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**Sudan University of Sciences and Technology**

**College of Engineering**

**Electrical Engineering**

**Design and Implementation of Non-  
Stopping Electric Train System**

تصميم وتنفيذ نظام قطار كهربائي لا يتوقف

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

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## الآية

قال تعالى:

(وَلَقَدْ كَرَّمْنَا بَنِي آدَمَ وَحَمَلْنَاهُمْ فِي الْبَرِّ وَالْبَحْرِ وَرَزَقْنَاهُمْ مِنَ  
الطَّيِّبَاتِ وَفَضَّلْنَاهُمْ عَلَى كَثِيرٍ مِمَّنْ خَلَقْنَا تَفْضِيلاً )

صِدْقَةُ اللَّهِ الْعَظِيمَةُ

(سورة الإسراء 70)

## **DEDICATION**

As well as everything that we do, we would be honor to dedicate this work to our parents for their emotional and financial support, our brothers, our sisters and our friends whose affection, love, encouragement and prays in days and nights make us able to get such success and honor. Without their love and support this project would have never been made possible.

## **ACKNOWLEDGEMENT**

First and above all, we praise God, the almighty for providing us this opportunity, and granting us the capability to proceed successfully. Grateful for this opportunity, we would like to give our sincere thanks to our supervisor, **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 assistant and dedicated involvement in every step throughout the process, this project would have never been accomplished.

# ABSTRACT

This project concerned with study and design of electric train system work inside large cities without stopping in the stations but decrease its speed only. The passengers get up the train and left it automatically by connector cabins. The main goal of this project is to gain the lost time due to frequent stopping at the stations, also provide sufficient time for passengers to get up or left the train without congestion and save the lost power due to stop and start. The challenge is to design a model to perform the same tasks. When the train enter the station, the connector cabin separate from the train and run on the platform railway and stop by the electromagnetic brake. The lifting cabin will be in the end of the platform it will connect to the train by electromagnetic brake. The result of this thesis modify the train body, design connector cabins, build an elevated platform in the station to exchange the connector cabins between the train and the station.

A control circuit was designed. Components used in the design and the implementation of the system are Arduino Uno controller, limit switches, DC motor, L239D Motor drivers and Relays. The Arduino C programming language has been used for programming the system, and Proteus simulation program has been used for circuit's simulation. The practical tests showed that the non-stopping electric train works as planned.

## مستخلص

يُعنى هذا المشروع بدراسة وتصميم نظام قطار كهربائي يعمل كوسيلة نقل داخل المدن الكبيرة دون الحاجة للتوقف عند المحطات ويكتفي بتقليل سرعته فقط. صعود الركاب ومغادرتهم للقطار تتم آليا عن طريق القاطرة الوصلة، الهدف الأساسي من هذا المشروع هو تصميم قطار كهربائي يمكن من كسب الوقت الضائع نسبة للوقوف المتكرر وتوفير وقت كافي لصعود ونزول الركاب دون إزدحام وكسب الطاقة المهدرة بسبب التوقف والإقلاع المتكرر، يتمثل التحدي في كيفية تصميم نموذج يؤدي المهام السابقة. عند دخول القطار للمحطة، تنفصل القاطرة الوصلة عن القطار وتسير على سكة المنصة وتتوقف عند تفعيل الكابحة المغنطيسية. القاطرة المغادرة تكون في نهاية المنصة وتتصل بالقطار عن طريق الكابحة المغنطيسية. نتيجة لهذا المقترح تم التعديل في هيكل القطار وتصميم قاطرات وصله وبناء منصة علوية في المحطة لتقوم بتبديل القاطرة الوصلة بين القطار والمحطة.

صُممت دائرة التحكم للنموذج المصغر لهذا النظام باستخدام متحكم من نوع Arduino Uno وحساس مفتاح نهاية الشوط لأغراض التحكم، محرك تيار مستمر، مرحل و L239D Motor drivers . اللغة المستخدمة في البرمجة هي Arduino C. إستخدم برنامج Proteus لعمل محاكاة للدائرة الكهربائية للنظام وأظهرت نتائج الإختبارات العملية أن النظام يعمل بشكل جيد كما مخطط مسبقا.

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## **LIST OF ABBREVIATIONS**

AC	Alternating Current
ADC	Analog to Digital Converter
ATO	Automatic Train Operation
ATX	Advanced Technology Extended
COM	Common
CPU	Central Processing Unit
DAC	Analog to Digital Converter
DC	Direct Current
DTO	Driverless Train Operation
GND	Ground
GoA	Grads of Automation
IC	Integrated circuit
LED	Light Emitting Diode
NC	Normally Close
NO	Normally Open
PC	Personal Computer
RAM	Random Access Memory
ROM	Read Only Memory
STO	Semi-automation Train Operation
USB	Universal Serial Bus
UTO	Unattended Train Operation

# **CHAPTER ONE**

## **INTRODUCTION**

### **1.1 General**

In recent years, trains are considered the most important means of transport within large cities due to the congestion of cities by cars. Electric trains were created to help people to transport faster, easily and with minimum risk for their lives.

The system under design is nonstop electric train. In this system an additional cabins (connector cabins) added to the train system with suitable station design to make the train not need to stop in the stations to carry the passengers or allow them to leave, These two processes are automated by connector cabin to carry the passengers from the train to the station and vice versa. This system provides the power consumed by the train and keep more time to the people.

### **1.2 Problems Statement**

The Electric Train that work inside the large cities have frequent stopping, this frequent stopping causes many problems, when the train starts running after each stopping it take high current from the supply because of suddenly load, this currents value increases with the high load, furthermore if this current is higher than the motors rated current it will damage the motors coils. The frequent stopping by a mechanical brake causes a great fraction that will make great corrosion in wheels and increase the needing of maintenance. Because the time is priceless, losing time is main problem. The passengers always lose a lot of time when the train stopping at any station to get passengers for example if there is a passenger want to go from station one to station four he will lose a time because of stopping in station two and three. Another problem the limited time which gives to the passengers for entering and leaving cause crowding in the train doors.

## **1.3 Objectives**

The main objectives of this study are to:

- Design a control circuit for nonstop electrical train.
- Design braking system.
- Simulate the control circuit.
- Implement and test of proposed control system.

## **1.4 Methodology**

- Study all of previous studies.
- Build the model by using arduino microcontroller.
- Arduino C language is used to program the arduino.
- Proteus software is used for simulation.

## **1.5 Project Layout**

The project consists of five chapters: Chapter One presents an introduction to the principles of the project, project motivation and objectives. Chapter Two consists of theoretical background of automatic control, electric train, automatic train, microcontroller system and electromagnetic braking. Chapter Three concerns with system software and hardware. Chapter Four presents the practical side of the project deals with the system fabrication and the system control circuit implementation. Finally, Chapter Five presents a conclusion and recommendations for future works.

# **CHAPTER TWO**

## **THEORETICAL BACKGROUND and LITERATURE REVIEW**

### **2.1 Control System**

Automatic control system is integral part of modern society [1]. The technological Explosion of the twentieth century , which was accelerated by the advent of computers and control systems has resulted in tremendous advance in the field of science. The automatic control system and computer permeate life in all advanced societies today ; these control system and computer have acted and are acting as catalysts in Promoting progress and development. Technological developments have made possible high speed bullet trains; exotic vehicles capable of exploration of other planets and outer space; the establishment of the alpha space station, safe, comfortable , and efficient automobiles. The successful operation of all of this system depends on the proper functioning of the large number of A control system control system used in such ventures [2].

is a device, or set of devices, that manages, commands, directs or regulates the behavior of other devices or systems. Industrial control systems are used in industrial production for controlling equipment or machines [1].

There are two common classes of control systems, open loop control systems and closed loop control systems. In open loop control systems output is generated based on inputs. In closed loop control systems current output is taken into consideration and corrections are made based on feedback. A closed loop system is also called a feedback control system.

### 2.1.1 Historical review

The first significant work in automatic control was James Watt's Centrifugal governor for the speed control of a steam engine in the eighteenth century. Other significant works in the early stages of development of control theory were due to Minor sky, Hazen and Nyquist among many others. In 1922, Minor sky worked on automatic controllers for steering ships and showed how stability could be determined from the differential equations describing the system. In 1932, Nyquist developed a relatively simple procedure for determining the stability of closed-loop systems on the basis of open-loop response to steady-state sinusoidal inputs.

A significant date in the history of automatic feedback control systems is 1934, when Hazen's paper "Theory of Servomechanisms" was published in the Journal of the Franklin Institute, marking the beginning of the very intense interest in this new field. It was in this paper that the word servomechanism originated, from the words servant (or slave) and mechanism.

