بسم الله الرحمن الرحيم

Sudan University of Sciences and Technology

College of Engineering

Electrical Engineering

Smart Electrical Train

القطار الكهربائي الذكي

A Project Submitted In Partial Fulfillment for the Requirements of the Degree of B.E (Honor) In Electrical Engineering

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الآيـــــــة

وَقَالَ ارْكَبُوا فِيهَا بِسْمِ اللَّهِ مَجْرَاهَا وَمُرْسَاهَا إِنَّ رَبِّي لَغَفُورٌ رَّحِيمٌ ﴿41﴾
وَهِيَ تَجْرِي بِهِمْ فِي مَوْجٍ كَالْجِبَالِ وَنَادَىٰ نُوحٌ ابْنَهُ وَكَانَ فِي مَعْزِلٍ يَا بُنَيَّ
ارْكَب مَّعَنَا وَلَا تَكُن مَّعَ الْكَافِرِينَ ﴿42﴾

صدق الله العظيم

هود[41–42]

DEDICATION

This modest work is dedicated to everyone who helped us in our project, our families who supported us and our friends who stood by us.

ACKNOWLEDGMENT

First and foremost we would like to express our sincere gratitude to our advisor **Dr.Awadalla Taifour Ali** for his continuous support in this project. His sharp mind, intuitive understanding, powerful observation and immense knowledge were great help to us. Without his assistance and dedicated involvement in every step throughout the process, this project would have never been accomplished.

ABSTRACT

Trains have become important transport means in most countries, with the increase in population and traffic congestion in addition to the excessive consumption of fuel for diesel locomotives, which is a non-renewable energy and causes environmental pollution. By using the line flower technic with an automatic system to create a smart train running in a certain path. Which ensures speed and safety of the transportation and stops at certain stations. A model with a three-wheeled vehicle had been represented as a smart train.

المستخلص

أصبحت القطارات من وسائل النقل المهمة في أغلب الدول. مع زيادة السكان وازدياد الازدحام المروري, بالإضافة إلى الإستهلاك الزائد للوقود لقاطرات الديزل والذي يعتبر طاقة غير متجددة حيث يتسبب في التلوث البيئي, ونسبة لذلك تم استخدام تقنية متتبع الخط مع نظام تغذية كهربائي مزود بدوائر تحكم لإنشاء قطار ذكي يسير في مسار معين يضمن سرعة وسلامة النقل ويتوقف في محطات معينة . تم عمل نموذج مصغر عبارة عن عربة مكونة من ثلاث عجلات تمثل القطار الذكي.

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LIST OF ABBREVIATIONS

CRRC	Rail transit firm in China named (CRRC)
USA	United States of America
DC	Direct Current
AC	Alternative Current
EMUs	Electric Multiple Units
ART	Autonomous Rail Transit
USD	United State Dollar
I/O	Inputs and Outputs
CPU	Central Process Unit
RAM	Random Access Memory
ROM	Read Only Memory
A/D	Analog to Digital
D/A	Digital to Analog
ALU	Arithmetic and Logical Unit
CISC	Complex Instruction Set Computer
RISC	Reduced Instruction Set Computer
SISC	Specific Instruction Set Computer
USB	Universal Serial Bus
E.M.F	Electromotive Force
M.M.F	Magneto Motive Force
e.g.	For Example
PWM	Pulse Width Modulation
DIP	Dual-in Line Package

LIST OF SYMBOLS

F	Force
B	Flux Density
I	Current
L	Length of Conductor
E_b	Back E.M.F
P	Number of Poles
Ø	Flux
Z	Number of Conductors
N	Speed of The Motor
A	Constant
V	Applied Voltage
R_a	Armature Resistance
I_a	Armature Current
K	Constant
T_a	Torque
η	Efficiency

CHAPTER ONE

INTRODUCTION

1.1 General Concepts

Over the centuries, trains have been the ideal solution for safe and economical transportation. The project includes the design of an electric train using line-flower technology with sensors that will enable it to move within the city. The train tracer of the line finder solve many problems of transport within the cities as he is friendly to the environment. The electrical train is a self-operating machine that detects and follows a line that is drawn on the street. The path consists of a black line on a white surface (or it may be reverse of that). The control system used must sense a line and maneuver the train to stay on course, while constantly correcting the wrong moves using feedback mechanism, thus forming a simple yet effective closed loop System. The train is designed to follow very tight curves.

1.2 Problem Statement

The street become crowded. Everyone got a car and there is a lot of transporter vehicles. The cost of rail used in train in the cities and the frequent accidents are the emissions of exhaust gases.

1.3 Objectives

- Reduce traffic congestion.
- Reduce the cost of railways used for trains within cities.
- Increase security and safety in transportation and reduce traffic accidents.
- Protect the environment and reduce the emission of exhaust gases through the use of renewable energy.

1.4 Methodology

- Study of all previous studies.
- Build Arduino microcontroller program to control the system of the train and to control the dc motors by using driver.
- Build a dedicated road with a line followed by the train.
- Providing sources of electric energy.

1.5 Project Lay-Out

This study consists of five chapters: Chapter One gives an introduction to the principles of the work, in addition its reasons, motivation and objectives. Chapter Two discuss the theoretical background of control systems, smart train system, sensors, dc motors and microcontroller systems. Chapter Three presents the system mathematical modeling and control design of line flower system. Chapter Four deal with the practical model of the system and shows the experimental results. Finally Chapter five provides the conclusions and recommendations.

CHAPTER TWO

THEORTICAL BACKGROUND AND LITERATURE REVIEW

2.1 Introduction

Despite the competition of airplanes, buses, trucks and cars, trains still play a major transportation role in society, filling specific markets such as high-speed and non-high-speed intercity passenger service, heavy haul of minerals and freight, urban light rail systems and commuter rail. Rail or train transportation is one of important and economical transportation systems available. In rail transportation, a series of vehicles are run by means of wheels and guided track to carry passengers or freight stock from one place to another. A series of vehicles are pulled by single or multiple locomotives. Locomotives are powered by steam or diesel engines or through electricity. Today we are living in a world where everything has become automatic while manual efforts have become minimal. Autonomous vehicle technology is one such concept which is currently being explored to its core,[1]. Recently, a Rail transit firm in China named (CRRC) has introduced a train that runs on the road instead of rails. This is the world's first train that doesn't need rails to travel; rather it uses virtual dotted lines on the road for transit.

2.2 Historical Background

The history of trains begins in the mid-1400s in Europe, when horse-drawn carts with flanged wooden wheels first were used to transport coal and stone by wooden rail. Later, in the mid-1700s, iron rails and wheels began to replace the less durable wooden ones. The first true locomotive have a self-propelled, called the "Penn y Darren," was built and operated in 1804 to pull cars to and from a mine in "Wales", by "Richard Trevithick". In 1825 "Colonel John Stevens" of

Hoboken, New Jersey, built a small demonstration locomotive and ran it on a circular track in his yard to prove that the idea of a steam engine operating on tracks was practical. In 1830, Peter Cooper built his "Tom Thumb," the first American-built steam locomotive to run on a railway. In 1831, the "De Witt Clinton," began service between Albany and Schenectady, New York. In addition, the Camden and Amboy Railroad began construction in New Jersey. The "John Bull," which now belongs to the Smithsonian, was this line's first locomotive. First diesel powered railcar enters service in Sweden. In Austria-Hungary, the first electrified metric railway was opened between Arad and he neighboring vineyards, facilitating transportation of goods and people and reducing travel time from half a day to just one hour (total distance around 60 km). The first electric train was developed in 1879 by German engineer Werner von Siemens. He built a train that could carry 30 passengers on a short journey. It travelled at a modest 6.5 km/h. In 1899 the Mount Morgan Gold Mining Company purchased three electric locomotives to haul ore on its underground rail system. Electrification of Brisbane's suburban railways was not seriously considered by the Queensland government until the late 1940s.Work was commenced but abandoned during the 1950s in favor of diesel electric locomotives,[2].

2.3 Types of Locomotives

Trains can be sorted in several distinct categories, separated by the way their locomotives are powered, their use, and by the design of their tracks.

A. Steam locomotives :

   This type of propulsion disappeared only after Diesel engines became undeniably cheaper and reliable.

B. Diesel locomotives :

   With the lowering prices of diesel fuel, and the increasing industrial pressure for transporting ever larger amounts of coal and goods, diesel engine locomotives became the predominant choice for trains.

C. Electric locomotives :

   Advances in electrical grid infrastructure and electric engine manufacture enabled trains to adopt electrical power as one of the most reliable sources of propulsion. Today electrical trains can be found everywhere, from city transit trains, subways, trams, to high speed rapid transit trains.

2.4 Electric Trains

Electric traction started in Europe and the United States of America (USA) as tramcars and subway locomotives in the 1880s powered by 500/600V direct current (DC). However, the low-voltage DC feed made it difficult to develop electric locomotives with sufficiently high output to replace steam locomotives for hauling heavy passenger and freight trains, and to introduce electric traction on lines with steep grades and long tunnels where steam operation was difficult. Trials were made with high-voltage DC-motor, but commutation of DC motor did not go well, so alternative current (AC) feeds were developed but caused problems with control of speed and traction effort of AC motors. In addition, supply of three-phase AC through overhead lines and pantographs was complex and finally AC commutator motors (very similar to DC motors) were used at lower frequency. AC supply only became reliable and problem-free much later in the 20th century. Many attempts were made using different current collection and power transmission methods for electric trams which started operation in 1881. However, Sprague found commercial success with a nose-suspension drive reduction gear method and a pole-pushed current collection method in 1888. The so-called Sprague system spread rapidly in the USA, followed by practical application for electric multiple units (EMUs) in 1897, leading to EMUs taking the railway world by storm. “Ichisuke Fujioka” (1857–1918) studied electric engineering under Professor “William E. Ayrton” (1847–1908) at the Imperial College of Engineering (predecessor of today’s University of Tokyo Faculty of Engineering). He travelled to the USA in 1884 where he met

Thomas Edison (1847– 1931) and received advice on domestic manufacturing of electrical equipment,[3].

2.5 Smart Train

A rail transit firm in China named CRRC has introduced a train that runs on the road instead of rails as shown in Figure 2.1. This is the world's first train that doesn't need rails to travel; rather it uses virtual dotted lines on the road for transit. The technology has been termed as Autonomous Rail Transit (ART) while the vehicle has been labeled as a "Smart Bus" by CRRC. It's a 30-meter long bus which is operated electrically and is fitted with sensors that follow the virtual rails on the road while adapting to the surroundings and situations in real time.

Figure 2.1: First train that runs on the road

A. Design and cost :

   China's railcar-maker CRRC has recently unveiled a bus-rail combo road transit system in "Zhuzhou Hunan" province. The Chinese Rail

Corporation began designing this system in 2013 and now finally in June 2017, the system has been tested successfully .Apart from being fast, this rail less transit is highly economical in terms of its construction. It takes 400-700 Million Yuan i.e. United State Dollar (USD) 58-102 Million to build one kilometer of subway while the electric streetcars carry a development cost of around 150-200 Million Yuan per km. However, ART i.e. Autonomous Rail Rapid Transit will cost one-fifth of the amount of a conventional metro. As per the reports, a standard-length ART bus can be constructed with just 15 Million Yuan i.e. USD 2.2 Million or even less.

