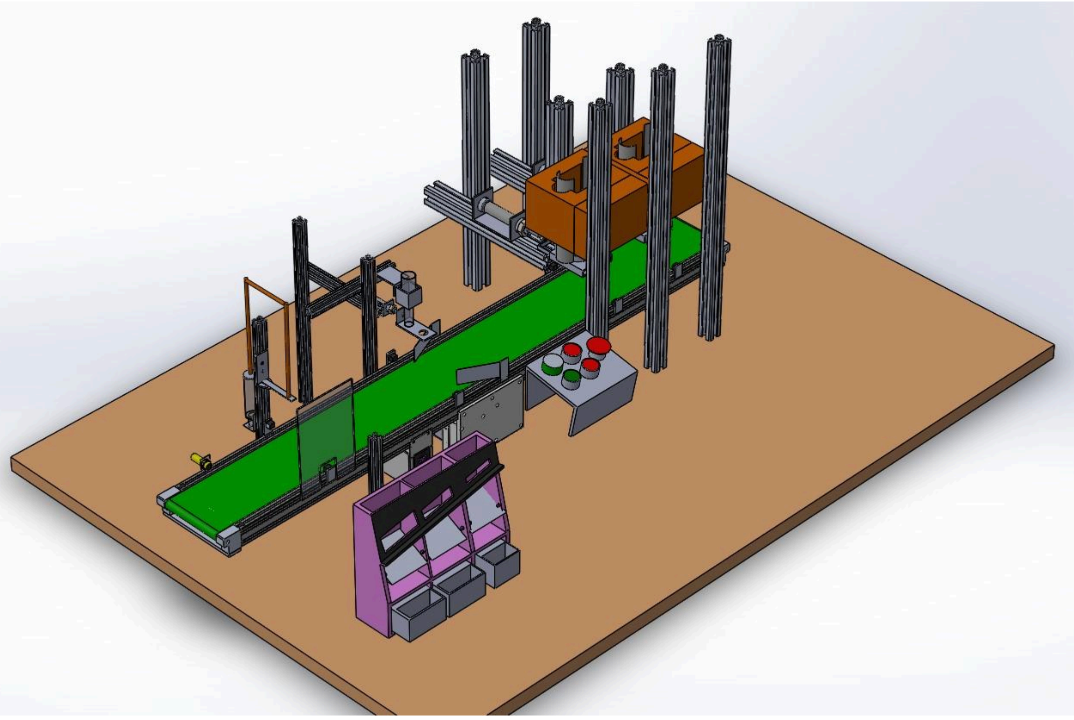
Automated Vending Machine

TRC2001 Project Report



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Abstract

This report provides full documentation of the automated vending machine system. The aim of this project is to produce a fully automated vending machine that can work 24/7 and it is convenient for the users.

Our team have discussed the problem that we wanted to solve and we have come up with a few possible solutions and multiple designs that we can build in this project. Then with all the ideas we have we compare each of them slowly and determine the strength and difficulties to implement them in our system. After that, the team has chosen the best design that we can implement in this project.

All the detailed drawings of our design and circuit infographics are included to help guide users on the system. All the components that we used to build the system are also included and detailed explanation on how we use them are also included.

Besides, the issues that the team encountered during the process of building the system are addressed and all the possible solutions are highlighted. Furthermore, suggestions for future upgrades that can be made into the system we have built are discussed. Lastly, the environmental and sustainability aspects of this project are discussed.

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1.0 Introduction

1.1 Problem Definition

Vending machines are automated machines that provide beverages, snacks or even toys after some form of money is inserted into the machine. Automation means that no workers are required for serving or making any transactions.

Following the major refurbishment of the cafeteria in Monash Malaysia, the issue of long queue lines remains overlooked and is a hassle for the students in Monash Malaysia. Most students only have a short lunch break and because of the long queue lines, many do not get the chance to purchase any food or drinks and opt to skip their meals instead. Cleanliness and hygiene are also issues that have yet to be tackled. Food that is to be served to students is left in the open, exposing them to houseflies and other pests, causing food poisoning. Furthermore, most of the stalls in the cafeteria, if not all, closes in the early evening before dinner. Many students have to stay back late to complete their assignments or projects and are not able to buy any food or drinks.

The objective of this project is to develop an automated vending machine that dispenses drinks and works 24/7. The system will start dispensing, depending on the user input, after the right amount of money is inserted into the coin box. This eliminates the need for workers and ensures that the system can work as long as electricity is provided. There is also an option to not add ice into the drink to cater to the user’s needs.

1.2 System Overview

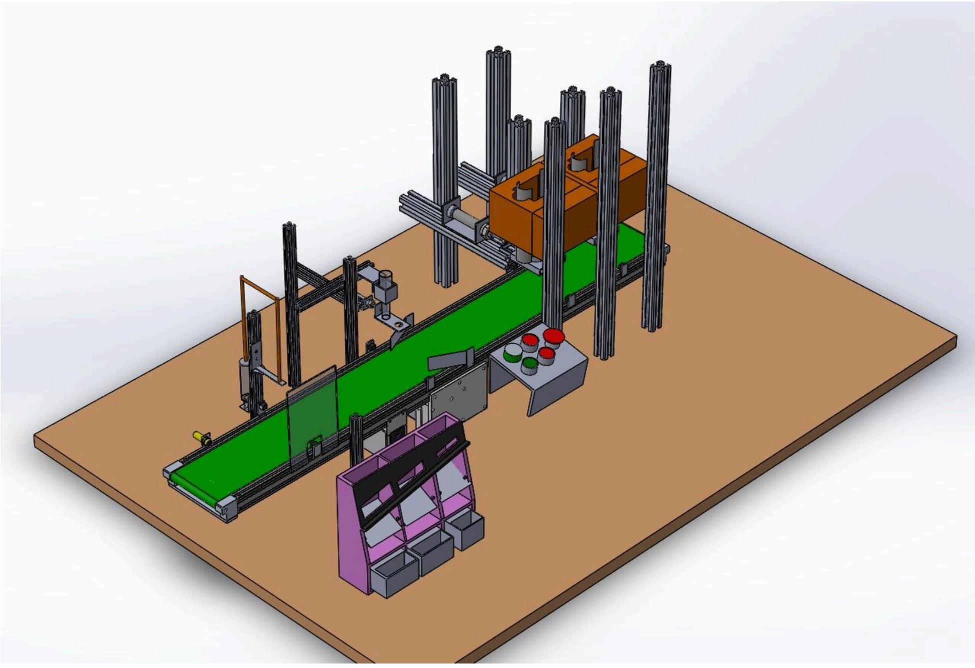

Figure 1: Top left-sided view of the vending machine system

The vending machine that we aim to create will have an overall model design shown in Figure 1. This design is made up of a few components, which are electrical, pneumatic and mechanical components. For the electrical part, there is a conveyor belt, a programmable logic controller (PLC), electrical relays, sensors and switch panel. An electrical relay is used to start up the conveyor belt. Sensors are used to detect the presence of the coins and the position of the cup. The switch panel is for the user to choose the size of the cup and the need for ice. For the pneumatic part, there are directional control valves, linear actuators and flow control valves (throttle valves). The water valve will be the only mechanical component and be used to dispense a drink.

1.3 System Design

1.3.1 Alternative designs

These are a few other ideas that the team has for the features of the vending machine system. These ideas are rejected as they are less practical than the chosen design, which is described further in detail under the section for the proposed solution or due to time constraints.

Detecting counterfeit coins

A vending machine will be able to detect any counterfeit coins that are inserted into the coin acceptor. These counterfeit coins will enter the reject chute. Photoelectric measurement sensors could be used to implement this feature. A measurement sensor is a device that measures the dimensions of an object by converting changes in the amount of light into electrical signals when the object interrupts a wide laser beam [1]. This feature was not implemented as measurement sensors were not available in the lab and buying the sensors would take a long time to arrive.

Placing a lid on the cup

A lid would be placed on the cup after water and ice are dispensed into the cup. This will ease the consumer as a lid would prevent spillage and contamination of drink. A lid dispensing station will dispense lids and a rotary actuator connected to a sucker will pick the lid and place it on the cup. This design is not practical as it is difficult to adjust the pressure that the actuator exerts on the lid. Since cup lids are fairly thin, the extension of the actuator might crush the lid.

Using own cup or bottle

A consumer can place his/her own cup or bottle into a designated area of the vending machine to replace the usage of the cups from the vending machine. A set of photoelectric sensors will detect the presence of the bottle or cup. Another set of measurement sensors would be used to measure the size of the bottle/cup used and calculate the amount of money to charge the consumer. This design is impractical as the bottle/cup used could be damaged which would cause leakage inside the vending machine when water is dispensed. This would damage the sensors in the vending machine.

Returning change

A vending machine will return change based on how much the consumer has paid. 10, 20 and 50 cents will be sorted into different chutes. At the bottom of the chute is a holder that is connected to a cylinder. When the cylinder extends, a single coin will be dispensed. The value of the coin will be detected by the measurement sensors and based on the PLC logic, the right amount of change will be returned. This design was not used as the mechanism was too complicated to be implemented in such a brief period.

1.3.2 Possible solutions

Detecting coins
i. Proximity sensor
The proximity sensor can only work normally if the coin which is to be detected is at a further distance. In other words, the coinbox that we design needs to be large enough to fit the distance between the sensor and the coins. If not, the sensor will keep detecting the coinbox itself.

ii. Photoelectric sensor
It is still able to detect even though the coins are dropping at a high speed. Since the photoelectric sensor comes with a pair, which are transmitter and receiver, the distance between those two can be adjusted based on our preference.

Cup dispensing mechanism
i. Guiding system
A guiding system that is made from cardboard is added below the cup dispensing system to ensure the cup is dropped vertically on the conveyor belt.

ii. Conveyor belt
A delay timer is added to the PLC circuit. When the sensor senses the presence of a cup, there will be a delay of 1.5s. This is to make sure that the cup will not be shaky once the conveyor belt starts moving.

Stabilizing the icebox
i. Holder
The holder is made up of an aluminium plate (4mm thick). It is bent into a cube shape so that the icebox can fit perfectly.

ii. Cable tie
When the linear actuator retracts to dispense ice, the metal plate will rub with the mouth of the icebox causing it to be slanted. Thus, the bottom part of the icebox is tied with the holder of the linear actuator using cable ties.

Water dispensing mechanism
i. Using Pneumatics
A 5/2 way single solenoid-actuated pilot returned valve is used to dispense a drink. There is a throttle valve installed between the pipes to decrease the speed flow of pressurized air. This is to prevent the water splashing while water is flowing into the cup.

ii. Using 12V DC motor
When the cup reaches the sensor, the DC motor will be switched on to allow water flow into the cup. After a set time, the needle inside the motor will block the water flow immediately to prevent further dripping while air is still pressurized on the water.

1.3.3 Proposed solution

The proposed solution is to build a vending machine that accepts coins only and provides beverages with different cup sizes according to the users' preference. 20 cents is for a small cup and 50 cents is for a big cup. Besides, the machine will dispense a warm drink if the no ice button is pressed and vice versa.

For the coin box mechanism, we decided to use 3 photoelectric sensors to detect 10, 20 and 50 cents coins. As mentioned in 1.3.2.1(i), we are able to adjust the distance between transmitter and receiver, therefore the sensors will only detect and send the signal to PLC only if the coin is passing through them. Hence, a smaller coin box can be made. In order for the vending machine to operate, the user must insert a correct amount of coins and press a button (small cup button or big cup button).

For the cup dispensing mechanism, a guiding system is added respectively to the bottom part of the small and big cup dispenser. A delay timer is also added into PLC circuit to make sure that the conveyor belt will only start moving only after 0.5s when the sensor detects the presence of a cup. Both modifications guarantee stability when the cup is dropped.

In addition, the icebox is stabilized by using a box holder and a few cable ties. At first, an icebox is placed inside the holder. Cable ties are then used to tie the bottom part of the icebox and the holder of a linear actuator. Correspondingly, the icebox will not be slanted when the metal plate is rubbing the mouth. Refer to Figure 10 in Section 3.2 for a better visualization.

