ADAMA SCIENCE AND TECHNOLOGY UNIVERSITY

SCHOOL OF ELECTRICAL ENGINEERING AND COMPUTING

DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING

DESIGN AND IMPLEMENTION OF PLC BASED AUTOMATIC RAILWAY GATE CONTROL

THESIS **SUBMITTED TO THE SCHOOL OF ELECTRICAL ENGINEERING AND COMPUTING OF ADAMA SCIENCE AND TECHNOLOGY UNIVERSITY**

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF MASTER OF SCIENCE IN INDUSTRIAL CONTROL &AUTOMATON TECHNOLOGY

By

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05, June 2015

Adama Ethiopia

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DECLARATION

We Abayneh Mekonnen, Fiseha G/Slasie, Yezbalem Mandefro and Teumzgi Gebru hereby declare that this project entitled **Design and Implementation of PLC based automatic railway gate control** entirely our own work and to our knowledge it has not been done or presented by other person. The result of our own work carried out under the supervision of **Ato. Tafese Asrat (PhD Scholar).**

We swear that all the material used has been properly referenced.

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This is to certify that the above statement made by the candidates is correct to the best of our knowledge and belief. This has been submitted for examination with our approval

Advisor Name Ato Tafese Asrat (PhD Scholar)

Advisor Signature:_____________________ Date :_________________

ACKNOWLEDGMENT

Praise GOD for his Almighty and Graciousness, we were able to complete this project report in the dateline given.

First and foremost, we would like to thank our respective advisor **Ato. Tafese Asrat (PhD Scholar)**.for the guidance and brilliant ideas from him. Besides that,

We would like to thank **Ato Mekonnen Getachew** project director of Ethio –Djibouti cross country railway project for his cooperation during data collection.

We would like to thanks **Ato Kumineger Hussen** project supervisor of light rail transit (LRT) of Addis Ababa railway project for his cooperation during data collection

We would like to thank **Dr. Ayele Abebe** director of further training institute (FTI) at Adama science and technology university for his support in borrowing PLC logo for practical demonstration.

We would like to thank **Ato. Abenet Mekonnen** General Manger of V.I..C .general import and export for his support in supplying the required materials.

We would like to thank **Ato. Ahimed Mehammed** Assistant lecturer of Adama science and technology university for his support in borrowing Reed switch for practical demonstration.

We would like to thank **Ato Abiti Takele** for his support in preparing the board that we use to mount the rail for practical demonstration.

Furthermore, all the staffs of Electrical and Computer Engineering department for their contribution involved with our project by providing full support since proposal phase and laboratory assistances for their cooperation at practical section.

Last but not least, thanks to our beloved family and friends that gave us encouragement and morale support.

Thank you so much

TABLE CONTENT

LIST OF FIGURES

FIGURE TITLE PAGE

LIST OF TABLES

ACRONYMS

Abbreviation	Description	
PLC	Programmable logic controller	1
LRT	Light rail transit	1
IR	Infra read sensor	5
RFI	Radio frequency interface	11
EMI	Electromagnetic interference	11
PCB	print circuit boards	14
CPU	Central Processing Unit	15
I/O	input /output	15
RAM	Random Access Memory	16
ROM	Read Only Memory	16
STL	Statement list	17
FBD	Functional block diagram	18
LAD	Ladder logic Diagram	19

Abstract

Railway is the cheapest modes of transportation and preferred over all other means of transportation. In our country it is newly emerging technology and the Addis Ababa LRT project gate control system is semiautomatic. Manually operated level crossings are exposed to accidents due to human error. Our project deals with automatic railway gate operation that reduces the possibility of accidents at the level crossing. Detection of train approaching the gate can be sensed by means of four sensors placed on either side of the gate two for arrival and the rest for departure.

Train arrival and departure sensing can be achieved by means of vibration sensor. When the wheels of the train moves over, vibration of the rail is sensed and converted to electrical signal (voltage) by the sensor which is used as input signal of the PLC for the train arrival. The sensor is placed at 500m from the gate. If no train is approaching, Green light is ON. But as it approaches the arrival sensor, a buzzer and YELLOW signals warn the road users, after 30seconds the gate is closed and RED signal.

By implementing the automatic railway gate control at the level crossing the arrival and departure of the train is detected by the sensors placed in the two sides of the tracks. Then stepper motor will close and open the gate respectively for more safety.

The train passes without any collision as all vehicles and pedestrians are out of the crossing level.

The automatic gate developed in this project is unique in that it is controlled by software, which can be modified any time as the system demands a change.

***Key words*:** PLC, Stepper motor, Vibration sensor, Level crossing

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND

The railway system is the cheapest transportation mode in the world. But it is also one of those modes of transport that faces a lot of challenges due to human errors such as level cross accidents, collisions, etc. Level crossing is the place where railway track and highway/road intersects each other at the same level. When we go through the daily newspapers we come across many railway accidents occurring at level crossings. This is mainly due to the carelessness in manual operations and inaccuracy in estimation [1].

The earlier scenario, Level crossing was controlled by manually operated gates. The human errors that could occur during the operation of gates, such as delay in informing the gatekeeper about the arrival of the train, delay in the gate operation by the gate keeper, etc. leads to the increasing rate of accidents at the level cross [2]

The ongoing project of light rail transit in Addis Ababa is a semi-automatic (manually closed and automatically opened) level crossing control system. So, this system may lead to human error. Having this ground in to account our project thesis presents design and implementation of automatic railway gate control at level crossing is purposefully, to reduce the accident and collision at Level crossing [3].

This control system consists of three important parts. The first part PLC control system, the second part the gate control unit and the third part the announcement and signal display unit. The automatic railway gate system at level crossing aims to deal with two things. It reduces the total time taken for the gate operation at the level cross and also ensures the safety of the pedestrians and vehicles at the level cross when the train passes. The reduction in the direct human intervention during the gate operation in turn helps to reduce the collision and accidents at the level cross. Since the gate operations are automated based on the sensors, the time for which the gate is closed is less. The project intends to develop an automatic railway gate control system which is reliable and secured than the ongoing semi-automatic project of LRT in Addis Ababa.

This paper has come up with a solution for the problem stated above. As a train approaches the railway crossing from either side, the sensors placed in the rail at a certain distance from the gate detects the approaching train and accordingly Controls the operation of the gate. When the train moves on the rail, it will create vibration.

The sensor senses the vibration and sends the signal to PLC to indicate train arrival. Automatic railway gate control is highly economical with PLC based arrangements that could be designed for level crossings. The system is described here incorporate with the use of PLC as a controller to achieve the aim of the project.

1.2 Statement of the problem

In most African countries, railway gate control system is operating by manual operation. It is operating in the area that there are railway line junction with the road. The railway gate management has to employ workers to be on duty for control operation. Due to this, the worker will manually open and close the gate. When we go through the daily newspapers we come across many accidents in railroad railings. Railroad-related accidents are more dangerous than other transportation accidents in terms of severity and death rate. Currently the Addis Ababa transport access is not in the required amount compared to the population, but a lot of car accidents are reported every day. And now Light Rail Transit is emerging which needs an accident controlling mechanism to improve safety. Train accidents are generally catastrophic, in that the destructive forces of a train usually no match for any other type of vehicle, as they cause severe damage to life and property. Therefore there must be a control mechanism for improving safety and to avoid these severe accidents using PLC based automatic railway gate controller.

1.3 Objective of the study

1.3.1 General objective

The general objective of this project is to design an automatic railway gate control by using PLC system to avoid car and train collision accident and to apply cost effective railway gate control mechanism.

1.3.2 Specific objective

- To develop a prototype of railway gate control that function automatically by using PLC.

- To see the arrival and departure of the train using vibration sensor.
- To open and close the gate as the train arrive and depart using stepper motor.

1.4 Scope of the project

The scope of this project covers the hard ware design and programming of the sequential operation of Automatic railway gate control. Although there are some focus areas that must be included for fully safe rail way system. Such as obstacle detection, track switching, train to train priority, priority to train over the cars and other road users. Among these the project focus on giving priority to train over the cars and other road users by automatically closing/opening closing/opening the gate and traffic signals.

1.5 Significance of the project

The significance of the study is to reduce the severe collision at the gate level crossing of rail road and high way by reducing human error. It saves time and human resource. This results in accurate and cost effective control system. The beneficiaries are all transport users in general and road and transportation authority in particular. This project focus on Addis Ababa Light Rail Transit control system.

1.6 Methodology

1.6.1 Research Method

Systematic design methods (called design methodologies) are necessary for successfully designing a complex digital hardware. There are specific tasks involved with system development. A system development project typically consists of five steps –problem analysis, program design, program addressing, program running and program maintenance.

As each critical development activity is taking place, documentations are generated. Documentation consists of details about what the program does and how it works. During the first few steps of the system development life cycle, the systems analyst develops a set of specification’s indicating exactly what the new system should do and how it will work. These specifications include data flow diagrams, system flow charts, input and output designs, and so on.

In this step of the system development life cycle, the specifications developed during the problem analysis step are used to define a precise description of the nature of the required program.

In this project two main methods considered in designing the system: Hardware design methodology and software design methodology.

In hardware designing different types of the components can be selected according to their specifications and connected together to build the complete system. The complete system circuit can be drawn using different circuit making software. But, in this project multisim _ultiboard circuit 12.0 is used to draw and to build the PCB of the system.

In software designing the control algorithm can be written in the form of flow chart and the program can be written in ladder logic diagram of semen's LOGO version 7.1. Then the entire program can be built and simulated.

1.6.2 Sources of Data

The different sources of all the necessary data and information for this project is obtained from different written documents about railway level crossing gate control mechanisms, advantages, disadvantages, drawbacks, and problem faced to be effective and Currently, the on process LRT project in Addis Ababa as a secondary data.

1.7 Outline of the thesis

The thesis has the following parts, and organized as follows:

Chapter 1:- Introduce the project as a whole. The early and basic explanations are mentioned in this chapter. This chapter consists of the project introduction, objectives, statement of problem, scope of the project, significance of the project and methodology.

Chapter 2 Review different papers, books and journals related to the thesis

Chapter 3 Provide block diagram and its detailed description.

Chapter 4 Presents an in-depth look at the system design and implementation of the developed models. The modifications and the challenges that have to be overcome at a control level are covered here.

Chapter 5 Present the result, conclusions and recommendation based on chapter three and chapter four.

CHAPTER TWO

REVIEW OF THE LITERATURES

2.1 The existing scenario

The existing scenario for most African countries, level crossing line the railway gate is operated normally by a gate keeper. This happen when the railway line is cross over the road and there are a gate that have to be controlled. The gate keeper work after receiving the information about the train arrival from the nearer station. When the train starts to leave the station, the particular station delivers the information to give the signal for gate keeper to get ready. This is the operation followed for operating the railway gates

In addition, this automatic railway gate system can contribute a lot of benefit either to the road user or to the railway management. This type of gate can be implementing in the level crossing where the chances of accidents are higher. The computer integration is used to provide additional benefits in the latest technology [4]. Ahmad Hafizi Bin Mohammad "Automatic railway gate control by using microcontroller" May, 2011

The conventional signaling system most of the times rely on the oral communication through telephonic and telegraphic conversations as input for the decision making in track allocation for trains. There is large scope for miscommunication of the information or Communication gap due to the higher human interference in the system. This miscommunication may lead to wrong allocation of the track for trains, which ultimately leads to the train collision. The statistics in the developing countries showing that 80% of worst collisions occurred so far is due to either human error or incorrect decision making through miscommunication in signaling and its implementation [5].

"**Automatic Railway Gate Control using Microcontroller"** aims to control the railway accident using anti-collision techniques is proposed. Train collision occurs mainly due to the carelessness in manual operation. This model is implemented using sensor technology [6].

"**Microcontroller based model design of a train collision avoidance system"** comprises an apparatus for detecting the presence of an approaching locomotive within a specified limited area. The system is integrated with the braking system of the train using embedded technology; hence rail traffic accident can be minimized .The design comprises apparatus for detecting the presence of an approaching locomotive within a specified limited area, while being insensitive to the presence of objects outside the specified region and triggering braking circuits which will stop the train. The system is integrated with the braking system of the train and is capable of detecting the possibility of collisions in real time. The design is intended to automate fully the communication system between locomotives so that rail traffic accidents can be minimized or eliminated [7] .

"Advanced railway accidents prevention system using sensor network", which includes several features to prevent trains accidents. This system makes use of IR sensor and the train speed is controlled using electric braking system [8].

2.2 The Ongoing Project of Addis Ababa Light Rail Transit (LRT)

The ongoing project of Addis Ababa Light Rail Transit (LRT) is a "semi- automatic gate control system "that closes the barrier manually and opens automatically by using relay interface .

What so ever it is semi automatic gate control, it may create a potential human error that leads to accident.

In the project of light rail transit of Addis Ababa the level crossing is designed to be controlled semi-automatically. The lifting of the crossing barrier can be achieved by three control modes:

- Automatic control,
- Indoor manual control and
- The on-site manual operation:

- Normally, when a train approaches the crossing, the operator should press the lowering button of barrier for lowering control of the barrier;(indoor manual control)
- When a train is leave of a crossing and relevant requirements are met, the protection system will stop the train approaching alarm in up/down direction and the road signal system will make the barrier lifting automatically [3].

In our project ’an automatic railway level crossing gate control using PLC’ is used to control the railway gate automatically that reduces the railway accident at the level crosses.

Thus enhances safety in train operations and road users by using this control system over the above mentioned systems. This control system gets data from the vibration sensor. The efficiency of the system is expected to be considerably increased as the system takes its input from the sensor immediately. As more relevant data are included, it is expected that the present system may assist loco drivers in averting accidents efficiently. As no change is necessary to be made to the infrastructure of the ongoing project, the cost of implementation of this system is also less. The system has been designed and simulated using Siemens Logo real time simulation software.

CHAPTER THREE

SYSTEM BLOCK DIAGRAM DESCRIPTION:

3.1 Hardware Description

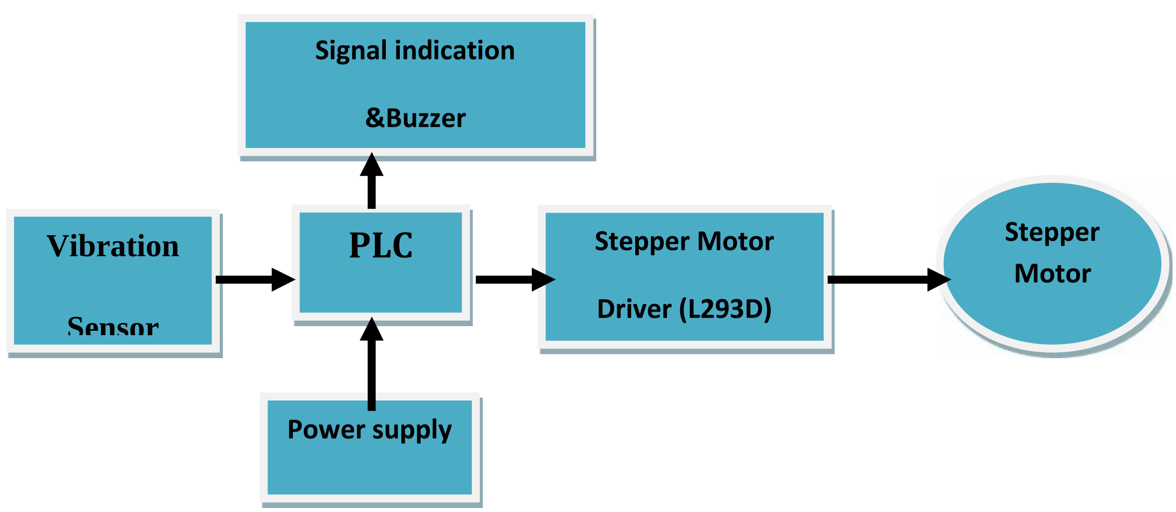


Figure 3. 1 Block diagram of automatic railway gate control.

