

Final Report
Lotion in Motion Inc.
Sortation Machine

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ENME 464: Machine Design II
16 December 2024
Submission to Professor Bridendolph

UMBC
COLLEGE *of*
ENGINEERING *and*
INFORMATION
TECHNOLOGY



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INTRODUCTION

Lotion in Motion Incorporation is a new manufacturing company that produces small, plastic containers of lotion. The corporation's goal is to develop a fully automated sortation line to sort the plastic containers of lotion and remove any faulty products from the line. In less than four months, the team worked with a strict budget of two-hundred (200) dollars and donated parts to create a successful sortation line for their learning purposes.

The specifications and requirements are important to consider while creating this sortation line. The sortation machine must fit within a 3' W x 2' L x 2' H box. The company sorted out faulty products that potentially included water and metal and was repeatable in sortation. This way, only the containers with the lotion product would make it through the line. The company used the conveyor belt and PLC provided. PVC pipe to hold all three (3) plastic containers. Another requirement was that a minimum of two (2) separate sensors for sortation were needed. Lotion in Motion Inc. decided to use three sensors including a photo eye, inductive, and capacitive. The photo eye sensor was used to sense any product in the dispenser that needed to be pushed on the conveyor belt. The inductive sensor sensed potential metal in our containers, while the capacitive sensor sensed water in our product. A minimum of two cylinders must be used for sortation and at least one cylinder position sensor is required per cylinder. The team used a total of three (3) piston-cylinders on the line and three (3) position sensors to sense that the piston was at full-extension. In addition, an emergency stop was accessible for safety precautions and was programmed to stop the whole automated system. An on and off switch was used to start and stop the system. A regulator was also required for compressed air. All wiring and air lines passed the tug test before use, and all wiring was done using proper colors. Considering the value of both cost and time, Lotion in Motion Inc. made carefully thought-out decisions for the overall success of the sortation system using available resources.

DESIGN PROCESS

There was a list of 12 requirements given by Professor Bridendolph that had to be met by the final result. The only dimensional specification was that the project must fit within a 3' W x 2' L x 2' H box. The requirements were as follows:

1. A minimum of three different widgets had to be sorted based on either materials, shape, color, or defects.
2. A minimum of two different sensors had to be used for sortation, with cylinder proximity switches not counting as one of these sensors.
3. A minimum of two cylinders had to be used for sortation, and each cylinder had to be paired with one cylinder position sensor.
4. An emergency stop (e-stop) button had to be clearly visible and readily accessible.



5. The provided conveyor belt and Click PLC needed to be used.
6. The project had to be repeatable in sortation and able to go through three cycles of sortation.
7. At least one sensor was required to identify when a widget was ready for pickup.
8. A fully automated dispenser capable of holding a minimum of three widgets was required.
9. The pneumatics needed to have a pressure regulator for the compressed air.
10. All wiring and air lines needed to be secure and pass the tug test.
11. All wiring had to follow the proper color coding for organization.
12. After the final demonstration, all parts needed to be returned to receive full credit

To satisfy the dimensional specification while still providing adequate space to place the sensors about 8 inches apart and allow room for the cylinders to actuate and eject the defective widgets from the conveyor belt after detection by the appropriate sensor, the company ultimately wanted the project width to meet the exact 3-foot specification with no margin. The final dimensions were 3' W x 1' L x 0.75' H, where both the length and height requirements were easily met. To build a solid structure for the project while still meeting the desired final dimensions, aluminum extrusion was used. The purchased aluminum extrusion was made from aluminum 6063-T5, which has a low density of 0.098 lb/in³ and a tensile yield strength of 21 ksi, making it ideal for this project [5]. The project weighed about 25 lbs. Furthermore, the aluminum was anodized and came in black, providing a smooth surface finish and clean aesthetic appeal.

To meet Requirement 1 and the company's goal of sorting lotion through the system, in addition to a container of lotion, the company decided to fill one container with water, which could be extended to other types of liquids. The second defective widget would be a container of metallic objects. The rationale was that if the containers ever contained liquids other than the desired lotion, it would significantly undermine the quality of the product and customer trust, as consumers expect to receive exactly what was requested. Additionally, consumers would want nothing more than lotion in their lotion containers. It could be detrimental to their safety if any foreign objects, especially metallic ones, were present in the container, as lotion is meant to be rubbed into the skin for moisturization. Therefore, a container of various metallic objects, most of which were aluminum 6063-T5 and galvanized carbon steel, was filled and used.

To meet Requirement 2, after determining the containers/widgets that the company wanted to sort out of the line, the two sensors that would be best for this project were a capacitive proximity sensor and an inductive proximity sensor. The capacitive proximity sensor was selected because it is effective at detecting liquids within non-metallic containers. The capacitive sensor also features a sensing range that can be calibrated to the specific dielectric constant of the water. As the water enters the electrostatic field of the sensor's electrodes, it changes the capacitance of the oscillator circuit contained within the sensor, turning the sensor "on" [6]. It should be noted that the sensor was wired normally open. The inductive proximity sensor was



selected to detect the container with metallic objects inside. The inductive proximity sensor works by creating an electromagnetic field through the sensor's surface, and when a metallic object enters the field, it reduces (dampens) the amount of current sent to the oscillator circuit, resulting in an output switching signal that turns the sensor "off" [4]. It should be noted that the sensor was wired normally closed.

To meet Requirement 3, one cylinder and one cylinder position sensor were paired with each sensor, where the sensor served as the input for the operation (output) of the cylinder. One cylinder was paired with the capacitive sensor, one with the inductive sensor, and one with a photoelectric sensor (which will be discussed later in the report), for a total of three cylinders and three cylinder position sensors.

To satisfy Requirement 4, the company used the emergency stop (E-stop) button from the inventory list and placed it at the top base of the project, where the start and stop buttons were also located. Therefore, in the event of any unexpected situations, users could quickly press the button to halt the operation altogether. In the original CAD model, the plan was to place the E-stop alongside the start and stop buttons at the top corner. However, in the final assembly, the E-stop was placed at the bottom corner. This change was made because the directional control valves (DCVs) were moved and placed next to each other to improve both aesthetics and pneumatic wiring, as the tubes for each cylinder were routed underneath the base. Additionally, this arrangement allowed all the DCVs to be troubleshooted simultaneously if necessary.

Notice the original concept model, shown in *Figure 1*, indicates the original layout idea for the project. All of the directional control valves were intended to be placed near the piston cylinder it corresponds with. The original model also consists of a pick and place, which was removed from the final design due to a limited budget and time. During development and assembly, the layout was slightly altered in order to make the design more efficient. *Figure 2* is an image of the original CAD model assembly. As noticeable, Lotion in Motion Inc. prioritized a well organized and clean design. Not only does this add to the aesthetics of the machine, the organization helped the team keep track of the wiring and tubing better. This way, if any issues came about, tracing the wire or tube's location was less hectic. *Figure 3* is an image of the fully functional sortation machine, from a top view. This view shows the organized layout the company worked hard to achieve. *Figure 4* is a closer detail, highlighting the changed layout of the directional control valves and push buttons. Many changes were made during the building process, as more efficient ideas were formed hands-on.

