AUTOMATED TYRE SORTING SYSTEM USING MITSUBISHI FX3U PLC CONTROLLER

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ABSTRACT

This research presents a case study of development of automated tyre sortation system by using integration of Programmable Logic Controller with barcode system. The objective of this research is to identify the possible improvements for tyre sortation system, increase flexibility of tyre sortation system by changing from manual to fully-automated, reduce hiring cost and the number of workers and reduce tasks of workers. Tyre sortation process is performed manually which is not flexible and can cause the mistake of sortation. Therefore, the manual sorting operation should be eliminated and the automated system should be developed or designed. Mitsubishi FX3U was chosen to integrate with barcode system and ladder diagram was designed to control the sorting operation. Laboratory test was performed to test the operation of program. The test shows that the program can work successfully. If this project is applied in the real process, it can increase flexibility, reduce task and number of operator and can save hiring cost of around 71,280 USD / year.

ABSTRAK

Kajian kes ini membentangkan pembangunan sistem penyusunan tayar automatik dengan menggunakan integrasi logik boleh aturcara dan sistem kawalan kod bar. Objektif kajian ini adalah untuk mengenal pasti penambahbaikan yang boleh dilakukan untuk sistem penyusunan tayar, meningkatkan fleksibiliti tayar sistem penyusunan dengan menukar dari manual ke separa automatik atau automatik sepenuhnya, mengurangkan pengambilan kos dan bilangan pekerja, dan mengurangkan tugas-tugas pekerja. Proses penyusunan tayar yang dilakukan secara manual adalah tidak fleksibel dan boleh menyebabkan kesilapan penyusunan. Oleh yang demikian, operasi susunan manual hendaklah dihapuskan dan sistem automatik perlu dibangunkan atau direka sebagai penggantian. Mitsubishi FX3U telah dipilih untuk mengintegrasikan dengan sistem kawalan kod bar dan gambarajah tangga direka untuk mengawal operasi susunan. Ujian makmal telah dijalankan untuk menguji pengoperasian program ini. Dapatan menunjukkan bahawa program ini boleh bekerja dengan jayanya. Jika projek ini digunakan dalam proses yang sebenar, ia boleh meningkatkan fleksibiliti, mengurangkan tugas dan bilangan pengendali, dan boleh menjimatkan kos menyewa sebanyak 71.280 USD / tahun.

ACKNOWLEDGEMENT

Firstly, I would like to convey my highest gratitude towards my project supervisor Dr. Mahidzal Bin Dahari for his advice and support, and direction throughout this dissertation. He has provided useful insights and comments during the research work. I would also like to thank all the Faculty of Engineering lecturers for their help and guidance during my academic program at University of Malaya. Unforgettably, I would like to thank you for AUN SEED-Net JICA who provide scholarship and give me a chance to continue Master degree.

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CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

During the last decades, the capability of technological for performing in sorting or grading was increased continuously. Nowadays, many devices for inspection are used for specimen machining or object characterization over an extended scale range. These devices are provided with servo-controlled positioning and required level of resolution. The processes of operation system are complex structures with numerous steps may be transferred several times from an instrument to another one(Jacquot, 2011).

Machine visions are an efficient method for noncontact sensing of many physical quantities. The principle application of vision is to automate inspection processes. They can be used for stacked bar codes and also included other type identification processes. For example, machine vision system can be used to inspect for sorting a limited variety of products moving on a conveyor belt, this process is not required any identification codes on product because it detects on the geometric of products. Industries usually use machine vision installations to perform a variety of automated inspection tasks which are either on-line in-process or on-line post-process. Normally, vision system is applied for mass production. Typical of tasks can be done such as dimensional measurement, verification of the presence of components and detection of surface flaws and defects and so on(X. Cheng, 2003).

This research project focused on a case study from one company which produces tyres in Thailand. This feasibility study has been focusing on tyres sortation system because the process is performed manually by workers. The problem is that sortation line is not flexible. Possible automation system and design software or simulations were suggested to improve the performance. Therefore, semi-automated or fully-automated should be applied. Figure 1.1 shows the current process of tyre sortation system which is performed manually, each station has one worker to press the button of actuator to hit tyres when they are sorted. Worker will see the number of barcode that indicates the size of tyres.

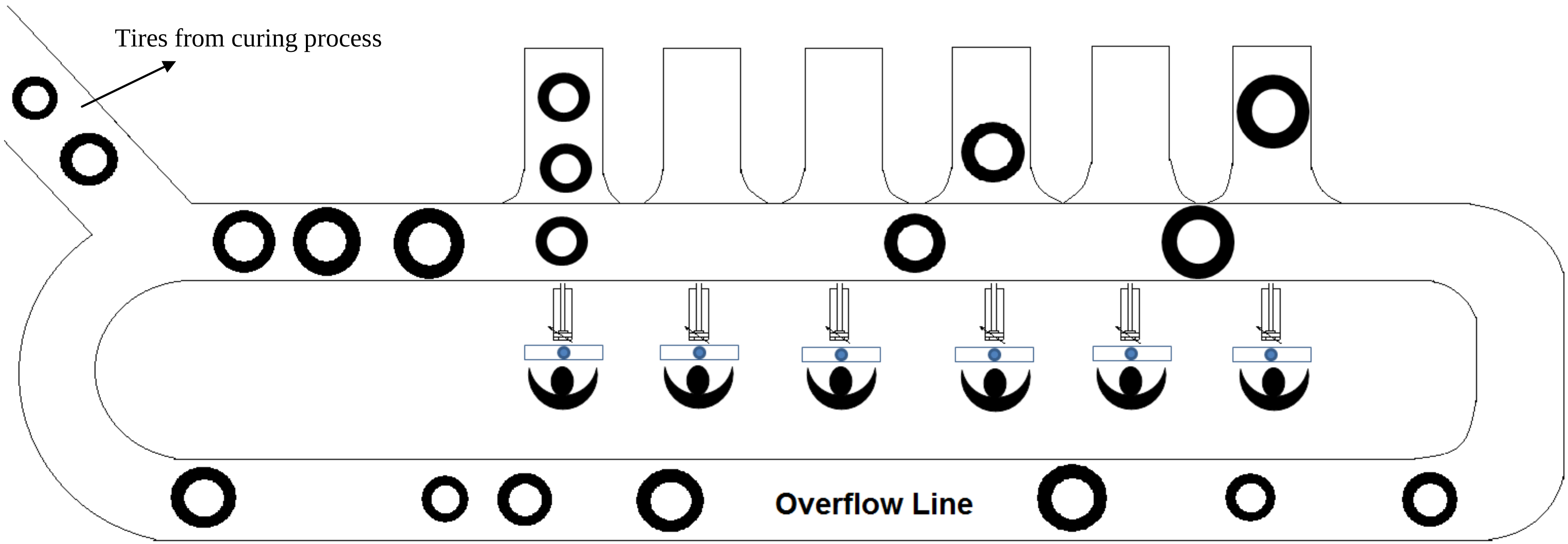


Figure 1.1 Current process of tyre sortation system

1.2 PROBLEM STATEMENT

This research project focuses on the sortation system of the company that sorts the different size of internal diameter of tyres which are classified into 13 inches to 18 inches. Sortation process of the company will only sort internal diameter but external diameter and thickness of tyre will be a duty of supplier or distribution substitute. The study investigated low flexibility of the process and found the difficulty for the workers to observe the barcode of each size of tyres, this may cause the mistake of sortation process. Therefore, the implementations of automation to eliminate manual operation should be performed. In addition, after automation is applied, the number of workers can be reduced or terminated.

1.3 OBJECTIVE

- To identify the possible improvements for tyre sortation system.
- To develop tyre size sensors for sortation of the various sizes of tyre.
- To increase the flexibility of tyres sortation system by changing from manual to semi-automated or fully-automated.
- To reduce hiring cost and the number of workers.
- To reduce tasks of workers by changing sortation process to automated system, workers can be used for the other job.

1.4 SCOPE OF STUDY

The scope of this study is to investigate the adequate and possible automation system to replace the manual operation of tyre sortation system. The software program of PLCs integrated with barcode system will be designed. Actual test might be performed in the real process, otherwise, the laboratory test or simulation will be done instead. The real application in industry depends on consideration of the company.

1.5 EXPECTED RESULT

An expected goal of this research is to design an automated tyres sortation system. This system may be applied in the real process in industry to achieve high accuracy, repeatability, flexibility, increase the productivity and reduce time and hiring cost. Anyway, if it does not apply in the real process, laboratory test and simulation method will be done.

1.6 RESEARCH PLAN

1.6.1 Study on tyre sortation process.

1.6.2 Perform data collection.

1.6.3 Define the problem.

1.6.4 Create the way to solve the problem.

1.6.5 Design the software program to operate the system.

1.6.6 Test the program.

1.6.7 Measure the result of improvement.

1.6.8 Assess and conclude the operation result.

Table 1.1 Research plan

No	Research plan	2012-2013							
		Nov	Dec	Jan	Feb	Mar	Apr	May	June
		1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4
1	Study on tyre sortation process.								
2	Perform data collection.								
3	Define the problem.								
4	Investigate the way to solve the problem.								
5	Design the software program to operate the system.								
6	Test the program and simulation.								
7	Measure the result of improvement.								
8	Assess and conclude the operation result.								

CHAPTER 2

LITERATURE REVIEW

This study is to develop program design and test the system of automated tyre sorting system by using appropriate hardware and software Mitsubishi developer which has involved theory and previous research. The detail of this chapter will cover history of company, automation system, Programmable Logic Controller, Mitsubishi PLC, hardware, barcode system and the historical research of automation field and automated sorting system.

2.1 HISTORY OF COMPANY

Bridgestone is the leader of tyres manufacturer in the world, the original plant (company) was established by Shojiro Ishibashi in Kurume, Japan in 1931 which was the first local tyre supplier for the Japanese automotive industry. Name "Bridgestone" came from Shojiro Ishibashi, his name means "stone bridge." Headquarters of Bridgestone were relocated to Tokyo in 1937. In 1942, the name was changed to the Nippon Tyre Co., Ltd., but was renamed Bridgestone Tyre Co., Ltd. in 1951. Bridgestone achieved a U.S. production on purchasing of a plant in LaVergne, Tennessee, belonging to the Firestone Tyre & Rubber Company in 1983 and became Bridgestone Corporation in 1984 and expand the market segment of tyre business to worldwide. Mr. Noboyuki Takamura is the general manager of Bridgestone plant in Thailand which is established in 1967 and started production on January 22, 1969, head office is located in Rama IV road, Bangkok. Nowadays, Bridgestone has two plants in Thailand which are Rangsit plant (established in June, 1967) and Nongkhae plant (established in October, 1993). Rangsit plant produces tyres for automotive for commerce, large automotive tyres and aircraft tyres and Nongkhae plant in Saraburi produced tyres for automotive cars and pick up cars.

2.2 AUTOMATION SYSTEM

Automation system is the system or mechanism that is controlled by program and capable to work automatically. The design of automation system starts from the study of the problem statement in the work station and tries to set the equipment and software program to test or simulate the system before the actual implementation. The basic components of automation system can be divided into input, process and output. The design can be perform easily by positional sketch to show the position of equipment and to understand the real work station. Figure 2.1 is the example of positional sketch.

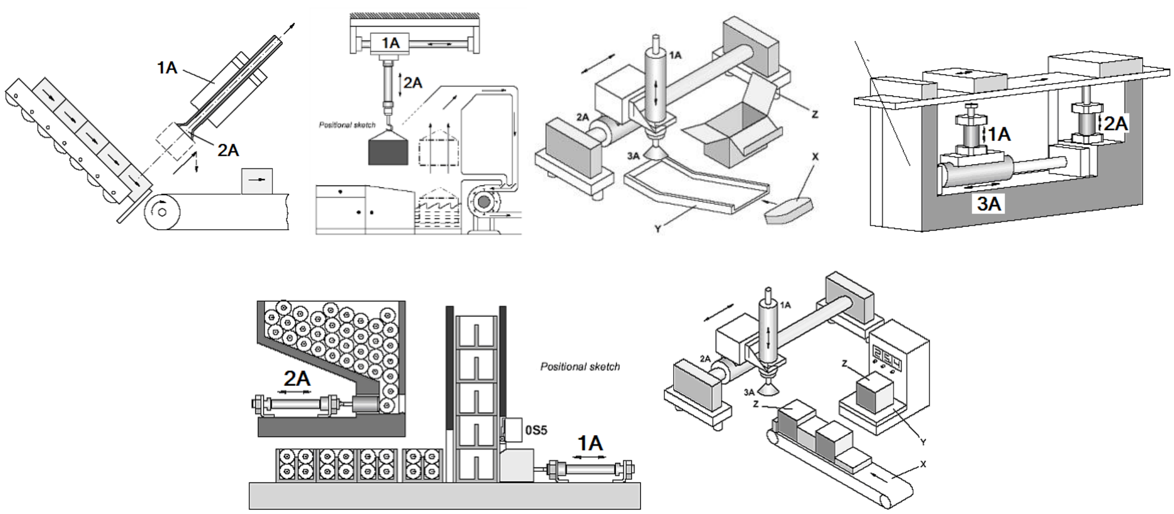


Figure 2.1 Positional sketch

The design of automation system for any workstations has following step.

1. Study on the original and real system to understand the characteristic and statement of the process.

2. Design the movement of equipment and select the power equipment. Sketch the equipment to show the function and position and step of working condition.

3. Analyze the control signal that needs knowledge on electrical and program.

4. Design pneumatic or hydraulic system (depend on the type of work). Select the appropriate detector and control equipment to perform wiring diagram.

5. Install equipment and test.

The purpose of automation system in industry is not only to increase productivity and reduce cost but also increase the production efficiency in the part of quality and flexibility of production system. For example, automotive industry uses expert human to perform assembly, error is about 1-1.5%, but when automation system is applied by using robot and error detection, error is reduced to 0.00001%. Automation system is also appropriate for danger workstation, refinery, chemical industries and so on. Automation system has become the main thing for rapid production. The importance is to control the quality requirement. Automation systems are widely used in many industries such as Programmable Logic Controller (PLC) or Distributed Control System (DCS) and Supervisory Control and Data Acquisition (SCADA). However, automation system in industry needs to integrate with computer and technology to achieve high efficiency of the process(GROOVER, 2008).

The main components of automation control system can be divided into 2 parts are

1. Control part: the function of control part is to convert external signal that is sent to the system or input to appreciate signal for driving output or actuator to control the system. In general, control part composes of receiver, detector, amplifier and controller as shown in figure 2.2.

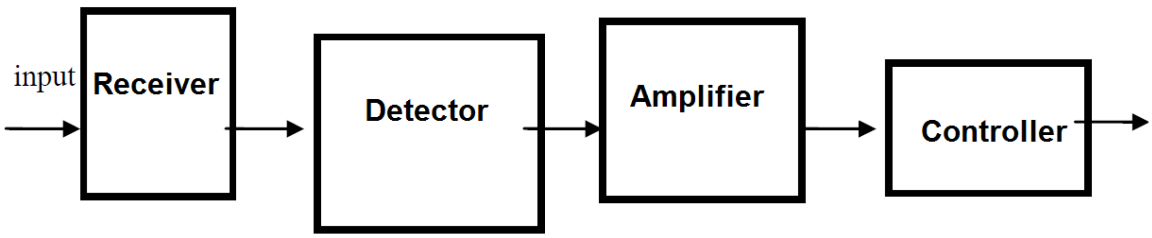


Figure 2.2 Components of control part

2. Output: the part that receive the signal from control part to drive hardware such as solenoid valve, motor, bulb and so on.

Automation control system can be divided into two types:

1. Opened loop control system: the system that transfers signal to controller only one way and has no feedback from output, it is the easiest system.

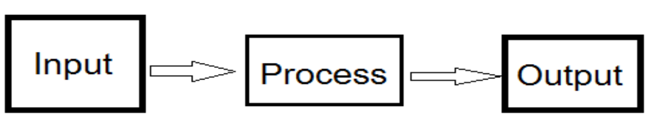


Figure 2.3 Opened control system

2. Closed loop or feedback control system: the system that transfers signal to controller and read feedback from output to compare and control output to work in the desired condition.

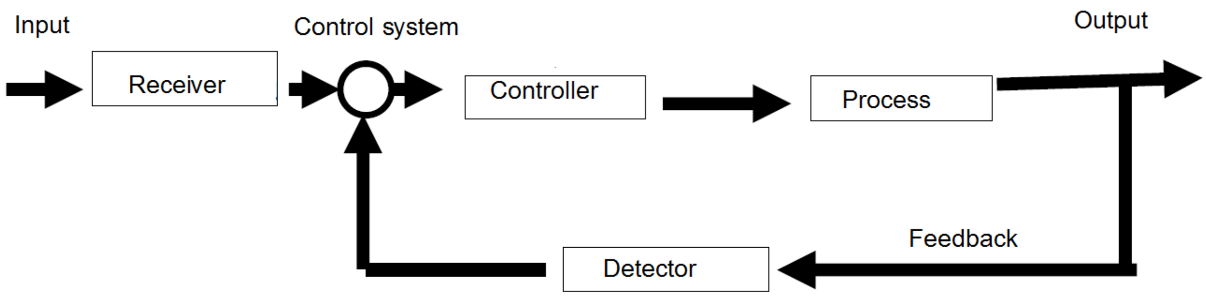


Figure 2.4 Closed loop or feedback control system

2.3 PROGRAMMABLE LOGIC CONTROLLERS (PLCs)

2.3.1 History of PLCs

Programmable Logic Controllers or PLCs were invented by GM (General Motors) company of United State to replace the conventional electric circuit that was using in company. PLCs were first produced to distribute in United State in 1969. PLCs were developed later in Japan after Omron Company succeeded in producing of Solid State Relay in 1975. Five years later, PLC was widespread distribution in the market of industrial organization.

2.3.2 What are PLCs?

PLCs are the Solid State equipment controlled by logic function. The operation of PLCs is similar to the operation of computer. Basically, PLCs compose of equipment called Solid State- Digital Logic Elements to make decision in logic system. PLCs are used to control the operation of machine in industries. Nowadays, many industries generally apply PLCs to control the production system instead of the conventional relay circuit because of the PLC is the microprocessor of electronic device and the programming is similar to general program computer which differs from the wire installation of conventional relay systems. Therefore, PLCs control systems can be easily changed the conditions of programs which only modifies programs in memory unit but the conventional relay systems must be reinstalled if we need to change the condition of systems. In addition, PLCs also have higher efficiency in analyzing than the relay systems. They can control many types of work and also can transfer the signals with other devices.

Table 2.1 Comparison between conventional relay system and PLCs

	Conventional relay system	PLCs
System Control	Difficult	Easy
Modification	Difficult	Easy
Connection with external equipment	Difficult because of much wiring	Easy because of lease wiring
Lifetime	Shorter because of higher movement part	Longer because of lower movement part
Speed	Slow	Fast
Installation	Take long time	Take short time
Working for complicated system	Difficult, must use many relays	Easy

2.3.3 Structure of PLCs

PLCs were designed for control work in industries that must be enduring with temperature, humidity, dust, force, vibration and so on. PLCs compose of Control processing Unit (CPU), memory, receiver unit, transfer unit and program device. Memory of PLCs composes of Random Access Memory (RAM) and Read Only Memory (ROM), RAM's function is to store the program and data of user, ROM's function is to store the program for operation of PLCs which has small battery connected to maintain the data, RAM is suitable to use for machine testing that needs to change or correct program frequently because reading and writing program into RAM can be performed easily. CPU is the brain of PLCs, inside CPU composes of many logic gates and Microprocessor-based that are used to replace equipment such as relay, counter, and timer for user to build ladder logic. CPU receives input data from sensing devices and store in memory, data will be transferred to control devices. DC current source will produced low level voltage that is used by processor and I/O modules.

Input and output unit (I/O Unit) will be connected with controller to receive signals and transfer to CPU for processing and transfer to output unit. External input signal from switches or detectors will be transformed to appropriate signal for transfer to CPU. Output unit will receive signals from processing of CPU and use them to control hardware such as motor, solenoid valve or bulb(Tancheewawong, 2012).

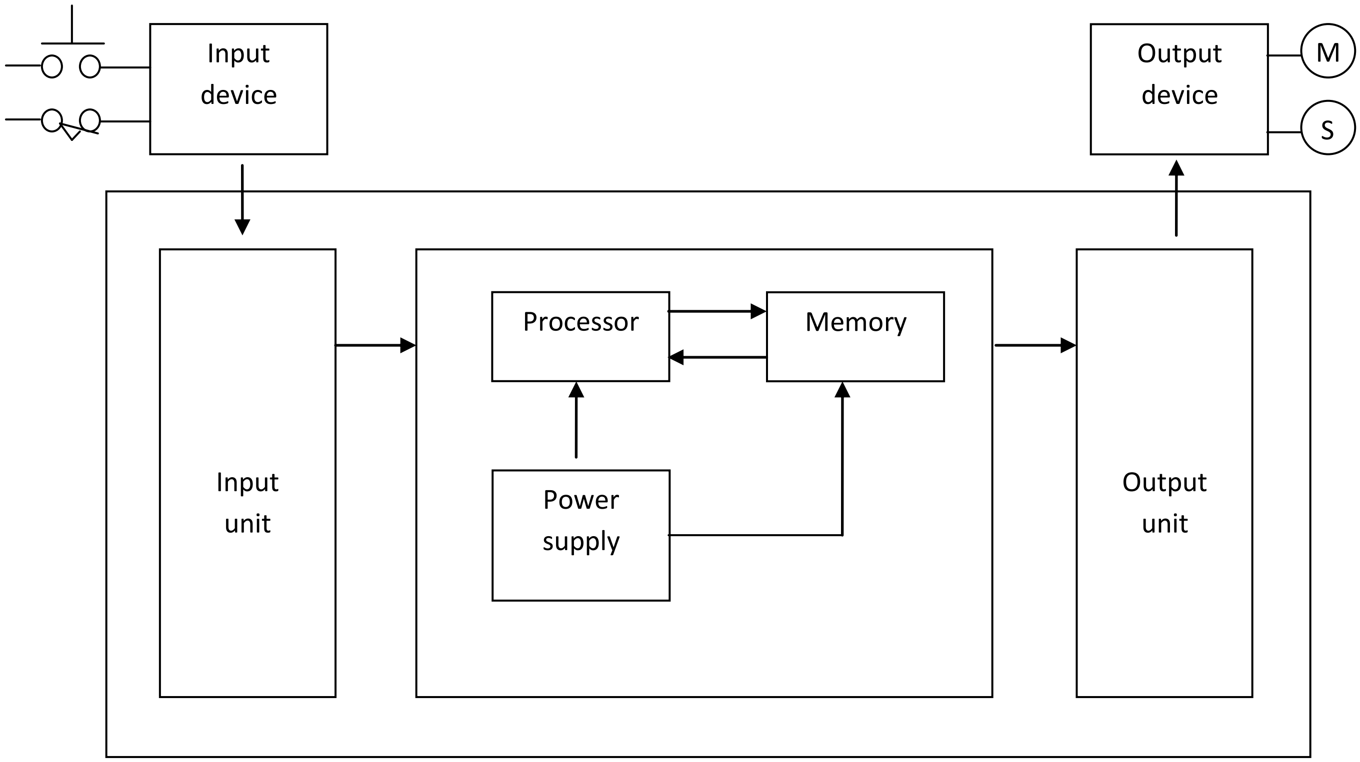


Figure 2.5 Basic components of PLCs

2.3.4 PLC Operating

1. Receive input signals from input devices which can be pushbutton switches or sensors for analog signal.

2. The signals from input devices will be adapted for understandable processor and it will be stored in memory.

3. The processor will run the program step by step which starts from the first until the end in memory. The condition of the program will be generated by using the statuses of input devices.

4. Output unit transforms the output statuses to be the signals that can control and transfer to output devices.

5. Output devices which can be lamp, motor, control valve and so on will be controlled by signals that are sent from output unit.

2.3.5 Programming the PLC

Programming is the process which the user enters the control instructions to the PLC through the programming device. The instructions of PLC programming have three languages such as

- Control System Flowchart or Function Block

- Ladder Diagram

- Statement List

Ladder diagram is the basic language which was used for small PLC to replace relay devices, timer and counter in ON/OFF control. Function block and Statement list are high language application that uses for complicated control or mathematical calculation. PLC programming consist of steps which are

1) Specification is the detail of work that we need to control it.
2) Design can be shown by Function chart or Displacement Step Diagram and have to show devices, installation, and circuit diagram.
3) Programming to control the work operation.
4) Commissioning used to test the working of program with the operation to detect the error for correcting before it will be used.

In this section, we would like to show the basic programming of PLC by using Ladder diagram in figure 2.

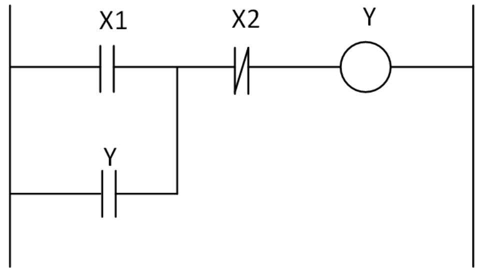


Figure2.6 Ladder logic diagram for the push-button switch

X1(normally open) and X2(normally close) are input contacts, and Y is a load in the diagram which can be lamp, motor, solenoid valve and so on. Note Y also serves as an input contact to provide the power connection. If we press switch X1, the signal will transfer to a load Y (assume Y is a motor). Motor will run immediately and its contact also holds the signal of system to allow motor run continuously. When we press switch X2, the signal will be cut and motor will stop(Jack, 2005).

2.4 MITSUBISHI PLC

Mitsubishi is the one popular brand used in automation process in many factories. The basics PLC of Mitsubishi are not different from the other brand. In addition, Mitsubishi PLC can be applied broadly from simple to complicated process which depends on the type of PLC. In general, the operation of processes in factories are mostly complicated, basic PLC cannot be applied to run the processes. Therefore, data registers are required for these processes, data register is the site to store the data or address when PLC is connected to the other source of input such as barcode reader and camera. GX Developer is the software of Mitsubishi PLC to design program, this software can be used to control every type of Mitsubishi PLC for various types of process. The detail of using software is explained in appendix.

2.5 HARDWARE

2.5.1 Sensors

Sensors are used for a wide variety of the manufacturing process for collecting data in feedback control. They are a transducer which is a device to convert a physical variable one form to another one form. In this section, we will briefly discuss the types of sensors that normally used in manufacturing application.

2.5.1.1 Inductive proximity sensor

Inductive proximity sensor can be used to detect metals by using inductive transformation. The important components are Oscillator, Evaluator and Amplifier. At the tip of this sensor has a high frequency of magnetic fields to detect nearby metal objects. If a metal object is near the changing of magnetic field, current will flow in the object. This resulting current flow will set up a new magnetic field to be the original magnetic field. The net effect is to change the inductance of the coil in the inductive sensor by measuring the inductance of the sensor can determine when a metal have been brought nearby.

