Design of a Data Acquisition and Logging System for Air Quality Monitoring and Meteorology Application

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Abstract
Human activities contribute immensely to the increase in heat-trapping gaseous concentration in the atmosphere and this continuous increase could gravely affect our climate. This paper reports the design and deployment of an automated low cost portable air pollution monitoring and meteorological data acquisition and logging system. The air pollution monitoring system contains electrochemical gas sensors to monitor the interest pollution parameters in the environment. Important climatic parameters are measured with selected sensors, all connected to a microcontroller with real-time communication and monitoring. The data obtained were compared with the standard Meteorological data.

Key words: Air Pollution, Microcontroller, Sensors, Data Acquisition, Real-time Monitoring.

1.0. Introduction

Air pollution is currently one of the leading environmental causes of premature death in the world. According to the World Health Organization (WHO), approximately seven million premature deaths annually are due to the effects of air pollution [1]. Governments and private sectors all over the world have taken drastic measures to reduce emissions and curb pollution in the air we breathe. Many health-harmful air pollutants also damage our climate.

Since the beginning of the industrial era (1850), human activities have raised atmospheric concentrations of CO_2 by nearly 49% [3]. The Intergovernmental Panel on Climate Change (IPCC) in its Fifth Assessment Report, concluded there's a better than 95 percent probability that human-produced greenhouse gases such as carbon dioxide(CO_2), methane and nitrous oxide have caused much of the observed increase in Earth's temperatures over the past 50 years[4]. The global average atmospheric carbon dioxide in 2020 was 412.5 parts per million (ppm), setting a new record high amount despite the economic slowdown due to the COVID-19 pandemic. The United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO) have estimated that reducing short-lived climate pollutant (SLCP) emissions from key sources such as traffic, cooking stoves, waste, agriculture and industry could reduce global warming by about 0.5° C (2010 - 2050) [3,9].

Weather affects a wide range of the human activities; therefore weather monitoring is very much helpful to keep track of different climates behavior. Advances in microelectronics and gas sensing technology has opened up the scene for low-cost portable air pollution stations, capable of measuring and logging air pollution factors in real time.

2.0. Aim

The purpose of this work is to develop a low-cost portable device capable of regularly monitoring and logging the air pollution and meteorological parameters such as Temperature, Heat index, Relative Humidity, Light intensity, CO_2, NH_3 and CO in real time.

This is to provide a system which is user friendly, straightforward and robust solution to monitor the air quality continuously and in real-time. The system is a portable device that can be located anywhere to monitor the indoor and outdoor air parameters with high measurement accuracy and low power consumption.

3.0. Components of the System

A. Microcontroller Development Board (Arduino Uno)

The Arduino Uno is a microcontroller development board on the ATmega328. It has 20 digital input/output pins, out of which 6 can be used as Pulse Width Modulation (PWM) outputs and 6 can be used as analog inputs, a 16MHz resonator, a USB connection, a power jack, an in-circuit system programming (ICSP) header, and a reset button. It contains everything needed to support the microcontroller; it is usually connected to a computer with a USB cable or powered with an AC-to-DC adapter or battery to get started. It is being programmed with C/C++.

B. MQs Gas Sensors

A Sensitive film of MQs gas sensor is tin oxide (SnO_2), which has lower conductivity in clean air. The gas sensitive film changes its resistance when subject to certain gases. The sensor's conductivity is increasing with the gas concentration rising. A 5V voltage is applied to the heater of each sensor. This is necessary to increase the response of the SnO_2 element to various gases. Prior to application in circuit, each senor was preheated for at least 24 hours. This one-off errand is necessary to achieve stable readings. The

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reading from the sensors of pollutants detected has to be converted to the corresponding ppm values

MQ7 is used to measure Carbon Monoxide (CO) concentration in ppm.

MQ135 is used here to measure Carbon Dioxide (CO_2) and Methane (NH_3) concentration in Parts per million (ppm). The detection range is 10-10,000ppm with the voltage rate of about 5.0V±0.1V AC or DC.

