"I hereby declare that I have read through this report entitle "Development of Heavy Duty Automatic Guided Vehicle for Industrial Application" and found that it has comply the partial fulfilment for awarding the degree of Bachelor of Electrical Engineering (Control, Instrumentation and Automation)"

Signature : ....

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Date : 31th May 2016

DEVELOPMENT OF HEAVY DUTY AUTOMATIC GUIDED VEHICLE FOR INDUSTRIAL APPLICATION (AGV)

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This Report Is Submitted In Partial Fullfillment Of Requirements For The Bachelor Of Electrical Engineering (Control, Instrumentation, and Automation)

Fakulti of Electrical Engineering
Universti Teknikal Malaysia Melaka

2016

I declare that this report entitle "Development of Heavy Duty Automatic Guided Vehicle for Industrial Application (AGV)" is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : ....

Name : Muhd Izwan Ikhmal Bin Rosli

Date : 31th May 2016

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ABSTRACT

With the improvement of robotic technologies nowadays, industrial application is adopting more aspect of automation to enhance product quality and accuracy to reduce product cost. Entitled as the development of heavy-duty Automatic Guided Vehicle (AGV), this project is about to develop a vehicle without drivers. It consists of mechanical body, rotational mechanism, microcontroller, sensor, and DC motors. AGV in this project is a mobile robot that follows line on the floor. An Arduino Uno Microcontroller will be used to reduce a cost and increase system performance instead of traditional AGV using PLC as controller. It is used to sequence the movement of the wheels by controlling the motors. The motor driver BTS7960 43A are used to controlled the movement of motor by adjusting the Pulse Width Modulation (PWM) to control the speed and direction. AGVs are widely used for transporting material in manufacturing and warehousing applications. On the development of heavy duty automatic guided vehicle, the specification is to implement the AGV to be used in industrial application. It is 1 meter in length, 0.6 meter in width and 0.3 meter in height. Its weight is about 8kg without load and the maximum weight it can carry is 30kg load on the top speed and low torque condition. In addition, a 255 Pulse Width Modulation (PWM) value is set up in the Arduino Uno coding, the motor is said to be on the top speed condition which is equal to 60 rpm and 2.724 N.m in torque for each motor.

ABSTRAK

Dengan peningkatan teknologi robotik pada masa kini, aplikasi industri sedang menerapkan aspek automasi dalam meningkatkan kualiti produk dan ketepatan untuk mengurangkan kos produksi. Berdasarkan tajuk 'Development of Heavy-duty Automated Guided Vehicle for Industrial Application (AGV)', projek ini adalah untuk membina kenderaan tanpa pemandu. Ia terdiri daripada konsep mekanikal, mekanisme putaran, mikropengawal, sensor, dan motor arus terus. AGV dalam projek ini adalah sebuah robot mudah alih yang bergerak mengikut garisas yang ditampal diatas lantai. Mikropengawal Arduino Uno akan digunakan untuk mengurangkan kos dan meningkatkan prestasi sistem dan bukannya mengikut sistem AGV tradisional menggunakan PLC sebagai pengawal. Ia digunakan untuk mengawal pergerakan motor supaya mengikut urutan. Pemandu motor BTS7960 43A digunakan untuk mengawal arah pusingan serta kelajuan motor dengan melaraskan 'Pulse Width Modulation (PWM)'. AGV digunakan secara meluas untuk mengangkut barang dalam sektor pembuatan dan di dalam gudang.Mengenai 'Development of Heavy-duty Automated Guided Vehicle for Industrial Application (AGV), spesifikasi AGV yang akan digunakan dalam aplikasi industri adalah 1 meter panjang, 0.6 meter lebar dan 0.3 meter tinggi. Beratnya kira-kira 8kg tanpa beban dan berat maksimum ia boleh membawa beban adalah 30 kg pada kelajuan tertinggi serta keadaan tork yang rendah. Tambahan lagi, nilai 255 perlu diubah didalam kod Arduino Uno yang merupakan nilai maksima bagi Pulse Width Modulation (PWM) untuk kelajuan tertinggi motor. Ia bersamaan dengan 60 rpm dan tork bernilai 2.724 N.m untuk setiap motor.

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LIST OF ABRREVIOTIONS

AGV	**-**	Automatic Guided Vehicle
AGC	**-**	Automatic Guided Chart
PLC	**-**	Programmable Logic Control
PIC	**-**	Peripheral Interface Controller

CHAPTER 1

INTRODUCTION

1.1 Introduction

Nowadays, Automated Guided Vehicle (AGV) is widely used especially in industry. AGV is a vehicle that is fully automated to carry load, handle load or do some tasks in factory or warehouse.

In industrial, AGV brings a lot of advantages to industry. One of the advantages of using industrial AGV is it can carry a big capacity of load without any human's guidance. The AGV nowadays is very advance in the mechanism structure and most of the AGVs can carry a big capacity of load, like pallets, carts, rolls and others. Besides, it can work 24 hours per day and this helps to increase the productivity of a company [1].

Early AGV is customized and guided by wires embedded in floor. The AGVs were also very expensive and cost about USD 100k per vehicle. Nowadays, there is demand to have a low cost AGVs with high power. The AGVs are very advances in software and most of them are controlled by wireless communication. In addition, most the AGVs also equipped with the advance sensor technology [1].

For industrial usage, AGV can carry a high capacity of load, like pallets, cart, rolls and others. On the other hand, it can save the space of the warehouse as it can lift the load to higher position neatly. Although the initial cost of an AGV is very high, it saves money in the aspect of production and labour cost [2].

A Development of Automated Heavy-duty Guided Vehicle for Industrial Application (AGV) is widely being used in industry. AGV is a transport that is fully automated and works to carry load, handle load or do a task in an industry. With the advancements of robotic technologies, the industrial environments are adopting more and more aspects of automation to enhance product quality and accuracy which is gaining importance in industrial logistics and transportation system [2]. These systems provide for asynchronous movement of material through the system. They offer many advantages relative to other types of material handling systems, including reliable automatic operation, flexibility to changes in the material handling requirement, improved positioning accuracy, reduced handling damages and automated interfaces with other systems.

This project is a development an Automated Heavy-duty Guided Vehicle for Industrial Application (AGV) prototype. Traditionally, AGVs are mostly used at manufacturing systems. AGVs are also used for repeating transportation tasks in other areas, such as warehouses, container terminals and external transportation system [3].

The important things in this development of AGVs are the integration between Arduino Uno microprocessor, sensor, Direct Current (DC) motor, and rotational mechanism. This project is divided into two sections which are mechanical part and electrical part. The mechanical parts are consisting of mechanical drawing using Solid Work software, measuring, and fabrication process. The electrical parts are consisting of electrical drawing and analysis using Proteus / Multisim / PSpice , electrical wiring and programming a microcontroller.

After the fabrication process and assembly, the AGVs will be ready to be tested in the outdoor and indoor field. The first approach is to run the vehicle individually and observe their responses to the environment. Wheels are adjusted and the couplings and bearings are set to correct alignment as they are showing deviations after the very first few test runs. Then the individual sensors will be tested for their accuracy and corrected wherever required. The drive electronics will go through some load tests where the AGVs are loaded and the corresponding current flow through the motors are measured. This was done to incorporate the electronic safety actions in the circuits [4].

AGVs development has a bright future in many industry and they should come forwards in such research works instead of becoming too much depend on foreign technology.

1.2 Objective

The Development of Automated Heavy-duty Guided Vehicle for Industrial Application (AGV) is to help the industries delivery the load from one section to another section automatically. The AGV prototype has been designed and constructed for a heavy-duty application. Thus, the title a Development of Automated Heavy-duty Guided Vehicle for Industrial Application (AGV) is chosen for PSM and the objectives of the project are :

a) To investigate the parameter involve that can be used to be implemented in AGV.

b) To design a control algorithm for a smooth AGV operation system.

c) To develop an AGV prototype by using Arduino Uno microcontroller as control unit in AGV operation system.

d) To analyse the performance of the AGV.

1.3 Motivation

The field of robotics and automation holds enormous potential as a key transformative technology to positively impact the manufacturing industries. From traditional and well-established applications in the automotive industry to emerging applications such as material handling, palletizing, and logistics in warehouses, the use of robots can increase productivity whilst ensuring personnel safety. A Development of Automated Heavy-duty Guided Vehicle for Industrial Application (AGV) represents an integral component of today industries. AGVs can be widely use in the factory, warehouses, hospital or any needs industry for transportation goods between conveyors to assembly section, parts to frame movements, and truck loading or unloading. In this development of Automated Heavy-duty Guided Vehicle (AGVs), the main goal is to get it implemented in the industries that can do an outdoor and indoor job with variety application such as transporting goods in hospital, warehouses, and store without the needs of many workers.

1.4 Problem Statement

The Development of Automated Heavy-duty Guided Vehicle for Industrial Application (AGV) is still new and not much applied in local industry especially in Small Medium Enterprises (SME) and the application is rarely used in local industry compare with multinational country.

The AGV is developed to replace the older method where the load is delivered manually by using man power or used a fork lift. Usually, there will be some random error due to human fault. The workers maybe forget which station for loading and waste the production time. By using AGV, the company maybe can save their production cost that is deducted from labour charge and also can increase the production because AGV can work 24 hours a day compared to labour.

The AGV for market price is very expensive. The only suitable market is mostly focuses in manufacturing factories. The AGV project is the best chance to build a low cost but flexibility prototype. With the lower cost AGV product, it may widely commercialize in medium or small company for future planning.

The AGV system uses in industry has produce a good efficient output than workforce. The system can deliver the load automatically from one section to another section. This system will save a lot of working space as the path is fixed. The user also can save the labour charge and money.

1.5 Scopes

Generally, all projects have their own scope or limitation as a guideline. The Development of Automated Heavy-duty Guided Vehicle for Industrial Application (AGV) aspires to construct a vehicle automatically guided with intelligence way to choose the correct path of travel.

Firstly, the major scope of this project is to build up and construct a prototype of AGVs to carry the load up for 30 kg load. It should be in heavy-duty condition so that it can endure much load to carry.

Secondly, the AGV system is controlled by using the Arduino UNO microcontroller board. It's used to integrate the sensor and motor to move through the line. The microcontroller must be working effectively as a brain of the AGV system.

Thirdly, the selection of effective sensor range is set as navigation guidance for the AGV. The sensor is used for the left and right manoeuvring as well as enable to move forward and reverse track.

Lastly, there will be several of motor being used in order to control the movement of AGV. DC motor is implemented for AGV moving on the setting track.

CHAPTER 2

LITERATURE REVIEW

2.1 Automated Guided Vehicle (AGV)

AGV system essentially consists of vehicles, peripheral and on-site components as well as the stationary control system. Only the faultless interaction of all these components ensures efficiently working plants.

Vehicle component is the central element of AGVs as it performs the actual transportation task. The vehicle has to be designed following the specific conditions of the environment to be implemented. This including loads handling equipment, the navigation system, the drive configuration and other aspects [3].

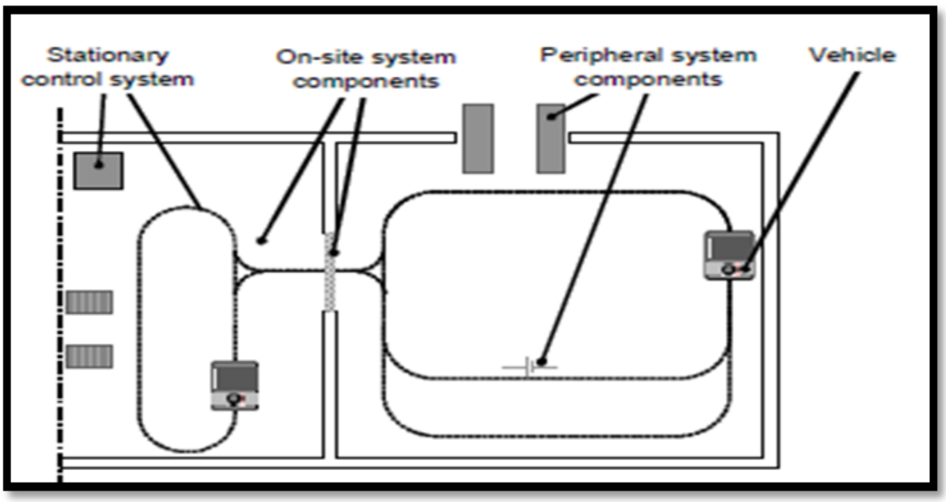


Figure 2.1: Component of an AGVs system

Figure 2.1 briefly shows the component in basic working area of AGV. With the advancements of robotic technologies, the industrial environments are now focusing on aspect of automation to enhance quality of production and accuracy with better time management. Back then, AGVs are mostly used in manufacturing area. Nowadays, AGVs are used for repeating transportation tasks in many other areas application, such as warehouses, store and many other indoor or outdoor applications. Figure 2.2 below shows the example of working area of AGVs in laboratory.

Figure 2.2: Example of AGV working area [4]

According to Garcia et al. (2007), with the rapid modernization of the First World, new types of services are being required to maintain a certain quality of life. A new, promising robotics sector is arising to serve the human being [4]. Schulze and Zhao (2007) performed research on the usage of AGVs in Europe and China. In the developing country, application of robotics is very popular in the field of industry [4]. High labour cost plays an important role for this situation in such countries. It increases the production speed and accuracy.

In the industries, there are many components need to be transferred from one place to another during the manufacturing process. These components are divided according to their size and shape. AGVs are designed to meet the needs of definite industry. As an example, the operations of an interaction of the AGVs is based on imaginary industrial environment where one of the AGVs picks up a block from a predefined loading place and supply it to another AGVs after manoeuvring at a certain distance. Then the other AGVs sensed the delivery and travelled a linear trajectory to perform final delivery of the block to unload it [4].

As the years passing by, AGV are characterized by significant technological advancements. They contributed to increase attractiveness for the user's essential concern, navigation systems, automation of series vehicles and safety system. Significant technological advancements contributed to increase the attractiveness of Automated Guided Vehicle (AGV) system for the users [5].

There are a bunch of research conducted by many higher learning institutes around the world to study about Automated Guided Vehicle (AGV) and improve it in terms of the mechanical arms, the movement speed, the stability and many others. For this project, the industrial AGVs were studied before the AGV prototype is designed.

Generally, there are two type of application related to AGV. Firstly is the Automated Trailer Loading (ATL). As shown in Figure 2.3 below. ATL is a type of AGV that are widely used in the warehouse and factory to pick up and deliver load such as pallets, carts and rolls [6].

Figure 2.3: Automatic Trailer Loading [6]

ATL can carry much load and carry any conventional trailer without any modification. It can also interlace load patterns. ATL is guided by using laser and it uses sonic guidance in trailer. The side forks of the ATL can shift independently and both the left and right forks can rise independently. The fork tip sensors of the ATL can detect whether there is any space available.

ATL does not have an obstacle avoidance system and even the protective bar to protect itself from collisions. Besides, ATL does not have an auto parking system and rechargeable battery. It has to be changed manually when the battery is finished [6].

Secondly, is the Automatic Guided Cart (AGC). As shown in Figure 2.4, AGC is used to carry the trolley from one place to another and it is basically used in the warehouse.

Figure 2.4: Automatic Guided Cart (AGC) [6]

It is not expensive in price where the cost is about USD 10k to USD 30k per vehicle. It is versatile which is easy to be changed from one job to another. It is guided by magnetic tape and the systems of AGC can be installed and easily configured [6]. Figure 2.5 below are the AGC Modular component.

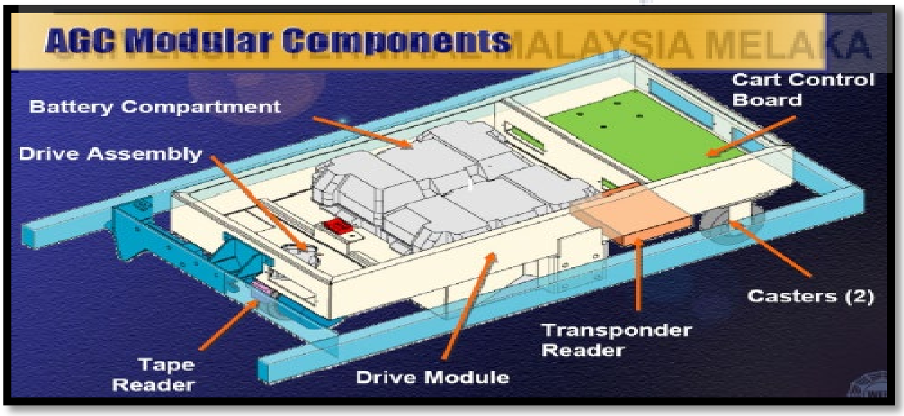


Figure 2.5: AGC Modular Component [6]

One of the disadvantages of the AGC is that the AGC does not have an obstacle avoidance system. It uses the protective bar to protect itself from collision with the walls and the obstacles. Hence, it requires an amount of repairing cost for the AGC when it collides with any obstacle.

2.2 Type of AGV Guidance System

AGVs are used to transport an object from one point to another. AGVs navigate manufacturing areas with the implementation of sensors. There are two main sensors that AGV use for guidance system, a wired and a wireless sensor. There are several types of guidance system of AGV. Firstly is a Laser Guidance System. It uses the integration of a laser beam with the receiver that is plucked on the wall of the room.

