iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 6 **Issue:** V **Month of publication:** May 2018

DOI: http://doi.org/10.22214/ijraset.2018.5008

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 6.887
Volume 6 Issue V, May 2018- Available at www.ijraset.com

Vehicle Engine Health Monitoring for early Detection of Excessive Emission to Control Air Pollution

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Abstract: The increase in the number of automobiles day by day is very impending to resolve the problem of air pollution. This results in emission of automobile exhaust gases, which are hazardous for human health. Although government forces all cars for testing or examining periodically as the local standard, the actual vehicle on-road emissions are usually much higher than those which are measured during the emission inspections. To realize green traffic, an automated vehicle health monitoring is the need of the day to control the carbon-di-oxide emission. CO2 emission causes global warming, acid rain and harms the environment, there is a need to develop a vehicle engine health monitoring system for early detection of CO2 emission to reduce air pollution. Vehicle Engine Health Monitoring is to develop an embedded system for detecting the vehicle condition by monitoring the internal parameters that are used in evaluating the vehicle's current health condition. The on-board monitoring equipment consist five gas analyzers for CO, HC(CH4), NO, CO2, SO2which are sensed using gas sensor. The data collected from gas sensor is compared with the standard emission value. Once the emission range varies, the data are transmitted to control system. The control system act as a vehicle notification center, its main role is to notify drivers with a SMS or E-mail to repair their car as soon as possible which helps in increasing life span of vehicle.

I. INTRODUCTION

A. Air Pollution And Its Impact

There is increase in the number of automobiles day by day and it is very impending to resolve the problem of air pollution resulting from automobile exhaust gases, which are hazardous for human health. Many developed countries have established and promoted the motor emission standards to solve the problem of air pollution.

Furthermore, some improved measure in vehicle engines or the quality of gasoline have also been developed by researchers. However, these methods do not seem to solve the emissions pollution problems.

The motor emissions standard is very difficult to implement in real-life. Although government forces all cars for testing or examining periodically as the local standard, the actual vehicle on-road emissions are usually much higher than those which are measured during the emission inspections.

B. CO_2 EMISSION

CO_2 emission causes global warming, acid rain and harms the environment. In spite of using alternative fuel (CNG - Compressed Natural Gas) and (LPG-Low Ground Pressure) and Emission control technologies (Electronic fuel injection to decrease toxity of exhaust leaving engine, Catalytic convertors to detoxify exhaust and Nano fuel additive that is special nanoparticle which detoxify the exhaust without any special device), there is a need to develop a vehicle health monitoring system for early detection of CO_2 emission to reduce air pollution.

C. Embedded Device

The pollutant is monitored and controlled by using real time embedded devices which includes microprocessor, gas sensor, GSM and GPS. The devices are integrated to a controller board.

The CO_2 emission from vehicle is determined. To realize green traffic, an automated vehicle health monitoring is the need of the day to control the carbon-di-oxide emission. The Internet of Things plays a vital role in vehicle engine health monitoring to reduce CO_2 emission

D. Internet Of Things

The term of Internet of Things (IoT) was first invented in 1998. It is a network of networks where many objects or sensors are connected through a communications and information infrastructure to provide value-added services. It assured in creating a world where all the objects around us are connected to the internet and therefore the communication to each other with minimal human intervention. The Internet of Things (IOT) has been defined in a variety of ways. It includes a global, distributed network of physical objects which can sense their environment, and able to communicate with each other. 'Smart' objects can be used in a wide range of sizes and has a capacity to embed simple objects. The aim of Internet of Things is to create a better world for human beings where the objects around us understand our needs and act without any explicit instructions.

E. Need For Vehicle Health Monitoring

A real-time evaluation system is used for rapid condition screening and to provide a reliable information about the vehicle conditions. The real-time evaluation system can also be called as Vehicle Health Monitoring System. The system uses HMI display so that the reports and the alerts can be displayed on it and feedback from the user can be done using a touch response. The system model being developed is a standalone on-board model which will be a black box for outside world. The vehicle health monitoring is one of the applications of IOT. The vehicle health can be monitored automatically with the help of sensing devices and the life span of the vehicle is analyzed. The report can be sent to authorized service center through a wireless communication.

