DEVELOPMENT OF A SENSOR SYTEM SUITABLE FOR CONDITION MONITORING OF RAILWAYS PART-I

A Project Report

submitted by

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CERTIFICATE

This is to certify that the thesis titled **DEVELOPMENT OF A SENSOR SYSTEM SUITABLE FOR CONDITION MONITORING OF RAILWAYS PART-I**, submitted by Shekhar Yadav, to the Indian Institute of Technology Madras, Chennai for the award of the degree of **Master of Technology**, is a bonafide record of the research work done by him under my supervision. The contents of this thesis, in full or in parts, have not been submitted to any other Institute or University for the award of any degree or diploma.

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Place: Chennai

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Shekhar Yadav

ABSTRACT

Keywords: GSM Module, 3 Axis Accelerometer and signal conditioning, GPS Module.

The fault detection and analysis system is used to monitor Rolling vibrations to detect any deterioration of track performance prior to a serious condition. This is also the case for bearing wear, wheel wear/imbalance, dampers/suspension fatigue as well as abnormal vibrations or displacement levels around the axle. Vibration measurements can help to detect problems in the rails such as dislocations, breaks, chipping, squats or track waves. They support preventive maintenance and can help prevent derailments.

An accelerometer with inbuilt signal conditioning circuit suitable for acceleration pickup is proposed as transducers. The accelerometer selected is capable of providing a linear output over the range of values up to 16 g, as the maximum acceleration limit at axle level during normal operation is10g-12g. The accelerometer which is designed becomes an integral part of the circuit, the output of which becomes proportional to the measurand (Acceleration).

The prototype of the circuit is fabricated using GSM, GPS module. GSM module sends the alert message on your Mobile Phone with the location of the fault. Location of fault is sent in the form of Google Map link, derived from the latitude and longitude from GPS module. The hardware testing is done by implementing and establishing communication between various modules using Arduino microcontroller. Arduino IDE software is used for implementing an indicator which helps in easy read out after doing appropriate mathematical calculations. The results obtained from conducting tests on the prototype indicate that the circuit possesses very low systematic errors. The main idea of the system can be implemented on a large scale in order to have automated assessment of track for preventive maintenance.

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ABBREVIATIONS

GSM	Global System for Mobile Communications
GPS	Global Positioning System
MEMS	Micro-Electro-mechanical System
NDT	Non-Destructive Testing
LCD	Liquid Crystal Display
$GPGGA	Global Positioning System Fix Data
NMEA	National Marine Electronics Association
DAQ	Data Acquisition
GPRS	General Packet Radio Service
ADC	Analog to Digital Converter

NOTATIONS

m	Proof mass of the Body
x	Relative movement of the proof mass with respect to the frame
C	Damping Coefficient
k	Spring Stiffness
V_R	Reference voltage

CHAPTER1

INTRODUCTION

1.1 RAIL TRANSPORT NETWORK AND CHALLENGES

The Indian Railway network is the fourth largest rail-passenger network and it is now the backbone of the country's transport infrastructure. In India, most of the commercial transport is being carried out by the railway network because it is being cheapest mode of transportation preferred over all other means of transportation such as buses, flights etc. The rapidly improving economy of India has resulted in an exponentially increasing demand for transportation in recent years, and this has resulted into a very huge rise in the volume of traffic in the Indian Railway network. Transport is a key necessity for specialization that allows production and consumption of products to occur at different locations. Economic prosperity has always been dependent on increasing the capacity and rationality of transport. But the infrastructure and operation of transport has a great impact on the land and is the largest resource of energy, making transport sustainability and safety a major issue Transport is very important to carry the passengers and goods from one place to another. The better transport leads to more trade. Economic level is mainly depends on increasing the capacity and level of transport.

Though rail transport in India growing at a rapid pace, the associated safety infrastructure facilities have not kept up with the aforementioned proliferation. Our facilities are inadequate compared to the international standards and as a result, there have been frequent derailments that have resulted in severe loss of valuable human lives and property as well. The principal problem has been the lack of cheap and efficient technology to detect problems in the rail tracks and of course, the lack of proper maintenance of rails which have resulted in the formation of cracks in the rail. A broken rail represents one of the leading causes of the most expensive and dangerous rail derailments that occur around the world.

1.2 EXISTING SYSTEMS FOR CRACK DETECTION AND MONITERING

In general, there exist three main categories of techniques excitingly used for damage identification and condition monitoring of Railway tracks. These include:

- **Graphical and Visual Inspections:** This is the primary technique used for defect identification in tracks, and is effectively used in specialized disciplines. The successful implementation of this method generally requires the regions of the suspected damage to be known as a first step, and be readily accessible for physical inspection. As a result, this method can be costly, time consuming and ineffective for large and complex structural systems such as the rail track [4].

- **Non-destructive testing technologies:** NDT techniques have resulted in a number of tools for us to choose from. Among the inspection methods used to ensure rail integrity, the common ones are ultrasonic inspection and eddy Existing inspection. Ultrasonic Inspections are common place in the rail industry in many foreign countries. It is a relatively well understood technique and was thought to be the best solution to crack detection. The Ultrasonic Broken Rail Detector system is the first and only alternative broken rail detection system developed, produced and implemented on a large scale [4].

- **Shuddering-based global methods.**

. 1.3 PROPOSED SYSTEM:

In this project we have used accelerometer to detect the crack in railroads. When the crack is detected, its latitude and longitude values are sent as a message to designated mobile phone over GSM network. Then accelerometer sensor is used for the surveying process. This system is designed using Arduino Uno (ATmega328), accelerometer (ADXL 335) sensors, GPS module, GSM Module and Bluetooth Module to perform railway safety monitoring system. Energy requirement of the system is obtained from a **power module** specifically design for the system and is presented in part II of the thesis.

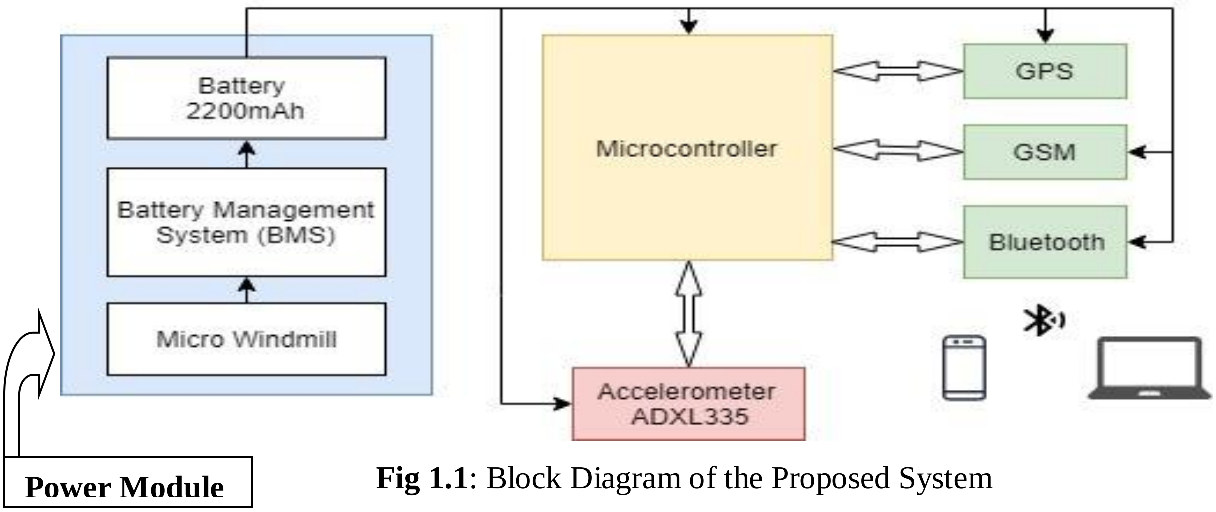

Fig 1.1: Block Diagram of the Proposed System

1.4 OBJECTIVE AND SCOPE OF THE WORK

The main objective of the work described in this thesis is to design prototype track faults detection and analysis system which will sense the sudden change in the axes/acceleration at the bogie/axle level and sends the alert message on your Mobile Phone with the location of the fault. This system may find application in automobile airbag system and aviation/car crash site location, to sense the sudden acceleration. As the car/aircraft crashes, the accelerometer produces a signal that exceeds the normal vibration/acceleration level to generate a trigger. If we attach the accelerometer of our system to the wheel axle, the axes accelerations of this wheel axle can be sensed and hence, can be continuously monitored. Since the sensor is a low cost and low power sensor, it is an affordable sensor and also has the advantages of a piezoelectric sensor over the other types of sensors as mentioned above.

