AUTONOMOUS MOBILE ROBOT USING PROGRAMMABLE LOGIC CONTROLLER (PLC)

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Abstract

In the era of technology, robots are commonly used in almost all activities whether in industries or even at home. The development in robot technology has increased gradually as the time passes. Nowadays most robots are intelligent whereby they have "brain" that can sense the presence of input variables, map or locate the source of presence factor, plan for further step of actions and act according to the program being set by the programmer or Sense, Map, Plan and Act (SMPA) theory of operation [1]. This paper will explain about the software development using SYSWIN 3.4 programming Ladder Diagram tool for Omron CPM2A PLC controller and brief explanation on the hardware model.

Keywords

Programmable Logic Controller (PLC), Ladder Diagram, Pre-determined environment, Input / Output (I/O).

1.0 INTRODUCTION

The Autonomous Mobile Robot is an indoor multitask robot that accomplish certain tasks such as pick and place object and do cleaning process like vacuuming and sweeping dust in a pre-determined or set environment. The robot will complete the tasks while avoiding obstacles and able to prevent collision with unwanted objects when reaching the destinations. The robot is equipped with sensors and limit switches so that it will able to connect with the outside world and be given the information about the environment.

The robot consists of three hardware parts; motor driver to control the robot movements, robot arm with attached gripper to pick object at a time and vacuum cleaner with sweeper brush to do cleaning process. The pre-determined environment layout which consists of start area, picking objects area, cleaning area and service area are shown in Figure 1.1.

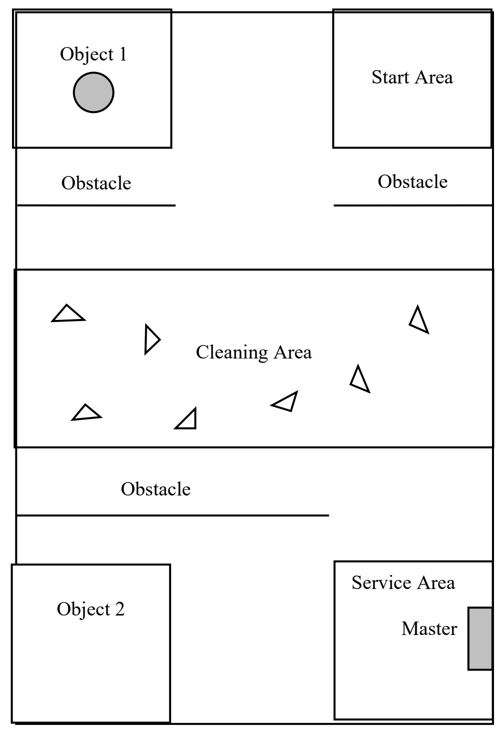

Figure 1.1 Pre-determined layout

2.0 SOFTWARE DEVELOPMENT

Ladder diagram for the overall operation is designed by using programming software SYSWIN version 3.4. It is an easy and understandable tool for designing PLC ladder diagram. Figure 2.1 shows the overall flowchart of the system or the sequential operation of the Autonomous Mobile Robot.

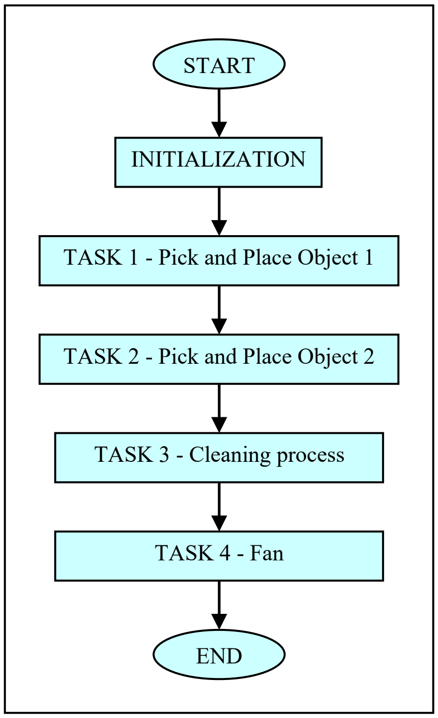

Figure 2.1 Flowchart of Overall Operation

The whole operation is designed for the mobile robot to do indoor housework tasks like serving drink, deliver book, cleaning the house area and turn On fan to its master. When Push START button is pressed, the mobile robot PLC CPM2A controller will first initialize all data at the input and output module. Then it will execute Task 1 whereby the mobile robot will move to area Object 1, pick the object (glass) and deliver it to its Master at the Service Area while avoiding all obstacles.

