Journal of VLSI Design and Signal Processing
Volume 2 Issue 1

Real Time Air Pollution Monitoring and Control System for Diesel Engine

S Jaganth Nivasan, S V Jegan, Ramkumar R, Sanjoy Deb

Department of ECE, Bannari Amman Institute of Technology,

Sathyamangalam, Tamil Nadu, India

E-mail: sjn.nivas@gmail.com, jegansv3339@gamil.com, ramkumarr@bitsathy.ac.in, sanjoydeb@bitsathy.ac.in

Abstract

In recent years, the motor industry has been promoting the diesel car due to their greater fuel economy and reduced maintenance requirements. However, diesel cars have much harmful emission characteristics and an increase in diesel cars at the expense of petrol cars have caused negative impacts on urban air quality and caused global warming and other environmental issues. Apart from the various particulate matters, diesel engine mainly emits two pollutant gasses, carbon monoxide (CO) and nitrogen oxides (NOx). Among those two, the NOx is more harmful and is causing various negative environmental and harmful health related issues. Although, there are many systems proposed to encounter these issues but most of them either costly or difficult to implement and handle. Under such demand and availability scenario, present research has successfully designed and implemented a real-time low-cost NOx monitoring and removal system applicable for diesel engine. System designed under present research has successfully monitored and displayed NOx level in engine exhaust at various operating scenarios and also achieved 20% reduction in NOx level with its low-cost chemical filter. Although, technology proposed and developed under present research is at its early stage but with maturity, in near future it will successfully encounter diesel engine related harmful air pollution.

Keywords*: Air pollution, vehicle engine operation, diesel exhaust, air parameter sensor, catalyst convertor, system design*

INTRODUCTION

As per the published report of World Health Organization (WHO), every single year, around two million people die prematurely from the effects of air pollution [1]. The air pollution seriously effects our environment in a number of ways [2]. The emissions of greenhouse gases are bringing climate change like global warming. Such global warming is causing significant rise in sea water level by melting ice from colder regions and rise of sea water level is causing human and animal displacement due to loss of habitat [3]. On the other hand ozone-depleting gaseous substances produced through air pollution are creating larger holes in the ozone layer which is causing high UV radiation effect and acid rain [4]. In one side, the acid rain significantly polluting fresh water and sea water, on the other side, the high UV ray is affecting all existing life form present on the earth [5]. Not only environment hazards, air pollution has brought many associated risks to human health, e.g., lung and breathing problems, skin cancer and organ damage etc. [1]. There are numerous of gases and particles are on the list which is causing air pollution, e.g., sulfur dioxide, carbon monoxide, carbon dioxide, nitrogen oxides, volatile organic compounds (VOCs), unburned hydrocarbons, suspended particulates, aerosols, fly ash etc. [3]. Presently, there is plenty of air pollution sources, some of them are natural, e.g., forest fires, erupting volcanoes, and gases released from radioactive earth rocks etc. but most of them are manmade, e.g., burning of fossil fuels, agricultural activities, exhaust from factories and industries, mining operations etc. [2]. Among those manmade sources burning of fossil fuel is the phenomenal source of air pollution and it is mainly caused by vehicular exhaust [5]. Presently billion cars are on road today and virtually all of them are powered by fuel engines that burn mainly petroleum to release energy. The petroleum is made up of hydrocarbons and burning them fully in oxygen environment produces carbon dioxide and water [6]. But, in practice petroleum fuel is not pure hydrocarbon and engine does not burn them cleanly as a result engine exhaust contains all kinds of pollutants, e.g., carbon monoxide, nitrogen oxides (NOx), VOCs and ozone etc. [6].

During last few decades, air pollution from petrol car exhaust has been on the rise but use of fuel efficient diesel car has made air pollution scenario worst [5]. Apart from the particulate matter (sulfates, ammonium, nitrates, elemental carbon,

condensed organic compounds, arsenic, selenium, cadmium and zinc etc.) emissions, diesel engine mainly emits two pollutant gasses carbon monoxide (CO) and nitrogen oxides (NOx) [7]. Among those two types of gases are emitted from the diesel engine, the Nitrogen dioxide is more harmful than other gases. The nitrogen oxides cause acid rain, ozone depletion, decrease in aquatic oxygen level etc. as environmental impact and also cause various health related effects like lung disease, asthma etc. [7]. So, contentious monitoring harmful nitrogen oxides contain in diesel engine exhaust and possible conversion of nitrogen oxides into other general gaseous compounds can reduce the harmful effects air pollution considerably [8–10]. Various systems to monitor NOx level in diesel engine exhaust have been developed around the last decades but most of them either costly or difficult to handle in practice [11–15]. So, there are existing demands of low-cost handy monitoring and reduction system.

