INDUCTIVE NAVIGATION SYSTEM FOR AUTOMATIC GUIDED SINGLE CENTRAL TRACK TRAM

DISSERTATION-II
Submitted in partial fulfillment of the requirement for the award of the Degree

Master of Technology
in
Electronic and Communication Engineering

By

Laveen Kumar

Under the Guidance of

Bikash Kant
Project Supervisor

Transforming Education Transforming India

Lovely School of Electronics and Communication
Lovely Professional University
Punjab
May-2015

DECLARATION

I hereby declare that the thesis titled, **Inductive Navigation System for Automatic Guided Single Central Track Tram** is an authentic record of my own work carried out as requirements of dissertation for the award of degree of Master of Technology in Electronics and Communication from Lovely Professional University, Phagwara, under the guidance of Bikash Kant, during January-2015 toMay-2015.

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3. Single central track navigation system

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This is to certify that **Laveen Kumar** bearing Registration No. **11000552** has completed objective formulation of thesis titled, **Inductive Navigation System for Automatic Guided Single Central Track Tram** under my guidance and supervision. To the best of my knowledge, the present work is the result of his original investigation and study. No part of the thesis has ever been submitted for any other degree at any University.

The Dissertation-II report is fit for submission and the partial fulfillment of the conditions for the award of Master of Technology in Electronics and Communication.

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ABSTRACT

Most of the trams usually run on the double tracks and only few of them are guided by the single central tracks but still having mechanical guiding mechanism thus require more cost and infrastructure to build tracks and guiding mechanism. So, a new navigation system based on inductive navigation technique is proposed which uses metal strips as track to guide the automatic guided tram running on the wheels made up of the rubber tires along the predefined path. Metal strip used for making the path of tram is very thin and have small width which is laid on the surface of ground in such a way that tram is guide by central track. Track made up using metal strip is sensed by inductive sensors facing towards the track placed at the front of each bogie. Amount of deviation from predefined path is measured by inductive sensors placed at the front of each bogie and results from inductive sensors are provided to the electronic control unit placed in the bogie of the automatic guided tram. Each bogie contains an independent steering system to steer the bogie along the track and the steering effort required to change the direction of the tram according to the track is provided by an electric motor attached to the steering column of steering system. The proposed inductive navigation technique offers a low cost and less infrastructure requiring navigation system for automatic guided central track trams. The design of inductive navigation system is implemented and tested on the prototype model of tram.

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List of Abbreviation

AC	Alternating Current
AGV	Automatic Guided Vehicle
AGV	Automatic Guided Vehicle
BLDC	Brushless DC Motor
DC	Direct Current
GPS	Global Positioning System
IMU	Inertial Measurement Unit
LDR	Light Dependent Resistor
LFR	Line Following Robot
MIPS	Microprocessor without Interlocked Pipeline Stages
MSR	Magnetic Sensing Ruler RFID Radio Frequency Identification
RTK DGPS	Real Time Kinematic Differential GPS

Chapter 1

INTRODUCTION

1.1 Introduction

Trams play an important role in public transport systems as they serve as cheapest means for transporting large number of passengers from one station to another station in large urban areas. Trams also helps in reducing the problem of traffic control and making the eco-friendly environment in urban areas. Trams require navigation system to traverse a path along the predefined track. Different types of mechanical navigation systems which require high cost and infrastructure for building the tracks are used by trams guided by the double track and single central track. Also navigation systems used by automatic guided vehicle and mobile robots can be used for navigation of tram. In order to reduce the development cost and infrastructure required for building the tracks and guidance system we have proposed a inductive navigation technique using single central metal strip as track which provide more cost effective, flexible and robust guidance for trams running on the rubber tire wheels. The study of proposed navigation system in this report is organized as follows: chapter 2 covers the literature review related to the various navigations systems, chapter 3 covers the aim, objectives and research methodology, equipment's, material, experimental setup and chapter 4provides the outcome for the proposed study.

1.2 Significance of the Problem

Most of trams are guided by double track and very few are guided by single central track which are navigated using mechanical system thus requiring more cost and infrastructure for laying tracks. So, a new type navigation system based on the electronic guidance system using inductive navigation technique and requiring less cost and infrastructure is proposed in this research work.

1.3 Purpose of the study

To design an electronic guide system for automatic guided trams guided by predefined path, requiring very low infrastructure and cost for laying the track on the same roads on which the automobiles moves.

1.4 Information Sources

Information for making the navigation system for automatic guided single tram is collected from various sources like research papers published in various journals, research articles published in magazines and websites related to automatic guided vehicle and tram manufacturing companies.

1.5 Important Definitions

Tram

Tram is the term used for vehicle which is guided by rail track usually laid on the surface of the street roads, used to carry a group of people from one station to another station.

Translohr

A tram manufactured by Lohr Industry of France which is guided by single central track.

Bogie

A bogie is framework consisting of wheels and axles which carries the passenger in passenger trains and goods in goods carrying trains.

Flange

A flange is inward or outward projection of tram or train wheel so that wheel is not derailed.

Rail Track

A guiding path used for guiding the tram or train to from source to target station.

Guiding or Navigation System

A system used for guiding the automatic guided tram or vehicle to follow a predefined path.

Radio Frequency Identification

Radio Frequency Identification is type of technology in which the identity (in the form of a unique serial number) of an object or person is transmitted wirelessly by transmitter, using radio waves and transmitted radio waves are received by RFID Reader.

Global Positioning System

Global positioning system is a system which uses satellites for locating the latitudinal and longitudinal position of object having GPS module on the earth.

Microprocessor without Interlocked Pipeline Stages

MIPS is defined as microprocessor without interlocking pipeline stages which is based on the reduced instruction set architecture which is developed by MIPS Technologies Inclusive.

Steering

Steering is the effort required to change the direction of the vehicle in the desired direction.

Automatic Guided Vehicles

The term automatic guided vehicle is used for vehicle which has ability to drive without any need of driver operation. It is an unmanned, computer controlled vehicle which is capable of handling materials and powered by electricity.

Line Following Robot

It is a robot which detects a particular line and follows the path according the track of the line. A line defined here is simply a path which is predefined that can be made using high contrasted color on low contrasted color surface.

Steering Wheel

Wheel used for transmit the effort required changing the direction of vehicle in desired direction to the gear box (gear mechanism is used for translating the rotational motion of steering wheel into linear motion rotating the wheels).

Steering Column

Steering column is link joining the steering wheel and gear box of the steering system.

Chapter 2
LITERATURE REVIEW

2.1 Tram Guiding Systems

2.1.1 Double Track Guide

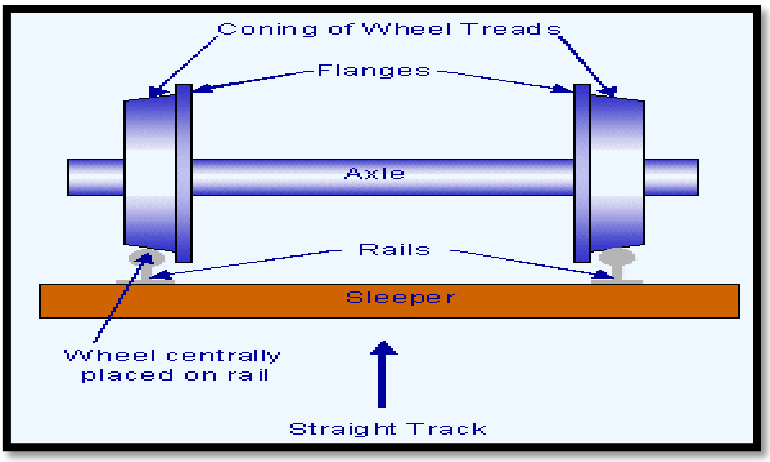
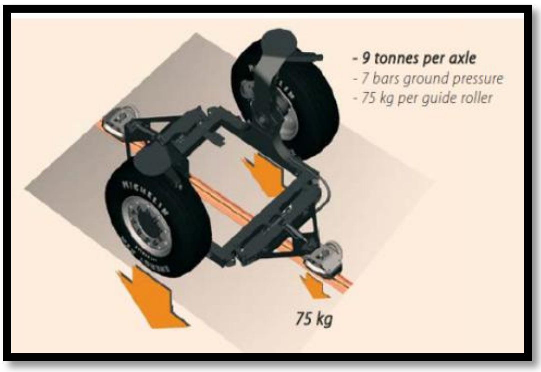
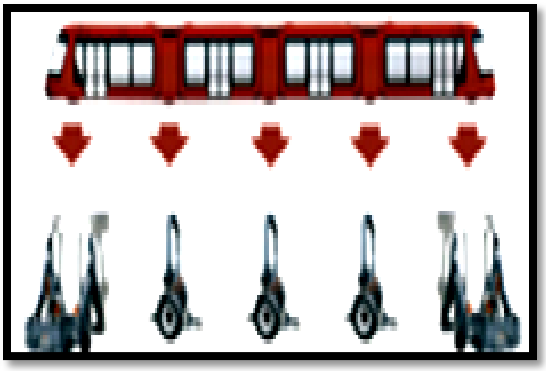


Figure:2.1 Single straight track[1]

Trams using double rail track as the guided path runs on steel wheels mounted on the solid axle. The wheels of tram are designed to fit according the type rail so that both the wheels and rail has gripping among each other. These wheels has slightly tapered rim so wheel cannot slip on turning. When the tram reaches curved track then tram tries to move in the straight direction but flanges of wheels pressed by the rail track tries to move the wheels along the curved rail track. This tracking is possible as tram wheels has slopping in the cone shape having inside diameter slightly larger as compared to outer diameter[1,2].

2.1.2 Single Central Rail Track





(a) (b)

Figure:2.2 (a)Translohr guide system [4]; (b) Guide system in each bogie [4]

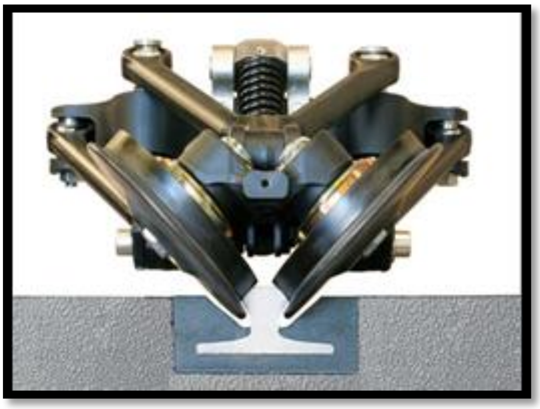


Figure:2.3 Translohr guiding rollers[4]

Trams which using single central track as guided path runs on rubber tires mounted on the axle. An example of such a tram is Translohr(manufactured by Lohr Industry of France)which is guided by single central rail uses the mechanical guiding system mounted on axles of each bogie of tram. Guiding system of translohr is mechanically locked with the guide rail which consists of two rollers as shown in above figure no. 2.3. As the translohr moves on the curved path rollers are pressed against the guide rail which in turn applies the pressure on the rubber wheels so that tram moves in the desired guided path[4].

2.2 Inductive Guidance

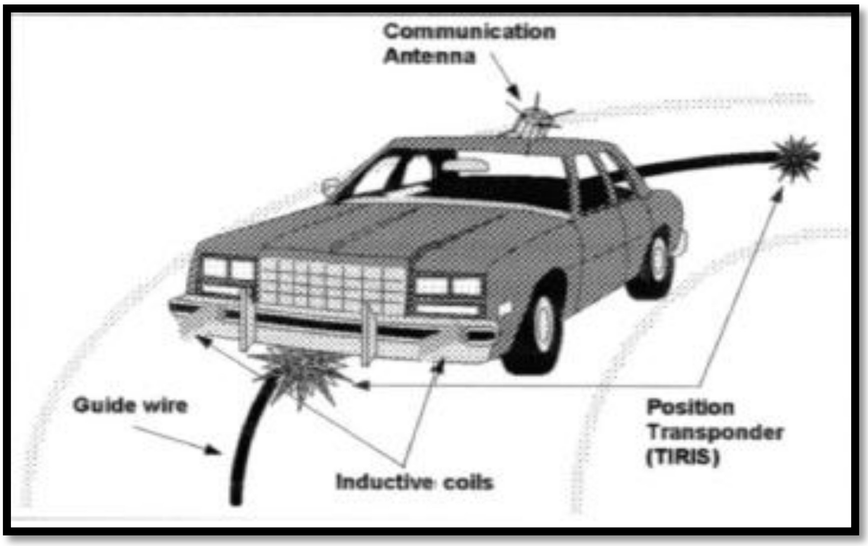
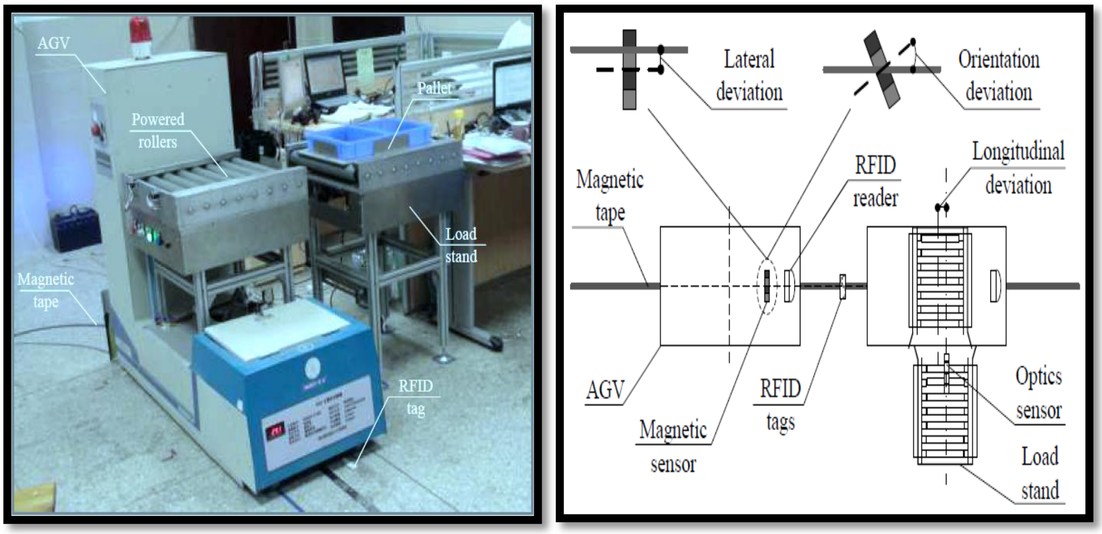


Figure:2.4 Inductive guidance system [5]

Shraga Shoval, Jeff P.Zyburt, &Don.W.Grimaudo (1998)has proposed robotic system that is used for guiding the vehicle which is used testing the durability of road. The vehicle uses inductive wires (each wire carry unique frequency signal) embedded in the floor as the guiding track. Vehicle receives the signals generated by inductive wire by using two inductive coils which are mounted to the front of the vehicle. It uses on-board controller for performing the tasks of diving the vehicle like controlling the actuators (brake pedal, accelerator pedal,steering wheel and gear stick) and for interacting with the sensors mounted on it. The details of path which the vehicle has to follow, speed along path and facility control like fueling, cooling, service etc. are provided by the base station[5].

2.3 Magnetic Tape Guidance

Xing Wu, Peihuang Lou, KeShen, GuangqingPeng, Dunbing Tang, (2014)has proposed a guidance system and docking control system for unit load AGV which uses magnetic tape fixed on the floor as the guiding track for guiding the AGV. Two magnetic sensors mounted at the centre of AGV in parallel way at some longitudinal interval. These two magnetic sensors are used for measuring the orientation deviation (angle between the path of an AGV and lateral center lines) and lateral deviation (the lateral distance from a path an AGV to the center of middle of AGV) from track are mounted on the AGV. RFID system is used for locating the load stand of vehicle. AGV also use fuzzy control system for more efficient and accurate tracking of the track[6].



(a) (b)

Figure:2.5 (a) AGV guided by magnetic tape [6]; (b**)**AGV docking process [6]

2.4 Optical Guidance

(Material Handling Institue, 2012) Optical guidance system uses non visible tape or chemical which is illuminated only by ultra violet light rays as a guided path for automatic guided vehicles. AGV has onboard sensor that contains ultraviolet light source for illuminating the guiding path of AGV so that the guided path is detected by the sensor. This type of guidance system is used for non-industrial applications. It can be used for different variety of floor surfaces which includes tile, concrete and wood etc.[7].

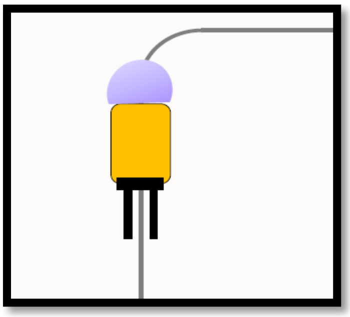


Figure:2.6 Optical guidance [7]

2.5 Magnetic Spot Navigation

Ana C. Lopes, Fernando Moita, UrbanoNunes, RazvanSolea, (2007)has proposed navigation system based on magnetic markers for autonomous mobile robots. Permanent magnet embedded in the floor is used as guiding path for guiding the mobile robots. The magnetic sensing ruler (MSR) mounted on the mobile robot is used for detection of magnetic markers. 3D-detection algorithm (includes longitudinal-fitting and cross-fitting detection) is used for detecting the magnetic markers. Navigation system proposed here fuses odometric data with magnetic marker detection and extended kalman filter is used reducing the signal noise generated in fusion process. The experiment is performed on the Robochair (a wheel chair developed by ISR-UC) as shown in the figureno.2.7 [8].

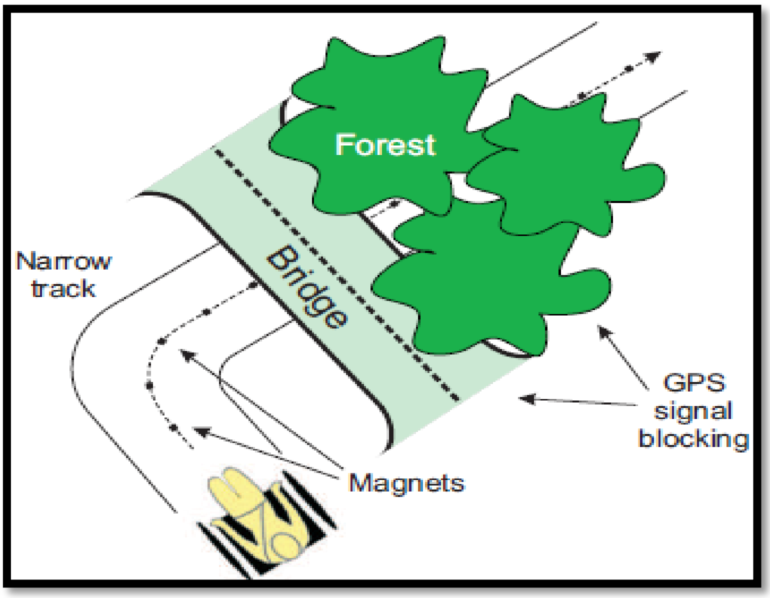


Figure:2.7 Magnetic spot navigation [8]

2.6 Laser Target Navigation

Huosheng Hu and DongbingGu, (2000)has proposed the navigation system for the mobile robots whose positions are estimated on the basis of artificial landmarks present in the environment. A rotating laser scanner is placed on top of the physical centre of mobile robot as shown in the figure no. 2.8 is used for measuring the angle between the beam line from leading or falling edge of artificial landmarks. Landmarks can return the reflected light back to the photo detector placed inside the scanner. Triangulation algorithm is used to calculate three angle measurements from the three landmarks then kohonen neural network is used to recognize the landmarks so that co-ordinates of landmarks detected. After this extended kalman filter is used for reducing the uncertainties in the measured readings[9].