After finished Task 1, it will execute Task 2 where the robot will move to area Object 2, pick the object (book) and deliver it to the Master at the Service Area. Then it will execute Task 3 which is the cleaning process. The mobile robot will move to Cleaning Area and turn ON the vacuum with sweeper and clean the area for a limit of time. Lastly, after finished cleaning the area, the mobile robot will execute Task 4, it will move to the Service Area and positioned in front of its Master and will turn ON the fan for the comfort of its Master.

The main parts in the software development are program Timer and Delay for robot positioning and movements, clock pulse generation for controlling the speed of robot arm and the robot arm positioning coordinates. For robot positioning and movement, there are two motors located at the base level of the model and named Left Motor and Right Motor. For straight movement whether forward or reverse, both motor will be powered for an exact amount of time as the environment is pre-determined. Meanwhile for left turning, Right motor will be powered and as for right turning, the Left motor will turned ON. The movements are fully controlled by the ladder diagram program Timer, Delay and Counter.

For robot arm positioning, clock pulse generation in the PLC program is used to control the speed of arm movements. In order to get the ideal speed of robot arm movement, three clock pulses 0.1s, 0.2s and 1.0s in Special Relay (SR) functions have been tested and clock pulse of 0.2s (SR 255.01) is the most suitable clock pulse for the arm. Figure 2.2 shows the results from the three tests that have been made to the clock pulse.

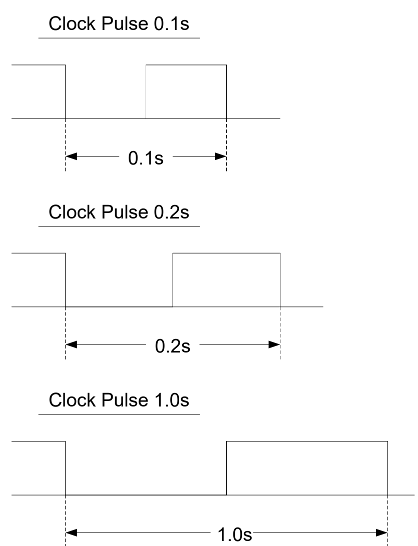

Figure 2.2 Square-wave clock pulses

2.1 INPUT / OUTPUT ASSIGNMENT

When using PLC as the controller for any system, all input and output devices must have different set of addresses and must be assign carefully to avoid program clash in the ladder diagram. In this project, the Omron CPM2A PLC controller have 18 input contacts and 12 output contacts which means 18 inputs and 12 outputs attached to the controller I/O module can be operated at one time. Table 1 shows the input assignments while Table 2 shows the output assignments of the system.

Table 1 Input Assignment

INPUT ASSIGNMENT	
ADDRESS	**DESCRIPTION**
0000	Push START button
0001	Push STOP button
0002	Front Base sensor
0003	Gripper sensor
0004	Limit Switch Gripper Open
0005	Limit Switch Gripper Close

Table 2 Output Assignments

OUTPUT ASSIGNMENTS	
ADDRESS	**COMMENT**
1000	Motor Left Forward
1001	Motor Right Forward
1002	Motor Left Reverse
1003	Motor Right Reverse
1004	Gripper Close
1005	Gripper Open
1006	J1 Forward (+)
1007	J2 Reverse (-)
1100	Sweeper
1101	Vacuum
1102	Fan

3.0 HARDWARE DEVELOPMENT

There are four main hardware parts in the robot which are robot base, robot arm, gripper and vacuum cleaner with sweeper. The robot base consists of two 12V DC motors to control the robot movements while gripper uses 6V Tamiya motor to actuate the grip process. In front of the robot base is the sweeper that uses 12V Small Johnson motor to operate combined with vacuum cleaner.