Considering its importance, under present research a real time low cost NOx monitoring system for diesel engine exhausts has been designed and hardware implemented. Present system is a microcontroller based automated system which has used WSP1110 Sensor module as NOx sensor and LED as well as LCD for indicating NOx level in diesel engine exhaust. A chemical filter has been designed with a mixer of 32.5% urea (ammonia) and 67.5% of deionized water and has been attached with the monitoring system. The chemical filter system has been attached to reduce harmful NOx level in exhaust gas by converting it into less harmful combinations of CO_2, N_2 and H_2O. The designed filter section can be operated in on or off mode based on the predefined NOx threshold level set at the controller section using a relay switch. Designed system has been tested with practical diesel vehicle exhaust. It has been found to be functioning well by effectively monitoring NOx level and successful reduction of NOx under tolerable limit. In the following sections, system architecture (with detail block level design), system operation (both physical and chemical) and test results are presented and discussed elaborately.

SYSTEM ARCHITECTURE

Present system is composed of a NOx sensor unit, power supply block, microcontroller block, LED indicator, LCD display block, submersible motor and relay block connect with filter section as shown in Figure 1 below:

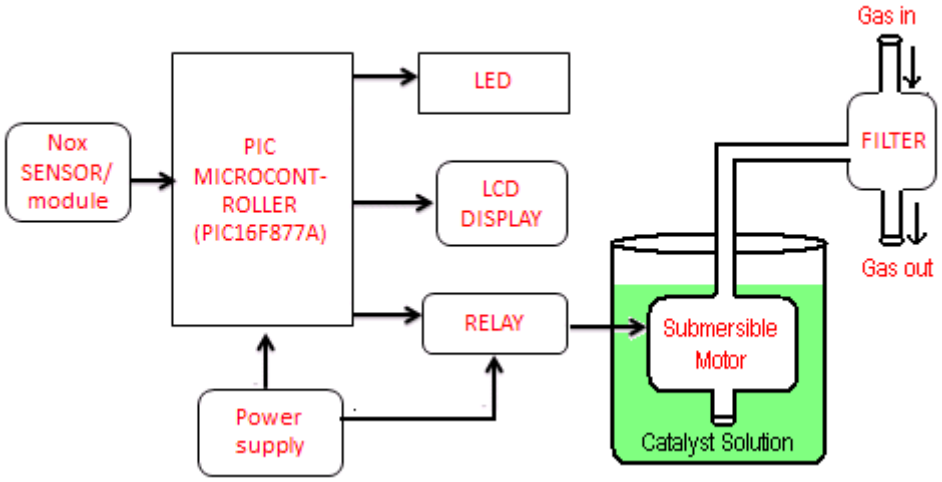

Fig. 1: *Present System Architecture at Block Level.*

Power Supply

Since different functional block of the proposed system requires different dc power supply voltage levels, e.g., micron roller will operate with +5V whereas relay section will operate with ±12V. So, multiple level power supply has been designed with center tapped transformer, diode regulators and IC 7805 and 7812, 7912 for +5V and ±12V, respectively.

Submersible Motor and Relay

A submersible motor has been used for pumping the catalyst solution in to the filter section if NOx level in exhaust gas is more than tolerance threshold. The submersible motor gets on and off by a relay switch (model: P43 single relay switch, make: ACTion) which is being controlled by PIC controller.

NOx Sensor

A relatively low cost and reliable NOx sensor was required for the effective sensing so WSP1110 Nitrogen Dioxide Sensor module has been used under present design. It is a small size, light weight sensor works with NO_2 range of 0.1–10 ppm. Among various nitrogen oxide (NOx), NO is unstable and always oxidizes to produce stabile nitrogen oxide NO_2, so only NO_2 sensor has been used for present system design.

LED and LCD Unit

Simple LED of 5V is attached to the PIC to indicate NOx level is higher the tolerable threshold. Same time to display NOx value in ppm a 240×128 pixel LCD display (model: T6963C make: Toshiba) has been attached to the controller.

