TELSIKS 2013 Serbia, Niš, October 16 - 19, 2013

Low-cost Wireless Dust Monitoring System

Uglješa Z. Jovanović[1], Igor D. Jovanović[2], Andrija Z. Petrušić[3], Zoran M. Petrušić[4], Dragan D. Mančić[5]

Abstract – **In this paper a prototype of wireless system for dust density measurement is presented. The system is developed with inexpensive commercially available components and can measure dust density up to 0.5mg/m^3. The system is modular and consists of a base station connected to a PC via USB communication and an autonomous sensing node equipped with an optical dust sensor GP2Y1010AU0F. A virtual instrument made in LabVIEW is created to monitor the system operation, data acquisition and data storage.**

Keywords – **Wireless system, Dust density measurement, Virtual instrument, LabVIEW.**

I. Introduction

Exposure to dust particles can lead to serious health problems. Coarse particles, PM_{10}, (usually found in wind-blown dust) and fine particles, $PM_{2.5}$, (found in smoke and haze) pose the greatest problems because they can get deep into the lungs. Scientific studies have linked particle exposure to development of chronic bronchitis, increased respiratory symptoms, etc. Therefore, the dust density in the environment needs to be continuously monitored [1]. According to the European Commission maximal permissible annual average values are: 28μg/m^3 for PM_{10} and 17μg/m^3 for $PM_{2.5}$ [1].

Wide range of instruments for dust density measurement is available on the market, but most of them are either quite expensive or can't be easily employed as a portable units. The solution for this issue is to develop a custom-made measuring system using low-cost off-the-shelf components similar to systems presented in papers [2, 3]. Of course, compared to commercially available instruments such system will have a lower accuracy but it can still be used in many practical applications. By implementing a wireless communication into the system it can be employed as a wireless sensor network [4].

[1]Uglješa Z. Jovanović is with the Innovation Centre of Advanced Technologies, Vojvode Mišića 58/2, 18000 Niš, Serbia, E-mail: ugljesa.jovanovic@elfak.ni.ac.rs

[2]Igor D. Jovanović is with the Faculty of Electronic Engineering, University of Nis, Aleksandra Medvedeva 14, 18000 Niš, Serbia, E-mail: igor.jovanovic@elfak.ni.ac.rs

[3]Andrija Z. Petrušić is with the Innovation Centre of Advanced Technologies, Vojvode Mišića 58/2, 18000 Niš, Serbia, E-mail: andrija.petrusic@icnt.rs

[4]Zoran M. Petrušić is with the Faculty of Electronic Engineering, University of Nis, Aleksandra Medvedeva 14, 18000 Niš, Serbia, E-mail: zoran.petrusic@gmail.com

[5]Dragan D. Mančić is with the Faculty of Electronic Engineering, University of Nis, Aleksandra Medvedeva 14, 18000 Niš, Serbia, E-mail: dragan.mancic@elfak.ni.ac.rs

Among several methods for dust density measurement the most preferred one is the optical principle [5]. Sensors operating on this principle emit a light beam which is in the presence of dust scattered onto a receptor and transformed into a pulse signal proportional to the particle concentration.

Monitoring the dust density also requires analysis and storage of the acquired results which are usually accomplished by a PC application. Furthermore, the PC application can also provide complex data processing and various visual presentations of results. Hence, the PC application plays a significant role in system operation and represents an essential feature of every monitoring system.

This paper presents the design, development and testing of the dust density monitoring system. The main features of the system are ease use, remote operation at a very low cost. The proposed system can have applications in a huge variety of fields.

II. System Design

The system is developed with inexpensive off-the-shelf components and can measure dust density up to 0.5mg/m^3. It consists of a base station connected to a PC and an autonomous sensing node equipped with an optical dust sensor GP2Y1010AU0F made by *Sharp* [6]. Wireless communication between these two units is realized using RF transceivers *Chipcon* ST-TR1100 based on *Texas Instruments* CC1100 modules which operate on 433MHz. The greatest distance between the two units is 300m on open space and 100m in buildings.

