

Palestine Polytechnic University



College of engineering and technology
Mechanical engineering department

Monitoring of Vehicle Exhaust Gases (CO₂, NO_x, CO) Using Embedded Controller

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Project Name

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According to the project supervisor and according to the agreement of the Testing Committee Members, this project is submitted to the Department of Mechanical Engineering at College of Engineering and Technology in partial fulfillments of the requirements of (B. SC) degree.

Supervisor's Signature

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Examine Community Signature

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December- 2019

Dedication

الى الأبوّة والأخوة .. الى اللذين لولاهم ما كنا
الى دائرة الهندسة الميكانيكية في جامعة بوليتكنك فلسطين

الى التي تعرقت جبهتها لتقديم اليد التي زرعت هذه البذرة فأنبئت هذه الفكرة

الى من قدم لي الكثير الكثير
الى مشرفي العزيز

الى من ساندني وزرع حب العلم في نفسي
الى من ساندني ووقف بجاني يدا بيد

Abstract

Air pollution is one of the most important problems facing our society, The increase in the number of automobiles day by day is very impending to resolve the problem of air pollution, CO₂ emission causes global warming, acid rain and harms the environment This results in the 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-dioxide emission, 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 consists three gas analyzers for CO, NO_x, CO₂, which are sensed using gas sensor. The data collected from gas sensor are compared with the standard emission value. Once the emission range varies, the data are transmitted to the control system, and to help the Environment Quantity Authority identify illegal cars and repair their car as soon as possible, which helps in increasing life span of a vehicle and reduce operating cost through efficient combustion process.

يعد تلوث الهواء أحد أهم المشكلات التي تواجه مجتمعنا مع زيادة عدد السيارات يوما تلو الآخر وهذا يؤدي الى تلوث الهواء بسبب الانبعاثات الصادرة من عوادم السيارات ويؤثر على صحة الانسان والبيئية وتعمل الحكومات على مراقبة نسبة الانبعاثات عن طريق اختبارات وفحوصات سنوية ولكن انبعاثات سيارات على الطريق تكون أكثر مما هي موجودة أثناء الفحوصات ومن خلال هذا النظام سنراقب انبعاثات أكاسيد النيتروجين وأول أكسيد الكربون وثاني أكسيد الكربون من خلال مجموعة من السنسور سيتم تثبيتها داخل أنابيب العادم واطهارها بمجرد اختلاف نطاق الانبعاث ، يتم نقل البيانات إلى نظام التحكم ، ولمساعدة هيئة البيئة على تحديد السيارات غير القانونية وإصلاح سياراتهم في أسرع وقت ممكن مما يساعد في زيادة العمر الافتراضي للسيارة.

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Chapter One

Introduction

1.1 Overview

1.2 Background

1.3 Objectives

1.4 Project Importance

1.5 Literature Review

1.6 Implementation Plan Time Table

1.7 Project Budget

1.1 Overview

This chapter presents a general description of the system, starting with a background, objectives, the importance of the system, requirements, motivation, project schedule, time plan and budget.

1.2 Background

Emissions of the combustion of the fuel inside the engine are one of the greatest challenges that face the automotive engineers and the automotive companies. Most of the studies today head to reduce the effect of pollution that can be recognized everywhere like global warming, acid rain, smog and particles in the air. Lots of research have been established to focus on this purpose.

Emissions of burning the fuel inside the engine show in figure (1.1) contain four major kinds of elements which are the high percentage of the automotive emissions and they are:

- 1) Carbon monoxide (CO); this compound is produced during incomplete combustion (insufficient amount of air).
- 2) Unburned hydrocarbon (UHC); this compound is produced during incomplete combustion or unsuitable mixing (partial combustion).
- 3) Nitrogen oxides (NO_x) include Nitric oxide (NO), Nitrogen dioxide (NO_2), and Nitric oxide (NO) are produced during combustion in the hot burned gases.
- 4) Particulate matters PM; this compound produced during the compression ignition engines (CIE) more than spark ignition engines (SIE).

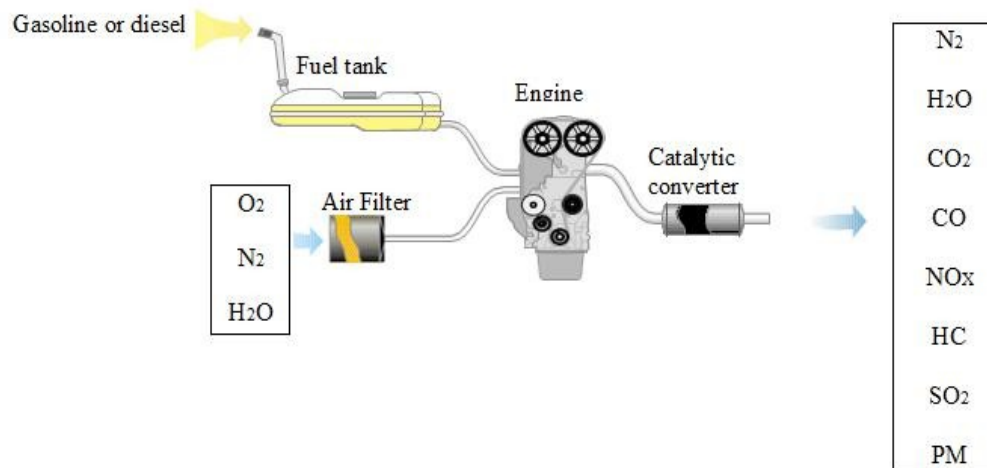


Figure 1.1: Combustion Components and Combustion Product [1].

1.3 Objectives

The main objectives that we want to achieve in our project are the following:

- 1) Design and construction of a system for monitoring the proportion of exhaust gases, and link these readings in the application.
- 2) Reduce operating cost through efficient combustion process based on gas readings.
- 3) Enable the environmental authorities to determine the validity of the vehicle on the road.
- 4) Show the gases concentrations on an application to warn the driver when any problem occurs in the proportion of exhaust gases and go to maintain this problem.

1.4 Project Importance:

The importance of the project is summarized as follows:

- 1) Cars powered by internal combustion engines rely on systems designed for the environment to reduce these emissions specifically. However, in case of any problems in these systems, workshops cancel these systems to reduce the cost of replacing them. This affects human health, the environment, and the ozone layer.
- 2) Through our designed system, we will enable the environmental authorities to detect any manipulation of environmental systems by showing the emissions percentage on the application.
- 3) The device we are going to design will be easy to handle by environmental authorities unlike other devices, it does not need experienced people to deal with the system.
- 4) The price of the device is cheap in comparison with other devices and does not require special equipment for installation.
- 5) The device will be able to store the exhaust gas readings and refer to them at any time.

1.5 Literature Review

Many studies about emission reduction had been investigated; the following studies were introduced in that field.

1.5.1 Estimation of Emitted vehicles Emissions in Palestine

Basil Shalabe, Ahmad Hoshia, Ibrahim Khraiwesh, under supervision of Zuhdi.Salhab introduced this study, study description as the following:

This study about air pollution as one of the most important problems facing our society, through the increasing of pollution sources, and it causes many problems and diseases in humans, animals and plants. Vehicles are considered to be the most important source of pollution due to their increasing numbers and there are no specific emission standards, The pollutant such as Carbon monoxide (CO), Nitrogen Oxides (NO_x), Particulate Matters (PM), Hydrocarbons (HC), Volatile Organic Compounds (VOCs) and sulfur dioxide (SO₂) and this emission cause many problems like acid rain, health hazards and destroy the Ozone. In this project study was made about the traffic emissions estimated in West Bank relying on the

emission factors as input together with vehicle types, annual traveled distance, etc., The amount of pollution was large because air pollution is growing with increasing number of vehicles and with absence of the censorship a large quantity of air pollution resurrect in air, this endanger the environment.

1.5.2 Controlling Toxic Emission Exhaust in vehicle Using Chemically Modified Catalytic Converter

H.AL-Sarsour, and M Nairoukh; under supervision of Zudhi.Salhab, and M.Jabari introduced this study, study description as the following:

Exhaust gas pollutants emitted to the atmosphere are seriously hygienic and environmental risk. This project responds to environmental and humanity needs to reduce the concentration of toxic emissions by injection an optimum amount of urea into the exhaust manifold to react with NO_x and CO emissions inside catalytic converter. In order to achieve these goals, a new system was designed and implemented. The designed system is composed of mechanical and electronic parts such as sensors. Sensors are located before and after catalytic converter for measuring removal efficiency of catalytic converter. The effect of operational parameters was investigated for reducing the emission concentration. Experiments with new system were performed on a diesel engine. The effect of operational parameters such as (engine speed, diesel injection timing, A/F ratio and urea injection quantity) on the efficiency of the catalytic converter before and after urea injection. We observed that the concentrations of NO_x and CO emissions reduced with injection urea in the exhaust, and the removal efficiency of catalytic converter is enhanced.

1.5.3 Reduction of the Car Toxic Emissions by using Double Catalytic Converter:

Mohammed Aljamal, under supervisor: Dr.Zuhdi Salhab introduced this study, study description is as the following:

Internal combustion engine vehicles are responsible for the vast majority of pollutants that plague urban areas today. Studies of the sources of air pollution have shown that transportation accounts for the majority of nitrogen oxide (54%) and carbon monoxide (89%) emissions in urban areas. Furthermore, internal combustion engines are also considered to be one of the largest sources of carbon dioxide. Internal combustion engine vehicles also generate other types of pollutants including sulfur oxides and hydrocarbons.

These emissions are directly responsible for many of the air quality and human health problems, therefore the scientists focused on finding a solution for reducing these emissions, then they found many solutions for control of these emissions such as using catalytic converter. A catalytic converter is a vehicle emissions control device that converts toxic pollutants in exhaust gas to less toxic pollutants by catalyzing a redox reaction (oxidation or reduction).Due to the effectiveness of catalytic converter in reduction of the exhaust gas pollutants, this project introduces studying and evaluating the effect of adding secondary catalytic converter on emissions performance by designing and building a new exhaust system by using double catalytic converters.

1.5.4 Automated Control System for Air Pollution Detection and Rash Driving Prevention in Vehicles:

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.

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.

1.6 Implementation Plan Time Table

The project is divided into two stages (semesters). In the first stage, the following tasks were implemented.

- 1) Planning and setting project concept and aim.
- 2) Establishing scientific background.
- 3) Literature review is being introduced.
- 4) Choosing suitable requirements for implementation.
- 5) Proposition suitable experimental setup design.

In the second stage (semester), the following tasks will be implemented

- 1) Preparing the system parts.
- 2) Building experimental setup.
- 3) Checking the project parts and perform initial experiments.
- 4) Performing final experiments.
- 5) Analyzing the experimental results.

Table 1.1: The Time Table For the First Semester

TASKS	1 st Month				2 nd Month				3 rd Month				4 th Month			
	WK ₁	WK ₂	WK ₃	WK ₄	WK ₁	WK ₂	WK ₃	WK ₄	WK ₁	WK ₂	WK ₃	WK ₄	WK ₁	WK ₂	WK ₃	WK ₄
Identification of project idea	█	█														
Drafting a preliminary project Proposal			█	█												
Establishing scientific background					█	█	█									
Documentation of literature review						█	█	█								
Choosing suitable requirements for implementation								█	█	█	█					
Suggestion a setup project design										█	█	█	█			
Writing first draft report									█	█	█	█	█	█	█	
Presentation of first semester																█

Table 1.2: The Time Table For the Second Semester

TASKS	1 st Month				2 nd Month				3 rd Month				4 th Month			
	WK ₁	WK ₂	WK ₃	WK ₄	WK ₁	WK ₂	WK ₃	WK ₄	WK ₁	WK ₂	WK ₃	WK ₄	WK ₁	WK ₂	WK ₃	WK ₄
Preparing a system parts	█	█	█	█												
Building an experimental setup			█	█	█	█	█									
Checking the project parts and Perform initial experiments						█	█	█	█							
Performing the final experiment									█	█	█					
Taking and analyzing the Experimental results											█	█	█			
Writing a second report												█	█	█	█	
Presentation of second semester																█

1.7 Project Budget

The total estimated cost for implementing this project is estimated at 810 \$ as detailed in Table (1.3).

Table 1.3: The total estimated cost for implementing

NO.	Item	Quantity	Unit Cost (\$)	Total cost (\$)
1	CO Sensor	1	100	100
2	CO ₂ Sensor	1	100	100
3	NO _x Sensor	1	80	80
4	Pressure Sensor	1	100	100
5	OBD-II Adaptor	1	40	30
6	Microcontroller	1	250	250
7	Nano Arduino	1	20	20
8	Wires	1	50	50
9	Pipe	1	80	80
10	Total Estimated Costs			810

Chapter Two

Combustion and Factors Affecting Vehicle Emissions

2.1 Introduction

2.2: Combustion

2.3: Exhaust Emission

2.4 The Factors Affecting Vehicle Emissions

2.5: Evaporative Emissions

2.6: The Problems of Emissions

2.7: Emission control methods

2.1 Introduction

Community and government pressure to reduce vehicle exhaust emissions is reflected in the current and projected future. Various factors affect the amount of emissions from internal combustion engines in any given situation such as vehicle class and weight, vehicle setup, fuel type, engine exhaust after processing, vehicle age, impacts of terrain and engine control (such as injection timing strategies) on measured emissions.

2.2 Combustion

Combustion in an internal frequency combustion engine starts sometime near the end of the compression pressure, and ends during the expansion stroke, when most of the fuel is oxidized. It is combustion, that is, the conversion of reactants into products and chemical energy into thermal energy. The figure (2.1) shows the combustion components and the combustion product of the gasoline engine and diesel engine.

