A Mobile Application to Track Urban Air Pollution

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ABSTRACT: *To measure various pollutants and to identify the extent of air quality we have used a mobile application that helped to find pollution concentrations. It is required to find out the extent of pollutants' concentrations and its affect the health. The proposed model is useful to track the pollution which is high in cities and other environment and the system is easy to use.*

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1. Introduction

Continuous air pollution component measurements for precursor gases, ions, *PM* and carbon dioxide have been available since the late 1990s. Pollutants for which air quality standards have been established in many countries (called "criteria pollutants" under the statute defined by the US EPA, i.e. CO, NO_2, SO_2, ozone, $PM_{2.5}$ mass, PM_{10} mass, TSP, and lead) are monitored in populated areas to determine compliance with the ambient air quality standards (AAQS) [1]. Most of the measurements systems detect only one of the possible air pollutants while it is very important to scan all very poisonous gases such as NO_x, SO_2, CO and NH_3.

Reliable measurements of atmospheric trace gases are necessary for safety reasons because some of them are very toxic (NO_x) [2], indetectable to humans, being both tasteless and odorless (CO) [3] and irritating in small concentration or in high concentrations is an immediate hazard to life (NH_3) [4].

The mobile measurement of the air quality and gas concentrations is a very actual problem due to the great human mobility, pollution motion and the absence of measurement stations in most places especially for the closed spaces. The requirements to the proposed systems are based on the device functionality such as small size, battery powered with recharge capabilities, data filtering and analysis. Also the system have to combine different types of communication devices such as short-range and long-range ones to ensure the continuous data transmission and long-term operation time during the sensor motion and data acquisition. These requirements are fulfilled by using the latest communication chips which combine GSM and Bluetooth connectivity, integrated GPS receiver, dual SIM card integration and chip antennas.

2. System Description

The proposed measurement and communication system has to fulfill the following requirement:

1. Measurement of the poising gases such as carbon oxide (CO), ammonia (NH_3), nitrogen oxides (NO_x)

2. Measurement of air quality respect to the concentration of carbon dioxide (CO_2) and organic compounds (tVOC)

3. Battery powered device with low current consumption and recharge possibilities via common used mini USB interface

4. Measurement of the device position via GPS service

5. Send the air quality and navigation data to the remote server via Bluetooth or GPRS link

The mobile device consists from two main blocks (Figure 1)

– Navigation and communication board, which includes GPS receiver, GSM/GPRS modem and Bluetooth transceiver, and measurement board, which integrates the sensors

- Gas sensors, air quality (AQ) sensor or particle measurement (PM) sensor and user indication.