Robot arm consists of two joints, Joint 1 (J1) and Joint 2 (J2) that uses 12V DC motors. There are four positions and movements for the robot arm which are Position 0 (P0), Position 1 (P1), Position 2 (P2) and Position 3 (P3). These positions are controlled by timers that are being set in the controller. The initial condition for the robot arm is Position 0 (P0). For the robot arm to move in a different position, the motor for J1 and J2 will be controlled whether to forward or reverse directions. The overall times taken for the movements have been calculated and are set in the robot program after comparing the clock pulse generated by the PLC controller and the robot motors. Figure 3.1 until 3.4 shows the positions of Joint 1 (J1) and Joint 2 (J2) of the robot arm.

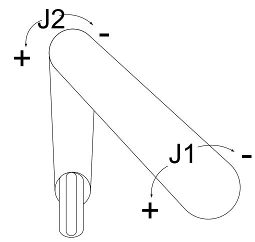

Figure 3.1 Position 0

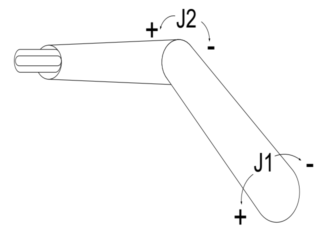

Figure 3.2 Position 1

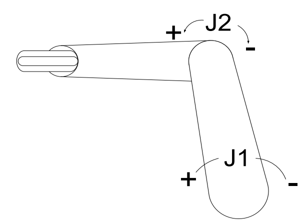

Figure 3.3 Position 2

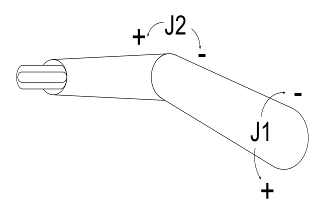

Figure 3.4 Position 3

4.0 RESULT AND DISCUSSION

Several experiments have been conducted to test the functionalities and the efficiencies of each components and parts of the Autonomous Mobile Robot. The experiments divided into two sections which is hardware experiments and software simulations. In hardware experiments, there are two types of sensors used in this project that are dark ON Photoelectric sensor (E3T-ST12) and Proximity sensor (E3Z-D62). The (E3T-ST12) sensor consists of infrared transmitter and receiver is attached at one end of the robot gripper. When the infrared beam is blocked, it means that there is an object within the gripper range so the gripper will close and grip the object. The output respond of the sensor is shown in Figure 4.1. The sensor produces an output of 11.4V when it is activated or when it senses an object. There is some error at the value as the supply for the sensor is 12V DC. The output will be considered as HIGH input by the Omron PLC CPM2A controller and will respond according to the program.

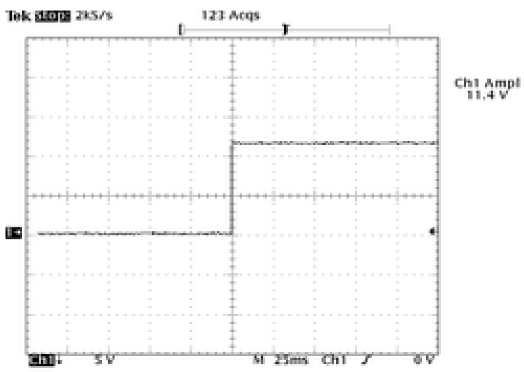

Figure 4.1 Output of Sensor E3T-ST12

Meanwhile, four proximity sensors or (E3Z-D62) are attached at the robot base model. Two sensors are placed at front left and right of the robot and the other two are at the back left and right of the model. The sensors are used to sense obstacles or object at front and rear of the robot so that it will avoid and prevent collision with the obstacles. The infrared beam is always transmitted in the range of 1 meter.

