Microcontroller ATMEGA8535 based Design of Carbon Monoxide (CO) Gas Detector

Ansar Suyuti, Syafaruddin, Habib Mihdar Ali, Muhammad Tola and Takashi Hiyama, *Member, IEEE*

Abstract—**This paper presents design of Carbon Monoxide (CO) gas detector based on microcontroller performance. The device is embedded with real-time measurement through visualization in Liquid Crystal Display (LCD) and computer monitor. In addition, the data processing utilizes microcontroller ATMEGA8535 under programming environment of CodeVision AVR V2.03.4. The visualization itself is designed based on the combination between programming language of Microsoft Visual Basic ver. 6.0 and C. Data transmission can be very flexible in this case due to the capability standard of microcontroller for communication networks. Also, for one day measurement, the data can be simple stored inside the device. The device has been initially tested in the laboratory on several physical data output. In the implementation, the device has been used to measure the CO level on different locations, such as indoor and outdoor testing and it has shown proper results of measurement.**

Index Terms—**Carbon Monoxide (CO), microcontroller, ATMEGA8535, CodeVision AVR, Microsoft Visual Basic.**

I. Introduction

In recent years, environmental effects from human activities have gained important consideration globally. Air pollution is one of the significant impacts nowadays due to the increase in number of industrial process, vehicles for transportation systems or just from simple kitchen-households activities. Many efforts have been proposed and performed from individual to institutional contexts to solve the problems related to air pollution control. From individual basis, the encouragement to use of vehicles with low carbon emission is remarkably giving great contribution for clean air. From industrial basis, the use of sophisticated technology of filtering in the chimneys before the gas exhausted to the air can reduce the concentrate of gas pollution. In the governmental level, the active campaign to promote green energy concepts, green city and green society will bring positive results in the future clean air environments.

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Ansar Suyuti [(a)], Syafaruddin [(b)], Habib Mihdar Ali [(c)], Muhammad Tola [(d)] are with the Department of Electrical Engineering of Universitas Hasanuddin, 90245 Tamalanrea-Makassar, Indonesia (e-mail: [(a)]asuyuti06@yahoo.com; [(b)]syafaruddin@unhas.ac.id; [(c)]abi_fridry@yahoo.com; [(d)]tola@unhas.ac.id).

Takashi Hiyama is with the Department of Computer Science and Electrical Engineering of Kumamoto University, 2-39-1 Kurokami, Kumamoto 860-8555, Japan (e-mail: hiyama@kumamoto-u.ac.jp).

Clean air must be continuously available in nature for the sake of human and other living things existences. People are supposed to inhale clean air for respiratory process in order to maintain their health condition. For this reason, clean air is absolutely needed, reserved and no tolerance for the activities that worsening the air quality. Extensive studies have been performed to provide design, recruitment, methodology, time activity diary, surveys, and quality assurance and control results of the contribution from air pollutants to people related to asthma problems [1]. In addition, the wise use of clean air respect to the nature preservation must be aware from now on in order to make it available for the future generation. This could be high challenges behind the great benefits of some recent innovations and technology that may contribute to the increase in air pollution or decrease in clean air quality.

Air pollution control is one of the important efforts beside the prevention air pollution itself. Some previous techniques and methods are presented as follows. The predicted assessment of air pollution based on geographical information system (GIS) processing has been developed to measure mixture particles of some points in London city, UK [2]. The method is claimed to be able to improve the reliable estimation air pollution concentration and potentially used for large scale measurements. However, this method is highly depending on data location and the capability of networking information and telecommunication systems. The next method is the direct measurement of metal gas arsenic release in the air with national sampling approach and arsenic analysis [3]. The important results from this review that the arsenic fumes in submicron level are not easy being control using conventional control devices and it needs extra device to combine between particles and vapor controls.

In terms of air pollution monitoring, sampling method is applied to measure the indoor and outdoor residential of some gaseous and particles that potentially exposure to children and adults respiratory health [4]. Since the approach from statistical point of view by means the data is discretely obtained, the bias might be occurred especially for the locations where the standard data comparator is not available. In other methods, the usage of Scanning Electron Microscope and Energy Dispersive Spectrometer (SEM/EDS) for micro-analysis of dust particles absorbed by the leaf surfaces [5]. However, using such techniques require detail analysis since the characterize materials based on some patterns of points and element mapping. The analysis of periodic pattern of air pollutant and source contamination is also used to provide predictive monitoring of air pollutants in subway systems [6]. Again, similar to the previous method in [5], it needs to asses data periodically or seasonal with possibly multivariate relationship between measured data.

The previous proposed systems are sometimes very large as a big system, therefore it is not easy to move to other locations, requires raw data from the case sites because another additional techniques are utilized to process this data and the technology is only available for laboratory experiments. Meanwhile, air pollution monitoring and control are totally required in order to maintain the air quality in the tolerable and expected limits. In the long term monitoring, data of hourly total hydrocarbon in oil and coal mining field for almost 20 years is analyzed to show the methane emission [7]. However, although the study was able to show the emission patterns due to geologic process, the method requires consistently large number of data; therefore the complexity task of analyzing become highly challenges. The monitoring of specific location with optimal sitting station was investigated in [8]. However, the compulsory to make this standard make the system is less flexible in terms of portability and it needs extensive study to where the best location for the station. In associated with pattern and feature of the location which is unpredicted, this data spatial is analyzed using space-time prediction model based Bayesian maximum entropy and visualization of high dimension of data [9]. Again this method, the accuracy outcome is highly depending on the high number of the previous data on site.