During the decade of the 1940s frequency response methods (especially the Bode diagram methods due to Bode) made it possible for engineers to design linear closed loop control systems that satisfied performance requirements. From the end of the 1940s to the early 1950s the root-locus method due to Evans was fully developed. The frequency-response and root-locus methods, which are the core of classical control theory, lead to systems that are stable and satisfy a set of more or less arbitrary performance requirements. Such systems are, in general, acceptable but not optimal in any meaningful sense.

Classical control theory, which deals only with single input single output systems, becomes powerless for multiple input multiple output systems. Since about 1960, because the availability of digital computers made possible time domain analysis of complex systems, modern control theory, based on time domain analysis and synthesis using state variables, has been developed to cope

with the increased complexity of modern plants and the stringent requirements on accuracy, weight, cost in military, space and industrial applications [4].

### **2.1.2 Open-loop systems**

A generic open-loop system starts with a subsystem called an input transducer, which converts the form of the input to that used by the controller. The controller drives a process or a plant. The input is sometimes called the reference, while the output can be called the controlled variable. Other signals, such as disturbances, are shown added to the controller and process outputs via summing junctions, which yield the algebraic sum of their input signals using associated signs [1].

In an open-loop control system the output is neither measured nor fed back for comparison with the input. In any open-loop control system the output is not compared with the reference input. Thus, to each reference input there corresponds a fixed operating condition; as a result, the accuracy of the system depends on calibration. In the presence of disturbances, an open-loop control system will not perform the desired task. Open-loop control can be used, in practice, only if the relationship between the input and output is known and if there are neither internal nor external disturbances. Clearly, such systems are not feedback control systems. Note that any control system that operates on a time basis is open loop. For instance, traffic control by means of signals operated on a time basis is another [3].

### **2.1.3 Closed-loop (feedback control) system**

The disadvantages of open-loop systems, namely sensitivity to disturbances and inability to correct for these disturbances, may be overcome in closed-loop systems, the input transducer converts the form of the input to the form used by the controller. An output transducer, or sensor, measures the output response and converts it into the form used by the controller. For example, if the controller uses electrical signals to operate the valves of a temperature



control system, the input position and the output temperature are converted to electrical signals. The closed-loop system compensates for disturbances by measuring the output response, feeding that measurement back through a feedback path, and comparing that response to the input at the summing junction. If there is any difference between the two responses, the system drives the plant, via the actuating signal, to make a correction. If there is no difference, the system does not drive the plant, since the plant's response is already the desired response.

Closed-loop systems, have the obvious advantage of greater accuracy than open-loop systems. They are less sensitive to noise, disturbances, and changes in the environment. Transient response and steady-state error can be controlled more conveniently and with greater flexibility in closed-loop systems, often by a simple adjustment of gain (amplification) in the loop and sometimes by redesigning the controller [3].

#### **2.1.4 Advantages of control system**

With control systems we can move large equipment with precision that would otherwise be impossible. We can point huge antennas toward the farthest reaches of the universe to pick up faint radio signal controlling these antennas by hand would be impossible. Because of control systems, elevators carry us quickly to our destination, automatically stopping at the right floor. We alone could not provide the power required for the load and the speed; motors provide the power, and control systems regulate the position and speed [1].

## **2.2 Electric Train**

An electric locomotive is a railway vehicle that can move along rails and push or pull a train attached to it using electric power drawn from an external source, usually from overhead cables or third rail. Or on-board energy storage such as a battery or fuel cell. Electric locomotives with on-board fuelled prime movers,

such as diesel engines or gas turbines, are classed as diesel-electric or gas turbine-electric locomotives because the electric generator/motor combination serves only as a power transmission system. Electricity is used to eliminate smoke and take advantage of the high efficiency of electric motors, but the cost of electrification means that usually only heavily used lines can be electrified. In general electric locomotives are of three types those which can work on DC, AC or on both (AC/DC – Bi-current).

One advantage of electrification is the lack of pollution from the locomotives. Electrification results in higher performance, lower maintenance costs and lower energy costs. Power plants, even if they burn fossil fuels, are far cleaner than mobile sources such as locomotive engines. The power can come from clean or renewable sources, including geothermal power, hydroelectric power, nuclear power, and solar power and wind turbines [5].

Electric locomotives are quiet compared to diesel locomotives since there is no engine and exhaust noise and less mechanical noise. The lack of reciprocating parts means electric locomotives are easier on the track, reducing track maintenance. Power plant capacity is far greater than any individual locomotive uses, so electric locomotives can have a higher power output than diesel locomotives and they can produce even higher Short-term surge power for fast acceleration. Electric locomotives are ideal for commuter rail service with frequent stops.

### **2.2.1 History**

The first known electric locomotive was built in 1837 by chemist Robert Davidson of Aberdeen. It was powered by galvanic cells (batteries). Davidson later built a larger locomotive named Galvani, exhibited at the Royal Scottish Society of Arts Exhibition in 1841. The seven-ton vehicle had two direct-drive reluctance motors, with fixed electromagnets acting on iron bars attached to a wooden cylinder on each axle, and simple commutators [6]. It hauled a load of six tons at four miles per hour for a distance of one and a half miles. It was tested

on the Edinburgh and Glasgow Railway in September of the following year, but the limited power from batteries prevented its general use. It was destroyed by railway workers, who saw it as a threat to their security of employment [7].

The first electric passenger train was presented by Werner von Siemens at Berlin in 1879. The locomotive was driven by a 2.2 kW, series-wound motor, and the train consisting of the locomotive and three cars, reached a speed of 13 km/h. During four months, the train carried 90,000 passengers on a 300-metre-long circular track. The electricity (150V DC) was supplied through a third insulated rail between the tracks. The electricity (150V DC) was supplied through a third insulated rail between the tracks. A contact roller was used to collect the electricity. The world's first electric tram line opened in Lichterfelde near Berlin, Germany, in 1881. It was built by Werner von Siemens (see Gross-Lichterfelde Tramway and Berlin Straßenbahn). Volk's Electric Railway opened in 1883 in Brighton. Also in 1883, Mödling and Hinterbrühl Tram opened near Vienna in Austria. It was the first in the world in regular service powered from an overhead line. Five years later, in the U.S. electric trolleys were pioneered in 1888 on the Richmond Union Passenger Railway, using equipment designed by Frank J. Sprague [8].

Electric railways use electric locomotives to haul passengers or freight in separate cars or electric multiple units, passenger cars with their own motors. Electricity is typically generated in large and relatively efficient generating stations, transmitted to the railway network and distributed to the trains. Some electric railways have their own dedicated generating stations and transmission lines but most purchase power from an electric utility. The railway usually provides its own distribution lines, switches and transformers.

Power is supplied to moving trains with a (nearly) continuous conductor running along the track that usually takes one of two forms.

The first is an overhead line or catenary wire suspended from poles or towers along the track or from structure or tunnel ceilings. Locomotives or multiple units pick up power from the contact wire with pantographs on their roofs that

press a conductive strip against it with a spring or air pressure. Examples are described later in this article.

The second is a third rail mounted at track level and contacted by a sliding "pickup shoe". Both overhead wire and third-rail systems usually use the running rails as the return conductor but some systems use a separate fourth rail for this purpose. In comparison to the principal alternative, the diesel engine, electric railways offer substantially better energy efficiency, lower emissions and lower operating costs.

Electric locomotives are usually quieter, more powerful, and more responsive and reliable than diesels. They have no local emissions, an important advantage in tunnels and urban areas. Some electric traction systems provide regenerative braking that turns the train's kinetic energy back into electricity and returns it to the supply system to be used by other trains or the general utility grid. While diesel locomotives burn petroleum, electricity is generated from diverse sources including many that do not produce carbon dioxide such as nuclear power and renewable forms including hydroelectric, geothermal, wind and solar.

### **2.2.2 Automatic train**

In metro systems, automatic refers to the process by which responsibility for operation management of the trains is transferred from the driver to the train control system. There are various degrees of automation (or Grades of Automation, GoA); these are defined according to which basic functions of train operation are the responsibility of staff, and which the responsibility of the system itself are. For example, a Grade of Automation 0 would correspond to on-sight operation, like a tram running on street traffic. Grade of Automation 4 would refer to a system in which vehicles are run fully. According to the International Association of Public Transport, there are five Grades of Automation (GoA) of trains:

GoA 0 is on-sight train operation, similar to a tram running in street traffic  
GoA 1 is manual train operation where a train driver controls starting and stopping, operation of doors and handling of emergencies or sudden diversions.

GoA 2 is semi-automatic train operation (STO) where starting and stopping is automated, but a driver operates the doors, drives the train if needed and handles emergencies. Many ATO systems are GoA 2.

GoA 3 is driverless train operation (DTO) where starting and stopping are automated but a train attendant operates the doors and drives the train in case of emergencies.