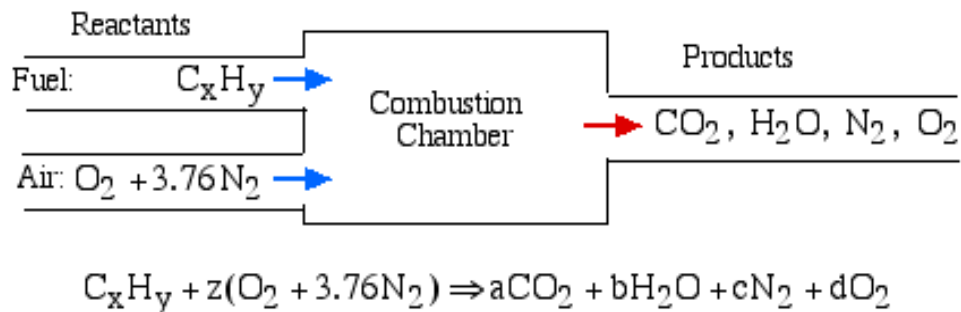


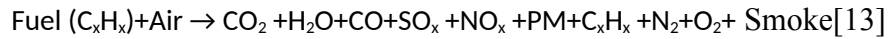
Figure 2.1: Combustion components and combustion product.

Automotive emissions typically consist of water vapor, carbon dioxide (CO₂), carbon monoxide (CO), oxides of nitrogen (NO_x), oxides of Sulphur (SO_x), smoke particles (diameters of 0.05µm to 1µm) and also particulate matter (diameters greater than 1µm). Under perfect combustion conditions the following relationship would hold:

Air: $Z(O_2 + 3.76N_2)$

Fuel (C_xH_x)+Air → CO₂ +H₂O

As carbon dioxide (CO₂) and water vapor (H₂O) are both present as trace gases in the atmosphere, no pollution would result from this process. However, in reality perfect combustion does not occur and the following relationship holds as fuel burnt in an engine:



2.3: Exhaust Emission

An internal combustion engine produces the following exhaust components:

1) Nitrogen (N₂):

Nitrogen gas is non-flammable, colorless and odorless, and constitutes 78% of the air we breathe. While most of the nitrogen drawn into the combustion chamber during a stroke is expelled during the exhaust run, a small fraction of nitrogen can combine with oxygen (O₂) to form nitrogen oxides (NO_x).



Figure 2.2: Chemical Structure of Nitrogen [1]

2) Oxygen:

Oxygen gas (O_2) is colorless, odorless, and tasteless, it contains 21% of the air we breathe.



Figure 2.3: Chemical structure of Oxygen [1]

3) Water (H_2O):

Water may be present in the combustion chamber either in gaseous form (due to moisture in the atmosphere) or liquid (by fuel injector when using low quality fuel). Water also a natural by-product of combustion.

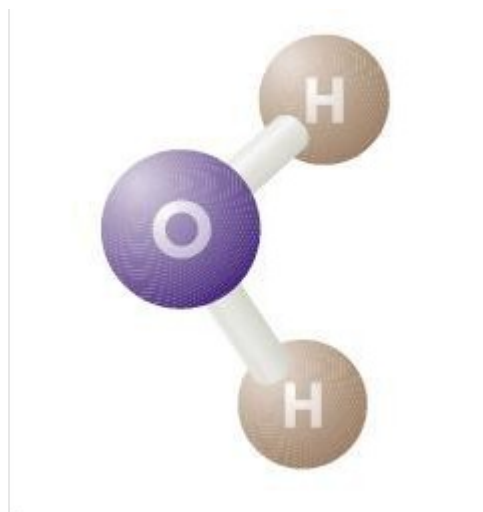


Figure 2.4: Chemical structure of water [1]

4) Carbon Dioxide (CO₂):

Carbon dioxide gas is colorless and non- flammable, and is a by-product of the combustion process. Carbon dioxide traps a portion of this outgoing energy, retaining heat. The higher the concentration of Carbon dioxide released into the atmosphere, the greater the impact on the world's climate. The emissions of Carbon dioxide (CO₂), however, are directly proportional to fuel consumption.

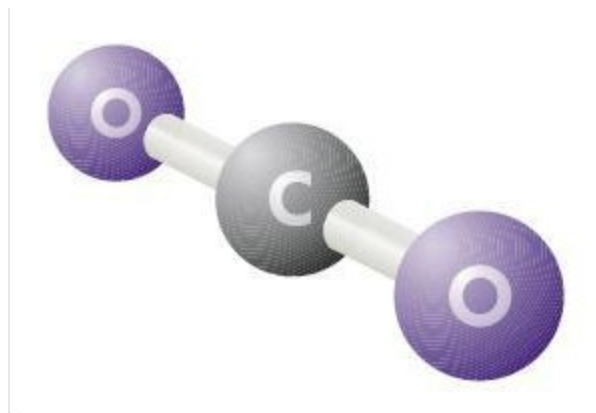


Figure 2.5: Chemical structure of Carbon Dioxide [1]

5) Carbon Monoxide (CO):

Carbon monoxide is a colorless, odorless, tasteless, highly toxic gas that results from incomplete combustion of carbon-containing cloud components. When released outdoors, carbon monoxide is rapidly oxidized to form carbon dioxide. At very small concentrations, carbon monoxide can cause respiratory problems and impair visual perception, manual creativity and learning function. At slightly larger concentrations, they can be fatal.



Figure 2.6: Chemical structure of Carbon monoxide [1]

6) Oxides of Nitrogen (NO_x):

Nitrogen oxides are nitrogen compounds (N₂) and oxygen (O₂) (eg NO, NO₂, N₂O, etc.). Nitrogen oxides are produced by high pressure, high temperature and excess oxygen in the engine during the combustion cycle. Multiple NO_x is harmful to health. Measures to reduce fuel consumption have often led to higher nitrogen oxide concentrations in exhaust emissions. This is because the most efficient combustion process generates higher temperatures.

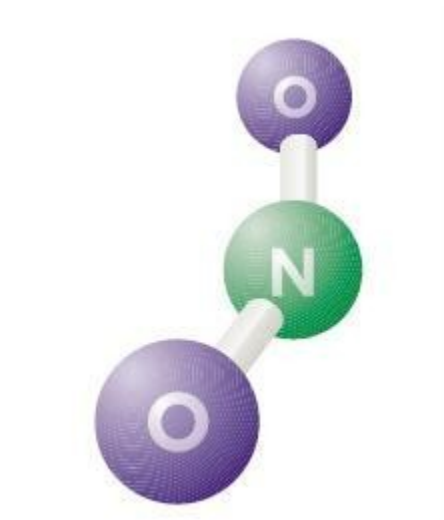


Figure 2.7: Chemical structure of (NO_x) [1]

7) Hydrocarbons (HC):

Hydrocarbons are unburned fuel components which occur in the exhaust emissions after incomplete combustion. Hydrocarbons occur in a variety of forms, including C₆H₆ (Benzene) and C₈H₁₈ (Octane). Each has different effects on humans; some irritate sensory organs, while others, such as Benzene, are cancer causing

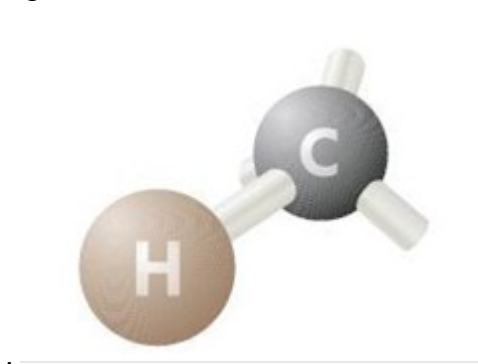


Figure 2.8: Chemical structure of Hydrocarbons [1]

8) Sulphur Dioxide (SO₂):

Sulfur dioxide is colorless, jet and non-flammable. It is present at very low concentrations in exhaust gases and can cause respiratory diseases. Sulfur dioxide emissions can only be reduced by reducing the sulfur content of the fuel [1].



Figure 2.9: Chemical structure of Sulphur dioxide [1]

9) Lead (Pb):

Lead is highly toxic once the gasoline has been used to prevent knockdown. In 1985, 3,000 tons of yans were released into the atmosphere. Environmentally friendly alternative additives from gasoline today instead of lead [1].



Figure 2.10: Chemical structure of lead [1]

10) Particulate Matter (PM):

Particle matter is mainly produced by diesel engines. It consists of the basic components and several related elements. One of the attached components, hydrocarbons, is oxidized in the catalytic converter. The remaining particles can only be collected by specialized particle filters.

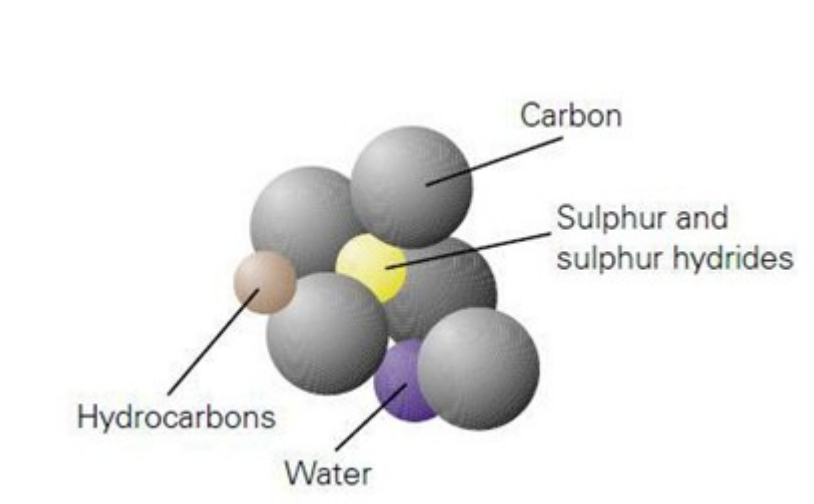


Figure 2.11: Chemical structure of particulate matter [1]

2.4 The Factors Affecting Vehicle Emissions

2.4.1 Vehicle Weight

The impact of vehicle weight on emissions is significant. The increase in engine weight is offset by an increase in fuel savings for the engine as the driver moves to the lower gears. This increases the ratio of fuel and air in the engine which in turn affect the emission rates of the combustion process. NO_x emissions will increase as the combustion temperature increases and pressure increases to accommodate the combustion of the fuel-rich mix in the room and increase the engine load. Carbon dioxide emissions will increase as the excess oxygen in the combustion chamber decreases and much of the carbon from the fuel fails to convert it to carbon dioxide [4].

2.4.2 Vehicle Vocation

The specific task or specific use of the vehicle can have an impact on the resulting emissions. Transit and cruising behavior can be reproduced for each craft profession, along with a portable load, in the test by changing the weight of the test. The weight analysis of the vehicle using the road load equation ignores the fact that the vehicle must accelerate to the assumed stability. Under acceleration, it is assumed that a heavy vehicle typically uses the maximum power available from its engine, thus producing the maximum amount of exhaust gas and 16 typically high rates of nitrogen and magnetic oxides. So, during a typical day of use of any vehicle, a car that stops and then accelerates will often result in higher distance emissions, provided everything else is constant. This effect is caused by differences in car use, also called car profession [4].

2.4.3 Fuel Type

There are different components and proportion of exhaust gases from one fuel to another because the chemical composition of each fuel chemistry has a direct effect on the combustion properties but also affects the exhaust chemistry at the downstream as well. In particular, different hydrocarbons in fuels lead to the use of different “unburned” hydrocarbons in the exhaust as emissions, and the oxidation efficiency of catalysts varies with different hydrocarbons. Therefore,

understanding the chemical composition of the exhaust and the species-based dependencies of catalytic processes are critical to ensuring emissions control in a range of fuels [4].

2.4.4 Vehicle Age

There are two separate factors for vehicle life that affect the resulting emissions. First, it is assumed that as the vehicle ages and the mileage accumulate high, the engine will wear slowly and result in higher emissions even though engine degradation is slow for certification purposes. The second factor is the change in technology. Variable technology suggests that the engines produced today differ from older engines and must meet the most stringent emission standards [4].

2.4.5 The Terrain Traveled

Terrain effects transmitted by the vehicle are referred to as class effects. The chassis test performed uses power dampers and inertial flywheels to provide vehicle load based on the road load equation. For this equation, it is assumed that there are no hills, and the load is calculated for perfectly flat terrain. To compare emissions from a vehicle traveling on varying ground, theoretical energy requirements can be determined. The force can then be correlated with the emission rate for a particular vehicle from the experimental brake emission data [4].

2.4.6 Injection Timing Variances

It is known that NO_x and PM emissions are strongly influenced by the timing of fuel injection into the cylinder in engines. In fact, it is common to introduce an excessive NO_x-PM swap curve for an engine, with more advanced timing at the same speed and loading leading to higher NO_x and less PM. Within a reasonable operating range, there is also a trade-off between NO_x and efficiency, with advanced timing leading to higher NO_x and higher thermal efficiency [4].

2.4.7 Engine load

The resulting engine load or engine torque has different effects on the components of pollutants carbon monoxide (CO), unburned hydrocarbons (HC) and nitrogen oxides (NOX) [2].

2.4.8 Engine speed

Higher engine speeds result in greater friction loss within the engine as well as increased power consumption by auxiliary systems (for example, water pump). Under these conditions, energy production per unit of energy consumed decreases [2].

2.4.9 Mixture Formation

In order to achieve optimal combustion efficiency, the combustion fuel should be completely dispersed to form the most homogeneous mixture with the air. In multiple injection engines, this indicates the total combustion chamber, and the uniform distribution of the uniform mixture on all cylinders is important for low pollutant emissions [2].

2.4.10 Compression Ratio

Compression ratio is the ratio of the total volume of the combustion chamber when the piston is at the bottom dead center to the total volume of the combustion chamber when the piston is at the highest dead position, the increase in the compression ratio improves thermal efficiency and simultaneously increases the specified power and reduces the specified fuel consumption. The compression ratio can be associated with combustion chamber forms and this combined parameter can have a significant effect on emissions [2].

2.4.11 Moment of Ignition

The ignition of the air / fuel mixture, is the time interval between the fast flash and the formation of a stable flame front, is crucial in the combustion sequence. The nature of the ignition process is formed by flash timing, ignition energy, and the formation of the mixture in spark plugs. A large amount of ignition energy is translated into 19 stable ignitions with positive effects, both on the consistency of successive combustion cycles and the formation of exhaust gases [3].