For the water dispensing mechanism, 12V DC motor is ineffective due to its flaws in mechanical parts. The needle cannot fully block the water and water will continue dripping. When the sensor detects the water drops, the motor will be switched on again and it wets the conveyor belt and the photoelectric sensor. This would damage the conveyor belt as well as the sensor. Pneumatics are best used for water dispensing mechanism as mentioned in 1.3.2.4(i).

2.0 Project management

2.1 Project brief

As the name suggests, the objective of this project is to build an automated drink vending machine. This system was built to overcome the issue of unhygienic drinks, the time that would be required in waiting in queues for a drink as well as the inconsistencies in dispensing drinks of the conventional vending machines.

The system is designed such that it will start dispensing, depending on the user input, after the right amount of money is inserted into the coin box. This eliminates the need for workers and ensures that the system can work as long as electricity is provided. There is also an option to not add sugar into the drink to cater to the user's needs.

Our system combines the three main aspects of mechatronics:

1. Mechanical (cup holder and separator, icebox holder and acrylic sheet),

2. Pneumatics (directional control valves, linear actuators, and flow control valves)

3. Electrical (mainly the connections, conveyor belt, a programmable logic controller (PLC), an

   electrical relay, sensors and switch panel).

In this project, Lim Wei Jun is the project manager and head in electronics, Clifton Mak Ren Ming as the lead programmer, Huan Jiun Yeong as the electrical head, Abu Bakr Siddique as the Solidworks developer and Abhinav Jayaprakash, Tanha Tahsin ,Chua Kah Liang and Kang Xin Thean all involved with the structural as well as the mechanical aspects of the system.

The project was completed in the required time frame (6 weeks) and meets the set requirements, proving to be a huge success. Some of the issues the team encountered and suggestions for future upgrades are also highlighted.

2.2 Project scope

Objective:

To develop an automated vending machine that dispenses drinks and works 24/7, which is more effective than the conventional machines usually found in school cafeterias. Since it is automated and has low maintenance, the least manpower is used.

Deliverables:

An effective and hygienic way of dispensing drinks; a well-built automated drink vending machine.

System and Process Requirements:

1. Able to dispense different sizes of a cup depending upon the amount of money that is inserted into the coin box, which is 20 cents for a small cup and 50 cents for a big cup.

2. Able to dispense two additional items: ice and water.

3. Able to detect the cup at various positions on the conveyor belt with the help of photo-electronic and proximity sensors.

4. Achieves safety requirement

5. Environmentally-friendly and User-friendly

6. The system can be entirely stopped at any moment with the press of an emergency stop button on the control panel.

Limitations:

1. System can only dispense one type of drink.

2. System allows the process of dispensing ice and water, only one cup at a time.

Deadline: 25th October 2019

2.3 Work Breakdown Structure

The block diagram below serves as a concise view of the subsystems that need to be built and assembled to achieve a functioning automated drink vending machine. There are six subsystems that constitute the system: Coin box, control panel, conveyor belt, cup dispenser station, ice dispenser station, and water dispenser station.

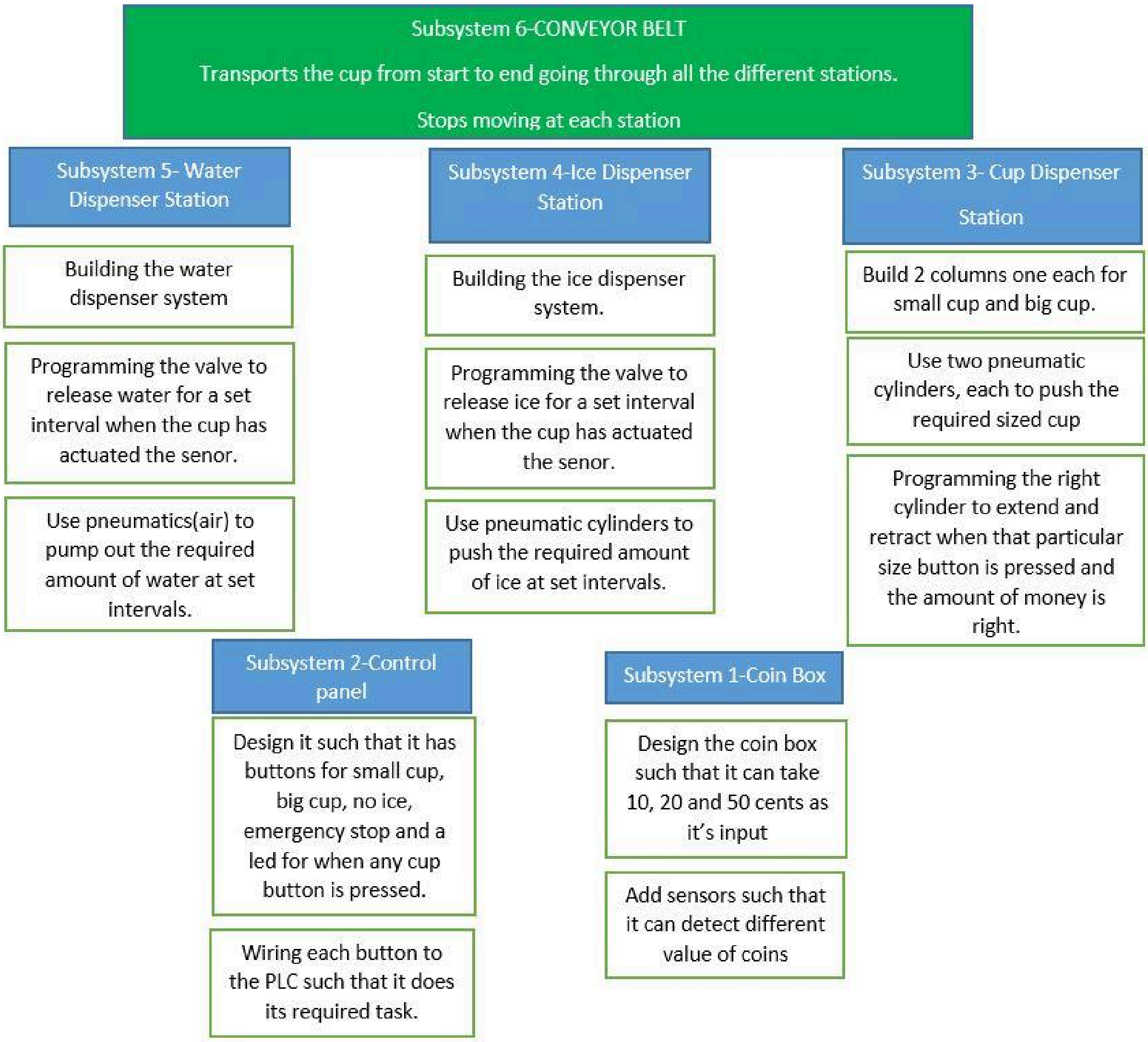

Figure 2: Work Breakdown Structure

2.4 Gantt chart

Figure 3: Gantt Chart

2.5 Resource management

Table 1: Bill of Materials

No.	Name of equipment	Specifications	Price per quantity(RM)	Quantity	Total Price (RM)
1	Double-acting cylinders	Magnetic, Double cushion and Adjustable Koganei Air Cylinder “slim” DAC 25x50 (2) Koganei Air Cylinder “slim” DAC 20x 50 (1)	165.82[2]	3	497.46
2	5/2 ways Direction Controlled Valve	Solenoid actuated and pilot returned Model: Koganei T110-4E1-PLL	64.15 [3]	4	256.60
3	AC to DC converter	240V AC to 24V DC Model: HDR 60-24	36.00 [4]	1	36.00
4	Photoelectric sensor	NPN Model: SUNX EX 13BD	225.00[5]	7	1575.00
5	Conveyor Belt	Length: 2m Speed control unit USP540-2E	2858.30 [6]	1	2858.30
6	Electrical Relay	2 change-over contacts Model: Omron MY2N-J	27.35 [7]	1	27.35
7	Switch panel	3 buttons, 1 Green LED,	83.00 [8]	1	83.00
8	Terminal strips	12 pairs of connections	19.42 [9]	4	77.68
9	Pneumatic Service unit	Filter, Regulator, Lubricator and Pressure Gauge with 6mm connection	52.00 [10]	1	52.00
10	Programmable Logic Controller	Model: CPU 1214C AC/DC/RLY	1346.00 [11]	1	1346.00
11	Aluminium Plate	2mm thickness	46.50[12]	1	46.50
12	Proximity sensor	NPN Model: E18-B03N1	16.90 [13]	1	16.90
13	Flow control valve	Adjustable and with bypass NITTA Moore ESU4 (2) Janatics (1)	8.00 [14]	3	24.00
14	PVC Pipe	BS 3506	6.00[15]	2	12.00

		Length: 40 cm			
15	Small Pebbles	-	5.00[16]	4	20.00
16	Plastic bottles	Volume: 2 litres	2.00	2	4.00

2.6 Project team performance

2.6.1 Communication

Communication between team members was done through many platforms namely Whatsapp and Google Docs. Whatsapp was chosen as one of the modes of communication as it is accessible by anyone who has a smartphone in their possession. A group was created by the group leader, where members were informed of any meetings and urgent discussions. Task distribution, as well as deadlines of when each member had to complete their respective parts of the project, were also discussed. This led to an increase in efficiency and productivity as a group.

Google Drive and Google Docs were used to record our documentation. The project manager created a team drive inside Google Drive where all relevant documentation was stored. Documents such as the report, presentation slides, and Solidworks pictures were saved in it. Information written onto Google Docs is saved automatically and allows editing by any member. These documents could be reviewed at any time as they are shared with each member. If any team member is discontent with the content, he or she can edit it anytime. Members were able to add small notes just beside each part of the report mentioning what extra points could be added or unnecessary information is removed such that it's concise and presents the required content. This alternate form of communication help made the process more efficient.

Lastly, face-to-face meetings were also held between all group members on specific days of the week. The schedule of when and where the meetings would take place was decided at the very start of the project. During the meetings, everyone had the freedom to voice out their opinion and to agree or disagree with anybody. Some of the drawbacks of the project as well as these respective solutions were discussed during these meetings. This form of communication was very reliable as there were no misunderstandings between the members; everyone understood what they had to do for the project to be a success.

2.6.2 Planning

Everything that was required to be done for the project was discussed well in advance. From project goals and objectives to each member being delegated a task, everything had to be done by their respective deadlines. This was done through detailed discussions as a group with the project manager leading the discussion. Tasks were distributed evenly to each member by the project manager according to their individual strengths and how much knowledge they had about that particular task, as shown in Appendix C.

2.6.3 Productivity

The project manager kept all members updated and on track by providing daily updates on what tasks we had to do on that particular day, mainly done through WhatsApp. This ensured that the team had clarity in what they had to and allowed us to work like a well-oiled machine.

The team put in a lot of effort and worked day and night to make sure that the project was a success. Everyone worked in unity to ensure this project was of the highest quality.

3.0 System Design and Development

3.1 Design objectives, requirements, alternatives, selections

3.1.1 Design requirements

The system was built to achieve the requirements below:

1. Dispense either small cup or big cup automatically after users make their choices and payments.
2. Dispense ice based on user's choice
3. The process is repeatable for any number of times with low maintenance needed.

3.1.2 Design objectives

Once users press on the big cup or small cup button on the button panel the green LED on the button panel will light up. Then, users can also choose to press on the no ice button or not. The emergency button on the button panel is also used to stop the whole system if any unpredictable event happens during the process or it is used during the maintenance work of the system. After that, the users will need to pay according to the option they have chosen, 20 cents for a small cup and 50 cents for a big cup.

After the user has paid the correct amount of money needed, the system will then dispense the cup accordingly onto the conveyor belt. When the cup is in its correct position determined by the photoelectric sensors below each cup dispenser, the conveyor belt will start moving until the cup reaches directly below the ice dispenser and the conveyor belt will halt.

The system will then start dispensing ice into the cup, but if the no ice option was chosen by the users earlier on, the system will not dispense ice and continue moving the cup to the next liquid dispensing station.