B. Exteriors and interiors :

As shown in Figure 2.2 this vehicle developed by CRRC is a hybrid of a bus and train with a certain resemblance to a Tram. It’s fitted with rubber wheels and travels on the road much like a regular bus with a larger carrying capacity. The carriages on the vehicle can be altered by adding or removing carriages depending upon the requirement. Dimensionally, its 3.4 meters high, 2.65 meters wide, and 31.64 meters long. Besides, it has a safe channel width of 3.83 meters and a minimum turning radius of 15 meters which renders flexibility in its movements, particularly while taking turns. An important aspect of its design is that the body structure of this smart bus is claimed to have a long life of 25+ years implying economic viability. Moving to the interiors of the smart bus, there is a lot of space with a carrying capacity of 307 passengers. A unique feature of the vehicle is that its carriages are detachable, thereby allowing the flexibility to add or remove carriages as per the requirement. Further, there are baby and mother priority seats along with adequate space for passengers in a wheelchair. From inside, it appears much like a subway fitted with digital displays, comfortable seats, and an adequate amount of space.

Figure 2.2: Inside the smart train

C. Key features :

Just like any other autonomous vehicle, this transit features advanced functionality which, in turn, reduces manual efforts on the part of the driver. These functions include:

i. Lane departure warning system :

This system aids in guiding the vehicle to keep running on its track and warns whenever it drifts away from the lane.

ii. Electronic rearview mirror :

These kinds of rearview mirrors are electrically adjustable and render a clearer view. Besides, these are also equipped with auto dimming technology to reduce the glare.

iii. Collision warning system :

The collision warning helps the driver to maintain a safe distance with other vehicles on the road and whenever the proximity reduces, it shows a sign so as to provide a warning.

iv. Route change authorization :

The navigation facility equipped with the vehicle can analyze the route on which it's traveling and re-directs for a different route in order to avoid traffic congestion.

2.6 Microcontroller

A microcontroller is a single-chip computer, including most of a computer's features, but in limited sizes. Today, there are hundreds of different types of microcontrollers, ranging from 8-pin devices to 40-pin, or even 64- or higher pin devices. It's a microprocessor system which contains data and program memory, serial and parallel Inputs and Outputs (I/O), timers, and external and internal interrupts all integrated into a single chip that can be purchased for a relatively cheap price. The term microcomputer is used to describe a system that includes at minimum a microprocessor, program memory, data memory, and an Input-Output (I/O) device. Some microcomputer systems include additional components such as timers, counters, and analog-to-digital converters. Thus, a microcomputer system can be anything from a large computer having hard disks, floppy disks, and printers to a single-chip embedded controller. Therefore a microcontroller is meant to perform a specific task unlike the general-purpose computer which can do multiple tasks at once,[4].

2.6.1 Microcontroller Basics

A microcontroller is a small, low-cost computer-on-a-chip which usually includes:

- An 8 or 16 bit microprocessor central process unit (CPU).
- A small amount of random access memory (RAM).
- Programmable read only memory (ROM) and/or flash memory.
- Parallel and/or serial I/O.
- Timers and signal generators.
- Analog to Digital (A/D) and/or Digital to Analog (D/A) conversion.

2.6.2 Types of Microcontrollers

Microcontrollers can be classified on the basis of internal bus width, architecture, memory and instruction set.

A. The 8,16 and 32-bit microcontrollers :

i. The 8-bit Microcontroller :

When the arithmetic and logical unit (ALU) performs arithmetic and logical operations on a byte (8-bits) at an instruction, the microcontroller is an 8-bit microcontroller. The internal bus width of 8-bit microcontroller is of 8-bit. Examples of 8-bit microcontrollers are Intel 8051 family and Motorola MC68HC11 family.

ii. The 16-bit Microcontroller :

When the ALU performs arithmetic and logical operations on a word (16-bits) at an instruction, the microcontroller is a 16-bit microcontroller. The internal bus width of 16-bit microcontroller is of 16-bit. Examples of 16-bit microcontrollers are Intel 8096 family and Motorola MC68HC12 and MC68332 families. The performance and computing capability of 16 bit microcontrollers are enhanced with greater precision as compared to the 8-bit microcontrollers.

iii. The 32- bit Microcontroller :

When the ALU performs arithmetic and logical operations on a double word (32-bits) at an instruction, the microcontroller is a 32-bit microcontroller. The internal bus width of 32-bit microcontroller is of 32-bit. Examples of 32-bit microcontrollers are Intel 80960 family and Motorola M683xx and Intel/Atmel 251 family. The performance and computing capability of 32 bit microcontrollers are enhanced with greater precision as compared to the 16-bit microcontrollers.

B. Embedded and external memory microcontrollers :

i. Embedded microcontroller. :

When an embedded system has a microcontroller unit that has all the functional blocks (including program as well as data memory) available on a chip is called an embedded microcontroller. For example, 8051 having Program & Data Memory, I/O Ports, Serial Communication, Counters and Timers and Interrupt Control logic on the chip is an embedded microcontroller.

ii. External Memory Microcontrollers :

When an embedded system has a microcontroller unit that has not all the functional blocks available on a chip is called an external memory microcontroller. In external memory microcontroller, all or part of the memory units are externally interfaced using an interfacing circuit called the glue circuit. For example, 8031 has no program memory on the chip is an external memory microcontroller.

C. Microcontroller architectural features :

There are mainly two categories of processors, namely, Von-Neuman (or Princeton) architecture and Harvard Architecture. These two architecture differ in the way data and programs are stored and accessed.

i. Von-Neuman Architectural :

Microcontrollers based on the Von-Neuman architecture have a single data bus that is used to fetch both instructions and data. Program instructions and data are stored in a common main memory. When such a controller addresses main memory, it first fetches an instruction, and then it fetches the data to support the instruction. The two separate fetches slows up the controller's operation The Von-Neuman architecture's main advantage is that it simplifies the microcontroller design because only one memory is accessed. In microcontrollers, the contents of RAM can be used for data storage and program instruction storage. For example, the Motorola 68HC11 microcontroller Von-Neuman architecture.

ii. Harvard architecture :

Microcontrollers based on the Harvard Architecture have separate data bus and an instruction bus. This allows execution to occur in parallel. As an instruction is being "pre-fetched", the current instruction is executing on the data bus. Once the current instruction is complete, the next instruction is ready to go. This pre-fetch theoretically allows for much faster execution than Von-Neuman architecture, on the expense of complexity. The Harvard Architecture executes instructions in fewer instruction cycles than the Von-Neuman architecture. For example, the Intel MCS-51 family of microcontrollers and PIC microcontrollers uses Harvard Architecture.

iii. Complex instruction set computer (CISC) architecture microcontrollers :

Almost all of today's microcontrollers are based on the CISC (Complex Instruction Set Computer) concept. When a microcontroller has an instruction set that supports many addressing modes for the arithmetic and logical instructions, data transfer and memory accesses instructions, the microcontroller is said to be of CISC architecture. The typical CISC microcontroller has well over 80 instructions, many of them very powerful and very specialized for specific control tasks. It is quite common for the instructions to all behave quite differently. Some might only operate on certain address spaces or registers, and others might only recognize certain addressing modes. The advantages of the CISC architecture are that many of the instructions are macro like, allowing the programmer to use one instruction in place of many simpler instructions. An example of CISC architecture microcontroller is Intel 8096 family.

iv. Reduced instruction set computer (RISC) architecture microcontrollers :

The industry trend for microprocessor design is for Reduced Instruction Set Computers (RISC) designs. When a microcontroller has an instruction set that supports fewer addressing modes for the arithmetic and logical instructions and for data transfer instructions, the microcontroller is said to be of RISC architecture. The benefits of RISC design simplicity are a smaller chip, smaller pin count, and very low power consumption.

v. Specific instruction set computer (SISC) :

Actually, a microcontroller is by definition a Reduced Instruction Set Computer. It could really be called a Specific Instruction Set Computer (SISC). The basic idea behind the microcontroller was to limit the capabilities of the CPU itself, allowing a complete computer (memory, I/O, interrupts, etc.) to fit on the single chip. At the expense of the more general purpose instructions that make the standard microprocessors (8088, 68000, 32032) so easy to use, the instruction set was designed for the specific purpose of control (powerful bit manipulation, easy and efficient I/O, and so on),[5].

2.6.3 Arduino Microcontroller

Arduino is a small microcontroller board with a universal serial bus (USB) plug to connect to The computer and a number of connection sockets that can be wired up to external electronics, such as motors, relays, light sensors, laser diodes, loudspeakers, microphones, etc. Arduino can either be powered through the USB connection from the computer or from a 9V battery. Arduino can be controlled from the computer or programmed by the computer and then disconnected and allowed to work independently. The Arduino board it is an open-source electronics prototyping platform based on flexible, easy-to-use hardware and software. It's intended for artists, designers, hobbyists, and anyone interested in creating inter active objects or environments in simple terms, the Arduino is a tiny computer system that can be programmed with instructions to interact with various forms of input and output. The current Arduino board model, the Uno, is quite small in size compared to the average human hand. Although it might not look like much to the new observer, the Arduino system allows creating devices that can interact with the world. By using an almost unlimited range of input and output devices, sensors, indicators, displays, motors, and more, the exact interactions required to create a functional device can be programmed,[6].

2.6.4 Comparing Microprocessors and Microcontrollers

The term microprocessor and microcontrollers have always been confused with each other. Both of them have been designed for real time application. They share many common features and at the same time they have significant differences.

i. Microprocessor is a single chip CPU, microcontroller contains, a CPU and much of the remaining circuitry of a complete microcomputer system in a single chip.
ii. Microcontroller includes RAM, ROM, serial and parallel interface, timer, interrupt schedule circuitry (in addition to CPU) in a single chip.
iii. RAM is smaller than that of even an ordinary microcomputer, but enough for its applications.
iv. Interrupt system is an important feature, as microcontrollers have to respond to control oriented devices in real time. For example, opening of microwave oven’s door cause an interrupt to stop the operation. (Most microprocessors can also implement powerful interrupt schemes, but external components are usually needed).

v. Microprocessors are most commonly used as the CPU in microcomputer systems.

vi. Microcontrollers are used in small, minimum component designs performing control-oriented activities.

vii. Microprocessor instruction sets are ‘processing intensive’, implying powerful addressing modes with instructions catering to large volumes of data. Their instructions operate on nibbles, bytes, etc. Microcontrollers have instruction sets catering to the control of inputs and outputs. Their instructions operate also on a single bit. For example a motor may be turned ON and OFF by a 1-bit output port, [4].

2.7 DC motors

A machine that converts DC power into mechanical power is known as a DC motor. It’s seldom used in ordinary applications because all electrical supply companies furnish alternating current However, for special application such as in steel mills, mines and electric train .Dc motors are as popular as 3-phase induction motors, like dc generator, dc motors are also of three types: series-wound, shunt –wound and compound-wound. The use of a particular motor depends upon the mechanical load it has to drive,[7].

2.7.1 DC motors principle

It’s operation is based on the principle that when a current carrying conductor is placed in a magnetic field , the conductor experiences a mechanical force .The direction of this force is given by Fleming’s left hand rule and magnitude is given by :

$$F = B * I * L \quad \text{Newtons} \qquad (2.1)$$

Where:

$F \equiv$ force.