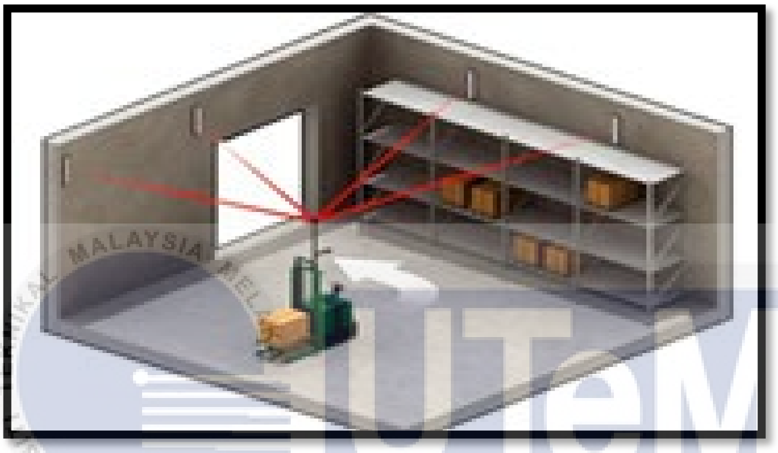


Figure 2.6: Laser Guidance AGV [7]

As shown in Figure 2.6, the area is mapped and stored in the computer memory attached in the AGVs. Multiple fixed reference points and reflective strips located within the operating area can be detected by a laser head that is mounted on the vehicle. By using laser guidance technology, the guide path can easily be changed and expanded. It is very flexible for vehicle movement, accurate and reliable in the form of navigation. Other than that, the system can be expanded without alteration to the facility. Generally, it is being used for most dynamic control of blocking and traffic management [7].

Secondly is the Magnetic Spot Guidance Technology. As shown in Figure 2.7, Magnetic Spot Guidance is the technology where the guide path is marked with magnetic pucks that are placed on the floor.

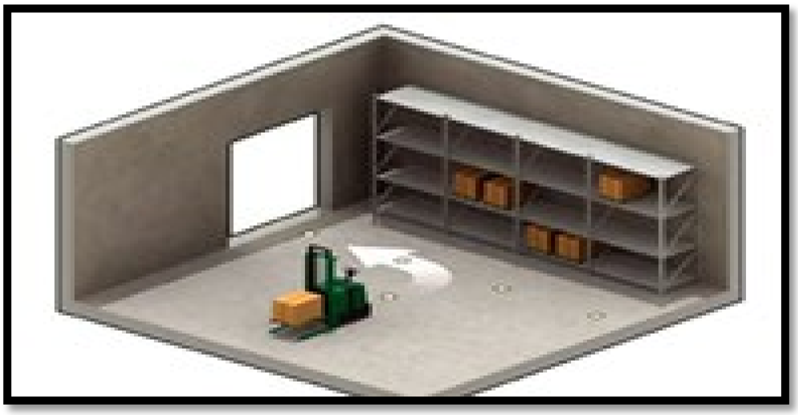


Figure 2.7: Magnetic Spot Guidance AGV [7]

The guide path sensor is mounted on the vehicle. The mounted sensor will integrate with the guide path that is marked with magnetic pucks and move accordingly. If the path is open, the systems guide path can be changed. Other than that, extensive layouts can complicate the layout of magnetic pucks. The navigation of the AGV is depending on the accuracy of the magnetic sensor and the calibration of the position may be required for different vehicles. The advantage of this system, it can be expended without damage or major alteration to the facility [7].

Figure 2.8 shows the application of Magnetic Tape Guidance Technology. It is the technology where the vehicle follows the guided path that is marked with a magnetic tape. It is placed on the floor surface. Commonly, the guide path sensor is mounted on the vehicle. The AGV will follow the tape that is marked on the floor. Moreover, the path is continuous and fixed to its direction. The system guide path can be changed easily and quickly. In addition, the tape has to be epoxy coated to floor so that it can be long lasting. This type of navigation is recommended for Automatic Guided Carts (AGC) that is shown in Figure 2.9 [7].

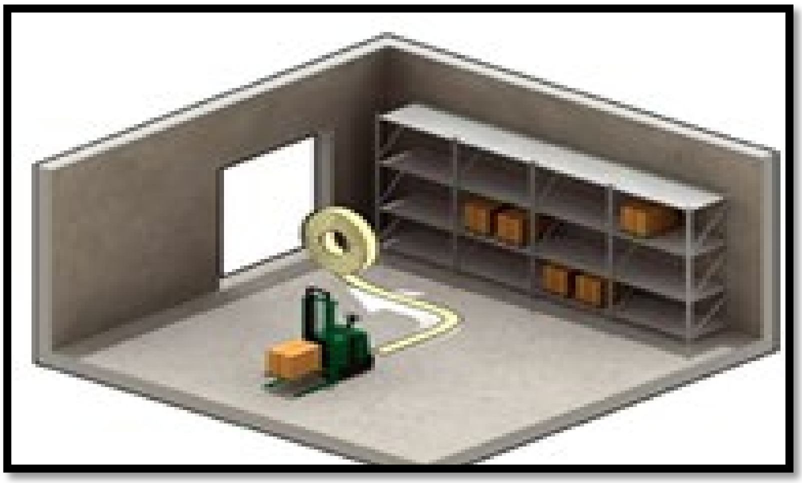


Figure 2.8: Magnetic Tape Guidance AGV [7]

Figure 2.9: Automatic Guided Carts (AGC)

Another example of guidance system is the Inductive Guidance Technology. Inductive Guidance or wire guidance is the technology where the floor is cut and a wire is imbedded to represent the guide path. As usual, the guide path sensor is mounted on the vehicle.

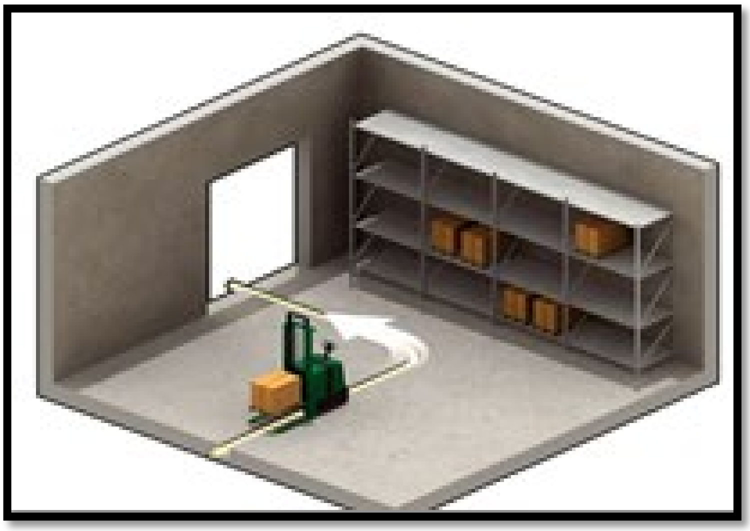


Figure 2.10: Inductive Guidance Technology AGV [7]

As shown in Figure 2.10, the paths are well marked on the floor to make the AGV navigate easily. Other than that, the paths are continuous and fixed. The system guide path is not easily changed. For this type of navigation system, the expansion of the facility is not as flexible as some other navigation technologies and may be limited due to constraints [7].

2.3 Type of sensors implement in AGV System

Sensor is an object whose purpose is to detect events or changes in its environment, and then provides a corresponding output. Sensor is a type of transducer. Direct – indicating sensors, such as mercury thermometer is human-readable type of sensor. Besides a thermocouple, only produce an output voltage or other electrical output which must be interpreted by a microcontroller [8-9].

Sensors are widely used in daily application such as touch-sensitive elevator buttons and lamps which dim or brighten by touching the base. There are also innumerable applications for sensors of which most people are never aware. Application includes automobiles, machines, aerospace, medicine, industry, and robotics [8].

There are various types of sensor such as limit switch, photoelectric, inductive, capacitive and ultrasonic sensors. Table 2.1 shows the briefly explanation of each sensors.

Table 2.1: Advantage and disadvantage of sensors [8]

Sensor	Advantage	Disadvantage	Applications
Limit Switch	- High current capability - Low cost	- Requires physical contact with target. - Slow response	- Interlocking
Photoelectric	- Sense all kind of material - Long life - Longest sensing range	- Lens subject to contamination - Sensing range affected by colour and reflectivity target	- Packaging - Material handling - Parts detection
Inductive	- Resistant to harsh environment - Very predictable Long life - Easy to install	- Distance limitation	- Industrial and machine - Machine tool - Sense metal-only target
Capacitive	- Detect through some containers - Can detect non-metallic targets	- Very sensitive to extreme environmental changes	- Level sensing
Ultrasonic	- Sense all material	- Resolution - Repeatability - Sensitive to temp.	- Anti-collision - Doors - Web brake

Nowadays, Most AGV used photo logic optical sensor in their technology. The photo interrupters consist of an IR emitter and a photo detector. Usually, a white reflected tape will be attached on the ground. The photo detector detects the light reflected from the ground. If the detector detects a reflected light, then it gives a signal low else it gives a signal high to the microcontroller [10]. Figure 2.11 below shows one of the type of sensor used in the application explained above.

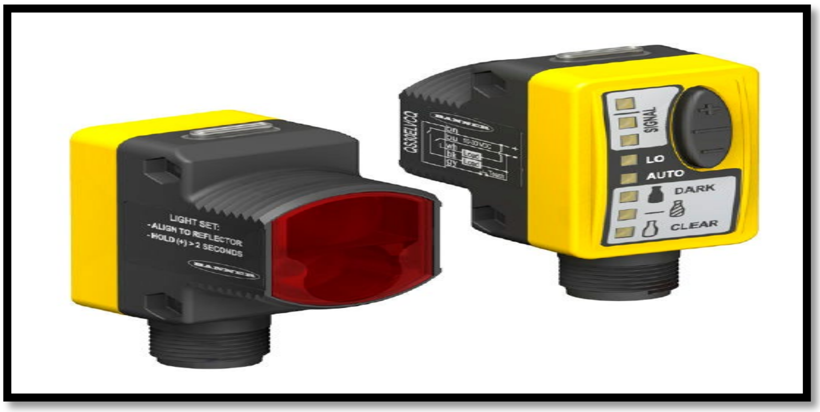


Figure 2.11: Photoelectric sensor [9]

During the construction of an AGV, the sensors are aligned so that if the AGV is centred on the track. This technique is to ensure all the three sensors can see track – the output from all detectors will be high and the robot will continue in the previous direction.

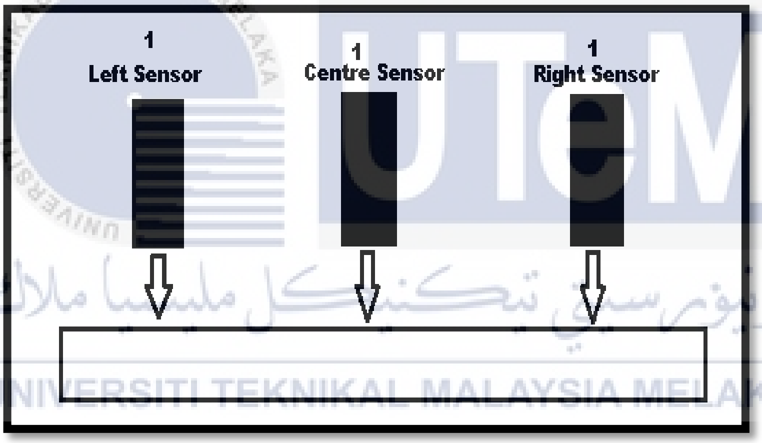


Figure 2.12: Position of sensor on AGV [10]

As shown in Figure 2.12, if the AGV goes either left or right on the line, initially one sensor will not see the track and other two will see the track, then one sensor will be low and the other two will be high. The AGV will move on a direction such that sensor which is low at this stage starts sensing again.

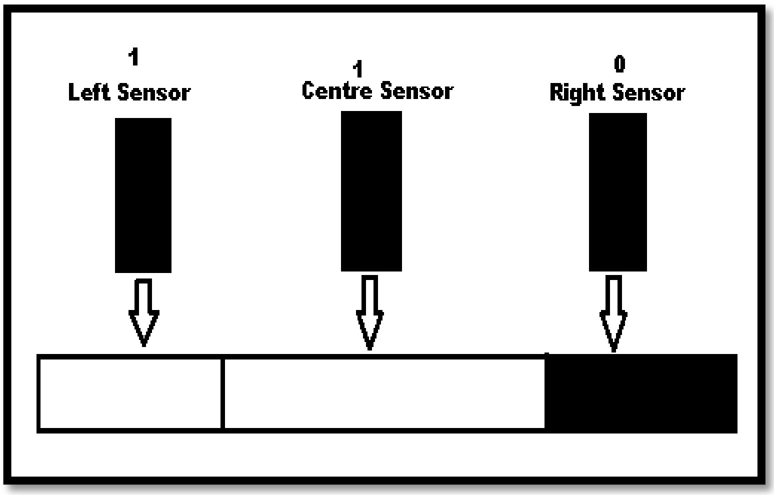


Figure 2.13: Position of sensor on AGV (Right sensor not detect) [10]

As we can notice from Figure 2.13, when the right sensor does not sense the track, then that detector will be low and correspondingly the AGV will move left until the right sensor detects the track.

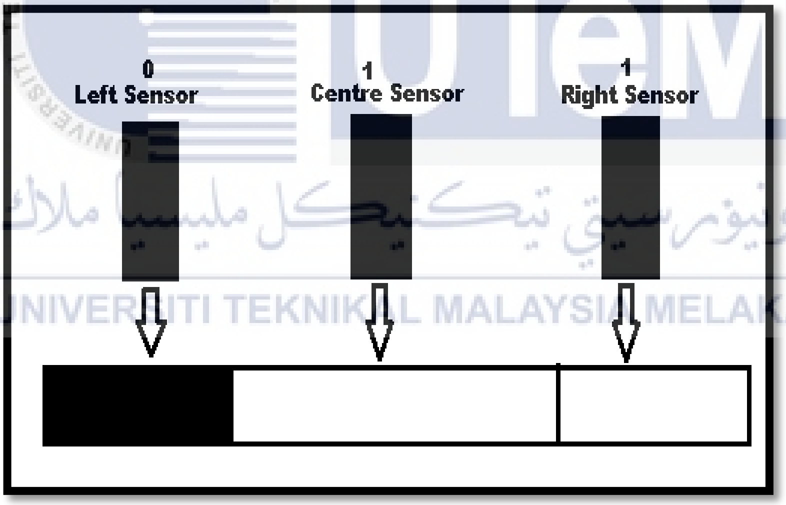


Figure 2.14: Position of sensor on AGV (Left sensor not detect) [10]

We can notice from the Figure 2.14 when the left sensor does not sense the track, then that detector will be low and correspondingly the AGV will be made to move right until the left sensor detects the tracks.

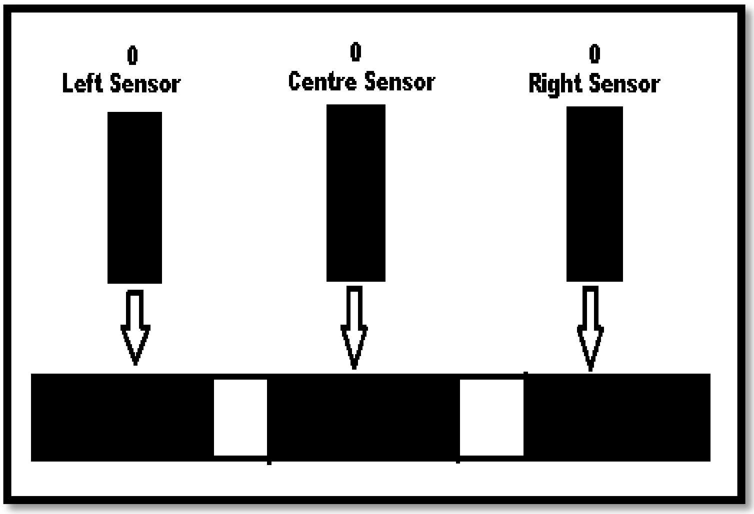


Figure 2.15: Position of sensor on AGV (All sensor not detect) [10]

When all the three sensors cannot see the line as shown in the Figure 2.15, then the output from all the sensors will be low and the AGV will then move according to the last sensor values to see the tracks.

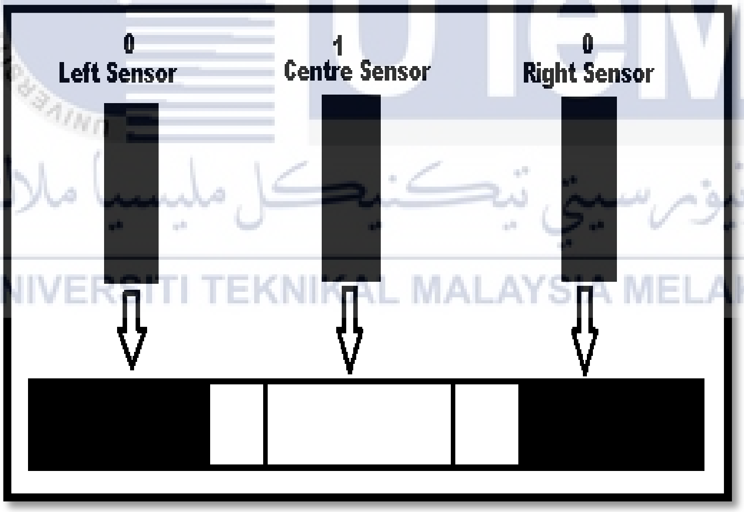


Figure 2.16: Position of sensor on AGV (Left & Right sensor not detect) [10]

When only the centred sensor detects the track and the other two sensors go low as shown in Figure 2.16, then the AGV moves to forward direction with both the motors working. Table 2.2 shows the table indicating which sensing the path and the AGV direction.

