A MICROCONTROLLER BASED DATA ACQUISITION SYSTEM FOR INDUSTRIAL AIR POLLUTION CONCENTRATION MEASUREMENT IN NIGERIA

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Abstract— Clean air is a basic necessity for all human beings living on earth, yet about 80% of the world's population breathes air that has pollutants which exceed the World Health Organization's recommended level. This paper presents a microcontroller based data acquisition system for industrial air pollutant concentration measurement in industrial facilities in Nigeria using Ile-Ife Steel Company as a case study. A prototype design methodology and system flow chart was used in the design of the system while a PIC18F4550, MQ7 sensor, capacitors, resistors, connecting wires, transistors, voltage regulator, transformer, Light Emitting Diodes (LED's), Fan, Liquid Crystal Display (LCD), Buzzer, Temperature Sensor, Oscillator, Bread Board, Zener Diode, etc. were used in the implementation of the system design. The system developed was able to measure CO pollutant concentration, trigger alarms, classify pollutant level, and display pollutant level on an LCD and save measured data in an external memory for future access. Performance test and reliability test were performed to ensure conformity to the designed objectives

Keywords— *Microcontroller, Sensor, Air pollution, CO*

I. INTRODUCTION

Air pollution has been aggravated by developments that typically occur as countries become industrialized thus, growing cities, increased traffic, rapid economic development, industrialization, and higher levels of energy consumption become factors of the industrialization effort. The high influx of population to urban areas, increase in consumption patterns and unplanned urban and industrial development has contributed to the air pollution problem. Stratospheric ozone depletion due to air pollution has long been recognized as a threat to human health as well as to the Earth's ecosystems [1,2] The report, prepared by Global Scientific Inc., found that suspended particulate matter (SPM) including dust, fumes, mist, and smoke in the air in commercial, industrial and even residential areas of the city exceeds the National Ambient Air Quality Standards throughout the year [1,3]. In the majority of the developed world, legislation has already been introduced to the extent that local authorities are required by law to conduct regular Local Air Quality reviews of key urban pollutants such as Benzene, SO_2, NO_x, CO or Ozone produced by industrial activity and/or road transport. In order to achieve this, pollutant concentrations must be monitored accurately and ideally so that sources may be identified quickly and the atmospheric dynamics of the process are understood [4, 6]. Furthermore, such data would lend itself to real-time environmental decision making. This report will also address the relevant background surrounding the causes and effects of air pollution as well as bring to light recent research and initiatives employed by cities both local and global and comparisons will be made between the previous prototype and the changes that have been implemented in achieving the new design.

Impacts on Health

The impact of air pollution on health is one of the most significant concerns of the World Health Organization. It is estimated by the WHO that around 2 million people per year die globally from a direct result of poor air quality. Reports show that this is not only affecting developing countries but health issues such as respiratory infections, heart diseases, asthma and lung cancer are all on the rise in developed countries such as the USA and the UK [7]. We must recognize and acknowledge that the issue of air pollution is a growing health burden within society and thus find more efficient and effective ways to monitor it in order to find a sustainable solution. Especially in recent decades more research has gone into the study of the looking more closely at specific cities around the world and how pollutant levels in the air affect the people living there. An article in the BBC News stated that the negative health consequences of air pollution could shorten a person's lifespan and breathing in unclean air was likened to inhaling second-hand smoke from a smoker continuously.

Other Associated Health Issues:

i. Respiratory Infections

ii. Heart Disease
iii. Asthma
iv. Chronic Bronchitis
v. Lung Cancer

Impacts on the Economy

With the rising cost in Health Care, the burden on the economy is another major impact that air pollution has on society. Billions of dollars are spent globally to address the health concerns, and in one article it was seen that in California alone the 'dirty air' caused $193 million in hospital based health care within a 2-year period [8]. The elevated pollution levels meant that "exposure to excessive levels of toxic gases and particulate pollution caused nearly 30,000 emergency room visits and hospital admissions. This impact may not be as disturbing as the health concerns however it proves that air pollution does have a significant impact on the state's economy.

Impacts on the Environment

Global Warming is a collective world issue as climate change affects and threatens the existence of everyone irrespective of nationality and culture. The advent of the industrial age resulted in processes whose output included pollution sources and pollutants such as CFC's and other oxides and particulate matter which have been attributed for the collapse of the ozone layer.