When the cup reaches the water dispensing station, the system will start to fill the cup, After that, the conveyor belt will start moving to the end of the system, a proximity sensor was placed there to detect the presence of the cup. If a cup is still at the end of the conveyor belt, it will stop moving until the cup was removed.

3.1.3 Design alternatives

Table 2: Design Alternatives

Operation	Design alternatives	Cost	Accuracy	Power consumption	Comments	Usage
Dispensing cups	Manual placement	Low	High	-	Need labour force	No
	Cup holder and separator (Refer to Figure 8)	Low	Medium	Low	Need 3D printing but easy to implement	Yes
	Using pick and place module	High	High	Low	More complicated to implement as accuracy is hard to set	No
Detecting coins	Proximity sensor	Medium	High	Low	Smallest range of detection is too big	No
	Photoelectric sensor	High	High	Low	Good for fast detection	Yes
Dispensing ice	Ice auger connected to a motor	High	-	Medium	Very costly and will take up more space	No
	Metal plate controlled by pneumatics. (Refer to Figure 10)	Low	-	Loq	May sometimes get stuck at pathway where ice is released	Yes
Dispensing water	Pneumatics	Medium	-	Low	Not consistent and need to wait for a long time	Yes
	Water solenoid valve	Medium	-	Low	Good but not available in the lab	No
Moving cups to different stations	Conveyor	High	-	High	Takes up more space but can implement more features	Yes
	Rotary	High	-	High	Takes up less space but can handle fewer features	No

3.2 Mechanical, Electrical, Electronics, Mechatronics aspects

Pneumatics

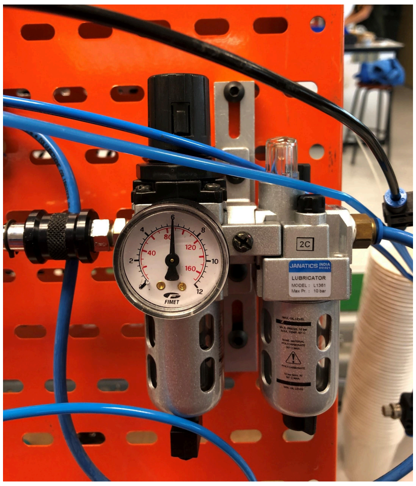

Figure 4: Filter regulator lubricator unit

The pneumatics system is powered by air supply. Air leaving the compressor is unfiltered. If the air is put directly into our system, it may cause damage or shorten the lifespan of the pneumatics components in the system. Therefore, a filter regulator lubricator unit shown in Figure 4 is implemented into the system to filter, lubricate, and regulate the air before supplying any air into the pneumatics system and the operating pressure of the pneumatics system is set to 5 – 6 bar.

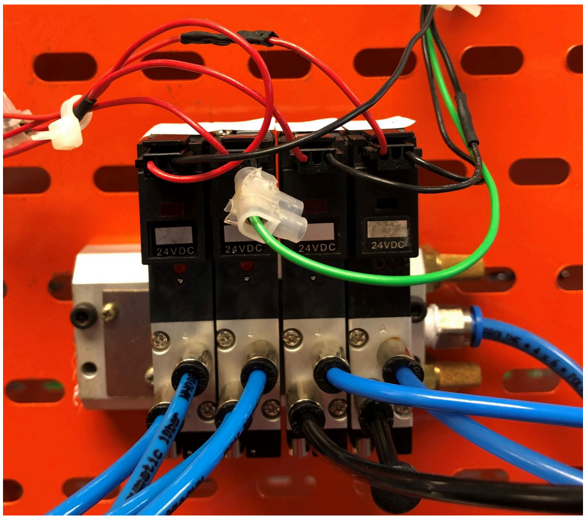

Figure 5: 5/2 way solenoid actuated and pilot-returned DCV

A total of four 5/2 way solenoid actuated and pilot-returned DCV as shown in Figure 5 was used in the system to control the actuation of the 3 of the double-acting cylinders and 1 to pressurize the water tank. We used PLC outputs to actuate each of the valves accordingly.

Figure 6: Double acting cylinder

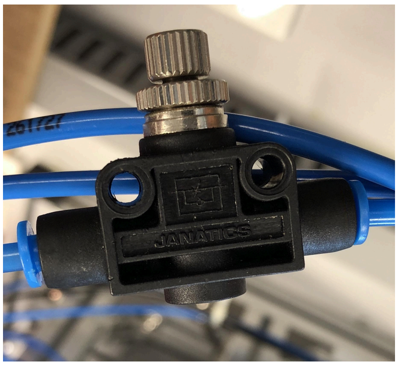

Figure 7: Flow control valve

By using the directional control valve in Figure 7 to control the actuation of these cylinders at each station. In order for us to control the actuation speed of the cylinders, few of these flow control valves are used to limit the amount of air input into the cylinders. For example, a flow control valve is used at the water tank because we want to pressurize it slowly so that the water will not spray out too fast.

Mechanical Design

Figure 8: Cup dispensing station

The system we designed is meant to be automated which requires low maintenance. In order for the system to meet the requirements, we design this cup holder and separator shown in Figure 8 for the small cup and the big cup because it can hold a lot of cups stacked together at the same time but it will only dispense one cup at a time. This is because when the cylinder behind the cup holder extends, the mechanism in it will release the bottom cup and separate out the cup above it and preventing it to drop together. Furthermore, the cup dispensing station that we design also have a guiding mounted below the cup holder as shown in Figure 8 . This is because we want to use it to prevent the cups to topple on the conveyor belt.

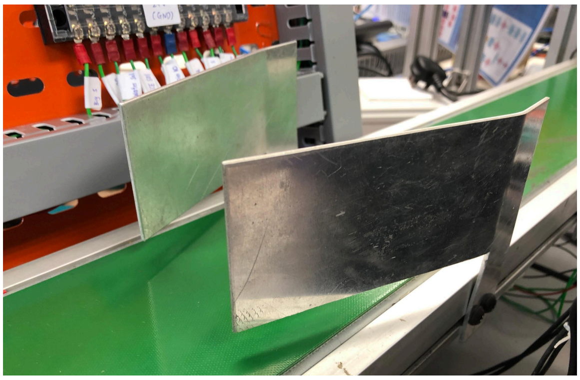

Figure 9: Guiding to centre the cups

In order to make sure the cup is centred on the conveyor belt after the cup was dispensed, we bend two metal plates at an angle as shown in Figure 9 to push the cups to the centre and force the cups to pass through the gap we make when it is travelling along the conveyor belt.

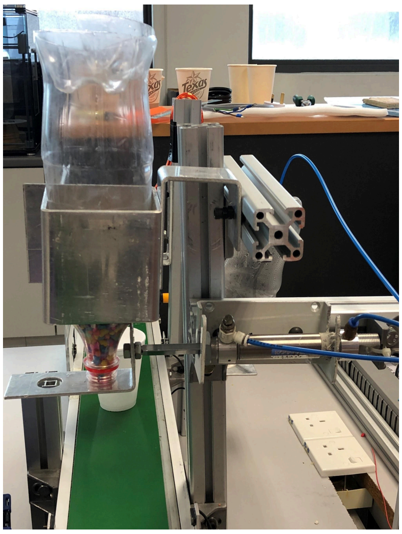

Figure 10: Ice holder

For ice dispensing station in Figure 10, we used small pebbles to replace ice because ice is inconvenient to be used in the lab and an aluminium plate was used to cover up the outlet of the plastic bottle that contains the small pebbles. Then the double-acting cylinder was at the actuation position when the pneumatics system was turned on. When the photoelectric sensors below the ice dispensing station detected a cup have reached the station it will stop the conveyor belt and then it will dispense the small pebbles into the cup. This happens by retracting the double-acting cylinder and it will move the aluminium plate away from the bottle outlet and the small pebbles will fall into the cup by passing through a small hole on the aluminium. The number of small pebbles that the station will dispense was determined by the length of time that the cylinder retracts, the longer it retract, the more small pebbles it will dispense.

Figure 11: Coin box

Based on the design of the coin box we made in Figure 11, it can accept old 10 cents, 20 cents and 50 cents coin. At the front of the coin box, it has 3 cut-out holes, each of them is cut based on the diameter of each of the coin. When a coin is inserted from the top left, it will start rolling on a slope on the coin box until it reaches the size of a hole that fits. Then, it will drop and be detected by a sensor we placed at the side of each coin slot. The amount of money that the users have paid will be determined by the counter and the maths module in the PLC ladder diagram that we have designed.

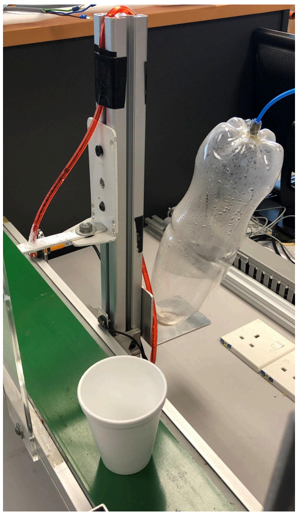

Figure 12: Water dispenser

For the water dispensing station in Figure 12, a plastic bottle was used as the water tank and water is pumped out by pressurizing the plastic bottle. When the photoelectric sensors below the water dispenser detect a cup it will start dispensing water. We will only pressurize the plastic bottle for a few seconds and from there the cup will only start moving when the water has fully dispensed into the cup. The amount of water that it will dispense is also determined by how long we pressurize the plastic bottle.

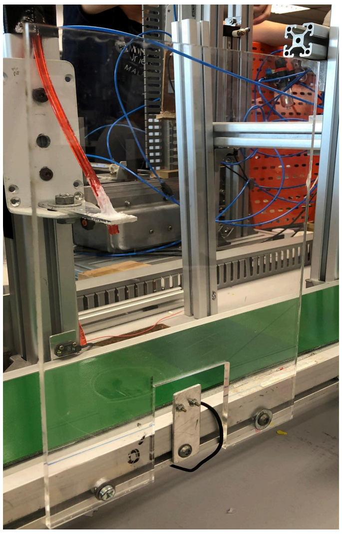

Figure 13: Acrylic sheet

This acrylic sheet in Figure 13, is a very important element in the system. The system we design at first was to hide the whole system in a closed environment but after considering the large cost of covering up this 2m long system with acrylic sheet, the idea was scrapped. However, we think that it is necessary to just cover up the water station from any external disturbance when the system is functioning. For example, when users have chosen their drink and users tried to place their hands at the water station sensor when the cup is absent, the water will start spraying out on the conveyor belt and might damage the electrical components in the system. So in order to prevent this disastrous event, the acrylic sheet was necessary.

Electrical and Electronics

Figure 14: Fuse Box

Instead of using a direct 240 AC supply from the power socket we pass through this fuse box in Figure 14. By doing this we can prevent a power outage in the lab since there is a possibility that we have done some wrong connections when we are building our system.

Figure 15: Switch Panel

We design the switch panel shown in Figure 15 for the users to give inputs to the system that we designed. This button panel consist of 1 Green LED to give users some feedback when the system has started working but taking inputs from the users. Then there are 1 green button as the input for users choosing for small cup, 1 red button as the input for users choosing big cup, another red button is for user choosing for no ice option and the last red button with the word “STOP” on it is the emergency stop button, when it was pressed the whole system will stop working and back to its usual state until the button is unlatched.

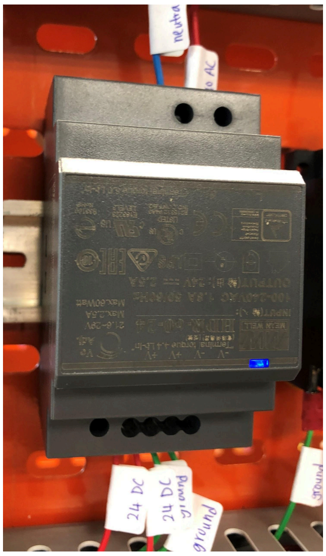

Figure 16: DC power supply for the system

Most of the electrical components we use in the system can only work with a voltage supply of 24V DC (Examples: LED and sensors). Therefore, we need to convert and step down the 240V AC main supply to a 24 DC voltage supply using HDR 60-24 as shown in Figure 16. Besides, according to the datasheet of HDR 60-24, the total maximum output current of it is 2.5A.

