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DEVELOPMENT OF AN AUTOMATED PACKAGING CONTROL SYSTEM

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CERTIFICATION OF APPROVAL

DEVELOPMENT OF AN AUTOMATED PACKAGING CONTROL SYSTEM

By

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A project dissertation submitted to the
Department of Electrical & Electronic Engineering
Universiti Teknologi PETRONAS
in partial fulfillment of the requirement for the
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(Electrical & Electronic Engineering)

Approved by,

____

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DEC 2013

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

____

Sadiq Husayni Bin Saharuddin

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ABSTRACT

There are 3 major key subjects that resulting the project which are Automation, Packaging and Control System. This project is designing automation system that the technique to make the system to operate automatically. By this implementation, automation can operate beyond the limitation of human capability. In production system, automation is rapidly used to increase the performance because the mechanism that control is reliable to any operation. This project is focusing in packaging process. It is focus in packing 24 canned foods in a box using pneumatic system control by Programmable Logic Control (PLC). The packing sequences are sorting 4 cans for 1 row and completed for 3 rows. The total would be 12 cans for the 1st stack. The process repeated for 2nd stack. Full 24 cans in 1 box would be sent to inventory. The automation consist of proximity sensors, electropneumatic circuit, directional valves, drive system and actuator. Then, proceed with constructing a ladder logic diagram via PLC. A structured method of developing the routines for a packing process is developed. The approach used in this work provides the proper documentation of the program. The Boolean expressions derived from the timing diagram were documented and would allow easy modification based on requirements. The project is to come out the demo system of the automation packaging using the equipment at the automation lab.

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LIST OF ABBREVIATIONS

PLC	Programmable Logic Control
SMI	Small Medium Industry
SOP	Standard Operating Procedure
PROX.S	Proximity Sensor
LS	Limit Switch
HR	Holding Relay
HRT	Holding Relay Timer
TIM	Timer
CNT	Counter

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

Manufacturing process in many industrial stresses on the time taken of the production to come out the output. The control and monitoring of the production system have to be fully efficient and accurate to reduce the production time. Thus, various manufacturing support systems is design to manage the set of procedures used by the companies which to solve the technical and logistics problems encountered such as in ordering material, material movement, and ensuring that products meet quality standards. Hence, the industry is looking into a system for reliability, speed and cost effectiveness. Through the long process in manufacturing, processing and packaging are the main processes to be completed in production system, there are standard operating procedures (SOPs) to be followed. Every manufacturing process has to end with the packaging of the output or product. Therefore, a quality and fast packaging can increase the performance of the production line in the industry.

This project is focusing on food industry, particularly in the canned food production for small medium industries. The trends of canned food are more economical alternative compared to other food packaged in market such as frozen food. The capital investment for canned food is within the budget for small medium industry. For example, ‘Ayam brand’ is one of the highly marketable canned foods in Malaysia. The brand is majorly processes in fish and seafood products. All of the products have to be packaged fast to load out to the market. It shows that the growth of canned food industry is potential because its market value is very high which convenient when travelling and picnic. There are also a lot of other foods for canned products instead of seafood such as baked beans, green peas and meats. After all, it is relevance to improvise the packaging system since the high demand of the canned foods.

1.2 PROJECT OBJECTIVES

The objectives of this project are:

1. Design an automation system to control packaging process, consisting of electropneumatic connection, actuators, sensors and valves.
2. Develop and construct a ladder diagram for the system via PLC programming using a structured method.
3. To construct a fully functioning prototype to prove the marketability of the automated packaging system for small medium industry.

The approach would be on improvising a system in packing a batch of 24 canned food into a cardboard box for a small and medium industry (SMI) production system. This work would lead to the development of a packaging system that is flexible and adjustable to needs.

1.3 PROBLEM STATEMENT

In small medium industry in Malaysia, the industries are often faced with the problem of achieving fast system in packaging product. As manual process by the operator previously, the small medium industry has to develop the production system by increasing the performance in fast processing and packaging. It is important to have fast packaging since the demand is highly increase. This work aims to answer a part of this problem, and hence a design in developing a fast packaging system is vital to archieve the high performance in production system. Thus, an automated packaging system to be designed would function to arrange finished products that is canned food in repetitive and rapidly fast operation which should be accurate and efficient. The finished products will have to be packaged in a batch of 24 cans in a cardboard boxes before inventorying and to marketing. Hence to develop a controller consisting of a PLC and ladder support software, to the control and monitoring of the electropneumatic actuators would involve an in-depth engineering study and design.

1.4 SCOPE OF STUDY

In this study, the main subjects under investigation are:

i. Understanding and learning Programmable Logic Control (PLC) application in production industry.
ii. Implementing electropneumatic system consists of sensors, valves and actuators executed with ladder logic program from PLC.
iii. Designing an industrial automation control system for small medium industry in Malaysia.

1.5 RELEVANCY OF THE PROJECT

This project is very much relevant to my 4 years of undergraduate study majoring in electrical and electronics engineering. It is mainly dealing with programmable logic control which is included in the major syllabus under Industrial Automation Control System. Besides technical knowledge in programming, project management skill like time management and interpersonal communication skills are required. Also, this project challenges critical, analytical, innovative and creative thinking, which are all highly demanded in real working environment of a professional, competent and qualified engineer.

CHAPTER 2

LITERATURE REVIEW

2.1 AUTOMATION

The dictionary defines automation as “the techniques of making apparatus, a process, or a system operate automatically”. In automation federation, stated that automation as “the creation and application of technology to monitor and control the production and delivery of products and services”. Thus, in this day and age of computers, automation is becoming increasingly important in the manufacturing process because computerized or automated machines are capable of handling repetitive tasks quickly and efficiently. Nevertheless, the automation system mainly uses in challenges working environment to increase the performance whereas the system is designed to extend the capacity of machines to perform tasks formerly done by human, and to control sequences of operation without human intervention.

The food industry is facing global competitive challenge, similar to the other businesses that have developed new fast system in control and operation of manufacturing such as electronic and automotive industry. Thereupon, the implementation of proper plan and system such as re-engineering, process improvement, process control and automation have become common in the race to improve productivity and to lower cost. Above all, automation is essential in the struggle for manufacturing competitiveness[1].

Some of the earliest food industry application of robot and automation evolved in the year of 1980. As compared to other industries which have implemented automation earlier, food industry is slow because the technology was expensive at that time. In the food industry today, automations are used in production system mainly in material handling and packaging operation. There are some characteristic that make this compatible for packaging such as the material is rigid, the packaging is of a regular shape and the material is structured that can be presented in an ordered format [2].

Afterward, automation has improved to a new extend which is in lean manufacturing system. It is identified that the lean manufacturing uses a lot of automation system to develop the production output and increase the performance. It is perceived that the operational performance of food processing in small medium industry do have implemented lean manufacturing practices. The findings indicated that the productivity and quality improved[3]. Thus, it is not new to implement automation system for packaging operation.

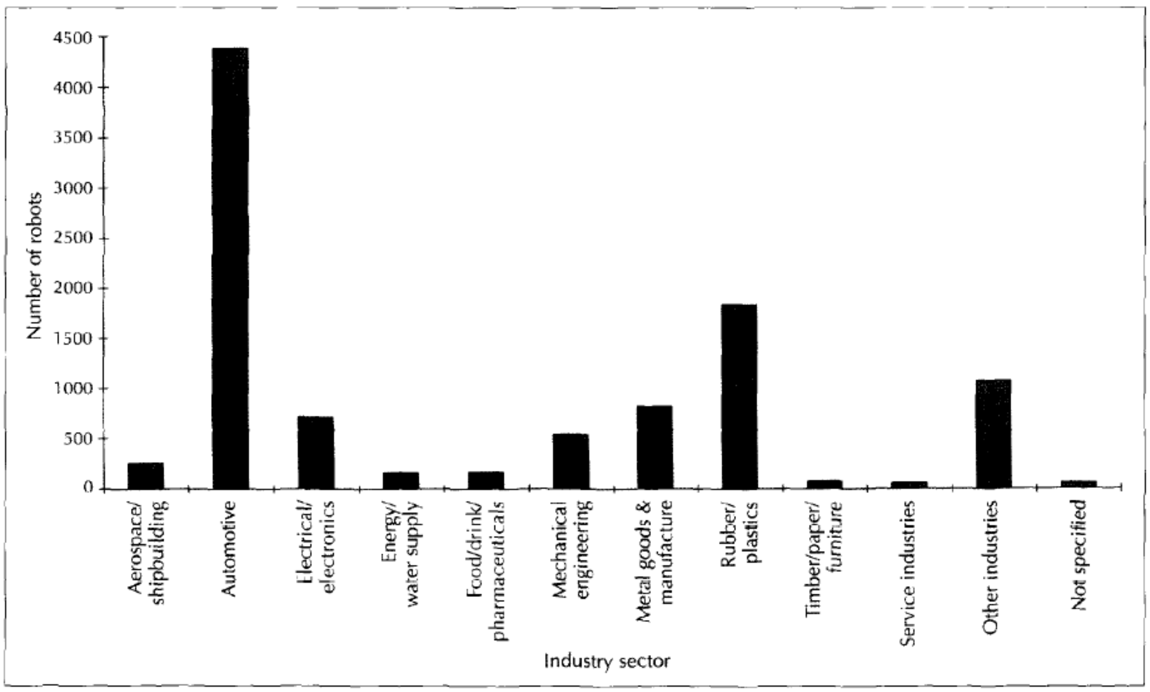


Figure 1: Sales of robot in each industry sector [2]

Figure 1 shows that the automation is less used in food industry especially in small medium industry. It is because the automation system is costly for small medium industry. However, the marketability of the system later on has implemented to all type of industries. Thus, the implementation of the new system can boost the performance and increase the production system. There are a lot of advantages by improvising the industry in using the modern control of automation. Briefly, there are some reasons on why the automation is compatible to any manufacturing industry. The reasons for automation as listed below;

Reasons for automating:

1. Reduce labor cost
2. Mitigate the effects of labor shortages
3. Reduce or eliminate routine manual
4. Improve product quality
5. Reduce manufacturing lead time

Table 1: Comparison of Human and Automation

Human	Automation
Sense unexpected stimuli	Perform repetitive task consistently
Limited force and power	Apply high force and power
Make difficult decision based on incomplete information	Make routine decision quickly
Learn from experience	Maintenance

Table 1 above shows the comparison between the ability for human and automation. It is proven that, automation in packaging operation is more reliable to increase the performance in production system.

2.2 PROGRAMMABLE LOGIC CONTROL

Before the PLC, control and sequencing was using relays controllers. PLC has developed the manufacturing industry to be more reliable and efficient. PLC can be define as an industrial computer control system that continuously monitors the state of input devices and make decisions based on programmed to control the output devices. A PLC has many input terminals, which interprets digital signal 'high' and 'low' logical states from sensors. Hence, the output will receive the signal to on/off control of the output devices such as solenoid and motor. PLC has its own programming language that using ladder logic diagram. Furthermore, it is programmable for any modification. It is comfortable to read the ladder logic schematic to perform the control function.

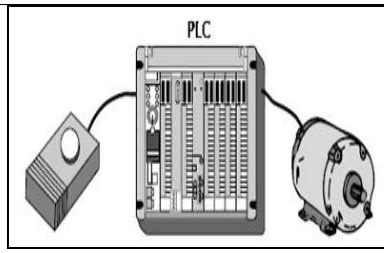
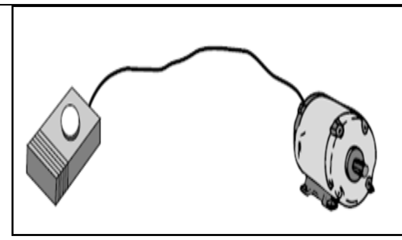
Programmable controllers offer several advantages over a conventional relay or direct logic type of control. Relays have to be hard wired for connection. For any modification, the wiring connection need to be removed and rewired which waste of time. In this case for automation in food industry, complete control panels had to be replaced since it was not economically feasible to rewire the old control panel. Programmable controllers also have constant reliability, lower power consumption and ease of expandability [4]. PLC has different type such as modular type PLC that can be installed to main PLC to increase the relay function.

Table 3 below shows the comparison of the advantages and disadvantages between PLC and PC. There are a lot of specifications and features of PLC to perform well rather than PC. However, it is still depends on the scenario and case study to design the system. Furthermore, Table 4 also shows the comparison if using wired logic.

Table 2: Comparison of PLC and PC

	PLC	**PC**
Environment	Designed for harsh conditions with electrical noise, magnetic fields, vibration, extreme temperatures or humidity	Not designed for harsh environments. Industrial PCs are available but cost more
Ease of Use	Friendlier to technicians since they are in ladder logic and have easy connections.	Operating systems like Windows are common. Connecting I/O to the PC is not always as easy
Flexibility	In rack form are easy to exchange and add parts. They are designed for modularity and expansion	Typical PCs are limited by the number of cards they can accommodate and are not easily expandable.
Speed	Execute a single program in sequential order. The have better ability to handle events in real time	By design, are meant to handle simultaneous tasks. They have difficulty handling real time events
Reliability	Seldom crashes	A PC locking up and crashing is frequent
Programming Language	Languages are typically fixed to ladder logic, function block or structured text	A PC is very flexible and powerful in what to use for programming
Data Management	Memory is limited in its ability to store a lot of data.	Any long term data storage, history and trending is stored in hard drive

Table 3: Comparison of PLC and Wired Logic

PLC	Wired Logic
Eliminates much of the hard wiring that was associated with conventional relay control	Large amount of work required connecting wires
Flexible in changes by programming	Difficulty with changes or replacements
Easier to troubleshoot	Difficulty in finding errors; requiring skillful/experience work force
Short downtime	Long downtime
 All control devices are wired input and output to the PLC	 All control devices are wired input and output directly to each other

2.3 PACKAGING

In a modern control system, most of the huge manufacturing plant has developed the packaging process by automation. Most plants (94%) have completely automated for food processing. However, it was found that 95% of the plants are from huge industries but 50% are from a smaller scale plants. Moreover, they also surveyed that the level of automation among the different operations. Packaging is second most important process that have automated (82%) operations [5]. It is usually find some cases that contain typically 12, 24, 36 individual product to be packaged. The filling operation of canned food into cardboard boxes can be carried out manually by the operator. Accordingly, using fixed automation, the packaging process is not too difficult to handle this number of units.