3.1.1 Vibration Sensor

A vibration sensor uses piezoelectric effect to detect the vibration in the track which detects the arrival and departure of the train. The output signal from the vibration sensor is fed into the programmable logic controller (PLC) and it automates the gate operations. The major application of the vibration sensor is vibration detection.

According to the direction of the vibration it determines the train is arriving or departing. It works based on piezoelectric effect to detect the vibrations in the rails due to the arrival or departure of train. That means it converts mechanical vibration into electric pulses. This could sense the train’s position from 500m away from the arrival and 200m to the departure side.

➢ **Common Vibration Sensors**

Three parameters representing motion detected by vibration monitors are displacement (in inches), velocity (in inches per second), and acceleration (in g’s). Selection of a sensor proportional to displacement, velocity or acceleration depends on the frequencies of interest and the signal levels involved. Sensor selection and installation is often the determining factor in accurate diagnoses of machinery condition.

- **Displacement sensors**

Displacement sensors are used to measure shaft motion and internal clearances. Monitors have used non-contact proximity sensors such as eddy probes to sense shaft vibration relative to bearings or some other support structure. These sensors are best suited for measuring low frequency and low amplitude displacement. Piezoelectric displacement transducers (doubly integrated accelerometers) have been developed to overcome problems associated with mounting non-contact probes, and are more suitable for rolling element bearing machine designs. Piezoelectric sensors yield an output proportional to the absolute motion of a structure, rather than relative motion between the proximity sensor mounting point and target surface, such as a shaft.

- **Velocity sensors**

Velocity sensors are used for low to medium frequency measurements. They are useful for vibration monitoring and balancing operations on rotating machinery. As compared to accelerometers, velocity sensors have lower sensitivity to high frequency vibrations. Thus, they are less susceptible to amplifier overloads. Overloads can compromise the fidelity of low amplitude, low frequency signals. Traditional velocity sensors use an electromagnetic (coil and magnet) system to generate the velocity signal. Now, hardier piezoelectric velocity sensors (internally integrated accelerometers) are gaining in popularity due to their improved capabilities.

- **Accelerometers**

Accelerometers are the preferred motion sensors for most vibration monitoring applications. They are useful for measuring low to very high frequencies and are available in a wide variety of general purpose and application specific designs. The piezoelectric accelerometer is unmatched for frequency and amplitude range. The piezoelectric sensor is versatile, reliable and the most popular vibration sensor for machinery monitoring. Among the different accelerometer vibration sensors the piezoelectric type of vibration sensor is the most and preferable one for railway gate control to senses a critical frequency.

The piezoelectric crystals are usually preloaded so that either an increase or decrease in acceleration causes a change in the charge produced by them. But they are not reliable at very low frequencies.

The rugged, solid-state construction of industrial piezoelectric sensors enables them to operate under most harsh environmental conditions. They are unaffected by dirt, oil, and most chemical atmospheres. They perform well over a wide temperature range and resist damage due to severe shocks and vibrations. Most piezoelectric sensors used in vibration monitoring today contain internal amplifiers.

➢ **Choosing vibration sensor**

When selecting a piezoelectric vibration sensor (acceleration, velocity, or displacement), many factors should be considered so that the best sensor is chosen for the application.

➢ **Primary sensor considerations**

Two of the main parameters of a piezoelectric sensor are the sensitivity and the frequency range. In general, most high frequency sensors have low sensitivities, and conversely, most high sensitivity sensors have low frequency ranges. It is therefore necessary to compromise between the sensitivity and the frequency response.

✓ **The sensitivity range**

The sensitivity of industrial accelerometers typically ranges between 10 and 100 mV/g; higher and lower sensitivities are also available. To choose the correct sensitivity for an application, it is necessary to understand the range of vibration amplitude levels to which the sensor will be exposed during measurements.

As a rule of thumb, if the machine produces high amplitude vibrations at the measurement point, a low sensitivity (10 mV/g) sensor is preferable. If the vibration has low amplitude a 100 mV/g sensor should generally be used.

Higher sensitivity accelerometers are available for special applications, such as low frequency/low amplitude measurements. In general, higher sensitivity accelerometers have limited high frequency operating ranges. One of the excellent properties of the piezoelectric sensor is its wide operating range. It is important that anticipated amplitudes of the application fall reasonably within the operating range of the sensor. Velocity sensors with sensitivities from 20 mV/in/sec up to 500 mV/in/sec are available. For most applications, a sensitivity of 100 mV/in/sec is satisfactory.

- ✓ **The frequency range**

In order to select the frequency range of a piezoelectric sensor, it is necessary to determine the frequency requirements of the application. The required frequency range is often already known from vibration data collected from similar systems or applications. The plant engineer may have enough information on the machinery to calculate the frequencies of interest. Sometimes the best method to determine the frequency content of a machine is to place a test sensor at various locations on the machine and evaluate the data collected.

Vibration sensors are several types. Before selecting the vibration sensor must consider five factors.

- It’s measuring range,
- frequency range,
- accuracy,
- transverse sensitivity
- Ambient conditions.

Based on the above mentioned criteria, for our project minisense100 piezoelectric is the most suitable type of vibration sensor to get the required output signal that can activate the PLC.

- **Operation of an accelerometer**

The piezoelectric element in the sensor produces a signal proportional to acceleration. This small acceleration signal can be amplified for acceleration measurements.

The active elements of the accelerometer are the piezoelectric elements. These act as springs connecting the base of the accelerometer to the seismic masses via the rigid triangular center post. When the accelerometer is vibrated a force, equal to the product of the acceleration of a seismic mass and its mass, acts on each piezoelectric element. The piezoelectric elements produce a charge proportional to the applied force. The seismic masses are constant and consequently the elements produce a charge which is proportional to the acceleration of the seismic masses.

As the seismic masses accelerate with the same magnitude and phase as the accelerometer base over a wide frequency range, the output of the accelerometer is proportional to the acceleration of the base and hence to the acceleration of the surface onto which the accelerometer is mounted.

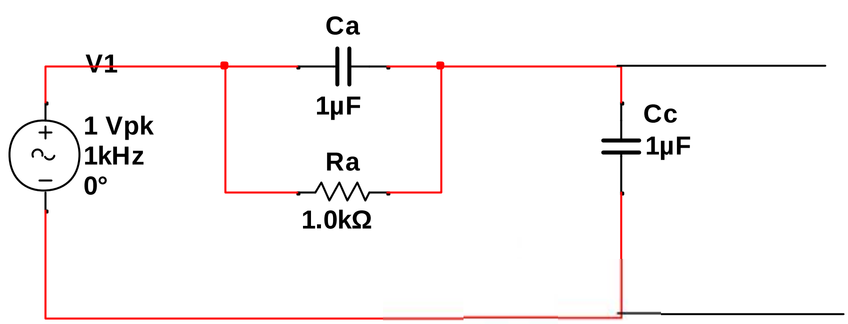
- **Voltage Sensitivity**

The piezoelectric accelerometer can be regarded as either a charge source or a voltage source. The piezoelectric element acts as a capacitor Ca in parallel with a very high internal leakage resistance, Ra, Va in series with Ca and loaded by Cc, as shown in Fig. bellow. The equivalent circuit for the model is shown.

The choice of accelerometer preamplifier depends on whether we want to detect charge or voltage as the electrical output from the accelerometer.

The voltage sensitivity can be expressed in terms of voltage per unit of acceleration:

Sva = mV/ g = mVRMS/g RMS = mV Peak/ g Peak



Voltage Equivalent circuit ,$Va = \frac{Qa}{Ca+Cc}$

Figure 3.2 voltage sensitivity

Sva = Va/ Unit of acceleration

Qa = charge generated by the piezoelectric elements (proportional to the applied acceleration)

Ca = capacitance of accelerometer

Ra = resistance of accelerometer

Cc = capacitance of cable and connectors

Va = voltage output of the preamplifier

Sva = voltage sensitivity

- **MiniSense100 Vibration Sensor**

The Minisense100 is a low-cost cantilever-type vibration sensor loaded by a mass to offer high sensitivity at low frequencies. The pins are designed for easy installation and are solder able.

Horizontal and vertical mounting options are offered as well as a reduced height version. The active sensor area is shielded for improved RFI/EMI rejection. Rugged, flexible, sensing element withstands high shock overload. This sensor has excellent linearity and dynamic range, and may be used for detecting either continuous vibration or impacts. It has:

FEATURES

• High Voltage Sensitivity (1 V/g)

• Over 5 V/g at Resonance

• Horizontal or Vertical Mounting

• Shielded Construction

• Solder able Pins, PCB Mounting

Up to 40 Hz (2,400 rpm) Operation below Resonance

• Low Cost [8]

- **Sensor circuit**

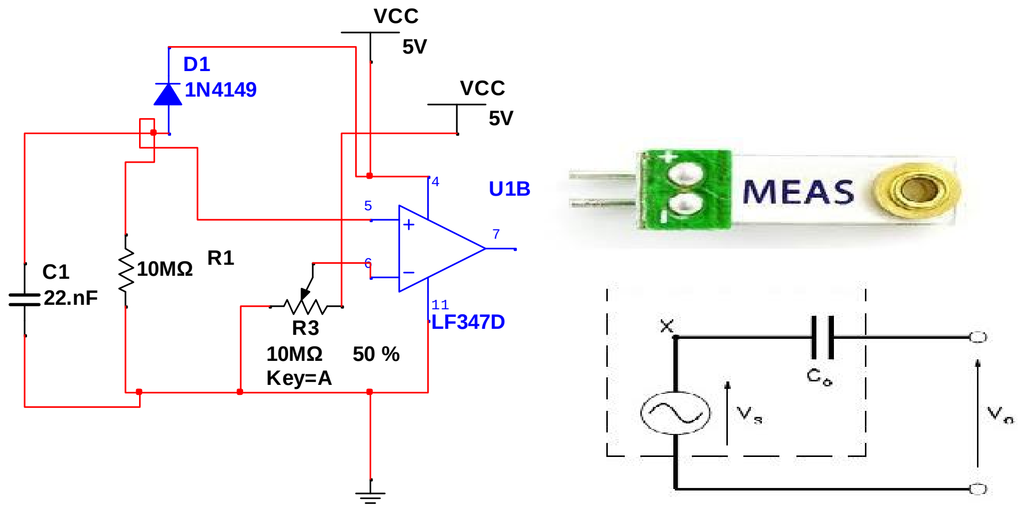


Figure 3.2.1 Minisense100 piezoelectric Sensor circuit

- **Electrical Description**

The Minisense100behaves electrically as an “active” capacitor: it may be modeled as a perfect voltage source (voltage proportional to applied acceleration) in series with the quoted device capacitance. Any external input or load resistance will form a high-pass filter, with a roll-off frequency as tabulated below or calculated from the formula f(c) = 1/(2πRC). The impedance of the sensor is approximately 650 M ohm at 1 Hz. The active sensor element is electrically shielded, although care should be taken in the PCB design to keep unshielded traces as short as possible.

If we look at Piezo film based transducer we will see that it can be seen as ideal voltage source and series capacitor. From datasheet we know that capacitance is 244pF.

Let’s say we want the cut off frequency to be at 2Hz. At this point the magnitude of Piezo signal will fall to 0.707 level or -3dB. Using simple formula we can find load resistor:

R = 1/(2πfC) ……………………………………………………………………………equ (1)

$1/(2*\pi*2*244*10^{-12}) = 326M\Omega$

This means that in order to get low frequency response you need high resistance load or input of next stage. Next stage would be signal buffering. In order to ensure our filter to be effective, we need that buffer input impedance were even higher than load resistor. If you take LM741 operational amplifier you will see that input resistance is about 2MΩ. So this would shift filter's cut-off frequency to higher frequency and measuring slow signals would become problematic. You should look for low bias current operational amplifier. For instance Linear Technology has LTC6240which input resistance is 10^{12}Ω. It could be a good candidate. Then signal conditioning would look like:

Table 3.1 Lower Limiting Frequency

External R (Ω	LLF (Hz	Desired LLF (Hz	Required R (Ω
10 M	65	10	65M
100 M	6.5	1	650M
1G	0.65	0.1	6.5G

Therefore, for our project we select minisense100 piezoelectric vibration sensor due to the above mention reasons.

3.1.2 Programming logic controller (PLC)

Programmable Logic Controllers are a solid-state, digital electronic device that controls the operation of a machine. In other words Programmable Logic Controllers (PLCs) are digital devices that are used to control the state of output ports based on the state of input ports.

It uses Logic functions, which are programmed into its memory via programming software also referred to as programmable controllers, are in the computer family. They are used in commercial and industrial applications. A PLC monitors inputs, makes decisions based on its program, and controls outputs to automate a process or machine.

Figure 3.3 Programming logic controller (PLC) SEMEN'S LOGO devices [9]

The need for low cost, versatile and easily commissionable controller resulted in the development of programmable logic controller. The primary reason for designing such a device was eliminating the large cost involved in replacing the complicated relay based machine control systems .Relays are mechanical devices with limited life time which required strict maintenance schedules. Troubleshooting was also quite tedious when so many relays are involved.

The most powerful facility which PLCs have is that they can be easily programmed to produce their control function instead of having to be laboriously hard-wired as is required in relay control systems. We can consider a PLC to be a box full of hundreds or thousands of relay, counters, timers and data storage locations. These counter, timers and relays don't exist physically but rather they are software. These relays are represented with bit locations in special memory.

The typical system components of PLC:

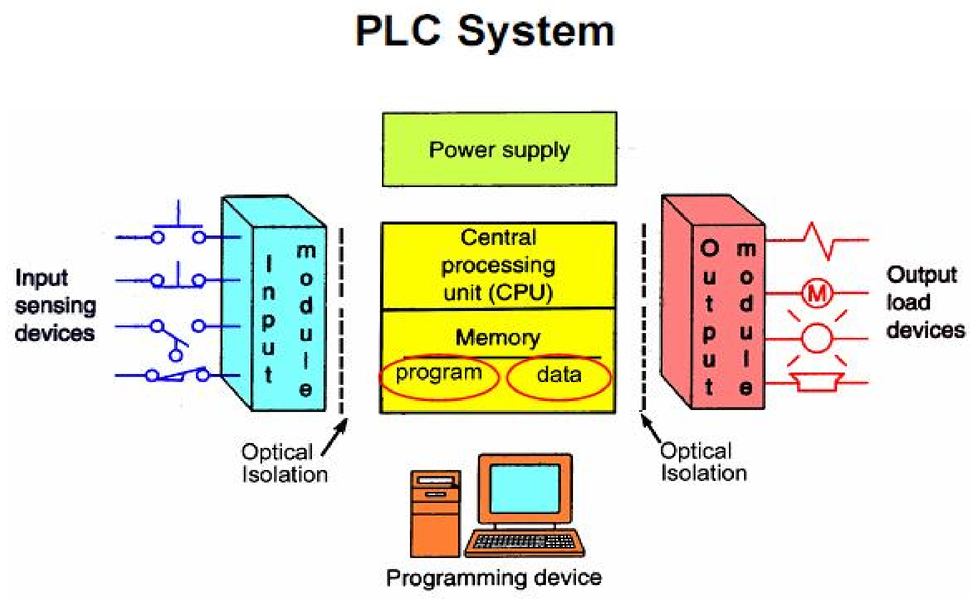


Figure 3.4 Block diagram of programming logic controller systems

1. **CPU**:

Central Processing Unit (CPU) is the brain of a PLC controller. The central processor unit (CPU) is a microprocessor system that contains the system memory and is the PLC decision making unit. The CPU monitors the inputs and makes decisions based on instructions held in the program memory. The CPU performs relay, counting, timing, data comparison, and sequential operations.

