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An Electronic Device for Detecting Adulteration of Petroleum Products at Point-of-Sale Terminals

Aaron Okiemute Onyan[1] and Emmanuel Ighodalo Okhueleigbe[1]
[1]Department of Electrical and Electronics Engineering, Federal University of Petroleum Resources, Effurun
Corresponding author onyan.aaron@fupre.edu.ng, (+2348133899246)

Abstract
This work presents the design and implementation of a locally made portable electronic device for detecting adulteration of petroleum products (petrol and diesel) at point-of-sale (POS) terminals. The device uses the chemical signature of emitted vapour of petroleum products to check for adulteration. The device consists of an ATmega328P microcontroller programmed with the source code for controlling the entire system, MQ-4 and MQ-6 Gas Sensors for detecting the constituent gases in the samples, GPS and GSM modules for communication, a Keypad for selecting desired inputs, and a Buck Converter that regulates the voltage to the desired constant values. The gas sensors are placed over a container sealed with a sample of petroleum product for less than 1 minute, during which time the sensors send signals to the microcontroller. The microcontroller analyzes the signals, generates a result, and then sends information to approved mobile phone numbers through GPS and GSM. The electronic device developed in this work provides a test result when it senses and analyzes vapour emitted by a petroleum product for concentrations of methane, iso-butane, and natural gas, thus obtaining the chemical emission signature of the sample of petroleum product being checked for adulteration. Thereafter, it displays the result on a Liquid Crystal Display (LCD) and transmits the data and location to authorized mobile phone numbers via SMS if the product is detected to be adulterated.

Keywords: Adulteration, Methane, LPG, Gas sensors, GSM module, GPS module.

1. Introduction
Petroleum products are classified as either fuel or non-fuel products. Petrol and diesel are major petroleum products obtained from crude oil refining and are used as primary sources of energy for vehicles, machines, and household use. In various countries, there are codes, standards, and specifications in place to ensure that supplied petroleum products meet a minimum standard or quality to ensure vehicles run satisfactorily and safely. Adulteration of petroleum products, on the other hand, has become a thriving business in many developing countries.

Adulteration is the act of weakening or contaminating a substance by adding another substance of lower value to it. It is introduction of foreign substance into fuel illegally or unauthorized,thus resulting inthe product not conforming to the requirements and specifications (DPRGazette, 2009; NNPC, 2008). Financial incentives that arise from differential petroleum product prices, as well as greed inflamed by a differential tax system on different petroleum fractions are generally the primary causes of petroleum product adulteration (Otobrise, 2013). Adulteration of petroleum products

increases tailpipe emissions of hydrocarbons, carbon monoxide, nitrogen oxides, and particulate matter, with negative consequences for public health, it causes explosions, resulting in deaths, deformities, irreparable damage to engines of automobiles and machines that make use of petroleum products, such as sudden failure, difficulty in starting, increased emissions of harmful gases, increased fuel consumption and safety related problems and incalculable losses to the country's petroleum product consumers (Mohan, et al., 2006;Muralikrisha et al., 2006).

Several tests and methods have been developed for detection of adulteration of petroleum products, (Roy, 1999) described a technique for detecting/estimating kerosene adulteration in gasoline or diesel using an optical fiber sensor. The evanescent absorption of monochromatic light caused by the addition of kerosene to gasoline or diesel is exploited in this method. (ASTM, D,2018;ASTM, D, 2020; ASTM, D, 3810 (n.d)), spearheaded tests for adulteration of petroleum products by measuring parameters such as density, boiling points, and evaporation points (Onyishi & Ejofodomi, 2020) explored Gaseous Vapor Emission, a new technique for detecting adulteration at POS terminals (GVE). GVE correctly identified the petrol sample as pure by confirming the presence of the characteristic methane and butane emission peaks.Most current methods for detecting adulteration in petroleum products necessitate chemical laboratory experiments to measure parameters. Consumers cannot use these methods at point-of-sale (POS) terminals. Ongoing research is being carried out to incorporate sensors into automobiles and machines to detect fuel adulteration quickly. As a result, there is a need for a simple electronic device that can detect adulteration.

