

**Design and Implementation of a Small Scale Flexible
Manufacturing System**

By

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FINAL PROJECT REPORT

Submitted to the Electrical & Electronics Engineering Programme
in Partial Fulfillment of the Requirements
for the Degree
Bachelor of Engineering (Hons)
(Electrical & Electronics Engineering)

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By

Khairil Azwan Bin Khabri, 2005

CERTIFICATION OF APPROVAL

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A project dissertation submitted to the
Electrical & Electronics Engineering Programme
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Approved:

A handwritten signature in black ink, appearing to read 'Haris', is written over a horizontal line.

Mohd Haris Bin Md Khir

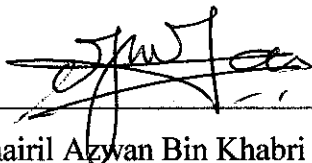
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December 2005

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.



Khairil Azywan Bin Khabri

ABSTRACT

A Flexible Manufacturing System (FMS) is a “reprogrammable” manufacturing system capable of producing a variety of products automatically. FMS consist of the integration of several equipment such as robot, Programmable Logic Controller (PLC) and sensors. In the FMS world, a robot is used in areas that require flexible automation or in other words to produce certain work loop motion to complete the pre-assigned or sequence of motion. PLC acts as the brain for this system while sensors work as the detectors in the FMS system. This project is mainly representing the small scale FMS using the KUKA KR3 robot, Siemens SIMATIC PLC and the test bed. The Siemens SIMATIC PLC is programmed to control the FMS flow and it is responsible to give the direction for KUKA KR3 to move and also capable to receive any information signal from the sensors. By creating a string of commands and download it into the Siemens SIMATIC PLC through STEP 7 Microwin 32 software, one complete system including robot and sensors can be designed to work together. The movement of the robot is directed by the coding through their own software in the KUKA CONTROL PANEL. The main task is to connect the robot used in the lab with the PLC. To direct the robot by using the PLC, the interface between the PLC and robot need to be identified. The synchronization between the two devices must be achieved to make sure that movement of the whole process of the small FMS system can be controlled by PLC. The use of robot and PLC as the controller is widely used in the industry of automation. As a conclusion, this project will provide a good exposure to the student in understanding more on handling robot and PLC in the real world of FMS.

ACKNOWLEDGEMENTS

In the name of Allah the most merciful.

I wish to express my gratitude to Mr. Mohd Haris Bin Md Khir, for his guidance and support throughout this work. I am always amazed by his quick ability to digest new concepts. He always fostered a positive working environment and allowed me to solve problems in my own approach and at my own time. I find the most educational part of this program is not only in technical report but the ability to identify an open ended problem and to spend my time appropriately on the vital parts of the problems. The other lecturers' attitude towards advising me have emphasized this part of my education and allowed me to mend my mistakes and succeed.

Not to forget the technicians from the Automation and Robotics Lab at block 22 which are Mr. Azhar, Mr. Megat, Mr. Yasin, and Mr. Isnaini. They have given an advices, opportunity and freedom for me to learn more about proper using of the Lab equipments.

To my dear friend Noor Farrah Wahida, Gee, Khalid Rafee, Boboo, Cak, Rizal, Khal, Hairil, Maggott, Joko, Gaban, deli, mamat, nizam hailon, Razak, Joe, Nuzral, Komal, Labi, Nurus Sadiqin, Sabrina Rashid and all my close friends in UTP or others, thanks for making my life so colorful and enjoyable. Thanks for being my friend.

Finally I would like to thank my family members, my father Mr. Khabri Bin Dollah, my mother Mrs. Darna Bte. Derani and my sister Amirahtul Husna Khabri. They have been tremendous source of encouragement and joy to me to pursue my first Degree in Electrical and Electronics. Once again I really appreciate the effort of my supervisor Mr. Mohd. Haris Bin Md Khir to realize the vision. All the encouragement from people who have always asked me to give my best effort to whatever I do and thank them all for the values the have passed on to me. May ALLAH bless all of us and only HE, the Almighty could repay all my debts to you.

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LIST OF ABBREVIATIONS

PLC	Programmable Logic Controller
FMS	Flexible Manufacturing System
KCP	KUKA Control Panel
PPI	Programming Interface Port

CHAPTER 1

INTRODUCTION

Basically, this project is to design and implement of a small scale **Flexible Manufacturing System (FMS)**. A complete small scale **FMS** consists of several machine tools along with part and tool handling devices such as robots, to perform certain predefined sequence of operation. For completing this project, the Small Scale **FMS** needs to be attached with the **KUKA KR3 ROBOT** as the programmable machine tool and also **Siemens SIMATIC S7-200** as the controller. Combining the test bed unit, this project is a true simulation of the actual industrial process.

1.1 Problem Statement

This project requires the knowledge on the coding of the robot movement using the **KUKA Controller**. It also requires some familiarization with the **PLC** unit which is actually the brain for the small scale **FMS**. A continuation from the last semester which was integrate the robot with the **PLC**, this final semester, the extension is concerned in completing the full integration of the Small scale **FMS** system. This project applies previous knowledge in Electrical & Electronic courses like constructing a ladder diagram and also on how to operate basic electrical equipment in the lab.

For brief explanations about **FMS**, it is a “reprogrammable” manufacturing system capable of producing a variety of products automatically. The reasons to bring in **FMS** in the industrial field are actually to make the production faster and continuous without human interactions. **FMS** reduces operating costs as a result of manpower downscaling. These are among many reasons why **FMS** are now very popular and convenient system to be implemented in the industrial field.

1.2 Project Objectives

The objectives of the project can be divided into few sections. These objectives help and keep all processes on track following this project title and its requirement. The Objectives are:

- **Design and implement of a small scale Flexible Manufacturing System (FMS)**

An FMS is a “reprogrammable” manufacturing system capable of producing a variety of products automatically. Students exposed to the FMS system will be able to observe the system which could operate 24 hours a day under computer control without human supervision This exposure is also beneficial for the student as a preparation to face the engineering practice.

- **The studies of KUKA KR3 Robot**

The **KUKA KR3 Robot** is a new robot purchased by the university for the purpose of learning about robotics. It is the first mobile robot training cell with an exchangeable application plate for flexibility in the industrial training. This robot offers a high performance combination of fast, flexible automation and high reliability. Creative attachment to other equipments such conveyor belts and other machine can create new systems that can be more efficient for future use and can be innovative for the development of system design.

- **The studies of SIEMENS SIMATIC PLC**

The SIEMENS SIMATIC PLC is one of the most favorable PLC in the market. It is mostly used by industries which require the PLC in their system. The SIEMENS SIMATIC PLC is newly introduced as a replacement for the existing type of PLC used in the university which is the OMRON PLC. The SIEMENS SIMATIC PLC has the advantage of being more durable and suit the industrial environment technology advancement. Application of The SIEMENS SIMATIC PLC in this project will mimic the actual industrial operation.

▪ **The full system integration**

The KUKA robot, the SIEMENS PLC and the Sensors are self standing devices. It does not communicate with each other. The purpose of this project is to combine these three devices into a flexible manufacturing system. The three non recognizing devices are put together physically by wires and taking into account the signal transmission polarity. Upon completion, the PLC will act as a brain of the system and the robot as the manpower while the sensors identify the materials.

1.3 Scope of Study

There are limitations considered in this project. The KUKA KR3 and SIEMENS SIMATIC PLC are two different equipments. Both of this equipment is independent and not interconnected. Thus a communication must be established between the two equipments. For the connection, There two different coding used in designing this small FMS.

In designing the whole system or in the industrial world known as the working envelope, KUKA Sim-Pro is used to pattern the whole system. KUKA Sim-Pro software will be able to simulate the whole industrial process before going into the actual hardware implementation. Having to work with the simulator will allow the student to tune the process to the optimum level.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction to Flexible Manufacturing System

Flexible Manufacturing System (FMS) consists of several machine tools along with part and tool handling devices such as robots, PLC, and sensors and it is arranged so that it can handle any family of parts for which it has been designed and developed [1]. Flexible manufacturing can produce small lots like intermittent manufacturing. But it uses continuous manufacturing actions. Thus, flexible manufacturing is seen as the way for the future. It produces low-cost products as they are needed.

For completing this project, the SMALL-SCALE FMS requires the integration of **KUKA KR3 ROBOT** as the programmable machine tools with the **Siemens SIMATIC S7-200** as the controller and the sensors to provide feedback-signal to the system. Consists of test bed unit, this project is a real simulation of an actual industrial process. All the instruments have to be compiled and must communicate with each other to make the FMS work smoothly. In FMS world, the robot is functioning as a human replacement to do the job. The reasons are robot can perform better than a human is because robots can work in hostile environments; long hour's and also consistent [2]. Considerations of the cost of labor are among the reason why human have been replaced by robots.

PLC (Programmable Logic Control) in FMS functions to control or in other words acts like a "brain" in the system. PLC can be the medium for the sensor (test bed) to deliver the signal for robot to perform proper action that already been set up for the whole system [3]. Figure 2.1 show, the design of a simple flow chart to show how the instruments work as a one system.

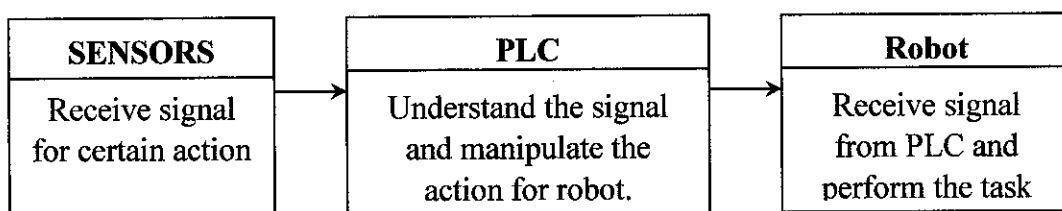


Figure 2.1: Diagram of instruments work in the system

The PLC and the Robot will be explained in details covering their specification and the function for both of the instruments.

2.2 Role of SIEMENS SIMATICS S7-200 PLC (Programmable Logic Controller)

The S7-200 series is a line of micro-programmable logic controllers (Micro PLC) that can control a variety of automation applications. Compact design, and a powerful instruction set make the S7-200 controllers a perfect solution for controlling small applications. The wide variety of CPU sizes and voltages, and the multiple programming options available, give the flexibility in solving the automation problems.

An S7-200 Micro PLC consists of an S7-200 CPU module alone or with a variety of optional expansion modules. The S7-200 CPU module combines a central processing unit (CPU), power supply, and discrete I/O points into a compact, stand-alone device. The CPU executes the program and stores the data for controlling the automation task or process [4]. Meanwhile the power supply provides electrical power for the base unit and for any expansion module that is connected. The inputs and outputs are the system control points: the inputs monitor the signals from the field devices (such as

Structure of a S7-200 (CPU 221)

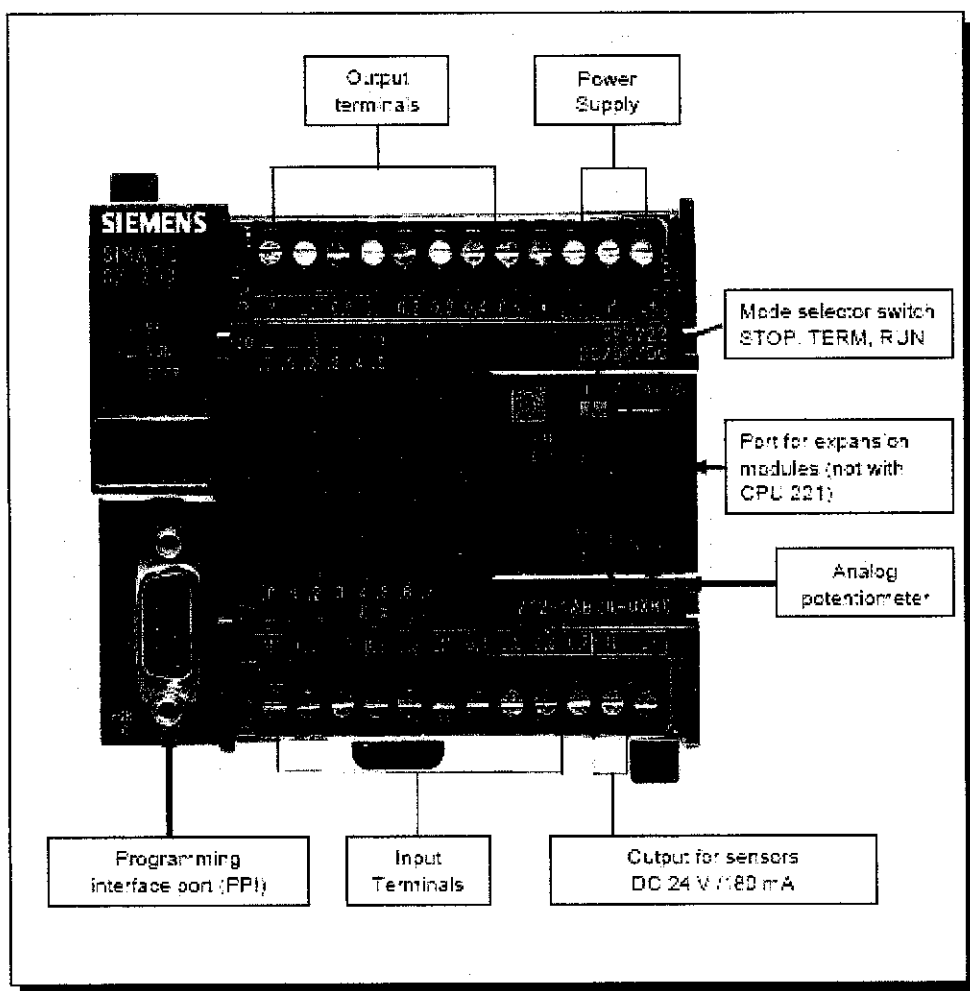


Figure 2.2: Siemens SIMATIC PLC

sensors and switches), and the outputs control pumps, motors, or other devices in the process. The communications port allows you to connect the CPU to a programming device or to other devices. Status lights provide visual information about the CPU mode (RUN or STOP), the current state of the local I/O, and whether a system fault has been detected. Figure 2.2 shows the actual Siemens SIMATIC PLC

The S7-200 CPU module provides a certain number of digital local I/O points. For this Small Scale FMS project the main focus is the local I/O connection which these PLC offers. It is very important to study about delivering and receiving the signal

from Robot and sensor. The information is obtained from research, the Robot manual and consultation with the laboratory technician on how the connections can be made. [5]

2.3 KUKA KR3 Robot

The **KUKA KR 3 Robot** is a six- axis industrial robot designed for light payload applications that require articulated motion in the horizontal and vertical planes. Typical applications for the KR 3 include:

- **machine loading and parts handling**
- **laboratory automation**
- **product testing**
- **assembly**
- **arc welding**
- **machining tasks, such as grinding, polishing, floor and deburring**

Designed for a nominal 3 kg payload, the KR 3 provides a powerful combination of high-speed flexible automation, reliability, and ease-of-use. The robot can be mounted upright or inverted, and is sealed to IP54, allowing for a wide range of possible uses. The brushless servomotors and high—stiffness harmonic drives used in the KR 3 design makes it one of the fastest and most durable robots in its class. Absolute encoders built into each joint allow the KR 3 to retain positional information, making it possible to turn on the robot and be ready to operate merely in seconds. Arm position parameters can be maintained in memory for up to 2 months, even when the robot and controller are disconnected. Re-mastering is only required after prolonged shelf-storage of the robotic system [6].

A fully integrated servo control network located within the robot makes the KR 3 virtually immune to interference from external electromagnetic radiation. This internal design also allows for a smaller controller, and reduces the complexity of

umbilical cable management. The ISO- standard mounting flange on the wrist allows a wide range of end effectors (e.g. grippers, dispensing tools) to be used with the KR 3. The working range of the robot can be limited by means of software limit switches on all axes [7]. The working ranges of the main joints are designed for light payload applications that mechanically limited by hardstops, which can be pre-adjusted at the factory.

For controlling this robot one KUKA controller is attached to the KUKA PC which is for the user to code and also move the robot in the require axis. The KUKA PC control system is equipped with Intel Celeron micro processing technology and using the Technology-oriented application programming.

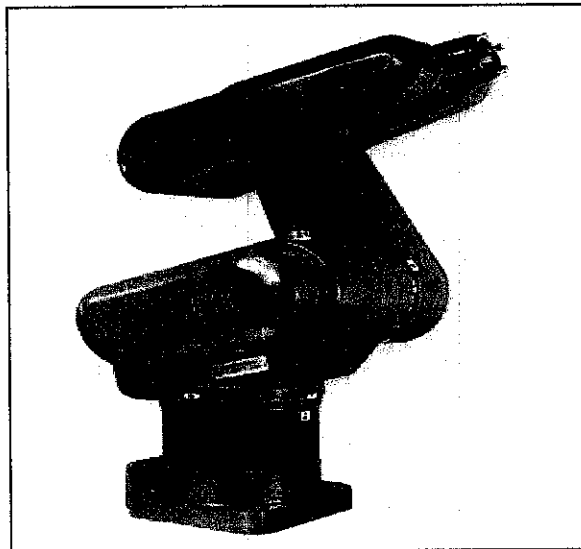


Figure 2.3: KUKA KR3

The KUKA KR3 is divided into 2 major parts to operate which are:

- KR C3 controller unit (computer unit)
- KUKA Control Panel

2.3.1 KR C3 Controller Unit (Computer Unit)

The KR C3 Controller contains all the components and functions which are required to operate the robot. It comprises the computer and power units, which are both installed in a common housing. The computer unit occupies the upper section of the KR C3 controller, while the power unit is located in the lower section. This

equipment will be controlled by KUKA Control Panel for operating control and programming.

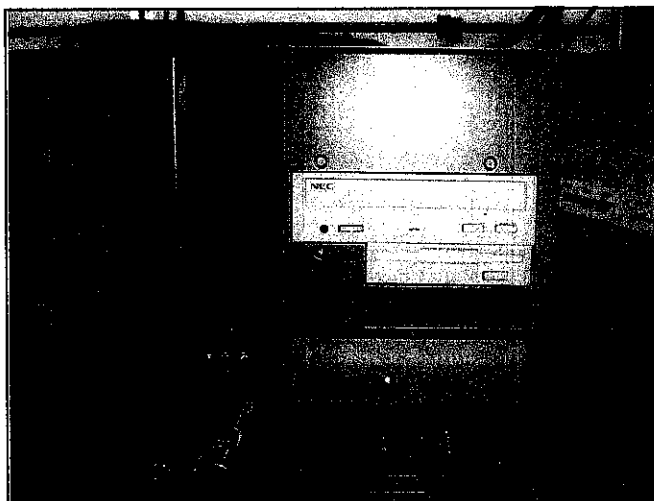


Figure 2.4: Front View of KR C3

2.3.2 KUKA Control Panel

The KUKA Control Panel, Called KCP2 in the following text, forms the man-machine interface and is used for operator control of the KR C robot controller. Apart from the main switch, all the elements required for operator control and programming are located on the KCP2. Due to its ergonomics design and its lightness, the KCP2 can also be used as a handheld unit. Holding domes and enabling switches on the back of the KCP2 are arranged in such a way that it can be used by both left-handed and right handed people. The graphic LCD display helps to visualize operator and programming actions [8]. This Control Panel divides into 2 components which are ESC bus and CAN Bus.

- ESC bus operator control elements:
 - Mode selector switch
 - EMERGENCY STOP
 - Drives ON/OFF
 - Enabling Switches
- Can Bus operator control elements:
 - LCD color display

- Keyboard
- Space Mouse for moving the robot.

