

Remote Environmental Monitoring System

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Abstract— This paper gives custom designed implementation details of unmanned environment sensing and monitoring embedded system. This embedded system will be helpful to monitor the air pollution levels in the remote areas where it is difficult for the human beings to travel. In this design, we intend to monitor pollution levels and gauge the suitability of environment for living conditions as per the standards set by the environmentalists. The uniqueness of this Envi-Quadcopter is that, the electronic system designed is mounted on the DJI Phantom 3 drone which has visual positioning system that allows quad copter to maintain its position at lower altitudes and even when GPS is weak or unavailable. A box is custom designed and light weight 3D printed to be integrated with DJI Phantom 3 drone using CAD software to hold the circuitry. This system consists of four pollution gas sensors NO₂, CO, CO₂, O₃ and two meteorological condition sensing components for sensing pressure, temperature and humidity. The meteorological parameters help to determine accurate concentration of pollutants and seeing the trend of change in concentration of gases with changes in temperature and pressure. The sensed parameters are logged into SD card and also transmitted to the server for real time monitoring. The transmission is done by ATSIM900 module. These values can be then analyzed and helpful in formulating laws for environmental protection.

Keywords: Air pollution, Payload limit, Real time monitoring, Sensors, Quad copter, Wireless data transmission.

I. INTRODUCTION

Air pollution is the increase in levels of various harmful gases and other substances in the atmosphere. It leads to various health problems like asthma, skin cancer etc. It also harms the environment in many ways like global warming, ozone depletion etc. There has been a rapid increase of air pollution in the 21st century, major contributors being industrial and vehicular emission. Recent study shows that road traffic emission contributes to 97% of total CO and 75% of total NO emission [1]. Six common air pollutants present in the atmosphere are particulate matter, ground level ozone, carbon monoxide, sculpture oxides, nitrogen oxides and lead. These are called the criteria pollutants. Measuring the concentration of these pollutants is necessary for determining the air quality. Therefore, air quality monitoring is necessary for checking air pollution and taking appropriate preventive measures against its increasing levels. Air pollution monitoring also provides the information required by the scientists, planners, policy makers to make decision on improving and managing the environment [2]. An ambient real time air quality monitoring system equipped with gaseous, meteorological sensors as well as data logging and wireless communication capabilities has been designed by [3]. It explains work going on where multiple monitoring stations communicate with backend server using machine to machine communication.

The present paper is divided into mainly two sections. First one is mechanical section which gives the details about the custom designed mechanical structure built considering the payload limit of the DJI Phantom-3 and on the other hand providing enclosure and protection to the electronic subsystem. Second one is the electronic section which details the different components used to monitor the ambient pollution in real time.

II. MECHANICAL DESIGN

The 3D printed models used in the system including circuitry box that provides enclosure for sensors over PCB, battery and GSM module, a clamping joint between the horizontal bars of the old landing gears and the circuitry box and a pair of new landing bars at the bottom of the circuitry box. There were four main facts taken into consideration while designing the system:

1. Light weight of the system for durability of the drone. The system should weigh less than the payload capacity of DJI Phantom-3. The material used is poly lactic acid (PLA) due to its good strength with low density. The density of the system is further optimised by 3D printing specifications by varying the infill.
2. The design does not interrupt the motion of the Camera and Vision Positioning Sensor of the quadcopter.

3. The design is to be mechanically balanced so that the total payload is uniformly distributed. Also, the extended landing bars at the bottom of the attachment gives the quadcopter a proper landing and hovering.
4. The system should have appropriate strength to withstand the total weight of DJI phantom-3 and payload.