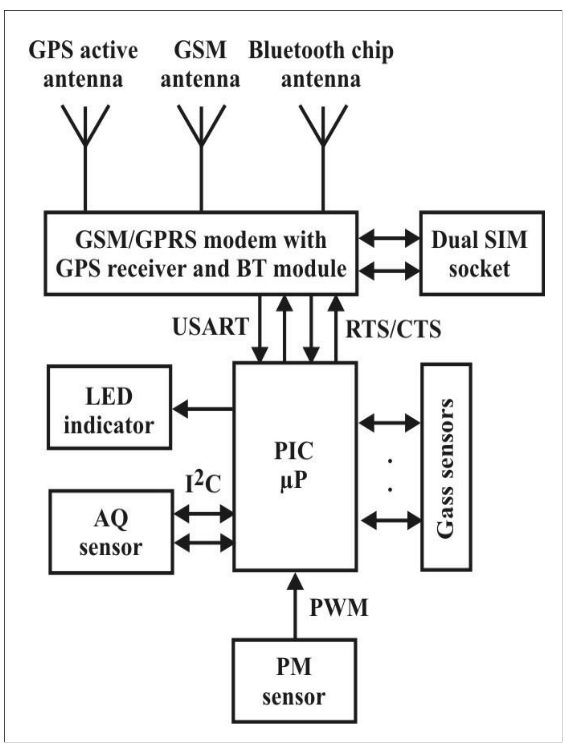

Figure 1. Block diagram of the system

The system connectivity is ensured by MC60 as GSM/GPRS modem which supports Bluetooth interface, it is fully compliant with Bluetooth specification 3.0 and supports SPP (Serial Port Profile). It also features GPRS class 12 and is distinguished with an integrated TCP/UDP, FTP and PPP protocols. The current consumption is as low as 1.3 mA in SLEEP mode. The portable size of the system and the best network coverage are provided by the integrated chip-antenna WE-MCA 7488910245 for the frequency range 2400- 2500MHz (Bluetooth module) and external GSM antenna via female SMA connector. The chip antenna peak gain and average gain are equal to 3dBi and 1.0dBi respectively. The system microcontroller is based on PIC16F family (PIC16F1825) and has built-in I2C interface as a part of Master synchronous serial port (MSSP) module and EUSART with an autobaud interface, which is connected to the GSM/GPRS modem with RTS/CTS hardware flow control. The microcontroller oscillator scheme uses SMD (QFN) crystal at 16.000MHz as a low-profile resonator. The frequency tolerance is equal to approximately ±15ppm@25ºC.

The power supply (Figure 2) is based on LDO (low-dropout) regulator BA00DD0WHFP with adjusted output voltage which may set in the range from 3.8V to 4.2V to power the GSM/GPRS modem. This chip has a high-precision output voltage of ±1% and may deliver up to 2A with maximum dropout voltage of 0.5V. It also is distinguished with a built-in over-current protection, over-voltage protection and thermal shutdown circuit. The LDO regulator is chosen to allow an USB charging.

The output voltage of 4.2V is additionally used to power LDO chips for the microcontroller, sensor board and GPS receiver. These LDO are recognized as MCP1700T-3.0, MCP1700T-3.3 and TC1224 respectively. The LDO chips are high accuracy (typically ±0.5%) CMOS low dropout regulators and are designed specifically for battery-operated systems, while the CMOS construction eliminates wasted ground current, significantly extending battery life. The TC1224 regulator is distinguishes with an enable input which is controlled via AT command by GSM/GPRS modem to on/off GPS receiver to save power if GPS module is not needed or the device is stationary.