When the beam hits an obstacle, the beam will be reflected back to the receiver in the sensor. The faster the beam is reflected, the closer the obstacle is to the robot. Figure 4.2 shows the output respond for the sensor (E3Z-D62). The sensor produces an output of 12.4V when the beam is reflected back from an obstacle located at about 15cm from the model. It is considered HIGH by the PLC controller and decides the next action set by the program.

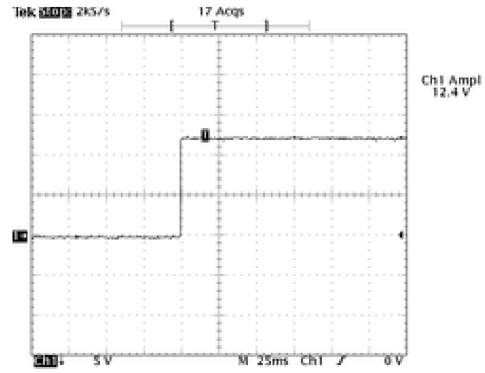

Figure 4.2Output of Sensor E3Z-D62

For a better robot positioning and arm movement controls, the clock pulses from robot motors and the PLC controller are tested. The power supplies that being used to the arm motor and PLC controller is 6V and 12V DC respectively. Figure 4.3 shows the output pulse from PLC controller at Channel 1 and robot arm motor pulse at Channel 2. The result shows there is a time delay of 95ms between PLC pulse and the arm motor pulse. It is the ideal time delay and clock speed for the PLC controller to control the robot arm movements.

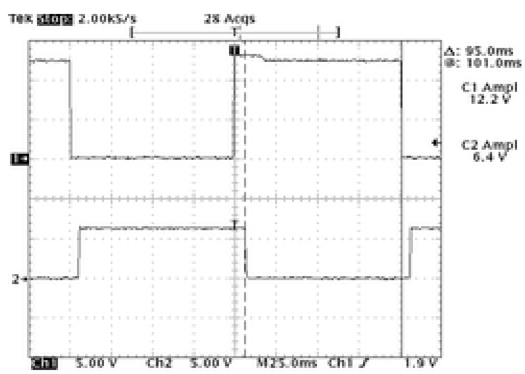

Figure 4.3 Output of PLC and Arm motor

From the clock pulse comparison, the values for the timer to control the robot positioning and arm movements are determined. Table 3 shows the time taken for the robot arm to move from one position to another. The unit of time used is in second (s).

ROBOT ARM POSITION	JOINT 1 (J1)		JOINT 2 (J2)	
	FORWARD (+)	REVERSE (-)	FORWARD (+)	REVERSE (-)
P0 – P1	0	0	0	5
P1 – P0	0	0	0	3
P1 – P2	0	2	1	0
P2 – P1	2	0	0	2
P2 – P3	2	0	0	2
P3 – P2	0	3	2	0

Table 3 Time taken for Arm Positioning

The time taken value when the arm goes back to its starting position is different because of the gravity force that pull the arm forward to the ground.

In software simulations section, the robot ladder diagram is simulated virtually using computer. The results were taken at three conditions. First at the starting program, subroutine execution and the end of the ladder diagram.

When Push Start button (0000) is pressed, the contact relay (0000) will be latched and energized the output contact of J2_Reverse (1007). At the same time, TIM000 will be activated and turn the J2 motor to reverse for 5 seconds as shown in Figure 4.4 below.

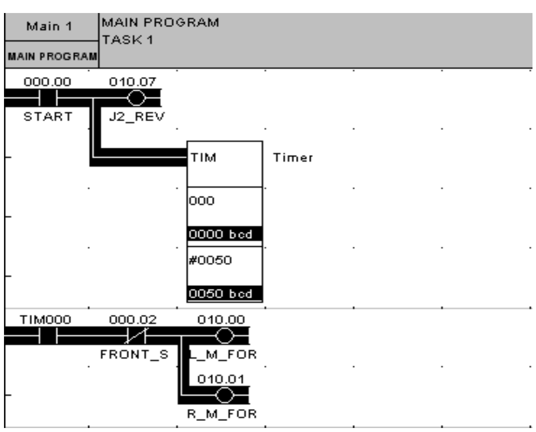

Figure 4.4 Output Contact Lathed

When subroutine (SBS 91) with N number is latched, the controller will execute any instruction set that included within (SBN 92) of same N number and the first (RET 93). Then it will jump back to the main program. Figure 4.5 show the program of Subroutine 1 is activated.