2.5: Evaporative Emissions

Hydrocarbon pollutants also escape into the air through fuel evaporation. With today's efficient exhaust emission controls and today's gasoline formulations, evaporative losses can account for a majority of the total hydrocarbon pollution from current model cars on hot days when Ozone levels are highest. Evaporative emissions occur several ways [3]:

- 1) Diurnal:
- 2) Gasoline evaporation increases as the temperature rises during the day, heating the fuel tank and venting gasoline vapors.
- 3) Running Losses:
- 4) The hot engine and exhaust system can vaporize gasoline when the car is running.
- 5) Hot Soak:
- 6) The engine remains hot for a period of time after the car is turned off, and gasoline evaporation continues when the car is parked.
- 7) Refueling: Gasoline vapors are always present in fuel tanks. These vapors are forced out when the tank is filled with liquid fuel.

2.6: The Problems of Emissions

- 1) Global warming: Are terms of the observed rise in temperature over the century in the average temperature of the Earth's climate system and associated effects, and that scientists were more than 95% certain that global warming was mostly caused by human (human) activities, which increased significantly. Major concentrations of greenhouse gases such as methane and carbon dioxide (CO₂) [2].

- 2) Acid rain: The rain, which has a high concentration of pollutants, the most important of which is dioxide sulfide and nitrogen oxide, is released into the atmosphere by burning fossil fuels such as coal or oil.
- 3) Smog.
- 4) Health Hazards.
- 5) Destroy the Ozone.
- 6) Produce colorless, gases, toxic harmful.

2.6.1 Impact on Health

Table 2.1: Physiological Effects on Human [12]

Name	Physiological Effects on Human	
	Acute Effects	Chronic Effects
1. Carbon Monoxide (CO)	Asphyxiation, heat and brain damage	Increased red blood cells (polycythemia) in blood, leading to increased resistance to blood to flow, weakness fatigue, and headaches.
2. Carbon Dioxide (CO ₂)	Carbon Dioxide reduces the volume of oxygen enters the blood stream and can slow reflexes.	Cause drowsiness, impair judgment and vision and even cause death.
3. Nitrogen Dioxide (NO ₂)	Incompletely understood, although cell membrane disruption appears to be the principal reason for respiratory tract edema.	Cell membrane damage and acid- induced irritation Leading to or contributing to diminished pulmonary function and right-heart stress.
4. Sulfur Dioxide (SO ₂)	Give rise to irritation reactions, which cause capillaries to dilate and exude fluid accumulation and swelling (edema).	Contributes to and aggravates lung diseases like chronic bronchitis, pulmonary fibrosis via irritation leading to decrease pulmonary function and increase in stress on the heart.
5. Hydrocarbons (C _x H _y)	The primary harm of	Cancer is one direct primary

	hydrocarbons are in their participation in ozone production	effect of some organic compounds.
6.Particulate Matters (PM)	Effect varies depending on nature and size of particles. Can cause irritation, altered immune, or systematic toxicity.	Depending on the nature and size of the particles can cause decreased pulmonary function and stress on the heart.

2.7: Emission Control Methods

The combustion system includes the combustion chamber, its shape and characteristics such as charge composition, charge motion, and fuel distribution. This is where pollutants such as NO_x, CO and PM are created as well as where incomplete oxidation of fuel occurs. What happens in the combustion system is greatly influenced by other engine systems such as the intake charge management system and the fuel injection system. In fact, the primary purpose of these secondary systems is to influence what happens during the combustion process. Numerous options are available to limit the formation of pollutants resulting from the combustion system.

Exhaust system consists basically of three main components:

- 1) The muffler consists of chambers from different sizes. The major function of muffler is damp the sound waves.
- 2) The catalytic converter serves as an exhaust gas cleaning device for internal combustion engines. It is mounted as close as possible to the engine so that it can quickly reach its operating temperature.
- 3) The exhaust pipes combine the exhaust gas outlets in the cylinder head into one or more pipes (manifolds).

2.7.1 Catalytic Converter

A catalytic converter is an exhaust emission control device that reduces toxic gases and pollutants in exhaust gas from an internal combustion engine into less-toxic pollutants by catalyzing a redox reaction (an oxidation and a reduction reaction). Catalytic converters are

usually used with internal combustion engines fueled by either gasoline or diesel the Catalytic converters were first widely introduced in American production cars in 1975 due to EPA regulations on toxic emissions reductions. The United States Clean Air Act required a 75% decrease in emissions in all new model vehicles after 1975, a decrease to be carried out with the use of catalytic converters [2].

2.7.1.1 How it Works

Catalyst is a substance that accelerates a chemical reaction, catalytic converter are mounted in the flow system(exhaust) through which the exhaust gases pass through, these chambers contain catalytic material which promotes the oxidation of the emission contained in the exhaust flow, the most catalyst materials used are Rhodium (Rh), Platinum(pt).

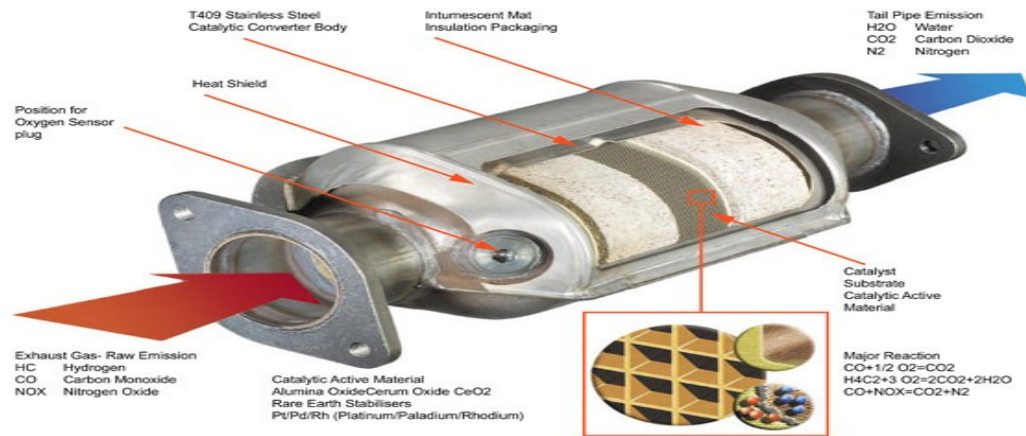
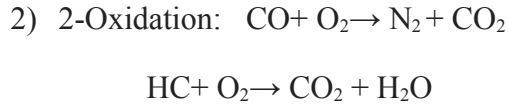
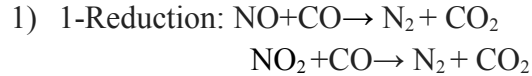


Figure 2.12: 3 Way Catalytic

The first part in three-way catalyst chamber is which acts as a buffer and the second part is consisted of two way.



2.7.2 Exhaust Gas Recirculation

The Exhaust Gas Recirculation or EGR system is one of several vehicle emission control systems. It helps reduce the amount of the nitrogen oxides (NO_x) in the exhaust gases. Nitrogen oxides are normally formed in the process of combustion in the engine cylinders [2].

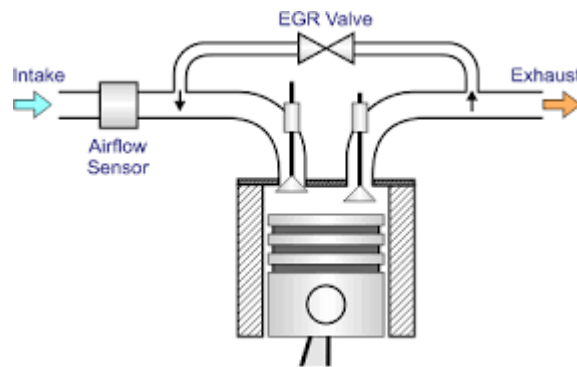


Figure 2.13: Principle operation of EGR.

However, their formation increases dramatically at higher combustion temperatures (above 1600 °C or 2912 °F).

Higher combustion temperatures are also harmful to the engine. One of the effects caused by high combustion temperatures is a pre-ignition or detonation (pinging), when the air/fuel mixture ignites in the cylinders not from the spark, but from excessive heat. Because it happens at the wrong time, before the spark, the detonation adds strain on engine components, Prolonged detonation can damage the valves, pistons and other parts, a turbocharger also fails sooner when exposed to excessive heat, The EGR system reduces the combustion temperature by diverting a small portion of the exhaust gases back into the intake manifold.

2.7.3 Diesel Particulate Filter

The NO_x & particulate emission from diesel engines is a greater threat to the environment. To reduce its impact, automotive engineers developed DPF to conform to the stricter Euro-6 emission standard. The term DPF stands for Diesel Particulate Filter. It is used in the diesel engine that is Euro-6 emission compliant. The manufacturers use the Diesel Particulate Filter to filter, store and burn the soot particles which are emitted as a result of the combustion process of the diesel [3].

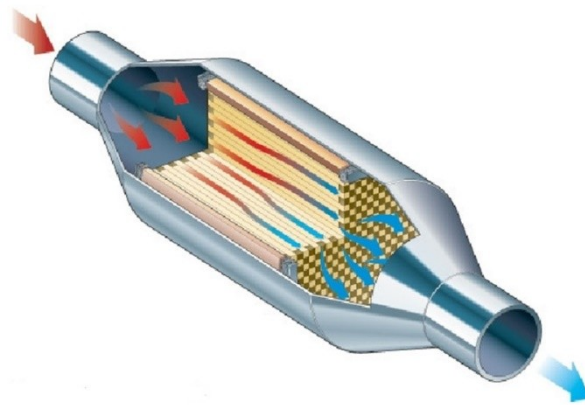


Figure 2.14: Diesel Particulate Filter

Generally, the oxidation catalytic converter and Diesel Particulate Filter come in a common cylindrical unit. Diesel Particulate Filter consists of silicon carbide. It can filter about 99% of solid particulate matter from the exhaust of a diesel engine. The soot particles or the carbon particles deposited on the filter channels are oxidized into carbon dioxide (CO₂) at exhaust temperatures above 600°C. The basic Diesel Particulate Filters are the single-use type. You need to dispose and replace them when they get full after accumulating the ash. More advanced design can also burn off the accumulated soot by using a catalyst.

2.7.3.1 How does a Diesel Particulate Filter work

The unfiltered exhaust flows thru' the DPF's channels that are open at the inlet end. The Diesel Particulate Filter core contains porous walls of a ceramic honeycomb structure made of silicon carbide. The exhaust gases then enter into the channels that are open at the outlet end. Furthermore, the exhaust systems take away the exhaust gases. The DPF core retains the soot particles physically. It later burns them off during the regeneration phase. The CDI control unit computes the amount of soot and ash accumulation in the Diesel Particulate Filter with the help of DPF differential pressure sensor.

Chapter Three

Hardwired Build

3.1 Introduction

3.2 Electrical, Electronic Components and Electrical Circuit

3.3 Mechanical Components, Design and Final Assembly

3.1 Introduction

Toxic Emissions of the combustion of the fuel are one of the greatest challenges that face the automotive engineers and the automotive companies. The main aim of this project is to design a new system to monitor the gas emissions percentage and discover any manipulation of the Environmental system for the vehicle by showing the readings and determine if these readings are within the legal specifications or not on a mobile application.

The system includes 3 sensors for the car exhaust gases (NO_x, CO, CO₂), these sensors are installed in the exhaust pipes to read the percentage for each gas emitted by the car. These readings are to be sent to a controller that store these readings and compare them with the stored values, then output the results in a screen installed in the car interior.

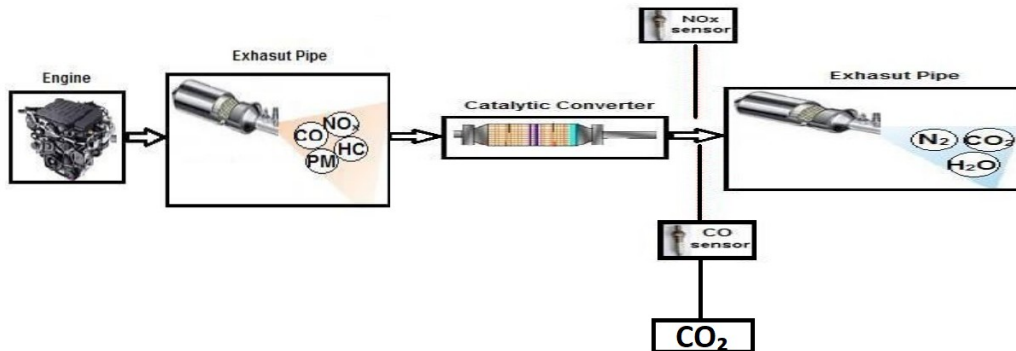


Figure 3.1: Block diagram for the main components of the system.

3.2 Electrical, Electronic Components and Electrical Circuit.

The Components of the system include the followings:

- 1) ATmega Development Board.
- 2) Arduino cable type A/B.
- 3) ESP8266 D1 Wi-Fi Shield.
- 4) NO_x sensor after catalytic converter.
- 5) Co₂ sensor after catalytic converter.
- 6) CO sensor after catalytic converter.
- 7) OBD II Adapter.
- 8) 9 V Battery with power jack adapter
- 9) PCB Breadboard 50*100 mm.
- 10) Jumper wires.

3.2.1 ATmega Development Board

The new ATmega Development Board is a great way to start working with Atmel's latest range of microcontrollers the ATmega series.

The board is ideal for experimenters or as a main CPU board for a more advanced system. Program download and run is easily executed in-system by an RS232 connection to the computer parallel port. The board utilizes the new advanced Atmel AVR ATmega168 microcontroller with 16k of In-System Flash Memory, running at 16 MHz, allowing up to 8 MIPS (million-instructions-per-second). All power supply components and main crystal is in place for the microcontroller. Connectors are provided for RS232, SPI, power and all I/O pins, via standard polarized connections and IDCC connectors.