1.5 ORGANIZATION OF WORK

A brief introduction to rail network, existing methods of crack sensing and analysis and proposed system is presented in Chapter1. Chapter 2 deals with selection and Adjustment of Sensor (ADXL335 Accelerometer). Chapter 3 deals with Data Acquisition, Analysis and Alert. Chapter 4 describes hardware set up used for the experiment. Chapter 5 provides experimental results of the designed system. The conclusion of the work carried out and its future scope is provided in Chapter 6.

CHAPTER 2

SENSOR SELECTION AND ADJUSTMENT

2.1 INTRODUCTION

Body in motion usually experience vibration as well as shock. When a mobile falls on a floor, it is subjected to shock. When a vehicle moves on a bumpy road, it experiences vibrations. Likewise, there are many situations, where an object encounters shock and vibrations. While some vibrations are desirable, some may be disturbing or even destructive. Hence, often a need is felt to understand the causes of vibrations and to develop methods to measure and prevent them.

2.2 VARIOUS FAULTS AND TECHNOLOGIES IN CRACK DETECTION

There are various types of faults that are encountered on a damaged track. However, the major faults are the ones that cause large changes in the acceleration [6]. These accelerations are significant at wheel axle level and coach floor level and can be monitored easily and analysed accordingly to implement a repair scheme. The major faults that have significant changes in acceleration are.

- **Obstacle on Tracks**
- **Discontinuity**
- **Absence of Nuts and Bolts**
- **Misalignment**
- **Surface Cracks**

Broken Rail

Misaligned Rail

Fig 2.1: Some Faults in Rail Track

Various other technologies are available in market to monitor and report the condition of the rail tracks. Some of the technologies are.

- Oral communication through telephonic and telegraphic conversations.
- IR sensors are also used to identify the cracks in the railway tracks.
- Ultra Sonic crack detection method is also available to detect crack.
- Use of satellites for communication.

2.3 MERITS OF ACCELEROMETER BASED POSITION RECORDING

The ability of a system to withstand vibrations and shock depends upon the 'g' level the system can withstand. To measure these 'g' levels, a sensor – accelerometer is used.

An accelerometer is a sensor that measures the physical acceleration experienced by an object due to inertial forces or due to mechanical excitation. Acceleration is defined as rate of change of velocity with respect to time. It is a measure of how fast speed changes. It is a vector quantity having both magnitude and direction. As a speedometer is a meter to measures speed, an accelerometer is a meter to measure acceleration. An ability of an accelerometer to sense acceleration can be put to use to measure a variety of things like tilt, vibration, rotation, collision, gravity, etc. Accelerometers measure in terms of 'g' ('g' is acceleration measurement for gravity which is equal to $9.81 m/s^2$). Accelerometers are made using tilt sensors.

As per Ministry of Railways, Government of India, Draft Technical Specification for Track Inspection and Monitoring System these acceleration could be as high as +2g at coach floor level and +12g at wheel axle level [9]. These accelerations are significant enough to be picked up by an accelerometer and sensor system can be defined accordingly. In this project we have designed a system that can detect crack using accelerometer as sensor and send location while also storing data for future analysis.

The integration of accelerometer with GPS is aimed towards addressing the issue by developing an automatic railway track crack detection module and a communication module based on GSM technology by which information about the location of the crack can be conveyed to a central location enabling the immediate attention and intervention of maintenance personals. The data can also be saved for future trend analysis and prevention techniques. Various other advantages that this system provides are:

- Achieves Quick Response
- Reduces man power
- Increases the system efficiency
- Reduces the work load
- Reduces the fatigue of workers

Similar systems which use Sensor and GPS have been used to detect and report crack locations. Accelerometers have also been used to measure and study vibrations at passenger seat level to design and develop better seats for customer satisfaction. However, the choice of sensor has been mostly an Ultrasonic or IR sensor type and is generally used only to report the defect but not storage of date for future reference and analysis.

2.4 THEORY OF ACCELEROMETER

The term '**Accelerometers**' refer to the transducers which comprises of mechanical sensing element and a mechanism which converts the mechanical motion into an electrical output.

Theory behind working of accelerometers can be understood from the mechanical model of accelerometer, using Newtonian mechanics. The sensing element essentially is a proof mass (also known as seismic mass). The proof mass is attached to spring which in turn is connected to its casing. In addition, a dashpot is also included in a system to provide desirable damping effect; otherwise system may oscillate at its natural frequency. The dashpot is attached (in parallel or in series) between the mass and the casing. The unit is rigidly mounted on the body whose acceleration is of interest. The Basic schematic of a regular accelerometer is shown below.

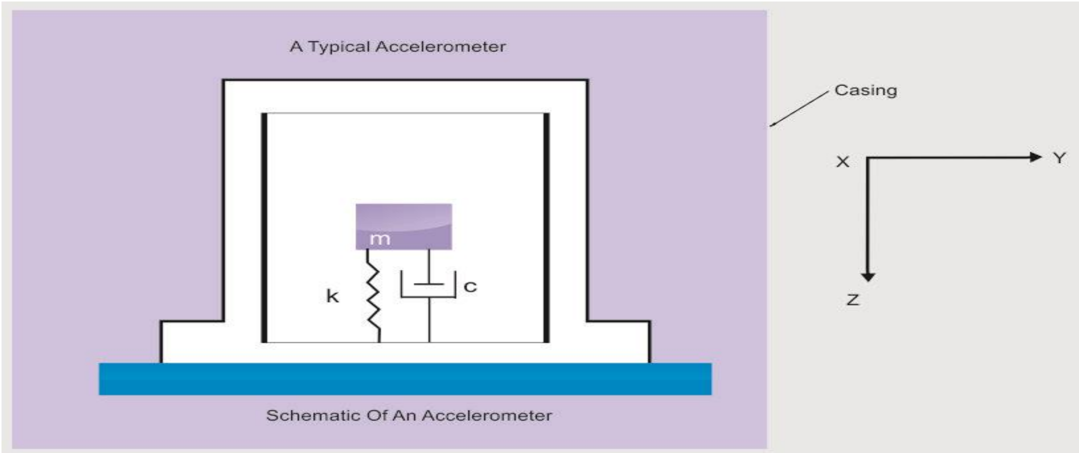

Fig. 2.2: Regular Accelerometer Schematic

When the system is subjected to linear acceleration, a force (= mass * acceleration) acts on the proof-mass. This causes it to deflect; the deflection is sensed by a suitable means and is converted into an equivalent electrical signal. When force is applied on the body, proof mass moves. Its movement is countered by spring and damper. A parallel plate capacitor comprises of two parallel metal plates that are separated by a dielectric material. In the typical parallel plate capacitor, the distance, area and dielectric constant between the two plates is fixed.

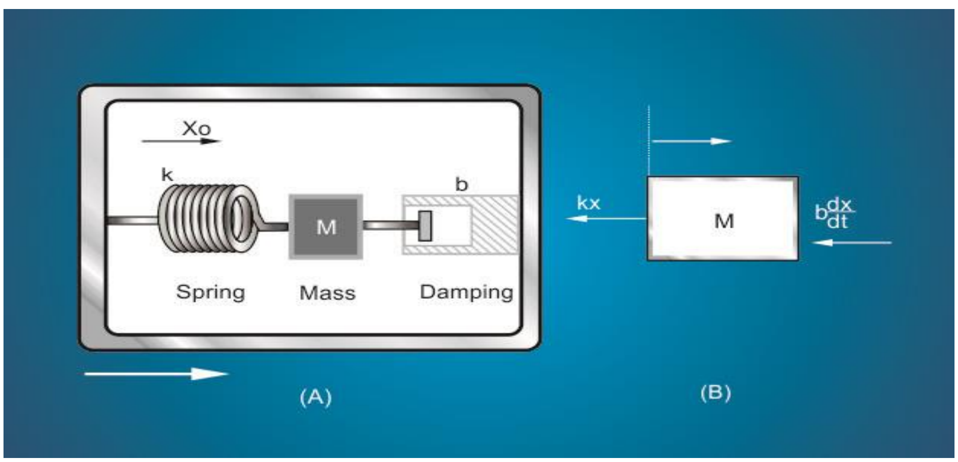

Fig. 2.3: Working of Accelerometer

Therefore, if m = proof mass of the body

x = relative movement of the proof-mass with respect to the frame

c = damping coefficient

k = spring stiffness

then,

$$\text{Summation of all forces on Proof mass} = 0$$

$$m\,a + Fd + Fs = 0$$

$$m\,a = -Fd - Fs$$

$$m\,a = -c\,\dot{x} - k\,x$$

$$a = -\left(\frac{c}{m}\right)\dot{x} - \left(\frac{k}{m}\right)x$$

Thus, with the knowledge of damping coefficient(c), spring stiffness (k), and proof mass (m), for a useful acceleration sensor, it is sufficient to provide a component that can move relative to sensors housing and a means to sense the movement. Displacement and acceleration are related by fundamental scaling law. A higher resonant frequency implies less displacement or low sensitivity.