A proper virtual instrument made in LabVIEW is created to monitor the system operation and to process, visualize and store the acquired measurements.

A. Sensor Selection

Wide range of dust sensors based on the optical principle of operation is currently available on the market. However, most of them require an additional heating resistor which is used to create an air flow (updraft) through the measurement chamber. Furthermore, this imposes some drawbacks mainly due to increased power consumption and problems with orientation of the sensor during the operation. Among a few optical dust sensors which operate without the additional heating resistor is the sensor GP2Y1010AU0F which makes it suitable for low-power systems. The sensor is also relatively cheap (it costs roughly 12$) which makes it especially suitable for low-cost applications. The internal schematic of the sensor GP2Y1010AU0F is shown in Fig. 1 [6].

978-1-4799-0902-5/13/$31.00 ©2013 IEEE

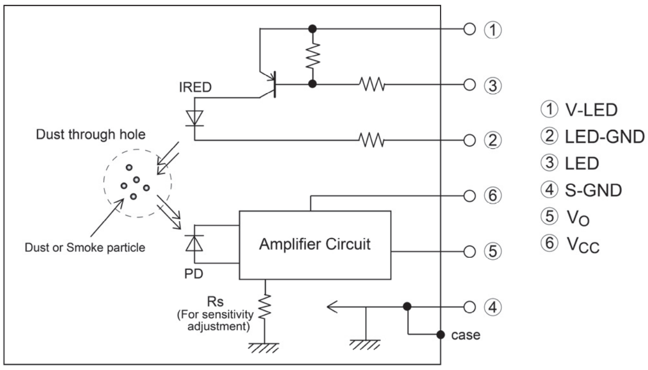

Fig. 1. Internal schematic of the sensor

The infrared emitting diode (IRED) is diagonally arranged with the phototransistor (PD) which detects the reflected light by an airborne dust in the measurement chamber as shown in Fig. 1. According to the manufacture, the sensor easily detects very fine particles like the cigarette smoke. In addition, it can distinguish smoke from a house dust by pulse pattern of output voltage.

In order for sensor to properly operate the IRED needs to be driven with a pulse waveform shown in Fig. 2 [6].

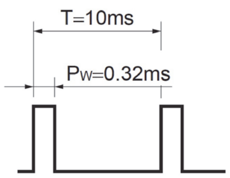

Fig. 2. Pulse-driven waveform for IRED

The output of the sensor is an analog voltage proportional to the measured dust density and it takes approximately 280μs before its being stabilized as shown in Fig. 3 [6].

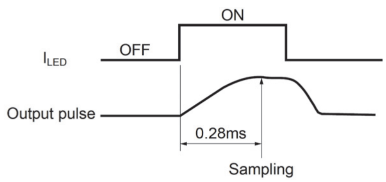

Fig. 3. Output pulse timing

The output voltage can be converted to represent the density value from the chart shown in Fig. 4 [6].

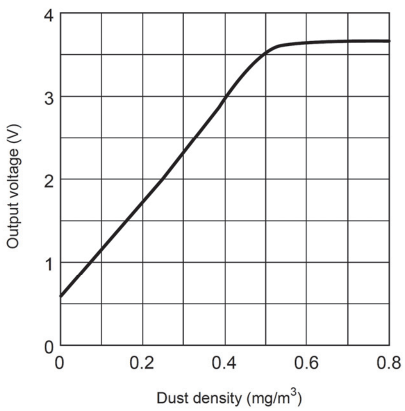

Fig. 4. Sensor's output characteristics

B. Hardware Design

The proposed system is PC based which means that all the real-time readings and data storage are carried out by a PC. As already mentioned the system comprises two functional units, the sensing node and the base unit which are linked via RF communication. The functional block diagram of the proposed system is shown in Fig. 5.