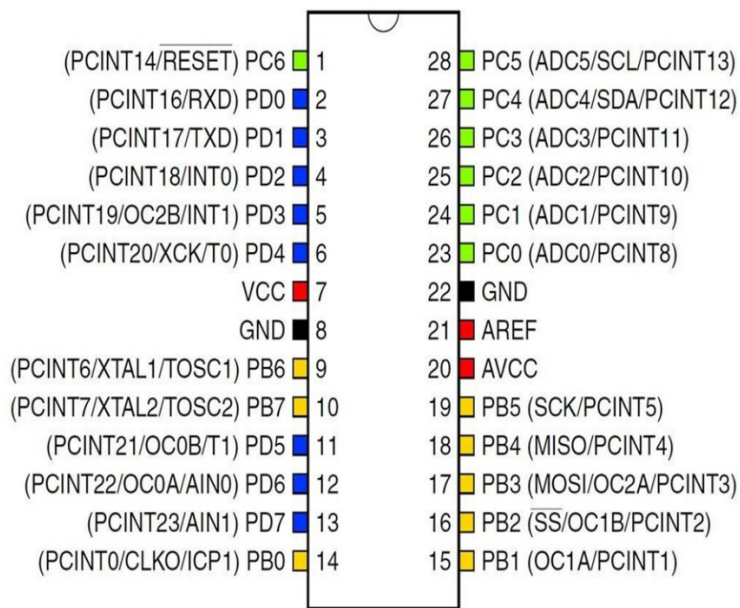


Figure 3.2: Microcontroller ATmega 168 Pin Diagram.

Table 3.1: Pin Description.

Table 1Pin Description.

Pin No.	Pin name	Arduino Function	Pin No.	Pin name	Arduino Function

1	PC6	Reset	15	PB1	Digital pin 9 (PMW)
2	PD0	Digital pin0 (RX)	16	PB2	Digital pin 10 (PMW)
3	PD1	Digital pin1(TX)	17	PB3	Digital pin 11 (PMW)
4	PD2	Digital pin2	18	PB4	Digital pin 12
5	PD3	Digital pin 3(PWM)	19	PB5	Digital pin 13
6	PD4	Digital pin 4	20	AVCC	VCC
7	VCC	VCC	21	AREF	Analog reference
8	GND	GND	22	GND	GND
9	PB6	Crystal	23	PC0	Analog input 0
10	PB7	Crystal	24	PC1	Analog input 1
11	PD5	Digital pin 5(PWM)	2 5	PC2	Analog input 2
12	PD6	Digital pin 6(PWM)	2 6	PC3	Analog input 3
13	PD7	Digital pin 7	2 7	PC4	Analog input 4
14	PB0	Digital pin 8	28	PC5	Analog input 5

Arduino hardware is available in the final form as shown in Figure (3.3), without building in the electrical lab, this requires to be connected to a computer using a USB cable A/B to program it using Arduino software.

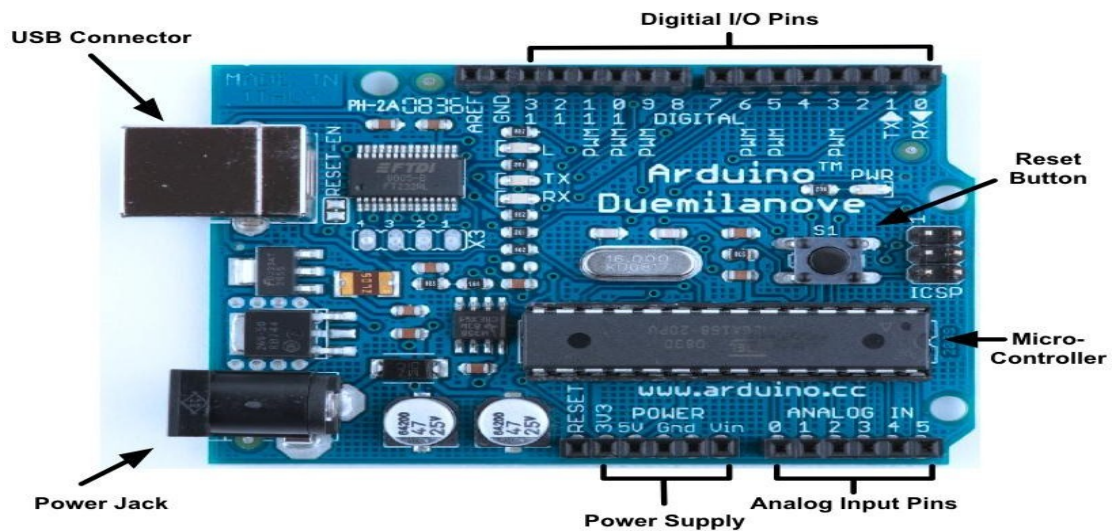


Figure 2 Arduino microcontroller.

Figure 3.3: Arduino microcontroller.

The features of the Arduino include the followings:

- 1) Includes ATmega168 with 16kb internal Flash Program Memory.
- 2) All necessary power supply components and crystal (8.000MHz) already installed.
- 3) All input/output pins connected to headers for easy external connections.
- 4) In-circuit programming via computer download cable (provided).
- 5) Easy to understand.
- 6) Test LED for program run testing.
- 7) Power and Programming LED.
- 8) Code Examples Provided.
- 9) Dramatically reduces program development time.

3.2.2 Arduino A/B Cable

It's a type of USB cables with one end of type A and the other is type B. It's used in the system to connect the Arduino Uno board with the power bank. Approximately 30 cm.



Figure 3.4: USB Cable A/B.

3.2.3 ESP8266 D1 Wi-Fi Shield

is programmable via Arduino IDE. This is an ESP8266 based Wi-Fi enabled microprocessor unit on an Arduino-UNO footprint. That means the board looks and works (in most cases) like an UNO.

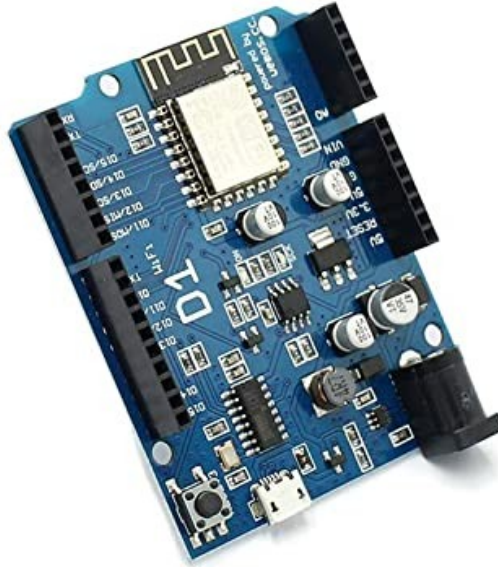


Figure 3.5: ESP8266 D1 Wi-Fi Shield

3.2.3.1 Features of Wemos D1 R2 Wi-Fi -Esp8266 Development Board:

- 1) The D1 R2 is a mini Wi-Fi board based on ESP-8266EX.
- 2) 11 digital input/output pins, all pins have interrupt/pwm/I2C/one-wire supported (except D0).
- 3) 1 analog input (3.3V max input).
- 4) A Micro USB connection.
- 5) A power jack, 9-24V power input.
- 6) Compatible with Arduino.
- 7) Compatible with nodemcu.

Table 3.2: Technical specifications 1

Microcontroller	ESP-8266EX
Operating Voltage	3.3V
Digital I/O Pins	11
Analog Input Pins	1
Clock Speed	80MHz/160MHz
Flash	4M bytes
Length	68.6mm
Width	53.4mm
Weight	25g

Table 3.3: Technical specifications 2

Pin	Function	ESP-8266 Pin
TX	TXD	TXD
RX	RXD	RXD
A0	Analog input, max 3.3V input	A0
D0	IO	GPIO16
D1	IO, SCL	GPIO5
D2	IO, SDA	GPIO4
D3	IO, Pull-up	GPIO0
D4	IO, pull-up, BUILTIN_LED	GPIO2
D5	IO, SCK	GPIO14
D6	IO, MISO	GPIO12
D7	IO, MOSI	GPIO13
D8	IO, pull-down, SS	GPIO15
G	Ground	GND
5V	5V	-
3V3	3.3V	3.3V
RST	Reset	RST

3.2.4 Sensors

Sensor is an electronic device used to measure a physical quantity such as pressure, temperature, speed and convert it into an electrical signal of some kind such as voltage. Sensor is normally a component of some larger electronic system such as a computer control and/or measurement system. In this project the used sensors are gas sensors which will be used to measure the percentage of NO_x, CO and CO₂.

3.2.4.1 Carbon Monoxide (MQ-7) Sensor

A carbon monoxide detector or CO detector illustrated in figure (3.5) is a device that detects and measures the concentration of the CO gas. This Carbon Monoxide gas sensor detects the concentrations of CO and outputs its reading as an analog voltage.

The sensor can measure CO concentrations in the range of 10 to 10,000 ppm. The sensor can operate at temperatures from -10 to 50°C and consumes less than 150 mA at 5 V.

Sensitive material of MQ-7 gas sensor is SnO_2 , which has lower conductivity in clean air. It makes detection by method of cycle high and low temperature. The sensors conductivity is higher along with the gas concentration rising. A simple electrical circuit can convert the change in conductivity to an output signal which corresponds to the gas concentration.



Figure 3.6: CO sensor MQ-7.

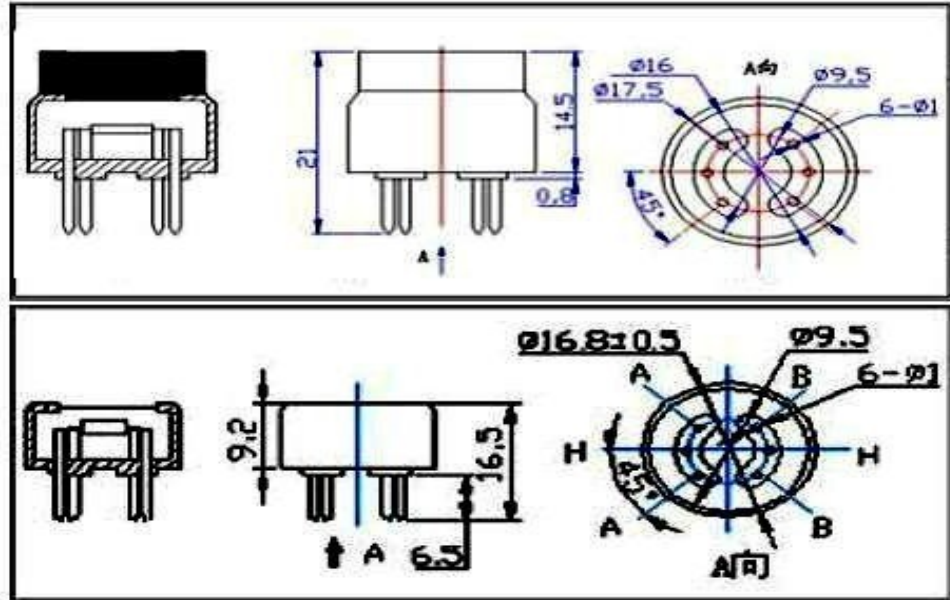


Figure 3.7: Configuration of MQ-7 CO sensor.

Structure and configuration of MQ-7 gas sensor is shown in Figure (3.6). The sensor is composed by micro AL_2O_3 ceramic tube with Tin Dioxide (SnO_2) sensitive layer, measuring electrode and heater are fixed into a crust made by plastic and stainless-steel net. The heater provides necessary work conditions for work of sensitive components. The enveloped MQ-7 has 6 pins, 4 of them are used to fetch signals, and the other 2 are used for providing heating current.

3.2.4.1.1 The features of CO (MQ-7) sensor

- 1) High sensitivity to carbon monoxide.
- 2) Stable and long life.
- 3) High sensitivity to organic solvent vapors such as ethanol.

3.2.4.1.2 Specifications

Table 3.4: Standard work condition

Symbol	Parameter name	Technical condition	Remark
Vc	circuit voltage	5V±0.1	Ac or Dc
VH (H)	Heating voltage (high)	5V±0.1	Ac or Dc
VH (L)	Heating voltage (low)	1.4V±0.1	Ac or Dc
RL	Load resistance	Can adjust	
RH	Heating resistance	33Ω±5%	Room temperature
TH (H)	Heating time (high)	60±1 second	
TH (L)	Heating time (low)	90±1 second	
PH	Heating consumption	About 350mW	

Table 3.5: Environment conditions

Symbol	Parameters	Technical conditions	Remark
Tao	Using temperature	-20°C-50°C	
Tas	Storage temperature	-20°C-50°C	Advice using scope
RH	Relative humidity	Less than 95%RH	
O2	Oxygen concentration	21% (stand condition) the oxygen concentration can affect the sensitivity characteristic	Minimum value is over 2%

Table 3.6: Environment conditions

symbol	Parameters	Technical parameters	Remark
Rs	Surface resistance Of sensitive body	2-20k	In 100ppm Carbon Monoxide
a(300/100ppm)	Concentration slope rate	Less than 0.5	Rs (300ppm)/Rs(100ppm)
Standard working condition	Temperature -20°C±2°C relative humidity 65%±5% RL:10KΩ±5%		
Vc:5V±0.1V VH:5V±0.1V VH:1.4V±0.1V			
Preheat time	No less than 48 hours	Detecting range: 20ppm-2000ppm carbon monoxide	

3.2.4.2 Nitrogen Oxide Sensor (MQ-135) Sensor

A nitrogen oxide detector or NO_x detector is a device that detects and measures the concentration of NO_x gas. This NO_x gas sensor detects the concentrations of NO_x and outputs its reading as an analog voltage.

Sensitive material of (MQ-135) gas sensor is SnO_2 , which with lower conductivity in clean air. When the target combustible gas exists, the sensor's conductivity is higher along with the gas concentration rising. A simple electrical circuit can convert the change in conductivity to an output signal which corresponds to the gas concentration.