This paper is focused on developing a portable locally made electronic device for detecting adulteration of petroleum products. The device sends a report and the location of the test via SMS to a mobile phone number defined by the system when a tested petroleum product is detected to be adulterated. This creates an avenue for the user to know the quality of petroleum products being purchased and also give a report of adulteration to regulatory bodies. The sensors utilized in this electronic device have a higher sampling rate, hence they give off results quickly as compared to the method described by (Onyishiand Ejofodomi, 2020). Besides, there is a reconfiguration function added to the electronic device to adjust the timing parameter for a more accurate result.Moreover, the portable electronic device is locally designed and constructed.

2. Methodology

The developed electronic device for detecting adulteration of petroleum products consists of an ATmega328PArduino Uno microcontroller programmed to carry-out all the control functions and to give corresponding digital outputs of the chemical emission signature of the petroleum product sample tested, with data transmitted via GPS and GSM technology. To avoid false messages, the system is designed in such a way that it only sends an alert message based on the programmed

threshold value of the different gas sensors and ignores any value that corresponds to the pre-set threshold values. When the system analyzes a petroleum product sample and detects adulteration, it sends a message indicating the precise location of the point-of-sale (POS) terminals, whether a gas station or a roadside vendor, where a petroleum product sample was tested and found to be adulterated. The program algorithm specifies certain parameters for the microcontroller to send text output indicating the exact location via a GSM module. The block diagram of the electronic device for detecting adulteration of petroleum products is shown in Fig. 1.

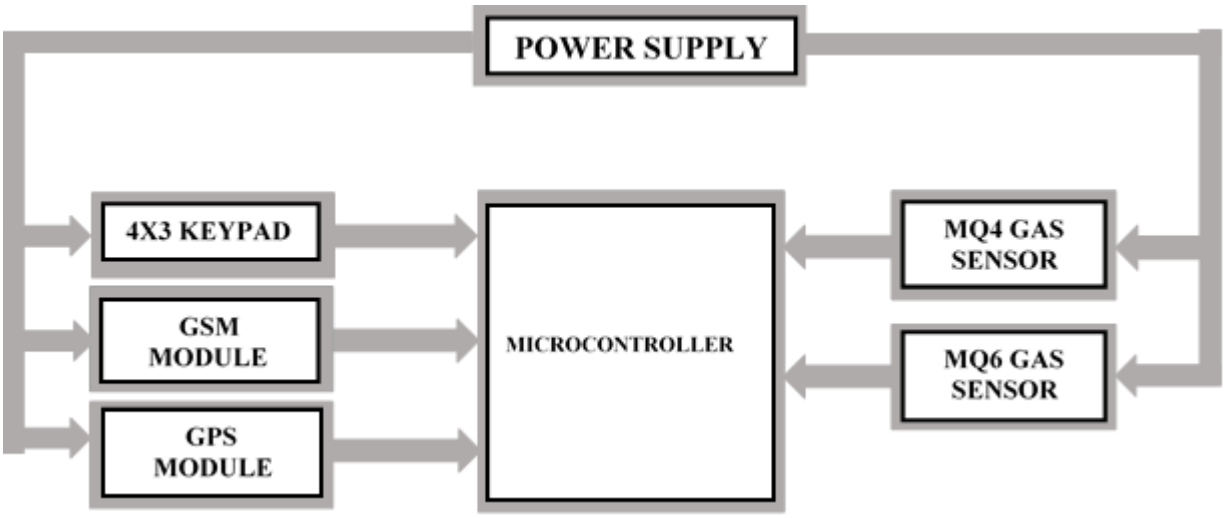

Fig 1: Block diagram of electronic device for detecting Adulteration of Petroleum Products

2.1 Microcontroller Unit

The Arduino Uno microcontroller unit is programmed to send a pulse to the trigger pin of the sensor, after which the gas sensors are enabled to receive vapor emissions from the sample being tested. The microcontroller receives sensor signals, converts them from analog to digital, processes them, and outputs the desired output based on its predefined knowledge base, that is, the initial conditions programmed on the microcontroller. The value of the concentrations of methane and LPG obtained from the sample being tested is compared with the preset value in the program. When it gets to the preset minimum or maximum value, the microcontroller gives a digital output to display if the sample being tested is adulterated or pure.

