PLC CONTROLLED AUTOMATED GUIDED VEHICLE (AGV)

By

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FINAL PROJECT REPORT

Submitted to the Electrical & Electronics Engineering Programme
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CERTIFICATION OF APPROVAL

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Approved:

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Project Supervisor

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TRONOH, PERAK

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CERTIFICATION OF ORIGINALITY

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

(NGOOI GUAN KEONG)

ABSTRACT

A programmable logic controller (PLC) is a specialized computer and designed to be used in industrial for control purpose. In general, an automated guided vehicle (AGV) is a kind of transportation that mostly used in material handling system. It is self-propelled (driverless) vehicles guided along defined pathways and controlled by a computer. The objective of the project is to design an AGV vehicle prototype which is controlled by PLC for industrial application (material handling). Most of the AGV used in industries are controlled by a microprocessor. In this project the main focus is to have a reliable design, easier maintenance and advanced PLC controlled automated guided vehicle (AGV). The significant part of the project is of using sensors to guide the vehicle along the pre-determined path instead of using embedded wire guided method. The initial stage of the project involves feasibility studies of the PLC controlled automated guided vehicle (AGV) which includes the ability of the PLC and the automated guided vehicle system (AGVS). The AGV design requires the determining of the type of hardware needed, for example PLC (CPM2A), sensors (metal), rechargeable battery, power window motors and others. The design of AGV and its path are implemented. The AGV prototype is built part by part and then assembled. Two safety features are added on the prototype, i.e., the emergency reset and obstacles detection by using sensor. The ladder diagram for controlling the AGV is designed base on the path design and tested with PLC CPM1A training kit. The input and output components and the rechargeable battery is interfaced with the PLC on the AGV. Finally, the PLC controlled AGV was tested and some modification is required on the ladder diagram and also on the AGV. The project is successfully executed by using a PLC to control the AGV to find its route in a predefined path.

ACKNOWLEDGEMENT

This project would not become possible without the help of a number of people. I would like to express my gratitude to all of them.

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INTRODUCTION

CHAPTER 1

1.1 BACKGROUND OF STUDY

The first automated guided vehicle (AGV) was developed in 1954 by A.M. Barrett, Jr. who used an overhead wire to guide a modified towing truck pulling a trailer in a grocery warehouse. Commercial AGVs were subsequently introduced by Barrett. Advances in AGV system technology have been motivated largely by rapid developments in electronics and computer technologies.

An automated guided vehicle system (AGVS) is a material handling system that uses independently operated; self-propelled (driverless) vehicles guided along defined pathways and are controlled by computer. The vehicles are powered by on-board batteries that allow many hours of operation (8-16 hours is typical) between recharging.

AGVs can be used in two different ways. The first approach is to attach a work piece to the AGV having all manufacturing processes done while the AGV carries the work piece from station to station. The second approach is to use vehicles only for moving the work pieces from one station to another. Vehicle is assigned to the work piece only for a single trip.

A programmable logic controller (PLC) is a solid-state system designed to perform the logic functions previously accomplished by components such as electromechanical relays, drum switches, mechanical timers/counters, etc., for the control and operation of manufacturing process equipment and machinery. The National Electrical Manufacturing Association (NEMA) defines a programmable controller as follows:

"A programmable controller is a digital electronic apparatus with a programmable memory for storing instructions to implement specific functions such as logic, sequencing, timing, counting, and arithmetic to control machines and processes."

Programmable logic controllers are sometimes called programmable controllers but are more commonly called PLCs. A PLC is different from a standard personal computer in two ways: (1) PLCs are constructed to make it easier for a user to put together a PLC-controlled system, and (2) PLCs come preprogrammed with an operating system and applications programs optimized for control. The programming used in PLC is the ladder diagram/logic program.

A typical PLC can be divided into four components. These components consist of the CPU module, power supply, the input/output section (interface), and a rack.

CX-Programmer 3.0 is software developed by OMRON PLC company. This software is used to program the ladder diagram for the PLC. In the CX-programmer, the ladder diagram is programmed in rung. The programming technique is that the PLC scans the ladder diagram rung by rung from the first to the end and connected them according to the program designed. The common ladder logics used in CX-Programmer are normally open input, normally closed input, output, holding relay, timer and counter. There are some additional functions such as comparing, adding, and subtracting and others. Once the ladder diagram has been developed, the CX-Programmer has a server to interface the program with the PLC. The program is sent to the PLC. Then the PLC read the program form the CX-Programmer and implemented to control the system according to the ladder diagram.

1.2 PROBLEM STATEMENT

1.2.1 Problem Identification

Modern manufacturing plant requires efficient management of transporting tools/product within the production line. AGV is one of the elements of the system that requires proper development.

An automated guided vehicle (AGV) can be controlled via computer based microprocessor, digital circuits or programmable logic controller. Normally the AGV is controlled by computer-base microprocessor with certain programming language such as neural network or fuzzy logic. For this project, a PLC will be used to control the vehicle, which may ease the maintenance and troubleshooting purposes. The movement of the vehicle is controlled by sensors, which will function according to the path design. The movement of the AGV along the path is the critical parts in the AGV system. The route of the AGV need to be determined. A ladder diagram will be designed and suit the route of the AGV along the path.

1.2.2 Significance of the Project

This project serves an automation system control for an automated guided vehicle system in order to be applied in material handling system in industrial. As mentioned, the AGV is driverless and is operated automatically base on the designed program. This project will implement the PLC in the AGV which is easier to set up, easier for maintenance and trouble shooting, easier to understand the program that has been developed and modify comparing to using a microprocessor. The PLC will be interfaced with the AGV hardware such as motors and sensors. The ladder diagram is designed to suite the route of the AGV and can be easily modified for other routes.

1.3 OBJECTIVES AND SCOPES OF STUDY

1.3.1 Objectives

- To build an automated guided vehicle prototype (AGV) for industrial application.
- To implement the PLC for controlling of the AGV system.
- To design an optimum ladder diagram for the PLC to control the AGV system.
- To interface the PLC control system with the AGV hardware.
- To design a reliable, high efficiency and smooth PLC controlled automated guided vehicle system.

- To integrate and utilize the knowledge that is learnt throughout this 5-year university program.

1.3.2 Scope of study

A profound study has been conducted before deciding on the PLC controlled automated guided vehicle (AGV). The scopes of study include the PLC, the hardware, the features, applications and programming of the PLC. Familiarization on the using of The CX-Programmer software is anyhow important part of the work.

The feasibility studies of the automated guided vehicle (AGV) system includes the electrical and mechanical aspects of the system such as the features of the hardware used such as motors, sensors and other materials to build the prototype. However, the research on the hardware aspects of the AGV is a continuous activity to achieve building a prototype and getting more design ideas to produce a good outcome.

CHAPTER 2

LITERATURE REVIEW AND THEORY

2.1. INTRODUCTION

Material handling in manufacturing systems is becoming easier as the automated machine technology is improved. Today's rapid developments in technology present manufacturing firm a variety of alternatives for in-plant transportation. An Automated Guided Vehicle (AGV) system is such an advanced material handling system that involves a fleet of driverless vehicles (AGVs) which follow a guided path and are controlled by a computer.

2.2 PROGRAMMABLE LOGIC CONTROLLER (PLC)

Early machines were controlled mechanical devices such as cams, gears, levers and others. As the machines become more complex, so did the need for a more advance control system. Then hard wired relay system was introduced. These elements were wired as required to control logic for the certain type of machine operation. This system is only suitable for the machine which no need to change or modified. But as manufacturing process had improved and frequently changes of plant to new products become necessary, a more advance control system is needed. This is because hardwired relay and switch logic was cumbersome and time consuming to modify. Therefore Programmable Logic Controller (PLC) was invented.

A programmable logic controller is a solid-state system designed to perform logic functions such as sequencing, timing, counting, and arithmetic to control machines and processes which is previously done by hardwired relays system. PLC is operated by the instruction input from the input devices such as push button, switches, sensors and others used to detect the operation condition of the equipment, output devices such as solenoid valves, motors, indication loads like pilot lamp, digital indicator and so on. The transmission of output signal base on input signals is determined by the contents of program provide to the PLC. The light loads such as small type solenoid valve, pilot lamp, etc. can be directly driven by the PLC. However, the heavy loads like 3-phase motor, large capacity solenoid valve, etc. need to be driven through the intermediate relay. The intermediate relay is installed in the control panel together with the PLC for safety purpose. The PLC plays an important role as the brain of the automated manufacturing process.

2.2.1 Components of PLC

The typical PLC contains four major components as following:

- CPU module
- Power supply
- Rack/Bus
- Input/Output modules

2.2.2 Applications of PLC

PLC can be applied in so many industries. Some of the applications are as below:

- Material handling
- Traffic light system
- Power plant
- Conveyor system
- Food processing

2.2.3 The programming of PLC

A ladder diagram is a graphic-based technique of programming the PLC. It is concerned with the basic techniques involved in developing such programs to represent basic switching operations such as the logic functions of AND, OR, Exclusive OR, NAND and NOR. A simple wiring circuit for an electrical circuit can be represented with a ladder diagram. Writing a ladder diagram is equivalent to drawing a switching circuit. Wiring diagrams show the relative physical location of the circuit components and how they are actually wired. With ladder diagrams there is no attempt to show the actual physical locations but it emphasizes on how the control is implemented. A ladder diagram consists of horizontal rungs between two vertical rails which represent the power rails. Each rung contains instruction elements that examine memory bits and at least one output element that controls a memory bit. Each rung must start with an input or inputs and end with at least one output.

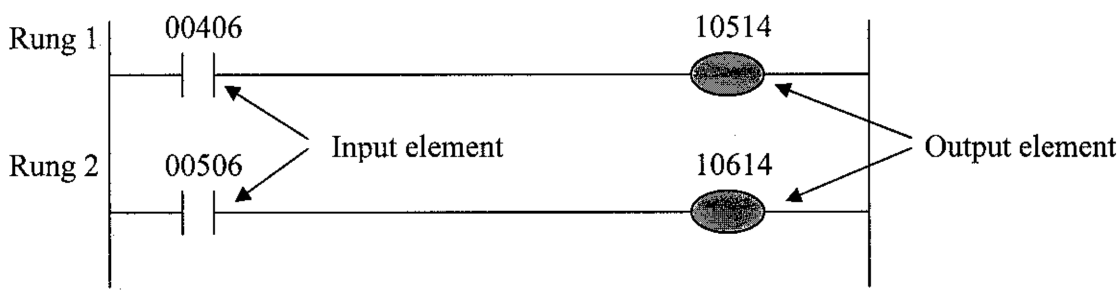


Figure 2.1: An example of ladder diagram

2.2.4 Types of PLC

There are two types of PLC namely the Integrated PLC and Modular PLC. Integrated PLC contains a CPU, power supply, I/O modules components in a single case. Some integrated PLC can be expanded to have additional I/O modules plugged into its expansion sockets.

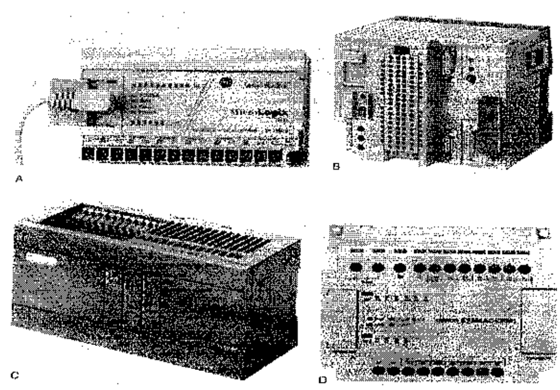


Figure 2.2: Pictures of Integrated type PLCs

A Modular PLC must contain a CPU module, a power supply, and I/O modules in components purchased separately. It can be classified into small, medium or large based on the power in the CPU and the amount of memory of the CPU.

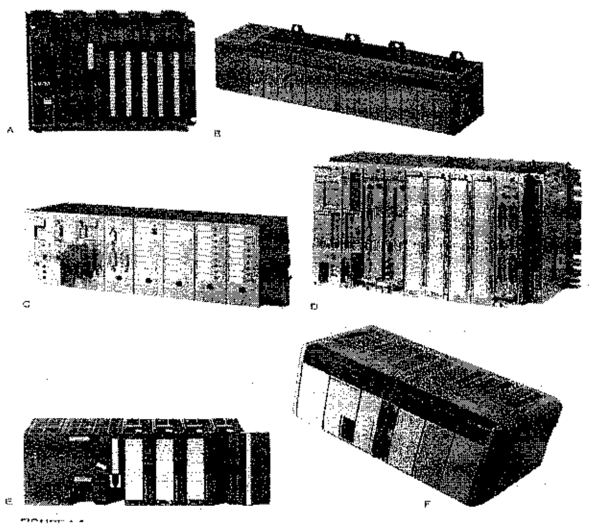


Figure 2.3: Picture of Modular type PLCs

2.3 AUTOMATED GUIDED VEHICLE (AGV)

A typical AGV consist of the frame, batteries, electrical system, drive unit, steering, precision stop unit, on-board controller, communication unit, safety system, and work platform. AGV systems are usually used for distribution of materials in warehouse environments, and movement of material to and from production areas and storage areas in manufacturing facilities. Driverless towing tractors guided by wires embedded into the floor have been available since the early 1950s[3]. Currently, the addition of computer controls, sensors that can monitor remote conditions, real-time feedback, switching capabilities and a whole new family of vehicles have created automatic guided vehicle systems (AGVs) that compete with industrial trucks and conveyors as material handling devices. Most AGVs have only horizontal motion capabilities. The vertical motion is limited. Fork lift trucks usually have more vertical motion capabilities than the AGVs. Power for the automatic guided vehicle is usually a battery. Guidance may be provided in several ways. In electrical or magnetic guidance technique, the wires are embedded in the narrow, shallow slot cut in the floor of the path. The electromagnetic field emitted by the conductor wire is sensed by devices on-board the vehicle which will activate a steering mechanism, causing the vehicle to follow the wire. An *optical* guidance system has a similar steering mechanism, but the path is detected by a photo sensor which picking out the bright path (paint, tape, or fluorescent chemicals) previously. The embedded wire system seems more popular in factories, as it is in a protective groove, whereas the optical tape or painted line can get dirty and/or damaged easily. In offices, where the AGV may be used to pick up and deliver mail, the optical system may be preferred, as it is less expensive to install and less likely to deteriorate in such an environment. The directions that an AGV can travel may be classified as unidirectional (one way), bidirectional (forward or backward along its path), or omni directional (all directions). Omni directional AGVs with five or more on-board microprocessors and a multitude of sensors are sometimes called self-guided vehicles (SGVs). Automatic guided vehicles require smooth and level floors in order to operate properly.[1].

AGVs can be used in two different ways. The first approach is to attach a work piece to the AGV having all manufacturing processes done while the AGV carries the work piece from station to station. In this approach, the AGV is freed only after all the processes for the work piece are completed. The second approach is to use vehicles only for moving the work pieces from one station to another. Vehicle is assigned to the work piece only for a single trip. In the former, number of vehicles required is significantly greater than in a normal AGV system [8].