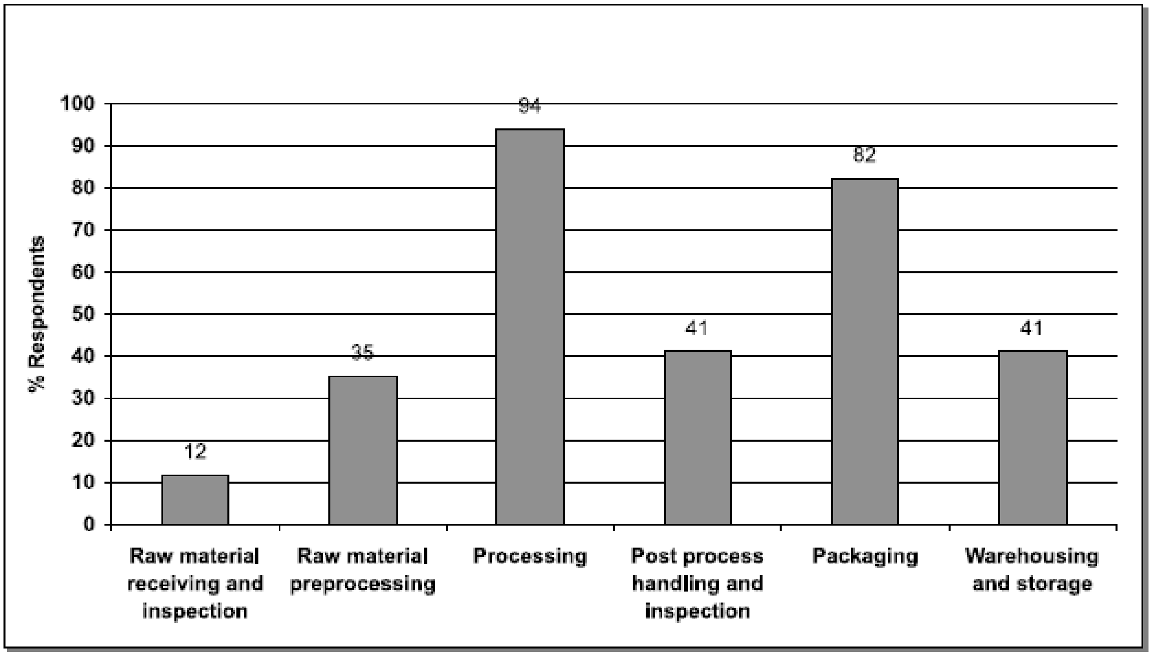


Figure 2: Level of automation in different process in food industry [5]

There are a lot of similarities between the food processing and packaging. In the food industry, more automation reduces the tidies of repetitive operation. Figure 3 shows the percentage of food industry that typically integrates the number of packaging machines in the production lines [6].

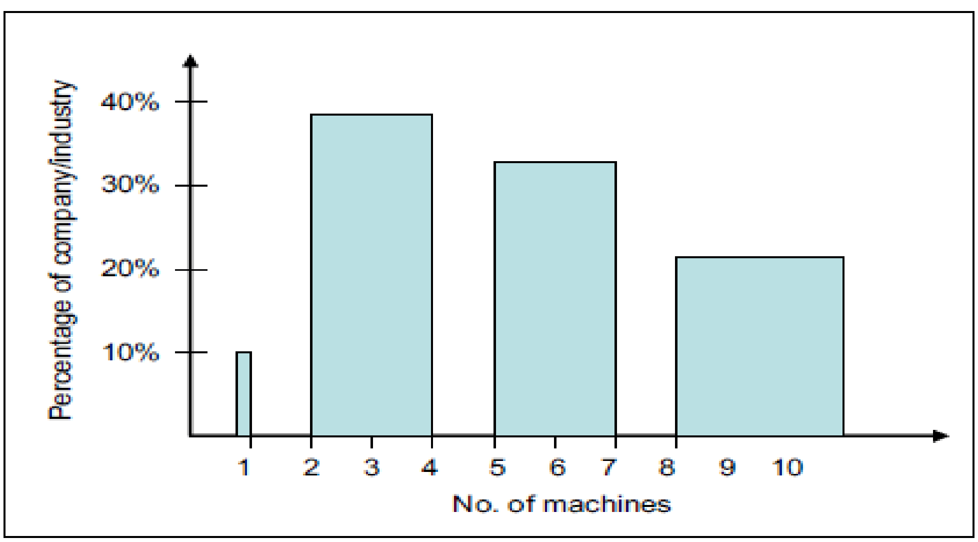


Figure 3: Number of machine for packaging

2.4 MOTIVATION

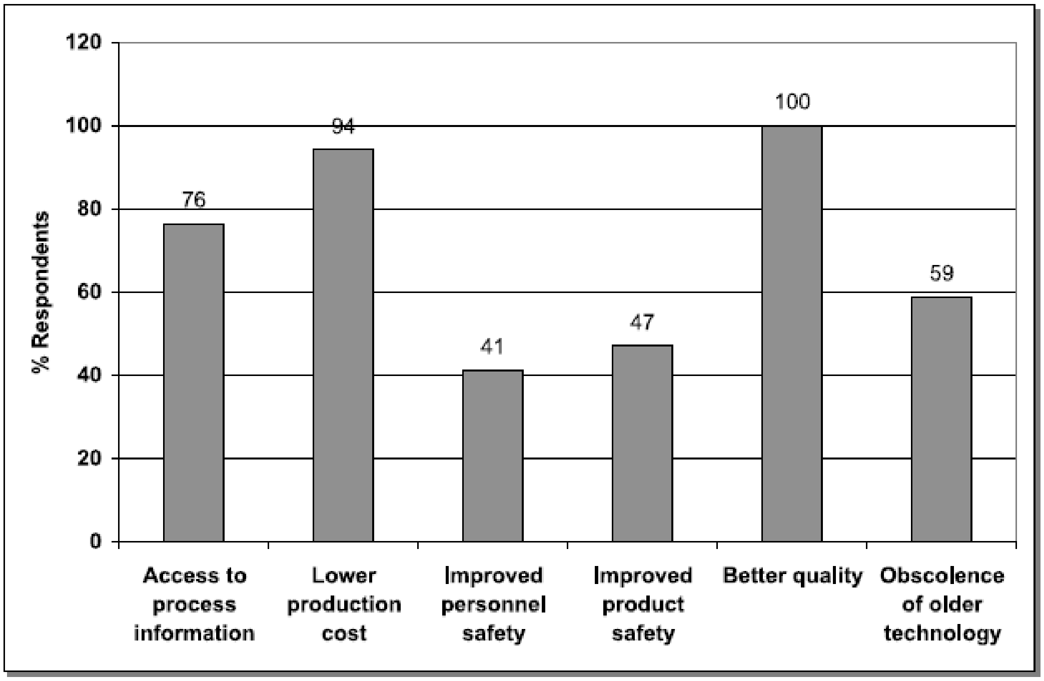


Figure 4: Motivational factors for implementing of automation technology [5]

A key step that needs addressing is finding the best packaging materials for commodities which preserve the benefits of improved product quality imparted by preservation technologies. Proper selection and optimizing of packaging are of major importance to food manufacturers due to aspects such as economy, marketing, logistics, distribution, environmental impact of the packaging as well as the consumer demands.

Critical protective barrier properties of packaging materials must be preserved to prevent chemical, physical, or microbial degradation of contents after processing. Therefore, it is necessary to understand the process parameters and mechanisms/kinetics of the process and their effects on packaging material properties[7].

Food packaging has no longer just a passive role in protecting and marketing a food product. New concepts of active and intelligent packaging are due to play an increasingly important role by offering numerous and innovative solutions for extending the shelf-life or maintain, improve or monitor food quality and safety[8].

CHAPTER 3

METHODOLOGY

3.1 DESIGN APPROACH

The system as shown in Figure 5 and Figure 6 are used for packing 24 cans of canned food into cardboard boxes. Every operation of actuator A inserts a canned food into the loading section. Actuator B then places a row of four cans into a box. The box is full after two-stacks of three rows of cans have been introduced.

The system starts when PLC power switch is on. The first loop starts by checking the START push button to execute the program and run the process. Once the START button is pressed, it will check the STOP push button condition. The process would not start if the STOP button is pressed.

The flowchart shows the different implication where the rectangular box is the process of the output or the actuator. There are 4 actuators in the system which all of it are double acting cylinders. The diamond box represents for the input and signal condition. It indicates the decision making process to determine the sequence either to loop back or proceed to next step. Thus, the sequence is initiated the required cycle is as Figure 5 below:

3.2 FLOW CHART

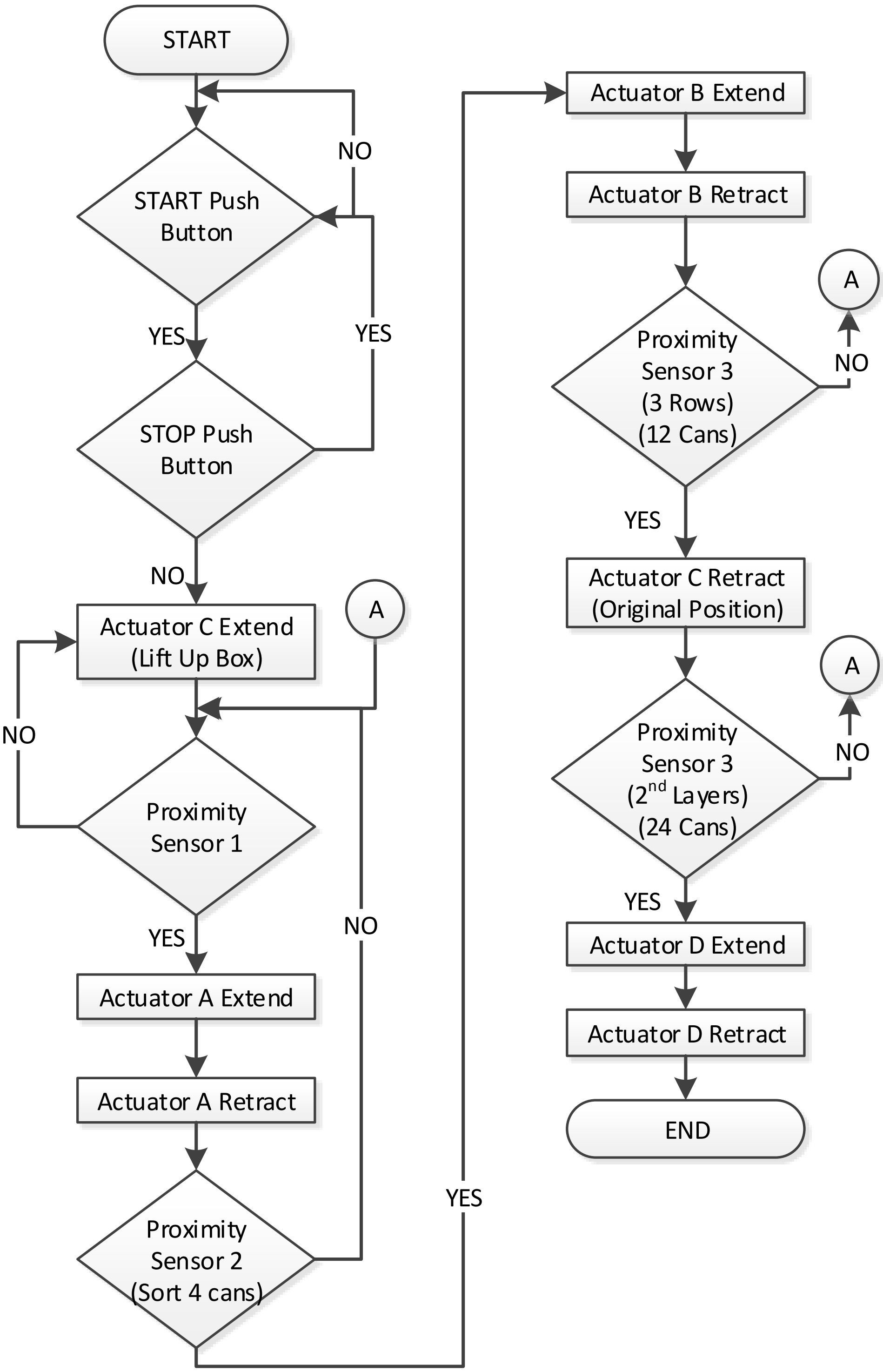


Figure 5: Flowchart of Packaging Process

3.3 SYSTEM LAYOUT

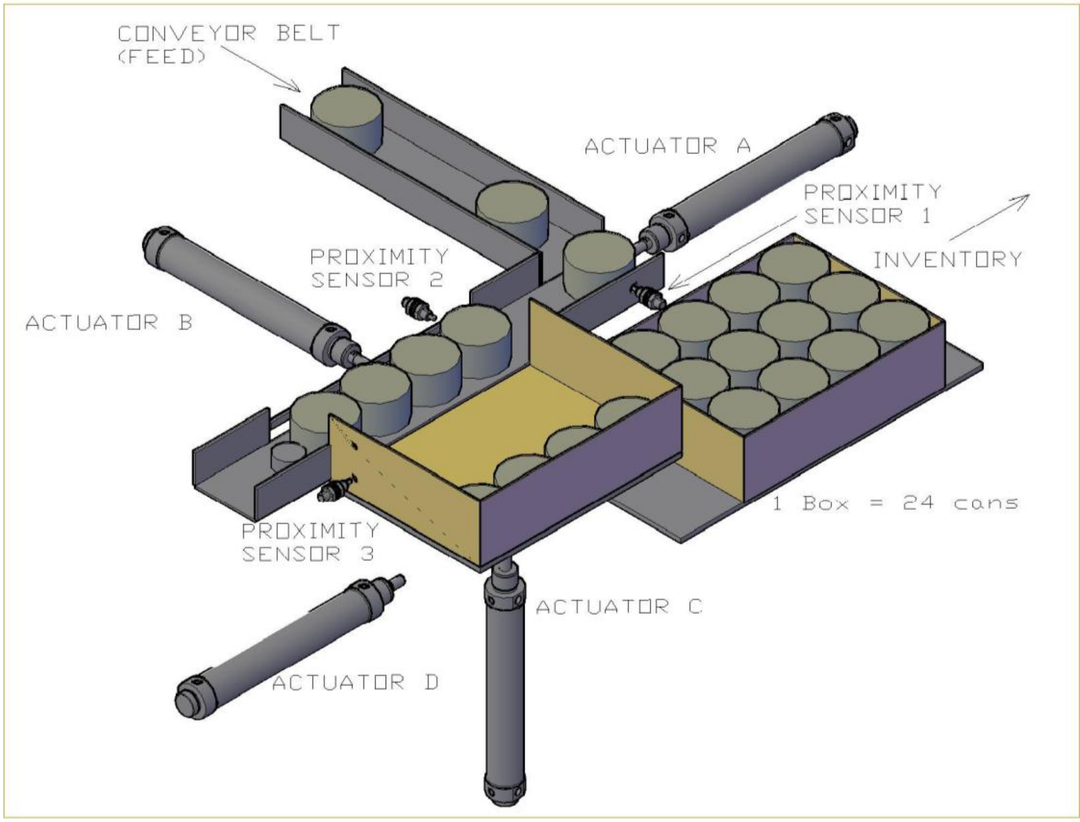


Figure 6: Packaging System Layout

Figure 6 shows the illustration design of the automated packaging control system. The system is to pack 24 cans into a cardboard box. 12 cans for each layer which the second layer is stacked above the first layer. Based on the flow chart in figure 5, the process is repeated when proximity sensors give the feedback to the controller. When proximity sensor 1 triggered, actuator A will sort 4 cans and proximity sensor 2 will perform the decision making. Thus, actuator B will continue it by pushing the 4 cans to the cardboard box. Proximity sensor 3 will determine the completion of 12 cans for one layer. The process will repeat to sort another 12 cans for the second layer which is stacked above the first layer by retracting the actuator C. Hence, there are 3 variables as for feedback system. The complete 24 cans in a cardboard box to be sent to the inventory after actuator D is extend. The conveyor belt from feed and for inventory is continuously operated after START button is pressed.