$B \equiv$ flux density.

I ≡ current.

L ≡ length of conductor.

2.7.2 Back or counter electromotive force (E.M.F)

When the armature of a DC motor rotates under the influence of the driving torque, the armature conductors move through the magnetic field and hence E.M.F is induced in them as in a generator. The induced E.M.F. acts in opposite direction to the applied voltage and in known as back or counter E.M.F.E_b As shown in Figure 2.3.

$$E_b = \frac{P\phi ZN}{60A} \text{ volt} \qquad (2.2)$$

E_b ≡ Back E.M.F

P ≡ number of poles.

∅ ≡ Flux.

Z ≡ number of conductors.

N ≡ speed of the motor.

A ≡ constant.

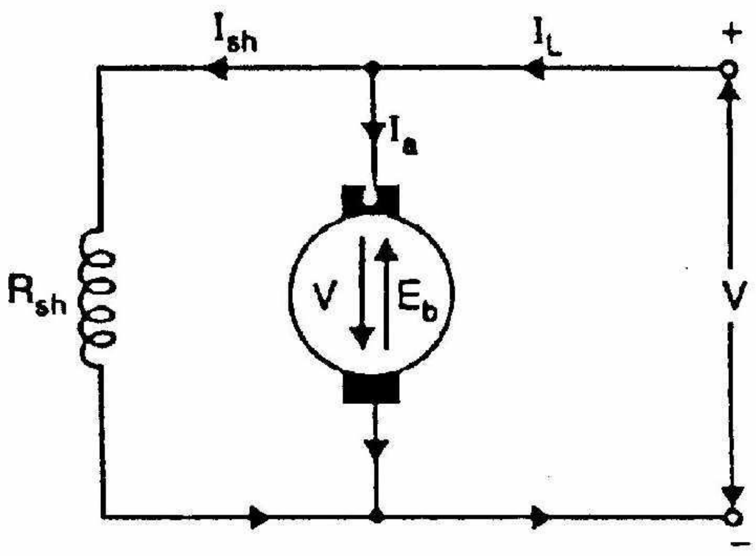


Figure 2.3: Back E.M.F

The back E.M.F is always less than the applied voltage although this difference is small when the motor is running under normal conditions.

2.7.3 Voltage equations

$$I_a = \frac{V - E_b}{R_a} \tag{2.3}$$

$$V = E_b + I_a R_a \tag{2.4}$$

Where:

V ≡ applied voltage.

E_b ≡ Back E.M.F.

R_a ≡ Armature resistance.

I_a ≡ Armature current.

2.7.4 Power equations

$$VI_a = E_b I_a + I_a^2 R_a \tag{2.5}$$

VI_a ≡ Electric power supplied to armature (armature input).

$E_b I_a$ ≡ Power developed by armature (armature output).

$I_a^2 R_a$ ≡ Electric power wasted in armature (armature Cu loss).

2.7.5 Types of DC motors

A. Shunt-wound motor :

In which the field winding is connected in parallel with the armature. The current through the shunt field winding is not the same as the armature current. Shunt field windings are designed to produce the necessary magneto motive force (M.M.F) by means of a relatively large number of turns of wire having high resistance.

Therefore, shunt field current is relatively small compared with the armature current as shown in Figure 2.4.

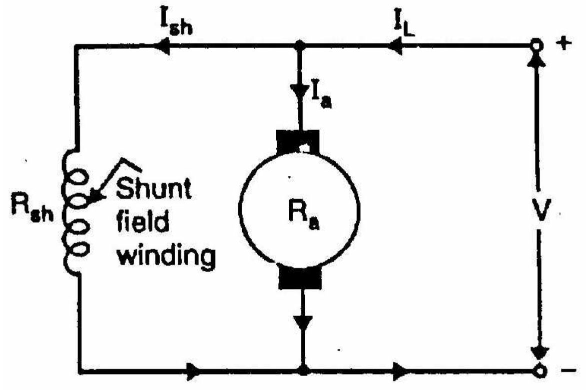


Figure 2.4: Shunt-wound motor

B. Series- wound motor :

In which the field winding is connected in series with the armature. Therefore, series field winding carries the armature current. Since the current passing through a series field winding is the same as the armature current, series field windings must be designed with much fewer turns than shunt field windings for the same M.M.F. Therefore, a series field winding has a relatively small number of turns of thick wire and, therefore, will possess a low resistance. As shown in Figure 2.5.

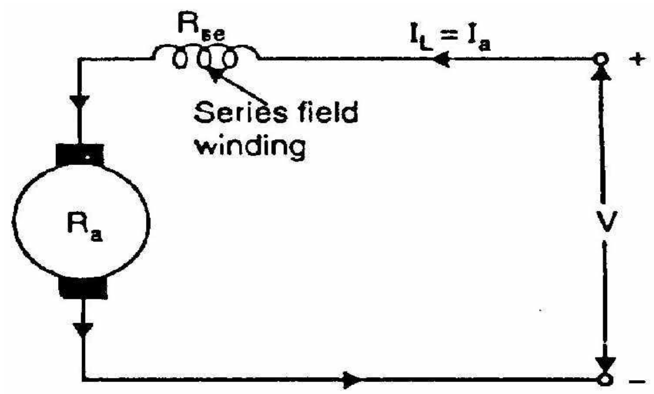


Figure 2.5: Series- wound motor

C. Compound-wound motor :

Which has two field windings as shown in Figure 2.6; one connected in parallel with the armature and the other in series with it. There are two types of compound motor connections (like generators). When the shunt field winding is directly connected across the armature terminals, it is called short-shunt connection. When the shunt winding is so connected that it shunts the series combination of armature and series field, it is called long-shunt connection. The compound machines (generators or motors) are always designed so that the flux produced by shunt field winding is considerably larger than the flux produced by the series field winding. Therefore, shunt field in compound machines is the basic dominant factor in the production of the magnetic field in the machine.

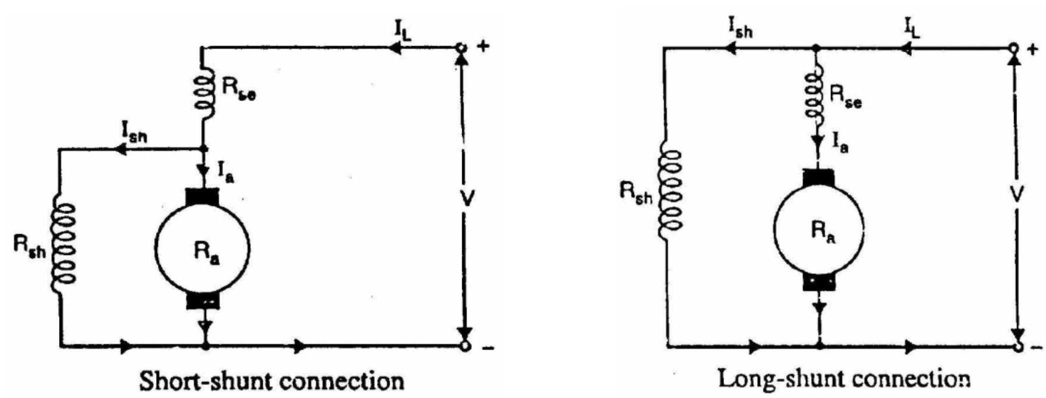


Figure 2.6: Compound-wound motor

2.7.6 Torque and speed of DC motor

For any motor, the speed and torque are very important factors. When the torque increases, the speed of a motor increases and vice-versa. We have seen that for a DC motor:

$$N = \frac{KE_b}{\emptyset} \quad (2.6)$$

$$T_a \propto \emptyset I_a \quad (2.7)$$

If the flux decreases, from Equation (2.6) the motor speed increases but from Equation (2.7) the motor torque decreases. This is not possible because the increase in motor speed must be the result of increased torque. Indeed it is so in this case. When the flux decreases slightly the armature current increases to a large value.

2.7.7 Efficiency of a DC motor

The efficiency of a DC motor is the ratio of output power to the input power.

$$Efficiency, \eta = \frac{output}{input} * 100 \quad (2.8)$$

$$Efficiency, \eta = \frac{output}{output+losses} * 100 \quad (2.9)$$

2.7.8 DC motor characteristics

The performance of a DC motor can be judged from its characteristic curves known as motor characteristics; following are the three important characteristics of a DC motor:

- Torque and Armature current characteristic(T_a/I_a):
  It is the curve between armature torque T_a and armature current I_a of a DC motor. It is also known as electrical characteristic of the motor.

- Speed and armature current characteristic (N/I_a):
  It is the curve between speed N and armature current I_a of a DC motor. It is very important characteristic as it is often the deciding factor in the selection of the motor for a particular application.

- Speed and torque characteristic (N/T_a):
  It is the curve between speed N and armature torque Ta of a DC motor. It is also known as mechanical characteristic.

2.7.9 Applications of D.C. Motors

A. Shunt motors :

The characteristics of a shunt motor reveal that it is an approximately constant speed motor. It is, therefore, used:

- Where the speed is required to remain almost constant from no-load to full-load.
- Where the load has 10 be driven at a number of speeds and any one of which is required to remain nearly constant.
- Industrial use:
  Lathes, drills, boring mills, shapers, spinning and weaving machines etc.

B. Series motors :

It is a variable speed motor i.e., speed is low at high torque and vice-versa. However, at light or no-load, the motor tends to attain dangerously high speed. The motor has a high starting torque. It is, therefore, used:

- Where large starting torque is required, for example, in elevators and electric traction.
- Where the load is subjected to heavy fluctuations and the speed is automatically required to reduce at high torques and vice-versa.
- Industrial use:
  Electric traction, cranes, elevators, air compressors, vacuum cleaners, hair drier, sewing machines etc.

2.8 Sensors

A sensor is a device which is capable of converting any physical quantity to be measured into a signal which can be read, displayed, stored or used to control some other quantity. This signal produced by the sensor is equivalent to the quantity to be measured. Sensors are used to measure a particular characteristic of any object or device. For example a thermocouple, a thermocouple will sense heat energy (temperature) at one of its junction and produce equivalent output voltage which can be measured by a voltmeter. More the temperature rise, higher the voltage read by the voltmeter. All sensors need to be calibrated with respect with some reference value or standard device for accurate measurement,[8].

2.8.1 Types of sensors

Sensors are classified based on the nature of quantity they measure:

i. Acoustic and sound sensors for example (e.g.): Microphone, Hydrophone.
ii. Automotive sensors e.g.: Speedometer, Radar gun, Speedometer, fuel ratio meter.
iii. Chemical Sensors e.g.: Sensors to detect presences of different gases or liquids.
iv. Electric and Magnetic Sensors e.g.: Galvanometer, Hall sensor (measures flux density), Metal detector.
v. Environmental Sensors e.g.: Rain gauge, snow gauge, moisture sensor.
vi. Optical Sensors e.g.: Photo diode, Photo transistor, Wave front sensor.
vii. Mechanical Sensors e.g.: Strain Gauge, Potential meter (measures displacement).
viii. Thermal and Temperature sensors. e.g.: Calorimeter, Thermocouple, Thermistor, Garden gauge.
ix. Proximity and Presences sensors.
x. A proximity or presences sensor is the one which is able to detect the presences of nearby objects without any physical contact. They usually emit electromagnetic radiations and detect the changes in reflected signal if any. e.g.: Doppler radar, Motion detector.