The various benefits of Vehicle Health Monitoring can be listed as,

- ✓ Avoid accidents
- ✓ Time consumption
- ✓ Cost reduction

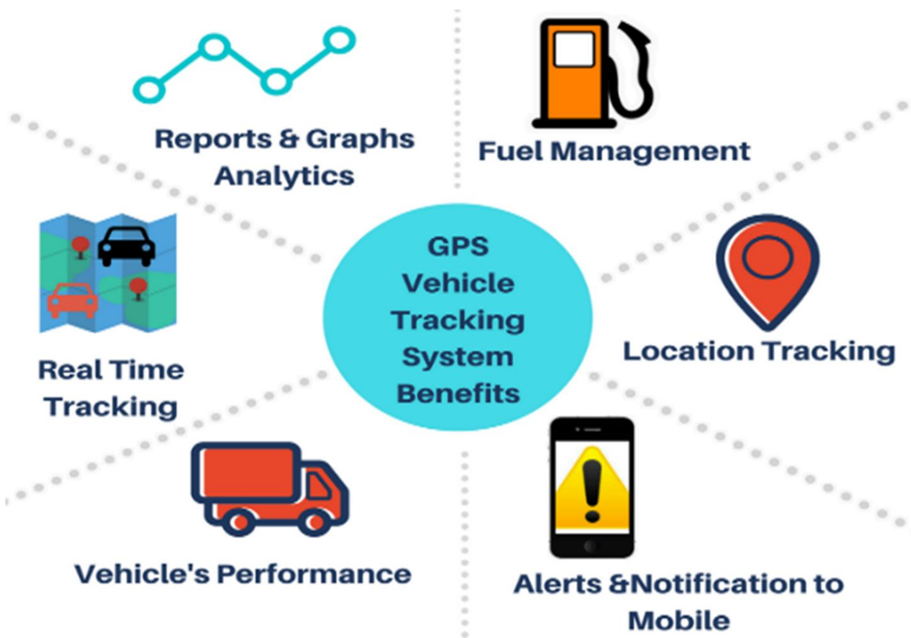

Fig.1.1 Benefits of Vehicle Health Monitoring

The vehicle health monitoring system used to help mechanics to increase maintenance and decrease the costs of engine service by reviewing engine report cards which was generated by a separate on-board computer, the report obtained by the report card can be downloaded at the day end.

The system aims to improve,

1) Safety
2) Availability through better maintenance scheduling
3) Reliability
4) Reduce cost of maintenance

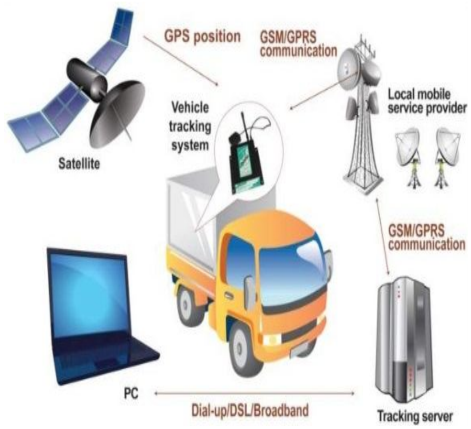

Fig.1.2 Vehicle Tracking System

II. PROPOSED SYSTEM AND METHODOLOGY

The proposed air quality monitoring is based on the data acquired by CO_2 sensor, CO sensor or gas leakage detection sensor. After the data acquisition stage, the pre-processing stage comes in which the Arduino processes the information received from the sensors and changes it into more viable form to be accessed at the base station and by the user. The text message though GSM module marks an extra precaution for the level of CO in air.

The proposed system is depicted in Figure 2.1. The methodology involves various steps such as,

1) *Step 1:* Collection of data from respective sensors about parameters such as air-fuel ratio, engine speed.
2) *Step 2:* Check and determine whether the condition of the inspected vehicle exceeds the local standard
3) *Step 3:* Raise SMS alert to indicate engine health and maintenance requirement.

A. Block Diagram Of Proposed System

The Block diagram of the Vehicle Engine Health Monitoring for Early Detection of Excessive Emission to Control Air Pollution and to send SMS alert is depicted in Fig.2.1.

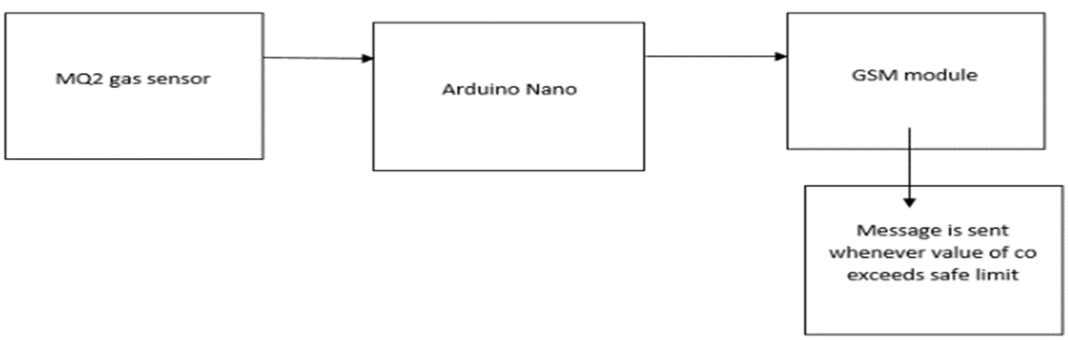

Fig 2.1 Block Diagram of Proposed System

B. Architecture Of Vehicle Engine Health Monitoring System

The architecture of vehicle engine health monitoring system for early detection of excessive emission to control air pollution and to send SMS alert is depicted in Fig.2.2.

