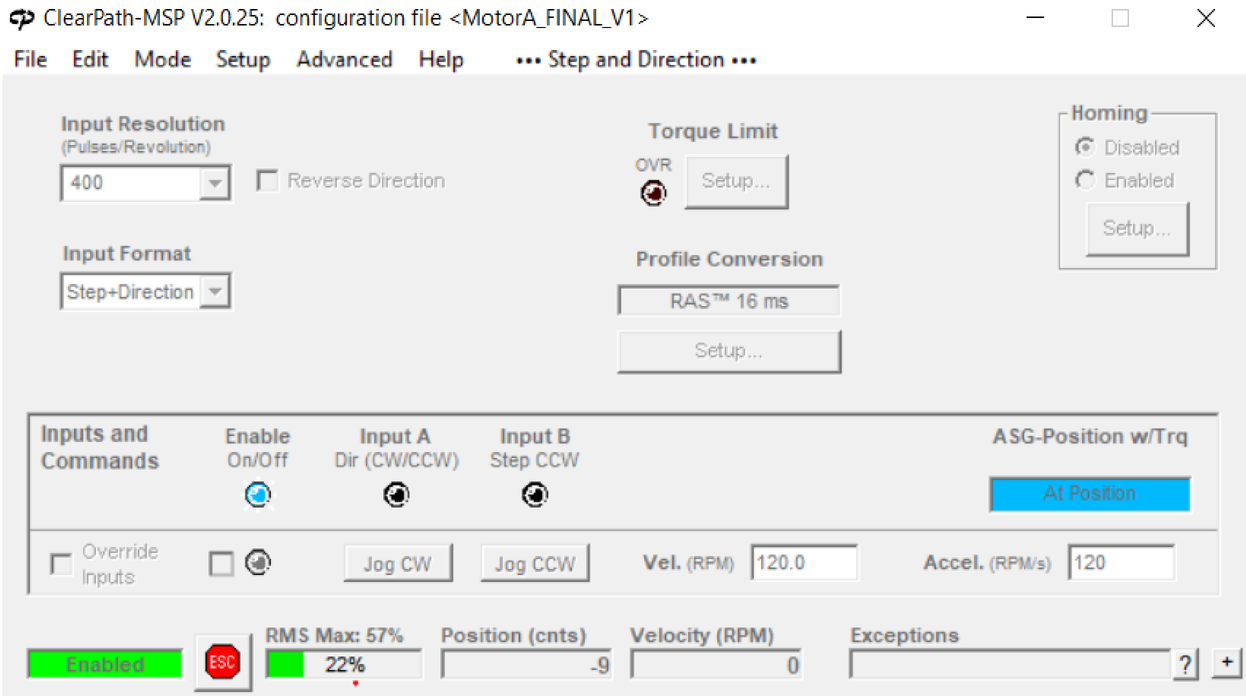

Figure 14. Screen Capture of the settings of "Motor A" (East Motor) in MSP.