It is the main control unit for the PLC system and is a microprocessor that coordinates the activities of the PLC system. It executes the program, processes I/O signals and communicates with external devices. CPU performs the following tasks.

- It down load and upload control programs via interface
- Storage and execution of the programs is done by CPU
- It monitors program in operation
- Interfacing of other units is also through CPU.

2. Memory:

Memory is the component that store information, programs and data in a PLC.the process of putting information into a memory location is called writing. The process of retrieving information from memory location is called reading. This place store data temporarily or permanently.

They also typically be used to store data when power is removed from the PLC. Memory or flag, Shift registers, scan registers are part of this units.

- **Type of memory:**
  - **RAM:**

Random Access Memory (RAM) is memory where data can be directly accessed at any address. Data can be written to and read from RAM. RAM is used as a temporary storage area. RAM is volatile, meaning that the data stored in RAM will be lost if power is lost. A battery backup is required to avoid losing data in the event of a power loss.

  - **ROM:**

Read Only Memory (ROM) is a type of memory that data can be read from but not written to. This type of memory is used to protect data or programs from accidental erasure. ROM memory is nonvolatile. This means a user program will not lose data during a loss of electrical power. ROM is normally used to store the programs that define the capabilities of the PLC.

2. **Input/output systems**

A PLC is a control device. It takes information from inputs and makes decisions to energize or de-energize outputs. The decisions are made based on the statuses of inputs and outputs and the ladder logic program that is being executed.

The input devices used with a PLC include pushbuttons, limit switches, relay contacts, photo sensors, proximity switches, temperature sensors, vibration sensor and the like. These input devices can be AC (alternating current) or DC (direct current). The input voltages can be high or low. The input signals can be digital or analog. Different inputs require different input modules. An input module provides an interface between input devices and a PLC's CPU, which uses only a low DC voltage. The input module's function is to convert the input signals to DC voltages that are acceptable to the CPU. The output devices controlled by a PLC include relays, alarms, solenoids, fans, lights, and motor starters. These devices may require different levels of AC or DC voltages. Since the signals processed in a PLC are low DC voltages, it is the function of the output module to convert PLC control signals to the voltages required by the controlled circuits or devices.

3. Power supply:

The power supply specified depends upon the manufacturer's PLC being utilized in the application. As stated above, in some cases a power supply capable of delivering all required power for the system is furnished as part of the processor module.

If the power supply is a separate module, it must be capable of delivering a current greater than the sum of all the currents needed by the other modules. For systems with the power supply inside the CPU module, there may be some modules in the system which require excessive power not available from the processor either because of voltage or current requirements that can only be achieved through the addition of a second power source. This is generally true if analog or external communication modules are present since these require DC supplies which, in the case of analog modules, must be well regulated.

Programming:

A program consists of one or more instructions that accomplish a task. Programming a PLC is simply constructing a set of instructions.

There are several ways to look at a program such as ladder logic, statement lists, or function block diagrams.

- Statement list:

A statement list (STL) provides another view of a set of instructions. The operation, what is to be done, is shown on the left. The operand, the item to be operated on by the operation, is shown on the right. A comparison between the statement list shown below, and the ladder logic shown on the previous page, reveals a similar structure. The set of instructions in this statement list perform the same task as the ladder diagram.

```
NETWORK 1
          LD      I0.0
          A       I0.1     (AND)
          =       Q0.0
NETWORK 2
          LD      I0.4
          O       I0.5     (OR)
          =       Q0.1
```

Figure .3.5 statement list

-Function Block Diagrams

Function Block Diagrams (FBD) provide another view of a set of instructions. Each function has a name to designate its specific task. Functions are indicated by a rectangle. Inputs are shown on the left hand side of the rectangle and outputs are shown on the right-hand side. The function block diagram shown below performs the same function as shown by the ladder diagram and statement list.

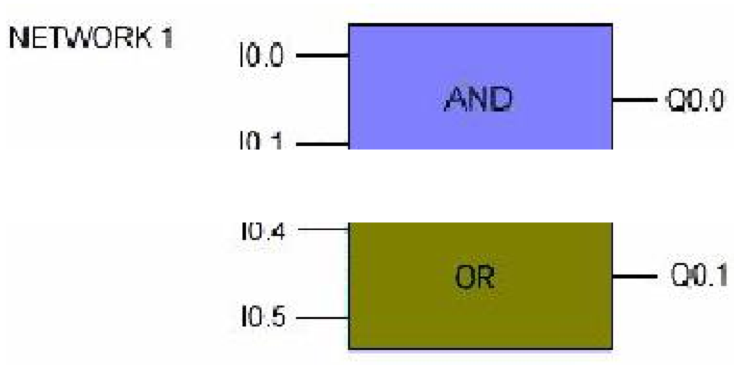


Figure3.6 function block diagram

Ladder Logic Diagram:

Ladder logic (LAD) is one programming language used with PLCs. Ladder logic uses components that resemble elements used in a line diagram format to describe hard-wired control. The left vertical line of a ladder logic diagram represents the power or energized conductor. The output element or instruction represents the neutral or return path of the circuit. The right vertical line, which represents the return path on a hard-wired control line diagram, is omitted. Ladder logic diagrams are read from left-to-right, top-to-bottom. Rungs are sometimes referred to as networks. A network may have several control elements, but only one output coil.

Figure .3.7 Ladder logic

Because of its similarity with circuit diagram, we have chosen ladder logic diagram programming language for this project.

Symbols:

In order to understand the instructions a PLC is to carry out, an understanding of the language is necessary. The language of PLC ladder logic consists of a commonly used set of symbols that represent control components and instructions.

-Contacts:

One of the most confusing aspects of PLC programming for first-time users is the relationship between the device that controls a status bit and the programming function that uses a status bit. Two of the most common programming functions are the normally open (NO) contact and the normally closed (NC) contact.

Symbolically, power flows through these contacts when they are closed. The normally open contact (NO) is closed when the input or output status bit controlling the contact is 1. The normally closed contact (NC) is closed when the input or output status bit controlling the contact is 0.

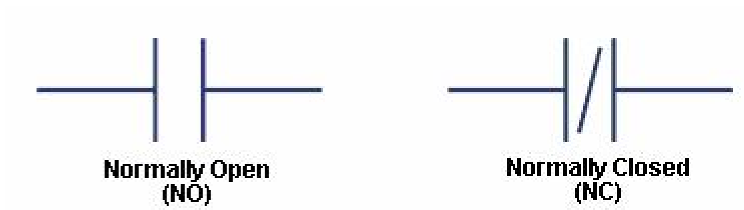


Figure 3.8 contacts

-Coils:

Coils represent relays that are energized when power flows to them. When a coil is energized, it causes a corresponding output to turn on by changing the state of the status bit controlling that output to 1. That same output status bit may be used to control normally open and normally closed contacts elsewhere in the program

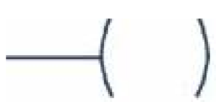


Figure .3.9 coils

- Boxes:

Boxes represent various instructions or functions that are executed when power flows to the box. Typical box functions are timers, counters, and math operations.

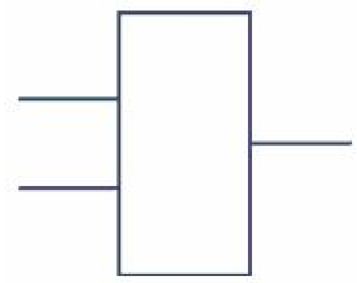


Figure .3.10 boxes

- **PLC Scan:**

The PLC program is executed as part of a repetitive process referred to as a scan. A PLC scan starts with the CPU reading the status of inputs. The application program is executed using the status of the inputs. Once the program is completed, the CPU performs internal diagnostics and communication tasks. The scan cycle ends by updating the outputs, and then starts over. The cycle time depends on the size of the program, the number of I/Os, and the amount of communication required.

Figure .3.11 PLC scan

Software:

Software is any information in a form that a computer or PLC can use. Software includes the instructions or programs that direct hardware.

Hardware:

Hardware is the actual equipment. The PLC, the programming device, and the connecting cable are examples of hardware[10].

The advantage of a PLC over a microcontroller

The advantage of a PLC over a microcontroller is that it is easy to program, similar to microcontroller the PLC also accepts the analog as well as digital signals, but it do not need to be configured such as in microcontroller, one of the major advantage over a microcontroller would be the ability to operate with both low as well as high level voltages, the programming and execution can be done simultaneously.

3.1.3 Stepper Motors

A stepper motor is +an electromechanical actuators, converts electrical pulses into mechanical actions. When the right sequence pulses signal are applied to the system, the shaft of a stepper motor rotates in discrete step. The stepper motors revolution has various direct relationships to applied input pulses. The speed of the shafts rotation is connected to the frequency of the input pulses and the length of rotation is associated to the amount of input pulses applied. Meanwhile the direction of the shaft rotation is depends on sequences of the input pulses. Not like other type of motor, the stepper motor has no contacts or brushes. It is a synchronous motor in order to rotate armature magnet through the magnetic field switching. The essential function of a stepper motor is to translate switching excitation changes into precisely defined increments of rotor position. Generally the stepper motor capable works as an electric motor when the drive running without commutator. The rotor of the stepper motor can be permanent magnet or variable reluctance motor which has a toothed block of some magnetically soft material. Typically, all the windings in the stepper motor are part of the stator. A stepping motor control system consists of three basic elements; controller, driver and motor.

Figure 3.12 Cross Section of Stepper Motor

The name stepper is used because this motor rotates through a fixed angular step in response to each input current pulse received by its controller. In recent years, there has been wide-spread demand of stepping motors because of the explosive growth of computer industry. Their popularity is due to the effect that they can be controlled directly by computers and programmable controllers. Stepper motors are ideally suited for situations where precise position and precise speed control are required without the use of closed-loop feedback. When a definite number of pulses are supplied, the shaft turns through a definite known angle. This fact makes the motor well suited for open-loop position control because no feedback need be taken from the output shaft [11].

The shaft or spindle of a stepper motor rotates in discrete step increments when electrical command pulses are applied to it in the proper sequence. The direction of the rotation is determined by the stator poles. The stator poles are determined by the current sent through the wire coils. As the polarity of the current is changed, the polarity of the winding sequence is also changed causing the reverse motion of the motor. The sequence of the applied pulses is directly related to the direction of motor shafts rotation. The speed of the motor shafts rotation is directly related to the frequency of the input pulses and the length of rotation is directly related to the number of input pulses applied. While a conventional motor shaft moves freely, stepper motor shaft moves in a fixed repeatable increment which allows one to move it to a precise position. This repeatable fixed movement is possible as a result of basic magnetic theory where poles of the same polarity repel and opposite poles attract.

The stepper motor converts digital signals into fixed mechanical increment of motion. It thereby provides a natural interface with the digital computer. It is a synchronous motor such that the rotor rotates a specific incremental number of degrees for each pulse input given to the motor system. These motors can provide accurate positioning without the need of position feedback sensors when compared to other motors. The position is known simply by keeping track of the input step pulses. Usually, position information can be obtained simply by keeping count of the pulses sent to the motor thereby eliminating the need of expensive position sensors and feedback control.

Stepper motors are rated by the torque they produce, step angle, steps per second and the number of teeth on rotor. The minimum degree of rotation with which the stepper motor turns for a single pulse if supply to one wire or a pair is called step angle.

The minimum step angle is always a function of the number of teeth on rotor .i.e., the smaller the step angle the more teeth the rotor possess.

Steps per complete revolution= Number of phases (coils) x Number of teeth on rotor

Smaller the step angle, greater the number of steps per revolution and higher the resolution or the accuracy of positioning obtained. The step angles can be as small as 0.72˚ or as large as 90˚.

The motor speed is measured in steps per second,

Steps per second = (Revolution per minute x steps per Revolution)/ 60

Stepping motors has the extra ordinary ability to operate at very high speeds (up to 20,000 steps per second) and yet to remain fully in synchronism with the command pulses, when the pulse rate is high, the shaft rotation seems continuous. If the stepping rate is increased too quickly, the motor loses synchronism and stops. Stepper motors are designed to operate for long periods with the rotor held in a fixed position and with rated current flowing in the stator windings whereas for most of the other motors, this results in collapse of back emf and a very high current which can lead to a quick burn out.

A stepper motor is a special kind of motor that moves in individual steps which are usually 3.6 degrees each. Each step is controlled by energizing coils inside the motor causing the shaft to move to the next position. Turning these coils on and off in sequence will cause the motor to rotate forward or reverse. The time delay between each step determines the motor's speed. Steppers can be moved to any desired position reliably by sending them the proper number of step pulses.

A stepper motor's shaft has permanent magnets attached to it. Inside the body of the motor is a series of coils that create a magnetic field that interacts with the permanent magnets. When these coils are turned on and off the magnetic field cause the rotor to move. As the coils are turned on and off in sequence the motor will rotate forward or reverse.

- **Stepper motor operation**

A simple drive system of a stepping motor is expressed by the figure shown that the stepper motor system can be an open loop system [12]. The figure represents the portion from logic sequence to motor.

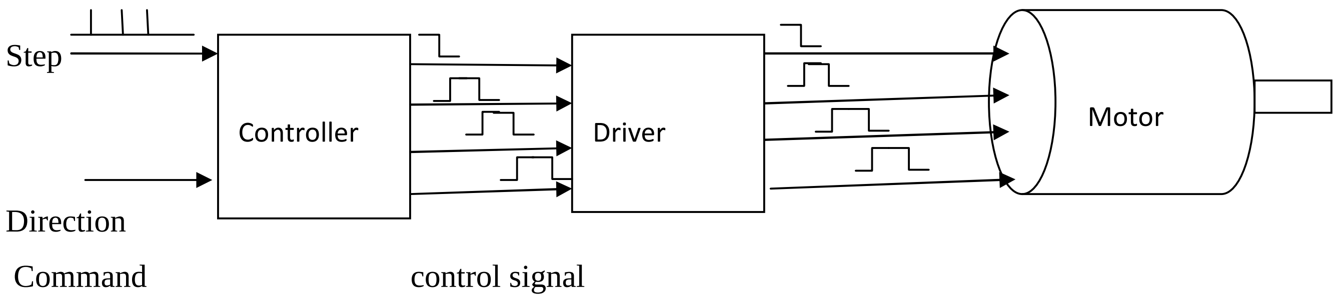


Figure 3.13 Stepper motor operations (Logic Sequencer)

Stepper motor uses electromagnetic field to create the motor shaft turn into a precise distance when a sequence of pulses is applied to the input pulses. However for different stepper motor has different degree rotation for each pulse.

The shaft or spindle of a stepper motor rotates indiscrete step increments when electrical command pulses are applied to it in the proper sequence. The motors rotation has several direct relationships to these applied input pulses. The sequence of the applied pulses is directly related to the direction of motor shafts rotation. The speed of the motor shafts rotation is directly related to the frequency of the input pulses and the length of rotation is directly related to the number of input pulses applied.