Table 2.2: Table indicating which sensing the path and the AGV direction

Left Sensor	Centre Sensor	Right Sensor	AGV Movement
0	0	0	
0	0	1	Turn Right
0	1	0	Move Forward
0	1	1	Turn Right
1	0	0	Turn Left
1	0	1	Turn Right
1	1	0	Turn Left
1	1	1	

2.4 Controller in Development of AGV System

A microcontroller (µC, uC or MCU) is a small computer on a single integrated circuit containing a processor core, memory, and programmable input or output peripherals. Microcontrollers are designed for embedded applications, in contrast to the microprocessors used in personal computers or other general purpose applications [11]. Nowadays, the type microcontrollers used in the AGV are Arduino UNO, Peripheral Interface Controller (PIC) and Programmable Logic Controller (PLC).

The microcontroller is programmed with the required program to accept the data from the transmitter, interpret it, and calculate the path in terms of spatial orientation and accurate motor driver.

2.4.1 Arduino UNO Microcontroller

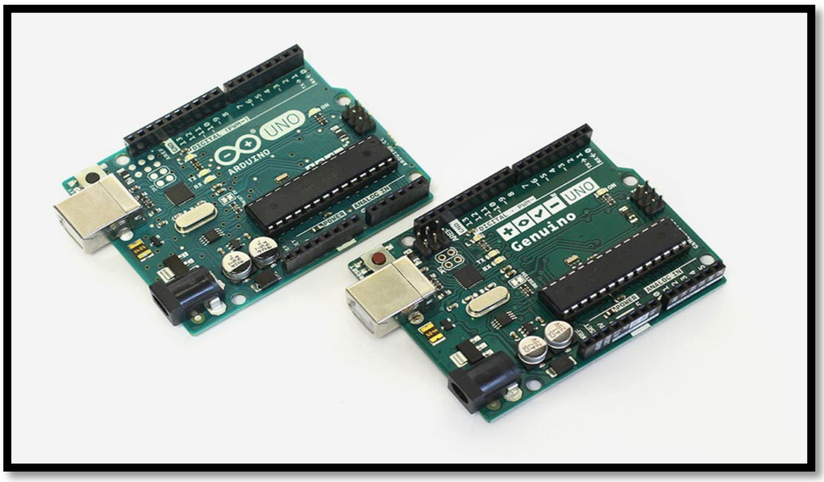


Figure 2.17: Arduino UNO [12]

The Arduino Uno is a microcontroller board based on the ATmega328P. It has 14 digital input and output pins (of which 6 can be used as PWM outputs), 6 analogue inputs, a 16 MHz quartz crystal, a USB connection, a power jack, an ICSP header and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started [12].

The Arduino is an open source development platform which is based on Atmel AVR microcontroller. The equipment is widely used due to the simple programming and configuration. Besides, the programs can be prepared in a virtual development environment (IDE), which can be loaded and tested on computer and it is easy to download to the controller on an USB port. The IDE is a cross platform which is written in JAVA. The device can be programmed by C and C++ [12].

In the application of this AGV, Arduino UNO acts as the main controller to control the movement of the AGV. The controller is implemented with a sensor as the input and the DC Motor as the output. To control the DC Motor, the H-bridge that is shown in Figure 2.18 is used along with the Arduino UNO.

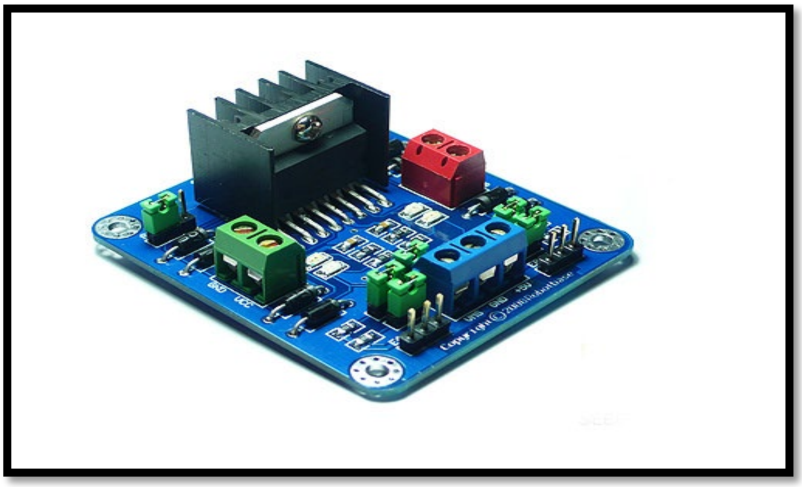


Figure 2.18: H-Bridge [13]

H-Bridge are typically used in controlling motors speed and direction, it also can be used for other projects such as driving the brightness of certain lighting projects such as high powered LED arrays.

The advantages of using Arduino UNO in AGV development are, it is less expensive controller and easy to be programmed. Another than that, the size of the controller is small and can be implemented in many application whether large or small type of application. It is also can be implemented with many usage of input and output device in one controller.

2.4.2 Peripheral Interface Controller (PIC)

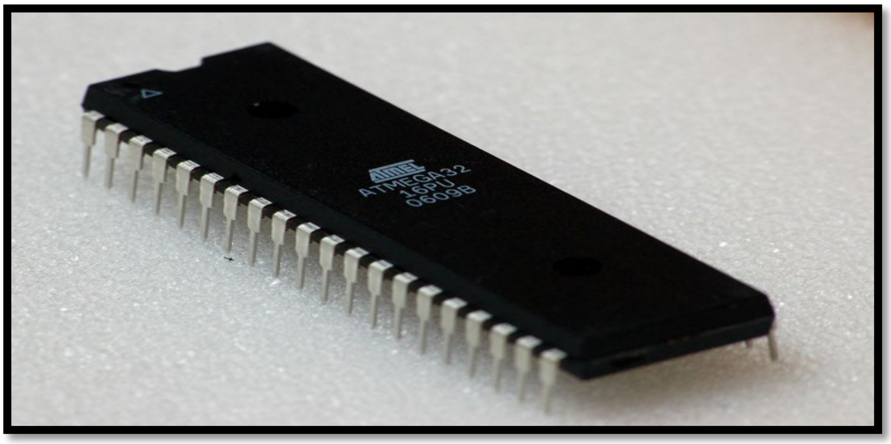


Figure 2.19: PIC Microcontroller [14]

Peripheral Interface Controller (PIC) ATmega 328. As shown in Figure 2.19, it is commonly used in the AGV design. The Atmel®AVR® ATmega 328 Controller is a low-power CMOS 8-bit microcontroller based on the AVR RISC architecture. By executing powerful instructions in a single clock cycle, the ATmega 8 Controller achieves throughputs approaching 1MIPS per MHz, allowing the system designed to optimize power consumption versus processing speed [14].

The Microcontroller is programmed with the required program to accept the data from the sensing unit, interpret it, and give responses to the driving and lifting mechanism in very small time interval [14].

The main advantage of using PIC is the high performance component but using low power. Therefore, it can last longer if using battery as a power supply. Another than that, it has many input and output pin out that can be implemented with variety of application in one component.

2.4.3 Programmable Logic Controller (PLC)

Figure 2.20: PLC Microcontroller [15]

A programmable logic controller (PLC) is a digital electronic device that uses a programmable memory to store instruction and to implement functions such as logic, sequencing, counting, and arithmetic in order to control machines, processes, and has been specifically design to make programming to be easy.

The basic structure of PLC consists of central processing unit (CPU), power supply, memory (ROM/RAM), input modules, output modules, communication and expansions unit or connections. The PLC activates its output terminal in order to switch things ON or OFF. The decision to activate an output is based on the status of the system's feedback sensors and these sensors are connected to the input terminals on the PLC. The decision is based on logic programmed stores in the RAM or ROM memory [15].

The PLC has a central processing unit (CPU), data bus, and address bus. The supply voltage is depending to the PLC either AC voltage (110-120V/220-240Vac) or DC voltage (24Vdc). Usually the PLC that made from Japan is NPN type (common positive) and the PLC that made from Europe is PNP type (common negative). The OMROM PLC type CQM1H is used in this project [15]. Figure 2.17 shows the output device that can be connected to PLC.

The main advantages of PLC are easier and faster to make changes in programming and application can be duplicated faster and less expensive.

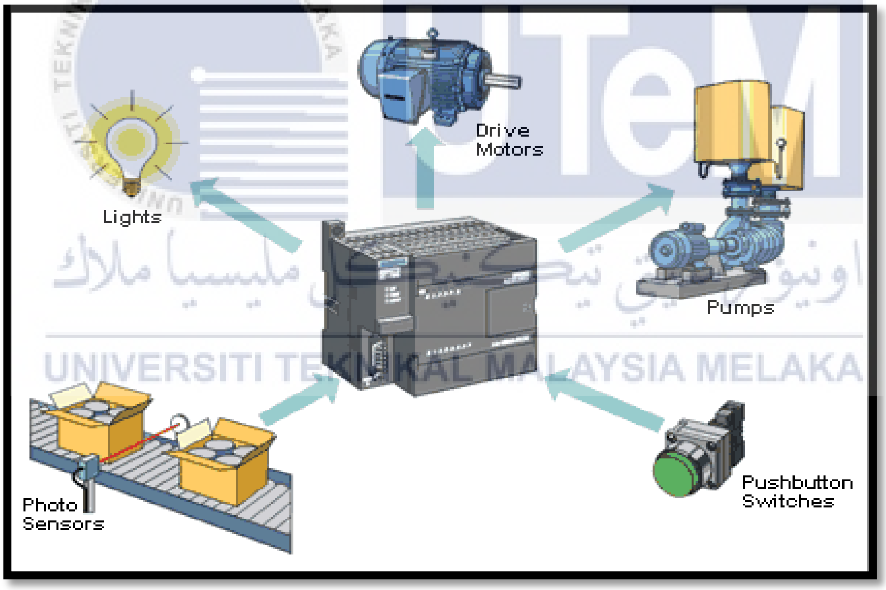


Figure 2.21: PLC Function [16]

2.5 Drive System (Driving Element)

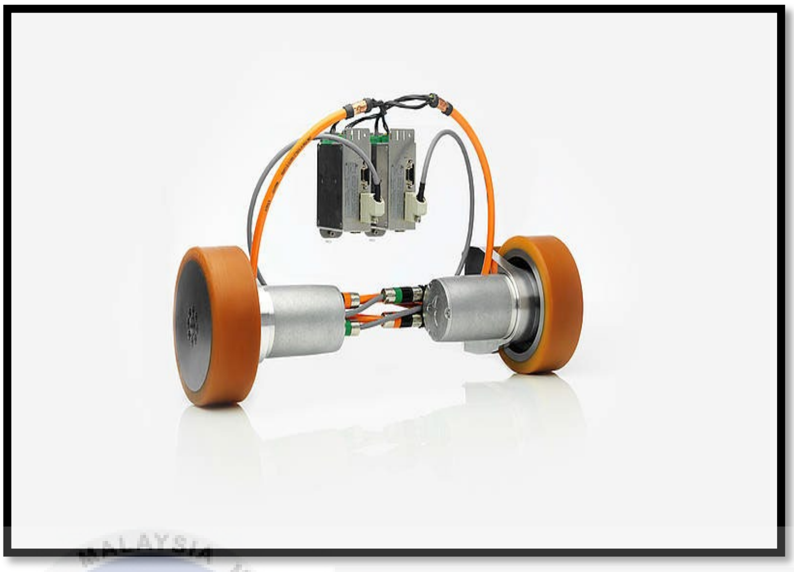


Figure 2.22: Example of driving system with DC Motor [17]

Automated Guided Vehicles uses differential drive where two drive wheels, one on each side of the vehicle and each driven independently. Figure 2.22 shows the assembly of a drive motor to the wheel of an AGV. Commonly, the AGVs operate with two DC motors to make it move forward and backward [16].

Further mechanical part that will be used is the front wheels that will be connected with shaft to make the AGV more stable and can carry much load. The movement of AGV will be controlled by a different speed of DC Motor on the back wheel.

Most vehicles use four quadrant drives for speed control in which wheel can be accelerated or decelerated in either the forward or reverse direction. Deceleration is accomplished via dynamic braking where motion of the vehicle is used to generate power back into the batteries. This provides excellent speed control on ramps or uneven surfaces as well as improving efficiency and battery life.

2.6 Power Supply

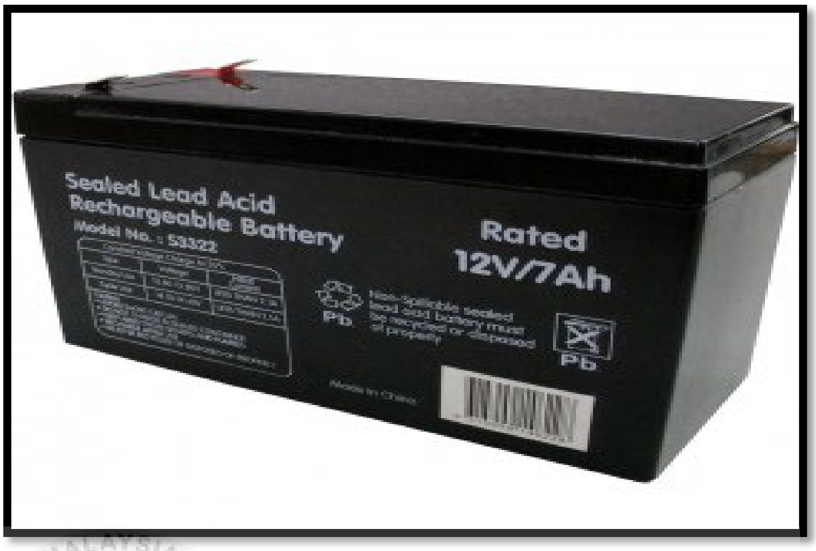


Figure 2.23: Example of 12 V Battery

An acceptable and constantly available power supply is the basic precondition for the functioning of AGV systems. The choice of power supply for an AGV system depends on many parameters related to the nature and place of used

There are four criteria's for selecting optimal power supply. Firstly, the mechanical structure of the vehicle. The movement part requires more consumption of power supply. Other than that, the type of the vehicle used is very important to suit with the light and heavy type of industries. Moreover, the usable capability that consist of the running, standing, and loading times of the AGV must be considered. Lastly, the maintenance and working life of AGV is very important in the selecting criteria for optimal power supply [18].

Normally, AGVs operate on battery power ranging from 12 to 48 V_{DC} as a power supply. Figure 2.23 show the example type of 12 V batteries. It is usually able to last at least eight hours during normal use. The batteries are often recharged with an on-board charger that can be plugged into any conventional wall outlet. An alternative way for AGVs to operate around the clock is a power system that uses batteries that are easily swapped out and can be recharged anywhere [19].

As a result, Arduino Uno is selected as the microcontroller to control the AGV that will be synchronizing with input Infrared Sensor and output DC motor that is discussed above. The high power DC motor is selected along with a BTS 7960 motor driver to control the smooth movement of AGV.

CHAPTER 3

METHODOLOGY

3.1 Overview

The procedure of developing and designing an AGV is a complex process. There will be various issues which directly impact the design of the AGV that was explained before. These issues are not only on hardware but also software issues.

The aim of this project is to investigate the parameter involve that can be used to be implemented in AGV. In this part, several related calculations about the component and hardware in this development of AGV are shown. Other than that, it is to design a control algorithm for a smooth AGV operation system. The control algorithm will be applied with the Arduino UNO Controller to control the operation of AGV.

This project is also to develop an AGV prototype by using Arduino Uno microcontroller as control unit in AGV operation system then the analysis can be done properly in completion of this project.

3.2 AGV Design Parameter

For this part, there are several design parameters that will be considered for the development of heavy-duty Automated Guided Vehicle (AGV). Firstly, the chassis design and size of AGV component will be stated here. It must be well planned in order to build a heavy-duty Automatic Guided Vehicle (AGV) and determine its parameter. Besides, the calculation of motor selection will be discussed here in order to select a suitable DC Motor for the AGV.

3.2.1 Selection of DC Motor

A direct current (DC) motor consists of a set of magnets, rotor coil, and commutator. When the current is applied to the rotor coil, it will turn into an electromagnet and repel the magnets. The commutator causes the current in the rotor coil to switch polarity as it rotates. This polarity switch causes the rotor coil to repel the magnets and generate continuous torque. Speed in a DC motor is proportional to the voltage applied to the rotor. The power produced by the motor is proportional to the voltage multiplied by the current.

To select the size of motor for this AGV, there will be several parameters that should be defined. It consists of weight (w), maximum target speed (s), maximum degree incline to climb (ϴ), the acceleration (a) and the drive wheel diameter (r) of an AGV. The designed parameter must be defined roughly in order to determine the type of motor used. In this part, the calculation of selecting the DC motor will be shown.

Firstly, need to calculate the required torque of the DC Motor that will be attached with the AGV. The free body diagram in Figure 3.1 roughly shows the forces working in parallel to the inclined surface. It should be assumed that the AGV will move from rest and need to accelerate up the incline to full speed.