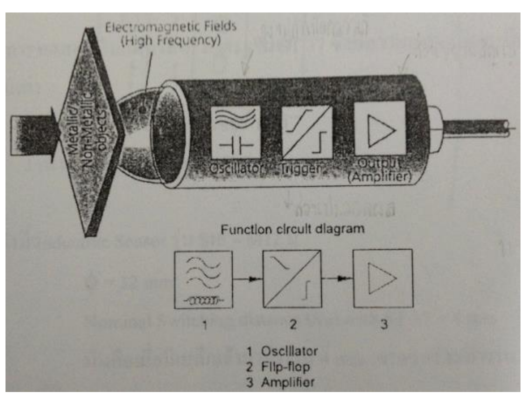


Figure2.7 Inductive proximity sensor

2.5.1.2 Capacitive proximity sensor

Capacitive proximity sensor is similar to inductive proximity sensor but the operation is different. Capacitive proximity sensor use Capacitance transformation due to the distance and type of objects. It can detect both metals and non-metals which is specifically high dielectric coefficients. The capacitance transformation of capacitive proximity sensor occurs when objects are brought near the sensor. The proximity of any material near the electrodes will increase the capacitance. This will vary the magnitude of the oscillating signal and the detector will decide when this is great enough to determine proximity.

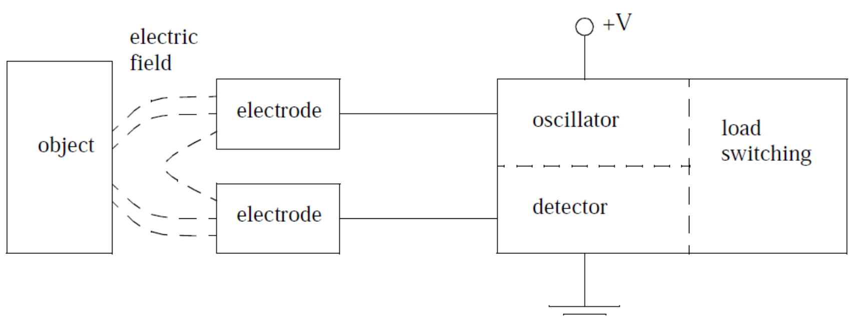


Figure2.8 Capacitive proximity sensor

2.5.1.3 Optical proximity sensor

Optical proximity sensor consists of two main components which are Receiver and Emitter. Receiver normally uses Photo Diode and Photo Transistor and emitter normally uses LED (Light Emitting Diode) to produce the light (red light or infrared). Optical proximity sensor can be classified to be three types which are

1) *Through-beam sensor.* Receiver and Emitter are separated by using an object to oppose the beam when it moves between receiver and emitter. This arrangement works

well with opaque and reflective objects with the emitter and detector separated by distances of up to hundreds of feet.

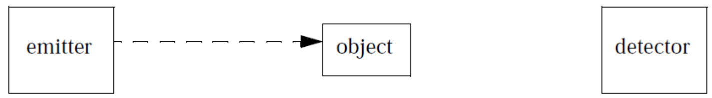


Figure2.9 Through-beam sensor

2) Retro-reflective Sensor. Emitter and receiver are combined with polarizing screens oriented at 90 deg. The light will be sent to reflector and reflected back directly to receiver. If the light is obstructed by an object, the light does not pass through the screen in front of the detector. So, that object can be detected.

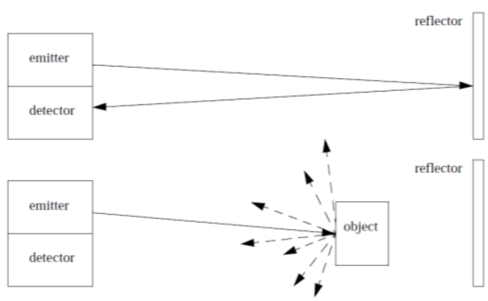


Figure2.10 Retro-reflective Sensor

3) Diffuse sensor. This sensor is similar to Retro-reflective Sensor but the difference is the light will be sent directly to an object and reflected back to receiver without reflector.

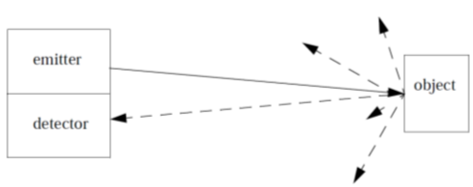


Figure2.11 Diffuse sensor

2.5.2 Hydraulic cylinders

Hydraulic cylinders function by power transfer of liquid in linear direction. When power is transferred into cylinder, cylinder will convert from hydraulic power to mechanical power in the form of linear movement direction or rotary direction. Hydraulic cylinders can be classified into 4 types:

1) Double Acting Single Rod Cylinder is two-way cylinder with one rod inside cylinder.

2) Double Rod Cylinder is two-way cylinder with two rods connected with piston in the middle.

3) Tandem Cylinder is two-way cylinder with two or more piston but only one rod. This type can increase force of cylinder and it is normally used when pressure is limited and area of piston cannot be changed to be bigger.

4) Duplex cylinder is two-way cylinder but rods are not connected together. It is normally used when the position of piston is difficult to control(Pontri, 2009).

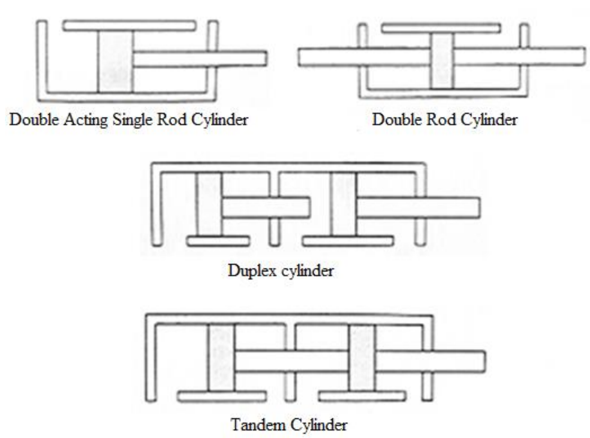


Figure2.12 Hydraulic cylinders

Double Acting Rod Cylinders are normally used in industries which converts from hydraulic power (Gallon Per Minute: GPM and Pound Per Square Inch: PSI) to mechanical power and can achieve the required speed. Speed and force of rod are defined by GPM and PSI respectively. These two parameters affect to area of piston (Major area) and area of rod (Minor area).

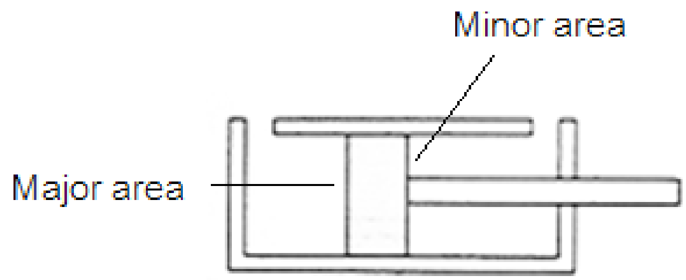


Figure2.13 Major and Minor area

Speed of rod for extending depends on flow rate of oil into cylinder which normally measured in ft/min and can be calculated by:

Extending Rod speed, ft/min = (GPM x 19.25) / (area of piston (Major area), inch^2)

Retraction Rod Speed:

Retraction Rod Speed, ft/min = (GPM x 19.25) / (area of rod (Minor area), inch^2)

Flow rate of oil at rod end side (extending cylinder):

GPM = Rod speed, ft/min x (area of rod (Minor area), inch^2) / 19.25

Flow rate of oil at piston side (retraction cylinder):

GPM = Rod speed, ft/min x (area of piston (Major area), inch^2) / 19.25

Extending force:

$$F \text{ (pound)} = \text{Pressure (PSI)} \times (\text{area of piston (Major area), inch}^2)$$

Retraction force:

$$F \text{ (pound)} = \text{Pressure (PSI)} \times (\text{area of rod (Minor area), inch}^2)$$

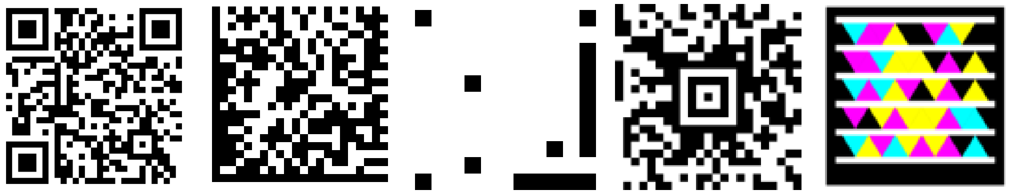
2.6 BARCODE SYSTEM

Barcode was invented by Norman Joseph Woodland and Bernard Silver, student of Drexel Institute of Technology in Philadelphia United State. The commencement of invention started from Wallace Flint from Harvard School in 1932, he proposed product selection by using bored card to divide categories of products but this idea was not developed until Bernard Silver accidentally heard the manager of retail product company in Philadelphia was consulting with the Faculty dean to supplement about data storage and clarification experimental to afford convenience for retail business to manage stock. Bernard invited Norman Joseph Woodland to join this challenge and in 1952, both of them invented barcode after experimental for many years and they got patent on 7 October 1952. Barcode was firstly produced in the form of circular shape similar to shooting butt. Nevertheless, retail store in Kroger group in Cincinnati, Ohio state USA was the first company in the world used this first form in 1967. Afterwards, barcode was developed and barcode scanned was invented and firstly used in Marsh's supermarket on June 1974 and on 26 June 1974, Wrigley's Juicy Fruit gum was the first product to be scanned by barcode reader because it was the first product of the first customer on that day.

Barcode is the sign used to replace and store any kinds of data by using binary codes. It can be read by barcode reader (Optical machine-readable). Technology of barcode was used to replace data entry by keyboard which has 0.01% error, but for barcode system, error is reduced to 1/10,000,000. Data kept inside barcode mostly concern with the thing attached by barcode, it is mostly used to clarify data of every product as we can see in the general market. Barcode firstly used in the form of "Bar" or parallel lines with thickness and space white and black colors, this is called 1D Barcode. Subsequently, barcode was developed to have point, rectangular, hexagonal and other geometries form which are called "2D barcode". Conventional barcode can be read by barcode reader. Currently, other equipment and software ware developed to clarify barcode such as printing machine and smartphone.

Barcode is firstly used to control tram but it was not succeed for commercial business until supermarket applied barcode to use for automated casher counter, this made barcode to be widespread in the world. Barcode was widely used for other tasks that concerned with automatic identification and data capture (AIDC). Modern barcode are made in the form of Universal Product Code (UPC).

Nowadays, evolution of barcode system has undoubtedly developed both the form and capability to store data. Barcode in this time has 1D, 2D, and 3D but the general barcode used is 1D which is limited to store data. 2D barcode can store data more than the other type and the shape is smaller. 2D barcode is used to store huge number of data included Radio Frequency Identification (RFID) technology which used radio wave to inspect data instead of laser. In addition, 2D barcode can be alteration in many applications, for example, it can unbelievably store large file such as photos. 2D barcode that mostly used has many types such as QR code, Data matrix, EZcode, Aztec Code and MS tag.



QR code Data matrix EZcode Aztec Code MS tag

Figure2.14 2D barcode

The purpose of 3D barcode is to eliminate the limit of barcode. The problem of barcode is when barcodes are attached in atrocious environment such as very hot, very cold or dirty from color or dust. 3D barcode is mostly used in heavy industrial such as machine and automobile industrial. 3D barcode can be produced by using laser cut on metal or makes the surface to be convex.

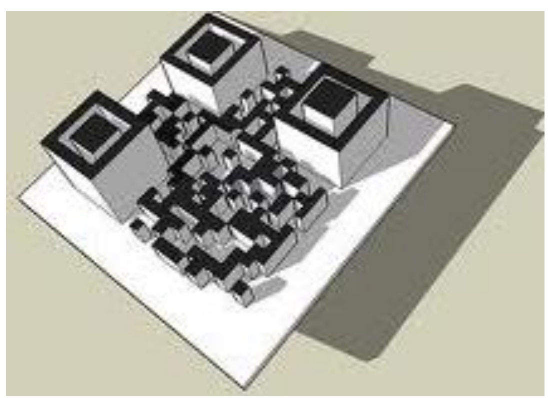


Figure2.15 3D barcode

Barcode is a good way to check selling products, selling point, price and inventory. We can read barcode by using barcode reader which is faster than transfer data into computer or eye vision. In general, we can see the uses of barcode in the grocery stores, book stores and consumable stores. In Europe region, every truck run between French and Germany must use barcode attached on the window to show identification card, permission document and truck weight to the custom house to check easily and quickly, when the driver decreases the speed of the truck, barcode reader will read and shown data on the computer immediately(book, 2009).

Barcode system was seriously brought to use in Thailand by Thai Article Numbering Council or TANC which is substitute organization under Thai Industrial Council. Barcode system in Thailand uses 13 digits number which means thus

885: First 3 digits are Thailand's code.

XXXX: Next 4 digits are manufacturer's code or member's code.

XXXXX: Next 5 digits are product's code.

X: The last digit is used to ensure that the first 12 digits are correct. If the last digit is wrong, that barcode cannot be read or interpreted data.

Barcode system will be integrated with PLC to classify sizes of tires and transfer signal to PLC for this project. The main operations of barcode system are:

1. Light from barcode reader will be shined to barcode tag. Barcode reader consists of light source, decoder, detector inside and cable to connect to the computer.

2. Receive the reflection and measure the number of light from barcode tag (black bar will reflect light lower than the white space between them).

3. Barcode reader will convert the number of reflected light to electrical signal.

4. Electrical signal will be converted to usable data by decoder.

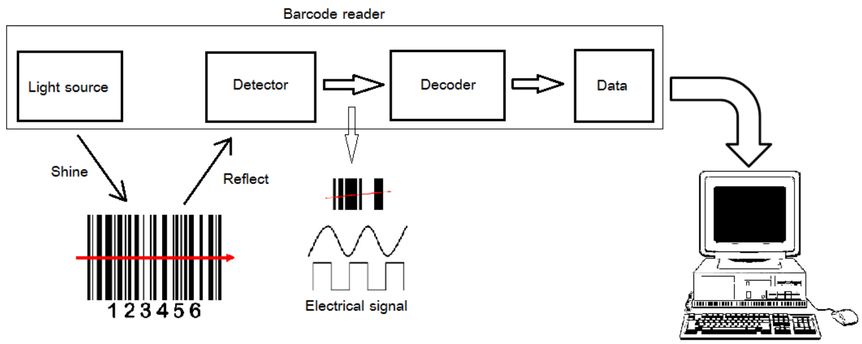


Figure2.16 Barcode system

2.7 THE HISTORICAL RESEARCH OF AUTOMATION FIELD AND AUTOMATED SORTING SYSTEM.

A vision system was integrated to the manipulation system which consists of a conveyor belt, objects moving on it, a robotic manipulator and a visual sensor above the conveyor for applying on a real industrial manipulation. The applications for industrial are purposed to utilize robotic manipulators. The combining vision and robotic applications have appeared in many studies. There is a conveyor belt and a digital camera takes pictures of the object. The system gets the captured image data and analyzes it and decides for next process which depends on the result of the detection(Adıg¨uzel, 2007).

NBS Vision System was developed by Sensory Intelligence Group of Robotics System which can be used in the Automated Manufacturing Research Facility (AMRF) to provide information of the Real-time Control System and the Material Handling Workstation. A vision system could be integrated with robotics for a robotic manipulation problem in industrial settings. A problem could be formulated as combining the components which consisted of a conveyor belt, objects moving on it, a robotic and a vision sensor above the conveyor (Nashman & Chaconas, 1988).

The sorting system of grain color of rice seeds was studied to determine the parameters that are influential with the effective of inspection for sorting. Background component were installed to be opposite with inspector's lenses and two fluorescent lamps were located at the top and bottom of sensor unit. The result shows that parameters affect to the best performance of sorting. The controlled parameters are average grain velocity at 0.0817 m/s, light intensity between 8,800-9,600 lux, the average background voltage 8.2 volt DC, focus distance of sensing 123 millimeters, the average distance of background 54 millimeters, voltage of feeder 80 volts, the average air pressure 2.5 bars, these parameters will result 74-82% sorting efficiency (Rattanapussadeekul, 2006).

Automatic Rice Seeds Separator Machine was invented by using micro-controller to control sorting system efficiently and can reduce wasteful rate of rice seeds more than conventional machine, faster and more convenient. The process of rice seeds sortation has many steps and need high volume number of workers. For conventional method, Rice seeds will be fed and flowed into blank cavity. Wind is produced by manpower machine to blow rice seeds and wind power is not stable, this is the cause that makes rice seeds become dirty and waste. Automatic machine was developed to increase the efficiency of sorting process and reduce the procedure of process by controlling speed of wind to be appropriate with flow of rice seeds. The operations of automatic machine, rice seeds will be fed into blank holder and choose the level of wind's speed which has high and low flow rate, wind's speeds are controlled by motor's speed. The experimental was done to compare the efficiency between conventional and automatic machine. The result shows 85.7% efficiency for conventional machine and 92.5% efficiency for automatic machine (Anusorn Srisawas, 2007).

Automatic Fish Measurement and Classification System using Video Image Analysis were developed to achieve high efficiency in fish grading. Fish grading is now important process for fishery industry, this process mostly uses human and it is not efficient enough. Automatic Fish Measurement and Classification System will support fishery to get more benefit, this system uses technology in image analysis from video camera by using digital image processing. Fishes will flow on the conveyor belt and pass to processing system to analyze the length of body and compare with database, the result will be the standard size which is the beginning value of mechanic system to sort the size of fishes. Users can use this program from user interface that is easily used without personal expertise to be usable in the real fishery industry (Similan Arsaiphanish, 2007).

A Simple Material Selection Educational Training Kit Controlled by PLC was presented by using the knowledge of conveyance system and automation operation applied to control the operation of the system. The training kit has component both software program and mechanic hardware of electro pneumatic and DC electric motor functions to control conveyance system to the desired position. The experimental was done to determine efficiency of training kit, error of selection test was a parameter, tested 30 times and 12 work pieces per one time to become 360 work pieces. The result shows that the training kit was operated according to the control program and capable to sort different material work pieces, the efficiency of material selection was 95% (Saithong Sriyotha, 2007).

Edward A Bruno presented a synthesis of available information on automated sorting of plastics. The material includes technologies that are commercially available and those that are still in the research phase of development. The information is broken into two categories: macrosorting and microsorting. The macrosorting section deals with the sorting of whole bottles or containers. The section covers the following technologies: infrared spectroscopy, x-ray, laser-aided identification, and marker systems. The microsorting section follows the sorting of plastic after it has been chopped into pieces. The section covers the following areas: Sink float systems, froth-floatation, and selective dissolution. As a final note, future areas of research are suggested(Bruno, 2005).

An automatic color sorting system was described for red oak edge-glued panel parts. The color sorting system simultaneously examines both faces of a panel part and then determines which face has the “best” color, and sorts the part into one of a number of color classes at plant production speeds. Initial test results show that the system generated over 91 percent acceptable panels from automatically sorted red oak panel parts, which exceeded target plant production goals. The color sorting system was developed in cooperation with NOVA Technologies and is now commercially available under the name of CESYS by Group Seven Systems(D. Earl Kline, 1997).

Baggage sorting is one of the major requirements for rapid processing in an airport. For larger airport automated system is must to match with the dynamic world. But there are many small to medium size airports handling between 1.5 and 6 million passengers a year, still haven’t automated. For many of these airports, there are still big gains to be made – in cost, time, efficiency and sorting quality – by introducing automated sorting system. The problem for many of those airports is finding the right systems to do the job. Because in many cases, solutions are designed primarily for the larger airports where much of the automation market is to be found are not cost effective for lower volume environments, and often those system cannot be accommodated within the space constraints of smaller terminal buildings. In the present project, an automated baggage handling and sorting system has been designed using microcontroller so that it could be cheaply implemented on a small size terminal with a low cost. A small scale model of the project has also been constructed. The sorting system is based on bar code reading and tracking of the baggage in a terminal. The baggages are then diverted to their destined terminal using a gate control system. The model can also be used in any packaging and distribution system(Aashique Alam Rezwan, 2012).

Low cost parcel sorting system demonstrates the functional elements of an automated sorting system by using a bar code reader (BCR).The adaptability of Bar Code Reader (BCR) is destined for the recognition of the destination code through the bar code available in the parcel and sorting them accordingly. A parcel usually comes with a consignment number with a set of bar code representing them. The destination code must also be included in the bar code set, so as to enable the recognition of the destination by the bar code reader. The process of sorting can be continued by using a timed rolling system which will be in the conveyer belt as a cross member which will drop down the parcel to the destination box. There must be separate sorting system for incoming and outgoing parcels to avoid complications(Ninja Agrawal1, 2013).

A.M Gaur, Rajesh Kumar, Amod Kumar and Dinesh Singh Rana described the automatic control of disc type rheometer. This developed device will able to provide flexibility to operator for testing of rubber. The operator has to just enter the duration of test and parameters through man machine interface. All the operations will occur automatically without any intervention in a prescribed sequence stored in programmable logic controller (PLC). This developed apparatus is useful not only for testing purpose, but it can be used for research for other types of materials also. With this state of art apparatus one can control the quality of rubber for various applications such as tyre industry. Also this would help to increase the production of rubber as automatic control comes which reduces the test duration to few minutes only(A.M Gaur1*, 2010).

Nutdanai and Anake presents position and velocity control of a hydraulic cylinder in the automated repeated opening and closing of doors and windows testing machine using fixed displacement hydraulic pump coupled with servomotor in place of typical servo valve. The opening and closing cycle of 10,000 to 100,000 must be achieved to represent realistic working condition. The test machine consists of hydraulic power unit 4/3 directional control valve and hydraulic cylinder attached to door swing arm linkage. Servomotor and swing arm angular position was measured using optical encoder. The controller is PC running LabVIEW Real-Time operating system using proportional torque control scheme. Specimen was aluminum door frame set 73x193 cm in size. Results after 20,000 test show that for generated polynomial trajectory tracking error was less than 3 degree and steady-state error was less than 0.5 degree. Acceleration and deceleration time from 0 degree to 83 degree opening was 3 second and maximum pressure was 30 bars(Nutdanai Tanwirun, 2012).

A Programmable Logic Controller (PLC) is a specialized computer used for the control and operation of manufacturing process and machinery. A junior/senior level PLC course in a four-year electrical engineering technology institution mainly covers the following topics: PLC hardware components, developing fundamental PLC wiring diagrams, basics of PLC programming, timers, counters, program control instructions, data manipulation instructions, math instructions, sequencer and shift register instructions, PLC installation, editing and troubleshooting. After the lectures, students practice PLC programming using

RSLogix® from Rockwell Automation. Students are able to observe the operation of the program and make necessary modifications as necessary. Towards the end of the semester, students have learned the basic PLC programming instructions. It is a good time to enhance their practical problem solving abilities by working on an extensive design project using PLCs. This paper discusses three separate design projects aided with PLCs to solve practical process and machinery problems in industrial environments(Guo, 2009).

The Top Cover Screw Floating Check at Final Inspection project is established to study and check screws on the top cover of a hard drive. The purpose of this project is to reduce an error of human's eye. This image processing method is applied to this project to check and compare the difference between original and test picture. The Top Cover Screw Floating Check at Final Inspection project consists of 3 major parts: 1. Designing the Graphic User Interface (GUI) process for a user. 2. Checking and showing a result of the level of top cover screws. 3. Keeping the result in the database. From the experiments, the designed program can successfully check and show the level of top cover screws. Finally, the obtained result can be kept to the database as the objective of this project(KANITTA HONGPAKMANOON, 2009).

2.8 CONCLUSION

Many research walk through the improve flexibility by using another tool on the automation system, therefore make the feasibility to study the automation on many kind of production process and manufacturing machine, one kind is hydraulic control system, also widely used for improvement and install for increase performance to the system process, due to this research considering to study the automation system in tyre production company by applying PLC control for improvement on the tyre sortation system .

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

In this study, tyre sortation process line of Thai Bridgestone needs to be improved. Integration of Programmable Logic Controller (PLC) is chosen to solve the problem. Therefore, software program design is applied to modify the sortation line from manual operation to automated operation and laboratory test is performed to test the operation of program. This chapter covers the topics include current operation of tyre sortation process, research procedure methodology, detail of research procedure methodology, concept design of process improvement, integration of barcode reader with FX3U Mitsubishi PLC and program design concept.

3.2 CURRENT OPERATION OF TYRE SORTATION PROCESS

Tyre sortation process is performed to classify sizes of automobile tyres because tyres are mixed after curing processes. Therefore, sortation process is required to sort different sizes of tyres for distribution. Tyre's sizes of Thai Bridgestone Co., Ltd company can be classified into mainly 6 sizes which is 13-18 inches measures from the internal diameter as shown in figure 3.1, but the external diameter and thickness of tyres can be classified more than 200 types, these sizes are produced to support various types of automobiles such as sedan, pick up car, truck and so on.

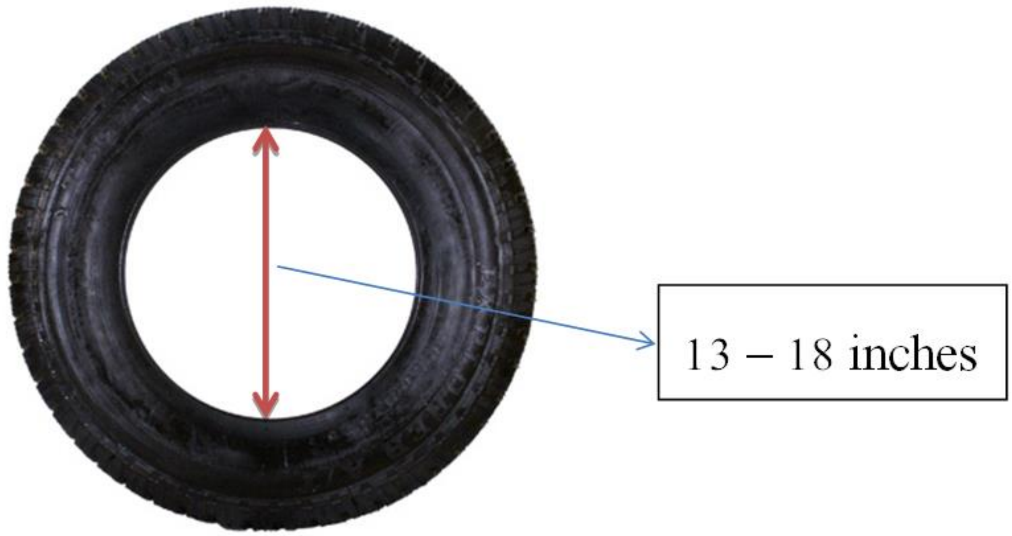


Figure 3.1 Tyre's sizes

Tyre sortation process is performed manually which uses worker to operate. Sortation process has 6 station divided for 6 sizes, workers stand at each station and tyres will be moved on the conveyor belt, workers have to sort tyre's sizes by eyes to see tag code attached on tyres and press the bottom to move cylinder forward to hit tyre for sortation. This can be a cause of mistake in case of workers are unaware or forgetful and tyre's sizes will be incorrectly sorted. In addition, overflow conveyor has been installed to prevent when some of tyres are not sorted because of worker's mistake or process maintenance and setup. This overall process is shown in figure 1.1.

Tag codes will be attached on tyres which is the sign for workers to classify sizes. Tag code of Thai Bridgestone uses 9 digits shown in figure 3.2.