C. DHT22

The DHT22 is a basic, low-cost digital temperature and humidity sensor. Compared to the DHT11, this sensor is more precise, more accurate and works in a bigger range of temperature/humidity (-40 to 80 °C temperature readings ±0.5 °C accuracy and 0-100% humidity readings).

D. Light Sensor (LDR)

LDR measures the light intensity in Lux. The resistance of Cadmium Sulfide (CdS) or light dependent resistor (LDR) is inversely dependent on the amount of light falling on it.

E. RTC DS3231

In data acquisition and data logging application the actual time of the acquired signal is required. Therefore, RTC is used to keep track of current time. The DS3231 is much more accurate, as it comes with an internal Temperature Compensated Crystal Oscillator (TCXO) which isn't affected by temperature, making it accurate down to a few minutes per year at the most.

F. Liquid Crystal Display (LCD)

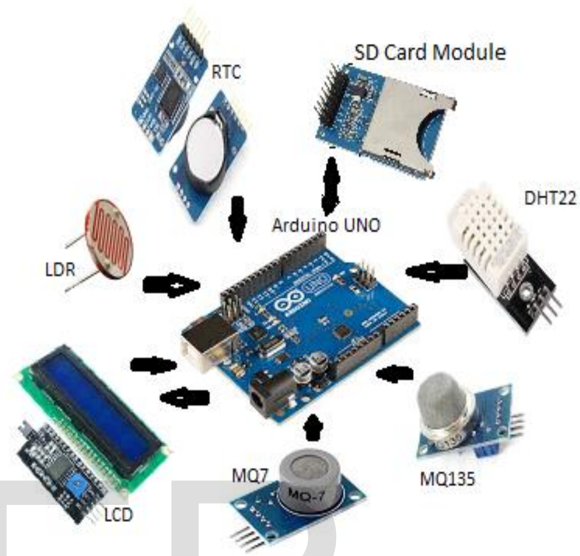
LCD screen is an electronic display module that uses liquid crystal to produce a visible image. The 16×2 LCD display is a very basic module commonly used in electronics circuits. The 16×2 translates and displays 16 characters per line in 2 such lines. In this LCD, each character is displayed in a 5×7 pixel matrix. LCD with I2C module communicates with Arduino Uno to displays sensors data.

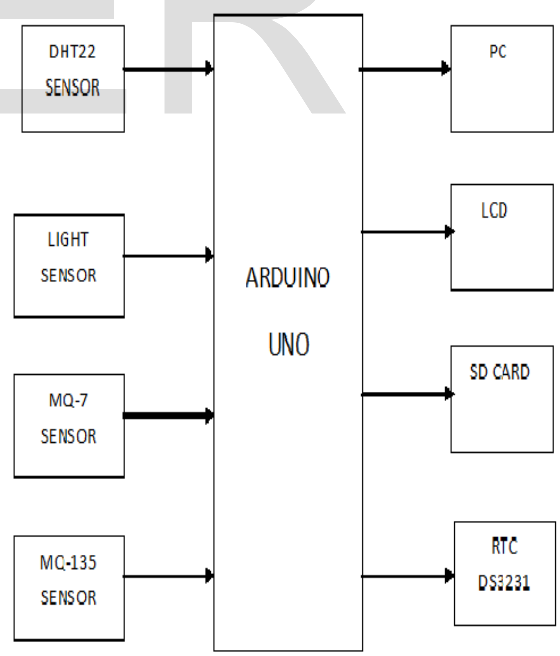
G. SD Card Module

The micro- SD Card Module is used for transferring data to and from a standard SD card. The pin out is directly compatible with Arduino, but can also be used with other microcontrollers. It allows addition of mass storage and data logging. This module has SPI interface which is compatible with any SD card. It uses 5V or 3.3V power supply which is compatible with Arduino UNO/Mega. This saves the data read by the sensors on the micro SD card inserted