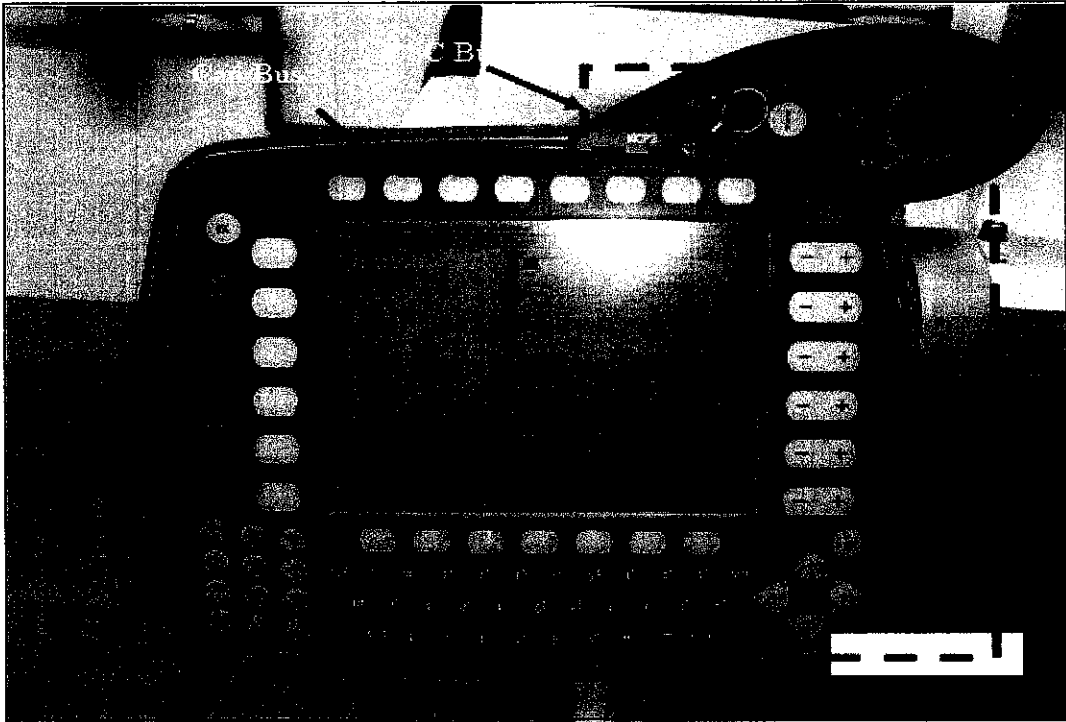


Figure 2.5: KUKA Control Panel

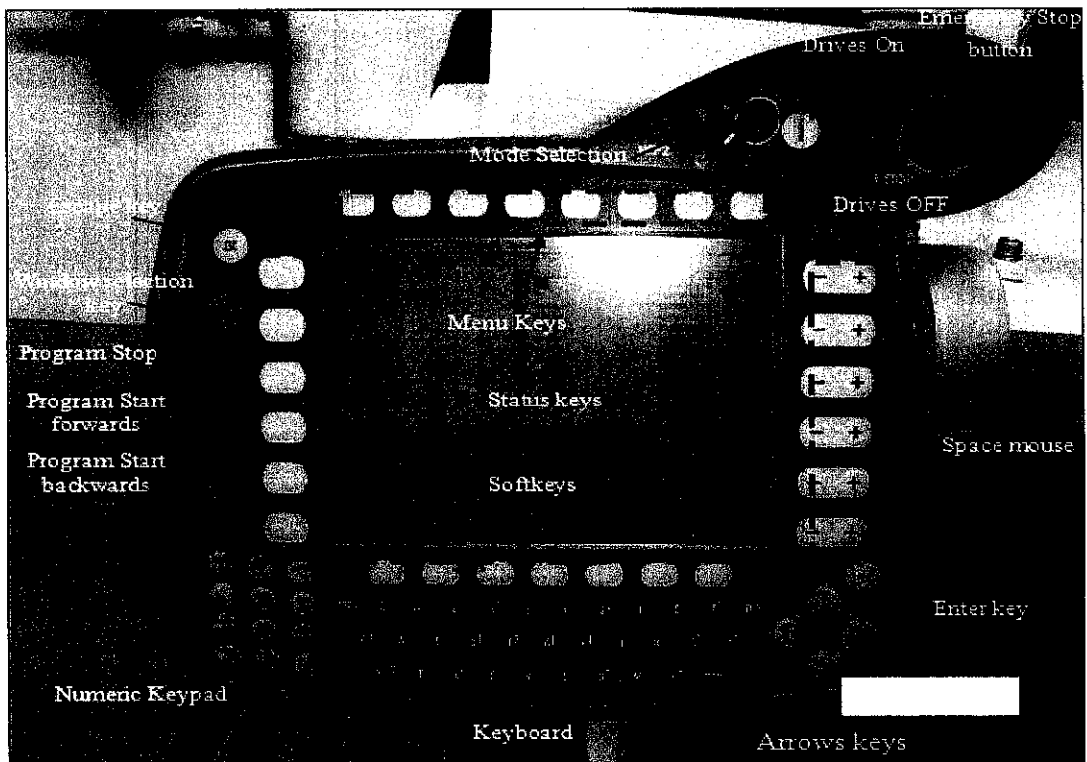


Figure 2.6: KCP's Operator Control Elements

The following description gives an overview of KCP's operator control elements:

Program Stop

Pressing this key stops a program that is running

Program start forwards

This key used to start a selected program.

EMERGENCY STOP button

It is the most important safety element. This red push-button can be pressed in dangerous situations and causes the drives of the robot to be switched off immediately.

Drives ON

Pressing this push button switches the drives of the robot ON.

Drives OFF

Pressing this push button switches the drives of the robot OFF. The brakes of the motors are also engaged after a slight delay and it keep the axes in their position

Mode Selection Switch

Using this keyswitch user can switch between the following operations modes:

- Test 1
 - The robot moves only as long as only one of the two enabling switches is pressed
- Test 2
 - The robot moves only as long as only one of the two enabling switches is pressed
- Automatic
 - The robot executes the selected program automatically and is monitored using KCP. Movements are executed at the program's speed.
- External
 - The robot executes the selected program automatically and is controlled using a host computer or a PLC.

Space Mouse

This is used for the manually controlled motion of all 6 axes of the robot. The magnitude of the deflection affects the velocity of the robot.

Menu Keys

These keys are used to open a menu in the menu bar (at the top of the display). A menu can be closed one step at a time by pressing the Escape key.

Status Keys

The Status Keys (on the left and right display) are used for selecting operating options, switching individual functions and setting values.

Softkeys

These operator control elements are used to select the functions indicated in the softkeys bar (at the bottom of the display). The functions available are dynamically adapted.

Escape Key

An action that has been started can be aborted at any time using the Escape key.

Window selection key

With this key, user can switch between the program, status and message windows if available.

Program start backwards

By pressing this key, the motion blocks of the selected program are executed step by step towards the beginning of the program.

Enter key

This operator control element corresponds to the “Enter” or “Return” key that establish from a PC keyboard.

2.4 Sensors

Sensor is equipment, which responds to an input quantity by producing a functionally related output regularly in the form of an electrical or optical signal. Some of the environmental parameters can be spotted by human senses such as sight, hearing, taste, smell, and touch but sensor devices are even able to calculate parameters like magnetic and electric field, radiation, gas concentration, chemical activity, and many more. In this project 3 types of sensors have been use:

- **Capacitive Proximity Sensor**
- **Inductive Proximity sensors**
- **High capacity Basic switch (Infra red sensors)**

2.4.1 Capacitive Proximity Sensors

A capacitive proximity sensor belongs in a class of sensors, called proximity sensors, which detects objects without actually touching them. The capacitive proximity sensor detects objects based on their dielectric strength, and has many uses which capitalize on this feature [9].



Figure 2.7: Capacitive Sensor

The heart of a capacitive proximity sensor is one capacitor plate (half a capacitor). A capacitor is one of the three basic passive elements in electric circuitry, along with inductors and resistors. While resistors resist electric current and inductors store electric current, capacitors store electric charge. A capacitor takes the form of two

conductive plates separated by a dielectric material. A voltage difference applied to these plates creates an electric field across the dielectric between them. This electric field is what stores the electric charge, and if the source of electricity is cut off the electric field will collapse and release its energy as a voltage falling asymptotically toward zero from its initial level. Storing and releasing charge has the effect of dampening out changes in voltage in the circuit [10]. This makes capacitors very useful for decoupling low voltage circuits.

2.4.2 Inductive Proximity Sensors

An inductive proximity sensor is in the same class named proximity sensors, which identify objects without actually contact them. The inductive proximity sensor only detects metallic objects and ignores all others [11].

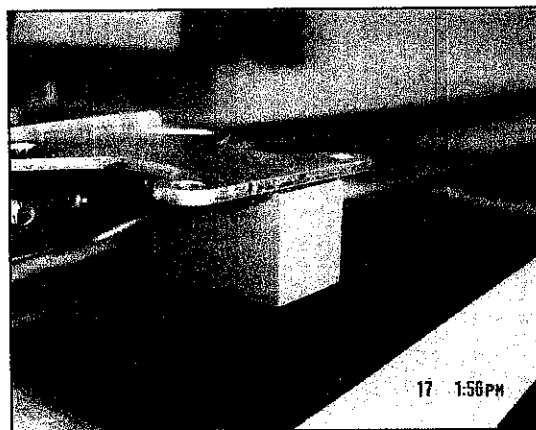


Figure 2.8: Inductive Proximity Sensor

The inductive sensor is a straightforward enough device at the fundamental level. It is simply a coil of wire with a current passing through it. It completely ignores most objects which pass near this coil. However, when a metallic object passes near it, it acts as a core material in the inductive loop which increases its inductance significantly. Most non-metallic objects have a negligible effect on its inductance. The complex part of the sensor is the sensing circuitry which detects this change in inductance by monitoring the electric current in the loop. When the inductance changes enough, it triggers the sensor's output, which sends a signal to some other machine to do whatever it is it is supposed to do when a metallic object is near the sensor.

The inductive proximity sensor is one more item in the massive line of sensor packages used in industrial automation. In this case, they are usually connected to a relay or PLC to provide sensing as part of a larger automated process. The major advantage of an inductive proximity sensor is the fact that it ignores nonmetallic objects. This is useful for locating metal parts, such as conveyors, lift tables, tipples, and machine parts, while ignoring any nonmetallic objects around, such as the goods being manufactured or packaging material like cardboard boxes or loading pallets, or the operator running the machine.

2.4.3 High Capacitive Basic Switch (Infra red Sensors)

A High Capacitive Basic Switch is not in the same class of proximity sensors, but this instrument is used to detect electromagnetic energy in the infrared spectrum.

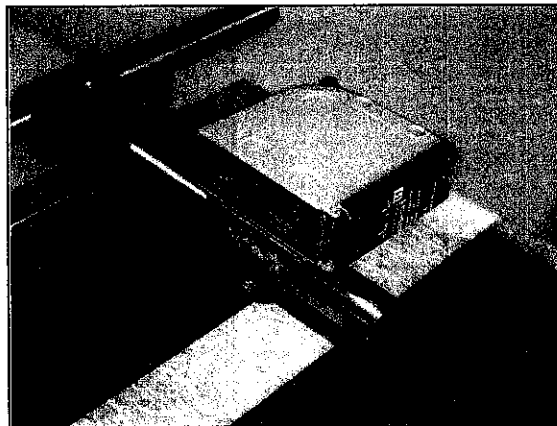


Figure 2.9: Infra red Sensor

This sensor is built from several millions photosensitive cells. When light hits the one of these cells, a release of free electrons in the silicon will occur. By applying a negative charge to the connected electrodes, the free electrons in the silicon will be repelled and the part of the substrate that is closest to the electrodes gets a positive charge. This charge is used to find out how much light hit the cell, the higher the charge, the higher amount of light hits [12].

2.5 Conveyer Belt

This project required 2 conveyers have been use for this project where one of the conveyers can move forward and backward. The relays connection box has controlled the direction of the conveyer movement. This device built of three relays inside and power by 24-volt dc. Output from PLC going straight following the connection that has been design into the connection box and the output from the connection box has been distributed to the following conveyer. Below are the pictures of PLC output terminal, Relays connection box and conveyer belt

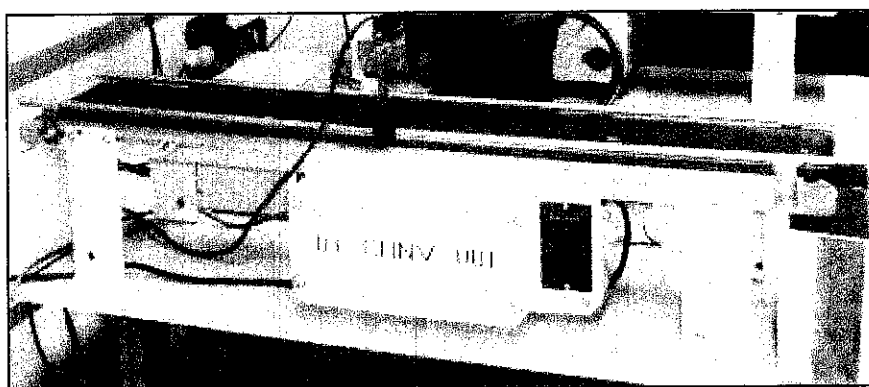


Figure 2.10: Conveyer Belt

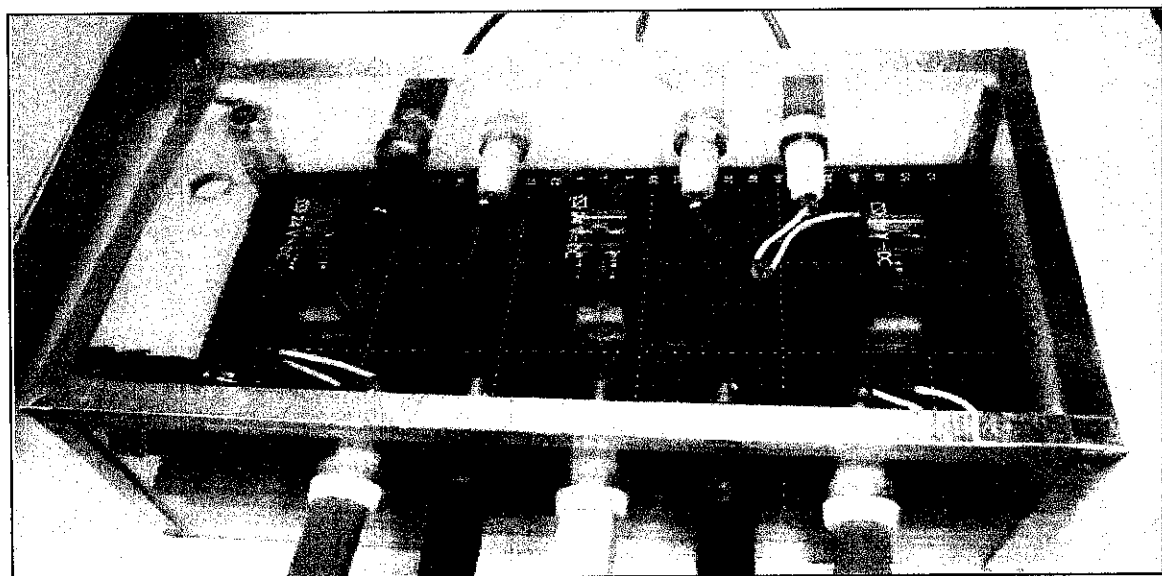


Figure 2.11: Relay connection box

CHAPTER 3

METHODOLOGY

3.1 Design Procedure

In conducting this project, the step-by-step methodologies have been outlined. The methods are divided into:-

- (i) Concept
- (ii) Integration / Programming
- (iii) Fabrication / Assembly
- (iv) Testing

3.1.1 Concept

The initial stage is brainstorming the purpose and task of the project. This is the key element for furthering in designing the FMS. The base idea of this project is to design and implement a pick and place system. The objective is to divide the product following the type of material of the component (metal and non-metal). The product is put into different boxes according to the material types. The signals from sensors (indicating material of product) are sent to the PLC. The PLC will then analyze the data received to determine the course of the robot for the next task. The PLC will then deliver the handshake signal to the robot to arrange the product in the required manner. From the concept of this project, the number of sensors used in the system can be determined. The detailed movement of the robot to pick and place the product is laid out carefully to ensure the smooth operation of the system. The important details like time sequence of the movement between each action of the robot are calculated carefully.

3.1.2 Integration / Programming

After perfecting the design, next is to concentrate on the integration part. This project involves 2 types of programming. First is completing the ladder diagram for PLC and later designing the coding for the robot movement. For this part, only the basic coding has been developed to allow modification once full system has been developed. Before starting the coding process, the flowchart has been designed to show the flow of the working diagram.

3.1.3 Fabrication / Assembly

After completing the coding and implementing it for both of the instruments, the next step is to fabricate the entire instrument including the sensors, PLC and robot. Equipment additions such as a rack or the box have been included to give a realization of an industrial atmosphere. Once the system is assembled, it will describe the relationship of the devices. The arrangement and placement of the sensors and the conveyor belts within the system and the distance from one device to another, is set considering the working envelope (area covered by movement) of the robot. The basic codes developed will determine the course of action of the robot.

3.1.4 Testing

The last step is to test all the systems. All of the error and weakness can be defined in this process. By doing simple modification to the integration the system can be further improved to produce a smooth flow reflecting the actual industrial system.

3.2 Running Siemens SIMATIC PLC

The initial stage in using Siemens SIMATIC PLC is to program the PLC itself. Ladder Diagram is the main programming method used for PLCs. STEP7-Micro/WIN 32 is the software which is the interface for the user to build the ladder diagram for Siemens PLC. This software is user friendly which includes all the instructions needed in constructing a complete system. Below figure shows the interface of the software

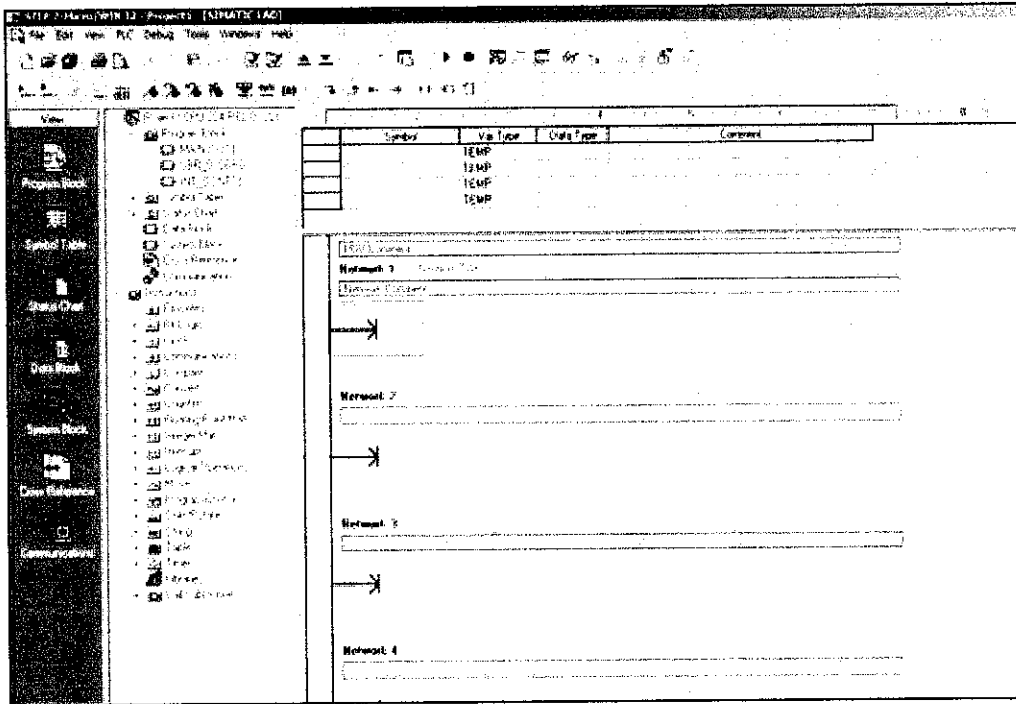


Figure 3.1: STEP7-Micro/WIN 32 software interface

To represent a complete control circuit, the development of the coding has to be made rung by rung. After designing the ladder diagram, the program will be sent to the PLC directly using cable. The connection is made between I/O serial port of user computer to the PPI (Programming interface port) at the PLC. After transferring the codes, the system can be tested using the internal input (switch) and the output result can be seen directly from the output LED. If the process needs any changes and modification, the same method as described above will be repeated until it suits the system. Finally all the external equipment such as sensors, conveyer and robot will be integrated into the input or output terminal orderly at the PLC.

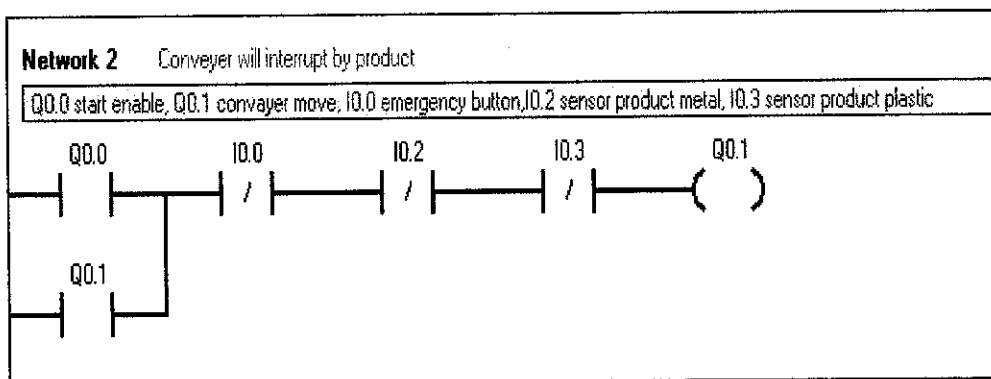
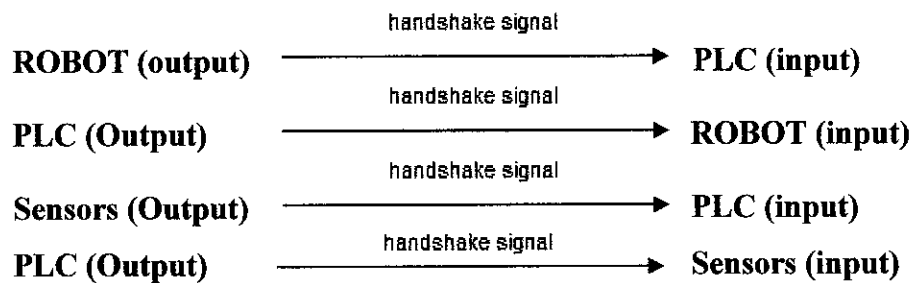


Figure 3.2: Example of the Ladder diagram develop in one complete rung

3.3 Integration of all the Equipment

The complete FMS must include robots, PLC, and sensors. For this setup, PLC is the brain of the system. Both sensors and robot only receives and gives the output signal to the PLC and PLC will conduct the following direction according to the ladder diagram. This is the idea of the integration of these 3 equipment:



For the wiring connection, sensors and robot are connected to the input and output panel at the PLC. For robot, the connection has to be made at the wago card (behind the KR C3). Figure 3.3 show the complete picture of wago card. There are 24 inputs and outputs panel can be used for the external input to connect to the robot.