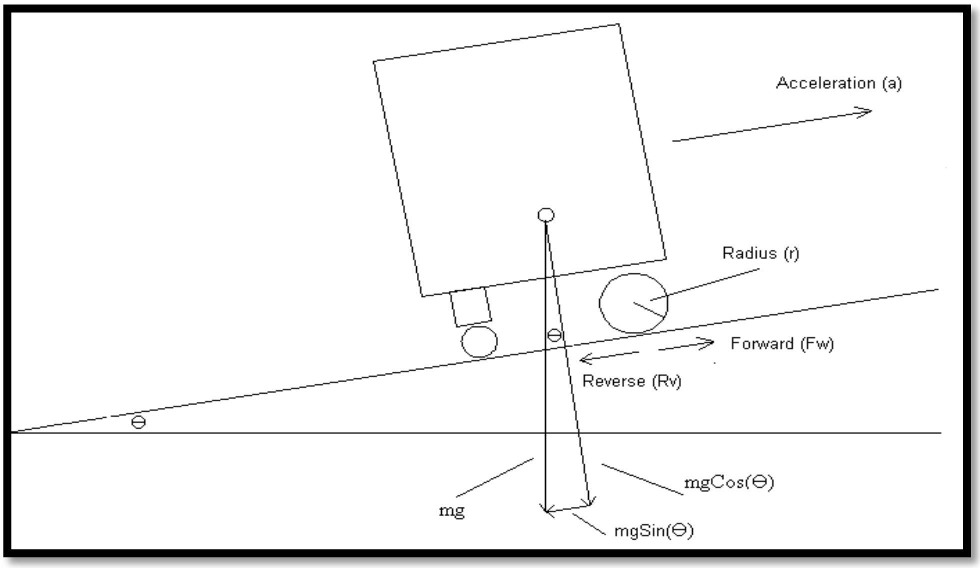


Figure 3.1: Free Body Diagram of AGV Movement [21]

For the calculation of torque,

$$\boldsymbol{Torque, T = Fw\ x\ r}$$ **--------------------------------Equation (3.1)**

As shown in Equation 3.1, Fw is the force pushing against the wheel and r is the radius of the wheel. In physics, all forces must balance which gives the equation:

$$\boldsymbol{\sum \text{Forces} = 0}$$ **--Equation (3.2)**

If the AGV is moving at a constant speed, the summation of all forces will equal zero**.**

$$\boldsymbol{\sum \text{Forces} = \text{Ftotal} = \text{Fw} - \text{Fg} = 0}$$ **---------------Equation (3.3)**

Where Fg is the force pulling AGV down incline due to gravity. To properly size the DC Motor, it should be focus on the situation where the robot is accelerating from rest to full speed. This is where the size of motors to be large enough to get the task done. The torque required to get the AGV moving can be much greater than keeping it in motion.

In this case, as shown in Equation 3.4, the summation of the forces acting of the AGV will equal the total mass multiplied by acceleration.

$$\boldsymbol{\sum Forces = Ftotal = Fw - Fg = Ma}$$ **---------- Equation (3.4)**

$$\mathbf{Fw = Ma + Fg} \quad \text{------------------------------------} \textbf{ Equation (3.5)}$$

$$\frac{\mathbf{T}}{\mathbf{r}} = \boldsymbol{M(a + gsin\Theta)} \quad \text{---------------------------------} \textbf{ Equation (3.6)}$$

Finally,

$$\boldsymbol{T = M(a + gsin\Theta)r} \quad \text{-----------------------------} \textbf{ Equation (3.7)}$$

Where,

M = mass of AGV (Kg)
a = acceleration of AGV (m/s^2)
g = the gravitational force (m/s^2)
ϴ = the degree inclined of AGV (ϴ)
r = is the radius of wheel (m)

The calculated torque value represented the total torque required to accelerate the AGV moving incline. However, as shown in Equation 3.8, the value must be divided with the total number of drive wheel to obtain the torque needed for each drive motor. In this project, two drive motor is needed to drive the AGV.

$$\boldsymbol{T = \frac{M(a+gsin\Theta)r}{2}} \quad \text{---------------------------------} \textbf{ Equation (3.8)}$$

The final part that should be considered is the efficiency of the motor. The value of efficiency must be defined. In this case, 70% efficiency is choosing because in motor design, the better efficiency is in between 70% - 90%. It is crucial for the motor to achieve 100% efficiency.

$$\boldsymbol{T = \frac{M(a+gsin\Theta)r}{2} x \; \% \; efficiency} \quad \text{--------} \textbf{ Equation (3.9)}$$

Next, the speed of the motor must be determined to observe how fast the rpms the motor will need to turn.

$$\boldsymbol{Speed, s = \frac{\left(\{Velocity, V \; (in \frac{inch}{sec})\right)}{2x \; \pi \; x \; [r \; (in \; inch)]}} \quad \text{--------------------} \textbf{ Equation (3.10)}$$

Finally, to determine how much power the motors are required to supply, the following equation should be used,

$$P = Torque\ , T\ x\ Angular\ Velocity\ (w)$$ ------------- **Equation (3.11)**

Angular velocity (w) is measured in radians per second (rad/sec) where,

$$One\ revolution = 2x\ \pi\ \ radians$$ ---------------------- **Equation (3.12)**

To calculate the value of an angular velocity, w the formula below should be considered,

$$w = s\ \left(\frac{rev}{\min}\right) x\ 2\pi\ \left(\frac{Rads}{sec}\right) x\ \frac{1}{60} \left(\frac{min}{sec}\right)$$ --------------- **Equation (3.13)**

After all the details calculation for the selection of motor are acquire, the performance of DC Motor can be analyse from the speed-torque curve as shown in Figure 3.2 below is to select the correct type of DC Motor that should be used in the AGV.

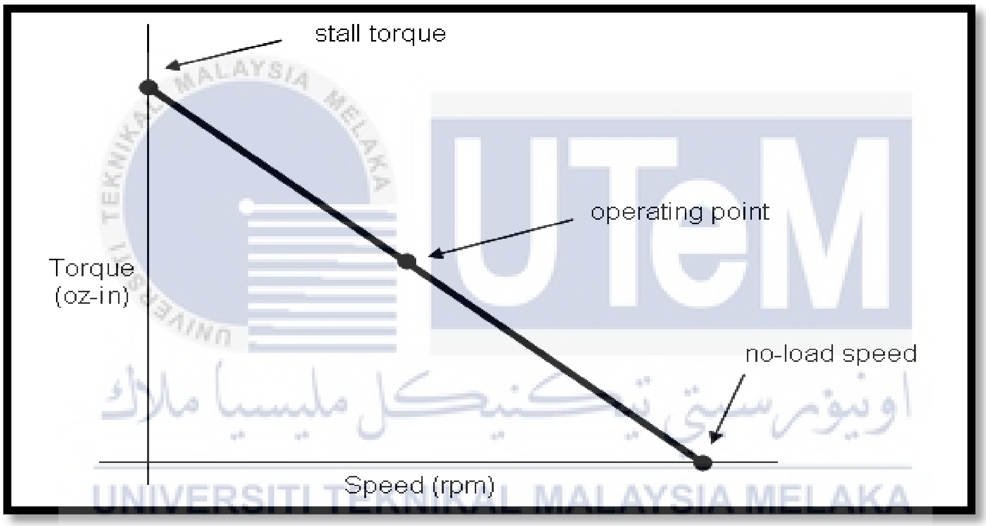


Figure 3.2: Speed – Torque Curve Graph

In order to obtained the value of current for each motor, the following relation is needed,

$$Current, I = \frac{Torque,T\ x\ angular\ velocity,w}{supply\ voltage,V}$$ --------- **Equation (3.14)**

For selection for suitable power supply used for the motor, the capacity of battery pack required can be estimated by using the following relation.

$$Capacitive, c = I\ x\ t$$ ------------------------------------ **Equation (3.15)**

Where, I is the value of current of the motor and t is the desired time for the battery usage.

3.3 System Operation

The sensor and guidance in system operation will be discussed. An overview about this component will be shown here.

3.3.1 Sensor

Infrared obstacle avoidance sensor is designed for the wheeled robot to avoid obstacle. Moreover, this sensor can be implemented in various applications, such as used in line follower robot. The principle of operation of an infrared sensor in line following robot is based on infrared light that is reflected when hitting a black or white tape. As shown in Figure 3.3, an IR receiver captures the reflected light from the white tape and the voltage are measured based on the amount of light received.

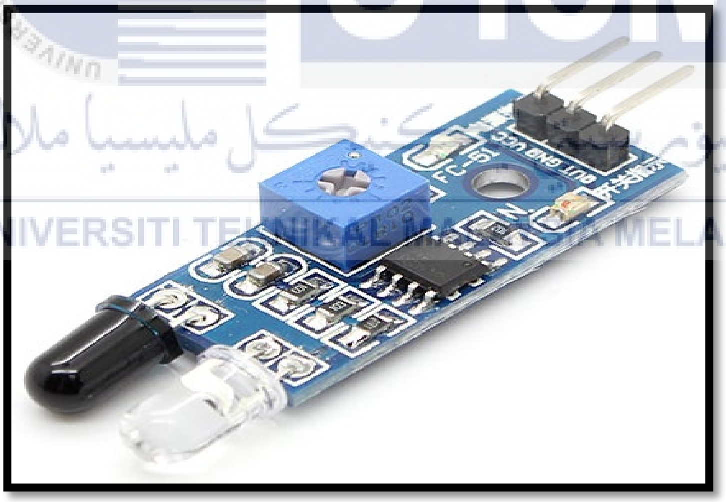


Figure 3.3: Infrared (IR) Obstacle Avoidance Sensor Module

In this development of automatic guided vehicle (AGV), this sensor will act as tracking and obstacle avoidance sensor. After the sensor detects the correct path, the AGV will move accordingly through the part by the detection and tracking of the sensor.

3.3.2 Guidance System of AGV

In this development of Heavy-duty Automatic Guided Vehicle (AGV), the tape guidance technology has been chosen. It is the technology where the floor is attach with a white tape or black tape to represent the guide path. As usual, the guide path sensor is mounted on the vehicle.

As shown in Figure 3.4, the sensor will detect the black path or white path (which can be set in the microcontroller) and the AGV will move accordingly through the path. This system has been mostly used in an AGV Manufacturing Industry.

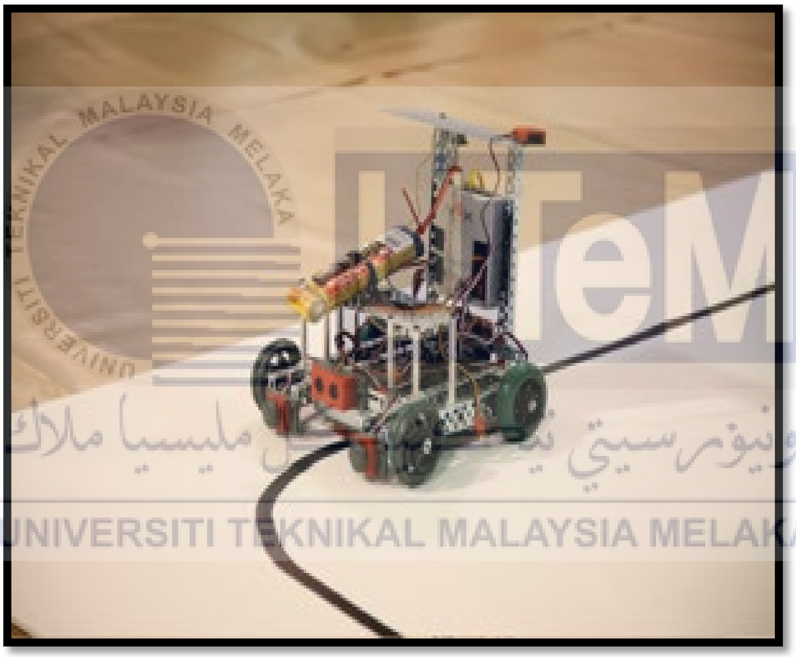


Figure 3.4: Example of Inductive Guidance Technology AGV [20]

3.4 Control Medium of AGV

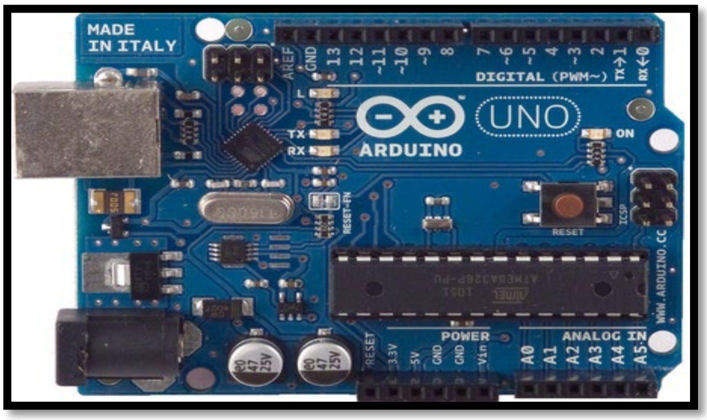


Figure 3.5: Arduino UNO Microprocessor

In the development of this AGV, Arduino UNO as shown in Figure 3.5 has been chosen as main microprocessor to control its process. This microprocessor will be synchronized with sensor as the input and DC Servo Motor as an output to control the direction of AGV. Figure 3.6 below shows the block diagram showing the brief connection and process of the sensor when implemented with Arduino Uno.

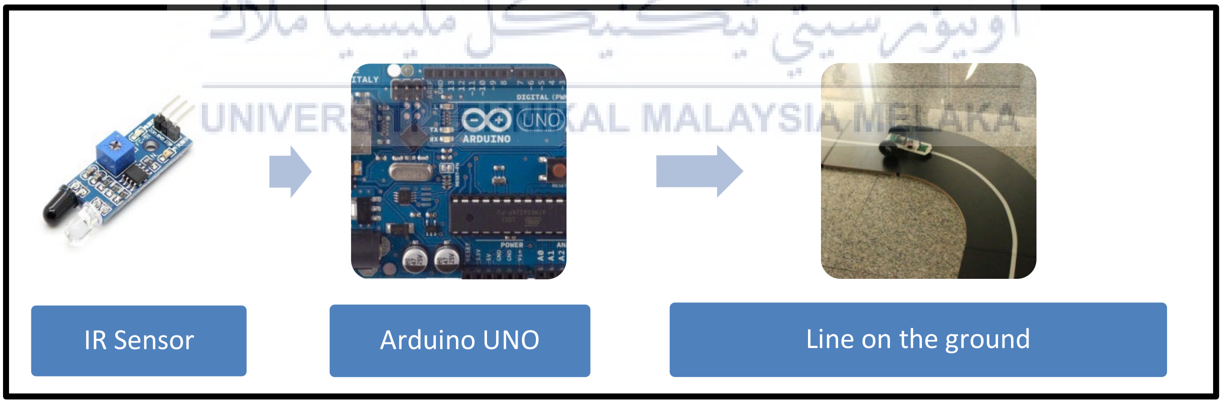


Figure 3.6: Block Diagram of Line Follower Sensor

H-Bridge will be another circuit configuration that will be synchronized with Arduino UNO to control the driver motor to move back and forward of the AGV. Figure 3.7 below is the block diagram showing the flow of the process. By using the H- Bridge, the movement of the DC Motor can be control either to control in forward and reverse direction or to control the speed of the motor.

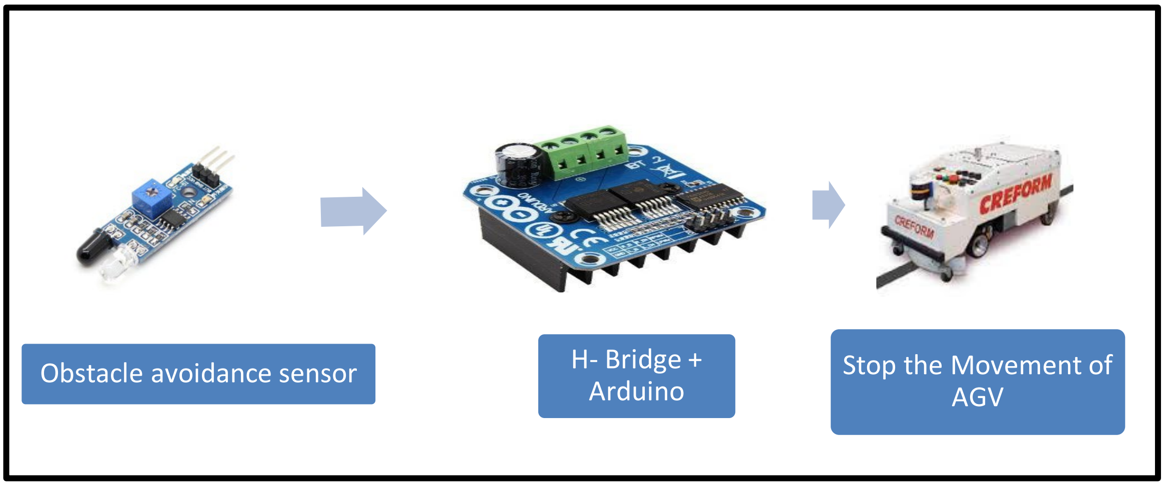


Figure 3.7: Block diagram of H-Bridge Motor Driver with Obstacle Sensor

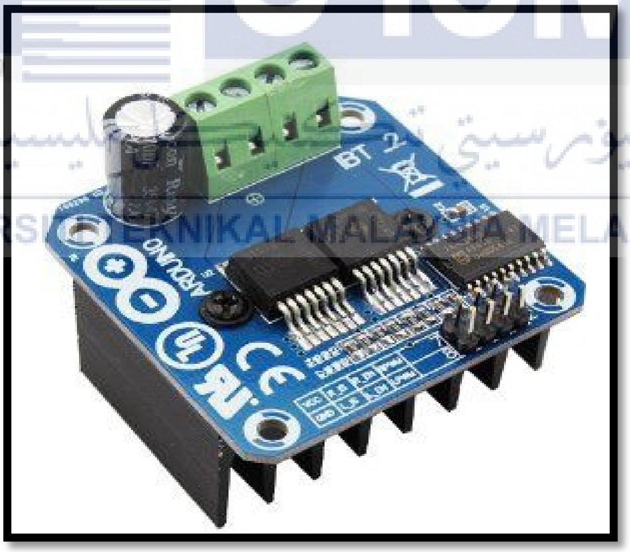


Figure 3.8: H-Bridge Motor Controller

The H-bridge that is shown in Figure 3.8 arrangement is generally used to reverse the polarity and direction of rotation of the motor, but it can also be used to stop the motor, where the motor comes to a sudden stop, as the motor's terminals are shorted or disconnected from the circuit.

