Wall Climbing Robot

by

Mazhar Azrin bin Jamaludin
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Universiti Teknologi PETRONAS
Bandar Seri Iskandar
31750 Tronoh
Perak Darul Ridzuan

CERTIFICATION OF APPROVAL

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Mazhar Azrin Bin Jamaludin

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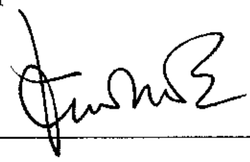

A.P DR. Mohd Noh Bin Karsiti

(Project Supervisor)

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK

December 2008

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.

Mazhar Azrin Bin Jamaludin

ABSTRACT

This report basically discusses the preliminary research done and basic understanding of the chosen topic, which is Wall Climbing Robots. The objective of this project is to develop of robot manipulator capable of ascending glass wall to do cleaning duties. The operation of the wall climbing robot in this project will be based on the pneumatic concept that is the suction of air to make robot can move along the vertical glass. This project will require a program using Programmable Logic Controller (PLC) to be the controller to its movement. The PLC ladder program will execute a sequence automatically according to the pre-defined sequence of robot motion.

ACKNOWLEDGMENTS

My gratitude to Allah S.W.T for His blessing towards the completion of this Final Year Project.

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2. Mr Azhar b. Zainal Abidin

3. EE Final Year Project Committee

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LIST OF FIGURES

LIST OF TABLES

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Both automation and robots are two closely related technologies that are connected with the use and control of production operation. A robot can be defined as a machine that consists of joined links. Programmable controller and precision actuators can be used to articulate these joined links to desired position so that they can perform a variety of tasks. Robots are available in a form of simple devices to very complex and intelligent system by virtue of added sensors, computers and special features. There are several hundred types and models of robots, which are classified by their intended application. This includes industrial, laboratory, mobile, military, security, service, hobby, home and personal robots. These robots come in a wide range of shapes, sizes , speed, load capacities and other characteristics. The robot would have wide application in the industry. This includes the maintenance works, delivery and wall painting. Since the main function of this robot is to do the climbing job, the stability reliability and durability analysis of this robot is of main concern.

In this project , the climbing robot uses pneumatic concept and controlled by Programmable Logic Controller (PLC). This project is divided into two part, those are the software development and the hardware implementation. The PLC program being developed is used to control the movement of the robot. The movement of the robot is based on the pneumatic concept whereby pneumatic components would also be the basic constituents of the robot structure.

Specifically , an industrial robot has been described by the International Standards Organization (ISO) as follows:

" A machine formed by a mechanism, including several degrees of freedom, often having the appearance of one or several arms ending in a wrist capable of holding a tool, a work piece, or an inspection device. In particular, its control unit must use a memorizing device and it may sometimes use sensing or adaptation appliances to take into account environment and circumstances. These multipurpose machines are generally designed to carry out a repetitive function and can be adapted to other function.' (James G. Keramas, 1999)

The robot to be designed in this project is a climbing robot and could be classified as a service robot. Particularly, this project is regarding on the design and implementation of a climbing robot by mean of programmable logic controller (PLC) and electro-pneumatic system. Nowadays, there are many esearches and projects conducted on climbing robot. Therefore, many types of climbing robot existed in today's world like the wall climbing, surf climbing , space elevator and rope climbing robots. These robots, which are available in various sizes and shapes, were designed to do various tasks like the wall inspection , bridges inspection, painting as well as space elevating. The robots make use of various kinds of concept and their structures were built using motors, servo controller , microchip and sensors. Climbing robots developed today are like the Gecko Wall Climbing Robot, Quadruped Wall Climbing Robot Ninja 1 and Ninja 2, ROMA (Multifunctional autonomous self – supported climbing robot), Space Elevator Ribbon Climbing Robot, Robosense (Bridges Inspection Robot), Sloth (Rope Climbing Robot) and SURFY (Surface Climbing Robot).

1.2 Problem Statement

Cleaning building glass job sometimes involves patching up work like at the top of a tower, building or pole. This works usually need man to climb up the tower or pole in order to the cleaning job. This works are dangerous and exposed the person to the risk of falling down. Therefore, the idea of designing this robot exists from observation of this situation. Intelligently designed, this robot might be the solution to eliminate the need of the manpower to do the climbing job.

The idea of this project also comes from the fact that the programmable logic controller (PLC) has wide application in automated control system. The applicability of the controller to be integrated with the electro-pneumatic system is also true. Therefore, this give the idea of building the climbing robot by means of this two subjects.

1.3 Objectives and Scope of Works

The objectives of this project are as follow:

(a) To design a wall climbing robot capable of ascending glass to do cleaning duties.
(b) To implement the hardware for this robot that used pneumatic components as the basic constituents.
(c) To design a PLC program as the controller for the operation of the robot.
(d) To build the prototype of the robot that could show the operation concept of the robot.

This Project involves two parts, which are the creation of the PLC ladder program and the hardware implementation of the robot. In the first part of the project, the student is required to construct a basic ladder program using window based programming software to show the fundamental concept of the robot movement. The concept has to be shown by integrating the PLC to the electropneumatic system and using the on board pneumatic components to represent the robot parts. The second stage of the project involves defining the robot structure, preparing detail design, locating the components and building the prototype. The prototype to be constructed should at least showing the fundamental principle of the robot movement. The robot design subjected to changes for future improvement of its stability, reliability and durability.

TABLE OF CONTENTS

CHAPTER 2

LITERATURE REVIEW

2.1 Programmable logic controller

Programmable logic controller (PLC) , have been used in industry since 1969 and since this time they have become firmly established as the most popular means of controlling the operation of plant and machinery. They have of course evolved in terms if hardware and software. Since around 1974 microprocessors have been used as the very 'brain' of the PLC and this , along with the advances in electronic circuits and components, has enabled cheaper, smaller, more powerful and reliable units to be developed. Similarly and sometimes available, communication features, the means of documenting programs and faults finding have all been enhanced so that modern day PLC's are vastly superior to those encountered in the 1970s.

A PLC- controlled system consists of:

- A power supply
- An input device such as a limit switch, push button, sensor
- An input module, which is part of the PLC
- A logic unit, which is the "brains" within the PLC

Power Supply

The power supply provides power for the PLC system. The power supply provides internal DC current to operate the processor logic circuitry and input/output assemblies. Common power levels used are 24V DC or 120 VAC.

Processor (CPU)

The processor, central processing unit, or CPU is the "brain" of the PLC. The size and type of CPU will determine things like: the programming functions available, size of the application logic available, amount of memory available, and processing speed. Understanding the CPU can be a complex subject and we will tackle that in other articles.

Input / Output Assembly

Inputs carry signals from the process into the controller, they can be input switches, pressure sensors, operator inputs, etc. These are like the senses and sensors of the PLC.

Outputs are the devices that the PLC uses to send changes out to the world. These are the actuator the PLC can change to adjust or control the process - motors, lights, relays, pumps.

Many types of inputs and outputs can be connected to a PLC, and they can all be divided into two large groups - analog and digital. Digital inputs and outputs are those that operate due to a discrete or binary change - on/off, yes/no. Analog inputs and outputs change continuously over a variable range - pressure, temperature, potentiometer.

Programming Device

The PLC is programmed using a specialty programmer or software on a computer that can load and change the logic inside. Most modern PLCs are programmed using software on a PC or laptop computer. Older systems used a custom programming device.

2.1.1 Basic Operation of PLC

The operation of the PLC system is simple and straightforward. The Process or CPU completes three processes:

1.scans, or reads, from the input devices

2.executes or "solves" the program logic, and

3.updates, or writes, to the output devices.

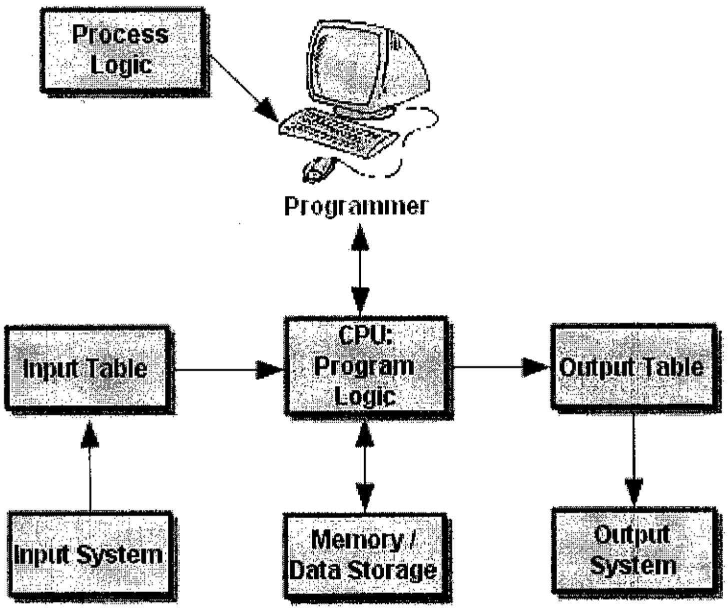


Figure 1 : PLC overall view

2.3 Pneumatics and hydraulics

As described in section 2.1, the PLC is the controller or 'brain' if the plant or machine that is being controlled. Pneumatic actuators are used in profusion within automatic an semi- automatic plant and machines and so it is well worth understanding the basic operation, symbols and control problem of electropneumatic systems. An understanding of this subject will enable me to create suitable ladder diagrams, convert these into a PLC program and thus control such systems.