GoA 4 is unattended train operation (UTO) where starting and stopping, operation of doors and handling of emergencies are fully automated without any on-train staff.

Driverless trains run by computer systems located in a remote control room, laser detectors to pick up the smallest movement on tracks, and advanced control algorithms for best performance.

Train operations become more exact and timely as the automation system controls the trains; the duty of any metro transportation system is to provide secure, consistent, efficient and high-quality service to passengers. As many operators run at or near their capacity limits, automation is often the only way to maximize the operational performance of a metro system. Implemented on existing lines, automation is in many cases more cost-effective than constructing new lines or extending platform. In Kuala Lumpur, Dubai, Tokyo and Copenhagen, fully automated metros have been running for several years. Other major cities across Europe, North America and Asia are following the example and have partly automated their systems.

The move to train automation can be justified by their numerous benefits: Schedules of train operations become more exact and timely, the frequency of the trains can be improved, especially in low traffic hours, as more and shorter trains can be inserted in traffic without the need for more operational staff, and

the enhanced safety, where the element of human error is taken out completely. Besides, automation can reduce the wear-and-tear of train by optimizing energy consumption and potentially reduce operating costs through more effective and regular train operation.

In a fully automatic driving system, care should be taken for all the processes that are normally requiring human intervention. The initial train departure, trips between two stations, timing of train stoppage at individual stations, and controlling the train doors are examples of such processes.

In addition, there are normally more activities that should be automated too. The safety systems represents important activities that driverless trains must have; like fire alarms with automatic fire fighting systems, sensing of any possible damage in the track and providing the information to the next train on the same track as well as to the base [9].

## **2.3 Microcontroller**

A microcontroller is a single-chip computer .Micro suggests that the device is small, and controller suggests that it is used in control applications. Another term for microcontroller is embedded controller, since most of the microcontrollers are built into or embedded in the devices that controlling. Microcontrollers have traditionally been programmed using the assembly language of the target device. Although the assembly language is fast, it has several disadvantages. An assembly program consists of mnemonics, which makes learning and maintaining a program written using the assembly language difficult.

Also microcontrollers manufactured by different firms have different assembly languages, so the user must learn a new language with every new microcontroller he or she uses. Microcontrollers can also be programmed using a high-level language, such as BASIC, PASCAL, or C. High-level languages are much easier to learn than assembly languages and also facilitate the development of large and Complex programs. Microcontroller is a highly

integrated chip that contains Central Processing Unit (CPU), Random Access Memory (RAM), Read Only Memory (ROM) and Input/output ports. Unlike general-purpose computer, which also includes all of these components, microcontroller is designed for a 9 very specific task to control a particular system. As a result, the parts can be simplified and reduced, which cuts down on production cost.

### **2.3.1 Microcontroller components**

A microcontroller basically contains one or more following components:

- Central processing unit

Central Processing Unit is the brain of a microcontroller. CPU is responsible for fetching the instruction, decodes it, and then finally executed. CPU connects every part of a microcontroller into a single system. The primary function of CPU is fetching and decoding instructions. Instruction fetched from program memory must be decoded by the CPU.

- Memory

Memory in a microcontroller is same as microprocessor. It is used to store data and program. A microcontroller usually has a certain amount of RAM and ROM or flash memories for storing program source codes.

- Parallel input/output ports

Parallel input/output ports are mainly used to drive/interface various devices such as LCD'S, LED'S, printers, memories, etc. to a microcontroller.

- Serial interfacing ports

Serial ports provide various serial interfaces between microcontroller and other peripherals like parallel ports.

- Timers and counters

This is the one of the useful function of a microcontroller. A microcontroller may have more than one timer and counters. The timers and counters provide

all timing and counting functions inside the microcontroller. The major 10 operations of this section are perform

Clock functions, modulations, pulse generations, frequency measuring, making oscillations, etc. This also can be used for counting external pulses.

- Analog to digital converter

Analog to Digital Converter (ADC) converters are used for converting the analog signal to digital form. The input signal in this converter should be in analog form (e.g. sensor output) and the output from this unit is in digital form. The digital output can be used for various digital applications (e.g. measurement devices).

- Digital to analog converter

Digital to Analog Converter (DAC) perform reversal operation of ADC conversion. DAC convert the digital signal into analog format. It usually used for controlling analog devices like DC motors, various drives, etc.

- Interrupt control

The interrupt control used for providing interrupt (delay) for a working Program. The interrupt may be external (activated by using interrupt pin) or internal (by using interrupt instruction during programming).

- Special functioning block

Some microcontrollers used only for some special applications (e.g. space systems and robotics) these controllers containing additional ports to perform such special operations. This considered as special functioning block [10].

### **2.3.2 Microcontroller applications**

Microcontrollers are widely used in modern electronic equipment. Some basic applications of microcontroller are given below:

- Used in biomedical instruments.
- Widely used in communication systems.
- Used as peripheral controller in Personal Computer



- Used in robotics.
- Used in automobile fields.

Microcontroller applications found in many lives filed, for example in Cell phone, watch, recorder, calculators, mouse, keyboard, modem, fax card, sound card, battery charger, door lock, alarm clock, thermostat, air conditioner, TV Remotes, in Industrial equipment like Temperature and pressure controllers, counters and timers [10].

## **2.4 Electromagnetic Braking**

Electromagnetic brakes (also called electro\_mechanical brakes) slow or stop motion using electromagnetic force to apply mechanical resistance (friction).the original name was "electromechanically brakes", but over the years the name change to "Electromagnetic brakes" referring to their actuation method. Magnetic braking has dramatically increased in popularity in recent years. Since 1987, numerous articles about magnetic braking were published. These articles describe both experiments dealing with magnetic braking, as well as the theory behind the phenomenon.

Magnetic braking works because of induced currents and Lenz's law. If you attach a metal plate to the end of a pendulum and let it swing, its speed will greatly decrease when it passes between the poles of a magnet. When the plate enters the magnetic field, an electric field is induced in metal and circulating eddy currents are generated. These currents act to oppose the change in flux through the plate, in accordance with Lenz's Law. The currents in turn heat the plate, thereby reducing its kinetic energy. The practical uses for magnetic braking are numerous and commonly found in industry today.

This phenomenon can be used to damp unwanted notations in satellites, to eliminate vibrations in space crafts, and to separate nonmagnetic metals from solid waste [11].

Magnetic braking forms the basis of growing technology. Braking system is generally classified based upon the principle of operation. The principle of braking in road vehicles involves the conversion of kinetic energy into thermal energy (heat). When stepping on the brakes, the driver commands a stopping force several times as powerful as the force that puts the car in motion and dissipates the associated kinetic energy as heat. Ineffective braking results in a lot of accidents. Brakes must be able to arrest the speed of a vehicle in a short period of time regardless how fast the speed is. As a result, the brakes are required to have the ability to generating high torque and absorbing energy at extremely high rates for short periods of time. Brakes may be applied for a prolonged periods of time in some applications such as a heavy vehicle descending a long gradient at high speed. Brakes must have the mechanism to keep the heat absorption capability for prolonged periods of time. The frequency of accidents is now-a-days increasing due to inefficient braking system. Hence braking system needs to be enhanced for effective and efficient braking. These performance of electromagnetic brakes make them much more competitive candidate for alternative retardation equipments compared with other retarders. In this research work, with a view to enhance to the braking system in automobile, a prototype model is created and analyzed. It aims to minimize the brake failure to avoid the road accidents. It also reduces the maintenance of braking system.

An advantage of this system is that it can be used on any vehicle with minor modifications to the transmission and electrical systems. Electromagnetic brakes operate electrically, but transmit torque mechanically. This is why they used to be referred to as electro mechanical brakes. Over the years, EM brakes became known as electromagnetic, referring to their actuation method. Since the brakes started becoming popular over sixty years ago, the variety of applications and brake designs has increased dramatically, but the basic operation remains the same. Single face electromagnetic brakes make up approximately 80% of all of the power applied brake applications. Electromagnetic brakes have

been used as supplementary retardation equipment in addition to the regular friction brakes on heavy vehicle [12].

