Indoor Air Monitoring & Control System

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Abstract— In the present scenario of the world, air pollution is one of the leading challenges. Air pollution is a growing health risk and should be considered as a serious problem and action to improve air quality should be taken. Both outdoor and indoor air pollution has an impact on the health of a person. According to the Environmental Protection Agency (EPA), the average person spends almost 93% of their life indoors. Hence, indoor air pollution control methods are very essential and should be considered seriously. This paper proposes an open platform for monitoring and controlling air quality for healthy living. Modern buildings are equipped with advanced sensing and control technologies, offering control and optimization capabilities over a large range of parameters. A variety of sensors and actuators are incorporated into a room and interconnected together to deliver monitoring, management and optimization functionalities on illumination, temperature, air quality, etc.

Key words: Indoor Air Monitoring, Control System

I. INTRODUCTION

“Pollution- If you don’t kill it, it will kill you’’ Air pollution is one of the major public health and environmental concern. Reports from the World Health Organization (WHO) describes air pollution as a significant risk factor for multiple health conditions, including skin and eye infections, irritation of the nose, throat and eyes. It also causes serious conditions like heart disease, lung cancer, pneumonia, bronchitis, difficulty in breathing and coughing due to aggravated asthma. The World Health Organization concludes that there are 3 million deaths every year as a result of exposure to ambient (outdoor) air pollution and 4.3 million deaths every year as a result of household exposure to smoke from dirty cook stoves and fuels. Indoor air quality has a large impact on health and work efficiency [1]. Air pollution not only has a worse effect on people's health but also on the environment and can lead to acid rain, smog, deterioration of the ozone layer and global warming. So, it is essential to monitor and control the air pollution as much as possible. One of the best ways to control air pollution is to monitor exceeded levels of air pollutants and then take appropriate actions to control it.

In recent times, indoor air quality monitoring has been focused as people spend more than 93% of their time in closed environments. According to the Environment Protection Agency (EPA), indoor air is 2-5 times more polluted than the outdoor air. Hence, indoor air pollution control methods are also very essential and should be considered seriously.

Air quality is measured by the concentrations of different pollutant like Ground level Ozone (O_3), Carbon Dioxide (CO_2), Carbon Monoxide (CO), Particulate Matter ($PM_{2.5}$), Nitrogen Dioxide (NO_2) etc. Ozone is very dangerous and breathing it can trigger a variety of health problems for people of all ages who have lung diseases such as asthma. Air with high concentration of NO_2 when inhaled can irritate airways in the human respiratory system. Exposures of NO_2 even for a short period of time can aggravate respiratory diseases, particularly asthma, leading to respiratory symptoms. CO is released when something is burned. Items such as kerosene, gas stoves, leaking chimneys and furnaces also release CO and can affect air quality indoors. The high concentration of CO can affect the heart rate and respiratory system. High CO_2 concentration exposure affects breathing, decreases the oxygen supply to the heart, and may result in suffocation [2].

Worldwide pollution is increasing day by day, which is an important problem in developing countries and poses a hazard to human health especially in indoor environments. With the advancement in technologies, modern buildings are equipped with advanced sensing and control technologies, offering control and optimization capabilities over a large range of parameters. Using a variety of sensors and actuators, this system is incorporated into a room, interconnected to deliver monitoring, management and optimization functionalities on temperature and air quality. The problem of indoor air pollution can be partially solved by automatic control of the existing resources that are present in smart buildings. The development of smart technologies and modernization of homes makes it possible to achieve greater health standards for people. New technologies are emerging day by day and buildings are getting smarter. Considering this scenario, this paper presents an open platform for monitoring and controlling air quality for healthy living.

II. RELATED WORK

This section provides some of the existing works in the literature related to air quality monitoring and control operation. Tsang-Chu et al. proposed [3] an intelligent air quality control system that monitors indoor air quality by combining the three technologies they are wireless sensing technology, ARIMA (autoregressive integrated moving average) prediction models, and fuzzy theory. This model provides an analysis and prediction of the indoor working environment. Xiaoke Yang et al. proposed [4] Wi-Fi enabled air quality monitoring and control system. The proposed hardware structure has three individual units, the server, the sensor unit, and the control unit, interconnected via a Wi-Fi network. An air purifier is connected to the control unit. Sensor network is described in [5] measuring vibration, temperature, humidity, illumination, as well as the electrical load of the air conditioning system, to achieve a balance between the building’s electricity load and occupants comfort level to provide sustainability and energy efficiency environment. Wi-Fi based indoor air quality monitor with multiple sensors is proposed in [6] to provide a low cost alternative to commercially available products.

