



Addis Ababa University
Addis Ababa Institute of Technology
School of Electrical and Computer Engineering

Railway Security Monitoring System Using Vibration Sensor and ZigBee for Addis Ababa Light Rail Transit

A Thesis Submitted to the Addis Ababa Institute of Technology, School of
Graduate Studies, Addis Ababa University

In Partial Fulfillment of the Requirements for the Degree of Master of Science in
Electrical Engineering (Railway Electrical Engineering)

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August, 2015



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Declaration

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Abstract

Railways are prime mode of transportation and large infrastructures in many countries. Accidents occurring in railway transportation systems cause loss of precious lives and property. One of the major accidents occurring on railway transportation is at level crossing. So to avoid the level crossing accidents automatic gate control at a level crossing should be designed and applied. In this thesis automatic gate opening/closing operation is developed using PIC16F877A microcontroller and ZigBee technology.

The system consists of mainly two sub sections, the base station and the train station. The base station receives an input from vibration sensor and feeds to the microcontroller to be processed and send to control center via ZigBee transceiver. The amount of vibration coming from the train is measured using directional vibration sensor.

In this thesis to find the level of the vibration a data measured from Sweden city train is taken and customized to fit the AA-LRT Salitemihret case. So using these data a corresponding analog voltage is obtained. The analog voltage is then converted to equivalent binary digits into a way the microcontroller is understood using ADC804. The binary digits are programmed in to away they give information about the position of the trains.

Control central gets the position of the train then decision is made and a command to control the train side signals, road user signals and to operate the gate is sent back Via ZigBee.

A voltage level 3.75 -5 volts (05 H) means the train is 282 meters away from the level crossing) a Red signal is displayed to the cars and passengers and a message '' Away is clear you can proceed with limited speed and care, thank you'' is displayed to the driver. In this thesis the simulation is done using Proteus software which is a nice interfacing environment and the program for this thesis is embedded C program.

Key words: Microcontroller, PIC16F877A, ZigBee, CBI, Control center, Vibration sensor, Step size, hex, embedded C

Acknowledgment

I would like to express my appreciation to many people who have contributed to the Successful completion of this thesis work, most especially I thank for the Railway community who has helped me by providing resources. This thesis would have been very hard to accomplish without the help of some individuals. I would like to express my gratitude and respect to all those who gave their magnificent support and advice for the completion of this thesis.

I would like to express my deep and sincere gratitude to my advisor, Dr. Yalemzewd Negash and Mr. Abi Abate for their guidance, optimism, and continuous support throughout the study. I like to thank to all Addis Ababa university instructors, for their encouragement, unlimited technical reviews, constructive ideas, and valuable suggestions and for scarifying their time during the course of this thesis.

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List of symbols and abbreviation

AA-LRT	Addis Ababa Light Rail Transit
ADC	Analog to Digital Converter
PIC	Peripheral Integrated Circuit
CBI	Computer Based Interlocking
DAC	Digital to Analog Converter
EW	East-West
NS	North-South
IC	Integrated Circuit
KM	kilo Meter
KMPH	Kilo Meter Per Hour
LX	Level Crossing Box
MCS	Microcontrollers
TRANSEIVER	Transmitter and receiver

Chapter 1

Introduction

1.1 Overview of railway system

One of the most widely used and comfortable modes of transportation system is railway mode of transportation, but occasionally, accidents occur due to collision and by other reasons. It is very difficult to stop such collisions because of speed of moving trains, which needs a lead distance to stop. Collisions are happened due to human errors and/or faulty equipment.

This thesis deals with automatic railway gate operation (i.e.,) automatic railway gate at a level crossing replacing the gates operated by the gatekeepers. It deals with two things. Firstly it deals with the reduction of time for which the gate is being kept closed and secondly, to provide safety to the road users by reducing the accidents. By employing the automatic railway gate control at the level crossing the arrival of the train is detected by the sensors placed near to the gate. Hence, the time for which it is closed is less compared to the manually operated gates. The operation is automatic; error due to manual operation is prevented. Automatic railway gate control is highly microcontroller based arrangements, designed for use in almost all the unmanned level crossing in the train. In this thesis work aims at designing and testing of working model entitled railway security monitoring system using vibration sensor and it also provides an automatic railway gate at a level crossing replacing the gates operated by the gatekeeper. Level crossings cannot be used simultaneously both by road traffic and trains, as this result in accidents leading to loss of precious lives. This type of gates can be employed in an unmanned level crossing where the chances of accidents are higher and reliable operation is required. Since, the operation is automatic; error due to manual operation is prevented. The model of railway track controller is designed by using PIC16F877A microcontroller by employing the automatic railway gate control at the level crossing the arrival of the train is detected by the sensor placed near to the gate. Hence, the time for which it is closed is less compared to the manually operated gates and also

reduces the human labor. Automatic railway gate control is highly economical microcontroller based arrangement, designed for use in almost all the unmanned level crossings in AA-LRT.

As the use of Railway is very essential for transportation, railway safety is a crucial aspect of rail operation over the world. Malfunctions resulting in accidents usually get wide media coverage even when the railway is not at fault and give to rail transport, among the uninformed public, an undeserved image of inefficiency often fueling calls for immediate reforms. This paper is aimed at helping the railway administrations concerned to strengthen their safety culture and develop the monitoring tools required by modern safety management. Railroad intersections are very unique, special, potentially dangerous and yet unavoidable in the World [1].

The railway accidents are happening due to the carelessness in manual operations or lack of workers.

The other main reasons for the collisions of train are:

- Train derailment in curves and bends
- Running train collisions with the standing train

To this end, the thesis work found to be one of the efficient methods to prevent avoid train collision for AA-LRT using simple electronic components and automatically control of railway gates in an embedded platform. The system can be implemented and demonstrated by using vibration sensor and ZigBee with the help of microcontroller.

1.2 Overview of Railway system in Ethiopia

Railway transportation system had been used as a major freight and passenger transport to the eastern part of Ethiopia starting from 1917 to 2007 E.C. The system comes to existence during the reign of Emperor Menelik II and covers a total of 781km powered by diesel engine and jointly owned by Ethiopia and Djibouti. Great improvement of road network is prevailing in Ethiopia, but with limited connectivity, high cost of transportation and poor quality of service. The mobility need of the country population and the development of transportation system are far from compatibility. Therefore; the country is in need of modern, economic, time saving and

long lasting transportation which will ease import-export system and result fast development. To this end, the government of Ethiopia has embarked on railway system. The main reasons for the renewed interest in the railway are environmental, economical, and safety related issues [1] [2].

1.3 Introduction to AA-LRT Project (Thesis Area)

Addis Ababa Light Rail Transit (AA-LRT) Project is Ethiopian government plan of Transformation plan to satisfy the demands of transportation shortage problem in Addis Ababa. It is Electrified light rail transit with total length of 34.25 km (North-South line 16.9 km and East-West line 17.35 km). To effectively solve the problem of urban transportation, especially that of the Addis Ababa city, the government of Ethiopia decides to build a light rail in the city of Addis Ababa. Currently this project has planned two lines, the east-west line and the south-north line. About 3 km is the sharing section for both E-W route and N-S route, which has the greatest passenger current. The altitude of the plateau is 2,400m. With an urban population of over 3,400,000. The urban area is 530.14 km², and the density reached 5,607.96 per km² [1].

1.3.1 East-West Line

The east-west line project starts from Ayat and ends at Torhailoch. The total length is 17.4km. There are 22 stations, among which 5 are elevated stations, 1 underground station and 16 ground stations. The 22 LRT stations are placed in phase one of E-W route project, 5 of which are shared with N-S route. Average interval between two adjacent stations is 815 meters. The longest interval is 1210 meters and the shortest interval is 525 meters [1].

1.3.2 North-South Line

The south-north line phase I project starts from Menelik II Square and ends at Kality. The total length is 16.97km. There are 22 stations, five of which are shared with E-W route among which 9 are elevated stations 5 common stations at the common line), 2 underground station and 11 ground stations. Average interval between two adjacent stations is 793 meters. The longest interval is 1370 meters and the shortest interval is 510 meters. The depot locates at the south end

of the project. The control center (commonly used by both lines) is temporarily considered to be placed inside the parking yard [1].

1.3.3 Introduction to the shared line

The AA-LRT project as said earlier has two routes and these route share a common route with length of around 3 Km. EW line starts from Ayat is shares with the Kality line which meet at EW16/NS16 at stadium and ends EW20/NS20 with 5 stations.

1.3.4 Tramcar used in AA-LRT

The tram cars used in AA-LRT project are 6-axel double-articulated 70% low floor light tramcar. It allows bidirectional drive and it has the capacity of 286 passengers (64 seats and 6 passengers per m²) with the life time of about 30 years. The design speed of the tramcar is 70kmphr [3]. The dead weight (which is the crucial component for generating speed profile) of the tramcar is 59.42 tone with length of 28.4 meter and width of 2.65 meter.

At start up, tramcar has the chance to accelerate at maximum acceleration which is greater than or equal to 1.0 m/s², on the other hand, average braking deceleration is dependent on the type of braking applied. It has to be greater than or equal to 1.1m/s² for normal braking and greater than or equal to 2.0m/s²for emergency braking.

1.4 Statement of the Problem

Despite the fact that railway is the cheapest modes of transportation and preferred over all other means of transportation, there are challenges associated with this system. 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 etc. Therefore more efforts are necessary for improving safety. Collisions with train are generally catastrophic in that the destructive forces of a train usually no match for any other type of vehicle. Train collisions form a major catastrophe, as they cause severe damage to life and

property. Train collisions occur frequently eluding all the latest technology. This system is to manage the control system of railway gate using the microcontroller. The main purpose of this system is about railway gate control system and level crossing between railroad and highway for decreasing railroad-related accident and increasing safety. In addition, it also provides safety road users by reducing the accidents that usually occur due to carelessness of road users and errors made by the gatekeepers.

1.5 Objective of the thesis

1.5.1 General Objective

The general objective of this thesis is to make a railway transportation service make secure by avoiding train collision on level crossing by automatic control of the railway gate.

1.5.2 Specific Objective

The specific aim of this thesis is to:

- Review the conventional train detection schemes and analyze their role in railway network.
- To convert the amount of vibration level to distance /voltage and use the result for assessment of level crossing safety performance and safety measures.

1.6 Methodology

The following methods are employed to achieve the objectives of the research.

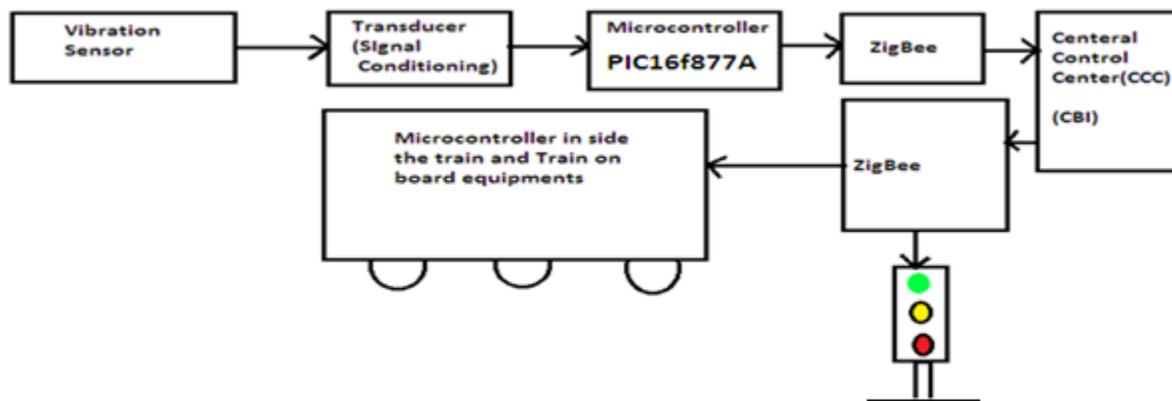


Figure 1.1: Overall system methodology

As it is shown on the figure above this thesis is mainly done based on PIC16f877A microcontroller and ZigBee technology. First the vibration generated by the train is sensed by the MINI sense 100 vibration sensors and recorded using Sony recorder and conditioned in a way the PIC16f877A microcontroller understands using ADC converter and the vibration level is then mapped in to a corresponding voltage and is given to the PIC16f877A.

The PIC16f877A is then makes a decision based on the voltage levels and the decision to the control center via ZigBee. The control center is makes a decision based the command it gets from the PIC16f877A and sends back the decision to the train on board equipment and the way side signals. The train is then controlled by the command it display on the on board equipment and the way side signal again the road user operates based on the way side signal that displayed to them.

1.7 Scope of the thesis

- Review the present status of level-crossing accidents and train collisions.
- Present statistics, indicators, technology and problems relating to the systems adopted for railway protection; in practice.
- Analyze various alternative systems for train collision avoidance; and make recommendations pertaining to the selection of cost-effective.

1.8 Thesis Organization

The thesis organization is as follows. In chapter 1 discuss introduction to level crossing and gives high lights to the AA-LRT project. It also discusses the objective of the thesis, methodology of the thesis and gives good insight to the history of railway transportation.

In the following chapter; chapter 2 we are going to discuss about the proposed system.it discuss about the block diagram for both train station side and base station side and discuss the detail working principle of both stations sides.

In chapter 3 modeling of the vibration is done and different factors that affect the vibration are discussed; in chapter 4 detail model of level crossing for AA-LRT case is presented. In chapter 5 the software development is discussed.

In chapter 6 Result and discussion are discussed and analyzed. In the last chapter 7 conclusion and recommendation are discussed. Finally the different supporting materials are cited under the reference section.

Chapter 2

PROPOSED SYSTEM

2.1 Railway Security Monitoring Using Vibration Sensor and ZigBee

The proposed Train Anti Collision and Level Crossing Protection System consists of a self-acting microcontroller and two way ZigBee based data communication system which works round-the-clock to avert train collisions and accidents at the level crosses. Thus enhances safety in train operations by providing a NON-SIGNAL additional safety overlay over the existing signaling system. The system operates without replacing any of the existing signaling and nowhere affects the vital functioning of the present safety systems deployed for train operations. The proposed system gets data from the vibration sensor. The efficiency of the system is expected to be considerably increased as the proposed system takes inputs from the sensor and also from the level crossing gates. 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 existing system, the cost of implementation of this system is also less. The overall system block diagram is will be discussed next.

2.2 Block diagram of the proposed system

In this thesis the entire system can be classified into three sub systems. The first system can be placed in the base station side and the second system can be placed in the train side and the third system is the central control system.

- The system in the base station consists, Micro controller PIC16F877A, Vibration sensor, Servo motor, zigBee transceiver and necessary power supply conditions.
- The system in the train side consists, Micro controller PIC16F877A, zigBee transceiver, Brake control system and necessary power supply conditions.
- The Central control system

The fundamental block diagram of base station side and train side are shown below

2.2.1 Fundamental block diagram of base station side

Block diagram of base station side

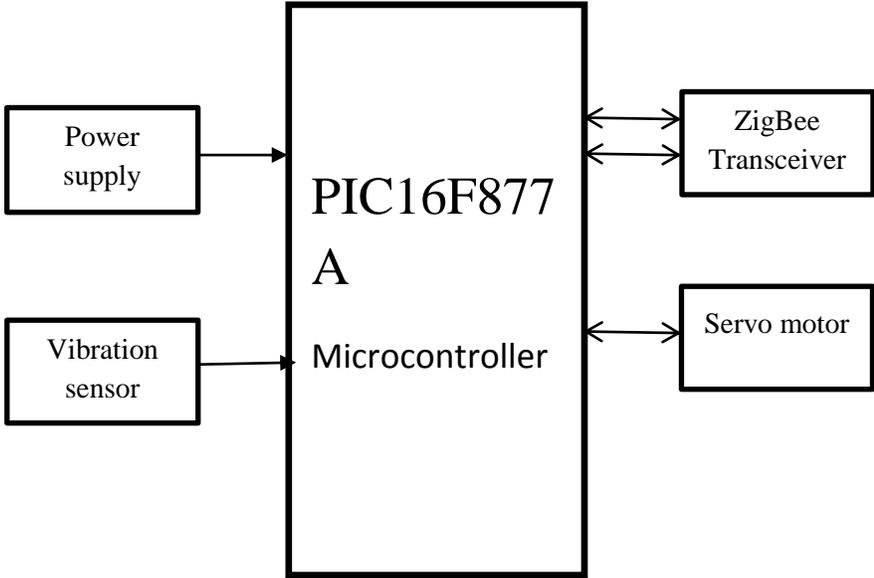


Figure 2.1: block diagram of base station

2.2.2 Fundamental block diagram train side

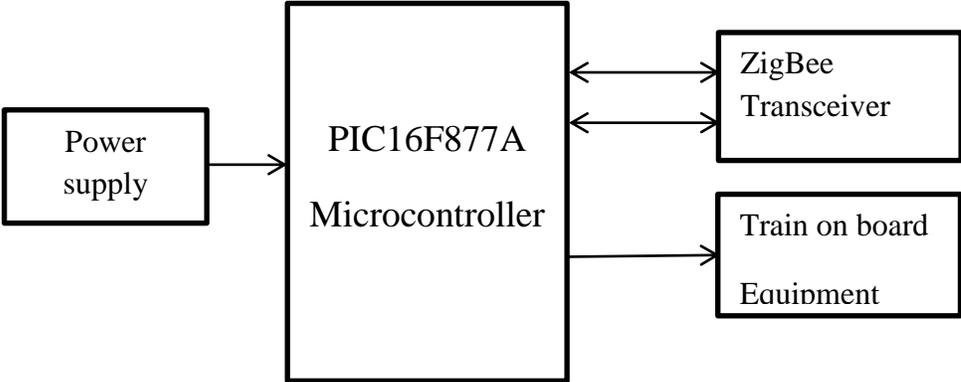


Figure 2.2: Block diagram of train side

2.3 Detail description of the block diagram components

- **Regulated Power supply to microcontroller**

A variable regulated power supply, also called a variable bench power supply, is one which you can continuously adjust the output voltage to your requirements. Varying the output of the power supply is recommended way to test a project after having double checked parts placement against circuit drawings and the parts placement.

This type of regulation is ideal for having a simple variable bench power supply. Actually this is quite important because one of the first projects a hobbyist should undertake is the construction of a variable regulated power supply. While a dedicated supply is quite handy e.g. 5V or 12V, it's much handier to have a variable supply on hand, especially for testing. Most digital logic circuits and processors need a 5 volt power supply. To use these parts we need to build a regulated 5 volt source. Usually you start with an unregulated power to make a 5 volt power supply; we use a LM7805 voltage regulator IC (Integrated Circuit).

Vibration sensor

The sensors sense the input and sends to the microcontroller, where it responds and gives command to the particular component with predefined algorithm. The time parameters are crucial which can be easily changed and modified using Micro-controllers. Thus, this device would work in coherence would help to reduce the train collisions.

- Sense the vibration of the train. According to the vibration it determines the train is arriving or departure.
- It works based on piezoelectric effect. That means it converts mechanical vibration of train into electric pulses.
- The vibration sensor used in this thesis is mini sense 100 vertical.

- **PIC16F877A microcontroller**

The microcontroller employed in this thesis is AT89S5

- **ZigBee transceiver**

ZigBee devices are often used in mesh network form to transmit data over longer distances, passing data through intermediate devices to reach more distant ones.

Why ZigBee is selected from other wireless data transmission networks?

- Low power consumption.
- Can cover 10-100 meters away from line of sight depending on output power and environmental characteristics.
- Can cover more distance by passing data through mesh networks of intermediate devices.
- ZigBee is a specification for a suite of high level communication protocols
- The IEEE specification of ZigBee is IEEE 802.15.4.