2.3.1 Electropneumatic valves

The essence of electropneumatic circuits is the electropneumatic directional control valve which acts as a 'switch' to direct compressed air to each side of pneumatic actuators or to different actuators.

The five-port, two position solenoid valve is the most commonly used valve. It is called 'five-port' because there are five drilled and tapped ports in the body of the valve. 'Two position' because the directional spool within the valve has two positions and 'solenoid' because the spool is moved back and forth by the electromagnetic actuation solenoid.

The purpose of the five port valve is to extend and retract a pneumatic piston in response to an electric signal being supplied to the appropriate solenoid.

CHAPTER 3

METHODOLOGY

3.1 Project Flowchart

The flowchart of the project is as shown in figure 3.1. This project started with the literature research via internet and books on the PLC and the procedure in creating ladder program. Therefore, the knowledge on the proper steps of designing the ladder program is important.

After ladder program is being constructed, it has to tested using training kit and output indicators. Once the program is verified, the simulation of the program to the electro-pneumatic system. The construction of the robot unit tool place when the workability of the whole system is proved.

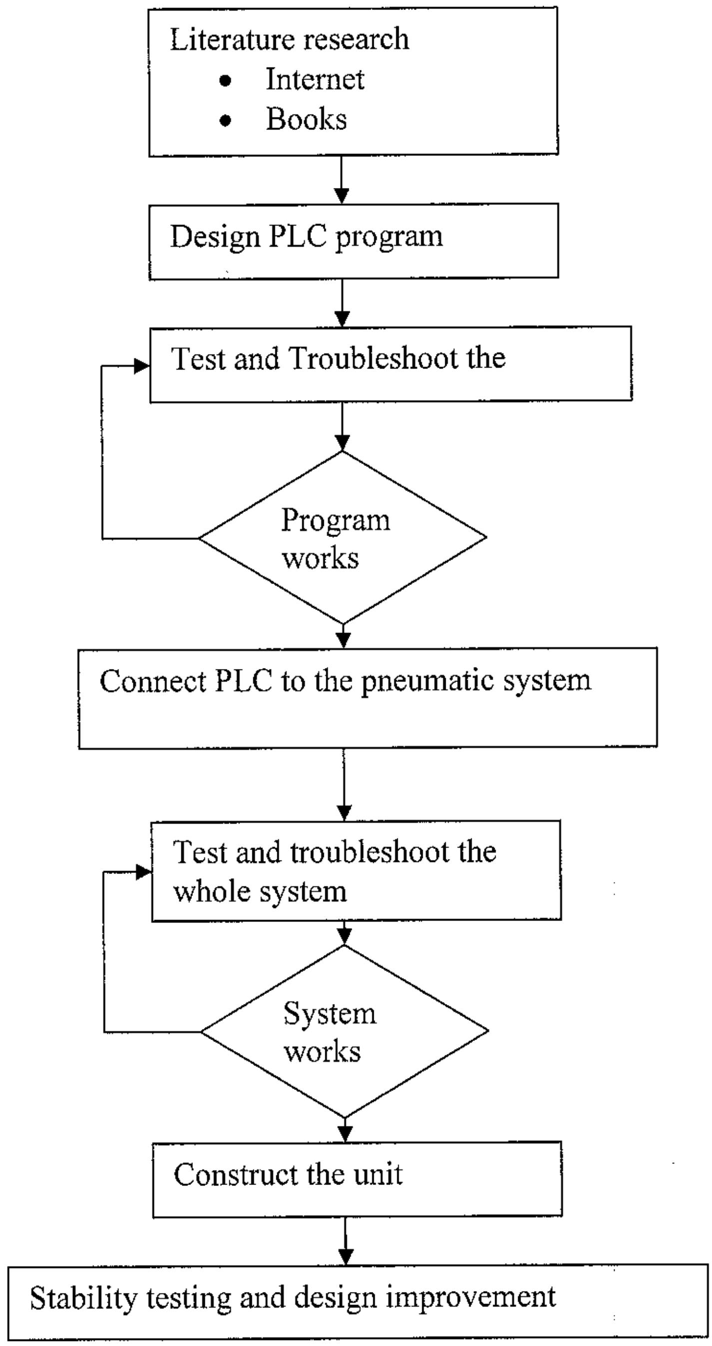


Figure 2: The Project Flowchart

3.2 Programmable Logic Controller

The Programmable Logic Controller is chosen in this project because of its reliability in accomplishing from simple to complicated control tasks. The PLC is a programmable controller that exists from the rapid advancement of technology in control system. In an automated control system, the PLC is commonly regarded as the heart of the control system. With a control application program (stored within the PLC memory) in execution, the PLC constantly monitors the state of the system through the field input devices feedback signal. It will the base on the program logic to determine the course of the action to be carried out at the field output devices. The PLC may be used to control simple and repetitive task, or a few of them may be interconnected together with other host controllers or host computers through a sort of communication network, in order to integrate the control of a complex process.

There are two types of PLCs: those are the integrated and modular PLC. An integrated PLC is PLC that is integrated into one single unit. IT sometimes called the shoebox or brick PLC because of its small size. This type of PLC is the most economical option if it could provide all the capabilities that a user needs. Allen- Bradley's Micrologiz 1000, Siemen's S7-100 and OMRON's CPM1 are typical but reasonably powerful integrated PLCs. Most PLCs of this type have a built in 24V dc power supply to drive typical sensor. On the other hand, modular PLCs consist of optional components required for a more complex control application as selected and assembled by the user.

A PLC consists of a Central Processing Unit (CPU) containing and application program and input/output interfaces modules, which is directly connected to the field I/O devices. The program control the PLC so that when an input signal from an input device turns ON, an appropriate response is made. The response normally involves turning ON an output signal to some sort of output devices.

Intelligence of an automated system is greatly depending on the ability of a PLC to read in the signal from various types of automatic sensing and manual input field devices.

Push buttons, keypad and toggle switches, which form the basic man- machine interface, are type of manual input devices. On the other hand , for detection of work piece, monitoring of moving mechanism, checking on pressure and many others, the PLC will have to tap the signal from the specific automatic sensing devices like proximity switch and limit switch.

The sensors and actuators are connected to the PLC via the input/output module (I/O modules). The I/O module normally isolates the low-voltage, low currents signal that the PLC internally uses from the higher-power electrical circuits required by the sensors and actuators. The I/O modules include the digital I/O modules and analog I/O modules, miscellaneous intelligent I/O modules and communication interface modules. The function of each I/O module are as discussed below:

1. Digital I/O modules- used to connect the PLC to sensors and actuators that can only switch on and off.
2. Analog I/O modules- used to connect the PLC sensors that can provide electrical signals that are proportional to the measured value or to actuators that vary their output proportional with the electrical signals received from an output analog module.
3. Miscellaneous intelligent I/O modules- Has its own built-in microprocessor and memory and this I/O module is designed for special purposes such as counting high frequency signals.
4. Communication interface modules – Handle the exchange of data via a communication link.

3.2.1 The Procedure for Creating PLC Ladder Program

The systematic operation procedure that are applied in the creation of the PLC ladder program are as discussed below:

1. Define the robot sequence of operation.

   The first step in the procedure is to decide what type of equipment or system involved in the robot design that is to be controlled. In this case, the input devices constantly monitor the movement of the controlled system and give a specified condition as well as sending a signal to the programmable controller. In response, the programmable controller gives outputs in term of signal to the external output devices that control the movement of the controlled systems. Generally, the sequence of operation can be described by a flowchart of timing diagram.

2. Assignment of Inputs and Outputs

   After determining the sequence of operation, the external input and output devices to be connected to the PLC must be specified. In this project, the external input to the PLC is toggle switch whereas the outputs are the electro-pneumatic valves. The input and output devices are then being assigned numbers corresponding to the input and output number of the particular programmable controller. The actual wiring will follow the numbers of the particular programmable controller. The assignment of inputs and outputs must be performed before the ladder program is created. This is because the assigned number will dictate what is the precise meaning of the contacts in the ladder program.