Figure 17: Electrical Relay

One of the outputs of the PLC is connected to terminal 13 of the electrical relay shown in Figure 17. Terminal 14 is connected to the ground (0V), 240V AC power supply is connected to terminal 9 and the live wire of the conveyor belt is connected to terminal 5. When the signal is sent from PLC, this relay will turn on, then the change over a contact in the relay will connect 240V AC power supply to the conveyor belt. Then, the conveyor belt will start moving until the output of the PLC stop giving out signals.

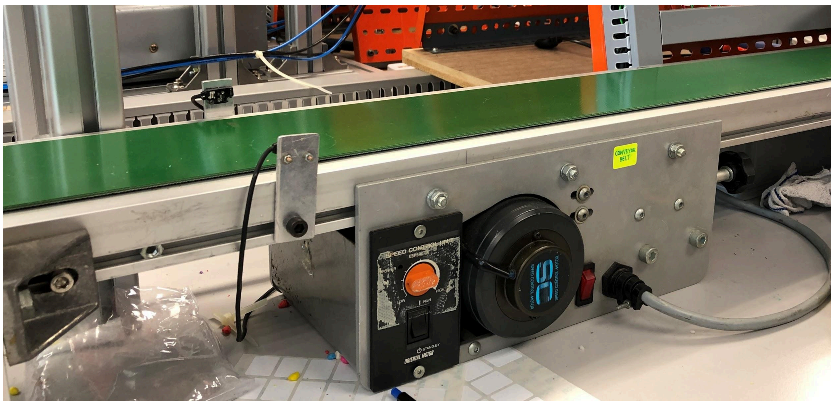

Figure 18: Conveyor belt

In the system, we designed we used a 2m long conveyor belt as shown in Figure 18 to move the paper cups from the cup dispenser station to other stations. We also used the speed control unit of the conveyor belt to adjust the optimum speed so that the paper cup would not fall on the conveyor belt when it is travelling from one station to another.

Figure 19: Digital Adjustable Infrared Proximity Sensor

The proximity sensor shown in Figure 19 is placed at the end of the conveyor belt to detect whether any item or the finished drink is still at the end of the conveyor belt. If something is detected by it, it will send a signal to the input of the PLC then the conveyor belt will not start moving at all. This is because we wanted to use it to prevent the finished drink at the end of the conveyor belt fall off the conveyor belt.

Figure 20: Photoelectric sensor

In the system that we design, we have used a total of 7 sets of this Photoelectric sensor shown in Figure 20. We used 3 of them at the coin box to detect the coins and we used the remaining 4 of them are used to detect the presence of the cup on the conveyor belt below the big cup and small dispenser and at the water and ice station. This photoelectric sensor will send a signal to the input of the PLC when either the cup or the coin cut the infrared emitted from the sensors. The reason why we choose to use NPN sensor over PNP sensor is that NPN sensor can give out signals faster than the PNP sensor. This is because the “N” type substrate can transfer electrons faster as compared to “P” type substrates in transporting positive electron holes.

Mechatronics

Figure 21: Programmable Logic Controller

The system we designed was supposed to take inputs from the users, then based on that we will create an automated system to do the work that the user requested. For example; when a user presses on the “Big Cup” button and they paid the correct amount of money, the system will dispense the big cup and not the small cup.

All the processes and features of our system are operated by the Programmable Logic Controllers (PLC) shown in Figure 21. When the users give input to the system, this action will become input signals into the PLC. Then based on how we code the PLC, a certain output signal will be given out by the PLC. In this vending machine system, we used up a total of 12 inputs and 6 outputs of the PLC.

Inputs into PLC	- Big Cup button
	- Small Cup button
	- No Ice button
	- Emergency Stop button
	- Sensors detecting
	    - 10, 20 and 50 cents
	    - either a big cup or a small cup has dispensed onto the conveyor belt
	    - the cup reached the Ice station and Water station
	    - the cup has reached the end of the conveyor belt

Outputs from PLC	- Green LED on the switch panel
	- Relay that controls the conveyor belt
	- Solenoids that actuate the
	    - Big Cup cylinder’s Directional Controlled Valve
	    - Small Cup cylinder’s Directional Controlled Valve
	    - Ice station cylinder’s Directional Controlled Valve
	    - Water station bottle

3.3 Challenges faced and solved

Lack of Solidworks Knowledge

All team members had little to no knowledge of using Solidworks early on in the project. Solidworks is needed to draw out parts with accurate dimensions for 3D printing of the parts. Learning how to use the software would require a lot of time and this would halt the team's progress. To overcome this problem, some small parts, in particular, the coin box was made out of plastic cardboard.

Usage of NPN sensors

The photoelectric and proximity sensors that were given are of NPN kind. In order to connect them to the PLC inputs, a relay must be used for each sensor or else no signal will be detected by the PLC. This was the method that was taught in the lab. Besides, we need to use a total of 8 of the sensors in the system that we designed, hence 8 extra relays were needed.

In order to solve this problem, we decided to change the method of connection to the PLC. Since all the sensors are the same type of NPN sensors, instead of connecting a 0V DC ground to 1M at the input of the PLC, a 24V DC to it. By making this change we can directly connect the output wire of the sensors to the input terminals of the PLC without passing through any relay.

Water dispensing mechanism

The initial idea was to use a water solenoid valve together with pneumatics to dispense water into the cup. The normally closed water solenoid valve would have a hose that is connected to pneumatics going through it. When no current flows through the solenoid, the valve will be closed and no fluid will be able to flow through. On the other hand, when there is current flow, the valve will open and fluid will be able to flow through [9].

The only two water solenoid valves that were available in the lab were faulty and not able to impede the flow of water. This issue was discovered in Week 11 and there was not enough time left to purchase a new water solenoid valve.

The issue was settled by using only pneumatics to dispense the water. When the solenoid valve is actuated, the bottle with one end connected to pneumatics will be pressurized, pumping the water out from the bottle. When the solenoid valve is de-actuated, the pressure in the bottle will decrease. When atmospheric pressure becomes higher than the pressure in the bottle, water will stop flowing out of the bottle. During the wait for the pressure in the bottle to decrease, water will continue flowing out of the bottle. A timer was added in the PLC logic to wait long enough for the water to stop flowing out before the conveyor starts moving again.

Cups falling over

When both the small and big cup are dispensed onto the conveyor belt, there were many instances where the cups might fall over on the conveyor belt. This would be an issue as nothing will be able to be dispensed into the cup. There were even times where the cup falls over and can no longer be detected by the sensors as they are no longer in sensing position.

Figure 22: Guiding system

To solve this, a guiding system(refer to Figure 22) made out of plastic cardboard was built below the cup dispensers. This ensures that the cups have something to support on after landing on the conveyor belt. The PLC logic was also modified to ensure that the conveyor belt only starts moving after the sensors have detected the cup for 2 seconds. The cups shake back and forth for a while after landing on the conveyor belt. Delaying the movement of the conveyor for 2 seconds ensures that the cups have time to settle and get a stable position on the conveyor belt.

4.0 Discussion, recommendation, and future work

While working on the automated vending machine, a few limitations were identified but were not addressed due to time constraints. Given more time, however, all these limitations can be overcome if some modifications or new implementations are integrated into the current design of the system, which will, in turn, improve the functionality of the system.

In the system's current state, the time taken to finish preparing a drink could be considered lengthy. The main factor contributing to this lies in the water dispensing mechanism used to dispense water into the cups. The current design utilizes pneumatics to pressurize the water tank for a brief moment to pump water out of the tank and into the cup. After pneumatics is turned off, a timer is then used to delay the movement of the conveyor for a long time, to wait for the water to fully dispense into the cup. A change in pneumatics pressure will affect the waiting time after pneumatics is turned off. The use of a solenoid actuated water valve can improve the time taken to finish preparing a drink. It is used to control the flow of water through it by using a valve that closes when it is not powered up. Water will then be dispensed based on the pull of gravity alone; without the need for pneumatics and a timer. An added advantage of using a solenoid actuated valve is that it does not contain any gas from the pneumatics. Pressurizing the water tank is not a very hygienic method. Although the air used in the system is filtered, it might still contain some small unfiltered particles.

The current coin box design also has a limitation. It only accepts the old 10, 20 and 50 cent and new 10 cent coin design. As mentioned in section 1.3, the coins can be differentiated; new or old design by using measurement sensors. These sensors are able to accurately measure the size of the coin and based on the size, the value of the coin can be identified. Adding a feature whereby changed is a return to the consumer would also improve functionality. This can be done by using the math function in PLC to calculate the amount of change needed to be returned. The design of the chute holding the coins needs to be done in such a way that a single coin is dispensed at a time.

Another limitation of the system is in the ice dispensing station. The current mechanism will sometimes have ice stuck together, blocking the pathway of the ice. This will cause less ice to be dispensed into the cup. A better way would be to utilize an ice auger that is connected to a motor and a solenoid. The solenoid is connected to a rod that will open a pathway for the ice to be dispensed when current flows through the solenoid. As the ice auger rotates, it will push the ice out to be dispensed into the cup [4]. Adding to this, river rocks were used to substitute ice. If real ice was used, a cooling system could be added to ensure that the ice does not melt.

Lastly, the current design of the automated vending machine can only produce one particular kind of drink and choices are limited, for example, the choices that the users can choose are only a drink with ice or no ice. So, we can make use of Arduino to take different kinds of input from the users like coffee, milo, milk, drinks with a percentage of sugar or ice that the user favours and more. This is because from Arduino we can create more choices for the users and also use it as an indirect input to the PLC because Arduino can take many different kinds of input and convert it into simple binary input signal to the PLC. Since we are providing more choices for the users, providing hot drinks is something that we should implement into the system. A station that can heat up liquid is needed to produce hot drinks.

5.0 Discussion on environmental and sustainability aspects of your project

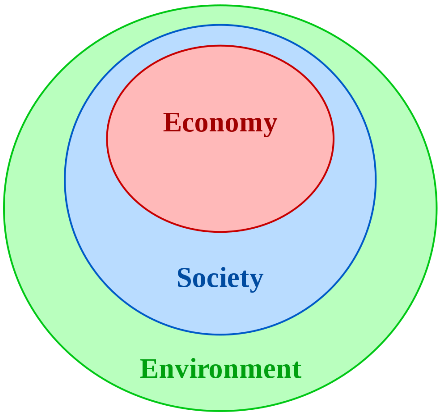

Figure 23: Relationship between the "three pillars of sustainability

Sustainability focuses on meeting the needs of the present without compromising the ability of future generations to meet their needs. Figure 23 shows the relationship between the “three pillars of sustainability”, in which both the economy and society are constrained by environmental limits.[17]

This machine is environment-friendly as it does not produce any fumes or gases that are harmful to the environment when in operation. Environmental friendly materials like paper and plastic cardboard were used in building systems such as the coin box and the guiding system for the cups. These can be recycled again and therefore no materials are wasted. To improve the environmental aspect, the user can use their own cup instead of paper cups.

This machine is also sustainable in economic health. As an example, the drink our system offers is not too expensive hence most can afford it. Besides, since it is an automated machine, less manpower is needed. Therefore, a higher profit is made as a minimum salary is given to run the machine, only when the vending machine is to be refilled.

Furthermore, this machine aids in social development, as it works 24/7 to serve people whenever they need it. It also ensures hygiene. As an instance, the drink in the machine is covered and abstained from outer pests.

6.0 Conclusion

The automated vending machine is a system that utilizes the concept of pneumatics and signals control elements as a basis of operation. The designed mechanism was developed in hopes of tackling the long queue issue in Monash Cafeteria and also the lack of food vendors available at night in Monash.

The designed vending machine has 3 stations to dispense big or small cups, ice and water or juice at each respective station. The system will only start running after the correct amount of coins are inserted into the coin box. Photoelectric and proximity sensors are widely used to detect the position of cups at each station and also the different types of coins. Pneumatics, on the other hand, is used in the dispensing stations and linear actuators and directional control valves were used to perform a particular job(extension/retraction) at each station. The system was made fully automated by just taking inputs from the user and performing the requests with the use of PLC programming.