- **Types of stepper motor and operation**

Based on the construction of the magnetic circuit there are three basic type of stepper motor. They are as follows:

1. Variable reluctance motor – reactive type
2. Permanent magnet motor – active type
3. Hybrid motor

1. Variable reluctance (VR) stepper motors

The variable reluctance Stepper motor consists of a soft iron multi-toothed rotor and a wound stator. When the stator windings are energized with DC current the poles become magnetized. Rotation occurs when the rotor teeth are attracted to the energized stator poles [13].

The Variable-reluctance (VR) stepper motor at its core basically differs from the PM stepper in that it has no permanent-magnet rotor and thus no residual torque to hold the rotor at one position when turned off. This means the field strength can be varied. The stator of a variable reluctance stepper motor has a magnetic core constructed with a stack of steel laminations. The rotor is made of demagnetized soft steel with teeth and slots, or any other such magnetically permeable substance, unlike PM stepper motors. When the stator coils are energized, the rotor teeth will align with the energized stator poles. In the non-energized condition there is no magnetic flux in the air gap so there is no detent torque. This type of motor operates on the principle of minimizing the reluctance along the path of the applied magnetic field. By alternating the windings that are energized in the stator, the stator field changes, and the rotor moves to a new position .this type of construction allows for achieving small to medium step angles and operation at high control frequencies. However a motor of this type cannot hold its position i.e. has no holding torque, when no current flows through the stator windings. That the flow of the current through the windings of a VR motor must not be reversed to change the direction of rotation, this is achieved through the impulse sequence. This type of control, where the current flow must not be reversed is called unipolar.[13].

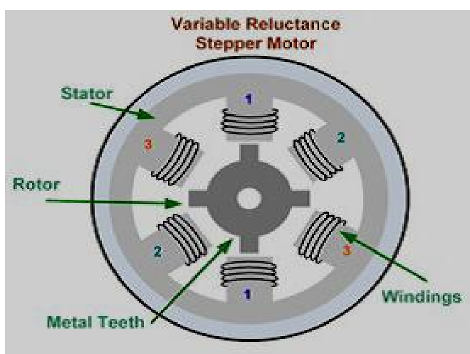


Figure 3.14a Cross Section of VR Stepper Motor

2. **Permanent magnet (PM) stepper motors**

The permanent magnet step motor also known as a “tin can” or “can stock” is a low cost and low resolution type motor with typical step angles of 7.5° to 15° or 48 – 24 steps/revolution respectively.

The PM motors have permanent magnets which added to the motor structure. Contrary to the variable reluctance (VR), the rotor of the PM motor no longer has teeth as in the motor structure. Instead the rotor is magnetized with alternating north and south poles situated in a straight line parallel to the rotor shaft. These magnetized rotor poles provide an increased magnetic flux intensity and because of this the PM motor exhibits improved torque characteristics when compared with the VR type.

A PM stepper motor operates on the reaction between a permanent-magnet rotor and an electromagnetic field. Figure 3.14b. shows a cutaway diagram of a typical permanent magnet stepper motor and shows that the permanent magnet motor can have multiple rotor windings, which means that the shaft for this type of

Stepper motor will turn fewer degrees as each pulse of current is received at the stator [13].

Have a different construction; here the teeth on the rotor are made of permanent magnet material with poles set up in a radial fashion, the stator construction being similar. When the stator windings are energized, magnetic fields that are generated interact with the PM's flux, generating torque to move the rotor.

Control sequences are similar to VR motors however when for instance the south pole of a PM Approaches an electromagnetic south pole on the stator, the current flow through that respective Winding must be reversed, in order to generate an electromagnetic north pole for the purpose of Maintaining the direction of the forces. So, the phases are energized by alternating polarity impulses, this type of control being called ***bipolar*.**

This type of motor can provide higher torque and also has the property of holding torque, when the windings are not energized. Steps are large, 45 to 120 degrees, because the number of permanent magnets that can be mounted on the rotor is much smaller than the number of teeth found on the stator of a VR motor.

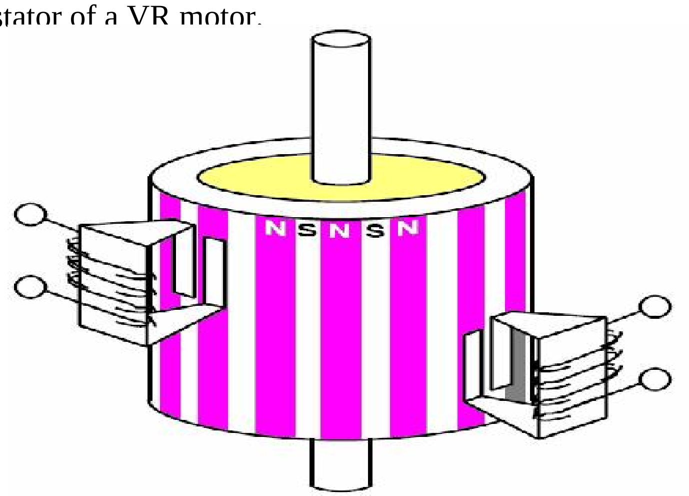


Figure 3.14b. Principle of a Permanent magnet Stepper Motor

3. **Hybrid stepper motors**

The hybrid stepper motor is blended feature of both the PM and VR type stepper motors. The rotor of the hybrid motor is a multi-toothed like the VR motor and includes an axially magnetized concentric magnet around its shaft. The teeth on the rotor provide a path which helps guide the magnetic flux to preferred locations in the air gap. As a result, the detent, holding and dynamic torque characteristics of the motor increase when compared with both the VR and PM types. Normally, the hybrid stepper motor is more expensive than the PM stepper motor but provides better performance with respect to step resolution, torque and speed. A Typical step angles for the hybrid stepper motor is range from 3.6° to 0.9° or 100 –400 steps per revolution respectively .

A typical hybrid motor is shown in Figure 3.14c.The stator construction is similar to the permanent magnet motor where the rotor is a cylindrical type and magnetized like the PM motor with numerous teeth like a VR motor. The teeth on the rotor provide a better path for the flux to flow through the preferred locations in the air gap. This increases the detent, holding, and dynamic torque characteristics of the motor compared to the other two types of motors.

Even the hybrid motor are more expensive compare to the other two motors, one of the advantages of hybrid motors is it offer a smaller step angle compared to the permanent magnet motor. This feature gives a precise position compare with PM and VR motors. For low cost applications, the step angle of a permanent magnet motor is divided into smaller angles using better control techniques [14].

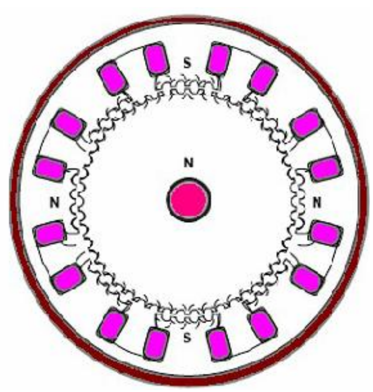


Figure 3.14c Principle of a Hybrid Stepper Motor

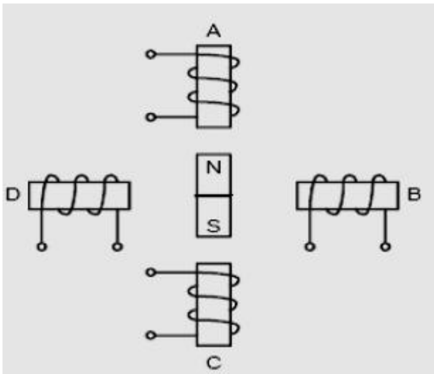
- **Working principle of Stepper motor:**

To make a stepper motor rotate, you must constantly turn on and off the coils. If you simply energize one coil the motor will just jump to that position and stay there resisting change. This energized coil pulls full current even though the motor is not turning. The stepper motor will generate a lot of heat at standstill. The ability to stay put at one position rigidly is often an advantage of stepper motors. The torque at standstill is called the holding torque. Because steppers can be controlled by turning coils on and off, they are easy to control using digital circuitry. The controller simply energizes the coils in a certain pattern and the motor will move accordingly.

The number of times the stepper motor turns on and off depends on the number of teeth present on the rotor. Illustration of one complete rotation of a stepper motor is shown in figure 3.15a below.

At position 1, we can see that the rotor is beginning at the upper electromagnet, which is currently active (has voltage applied to it). To move the rotor clockwise (CW), the upper electromagnet is deactivated and the right electromagnet is activated (postion-2), causing the rotor to move 90 degrees CW, aligning itself with the active magnet. This process is repeated in the same manner at the south and north electromagnets until it once again reach the starting position.

You may double the resolution of some motors by a process known as "half-stepping". Instead of switching the next electromagnet in the rotation on one at a time, with half stepping you turn on both electromagnets, causing an equal attraction between, thereby doubling the resolution.



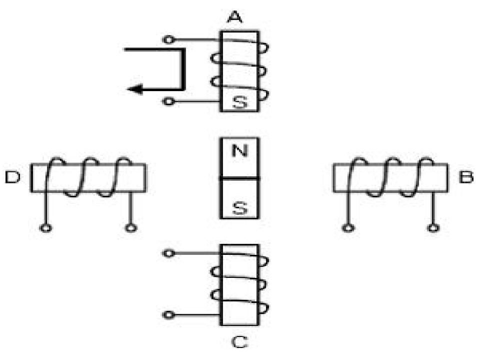
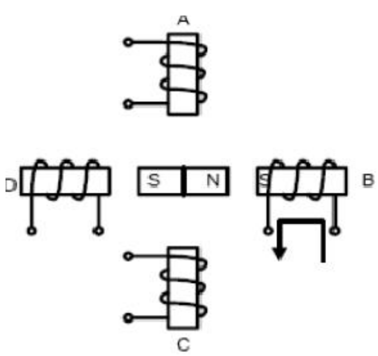


Fig.1. Non magnetized **Fig.2. Position (1) voltage is applied**



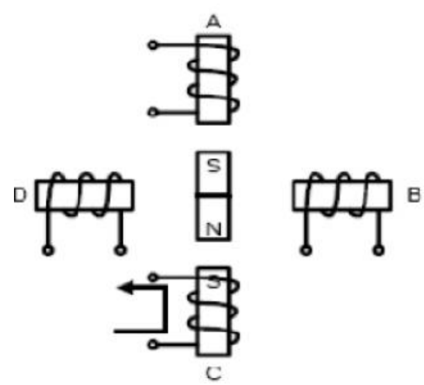


Fig.3 position (2) **Fig.3 position (3)**

Figure 3.15aWorking Principle of Stepper Motor

There are basically two types of stepper motors depending on the arrangements of the electromagnetic coils. They are unipolar and bipolar

- **Uni polar:**

In a unipolar stepper motor, there are four separate electromagnets. To turn the motor, first coil "1" is given current, then it's turned off and coil 2 is given current, and then coils 3, then 4, and then 1 again in a repeating pattern. Current is only sent through the coils in one direction; thus the name unipolar.

A unipolar stepper motor will have 5 (or 6) wires coming out of it. Four of those wires are each connected to one end of one coil. The extra wire (or 2) is called "common" and is connected to the other ends of all four coils. To operate the motor, the "common" wire is connected to the supply voltage, and the other four wires are connected to ground through transistors, so the transistors control whether current flows or not. Stepper motor controller is used to activate the transistors in the right order. These are the cheapest way to get precise angular movements [15].

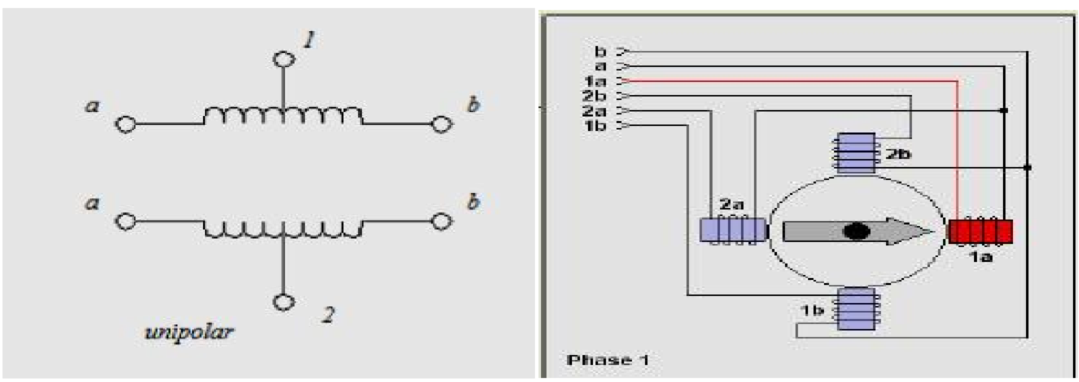


Figure 3.15b Principle of a unipolar stepper motor

- **Bipolar motor:**

In a bipolar motor, there are only two coils, and current must be sent through a coil first in one direction and then in the other direction; thus the name bipolar. Bipolar motors need more than 4 transistors to operate them, but they are also more powerful than a unipolar motor of the same weight. To be able to send current in both directions, engineers can use an H-bridge to control each coil or a step motor driver chip. This type of motor is not regularly used for robotics. Unipolar controllers can switch between supply voltage, ground, and unconnected.

Unipolar controllers can only connect or disconnect a cable, because the voltage is already hard wired. Unipolar controllers need center-tapped windings. It is possible to drive unipolar stepper motors with bipolar drivers. The idea is to connect the output pins of the driver to 4 transistors.

The transistor must be grounded at the emitter and the driver pin must be connected to the base. Collector is connected to the coil wire of the motor .

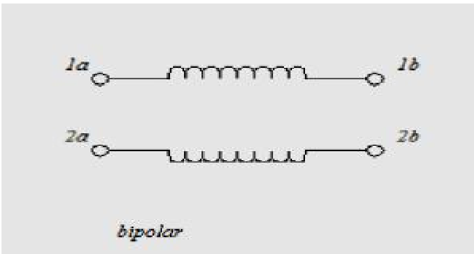


Figure 3.15c bipolar stepper motor coil

The bipolar stepper motor has two coils that must be controlled so that the current flows in different directions through the coils in a certain order. The changing magnetic fields that these coils create cause the rotor of the motor to move around in steps.

The circuit that is normally used to control one of the coils is shown below. Notice how there is four ‘control’ transistors that are switched on in ‘pairs’. Therefore with two coils there are four control transistor pairs (Q1-Q4) which must be switched on and off in a certain sequence.

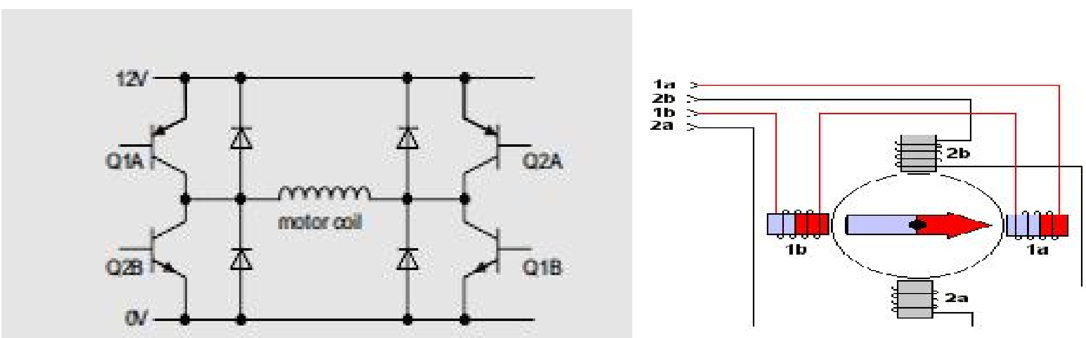


Figure 3.15d Conceptual model of bipolar stepper motor

- **Stepper motor characteristics**
  - Stepper motors are constant power devices.
  - As motor speed increases, torque decreases.
  - Steppers exhibit more vibration than other motor types, as the discrete step tends to snap the rotor from one position to another.