### **2.4.1 General principle of electromagnetic brake**

The conventional friction brake can absorb and convert enormous energy values, but only on the condition that the temperature of the friction contact materials is controlled. Electromagnetic brakes work in a relatively cool condition and satisfy all the energy requirements of braking at high speeds. Electromagnetic brakes can be applied separately completely without these of friction brakes [13]. Due to their specific method of installation, electromagnetic brakes can avoid problems that friction brakes face as we mentioned before. Typically, electromagnetic brakes have been mounted in the transmission line of vehicles [12]. The propeller shaft is divided and fitted with a sliding universal joint and is connected to the coupling flange on the brake. The brake is fitted into the chassis of the vehicle by means of anti-vibration mounting. The working principle of the electric retarder is based on the creation of eddy currents within a metal disc rotating between two electromagnets, which activate a force opposing the rotation of the disc. If the electromagnet is not energized, the rotation of the disc is unaffected by the retarder and accelerates under the action of the weight to which its shaft is connected. When the electromagnet is energized, the rotation of the disc is retarded and the energy absorbed is converted into heating of the disc. A typical retarder consists of a stator and a rotor. The stator holds induction coils, energized separately in groups (e.g. four coils in a group). The stator assembly is supported through anti-vibration mountings on the chassis frame of the vehicle. The rotor is made up of two discs, which provide the braking force when subject to the electromagnetic influence when the coils are excited [13].

It was found that electromagnetic brakes can develop a negative power which represents nearly twice the maximum power output of a typical engine, and at least three times the braking power of an exhaust brake [12].

By using the electromagnetic brake as supplementary retardation equipment, the friction brakes can be used less frequently, and practically never reach high temperatures. The brake linings last considerably longer before requiring maintenance, and the potential "brake fade" problem can be avoided. In research conducted by a truck manufacturer, it was proven that the electromagnetic brake assumed 80 percent of the duty which would otherwise have been demanded of the regular service brake [13]. On the other hand, the electromagnetic brake prevents the dangers that can arise from the overuse of friction brakes beyond their capability to dissipate heat.

#### **2.4.2 Application of electromagnetic brakes**

In locomotives, mechanical linkage transmit torque to electromagnetic braking component. Trams and trains use electromagnetic tracks where the braking element is pressed by magnetic force to the rail.

They are distinguished from mechanical tracked brakes, where the braking element is mechanically pressed on the rail. Electric motor in industrial and robotic applications also employ electromagnetic brakes recent design innovations have led to the application of electromagnetic brakes to aircraft application [14].

- **Maglev Vehicle**

Magnetic levitation (maglev) is a relatively new transportation technology in which non contacting vehicles travel safely at speeds of 250 to 300 miles-per-hour or higher while suspended, guided, and propelled above a guide way by magnetic fields. The guide way is the physical structure along which maglev vehicles are levitated. Figure 2.1 depicts the three primary functions basic to maglev technology: levitation or suspension, propulsion and guidance. In most

current designs, magnetic forces are used to perform all three functions. There are two primary types of maglev technology: electromagnetic suspension (EMS) and electrodynamic suspension (EDS) [14], as shown in Figure 2.2.

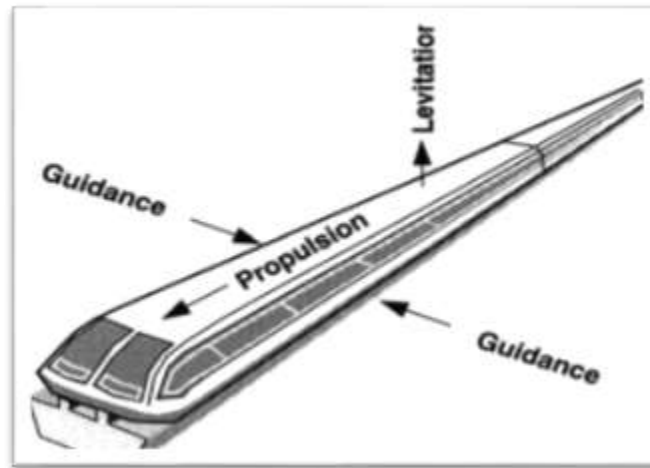


Figure 2.1: Three primary functions basic to maglev technology.

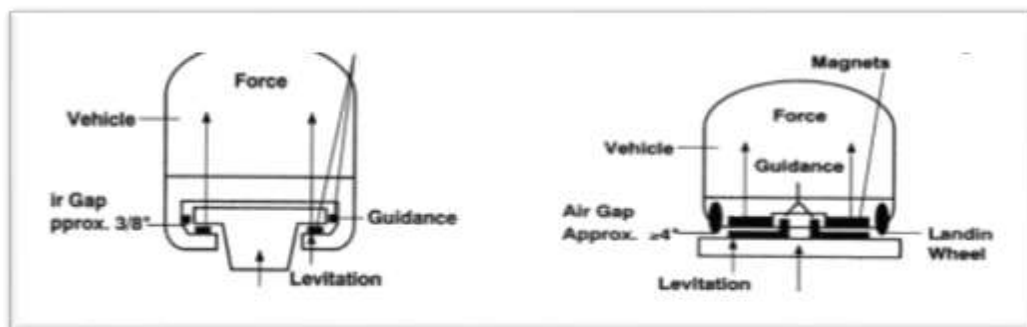


Figure 2.2: EMS and EDS maglev system.

### 2.4.3 Types of electromagnetic brake

There are many types of the brakes ,here we tacked about some of these types:

- **Single face brake**

A friction plate brake uses a single plate. Friction surface to engage the input and output members of the clutch .Single face electromagnetic brakes make up approximately 80% of all the power applied brake applications .

- **Power off brake**

Power off brake stop or hold when electrical power is either accidentally lost or intentionally disconnected. These brakes are typically used on or near an electric motor, typical applications include robotics, holding brakes for Z axis ball screw and servo motor brakes. Brakes are available in multiple voltage and can have either standard backlash or zero backlash huts. there are two types of holding brakes, The first is spring applied brakes. The second is permanent magnet brakes.

- **Eddy currents brakes (magnetic brakes)**

To slow vehicles down, we can use eddy current brakes as shown in Figure 2.3. Eddy current brakes are a relatively new technology that are beginning to gain popularity due to their high degree of safety. Rather than slowing a train via friction, which can often be affected by various elements such as rain, eddy current brakes rely completely on certain magnetic properties and resistance. The linear eddy current brake consists of an electromagnet, which is fixed on a train (vehicle), this electromagnet is held at a definite small distance from the rail (approximately 7 millimeters). When electric current is passed through the electromagnet and the electromagnet is moved along the rail, eddy currents are generated in the rail. These eddy currents generate an opposing magnetic field, providing braking force. The first train in Commercial circulation to use such a braking is the ICE 3.

The eddy current brake does not have any mechanical contact with the rail, and thus no wear and tear of it, and creates no noise. Because the braking force is directly proportional to the speed, the eddy current brake itself can never completely stop a train. It is then often necessary to bring the train to a complete stop with an additional set of fin brakes (friction brakes) or "kicker wheels" which are simple rubber tires that make contact with the train and effectively park it [14].



Figure 2.3: An eddy current brake of an ICE 3.

# CHAPTER THREE

## SYSTEM HARDWARE AND SOFTWARE

### 3.1 System Description

The proposed system consists of the main train, the station and the connector cabin. The block diagram describes sequence of system control operations either to move the connector cabin from the main train to the station or vice versa, the microcontroller receives signal from the limit switch, according to this signal the microcontroller sends two control signals, one to the driver to decrease the DC motor speed and the other to the relay to energize the electromagnetic coil from the power supply +12V, The block diagram in Figure 3.1 shows the sequence of control operations that running in the main train and the station.