2.8.2 Position Sensors

One method of determining a position, is to use either “distance”, which could be the distance between two points such as the distance travelled or moved away from some fixed point, or by “rotation” (angular movement). For example, the rotation of a robots wheel to determine its distance travelled along the ground. Either way, Position Sensors can detect the movement of an object in a straight line using Linear Sensors or by its angular movement using Rotational Sensors.

CHAPTER THREE

SYSTEM COMPONENTS

3.1 System Description

This project show a miniature train system that operates without need to railway, the block diagram shown in Figure 3.1 describes sequence of system control operations where he explains the process of tracking the vehicle to the line and stop the train at the stations and sense objects facing it. The Arduino (microcontroller) receives signal from IR sensor and Ultrasonic sensor, under this signal it creates two pulses that send one to the driver to control the movement of DC motors and the other pulse send to control the smart door.

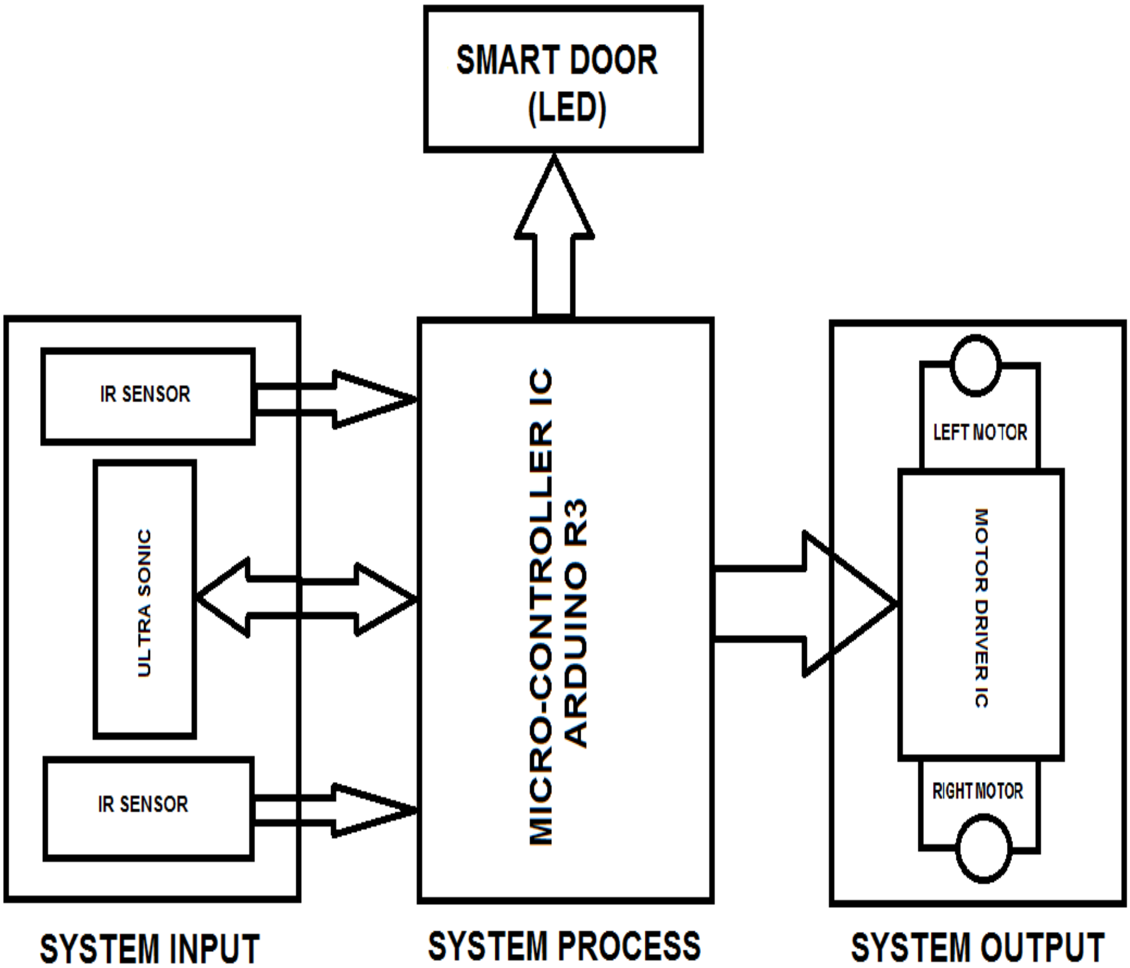


Figure 3.1: System block diagram

3.2 Hardware Equipment

The hardware equipment of system is built with DC motor, IR sensors, Ultrasonic, Arduino UNO R3 and IC driver (L293D).

3.2.1 DC motor

A machine that converts DC power into mechanical power is known as a DC motor. It's seldom used in ordinary applications because all electrical supply companies furnish alternating current, however, for special application such as in steel mills, mines and electric train .DC motors are as popular as 3-phase induction motors, like dc generator, dc motors are also of three types: series-wound, shunt –wound and compound-wound ,[7]. The use of a particular motor depends upon the mechanical load it has to drive. A simple DC motor is shown in Figure 3.2.

Figure 3.2: Simple DC motor

3.2.2 IR (INFRARED) sensor

An infrared sensor is an electronic device that emits in order to sense the surroundings. An IR sensor can measure the heat of an object as well as detects the motion, these types of sensors measures only infrared radiations. IR reflective sensors have one emitter (IR LED) and one receiver (Photo- Transistor or photo diode) as shown in Figure 3.3. This project had black track on white surface. The Figure 3.4 below shows the components of IR infrared sensor.

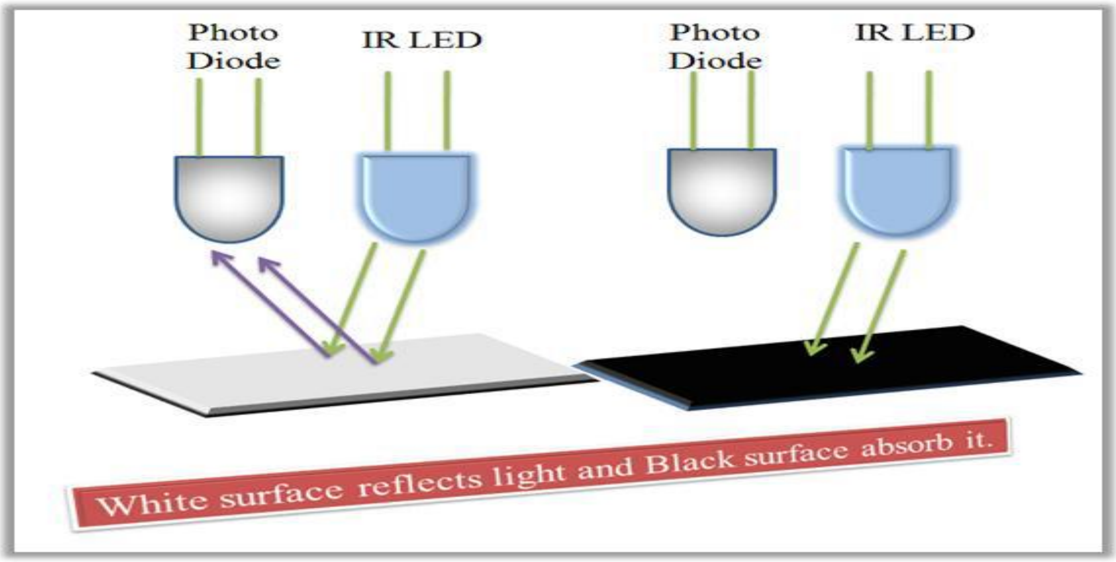


Figure 3.3: IR sensor working principle

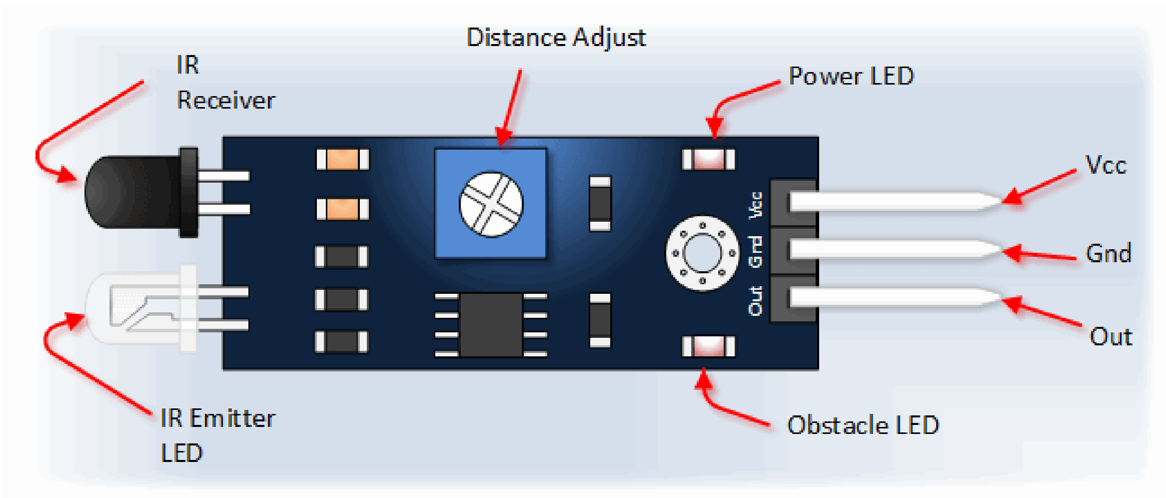


Figure 3.4: IR Sensor

3.2.3 Ultrasonic (HC-SR04)

Ultrasonic Sensor as shown in Figure 3.5 are self-contained solid-state devices designed for non-contact sensing of solid and liquid objects,[9]. For many applications, such as monitoring the level of water in a tank, ultrasonic technology lets a single device to do a job that would otherwise require multiple sensors. Active ultrasonic sensors generate high-frequency sound waves and evaluate the echo which is received back by the sensor, measuring the time interval between sending the signal and receiving the echo to determine the distance to an object, HC-SR04/5 module as shown as Figure 3.5 has 4 pins:

- VCC: 5V of the power supply.
- TRIG: Trigger Pin.
- ECHO: Echo Pin.
- GND: to ground.

The basic principal of an Ultrasonic Sensor is that generates sound waves and reads their echoes to detect and measure distance from objects as shown in Figure 3.6. It can also send single sound waves to work as sonar or listen for a sound wave that triggers the start of a program in our case it is used to measure the distance from the obstacle.