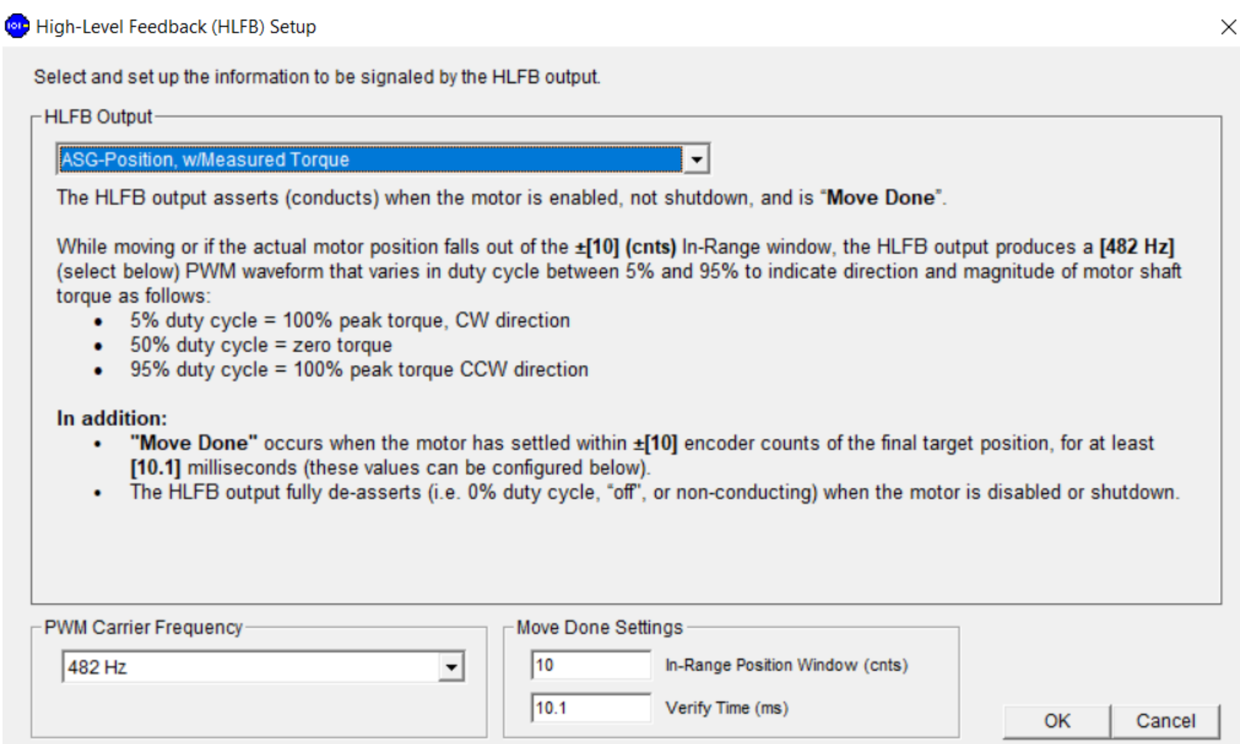

Figure 15. Screen Capture of the High-Level Feedback settings of "Motor A" (East Motor) in MSP.

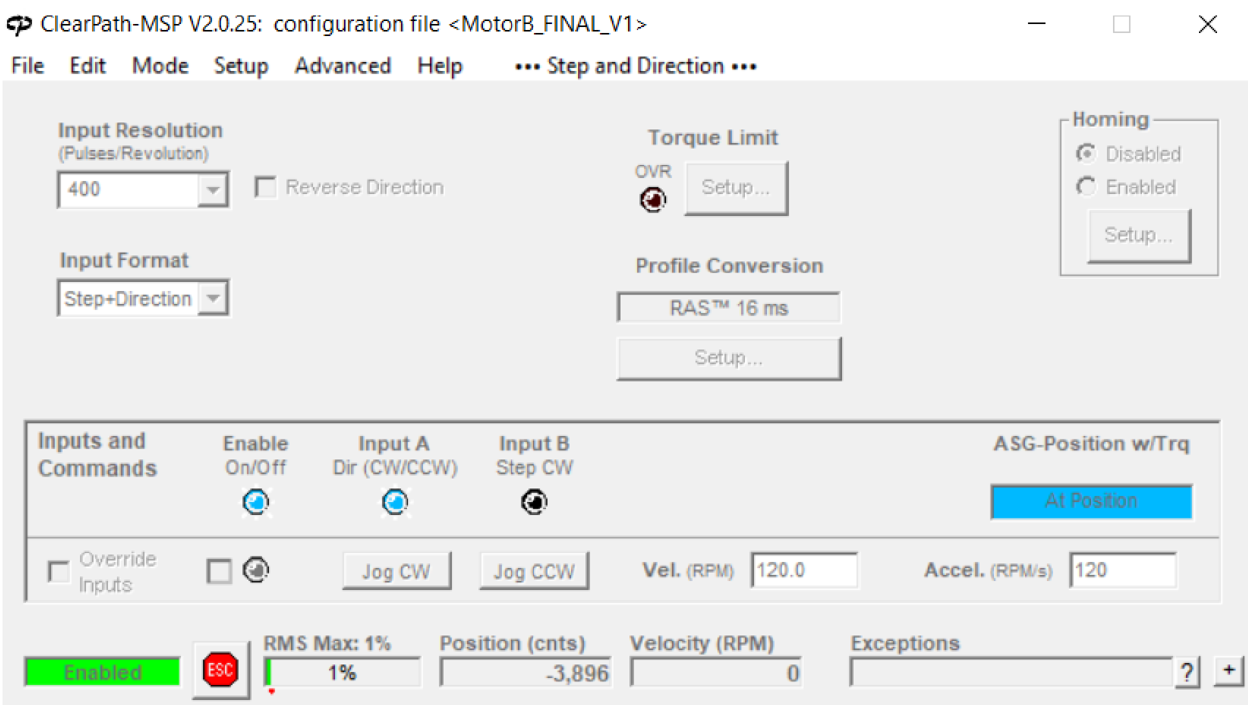

Figure 16. Screen Capture of the settings of "Motor B" (West Motor) in MSP.