- **Servo motor**

It is the modified form of DC motor

- It consist DC motor, potentiometer, gearing system.
- The servo motor works based on PWM switching

The main advantage of servo motor is precise control of angular position.

2.4 Hardware description of the block diagram components

2.4.1 Vibration sensor

2.4.1.1 Vibration

Every time a train hits a new piece of track it produces a vibration which travels down the track.

These vibrations are affected by many different factors, which make it necessary for the thesis to be calibrated for each case as the speed and amplitude of the vibration is different for each case.

Different factors effecting the vibrations are:

- Temperature of the surroundings and the track

- The materials the track consists of.
- Installation method of the track.
- The type and materials of the track joints.
- Cracks and defects in rail track.
- Defects in the trains wheels (eccentric wheels, unbalanced wheels, wheel flats)
- Sleepers (railroad ties), placed at regular intervals.

The figure blow shows an example of a train approaching the device and what the vibration signal may look like. (1000Hz, 200Hz, 500Hz, 12500Hz frequency components)

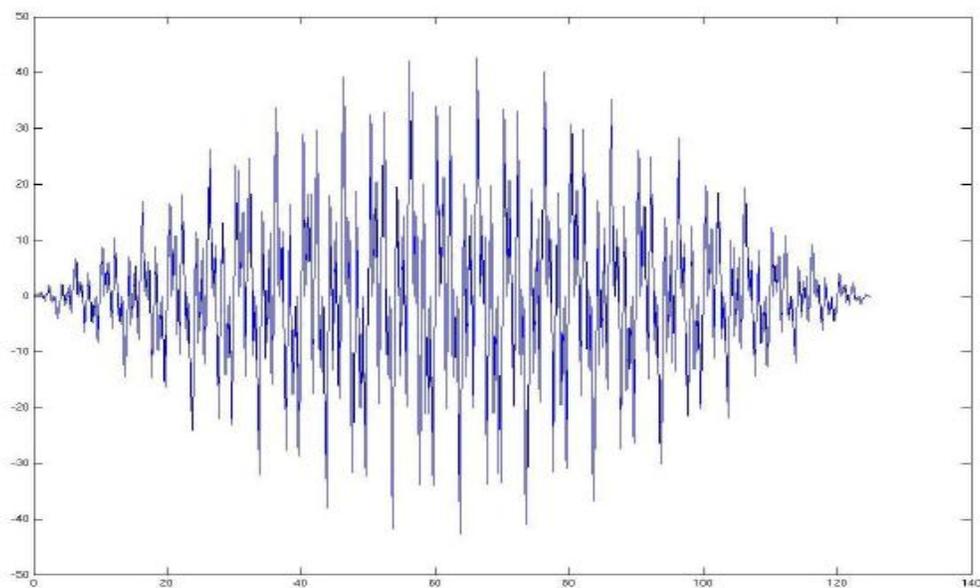


Figure 2.3: Vibration signal of approaching train [8]

2.4.1.2 Sensor

To convert the vibrations on the rails to an electrical signal, we will need a transducer. Some of the most common vibration sensors are piezoelectric sensors which offer one to three orthogonal axes of measurement. Another transducer that is becoming more commonly used is an accelerometer. These devices also take advantage of the piezoelectric effect to output the static acceleration or g-force of the object they are mounted to. The output of these devices can be analog or digital signals which can be read with other circuitry.

2.4.2 Signal Conditioning

The output of the sensor will require conditioning to properly interface with the train detection circuitry. Amplification will adjust the signal to the required levels and remove noise. Additionally, the signal will be filtered to remove undesired frequency components and produce the most comprehensible signal.

2.4.3 Signal Processing

The method of detecting approaching trains will be determined based on the circuitry. There are two options for processing the conditioned signal from the sensor; however, they operate on similar principals. The first option is to use a software solution by implementing a low-cost microcontroller. The microcontroller will convert the analog signal to a digital value and determine if the train is within a specific range. The second option utilizes discrete components and integrated circuits to perform the same function, keeping the signal analog.

The software solution provides more flexibility and functionality in that it can be updated with new firmware to improve reliability. The extra functions on the microcontroller allow it to do many other tasks if required. Alternatively, the analog solution is expected to be much lowering cost and simpler to calibrate.

Microcontroller PIC16f887

The analog signal output of the filter is converted to a digital signal by the ADC of the Microcontroller. The sampling frequency of the microcontroller must be, at the very least, double that of the highest frequency the filter outputs. A higher sampling frequency is recommended to accurately represent the mixed frequency signal as a set of discrete levels. Missing important points of the signal could result in a misidentification or delay in detecting a train. The microcontroller's ADC must also have adequate resolution to ensure the signal is accurate. 12-bit resolution is likely sufficient for this purposes. The ability to do many analog readings and arithmetic operations quickly is essential. For this we require the highest clock frequency possible for a specific microcontroller. This will likely be achieved by an external

Crystal oscillator. These few requirements could easily be met by an 8-bit microcontroller and give us many options to choose from for the final design. This type of microcontroller also has the added advantage of being inexpensive.

It uses piezoelectric effect to detect the vibrations in the rails due to the arrival or departure of train and the direction of vibration indicate the arrival or departure. This could sense the train's position at roughly at 700m away. This input is fed to the microcontroller. This could help in avoiding accidents between trains in slopes because the arrival of one train found out using vibration sensor can be immediately sent to the Control Room and the power supply can be switched off within 3 minutes so trains could be stopped without colliding each other. Vibration or shock sensors are commonly used in alarm systems to activate an alarm whenever the devices to which they are attached are touched, moved, or otherwise vibrated. Commercial vibration sensors use a piezoelectric ceramic strain transducer attached to a metallic proof mass in order to respond to an externally imposed acceleration. Piezoelectric vibration sensors used for detecting vibration from various vibration sources are generally classified into two large types, resonant type and no resonant type.

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

- Its measuring range,
- Frequency range,
- Accuracy,
- Transverse sensitivity
- Ambient conditions.

Mini sense 100 Vibration sensor

The Mini sense 100 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 solderable. 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 PVDF sensing

element withstands high shock overload. Sensor has excellent linearity and dynamic range, and may be used for detecting either continuous vibration or impacts. The mass may be modified to obtain alternative frequency response and sensitivity selection. It can be classified into two 1) mini sense 100 vertical,2)mini sense 100 horizontal. The vibration sensor used here is mini sense 100 vertical

Why Servomotor for barrier control

Servomotors are generally used as a high performance alternative to the stepper motor. Stepper motors have some inherent ability to control position, as they have inbuilt output steps. This often allows them to be used as an open loop position control, without any feedback encoder, as their drive signal specifies the number of steps of movement to rotate. This lack of feedback though limits their performance, as the stepper motor can only drive a load that is well within its capacity, otherwise missed steps under load may lead to positioning errors.

The encoder and controller of a servomotor are an additional cost, but they optimize the performance of the overall system (for all of speed, power and accuracy) relative to the capacity of the basic motor. With larger systems, where a powerful motor represents an increasing proportion of the system cost, servomotors have the advantage. Many applications, such as laser cutting machines, may be offered in two ranges, the low-priced range using stepper motors and the high-performance range using servomotors.

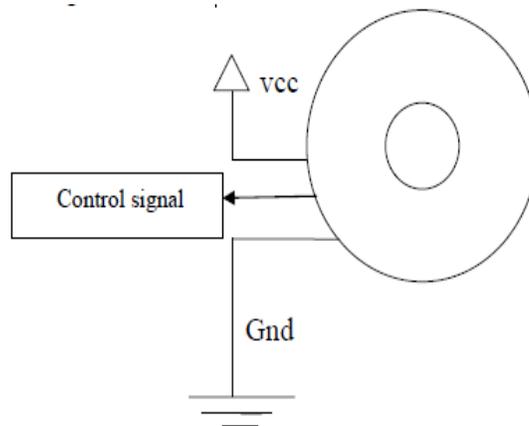


Figure 2.4: servo motor configuration [7]

Working principle of servo motor

Servomechanism is used for controlling the servomotor. The servos are controlled by sending them a pulse of variable width. The control wire is used to send this pulse. The parameters for this pulse are that it has a minimum pulse, a maximum pulse, and a repetition rate. Given the rotation constraints of the servo, neutral is defined to be the position where the servo has exactly the same amount of potential rotation in the clockwise direction as it does in the counter clockwise direction. It is important to note that different servos will have different constraints on their rotation but they all have a neutral position, and that position is always around 1.5 milliseconds (ms). The angle is determined by the duration of a pulse that is applied to the control wire. This is called Pulse width Modulation. The servo expects to see a pulse every 20 ms. The length of the pulse will determine how far the motor turns. For example, a 1.5 ms pulse will make the motor turn to the 90 degree position (neutral position).

When these servos are commanded to move they will move to the position and hold that position. If an external force pushes against the servo while the servo is holding a position, the servo will resist from moving out of that position. The maximum amount of force the servo can exert is the torque rating of the servo. Servos will not hold their position forever though; the position pulse must be repeated to instruct the servo to stay in position.

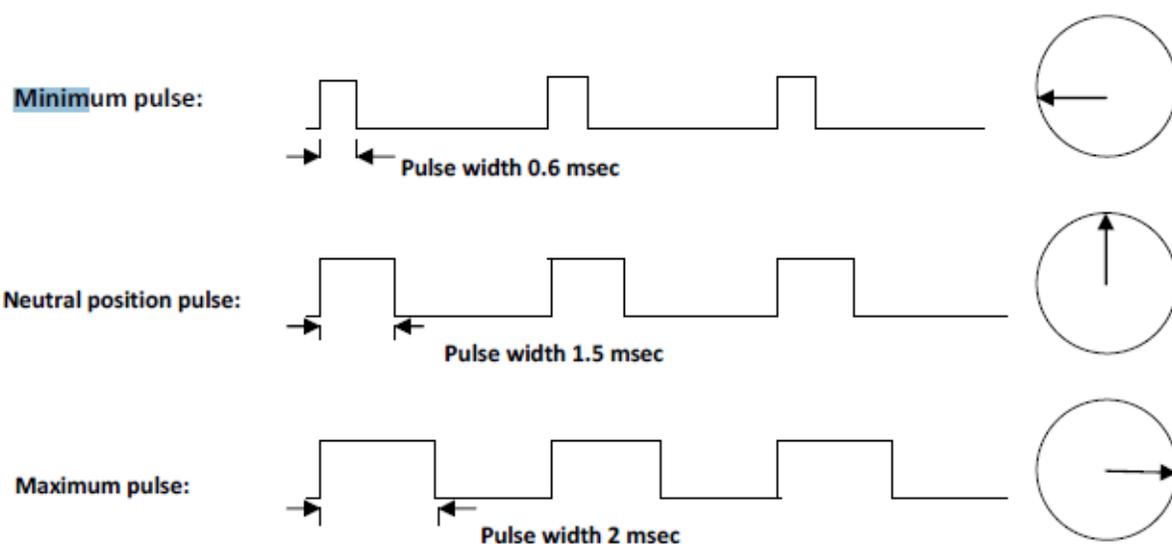


Figure 2.5: PWM switching of servo motor

When a pulse is sent to a servo that is less than about 0.6 ms the servo does not rotate to any position and holds its output shaft at zero degree. If the pulse is wider than 0.6 ms the servo rotates. For example, if pulse width is equal to 1,5ms servo will rotate 90 degrees and for pulse width is equal or greater than 2 ms, servo will make rotation of 180 degrees. The minimal width and the maximum width of pulse that will command the servo to turn to a valid position are functions of each servo. Different brands, and even different servos of the same brand, will have different maximum and minimums. Generally the minimum pulse will be about 1 ms wide and the maximum pulse will be 2 ms wide. PWM switching This Light Weight Servo (1.5 Kg) can be used for this thesis development. This comes with a standard 3 pin power, control cable. Can be used in Electric aircraft, glider etc.

2.5 Automatic gate control working of model

It deals with two things. Firstly, it deals with the reduction of time for which the gate is being kept closed. And secondly, to provide safety to the road users by reducing the accidents that usually occur due to carelessness of road users and at times errors made by the gatekeepers.

By employing the automatic railway gate control at the level crossing the arrival of train is detected by the sensor placed on either side of the gate. Once the arrival is sensed, the sensed signal is sent to the microcontroller and it checks for possible presence of vehicle between the gates, again using sensors. Subsequently, buzzer indication and light signals on either side are provided to the road users indicating the closure of gates. Once, no vehicle is sensed in between the gate the motor is activated and the gates are closed.

But, for the worst case if any obstacle is sensed, it is indicated to the train driver by signals (RED) placed at about 1km, so as to bring it to halt well before the level crossing. When no obstacle is sensed GREEN light is indicated, and the train is to free to move. The departure of the train is detected by sensors placed at about 1km from the gate. The signal about the departure is

sent to the microcontroller, which in turn operates the motor and opens the gate. Thus, the time for which the gate is closed is less compared to the manually operated gates.

One of the main objectives of this thesis is to control the unmanned rail gate automatically using an embedded platform to reduce maintenance expenditure, human mistakes, and accidents. An embedded system is a combination of computer hardware and software, and perhaps additional mechanical or other parts, designed to perform a specific function.

The points or places where the Railway track crosses the road are called level crossings. Level crossings cannot be used simultaneously both by road traffic and trains, as this results in accidents leading to loss of precious lives. The program for this thesis is embedded in this Microcontroller Integrated Chip and interfaced to all the peripherals. Crossing gates, when closed to road traffic, cross the entire width of the road.

Existing System:-

- Manual/Physical gate closing & opening.
- Manual switch based gate closing & opening.

Limitations of existing system:-

- Chances of human error.
- Time consuming.
- A lot of human resource is required.

An automatic railway gate control at level crossing replaces the gates operated by the gatekeeper. It deals with two things. Firstly, it deals with the reduction of time for which the gate is being kept closed and secondly, to provide safety to the road users by reducing the accidents. In the existing system once the train leaves the station, the stationmaster informs the gatekeeper about the arrival of the train through the telephone. Once the gatekeeper receives the information, he closes the gate depending on the timing at which the train arrives. Hence, if the train is late due to certain reasons, then gates remain closed for a long time causing traffic near the gates. By employing the automatic railway gate control at the level crossing the arrival of the train is detected by the sensor placed near to the gate. Hence, the time for which it is closed is less compared to the manually operated gates and also reduces the human labor.

This type of gates can be employed in an unmanned level crossing where the chances of accidents are higher and reliable operation is required. Since, the operation is automatic; error

due to manual operation is prevented. Automatic railway gate control is highly economical microcontroller based arrangement, designed for use in almost all the unmanned level crossings in the country”. It intends to attain the following objectives:

- To design a system that will enhance the existing railway gate control system.
- To incorporate C Programming in the design of the “Automatic Railway Gate Control”.
- To show the application of automation in the miniature prototype of the “Automatic Railway Gate Control”.

Chapter 3

System Input Modeling

3.1 Vibration modeling

It is clear that when a train stands on the track, a stress pattern is produced in the ground beneath and around the train, which is sufficient to support the train (or any other vehicle). When a train moves the its stress pattern will move with it, although modified to a small extent by the finite propagation velocity of the stress waves. This moving stress pattern must impress stress waves into the surrounding ground even in the absence of any imperfections or periodic irregularities in the vehicle or the track. Whether this basic moving stress pattern generates a sufficient response in the surrounding soil property is unknown, but their particular geological conditions in which this might happen. See [10].

Obviously the particular railway has many features, which are capable of supplementing the basic stress field beneath the train. Any unsteady riding of the vehicle such as bouncing, rolling, pitching and yawing must result in additional fluctuating forces on the track structure. Recognized defects such as eccentric wheels, unbalanced wheels and wheel flats may also contribute to ground disturbance. The track itself does not provide uniform support; the rails, themselves of fixed length, are supported on sleepers placed at regular intervals, and the sleepers are in turn surrounded by and resting upon stone ballast. This ballast bed may by very nature provide a somewhat variable support, and void age below the occasional sleeper is a well-known fault.

All of these track features can be expected to contribute to the stress field present in the ground below and beside the train, and hence contributed to the vibration disturbances, which propagate to the surrounding soil. Clearly some of these will produce a purely local effect in the case of isolated features, whilst others will provide a regular pattern moving with the train. The extent to which these features promote vibration can be expected to depend on the speed of the train and the weights of the vehicles within it. The static weight of the train provides the basic stress field

due to the train, whilst the unsprung masses and the suspension characteristics of the vehicles, associated with their speed, will determine the extent to which track and rolling stock characteristics enhance this stress field.

Sources of Vibration for trains

3.1.1 Train/Track Interaction

It is believed that as the train proceeds down the track, dynamic forces arise between the wheel and the rail due to irregularities of the surface and wheel, as in figure 1.2, and possibly to irregularities in the support structure beneath the rail.

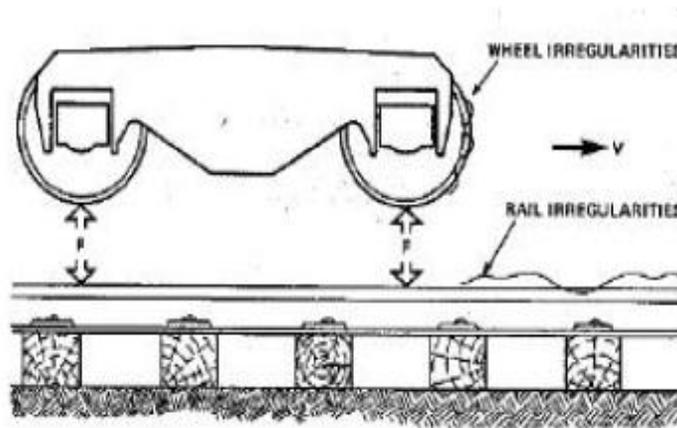


Figure 3.1: train/track interaction [11]

The rail response velocity, V_R , can be shown to be proportional to the wheel, $Z_w(\omega)$, and the rail, $Z_R(\omega)$, impedances according to the following equation:-

$$V_R \propto \frac{Z_w(\omega)}{[Z_w(\omega) + Z_R(\omega)]} \quad 1.1$$

Rail roughness is taken to mean the profile irregularities on the rail such as might be measured by a track geometry car; and wheel roughness refers to the out of roundness of the wheel, due to wheel flats, for example. $Z_w(\omega)$ and $Z_R(\omega)$ are the vertical point impedances of the wheel and

the rail respectively, i.e. the amplitude and the phase of the force required to generate a unit velocity at frequency. It should be noted that $Z_w(\omega)$ is not just the impedance of the wheel but includes the influence of the axle, the bogie, the car body, and bogie suspension elements. The most efficient impedance will be the wheel impedance $Z_w(\omega)$.

Resonances below 10 Hz associated with the secondary suspension (between the car body and bogie) and first car body bending mode are generally of no interest since ground vibration levels below 10 Hz are usually too small to be of any concern. The reason ground vibration levels are so low at very low frequency is illustrated clearly in figure 3.1. For frequencies less than about 5 Hz, Z_w is so much less than Z_R that is the rail simply does not respond. Consequently, in this frequency region it can be reasonably assumed that when the wheel encounters an irregularity it moves up and over the irregularity and the rail remains essentially stationary.

