CAPSTONE PROJECT PHASE-II REPORT

ON

VIBRATION MEASUREMENT SYSTEM USING ACCELEROMETER SENSOR

SUBMITTED

BY

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UNDER THE GUIDANCE OF

(PROF. R.D. KOMATI)

Sponsored by

MIT-WPU, PUNE

School of Electronics & Communication Engineering

DR. VISHWANATH KARAD
MIT WORLD PEACE UNIVERSITY, PUNE.
[2020-2021]

SCHOOL OF
ELECTRONICS & COMMUNICATION ENGINEERING

Academic Year 2020-2021

CERTIFICATE

This is to certify that ROHIT RAJ PRN No. 1032170928 has successfully completed his/her Capstone Project Phase-II entitled "**IOT BASED VIBRATION MEASUREMENT SYSTEM USING ACCELEROMETER SENSOR**" and submitted the same during the academic year 2020-2021 towards the partial fulfilment of degree of **Bachelor of Technology in Electronics & Communication Engineering** as per the guidelines prescribed by Dr. Vishwanath Karad MIT World Peace University, Pune.

Project Guide	Project Coordinator	Head of School
Prof. R.D. Komati	Prof. R.D. Komati	Dr. Vinaya Gohokar

Date: June 16, 2021

Place: Pune

DECLARATION

We the undersigned, declare that the work carried under Capstone Project Phase-II entitled "**_Shubhangi Kumari & Rohit Raj**" represents our idea in our own words. We have adequately cited and referenced the original sources where other ideas or words have been included. We also declare that We have adhered to all principles of academic honesty and integrity and have not misprinted or fabricated or falsified any ideas/data/fact/source in my/our submission. I/We understand that any violation of the above will be cause for disciplinary action by the University and can also evoke penal action from the sources which have thus not been properly cited or whom proper permission has not been taken when needed.

Date:

Place:

PRN Number	Name of student	Signature with date
1032170867	Shubhangi Kumari	Shubhangi 16-04-21
1032170928	Rohit Raj	Rohit Raj 16/04/2021

ACKNOWLEDGEMENT

It is great pleasure for me and my project partner. We feel highly doing the project entitled- **"IOT Based Vibration Measurement System Using Accelerometer”.**

We are grateful to our project guide Prof. R.D. Komati sir and our HOS Dr. Vinaya Gohokar ma’am. This project would not have completed without their enormous help and worthy experience.

Whenever we were in need, they were there behind us. Although this report has been prepared with utmost care and deep routed interest. Even then we accept respondent and imperfection.

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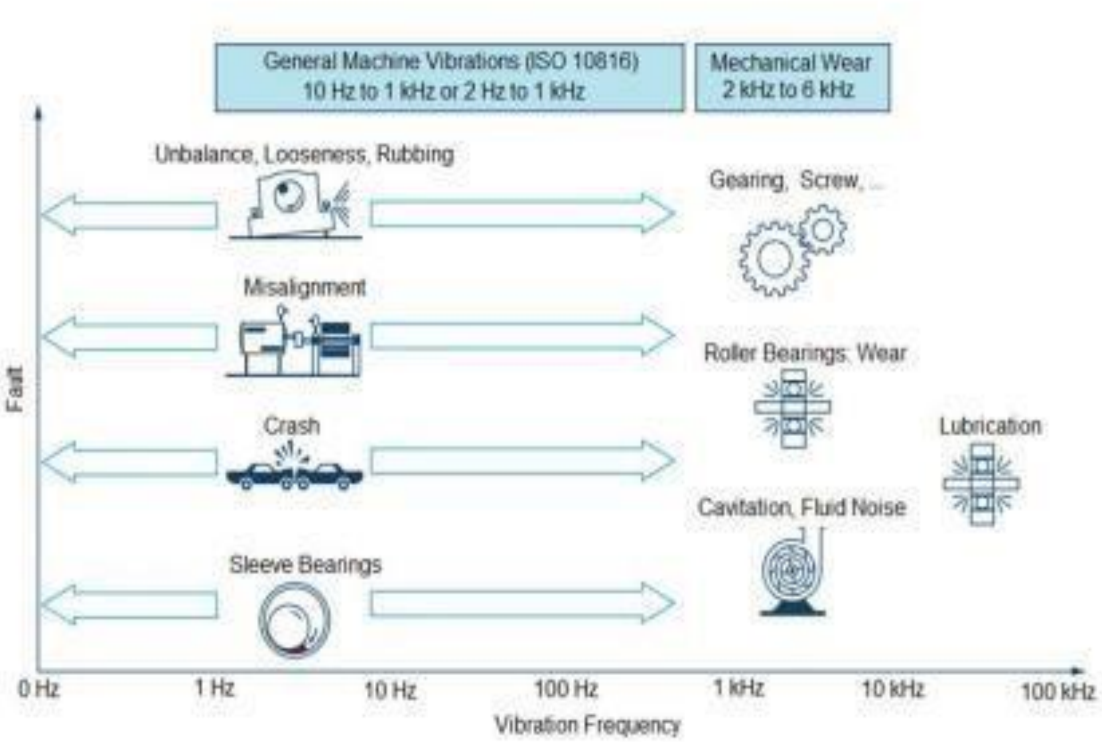
ABSTRACT

The vibration analysis demands appropriate vibration transducers. Vibration measurement can be done by measuring displacement, velocity, acceleration, acoustic, magnetic, optical etc. of specific points, of otherwise static structure. These parameters can be measured with different types of sensing devices based on different principles. Several techniques mainly based on capacitive/piezoelectric accelerometers and acoustic are available commercially. Optical and GMR (Giant Magnetoresistance) based vibration measurement are emerging technologies. Fig. presents different physical parameters for vibration sensing, sensors adopted for sensing, and technologies available for vibration monitoring. [4]



LIST OF FIGURES

CHAPTER 1

INTRODUCTION

1.1 Motivation/Introduction/Relevance

Maintenance costs are a significant part of the total operating cost of all manufacturing plants. Condition monitoring is a key element of the maintenance program. Most comprehensive predictive maintenance programs use vibration as the primary parameter to monitor. However, the typical process of vibration monitoring relies too much on the human factor and has limitations.[1] To overcome these shortcomings, a method is proposed in this paper. Moreover, the potential IoT using for smart maintenance is demonstrated.[2] Additionally, it is explained how it can shape the maintenance toward the industry 4.0. and how industrial IoT can help the condition monitoring of rotating machinery using vibration analysis. In this way, a method is proposed to make rotating machinery to IoT enabled devices by adding hardware to them.[6] This hardware was designed and developed based on the requirements. Moreover, a new generation of accelerometer sensors has been introduced to measure the vibrations.[5] For this purpose, a data acquisition web application is developed to evaluate the hardware. The evaluations show the quite precise of the results.[3]

1.2 Organization of report

The fault diagnosis and prognosis of a rotating machine using vibration pattern analysis, is one of the efficient and most successful techniques. Analytical and practical understanding of machine vibration is well defined in literatures. The machine vibration behavior, in time and frequency domain, forms the basis for monitoring of rotating machines. It has gained enormous importance in the last decade, as machine vibration response is sensitive to any small change in operating condition or mechanical structural. [5]

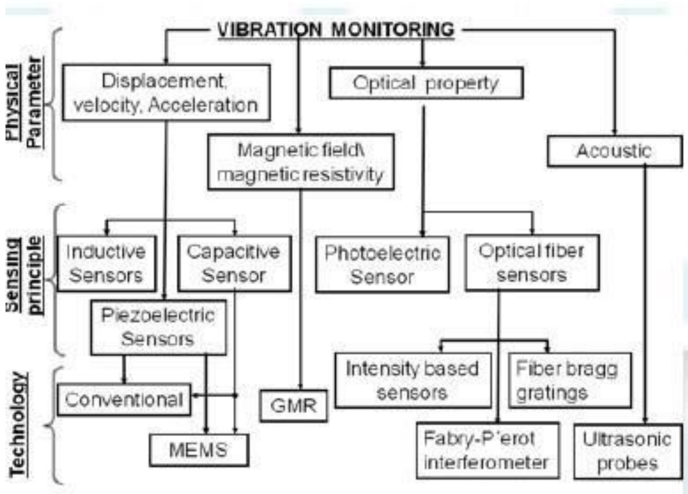


Figure1: Overview of different vibration sensors and technologies used for vibration monitoring [3]

CHAPTER 2
REVIEW OF LITERATURE

2.1 LITERATURE REVIEW

Existing problem

Maintenance of equipment means using a method to prevent equipment failure and keep them operational. Maintenance costs are a significant part of the total costs of operation for all factories and manufacturing plants. Maintenance costs can be from 15% to 60% even 70% depending on the industry of total costs. Maintenance management techniques can be classified into three key categories that are as follows in order of efficiency:

a. Run-to-Failure (R2F) or Corrective Maintenance - Maintenance procedures are carried out only after failures have occurred.

b. Preventive or Planned Maintenance (PvM) - Maintenance is performed based on time or process iterations according to a planned schedule.

c. Predictive Maintenance (PdM) - Maintenance is conducted based on an assessment of the health

status of the equipment that comes from monitoring. [1]

Monitoring is the key element of PdM, in other words, PdM can be considered as condition based PvM. The maintenance program, particularly the PdM approach, that requires constant monitoring of the equipment, is often applied for an important equipment category called rotating machinery, which includes motors, pumps, fans, turbines, gearboxes, etc. A comprehensive predictive maintenance program employs several technologies concurrently, such as vibration analysis, ultrasonic, oil analysis, thermography, process parameters, tribology, etc. [3] Almost all predictive maintenance programs use vibration analysis as the main technique. Vibration analysis is one of the most efficient and successful techniques for fault diagnosis of rotating machinery. [6]

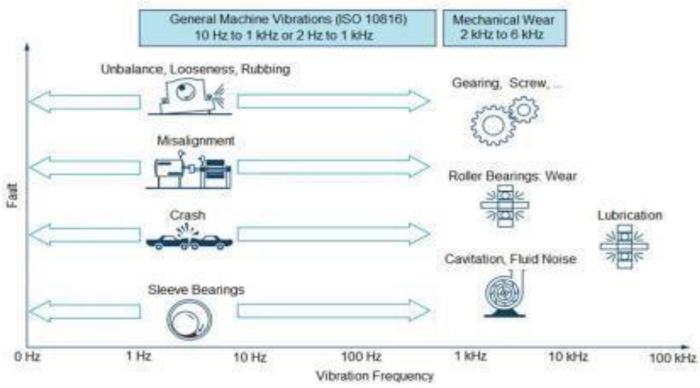


Figure 2: Rotation equipment fault vibration artifacts

Proposed solution

The solution that can address these problems is to make the equipment smart. Equipment must be able to announce its status at any time and this capability leads us to the concept of the Internet of Things (IoT). Internet of Things was first employed in 1999. The IoT is the network that connects things together. [3] These things can be computers, smartphones, people, data, processes, and physical objects such as machines, devices, and appliances. IoT can integrate various manufacturing devices in order to sense, identify, process, communicate, operate and network. This deeply integrated intelligent cyber physical environment brings so many opportunities and values for manufacturing businesses. Using IoT inside the industry is called industrial Internet of things (IIoT). [2] This term refers to the industrial subset of the IoT. IIoT in manufacturing could make so much value that it will finally head to the Fourth Industrial Revolution or Industry 4.0.

In fact, the equipment is needed to move from a static entity to a network entity that can share its status and condition to the network at any time and become one of the things of the IoT. Such equipment that can share its status in the network is called IoT Enabled Device. Sharing the status is not the only desirable characteristics of an IoT enabled device. Things in IoT are expected to have various characteristics which include sensing, connectivity, processing, energy efficiency, cost effectiveness, quality and reliability and security. [7]

2.2 AIM AND OBJECTIVES OF PROJECT

To overcome those problem, which is the missing data between sampling sessions, there should be a solution that can convert sectional sampling to continuous sampling or data streaming. The second problem is human error during sampling. The technician may place the sampling device at different points at different sampling sessions and obtain different results. The sampling should be done automatically to prevent human errors; such as mistakes in reading or inserting numbers. The next problem is sampling at different conditions of the equipment in terms of load, which means that sampling may be performed at a time of extreme load and subsequently be performed at a lower load, which may make the results incomparable. This problem will be resolved by solving the first problem, because if the sectional sampling converts to a data stream, the equipment data will be sampled at all times and it will be possible to examine the data at a specified time. Another problem is the inaccessibility of some equipment for human. To solve the problem, we need to look for a solution that does not require the technician to be at the location of the equipment for sampling. [3]

Problem Statement

The typical process of vibration analysis in factories is that condition monitoring technician goes into the factory and measures the vibration of machines using a data logger; then, he/she investigates the gathered data and according to the known patterns of various possible defects that may occur detects the faults. Regarding the diagnosis of severity and type of faults, he/she announces the need for repair or replacement of the equipment. This method has some shortcomings such as:

- Human error in sampling. [1]
- Missing data between different data sampling sessions which may include important information about faults. [4]
- Lack of access to some equipment for human. [5]
- Limited amount of equipment under monitoring due to the high cost of sampling devices. [4]