In comparison, this work is to design handy and portable air pollution monitoring with real-time performance, capability in measurement data storage and it is adaptive to different types of communication network. In associated with communication network, the utilization of wireless sensor network for air pollution monitoring system combined with data aggregation algorithm to improve the efficiency of sensor network is implemented [10]. The algorithm is basically to reduce the number of data transmitted by transferring the invalid data reading into simpler form. Our approach to the sensor utilization is the use of gaseous sensor Figaro TGS 2600 with high sensitivity to the air pollutant. Basically, our target in the future is to design a monitoring system with capability to sense all gas emission completely, but at this current work, we have succeeded to monitor carbon monoxide (CO) gas with high accuracy. Our proposed model is quite simple and has small dimension; therefore it is very easy to remove from one place to others. To verify our results, real-time measurement can be monitor through visualization in Liquid Crystal Display (LCD) and computer monitor after data processing using microcontroller ATMEGA8535 under programming environment of CodeVision AVR V2.03.4. The visualization itself is designed based on the combination between programming language of Microsoft Visual Basic ver. 6.0 and C. Data transmission can be very flexible due to the capability standard of microcontroller, for instance using simple coaxial cable, GSM line or through standard internet connection. Also, for one day measurement, the data can be simple stored inside the device. The detailed explanation of the proposed method is presented in the following section.

II. Configuration of Proposed System

There are two main configurations of basic design; hardware and software. In designing hardware, the focus is on the physical system design of monitoring device including electronic circuit. On the other hand, the software design consists of how to visualize the level of pollutant on Liquid Crystal Display (LCD) and computer programming using application of Microsoft Visual Basic 6.0. In addition, the C language is composed using *CodeVisionAVR V2.03.4* including compiling and downloading process.

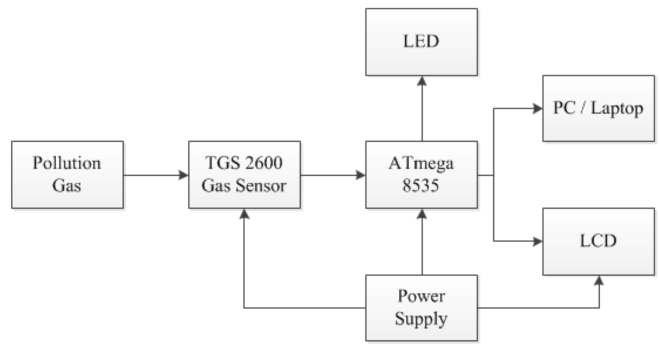

Fig. 1. Basic diagram of monitoring air pollution system.

The configuration of monitoring system for Carbon Monoxide gas shown in Fig. 1 is explained as follows. Sensor of Figaro TGS 2600 functions to detect the air pollutant using data analog of output voltage. Therefore, this data needs to be converted into digital data of 8 bit by connecting to ADC pin of ATMega8535. The microprocessor chip with downloaded C program inside will process all received. After this stage, the microcontroller ATMega8535 will send the processed data to LCD. The level shown in LCD is equal to the level intensity of air pollutant measured by Figaro sensor TGS 2600. In this work, we utilize five LED lamps as indicators of air pollution level. To visualize this measurement in the computer monitor, it requires serial interface systems as a communication gate between computer and microcontroller.

A. Hardware Design

Hardware design is divided into two categories i.e physical design and electronic design. The material for physical design based on Aluminum plate to cover the designed electronic circuit. The physical design in two and three dimensional views is shown in Fig. 2, as follows:

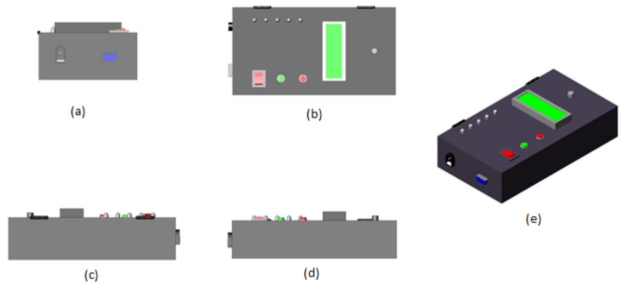

Fig. 2. Physical design in two and three dimensional views
(a). front, (b). top, (c). right, (d). left, (e). three dimensional views.

For electronic design, it is necessary to select and to classify the electronic components used in this model. In Fig. 3, it is shown the electronic circuit of our proposed model. The circuit is divided into five blocks. The yellow, green, red, pink and orange blocks represent sensor, controller, display, level indicator of gas pollutant and serial communication circuits, respectively. The sensor circuit is designed based on the performance of sensor of Figaro TGS 2600 to detect the air quality, especially the existence of the Carbon Monoxide (CO) gas. Meanwhile, the processing for control unit utilizes Microcontroller ATMega 8535. The display for the measurement results uses LCD with 16x2 characters. The other components are light emitting diode (LED) and IC MAX 232 including the connector RS232 which each function as indicator level and serial communication to the personal computer. More detailed about the features of each component is presented as follows.

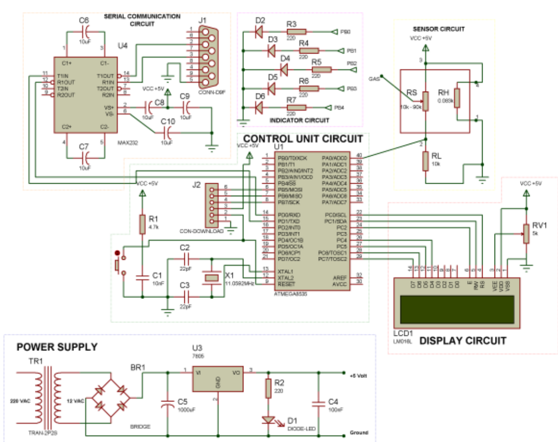

Fig. 3. Electronic circuit for electronic design

Sensor Circuit of Figaro TGS 2600

The front end of air pollutant monitoring system is the sensor circuit detector of Figaro TGS 2600. This type of sensor is a chemical sensor to detect the contaminated level of air from Hydrogen and Carbon monoxide gases. The main component of this gas detector is metal oxide, especially SnO_2 [11]. The mechanism of detection starts when the temperature of crystal of metal oxide (SnO_2) increases, the oxygen absorbed on the crystal surface which make the oxygen becomes negatively charged. Because of the crystal surface donors electron to the oxygen located in the outer layer, the oxygen then remained negatively charged and positive charges appear on the outer surface. The established surface voltage will slow down the electron movements, and then the electric current will flow at the grain boundary of the crystal. In this junction the absorbed oxygen will prevent the charge move freely. If the gas concentration decreases, the deoxidation process starts and causes the surface charge density of negatively charge oxygen decreases. As results, the wide of barrier in the junction area reduces which means the resistance value of the sensor decreases, especially when the targeted pollutant gas detected. The electronic circuit of Figaro sensor TGS 2600 is shown in Fig. 4.