2.3.1 Basic Vehicle Types

AGV equipment can be categorized as:

1. Driverless tractors
2. Guided pallet trucks

3. Unit load transporters and platform carriers

4. Assembly or tool bed robot transporters

Driverless tractors can be used to tow a series of powerless material handling carts, like a locomotive pulls a train. They can be routed, stopped, coupled, uncoupled, and restarted either manually, by a programmed sequence, or from a central control computer. They are suited to low-volume, heavy or irregularly shaped loads, which have to be moved over longer distances than, would be economical for a conveyor. Guided pallet trucks, like the conventional manually operated trucks they replaced, are available in a wide range of sizes and configurations. In operation, they usually are loaded under the control of a person, who then drives them over the guide wire, programs in their desired destination, then switches them to automatic. At their destination, they can turn off the main guide path onto a siding, automatically drop off their load, and then continue back onto the main guide path. The use of guided pallet trucks reduces the need for conventional manually operated trucks and their operators. Unit load transporters and platform carriers are designed so as to carry their loads directly on their flat or specially contoured surface, rather than on forks or on carts towed behind. They can either carry material or work-in-process from workstation to workstation or they can be workstations themselves and process the material while they transport it. The assembly or tool bed type of AGV is used to carry either work-in process or tooling to machines. It may also be used to carry equipment for an entire process step—a machine plus its tooling—to large, heavy, or immovable products. Robot transporters are used to make robots mobile. A robot can be fitted atop the transporter and carried to the work. Further, the robot can process the work as the transporter carries it along to the next station, thereby combining productive work with material handling and transportation. Most AGVs and SGVs have several safety devices, including flashing in-motion lights, infrared scanners to slow them down when approaching an obstacle, sound warnings and alarms, stop-on-impact bumpers, speed regulators, and the like [2].

2.3.2 Guide-path design

Guide-path design is an important problem in AGV system design and is one of the very first problems to be considered. The guide-path depends greatly on the allocation of shop-floor space, layout of storage zones and the arrangement of handling stations. In most cases, the shop-floor space is fixed and it imposes constraints on the guide-path design problem. The vehicle guide-path is usually represented such that aisle intersections, pick-up and delivery (P/D) locations can be considered as nodes on a graph connected by a set of arcs. The arcs describe the paths that vehicles can follow when moving from node to node. Directed arcs between two nodes indicate the direction of the vehicle flow. Cost can be assigned to each arc representing the distance between the two end points of a segment or the time required by a vehicle to travel along the arc. This representation can be seen as a network-based system that is useful for formulating the guide-path design problem. The guide-path system can be classified by the characteristics indicated in Table 2-1.

Table 2 - 1 Characteristics of guide-path systems

Flow Topology	Number of parallel plane	Flow Direction
Conventional	Single lane	Unidirectional flow
Single-loop	Multiple lane	Bidirectional flow
Tandem		

2.3.2.1 Conventional guide-path system

A conventional guide-path system is a network of guide-paths connecting all workstations in a system that have transportation requirements. This network may contain junctions, intersections, and shortcuts. The conventional guide-path can be unidirectional or bidirectional. In the unidirectional guide-path system vehicles travel in only one direction of the guide-path. In the bidirectional system, both travel directions are possible.

2.3.2.2 Single-loop guide-path system

The main difference between the single-loop and the conventional guide-path system is that in the single-loop layout, vehicles travel in only one loop without any shortcut or alternative routes. The travel mode in the single-loop system is usually unidirectional. Bidirectional traveling is possible but in this case vehicle interference is likely to happen. Vehicles in single-loop systems can be controlled by simple dispatching rules such as first-encountered-first-serve (FEFS), implying that an empty vehicle should pick up the first load it encounters [8].

The throughput of the single-loop system drops slightly compared with the throughput of the conventional system. To obtain the same throughput with the conventional system, the single-loop system needs more vehicles. Obviously, the single-loop system eliminates the inference problem at intersections (this system has no intersection at all).

2.4 DC MOTOR REVERSING

There are a few methods that can be used to switch a DC motor to move forward and reverse. These methods include using change over switch, relays and H-bridge Integrated Circuit (IC). The basic principle of DC motor reversing is by changing the voltage polarity when the motor is operating and therefore changing the direction of the motor. The change over switch and relays methods are actually almost the same. The main difference between these two methods is the change over switch method has to manually implement by using our fingers to turn the switch in order to change the motor's direction. With the relays methods the direction of the motor can be changed by using electricity instead of our fingers. The circuit set-up of these two methods is actually the same. It is all about the wiring connection between the DC motor and the power supply to the change over switch or relays. The wiring connection of the two methods can be referred to *Appendix 1.* About the H-Bridge Integrated Circuit (IC), the set-up is more complicated since a circuit board is needed to build an H-Bridge circuit with some additional electronic components.

CHAPTER 3

METHODOLOGY

The methodology of designing and building the PLC controlled Automatic Guided Vehicle (AGV) will be discussed in this chapter. A flowchart as shown in Figure 3.1 explains the procedure used in the development of the AGV.

3.1 PROCEDURE IDENTIFICATION

Step 1. Literature review (AGV/AGV system and PLC)

Step 2. AGV studies and PLC studies

Step 3. Identification of hardware required

- o Refer to literature review for basic components needed and also control equipment (such as PLC or microcontroller)

Step 4. AGV outlook design

- o Determine the dimension of the AGV
- o Produce the AGV drawing

Step 5. Determine the motor control method

As mentioned before, an external circuit is needed to control the DC motor so that the motor is able to move in forward and reverse. It is a relay switching circuit that is easier to construct compare to an H-Bridge circuit, and needs fewer components.

Step 6. Determine the path design

Step 7. PLC program design

- o Think of the desired operation of the AGV base on the path (such as be able to move forward, backward, or turning, move from initial point to the end point without stop down along the track, how many times the AGV need to stop before reaching the end point.)

- Draw out the flow chart that describe these movements
- Consider the input and output devices needed and assign the address for each of the devices
- Draw the ladder diagram base on the flow chart and the input output devices
- Refer to Results and Discussion

Step 8. Test and run the program with PLC training kit

- Check the sequence of the operation
- Modify the program if necessary

Step 9. Prototype and path building

- Include all the necessary modify on the hardware, motor control circuit

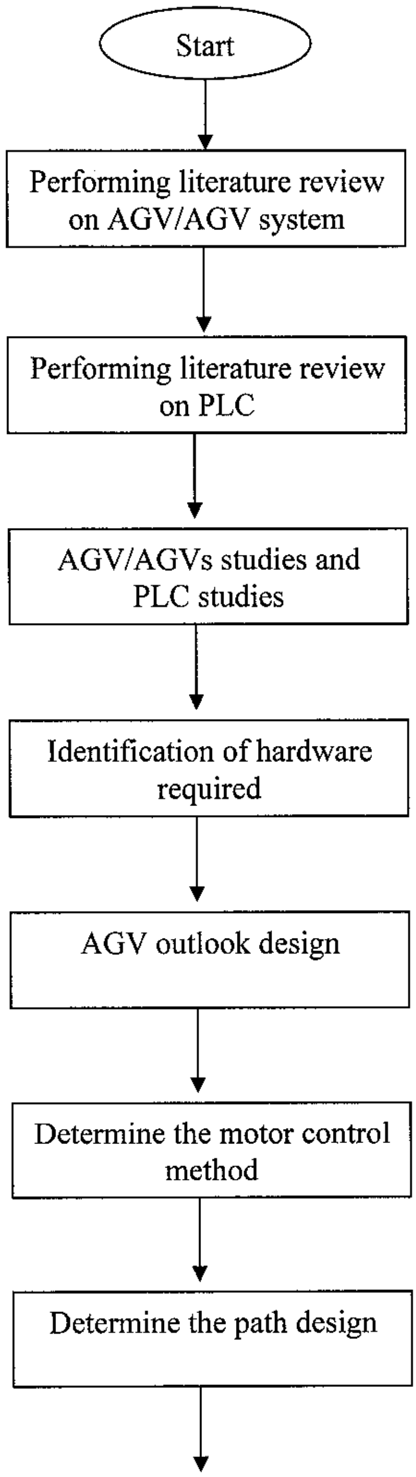
Step 10. Interface the input and output devices circuitry with PLC

- Wiring connection of I/O devices with PLC

Step 11. Test and run the AGV

Step 12. Modification (if necessary)

3.2 PROCEDURE FLOWCHART



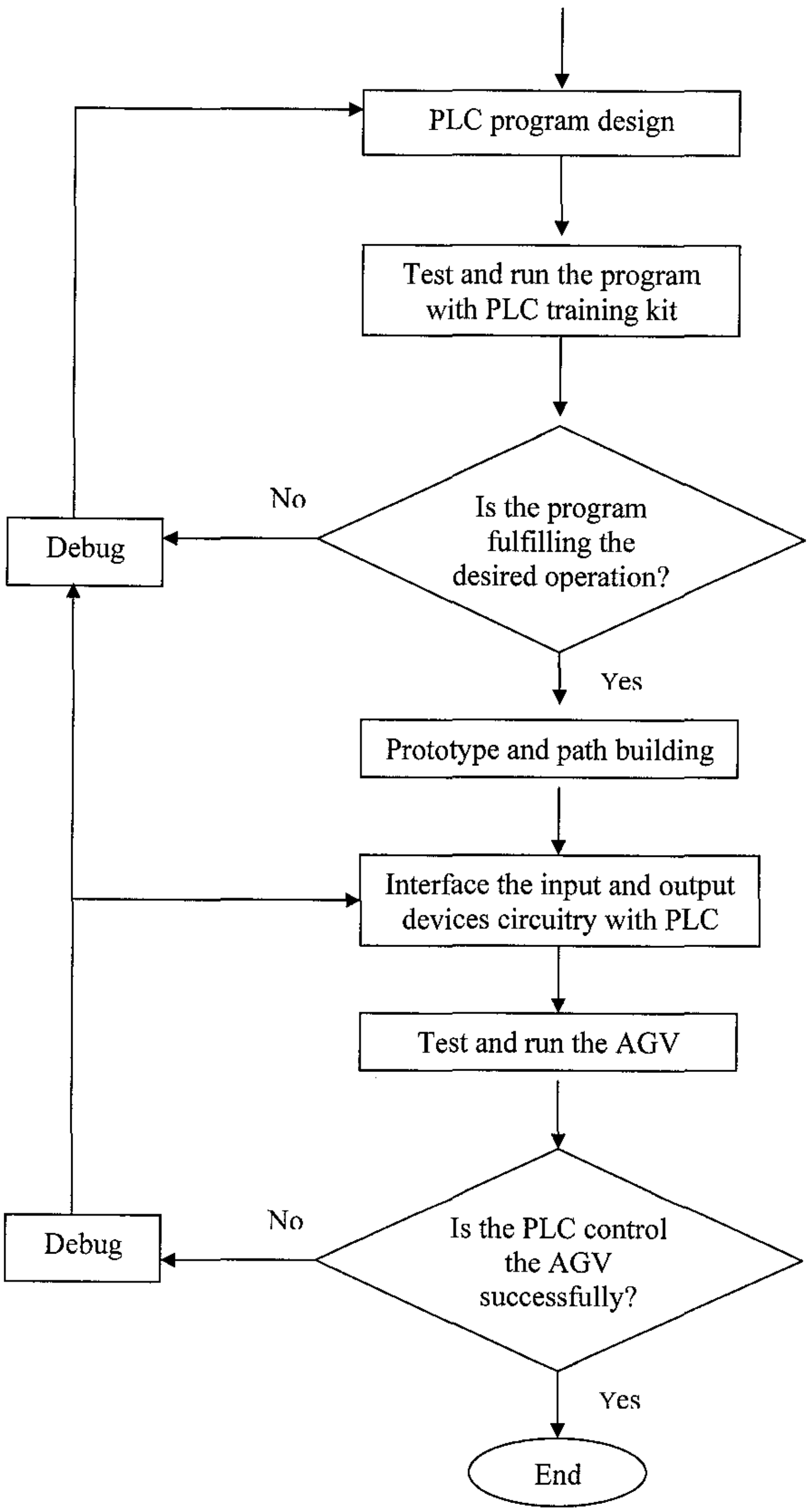


Figure 3.1: Flowchart describing the procedures for designing and building an AGV

3.3 TOOLS/COMPONENTS

The tools and components required to build an AGV are as follow

i. Programmable Logic Controller (PLC) – OMRON PLC CPM 2A
ii. Programmable Logic Controller (PLC) – OMRON PLC Training Kit
iii. DC power window motors (x2)
iv. Metal sensors (x3)
v. Proximity sensors (x2)
vi. Plastic wheels (a pair)
vii. Ball bearing castor
viii. Perspex
ix. 24 V relays (x6)
x. Rechargeable battery (6V 4Ah)
xi. Steel
xii. Screws and nuts
xiii. DC power supply
xiv. Ladder logic programmer – CX Programmer Version 3.0
xv. L-shape aluminums
xvi. Buzzer
xvii. Wires
xviii. Araldite

3.4 METHODOLOGY OF PROTOTYPE CONSTRUCTION

3.4.1 Chassis Construction

The chassis of the AGV is made from Perspex. It is cut into some pre-determined dimensions base on the design. The dimension of the Perspex is 37cm x 22.8cm and the thickness is 3mm. Since the AGV will carry quite a heavy load, two sheets of Perspex are used as the chassis to support the loads. The Perspex is cut to the shape as shown below:

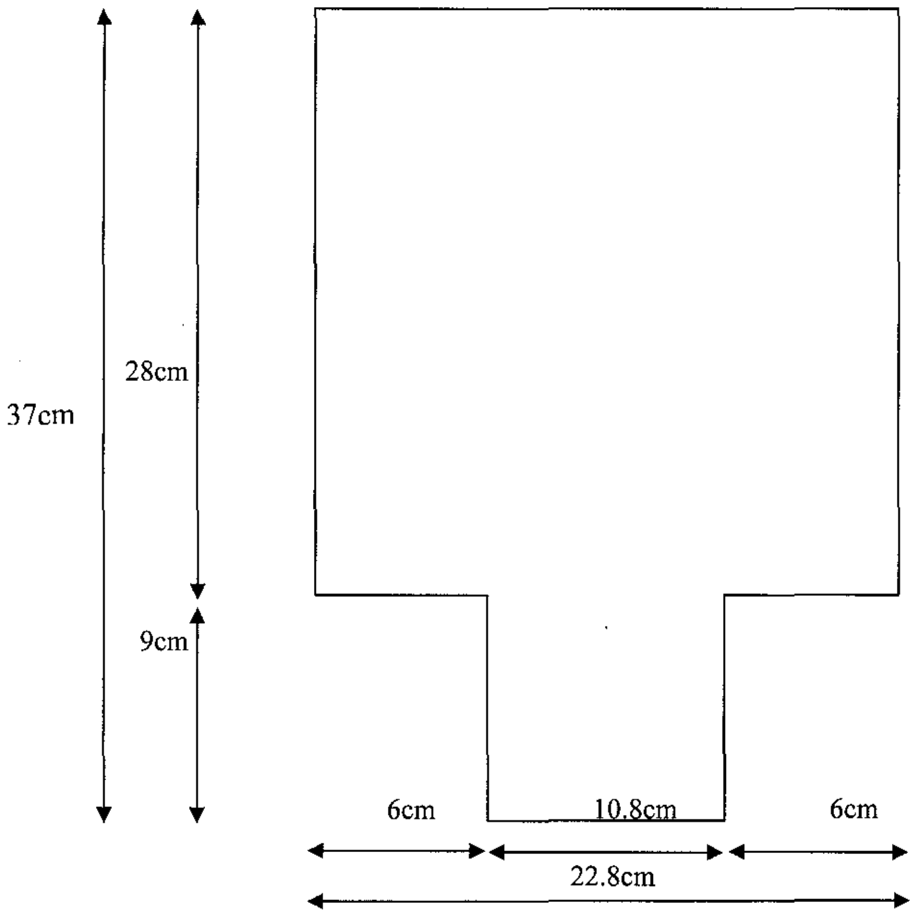
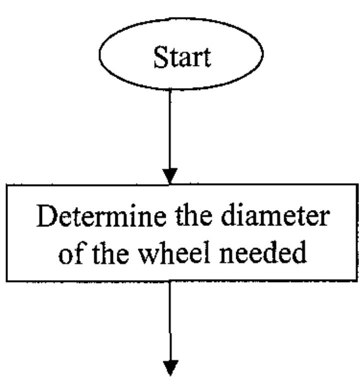