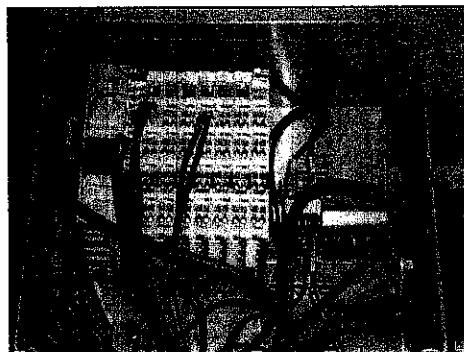


Figure 3.3: Wago Card

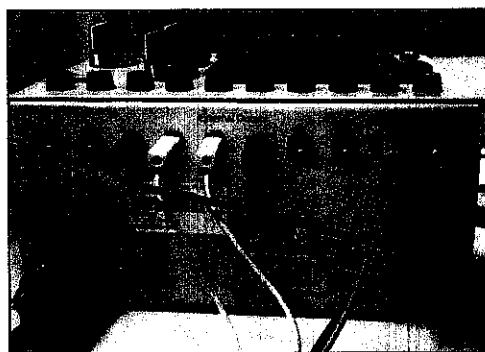


Figure 3.4: PLC External input

All this equipment must understand each other's signal in order to establish the connection. The most important thing is to make sure the entire signal given by each other is equal according to their input and output polarity. This is because in establishing the connection with PLC, consideration of sinking and sourcing input module and types of output NPN or PNP are important in selecting types of sensor and building the programming for robot (regarding their state "true" or "false"). For this project negative input and polarity have been used. Therefore the sensors have to come from the NPN type and robot has to use "false" state during establishing the external input connection.

CHAPTER 4

RESULT & DISCUSSION

After conducting the step-by-step methodologies of this project, including the assembly and modification of codes, the outcome of the project is observed. The results are recorded for further improvements of the system. The results are then elaborated to give a detailed description of the project. This section lays out the results and the discussion of the project.

4.1 Complete Small Scale of FMS

The systems define the operation of the FMS. Figure 4.3 give the complete real picture of FMS. The robot is given a task of dividing the products of a manufacturing line according to the material of the product. At the start of the system, the sensors will determine the material of the product manufactured whether it is metal or non metal. It is then picked up and put onto the conveyor belts leading to two boxes marked A and B. The conveyor belts will move to the right to box A or to the left to box B. At the box is a counter that will monitor the number of products put into the box. Upon reaching the desired maximum number of products in box, the conveyor belt will stop moving and no more products will be put in the box. Figure 4.1 show the complete flowchart:

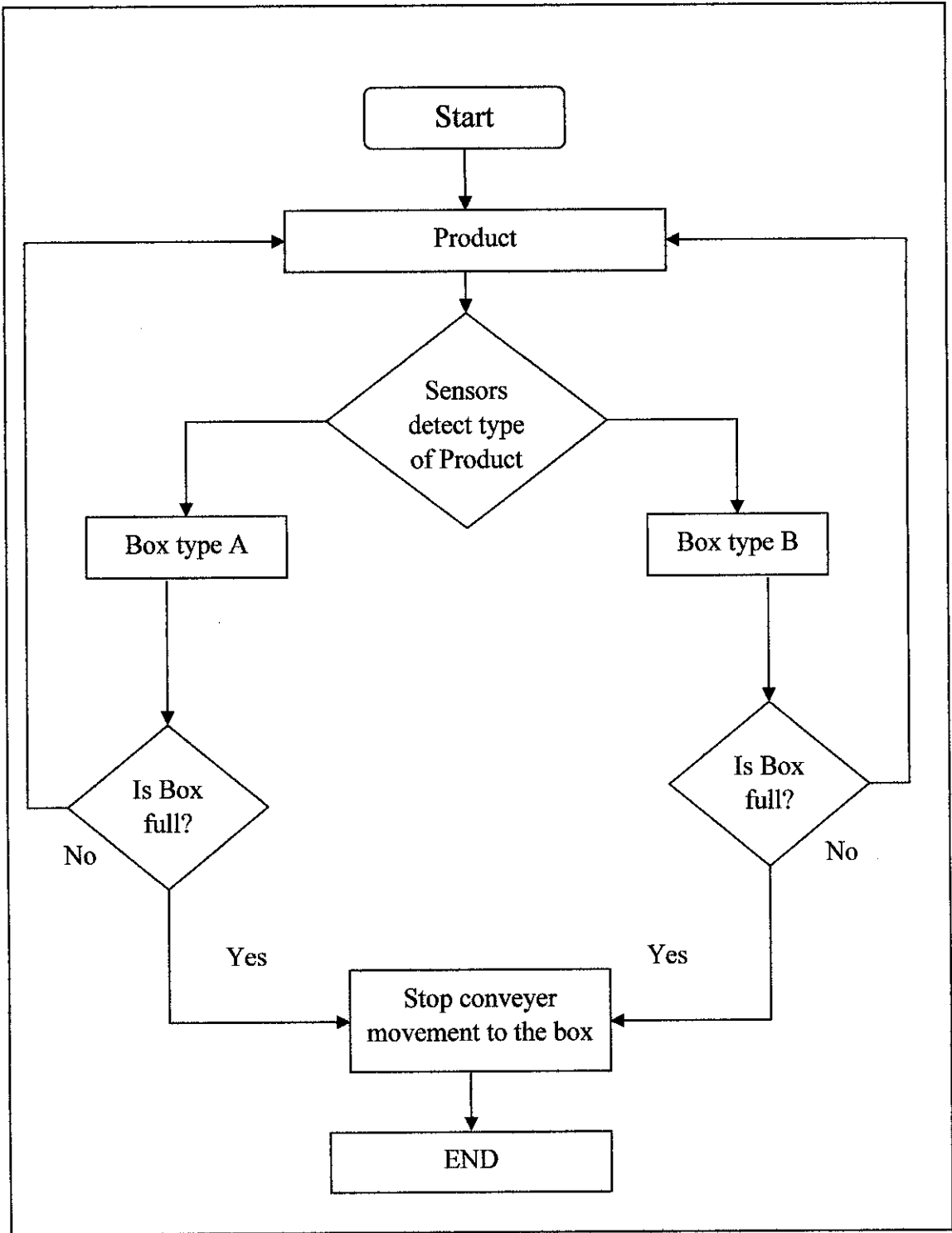


Figure 4.1: System Flowchart

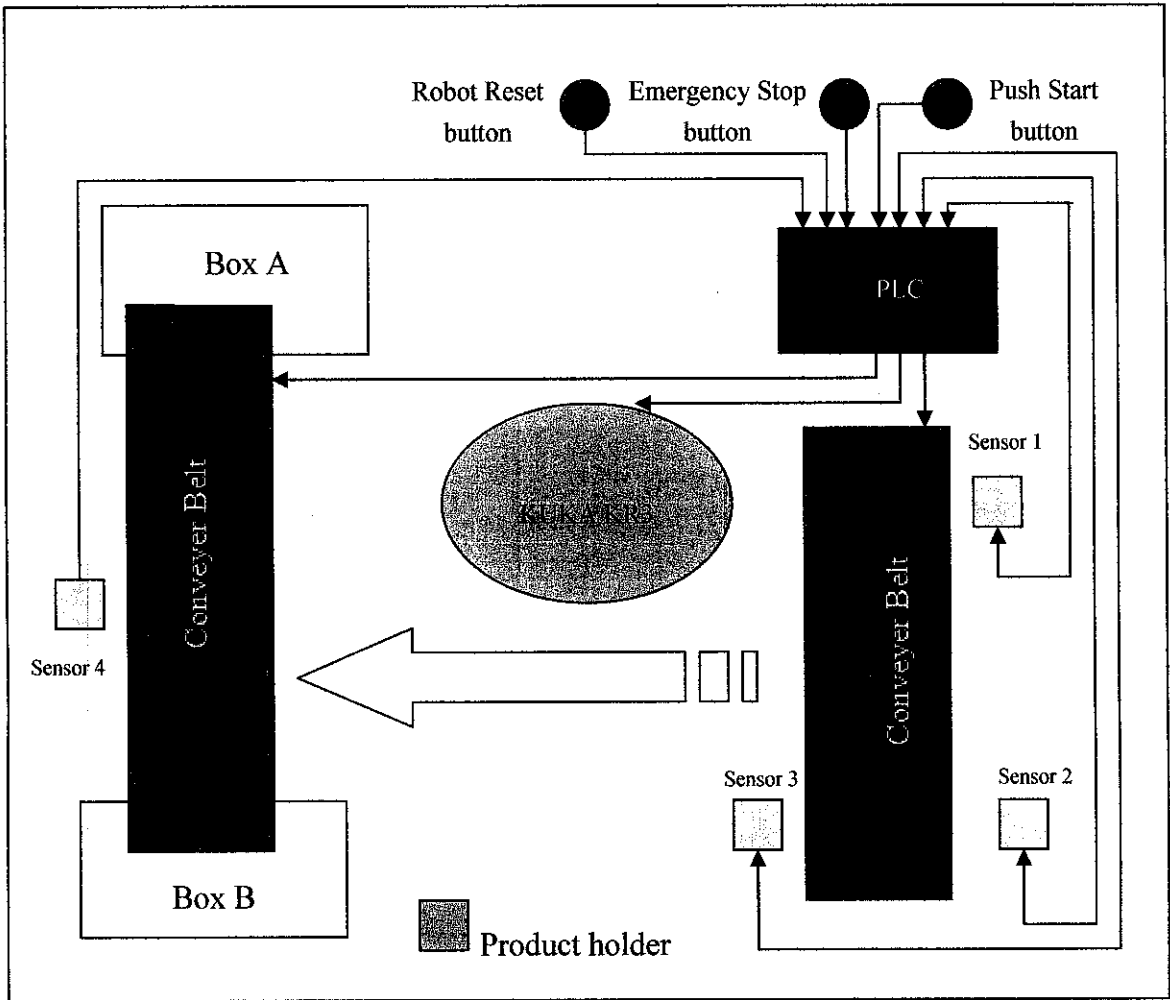


Figure 4.2: Diagram of the Small Scale of FMS

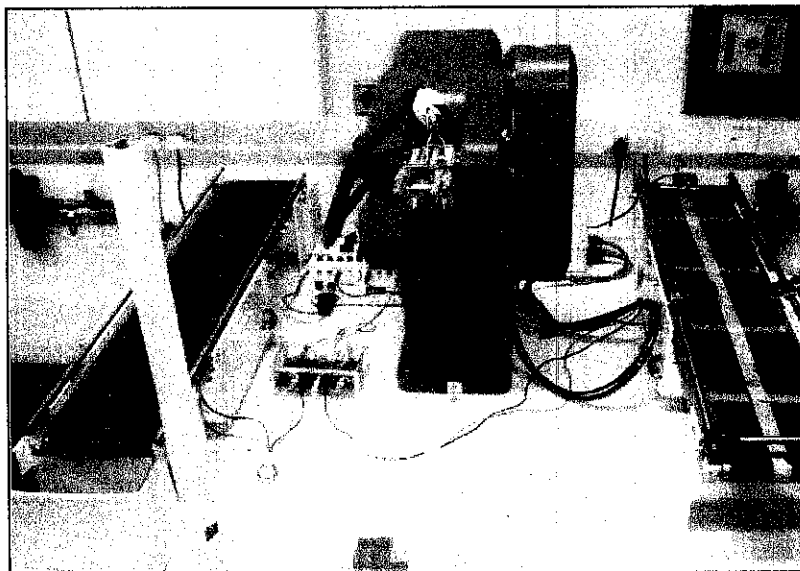


Figure 4.3: Picture of FMS

Flow of the FMS process

Firstly, user will push the Start button to Switch on the system. Then the Robot Reset button is pushed to enable the process. Secondly, the robot will take the product from the product holder. The robot will move the product onto the conveyor belt placing it within the sensor 1 sensitivity area. Next, Sensor 1 detects the object and object will move along the conveyer belt. Then the conveyer belt automatically stops when it reaches the sensitivity area of the second and the third sensor. Sensors 2 and 3 will identify the material of the product. The robot will receive a signal from the second and third sensor and move the product onto the other conveyer belt.

Upon arriving at the second conveyor belt, the fourth sensor will detect the arrival of product. The conveyer belt automatically moves the product directly to the proper packaging based on the information (type of material) provided by the sensor 1 and 2. The conveyor belt will move towards the right to the box marked A for plastic and move to the left towards box marked B for metal.

The processes will repeat itself with the robot collecting another product. The robot will start collecting the second product as soon as the last product has been put into the box and the conveyor belt has stopped moving.

If one of the packaging boxes has reached desired number of products, the process will only concentrate to the other packaging which is still not full. In the case a full box, if the KUKA robot picks up a material of the said box, when the product is put on the conveyer belt, the conveyor belt will stop moving and the operation of the system is halted until the box is replaced with a new one and the product is removed from the conveyor belt. The reset button must be pushed in order to restart the operation of the system.

4.2 KUKA KR3 coding and explanation

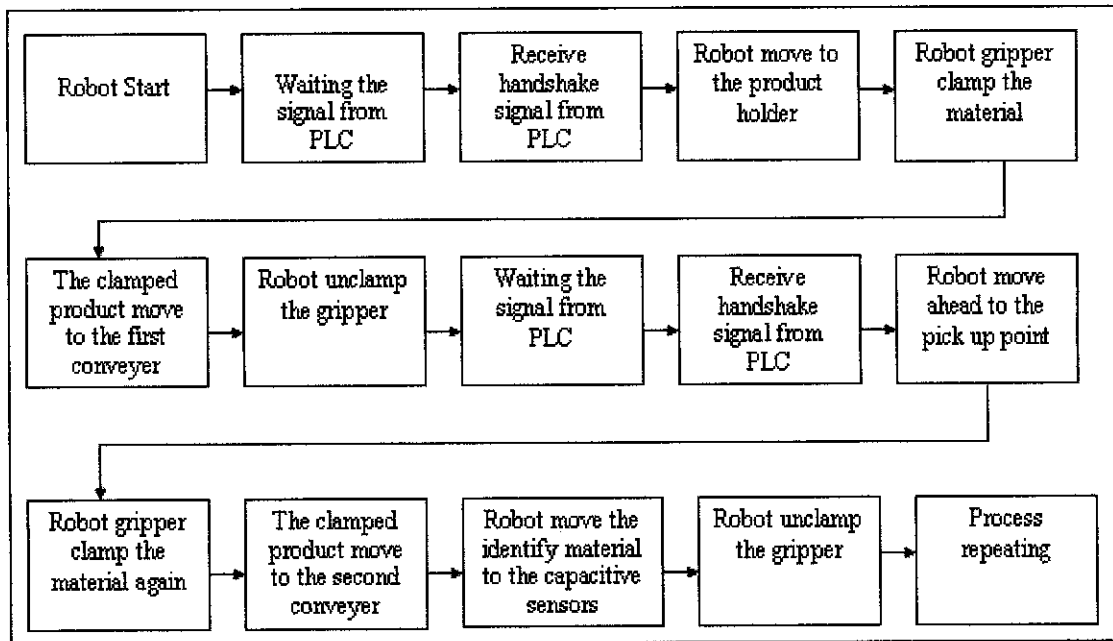


Figure 4.4: Robot Flowchart

Flowchart above (figure 4.4), describe the robot movement for the whole complete FMS. Robot will move by the following coding that been design following the desire movement. Next is describing all the programming coding for robot movement.



Figure 4.5: Robot code line 1-3

Figure 4.5, the programming starts with sign “INI” which mean initial. This is the basic code which will appear during starting of the program window. At line 2 the code “LOOP” is to repeat all the program code when it reaches the end. This code is followed by “ENDLOOP” at the line 37(last line). Line 3 coding is to coordinate the robot in the home position. Figure 4.6 describe the robot initial position.

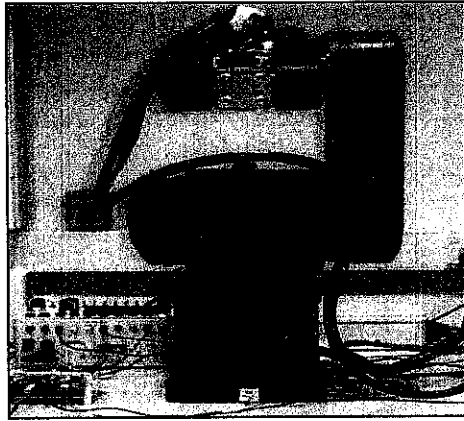


Figure 4.6: Robot in initial position

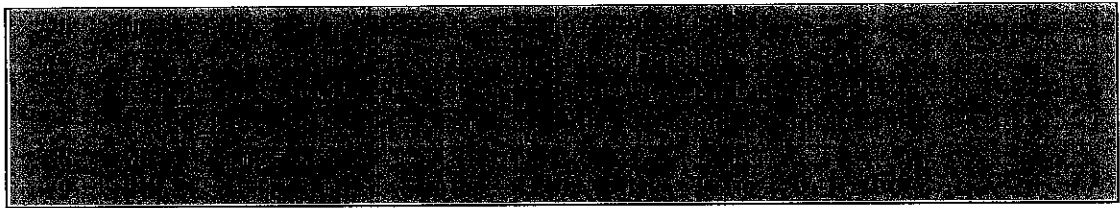


Figure 4.7: Robot code line 4-9

Next coding is “**WAITFOR in 6 ‘infra’** referring figure 4.7. This coding means the robot will not take any action before receiving an external input from PLC. Line 5-7 is actually the program for the robot to go to the product holder and pick the materials. Then robot will freeze for 1 second for the coding “**WAIT Time 1**” before move to the other task. The code for the next line is “**PULSE 1 ‘clamp’**”. The purpose of this code is to clamp the product from the product holder by the gripper.

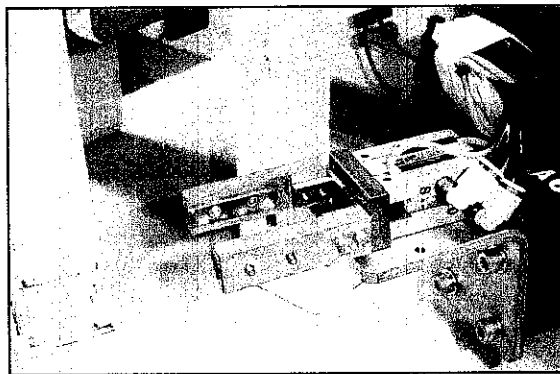


Figure 4.7: Gripper ready to clamp the product

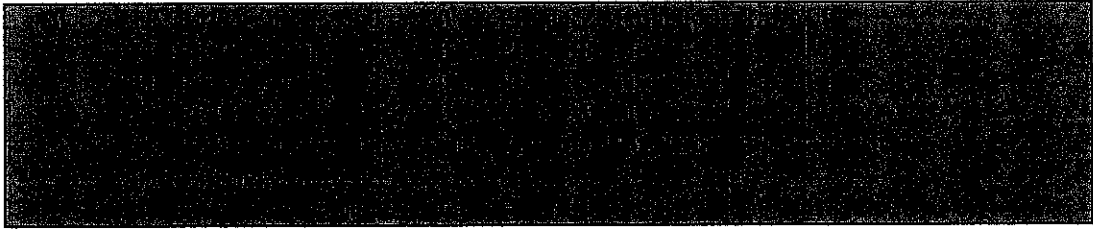


Figure 4.8: Robot code line 10-16

Figure 4.8, the codes from line 10-14, show the robot to move the clamped product to the first conveyer belt. The next line, Line 15 is “**WAIT Time 1**”. Then the robot is unclamping the product using “**PULSE 2 ‘unclamp’**” code in line 16. Robot unclamps the material on the conveyer belt.



Figure 4.9: Gripper unclamp the product

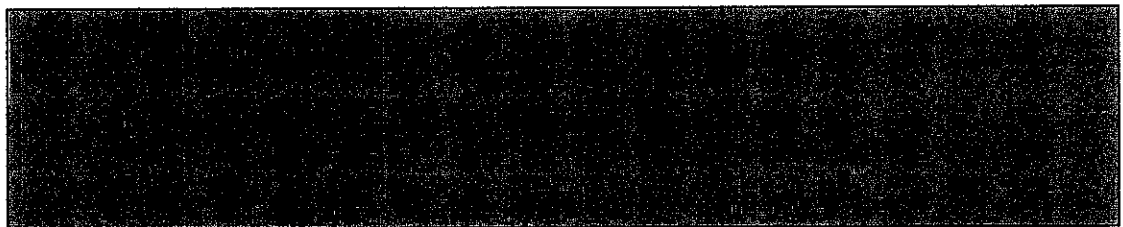


Figure 4.10: Robot code line 17-23

Figure 4.10, line 17 requires the robot to wait for 6 second under coding “**WAIT Time 6**”. Line 18 is the program for the robot to move to the other position at the conveyer belt. Next code is “**WAITFOR in 4 ‘plc’**“. The Robot will wait before moving to another task until PLC sends a signal. Line 20-21, shows the code for the robot to adjust the gripper to the same position where the material will be dropped. At

the next line robot will freeze for another second for the code **“WAIT Time 1”**. At Line 23 the code is **“PULSE 1 ‘clamp”**”. Figure 4.11 shows the gripper clamps back the materials which have already been identified of the material type by the sensors.

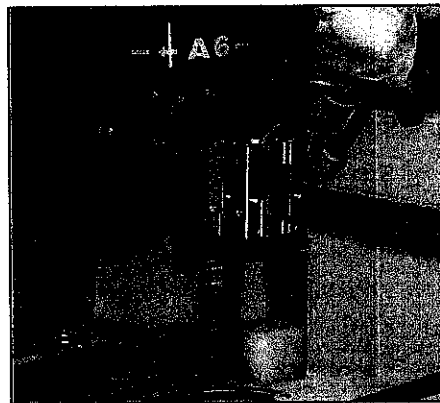


Figure 4.11: Gripper clamp back the product and move to the other conveyer



Figure 4.12: Robot code line 24-29

At line 24-27 referring figure 4.12, the code describes the movement of the robot to bring the material to the next conveyer belt. After that, the robot will freeze for a second under the code **“WAIT Time 1”** before moving onto the other task. At line 29, coding of **“PULSE 2 ‘unclamp”**” refers to the robot releasing the gripper and drop the product at the second conveyer belt.