II. RELATED WORKS

Aruljothi .R M. et al [9] designed an Air Pollution Measuring System with Mobile Sensor Arrays which measure Carbon Monoxide and Nitrogen Oxide to develop an effective solution for pollution measuring using wireless sensor networks (WSN). The gas sensors are integrated with the ARM controller and location tracer GPS in User terminal. Other parameters like temperature are also sensed along with gas pollutant to enable data analysis through data aggregation techniques. Experimentation carried out using the developed air pollution measuring system under different physical conditions show that the system collects reliable source of fine-grain pollution data along with location of mobile vehicle. The system also collected pollution data using mobile hardware modules, transmits the data regularly using a GSM modem to a back-end server, and integrates the data to generate a pollution frame with geographical location and send to handheld devices of the user.

Sukwon C., et. Al [10] designed and implemented a Micro Sensor Node for Air Pollutant Monitoring called APOLLO (Air Pollutants Monitoring System) sensor node, APOLLO was constructed with off the shelf MEMS based or infrared based micro gas sensors. APOLLO provides air quality information by collecting independent sensing information from various air components and forwarding the collected data to the host system.

Barrenetxea et al [11] designed Out of the Box Environmental Monitoring device called Sensor Scope. Sensor Scope is a large-scale wireless environmental monitoring system. Sensor Scope was developed to provide *in-situ* spatial and temporal observations across the landscape. Sensor Scope makes use of solar energy with extensive radio duty cycling to prevent power outages.

Murty, R.N, et al [12] Proposed a monitoring system called City Sense. City Sense is an Urban-Scale wireless sensor network and test bed is also a large-scale wireless environmental monitoring system .City Sense supports the development and evaluation of wireless systems that span an entire city by employing over 100 Wi-Fi enabled Linux-based PCs embedded throughout buildings and streetlights. City Sense used a wired power supply.

Honicky, R. et al [18] developed N-smarts which is a network suite mobile atmospheric real-time sensors. N-SMARTS is a GPS-enabled cell phone-based or car mounted citywide environmental data acquisition system. Its sensor module consists of carbon dioxide, carbon monoxide, three-axis accelerometer, and temperature sensors.

Lozano, P.et al [1] proposed a mobile air quality-monitoring network comprising of sensors that can detect O_3, NO_2 and CO/VOC. The scheme focused on data collection and presentation, but did not consider issues like the characteristics of the gas sensors and energy management

Koushanfar, F. et al [15] designed a laser spectroscopic trace-gas sensor networks, sensor integration and applications Laser Specks was developed based on a laser spectroscopic trace-gas sensor platform. By integrating quantum cascade laser technology, both the size and cost of the system are reduced, while providing a wide range of detectable gases. However, the power consumption is not negligible.

Simon J. et al [14] were collaboration between Cambridge University, Imperial College London, Leeds University, Newcastle University and Southampton University. This system monitors vehicle occupancy, position, movement, temperature, humidity, noise, CO and NO_2. It has a low cost, low power ZIGBEE transceiver and a data logger on board. It collects data through a gateway to a central server.

III. METHODS

The choice of research methodology used in carrying out this project design is;

- Prototype research methodology
- Top-design research methodology

Where a prototype represents the shell of an actual production application. Prototypes are built early in the development lifecycle and are used to provide valuable insight into the look-and-feel, as well as the general workflow of an application.

Top-down research design methodology is essentially the breaking down of a system to gain insight into its compositional subsystem. In a top-down design, an overview of the system is formulated, specifying but not detailing any first – level subsystems [4, 5].

The system can be classified into its hardware and software components. The hardware which was implemented in the next section consisted of components such as a PIC18F4550, MQ7 sensor, capacitors, resistors, connecting wires, transistors, voltage regulator, transformer, Light Emitting Diodes (LED's), Fan, Liquid Crystal Display (LCD), Buzzer, Temperature Sensor, Oscillator, Bread Board, Zener Diode etc while the software involved utilizing assembly language written using the MIDE development environment for the microcontroller. The developed system comprises of the power supply unit, the signal conditioning unit and the output unit.