2.2 MQ-Series Gas Sensors

The MQ-4 and MQ-6 gas sensors were used. MQ-4 gas sensor detects the presence and concentration of methane in the atmosphere. The MQ-4 gas sensor is extremely sensitive to methane-CH4 emissions. MQ-6 gas sensor detects the presence and concentrations of LPG, iso-butane, propane, and LNG due to its high sensitivity to them. The heater in them creates the necessary working conditions for sensitive components. The gas sensors output the concentration of the gases as an analog voltage that is proportional to the concentration of the gases. When the target

gases are present, the sensors conductivity rises in tandem with the gas concentration, and the sensor converts the change in conductivity to the corresponding output signal of gas concentration. It also has an onboard comparator for comparing to a user-defined preset value and displaying a digital high or low indicating whether the sample being tested is adulterated or pure.

To Interface the MQ-series gas sensors with the microcontroller, the MQ-4 and MQ-6 gas sensors are connected to the AN2 and AN3 of the microcontroller, the terminals tagged VCC and GND are connected to +5 V and 0 V respectively. Figs. 2a and 2b show the MQ-4 and MQ-6 gas sensors interfaced with the Arduino Uno microcontroller.

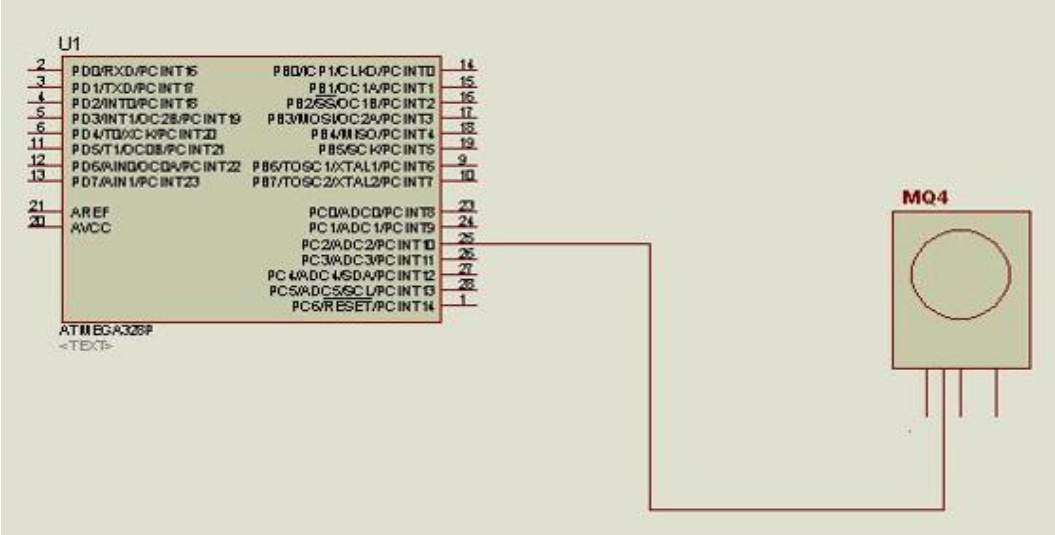

Fig 2(a): Connection of the MQ-4 gas sensor to microcontroller

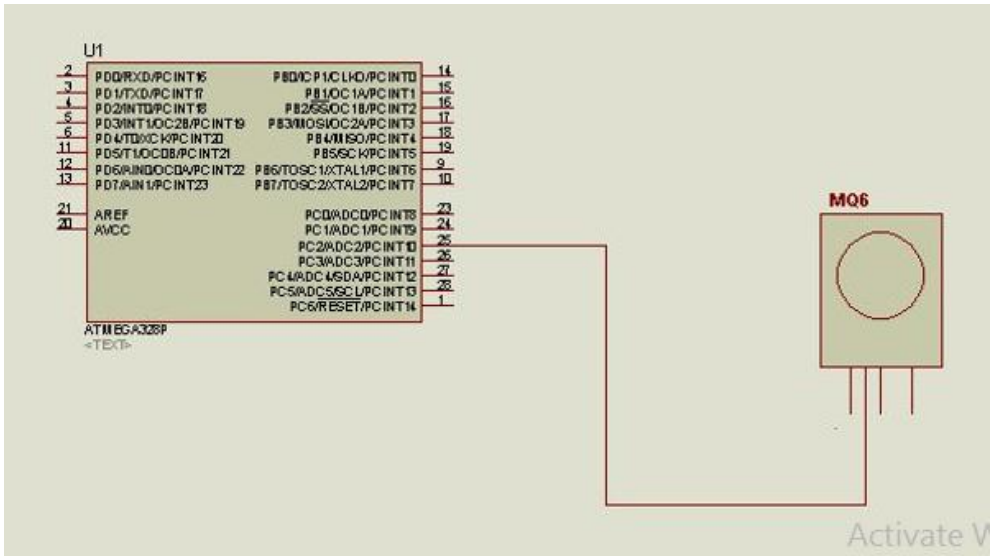

Fig 2(b): Connection of the MQ-6 gas sensor to microcontroller

2.3 Communication Unit