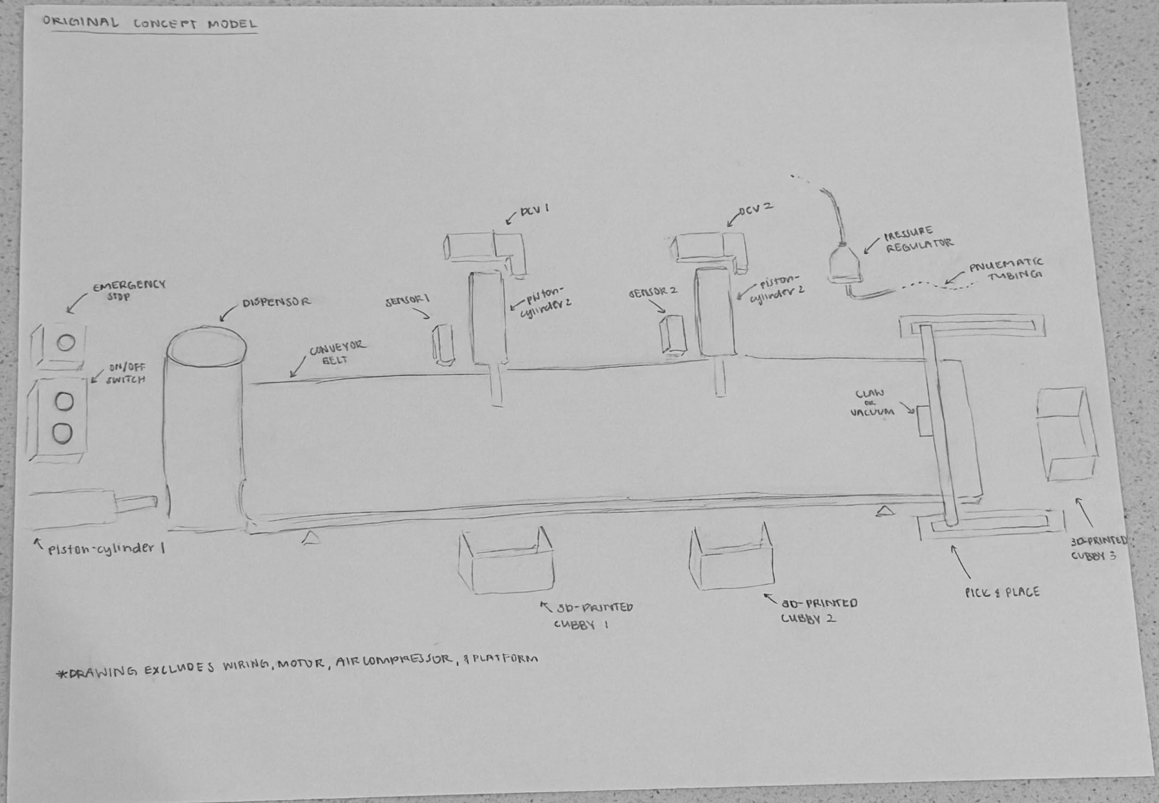


Figure 1: Original Concept Model Sketch

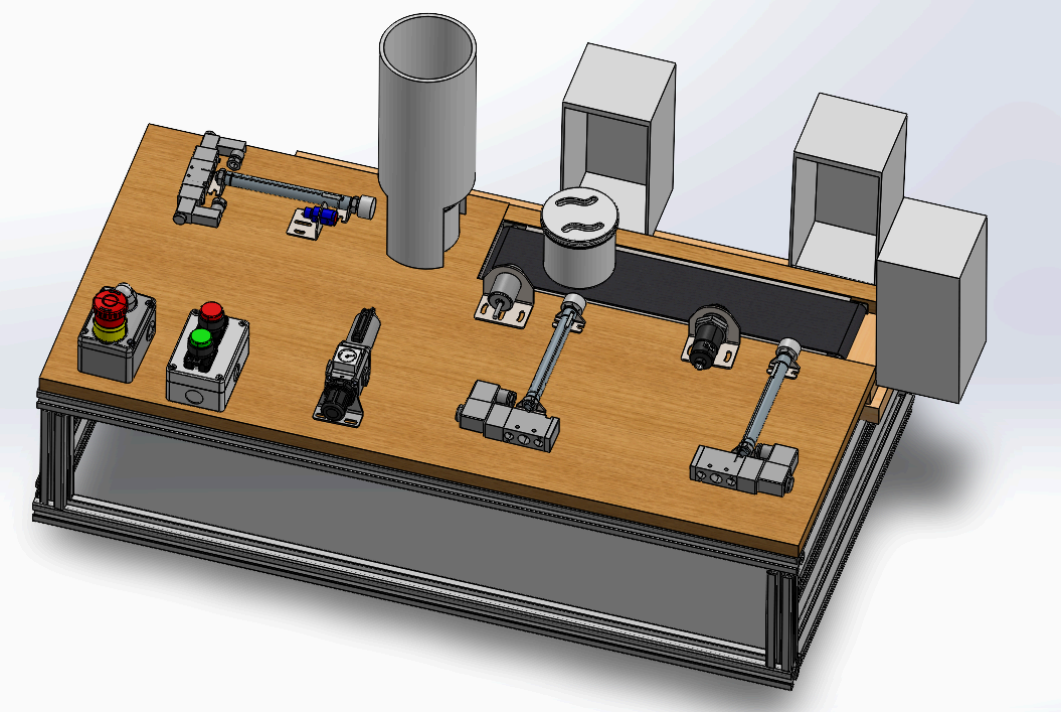


Figure 2: Original CAD Model

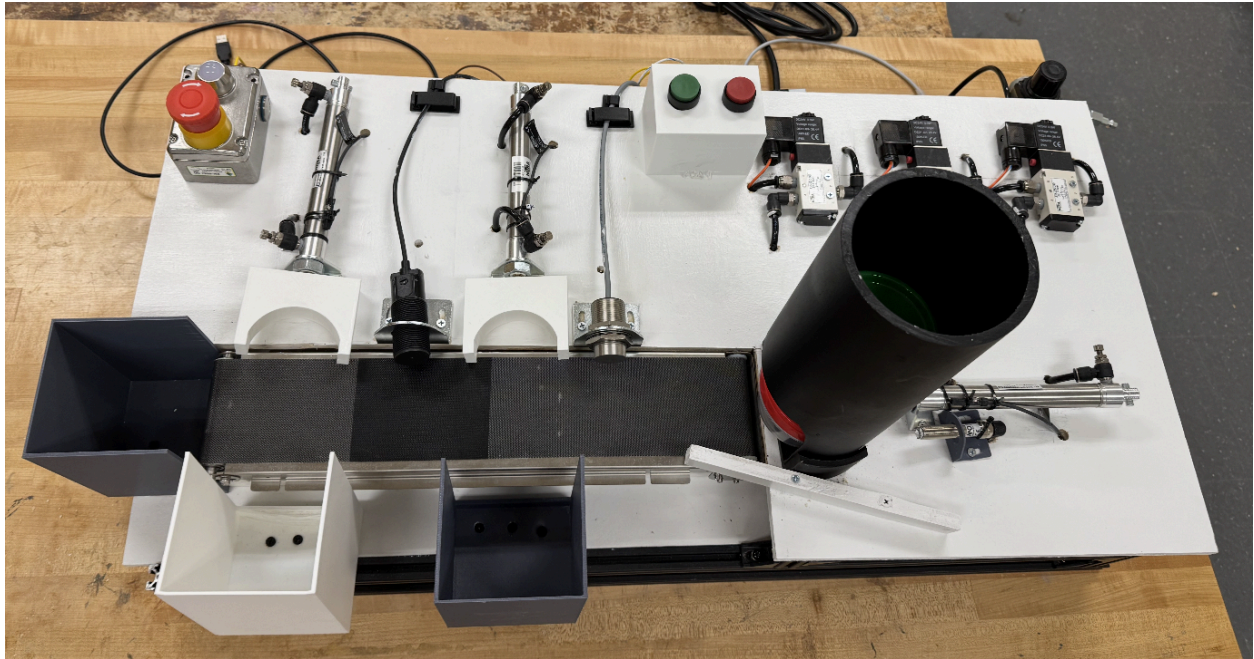


Figure 3: Final Model Orientation - Top View





Figure 4: Final Model Orientation - Side View

Requirement 5 was simple; however, it required slight modifications for the provided conveyor belt to be compatible with the CLICK PLC. The conveyor belt, which features a motor, was originally designed to be powered by a 120V AC wall outlet. However, by using a relay, it was adapted to be powered with 24V DC. Therefore, the conveyor motor was hardwired directly to the relay.

To meet Requirement 6, which required the project to sort the containers for at least three cycles, the project was tested dozens of times. Initially, the work breakdown structure and Gantt chart allocated about ten days solely to testing. The company made several changes to improve the operation of the sortation. Most notably, a piece of wood was added as both a damper and a guide rail to prevent the containers from falling off the conveyor as they were ejected from the dispenser, as shown in Figure 5. The correct angle for securing the guide rail was determined through trial and error. Also, for simplicity, all the containers used were the same, which helped with predictability. The company realized that since the containers already varied in weight, minimizing variability between them would allow for more consistent test results.

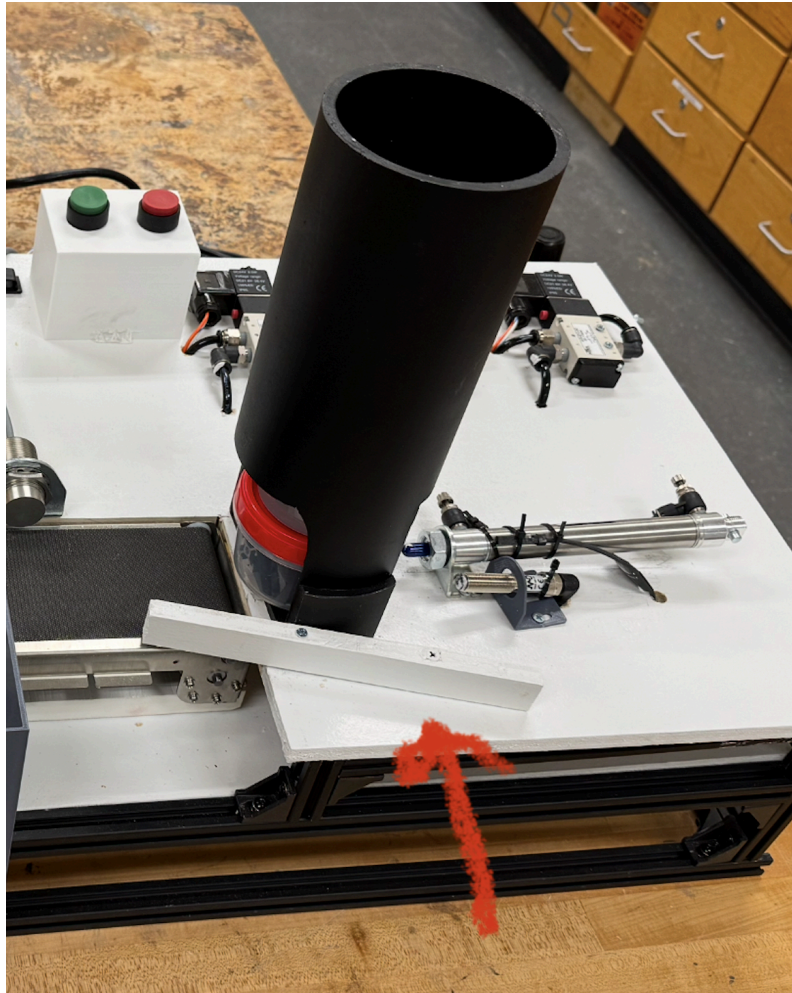


Figure 5: Detail image indicating wooden dampener

To meet Requirement 7, where at least one sensor was required to identify when a widget was ready for pickup, the company did not emphasize this requirement, as it was decided that a pick-and-place mechanism would not be built for this project. Therefore, the time that would have been allocated to include another sensor was instead used to optimize the three separate sensors and three cylinder position switches that had already been selected.

To satisfy Requirement 8, which called for a fully automated dispenser capable of holding at least three widgets, a polyvinyl chloride (PVC) pipe, a photoelectric sensor, a cylinder, and a cylinder position sensor were used. The containers were approximately 4 inches (3.7 inches) in height and 3 inches (2.6 inches) in diameter. Therefore, a 4-inch diameter PVC pipe was used, as it could be donated and cut to create openings for both the widgets and the cylinder