The logic in the PLC that was used was timers and counters with maths function. We used the timers to control the amount of ice and water we wanted to dispense at each station. Counters were used to count the number of coins, the user input into the coin box. Extra features were implemented into the system such as emergency stop and ‘no ice’. These were incorporated to improve the functionality of the system. The team had also improvised some mechanical components to let the system run smoothly. For example, the guiding system and the structural design of our system is very stable.

Despite facing many challenges such as the lack of Solidworks knowledge, material constraints and dispensing mechanisms, the team persevered and managed to overcome them. Some further improvements about the current system were also suggested by the team. For example, a better dispensing mechanism for the ice and water station could be implemented. The coin box could be designed better to ensure that changes will be returned to the users. Furthermore, providing more drink varieties and features such as the option to add sugar and milk could be included into the system.

To conclude, the project was completed within the set time frame and meets the set requirements. In the proposed design, the mechanism shown is only a basic one, but with more development and improvements, a better design could be created that will have greater functionalities to attract more users. The team has learned a lot of new knowledge and skills during the process of building the machine and we are truly satisfied, such that we are able to complete what we have planned at the beginning.

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Appendix A Technical Drawings

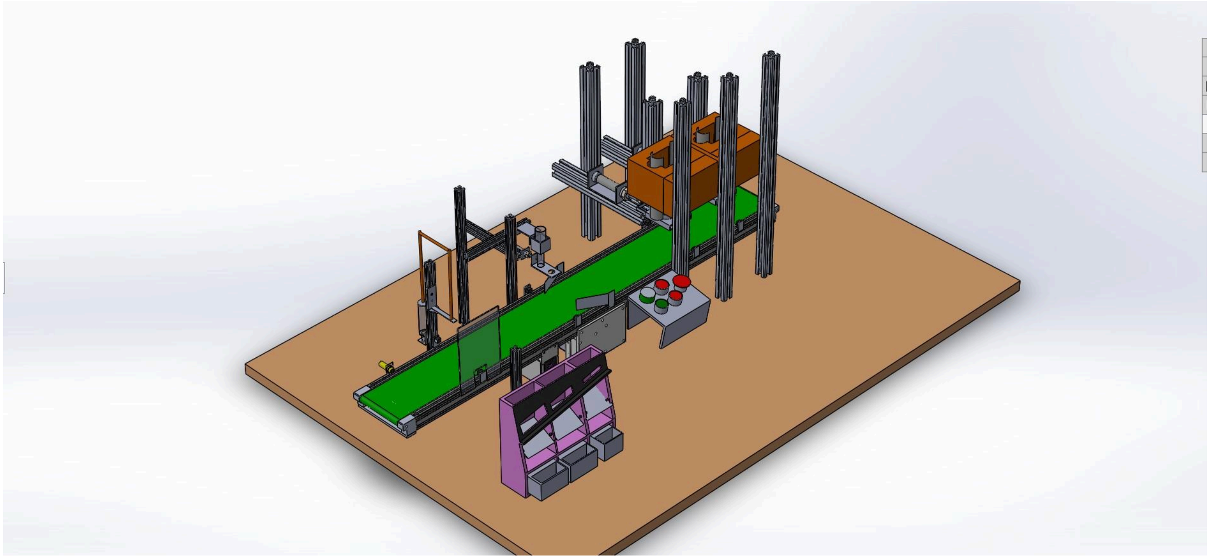


Figure A1: Slanted side view of system structure

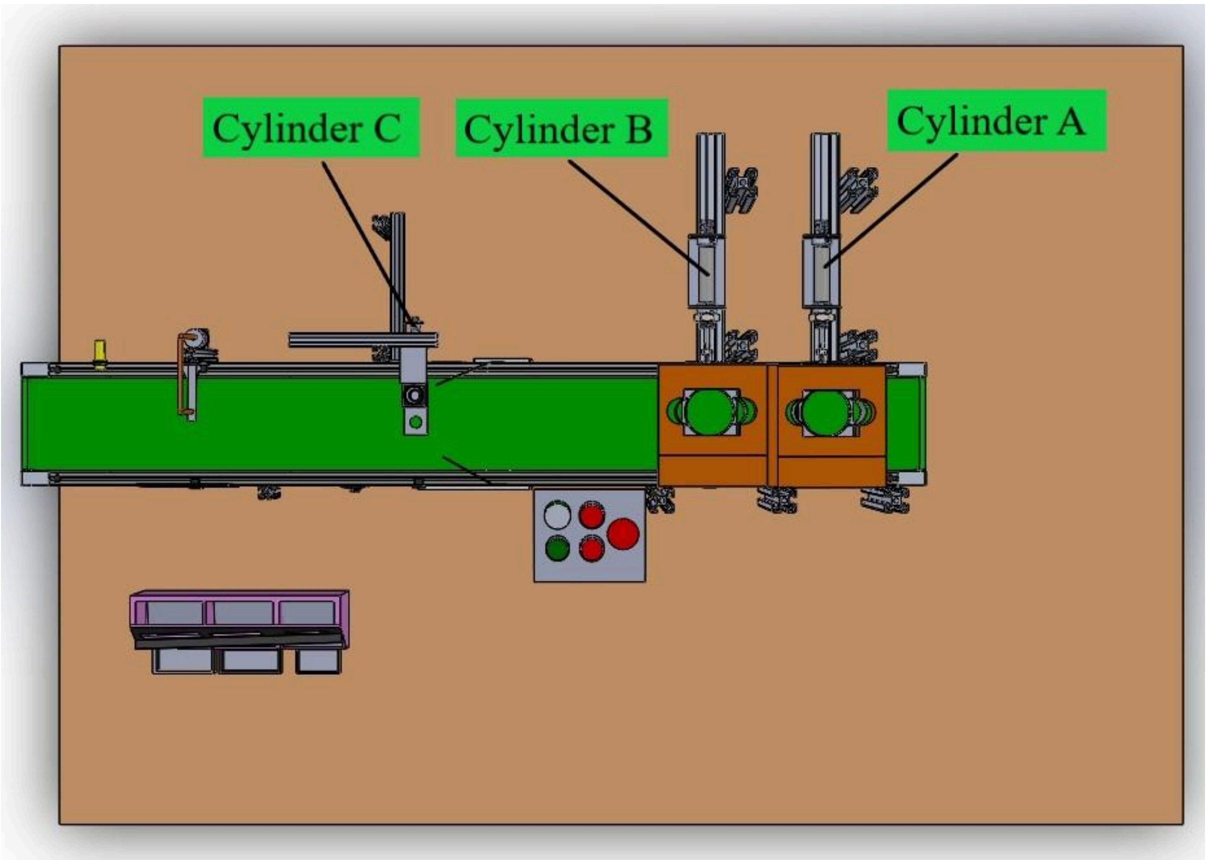


Figure A2: Top view of system structure

Figure A3: Front side view of coin box

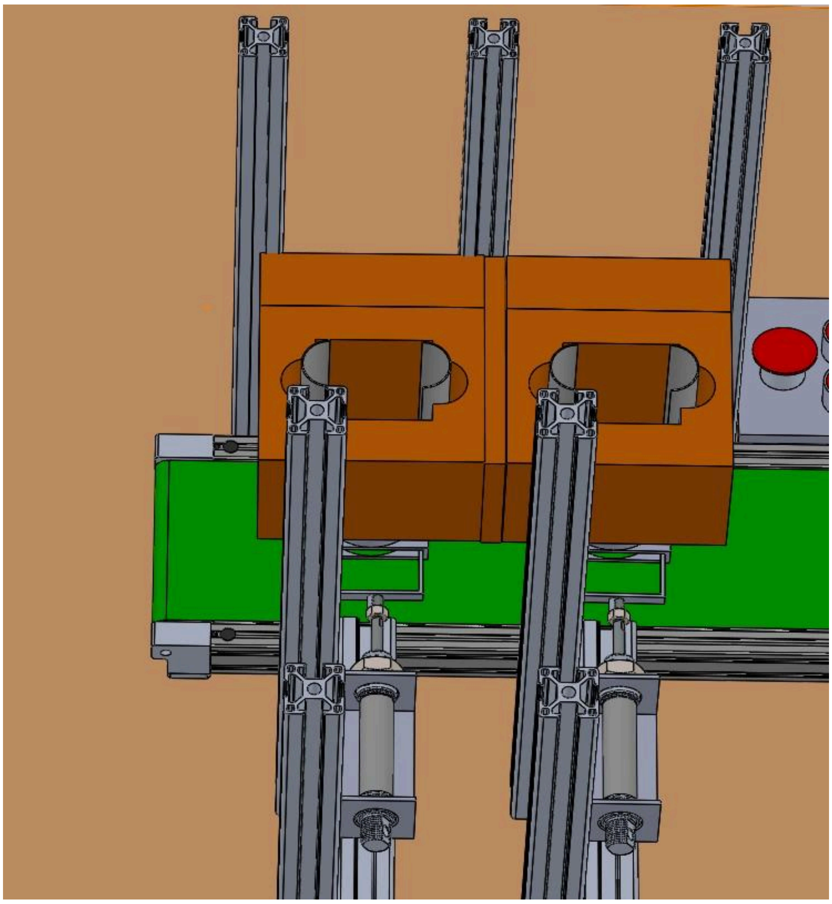


Figure A4: Behind side view of cup dispenser

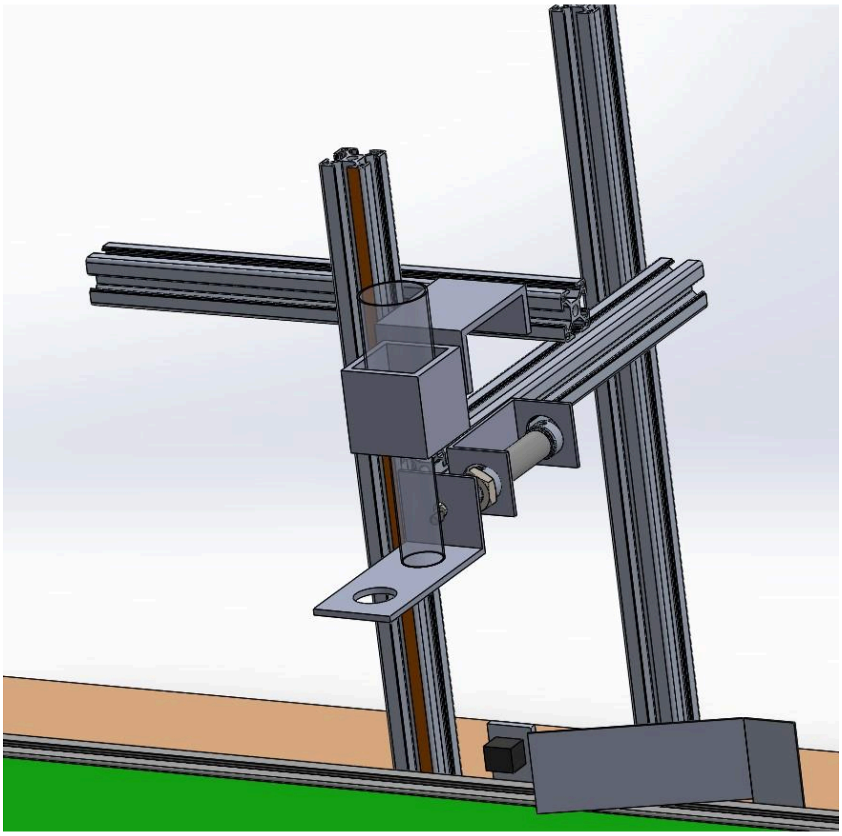


Figure A5: Slanted side view of ice dispenser

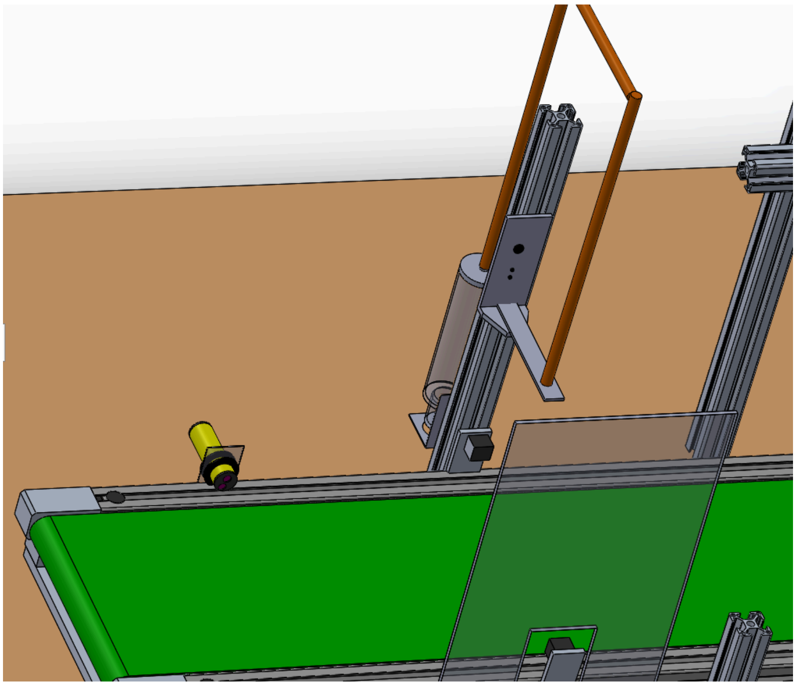


Figure A6: Slanted side view of water dispenser

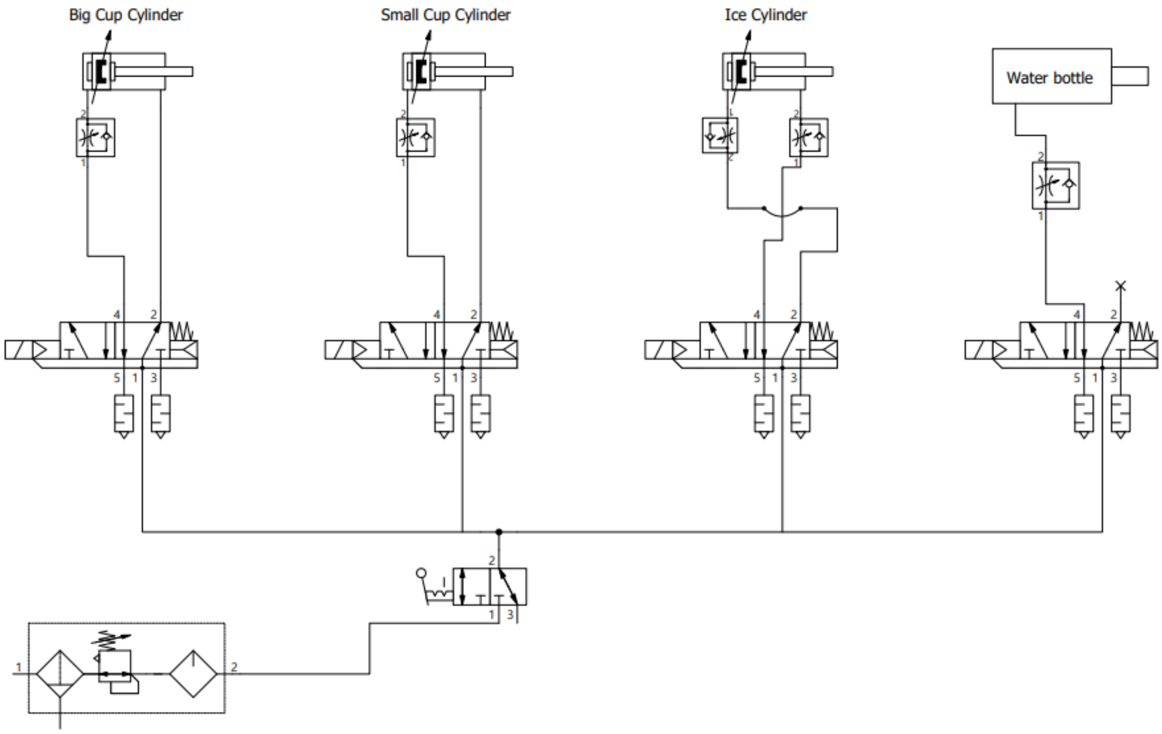


Figure A7: Pneumatics diagram

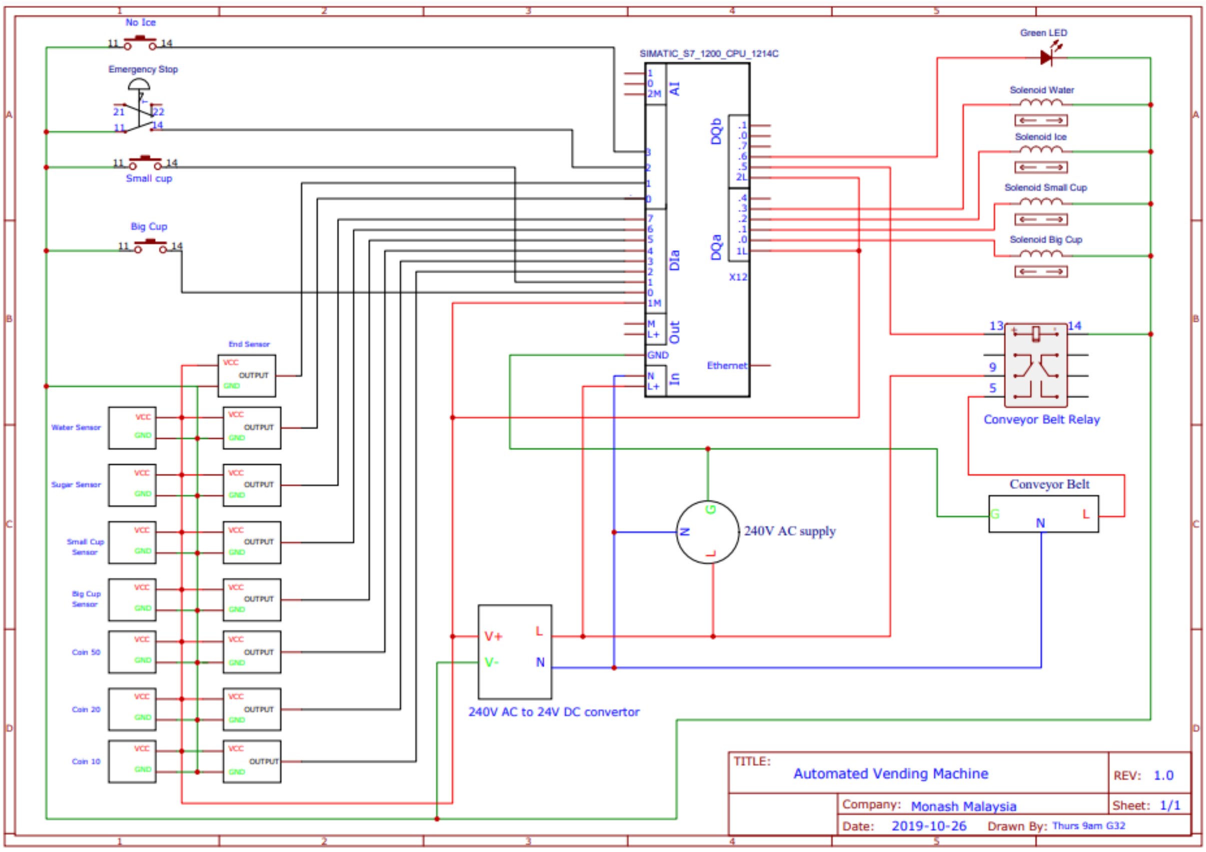


Figure A8: PLC wiring diagram

Appendix B PLC Program

Final Project / PLC_1 [CPU 1214C AC/DC/Rly] / PLC tags

Default tag table [63]

PLC tags

Name	Data type	Address	Retain	Accessible from HMI/OPC UA	Writable from HMI/OPC UA	Visible in HMI engineering	Supervision	Comment
Big Cup button	Bool	%I0.0	False	True	True	True		Button for big cup option
Small Cup button	Bool	%I0.1	False	True	True	True		Button for small cup option
Coin 10	Bool	%I0.2	False	True	True	True		Photoelectric sensor to detect 10 cents
Coin 20	Bool	%I0.3	False	True	True	True		Photoelectric sensor to detect 20 cents
Coin 50	Bool	%I0.4	False	True	True	True		Photoelectric sensor to detect 50 cents