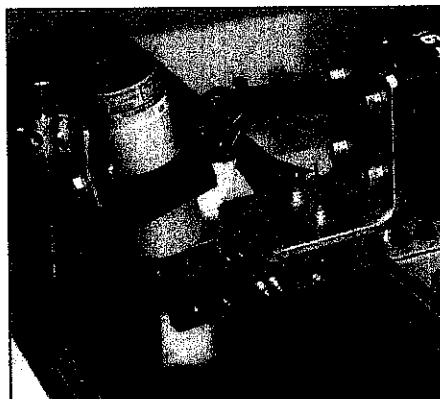


Figure 4.13: Gripper unclamp the material at the second conveyer

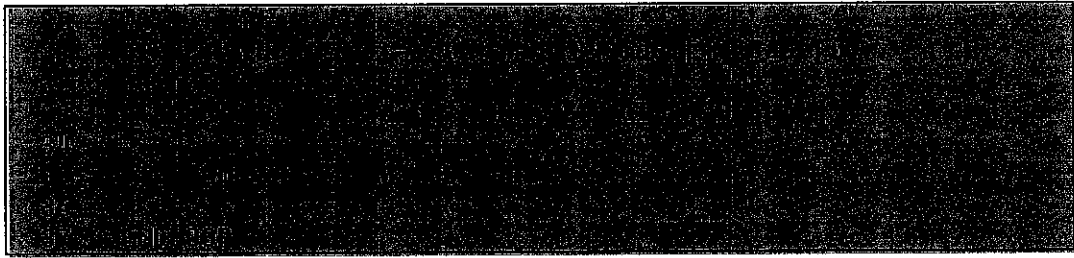


Figure 4.14: Robot code line 30-37

At line 30 following figure 4.14, the robot will again freeze for one second following the “**WAIT Time 1**” code. Lastly from line 31-35 are the codes for to robot move back to the initial position and this process will repeat until it is stopped by the user.

4.3 PLC

This section covers all parts regarding PLC involving inputs & outputs and all the explanations regarding Ladder diagram corresponding to the flow of the system

4.3.1 Inputs & Outputs

This part introduces the input and output of the PLC. It is divided into three parts which is input signal, output signal and counter/timer.

Input	Assigned equipment / signal and task
I 0.0	Switch button (Emergency Stop)
I 0.1	Push Start button
I 0.2	Sensor detect product A
I 0.3	Sensor detect product B
I 0.4	Sensor spot product arrive at conveyer
I 0.5	Reset counter 1
I 0.6	Reset counter 2

I 0.7	Sensor detect product reach the conveyer belt
I 1.0	Switch button (Robot initial start)

Table 4.1: Inputs of the PLC

Table 4.1 describe about inputs of the PLC. Input signals come from the sensor and the Switch button. It will be fed into the PLC to trigger the PLC to begin to operate to identify type of material and reset the system. It also serves the purpose of system protection by using the emergency stop button. The sensors also work to detect the presence of the product at the conveyor belt.

Output	Assigned equipment / signal and task
Q 0.0	Output signal ('Enable Start')
Q 0.1	Output signal (to move the conveyer 1)
Q 0.2	Output signal (Direct robot to pick the product)
Q 0.3	Output signal (Detect product at conveyer 2)
Q 0.4	Output signal (Indicating product A)
Q 0.5	Output signal (Indicating product B)
Q 0.6	Output signal (Move conveyer to box A)
Q 0.7	Output signal (Move conveyer to box B)

Table 4.2: Outputs of the PLC

Next table 4.2 tells about Output of the PLC. The output signals are the effects of the processing of the input by the PLC. There are eight outputs in the system. The effect of the output is the movement of the first conveyor belt. It will then communicate with the second conveyor belt to move either to right or left. The output also sends a handshake signal to the input of the robot.

Counter/Timer	Assigned equipment / signal and task
C 1	Counter Product A
C 2	Counter Product B
T 33	Timer for conveyer belt to move the product to metal box
T 34	Timer for conveyer belt to move the product to plastic box
T 35	Timer indicating material- metal
T 36	Timer indicating material- plastic
T 97	Timer for conveyer to move the material near to sensors sensitivity area

Table 4.3: Counter and timer of the PLC

The counter will count the number of products put into the box depending on the desired amount set beforehand. Table 4.3 describe about the counter and timer of the PLC. The timer limits certain movement of the conveyer belt. It also allocates the time for the sensor to identify the material.

4.3.2 Ladder diagram explanation

The explanation of the ladder diagram is been describe rung by rung. These Ladder diagrams have 15 rung all together in completing this whole small scale FMS system. Below is the complete ladder diagram including the explanation of each rung:

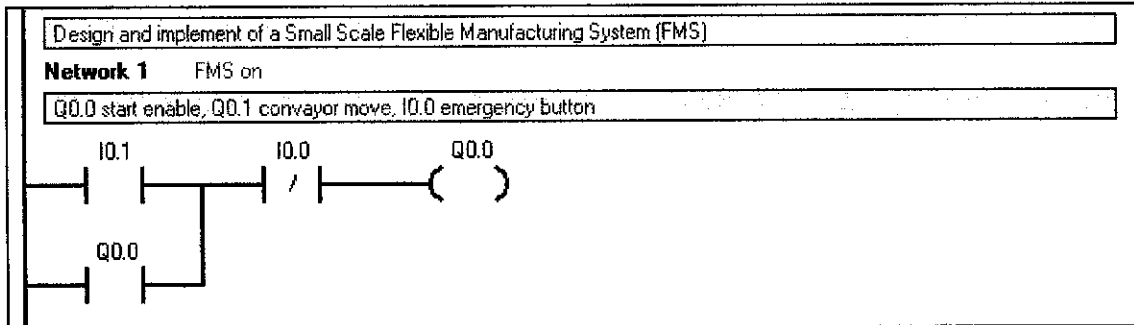


Figure 4.15: First rung

- Figure 4,15, output Q0.0 will turn on if I0.1 is on. It will be on continuously once. It is turned on but will only stop when I0.0 is turned on.

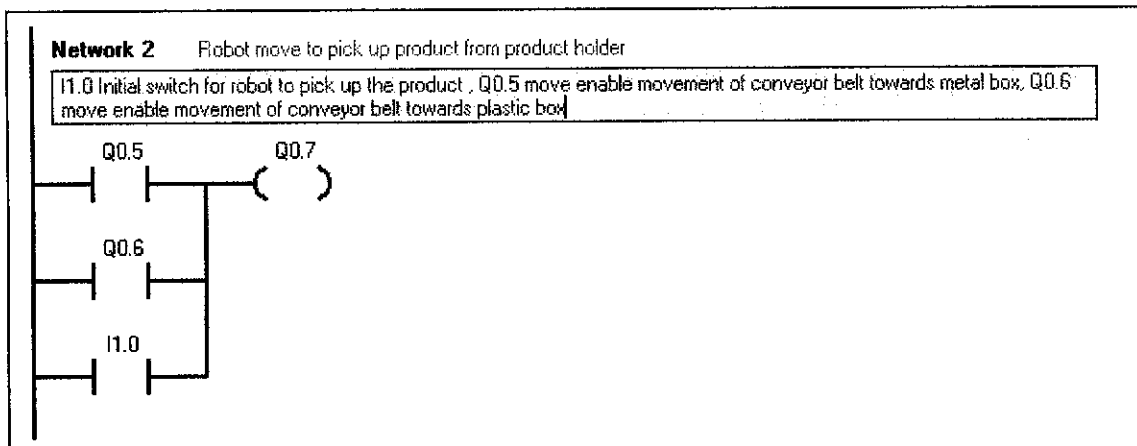


Figure 4.16: Second rung

- Figure 4.16, Q0.7 will only function when either Q0.5,Q0.6 and I1.0 turns on

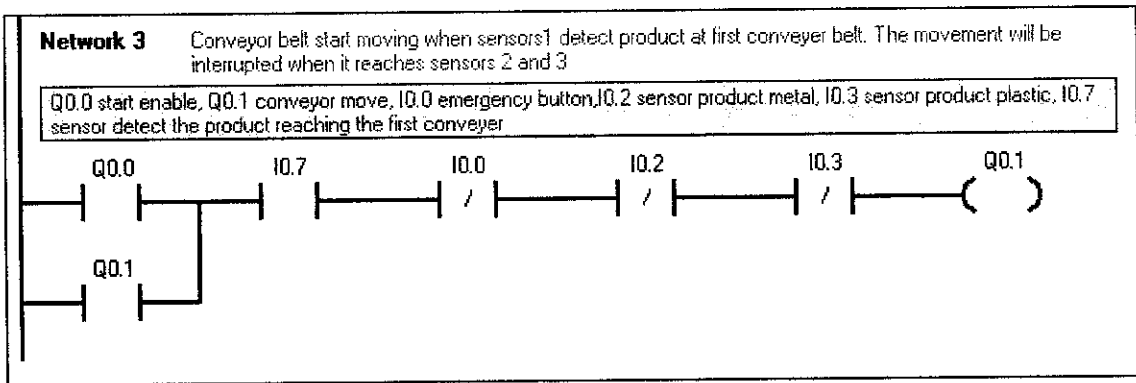


Figure 4.17: Third rung

- Figure 4,17, Q0.1 will only function when Q0.0 and Q0.7 in on. It will run continuously even Q0.0 will turn off back. The process of this rung will be interrupted if any one of I0.7, I0.0, I0.2, or I0.3 is turned on.

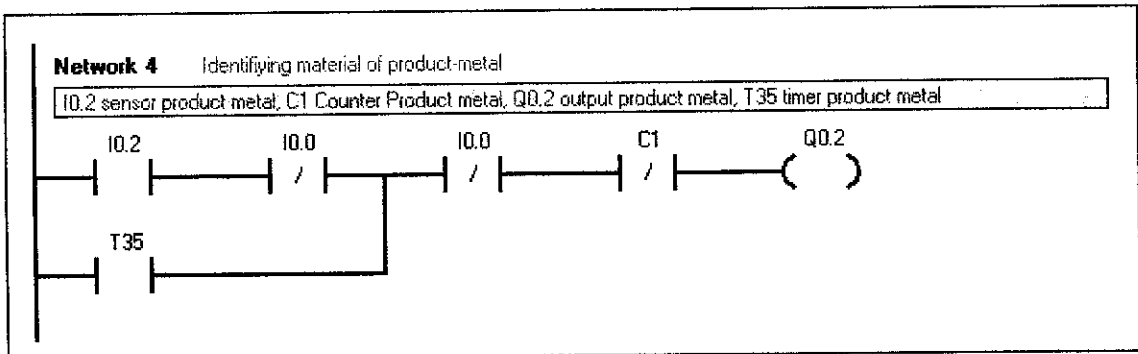


Figure 4.18: Fourth rung

- Figure 4.18, this rung will function when I0.2 is on. It also will continue function when T35 is turn on. Output Q0.2 only can be interrupted when I0.0 and C1 is switch to normally open.

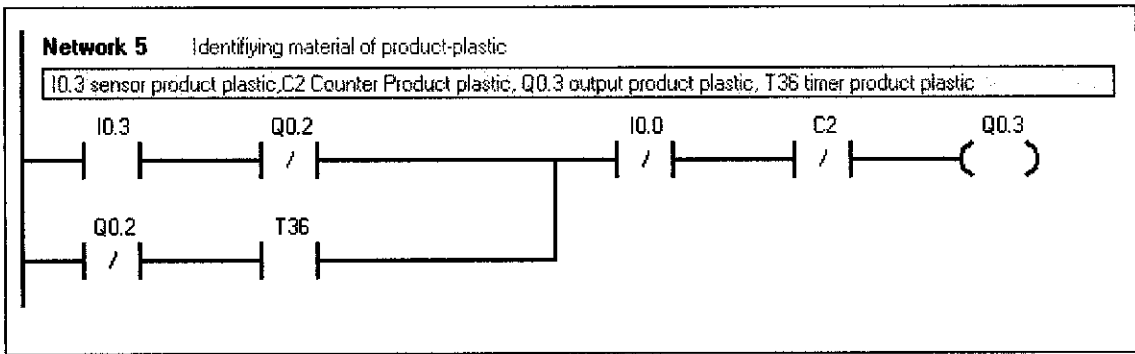


Figure 4.19: Fifth rung

- Figure 4.19, this rung will function when I0.3 is on. It also will continue function when T36 is turn on. Output Q0.3 only can be interrupted when Q0.2, I0.0 and C2 is switch to normally open.

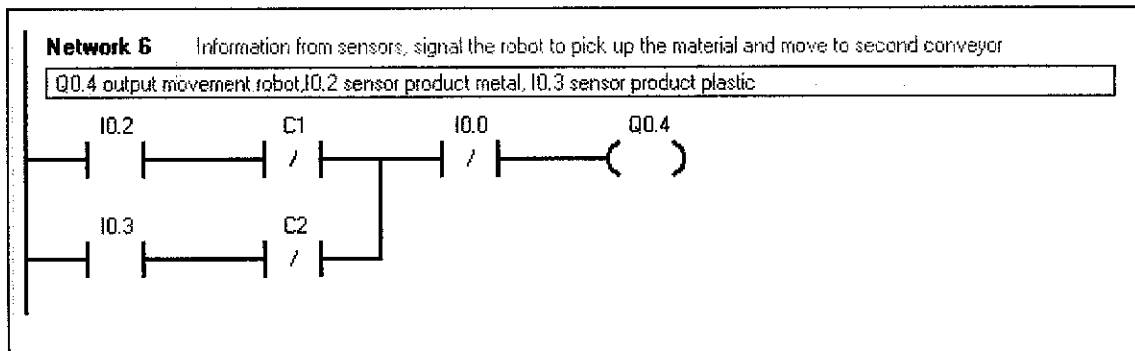


Figure 4.20: Sixth rung

- Figure 4.20, Q0.4 will turn on when either I0.2 is on or I0.3 is on. This rung can only be stop if I0.0 is open.

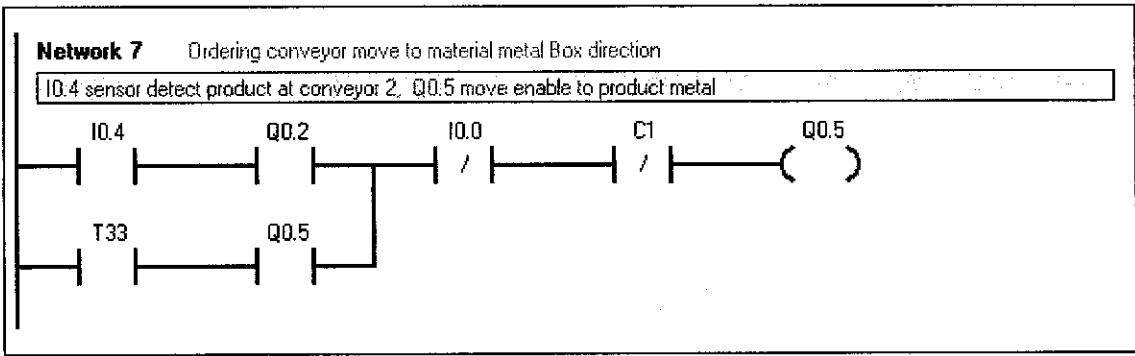


Figure 4.21: Seventh rung

- Figure 4.21, Q0.5 will turn on when either I0.4 with Q0.2 is on or T33 with Q0.5 is on. This rung can only be stop if I0.0 or C1 is open.

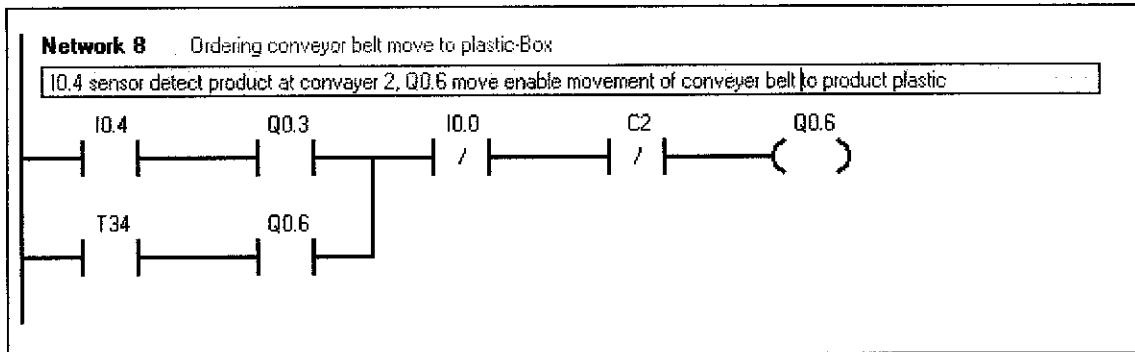


Figure 4.22: Eighth rung

- Figure 4.22, Q0.6 will turn on when either I0.4 with Q0.3 is on or T34 with Q0.6 is on. This rung can only be stop if I0.0 or C2 is open.

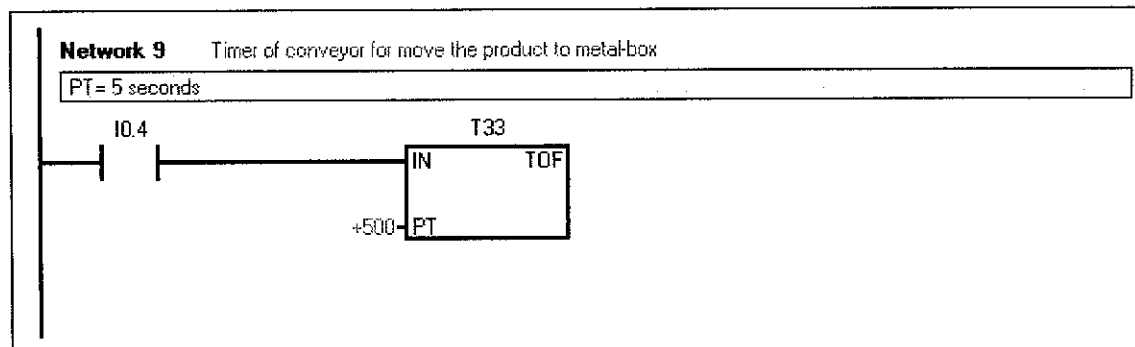


Figure 4.23: Ninth rung

- Figure 4.23, Timer T33 will start counting when I0.4 function

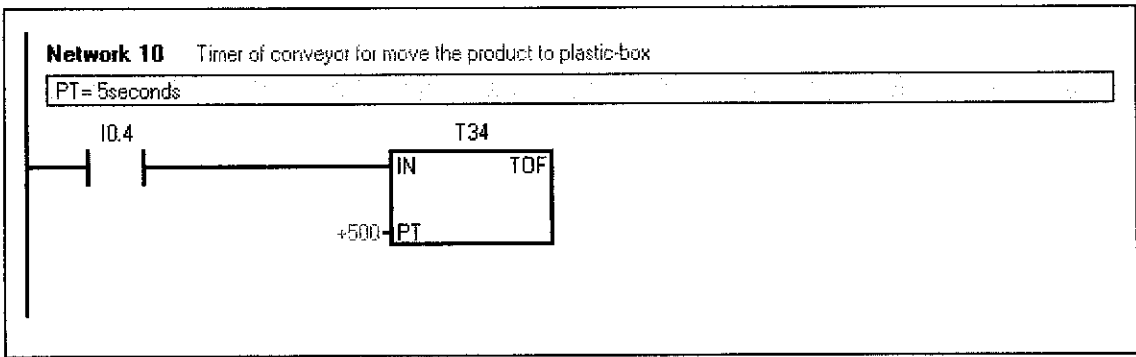


Figure 4.24: Tenth rung

- Figure 4.24, timer T34 will start counting when I0.4 function

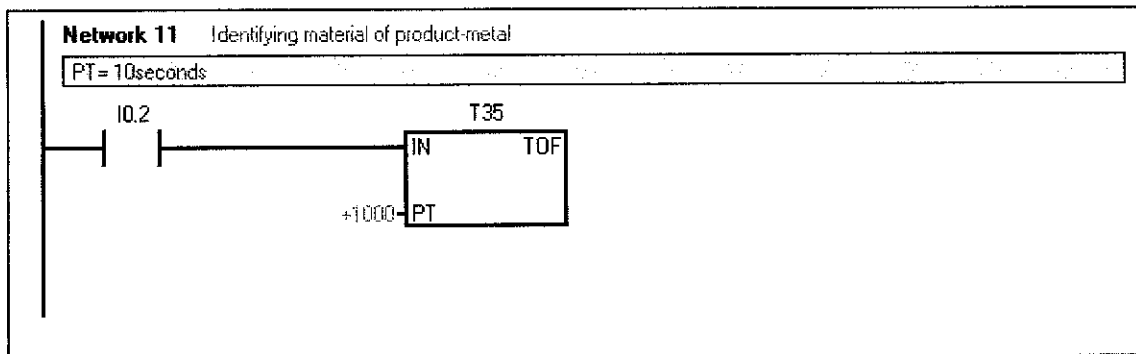


Figure 4.25: Eleventh rung

- Figure 4.25, timer T35 will start counting when I0.2 function

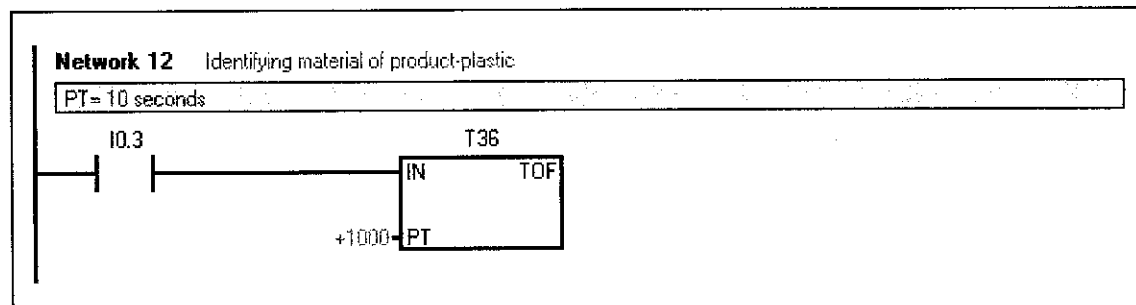


Figure 4.26: Twelfth rung

- Figure 4.26, timer T36 will start counting when I0.3 function

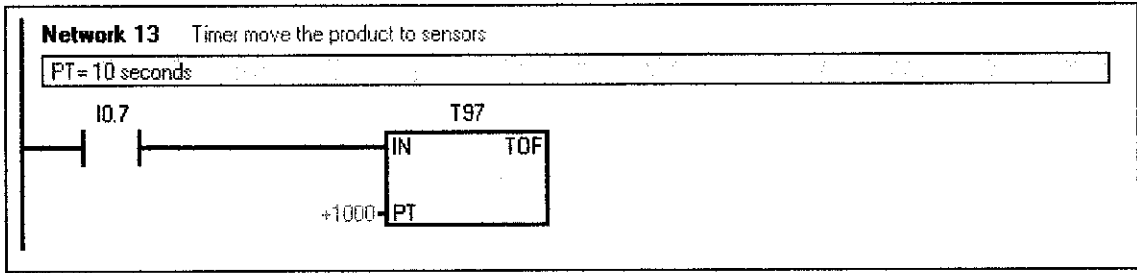


Figure 4.27: Thirteenth rung

- Figure 4.27, timer T97 will start counting when I0.7 function

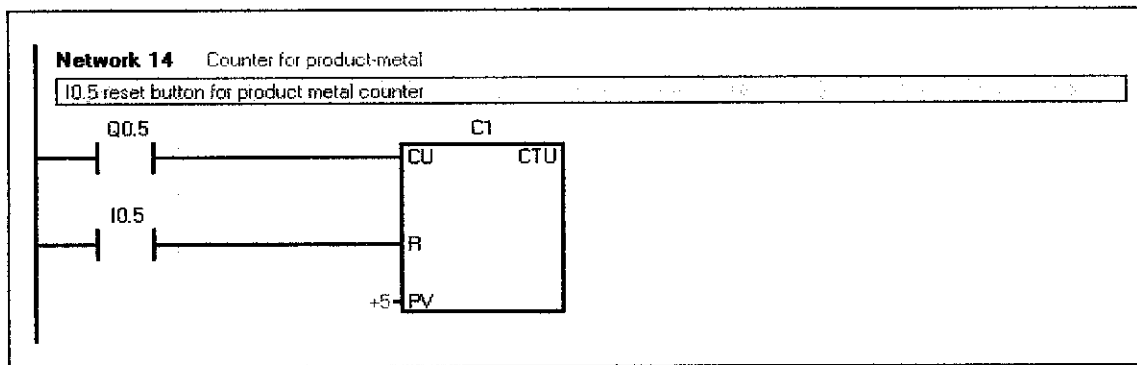


Figure 4.28: Fourteenth rung

- Figure 4.28, counter CI will start counting when Q0.5 function and can be reset back by I0.5