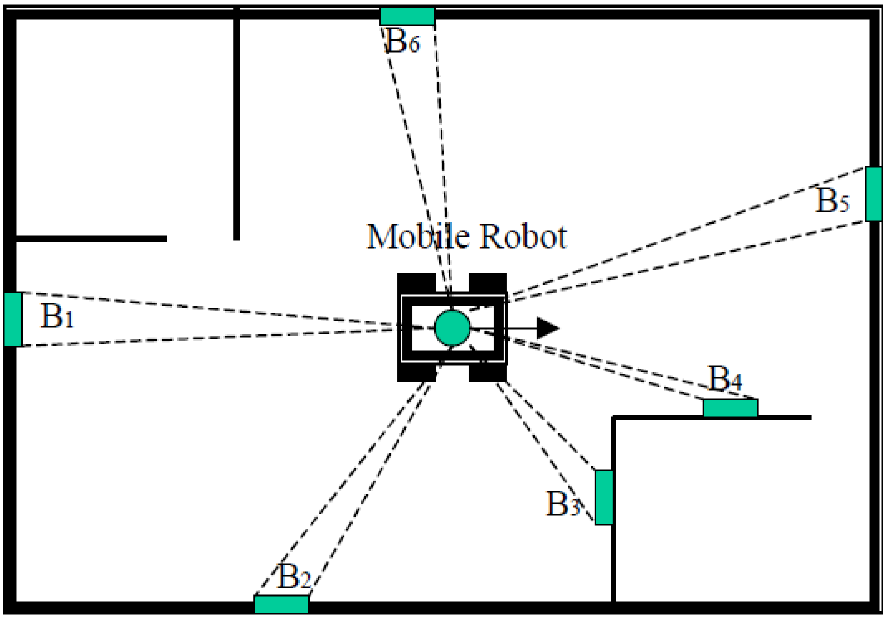


Figure:2.8 Laser scanner and landmarks[9]

Hongpeng Chi, Kai Zhan, Boqiang Shi (2011), has proposed navigation system for automatic guided vehicles used for mining purpose. The system uses the combination of two technology i.e. laser technology to detect the position of vehicle and barcode code technology for locating the vehicle in the tunnel. Two laser scanners mounted on the vehicle are used to calculate the distance from wall along with angle between wall and vehicle central axis in order to find position of the vehicle with respect to the wall of laneway. The vehicle control is driven by an industrial computer to issue the various commands required to follow the trajectory [17].

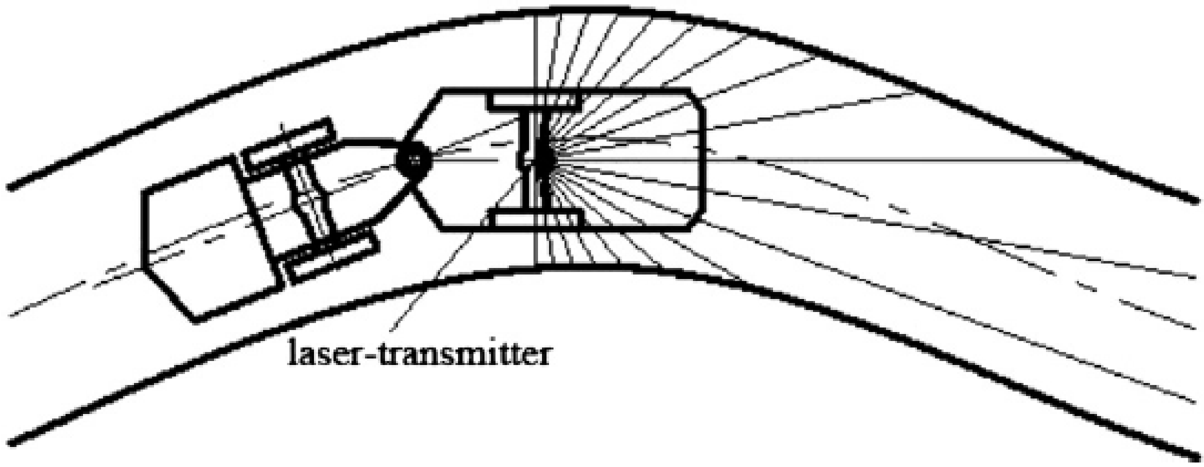


Figure:2.9 Laser Based Positioning [17]

2.7 RFID Based Navigation

Wail Gueaieb, Senior Member, IEEE, and Md. SuruzMiah, Student Member, IEEE, (2008)hasproposed a real time navigation technique for the mobile robots. Passive RFID tags are mounted in 3D space at predefined fixed locations is used as guiding track for navigation of mobile robots. A RFID reader having two RFID antennas is mounted on the robot to transmits and receive the signals from the RFID tags. To move the robot to the target position robot is firstly programmed with RFID tag with ordered list of tags defining the target position. Phase difference is calculated from phase angles received from the different RFID tags and the phase difference is passed to the fuzzy logic controller which turns the robot direction according the desired path to the target position. In this way robot moves to target position by following a free path defined RFID tags [10].

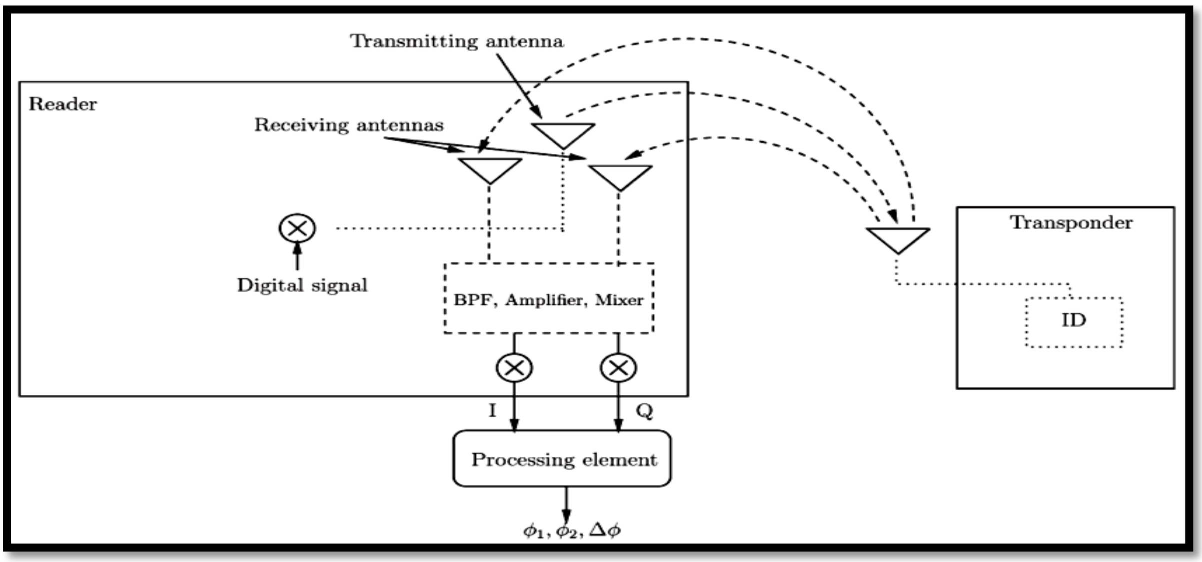


Figure:2.10 RFID system for phase difference calculation[10]

Ali Asghar Nazari Shirehjini, Abdulsalam Yassine, and Shervin Shir mohammadi, Senior Member, IEEE, (2012) has proposed navigation system using RFID tags for localization of the robots and ultrasonic and infrared sensors for obstacle avoidance. Three RFID antennas mounted in an equilateral triangle position on the robot are used to calculate the present position of the robot. After calculating the present location system calculates the destination position of target with respect to the current position of the robot. With the help of trigonometric analysis angle and distance it has to travel is calculated for reaching to the target. Obstacle avoidance system is used to protect the robot from striking the obstacle present in its path[11].

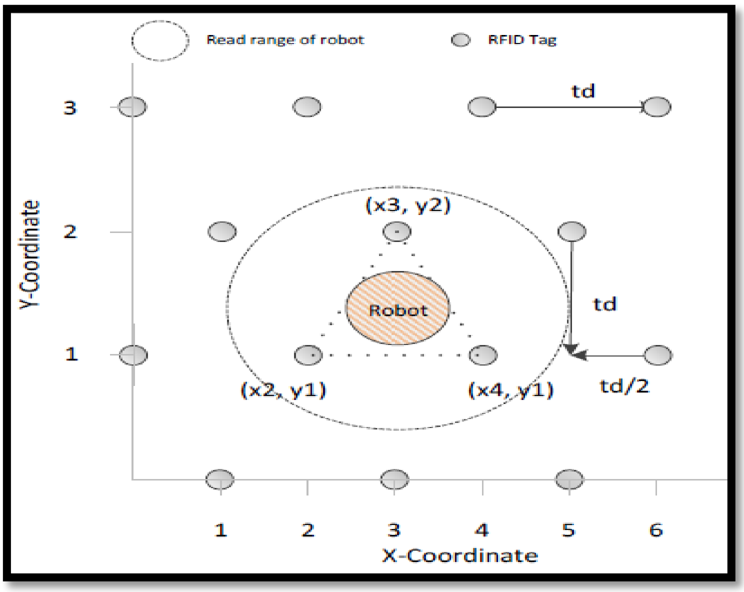


Figure:2.11 RFID tags positions [11]

2.8 GPS and Inertial Navigation

Vicente Milan'es, Jos'e E. Naranjo, Carlos Gonz'alez, Javier Alonso and Teresa de Pedro, (2008) has proposed a guidance system based on the global positioning system along with inertial navigation system for automatic guided vehicles. Normally, Real Time Kinematic Differential GPS (RTK DGPS) is used for guiding the vehicle to the target but in case if the DGPS fails to receive the signals then a decision control system present in the vehicle uses inertial measurement unit (IMU300CC) for guiding the vehicle to the target position. IMU needs initial values of position and altitude for calculating the vehicle position so these values are calculated initially by DGPS. IMU provide more accurate results initially but due to degradation of the drift vehicle position deviates from its path so here DGPS is used to correct the position of the vehicle[12].

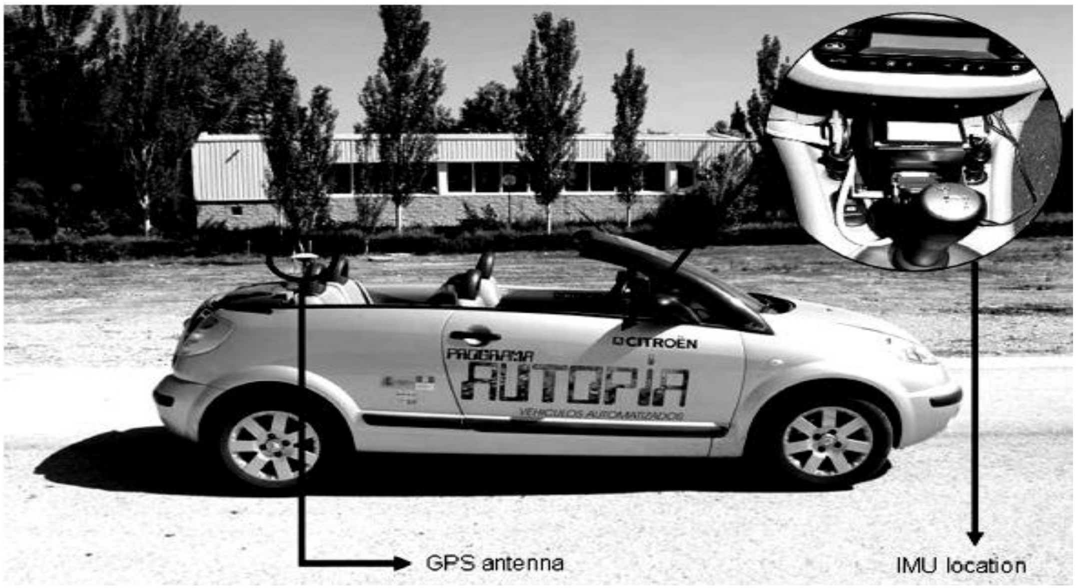


Figure:2.12 GPS and Inertial Navigation [12]

Tijmen Bakker a, Kees van Asselt, Jan Bontsema, Joachim Muller,1, Gerrit van Straten has proposed guidance system based on RTK-DGPS for conducting the experiment of automatic guided vehicle to monitor the sugar beet fields. Firstly the field consisting of rows is mapped with camera and GPS system which produces four files (one field, two headland and one path files) as the output containing the coordinates of the field. Initially the field and headland files are loaded to set the origin and then other files are loaded to find the position of the vehicle. Vehicle is fixed to move with the constant speed of 0.3 m/s [18].

2.9 Vision Based Navigation

Quan Nguyen Van, Hyuk-Min Eum, Jeisung Lee, and Chang-Ho Hyun, (2013) has proposed driving algorithm for indoor automatic guided (AGV) based on vision sensors consisting of two USB cameras. One camera is mounted on the second layer of plate perpendicular to the floor to detect the nearest marker placed on the floor and another camera is mounted on the third layer of plate to obtain the angle subtended between floor and its view. Laptop (Lenovo ThinkPad) is used as controller for performing the robot controlling tasks. Angle and distance information obtained from two cameras is used by the robot to move along the desired path. Five different movement patterns of robot which are moving straight, left/right turning, moving straight, starting and stopping are used for smooth and robust tracking of the path[13].

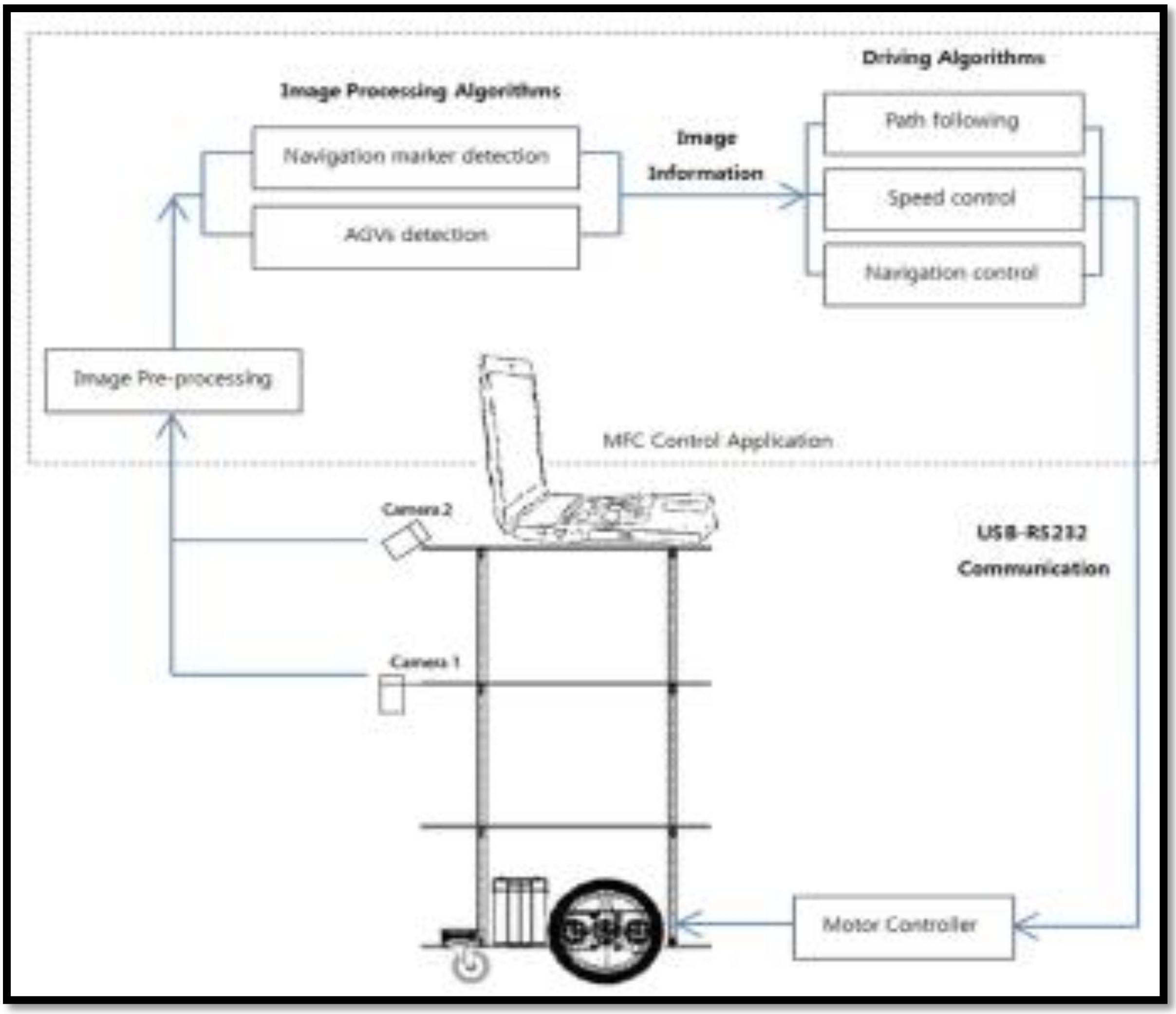


Figure:2.13 Vision based navigation for automatic guided vehicle [13]

Sulaiman Sabikan Marizan Sulaiman, Sy. NajibSy. Salim and M. Fahmi Miskon, (2010) has proposed vision based navigation system which uses various algorithms for tracking the robot path..Two navigation modules (main navigation module and conflict-free navigation module) are used for tracking of the robot path. Track used for guiding the robot consists of two colored layers having opposite colors (white and black) are used for constructing different guidelines indicating different robot movement directions. Second layer is placed on middle of the first layer (fixed permanently to the floor). Main navigation module uses USB camera for following the line placed on the floor, detecting the signs placed on the track, detecting the obstacles and junctions present in the path. In case if obstacle appears on the track then conflict-free navigation module generates a new path so that obstacle is avoided after crossing the obstacle robot comes back to original path[14].