Big Cup Sensor	Bool	%I0.5	False	True	True	True		Photoelectric sensor to detect position of big cup at cup dispensing station
Small Cup Sensor	Bool	%I0.6	False	True	True	True		Photoelectric sensor to detect position of small cup at cup dispensing station
Ice sensor	Bool	%I0.7	False	True	True	True		Photoelectric sensor to detect position of cup at sugar dispensing station
Water sensor	Bool	%I1.0	False	True	True	True		Photoelectric sensor to detect position of cup a water dispensing station
End sensor	Bool	%I1.1	False	True	True	True		Proximity sensor to detect position of cup at the pickup area(end of conveyor belt)
Solenoid Big Cup	Bool	%Q0.0	False	True	True	True		Output to 5/2 way solenoid valve. When energized, cylinder will extend and big cup will be dispensed.
Solenoid Small Cup	Bool	%Q0.1	False	True	True	True		Output to 5/2 way solenoid valve. When energized, cylinder will extend and small cup will be dispensed.
Solenoid Ice	Bool	%Q0.2	False	True	True	True		Output to 5/2 way solenoid valve. When energized, cylinder deactuates(retracts) and ice is dispensed.
Solenoid Water	Bool	%Q0.3	False	True	True	True		Output to 5/2 way solenoid valve. When energized, air flow will pressurized the nottle and water will be dispensed.
M1 (small)	Bool	%M0.0	False	True	True	True		Relay to save small cup option
M2(ice)	Bool	%M0.1	False	True	True	True		Relay to save accumulated time for when solenoid ice is energized
M3 (conveyor)	Bool	%M0.2	False	True	True	True		Relay that moves the conveyor when actuated
M4(ice)	Bool	%M0.3	False	True	True	True		Relay that actuates when M2 is actuated to start the timer that will move the conveyor belt after 2s.
M5(water)	Bool	%M0.4	False	True	True	True		Relay to save accumulated time for when solenoid water is energized
M6 (big)	Bool	%M0.5	False	True	True	True		Variable to save big cup option
M7(water)	Bool	%M0.6	False	True	True	True		Relay that actuates when M5 and M6 are actuated. It will start the timer that will move the conveyor belt after 16.5s.
M8 (no ice)	Bool	%M0.7	False	True	True	True		Variable to save no ice option
M10 (conveyor)	Bool	%M4.0	False	True	True	True		Relay that moves the conveyor belt when actuated
M20 (conveyor)	Bool	%M4.1	False	True	True	True		Relay that moves the conveyor when actuated
M21(water)	Bool	%M4.2	False	True	True	True		Relay that actuates when M5 and M1 are actuated. It will start the timer that will move the conveyor belt after 10s.
M22(conveyor safety)	Bool	%M4.3	False	True	True	True		Safety relay that is actuated when big cup sensor has detected a cup. Acts as one of the inputs to energize solenoid ice.
M23(conveyor safety)	Bool	%M4.4	False	True	True	True		Safety relay that is actuated when M22 is actuated and ice sensor has detected a cup. Acts as one of the inputs to energize solenoid water.
M24(coin input safety)	Bool	%M4.5	False	True	True	True		Relay that is actuated when M15 and coin 20 are actuated. Acts as one of the inputs to M3 conveyor.
M15(addition)	Int	%MW2	False	True	True	True		Variable that stores the value of the addition of the counter values that are connected to coin 10 and coin 20.