CHAPTER 3
SYSTEM DEVELOPMENT

3.1 SYSTEM BLOCK DIAGRAM

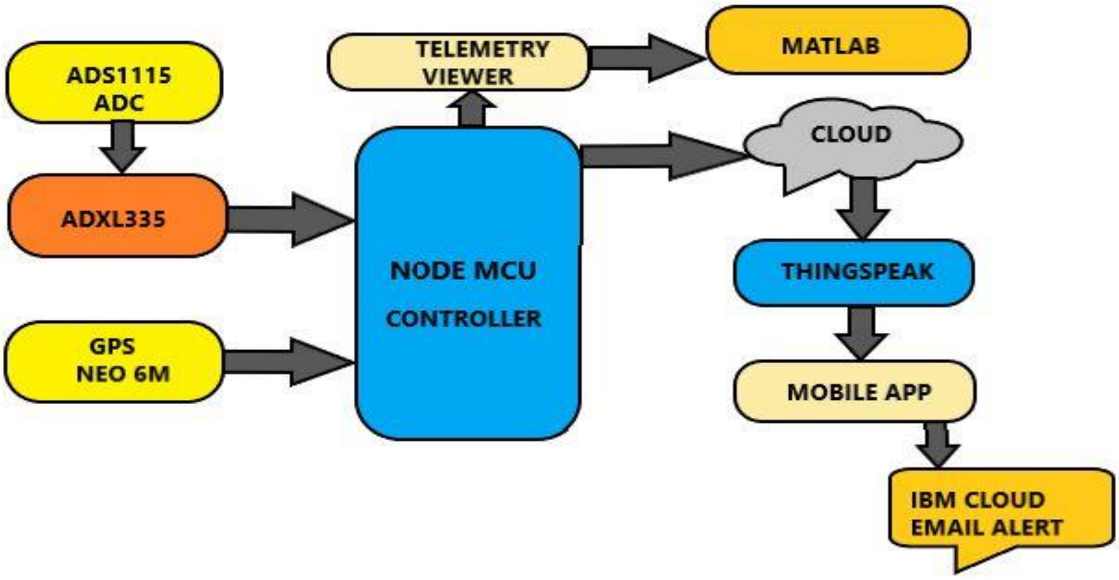


FIGURE 3: Block Diagram of Project

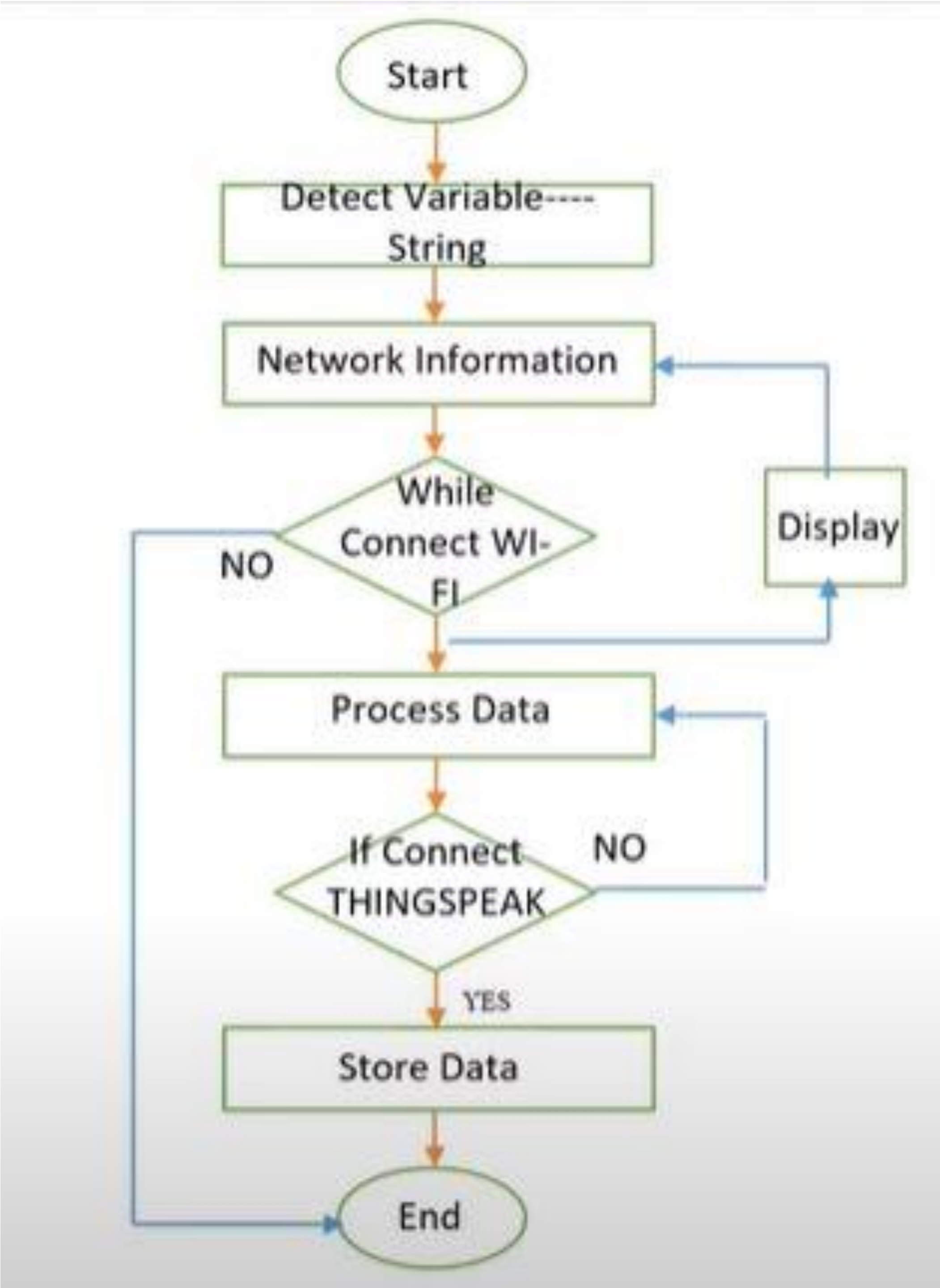


FIGURE 4: Flow chart for THINGSPEAK data analysis process.

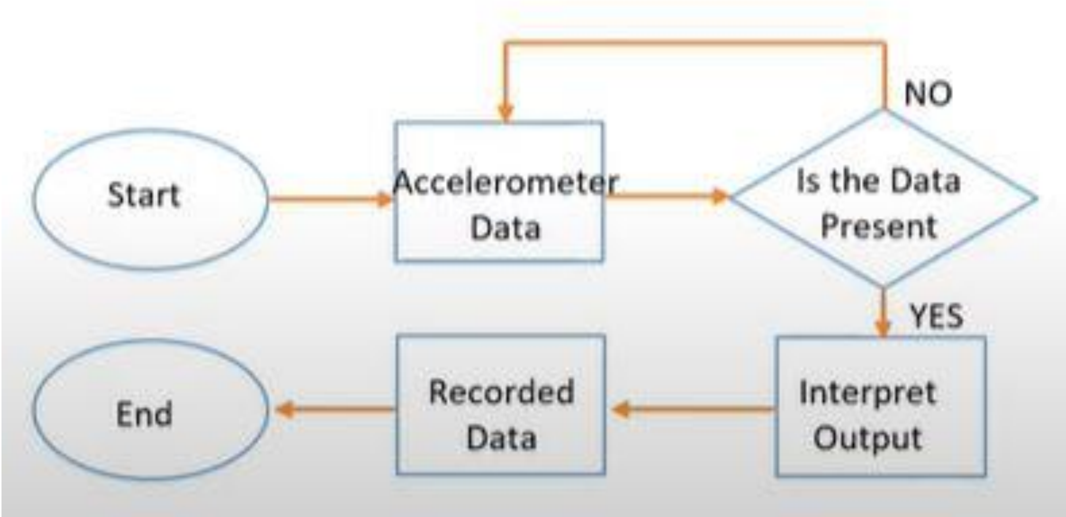


FIGURE 5: Flow Chart of ADXL-335 data sensing operation

3.2 SYSTEM SPECIFICATION

The required hardware should be able to perform three main tasks which are: **A) Sensing B) Processing C) Transmitting Data**. In the following, the details of implementing the hardware for performing these tasks are provided. The final section brings the manufactured hardware with technical specifications. [4]

The specifications of our hardware are described as follows and at last the price is included for the same.

ADXL335 MODULE SPECIFICATION	
INTERFACE:	3V3/5V Microcontroller
VOLTAGE REQUIREMENT:	3 – 6V DC
OUTPUT FORMAT:	ANALOG OUTPUT
MEASURING RANGE:	+- 3g
MEASURING VALUES (-3 to+3):	X (-274 to +325) Y (-275 to +330) Z (-275 to +310)

FIGURE 6: ADXL Specification

NEO 6M GPS MOSULE SPECIFICATION	
RECEIVER TYPE:	50 channels, GPS L1(1575.42Mhz)
OPERATING VOLTAGE:	2.7V ~ 3.6V
OPERATING CURRENT:	45mA
SERIAL BAUD RATE:	4800 -230400(9600 default)
CAPTURE TIME:	Cool start: 27sHot start: 1s
HORIZONTAL POSITION ACCURACY:	2.5m
COST:	₹715.00

FIGURE 7: GPS Module Specification

NODE MCU(ESP8266-12F) SPECIFICATOION	
OPERATING VOLTAGE:	3.3V
DIGITIAL I/O PINS:	12
ANALOG INPUT PINS:	1
CLOCK SPEED:	80MHZ/160MHZ
FLASH:	4M BYTES
WIDTH:	29.1mm
COST:	₹ 575.00

FIGURE 8: Node MCU Specification

BILL OF MATERIAL : ELECTRONICS COMPONENTS REQUIRED IN CAPSTONE PROJECT					
VIBRATION MEASUREMENT USING ACCELEROMETER SENSOR					
SR.NO	COMPONENT NAME	QUANTITY	COST PER PC(₹)	TOTAL AMOUNT(₹)	PURCHASE SITE
1.	GENERIC ESP8266 NODEMCU WIFI IOT DEVELOPMENT BOARD.	1	383.00	383.00	AMAZON
2.	ADXL335 3-AXIS ACCELEROMETER SENSOR.	1	399.00	399.00	AMAZON
3.	1K AND 100OHM RESISTOR ,5mm RED, GREEN LED	1 SET	79.00	79.00	AMAZON
4.	ADS1115 16BIT I2C 4 CHANNEL MODULE	2	453.00	906.00	AMAZON
4.	BERG STRIP FEMALE HEADER PIN	5	20.00	100.00	AMAZON
5.	DOUBLE SIDE COPPER PROTOTYPE PCB BOARD 9 X 15 Cm	1	199.00	199.00	AMAZON
6.	SOLDER IRON KIT 7 IN 1 SOLDERING IRON WITH IRON CUTTER, IRON STAND, SOLDERING PASTE,TWEEZER,DESOLDERING WICK.	1 SET	299.00	299.00	AMAZON
7.	NEO 6M U-BLOX GPS POSITIONING MODULE TO SERIAL TTL.	1	599.00	599.00	AMAZON
8.	BREADBOARD + 60 PIECES JUMPER WIRES SET.	1 SET	254.00	254.00	AMAZON
			TOTAL:	₹3,218.00	

Fig. 9: Bill of Total Components

A) Sensing: Based on the discussed reasons and explanations in the previous section, MEMS accelerometer is used in this paper to develop the required hardware. An essential factor for selecting the proper MEMS sensors is bandwidth. The maximum frequency that the accelerometer can capture is the bandwidth of the sensor. The occurrence of prominent frequency components in the frequency analysis of the captured signal represents the machine state. [8] These frequencies are associated with the rotational speed of the equipment. For instance, if the rotational speed of the machine is considered as (fr), the coupling misalignment will cause a prominent component at (fr), while, misaligned will appear at 2×fr. Therefore, the rotational speed of the equipment, as well as the type of faults to be detected, are factors that are important in determining the required bandwidth. In this paper, the plan is to use a hardware on low-speed motors around 1500 RPM (25Hz). Hence, the ADXL335 accelerometer sensor from Analog Devices was selected. The ADXL335 is a small, lightweight, and low power accelerometer. This sensor can measure acceleration in the range of ±3 g within a bandwidth from 0.5 Hz to 1600 Hz, which is within the scope of this paper and beyond. [1]

B) Processing: In order to receive, process and send data to the sender module, the Node MCU ESP8266 microcontroller is selected. The processor receives data from the sensor and samples the signal by using the microcontroller's internal A2D unit to convert it from analog to digital signal. The Nyquist–Shannon sampling theorem states that "If a function x(t) contains no frequencies higher than B hertz, it is completely determined by giving its ordinates at a series of points spaced 1/(2B) seconds apart". Therefore, for a particular sample rate fs, a band limit of B<fs/2 is needed to ensure accurate reconstruction. Therefore, if it is intended to detect shaft misalignment on a machine with a 25Hz rotating speed, it will generate a prominent component at 2f or 50Hz. Based on the explained Nyquist–
Shannon sampling theorem, the sampling rate should be 100Hz at least. Here, a sampling rate of 2500Hz is chosen for more precise results plus to cover more complicated faults as well as higher rotating speeds.

Each sent sample from the sensor is a 4-digit number from 0 to 4096. 0 shows -3g and 4096 represents the maximum range which is +3g in this sensor. The sensor sends each sample in 12 bits which fits in 2 bytes. In order to reduce the overhead, a simple buffering is performed by putting every 500 bytes into a frame and the frame is sent to the sender module (Wi-Fi module). [4] [2]

C) Transmitting Data: In order to send data from the board to the internet, a Wi-Fi module is needed. The ESP8266 module has been selected to do this job. This module connects to the microcontroller using a serial connection via the UART interface. ESP8266 requires to recognize the server address, which is going to send the data, as well as the credential of an access point, to get connected. Afterward, by turning the board on, this module tries to be connected to the access point and after a successful connection, it will establish a TCP connection to the socket running on the server. Later, the data frames are transmitted over this socket to the cloud. [1]

D) Manufactured Hardware: The complete assembly of the sensor, designed and developed for this research. Part (A) is the ADXL335 accelerometer sensor, connected to the board via four 20cm long wires. The sensor is not on-board to make it possible attaching the sensor on the machines. Part (B) is the LPC1768 microcontroller which the processing unit. Part (C) is the ESP8266 module which sends the data to the server. Part (D) represents the LED indicator for receiving data from the sensor and the LED indicator for sending data to server. Part (E) shows the button for restarting the board and finally part (F) shows the mini-USB port used for connecting to a 5-volt power supply. The block diagram of the circuit is shown in **Fig. 4.** This hardware can measure dynamic and static vibrations with a sampling rate of 2500Hz and send it to the user specified server on the cloud in real-time.

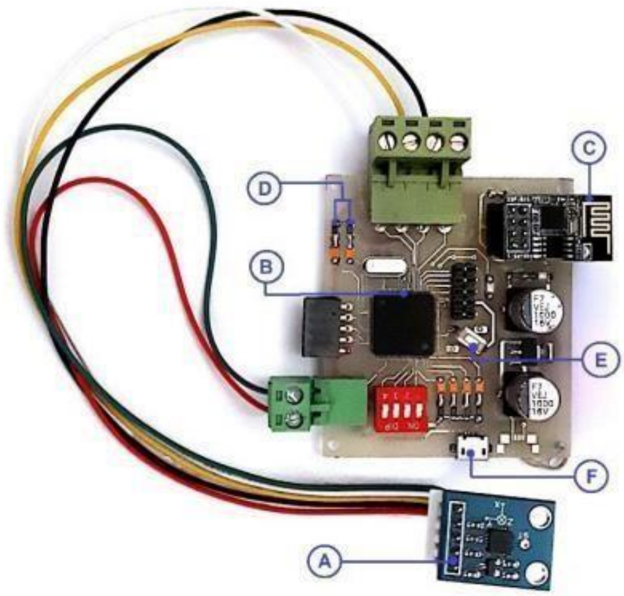


Figure 10: The developed hardware for IOT enabled vibration measurement

To evaluate the designed hardware, a data acquisition web application has been developed. This application consists of three main components. The first component is responsible for receiving data from the sensor. This component is written in python and consists of two threads working simultaneously. [2] The first thread task is to receive data. It opens a TCP socket and listens to it, waiting for a connection from the sensor. When the connection is established, it receives the data frames from the sensor and puts them in a queue. The second thread is responsible for storing data. It reads data from the queue, processes and saves them into the database. The process includes:

• Converting the received bytes to 4-digit numbers by merging each pair of bytes.