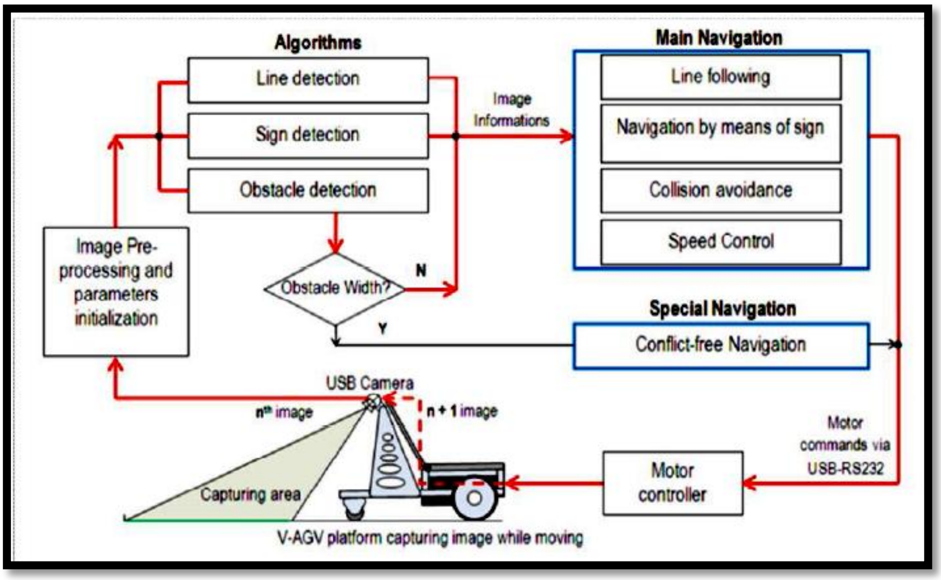
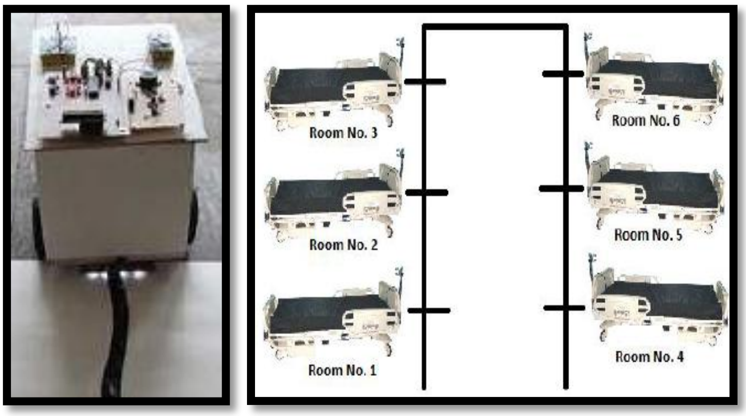


Figure:2.14 Vision Based Navigation System [14]

2.10 Infrared Guidance



(a) (b)

Figure:2.15 (a) LFR [15]; (b) Patient rooms & track line [15]

Deepak Punetha, Neeraj Kumar, Vartika Mehta, (2013) has proposed a line following robot for health care management system which is used to deliver the medicine to the patient. A robot uses the black line placed on the white surface as track for guiding the robot to the target position. Light dependent resistor is used as sensor to detect the black line used as a track. Resistance of LDR approaches to zero as it face towards the white surface and it becomes maximum when it face towards black surface. Sensitivity of LDR is set by comparator circuit which is also used to convert the analog logic of LDR sensors to digital logic. Output from comparator is given to the microcontroller which control the robot movement by providing the desired logic to the motors (used for driving the robot) attached to robot through motor driver IC L293d. A robot uses infrared proximity sensor to avoid any collision with the obstacle. Patient uses an infrared sensor switch placed near to him/her for bringing the medicine by LFR to him/her [15].

Table:2.1 Direction of robot movement [15]

Robot Movement	Left Motor	Right Motor
Forward	Forward (Clockwise)	Forward (Clockwise)
Left	Stop	Forward (Clockwise)
Sharp Left	Backward (Anti-Clockwise)	Forward (Clockwise)
Right	Forward (Clockwise)	Stop
Sharp Right	Forward (Clockwise)	Backward (Anti-Clockwise)
Backward	Backward(Anti-Clockwise)	Backward(Anti-Clockwise)

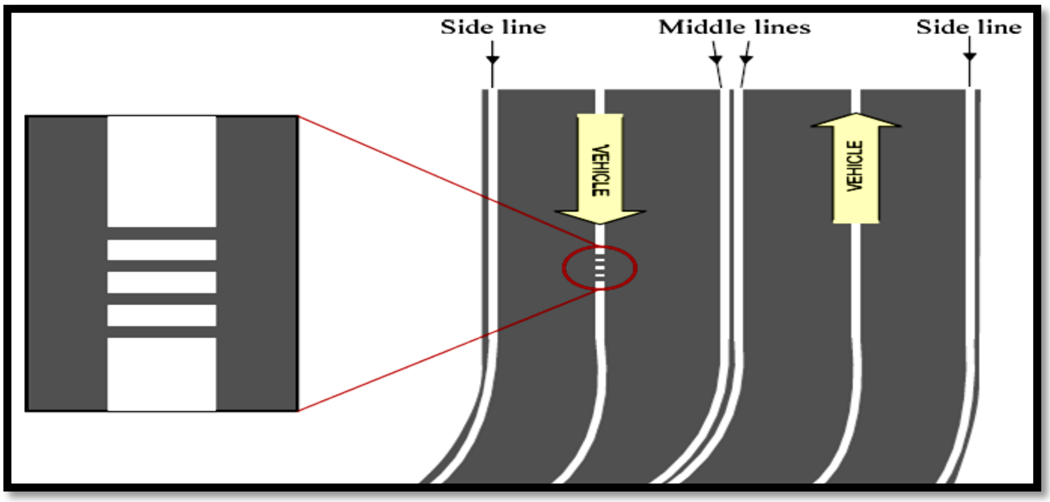


Figure:2.16 Tracking dashed lines [16]

Yahya Zare Khafri, Ali Jahanian, (2012) has proposed a line tracking system for high speed vehicles for autonomous navigation of vehicles along the predefined path. White colored line consisting of continuous white line and dashed lines is placed on the black surface is used to provide the information of track to the vehicle such as left/right turn, turning angle and intersections of turns etc. A vehicle uses two sets four infrared sensors as shown in the figure no. 2.16out of which one set is used for navigation of vehicle along the continuous white line and another set is used for reading the dashed lines. MIPS based processor is used for processing various operations of robot. Finally, a navigation algorithm based on checking the status of various sensors is used for guiding the vehicle along the desired path. Experimental results provide the tracking accuracy, speed accuracy and performance analysis of tracking the given path over different speeds of the vehicle [16].

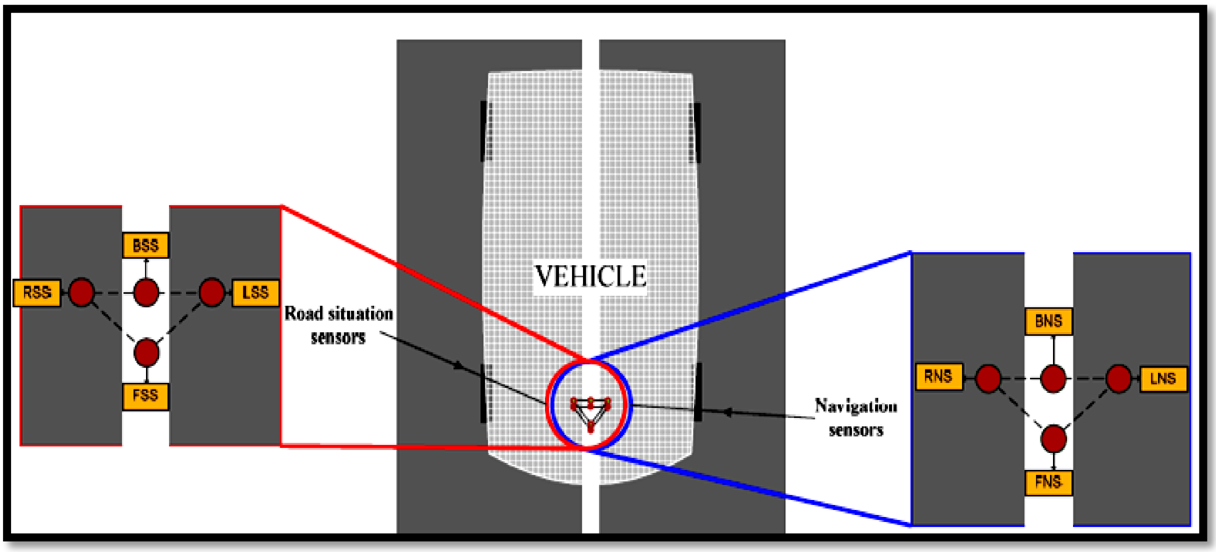


Figure:2.17 Infrared sensors configuration [16]

2.11 Reactive Navigation with Opportunistic Localization

Jonathan M. Roberts, Elliot S. Duff, Peter I. Corke, has proposed a reactive localization system for very large vehicles used for mining. Navigation system uses 2d laser scanner as sensor and works on the basis of three functional layers which are strategic layer, tactical and operational layer. Strategic layer acts based on the hints provided by the route selected to determine when and where it has to do the task. Results obtained from strategic are passed to the tactical layer which senses the walls in the mining tunnel and passes the velocity and steering parameter to the operational layer. Operational layer performs the actual controlling tasks to of driving the vehicle based on the parameters provided by the tactical layer [19].

Table:2.2 Comparison of different navigation techniques for automatic guided vehicles.

Sr. No.	Guidance Technique	Key Idea	Advantage	Disadvantage
1	Inductive Guidance	Detection of inductive track with principle of mutual induction [5]	1. Technique is robust in nature. 2. High accuracy can be achieved by using high quality components. 3. Free from interference.	1. Hard and expensive to install. 2. Difficult to repair embedded wires used as track. 3. Path is not easy to change [22].
2	Magnetic Tape Guidance	Detection of magnetic track along horizontal axis [6]	1. Easy to install track. 2. Tracking accuracy is high. 3. Track is flexible to change and repair [22].	1. Require repairing of tape that wears with the passage of time [21].
3	Magnetic Spot Guidance	Magnetic spots are used for localization [8]	1. Well suited to work in harsh environmental conditions. 2. Operates easily on uneven and rough floors [21].	1. Hard to install. 2. Magnetic markers get damaged with passage of time. 3. Misguidance can occur at a place where marker is absent.
4	Optical Guidance	Detection of optically active track[7]	1. Cheap and easy to install. 2. Track is flexible to change and repair.	1. Interfered by the UV light sources. 2. Not suitable for outdoor applications.

5	Laser Target Guidance	Position detection via triangulation[9]	1. Easy to install the track [22]. 2. Technique is suitable for complex paths.	1. Require line of sight operation [21]. 2. Interference from other laser sources.
6	RFID Based Guidance	Based on physical landmark detection [10]	1. Easy to install track. 2. Track is flexible to change.	1. Interference from other radio signals. 2. Misguidance can occur at a place where marker is absent.
7	GPS Guidance with Inertial Guidance	Based on landmark detection and geographical location calculation [12]	1. Can be programmed easily for curved paths. 2. It does not depend on any visual guidance.	1. Not suitable for microwave-shielded areas. 2. Kinematic GPS is expensive.
8	Infrared Guidance	Detection of colored track along horizontal axis [16]	1. Most cost effective and most easy to install the track. 2. Track is flexible to repair and change.	1. Interfered by infrared light sources present in the environment. 2. Not suitable for outdoor applications.
9	Vision Guidance	Detection of visual features present in the environment [13]	1. No physical landmarks required. 2. Easy to install and change the track.	1. Difficulty in case of changing light conditions.
10	Rail Guidance	Rail griped with wheels of vehicle is used for guiding the vehicle [1]	1. Most robust technique. 2. High tracking accuracy	1. Hard and very expensive to install. 2. Hard to change the route.

Chapter 3
PRESENT WORK

3.1 Problem Formulation

Trams are widely used for transportation of the passengers from one location to another location. But most of the trams are mechanically guided hence more infrastructure and cost is required to build a navigation system for such trams. So, here the research is conducted to design electronic based a robust, cost efficient and low infrastructure requiring navigation system for automatic guided single central track tram based on the inductive navigation technique.

3.2 Objectives

- To design a navigation system for tram which can be run on roads.
- Navigation system should be less infrastructure requiring.
- To design a single central track guided tram.
- Navigation system should be electronically controlled.
- To develop a mathematical model for calculating the amount of deviation and amount steering required for vehicle to efficiently track the predefined path of the vehicle.
- To test the system working with the all possible conditions according to sensor array.

3.3 Scope of study

The study of inductive navigation system for automatic guided single central track tram focuses on the development of cost-effective and robust navigation system for trams. The study will be done in the area of robotics and automation. The various concepts of robotics and automation field which will be important to complete the proposed study will also be used in development of proposed inductive navigation system for automatic guided tram. For more accurate development of the proposed navigation system, system performance is analyzed under various possible sensor conditions. The inductive navigation system developed here will be used trams running on the roads along with the other vehicles. The tram developed with this type of navigation will be guided by single central track. The navigation system that will developed in this study can serve as low infrastructure requiring navigation system for railway industry as very less effort will be required in laying the tracks made up of metal strips and also the maintenance cost required for the tracks is also less.

3.4 Equipment, Materials and Experimental Setup

A. Equipment Required

1. Transmission Motor

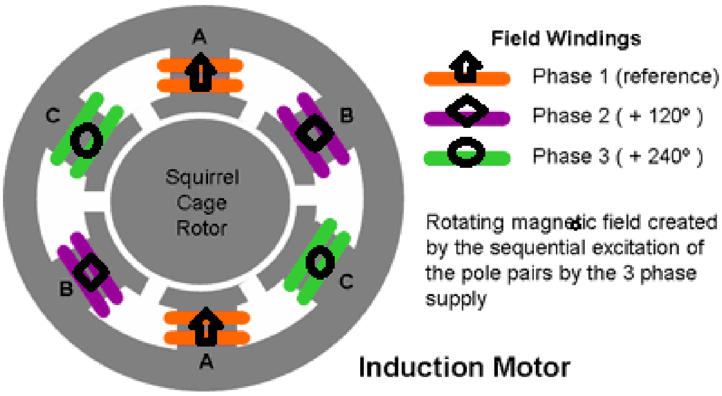


Figure:3.1 Rotating magnetic field inside induction motor [25]

Transmission motor is used is a type of three phase AC motor manufactured by Siemens company which provides the transmission power to the tram. It also encloses a fan for cooling purpose. It is suitable for variable frequency drive operation. Rotor in this motor is rotated by rotating magnetic field generated by a three phase ac supply. Magnetic flux generated in rotor is directly proportional to the current in stator windings. Initially, the current is induced in one of the pair of the poles due to first phase, as it reaches to peak value the flux induced will be maximum, after reaching the peak value current starts decreasing but at the same time current starts increasing in another pairs of poles the due to 2nd phase which rise the magnetic flux in the rotor and so on with 3rd phase. In this way a rotating magnetic field is created in stator winding which rotates the rotor of motor [25].

Table:3.1 Transmission motor parameters

Sr. No.	Parameter	Specification
1.	Motor Type	Three Phase AC Induction Motor
2.	Power of Motor	11 KW
3.	Speed	1450 rpm
4.	Operating Voltage	AC 440 Volt
5.	Max. Rated Current	21 Ampere
6.	Power factor	0.81
7.	Ambient Temperature	50 °C
8.	No. of poles	4

2. AC Drive

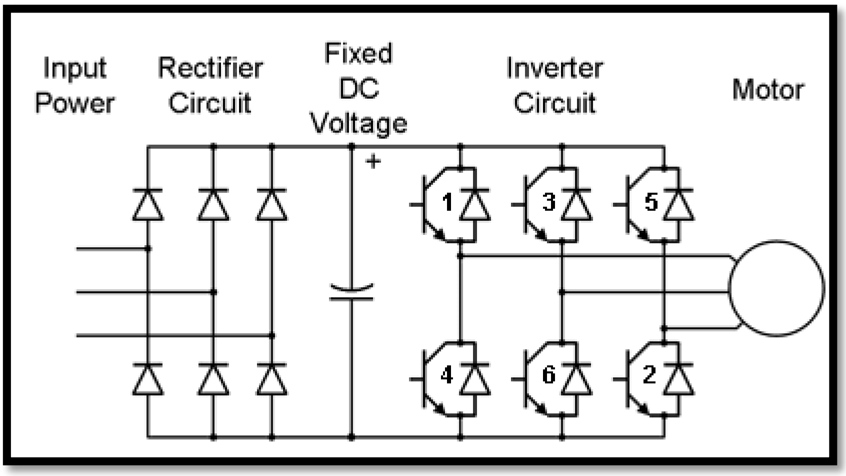


Figure:3.2 Main components of 3-phase AC drive [27]

AC drive is controller which is used for controlling the speed of ac induction motor by changing the operating frequency of electric supply. 3-phase ac supply is fed to the silicon controlled rectifier circuit which converts the ac voltage of instantaneous amplitude into variable dc voltage. The transistors in the inverter circuit are switched on in the sequence as numbered in the circuit diagram shown below to provide the three phase ac voltage at output of required frequency [27].

3. Steering Motor and Operation Controller

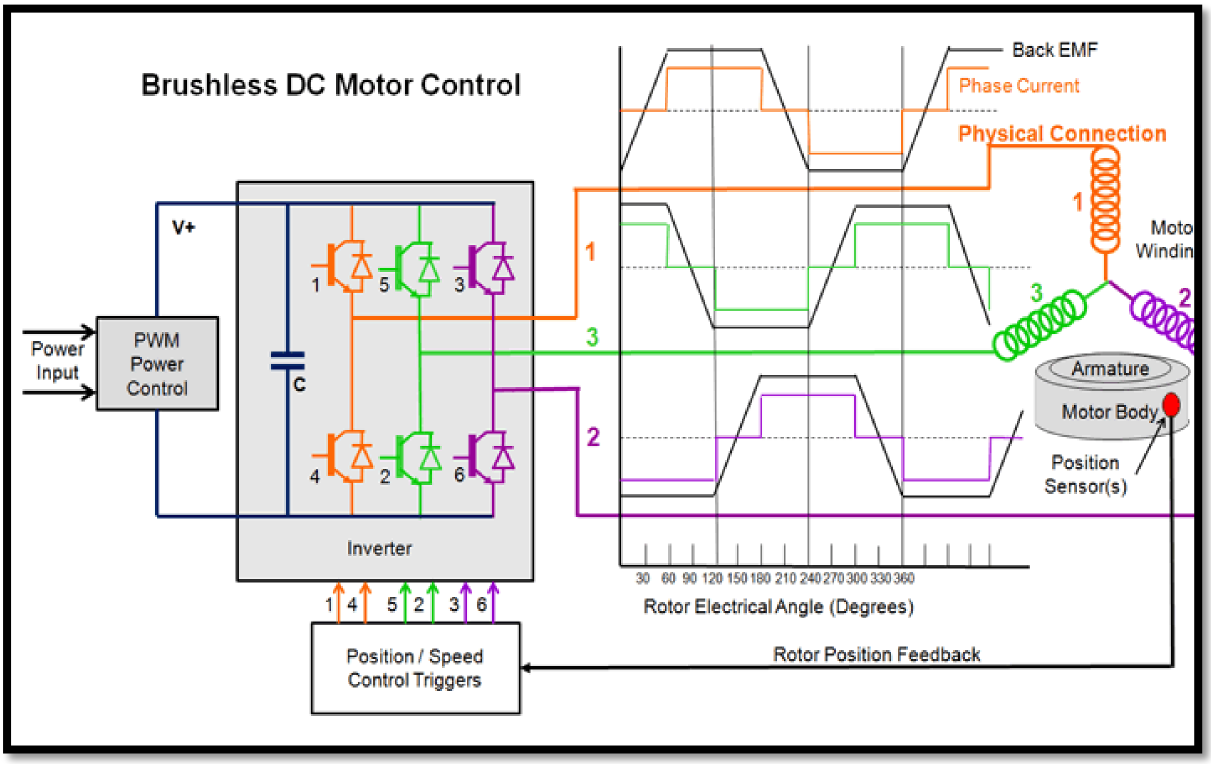


Figure:3.3 Control of brushless DC motor[26]

Steering motor used for the purpose of steering is a type of brushless DC hub motor having operating power 800W (1500W-Peak) and operating voltage of 48Volt. In BLDC motor a DC pulse having positive and negative pulses of 120 degree duration is used to create a rotating magnetic field in stator winding of the motor which led to operate it at synchronous speed. DC pulse is generated by the combination of the six transistors present in the operation controller and three pairs of stator windings [26].