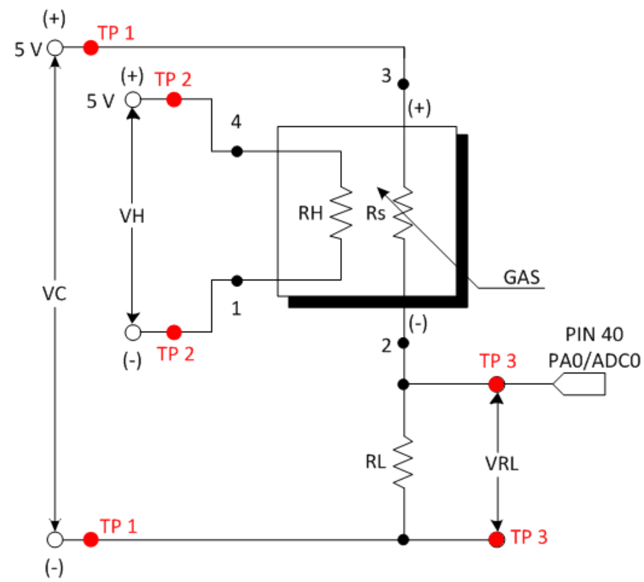

Fig. 4. The electronic circuit of Figaro sensor TGS 2600

The sensor circuit is clearly shown that the value of the resistance R_S changes when the pollutant gas detected. The voltage drop at R_L or V_{out} is the input for the microcontroller. The value of the resistance R_L is selected sufficiently to make the power consumption is less than 15 mW since the power losses increase as the sensor resistance R_S equal to R_L. In addition, the sensor requires some kind of heater to clean the inside part from the contaminated outside air. This heater needs a constant voltage (±5 Volt DC) in order to keep the stability of output signals. To find the DC voltage, the voltage adaptor is required. In this work, the adaptor type Mitoyuri AC-DC with input voltage and frequency of 220 V_{AC} and 50/60Hz, respectively; and output voltage of 1.5-12V_{DC} with maximum current of 1000mA.

Microcontroller Circuit of ATMega8535

In the field of microelectronics, Atmel is one of the well-known vendors that developed AVR *(Alf and Vegard's Risc Processor)* in 1997. AVR utilizes architecture of RISC *(Reduced Instruction Set Computer)* with width capability bus data of 8 bit, where all instructions or commands are formed into code of 16 bit word and most of commands are executed in one clock cycle. In comparison to the type of microcontrollers

MCS51 that using CISC (*Complex Instruction Set Computing*), they need 12 clock cycles to execute commands. For this reason, the speed of AVR is 12 times faster than MCS51. In general, the AVR can be classified into 4 classes; Attiny, AT90Sxx, ATMega and AT86RFxx. The differences between types are one the size of *onboard memory*, *onboard peripheral* and their functions, while their architectures and the set of instructions are basically the same.

In this work, we are using the AVR microcontroller of ATMEGA8535 for some reasons. This microcontroller type has complete facility, fast instruction process and it is supported by Code Vision AVR Evaluation software for simulation and compiler. In addition, the Microcontroller of ATMEGA8535 has special feature, especially the facility of Analog to Digital converter. This feature is very important to convert the analog to digital signals since the sensor output is the analog signal, while this signal needs to be processed as digital signal in the microcontroller.

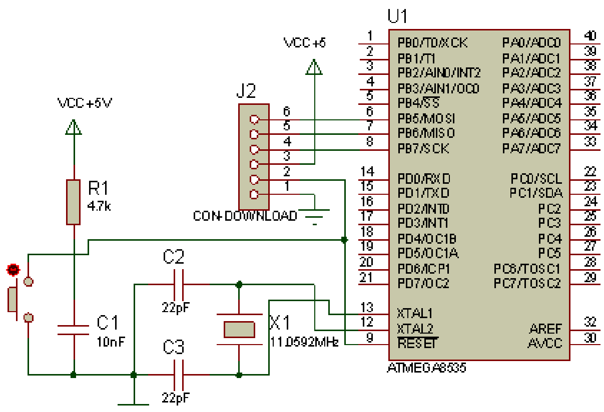

Fig. 5. Microcontroller circuit of ATMega8535

Microcontroller circuit in Fig.5 is designed to control the overall system performance. To activate the microcontroller of ATMega8535, the power source with dc voltage of ±5 Volt is required. The clock source of microcontroller is obtained from the connection of crystal oscillator between XTAL1 (pin 13) and XTAL2 (pin 12), then grounded through a capacitor. The frequency of crystal oscillator in this work is 11.0592 MHz with capasitor value of 22 µF. One of the pin, called pin A (PA0) functions as an input signal to the analog digital converter (ADC) from the sensor circuit. The other pins, such as pin C0 (PC0) to C7 (PC7), except PC3 are used to the output of Liquid Crystal Display (LCD). Meanwhile, pin PB5 (MOSI) to PB7 (SCK) and Reset pin are formed to the downloader connection.