rod as it extended. The pipe had a height of 12 inches (1 foot), allowing it to hold three containers at a time. The hole was cut about 5 inches high, and the edges needed to be sanded afterward. Initially, the corners of the hole were too small, and the containers couldn't be pushed out of the PVC. The diffuse photoelectric sensor was used to detect when a container was present. The



sensor was selected specifically because it contained both the beam receiver and emitter, eliminating the need for an additional receiver or emitter. The photoelectric sensor was positioned next to the cylinder, and when a container was dropped into the line of sight, it triggered the sensor. The sensor served as an input for the cylinder to extend and push the container onto the conveyor belt. When the cylinder was fully extended, the cylinder position sensor would detect this and momentarily turn on, breaking the circuit to the cylinder and causing it to retract. Although the design can be improved, it successfully met this requirement.

To meet Requirement 9, which called for a regulator for the compressed air, the company used the automation direct pressure regulator provided in the inventory list, in addition to flow control valves for the extend and retract ports of each cylinder. Lastly, a dump valve was purchased to prevent pressure build-up. The pressure regulator was set to approximately 20 psi. These regulators allowed for the safe operation of the project, as the force and pressure of each cylinder were controlled. Lastly, after trial and error, the minimum pressure and flow rate necessary for successful operation were determined and maintained.

Requirements 10 and 11, which stated that all pneumatics and electrical connections needed to pass the tug test and that the proper wiring color coding must be followed, were both met, as shown in Figure 6. The wires and tubing were routed from underneath the platform to consolidate the wiring for safety reasons and aesthetic purposes. The use of terminal blocks significantly helped ensure secure electrical connections. Likewise, the push-to-connect fittings were effective for maintaining tight pneumatic connections. Fortunately, all the fittings were $\frac{1}{4}$ " and the pneumatic tubing was also $\frac{1}{4}$ ", so no additional adapters were needed, reducing the potential for air leaks. The electrical wire colors followed throughout the project were brown for 24V, white or white/blue for 0V, yellow for PLC inputs, and orange for PLC outputs.