Figure 3.2: The dimension of the chassis (Perspex)

3.4.2 Rear wheels construction



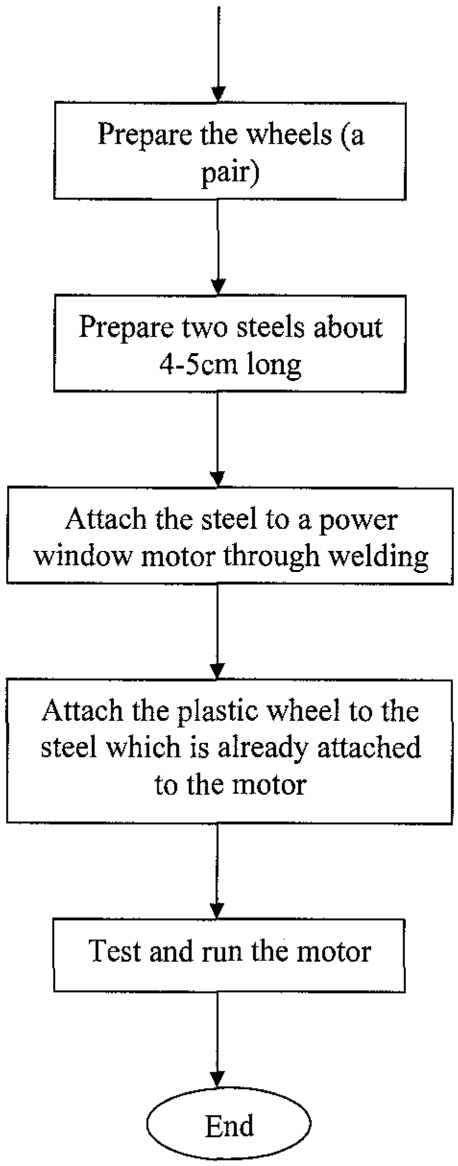


Figure 3.3: The flow chart of rear wheels construction

3.4.3 Relay Switching Circuit Construction

The basic idea for the AGV to be able to turn left or right or even rotate is by making one of the rear wheel moves forward while the another wheel moves reverse. In order to achieve that, a switching circuit is needed to switch or change the current flow of the battery through the motors when the relay is energized. There are three relays needed to construct the circuit, they are the main relay, the left relay and the right relay. The main relay is used to switch on both the motors to make them move forward when the coil is energized. While the other two relays are used to switch the flow of the current through the motors respectively. That's mean the motors will move forward when the main relay is energized by the start button. When there is a signal from the PLC to the other two relays' coil, the motors will move backward (reverse).

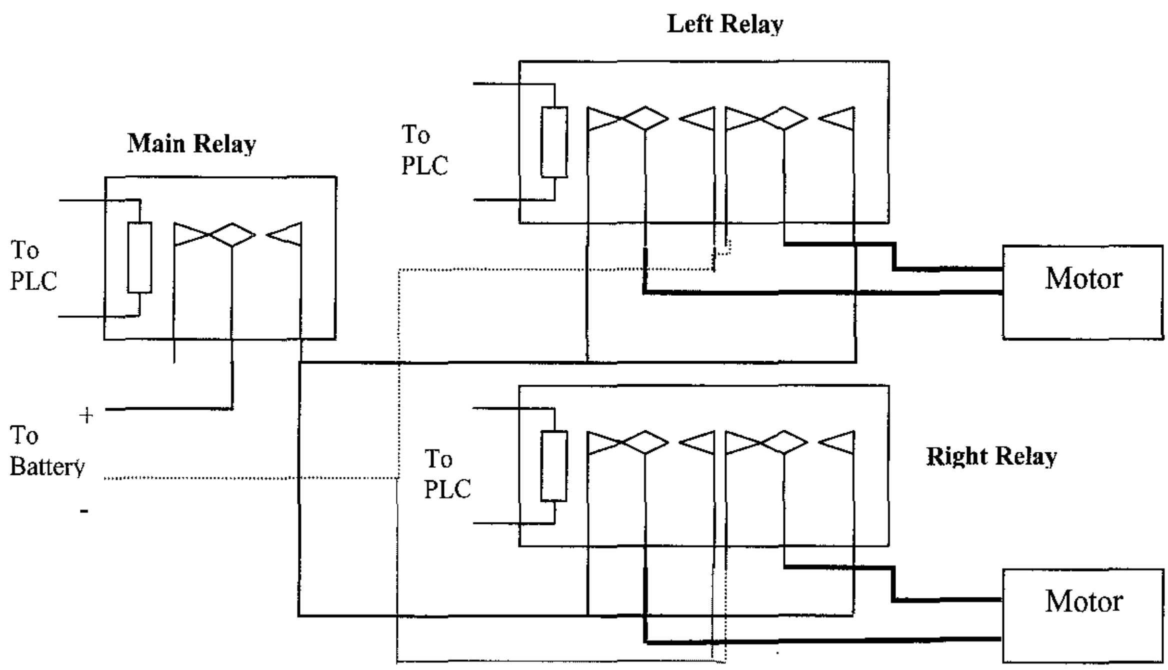


Figure 3.4: The diagram of the relay switching circuit

Base on the layout shown in Figure 3.3, the circuit is constructed on the PCB board with proper soldering and wiring connection between the terminals of the relays with the motors and battery.

3.5 PLC Interfacing

3.5.1 PLC Input Interfacing

For this AGV prototype, the input components are the metal sensors and the start push button. The input interfacing does not have special connecting path. It is just interface the output of the input components by connecting the output signal to the PLC input channels. Then the common terminal of the input components (metal sensors) is connected to the common ground of the PLC input module. Generally this can be graphically shown as Figure 3.5.

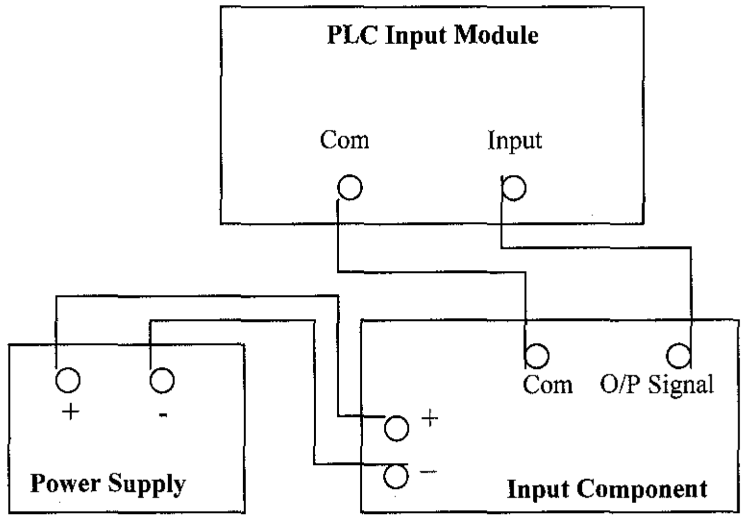


Figure 3.5: The diagram of PLC input interfacing

The interfacing of the metal sensor is a slightly different since the sensor has 3 wires to be connected. These wires are brown wire (+24V), black wire (input for PLC) and blue wire (ground). The interfacing is shown in Figure 3.6.

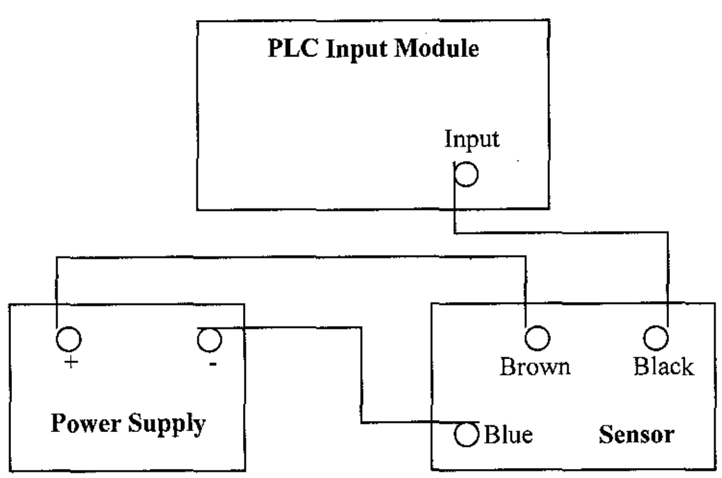


Figure 3.6: The diagram of interfacing of PLC and sensor

3.5.2 PLC Output Interfacing

The output interfacing is different from the input interfacing. The power supply is needed to supply to the output components/loads such as DC motor. Here, the PLC output module is connected to the positive terminal of the load. The ground of the power supply is grounded to the PLC output common ground. This can be graphically shown as Figure 3.7.

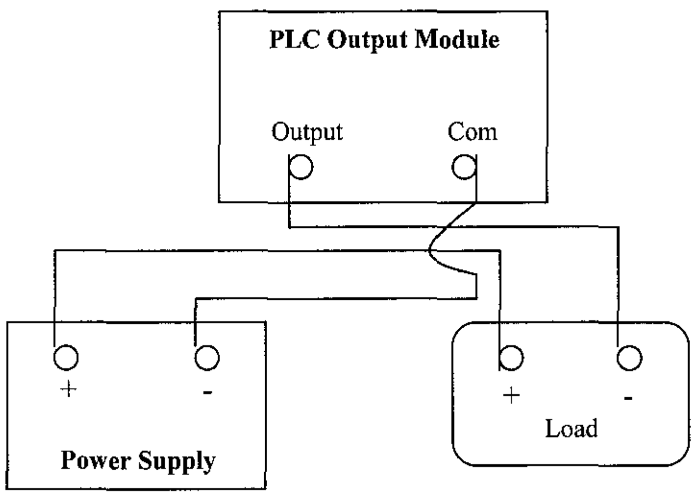


Figure 3.7: The diagram of PLC output interfacing

In this project, relay is used in the interfacing because it is needed to switch the flow direction of the current in the circuit in order to make the wheels move reverse. Therefore, the wire connection will be slightly different but the concept still the same that is to make a loop for current flow. The interfacing is like figure 3.7. Always remember that the function of the relay in this circuit is to act as a switch. The 24V relay has to be energized by 24V DC and the power supply can be obtained from the PLC which has the feature. An external DC power supply is needed to supply the motor.

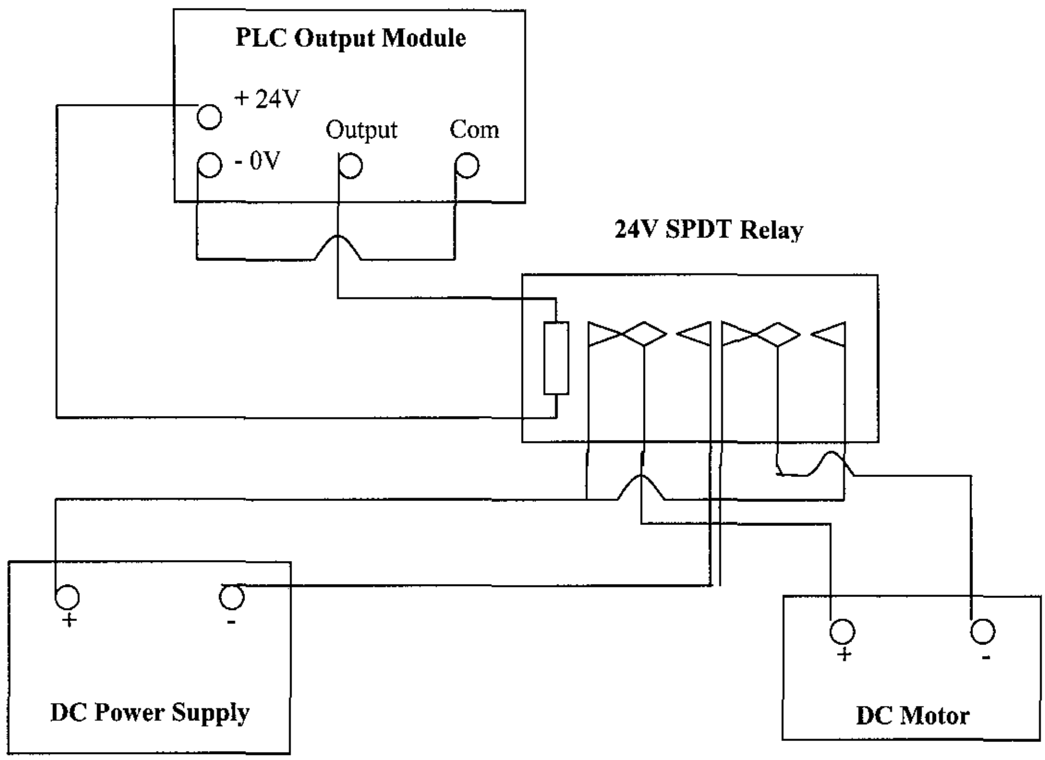


Figure 3.8: The diagram of PLC output interfacing with relay

3.6 Installation of Ladder Diagram

The software used in the design of the ladder logic diagram is CX-Programmer 3.0. The software is installed into the computer and the ladder diagram is developed base on the flow chart created. Once the simulation with the PLC training kit is completed the ladder diagram is loaded into the PLC CPM 2A with cable RS 232 connected between the PLC and the computer.

3.7 Testing & Modification

Once all the components have been installed and the input and output components interfacing have been made, the AGV prototype is ready for testing. But, before that make sure the wires connection are properly installed and the AC source cables are connected correctly to the terminal of the PLC to prevent any short circuit which may cause damages to the PLC and the input and output components. When that has been done, it is now to place the AGV prototype on the designed path. Press the start button and observe the performance of the AGV. Modify the hardware or program as necessary if the AGV prototype movement is not operateing as expected. The testing starts with a straight path where the AGV prototype will move on the metal track and then turns 180° at the end of the track. Then it will turn 360° and move on the track again. The metal sheets have to be of smaller width and the sensors' positions are adjusted to give better performance. The trial-and error method to achieve the desired performance is applied here.

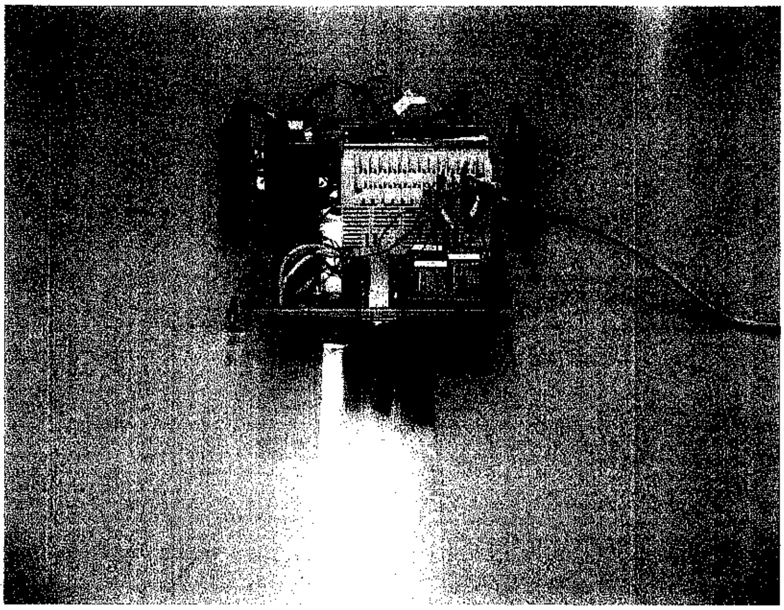


Figure 3.9: The AGV prototype is tested on the metal sheet track

CHAPTER 4

RESULTS AND DISCUSSION

4.1 ANALYSIS ON AUTOMATIC GUIDED VEHICLE SYSTEM (AGVS)

The designed development of Automatic Guided Vehicle system (AGVs) had been explained. Usually in a manufacturing system more than one AGV is needed to perform the tasks. It depends to the production rate and the path design. Therefore, a proper design of the path is important in order to produce an effective AGV system since the path design depends to the layout of the production floor. To program the PLC ladder diagram of the AGV system, the understanding on the operation of the AGV system is very important.