Figure 3.5: Ultrasonic

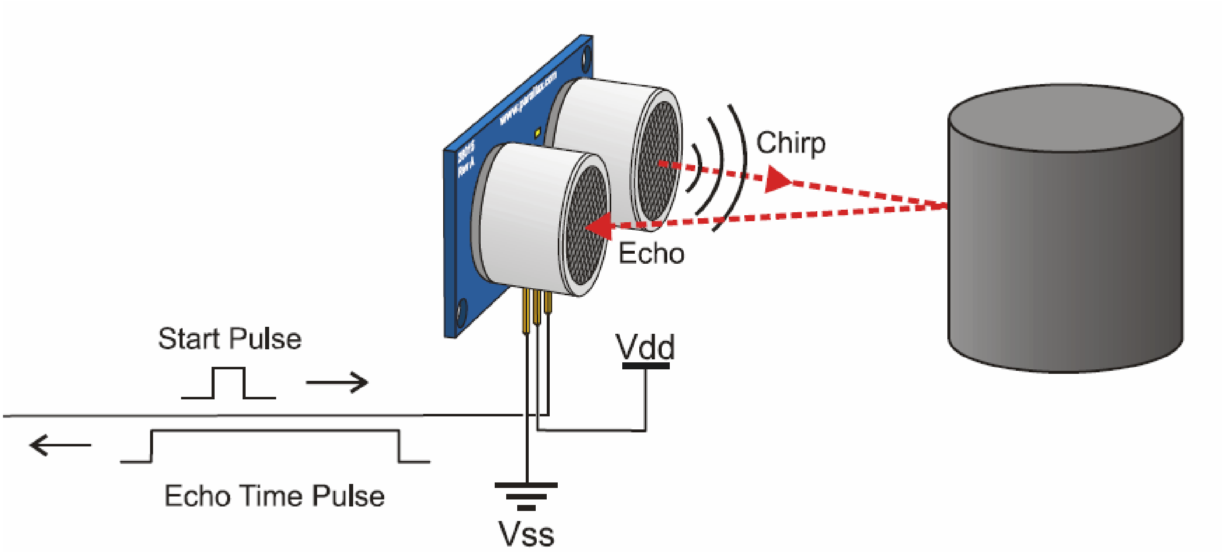


Figure 3.6: Ultrasonic sensor principle

3.2.4 Arduino Uno

As shown in Figure 3.7 Arduino is a small microcontroller board with a USB plug to connect to your computer and a number of connection sockets that can be wired up to external electronics, such as motors, relays, light sensors, laser diodes, loudspeakers, microphones, etc.

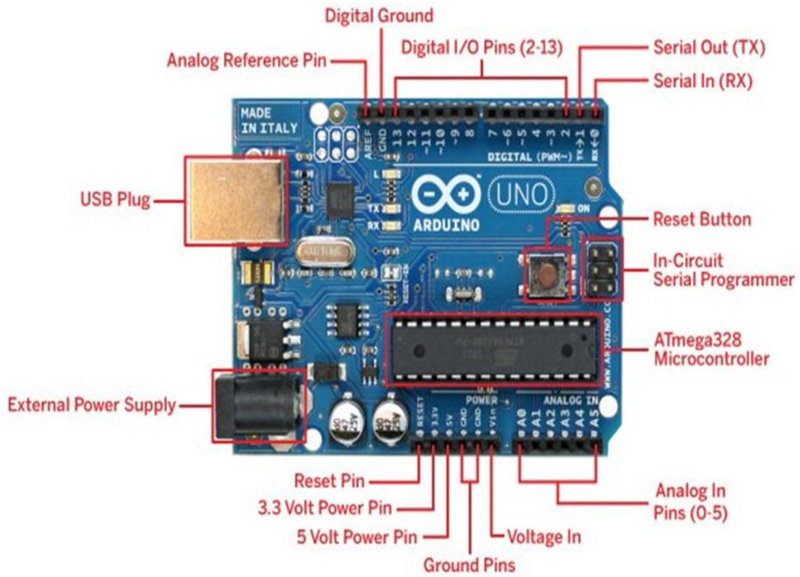


Figure 3.7: Arduino R3 details

Arduino can either be powered through the USB connection from the computer or from a 9V battery,[10]. Arduino can be controlled from the computer or programmed by the computer and then disconnected and allowed to work independently Arduino microcontroller board. Arduino Uno is a microcontroller board based on ATmega 328P microcontroller. It has 14 digital input/output pins (of which 6 can be used as pulse width modulation (PWM) outputs), 6 analog inputs, a 16 MHz quartz crystal, a USB connection, a power jack, header and a reset button.

3.2.5 Driver (L293D)

L293D IC generally comes as a standard 16-pin dual-in line package (DIP) as shown in Figure 3.8. This motor driver IC can simultaneously control two small motors in either direction forward and reverse with just 4 microcontroller pins (if you do not use enable pins). Some of the features (and drawbacks) of this IC are Output current capability is limited to 600mA per channel with peak output current limited to 1.2A (non-repetitive).This means that cannot drive bigger motors with this IC. Supply voltage can be as large as 36 Volts. This means that one does not have to worry much about voltage regulation. L293D has an enable facility which helps you enable the IC output pins. If an enable pin is set to logic high, then state of the inputs match the state of the outputs. If this is pulled low, then the outputs will be turned off regardless of the input states.

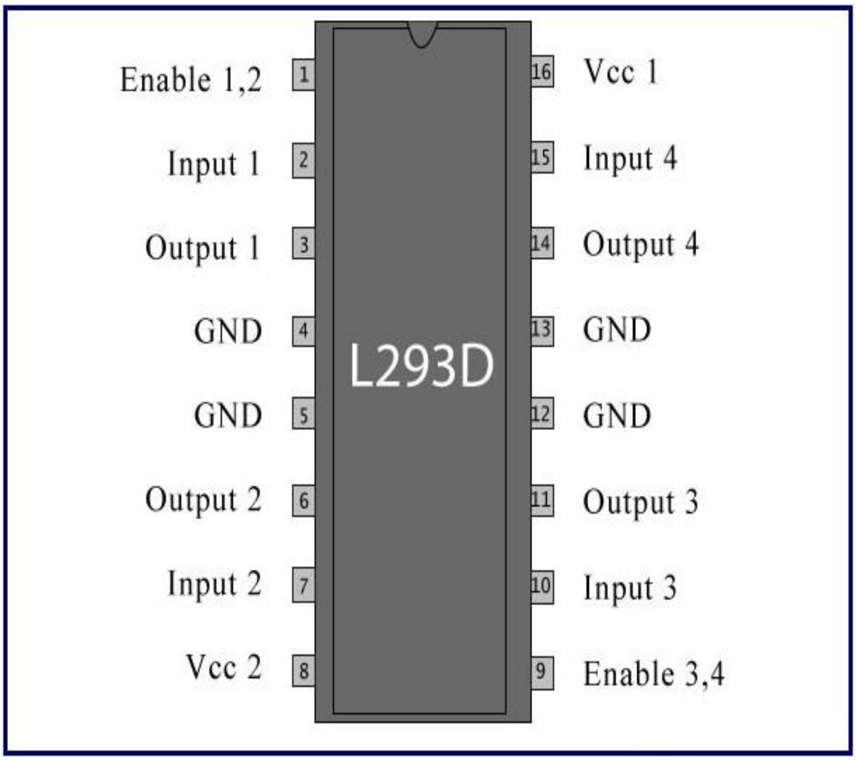


Figure 3.8: Driver L293D

3.3 System Flow Chart

The system is built with Arduino, IC driver (L293D), IR sensors, and platform consisting of a toy car chassis. The system is designed using two motors controlling wheels. It has infrared sensors on the bottom for detect black tracking tape. This flow chart in Figure 3.9 represent the control operation that running in the main train and the station.

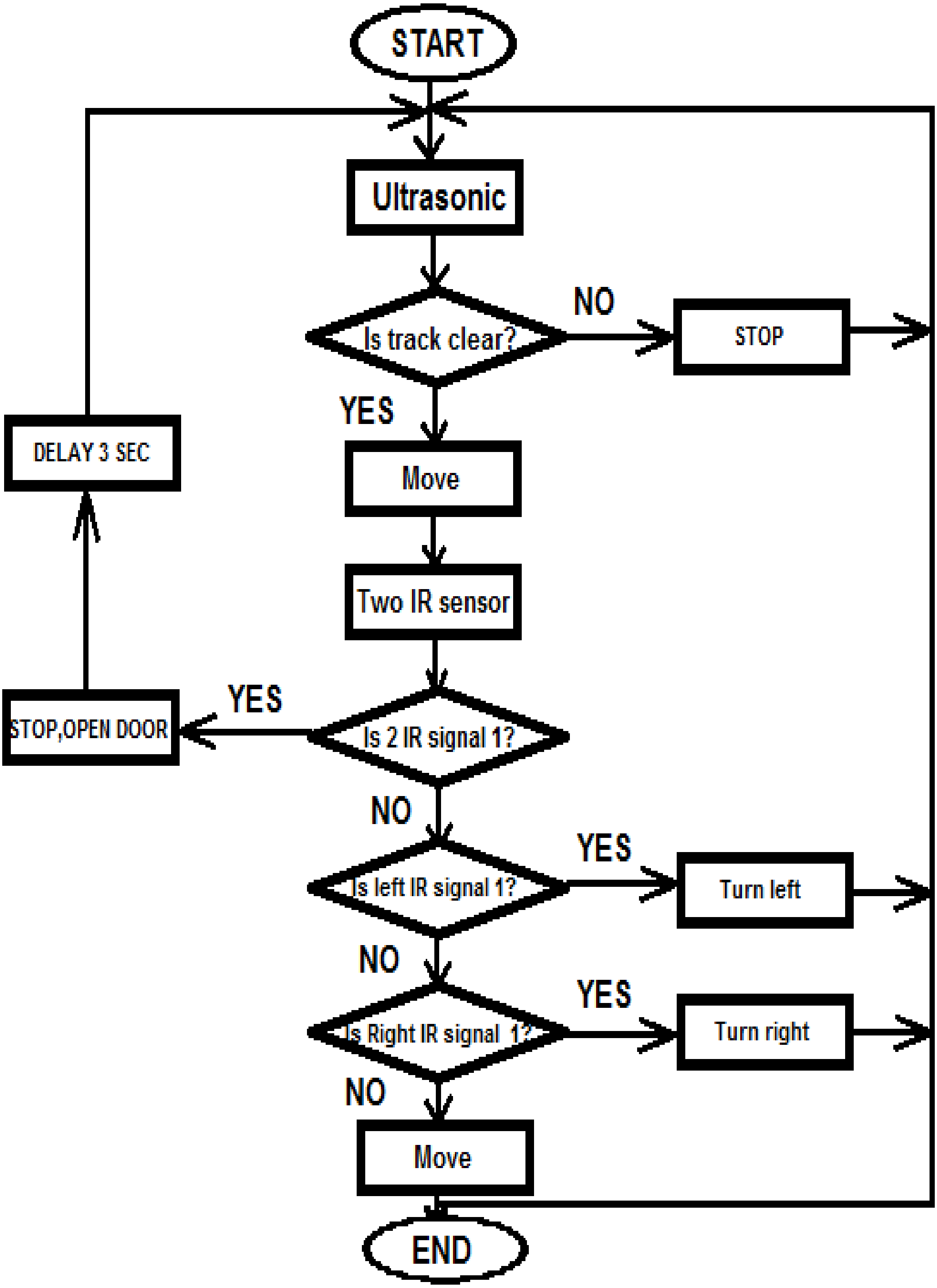


Figure 3.9: System flow chart

CHAPTER FOUR

SYSTEM MODELLING AND DESIGN

4.1 System Fabrication

Depending on the form of performance required of the system it had been consisted from two parts, mechanical part include the system body that was constructed from track line and two wheels with two DC motor, one rolling wheel and the main body made from fiber material, and the electrical part that had been configured from Arduino board which is processing equipment, L293D driver that supply the DC motors by pulses to control it, and input device consist from ultrasonic sensor and two IR sensors and output device consist from two DC motors

4.1.1 The main body system

According to the optimal performance method the main body of the system consist of:

i. The black track line :

   It is a black line on a hard paper and it was designed to be a track for the train, the width of the line was measured in an area proportional to the positions of the IR sensor in the main body. The track contains stations set with black lines that cut off the main line. The train is running in the black line and it subject to three possibilities:

- When both left and right sensor senses white then robot move forward as shown in Figure 4.1.