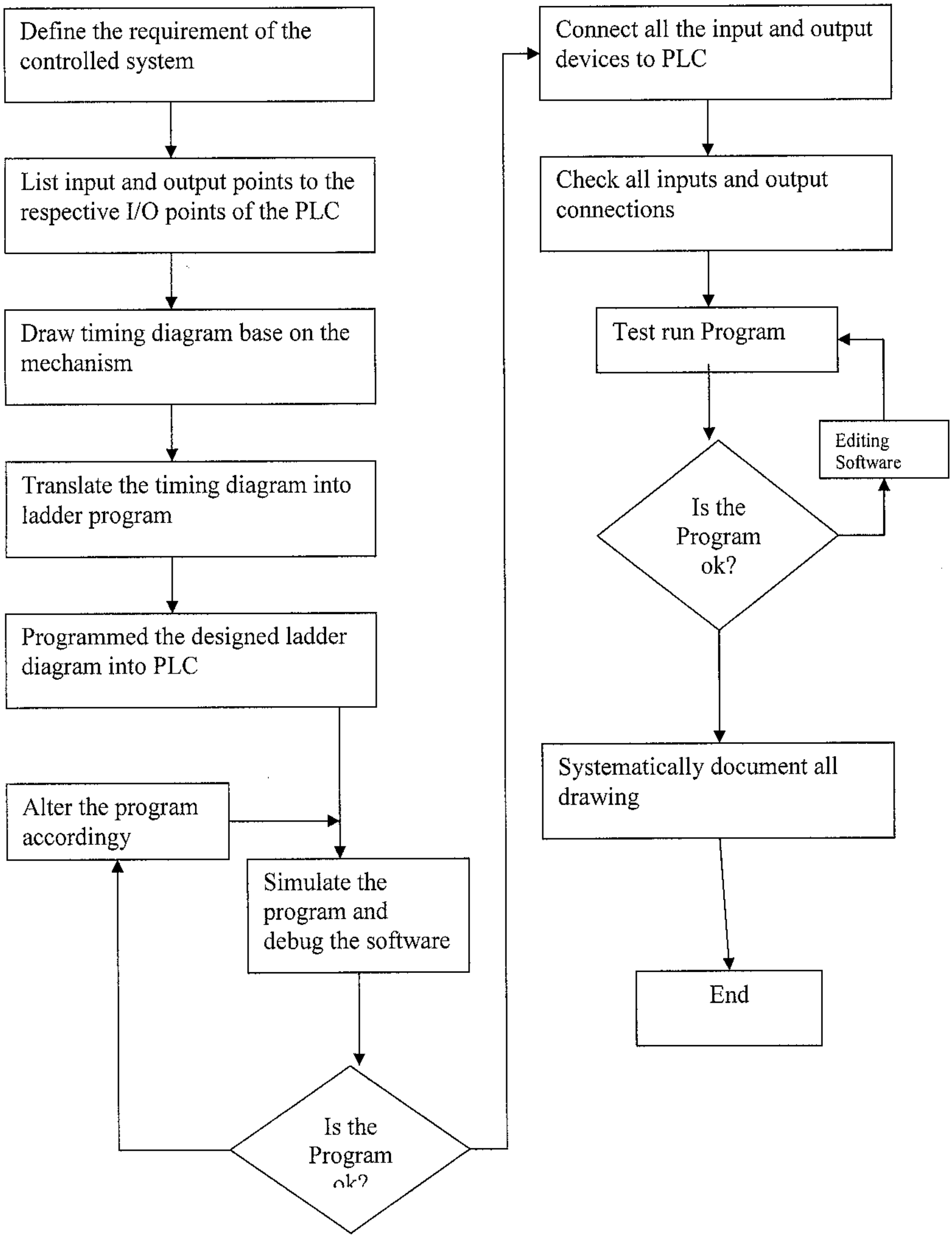


Figure 3: The systematical Approach of Control System Design Using PLC

3.3 Prototype Construction Process

The prototype construction process involved several steps as described in the flowchart below.

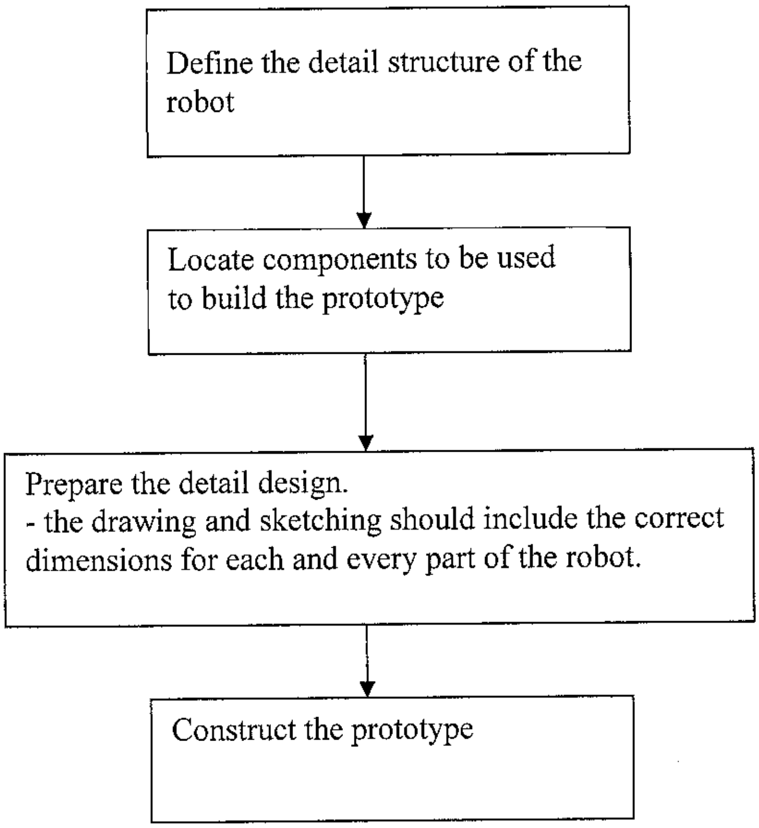


Figure 4: The Flowchart for Prototype Construction Process

3.3.1 Prototype components

The Climbing Robot works based on the pneumatic concept and uses electro-pneumatic components as the main parts for its structure. These include the elector-pneumatic valves and cylinders, toggle switch, pressure regulator and pneumatic tubes. Principally, the pneumatic controls are designed to control and direct the air stream through an air circuit. The regulating valve is usually the first control through which the air stream passes as it enters the circuit. Regulated air pressure flows from this valve on the master control valve. The master control valve is a directional control either the three way or four way type.

The three-way type has three ports – an inlet, an exhaust and a cylinder port. The four- way type has four ports – an inlet, an exhaust and two cylinder ports. The electropneumatics system is a system that uses the fundamental of pneumatic controls but also needs electrical energy. The electro- pneumatic valve usually equipped with solenoid whereby the electrical energy would be needed to activate the valve.

3.3.1.1 Single Acting (SA) Cylinder (Spring Extend)

SA cylinders (spring extend) are used when pneumatic energy is required only to retract the rod. The spring force will allow the rod to extend. This force is opposed to the rod retraction and must therefore be considered when calculating the diameter of the cylinder. SA cylinders are usually controlled by a 3/2 directional valve. In this project, the single acting cylinders are mounted as a part of the robot body. During the climbing process, these cylinders will act as the leg of the robot, it will push and pull the suction cup against the glass wall.

3.3.1.2 Pneumatic Slider

Pneumatic Slider are used when pneumatic energy us required in both directions of the slider movement. The areas on which pressure is applied are not equal on both sides, there will be a difference in speed depending whether the rod is extend or retracting. In this project the pneumatic slider are mounted as a main part of the robot body. During the climbing process, these slider will push upward or downward the robot against the wall.

3.3.1.3 Filter Regulator Gauge

The pressure regulator regulates compresses air to be supplied to the pneumatic cylinders. Normally , 24 psi or 2 bar pressure is supplied to the system. However, the pressure could be increased up to 8 bar provided that it does exceed the pressure rating of the valves.

3.3.1.4 Pneumatic Tube

The pneumatic tubes link the pressure from the pressure regulator to the electro- pneumatic valve and from the electro- pneumatic valve to the single acting cylinders and pneumatic slider.

3.3.1.5 Suction Cup

A suction cup is a device, usually made of rubber or plastic, that sticks to smooth, nonporous surfaces. They are usually used to attach objects together with the use of suction. Upon pressing the suction cup to a surface, the air pressure inside is drastically reduced. The relatively higher atmospheric pressure outside prevents the cup from lifting off the surface; friction does the rest of the work. In this project, the suction cup will be the main component for the robot to stick to the wall.

3.3.1.6 Air ejector

Ejector is a pump like devices uses the Venturi effect of a converging-diverging nozzle to convert the pressure energy of a motive fluid to velocity energy which creates a low pressure zone that draws in and entrains a suction fluid and then recompresses the mixed fluids by converting velocity energy back into pressure energy. This phenomenon will create a vacuum spaces, that will suck all the air out. In this project, ejector are used to suck all the air inside suction cup , and create a vacuum so that the robot can stick to the wall.