As movement of the proof mass is sufficient for an accelerometer, two important sensing principles used in accelerometers designed are.

2.5 PIEZOELECTRIC ACCELEROMETERS

Piezoelectric accelerometers employ piezoelectric effect. When piezoelectric materials are stressed, they are deformed and an electric charge is generated on the piezoelectric materials.

In piezoelectric accelerometers, piezoelectric material is used as an active element. One side of the piezoelectric material is connected to rigid base. Seismic or proof mass is attached to the other side. When force (generated due to acceleration) is applied, piezoelectric material deforms to generate the charge. This charge is proportional to the applied force or in other words, proportional to acceleration (as mass is constant). The charge is converted to voltage using charge amplifiers and associated signal conditioning circuit.

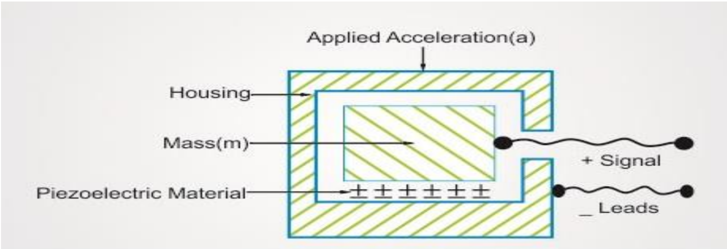

Fig. 2.4: Piezoelectric Accelerometer Schematic

Compared to other type of accelerometers, piezoelectric accelerometers offer unique advantages –

- Wide dynamic range
- Excellent linearity
- Wide frequency range
- No wear and tear due to absence of moving parts
- No external power requirement

2.6 MEMS-BASED ACCELEROMETERS

MEMS are an enabling technology which allows miniaturization of existing devices, to offer solutions which cannot be attained by macro-machined products. MEM allows the complex electromechanical systems to be manufactured using batch fabrication techniques, decreasing the cost and increasing the reliability. It allows integrated systems, viz., sensors, actuators, circuits, etc. in a single package and offers advantages of reliability, performance, cost, ease of use, etc. This technology is being utilized widely to manufacture state of the art MEMS-Based Accelerometers.

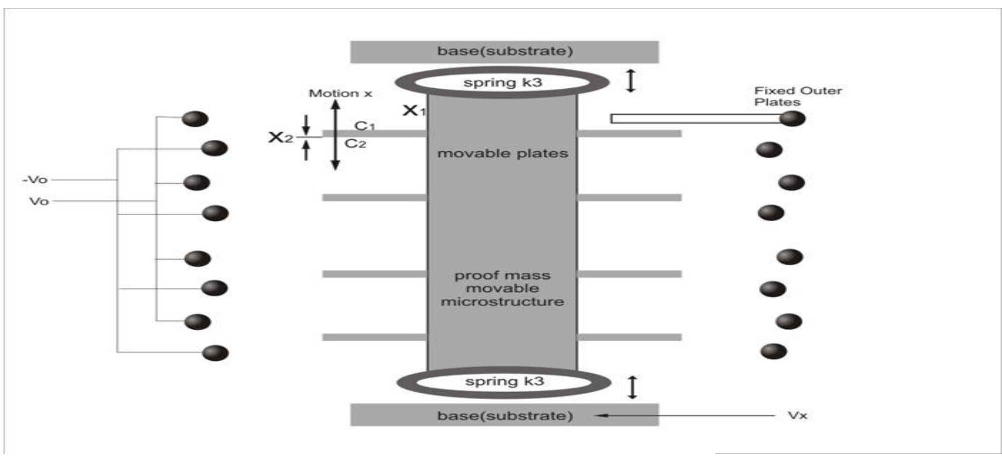

Fig.2.5: MEMS Based Accelerometer

Typical MEMS accelerometer is composed of movable proof mass with plates that is attached through a mechanical suspension system to a reference frame. Movable plates (part of the proof mass) and fixed outer plates form differential capacitor. Due to application of the force, proof mass deflects; the deflection is measured in terms of capacitance change.

2.7 ACCELEROMETER ADXL335 AND ADJUSTMENT

Indian railways deploy various methods for crack detection and monitoring on daily basis which are governed by various rules and regulations as issued by Government of India, ministry of railways. As per **Government Of India Ministry Of Railway Research Designs And Standards Organisation,** Technical Draft Specification for Track Inspection and Monitoring System, following are the desired requirements for track monitoring and inspection pertaining to accelerometer as a sensor [9].

i) System shall be capable for measurement of vertical and lateral acceleration at axle box level and on pivot at coach floor level in time domain.

ii) The accelerometer mounted on bogie level shall be capable to measure the maximum acceleration of "+2g".

iii) The System shall be capable of on line (during recording) processing, analysis, storage, reporting and printing of the recorded data/reports. Option to take or not to take the print of exception report and analogue report shall be available to user.

- **ADXL335- THREE AXIS ACCELEROMETER**

In this project we have selected is ADXL 335 accelerometer as sensor. The ADXL335 is a small, thin, low power, complete 3-axis accelerometer with signal conditioned voltage outputs. The product measures acceleration with a minimum full-scale range of ±3 g. It can measure the static acceleration of gravity in tilt-sensing applications, as well as dynamic acceleration resulting from motion, shock, or vibration. The user selects the bandwidth of the accelerometer using the CX, CY, and CZ capacitors at the XOUT, YOUT, and ZOUT pins. Bandwidths can be selected to suit the application, with a range of 0.5 Hz to 1600 Hz for the X and Y axes, and a range of 0.5 Hz to 550 Hz for the Z axis.

The ADXL335 uses a single structure for sensing the X, Y, and Z axes. As a result, the three axes' sense directions are highly orthogonal and have little cross-axis sensitivity. The device has a working range of -55 Deg to +125 Deg

Celsius. There is no quantization error or non-monotonic behavior, and temperature hysteresis is very low (typically less than 3 mg over the −25°C to +70°C temperature range).

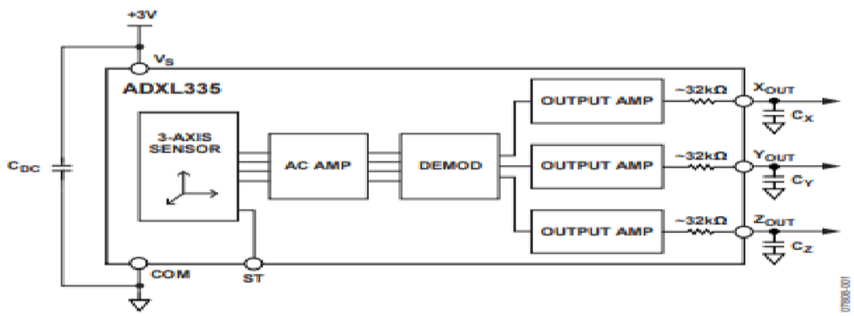

Fig 2.6: Functional Block Diagram of ADXL335

- **Angles using ADXL335**

We can calculate angle of inclination or tilt by using X, Y, Z's value. Also, we can calculate Roll, Pitch and Yaw angles with respect to X, Y and Z axis. So first we need to convert 10-bit ADC values into g unit. As per ADXL335 datasheet maximum voltage level at 0g are, X axis – 1.65V, Yaxis – 1.65V and Z axis – 1.85V. Sensitivity scale factor is 330mV/g.

- **FORMULA FOR CONVERSION IN g for X, Y and Z axis**

Axout = (((X axis ADC value * Vref) / 1024) – 1.65) / 0.330

Ayout = (((Y axis ADC value * Vref) / 1024) – 1.65) / 0.330

Azout = (((Z axis ADC value * Vref) / 1024) – 1.85) / 0.330

Note that, practically we get slightly different voltage at 0g. So, put the practical value of voltage at 0g.

Here in this project, **we have set the sensitivity of Accelerometer** by putting min and max value in the code corresponding to -2g to +2g.

CHAPTER 3

DATA ACQUISITION, ANALYSIS AND ALERT

3.1 INTRODUCTION

The information or data generated by a basic measuring device generally require "processing" or "conditioning" of one sort or another before they are presented to the observer as an indication or as an alert.