- **Stepper motor selection**

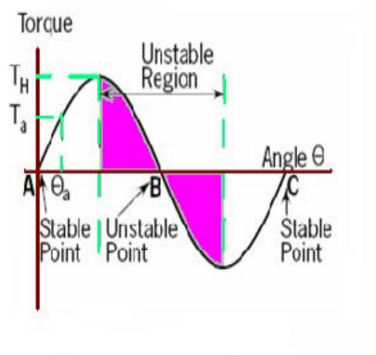
The hybrid stepper motor is manufactured by EM modeled EM 242 is chosen for this project. This two phase hybrid stepper motor is capable of delivering much higher working torques and stepping rates than permanent magnet types. The stepper motor can produce 3.6° per step. Whilst at the same time maintaining a high detent torque even when not energized. This feature is important for position integrity. The chosen stepper motor is supplied in 4-lead wire configuration.

- **The rotating magnetic field:**

When a phase winding of a stepper motor is energized with current a magnetic flux is developed in the stator. The direction of this flux is determined by the "Right Hand Rule" .The magnetic flux path developed when phase is energized with winding current in the direction.

The rotor then aligns itself so that the flux opposition is minimized. In this case the motor would rotate clockwise so that its south pole aligns with the North Pole and its north pole is aligns with the South Pole. To get motor rotate we can provide a sequence of energizing the stator winding in such a fashion that provides a rotating magnetizing flux field which the rotor follows due to magnetic attraction.

- **Torque vs. angle characteristics:**



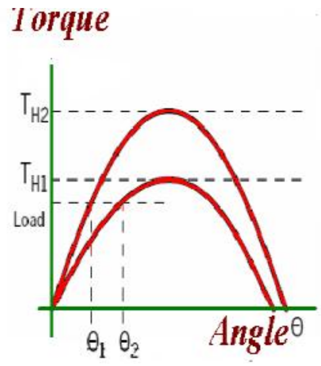


Figure 3.16aTorque vs. rotor Angular position at different holding torque

Figure 3.16b Torque vs. rotor angle

- **Torque vs., Angle Characteristics**

The torque vs. angle characteristics of a stepper motor is the relationship between the displacement of the rotor and the torque which applied to the rotor shaft when the stepper motor is energized at its rated voltage. An ideal stepper motor has a sinusoidal torque vs. displacement characteristic as shown in figure 3.16. Positions A and C represent stable equilibrium points when no external force or load is applied to the rotor shaft. When you apply an external force T_a to the motor shaft you in essence create an angular displacement, $\Theta_{a.}$This angular displacement Θ_a, is referred to as a lead or lag angle depending on whether the motor is actively accelerating or decelerating. When the rotor stops with an applied load it will come to rest at the position defined by this displacement angle. The motor develops a torque, T_a, in opposition to the applied external force in order to balance the load. As the load is increased the displacement angle also increases until it reaches the maximum holding torque, T_h, of the motor. Once T_h is exceeded the motor enters an unstable region. In this region a torque in the opposite direction is created and the rotor jumps over the unstable point to the next stable point.

- **Torque vs. speed characteristics of steeper motor**

The Speed-Torque graph indicates the characteristic relationship between the speed and torque when the stepping motor is driven. The torque vs speed characteristics are the key to selecting the right motor and drive method for a specific application. These characteristics are dependent upon (change with) the motor, excitation mode and type of driver or drive method. On the graph, the horizontal axis is the speed at the motor's output shaft while the vertical axis is the torque

1. **Maximum Holding Torque**

The holding torque is the maximum holding power (torque) the stepping motor has when power (rated current) is being supplied but the motor is not rotating (with consideration given to the permissible strength of the gear when applicable).

2. **Pull-in Curve**

The pull-in curve defines the area referred to as the start stop region. This is the maximum frequency at which the motor can start/stop instantaneously, with a load applied, without loss of synchronism.

3. **Pullout Torque Curve**

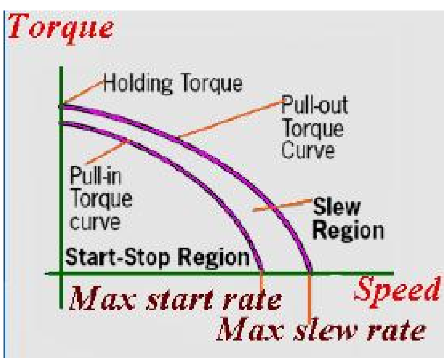
Pullout torque is the maximum torque that can be output at a given speed. When selecting a motor, be sure the required torque falls within this curve.

4. **Maximum Starting Frequency**

This is the maximum pulse speed at which the motor can start or stop instantaneously (without an acceleration or deceleration time) when the frictional load and inertial load of the stepping motor are 0. Driving the motor at greater than this pulse speed requires gradual acceleration or deceleration. This frequency drops when there is an inertial load on the motor.

5. **Maximum Slew Rate**

The maximum operating frequency of the motor with no load applied. **[17].**



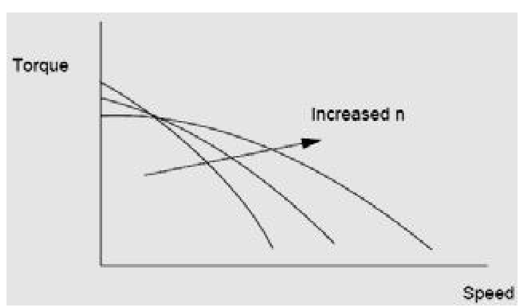


Figure-3.17 Torque Vs Speed characteristics of stepper motor [16].

Stepper motor advantages and disadvantages:

A stepper motor can be a good choice whenever controlled movement is required they can be used to advantage in applications where you need to control rotation angle, speed, position and synchronism. Because of inherent advantages of stepper motor have their place in many different applications?

Advantages:

• The rotation angle of the motor is proportional to the input pulse.

• The motor has full torque at standstill (if the windings are energized)

• Precise positioning and repeatability of movement since good stepper motors have an accuracy of 3-5% of a step and this error is non cumulative from one step to the next.

• Excellent response to starting/stopping/reversing.

• Very reliable since they are no contact brushes in the motor. Therefore the life of the motor is simply dependent on the life of the bearing.

• The motor response to the digital input pulses provides open-loop control, making the motor simpler and less costly to control.

• It is possible to achieve very slow speed synchronous rotation with a load that is directly coupled to the shaft.

• A wide range of rotational speeds can be realized as the speed is proportional to the frequency of the input pulses.

Disadvantages:

• Resonances can occur if not properly controlled

• Not easy to operate at extremely high speeds.

• This motor can also be heated at standing because of the torque required to hold it in position.

3.1.4 Stepper Motor Driver (L293D):

Stepper motors driver is a current driver chip used for supply control to the stepper motor. It is used to drive stepper motors because stepper motors are, in fact, two (or more) coils being driven in a sequence, backwards and forwards. One L293D can, in theory, drive one bi-polar 2 phase stepper motor, if we supply the correct sequence.

L293D is a quadruple half-H driver a typical Motor driver or Motor Driver IC which allows Stepper motor to drive on either direction. L293D is a 16-pin IC which can control a set of Stepper motors in both directions. It means that you can control Stepper motor with a single L293D IC.

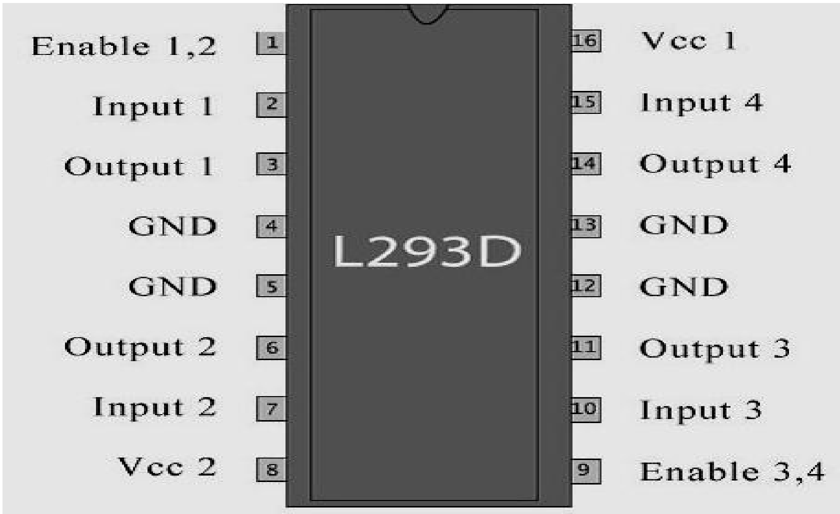


Figure-3.18 Half-H driver of Stepper Motor driver (L293D)

The L293D is quadruple high-current half-H drivers. The L293D is designed to provide bidirectional drive currents of up to 600-mA at voltages from 4.5 V to 36 V. It is designed to drive inductive loads such as relays, solenoids, dc and bipolar stepping motors, as well as other high-current/high-voltage loads in positive-supply applications [17].

Features

- Wide Supply-Voltage Range: 4.5 V to 36 V
- Separate Input-Logic Supply
- Internal electrostatic device(ESD) Protection
- High-Noise-Immunity Inputs
- Output Current 600 mA
- Peak Output Current 1.2 A Per Channel
- Output Clamp Diodes for Inductive
- Transient Suppression (L293D)

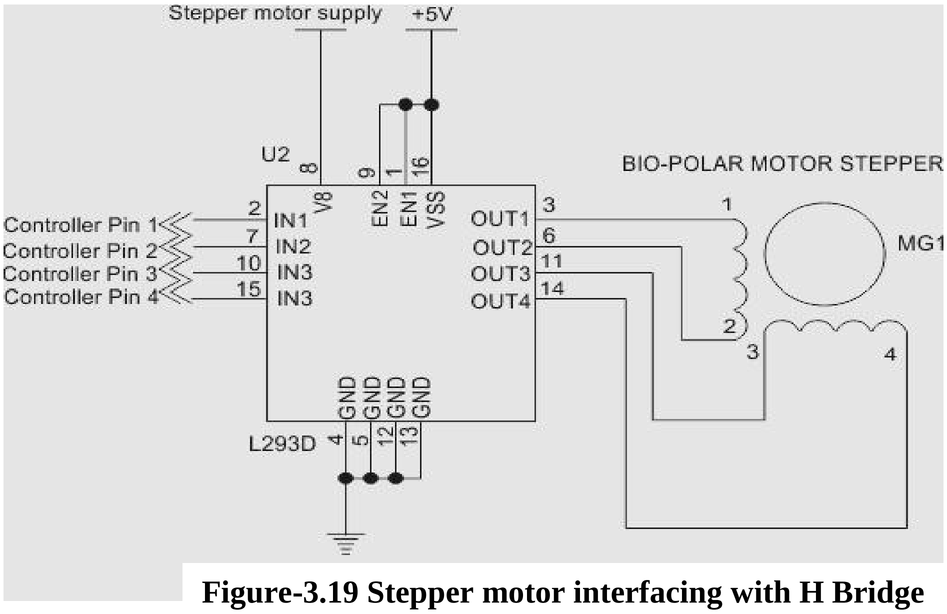


Figure-3.19 Stepper motor interfacing with H Bridge

3.1.5 Power supply unit:

For real working implementation the total power consumption can be determine by the following

Table 3.2 power calculation

For stepper motor	Rating
Imax	6A
Voltage	50-80V
Resistance	0.8ohm
Power	300-500w
Power of Indicator LED lamp	
Green	25w
Yellow	25w
Red	25w
PLC power rating	
Voltage	24V
Current	10A

The maximum possible power consumed is when a stepper motor is working with a red light and the PLC power rating

Total power = (stepper power +red light power) x4+ PLC power, Where 4 is indicates for four direction

Pt= (500w+25w) x4+24vx10A=2340w

Pt=2.34KW

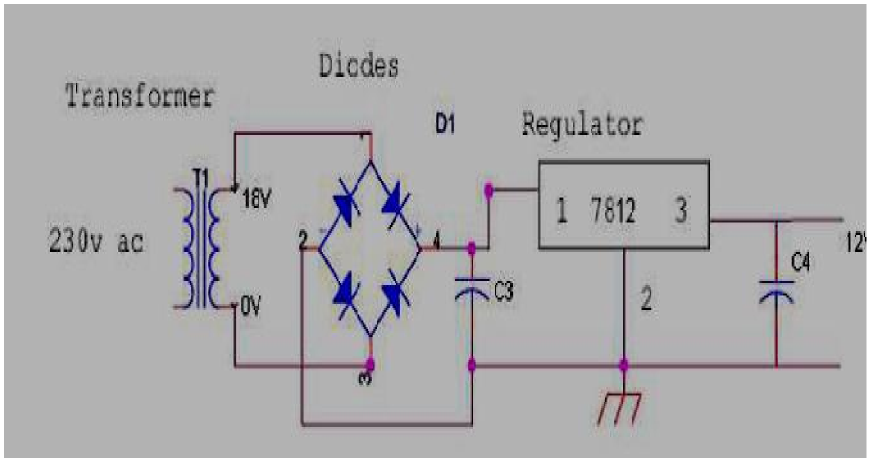


Figure 3.20 Power supply circuit diagram

Power supply unit consists of following units:

- Step down transformer
- Rectifier unit
- Input filter
- Regulator unit
- Output filter
- **Step-down Transformer**

The Step down Transformer is used to step down the main supply voltage from 230V AC to lower value. This 230 AC voltage cannot be used directly, thus it is stepped down. The Transformer consists of primary and secondary coils. To reduce or step down the voltage, the transformer is designed to contain less number of turns in its secondary core. The output from the secondary coil is also AC waveform. Thus the conversion from AC to DC is essential. This conversion is achieved by using the Rectifier Circuit/Unit.

- **Rectifier Unit:**

The Rectifier circuit is used to convert the AC voltage into its corresponding DC voltage. There are Half-Wave, Full-Wave and bridge Rectifiers available for this specific function. The most important and simple device used in Rectifier circuit is the diode. The simple function of the diode is to conduct when forward biased and not to conduct in reverse bias.

The Forward Bias is achieved by connecting the diode's positive with positive of the battery and negative with battery's negative. The efficient circuit used is the Full wave Bridge rectifier circuit. The output voltage of the rectifier is in rippled form, the ripples from the obtained DC voltage are removed using other circuits available. The circuit used for removing the ripples is called Filter circuit.

- **Input filter**:

Capacitors are used as filter. The ripples from the DC voltage are removed and pure DC voltage is obtained. And also these capacitors are used to reduce the harmonics of the input voltage. The primary action performed by capacitor is charging and discharging. It charges in positive half cycle of the AC voltage and it will discharge in negative half cycle. So it allows only AC voltage and does not allow the DC voltage. This filter is fixed before the regulator. Thus the output is free from ripples.