Figure 5: Final Wiring, Cables, and Tubing Orientation Underneath the Platform

Lastly, much to the dismay of the company, the project has been disassembled, the inventory parts have been returned, and the additional purchased components have been donated satisfying requirement 12.

Theory of Operations

The sortation project follows this procedure:

Step 1: The user drops the three containers—water, metallic objects, and lotion—into the dispenser.

Step 2: The user presses the green start button. All components should now be powered on, and the conveyor belt should begin running.

Step 3: The diffuse photoelectric sensor will detect the first container and send an input signal to DCV 1, which will allow the first cylinder to extend and eject the container onto the conveyor belt after a two-second delay. This process continues until all containers are ejected onto the conveyor belt.

Step 4: Assuming the container of water is the first to be ejected onto the conveyor belt, it will pass the inductive sensor and continue towards the capacitive sensor. When the container passes the capacitive sensor (normally open), it will trigger the indicator light and send an input signal to DCV 3, causing cylinder 3 to extend and push the container into the second compartment.

Step 5: Assuming the container of metallic objects is the next to be ejected from the dispenser, it will trigger the inductive sensor (normally closed) and send an input signal to DCV 2, causing cylinder 2 to extend and push the container into the first compartment.

Step 6: The container of lotion, being the last onto the conveyor belt, will pass both the



inductive and capacitive sensors without triggering them and will be placed in the compartment at the end of the belt.

DISCUSSION

Overall the design was effective. All of the wires and pneumatic tubing was hidden underneath the sortation machine allowing for all the components to be easily accessible. Despite the success of Lotion in Motion Inc., there were several drawbacks to the project that could be improved with future machines. One of the limitations of the sortation machine was the lack of repeatability. Due to the strict constraints of the machine, a specific order of widgets was required for the machine to work optimally. To improve this, the company would suggest using different containers to ensure they stack more smoothly after the first widget is ejected. In conjunction with the aforementioned suggestion, the height of the cutout hole in the PVC should be decreased to the height of one container to prevent the next container from accidentally falling out of the dispenser. Another shortcoming of the sortation machine was a semi-functional photoeye sensor. The photoeye sensor was very sensitive and detected everything, which caused DCV 1 to activate permanently and eject every 2 seconds. In future iterations of the sorting machine, there will be an upgrade on the photoeye sensor to ensure it works as intended. Besides these few flaws, there was nothing else worth noting that the company will be looking to fix when creating new machines, especially considering the time and cost constraints.

BUDGET

Lotion in Motion Inc. had a budget of \$200 dollars to work with throughout the development of the sortation machine. The budget excludes any parts from the inventory list. The team used \$199.66 of the \$200.00 budget. The majority of the budget included parts used for the structure and assembly of the machine including connectors, electrical cables, mounting brackets, aluminum extrusion, as well as a dump valve. Aluminium extrusion was one key expense in the budget, taking up \$83.99 or 42% of the budget. While this material was not required, the company found it necessary to provide the sturdiness and stability of the base, as well as for aesthetic purposes. One cost effective part includes the *3D Printing Filament* (Table 1) purchased from Amazon. A large roll of the material only cost \$12.69 of the budget and was used to create multiple components of the project. Other major components of the sortation machine including the piston-cylinders, single solenoid directional control valves, sensors, wiring, tubing, the regulator, fittings, emergency stop, push buttons, etc. were gathered from the inventory list. Besides materials acquired from the inventory list and the \$199.66-worth of materials ordered through Automation Direct and Amazon, other components such as plywood, zip ties, and PVC pipe were donated to the team. Ultimately, Lotion in Motion Inc. carefully managed the budget to stay within the \$200 allotted budget, as illustrated in *Table 1*. The combination of purchased materials, inventory items, and donations allowed the team to develop a fully functioning, yet cost effective sortation machine. The team's financial planning and



resourcefulness contributed to the success of the sortation machine.

Table 1: Final Budget

Part Name/ Description	Price	Quantity	Total Cost	Link
3D Printing Filament	\$12.69	1	\$12.69	Link
80/20 Aluminum Extrusion	\$83.99	1	\$83.99	Link
Inductive and Capacitive Sensor Mounting Brackets	\$2.25	2	\$4.50	Link
Photoelectric Mounting Brackets	\$2.00	2	\$4.00	Link
Widgets/Containers For Different Fluids	\$9.99	1	\$9.99	Link
Capacitive Sensor Connection Cable	\$26.50	1	\$26.50	Link
Photoelectric Sensor Connection Cable	\$11.00	1	\$11.00	Link
Inductive Sensor Connection Cable	\$14.00	1	\$14.00	Link
Dump Valve	\$14.00	1	\$14.00	Link
8020 Connectors	\$18.99	1	\$18.99	Link
Plywood	Donated	2	\$0.00	
PVC Pipe (>4in D)	Donated	1	\$0.00	
Zip Ties	Donated	1	\$0.00	
Total Cost			\$199.66	