3.4 SYSTEM MAIN ELEMENTS

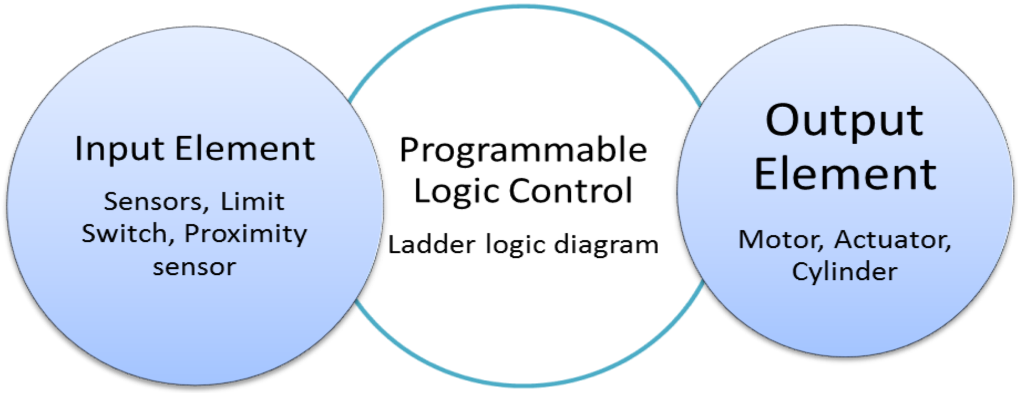


Figure 7: Main Elements for Automation System

The first part of the work will be to solve for a one-stacked arrangement, consisting of 12 containers of canned- food of similar sizes. The design will be expanded to a two-staked arrangement once the one-stacked arrangement is solved. Considering the benefit of PLC-controlled systems, the packaging system to be developed should be flexible and adjustable to the different quantity of cans and the number of stacking required.

The elements of the automation system are to be designed with the sensors, valves and actuators. There are various algorithms for each process such as in determining the product presence, cylinder position, sequence between 2 cylinders and etc. The types of the sensors need to be determined to make it compatible with the product and cylinder. Furthermore, the valves types for pneumatic control also need to be considered. Lastly, the mechanism of the cylinder should be flexible for gripping product.

Apart from that, PLC configurations need to be figured for example in its programming language, connection with pneumatic system, and the PLC model. The simulation of the design system can use automation studio software to develop the sequence and write the program before execute to a demo system at automation lab. Then, analysis activities on the project can be done for the result.

3.5 PROJECT METHODOLOGY

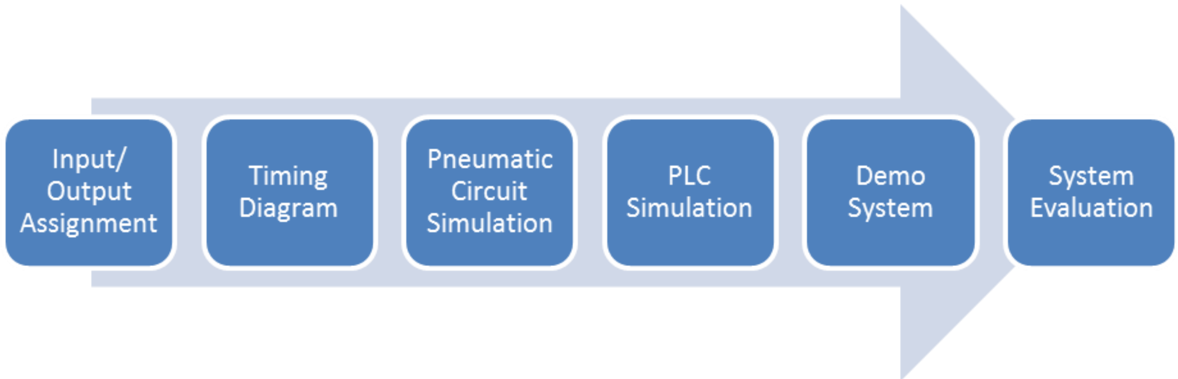


Figure 8: Project Methodology

Figure 8 shows specifically the main element to be completed for this project. It starts with the input output assignment based on the system that designed. Inputs that been used are push buttons, limit switches and proximity sensors. On the other hand, the outputs that been used are 4 actuators particularly Actuator A, B, C and D. However, the actuator is only activates when its solenoid valves is triggered. The second procedure is to draw the timing diagram for each variable includes the inputs, outputs, and PLC functions such as Timer and Counter. The diagram will assist the programmer when to check the sequence, process and logic combination between the variables.

Then, the process is continued by simulation design on the pneumatic circuit. The process need to determine the suitable cylinder, as example either using double acting or single acting cylinder. Valves also need to be simulated with the cylinder to check the circuit is reliable to connect with the hose and PLC for triggering. The simulation for pneumatic circuit is using Automation Studio software.

Next step is to simulate the PLC circuit. The language of PLC which using ladder logic diagram need to be mastered on how the element of relays is been used. Before drawing the circuit, the sequence or timing diagram need to be revised to analyze the packaging process. The sequence need to check on the actuator position, signal that triggered, and the timer as the clock for delay. The PLC circuit can be designed simply when the timing diagram is perfect.

Next, the step is continued with constructing the demo system consisting of electropneumatic connection, actuators, switches, sensors and valves. This is to check the reliability test after the simulation. This steps need to test the compatibility between the simulation circuit and the real equipment. The final procedure is the evaluation which is to check the timely coordination of the system speed and result analysis.

3.6 INPUT AND OUTPUT ASSIGNMENT

The Table 4 below shows the input and output assignment for each devices and equipment that been used in the packaging system. Output devices is connected to 5/2 Double Solenoid Valve. The input and output have different channel which channels at '0.XX' for input and output channels at '100.XX'. The number is the memory address for the PLC. There are 14 input slots at OMRON PLC input port and 16 output slots at output port. Moreover, PLC is in modular form which the port can be slotting in to increase the input/output assignment for heavy system.

The inputs that been used are from 0.00 to 0.01 for push buttons, 0.02 to 0.09 for limit switches particularly for Actuator A, B, C, and D, 0.10 to 0.12 for Proximity Sensors 1, 2, and 3. Figure 9 below shows the input ports that connected with signal wires.

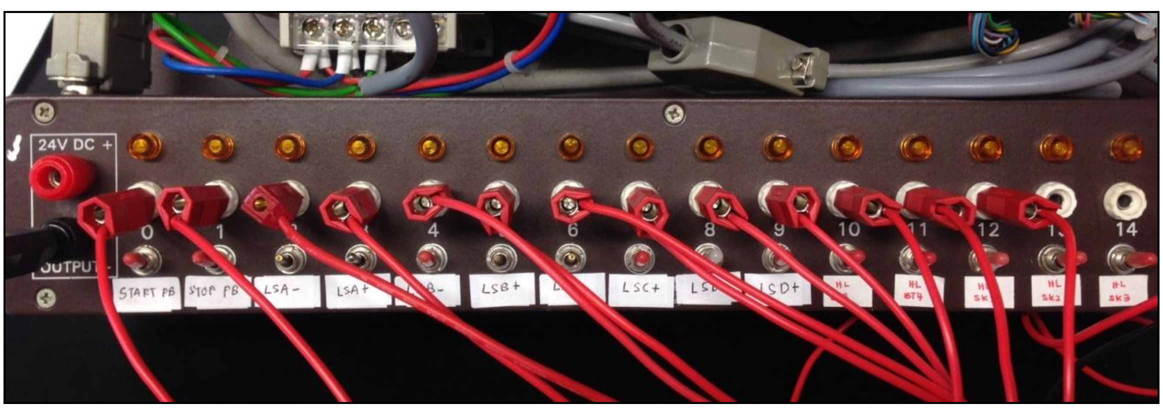


Figure 9: Input ports

The outputs that been assigned are address from 100.00 to 100.07 for all actuators A, B, C and D. 2 outputs for each actuator which A+ for Actuator A to extend and A- for Actuator A to retract. It is similar to other outputs also for extend and retract. Figure 10 below shows the output ports.

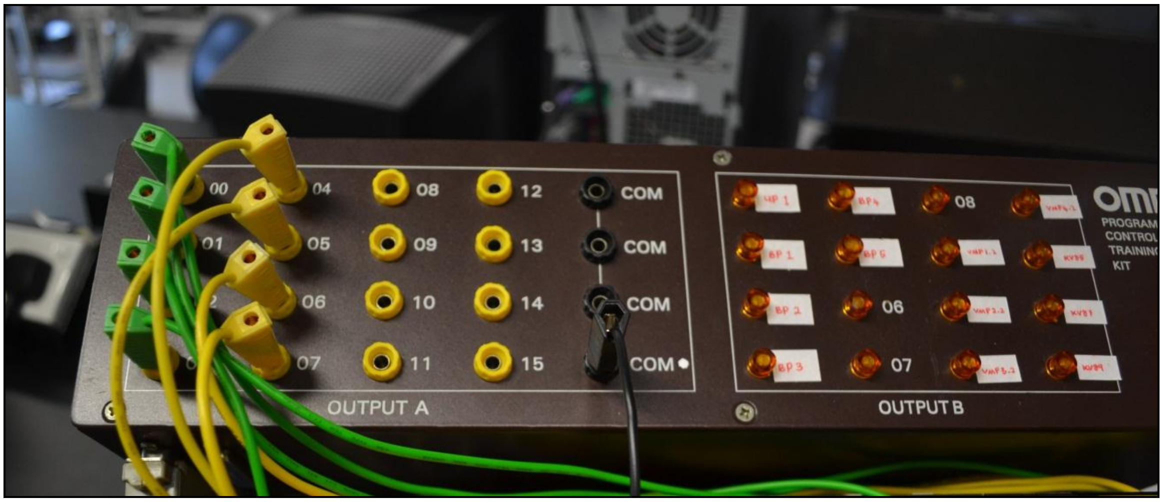


Figure 10: Output Ports

Table 4: Input/Output Assignment

INPUT	DEVICES	OUTPUT	DEVICES
0.00	START	100.00	Actuator A+
0.01	STOP	100.01	Actuator A-
0.02	Limit Switch A+	100.02	Actuator B+
0.03	Limit Switch A-	100.03	Actuator B-
0.04	Limit Switch B+	100.04	Actuator C+
0.05	Limit Switch B-	100.05	Actuator C-
0.06	Limit Switch C+	100.06	Actuator D+
0.07	Limit Switch C-	100.07	Actuator D-
0.08	Limit Switch D+		
0.09	Limit Switch D-		
0.10	Proximity Sensor 1		
0.11	Proximity Sensor 2		
0.12	Proximity Sensor 3		

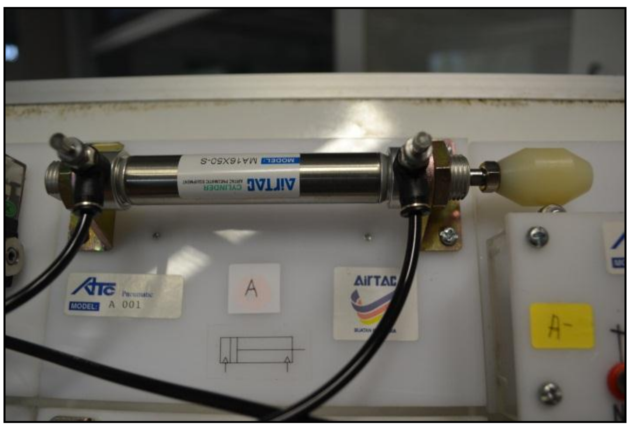
3.6.1 INPUT DEVICES

Table 5: Input Devices Specification

INPUT DEVICES	SPECIFICATION
	START and STOP push button 2ea Normally open push button to start and stop the process.
	Capacitive Proximity Sensor (PNP) Model No: E2K-C25MF1 3ea Proximity sensors have been used to determine the presence of product and count the quantity.
	Limit Switch Normally open limit switch 2ea limit switches for one actuator to determine the extent and retract position. 8ea limit switches total for 4 actuators.

3.6.2 OUTPUT DEVICES

Table 6: Output Specification

OUTPUT	SPECIFICATION
	5/2 Double Solenoid Valve 4ea Valves are used to actuate the 4 actuators consequently. 12V DC signal from PLC will trigger the solenoid to energize the coil. Its contact will trigger.
	Double Acting Cylinder 4ea Actuators particularly A, B, C and D. The actuator will extend and retract when the solenoid valve that triggered open the air flow to actuator.

3.7 EVENT DIAGRAM

The PLC ladder logic diagram needs a sequence or timing diagram for ease in programming the PLC. The control of the system can be shown graphically. The timing diagram is significant for troubleshoot purpose and to expand the system by modification. Besides that, the equation for PLC programming can be simply derived from the timing diagram. The timing diagram is shown in Figure 11. It shows all the variables sequence that used such as the input signals, proximity sensors, output which are the actuators, holding relay, holding relay timer and counter.

Holding Relay (HR) and Holding Relay Timer (HRT) are the virtual relays that can be programmed in the PLC. The holding relay is not a hard relay with hard component but it is only exists in the program. The special function of it is the holding relay can acts as a real relay to utilize its coil and contact. The holding relay uses memory to store the conditions which need to assign different channel.

The timing diagram shows the sequence by using 4 actuators to sort 24 canned foods. The actuator A will operates 4 times extend and retract to sort for the first row of canned food. Then, actuator B will operates a time extend and retract to sort the first row into a box. The cycle is repeated 4 times to complete 1 layer of 12 canned foods. Each position of the cylinder either in extend or retract, it has to be delayed about 2 seconds.