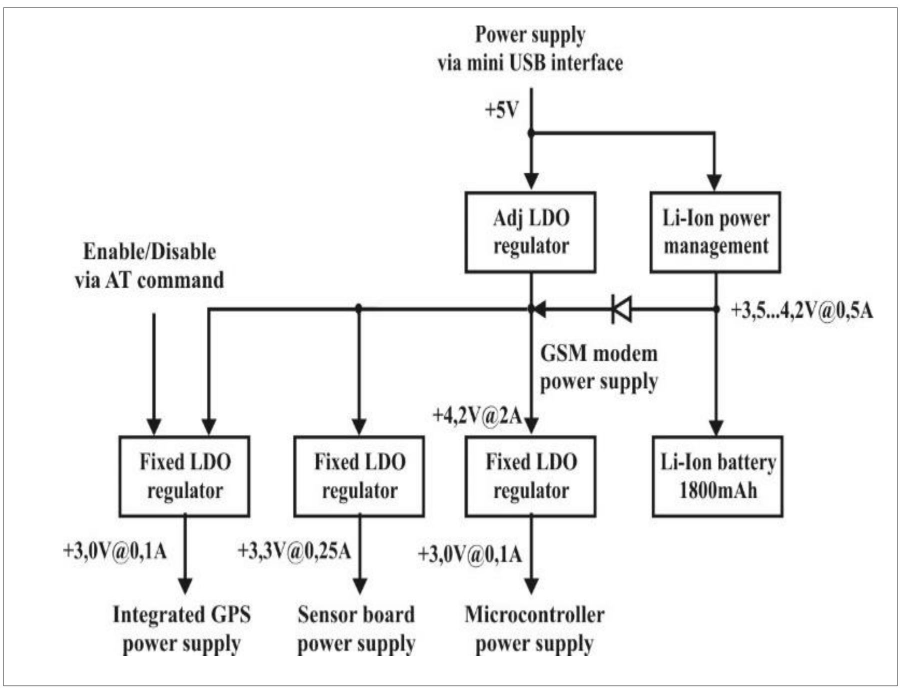

Figure 2. Power supply schematic

There chargeable Li-Ion battery is used as a backup power supply and is supported by MCP73831T-2ACI/OT ICs as a Li- Ion charge management controller. The charging current is set via an external resistor and its maximum value is equal to 500mA. The power management chip employ a constantcurrent/ constant-voltage charge algorithm and charge termination.

The sensor board contains the gas sensors such as MiCS- 6814, which is the compact MOS sensor with three independent sensing elements for ammonia, carbon oxide and nitrogen oxides on one package. Each sensor includes a heating circuit and sensing element (Figure 3). The detecting layer changes its resistance according to the pollutant concentration. The sensing resistance in air varies from 10 to 1500kΩ for the NH_3 sensor, therefore the sensor requires a calibration to measure the real concentrations.

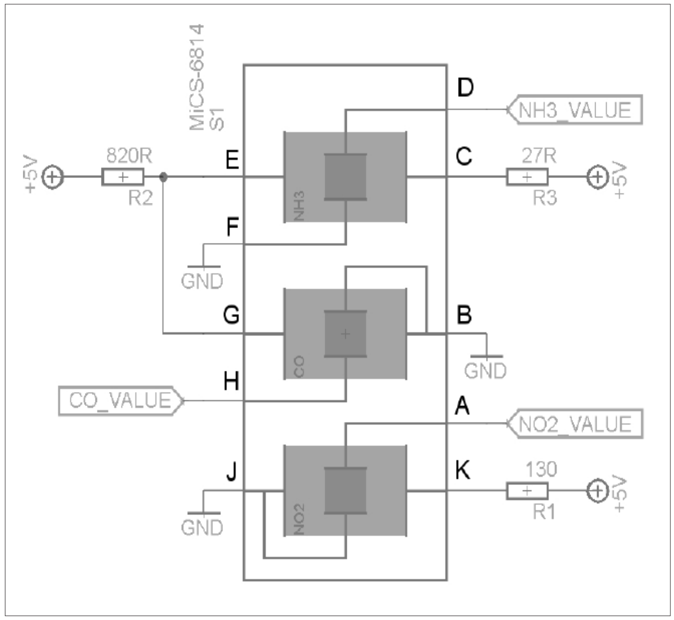

Figure 3. Gas sensor [5]

The sensor board also contains the air quality (AQ) sensor which is recognized as a MiCS-VZ-89TE of the same company (Figure 4). It is a digital output sensor for carbon dioxide (CO_2) and tVOC concentrations. It has two independent digital outputs – I^2C and PWM.

