Design of Indoor Environment Monitoring System using Arduino

Yasen S. Kalinin, Edy K. Velikov, Valentina I. Markova

Abstract— ***This paper presents the development of a flexible environmental monitoring system that allows the monitoring of parameters in the workplace, required for optimal performance. Several sensors and three modules, with different functionalities, are used to complete the system.***

Index Terms— ***Arduino, air quality, indoor monitoring.***

I. INTRODUCTION

Indoor environment quality (IEQ) refers to the quality of a building's environment in relation to the health and wellbeing of those who occupy space within it [1]. IEQ depends on many factors, such as temperature, humidity, light, noise, air quality. Being healthy (physically and psychologically) means the absence of diseases and illnesses. The improvement of IEQ can increase the comfort, decrease adverse health effects, decrease absence rates, and increase the work and school work performance. The potential health benefits of improved IEQ are widely discussed in [2][3]. Practical guidance for improving and maintaining the indoor environment is available in [4][5]. Organizations like Who (World Health Organization), OSHA (Occupational Safety and Health Administration) are committed to act on the present environmental and health challenges, including the health risks with regard to children/workers caused by poor environmental, working and living conditions [6]. The people spend the majority of their time indoors. That is why, it is very important to perform regular monitoring on the indoor environment. It makes possible the elimination, or at least the minimization of the available risks for their health on one hand, and the creation of conditions supporting their emotional and social wellbeing on the other. The implementation of environmental monitoring very often relies on utilization of wireless sensor networks (WSN). WSN are composed of a large number of sensor nodes that have the ability to sense, compute and analyze specific physical parameters. Many researchers around the world have developed variety of WSN for environmental monitoring, using different communication technologies like ZigBee, Bluetooth, CAN protocol [7][8][9]. This paper focuses on the design and the implementations of an indoor environmental monitoring system based on Arduino. The system consists of 3 modules, described later on. The paper is organized into V sections including the introduction.

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Y. S. Kalinin, B.Sc. Degree Students in Telecommunication at Technical University of Varna, 9000 Bulgaria.

E. K. Velikov, B.Sc. Degree Students in Telecommunication at Technical University of Varna, 9000 Bulgaria.

Dr. V. Markova, Department of Telecommunication, Technical university of Varna, 9000 Bulgaria.

Section II presents the architecture of the proposed system. Section III describes the calibration. The experimental results are shown in section IV. Finally, ideas for the future development of the project are presented in section V.

II. SYSTEM OVERVIEW

A. System Design

The block diagram of the proposed system, shown on Fig.1, consists of 3 modules – Wireless, Main and Dialer. The Main Module (MM) includes an Arduino Mega, receiver, several sensors, display, LEDs and sound indication. The Arduino Mega constantly processes the readings from all sensors. The data from the Wireless Module (WM) sensors are acquired via the receiver. The different sensors described in table 1 are included in the MM and their data are presented on the TFT breakout touchscreen. For every parameter (except for fire), the display has options for current value and maximum, minimum and average values for the last 24 hours.

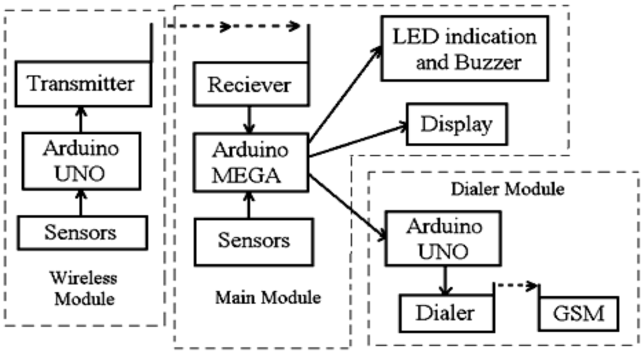

Fig. 1. Block Diagram

Table I.

Sensors in the MM	*Measurement unit*	
	name	*symbol*
Temperature	Celsius and Fahrenheit degrees	[°C] [°F]
Humidity	Percent	[%]
Noise level	Decibels	[dB]
CO2	Part per million	[ppm]
Fire	Boolean	[boolean]
Illuminance	Lux	[lx]

The readings of every sensor have acceptable range of values for optimal working environment. For example, according to ISO standards [10] the temperature limits for working,

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in degrees Celsius should not be lower than 18 and higher than 24. The acceptable ranges of values for the sensors are shown in Table II. If the readings go outside the acceptable range, the LED and sound indicators are activated. For every sensor, there are two LEDs, one green and one red. If the values are acceptable the green one is on, if they are not – the red one is. If there is a fire, or two or more readings of the other sensors go out of range the buzzer is turned on.