To obtain an alert relative to the parameter being sensed by an accelerometer sensor, an on-board signal conditioning circuit that converts the variations in the sensor to a proportional analog voltage along the axes. These analog inputs from the sensor is then analysed by successive iteration through a software compilation in microcontroller which also interfaces and communicates with a GPS module to fetch the coordinates and transmit the same over a GSM network.

3.2 DATA ACQUISITION WITH ARDUINO IDE SOFTWARE

The goal of data acquisition is to capture data from one or more laboratory instruments on a computer so that it can be analysed, stored and displayed.

The heart of most data acquisition systems is an analog-to-digital converter (ADC) that can receive an analog signal and convert it to a digital form that can be used and stored on a computer system.

By default Pin 0 and 1 of Arduino are used for serial communication but by using Software Serial library, we can allow serial communication on other digital pins of the Arduino. In this project Serial data obtained from pin 0 is transmitted to a storing and presentation device using Bluetooth module HC-05/06 or can be seen on a serial Monitor.

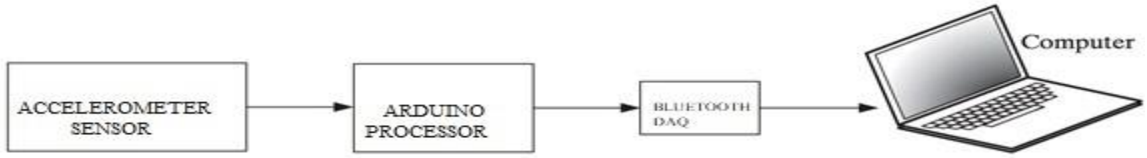

Fig 3.1: Data acquisition over Bluetooth.

3.3 DATA PRESENTATION

The output of accelerometer is processed and analyzed by microcontroller. This output can be observed on a serial Monitor on computer screen or can also be obtained and sent as a log file on Bluetooth terminal App on mobile phone. The output can also be calibrated so as to generate trigger for transmitting of SMS for coordinates. In order to make this data presentable and meaningful Serial monitor, Serial plotter and MS Excel were used for acquiring and displaying the signals in the desired manner.

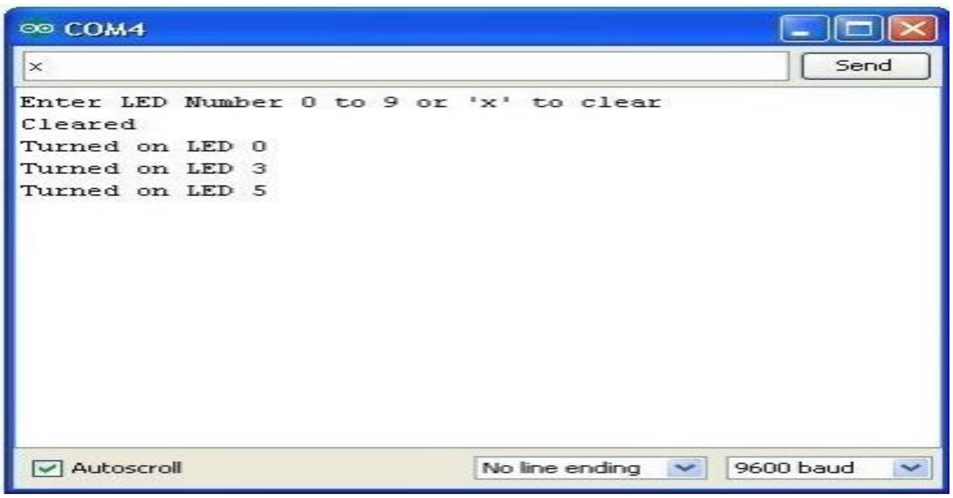

Fig 3.2: Data Presentation on Serial Monitor

3.4 ALERT GENERATION

Now whenever there is a fault in the tracks, the axle/bogie gets a tilt and accelerometer changes his axis values. These values read by Arduino and checks if any change occurs in any axis. If any change occurs then Arduino reads coordinates by extracting $GPGGA String from GPS module data and send SMS to the predefined number to the authorities with the location coordinates of fault. The message also contains a Google Map link to the accident location, so that location can be easily tracked. When we receive the message then we only need to click the link and we will redirect to the Google map and then we can see the exact location of the vehicle. **Speed of train, in knots** (1.852 KPH), is also sent in the SMS and displayed on the LCD panel.

CHAPTER 4

HARDWARE SETUP FOR THE EXPERIMENT

4.1 INTRODUCTION

In this project, Arduino is used for controlling whole the process with a GPS Receiver and GSM module. GPS Receiver is used for detecting coordinates of the vehicle, GSM module is used for sending the alert SMS with the coordinates and the link to Google Map. Accelerometer namely ADXL335 is used for detecting accident or sudden change in any axis. And an optional 16x2 LCD is also used for displaying status messages or coordinates. We have used GPS Module SIM28ML and GSM Module SIM900A.

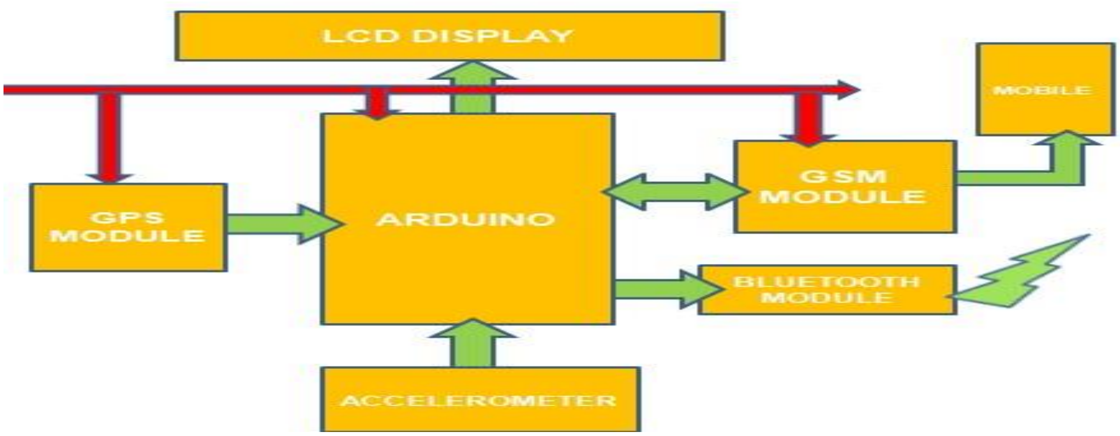

Fig 4.1: Block Diagram

4.2 GLOBAL SYSTEM FOR MOBILE COMMUNICATIONS (GSM 900A):

GSM is a standard developed by the European Telecommunications Standards Institute to describe the protocols for second-generation (2G) digital cellular networks used by mobile devices such as mobile phones and tablets. It was first deployed in Finland in December 1991.As of 2014, it has become the global standard for mobile communications – with over 90% market share, operating in over 193 countries.

GSM/GPRS Modem-RS232 is built with Dual Band GSM/GPRS engine-SIM900A, works on frequencies 900/ 1800 MHz. The Modem is coming with RS232 interface, which allows you connect PC as well as microcontroller with RS232 Chip (MAX232). The baud rate is configurable from 9600-115200 through AT command. The GSM/GPRS Modem is having internal TCP/IP stack to enable you to connect with internet via GPRS. It is suitable for SMS, Voice as well as DATA transfer application in M2M interface. The on-board Regulated Power supply allows you to connect wide range unregulated power supply. Using this modem, you can make audio calls, SMS, Read SMS,attend the incoming calls and internet through simple AT commands

Fig 4.2: SIM 900A GSM Module

- **IMPORTANT FEATURES OF SIM900A GSM MODEM**
  - Dual-Band GSM/GPRS 900/ 1800 MHz.
  - RS232 interface for direct communication with computer or MCU kit.
  - Configurable baud rate.
  - Power controlled using 29302WU IC.
  - ESD Compliance.
  - Enable with MIC and SPeaker socket.
  - With slid in SIM card tray.
  - With Stub antenna and SMA connector.
  - Input Voltage: 12V DC.

- **VARIOUS GSM AT COMMANDS USED FOR GSM 900A**
    - TO CHECK THE MODEM:

      AT ↲
      OK

    - TO CHANGE SMS SENDING MODE:

      AT+CMGF=1 ↲
      OK

    - TO SEND NEW SMS:

      AT+CMGS="MOBILE NO." ↲
      <MESSAGE {CTRL+Z}

Similarly, various other commands can also be evoked to utilize other functions and utility of this modem like TO RECEIVE SMS, TO HANGUP OR DISCONNECT A CALL, TO RECEIVE INCOMING CALL,TO MAKE A VOICE CALL etc.

