Data acquisition system in measuring carbon dioxide, humidity and temperature: design and fabrication

I Sugriwan *, A S Ramdhani, A E Fahrudin, and Suryajaya

Department of Physics, Faculty of Mathematics and Natural Sciences, Universitas Lambung Mangkurat, Banjarmasin, Indonesia, Jl. Yani KM 36 Banjarbaru, Kalimantan Selatan 70714

*Email : iwansugriwan@ulm.ac.id

Abstract. This research aims at designing and fabricating data acquisition systems in measuring concentration of carbon dioxide, relative humidity (RH) and temperature (T) of peatland which were trapped by closed-chamber measurement. Carbon dioxide was sensed by TGS4160 modul sensor while relative humidity and temperature were detected by SHT11 modul sensor. TGS4160 is carbon dioxide gas sensor that operated together with voltage follower and connected with ATMega8535 microcontroller via port A.0. SHT11 is a modul sensor that detect two parameters simultaneously, relative humidity and temperature, that operated with fully calibrated and digital output. SHT11 is connected to ATMega8535 via port B.0 for data and port B.1 for clock with two wire interface mode. The ATMega8535 microcontroller is single chip to catch input signal from sensors, to compute the characteristic equation of sensor and to send measuring data to LCD 16x2 character as display unit which was programmed by basic compiler. The measuring devices interfaced with personal computer via universal serial bus to formed data acquisition systems. In personal computer, the data measurement were displayed on monitor screen that was developed by delphi. The data result were recorded and stored in excell and data base.

Keywords: ATMega8535 microcontroller, peatland, SHT11, TGS4160

1. Introduction

The area of peatlands in Indonesia is about 14.9 million hectares or about 13% of world’s tropical peatland. The Indonesian peatland spreading out to Sumatera Island (35%), Kalimantan Island (32%), Papua Island (30%), Sulawesi Island and other islands (3%) [1]. Peatlands could emit carbon dioxide (CO2) [2], methane (CH4) [3], and dinitrogen oxide (N2O) that contributed massively to greenhouse effect [4]. Carbon dioxide is the most important that caused greenhouse effect. Compared to CH4 and N2O, warming force of CO2 emissions is the biggest, namely 55%, 15% and 6% [5][5][5][5] for CO2, CH4 and N2O, respectively. Therefore, measurement of CO2 emissions in peatland are the aim of many studies.

Peatlands is a specific wetland that is formed as an imperfect decay accumulation of organic material that forms peat layers. Peatlands is also an area between terrestrial and wetlands that are always cover by water. Peatlands depth could be ranged between 30 cm to 40 cm. Peatlands ecosystems are characterized by the accumulation of organic material that takes place over a long period of time and a low decomposition rate [6].

Peatlands are stored with large carbon deposits (C) either on the surface or below the surface. Carbon on the surface if oxidized would produce CO2. CO2 production would also cause by several...
other things, such as deforestation, land fires and the use of peatlands as agricultural land where drainage with a depth of more than 30 cm is needed [7]. The CO\textsubscript{2} emissions, besides being affected by deforestation, land fires and the conversion of peatlands into agricultural land, are also influenced by climate parameters, such as temperature, air humidity, rainfall and rainfall distribution [8].

The objective of measurement of carbon dioxide concentration on peatland is to monitor concentration of CO\textsubscript{2} emission that will be released to atmosphere. The results of this measurements could be used to manage agriculture field on peatland and knowing the potency of land fire disaster on peatland [9]. There is other parameter that were closely related to CO\textsubscript{2} measurement, that are relative humidity and temperature. The instrument used for measuring CO\textsubscript{2} concentration is using Gas Chromatography (GC). The gas is trapped in a chamber and is taken using a syringe then was analyzed [10]. The temperature was measured by using a thermometer installed into the chamber. Methods of measuring CO\textsubscript{2} and temperature could not be carried out simultaneously and not in real time and certainly require costs and effort [11].