Once completed the first layer, actuator C will retract to hold the box to be readied for second layer process. Furthermore, there is actuator D to push the completed box to the inventory. The initial condition for each actuators are in retract position when the system is stop or in rest condition.

Figure 9 shows the detail for inputs and outputs elements for the whole system. There are 2 limit switches particularly for each of the cylinders. Since the figure is in 2 dimensions drawing, the actuator C could not be drawn below than the cardboard box. However, the system still can operate following the sequence. Furthermore, Figure 10 shows the location of the proximity sensors to determine the presence of product and count the quantity.

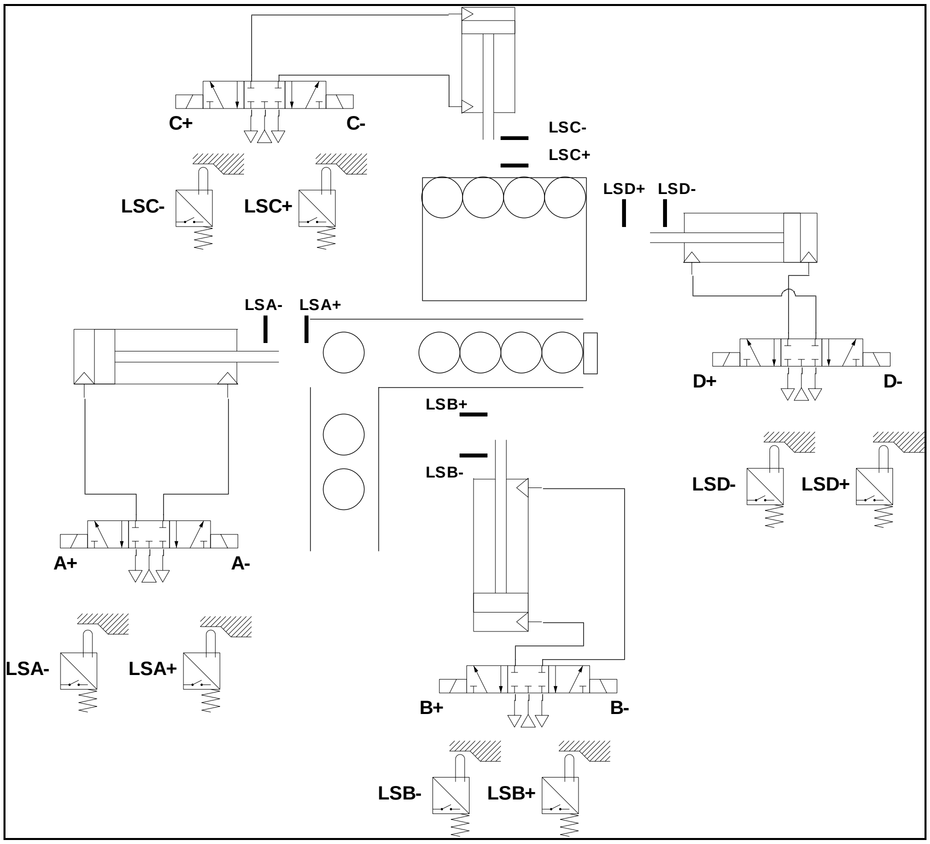


Figure 11: System Design

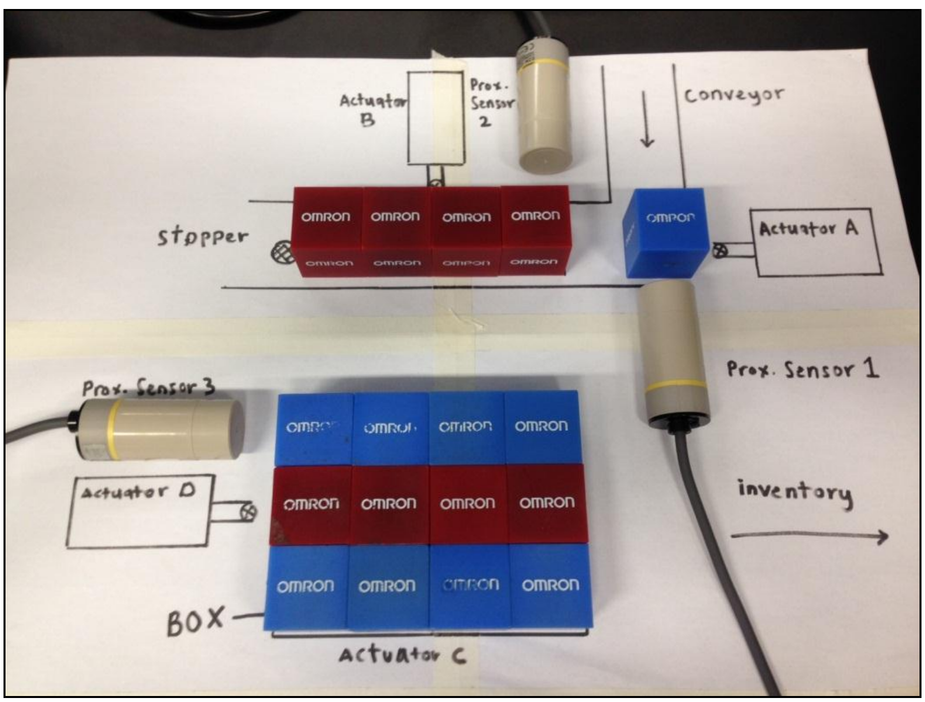


Figure 12: Sensors Position and System Illustration

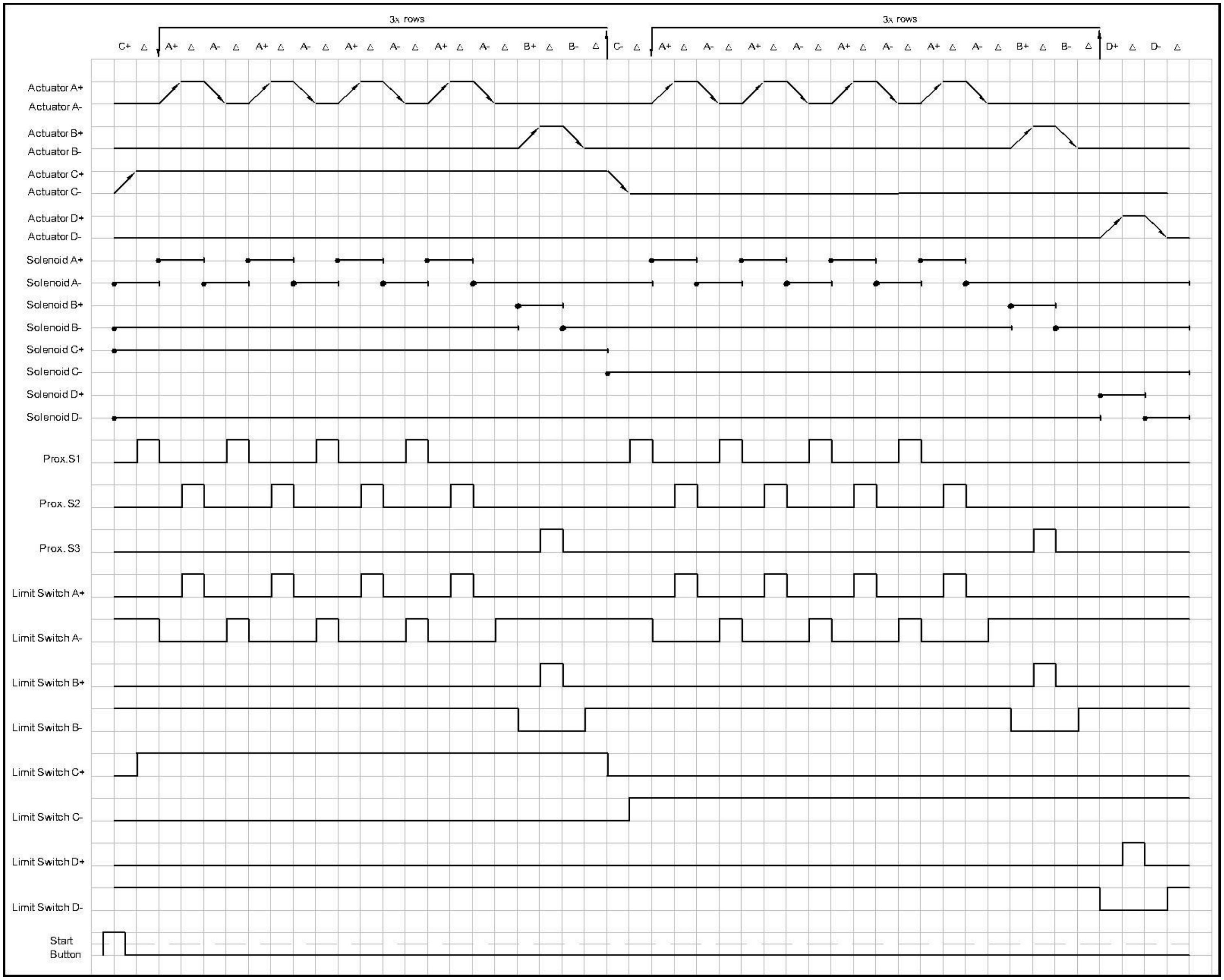


Figure 13: Timing Diagram (i)

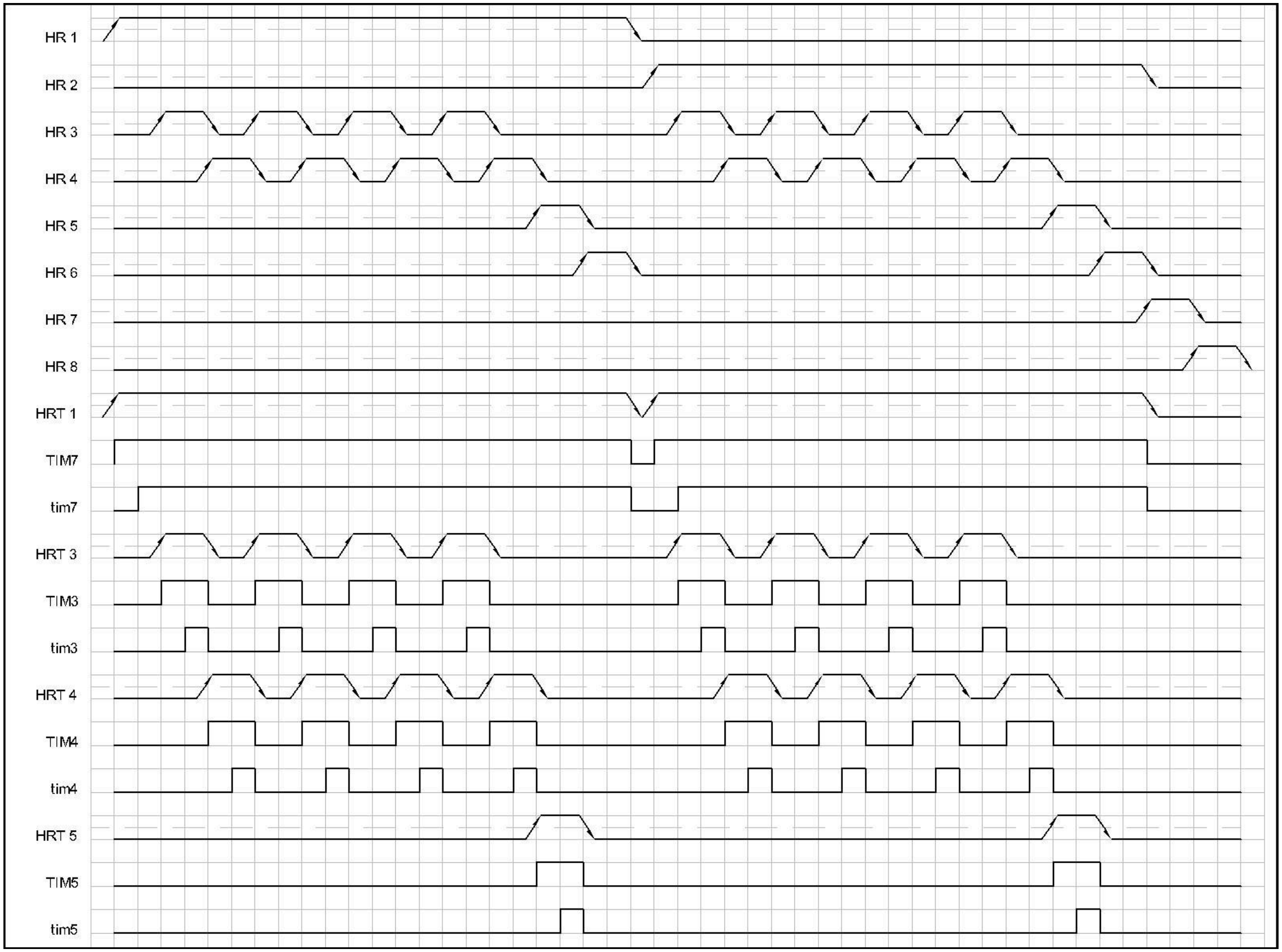


Figure 14: Timing Diagram (ii)