A regulatory power supply device is connected to the Micro-Controller Unit. The coding is loaded into Micro-Controller and it is connected to the LCD display. The LCD display is used to display the output. The temperature sensor and flow sensor is connected to Micro-Controller which senses the air-fuel ratio, temperature, and engine speed value and air quality of the vehicle. If the CO2 emission is harmful to the environment, then a beep sound will be produced using the buzzer via the Micro-controller. The vehicle health and CO2 emission are monitored daily, and the report is generated to the vehicle owner via SMS.

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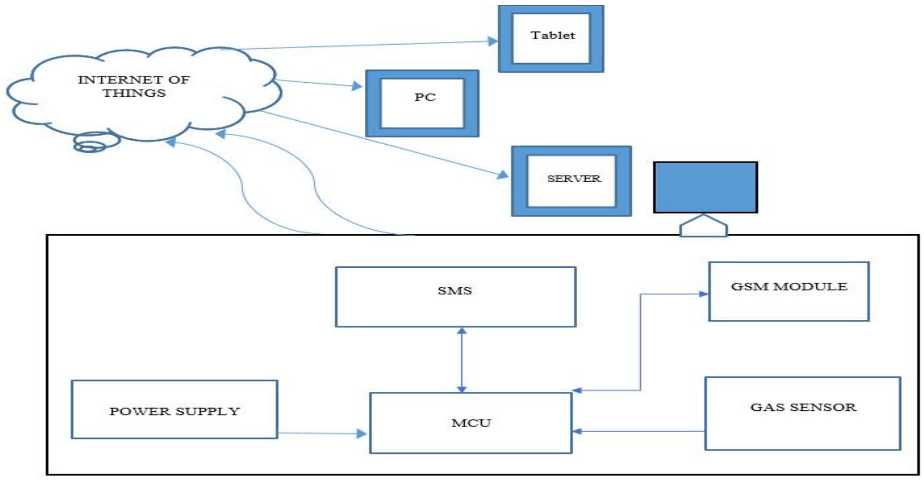

Fig.2.2 Architecture Diagram of Vehicle Engine Health Monitoring System

III. IMPLEMENTATION

The proposed system is implemented in real time by modelling prototype by monitoring vehicle engine health using Gas sensor and Arduino Nano microcontroller and GSM module. GSM board sim900 is used to send SMS alert to the vehicle owner if the CO_2 emission exceeds the standardized value.

A. Vehicle Engine Health Monitoring System

1) Module 1: Air Pollution Data Acquisition
2) Module 2: Engine Health Monitoring System
3) Module 3: SMS Notification

B. Air Pollution Data Acquisition

The initial process is to collect the dataset about the air pollution and emission range of all type of vehicles. The dataset includes Fuel ratio, Engine speed, CO_2 consumption, Vehicle class, Vehicle ID, Miles Per Gallon, so on. The dataset includes 1612 data of different vehicles each vehicle has a unique Id and model name. The data and emission range are inferred from the following web sources provided by Tamil Nadu Air Pollution Control Board (TNAPCB) and World Health Organization(WHO).
http://www.arthapedia.in/index.php?title=Ambient_Air_Quality_Standards_in_India
https://en.wikipedia.org/wiki/Bharat_Stage_emission_standards
http://cpcb.nic.in/Vehicular_Exhaust.php
http://cpcb.nic.in/agra_data.php
http://www.transportpolicy.net/standard/india-air-quality-standards/
https://www.dieselnet.com/standards/in/