• Confirming the integrity of received data.

• Filling the missing data in case of a buffer overflow in the sensor.

• Removing irrelevant data in case of existence.

• Store the processed data into a queue to perform a bulk create in the database to reduce the overhead of inserting data into the database. [8]

The second component of this web application is a Django application providing a RESTful API for accessing to stored data in the database over HTTP protocol for clients. The third and last component is the client-side application. This application retrieves data from the server's API and plots the real-time graph of them. The graph is a line chart, represents the vibration data in order of G. In order to evaluate the hardware, the accuracy of data received on the server is compared with data captured locally from the sensor at the same time. We attached the sensor to a motor with 1500 RMP speed and then we ran the server and client applications. The vibration data presented on the graph in real-time. Meanwhile, by connecting the sensor locally to an oscilloscope, vibration data would be captured and presented on the oscilloscope, too. After collecting data, it will be displayed by the client application and oscilloscope at the same time. [1]

As seen, the data retrieved from the server matches the data measured locally on the oscilloscope at the same time with reasonable precision. The second round of the motor rotation is collected to show the similarity. [5]

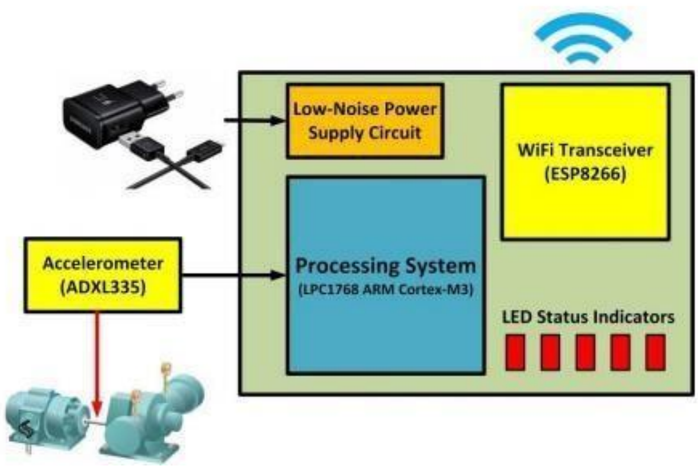


Figure 11: Block Diagram of Desired Hardware

3.3 CHALLENGES FACED/ COMPLEXITIES INVOLVED

→ **Technical** – Due to the unique nature of projects we frequently need to employ new technology.

→ **Environment –** A project does not exist in a vacuum; in order to deliver successful projects college must be aware of those factors (both internal and external) that will have an impact on the project**.**

→ **Time, cost and quality** – The biggest challenge faced by us was that we wish to use project management is ensuring that our projects deliver the agreed objectives within time, cost and to the agreed quality. These factors must be balanced in relation to the overall scope of the project.

→ **Resources –** Projects rely on the effective employment of finite resources, whether these are people, equipment or facilities – in other words anything required to complete a project activity – and these will cost money. We faced the challenge of ensuring that we make the most of these finite resources.

→ **COVID-** Due to lockdown we faced many problems like delay in orders, PCB designs unavailability and staying at different locations cause a proper connectivity issue.