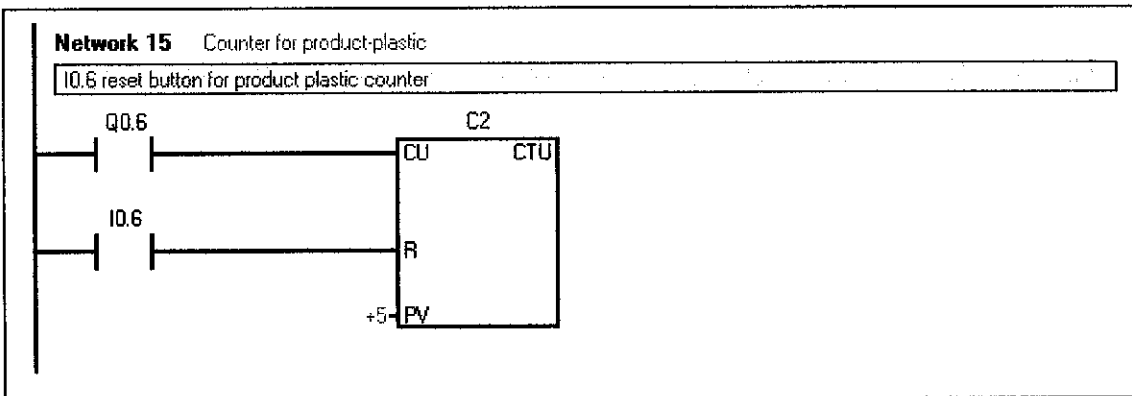


Figure 4.29: Fifteenth rung

- Figure 4.29, counter C2 will start counting when Q0.6 function and can be reset back by I0.5

4.4 System Efficiency

After the FMS system works, this system has been tested on the sensor efficiency and the whole movement of the system has been monitored. For each test, the system will be run thirty times without stopping and all the data is obtained. Below are the results of the efficiency test of the system:

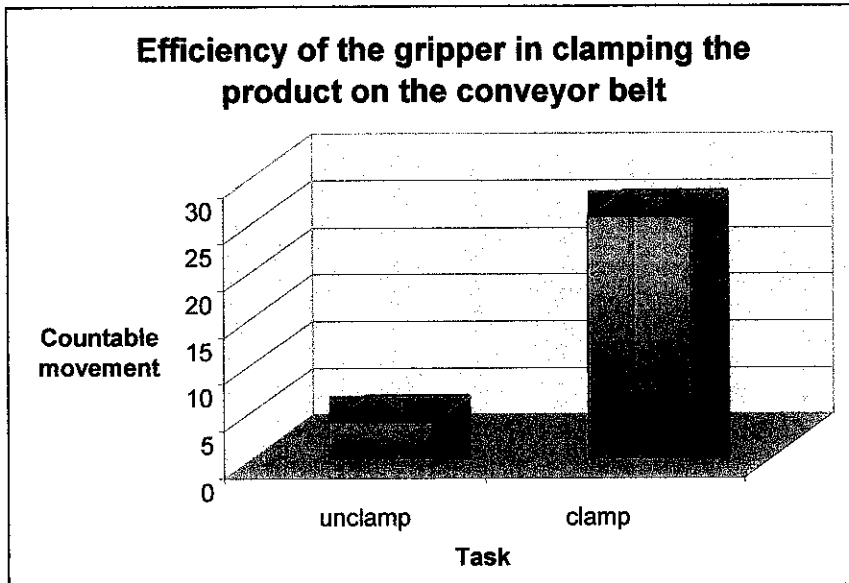


Figure 4.30: Efficiency the Gripper in Clamping the Product on Conveyor Belt

The graph has shown in figure 4.30 the efficiency of the robot gripper in moving the product from the first conveyor belt to the second conveyor belt. The reason why at some time of operation the gripper did not grip the product is because the conveyor belt did not run smoothly. The conveyor belt jerks occasionally which caused the product on the belt to move out of place making the gripper did not clamp the product.

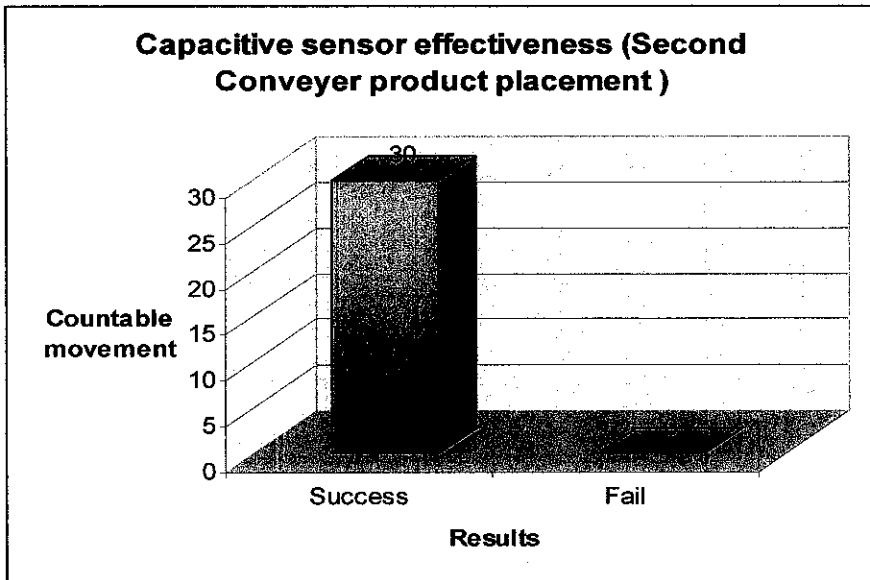


Figure 4.31: Graph of Capacitive Sensor Effectiveness

The graph has shown in figure 4.31 that the capacitive sensor works correctly. The sensor is 100% efficient. This is a wide sensor range. The success is also helped by the accurate placement of the product within the sensor sensitivity range.

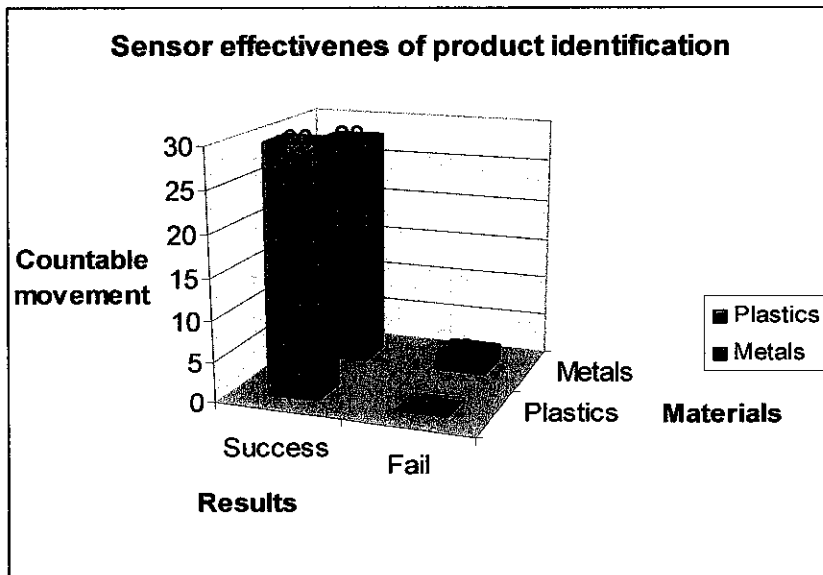


Figure 4.32: Graph of Sensor effectiveness of product identification

The graph has shown figure 4.32 the efficiency of the second and third sensor. These two sensors detect and identify the material of the product whether it is metal or plastics. The plastics sensor is 100% accurate but the metal sensor has the success rate 93%. This is due to small sensitivity range of the metal sensor. The conveyor belt

does not have a smooth movement. A shift displacement of the product away from the sensitivity range caused by sudden jerk in the movement at the conveyor belt makes it impossible for the sensor to detect the product material

CHAPTER 5

CONCLUSION

Flexible Manufacturing System (FMS) is a “programmable” manufacturing system capable of producing a variety of products automatically. FMS consist of the integration of several equipment such as robot, Programmable Logic Controller (PLC) and sensors. In completing the project, we have to find the conditions and limitations for the devices to communicate with each other. The objective of this project is to bring the industrial technology students and study the functions and simulate the actual industrial operation. The main challenge of this project is to integrate three stand alone devices and put it into a system. The devices are connected by modifying the input polarity of the devices to wire it together. Processes to complete this project include research on concept, integration and programming and fabrication and assembly. After that, the system is tested to observe how it works and to improve the system. The FMS functions to divide two types of material, metal and plastic and place it according to boxes within the desired number in each box. The system proved to be successful. The system can be improved in many ways such as the ability of robot to identify material by improving the movement of the conveyor belt. The robot movement can also be extended and not only restricted to pick and place. Codes can be added to add task like changing position of products and rearranging products. This project is a simulation of an actual industrial operation. This project is completed in hopes of exposing students to the FMS and encourage student to appreciate and study FMS.

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- [7] Operating manual for KUKA KR3 with KR C3 Control Cabinet: Section Introduction of KUKA KR3, Page 3
- [8] Operating manual for KUKA KR3 with KR C3 Control Cabinet: Section Operate KUKA KR3, Page 1-15
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- [11] Manual of Omron TLQ Compact Rectangular Inductive proximity sensors
- [12] E3S-AT21 High Capacity 20A Basic Switch Manual

APPENDICES

APPENDIX A

Developing the Coding

Before starting to write the coding, the user has to create a new module for storing all the coding. Below are the steps by steps instructions in developing the folder at The Navigator (file manager):

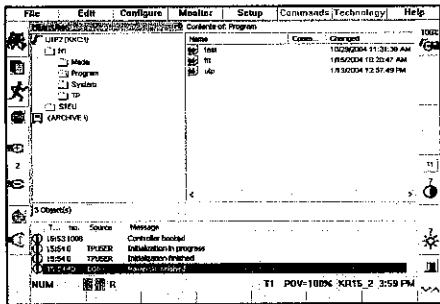


Figure 1: The Navigator

- This is the KCP displays after the controller has run up which called The Navigator (file manager).

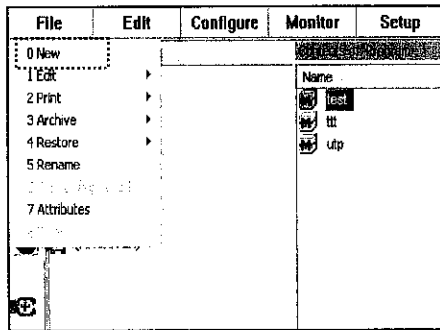


Figure 2: Built the new module

- Next, open “File” by pressing the corresponding menu keys. Then select “New” from the menu

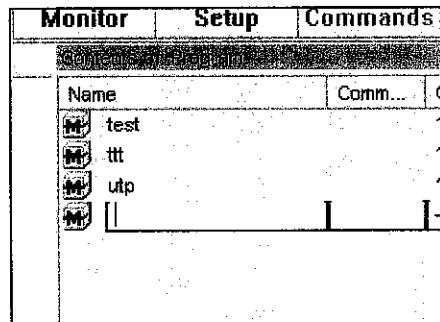


Figure 3: Write the module name

- An empty input line will come out at the file window, then enter the desired name of the module in the input line. Example “KUKA”. Press the softkey “OK” to save

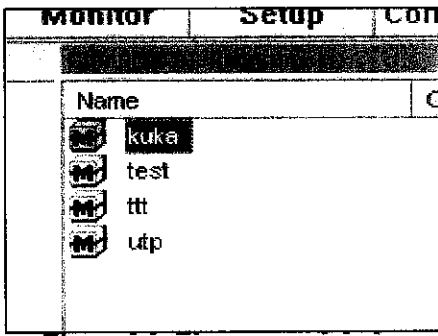


Figure 4: The new module for programming robot

- The desired file will be displayed in the file window. The module is ready for the user to develop the coding. By pressing the Enter key, the interface will switch to the program window and is ready for the coding to be done.

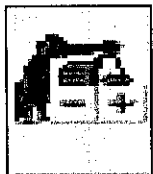
In developing the coding for the robots movements, a few adjustments have to be considered. First is selecting the coordinate system (at the middle right of the display). To move the robot manually, using the traversing keys (left of the display); users have to select a coordinate system on which the robot movements are to be based. The most popular and easiest coordinate system is the “Joint coordinate system”.



Joint coordinate System

- Each of the robot axes can be individually move in positive or direction

Next is to select the Traversing mode (at the top left of the display). This is the function used to select whether to use “Space mouse” or “Traversing keys” in moving the robot for the coding purpose. For the beginners, traversing keys are the best because it indicates the axis of the robots movement corresponding to the left side of the status keys.



Traversing keys

- Enabling to move robot using the left-side status keys

After this 2 major setup has been made, the user can write the coding for the robot. For the coding, the user has to move the robot from its home position. Next move the robot in the direction of interest and the coding for the robots movements will be recorded. Users have to use push button commands from the interface then select

'PTP' from the commands subfolder. The direction of the robot movement will be recorded. For using external inputs such as gripper, user has to select button command then choose logic subfolder. By selecting "WAIT FOR IN" there are a few options that the user has to choose before finalizing the coding, and then automatically the coding will appear on the program windows. In making the coding for this robot, there are many other options on the command menu applicable for the user to select in order to move the robot. Below are the step by step instructions in writing the codes.

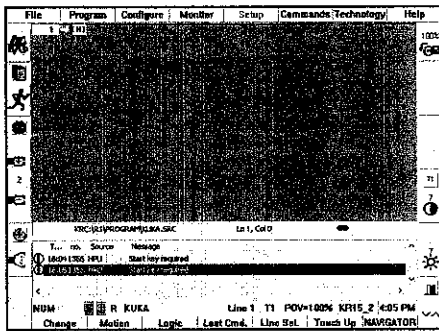


Figure 5: Program window

- This is the initial screenshot of the program window to shows the content of the program.

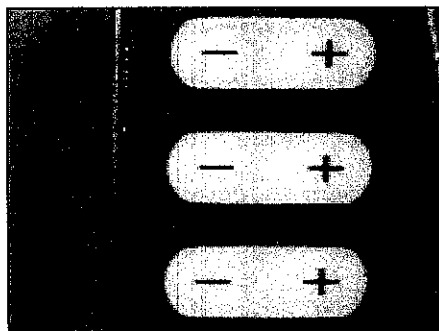


Figure 6: Traversing keys

- Move the robot using the left side status keys with the enabling switch (rear of the KCP) for the direction or movement that user requires

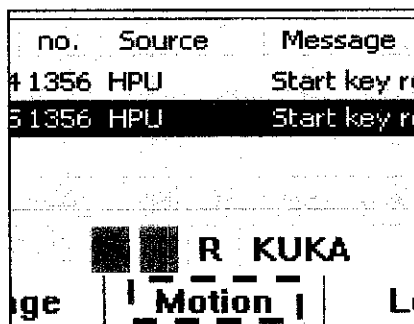


Figure 7: Select "Motion"

- Then press the softkeys corresponding to select the "motion" function.

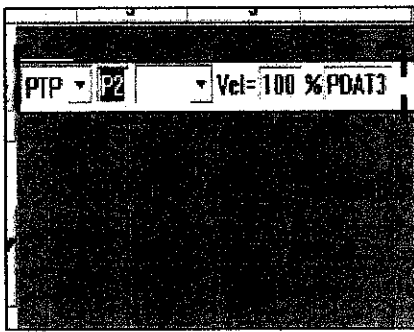


Figure 8: Input line

- An input line will be displayed on the program window. User can change the robots way of movement and the velocity.

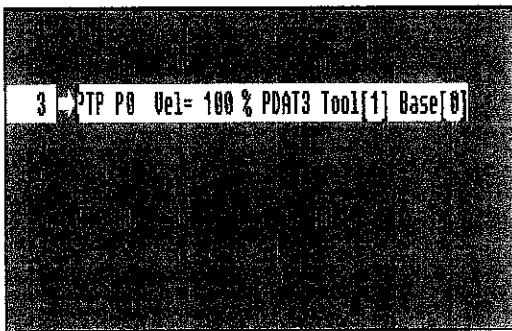


Figure 9: New line coding

- After pressing the enter key, a new line will be displayed indicating the robot movement programming

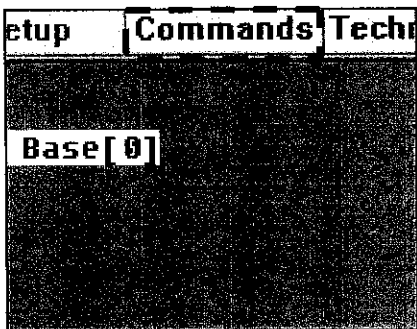


Figure 10: Select command function

- Another condition is to include external sensor such as gripper or handshake signal from PLC in the robot programming. To enable it, open the “Commands” by pressing the corresponding menu key.

Commands	Technology	Help
0 Last command		100%
1 Motion		
2 Moveparams		
3 Logic		0 WAIT
4 Analog output		1 WAITFOR
5 Comment		2 OUT
6 KRL assistant		3 IBUS-Seg. on/off

Figure 11: External input

- Select the “Logic” from the menu open. Then go for “WAITFOR” option from another open menu.

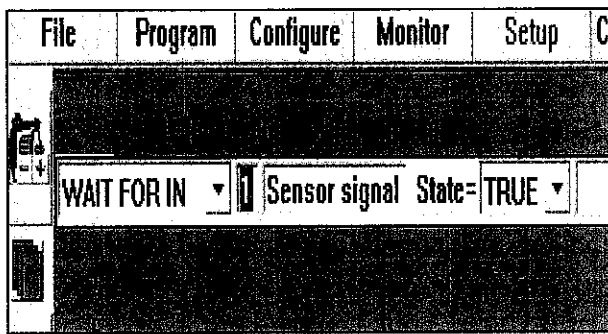


Figure 12: Input line

- Input line will be displayed in the program window. It gives an option for user to set the responsible sensor connected to the wago card and also the state of the motion.

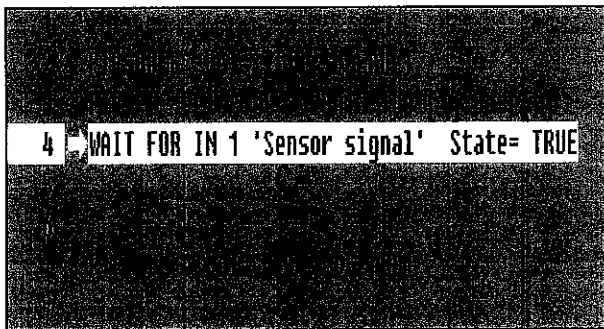


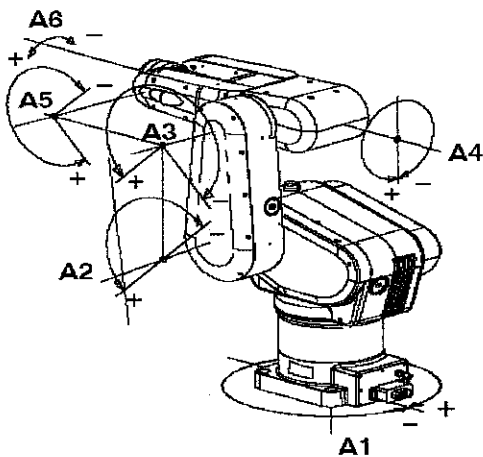
Figure 13: Complete programming for external input

- After pressing the Enter key a new programming line will be displayed this indicates the command for external device working with the programme.