Model	Fuel	Stnd	Underhood ID	Air Pollution Score	City MPG	Hwy MPG	Cmb MPG	Greenhouse Gas Score	Comb CO2
CHEVROLET Camaro	Gasoline	L3ULEV70	JGMXV02.0031	5	20	30	23	5	379
CHEVROLET Colorado	Gasoline	T3B70	JGMXT02.5200	5	19	24	21	4	429
CHEVROLET Colorado	Gasoline	L3ULEV70	JGMXT02.5200	5	20	26	22	4	403
CHEVROLET Colorado	Diesel	L3ULEV125	JGMXT02.8358	3	22	30	25	4	413
CHEVROLET Colorado	Diesel	T3B125	JGMXT02.8358	3	22	30	25	4	413
CHEVROLET Colorado	Diesel	L3ULEV125	JGMXT02.8358	3	20	28	23	4	450
CHEVROLET Colorado	Diesel	T3B125	JGMXT02.8358	3	20	28	23	4	450
CHEVROLET Cruze	Gasoline	L3ULEV50	JGMXV01.5002	6	27	40	32	7	277
CHEVROLET Cruze	Diesel	L3ULEV125	JGMXJ01.6356	3	31	47	37	7	276
CHEVROLET Cruze	Diesel	T3B125	JGMXJ01.6356	3	31	47	37	7	276
CHEVROLET Cruze Hatchback	Gasoline	L3ULEV50	JGMXV01.5002	6	27	38	31	7	285
CHEVROLET Cruze Hatchback	Diesel	L3ULEV125	JGMXJ01.6356	3	30	45	35	7	291
FORD F150	Gasoline	L3ULEV70	JFMXT02.73JK	5	19	25	21	4	420
FORD Fusion	Gasoline	L3SULEV30	JFMXV01.5VZ3	7	23	34	27	6	327
HONDA Civic 5Dr	Gasoline	L3SULEV30	JHNXV01.5362	7	31	40	34	8	259
HONDA Ridgeline	Gasoline	L3ULEV125	JHNXT03.5SW4	3	19	26	22	4	410
HYUNDAI Elantra	Gasoline	L3ULEV125	JHYXV01.41D6	3	32	40	35	8	256
HYUNDAI Santa Fe	Gasoline	T3B125	JHYXV03.31XF	3	18	25	21	4	427
HYUNDAI Sonata	Gasoline	L3ULEV70	JHYXV01.61F5	5	28	37	31	7	284
JEEP Cherokee	Gasoline	L3SULEV30	JCRXT02.45P1	7	21	30	25	5	361

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Model	Fuel	Stnd	Underhood ID	Air Pollution Score	City MPG	Hwy MPG	Cmb MPG	Greenhouse Gas Score	Comb CO2
JEEP Cherokee	Gasoline	T3B30	JCRXT02.45P1	7	21	30	25	5	361
TOYOTA 4Runner	Gasoline	T3B125	JTYXT04.0B6S	3	17	21	18	3	479
TOYOTA Avalon	Gasoline	U2	JTYXV03.5B6C	3	21	30	24	5	366
TOYOTA Avalon Hybrid	Gasoline	L3SULEV30	JTYXV02.5P34	7	40	39	40	9	223
TOYOTA C-HR	Gasoline	T3B125	JTYXV02.0K6B	3	27	31	29	6	305
TOYOTA Camry	Gasoline	L3SULEV30	JTYXV02.5P3A	7	29	41	34	8	264
TOYOTA Camry Hybrid XLE/SE	Gasoline	T3B30	JTYXV02.5P33	7	44	47	46	10	195
TOYOTA Camry LE/SE	Gasoline	L3SULEV30	JTYXV02.5P3A	7	28	39	32	7	277
TOYOTA Camry XLE/XSE	Gasoline	T3B30	JTYXV02.5P3A	7	28	39	32	7	274
TOYOTA Camry XSE	Gasoline	L3ULEV70	JTYXV03.5M5B	5	22	32	26	5	345
TOYOTA Corolla	Gasoline	U2	JTYXV01.8B6A	3	28	35	31	7	286
TOYOTA Corolla LE Eco	Gasoline	L3ULEV70	JTYXV01.8M5B	5	29	38	33	8	271
VOLKSWAGEN Beetle	Gasoline	L3SULEV30	JVGAV02.0V3R	7	26	33	29	6	308
VOLKSWAGEN Beetle Dune Con	Gasoline	T3B30	JVGAV02.0V3R	7	26	34	29	6	305
VOLKSWAGEN Golf R	Gasoline	T3B125	JVGAV02.0AUA	3	22	29	25	5	354
VOLKSWAGEN Jetta	Gasoline	T3B125	JVGAV01.4VUP	3	28	40	33	8	271
VOLKSWAGEN Jetta	Gasoline	T3B30	JVGAV02.0VPD	7	24	33	27	6	326
VOLKSWAGEN Passat	Gasoline	L3SULEV30	JVGAV02.0V3R	7	25	36	29	6	302
VOLKSWAGEN Passat	Gasoline	T3B30	JVGAV02.0V3R	7	25	36	29	6	302
VOLKSWAGEN Tiguan	Gasoline	L3SULEV30	JVGAJ02.0A3A	7	22	27	24	5	368