CHAPTER 4
SYSTEM IMPLEMENTATION

4.1 SYSTEM DESIGN AND DESCRIPTION

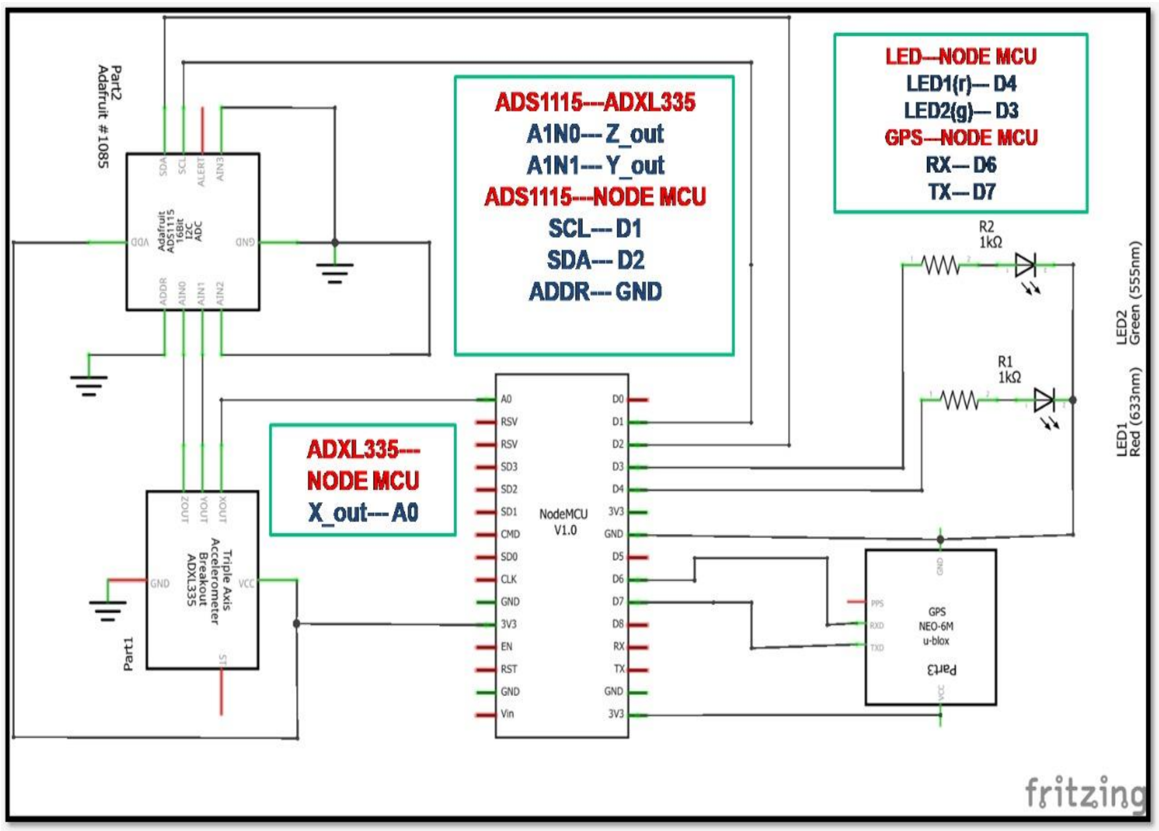


FIGURE 12: CIRCUIT DIAGRAM

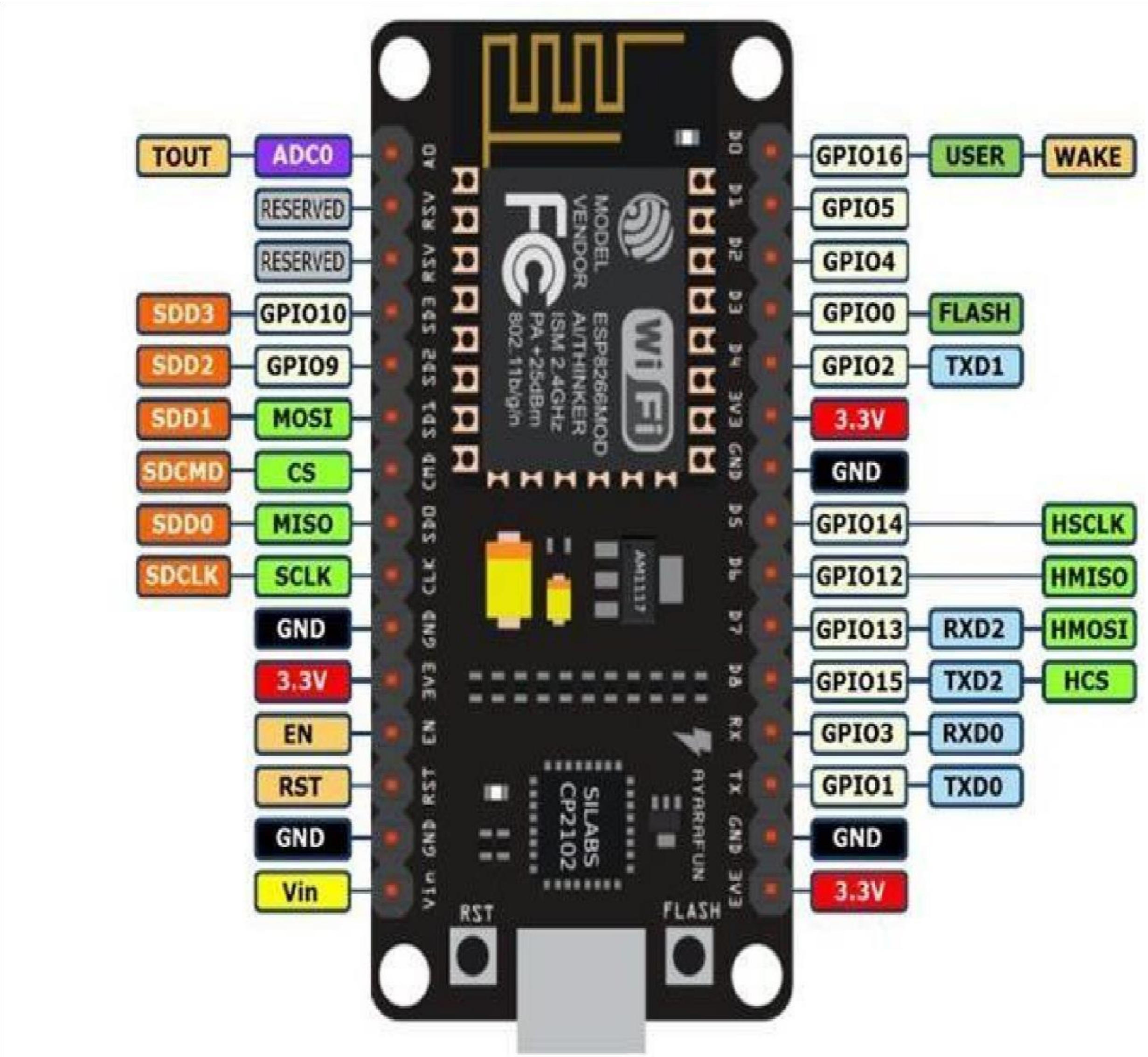


FIGURE: 13: Pin’s specification of NODE MCU

b) THINGSPEAK CLOUD PLATFORM

FIGURE 14: Thing speak charts for various data from Node MCU

Thing Speak Dashboard

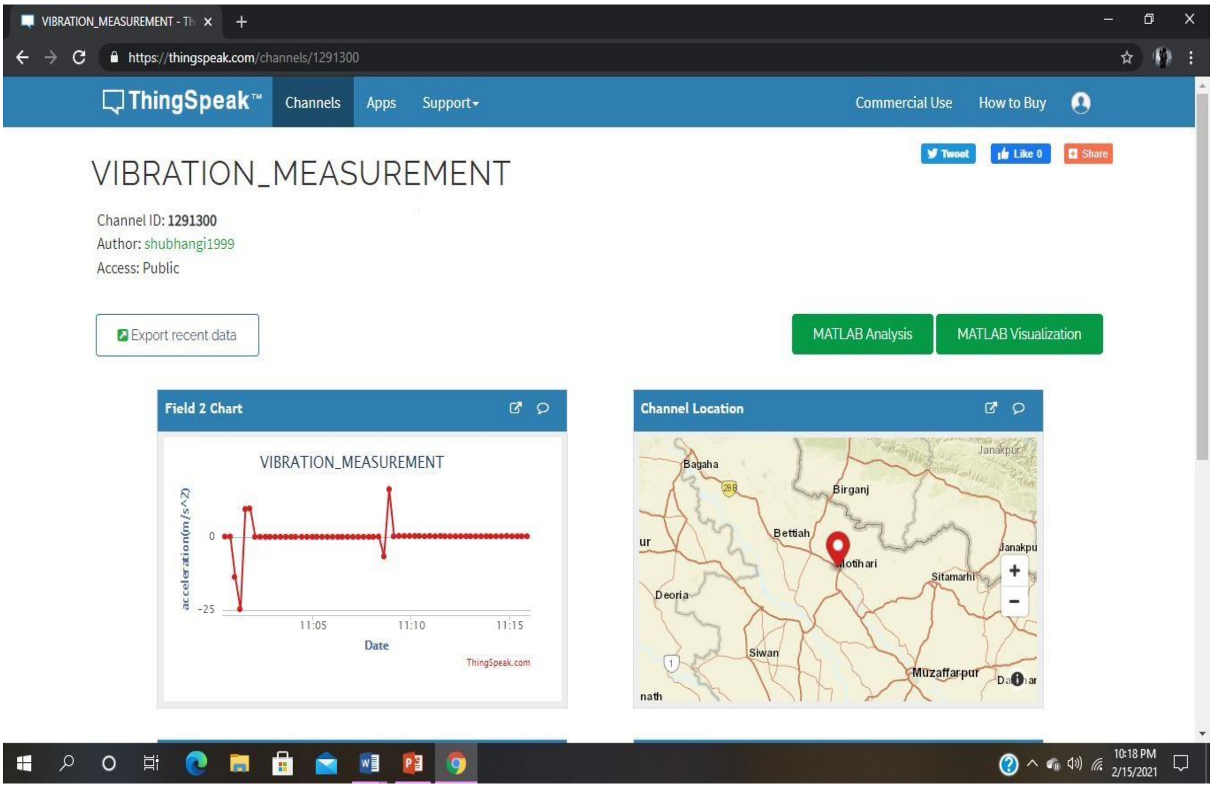


FIGURE 15: Thing speak Dashboard

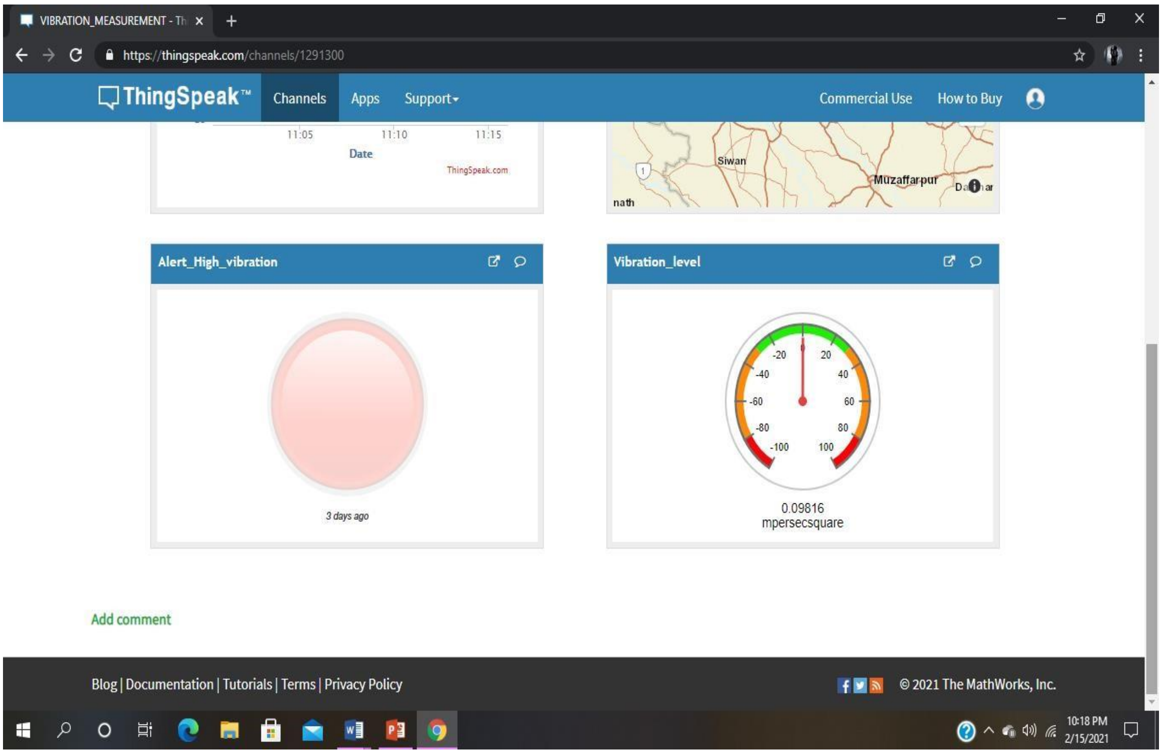


FIGURE 16: Thing Speak Dashboard

c) MATLAB PLOT

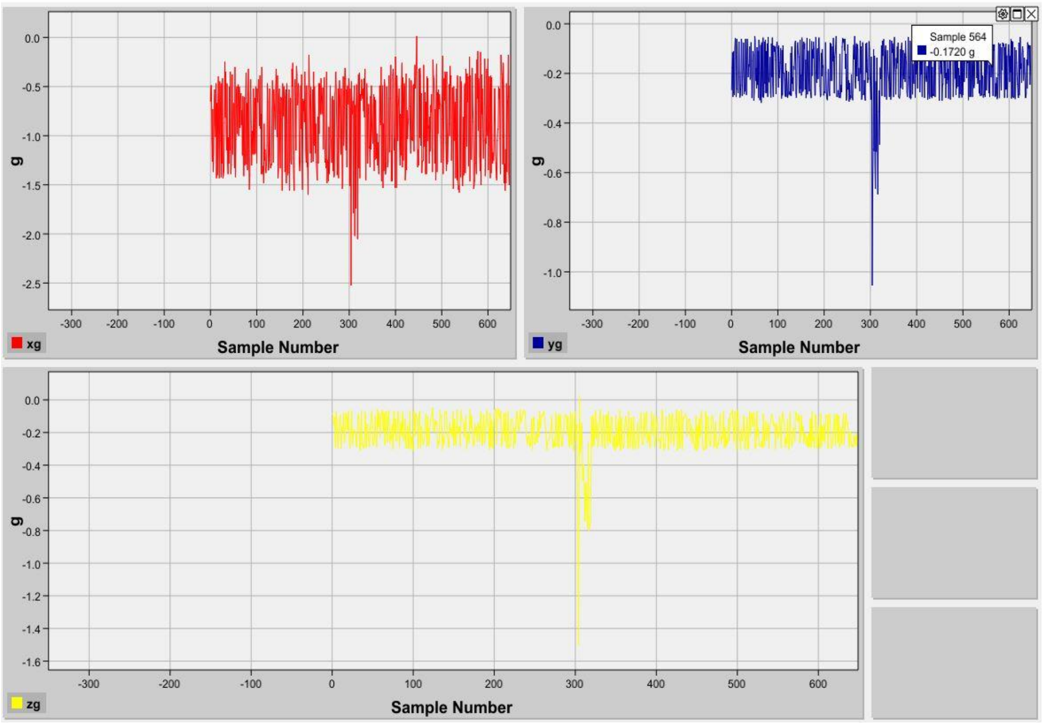


FIGURE 17: MATLAB Plots

Untitled4.m | Untitled1.m | Untitled2.m | Untitled.m

```
xg=xlsread('fan_data.csv','c:c');
yg=xlsread('fan_data.csv','d:d');
zg=xlsread('fan_data.csv','e:e');
s=xlsread('fan_data.csv','A:A');
fs=1000;
LL = length(xg);
LL1 = length(yg);
LL2 = length(zg);
Ts = 1/fs; %sampling time interval
t = 0:Ts:Ts*(LL-1);
f = fs*(0:(LL/2))/LL;  % Frequency values
subplot(2,1,1);
plot(t,xg,'g');
xlabel('Time,sec')
ylabel('Acc,g/s^2')
legend('Acc X')
title('Time-domain Spectrum') , shg
subplot(2,1,2);
plot(t,yg,'g');
xlabel('Time,sec')
```