Breakdown of Engineering Documentation

PNEUMATIC SCHEMATIC

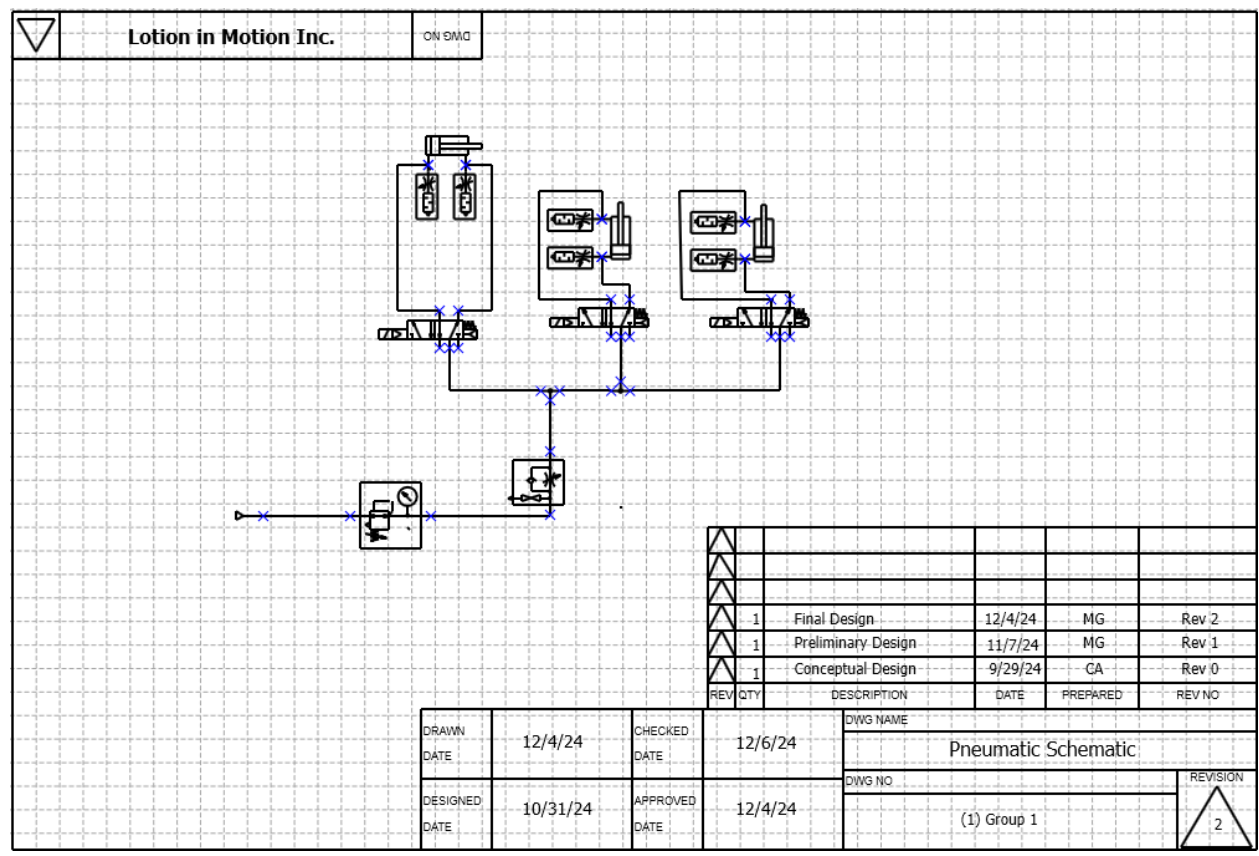


Figure 6: Final Pneumatic Schematic

The pneumatic schematic shows the layout of air flow and its connections throughout the system. The company used a 3/8" air hose with 1/4" couplings to connect to the air supply. The air travels through the regulator to control the pressure of the air throughout the system. From the regulator, the air goes to a dump valve and then to a 3-way splitter. Next, the schematic shows one tube going to one single solenoid DCV and the other side going to another 3-way splitter. From there, the tube goes to two different single solenoid DCVs. There are 3 piston-cylinders. Each cylinder has two metering valves in order to control the speed of the piston cylinder and three single solenoids DCVs to control the direction of the air flow. All fittings were 1/4".

ELECTRICAL SCHEMATIC

The electrical schematic is the layout that defines the logical connections between components electrically. The components are color coded, indicating the voltage source for each item. The diagram generally follows the same contact logic as the PLC program in regards to what is normally closed or open. The white/blue wires designate the ground wires or components



receiving zero volts. The brown wires are assigned to all connections receiving 24 volts and yellow wires indicate the inputs.

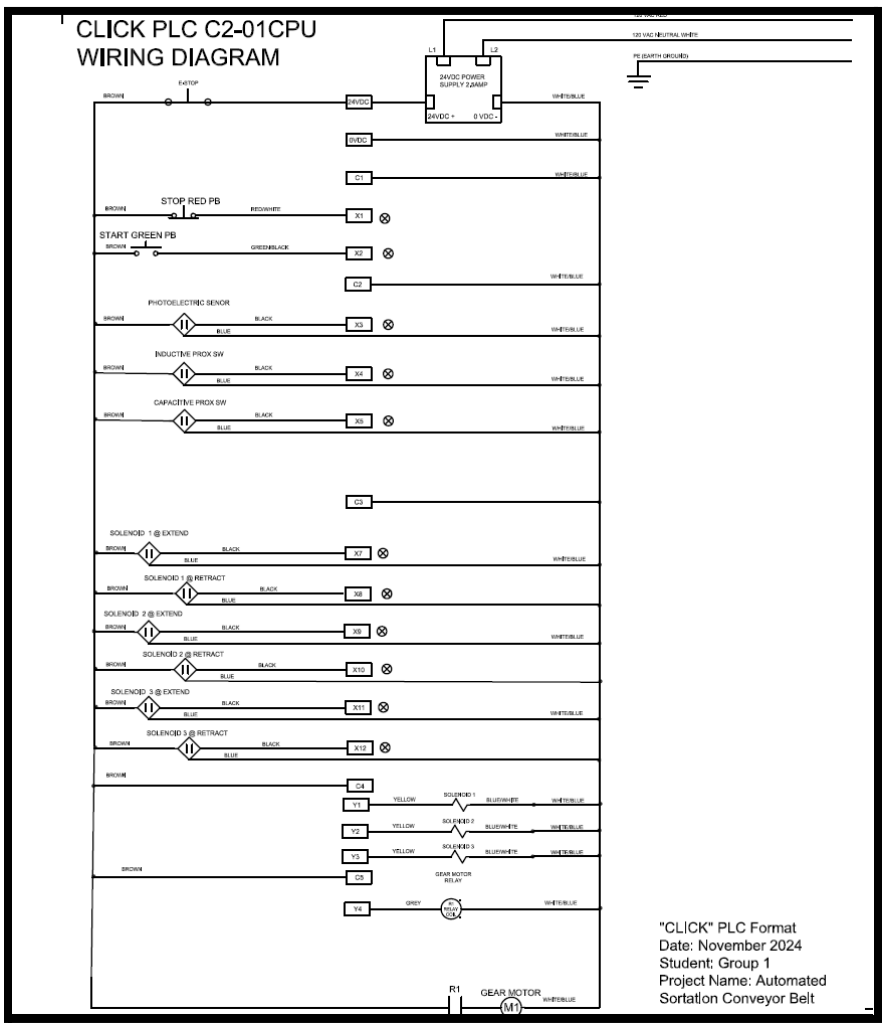


Figure 7: Electrical Schematic

LADDER LOGIC

The ladder logic details the programming diagram of the system. The company went through several concepts before arriving at the final design.

1. The first rung contains all of the overarching control functions. The stop, start, and E-Stop button dictate whether or not the machine operates. The Gear Motor Relay is in a parallel rung (memory circuit) with the start button therefore when the start button is momentarily pushed the conveyor belt will start as well. The E-Stop is coded in every line to ensure the machine can completely shut off in case of an emergency.



2. On rung 2, the start button or the photoelectric sensor can activate the circuit. Cylinder Switch 2 is normally closed to ensure that solenoid 1's normal state is retracted. Timer 1 is the output to delay the energization of solenoid 1.
3. In rung 3, the parallel branch functions as the other parallel branch in rung 1. The timer delays the output signal of solenoid 1 to extend cylinder 1. After cylinder 1 is fully actuated, the cylinder switch (cylinder position sensor) detects this and opens the circuit de-energizing DCV 1, causing cylinder 1 to retract. The holding circuit allows solenoid 1 to stay energized, while timer 1 is no longer on.
4. The capacitive sensor is in a holding circuit with C1, a memory bit. C1 is a virtual output and input device that stores the state of the capacitive sensor. Cylinder switch 2 serves the same function as the cylinder switch 1.
5. In rung 5, C1 relays this information to Timer 2
6. In rung 6, Timer 2 energizes solenoid 2. Overall solenoid 2 is energized and causes cylinder 3 to extend when the capacitive sensor detects the container of water and retracts once the timer resets. C1 holds the memory of the capacitive sensor in its dormant state.
7. Rung 7 mirrors Rung 4
8. Rung 8 mirrors Rung 5
9. Rung 9 mirrors Rung 6
10. Rung 10 is the end of the program