APPENDIX B

KUKA KR3 SPECIFICATION

Number of axes	6
Weight	53 kg
Mounting position	Upright or inverted
Nominal payload	3 kg
Reach	635 mm
Repeatability	±0.05 mm
Encoder resolution	2048 counts per turn
Drive system	Electromechanical, brushless motors Absolute encoders in each joint
Transmission	Harmonic Drive
Brakes	Brakes on joints 1, 2, 3, and 5
Motion modes	Teach Automatic
End-of-arm connections	ISO9409-compliant tool flange
Energy supply	Support for pneumatic tools Up to 4 digital inputs and outputs to axis 5



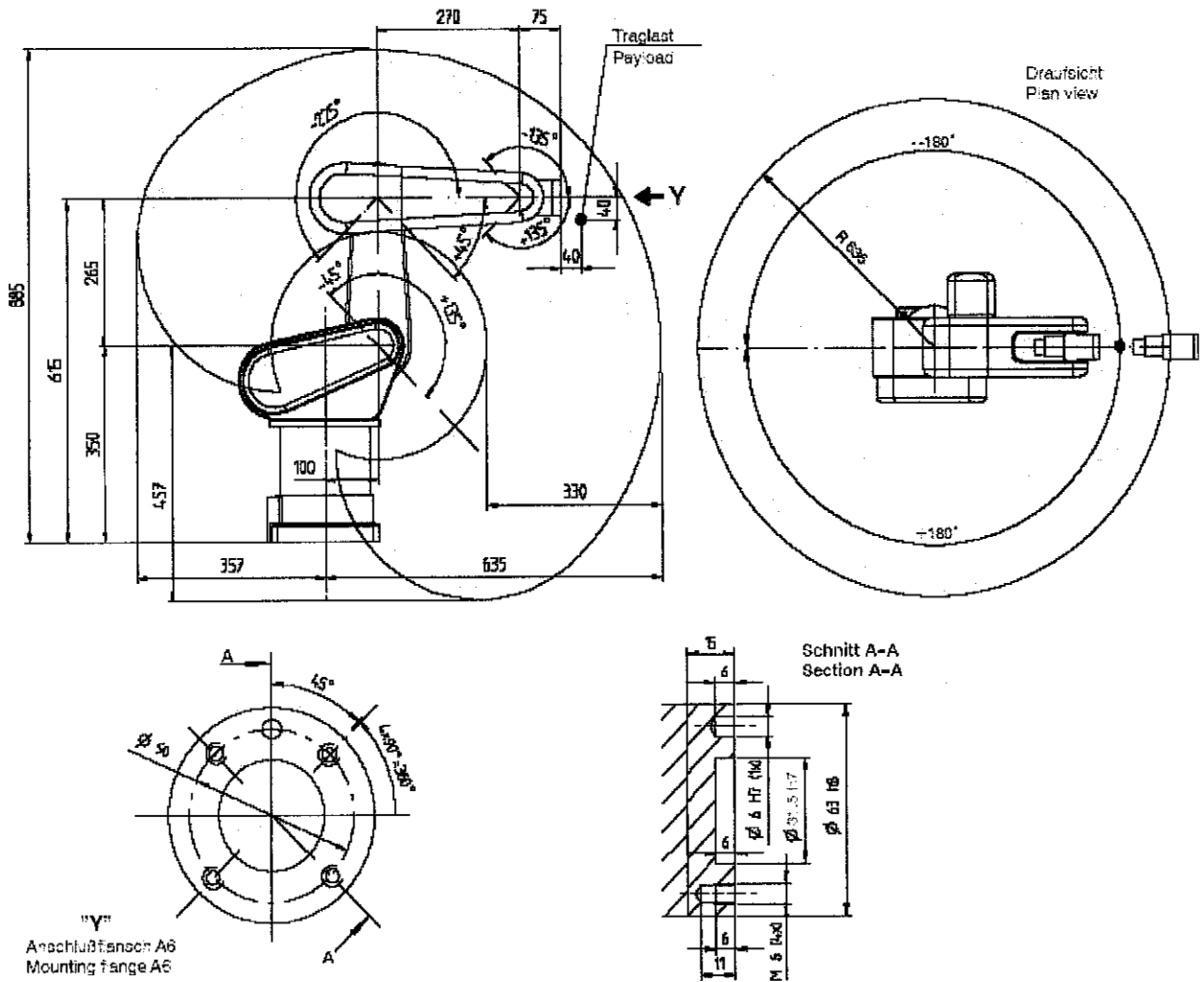
The axis data are given in the following table:

Axis	Range of motion	Maximum speed
1	± 180°	240 °/s
2	-135° to -45°	210 °/s
3	± 135°	240 °/s
4	± 180°	375 °/s
5	± 135°	300 °/s
6	continuous turn [†]	375 °/s

Axes 1 to 3 are main axes, axes 4 to 6 are wrist axes.

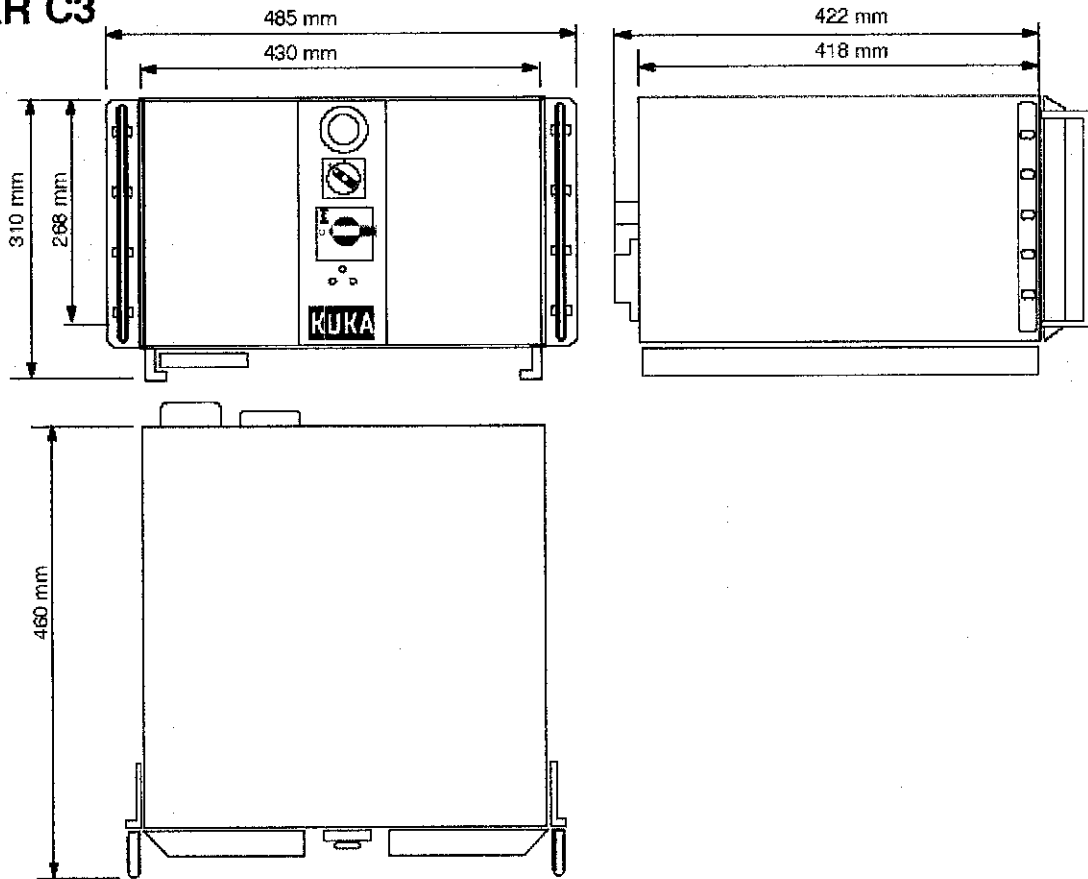
KR 3

Maße / Dimensions: mm



Typ / Type:	KR 3	
Traglast / Payload:	3 kg	
Anzahl der Achsen / Number of axes:	6	
Anschlußflansch A6 / Mounting flange A6:	DIN ISO 9409-1-A50	
Einbauart / Mounting position:	Boden / Decke	
Wiederholgenauigkeit / Repeatability:	± 0,05 mm	
Steuerung / Controller:	KR C3	
Gewicht (ohne Steuerung) ca. / Weight (excl. controller) approx.:	53 kg	
Arbeitsraumvolumen / Work envelope volume:	0,679 m ³	
Achsdaten / Axis data:	Bereich (Software) Range (software)	Geschwindigkeit / Speed
Achse / Axis 1 (A1)	± 180°	240°/s
Achse / Axis 2 (A2)	- 45° / + 135°	210°/s
Achse / Axis 3 (A3)	- 225° / + 45°	240°/s
Achse / Axis 4 (A4)	± 180°	375°/s
Achse / Axis 5 (A5)	± 135°	300°/s
Achse / Axis 6 (A6)	endlos drehend / infinitely rotating	375°/s


KR C3



Roboter-Steuerung / Robot control system:

Rechnerteil / Processor unit:	KUKA PC
Mikroprozessortechnik / Microprocessor technology:	Intel® Celeron™
Programmierung / Programming:	Technologieorientierte Anwenderprogrammierung/ Technology-orientated application programming

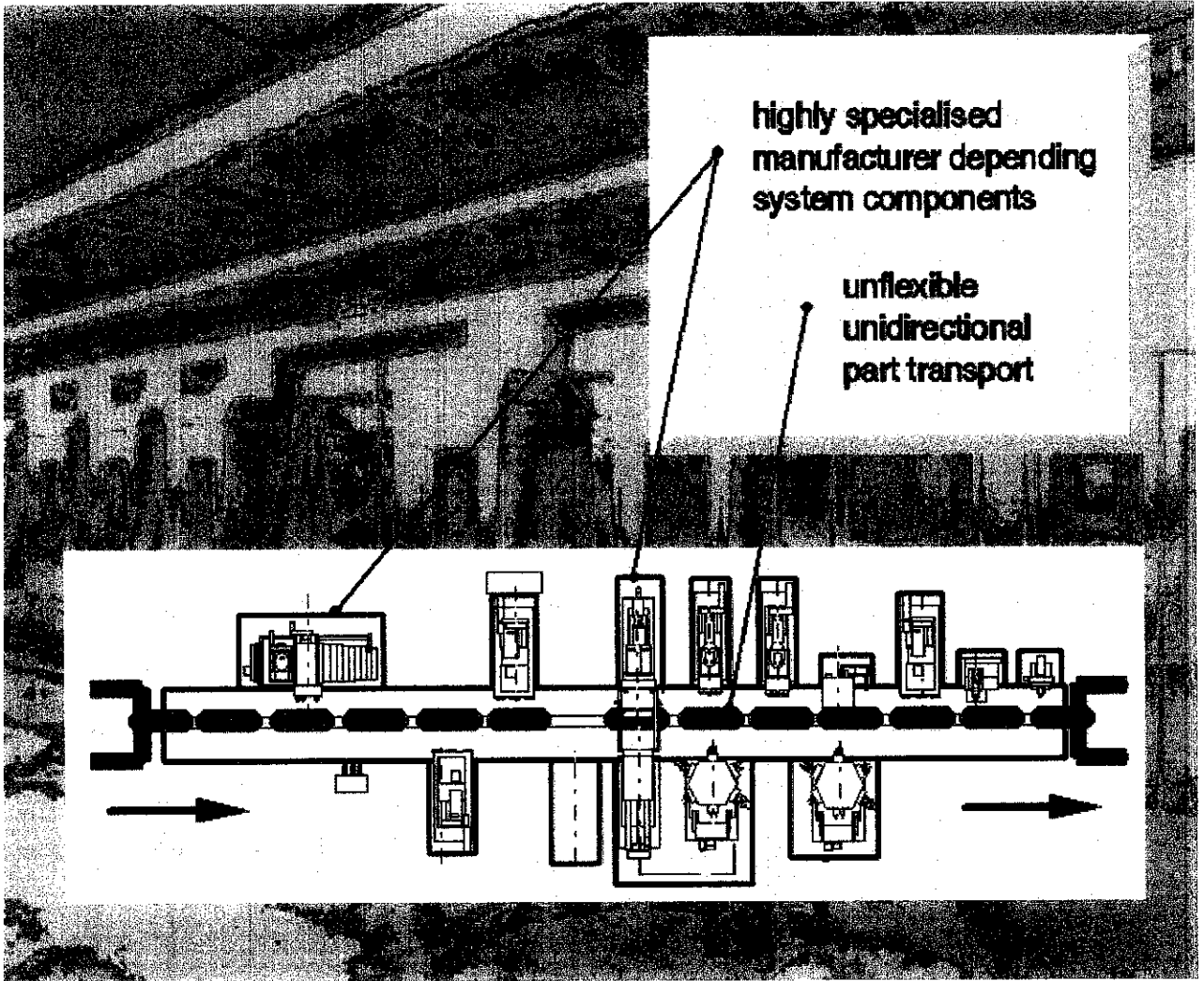
Steuerschrank / Control cabinet:

Typ / Type:	KR C3
Normen und Vorschriften / Standards and specifications:	DIN EN 292, DIN EN 418, DIN EN 614-1, DIN EN 775, DIN EN 954, DIN EN 50081-2, DIN EN 50082-2, DIN EN 60204-1,
Schutzart / Protection classification:	IP 20
Umgebungstemperatur bei Betrieb / Ambient temperature during operation:	-5 °C bis to +35 °C
Max. Anzahl der Achsen / Maximum number of axes:	6
Gewicht ca. / Weight approx.:	31 kg
Farbe Schrank, Vordertüren, Innen / Color of cabinet, front doors, inside:	dunkelgrau, metallic silber, innen verzinkt / dark gray, metallic silver, inside galvanized
Nennanschlußspannung nach DIN/IEC 38 (zulässige Toleranz) / Rated supply voltage acc. to DIN/IEC 38 (permissible tolerance):	 1 x 110 - 230 V AC (99 V - 253 V)
Netzfrequenz / Power frequency:	49 - 61 Hz
Nennanschlußleistung / Rated connected load:	650 VA
Absicherung netzseitig min. / Mains-side fusing min.:	16 A
Vernetzung / Networks:	DeviceNet ¹⁾ , CAN ¹⁾ , INTERBUS ²⁾
Zulässige Verbindungskabellängen / Permissible connecting cable lengths:	7 m

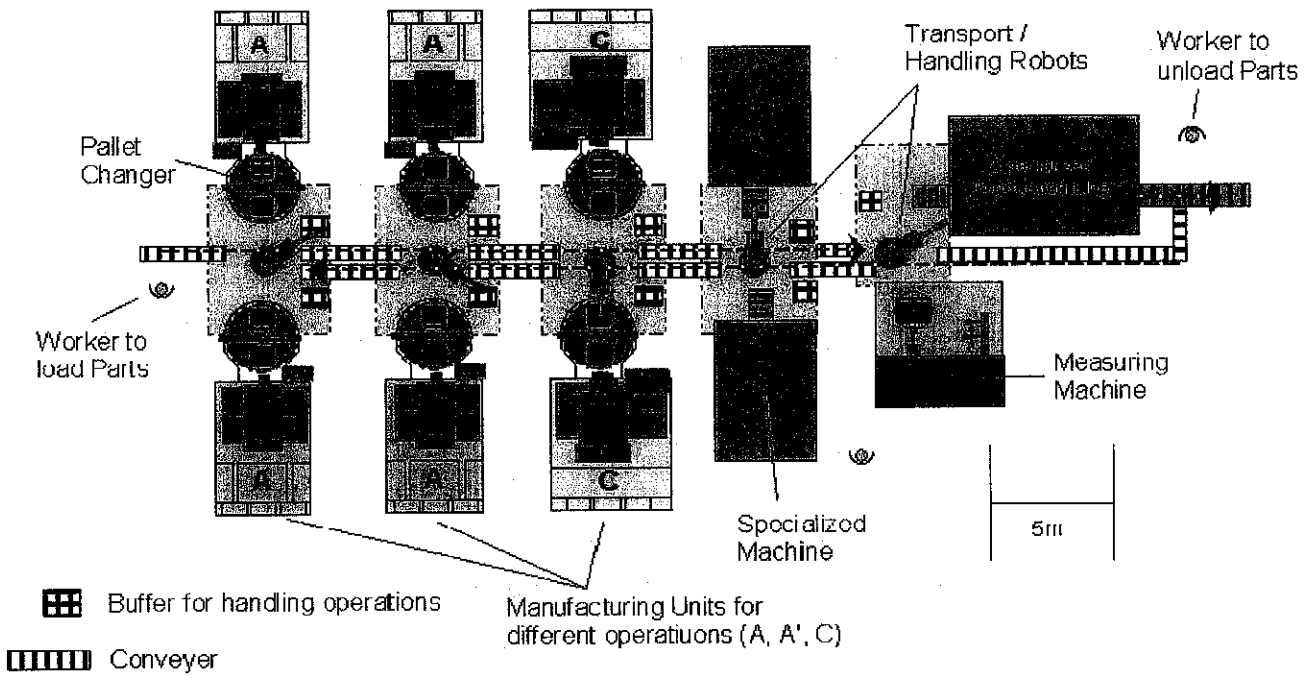
Programmierhandgerät / Hand programming unit KCP:

Abmessungen (B x H x T) / Dimensions (W x H x D):	330 x 260 x 110 mm ³⁾
Schutzart / Protection classification:	IP 54