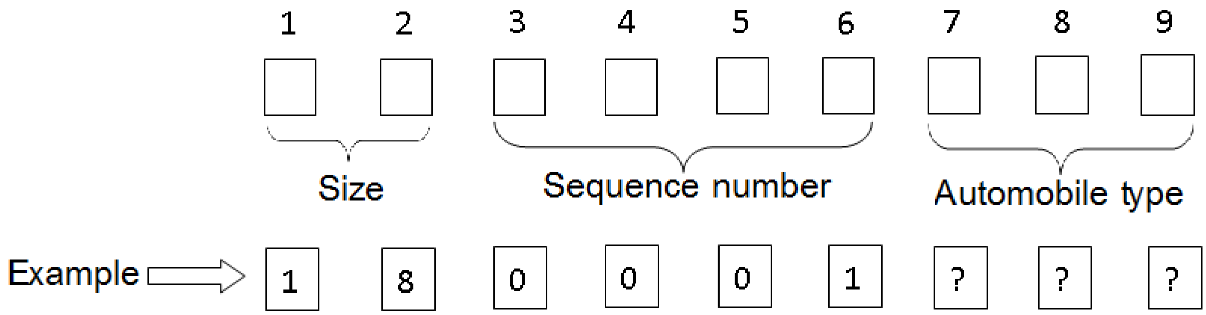


Figure 3.2 Tag code of tire

Tag code can be used to classify sizes and number of tyres. The first 2 digits classify sizes which are 13-18 inches, the next 4 digits classify sequence number of tyres in one lot, and the last 3 digits classify automobile types such as 100-155 are used for sedan. For example, tyre 13 inches are produced 10,000 tyres in one lot and tag code 132345132 shows tyre size 13 inches, number 2,345 of 10,000 and used for sedan.

3.3 RESEARCH PROCEDURE METHODOLOGY

The methodology of this research project applies operation of programmable logic controller (PLC) integrated with barcode reader to model automated tyre sortation system and laboratory test is applied to simulate the overall system. These are performed to replace real testing operation in industry. The research study flowchart is shown in figure 3.3.

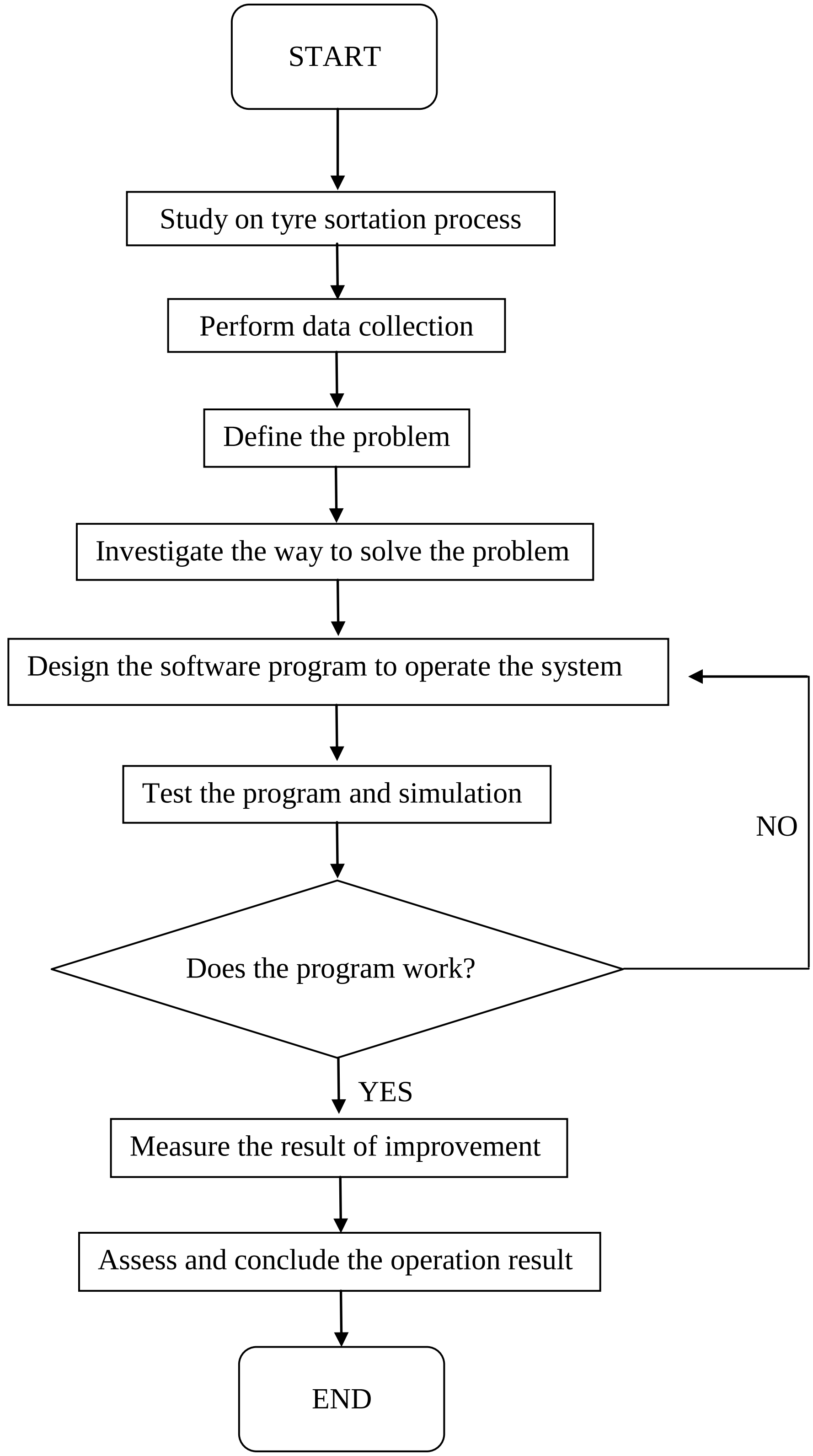


Figure 3.3 Research study flowchart

3.4 DETAIL OF RESEARCH PROCEDURE METHODOLOGY

Detail of research procedure methodology in automated tyre sorting system using Mitsubishi FX3U PLC controller composes of research procedure, operation objective, method and tool as shown in table 3.1

Table3.1 Detail of research procedure methodology

Research procedure	Operation objective	Method and tool
1. Study on tyre sortation process.	To know how is the current operation of process.	Observation on the operation.
2. Perform data collection.	To know which parameter can be improved.	Check sheet and notebook writing.
3. Define the problem.	To investigate and analyze the problem.	Converse with operators.
4. Investigate the way to solve the problem.	To solve the problem.	Study from manual PLC book.
5. Design the software program to operate the system.	To run the system and replace manual operation.	Design program by using software GX Developer

Table3.1 Detail of research procedure methodology (continued)

Research procedure	Operation objective	Method and tool
6. Test the program and simulation.	To test that does the program can work as desire?	Connect barcode reader and switches (replace sensors) with PLC as input and connect lamps (replace solenoid valves) as output.
7. Measure the result of improvement.	To study the result of research project.	Calculation
8. Assess and conclude the operation result	To monitor and predict for future improvement.	Compare the result before and after improvement.

3.5 CONCEPT DESIGN OF PROCESS IMPROVEMENT

The manual operation of tyre sortation process should be eliminated. Integrated of Programmable Logic Controller (PLC) with barcode system will be applied to automate the system. Barcode reader is the input devices to receive barcode data number and transfer data to PLC to operate process. Barcode readers will be installed for each sortation station which 6 barcode readers will be used. Cylinders are the equipment used to sort for each size and the movement of cylinder will be controlled by solenoid valve and hydraulic system. Proximity sensors will be installed to check that tyre has reached to cylinder. The functions of equipment are concluded in table 3.2.

Table3.2 Function of equipment

Equipment	Function
Barcode reader	Receive data input number of barcode tag.
Cylinder1	Sort tyre size 13 inches
Cylinder2	Sort tyre size 14 inches
Cylinder3	Sort tyre size 15 inches
Cylinder4	Sort tyre size 16 inches
Cylinder5	Sort tyre size 17 inches
Cylinder6	Sort tyre size 18 inches
Sensor X1	Check position of tyre size 13 inches
Sensor X2	Check position of tyre size 14 inches
Sensor X3	Check position of tyre size 15 inches
Sensor X4	Check position of tyre size 16 inches
Sensor X5	Check position of tyre size 17 inches
Sensor X6	Check position of tyre size 18 inches
Solenoid valve Y000	Advance cylinder 1
Solenoid valve Y001	Return cylinder 1

Table3.2 Function of equipment (continued)

Equipment	Function
Solenoid valve Y002	Advance cylinder 2
Solenoid valve Y003	Return cylinder 2
Solenoid valve Y004	Advance cylinder 3
Solenoid valve Y005	Return cylinder 3
Solenoid valve Y006	Advance cylinder 4
Solenoid valve Y007	Return cylinder 4
Solenoid valve Y010	Advance cylinder 5
Solenoid valve Y011	Return cylinder 5
Solenoid valve Y012	Advance cylinder 6
Solenoid valve Y013	Return cylinder 6

The operation of each sortation station is separately controlled. This will result in simplification the program and can also prevent bug of program, wrong sorting problem or work in process in case of some tyre cannot be sorted because of defective program. The operation of the system at each station is, when tyre moves pass barcode reader, barcode reader will read barcode tag and transfer data to PLC to operate follow the designed program, when proximity sensor is trigged because tyre move pass it, solenoid valve will be commanded to control movement of cylinder to push tyre to the opposite path for sorting, cylinders are driven by hydraulic system. The sequence of operation is shown in figure 3.4 and aid of sketch of concept design is shown in figure 3.5.

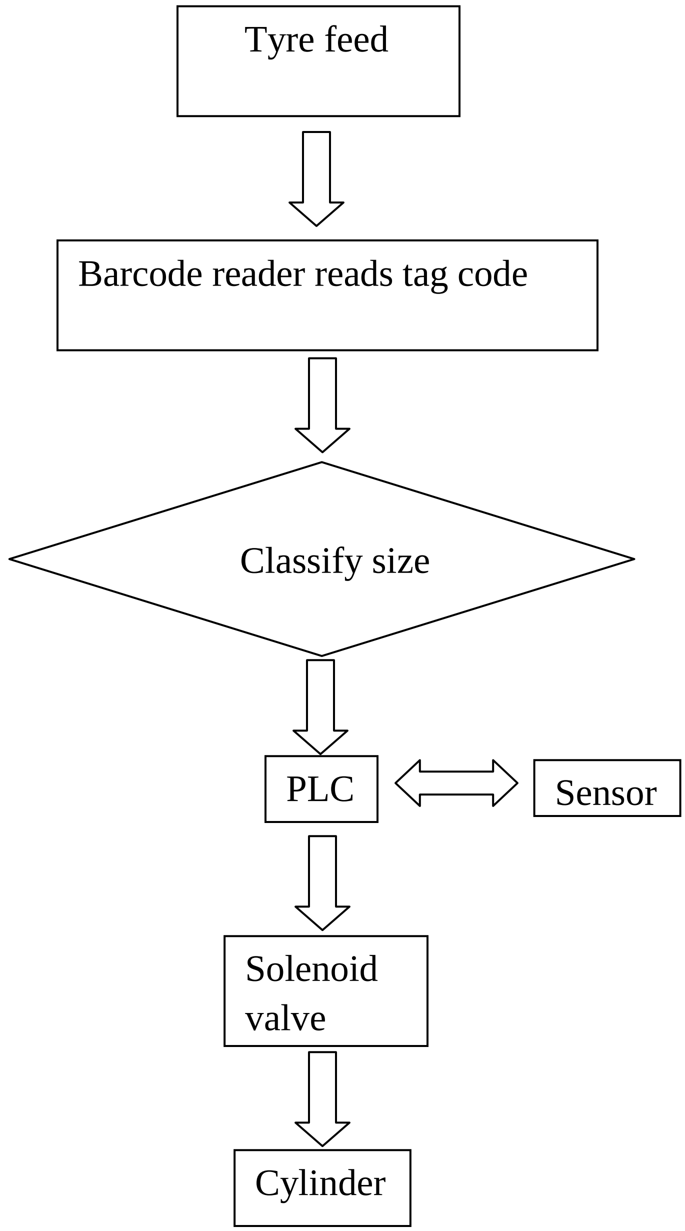


Figure 3.4 Sequence of operation

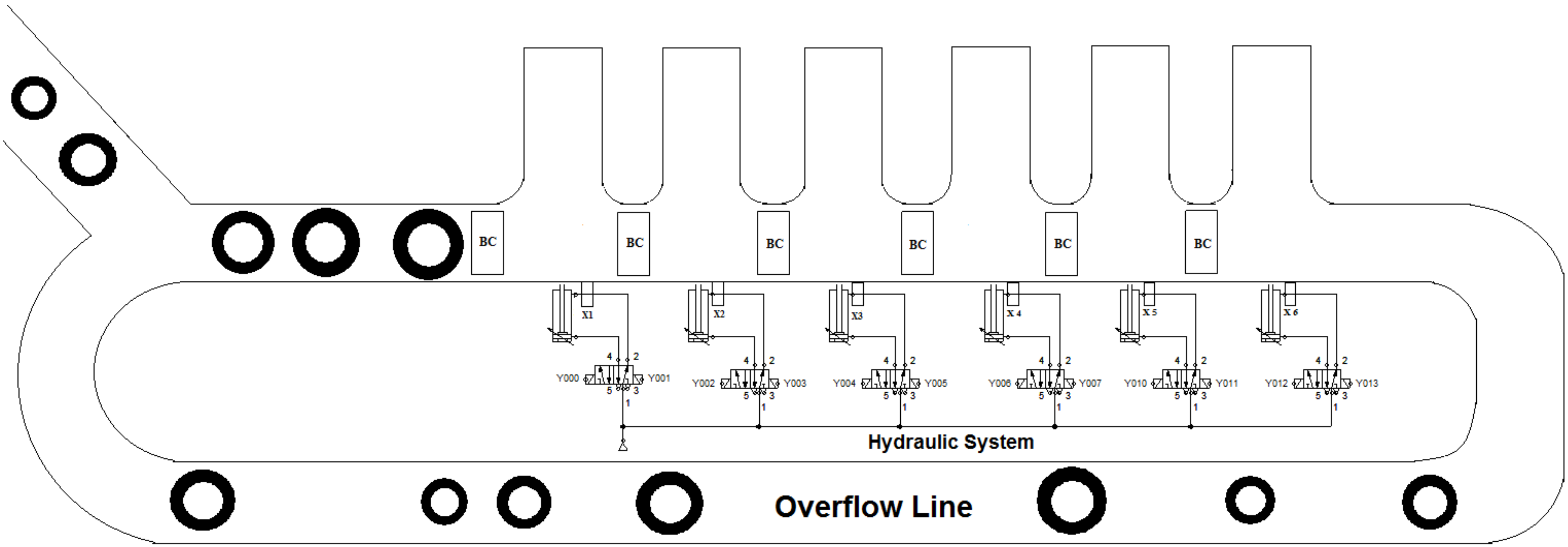


Figure3.5 New design concept

3.6 INTEGRATION OF BARCODE READER WITH FX3U MITSUBISHI PLC

Barcode is integrated with PLC as an input device to classify data of each size. The important thing is how to manage data from barcode reader to easily connect with PLC? Data from barcode must also be transformed to be usable for PLC. Barcode reader HT700RB RS-232 series as shown in figure 3.6 and PLC Mitsubishi FX3U as shown in figure 3.7 are used for experimental. Barcode reader and PLC are connected to transfer data by RS-232 wire port connector as shown in figure3.8.

Figure3.6 Barcode reader HT700RB series

Figure3.7 PLC Mitsubishi FX3U

Figure3.8 RS-232 wire port connector

Each size of tyre is specified by tag number in barcode to classify size for PLC to operate. Barcode tag number for each tyre's size is shown in table3.3 and figure3.9.

Table3.3 Specification of barcode tag number

Barcode tag number	Specify
8851019010274	Tyre size 13 inches
8851019030272	Tyre size 14 inches
8851019030425	Tyre size 15 inches
8851019030241	Tyre size 16 inches
8851019030340	Tyre size 17 inches
8851019030432	Tyre size 18 inches

Figure3.9 Barcode tag

Data from barcode are called ASCII characters which are the same number shown on barcode tag. Data are continuously stored in Data register (D500), this is set by reading command in ladder program of GX Developer software. ASCII data of each barcode tag for each tyre's size are shown in appendix. However, ASCII data from barcode tag are not usable with PLC. Therefore, data received from barcode must be transformed to be usable for PLC. Data can be transformed by PLC and GX Developer software to become 16 bits and 32 bits. In this case, 32 bits data are chosen to save the step of writing ladder diagram. Transformation from ASCII to 32 bits data are decoding of PLC by using special function inside microprocessor. Data are chosen and used to build ladder diagram. 32 bits data of each barcode tag for each tyre's size are shown in appendix.

Barcode reader that should be applied for the real sortation process must be high performance such as enable to read barcode tag in all direction, long distance scanning, and fast reading because when tyres are put on the conveyor belt, it is very difficult to control or set the direction of barcode tag to be readable for barcode reader.

Nowadays, performance of barcode reader has been developing to support wide variety of industrial processes, iVu Barcode Reader (BCR) is a barcode reader used to read a variety of barcodes and to optionally compare data to known values that can be used for this task which is high-performance barcode reader of industry standard barcode. The sensor has an integrated color touch screen display making installation, setup and configuration easy without requiring a PC. It can read up to ten codes in any directions and a variety of barcode types at one time, including: 2D barcode data matrix, 1D barcode (Code 128, code39 and so on).

Figure3.10 iVu Barcode Reader (BCR)

The iVu BCR has an RS232 serial communications port that is used to output barcode data to other applications. The user can enable or disable serial output. Table3.4 shows the specification of iVu Barcode Reader (D, 2012).

Table3.4 iVu specification

Power Connection	12-pin Euro-style (M12) male connector Accessory cord set required for operation; QD cord sets are ordered separately.
Remote Display Connection **(Remote Touch Screen Models Only)**	8-pin Euro-style (M12) female connector Accessory cord set required for remote display; QD cord sets are ordered separately.
Power Requirements	Voltage: 10-30V dc Current: 500 mA maximum (exclusive of I/O load)
Output Configuration	NPN or PNP determined by model
Sensor Lock	Optional password protection
Output Rating	150 mA
Display	Integrated Touch Screen models: 68.5 mm (2.7") LCD Color Integrated Display 320 x 240 Transfer reflective Remote Touch Screen models: See RD35 Remote Display specifications below.
Exposure Time (Decode)	0.1 milliseconds to 1.049 seconds
Weight	Integrated Touch Screen models approximately 0.295 kg Remote Touch Screen models approximately 0.204 kg

Table3.4 iVu specification (continued)

Operating Conditions	Stable Ambient Temperature: 0° to + 50° C Relative Humidity: 95%, max. relative, non-condensing
Maximum operation distance	2 m
Certifications	CE

3.7 PROGRAM DESIGN CONCEPT

32 bits data of barcode are chosen to design ladder diagram. The concept of program design is to read data from barcode tag and use them to classify tyre's sizes. After that, use classified data to control operation of program and cylinders. The detail of concept of ladder diagram can be briefly explained as follow:

1) Read barcode tag to receive 32 bits data to store in the first data register (let say D500-D506) and move data to store in another data register (let say D200-D206). After data are moved, the first data register must be reset or clear values to be able to receive new data from the next coming tyre.

2) 32 bits data that are move to store in another data register (D200-D206) will be compared by using compare function to classify which tyre's size has passed to the process, in this step, data register (D200-D206) must also be reset or clear values to be able to receive new data. Data of that size will be store in one more data register (let say D10). Data comparison of each size will be the same.

3) After PLC has already known tyre's size, program must count the number of that size and give signal to wait until sensor is trigged. D10 must be reset or clear values to be able to receive new data.

4) After sensor is trigged, program will command solenoid valve to control cylinder to push tyre to the sortation way. After one tyre is pushed, number of tyre inside program must be decrease at once.

The program's operation of every tyre's sizes will be the same basic and ladder diagram will be expressed and explained in chapter 4.

CHAPTER 4

RESULT AND DISCUSSION

This chapter presents the result of system development, including actuator system design, ladder diagram design, and laboratory test to provide the possible automated tyre sorting system. Overall detail will be explained and discussed on the result of development.

4.1 ACTUATOR SYSTEM DESIGN

Figure4.1 shows the actuator system which consist of six linear double acting cylinders (1, 2, 3, 4, 5 and 6) and six 5/2 way, double solenoid valves, detail and function of each equipment were already shown in chapter3. The actuator system is driven by hydraulic system and controlled by a typical PLC.

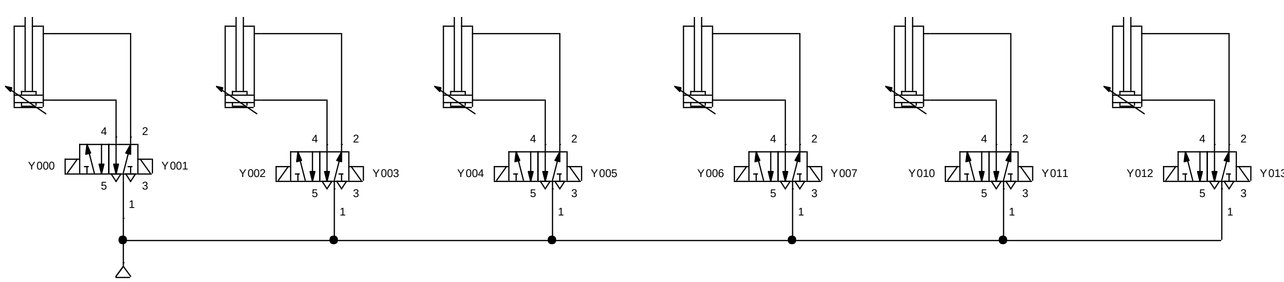


Figure4.1 Actuator system

In the real process, should have limit switch to check the position and control the movement of cylinder. For example, if cylinder advances to the end position to push tyre to the sortation way, cylinder will return immediately by function of limit switch which needs to be designed in the actual implementation. In this program design, function of Timer is used to replace limit switch by assume cylinder take 5 seconds to push tyre, this is for convenience in laboratory test. The aid of sketch of double acting cylinder shown in figure 4.2

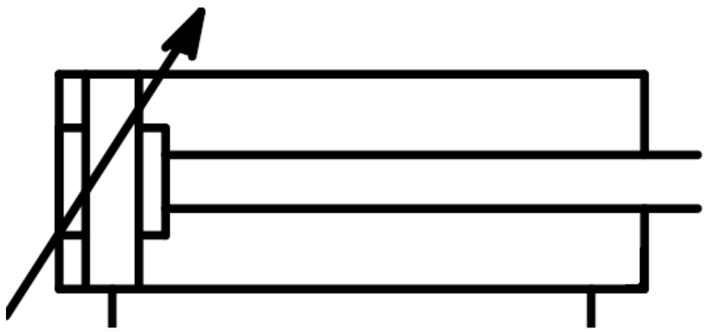


Figure4.2 Double acting cylinder

4.2 PROGRAM DESIGN

Program design of this study uses PLC controlled by ladder diagram and GX Developer software of Mitsubishi is applied. Numbers are defined for each size to be easy for ladder diagram design. Tyre size 13-18 inches are defined by numbers 1-6 respectively.

4.2.1 Set/Reset function

Set/Reset function is expressed to clarify ladder diagram how each variable is set and reset. Set and Reset function are shown in table4.1

Table4.1 Set/Reset function

Section	Variable	Set function	Reset function
Start	X000	ALT M100	ALT M100
Read barcode	D500-D510	RS2	ZRST
Compare size1 (13 inches)	D200-D206	DMOVP	T10
	M20	D200.D202	D200 or D202
	M21	M20.D204.D206	M20 or D204 or D206
	T10	M21	M21
Compare size2 (14 inches)	D200-D206	DMOVP	T11
	M30	D200.D202	D200 or D202
	M31	M30.D204.D206	M30 or D204 or D206
	T11	M31	M31
Compare size3 (15 inches)	D200-D206	DMOVP	T12
	M40	D200.D202	D200 or D202
	M41	M40.D204.D206	M40 or D204 or D206
	T12	M41	M41

Table4.1 Set/Reset function (continued)

Section	Variable	Set function	Reset function
Compare size4 (16 inches)	D200-D206	DMOVP	T13
	M50	D200.D202	D200 or D202
	M51	M50.D204.D206	M50 or D204 or D206
	T13	M51	M51
Compare size5 (17 inches)	D200-D206	DMOVP	T14
	M60	D200.D202	D200 or D202
	M61	M60.D204.D206	M60 or D204 or D206
	T14	M61	M61
Compare size6 (18 inches)	D200-D206	DMOVP	T15
	M70	D200.D202	D200 or D202
	M71	M70.D204.D206	M70 or D204 or D206
	T15	M71	M71
Operate size1 (13 inches)	D10	M21	T20
	D1	D10	T1
	T20	D10	D10
	M10	D1.X001	T1
	T1	M10	M10
	M1	M10	T1

Table4.1 Set/Reset function (continued)

Section	Variable	Set function	Reset function
Operate size2 (14 inches)	D10	M31	T21
	D2	D10	T2
	T21	D10	D10
	M11	D2.X002	T2
	T2	M11	M11
	M2	M11	T2
Operate size3 (15 inches)	D10	M41	T22
	D3	D10	T3
	T22	D10	D10
	M12	D3.X003	T3
	T3	M12	M12
	M3	M12	T3
Operate size4 (16 inches)	D10	M51	T23
	D4	D10	T4
	T23	D10	D10
	M13	D4.X007	T4
	T4	M13	M13
	M4	M13	T4
Operate size5 (17 inches)	D10	M61	T24
	D5	D10	T5
	T24	D10	D10
	M14	D5.X005	T5
	T5	M14	M14
	M5	M14	T5

Table4.1 Set/Reset function (continued)

Section	Variable	Set function	Reset function
Operate size6 (18 inches)	D10	M71	T25
	D6	D10	T6
	T25	D10	D10
	M15	D6.X006	T6
	T6	M15	M15
	M6	M15	T6
Output	Y000	M100.M1	M1
	Y001	M100	Y000
	Y002	M100.M2	M2
	Y003	M100	Y002
	Y004	M100.M3	M3
	Y005	M100	Y004
	Y006	M100.M4	M4
	Y007	M100	Y006
	Y010	M100.M5	M5
	Y011	M100	Y010
	Y012	M100.M6	M6
	Y013	M100	Y012

4.2.2 Ladder diagram

Ladder diagram is programmed to run the process. In the design, ladder diagram is separated to 5 sections are START, READ BARCODE, COMPARE, OPERATE and OUTPUT, this is for easiness when we need to modify or correct program. Each section of ladder diagram is explained for tyre size1 (13 inches) only because the other sizes are performed the same configuration and overall ladder diagram will be shown later.

(1) START section

START section is used to turn on/off the process, it uses switch X000 to operate with ALT function. When switch X000 is pressed first time, system will be turned on and when switch X000 is pressed again, system will be turned off. Ladder diagram of START section is shown in figure4.3

Figure4.3 START section

M100 is chosen to be holding relay, when M100 is turned on, output Y001, Y003, Y005,Y007, Y011 and Y013 will be trigged (turned on) as will be expressed in output section.