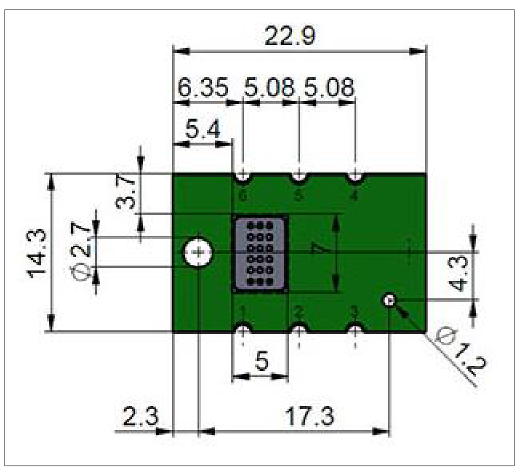

Figure 4. Air quality sensor

3. Experiments

The first step of the experiment is the sensor calibration due to the high range of the sensor resistance in air. The calibration is made in the environment of a pure nitrogen at normal temperature by measuring the sensing resistance R_0. When the sensor is exposed to the air the resistance is change to *Rs* value which corresponded to the gas concentration according to the Rs/R_0 to Concentration graphics (Figure 5) [5]. The sensing resistance *Rs* is converted to voltage using resistor divider and then the integrated 10-bit ADC converts this voltage to a digital word. The second resistor in the divider is chosen to be equal to R_0, measured in the calibration step, to guarantee the maximum amplitude response to the gases.

The sensing resistance may be affected by the temperature, humidity and time [6], so the calibration procedure have to be accomplished if an optimum accuracy is required.