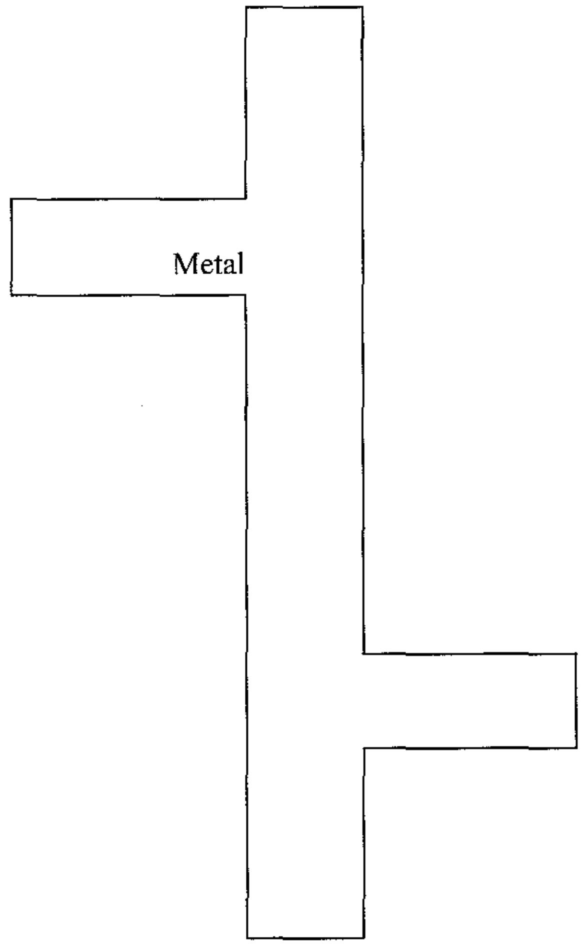


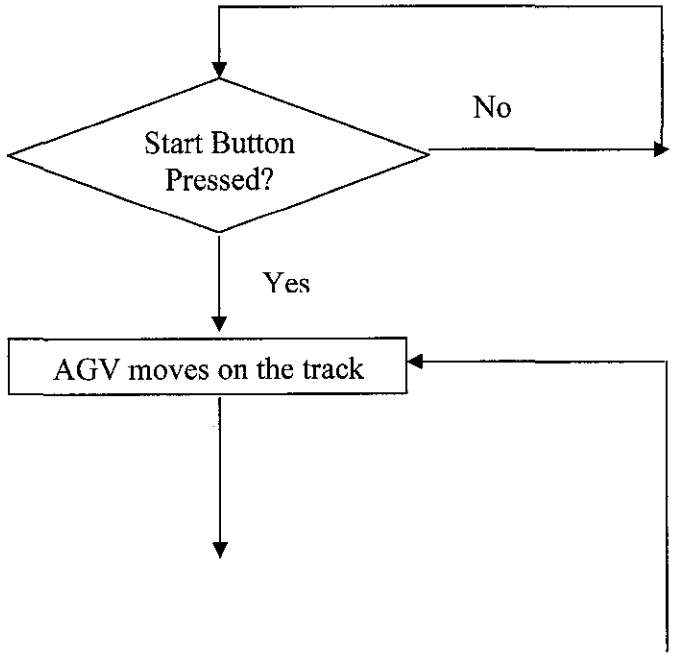
Figure 4.1: The path design of the AGV

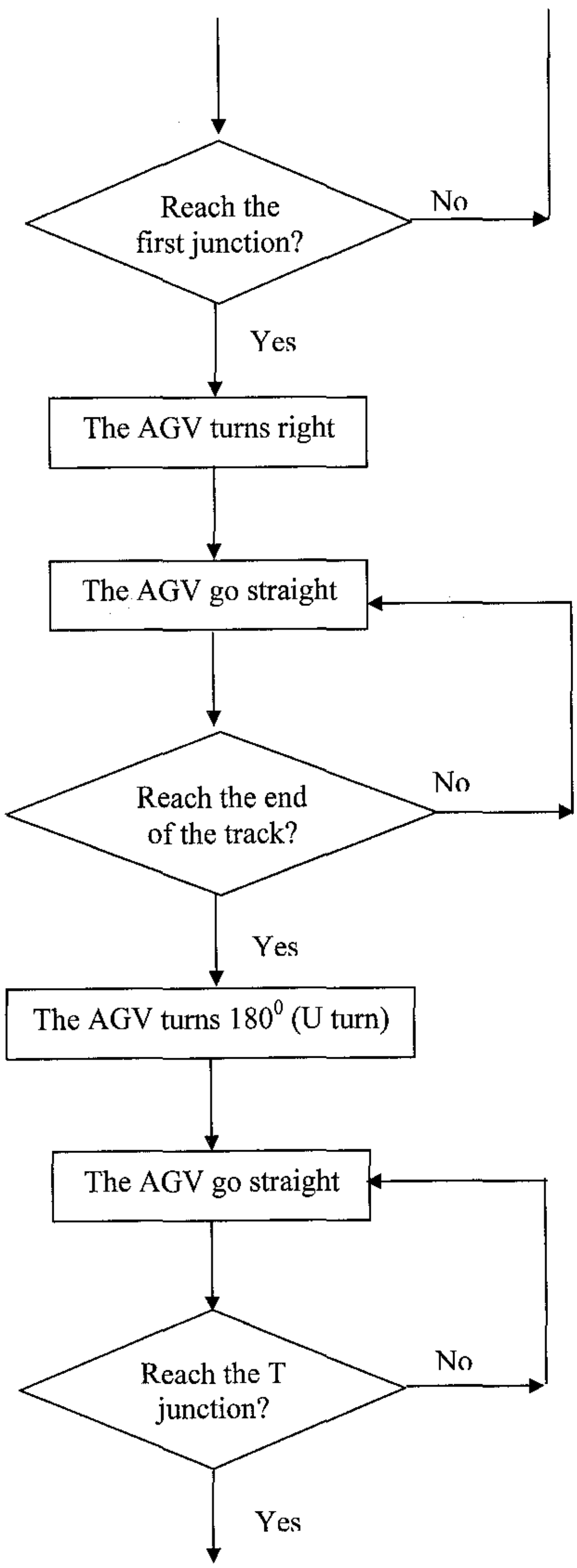
The ladder diagram has been designed based on the operation of the AGV. The operation of the AGV is summarized as flow chart shown in Figure 4.2.

Table 4-1 summaries the status condition of the metal sensors in order to perform certain actions.

Table 4-1 Sensor status and respective actions

Left Sensor	Middle Sensor	Right Sensor	Action
0	0	0	Right
0	0	1	Right
0	1	0	Straight
0	1	1	Right
1	0	0	Right
1	0	1	Don't care
1	1	0	Don't care
1	1	1	Right




Reach the first junction?
No
Yes
The AGV turns right
The AGV go straight
Reach the end of the track?
No
Yes
The AGV turns 180^0 (U turn)
The AGV go straight
Reach the T junction?
No
Yes

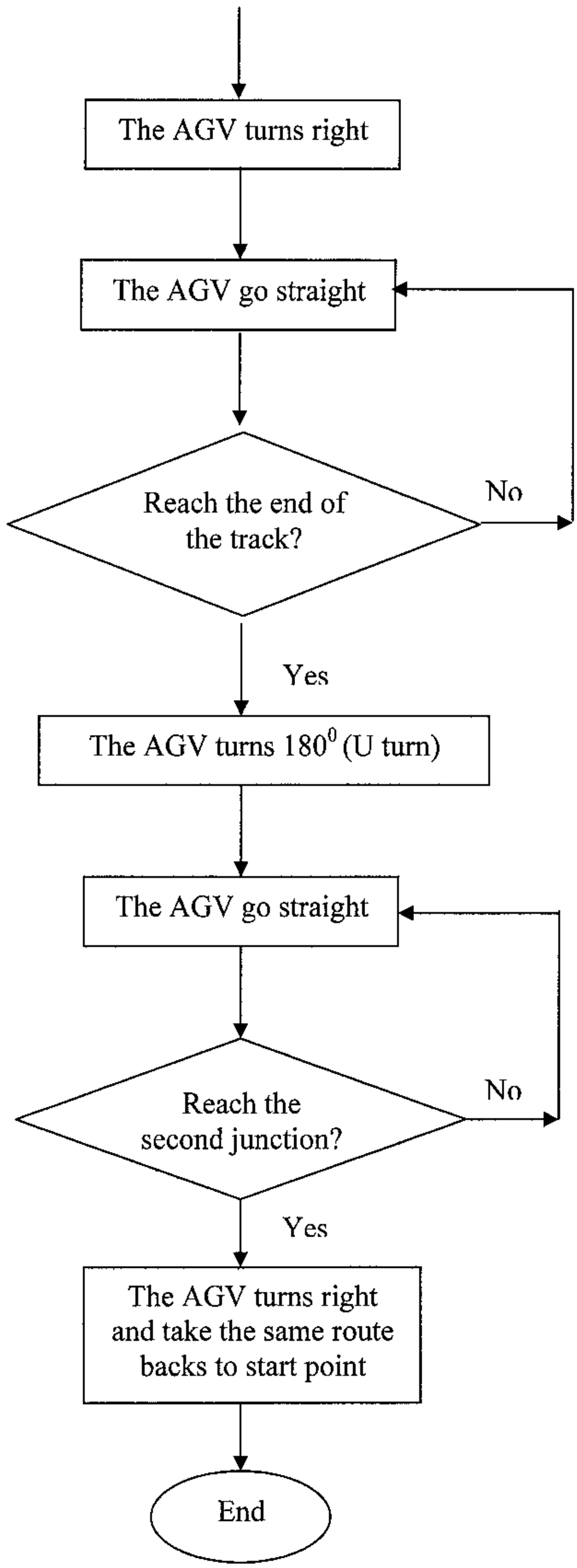


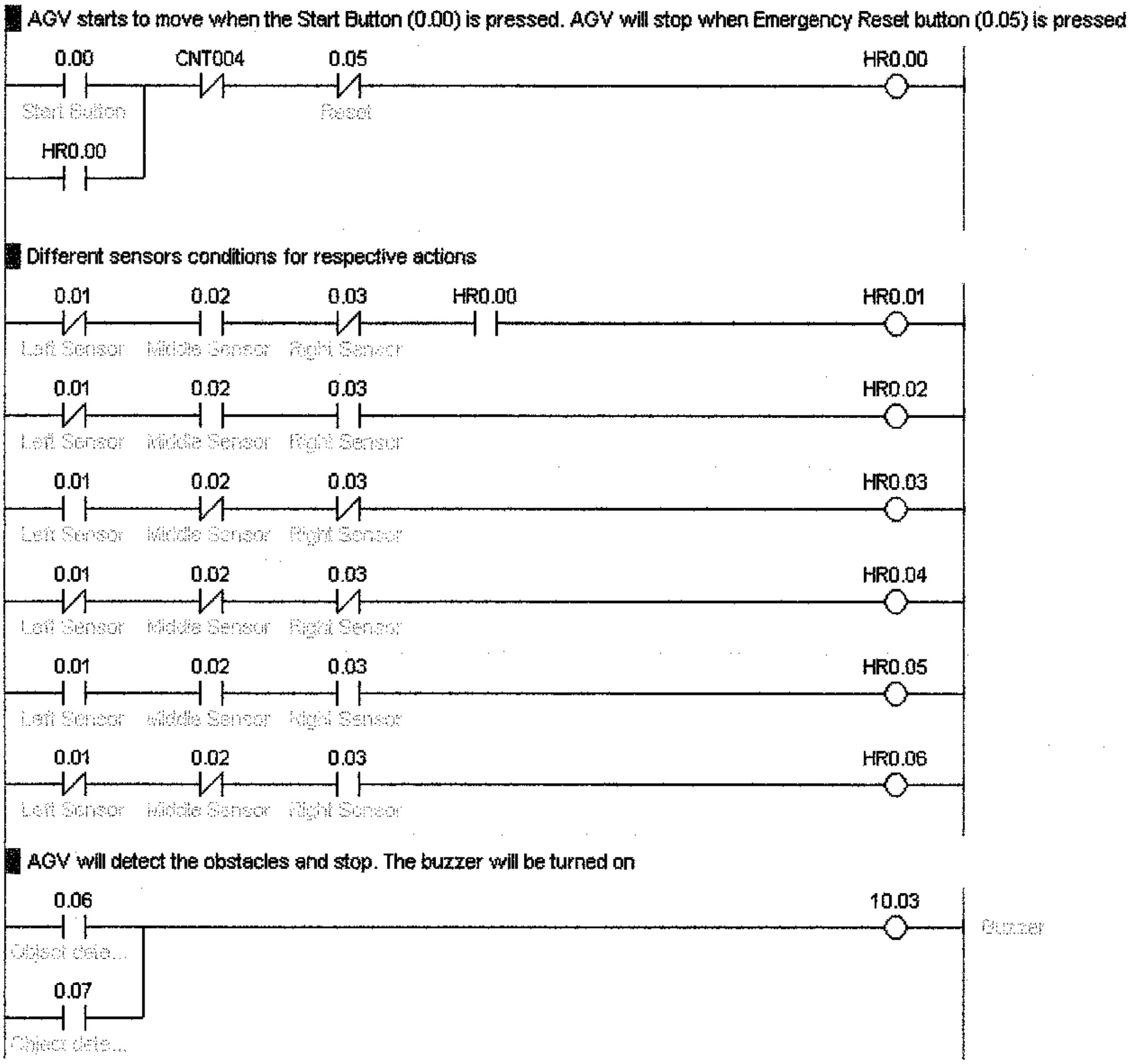
Figure 4.2: The AGV's operation flow chart