3.2.4.2.1 The features of NO_x (MQ-135) sensor

- 1) High sensitivity to exhaust gases diesel-fueled engines.
- 2) Long life, low cost, stable and fast response.
- 3) Uses simple electrical circuit.
- 4) Measure concentration 10-10000 ppm.



Figure 3.8 sensor NO_x (MQ-135)

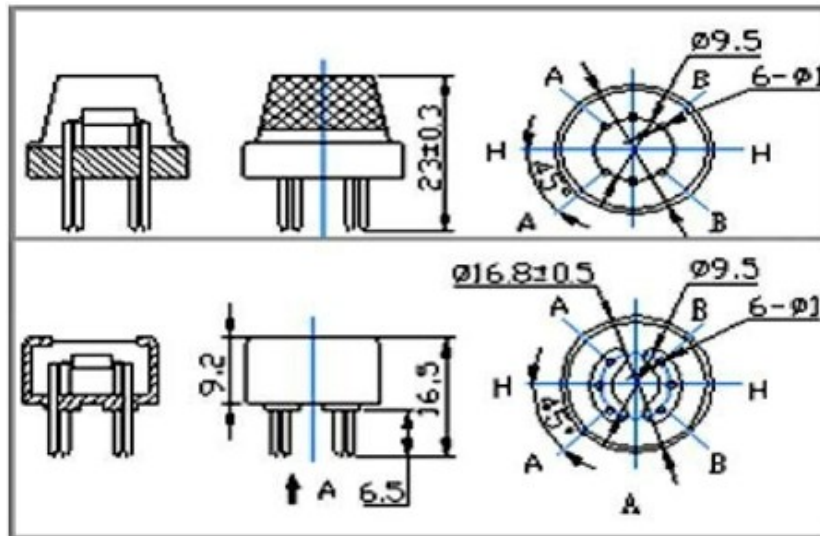


Figure 3.9: Configuration of (MQ-135) NO_x sensor.

3.2.4.2.2 Specifications

Table 3.7 Standard Word Condition's for MQ-135.

Symbol	Parameter name	Technical condition	Remarks
Vc	Circuit voltage	5V±0.1	AC OR DC
VH	Heating voltage	5V±0.1	ACOR DC
RL	Load resistance	can adjust	
RH	Heater resistance	33Ω±5%	Room Tem
PH	Heating consumption	less than 800mw	

Table 3.8 Environment condition for MQ-135

Symbol	Parameter name	Technical condition	Remarks
Tao	Using Tem	-10-45	
Tas	Storage Tem	-20-70	
RH	Related humidity	less than 95%Rh	
O2	Oxygen concentration	21% (standard condition) Oxygen concentration can affect sensitivity	minimum value is over 2%

Table 3.9 Sensitivity characteristic for MQ-135

Symbol	Parameter name	Technical parameter	Remark 2
R_s	Sensing Resistance	30K Ω -200K Ω (100ppm NH ₃)	
α (200/50) NH ₃	Concentration Slope rate	≤ 0.65	
Standard Detecting Condition	Temp: 20 \pm 2 Vc:5V \pm 0.1 Humidity: 65% \pm 5% Vh: 5V \pm 0.1		
Preheat time	Over 24 hours		

3.2.4.3 Carbon dioxide MG-811 sensor

A Carbon dioxide detector is a device that detects and measures the concentration of CO₂ gas. And the output is the reading as an analog voltage.

3.2.4.3.1 The features of CO₂ sensor (MG-811)

- 1) Good sensitivity and selectivity to CO₂.
- 2) Low humidity and temperature dependency.
- 3) Long stability and reproducibility.



Figure 3.10: MG-811 CO₂ Sensor

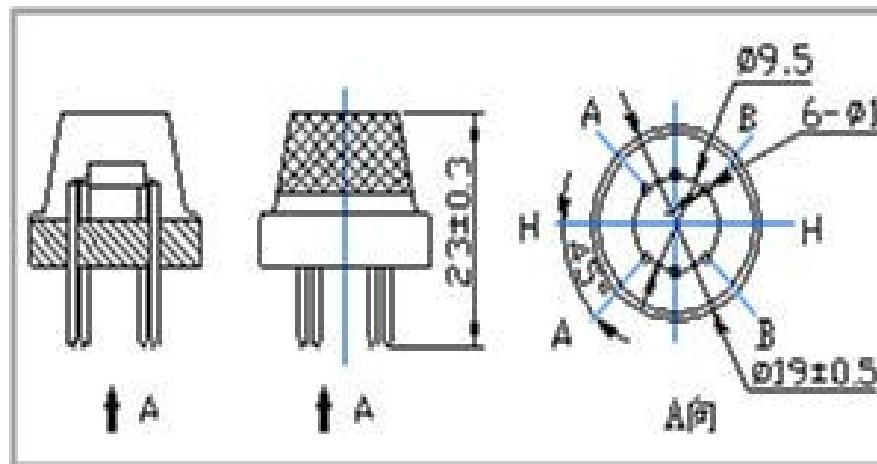


Figure 3.11: Configuration of MG811 gas sensor.

3.2.4.3.2 Specifications

Table 3.10: Specs of MG8111 Sensor

Symb ol	Parameter Name	Technical	Remarks
V _H	Heating Voltage	6.0±0.1 V	AC or DC
R _H	Heating Resistor	30.0±5%Ω	Room Temperature
I _H	Heating Current	@200mA	
P _H	Heating Power	@1200mW	
Tao	Operating Temperature	-20—150	
Tas	Storage Temperature	-20—70	
	Output	30—50mV	350—10000ppmCO2

3.2.5 OBD-II

OBD II adapter is an electronic gauge that connects to the OBD-II plug in the car, and displays various information like RPM of the engine, speed, etc. as well as detailed fuel consumption, OBD-II data logger device which reads out sensor data from vehicle and records the data on mass storage (e.g. SD card). Besides data logging, it also displays some real time data and states on a screen or on an application.



Figure 3.12: OBD-II

3.2.5.1 Objectives:

- 1) Displaying real time engine RPM and vehicle speed on android application.
- 2) Recording real time OBD-II data to SD card in text-based CSV file format.
- 3) Illustrating the recorded data in as Simplified numbers.
- 4) Software fully open-source so that people can easily modify the way the device works.

3.2.5.2 Parts used in Arduino OBD-II adapter

- 1) Arduino Nano (main controller)
- 2) Arduino OBD-II adapter (for retrieving data from vehicle)
- 3) SD breakout board (for storing data to SD card)
- 4) android application module (for displaying data, the logger will work either with or without it)

3.2.5.3 Output Data

- 1) Engine RPM.
- 2) Speed.
- 3) Throttle position.
- 4) Engine load.
- 5) Engine coolant temperature.
- 6) Intake manifold absolute pressure.
- 7) Intake temperature.

3.2.5.4 Power Lines

- 1) Red: VCC (connecting to Arduino's VCC).
- 2) Black: GND (connecting to Arduino's GND).

3.2.5.5 Data Lines

- 1) White: Rx (connected to Arduino's serial Tx).
- 2) Green: Tx (connected to Arduino's serial Rx).

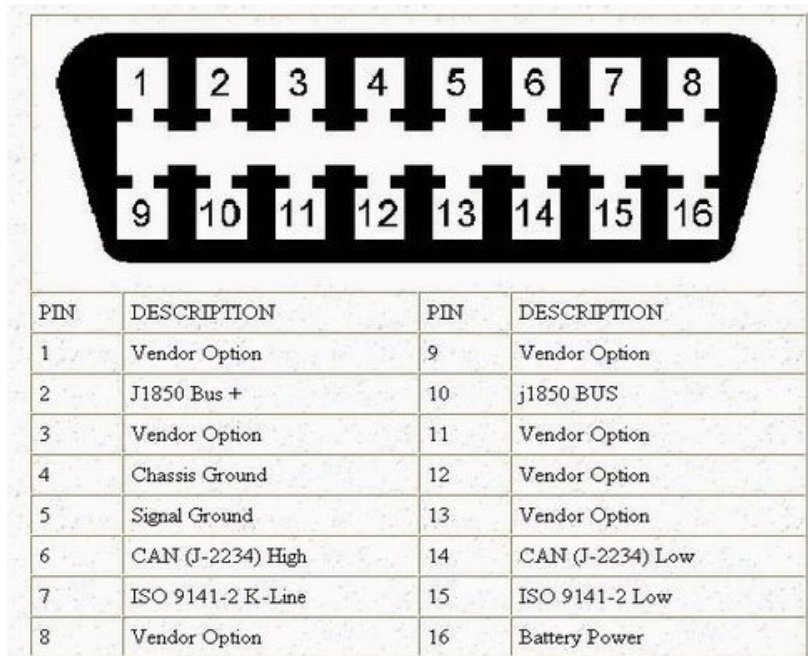


Figure 3.13: OBD-II Pin Out and Connector.

3.2.6 Battery

The nine-volt battery, or 9-volt battery, is a common size of battery that was introduced for the early transistor radios. It has a rectangular prism shape with rounded edges and a polarized snap connector at the top. This type is commonly used in walkie-talkies, clocks and smoke detectors.



Figure 3.14: a 9 V Battery

3.2.7 PCB Breadboard

Is a plastic-copper permeant breadboard used to connect the electrical circuit for any project.

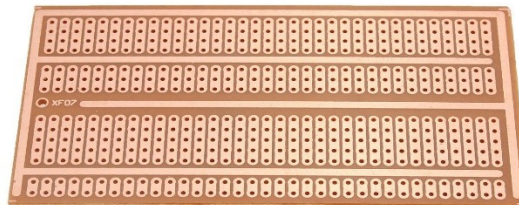


Figure 3.15: PCB Copper Breadboard

3.2.7 Jumper Wires

Jumper wires are simply wiring that have connector at each end, allowing them to be used to connect two points to each other without soldering. Jumper wires are typically used with breadboards and other prototyping tools in order to make it easy to change a circuit as needed. Fairly simple. In fact, it doesn't get much more basic than jumper wires.



Figure 3.16: Jumper Wires (Females and Males)

3.2.8 Electrical Circuit

The sensors in this system are three sensor MQ-135, MQ-7, MG811. Respectively are nitrogen oxide, carbon monoxide and carbon dioxide sensors. The control unit receives a multi input signal from the sensors and the OBD-II adapter and then sends the live data to an android application to determine the percentages of the three gases emitted from the car exhaust.

The output of CO sensor which is the CO concentration emission will be send as a signal to the control unit (Arduino) as analog signal. The same goes for the NO_x sensor, which measures the NO_x concentration and the CO₂ sensor that measure the CO₂ concentration.

The circuit breadboard diagram shown in Figure 3.17 was designed using Fritzing software.

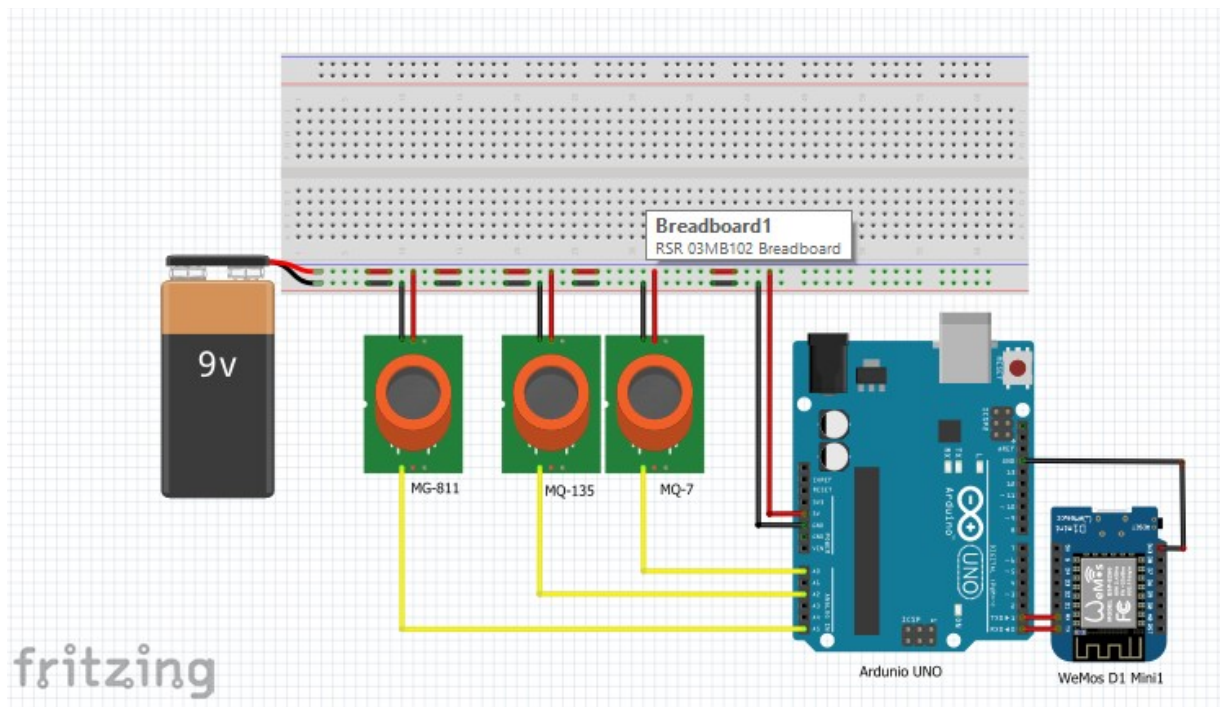


Figure 3.17: Circuit Diagram of the Device

3.3 Mechanical Components, Design and Final Assembly

The Components of the system include the followings:

- 1) 2 in Stainless Steel pipe.
- 2) Electrical plastic enclosure.

3.3.1 Stainless Steel pipe

Stainless steel is a versatile material comprised of a steel alloy and a small percentage of chromium, the addition of chromium adds to the material's corrosion resistance, a trait that earned stainless steel its name. Because stainless steel is also low-maintenance, oxidation resistant, and doesn't affect other metals it comes in contact with, it is frequently used in a large array of applications, especially in piping and tubing manufacturing.