FIGURE 18: Code for FFT- Graphs in MTLAB

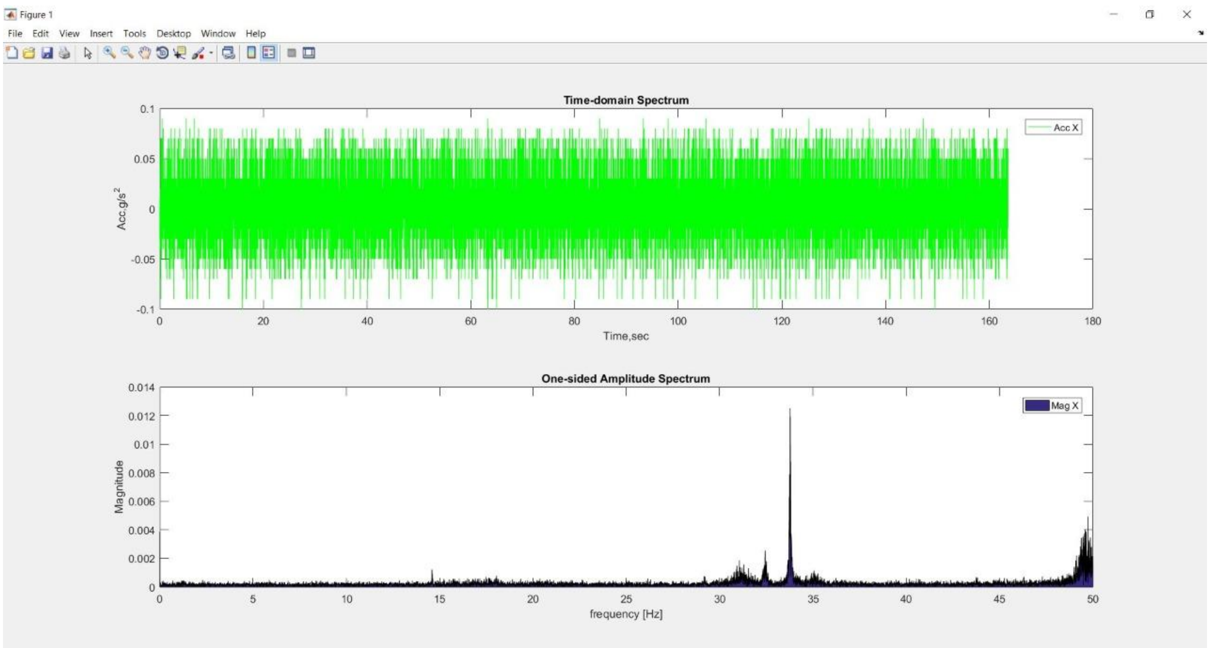


FIGURE 19: FFT Graph

d) MIT APP INVENTOR

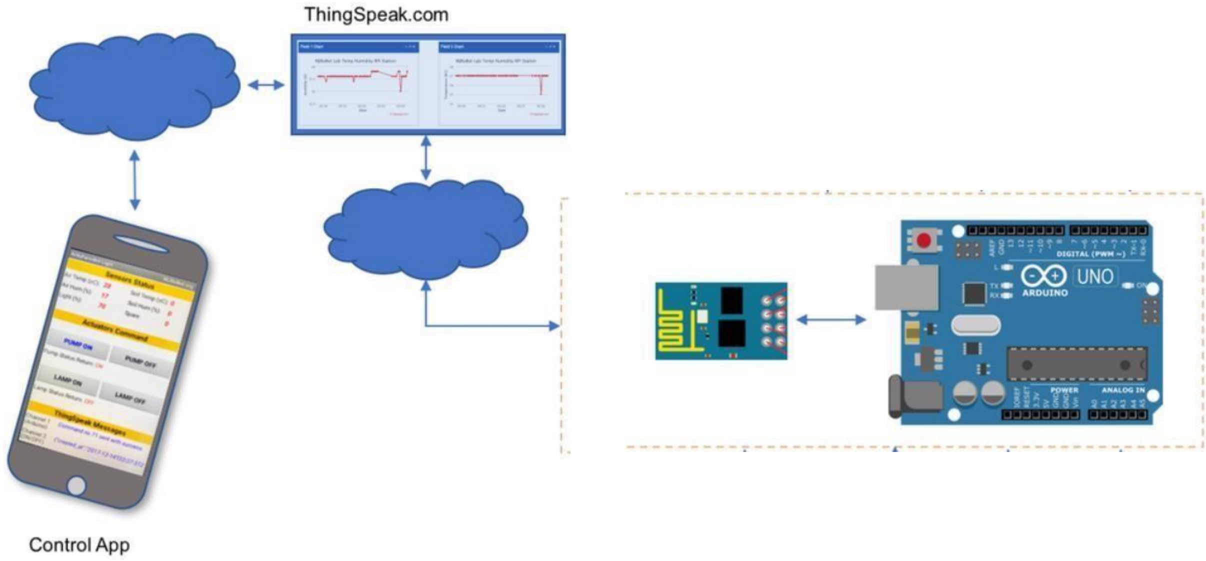


FIGURE 20: App Deployment flow chart

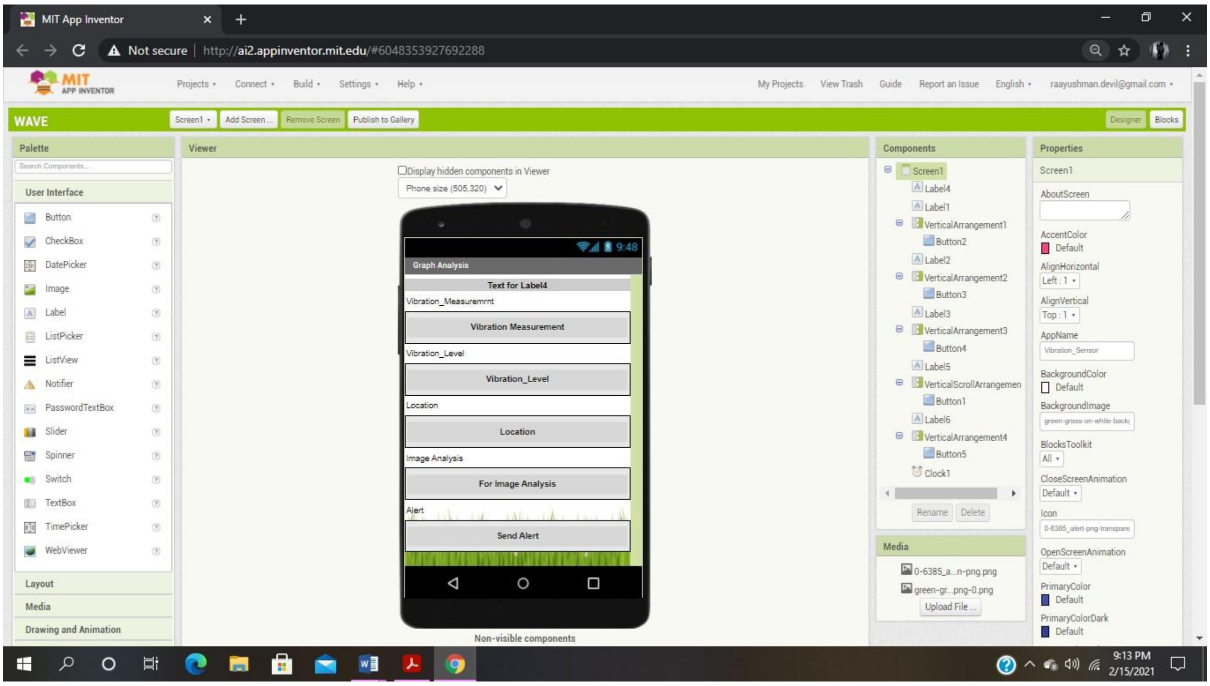


FIGURE 21: FRONTEND MOBILE DEVELOPMENT

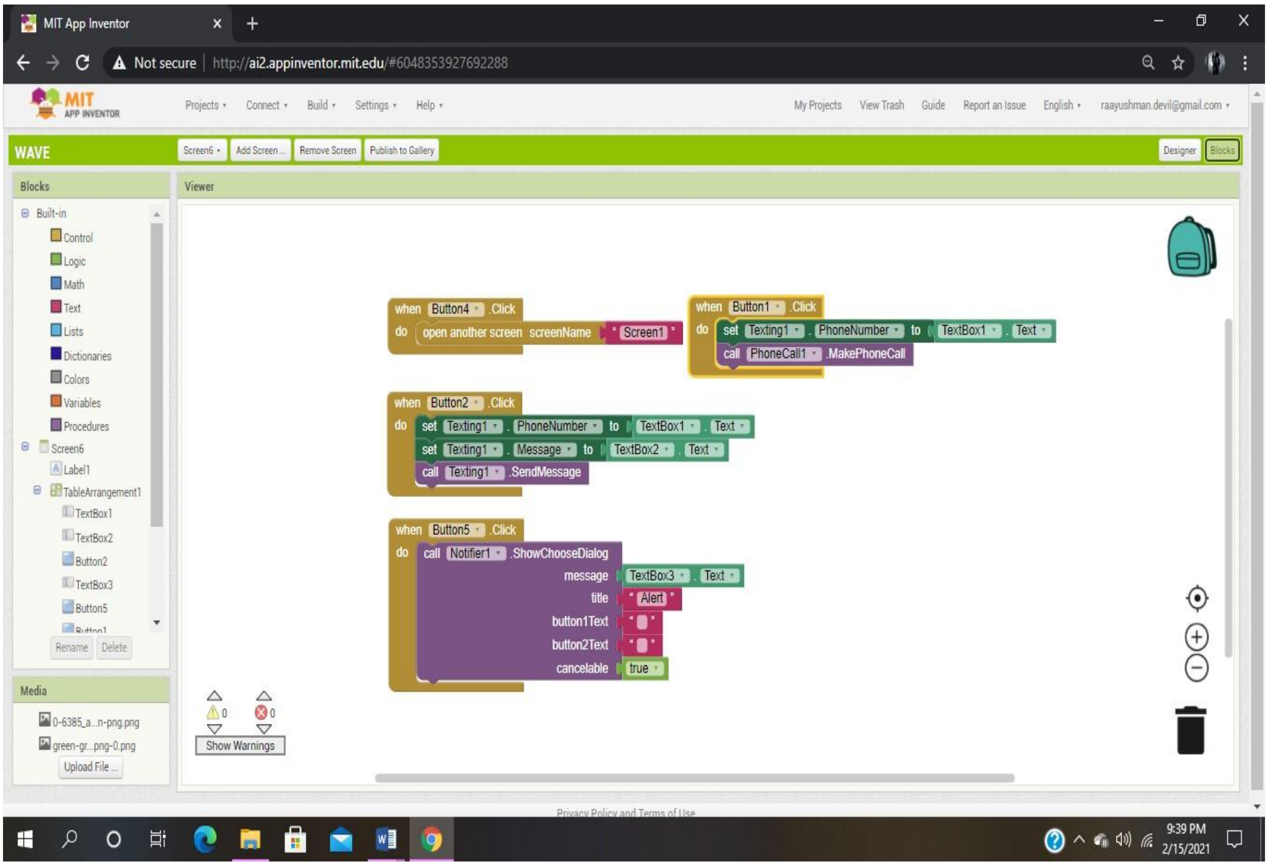


FIGURE 22: BACKEND MOBILE VIEW

WORKING OF APP

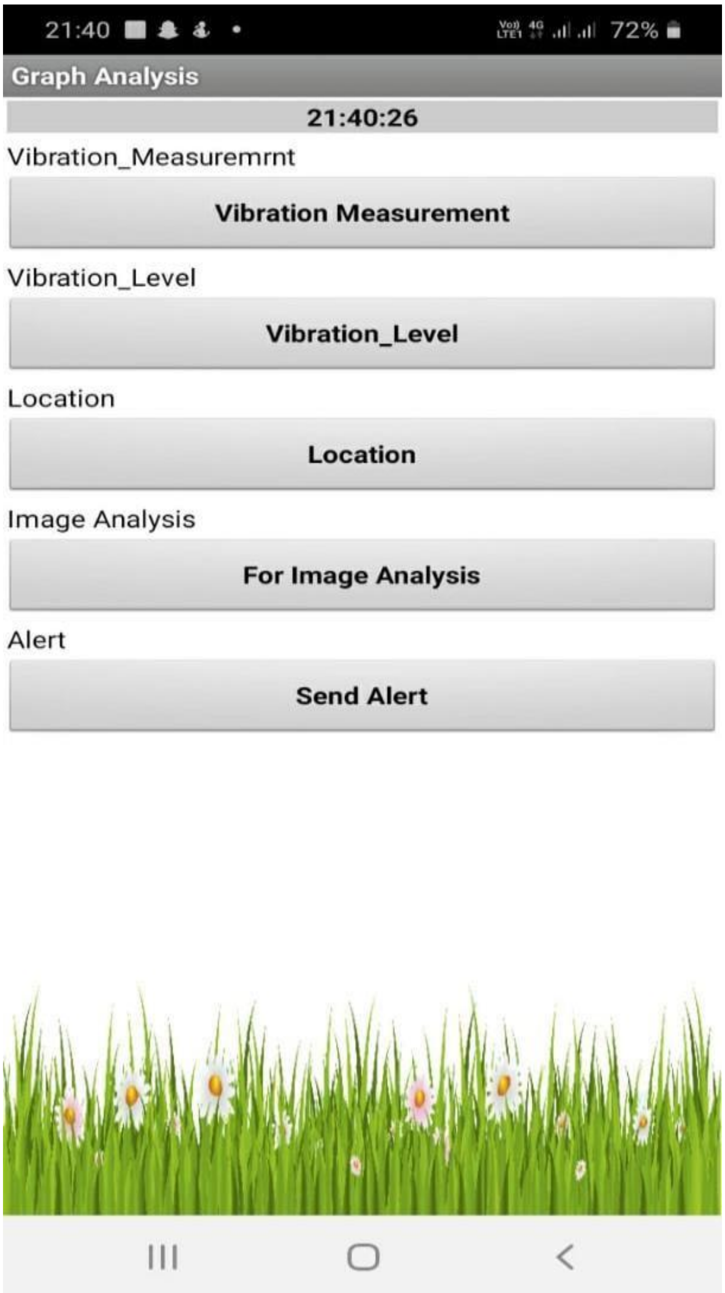


FIGURE 23: HOME SCREEN OF APP

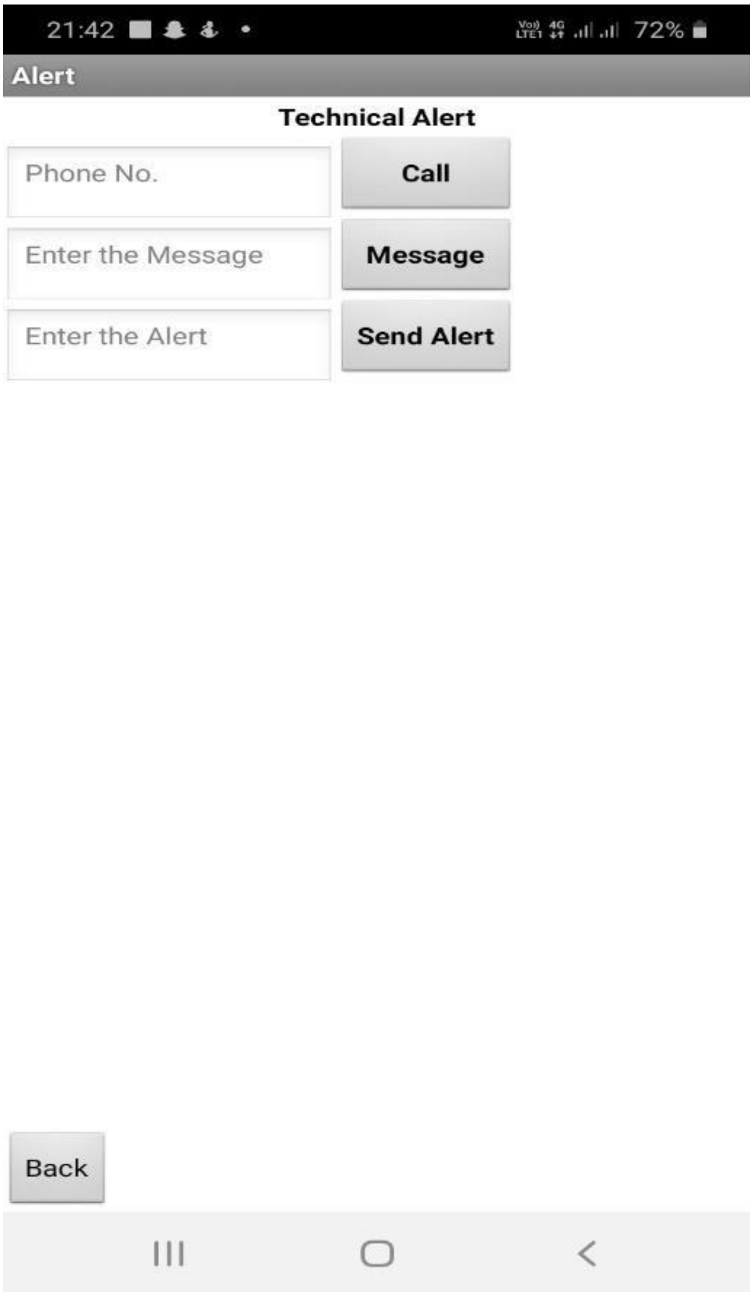


FIGURE 24: ALERT SCREEN OF APP

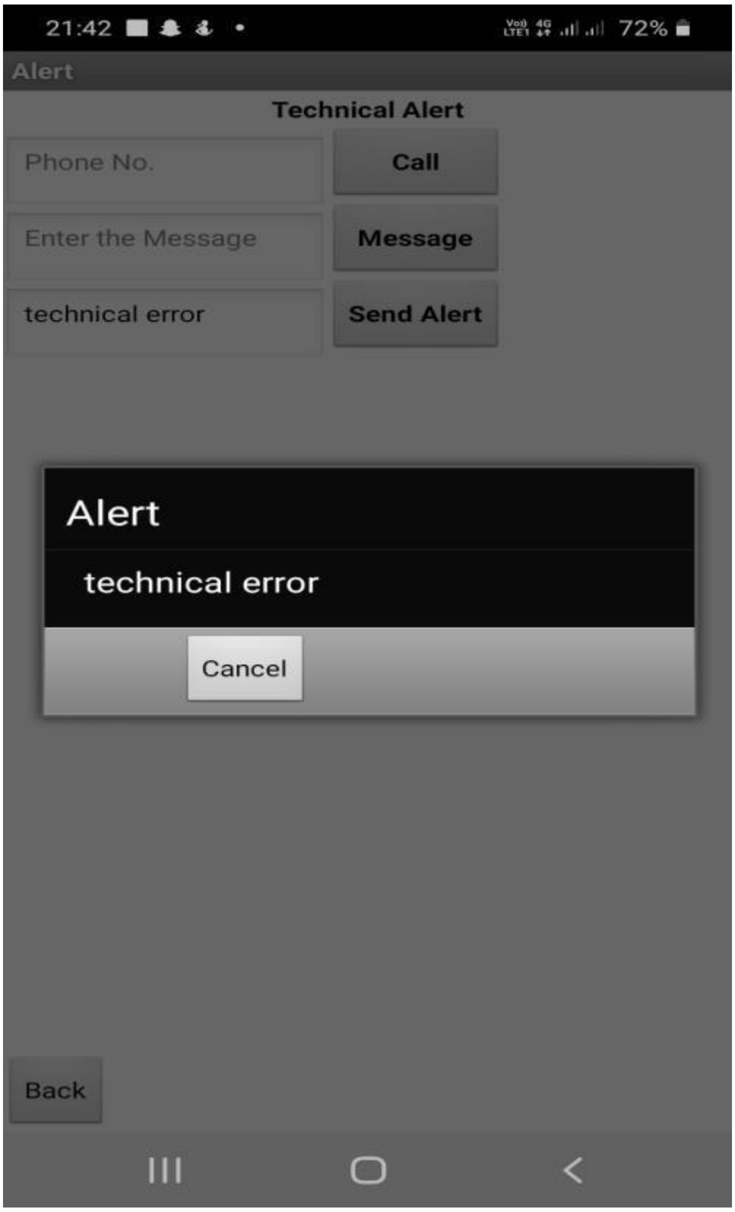


FIGURE 25: ALERT NOTIFICATION IN APP

FIGURE 26: Graph Plot in APP

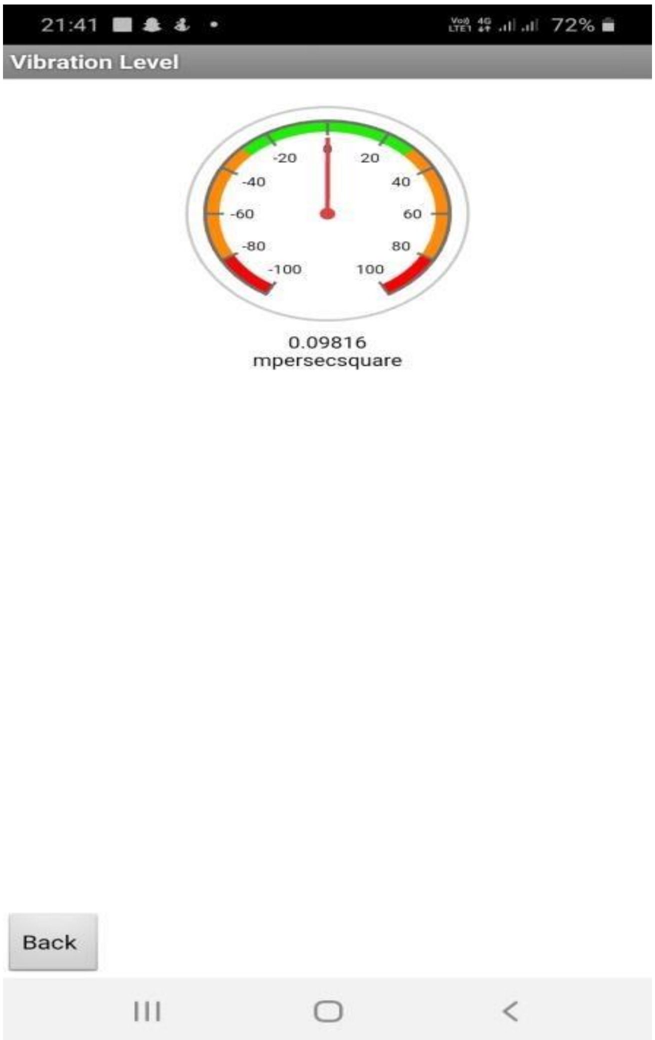


FIGURE 27: VIBRATION LEVEL SCREEN OF APP

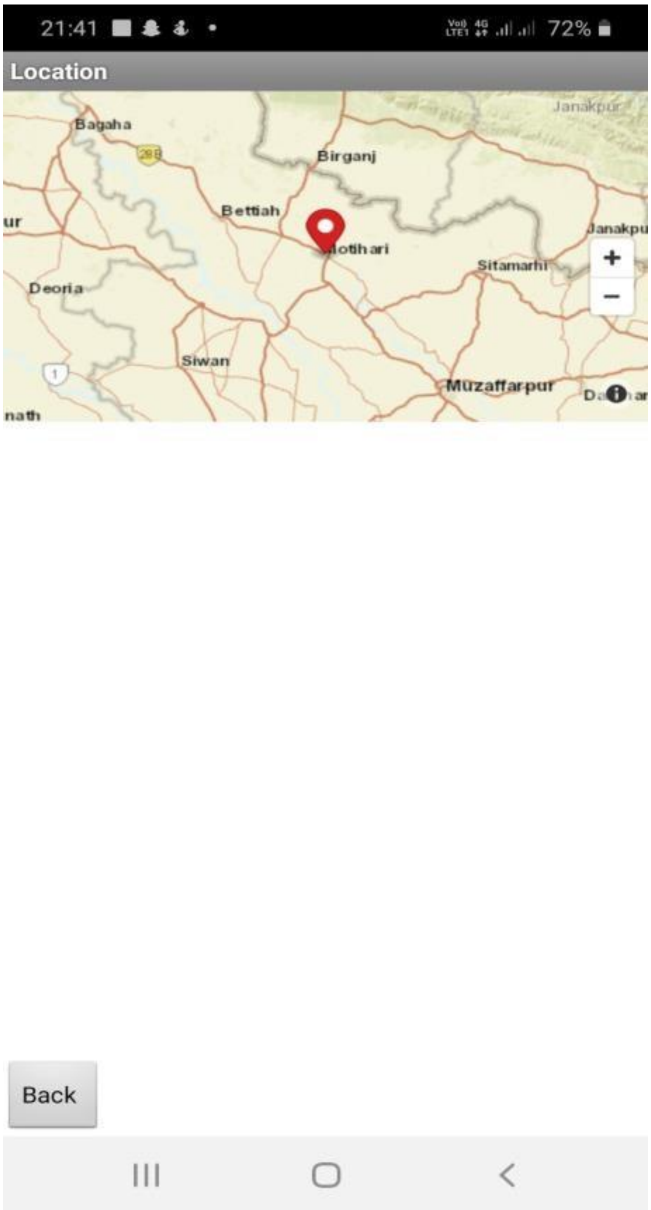


FIGURE 28: GPS SCREEN OF APP

e) DEPLOYMENT OF NODES IN NODE RED (IBM CLOUD)