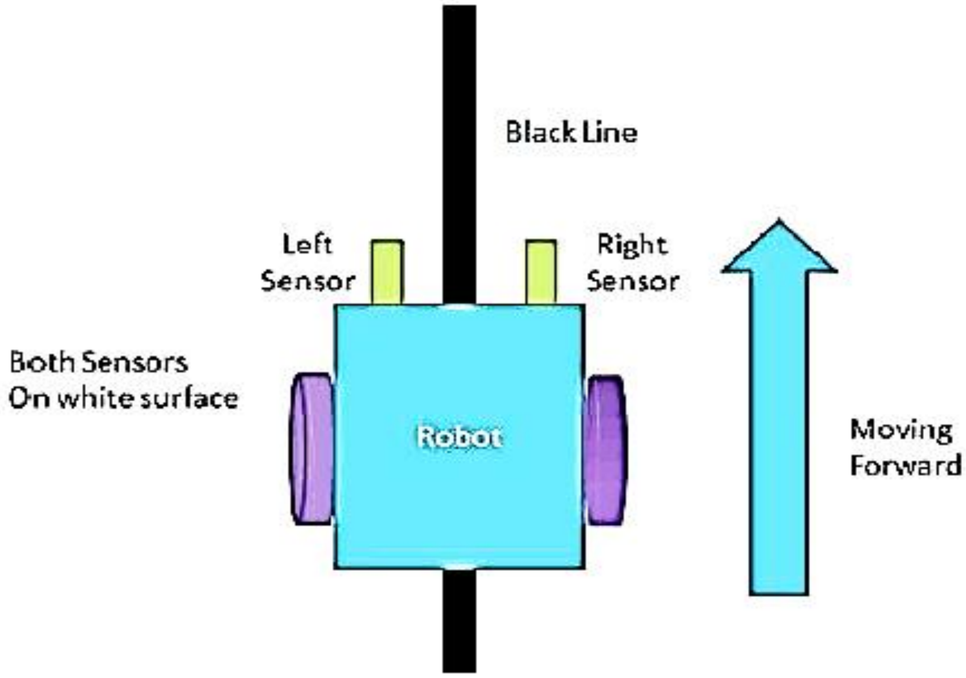


Figure 4.1: Both left and right sensor senses white

- If left sensor comes on black line then robot turn left side as shown in Figure4.2.

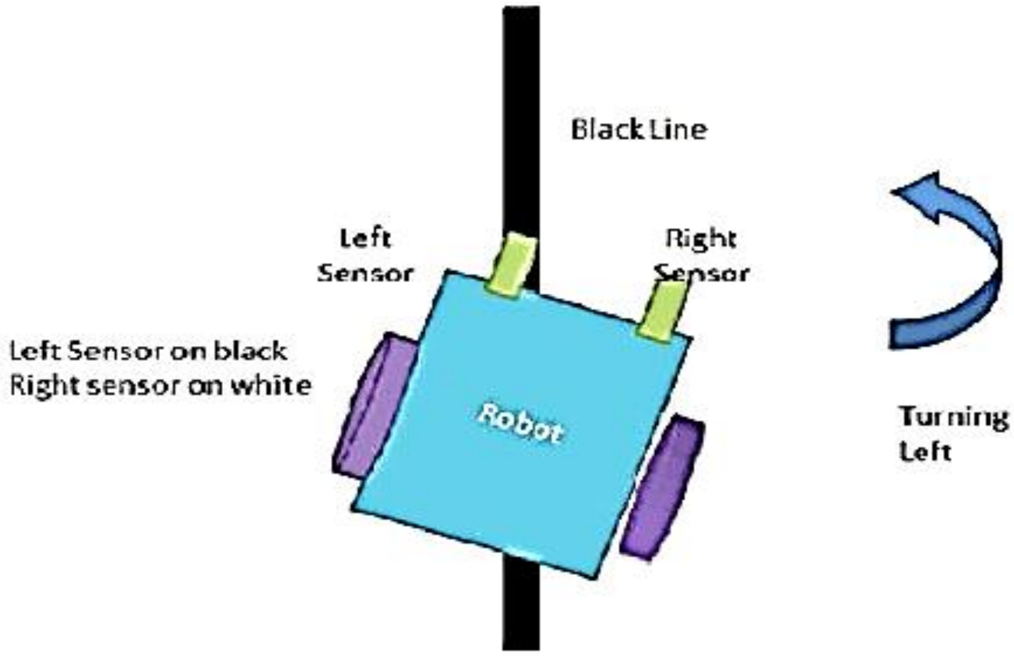


Figure 4.2: Left sensor comes on black line

- If right sensor sense black line then robot turn right side until both sensor comes at white surface. When white surface comes robot starts moving on forward again. And if no line detected robot will stop. That shown in Figure 4.3.

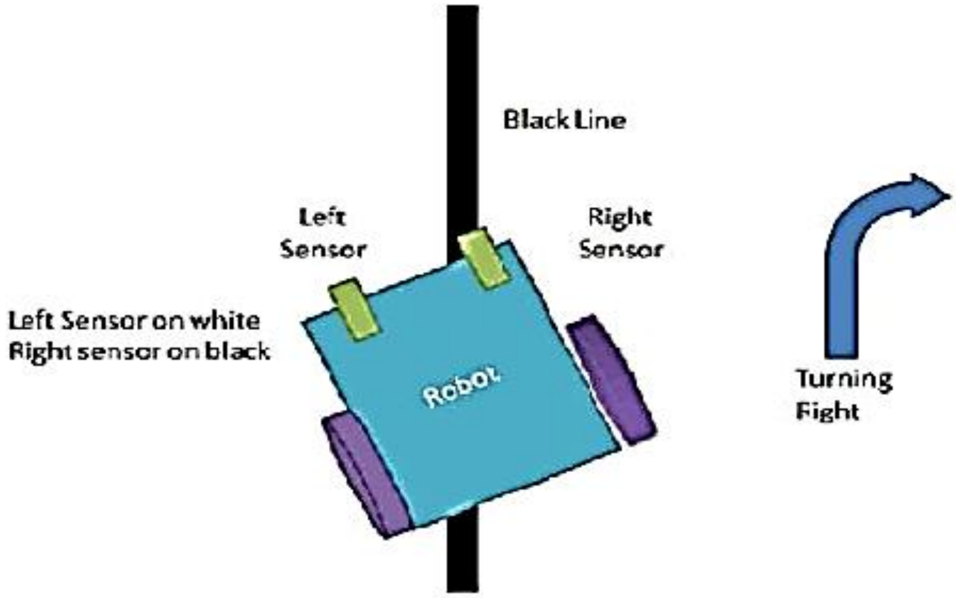


Figure 4:3 Right sensor sense black lines

ii. The rolling wheel:

The rolling wheel enable the system to moving in the curves with smooth movement and it was set in the rear of the train. The Figure 4.4 below show the type the wheel that was used in the system.

Figure 4.4: Rolling wheel

iii. DC motor with Wheels :

Two DC motors as shown in Figure 4.5 attached to wheels gears was set in front of the system body.

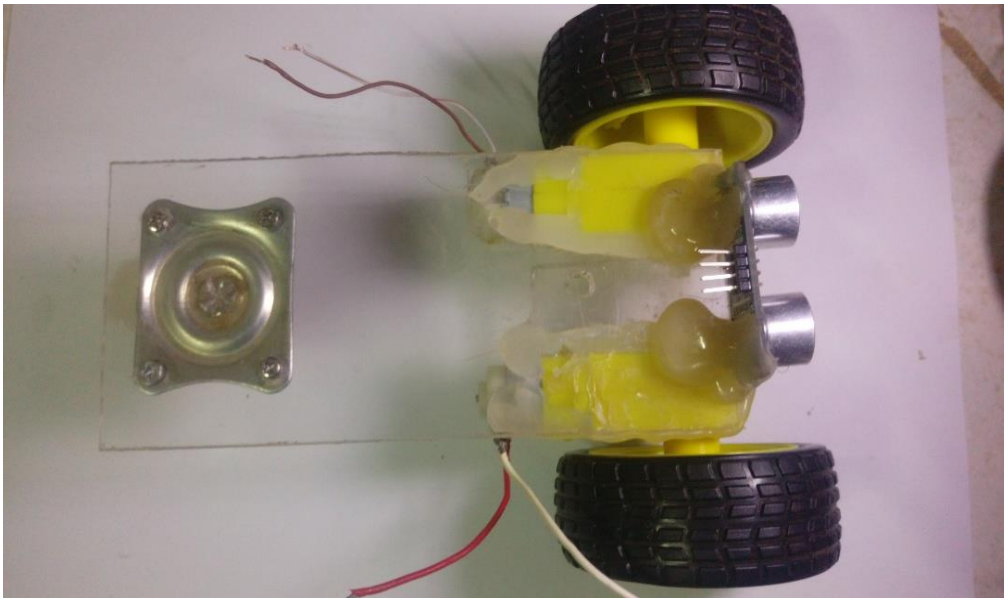


Figure 4.5: DC motor with wheel

4.1.2 System control circuit

The system required an electrical device to controlling the movement of the train and the smart door that was represented by LED, and it divided to an input device and processing device and output device.

A. Input devices :

All input devices connected with Arduino to process the signal from it and give an output pulses.

i. There are two IR sensors was set in front of the body system in parallel, the left IR sensor consist from three pins the VCC, GND and Signal, VCC produce connected with 5 volt in Arduino, the GND was connected with ground in Arduino and the signal connect with pin (13) in Arduino, the right IR sensor connected with the Arduino in 3 point VCC and GND in5 volt and GND respectively and signal was connected with pin (10).The Figure 4.6 below show the connection of IR sensor with Arduino.

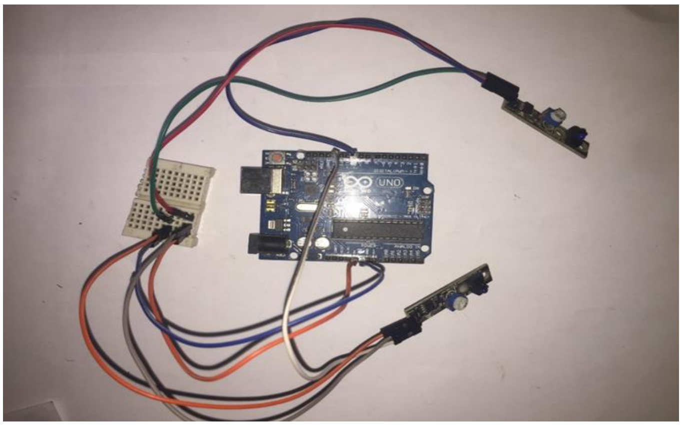


Figure 4.6: Connecting IR with Arduino

ii. Ultrasonic consist from 4 pins the VCC connected with 5 volt, the GND connected with GND, ECHO pin connected with pin (7) in Arduino and the TRIG connected with pin (8).The Figure 4.7 below show the connection of ultrasonic with Arduino.