4.2 LADDER DIAGRAM

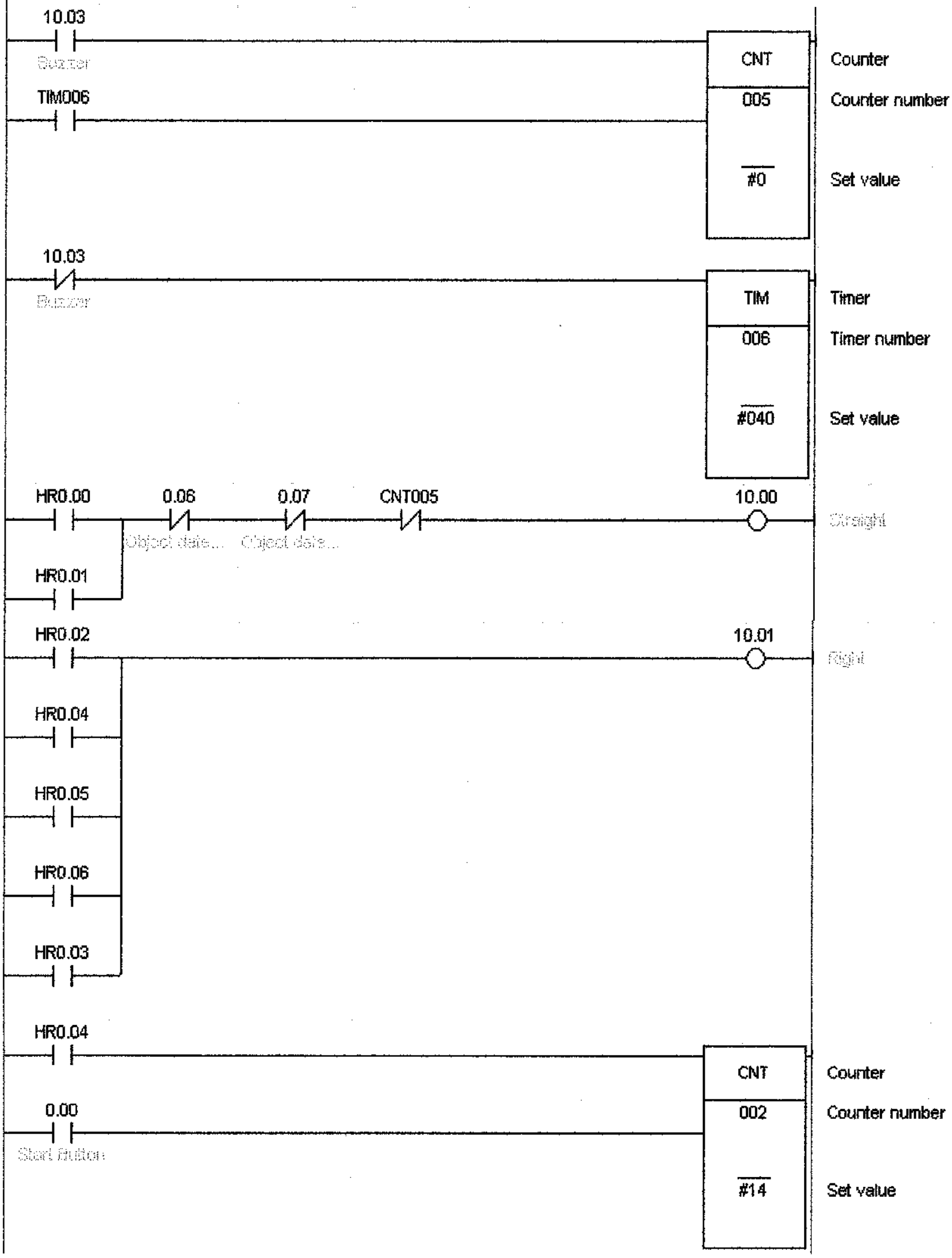
Table 4-2: Assignment of Inputs and Outputs

Input	Description	Output	Description
00000	Start Push Button	1000	Go Straight
00001	Left Sensor	1001	Turn Right
00002	Right Sensor	1002	Turn Left
00003	Middle Sensor		
00005	Reset Button		

Figure 4.3 shows the ladder diagram for the operation of the AGV.



AGV will delay for 4s after the obstacle has been removed



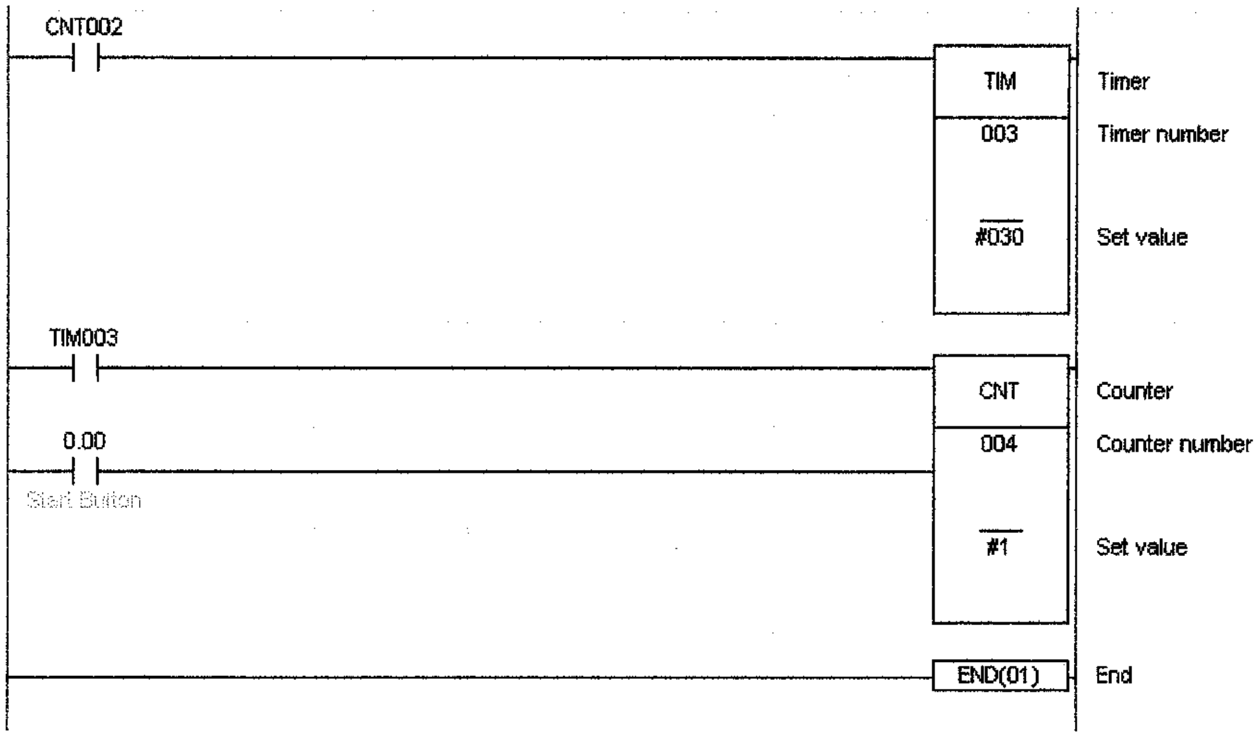


Figure 4.3: The ladder diagram for the AGV

4.3 PROTOTYPE CONSTRUCTION

4.3.1 Chassis

The 3mm thick Perspex is cut into the designed shape as required in the design. Figure 4.4 shows the shape of the chassis.

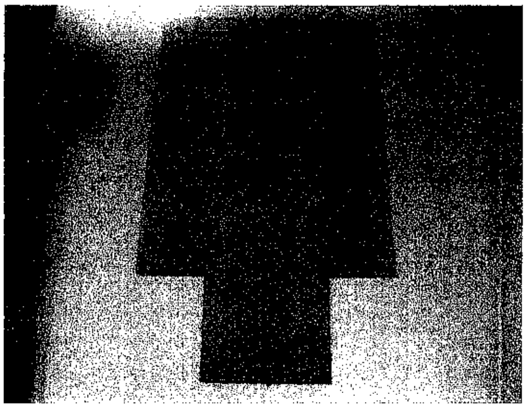


Figure 4.4: The shape of chassis (Perspex)

4.3.2 Rear Wheels

The methodology explained at chapter 3 is referred. The rear wheels (left and right) of the AGV are constructed using plastic wheels. They are attached to the steel by using Araldite. The steel is attached to the extended shaft from the power window motor through welding process.

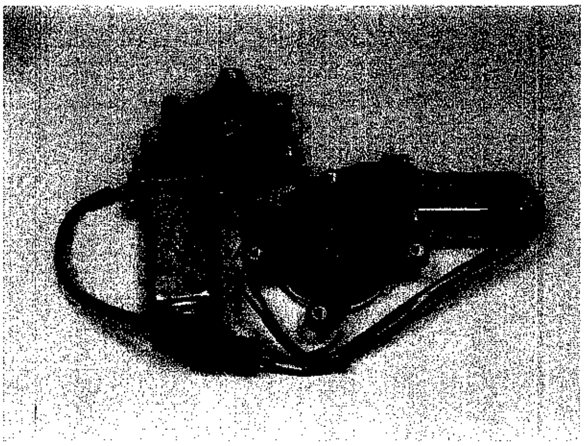


Figure 4.5: Power window motors

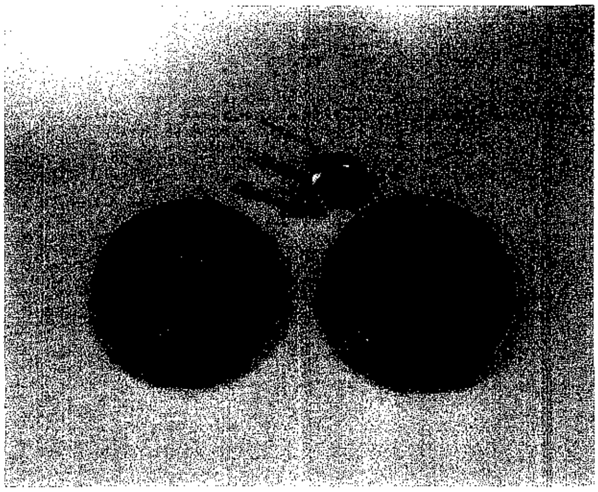


Figure 4.6: Front wheel and rear wheels

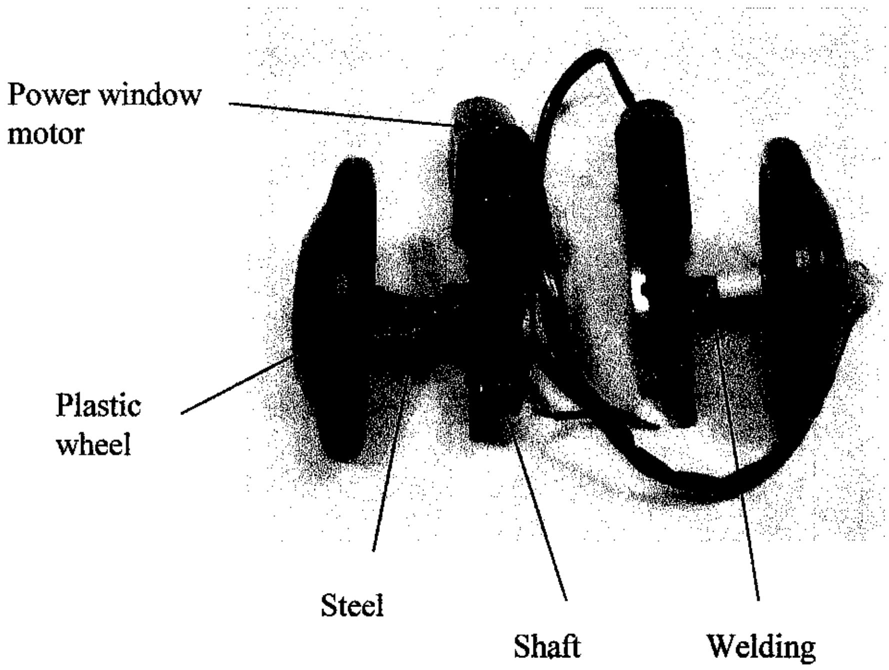


Figure 4.7: Rear wheels attached to the motors (left and right)

4.3.3 Relay Switching Circuit

Base on the layout shown in Figure 3.3, the relay switching circuit is constructed. Each relay's terminal is soldered and connected with wires which will be connected to other devices like PLC, motor and battery.

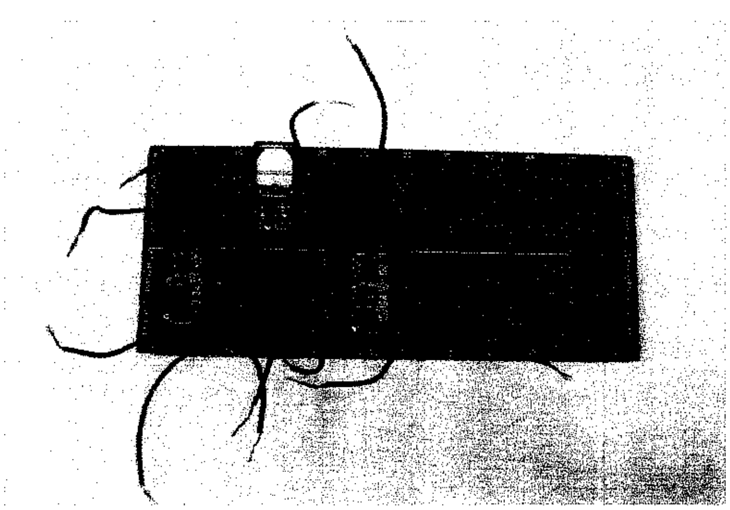


Figure 4.8: The relay switching circuit

4.4 PLC INPUT INTERFACING

The input components of the AGV are the metal sensors (guidance for AGV), proximity sensors (obstacles detection), the start push button and the emergency reset button. The metal sensors are not interfaced directly with the PLC. A relay circuit is built where the metal sensors are connected to the relay circuit to protect the sensors and the relays are connected to the PLC input module. The proximity sensors are directly connected to the PLC since they are industrial sensors and there is no problem directly connects them to the PLC. The start push button and emergency reset button are directly connected to the PLC since they are only switches that provide a signal to the PLC when necessary. The wiring connections of the push buttons are same. One of the push button terminals is connected to power supply (+24 V DC) and the other terminal is connected to the input module of the PLC.

Figure 4.9: PLC input interfacing

4.5 PLC OUTPUT INTERFACING

The output components of the AGV are the two DC motors which are attached to the left and right wheels. The motors were not interfaced directly with the PLC because they can move only in one direction if they are connected as mentioned. Therefore, relays are used in the interfacing to provide the reverse direction when required in the program. When there is a signal sent out from the output module into the main relay's coil, the motors will move forward. If a signal sent to the left (or the right) relay's coil, the common contact of the relay will be switched and the left motor (or the right motor) will move reverse and the AGV will turn left (or turn right). (Refers to Figure 3.4 and 3.8)

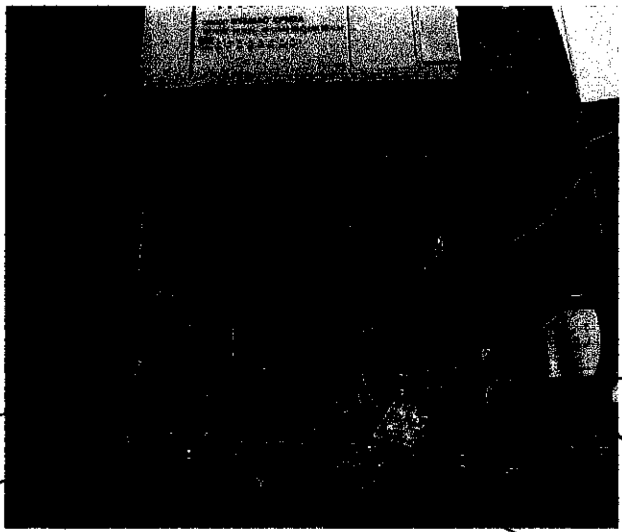


Figure 4.10: PLC output interfacing with relay

4.6 TESTING & MODIFICATION

The AGV prototype was tested on a straight path. It started well where it moves along the path. However, after some while it started to shift to the left because of the speed difference between the motors. The AGV prototype tends to move out of the track but the metal sensors are able to detect the condition as set in the program and make it to move to other way which will keep it on the track. To get a better performance, the metal sheet is metal sheet is cut to smaller width and the positions of the metal sensors are adjusted so that the prototype is able to move smoothly.