Model	Fuel	Stnd	Underhood ID	Air Pollution Score	City MPG	Hwy MPG	Cmb MPG	Greenhouse Gas Score	Comb CO2
VOLKSWAGEN Tiguan	Gasoline	T3B30	JVGAJ02.0A3A	7	22	27	24	5	368
VOLKSWAGEN Tiguan 4Motion	Gasoline	L3SULEV30	JVGAJ02.0A3A	7	21	27	23	5	382
VOLKSWAGEN Tiguan 4Motion	Gasoline	T3B30	JVGAJ02.0A3A	7	21	27	23	5	382
VOLVO Atlas	Gasoline	L3ULEV70	JVGAT03.6VAS	5	18	25	20	4	438
VOLVO Atlas	Gasoline	T3B70	JVGAT03.6VAS	5	18	25	20	4	438
VOLVO Atlas 4Motion	Gasoline	L3ULEV70	JVGAT03.6VAS	5	17	23	19	3	454
VOLVO Atlas 4Motion	Gasoline	T3B70	JVGAT03.6VAS	5	17	23	19	3	454
VOLVO S60	Gasoline	L3SULEV30	JVVXV02.0030	7	25	36	29	6	304
VOLVO S60	Gasoline	T3B30	JVVXV02.0030	7	25	36	29	6	304
VOLVO S60 Polestar	Gasoline	L3LEV160	JVVXV02.0160	1	20	27	22	4	393
VOLVO S60 Polestar	Gasoline	T3B160	JVVXV02.0160	1	20	27	22	4	393
VOLVO S90	Gasoline	L3ULEV125	JVVXJ02.0125	3	24	34	27	6	322
VOLVO S90	Gasoline	T3B125	JVVXJ02.0125	3	24	34	27	6	322

Fig.3.1 Air Pollution Data Acquisition

C. Engine Health Monitoring System

The engine health is monitored mainly to reduce the air pollution and to increase the life span of the vehicle. A typical passenger vehicle emits 4.7 tons of carbon dioxide per year. The average gasoline vehicle on road today has Fuel economy of about 21.6 miles per gallon. Drives around 11,400 miles per year. Every gasoline burn creates about 8,887 grams of CO_2.

S.NO	CO_2 EMISSION	CO_2/GALLON
1	Petrol	8,887 grams
2	Diesel	1,180 grams

Table.3.1 CO_2 Emission Range

The parameter of engine includes Fuel economy, Vehicle speed limit, Engine speed limit, Air pollution class, Engine Oil, Coolant Oil, Break Oil, Break Shoe, CO_2 combustion. The engine health monitoring system consist of Arduino Nano, Gas sensor and GSM module. The working of engine health monitoring is depicted in Fig.3.2. The Arduino Nano and gas sensor are used to control CO_2 emission from vehicle.

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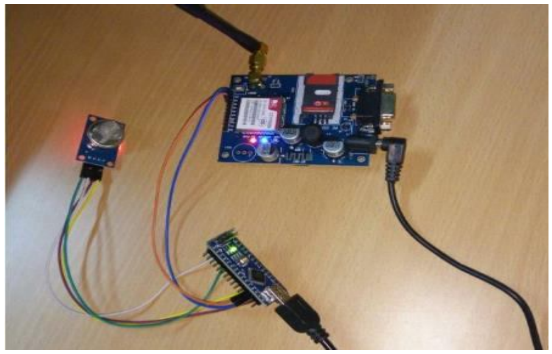

Fig.3.2 Interfacing MQ-2 Gas Sensor, Arduino Nano and GSM Board

D. Arduino Nano

The Arduino Nano is a breadboard-friendly small board on the ATmega328 (Arduino Nano 3.x) or ATmega168 (Arduino Nano 2.x). The powered supplied to Arduino Nano via the Mini-B USB connection, in which 6-20V unregulated external power supply (pin 30), or 5V regulated external power supply (pin 27) is applied. The power source is selected to the highest voltage automatically if needed. The code will be uploaded into the microcontroller that present inside the Arduino Nano and using serial monitor the output will be generated

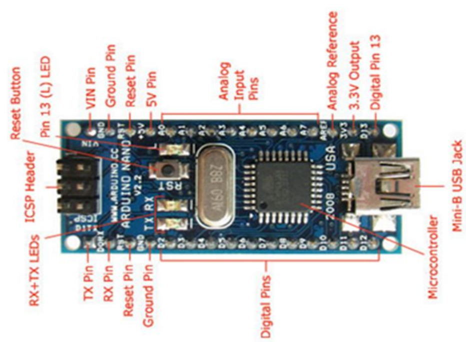

Fig.3.3 Arduino Nano(ATmega328)

E. CO_2 Gas Sensor

The MQ gas sensors has a small heater inside a electro-chemical sensor. The output is a analog signal which can be read using an analog input from Arduino. The resistance of the sensor is varies depending on the type of the gas. The smoke sensor provided with a built-in potentiometer which help us to adjust the sensor sensitivity based on the accuracy which you want to detect gas.