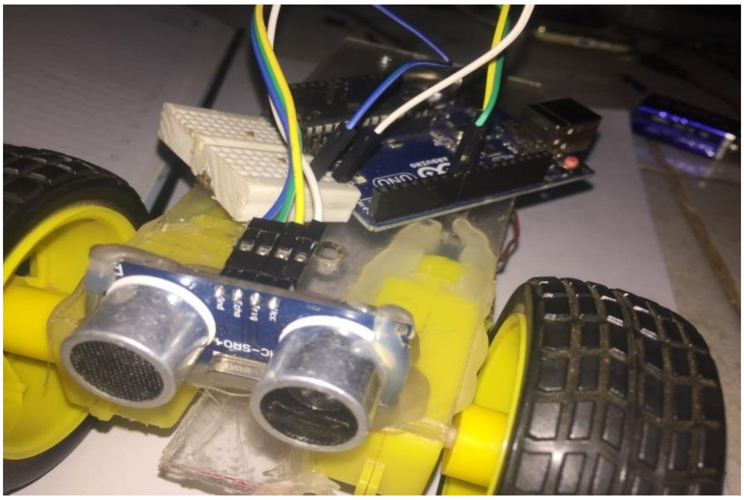


Figure 4.7: Connecting ultrasonic with Arduino

B. Processing devices :

The processing device receives signals from the input devices and processed it to give an output pulses to output devices.

i. The IC driver had been connected to the board and it receives a pulse from Arduino and control the DC motors. The Figure 4.8 show the connection of the board and driver.

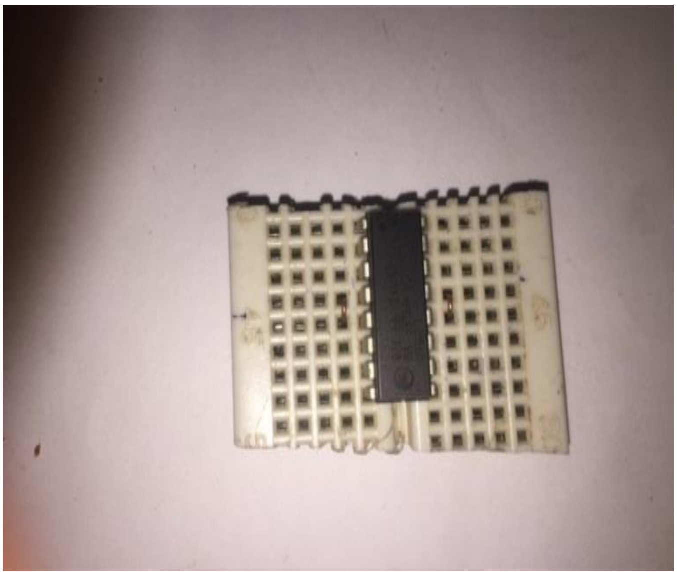


Figure 4.8: Connecting the driver to the board

ii. The driver connect with Arduino, in driver pin (4,5) and pin (12,13) had been shorted and connected with GND pin in Arduino, pin(9,16,1) in driver had been shorted and connect with 5 volt in Arduino, pin(8) in driver connected with 9 volt (Battery) that shown in Figure 4.9.

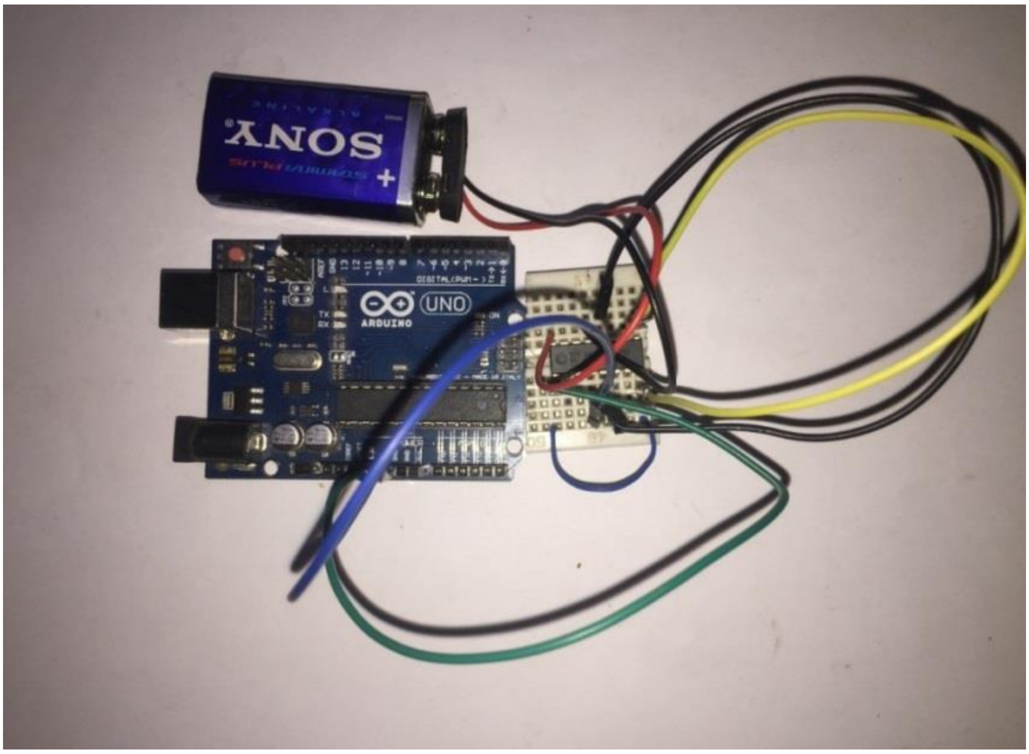


Figure 4.9: Connecting the driver with Arduino

C. Output device :

The output devices consist of two DC motors and led:

i. There are two DC motors connected with driver and Arduino, pin (3) in digital side of Arduino connected with pin (7) in driver, pin (4) in Arduino with pin (10).

ii. The left motor, the VCC of it was connected with pin (6) in driver and GND of the motor connected with GND in board. The right motor, the VCC of it was connected with pin (11) in driver and GND of the motor connected with GND in board. The Figure 4.10 below show the connected of the driver with two motors.

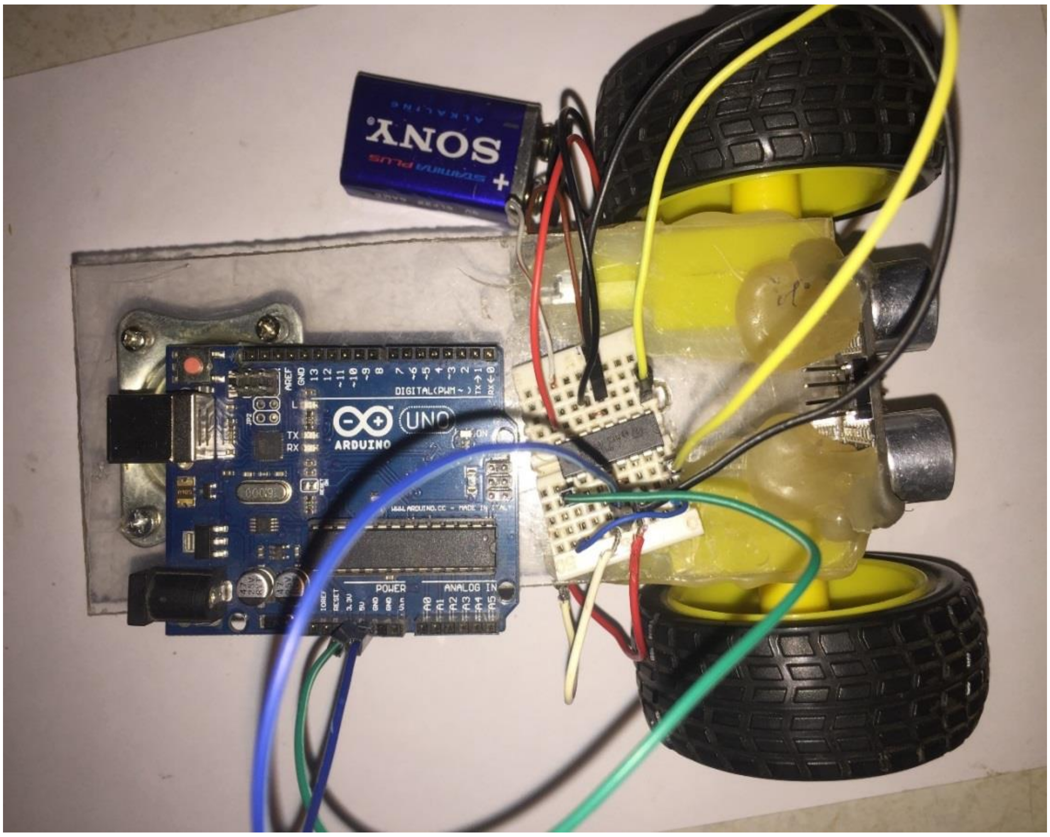


Figure 4.10: Connection of the motor with Arduino

iii. LED (door) was connected with resistance (310 ohm) in series and had been set on Arduino in pin (12) and the other terminal connected with GND that was showing in Figure 4.11 below.

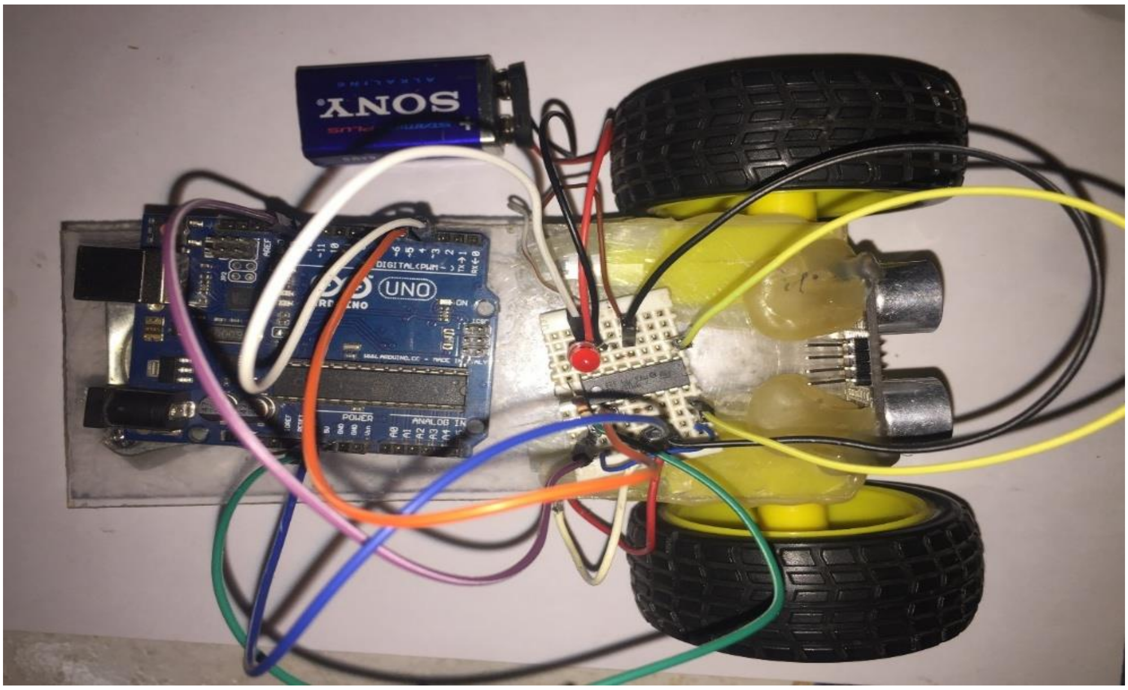


Figure 4.11: Connecting the LED to the system

The Figure 4.12 below shows the all hardware connection of the system.