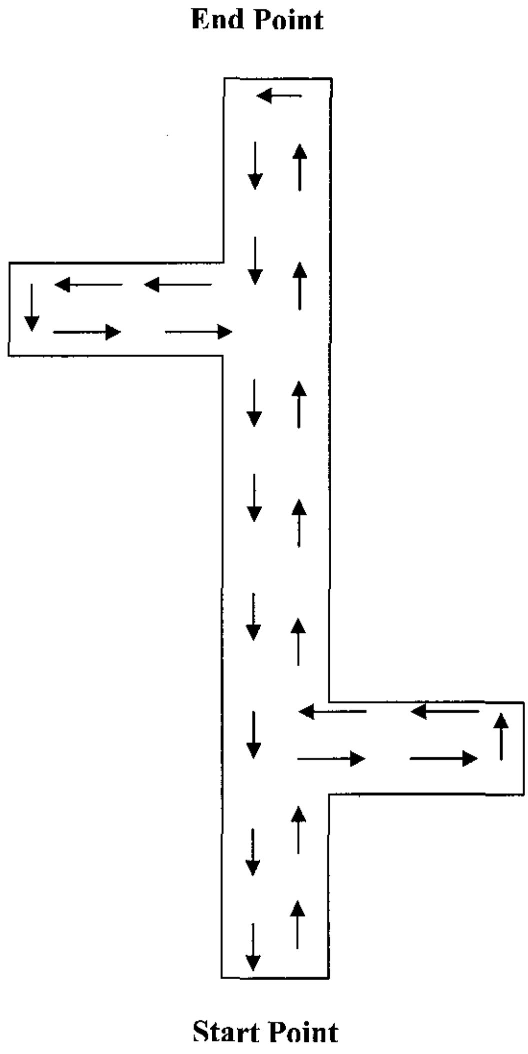


Figure 4.11: AGV's operation route

When the AGV arrives at the end of the path, it will turn 180^0 and stay on the same track and take the route to go back to the starting point. (Refer Figure 4.11) That is the desired operation but the AGV in many occasions may not be able to do so and turn around at the end point because the sensors are not able to detect the metal sheet due to slow response of the sensors. Therefore, the metal sheet cannot be too small in width to provide the sensors have time to response. The other consideration is that the sensors are placed as close as possible to the floor so that the signal can be sent back faster since the distance between the sensors and the metal sheet is short. Besides that, the number of sensors used can be increased to have more conditions that can be set in the program to control the prototype. The above tasks have been repeated several times until the AGV prototype's performance is as expected and intended.

4.7 SAFETY FEATURES

In the AGV operation, there are two safety features being added to the AGV prototype. These safety features may enhance not only the safety of the plant but also the hardware equipment.

4.7.1 Emergency Reset

The first feature is the centralized emergency reset. In this feature, a push button is installed on the prototype beside the start push button. This emergency reset button is linked to the holding circuit of Holding Relay (HR) of the PLC. The ladder diagram of the emergency reset is as figure below.

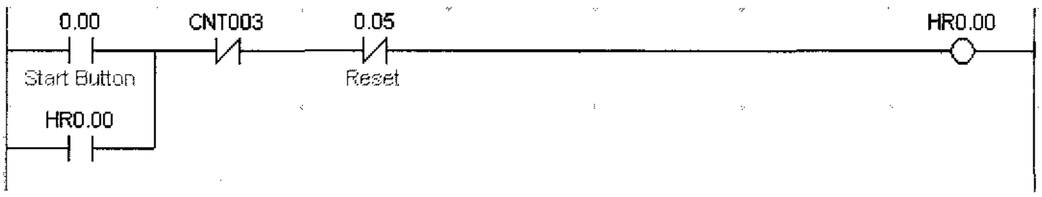


Figure 4.12: Ladder diagram for the emergency reset

From Figure 4.12, the reset button is set as a normally closed logic. When the button is pressed, the holding circuit is cut off. Therefore, the output (HR0.00) which is the input for the AGV prototype to start to move is disabled. Please refer section 4.2 for the ladder diagram of the AGV's operation. The power supply to the motors is cut off and the AGV prototype will be stopped.

4.7.2 Obstacles detection

The second safety feature of the AGV prototype is the obstacles detection. In this case, two proximity sensors are installed on the prototype. The sensors will function when there is an obstacle in front of the prototype. The sensors will detect the obstacle and a signal is sent to input module of the PLC. Based on the ladder diagram, a buzzer will produce a sound when either one of the sensors is detecting an object. At the same time, it will be cut off the power supply to the motor (10.00) and the prototype will stop. It will delay for 4 seconds and then continues moving after the obstacle has been removed. The ladder diagram for this feature is as illustrate in Figure 4.13.

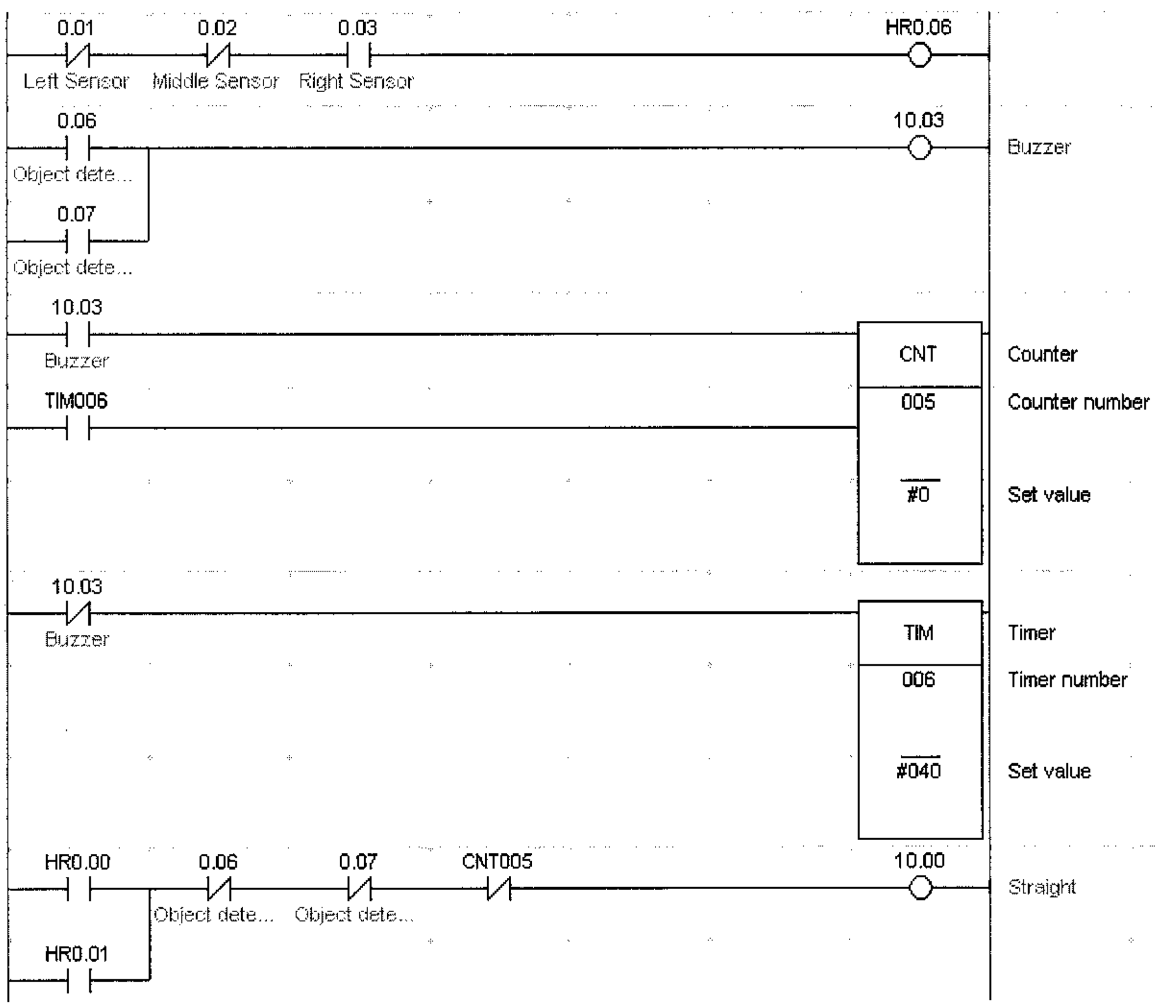


Figure 4.13: Ladder diagram for the obstacles detection

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

The PLC Controlled Automated Guided Vehicle (AGV) is a project that provides student a good learning and practical experience in working with hardware and software where the student has the opportunities to apply the knowledge that learnt. The PLC controlled Automated Guided Vehicle (AGV) prototype can be improved to provide better performances. Students had obtained some hand on experiences in the wiring and designing the PLC controlling and interfacing circuitries, as well as getting familiar with the ladder logic programming, relay switching circuitry, motors and sensors.

PLC, rechargeable battery, motors and sensors are the main components to build the AGV prototype. PLC used is the model CPM 2A, a small size PLC (13cm x 9cm x 9cm). The PLC is the controller that controls the operation of the AGV prototype base on the program designed. The motors used are the power window DC motors. The motors have high torque and need high current to operate so that it can support heavy load. A 6V rechargeable battery is applied to provide power to the motors. Metal sensors are used to guide the AGV prototype during its operation. The input devices are the metal sensors while the motors are the output device. PLC is operated by the instruction input from the input devices – metal sensors used to detect the operation condition of the motors. The transmission of output signal base on input signals is determined by the contents of the program to the PLC. In order to make the AGV prototype be able to turn left or right, a relay switching circuit is built to control the current flow direction to change the direction of the wheels. The spinning direction of the wheels must be opposite to each other so that the AGV prototype is able to turn.

The construction of the prototype starts from chassis design and implementation, attachment of wheels with motors, relay switching circuits, assembly, and wiring interfacing between input/output devices with PLC. The operation of the AGV is controlled by the PLC through the designed Ladder Diagram and it moves along the metal path. The ladder diagram designed is simulated with PLC CPM 1A training kit before transfer to PLC CPM 2A. Changes of the ladder diagram or modification of the hardware and path were done accordingly to obtain optimum performance. The prototype has been tested for many times to make sure it works well.

5.2 RECOMMENDATIONS

This section presents some recommendations for future improvements of the PLC controlled Automated Guided Vehicle (AGV).

- For the hardware part, the metal sensors can be replaced with optical sensor because of the greater sensitivity the optical sensor can provide. The optical sensor has higher accuracy and sensing distance.

- The front wheel of the AGV prototype can be controlled by a DC servo motor with encoder which will act as a steering for the prototype. It is able to control the prototype better especially when come to the turning part where the angle of turning can be set. At the same time the relay switching circuit built for changing the direction of the rear wheels can be eliminated.

- The motors used should have almost the same speed when power supply is applied so that the prototype can move straight without tend to shift to left or right. So get a pair of motors which are of the same type and specifications.

CHAPTER 6

REFERENCES

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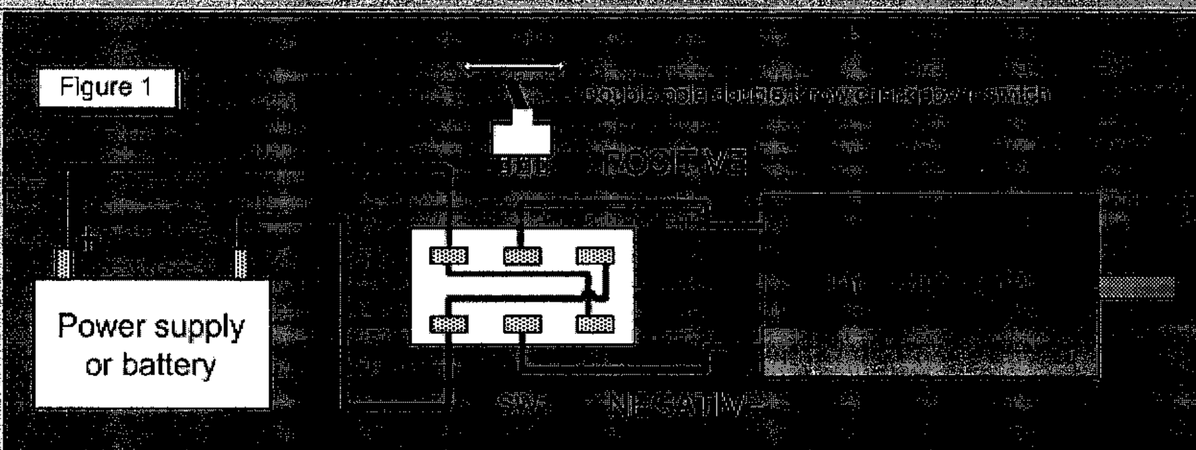
APPENDIX 1

Methods of DC Motor Reversing

The Changeover Switch

DC motor reversing can be achieved with the use of a simple changeover switch, and when wired as shown in figure 1, does exactly what it says, it changes over the polarity of the voltage when operated therefore changing the direction of the motor. As DC motors can draw lots more current under loaded conditions, it's a good idea to ensure the DC Amps rating of your switch can handle the required *loaded* current of the motor. Figure 1 shows a typical hook-up with the changeover switch shown as SW1, the switch has six connections and when wired as shown the motor will change direction when the switch is operated. This simple solution may be enhanced by using a 3 position double pole changeover switch. This will then give FORWARD, REVERSE and OFF control without any additional wiring. When DC Amperage exceeds 8 to 10 Amps it is often no longer practical to use a simple switch - this is when the use of a clever device called a relay comes to the rescue !



Relays

Relays are electro mechanical devices and basically consist of an electro magnet and a number of contact sets. In fact the circuit of the relay shown in figure 2 is exactly the same set-up as the changeover switch shown above - the only difference is that we are going to use electricity to change the direction of our motor instead of our finger ! The prime function of a relay is the switching of large currents from small currents. In fact currents of many hundreds or even thousands of Amps (depending on type, they can get quite large !) can be switched by just a couple of hundred milli Amps. Many configurations of relay are available, but for our purposes, figure 2 shows a 2 changeover device. Our 2 changeover relay (bounded by the blue dotted line) shows the coil marked CL1 and the two changeover contact sets A & B. Each set has three connections, the common being A2 & B2. The normally open contacts being A1 & B1, and the normally closed contacts A3 & B3. The 'normally' word in the context of relays always refers to the de-energised (no power to the coil) state. The circuit shows a battery B1, to supply power to operate the relay and a simple pushbutton switch SW1. SW1 is shown in the OPEN (not pressed) position so no Volts are connected to the relay coil. In this condition 2 separate circuits via contact sets A2 / A3 and B2 / B3 are electrically connected. When voltage is applied to the relay coil CL1 the magnet energises and closes the contact set changing the connected circuits to A1 / A2 & B1 / B2.

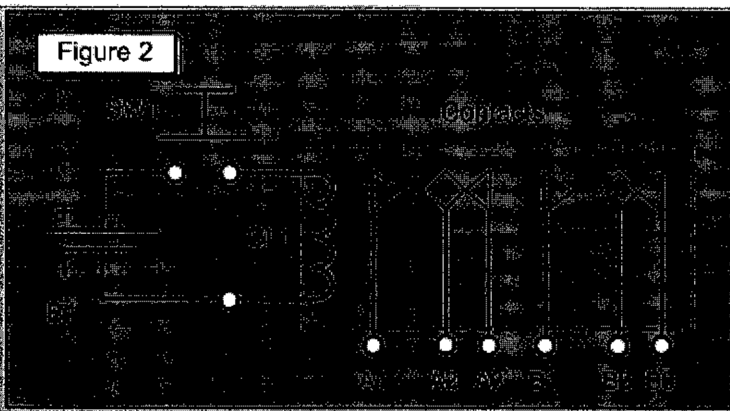


Figure 2

Now you understand the basic operation of a relay, take a look below at Figure 3. This shows the same relay but with the pushbutton in the CLOSED (button pressed) position. This supplies voltage to the coil, energising the magnet and moving the contacts to the energised state. The circuit also shows the wiring needed to make our motor change direction whenever the button is pressed. We have deliberately shown the DC supply to the motor as a separate connection. This highlights another advantage of relay use - isolation - this means that the coil voltage does not have to be the same as the voltage being switched via the contacts. For example we could use a relay with a DC coil voltage rating of 12 Volts (easy to drive from solid state devices such as PIC's or transistors) and use the contacts to switch a motor with a 48 Volt requirement. The two Voltages being completely isolated from each other.