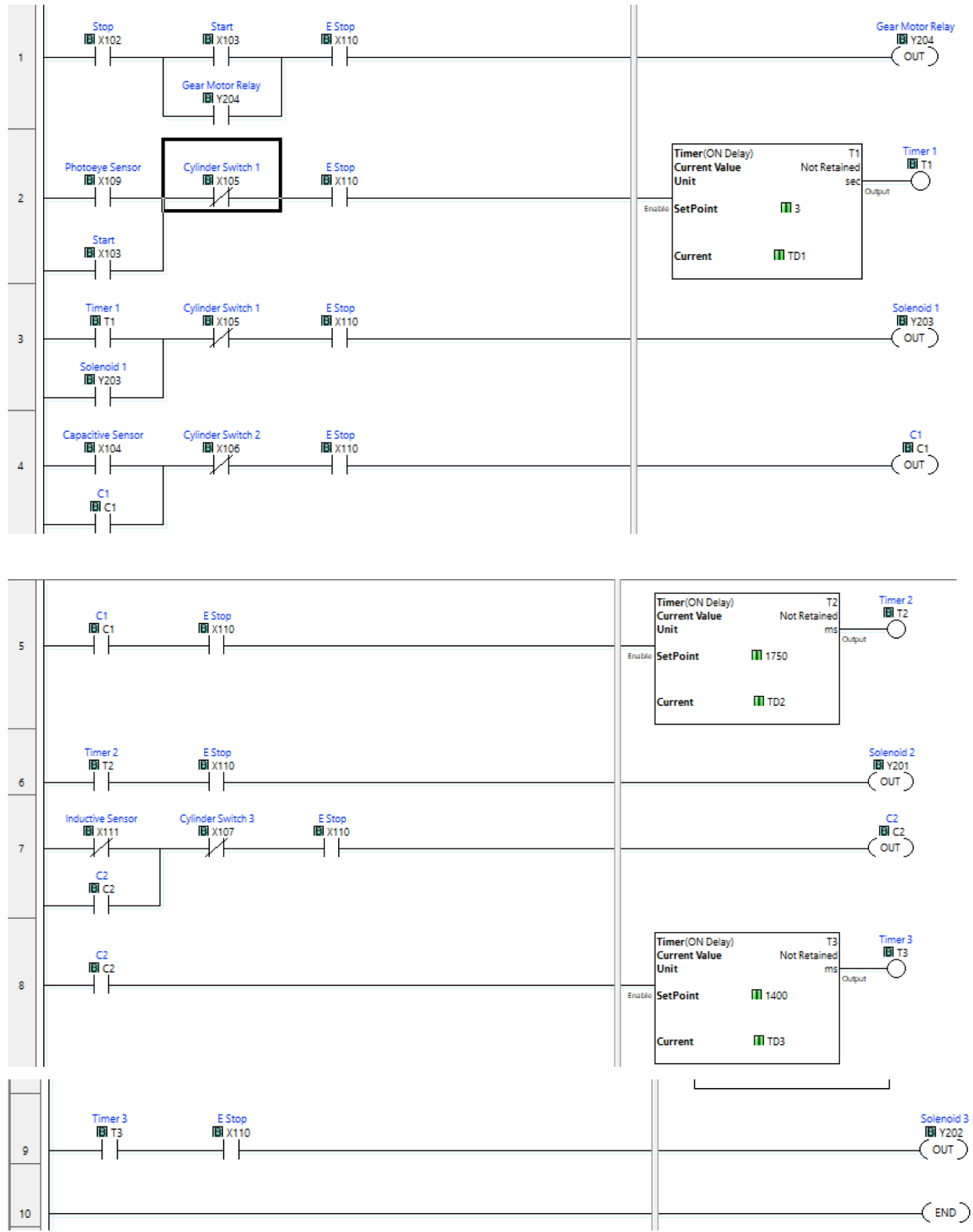


Figure 8: Final Ladder Logic



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APPENDIX

Appendix A: Gantt Chart

GANTT CHART

PROJECT TITLE	ENME 464: Sortation Line	COMPANY NAME	Lotion in Motion Inc.
PROJECT MANAGERS	Christopher Appiah, JT Klassou, & Macy Granzow	DATE	12/16/24

WBS NUMBER	TASK TITLE	TASK OWNER	START DATE	DUE DATE	DURATION	PCT OF TASK COMPLETE	PHASE ONE															
							WEEK 1				WEEK 2				WEEK 3							
							M	T	W	R	F	M	T	W	R	F	M	T	W	R		
1	Project Conception and Initialization																					
1.1	Background Research	Everyone	9/16/24	9/19/24	3	100%																
1.1.1	Brainstorm	Everyone	9/16/24	9/19/24	3	100%																
1.2	Material Selection	Everyone	9/16/24	9/19/24	3	100%																
1.2.1	Initial BOM	JT	9/19/24	9/27/24	8	100%																
1.2.2	Initial Project Budget	JT	9/19/24	9/27/24	8	100%																
1.3	Sketches, Models, and design concepts	Everyone	9/19/24	9/27/24	8	100%																
1.3.1	Initial Pneumatic Schematic	Chris	9/19/24	9/27/24	8	100%																
1.4	Explanation of Methodology	Everyone	9/19/24	9/27/24	8	100%																
1.4.1	List of Inputs and Outputs	Chris	9/19/24	9/27/24	9	100%																
1.5	CoDR	Everyone	9/19/24	9/28/24	9	100%																
1.5.1	Presentation about Initial Conceptual Design	Everyone	9/19/24	9/30/24	11	100%																

2	Project Planning and Designing						
2.1	Team Communication and Task List	Everyone	9/16/24	9/19/24	3	100%	
2.1.1	Initial Work Breakdown Structure	Macy	9/19/24	9/27/24	8	100%	
2.1.2	Initial Gantt Chart	Macy	9/19/24	9/27/24	8	100%	
2.2	Finalize Machine Concept, Sketches, and Design	Everyone	9/30/24	10/16/24	17	100%	
2.2.1	Project Material Organizaiton	Everyone	9/30/24	11/7/24	17	100%	
2.3	Initial CAD Model of Machine	JT	10/16/24	10/27/24	11	100%	
2.3.1	Consider Building Requirements and Specifications	Everyone	10/16/24	10/23/24	7	100%	
2.3.2	Identify Potential Issues	Everyone	10/16/24	10/23/24	7	100%	
2.4	Design 3D Printed Parts	JT	10/16/24	10/27/27	11	100%	
2.4.1	First 3D Print Upload	Everyone	10/1/24	10/27/24	26	100%	