(2) READ BARCODE section

READ BARCODE section is used to receive data number of barcode tag. Ladder diagram of this section is shown in figure4.4

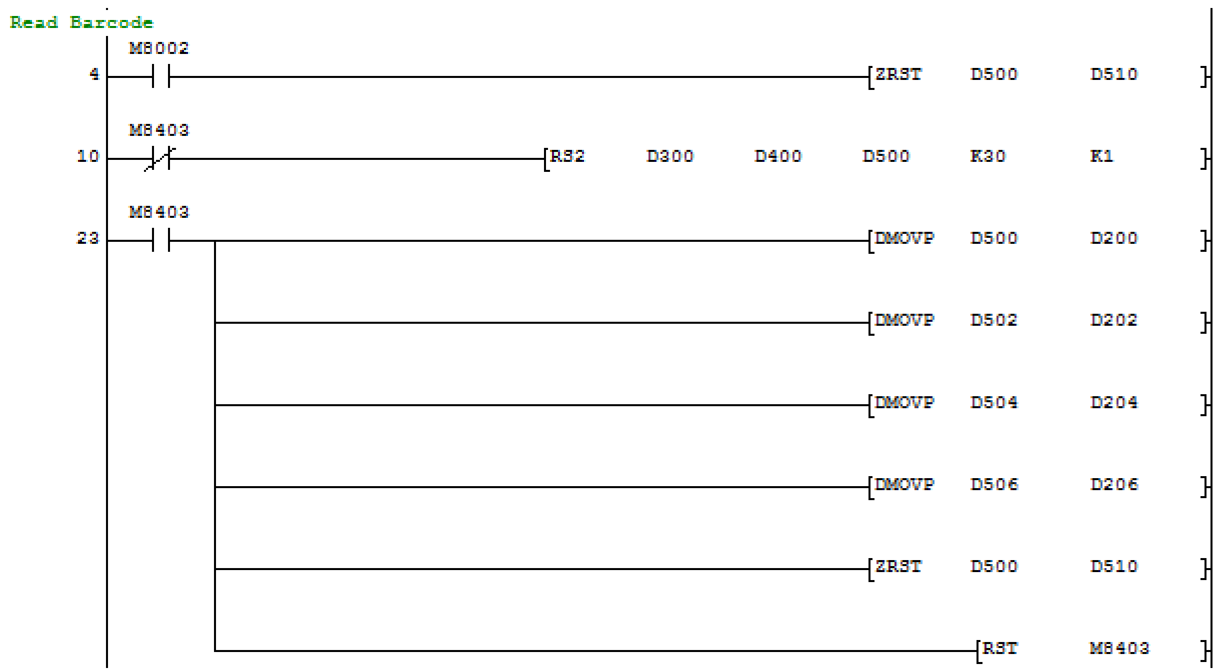


Figure4.4 READ BARCODE section

The operation of this section can be explained:

(2.1) Contact M8002 (Initial pulse NO contact) is special relay which will turn on one time when the system is turned on. In this case, if X000 is pressed, M8002 will turn on one time to reset D500-D510 to prevent some remaining data disturbing the program, function ZRST means zone reset.

(2.2) Function of receiving data from barcode reader is RS2 instruction which is the function of FX3U type. The composition of RS2 instruction is shown in figure4.5

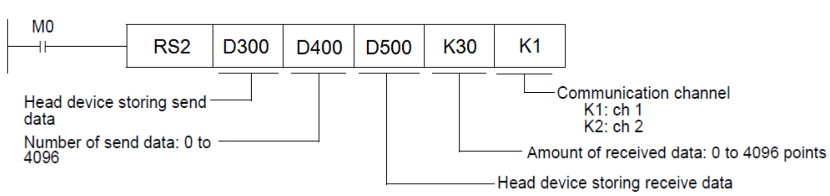


Figure4.5 RS2 instruction

Data will be store in D500 henceforward (D500-D506 for this case) and we use 32 bits data (mentioned in chapter3) to classify tyre's size. Contact M8403 is called "Receive Completion Flag" which normally used with RS2 instruction, when RS2 finishes receiving data, it will turn on. In this case, when M8403 is on, it will:

- Cut signal to reset RS2 to be able to receive new data.

- Operate to move data from D500-D506 to store in D200-D206 for use them in COMPARE section by DMOVP (Double bit move) function. D200-D206 will be reset in COMPARE section.

- Reset D500-D510 to be able to receive new data by ZRST function.

- Reset M8403 itself to be able to work again.

(3) COMPARE section

The explanation of COMPARE section will be only explained for tyre number1 (13 inches) because for the other sizes are also the same configuration. Ladder diagram of this section is shown in figure4.6

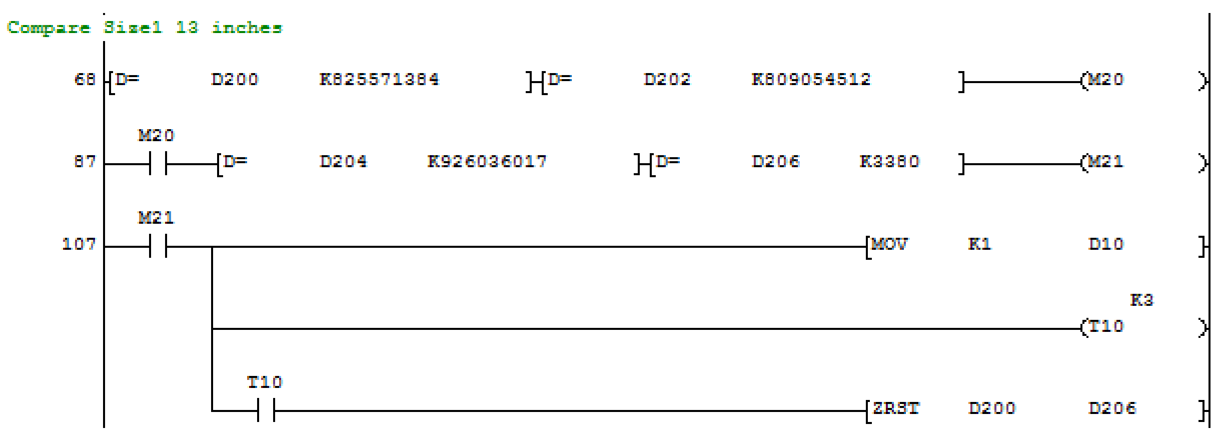


Figure4.6 COMPARE section for tyre number1 (13 inches)

D200-D206 received data from READ BARCODE section. The operations of COMPARE section are:

- If D200 is equal to 825571384 and D202 is equal to 809054512, M20 will be turned on (M20 is used only to connect between D200 and D202 with D204 and D206).

- After M20 is turned on, if D204 is equal to 926036017 and D206 is equal to 3380, M21 will be turned on.

- After M21 is turned on, it will move value 1 to store in D10, this is to know that tyre size 13 inches (type1) has already passed to the process. D10 will be used in OPERATE section.

- After M21 is turned on, T10 will count 0.3 second until complete and then reset D200-D206 by ZRST function to be able to receive new data again.

(4) OPERATE and OUTPUT section

OPERATE and OUTPUT section should be explained together. Figure4.7 shows OPERATE and OUTPUT section for tyre number1 (13 inches) and the operation can be explained step by step.

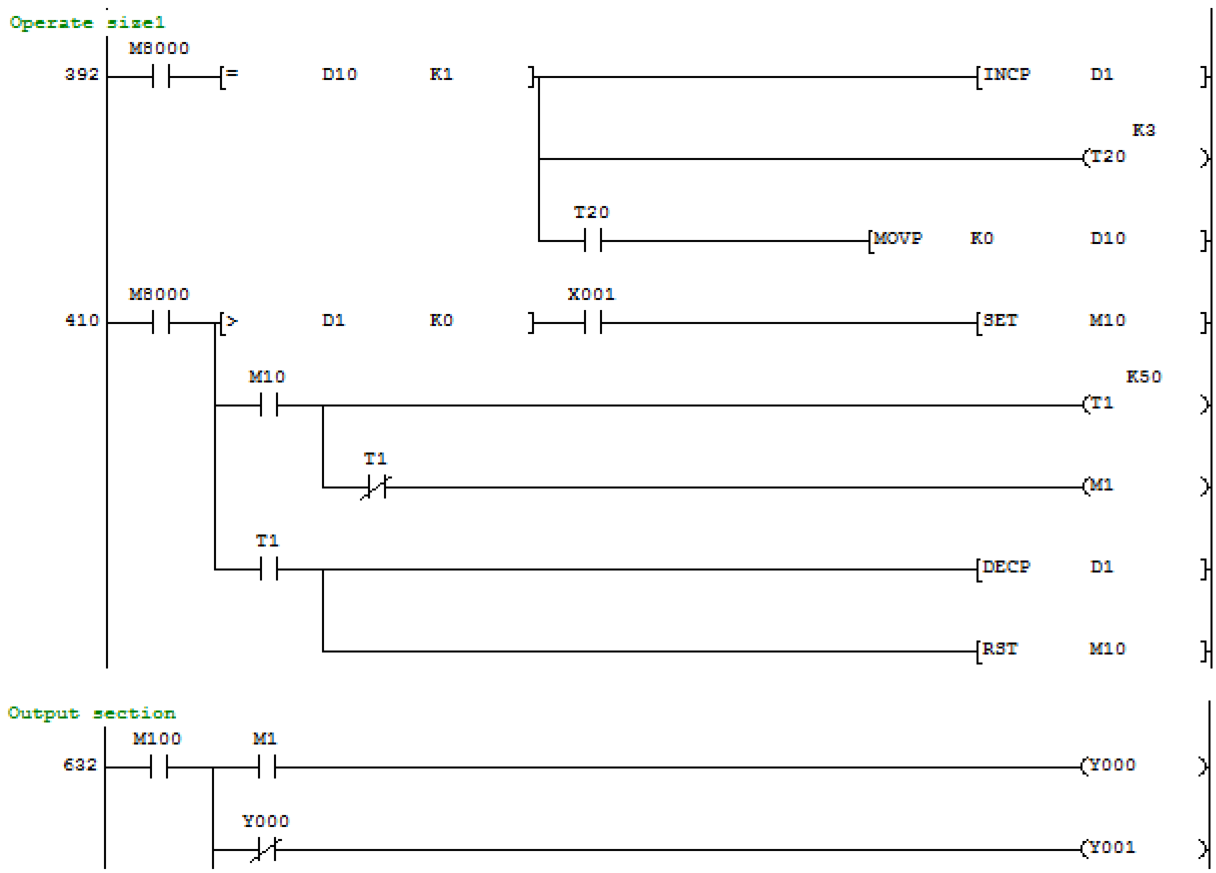


Figure4.7 OPERATE and OUTPUT section for tyre number1 (13 inches)

- Contact M8000 (Run Monitor NO contact) is special auxiliary relay which is turned on all the time.

- If D10 is equal to 1 (type1), D1 will be increased one (number of tyre come to the process) by INCP (Increase pulse) function, T20 will count 0.3 second and then reset D10 to be able to receive new data by moving value 0 to D10.

- If D1 is more than 0 (have tyre come to the process) and sensor X001 is turned on (tyre has already reached sensor), relay M10 is set.

- After M10 is set, M1 will be turned on, T1 will count 5 seconds (cylinder is pushing tyre).

- After M1 is turned on, solenoid valve Y000 will be turned on (cylinder advances to push tyre).

- Y000 is turning on, Y001 will be turned off.

- After T1 completed 5 seconds, M1 will be turned off, Y000 will be turned off, Y001 will be turned on (cylinder returns), D1 will be decreased one (number of tyre decreases after one tyre was pushed) by DECP (Decrease pulse) function, M10 will be reset to be able to work again. All the operations are formed into a loop. The overall ladder diagram is shown in figure4.8.

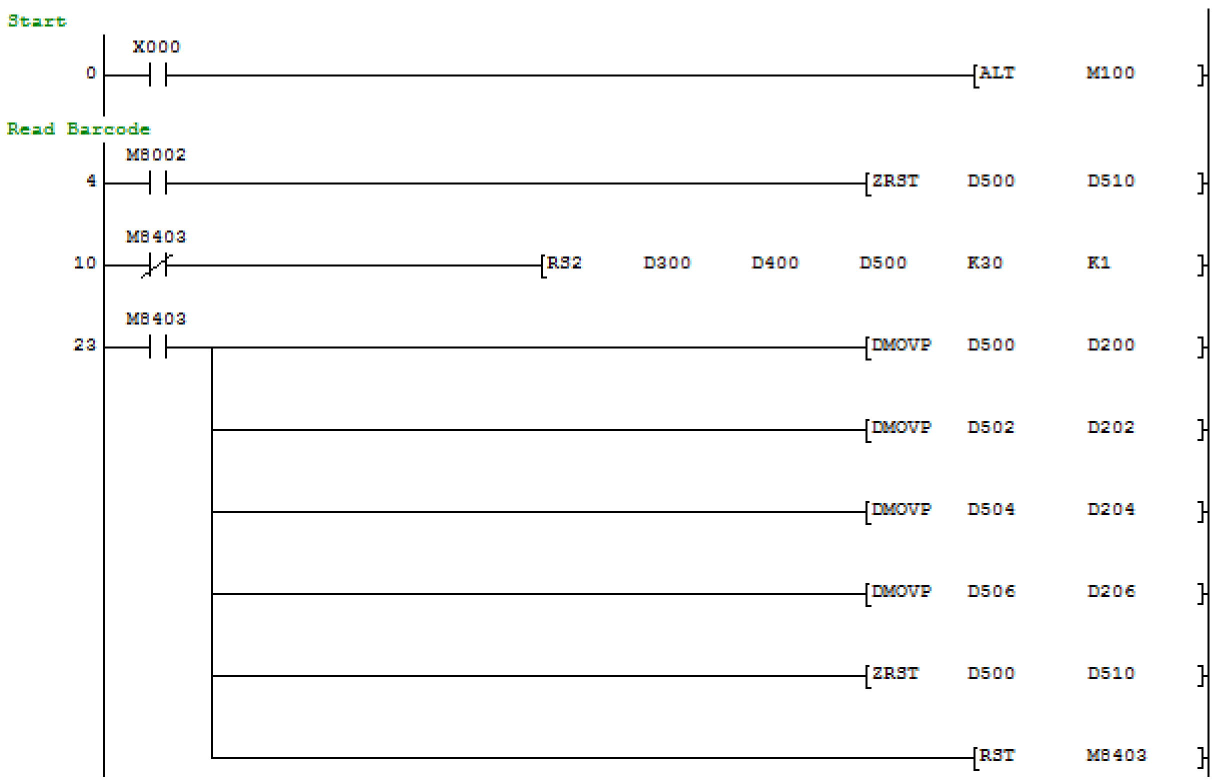


Figure4.8 Ladder diagram

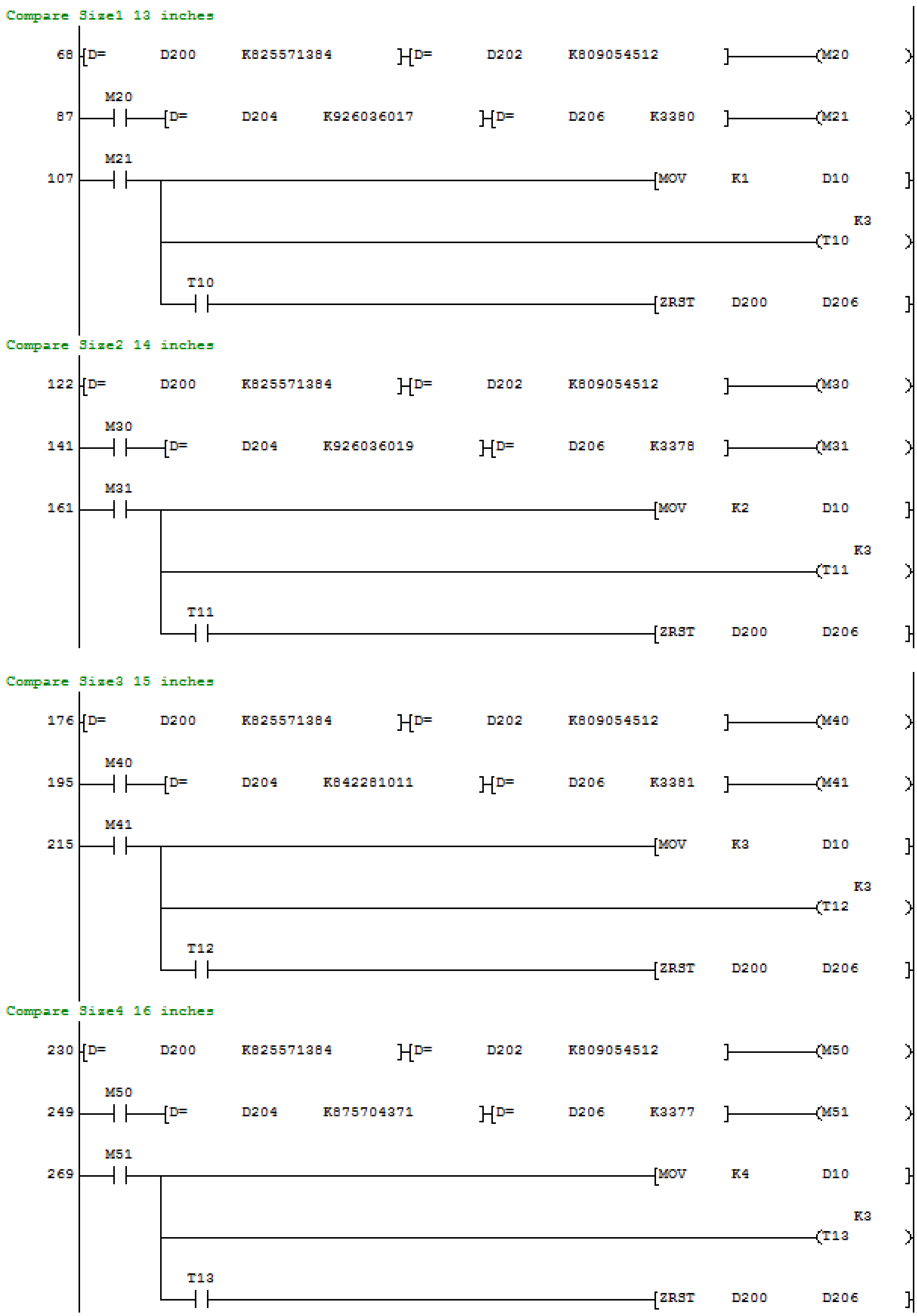


Figure4.8 Ladder diagram (continued)

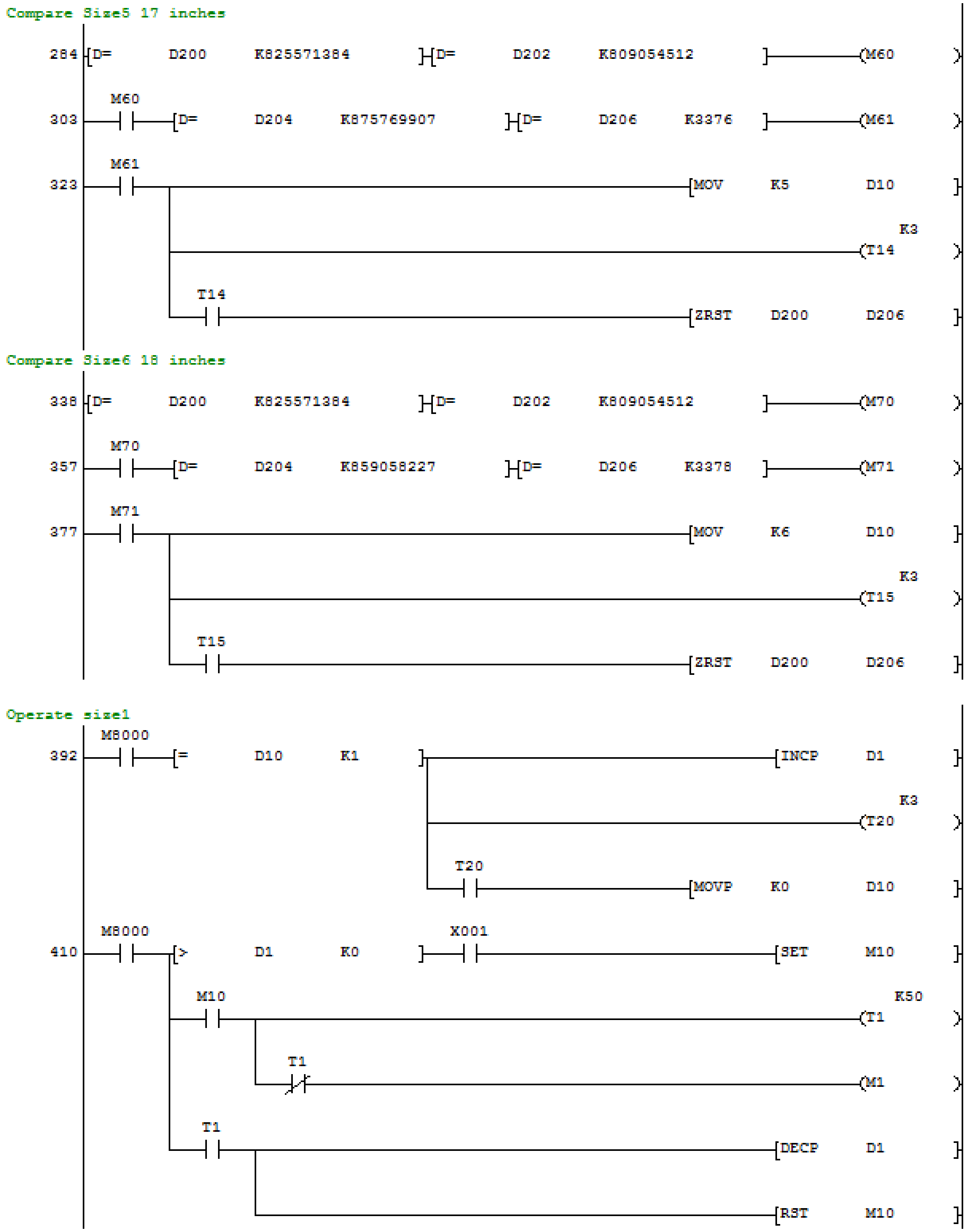


Figure4.8 Ladder diagram (continued)

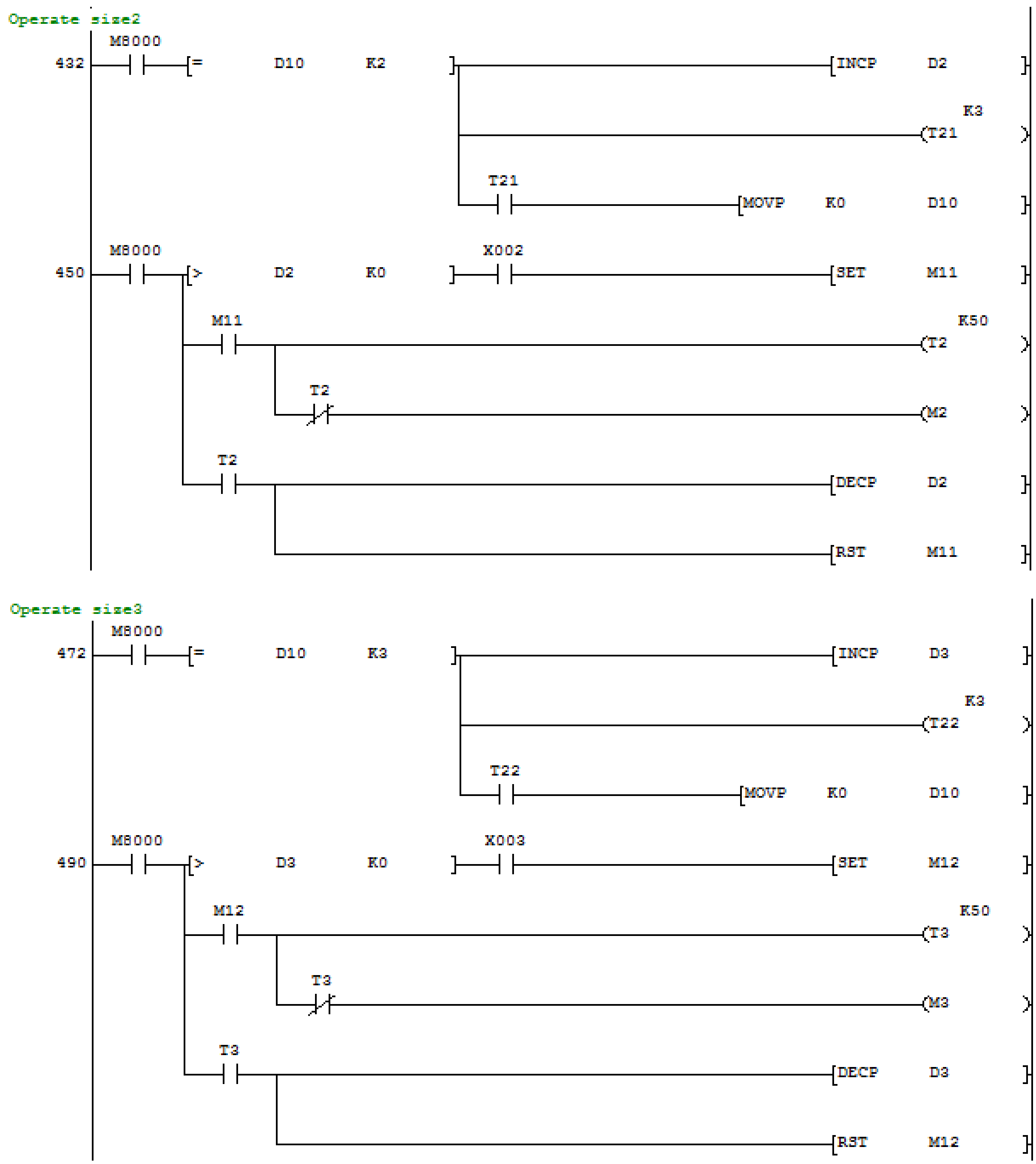


Figure4.8 Ladder diagram (continued)