Between 10 Hz and 30 Hz the vehicle impedance Z_w and rail impedance become more comparable in value although Z_w is still less than Z_R . The primary suspension resonances that usually occur in this frequency range can have significant effect on ground vibration. See [2]. To see why, note that below 30 Hz in the figure 3.1, $Z_R \gg Z_w$ and from equation 1.1.

$$V_R \propto Z_w/Z_R \tag{1.2}$$

Equation (1.2) shows that if Z_w is made larger than the rail, due to some design change to the bogie, the ground will respond more. The rail vehicle impedance Z_w in, figure 3.1, between the peak below 10 Hz and the trough above 10 Hz is controlled by the primary suspension stiffness. Increasing that stiffness increases Z_w and, as Equation 1.2 shows; increasing Z_w will increase ground vibration. This phenomenon is not speculative and has, in fact, been observed in field measurements [2].

3.1.2 Wheel/Rail Excitation

As mentioned above, one of the excitation mechanisms for ground vibration is the irregularities on the surface of the wheel and rail. If we are interested in train speeds from 30 to 110 km/h and

frequencies of 10 – 250 Hz, then the irregularities with the wavelengths from 35 mm to 3 m are of primary interest. For the wheel the irregularities of greatest importance are flat spots, which are generated when the wheel slides during the braking. A full study is available in [3] and [4].

3.1.3 Ground Response

In the following we will consider a train moving with speed v on a welded track with sleeper period d . The quasistatic pressure mechanism of excitation results from load forces applied to the track from each wheel axle, causing downward deflection of the track. These deflections produce a wave – like motion along the track with speed v that results in a distribution of each axle load over all the sleepers, involved in the deflection distance. Each sleeper, in turn, acts as a vertical force applied to the ground during the time necessary for a deflection curve to pass through the sleeper and this results in generation of elastic ground vibration. Since, in the low frequency band, the characteristics wavelengths of generated elastic waves are much larger than the sleeper dimensions. Each sleeper can be considered as a point source. Calculating the vibration field radiated by a moving train requires the superposition of fields generated by each sleeper activated by all axles of all carriages, with the time and space difference between source (sleepers) being taken into account.

3.1.4 Vibration propagation

3.1.4.1 Background

Once transient stress variation is produced in the ground below the track, they will propagate away from the track as ground – borne vibration. A variety of modes of vibration are possible within the ground, and the principal types are the following:-

- Compression waves, (Longitudinal waves), with particle motion being an oscillation in the direction of propagation;

- Shear waves; with particle motion being an oscillation in a plane normal to the direction of propagation;
- Rayleigh waves, which are surface waves, with a particle motion generally elliptical in a vertical plane through the direction of propagation.

In the ideal case when the ground is homogenous the longitudinal and shear waves propagate in all directions away from the source, and hence suffer substantial geometric attenuation, as well as losses due to the damping properties of the ground. The Rayleigh waves, being surface waves, do not suffer the same geometric attenuation, but are still subject to loss by damping. In practice the ground is far from homogenous; it may well be stratified and possess discontinuities. In such a case additional modes of vibration can propagate along the interfaces of strata, and mode conversion from one type of wave to another may be encouraged.

The various modes have different propagation velocities. The compression waves travel at typically 1000 m/s, whilst the shear and Rayleigh waves are much slower. Velocities for these seem typically to be about 200 m/s, but Rayleigh waves have been reported as slow as 35 m/s, see [29]. The vibration energy is not shared equally among the modes. Because of different geometric attenuations, the Rayleigh wave carries most of the vibration energy at significant distances away from the track. Reference [6] suggests that the ground vibrations generated by the vertical oscillation of a flat plate on the ground is about two thirds of the total energy is carried by the Rayleigh waves. A further significant factor is that high frequencies are attenuated much more rapidly than low frequencies, so that low frequencies dominate the spectrum at distances of more than a few meters from the source.

3.1.5 Effects of the Ground – Borne Vibration

3.1.5.1 Types of Vibrations

Whole-Body Vibration typically results from two types of forces acting on the operator. A noncyclical force transmitted over a very short period of time, and for which the peak level is reached instantaneously is called a shock load. A vehicle striking an obstacle or a sudden drop into a hole may produce these shock loads. If these shock loads are sufficiently great, the

operator may be thrown from his seat or struck by objects flying around in the car. Less sudden forces are created by the vehicles regular motion over rough terrain. These are the most common motion-induced vibration forces that an operator encounters during his daily work. The effects of such forces vary with the duration of exposure. Thus they are more difficult to define than the instantaneous damage caused by high shock loads. Whole-body Vibration considers these forces in combination and defines the effects of repetitive forces acting in a specific frequency range.

To have an overview of the bandwidth spectrum for the ground vibration, which could be expected for the railway, one should look on the geometrical properties of the train in relation to its velocity. Typical dimensions are overall length of the car and axel distances. Axle distances of a car may vary between 2 m and 10 m. a train with a velocity of 25 m/s (90 km/h) maybe expected to produce axle passage frequency in the range of 2.5 Hz to 12.5 Hz [26]. If a typical railway wheel, having a diameter of 0.75 m to 1.0 m, with a single wheel flat is considered, the corresponding wheel flat occurrence frequencies may vary between approximately 8 Hz and 11 Hz. A railway wheel passing equidistant sleepers may generate what is often referred to as the sleeper passing frequency. For Swedish railways, where the nominal centre – to – centre distance of sleepers is 0.65 m, the corresponding sleeper passage frequency for a train with velocity of 25 m/s (90 km/h) becomes approximately 38.5 Hz.

Applying the equations below, the frequency ranges from the railways could be calculated.

- The sleeper passing frequency f_s can be found by, see [2]

$$f_s = (U/l_s) \text{ Hz} \quad 3.3$$

Where; U is the train speed in m/s and l_s the sleeper distance in m.

- The wheel passing frequency

$$f_a = (U/ a) \text{ Hz} \quad 3.4$$

Where; a is the distance between two wheels in a bogie.

- Bending wave speed in rails

A good low frequency model for a rail is a beam on an elastic foundation. The bending wave speed is given by

$$C_{b, \min} = \sqrt[4]{4S'B/M'^2} = \sqrt[4]{4\omega o^2 B/M'} \quad 3.5$$

This occurs at a frequency

$$\text{Min } \omega = \sqrt[2]{2s/m} = \sqrt[2]{2 \cdot \omega o} \quad 3.6$$

Where: B is the bending stiffness of rail, $B=6.4 \cdot 10^6 \text{ Nm}^2$ for UIC60, [See chapter 11].

M' = mass per unit length of rail, $M' = 60 + m_s/2l_s \text{ kg/m}$

ωo = resonance radian frequency of the rail including the sleepers against the elastic foundation

where; f varied between 30 and 80 Hz,

$$\omega o = 2\pi f \quad 3.7$$

- S' : Stiffness per unit length of elastic foundation.
- m_s : mass for one sleeper
- l_s is the distance between two sleepers, $l_s = 0.6$

If we take the typical numbers like

$m_s = 150 \text{ kg}$, $\omega o = 50 \text{ Hz} \cdot \pi$, $s' = 18 \cdot 10^6 \text{ N/m}^2$ and put them into the equations we will get the minimum wave speed is approximately $340 \text{ m/s} = 1224 \text{ Km/h}$ at 70Hz.

This value is much higher even if the elastic foundation were 20 times softer, the minimum wave speed would still be approximately $160 \text{ m/s} = 576 \text{ Km/h}$ thus for this type of motion, coincidence of train speed and wave speed is extremely unlikely.

The results from the equations above described that the frequencies generated by the railway traffic are within the response of the human body.

3.1.6 Prediction and Final Results

Depending on the vibration measurements it has been concluded that the ground vibration affects by many factors. These factors can be summarized as:

- Ground quality (which is the most important factor)
- Train type
- Railway track and the embankment design
- Train speed
- Distance from the rail way track to the building (receiver)
- Building type and the foundation design

In this thesis a simplification was applied, in which the factors assumed to be frequency independent and directly related to the time weighting for the maximum velocity rms. values. According to the literatures for previous studies and the results, the vertical on the ground (Z direction) is the most dominating direction comparing with the others directions (X and Y).

3.1.6.1 The General Prediction Formula

According to [13], the following equation describes prediction of ground vibration from railways,

$$V = V_T * F_D * F_S * F_R * F_B \quad 3.8$$

Where;

- V = the vibration velocity [mm/s].
- V_T = train vibration level perpendicular on the ground (Z direction) at a reference distance D_o , from the center of the railway track and the reference speed S_o [m/s].
- F_S is a function of the train speed. It could be found by using the equation below.

$$F_S = \left(\frac{S}{S_o}\right)^A \quad 3.9$$

Where; S is the train speed and S_0 is the reference speed at which V_T has been measured. A can be between 0.5 – 1.5, we will later use $A = 0.9$.

- FD is a function of the distance, which could be obtained by

$$F_S = \left(\frac{D}{D_0}\right)^B \quad 3.10$$

Where; D is the distance to the track and D_0 is the reference distance for which V_T has been measured. B will be calculated from the measurements results.

- FR is a function of the bedrock. FR for the bedrock can be 0.7 – 1.3 depending on the type of the railway track if it is single or doubled.
- FB is a function of the buildings. For Swedish houses the resonance up to 3 floors, F_B is 2 – 3.
- Parameter A . When the train is moving on a “perfect” track and rail then there is a steady-state condition. A passenger in the train observes a static deflection of the rail. This deflection has a characteristic wavelength. If this deflection and the characteristic wavelength are independent of the speed of the train then the exponential A is equal to unity. But there are evidences that the deflection of the rail depends on the speed of the train. The deflection increases with speed and the characteristic wavelength decrease with speed. In that case the exponential A is greater than unity, say 1.3 - 1.51. To calculate the exponential A , we need the same type of train in different speeds; unfortunately we were unable to find cases with large enough differences in speed.
- Exponential B . As vibrations of the ground mostly consist of Rayleigh waves the exponential B should be 0.5 to fit the equation for FD . But there is also internal damping, dissipation, in the material. So the parameter will be calculated from the obtained data.

As was mentioned before, these measurements were carried out for more than 160 trains from different types, speeds and directions, the problem for these measurements is, one acquire a lot of

data from each individual train. To summarize all these data, the trains will be categorized according to the type. The analyses will be for three types of trains, X2000 (fast train), intercity, and freight train (Heavy train).

The important factors for the prediction formula are, exponential A , and exponential B . If we can determine these exponential factors from the measurement results for all the trains types then we can use the formula (8.11) for prediction thus the measurements will be analyzed according to find A and B , and the procedure of these calculation will be used for all types of trains respectively.

3.1.6.2 Calculation of Vibration Levels V

The following data are collected for Swedish Intercity train (city trams with three coaches).

3.1.6.3 Distance Dependence FD

To calculate the Factor FD for each train, we should first find the exponential B .

3.1.6.4 Calculating the Exponential B Intercity train (city tram)

The exponential B will be calculated for each city tram/train individually. All Z direction for all the trains were measured at least in two different distances from the railway track center, 20m is the reference and the other distance were 10m, 40m and 80m.

By applying the equation $V = V_T * F_D * F_S * F_R * F_B$, the exponential B will be calculated as follow

$$\frac{V}{V_{20m}} = \frac{V_T * F_D * F_S * F_R * F_B}{V_T * F_{D,20m} * F_S * F_R * F_B} \quad 3.11$$

Where; V_T , F_S , F_R , and F_B are constant for the same train. So

$$V/V_{20m} = F_D/F_{D,20m} \quad 3.12$$

And

$$F_D = \left(D/D_o \right)^B$$

Then with $D_o = 20m$

$$V/V_{20m} = D/20$$

$\text{Log} (V/V_{20m}) = B * \text{Log} (D/20)$, solve for B gives

$$B = \frac{\text{Log} (V/V_{20m})}{\text{Log} (D/20)}$$

3.1.6.5 Speed Dependence FS

FS is a speed factor, which account to for the effect of the train speed, *S*. this factor is given by the equation (8.2)

The exponential *A* will be chose equal to 0.9, for calculating the factor *FS*

3.1.6.6 Calculating the Factor FS for Intercity Trains

To calculate *FS*, (function of train speed), from the equation below

$$F_S = \left(S/S_o \right)^A \quad 3.13$$

We need to use the average value of the exponential *A*, which is as mentioned before will be equal to 0.9. The reference speed is chosen equal to, $s_o = 70 \text{ km/h}$.

By applying the eq. (3.13) one can calculate the factor FS , an example for that, we will calculate F_S for the fastest train and the slowest one for Intercity, see Appendix (1), where the train with ID96 was driven with 71 Km/h, and the train with the ID31 was driven with 25 km/h.

3.1.6.7 The Factor FR

The track quality factor FR , takes into account the effect on the vibration of the quality of the tracks and the embankment. A massive and stiff embankment below the railway tracks will generally give less vibration than the “standard”, and a thin and flexible embankment or tracks on grade will give more vibration than “standards”. Furthermore, smooth and well-adjusted tracks with heavy rails gives less vibration compared to rough, low quality tracks.

FR is a function of the bedrock. The factor FR for the bedrock can be 0.7 – 1.3 depending on the type of the railway track, if it is single or doubled. See [43].

For this purpose FR will be equal to 0.8. This value chose according to the railway track were measurements took place, it was doubled track (with two direction) and the embankment was assort of thick and deep, that means less generating of vibration, so the value should be less than 1, say 0.8.

3.1.6.8 The FB Factor

The building amplification factor FB is used to transform the free field ground vibration to floor vibration at the most unfavorable place, due to ground foundation coupling and building resonances. This factor is generally frequency dependent, the first natural frequency of the floor in question being of greatest importance. This factor is different from house to house depending on the number of the floors for example or if it is wooden house or rock house foundations. According to reference [43], this factor found to be 2 to 3.

3.1.7 VT Calculations

As a last step to apply the prediction formula, VT should be calculated for the different trains. After we found most of the parameters for the equation

$$V = V_T * F_D * F_S * F_R * F_B$$

Now, one could calculate VT for each type of train. VT will have a certain value at a certain distance depending on the values of the exponential B .

By applying the equation above, VT was calculated for the measured X2000 trains, and as a result of taking the average value for VT to these trains. VT found to be equal to 0.0337 [mm/s], for distances 20m. The same procedure was followed by calculating VT for the intercity trains and taking the average value for it. VT obtained to be equal to 0.0319 [mm/s], for distances ³ 20m. For the last type of trains, freight trains, an equivalent method was followed for finding the values of VT . By taking the average value for them, VT was obtained to be 0.047, for distances ³ 20m. This is higher than the first type of trains.

3.1.8 Applying the prediction formula

From the previous chapters the most important parameter have been found and the information which has been measured can be presented in general form by applying the equation below for the obtained results for FR , FB , FD , Fs .

$$V = V_T * \left(\frac{D}{D_o}\right)^B * \left(\frac{S}{S_o}\right)^A * F_R * F_B \quad 3.14$$

This equation could be applied to find the vibration velocities for different train types and at different distances as well.

Where

- **VT** : Measured vibration levels for the trains at 20m and 70 Km/h.

V_T for intercity = 0.0319 [mm/s], for distances 20m.

- **D** : Any distance from the center of the railway track.
- **D_o** : Selected to be 20m, to avoid the influence of the near field waves.
- **B** : Calculated as a distance dependent, B varied also depending on the train type. The exponential B was calculated at the reference distance 20m.

B : for intercity trains = -0.7, for distances 20m.

- **S** : Any speed for any kind of trains.
- **S_o** : Was chosen to be 70 Km/h, to be the reference for all train types

- **A**: Speed dependent exponential, its value has been assumed to be 0.9 according to [43], unfortunately we couldn't calculate due to that we need more measurements for the trains at very wide-ranging speeds, which we couldn't have it during the measurements stage.
- **FR**: The track quality factor, according to [12] will be equal to 0.8 in this assignment.
- **FB**: The building amplification factor, the typical value for it is 2 for the Swedish houses, due to [13].

The vibration level I have found is changed to distance as shown above and the distance obtained is converted to voltage using the following formula.

3.1.9 Calculation of braking distance

Stopping a train requires work. This work equals the change in the train's kinetic energy plus the change in its potential energy (change in height due to the gradient of the track. Mathematically this can be expressed as:

$$M * a * s_b + \frac{1}{2} * M * V^2 + M * g * h_1 - h_2 \quad 3.15$$

Note: The change in height relates to the track gradient. The track gradient is the change of vertical height over the corresponding change in horizontal distance i.e. $\tan \alpha$ where, α the angle of slope.

Solving S_b for gives

$$S_b = (-U^2/2. (a_d \pm g. \tan \alpha)) \quad 3.16$$

$$S_{b,max} = 680 \text{ m} > 510 \text{ m}$$

As we can see the braking distance is greater than the minimum station length so the speed 70 kmph is not practical so other practical recommended speed is calculated next. So to find the distance that the warning signals to be placed is using the recommended speed of the trains.

3.1.10 Calculation of the recommended speed.

From the previous calculations (see calculation of braking distance) the train needs 686 meter to stop if it is broken from 70 kmph. From UIC 2010/04 standard the overlap distance is 150 meter, see reference [8].

The net distance used for braking is = 481- 150 = 331 meters.

Now use this as braking distance, calculate the recommend speed.

$$S_b = V_m^2 / 2(\alpha \pm g \tan \theta), \text{ solve for } V_m^2$$

$$V_m^2 = S_b * 2(\alpha \pm g \tan \theta) = 331 * 2(3.5), \text{ solving for } V_m$$

$$V_m = 45 \text{ kmph}$$

So, the maximum speed for the non-shared station is 45 kmph.

Note that the designed timetable designs for maximum speed of 70 kmph; it also works suitable at 45 kmph.

So the new braking distance is equal to = 282 meters.

As discussed above the vibration levels are measured at 10m, 20m, 40m and 80m so the above vibration level should change to distance in the way it includes the braking speed. This will discuss in the next chapter 4 in the design part.

How to change the vibration to corresponding voltage

Let D_{out} is the voltage level that is obtained from corresponding vibration level. as we know the peak voltage a microcontroller can tolerate is 5 volts so in order to give a command to it we have to vary this voltage input so that it can sense that there is a difference in vibration level means the incoming train is at different distance away from the level crossing. There are four different places to place the warning signals at $S_{b,min}(282m, +20m, +40m, +80m)$.

The following formula is used to find the corresponding voltage input to the microcontroller.

$$D_{out} = \frac{V_{in}}{\text{step size}} = \frac{5V}{4} = 1.25 \text{ volts} \quad 3.17$$

Where; V_{in} is input voltage to the microcontroller usually 5 volts and step size is the number of the place where the vibration level is measured (10 m, 20 m, 40m, 80 m). The vibration level near the vibration sensor (level crossing) is high so a high voltage is correspondingly given to the microcontroller.

Note: 10m is mapped to 282 meters and the other distances are obtained just by adding the corresponding distance to 282 meters.

The following table can be easily summarizing for the voltage levels and distance of train away from level crossing.

Table 3.1 distances from level crossing and corresponding analog voltage

Distance of train from level crossing in m	Corresponding analog voltage in volts
$(10 \rightarrow 282) = 282$	$3.76 - 5$
$282 + 20 = 302$	$2.6 - 3.75$
$282 + 40 = 322$	$1.26 - 2.5$
$282 + 80 = 362$	$0 - 1.25$

This voltage given to the ADC804 (usually peak detector) and converts to a single valued usually to the peak digital value and sends to microcontroller serially.

How to convert the Analog voltage to discretized digital voltage

ADCs (analog-to-digital converters) are among the most widely used devices for data acquisition. A physical quantity, like temperature, pressure, humidity, and velocity, etc., is converted to electrical (voltage, current) signals using a device called a transducer, or sensor

We need an analog-to-digital converter to translate the analog signals to digital numbers, so microcontroller can read them.

ADC804 IC is an analog-to-digital converter.

