STUDY OF AN AUTOMATED GUIDED VEHICLE (AGV) SYSTEM THROUGH REVERSE ENGINEERING

By

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THESIS

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CHAPTER-1

INTRODUCTION

1.1 INTRODUCTION:

Automation has become the core of modern manufacturing so much that, no company is able to survive in a competitive market without automating its operations. In fact the term automation basically refers to the use of computer and other automated machinery for the execution of tasks that human labour would otherwise perform. Automation is used to manage systems and to control processes that lead to reduce the necessity of human intervention.

Nowadays, manufacturers seek to implement methods of automation appropriate to their needs and purposes. Companies automate their activities for a variety of reasons. Increasing productivity is normally the main aim for companies desiring competitive advantages. Automation reduces human errors and improves the quality of output. Other reasons of automation include the presence of hazardous working environments and high cost of human labour in such areas. The decision regarding automation is often associated with economic and social considerations Ravazzi and Villa [1], Chadwick and Jones [2].

In order to have adequate automation, there are number of issues to be taken into account. Depending on the product and area, the components of automation might be different, but there are some elements that must always be considered such as the field of automation, scale or size of the place that is going to be automated, and order of flexibility.

One of the key components of automation in a manufacturing process is the MHS (Material Handling System). This system is responsible for loading, unloading, and transporting any type of material (raw material, work in process, and finished good) within and out of the manufacturing cells such as machines, assembly lines and warehouses. MHS consists of different components i.e. Conveyors, AGVS (Automated Guided Vehicle System), Robots, Automated Storage and Retrieval system (AS/RS). Utilization of components, either individually or from combination point of view, is determined by its application or pre-assigned flexibility.

In this study, AGV is considered as the most flexible equipment of MHS. An AGV is a driverless transportation system used for horizontal movement of materials. On the other hand it is an unmanned vehicle, controlled and driven by a host computer, to carry out the required material movement in a manufacturing floor. AGVS can be used in both interior and exterior environments such as manufacturing, distribution, transhipment and (external) transportation areas. In manufacturing areas, AGV Systems are used to transport all types of materials related to the manufacturing process.

1.2 AGVS (Automated Guided Vehicle System):

An AGVS (Automated Guided Vehicle System) is a system consisting of an unmanned battery-powered vehicle, a guidance system with other associated components. The vehicle can be programmed to pick up a load at one location and take it to another location automatically. Unlike a conveyor, AGV Systems are actual vehicles that can take materials/products from one location to another following a variety of different paths based on traffic in the area. An AGV path is so programmed that the AGV will move along the path to arrive its final location quickly. Since AGV system is unmanned, it can work 24x7 hours. AGV System can use a PLC (programmable logic controller uses a microprocessor/microcontroller for automation of typical industrial electromechanical processes) to set its course and to stop the AGV System when it has an object in close proximity that it might hit. Several types of AGV System can be used to do the necessary work and various components on the AGV System help it to perform its desired functions.

1.3 Complete Set of an AGV System:

A complete set of an AGV system is shown in Fig 1.1.

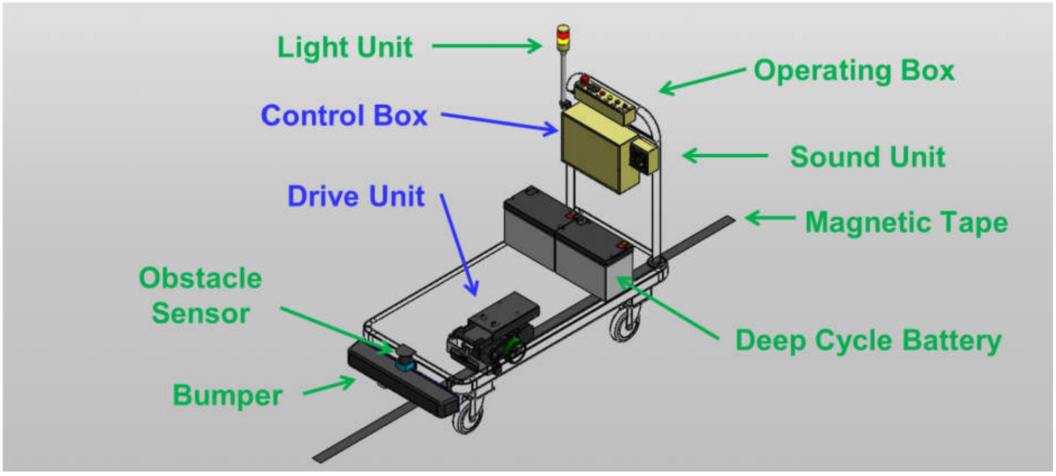


Fig.1.1 Complete set of an AGV System

The accessories [3] of complete set are as follows:


Operating Box-to make an easy command right at the vehicle


Battery to provide power to the AGV


Object detecting sensor- to detect any object that block or approaching towards AGV while it is running


Light alarm- to notify AGV's working State visually


Sound unit- to notify AGV's working State by voice


Bumper- to protect dolly, shelves, racks from bumping and prevent damage impact to AGV's kit


Magnetic tape- for guide AGV track

1.4 AGV System Classification:

Modern AGV systems differ from the classic ones. In Many modern AGV , free ranging path are used than fixed path, which means the path of the vehicle are software programmed and can be changed in a relatively easy way when new stations or paths are added. Modern technology also allows the vehicle to make decisions on its own way, rather than control by the central controllers, done in the past. This leads to adaptive, self-learning system of AGV. In this section, AGV System classification introduced by Peters et al. [4] has been shown in Fig. 1.1a:

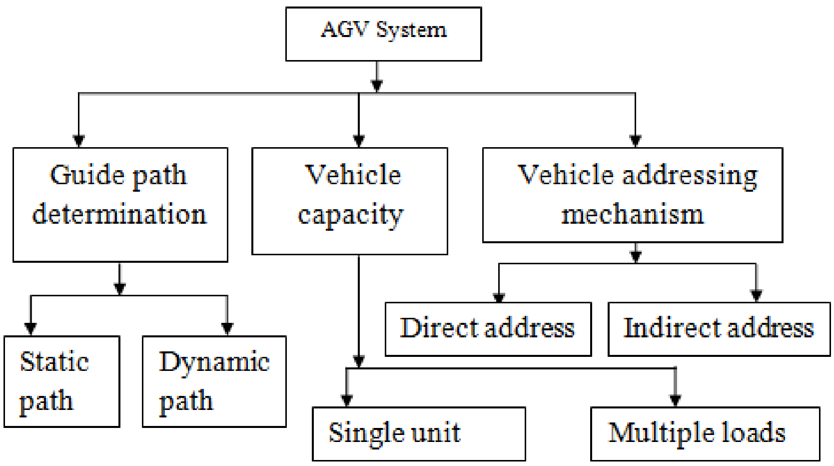


Fig.1.1a AGV System Classification

1.4.1Guide path Determination:

AGV System guide paths [4] can be determined in two ways, which are static or dynamic determination. **Static guide path system** can be further divided into unidirectional and bidirectional systems. In static guide path, the vehicles use a set of predetermined paths between various possible origins and destinations. Variety of guidance mechanisms can be used such as wires embedded in the floor, chemical or optical sensors, dead reckoning and mapping of the paths by using software. In **unidirectional system**, the vehicle will only travel in single direction following single predetermined path. If many vehicles are used, each of them will have its own path and each of the paths is controlled independently even though the directions are different. This type of system is easier to control and collision can be avoided. In **bidirectional system**, vehicles can travel in forward and backward movement using the same guide path. In order to do so, a turning or turn around point is specified for the vehicle. Although this type of system can bring improvement in productivity and less vehicle usage, however, the control system is complex since multiple vehicle share the same guide path and must be able to avoid deadlock situations (deadlock is a situation in which two or more competing actions are each waiting for the other to finish, and thus neither ever does).

Dynamic guide path [4] system use fully autonomous vehicles which are capable of determining its path through obstacle detection and avoidance systems. In this system, the vehicle is given the destination, a location that the vehicle knows through coordinate system (mostly Cartesian). The vehicle then determines its path from its current position to the desired position through its internal navigation scheme.

1.4.2 Vehicle Capacity:

In automated guided vehicle system, the vehicle can be classified based on its load capacity [4], which is either single load or multiple load vehicles. System that use single load vehicle is known as single load system and if multiple load vehicles are used, it is known as the multiple load system. In a single load system, an empty vehicle will be assigned for a task. From its current position to a station to pick up the load and then travel to the desired position to drop off the load. During performing its task, it is not interrupted with another assignment and will only move in the path to pick up and drop off the load. In multiple load system, the task of the vehicle is more complicated where the vehicle may be interrupted while performing its task. It may stop to another station to pick up another load. In this type of system, the planning and scheduling functions of the controller might be difficult as the plan and schedule must be integrated with the new tasks into previously assigned tasks.

1.4.3 Vehicle Addressing Mechanism:

Vehicle addressing system in AGV System can be grouped into two, which are direct or indirect address system. In **direct address** system, any vehicle is allowed to visit any stations available in the same system. This system is much similar to taxi service. The planning function for this system routes vehicle from its current location to its destination considering the current status of the system. In other words, the routes are not determined in advanced. Vehicles must be assigned to tasks since vehicles are not restricted to serve any particular station. The planning action might be complicated since the location of the vehicle is not known initially but takes place according to the change of location.

In **indirect address** [4] system, vehicles will stop at stations in a fixed sequence, which is more likely a bus service. The routes are predetermined as part of the system design, not one of the controller planning function. Compare to direct address system, the dispatching in this system is straightforward. As the route of the vehicle is predetermined, it will pick up and drop off loads when it reaches each station in its route.

1.5 Systems in AGV:

The AGV System [5] consists of the vehicle, onboard controller, management system, communication system, and navigation system:

An automated guided **vehicle** (AGV) is a vehicle that is driven by an automatic control system that serves the role of a driver. Sensors on the path or infrastructure and onboard the vehicle provide measurements about the location and speed of the vehicle which are used by the automatic control system to generate the appropriate commands for the brake actuators in order to follow certain position and speed trajectories. AGV System is considered to be the most flexible type of material handling system. Their size ranges from small load carriers of a few kilograms to over 125-ton transporters. The vehicles working environment ranges from small offices to huge harbour dockside areas

The **onboard controller system** is responsible for initiating start-up and shutdown procedures. It manages the propulsion, steering, braking, and other functions of the vehicle. It also monitors and detects any error and issues the necessary commands for error correction.

The **management system** deals with planning, scheduling, and traffic control. It is responsible for optimizing the vehicle utilization, giving transport orders such as dispatching and routing, and tracking the material in the manufacturing environment.

The **communication system** is used to transmit data from the AGV to a central controller and vice-versa. This information consists of the position and the status of the vehicle, the position of currently assigned job(s), and possibly the position of the next scheduled job(s).

The **navigation system** provides guidance and navigation to the AGV in the operating environment. The guidance and navigation could be based on a fixed path or free path approach.

In the fixed path approach, the AGV is restricted to follow a fixed path and there is no flexibility to change the guide-path. Examples of fixed path include rail tracks, embedded wires or other type of guide-ways (Fig. 1.2)

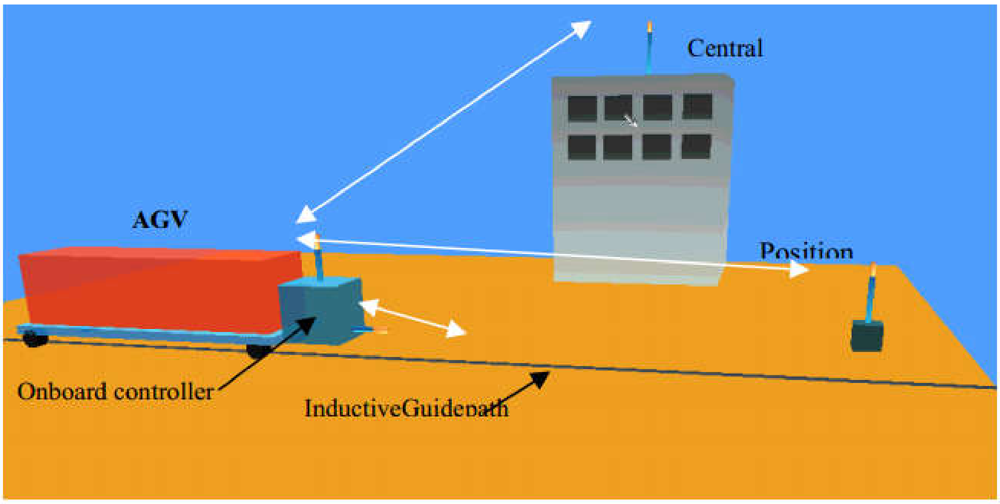


Fig.1.2 basic scheme of AGV System using a fixed path method

In the free path method, the path of the AGV can be changed dynamically. The system is autonomous and is capable of detecting the path using online information, obstacle detection and collision avoidance systems.

1.6 AGV System Basic Functions:

In automated or semi-automated manufacturing systems, the AGV System controller is an integral part of the shop floor control system. The shop floor control system is responsible for routing products through the individual processing stations and interacting with the shop floor equipment and operators to affect production. The AGVS's role is to facilitate the transport of parts, tools, fixtures, etc., between individual processing centres as specified by the shop floor control system.

The AGVSC (AGV System Controller) **planning function** [4] is responsible for selecting an appropriate vehicle and determining the appropriate routing for that vehicle. Planning is often referred to as *routing* and *dispatching* in the context of AGV System.

The **scheduling function** [4] is also responsible for resolving vehicle conflicts or deadlocks and generating/updating expected start and finish times for the selected routes. A number of alternate routes for a given starting/destination pair may have to be evaluated before identifying a feasible route. In this context, *feasibility* means a selected route which is not blocked and starting the vehicle along the route will not lead to an un-resolvable deadlock. It is noted that both blocking and deadlock are dynamic problems and can only be handled by considering other vehicles in the system.

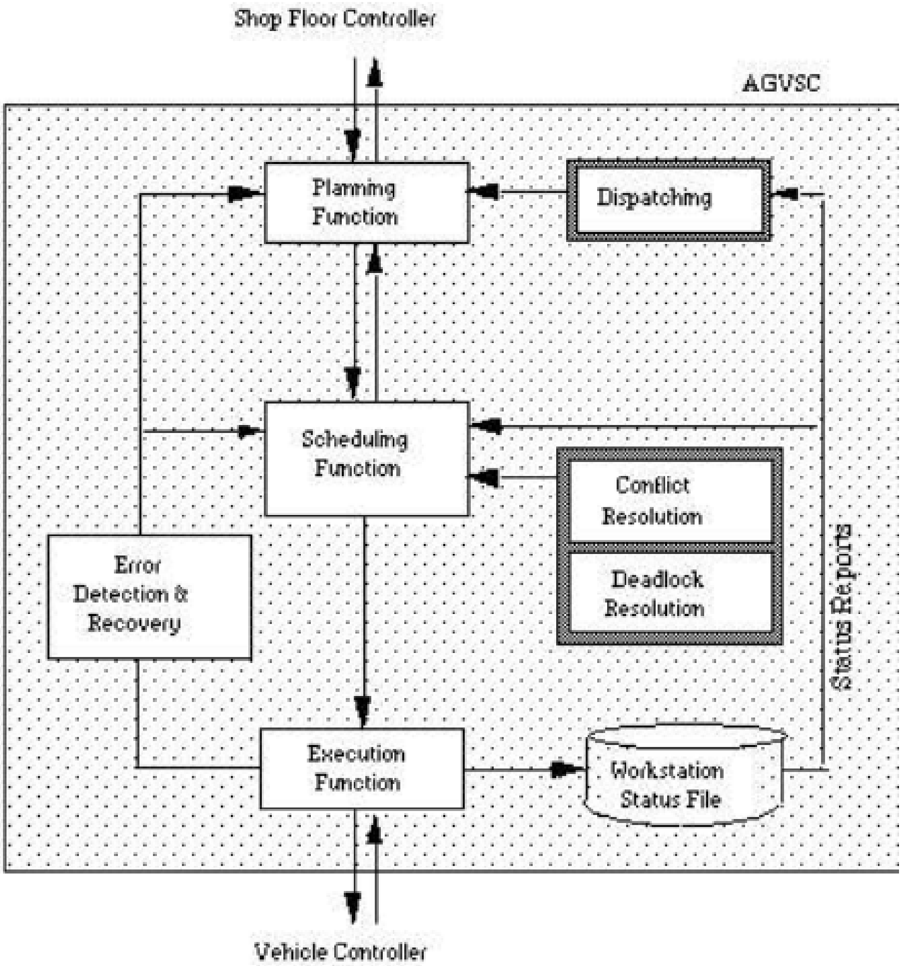


Figure 1.3 a Detailed Schematic of AGV System Controller

Conflict [4] in automated guided vehicle routing is said to occur when two or more vehicles are temporarily delayed if they:

(1) Travel along the same guide path but at different speeds, or
(2) Arrive at the same intersection position from different guide path segments.

The AGV System Controller must be able to resolve the conflict. Researchers have proposed several rules for resolving conflict at intersections in unidirectional, single lane/aisle, guide path networks, such as: allowing departure of vehicles from an intersection position on a first-come-first served basis. Restricting the first-come-first-served rule to vehicles transferring to the same path segment, prioritizing tasks and allowing departure based on these priorities, etc.

Deadlock resolution [4] is another important support function of the AGV System Controller, which aids the scheduling function in evaluating feasible routes. Deadlock is a situation where further movement of a set of vehicles is inhibited due to the current status of the AGV system. Researchers have identified three standard approaches to manage deadlock situations: prevention, avoidance, and detection and resolution. While the first two approaches ensure that deadlock will never occur, the last approach allows deadlock to occur and resolves it appropriately. It is the responsibility of the scheduling function to avoid or detect and resolve a deadlock in the AGV System to prevent eventual shop floor lockup.

We categorize two distinct deadlock situations that may arise in a general manufacturing system:

(1) Part routing deadlock; and
(2) Material handling deadlock.

Part routing deadlock is a state when parts are assigned to various machines in such a way that any further progress of part movement is inhibited. Material handling deadlock is a state of deadlock when further movement of a material handling entity is inhibited due to the routing of the material handling entity (as against the routing of a part). This situation is equivalent to a traffic gridlock in a city road network.

Material handling deadlock can occur in material handling systems such as AGVS or bridge cranes due to the conflicting routes of the material transporters.

1.7 AGV SYSTEM COMPONENTS:

AGVS use many different components to assist it in getting a load from one point to another. The various components of the AGV System are listed below:

1.7.1 Mechanical Components:

The Mechanical components [6] in an AGV System are -

a. Chassis or Main body
b. Steering system
c. Lift mechanism
d. Driver gears
e. Pinion gears
f. Belts

a. <u>Chassis:</u>

Functions of chassis-

i. Acting as a frame for attaching other components
ii. Carrying the load of other components and the payload.
iii. Acting as sacrificial component to prevent damage of expensive payload in case of accidents

b. <u>Steering System:</u>

To help an AGV navigate it can use three different steer control [7] systems. The differential speed control is the most common. In this method there are two independent drive wheels. Each drive is driven at different speeds in order to turn or the same speed to allow the AGV to go forwards or backwards. The AGV turns in a similar fashion like a tank. This method of steering is the simplest as it does not require additional steering motors and mechanism. Sometimes, this is seen on an AGV that is used to transport and turn in tight spaces or when the AGV is working near machines. This setup for the wheels is not used in towing applications because the AGV would cause the trailer to jack_knife when it is turned.

The second type of steering is steered wheel control AGV. This type of steering can be similar to a cars steering. But this is not very manoeuvrable. It is more common to use a three-wheeled vehicle similar to a conventional three wheeled forklift. The drive wheel is the turning wheel. It is more precise in following the programmed path than the differential speed controlled method. This type of AGV has smoother turning. Steered wheel control AGV can be used in all applications; unlike the differential controlled. Steered wheel control is used for towing and can also at times have an operator control it.

The third type is a combination of differential and steered system. Two independent steer/drive motors are placed on diagonal corners of the AGV and swivelling castors are placed on the other corners. It can turn like a car (rotating in an arc) in any direction. It can drive in differential mode in any direction.

The steering system used in the model is of differential type. A differential wheeled vehicle is a vehicle whose movement is based on two separately driven wheels placed on either side of the body. It can thus change its direction by varying the relative rate of rotation of its wheels and hence does not require an additional steering motion. It allows the turning centre to be on the vehicle body thus the ability to rotate on the point.

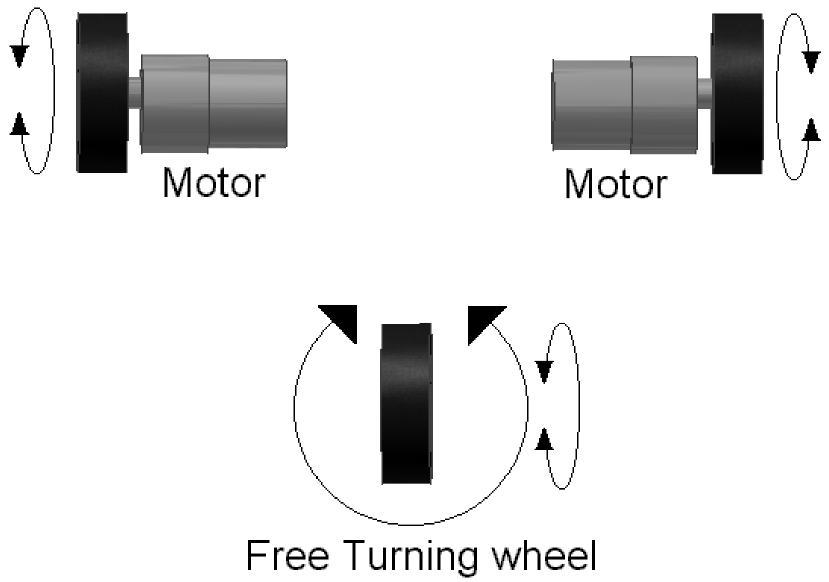


Fig. 1.4 Differential Steering

If both wheels rotate at the same speed and in the same direction, the AGV System will move in a straight line.

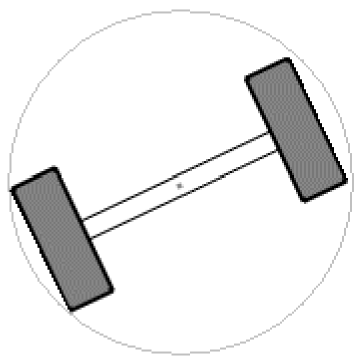


Fig. 1.5 spinning by differential steering

If the wheels rotate at equal speed, but in opposite directions, both wheels will traverse a circular path around a point centred half way between the two wheels. Therefore the AGV System will pivot, or spin in place. (Fig. 1.5)

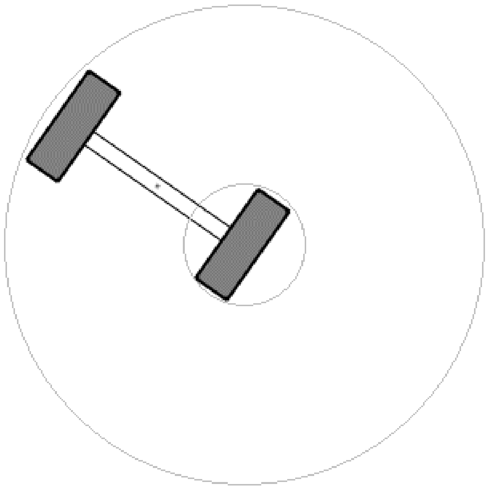


Fig. 1.6 Small radius turning

If one of the wheels is stopped, while the other continues to rotate, the AGV System will pivot around a point centred approximately at the mid-point of the static wheel. (Fig. 1.6)

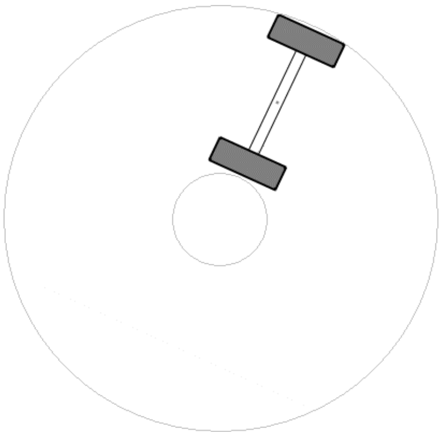


Fig. 1.7 large radius turning

If one of the wheels rotates faster than the other, the AGV will follow a curved path, turning inward toward the slower wheel. (Fig. 1.7)

c. <u>Lifting Mechanism:</u> Lifting mechanisms is one of the important components of AGV, the lifting surface moves upward and downward at specified stations and carry the load during load transfer.

d. Driver Gears: A spur gear is fixed to the motor output axis This gear is not only transfer the power from the motor shaft to the driven gears, but also keep the belt over the gear set in order to have continuous revolution under the load. This is done by special two fixture rings attached to each side of this gear, called gear guards.

e. Gears: There is a pair of spur gears on each side, seated on the fixed shaft with ball bearings. Consequently, these gears have only one rotational degree of freedom around the shaft.

f. Belt: A 90 teeth timing belt is meant to transfer the power for each side.

1.7.2 Electrical Components:

Electrical components include the motor and the power supply unit for motors.

a. Motor,
b. Battery

a. Motor:

There are two 12V DC servo Motors adjusted and tighten to the motor plates on each side. These motors are considered to drive the AGV. Below figure shows the Motor Driver. One pinion is attached to the motor shaft in each side.

b. Battery:

The power required for the entire working process is given by a Rechargeable 12V, 7Ah valve regulated Lead Acid battery. The power from the battery is divided into two and one part is given to microcontroller, display unit, driving unit and other part is given to lifting mechanism/motor.

There are two 12V, 7Ah rechargeable battery and consist within a proper channel which is fitted to the chassis.

1.7.3 Electronics Components:

The various Electronics Component of an AGV System are listed as below:

a. Controller
b. Motor driver kit
c. Main kit
d. Intermediate Kit
e. Modem
f. Sensors/ Obstacle Detector

1.8 Various Types of AGV System: Various types of AGV System are:

1. Towing Vehicles AGVS
2. Unit Load AGVS
3. Pallet Trucks AGVS
4. Forklift Trucks AGVS
5. Light-load AGVS
6. Assembly line AGVS

1.8.1 Towing Vehicles AGVS:

AGV System towing vehicles were the earliest type AGV. A towing vehicle is an automated guided tractor. A wide variety of tractors can be used, such as flatbed trailers, pallet trucks, custom trailers, and bin trailers. Different types of loading equipment used for loading and unloading the trailer include an AGV-pulled train, hand pallet truck, cranes, forklift truck, automatic transfer equipment, manual labour, shuttle transfer, and programmed automatic loading and unloading device.

As the first when AGV introduced in the market, towing vehicles [8] are still highly popular automatic guided vehicles. Capable of navigating a guide path network that is flexible and easy to program, various navigation methods used on AGV towing vehicles include laser, camera, optical, inertial and wire guided systems. These methods are generally divided into two categories: fixed path guidance systems where wire, tape or paint can be used as a physical guide path on the floor for guidance; and free-ranging, which have no physical pathway to guide them, making it easier to change towing vehicle pathways through software. In general, towing vehicles use a navigation method from one of the two categories for guidance. Most towing vehicles are equipped with onboard microprocessors as well as a supervisory control system which helps to perform various tasks, such as tracking and tracing modules and generating and/or distributing transport orders. Free-ranging towing vehicles such as laser guided towing vehicles have advanced navigation capabilities and are able to navigate around objects along a programmed path and avoid collisions independently using laser beam sensors. Some towing vehicles are designed for the use of an operator, but most of them operate independently.

Fig.1.8 Towing Vehicles

Advantages:

- Very simple in design
- Can complete repetitive transports with little to no error
- Optimal path can be determined and used continuously
- Reduction of aisle traffic

Applications:

- This AGV is commonly used to transport pallets, totes, rolls and racks, usually one or two at a time over a long distance. It can also be used in places such as hospitals to retrieve used carts, and to carry new carts to a desired location.