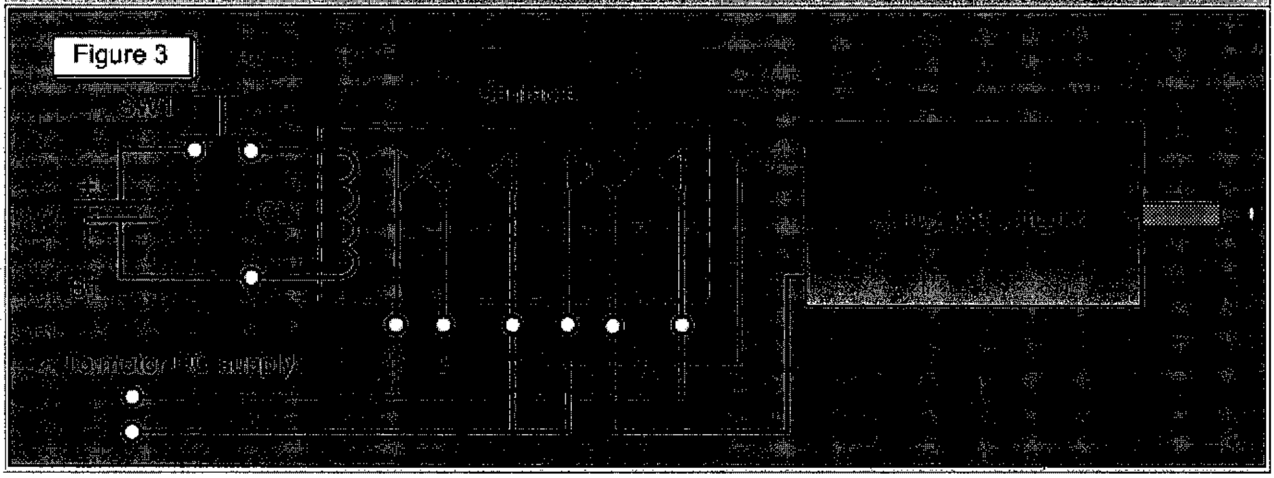


Figure 3

APPENDIX 2

Gantt Chart for Final Year Project – Semester 1

N0.	Detail/ Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	SW	EW
1	**Proposing Of Project Topic**																	
	-Proposing Topic																	
	-Conforming The Project's Title																	
2	**Preliminary Research Work**																	
	-Introduction																	
	-Background Of Problem																	
	-Statement Of Problem																	
	-Objective																	
	-Important Of The Study																	
	-Scope Of The Study																	
	-Literature review																	
	-Project Planning																	
3	**Submission Of Preliminary Report**																	
4	**Project Work**																	
	-Reference/Literature Review																	
	-Identifying the basic concept of AGV design																	
	-Identifying the specifications of the AGV																	
	-Generate the PLC program																	
	-Program simulation																	
5	**Submission Of Progress Report**																	
6	**Project Work Continue**																	
	-Reference/Literature Review																	
	-Identifying the specifications of the AGV																	
	-Program simulation																	
7	**Submission Of Interim Report**																	
8	**Oral Presentation**																	

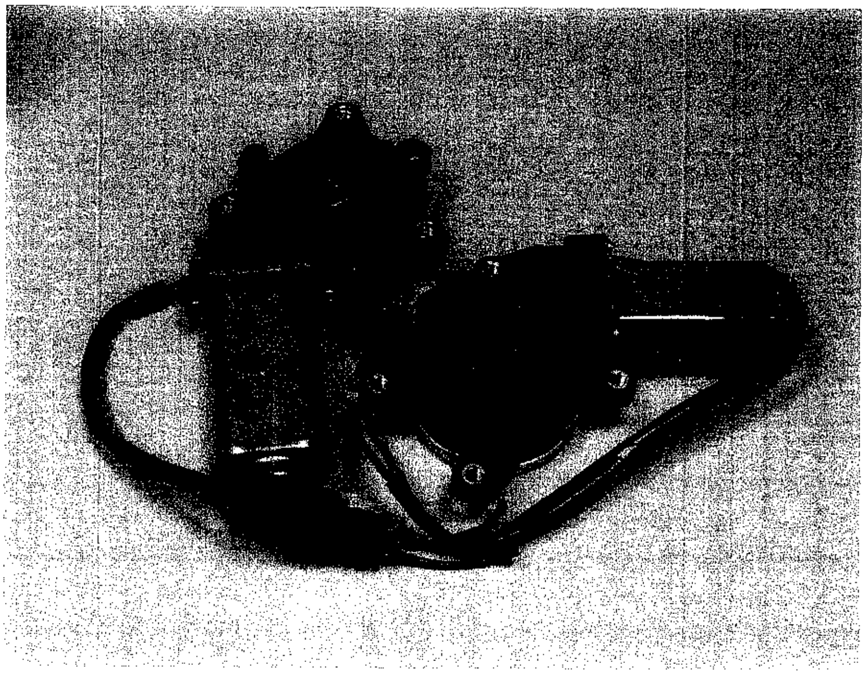
APPENDIX 3

Gantt Chart for Final Year Project – Semester 2

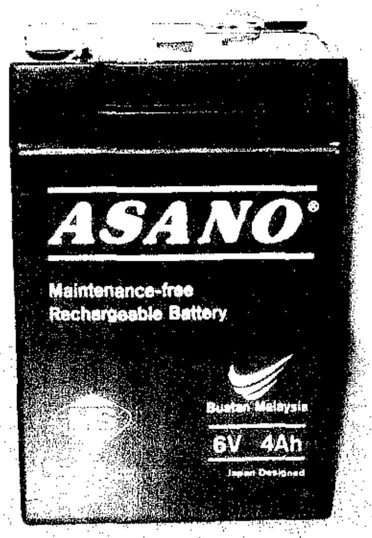
N0.	Detail/ Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	SW	EW
1	**Project Work Continue**																	
	-Prepare components needed																	
	-Test the components (motors and sensors)																	
2	**Submission of Progress Report 1**																	
3	**Project Work Continue**																	
	-Build the relay switching circuit																	
	-Test the circuit																	
	-Build the rear wheels																	
	-Build the chassis																	
4	**Submission of Progress Report 2**																	
5	**Project Work Continue**																	
	-Build the chassis																	
	-PLC input and output interfacing																	
	-Test the ladder diagram																	
	-Build the track																	
	-Assembly the AGV prototype																	
	-Testing and modification																	
6	**Submission of Draft Report**																	
7	**Submission of Final Report**																	
8	**Oral Presentation**																	

APPENDIX 4

Main Components of AGV Prototype

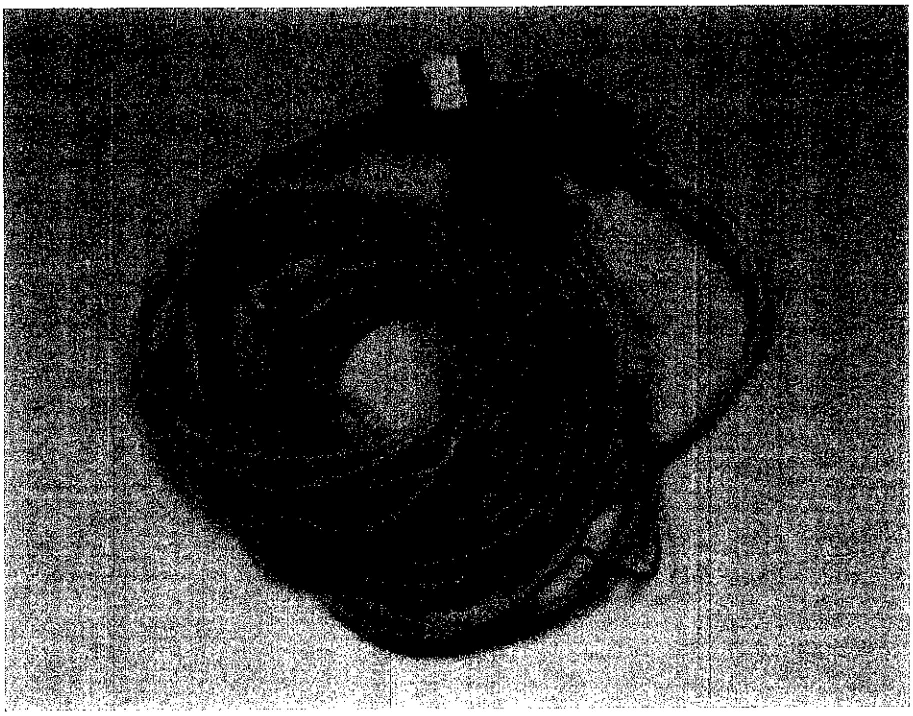


Power window dc motors



6V rechargeable battery

PLC CPM 2A

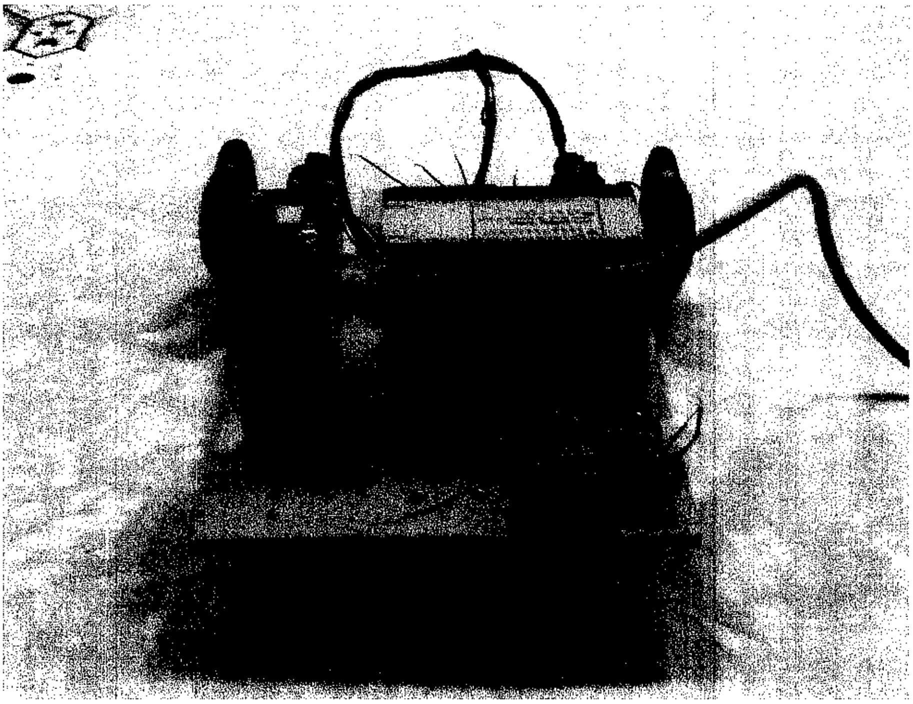


Metal sensors

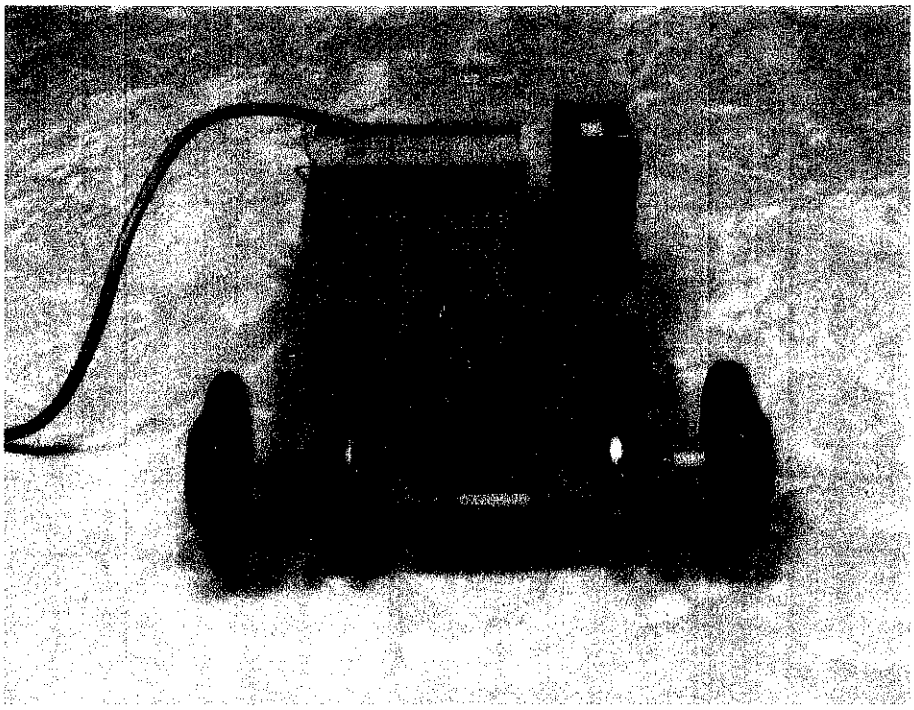
APPENDIX 5

AGV Prototype Construction

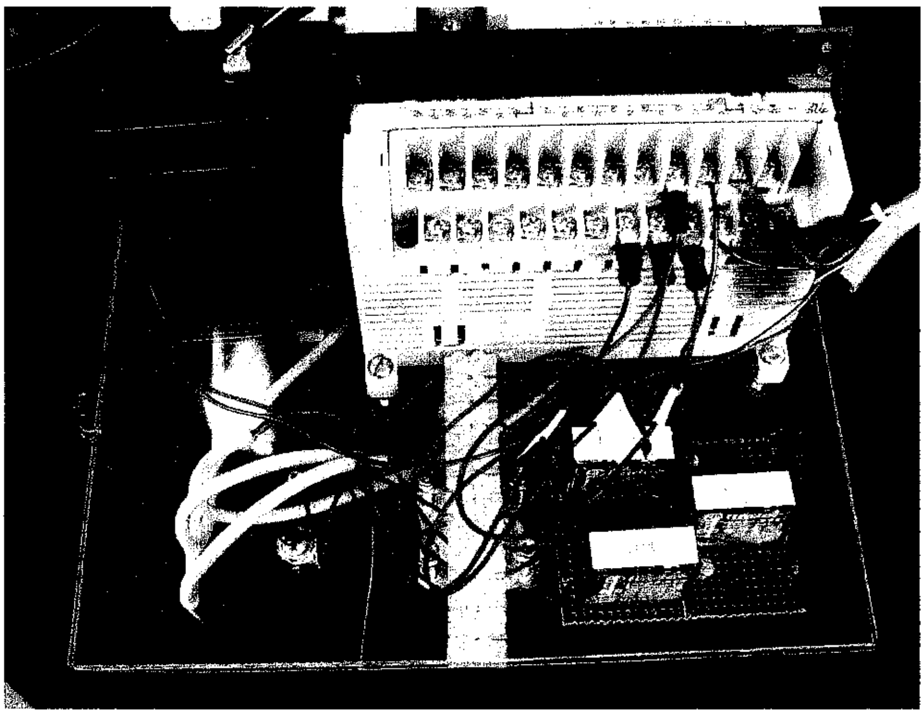
Chassis attached with dc motors and wheels