4.3 GLOBAL POSITIONING SYSTEM (GPS 28M) MODULE:

GPS stands for Global Positioning System and used to detect the Latitude and Longitude of any location on the Earth, with exact UTC time (Universal Time Coordinated). GPS module is the main component in our vehicle tracking system project. This device receives the coordinates from the satellite for each and every second, with time and date.

GPS module sends the data related to tracking position in real time, and it sends so many data in NMEA format (see the screenshot below). NMEA format consist several sentences, in which we only need one sentence. This sentence starts from $GPGGA and contains the coordinates, time and other useful information. This GPGGA is referred to Global Positioning System Fix Data.

The GPS Module used in the project is SIM28M/ML. SIM28M is a stand-alone or A-GPS receiver. With built-in LNA, SIM28M can relax antenna requirement and don't need for external LNA. SIM28M can track as low as -165dBm signal even without network assistance. The SIM28M has excellent low power consumption characteristic (acquisition 17mA, tracking 16mA). SIM28M supports various location and navigation applications, including autonomous GPS, QZSS, SBAS ranging (WAAS, EGNOS, GAGAN, and MSAS), DGPS and A-GPS.

Fig 4.3: SIM 28M GPS Module

- **KEY FEATURES OF SIM28M MODULE**

Parameter	Description	Performance			
		Min	Type	Max	Unit
Horizontal Position Accuracy(1)	Autonomous		<2.5		m
Velocity Accuracy(2)	Without Aid		0.1		m/s
	DGPS		0.05		m/s
Acceleration Accuracy	Without Aid		0.1		m/s^2
	DGPS		0.05		m/s^2
Timing Accuracy			10		nS
Dynamic Performance	Maximum Altitude			18000	m
	Maximum Velocity			515	m/s
	Maximum Acceleration			4	G
Time To First Fix(3)	Hot start		<1		s
	Warm start		30		s
	Cold start		32		s
A-GPS TTFF(EASY mode)	Hot start		1		s
	Warm start		5		s
	Cold start		15		s
Sensitivity	Autonomous acquisition(cold start)		-148		dBm

Table 4.1 : Key Specification of SIM28ML

We can extract coordinate from $GPGGA string by counting the commas in the string. Suppose you find $GPGGA string and stores it in an array, then Latitude can be found after two commas and Longitude can be found after four commas. Now these latitude and longitude can be put in other arrays.

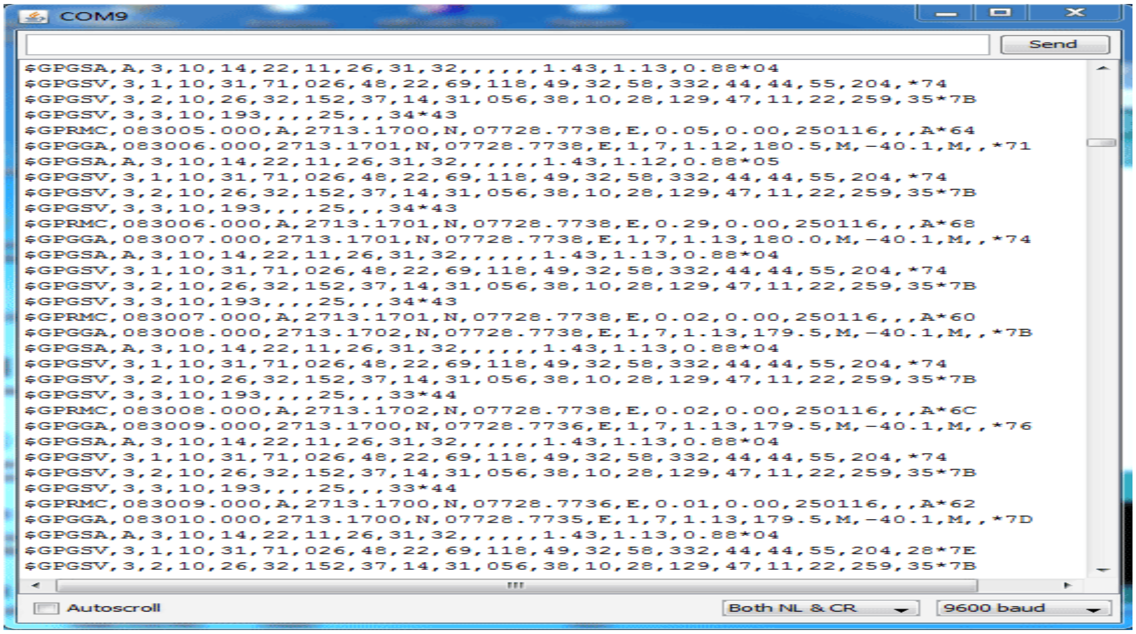

Fig 4.4: $GPGGA string from the GPS

Below is the $GPGGA String, along with its description:

$GPGGA,104534.000,7791.0381,N,06727.4434,E,1,08,0.9,510.4,M,43.9,M,,*47

$GPGGA,HHMMSS.SSS,latitude,N,longitude,E,FQ,NOS,HDP,altitude,M,height,M,,checksum data.

Identifier	Description
$GPGGA	Global Positioning system fix data
HHMMSS.SSS	Time in hour minute seconds and milliseconds format.
Latitude	Latitude (Coordinate)
N	Direction N=North, S=South
Longitude	Longitude(Coordinate)
E	Direction E= East, W=West
FQ	Fix Quality Data
NOS	No. of Satellites being Used
HPD	Horizontal Dilution of Precision
Altitude	Altitude from sea level
M	Meter
Height	Height
Checksum	Checksum Data

Table 4.2: $GPGGA String identifier

Main two technical challenges face by GPS are Time synchronization between individual satellites and the GPS receiver and Interference with other signal.

4.4 ARDUINO UNO R3 MICROCONTROLLER:

This forms the heart of the project and is responsible for all interfacing and communication between various modules. It also analyses data received from the sensor and does a comparison with threshold value to initiate a the trigger and generation of SMS for location of fault.

The Arduino Uno is a microcontroller board based on the ATmega328. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz ceramic resonator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with an AC-to-DC adapter or battery to get started. The Uno differs from all preceding boards in that it does not use the FTDI USB-to-serial driver chip. Instead, it features the Atmega16U2 (Atmega8U2 up to version R2) programmed as a USB-to-serial converter.

Fig 4.5: Arduino UNO R3 Microcontroller

- **Memory**

The ATmega328 has 32 KB (with 0.5 KB used for the bootloader). It also has 2 KB of SRAM and 1 KB of EEPROM (which can be read and written with the EEPROM library).

- **Input and Output**

Each of the 14 digital pins on the Uno can be used as an input or output, using pinMode(), digitalWrite(), and digitalRead() functions. They operate at 5 volts. Each pin can provide or receive a maximum of 40 mA and has an internal pull-up resistor (disconnected by default) of 20-50 kOhms. Inaddition, some pins have specialized functions:

Serial: 0 (RX) and 1 (TX). Used to receive (RX) and transmit (TX) TTL serial data. These pinsare connected to the corresponding pins of the ATmega8U2 USB-to-TTL Serial chip.

External Interrupts: 2 and 3. These pins can be configured to trigger an interrupt on a lowvalue, a rising or falling edge, or a change in value. .

PWM: 3, 5, 6, 9, 10, and 11. Provide 8-bit PWM output with the analogWrite() function.

SPI: 10 (SS), 11 (MOSI), 12 (MISO), 13 (SCK). These pins support SPI communicationusing the SPI library.

LED: 13. There is a built-in LED connected to digital pin 13. When the pin is HIGH value, theLED is on, when the pin is LOW, it's off.

The Uno has 6 analog inputs, labeled A0 through A5, each of which provide 10 bits of resolution (i.e.1024 different values). By default they measure from ground to 5 volts, though is it possible to changethe upper end of their range using the AREF pin and the analogReference() function. Additionally, somepins have specialized functionality:

TWI: A4 or SDA pin and A5 or SCL pin. Support TWI communication using the Wire library.

There are a couple of other pins on the board:

AREF. Reference voltage for the analog inputs. Used with analogReference().

Reset. Bring this line LOW to reset the microcontroller. Typically used to add a reset button toshields which block the one on the board.