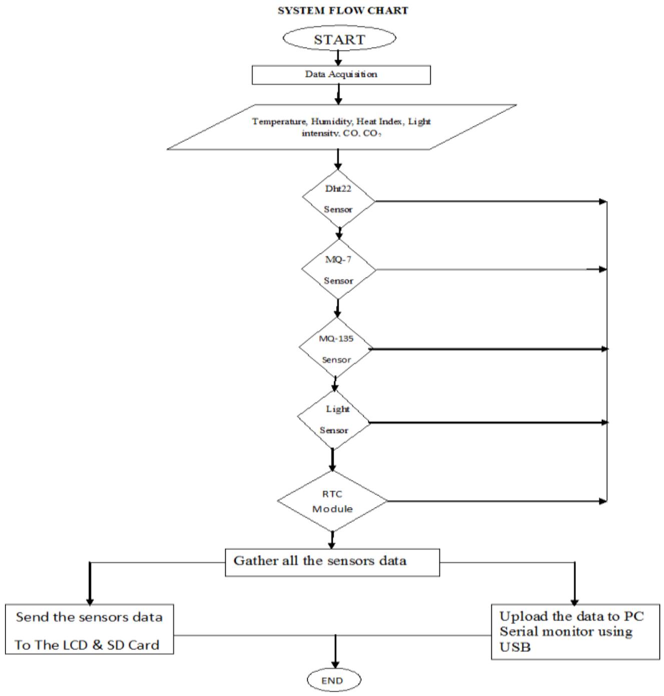
4.0. <u>System Development/ Integration</u>

The circuit was connected as shown in the diagram below. A USB cable was used to directly connect the Arduino to the computer or give power using battery source or AC to DC adapter of 5V DC output to get started. Then, through the IDE (integrated development environment), the code was loaded, the various sensors data then displayed on the LCD, and automatically saved on the SD card.