Display Circuit to the Liquid Crystal Display (LCD)

The liquid crystal display (LCD) is used as the display device in our proposed air pollution monitoring system. One of common LCD type used is the type of Topway LCD LMB162A. This module is designed with matrix of liquid crystal with the internal controller. The controller has special ROM/RAM as generator character and RAM for display data. All display functions are controlled by set of instructions. The LMB162A is the module of LCD Matrix with configuration of 16 characters and 2 rows. Each character is formed by pixels of 8 rows and 5 columns, while the last pixel with 1 row is the cursor indicator. One of the advantages of using LCD is the simplicity of interfacing circuit where unnecessary to have complicated supported components. Only one resistor is needed to provide contrast voltage to the LCD matrix.

In this work, the LCD will give us the indicator value about the air quality in µg/m^3. The type of LCD is Topway LMB162A. The configuration of LCD pins and their connectivity to the microcontroller circuit shown in Fig.6 as follows:

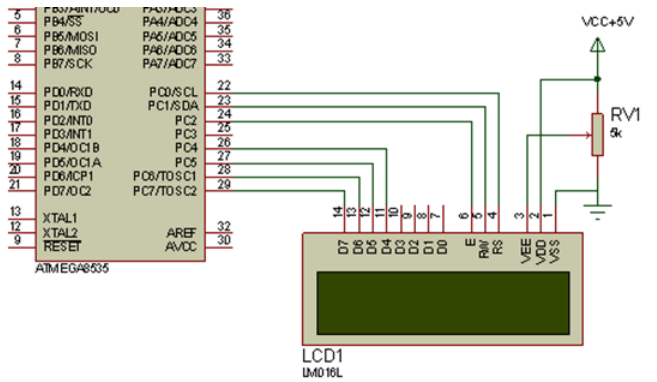

Fig. 6. The LCD circuit connection to the microcontroller

Serial Communication Interface Circuit

It is well-known that serial communication interface circuit is the communication gate between the microcontroller and the personal computer. The IC serial RS 232 is used as the interface from PC to the external device, or viceversa. There are two type of serial data communications; syncronous and asyncronous types. In the syncronous type, the clock and data communication are sent together. While not in the asynchronous type, where the data and the clock are generated independently both at sending and receiving ends. The IC Serial RS 232 needs connector to the external devices. In this part, there are two type standard of connectors; RS 232 with 25 pin (DB25 connector) dan 9 pin (DB9 connector).

In this work, the standard serial communication UART with 1 start-bit, 8 data-bit and 1 stop-bit is used. The required baudrate is 9600 bps as the sufficient baudrate of computer. In this serial interface, the IC MAX232 is needed to convert the digital voltage of serial interface voltage output from the standard voltage 0.5 V to ±15 volt in order to maintain the compatibility with serial Port standard of computer. This configuration is shown in Fig.7. The RXD points are the points where the circuit receives serial data, while TXD functions to transmit the serial data came from microcontroller.

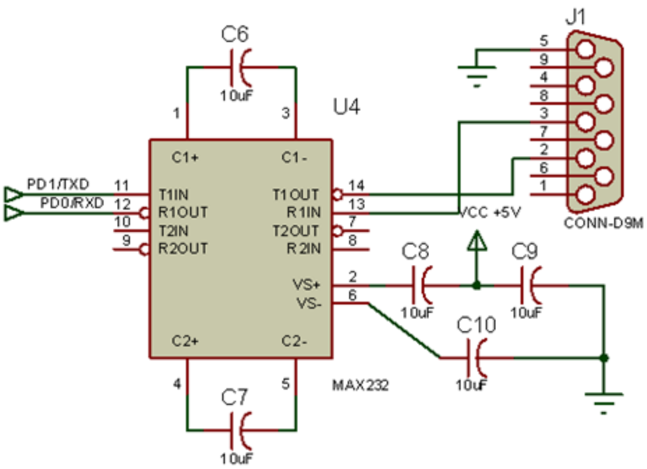

Fig. 7. Serial interface circuit of IC MAX232

B. *Software Design*

The software design is divided into two parts, i.e design of microcontroller program and design of interface computer application. The design of microcontroller program follows the flowchart related to the air pollution monitoring system shown in Fig. 8 below.

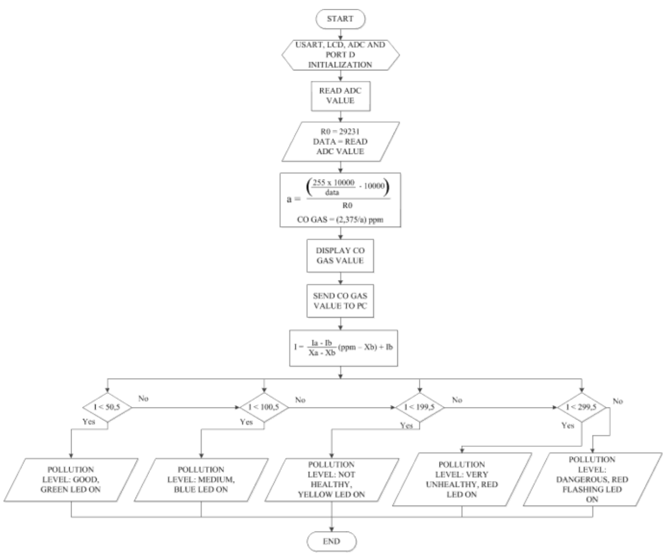

Fig. 8. Flowchart of software design of air pollution monitoring system

The flowchart shown in Fig. 8 is the steps for data processing of air pollution monitoring system. In the beginning, initialisation step with setting of USART, LCD, ADC dan PORT D. Then, the next process focuses on PORT D or value the data processing of ADC is the output signal of sensor unit. In this step, the conversion value from ADC unit to ppm (part per million) unit is required. The converted value will be displayed in the LCD monitor, before sending the measured value into computer. In this case, the measurement is focused on the carbon monoxide (CO) gas air pollutant. The criteria is determined that the level of gas follows the regulation of air quality based on Environmental control and regulation agency in Indonesia shown in Table I. The process continues to read the data information in PORT D, the measurement results are displayed on LCD, LED dan PC. The proces is repeated during the monitoring process.