CHAPTER 4

RESULT AND DISCUSSION

4.1 Software Development for Climbing Robot

The Climbing Robot software was written in the form of PLC ladder program using Omron Cx- Programmer software. The systematic approach for control system design using PLC was applied in order to construct the ladder program. The complete ladder program for the climbing robot is as in **Appendix.**

4.1.1 Software Analysis

In the ladder program, three inputs and six outputs are used. Each output represent an electropneumatic valve. Note that each electropneumatic valve is connected to pneumatic cylinders, pneumatic sliders and suction cups. Therefore the output activate the components using the valve. The address for each input ,output and virtual output are as in Table 1.

Table 1 Assignments of inputs and Outputs

Address	Variables	Components	Description
000	Start	Switch	Input
001	Reset	Switch	Input
003	Stop	Switch	Input
10000	A	Suction Cup	Output
10002	B	Suction Cup	Output
10003	Cup	Pneumatic Slider	Output
10004	Cdown	Pneumatic Slider	Output
10005	Da	Single Acting Cylinder	Output
10006	Db	Single Acting Cylinder	Output
20000	Loop	-	Virtual Output
20001	Offcup	-	Virtual Output
20002	Offcdown	-	Virtual Output

Timers are the main components in the ladder program. The timers are used because there is time delay between the operation of each of the pneumatic components. The timer will control the triggering time for each output. One timer is needed to activate each output and another one to deactivate the output.

4.2 Basic Configuration of the Climbing Robot Control System

The basic configuration of the Climbing Robot control system is as shown in Figure 4.1. The system consists of the robot unit itself, pressure regulator to supply compressed air to the pneumatic valve and cylinders, OMRON- PLC CPM1A Training Kit where the ladder program is down loaded into and ladder program written in OMRON CX-Programmer.

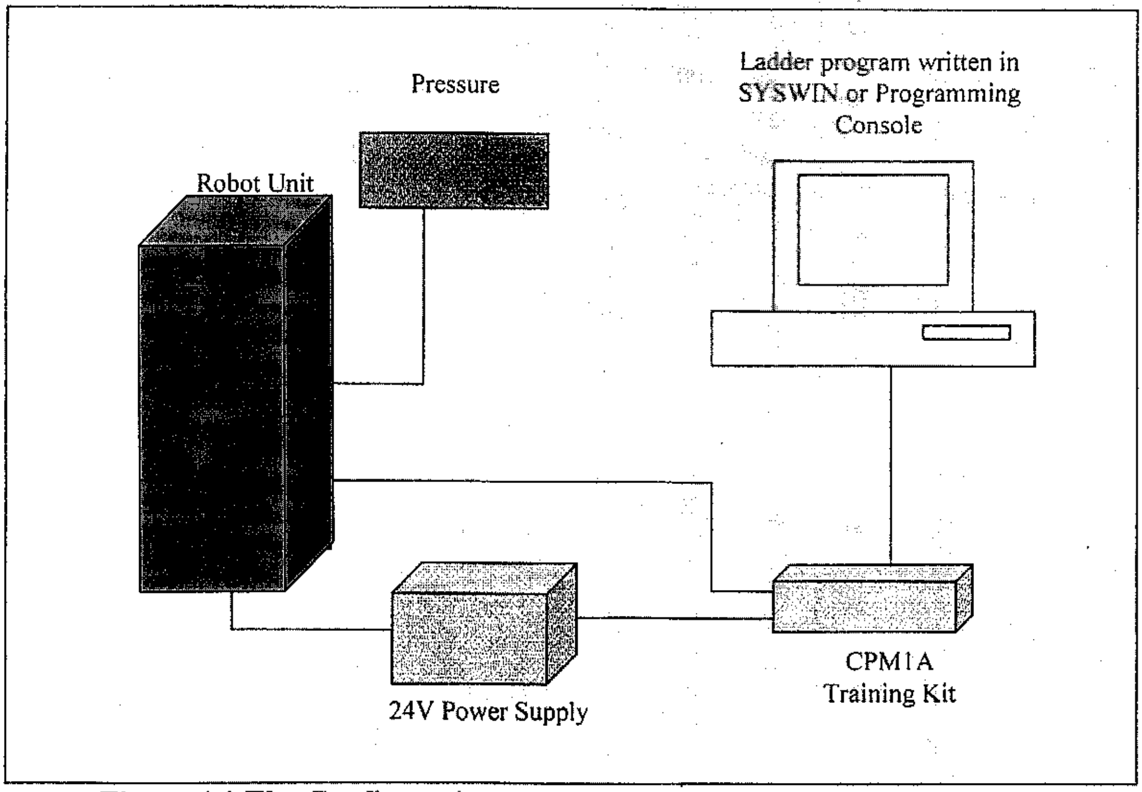


Figure 5 : The Configuration for the Climbing Robot Control System

The wiring connection between the OMRON PLC CPM1A Training Kit to the electropneumatic system is as shown in figure 4.2 A switch, which act as input to the system is connected to the CPM1A input port. This switch links the CPM1A to the 24V dc power supply. This 24dc power supply is needed as the power source for the pneumatic system. Both COM input and COM output of the PLC has to be connected to power source. Connecting the directional valve to the PLC output port at one end and ground at the other end completes the wiring setup of the whole system.

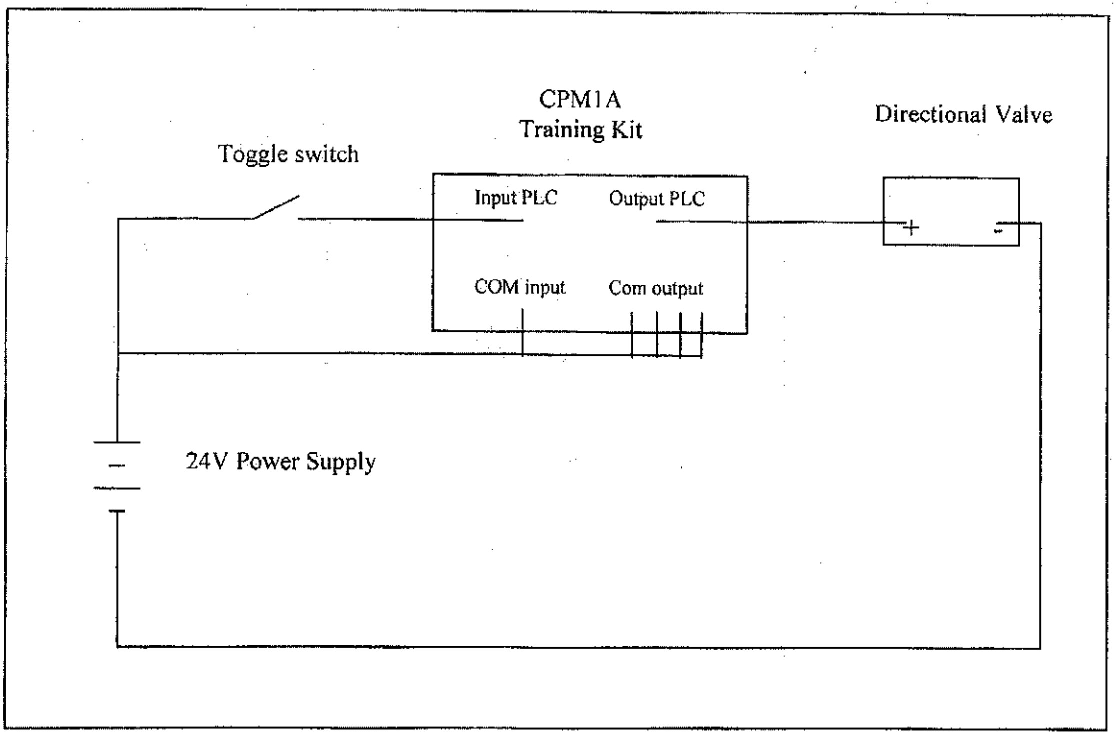


Figure 6 : The Connection Setup between PLC and the Electropneumatic System

4.3 Climbing Mechanism

The Climbing Robot is divided into two parts those are the climbing mechanism and the washing mechanism. For this semester I'm focusing on doing climbing mechanism part. Since the climbing robot works in one degree of freedom motion, this mean the robot only can move upward and downward. The robot climb along the glass wall using the principle of extension and retraction of pneumatic cylinders. Therefore, the body of the Climbing Robot will mainly constructed using pneumatic cylinders. Basically my design of the climbing mechanism is divided into two set of mechanism, which are.