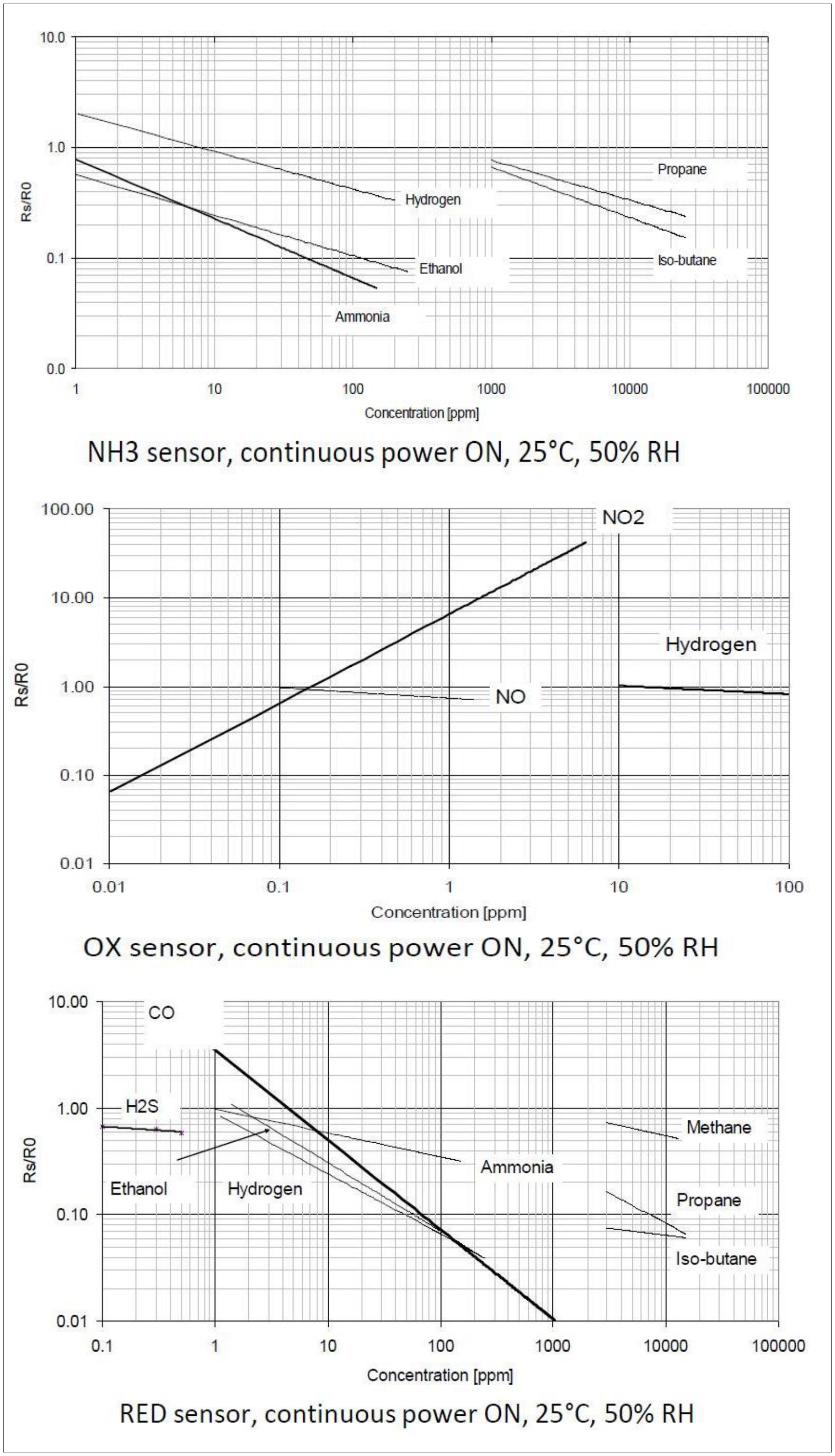

Figure 5. Ratio Rs/R0 as a function of concentration [5]

According to the manufacturer curves [5], we calculate the gas concentration by the equation $lgY = a*lgX + b$, where X and Y denote the gas concentration in ppm and Rs/R_0 value respectively and a and b are constants. We establish the following constants for the dependence of the Rs/R_0 value towards the concentration:

1. CO sensor: a = -0,82709; b = 0,526057
2. NO_2 sensor: a = 1.032031; b = 0,831015
3. NH_3 sensor: a = -0,50084; b = -0,1728

The CO_2 and tVOC concentrations are established via I^2C interface according to the equations [7]:

tVOC[ppb]= (tVOC- 13) * (1000.0 / 229)
CO_2[ppm] = (CO2 - 13) * (1600.0 / 229) + 400

The experiments are made in the indoor situations and the concentration of the carbon dioxide (CO_2) and volatile organic compound (tVOC) are shown at Figure 6 while the gas sensor data for NH_3, CO and NO_x as a ADC word and concentration in ppm are given at Figure 7.

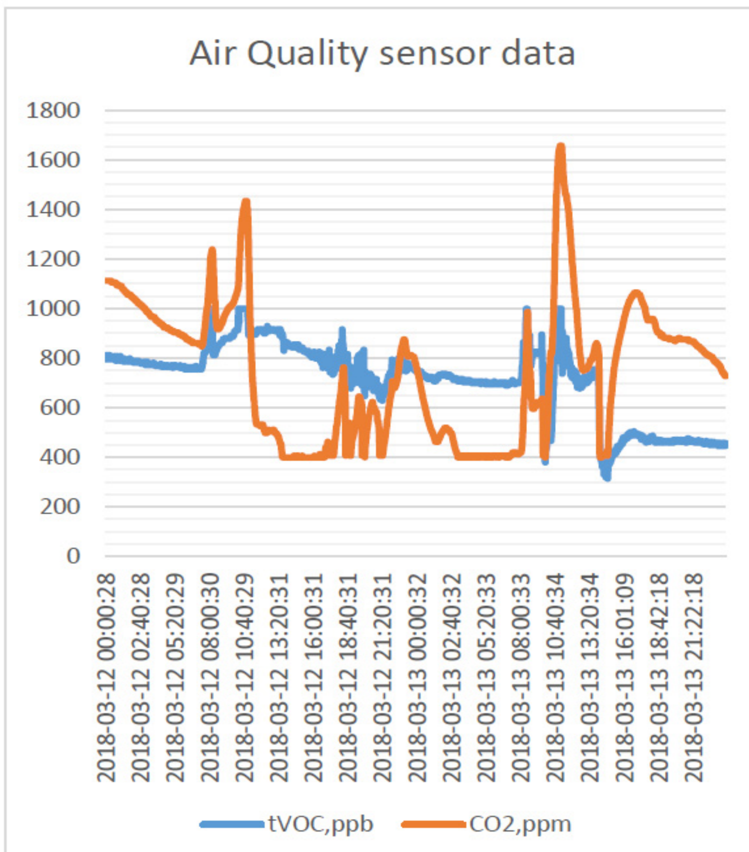

Figure 6. Air quality sensor data

The data represent a continuous 48 hour measurement of the air quality and gas concentrations of all gas sensors. The represented data shows that NH_3 concentration is under 25ppm limit (Detectable by smell. Maximum Permissible Exposure Limit (PEL)), CO concentration also is under the maximum recommended indoor CO level of 9ppm (ASHRAE) [8] and the NO_2 value is approximately equal to 0ppm.