	Name	Data type	Address	Retain	Accessible from HMI/OPC UA	Writable from HMI/OPC UA	Visible in HMI engineering	Supervision	Comment
	Positive edge 2	Bool	%M1.7	False	True	True	True		Relay that saves positive edge of signal from coin 20
	Emergency stop	Bool	%I1.2	False	True	True	True		Stops the whole system when button is pressed
	No ICE button	Bool	%I1.3	False	True	True	True		Button for no ice option. Ice solenoid will not deactuate(retracts)
	Conveyor Belt	Bool	%Q0.5	False	True	True	True		Output to conveyor belt. When M3, M10 and M20 are actuated, conveyor belt will move.
	LEDG	Bool	%Q0.6	False	True	True	True		Output to green LED. When small cup button or big cup button is actuated, the green LED will light up.
	Positive edge 1	Bool	%M1.6	False	True	True	True		Relay that saves positive edge of signal from coin 10 sensor

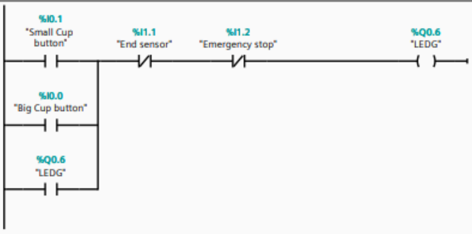
Figure A9: PLC default tag table

Network 1: Start cycle

There are two ways the cycle can be started:
- Small cup button is pressed
- Big cup button is pressed

When any of the buttons are pressed, LEDG will be actuated and the green LED lights up.

LEDG will be deactuated if end sensor is actuated(end sensor detects a cup) or emergency stop button is pushed.



Network 2: Remembering small cup option

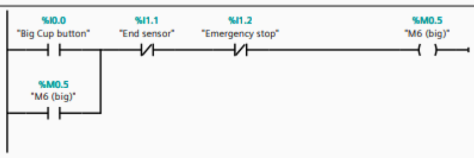
When small cup button is actuated, M1(small) will be actuated and small cup option will be remembered.

M1(small) will only be deactuated when end sensor is actuated(cup is detected) or when emergency stop button is actuated.

Network 3: Remembering the big cup option

When big cup button is actuated, M6(big) will be actuated and big cup option will be remembered.

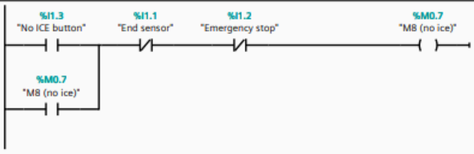
M6(big) will only be deactuated when end sensor is actuated(cup is detected) or when emergency stop button is actuated.



Network 4: Remembering no ice option

When No ICE button is actuated, M8(no ice) will be actuated and no ice option will be remembered.

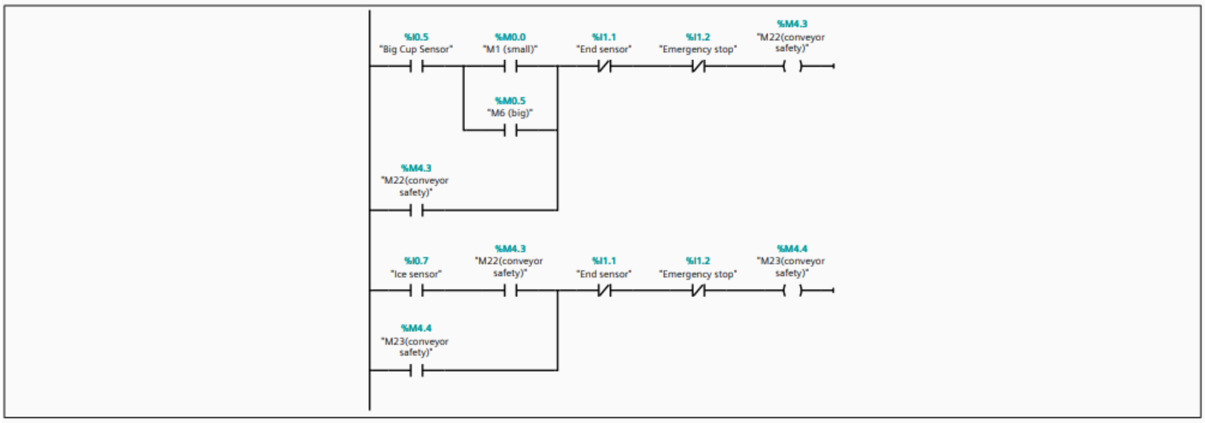
M8(no ice) will only be deactuated when end sensor is actuated(cup is detected) or when emergency stop button is actuated.

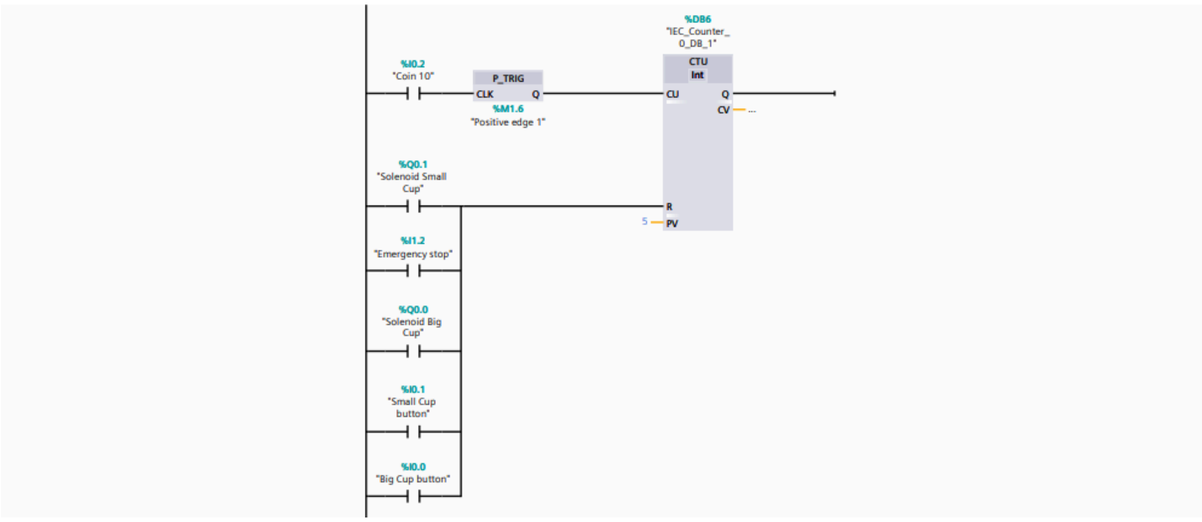


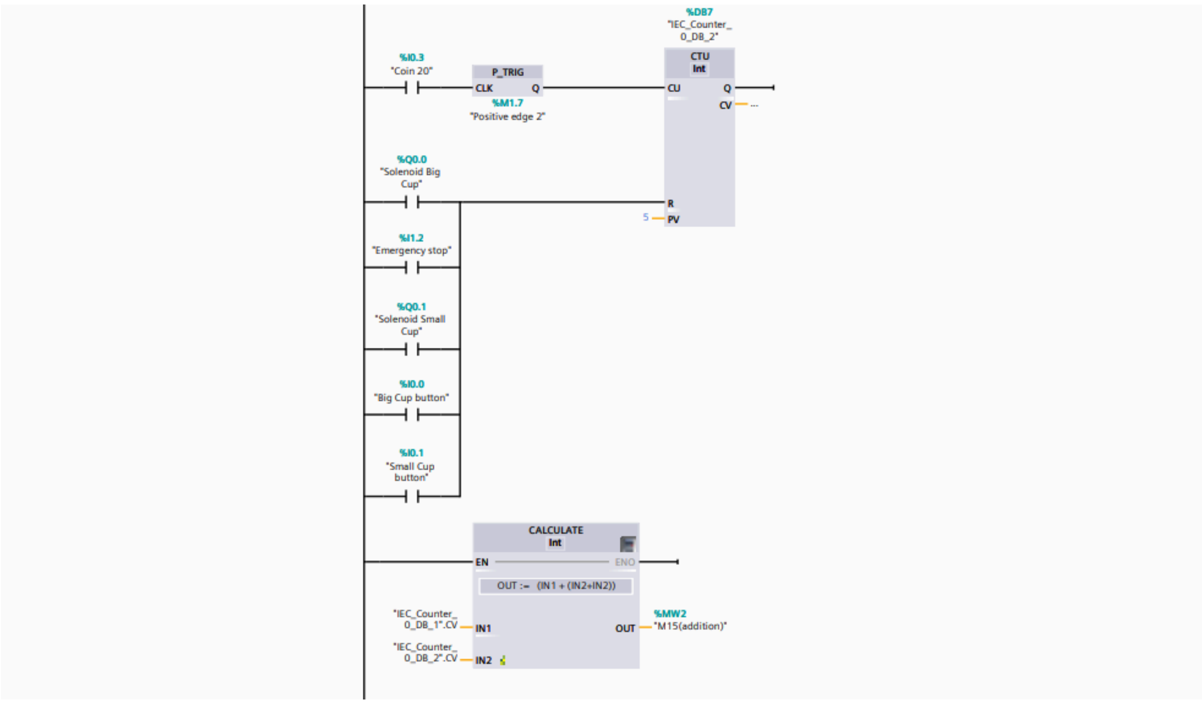
Network 5: Safety measure(conveyor)

M22(safety) relay will be actuated when big cup sensor is actuated and either M1(small) or M6(big) are actuated. M22(safety) will play a role in network 11(ice station). It will ensure that solenoid ice can only be actuated if big cup sensor has previously detected a cup.

M23(safety) will be actuated when ice sensor and M22(safety) are both actuated. M23(safety) will play a role in network 12. It will ensure that solenoid water can only be actuated if big cup sensor and ice sensor have previously detected a cup.







Network 6: Coin combination

When coin 10 and coin 20 sensors detect a coin, they will be actuated for a brief moment a signal would be sent to counters 1 and 2 respectively.

M16 and and M17 are positive edge trigger blocks that will ensure that only the positive edge of the signal is detected. This is so that the counter will only have one count for each coin detection.

The count values of counters 1 and 2 acts as inputs to the calculate math function block. The math function block will total the count values from counter 1 and (2*counter 2).

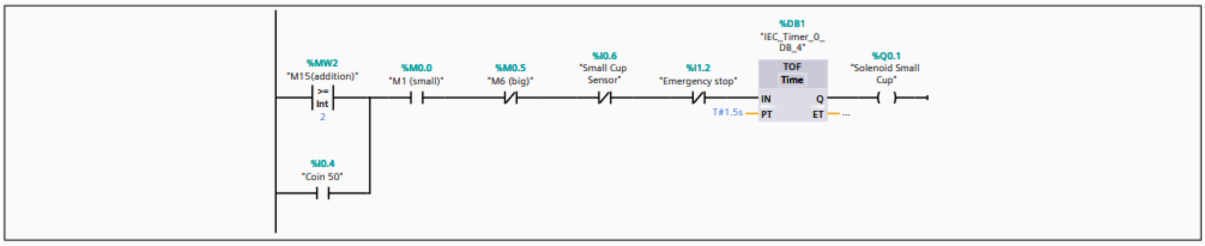
M15 is a variable that will store the calculated value from the math function block.

Solenoid small cup, emergency stop, solenoid big cup, small cup button and big cup button are used to reset the counters.

Network 7: Dispensing small cup

M15 is placed as an input in the comparator function block. When M15 has a value of 2, the comparator contact will close. If M1(small) has already been actuated, solenoid small cup will be actuated.
..
If coin 50 sensor and M1(small) are actuated, solenoid small cup will also be actuated.