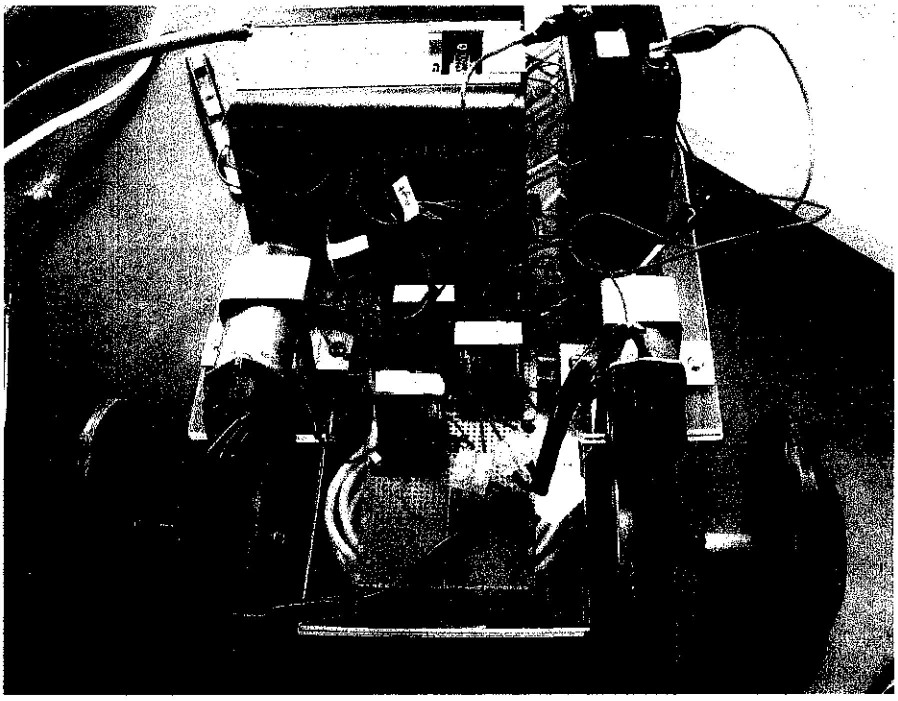
Rechargeable battery, PLC and relay circuit for sensors on the chassis



Rechargeable battery, PLC and relay switching circuit for dc motors on the chassis

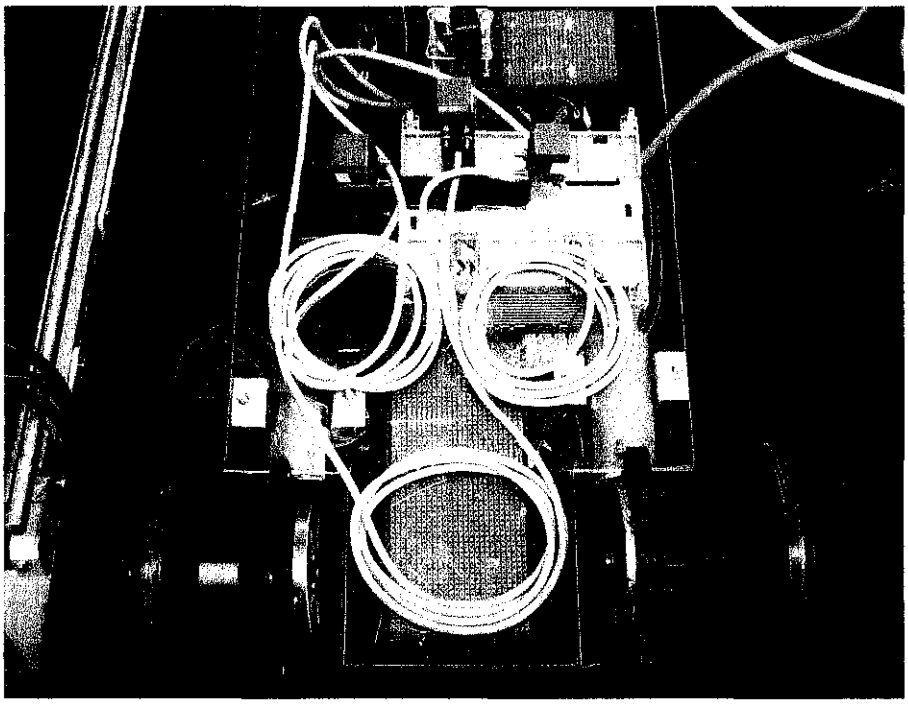


Interfacing between PLC and input components (metal sensors)

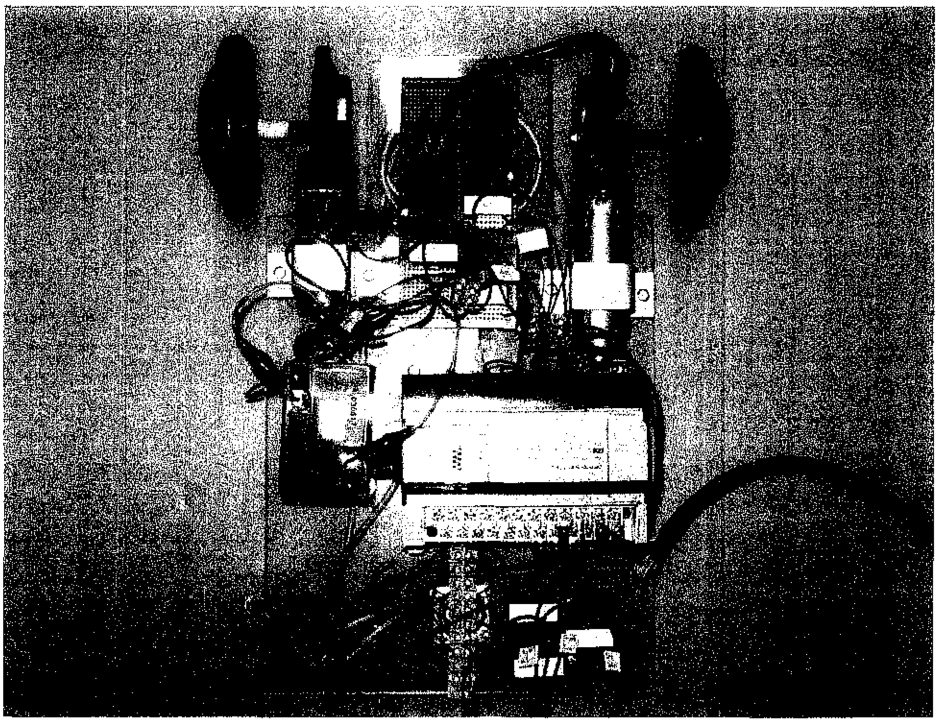


Interfacing between PLC and output components (dc motors)

AGV prototype without installation of metal sensors



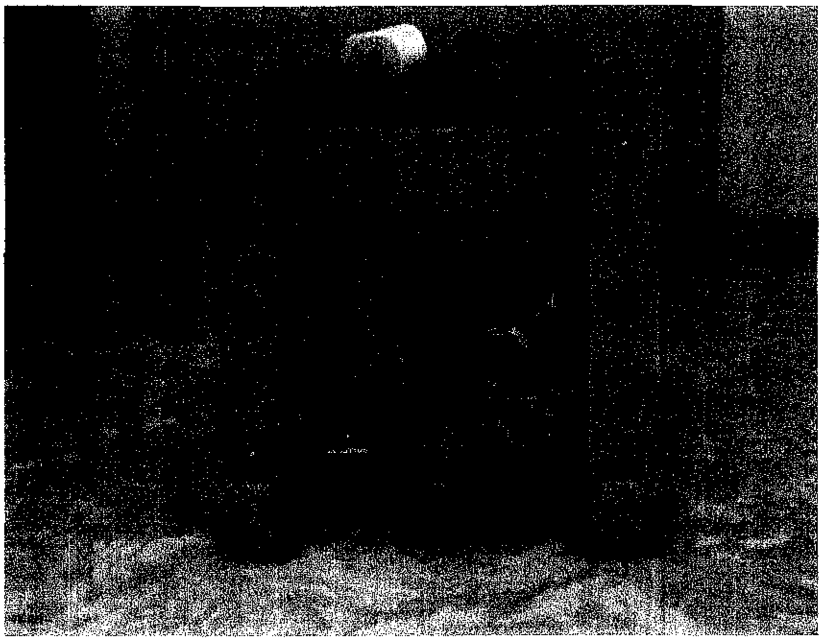
Bottom view of the chassis with metal sensors



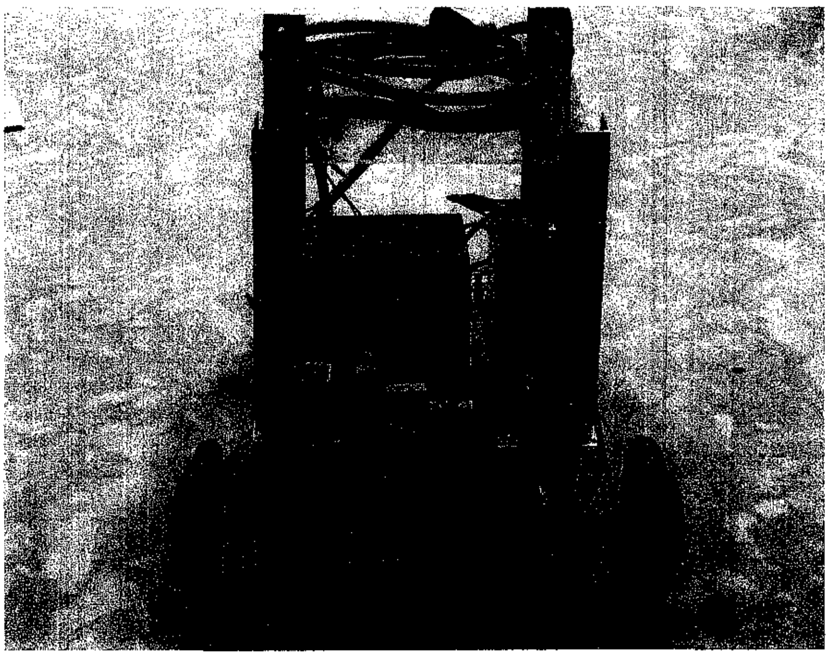
AGV prototype with all components installed

APPENDIX 6

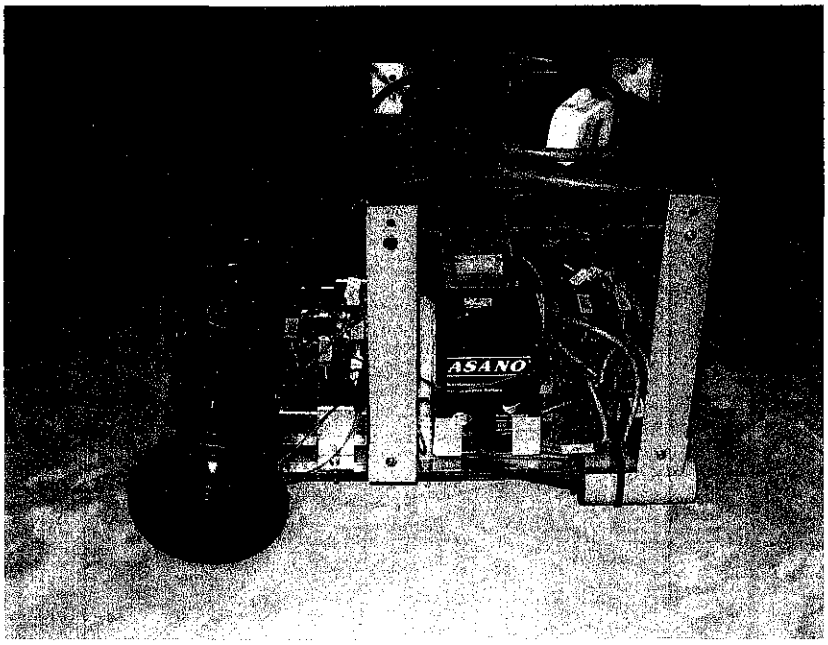
Completed AGV Prototype



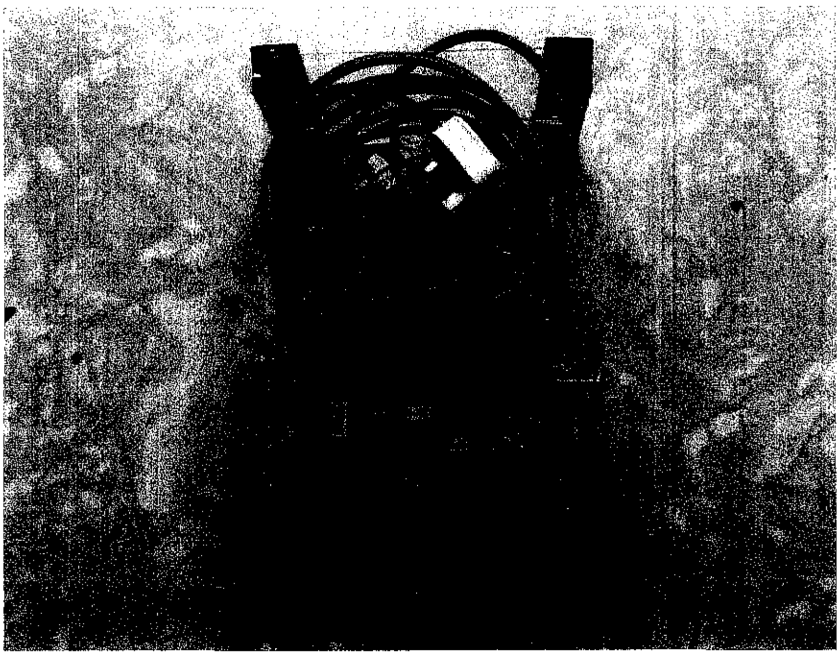
Front view



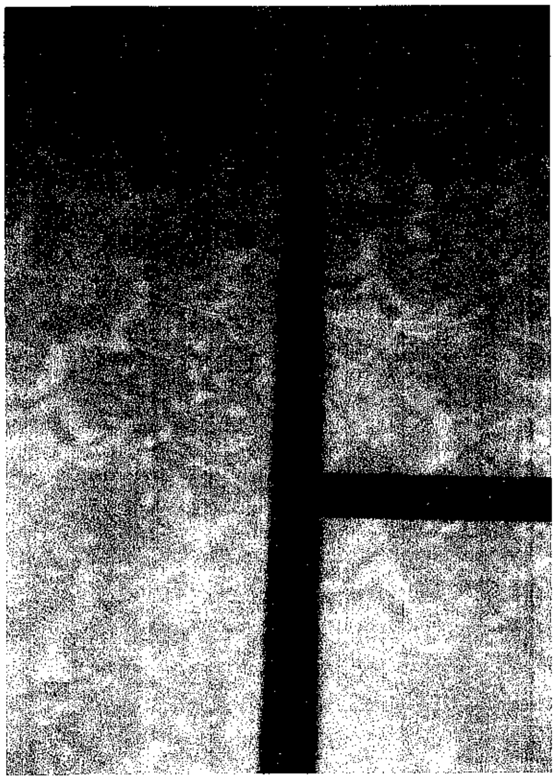
Rear view



Side view



Top view



The track (metal) of the AGV

AGV moves on the track

APPENDIX 7

AGV Prototype model Implemented with Solid Work