III. PROPOSED METHODOLOGY

The hardware structure of the indoor air quality monitoring and control system is shown in Fig. 1. It has four units, the sensor unit which contains different sensors for air quality monitoring, the control unit which is used to control several outputs according to the air quality level, the display unit which has a GLCD that is used to display the data obtained from the sensors and a power supply unit which is used to power the entire system. The ARM7 microcontroller is used to monitor and control the entire operation.

The microcontroller performs three operations, (1) Data acquisition: The environmental indicators such as the temperature and humidity, CO_2, NO_2, and CO concentration is obtained from the sensors. (2) Data analysis: the collected data are placed into a predictive model that predicts the trend of air quality. (3) Data feedback: according to the results obtained from data analysis, several actions may be performed. For instance, a warning message may be displayed, or the fan may be automatically controlled.

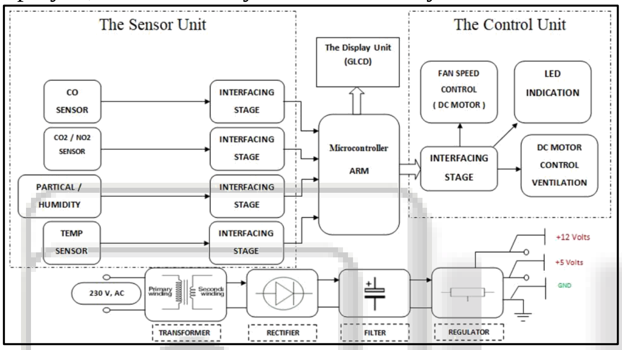

Fig. 1: Hardware Structure of the Indoor Air Quality Monitoring & Control System

A. *The Sensor Unit Hardware*

The sensor unit consists of a particulate matter (PM) sensor, temperature sensor, humidity sensor, CO_2 sensor, NO_2 sensor and CO sensor. All of the sensors are connected to the microcontroller through interfacing stages. Sensors are used for data acquisition.

1) *Temperature Sensor*

The LM35 as shown in Fig. 2 is used as a temperature sensor. LM35 can be used to measure temperature more accurately than a thermistor. The sensor circuitry of LM35 is sealed and it is not subject to oxidation. A higher output voltage is generated by the LM35 than thermocouples and it may not require that the output voltage be amplified. The LM35 has an output voltage that is proportional to the Celsius temperature. The LM35 does not require any external calibration or trimming and maintains accuracy of +/-0.4°C at room temperature and +/-0.8°C over a range of 0°C to +100°C.

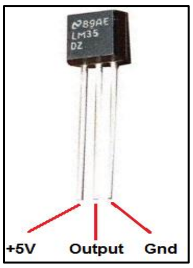

Fig. 2: LM35 Temperature Sensor

2) *Humidity Sensor*

Humidity sensor HSM 20g is used to measure relative humidity. The air in our normal environment always holds humidity. The number of water molecules in the air can vary substantially. The amount of humidity which air can hold at a given temperature has an upper limit. Beyond this limit, saturation will occur. If humidity levels are pushed up to the point of saturation, condensation occurs and fog or water droplets form. Relative humidity is the maximum amount of humidity that is present in the air. Relative humidity is expressed in percentage. Humidity that air can hold is directly related to the temperature of the air.

Fig. 3. HSM 20g Humidity Sensor

3) *CO Sensor*

CO sensor is used to measure the amount of carbon monoxide present in the air. For calibrating the CO sensor procedure in [7] is followed. The procedure involved using the typical characteristic output curves provided in the manual of a sensor and adjusting it according to the measurements received from the government air quality stations. CO is a colour less, odour less gas that can be harmful when inhaled in large amounts. CO is released when something is burned. The greatest sources of CO are machinery that burns fossil fuels such as cars, buses, trucks and other vehicles. A variety of items inside a home such as kerosene and gas space heaters, leaking chimneys and furnaces, and gas stoves also release CO and can affect air quality indoors.