TABLE I
THE ENVIRONMENTAL CONTROL AND REGULATION RELATED TO AIR POLLUTION IN INDONESIA (1997)

Standard index of gas pollutants	24 hours of PM_{10} µg/m^3	24 hours of SO_2 µg /m^3	8 hours of CO µg /m^3	1 hours of O_3 µg /m^3	1 hours of NO_2 µg /m^3
10	50	80	5	120	(2)
100	150	365	10	235	(2)
200	350	800	17	400	1130
300	420	1600	34	800	2260
400	500	2100	46	1000	3000
500	600	2620	57.5	1200	3750

Meanwhile, the design of interface computer application utilizes the Visual Basic 6.0 which comprises of main menu and submenu of CO gas monitoring system. The measurement results can be saved in database using application of Microsoft Access Database. In the main page shown in Fig. 9, there are basically some buttons related different gas pollutant measurement indicators, but at this moment, we are focusing only on the menu of carbonmonoksida (CO) gas, while the work continuing to proceed the completion of our proposed monitoring system. Another feature is the menu setting to give information about the port number from USB converter to the serial connector and the location of data measurement given in Fig. 10. In the menu of CO monitoring as in Fig. 11, the changes

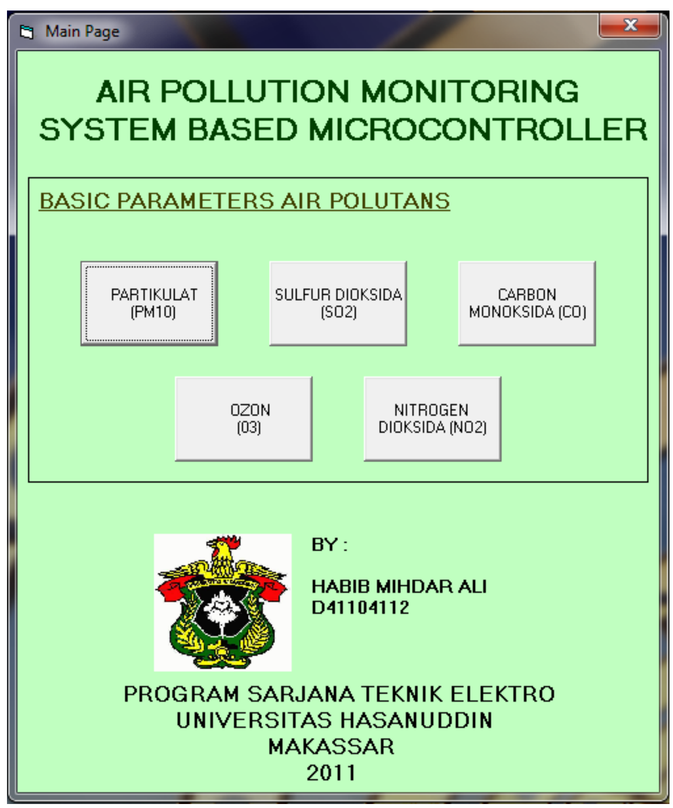

Fig. 9. The main page or menu of air pollution monitoring system

in air quality level can be observed from graph, blinking of colour indicators, the ratio of R_s/R_o, V_{out} and level of measured CO gas based on standar index of air pollution. The example result about the application of interface system of air pollution monitoring Microsoft Visual Basic 6.0 shown in Fig. 9, 10 and 11, consequtively.

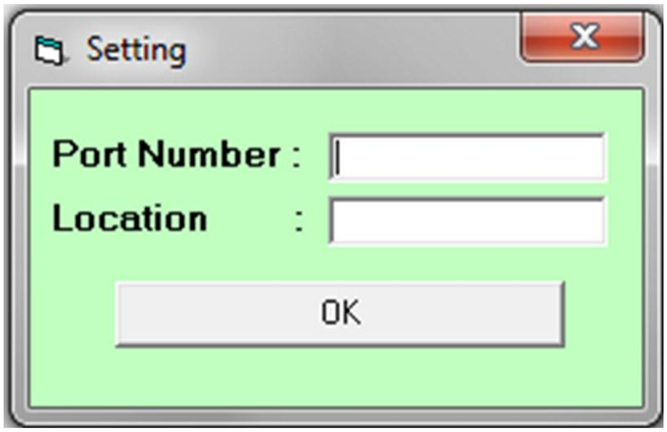

Fig. 10. The setting page about location and port connection

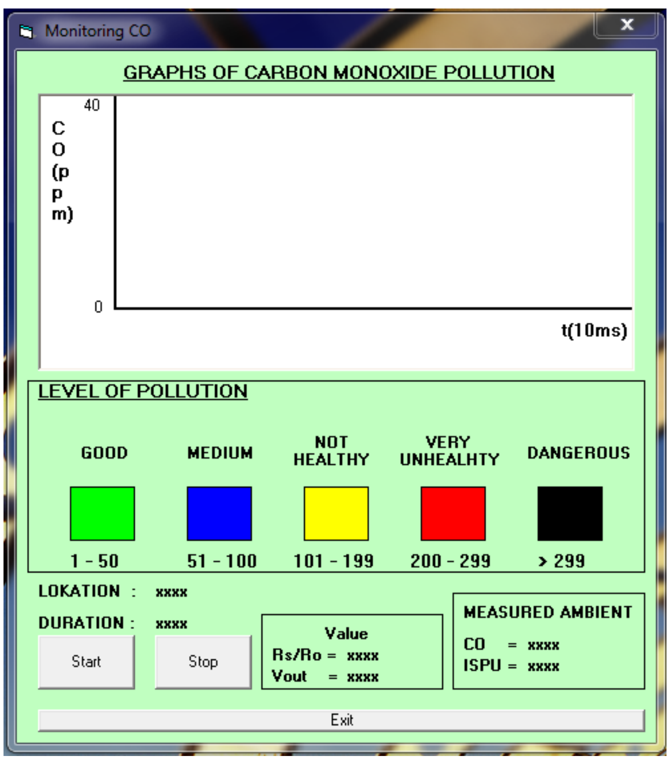

Fig. 11. Complete page of gas pollutant monitoring indicators

C. Computer Programming Environment

Language programming is a media to initialize systems connected to the hardware for controlling purposes. One of the language programming software is Visual Basic or VB, used to compose the application program in the Windows operating system environment. The benefit of using Visual Basic is the simplicity to set the application program with perfect graphical display in the short time period.