Controller Unit

The PIC16F877A microcontroller is used in present system which is a CMOS FLASH-based 8-bit microcontroller. This controller is having 20 MHz operating speed, 256 bytes of EEPROM data memory, 2 Comparators, 8 channels of 10-bit Analog-to-Digital (A/D) converter, a synchronous serial port and a parallel port etc. which makes it a suitable choice for present application. Equivalent "c" code of full system operational algorithm has written and saved in PIC to monitor NOx level at real time and switch on filter section when required.

SYSTEM OPERATION

Present system involves physical as well as chemical operations to perform NOx detection and NOx filtering from diesel engine exhausts, as follows:

Physical Operation

The sensor has been fitted outside of the engine outlet pipe, which continuously senses the NOx level in gas exhausts from the diesel engine. After sensing NOx, the sensor will generate an equivalent voltage signal (analog) which will be contentiously converted into digital with ADC through PIC analog input port. The microcontroller will monitor the input from the sensor and will compare it with the predefined threshold value. If the input signal value from sensor is above the threshold value then controller will generate signal to switch on the relay and relay will make the submersible motor on. The corresponding NOx value will be also get displayed on LCD and LED will start blinking. The submersible motor which is dipped inside the catalyst solution will pump the solution into the filter section where it will chemically interact with NOx gases coming out from the engine. Finally, through several chemical reaction stapes the harmful NOx will get reduced in out coming gases from filter.

Chemical Operation

The catalyst solution contains a mixer of 32.5% of urea (ammonia) and 67.5% of deionized water which is used to reduce the NO_x concentration in diesel exhaust. When solution is injected into the hot exhaust gas stream, the water evaporates and the urea thermally decomposes to from ammonia and isocyanic acid as:

$(NH_2)_2CO \rightarrow NH_3 + HNCO$

1.The isocyanic acid will go through hydrolyses to create carbon dioxide and ammonia as;

$HNCO + H_2O \rightarrow CO_2 + NH_3$

2. Next, ammonia, in presence of oxygen (a catalyst), will interact with NOx and reduce it into nitrogen oxides:

$2NO + 2NH_3 + {}^{1/2}O \rightarrow 2N_2 + 3H_2O$

3. $3NO_2 + 4NH_3 + 3O_2 \rightarrow 7/2N_2 + 6H_2O$

4. Final outcome of overall reaction will be common CO_2, N_2 and H_2O mixture.

RESULTS AND DISCUSSIONS

Various outdoor laboratory tests have been performed to calibrate the system and also experiments have been conducted to find some useful test results. The system hardware has been shown in the following Figure:

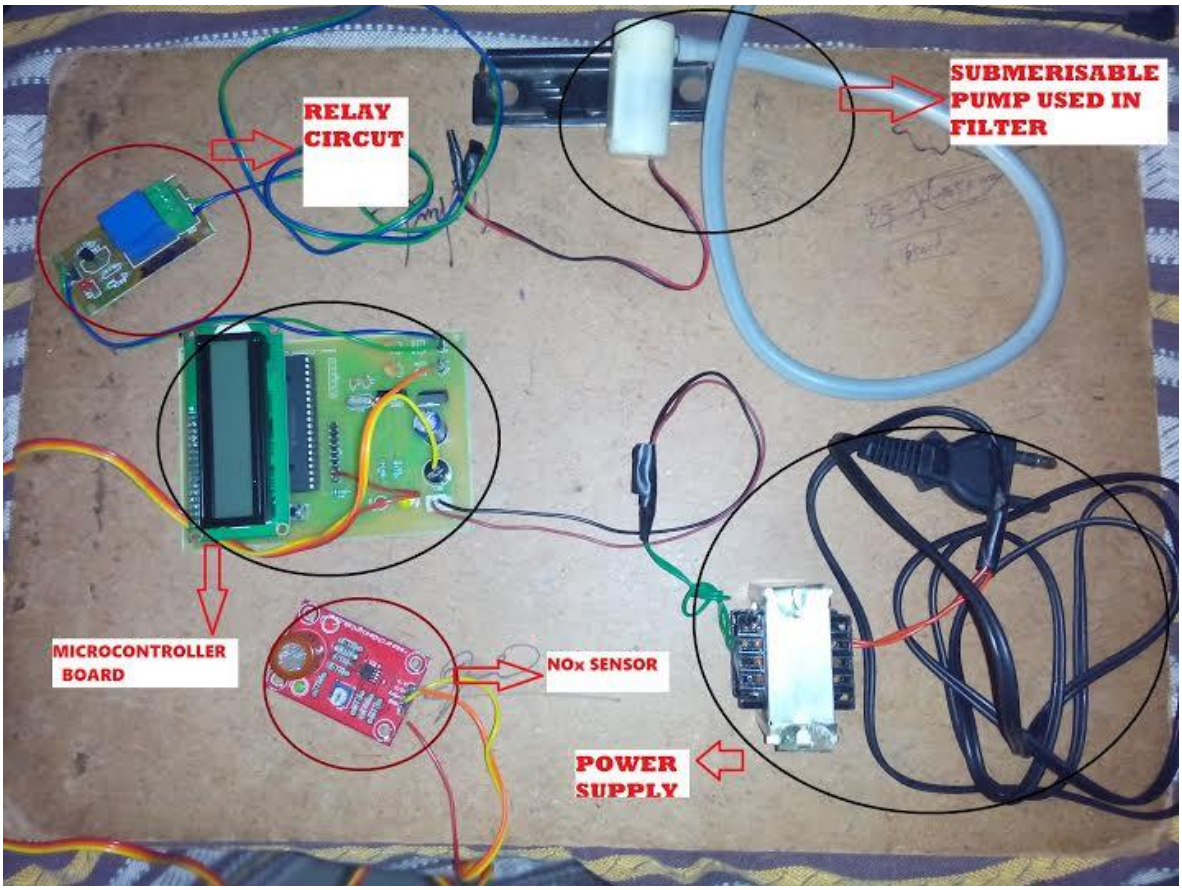

Fig. 2: *Full System Hardware with Various Functional Blocks.*

When the vehicle is moving at a constant speed, the NOx contain in diesel engine gas exhaust from a standard four-wheeler (model: Maruti Alto K10) is considered to be the reference threshold level for present system. When the vehicle gates sudden acceleration or moving up-hill, it produces NOx with higher rate, as observed by field test. For all the cases either the vehicle is moving constant speed or gates accelerated, the output reading has been taken for hours and then averaged to find an acceptable value of NOx gas. Test results are presented in following Table.

Table 1: *Different System Operation Scenarios (SOS) and Corresponding Averaged NOx Level.*

System Operation Senario (SOS)	**NO_2 Level (Averaged for 30 mins)**
SOS 1: Readings from the sensor when vechicle engine runs at nutral condition. Frequency of taking reading is once every minite.	989.23 ppm
SOS 2: Reeding from the sensor when the vechicle escalator is pressed suddenly. Frequency of pressing escalator is once in every minit.	1016.43 ppm
SOS 3: When the exhust gas passed through the Filter in case of SOS 2. Frequency of taking reading is once every minite.	855.93 ppm

Every SOS 1, 2 and 3 are executed for 6 times and got averaged to authenticate the system output readings. It has been found filter takes little time to gate activated which has been found 5 mins approximately [16].

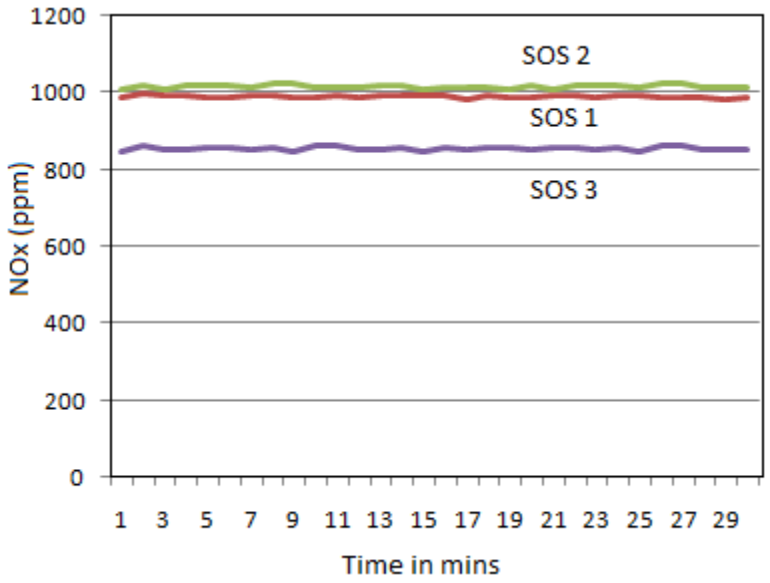

Fig. 3: *Different SOSs (1, 2 and 3) are Plotted with Time Scale.*

The SOS 1, 2 and 3 are plotted with time and it has been found that there is almost 2.73% increase in NOx level in gas exhaust from SOS 1 to SOS 2. But with the application of filter the effective reduction in NOx level from SOS 2 to SOS 3 is approximately 18.69% which is quite remarkable.