1.8.2 Unit Load AGVS:

Unit load automated guided vehicles (AGVS) are the most traditional type of automated guided vehicle (AGV). Unit load AGVS [9] are sometimes referred to as a "top carrier" because the load rests over the majority of the vehicle.

The unit load AGV is available for loads of different sizes and shapes and is sometimes used as an assembly AGV where a product is moved from one manufacturing cell to other when it is assembled. The types of loads typically moved by unit load AGV System include standard pallets (wrapped and unwrapped), drums, carts, racks, rolls and custom containers.

Fig. 1.9 Unit Load AGVS

The unit load AGV typically interfaces with stands and conveyors or it is loaded by other manual or automatic equipment (cranes, forklift trucks, other AGV sytem, etc). This type of unit load AGV can include a device such as a roller conveyor, chain conveyor, scissors lift, etc to transfer the load onto and off it. When this AGV interfaces with conveyor, it typically includes a "handshake" sensor which provides for communication. This ensures that both the AGV and the conveyor are ready and working together for a smooth transfer of the load.

Unit load AGV System has more complex type of drive/steer wheel combinations. Although more expensive, dual and quad steer unit load

AGV Systems are sometimes required where the AGV must manoeuvre in extremely tight space to pick up or deliver the load.

Fig. 1.10 Unit Load AGV System

<u>Advantages:</u>

- Capable of moving through tight spaces
- Interfaces with stands and conveyors
- Loads delivered upon command
- Improved response time
- Reduced product damage
- Efficient scheduling
- Reduced aisle traffic
- Flexible routing

<u>Applications:</u>

- Unit Loads have a variety of workplaces
- They can be used in any type of working place where simple autonomous transportation is needed such as
  - Hospitals
  - Manufacturing Sites
  - Distribution Centres
  - Supermarkets
  - Retail stores

1.8.3 Pallet Trucks AGVS:

AGV System pallet trucks [10] are designed to lift, manoeuvre, and transport palletized loads. It is used for picking up or dropping off loads from and on to floor level. No special accessories are needed for loading and unloading the AGVS pallet except the loads should be on a pallet. It is basically used in floor-level loading and unloading operation. Loading and unloading can be done in two ways: automatically or manually. For the transportation of load, the normal course followed by the vehicle is determined by the storage area destination. Normal operations carried out in pallet trucks are:

(i) Pulled off loads onto a spur,
(ii) Lowering of the pallet forks to the floor,
(iii) Pulling out from the pallet, and
(iv) Finally automatically returns empty to the loading area.

Fig. 1.11 Pallet Truck AGV System

Advantages:

- AGV System go on set paths repeatedly, unlike a human operating a forklift, which increases overall efficiency.
- Handling/Transportation can be done at the same rate/efficiency levels on a daily and hourly basis.
- Easily handles transportation that is repeated on a frequent basis.

Applications:

- Pallet Trucks currently are seen in more high technology distribution and manufacturing centres.
- Some are seen in retail stores where large items, or a high volume of items, are moved on the same path repeatedly.
- As technology becomes cheaper, and more companies realize the benefits, these can be implemented into nearly all manufacturing/ distribution centres.

1.8.4 Forklift Trucks AGVS:

An AGV System forklift truck has the capability to pick up and drop off palletized loads both at floor level and on stands, and the pickup height may be different from the drop-off height. They are capable of picking up and dropping off a palletized load automatically. It has the ability to position its forks at any height so that conveyors or load stands with different heights in the material-handling system can be serviced.

Therefore, they are used in the case of full automated plant. The truck is accoutred with sensors at the fork end, so that it can handle high-level stacking on its own. These systems have the advantage of greater flexibility in integrating with other subsystems of various loading and unloading heights throughout the material handling system. It is one of the most expensive types AGV System.

Fig 1.12 Forklift AGV System

Forklift Application:

Forklift AGV systems are the ideal solution for warehouse and distribution areas. Due to their versatility, forked automated guided vehicles can be used for a wide range of applications:

- moving loads from receiving zone to production / warehouse
- warehousing (narrow aisle, deep-lane stacking, block storage, racking)
- buffer storage
- end-of-line handling: picking from conveyors, palletisers, stretch wrappers
- trailer loading / unloading
- transport between production and warehouse

1.8.5. Light Load AGVS:

They are suitable in handling small, light parts over a moderate distance and distribute the parts between storage and number of work stations.

Light load AGV [11] System applications are used in light manufacturing processes. The product can be distributed from a small parts storage area to individual workstations where operators are engaged for light assembly. The AGV System can be driven according to product demand at the various assembly stations. The light load AGV System is smaller and has only a several hundred pound capacity. It is ideal for moving small parts in trays or baskets and for manoeuvring in very small, tight areas. Electronic fabrication, small assembly manufacturing and parts kitting applications are proper uses for light loads AGV System.

Fig. 1.13 Light Load AGV System

1.8.6. Assembly-Line AGV System:

Assembly line AGV System applications are only now being introduced in the U.S. This is an adaptation of the small light load AGV System for an assembly line process. Here the guided vehicles carry major subassemblies such as motors or transmissions to which parts are added in a serial assembly process. Prior to each assembly area is a parts staging area where small parts are placed in a tray onboard the vehicle beneath the major subassembly. The vehicle the proceeds into an assembly area where it stops at assembly work station. The assembler takes the parts from the tray onboard the vehicle and then assembles them onto the major subassembly. When that process is completed, he then releases the vehicle, which proceeds to the next parts assembly area the process repeats several more times. When the assembly process is complete, the finished assembly such as an engine block or chassis is unloaded from the vehicle, which is then sent to the start area for the assembly process. There it is again loaded with a raw subassembly.

AGV assembly [11] systems give good flexibility to a manufacturing process by allowing parallel operations. They also allow for individual tracking of items and measured work rates. Normally these systems are integrated into an overall production system, which requires computer control and extensive planning.

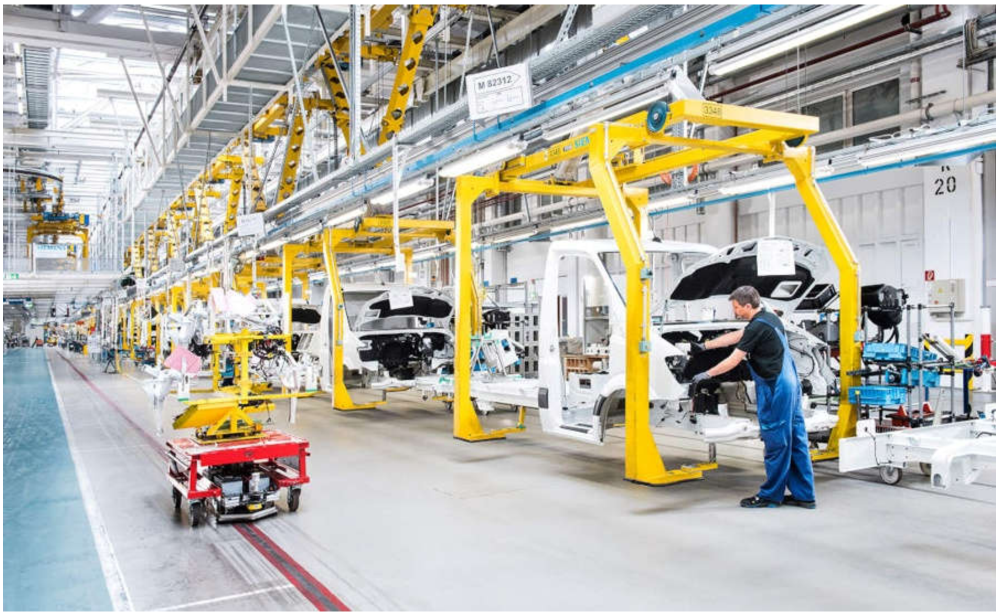


Fig. 1.14 Assemble Line AGV System

1.9 Navigation and Guidance Systems:

A guidance system is what directs the vehicle on the path it will take to get from one point to point another. The decision about the type of guidance system that will be used is one of the most crucial that will be made. Some guidance systems have a high reliability and very rarely fail, but these same guidance systems restrict the flexibility of the factory. Other systems are slightly less reliable, but, if the factory decides to expand or change the layout of an AGV area, components can easily be moved and added to accommodate the changes. Wire guidance, optical guidance, laser guidance, inertial guidance, dead reckoning guidance, and beacon guidance are the most common guidance systems.

Various type of guidance systems are:

i. Wire Guidance System
ii. Laser Guidance System
iii. Spot Guidance System
iv. Paint/Chemical Guidance System
v. Dead Reckoning Guidance System
vi. Beacon Guidance System
vii. Inertial Guidance System or gyro navigation

1.9.1 Wire Guidance System:

Wire guidance is defined as an electromechanical system that controls vehicle steering by tracking an energized guide wire secured in the floor. This exclusive system frees operators from steering responsibilities in very narrow aisles. It quickly and reliably engages guide signals.

Wire guidance is the most common type of guidance system. It is known to be reliable, but not very flexible. The wire that carries an electric current is embedded in concrete along the pre-determined path. The groove that carries the guidance wire can also be used to carry communication cables so messages can be transmitted to the AGV without the use of an RF modem.

A small groove (typically 1/8" wide x 3/8" deep) is cut down in the middle of the working aisle. A signal generator (line driver) sends a frequency through the wire at a very low DC voltage. The vehicles guidance [12] system is tuned to this frequency and can automatically sense and steer the vehicle along the guide path in both travel directions. The vehicle velocity is automatically reduced during the acquisition of the wire path. Once locked ON to the guide signal, travel resumes at normal velocity.

Features include the ability to maintain a clean warehouse without floor mounted rails, however primarily guide wire does not require the use of a lower rack beam. Loads may be placed directly on the floor.

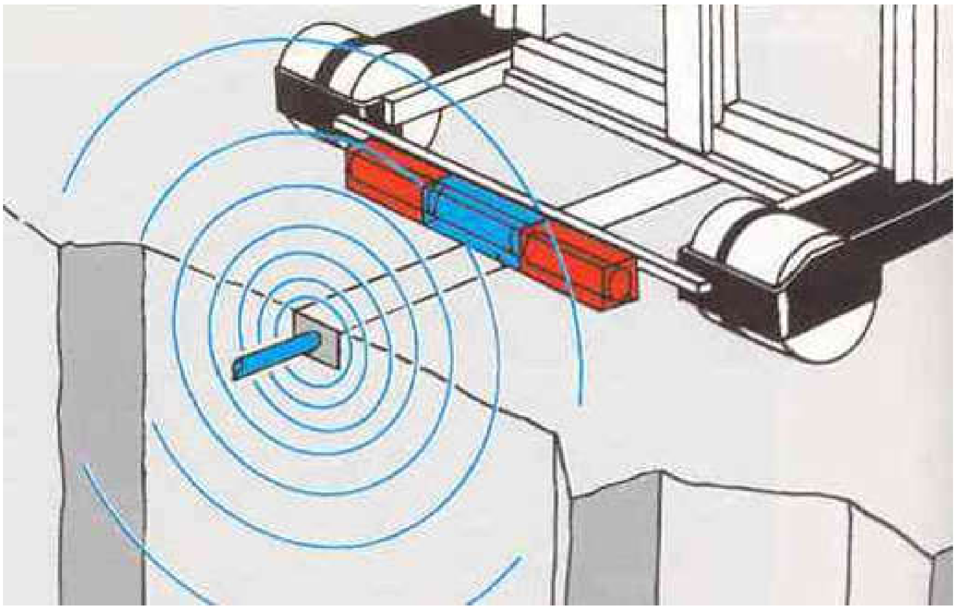


Fig. 1.15 Wire guidance

Technical Details:

Wire guidance [13] is based on the fact that an electrical conductor through which an AC current is flowing will create an electromagnetic field around itself. Shown in Fig. 1.16, since the field is stronger closer to the wire, the AGV is able to steer itself using an antenna that detects the strength of the field. More than one AGV can be located on a single wire, and different guide wires can carry electricity at different frequencies, which enables a single system to control AGVs on different paths.

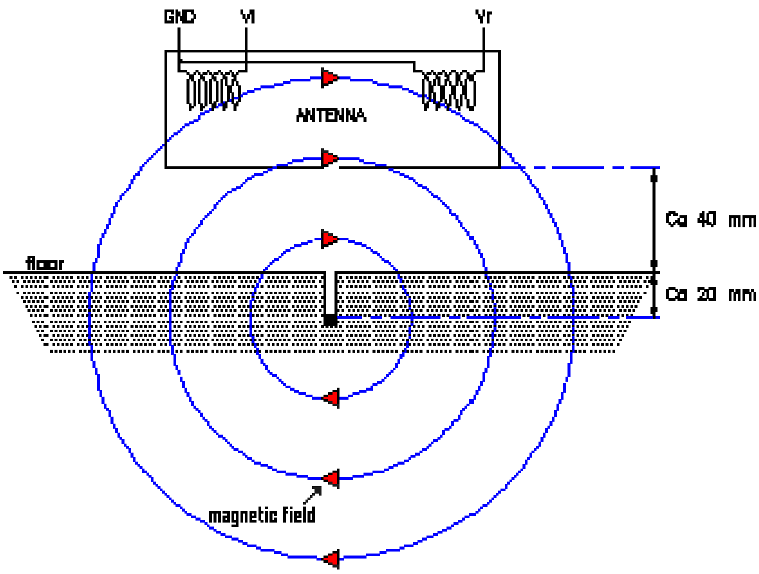


Fig. 1.16. Field around Wire

The guiding antenna consists of two coils that straddle the guide wire. The difference in electric voltage between the two coils will create the steering signal. The steering signal indicates to the steering motor which directs to turn. As long as the antenna coils are centred over the guide wire, there is no difference in voltage, and the steering signal will be zero. If the vehicle begins to wander off centre, the voltage will rise in one coil on the antenna and drop in the other coil which will change the steering signal and cause the vehicle to steer in one direction or the other.

Even though the vehicle may be on path, it must also know with respect to its target, pick up point, or drop off point. Guide wires are used for indicating position relative to these points as well. The vehicle position is updated using a cross antenna that detects guide wires that are perpendicular to the guide path. From these perpendicular guide wires, the controller or supervisor can find out the location of the AGV.

1.9.2 Laser Guidance System:

Laser guidance allows a vehicle to be guided off line. Using reflective targets and a laser scanner, the exact location of the AGV can be calculated. Unlike the wire guided and optical systems, a laser guidance system does not rely on floor-based reference point. The targets are mounted on the wall and are scanned by the scanner on the AGV. Two or three targets are used to pinpoint the location of the AGV, and the on board controller or the supervisor can make adjustments based on expected location and traffic.

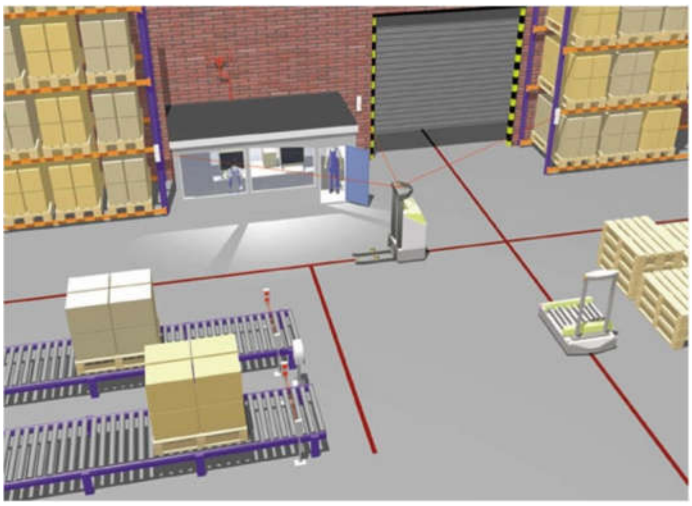


Fig. 1.17 Laser guidance systems

With laser measurement and odometry, the AGV [14] finds its way to move. On board laser scanners detects the position of reflectors in the facility. The reflectors are usually mounted on walls, pillars, fixed machines and equipment in the proximity of the vehicle driveway. The reflector map of the entire route layout is stored in a Master controller located in a stationary PC. The laser navigation enables free range navigation i.e. physical floor reference points, wires, dots or position-Ids are not required.

1.9.3 Magnet Spot Guidance:

The magnet spot guidance [15] navigation of an AGV uses the Halleffect sensor to detect a small magnet installed on the floor and measure the distribution of the magnetic flux density for computing the moving distances of the wheel and the steering angle. This system is a continuous inductive wire guidance navigation system. The Hall-effect sensor calculates the distance moved from the magnet spot as the AGV deviates from its track and provides information for new data updates for navigation. Small magnet spots are discontinuously and randomly installed on the floor surface of the virtual navigation path for guiding the AGV navigation.

In addition, compared with the laser guidance method, the method is not restricted by the surrounding environmental conditions and has the advantage of simpler control, lower price, high precision, and better space utilisation since spin-turning is allowed. The steering control and navigation control are independently controlled by two DC motors.

For AGV guidance, the components of the Hall-effect sensor are installed at the forward, backward, and central locations of the AGV. The AGV system is the centre of the magnet spot installed on the floor to be the guide path of the AGV. The magnetic flux density distribution as measured by the Hall-effect sensor with its embedded Hall-effect element will then have the maximum value at the centre of the Hall-effect sensor. Moreover, the magnetic flux density detected by the Hall-effect sensors on both sides is assumed to be symmetrical for the purpose of the navigation design. In such a case, the AGV maintained high precision and realized high-speed navigation. The magnet spot guidance system detects the displacement at both sides from the centre of the Hall-effect sensor and obtains the information for determining the correction value by calculating the lateral distance deviation from the guide path at the instant the AGV passes the next magnet spot. An encoder is used to measure the distance to the next magnet spot, and the encoder data is reset at the instant when the AGV passes the magnet spot.

1.9.4 Paint/Chemical Guidance:

This type of system [13] uses a line of fluorescent particles or dye to indicate the path for the vehicle to follow. Once again, sensors on the vehicle are used to detect the reflected light to indicate the vehicle position in relation to the specified path. Information codes can also be set on the path and the sensor will "read" the codes and perform the action instructed by the code such as: Stop, turn left, slow down, etc.

Advantages:

The various advantages of paint guidance systems are-

i. The optical systems have advantages over the wire systems since they are so easily moved.
ii. A new path can be laid out or painted with very little expense.
iii. It is also easy to repair a path if it is damaged.

Disadvantages:

The various disadvantages of paint guidance systems are-

i. There is a necessity of clean environment. These optical systems must have a clean environment, and the path must remain clear of all obstructions including a piece of paper.
ii. The optical systems are also easily damaged.
iii. Paint/chemicals/glass beads will wear rapidly in a high traffic area.

1.9.5 Dead Reckoning Guidance System:

Dead-reckoning [13] refers to another type of non-wire guided system. This system uses an optical encoder on the drive wheels to measure rotation and steer angle. A controller is used to calculate the position of the AGV based on the starting position, the internal map, and the information that is provided by the optical encoder.

The dead-reckoning guidance system adds flexibility over the wire guided system or optical systems, but they require smooth surfaces to run on. Debris and foreign material in the path or on the wheels of the AGV will cause serious errors. This system is less expensive than the laser system since its controller is cheap, but the system is not reliable since it does not have absolute reference points that don't change.

Wheel slippage is the biggest cause for AGV Systemusing dead-reckoning to get off track, since the optical encoder acts more or less as an odometer. When the wheels are turning, the controller thinks the AGV is moving. Heavy loads can also cause problems due to a deformed wheel. For these reasons, it is very important that the surface the vehicle is being used on is smooth.

1.9.6 Beacon Guidance:

The beacon guidance [13] system operates on a concept similar to that of the laser guidance system. In the beacon system, beacons are placed in strategic locations around the plant. The AGV is programmed with the exact location of these beacons. As the AGV traverses through the plant, it receives signals from the various beacons and is able to use that information to determine where it is and how it needs to get to its destination.

As with all of the other non-wire guidance systems, the beacon system offers higher flexibility as compared to the wire guidance system or optical systems. Typically, depending on the scope of the change, the route of an AGV with a beacon system can be changed with software.

There are several drawbacks to the beacon system. The first is the required mounting of at least three transmitting beacons so that the AGV will be able to pinpoint its location. There is also additional programming that must be made during installation so that the AGV knows the exact location of all of the beacons. Finally, there is also an increased cost involved with this system over the wire-guided system due to the more complex controller, the beacon transmitters, and the vehicles tracing device.

1.10 Path Decision:

AGVs have to make decisions on path selection [16]. This is done through different methods: frequency select mode (wired navigation only), and path select mode (wireless navigation only) or via a magnetic tape on the floor that not only to guide the AGV but also to issue steering commands and speed commands.

(a) Frequency select mode:

Frequency select mode bases its decision on the frequencies being emitted from the floor. When an AGV approaches a point on the wire which splits the AGV detects the two frequencies and through a table stored in its memory decides on the best path. The different frequencies are required only at the decision point for the AGV. The frequencies can change back to one set signal after this point. This method is not easily expandable and requires extra cutting meaning more money.

(b) Path select mode:

Using the path select mode, an AGV chooses a path based on pre-programmed paths. It uses the measurements taken from the sensors and compares them to values given to them by programmers. When an AGV approaches a decision point it only has to decide which path. This decision is rather simple since it already knows its path from its programming. This method can increase the cost of an AGV because it is required to have a team of programmers to program the AGV with the correct paths and change the paths when necessary. This method is easy to change and set up.

(c) Magnetic tape mode:

The magnetic tape is laid on the surface of the floor or buried in a 10mm channel. not only does It provides not only the path for the AGV to follow but also strips of the tape in different combos of polarity, sequence, and distance laid alongside the track to direct the AGV to change lane, speed up, slow down, and stop.

1.11 LITERATURE REWIEW

A lot work relating to Automated Guided Vehicle (AGV) has been done throughout the previous decades. Out of this some of the most important works are described below:

1. Stevea H.Y. Lni and Su-Hna Hsieh [17] present a procedure to design the AGV travel mechanism. The philosophy of an "AGV travel mechanism" was introduced. A three-stage procedure to design a robust AGV mechanism is presented. The procedure consists of the design of composite-floor. Path system, cell control system, and collision free zone system. Examples related to validate the conceptual models designed by the proposed procedure was described by them. Results show the AGV travel mechanism thus obtained was economic, efficient and robust.

2. Vladimir R.Milaqic and Goran D. Putnik [18] proposed the complete structure of an AGV control system. The AGV control system is hierarchical and consists of five levels. The structure of one level does not depend on the structures of the other levels. This means that the control system depends on the design of the AGV at the lowest level only, at the actuator servo-control level and its coordination in realizing AGV primitive functions. The second part of the paper describes rules applicable to AGV steering. The structure of these rules depends on two groups of factors. The first group is dependent on information groups fed to the AGV processor by the position sensor. The second group of factors represents aims and conditions and AGV steering such as positioning accuracy, positioning time, allowed room-for manoeuvre, the shape of the given trajectory, etc. The AGV steering rules contain sequences of primitive functions. These primitive functions are of such types as "turn left", "straighten" (correct), "go straight on", etc. Trajectory, as one of the basic factors, is defined at the level of controlling an elementary movement. The term "to control an elementary movement" means to select a transport road throughout the transport network and to code it using "elementary movement" such as "go straight" (relating to road section), "turn left" (relating to turning at a crossroad) etc.

3. K.R.S.Kodagoda, W.S.Wijesoma, and E.K.Teoh [19] proposed the development of techniques for lateral and longitudinal control of vehicles

and it has become an important and active research topic in the face of emerging markets for advanced autonomous guided vehicles (AGVs) and mobile robots. In this respect there has been much literature published, although not so much on actual performance of such controllers in a practical setting. The primary focus in this paper is on the development and actual implementation of intelligent and stable fuzzy proportional derivative–proportional integral (PD–PI) controllers for steering and speed control of an AGV. The AGV used in this study is an electrically powered golf car suitably modified for autonomous navigation and control. The use of fuzzy logic for control law synthesis, among other things, facilitates the incorporation of control heuristics, while guaranteeing stability, uncoupling steering control from speed control, and providing for easy incorporation of a braking controller. Through experimentation, the designed controllers are demonstrated to be insensitive to parametric uncertainty, load and parameter fluctuations and most importantly amenable to real-time implementation. The performance of the proposed uncoupled direct fuzzy PD/PI control schemes for the particular outdoor AGV is also compared against conventional proportional integral derivative (PID) controllers. Experimental results demonstrate that the proposed fuzzy logic controllers, which are synthesized from a variable structure systems view point, also outperform conventional PID schemes, particularly in tracking accuracy, steady-state error, control chatter, and robustness.

4. Yuedong Zhan ,Youguang Guo,and JianGuo Zhu [20] presents the neural network, fuzzy control and bang-bang control, an intelligent coordination control strategy for automated guided vehicle (AGV) steering system. The dynamic steering model of distance error and orientation angle error for AGV was expressed. With least square method of system identification, the model of AGV was identified. Because a toy type of AGV was employed, its structure was simple, but AGV parameters were variable according to the operating conditions and environment, in order to improve the dynamic performances of AGV, the intelligent coordinated control strategy was used to design the AGV controller in the AGV steering control system. Simulation and experimental results showed the effectiveness of the proposed control strategy.

5. Mudit Sharma [22] showed an automated guided vehicle or automatic guided vehicle (AGV) was a mobile robot that follows markers or wires in the floor, or uses vision or lasers. They are most often used in industrial applications to move materials around a manufacturing facility or a warehouse. Application of the automatic guided vehicle has broadened during the late 20th century and they are no longer restricted to industrial environments. These systems offer many advantages over other forms of material transport. However, the design of these systems is complex due to the interrelated decisions that must be made and the large number of system design alternatives that are available. In particular, the design of the AGVS control system can be quite challenging, and it can dramatically affect the system cost and performance. This paper presents a classification of automated guided vehicle systems developed from a control perspective. This classification is demonstrated on several example systems from the literature. This paper develops a classification scheme that provides a structured mechanism for organizing the relevant information about the design of the AGVS from a control perspective. It allows the system designer to determine how design decisions will impact the control complexity. It also provides the foundation for a design aid that will help the system designer determine the most appropriate AGVS design for a specific application.

6. Khosro Bijanrostami [6] stated in his paper an Automated Guided Vehicle (AGV) is a set of cooperative driverless vehicle, used on manufacturing floor and coordinated by a centralized or distributed computer-based control system. AGVs-based Material Handling Systems (MHSs) are widely used in several Flexible Manufacturing Systems (FMS) installations. One of the challenge in MHSs is how flexible and adequate is the utilization. The key issue of the flexibility of MHSs is the routing system. It should be designed in a way that can be easily modified to become adaptable to new or replaced machines. The main focus of this study is to make an AGV with the convenient materials, simple and applicable routing system and more importantly reducing the cost and increasing the flexibility. For this propose an AGV is basically modelled and designed with CATIA software and developed with special specifications such as producing some parts by milling CNC when high accuracy was necessary. Moreover the flexibility of the system is improved

employing three more sensors which make the plan more intelligent dealing with multi directional guiding paths. Also benefiting from the colourful paths the flexible is enormously increased due to simplicity of the nature the paint to be plant or removed. Finally the users are able to extend components, add new machines, define them and specify routs for new settings without disturbing the operations in process. Here it addresses key issues involved in the design and operation of AGV-based MHSs for the FMS section of CAD-CAM laboratory of Mechanical Engineering Department of Eastern Mediterranean University.