Figure 3.18: 2 in Stainless Steel Pipe

3.3.2 Electrical plastic enclosure

An electrical enclosure is a cabinet for electrical or electronic equipment to enclosure wires or mount switches, knobs and displays and to prevent electrical shock to equipment users and protect the contents from the environment. The enclosure is the only part of the equipment which is seen by users. It may be designed not only for its utilitarian requirements, but also to be pleasing to the eye. Regulations may dictate the features and performance of enclosures for electrical equipment in hazardous areas, such as petrochemical plants or coal mines. Electronic packaging may place many demands on an enclosure for heat dissipation, radio frequency interference and electrostatic discharge protection, as well as functional, esthetic and commercial constraints.



Figure 3.19: Electrical plastic enclosure

3.3.3 Pipe Insulation

The insulator was used to serve two purposes, the first one is the insulate the stainless-steel pipe in summer days from high temperature, the second one is for the purpose of making a fit between the exhaust pipe and the stainless-steel pipe.



Figure 3.20: Pipe Insulator

3.3.3 Mechanical Design

The very famous and powerful CAD software Siemens NX 12 from Siemens were used to design the assembly of the system.

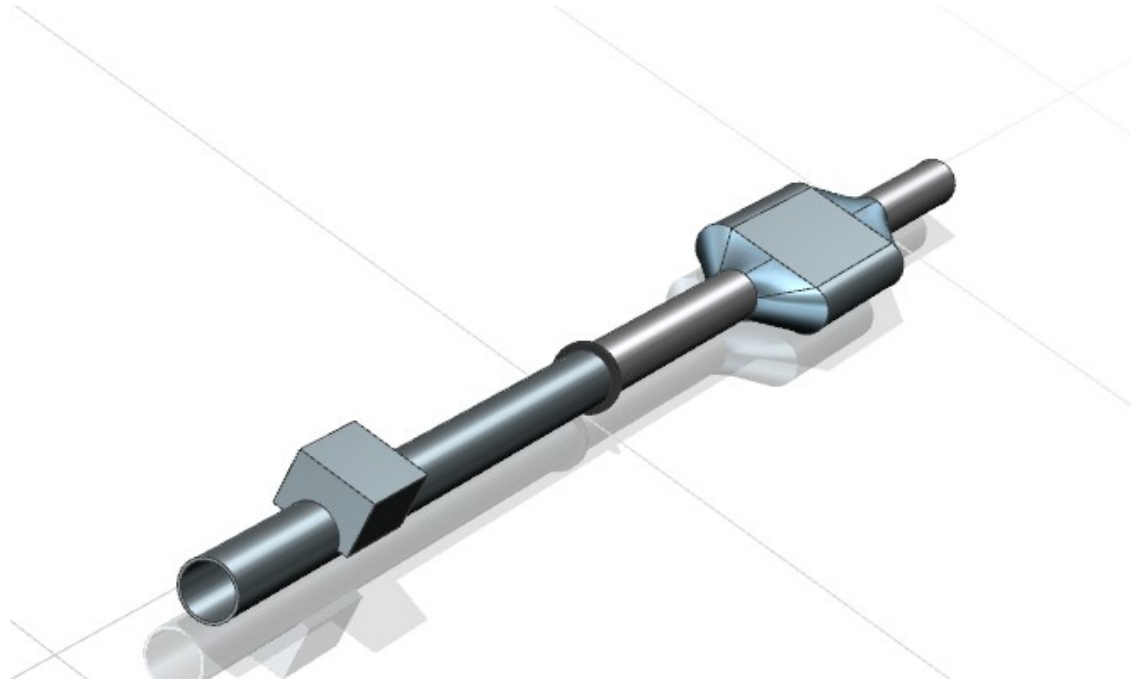


Figure 3.21 Isometric of the System



Figure 3.22: Side View of the System

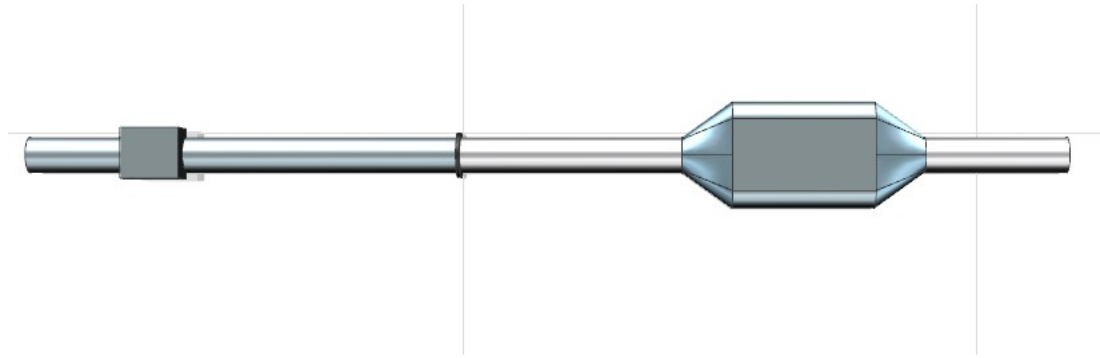


Figure 3.23: Top View of the System

3.3.4 System Assembly

1) Stainless Steel pipe:

Three gaps were drilled by using drill press to install the three sensors.



Figure 3.24: Holes Drilling Through the Pipe

2) Electrical plastic enclosure:

Using a milling machine, the enclosure was milled so that the pipe can fit almost half way through the enclosure and then two holes were made by heating the pipe itself then melting through the plastic



Figure 3.25: Holes Drilling Through the Pipe

Chapter 4

Software Build

4.1 Introduction

This chapter contains the stages of developing a data display system which is an android app, starting from the software used to program it, the code and finally the application UI itself.

4.2 Android Studio and Arduino IDE^[8]

Android Studio is the official integrated development environment (IDE) for Google's Android operating system, built on JetBrains' IntelliJ IDEA software and designed specifically for Android and Android apps development.^[8]

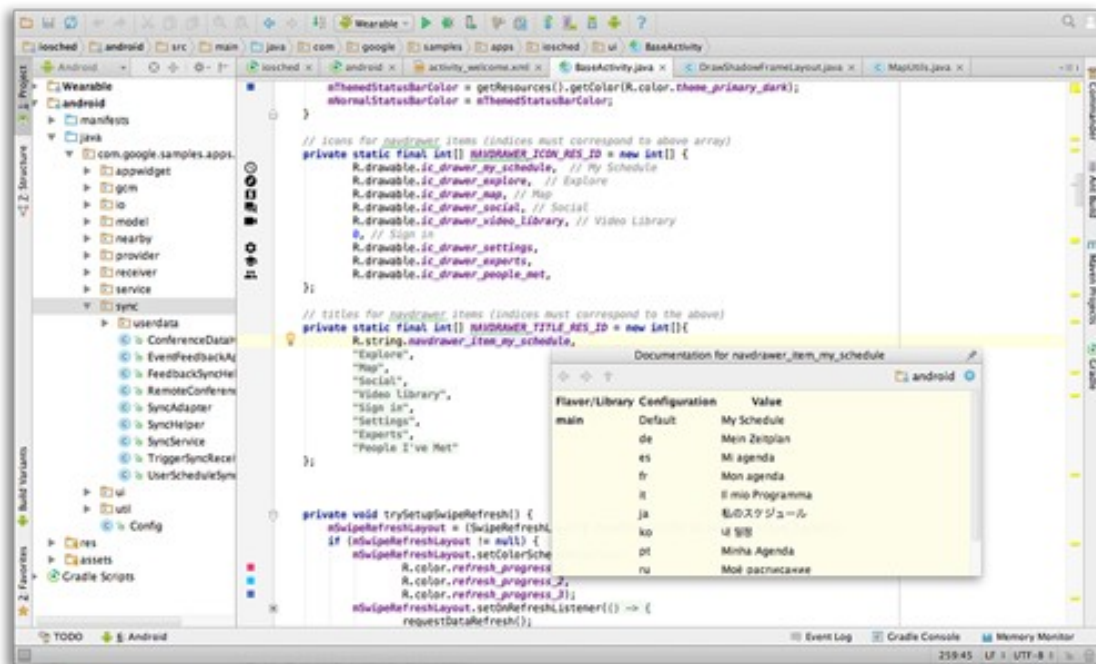
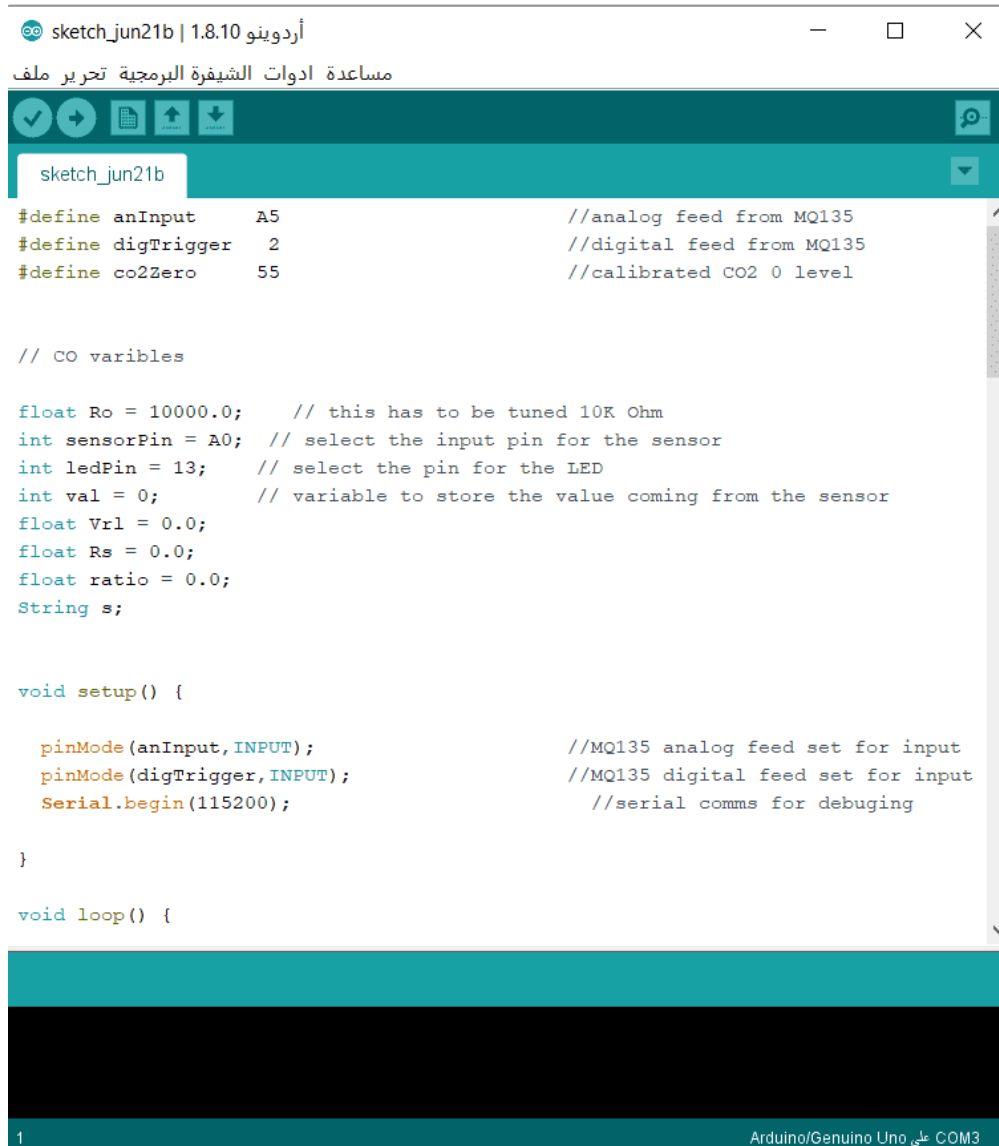


Figure 4.1: Android Studio Interface and the Application Code

The Arduino Integrated Development Environment (IDE) is a cross-platform application (for Windows, macOS, Linux) that is written in functions from C and C++. It is used to write and upload programs to Arduino compatible boards, but also, with the help of third-party cores, other vendor development boards.



The image shows a screenshot of the Android IDE interface. At the top, the window title is "sketch_jun21b | 1.8.10 أروينو" with standard window control buttons. Below the title bar is a menu bar with the text "مساعدة ادوات الشيفرة البرمجية تحرير ملف". A toolbar contains icons for running, saving, and other functions. The main workspace displays the following Arduino code:

```
sketch_jun21b
#define anInput    A5                //analog feed from MQ135
#define digTrigger  2                //digital feed from MQ135
#define co2Zero    55                //calibrated CO2 0 level

// CO variables

float Ro = 10000.0;    // this has to be tuned 10K Ohm
int sensorPin = A0;   // select the input pin for the sensor
int ledPin = 13;      // select the pin for the LED
int val = 0;          // variable to store the value coming from the sensor
float Vr1 = 0.0;
float Rs = 0.0;
float ratio = 0.0;
String s;

void setup() {

  pinMode(anInput, INPUT);           //MQ135 analog feed set for input
  pinMode(digTrigger, INPUT);        //MQ135 digital feed set for input
  Serial.begin(115200);              //serial comms for debugging
}

void loop() {
```

At the bottom of the IDE, the board and port are set to "Arduino/Genuino Uno على COM3".

Figure 4.2: Android IDE with Arduino Code

4.2 System Signal Flow Chart

The following Figure 4.3 demonstrates the way in which the signal transferred between the system electrical components.