3.5 Physical Model Development

For this project, the prototype of Automated Guided Vehicle (AGV) is builds with 1 meter length, 0.6 meter in width and about 0.3 meter height without load. The model of this AGV is made of heavy-duty steel material.

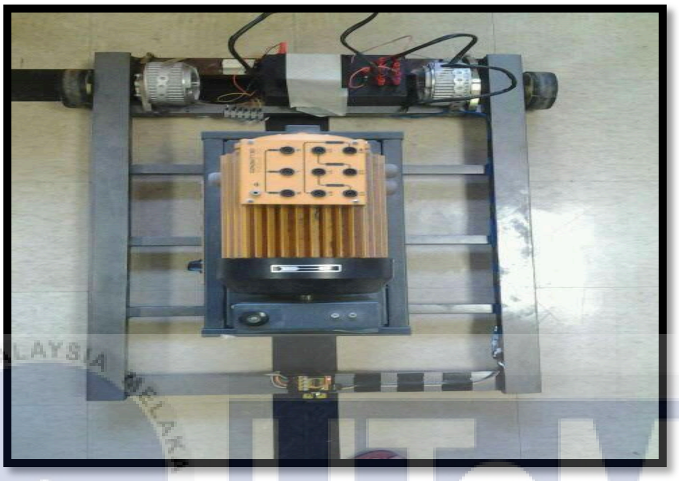


Figure 3.9: Top View of Designed AGV

Figure 3.9 shows the top view of designed AGV. There is three infrared sensor in-front of the AGV. Two of the sensor (left and right) is to control the movement of AGV and the other sensor that is attached in the middle is to stop the AGV whenever the sensor detects any object in-front. After the obstacle is removed, the AGV will move accordingly following the line.

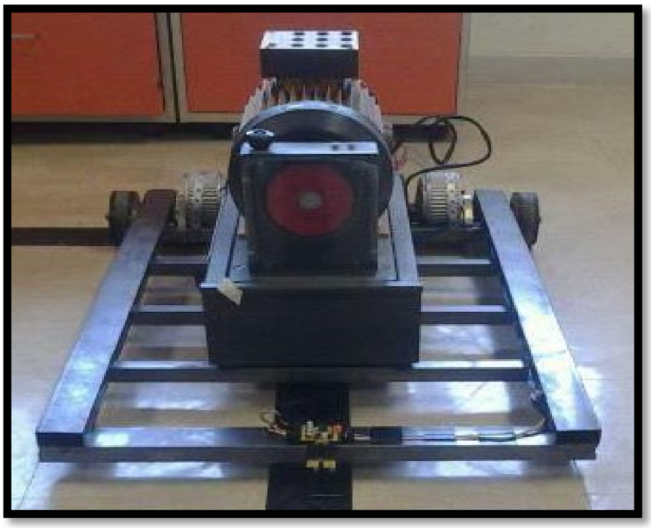


Figure 3.10: Front View of AGV

Figure 3.10 shows the front view of the designed AGV. There will be three IR sensor attached on the bottom front of the AGV. The sensor will detect the line on the ground then the AGV will move following the line. There will be two DC motors attached on the back wheel of the AGV. Each wheel will use one motor. Motor driver act as a driver to control the speed and direction of the AGV. Figure 3.11 shows the side view of AGV. A controller box will be attached on the back of the AGV. The microprocessor and power supply will be attached along with the controller box.

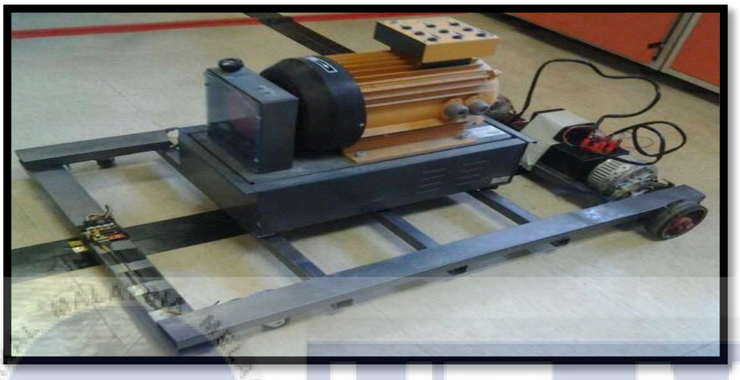


Figure 3.11: Side View of AGV

Table 3.1: Specification of Automatic Guided Vehicle (AGV)

Type of Material	**Body**	**Steel & Aluminium**
	Tyre	**Plastic Rims**
Size and dimension	**Length**	**1 m**
	Width	**0.6 m**
	Height	**0.3 m**
	Weight	**8 kg (without load)**
Tyre	**Diameter**	**5 inch**

Table 3.1 above shows the specification of Automatic Guided Vehicle (AGV) that is being used in the development of AGV. As being stated above, the value should be the same in the completion of the development of heavy-duty Automatic Guided Vehicle.

3.6 Controller Algorithm

The controller used is Arduino Uno Microcontroller and a BTS 7960 Motor Driver to control the movement of AGV along with the IR Sensor as an input of the microcontroller. The AGV will move accordingly through the line when the sensor not detecting the black tape. If the sensor slip off from the line depends on which sensor, it will send the signal to motor driver to control the motor so that the AGV move back into the line. Figure 3.12 below shows the flow chart of the control algorithm.

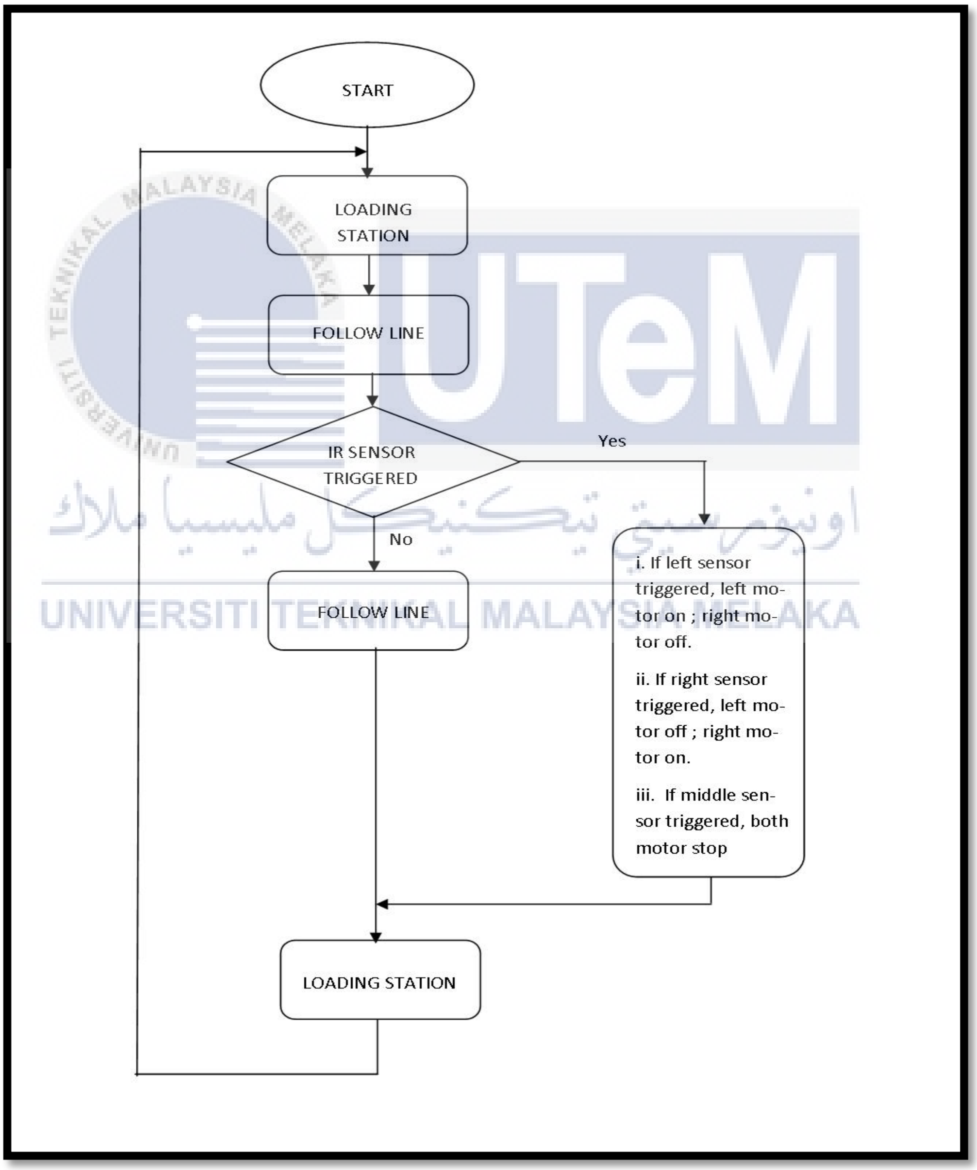
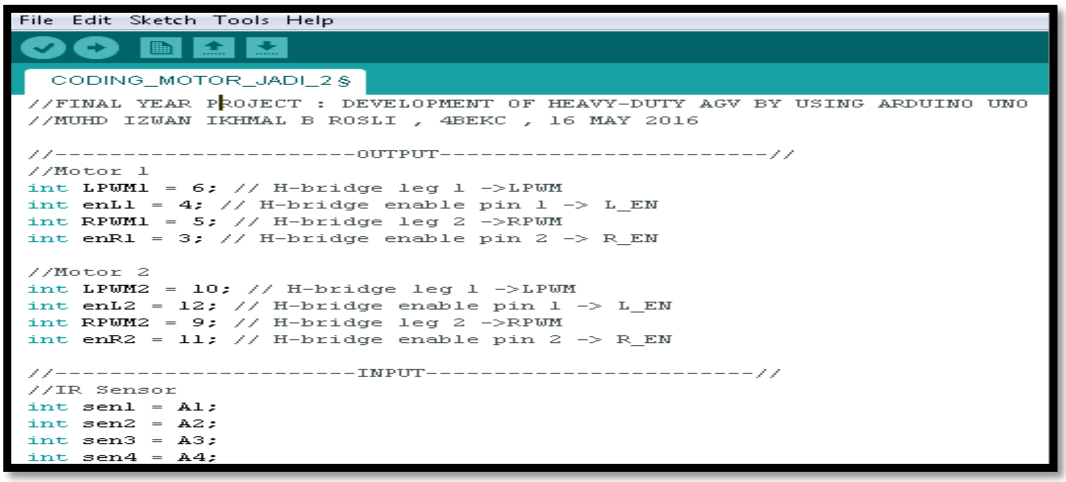


Figure 3.12: Flow Chart of Control Algorithm

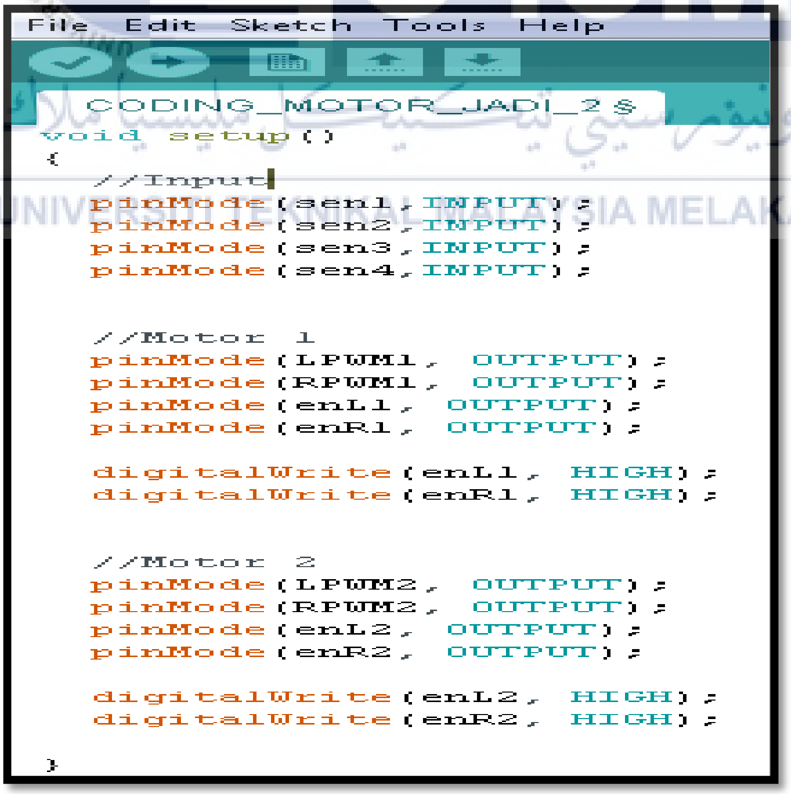
For the programming part, C-programming language is being implemented with the Arduino Compiler software. Figure 3.13 below shows the list of input and output of the AGV that is declared in the system.



```
File  Edit  Sketch  Tools  Help
CODING_MOTOR_JADI_2 §
//FINAL YEAR PROJECT : DEVELOPMENT OF HEAVY-DUTY AGV BY USING ARDUINO UNO
//MUHD IZWAN IKHMAL B ROSLI , 4BEKC , 16 MAY 2016

//-----------------------OUTPUT------------------------//
//Motor 1
int LPWM1 = 6; // H-bridge leg 1 ->LPWM
int enL1 = 4; // H-bridge enable pin 1 -> L_EN
int RPWM1 = 5; // H-bridge leg 2 ->RPWM
int enR1 = 3; // H-bridge enable pin 2 -> R_EN

//Motor 2
int LPWM2 = 10; // H-bridge leg 1 ->LPWM
int enL2 = 12; // H-bridge enable pin 1 -> L_EN
int RPWM2 = 9; // H-bridge leg 2 ->RPWM
int enR2 = 11; // H-bridge enable pin 2 -> R_EN

//-----------------------INPUT------------------------//
//IR Sensor
int sen1 = A1;
int sen2 = A2;
int sen3 = A3;
int sen4 = A4;
```

Figure 3.13: Input & Output in the Algorithm

Figure 3.14 below shows the void setup of the algorithm to make the system write the system properly in the void loop section.



```
File  Edit  Sketch  Tools  Help
CODING_MOTOR_JADI_2 §
void setup()
{
  //Input
  pinMode(sen1,INPUT);
  pinMode(sen2,INPUT);
  pinMode(sen3,INPUT);
  pinMode(sen4,INPUT);


  //Motor 1
  pinMode(LPWM1, OUTPUT);
  pinMode(RPWM1, OUTPUT);
  pinMode(enL1, OUTPUT);
  pinMode(enR1, OUTPUT);

  digitalWrite(enL1, HIGH);
  digitalWrite(enR1, HIGH);


  //Motor 2
  pinMode(LPWM2, OUTPUT);
  pinMode(RPWM2, OUTPUT);
  pinMode(enL2, OUTPUT);
  pinMode(enR2, OUTPUT);

  digitalWrite(enL2, HIGH);
  digitalWrite(enR2, HIGH);

}
```

Figure 3.14: Void Setup in the Algorithm

Figure 3.15 shows the void loop section of the algorithm used to implement the system that is wrote in the flowchart shown on Figure 3.12 before.

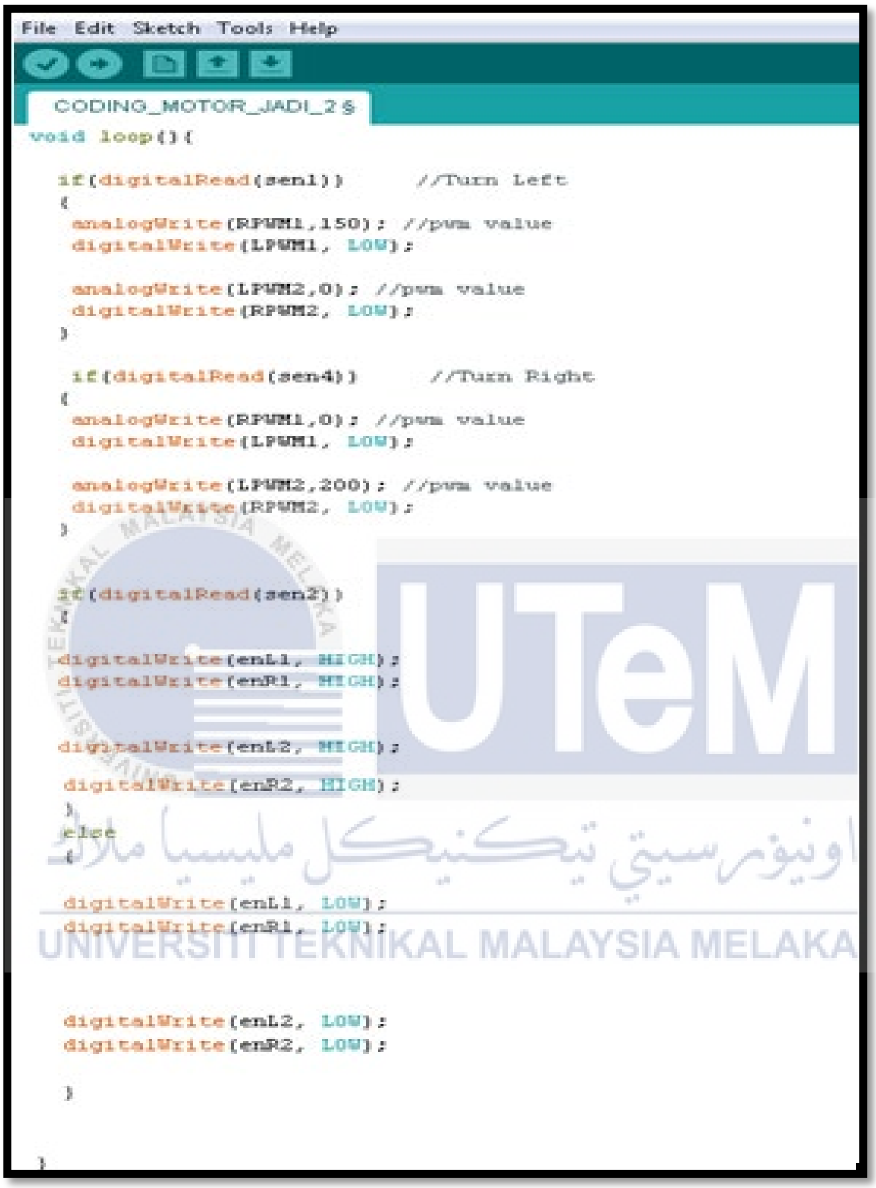


Figure 3.15: Void Loop in the Algorithm

The algorithm act to control the movement of AGV smoothly and accordingly as follow the flowchart constructed.