7. Suthep Butdee, Frederic Vignat, Anan Suebsomran and Prasad KDV Yarlagadda [22] proposed a control strategy of Automated Guided Vehicle (AGV). The vehicle movement controlled by an inboard PLC do not need physical guide. The vehicle has 3 wheels. The front wheel is used for steering and driving. The 2 rear wheels are free and equipped with 2 encoders. The strategy is based on 2 main purposes: the path is stored in the PLC memory and the vehicle displacement is calculated form the wheel rotation measurement. The comparison between the required path and the actual position of the AGV allow calculating deviation error. Function of this error, a correction strategy of driving speed and steering angle is applied in order to get a smooth and precise displacement. Mobile vehicles must know its position and orientation in order to movement to reach the goals precisely. They described localization techniques for AGV that is based on the principle of Kalman Filtering (KF) algorithm estimation. They also addresses the problems of factory navigation and modelling with focus on keeping automatic travelling along the control path of the AGV. Position and orientation is measured by using encoder sensor on driving and steering axes. The control and localization systems are developed. Reference path and observation measurement are matched. To keep track of the matching result of both positions, the estimated position information used to update the vehicle's position by using the Kalman Filtering (KF) algorithm.

8. Zuria Zaidura Hassan [23] builds a prototype of an Automated Guided Vehicle (AGV) model that can move on a flat surface with its two driving wheels and a free wheel. The prototype is able to follow line on floor with the M68HC11 microcontroller as it main brain that control all

the navigation and responses to the environment. The ability to follow line on floor is an advantage of this prototype as it can be further developed to do more complicated task in real life. To follow the line, the microcontroller is attached to a sensor that continuously reflecting to the surface condition. Therefore, this project involves of designing and fabrication of the hardware and circuitry.

9. Syed Mohd Safwan Bin Sayed Md Saifuddinthis [24] focused on development of the control system for Automated Guided Vehicle (AGV). He oncentrates on developing the control system for AGV involve about how the AGV will operate, involve of the movement and loading & unloading mechanism. The objectives of his work are to develop the control system parts involving develop the electronic circuit system and computer program of the system. The wired guided navigation used to communicate the computer to the AGV to ensure the AGV work accordingly. Subsequently, his work needs to be fabricating each of the electronic components to become one complete circuit. All the computer programmings are building by using Code Blocks software, the compiler which was compatible with electronic components and Visual Basic software. Afterwards, Visual Basic 6 is used in this project to create user friendly interface which is better than C interface (Command Prompt). His work also includes the test result of control system involving test program and test circuit for the AGV before proceed to the real AGV control system.

10. Thomas Davich [25] looked at two automated material handling solutions: Automatic Guided Vehicle Systems (AGVS) and Autonomous Mobile Robots (AMRs). Each of these is described in their applications to either manufacturing or distributing. His work recommends that companies perform various types of analysis, including simulation, before investing in any type of material handling system. It concludes that AMRs are a more cost effective material handling solution compared to AGVS because AMRs have a lower cost of ownership and can see a full return on investment much quicker.

11. Sigal Berman, Edna Schechtman and Yael Edan [26] present a methodology for detailed evaluation of autonomous automated guided vehicles systems (AGVS) used for material handling. The methodology includes: stand-alone sub-module evaluation, including comprehensive simulations and statistical analysis of the system's sub-modules, along with hardware validation; quantitative system evaluation for integrated system performance investigation; and structured qualitative analyses for identifying strengths and weaknesses not readily apparent. The defined performance measures include aspects from both multi-robot and AGV fields. The developed methodology provides a systematic way to model, experiment with, analyze, and compare different AGVS control methods. To demonstrate the methodology, it was applied to evaluate a recently developed decentralized AGVS control method

12. Dr.G.Arun Kumar and Mr.J.Paul James Thadhani [27] presents a paper and in it they stated that Automated Guided vehicle (AGV) is like a robot that can deliver the materials from the supply area to the technician automatically. This is faster and more efficient. The robot can be accessed wirelessly. A technician can directly control the robot to deliver the components rather than control it via a human operator (over phone, computer etc. who has to program the robot or ask a delivery person to make the delivery). The vehicle is automatically guided through its ways. To avoid collisions a proximity sensor is attached to the system. The sensor senses the signals of the obstacles and can stop the vehicle in the presence of obstacles. Thus vehicle can avoid accidents that can be very useful to the present industrial trend and material handling and equipment handling will be automated and easy time saving methodology.

13. Sanam Khalili, Reza Mohammad and Nezhad [28] tried to develop automated guided vehicles systems that autonomously transport material from loading to unloading stations but our teams have been designing new AGVs with more maximizing productivity across industry. The potential of robot technology to increase the intelligence and adaptability of AGVs is largely unexploited in contemporary commercially-available vehicles. AGVs are increasingly becoming the popular mode of container transport and factories. These unmanned vehicles are used to transfer containers between two or more destination. The efficiency of a container terminal is

directly related to the amount of the time each vessel spends in the port. Advanced technologies, and in particular automated guided vehicle systems, have been recently proposed as possible candidates for improving the terminal's efficiency not only due to their abilities of significantly improving the performance but also to the repetitive nature of operations in container terminals. To our knowledge, this is the first instance of an AGV that has operated successfully in a relevant environment for an extended period of time without relying on any expensive systems. These vehicles have successfully used strategies of deliberately structuring the environment and adapting the process to the automation.

14. NurulHuda Binti Muhamad Nasir [29] proposed that the automated Guided Vehicle or AGV is one of material handling equipment that has been used widely in most manufacturing industry today as it provides more flexibility to the system. The basic concept of the AGV incorporates battery-powered and driverless vehicles with programming capabilities for path selection and positioning. They are equipped to navigate a flexible guide path network that can be easily modified and expanded. Years ago when the AGV technology first implemented, it was called driverless vehicle and navigate base on embedded wire or reflected light from paint strip mounted on the floor where the route is pre-programmed in the AGV system. Through the years, advance in technology had lead to development of the AGV system. Instead of navigating using fixed path, the AGV now able to navigate freely through various method such as using sensor that enabling the vehicle to calculate the distance it has travelled or using other landmark or equipment as a reference. Through this report, the types of AGV, the basic concept, the classifications of the AGV, types of navigation techniques and the steering mechanism that usually used in common AGV will be reviewed. Then, this report will be focusing on the mechanical design concept of the AGV which combines knowledge on mechanical parts such as the electric motor, gears, wheels, structure of the AGV, control system and so on

15. Himanshu Dudeja, Laxman Bagal and Nityanand Zunjur [30] tried to make an AGV with the convenient materials, simple and applicable routing system and more importantly reducing the cost and increasing the flexibility. For this propose an AGV is basically modelled and designed

with CATIA software and developed with special specifications that an automated Guided Vehicle (AGV) is a set of cooperative driverless vehicle, used on manufacturing floor and coordinated by a centralized or distributed computer-based control system. AGVs-based Material Handling Systems (MHSs) are widely used in several Flexible Manufacturing Systems (FMS) installations. One of the challenge in MHSs is how flexible and adequate is the utilization. The key issue of the flexibility of MHSs is the routing system. It should be designed in a way that can be easily modified to become adaptable to new or replaced machines. The main focus of this study is to.

16. Kim et al. [31] proposed a deadlock detection and prevention algorithms for AGVs. It was assumed that vehicles reserve grid blocks in advance to prevent collisions and deadlocks among AGVs. A graphic representation method, called the "reservation graph," was proposed to express a reservation schedule in such a form that the possibility of a deadlock can be easily detected. A method to detect possible deadlocks by using the reservation graph was suggested.

17. Wuwei et al [32]. They presented the new navigation method for AGV with fuzzy neural network controller when in the presence of obstacles. Their AGV can avoid the dynamic and static obstacle and reach the target safely and reliably.

18. Wu et al. [33] used fuzzy logic control and artificial potential field (APF) for AGV navigation. The APF method is used to calculate the repulsive force between the vehicle and the closest obstacle and the attractive force generated by the goal. A fuzzy logic controller is used to modify the direction of the AGV in a way to avoid the obstacle.

19. Alves and Junior [34] used a step motor to turn the direction of the ultra -sonic sensors, so that each sensor can substitute two or more sensors in mobile robot navigation.

1.12 OBJECTIVES AND SCOPE:

1.12.1 Objectives:

Automated Guided Vehicle (AGV) is gaining importance day by day for Material Handling applications in automated factory environment. In develop countries, AGV based Material Handling is implemented in all Flexible Manufacturing System (FMS) installations. In the Indian context, few applications of AGV System have been started in automobile Industry.

The literature survey carried out in the present work reveals that there is a need for research and development on AGV System so that the requirement of the Industry for appropriate automated material handling devices, could be made a near future.

Keeping this view in mind the present work has the following objectives:

1) To study the different operational functions of an existing AGV System.
2) To study the different motions of the AGV driving wheels for carrying out motions like straight-forward motion, right turn motion, left turn motion, clockwise turn for 180 degree, anticlockwise turn for 180 degree and straight backward motion.
3) To apply reverse engineering technique for developing the 3D CAD model of the existing AGV system.
4) To implement necessary changes in the 3D CAD model for making the AGV suitable for carrying a payload of 50 Kg.
5) To analyse the developed model for stress and deflection under the payload.
6) To study the power drive and control system of the existing AGV using Reverse Engineering technique.
7) To carry out testing of the different control features of the AGV motions including the sensors.
8) To test the AGV for its basic motions by running test programs in personal computer.

1.12.2 Scope: The scope of the present investigation has been limited to the existing AGV System available in the Department of the Production Engineering, Jadavpur University. The present work has been carried out with the facilities available in the department.

CHAPTER-2
DETAILS OF EXISTING AGV SYSTEM

2.1 Existing AGV System:

In FMS Lab, (Production Engineering Department, Jadavpur University) there exist an AGV System imported from TQ International, U.K. The AGV System is lying inoperative for about 15 years. Maintenance support for this system is also not available from local vendors. In the present work an attempt has been made to bring the AGV system in an operative condition. This has led to carry out a study of the AGV system through Reverse Engineering technique. The photograph of the existing AGV system viewing from various directions are shown in Fig. 2.1, Fig. 2.2, Fig. 2.3 and Fig. 2.4:

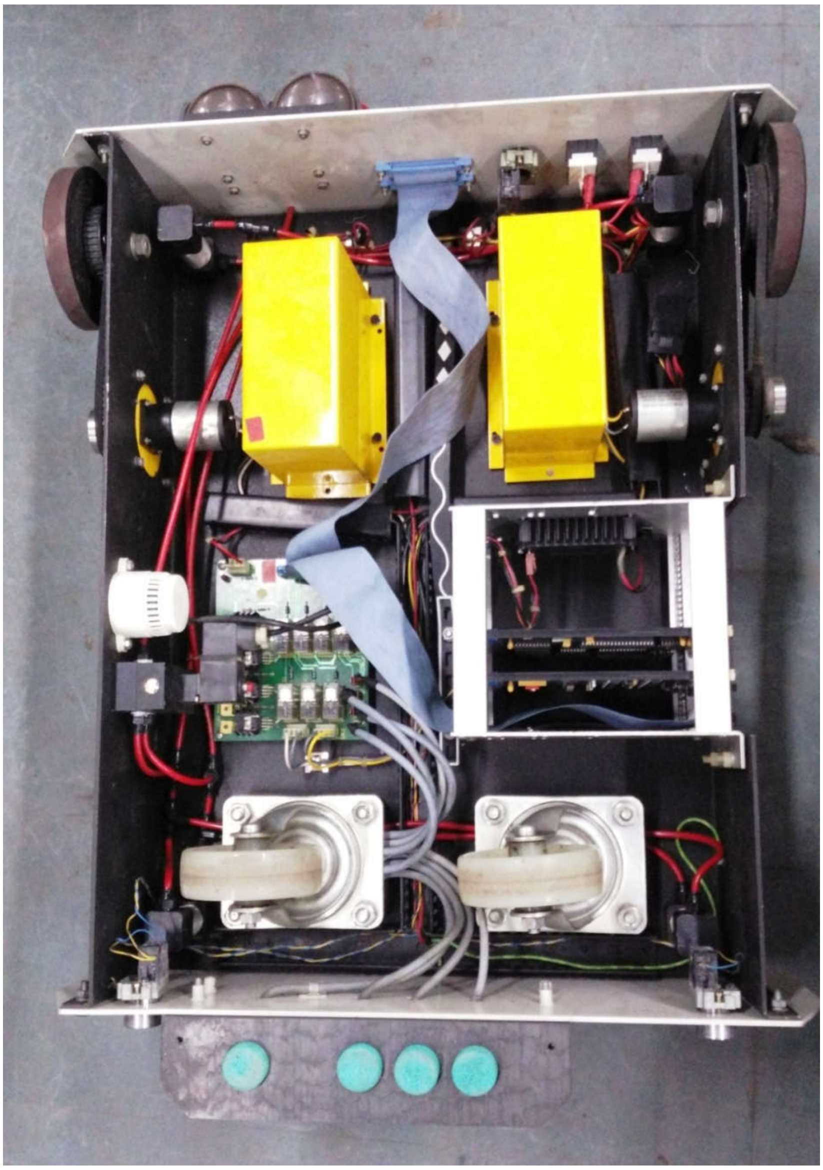


Fig. 2.1 Bottom View

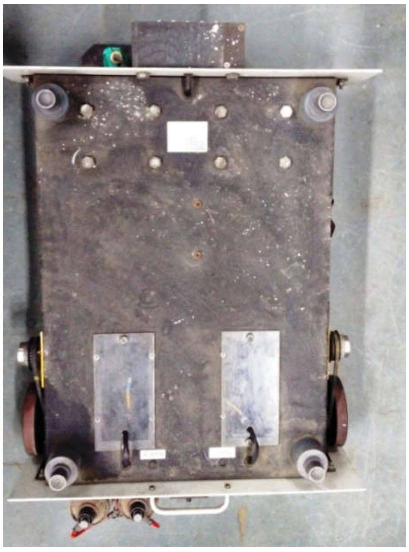


Fig. 2.2 Top View

Fig. 2.3 Front View

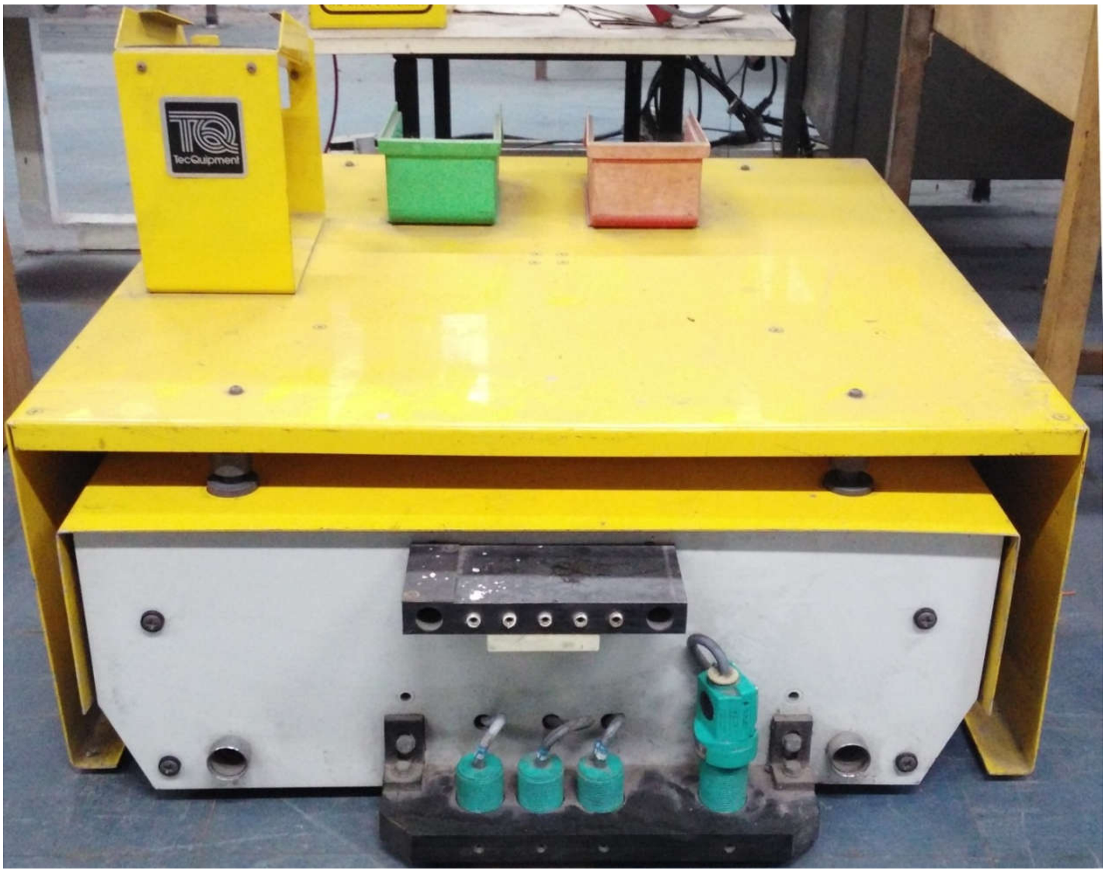


Fig. 2.4 3D View with pallet

The various parts of this AGV System are:

i. Battery Box
ii. Motor
iii. Timing Belt
iv. Control Box
v. Swivel Custer
vi. Docking Pins
vii. Power Drive System
viii. Wheel
ix. Toothed Wheel attached with motor Shaft
x. Reset Switch, Motor power and Battery power Switch

2.2 **Battery Box:**

There are two number of battery box in this AGV System each contain one rechargeable battery. Total required power to drive this AGV system is provided by these batteries. It has been seen that, the voltage and capacity of those two batteries are same i.e. 12V, 7Ah and they are connected through series. To protect both batteries from supply source, there is an individual fuse system. The power from the supply source like charger is provided to the battery through fuse. The location of the battery box with battery was shown in Fig. 2.1. The photograph of battery and battery box shown in Fig. 2.5 and Fig. 2.6:

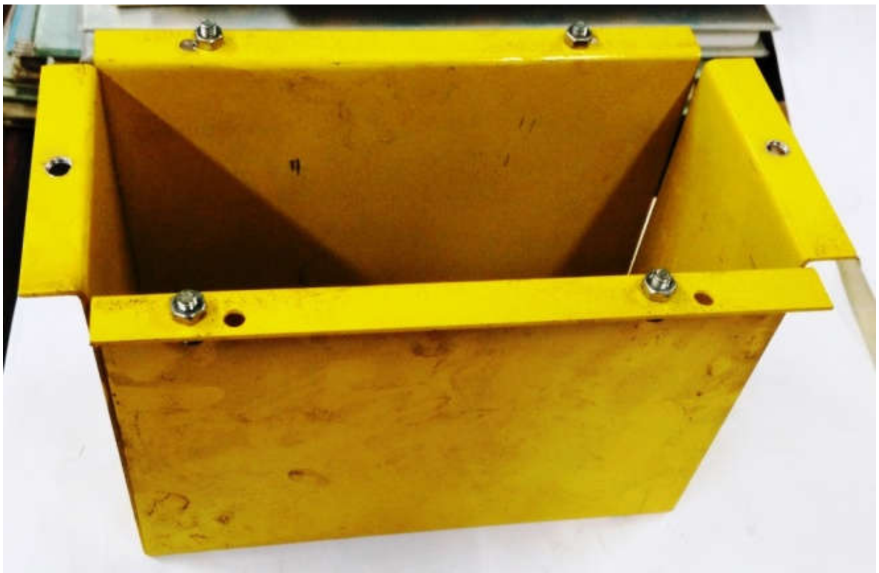


Fig. 2.5 Battery Box

Fig. 2.6 Rechargeable Battery

2.3 Motor:

The motion of the AGV system is induced from rotational speed of the motor whose nominal voltage is 24V. There are two stepper motors which deliver the rotational speed to the toothed wheel (motor shaft) through a gear train mechanism. From Specification of the motor, It is seen that gear train ratio is 17:75, maximum nominal rpm speed of the motor shaft is 2420rpm and maximum torque is 13.6 mN.m. To drive the motor, power is provided by batteries. The location of the motors in AGV was shown in Fig. 2.1. The rotation directions of those motors are controlled by the relay board. The photograph of the motor is shown in Fig. 2.7:

Fig. 2.7 Maxon DC Stepper Motor

2.4 Timing Belt:

In this AGV System, there exist two timing belts in each side of the main body. This belt plays an important role to transmit the power from toothed wheel (motor Shaft) which is connected with motor, to the toothed wheel (wheel housing) which is connected to the wheel shaft. In this belt, number of teeth is 90. The location of timing belt was shown in Fig. 2.1. The photocopy of the timing belt is shown in Fig 2.8:

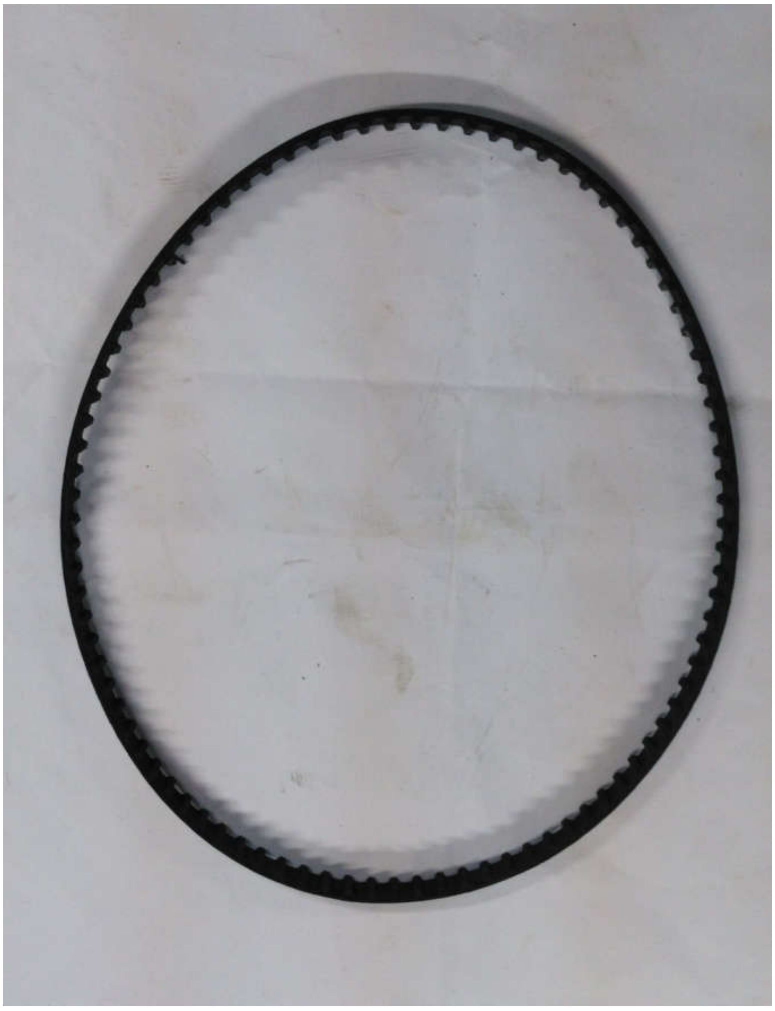


Fig. 2.8 Timing Belt

2.5 Control Box:

The most important part of this system is Control Box. It is made of Aluminium. There are two important electronic boards (interface board and microcontroller board) within this control box. The location of the control box was shown in Fig. 2.1 and the photocopy of the control is shown Fig. 2.9:

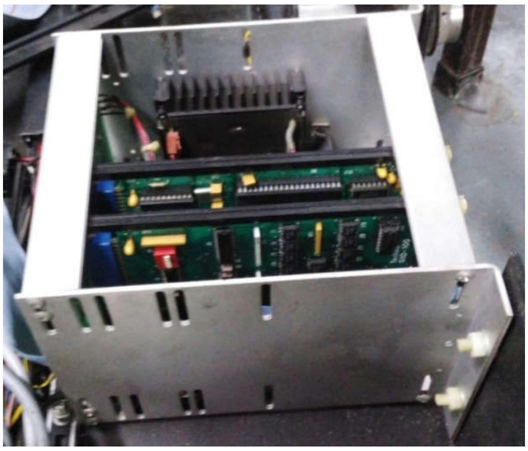


Fig. 2.9 Control Box

2.6 Swivel Custer:

In this AGV System, there are two Swivel Casters. It has two important functions.

a) It provides the support of the AGV and

b) It steers the system.

The location of Swivel Custer was shown in Fig. 2.1. The photograph of present Swivel Custer is shown in Fig. 2.10:

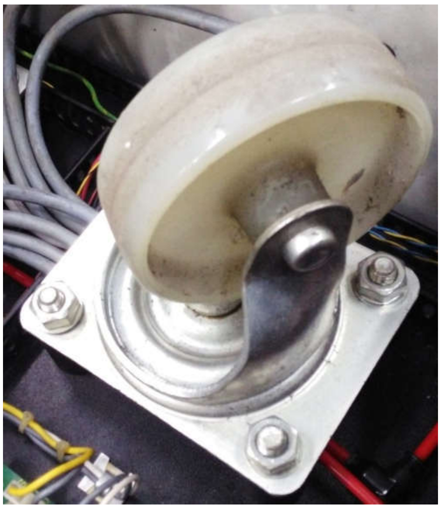


Fig. 2.10 Swivel Custer

2.7 **Docking Pins:**

It is an intermediate device between –

a. Charger and AGV, and
b. Computer and AGV

When connected between Charger and AGV, It is an intermediate device through which recharging of battery is possible.

When connected between Computer and AGV, It is an intermediate device through which it is possible to provide control program in microcontroller.

The photograph and layout of docking pin is shown in Fig. 2.11 and Fig. 2.12

Fig. 2.11 Docking Pin

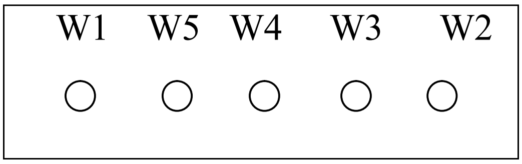


Fig. 2.12 Docking Pin Layout

W1 → Red wire, connected with battery
W2 → Small Red wire, connected with microcontroller through pin 2 of 25 pin communication port
W3 → Saffron wire, connected with Relay board
W4 → Small Yellow wire, connected with microcontroller through pin 3 of 25 pin communication port
W5 → Black wire, connected with battery

2.8 Power Drive System:

The power drive System is shown below. Actual movement of the vehicle is possible by this system. In this system, there consist two toothed wheel (whose teeth are 40 and 30) and one toothed belt (whose teeth is 90). It is located between motor output shaft and wheel shaft. Power is transmitted from motor shaft to wheel shaft through this system. The photograph of the power drive system is shown in Fig. 2.13.

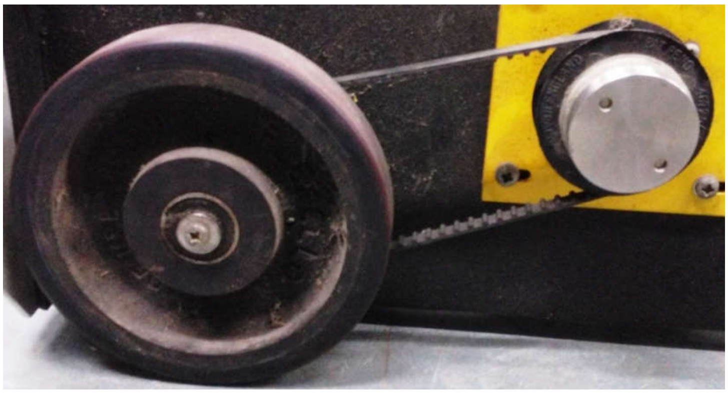


Fig. 2.13 Power Drive System

2.9 **Wheel:**

There are two wheels in each side of the AGV. It is used to support the AGV. AGV can attain any velocity by using both wheels. One toothed wheel is mounted on the one side of the wheel using four screws. Both the wheel and toothed wheel has one metallic hub at centre which is supported by ball bearing and fitted with the main body with the help of an axle. Photograph of the wheel are shown in Fig. 2.14a and Fig. 2.14b.

Fig. 2.14a wheel

Fig. 2.14b Outer Side View

2.10 **Reset or Emergency Button:**

There is one emergency switch at the rare side of the AGV. For an emergency situation, the AGV can be stopped by pressing this switch. There are another two switches: motor power switch and battery power switch. If power source (charger) is connected with the AGV, batteries will charge when 'battery power switch' of the AGV is in ON condition. If the power switch is off, batteries will not charge even power source is connected. Power will be provided to the motor from batteries when motor power switch is in ON condition only.