An alternative method for measurements of CO\textsubscript{2} levels of peatlands have been developed by [12]. In this method, carbon dioxide levels were sensed by the TGS4160 sensor module embedded in a closed-chamber measurement. As the result, the level of CO\textsubscript{2} emitted from peatlands could be measured directly and in real time and the results could be transferred to a personal computer and stored in excel format. However, in this system, humidity and temperature were not included.

Present research will develop a system of measuring CO\textsubscript{2}, humidity and temperature on peatlands at once. CO\textsubscript{2} sensor used was TGS4160 module while humidity and temperature used were SHT11. The TGS4160 sensor module is connected to port A of ATMega8535 microcontroller through a signal conditioner in the form of a voltage follower, while SHT11 will be connected to port B of ATMega8535 with a two wires interface procedure. ATMega8535 was connected to 16x2 character LCD in order to display the value of CO\textsubscript{2} (in ppm), relative humidity (in percent), and temperature (in degree Celsius). The results would also be displayed on the personal computer monitor (PC) or laptop, the results of measurements of the three parameters would be stored in formal excel. The ATMega8535 microcontroller was programmed with basic compiler to retrieve data and calculate the characteristic equation of the TGS4160 sensor, the two wires interface sensor SHT11 procedure, the 16x2 LCD configurations and send data to the personal computer. The interface between ATMega8535 and PC is developed in the Delphi language.

The ATMega8535 is a low-power 8-bit CMOS microcontroller based on the AVR microcontroller (Alf and Vegard's RISC processor) with the RISC (Reduces Instruction Set Computing) architecture. The ATMega8535 microcontroller has 8 internal ADC 10-bit channels so it does not require additional devices to convert analog signals into digital signals [13].

Liquid Crystal Display (LCD) is not like a viewer that uses 7-segment LED (Light Emitting Diode) which is only capable of displaying numbers, but the LCD is also capable of displaying letters, words and symbols. One common variation of shapes and sizes is 16x2 characters (16 columns, 2 lines, 32 characters) and 16 pins. Pins access have eight data connection lines, three power supply lines and on LCD modules with backlighting facilities there are two supply lines for backlighting so that they can be displayed in small light conditions [14].

Serial communication that commonly used for processors is the 8-bit shift register and UART (Universal Asynchronous Receiver Transmitter). Serial communication between the microcontroller and PC (Personal Computer) is often used for data acquisition. Devices that are commonly used as serial communication are RS-232 Standard which is a device developed by the Electronic Industry Association (EIA / TIA).

Serial communication connectors generally use DB9 pins. Parallax Serial Module to USB Converter is a module that uses a DB9 pin connector for RS-232 communication. This module is also a serial converter module between UART and USB, which is Parallax Serial to USB Converter [15].
2. Material And Methods

2.1 Data acquisition hardware

Data acquisition hardware to measure carbon dioxide, humidity and temperature on peatland consists of power supply circuits, TGS4160 CO$_2$ sensor module, SHT11 humidity and temperature sensor module, voltage follower circuit, ATMega8535 microcontroller, 16x2 character LCD and computer interface circuit. Electricity which is generated in the form of alternating current (AC), while in general electronic equipment requires direct current (DC). In this case, the power supply is needed to provide the appropriate voltage and current for electronic devices [16].

Sensors were electronic devices that work to respond to various physical parameter inputs and convert them into electrical signals. The TGS4160 sensor is a sensor made by Figaro that was specifically designed to detect carbon dioxide gas by becoming a sensor module. The output voltage of this module was directly proportional to the level of CO$_2$ gas sensed by this module. To detect the value of humidity and temperature in the air, SHT11 sensor was used. This sensor is Sensirion’s family of surface mountable relative humidity and temperature that manufactured by Sensirion company. This sensor can be used as a sensing device for humidity and temperature such as to control humidity and temperature in the room or monitoring the relative humidity and room temperature etc [17].