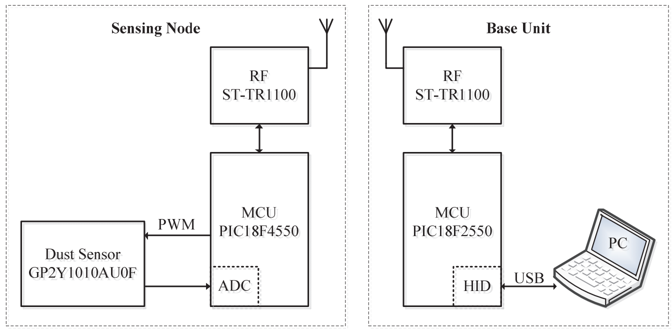

Fig. 5. Functional block diagram of the proposed system

The sensing node is responsible for dust density measurement and it transmits the results to the base unit. Photo of the node is shown in Fig. 6 and it is equipped with the following:

1. Microcontroller (MCU) PIC18F4550;
2. Optical dust sensor GP2Y1010AU0F;
3. RF transceiver ST-TR1100;
4. Power circuit.

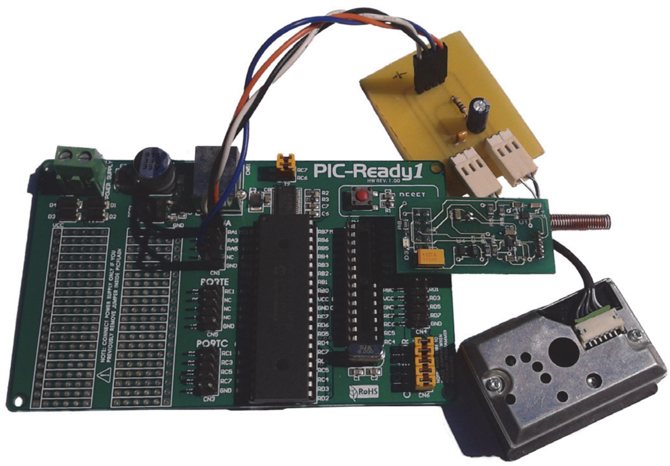

Fig. 6. Photo of the sensing node

Output of the GP2Y1010AU0F is connected to the MCU's built-in analog to digital converter (ADC) which performs digitalization of the sensor's output voltage according to the timing shown in Fig. 3. The MCU also simultaneously generates pulse waveform necessary to drive the sensor properly as shown in Fig. 2. The acquired results are then sent to the base unit via the RF transceiver.

The base unit receives the data transmitted from the sensing node and forwards them to the PC via USB communication. Photo of the unit is shown in Fig. 7 and it is equipped with the following:

1. MCU PIC18F2550;
2. RF transceiver ST-TR1100;
3. Power circuit.

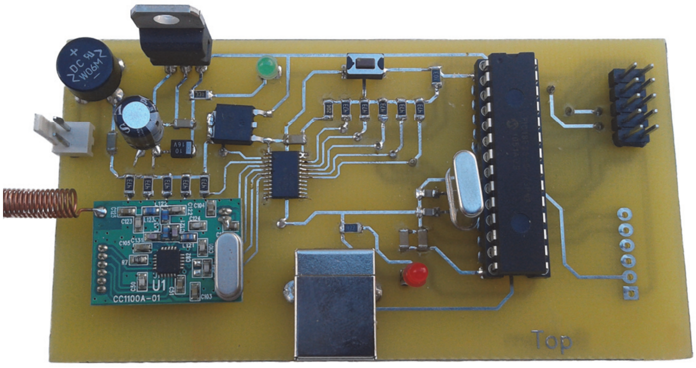

Fig. 7. Photo of the base unit

C. Software

A suitable virtual instrument for real-time readouts and visualization of the results is developed in LabVIEW. The virtual instrument handles data acquisition, processing, visualization and storage of the measured data. Additionally, the results can be saved in form of an Excel file format for further processing in different applications. The communication between the PC and system is realized via USB port using the PIC18F2550 built in HID protocol. Print screen of the virtual instrument while the system is running is shown in Fig. 8.