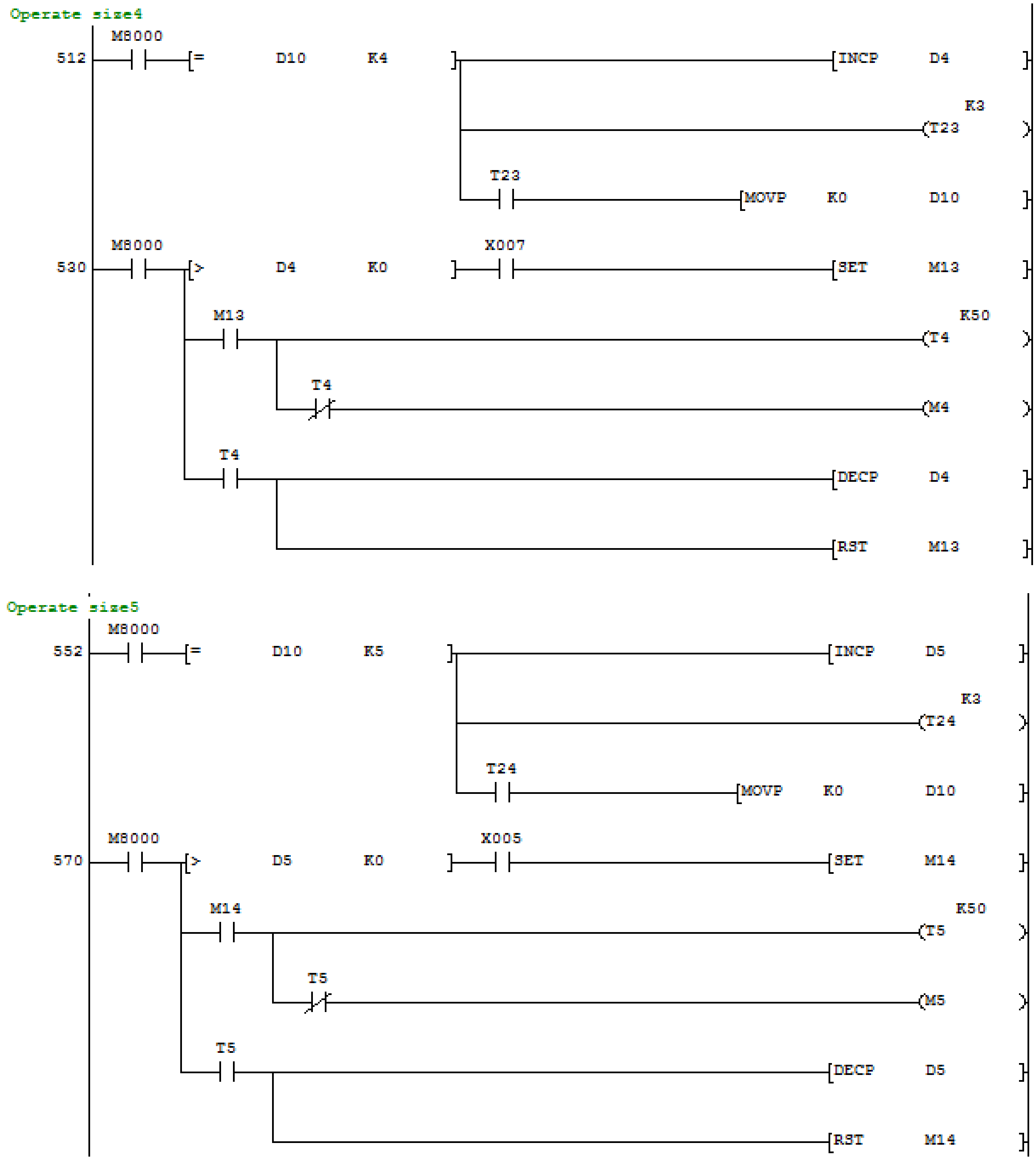


Figure4.8 Ladder diagram (continued)

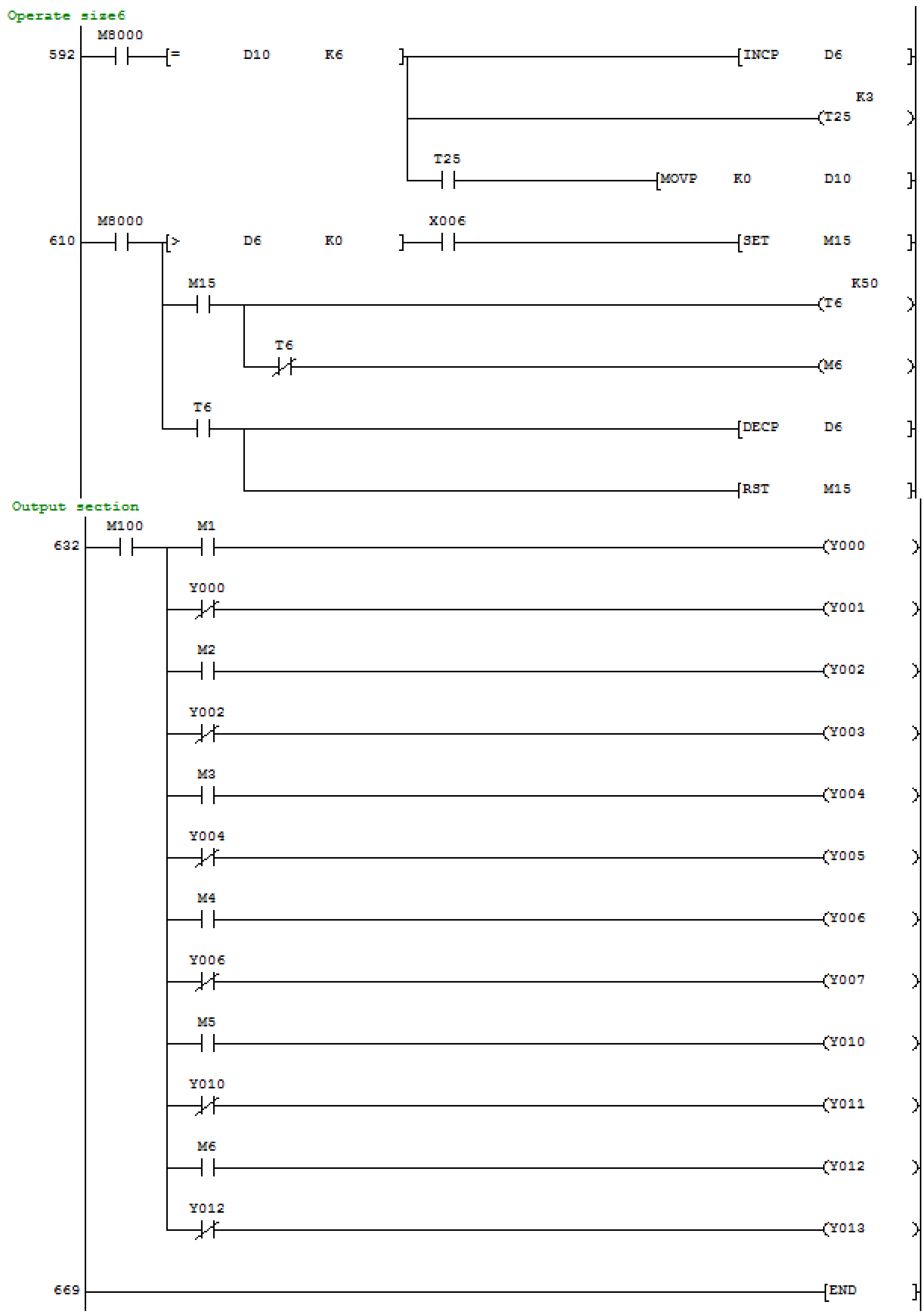


Figure4.8 Ladder diagram (continued)

4.3 LABORATORY TEST

Laboratory test is done to test that the program can work successfully as desire. Program is loaded to PLC and PLC is connected to model hardware. Aid of sketch of equipment connection and real equipment connection are shown in figure4.9 and 4.10 respectively.

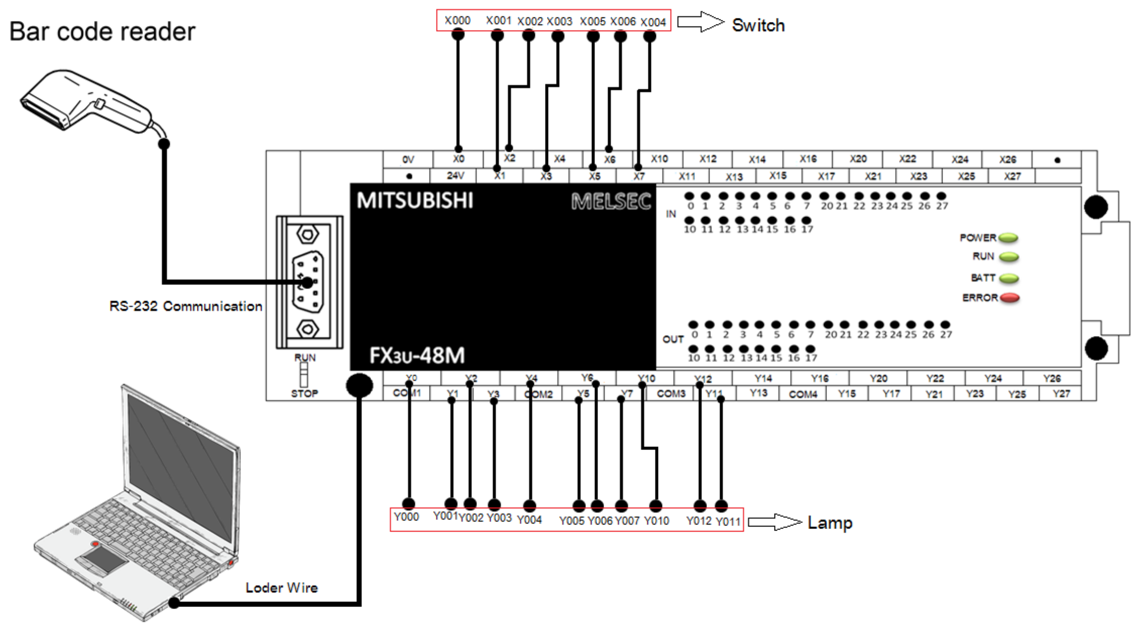


Figure4.9 Aid of sketch of equipment connection

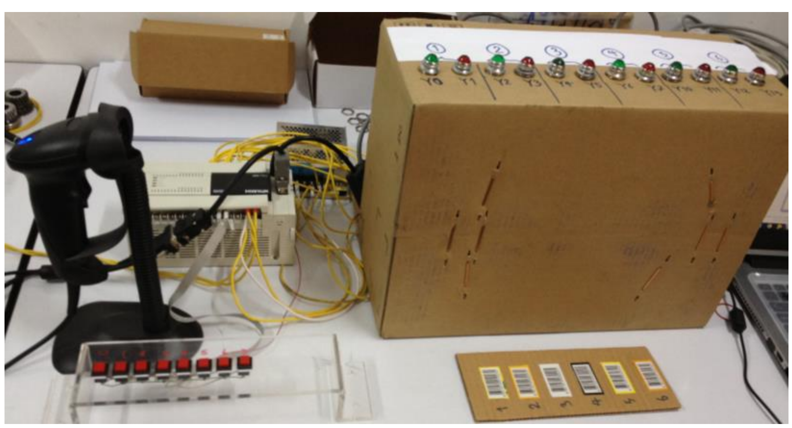


Figure4.10 Real equipment connection

Hardware are modeled to replace real hardware of the process, this is because of limited cost and cost reduction for testing. Lamps are used to replace solenoid valves (figure4.11), switch set is used to replace START/STOP switch and sensors (figure4.12), PLC is connected with barcode reader by RS-232 communication and connected to computer laptop by PLC wire loader as shown in figure4.13.

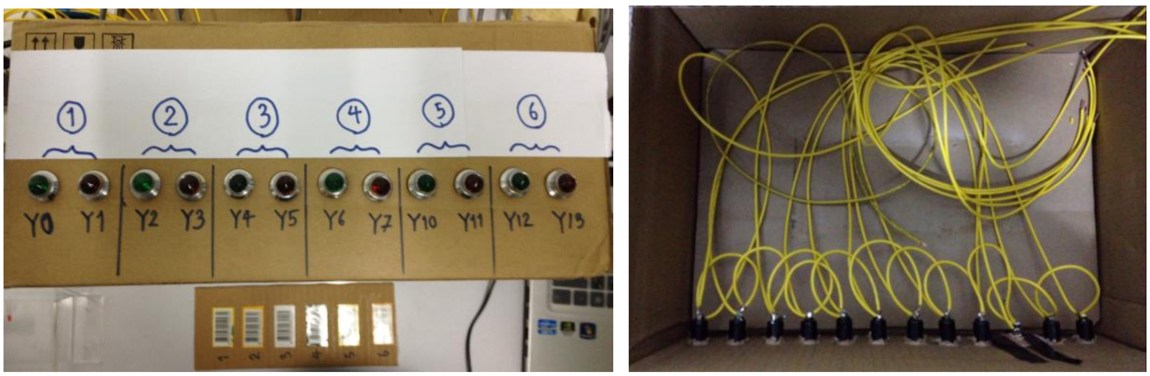


Figure4.11 Hardware lamp connection

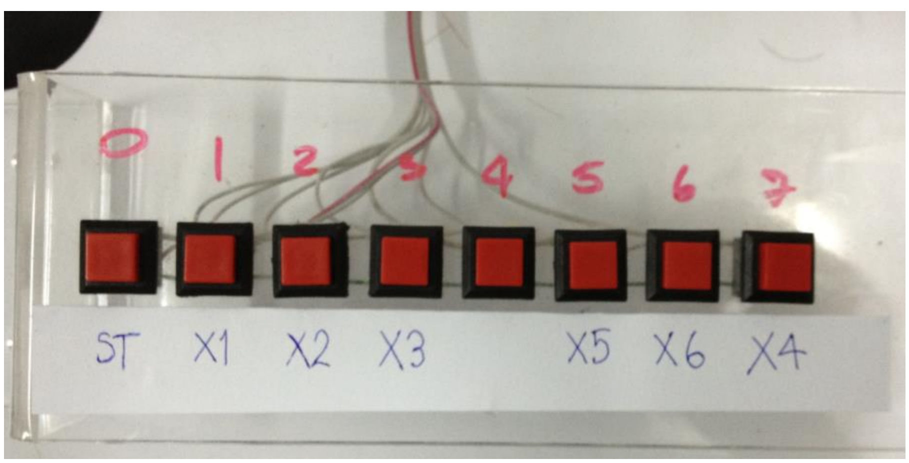


Figure4.12 Switch set

Figure4.13 Connection of PLC

Many test were performed to test the operation of the program, test method can be listed as follow:

1) Press switch to start the system, all return lights (substitute of Y1, Y3, Y5, Y7, Y11 and Y13) were turned on.

2) Scan barcode tag of tyre size 13 inches one time and press switch of sensor X1, return light Y1 was turned off and advance light Y0 was turned on (cylinder1 is pushing tyre). After 5 seconds, advance light Y0 was turned off and advance light Y1 was turned on (cylinder1 returns).

3) Assumed that nine tyres size 13 inches come to the process by scanning barcode tag nine times and then press switch of sensor X1 nine times, advance light Y0 could also be turned on only nine times.

4) Assumed that ten tyres size 14 inches come to the process by scanning barcode tag ten times. Tried to press switch of sensor X1 ten times, advance light Y0 did not turn on

just once (correct). Tried to press sensor X2 ten times, advance light Y2 could also be turned on only ten times.

5) Assumed that ten tyres size 15 inches come to the process by scanning barcode tag ten times. Tried to press switches of sensors X1 and X2 ten times per each, advance lights Y0 and Y2 did not turn on just once (correct). Tried to press switch of sensor X3 ten times, advance light Y4 could also be turned on only ten times.

6) Assumed that ten tyres size 16 inches come to the process by scanning barcode tag ten times. Tried to press switches of sensors X1, X2 and X3 ten times per each, advance lights Y0, Y2 and Y4 did not turn on just once (correct). Tried to press switch of sensor X4 ten times, advance light Y6 could also be turned on only ten times.

7) Assumed that ten tyres size 17 inches come to the process by scanning barcode tag ten times. Tried to press switches of sensors X1, X2, X3 and X4 ten times per each, advance lights Y0, Y2, Y4 and Y6 did not turned on just once (correct). Tried to press switch of sensor X5 ten times, advance light Y10 could also be turned on only ten times.

8) Assumed that ten tyres size 18 inches come to the process by scanning barcode tag ten times. Tried to press switches of sensors X1, X2, X3, X4 and X5 ten times per each, advance lights Y0, Y2, Y4, Y6 and Y10 did not turn on just once (correct). Tried to press switch of sensor X6 ten times, advance light Y12 could also be turned on only ten times.

9) Tried to scan barcode tag of tyre 13 inches one time and press switch of sensor X1, Y0 could be turned on and Y1 could be turned off (cylinder1 was pushing), after 5 seconds Y0 was turned off and Y1 was turned on (cylinder1 returned). This was done with five duplications.

10) Tried to scan barcode tag of tyre 14 inches one time and press switch of sensor X2, Y2 could be turned on and Y3 could be turned off (cylinder2 was pushing), after 5 seconds Y2 was turned off and Y3 was turned on (cylinder2 returned). This was done with five duplications.

11) Tried to scan barcode tag of tyre 15 inches one time and press switch of sensor X3, Y4 could be turned on and Y5 could be turned off (cylinder3 was pushing), after 5 seconds Y4 was turned off and Y5 was turned on (cylinder3 returned). This was done with five duplications.

12) Tried to scan barcode tag of tyre 16 inches one time and press switch of sensor X4, Y6 could be turned on and Y7 could be turned off (cylinder4 was pushing), after 5 seconds Y6 was turned off and Y7 was turned on (cylinder4 returned). This was done with five duplications.

13) Tried to scan barcode tag of tyre 17 inches one time and press switch of sensor X5, Y10 could be turned on and Y11 could be turned off (cylinder5 was pushing), after 5 seconds Y10 was turned off and Y11 was turned on (cylinder5 returned). This was done with five duplications.

14) Tried to scan barcode tag of tyre 18 inches one time and press switch of sensor X6, Y12 could be turned on and Y13 could be turned off (cylinder6 was pushing), after 5 seconds Y12 was turned off and Y13 was turned on (cylinder6 returned). This was done with five duplications.

4.4 COST REDUCTION PREDICTION

Hiring cost reduction can be predicted by eliminating sorting operators and try to calculate as follow:

Number of operator = 6 operators

Wage = 450 baht/8 hr/shift or 15 USD (let say)

1 day = 3 shifts

Total hiring cost reduction = 6 x 15 x 3 = 270 USD/day

= 270 x 22 = 5,940 USD/month

= 270 x 22 x 12 = 71,280 USD/year

4.5 SUMMARY

This project may be applied in the real production process of the factory which depends on consideration of the company. If this project is applied in the actual implementation, it will increase accuracy of tyre sorting, repeatability, flexibility and productivity of sorted tyres. Additionally, sorting time and hiring cost may reduce. However, time reduction need to be measure by real application or 3D simulation software.

The success of this study is the development of program sequence control which can be a prototype program for future improvement of model or actual implementation. Additionally, this study lets researcher to learn more for usefulness of Programmable Logic Controller which can be applied for future work as well.

CHAPTER 5

CONCLUSION AND SUGGESTION

5.1 CONCLUSION

This research project applies the integration of Mitsubishi FX3U PLC controller with barcode system to model automated tyre sorting system. Researcher studied on the current operation of tyre sortation system that sorts the different size of inside diameter of tyres which are classified into 13 inches to 18 inches, the problem is the difficulty for the workers to observe the barcode of each tyres and the operation are performed manually which is not flexible and can cause the mistake of sortation process. Therefore, the manual sorting operation should be eliminated and the automated system should be developed. After the integration and connection between barcode reader and PLC was successful, ladder diagram was designed to control the process based on data register from barcode reader. After ladder diagram was accomplished, laboratory test was performed to model the sortation process by connecting with the appropriate hardware. The test's result show that the program ladder diagram could successfully operate in the correct condition. This program can be a prototype program for future improvement of model or actual implementation.

However, this research project also has obstacle (weakness point) which are automated tyre sorting system needs data register from barcode reader, therefore, basic PLC is not applicable and this makes the difficulty for integration and programming. Actual implementation in the sortation process is quite difficult because of costing and need agreement from the company and also takes long time to perform it. Some of theory of PLC and barcode manual book is quite difficult to understand and need to take long time to study. Programming and laboratory test need long time to perform for suitability and was designed and corrected many time to be able to control the process. The application's cost of this project cannot be calculated because it is not applied in the real sortation process.

5.2 SUGGESTION

Future improvement should be performed such as application in the real sortation process. However, in the real application, program can be adjusted in the part of data register to be suitable for higher performance barcode reader. If actual implementation cannot be performed, laboratory test can be improved by integration of model conveyor system, sensors and cylinders for more truthfulness. The integration of PLC and barcode reader can be applied to sort for the other product that is applicable. Cost of the real application in the future improvement should be considered and the real application may need many experts in electrical and mechanical field.

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APPENDIX

1. ASCII code

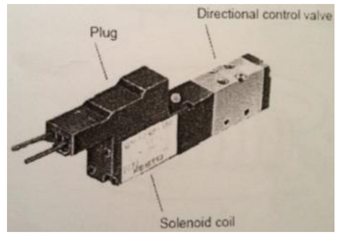
ASCII stand for American Standard Code for Information Interchange, it was developed by ANSI (American National Standards Institute) which normally used for personal computer (PC). ASCII uses 8 bits for one alphabet.

TableA1. ASCII code table

				b7	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1
				b6	0	0	0	0	1	1	1	1	0	0	0	0	1	1	1	1
				b5	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1
				b4	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
b3	b2	b1	b0																	
0	0	0	0					0	@	P	`	p				ฐ	ภ	ะ	เ	๐
0	0	0	1				!	1	A	Q	a	q			ก	ฑ	ม	ั	แ	๑
0	0	1	0				"	2	B	R	b	r			ข	ฒ	ย	า	โ	๒
0	0	1	1				#	3	C	S	c	s			ฃ	ณ	ร	ำ	ใ	๓
0	1	0	0				$	4	D	T	d	t			ค	ด	ฤ	ิ	ไ	๔
0	1	0	1				%	5	E	U	e	u			ฅ	ต	ล	ี	ๅ	๕
0	1	1	0				&	6	F	V	f	v			ฆ	ถ	ฦ	ึ	ๆ	๖
0	1	1	1				'	7	G	W	g	w			ง	ท	ว	ื	็	๗
1	0	0	0				(	8	H	X	h	x			จ	ธ	ศ	ุ	่	๘
1	0	0	1				)	9	I	Y	i	y			ฉ	น	ษ	ู	้	๙
1	0	1	0				*	:	J	Z	j	z			ช	บ	ส		๊	๚
1	0	1	1				+	;	K	[	k	{			ซ	ป	ห		๋	๛
1	1	0	0				,	<	L	\	l	|			ฌ	ผ	ฬ		์	
1	1	0	1				-	=	M	]	m	}			ญ	ฝ	อ		ํ	
1	1	1	0				.	>	N	^	n	~			ฎ	พ	ฮ		๎	
1	1	1	1				/	?	O	_	o				ฏ	ฟ	ฯ	฿	๏	

2. Solenoid Valve

Solenoid valve is used to control hydraulic system by using electric.

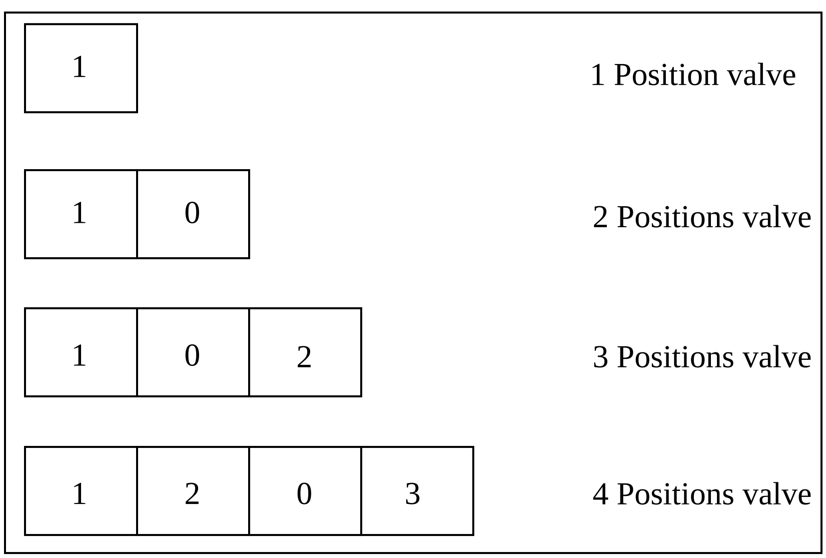


FigureA1. Solenoid valve

2.1 Valve symbols

The design of electro-hydraulic will only show the function of valves but the internal structures will not be shown. Therefore, we need to know basic of valve symbols in hydraulic system to be able to use them.

2.1.1 Position of control valve

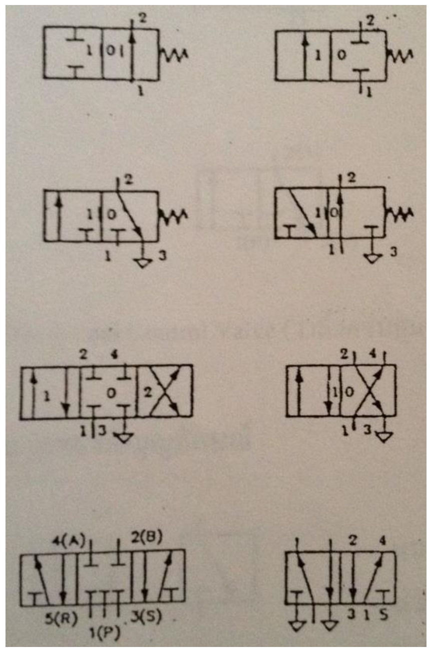


FigureA2. Working position of control valve

Position of control valve composes of normal position (0) and working position (1, 2, or 3).

2.1.2 Port of control valve

Port of valves in hydraulic system will be at normal position (0).



Valve 2 ways

Valve 3 ways

Valve 4 ways

Valve 5 ways

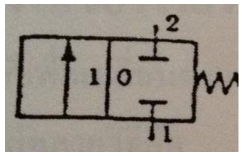
FigureA3. Port of control valve

TableA2. Code definition

Number	Alphabet	Meaning
1	P	Fluid flow in
2, 4	A,B	Fluid flow out for operation
3, 5	R, S	To let fluid out
12, 14	Y, Z	Port of control signal

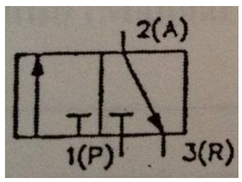
2.2 Valve's name

Valve's name in hydraulic system can be called by port and position of valve.



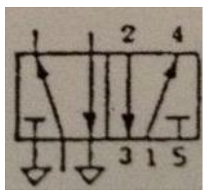
Valve 2 ways and 2 positions

2/2 D.C. valve normally closed



Valve 3 ways and 2 positions

3/2 D.C. valve normally closed



Valve 5 ways and 2 positions

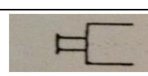
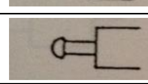
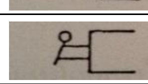
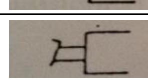
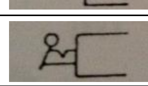
5/2 D.C. valve normally closed

FigureA4. Example of valve's name

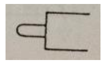
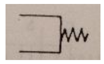
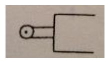
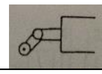
2.3 Valve operation control

Valve operation control is done to change the position of valve defined by user.