- **Regulator Unit:**

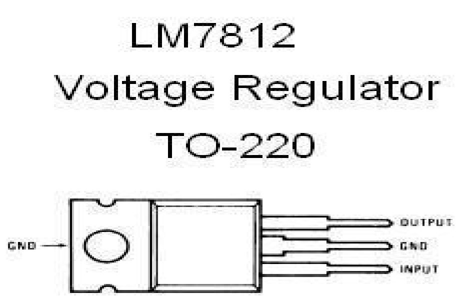


Figure 3.21 LM7812 Regulators IC

Regulator regulates the output voltage to be always constant. The output voltage is maintained irrespective of the fluctuations in the input AC voltage. As and then the AC voltage changes, the DC voltage also changes. Thus to avoid this Regulators are used.

Also when the internal resistance of the power supply is greater than 30 ohms, the output gets affected. Thus this can be successfully reduced here. The regulators are mainly classified for low voltage and for high voltage. Further they can also be classified as:

i) Positive regulator

1---> input pin

2---> ground pin

3---> output pin

It regulates the positive voltage.

ii) Negative regulator

1---> ground pin

2---> input pin

3---> output pin

It regulates the negative voltage.

- ## Output Filter:

The Filter circuit is often fixed after the Regulator circuit. Capacitor is most often used as filter. The principle of the capacitor is to charge and discharge. It charges during the positive half cycle of the AC voltage and discharges during the negative half cycle. So it allows only AC voltage and does not allow the DC voltage. This filter is fixed after the Regulator circuit to filter any of the possibly found ripples in the output received finally. Here we used 0.1µF capacitor. The output at this stage is 12V and is given to the programmable logic controller and by using LM7805 IC form 12 output to 5V for the stepper motor driver input. The rating of the above power supply is for the prototype. For real world implementation, the rating of the stepper motor is 80v, 6A, and 22Nm holding torque. So it needs 80v output power supply.

CHAPTER FOUR:

SYSTEM DESIGN AND IMPLEMENTATION

4.1 System Design

This is a problem-solving technique that decomposes a system into its component pieces for the purpose of studying how well those component parts work and interact to accomplish their purpose. Structured analysis is a model-driven, process-centered technique used to either analyze an existing system, define requirements for a new system, or both. The models are pictures that illustrate the system's component pieces: processes and their associated inputs, outputs, etc. System design is a complementary problem-solving technique (to system analysis) that reassembles a system's component pieces back into a complete system-hopefully, an improved system. This may involve adding, deleting, and changing pieces relative to the original system.

- **Top-Down Decomposition**

It is easier to understand the operation of the whole by looking at its pieces and their interactions. We "divide" a system into subsystems and components in order to more easily "conquer" the problem and build the larger system.

This is a good strategy for constructing any kind of complex system. The process of top-down decomposition starts with the description of a whole system and replaces it with a series of smaller steps-each step is a more primitive subsystem.

Figure4.1 shows one of the possible decompositions of the PLC based control system for light rail transit level crossing. It is broken down into input subsystem (sensor), control unit, output unit. The vibration sensor senses the train arrival and alerts the PLC. In this project control unit is responsible for the actual light sequencing, gate closing and opening of the level crossing. Output subsystem displays the control action to the users. Input unit produce needed information for the control unit by using the sensors for detecting the arrival and departure of the train.

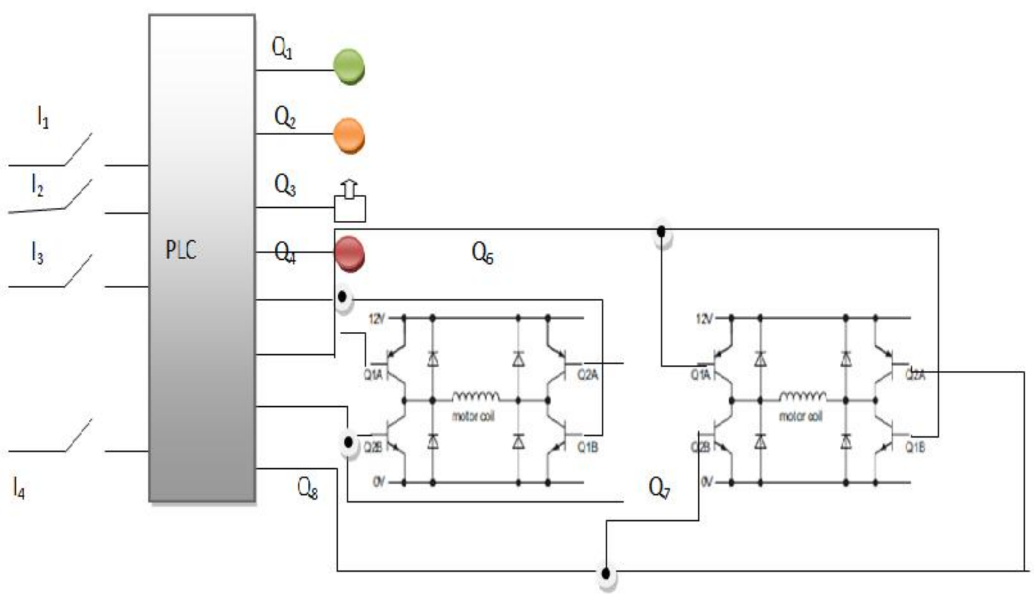
The decomposition of the design into its subsystems is its structural representation. The approach can continue to any finer level of detail.

i. **The Design Process**

Any design process comprises a basic sequence of tasks that are performed in various situations. Assuming that we have an initial concept about what should be achieved in the design process, the first step is to generate an initial design. This step often requires a lot of manual effort because most designs have some specific goals that can be reached only through the designer’s knowledge, skill, and intuition. The next step is the simulation of the design at hand.

To carry out the simulation successfully, it is necessary to have adequate input conditions that can be applied to the design that is being simulated and later to the final product that has to be tested. Applying these input conditions, the simulator tries to verify that the designed circuit will perform as required under the original product specifications. If the simulation reveals some errors, then the design must be changed to overcome the problems. The redesigned version is again simulated to determine whether the errors have disappeared. This loop is repeated until the simulation indicates a successful design.

A prudent designer expends considerable effort to remedy errors during simulation because errors are typically much harder to fix if they are discovered late in the design process. Even though, some errors may not be detected during simulation, in which case they have to be dealt with in later stages of the development cycle.



Input CPU Output Driver with motor

Figure. 4.1Complete system Designed

- **Input/output terminal address assigning of PLC**
- **I1** is the stop push button to stop the whole system in case of maintenance need or any outputs are in fault.
- **I2** is a start push button to initiate the system that a system is in standby to execute if any approaching train is coming.

- **I3** and **I4** are arrival and departure vibration sensor respectively, the signal produced is directly related to the accelerated vibration due to the train movement. Then piezoelectric based accelerometer measurement is proportional to vibration produced.

Hence, 4-20mA (0-10V) analog signal is sent to the PLC if either of them are activated.

- **Q1** is the output connected to a green light to indicate the users that the crossing is safe.
- **Q2** is the output connected to a yellow light to warn the users that a train is approaching to the crossing level.
- **Q3** is the output connected to buzzer alarming to warn for sleep of eye or seeing impaired.
- **Q4** is the output connected to a red light to indicate that train is at crossing level
- **Q5, Q6, Q7, Q8** are out puts connected to the stepper motor driver for closing and opening of the gate.

- ## Operation of L293D Driver

Drivers are enabled in pairs, with drivers 1 and 2 enabled by 1,2EN and drivers 3 and 4 enabled by 3,4EN. When an enable input is high, the associated drivers are enabled and their outputs are active and in phase with their inputs. When the enable input is low, those drivers are disabled and their outputs are off and in the high-impedance state. With the proper data inputs, each pair of drivers forms a full-H (or bridge) reversible drive suitable for solenoid or motor applications. A VCC1 terminal, separate from VCC2, is provided for the logic inputs to minimize device power dissipation. L293D is characterized for operation from 0°C to 70°C.

- ## Stepper motor operation

The bipolar stepper motor has two coils that must be controlled so that the current flows in different directions through the coils in a certain order. The changing magnetic fields that these coils create cause the rotor of the motor to move around in steps.

The circuit that is normally used to control one of the coils is shown below. Notice how these four ‘control’ transistors that are switched on in ‘pairs’. If Q1A and Q1B are biased at a time, current flows from the source to the ground then motor coil will energize easily. Therefore with two coils there are four control transistor pairs (Q1-Q4) which must be switched on and off in a certain sequence.

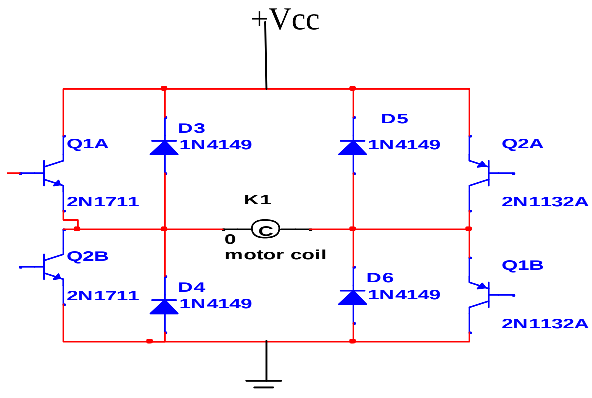


Figure 4.2 driver motor interface

4.2 System Implementation

4.2.1 Hardware Implementation

This project utilizes two powerful vibration sensor fixed at each side of the rail (one for the train arrival and one for departure) for one way. For the other way similarly another pair is fixed at each side of the rail. Sensor activation time is so adjusted by calculating the time taken at a certain speed to cross at least one compartment of standard minimum size of the train. The place where the sensor placed is depend on the speed of the train. We select the level crossing clearance time to be 45s since sensor activation. If the speed of train is 120km/h, the sensor position will be 1500m far from the level crossing. For our project prototype in Addis Ababa LRT the speed of the train is 40km/h. So the sensors are fixed at 500m on both sides of the gate. We call the sensor along the train direction as ‘arrival sensor’ and the other as ‘departure sensor’ fixed at 200m.When arrival sensor gets activated, buzzer will immediately sound, yellow light will turn ON and gate will close after 30 seconds which gives time to drivers to clear gate area in order to avoid trapping between the gates and remains closed until the train crosses the gate and reaches the departure sensor, at the same time red light turn ON, alarm stop and yellow turn OFF. After the train has crossed and reaches the departure sensor, gate motor is turned on in reverse direction and the gate is opened, so the RED Light is turn OFF and GREEN Light is turn ON again.

In this project PLC plays the main role. The program for this project is loaded in to the PLC and interfaced to all the peripherals. The timer program is inside the PLC to maintain all the functions as per the scheduled time. The indicator lights and buzzer are connected to PLC to warn the road users. Stepper motors are used for the purpose of gate control interfaced with current drivers chip L293D it's a 16 pin H-bridge IC.

Vibration sensors are used for the detection of the train whenever it sends a signal to PLC the stepper motor should operate and warning signal will be displayed. In case of sensor failures, manual push buttons are used for operation of the gate and warning signals.

- **Gate control unit**

As the figure shows below, it consists of two vibration sensors placed at two sides of gate. Arrival and departure sensors should keep at a distance of 500m and 200m respectively from the gate. Stepper motor is used for the purpose of the gate closing and opening interfaced to the L293D driver.

When train reaches the sensor, it is detected by (vibration) sensors placed 500m before the gate, then signal is sent to the PLC. The PLC control the pulse supplied to the stepper motor by giving the pulse in the correct sequence to the driver which control the supply sequence of the stepper motor that closes the gate. When train passes away the level crossing, departure sensor send the signal to the PLC to enable the current driver to open the gate by rotating the stepper motor to the reverse direction in steps to get back in to original position.

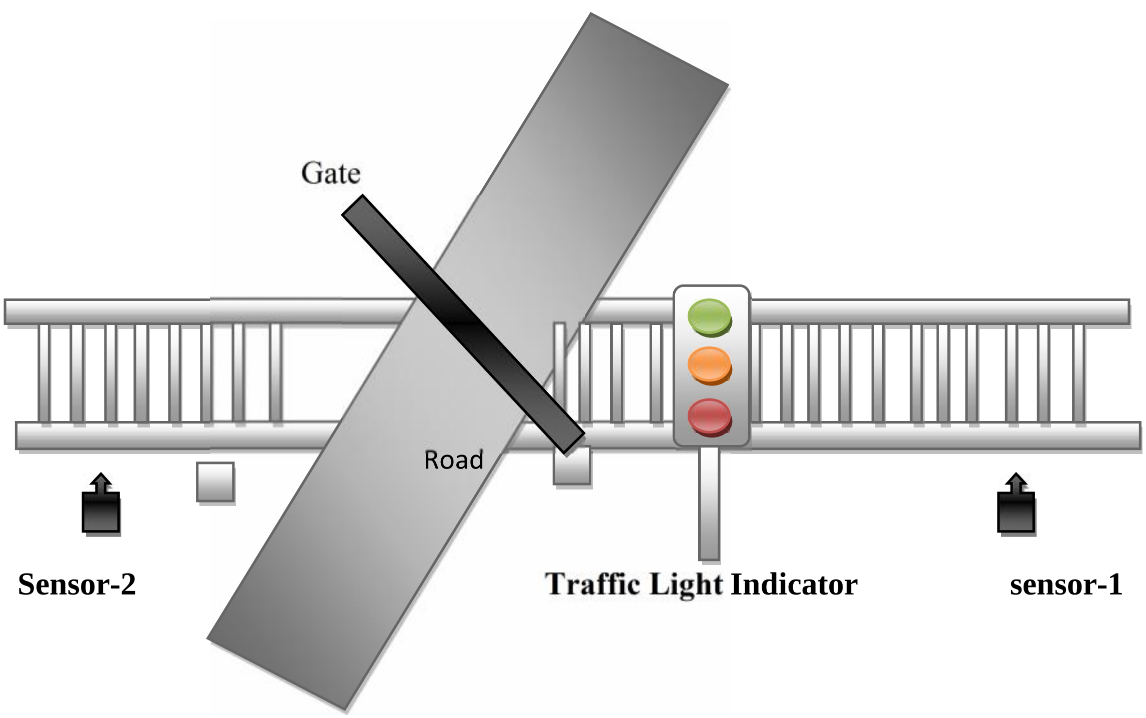


Figure 4.3 Automatic railway gate control system

- **Announcement unit:**

Usually, announcement made at the station for the information of train arrival and departure. In this model we are using a buzzer and indicator light for the announcement.

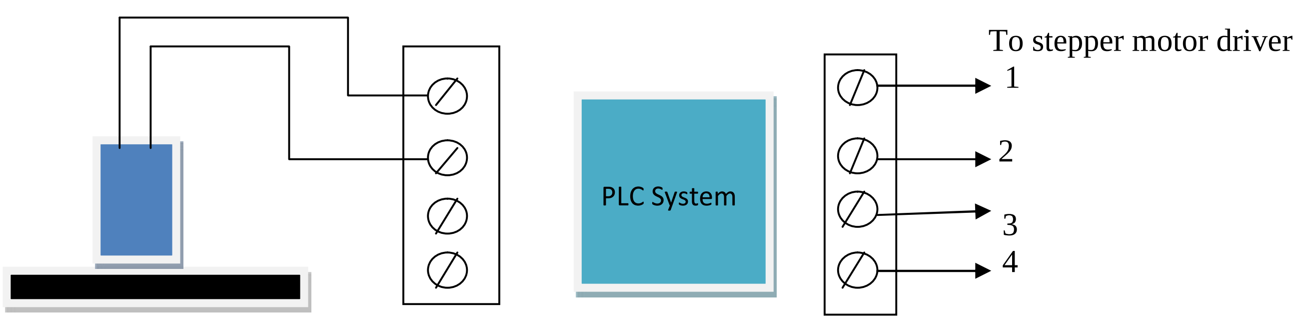
Train arrival Detection: When vibration of the rail is sensed by the arrival sensor signal is sent to the programmable Logic controller (PLC) to activate the buzzer and indicating lights.
At that moment the train arrival is sensed on either of the gate, road users are warned about the train approach first by YELLOW light and buzzer, after 30 second by **RED** light placed to caution the road users passing through the gate.