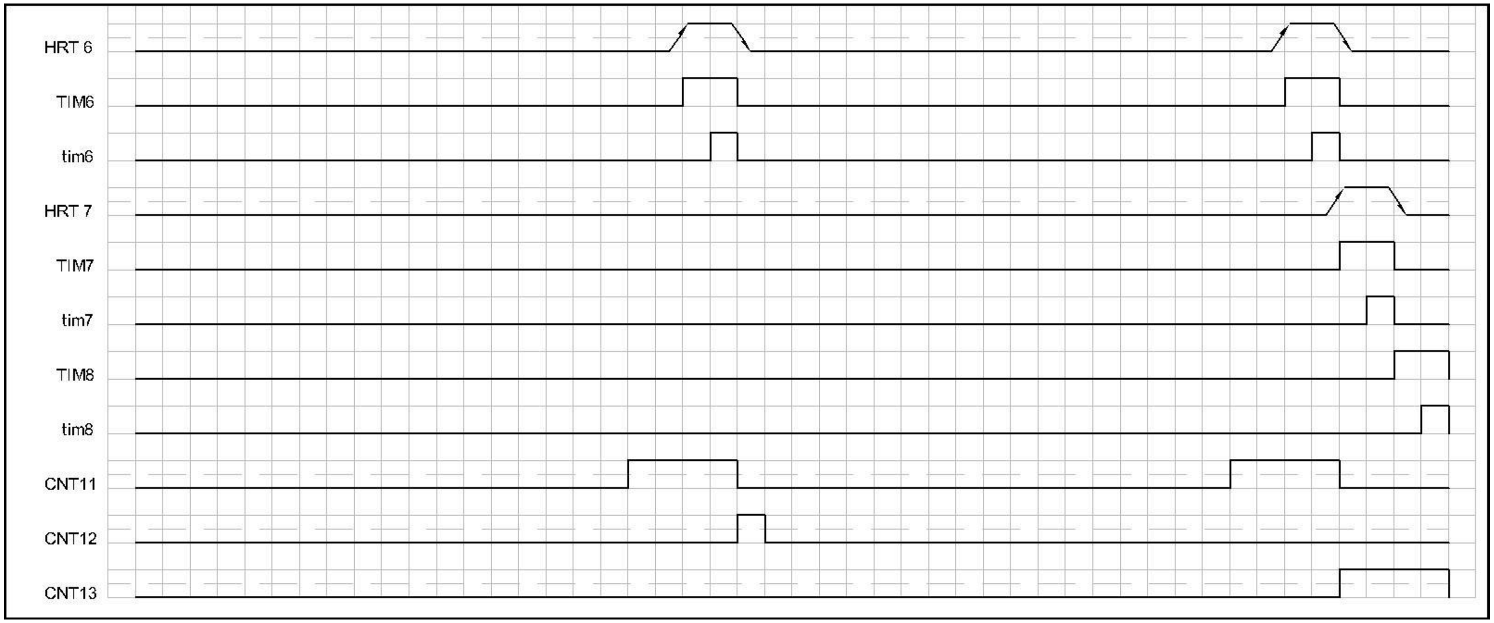


Figure 15: Timing Diagram (iii)

CHAPTER 4

RESULTS AND DISCUSSION

4.1 SIMULATION

4.1.1 ELECTROPNEUMATIC CIRCUIT

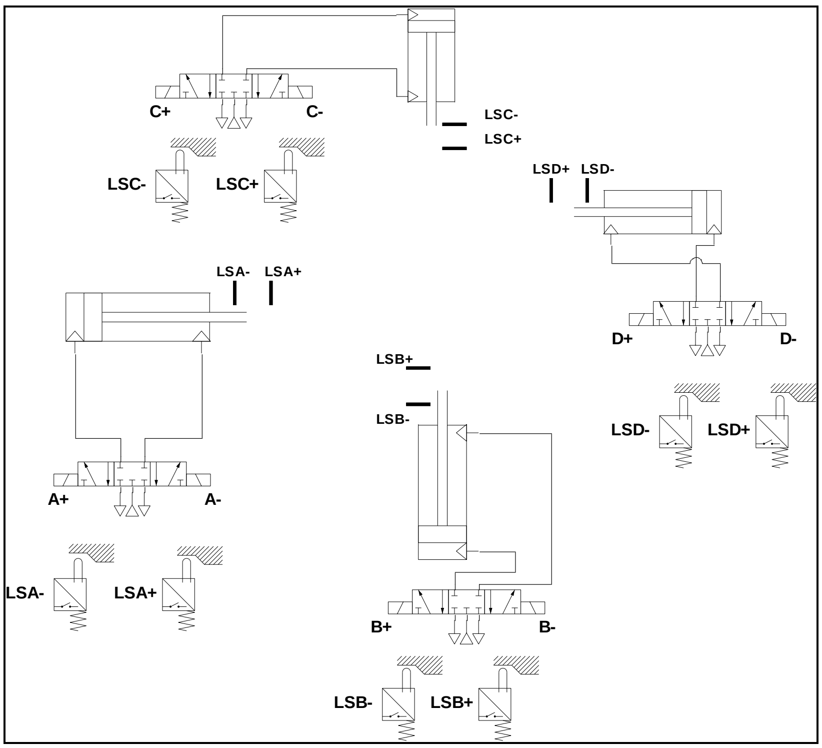


Figure 16: Pneumatic Circuit

Figure 11 shows the electropneumatic circuit consisting of 4 double acting cylinders and 4 5/3 way valves. The position of the cylinder is determined by 2 limit switches for each cylinder. Cylinder A is configured with LSA- limit switch for determining fully retract position, while the LSA+ limit switch for fully extend position. The configuration is also same for cylinder B, C and D particularly. The signal will activate the timer and sequence for next movement. Every position is delayed with 2 seconds timer.

Secondly, the valve is supplied with air flow from compressor. The downward triangle is the exhaust flow from the valve. There are solenoids to activate the both valves. The valve is triggered from PLC signal that programmed in the PLC board. Solenoid A+ is the trigger to extend cylinder A and solenoid A- is the trigger to retract cylinder A. The solenoid variables B also assigned with B+ to extend cylinder B and B- to retract cylinder B. The solenoid valves assignment similarly goes to cylinder C and cylinder D.

4.1.2 PLC INPUT OUTPUT PORTS DIAGRAM

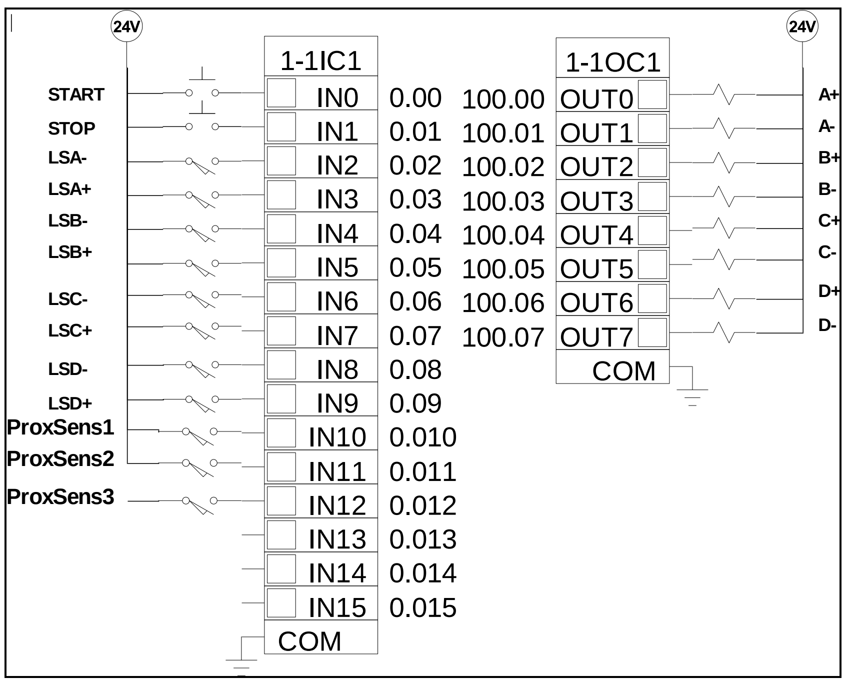


Figure 17: PLC to Input and Output Connection

Figure 12 shows the wiring connection between the PLC module with solenoids, sensors and switch buttons. The PLC module is sourced with 24 Volt Direct Current. 2 inputs are used which connect the START and STOP push buttons at INPUT0 and INPUT1. Another 8 inputs are used which connect the limit switches, LSA-, LSA+, LSB-, LSB+, LSC-, LSC+, LSD-, LSD+ to INPUT2, INPUT3, INPUT4 until INPUT9 accordingly.

The output module is connected with solenoid A+, A-, B+, B-, C+, C-, D+ and D- to OUTPUT0, OUTPUT1, OUTPUT2, and until OUTPUT7 particularly. Once the PLC output is triggered, it will energize the solenoid and activate the directional valves. The slots can be increase, thus available for the output which PLC is very reliable for any modification.

4.1.3 PLC MODULE - VIRTUAL HOLDING RELAY (MEMORY)

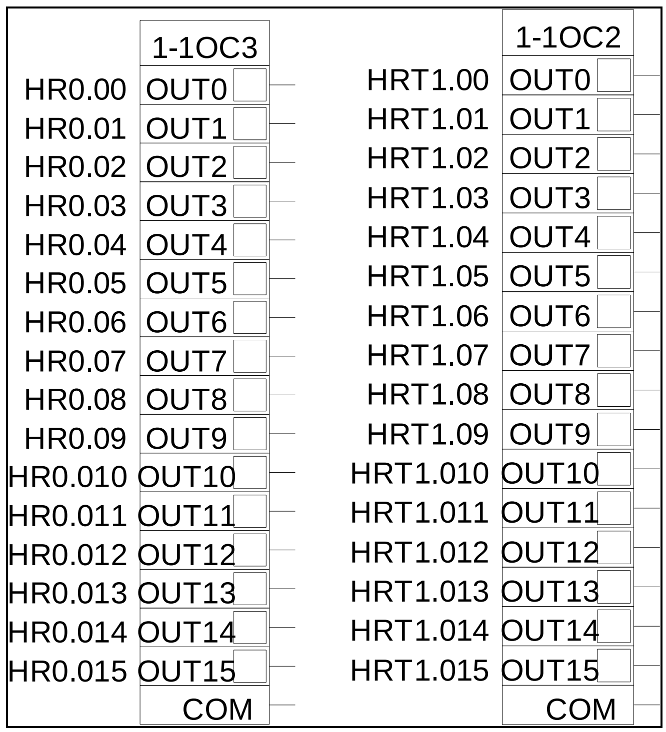


Figure 18: Holding Relay (memory)

PLC module is designed to capable in assigning virtual variables for the system. The variables are stored in memory for extra function such as Holding Relay, Timer and Counter. The variables are assigned with HR which is stands for Holding Relay and HRT for Holding Relay Timer. Signals process information is available and to create secondary variables needed in the program development such as variables HR1, HR2, and HR3, to HR15 in the figure. However, the variables needed are from HR0 to HR8 and HRT1 to HRT7.

Holding Relay (HR) is logic control which use for triggering output solenoid and determining the Holding Relay Timer (HRT) sequence. Besides that, HRT output is used to energize Timer and Counter for every sequence. For example, output HRT1 is used for TIMER1 (TIM1), HRT3 for TIM3, HRT4 for TIM4, HRT5 for TIM5, HRT6 for TIM6 and HRT7 for TIM7 consequently. There are light indicators at the PLC to indicate the output and timer that triggered.

4.2 BOOLEAN EXPRESSION AND LADDER DIAGRAM

Table 7: Symbol and Logic Expression in PLC

Symbol	Logic
+	OR
·	AND
—	INVERT

In ladder logic diagram, logic functions such as INVERT, OR and AND logic gates are used to control the variables. INVERT logic is to invert the input signal from 0 to 1 and oppositely for 1 to 0 signal. Besides that, AND logic is connecting contacts which is in series while OR logic is connecting contacts in parallel. These functions are very reliable if to connect more than 2 contacts either in series or parallel. Thus, the functions can ease in programming and reduce the combination for the PLC.

4.2.1 LATCHING CIRCUIT

VARIABLE (OUTPUT)	BOOLEAN EXPRESSION	LADDER DIAGRAM
HR0.00 (LATCH)	LATCH = [START + LATCH] . $\overline{STOP}$	

First latching circuit is programmed to act as emergency switch button. It shows from the ladder diagram that the START button to energize the coil output HR0.00 which address HR0.00 and latches its contact of OR logic with START button. STOP button is connected in between the input and output which use to disconnect the flow. STOP button is in normally closed contact which express as INVERT logic. The signal '1' given from the input STOP will convert to '0' signal. Thus, all the operation will stop when the STOP button is pressed. HR0.00 is latched in front of each rung to stop current process.

4.2.2 SOLENOID A, B, C and D

PLC ladder logic will control the operation by executing the program. Solenoids from pneumatic valves are triggered by output signal from PLC. Thus, coil in PLC program is assigned to each solenoid A, B, C and D. Furthermore, valves that been used are double solenoid valve and hence 2 coils were needed to activate left and right solenoid. Outputs are programmed as per sequence. The solenoid will energize when 24V DC from output port PLC is signaling to solenoid valve.

Figure 19: Output Port of 8 Solenoids

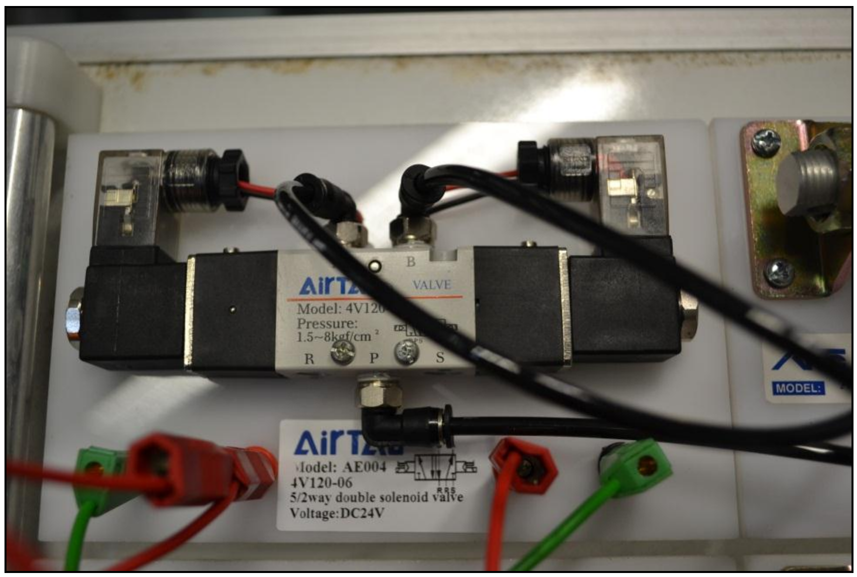
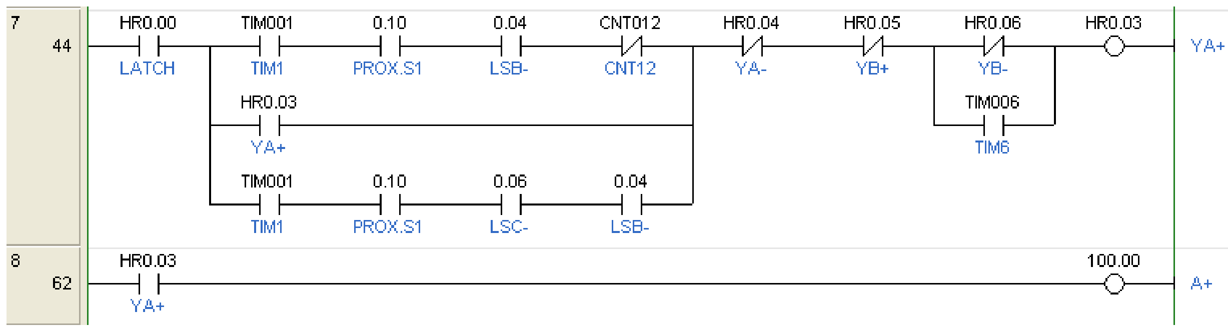


Figure 20: 5/2 Double Solenoid Valve

Figure 18 shows that there are 2 output green wires from PLC output ports connected to Double Solenoid Valve. Particularly one output from PLC is connected for one solenoid. The connection is consequently similar to other valves which are valve B, C and D. Once the solenoid is triggered, the valve will activate and open the air flow to the actuator for output mechanism. Besides that, red wires are the voltage supply for the valve.