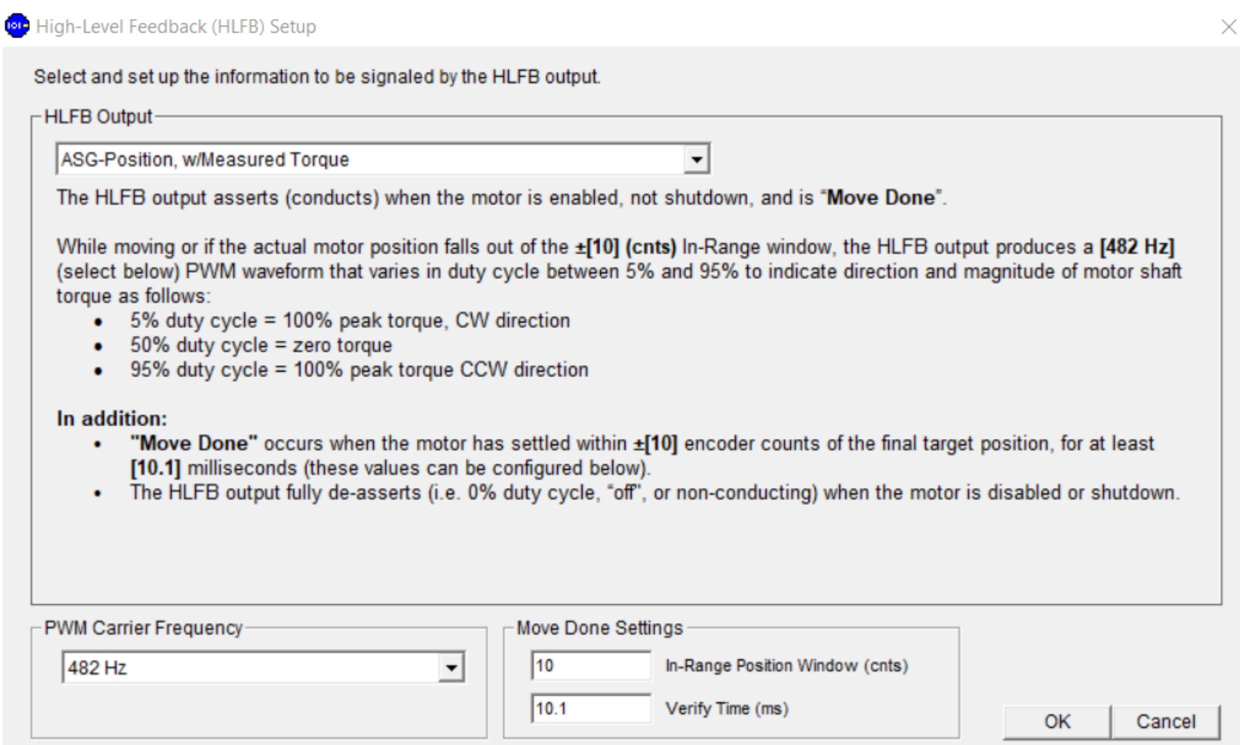

Figure 17. Screen Capture of the High-Level Feedback settings of "Motor B" (West Motor) in MSP.

Assembly Recommendations

There are a few recommendations for this project. One recommendation would be a shaft with a tighter tolerance. The shaft we used had a larger tolerance and the one we got in ended up being a little undersized. Another recommendation would be to purchase a larger power supply for the motors. With more power, the motors would have more range and capabilities, as this system is limited by the voltage output of the power supply we currently have. Also, a protective guard should be added to the rack and pinion intersection (“pinch point”) if operators will be around that area. Lastly, adding gussets between the stands would provide sturdiness for the whole assembly and decrease the chances of having any wobble during operation.

User Manuals

Product	**Link**	**Use**
ClearCore	https://www.teknic.com/files/downloads/clearcore_user_manual.pdf	Hardware and Wiring
ClearCore	https://www.teknic.com/files/downloads/ClearCore-Electrical-Schematic.pdf	Electrical Schematic
ClearCore	https://www.teknic.com/files/downloads/clearcore_system_diagram.pdf	System Diagram
ClearPath	https://www.teknic.com/files/downloads/clearpath_user_manual.pdf	Hardware and Software
Buttons	https://www.idec.com/language/english/catalog/Switches/TWSeries.pdf	Installation