Performance of AVR microcontroller-SMS gateway system for detecting SO_2 and NO_2

Sudarsono [1*], *Muhammad* Andang Novianta [2], Purnawan[3]

[1] Department of Mechanical Engineering, Institut Sains & Teknologi AKPRIND Yogyakarta 55222 Indonesia
[2] Department of Electrical Engineering, Institut Sains & Teknologi AKPRIND Yogyakarta 55222 Indonesia
[3] Department of Environmental Engineering, Institut Sains & Teknologi AKPRIND Yogyakarta 55222 Indonesia

Abstract. This study aims to investigate SO_2 and NO_2 level in atmospheric air using AVR microcontroller-SMS gateway system. This system could gather high-resolution spatiotemporal air pollution data by GSM network of low-cost sensors for monitoring real-time concentrations of different air pollutants, which can be then utilized for a variety of air pollution management tasks. The system able to provide information with threshold values, Good (1-50PPM), Medium (51-100PPM), No Health (101-199PPM), Very Unhealth (200-299PPM) and Dangerous (above 300 PPM). Level of NO_2 is higher than NO_2 standard. Meanwhile in general, level of SO_2 is slightly higher than the standard value. The response time to the SMS communication system averages about 5 seconds depending on signal quality and data traffic from cellular service providers. Differences in Voltage and ADC measurements are caused by several errors, such as ADC ± 2 bit output error, rounding ADC conversion error to volt, or due to errors in the measuring tool used.

Keywords: pollutant, detector, AVR microcontroler, sensor, SMS Gateway

1 Introduction

Outdoor air pollution is a major problem in the 21st century, attributing to ~3.7 million deaths globally [1]. Today, ~92% of the world's population lives in region where air pollutant levels are higher than the WHO-specified limits [2]. In addition, air pollution is also responsible for global climate change and environmental problems such as acid rain, haze, ozone depletion, and damage to crop Thus, there is a global drive to tackle this problem [3].

Traditionally, air pollution is monitored by measuring concentrations of various pollutants such as carbon monoxide (CO), ozone (O_3), nitrogen dioxide (NO_2), sulphur dioxide (SO_2), and particulate matter (PM) at fixed sites by using accurate and expensive instrumentation [4] and [5]. Monitoring sites are determined based on the Air Quality Standards, which clearly defines the minimum number of fixed monitoring stations for each target pollutant based on the air pollution levels, population, and coverage area. Such sites are generally spread in and around cities and provide temporal concentrations (typically hourly) of different pollutants. However, they are insufficient to provide accurate information about the spatial distribution of pollutants or identify pollution hotspots. Even though pollutant dispersion models can be used to address this issue, their accuracy is rather limited [6].

Recent advancements in the field of sensors, digital electronics, and wireless communication technology have led to the emergence of a new paradigm for air pollution monitoring [7]. This paradigm aims to gather high-resolution spatiotemporal air pollution data by using a ubiquitous network of low-cost sensors for monitoring real-time concentrations of different air pollutants, which can be then utilized for a variety of air pollution management tasks.

Several review articles have already addressed this emerging area of sensor-based air quality monitoring. Majority of these articles focus on the needs, benefits, challenges, and future directions of a sensor-based pollution monitoring paradigm for different applications [8], [9]. Traditional approaches for measuring air quality based on fixed measurements are inadequate for personal exposure monitoring. To combat this issue, the use of small, portable gas-sensing air pollution monitoring technologies is increasing, with researchers and individuals employing portable and mobile methods to obtain more spatially and temporally representative air pollution data. However, many commercially available options are built for various applications and based on different technologies, assumptions, and limitations.

Wireless sensor networks (WSNs) consist of small autonomous nodes that have the benefits of being small, efficient relatively low in price. Sensor networks have major application of real-time monitoring. Latterly, the progress on sensing, processing and communication technologies have reduced the cost of sensors, made them smaller in size and power efficient. However, the system performances of WSNs are still subject to unit computing speed, memory capacity and stability of communication, etc. Together the limitations of hardware, many issues on WSNs software have been

* Corresponding author: sudarsono1574@akprind.ac.id

https://doi.org/10.1051/e3sconf/20187305025

discussed, such as routing protocols, media access control, coverage and power management.