3 Project Development							
3.1	Begin Machine Assembly in CAD	JT	10/16/24	11/6/24	7	100%	
3.1.1	Determine Necessary Improvements	Everyone	10/21/24	11/6/24	7	100%	
3.2	Updated Gantt Chart	Macy	10/23/24	11/6/24	12	100%	
3.2.1	Updated WBS	Macy	10/23/24	11/6/24	12	100%	
3.3	Cost Analysis	Everyone	10/23/24	11/6/24	12	100%	
3.3.1	Updated Budget	JT	10/23/24	11/6/24	12	100%	
3.3.2	Updated BOM	JT	10/23/24	11/6/24	12	100%	
3.4	Programs and Diagrams	Everyone	10/21/24	11/6/24	14	100%	
3.4.1	Wiring Schematic	Chris/JT	10/21/24	11/6/24	14	100%	
3.4.2	Pnuematics Schematics	Macy	10/21/24	11/6/24	14	100%	
3.4.3	Ladder Logic	Chris	10/21/24	11/6/24	14	100%	
3.5	Complete CAD Model	JT	10/16/24	11/6/24	19	100%	
3.6	Order Materials	Everyone	10/28/24	11/6/24	10	100%	
3.6.1	Send Sensor List	Chris	10/31/24	11/6/24	7	100%	
3.7	Implement Design Changes	Everyone	10/28/24	11/6/24	10	100%	
3.7.1	Updated Explanation of Methodology and Changes in Design	Macy	10/28/24	11/6/24	10	100%	
3.7.2	Updated List of Inputs and Outputs	Chris	10/28/24	11/6/24	10	100%	
3.8	Preliminary Design Review	Everyone	10/28/24	11/7/24	11	100%	
3.8.1	Presentaion of Preliminary Design Review	Everyone	10/28/24	11/7/24	11	100%	

4 Project Verificaiton and Finalization							
4.1	Begin Building	Everyone	11/11/24	11/18/24	7	100%	
4.2	Machine Testing	Everyone	11/11/24	11/20/24	9	100%	
4.2.1	Verify System Integrity	JT	11/11/24	11/20/24	9	100%	
4.2.2	Engineering Calculations	Chris	11/11/24	11/25/24	14	100%	
4.2.3	Final Schematics	Chris and Macy	11/11/24	12/2/24	21	100%	
4.3	Analyze Testing Results	Macy	11/11/24	12/4/24	21	100%	
4.3.1	Identify Any Errors	Chris	11/11/24	12/7/24	24	100%	
4.3.2	Make Final Changes	Everyone	11/11/24	12/7/24	24	100%	
4.4	Solidify Final Product	Everyone	11/25/24	12/7/24	12	100%	
4.4.1	Finalize CAD Model with Simulation	JT	11/25/24	12/9/24	14	100%	
4.5	Final Presentaion	Everyone	11/18/24	12/9/24	27	100%	
4.6	Final Report	Everyone	11/18/24	12/16/24	28	100%	
4.6.1	Elaborate on Design Process	JT and Macy	11/18/24	12/16/24	28	100%	
4.6.2	Verify Final Product and its Results	Everyone	11/18/24	12/16/24	28	100%	



Appendix B: Bill of Materials

Table 2: Bill of Materials from Inventory List

Part Name	Part Number	Qty	Cost	Link
Sensor 1: Capacitive Proximity (CAD Model Downloaded)	CTV-00-2M	1	-	Link
Sensor 2: Inductive Proximity (CAD Model Downloaded)	DW-AD-714-M 30	1	-	Link
Sensor 3: Photoelectric Sensor	FAR/BP0E	1	-	
Piston-Cylinders (CAD Model Downloaded)	A12040DP-M	3	-	Link
Emergency Stop (CAD Model Downloaded)	ESL-SSL-23201 8-BS	1	-	Link
Pushbutton, 22mm, momentary, (1) N.C. contact(s), plastic base, plastic bezel, Operator: red, extended, 30mm, round, plastic.	GCX3111	1	-	Link
Pushbutton, 22mm, momentary, (1) N.O. contact(s), plastic base, plastic bezel, Operator: green, extended, 30mm, round, plastic.	GCX3112	1	-	Link
Filter Regulator	AFR2-2233-D	1	-	Link
Double Solenoid Directional Control Valve (1) (Dispenser)	AVS-5121-24D	1	-	Link
Single Solenoid Directional Control Valve (2) (Conveyor)	AVS-5212-24D	2	-	Link
Check Valve	CVU14	1	-	Link
Pressure Gauge	G15-BD100-8C B	1	-	Link
NITRA pneumatic push-to-connect fitting, union tee, thermoplastic (PBT) body, (3) 1/4in tube connection(s). Package of 5.	UT14	1	-	Link
Cylinder Position Sensors NITRA cylinder switch, square, PNP, N.O. output, 10-30 VDC operating voltage, LED indication, 0.3m (1ft) cable with 3-pin M8 snap-fit connector, straight cable entry, 5mm square T-slot mount, for position sensing.	CPS-AP-F	3	-	Link
AutomationDirect programming cable, USB A to microB-USB, 6ft cable length. For use with Productivity1000 and Productivity2000 CPUs and most	USB-CBL-AMI CB6	1	-	Link



USB devices.				
CLICK PLUS PLC, 24 VDC required, (2) option slots, Ethernet, serial and microB-USB ports, no on-board I/O.	C2-01CPU-2	1	-	Link
CLICK relay output module, 8-point, 6-27 VDC/6-240 VAC, (8) Form A (SPST) no-suppression, 4 isolated common(s), 2 point(s) per common, 3A/point. Removable terminal block included.	C0-08TR-3	1	-	Link
CLICK AC power supply, 100-240 VAC nominal input, 24 VDC nominal output, 0.5A continuous.	C0-00AC	1	-	Link
(Cylinder Switch Connection Cable) Murrelektronik connection cable, M8 axial female to pigtail, 3-pole, PVC jacket, gray, 16.4ft/5m cable length, IP65 IP66K IP67.	7000-08041-210 0500	3	-	Link
NITRA pneumatic push-to-connect fitting, male, straight, nickel-plated brass body, nickel-plated brass threads, 1/4in tube to 1/8in NPT connection(s). Package of 5.	MS14-18N	6	-	Link
NITRA pneumatic push-to-connect fitting, male, elbow, rotating, thermoplastic (PBT) body, nickel-plated brass threads, 1/4in tube to 1/8in NPT connection(s). Package of 5.	ME14-18N	6	-	Link
Cylinder Mounting Brackets	AMB-6	3	-	Link
NITRA pneumatic push-to-connect fitting, elbow flow control valve, rotating, meter-out, nickel-plated brass body, nickel-plated brass threads, 1/4in push-to-connect to 1/8in NPT. Package of 2.	FVS14-18N	6	-	Link
NITRA pneumatic tubing, ether-based polyurethane, black, 1/4in outside diameter, 0.156in inside diameter, 100ft package.	PU14BLK100	10ft	-	Link
NITRA mounting nut, 5/8-18 UNF thread, zinc plated steel. For use with A-series cylinders.	AN-58-18	3	-	Link
Screwdriver	TW-SD-MSL-2	1	-	Link
Tube Cutter	TC-12	1	-	Link
Pliers		1	-	
Brown Wire		4ft	-	
White & Blue Wire		4ft	-	
Yellow Wire		4ft	-	