- It works with +5 volts and has a resolution of 8 bits
- Conversion time is another major factor in judging an ADC

- Conversion time is defined as the time it takes the ADC to convert the analog input to a digital (binary) number
- In ADC804 conversion time varies depending on the clocking signals applied to CLK R and CLK IN pins, but it cannot be faster than 110 μ s. See next chapter for detail analysis.

ADC804 Free Running Test Mode

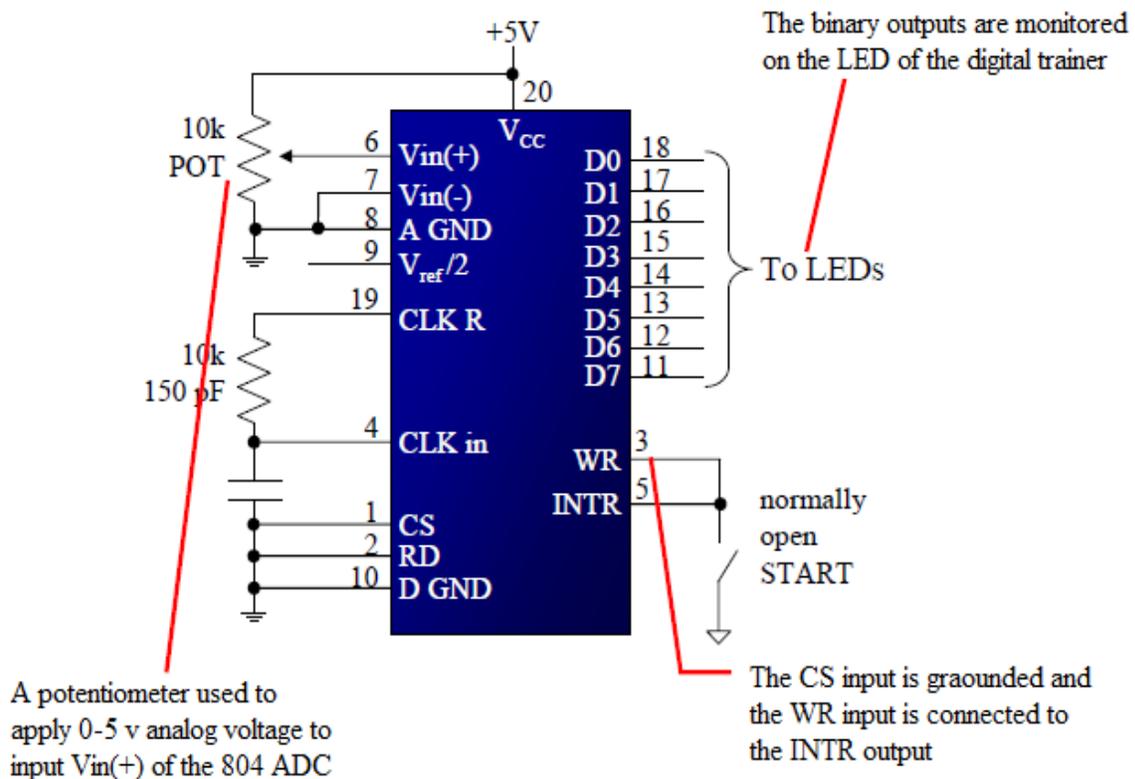


Figure 3.2: ADC804 configuration and digital output pins [10]

The following data are obtained from the digital trainer

Table 3.2 distance and voltage conversion

Vibration in mm/s	Distance from crossing in m	Digital output
0.0021	282	00000101(5)
0.00136	302	00000011(3)
0.00090	322	00000010(2)
0.00088	362	000000001(1)

The above hex values are sent to microcontroller so the micro controller is programmed to response according the way we need.

3.2 Serial communication

When the vibration sensor senses vibration it sends a status about the strength of the amount of vibration it collects to the microcontroller. This is done through a serial communication RS232 between the vibration sensor and microcontroller.

3.2.1 Basics of serial communication

Computers transfer data in two ways. There are parallel and serial data transfers.

- Parallel: Often 8 or more lines (wire conductors) are used to transfer data to a device that is only a few feet away

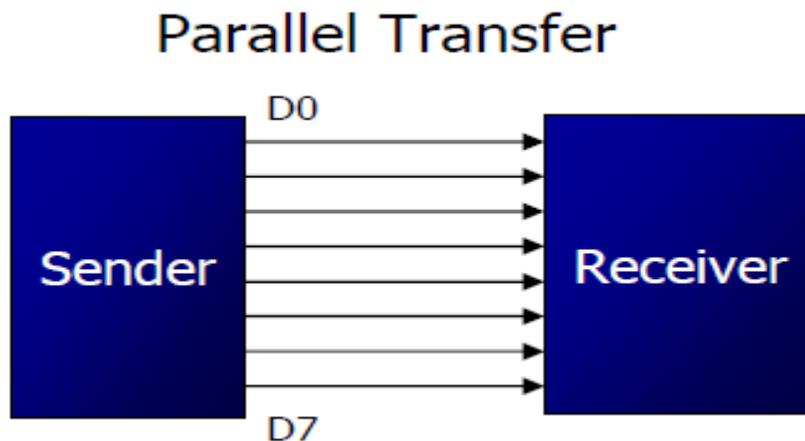


Figure 3.2 Parallel means of data transfer [10]

- Serial: To transfer to a device located many meters away, the serial method is used. The data is sent one bit at a time

Serial Transfer



Figure 3.3 serial means of data transfer [10]

Serial data communication uses two methods

- Synchronous method transfers a block of data at a time
- Asynchronous method transfers a single byte at a time

It is possible to write software to use either of these methods, but the programs can be tedious and long. There are special IC chips made by many manufacturers for serial communications

- UART (universal asynchronous Receiver-transmitter)
- USART (universal synchronous-asynchronous Receiver-transmitter)

A protocol is a set of rules agreed by both the sender and receiver on

- How the data is packed
- How many bits constitute a character
- When the data begins and ends

Asynchronous serial data communication is widely used for character-oriented transmissions. Each character is placed in between start and stop bits, this is called framing

Block-oriented data transfers use the synchronous method

The start bit is always one bit, but the stop bit can be one or two bits. The start bit is always a 0 (low) and the stop bit(s) is 1 (high) as shown below.

The data transfer rate of given computer system depends on communication ports incorporated into that system.

- IBM PC/XT could transfer data at the rate of 100 to 9600 bps
- Pentium-based PCs transfer data at rates as high as 56K bps

In asynchronous serial data communication, the baud rate is limited to 100K bps

3.2.2 RS232 standard

An interfacing standard RS232 was set by the Electronics Industries Association (EIA) in 1960

The standard was set long before the advent of the TTL logic family, its input and output voltage levels are not TTL compatible. In RS232, a 1 is represented by -3 ~ -25 V, while a 0 bit is +3 ~ +25 V, making -3 to +3 undefined.

RS232 DB-25 Pins			
Pin	Description	Pin	Description
1	Protective ground	14	Secondary transmitted data
2	Transmitted data (TxD)	15	Transmitted signal element timing
3	Received data (RxD)	16	Secondary receive data
4	Request to send (-RTS)	17	Receive signal element timing
5	Clear to send (-CTS)	18	Unassigned
6	Data set ready (-DSR)	19	Secondary receive data
7	Signal ground (GND)	20	Data terminal ready (-DTR)
8	Data carrier detect (-DCD)	21	Signal quality detector
9/10	Reserved for data testing	22	Ring indicator (RI)
11	Unassigned	23	Data signal rate select
12	Secondary data carrier detect	24	Transmit signal element timing
13	Secondary clear to send	25	Unassigned

Figure 3.4 Pin description of RS 232 [10]

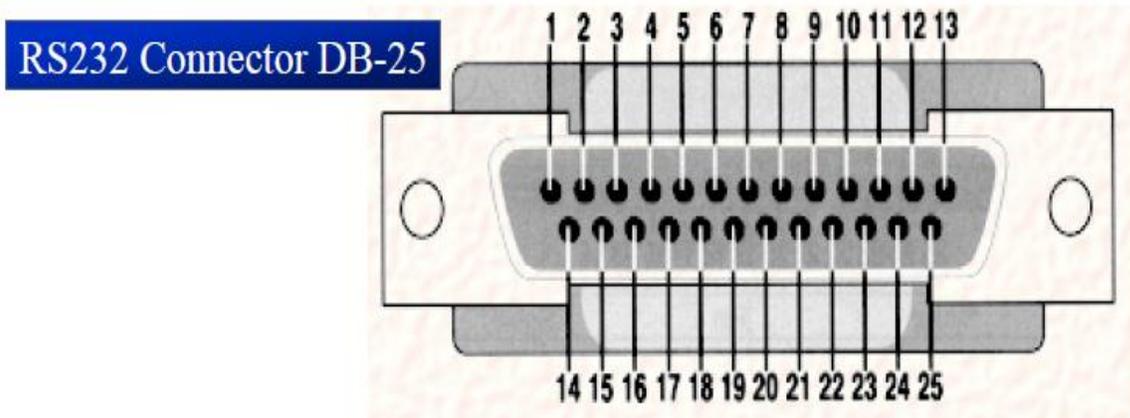


Figure 3.5: Configuration layout of RS 232 pins [11]

Since not all pins are used in PC cables, IBM introduced the DB-9 version of the serial I/O standard.

Pin	Description
1	Data carrier detect (-DCD)
2	Received data (RxD)
3	Transmitted data (TxD)
4	Data terminal ready (DTR)
5	Signal ground (GND)
6	Data set ready (-DSR)
7	Request to send (-RTS)
8	Clear to send (-CTS)
9	Ring indicator (RI)

Figure 3.6: Pin description of RS232 [11]

Current terminology classifies data communication equipment as

- DTE (data terminal equipment) refers to terminal and computers that send and receive data
- DCE (data communication equipment) refers to communication equipment, such as modems

The simplest connection between a Sensor and microcontroller requires a minimum of three pins, TxD, RxD, and ground.

RS 232 Pin description

- DTR (data terminal ready)

When terminal is turned on, it sends out signal DTR to indicate that it is ready for communication

- DSR (data set ready)

When DCE is turned on and has gone through the self-test, it assert DSR to indicate that it is ready to communicate

- RTS (request to send)

When the DTE device has byte to transmit, it assert RTS to signal the modem that it has a byte of data to transmit

- CTS (clear to send)

When the modem has room for storing the data it is to receive, it sends out signal CTS to DTE to indicate that it can receive the data now

- DCD (data carrier detect)

To save board space, some designers use MAX233 chip from Maxim. MAX233 performs the same job as MAX232 but eliminates the need for capacitors. Notice that MAX233 and MAX232 are not pin compatible.

3.2.4 Real world Sensor interfacing with PIC16f877A

As we discussed in chapter 3 the output of the sensor is Analog and should be converted to digital signal. The amount of vibration obtained should converted either to voltage or current so this is given as a pulse to the microcontroller so the microcontroller should analyze the input voltage level so it sends to the central control center.

- CLK IN and CLK R

CLK IN is an input pin connected to an external clock source. To use the internal clock generator (also called self-clocking), CLK IN and CLK R pins are connected to a capacitor and a resistor, and the clock frequency is determined by $f = \frac{1}{1.1 RC}$

Typical values are R = 10K ohms and C = 150 pf. We get f = 606 kHz and the conversion time is 110 μs.

Data Pins D0-D7

The digital data output pins. These are tri-state buffered

The converted data is accessed only when CS =0 and RD is forced low

To calculate the output voltage, use the following formula

$$D_{out} = V_{in} / \text{Step size} \quad 3.17$$

Where; D_{out} = digital data output (in decimal), V_{in} = analog voltage, and step size (resolution) is the smallest change

3.2.3 Interfacing ADC and Sensors

Analog ground and digital ground

- Analog ground is connected to the ground of the analog V_{in}
- Digital ground is connected to the ground of the V_{cc} pin

To isolate the analog V_{in} signal from transient voltages caused by digital switching of the output D0 – D7. This contributes to the accuracy of the digital data output.

The following steps must be followed for data conversion by the ADC804 chip

- Make CS = 0 and send a low-to-high pulse to pin WR to start conversion
- Keep monitoring the INTR pin
- If INTR is low, the conversion is finished
- If the INTR is high, keep polling until it goes low
- After the INTR has become low, we make CS = 0 and send a high-to-low pulse to the RD pin to get the data out of the ADC804.

3.2.4 Interfacing microcontroller and ADC804

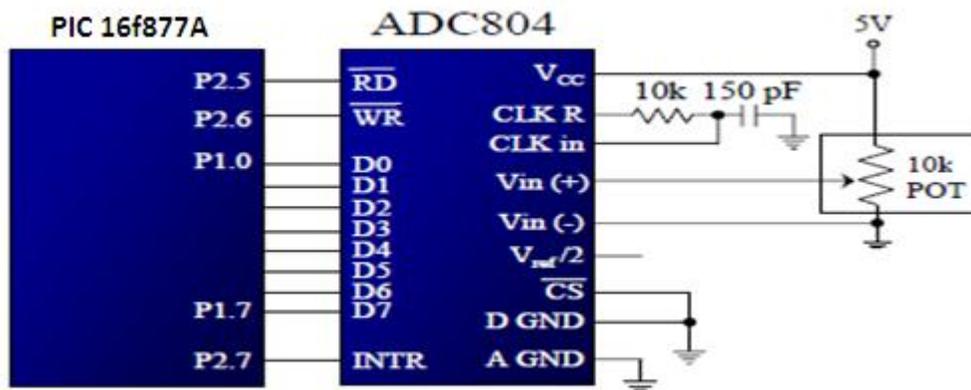


Figure 3.8: Connection between PIC16f877A and ADC804 [10]

Interfacing vibration sensor with microcontroller

After the vibration sensor sense the vibration it feed the analog vibration amount to ADC804 and the ADC804 feeds forward to microcontroller as shown above.

3.2.5 Signal conditioning

Signal conditioning is a widely used term in the world of data acquisition.

It is the conversion of the signals (voltage, current, charge, capacitance, and resistance) produced by transducers to voltage, which is sent to the input of an ADC converter

Signal conditioning can be a current-to-voltage conversion or signal amplification

The sensed vibration must be translated into voltage in order to be of any use to an ADC.

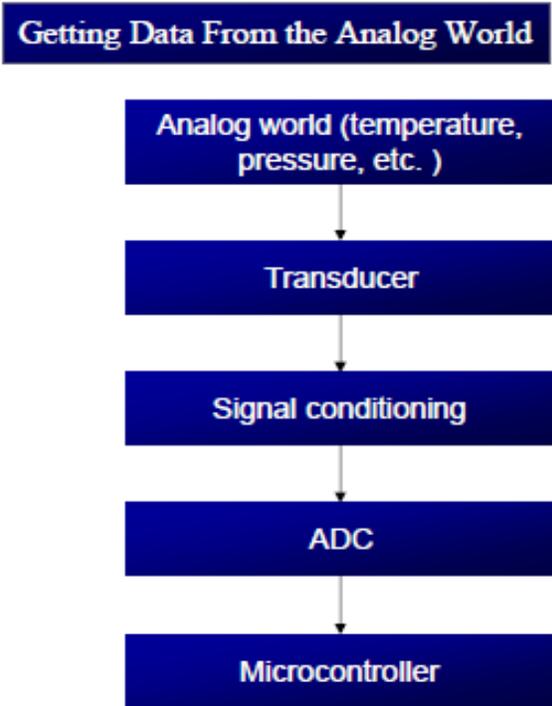


Figure 3.9: steps on signal conditioning [10]

Next we will discuss the programming of the chips which discussed above in detail on chapter 5 software development part.

3.3 Microcontroller PIC16f877A

3.3.1 Introduction to microcontroller:

Microcontroller is a computer-on-a-chip is a variation of a microprocessor, which combines the processor core (CPU), some memory, and I/O (input/output) lines, all on one chip. The computer-on-a-chip is called the microcomputer whose proper meaning is a computer using a (number of) microprocessor(s) as its CPUs, while the concept of the microcomputer is known to be a microcontroller. A microcontroller can be viewed as a set of digital logic circuits integrated on a single silicon chip. This chip is used for only specific applications.

Advantages of microcontroller:

A designer will use a Microcontroller to

- Gather input from various sensors
- Process this input into a set of actions
- Use the output mechanisms on the Microcontroller to do something useful
- RAM and ROM are inbuilt in the MC.
- Multi machine control is possible simultaneously.
- ROM, EPROM, [EEPROM] or Flash memory for program and operating parameter storage.

3.3.2 PIC16f877A Microcontroller:

3.3.2.1 PIC16f877A Microcontroller description

The microcontroller unit used here is a PIC16f877A .The core controller is a mid-range family having a built-in SPI master. 16F877A have enough I/O lines for current need. It is capable of initiating all intersystem communications.

The master controller controls each functions of the system with a supporting device. is an 8-bit, fully static, EPROM/EPROM/ROM-based CMOS microcontroller.

It employs RISC architecture with only 35 word/single cycle instructions. All these instructions are single cycle (1ms) except for program branches which takes two cycles. The PIC16f877A products are supported by a full featured macro assembler, a software simulator C compiler etc.

Features:

- High performance RISC CPU
- Only 35 single word instructions to learn
- Operating speed: DC - 20 MHz clock input DC - 200 ns instruction cycle
- Up to 8K x 14 words of FLASH Program Memory, Up to 368 x 8 bytes of Data up to Memory (RAM) 256 x 8 bytes of EEPROM Data Memory
- Wide operating voltage range: 2.0V to 5.5V
- High Sink/Source Current: 25 mA
- Low-power consumption: - < 0.6 mA typical @ 3V, 4 MHz - 20 μ A typical @ 3V, 32 kHz - < 1 μ A typical standby current

Peripheral features:

- Two Capture, Compare, PWM modules - Capture is 16-bit, max. Resolution is 12.5 ns - Compare is 16-bit, max. Resolution is 200 ns PWM max. Resolution is 10-bit
- 10-bit multi-channel Analog-to-Digital converter
- Synchronous Serial Port (SSP) with SPI (Master mode) and I2C(Master/Slave)

Analog features:

- 10-bit, up to 8-channel Analog-to-Digital Converter (A/D)
- Brown-out Reset (BOR)
- Analog Comparator module with: -Two analog comparators -

Special microcontroller features:

- 100,000 erase/write cycle Enhanced Flash program memory typical
- 1,000,000 erase/write cycle Data EEPROM memory typical
- Data EEPROM Retention > 40 years

I/O ports

Some pins for these I/O ports are multiplexed with an alternate function for the peripheral features on the device. In general, when a peripheral is enabled, that pin may not be used as a general purpose I/O pin.

- PORTA is a 6-bit wide, bidirectional port. The corresponding data direction register is TRISA. Setting a TRISA bit (= 1) will make the corresponding PORTA pin an input (i.e., put the corresponding output driver in a High-Impedance mode). Clearing a TRISA bit (= 0) will make the corresponding PORTA pin an output (i.e., put the contents of the output latch on the selected pin).

All write operations are read-modify-write operations. Therefore, a write to a port implies that the port pins are read; the value is modified and then written to the port data latch. Pin RA4 is multiplexed with the Timer0 module clock input to become the RA4/T0CKI pin. The RA4/T0CKI pin is a Schmitt Trigger input and an open-drain output.

