Multi Channel Data Acqusition and Data Logging System for Meteorology Application

Nisha Kashyap, Umesh Chandra Pati
Department of Electronics and Communication Engineering
National Institute of Technology
Rourkela, India
Email: shanu.gec@gmail.com, ucpati@nitrkl.ac.in

***Abstract*—This paper reports design of an automated, low cost multi-channel data acquisition and data logging system for meteorological application. Different meteorological parameters such as environmental temperature, barometric pressure, altitude, light intensity, and relative humidity are acquired in real time and stored in a database for future reference. ATmega328P microcontroller and LabVIEW are used to develop the system. The PC based system has been tested and is working satisfactorily.**

Keywords—Multi-channel data acquisition; data logging; meteorological parameters; microcontroller

I. INTRODUCTION

Meteorology is an interdisciplinary science, which studies about atmosphere. To study the behaviour of atmosphere, measurements of different atmospheric parameters are required. Some of the well-known meteorological parameters are air temperature, humidity, rainfall, wind speed, atmospheric pressure and atmospheric gas components. Automated Meteorological Data Acquisition System (AMDAS) is used to gather information about the current meteorological information which is used to predict the future trends of weather. This automated system can provide useful information regarding any impending disaster.

In order to develop a low cost application specific data acquisition system, a number of previous works have been reviewed. S. Rosiek et al., presented a microcontroller based data acquisition system for weather station monitoring [1]. The sensor data are transmitted to GSM modem every 24 hour via RS-232 interface. M. Benghanem et al., developed a low cost wireless autonomous remote weather monitoring system. This system collects data and transfers the data to a PC and a remote server using wireless technique [2,3]. Zigbee based data acquisition system is developed for online monitoring of grid connected photovoltaic (PV) system [4]. M. Funetes et al., designed a low cost autonomous data logger for PV system monitoring using microcontroller [5]. Wireless water quality measurement system is developed in [6]. Greenhouse monitoring using microcontroller based meteorological data acquisition system is developed in [7]. Several factors such as synchronization, data transmission, sampling time, analog to digital conversion, noise and isolation have to be considered for data acquisition in real time. During multi-channel data acquisition several sensors are connected to the microcontroller or PC. Sensor data should be stored in a memory unit. Now a day's high speed real time multi-channel data acquisition system is available with transmission rate up to 3 GigaSamples/Sec. For this kind of high data rate Field Programmable Gate Array (FPGA) and Advanced RISC Machine (ARM) processor are used [8]. A multi-channel data acquisition system is designed using PIC 16F877 microcontroller. The PIC16F877 is interfaced with FLASH memory using serial peripheral interface (SPI) communication. This approach stores all the data in FLASH memory which is easily accessible [9]. Data logging and supervisory control of a plant using LabVIEW is discussed in [10]. The traditional A/D converters can't match the high speed data transmission and multiple A/D converters have timing problem. Therefore, a high speed A/D converter should be used for data acquisition. MCU STC89C52 is used to develop multi-channel data acquisition system where CD4067 is used as channel selector and a high precision A/D converter (AD574A) is used [11].

In recent years, state of art sensors with in-built signal conditioning unit is available. These sensors are very small in size and have a moderate cost with best accuracy. The advent of inter integrated circuit (I2C) protocol by NXP semiconductor (formerly known as Philips Semiconductor) has revolutionized the sensor design. Interfacing these sensors with conventional data acquisition system provided by National Instruments is a big challenge which requires elaborate software and driver development. The selection of proper DAQ for proper sensor is also a big challenge. Due to availability of high performance, multi-functional microcontroller like ATmega328, the interfacing problem of advanced sensors with microcontroller is not a big challenge. But the main problem is the interfacing of microcontroller with LabVIEW based GUI. There are several toolboxes (LIFA, LYNX) available for interfacing ATmega328 with LabVIEW, but still the actual data is not available at the LabVIEW GUI. Therefore, Virtual Instrument Software Architecture (VISA) protocol of LabVIEW is used for serial communication between microcontroller and LabVIEW. With this technique, the microcontroller reads the sensor information regardless of the sensor connections (1-wire sensor or I2C based sensor or SPI based sensor). It sends the sensor data in serial mode to the PC where LabVIEW VISA protocol is used to display the corresponding data of sensor in LabVIEW GUI.

This paper provides a comprehensive design of a low cost multi-channel data acquisition system for meteorological application. The multi-channel data acquisition system acquires environmental temperature, barometric pressure, relative humidity, light intensity, soil moisture content and altitude. A real time clock is used which provides the time stamp for the data acquisition. The microcontroller is interfaced with PC through serial port. The data acquired from microcontroller is then interfaced with LabVIEW using VISA protocol and the LabVIEW based application saves the data in a separate database for future reference.