4. Microcontroller

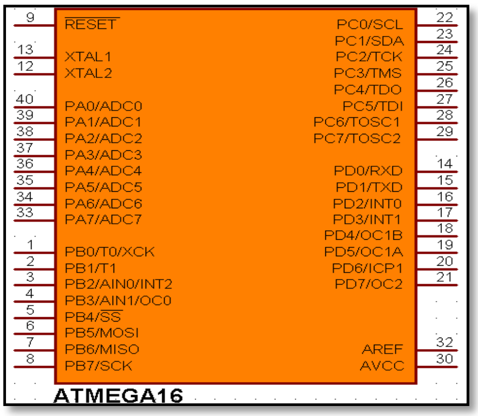


Figure:3.4 ATmega 16

ATmega16 microcontroller will be used as central controller for controlling the overall task of navigation process of the vehicle. ATmega16 is a low power requiring, 8 bit microcontroller, having high-performance. Microcontrollers based on RISC (Reduced Instruction Set Computing architecture) which has 131 instructions. In ATmega 16 the instructions are executed in one machine cycle. It can operate on a maximum frequency of 16MHz but in this work it is operated at a frequency of 8MHz [28].

Features of ATmega 16 used in Programming

- 16 Kb flash memory for program
- 32 I/O lines for i/o operations
- 512 B EEPROM for memory operation [28].

5. Voltage Regulation Unit

In the microcontroller board circuit, the energy is derived from 12V batteries. Since different circuits in navigation system require different voltage sources, so it is not always possible to use the battery directly to power the different circuits. The ICs in microcontroller board are designed to operate with a constant source of 5V. So in order to convert the 12V DC source into a 5V DC source we require a 5V voltage regulator.

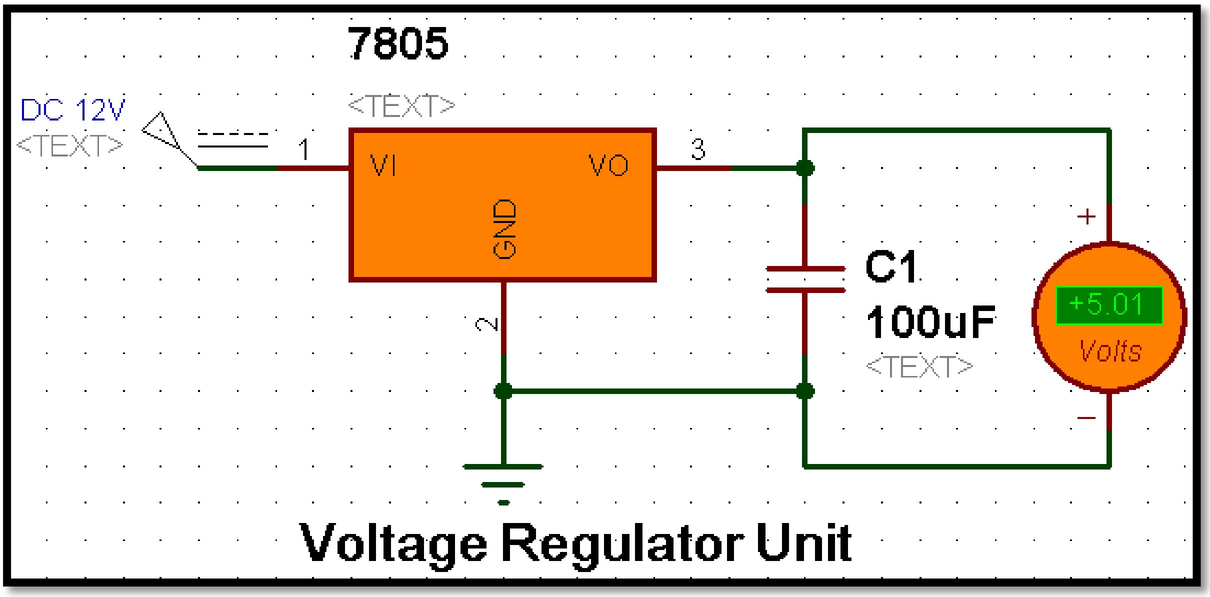


Figure:3.5 Voltage regulation unit

6. Steering Motor Direction Control Circuit

Steering motor used for purpose of controlling the steering of the vehicle is a type of hub motor which has three phases and operates on the 48V. So in order to control the motor with the help of low power microcontroller circuit we require a circuit for controlling low power to high power circuit. It controls the driving operation and direction control operation of the steering motor with the help of its operation controller. It consists of high current driver L293D IC for converting low current logic low voltage level (5V) from microcontroller output to high current logic at high voltage level (12V) at its output. This high logic level is used for driving the relays connected to outputs of L293D IC. These relay act as switch to connect and disconnect the circuit of steering motor controller. Steering motor possess different speed in reverse and forward direction. In order to equalize the speed in both directions, two potentiometers are used as follows speed in forward direction is controlled by potentiometer (POT1) and speed in reverse direction is controlled by potentiometer (POT2). Both the potentiometer has 5V at their input ends. In the figure no. 3.6Relay (RL1) output is connected to accelerator wire (thin green color wire) of the steering motor controller and input of relay (RL1) is connected to the potentiometer in order to control the speed of steering motor in forward direction. Relay (RL2) output is also connected to accelerator wire (thin green color wire) of the steering motor controller but input of relay (RL2) is connected to the potentiometer (POT2) in order to control the speed of steering motor in reverse direction. The two wires (thin black and yellow wire) present in steering controller must be short circuited to reverse the direction of steering motor. This operation is performed by Relay (RV3). Relay (RV3) input wire is connected to the yellow wire of the steering motor controller and output of relay (RV3) black wire is connected to the output of the steering motor controller. For the hub motor, in the Figure 3.7, INPUTS1,2,3,4 are from microcontroller, O/P 1, O/P 2 are 48V outputs fed to the motor and I/P 1, I/P 2 are 48 V inputs from controller of steering motor.

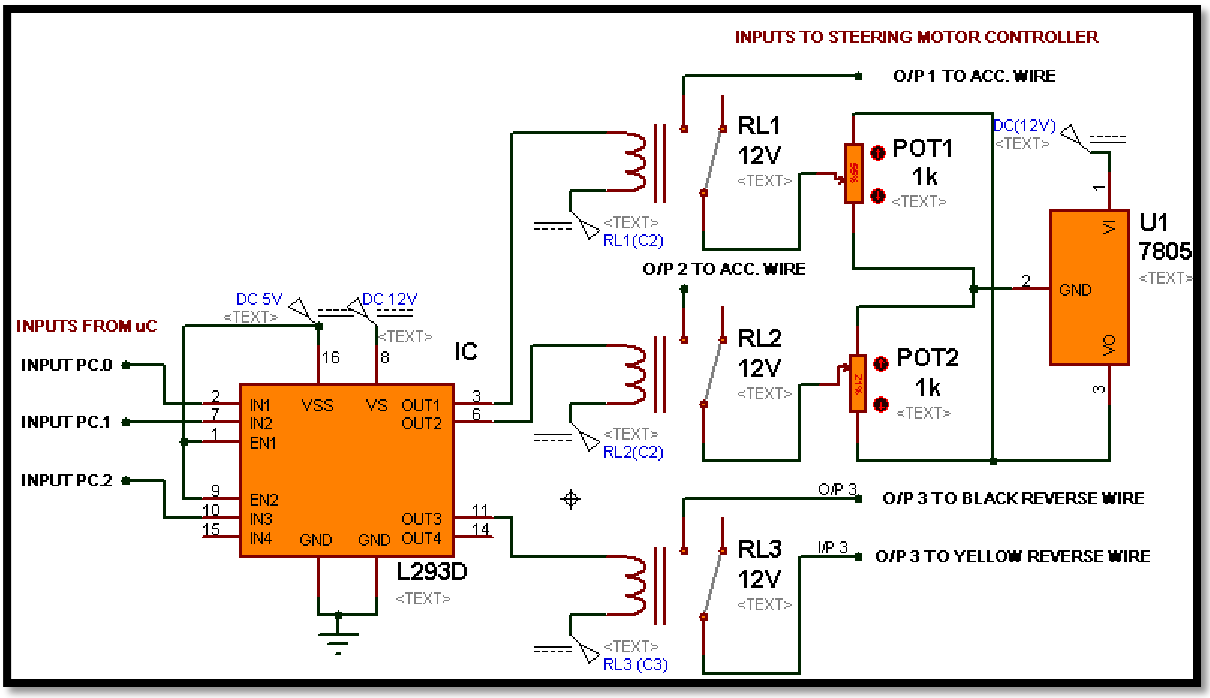


Figure:3.6 Steering motor control unit bldc motor

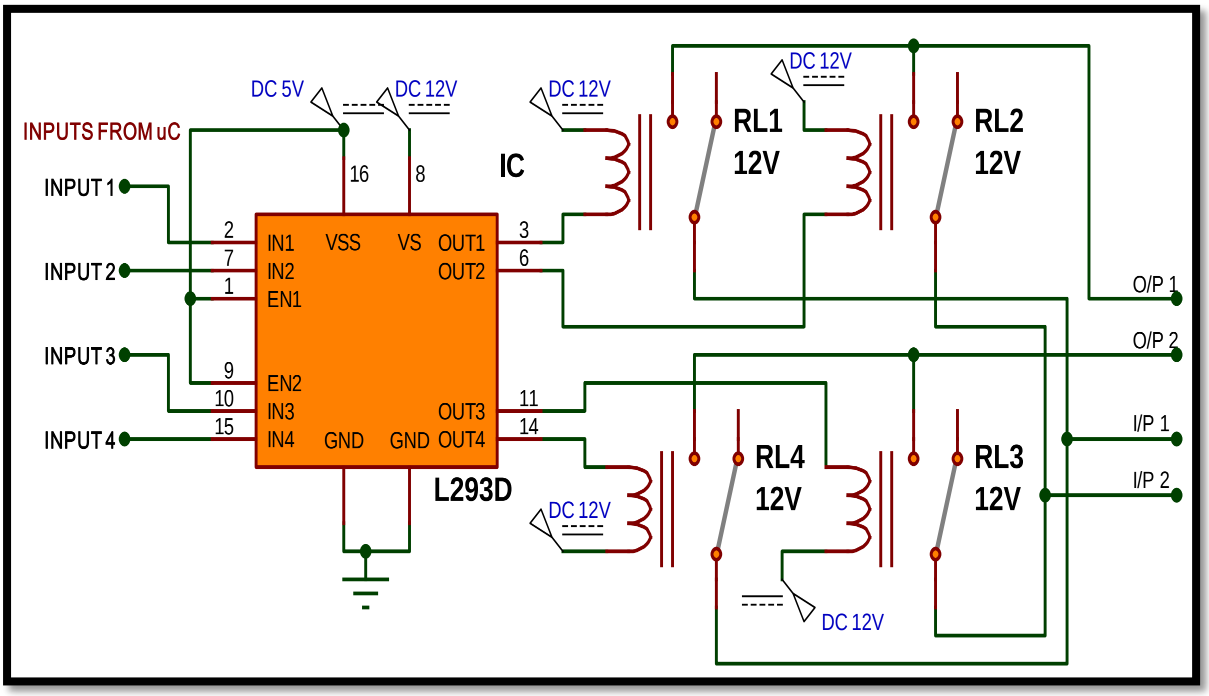


Figure:3.7 Steering motor control unit hub motor

7. Inductive Proximity Sensor

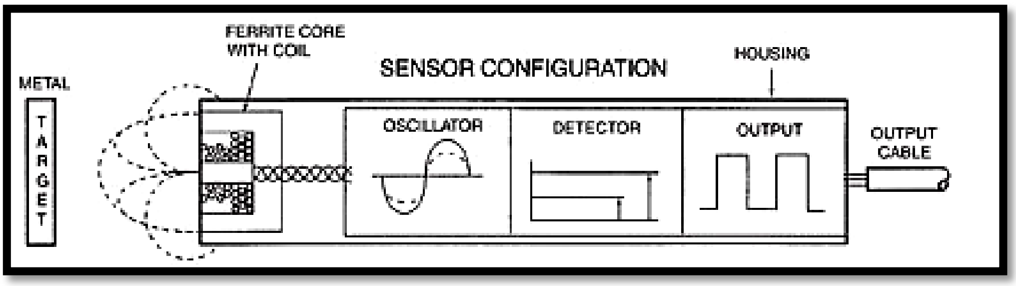


Figure:3.8 Composition of inductive proximity sensor [23]

Sensor array used to detect the metallic track is made using the digital inductive proximity sensor. Inductive proximity sensors are used for detecting the metallic objects. These sensors consist of a coil with ferrite core, an oscillator, detector and output circuit. A fixed frequency sinusoidal signal is generated by the oscillator which passes through the coil. The coil with combination of ferrite core generates an electromagnetic field and when this field is interrupted by the metallic object then due to the induced back emf in the metal due to the eddy current, voltage of oscillator is reduced. The detector circuit detects the reduced voltage of the oscillator and when it reaches below the threshold voltage level then output voltage and output current is provided at the output line of the sensor by the output circuit. The various parameters of inductive proximity sensor are shown in the tables given below [23].

Table:3.2 Parameters of inductive proximity sensor

Sr. No.	Parameter	Specification
1.	Type of Sensor	NPN Inductive Proximity
2.	Output Signal	Digital
3.	Sensing Distance	8 mm
4.	Operating Voltage	(5-35) Volt

Table:3.3 Sensing range of inductive proximity sensor with different material [23]

Sr. No.	Material	Sensing Range
1.	Mild Steel	1*Sn
2.	Nickel Chromium	0.9*Sn
3.	Stainless Steel	0.85*Sn
4.	Brass	0.5*Sn
5.	Aluminum	0.45*Sn
6.	Copper	0.40*Sn

Table:3.4 Sensor wiring connections

Sr. No.	Wire	Specification
1.	Brown Wire	Input (5V)
2.	Blue Wire	Input (GND)
3.	Black Wire	Output (5V,0V)

8. Break Protection Circuit

In order to protect the transmission motor and ac drive from any damage on applying breaks on the vehicle a breaking protection circuit is used. It consist a breaking switch, L293D IC and relay. The break switch detects whether the breaks are applied on vehicle (if breaks are applied then high logic output is provided otherwise it provides low logic output). This logic is fed to L293D IC which converts logic at low voltage level to a voltage level and current with which a relay connected to L293D is operated. The relay is switched on and off on the basis of operation of breaking switch. The relay input and output is connected to the accelerator wires of the ac drive connected to three phase ac motor. Thus accelerator wire is short circuited if the breaks are released and it will be disconnected if the breaks are pressed. Breaking protection circuit is shown below:

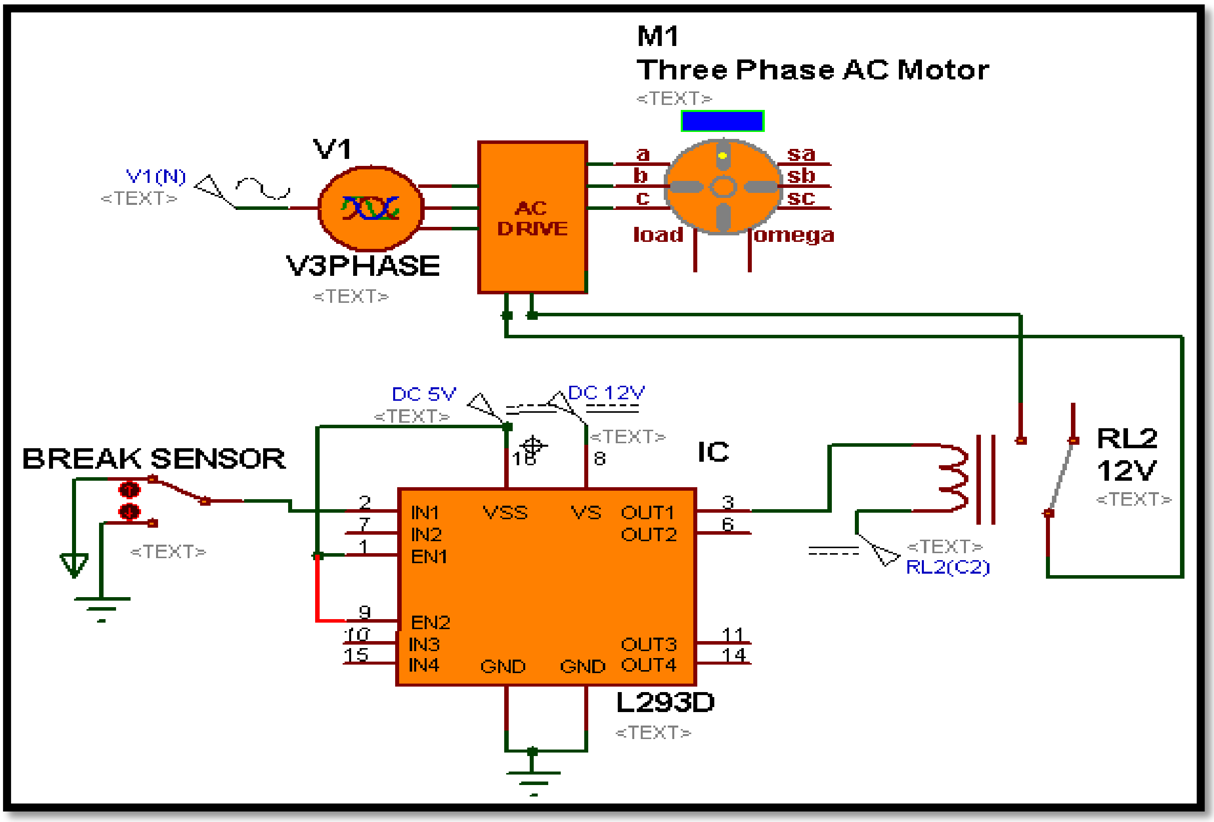


Figure:3.9 Break Protection Circuit

9. Battery

Four 48 V batteries are used for providing power for the operation of BLDC hub motor or simple BLDC motor used for the purpose of steering the vehicle. Out of four batteries one 12V battery is also used for providing the power to the low power electronic control unit consisting of microcontroller board and other electronic boards.

A. Mechanical Tools

Mechanical tools like hammer, pliers, screw driver kit, hack saw, drilling machine, power drill machine etc. are also required in building the different structures of the vehicle and the navigation system.

B. Material Required

Metallic L-plates, rectangular plates, nut-bolts and wooden ply etc. are required for constructing the structure for making the mechanical body of the vehicle, mounting the sensor array, dashboard, holding the controller and other circuits.

C. Software's Required

1. IDE (Integrated Development Environment)

Integrated development environment is a platform used by the programmers for developing the software.