CONCLUSSION

Designing a real time NOx monitoring system for diesel engine exhaust and a

subsequent filter system to convert harmful NOx into less harmful gaseous byproducts, is high on demand. Present research has been focused over designing the hardware of a real time NOx monitoring and removal system. Proposed system has been economically designed with low cost sensors, microcontroller, LED, LCD, submersible motor and chemical mixture for filter section etc. Proposed system has successfully calibrated and displayed NOx level in diesel engine exhaust for different System Operation Scenarios. It has been found that filter section can reduce almost 20% NOx from the engine exhaust through successive chemical reaction steps. Although, it is highly beneficial, it is also accepted that such type of chemical filter system is difficult to implement in practice due to its liquid nature. But efficient engineering tricks in future will make it possible to implement such filter system with real time monitoring system to keep air pollution within limit.

REFERENCES

1. 7 million premature deaths annually linked to air pollution, WHO press relise, 25 March 2014 | Geneva http://www.who.int/mediacentre/news/releases/2014/air-pollution/en/.
2. Z. Chen et al. The effect of air pollution on human health in china: a macro evaluation. *3rd International Conference on Bioinformatics and Biomedical Engineering*; 2009.
3. J. Lelieveld et al. The contribution of outdoor air pollution sources to premature mortality on a global scale. *Nature*. 2015; 525: 367–371p.
4. Peter Knippertz et al. The possible role of local air pollution in climate change in West Africa. *Nature Climate Change*. 2015; 5: 815–822p.
5. An online report by Damian Carrington. Diesel cars emit up to four times more toxic pollution than a bus, data reveals, 21 October 2015, http://www.theguardian.com/environment/2015/oct/21/diesel-cars-emissions-toxic-pollution-than-a-bus-data-reveals.
6. On line article by Natalie Obiko Pearson and Rakteem Katakey India's Diesel Cars Are Proving Lethal Exhaust from the subsidized fuel causes cancer, asthma, and more, March 8, 2014, http://www.bloomberg.com/news/articles/2014-03-06/indias-diesel-fuel-subsidy-breeds-toxic-air-pollution.
7. News paper report by By Miranda Prynne “Diesel drivers to be penalised in drive to cut air pollution, 29 Jul

2014, http://www.telegraph.co.uk/news/earth/greenertransport/10996836/Diesel-drivers-to-be-penalised-in-drive-to-cut-air-pollution.html.

8. K. Galatsis, W. Wlodarsla, K. Kalantar-Zadeh et al. Investigation of gas sensors for vehicle cabin air quality monitoring. 2002; 42: 167–175p.
9. S. S. Chandrasekaran et al. Automated control system for air pollution detection in vehicles. *4th International Conference on Intelligent Systems Modelling & Simulation (ISMS)*; 2013.
10. George F. Fine, Leon M. Cavanagh, Ayo Afonja et al. Metal oxide semi-conductor gas sensors in environmental monitoring. *Sensors*. 2010; 10: 5469–5502p.
11. Diesel Exhaust Monitoring System by Pinssar Pty Ltd. Australia, MPM-4M - Diesel Particle Measuring System, http://pinssar.com.au/product-view/diesel-exhaust-monitoring-system-3.
12. Serge V. Monros. On-board diesel emissions diagnostic and monitoring system, US patent US 20140217292 A1 on 7 Aug 2014.
13. Karmjit Sidhu. Monitoring and control of exhaust gases from diesel-powered engines. *Business Development American Sensor Technologies*. 2014.
14. MIRA-MONITOR (Continuous Parametric Monitoring System,CPMS), MIRATECH Tulsa, OK 74108 USA, http://www.miratechcorp.com/products/mira-monitor/.
15. Gaikwad Varsha Bhagwan, Puranik V.G. real time air pollution monitoring using mobile phone. *International Journal of Innovative Research in Science, Engineering and Technology*, 2014; 3(4).
16. Snehal Sirsikar, Priya Karemore. Review paper on air pollution monitoring system. *International Journal of Advanced Research in Computer and Communication Engineering*. 2015; 4(1).