3.7 Product Testing

This section will discuss about how the test of the end product is conducted. All the parameters that are considered before have been implemented in this designed AGV.

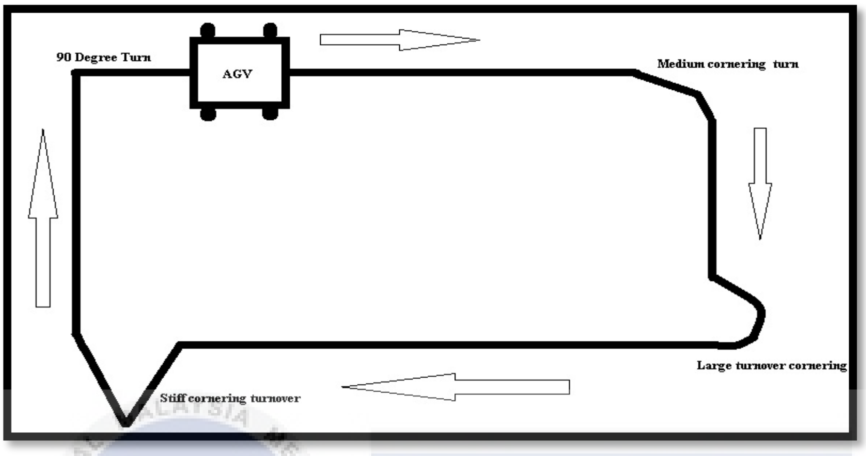


Figure 3.16: The Track Anatomy for Testing the AGV

Figure 3.16 shows the track anatomy for testing the AGV on track. The track is about 18m long including the cornering. On this track, there are several parameters that had been taken in order to test the performance of the AGV. The test including the time taken for a 90 degrees turn, medium cornering turn, large cornering turn and stiff cornering turn.

Besides during the cornering, the effective degree of the turn on each cornering is also being observed in order to analyse the AGV to move accordingly through the line. The time taken for the AGV to complete the whole track is also being observed including with two types of load (25kg & 10kg load). In addition, the speed of the AGV is also being adjusted into several speeds on the Arduino Uno Microcontroller. The speed is controlled by the motor driver by using the Pulse Width Modulation (PWM) technique.

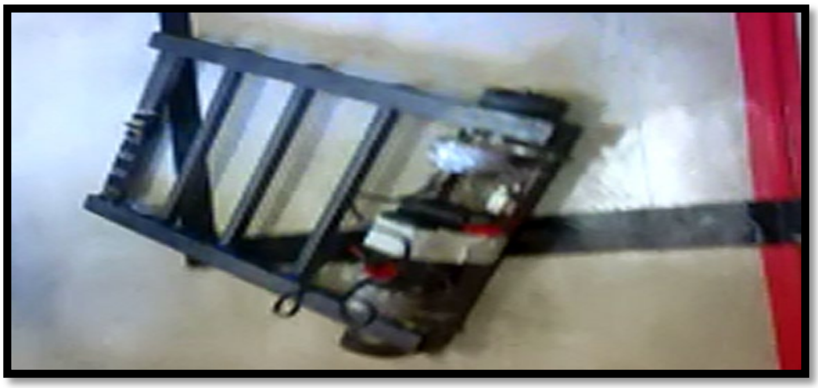


Figure 3.17: 90 Degrees Cornering with No Load Test

Figure 3.18: 90 Degrees Cornering with 25kg Load Test

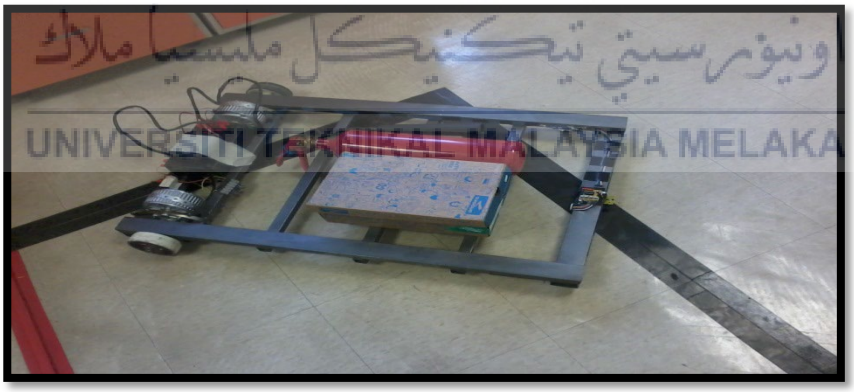


Figure 3.19: 90 Degree Cornering with 10kg Load Test

Figure 3.17, Figure 3.18 and Figure 3.19 show the testing of 90 degree cornering with 10 Kg load , 25 Kg load and no load test. During the test, the degree of cornering is being observed because the different in load affect the speed and cornering of the AGV.

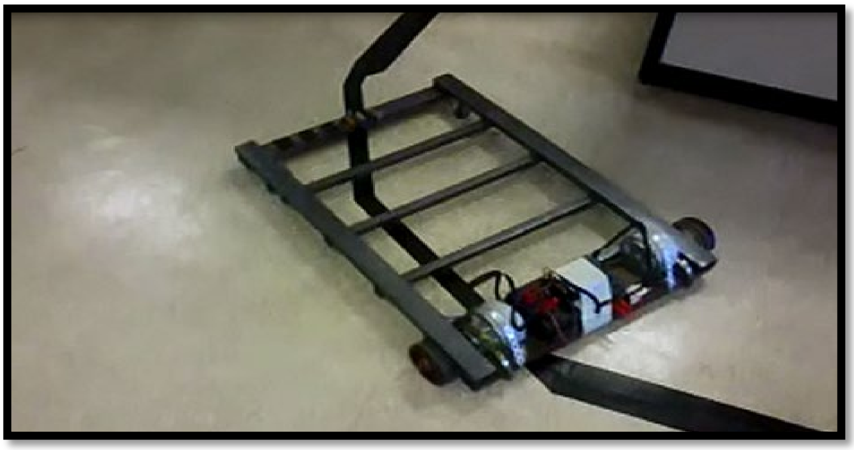


Figure 3.20: Medium Cornering with No Load Test

Figure 3.21: Medium Cornering with 25kg Load Test

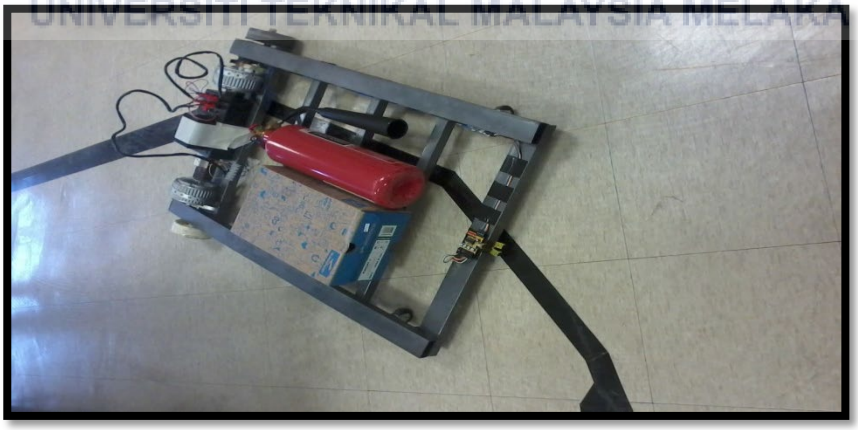


Figure 3.22: Medium Cornering with 10kg Load Test

Figure 3.20, Figure 3.21 and Figure 3.22 show how the test of AGV movement toward the medium cornering lane with different weight of load. During the test, the time is taken for the AGV to move along the medium cornering lane.

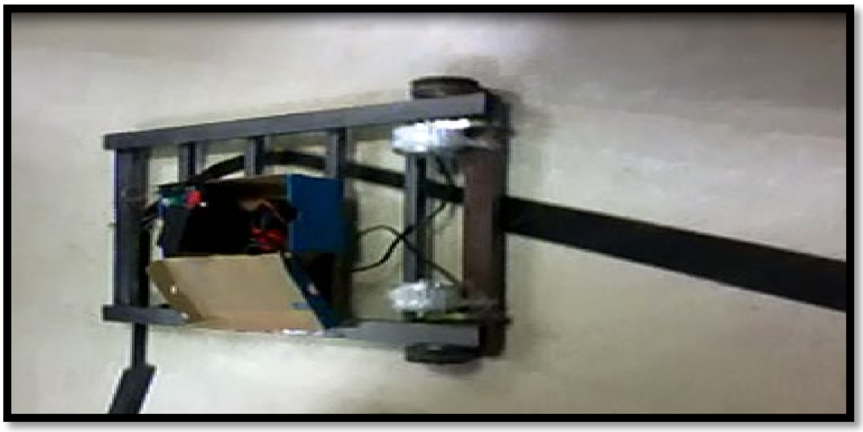


Figure 3.23: Large Turning Degree without Load Test

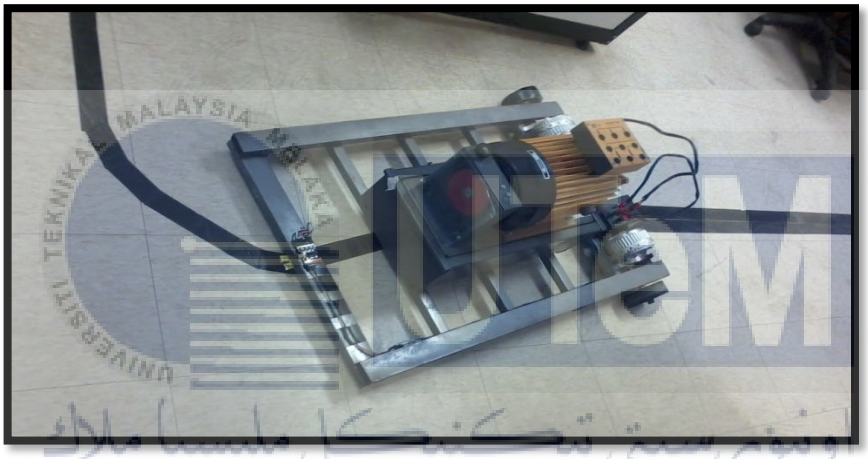


Figure 3.24: Large Turning Degree with 25kg Load

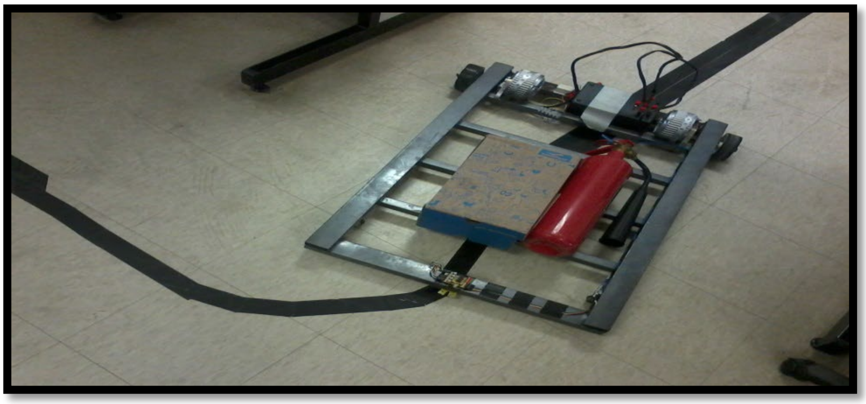


Figure 3.25: Large Turning Degree with 10kg Load

Figure 3.23, Figure 3.24 and Figure 3.25 shows the movement of the AGV on the large turning degree test with load and without load. This test is to observe how much time taken for the AGV to move along a large turning degree line.

Figure 3.26: Stiff Cornering without Load Test

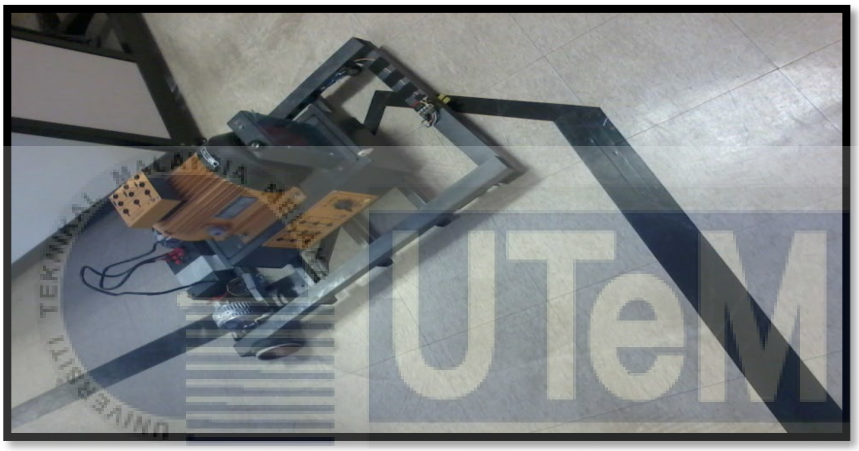


Figure 3.27: Stiff Cornering with 25kg Load Test

Figure 3.28: Stiff Cornering with 10kg Load Test

Figure 3.26, Figure 3.27 and Figure 3.28 shown above are the last test for AGV for the stiff cornering with and without load. The time is taken for the AGV to complete the stiff route to observing the performance of the AGV.

Hence, all the result and analysis findings will be discuss on the next chapter. Literally, the performance test that had been done helped to improvise this AGV in order to increase its performance into a high expectation device.

3.8 Project Development Flow Chart

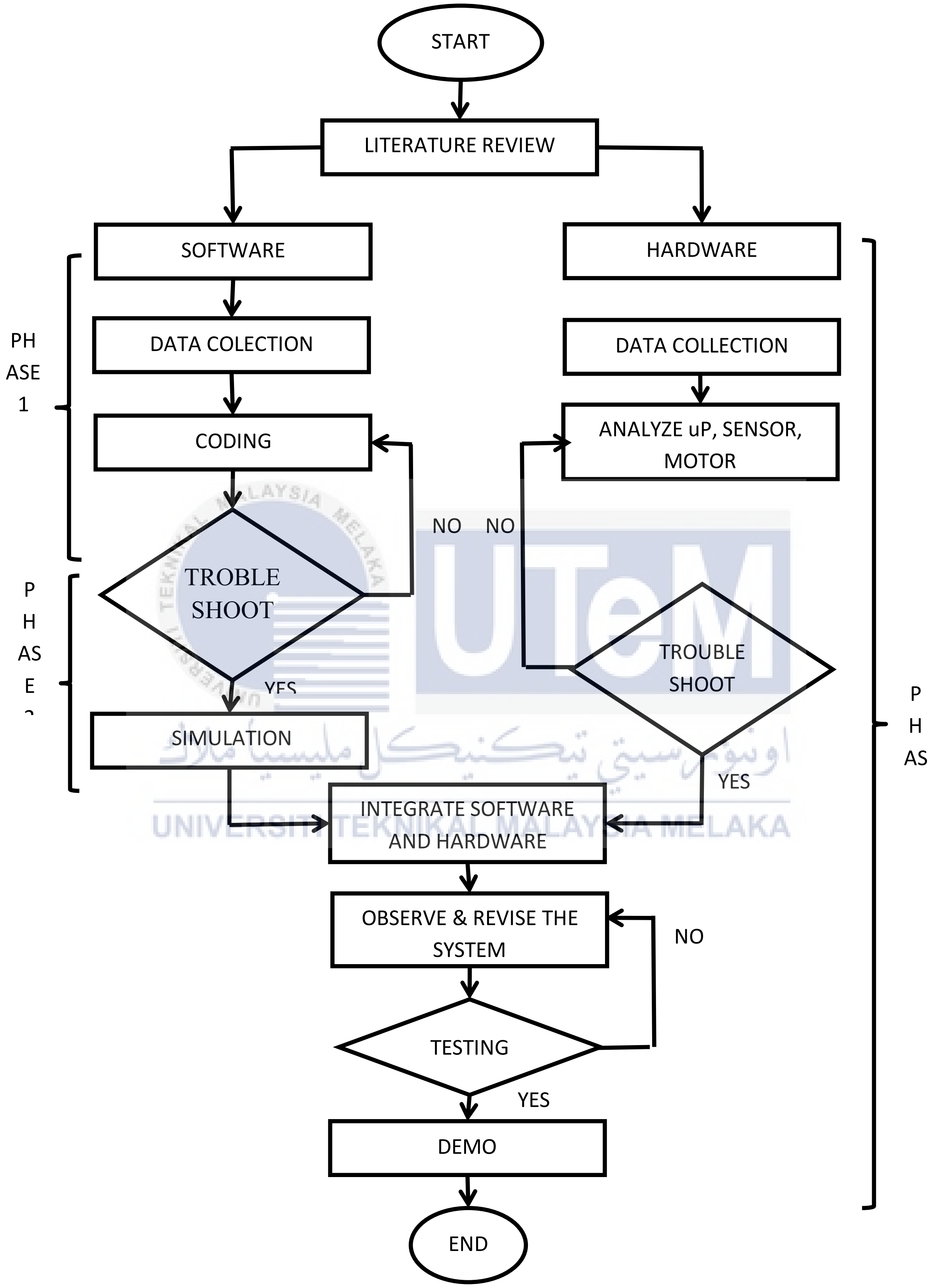


Figure 3.29: Flow Chart of Project Development

3.9 Gantt Chart

3.9.1 Semester 1

Activities	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14
Meeting with supervisor to assign as his student.														
Decide the Final Year Project (PSM) topics. - Discuss about the project about the overview how to complete the project. - Decide when to meet each week.														
Chapter 1: Introduction - Briefing session - Refer to the report criteria about what should have in the Introduction part. - Discuss about the content and format for the introduction part.														
Chapter 2 : Literature Review - Submit Chapter 1 for SV checking. - Briefing session for chapter 2 - Refer to the report criteria about what should have in the literature review part. - Discuss on the content should have in the part. - Discuss on the research paper in the completion of this part.														
Chapter 3 : Methodology - Submit chapter 2														

for SV checking - Briefing session - Refer to the report criteria about what should have in the methodology part. - Discuss on the content should have in the part.														
Chapter 4 : Result - Submit chapter 3 for SV checking - Briefing session - Refer to the report criteria about what should have in the result part. - Discuss about the progress of the project for this semester - Brainstorming about the how to test the project on the field later on. - Do calculation for the result part.														
Chapter 5 : Conclusion - Submit chapter 4 for SV checking - Briefing session - Refer to the report criteria about what should have in the conclusion part.														
- Submit chapter 5 for SV checking. - Discuss about the previous report and do correction for a little bit.														
Full report submission to panel														
Presentation														