Table II.

Parameter	***Range of acceptable values***	
	min	***max***
Temperature [°C]	18	24
Humidity [%]	40	60
Noise level [dB]	50	80
CO2 [ppm]	400	800
Illuminance [lx]	250	1000

The Arduino UNO of the Dialer Module (DM) is connected to the Arduino MEGA and continuously receives information about all of the sensors. This Arduino UNO controls the dialer (a GPRS shield). The dialer has three main functions. Firstly, if there is a fire, it makes a call. Secondly, if two or more readings are out of the acceptable range for more than 10 seconds the dialer sends an SMS. Lastly, there could be four numbers that the dialer consecutively calls or sends SMSs to and this third function allows the user to set those by sending a SMS to the dialer. The SMS "*a359892345XXX" sets one of the numbers for SMSs to be "359892345XXX", the second number is set by the same SMS starting with "*b" instead of "*a". The structure of the SMS for changing the number for calls is the same, however, the SMS must begin with a "#" instead off "*". To prevent the sending of multiple SMSs a simple counter is created. For example, if an SMS is sent that indicates the temperature and humidity values have risen, the same SMS cannot be sent in the next five minutes. The WM is a separate circuit that has few sensors and is created to increase the flexibility of the project. For more reliable readings, some sensors are usually measured /detected in more than one location. This module uses the sensors for illuminance and fire. Their data are stored in a message that the Arduino UNO of the WM sends to the MEGA via the transmitter. These values are displayed on the TFT breakout touchscreen. The sensors use the LED and sound indicator of the MM through the GPRS shield and work the same way as the sensors connected to the MM. This improves the flexibility of the system and allows its usage for different applications.

B. Software Design

The TFT Breakout Board is a resistive touchscreen display and is connected and managed by the Arduino MEGA. The code for the display is written in the Arduino development environment (ARDUINO version 1.6). The main software for the menu is JOS – Open Source Menu Interface for Arduino/TFTLCD. However, since the libraries used in the code were outdated some problems arose with this particular display and Arduino MEGA. For that reason, the newest libraries provided by Adafruit were used, which implied additional adjustments to be made. In the proposed system there are 5 main menus – Temperature, Humi/CO2(Humidity and CO2), Light(Illuminance), Fire, Noise. For every main menu there are 6 submenus. The readings of a sensor are displayed, at the bottom left-hand corner, after touching the correspondent submenu. If the touchscreen is, for some reason, out of order, the readings for all of the sensors can be monitored via the Serial Monitor in the processing environment.

III. SENSORS AND CALIBRATION

The hardware core of this project is its sensors. The following section will explain how they work and their calibration.

1) DHT11 Humidity & Temperature Sensor – this two in one sensor is the only sensor with digital output. Its calibration is done in a library created especially for this sensor by Arduino.

2) MG-811 CO2 Sensor Module – it was chosen to measure the CO2 gas concentration, since it has good sensitivity and low dependencies of temperature and humidity. The sensor gives the analog output of 30 – 50 mV. However, the graph for its calibration, as shown below in Fig. 2, is used from 260 mV to 325 mV. In order to make the output voltage in usable range, an operational amplifier with gain = 7 is used. The sensor needs power supply of +6V +/- 0.1% , for that reason, a LM2577S DC – DC converter is wired between the Arduino MEGA external(non-USB) power supply and the sensors Vin.

$$f(x) = 4.319.10^{10} e^{-0.2826X} \quad (1)$$

Fig.3 shows the acceptable range of detection in function of the output voltage.