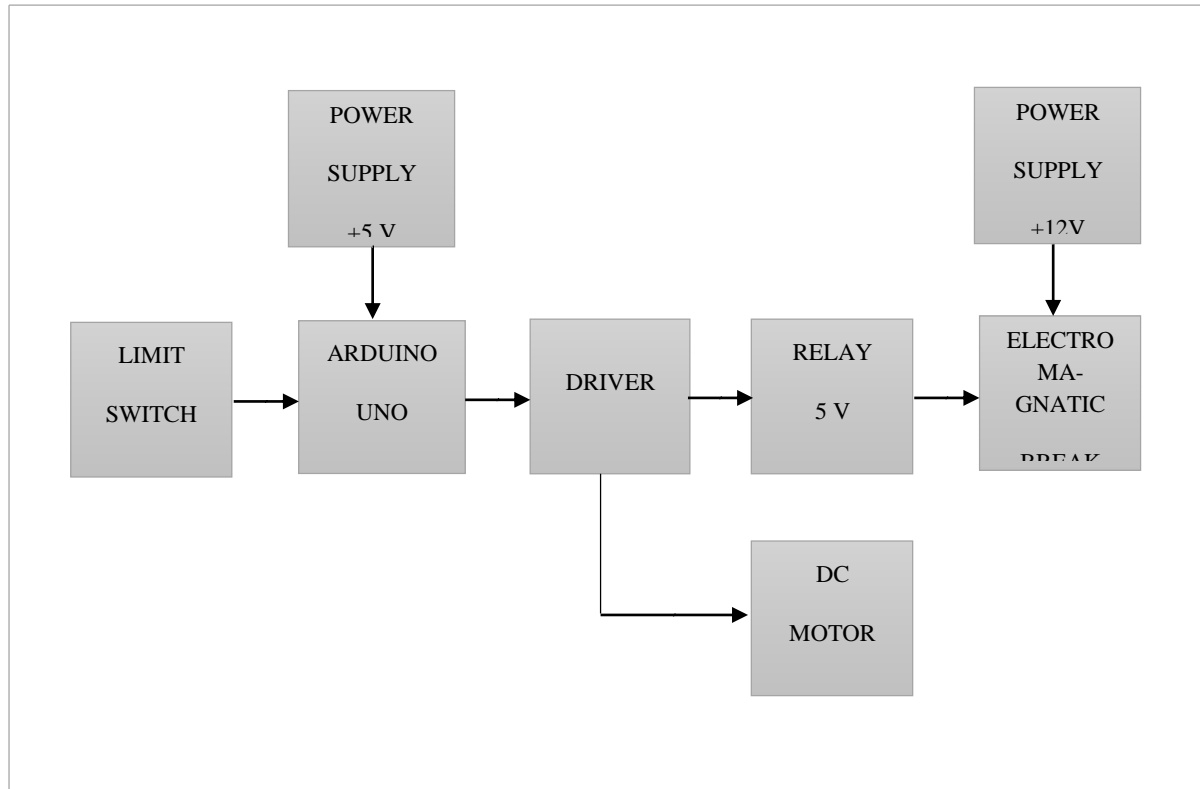


Figure 3.1: System block diagram



## 3.2 System Hardware

The control circuit of proposed system consists of relay, limit switch, L239D Motor driver IC, electromagnetic coil, power supply and arduino uno.

### 3.2.1 Relay

The relay is an automatic protective and switching device which is capable of sensing abnormal conditions in electrical circuits. These are operated to open or close the load contacts in response to one or more electrical quantities like voltage and current. Relays are used in a wide variety of applications like electric power systems, home appliances, automobiles, industrial equipment, digital computers, etc. Electromagnetic relays are those relay which operates on the principle of electromagnetic attraction. It is a type of a magnetic switch which uses the magnet for creating a magnetic field. The magnetic field then uses for opening and closing the switch and for performing the mechanical operation [15]. The electromagnetic relay is shown in Figure 3.2.

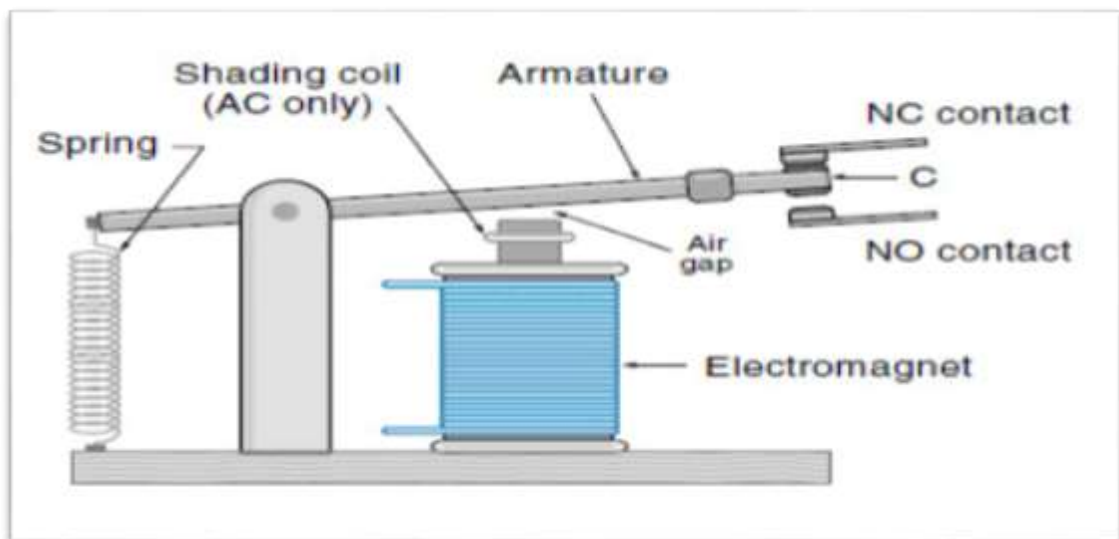


Figure 3.2: Electromagnetic relay constructions

The relay used in this project is 5volt relay as shown in Figure3.3, its one of different types of electromagnetic relay, its working when energize by 5 volt DC and changes the contacts from normal open to normal close and vice versa.



Figure 3.3: 5V Electromagnetic relay

### **3.2.2 Limit switch**

Limit switches are electro-mechanical devices that consist of an actuator mechanically linked to a set of contacts. When an object comes into contact with the actuator, the device operates the contacts to make or break an electrical connection. Limit switches work in a variety of applications and environments because of their ruggedness, simple visible operation, easy installation and reliable operation.

A typical limit switch consists of a switch body and an operating head. The switch body includes electrical contacts to energize and de energize a circuit. The operating head incorporates some type of lever arm or plunger, referred to as an actuator.

The standard limit switch is a mechanical device that uses physical contact to detect the presence of an object (target). When the target comes in contact with the actuator, the actuator is rotated from its normal position to the operating position. This mechanical operation activates contacts within the switch body [16], there are different types of limit switches as shown in Figure 3.4.



Figure 3.4: Types of limit switches

### 3.2.3 L293D motor driver IC

L293D as shown in Figure 3.5 is a typical Motor driver or Motor Driver IC which allows DC motor to drive on either direction. L293D is a 16-pin IC which can control a set of two DC motors simultaneously in any direction. It means that you can control two DC motors with a single L293D IC.

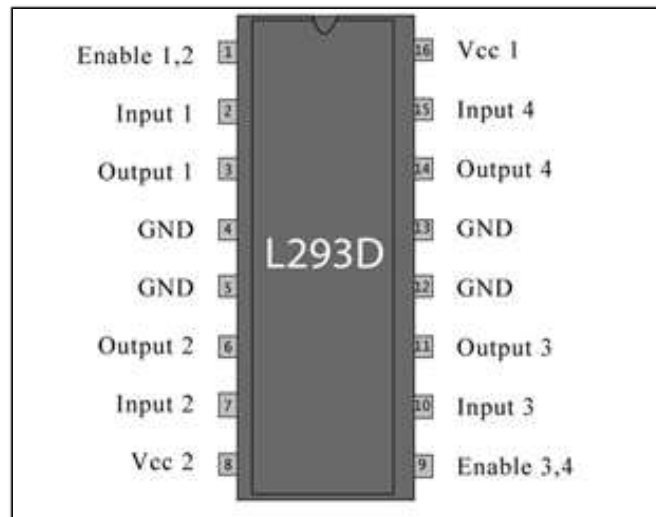


Figure 3.5: L239D Motor driver IC pins

The l293D can drive small and quite big motors as well. It works on the concept of H-bridge. In a single L293D chip there are two h-Bridge circuit inside the IC which can rotate two dc motor independently. Due its size it is very much used in robotic application for controlling DC motors and relay.in this study used to control of speed in DC motor and controlling in relay points.

### 3.2.4 Power supply

A power supply is an electronic device that supplies electric energy to an electrical load. The primary function of a power supply is to convert one form of electrical energy to another and as a result power supplies are sometimes referred as electric power converters. Some power supplies are discrete, stand-alone devices, whereas others are built into larger devices along with their loads. All power supplies have a power input, which receives energy from the energy source, and a power output that delivers energy to the load. Figure 3.6 shows some information about Advanced Technology extended (ATX) computer power supply which used as power supply for feeding the circuit. The ATX is the most common supply out there and is in use in most desktop computers today. Figure 3.7 shows the color code of power supply.



Figure 3.6: Power supply

+3.3V	1	11	+3.3V
+3.3V	2	12	-12V
Common	3	13	Common
+5V	4	14	PS On
Common	5	15	Common
+5V	6	16	Common
Common	7	17	Common
Pwr OK	8	18	-5V
+5V SB	9	19	+5V
+12V	10	20	+5V

Figure 3.7: Wire color code

### 3.2.5 Arduino uno

Arduino is a small microcontroller board with a 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.

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

As shown in Figure 3.8 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 interactive 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, as shown in Figure 3.9.