- **COMMUNICATION AND PROGRAMMING**

The Arduino Uno has a number of facilities for communicating with a computer, another Arduino, orother microcontrollers. The ATmega328 provides UART TTL (5V) serial communication, which isavailable on digital pins 0 (RX) and 1 (TX). An ATmega16U2 on the board channels this serialcommunication over USB and appears as a virtual com port to software on the computer. The '16U2firmware uses the standard USB COM drivers, and no external driver is needed. However, on Windows,a .inf file is required. The Arduino software includes a serial monitor which allows simple textual data tobe sent to and from the Arduino board. The RX and TX LEDs on the board will flash when data is beingtransmitted via the USB-to-serial chip and USB connection to the computer (but not for serialcommunication on pins 0 and 1).

A SoftwareSerial library allows for serial communication on any of the Uno's digital pins.The ATmega328 also supports I2C (TWI) and SPI communication. The Arduino software includes aWire library to simplify use of the I2C bus; see the documentation for details. For SPI communication,use the SPI library.

4.5 HC-05 BLUETOOTH MODULE

This Bluetooth module can easily achieve serial wireless data transmission. Its operating frequency is among the most popular 2.4GHz ISM frequency band (i.e. Industrial, scientific and medical). It adopts Bluetooth 2.0+EDR standard. In Bluetooth 2.0, signal transmit time of different devices stands at a 0.5 seconds interval so that the workload of Bluetooth chip can be reduced substantially and more sleeping time can be saved for Bluetooth. This module is set with serial interface, which is easy to use and simplifies the overall design/development cycle.

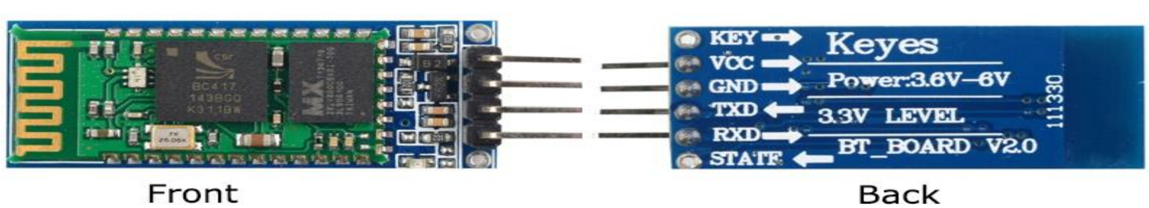

Fig 4.6: HC-05 Bluetooth Module

CHAPTER 5

EXPERIMENTAL SETUP AND RESULTS

5.1 INTRODUCTION

In order to demonstrate the practical functioning of the proposed track faults detection and analysis system, a prototype unit was built on the breadboards and tested. The system constructed was used to provide the real time value of accelerations and alert message in case of any fault detected. A voltage of 12v was provided by a DC battery.

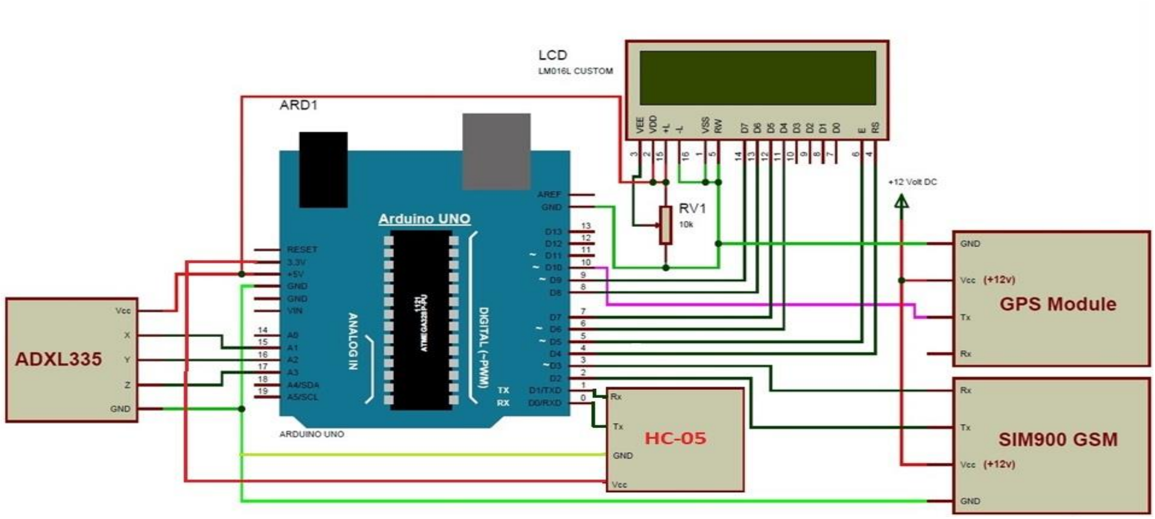

Fig 5.1: Circuit Diagram for the Detection and Communication Module

The entire circuit can be divided into a Power generation and harvesting module and a detection and communication module. This project focuses on the detection and communication module. Here Tx pin of **GPS module** is directly connected to digital pin number 10 of Arduino. By using Software Serial Library here, we have allowed serial communication on pin 10 and 11, and made them Rx and Tx respectively and left the Rx pin of GPS Module open. By default Pin 0 and 1 of Arduino are used for serial communication but by using the Software Serial library, we can allow serial communication on other digital pins of the Arduino.

GSM module's Tx and Rx pins are directly connected to pin D2 and D3 of Arduino. For GSM interfacing, here we have also used software serial library. GSM module is also powered by 12v supply. Command pin RS and EN of LCD are connected with pin number 4 and 5 of Arduino and RW pin is directly connected with ground.

Bluetooth module HC-05 Rx pin are directly connected to pin D0 of Arduino. Module is powered by 3.3V dc power supply from on-board the microcontroller.

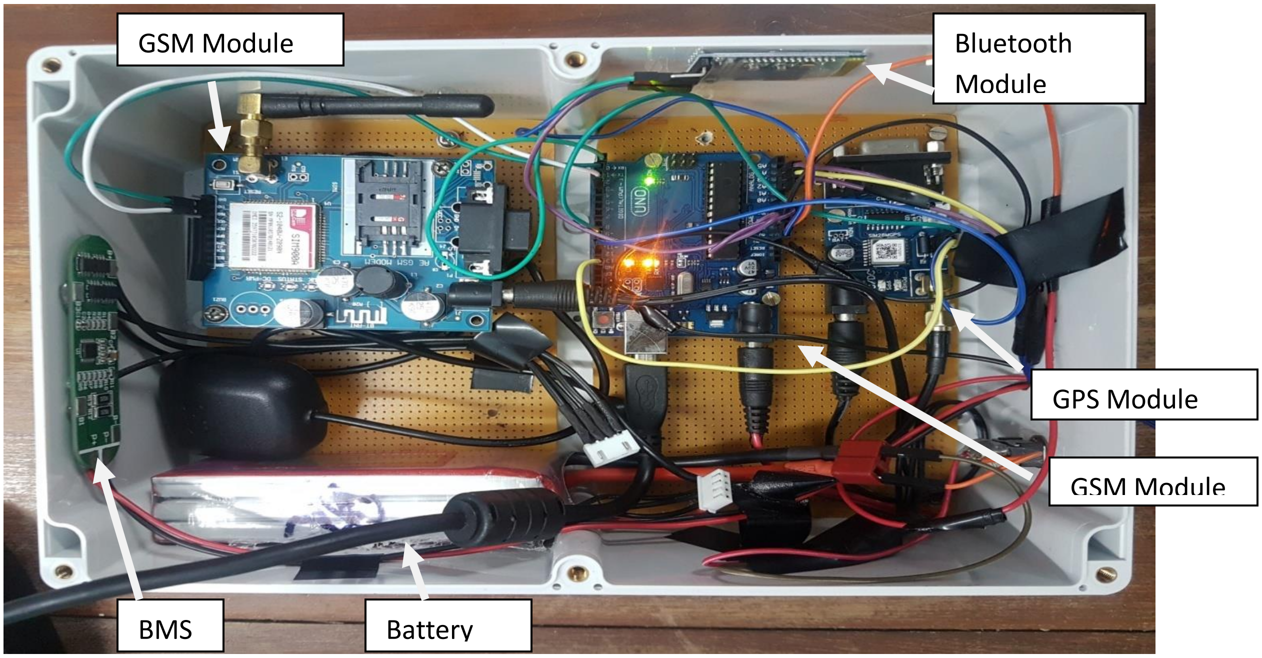

Fig 5.2: Experimental Setup of System

5.2 EXPERIMENTAL RESULTS

The accelerometer output for acceleration along three axes was observed on Both Serial Monitor and Serial Plotter with variation in acceleration with tilt. Initially the circuit was tested in laboratory to ascertain the functionality of the systems and prove the coding. The test was then done on a bike axle support to simulate real time on road data.