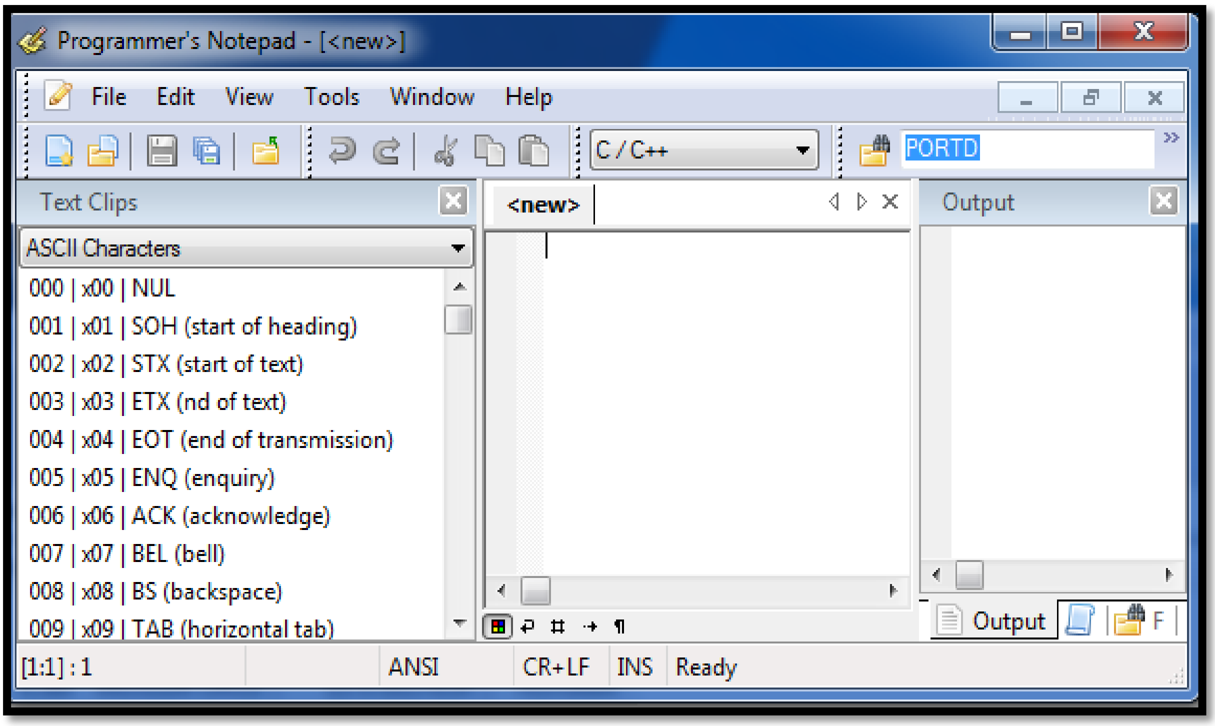


Figure:3.10 Programmer notepad in WinAVR

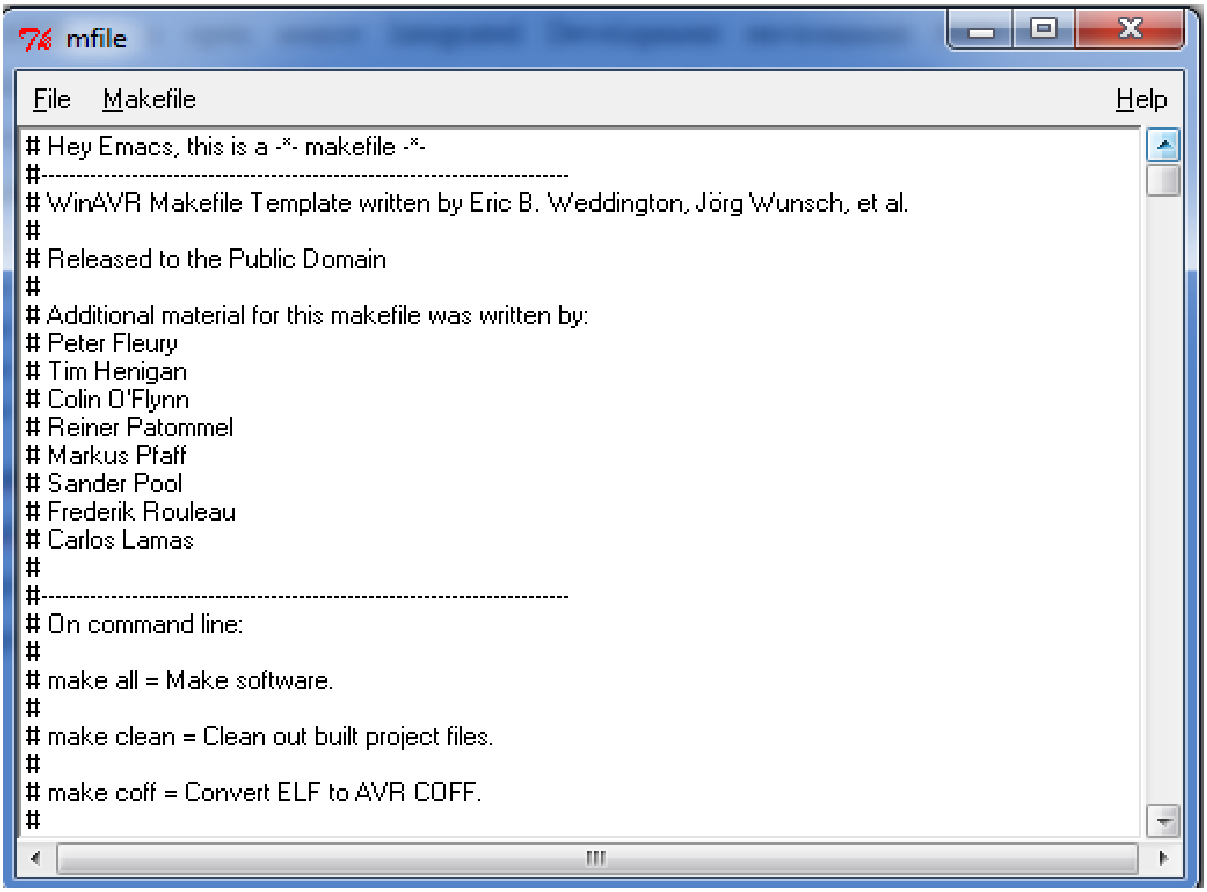


Figure:3.11 Mfile application

WinAVR is an open source Integrated Development environment built by Eric Weddington which is used for is a suite of executable, built for the Atmel AVR series of RISC microprocessors hosted on the windows platform.

It includes

- Programmers Notepad to write and edit the programs
- GNU GCC Compiler for compiling programs for the AVR target for C and C++
- An output window to show the errors or warning
- Text window showing ASCII and Hexadecimal Value of characters
- Mfile application for making makefile

Makefile

Makefile is a file which stores the entire configuration about the microcontroller. It is used by compiler of WinAVR to know the configuration of microcontroller for which it has to compile the program file written by user.

2. Simulation Software

Proteus Simulator is software developed by Labcenter Electronics Ltd. used to simulate the electronic circuits, capture schematic of circuits and for designing PCB layouts. Proteus software version 7.8 Sp2 is used in this project.

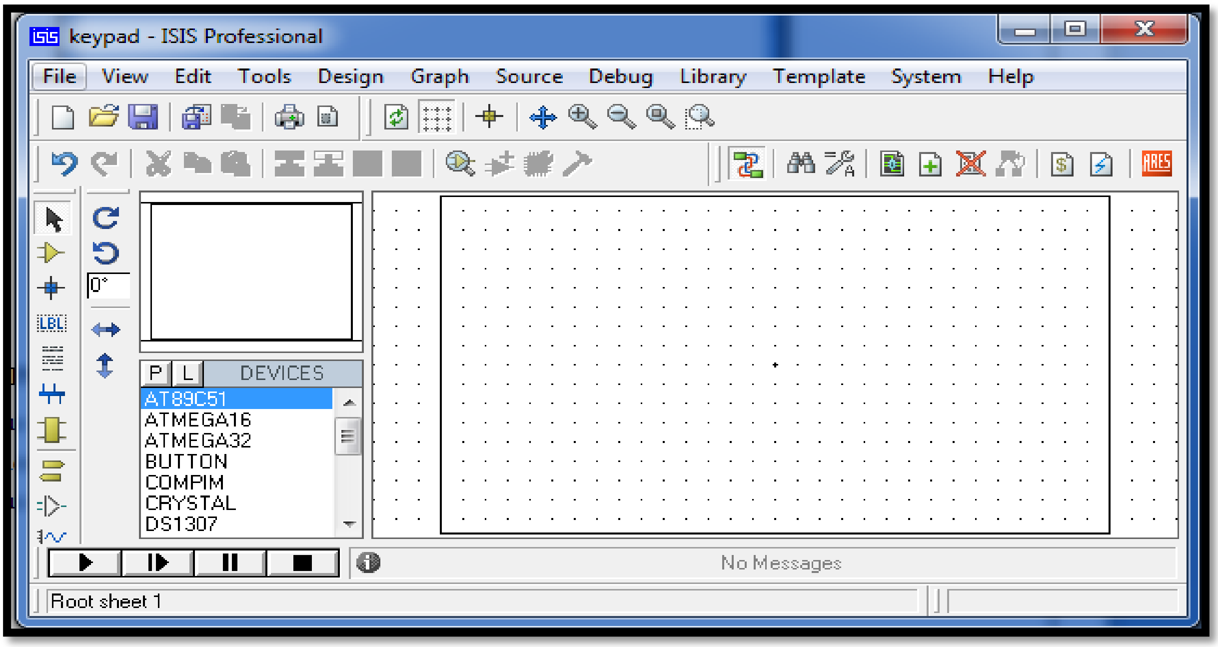


Figure:3.12 Proteus Simulator

3. Click Charts

Click chart software is developed by NCH Company which is used for making flowchart of the program data flow diagrams of a process. This software includes templates for the flowchart to get started. Functions like copy, undo, paste and cut etc. can be performed for editing the flowcharts. Multiple diagrams can be edited simultaneously which helps in solving complex processes. This software can be run windows platform; MAC OS X on 10.4.4 versions& above and it can be run android version of 2.3.3 or above. A snapshot of click charts software is shown below:

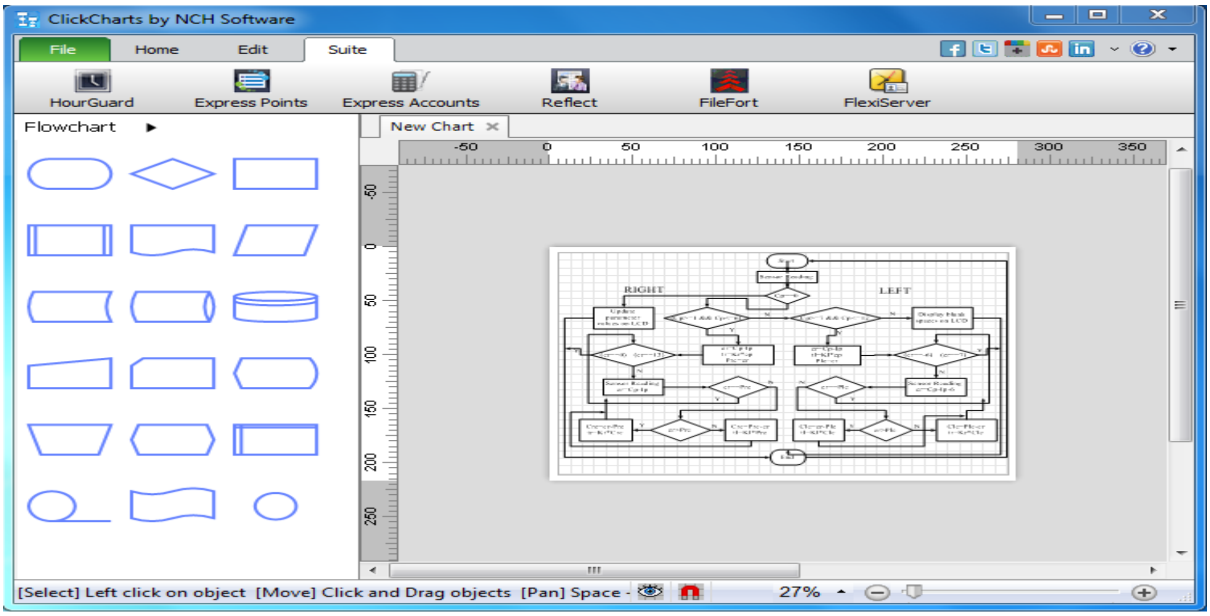


Figure:3.13 Click Charts

4. Google Sketchup

Google Sketchup is a 3D modeling software. The software is user friendly as functionality of the software is very easy. Almost all the simple geometry shapes are included in the software and simple pull and push options can be used to convert 2D model into 3D model. Models can be easily rotated 360 degree view. Simple functions used for editing the models like copy, cut, undo and paste is also available. A snapshot of Google Sketchup software is shown below:

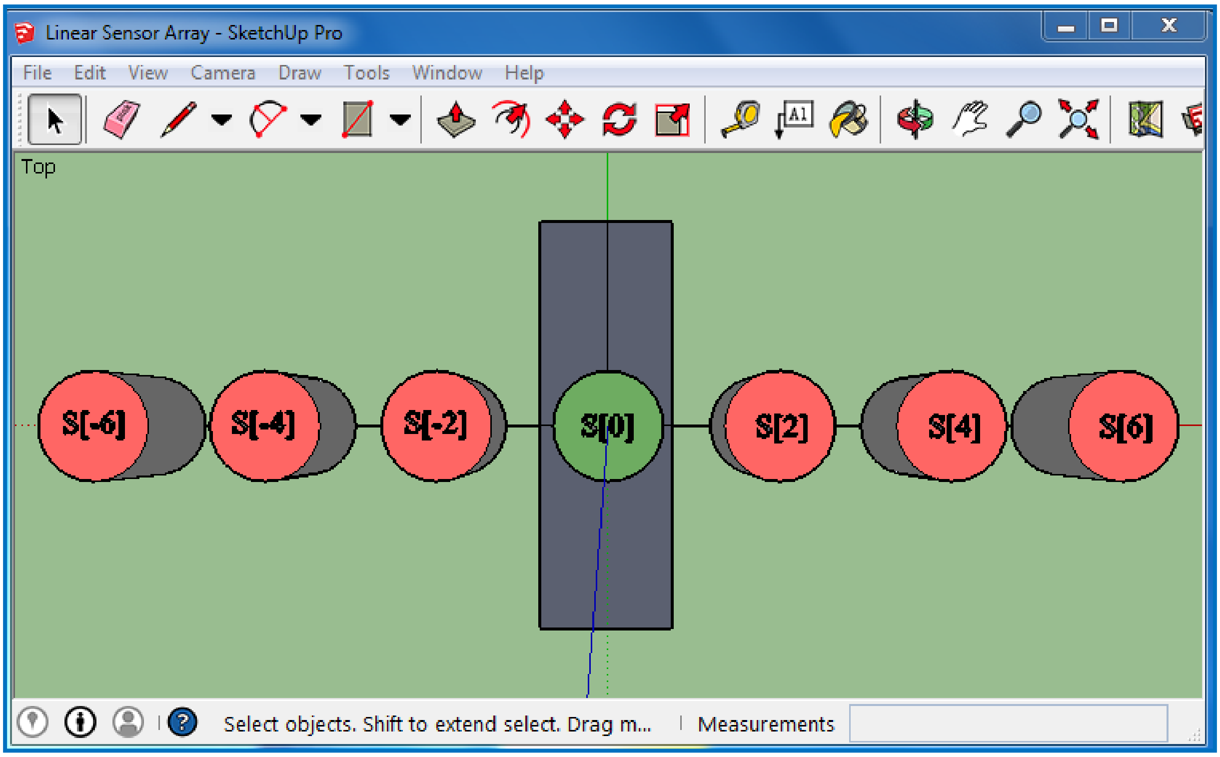


Figure:3.14 Google Sketchup

D. Experimental Setup

- The experiment will be carried out on the two chassis of "Sonalika Rhino" car which is already having four tires, suspension system, rack and pinion steering system and hydraulic breaking system attached to it.
- The track used for automatic guiding of vehicle is a rectangular metal plate having thickness of 2 mm and5 cm width. The track is linear and curvilinear in shape. The minimum turning radius of the track is 15 m.
- The automatic guided tram is driven by a three phase induction motor operated at 440 VAC is used as transmission motor for driving operation of automatic guided vehicle mounted on the chassis of vehicle. There is only one motor in this tram which will be placed in the front bogie of tram.

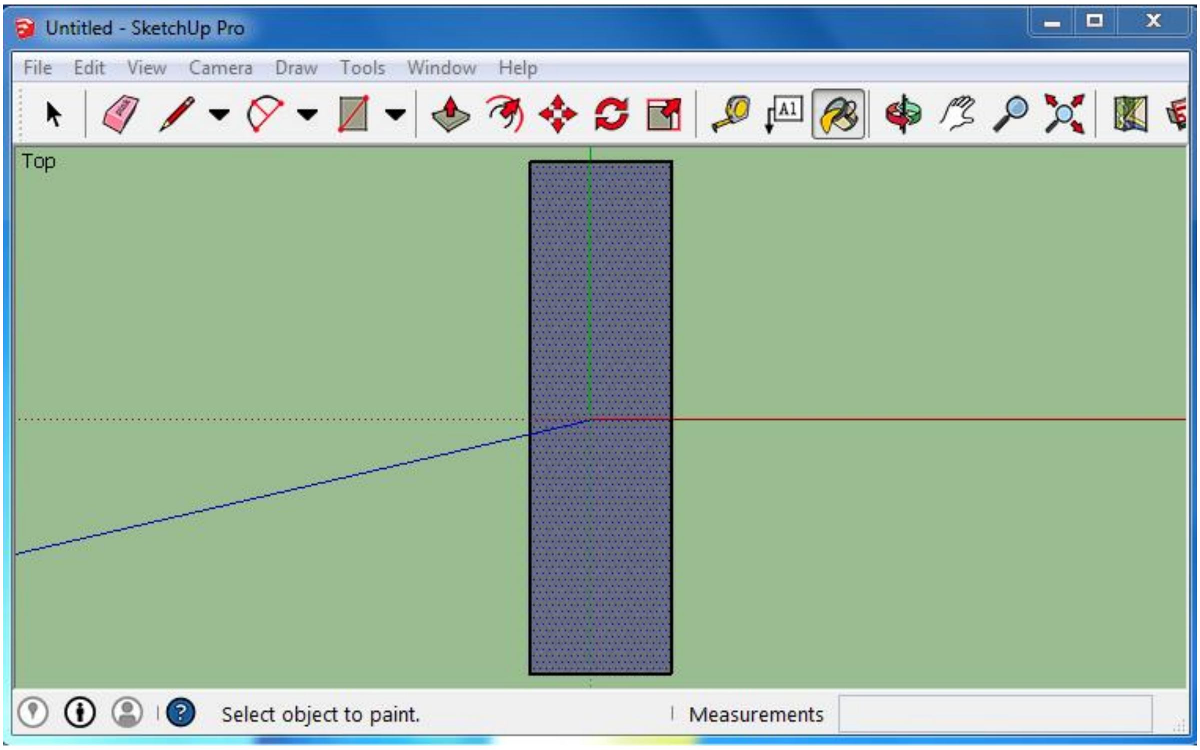


Figure:3.15 Metal plate as track

Figure:3.16 Three phase induction motor attached with the vehicle chassis

- AC drive required for controlling the operation of three phase induction motor used for transmission purpose in automatic guided tram is also attached with it. An AC drive (Siemens PM240) is attached to the transmission motor three phase induction motor for controlling its various parameters like speed, frequency of ac signal and current etc.