Signal conditioning used was amplification. To amplify the signal, an integrated circuit or integrated circuit (IC) operational amplifiers (op-amp) was used. In this study, the output signal sensor used is a voltage follower type. Amplification at the voltage follower circuit should have a value 1 [18].

2.2 Software of data acquisition system

The acquisition system software consists of two programs, namely basic compiler (BASCOM) and Delphi. BASCOM was used to program ATMega8535 microcontrollers. and Delphi is used to program the interface display on a PC screen. In the ATMega8535 microcontroller, BASCOM was programmed to get data from TGS4160 and SHT11, to calculate the characteristic equations of the two sensors, to send the measurement results to a 16x2 character LCD and to send the measurement results to the PC / laptop monitor screen. The BASCOM language uses basic language, which is a programming language that was between low-level languages and high-level languages [19]. The language used in Delphi was Pascal. In data acquisition system applications, Delphi can communicate between peripheral devices, such as microcontrollers, and computers through serial connections.

This research was conducted in three main stages, which were hardware fabrication, software programming and interface systems, and carried out at Instrumentation Laboratory of Physics Study Program, Faculty of Mathematics and Natural Sciences Lambung Mangkurat University. The hardware made was power supply circuits, voltage follower circuits and system interfaces. Software programming aimed to make a program to retrieve data from sensors, an analog to digital sensor voltage conversion program, interfacing program to display data on 16x2 Liquid Crystal Display (LCD) by Basic Compiler (BASCOM) AVR and acquisition of measurement data on a PC (Personal Computer) using Delphi 7.0.

The study to measure humidity and temperature by using sensor was carried out in the field for three days. In the first and the second days humidity and temperature were observed for two hours, while in the third day was for one hour. On the first and the second day, the measurements were carried out in Tegal Arum Village, Landasan Ulin sub-district, Banjarbaru District at Location 1 and Location 2 (Figure 1). On the third day the measurements was carried out with BALITTRA (Research Institute for Swamp Agriculture) Banjarbaru South Kalimantan which was held at 08.00 to 09.00 WITA and took place in the Experimental Garden (KP) in Blandean, Tanjung Harapan village, Alalak district, Barito Koala district, hereinafter referred to as Location 3.
The instruments used in this study consisted of laptops that were equipped with basic compiler and Delphi 7.0 software which were used to create interface programs and for data acquisition. Other equipment and materials were solder, tin suction, multimeter, tin, power supply circuit components, voltage follower circuit components, CDM4160-H00 module as carbon dioxide gas sensor, SHT11 module as humidity and temperature sensor, ATMega8535 microcontroller module, 16x2 character LCD, and the chamber to trap the gas.

3. Results And Discussion

The realization of the hardware that has been made was a power supply circuit that has three output voltages of +4.98 V, +11.95 V, and -12.23 V. The +4.98 volt voltage was used to power the sensor module CDM4160- H00, SHT11 sensor module, and ATMega8535 microcontroller module. Output voltage of +11.95 V and -12.23 volts was applied to give split voltage at IC OP-07 as voltage follower. Figure 2 showed a series of power supplies that have been done.

Voltage follower circuit was made by connecting foot number 2 (insert reversing) with foot number 6 (output) on IC OP-07, while foot number 3 (insert not reversing) was input signal which in this case was output from CDM4160-H00 sensor module. The voltage of -12.23 volt was connected to foot number 4 (-V) and the voltage of +11.95 V is connected to foot number 7 (+V). Figure 3 showed a voltage follower circuit that has been done.
The ATMega8535 microcontroller module was configured with a 16x2 character LCD as shown in Figure 4. The cascade between the legs of an ATMega8535 microcontroller with a 16x2 character LCD is shown in Table 1. The mode used was a 4-bit mode where the LCD legs were connected to the ATMega8535 C-port. The written application program with basic compiler was coded as ATMega8535 microcontroller program, so that the microcontroller can process carbon dioxide sensor data from CDM4160-H00 and humidity and temperature from the SHT11 sensor. The CDM4160-H00 sensor is connected with A.0 port ATMega8535 microcontroller, while SHT11 is connected to port-B.0 and B.1 ATMega8535. Port-B.0 for DATA feet in SHT11, and port-B.1 for SCK legs in SHT11. The data retrieval process on CDM4160-H00 through the process of converting analog to digital, considering that the A-port has been installed internally 10 bit analog to digital conversion. The humidity and temperature data from SHT11 are basically taken alternately with the configuration of the timing diagram shown on the SHT11 data sheet. Figure 4 below is the visualization of an ATMega8535 microcontroller with sensor and LCD circuit.