Fig 5.3: On Road Test Setup on Bike Axle Support

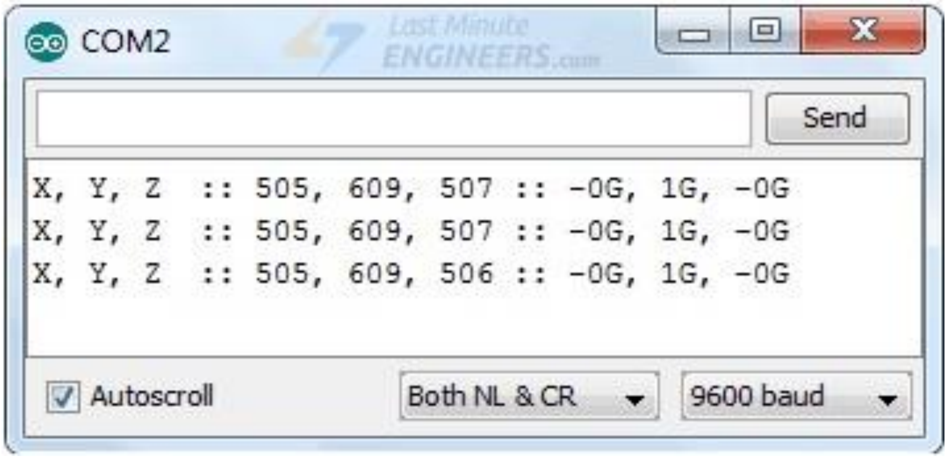

Fig 5.4: Presentation of Data on Serial monitor.

Variation in acceleration values along the three axes can be observed. The sudden increase in acceleration values denotes the irregularities (Humps and potholes) on road, similar to the fault on railway tracks. The same data can also be read on the Bluetooth compatible device and transferred as a log file over a range of 5 to 10 mts to any computer.

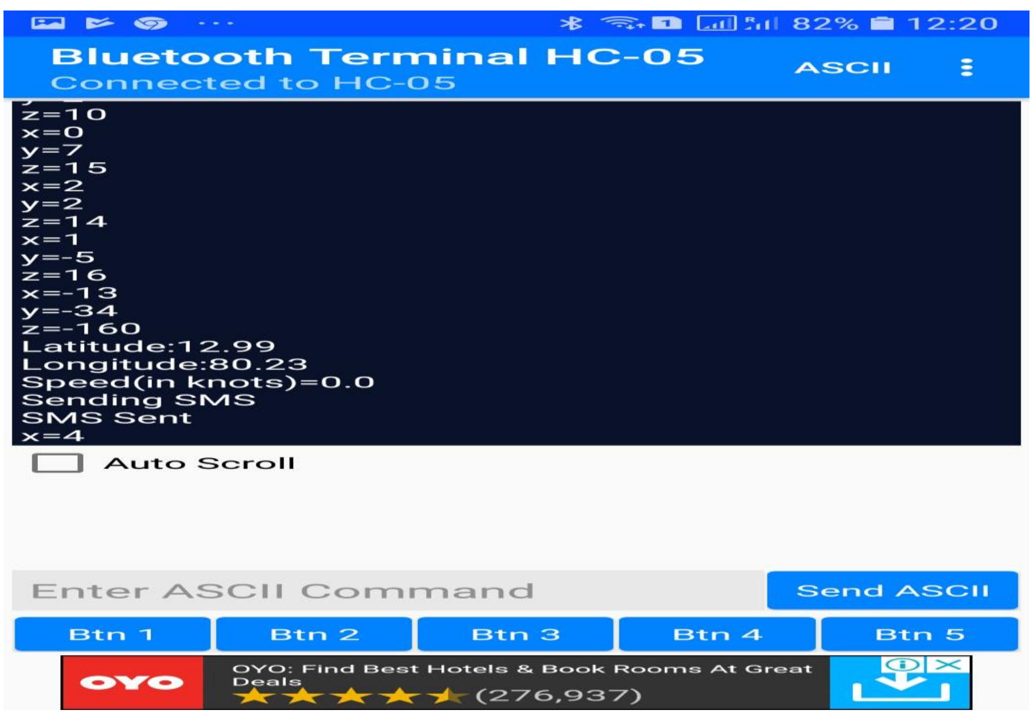

Fig 5.5: Reading over a Bluetooth Device

The data obtained over the Bluetooth device can be transferred over to a computer as a log file and can be plotted for analysis using plotting software like Excel.

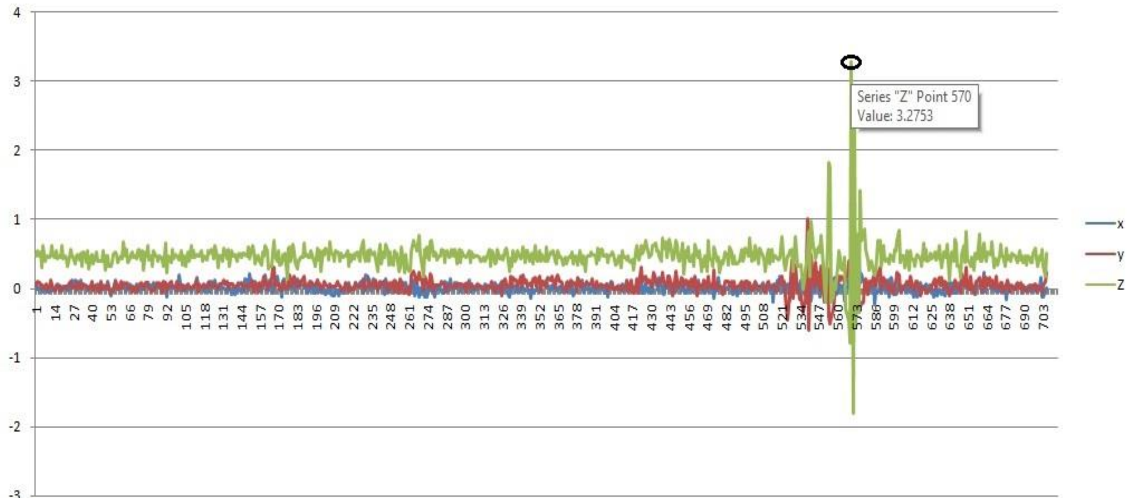

Fig 5.6: Acceleration Plots with Trigger Points

Further, Trigger points in the plot denote a major fault which needs to be analysed over a period of time to maintenance assessment or immediate repair. These points trigger a SMS on a predefined number pertaining to an authorised person with location of fault. The SMS also contain a link to locate the point on Google Maps as shown in the figures.

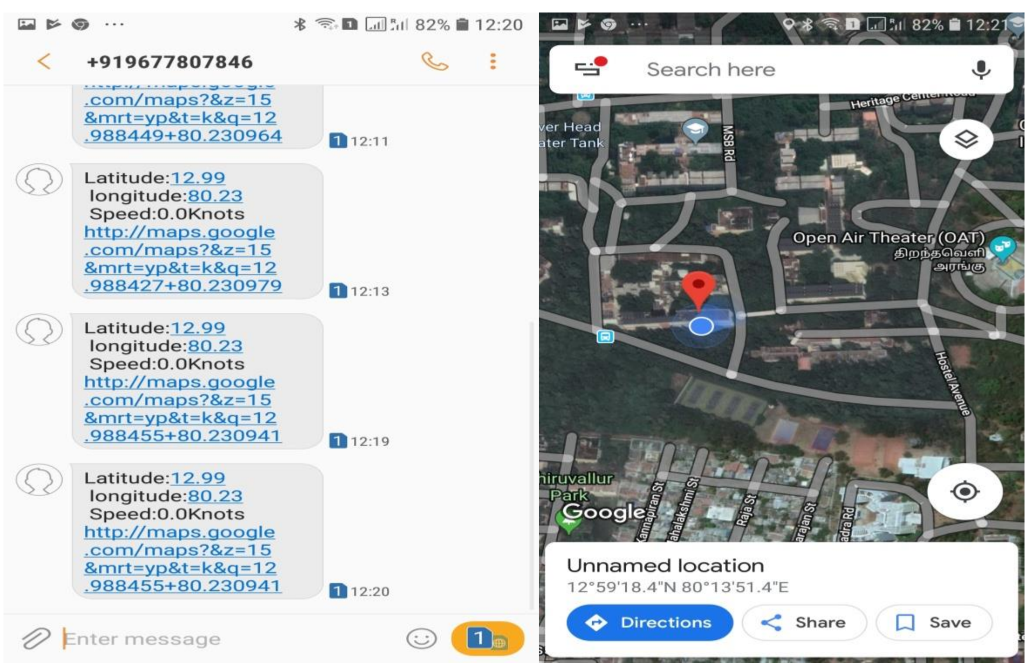

Fig 5.7: Location Coordinates SMS and Google Map Tracking

CHAPTER 6

CONCLUSION AND FUTURE SCOPE

6.1 CONCLUSION

A prototype Fault Detection and Analysis System using accelerometer was successfully designed and implemented for the purpose detecting railway track faults and intimating authorities for action. The vibration sensor realisation process was inexpensive as it required only low power accelerometer module. However, the considerable amount of efforts was required in obtaining, adjusting and setting the right “g” values for trigger. The hardware testing was successfully carried out with programmed Arduino board. An infrastructure was created, so as to obtain “g” values for various conditions after mathematical calculations. The out of threshold “g” values sensed by transducer generated a trigger and SMS with location of Faults was successfully received and identified on Google maps.