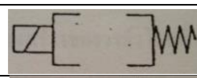
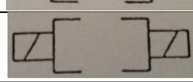
TableA3. Manual actuator

Symbol	Meaning
	Use force to operate (normal symbol)
	Hand press
	Lever
	Pedal
	Pulling with locker

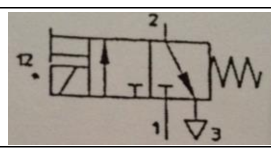
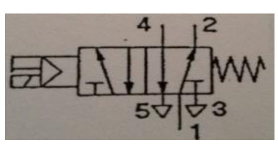
TableA4. Mechanical actuator

Symbol	Meaning
	Pressing
	Spring return
	Press rolling
	Press rolling one way

TableA5. Electromagnetic actuator

Symbol	Meaning
	Solenoid operation and spring return
	Solenoid operation and solenoid return

TableA6. Combine actuator

Symbol	Meaning
	Controlled by manual or electric and returned by spring
	Controlled by manual or electric to open small valve and uses fluid of small valve to control big valve, returned by spring

3. Software GX developer

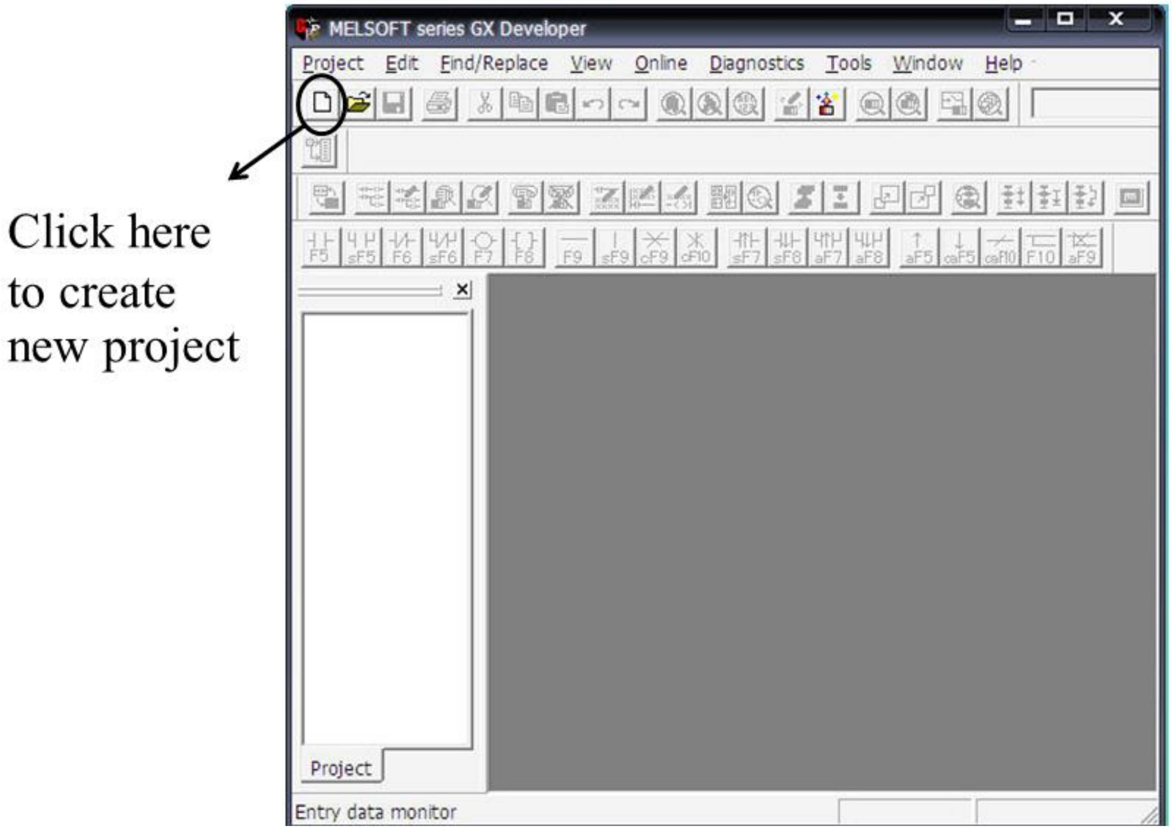


Figure A5. Table of software

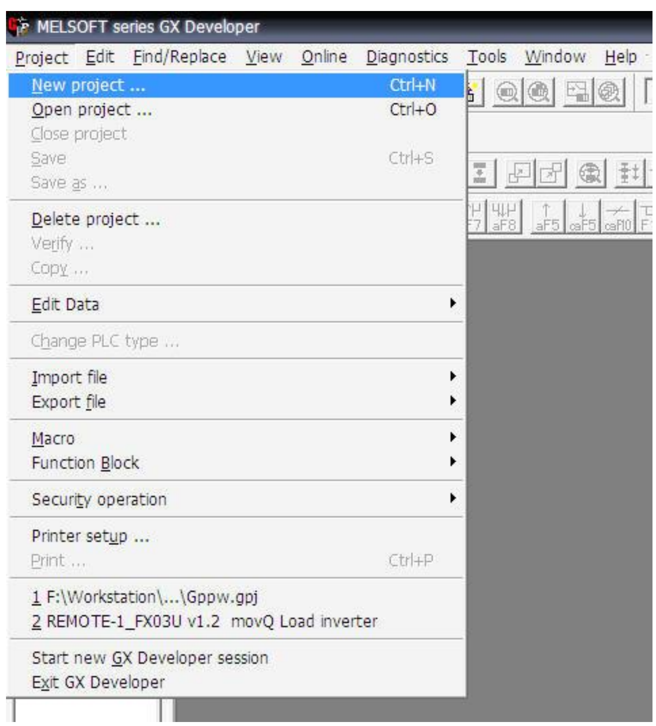


Figure A6. Create new project

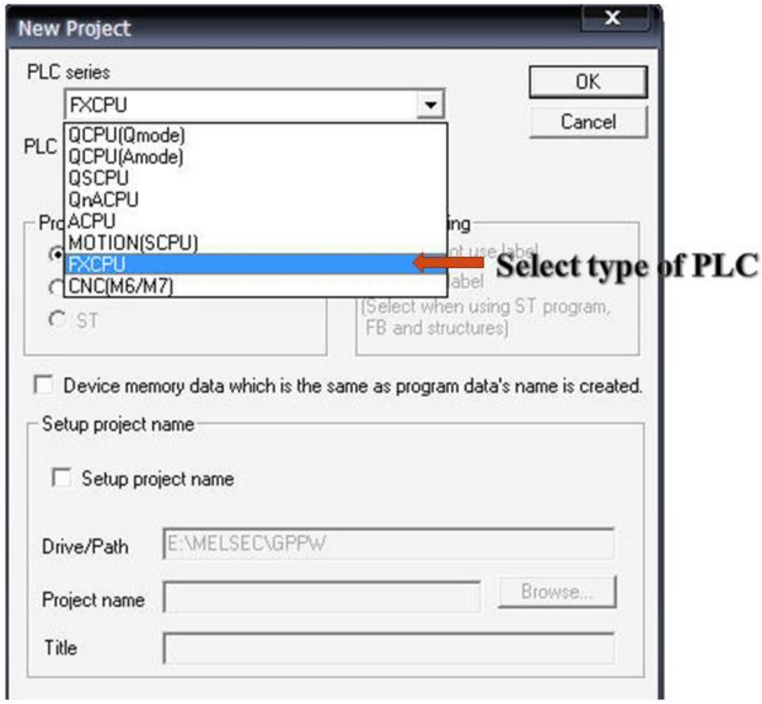


Figure A7. Select type of PLC

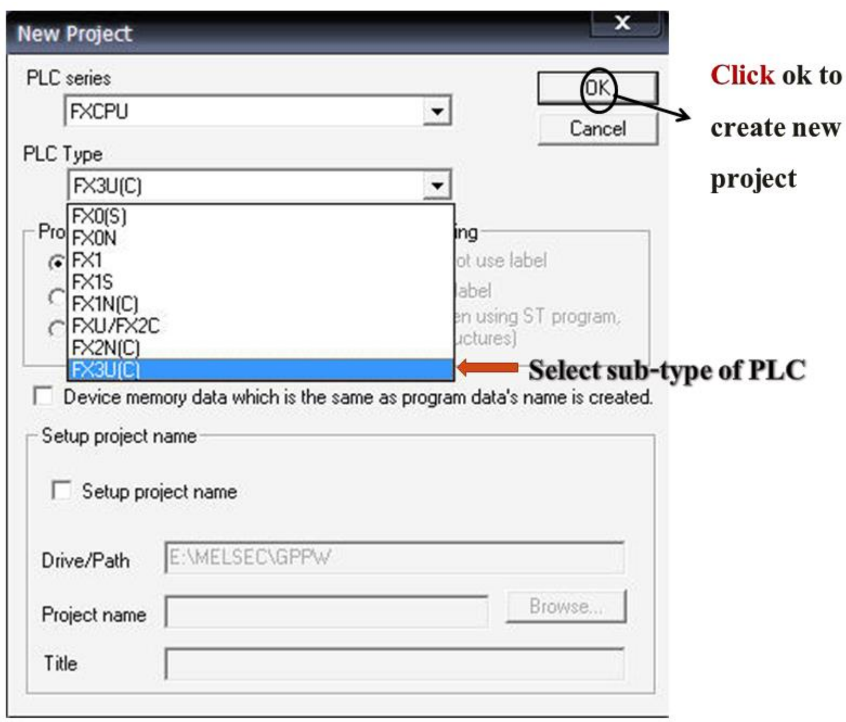


Figure A8. Select sub-type of PLC and click ok to create new project

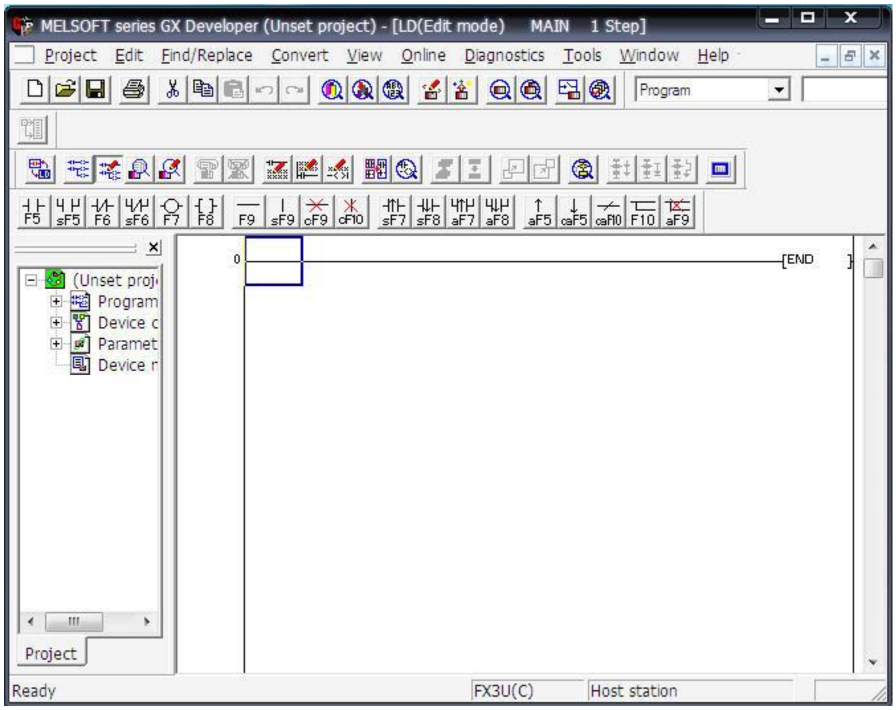


Figure A9. Table for new project

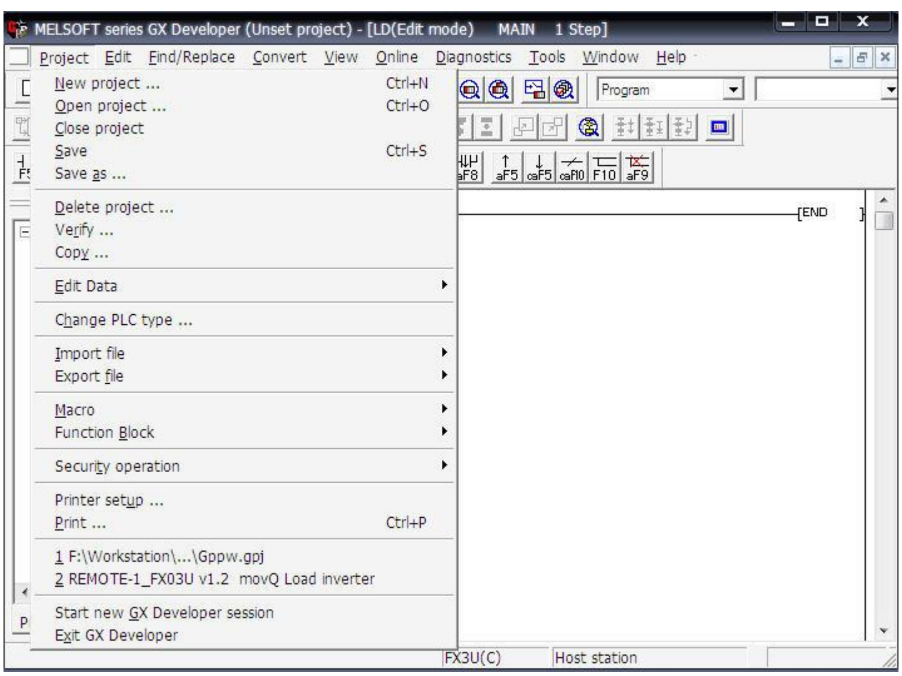


Figure A10. Project menu function

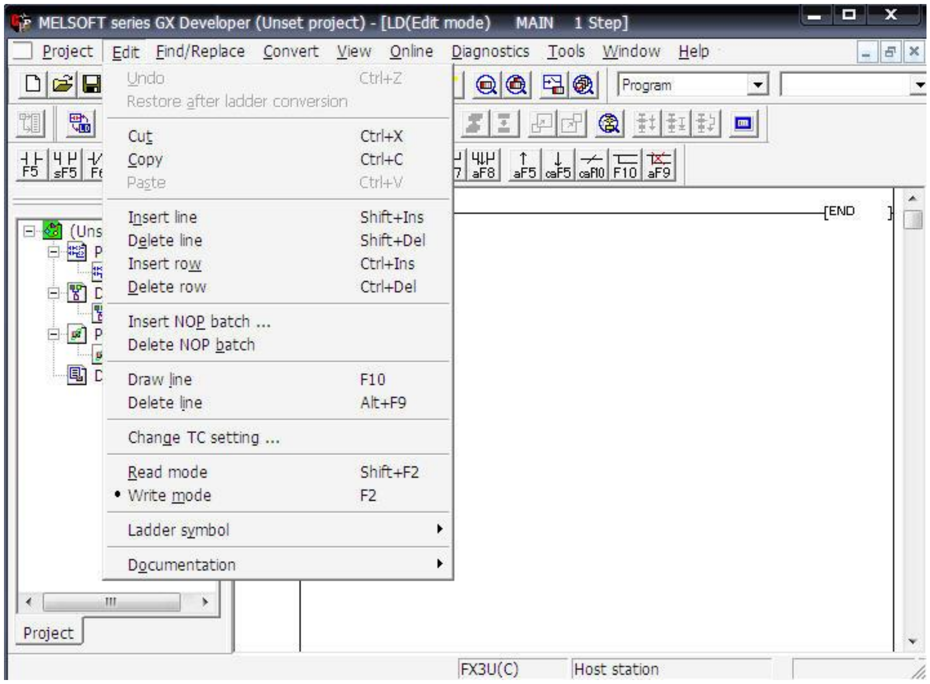


Figure A11. Edit menu function

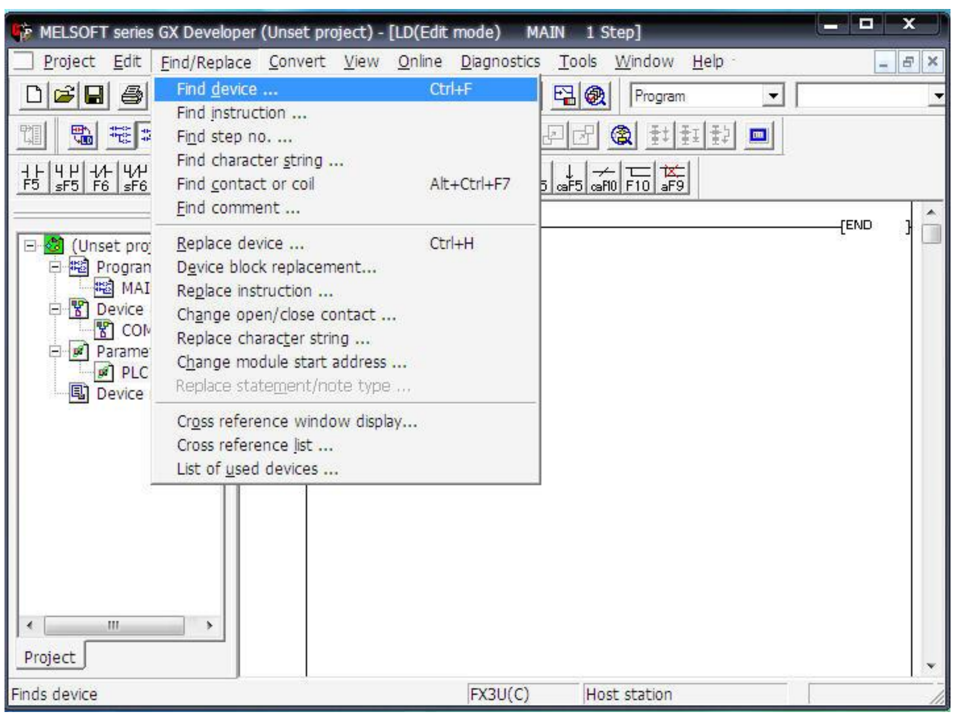


Figure A12. Find/Replace menu function

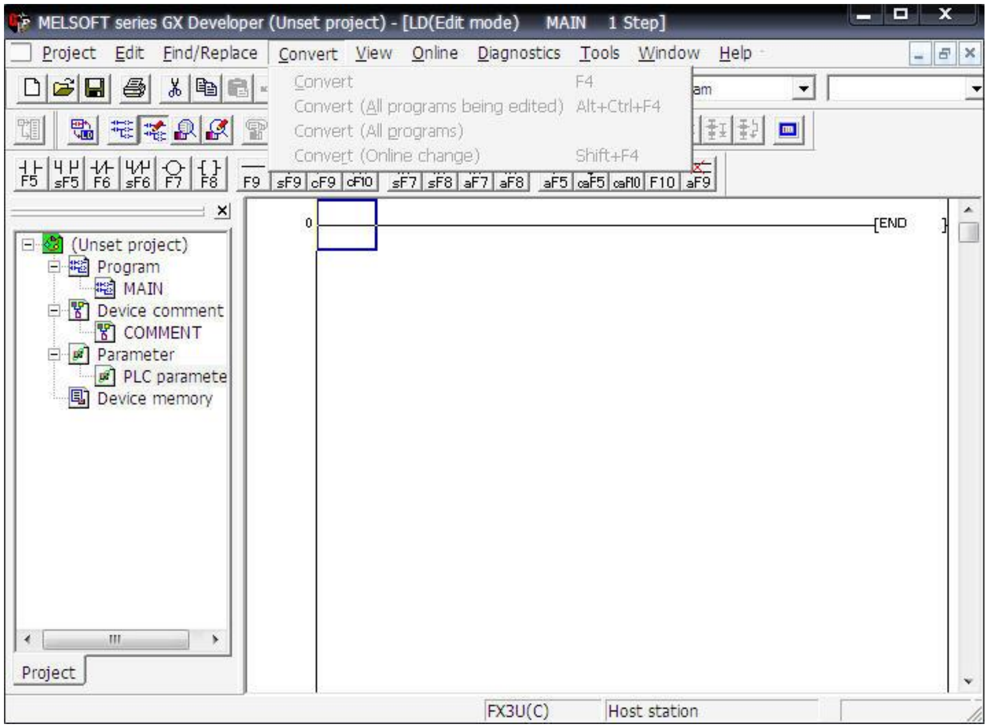


Figure A13. Convert menu function

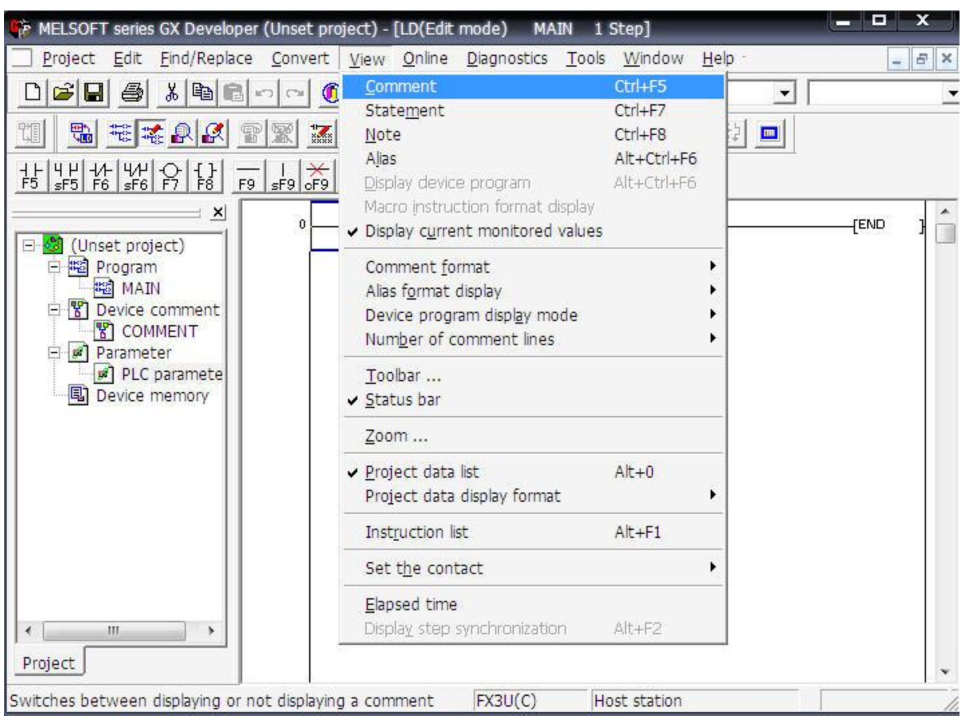


Figure A14. View menu function

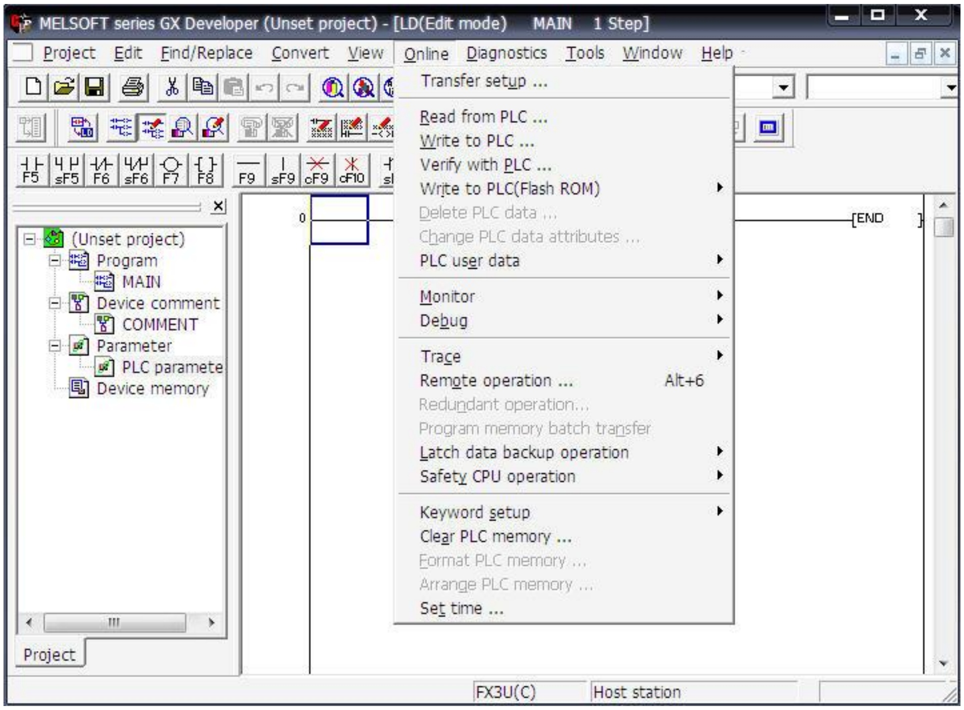


Figure A15. Online menu function

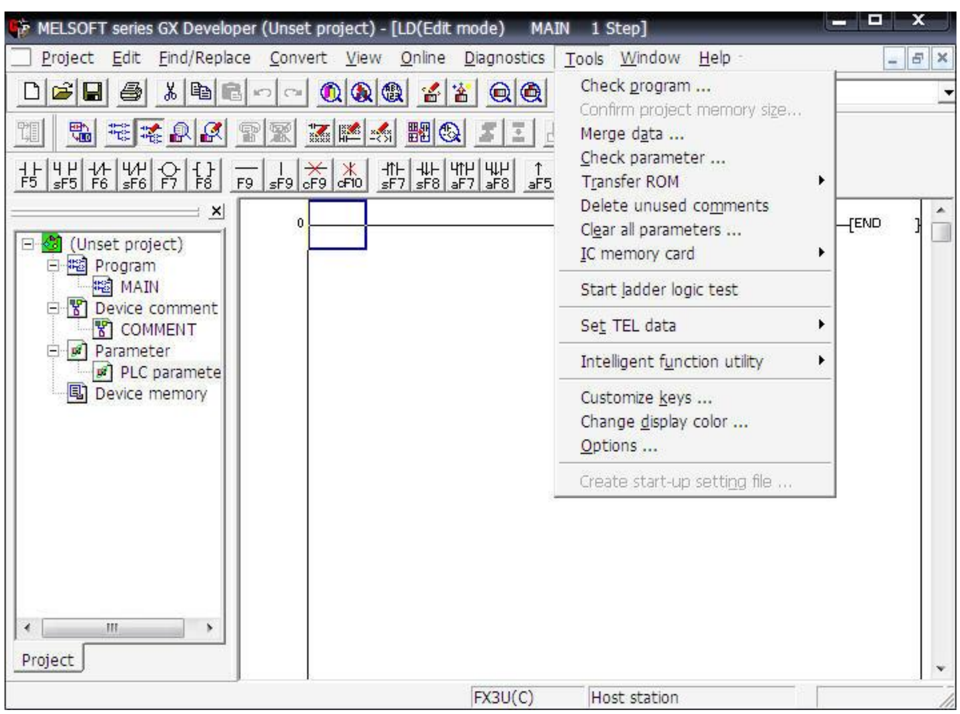


Figure A16. Tool menu function

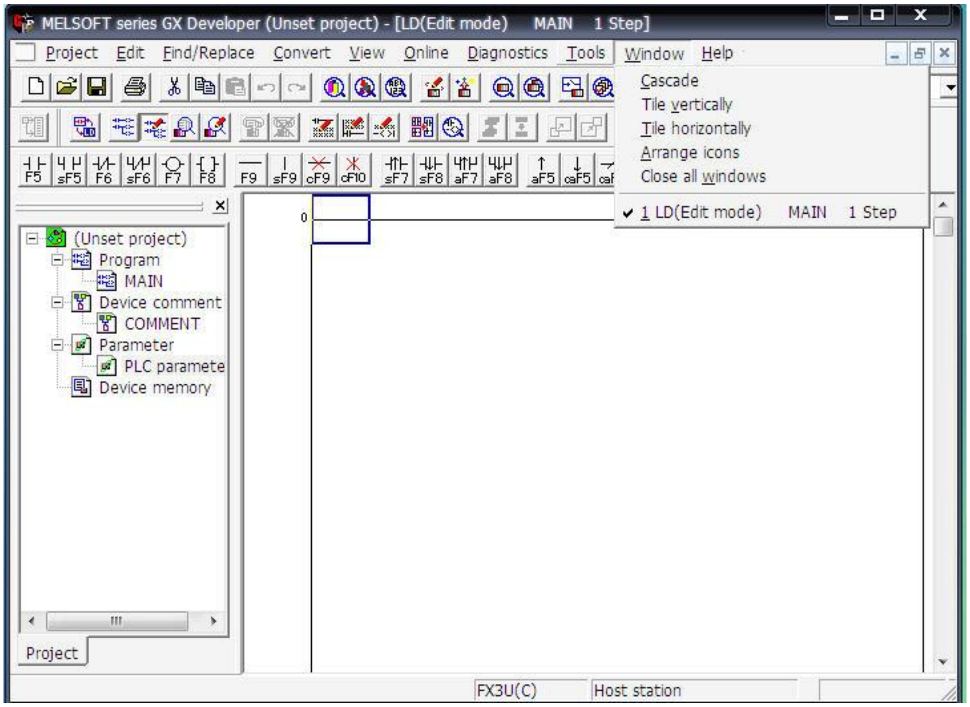


Figure A17. Window menu function

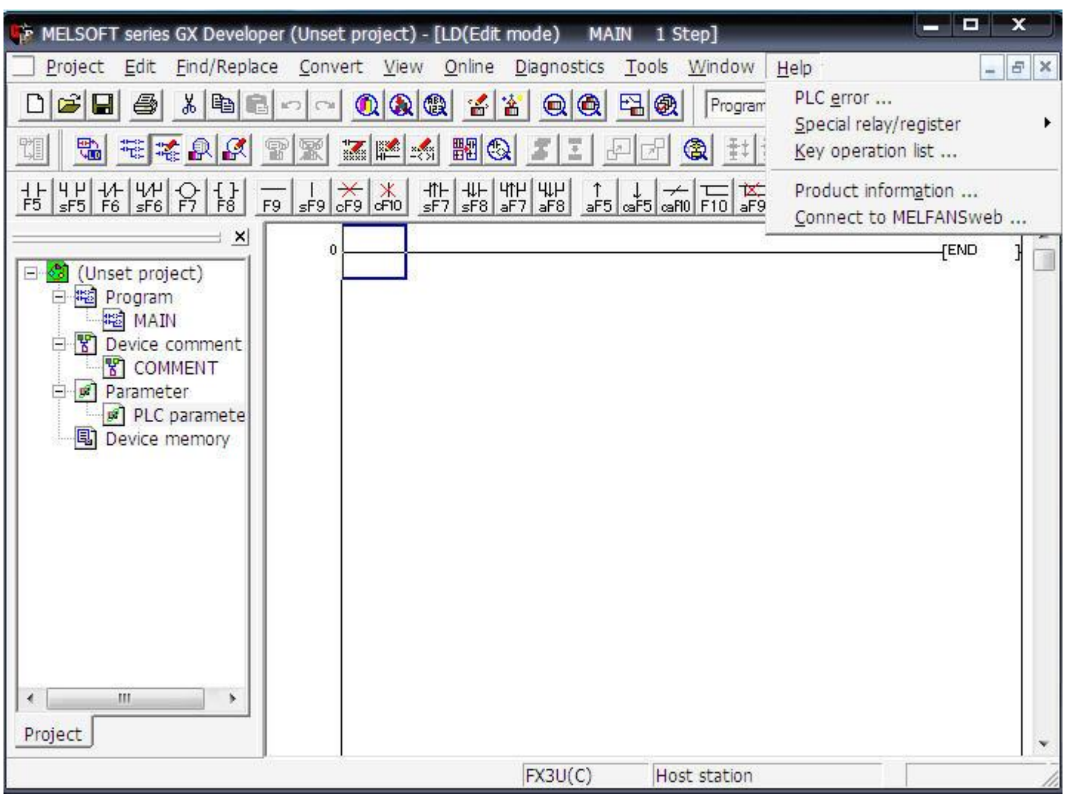


Figure A18. Help menu function

3.1 Basic function

3.1.1 Load, Load inverse and Out function

Load and load inverse are the function to receive input from switch or sensor, contact of load will be normally opened (NO) but contact of load inverse will be normally closed (NC). Out is the end of function after load or load inverse receive input, out is normally connected with output equipment such as motor, solenoid valve, coil, and bulb. The example of connection amount load, load inverse and out is shown in figure A19.