- PORTB is an 8-bit wide, bidirectional port. The corresponding data direction register is TRISB. Setting a TRISB bit (= 1) will make the corresponding PORTB pin an input (i.e., put the corresponding output driver in a High-Impedance mode). Clearing a TRISB bit (= 0) will make the corresponding PORTB pin an output (i.e., put the contents of the output latch on the selected pin). Three pins of PORTB are multiplexed with the In-Circuit Debugger and Low-Voltage Programming function: RB3/PGM, RB6/PGC and RB7/PGD. The alternate functions of these pins are described in “**Special**
- PORTC is an 8-bit wide, bidirectional port. The corresponding data direction register is TRISC. Setting a TRISC bit (= 1) will make the corresponding PORTC pin an input (i.e., put the corresponding output driver in a High-Impedance mode). Clearing a TRISC bit (= 0) will make the corresponding PORTC pin an output (i.e., put the contents of the output latch on the selected pin). PORTC is multiplexed with several peripheral functions.

Pin configuration of PIC16f877A

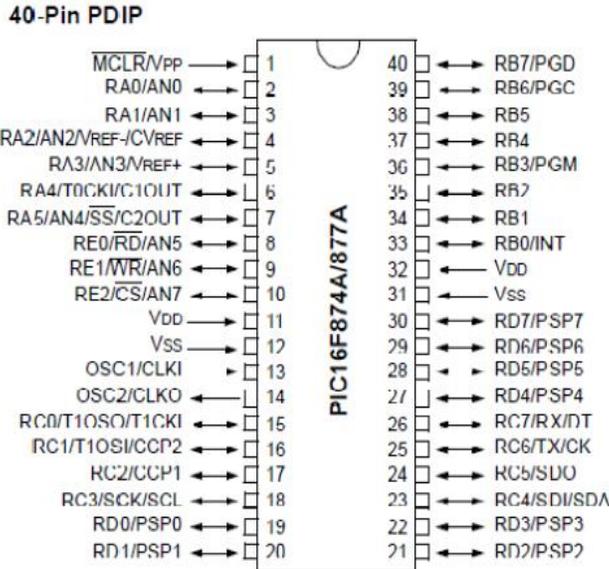


Figure 3.10: Pin details of PIC 16F877A [8]

The pins that are used in this system

MCLR/VPP: Master Clear (input) or programming voltage (output)

- MCLR: Master Clear (Reset) input. This pin is an active low RESET to the device.
- VPP: Programming voltage input.
- VSS: Ground reference for logic and I/O pins.
- **Osc1**: Oscillator crystal input or external clock source input. ST buffer when configured in RC mode.
- **OSC2**: Oscillator crystal output. Connects to crystal or resonator in Crystal

Oscillator mode

- **VDD**: Positive supply for logic and I/O pins.
- **RB0**: Digital I/O

3.4 ZigBee

The name ZigBee refers to the waggle dance of honey bees after their return to the beehive. It symbolizes the communication between nodes in a mesh network. So it is called as networking protocol. The network components are analogous to queen bee, drones and worker bees. It is also the technological Standard Created for Control and Sensor Networks based on the IEEE 802.15.4 Standard created by the ZigBee Alliance.

ZigBee is a specification for a suite of high level communication Protocols using small, low-power digital radios based on an IEEE 802 standard for personal area networks. In the IEEE 802.15.4 standard the 802 refers to the network operations and technologies, 15 refers to wireless networking and 4 refers to the low data rate or low power consumption [10].

3.4.1 Overview of ZigBee

It is used in embedded application for low data rates, low power consumption and long battery life. ZigBee lets battery powered devices can sleep for hours or even days, reducing battery use. The duty cycle of battery powered nodes within a ZigBee network is designed to be very low, offering even more energy efficiency and greater battery life. Once associated with a network, a ZigBee node can wake up and communicate with other ZigBee devices and return to sleep. It is the inexpensive small packet networks used for Home Entertainment and for Controlling Wireless sensor networks. It is having the physical range of about 10-100 meters and data rate of 250kbps/sec.

ZigBee Operates in the Unlicensed ISM bands .2.4 GHz is Global Band at 250kbps, 868 MHz is European Band at 20kbps and 915 MHz is North American Band at 40kbps. It mainly operates in Personal Area Networks and device-to-device networks. The Low duty cycle of ZigBee provide long battery life and Support for multiple network topologies like star and mesh up to 65000 nodes on a network. The 128-bit encryption standard provides secure connection. Collision can also be avoided by using ZigBee.

3.4.2 ZigBee Architecture

The architecture of ZigBee is closely related with OSI model. ZigBee builds upon the physical layer and medium access control defined in IEEE standard 802.15.4 (2003 version) for low-rate WPANs.

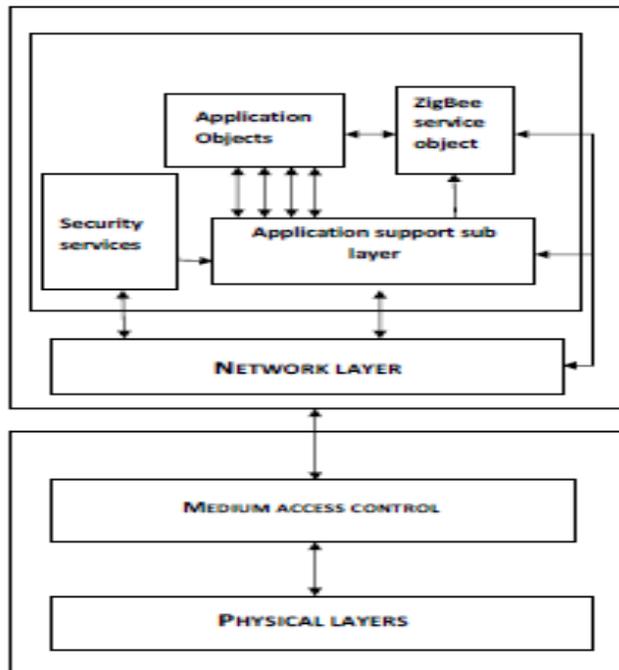


Figure 3.11: ZigBee architecture [12]

ZigBee architecture

The specification goes on to complete the standard by adding four main components: network layer, application layer, ZigBee device objects (ZDOs) and manufacturer-defined application objects which allow for customization and favor total integration. Besides adding two high-level network layers to the underlying structure, the most significant improvement is the introduction of ZDOs. These are responsible for a number of tasks, which include keeping of device roles, Management requests to join a network, device discovery and security. ZigBee is not intended to support power line networking but to interface with it at least for smart metering and smart appliance purposes. Because ZigBee nodes can go from sleep to active mode in 30 ms or less, the latency can be low and devices can be responsive, particularly compared to Bluetooth wake-

up delays, which are typically around three seconds. Because ZigBee nodes can sleep most of the time, average power consumption can be low, resulting in long battery.

- **Physical layer:** It contains electrical and physical specifications.
- **MAC layer:** The channel access is primarily through CSMA/CA. It takes care of transmitting data, scanning channels and encryption of data.
- **Network layer:** Take care of network setup, device configuration, routing and providing security.
- **Application layer:** It is mainly used for end user software applications.

Advantages

- **Power saving:** As a result of the short working period, low power consumption of communication, and standby mode
- **Reliability:** Collision avoidance is adopted, with a special time slot allocated for those communications that need fixed bandwidth so that competition and conflict are avoided when transmitting data. The MAC layer adopts completely confirmed data transmission, that is, every data packet sent must wait for the confirmation from the receiver.
- **Low cost of the modules:** The ZigBee protocol is patent fee free
- **Short time delay:** Typically 30 ms for device searching, 15 ms for standby to activation, and 15 ms for channel access of active devices
- **Large network capacity:** One ZigBee network contains one master device and maximum 254 slave devices. There can be as many as 100 ZigBee networks within one area.
- **Safety:** ZigBee provides a data integrity check and authentication function. AES-128 is adopted and at the same time each application can flexibly determine its safety property.
- **Long battery life:** The battery life is high compared to any other devices.
- **Security:** The data can be protected from any external interference.

Disadvantages

- Short range
- Low complexity
- Low data speed.

Applications

- Home automation
- Wireless sensor networks
- Industrial control
- Embedded sensing etc.

3.5 Servomotor

A Servo motor has three wire terminals: two of these wires are to provide ground and positive supply to the Servo DC motor, while the third wire is for the control signal. These wires of a servo motor are color coded. The servo motor can be driven only when PWM (pulse width modulated) signals are provided to the control terminal.

The total pulse duration for a typical servo motor should be of 20 milliseconds. The on-time duration of the control signal varies from 1ms to 2ms. This on-time variation provides angular variation from 0 to 180 degree also refer servo motor control using microcontroller

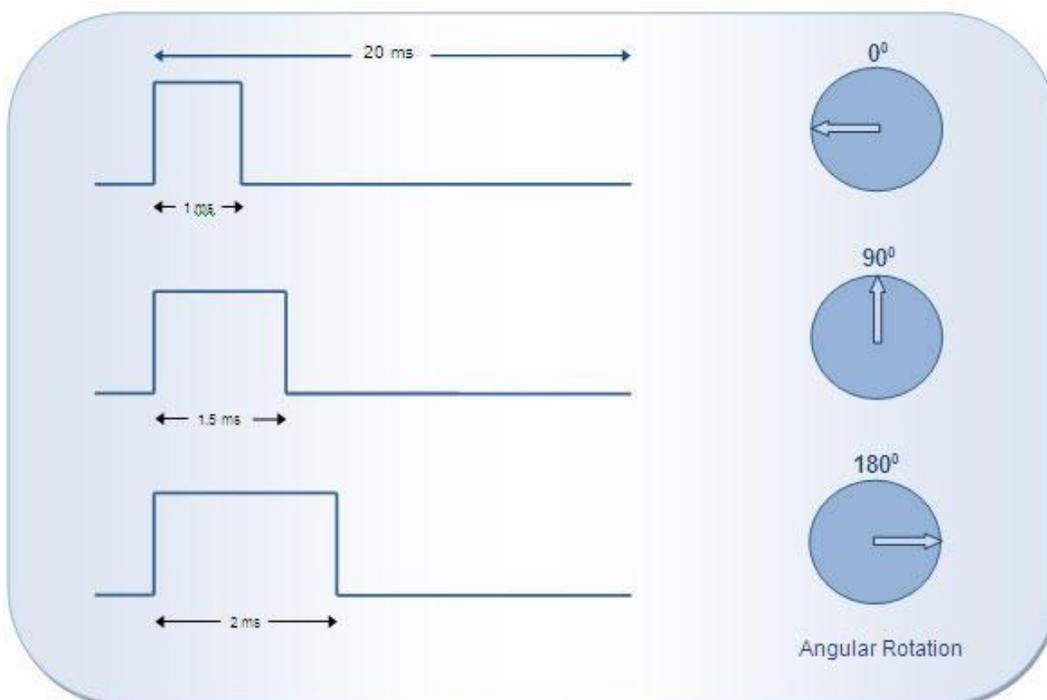


Figure 3.12: Relationships between pulse duration and servomotor angular rotation [11]

According to the above diagram, desired angular position can be calculated by simple interpolations. For example, if the servo motor should be positioned at 45° angle, the desired output control pulse can be obtained as follows:

- 180° angular displacement is achieved by the pulse duration = 1 ms
- 1° angular displacement is achieved by the pulse duration of = 1 /180 ms
- 45° angular displacement is achieved by the pulse duration of = (1/180) x 45 = **0.25 ms**

So total on-time pulse will be = 1ms + 0.25ms =**1.25 ms**

Please note that the on-time duration of the control signal may vary based on the manufacturer or certain other conditions. Therefore it is imperative that the on-time pulse for 0° and 180° positions must be obtained (either from the datasheet or by hit-n-trial) before using a servo motor for an application. The servo motor used here moves to 0° at 0.55 ms pulse.

Objective: To interface the servo motor with PIC16F877A microcontroller and generate pulses to rotate the servo spline in step angles (of 45°) from 0° to 180°. Please check the Video tab to see these rotations. After reaching 180° position, the spline is brought back to 0° position and the rotation thus continues.

Programming Steps:

- Calculate the on-time duration for 1° angular displacement.
- Create delay function to calculate time duration.
- Set the pin high at which control terminal of the servo motor is connected.
- Call the delay function (mentioned in 3) and repeat it number of times as much angular displacement needed.
- Set the control pin low.
- Generate delay of 18 ms.
- Repeat the steps from 4 to 7 continuously for about 50 times to send a train of pulses.

A servomotor is a rotary actuator that allows for precise control of angular position. It consists of a motor coupled to a sensor for position feedback, through a reduction gearbox. It also requires a relatively sophisticated controller, often a dedicated module designed specifically for use with servomotors. Servomotors are used in applications such as robotics, CNC machinery or automated manufacturing. It is the modified form of DC motor. As the name suggests, a servomotor is a servomechanism. More specifically, it is a closed-loop servomechanism that uses position feedback to control its motion and final position. The input to its control is some signal, either analogue or digital, representing the position commanded for the output shaft.

The motor is paired with some type of encoder to provide position and speed feedback. In the simplest case, only the position is measured. The measured position of the output is compared to the command position, the external input to the controller. If the output position differs from that required, an error signal is generated which then causes the motor to rotate in either direction, as needed to bring the output shaft to the appropriate position. As the positions approach, the error signal reduces to zero and the motor stops.

3.6 Central control center

This is the center of control of trains. It gets information about the strength of the vibration sensed by the vibration sensor via the ZigBee and generates control command to the train and way side signals.

Central control center

The function of central control system is control railway station signal devices by use of the computer technology to finish the transportation tasks. The modern control center now a days is known as computer based interlocking (CBI).

Attributes:

- High-reliability: MTBF (mean time between failure) $\geq 10^6$ h.
- Fault-safety: Even if the signal devices occurred fault, the CBI system controls the system to safety state.
- Safety: Safe integrated level 4 (SIL-4, the highest level).
- Real-time: the executive cycle ≤ 250 ms.

CBI structure

The main component of CBI looks like as shown below.

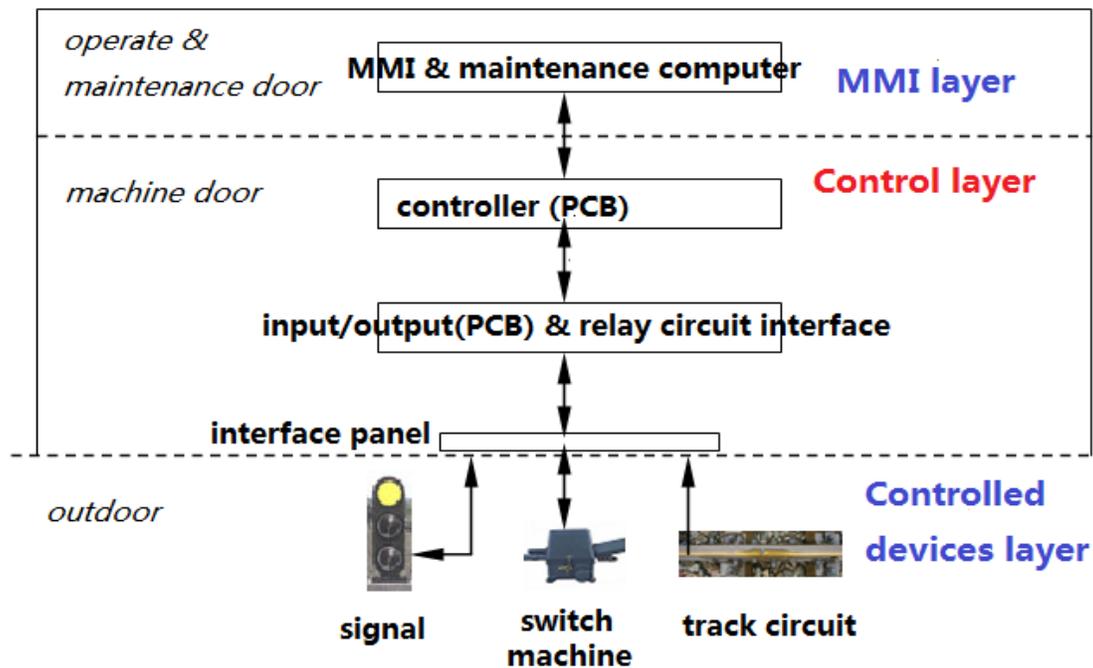


Figure 3.13: CBI structure [5]

3.6.1 CBI structure & functions

MMI layer

- Include: MMI & maintenance computer.
- Computer:
- Industry computer are adopted (high stability).

MMI: 2 computers– one work, the other is hot-standby

MMI-functions:

- Receives the operation from the operator → command. (For example: select-route command, cancel-route cmd.)
- Sends the command to controller
- Receives signal devices state information from controller. Includes
- Displays the state of all signal devices, provides voice guide, voice alarm.

Maintenance computer

Control layer

Include: controller and interface circuit;

Controller:

- Functions: interlocking logic control for signal switches and track circuits of a railway station.
- Includes: PCB(CPU board+ power supply board+ communication board)

Hardware attributes: redundancy (double of 2 of 2 votes)

Interface circuit

- **Includes: input/output boards (redundancy: 2 of 2 votes) & relay interface circuit.**

Functions:

- Output boards: receives commands from controller, and drives the related relays to up/down.
- Relay state change (up/down)→ the relay circuit switch on/off→ power supply on/off → signal devices works in different mode→ signal devices states change.

Input boards: get relay state change (up/down)→ send the state to controller

3.7 Train On board equipment

This includes devices that display the following important information to the driver

- Speed limit
- Status of way side signal
- Alarm

Chapter 4

Detail modeling of level crossing for LRT case

4.1 Vibration for LRT case

The vibration is measured in Sweden is converted for LRT case for the level crossing at around Salitemihret church in Gurd shola. The area is looks like a roundabout when the train is at the middle but the cars and passengers are crossing the train track. The area looks like as shown below.

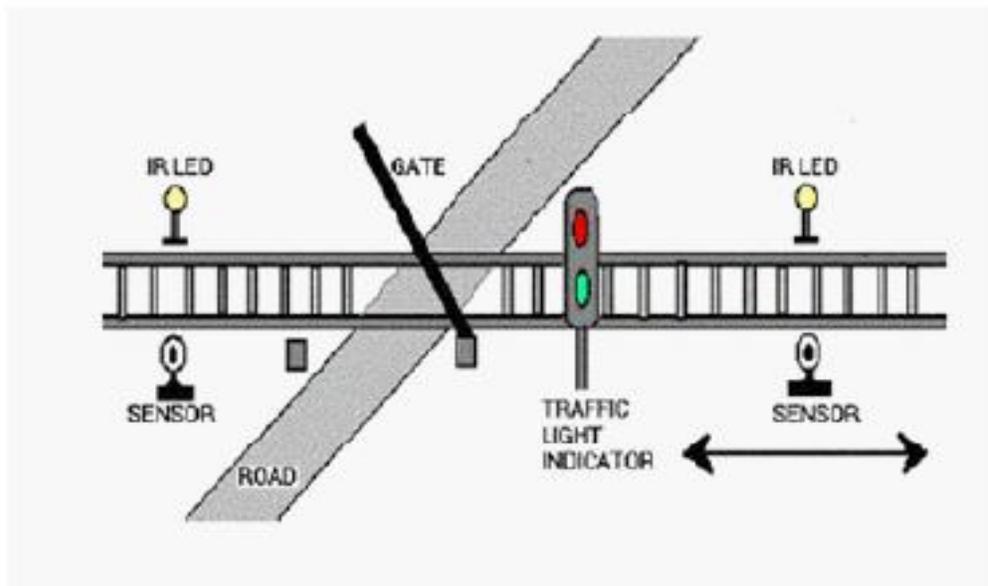


Figure 4.1: general level crossing layout [12]

The measured vibration levels are found on Appendix and modeling the different factors the vibration level for AA-LRT Salitemihret will discussed below.