There are three important points that need to be concerned in the Visual Basic environment; variable or data storage, program control and procedure. In control program, we consider the step of executed program including the decision to which point that needs to be taken. Therefore, the control program in visual basic covers the controls of conditions, decision, repetition and alternative flow. On the other hand, the procedure functions to divide the program into smaller component blocks in order to make it easy to establish computer program. The procedure is also very useful when recursive process exists or to share the information to another program. Also, the procedure make the debugging program become much easier because the capability assessment per procedure rather than the assessment of the whole procedure in one time execution.

The programming language that is commonly used for chip programming, such as microcontroller can be easily found in the market. They are basic, assembly, phyton, and C language. In this work, the C language is used to the microcontroller programming of ATMega8535. The CodeVisionAVR is one of the software compiler based on C language for the AVR application integrated by ANSI in its system. The other features that CodeVisionAVR also provide *Code Generator* or CodeWizardAVR; such a tool to develop a program pattern using special *library-library* in order to make it easy for the initialization process of *register-register* inside the programmed microcontroller AVR.

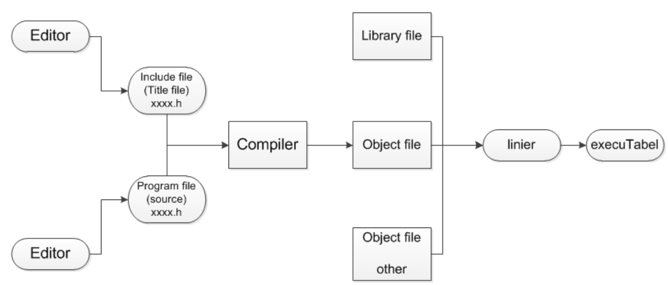

Fig. 12. Schematic of the hex file development in C compiler

The process to build the hex file in the C compiller including *editing*, *programming*, and *compiling* can be seen in the Fig. 12 as follows. The process of development of executable file also is also explained in this figure. The process starts with writing the *listing* program inside the editor which can be *notepad*, *word pad*, or just directly in the editor attached in the compiler. *File include* and the program file then compiled to yield a file with extention object (*. obj). After this process, the object file is united using linker including the library file and other object files before obtaining excecutable file (*.hex). This hex file is then installed to the microcontroller chip.

III. Testing of Proposed Design

In this section we will test our proposed design under several different locations based on the activities related to the carbon monoxide gas emission. For instances, the measurements inside closed room, shaded area due to tree plants, area with congested vehicles and industrial site during morning, noon and afternoon. However, before we reach this point, it is necessary to have initial testing related to the circuit design. In the circuit testing, we measured the electrical parameters in standby position for each circuits such as power supply, sensor, control unit and indicator circuit using digital multimeter of DT9205A. The complete circuit testing is explained as follows:

A. Power Supply Measurement

The type of power supply for this device is the adaptor AC-DC with input voltage of 220 V_{AC} 50/60Hz and the output voltage range of 1.5-12 V_{DC}. The measurement is performed in each output voltage range of this adaptor under supply from voltage regulator 7805. The measurement results are shown in Table II. From this table, it is shown that the output voltage from adaptor is between 3 and 12 V_{DC}, means this adaptor is able to supply circuit with 5 V_{DC}. The voltage which is coming from the regulator 7805 is indicated 'normal'. If the proposed device is used for the external duty as used to be, it is necessary to have battery with the total output voltage of 12 Volt DC.

TABLE II
Power supply measurement results

Measurement points	*Range voltage of adaptor (V_{DC})*	*Measured Output (V_{DC})*
TP 1	*1.5*	*3.9*
TP 2	*3.0*	*3.96*
TP 3	*4.5*	*4.76*
TP 4	*6.0*	*6.93*
TP 5	*7.5*	*7.58*
TP 6	*9.0*	*9.03*
TP 7	*12.0*	*10.22*
TP 8	Regulator output 7805	*4.87*

B. Sensor and Control Unit Circuit Measurements

In the measurement of sensor circuit, there are two type measurements; the input voltage and the heater voltage under normal condition. The measurement points are indicated as TP1, TP2 and TP3 in Fig. 4. The measurement results are presented in Table III. It is indicated from the measurement results that all the voltage levels of sensor is within the voltage written in the manufacturer datasheet of this sensor.

The normal measurement results are also obtained from the measurement in control unit circuit shown in Fig. 5. The measurement is performed at the voltage of each pin out of the control unit and it is tabulated in Table IV as follows:

TABLE III
Sensor circuit measurement results

Measurement points (TP)	Range Datasheet (V_{DC})	*Measured voltage (V_{DC})*	*Indicator*
TP1	*5.0±0.2*	*4.86*	*Input voltage*
TP2	*5.0±0.2*	*4.86*	*Heater voltage*
TP3	-	*1.30*	*Load voltage*

TABLE IV
Control unit circuit measurement results

Point of measurements		Voltage level (Volt)
PA.0	ADC	1.5
AREF		4.75
AVCC		4.75
XTAL1		0.63
XTAL2		0.69
VCC		4.75
RESET		4.75
PC.7	LCD	0.03
PC.6	LCD	4.74
PC.5	LCD	4.73
PC.4	LCD	4.75
PC.2	LCD	0.03
PC.1	LCD	4.73
PC.0	LCD	4.73
PD.6	*LED*	4.54
PD.5	*LED*	4.54
PD.4	*LED*	4.54
PD.3	*LED*	4.54
PD.2	*LED*	4.54
PD.1 (TX)	*MAX 232*	4.73
PD.0 (RX)	*MAX 232*	4.68