Train departure detection: Detection of train departure is also done using vibration sensor as explained the head of train arrival detection. As the sensor detects the departure of the train it activates the green light to allow the passage of road users.

- **Sensor Interface with PLC**

Vibration velocity of the train vibrates the vibration transducer/transmitter that integrates the acceleration measurement taken from a piezoelectric-based accelerometer, resulting in a velocity measurement proportional to the vibration. The vibration transducer/ transmitter then sends a 4–20 mA analog signal to the PLC that is proportional to the velocity of vibration in meters per second. As the PLC get the signal, it provide a warning indication, and close the gate automatically.
Figure 4-4 illustrates a typical direct interface application of a vibration transducer (4–20 mA) to a PLC system where the PLC is responsible for a warning command to the vehicle drivers & pedestrians approaching to level crossing.

4-20mA 4-20mA
Analog input Discrete outputs



, Rail truck **Fig.4.4 Sensor Interface with PLC**

- **PLC Interface with Stepper motor using L293D**

The Figure 4.5 below shows the stepper motor interfacing with PLC using L293D.The interfacing of stepper motor consists of PLC, stepper motor, and L293D current driver chip to switch electronically with 12V. It is used in this project for the purpose of gate control. L293D is a current driver chip used for supply control to the stepper motor; it is a 16 pin dip.

Here a stepper motor is used for controlling the gates. A stepper motor is a widely used device that translates electrical pulses into mechanical movement. They function as their name suggests - they "step" a certain angle at a time.

Steppers don't simply respond to a clock signal. They have several windings which need to be energized in the correct sequence before the motor's shaft will rotate. Reversing the order of the sequence will cause the motor to rotate in the other way.

L293D is used to drive stepper motors because stepper motors are, in fact, two (or more) coils being driven in a sequence, backwards and forwards.

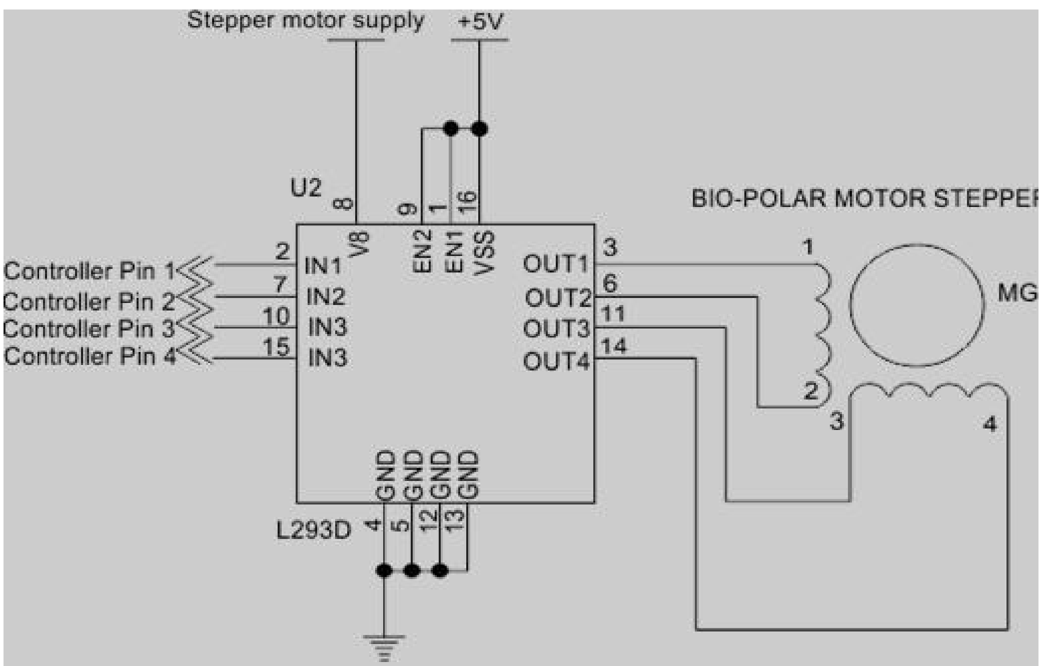


Figure 4.5 PLC output interface with stepper motor through L293D

The L293D chip has 16 pins. Here is how each of the pins should be connected:

Pin 1, 9 Enable pins. Hook them together and keep them high to run the motor all the time.

Pin 3, 6, 11, and 14 Here is where we plug in the two coils. To check which wires correspond to each coil, we use a multi-meter to measure the resistance between the wires. The wires correspond to the same coil has a much lower resistance than wires correspond to different coils. We can then get one coil hooked up to pin 3, 6 and another one hooked up to pin 11, 14.

Pin 4, 5, 12, and 13 Gets hooked to ground.

Pin 8 motor voltages, for the motors we are using, it is 12V.

Pin 16 +5V. It is the power supply of the chip and it's a good idea to keep this power supply separate from your motor power.

Pin 2, 7, 10, and 15 Control signals. Here is where we supply the pulse sequence. The following is how the pulse is applied sequentially for a single-cycle (to move the motor in the opposite direction, just reverse the steps. i.e. from step 8 to step1):

Table 4.1 Sequence of coil energizing

Forward Rotation

Reverse Rotation

	Coil A+	Coil B+	Coil A-	Coil B-
Step 1	High	-	Low	-
Step 2	-	High	-	Low
Step 3	Low	-	High	-
Step 4	-	Low	-	High
Step 5	High	-	Low	-
Step 6	-	High	-	Low
Step 7	Low	-	High	-
Step 8	-	Low	-	High

Where HIGH = 12v

LOW = 0v

'-' = No connection

4.2.2 Software Implementation

A software program is required in order to tell the PLC what instructions it must follow. Programming software is typically PLC specific. A software package for one PLC, or one family of PLCs, such as the S7 family, would not be useful on other PLCs. The S7-200 uses a Windows based software program called STEP 7-Micro/WIN32.

The PG 720 and PG 740 have STEP 7 software pre-installed. Micro/WIN32 is installed on a personal computer in a similar manner to any other computer software

- **Programming PLC to Control the system:**

We need to design control circuit program by using PLC to generate a signal (pulse) for both the speed and the angle location. The circuit program controls the indicating lamps, announcing buzzer & the stepper motor to save from level crossing damage. We will control the system by setting the program which generates eight output where (Q1,Q2,Q3,Q4)are connected for indicating lights & buzzer, (Q5,Q6,Q7,Q8) output to stepper motor driver input in order to drive for phase(coils) of bi polar stepper motor(A+,B+,A-,B-) . In this figure below is showing block diagram how connecting the PLC with stepper motor driver.

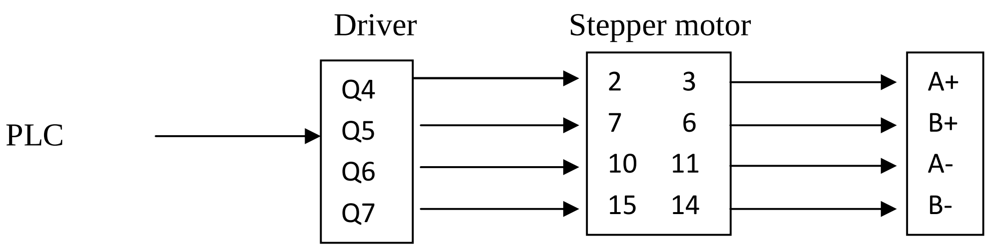


Fig 4.6 Block diagram of stepper motor control circuit

- **Programming PLC to control stepper motor**

Stepper motor needs a driver to control the pulses distribution of the motor points. That's to get the motor rotate. In this implementation we are able to activate the driver by using PLC to control motor rotation and position control.

We know from specification of stepper motor each pulse gives 3.6˚and if we want to get angle 90˚ for example, we have to calculate the number of continuous pulses as following:

$a = s * N$……………………………………………………...………………………………equ (2)

Where:-

a = required angle

s = small angle for one pulse=1.8˚

N = number of pulses

$N = a / s$…………………………..……………………………………………………………..equ (3)

$= 90^\circ/3.6^\circ = 25$ pulse

So, if we want the stepper motor rotate by angle 90˚ we need 25 pulse So we will use the (PLC) as generate pulses and same time it distribute pulses to coils, and design program in ladder diagram that generate 25 pulse.

If we want control the speed of motor then change preset time (PT) of each timer. In this program we will use the timer and counter to generate pulses .

- **Programming PLC to control the traffic light sequence**

Indicating traffic lights need an input vibration sensor to control their ON /OFF condition. The activation of the sensors have been done by the arriving or departure of train. Then signal is send to PLC to control their sequence

Now we need a control algorithm sequence program to control the automatic railway gate using traffic indicating, buzzer and stepping motor.

4.2.3 Project flow chart

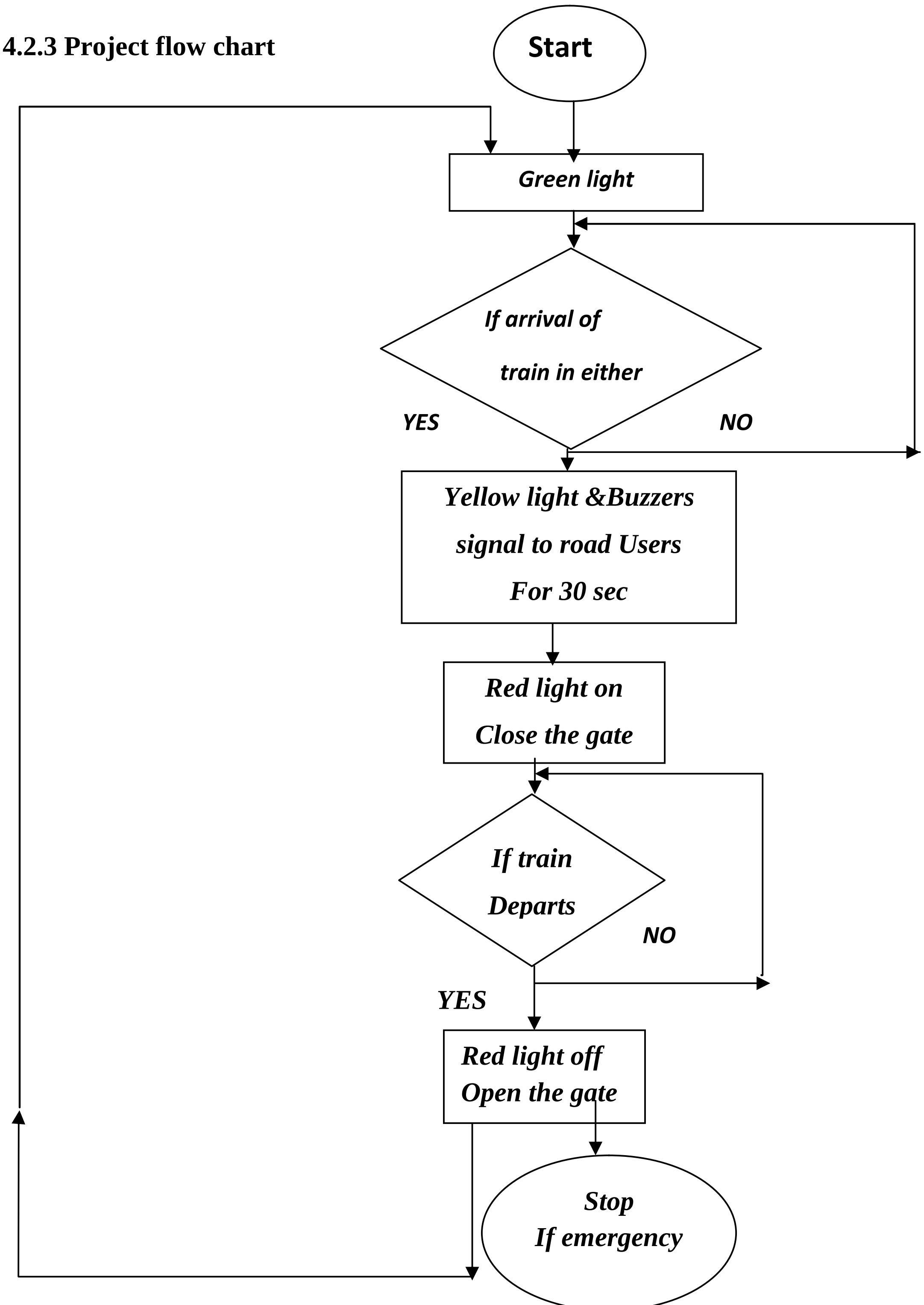


Figure . 4.7 Program Flow Chart

Basically to create or change a program, the required devices are PLC, Programming Device, and Programming Software and Connector Cables.

4.2.4 Simulation Result of the Project

After the compilation of the program written on Siemens logo programming device using the ladder logic programming system and all instructions are loaded to 12/24 Rc semiens logo CPU, then we are ready to run the simulation.

Initially when we run the program green light is ON to mean there is no train approaching(to allow vehicles and pedestrian cross the road), then if arrival sensor activates green light is OFF, yellow light with alarm is ON for warring the road vehicles and pedestrians that the train is approaching . After 30 seconds vehicles and pedestrians leave the level crossing, red light ON and motor closes the gate for total safety. As the train passes the gate, the departure sensor activates and opens the gate by reversing the motor, then a green light ON again to allow vehicle and pedestrian crossing the road.

CHAPTER FIVE

RESULT AND CONCLUSION

5.1 Result and Discussion

Result includes the successful operation of PLC based automatic gate control system. In the very beginning, we railed the toy train to the rail truck a certain distance far from arrival sensor side directing to the cross section area. When we push the start push button a green light is glowing (ON). Just as it approaches to the arrival sensor which is placed (located) at 70cm apart from the crossing level, it senses and send signal to the PLC. The output of the PLC activated the Yellow light and alarm at the same time for about 2seconds by switching the green light OFF. In the mean time, we have assured that yellow light and bell stop their operations after the predetermined time, a red light turned ON and motor closed the gate simultaneously.

Secondly, when the toy train departs from the crossing level located at 30cm apart from the crossing, just in a closing fashion the motor opens the gate, red light OFF and green light ON again at a time.

When we compared this project with Addis ongoing LRT project, it has greater comparative advantage. Because it is fully automatic which does not need a gate keeper to open and close the railway gate, while the Addis LRT is semi automatic type, used a gate keeper for closing case that could lead potential human error during closing operation of the gate, such as delay in informing the gatekeeper about the arrival of the train, delay in the gate operation by the gate keeper

Generally speaking, this proto type is successful that the expected output and result output are as we proposed. So, by all accounts this project is feasible, and applicable to real work activities.