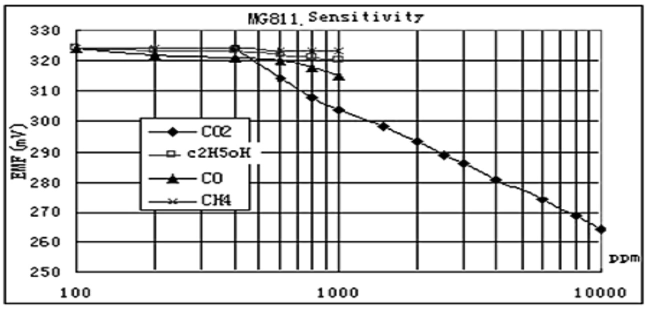

Fig. 2. CO2 gas sensitivity curve

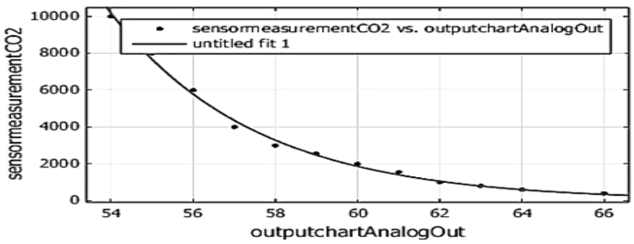

Fig. 3. CO2 (ppm) – AnalogRead() function

The outputcharAnalogOut is derived from the relation between the analogRead() function of Arduino and the output voltage. For example, analogRead() = 60, corresponds to an analog voltage of 294 mV (60 * 4.9 mV). The relationship between the output voltage and the CO2 is opposite - the lesser the analog out the higher the concentration of CO2.

Virtually no change in CO2 readings is registered with the increasing/decreasing of temperature and humidity (in the range that is expected in this type of working environment), subsequently, there is no need for further calibration and compensations.

3) TEMT6000 Ambient Light Sensor – an analog sensor measuring illuminance. Fig.5 shows the relationship between the output voltage and the lux. The correlation is straight - the higher the output voltage the higher the intensity of the light is. The calibration is done using the same program as with the CO2 sensor, as shown in Fig, 6 and the relationship between the output voltage and the illuminance in LUXs is described by the following function:

$$f(x) = 2.682X^{0.9347X} \quad (2)$$

Again, there is no need for compensations and further calibration for temperature and humidity according to the datasheet.

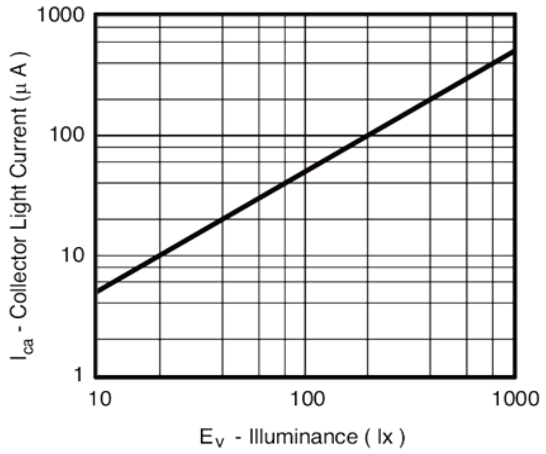

Fig. 5. Illuminance sensitivity curve

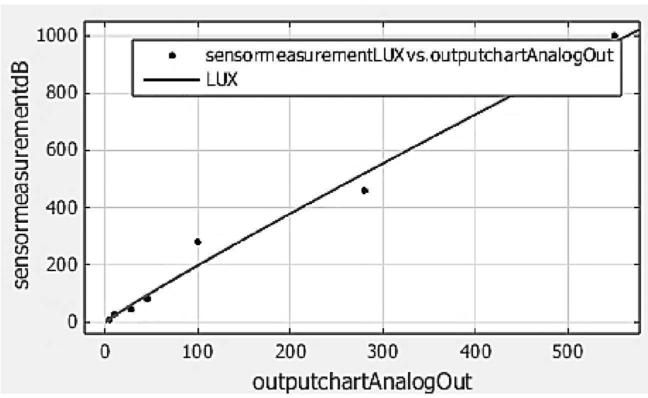

Fig. 6. Illuminance (lx) – Analog Read () function

4) Microphone Amplifier – MAX9814 with Auto Gain Control – an analog sensor with auto gain control and adjustable amplifier for starting gain of +40 / +50 / +60 dB.

The starting gain adjustment is done by wiring the gain pin to either Vcc(+40 dB) or GND(+50 dB).