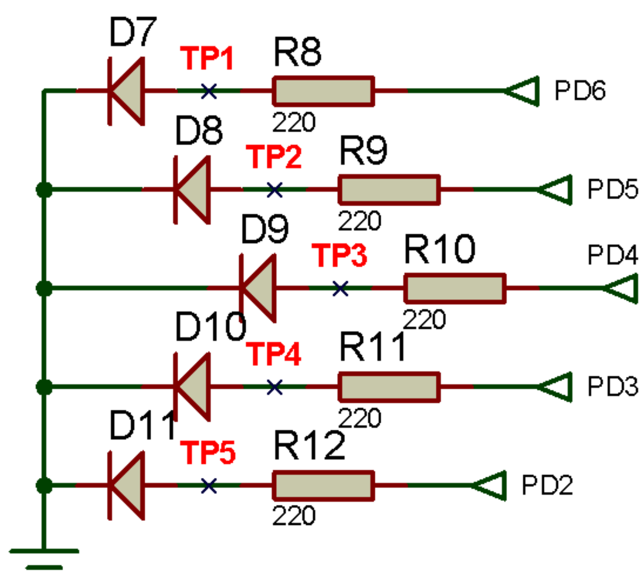

Fig. 13. Location of Indicator circuit measurements

C. Indicator Circuit Measurements

Indicator circuit measurement was basically performed in Fig. 6. However for more detailed circuit measurement purposes, then another figure is shown in Fig. 13. The measurement on this block circuit is done under standby position and the measured points are clearly presented in Table V. It is obtained that all LED indicators receive enough power supply to be operated.

TABLE V
INDICATOR CIRCUIT MEASUREMENT RESULTS

LED indicators	Measurement points	Measured voltage (Volt)
Green	TP1	2.83
Blue	TP2	2.83
Yellow	TP3	2.83
Red	TP4	2.83
Blinked Red	TP5	2.83

IV. Results of Measurements and Discussion

After ensuring that all components are properly working based on the initial laboratory testing as previously explained, now we are ready to show some measurement of gas pollution condition in our area. The testing area is divided into two types, i.e indoor and outdoor testing. The outdoor testing is performed in three different places in Makassar city of Indonesia. They are in the yard of registration building of Universitas Hasanuddin, the main Street in front of university and industrial sites, KIMA Makassar. The measurement is taken for every 30 minutes, during morning, noon and afternoon. The purpose of measurement is to have the information of air quality, especially containing of CO emission in those places.

A. *Indoor Testing*

The indoor testing is performed inside a room, which is dimensioned by 5x3x3 meter for 30 minutes. Basically, we have 1800 sample data measurement as results of this test, but we only show in the graph several samples for our convinience. The results can be guessed that the CO emmision inside this room is siginifcantly low. In addition, the index standard of air pollution set by our government shows in the clean category. The overall measurement results are shown in Fig. 14. Meanwhile, the index and category standard of air pollution as the official of environment control and utility in Indonesia in 1997, shown in Tabel VI. In addition, the output voltage and the ratio of R_s/R_o of the device can be averagely measured about 1.72 Volt and 0.66 Ohm, respectively; indicates that our proposed design is working properly.

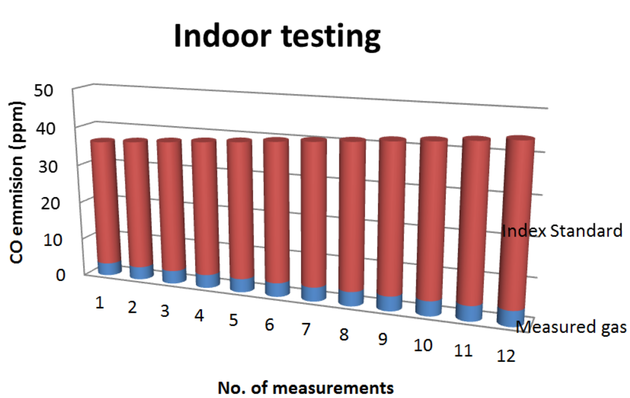

Fig. 14. The indoor CO emission measurement results

TABLE VI
INDEX AND CATEGORY STANDARD OF AIR POLLUTION IN INDONESIA

Index (ppm)	Category
1 - 50	Clean
51 - 100	Average
101 - 199	Not clean
200 - 299	Not very clean
Over than 300	Dangerous

B. *Outdoor Testing*

The outdoor testing is also performed for every 30 minutes, during morning and afternoon. The purpose of measurement in front of registry building of Univesitas Hasanuddin is to have information about the air quality in the area with full of trees. We are also collecting about 1800 data samples, but for the graph overview, we just show some samples of data. The measurement results of CO emmision is shown in Fig. 15. The results of testing is that the level of CO emmision is far below than the government index and standard during morning and afternoon. However, there is slight increase in the level during afternoon due to some activities in this site, but the increased level is totally acceptable. Therefore, we, can say that there is significant absobsion of trees to the air poluution in surrounding area. Also, again our device is properly working indicated by the output voltage and the ratio of R_s/R_o, which are averagely 1.51 Volt and 0.8 Ohm, respectively.