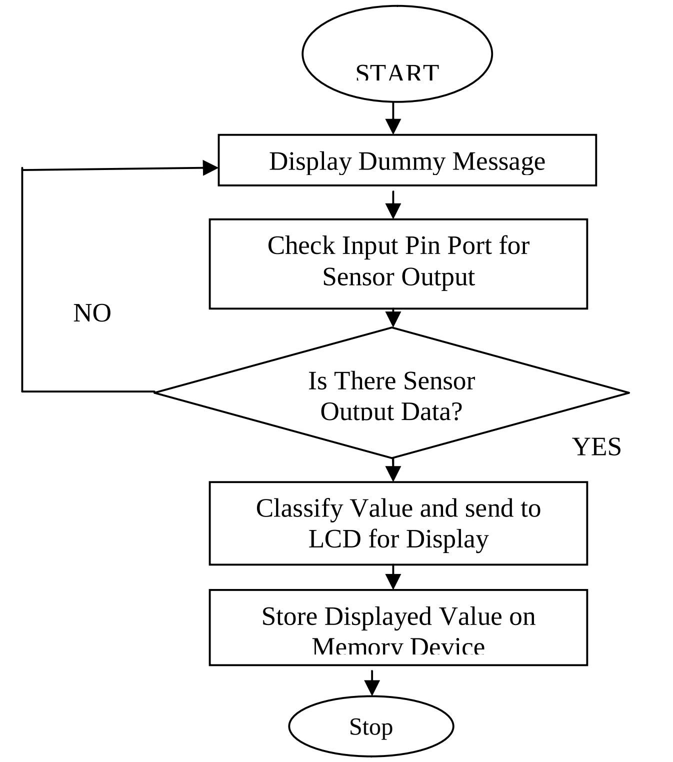

Fig 1: System Flow Chart for the Data Acquisition System

IV. Results And Discussions

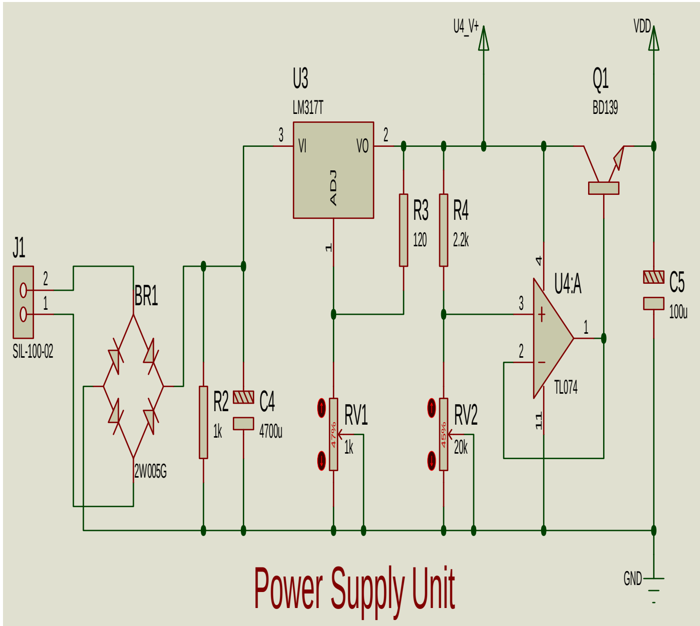

Fig 2: Power Supply Unit

The power for the circuit can be derived from a 15v AC or 15V - 22 V DC, with diodes (BR 1) providing reverse polarity protection. The nominal 12V supply rail is fed through an on/off switch to the input of a 3-terminal voltage regulator (LM317T), with filtering provided by a 3300uF 25V (C4) electrolytic capacitor. This 12V supply rail also drives a 12V fan via a 2 kilo ohms resistor. The resistor is there to reduce the fan speed and thus the noise it makes. The LM317 which is a variable regulator is configured to provide a 6Vsupply. The voltage between its OUT and ADJUST pins is nominally 1.25V, but in practice it ranges from 1.2V to 1.3V. If this voltage is 1.25, this means that a current of 10.4 mA flows through the 1kilo ohms resistor and the trimpot RV-1 sets the voltage across it to 4.75V and the output of the regulator to 6V (i.e. 4.75V + 1.25V). This 6V supply is used to drive the heaters in the MICS 4514 sensors. In addition, the 6V rail is fed to a voltage divider made up of RV1 and RV2 resistors. The resulting 5V output from the divider is then fed to the input op amp, which in turn drives the current amplifier. The resulting 5V rail powers the microcontroller, LDR1 and the LCD