Fig.3.4 Gas Sensor

The MQ-2 smoke sensor is sensitive to smoke and flammable gases such as LPG, Butane, Propane, Methane, Alcohol, Hydrogen The voltage that the sensor outputs changes accordingly to the smoke/gas level that exists in the atmosphere. The sensor outputs a voltage that is proportional to the concentration of smoke/gas.

The relationship between voltage and gas concentration is the following:

1) *The greater* the gas concentration, the greater the output voltage
2) The lower the gas concentration, the lower the output voltage

The output can be an analog signal (A0) that can be read with an analog input of the Arduino or a digital output (D0) that can be read with a digital input of the Arduino.

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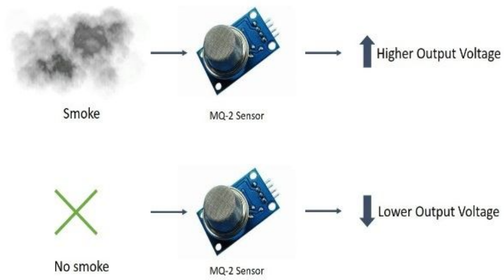

Fig.3.5 Relationship between Voltage and Gas Concentration

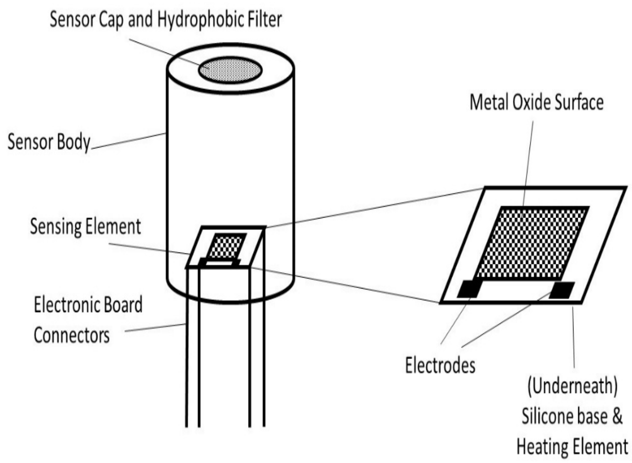

Fig.3.6 Gas Sensor Components

F. Interfacing Gas Sensor And Arduino Nano

The interface between Gas sensor and Arduino Nano are depicted in fig.3.9.

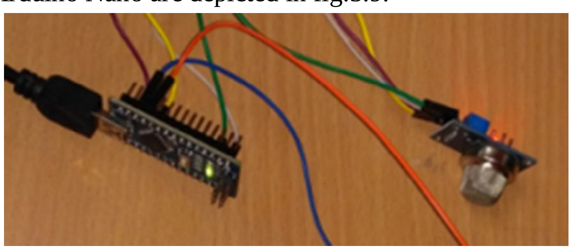

Fig.3.7 Working of Gas Sensor

G. SMS Notification

GSM module is a system of SIM900 Quad-band/SIM900A and a Dual-band GSM/GPRS module breakout board. It can be communicated using controllers via AT commands. This module supports software power on and reset. The SMS application is intended for the person who is monitoring the value of CO in a vehicle whenever it exceeds a safe limit chosen according to an application. The threshold safe limit as well as the mobile number of the person to which the text message is to be sent is programmed in the Arduino which can be changed for any specific purpose.

1) *GSM Module:* The vehicle health and CO2 emission are monitored daily, and the report is generated to the vehicle owner via SMS, whenever value of CO_2 exceeds safe limit using GSM we send a SMS alert to the vehicle owner.The component of GSM Board SIM900A is depicted in Fig.3.11.

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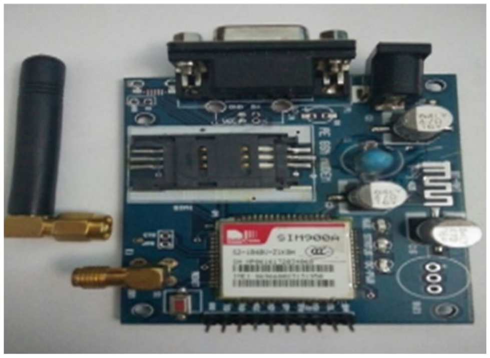

Fig.3.8 GSM Board SIM900A

The interfacing between Arduino Nano, Gas sensor and GSM module to notify SMS alert is depicted in Fig3.12.