Fig. 2.15 Reset Button with motor power and battery power switch

CHAPTER-3

REVERSE ENGINEERING OF THE AGV SYSTEM

3.1 REVERSE ENGINEERING:

3.1.1 Introduction:

Engineering is the profession involved in designing, manufacturing, constructing, and maintaining of products, systems, and structures. At a higher level, there are two types of engineering: forward engineering and reverse engineering.

Forward engineering is the traditional process of moving from high-level abstractions and logical designs to the physical implementation of a system. In some situations, there may be a physical part without any technical details, such as drawings, bill-of-material, or with engineering data, such as thermal and electrical properties.

The process of duplicating an existing component, subassembly, or product, without the aid of drawings, documentation, or computer model is known as reverse engineering.

Reverse engineering can be viewed as the process of analyzing a system to:

i. Identify the system's components and their interrelationships
ii. Create representations of the system in another form or a higher level of abstraction
iii. Create the physical representation of that system

Reverse engineering is very common in various fields such as software engineering, entertainment, automotive, consumer products, microchips, chemicals, electronics, and mechanical designs. For example, when a new machine comes to market, competing manufacturers may buy one machine and disassemble it to learn how it was built and how it works.

In some situations, designers give a shape to their ideas by using clay, plaster, wood, or foam rubber, but a CAD model is needed to enable the manufacturing of the part. As products become more organic in shape, designing in CAD may be challenging or impossible. There is no guarantee that the CAD model will be acceptably close to the sculpted model. Reverse engineering provides a solution to this problem because the physical model is the source of information for the CAD model. This is also referred to as the part-to-CAD process.

Another reason for reverse engineering is to compress product development times. In the intensely competitive global market, manufacturers are constantly seeking new ways to shorten lead-times to market a new product. Rapid product development (RPD) refers to recently developed technologies and techniques that assist manufacturers and designers in meeting the demands of reduced product development time. For example, injection-moulding companies must drastically reduce the tool and die development times. By using reverse engineering, a three-dimensional product or model can be quickly captured in digital form, re-modelled, and exported for rapid prototyping/tooling or rapid manufacturing.

3.1.2 Reasons for Reverse Engineering:

i. There is inadequate documentation of the original design
ii. The original design documentation has been lost or never existed
iii. The original CAD model is not sufficient to support modifications or current manufacturing methods
iv. To analyze the good and bad features of competitors' product
v. The original supplier is unable or unwilling to provide additional parts
vi. To gain competitive benchmarking methods to understand competitor's products and develop better products
vii. The original manufacturer of a product no longer produces a product
viii. The original manufacturer no longer exists, but a customer needs the product
ix. Some bad features of a product need to be designed out. For example, excessive wear might indicate where a product should be improved
x. To strengthen the good features of a product based on long- term usage of the product
xi. To explore new avenues to improve product performance and features

xii. The original equipment manufacturers are either unwilling or unable to supply replacement parts, or demand inflated costs for sole-source parts

Reverse engineering enables the duplication of an existing part by capturing the component's physical dimensions, features, and material properties. Before attempting reverse engineering, a well-planned life-cycle analysis and cost/benefit analysis should be conducted to justify the reverse engineering projects. Reverse engineering is typically cost effective only if the items to be reverse engineered reflect a high investment or will be reproduced in large quantities. Reverse engineering of a part may be attempted even if it is not cost effective, if the part is absolutely required and is critical to a system.

Reverse engineering of mechanical parts involves acquiring three-dimensional position data in the point cloud using laser scanners or computed tomography (CT). Representing geometry of the part in terms of surface points is the first step in creating parametric surface patches. A good polymesh is created from the point cloud using reverse engineering software. The cleaned-up polymesh, NURBS (Non-uniform rational B-spline) curves, or NURBS surfaces are exported to CAD packages for further refinement, analysis, and generation of cutter tool paths for CAM. Finally, the CAM produces the physical part.

It can be said that reverse engineering begins with the product and works through the design process in the opposite direction to arrive at a product definition statement (PDS). In doing so, it uncovers as much information as possible about the design ideas that were used to produce a particular product.

3.1.3 Difference Between Reverse Engineering and other types:

The most traditional method of the development of a technology is referred to as "forward engineering." In the construction of a technology, manufacturers develop a product by implementing engineering concepts and abstractions. By contrast, reverse engineering begins with final product, and works backward to recreate the engineering concepts by analyzing the design of the system and the interrelationships of its components.

Value engineering refers to the creation of an improved system or product to the one originally analyzed. While there is often overlap between the methods of value engineering and reverse engineering, the goal of reverse engineering itself is the improved documentation of how the original product works by uncovering the underlying design. The working product that results from a reverse engineering effort is more like a duplicate of the original system, without necessarily adding modifications or improvements to the original design.

3.1.4 Stages Involved in the Reverse Engineering Process:

Since the reverse engineering process is time-consuming and expensive, reverse engineers generally consider whether the financial risk of such an endeavour is preferable to purchasing or licensing the information from the original manufacturer, if possible.

In order to reverse engineer a product or component of a system, engineers and researchers generally follow the following four-stage process:

- Identifying the product or component which will be reverse engineered
- Observing or disassembling the information documenting how the original product works
- Implementing the technical data generated by reverse engineering in a replica or modified version of the original
- Creating a new product (and, perhaps, introducing it into the market)

In the **first stage** in the process, sometimes called "pre-screening," reverse engineers determine the candidate product for their project. Potential candidates for such a project include singular items, parts, components, units, subassemblies, some of which may contain many smaller parts sold as a single entity.

The **second stage**, disassembly or decompilation of the original product, is the most time-consuming aspect of the project. In this stage, reverse engineers attempt to construct a characterization of the system by accumulating all of the technical data and instructions of how the product works.

In the **third stage** of reverse engineering, reverse engineers try to verify that the data generated by disassembly or decompilation is an accurate reconstruction the original system. Engineers verify the accuracy and validity of their designs by testing the system, creating prototypes, and experimenting with the results.

The **final stage** of the reverse engineering process is the introduction of a new product into the marketplace. These new products are often innovations of the original product with competitive designs, features, or capabilities. These products may also be adaptations of the original product for use with other integrated systems, such as different platforms of computer operating systems.

Often different groups of engineers perform each step separately, using only documents to exchange the information learned at each step. This is to prevent duplication of the original technology, which may violate copyright. By contrast, reverse engineering creates a different implementation with the same functionality.

3.2 3D Model of the Existing System:

For the design and analysis of the AGVS Autodesk Inventor 2016 have been used. In the current research work Autodesk Inventor 2016 has been used to create the 3D models of different parts of the AGVS and to prepare 2D drawing of those parts. Stress analysis of the AGVS has been also done by Autodesk Inventor 2016.

The modelled Mechanically Assemble view of the AGV system shown below:

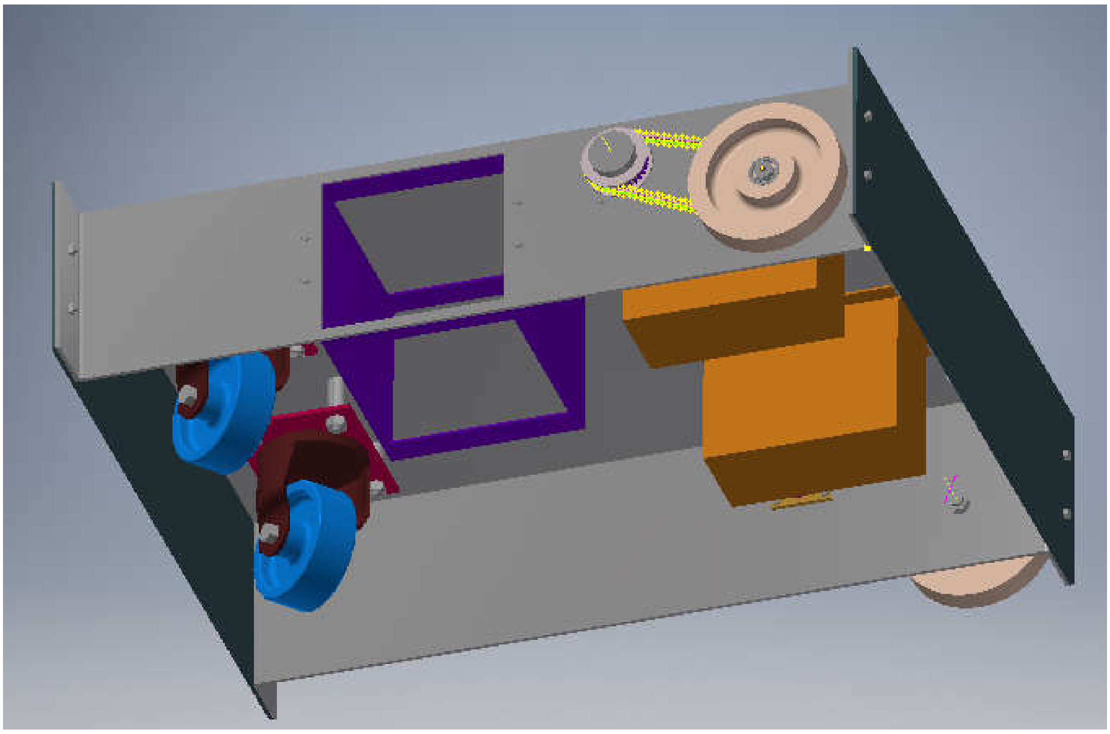


Fig. 3.1 Mechanically Assemble view of the AGV system

The various model parts of the AGV System are described below:

3.2.1 Main Body:

Metal: Mild Steel

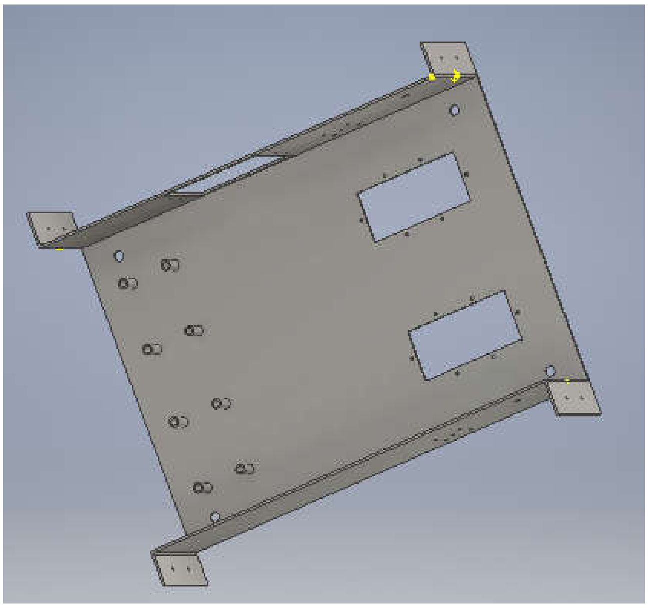


Fig. 3.2 Main Body

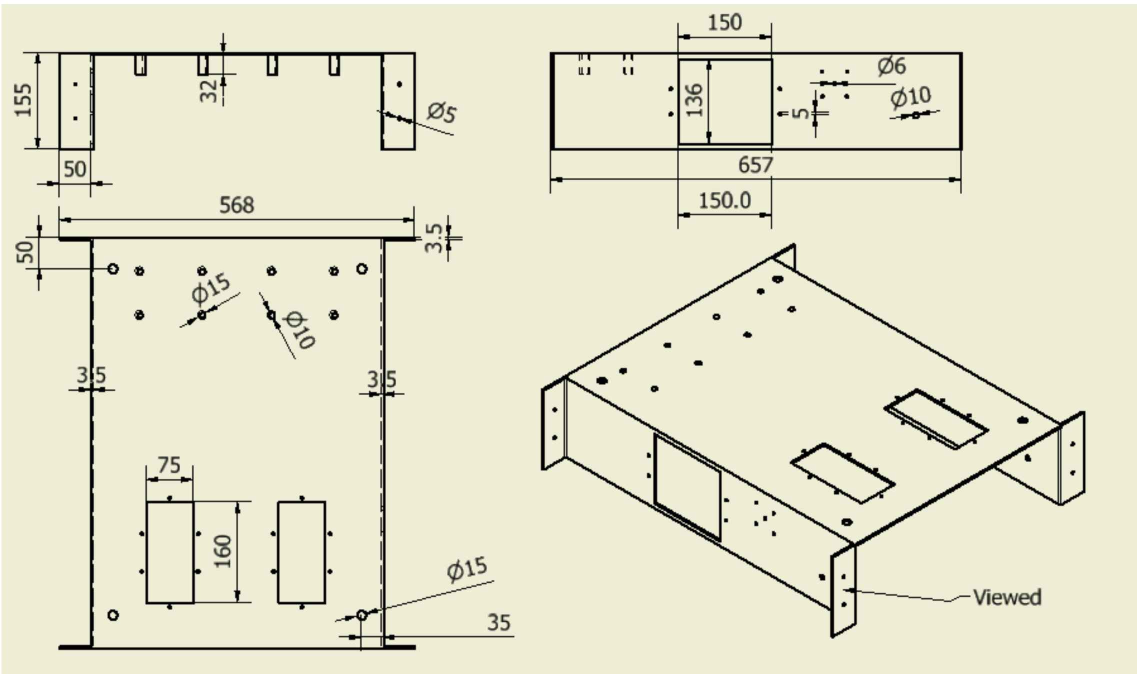


Fig. 3.3 Detail view of Main Body

3.2.2 Motor:

Two motors have been considered for this system. Axis of the motor is perpendicular to the side face of main body. The motors are fixed with the side face of main body using screw. The specifications of the motor are given in Table 3.1:

Table 3.1 Specification of the motor

Manufacturer	Maxon DC motor
Manufacturer Part No	2140.937-61.112-050
Type of motor	Stepper Motor
Quantity	2pc
Nominal Voltage	24V
No Load Speed	4110rpm
No Load Current	6019A
Nominal Speed	2420rpm
Nominal torque of motor (max. continuous torque)	13.6 mN m
Nominal current (max. Continuous current	0.164A
Motor Outer Dimension with gearbox	Ø 40mm x65mm
Spindle dimension	Ø6mm x37mm
Weight	190gm
Maximum torque after gearbox	0.1-0.6 Nm
Change gear ratio	17:75

Maximum torque after gearbox= 0.6Nm

Maximum torque of motor= 13.6mNm

So gear Ratio= $(13.6\text{x}10^{-3})/0.6=17/75$

Maximum Speed of motor=2420 rpm

So maximum output speed=2420x (17/75) =548.5 rpm

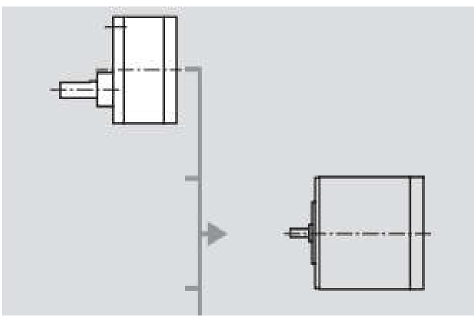


Fig. 3.4 Motor and gearbox arrangement
(Taken from Specification)

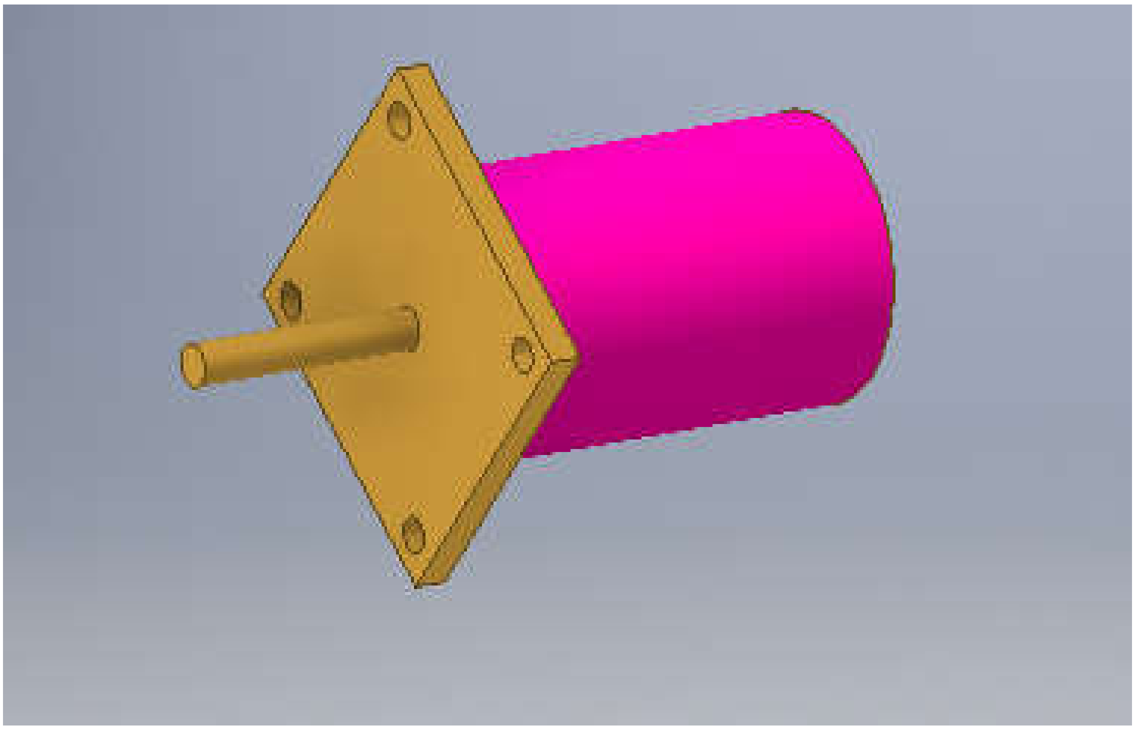


Fig. 3.5 Motor

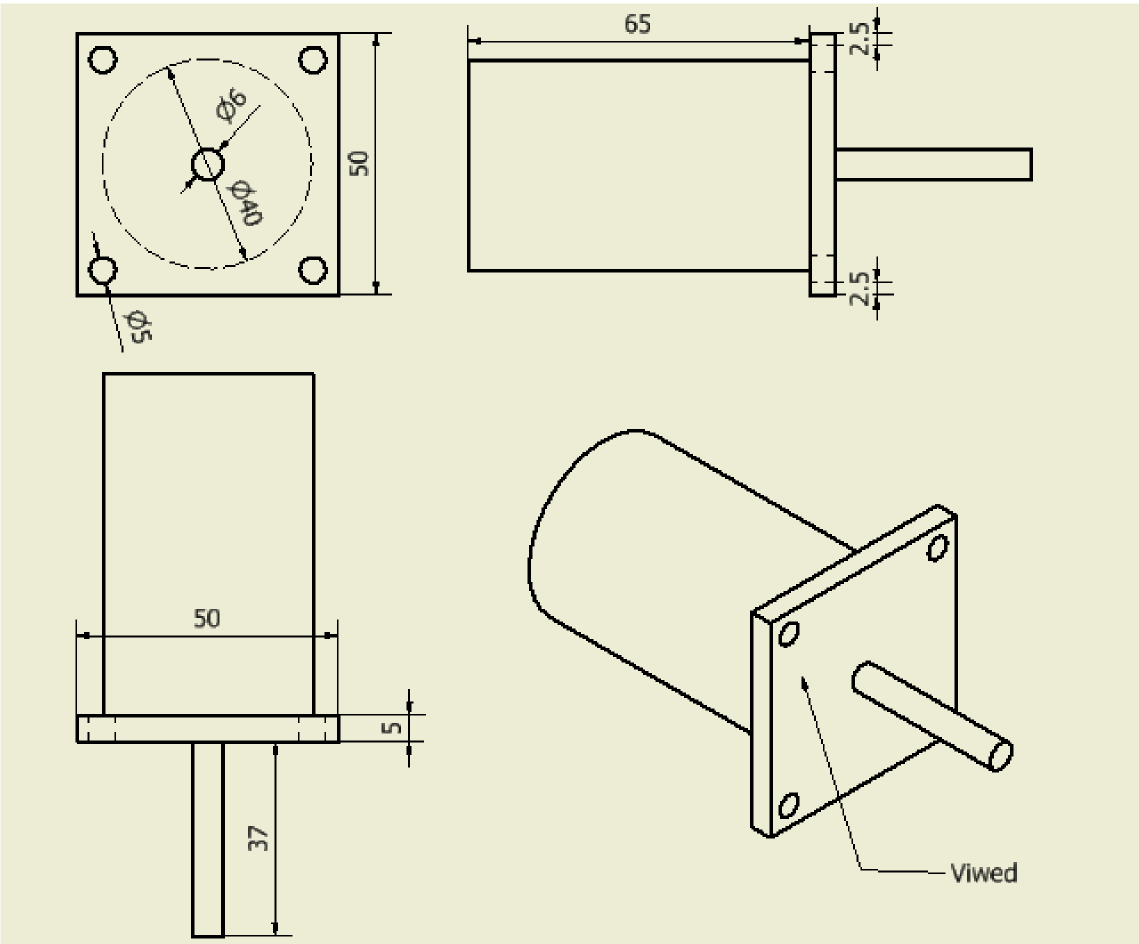


Fig. 3.6 Detail Drawing of Motor

3.2.3 Battery Box:

Two Battery connected in series has been considered for this system. Those batteries are placed in a sheet metal container which is fixed with upper face of chassis where slot is present in chassis. The specifications of the battery are given in Table 3.2:

Table 3.2 Specification of battery

Manufacturer	Exide Industries Ltd.
Battery Model	CS 7-12
Type	Lead acid battery
Battery Voltage (V)	12
Capacity	7Ah
Dimensions(mm)	151x100x65
Weight	2.6 kg
Metal of Battery container	Aluminium

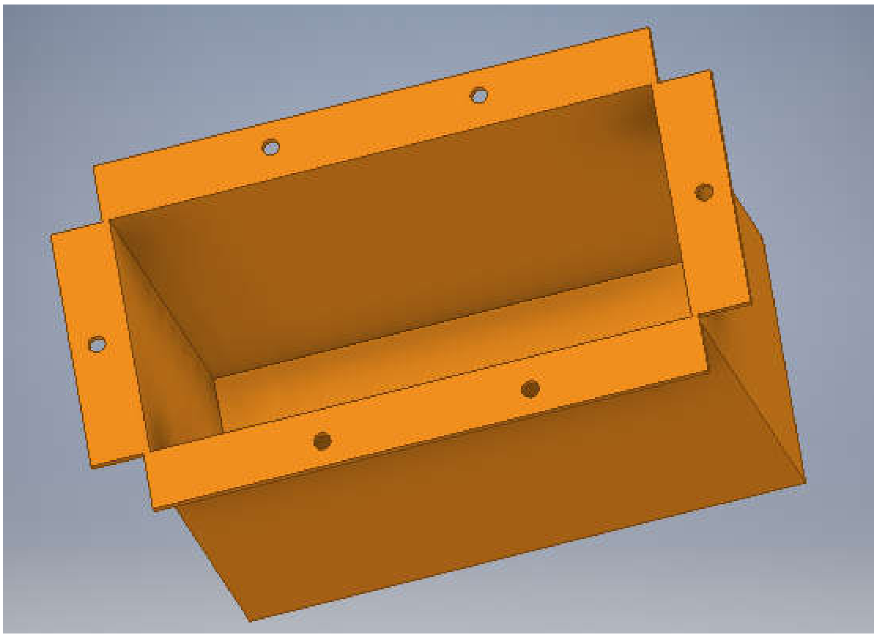


Fig. 3.7 Battery container

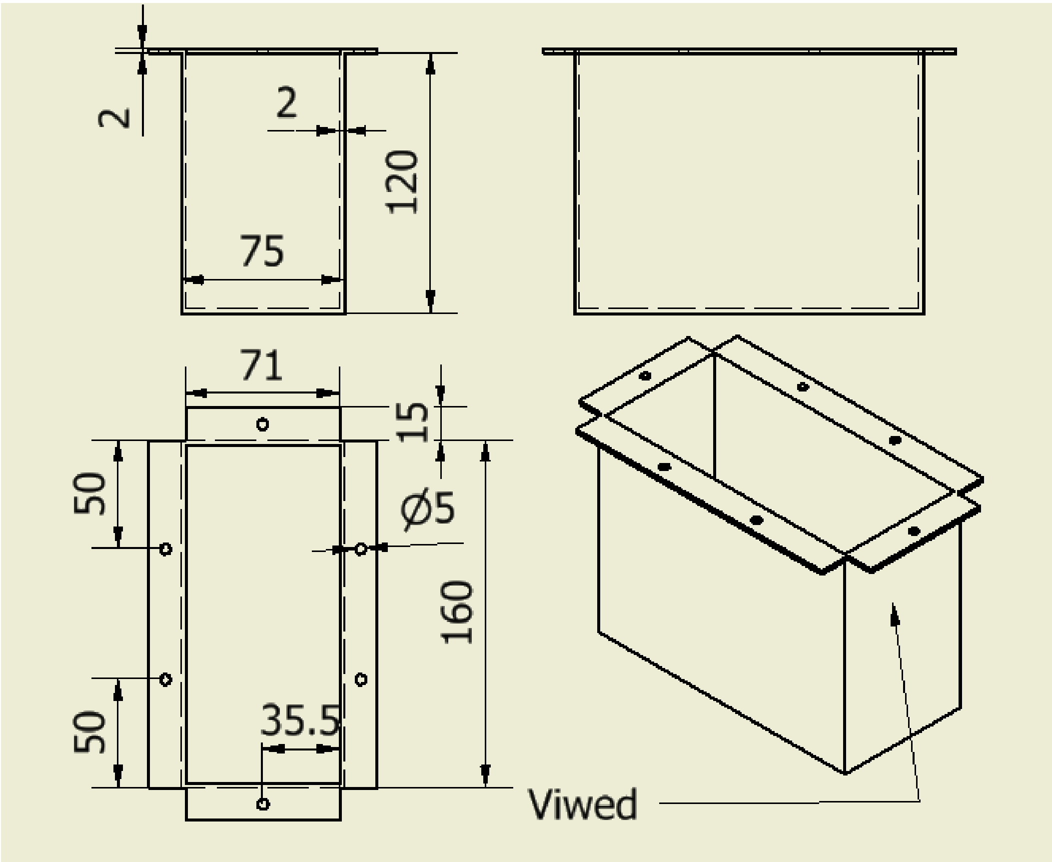


Fig. 3.8 Details Drawing of Battery Container

3.2.4 Bearing:

No of bearing= 2

Dimensions: Outer Diameter= 26mm, Thickness= 8mm

Family: PN-87/M-86160 (from Autodesk Inventor)

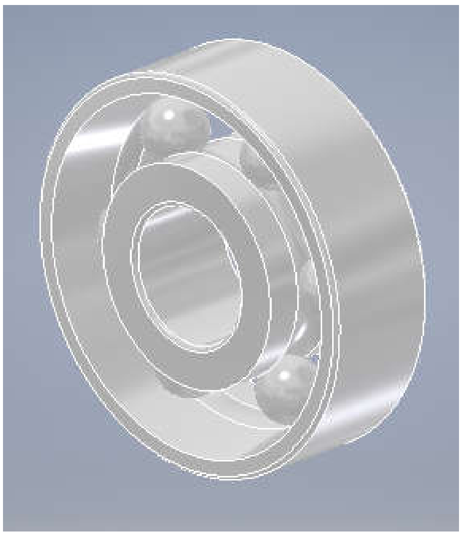


Fig. 3.9 Bearing

3.2.5 Front and End cover:

Two cover are present in this AGVS. One is situated in front of the vehicle and another is situated in the end of the vehicle. Details are given below:

Dimensions (mm): 568x155x3.5
Metal: Aluminium
Hole dimension= ø 5

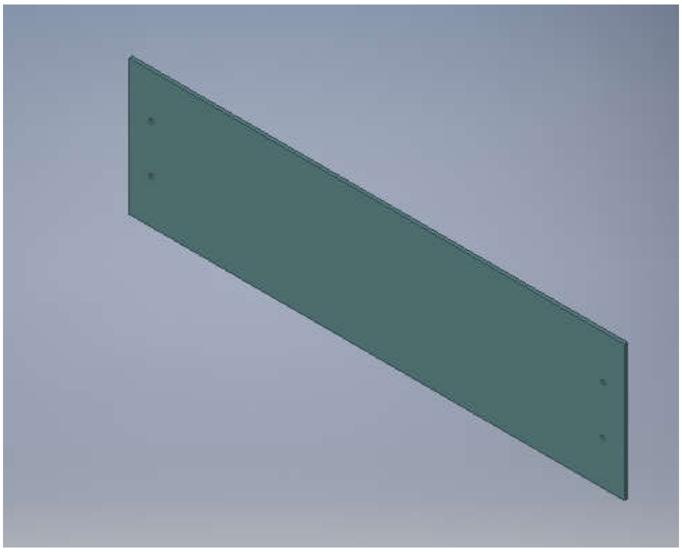


Fig. 3.10 Front and End Cover

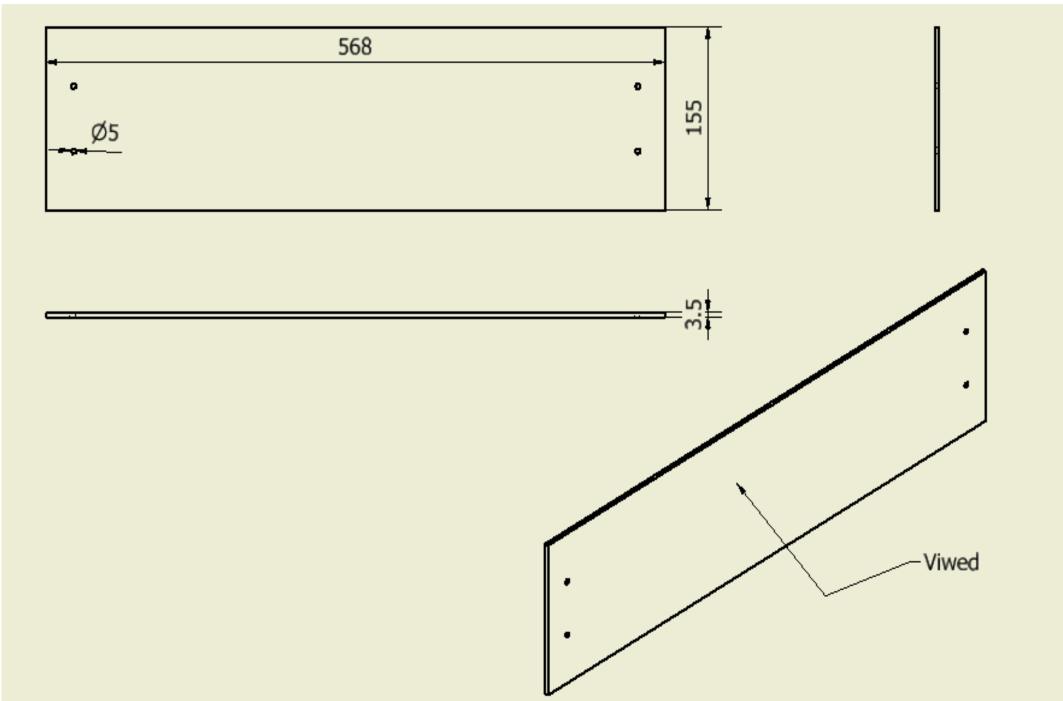


Fig. 3.11 Details Drawing of Front and End cover

3.2.6 Timing Belt:

No of teeth=90

Centre to centre distance=139.284 mm

Thickness of belt=1.3mm

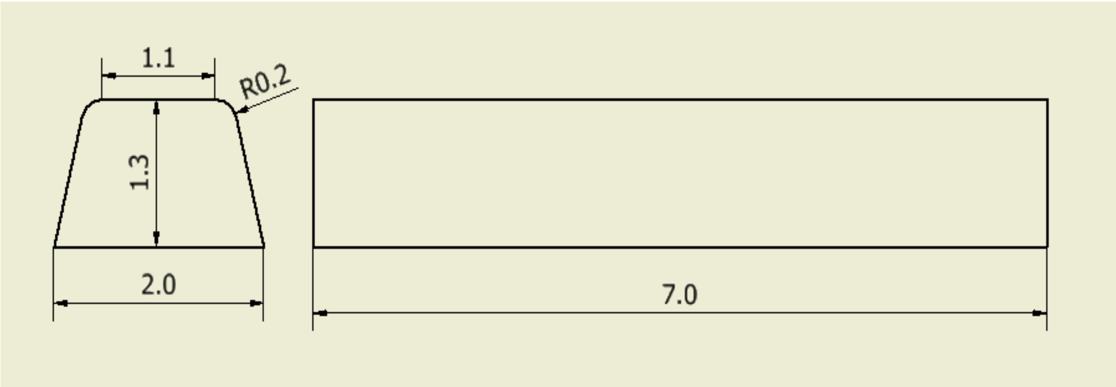


Fig. 3.12 Tooth cross section

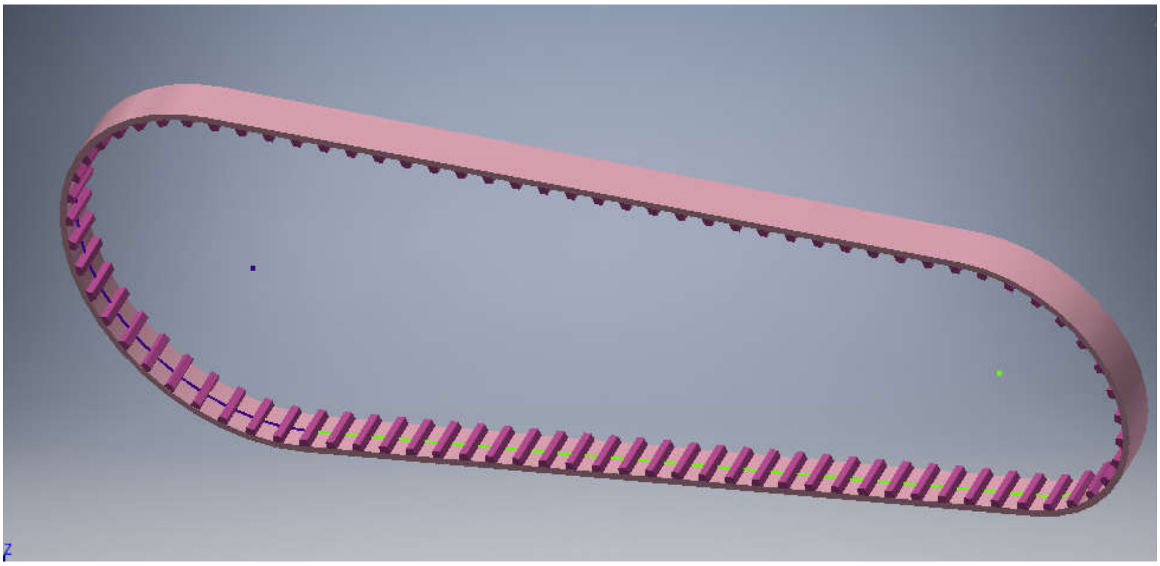


Fig. 3.13 Timing Belt

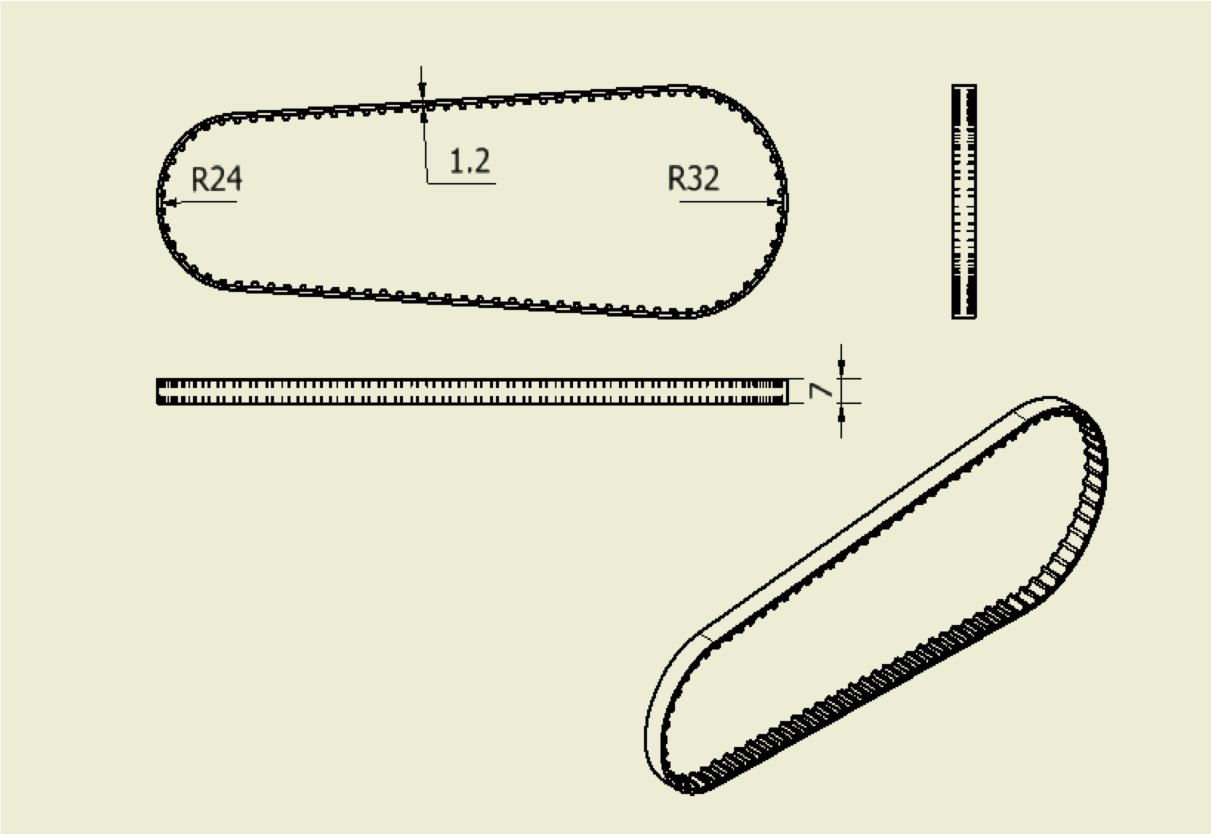


Fig. 3.14 Details drawing of Timing Belt

3.2.7 Toothed wheel:

i.Tooth Wheel (Axle Axis) :

No of teeth=40
Gear thickness=12.5mm
Hub dimension=ø38mm x24mm with a hole dimension (mm) =ø6x8
Hub material=Mild Steel
Gear material= Nylon
Dimension of gear guards=ø75mm x1.5mm
Wheel Material= Rubber

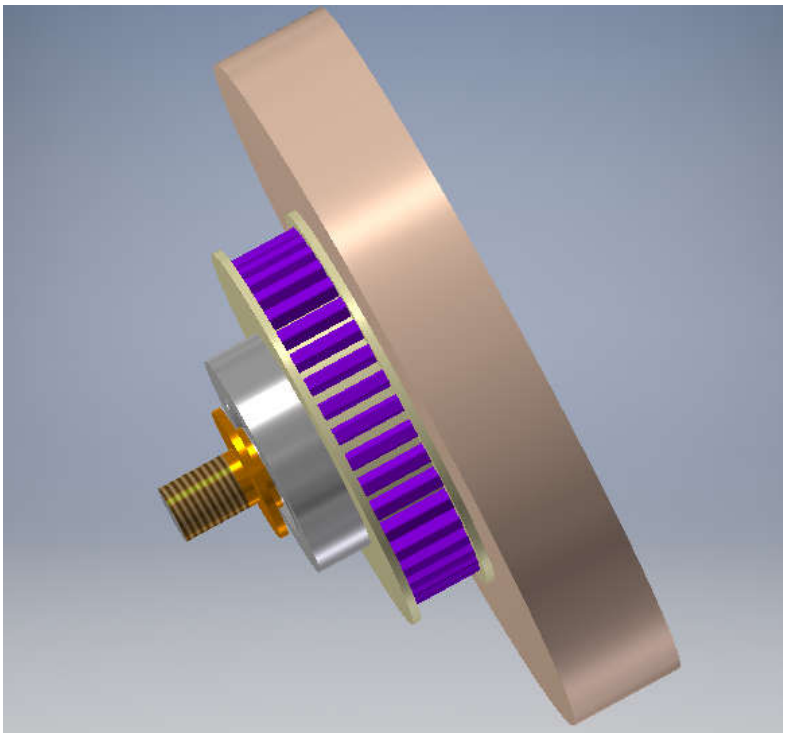


Fig. 3.15 Tooth Wheel (Wheel Shaft)

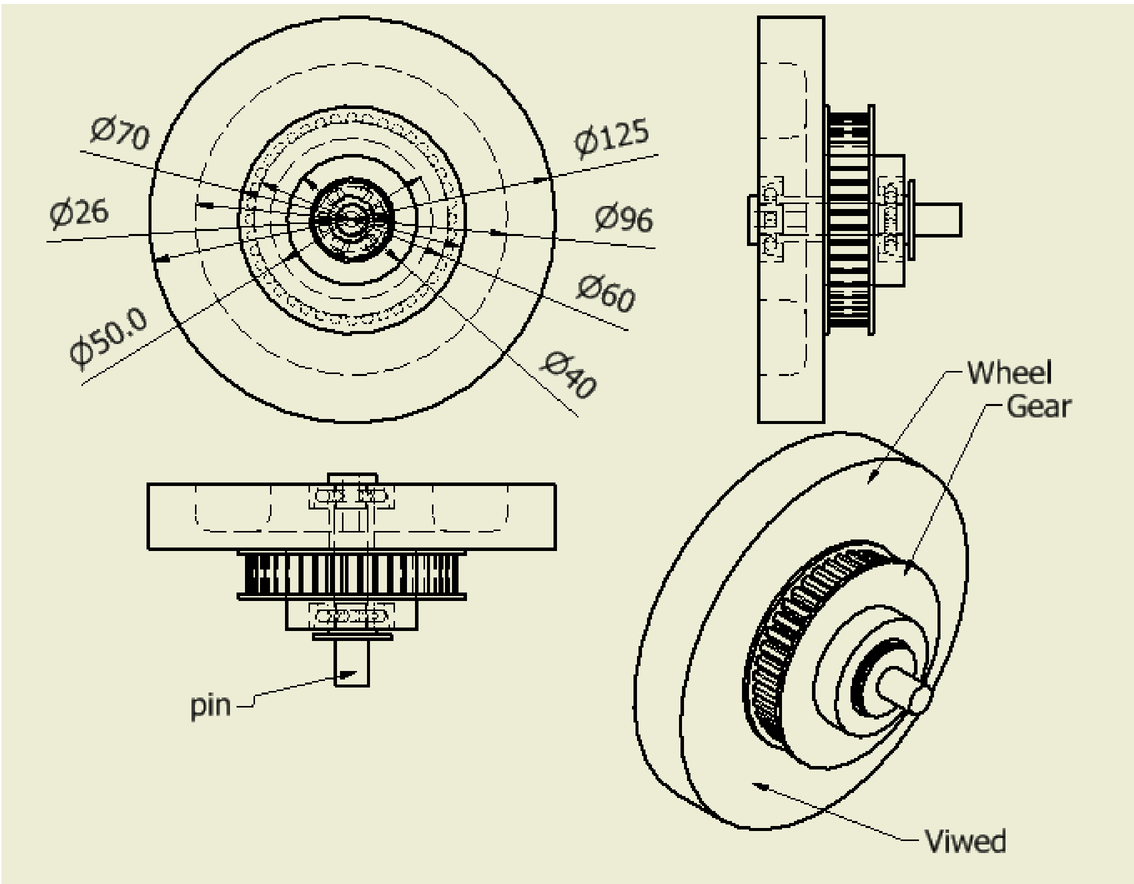


Fig. 3.16 Details drawing of the Tooth Wheel (Wheel Shaft)

ii. Tooth Wheel (Motor Shaft):

No of teeth=30
Gear thickness=12.5mm
Hub dimension=ø38mm x24mm with a hole dimension (mm) =ø6x8
Hub material=Mild Steel
Gear material= Nylon
Dimension of gear guards=ø55mm x1.5mm

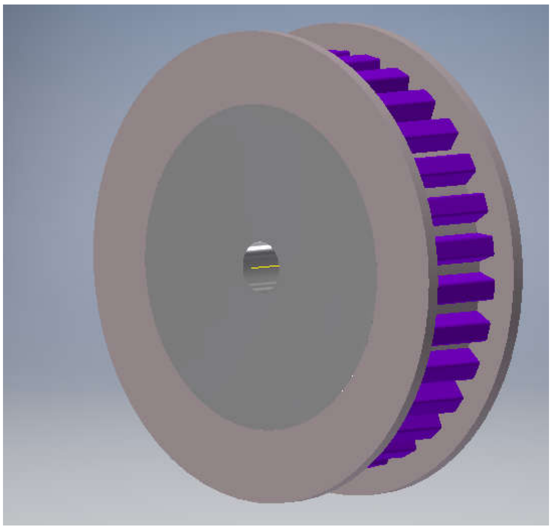


Fig. 3.17 Tooth Wheel (Motor Shaft)

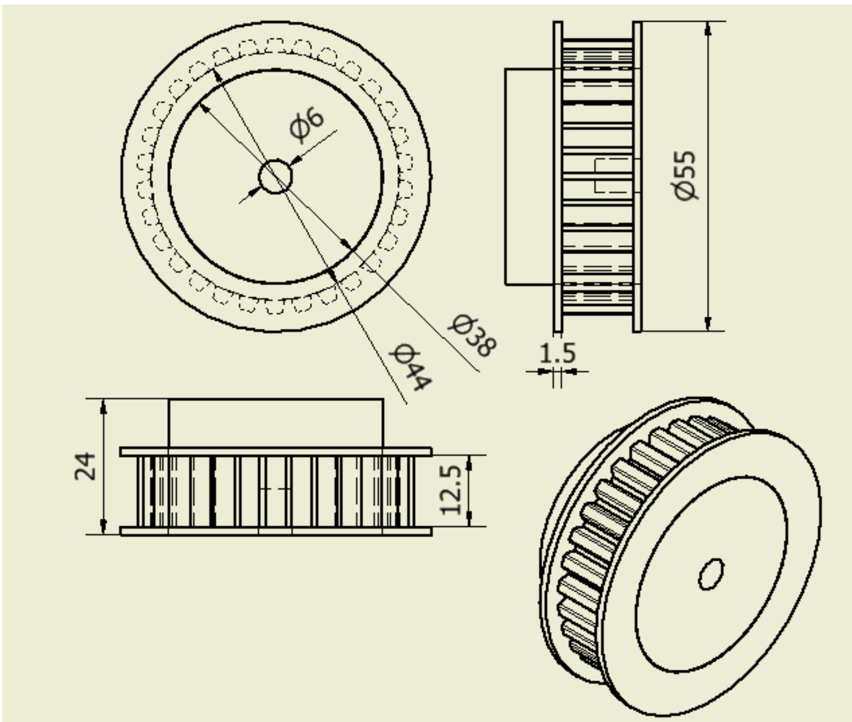


Fig. 3.18 Details drawing of Tooth Wheel (Motor Shaft)

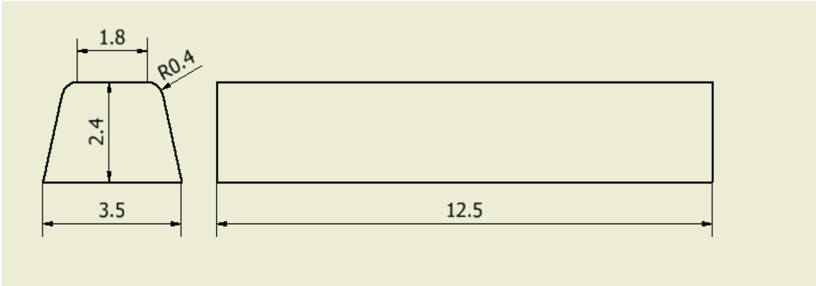


Fig. 3.19 Details drawing of tooth of the gear

3.2.8 Swivel Custer with Support:

Number of Swivel Cluster =2

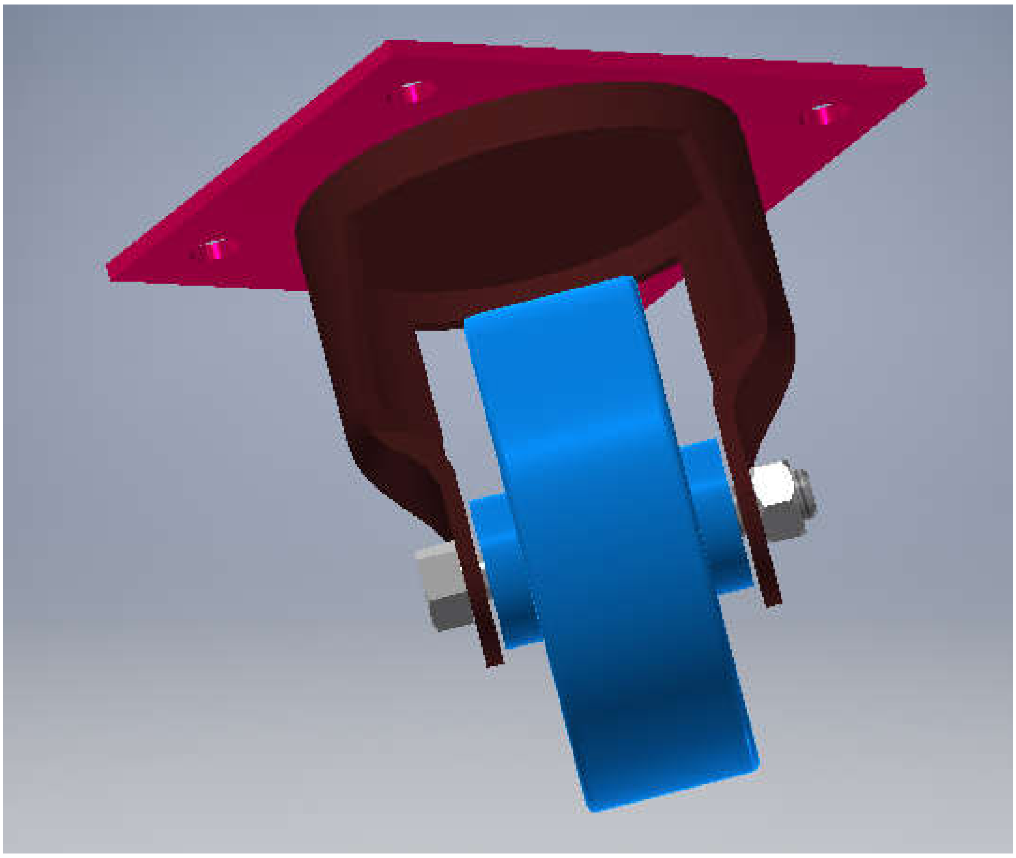


Fig. 3.20 Swivel Custer with Support

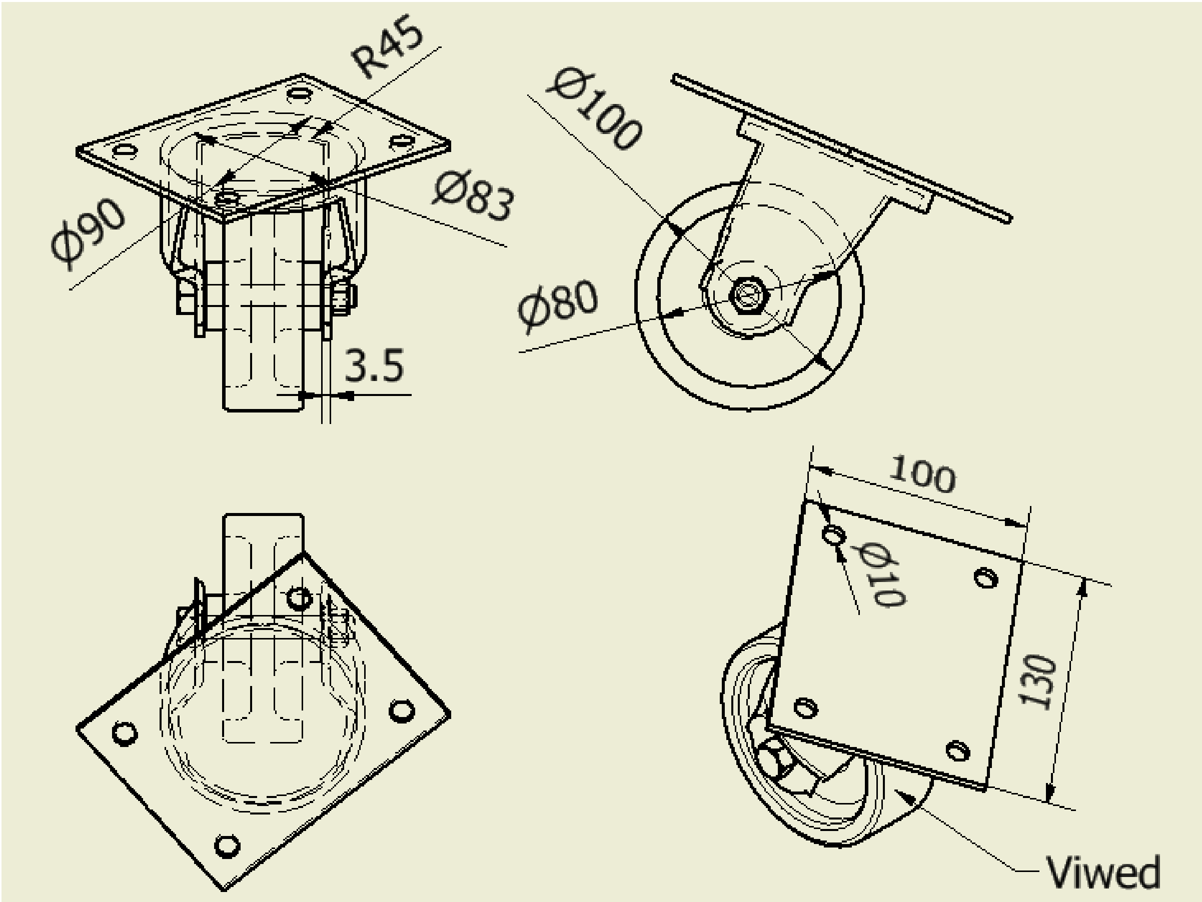


Fig. 3.21 Details Drawing of Swivel Custer

3.3 Power drives System:

The main power source or power storage system of this AGV setup is rechargeable Battery. The Power to the battery is provided through power supply whose input is 240V/115V and output is 24V (there are two batteries each of 12V connected in series and they are charged from the power source). The motor is driven by consuming power from the Battery and torque is transmitted to the toothed wheel (motor shaft) through gear train, shaft etc. The torque from toothed wheel (motor shaft) is transmitted to the toothed wheel (wheel housing) by using a timing belt (or toothed belt). Each wheel housing is supported by ball bearing which is fitted with the main body with the help of an axle. The 3D model of power drive system is shown below which is modelled in Autodesk Inventor 2016:

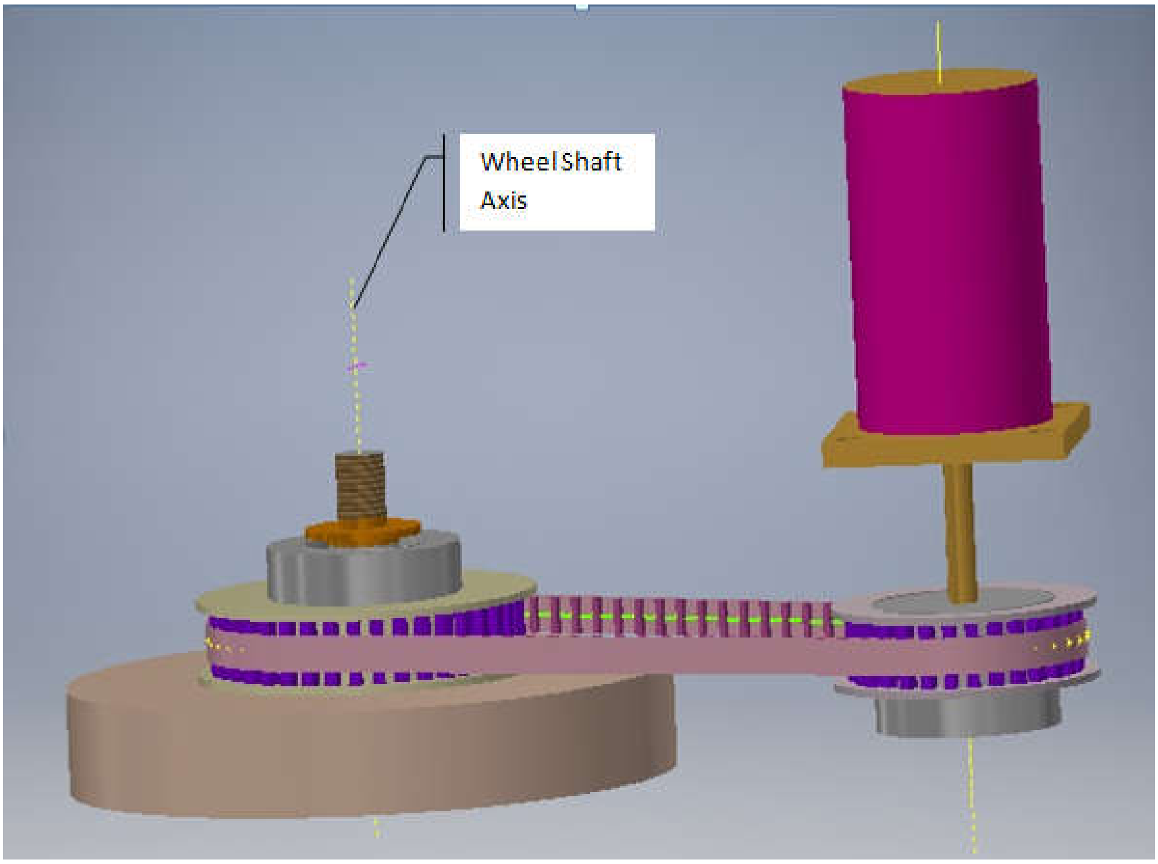


Fig. 3.22 Power Drive System

3.4 Drive Control Unit:

Drive Control unit is a combination of some units by which motor speed and rotation direction can be controlled from microcontroller or computer. It is the heart of this AGV system.