This unit comprises the SIM800L GSM and NEO-6M GPS modules shown in Figs 3 and 4. The SIM800L GSM module, like a mobile phone, accepts a SIM card and operates via a mobile operator subscription. It is a small cellular module that can transmit GPRS data, send and receive SMS messages, and make and receive voice calls. This deviceis in charge of sending SMS messages to user phones; it includes a SIM Module and communicates with the processor via AT Command.

Fig 3: SIM800L GSM module

The NEO-6M GPS module is a high-performance full GPS receiver with a 25 x 25 x 4mm ceramic antenna built in for robust satellite search capacity. The power and signal indicators allow you to keep track of the module's status. The module connects with the microcontroller serially via the USART communication protocol, which sends data bit by bit at a pace of 9600 bits per second

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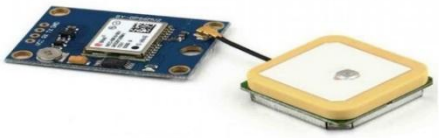

Fig 4: NEO-6M GPS Module

2.4 Program Development

The program for the electronic device for detecting adulteration of petroleum products was written in ***C*** programming language and developed using the Arduino Integrated Development Environment (IDE). The flow chart of the program is shown in Fig. 5.

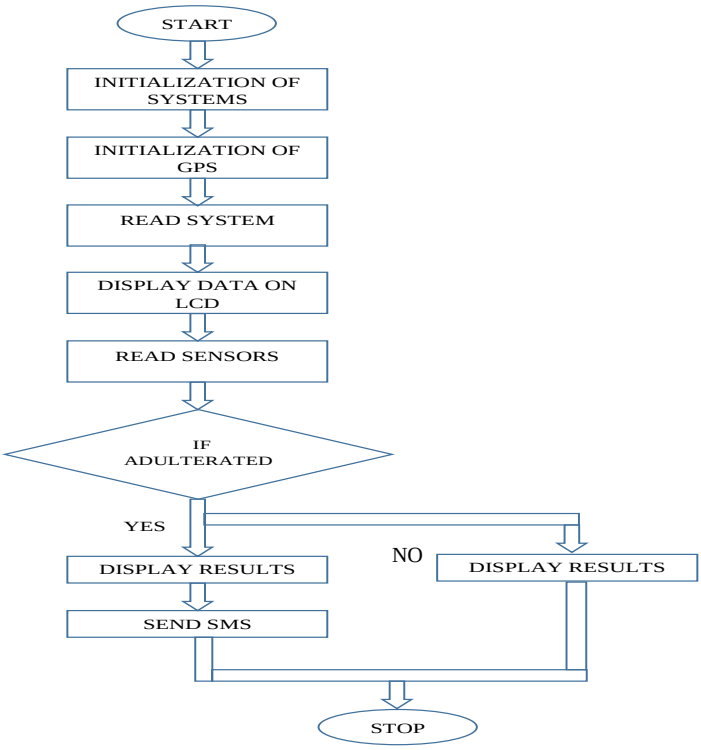

Fig 5: Flow chart of the program algorithm

2.5 Mode of Operation

Fig. 6 depicts the complete circuit diagram of the electronic device for detectingadulteration of petroleum products. This consists of the various hardware components that are interfaced together to make the device work.