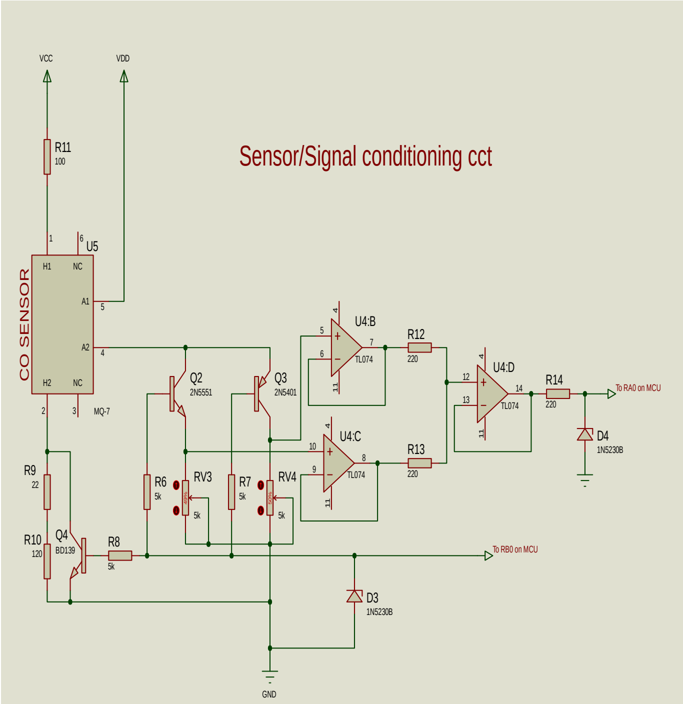

Fig 3: Signal Conditioning Circuit

This unit comprises of the sensors as an input device and the circuits which make it possible for it to communicate with microcontroller i.e. send signals to the microcontroller.

The output from the sensor is monitored at RB3/AN9 (pin 36) of the microcontroller. The manufacturer's specifications states that this sensor must initially be heated using a 5V supply connected across its element for 60s. The heater current is then reduced by placing just 1.4V across the element for 90s period. The carbon monoxide and the nitrogen oxide are then being measured, after which the initial 60 heating cycle begins again. In practice, this means that measurements are repeated at 2.5 minutes (i.e. 150 seconds). The heater is powered from 6v rail via two parallel resistors, while transistor ties the lower end of the heater element to 0V. The heater has a resistance of 33 ohms when Q1 is on, a current of 152mA flows through it. This results in a 1V drop across the two resistor, thus giving the required 5V supply for the heater. The transistor is controlled by the microcontroller's AN0 output (pin 2) and turns on when its gate is pulled high. The AN0 switches Q3 on for 60s to provide the heating current. And the other goes low for 90s, so the measurement can be made.

As a result, any changes in the sensor's resistance will result in a corresponding voltage change at the top of transistor. This signal is then applied to the AN3 input of the microcontroller and fed to its internal A/D converter. During set-up, RV5 is set so that AN3 is at 0.5 when the sensor is in normal air. However, this signal voltage can rise to around 3V when the CO concentration is over 300ppm. In operation, the sensor varies its resistance over a 10:1 range for CO concentrations ranging from 10 ppm to 1000 ppm.

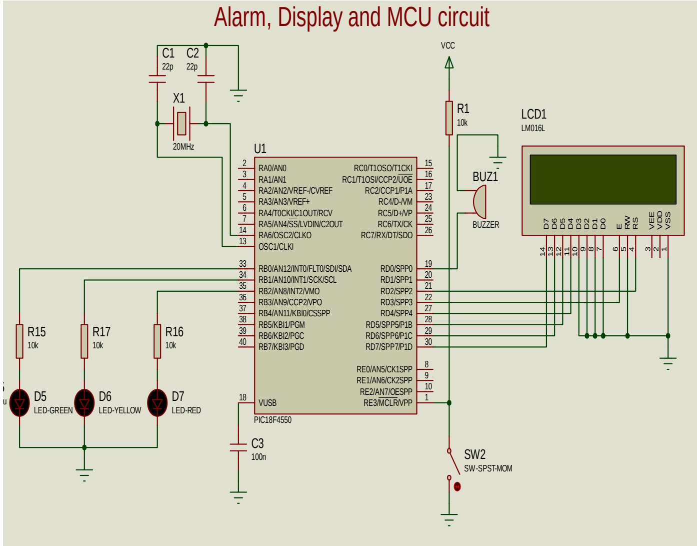

Fig 4: Alarm, Display and MCU Circuit

This consists of the interfacing of the microcontroller to the output devices such as the LCD display, buzzer and Light Emitting Diodes where the three LEDs are used to indicate the gas levels and these are wired with transistors R15, R16 and R17 driving their common cathode. R15-R17 are in turn driven by the RB0, RB1 and RB2 outputs of the microcontroller.Each transistor is driven on for about 1ms before switching off. As soon as it switches off, the next transistor is switched on to drive the next LED. However, there is a short gap (or 'dead time') between one transistor switching off and the other switching on to prevent display errors.