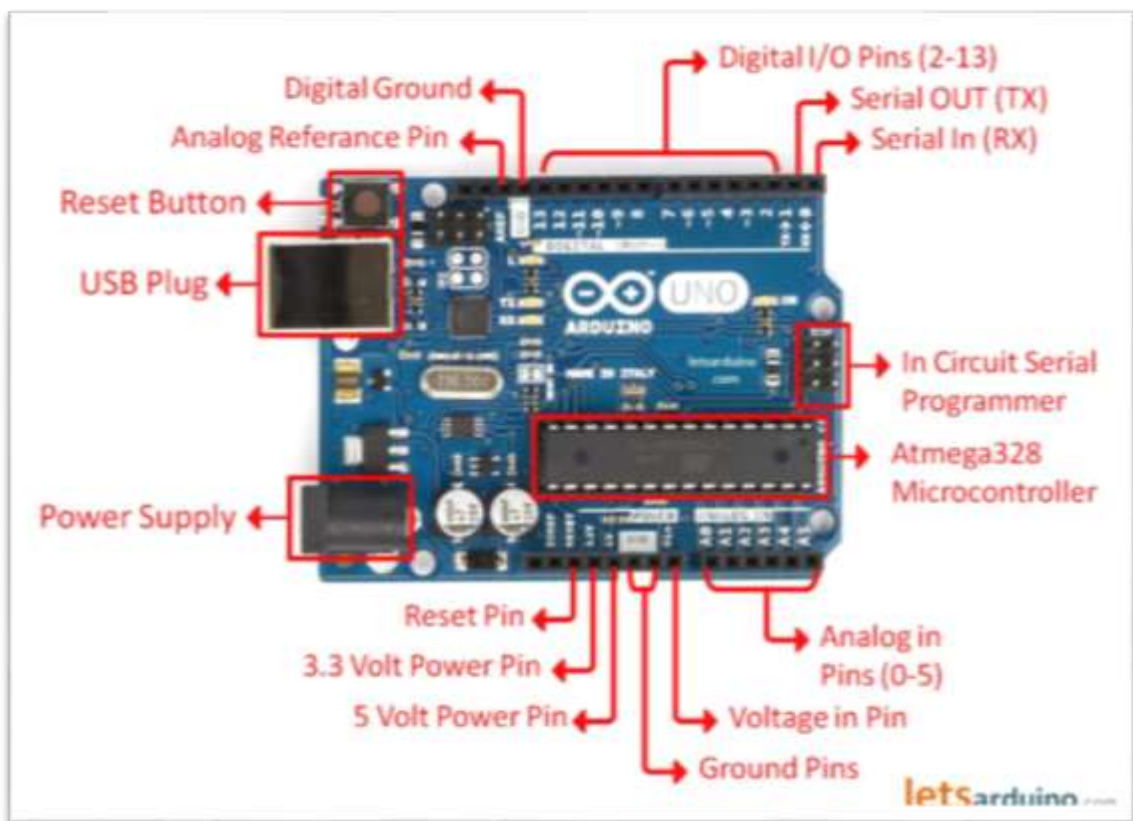


Figure 3.8: Open source arduino board



Figure 3.9: The size of Arduino.

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. For example, artists have created installations with patterns of blinking lights that respond to the movements of passers-by, high school students have built autonomous robots that can detect an open flame and extinguish it, and geographers have designed systems that monitor temperature and humidity and transmit this data back to their offices via text message. In fact, there are infinite numbers of examples with a quick search on the Internet .By taking a quick tour of the Uno Starting at the left side of the board there are two connectors, On the far left is the Universal Serial Bus (USB) connector .This connects the board to the computer for three reasons; to supply power to the board, to upload the instructions to the Arduino, and to send and receive from a computer. On the right is the power connector, this connector can power the Arduino with a standard mains power adapter.

At the lower middle is the heart of the board: the microcontroller, the microcontrollers represent the “brains” of the Arduino. It is a tiny computer that contains a processor to execute instructions, includes various types of memory to hold data and instructions from the sketches, and provides various avenues of sending and receiving data. Just below the microcontroller are two rows of small sockets, the first row offers power connections and the ability to use an external RESET button. The second row offers six analog inputs that are used to measure electrical signals that vary in voltage. Furthermore, pins A4 and A5 can also be used for sending data to and receiving it from other devices. Along the top of the board are two more rows of sockets, Sockets (or pins) numbered 0 to 13 are digital input/output (I/O) pins. They can either detect whether or not an electrical signal is present or generate a signal on command. Pins 0 and 1 are also known as the serial port, which is used to send and receive data to other devices, such as a computer via the USB Connector circuit. The pins labelled with a tilde (~) can also generate a varying electrical signal, which can be useful for such things as creating lighting effects or controlling electric motors. Next are some very useful devices called light-emitting diodes (LEDs); these very tiny devices light up when a current passes through them. The Arduino board has four LEDs: one on the far right labelled ON, which indicates when the board has power, and three in another group, The LEDs labelled TX and RX light up when data is being transmitted or received between the Arduino and attached devices via the serial port and USB. The L-LED connected to the digital I/O pin number 13. The little black square part to the left of the LEDs is a tiny microcontroller that controls the USB interface that allows Arduino to send data to and receive it from a computer. And, finally, the RESET button.



### 3.3 System Software

The algorithmic flow chart of the proposed system presents a brief explanation of the system.

#### 3.3.1 System flow chart

Figure 3.10 shows the flow chart which represent the control operation that running in the main train and the station.

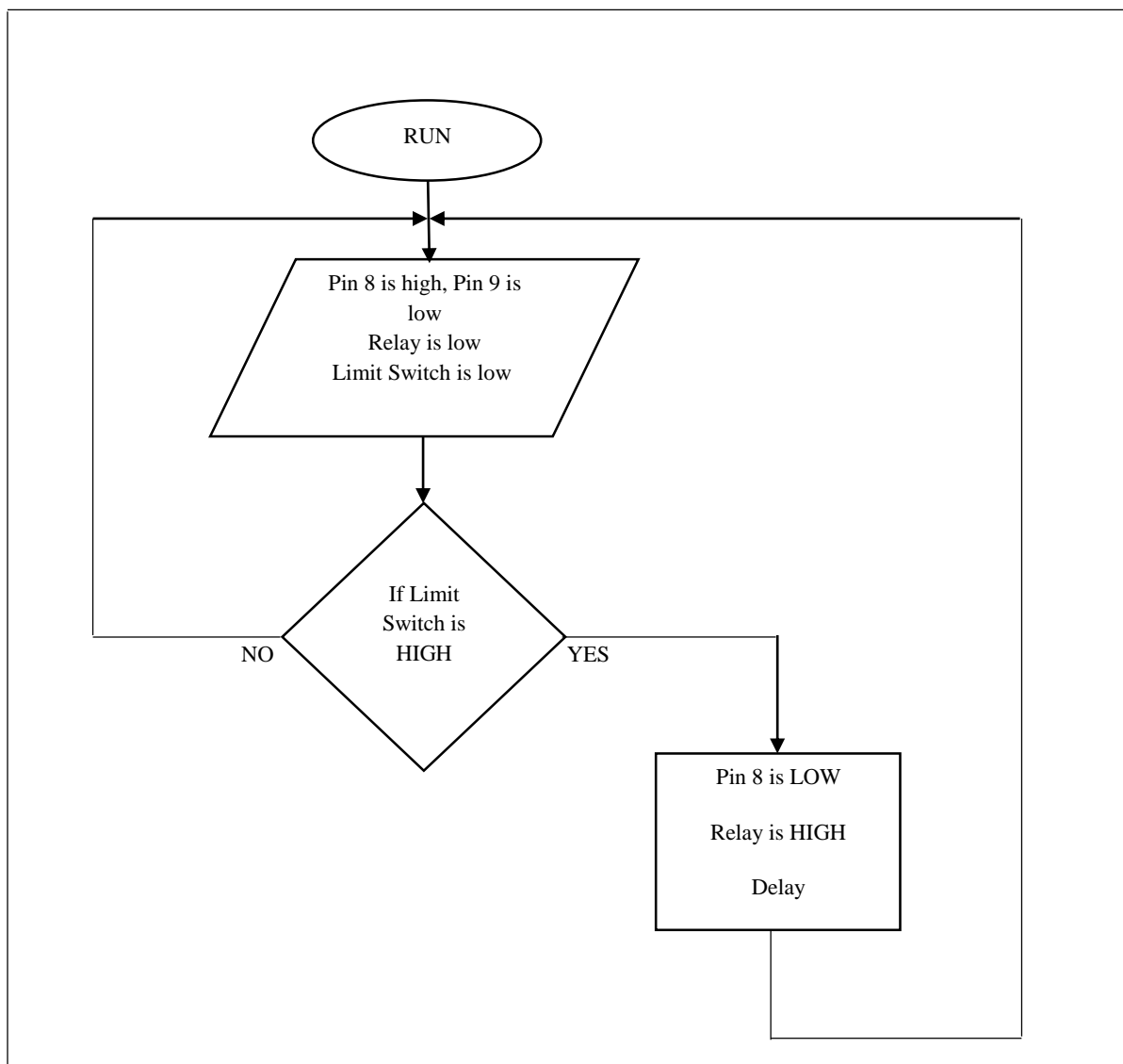


Figure 3.10: System flow chart

### 3.3.2 System code

The Arduino C programming language has been used for programming the system.