As shown in the circuit diagram, all the components are interfaced to the microcontroller, which serves as the brain of the system. The system is powered by a DC battery, and the battery voltage is connected to a non-Linear voltage regulator, which is a DC-DC buck converter that helps keep it at a constant 5V, 2A. This same regulator powers the remaining components on the board, and it is further stepped down to 3.3V by a diode for devices such as the GSM Module. The Matrix Keypad is connected to the Microcontroller's pins 14, 15, 16, 17, 18, 19, and 23, which are used to send key commands to the controller.The 20 x 4 LCD is connected to the Microcontroller's digital pins, and the controller sends commands and data to the LCD screen via its control and data pins. The MQ4 and MQ6 gas sensors are connected to the microcontroller's analogue pins, and the microcontroller reads both pins simultaneously to obtain readings for the LPG and Methane content of the product under test. The MQ gas sensors, like the MCU, operate on 5V, and the system constantly iterates over the sensor values for a much more accurate result and performs a computational analysis. The buzzer, which gives a beep sound, is connected to pin 13 and its other terminal is connected to ground; the buzzer is activated in the Gas leakage mode when the presence of LPG or Methane gas in the environment is high.

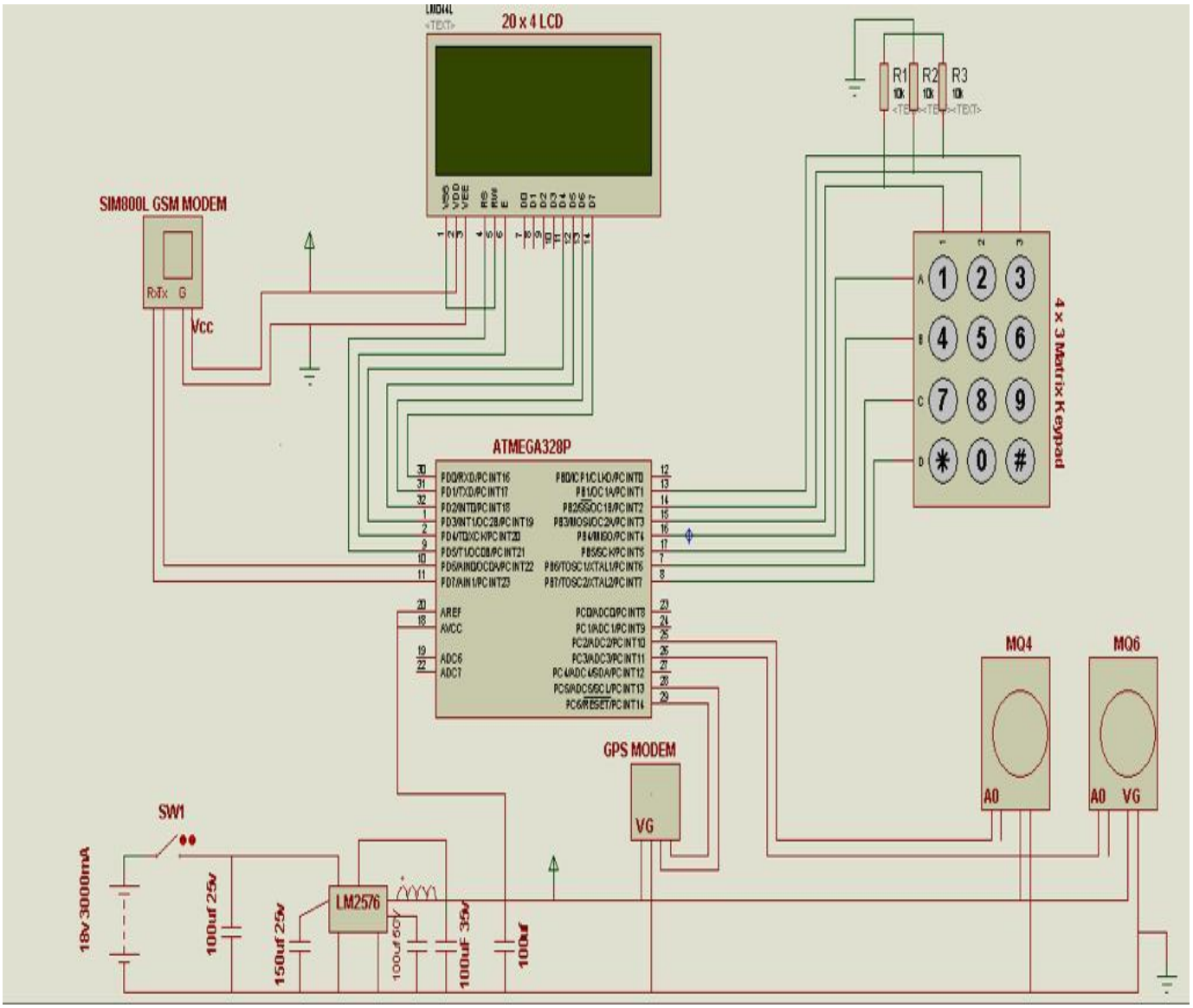

Fig. 6: Circuit diagram of the electronic device for detecting adulteration of petroleum products