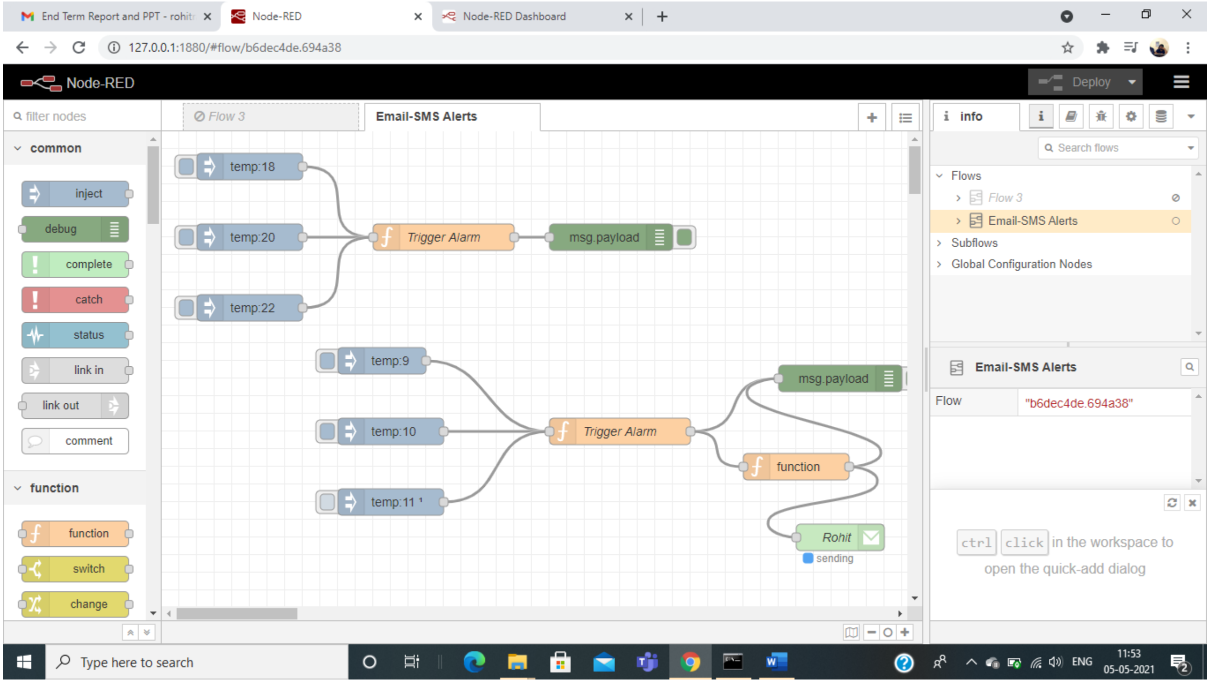


FIGURE 29: EMAIL SMS ALERTS

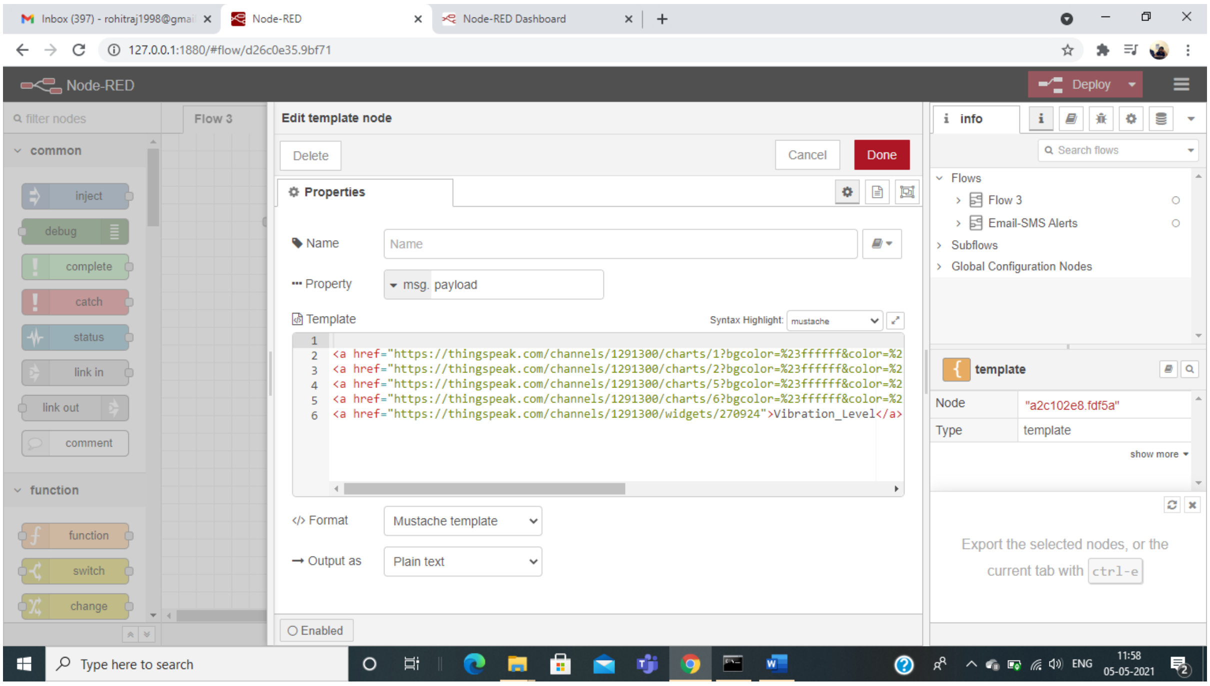


FIGURE 30: HTML CODES IN NODE RED

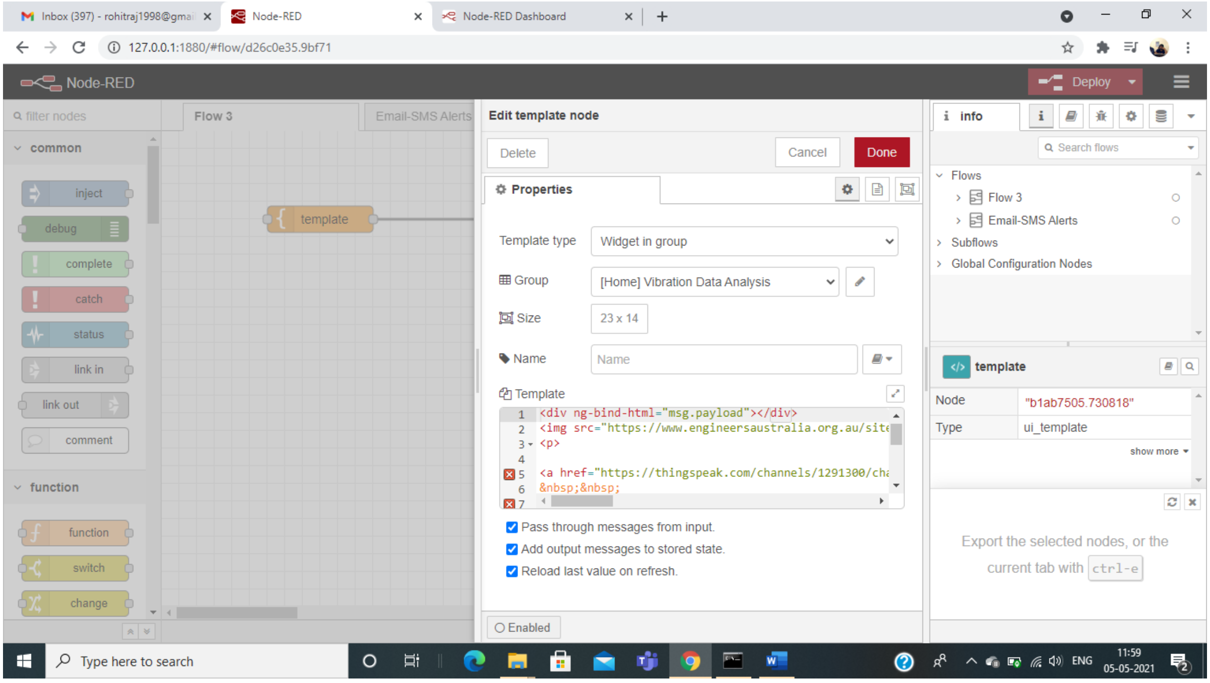


FIGURE 31: HTML CODES IN NODE RED

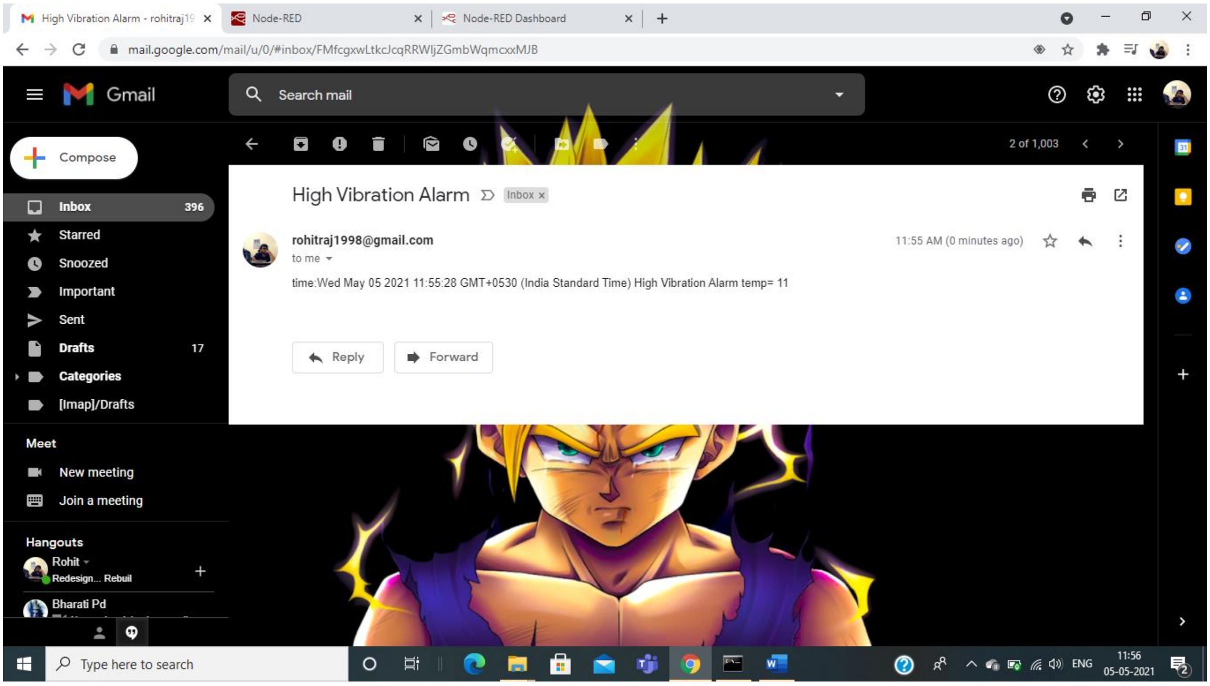


FIGURE 32: ALERT EMAIL RECEIVED BY USER

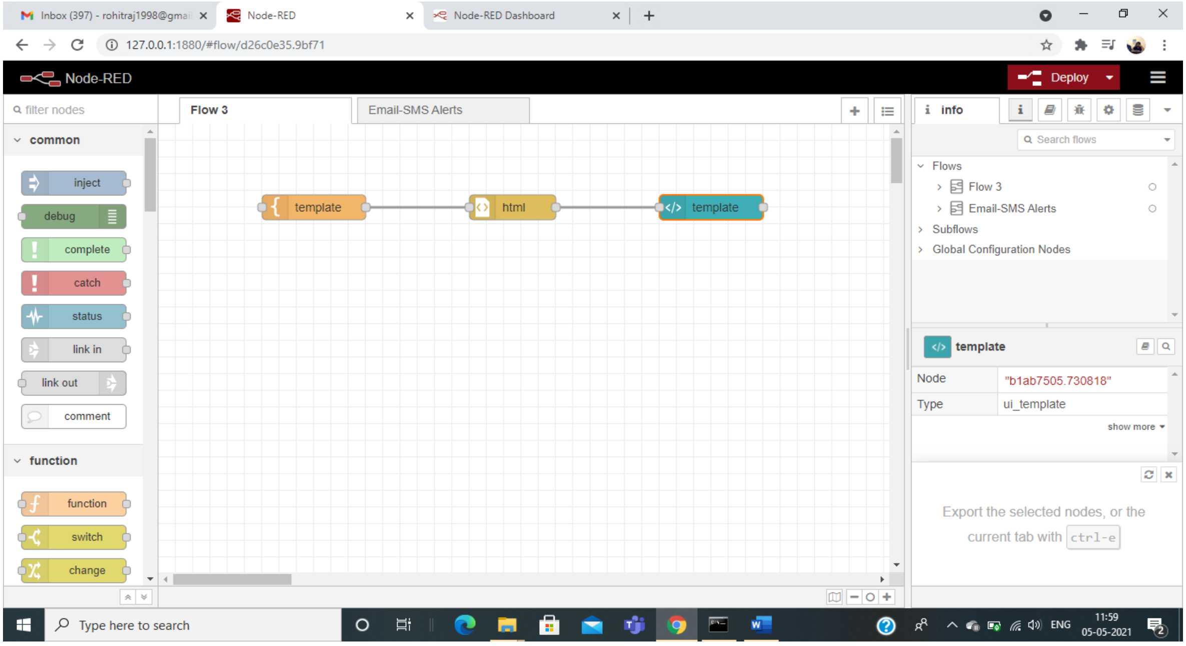


FIGURE 33: UI FOR WEB VIEW

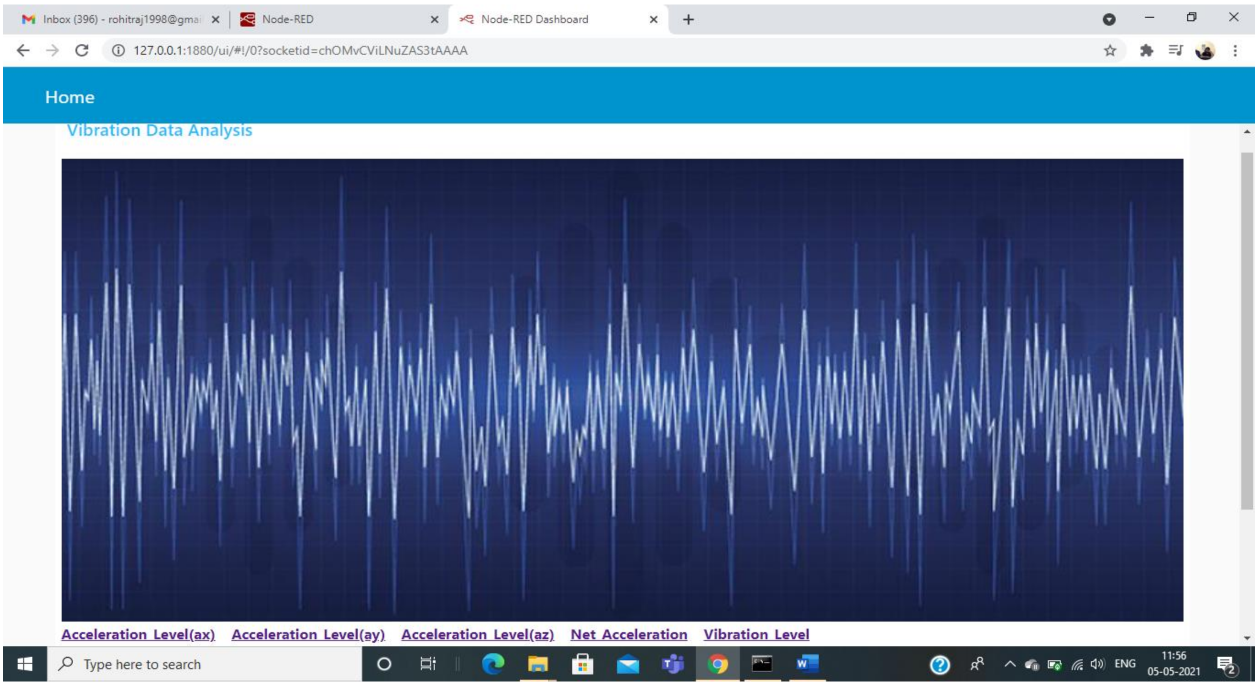


FIGURE 34: DASHBOARD THROUGH NODE RED

4.2 FLOW CHART/ ALGORITHM IMPLEMENTED

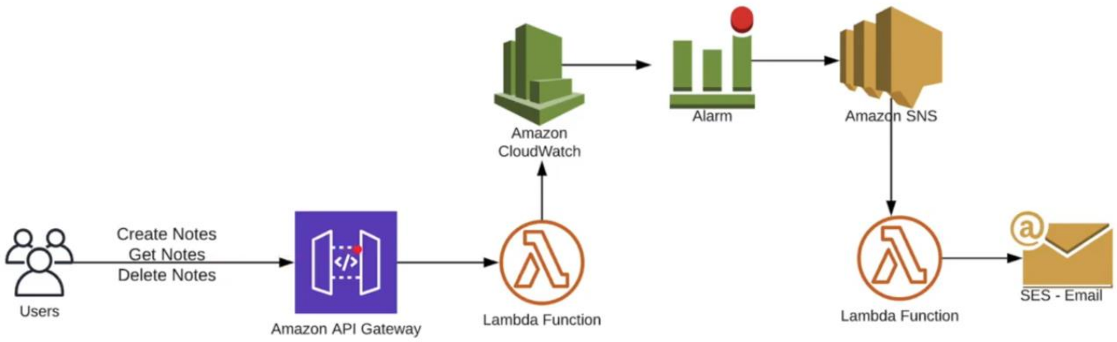


FIGURE 35: REAL-TIME ERROR REPORTING USING AWS FOR MOBILE APP

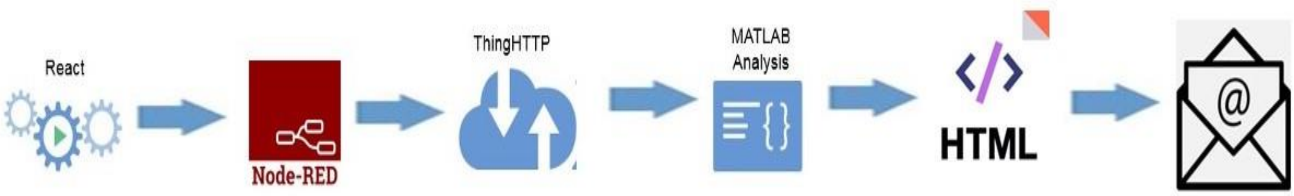


FIGURE 36: EMAIL ALERT AND SMS USING NODE-RED USING IBM CLOUD FOR WEB APPLICATION

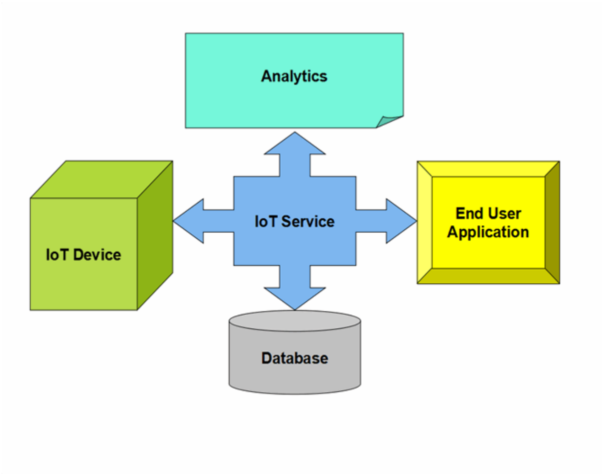


FIGURE 37: DATA ANALYSIS USING IOT BASED CLOUD SYSTEM

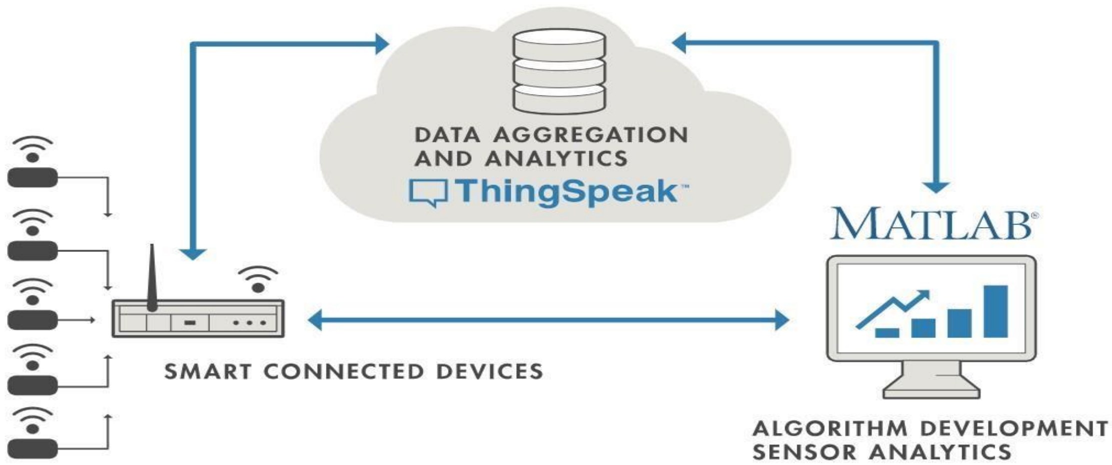


FIGURE 38: NODEMCU TO MATLAB TO THINGSPEAK

CHAPTER 5
RESULTS AND ANALYSIS

5.1 RESULTS OF IMPLEMENTATIONS

For vibration analysis it is required to properly measure the vibration. Vibration measurement can be accomplished measuring various parameters such as displacement, velocity, and acceleration. There are different types of sensing devices to measure the mentioned parameters. Each type of measuring is based on a distinct principle. Vibration is most measured through acceleration using an accelerometer. [3]