Figure:3.17 AC drive [24]

- An array of inductive proximity sensor consisting of 7 inductive proximity sensors is mounted in the front of vehicle on the wooden board. The inductive sensors are mounted in such a way that their face is toward the metal plate fixed on the floor which acts as the path tram. Sensor array and valid sensor condition: A linear sensor array consists of 7 inductive proximity sensors. Each sensor is operated at 5V power supply. Each sensor provides high or low logic with respect to the detection of metal. If any metallic object is present in the range of sensor then it will give 0 logic at its output otherwise it gives high logic(5V) at its output. Since sensor provides binary logic, so for an array of 7 inductive proximity sensor there will total 2^7 possible conditions. But in case of proposed inductive navigation system, sensors having a diameter of 1.8cm are placed linearly with gap of 2cm b/w each sensor. Thus centre to centre distance(dc) b/w the two sensors is 3.8cm. The width(w) of the metal plate used as track in navigation system is 5cm. So, at a time maximum of two sensor can be able to detect the metal plate as (dc=3.8cm<w=5cm). Since maximum of only two sensor can detect the metal at a time there number of possible sensors can detect the metal plate be 2, 1 and 0. Valid conditions out of the possible 128 conditions can be determined from the below diagram.

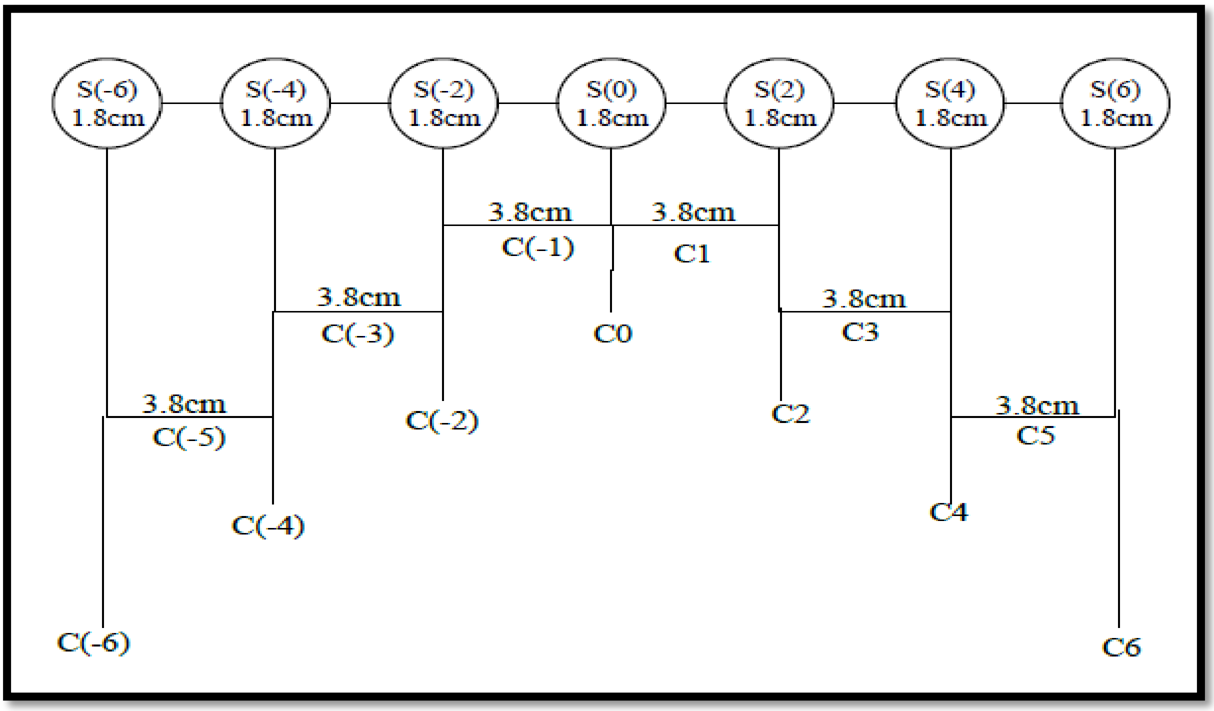


Figure:3.18 Sensor array dimensions

Table:3.5 Valid conditions for sensor array

Sr. No	Sensor S-5	Sensor S-4	Sensor S-2	Sensor S0	Sensor S2	Sensor S4	Sensor S6
1.	1	1	1	0	1	1	1
2.	1	1	1	0	1	1	1
3.	1	1	1	1	1	1	1
4.	1	1	1	1	0	1	1
5.	1	1	1	1	0	0	1
6.	1	1	1	1	1	0	0
7.	1	1	1	1	1	1	0
8.	1	1	1	1	1	1	1
9.	1	1	0	1	1	1	1
10.	1	1	0	1	1	1	1
11.	1	0	1	1	1	1	1
12.	1	0	1	1	1	1	1
13.	0	1	1	1	1	1	1
14.	0	1	1	1	1	1	1

- A setup required for attaching the inductive proximity sensor is attached with the vehicle chassis which is flexible in nature that it can be detached from vehicle easily if required.
- Automatic guided tram is steered by the DC hub motor or BLDC motor operated at 48 volt or AC three phase induction motor operated at 440VAC and instead of using manual steering a automatic electronic steering is used. Each independent bogie has independent steering motor for controlling the steering of the tram.
- DC hub motor is attached to the steering column of the vehicle in order to steer the vehicle with the motor.
- High power to low power circuit consisting of high current relays and L293D IC's is designed and implemented on the hardware which used for driving and controlling operation of the motors.
- A controller operated at 48Volt DC is attached to the steering motor for controlling its driving operation and direction control. Controller inputs are attached with 4 batteries to obtain DC 48 volt power supply and it is also attached to the microcontroller board which controls its operation.

Figure:3.19 Steering DC hub motor

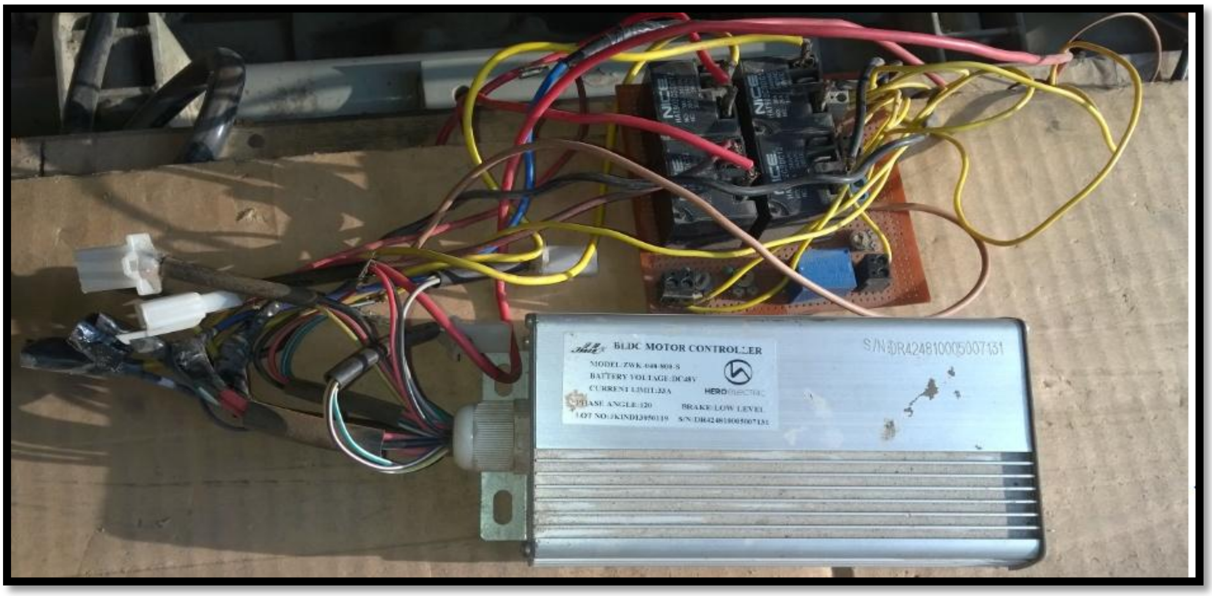


Figure:3.20 DC steering motor controller

- A microcontroller boards required for controlling the overall operation of independent bogie is designed and developed on the general PCB(Printed Circuit Board. A microcontroller board is attached to the controller of steering motor, the ac drive through low power to high power circuit and inductive proximity sensor. It consists of AVR ATmega 16 microcontroller basic circuit which is attached to motor driver IC's and display LCD to display the various parameters. It is used for controlling the overall operation of the vehicle.

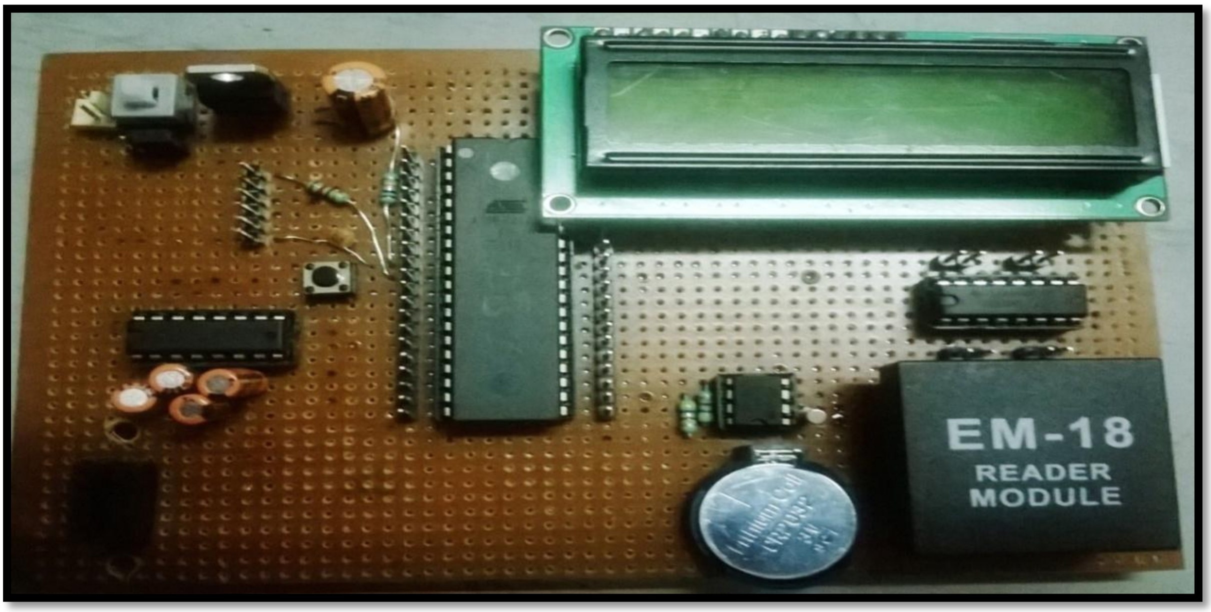


Figure:3.21 Microcontroller board with LCD for 1st bogie

- Vehicle uses differential drive system as shown below:

Figure:3.22 Differential System

- Automatic guided tram uses hydraulic breaking system as shown below:

Figure:3.23 Breaking system

3.5 Research Methodology

A navigation system for automatic guided central track tram proposed in this report is based on the inductive navigation technique. Automatic guided tram will consist of bogie supported on the rubber tire wheels. A three phase AC driving motor is used to drive the automatic guided tram which will be located in front bogie of the automatic guided tram. Steering system used by automatic guided tram in each bogie will be similar to steering system of vehicle running on the roads but steering wheel of steering system in each bogie will be rotated by electric motor attached with the steering column. Each bogie of the tram has independent inductive guiding and steering mechanism to guide the automatic guided tram along the predefined path. Automatic guided tram is be guided by the single central track made using metal strip which is to be laid on the floor. Inductive sensors will be placed on the automatic guided tram at the front of each bogie, facing toward the metal strip so as to sense the metal strip on the basis of principle of electromagnetic induction. Sensor array will provide readings to calculate the amount of deviation of automatic guided tram from predefined path and output of sensor array will be given to the electronic control unit. On the basis of sensor reading a deviation error from centre position of tram with respect to track is calculated. This deviation error is calculated by electronic control unit which consists of controller which computes the results based on the algorithm fed inside it. The controller performs the various mathematical operations on the basis of input readings received from the sensors provide the best suitable decision for steering the vehicle in order to efficiently track the predefined path.

3.5.1 Inductive Navigation Algorithm

Terms related to navigation algorithm

- **Ideal Position**
  It is the position along the path where vehicle is desired to be move without any deviation from its path. It is denoted by Ip.
- **Current Position**
  Current Position is defined as position of the vehicle at instant of time with respect to the track. It is denoted by Cp.
- **Position Error**
  It is difference between the ideal position and current position of the vehicle with respect to track which can be zero, positive or negative. It is denoted by er.
- **Previous Error**
  It is equal to position error at unit delay time [i.e. at (t-1) time]. It is denoted by Pre for right turn and it is denoted by Ple for left turn.
- **Current Error**
  It is the difference between the previous error and error at the instant of time. It is denoted by Cre for right turn and it is denoted by Cle for left turn.
- **Turn Time**
  It is time for which the steering motor operates. It is denoted by 'tr' for right turn and it is denoted by 'tl' for left turn.
- **Accelerator Potential**
  It is the amount of potential that is given to accelerator wire of the ac drive used to drive three phase induction motor used as transmission motor for driving the tram.

Constants involved in algorithm

- Kr: parameter associated with right turn (Kr=MT/6)
- Kl: parameter associated with left turn (Kl=MT/6)
- MT is maximum time taken to amount of steering required from maximum right to maximum left position
- Kr and Kl parameters are specific to type of motor and type of steering motor. Their value is calculated from the amount steering effort required to turn the wheels from maximum right to maximum left.
- Kt: parameter associated with the accelerator potential of three phase motor

Mathematical equations for implementing PID algorithm

Position Error (er) = Cp-Ip..(3.1)

Right turn time (tr)= Kr*e...(3.2)

Left turn time (tl) = Kl*e...(3.3)

Previous error for left (Ple) or right turn (Pre) = er (at t-1)..(3.4)

Acceleration Potential Ap=MV-Kt*er..(3.5)

Where MV stands for maximum potential and Kt=MV/7

Current Error Equations:

- **Case I:** if error (er) is larger than previous error(Pre) for right turn (er>Pre) then:
  Current error for right turn (Cre) = er-Pre...(3.6)
- **Case II:** if error (er) is larger than previous error(Ple) for left turn (er>Ple) then:
  Current error for left turn (Cle) = er-Ple..(3.7)
- **Case III:** if error (er) is smaller than previous error(Pre) for right turn (er<Pre) then:
  Current error for right turn (Cre) = Pre-er...(3.8)
- **Case IV:** if error (er) is smaller than previous error(Ple) for left turn (er<Ple) then:
  Current error for left turn (Cle) = Ple-er..(3.9)

Steps used in navigation algorithm

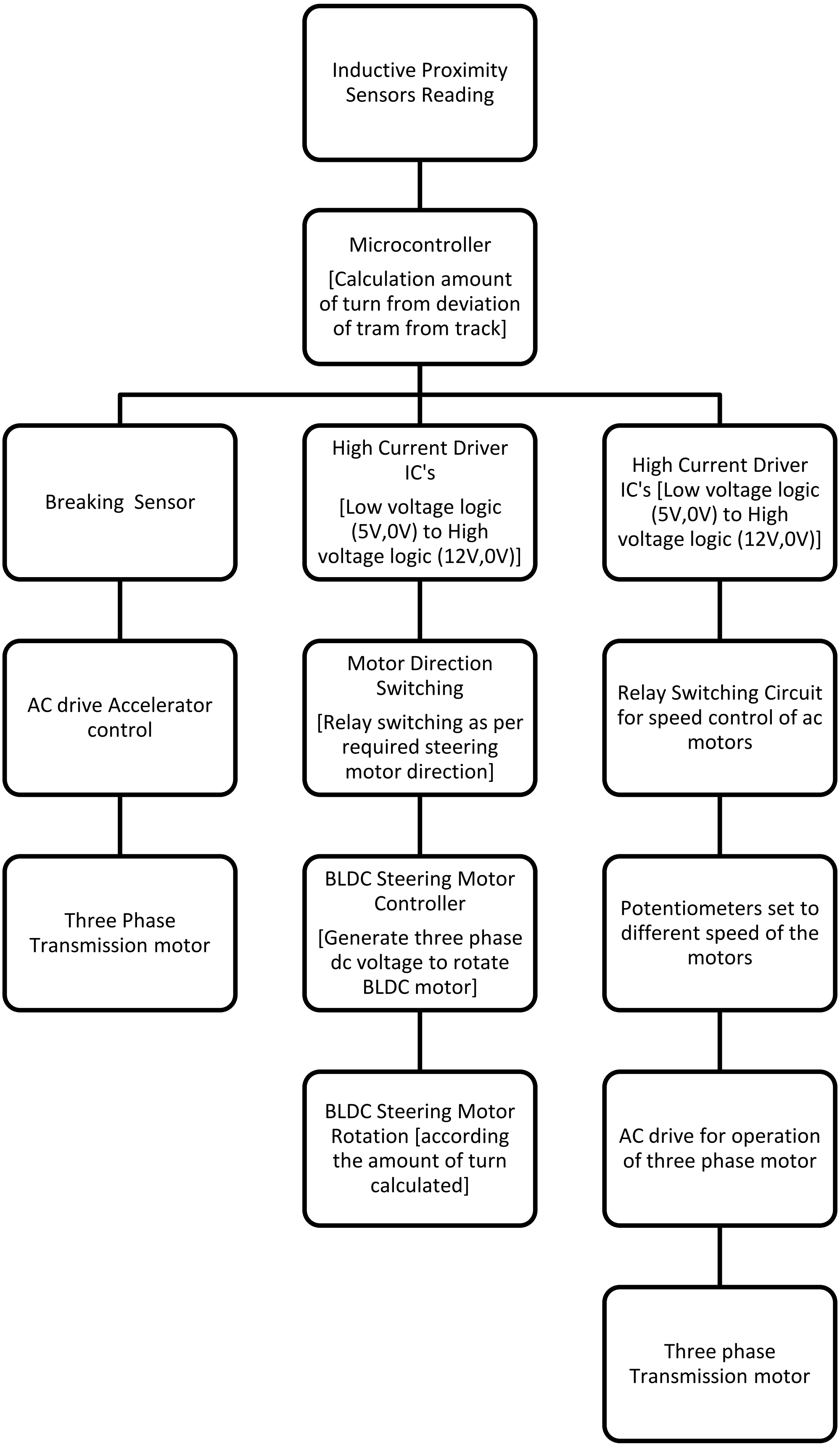
1. Initially the current position(Cp) of the vehicle with respect to the ideal position(Ip) of the vehicle is calculated.
2. Current position(Cp) decides whether the deviation of vehicle is towards left or right. If the value of current position is less than 7 but greater than 0 then turn will be towards the left and if the value of current position is less than 12 but greater than 6 then turn will be towards the right. If the value of current position is equal to the ideal position then there will be no turn towards left or right.