4.2 VT Calculations

As a last step to apply the prediction formula, VT should be calculated for the different trains.

After we found most of the parameters for the equation

$$V = V_T * F_D * F_S * F_R * F_B \quad 4.1$$

Now, one could calculate V_T for each type of train. V_T will have a certain value at a certain distance depending on the values of the exponential B .

For the Intercity trains, the average value of the exponential B , at 40m and 80m was equal to -1.0 . Then the value -1.0 is for B 20m, because of the method that we used to calculate the exponential B was to compare with the distance 20m all the time. The value of the exponential A was assumed to be 0.9 according to the reference [43], so the factor FS was calculated for each type of train individually. The values of the factors FR , and FB were found to be 0.8 and 2 respectively according to the same reference.

By applying the equation above, VT was calculated for the measured X2000 trains, and as a result of taking the average value for VT to these trains. VT found to be equal to 0.0337 [mm/s], for distances 20m. The same procedure was followed by calculating VT for the intercity trains and taking the average value for it. VT obtained to be equal to 0.0319 [mm/s], for distances ³ 20m. For the last type of trains, freight trains, an equivalent method was followed for finding the values of VT . By taking the average value for them, VT was obtained to be 0.047, for distances ³ 20m. This is higher than the first type of trains.

4.2.1 Calculating Vibration level Salitemihret level crossing (AA-LRT case)

Applying the prediction formula

From the previous chapter 3 the most important parameter have been found and the information which has been measured can be presented in general form by applying the equation below for the obtained results for FR , FB , FD , FS .

$$V = V_T * \left(\frac{D}{D_o}\right)^B * \left(\frac{S}{S_o}\right)^A * F_R * F_B \quad 4.1$$

This equation could be applied to find the vibration velocities for AA-LRT train type and at different distances as well.

4.2.2 Calculation of vibration for AA-LRT Salitemihret case

V_T is the measured vibration level. From the appendix the vibration level measured for speed 70 kmph. This value can be changed to AA-LRT case as follows.

The following data is found from field measurement of vibration for different train type hold on Sweden for speed of 70 kmph.

Table 4.1 average vibration for different train type

Train type	Vibration measured in mm/s			
	10 m	20 m	40 m	80
X2000	0.101	0.1063	0.0566	0.0255
City train	0.131	0.0983	0.0654	0.0252
Freight	0.107	0.106	0.067	0.0486

The average speed of the AA-LRT for Ayat to Torhailoch direction is 31 kmph [14].

$$V_{T, \text{Salt}} = \frac{31}{70} V_{T (\text{measured})} = 0.443 V_{T (\text{measured})} \quad 3.15$$

$$V_{T, \text{Salt}} (10 \text{ m}) = 0.058 \text{ mm/s}$$

$$V_{T, \text{Salt}} (20 \text{ m}) = 0.0436 \text{ mm/s}$$

$$V_{T, \text{Salt}} (40 \text{ m}) = 0.090 \text{ mm/s}$$

$$V_{T, \text{Salt}} (80 \text{ m}) = 0.112 \text{ mm/s}$$

Where; V_T : Measured vibration levels for the trains at 20m and 70 Km/h.

Note: since the AA-LRT train type is city tram our approximation is for the city train of the Swedish so the above data on the table are approximated for them.

Refer to chapter 3 on calculation of braking distance; the braking distance is 282 meters so the above value of vibration are changed in such a way that it includes the braking distance so that the train will stop at the required distance.

Next the above obtained vibrations are going to change for the distance it includes the braking distance.

To translate a vibration limit V_1 measured at a distance d_1 to a measurement distance d_2 (302 m), the new vibration limit V_2 will be calculated as follows:

$$V_2 = V_1 + 20 * \log \frac{d_1}{d_2} \quad 4.2$$

$$V_2 = 0.15 + 20 * \log \frac{20}{302}$$

The results at 282 m, 302 m, 322 m and 362 m are given below using the above formula.

$$V_{T, \text{Salt}} (282 \text{ m}) = 0.0021 \text{ mm/s}$$

$$V_{T, \text{Salt}} (302 \text{ m}) = 0.00136 \text{ mm/s}$$

$$V_{T, \text{Salt}} (322 \text{ m}) = 0.00090 \text{ mm/s}$$

$$V_{T, \text{Salt}} (362 \text{ m}) = 0.0008 \text{ mm/s}$$

Selection of area for measurement of vibration

This is the area where the vibration sensor is putted.

- ***D***: Any distance from the Centre of the railway track.
- ***Do***: Selected to be 20m, to avoid the influence of the near field waves.
- ***B***: Calculated as a distance dependent, *B* varied also depending on the train type. The exponential *B* was calculated at the reference distance 20m.

B: for AA-LRT trains = -1, for distances 20m (see chapter 3 for detail analysis)

Selection of speed of measured

The speed the measurement take place is 70 kmph but we have to change the values according the above discussed formula.

- ***S***: Any speed for any kind of trains.
- ***So***: Was chosen to be 70 Km/h (31 kmph for AA-LRT case), to be the reference for all train types,
- ***A***: Speed dependent exponential, its value has been assumed to be 0.9 according to, unfortunately we couldn't calculate due to that we need more measurements for the trains at very wide-ranging speeds, which we couldn't have it during the measurements stage.

A for AA-LRT case calculated as

$$A = 0.9 * 0.443 = 0.4$$

Selection *FR* and *FB* of AA-LRT

- ***FR***: The track quality factor, according to UIC 2010/04 will be equal to 0.8 in our assignment because there is no much difference on track quality.
- ***FB***: The building amplification factor, the typical value for it is 2 for the Swedish houses, due to (this is difficult to analyze but I can assume there is much vibrational noise from the building due to they are built in the city rather than outside city as the Swedish).

FB =2.5 for the case of AA-LRT case.

4.3 Level crossing sub system

4.3.1 Composition of LX subsystem

In this thesis, each of the 12 LXs for LRT line and highway will be provided with one set of independent LX equipment.

Level crossing control system is mainly composed of the following equipment:

- Main control cabinet MCC;
- Control and Indication panel CIP (in the control cabinet);
- Barrier Control Box
- Barrier and Road signal;
- Audible alarm device.

4.3.1.1 Main control cabinet MCC

MCC consists of main control unit, outdoor equipment interface board and power module. The main control unit adopts PLC technology; except the interlocking system interface, the LX subsystem adopts all-electronic mode for crossing equipment control, with the dimension of 1200*710*300mm (H*W*D) and wall mounting type.

4.3.2.2 Control and indication panel (CIP)

Control and indication panel CIP is integrated on the faceplate of the control cabinet and LCD screen is used for indicating the status of the LX equipment.

4.3.2.3 Barrier Control Box

The Barrier Control Box is used for the Crossing operator to control the barrier. Two sets (Set A and Set B) of lifting/lowering buttons are arranged in each Barrier Control Box and one set of lifting/lowering buttons may be shared by two opposite barriers for simultaneous lifting and lowering control.

The buttons are non-stick. As soon as the barrier is activated, under automatic mode, it will be lifted automatically till reaching the full-lifting position.

- Barrier lifting button –non-stick button is adopted, with pressing and times recorded by PLC;
- Barrier lowering button –non-stick button is adopted;
- Barrier bypass switch –two-position switch that can only be operated by inserting the dedicated key;
- Indoor alarm Acknowledge button –single and non-stick button;
- Indoor audible alarm.

4.3.2.4 Outdoor equipment

Outdoor equipment consists of barrier machine and road signal. Number of the barrier machine will be determined in accordance with the crossing type and width.

4.3.2.5 Configuration of equipment at the crossing

The main control cabinet MCC and control/indication panel are installed in the gate hut and the interlocking equipment concentration station provides UPS of 220V/50Hz $\pm 15\%$ for the LX protection system.

This thesis mainly involves the following two types of crossings:

Configuration of equipment for Type I crossing

Configuration of equipment for Type II crossing

The AA-LRT is type II level crossing which shown below with two side level crossing for the road users.

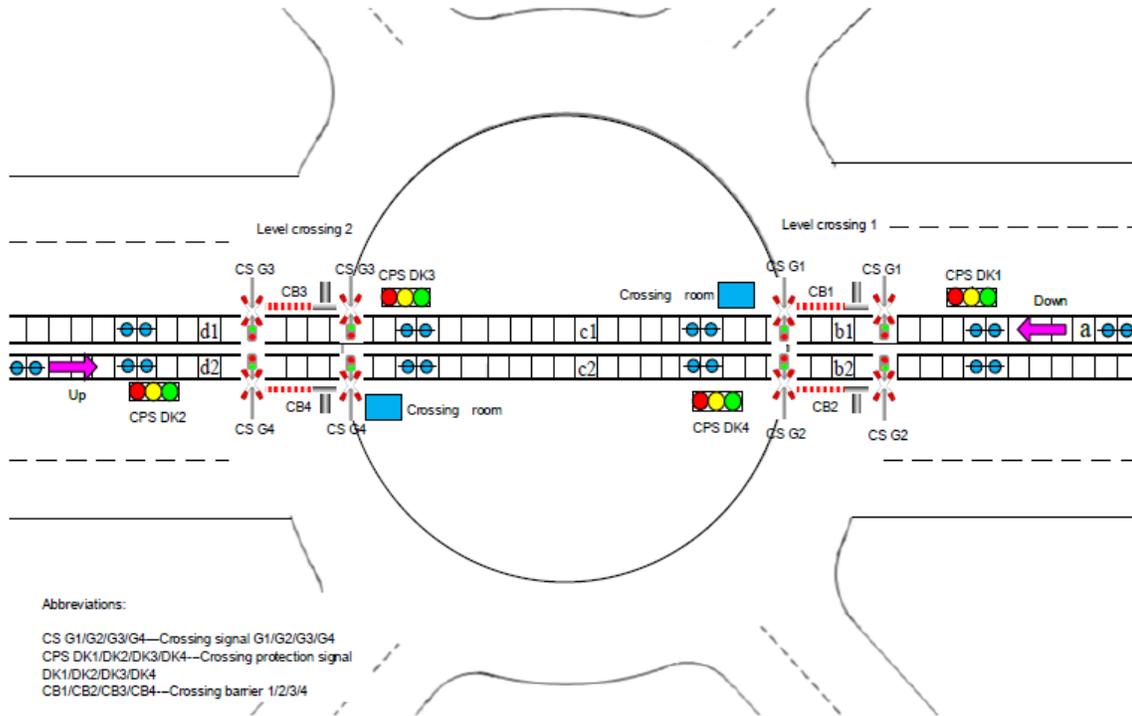


Figure 4.2: Schematic Diagram of Composition of LX Equipment at Type II Crossing [5]

Type II crossing consists of 2 crossings which are under independent control. Each crossing is provided with 4 road signals, 2 barriers, 1 control cabinet, 1 control and indication panel, 1 barrier control box and 1 set of automatic audible and visual alarm device for indoor and outdoor.

4.4 Function of LX subsystem

LX system is with the functions of giving approaching alarm notice and controlling road signals and barriers.

4.4.1 Approaching alarm notice

Via the relay interface with interlocking system, when LRT train approaches the crossing from any direction, the interlocking system will send the information of train approaching to the LX

subsystem according to the occupation condition of the approach section to the crossing or the condition of route setting.

The LX subsystem will, according to the information of train approaching, automatically send the indoor and outdoor train approaching alarm notices.

- Buzzer alarm will be adopted for indoor train approaching alarm notice;
- Audible and visual alarm and indication of signal are adopted for informing the pedestrians and the vehicle on the road of train approaching and status of LX. The outdoor audible alarm device is installed at the top of the road signal post and horn loudspeaker is adopted, with the sound level of 50~80dB and volume adjustment device. Voice alarm is adopted for audio alarm of the approaching notice.

If there are trains approaching the crossing in both up and down direction, the LX subsystem is able to send the train approaching alarm notice continuously or send such alarm once again. The indoor train approaching alarm notice can be canceled by the guard by pressing the Acknowledge button on the control and indication panel.

4.4.2 Barrier control

Manned mode is adopted for the crossing in this project and there are 3 operating modes of the barrier:

- Automatic operating mode (automatic lifting and manual lowering)
- All-manual operation mode
- On-site manual mode.

The automatic operation mode or all-manual operation mode will be set after system initialization and may be modified as required. Under normal condition, after train clearing out of the crossing and relevant conditions are satisfied, the barrier will be controlled by the LX subsystem to be lifted automatically.

When the barrier is lifted, it should be judged that the conditions for train approaching in up/down from the interlocking system are all high level; after train leaves the crossing, the route at the axle-counting section within the crossing area will be released.

The interlocking system sends the high-level of train approaching and notice LX LRT train leave the crossing and LX subsystem which will automatically stop the outdoor train approaching alarm and lift the barrier.

If the conditions for lifting are not satisfied, the barrier will remain in the status of lowering and the control circuit will cut off the operation of lifting. Both manual and automatic lifting of barrier are not allowed.

Lowering of the barrier will be controlled manually by the Crossing operator. When the train approaches the crossing, the Crossing operator will, according to the information of train approaching alarm notice, press the lowering button for manual control of lowering of the barrier after confirming that pedestrians and vehicles within the area of crossing road surface are cleared.

If the barrier cannot be lowered for some reasons or the interlock system does not get the status information about lowering of the crossing barrier for some reasons, the Crossing operator may press the barrier by-pass switch on the control and indication panel, to send the lowering status of crossing barrier to the interlock system, so as to control and open the road signal to allow LRT train passing through the crossing.

In case of power failure or malfunction, the barrier may be lifted or lowered manually by the hand crank at the site.

In case of power failure or malfunction during lifting or lowering, the barrier will stop and stay at the current position, under which condition it may be lifted or lowered by manual control at the site. In case of power failure or malfunction at the lifting or lowering position, it will stay at the current position.

Under automatic mode, unless power failure or system malfunction, the system must ensure that the crossing barrier will lift automatically until reaching the full lifting position.

Type II crossing consists of 2 crossings which are under independent control. At the same level crossing, all the barriers on both sides of LRT line are controlled by the same barrier control box.

4.4.3 Road signal control

The road signal will be controlled by the control cabinet. Its normal status will be displayed by green light, under which condition the municipal road vehicles and pedestrians are allowed to pass through the crossing.

When the train approaches the crossing, the road signal system will, after receiving the train approaching information from the interlocking system, turn into red light after the green light flickers for 5 seconds, reminding vehicles and pedestrians no entry of the LX or speed-up to pass the LX which is within the crossing area, automatically, the road signal will be automatically recovered to be in green light.

For the road signal with side indication, the lights at the front and at the side should be kept the same without occurrence of inconsistency of the light at the front with that at the side.

Operation of Crossing operator and failure state of all the equipment can be recorded on the indication panel:

- Provide working condition of PLC and give the alarm;
- Detect working condition of barrier: if the barrier does not reach the corresponding position after operation for 30s, alarm will be given to inform failure of the barrier;
- Detect the status of road signal and give the fault alarm upon 40% LED failure.

4.4.4 Control principle for crossing

The LX subsystem will provide a relative priority for LRT train's passing of level crossing. According to the busy extent of traffic flow and actual condition on site, a shortest opening time will be set for the control equipment at each crossing respectively.

If the shortest opening time is not met when a train approaches the crossing, the road signal system will not trigger the train approaching alarm. The interlocking system will, according to the lifting status of the barrier, maintain a close status of railway protective signal to allow no passing of LRT train through the LX and continuously send the LX subsystem the train

approaching alarm. Until the shortest opening time is met, the railway protective signal will then be opened to allow passing of the LRT train through the crossing.

In this project, the level crossing is designed to be manned. The lowering of the crossing barrier will be achieved by manual control of the Crossing operator who can adopt two modes for control, i.e. the indoor manual control and the on-site manual operation:

- Normally, when a train approaches the crossing, the operator should first make sure that the crossing area is cleared (without people and vehicle), and then press the lowering button of barrier for lowering control of the barrier;
- The crossing barrier can be lowered by on-site manual control in case of power failure or malfunction.

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 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;
- The crossing operator can adopt indoor manual control when the automatic-lifting function is invalid. After confirming that the light for indicating the lifting of the barrier is ON, he can then press the button on the crossing control panel to achieve manual-control lifting.
- The barrier can be made lifted by on-site manual control in case of power failure or malfunction.

In case of power failure or malfunction during the lifting or In case of power failure or malfunction during the lifting or lowering of crossing barrier, the action of the barrier will be stopped and it will be kept at the current position. At this time, it can be made lifted or lowered by on-site manual control.

When there is a train at the crossing area, or there is a train approaching the crossing and the route locked in the same direction with the train pass through, the crossing barrier cannot be

lifted. Meanwhile, the lifting of the crossing barrier will not lead to emergency braking of the train approaching the protective signal at the crossing.

After logical processing of interlocking system to the above conditions, the train approaching message in up/down direction will be sent to the LX subsystem. When the state of train approaching message in up/down direction is “1”, the crossing barrier will be authorized to be lifted; and when the status of train approaching message in up/down direction is “0”, the barrier will be always maintained at the horizontal position and the lifting operation will be cut off by the crossing control circuit.

Normally, interaction of LRT train and highway traffic operation is as follows, taking the EW8-EW7 section for example:

- There is no train occupation of approach section on both sides of the crossing, the crossing is open and the green light of the road signal is ON, allowing the passing of the highway traffic;
- The train 1 occupies the down platform of EW7 for departure, and when it occupies T10701, the interlocking system will process route S10807-S10805 according to ATS instruction;

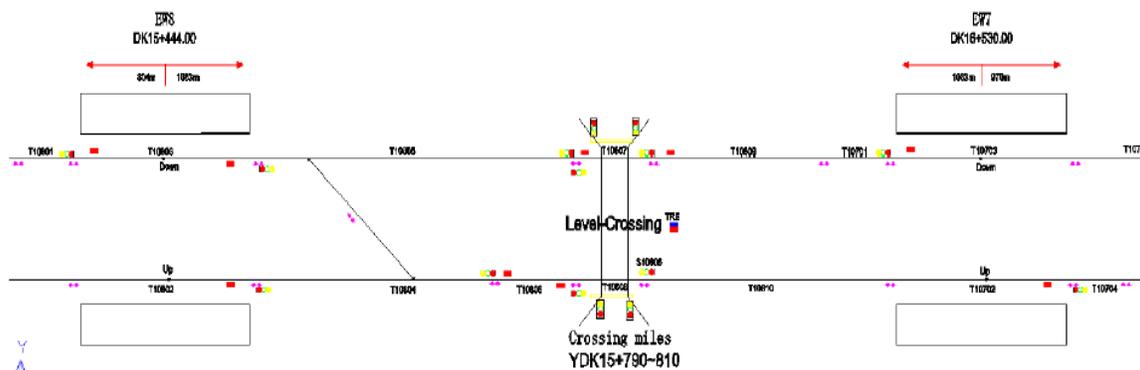


Figure 4.3: Display of Crossing Plane [5]

- After successful setting of route S10807-S10805, the interlocking system will send the LX subsystem train approaching message in down direction;
- When receiving the train approaching notice, the LX subsystem will automatically trigger the indoor and outdoor train approaching alarm notice. Meanwhile, the road signal will

automatically turn into flashing red light, reminding no entry of vehicles and pedestrians on municipal highway to the crossing area and passing of vehicles and pedestrians on municipal highway within the crossing area in an accelerating manner;

- After confirming that pedestrians and vehicles on the highway side are cleared out, the crossing operator should press the button on the barrier control box to lower of the barrier;
- When the barrier is horizontal position, the indoor train approaching alarm will be stopped automatically (the crossing guard can cancel the alarm by pressing Acknowledge Button on the control and indication panel), the road signal will turn into red light and the interlocking system will collect the close of LX and locking information. Then the railway protective signal S10807 at the LRT side will be opened immediately and authorize the passing of LRT train through the LX;
- When train 1 passes the crossing, the railway protective signal will light in red. After clearing and unlocking the T10807 section, the interlocking system will cancel the train approaching message in down direction. The LX subsystem will automatically stop the outdoor train approaching alarm. If the outdoor train approaching alarm cannot be cancelled due to malfunction, the Crossing operator can remove the alarm by manual operation after confirming the clearing of train.
- The LX subsystem automatically lifts the barrier, and the road signal will turn into green light.