- **Problem encountered**

In developing this prototype, the big challenging problems, we have faced were, vibration sensor 'mini sense 100' that is compatible to the system is not available in the market. So in the project prototype we are obliged to use a limit switch as a sensor for demonstration purpose.

5.2 Conclusion

In this project we have studied the optimization of an automatic rail way gate controller for Addis Ababa LRT (light rail transit) using Vibration sensor and programmable logic controller (PLC).

It is possible to reduce the possibilities of rail way gate sever accidents at level crossing caused by inappropriate controllers like manual and semi automatic types.

The accidents are avoided at places where there is no person to manage the railway crossing gates. Here we use the stepper motor to open and close the gates automatically when it rotates clockwise or anticlockwise direction to operate the gate automatically. When the train arrives in a particular direction the vibration sensor senses and generates appropriate signal, then at the same time the PLC provides certain output signal to the stepper motor to function. When the signal from PLC is sent to the stepper motor it rotates to open/closes the gate according to the signal output from sensor.

By this mechanism, gate keeper presence is not required. PLC performs all the operations like receiving sensor signals, alarming and gate opening &closing etc. The mechanism works on a simple principle and there is not much of complexity needed in the circuit.

5.3 Recommendation

This prototype or techno ware can easily be implemented in real life situation, by selecting or designing higher voltage, current and torque rating of a stepper motor, which can drive heavy and long boom barrier.

In our technique though it has many merits, but still the power supply of 220V AC POWER is required for functioning of the system. It can be avoided with the help of a battery charged by a solar panel. Since solar energy is an inexhaustible natural source of energy.

Another room of improvement is to replace the vibration sensor with an imaging system/ camera system. So that it has a wide range of detection capability, which can be up graded in to an excellent automatic rail way gate control system.

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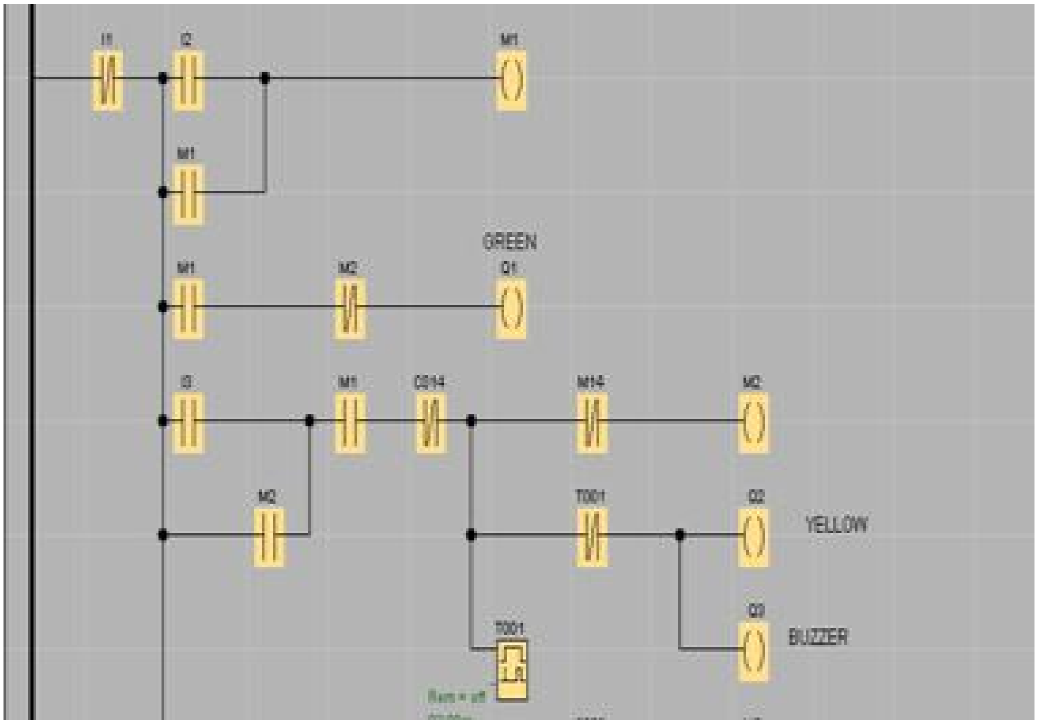
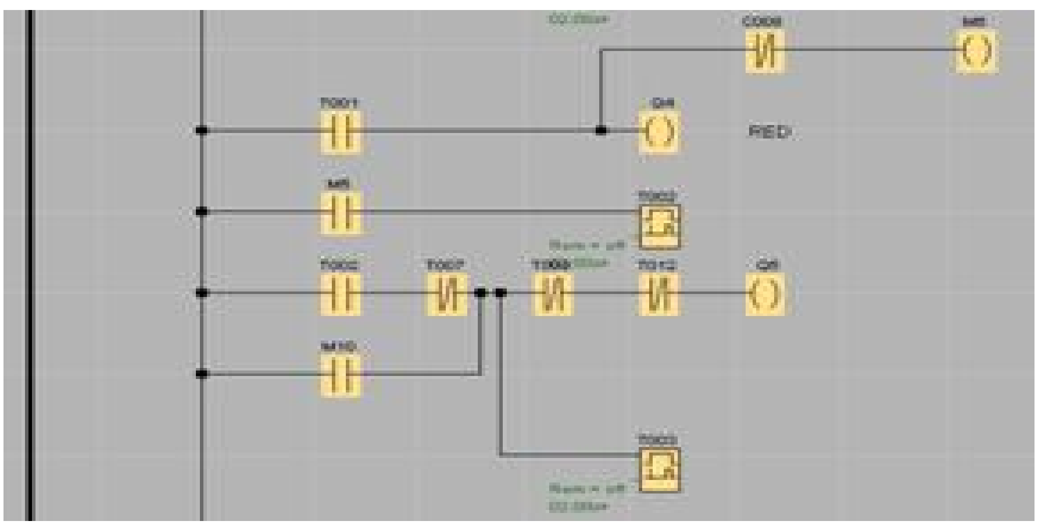
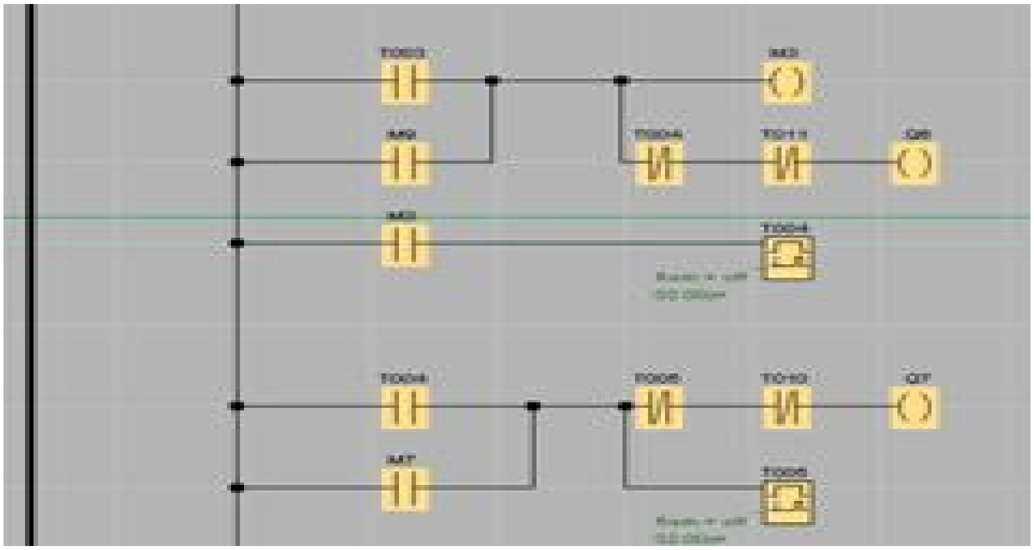
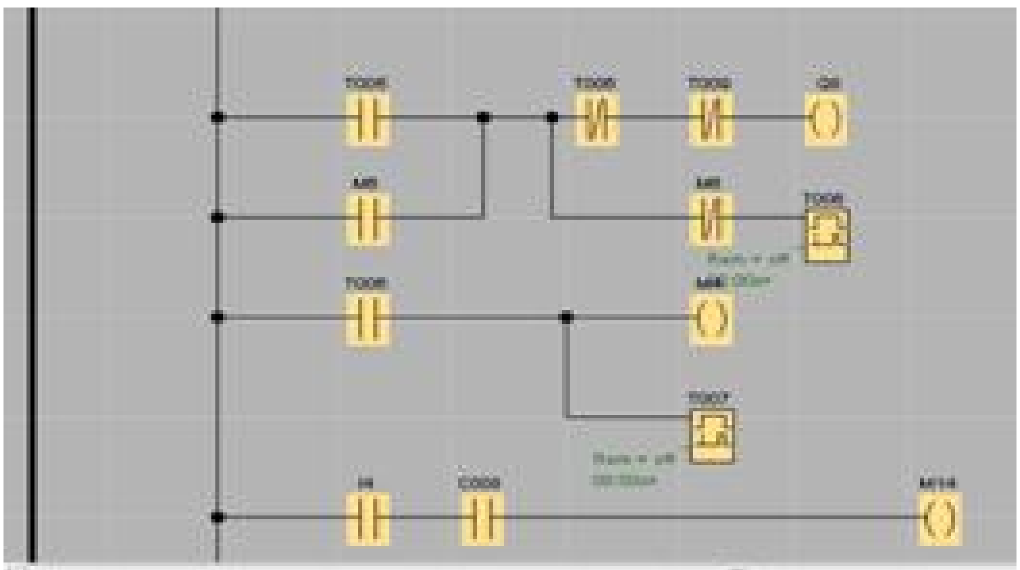
APPENDIX A

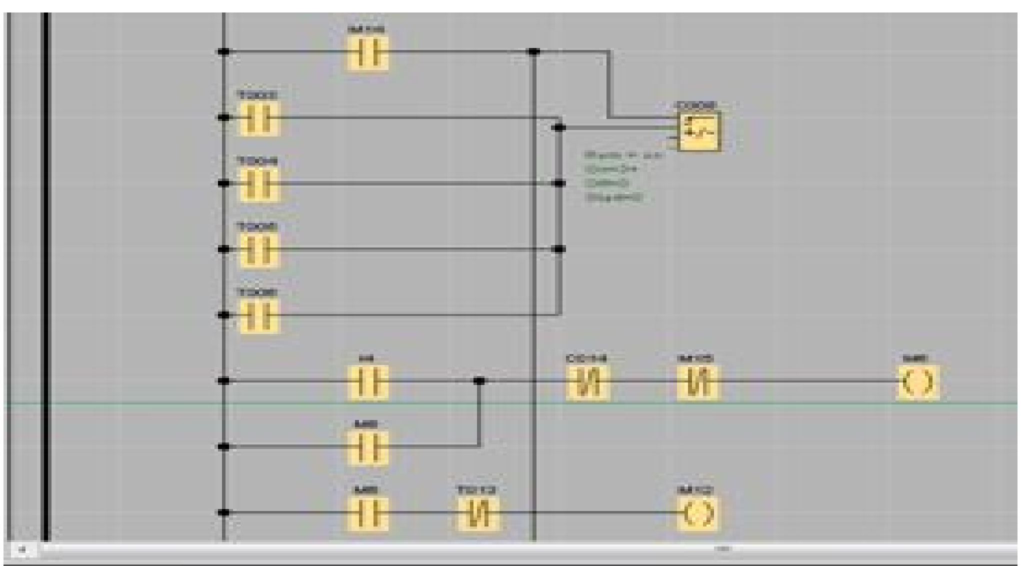
Announcement and motor control Sequences











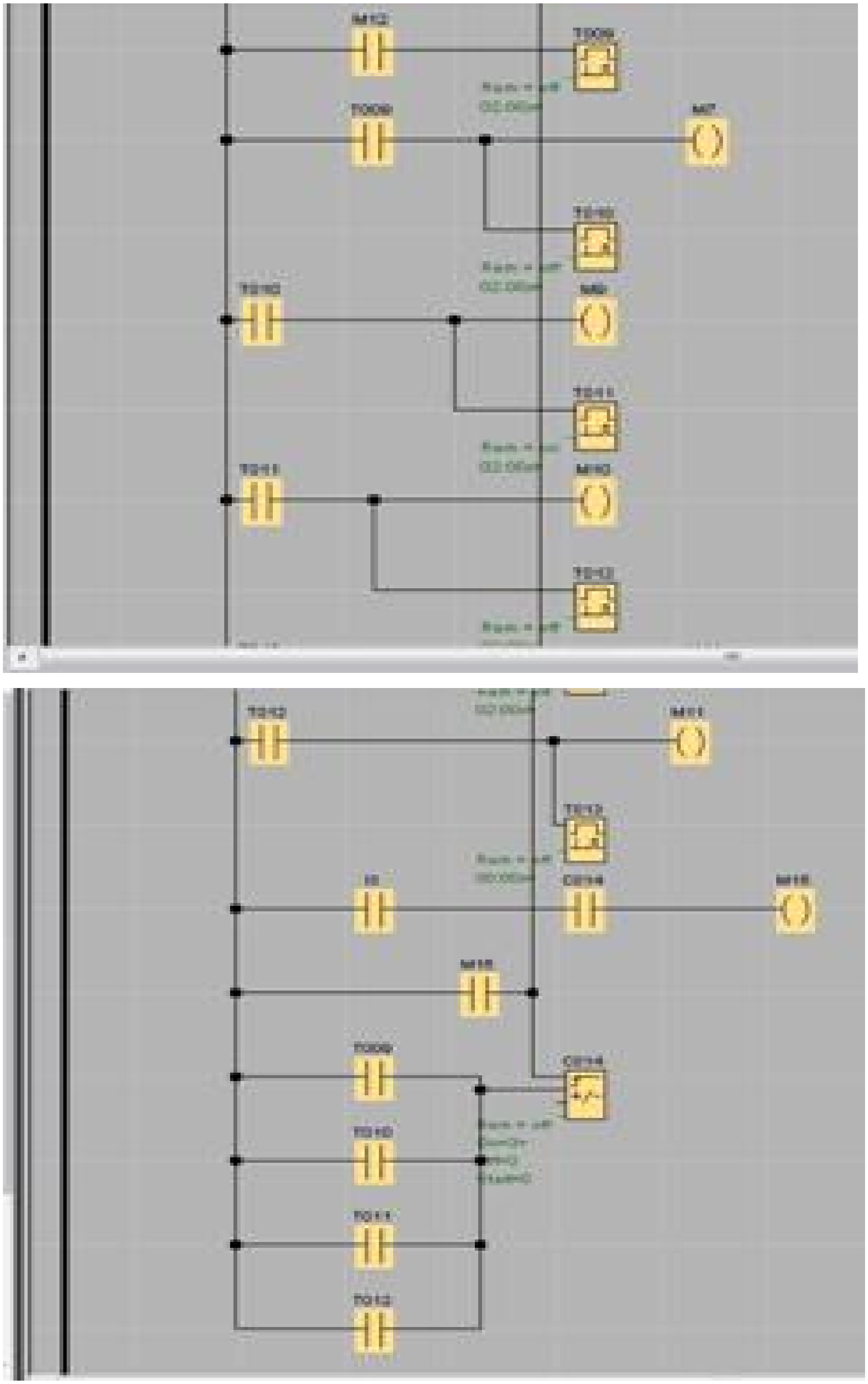


Fig 4. 7 PLC Ladder Diagram for Sequential operation of the system

APPENDIX B

- ***Proto type of automatic railway gate control***