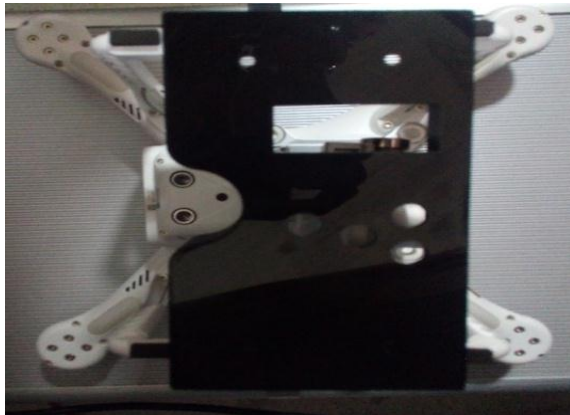


Figure 1: Light weight 3D printed box with opening for sensors

The net weight of the circuitry box assembly should act at very near to the sensorial axis of the Quad copter to get rid off from the mechanical imbalance i.e. reducing the x-distance and z-distance between the old and new centroids. In Figure 1, the two centroids have been shown in which one of them is the centroid (top one) of the DJI phantom-3 and the other one (bottom one) is of circuitry box assembly. In front view (XZ plane) $dX = 0.07 \text{ mm}$ and side view (YZ plane) $dZ = 2.11 \text{ mm}$. Figure 2 gives the bottom view of the enclosure with opening and seat for fitting sensors which are exposed to the environment for measuring parameters. The mechanical design including the circuitry box, u-clamps and landing bars is safe to withstand the load of 800gms or 7.8 Newtons without any significant deformation and fracture.

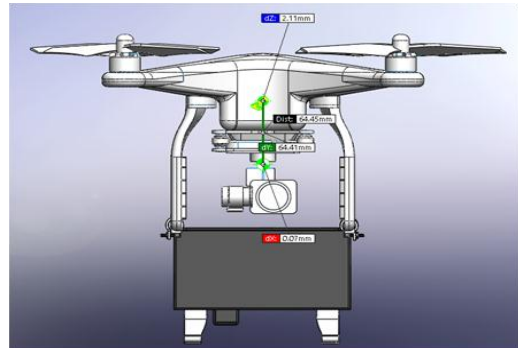


Figure 2: Fixing centroidal axis of PCB Box

III. ELECTRONIC DESIGN

Due to large amount of circuitry and compact space, a custom built, Printed Circuit Board (PCB) has been designed for the system. The PCB designed comprises the sensor circuitry, microcontroller and SD Card in a compact space of $120 \text{ mm} \times 44 \text{ mm}$. It also helped in reducing the wirings of system due to the internal circuit connections. The reduction in space used is due to the small package components soldered on the PCB. These components require very less space compared to the components of the same specification used on Bread Boards or Dot boards.

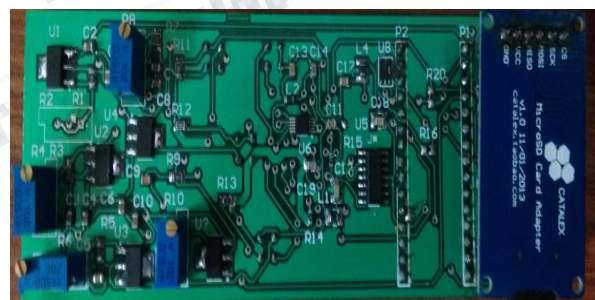


Figure 3: PCB Top view

Figure 3 gives the top view of the double sided custom designed PCB of the embedded system of Quad copter. The major components on front side are potentiometers, SD Card and voltage regulator circuitry along with necessary circuit for microcontroller. The microcontroller used is Arduino Nano which is at the bottom side as shown in Figure 4. Due to its small size and light weight (5gm), Arduino Nano is most suitable microcontroller for the project.



Figure 4: PCB Bottom View

3.1 Sensing System

The main aim of the sensing system is to monitor air pollution by sensing the amount of various harmful gases present in the atmosphere. For the system, four Solid state sensors MICS-2710, MICS-2610, MICS-5521 and TGS-4161 for sensing the gases – NO₂ (Nitrogen Dioxide), O₃ (Ozone), CO (Carbon Monoxide) and CO₂ (Carbon Dioxide) are being used.