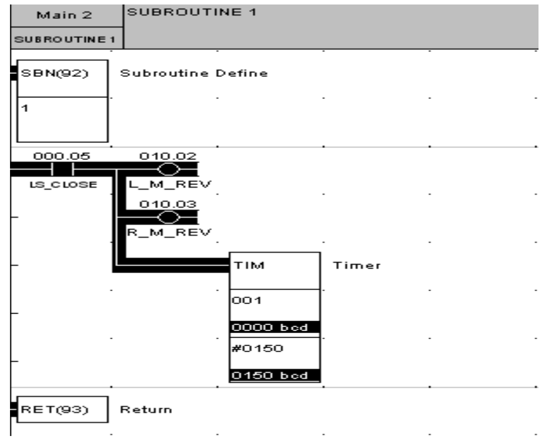

Figure 4.5 Subroutine 1 Latched

The instruction of (END 01) is used to end a program execution. It is placed at the last subroutine program which is at Subroutine 18 in the robot program. Figure 4.6 show the execution of Subroutine 18.

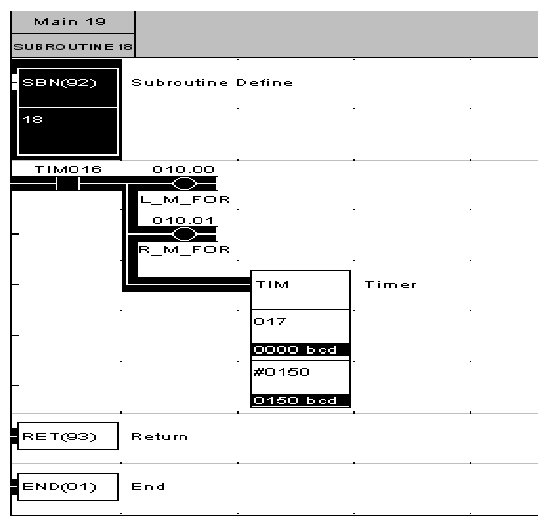

Figure 4.6 Last subroutine Latched

5.0 CONCLUSION

The hardware model and the software programming of the Autonomous Mobile Robot has been successfully developed and altered according to the objectives and the environment requirements. The several of tasks also have been accomplished and completed by the robot in the pre-determined environment with no human interference. Collisions avoiding maneuvers and automatic execution task concept have been successfully applied and achieved in this project by the use of other elements such as sensors, limit switches and timer in the program.

6.0 FUTURE DEVELOPMENT

There are weaknesses in this project that can be improved to get accurate and better results. In stead of using timer in the program for controlling the robot positioning and maneuvers, it is best if being replaced by the incremental colour sensor encoder. The robot driver wheels must be attaches with colour stripes disc so that the encoder will count the number of stripes and set the wheel rotations. This will result in better and accurate positioning.

The design of robot arm can be improved by adding more light joints so that it can move in a wider range and can pick object vertically as the current state, the robot arm only managed to pick object horizontally.

The use of timer in controlling robot arm is not very practical nowadays. By using more advance software program functions, the coordinates of each movements can be stored and be use easily through out the program executions.

7.0 ACKNOWLEDGEMENT

The author would like to express his gratitude and his sincere appreciations to his project supervisor, Puan Rosidah bte Sam for her guidance, comments, encouragements and full support to the author in completing this report. Also special thanks to Dr. Ahmad Maliki b. Omar, lecturer of subject Programmable Logic Controller (PLC) for the knowledge and support through out the program. Lastly to his friends and individuals that contribute to help him in completing his report.

8.0 REFERENCES

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Omron cpm2a
Photoelectric sensor - E3T-ST12
Proximity sensor - E3Z-D62
Limit switch