4.2.2.1 SOLENOID A+

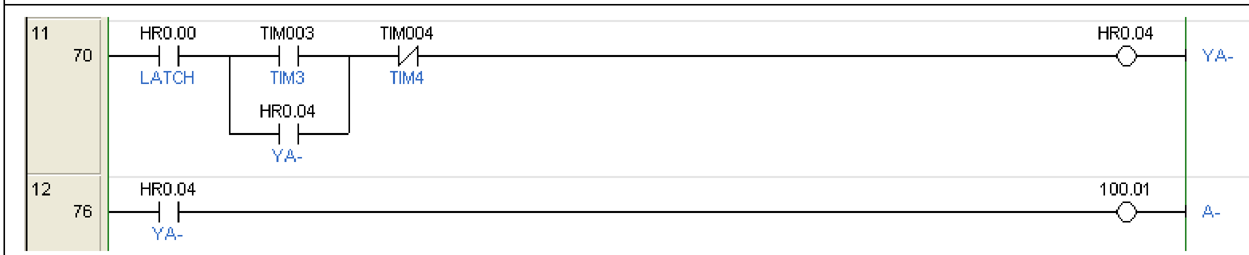
LADDER DIAGRAM



VARIABLE (OUTPUT)	BOOLEAN EXPRESSION
Relay Actuator A+ YA+ (HR0.03)	Rung 7: YA+ = [[TIM1 . PROXS1 . LSB- . $\overline{CNT12}$] + [TIM1 . PROXS1 . LSB- . LSC-] + YA+] . $\overline{YA-}$. $\overline{YB+}$. [$\overline{YB-}$ + TIM6]]
Actuator A Extend A+ (100.00)	Rung 8: A+ = YA+

4.2.2.2 SOLENOID A-

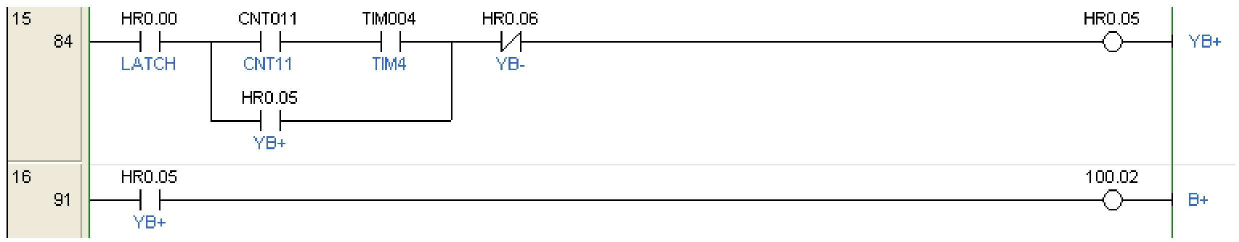
LADDER DIAGRAM



VARIABLE (OUTPUT)	BOOLEAN EXPRESSION
Relay Actuator A- YA- (HR0.04)	Rung 11: YA- = [LATCH . [(TIM3) + (YA-)] . $\overline{TIM4}$]
Actuator A Retract A- (100.01)	Rung 12: A- = YA-

4.2.2.3 SOLENOID B+

LADDER DIAGRAM



VARIABLE (OUTPUT)	BOOLEAN EXPRESSION
Relay Actuator B+ YB+ (HR0.05)	Rung 15: YB+ = LATCH . [[CNT11 . TIM4] + HR0.05] . $\overline{YB-}$]
Actuator B Extend B+ (100.02)	Rung 16: B+ = YB+

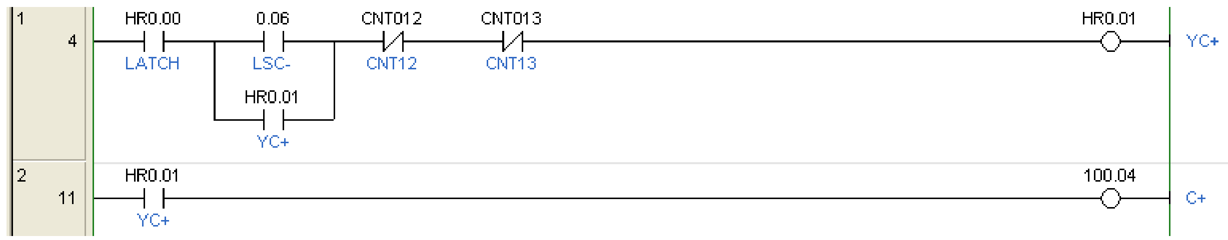
4.2.2.4 SOLENOID B-

LADDER DIAGRAM

VARIABLE (OUTPUT)	BOOLEAN EXPRESSION
Relay Actuator B- YB- (HR0.06)	Rung 19: YB- = [LATCH . [(TIM5) + (YB-)] . $\overline{TIM6}$]
Actuator B Retract B- (100.03)	Rung 20: B- = YB-

4.2.2.5 SOLENOID C+

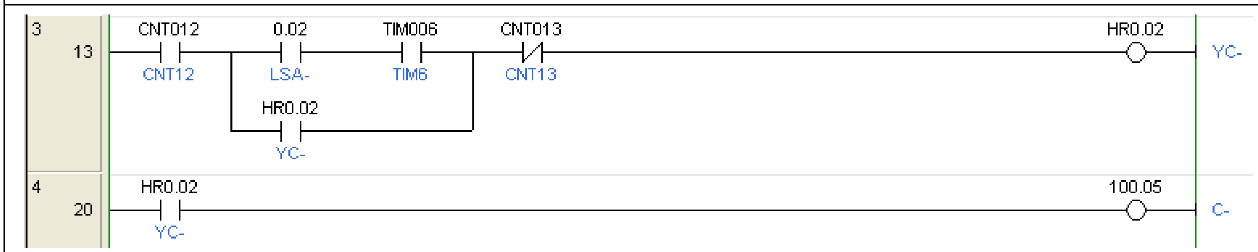
LADDER DIAGRAM



VARIABLE (OUTPUT)	BOOLEAN EXPRESSION
Relay Actuator C+ YC+ (HR0.01)	Rung 1: YC+ = LATCH . [$\overline{LSC -}$) + YC+] . $\overline{CNT12}$. $\overline{CNT13}$
Actuator C Extend C+ (100.04)	Rung 2: C+ = YC+

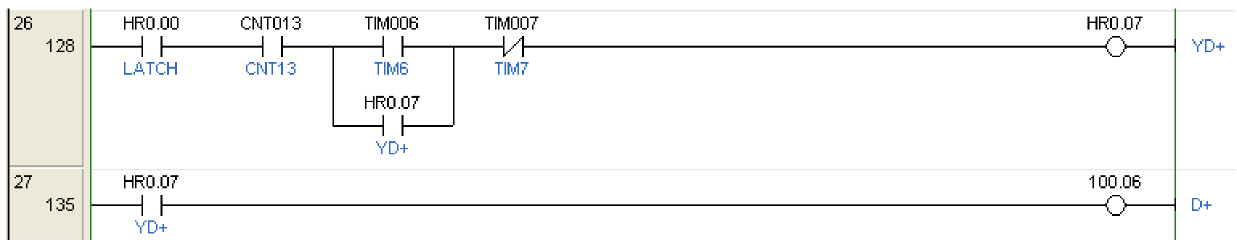
4.2.2.6 SOLENOID C-

LADDER DIAGRAM



VARIABLE (OUTPUT)	BOOLEAN EXPRESSION
Relay Actuator C- YC- (HR0.02)	Rung 3: YC- = CNT12 . [[LSA- . TIM6] . YC-] . $\overline{CNT13}$
Actuator C Retract C- (100.05)	Rung 4: C- = YC-

4.2.2.7 SOLENOID D+

LADDER DIAGRAM	
	
VARIABLE (OUTPUT)	**BOOLEAN EXPRESSION**
Relay Actuator D+ YD+ (HR0.07)	Rung 26: YD+ = LATCH **.** CNT13 **.** [TIM6 + YD+] **.** $\overline{TIM7}$
Actuator D Extend D+ (100.06)	Rung 27: D+ = YD+

4.2.2.8 SOLENOID D-

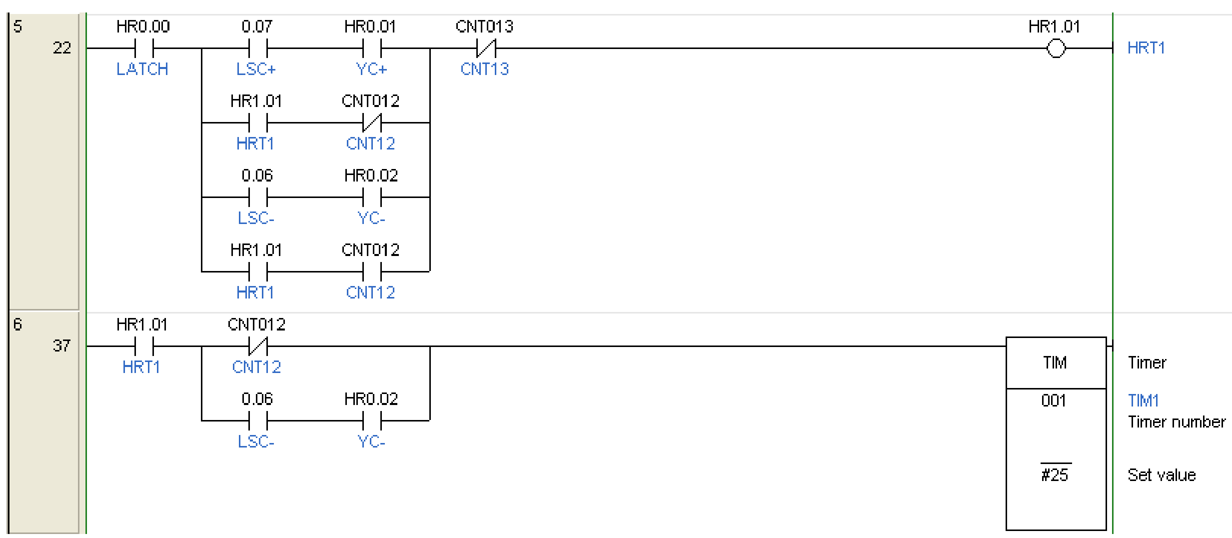
LADDER DIAGRAM	
	
VARIABLE (OUTPUT)	**BOOLEAN EXPRESSION**
Relay Actuator D- YD- (HR0.08)	Rung 30: YD- = LATCH **.** [(TIM7) + (YD-)] **.** $\overline{TIM8}$
Actuator D Retract D- (100.07)	Rung 31: D- = YD-

4.2.3 HOLDING RELAY TIMER (HRT)

Holding Relay Timer (HRT) is another virtual relay that assigned as memory to hold timer function. Thus, HRT1 is relay to hold timer 1 (TIM1), HRT3 for timer 3 (TIM3), HRT4 for timer 4 (TIM4), HRT5 for timer 5 (TIM5), HRT6 for timer 6 (TIM6), HRT7 for timer 7 and last for timer 8 (TIM8). TIM1 is to delay Actuator C in extend and retract position by 25 seconds. Besides that, TIM3 and TIM4 are to delay Actuator A in extend and retract position particularly by 1 second. Next, TIM5 is assigned for Actuator B in extend position and TIM6 for its retract position. Lastly, TIM7 and TIM8 particularly delay function for Actuator D in extend and retract position.

4.2.3.1 HOLDING RELAY TIMER 1

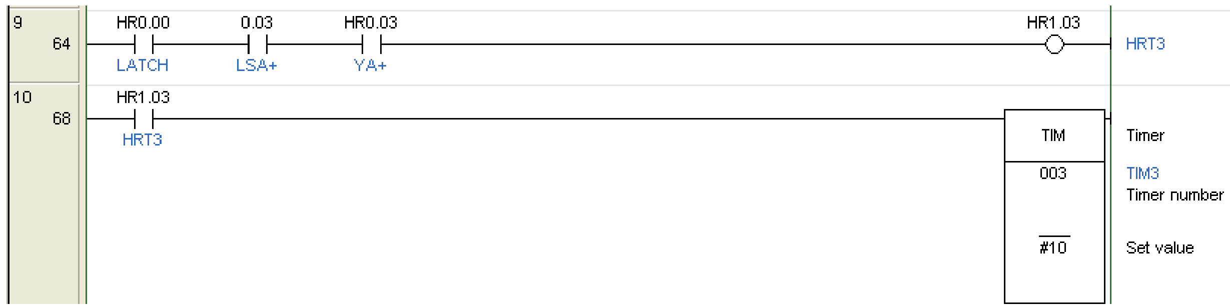
LADDER DIAGRAM



VARIABLE (OUTPUT)	BOOLEAN EXPRESSION
Relay Timer HRT1 (HR1.01)	Rung 5: HRT1 = LATCH . [[(LSC+) . (YC+)] + [(HRT1) . ($\overline{CNT12}$)] + [(LSC-) . (YC-)] + [(HRT1) . (CNT12)]] . $\overline{CNT13}$
2.5 seconds timer TIM1 (TIM001)	Rung 6: TIM1 = HRT1 . [$\overline{CNT12}$ + [(LSC-) . (YC-)]]

4.2.3.2 HOLDING RELAY TIMER 3

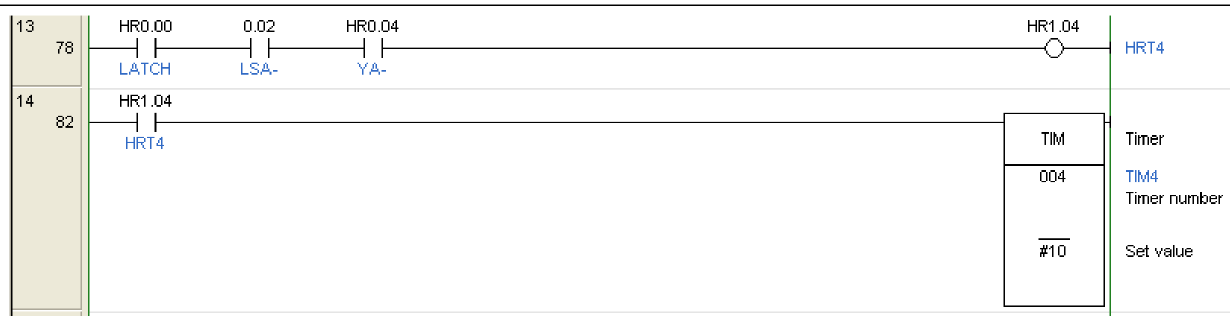
LADDER DIAGRAM



VARIABLE (OUTPUT)	BOOLEAN EXPRESSION
Relay Timer HRT3 (HR1.03)	Rung 9: HRT3 = LATCH . LSA+ . YA+
1 second timer TIM3 (TIM003)	Rung 10: TIM3 = HRT3