For the proposed project the most suitable starting gain is +50dB, and accordingly the gain pin is wired to the GND. In this case there is no information for the dependence of the sound level in dB by the output voltage. So, the calibration is done using an MASTECH Auto Ranging Multimeter. Afterwards, the process is the same as with the previous sensors. The obtained noise level sensitivity curve (fig.7) and the corresponding function is:

$$f(x) = 39.4e^{-0.003039X} \quad (3)$$

However, more sophisticated calibration is needed.

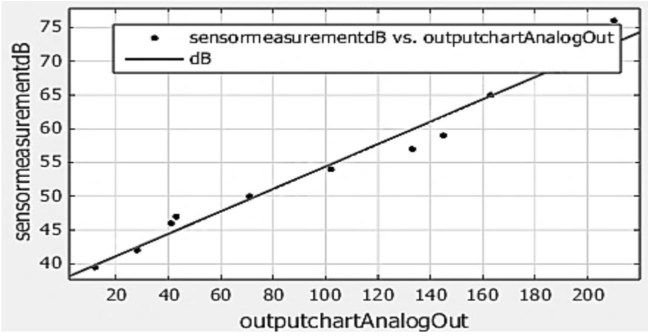

Fig.7. Noise (dB) – Analog Read () function

5) 1-Channel Flame Sensor Module – this sensor has analog output that varies between 0 and 1023(0 – 5 V). It detects infrared light in the wavelength range between 760 nm – 1100nm and is particularly sensitive to flame spectrum. The output voltage is mapped in 3 places, so there are three output options "No Fire", "Distant Fire" and "Close Fire". This simple sensor does not require further calibration.

6) The transmitter and the receiver (RF 433 MHz Transmitter-receiver Module) use OOK(On/Off Keying) modulation. For the encoding and the decoding of messages, the Virtual Wire library, presented by Arduino, is used.

IV. EXPERIMENTAL RESULTS

The realizations of the proposed modules 1) WM, 2) MM, 3) DM are presented on Fig.8. The two sensors for the WM are on top and the antenna is taken outside of the box so that if the module is put on a ceiling, the polarization could be changed easily, if necessary.

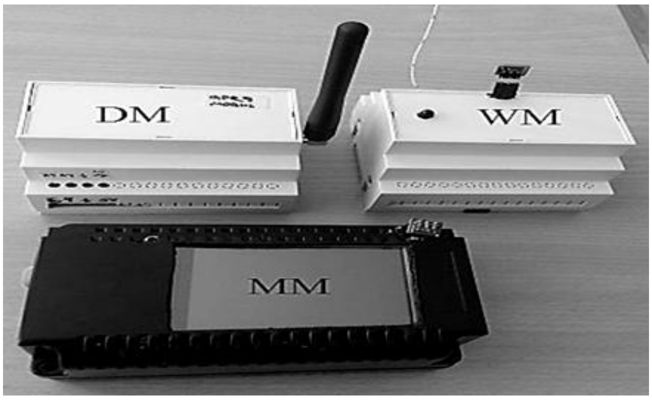

Fig. 8. Main Module, Wireless Module, Receiver Module

Three of the sensors of the MM are positioned outside (Illuminance, Fire and CO2). Experimental readings of all the sensors are displayed in Fig.9.

By default, the sensors for the WM have values of 0 and the breakout board displays "Connection LOST", as shown on Fig. 10. After the activation (+5V) of the WM, the transmission of information begins. This transmission lasts about a second and another one begins after 2. However, at some point in time the Arduino MEGA gets stuck in the receiver function, and, from this point onwards,

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the display freezes (for the duration of the transmission). Another possibility for visualization of the information transmitted by the sensor is given by the Serial Monitor (Fig. 11).