The controller typically consists of a microprocessor that is used to gather data and make decisions based on a program. The controller tells the vehicle how fast to go, where to go, where to turn, and when to stop. The controller gathers information from its guidance system about its location and about routes that are available. Information is also collected from the sensors to stop the vehicle, sound warnings, and maneuver if obstructions are in the vehicles path. New programs can be loaded into the controller to tell the vehicle of new routes that must be taken due to new obstructions such as construction areas.

This unit has three different Printed Circuit Board (PCB's) each having their individual functions. Microcontroller board and Interface board are plugged into common connector board. The relay board is separately placed within the main body with suitable supports. The three different PCB's are -

1. Microcontroller Board
2. Interface Board
3. Relay Board

The Component side and rear side Photocopy of three PCB's are shown in Fig. 3.22a & Fig. 3.22b, Fig. 3.23a & Fig. 3.23b, Fig. 3.24a & Fig. 3.24b.

3.22a Microcontroller Board
(Component Side)

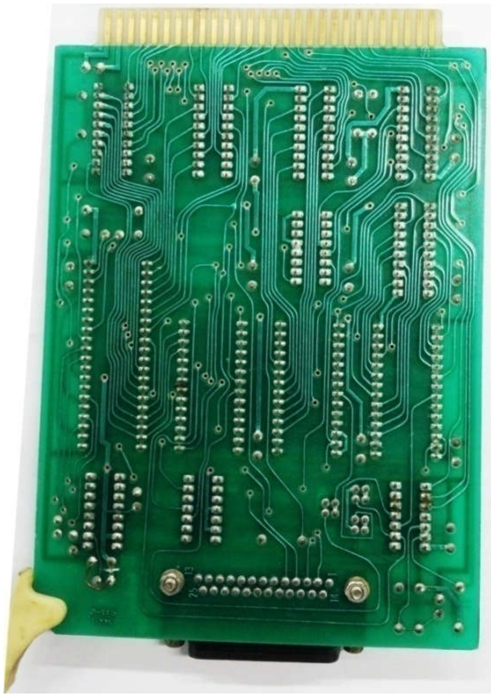
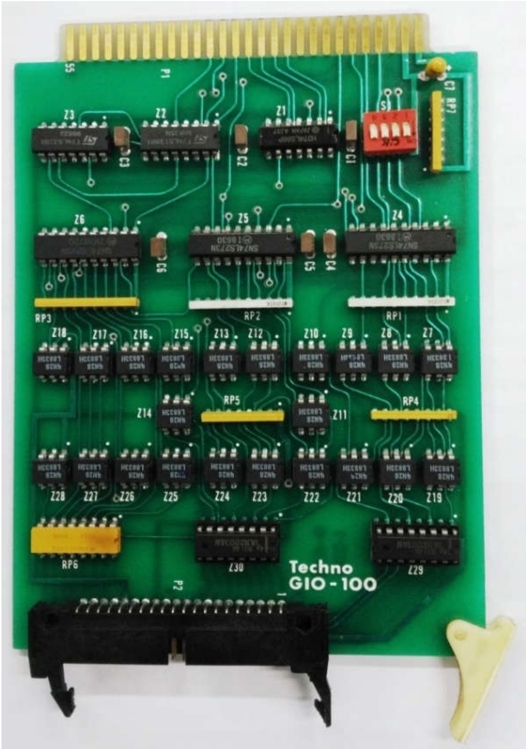


Fig. 3.22b Microcontroller Board
(Rear Side)



3.23a Interface Board
(Component Side)

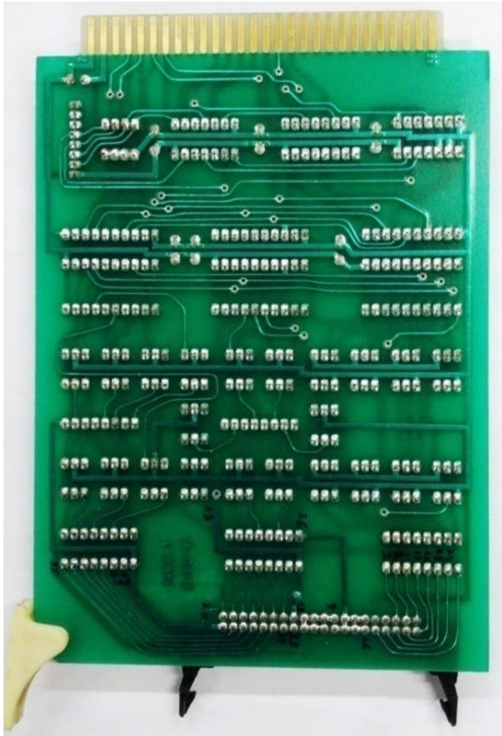
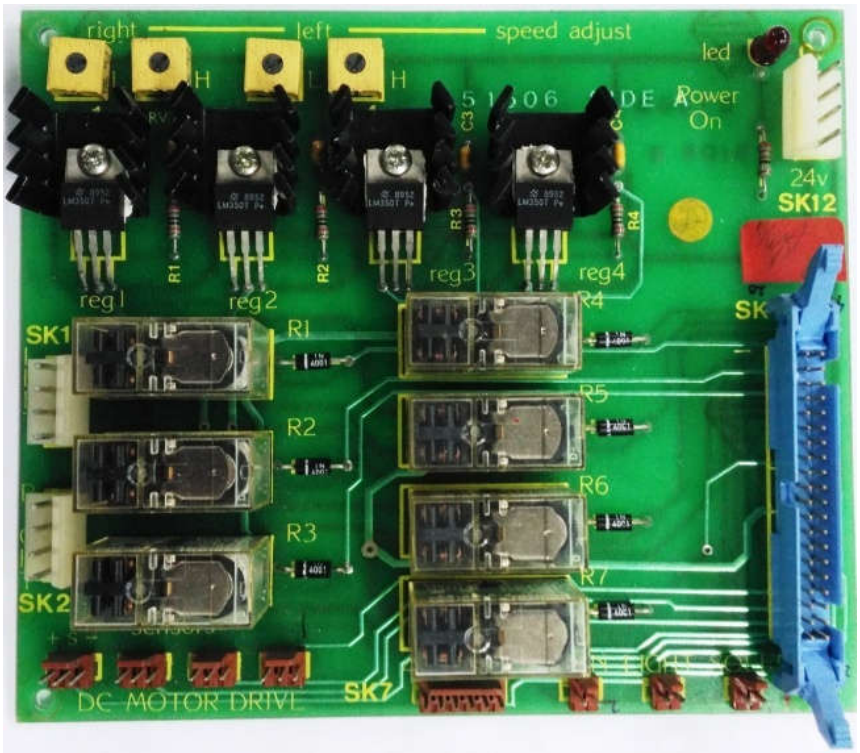


Fig. 3.23b Interface Board
(Rear Side)



3.24a Relay Board (Component Side)

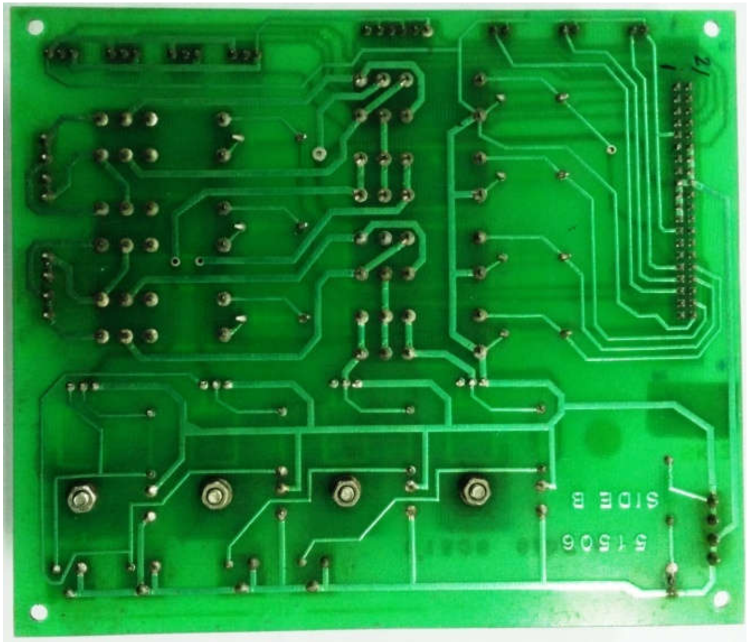


Fig. 3.24b Relay Board (Rear Side)

Microcontroller board consist of one 8bit microcontroller (P80C32-1), one EPROM chip, one I/O peripherical chip (8845B) and few logic gate chips. It also has a 25 pin RS232 male adapter. As the microcontroller program is difficult to be analyzed with the facility available in the department, its functioning could not be revealed.

Interface board Consist of 22 optocouplers (4N28) and associated single 16 pin Resistor networks (MDP 1603-102G), two 16 pins high voltage high current Darlington transistor arrays(ULN2003AN), three octal d-type flip-flop chips (SN74LS273N) and three Quadruple 2-input Exclusive-OR Gates (two T74LS32B1 and one HD74LS86P) .

This board has also 40pin flat cable adapter connected to the opposite side of the common connector board pins. The function of this board is to interface the signals received from the microcontroller to the Relay board through flat cable connector. On the other hand, it also interfaces the signals received from the sensors coming through the relay board and the cable connector to the microcontroller. The interface board is connected to 5V DC Supply received through common connector board. The cable connector adapter received 24V supply. Each Optocouplers when receives input signal, the photo diode at the input emits light and falls at the input of the photo transistor. This makes the output photo transistor ON which in-turn allows current to flow through the circuit connected to the optocouplers output. Thus optocouplers help to isolate 5V microprocessor signal from the 24V volt supply coming from the relay board through the flat cable connector. There are total 7 optocouplers used for receiving signals from the microcontroller board and sending output signal to the relay board.

On the other hand, there are 10 optocouplers that receive signals from the relay board through flat cable connector at the input side through high resistance. This puts the photo diode of the optocoupler to conduct current as well as emitting light. On receiving light, the photo transistor of the optocoupler start conducting and in-turn sense signal to the microcontroller board.

The Relay Board consists of 7No.s miniature 24V DC N/O (Normally Open) and N/C (Normally Close) Relays. The function of the Relays is to supply battery power to the two 24V DC motors. There are three Relays (RL1, RL2 and RL3) of which RL1 and RL3 has there outputs directly connected to the two motors in the normally open condition. On receiving voltage input to the respective solenoids of RL1 and RL3, these two Relays connect the battery power to the two individual motors. When the voltage input to these solenoids are put off then motor gets disconnected from the battery power.

The other 4 Relays grouped into two groups, one group (RL4 and RL5) is to connect battery power to Relay RL1 and the other (RL6 and RL7) is connecting battery power to Relay RL3. The contacts of the Relay RL4 and RL5 are connected to the contacts of Relay RL1 through the circuit on the relay board. It is done in such a manner that when Relay RL5 is in normally open condition, the battery power goes to Relay RL1 such that when solenoid of the RL1 is ON, the motor connected to Relay RL1 moves in clockwise direction. Again when solenoid of Relay RL5 is ON along with solenoid of Relay RL1 is ON, the battery power to motor connected to RL1 gets reverse.

The Relay RL4 is used to supply battery power to Relay RL5 through two voltage regulators (VR1 and VR2) set at two different preset volts (18.6V &16V). When the Relay RL4 is normal open condition, voltage set at VR1 is connected to Relay RL5. On the other hand, the solenoid of relay RL4 is ON, the voltage at VR2 is connected to RL5.

Similarly, Voltage regulators VR3 and VR4 preset at two voltages (19V and 15V) are connected to RL6. When RL6 is in normally open condition, VR3 supplies voltage to RL7. On the other hand, when solenoid of RL7 is ON, VR4 is connected to RL7.

The function of RL2 is to short the input leads to the two motors simultaneously when battery power to the motors are disconnected.

The Relay Board has two four pin different male adapters (AD1 and AD2) for connecting female adapters coming from the two motors driving the left and right wheel respectively. There is another male four pin adapter on the board (AD12) for connecting female adapter coming from the battery power. There is a 40 pin male adapter on the board (AD11) which is used for connecting female flat cable adapter coming from the Interface board.

There is one three pin male adapter (AD3) used to connect female adapter with three wires coming from JUNCTION sensor placed in front of the AGV. Three more three pin male adapters (AD4, AD5 and AD6) are on the board to connect three female adapters, each having three wires, coming from three TRACK sensors LEFT, MIDDLE and RIGHT respectively.

There is a six pin male adapter (AD7) used to connect a six pin female adapter with three wires (only three pins are used) coming from two obstacle detection push switches.

The Relay board has three additional two pin male adapters (AD8, AD9 and AD10) used to connect three two wire female adapters coming from HORN, LIGHT and PALLET LIFTING solenoid respectively.

On the relay board there is an LED indicating power supply ON/OFF connected to the board.

The Schematic diagram of the Relay board and Interface board is shown in Fig. 3.25 and Fig. 3.26

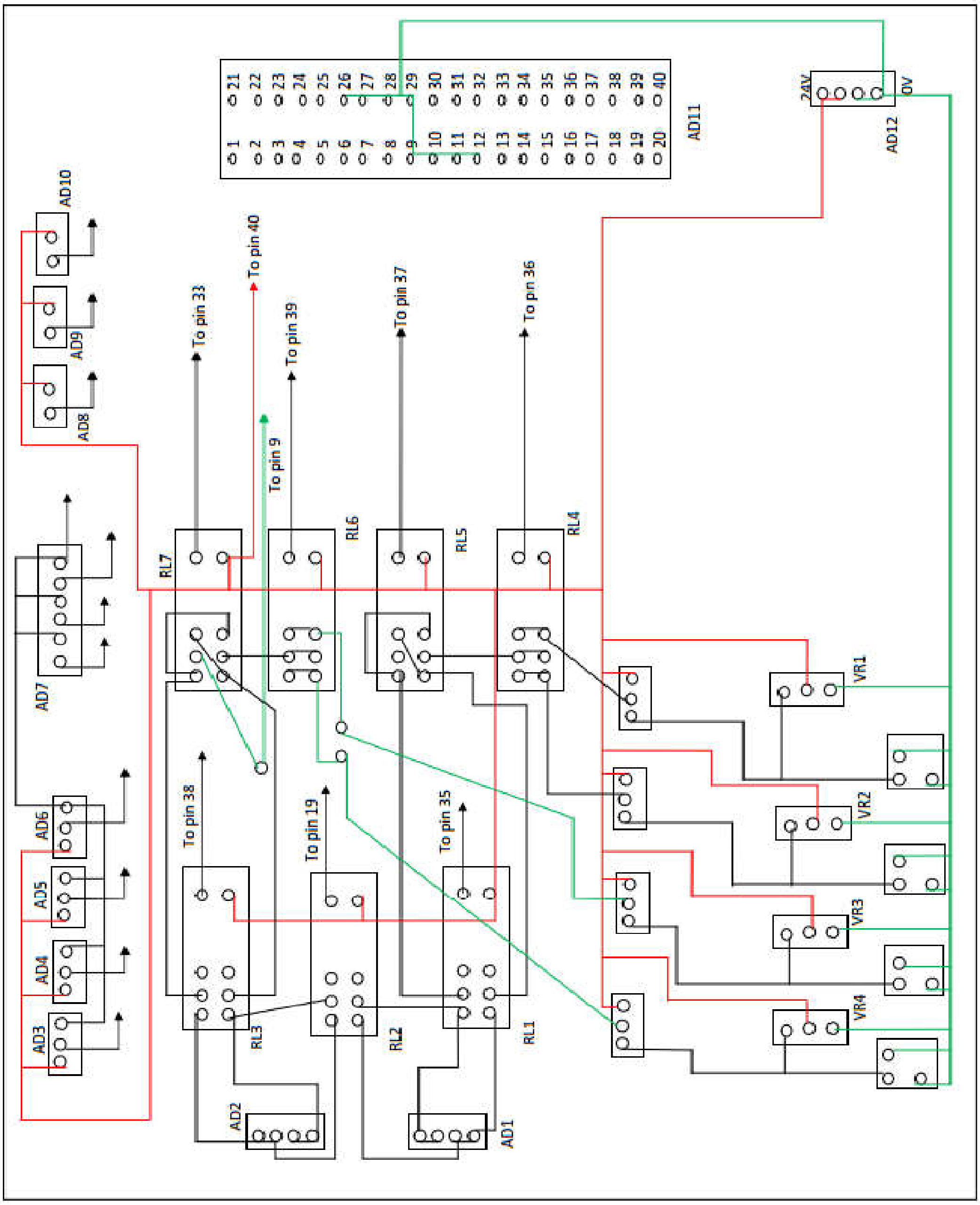
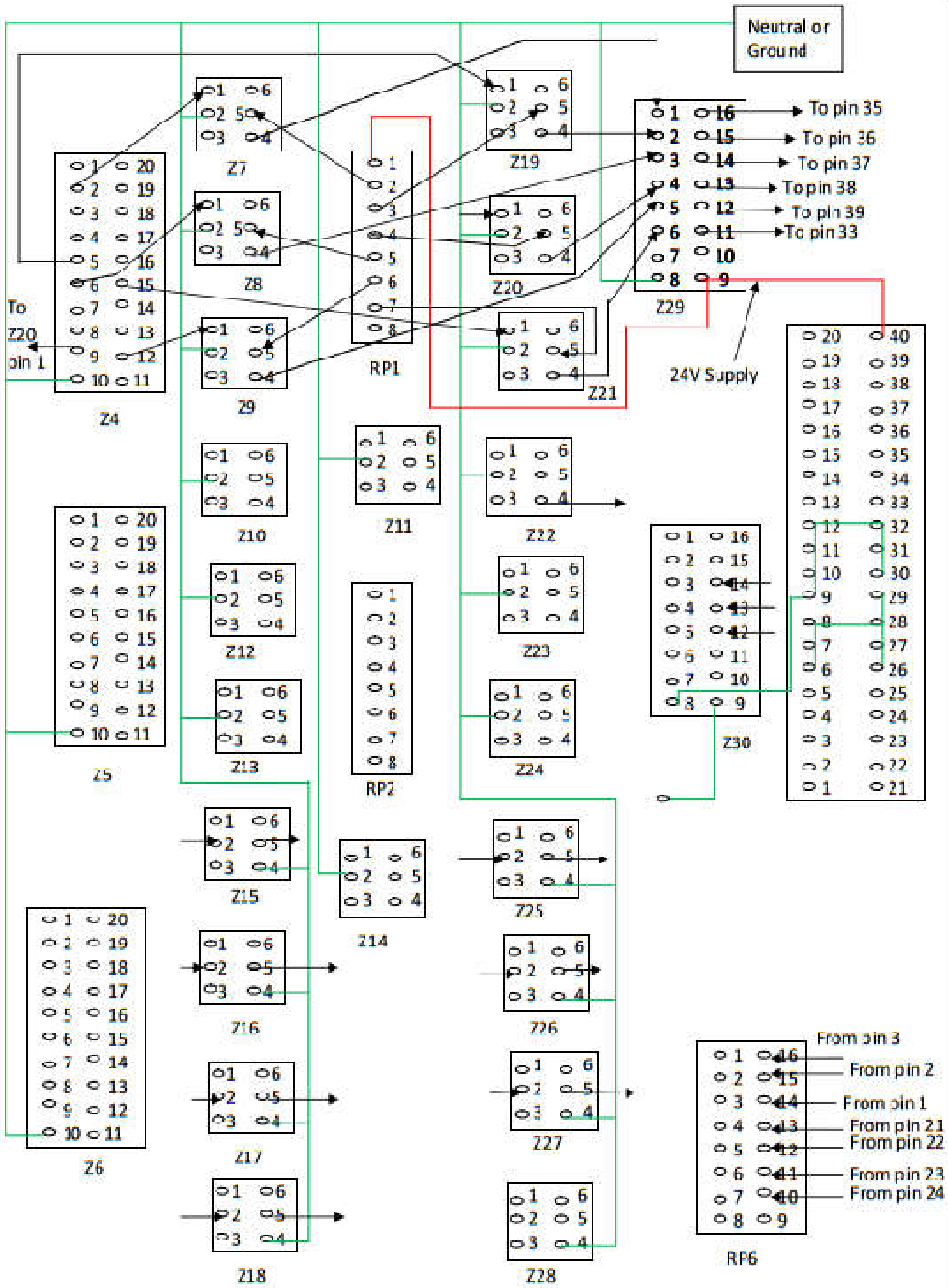


Fig. 3.25 Schematic Diagram of the Relay Board
(Seen from rear side)



Octal d-type flip-flop chips (Z4, Z5 and Z6), Optocouplers (Z7 toZ28)

Resistor networks (RP6), high voltage high current Darlington transistor (z 29, Z30)

Fig. 3.26 Schematic Diagram of the Interface Board
(Seen from component side)

3.5 Sensor System:

During movement of the AGV along a layed (metallic tape) path the three track sensors LEFT, MIDDLE and RIGHT are very important part for guiding the AGV. These sensors are inductive sensors and are operate at 24V. When these sensors are not in proximity of a metallic part, normally they give an output voltage of 12.3V. Any metallic substance when come in proximity of these sensors the output voltage of the sensors drop at 0.7V. This provides signal to the microcontroller through Relay and Interface board. While AGV is moving, all the three sensors remain placed just above the metallic tape with certain amount of gap from the floor. The metallic tape is placed on the floor according to the path along which AGV has to move. Due to some reason, any of the left or right sensors deviates from the track, the microcontroller senses the signal receives from the sensors and drives the two wheels at proper speed (Lowering or Raising the speed) to again bring the three sensors to follow the layed track. This keeps AGV to move along straight path.

There is a Junction Sensors placed left to these sensors arrays kept at a small distance from the left most sensors of the array. Whenever this sensor detects any metallic substance at a junction/crossing the AGV stops at that point and waits for controller command for the next motion. The next motion can be any one of the following motions: right turn (90^o), left turn (90^o), turns clockwise (180^o), anticlockwise (180^o) or forward motion.

There are two push switches connected to a common push bar for obstacle detection by making contact with the obstacle. When the push bar touches any obstacle signal from the push switches goes to the controller to stop the AGV motion.

Fig. 3.27 Sensors

CHAPTER-4

DESIGN AND ANALYSIS OF STRUCTURAL SYSTEM

4.1 Torque and Power Calculation for Motor:

Consider required time for the vehicle to reach a speed (v), t=1sec

So, angular speed of the housing wheel, $\omega 1$=24 rpm

$= (2\pi \times 24) \div 60 = 2.51$ rad/sec

So, linear velocity, $v = (\pi DN) \div 60 = (\pi x125x24) \div 60 = 157$mm/sec

= 9.42m/min

Angular speed of pinion, $\omega_2 = \omega_1 x (T_1/T_2) = 2.51x (40 \div 30) = 3.35$ rad/sec [Diameter of the housing wheel= 125mm]

Co-efficient of friction, μ= 0.3

<u>Limiting Frictional Forces:</u>

For 500N load, from analysis in Autodesk Inventor 2016, Reaction forces in Housing wheels are 214N and 200N. So, designing reaction force, N=214N

So limiting Frictional Force F`=μN= 0.3 x 214= 64.2

Acceleration of the body, a= v ÷ t=0.157/1=0.157 m/sec

Total mass of the body with 20% extra= 37.2 Kg

Pay load=50Kg acts on mass Centre of Gravity of the load.