4.2.3.3 HOLDING RELAY TIMER 4

LADDER DIAGRAM



VARIABLE (OUTPUT)	BOOLEAN EXPRESSION
Relay Timer HRT4 (HR1.04)	Rung 13: HRT4 = LATCH . LSA- . YA-
1 second timer TIM4 (TIM004)	Rung 14: TIM4 = HRT4

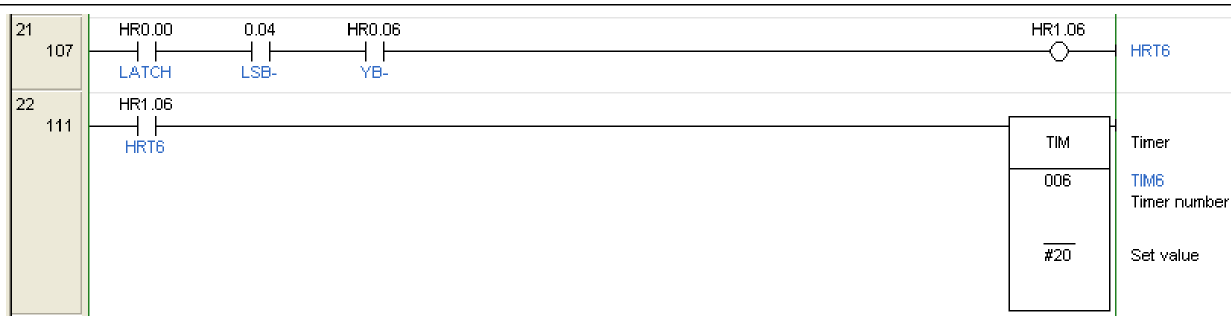
4.2.3.4 HOLDING RELAY TIMER 5

LADDER DIAGRAM

VARIABLE (OUTPUT)	BOOLEAN EXPRESSION
Relay Timer HRT5 (HR1.05)	Rung 17: HRT5 = LATCH **.** LSB+ **.** YB+
2 seconds timer TIM5 (TIM005)	Rung 18: TIM5 = HRT5

4.2.3.5 HOLDING RELAY TIMER 6

LADDER DIAGRAM



VARIABLE (OUTPUT)	BOOLEAN EXPRESSION
Relay Timer HRT6 (HR1.06)	Rung 21: HRT6 = TIM7 **.** LSB- **.** YB-
2 seconds timer TIM6 (TIM006)	Rung 22: TIM6 = HRT6

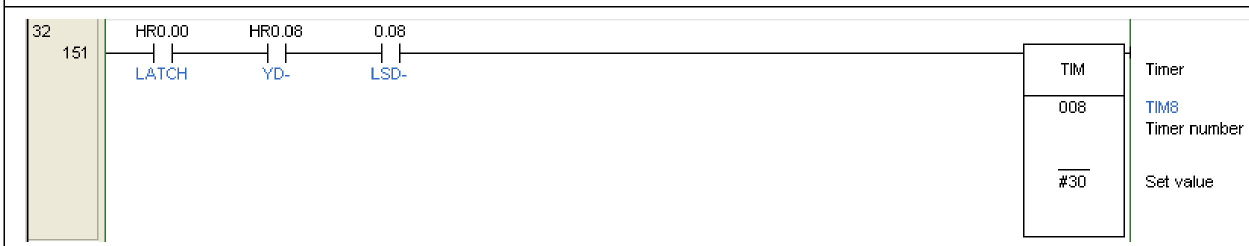
4.2.3.6 HOLDING RELAY TIMER 7

LADDER DIAGRAM

VARIABLE (OUTPUT)	BOOLEAN EXPRESSION
Relay Timer HRT7 (HR1.07)	Rung 28: HRT7 = LATCH **.** YD+ **.** LSD-
3 seconds timer TIM7 (TIM007)	Rung 29: TIM8 = HRT7

4.2.3.7 TIMER 8

LADDER DIAGRAM



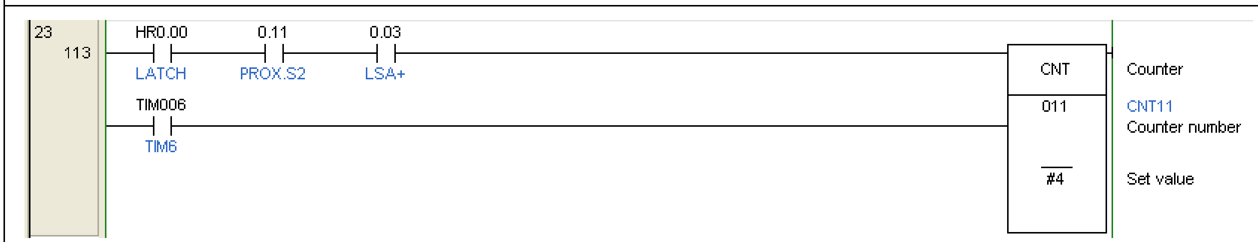
VARIABLE (OUTPUT)	BOOLEAN EXPRESSION
Relay Timer HRT6 (HR1.06)	Rung 31: D- = YD-
2 seconds timer TIM4 (TIM004)	Rung 32: TIM8 = HR0.00 **.** YD- **.** LSD-

4.2.4 COUNTER

COUNTER is special function that can be programmed in PLC ladder logic. Counter is used to count repetition process, looping input condition and checking quantity. Since counter has same memory with timer function, the address could not be the same. Thus, the address should be in increment order. CNT11 (CNT011) is used to perform the 4 repetition in sorting 4 cans food in one row. CNT11 is count when limit switch A+ triggered and proximity sensor S1 detect the canned food pass through. The process is Actuator A in extend position for sorting 4 cans. Then, CNT11 will be triggered to actuate Actuator B. CNT12 (CNT012) is used to perform the 3 repetition detecting by proximity sensor S3 in sorting 3 rows of canned food which equals to 12 cans. Lastly, CNT13 (CNT013) and proximity sensor S3 will proceed to count another 3 rows for the 2nd layer for stacking process.

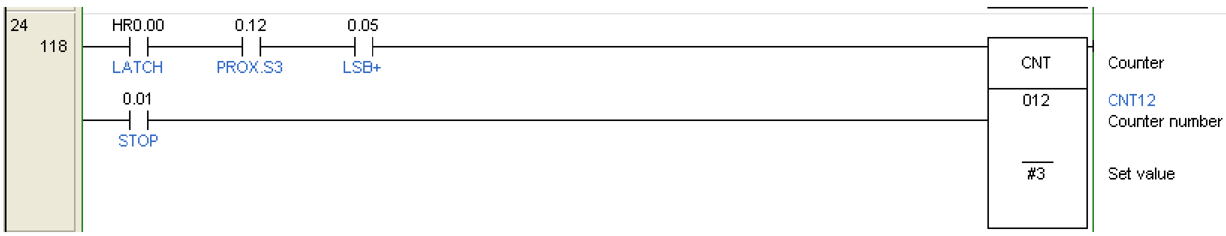
COUNTER has an extra input to reset the counter set values. When input for the reset is triggered, the counter will reset to initial or '0' even though the input signal to count is deenergize.

4.2.4.1 COUNTER 1

<table>
<tr><th colspan="2">LADDER DIAGRAM</th></tr>
<tr><td colspan="2">
</td></tr>
<tr><th>VARIABLE (OUTPUT)</th><th>BOOLEAN EXPRESSION</th></tr>
<tr><td>Relay Counter
CNT11 (CNT011)</td><td>Rung 23:
CNT11 = LATCH . PROXS2 . LSA+</td></tr>
<tr><td>Counter Reset
RESET (CNT011)</td><td>Rung 23:
RESET = TIM6</td></tr>
</table>

4.2.4.2 COUNTER 2

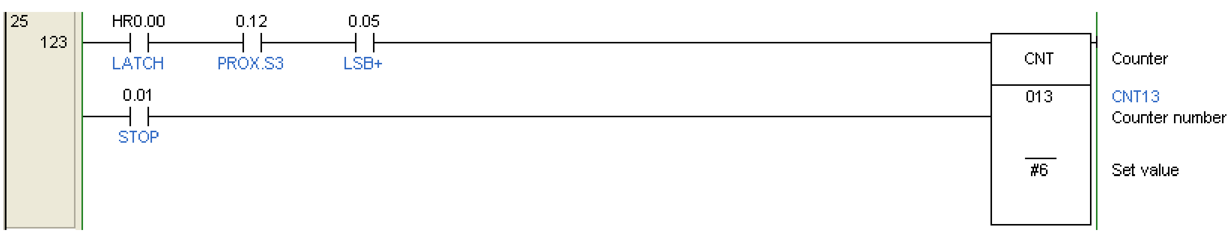
LADDER DIAGRAM



VARIABLE (OUTPUT)	BOOLEAN EXPRESSION
Relay Counter CNT12 (CNT012)	Rung 24: CNT12 = LATCH . PROXS3 . LSB+
Counter Reset RESET (CNT012)	Rung 24: RESET = STOP

4.2.4.3 COUNTER 3

LADDER DIAGRAM



VARIABLE (OUTPUT)	BOOLEAN EXPRESSION
Relay Counter CNT13 (CNT013)	Rung 25: CNT13 = LATCH . PROXS3 . LSB+
Counter Reset RESET (CNT013)	Rung 25: RESET = STOP

4.3 ELECTRO PNEUMATIC DIAGRAM

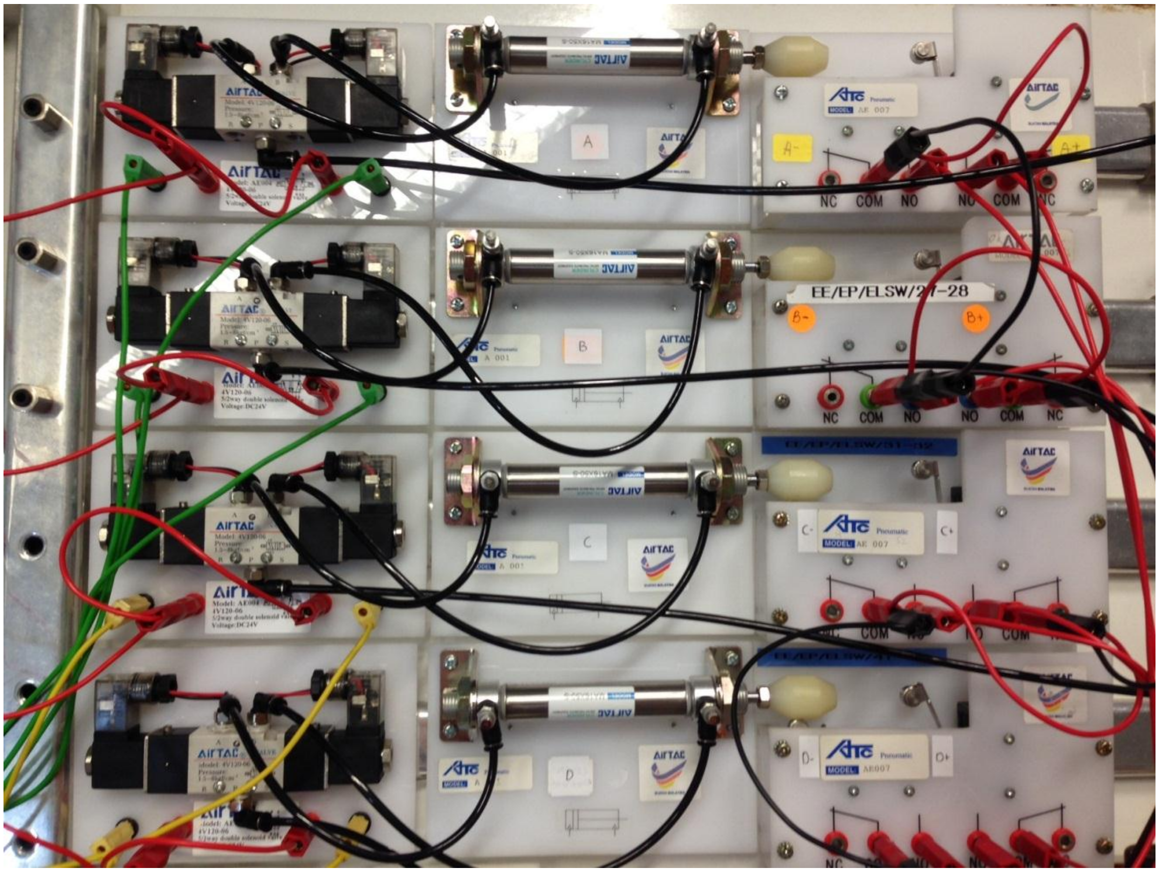


Figure 21: Full Electropneumatic System

The figure 21 above shows the complete diagram for electro pneumatic circuit. The system consist of 4 actuators which are double acting cylinder, 8 limit switches which 2 limit switches for each cylinder, 4 5/2 way directional valve which energize by 2 solenoids at all valves triggered from PLC. PLC module is programmed with secondary variables which is the virtual output. The variables are Holding Relay (HR) and Holding Relay Timer (HRT). HRT1, is the timer delay when cylinder C in extend position C+ and retract position C-. HRT3 is the timer delays when cylinder A in extends position A+ and HRT4 is the timer delay for retract position A-. HRT5 and HRT6 are used as timer delay for cylinder B in extend and retract position. Lastly, HRT7 for delaying cylinder D when in extend position and TIM8 delay in retract position. TIM8 does not require HRT because the process ends which stop and not triggering any output.

CNT11 will count the pass through canned food which forms a row when Actuator A extend and loop to repeat the sequence for 4 times. Then, the looping process will count until 3 times when proximity sensor S3 detects the canned food for 12 cans which CNT12 (CNT012) function is used. After completed 1 layer of canned food which amount of 12 cans, Actuator C will retract and the process will repeat. CNT13 (CNT013) will count 3 rows of canned food which similar function with CNT12. When CNT13 energize, the completed 24 cans of canned food will be pushed to the inventory by Actuator D.