3. Difference between current position (Cp)and ideal position (Ip) gives the error (er)or amount of deviation of vehicle from path.
4. Based on the position error, amount of turn is calculated and vehicle is steered by amount of turn calculated towards the left (tl) or right (tr) direction with respect to the deviation from the track.
5. If the vehicle does not approaches to the ideal position (Ip) then the value of error will be saved in the previous error parameter i.e. Pre for left turn and Ple for right turn. But if the vehicle has approached to the ideal position then algorithm jumps to step 1.
6. Now previous error (Pre or Ple) is compared with the error at that instant of time and if previous error is same as the error at that instant then there will be no change in the steering of vehicle.
7. If error (er) at that instant is greater than (Pre or Ple) then current error (Cre or Cle) is calculated from the difference between the error (Pre or Ple)and previous error (er) is calculated and according to the amount of current error (Cre or Cle) the value of right or left turn is calculated.
8. After step 7 the algorithm goes to step 5 and step 5,6,7,8 are repeated until error becomes zero or the vehicle approaches to ideal position.
9. Acceleration of three phase ac motor is adjusted on the basis of value of error.

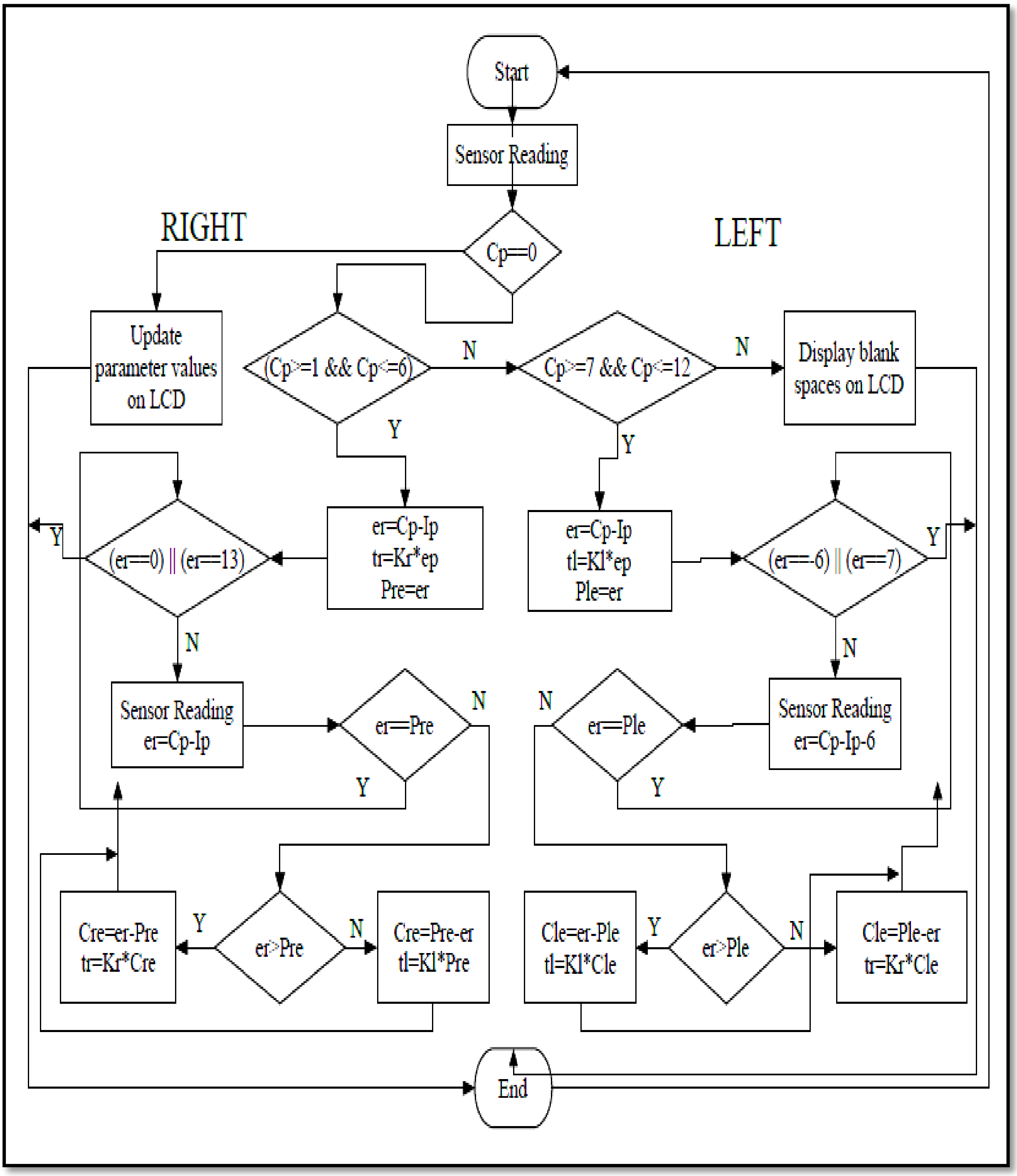
Requirements for implementing the inductive algorithm

A sensor array for calculating the deviation of the vehicle from the track of predefined path and a controller which can perform various mathematical operations involved in inductive navigation algorithm.

3.5.2Block diagram of automatic guided tram



3.5.3 Program flow chart of navigation system



3.5.4 Work Plan with Timeline

Month	Work to done
January-2015	Researching the algorithms of navigation systems. Study of proportional derivative, proportional integral and proportional derivative algorithm.
February-2015	Study of PID algorithm. Development of new and simple algorithm for inductive navigation system.
March-2015	Implementation the algorithm on the software. Testing the model with respect to all possible conditions.
April-2015	Implementation the algorithm on the hardware. Finalizing the results and finalization of thesis report. Preparation of the report.

Chapter 4

RESULT AND DISCUSSION

4.1 Outcome of the study

a. A navigation system developed on basis of inductive navigation technique is guided by single central track.

b. A mathematical of navigation system involving various parameter and equations for calculating the amount of deviation of vehicle from the track is developed.

c. The vehicle is steered according the amount of the turn calculated with respect to the amount of occurrence of deviation of at an instant of time.

d. A navigation system developed is more cost effective as compared to the existing navigation system for automatic guided vehicles.

e. A navigation system developed is less infrastructure requiring as compared to the existing navigation system for automatic guided vehicles as simple metal plate fixed to the floor is used as guiding path for navigating the vehicle.

f. A navigation system is tested under all possible conditions as generated according to the various possible deviation condition of vehicle with respect to track.

g. A developed navigation system is shown below with pictures of prototype model.