3.9.2 Semester 2

Activities	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14
Meeting with supervisor in order to completed next objective.														
-Proceed to the next step for development of AGV. - Discuss about the project overview how to complete the project. - Decide when to meet each week.														
- Start the development of AGV. - Develop a small testing AGV. - Do some testing for small application of AGV - Make some recommendation for the real development of AGV.														
- Development of the physical model of AGV. - Design the physical model based on the desired spec by using design software - Build up the prototype of the actual AGV. - Do some manufacturing work to suit the motor used with the AGV prototype. - Test the mechanical part of the AGV. - Test the robustness of the AGV.														

- Development of coding for the microprocessor based on the flow chart of the system. - Compile the coding in the microprocessor - Test the system on the desired track. - Do a checking if there is problems occur. - Completed the full report for the project.														
- Do a project cosmetic. - Test the product on another field. - Submit full report for the project to SV for checking.														
Full report submission to panel														
Presentation														

CHAPTER 4

RESULT

4.1 Overview

This chapter discusses the findings that had been completed throughout the final year project. As in the all objective of this project, the parameters involved, the control algorithm, the AGV prototype and the performance analysis is achieved.

4.2 AGV Design Parameters

The development of AGV includes the sizing of the DC motor that will be use. All of the following is defined in order to select the DC motor:

Table 4.1: Specification of AGV

Specification	
Weight of the AGV (include expected load)	30 kg
Maximum velocity of AGV	720 inch/min = 0.3048 m/s
Maximum incline to climb by AGV	10 degrees
Acceleration of AGV	0.3 m/s^2
Diameter of Drive Wheel	5 inch / 0.127 m

4.2.1 The Value of Torque

The torque equation includes the expected maximum inclined on the surface. This is to ensure the AGV can move if the surface which the AGV will operate is not purely horizontal. The equation of the torque is as follow:

$$\boldsymbol{T = m(a + g sin\theta)r} \qquad \textbf{; The radius is in meter, m}$$

$$\boldsymbol{T = 30(0.3 + (9.8) sin10) \times 0.0635 = 3.813\ N.m}$$

Since the value is for 100% efficiency, the DC motor must be considered not to have 100% efficiency due to factors like gearing and slip during operation. For the DC motor to have optimal performance, the minimum efficiency is 70%. The calculation below has been included with the 70% of efficiency.

$$\boldsymbol{T = [m(a + g sin\theta)r] \times \left[\frac{100}{e}\right]} \quad \textbf{: e = efficiency in \%}$$

$$\boldsymbol{T = (3.813\ N.m) \times \left(\frac{100}{70}\right) = 5.447\ N.m}$$

The torque value is the total torque needed for the AGV to navigate and carry the total weight of 30kg. Since the AGV use two drive DC motor the torque will be divided by two which is the value is:

$$\boldsymbol{T = (5.441\ N.m) \div 2 = 2.724\ N.m}$$

This torque value is for each of the DC motor. So the AGV will have two DC motor that have the value of 2.724 $N.m$ torque each.

4.2.2 The Value of Speed

The speed of the DC motor is given in revolutions per minute (rpm). The equation of the speed is given by:

$$\frac{Rev}{Min} = \left[\frac{velocity}{\pi} \times Diameter\ of\ Drive\ wheels\right]$$

$$;\ velocity\ and\ diameter\ is\ measured\ in\ inch$$

With the equation, the speed of the DC motor in rpm can calculated. The calculation of the speed is as follow:

$$\frac{Rev}{Min} = \left[\frac{720}{\pi} \times 5\right] = 46\ rpm$$

As the speed of motor is 46 rpm, the motor selection can be made near the speed value or exactly as the speed value calculated.

4.2.3 The Value of Power

The power is rated in watts and also in horsepower. The power of the DC motor is calculated using the following equation:

$$P = T \times \omega$$

$$\omega = angular\ velocity$$

The value of the angular velocity is measured in radians per second. Form the speed value, the angular velocity of the motor can be determined using the following equation:

$$1\ Revolution = 2\pi\ \text{radians}$$

$$\omega = \frac{Rev}{Min} \times \frac{2\pi\ Rad}{1\ Rev} \times 1\frac{min}{60}sec$$

$$\omega = 46\ rpm \times \frac{2\pi}{60} = 4.817\ rad/s$$

Since the value of angular velocity is determined, the value of power can be determined using the equation of the power.

$$P = 2.724\ N.m \times 4.817\frac{rad}{s} = 13.12\ watts$$

The value of power is for each of the motor. The selection of motor will be based on this value. The power also rated in horsepower (hp) and the value of power in hp is given as:

$$1\ hp = 746\ watts$$

$$P = \frac{13.12}{746}hp = 0.01759\ hp$$

4.2.4 The Total Value of Current and Capacity of Battery

The current value can be determined by using the power and voltage relationship.

$$P = I \times V$$

So the current is given by:

$$I = \frac{P}{V}$$

The voltage supply is determined between 12V and 24V. Both of voltage supply value is calculated to see the different in the total current use when two different voltage supplies is used.

$$V = 12\ V : I = \frac{13.12\ w}{12\ V} = 1.093\ A$$

$$V = 24\ V : I = \frac{13.12\ w}{24\ V} = 0.547\ A$$

The calculation shows that when using higher voltage supply value, the current that will be use is lower. Because of that, the higher rated voltage value is chosen for the battery as the voltage supply.

The capacity of the battery that will be use can be determine when the total current value is calculated. The equation for the battery capacity is as follow:

$$\boldsymbol{C = I \times t}$$

Since the battery is rated as ampere-hour (Ah), the desired time for the calculation is in hour unit. The estimated time for the operation of the AGV will be about 5 – 6 hours. Take the maximum operation time which is 6 hours and the calculation of the battery capacity is as follow:

$$\boldsymbol{C = 0.547\ A \times 6\ hours = 3.282\ Ah}$$

The calculated Ah value is for one motor. So, the total capacity of the battery that need to be use for both of the motor is:

$$\boldsymbol{C = 3.282\ Ah \times 2\ DC\ motors = 6.564\ Ah}$$

The total capacity for the battery is 6.564 Ah. When select the battery pack, the suitable to choose is higher than the calculated capacity of the battery because the rated ampere-hours is usually not an accurate indicate of the maximum capacity that the battery can produce to be use for extended of time. By select a higher rated capacity of battery can ensure the AGV can be operated within the estimated operation time.

4.3 Simulation using PROTEUS

This part will show the simulation result which is basically illustrates the movement of motor when the sensor detects the line.

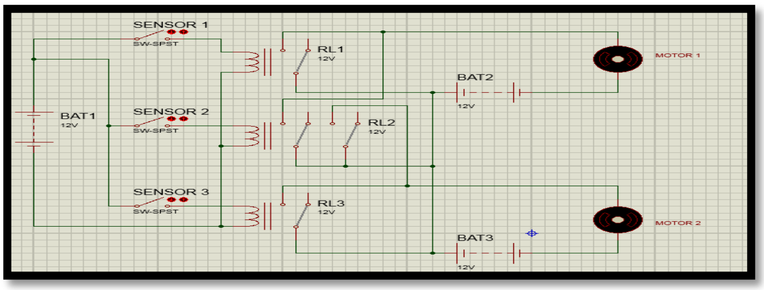


Figure 4.1: Schematic for the motor controller

Figure 4.1 shows the basic schematic for the motor controller. The briefly explanation about the process of movement of motor will be discussed below.

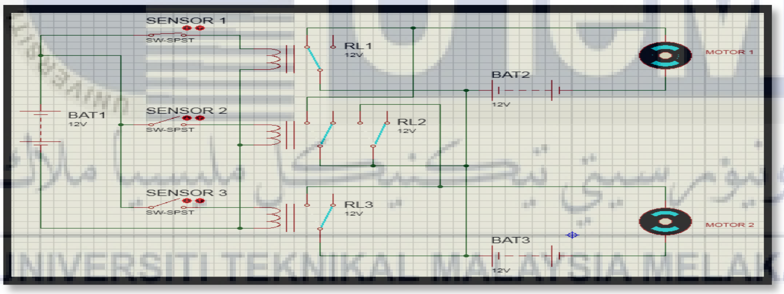


Figure 4.2: Sensor 1 Detect Line

As shown in Figure 4.2, when sensors 1 detect a line, motor 1 will spin. During this condition, the AGV will move directly to the right until other sensors detect the line.

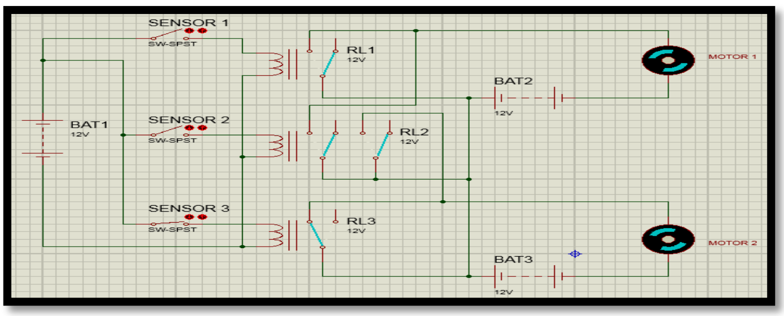


Figure 4.3: Sensor 3 Detect Line

As shown in Figure 4.3 above, when sensor 3 detect a line, motor 2 will spin. During this condition, the AGV will move directly to the left until other sensors detect the line.

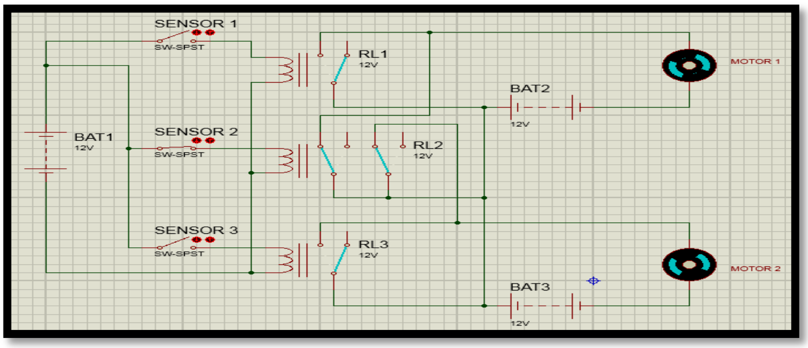


Figure 4.4: Sensor 2 Detect Line

As shown in the Figure 4.4 above, when sensor 2 detect the line, both motor will stop. During this condition, the AGV will stop until its meet the condition that has been explained before. Table 4.2 show the summary of the movement of AGV.

Table 4.2: Movement of AGV when Sensor Detect Line

Condition	Movement of AGV
Sensor 1 detect line	Move right
Sensor 2 detect line	Stop
Sensor 3 detect line	Move left

4.4 Analysis of AGV

This part will discuss about the analysis that has been done on the field to test the AGV movement. There are several parameters being considered in order to test the AGV whether it working perfectly or not. Arduino Uno is the main microcontroller that is used to control the motor driver and sensor of the AGV. With a proper algorithm, the AGV can be controlled perfectly as desired on the previous chapter.

4.4.1 The Speed Control Analysis

The speed control of AGV is based on the value of Pulse Width Modulation (PWM) involving with duty cycle value. A duty cycle is the percentage of one period in which a signal or system is active. Usually, this technique is implemented on the microcontroller to control the discrete signal. Figure 4.5 below shows the value of duty cycle with Pulse Width Modulation (PWM) value. The green lines represent a regular time period. This duration or period is the inverse of the PWM frequency. In other words, with Arduino's PWM frequency at about 500Hz, the green lines would measure 2 milliseconds each [22].

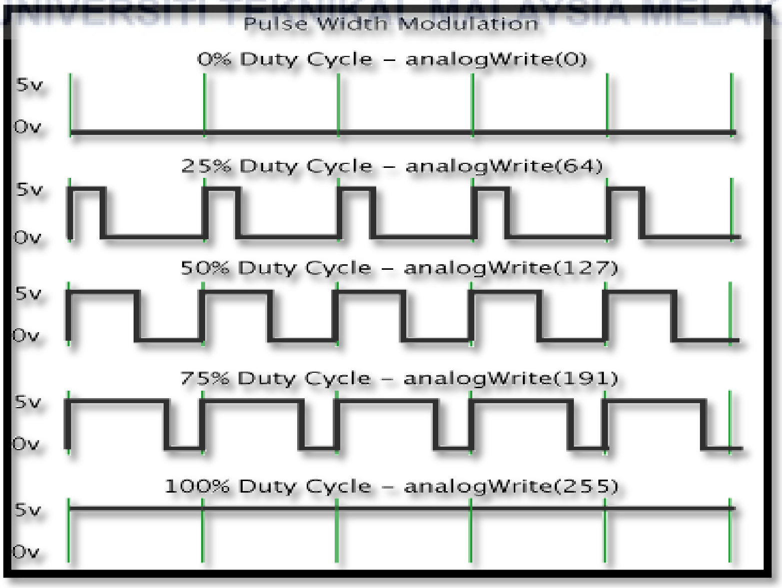


Figure 4.5: Value of Duty Cycle with Pulse Width Modulation (PWM)

Table 4.3 below shows the parameter involving calculating the speed of the AGV based on the value of Pulse Width Modulation (PWM).

Table 4.3: Parameter Value to Calculate the Speed of AGV

PWM	Duty Cycle (%)	Frequency (Hz)	Overall Time for frequency (s)	Speed (RPM)
255	100	500	1	60
240	94	470	0.94	56.4
160	62.6	313	0.626	37.5
80	31.3	156.5	0.313	18.78

Usually, the basic formula to calculate RPM for a motor is ;

$$RPM = (Total\ frequency\ time\ ) x\ 60$$

As stated above, the value of time per frequency is 2 ms. So ;

$$500Hz \times 2ms = 1s$$

$$470Hz \times 2ms = 0.95s$$

$$313Hz \times 2ms = 0.626s$$

$$156Hz \times 2ms = 0.313s$$

Hence, the value of the speed of motor in RPM is calculated below ;

$$1s \times 60 = 60\ RPM$$

$$0.95s \times 60 = 56.4\ RPM$$

$$0.626s \times 60 = 37.5\ RPM$$

$$0.313s \times 60 = 18.78\ RP$$

4.4.2 AGV Parameter Analysis

4.4.2.1 Experimental Setup at Unloaded Condition

The first parameter involve is how much the time taken for the AGV to complete a full loop track of 18 m with three different speed by controlling the Pulse Width Modulation (PWM) value. Table 4.3 shows the result that has been taken during the experiment.

Table 4.4: Speed vs Time Taken for 18m Loop

Speed (PWM)	Time Taken for 18m Loop
80	60s
160	55s
240	40s

Figure 4.6 below shows the response when the PWM is decreasing accordingly stated on the table 4.3. When the speed is decreased, the time taken for the AGV to complete the 18m loop is longer.