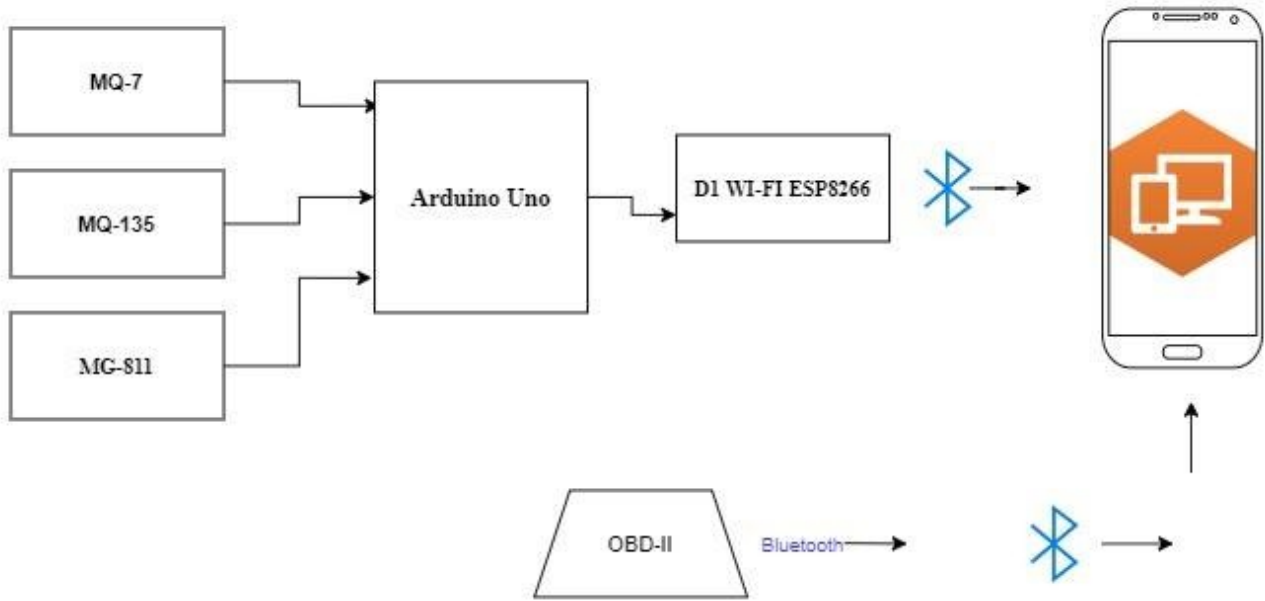


Figure 4.3: Signal Flow Chart

When the gases flow through the car exhaust the sensors detect their flow and then measure each gas (NO_x, CO and CO₂) percentage from the overall gases emissions, then each sensor by itself sends a signal to the Arduino and it will be analyzed using the code which contains a mathematical model that transform the signal from electrical voltage signal to a concentration, this concentration is now ready to be transferred through the D1 Wi-Fi shield and finally to the Android application and then the signal will be transferred to the D1 Wi-Fi shield. The OBD- II adapter which is connected to the car via Bluetooth to display the live data from ECU.

4.3 Android Application UI

The following Figure show the user interface of the Android application which displays the readings of the sensors in their final stage as a concentration and some live data about the engine which will be stored in database.

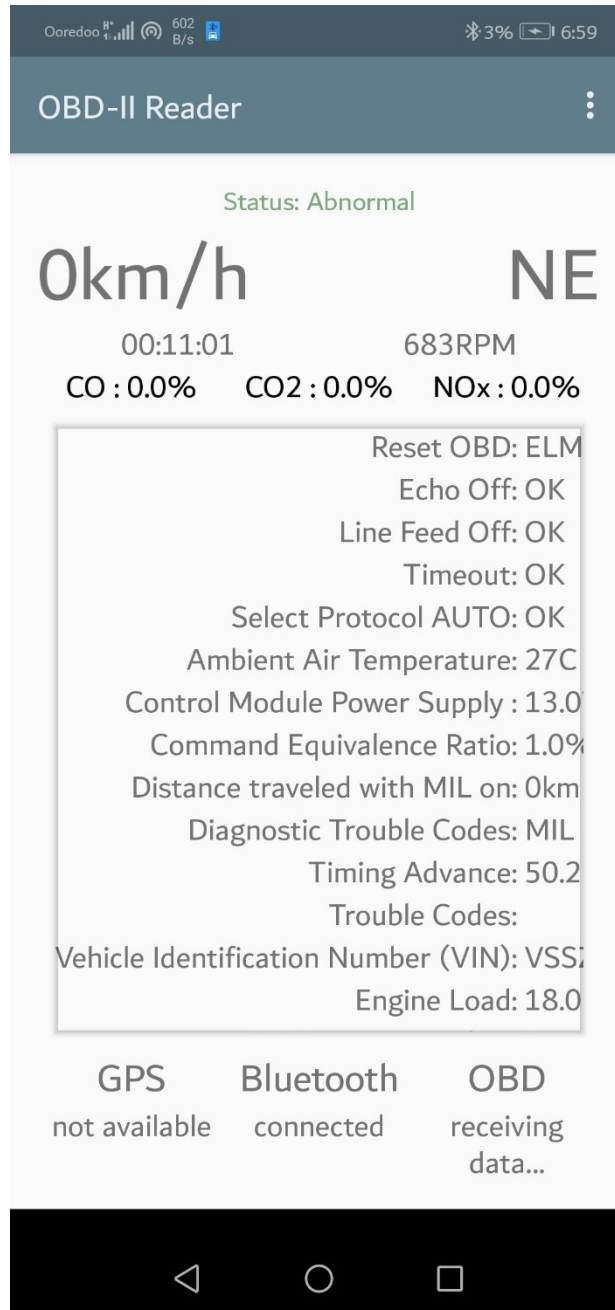


Figure 4.4: Main Screen

The main screen is shown in Figure 4.4, the status line shows two sentences: Normal and Abnormal to show if the emissions are in the legal range or not. The other live data are also shown like the vehicle engine speed, gases and concentrations. Figure 4.5 shows the side menu which contain the start and stop command for the readings also a database in the “Trips” to store every previous reading.

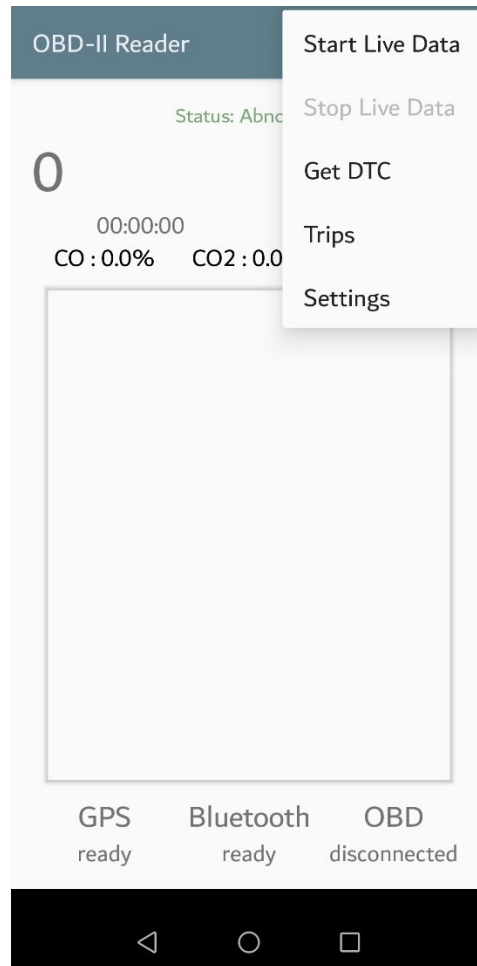


Figure 4.5: Side Menu

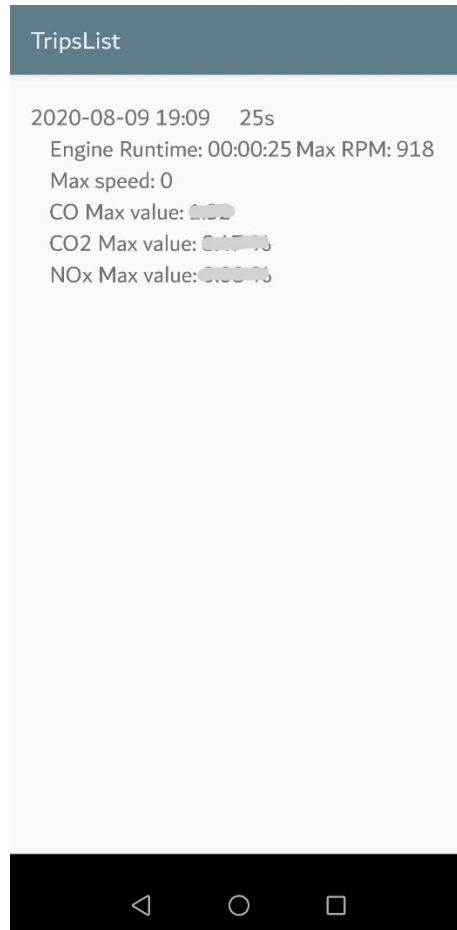


Figure 4.6 : Trips Screen

Chapter 5

Results and Conclusion

5.1: Introduction

5.2: Engine Specifications

5.3: Results and Results Discussion

5.4: Conclusion

5.1 Introduction

Our device main function is to measure the exhaust gases (NO_x , CO, CO_2) emission concentration, and it's to be mounted on the exhaust tail pipe which is after the catalytic converter. The device is tested on a petrol engine car.

Different cases were tested while the device is taking data such as changing the engine speed and load and then the data was analyzed to get information about the normal and abnormal status of the engine by comparing our data to the tested and true data taken from tables.

This project final outcome is to deliver a cheap but at the same time efficient monitoring system to monitor the gases concentration coming from the engine and this will give us an information about the engine status, environmental systems in the car and the simplicity of the device will make it available for all drivers and authorities to make sure that the car doesn't emission over the right and legal amounts.

5.2 Engine Specification

Table 5.1: Engine Specifications

Model	Seat Leon 2015
Displacement	1.2 l turbo
Cylinders	4
Valves per Cylinder	4
Bore	71 mm
Stroke	75.6 mm
○ Compression Ratio	10.5 :1
Engine Configuration	Inline
Power (kW)	81 kW
Rev. at Max Power	4600 – 5600
Torque	175
Rev. at Max Torque	1400 – 4000
Car transmission	Manual, 6 speed

Car fuel type	Petrol
---------------	--------

5.3 Results and Results Discussion

The results which obtained from the application in the final form as concentration are as shown in following figures:

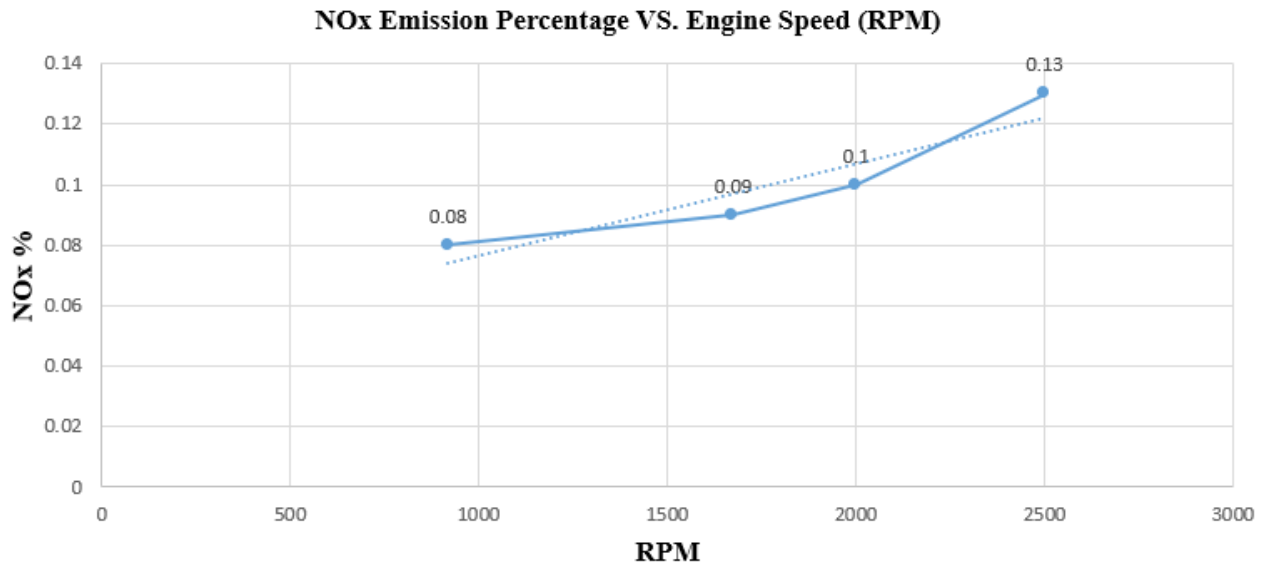


Figure 5.1: NO_x Emission Percentage VS. Engine Speed (RPM)

CO₂ Emission Percentage VS. Engine Speed (RPM)

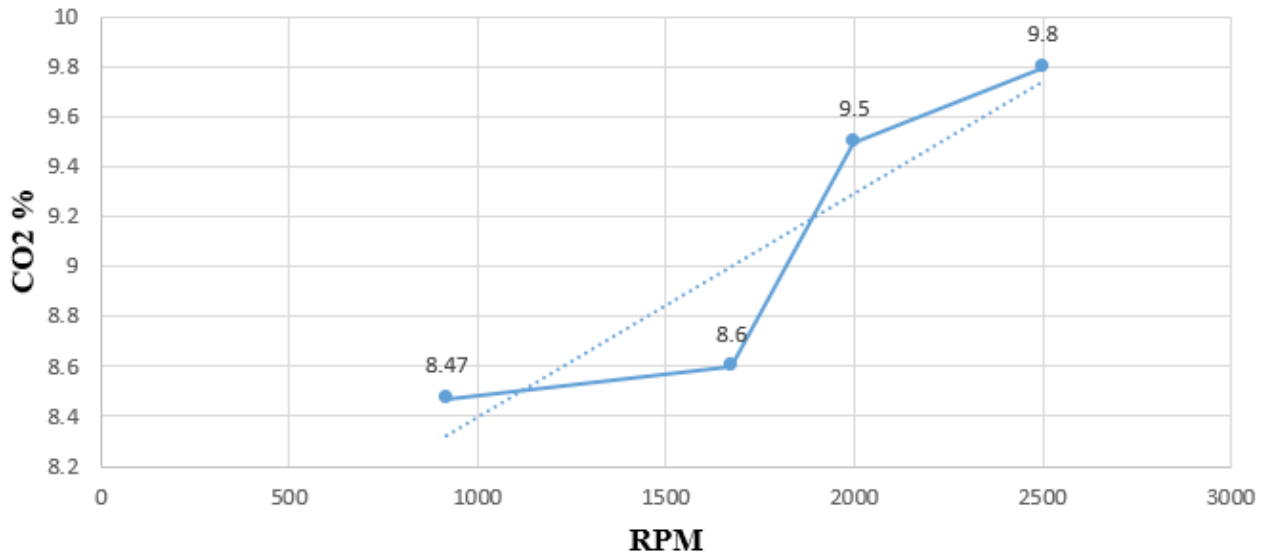


Figure 5.2: CO₂ Emission Percentage VS. Engine Speed (RPM)