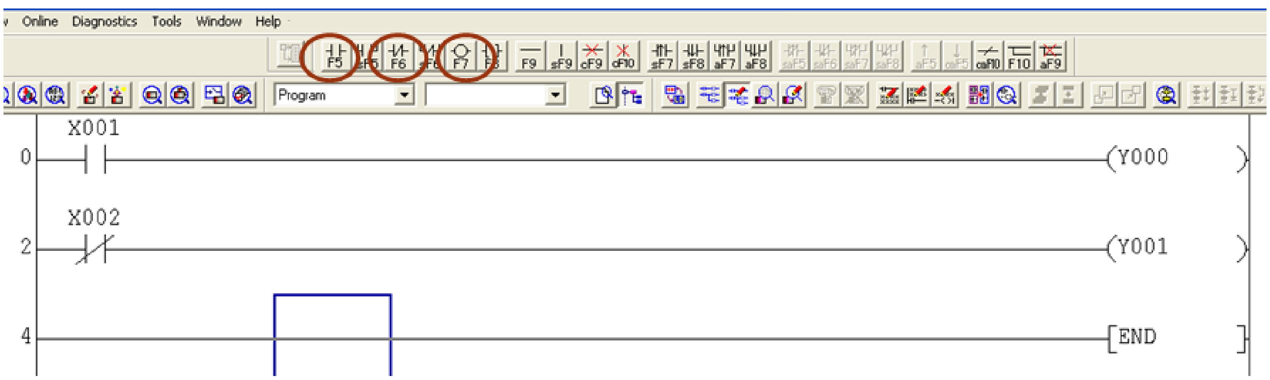


Figure A19. Connection amount load, load inverse and out

3.1.2 "AND" function

"AND" function is the series connection of load function in figure A20.

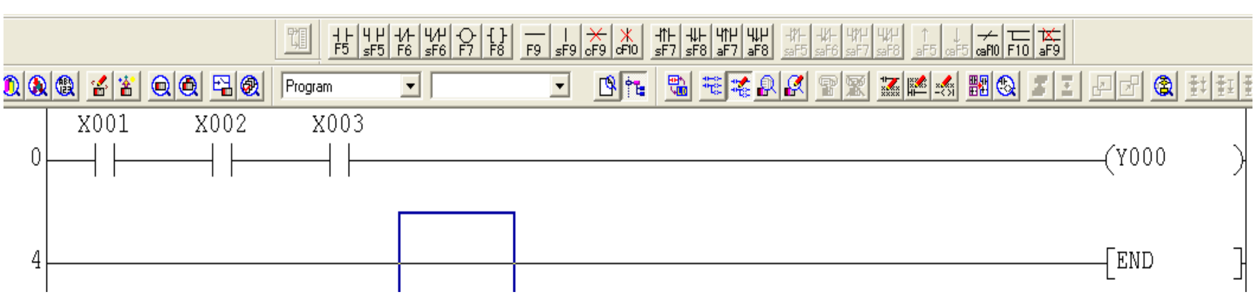


Figure A20. Example of "AND" function

3.1.3 "OR" function

"OR" function is the parallel connection of load function in figure A21.

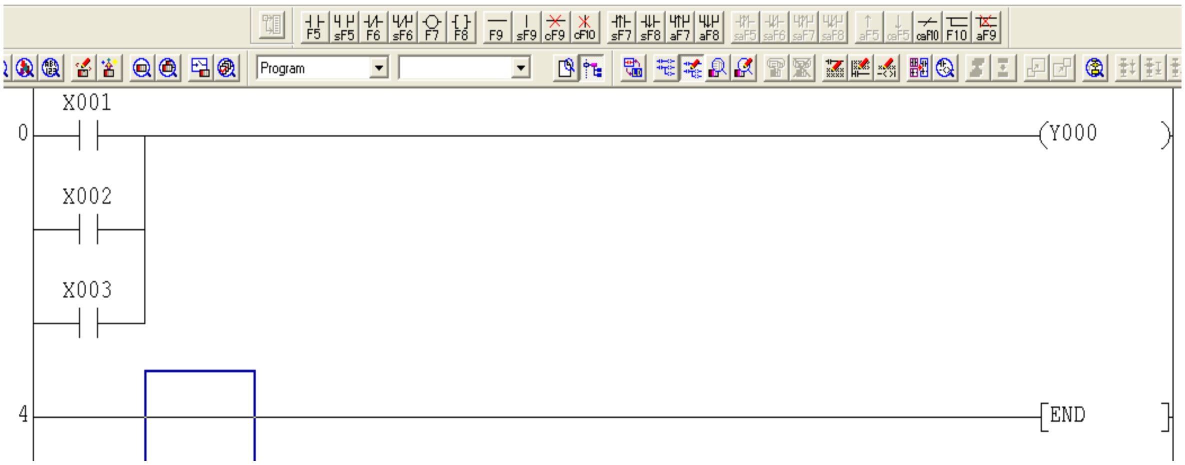


Figure A21. Example of "OR" function

3.1.4 Load Pulse function

Load pulse function will work only one time at uptime condition. For example in figure A22, if we press switch X0 and remain its condition, output Y0 will be trigged at the first time only one time.

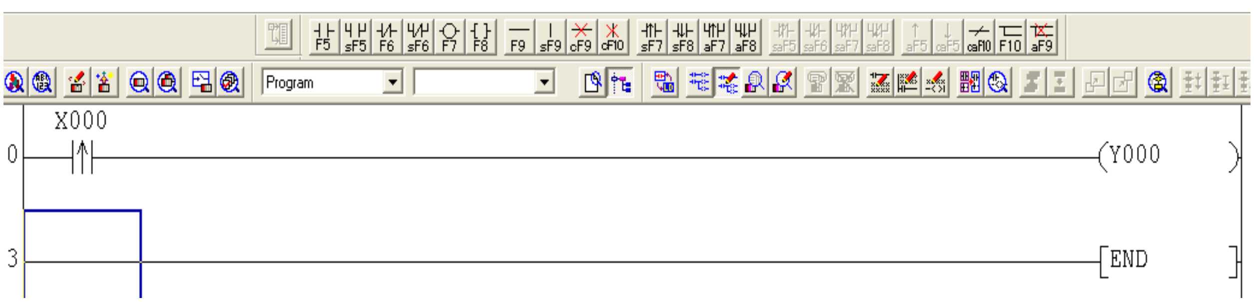


Figure A22. Example of Load Pulse function

3.1.5 Load Trailing Pulse function

Load Trailing Pulse function will work only one time at downtime condition. For example in figure A23, if we press switch X0, Y0 will not be trigged until switch X0 is released.

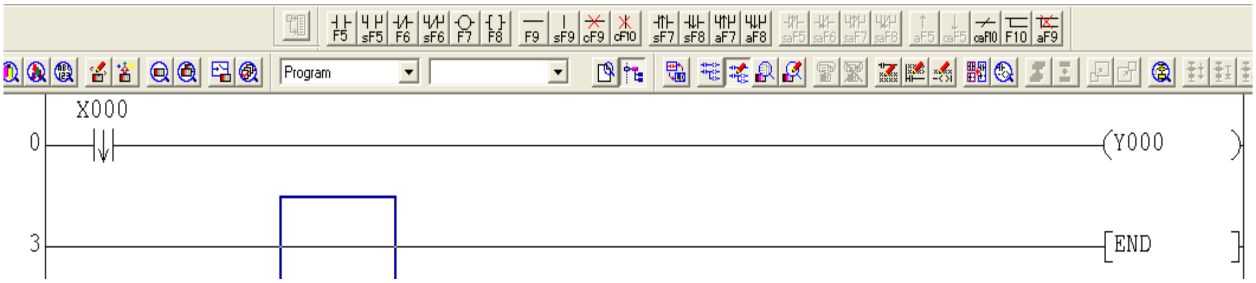


Figure A23. Example of Load Trailing Pulse function

3.1.6 SET and RESET function

SET function will be on output all the time until RESET function is trigged. For example in figure A24, if X0 is pressed, Y0 will be on until X1 is pressed.

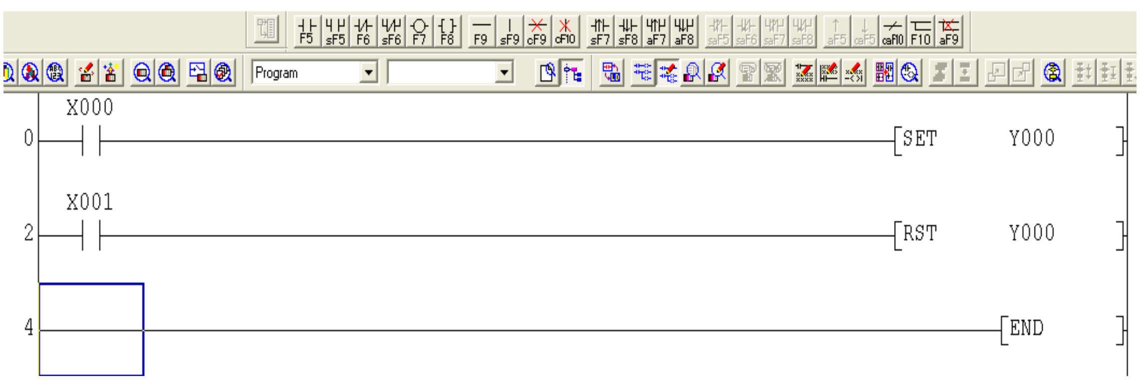


Figure A24. Example of SET and RESET function

3.1.7 TIMER function

TIMER function is used to prolong the time when the process is required. Example of TIMER is shown in figure A25, when X0 is presses, after 1 second, Y0 will be on (T0 is the sequence of TIMER and K10 = 1 second).

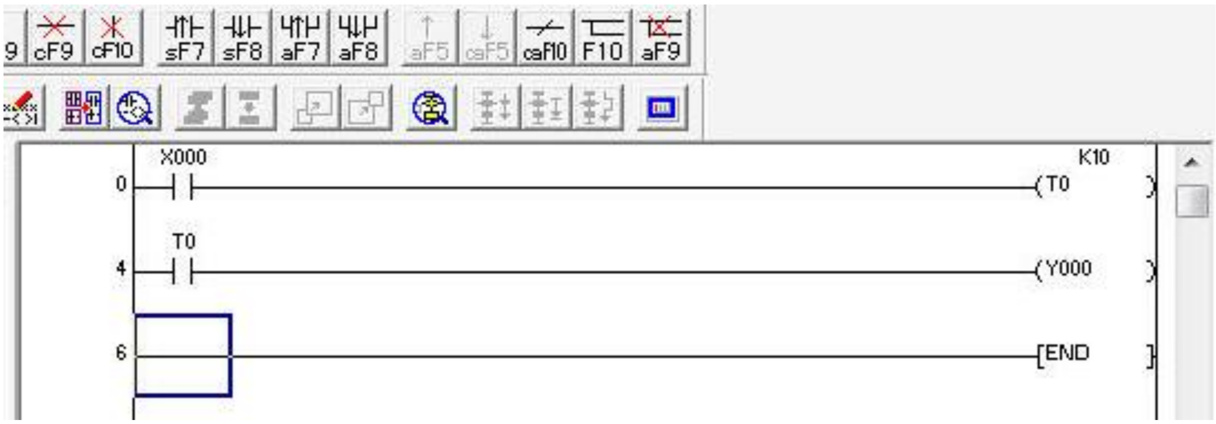


Figure A25. Example of TIMER function

3.1.8 Counter function

Counter function is used to count the work cycle of the program. Example of counter in figure A26, X0 must be pressed 15 times to be on Y0 and press X1 1 time to reset counter.

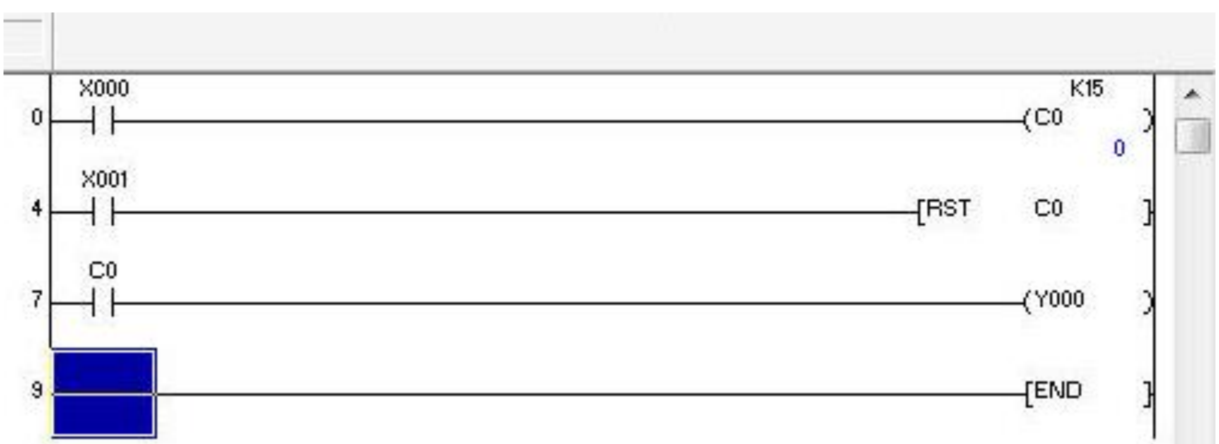


Figure A26. Example of counter function

3.2 PLC Data Register

Data register (D) is the site to store data or address.

3.2.1 INC and DEC function

INC is the function to increase one value at a time and DEC is the function to decrease one value at a time. Example in figure A27, press X0 to increase one value of D0 at a time and press X1 to decrease one value of D0 at a time.

Figure A27. Example of INC and DEC function

3.2.2 MOV function (Data transfer instructions)

MOV is the function to transfer data. Example in figure A28, when X0 is pressed and then value 1,000 will be move to store in D0.

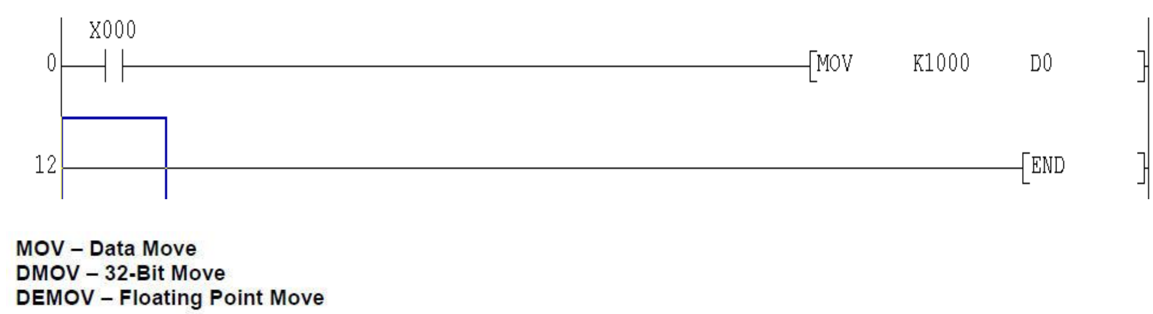


Figure A28. Example of MOV function

3.2.3 Compare function (=,>, <, >=, >=)

Compare function is used to compare value of data to run program. The function can be written as shown in figure A29.

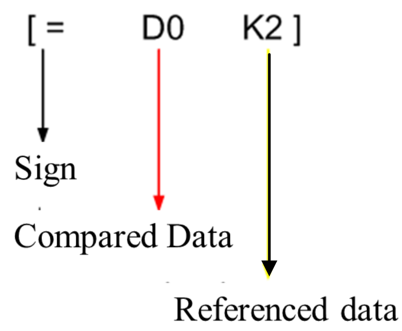


Figure A29. Characteristic of compare function

Figure A29 can be read that "if D0 is equal to 2". Example of compare function is explained in figure A30. Value of D0 is defined by X0. If D0 is less than 5, Y0 will be on. If D0 is equal 5, Y1 will be on. If D0 is more than 5, Y2 will be on.

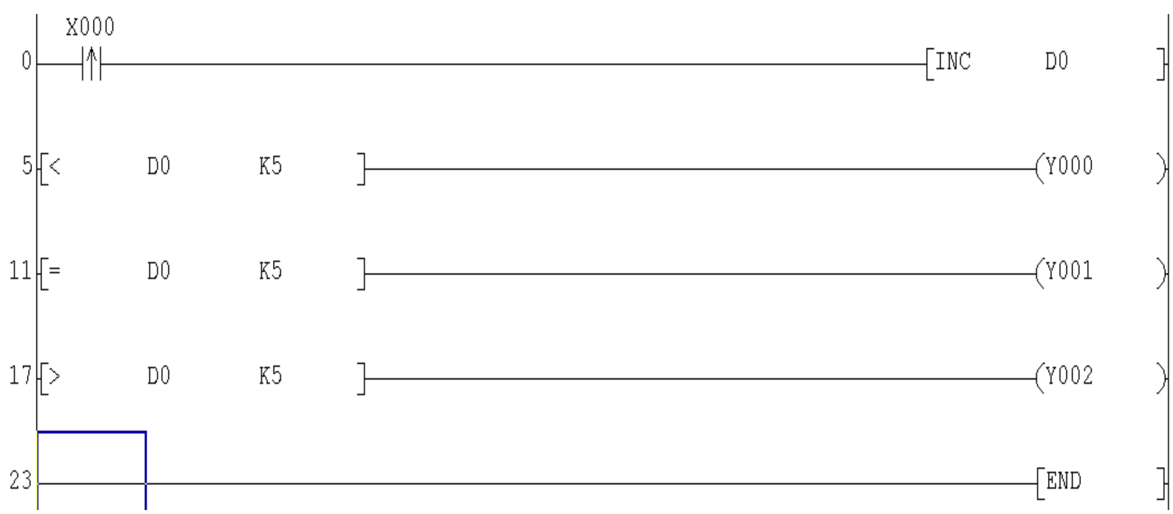


Figure A30. Example of compare function

3.2.4 ADD, SUB, MUL, and DIV function

ADD, SUB, MUL, and DIV are the function to calculate the value of data. ADD is plus, SUB is minus, MUL is multiply and DIV is division. The function can be written as shown in figure A31.

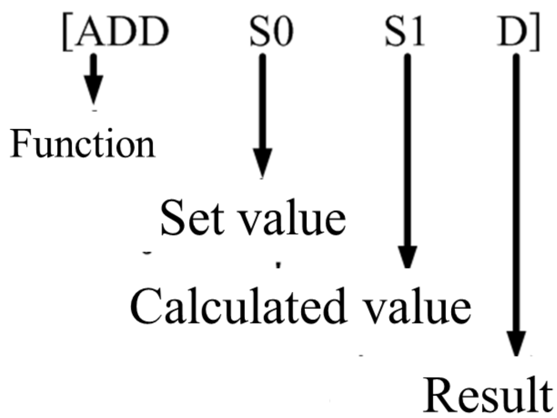


Figure A31. Characteristic of ADD, SUB, MUL, and DIV function

Figure A31 can be read that plus S0 by S1 and store in D. Example of ADD, SUB, MUL, and DIV function is explained in figure A32. Value of D0 is defined by X0 and M8000 is always on contact. The functions are Plus D0 by 5 and store in D1, minus D0 by 10 and store in D2, multiply D0 by 2 and store in D3, divide D3 by D1 and store in D4(Hongsuwan, 2010).