4.4 DISCUSSION

The testing on the PLC and pneumatic system is constructed at the lab. The evaluation on the demo system is analyzed on the reliability of the system and packaging speed control. The duration to complete 24 canned foods in a box is about 1.30 minutes. Moreover, the mechanism also will be varies to increase the performance and reduce the time period to complete the cycle.

Besides that, the analysis also takes place after simplifying of the ladder logic circuit. The timer usage has been reduced instead of using 10 timer HRT1 to HRT10 for each cylinder position, the process been loop by using same timer which its relates the counter and timer functions. However, the reliability would be decrease because the timer will be fix for entire operation compared to 10 timers can be different delay. Furthermore, the delay is 1 second for actuator A sequence, 2 seconds for Actuator B and 3 seconds for Actuator D which can be reduces to the lowest time to improve the operation speed but the safety precaution should be prepared first.

On the other hand, the operation only for two layers of sorting canned food. Thus, 4 cylinders have been connected to sort for the upper layer of canned food. The modification on the system to connect with conveyor can be made for fully function system. However, conveyor only require power switch button. This addition is use for canned food feeder and to inventory.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

A structured method of developing the routines for a packing process is developed. The approach used in this work provides the proper documentation of the program. The boolean expression derived from the timing diagram were documented and would allow easy modification based on requirements.

The demo of the automated packaging control system is successfully designed and the objectives are acheved using electropneumatic elements and controlled by programmable logic control (PLC). The system is highly reliable since the modification of the sequence can be adjust by only reprogram the PLC ladder logic diagram rather than rewire the circuit. PLC is flexible system as it has special functions and capabilities such as varying the value of timer and counter. Thus, PLC is suitable for a fast response of process flow.

The automation system for packaging control is significant to increase the performance of production system in industry. Furthermore, the purpose of packaging is to cover the canned food and protect for smooth and effective transportation and storing with minimal damages to all places. When the packaging process is done accurately, it will also create a good image of the product and the industry. A meaningful automation with proper system lead to economical aspect which can reduce cost for example the cost for labor force and local material for packaging.

5.2 RECOMMENDATION AND FUTURE WORK

This project completed for a demo system mimicking the real system. Thus, real system can be constructed by performing further design in larger scope of study. Furthermore, a fully function prototype can be constructed to prove the marketability of the automated packaging system for small medium industry (SMI). Hence, the cost estimation, marketing value of the system and parts assembly can be proceeded to have the real system on packaging.

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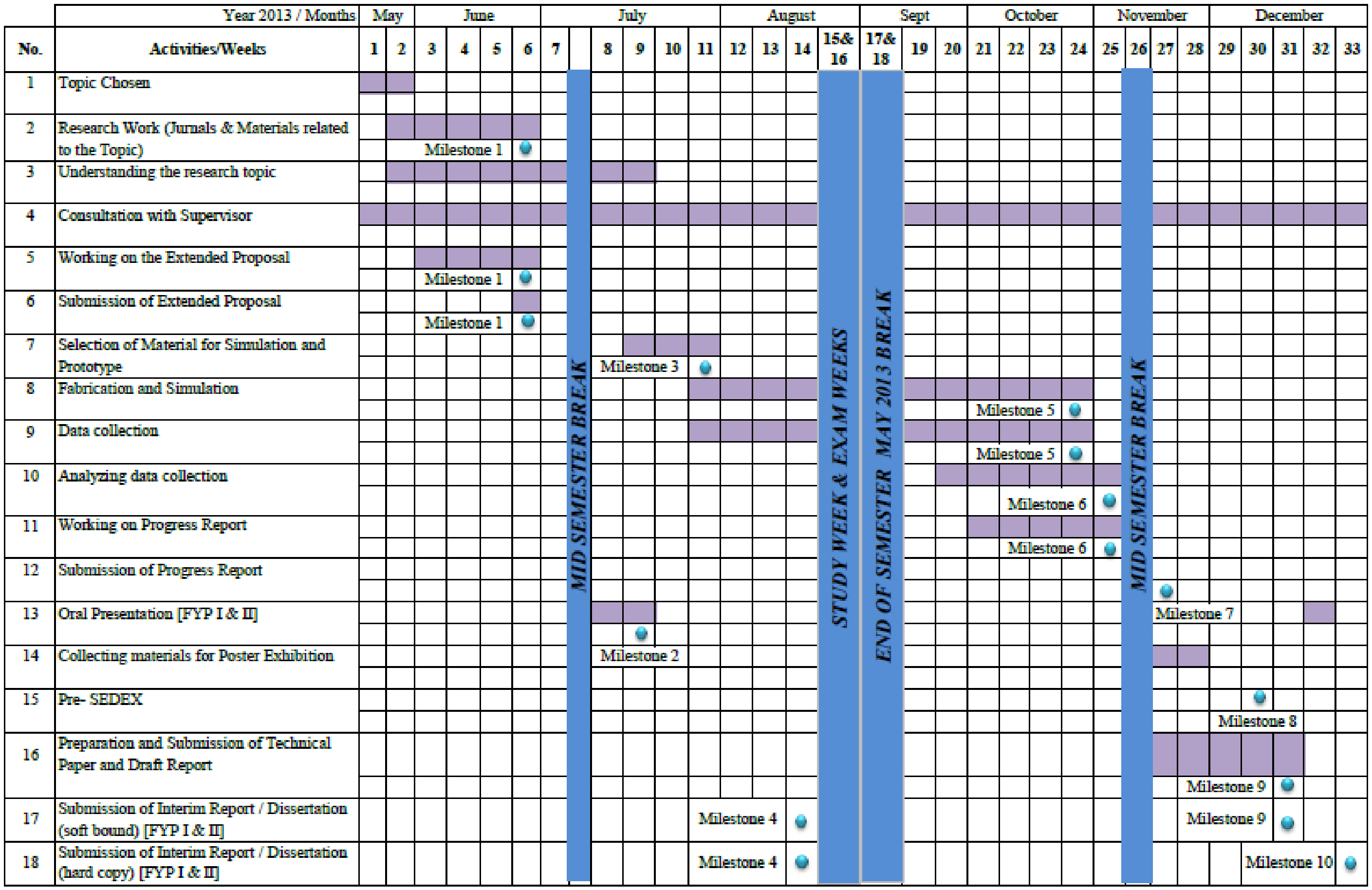
APPENDICES

APPENDIX A – GANTT CHART

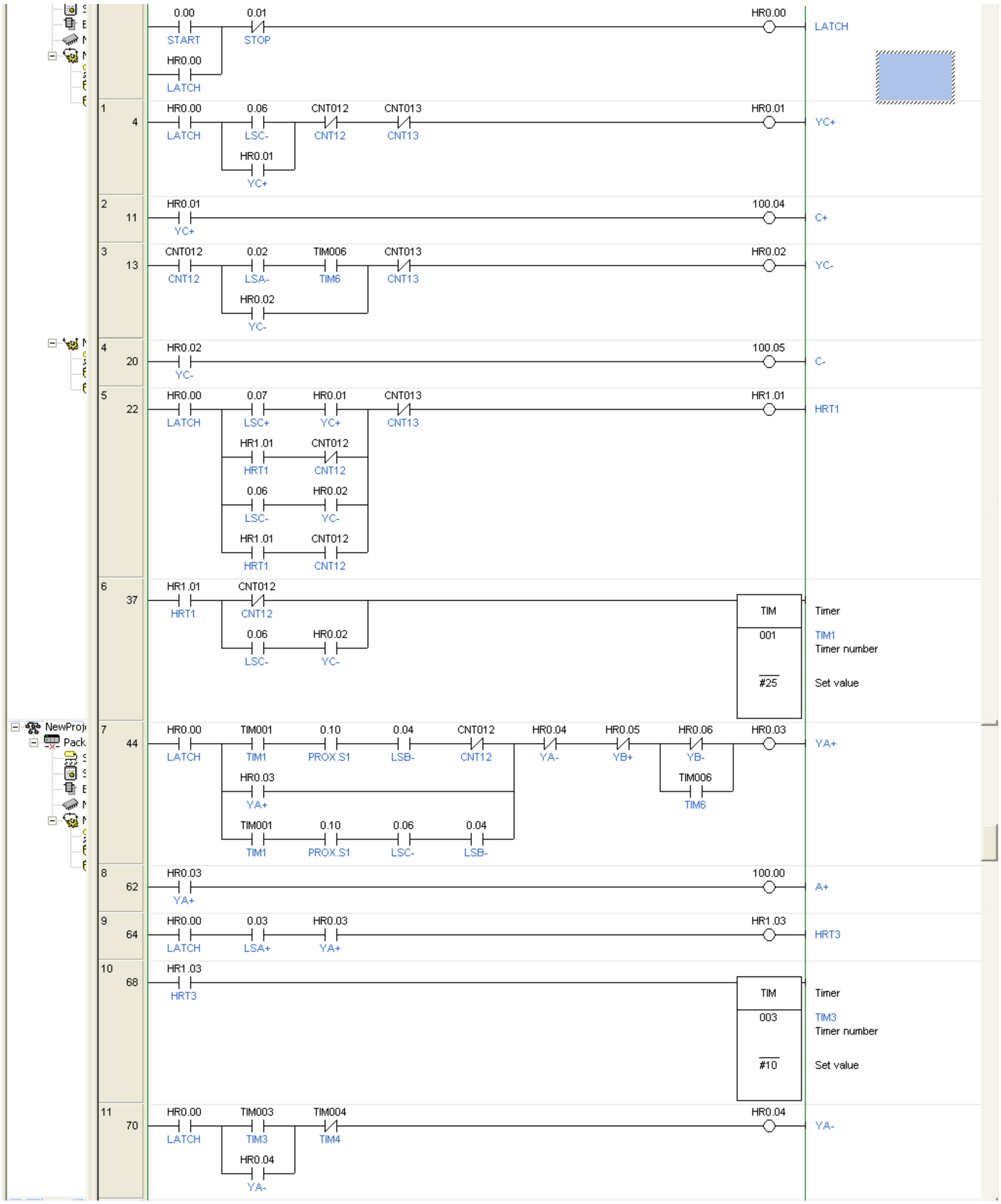


Note

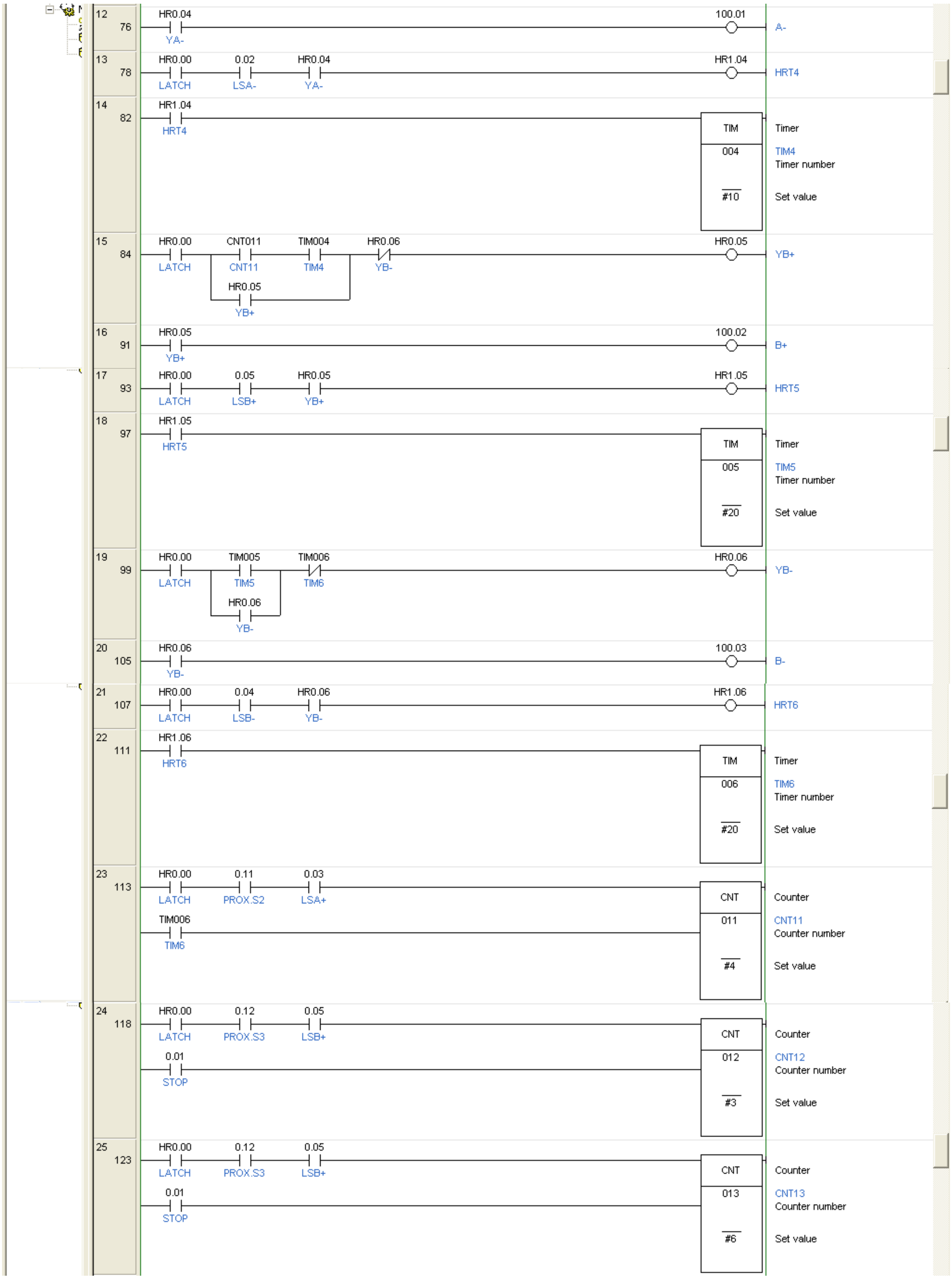
1	Milestone 1: Completion of Extended Proposal	28th June 2013	6	Milestone 6: Finalize Result	8th November 2013
2	Milestone 2: Completion of Proposal Defense	12th July 2013	7	Milestone 7: Completion of Progress Report	22nd November 2013
3	Milestone 3: Completion of First Design	3rd August 2013	8	Milestone 8: SEDEX	11th December 2013
4	Milestone 4: Completion of Interim Report FYP 1	24th August 2013	9	Milestone 9: Completion of Draft Report	20th December 2013
5	Milestone 5: Completion of Prototype	31st October 2013	10	Milestone 10: Completion of Final Report	27th December 2013

APPENDIX B – FULL PLC PROGRAM

Rung 0 to Rung 11



Rung 12 to Rung 25



Rung 26 to Rung 33 and END