An accelerometer calculates the dynamic acceleration and demonstrates it as a voltage in output. Measuring acceleration brings the ability to measure tilt, and vibration or shock. Therefore, accelerometers are employed in a wide range of purposes and applications such as crash detection, hard disk drive protection, impact detection, gaming, pointing devices, and wearable devices. [1]

Accelerometers have diversity in design, size, and range. Accelerometers have various types that are based on different principles. Vibration is mostly measured by a piezoelectric sensor in industry case. This type of sensor works based on the piezoelectric effect that happens when a voltage is produced across types of crystals as they are stressed as per the data shown an industrial piezoelectric accelerometer. IoT technology aims to reduce cabling in such a way to utilize wireless and low power technologies which works with onboard power supply. These are the desirable characteristics that have been mentioned for IoT enabled devices. Thus, the superiority for MEMS accelerometers over legacy piezoelectric sensors in terms of size, weight, power consumption, and potential for integrated intelligent solutions is shown. [5]

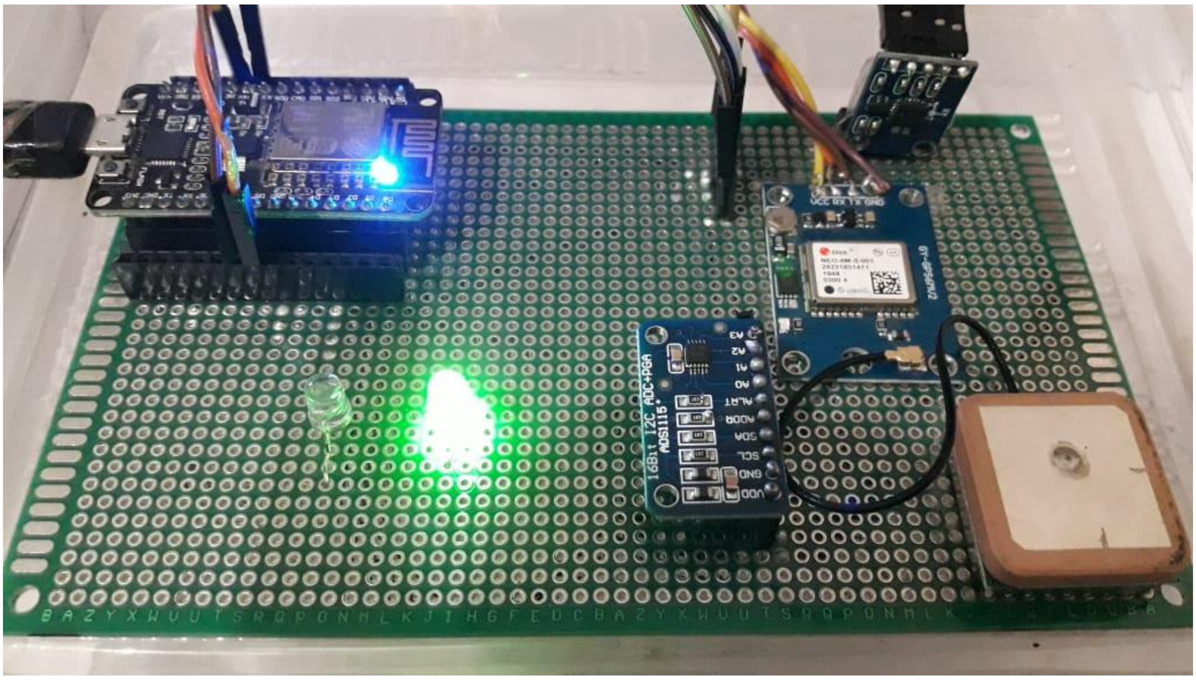
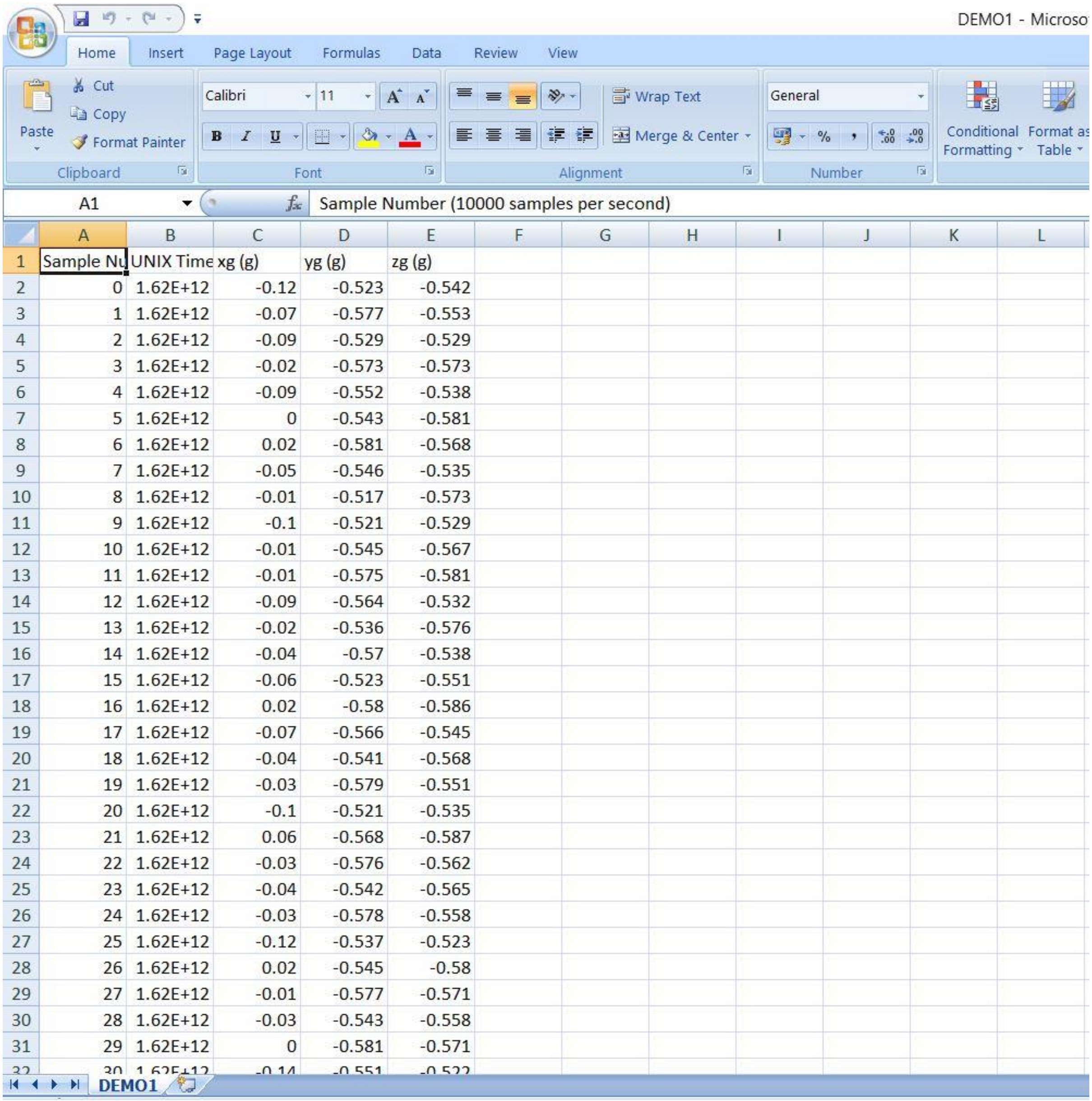