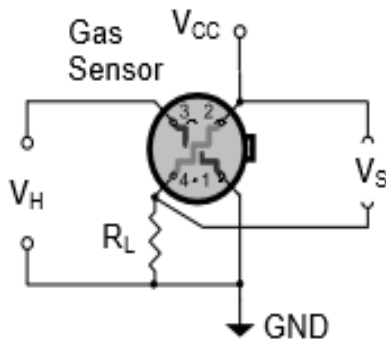


Figure 5: MICS Sensors Circuitry

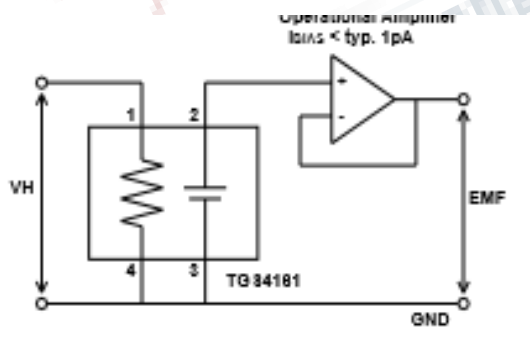


Figure 6: TGS-4161 Sensory Circuitry

In Figure 5, VH is the heater voltage required to maintain the MICS sensing element at a specific temperature which is optimum for its working. The

sensor, TGS4161 which is an electrolytic sensor has very high input impedance and hence requires an operational amplifier to amplify and feed the sensor output voltages to the Arduino board as seen in Figure 6. The op-amp used is TLC274.

In addition to these sensors, a temperature and humidity sensor SHT-21 and a pressure sensor BMP-180 is also used for analysing the trends of change in concentration of gases with changes in temperature and pressure. ADS1115, a 16 bit Analog to Digital Converter (ADC) can greatly improve the Arduino resolution and measurement accuracy. The output of the ADS1115 is a signed integer. That means, one of the bits in the 16 bit words is going to be used to tell if it's a positive or negative value being reported. The value of 32767 would represent a value of 6.144 volts. Dividing 6.144 volts by 32767 yields a scale factor of 0.1875 mV per bit. This is a significant improvement over the Arduino ADC which has resolution of approximately 5 mV per bit. ADS1115, BMP180 and SHT21 communicate with microcontroller using I2C communication. The advantage of I2C communication is that it uses only 2 wires (SDA and SCL) for bi-directional communication.

3.2 Wireless Communication System

For real-time monitoring of various gas concentrations and other parameters, a GSM SIM 900 module is used. The SIM Module receives various sensor output values transmitted by the Arduino and sends this 2G data wirelessly to a server continuously, where it is monitored in real time. GSM module interfaces with Arduino via three pins: TX pin of Arduino connected to RX pin of GSM Module and vice versa. The ground pins of both the components are connected as shown in Figure 7. The GSM Module connects to a server after execution of specific AT commands. The AT commands are incorporated in the Arduino code along with the IP address and port number of the server.

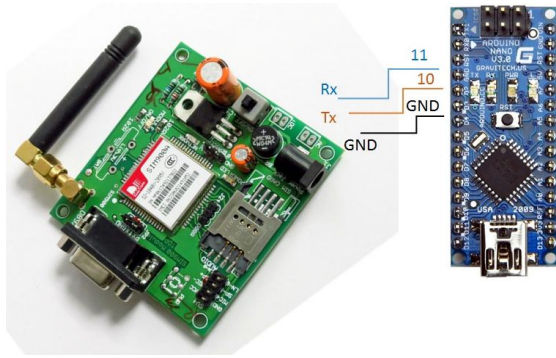


Figure 7: GSM module – Arduino Interfacing

3.3 Data Logging System

Observing and studying the change in sensor values over a period of time is important for deriving conclusion and taking preventive measures to control the amount of harmful gases in the air. For this purpose, the sensor values are stored in a Micro SD card in the form of an excel sheet which can be analysed once the drone has finished its survey. The SD card communicates with the Arduino by SPI communication. SPI is a protocol on 4 signal lines. The communication lines are: A data line from the master to the slaves, named MOSI (Master Out-Slave), a data line from the slaves to the master, named MISO (Master In-Slave Out).