So, Inertia Force $F_1 = m_1$ x a=37.2x 0.157=5.84N

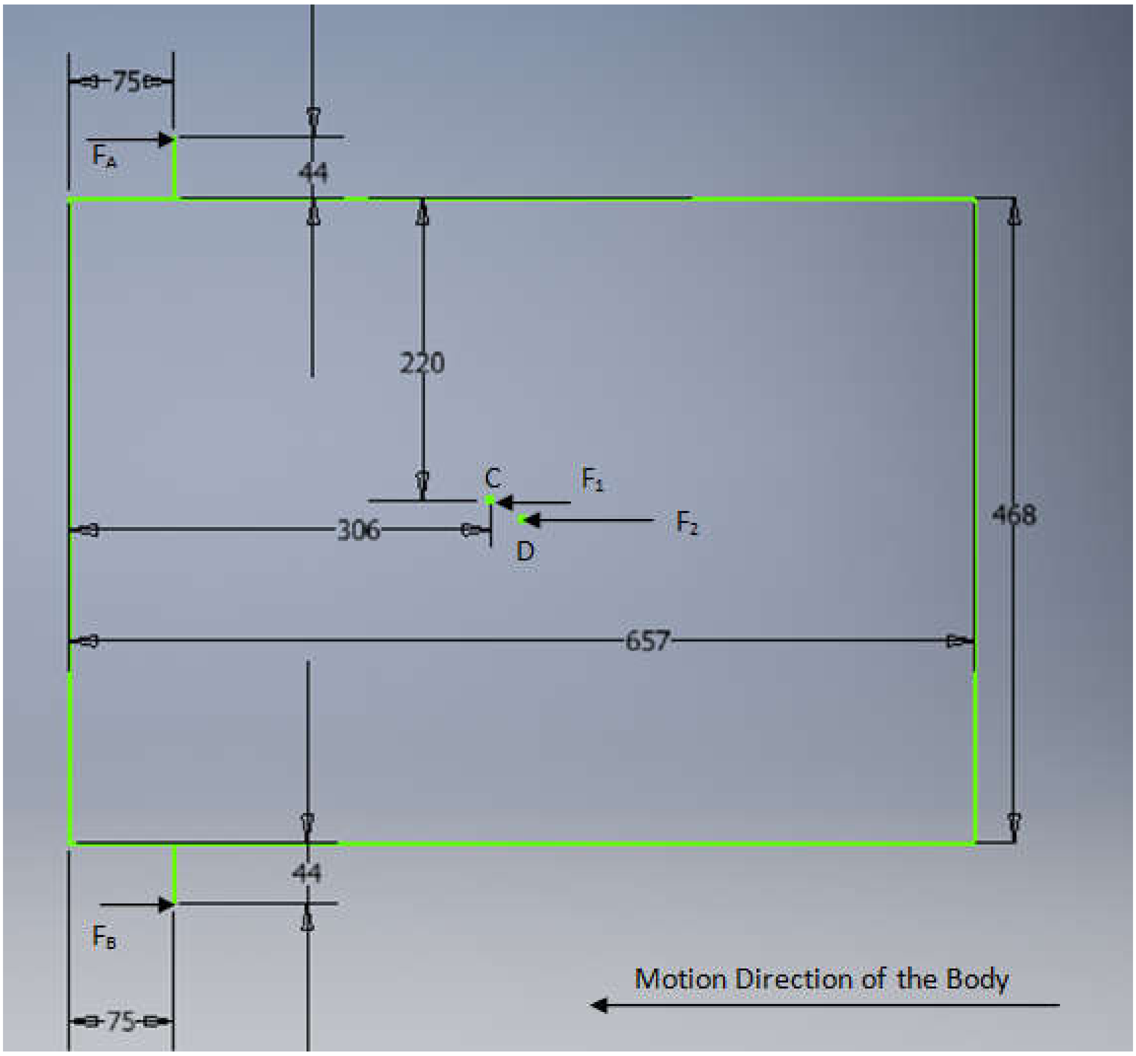
And $F_2 = m_2$ x a= 50x 0.157=7.85N

Now, Inertia force on wheel on one wheel,

$$F_B = ((F_1 \times 264) + (F_2 \times 278)) \div 556$$

$$=6.69N$$

And inertia force on another wheel, $F_A = F_1 + F_2 - F_B$=7N



So, maximum inertia force on the wheel< Frictional force (7<64.2)

So torque in wheel= torque in large toothed wheel, =64.2x (125÷2) N.mm

=4.01 Nm

Power in motor wheel= Torque in motor toothed wheel x Angular speed of motor toothed wheel= 4.01x 2.51=10.07 watt

So, power of motor =10 watt

And torque of the motor =10÷3.35 =2.99 N.m

4.2 Stress Analysis in Inventor:

Stress simulation and analysis process was done in inventor 2016 on the main body of the AGV system. Consider the metal of the main body is Mild Steel. Measured the all dimensions of the AGV and a 3D model in assembly view was developed using Autodesk Inventor software. The C.G. point and the mass of the whole system were measured using Autodesk Inventor.

The reference axis of the modelled part is shown in Fig. 4.1.

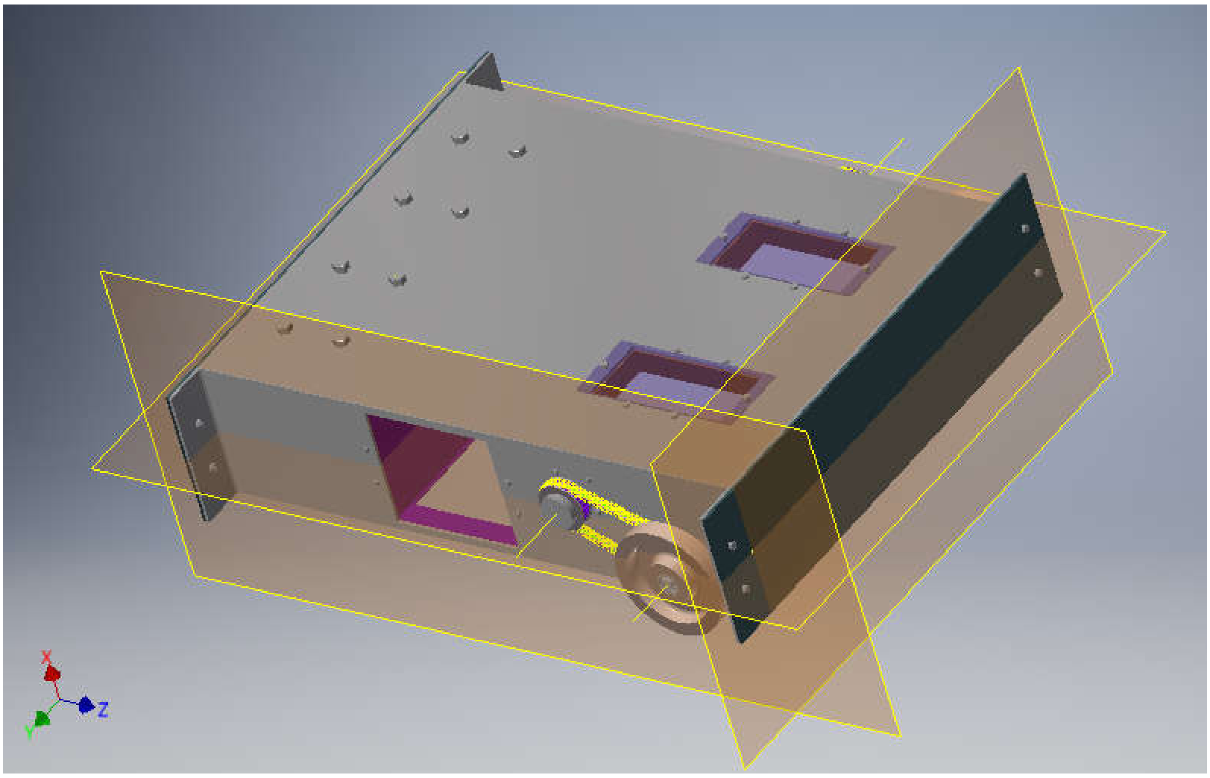


Fig.4.1 Reference axis for analysis of the Model

To simulate and stress analysis in Autodesk Inventor, there are several steps. After open the body in Inventor, go to "Environment" and then "Stress Analysis" option to create the Simulation page. A photocopy of that page is listed in Fig. 4.2. After creating simulation page, assign the material of the body, give constrains, apply load and simulate.

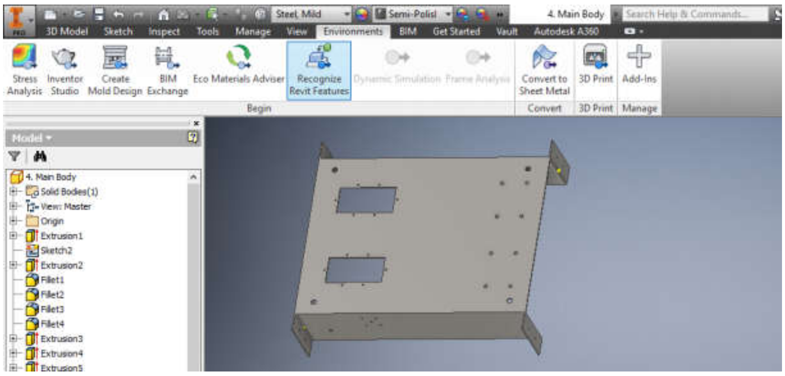


Fig. 4.2 Initial steps to create simulation page in Inventor

In this case, consider mild Steel as a metal of the body. The assign constraints for simulation are shown in Fig. 4.3a, Fig. 4.3b, Fig. 4.3c and Fig. 4.3d

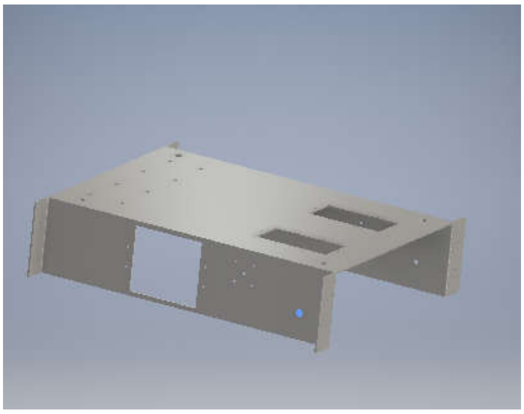


Fig. 4.3a pin Constraint: 1

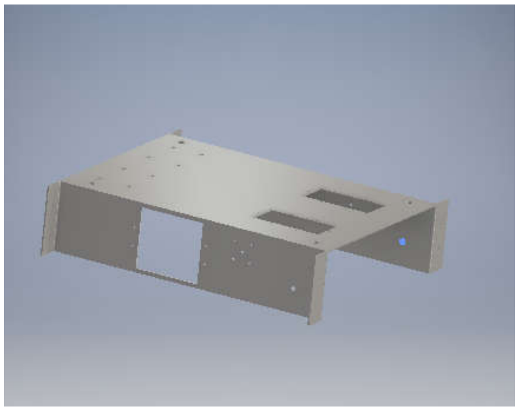


Fig. 4.3b pin Constraint: 2

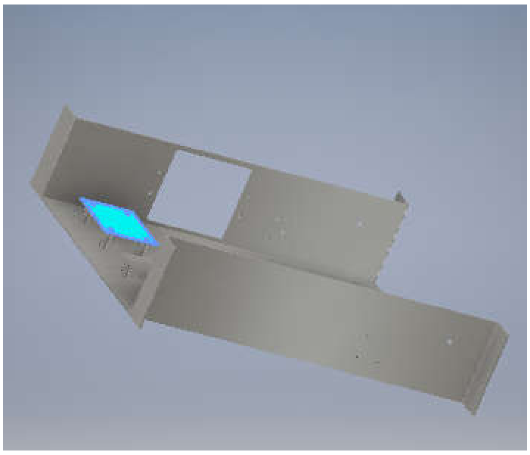


Fig. 4.3a Fixed Constraint: 1

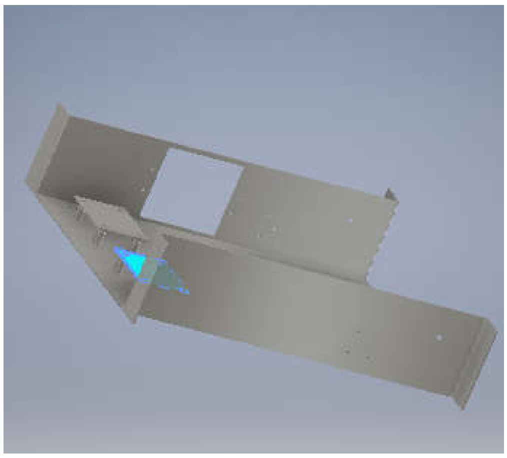


Fig. 4.3b Fixed Constraints: 2

The total weight of the AGV System (measured by Inventor) = 31 Kg

Taken 20% extra weight, then total weight =31x 1.2=37.2 Kg

The weight of the main body= 13.5 Kg

So, total weight of AGV excluding main body =37.2-13.5= 23.7Kg

The measured Centre of Gravity point with respect to the reference axis (Fig. 4.1) = (22, -220, -306)

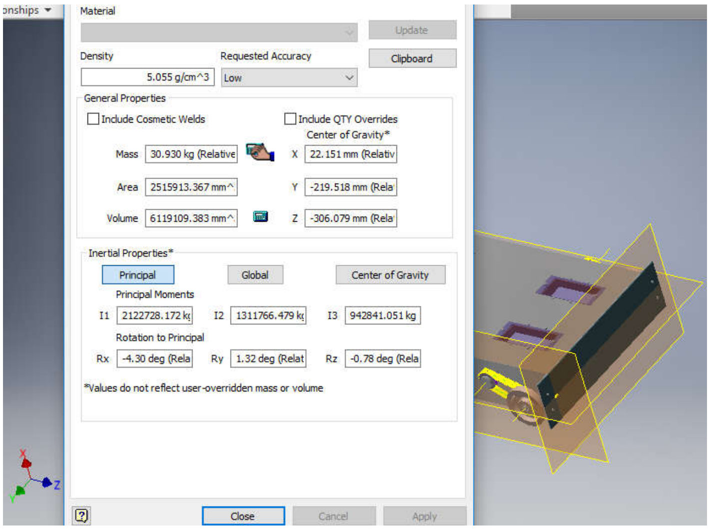


Fig. 4.4 C.G. of the AGV System

Now, applied the gravity load on the main body as shown in Fig.4.5 to analyze this part.

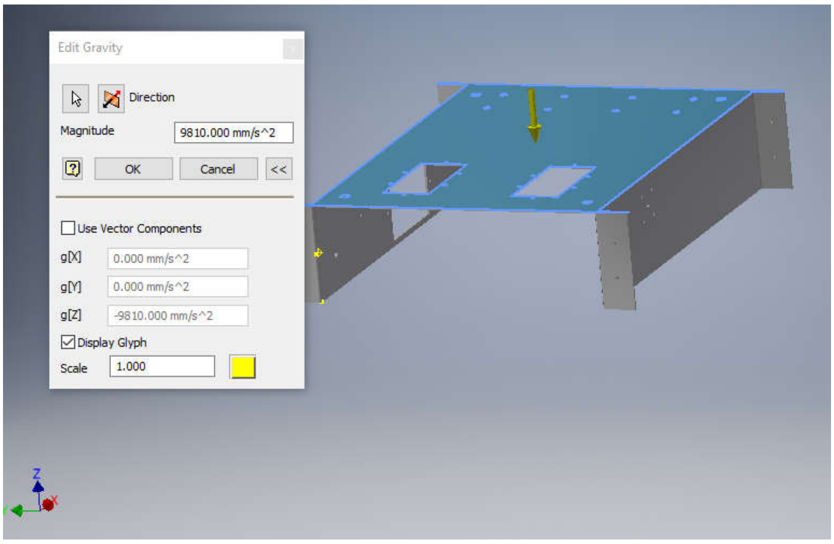


Fig. 4.5 Gravity Load

Followed that step, applied 50Kg as a pay load in CG point of the upper face where pay load is applying and 23.7Kg as a total weight of AGV excluding main body in CG point as shown in Fig. 4.6 and Fig. 4.7.

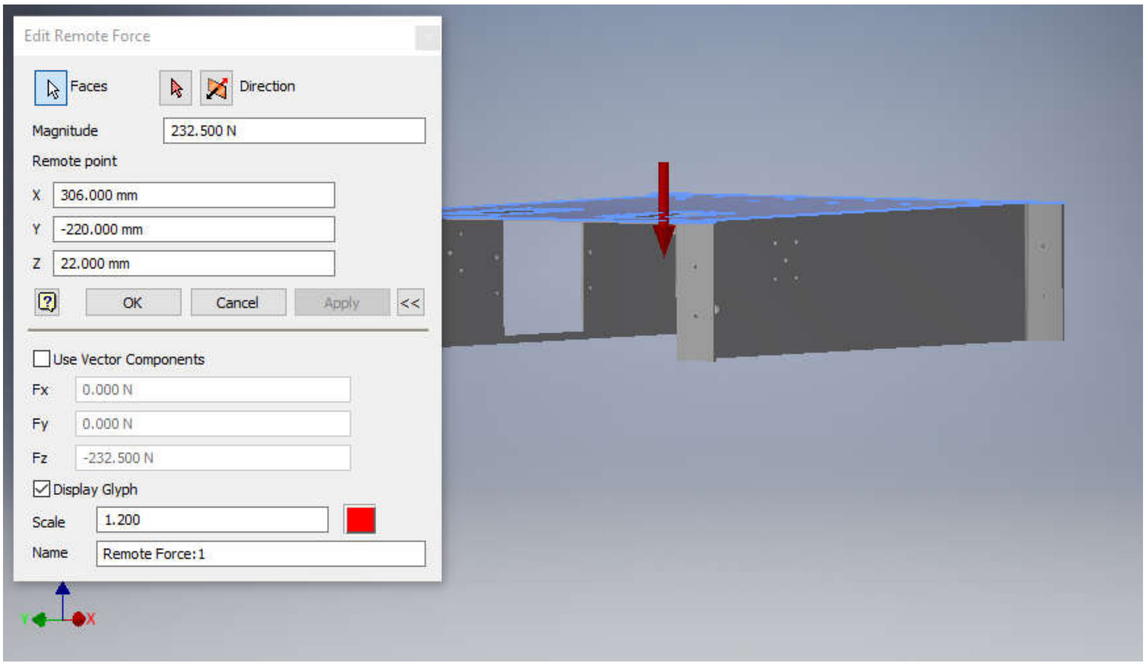


Fig. 4.6 Applied load in CG

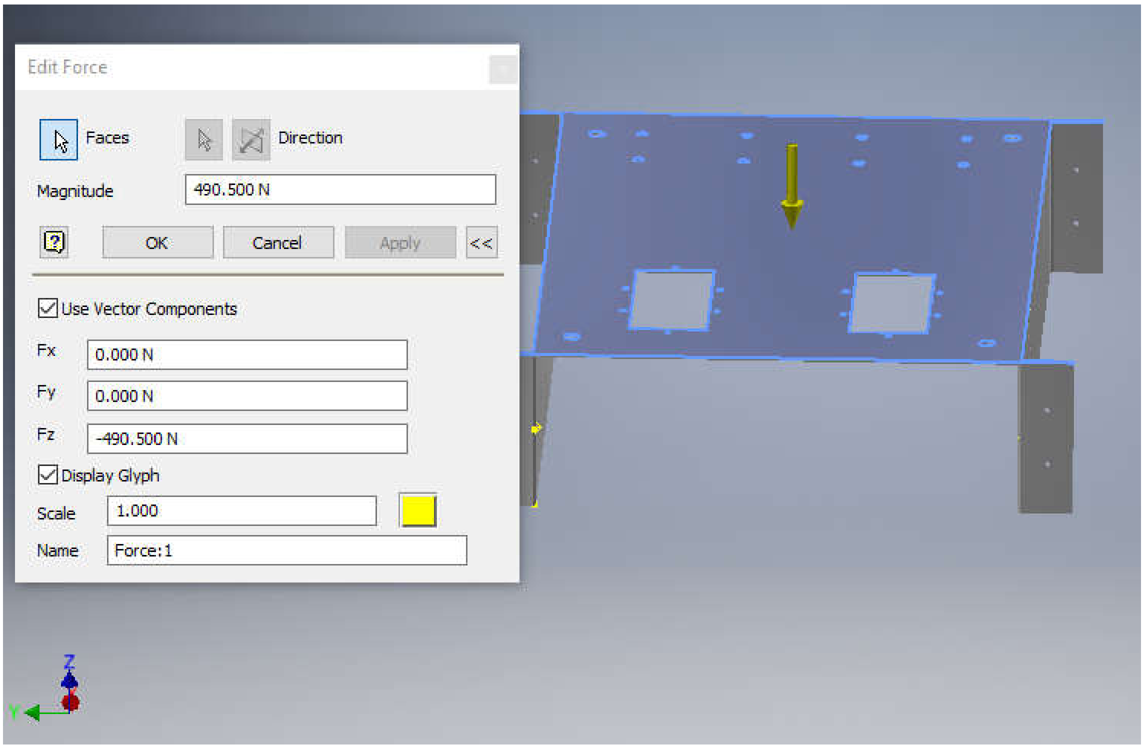


Fig. 4.7 Payload applied in upper face of the body

Stress analysis Results:

The results table after simulation of the main body in Inventor is shown in Fig.4.8.

Reaction Force and Moment on Constraints

Constraint Name	Reaction Force		Reaction Moment	
	Magnitude	Component (X,Y,Z)	Magnitude	Component (X,Y,Z)
Fixed Constraint:1	288.952 N	-186.335 N	4.46954 N m	-0.549517 N m
		4.61383 N		4.43453 N m
		220.797 N		0.0986607 N m
Fixed Constraint:2	243.167 N	-82.2572 N	9.3072 N m	-0.145654 N m
		-4.64439 N		8.19079 N m
		228.785 N		4.41745 N m
Pin Constraint:1	271.862 N	167.329 N	7.46965 N m	-7.45132 N m
		0 N		0 N m
		214.266 N		-0.52298 N m
Pin Constraint:2	224.44 N	101.286 N	7.29879 N m	7.28783 N m
		0 N		0 N m
		200.286 N		0.399875 N m

Fig. 4.8 Results table

The maximum and minimum stress on the main body using Von Misses Criteria is sown in Fig. 4.9.

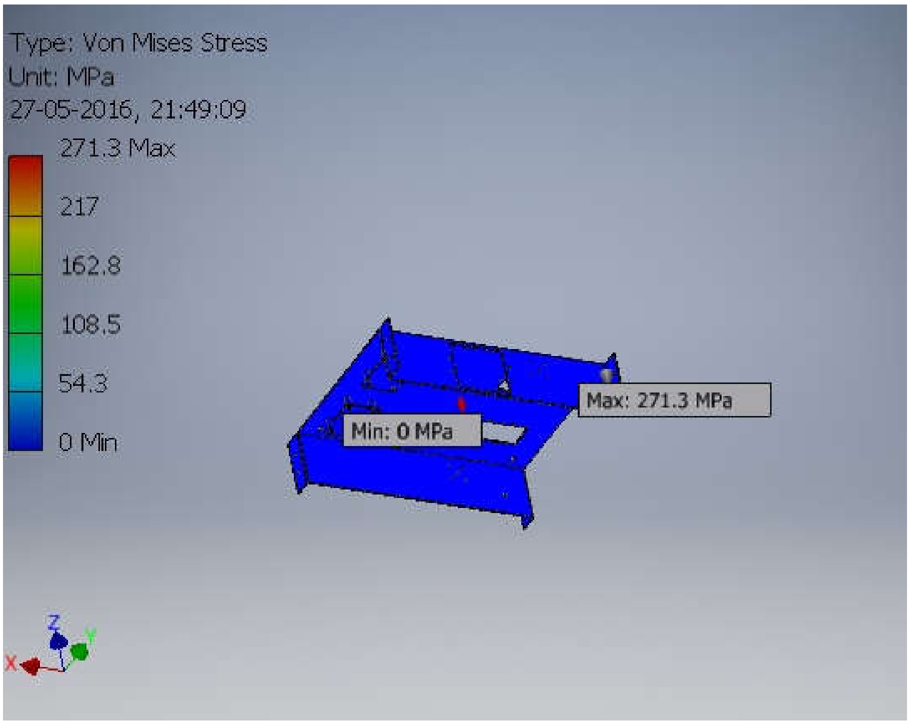


Fig. 4.9 Maximum and minimum Stress using Von Misses Criteria

4.3 Displacement Analysis:

The maximum and minimum displacement of the main body after analyse in Inventor is shown in Fig. 4.10.

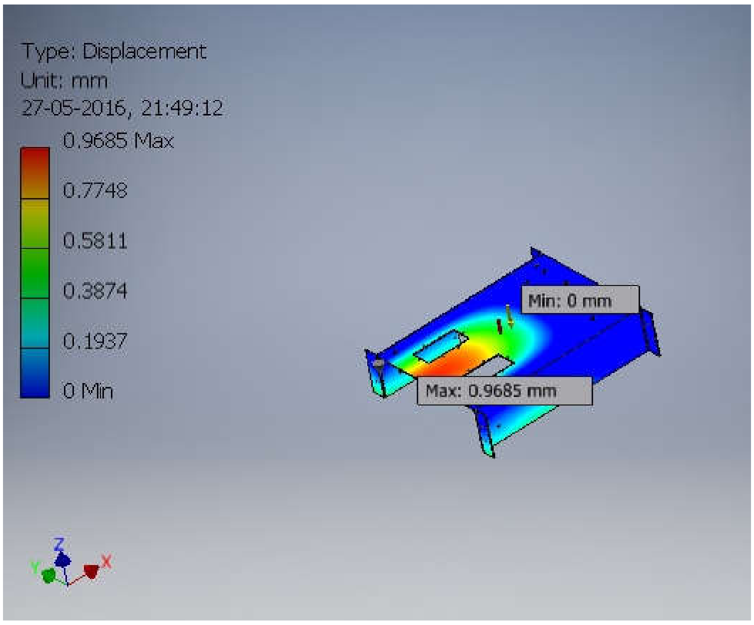


Fig.4.10 Maximum and minimum displacement

CHAPTER-5
AGV TEST PROCEDURE

5.1 AGV Wheel Motion Test:

An external power supply is used (shown in Fig.5.1) to test the wheel motion of the AGV. The external power supply is connected to the individual motor of the AGV to ensure that the motors are in working condition. The output voltage of the external power supply has been fixed at 24V.The two motors have been found in good condition during the test. By reversing the power supply leads the motors have run in reverse direction.

5.1 External Power Supply

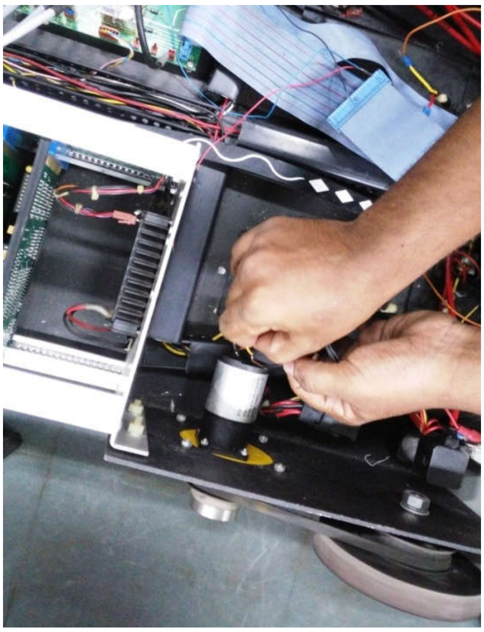


Fig. 5.2 Left Wheel motor test

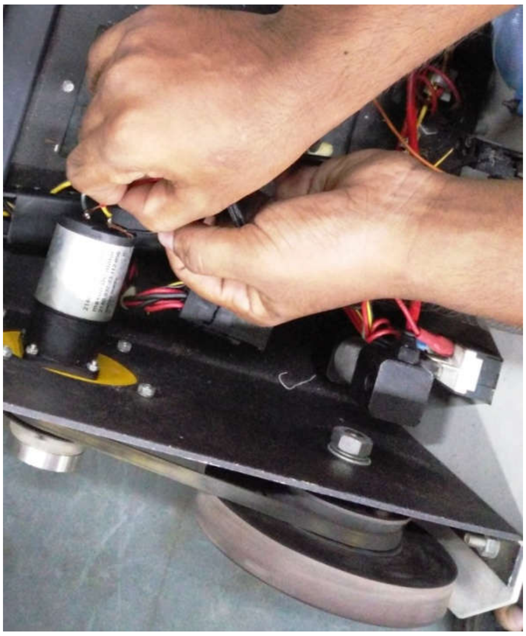


Fig. 5.3 Right Wheel motor test

5.2 Speed Change of Wheel:

The wheel motion of the AGV is controlled by the microcontroller with the help of Relay Board. Pin no. 38 of the flat cable adapter (shown in Fig. 3.25) connected to Relay RL3, pin no. 33 connected to Relay RL7 and pin no. 39 connected to Relay RL6 get signals from the microcontroller through Interface board. when the 38 no. Pin of the flat cable adapter is grounded and pin no. 39 and 33 are open the left wheel motor rotates in the forward direction at higher speed (24 rpm). Again, when pin no. 38 and pin no. 39 are connected to the ground and pin no. 33 is open the left motor rotates at the forward direction at a lower speed (18 rpm). The above speed change occurs as because Pin no. 39 being open and pin no 38 grounded the voltage applied to the motor is 19V where as when pin no. 39 and pin no. 38, both are grounded then the voltage applied to the motor is 15V.

On the other hand, when pin no. 38 and pin no. 33are both grounded with pin no. 39 open the left motor rotates in the reverse direction at higher speed (24 rpm). Again when pin no. 38, pin no. 33 and pin no. 39 all are grounded simultaneously, the left motor rotates the reverse direction at lower speed (18 rpm).

Similarly, Pin no. 35, pin no. 37 and pin no. 36 are tested for rotation of right motor in the forward/reverse direction at higher/lower speed.