Data acquisition program was made by using Delphi 7.0 to interface between microcontroller circuits with personal computers. The program display was arranged as shown in Figure 5. There are 3 columns that provide data for carbon dioxide, humidity and temperature and there were two graphs that were provided to display the measurement results of carbon dioxide and humidity and temperature. Both the data and graphics displayed were in real time (meaning real time), which means that changes in physical parameters can be acquired right away. The acquisition data was stored in the .xlsx format (Figure 5).
Table 1. ATMega8535 pin cascades and LCD of 16x2 character

| Pin LCD 16x2 | Pin Modul Mikrokontroller ATMega8535 |
|--------------|--------------------------------------|
| 15 (Vcc)     | Port A                               |
| 16 (Ground)  | Vcc                                  |
| 3 (Ground)   | Port B                               |
| 2 (Vcc)      | Ground                               |
| 1 (Ground)   | Port C                               |
| 4 (RS)       | C0                                   |
| 6 (E)        | C1                                   |
| 11 (Data 4)  | C2                                   |
| 12 (Data 5)  | C3                                   |
| 13 (Data 6)  | C4                                   |
| 14 (Data 7)  | C5                                   |
| 5 (Ground)   | Port D                               |
|              | Ground                               |

Figure 5. The acquisition form for measuring CO₂ concentrations, Relative Humidity and Temperature

The acquisition system device was integrated into a measuring system consisting of closed chamber measurement, hardware acquisition, software, and personal computers. The integration of this system was shown in Figure 6. Closed-chamber measurement, CDM4160 and SHT11 sensor modules have been installed, were chambers to trap gas. Insert the sensor connected with the acquisition device placed in a box. The 16x2 character LCD mounted block forming a carbon dioxide and humidity and temperature measuring system. This measuring system is connected to a laptop to form a data acquisition system. Testing of CO₂ gas, humidity and temperature were carried out in Tegal Arum Village Location 1 and Location 2. Tests were carried out by placing a chamber that had been integrated with measuring instruments and laptops on peat land. The measured CO₂ gas, humidity and temperature are displayed on 16x2 LCD display components and also on laptops. CO₂ gas, humidity and temperature data will be recorded in real time, ie data is recorded per second and the data can also be stored in *.xlsx format.
Figure 6. Integrated acquisition devices ready to installed into peatlands

Figure 7. Measurement results of CO₂, Humidity and Temperature, (a) Location 1, (b) Location 2, (c) Location 3
By this device, carbon dioxide, humidity and temperature measurements can be carried out automatically by sensors that had been placed in the chamber. The measurement results on Tegal Arum Village Landasan Ulin sub-district, Banjarbaru District (location 1 and 2), and in Blandean, Tanjung Harapan village, Alalak district, Barito Koala district (location 3) are presented in form of line the graph as shown in Figure 7.

The acquisition system that has been implemented on the peatland was going well. This is indicated by a system that was able to retrieve data directly, real time and continuously. Moreover, the results of measurements could be displayed and stored on a personal computer.

4. Conclusions
1. The system of data acquisition has been able to measure carbon dioxide, relative humidity and temperature directly by real time and continuously.
2. The date measurement could be monitored via LCD or personal computer And the software of acquisition system built by using Delphi 7.0 was able to measure and display the results in real time and the measured data can be saved in *xlsx format.
3. This acquisition system worked well on tropical peatlands.

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