FIGURE 39: LIVE DATA SENSING THROUGH NODE MCU

5.2 ANALYSIS OF RESULTS

Vibration measurement and analysis has traditionally been used to provide condition monitoring of machinery, dynamic qualification in design of novel components, fault prediction, defects within aging structures and the diagnosis of structural dynamic effects. Nevertheless, the usage of MEMS for vibration sensing has been limited to applications that can work with low bandwidth. [5] [3] The key criteria for industrial condition monitoring accelerometers are low noise and wide bandwidth. A few MEMS manufacturers provide MEMS accelerometers with bandwidths above 3.3 kHz while some producers provide accelerometers with bandwidth up to 7.7 kHz). There is no industry standard to define what category an accelerometer fit into, but the categories accelerometers are generally classified into and the corresponding applications are shown. Another limitation of MEMS accelerometer is noise. This is because; noise performance in MEMS is not low enough to detect faults in industrial machines. Although there are some low noise MEMS accelerometers available, they are limited to very-low bandwidth. [2]

Many automatic diagnosis systems for rotating machinery use a signal classification in order to increase accuracy and avoid human error identification. Multiple different sensors mounted on bearings provide information that would not be available from the single sensors. The fusion of data from different sensors enhances fault detection and diagnosis by supplying complementary information. [1]



Sample Nu	UNIX Time	xg (g)	yg (g)	zg (g)
0	1.62E+12	-0.12	-0.523	-0.542
1	1.62E+12	-0.07	-0.577	-0.553
2	1.62E+12	-0.09	-0.529	-0.529
3	1.62E+12	-0.02	-0.573	-0.573
4	1.62E+12	-0.09	-0.552	-0.538
5	1.62E+12	0	-0.543	-0.581
6	1.62E+12	0.02	-0.581	-0.568
7	1.62E+12	-0.05	-0.546	-0.535
8	1.62E+12	-0.01	-0.517	-0.573
9	1.62E+12	-0.1	-0.521	-0.529
10	1.62E+12	-0.01	-0.545	-0.567
11	1.62E+12	-0.01	-0.575	-0.581
12	1.62E+12	-0.09	-0.564	-0.532
13	1.62E+12	-0.02	-0.536	-0.576
14	1.62E+12	-0.04	-0.57	-0.538
15	1.62E+12	-0.06	-0.523	-0.551
16	1.62E+12	0.02	-0.58	-0.586
17	1.62E+12	-0.07	-0.566	-0.545
18	1.62E+12	-0.04	-0.541	-0.568
19	1.62E+12	-0.03	-0.579	-0.551
20	1.62E+12	-0.1	-0.521	-0.535
21	1.62E+12	0.06	-0.568	-0.587
22	1.62E+12	-0.03	-0.576	-0.562
23	1.62E+12	-0.04	-0.542	-0.565
24	1.62E+12	-0.03	-0.578	-0.558
25	1.62E+12	-0.12	-0.537	-0.523
26	1.62E+12	0.02	-0.545	-0.58
27	1.62E+12	-0.01	-0.577	-0.571
28	1.62E+12	-0.03	-0.543	-0.558
29	1.62E+12	0	-0.581	-0.571
30	1.62E+12	-0.14	-0.551	-0.522

FIGURE 40: LIVE DATA THROUGH TELEMETRY VIEWER

1.1.1 2. APPLICATIONS

- To measure Seismic Wave when Earthquake occurs.
- Health Monitoring of Semiconductor Equipment's.

- For predicting failure in Mechanical (e.g.: Motor, Ball Bearings, etc.) equipment's.
- For monitoring heavy machines in factory to avoid great disaster.

CHAPTER 6

CONCLUSION

6.1 DISCUSSION AND CONCLUSION

In this paper, we demonstrated the potentials of IoT for smart maintenance. We explained how IoT can help the condition monitoring and fault diagnosis of rotating machinery using vibration analysis. Further, vibration sensing has been investigated and the new generation of MEMS accelerometers has been introduced. We discussed the superiority of MEMS accelerometers on legacy piezoelectric accelerometers and their importance in the future of smart maintenance. [2] We proposed to make rotating equipment to IoT enabled devices by adding hardware to them. According to the requirements, the hardware was designed and developed. This hardware is able to measure vibrations with 2.5 kHz sampling rate in the range of ±3 g and send them in real-time to a specified server on the cloud. This way the machine will be able to send its vibration status to the server and the maintenance engineers will be able to monitor it anytime, anywhere. The developed hardware has been evaluated by comparing the results of online and local data measurements at the same time. The results of the evaluation have been proved to be very precise. [3]

This paper will prove the concept of using IoT enabled sensors in predictive maintenance to overcome some gaps in the commonly used methods of condition monitoring of rotating machinery. The results can be extended to a larger scope of equipment, faults, and parameters. [7]

6.2 FUTURE SCOPE

The future of smart vibration monitoring belongs to MEMS accelerometers. In this way, they gradually become an alternative approach for vibration monitoring in maintenance. However, MEMS technology has not been fully investigated for much broader applications. One example is that examine the feasibility of utilizing MEMS accelerometer in vibration sensing. It integrates the sensor with the intelligence of vibration analysis. This paper did a similar job to the current paper and has been a primary resource for us. [3] One major difference is that the sensor designed in does not have the ability to send data to the network and it processes the data locally. In other words, it is not IoT enabled. [3] Out of the different technologies, MEMS accelerometers are projected to hold great promise for the future of smart vibration sensing. Number of research studies exist in the literature about MEMS accelerometer construction, mounting considerations, measurement principle and performance evaluation. [7] These MEMS based accelerometers are emerging as an alternate method of sensing the vibration in rotating machines. Although MEMS technology is widely applied in biomedical, automotive and consumer sectors, yet there is a lack of rigorous investigation of MEMS accelerometers performance in vibration measurements under different operating and fault conditions of rotating machines. [8]

LIMITATIONS

The hardware casing is not satisfactory because the sensor is totally in open environment and the circuit is implemented in Vero board. On the other hand, the traditional Vibrometer available in the market has a small and standard casing and for operating some buttons are there. But we cannot do proper casing for ADXL-345 and Arduino due to shortage of time.

COMPARISON BETWEEN PROPOSED AND EXISTING ACCELEROMETER

Vibration Meter made with Accelerometer	VM-6360 VIBROMETER
Frequency sensing level is 3200Hz.	Frequency level is about 10 Hz to 1 KHz.
Accuracy is ± 4.5%	Accuracy level is near to ± 5%
With the help of Wi-Fi module, the resultant value can be observed far away from the experimental area.	There is no data transferring module in it. Now a days some company make laser doppler Vibrometer which contain data transferring module.
The sensor can measure the value without any physical touch.	A build in sensor is inside the vibrometer which sense the vibrating frequency.

Data transferring rate is fast.	There is no option to transfer data in this vibrometer.
Weight is low due to being small in size.	Weight is low but comparatively higher than accelerometer.
There is no use of probes.	With the help of probe or sensor tape data is measured.

6.3 PUBLICATIONS/ CERTIFICATE RECEIVED IF ANY REFERENCES

[1] Mobley, R. Keith. An introduction to predictive maintenance. Elsevier, 2002.

[2] Dhillon, Balbir S. Maintainability, maintenance, and reliability for engineers. CRC press, 2006.

[3] Susto, Gian Antonio, Andrea Schirru, Simone Pampuri, Seán McLoone, and Alessandro Beghi. "Machine learning for predictive maintenance: A multiple classifier approach." IEEE Transactions on Industrial Informatics 11, no. 3 (2015): 812-820.

[4] Susto, Gian Antonio, Alessandro Beghi, and Cristina De Luca. "A predictive maintenance system for epitaxy processes based on filtering and prediction techniques." IEEE Transactions on Semiconductor Manufacturing 25, no. 4 (2012): 638-649.

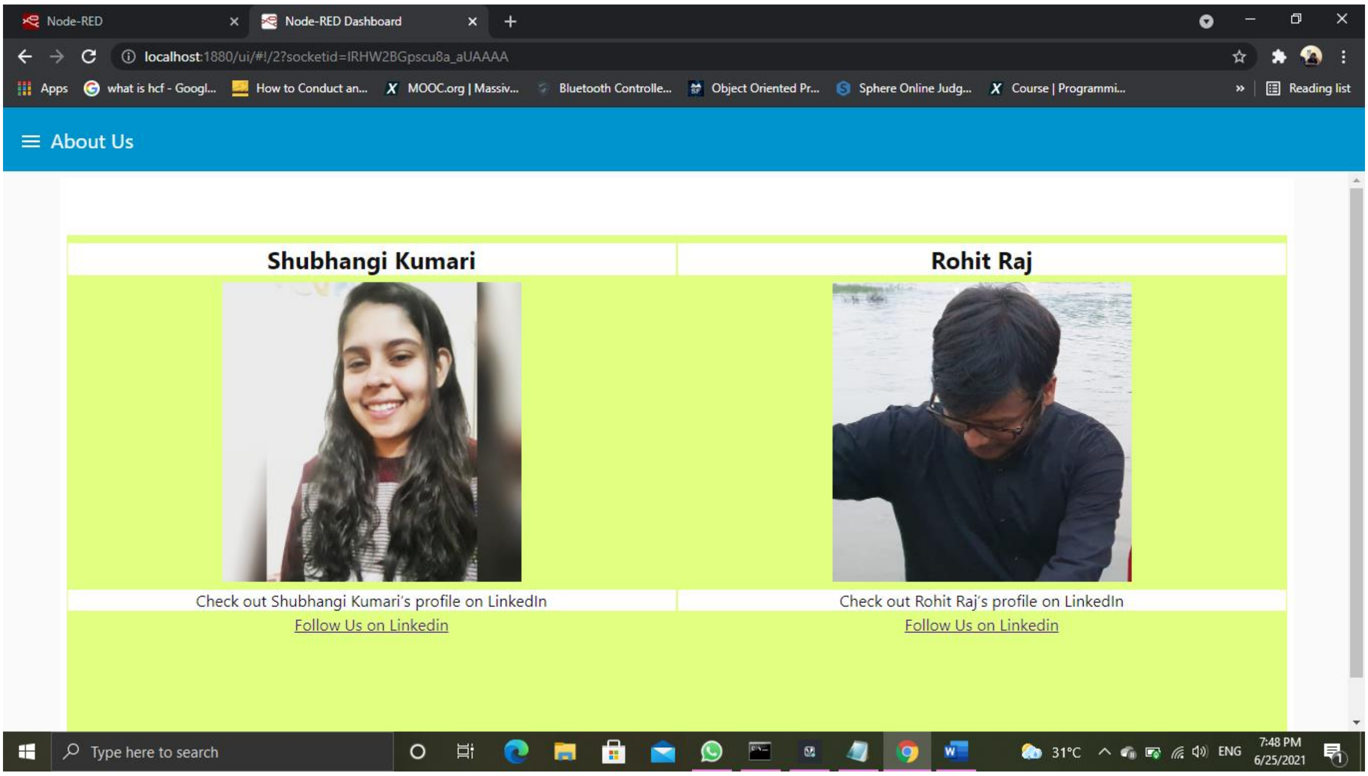
[5] Chaudhury, Subimal Bikash, Mainak Sengupta, and Kaushik Mukherjee. "Vibration monitoring of rotating machines using MEMS accelerometer." International Journal of Scientific Engineering and Research 2, no. 9 (2014): 11.

[6] Wang, Chen, Hoang Tam Vo, and Peng Ni. "An IoT application for fault diagnosis and prediction." In Data Science and Data Intensive Systems (DSDIS), 2015 IEEE International Conference on, pp. 726-731. IEEE, 2015.

[7] Yang, Chen, Weiming Shen, and Xianbin Wang. "The internet of things in manufacturing: Key issues and potential applications." IEEE Systems, Man, and Cybernetics Magazine 4, no. 1 (2018): 6-15.

[8] Daugherty, Paul, Prith Banerjee, Walid Negm, and Allan E. Alter. "Driving unconventional growth through the industrial internet of things." accenture technology (2015).

DEVELOPERS


Node-RED
Node-RED Dashboard
localhost:1880/ui/#!/2?socketid=IRHW2BGpscu8a_aUAAAA
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