If, before the train 1 passes the crossing, and the train 2 departs from EW8 up platform, then:

- When train 2 occupies T10804, the interlocking system will process route S10804-S10806 according to ATS instruction, and the signal S10804 will be opened and meanwhile send the LX subsystem the train approaching message in up direction;
- The LX subsystem will again trigger the train approaching alarm notice. The Crossing operator should press the acknowledge button on the control and indication panel to cancel the indoor train approaching alarm;
- When both train 1 and train 2 pass the crossing, the section T10807/T10808 will be cleared and unlocked;
- The LX subsystem automatically lifts the barrier, and the road signal will light in green.

If, when a train approaches the crossing, the barrier cannot be lowered due to malfunction, or the interlocking system does not obtain horizontal status information due to malfunction, the Crossing operator can, after confirming the LX close, press the bypass button of barrier to make the interlocking system open the railway protective signal, allowing passing of trains through the crossing.

In conclusion, the interface function of the LX subsystem and the main line interlocking system mainly includes: receiving train approaching message in up/down direction from the interlocking system; and sending the interlocking system the close status of barrier and barrier bypass information

4.4.5 Train approaching notice

When the LRT train approaches the crossing from any direction and the route for passing the crossing is processed (the railway protective signal remains closed due to the crossing barrier does not be lowered and locked), the interlocking system will send the LX subsystem train approaching notification in up/down direction, then the road signal system will automatically send out the indoor and outdoor train approaching alarm.

When there are trains approaching the crossing in both up and down direction, which means that the train approaching notices both in up and down direction, the LX subsystem can continuously or again send train approaching alarm notices. the train approaching alarm includes Audible indoor and outdoor alarms.

4.5 Performance of LX subsystem

4.5.1 Barrier control box

The barrier control box and the control box could be installed indoor together with the control cabinet. To facilitate real-time monitoring of the crossing by Crossing operator, and shall meet the following requirement:

- Stainless metal material shall be used. The metal parts of the case shall be free of corrosion and other mechanical damage. All the sliding or rotating components shall be flexible as required and the fastening pieces shall not be loose. No sharp prominence or corner likely to result in harm shall be found on the external surface of the case;
- The control panel shall have sufficient internal space and be conducive to heat radiation, easy for installation, use, maintenance and prevent water accumulation on the top face;
- Be able to sustain predictable operations during transport, installation, handling, maintenance, etc. under normal conditions and shall not be easily opened by general tools;
- A firm lock shall be equipped to prevent illegal opening. Protective device shall be set on the lock. After the case is locked, no loosening or deformation shall occur.

The electrical endurance buttons set on the control box shall be more than 500,000 times.

4.5.2 Road Signal

The road signal is used to provide “no passing” and “passing” signals for pedestrians and vehicles. It mainly consists of signal mechanism, LED light unit, visor, backboard, post , ladder, cross board and outdoor sounder, etc. The signal mechanism is of combined aluminum alloy structure with the bottom part directly fixed on the arm of the signal.

Chapter 5

Software Development Proteus

5.1 System Flow chart

As discussed above the main objective of this thesis is to design a safe crossing of passengers and vehicles on level crossing. This is done using a vibration sensor, microcontrollers and ZigBee.

The system is designed using Proteus software and simulated to check its validity by controlling (make it Green, Yellow, Red) the train side signal and road users side signal as well as by rotating the servo motor such that it makes to move the barrier up and down. The above simulation is build based on the following principle (flow chart)

Start: This is the idle state of the system it means the way is given to the road users and passenger; the barrier is on up position, road user signal is Green but the train side signal is Red there is no approaching signal or train is 362 m away from crossing.

Next the vibration is sensed/ detected and compared if its value is within the range of distance.

The flow chart also checks/ detects if there is an obstacle inside the level crossing and takes appropriate measure to solve the problem.

End: This is the last step in the flow chart. If the system encounters the exit/ departure of a train from the level crossing then the system ends and returns to the beginning of the flow chart i.e. start.

The above ideas are shown on the following flow chart.

Note: the obstacle detector is a load sensor that senses if there is additional load greater than the initial small load or no load. Strain gage is used to sense the load putted on the level crossing if there is, it changes the corresponding load to voltage level.

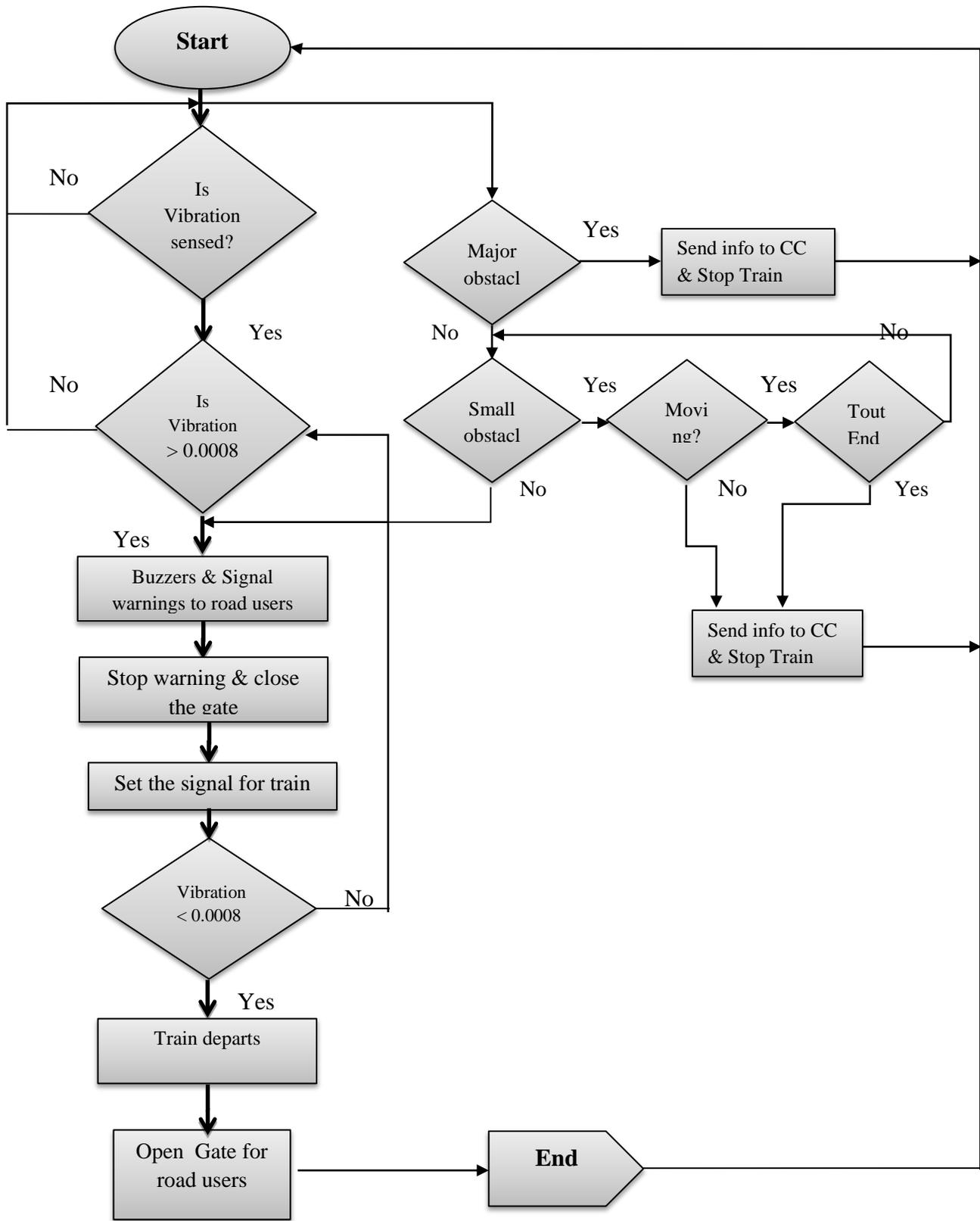


Figure 5.1: System flow chart [17]

Working principle of the flowchart

It deals with two things. Firstly, it deals with the reduction of time for which the gate is being kept closed. And secondly, to provide safety to the road users by reducing the accidents that usually occur due to carelessness of road users and at times errors made by the gate keepers. The flow chart starts by setting the signal system for the road users. If the directional vibration sensor senses it transmits information about the position of the coming train so the warnings to the signal user is given through the way side signal and a buzzer of alar is given to the gate keepers to make then alert for the next gate operation. But, if the vibrational sensor senses no information means there is no any coming train and there is no notification to both road user and gate keepers.

After the road user get notification they slow their speed and ready for the next instruction and the gate of the road user is closed automatically and set the signal for the train to proceed. If there is a vehicle inside the level crossing the gate keeper communicates with previous departures/gate keepers so they told to delay the train or to decrease the speed of the train so that to stop some meters away from the level crossing. This is done using a call from the gate keeper.

By employing the automatic railway gate control at the level crossing the arrival of train is detected by the sensor placed on either side of the gate at about 80m-10m from the level crossing. Once the arrival is sensed, the sensed signal is sent to the microcontroller and it checks for possible presence of vehicle between the gates, again using sensors. Subsequently, buzzer indication and light signals on either side are provided to the road users indicating the closure of gates. Once, no vehicle is sensed in between the gate the motor is activated and the gates are closed. But, for the worst case if any obstacle is sensed, it is indicated to the train driver by signals (RED) placed at about 362 m, so as to bring it to halt well before the level crossing.

When no obstacle is sensed GREEN light is indicated, and the train is to free to move. The departure of the train is detected by sensors placed at about 1km from the gate. The signal about the departure is sent to the microcontroller, which in turn operates the motor and opens the gate. Thus, the time for which the gate is closed is less compared to the manually operated gates.

When the vibration is greater than 0.0008 mm/s means that it is within the danger area and by detecting the vibration level its corresponding distance and type of signal warning is displayed. The simulation is done using Proteus software environment will be discussed next.

5.2 Introduction to Proteus

Proteus Virtual System Modeling (VSM) combines mixed mode SPICE circuit simulation, animated components and microprocessor models to facilitate co-simulation of complete microcontroller based designs. For the first time ever, it is possible to develop and test such designs before a physical prototype is constructed. This is possible because one can interact with the design using on screen indicators such as LED and LCD displays and actuators such as switches and buttons. The simulation takes place in real time (or near enough to it): a 300 MHz Pentium II can simulate a basic 8051 system clocking at over 12MHz. Proteus VSM also provides extensive debugging facilities including breakpoints, single stepping and variable display for both assembly code and high level language source.

In this thesis the system is developed using the block diagram discussed in chapter two i.e. for the train side, base station side and the control center which is designed and simulated using Proteus software.

Design setup for Analog to Digital conversion

As discussed above the analog 5 volts voltage is changed to digital binary digit and this binary number is given to the microcontroller.

Refer to table 3.1 the distances where the vibration are measured are changed to analog voltage. See chapter 3 for detail explanation. This analog voltage should convert to corresponding binary equivalent and the microcontroller understands and sends a command to the control center.

The Proteus set up is shown below.

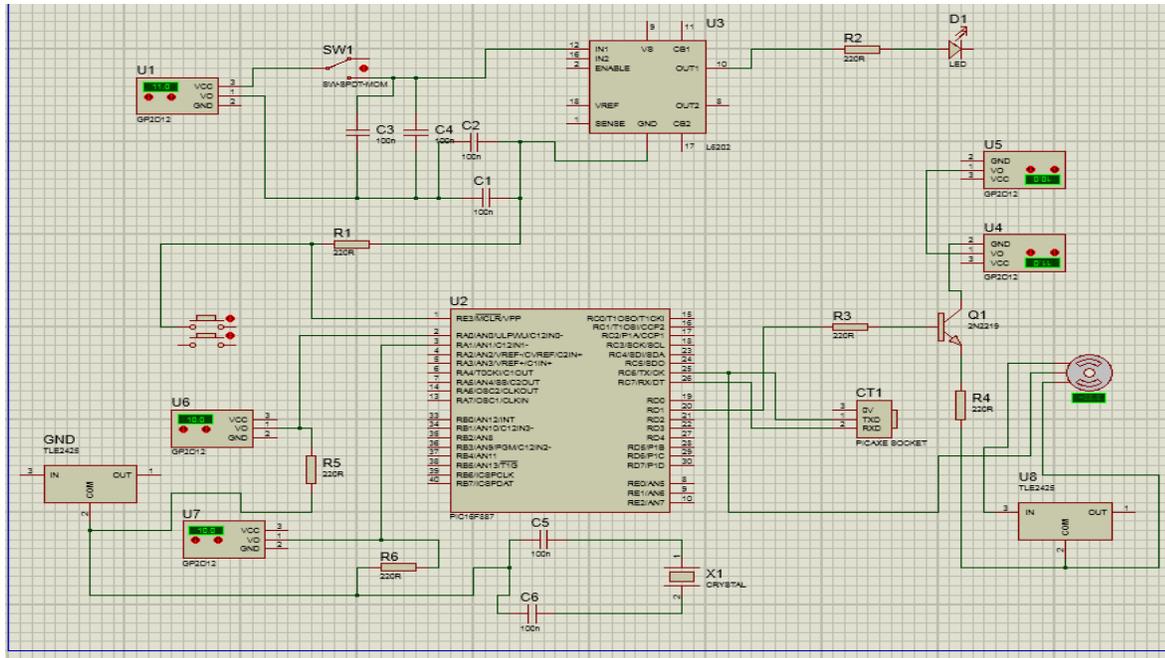


Figure 5.4: Proteus design of the base station

5.3 Programming the PIC16f88

The General Pseudo code in c that is used to program the PIC is shown below.

```

#include p16f887a.inc           % Include register definition file
VARIABLES
RESET and INTERRUPT VECTORS
Reset Vector
RST code 0x0
GOTO Start
CODE SEGMENT
PGM code
Start:
# include main                 %Main body of the program starts here
Loop
GOTO Loop

```

END

This is the general pseudo code to program the PIC16f887 chip and the detail program of the PIC will be given in appendix part

Next the actual design that I used in the simulation will be discussed

5.3.1 Simulation set up for train side and road side signals

The simulation for the train side and road signal is done using a traffic light LED and the vibration is changed to corresponding voltage levels and send to control center via ZigBee. The control center sends back a command that used to ON/OFF the side signals. The PIC16f887 is discussed in chapter 3. Below shows the schematic diagram of the way side signals both for the train control and road signal control that I used in the simulation.

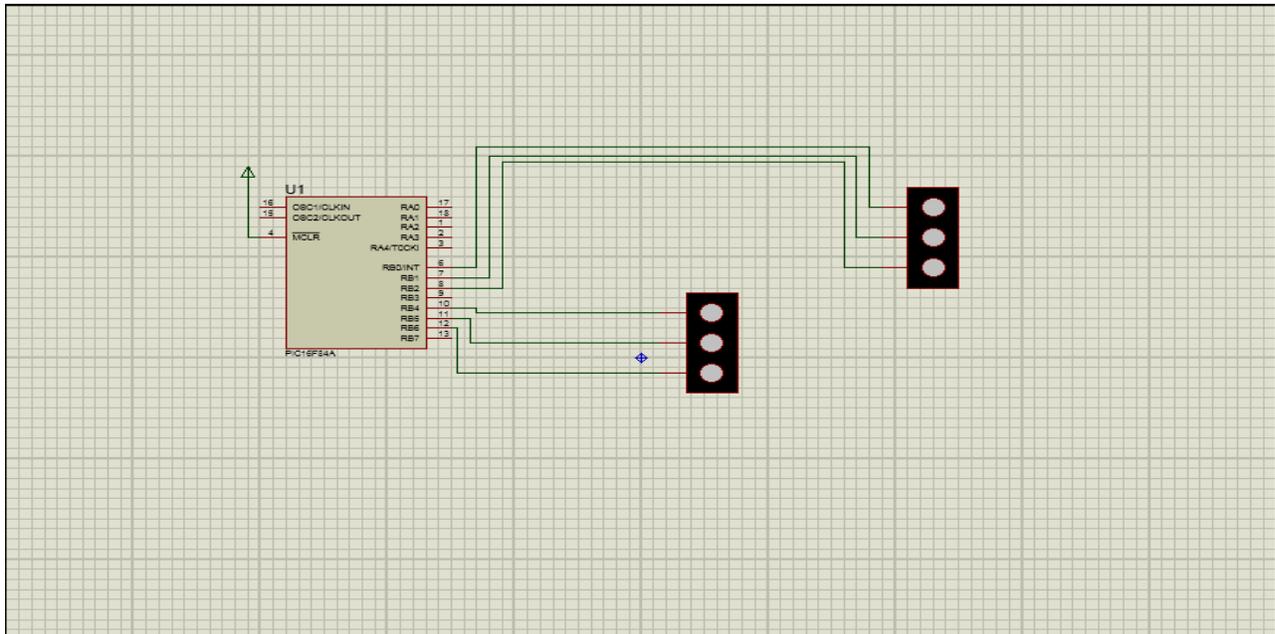


Figure 5.5: Way side signal design using Proteus used in the simulation

5.3.2 Simulation set up for barrier control using Servo motor

The barrier is controlled using the servo motor. So changing the position of the servo motor means opening/closing of the barrier gate. The results are displayed on the Proteus and will discuss in chapter 6.

5.3.2.1 Programming the PIC16f887 to control servo motor

The programming of the PIC16f887 is given in the Appendix part but below shows the schematic design representation of the servo motor control using Proteus software.