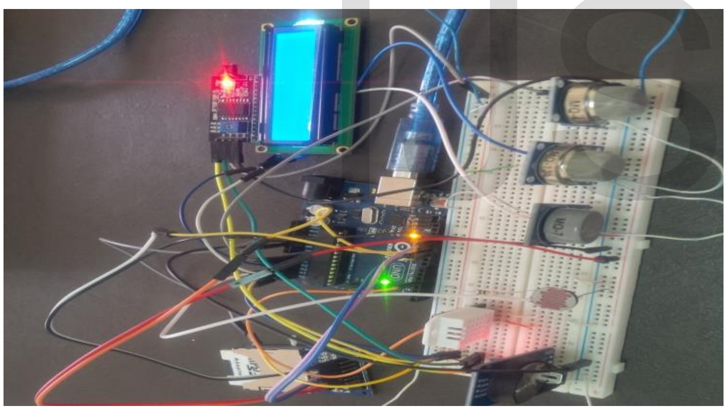
Block diagram of the Schematics



1					AIR POLUUTION AND WEATHER MEASUREMENT						
2	Date	Time	RH (%)	Temp(*C)	Temp(*F)	Heat Index (*C)	Heat Index (*F)	Light Int.(Lux)	CH3(ppm)	CO2(ppm)	CO(ppm)
3	02.09.2021	10:06:25	76.1	30.6	87.08	38.34	100.99	1020	1.2	358	0.95
4	02.09.2021	10:06:36	76.2	30.7	87.26	38.67	101.58	1019	1.2	357	0.95
5	02.09.2021	10:06:47	76.1	30.6	87.08	38.34	100.99	1019	1.3	357	0.95
6	02.09.2021	10:06:57	76.6	30.7	87.26	38.79	101.81	1019	1.3	358	0.93
7	02.09.2021	10:07:08	76.6	30.6	87.08	38.49	101.26	1025	1.3	358	0.93
8	02.09.2021	10:07:19	76.6	30.6	87.08	38.49	101.26	1025	1.3	357	0.93
9	02.09.2021	10:07:30	77.5	30.6	87.08	38.77	101.77	1025	1.3	340	0.93
10	02.09.2021	10:07:41	77.1	30.6	87.08	38.65	101.54	1025	1.3	362	0.93
11	02.09.2021	10:07:52	76.6	30.6	87.08	38.49	101.26	1025	1.4	322	0.93
12	02.09.2021	10:08:03	76.5	30.6	87.08	38.46	101.21	1025	1.4	333	0.93
13	02.09.2021	10:08:14	76.6	30.6	87.08	38.49	101.26	1025	1.2	333	0.93
14	02.09.2021	10:08:25	76.6	30.6	87.08	38.49	101.26	1025	1.3	356	0.93
15	02.09.2021	10:08:36	76.5	30.6	87.08	38.46	101.21	1025	1.3	366	0.91
16	02.09.2021	10:08:47	76.6	30.6	87.08	38.49	101.26	1025	1.2	356	0.95
17	02.09.2021	10:08:57	76.6	30.6	87.08	38.49	101.26	1025	1.2	345	0.93
18	02.09.2021	10:09:08	76.6	30.6	87.08	38.49	101.26	1025	1.2	354	0.93
19	02.09.2021	10:09:19	76.6	30.6	87.08	38.49	101.26	1025	1.2	345	0.93
20	02.09.2021	10:09:30	76.6	30.6	87.08	38.49	101.26	1025	1.3	346	0.93
21	02.09.2021	10:09:41	76.5	30.6	87.08	38.46	101.21	1025	1.3	346	0.93
22	02.09.2021	10:09:52	76.4	30.6	87.08	38.43	101.15	1025	1.3	346	0.93
23	02.09.2021	10:10:03	76.5	30.6	87.08	38.46	101.21	1025	1.3	349	0.91
24	02.09.2021	10:10:14	76.6	30.6	87.08	38.49	101.26	1025	1.3	348	0.98
25	02.09.2021	10:10:25	76.6	30.6	87.08	38.49	101.26	1025	1.3	346	0.98
26	02.09.2021	10:10:36	77.2	30.6	87.08	38.68	101.6	1025	1.3	346	0.98
27	02.09.2021	10:10:46	77.2	30.6	87.08	38.68	101.6	1025	1.3	346	0.98
28	02.09.2021	10:10:57	76.9	30.6	87.08	38.58	101.43	1025	1.3	347	0.95
29	02.09.2021	04:11:08	76.7	30.6	87.08	38.52	101.32	1025	1.3	345	0.95
30	02.09.2021	04:11:19	76.6	30.6	87.08	38.49	101.26	1025	1.3	344	0.95
31	02.09.2021	04:11:30	76.3	30.6	87.08	38.4	101.1	1025	1.3	344	0.95
32	02.09.2021	04:11:41	76.2	30.7	87.26	38.67	101.58	1025	1.3	344	0.93
33	02.09.2021	04:11:52	76.2	30.7	87.26	38.67	101.58	1025	1.3	346	0.93
34	02.09.2021	04:12:03	77.1	30.7	87.26	38.95	102.09	1025	1.3	344	0.93
35	02.09.2021	04:12:14	76.6	30.7	87.26	38.79	101.81	1025	1.3	347	0.93

Figure 1: Readings downloaded from the SD card inserted into the device.

The figure 1 above is the sample of reading of all the sensors saved on the SD-Card with the exact date and time input by the RTC module.