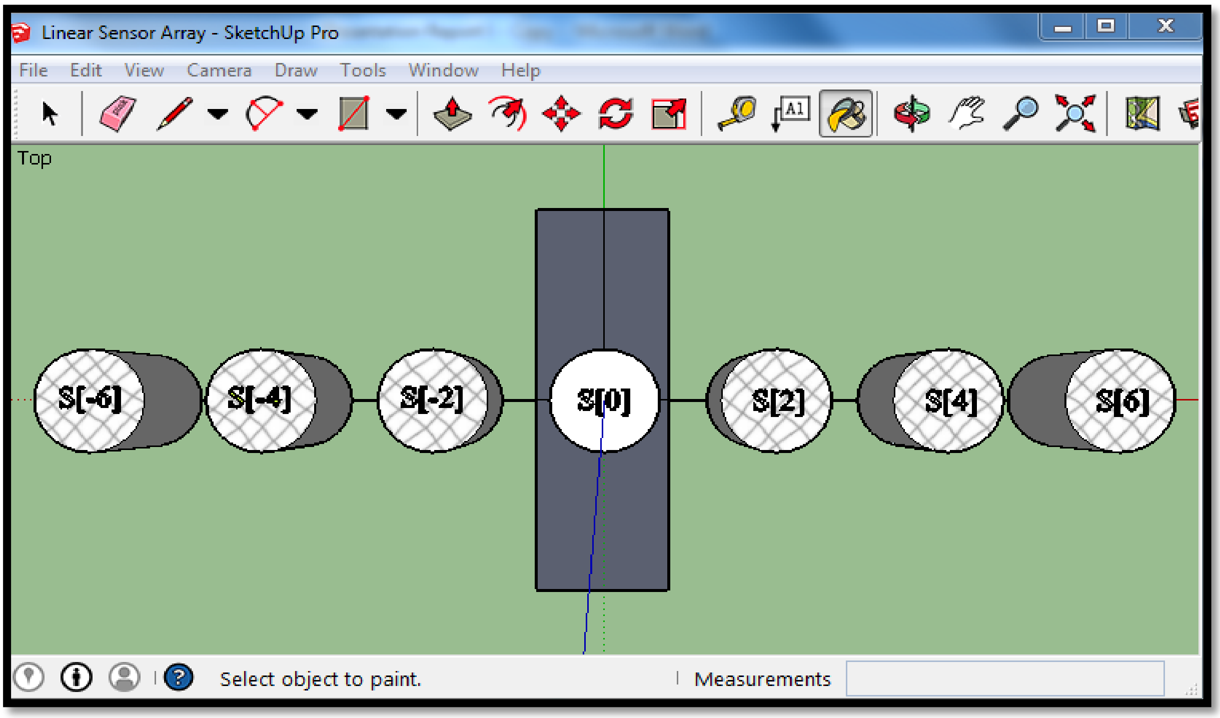


Figure:4.1 Top view of sensor array

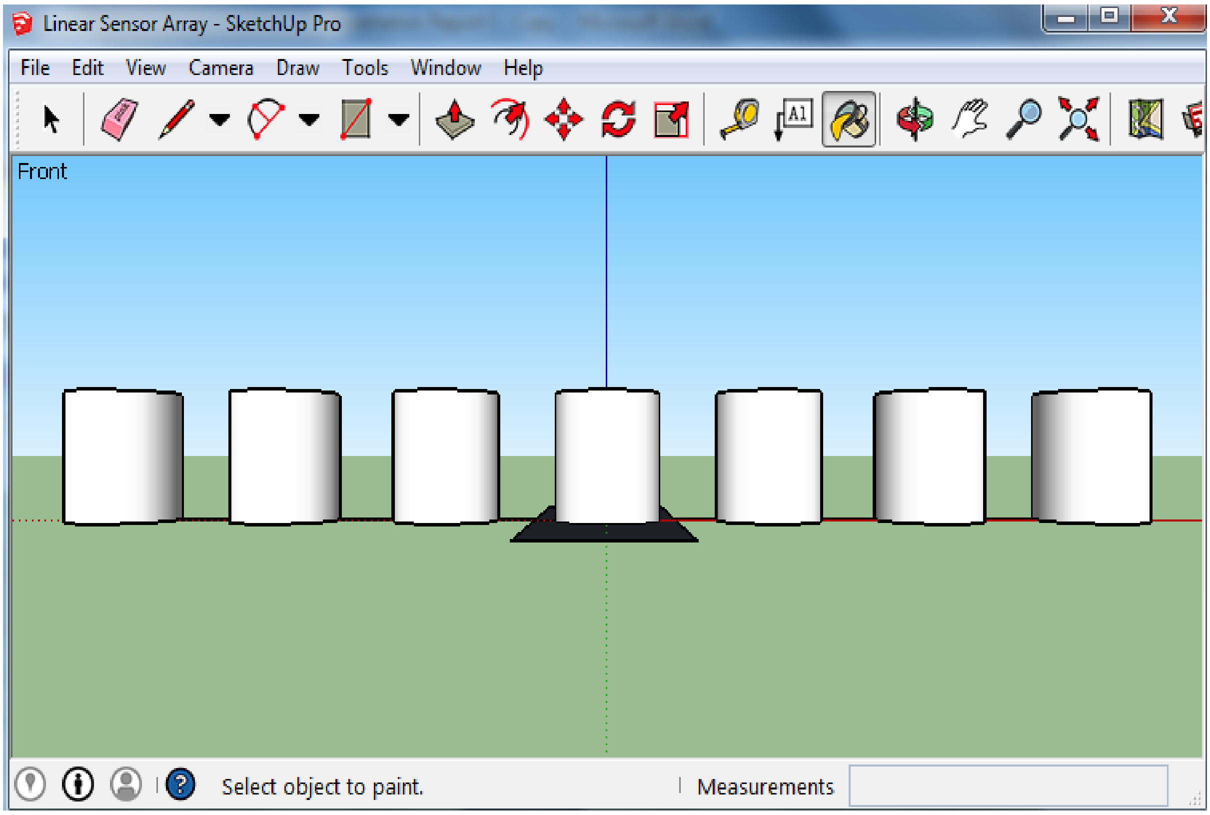


Figure:4.2 Front view of sensor array

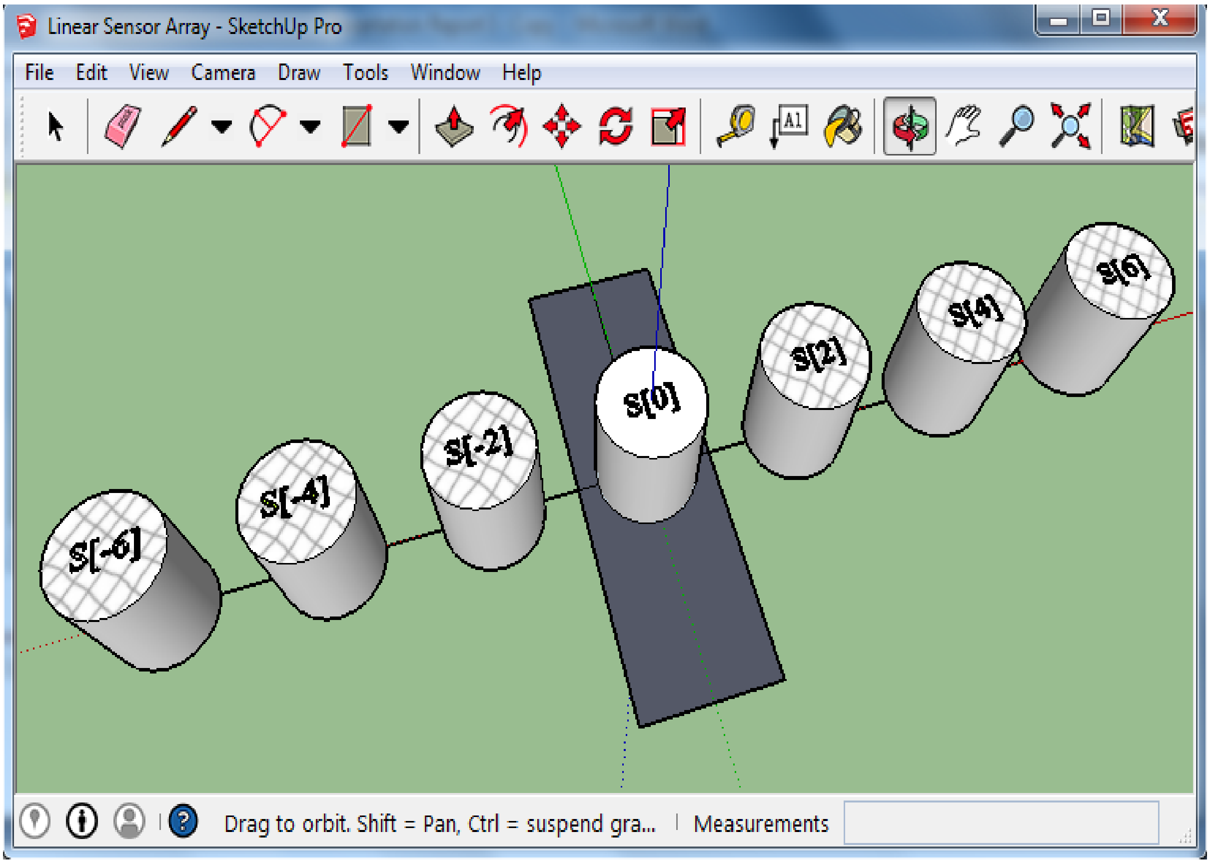


Figure:4.3 Isometric view of sensor array

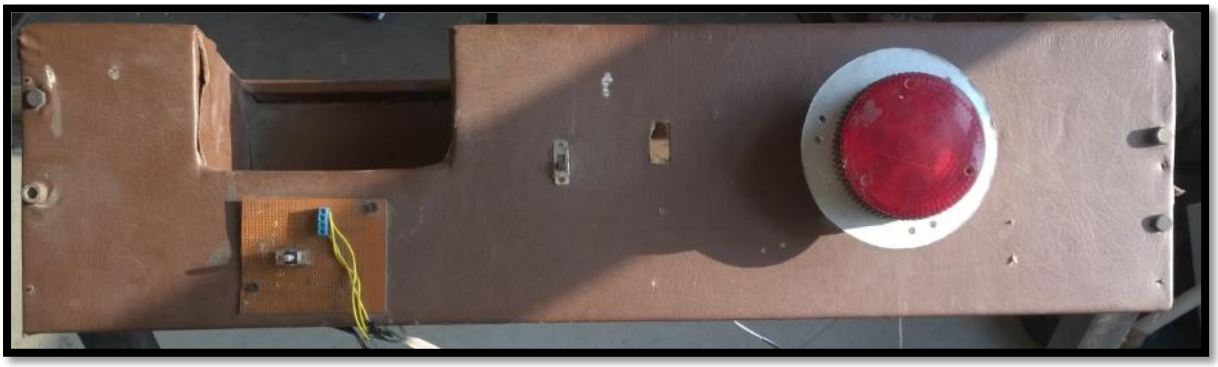


Figure:4.4 Dashboard for consisting accelerator and manual steering

Figure:4.5 Vehicle chassis of automatic guided tram

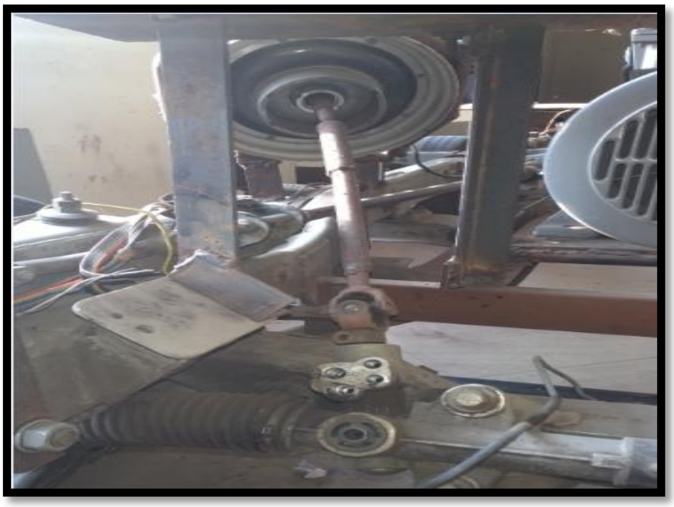


Figure:4.6 DC hub motor attached with the vehicle chassis

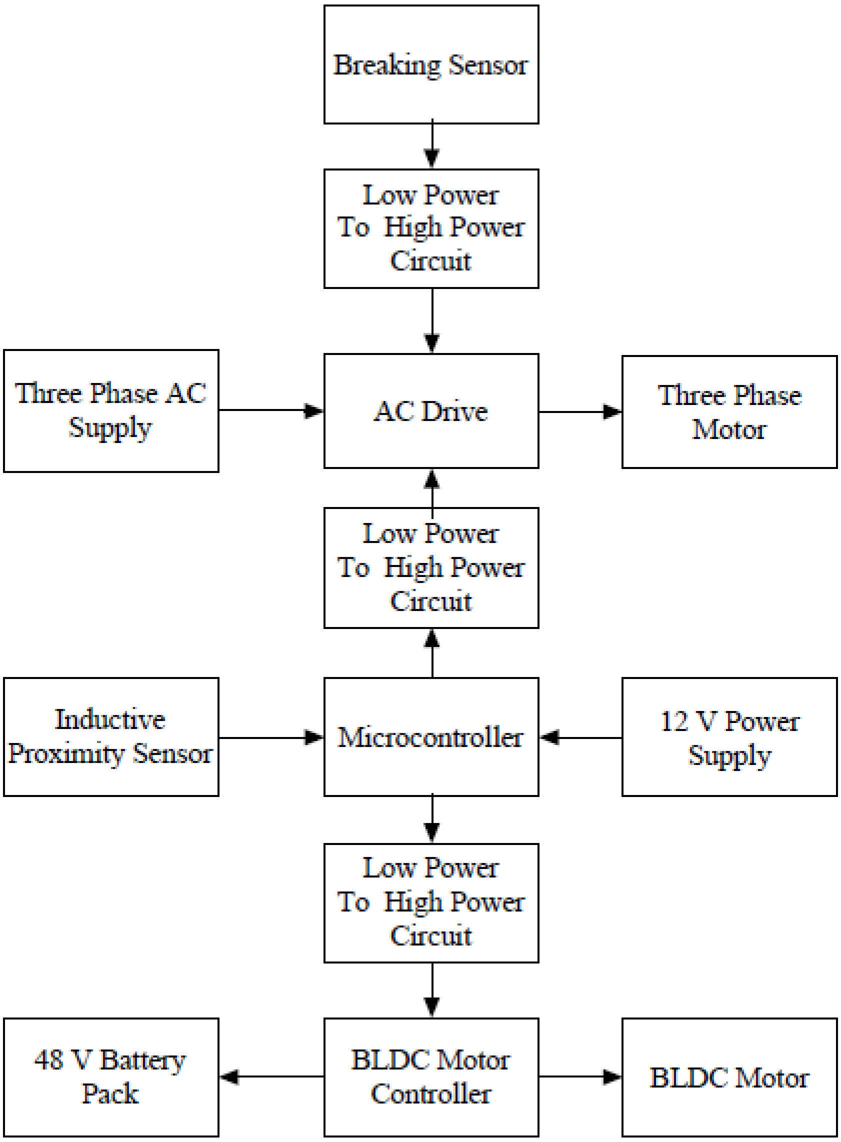


Figure:4.7 Block Diagram of navigation system developed

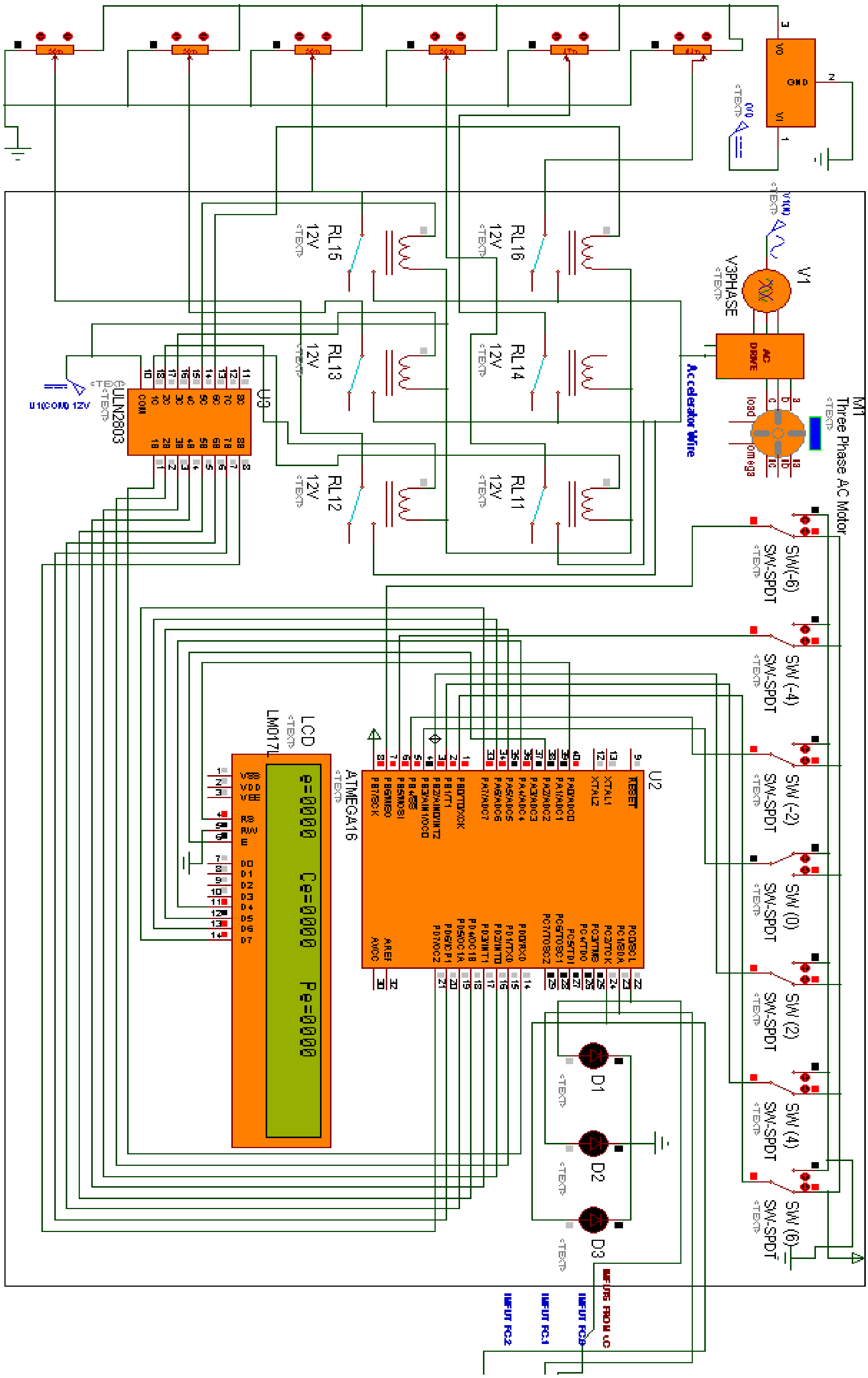


Figure:4.8 Electronic circuit of navigation system part-I

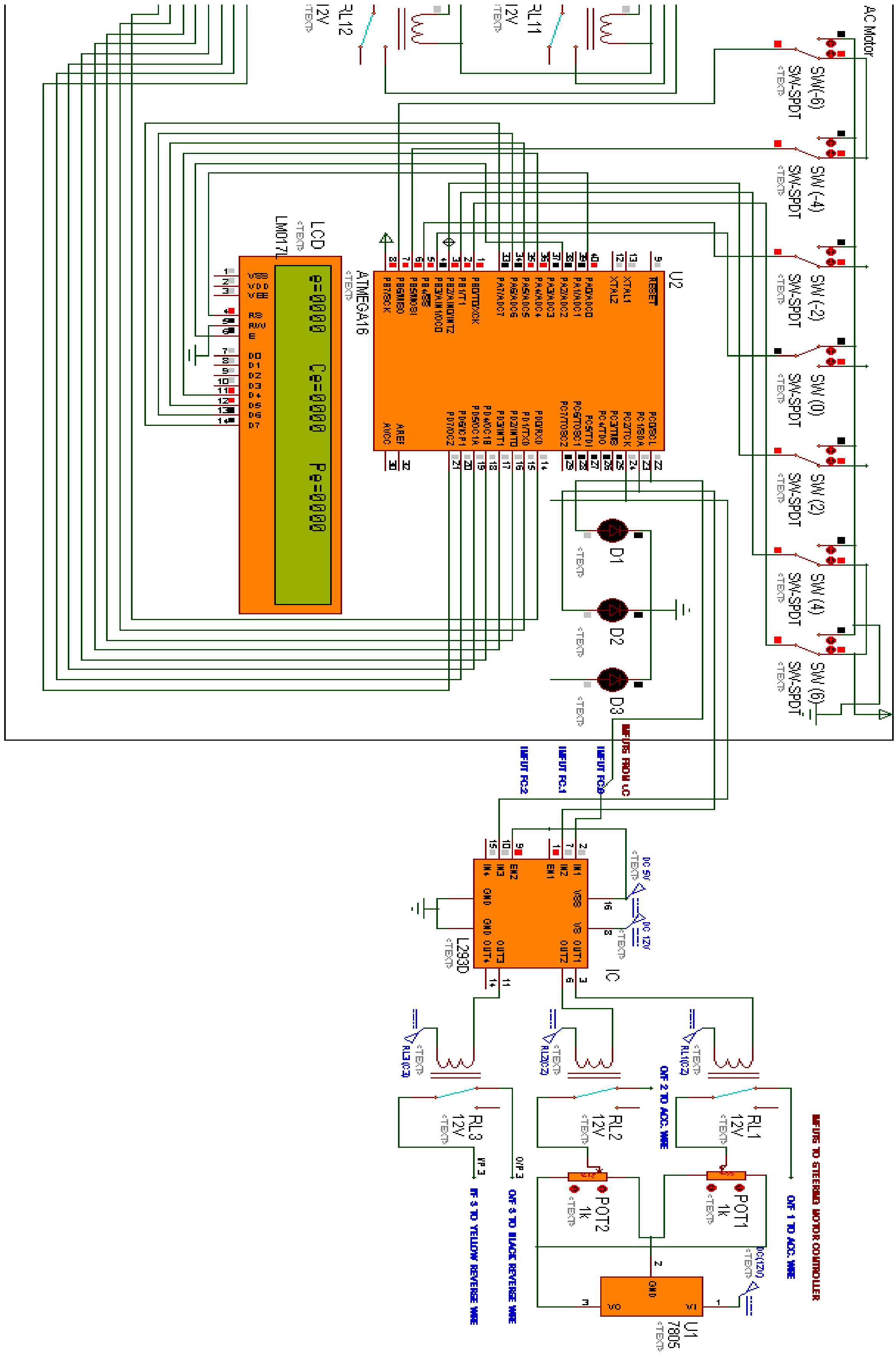


Figure:4.9 Electronic circuit of navigation system part-II

h. Possible deviation conditions under which a navigation system is tested:

Tables for initial right turn

Table:4.1 Parameter values for initial er=0 and minimum er=0 to maximum er=2

Sr. No.	Time	Error (er=Cp-Ip)	Previous Error [Pre=er (at t-1)]	Current Error Cre=e-Pre; er>Pre Cre=Pre-er; Pre>er	Amount of Turn tr=Kr*er (at t=1) tr=Kr*Cre; er>Pre tl=Kl*Cre; Pre>er	Accelerator Potential Ap=MV-Kt*0
1.	0	er=0-0 =>0	0	0	0	MV-Kt*0
2.	1	er=1-0 =>1	0	NC	Kr*1 (Right Turn)	MV-Kt*1
3.	2	er=2-0 =>2	1	Cre=2-1 =>1	Kr*1 (Right Turn)	MV-Kt*2
4.	3	er=1-0 =>1	2	Cre=2-1 =>1	Kl*1 (Left Turn)	MV-Kt*1
5.	4	er=0-0 =>0	1	Cre=Pre=1	Kl*1 (Left Turn)	MV-Kt*0

Table:4.2 Parameter values for initial er=3 and minimum er=0 to maximum er=3

Sr. No.	Time	Error (er=Cp-Ip)	Previous Error [Pre=er (at t-1)]	Current Error Cre=e-Pre; er>Pre Cre=Pre-er; Pre>er	Amount of Turn tr=Kr*er (at t=1) tr=Kr*Cre; er>Pre tl=Kl*Cre; Pre>er	Accelerator Potential Ap=MV-Kt*0
1.	0	er=3-0 =>3	0	NC	Kr*3 (Right Turn)	MV-Kt*3
2.	1	er=2-0 =>2	3	Cre=3-2 =>1	Kl*1 (Left Turn)	MV-Kt*2
3.	2	er=1-0 =>1	2	Cre=2-1 =>1	Kl*1 (Left Turn)	MV-Kt*1
4.	3	er=0-0 =>0	1	Cre=Pre=1	Kl*1 (Left Turn)	MV-Kt*0

Table:4.3 Parameter values for initial er=0 and minimum er=0 to maximum er=6

Sr. No.	Time	Error (er=Cp-Ip)	Previous Error [Pre=er (at t-1)]	Current Error Cre=e-Pre; er>Pre Cre=Pre-er; Pre>er	Amount of Turn tr=Kr*er (at t=1) tr=Kr*er; er>Pre tl=Kl*er; Pre>er	Accelerator Potential Ap=MV-Kt*0
1.	0	er=0-0 =>0	0	0	0	MV-Kt*0
2.	1	er=1-0 =>1	0	NC	Kr*1 (Right Turn)	MV-Kt*1
3.	2	er=2-0 =>2	1	Cre=2-1 =>1	Kr*1 (Right Turn)	MV-Kt*2
4.	3	er=3-0 =>3	2	Cre=3-2 =>1	Kr*1 (Right Turn)	MV-Kt*3
5.	4	er=4-0 =>4	3	Cre=4-3 =>1	Kr*1 (Right Turn)	MV-Kt*4

6.	5	er=5-0 =>5	4	Cre=5-4 =>1	Kr*1 (Right Turn)	MV-Kt*5
7.	6	er=6-0 =>6	5	Cre=6-5 =>1	Kr*1 (Right Turn)	MV-Kt*6
8.	7	er=5-0 =>5	6	Cre=6-5 =>1	Kl*1 (Left Turn)	MV-Kt*5
9.	8	er=4-0 =>4	5	Cre=5-4 =>1	Kl*1 (Left Turn)	MV-Kt*4
10.	9	er=3-0 =>3	4	Cre=4-3 =>1	Kl*1 (Left Turn)	MV-Kt*3
11.	10	er=2-0 =>2	3	Cre=3-2 =>1	Kl*1 (Left Turn)	MV-Kt*2
12.	11	er=1-0 =>1	2	Cre=2-1 =>1	Kl*1 (Left Turn)	MV-Kt*1
13.	12	er=0-0 =>0	1	Cre=Pre=1	Kl*1 (Left Turn)	MV-Kt*0

Tables for initial left turn

Table:4.4 Parameter values for initial er=0 and minimum er= -6 to maximum er=2

Sr. No.	**Time**	**Error (er=Cp-Ip-6)**	**Previous Error [Pre=er (at t-1)]**	**Current Error Cle=e-Ple; er>Pre Cle=Ple-er; Pre>er**	**Amount of Turn tl=Kl*er (at t=1) tr=Kl*er; er>Ple tl=Kr*er; Ple>er**	**Accelerator Potential Ap=MV-Kt*0**
1.	0	0	0	0	0	MV-Kt*0
2.	1	er=7-0-6 =>1	0	NC	Kl*1 (Left Turn)	MV-Kt*1
3.	2	er=8-0-6 =>2	1	Cle=2-1 =>1	Kl*1 (Left Turn)	MV-Kt*2
4.	3	er=7-0-6 =>1	2	Cle=2-1 =>1	Kl*1 (Right Turn)	MV-Kt*1
5.	4	er=0-0-6 =>-6	1	Cle=Ple=1	Kl*1 (Right Turn)	MV-Kt*0

Table:4.5 Parameter values for initial er=3 and minimum er= -6 to maximum er=3

Sr. No.	**Time**	**Error (er=Cp-Ip-6)**	**Previous Error [Pre=er (at t-1)]**	**Current Error Cle=e-Ple; er>Pre Cle=Ple-er; Pre>er**	**Amount of Turn tl=Kl*er (at t=1) tr=Kl*er; er>Ple tl=Kr*er; Ple>er**	**Accelerator Potential MV=Max. Voltage**
1.	0	er=9-0-6 =>3	0	NC	Kl*3 (Left Turn)	MV-Kt*3
2.	1	er=8-0-6 =>2	3	Cle=3-2 =>1	Kl*1 (Right Turn)	MV-Kt*2
3.	2	er=7-0-6 =>1	2	Cle=2-1 =>1	Kl*1 (Right Turn)	MV-Kt*1
4.	3	er=0-0-6 =>-6	1	Cle=Ple=1	Kl*1 (Right Turn)	MV-Kt*0

Table:4.6 Parameter values for initial er=0 and minimum er= -6 to maximum er=6

S. N.	Time	Error (er=Cp-Ip-6)	Previous Error [Pre=er (at t-1)]	Current Error Cre=er-Ple; er>Ple Cre=Ple-er; Ple>er	Amount of Turn tl=Kl*er (at t=1) tr=Kl*er; er>Ple tl=Kr*er; Ple>er	Accelerator Potential Ap=MV-Kt*0
1.	0	0	0	0	0	MV-Kt*0
2.	1	er=7-0-6 =>1	0	NC	Kl*1 (Left Turn)	MV-Kt*1
3.	2	er=8-0-6 =>2	1	Cle=2-1 =>1	Kl*1 (Left Turn)	MV-Kt*2
4.	3	er=9-0-6 =>3	2	Cle=3-2 =>1	Kl*1 (Left Turn)	MV-Kt*3
5.	4	er=10-0-6 =>4	3	Cle=4-3 =>1	Kl*1 (Left Turn)	MV-Kt*4
6.	5	er=11-0-6 =>5	4	Cle=5-4 =>1	Kl*1 (Left Turn)	MV-Kt*5
7.	6	er=12-0-6 =>6	5	Cle=6-5 =>1	Kl*1 (Left Turn)	MV-Kt*6
8.	7	er=11-0-6 =>5	6	Cle=6-5 =>1	Kl*1 (Right Turn)	MV-Kt*5
9.	8	er=10-0-6 =>4	5	Cle=5-4 =>1	Kl*1 (Right Turn)	MV-Kt*4
10.	9	er=9-0-6 =>3	4	Cle=4-3 =>1	Kl*1 (Right Turn)	MV-Kt*3
11.	10	er=8-0-6 =>2	3	Cle=3-2 =>1	Kl*1 (Right Turn)	MV-Kt*2
12.	11	er=7-0-6 =>1	2	Cle=2-1 =>1	Kl*1 (Right Turn)	MV-Kt*1
13.	12	er=0-0-6 =>-6	1	Cle=Ple=1	Kl*1 (Right Turn)	MV-Kt*0

4.2 Conclusion

An inductive navigation system for guiding the automatic guided tram along the predefined single central track is be developed which is more cost effective, less infrastructure requiring. It provides robust solution for public transport system used for transporting passengers from one station to another station. Navigation system is tested on various possible conditions according to the deviation of tram from track. The inductive navigation system is implemented on the prototype model of the automatic guided central track tram and various results related to different experiments will be shown using analysis tables and developed system is shown with the required images of various parts of navigation system.

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