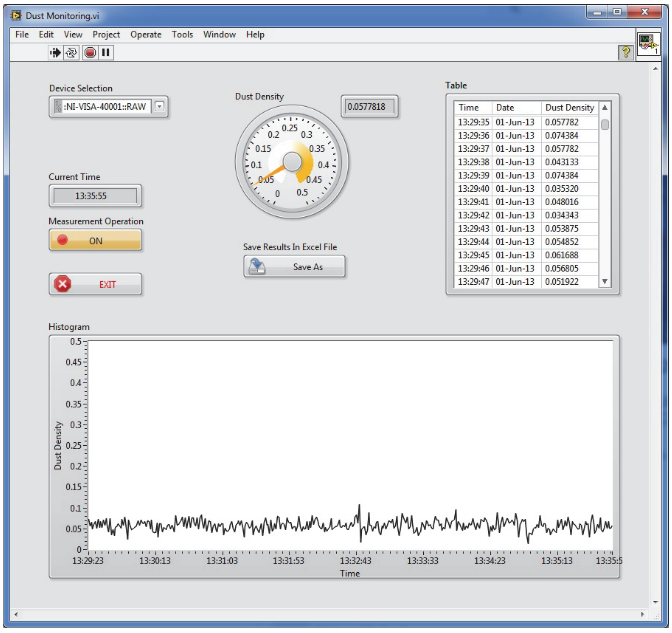

Fig. 8. Print screen of the virtual instrument

Real-time measurements are displayed on the gauge and in order to make data analysis a little bit easier the readings can also be displayed in the table along with a time of measurement and in the chart diagram in form of the histogram as it is shown in Fig. 8.

III. Test Results

In case of the sensor GP2Y1010AU0F there are several papers available which provide comparisons between the readings made by the sensor GP2Y1010AU0F and the readings coming from a high-quality grade reference instruments among which are papers [2, 3, 7]. Paper [7] presents the comparison between a DustTrak DRX Aerosol Monitor 8533 made by *TSI* (worth around 9000$) and the system similar to one presented in this paper. Results of this comparison are shown in Fig. 9 in which the red curve represents the results from a dust sensor GP2Y1010AU0F and the blue curve represents the results from the DustTrak DRX Aerosol Monitor 8533.

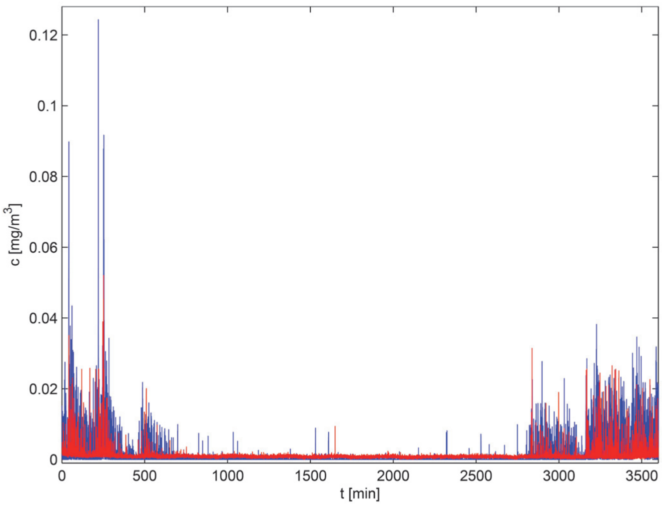

Fig. 9. Comparison between the readings from a DustTrak DRX Aerosol Monitor 8533 and a GP2Y1010AU0F presented in paper [7]

Based on the results shown in Fig. 9 it is evident that there is a good agreement between the readings from two instruments considering the massive price difference between them. Hence, it can be concluded that the sensor GP2Y1010AU0F satisfies the demands in terms of accuracy in order to be reliably employed as a sensor in an inexpensive low-range dust monitoring system such as one presented in this paper.