CO Emission Percentage VS. Engine Speed (RPM)

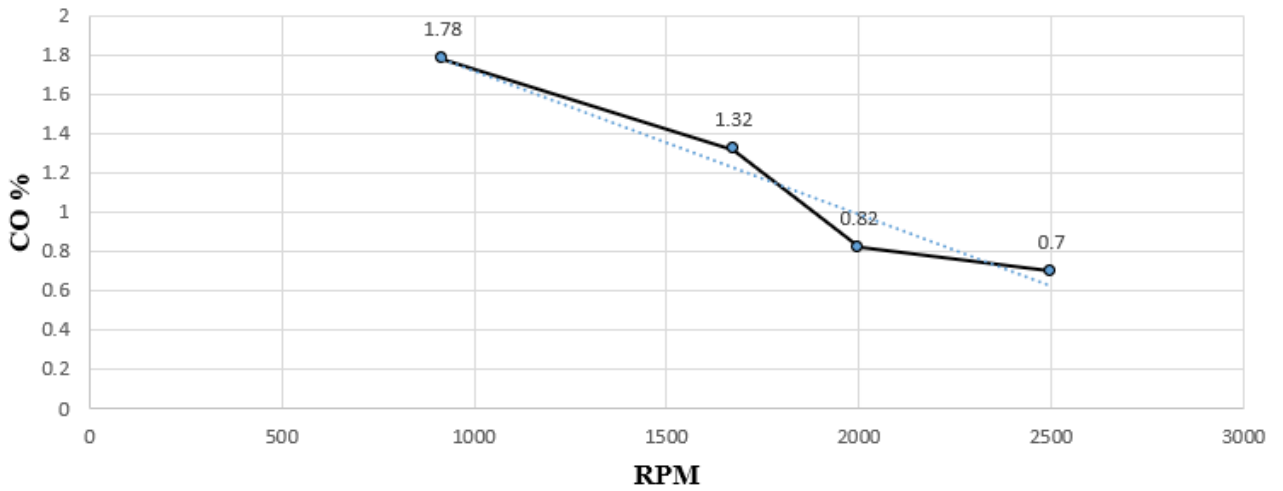


Figure 5.3: CO Emission Percentage VS. Engine Speed (RPM)

Describe of Three Figure:

An increase in NO_x Emission Percentage and CO₂ Emission Percentage is observed, because as the speed increases, the fuel consumption increases, and from oxidation and reduction within Catalytic Converter processes, the percentage increases NO_x and CO₂ Emission.

Control:

Due to the use of a personal car and the inability to deal with it and tampering with it, we could not complete the project, but in the near future there will be a screen to read live gases inside the car to monitor the percentage of gases and to be able to retrieve any value at any time. Before looking deep into the data, one must note a number of important rules for emission analysis:

- 1) If CO goes up, O₂ goes down, and conversely if O₂ goes up, CO goes down. CO readings are an indicator of a rich running engine and O₂ readings are an indicator of a lean running engine.
- 2) If HC increases as a result of a lean misfire, O₂ will also increase.
- 3) CO₂ will decrease in any of the above cases because of an air/fuel imbalance or misfire.
- 4) An increase in CO does not necessarily mean there will be an increase in HC. Additional HC will only be created at the point where rich misfire begins (3% to 4% CO).
- 5) High HC, low CO, and high O₂ at same time indicates a misfire due to lean or EGR diluted mixture.
- 6) High HC, high CO, and high O₂ at same time indicates a misfire due to excessively rich mixture.
- 7) High HC, Normal to marginally low CO, high O₂, indicates a misfire due to a mechanical engine problem or ignition misfire.
- 8) Normal to marginally high HC, Normal to marginally low CO, and high O₂ indicates a misfire due to false air or marginally lean mixture.

The analysis of the results depends on the percentage of emission for each gas compared to the data taken from Figure 5.4 which is a table in Automotive Technology: A Systems Approach by Jack Erjavec.

	IDLE	2500 RPM	PROBABLE CAUSE
HC ppm	0–150	0–75	Normal reading
CO%	1–15	0–0.8	
CO ₂ %	10–12	11–13	
O ₂ %	0.5–2.0	0.5–1.25	
NO _x ppm	100–300	200–1,000	
HC ppm	0–150	0–75	Rich mixture
CO%	3.0+	3.0+	
CO ₂ %	8–10	9–11	
O ₂ %	0–0.5	0–0.5	
NO _x ppm	0–200	100–500	
HC ppm	0–150	0–75	Lean mixture
CO%	0–1.0	0–0.25	
CO ₂ %	8–10	11	
O ₂ %	1.5–3.0	1.0–2.0	
NO _x ppm	300–1,000	1,000+	
HC ppm	50–850	50–750	Lean misfire
CO%	0–0.3	0–0.3	
CO ₂ %	5–9	6–10	
O ₂ %	4–9	2–7	
NO _x ppm	300–1,000	1,000+	
HC ppm	50–850	50–750	Misfire
CO%	0.1–1.5	0–0.8	
CO ₂ %	6–8	8–10	
O ₂ %	4–12	4–12	
NO _x ppm	0–200	100–500	

Figure 5.4: Emission Gases Reading at Different Conditions

Comparing the results which the device gives to the data in Figure 5.4, our results are very close. The following figures demonstrates the difference.

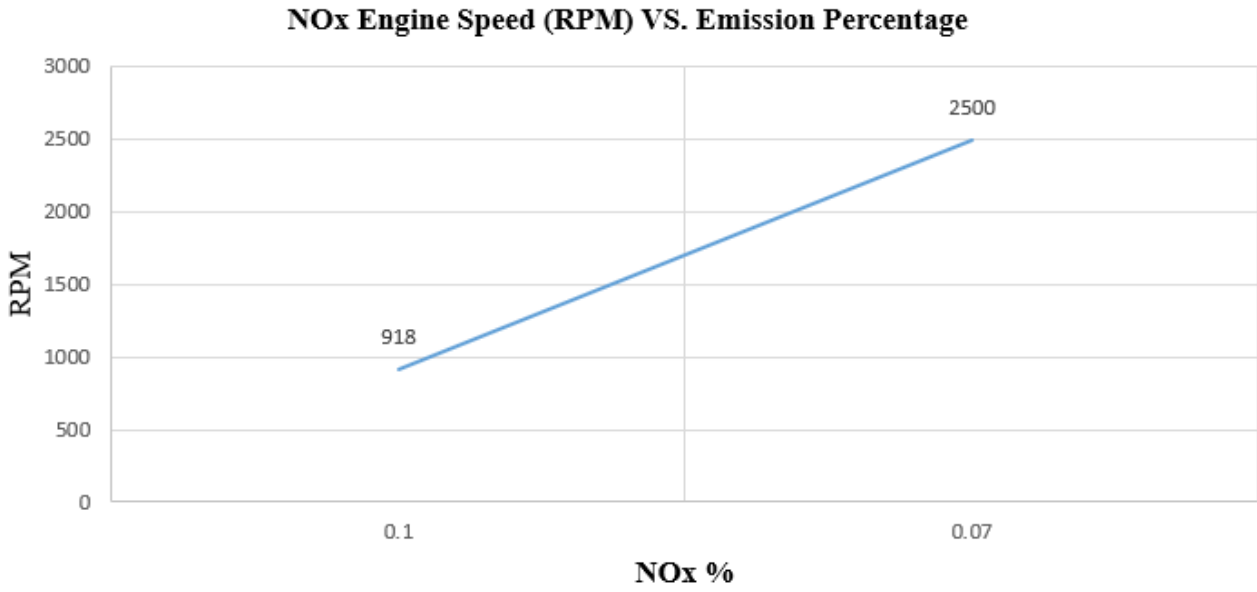


Figure 5.5: Engine Speed (RPM) VS. NO_x Emission Percentage

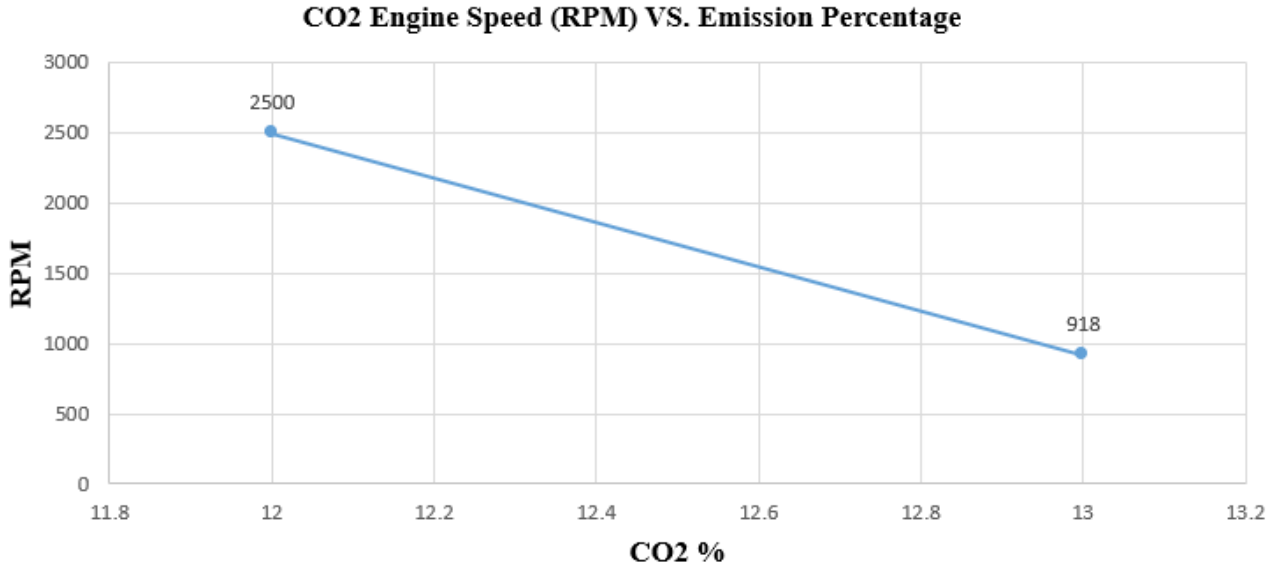


Figure 5.6: Engine Speed (RPM) VS. CO₂ Emission Percentage

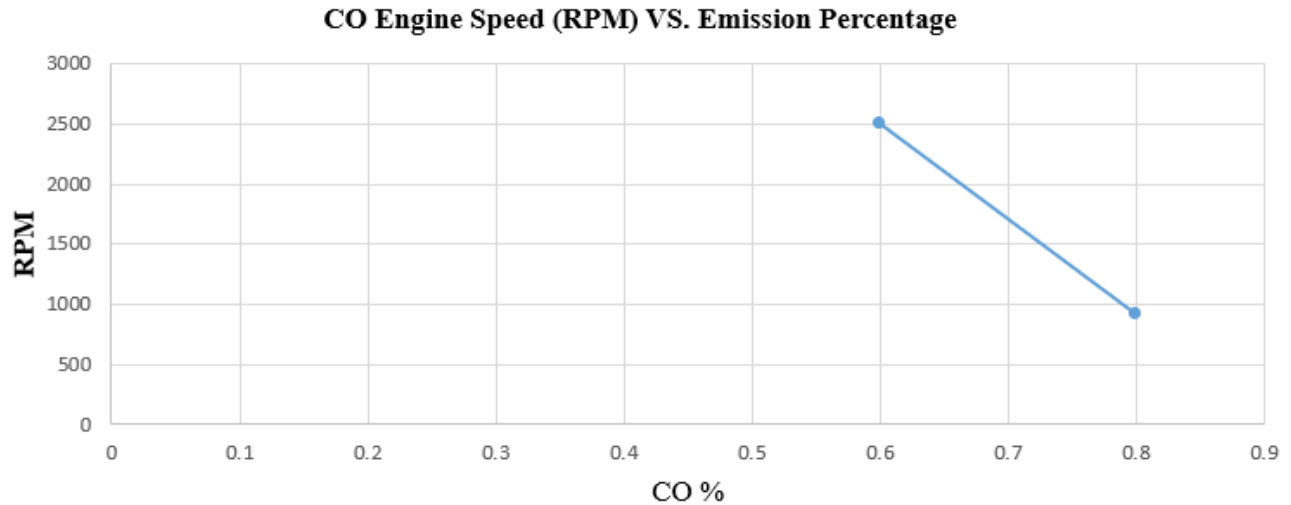


Figure 5.7: Engine Speed (RPM) VS. CO Emission Percentage

The device gives a relatively small percentage of error, but it's quite acceptable due to the following reasons:

- 1) The device is based on a low accuracy microcontroller.
- 2) The sensors are not for heavy work conditions nor accurate enough. But they did their job quite good because this is just a prototype and a high-quality sensors will be used in the future versions.
- 3) A problem appeared because there was not a testing car, and a personal car was used, thus not many tunings were available between the team hands.

5.4 Conclusion

The device did the required job and fulfilled the low price and the easy handling and usage, and even if the sensors and microcontrollers are changed with better higher quality ones the price will still be much lower than any gas analyzer.

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