6.2 FUTURE SCOPE

The present system developed on Bluetooth Module to display the data. This restricts the data transfer range of the system. In order to increase the range, system can be integrated with Cloud storage through Wi-Fi module. Also as we are mainly concentrating on accelerations along “Z” axis, therefore, by observing only “Z” axis and by blanking “X” and ”Y” and selecting bandwidths to suit the application as discussed in Para 2.7, we may improve the efficiency of the system.

APPENDIX

CODES FOR ACCELERATION PICK UP AND ALERT GENERATION

```
#include<SoftwareSerial.h>
SoftwareSerial Serial1(2,3); //make RX arduino line is pin 2, make TX arduino line is pin 3.
SoftwareSerial gps(10,11);
#include<LiquidCrystal.h>
LiquidCrystal lcd(4,5,6,7,8,9);

#define x A1
#define y A2
#define z A3

int xsample=0;
int ysample=0;
int zsample=0;

#define samples 10

#define minVal -50
#define MaxVal 50

int i=0,k=0;
int  gps_status=0;
float latitude=0;
float logitude=0;
String Speed="";
String gpsString="";
char *test="$GPRMC";

void initModule(String cmd, char *res, int t)
{
  while(1)
  {
    Serial.println(cmd);
    Serial1.println(cmd);
    delay(100);
    while(Serial1.available()>0)
    {
       if(Serial1.find(res))
       {
        Serial.println(res);
        delay(t);
        return;
```

```
      }

      else
      {
       Serial.println("Error");
      }
    }
    delay(t);
  }
}

void setup()
{
  Serial1.begin(9600);
  Serial.begin(9600);
  lcd.begin(16,2);
  lcd.print("Rail Crack detection  ");
  lcd.setCursor(0,1);
  lcd.print("     System     ");
  delay(2000);
  lcd.clear();
  lcd.print("Initializing");
  lcd.setCursor(0,1);
  lcd.print("Please Wait...");
  delay(100);

  Serial.println("Initializing....");
  initModule("AT","OK",1000);
  initModule("ATE1","OK",1000);
  initModule("AT+CPIN?","READY",1000);
  initModule("AT+CMGF=1","OK",1000);
  initModule("AT+CNMI=2,2,0,0,0","OK",1000);
  Serial.println("Initialized Successfully");
  lcd.clear();
  lcd.print("Initialized");
  lcd.setCursor(0,1);
  lcd.print("Successfully");
  delay(2000);
  lcd.clear();
  lcd.print("Callibrating ");
  lcd.setCursor(0,1);
  lcd.print("Acceleromiter");
  for(int i=0;i<samples;i++)
  {
    xsample+=analogRead(x);
    ysample+=analogRead(y);
```

```
    zsample+=analogRead(z);
  }

  xsample/=samples;
  ysample/=samples;
  zsample/=samples;

  Serial.println(xsample);
  Serial.println(ysample);
  Serial.println(zsample);
  delay(1000);

  lcd.clear();
  lcd.print("Waiting For GPS");
  lcd.setCursor(0,1);
  lcd.print("     Signal    ");
  delay(2000);
  gps.begin(9600);
  get_gps();
  show_coordinate();
  delay(2000);
  lcd.clear();
  lcd.print("GPS is Ready");
  delay(1000);
  lcd.clear();
  lcd.print("System Ready");
  Serial.println("System Ready..");
}

void loop()
{
    int value1=analogRead(x);
    int value2=analogRead(y);
    int value3=analogRead(z);

    int xValue=xsample-value1;
    int yValue=ysample-value2;
    int zValue=zsample-value3;

    Serial.print("x=");
    Serial.println(xValue);
    Serial.print("y=");
    Serial.println(yValue);
    Serial.print("z=");
    Serial.println(zValue);
```

```
if(xValue < minVal || xValue > MaxVal  || yValue < minVal || yValue > MaxVal  ||
   zValue < minVal || zValue > MaxVal)
    {
      get_gps();
      show_coordinate();
      lcd.clear();
      lcd.print("Sending SMS ");
      Serial.println("Sending SMS");
      Send();
      Serial.println("SMS Sent");
      delay(2000);
      lcd.clear();
      lcd.print("System Ready");
    }
}

void gpsEvent()
{
  gpsString="";
  while(1)
  {
   while (gps.available()>0)            //Serial incoming data from GPS
   {
    char inChar = (char)gps.read();
     gpsString+= inChar;                    //store incoming data from GPS to temparary string
str[]
     i++;
    // Serial.print(inChar);
     if (i < 7)
     {
      if(gpsString[i-1] != test[i-1])         //check for right string
      {
        i=0;
        gpsString="";
      }
     }
    if(inChar=='\r')
    {
     if(i>60)
     {
       gps_status=1;
       break;
     }
     else
     {
       i=0;
```

```
     }
    }
  }
   if(gps_status)
    break;
  }
}

void get_gps()
{
  lcd.clear();
  lcd.print("Getting GPS Data");
  lcd.setCursor(0,1);
  lcd.print("Please Wait.....");
   gps_status=0;
   int x=0;
   while(gps_status==0)
   {
    gpsEvent();
    int str_lenth=i;
    coordinate2dec();
    i=0;x=0;
    str_lenth=0;
   }
}

void show_coordinate()
{
    lcd.clear();
    lcd.print("Lat:");
    lcd.print(latitude);
    lcd.setCursor(0,1);
    lcd.print("Log:");
    lcd.print(logitude);
    Serial.print("Latitude:");
    Serial.println(latitude);
    Serial.print("Longitude:");
    Serial.println(logitude);
    Serial.print("Speed(in knots)=");
    Serial.println(Speed);
    delay(2000);
    lcd.clear();
    lcd.print("Speed(Knots):");
    lcd.setCursor(0,1);
    lcd.print(Speed);
}
```

```
void coordinate2dec()
{
  String lat_degree="";
    for(i=20;i<=21;i++)
      lat_degree+=gpsString[i];

  String lat_minut="";
     for(i=22;i<=28;i++)
      lat_minut+=gpsString[i];

  String log_degree="";
    for(i=32;i<=34;i++)
      log_degree+=gpsString[i];

  String log_minut="";
    for(i=35;i<=41;i++)
      log_minut+=gpsString[i];

    Speed="";
    for(i=45;i<48;i++)          //extract longitude from string
      Speed+=gpsString[i];

     float minut= lat_minut.toFloat();
     minut=minut/60;
     float degree=lat_degree.toFloat();
     latitude=degree+minut;

     minut= log_minut.toFloat();
     minut=minut/60;
     degree=log_degree.toFloat();
     logitude=degree+minut;
}

void Send()
{
   Serial1.println("AT");
   delay(500);
   serialPrint();
   Serial1.println("AT+CMGF=1");
   delay(500);
   serialPrint();
   Serial1.print("AT+CMGS=");
   Serial1.print("");
   Serial1.print("+917872872868");    //mobile no. for SMS alert
   Serial1.println("");
```

```
  delay(500);
  serialPrint();
  Serial1.print("Latitude:");
  Serial1.println(latitude);
  delay(500);
  serialPrint();
  Serial1.print(" longitude:");
  Serial1.println(logitude);
  delay(500);
  serialPrint();
  Serial1.print(" Speed:");
  Serial1.print(Speed);
  Serial1.println("Knots");
  delay(500);
  serialPrint();
  Serial1.print("http://maps.google.com/maps?&z=15&mrt=yp&t=k&q=");
  Serial1.print(latitude,6);
  Serial1.print("+");          //28.612953, 77.231545   //28.612953,77.2293563
  Serial1.print(logitude,6);
  Serial1.write(26);
  delay(2000);
  serialPrint();
}

void serialPrint()
{
 while(Serial1.available()>0)
 {
  Serial.print(Serial1.read());
 }
}
```

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