The Arduino code was compiled with the Arduino to execute the sequence commands of the control operation. The code is shown in the appendix.

### 3.3.3 Wire diagram

Wire diagram is network of wires showing how the circuit components connected, It explains the signals requirement for the movability and the ON-OFF control, also it declare the power feeding lines for the circuit. Wire diagram describe how all wires connected between the system circuit components. Microcontroller pins used for receives signal from the limit switch and sends signal to the driver, driver receives signal with two wires from microcontroller pins to perform the control speed of the DC motor and control of magnetic brake (active, inactive) by changing the relay points (NO, NC) also drivers receive power from power supply with two wires, one is the (+12V) DC and the other is ground as shown in Figure 3.11.

This diagram represent the control operation that running in the main train and the station.

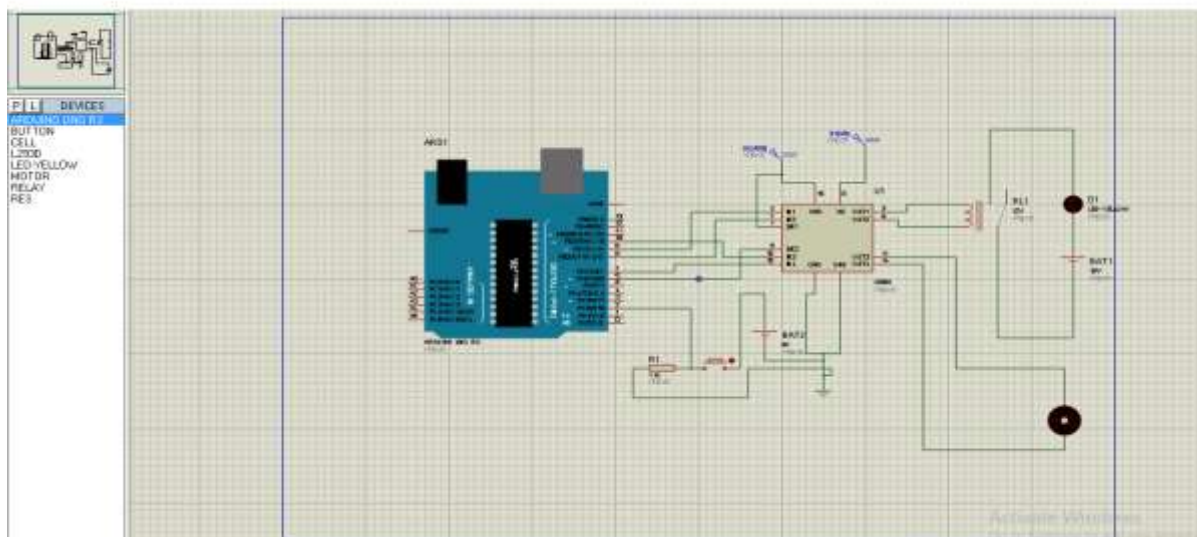


Figure 3.11: Wire diagram

# CHAPTER FOUR

## SYSTEM IMPLEMENTATION

### 4.1 System Fabrication

According to the system working techniques the system's components (station, train and the connector cabin) had been fabricated to get the best performance.

#### 4.1.1 The station

The station was fabricated by adding an elevated platform built from two wooden shelves there length 35 cm with height 12 cm fixed in parallel with main railway and the space between them 8 cm, there is an auxiliary railway inserted on the platform as a track for connector cabin movement, also there is an electromagnetic coil fixed above the platform as shown in Figure 4.1.

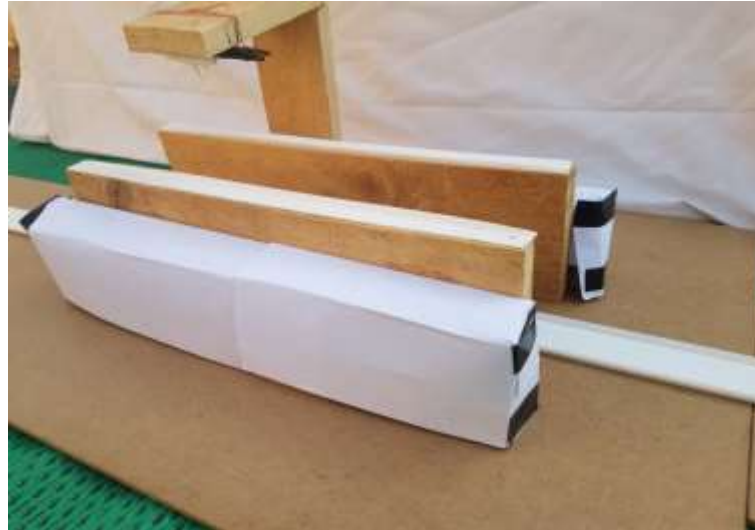


Figure 4.1: The station

### 4.1.2 The train

The train was modified by adding a railway at the top of train as a track for connector cabin movement, there is an electromagnetic coil fixed on the top of the train between the auxiliary railways as shown in Figure 4.2.



Figure 4.2: The train

### 4.1.3 The connector cabin

It's a small cabin modified by adding two external pairs of wheels with axle length 8 cm as shown in Figure 4.3, the internal and external wheels were designed to constrain the cabin motion on the train and the platform respectively, also there are two electromagnetic coils one at the bottom and other in the cabin top as shown in Figure 4.3 and Figure 4.4.