The proposed system is roughly calibrated using the information from datasheet [6] and the following equation:

$$Density = \frac{V_{OUT} - V_{OFFSET}}{Sens} \quad (1)$$

V_{OUT} is the output voltage from the sensor, V_{OFFSET} is the offset voltage and *Sens* is the sensitivity. Based on the specifications from datasheet [6], the offset voltage is roughly 0.9V and the sensitivity is approximately 0.5V/0.1mg/m^3. These parameters, however, can slightly vary so it is essential to precisely assess them.

The proposed system had undergone thorough test procedure in order to properly evaluate its performances. The results obtained during one hour of continuous measurements, conducted in the room with the windows closed and the air condition turned on, are shown in Fig. 10.

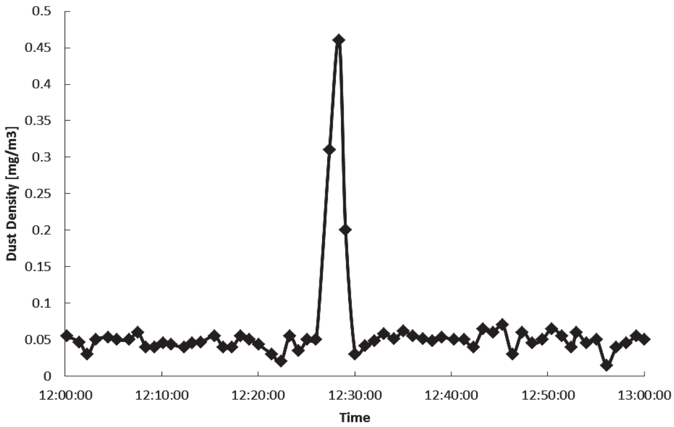

Fig. 10. Test results

The measurements in the chart were conducted on every minute. The peak in the middle of the chart is a consequence of a smoke coming from a burning match beneath the sensor.

IV. Conclusion and Outlook

This paper presents the implementation of the low-cost wireless system for monitoring dust density based on the sensor GP2Y1010AU0F. The requirements were that the system is modular and flexible in terms of use, with low power consumption and to be fairly inexpensive. The proposed solution is capable of measuring dust density up to $0.5 mg/m^3$, and it is intended to be the integral part of the air quality control system currently being developed.

The developed system has several advantages among which are small size, real-time communication, cost-effectiveness and easy to use functionality. It represents a good and inexpensive alternative to more expensive similar instruments currently available especially when it is necessary to monitor dust density on several locations.

The second is to make air flow through the sensor by using either a pump or a fan to suck the air in the measurement chamber. The third is to include the additional sensing nodes so that the greater wireless sensor network can be formed. Ultimately, in order to increase the measuring range it is necessary to evaluate a few alternative sensors to the GP2Y1010AU0F, primarily PPD4NS and PPD60PV particle sensors made by *Shinyei*.

Acknowledgement

The research presented in this paper is financed by the Ministry of Education, Science and Technological Development of the Republic of Serbia under the projects TR33035 and III43014.

References

[1] European Commission, “Directive 2008/50/EC”, 2008.
[2] M. Khadem, G. Stamatescu, V. Sgarciu, "Wireless Measurement Node for Dust Sensor Integration", *SENSORCOMM 2012*, pp. 159-164, Rome, Italy, 2012.
[3] G. Olivares, I. Longley, G. Coulson, "Development of a low-cost device for observing indoor particle levels associated with source activities in the home", *IES2012*, Seattle, USA, 2012.
[4] B. Ivanov, O. Zhelondz, L. Borodulkin and H. Ruser, "Distributed smart sensor system for indoor climate monitoring", 2002 *KONNEX*, München, Germany, 2002.
[5] J. Fraden, *Handbook of Modern Sensors: Physics, Designs, and Applications*, New York, Springer, 2010.
[6] SHARP Corporation, Sheet No. E4-A01501EN GP2Y1010AU0F Compact Optical Dust Sensor, 2006.
[7] M. Budde, M. Busse, and M. Beigl, "Investigating the Use of Commodity Dust Sensors for the Embedded Measurement of Particulate Matter", *Networked Sensing Systems (INSS),* Antwerp, Belgium, 2012.