<u>Picture of the System</u>

5.0. <u>Results</u>

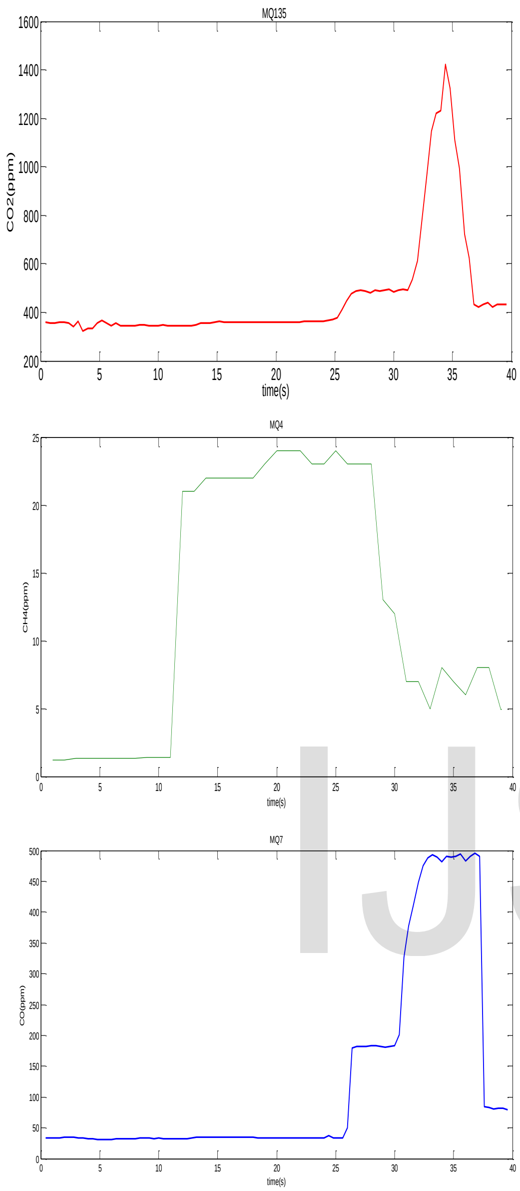


Figure 2 a, b and c

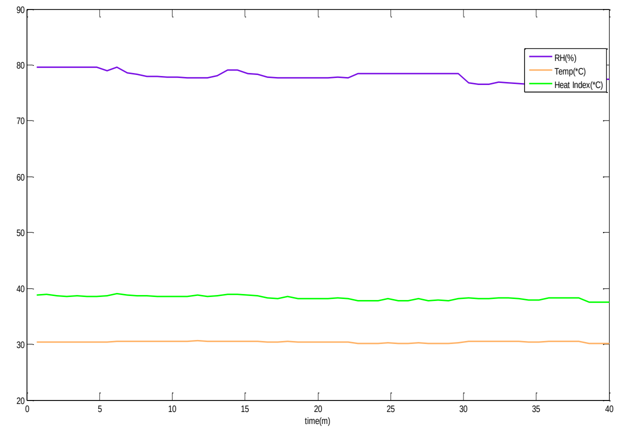


Fig. 2d

The figure 2a and 2b above shows the response of MQ135 to CO2 and NH3 gas concentrations, with the spikes indicating the introduction of the higher concentration of these gases.

Figure 2c show the response of the MQ7 to CO concentration in normal and higher concentrations, while figure 2d indicates the response of DH22 to Temperature, Heat index and Relative humidity

6.0 <u>Discussion and Conclusion</u>

<u>Discussion</u>

The device designed was set up, and the readings were taken from Gwagwalada, one of the highly populated areas of Abuja in Nigeria.

From the data obtained as shown in figure 1, the values of Temperature, Relative humidity, and heat index corresponds with the standard values obtainable in Abuja-Nigeria.

Also, the values obtained from gas sensors (MQ135 for CO2 and NH_3, and MQ7 for CO) were at the ranges of standard acceptable values until the introduction of air pollutants containing high concentration of the respective gases, where we observed a considerable spike as shown in figure 2a to 2c.

<u>Conclusion</u>

A low-cost portable device capable of regularly monitoring and logging the air pollution and meteorological parameters such as Temperature, Heat index, Relative Humidity, CO_2, NH3 and CO in real time has been developed. This is to provide a system which is user friendly, straightforward and robust solution to monitor the air quality continuously and in real-time. The system measures the indoor and outdoor air parameters with high accuracy and low power consumption.

To ensure proper monitoring and mitigation of Climate change, more gas sensors should be included to the system and the device needs to be employed especially in most congested urban areas in developing countries. A data storage platform can be created where data from across different areas in the country can be made available, therefore, providing a single platform to monitor and analyze air pollution at various locations across the country. This will provides an efficient and low cost solution for continuous monitoring of environment.

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