1. Set A (horizontal)
2. Set B (vertical)

Below are the operation on how the climbing mechanism work:

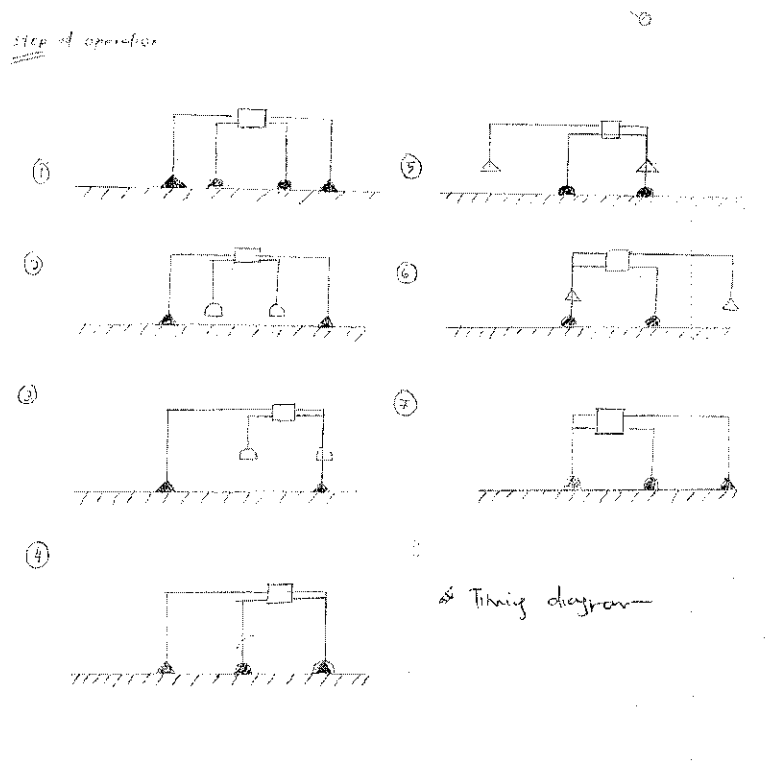
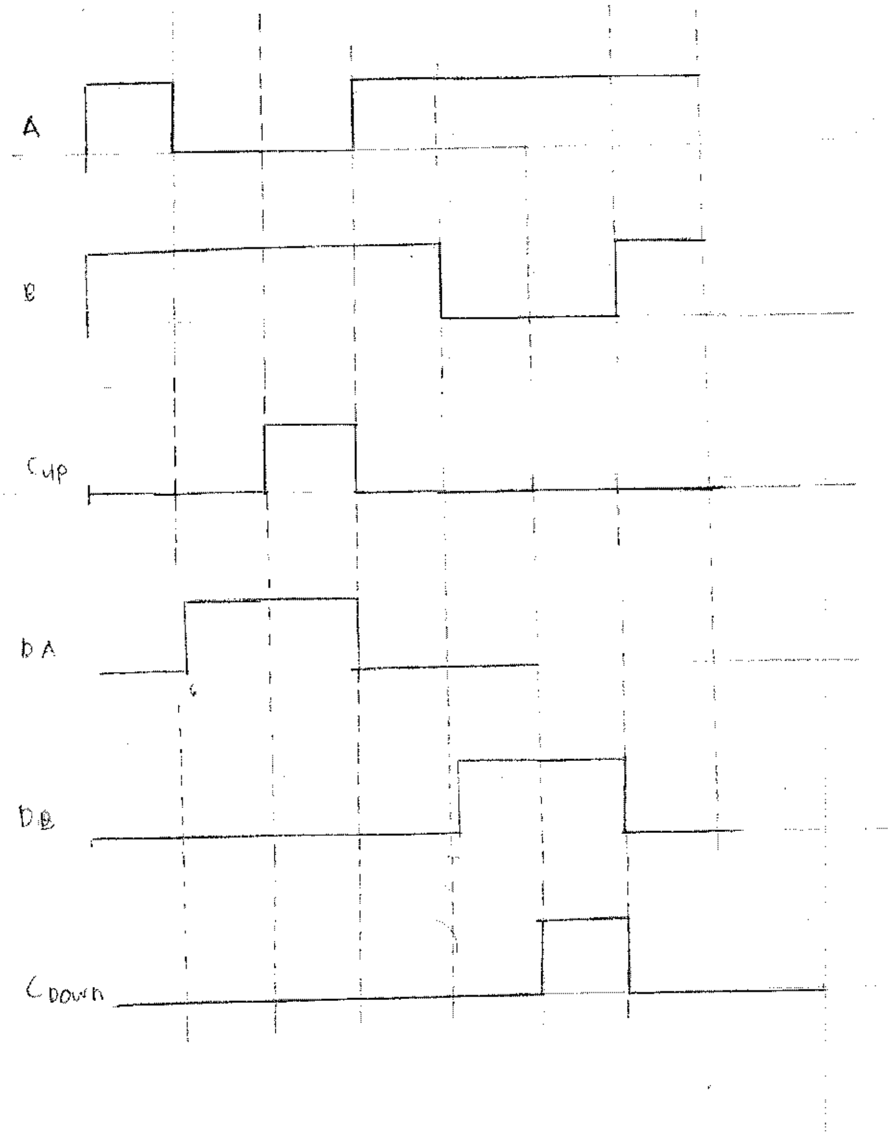


Figure 7 : basic climbing mechanism, the step

From the basic climbing mechanism, we can come out with the timing diagram on the operation of the robot



Legend:

A: Suction cup Set A, horizontal

B: Suction cup Set B, vertical

C: Pneumatic Slider

D: Pneumatic cylinder

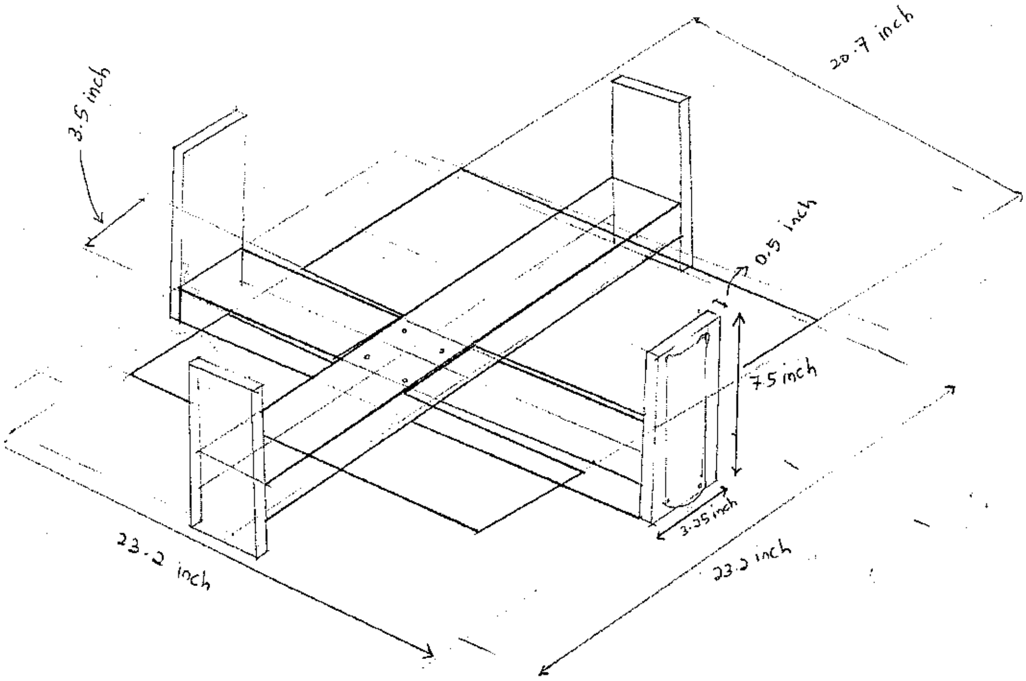


Figure 8 : The sketch of Climbing robot body and its dimension

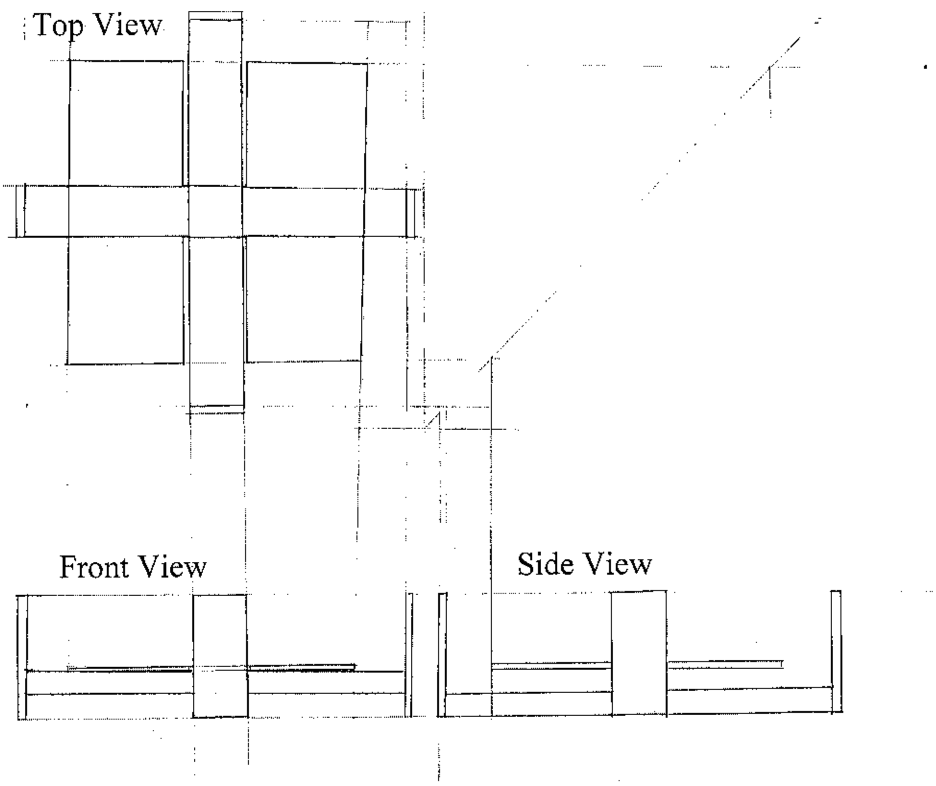


Figure 9 :Orthographic Drawing of wall climbing robot body

Based on the figure 4.1, we can defined the basic movement of the robot

Step of Operation

1. Suction Cup A and Suction Cup B stick to the wall
2. Suction Cup A release meanwhile Suction Cup B still on the same position
3. Pneumatic D1 pull Suction Cup A, the Slider C move upward.
4. Pneumatic D1 push Suction Cup A to the wall, the Suction Cup A stick to the wall.
5. Suction Cup B release meanwhile Suction Cup A still on the same position
6. Pneumatic D2 push Suction Cup B off the wall, and the Slider C move Downward.
7. Middle pneumatic D2 pull Suction Cup B back to the wall, The Suction Cup B stick to the wall.

4.3.1 Climbing Simulation

Based on the developed PLC ladder Diagram program that the author have working on. The author move on with a simulation of the pneumatic basic component to see the connection of the robot, the timing of the program and to understand more on the mechanical part of the project. After the simulation being done, the author need to do some adjustment to the PLC ladder program. Below are the picture of the equipment being used during the simulation. Appendix 1 show the whole PLC ladder diagram code for this project.

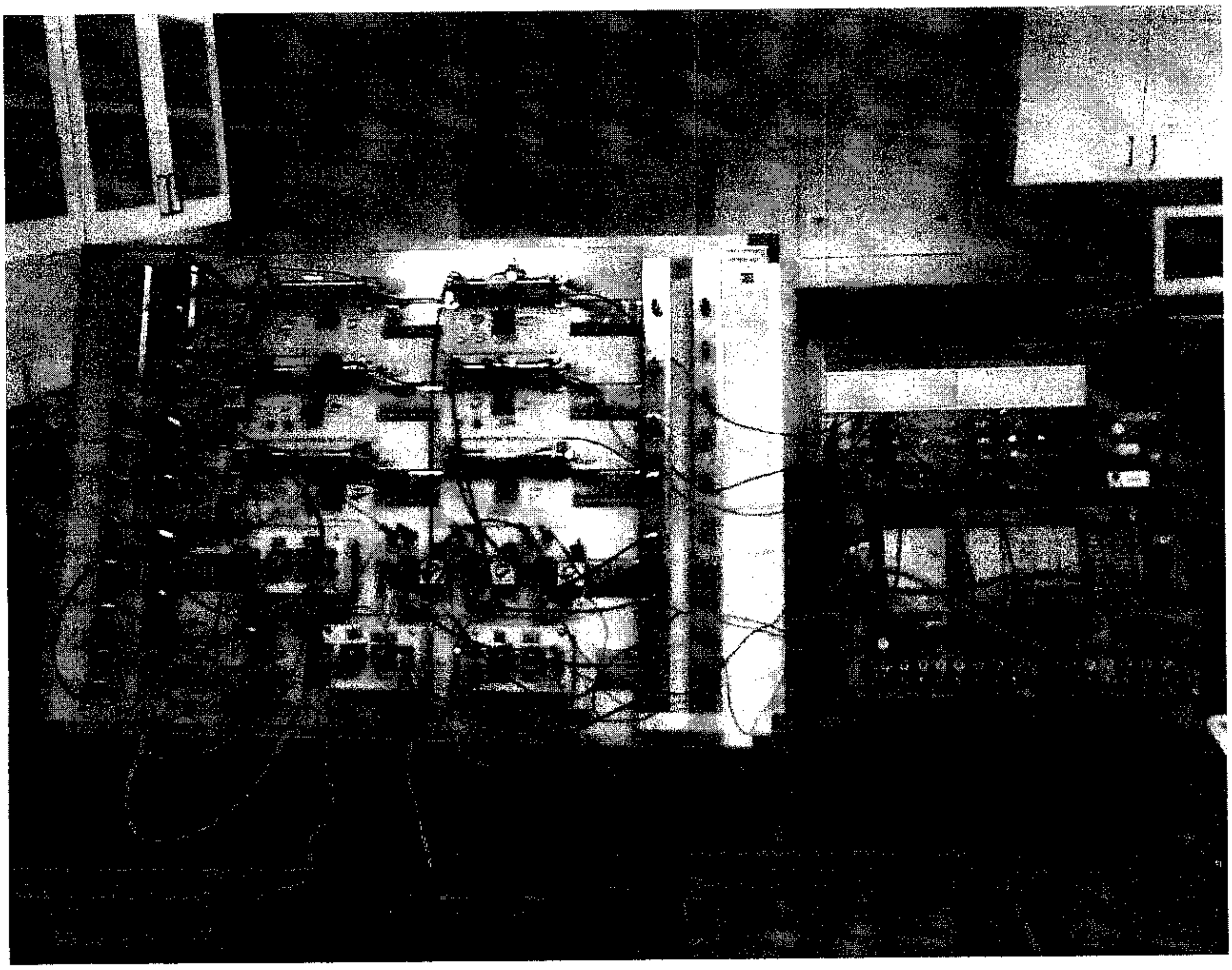


Figure 10 : Simulation of Pneumatic Equipment

4.3.2 Hardware Implementation of Climbing Robot

The climbing robot was designed to be completely made of aluminium ; so that the structure is strong enough and also lighter to perform the desired climbing job. The robot was built based on the design previously prepared.

The components that will work the prototype out are listed below:

(a) 4 units of Single Acting Cylinders (Spring extend)

(b) 6 units of directional valve

© 1 unit of pneumatic sliders

(d) Pressure Regulator

(e) Pneumatic Tubes

(f) 8 units of Suction Cups

(g) 2 units of ejectors

Each component used to build the robot body has its own function that acts together ini order to perform the climbing job.