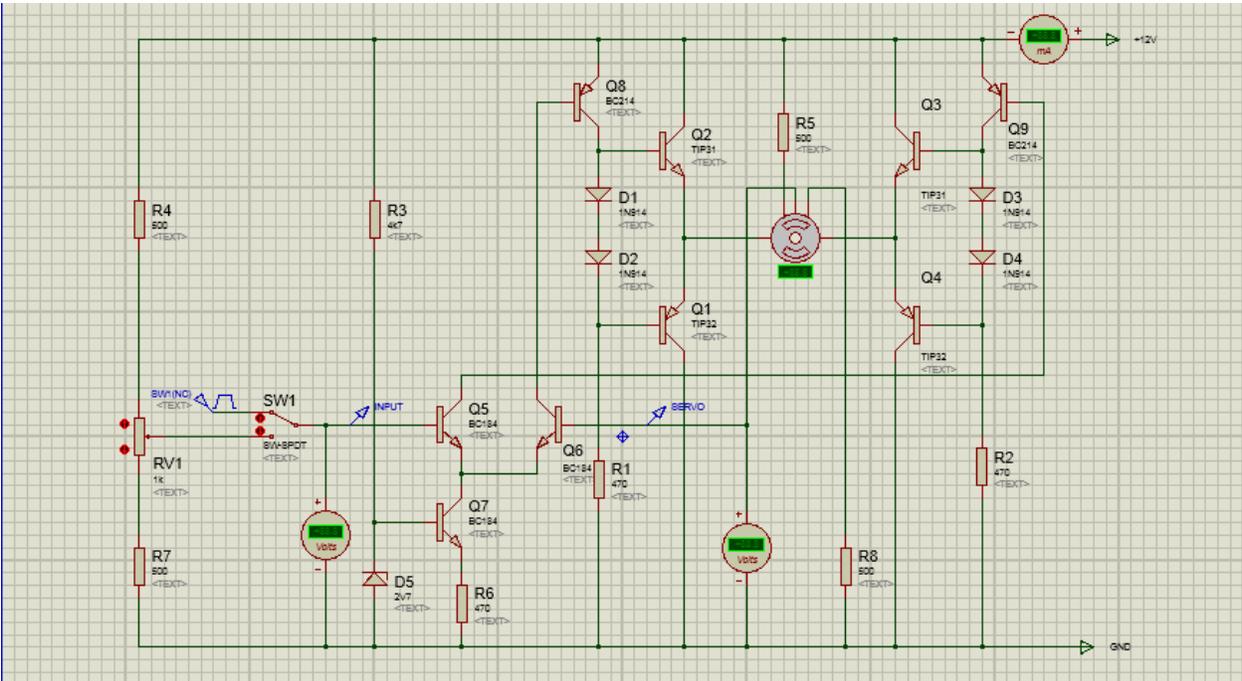


Figure 5.6 servo motor design using Proteus software

Chapter 6

Result and discussion

In the previous chapter, in chapter five the flow chart and Proteus software are discussed in detail. Using Proteus software the general system set up are designed. To simulate the way side signal I have designed the system using traffic light and the PIC16f877A microcontroller is designed based on the logic discussed in the flow chart.

In this chapter, the simulation results are presented. In the first part the vibration level and corresponding distance and voltage are presented.

From the Proteus simulation we found the following result in a tabular form for the analog voltage to digital conversion.

From the simulation of ADC804 converter the analog voltage is varied using the potentiometer in order to read a voltage from 1-5 volts and the corresponding LED are ON so the analog voltage and corresponding binary digits are recorded.

The following results are obtained.

Table 6.1 result of vibration level and corresponding voltage

Measured Vibration level In mm/s	Distance from level crossing in meters	Analog Voltage in Volts	Binary equivalent In digits
> 0.0021	282	3.76 - 5	00000101
0.0014	302	2.6 - 3.75	00000011
0.0009	322	2.1.26 - 5	00000010
< 0.0008	362	0 - 1.25	00000001

From the above table we can draw the following conclusion.

- When the vibration sensor sense a vibration level of 0.0021 mm/s it represents a distance of 282 meter away from the level crossing and a binary number 05H is send serially to the microcontroller and the microcontroller sends a command that says the train is at 282 meter away from the level crossing to the control center via a ZigBee and the control center make a diction to display a Red signal for the road user and Green signal for the train to proceed/cross the level crossing.
- For a vibration level below 0.0008 mm/s a binary number 01 H is send to the microcontroller and a command that indicates the train is at distance of 362 m away from the level crossing is sent to the control center and a decision of Green signal is displayed to the road user a warning is given as the train is approaching to the level crossing 362 meters away from the level crossing to the driver to slow down its speed. The same condition is performed for the other 0.0014 and 0.0009 mm/s vibration levels.

The train side signal is used to control the train and the road side signal is used to control the road users. The simulation is done using traffic light one for the road users and other for the train. The following results are obtained from the simulation of traffic light using PIC16f887 microcontroller.

The schematic diagram for the way side signals simulation is shown below.

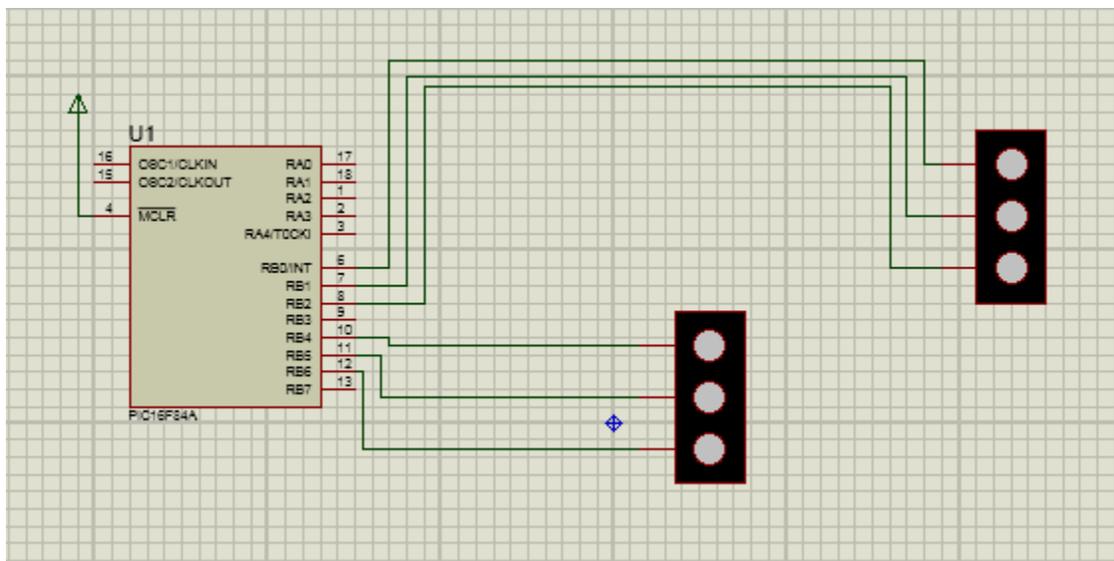


Figure 6.1 schematic design of the way side signals simulation

Results of the simulation is shown below

- When train side is RED and Road side signal is Green

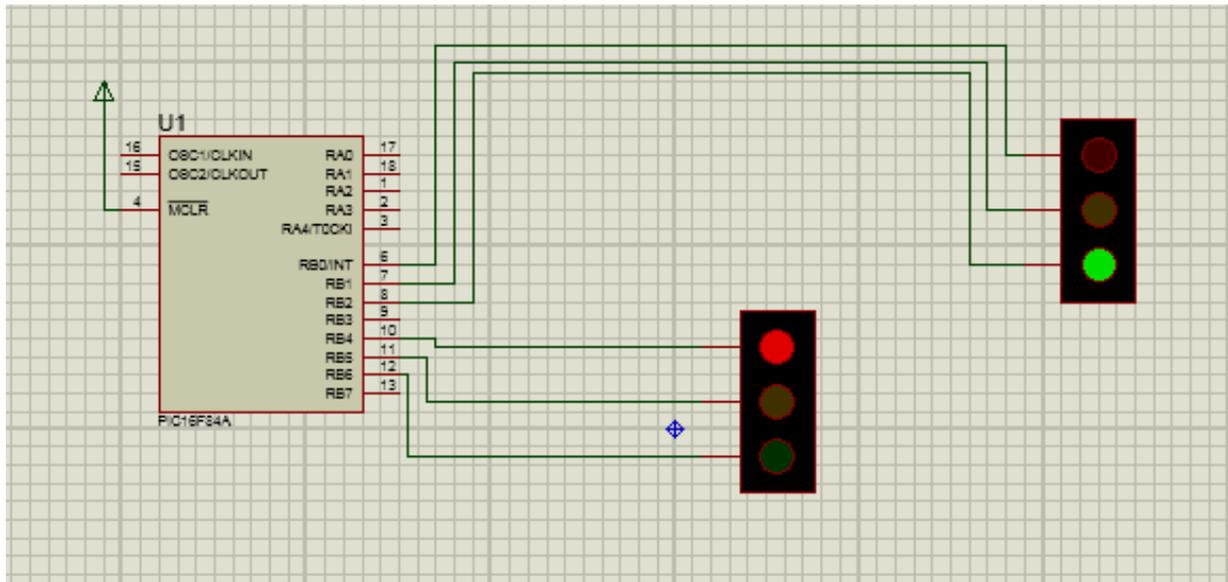


Figure 6.2 Train side signal is RED road side is GREEN

- When both train side and road side signals display Yellow

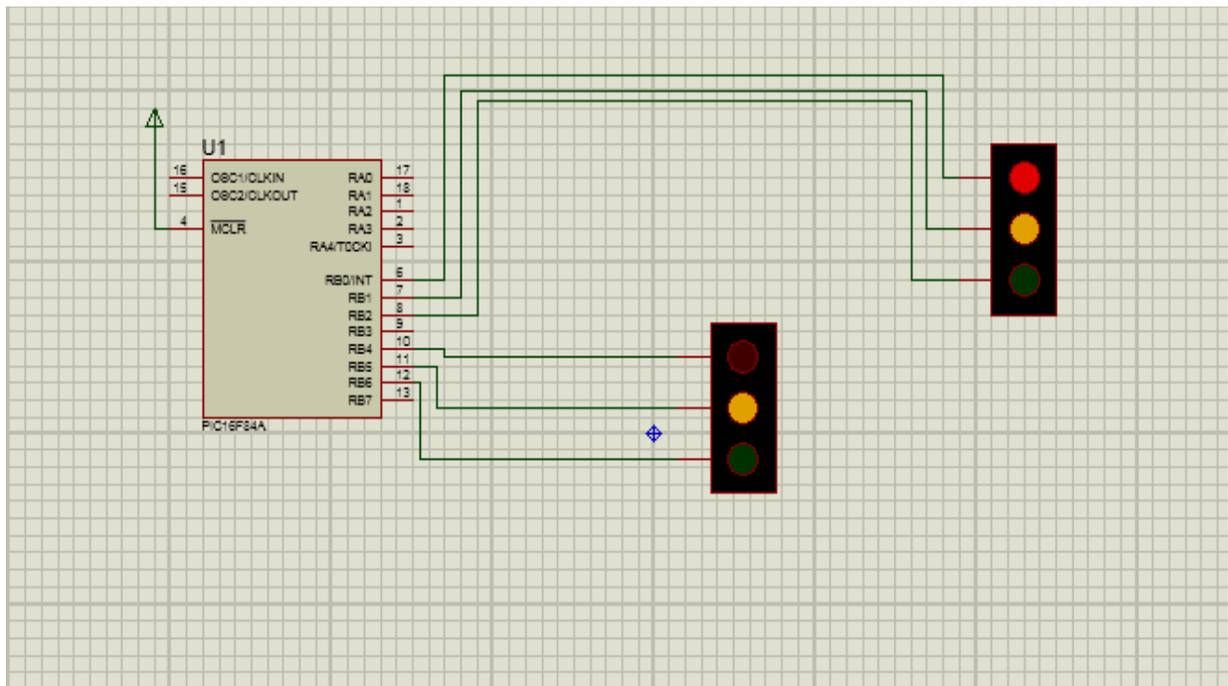


Figure 6.3: Train side displays yellow and road signal displays Yellow with Red

- When train side display Green and road signal is Red

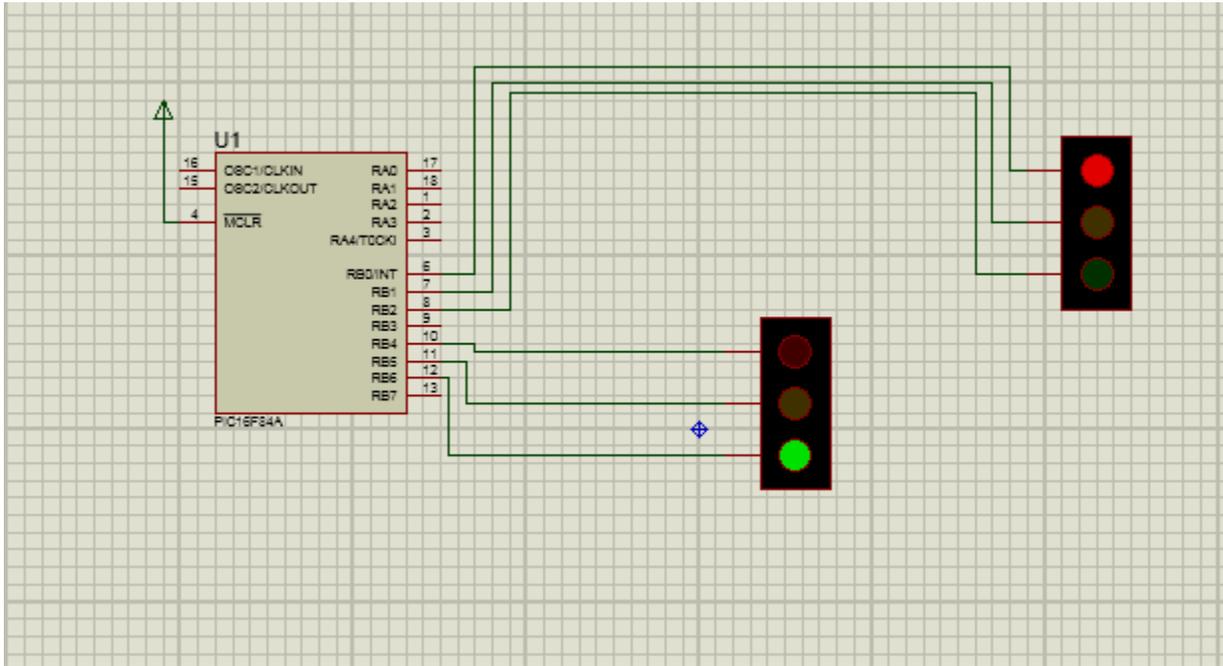


Figure 6.4: When train is allowed to pass with green signal and red signal for road users

The figure below takes from the simulation of the servo motor.it shows the stepper motor moves in such a way that the gate barrier opens and closes.

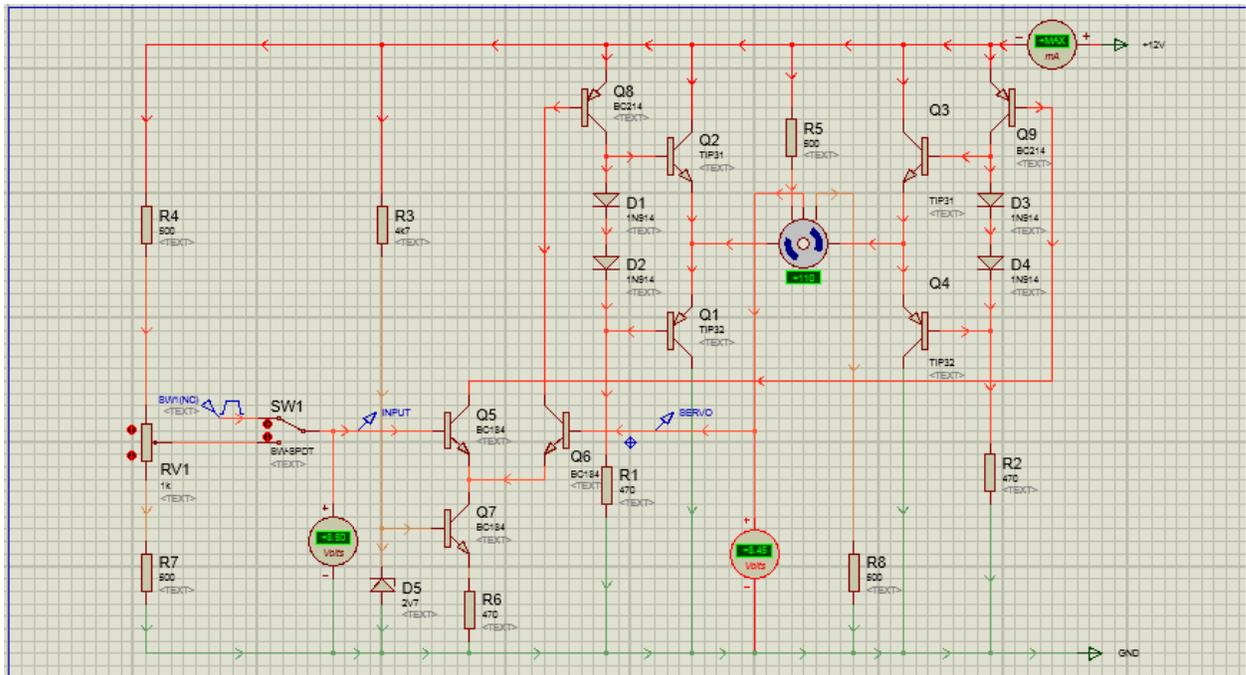


Figure 6.5: Servo motor rotates to lower and up the gate barrier

Table 6.2: Distance away from level crossing and condition of the gate

Distance away from level crossing in meters	Train side signal display	Road side signal display	Gate Position
282	Red	Green	Opened
302	Yellow	Yellow	Opened
322	Green	Red	Closed
362	Green	Red	Closed

As shown in the above table the road side signal are opened till the train approaches to only 40 meters so its speed is too small so it can cross without any collision with other vehicles and passengers.

When there is a hazard inside the level crossing a gate operator calls to the departures and the driver so that he will arrange his speed in order to stop before he passes the hazard point. This is condition is shown on the flow chart in chapter 5.

Table 6.3: Condition for clear during hazard

Check for call	Message display to driver	remarks
Yes	Slow your speed and stop before crossing hazard point	Stop 10 meters before level crossing
No	Proceed by respecting previous conditions	No stop pass with care

Chapter 7

Conclusion and Recommendation

7.1 Conclusion

As the system is completely automated it avoids manual error and thus provides ultimate safety to road users. Automatic gate control system of railway using ZigBee technology is discussed in this thesis. A microcontroller PIC16F877A performs the complete operation sensing, gate closing and opening operation is done by software code written for the controller.

Automatic gate control system offers an effective way to reduce the occurrence of railway accidents. This system can contribute a lot of benefit either to the road users or to the railway management. Since the design is completely automated it can be used in remote areas where no station master or line man is present. This system uses the DC motor to open and close the gates automatically when it is rotated clockwise or anticlockwise direction. The LED display shows the status of the way side signal and railway gate is automatically closed using the command from the control system. The system also generates buzzer and light indicators while the train passing through the level crossing. In this thesis, when there is a hazard in side level crossing the operator is calling to the driver so an alarm warning will display for the driver. This is properly controlled by using Programmable Integrated Circuit (PIC) i.e. the microcontroller) and zigBee technology. Future work will deal with the application of the designed approach for large-scale applications

7.2 Recommendation

Based on the work of this thesis, we recommend for further researchers the below cited points.

- Due to lack of real information, the mathematical models for the vibration levels developed takes approximation and some datasheet from international railway standards

(Swedish train experiment), assumptions and some planners experience are also used. Thus, by considering the actual information we can improve the result obtained in this thesis.

- The distance converted from the vibration level are discreet but cannot exist in real world so the microcontroller is assumed to take only fixed voltage levels so using the voltage levels a corresponding LED signal is displayed Green, Red and Yellow.
- As we conclude, or may someone guess the distance is too short for braking but the speed is too small starting from 100 meters so the train is easy to pass without any accident with the road users assuming that the road user are quickly cross or wait for the train to pass.

7.3 Future enhancement

As future expansion it is proposed that licensing procedures of satellite communications may be initiated so as to implement a system upgrade whereby real time data of moving trains like speed and current location may be tracked and monitored at the control station. Such real-time information can be utilized for system upgrade so as to avert accidents due to natural calamities such as land slide and anti-Collision Device/GPS based wireless Lx protection systems, the latest innovation, will give additional safety shield at manned and unmanned level crossings, through an audio-visual indication to road users. Moreover, in case of emergent needs, gate men at manned level crossings will be able to reduce the speed of an approaching train to prevent an accident at the crossing at a very nominal cost of procurement, installation and maintenance.

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