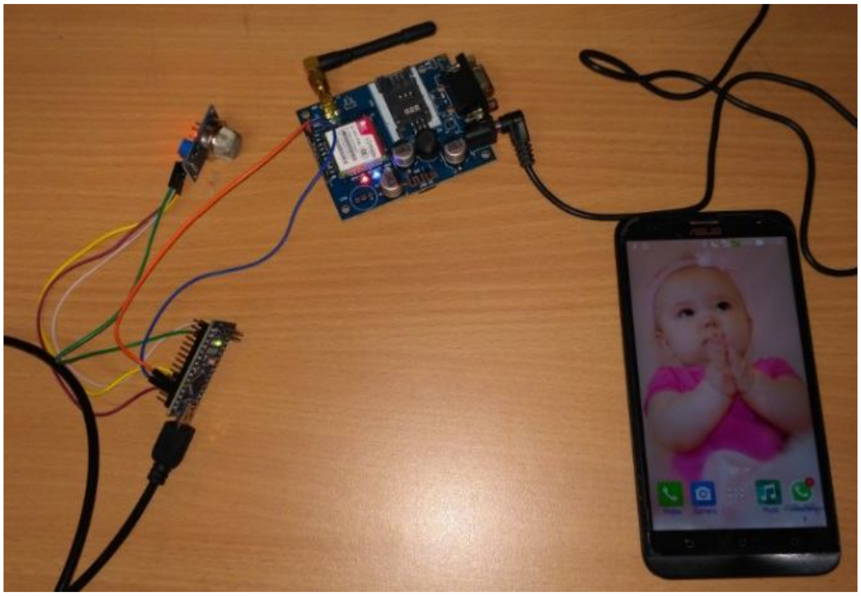

Fig.3.9 SMS Notification System

IV. RESULTS AND DISCUSSION

The standard values for allowable co2 emission for heavy diesel vehicles, 2/3 wheelers and passenger cars that are collected from web sources of Tamil Nadu Air Pollution Control Board(TNAPB) and World Health Organization(WHO) air quality guidelines. The results obtained from engine health monitoring system module has been compared with standard values.

A. Standard Emission Norms

The standard emission norms for heavy diesel vehicles includes range for CO, HC, NOX and PM are depicted in Table.4.1.

NORMS	CO(g/kmhr)	HC(g/kmhr)	NO_x(g/kmhr)	PM(g/kmhr)
1991 Norms	14	3.5	18	-
1996 Norms	11.2	2.4	14.4	-
India Stage 2000 norms	4.5	1.1	8.0	0.36
Bharat Stage-II	4.0	1.1	7.0	0.15
Bharat Stage-III	2.1	1.6	5.0	0.10
Bharat Stage-IV	1.5	0.96	3.5	0.02

Table.4.1 Standard Emission Norms for Heavy Diesel Vehicles

The standard emission norms for 2/3 wheelers are depicted in Table.4.2.

NORMS	CO(g/kmhr)	HC+ NO_x (g/kmhr)
1991 Norms	12-30	8-12(only HC)
1996 Norms	4.5	3.6
India Stage 2000 norms	2.0	2.0
Bharat Stage-II	1.6	1.5
Bharat Stage-III	1.0	1.0

Table.4.2 Standard Emission Norms for 2/3 Wheelers

The standard emission norms for passenger cars includes CO and HC+NOX gases are depicted in Table.4.3.

NORMS	CO(g/kmhr)	HC+ NO_x (g/kmhr)
1991 Norms	14.3-27.1	2.0(Only HC)
1996 Norms	8.68-12.40	3.00-4.36
1998 Norms	4.34-6.20	1.50-2.18
India Stage 2000 norms	2.72	0.97
Bharat Stage-II	2.2	0.5
Bharat Stage-III	2.3	0.35(combined)
Bharat Stage-IV	1.0	0.18(combined)

Table.4.3 Standard Emission Norms for Passenger Cars

B. *Excessive Emission Monitoring*

In the proposed vehicle health monitoring system, an automatic vehicle emission testing process is done based on gas sensors. The gas sensor detects the CO2 emissions from the vehicle under monitoring. The collected value from gas sensor is compared with the standard value. When the amount of CO2 released from the vehicles is greater than the standard value, an SMS alert will be sent to the concerned vehicle owner.