Air pollution causes a decrease in air quality that negatively impacts human health. Health effects for humans such as ISPA (Upper Respiratory Tract Infection), asthma, bronchitis, eye irritation to poisoning that can lead not only a death, but also can cause disturbance of plant growth and prone diseases such as chlorosis, necrosis, black spots and also can interfere with photosynthesis process plants, and other environmental impacts, such as triggers of acid rain, greenhouse effect, ozone layer damage and other environmental problems [10].

The Air Pollution Standards Index (ISPU) is an air quality report to the public to explain how clean or contaminated air quality is. In Indonesia ISPU is regulated by Decree of the Environmental Impact Management Agency (Bapedal) Number KEP-107 / Kabapedal / 11/1997. Table 1 describes the index and ISPU categories. Air pollutant components have their respective unit concentrations and different health standards according to the value of the units. Bapedal creates a standard air pollution index limit [11] as shown in Table 2.

Table 1. Index and ISPU Categories

Index	Categories
1 – 50	Good
51 – 100	Neutral
101 – 199	Harmful
200 – 299	Very harmful
>300	Dangerous

Table 2. Standard Air pollution

Pollutant	Standard
Sulfur Dioxide (SO2)	80 ug/m3 (0.03 ppm)
Nitrogen dioxide (NO2),	100 pg/m3 (0.05 ppm) for 1 hour

SO_2 gas is very easily dissolved in water, has odor, and is colorless. As with O_3, secondary pollutants formed from SO_2, such as sulfate particles, can migrate and are deposited away from the source. SO_2 and other sulfur oxide gases are formed during the burning of fossil fuels containing sulfur. The influence of SO_2 on society and the environment varies greatly depending on the amount of gas wasted into the atmosphere, the gas mileage to the Earth's atmosphere, the troposphere or the stratosphere and the regional or global wind and climate patterns that can spread the gas.

Meanwhile, NOx is a nitrogenous gas group present in the atmosphere comprising nitrogen monoxide (NO) and nitrogen dioxide (NO_2). Nitrogen monoxide is a colorless and odorless gas instead of nitrogen dioxide is reddish-brown and pungent. NOx emissions are affected by population density because the main sources of human-produced NOx are from combustion and most combustion is caused by motor vehicles, energy production and waste disposal.

Previous investigations as well as designing an instrumentation of SO_2 and NO_2 detector have been reported as follows. Otani [12], demonstrated the detection rate of nitrogen oxide (NOx) gas using a mid-infrared coherent light source based on the frequency level difference used in a fiber laser as a pumping source. The result obtained a high resolution spectroscopic measurement to measure NO_2 gas. Meanwhile, Yuzhan [13] has designed a Wireless The network system for monitoring sulfur dioxide and nitrogen dioxide gases in internal engine combustion systems. The built system consists of software and hardware. The monitoring system also added an algorithm called Artificial Fish Swarm to optimize coverage ability of the network area. The simulation results show a wider coverage of node network area 95% more efficient and the number of node points more efficient, with less power usage. The system aims to help the problem of air pollution due to increased automotive exhaust gas emission.

This study aims to investigate SO_2 and NO_2 level in atmospheric air using AVR microcontroller-SMS gateway system. The system is tested at three different locations.

2 Material and Method

2.1. Design and Installation

In this work, AVR microcontroller-SMS gateway based air pollutant detector is designed and evaluated. Hardware as well as software used for developing the system are shown in Table 3.

Table 3. Hardware and software of the system

Hardware	Software
Microcontroller ATMega 328 SMD	Arduino IDE 1.6.5
MiCS-5524	Eagle 7.6.0 CADSOFT
MiCS-2614	Corel Draw
Sharp GP2Y1010AU0F	ISIS Proteus Simulator
Module RTC DS1302	
Module Micro SD *data logger*	
Modem	
LCD character 20x4	
Module *buck converter* LM2576 5 volt	
Battery 12 volt	

Meanwhile, Figure 1 shows microcontroller circuit to measure the value of the gas sensor output. The microcontroller IC can read logic signals "0" (zero) and "1" (one) and can read analog value of ADC microcontroller feature. The sensor circuit is used to detect the presence of SO_2 and NO_2 gas in the air and then transmit data in analog form to microcontroller to be converted to digital form by ADC.