In operation, the LEDs are switched on and off at a fast rate that they appear to be continuously lit. The following are the colours of the LEDs used and their interpretations

i. Green (Safe-clean Air)

ii. Yellow (Moderate Concentration)

iii. Red (Dangerous –Polluted Air)

Automatic display dimming is achieved in the LCD by using a light dependant resistor (LDR), connected in series with the trimpot VR5 across the 5V supply.

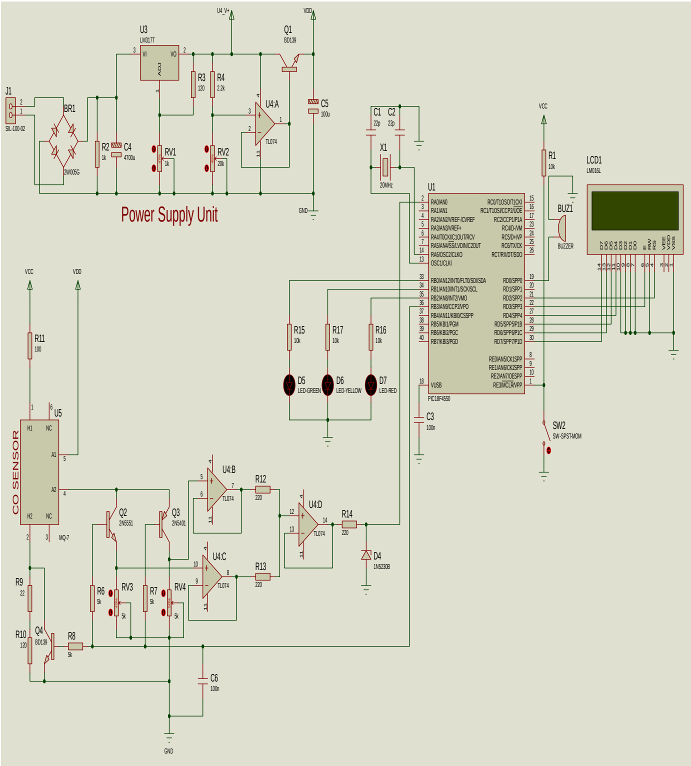

Fig. 5. Complete System Circuital Diagram

This research is aimed to develop a device to monitor and control the concentration level of air pollutant gases at industrial locations which in this case was Ife steel company. In this project, a signal is sent from the input units to know the specific amount of pollutant gases presented in the air which then transfers the command to the microcontroller. The microcontroller receives the command, decodes it and then carries out the task. The LCD is used to interact with the operator and also displays the reading of the input units after classification. However, the results are promising in terms of proving the performance and capability of of this design as a pollution monitoring device. This device is definitely in line with existing solutions and promises to be better in terms of cost, performance and form factor.

V. Conclusion

The microcontroller based data acquisition system provides a tool for real time monitoring of pollutant level at any location deployed. The system was deployed at the location earlier mentioned and it performed reliably. The use of control logic in the design is to provide flexibility as most industrial areas would require a measure of multiple pollutants not just CO. the system provides on site information to the industry of study to enable them deduce their pollution contribution and undertake whatever pollution control measure they may deem appropriate.

VI. Future Work

From the overall experience gathered during the course of this research it was discovered that a wireless sensor approach using very low cost sensors can provide similar results if placed close together. The research didn't take into cognizance the power problem in Nigeria and how the design addressed that but it can be assumed that since air pollution only occurs when the system is functioning therefore the system can be run on the companies power supply. A fault tolerant approach can be applied that would utilize redundancies in achieving higher reliability of the deployed system

Acknowledgment

I would like to thank the people of Intelligent Systems Research Group, in the Department of Mathematical Sciences, College of Natural and Applied Science, Oduduwa University, Ipetumodu, Ile-Ife, Nigeria, for the invaluable support towards the successful completion of this research.

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