The motor rotation and input condition of the pins receiving signals are shown in Table 5.1 and in Table 5.2.

Table 5.1: Input Condition and Right Motor Rotation

Input condition	Right motor rotation
Pin no. 38 grounded, Pin no. 33 and Pin no. 39 open	Higher speed, Forward direction
Both Pin no. 38 and Pin no. 39 grounded, Pin no. 37 open	Lower speed, Forward direction
Both Pin no. 38 and Pin no. 33 grounded, Pin no. 36 open	Higher speed, Reverse direction
All Pin no. 38, Pin no. 33 and Pin no. 39 grounded	Lower speed, Reverse direction

Table 5.2: Input condition and Left Motor Rotation

Input condition	Left motor rotation
Pin no. 35 grounded, Pin no. 36 and Pin no. 37 open	Higher speed, Forward direction
Both Pin no. 35 and Pin no. 36 grounded, Pin no. 37 open	Lower speed, Forward direction
Both Pin no. 35 and Pin no. 37 grounded, Pin no. 36 open	Higher speed, Reverse direction
All Pin no. 35,Pin no. 36 and Pin no. 37 grounded	Lower speed, Reverse direction

Speeds of the wheels have been measured with the help of a Tachometer and the voltages were measured with the help of a Multimeter (shown in Fig. 5.4).

Fig. 5.4 Multimeter

The photocopy of the Tachometer, motion test of right wheel at higher speed and lower speed in forward direction, motion test of right side wheel at higher speed in reverse direction and left side wheel at lower speed in reverse direction are shown in Fig. 5.5, Fig. 5.6, Fig. 5.7, Fig 5.8 and Fig. 5.9.

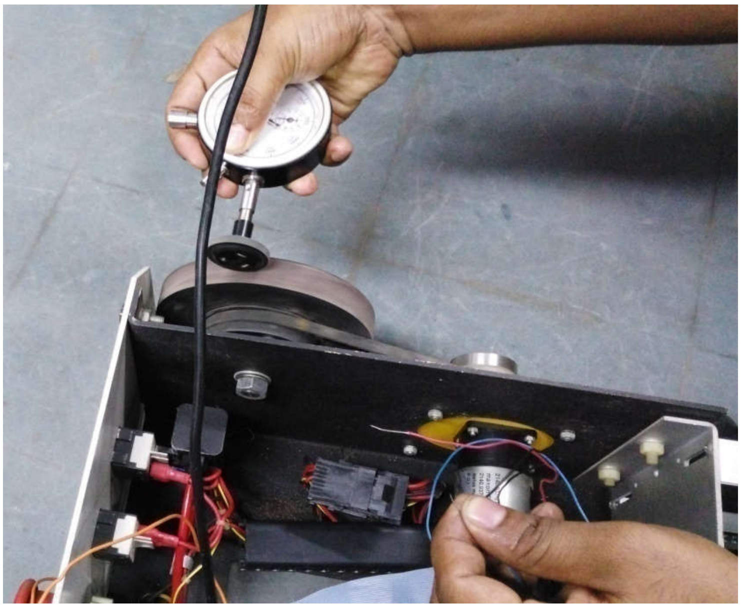


Fig. 5.5 Speed measurement using Tachometer

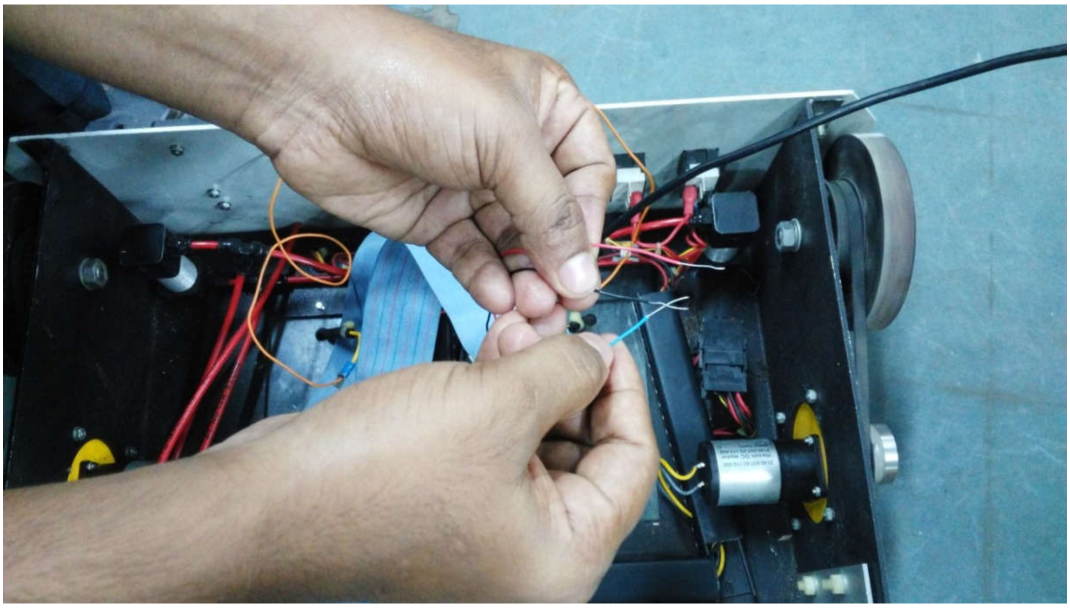


Fig. 5.6 Right wheel motion test at higher speed forward direction

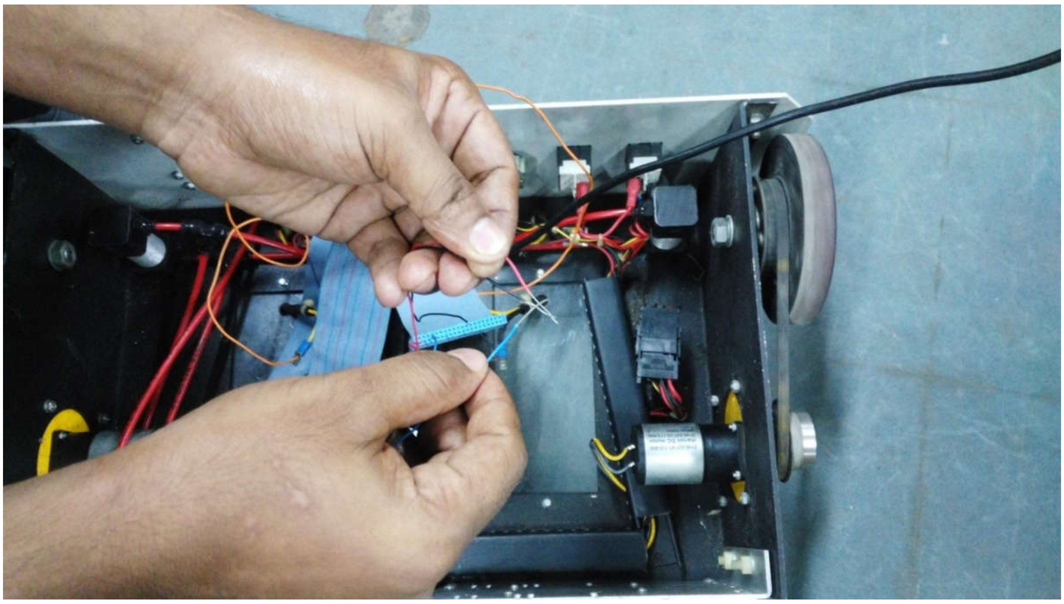


Fig. 5.7 Right wheel motion test at lower speed forward direction

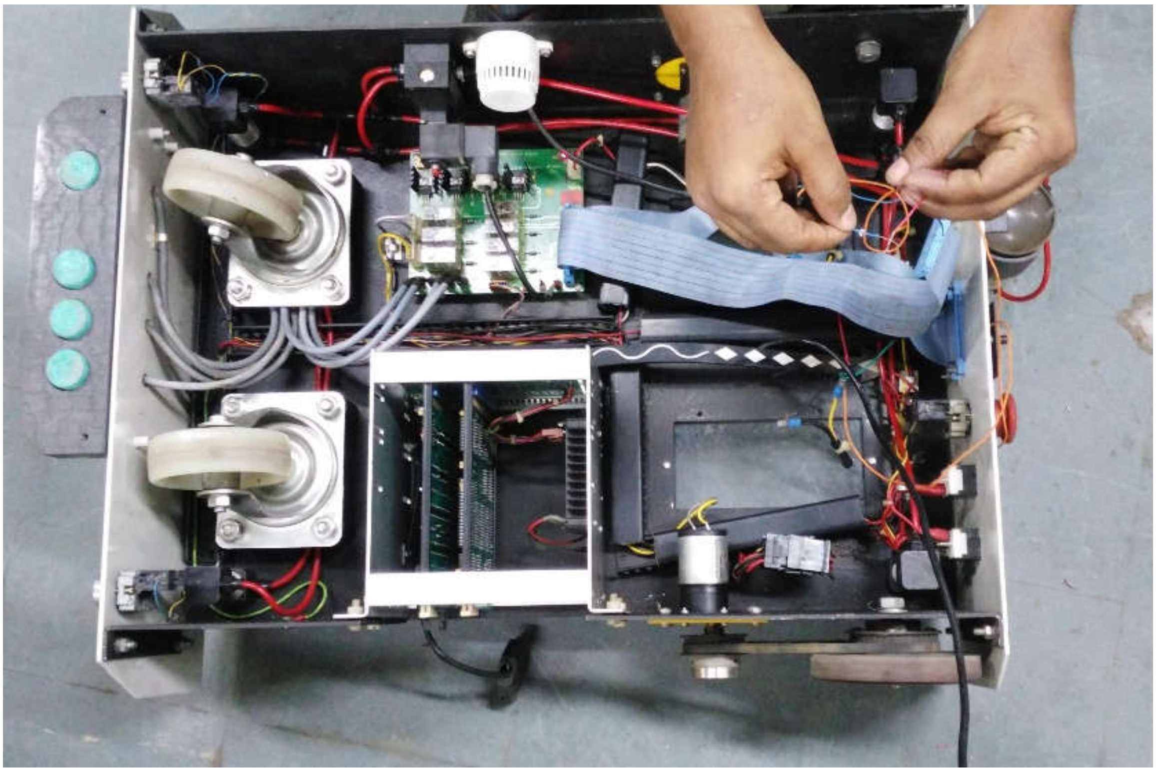


Fig. 5.8 Right wheel motion test at higher speed reverse direction

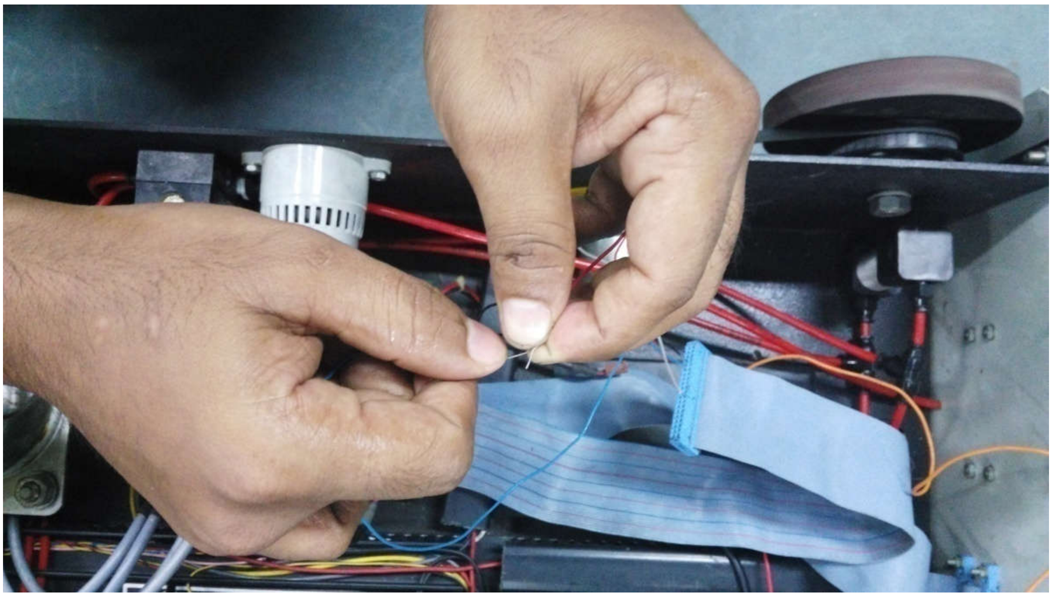


Fig 5.9 Left wheel motion test at lower speed reverse direction

5.3 AGV Braking During Stopping:

There is an arrangement of applying braking action to the wheels by shorting the motor coils both left and right simultaneously with the help of Relay RL2. In the normal condition, the Relay RL2 keeps the motor coils open. When pin no. 19, connected to Relay RL2 is grounded, the contacts of the Relay bring the two motor coils in the shorted condition separately. When the motor power supply is withdrawn for stopping the AGV the Relay RL2 immediately shorts the two motor coils. Under the shorted condition of the motor coils and AGV still in motion due to Inertia, the back e.m.f. generated in the coils causes a reverse current flow in the coil circuit. This produces an opposition torque and provides braking action to the AGV.

5.4 Sensor Action:

There are three type of sensors:

i. Track Sensor
ii. Junction Sensor
iii. Push switch Obstacle detection sensor

Power is provided to the sensors via external power supply. Pin no. 1, 2 and 3 of the flat cable adapter is connected to three track sensors and 21 no. Pin of the flat cable adapter is connected with the junction sensor.

The two leads of the multimeter are connected, one at Pin no.1 and the other at ground of the flat cable adapter. A voltage of 12.3V has been recorded. When a metal strip is brought near the track sensor, 0.7V is recorded in Multimeter. Similar procedure has been adapted for testing other two track sensors and similar voltage is recorded.

Now, Similar testing is carried out with the pin no. 21 of the junction sensor. When a metal strip is brought near the junction sensor the output from the sensor drops from 17.7 to 0.7V.

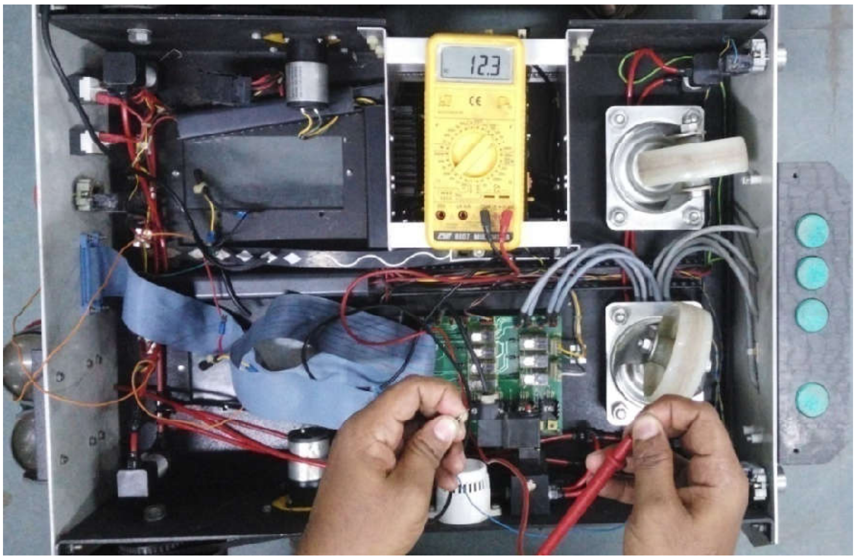


Fig. 5.10 Voltage before detect the metal of the Track Sensor

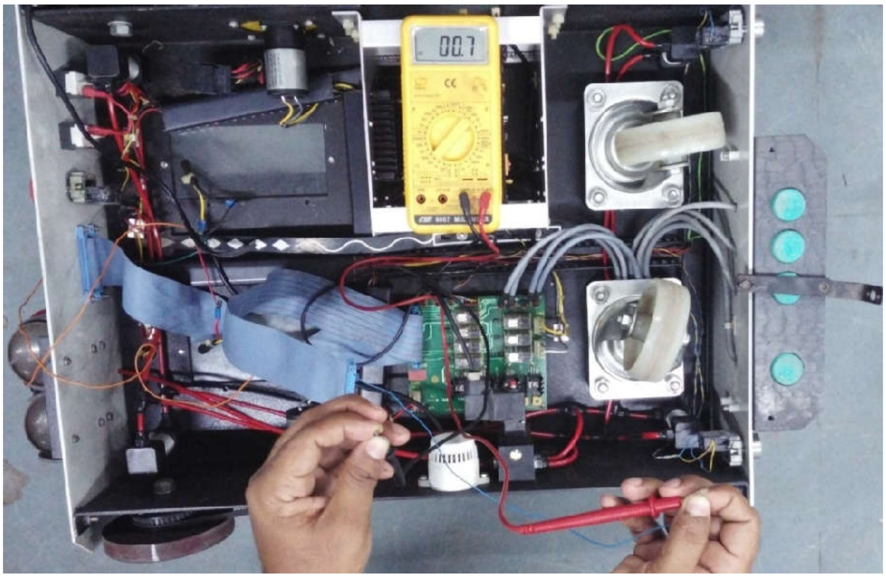


Fig. 5.11 Voltage after detect the metal of the Track Sensor

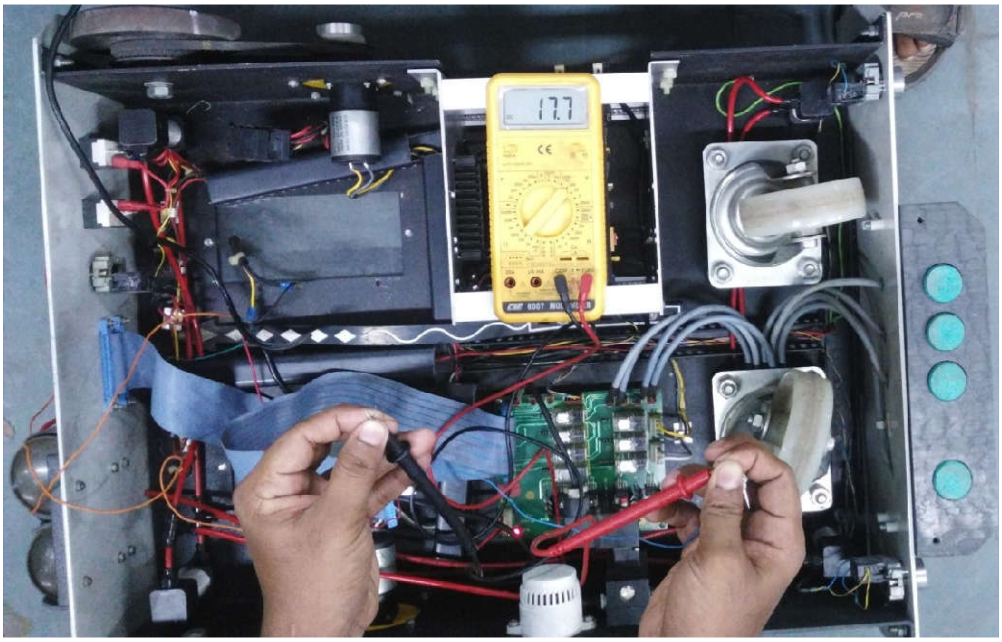


Fig. 5.12 Voltage before detect the metal of the Junction Sensor

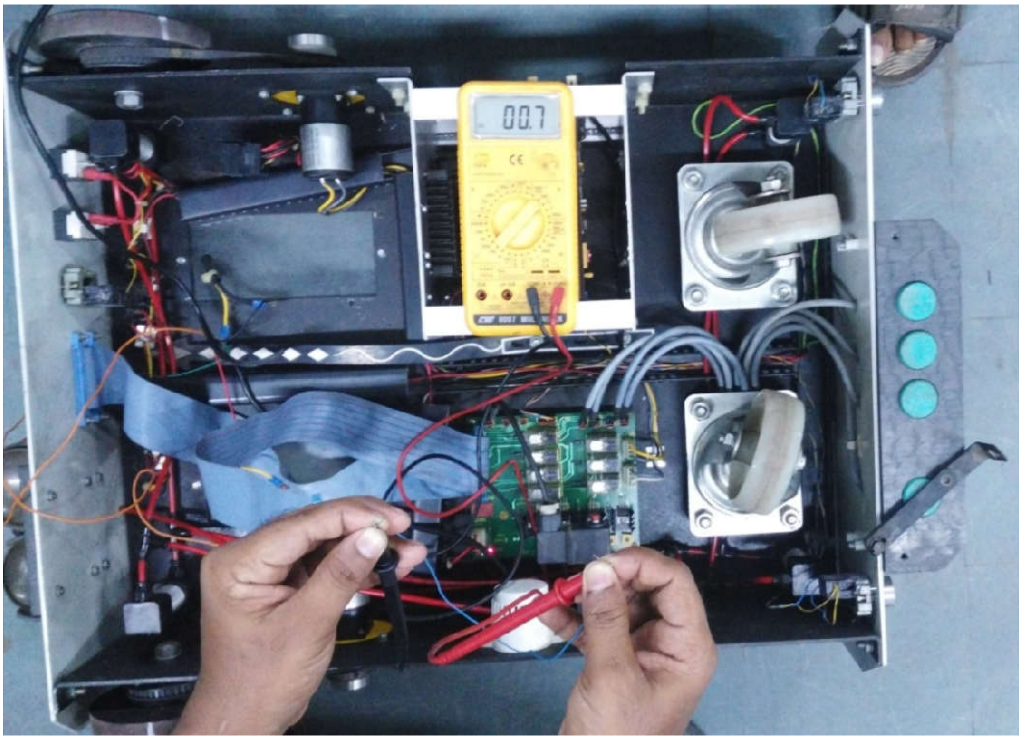


Fig. 5.13 Voltage after detect the metal of the Junction Sensor

CHAPTER -6

DISCUSSIONS

6.1 Discussions:

In the present work a study has been carried out on an existing AGV system whose photographs are shown in Fig. 2.1, Fig. 2.2, Fig. 2.3 and Fig. 2.4, using **Reverse Engineering** approach. The steps of Reverse Engineering include:

1. Creating 3D model of different parts of the AGV's structure.
2. Creating 3D model of different components of the AGV drive system.
3. Creating 2D dimensional drawings of different parts of the AGV System.
4. Carrying out structural analysis of the existing structure for a pay load of 50 Kg.
5. Collecting information regarding operation of the AGV system.
6. Study of the subsystems present in the control unit of the AGV.
7. Study of each such subsystem and their role in AGV's operation and control.
8. Identifying the control pin no.'s in the **Relay Board** subsystem which are responsible for receiving/sending signal from/to **Microcontroller Board** through **Interface Board**.
9. Identifying **Optocouplers** present in the **Interface Board** for being used as input/ output device.
10. Measurement of supply voltages to motor for both higher speed and lower speed.
11. Carrying out test for wheel motion for both the wheels in the forward and reverse direction.
12. Measurement of voltage levels of the track sensors and junction sensor when in proximity to metal substance and without such metal substance.
13. Testing the AGV for right turn and left turn operation sending appropriate signals to the motors.

All the above steps for Reverse Engineering of the AGV system has been carried out in a planned manner and found to be done successfully.

There was an attempt to run the AGV system through sending commands from the personal computer but this could not be done due to shortage of time and some complexity in the communication system with the microcontroller. The program for sending instructions for operating the AGV from a personal computer using GW Basic language has been given in Annexure-I.

CHAPTER-7
CONCLUSIONS
AND
FUTURE SCOPE

7.1 Conclusions:

In the present work Reverse Engineering approach has been followed for bringing an existing AGV System into operation, which was lying for a long time out of operation. Starting from creation of the basic 3D model of the existing AGV System, understanding the operational control action of the control unit and finally testing the AGV for some simple operations through sending appropriate signals to the Relay Board – all these activities have been performed successfully.

In view of the present work on the study of an AGV System through Reverse Engineering following conclusions may be drawn:

1. 3D CAD model of the existing AGV System has been developed through Reverse Engineering.
2. 2D CAD drawings of the different parts of the existing AGV System have been prepared.
3. Control actions for wheel motions forward/reverse at higher/lower speeds have been identified and understood.
4. The control pin no.'s that are responsible for control action as mentioned in 3 above have been identified.
5. The control pin no.'s that are responsible for sending signals from the track sensors and the junction sensor have been identified.
6. Testing for wheel motions as stated in 3 above have been performed successfully by applying suitable control voltages to the respective pin no.'s.
7. Testing for generating sensor signals as stated in 5 above have been performed successfully by measuring sensor output voltages while bringing metal substance in the proximity of the sensors.
8. Testing the AGV for its turning motion (right and left) has been performed successfully.

The work carried out in the present investigation has helped to bring the unused AGV system into operation. Though the complete AGV operation using a personal computer by sending various path programs has not been possible within the time frame work.

7.2 Future Scope:

The existing AGV system has been studied in details and many control information have been collected. These information may be utilized in near future for running the AGV with all its features with the help of a personal computer. There is also a need to interact with the existing microcontroller for proper control action and guidance for the AGV system. It may also happen such that the controller with its operational program may not be accessible. In such situation a new microcontroller may be considered and the program transfer from the personal computer has to be wireless.

CHAPTER-8

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ANNEXURE-I

The program for sending instructions for operating the AGV from a personal computer using GW Basic language:

```
10 CLOSE #1

60 REM OPEN “COM1:9600, N, 8, 2, RS, CS0, DS0, CD0” AS #1: REM COM
SETTUP FOR BASICA

18000 CLS: PRINT “COMMUNICATIONS TEST”: PRINT "-----------": PRINT

18010 GOSUB 30000

18011 BEFORE = LOC (1): PRINT #1, “M3002:20240000”; CHR$ (26);: REM AGV
SHOULD SEND BACK 2X16X2 = 64 HEX CHARRACTERS

18012 LOCATE 23, 1: FOR I= 1 TO 60: PRINT “ .”;: FOR J= 1 TO 10: NEXT: NEXT

18015 AFTER = LOC (1)

18018 IF AFTER – BEFORE < 60 THEN GOSUB 20000: GOTO 18010

18019 GOSUB 30000

18020 CLS: PRINT “OK THE PROCESSOR CARD IS TALKING”: GOSUB 18500

18030 CLS: PRINT “MOTOR TEST”: PRINT “-----------------”: PRINT: PRINT
“SWITCH ON THE MOTOR POWER AND THEN RAISE THE REAR OF THE
VEHICLE SO THAT THE DRIVE WHELS ARE OFF THE FLOOR WITH THE
AGV STILL MATED TO THE GROUND STATION”

18040 GOSUB 18500

18050 PRINT #1, “M3000: 20240000030003030625020002030014012400020115”;
CHR$ (26): V$ = INPUT$ (50, #1)

18060 PRINT #1, “M3004:00000000”; CHR$ (26): V$ = INPUT$ (15, #1)

18065 CLS: PRINT “BOTH WHEELS SHOULD HAVE RUN FOR A SHORT
PERIOD THEN STOPPED”

18066 PRINT “IF THEY FAILED TO DO SO CHECK”: PRINT: PRINT “A. THAT
ALL SWITCHES ARE ON”: PRINT “B.THAT THE I/O CARD IS FIRMLY
PLUGGRD IN”: PRINT “C. THAT THE MOTOR CABLES ARE CONNECTED TO
THE RELAY BOARD”
```

```
18067 PRINT "D. IF ONLY ONE WHEEL MOVES OR OTHER PECULIARITIES
OCCUR,": PRINT "THEN REPLACE ULN 2003 ON I/O CARD (Z29)

18500 Q$ = INKEY$: IF Q$< > "  " THEN 18500

18510 LOCATE 22, 1: PRINT "HIT ANY KEY WHEN PEADY TO CONTINUE"

18520 Q$ = INPUT$ (1)

18530 RETURN

20000 REM

20010 CLS: PRINT "AGV IS NOT COMMUNICATING"

20050 RETURN

30000 FIN = LOC (1)

30005 FOR X = 1 TO 100: NEXT X

30010 IF FIN>0 THEN V$ = INPUT$ (FIN, #1)

30050 RETURN
```