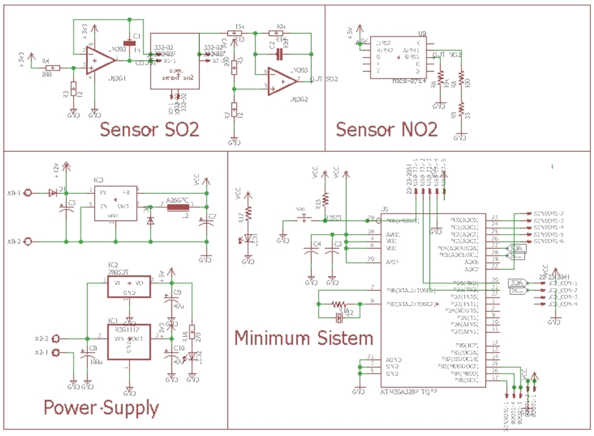

Fig. 1. Block diagram of the system

2.2 Testing the system

Figure 2 displays schematic layout of AVR microcontroller-SMS gateway system mechanism. The system will detect the presence of SO_2 and NO_2 gas in the air, then read by the gas sensor and produce analog output voltage. The data in the form of voltage is then processed by the microcontroller, resulting in a series of numbers displayed on the display. The microcontroller contains a program to calculate the variable voltage of the sensor. The sensor output voltage is analog voltage coming from the input voltage of 5 volt DC voltage as the controller of the heating temperature inside the sensor at 5 volts, so it must be converted to digital voltage by the ADC contained in microcontroller. After the electrical signal is processed to obtain data which is then displayed on the LED screen as an indicator of the value of SO_2 and NO_2 gas content contained in air. The last process is to send information on SO_2 and NO_2 gas concentration by SMS automatically.

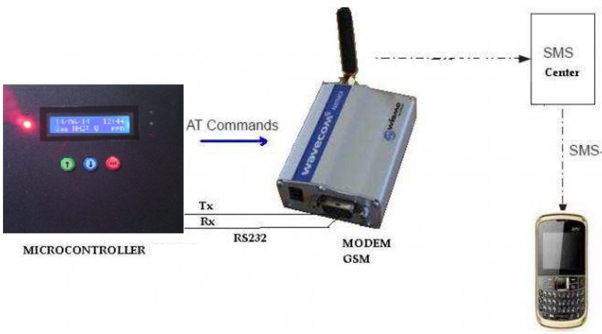

Fig. 2. Layout of the system mechanism

3 Result and Discussion

The system performance is evaluated at three different locations. The performance evaluation is performed for individual sensor as well as for overall system. Performance of overall system is investigated for 14 hours, from 06.04 am to 20.04 pm.

Table 4 to Table 5 show the results of individual sensor testing electrically and the display of detected SO_2 and NO_2. Meanwhile, Figure 3 displays the measured valued of SO_2 and NO_2 in system monitor.

Table 4. SO_2 levels on SO_2 Spec Sensor

No	SO_2 levels	Voltage	ADC
1	51,50 mg/m^3	1,38 volt	270
2	59,80 mg/m^3	1,39 volt	285

Table 5. NO_2 levels sensor MiCS-2714

No	NO_2 levels	Rs	Vottage	ADC
1	0.05 ppm	0.8 kΩ	4.63 volt	948
2	5 ppm	20 kΩ	1.67 volt	342

The measured data collected by the sensor is sent to smartphone, thus the detected level of SO_2 and NO_2 can be read via SMS on the phone as displayed in Figure 4. The format used to send the message must match the format specified in the design of the application. Table 6 indicates that at all three location, level of NO_2 is higher than NO_2 standard (0.05 ppm). Meanwhile in general, level of SO_2 slightly higher than standard value.

Fig. 3. Displays on LED screen

Figure 3 conveys the message content containing the SO_2 and NO_2 values detected via SMS. The format used to send the message must match the format specified in the design of the application.