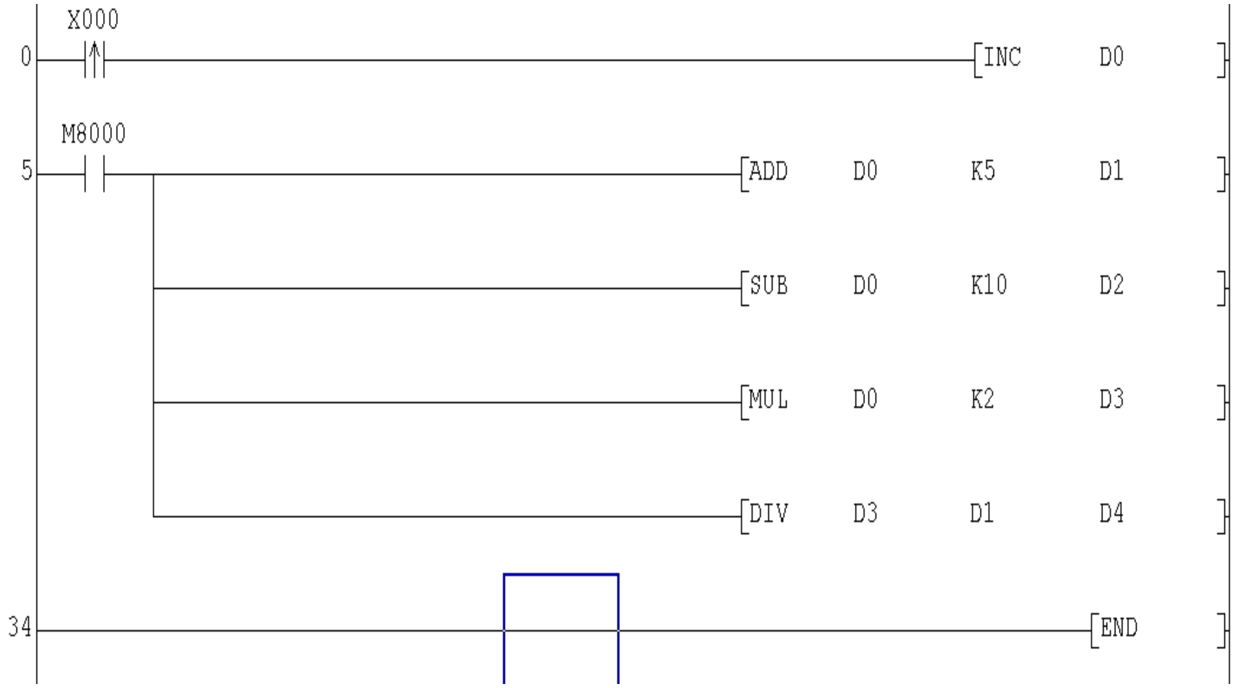


Figure A32. Example of ADD, SUB, MUL, and DIV function

4. ASCII Data

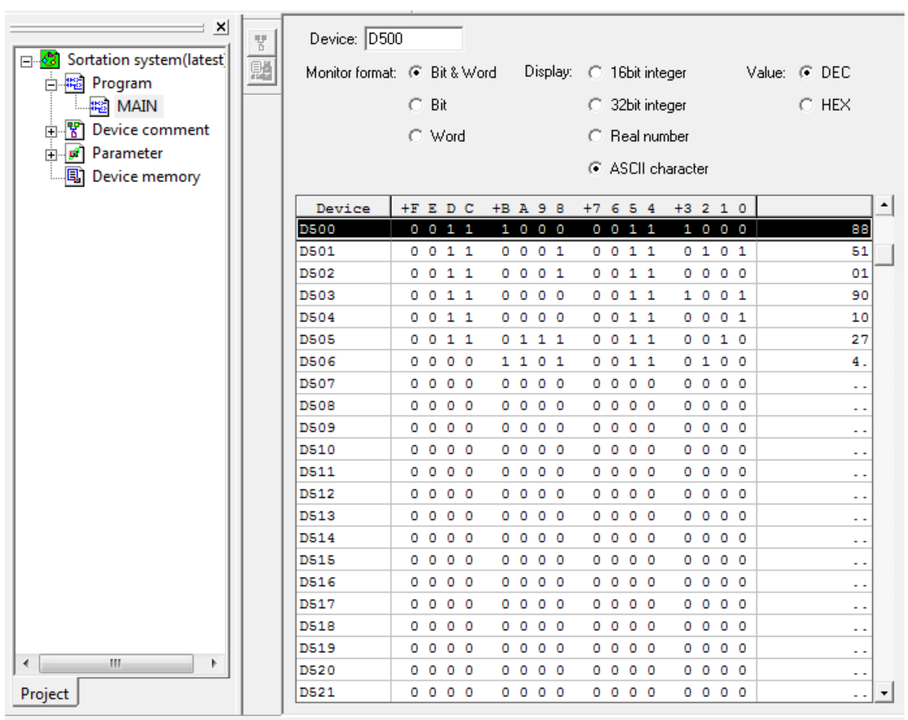
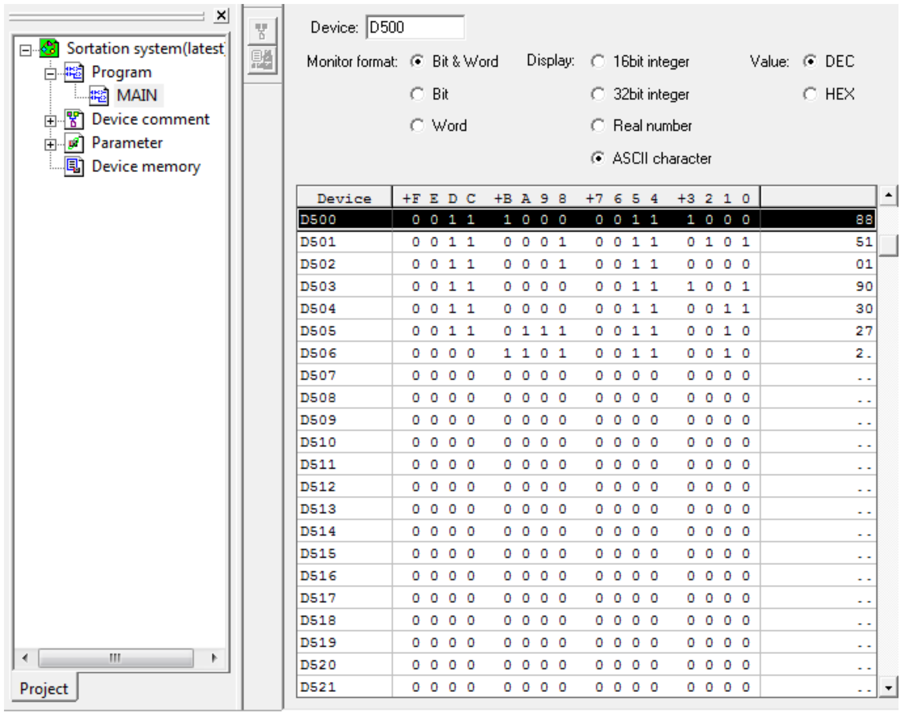
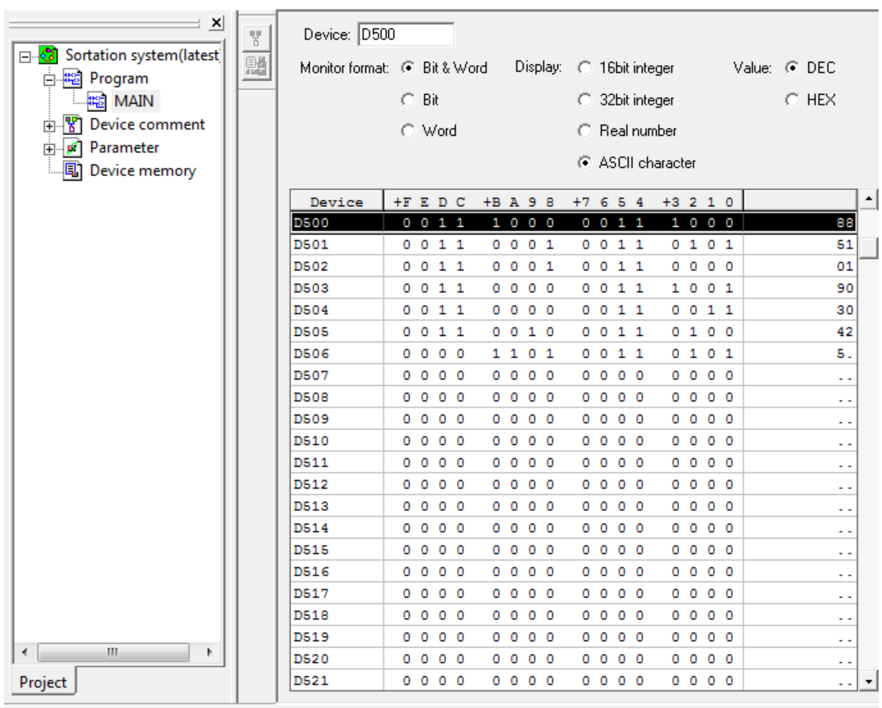


Figure A33. ASCII data of barcode tag for tyre size 13 inches



Device	+F E D C	+B A 9 8	+7 6 5 4	+3 2 1 0	
D500	0 0 1 1	1 0 0 0	0 0 1 1	1 0 0 0	88
D501	0 0 1 1	0 0 0 1	0 0 1 1	0 1 0 1	51
D502	0 0 1 1	0 0 0 1	0 0 1 1	0 0 0 0	01
D503	0 0 1 1	0 0 0 0	0 0 1 1	1 0 0 1	90
D504	0 0 1 1	0 0 0 0	0 0 1 1	0 0 1 1	30
D505	0 0 1 1	0 1 1 1	0 0 1 1	0 0 1 0	27
D506	0 0 0 0	1 1 0 1	0 0 1 1	0 0 1 0	2.
D507	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	..
D508	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	..
D509	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	..
D510	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	..
D511	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	..
D512	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	..
D513	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	..
D514	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	..
D515	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	..
D516	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	..
D517	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	..
D518	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	..
D519	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	..
D520	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	..
D521	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	..

Figure A34 ASCII data of barcode tag for tyre size 14 inches



Device	+F E D C	+B A 9 8	+7 6 5 4	+3 2 1 0	
D500	0 0 1 1	1 0 0 0	0 0 1 1	1 0 0 0	88
D501	0 0 1 1	0 0 0 1	0 0 1 1	0 1 0 1	51
D502	0 0 1 1	0 0 0 1	0 0 1 1	0 0 0 0	01
D503	0 0 1 1	0 0 0 0	0 0 1 1	1 0 0 1	90
D504	0 0 1 1	0 0 0 0	0 0 1 1	0 0 1 1	30
D505	0 0 1 1	0 0 1 0	0 0 1 1	0 1 0 0	42
D506	0 0 0 0	1 1 0 1	0 0 1 1	0 1 0 1	5.
D507	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	..
D508	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	..
D509	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	..
D510	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	..
D511	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	..
D512	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	..
D513	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	..
D514	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	..
D515	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	..
D516	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	..
D517	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	..
D518	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	..
D519	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	..
D520	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	..
D521	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	..

Figure A35. ASCII data of barcode tag for tyre size 15 inches

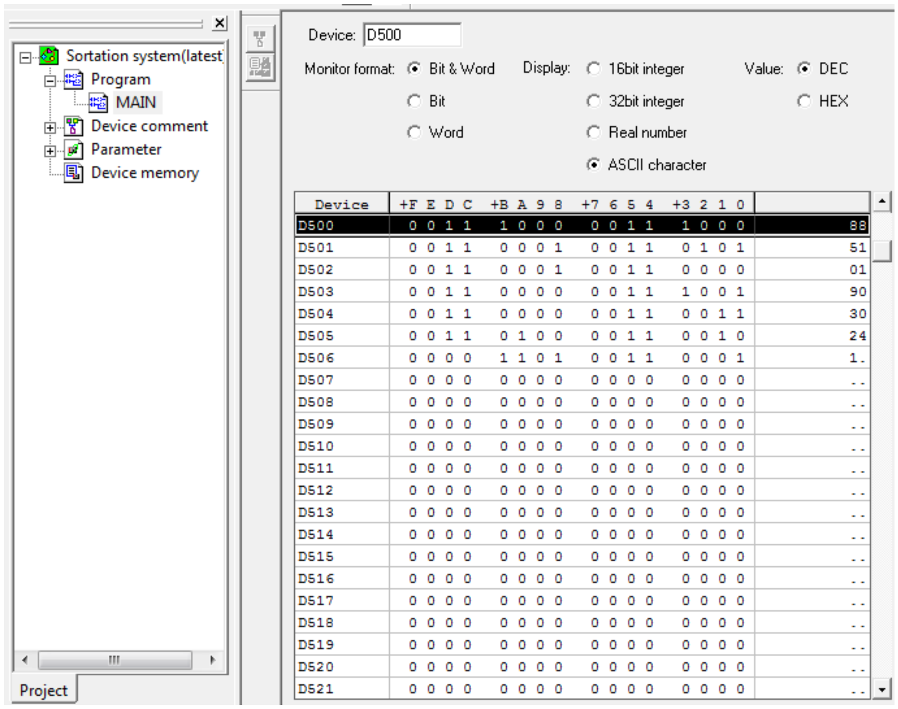


Figure A36. ASCII data of barcode tag for tyre size 16 inches

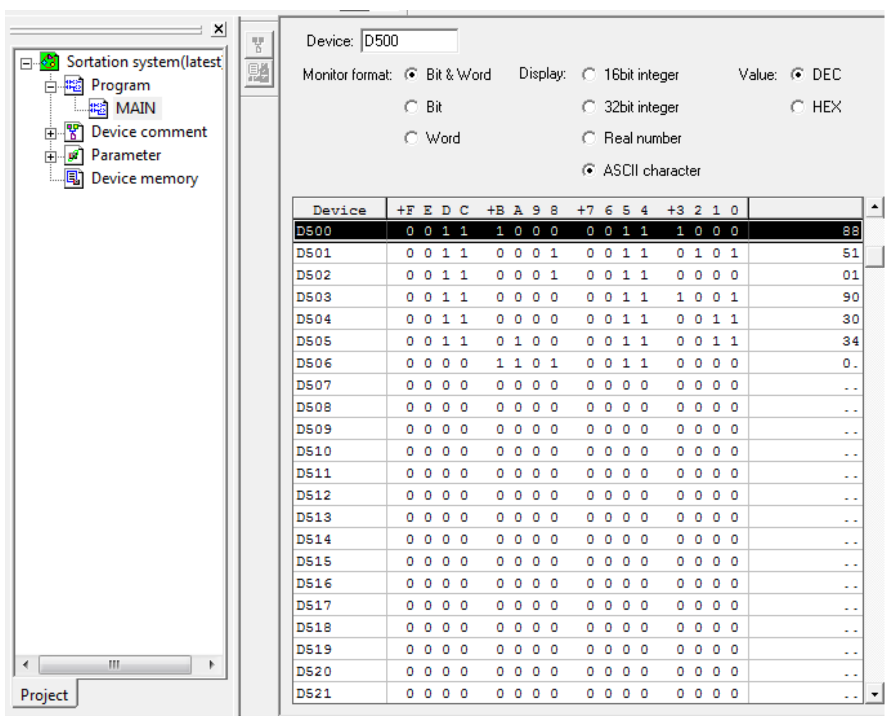


Figure A37. ASCII data of barcode tag for tyre size 17 inches

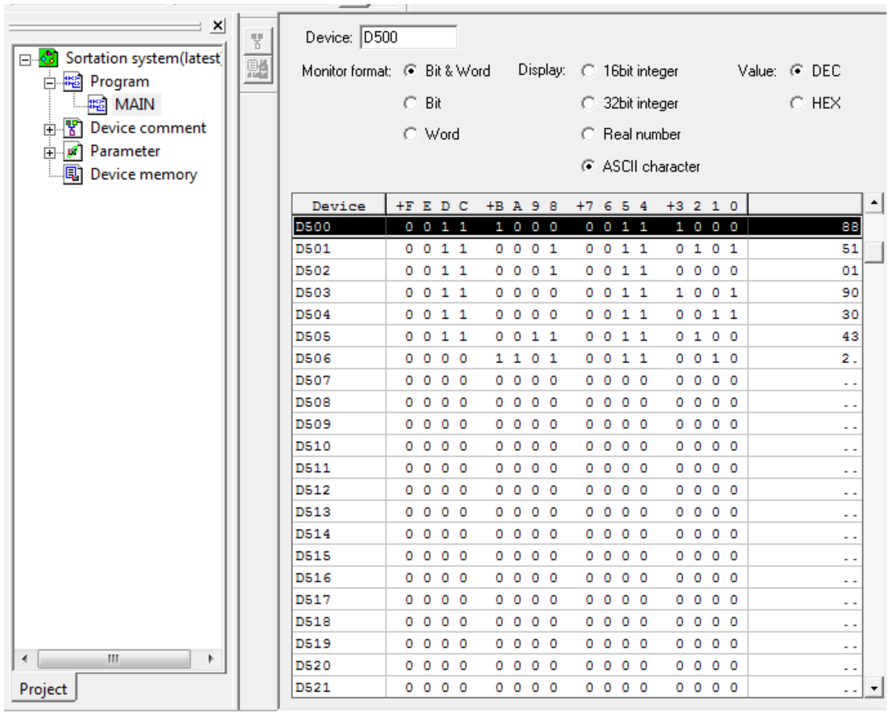


Figure A38. ASCII data of barcode tag for tyre size 18 inches

5. 32 bits data

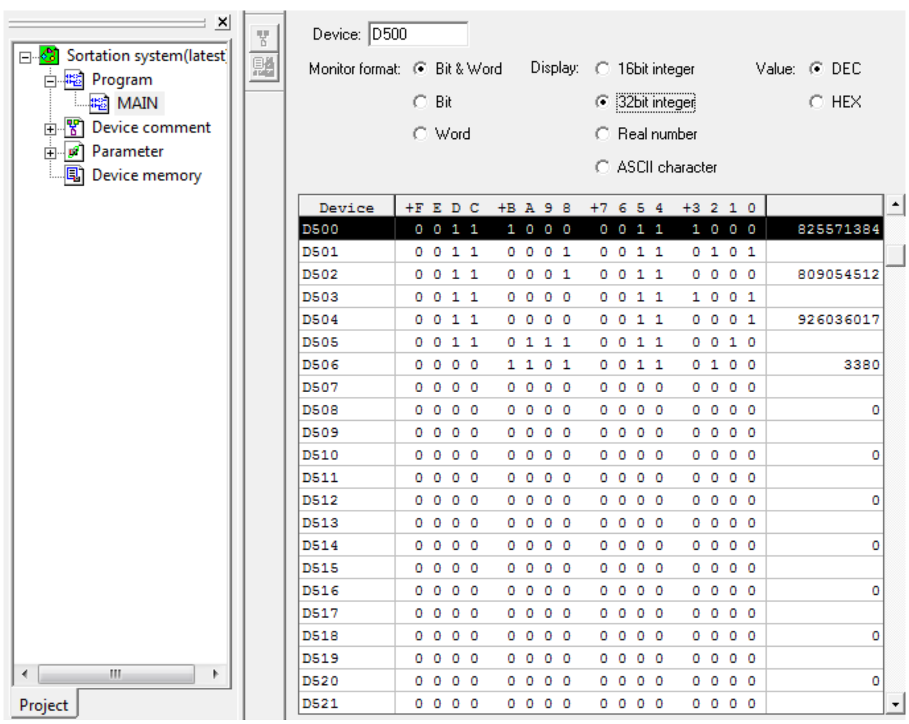
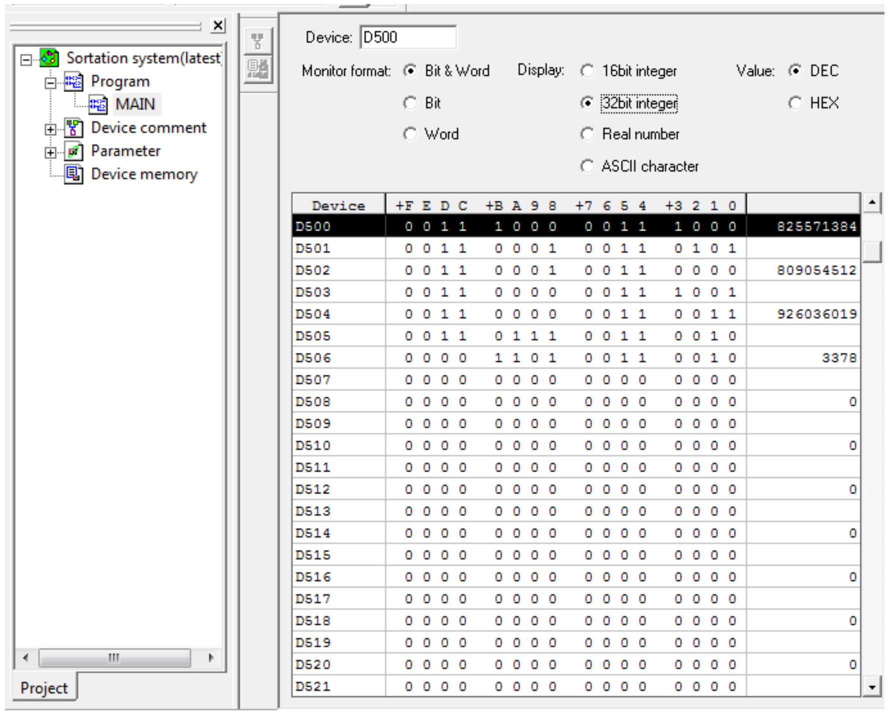
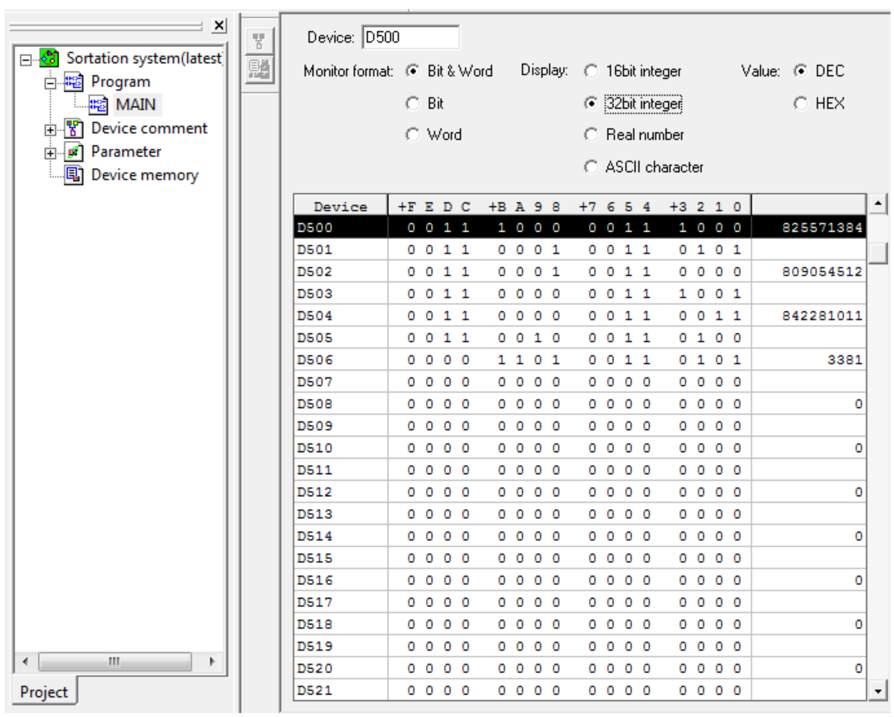


Figure A39. 32 bits data of barcode tag for tyre size 13 inches



Device	+F E D C	+B A 9 8	+7 6 5 4	+3 2 1 0	
D500	0 0 1 1	1 0 0 0	0 0 1 1	1 0 0 0	825571384
D501	0 0 1 1	0 0 0 1	0 0 1 1	0 1 0 1	
D502	0 0 1 1	0 0 0 1	0 0 1 1	0 0 0 0	809054512
D503	0 0 1 1	0 0 0 0	0 0 1 1	1 0 0 1	
D504	0 0 1 1	0 0 0 0	0 0 1 1	0 0 1 1	926036019
D505	0 0 1 1	0 1 1 1	0 0 1 1	0 0 1 0	
D506	0 0 0 0	1 1 0 1	0 0 1 1	0 0 1 0	3378
D507	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	
D508	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	0
D509	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	
D510	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	0
D511	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	
D512	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	0
D513	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	
D514	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	0
D515	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	
D516	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	0
D517	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	
D518	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	0
D519	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	
D520	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	0
D521	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	

Figure A40. 32 bits data of barcode tag for tyre size 14 inches



Device	+F E D C	+B A 9 8	+7 6 5 4	+3 2 1 0	
D500	0 0 1 1	1 0 0 0	0 0 1 1	1 0 0 0	825571384
D501	0 0 1 1	0 0 0 1	0 0 1 1	0 1 0 1	
D502	0 0 1 1	0 0 0 1	0 0 1 1	0 0 0 0	809054512
D503	0 0 1 1	0 0 0 0	0 0 1 1	1 0 0 1	
D504	0 0 1 1	0 0 0 0	0 0 1 1	0 0 1 1	842281011
D505	0 0 1 1	0 0 1 0	0 0 1 1	0 1 0 0	
D506	0 0 0 0	1 1 0 1	0 0 1 1	0 1 0 1	3381
D507	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	
D508	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	0
D509	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	
D510	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	0
D511	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	
D512	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	0
D513	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	
D514	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	0
D515	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	
D516	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	0
D517	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	
D518	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	0
D519	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	
D520	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	0
D521	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	

Figure A41. 32 bits data of barcode tag for tyre size 15 inches

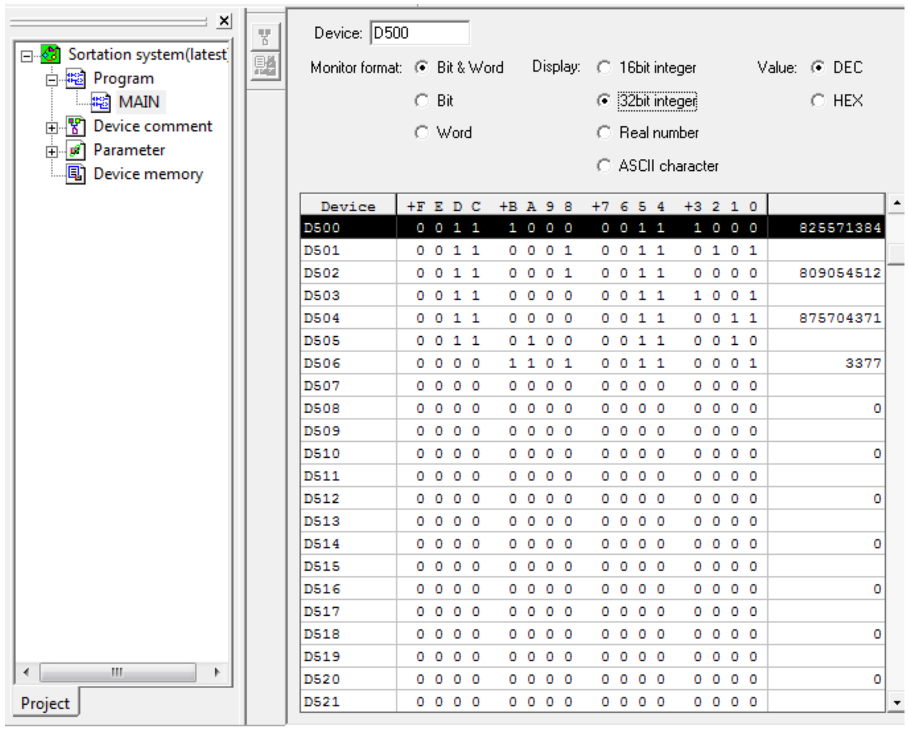


Figure A42. 32 bits data of barcode tag for tyre size 16 inches

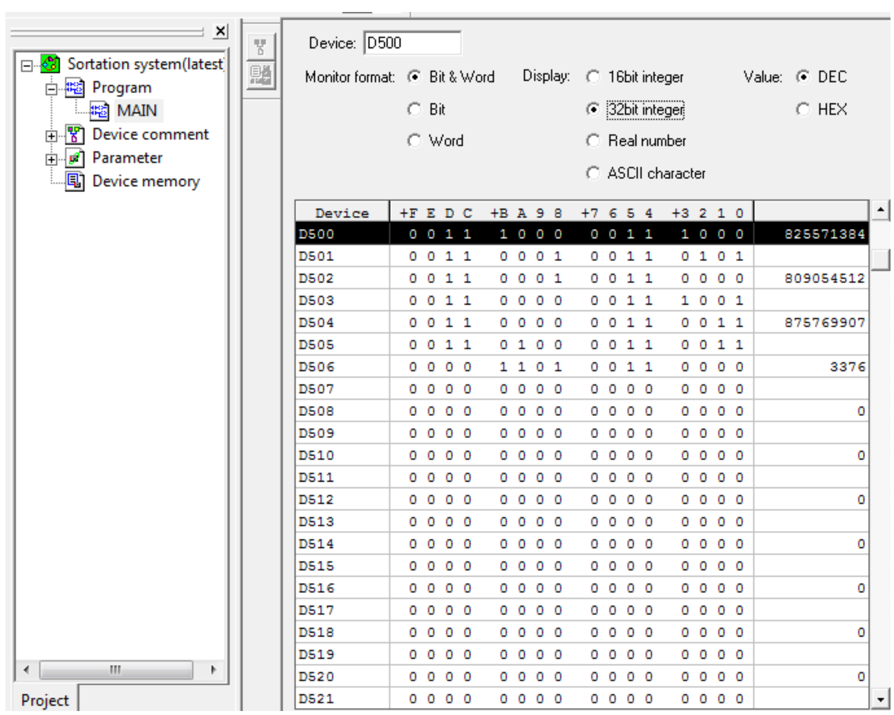


Figure A43 32 bits data of barcode tag for tyre size 17 inches

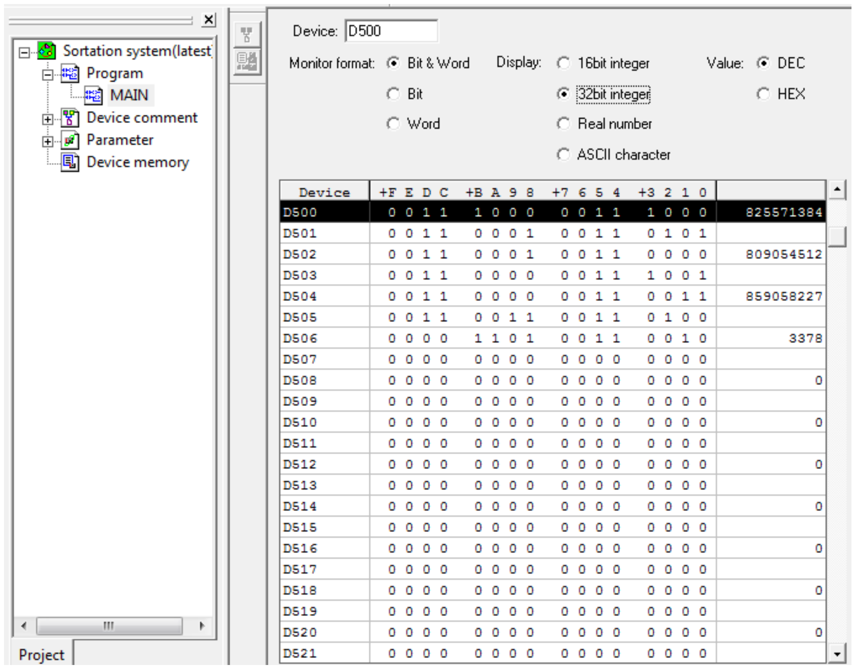


Figure A44. 32 bits data of barcode tag for tyre size 18 inches