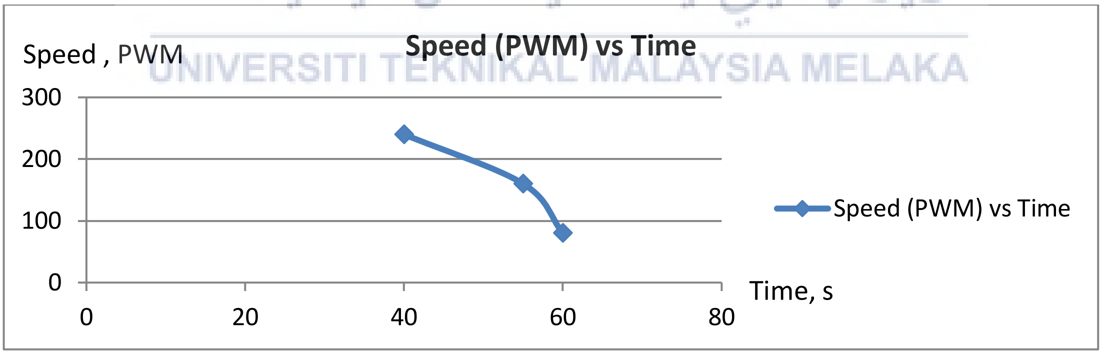


Figure 4.6: Speed (PWM) vs Time Taken for 18 m

The second parameter is how much the time taken for the AGV to move toward a four different type of detour. It consists of 90 degree cornering, medium cornering, large turn cornering and stiff cornering. In general, different cornering angle provide a different time taken for the AGV to complete the turn.

Table 4.5: Speed (PWM) vs Time Taken for 90 Degrees Turn

Speed (PWM)	Time Taken for 90 Degrees Turn
80	3s
160	2s
240	1s

Table 4.4 shows the result when the speed (PWM) is adjusted, how much the time taken for the AGV to complete the 90 degrees turn. Figure 4.7 below shows the response when the speed (PWM) is adjusted with different value when the AGV move toward 90 degrees turns. When the speed is increase, the time taken for the AGV to turn on 90 degrees detour is faster.

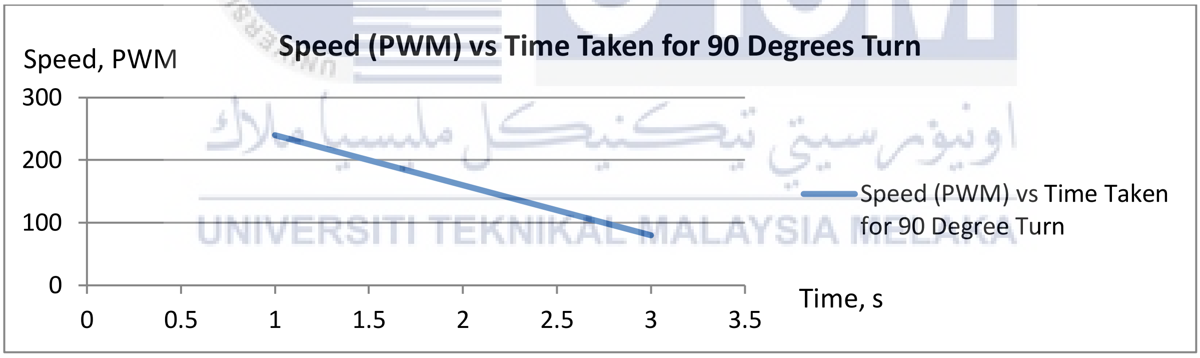


Figure 4.7: Speed (PWM) vs Time Taken for 90 Degrees Turn

The third parameter is for the medium cornering analysis; Table 4.5 shows the result taken during the experiment. It seems the medium cornering takes much time to turn compared to 90 degrees cornering.

Table 4.6: Speed (PWM) vs Time Taken for Medium Cornering

Speed (PWM)	Time Taken for Medium Cornering
80	2.8s
160	2.0s
240	1.2s

As shown in Figure 4.8, the faster the speed, the time taken for the AGV to take a cornering on a medium cornering is faster.

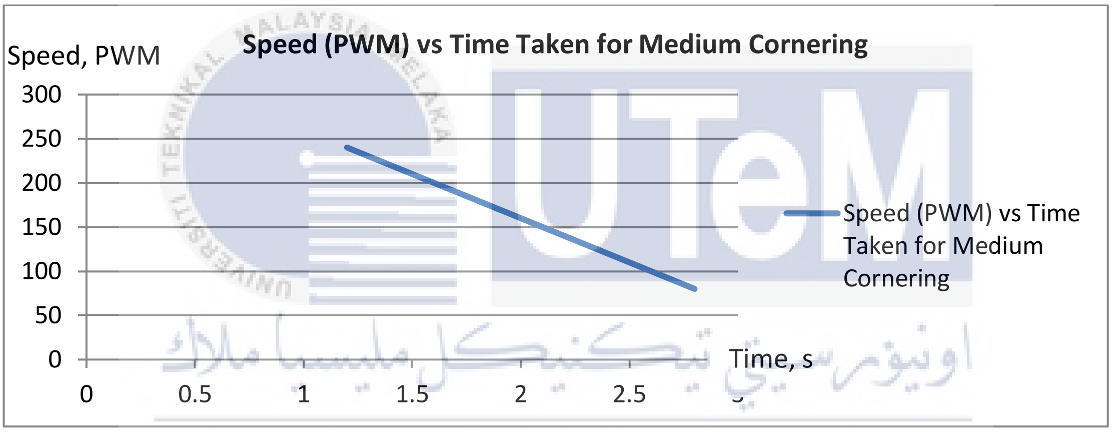


Figure 4.8: Speed (PWM) vs Time Taken for Medium Cornering

Another than that, the fourth parameter is for large turn cornering, as shown in Table 4.6, the time is taken for the AGV to complete the course of large turn cornering with different type of speed.

Table 4.7: Speed (PWM) vs Time Taken for Large Turn Cornering

Speed (PWM)	Time Taken for Large Turn Cornering
80	3.2s
160	2.7s
240	1.5s

As shown in Figure 4.9 below, it can be concluded that, the faster the speed, the time taken for the AGV to complete the large turn cornering is faster. However, the time is a little bit slower compared to the previous test.

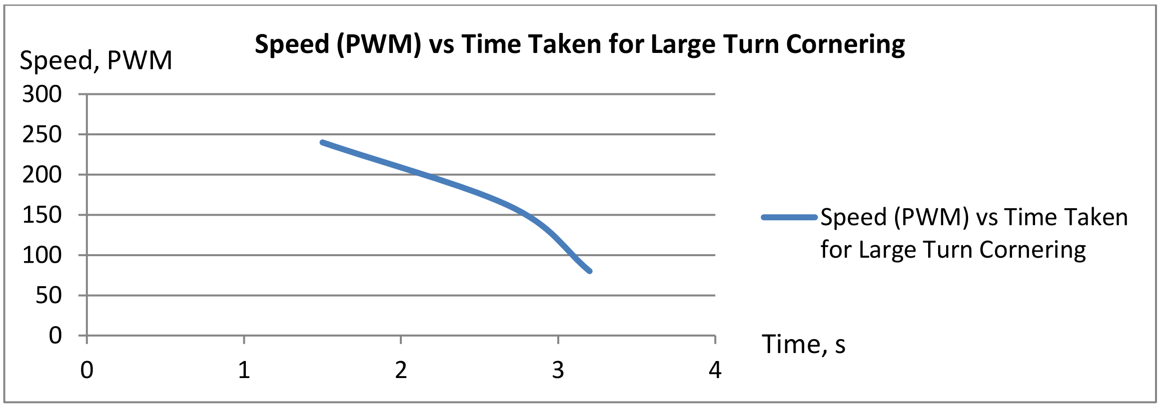


Figure 4.9: Speed (PWM) vs Time Taken for Large Turn Cornering

Lastly, for the fifth parameter is how much the time taken for the AGV with different speed to complete stiffs turn. As shown in Table 4.7, those are the result of time taken for large turn cornering during the experiment that has been carried out.

Table 4.8: Speed (PWM) vs Time Taken for Large Turn Cornering

Speed (PWM)	Time Taken for Large Turn Cornering
80	3.2s
160	2.7s
240	1.5s

Figure 4.10 shows the response when the speed (PWM) is adjusted with different value when the AGV move toward high degree turns cornering. AS the speed of AGV become faster, the faster the time taken for the AGV to complete the large turns cornering. However, the large turn cornering took more time compared to the previous experiment that has been done.

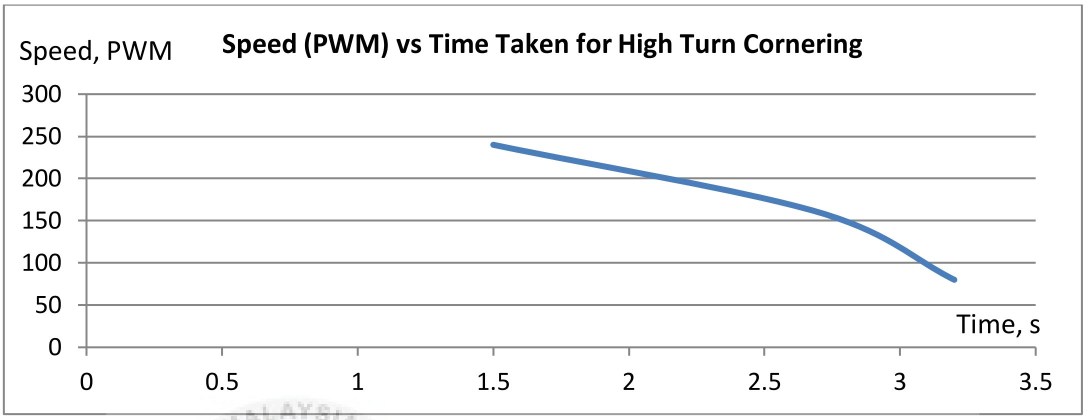


Figure 4.10: Speed (PWM) vs Time Taken for Large Turn Cornering

The last parameter is how much load the AGV can carry with three different speeds and 2 types of load which is 10kg and 25kg. The test is including the time taken for the AGV to complete 18 meter length of full loop track.

4.4.2.2 Experimental Setup for Load Condition

Table 4.9: Speed (PWM) Comparing with Different Load vs Time

Speed (PWM)	Load 1 (kg)	Time 1 (s)	Load 2 (kg)	Time 2 (s)
80	10 kg	50s	25kg	-
160	10 kg	40s	25kg	-
240	10 kg	30s	25kg	65s

Table 4.9 shows the result of the time taken when load is attached to the AGV. With the different speed in PWM that has been set, the heavier the load carried, the higher the time

taken for the AGV to complete an 18 meter full loop track. It shows that there's a big different in time while AGV is unloaded and when the AGV is loaded.

However, if the load is heavy and beyond the calculated specification, the speed must be set to be at maximum for the AGV to carry much load because slower speed cannot carry heavy load. Another than that, during the cornering while carrying the heaviest load, single motor cannot driven the AGV efficiently. In addition, the power supply must be in full capacity for the AGV to carry heavy load.

Regarding to the movement of AGV, there is no problem occur when its carries a less load but, when a heavier load is placed, it counter a problem during cornering because a single motor cannot carry one heavy load. In some cases, the AGV is slipped away from the track and lost controlled.

CHAPTER 5

CONCLUSION

5.1 Conclusion

The development of heavy-duty Automatic Guided Vehicle (AGV) is defined as a set of unmanned vehicle, which is used on manufacturing industries and coordinated by a centralized or distributed computer-based control system. The main usage of AGV as mentioned is to make the automation process run smooth in doing manufacturing work. Moreover, a guide line has been provided with the mentioned specifications as shown in chapter three.

The procedure of designing an AGV is a complicated process. Some issues which directly impact the design of the proposed AGV are listed and widely explained. These issues are not only hardware but also software issues. Software is not just constants in inputs but it is variable and outputs must be chosen to specify the design. Furthermore, these issues interact with each other so that each cannot be considered separately but all must be considered simultaneously.

For the first semester, the first objective which are to investigate the parameter involve that can be used to be implemented in AGV has been achieved. The main parameters that must be considered in this project have been identified. Those parameters are DC Motor, sensor and the physical model designed of an AGV.

The main focus of this development of heavy-duty Automatic Guided Vehicle (AGV) is to use for all of the required material handling in various industries. During this semester, many references from journal, paperwork and proposal about AGV had been well-thought-out.

In the completion of the first objective, there is some minor problem about how to determine and calculate the parameter needed during the selection of DC Motor. Literally, the AGV model must be build first to determine the actual weight that will be used in the parameter to choose the correct DC Motor. However, during this semester the weight of AGV is being set to be 30 kg and above including the weight of desired load. So, the rough calculation has been made in order to achieve the designed parameter.

Moreover, the design of physical model of an AGV using Sketch Up software is much more simple and easy to understand. Some people use Solid Work software which is more complex and hard to understand. However, there is no problem at all to understand the usage of software and design the model accordingly.

For the second semester, the entire objective had been successfully achieved. On the second objective, to design a control algorithm for a smooth AGV operation system, the programming had been successfully done and compiled by using Arduino Compiler Software. There is no error during the brainstorming process to develop the coding. The system flow chart constructed on chapter 3 help a lot to guide the development of system runs smooth. Hence, by the synchronization between the controller, input and output of the system, the AGV can move independently. However there is a small error that is just can be ignored.

On the third objective, for the development of an AGV prototype by using Arduino Uno microcontroller as control unit in AGV operation system, it is successfully constructed as it should be designed. The heavy-duty term has successfully achieved because it is made in metal and well designed. Test has been done by putting a 50 kg weight on the prototype and it’s not breaks apart. Besides, Arduino Uno Microcontroller is easy to be implemented in the system to control the movement of the AGV.

Lastly, the last objective is to analyse the performance of the AGV. There are several parameters that had been considered during the analysis to test the performance of the AGV. An 18 meter long track has been constructed which in one track consist of 90 degrees turn, medium cornering, large degree of cornering and stiff cornering turn. Another than that, the AGV is tested to move with load and without load. The time is taken for the AGV to complete the full loop track including on the cornering part. The analysis comes with a response to show that how the speed of AGV affect the time and movement of AGV considerably with load and without load.

From the analysis result, it is found that the faster the speeds of an AGV moving, the quicker time taken for the AGV to complete the full loop. Moreover, the heavier the load on the AGV affects the speed and movement of the AGV. So, when the heavy load is attached on the AGV, the speed must be set in full speed in order for the AGV to move accordingly to what is desired. In addition, the power supply must be in full capacity during the operation of the AGV in order for the AGV to operate in excellent condition.

5.2 Future Recommendation

For the future work recommendation, firstly, the AGV will be equipped with weight sensor so that, the speed of motor will change accordingly with the weight. For the example, if the weight is detected heavy, the speed of motor will be increased and if the weight is lighter, the speed of motor will be decreased. This will make the AGV move in synchronously speed even with different weight. Secondly, an obstacle avoidance system will also be equipped in order to avoid the AGV hit any unknown object in front it. It's also for a safety reason to avoid accident. Lastly, the line follower sensor method system will be changed to image processing method system in order to implement the technology of Artificial Intelligence that is popular nowadays. The system will be trained to follow the line by the implementation of camera as a sensor or maybe to move freely without any supervision.

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APPENDICES

Arduino Programming for AGV

```
//Motor 1
int LPWM1 = 6; // H-bridge leg 1 ->LPWM
int enL1 = 4; // H-bridge enable pin 1 -> L_EN
int RPWM1 = 5; // H-bridge leg 2 ->RPWM
int enR1 = 3; // H-bridge enable pin 2 -> R_EN

//Motor 2
int LPWM2 = 10; // H-bridge leg 1 ->LPWM
int enL2 = 12; // H-bridge enable pin 1 -> L_EN
int RPWM2 = 9; // H-bridge leg 2 ->RPWM
int enR2 = 11; // H-bridge enable pin 2 -> R_EN

//IR Sensor
int sen1 = A1;
int sen2 = A2;
int sen3 = A3;
int sen4 = A4;

void setup()
{
  Serial.begin (9600);
  //Input
  pinMode(sen1,INPUT);
  pinMode(sen2,INPUT);
  pinMode(sen3,INPUT);
```

```
  pinMode(sen4,INPUT);

  //Motor 1
  pinMode(LPWM1, OUTPUT);
  pinMode(RPWM1, OUTPUT);
  pinMode(enL1, OUTPUT);
  pinMode(enR1, OUTPUT);

  digitalWrite(enL1, HIGH);
  digitalWrite(enR1, HIGH);

  //Motor 2
  pinMode(LPWM2, OUTPUT);
  pinMode(RPWM2, OUTPUT);
  pinMode(enL2, OUTPUT);
  pinMode(enR2, OUTPUT);
```



```
  digitalWrite(enL2, HIGH);
  digitalWrite(enR2, HIGH);
}

void loop(){

  if(digitalRead(sen1))     //Turn Left
  {
   analogWrite(RPWM1,150); //pwm value
   digitalWrite(LPWM1, LOW);
```

```
}

 analogWrite(LPWM2,0); //pwm value
 digitalWrite(RPWM2, LOW);
}

 if(digitalRead(sen4))     //Turn Right
{
 analogWrite(RPWM1,0); //pwm value
 digitalWrite(LPWM1, LOW);

 analogWrite(LPWM2,200); //pwm value
 digitalWrite(RPWM2, LOW);
}

if(digitalRead(sen2))
{

digitalWrite(enL1, HIGH);
digitalWrite(enR1, HIGH);


digitalWrite(enL2, HIGH);
digitalWrite(enR2, HIGH);
}
else
{
```

```
  digitalWrite(enL1, LOW);
  digitalWrite(enR1, LOW);



  digitalWrite(enL2, LOW);
  digitalWrite(enR2, LOW);

  }

}
```