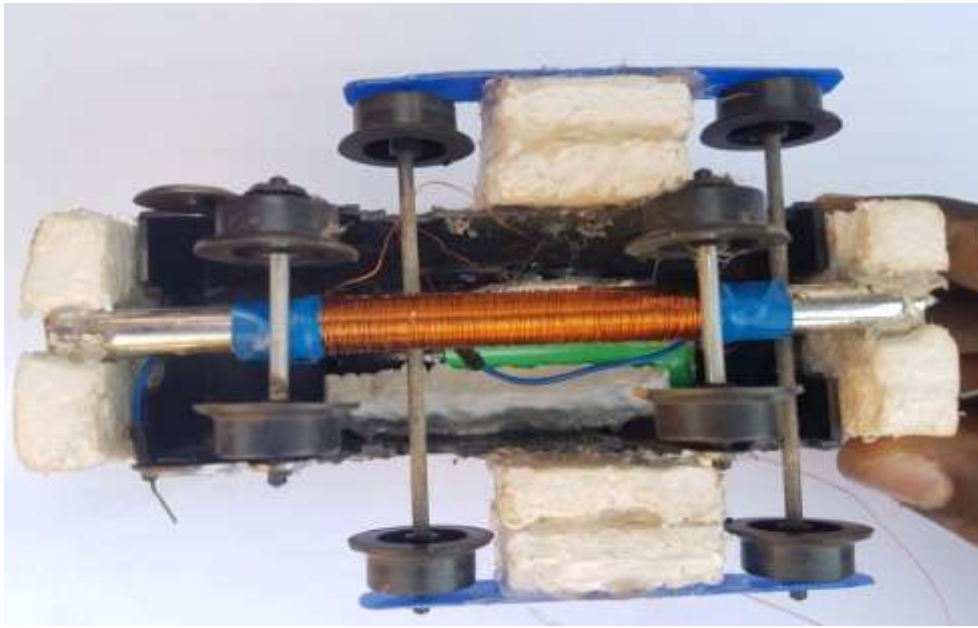


Figure 4.3: Bottom of connector cabin

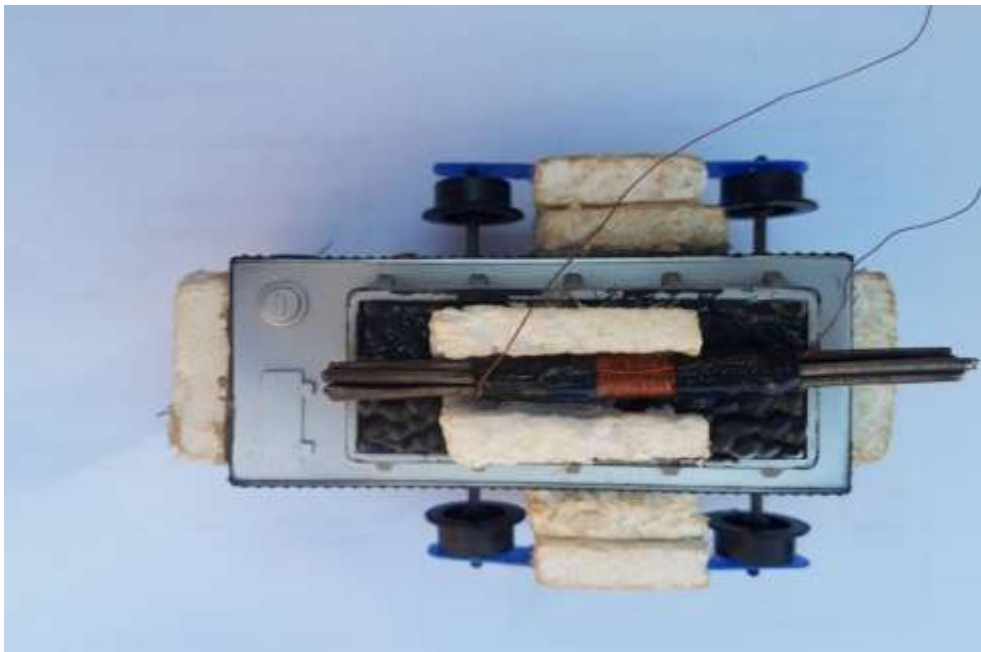


Figure 4.4: Top of connector cabin

Figure 4.5 shows the general view of the fabricated system components



Figure 4.5: The system components

## 4.2 System Control Circuit Implementation

The main electrical components required to implement the project are: Two arduino uno, DC motor, two drivers L293D, two relays, two limit switches and six electromagnetic coils. The control circuit performs the connector cabins exchanging between the train and the station platforms, when the train arrives the station it presses the limit switch which sends a signal to the microcontroller through pin 2. The microcontroller sends two signals through the output pin 8 and pin 9 to the driver pins (in1, in2). The driver sends signals through pins (out3, out4) to DC motor to decrease the train speed. The driver also sends another two signals through pins (out1, out2) to the relay to de energizes the electromagnetic brake which fixes the connector cabin on the train. So when the train arrives the station the connector cabin intertwines with the platform railway and separated from the train. Similarly, on the other hand the electromagnetic



brake which fixes the connector cabin on the platform will be energized when the station's limit switch has been pressed by the train.

The limit switch fixed in the train and connected with the Arduino as shown in Figure 4.6.



Figure 4.6: Limit switch connected with arduino

COM attached to +5V

NO attached to pin 2

The driver plugged in the breadboard as shown in Figure 4.7.

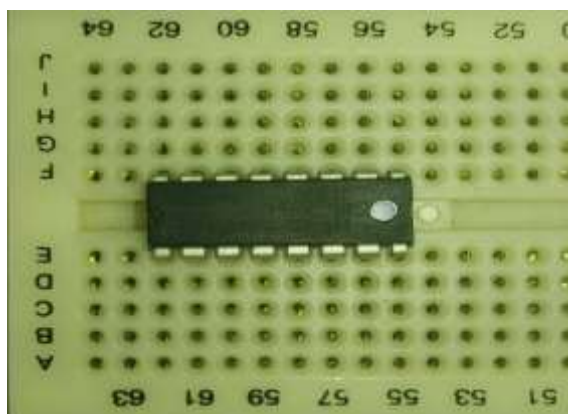


Figure 4.7: The driver plugged in the breadboard

The driver connected with Arduino as shown in Figure 4.8.

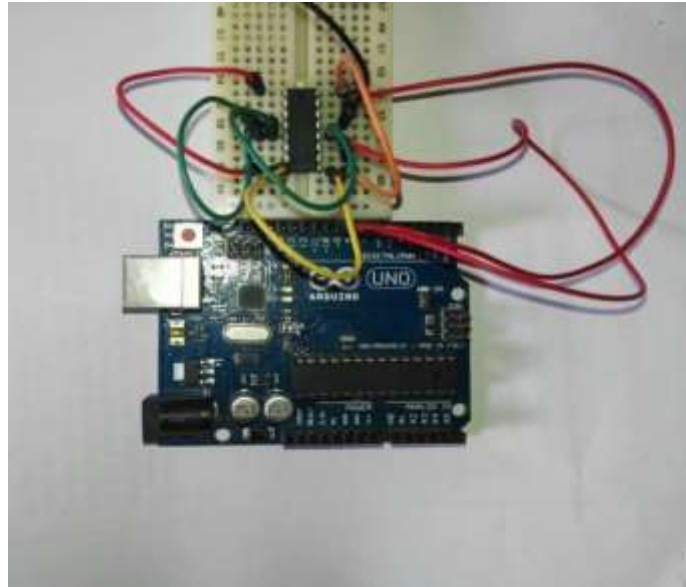


Figure 4.8: The driver connected with Arduino

IN1 attached to pin (8)

IN2 attached to pin (9)

VCC attached to 9v

GND attached to ground

The relay connected with the driver as shown in Figure 4.8.





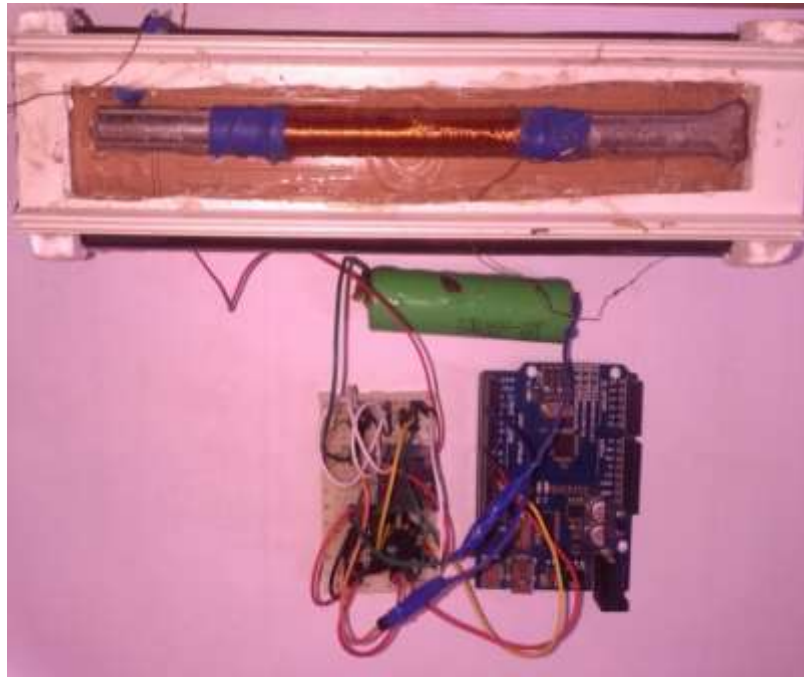


Figure 4.10: The electromagnet connected with the relay

Power supply +12v connected to the relay COM point and NC point attached to the one of electromagnetic coil terminals and the other terminal attached to the ground.

# **CHAPTER FIVE**

## **CONCLUSION AND RECOMMENDATIONS**

### **5.1 Conclusion**

In this study the components of nonstop electric train system was fabricated. The system control circuit was designed, simulated, implemented and tested the lost time cause of frequent stopping, successfully. This project decrease provides sufficient time for passengers to get up or left the train, prevents congestion and save the lost power due to stop and start, Therewith the project's goals was realized.

### **5.2 Recommendations**

To improve the performance of this prototype it is recommended that you:

- Implementation of multiple stations.
- Consideration advanced safety system.

# APPENDIX

## Arduino code written in Arduino C language

```
const int IN1 = 8;

const int IN2 = 9;

const int IN3 =10;

const int IN4= 7;

const int EN2 =6;

const int limit = 2;

int val ;

//EN1 attached to (+9v)

//OUT 1, OUT 2 attached to the terminal of relay coils

//OUT 3, OUT 4 attached to the DC motor

void setup()

{

  pinMode (IN1,OUTPUT);

  pinMode (IN2,OUTPUT);

  pinMode (IN3,OUTPUT);

  pinMode (IN4,OUTPUT);

  pinMode (EN2,OUTPUT);

  pinMode (2,INPUT);

}

void loop()

{

  val = digitalRead(2);

  digitalWrite(IN1,HIGH);
```

```

digitalWrite(IN2,LOW);
analogWrite(EN2,255);//full speed when the train is run
digitalWrite(IN3,HIGH);
digitalWrite(IN4,LOW);
if (val==HIGH)
{
digitalWrite(IN1,LOW);
digitalWrite(IN2,LOW);
for (int i=255;i>=80;i--)
{
analogWrite (EN2,i); //speed was decreased when limit switch is pressed
analogWrite(IN3,E2);
digitalWrite(IN4,LOW);
}
delay(1000);
}
else
{
digitalWrite(IN1,HIGH);
digitalWrite(IN2,LOW);
digitalWrite(IN3,HIGH);
digitalWrite(IN4,LOW);
}}

```

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