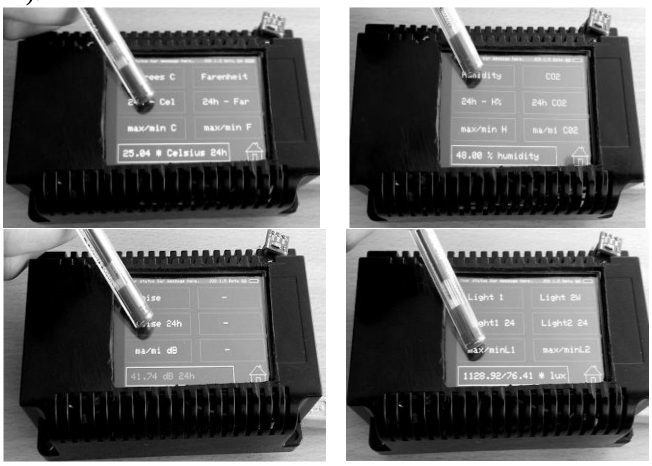

Fig. 9. Experimental readings – temperature, humidity, CO2, fire, illuminance

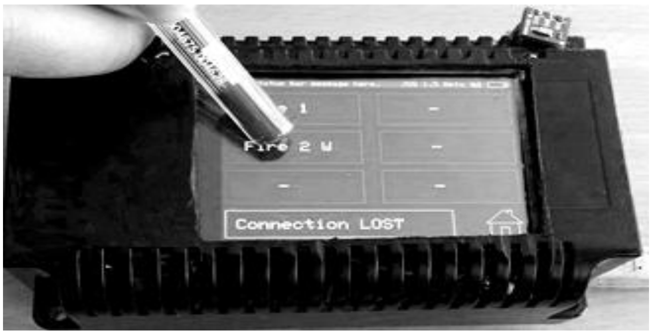

Fig. 10. Experimental readings – fire (wireless module)

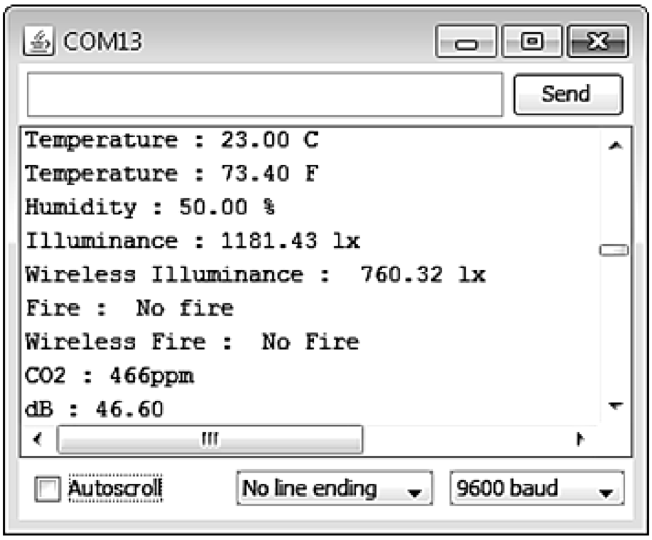

Fig.11. Snapshot of Serial Monitor

A SIM card is put in the GPRS module in the DM. In order to be test the dialer, a lighter is lit in close proximity to the MM. After 2 seconds the dialer calls the default number – Fig.12. Fig. 12 also shows the DM and its connection to the MM (Arduino UNO analog legs 4, 5 to Arduino Mega legs SDA and SDL, 20 - 21). Afterwards, the lighter is lit again. However the dialer is set up to wait 5 minutes until it calls again. In order to be assessed the functionality of the system, the temperature and humidity sensors are artificially affected to go out of the acceptable range and as a result the respective SMS is received.

Fig. 12. Dialer Module, Main Module

V. FUTURE DEVELOPMENT

We are going to propose a few ways to further develop this project. On one hand, in order to take more accurate measurements the sensors could be replaced with ones of higher quality. On the other, for better flexibility of the system (in order more accurate measurements of the parameters to be taken, especially those that depend on the placement of the sensor (e.g. illuminance)), the addition of more wireless transmitters, and a receiver controlling them, is needed. Furthermore, a solution for the freezing of the display during data receiving should be found.

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AUTHORS PROFILE

Yasen Kalinin, B. Sc. degree student Telecommunication, Technical University of Varna. His research interests are in telecommunication networks, data acquisition system, Arduino programming. Member of IEEE.
Edy Velikov, B. Sc. Degree student in Telecommunication, Technical University of Varna. His research interests are in analog circuit design, data acquisition system, and biomedical devices. Member of IEEE.
Dr. Valentina Markova received the PhD degree from Technical university of Sofia, in 2007. She is currently assistant professor in the Department of Telecommunications, Technical university of Varna, Bulgaria. Her research interests are in circuit design, data acquisition system, body sensor network. She participated in about 10 research projects and more than 30 international conferences and workshops. Member of IEEE.