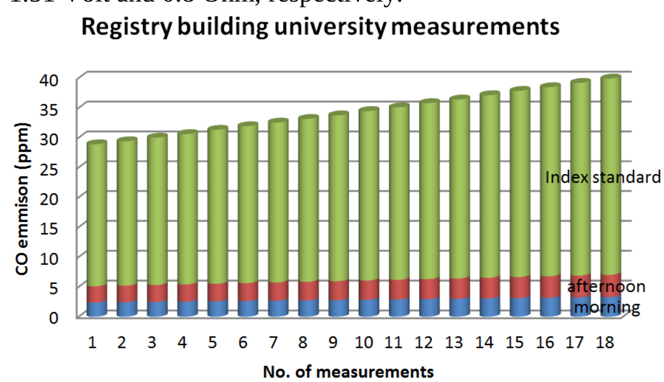

Fig. 15. The CO emission of the yard of registry building university

The next outdoor testing is to measure the air quality related to CO emission in the main street in front of our university. The street is recognized as the congested street with full of motor vehicles during the busy hours. The measurement is taken for 30 minutes during morning, noon and afternoon on Thursday 23 June 2011. The purpose of measurement is to ensure our designed device to able to detect the air pollutant in the right way. From the measurement results in Fig. 16, the level of CO emission increases from clean/average in the morning to average/not clean during noon. It is due the volume number of vehicles passing this street increase significantly. But, the trend back to the clean/average during night time. In addition to this measurement, the average output voltage of device is going highly when the pollution level approaches not clean situation. Conversely, the ratio of R_s/R_o is reduced significantly under this similar condition. Both trends of parameters indicate that our device is working properly.

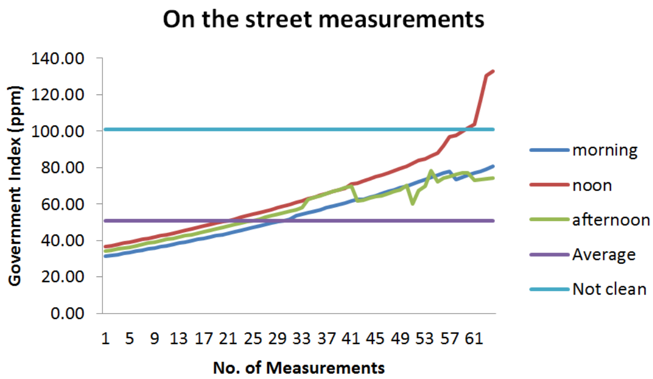

Fig. 16. Index measurement on the street path during morning, noon and afternoon

The last outdoor measurement is in the industrial site of PT. KIMA Indonesia. The same approach of measurement where data sample is taken for 30 minutes during morning, noon and afternoon. The measurement intends to figure out the air quality level related to the CO emission in the industrial plant. The measurement results in the industrial site are basically similar to the street measurement where the level of CO emission stays in the clean/average level in the morning. Then, it continues to the average/not clean during noon due to the peak time industrial activity. At night, the situation changes to the level of clean/average because of some machines turn off during that time. The CO level measurement during industrial hours can be seen in Fig. 17.

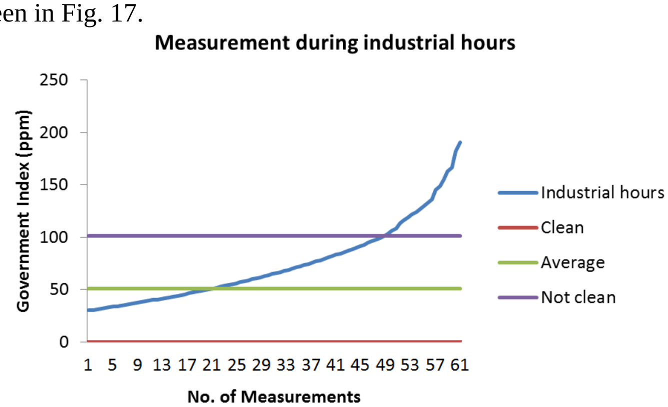

Fig. 17. Index measurement on the industrial site during industrial hours

V. Conclusions

Design of Carbon Monoxide gas detector based microcontroller has been demonstrated. Our proposed model is quite simple and has small dimension; therefore it is very easy to remove from one place to others. To verify our results, real-time measurement can be monitor through visualization in Liquid Crystal Display (LCD) and computer monitor after data processing using microcontroller ATMEGA8535 under programming environment of CodeVision AVR *V2.03.4*. The visualization itself is designed based on the combination between programming language of Microsoft Visual Basic ver. 6.0 and C. Data transmission can be very flexible due to the capability standard of microcontroller, for instance using simple coaxial cable, GSM line or through standard internet connection. Also, for one day measurement, the data can be simple stored inside the device. The device has been initially tested in the laboratory on several physical data output. In the implementation, the device has been used to measure the CO level on different locations and it has shown proper results of measurement.

VI. Future Study

In the future, we would like to extend this work to design a monitoring system with capability to sense all gas emission completely with high accuracy. Also, we want to improve our current design especially on the data transfer communication from the location to the center building using GSM network, therefore the updating measurement results can be monitored in real-time.

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Ansar Suyuti has been working in Department of Electrical Engineering of Universitas Hasanuddin, Indonesia since 1992. He is currently pursuing doctoral degree in Universitas Hasanuddin in the field civil and environmental engineering

Syafaruddin received his B.Eng degree in Electrical Engineering from Universitas Hasanuddin, Indonesia, in 1996, M.Eng degree in Electrical Engineering from University of Queensland, Australia, in 2004 and D.Eng degree from Kumamoto University, Japan in 2009. He has been working in Kumamoto University as a project assistant professor for Graduate School of Science and Technology. His research interests include distributed generation planning, maximum power point tracking control of photovoltaic system, power system real-time simulation and neuro-fuzzy logic control application in power system.

Habib Mihdar Ali received Bachelor degree from Department of Electrical Engineering of Universitas Hasanuddin in 2011.

Muhammad Tola is the professor in Department of Electrical Engineering of Universitas Hasanuddin. His research interest is the power electronics applications in engineering fields.

Takashi Hiyama received his B.E., M.S., and Ph.D degrees all in Electrical Engineering from Kyoto University Japan in 1969, 1971, and 1980, respectively. He joined Kumamoto University in 1971 and has been a Professor from 1989. During the period of June 1985 through September 1986, he was at Clarkson University, and was involved with power system harmonic research. His current interests include intelligent system applications to electric power systems and the applications of renewable energy power sources to power distribution systems operation, control and management. He is a Senior Member of IEEE, a member of IEE of Japan and Japan Solar Energy Society.

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