3. Test and Results

The constructed electronic device for detecting adulteration of petroleum products is shown in Fig. 7.The system was tested with two samples of petroleum products, one being a pure sample of petrol and the other a sample of adulterated petrol.The device was placed over the samples of petroleum products and turned on. The gas sensors send signals to the microcontroller after being placed over the container sealed with a sample of petroleum product for less than 1 minute. The microcontroller analyzes the signals and generates a result which is displayed on the LCD. Fig. 8(a) shows the test result of concentration of gases of pure petrol sample as displayed on the LCD, while Fig. 8(b) indicates detection of pure

petrol sample. On the other hand, Fig. 9(a) shows the test result of concentration of gases of adulterated petrol sample as
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displayed on the LCD, while Fig. 9(b) indicates detection of adulterated petrol sample

Fig. 7: Constructed electronic device for detecting adulteration of petroleum products

(a) Test result showing concentration of gases of pure petrol sample

(b) Test result indicating detection of pure petrol sample

Fig. 8: Pictorial views of the test result on the pure sample of petrol

(a)Test result showing concentration of gases of adulterated petrol sample

(b)Test result indicating detection of adulterated petrol sample

Fig.9: Pictorial views of the test result on the adulterated sample of petrol

Once the presence of adulterated petrol is detected, the information is sent to an approved mobile phone through GPS and GSM as shown in Fig. 10.

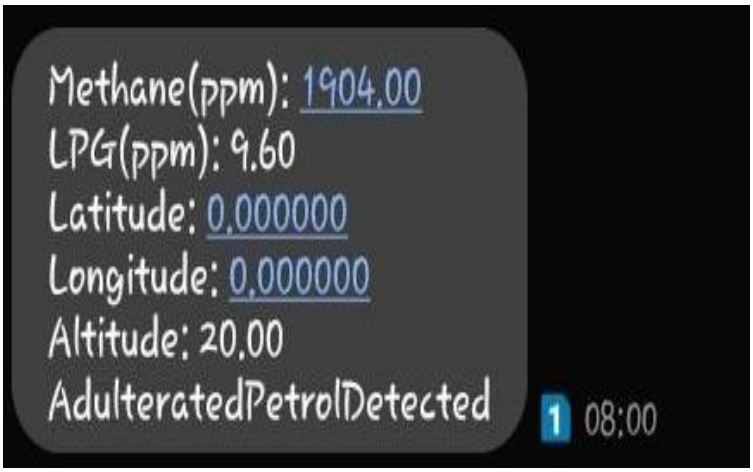

Fig 10: SMS Notification indicating adulteration of petrol.

The electronic device developed in this work provides a test result when it senses and analyzes vapor emitted by petroleum product for concentrations of methane and LPG. The values given off are because of the preset thresholds.

Conclusion

This work presents the design and implementation of an electronic device that detects the adulteration of petroleum products and sends a report and the location of the test via SMS to a designated mobile phone number when a tested petroleum product is detected to be adulterated. The device also detects gas leakage when the presence of LPG or Methane gas in the environment is high, and the buzzer is activated in the gas leakage mode.The GPS tracking algorithm and the GSM alert-based algorithm are implemented with the microcontroller in embedded system domain to enable the device to track the geographical information automatically and send an SMS alert when adulterated petroleum products are detected. This device will help the regulatory authorities to track the location of the adulterated products, and thus it would be easier to locate and apprehend offenders. Several tests were carried out carefully to obtain data for the emission signature of pure petroleum products and the results were precise. This system provides a more reliable and user-friendly method for detecting adulterated petroleum products. This method will help prevent the harmful effects of these adulterated products on the environment.

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