Fig.4.4. Excessive Emission Monitoring

V. CONCLUSION

An embedded system for air pollution detection has been implemented. Here only carbon monoxide gas has been detected as vehicle's exhaust gases contain maximum of 42% of CO gas. The gas sensors and the critical level of the relevant gas should be recognized, and then this system can be implemented for detecting various gases either in domestic area such as places of residential and industrial areas which avoids endangering of human lives. This system provides quick response and the dispersal of the critical situation can be made faster than the manual methods.

VI. FUTURE WORK

The future work can be extended by adding GPS with the GSM module and sending a message to the user about the details of the nearest service station. A server and database can be maintained to keep track of the pollution level of the system and control action on the owner can be taken if the pollution level alert is ignored.

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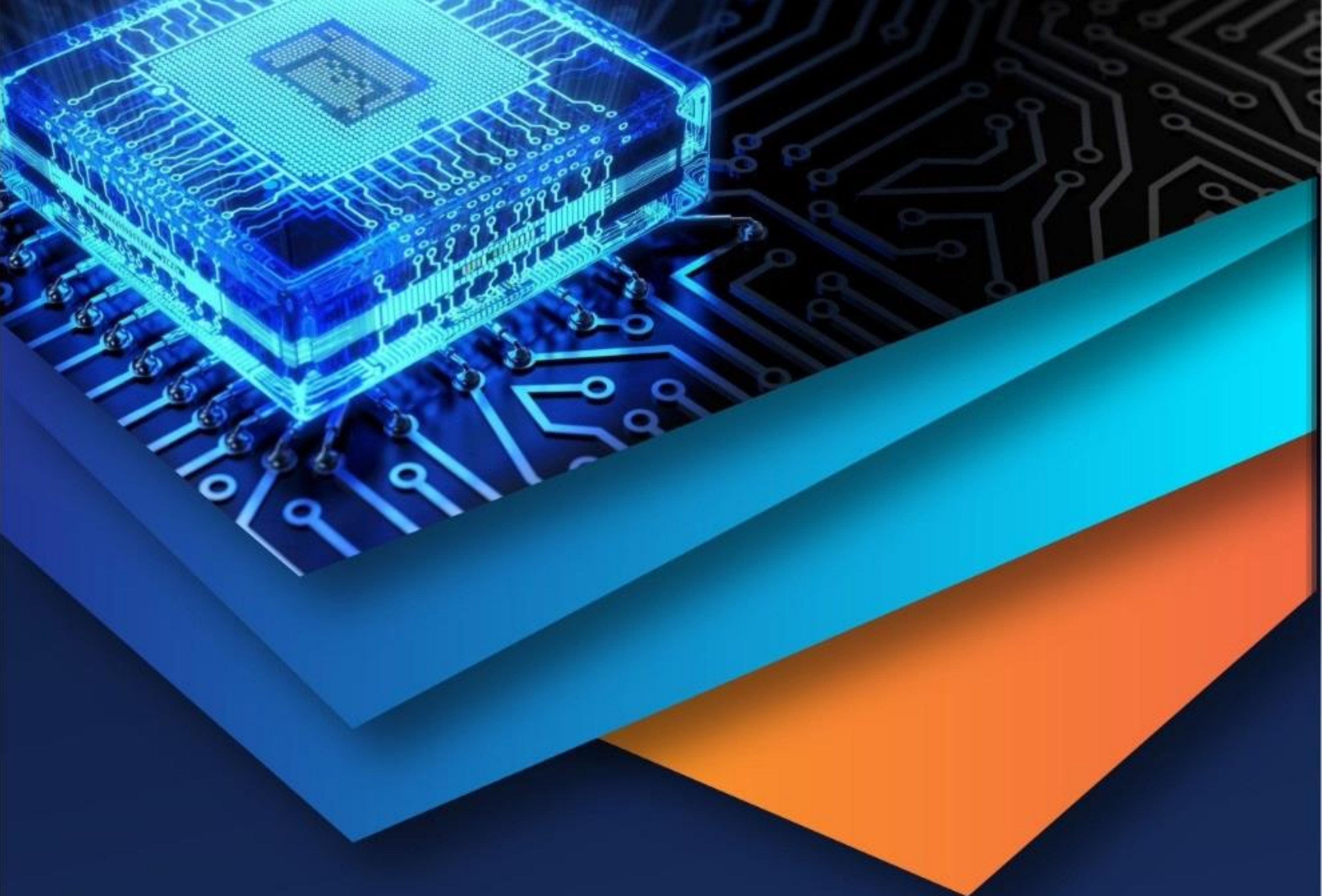

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