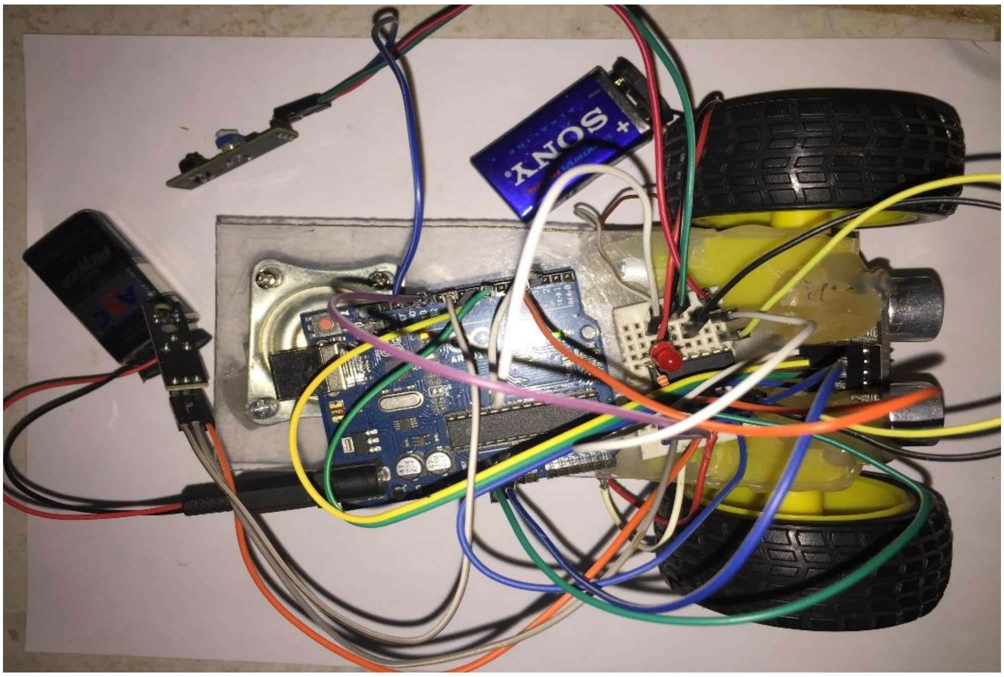


Figure 4.12: All hardware connections

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The design of the smart train system, which was represented by a small car with three wheels consisting of control circuits and a set of components that perform according to the work theory assigned to each component, was completed. The track that was designed according to the line flower technic was instead of the iron track and thus reduce the cost .The system nutrition is entirely dependent on electricity supply (renewable energy sources) that reduce the pollution caused by fuel combustion. The main objective of the project is to reduce traffic congestion within cities and to implement this system in a wider manner this problem can be overcome. The provision of fast and safe transportation at a lower economical cost depends entirely on the presence of a source of electrical effort with a city infrastructure to help establish the safe path. We encountered many difficulties in establishing this system because there are not enough sources of information and previous studies related to this type of system.

5.2 Recommendations

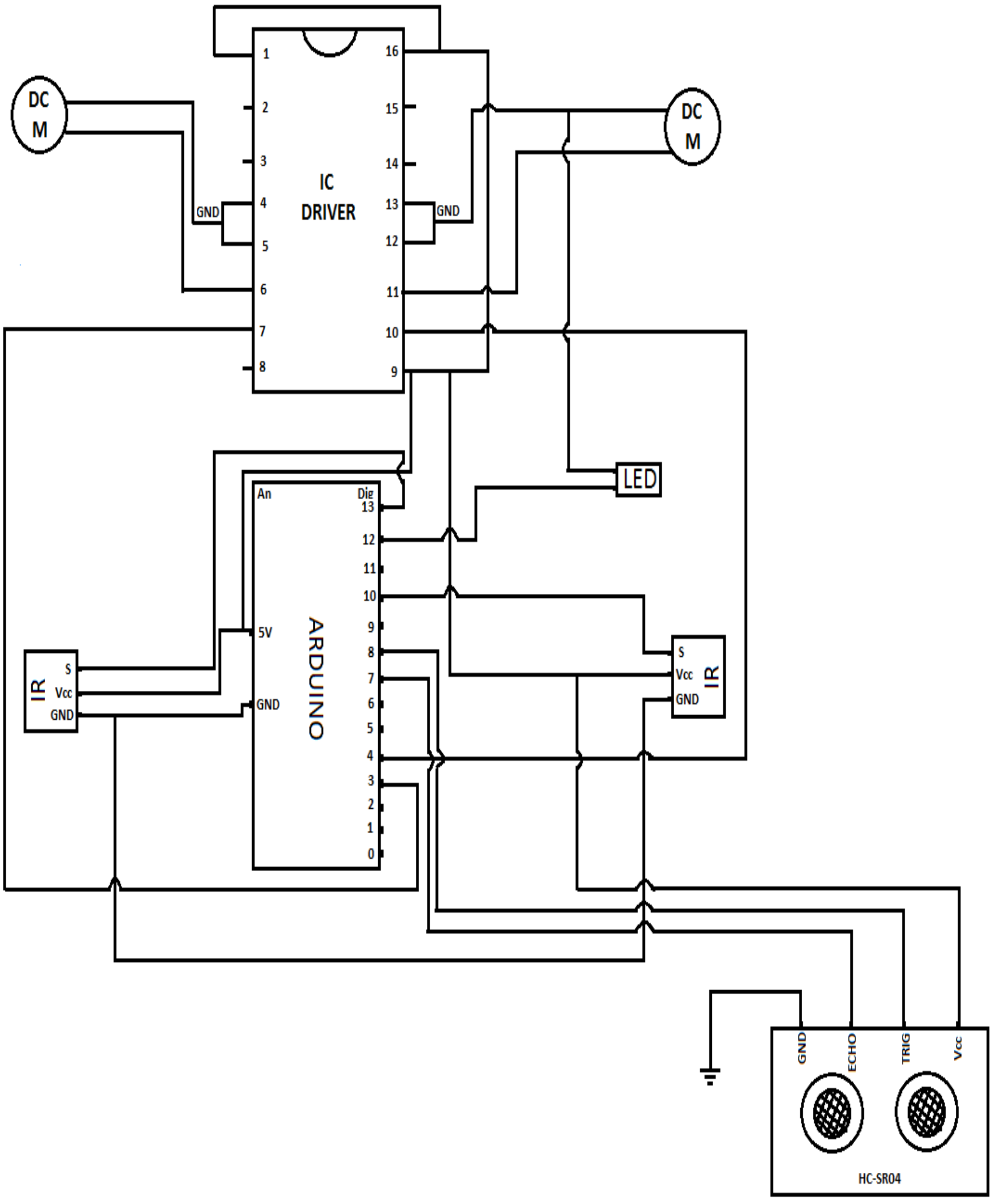
- After studying this project very carefully we recommend.
- Representing the program with simulator.
- Solve the problem of not being able to move smoothly in curves.
- Develop a complete scheme for system protection and safety.

REFERENCES

1. Yang, L.-f., J.-h. Xu, and P. Neuhausler, Electric vehicle technology in China: An exploratory patent analysis. World Patent Information, 2013. 35(4): p. 305-312.
2. Vanca, L., The Stourbridge Lion: America's First Locomotive. School Library Journal, 2012. 58(8): p. 95-95.
3. Mueller, M., Electric Trains and Trolleys (1800-Present)/The Railroad Comes to America (1820s-1830s)/The Birth of the Locomotive (1780s-1820s). School Library Journal, 2013. 59(3): p. 178-178.
4. MacKenzie, I.S. and R.C.W. Phan, The 8051 microcontroller. 4th ed. 2007, Upper Saddle River, N.J.: Pearson/Prentice Hall. xiv, 537 p.
5. Barrett, S.F., Arduino microcontroller processing for everyone! Third edition. ed. Synthesis lectures on digital circuits and systems,. 1 PDF (xx, 493 pages).
6. Ribaric, T. and J. Younker, Arduino-enabled Patron Interaction Counting. Code4Lib Journal, 2013(20): p. 1-1.
7. The Bibliography of New Scholarly Books: ELECTRICAL ENGINEERING, ELECTRONICS, NUCLEAR ENGINEERING. Reference & Research Book News, 2012. 27(5): p. 276-283.
8. Moravec, H.P., Sensor fusion in certainty grids for mobile robots. AI Magazine, 1988. 9(2): p. 61-74.
9. INDUSTRIAL ULTRASONIC INSPECTION Levels 1 and 2. Kirkus Reviews, 2017. 85(11): p. 383-383.
10. Monk, S., The TAB book of Arduino projects : 36 things to make with shields and protoshields. Tab electronics. 2015, New York: McGraw-Hill Education. xxx, 361 pages.

APPENDIX A

Circuit Diagram for the Real Connection



APPENDIX B

Arduino Microcontroller Code for Smart Electrical Train Operation

```
#define echoPin 7
#define trigPin 8
int maximumRange =400;
int minimumRange = 0;
long duration, distance;

int s1=10;
int s2=13;
int m1=3;
int m2=4;
int x1;
int x2;
int led = 12;
void setup() {

Serial.begin(9600);
 pinMode(s2, INPUT);
 pinMode(m2, OUTPUT);
  pinMode(m1, OUTPUT);
  pinMode(s1, INPUT);
   pinMode(led, OUTPUT);

   pinMode(trigPin, OUTPUT);
   pinMode(echoPin, INPUT);
```

```
  digitalWrite(led, LOW);
}

void loop() {

 digitalWrite(trigPin, LOW);
  digitalWrite(trigPin, HIGH);
  digitalWrite(trigPin, LOW);
  duration = pulseIn(echoPin, HIGH);

  distance = duration / 58.2;

  if (distance < 15) {
    digitalWrite(m1, LOW);
    digitalWrite(m2, LOW);
     }
     else {
x1 = digitalRead(s1);
x2 = digitalRead(s2);

if (x1 == 1 && x2 == 1)
{ digitalWrite(m1, LOW);
digitalWrite(m2, LOW);
digitalWrite(led, HIGH);
delay(3000);
analogWrite(m1,120);
analogWrite(m2,120);
digitalWrite(led, LOW);
```

```
 }
else {
  if(x1 == 1)

{digitalWrite(m1,LOW);}
else
{analogWrite(m1,120);}
if(x2 == 1)
{digitalWrite(m2,LOW);}
else
{analogWrite(m2,120);}
}
    }

}
```