Black Wire		4ft		
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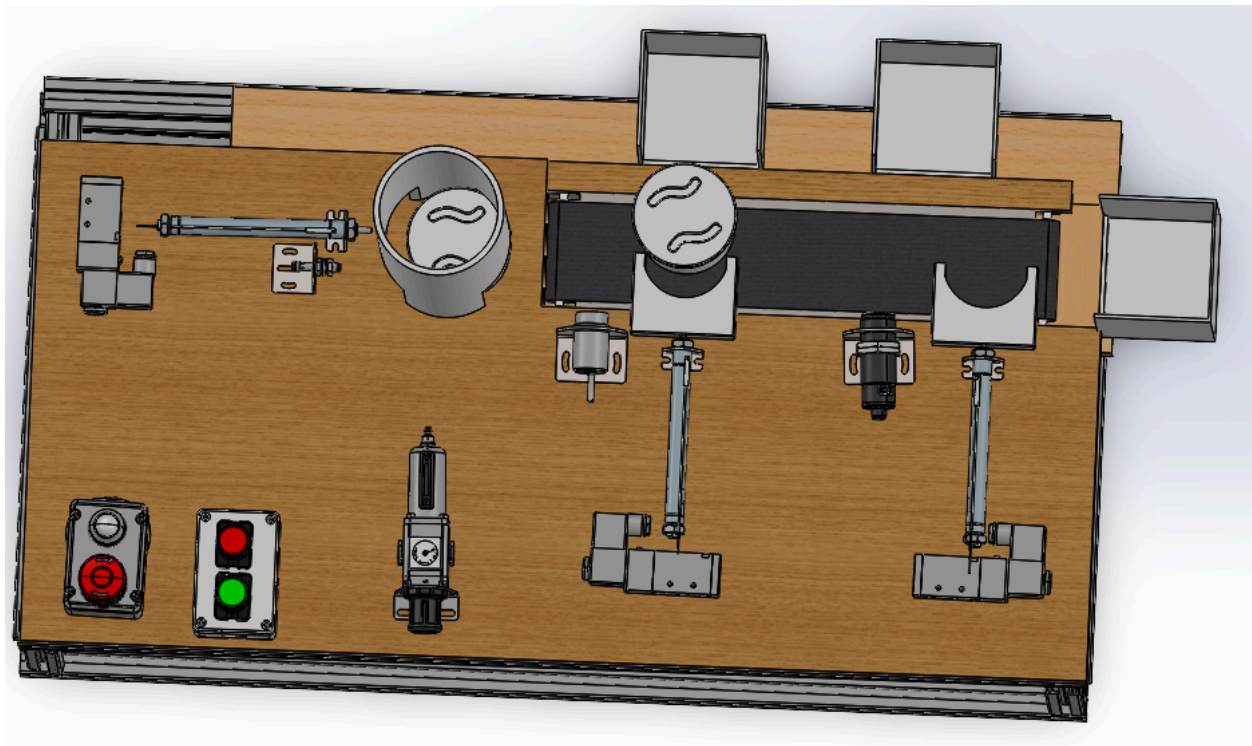
Table 3: Bill of Purchased Materials

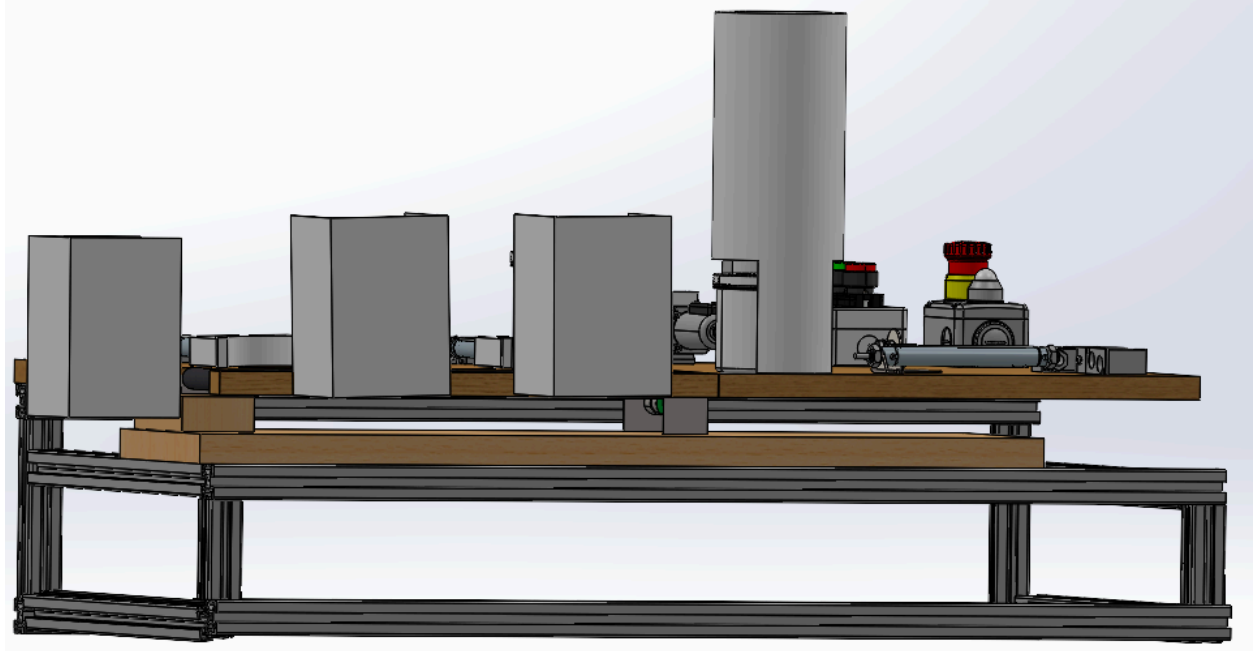
Part Name	Part Number	Qty	Cost	Link
3D Printing Filament	Amazon	1	\$12.69	Link
80/20 Aluminum Extrusion (To build Base) (2020)	Amazon	1	\$83.99	Link
Black Zip-Ties (For Wires)	Amazon	1	-	Link
Photoelectric Mounting Brackets	ST18C	2	\$4.00	Link
Widgets/Containers For Different Fluids	Amazon	1	\$9.99	Link
4.0" PVC Pipe 1-ft tall	Donation	1	-	
Plywood	Donation	2	-	
Inductive and Capacitive Sensor Mounting Brackets	ST30C	2	\$4.50	Link
Push Button Enclosure	SA105-40SL	1	\$7.50	Link
Dump Valve	HVU14-3	1	\$14.00	Link
(Capacitive Sensor Connection Cable) AutomationDirect connection cable, 1/2in-20 UNF thread axial female to pigtail, 3-pole, PVC jacket, yellow, 16.4ft/5m cable length, IP67 IP68 IP69K.	E18446	1	\$26.50	Link
(Photoelectric Sensor Connection Cable) AutomationDirect connection cable, M12 right-angle female to pigtail, 4-pole, PVC jacket, gray, 6.5ft/2m cable length, IP67.	CD12L-0B-020-C0	1	\$11.00	Link
(Inductive Sensor Connection Cable) AutomationDirect connection cable, M12 right-angle female to axial male, 4-pole, 10-36 VDC, PNP LED, PUR jacket, black, 0.9ft/0.3m cable length, IP67, IP68 and IP69K.	EVC322	1	\$14.00	Link
8020 Connectors	Amazon	1	\$18.99	Link

Table 4: List of 3D Printed Parts

Part Name	Qty
Cubbys	3
Cylinder Attachments	3
Push Button Enclosure	1
Photoelectric Mounting Brackets	1

Appendix C: Additional CAD Model Images





Appendix D: Additional Photos