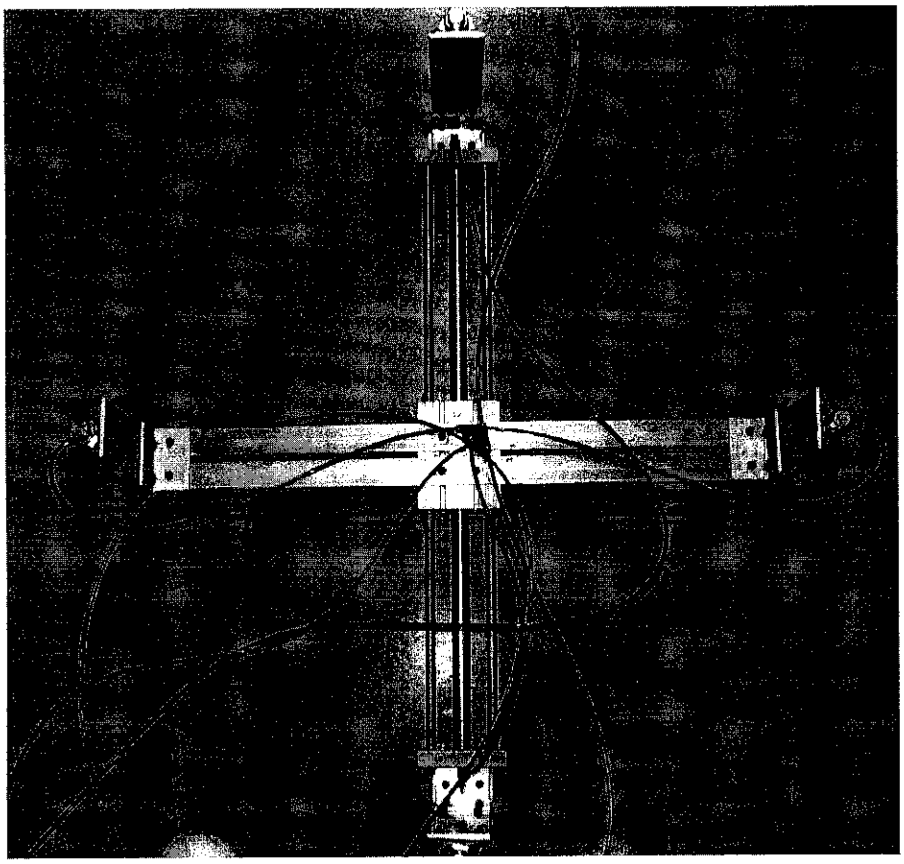


Figure 11: Main body of Wall Climbing Robot

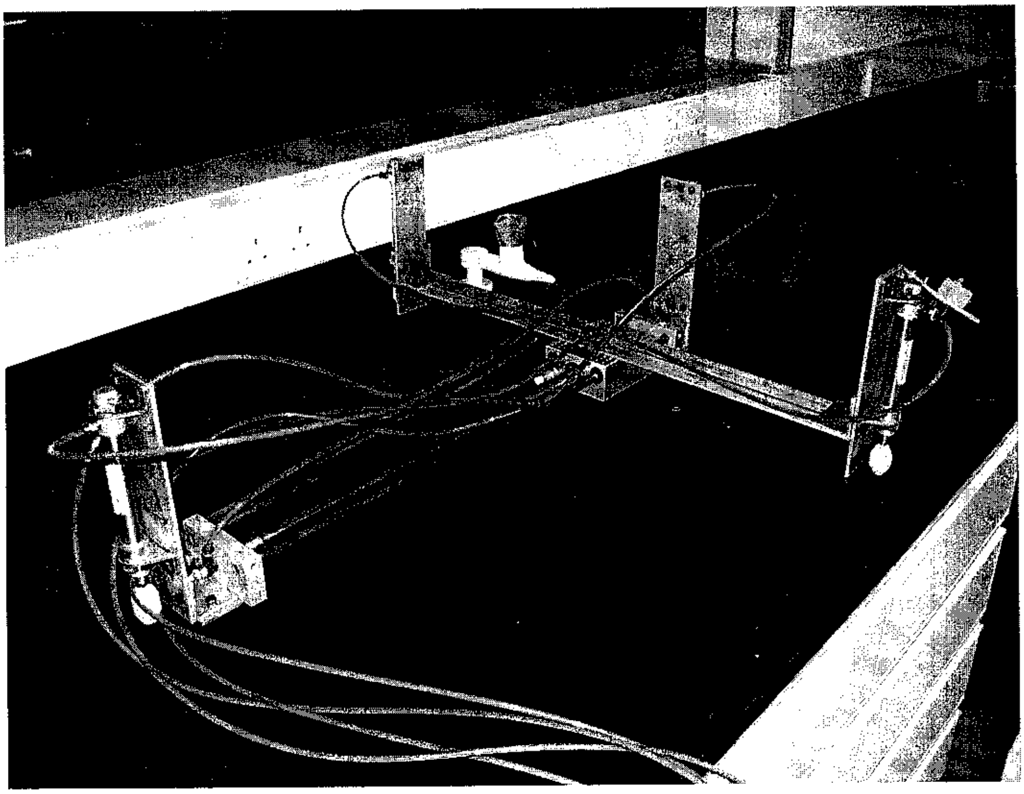
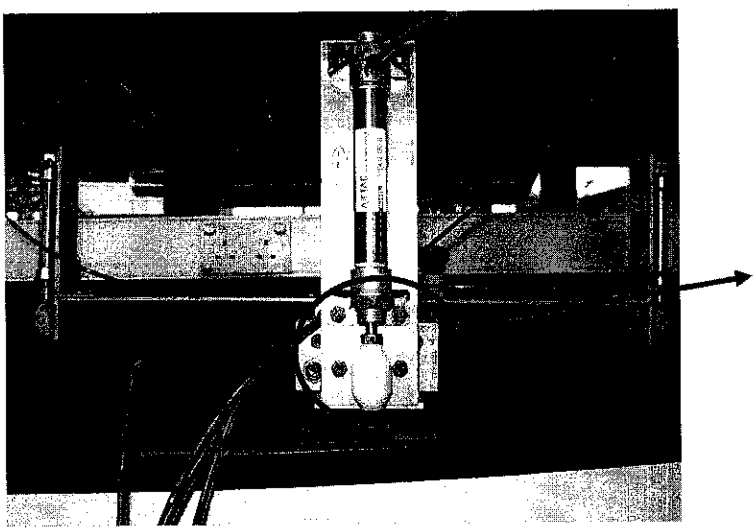


Figure 12: Another view of Wall Climbing Robot

4.3.2 Hardware Analysis

In designing the hardware, its stability and reliability is of main concern. This is to ensure that the robot could carry out its job properly. The Robot was designed such that the structure is strong and stable enough throughout the climbing process. In order to do this, the material used has to be carefully selected and the structure has to be appropriately fabricated. Aluminium was selected for this project, the material are strong and also light. To mount the part the author used nut and bolt.



In Addition to the pneumatic cylinders, pneumatic slider and suction cups, the wall climbing robot also uses electropneumatic valves to control pressure to be supplied to the cylinders. In order to reduce the size of the robot, the valves and pressure regulator are placed separately from the robot body itself. Therefore pneumatic tubes of adequate length are required to link the pressure from the valves to the cylinders.

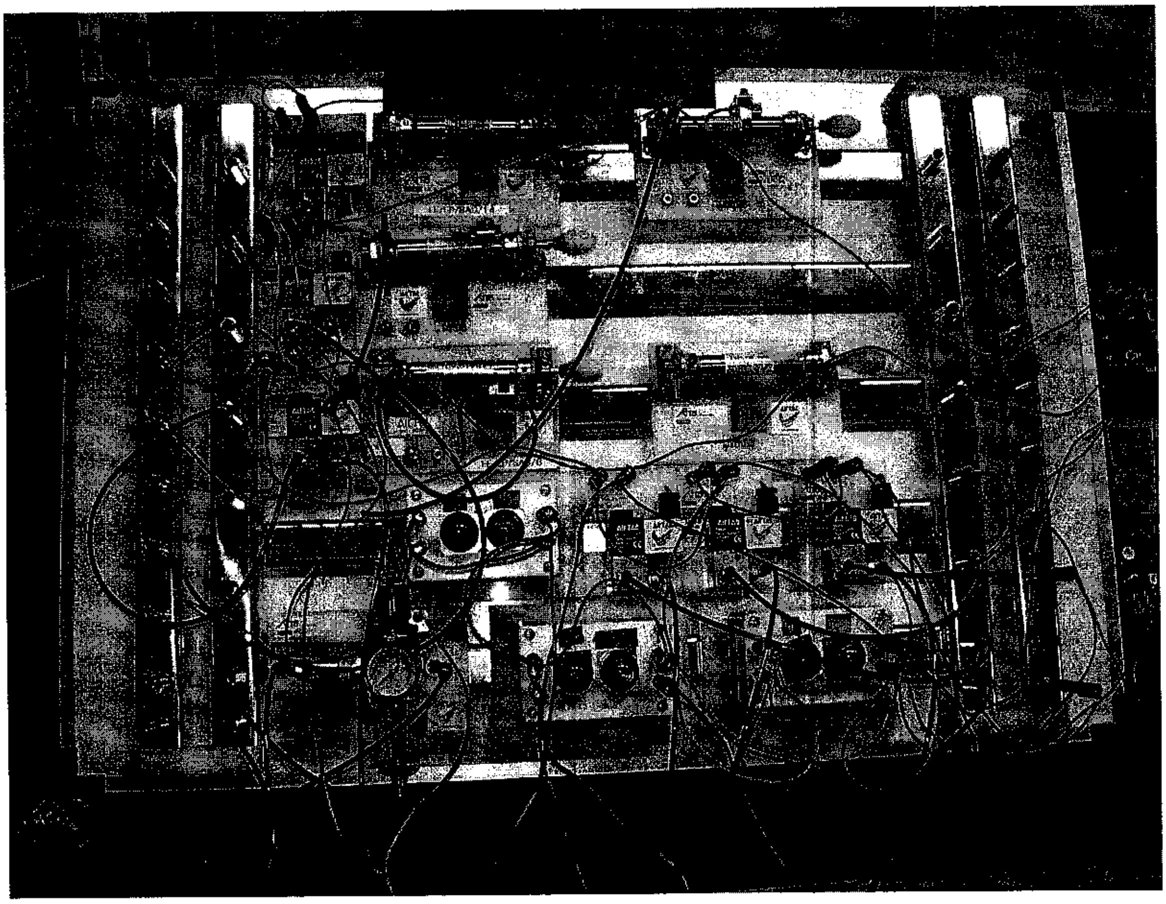


Figure 13: The Valves and Pressure Regulator placed Separately form the Wall Climbing Robot

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The Wall Climbing Robot was designed and will be implemented in this project operates based on the pneumatic concept. In this project, the movement of the robot is controlled by a PLC ladder program written in OMRON CX-Programmer .This ladder program was constructed based on the robot sequence of operation defined earlier. In this project, it has been experimentally shown that the PLC ladder program is reliable to control the operation of this robot.

The robot hardware was implemented by using pneumatic components as the basic constituents. The prototype of the robot constructed in this project was able to show the basic principle of the robot movement. This shows that the general objective of the project, that is to design and implement a robot that works based on pneumatic concept and controlled by programmable logic controller (PLC) was achieved. However, the structure of the robot has to be further refined in order to ensure the stability and reliability of the robot itself. This is because it has been observed that the steadiness and robustness of the robot is greatly depending on the structure or design and the material used to build the unit. Furthermore, it was verified that PLC is able to control the movement of the every single part of the robot prototype built in this project. In conclusion, the robot designed and implemented in this project had proved that the integration between PLC and pneumatic is potential in designing and fabricating a new type of climbing robot.