APPENDIX C
EXAMPLE OF INDUSTRIAL FMS



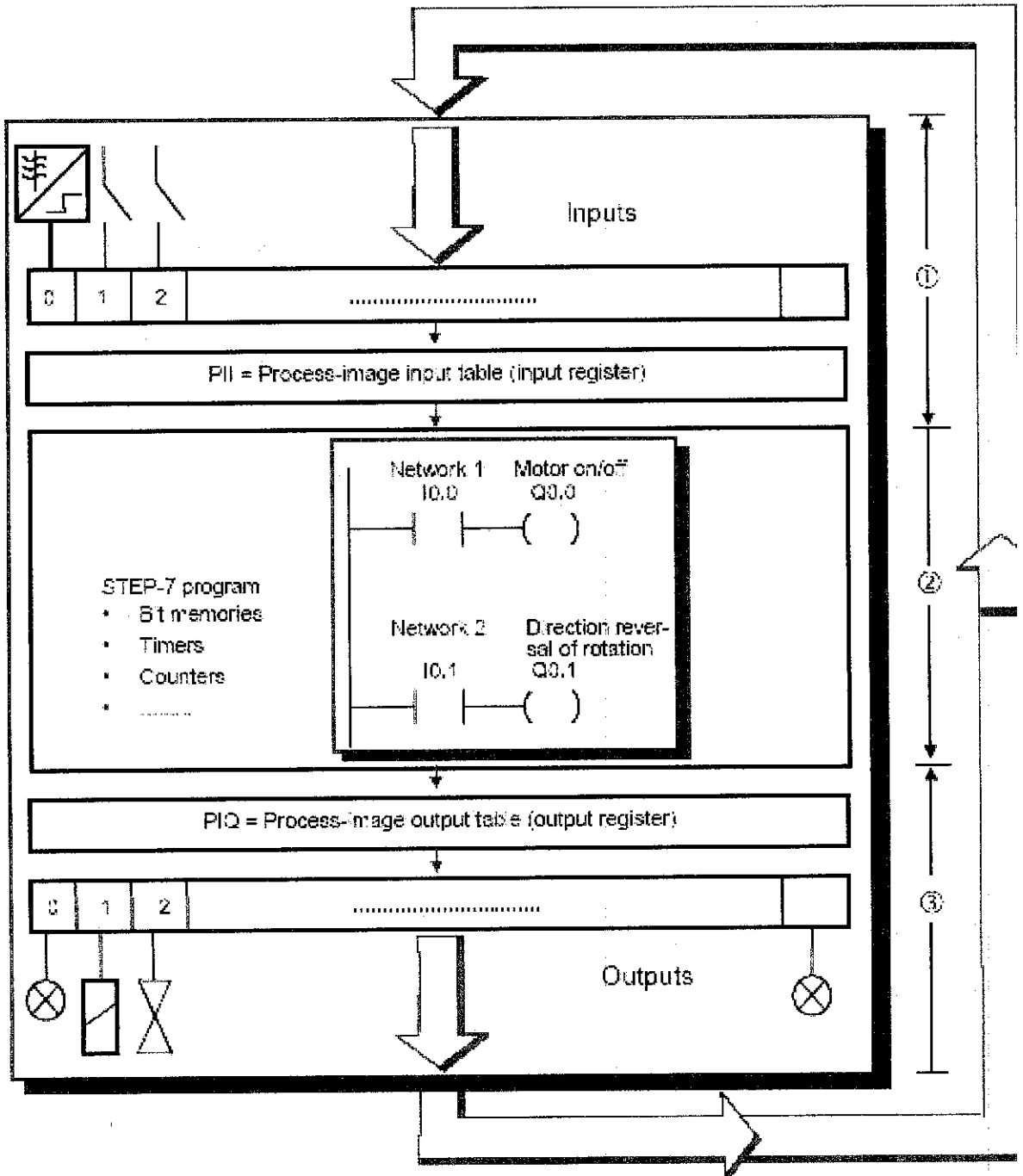
- Structure of production line



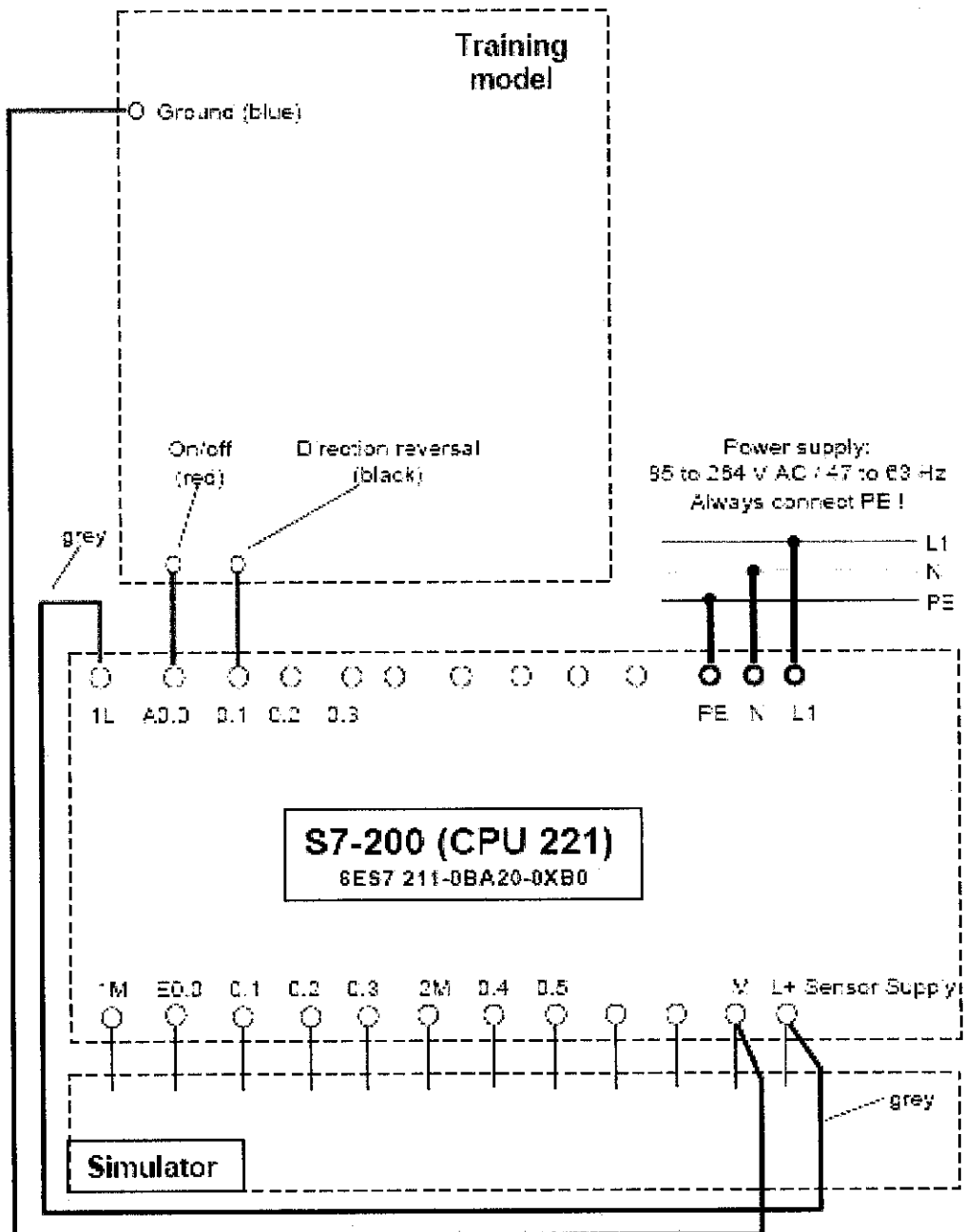
- Flexible production system

APPENDIX D

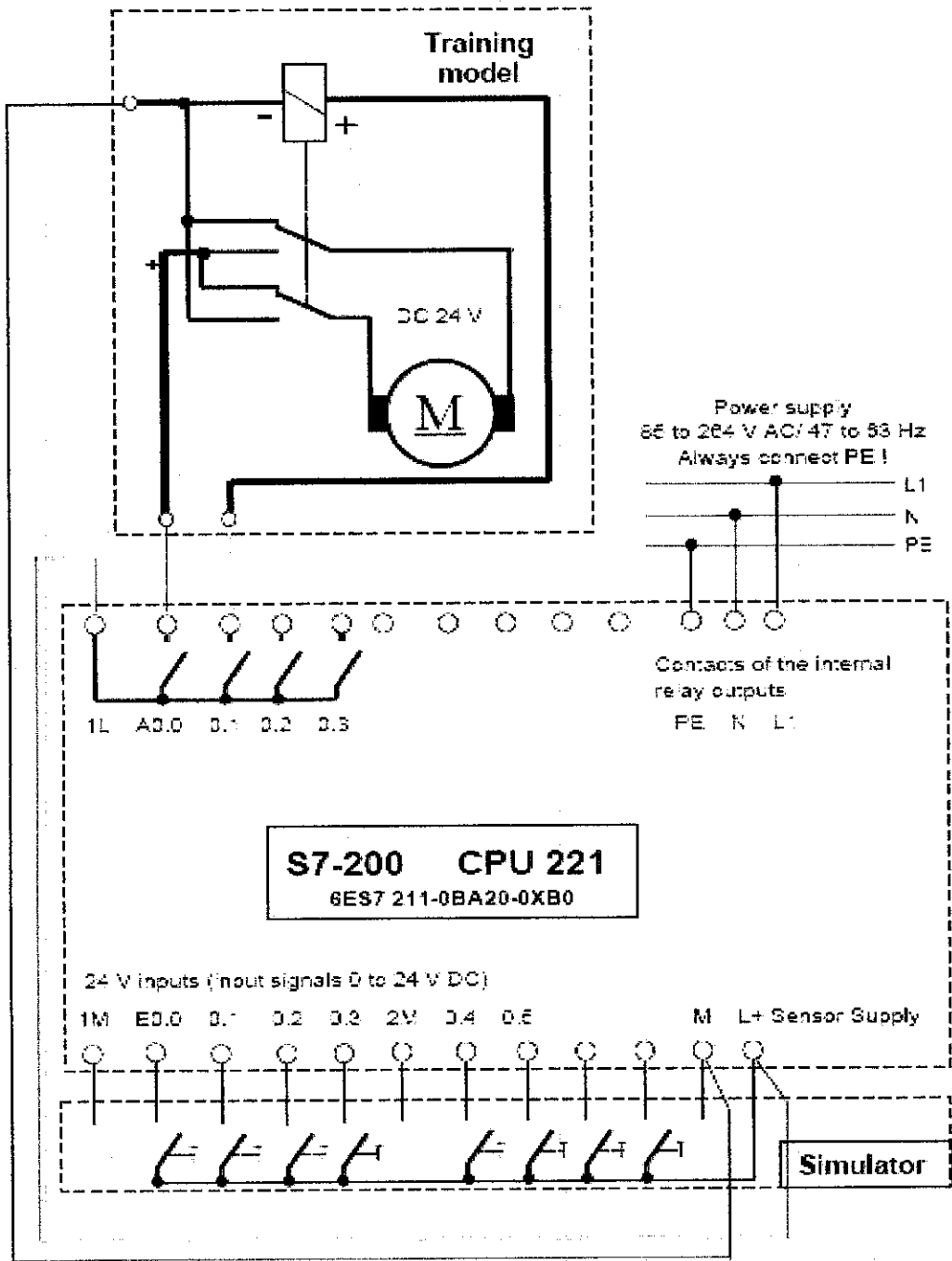
SPECIFICATION SIEMENS SIMATIC PLC S7-200



-Process Input Image



- Wiring of the exercise assembly



- Circuit diagram of the training assembly

APPENDIX E
OPERATION MANUAL

OPERATION MANUAL

This project manual is specially written for

**STUDENTS OF INDUSTRIAL AUTOMATION AND CONTROL
SYSTEMS**

Under the project of

SMALL SCALE OF FLEXIBLE MANUFACTURING SYSTEM (FMS)

Written By: KHAIRIL AZWAN BIN KHABRI

Date: December 12, 2005

Table of Content

Developing the coding for KUKA KR3.....	2
Description of SIEMENS SIMATIC PLC.....	7
Description of Sensor.....	11
Operating the Small Scale of Flexible Manufacturing System.....	14
Appendix.....	15

Developing the Coding for KUKA KR3

Before starting to write the coding, the user has to create a new module for storing all the coding. Below are the steps by steps instructions in developing the folder at The Navigator (file manager):

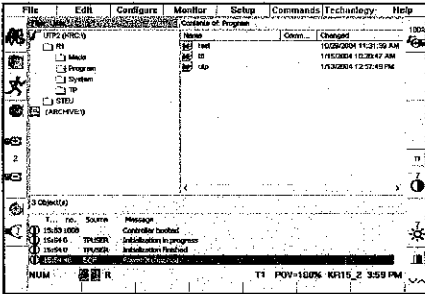


Figure 1: The Navigator

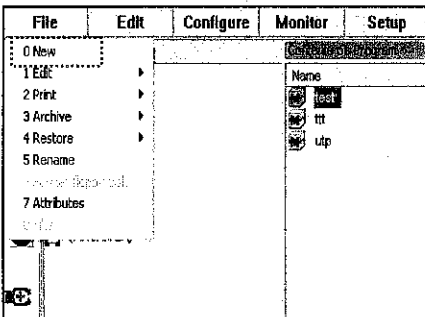


Figure 2: Built the new module

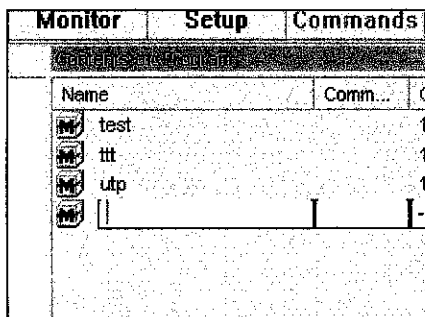


Figure 3: Write the module name

- This is the KCP displays after the controller has run up which called The Navigator (file manager).

- Next, open “File” by pressing the corresponding menu keys. Then select “New” from the menu

- An empty input line will come out at the file window, then enter the desired name of the module in the input line. Example “KUKA”. Press the softkey “OK” to save

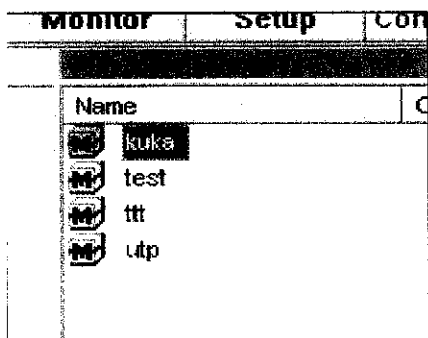


Figure 4: The new module for programming robot

- The desired file will be displayed in the file window. The module is ready for the user to develop the coding. By pressing the Enter key, the interface will switch to the program window and is ready for the coding to be done.

In developing the coding for the robots movements, a few adjustments have to be considered. First is selecting the coordinate system (at the middle right of the display). To move the robot manually, using the traversing keys (left of the display); users have to select a coordinate system on which the robot movements are to be based. The most popular and easiest coordinate system is the “Joint coordinate system”.



Joint coordinate System

- Each of the robot axes can be individually move in positive or negative direction

Next is to select the Traversing mode (at the top left of the display). This is the function used to select whether to use “Space mouse” or “Traversing keys” in moving the robot for the coding purpose. For the beginners, traversing keys are the best because it indicates the axis of the robots movement corresponding to the left side of the status keys.



Traversing keys

- Enabling to move robot using the left-side status keys

After this 2 major setup has been made, the user can write the coding for the robot. For the coding, the user has to move the robot from its home position. Next move the robot in the direction of interest and the coding for the robots movements will be recorded. Users have to use push button commands from the interface then select 'PTP' from the commands subfolder. The direction of the robot movement will be recorded. For using external inputs such as gripper, user has to select button command then choose logic subfolder. By selecting "WAIT FOR IN" there are a few options that the user has to choose before finalizing the coding, and then automatically the coding will appear on the program windows. In making the coding for this robot, there are many other options on the command menu applicable for the user to select in order to move the robot. Below are the step-by-step instructions in writing the codes.

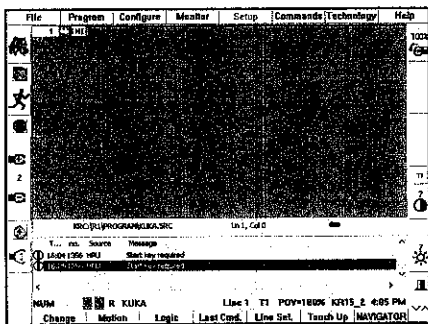


Figure 5: Program window

- This is the initial screenshot of the program window to shows the content of the program.

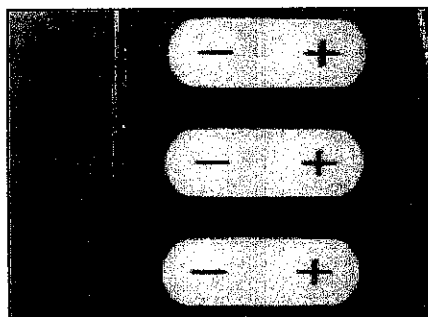


Figure 6: Traversing keys

- Move the robot using the left side status keys with the enabling switch (rear of the KCP) for the direction or movement that user requires

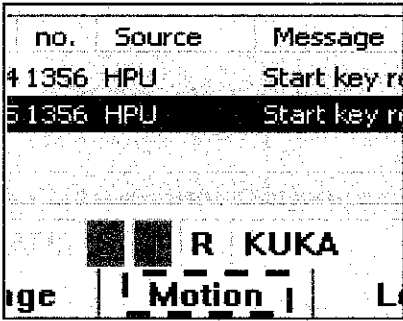


Figure 7: Select "Motion"

- Then press the softkeys corresponding to select the "motion" function.

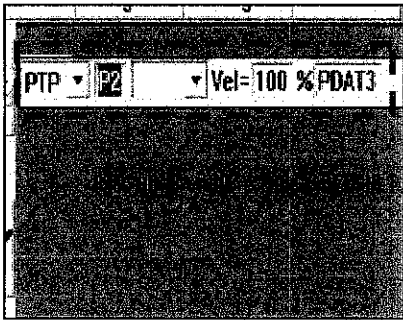


Figure 8: Input line

- An input line will be displayed on the program window. User can change the robots way of movement and the velocity.

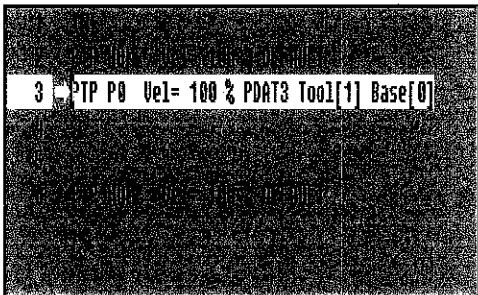


Figure 9: New line coding

- After pressing the enter key, a new line will be displayed indicating the robot movement programming

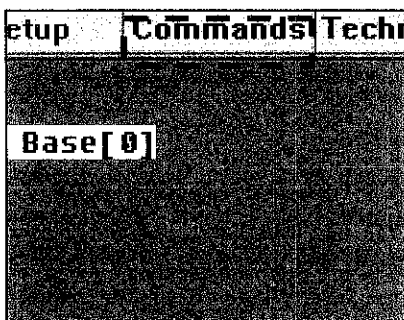
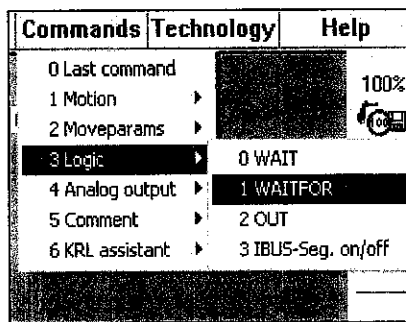


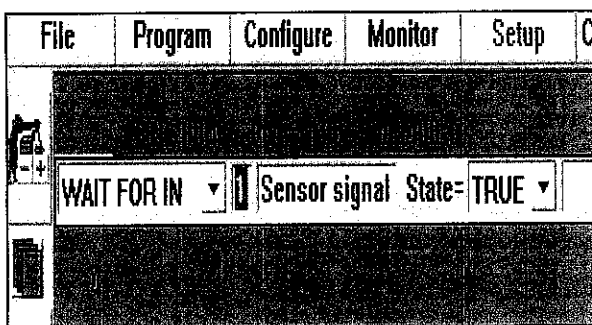
Figure 10: Select command function

- Another condition is to include external sensor such as gripper or handshake signal from PLC in the robot programming. To enable it, open the "Commands" by pressing the corresponding menu key.



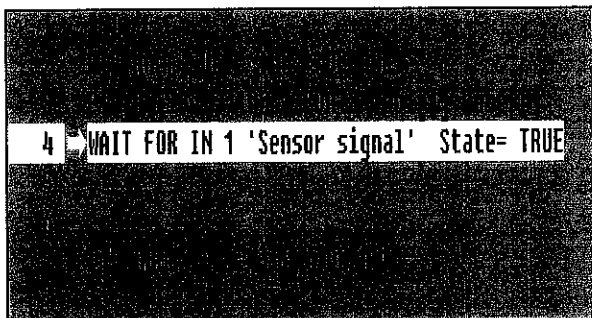
- Select the “Logic” from the menu open. Then go for “WAITFOR” option from another open menu.

Figure 11: External input



- Input line will be displayed in the program window. It gives an option for user to set the responsible sensor connected to the wago card and also the state of the motion.

Figure 12: Input line



- After pressing the Enter key a new programming line will be displayed this indicates the command for external device working with the programme.

Figure 13: Complete programming for external input

For more detail about KUKA Operator Control refer appendix [1]

Description of SIEMENS SIMATIC PLC

Below is the table shows the input and output functions of the PLC

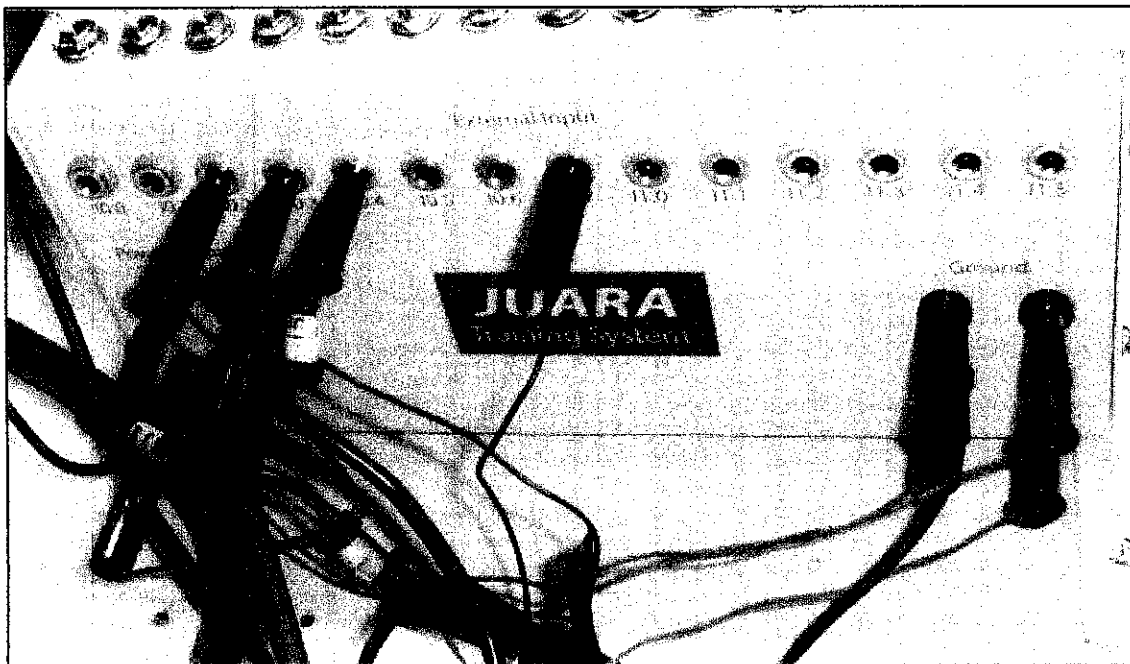
Input	Assigned equipment / signal and task
I 0.0	Switch button (Emergency Stop)
I 0.1	Push Start button
I 0.2	Sensor detect product A (External –inductive sensor)
I 0.3	Sensor detect product B (External-Infrared sensor)
I 0.4	Sensor spot product arrive at conveyer (External-infrared sensors)
I 0.5	Reset counter 1
I 0.6	Reset counter 2
I 0.7	Sensor detect product reach the conveyer belt (External-capacitive sensors)
I 1.0	Switch button (Robot initial start)

Table 1: Inputs of the PLC

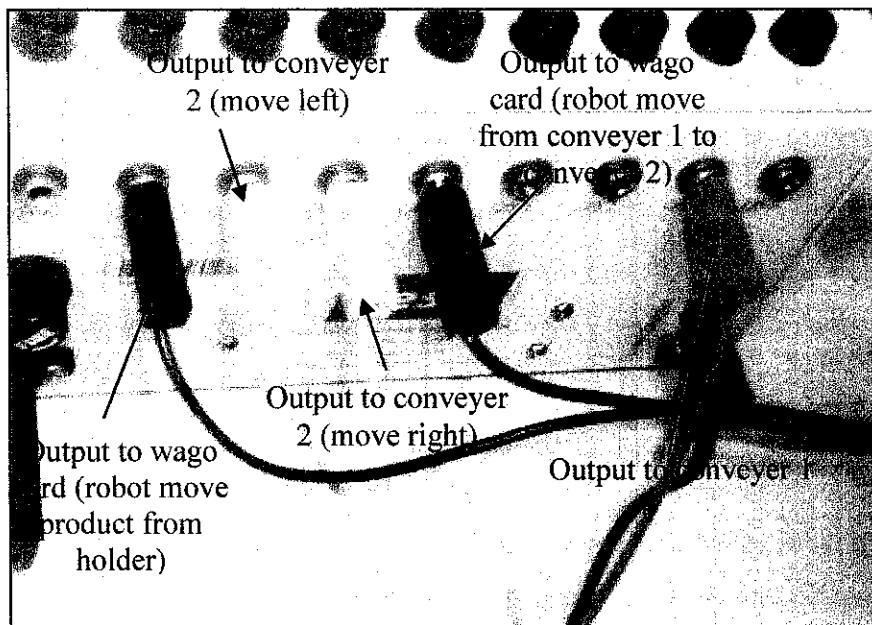
Output	Assigned equipment / signal and task
Q 0.0	Output signal ('Enable Start')
Q 0.1	Output signal (to move the conveyer 1)
Q 0.2	Output signal (Direct robot to pick the product)
Q 0.3	Output signal (Detect product at conveyer 2)
Q 0.4	Output signal (Indicating product A)
Q 0.5	Output signal (Indicating product B)
Q 0.6	Output signal (Move conveyer to box A)
Q 0.7	Output signal (Move conveyer to box B)