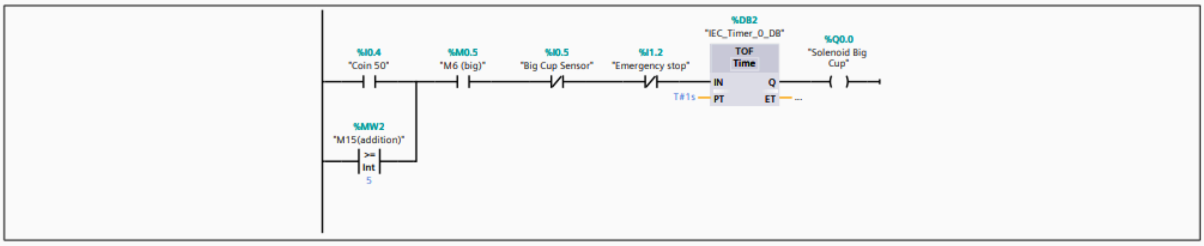
Solenoid small cup will only be deactuated after 1.5s or if emergency stop is actuated.



Network 8: Dispensing big cup

M15 is placed as an input in the comparator function block. When M15 has a value of 5, the comparator contact will close. If M6(big) has already been actuated, solenoid big cup will be actuated.
..
If coin 50 sensor and M6(big) are actuated, solenoid big cup will also be actuated.

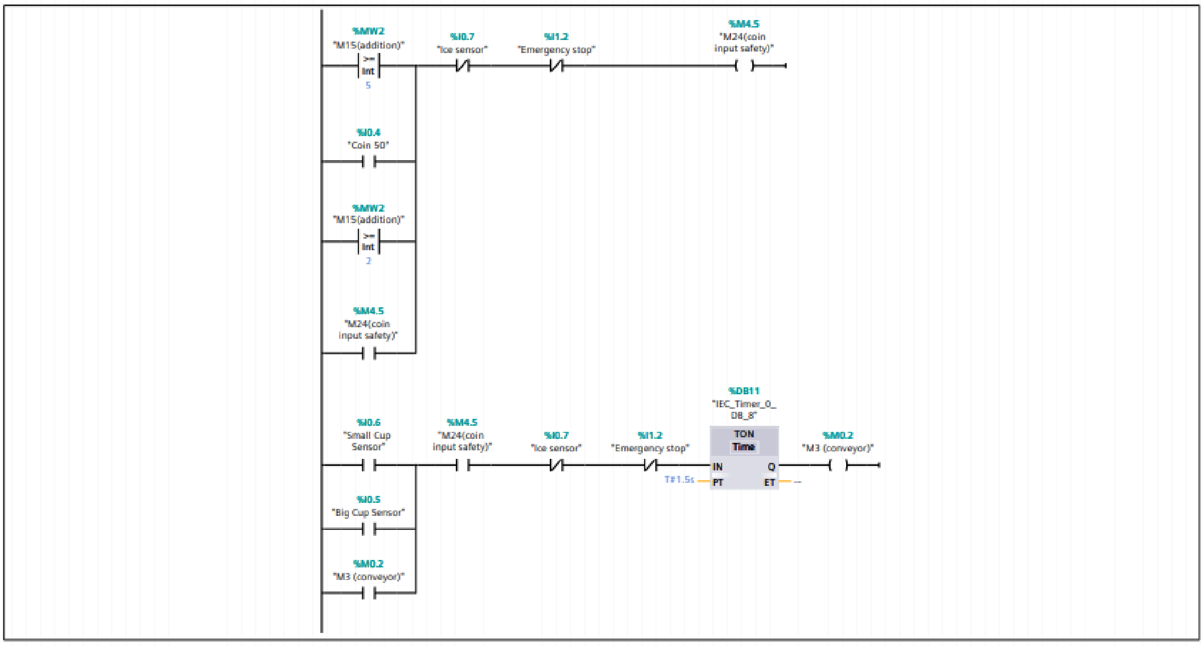
Solenoid big cup will only be deactuated after 1s or if emergency stop is actuated.



Network 9: Safety measure(coin inputs)

M24(coin input safety) willl be actuated when M15 has value of 2 or 5.

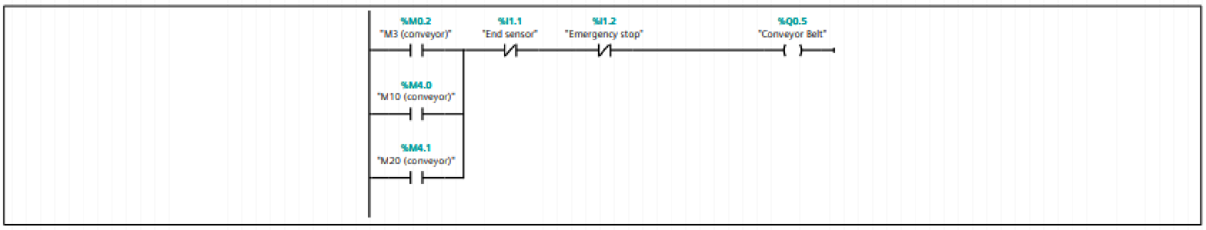
M24 will ensure that M3(conveyor will not be actuated) unless M24 has been actuated. This means that the conveyor will only be able to move after comparator conditions are met.



Network 10: Moving the conveyor

Conveyor belt ouput will only be actuated when M3, M10 or M20 are actuated.

It will deactuate if M3, M10 or M20 are deactuated. It will also deactuate if end sensor and emergency stop are actuated.

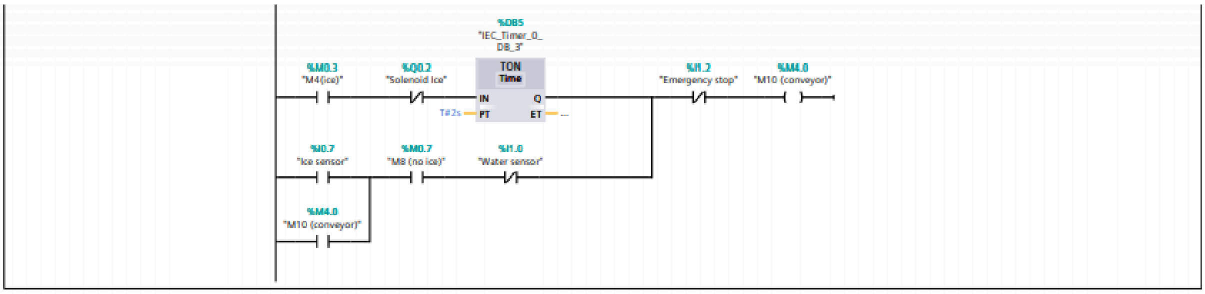


Network 11: Dispensing ice

When ice sensor and M22 are actuated, solenoid ice will be actuated. Cylinder will retract and ice will be dispensed.

When solenoid ice and either M1 or M6 are actuated, their respective timers will be activated. After timer conditions are met, M2 will be actuated.

M2 will then actuate M4 which will activate another timer and after timer conditions are met, M10 will be actuated and conveyor will start moving.



Network 12: Dispensing water

When water sensor and M23 are actuated, solenoid water will be actuated. Water will be dispensed.

When solenoid water and either M1 or M6 are actuated, their respective timers will be activated. After timer conditions are met, M5 will be actuated.

M5 will actuate M7 or M21 depending on whether M6 on M1 is actuated. When M7 or M21 is actuated, solenoid water will deactuate and water will stop dispensing.

M7 or M21 will activate their respective timers and after timer conditions are met, M20 will be actuated and conveyor will continue moving.

In any case if emergency stop is actuated, solenoid ice and M10 will be deactuated straight away.

If M8 is actuated, solenoid ice will not be actuated and M2 will actuate straight away, as long as ice sensor is also actuated. M10 will also be actuated straight away and conveyor will continue moving;it will not stop at ice station.

In any case if emergency stop is actuated, solenoid ice and M10 will be deactuated straight away.

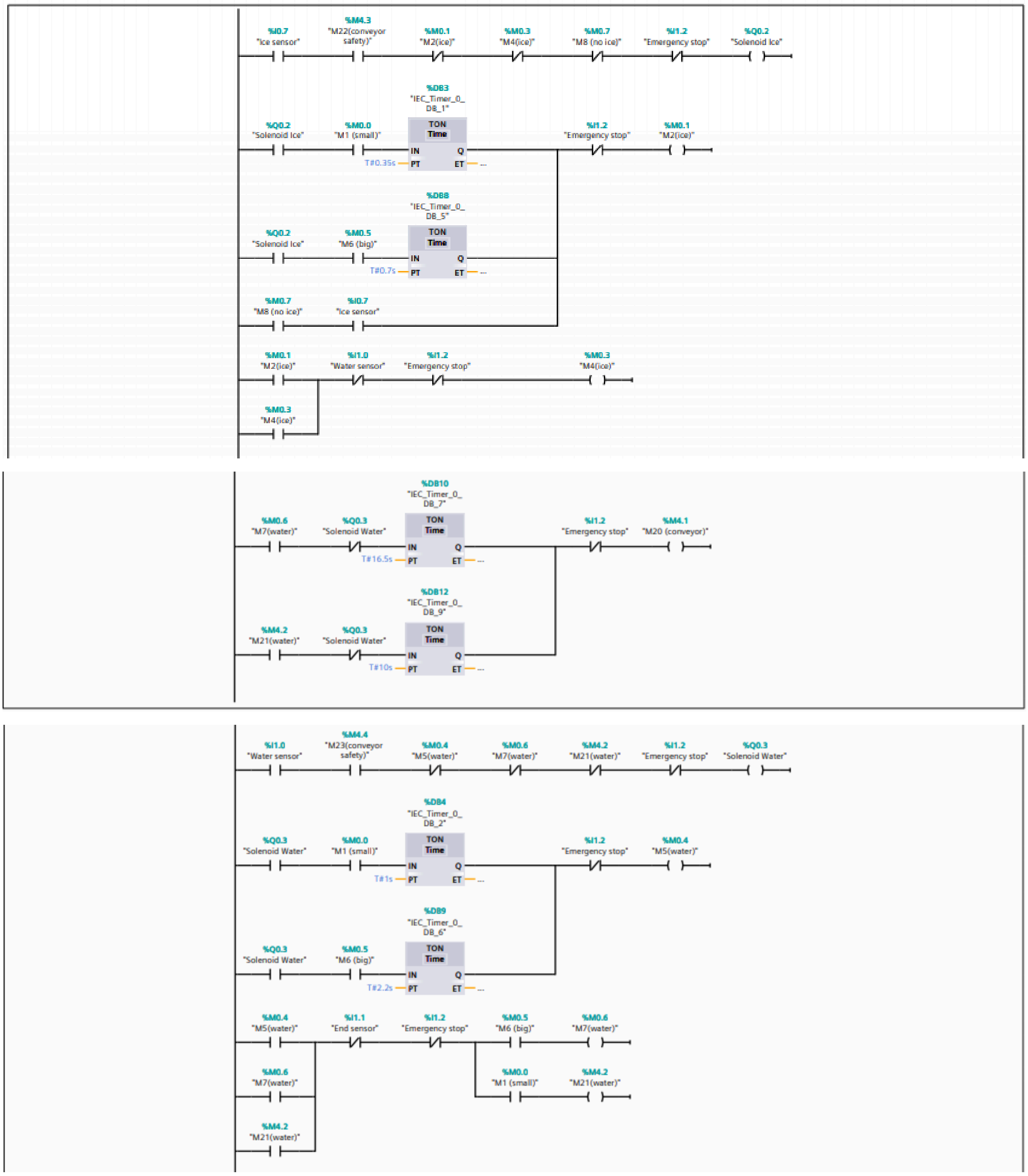


Figure A10: PLC diagram of the system

Appendix C Tasks Distribution

Table A1: Task Distribution

Team members	Student ID	Roles
Clifton Mak Ren Ming	29439701	PLC coder, Electrical, Structural, Documentor, Task Manager
Lim Wei Jun	29036348	PLC coder, Electrical, Structural, Documentor, Task Manager
Kang Xin Thean	29993881	Structural, Documentor, Poster Designer
Chua Kah Liang	30226236	Structural, Documentor, Poster Designer
Huan Jiun Yeong	30254531	Structural, Electrical, Documentor, PLC Debugger
Abhinav Jayaprakash	30162009	Structural, Documentor
Tanha Tahsin	29868483	Structural, Documentor
Abu Bakr Siddique	29790867	Structural, Video editor, CAD drawer

Appendix D Gantt Chart

Figure A11: Gantt Chart