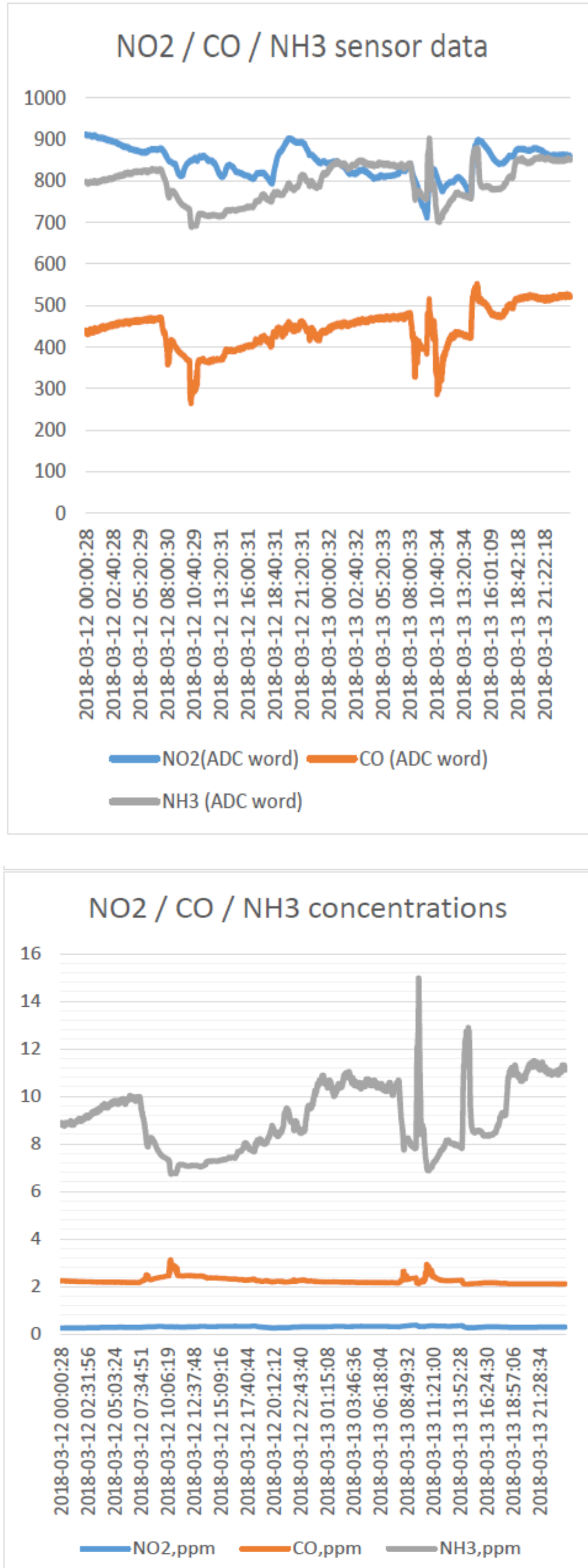

Figure 7. Gas sensor data for NH_3, NO_x and CO as ADC word and concentration ppm

4. Conclusion

The proposed mobile system is capable to measure most of the poisonous gases such as carbon oxide, ammonia and nitrogen oxides by three independent sensors in one package and the air quality as a function of the carbon dioxide and volatile organic compound concentration. The air quality sensor may be replaced or combined with PM2.5 and PM10 sensor, which is the goal of the future system development.

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