4) *CO_2 Sensor*

CO_2 sensor is used to measure the amount of carbon dioxide present in the air. CO_2 is a colour less gas that the human body produces naturally. Everyone is exposed, to some degree, to this gas every day. Air always contains an amount of CO_2 that we breathe in and out every day, and is perfectly harmless in normal conditions. Build-up of CO_2 will cause humans and animals to absorb less oxygen into their bloodstream, instead increasing the levels of CO_2 in the bloodstream in its place. This will slowly starve the body of oxygen, leading to brain damage and even death. For the CO_2 sensors the same calibration procedure as for the CO sensor is followed.

5) *NO_2 Sensor*

NO_2 sensor is used to measure the amount of nitrogen dioxide present in the atmosphere. Nitrogen dioxide (NO_2) is one of a group of highly reactive gases. They are known as oxides of nitrogen or nitrogen oxides (NO_x). If we breathe air with high concentration of NO_2 it can cause irritating the airways in the human respiratory system. Such exposures of NO_2 even for short periods can aggravate respiratory diseases, leading to respiratory symptoms such as wheezing coughing or difficulty in breathing. If people get exposed to elevated concentrations of NO_2 for a long period of time they may develop symptoms of asthma and this may increase susceptibility to respiratory infections. For the NO_2 sensors the same calibration procedure as for the CO sensor is followed.

6) Particle Detector

Particle Detector is used to measure the amount of $PM_{2.5}$ and PM_{10} present in the air. PM stands for particulate matter the term for a mixture of solid particles like dust, dirt or smoke and liquid droplets found in the air. Particles such as dust, dirt or smoke are large or dark enough to be seen by humans with their naked eye. Some are so small they can only be detected using an electron microscope. $PM_{2.5}$ are fine inhalable particles, with diameters of 2.5 micrometers or smaller. PM_{10} are also inhalable particles, with diameters of 10 micrometers or smaller. Light scattering is the main method for identifying the size of PM. Analysis of the fluctuation of the scattered light, thus yields information about the PM. From a microscopic point of view, the PM in the air sample scatters the light and thereby sends information about their motion to the sensor.

B. The Control Unit Hardware

The control unit consists of buffer, driver and relays. The internal control logic of some of the devices that should be controlled is not accessible. In this situation, an on-off controller would be a simple yet ideal option. In on-off control, a set point is determined for the controlled variable, for this system the controlled variables are reading obtained from the sensors. When the measurement exceeds the set point, the relay is switched on, otherwise it stays off. Output from the microcontroller is provided to the control unit according to which the relays respond. The relays are connected to the existing outputs like a fan, air purifier and others.

1) Hex Buffer IC 4050

Normally buffers are used to provide extra current drive at the output as well as to regularize the logic present at an interface. This IC can also be used as an inverter to complement the logical state. This 16-pin DIL packaged IC 4050 shown in Fig. 4 acts as Buffer as well as a Converter. The input signals may be of 2.5 to 5V digital TTL compatible or DC analogue the IC gives 5V constant signal output. The IC acts as a buffer and provides isolation to the main circuit for varying input signals.

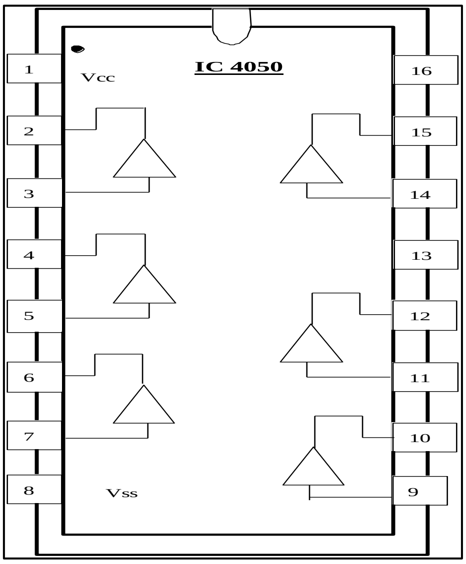

Fig. 4: Buffer IC 4050

2) Driver ULN 2003

The digital outputs of some circuits cannot sink much current they are not capable of driving relays directly. So, high voltage, high current Darlington arrays is designed for interfacing low-level logic circuitry and multiple peripheral power loads. The series ULN2000A/L ICs can drive up to seven relays with continuous load current ratings to 600mA for each input. The input of ULN 2003 shown in Fig. 5 is TTL compatible open-collector outputs. As each of these outputs can sink a maximum collector current of 500 mA, miniature Controller relays can be easily driven. No additional freewheeling clamp diode is required to be connected across the relay since each of the outputs has inbuilt freewheeling diodes.