IV. CIRCUIT PARAMETER ANALYSIS FOR BATTERY SELECTION

The analysis of consumption of voltages and currents of the circuit is done to decide the battery rating for the embedded system being designed here. Batteries are the powering source of the system. Based on the voltage and current requirement of each component as shown in Table 1 and Table 2, lithium polymer battery, which is light weight and is suitable for the system requirement is used.

Components	Heater Voltages (V _H)	Input Voltages (V _{DD})
MICS2710	1.7V	2.5V
MICS2610	2.35V	5V
MICS5521	2.4V	5V
TGS4161	2.4V	-
SHT21	-	3.3V
BMP180	-	3.3V
GSM Module	-	7-12V
Arduino Nano	-	7-12V

Table 1: Voltage requirement of components

COMPONENT	CURRENT (mA)
MICS2710	26
MICS5521	32
MICS2610	34
TGS4161	50
BMP180	0.65
SHT21	0.3
GSM and SD CARD	2A (active mode) 30 mA (standby mode)

Table 2: Current requirements of components

As total current requirement of the circuit is above 2A and GSM and Arduino Nano requires 7-12 V input voltage, two batteries of specification 3.7V and 3000mAH are connected in series to give output 7.4V. For meeting the voltage requirement of the components used, a voltage regulator LM1117 is used. It converts input voltage given to it as per the requirement of the components and provide stabilized input voltage to sensors.

V. RESULTANT INTEGRATED EMBEDDED QUADCOPTER SYSTEM

Figure 8 gives the block diagram representation of the final integrated Quad copter for air pollution monitoring. All the six sensors sense various gas concentrations, temperature, pressure and humidity and send these values to the Arduino in the form of voltage signals.

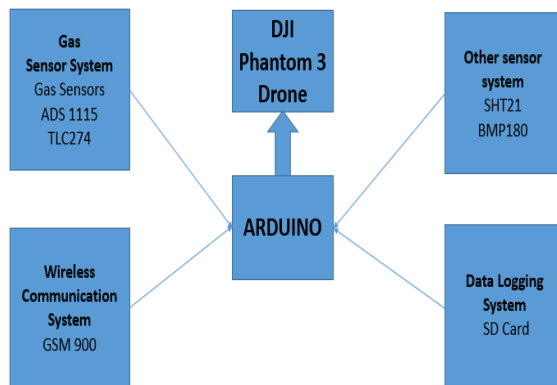


Figure 8: Integrated System Block Diagram

The four gas sensors send their respective outputs to the ADC, where they are enhanced and sent to the Arduino. The Arduino executes the code which is programmed in it to change this voltage signal back to ppm values and then send these values to the GSM module and the SD card. The GSM module then sendsthes values continuously to the server through wireless transmission. The SD card stores various values from different sensors in an excel sheet, from where they can be retrieved afterwards. All the functions performed are governed by the execution of the code programmed in the Arduino Nano microcontroller.



Figure9: Integration of the designed embedded circuit enclosure box with the Quad copter

Figure 9 is the final view of the integrated Quadcopter system which houses the designed PCB circuitry into mechanically designed box.

VI. CONCLUSION AND FUTURE WORK

The method of remote air pollution monitoring is comparatively cost effective, easy to install and provides real time data of air pollutant. This method is more advantageous compared to traditional methods where air pollution level was measured at fixed location or laboratory. The system attached with the drone doesn't affect its flight. The system can be improved by including some more sensors like SPM sensors which are used to measure the pollutant level and size of suspended particulate matter.

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