Table 6. Results of overall system evaluation

No	Initial time	Final time	Location 1		Location 2		Location 3	
			NO_2 (ppm)	SO_2 (ppm)	NO_2 (ppm)	SO_2 (ppm)	NO_2 (ppm)	SO_2 (ppm)
1	06:04	07:04	4,2	0,07	4,9	0,08	4,4	0,07
2	07:04	08:04	4,0	0,07	4,5	0,07	4,3	0,07
3	08:04	09:04	4,0	0,07	4,1	0,07	4,0	0,06
4	09:04	10:04	4,0	0,06	4,0	0,07	3,5	0,06
5	10:04	11:04	3,6	0,06	3,6	0,06	3,3	0,05
6	11:04	12:04	3,0	0,06	2,7	0,06	2,6	0,05
7	12:04	13:04	2,7	0,05	2,5	0,06	2,6	0,05
8	13:04	14:04	2,2	0,03	2,5	0,04	2,3	0,03
9	14:04	15:04	2,3	0,03	2,3	0,03	2,0	0,03
10	15:04	16:04	2,6	0,04	2,5	0,04	2,2	0,04
11	16:04	17:04	2,9	0,04	2,6	0,04	2,6	0,04
12	17:04	18:04	3,3	0,05	3,0	0,04	3,1	0,05
13	18:04	19:04	3,5	0,05	3,5	0,05	3,6	0,06
14	19:04	20:04	3,6	0,08	3,8	0,08	3,9	0,07
15	20:04	21:04	3,7	0,08	4,0	0,08	4,1	0,07

Fig. 4. SMS displays on the mobile screen

4 Conclusion

Gas SOx is detected using SPECS SO_2 sensor, NO_2 gas can be detected using MICS-2714 sensor based on electronic system. The test result of each sensor has output analog voltage which can be read by ADC feature on microcontroller with output voltage or ADC from sensor directly proportional to the concentration of gas that is around the sensor. This system is able to provide information with threshold values, GOOD (1-50PPM), MEDIUM (51-100PPM), NO HEALTH (101-199PPM), VERY UNHEALTH (200-299PPM) and DANGEROUS (ABOVE 300PPM). The response time to the SMS communication system averages about 5 seconds depending on signal quality and data traffic from cellular service providers. Differences in Vout and ADC measurements are caused by several errors, such as ADC ± 2 bit output error, rounding ADC conversion error to volt, or due to errors in the measuring tool used.

Acknowledgments

The authors would like to thank Direktorat Riset dan Pengabdian Masyarakat, Direktorat Jenderal Penguatan Riset dan Pengembangan (Kemenristekdikti) for providing financial assistance through a scheme of Hibah Penelitian No: 061/HB-LIT/IV/2017

References

1. Badan Pengendalian Dampak Lingkungan, Pedoman Teknis Perhitungan dan Pelaporan Serta Informasi Indeks Standar Pencemar Udara, http://www.cetsuii.org/BML/Udara/ISPU/ISPU 20 (Indeks Standar Pencemar Udara.htm, (Accessed on March 20, 2016)

2. N. Castell, Viana, M. Minguillón, X. Querol, M. Viana, C. Guerreiro, *J. Aero. Scie.* **42**, 9 (2013)

3. Departemen Kesehatan, Parameter Pencemaran Udara dan Dampaknya Bagi Kesehatan, http://www.depkes.go.id/downloads/udara.pdf, (Accessed on March 20, 2016)

4. P. Kumar, M. Ketzel, S. Vardoulakis, L. Pirjola, R. Britter, *J. Aero. Scie.* **42**, 580-603 (2011)

5. P. Kumar, L. Morawska, W. Birmili, P. Paasonen, M. Hu, M. Kulmala, R. Harrison, L. Norford, R. Britter, *Envi. Int.* **66**, 1-10 (2014)

6. P. Kumar, L. Morawska, C. Martani, G. Biskos, M. Neophytou, S. Sabatino, M. Bell, L. Norford, R. Britter, *Envi. Int.* **75**, 199-205 (2015)

7. P. Mouzourides, P. Kumar, M. Neophytou, *Atmo. Envi.* **107**, 148-165 (2015)

8. N. Otani, CLEO, 2 (2003)

https://doi.org/10.1051/e3sconf/20187305025

9. P. Sharma, P. Sharma, S. Jain, P. Kumar, *Atmo. Envi.* **70**, 7-17 (2013)
10. R. White, I. Paprotny, F. Doering, W. Cascio, P. Solomon, L. Gundel, EM Magz **5**, 36-40 (2012)
11. WHO, Burden of Disease From Ambient Air Pollution for 2012, http://www.who.int/phe/health_topics/outdoorair/databases/AAP_BoD_results_March2014.pdf, (Accessed on Oct 31, 2016)
12. WHO, Ambient Air Pollution: A Global Assessment of Exposure and Burden of Disease, http://apps.who.int/iris/bitstream/10665/250141/1/9789241511353-eng.pdf?ua=1, (Accessed on October 31, 2016)
13. Z. Youzhan, Z. Yiwei, C. Linlin, L. Congning, S. Yunbo, Int. Conf. on IMCCC, 1202-1205 (2015)