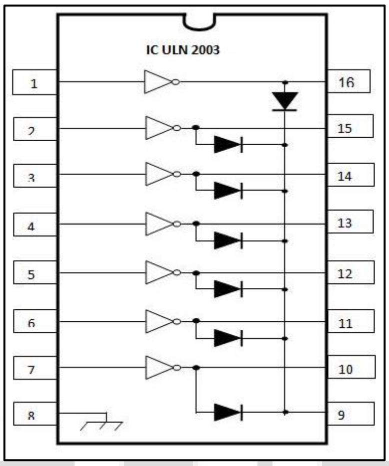

Fig. 5: Driver IC ULN 2003

C. The Display Unit Hardware

To display the data obtained from the sensors simultaneously GLCD (Graphical Liquid Crystal Display) is used. A 128x64 GLCD is able to display all the sensor data at once. GLCD is controlled by the microcontroller. Fig. 6 shows the GLCD which is used to display the data acquire from the sensors.

The TM12864A8CCWGWA that is used to display air pollutant level is a Graphics LCD unit consisting of 128 (segment) x 64 (common) dots dot matrix panel. It contains a single chip dot matrix ST7565R LCD driver. This LCD driver can be connected directly to a microcontroller bus. It has 18 pins which makes external connection easy.

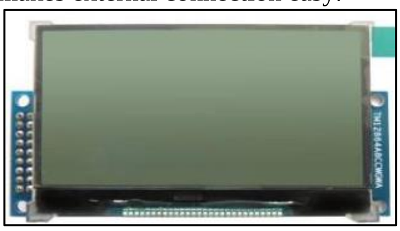

Fig. 6: GLCD 128X64 -TM12864A8CCWGWA

D. The Power Supply Unit Hardware

A voltage of 12 V and 5 V are required for this system. Hence specially designed power supply is constructed to get regulated power supplies. Regulated D.C. power supply is the power supply which maintains constant output voltage irrespective of A.C mains fluctuation or load variations. This laboratory power supply which is shown in Fig. 7 offers excellent line and load regulation and output voltages of 5V and 12 V at output currents up to one ampere.

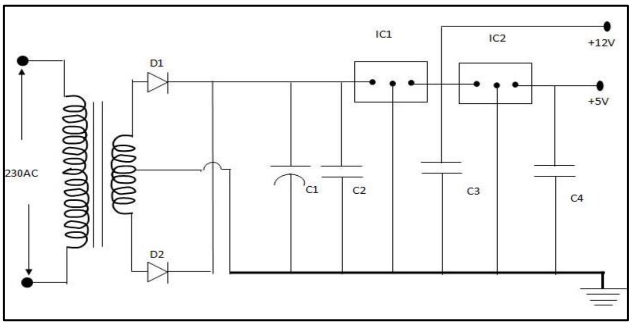

Fig. 7: Full Wave Regulated Power Supply

IV. ADVANTAGES

The proposed system has many advantages. Some of them are given below,

1) This system monitors the level of harmful pollutants in the air.
2) Information collected from the sensors is displayed simultaneously.
3) This system provides automatic control of the outputs according to the change in the air quality.
4) This system prevents the increment of air pollution level indoor.
5) This system helps to create a healthy environment for living.

V. CONCLUSIONS & FURTHER WORK

This paper proposes an air quality control system that monitors indoor air quality. Beyond establishing the air monitoring system, this system can also trigger an early warning and take action before air quality worsens. This system can provide health benefits for humans and animals in indoor environments. The current work focuses on wired monitoring and can be extended to wireless sensor using Wi-Fi. The sensor data can also be stored in the database for analysis of air quality index as well as hardware implementation of artificial neural network can be used to improve the control function of the system.

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