5.2 Recommendations

A few suggestions for improvement to the hardware and software of the robot are as listed below :

1. Since the climbing robot has wide application in maintenance work and industry, it is suggested that the robot is equipped with the sensors. The functions of the sensors are to detect obstacle and this could be implemented by using infrared sensor. The additional sensors incorporated to the climbing robot will make it more reliable to be applied in industries.

2. In order to perform further stability analysis to the climbing robot, it is recommended that a feedback signal to be used. Therefore, the PID controller could possibly be implemented to the climbing robot in order to do proper stability analysis as well as increasing its stability.

3. The usage of more lighter pneumatic components can make the robot climb faster and to ensure that it more stable.

Reference

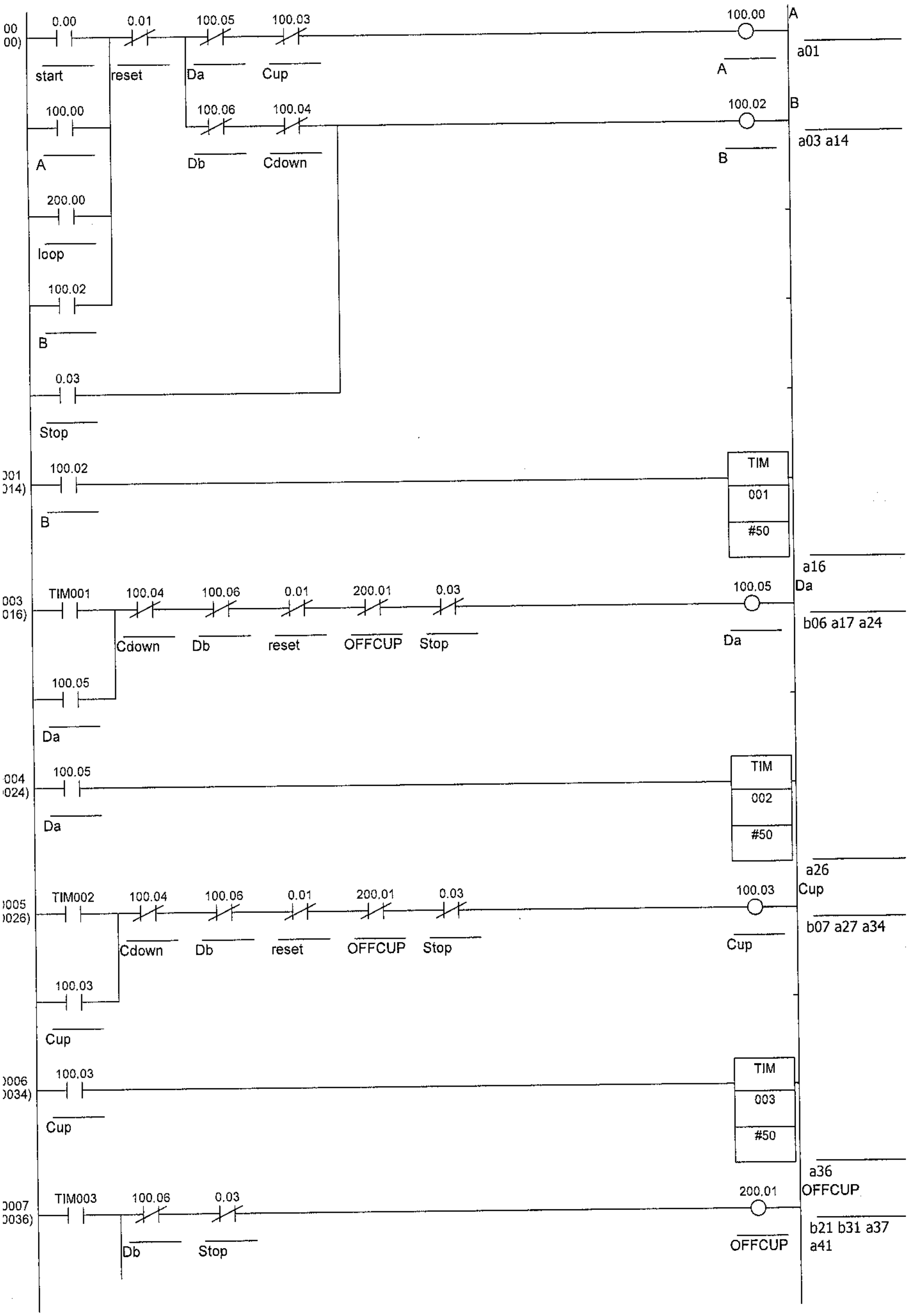
[1] K.Clements-Jewery, W. Jeffcoat, *The PLC Workbook,* Prentice Wall

[2] Gary Dunning, *Introduction To Programmable Logic Controllers,* Delmar Publishers : an internation Thomson Publishing company

[3] A beginner guide to PLC , OMRON Asia Pacific PTE. LTD

APPENDICES

APPENDIX A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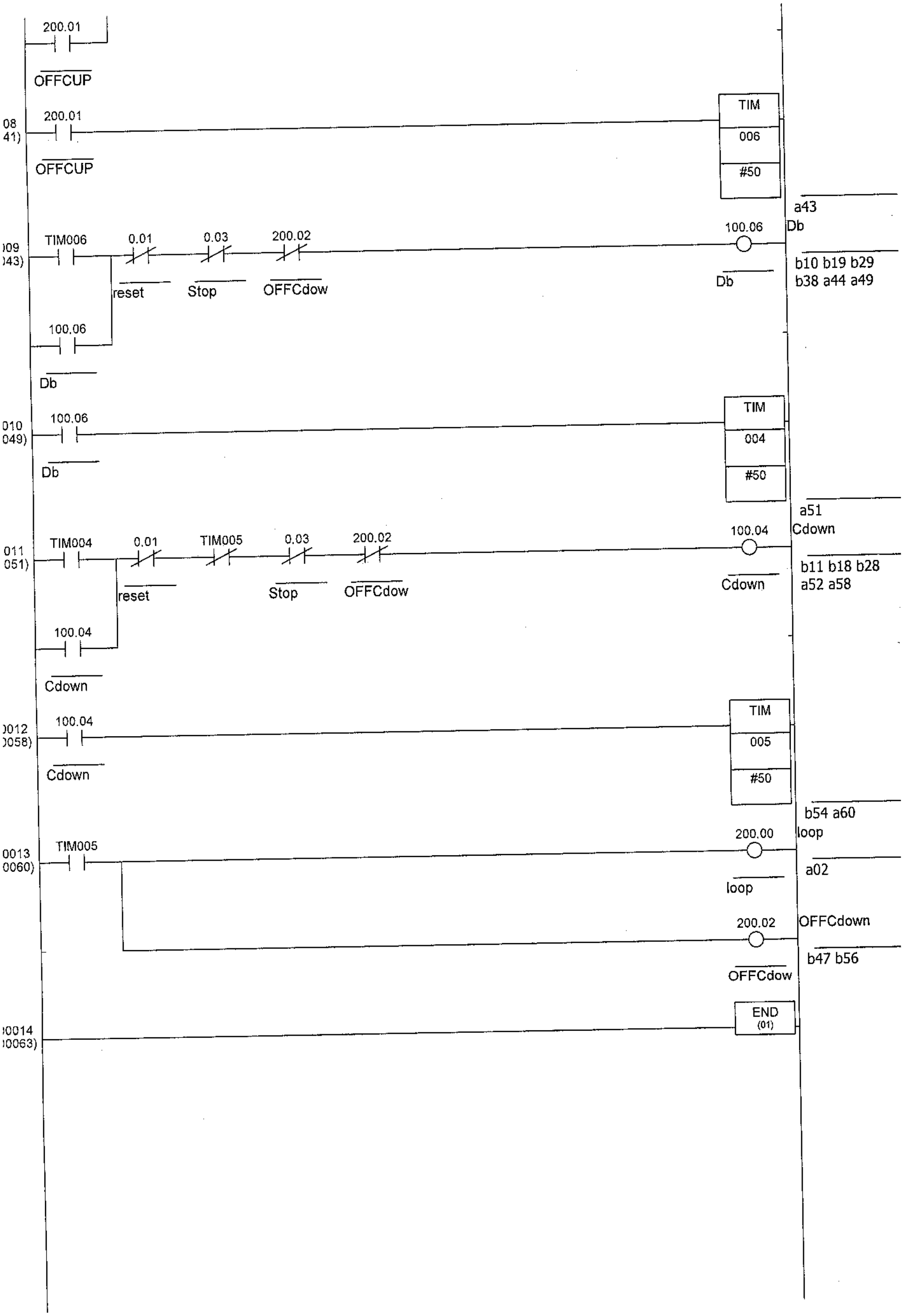

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