Table 2: Outputs of the PLC

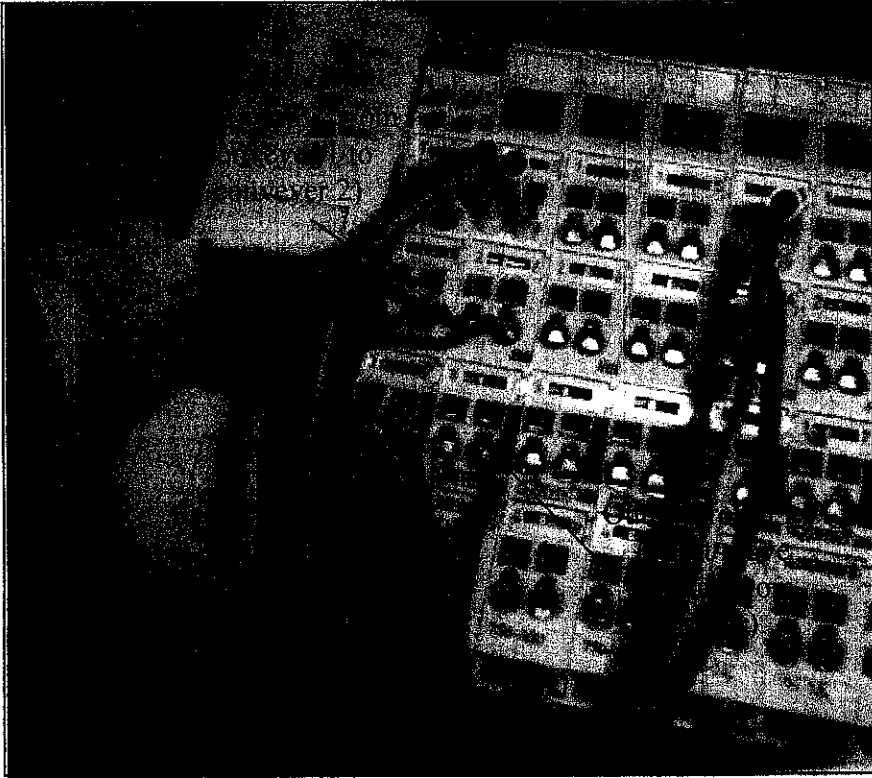
Below is the picture show the connection of input and output connect to the PLC:



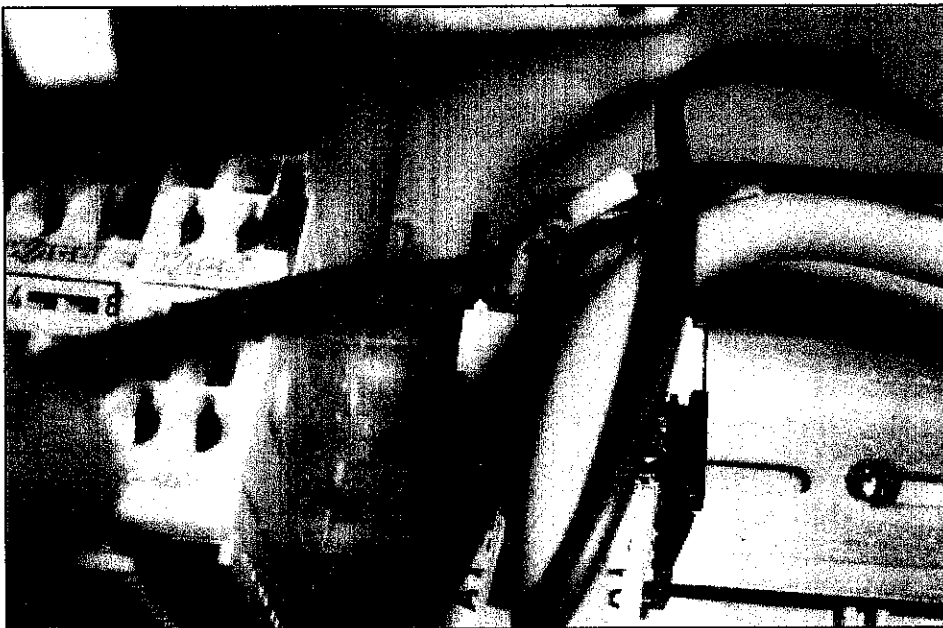
PLC Input terminal



PLC Output terminal



Robot input terminal (Wago Card)



One of the PLC 24 volt dc has to connect with 24-volt terminal at wago card
(For input polarity purpose)

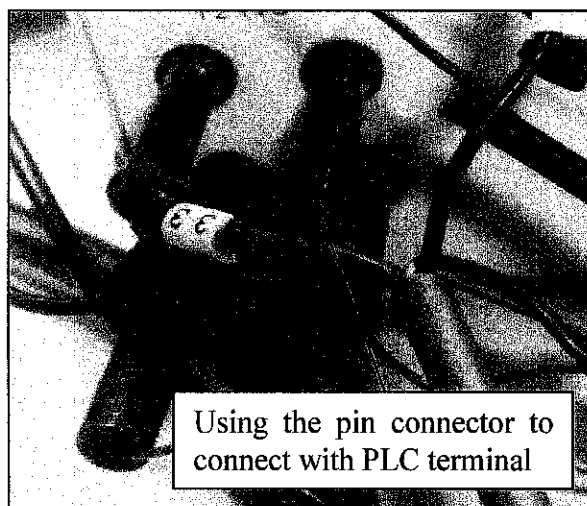
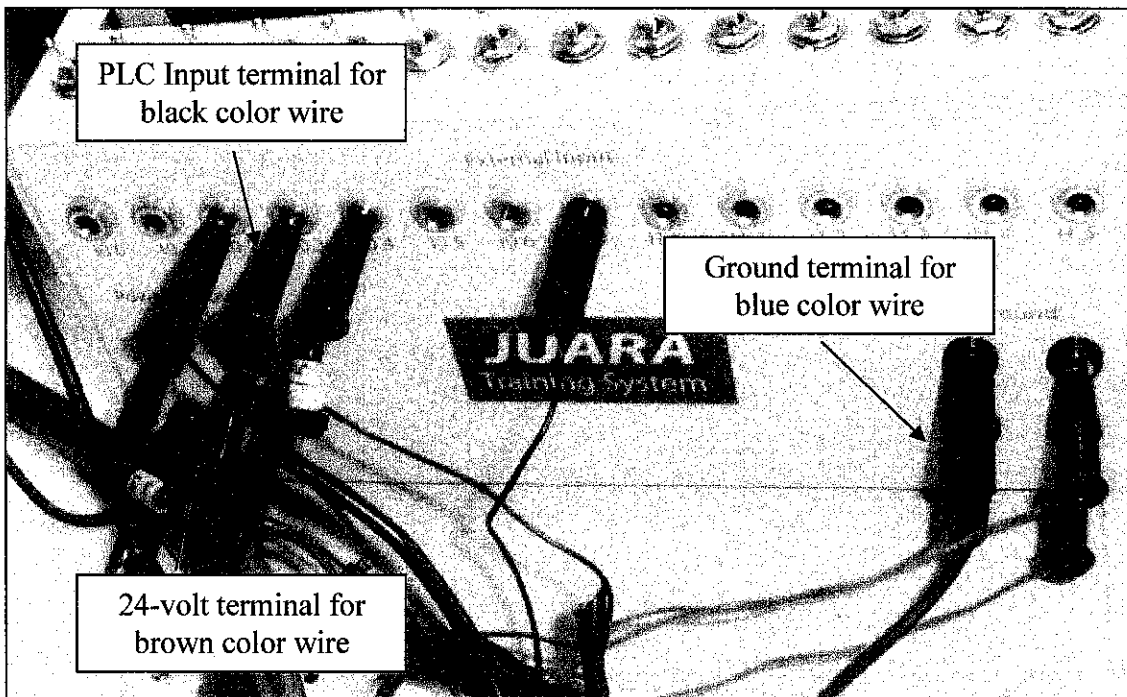
All the external equipment such as sensors, conveyer and robot will be integrated into the input or output terminal orderly at the PLC. For complete exercise in design the ladder diagram please refer appendix [2]

Description of sensors

All the three sensors have been use have 3 type of wire which is:

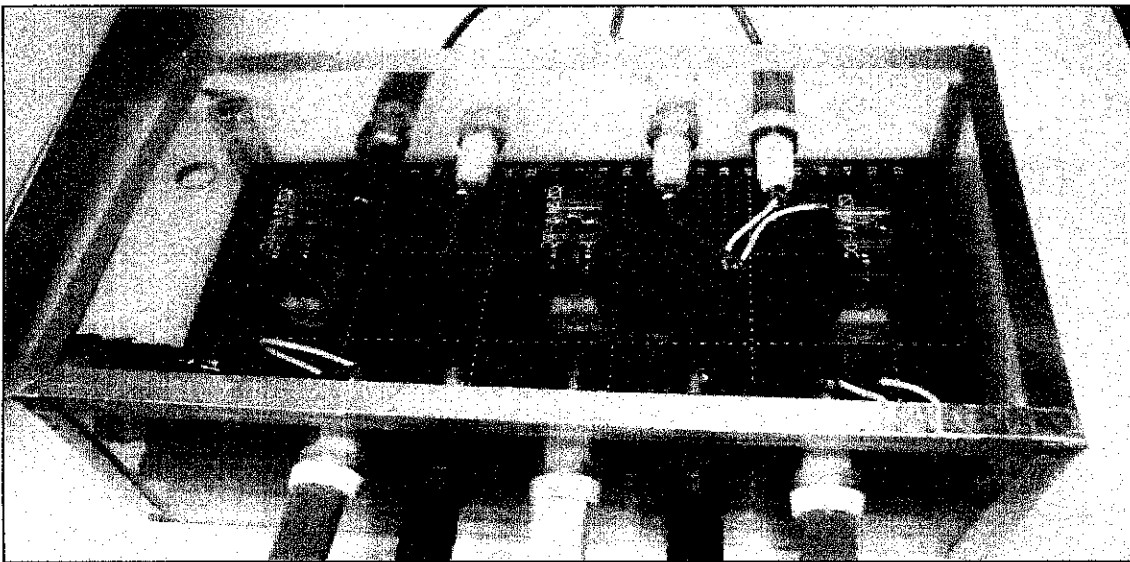
- Blue: Ground**
- Brown: 24 volt**
- Black: Input (PLC Connection)**

All the wire has to connect to all the PLC terminal Therefore, the wiring connections have to follow the color identification to make sure all the sensors function accordingly

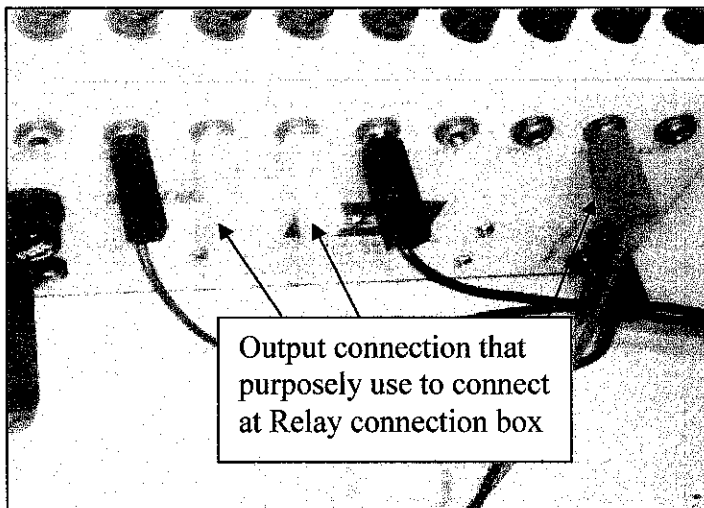


Descriptions of Conveyer Belt

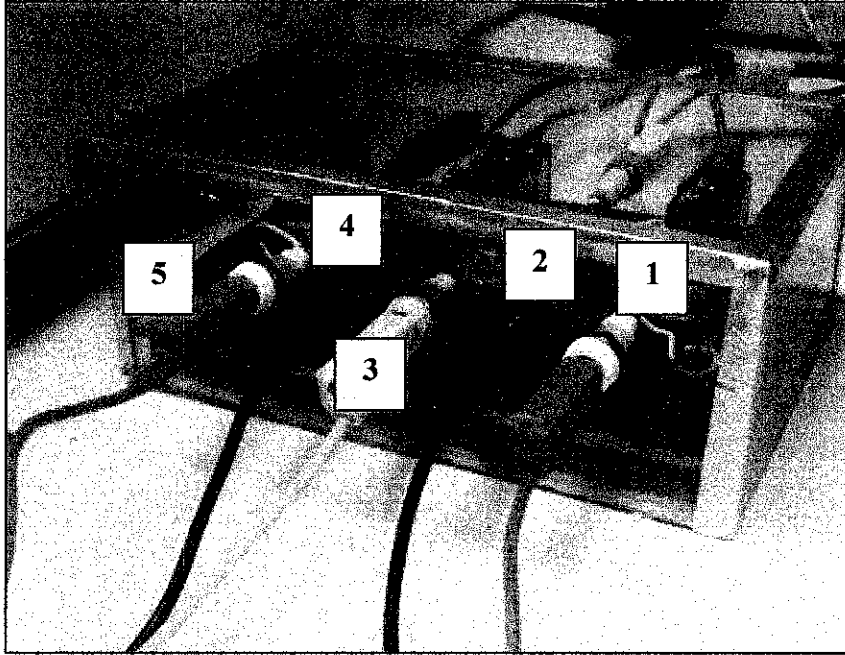
2 conveyers have been use for this project where one of the conveyers can move forward and backward. The relays connection box has controlled the direction of the conveyer movement. This device built of three relays inside and power by 24-volt dc. Output from PLC going straight following the connection that has been design into the connection box and the output from the connection box has been distributed to the following conveyer. Below are the pictures of PLC output terminal, Relays connection box and conveyer belt



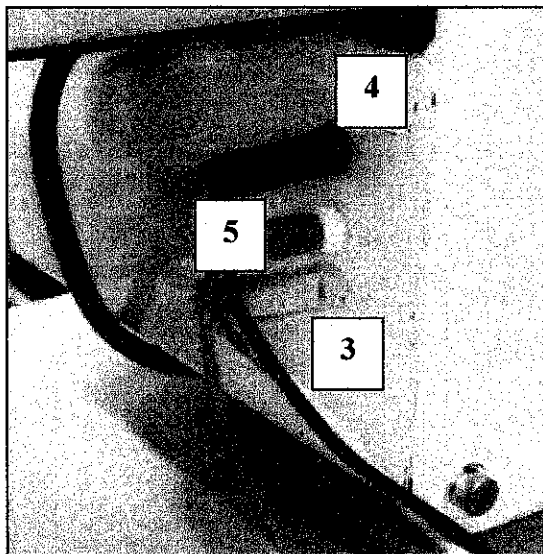
Relay connection box



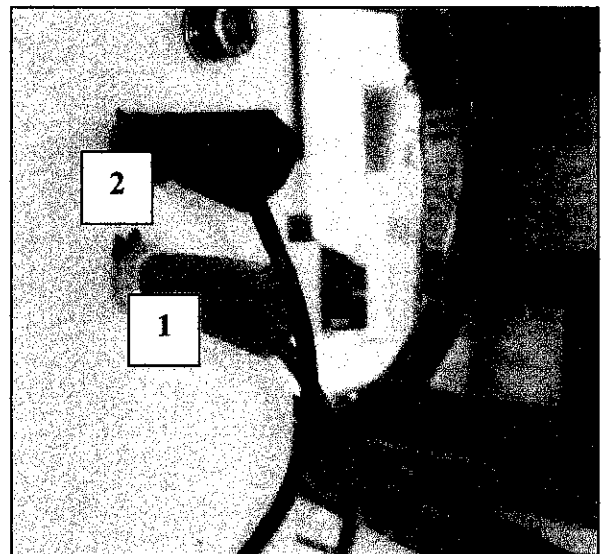
Connection between relays connection box and conveyer belt (Connection made according to the number assign)



Output connection of Relays connection box



Conveyer Belt 2 input connection



Conveyer Belt 1 input connection

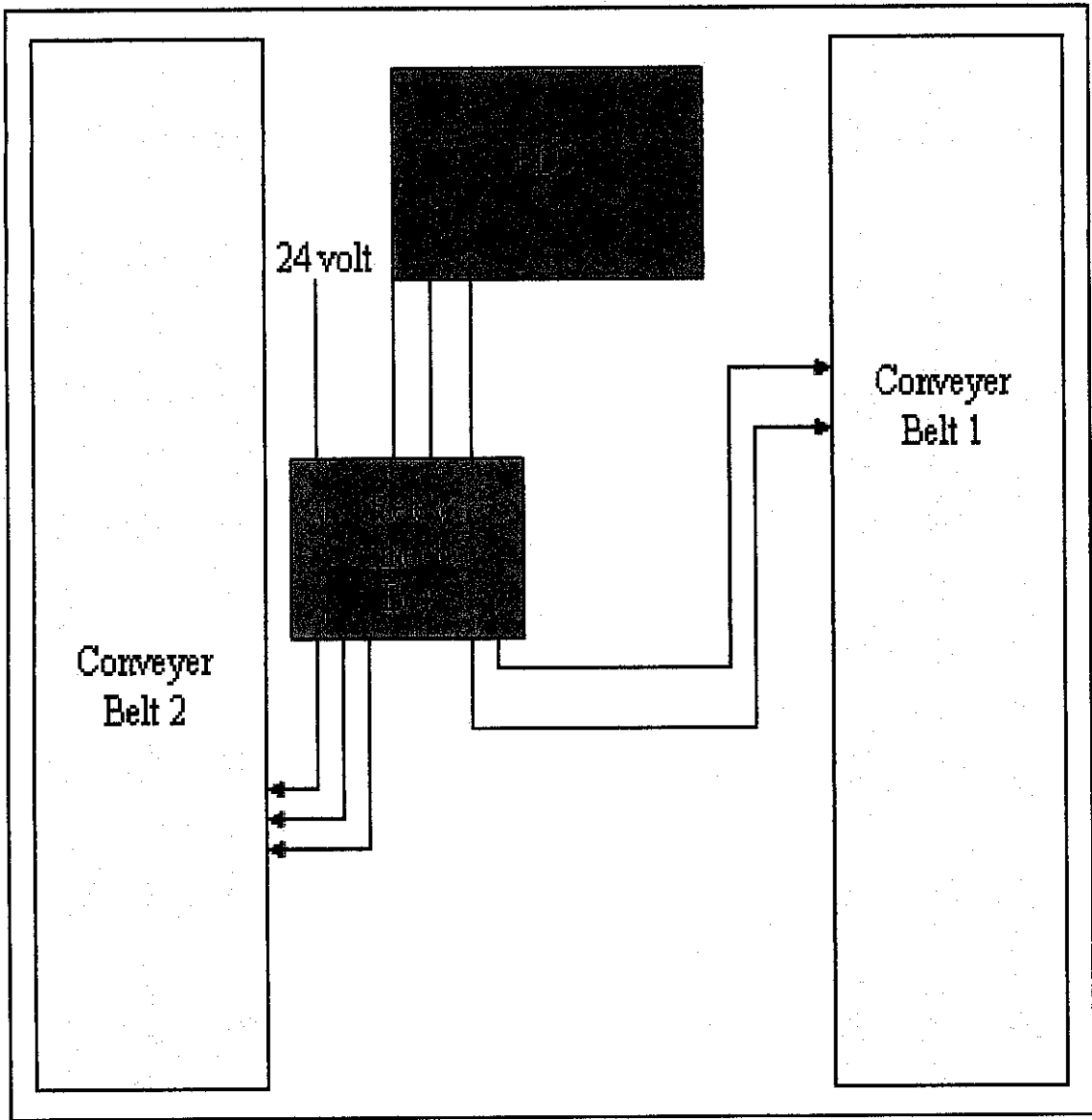


Diagram of Conveyer Belt connection with relay connection box

Operating the Small Scale of Flexible Manufacturing System

- a) Switch on all the devices
 - o PLC
 - o KUKA KR3
 - o Air pressure
 - o Conveyer Belt

- b) Put all the material at the product holder
- c) When KUKA KR3 finish loading, using KUKA Control Panel select file “presenta_2” in the file window
- d) Then go the mode selection at KUKA Control panel and move the key to the test 2
- e) Push “drives on” button at the KUKA Control Panel
- f) Press the enabling switch together with “Program start forward” button until it reaches line 4 at the robot coding.
- g) Now go to the PLC and select the input type “Int”
- h) Trigger switch input I0.5 and I0.6 for reset the counter.
- i) Then switch on the FMS by trigger switch I0.1
- j) After that switch on I1.0 then the FMS will start pick up the product.
- k) Immediately Switch back the input type from “Int” to “Ext”
- l) At one stage, when the box is already full repeat process “g”
- m) For ending the process push “drives off” button at KUKA Control panel and switch off the PLC by trigger switch I0.1

Appendix

KUKA Operator Manual

SIEMENS LADDER DIAGRAM EXERCISE