This paper is organized as follows: Section II provides the design details of multi-channel data acquisition system. Section III discusses the interfacing between microcontroller and LabVIEW. Section IV provides the problem formulation. Section V presents the experimental results and section VI concludes the paper.

II. MULTI CHANNEL DATA ACQUISITION SYSTEM

A generalized data acquisition system consists of different components such as sensing unit, signal conditioning unit, computing unit and display unit. The data acquisition system (DAQ) acquires particular environmental or physical parameters from the real world, performs signal conditioning on it and computes the actual value for display purpose. The block diagram representation of a generalized data acquisition and control system is shown in Fig. 1.

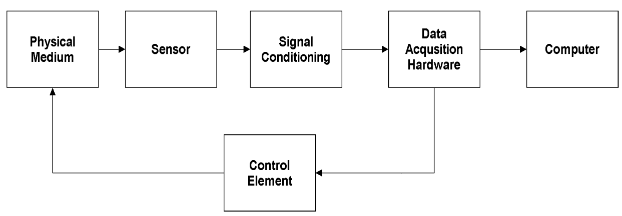

Fig. 1. Block diagram of generalized data acquisition and control system

The respective sensors which can acquire different meteorological parameters such as ambient temperature, light intensity, barometric pressure, altitude, relative humidity and soil moisture content are connected with input port of ATmega328 microcontroller and the collected data is sent to a PC using serial communication port of microcontroller. The serial communication port is connected to LabVIEW using VISA protocol.

A. Temperature Sensor

LM-35 is precision integrated circuit temperature device with voltage linearly proportional to centigrade temperature. LM-35 don't require any additional calibration or trimming for the temperature output. The specification of LM35 is summarized in Table I. The sensor has a wide range and draws a minimal current of 60 µA from the power supply.

TABLE I. SPECIFICATION OF LM-35

Output voltage	4V to 30V DC
Range	-55°C to 150°C
Accuracy	±5%, 50°C

B. Humidity Sensor

Humidity sensor (DHT11) includes a resistive-type humidity measurement component, a negative temperature coefficient (NTC) temperature measurement component and a high-performance 8-bit microcontroller. The humidity sensor provides calibrated digital signal output. It has high reliability and excellent long-term stability. The specification of humidity sensor is summarized in Table II.

TABLE II. SPECIFICATION OF DHT11

Power Supply	3.3V to 5V DC
Output	4 pin single row
Range	20 to 90% RH
Accuracy	±5%, ±2°C
Resolution	1% RH, 1°C
Long term stability	<±1% RH per year

C. Barometric Pressure Sensor

BMP085 is an inter integrated circuit (I2C) protocol based barometric pressure sensor. The main advantage of I2C protocol is that the pressure sensor can be interfaced with the microcontroller's I2C pins. Serial data line (SDA) and serial clock line (SCL) are two open drain lines used for I2C communication. I2C is a multi-master, multi slave protocol. Therefore more than one sensor can be interfaced with one single pin. The specification of BMP085 barometric pressure sensor is summarized in Table III.

From barometric pressure, altitude can be calculated. The measured pressure is p and the pressure at sea level p_o is 1013.25 hPa. The altitude can be calculated using the following formula

$$Altitude = 44330\left(1-\left(\frac{p}{p_o}\right)^{\frac{1}{5.255}}\right) \quad (1)$$

A pressure change Δp of 1 hPa corresponds to 8.43m at sea level.

TABLE III. SPECIFICATION OF BMP085

Power Supply	3V to 5V DC
Range	330 hPa to 1100 hPa
Resolution	0.03 hPa per 0.25m

D. Ambient Light Sensor

To measure the light intensity in Lux, ambient light sensor (TEMT 6000) is used. TEMT 6000 is a silicon NPN epitaxial planar phototransistor in a miniature transparent mould for surface mounting onto a printed circuit board. The device is sensitive to the visible spectrum.

E. Soil Hygrometer Sensor

Soil moisture sensor is sensitive to ambient humidity and is generally used to detect the moisture content of soil. The operating voltage is 5V DC. The module provides output in both analog mode as well as digital mode. Fig. 2 illustrates the circuit diagram of soil hygrometer sensor. Soil hygrometer consists of a probe, which is inserted in to the soil to detect the moisture content of the soil.

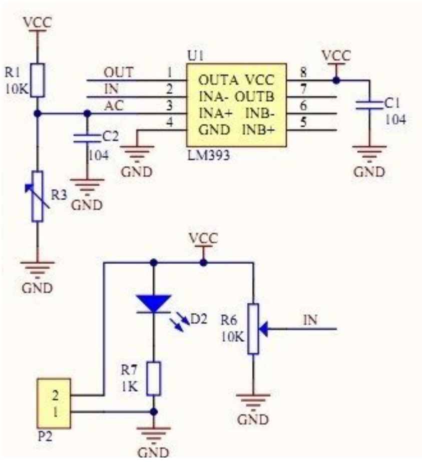

Fig. 2. Circuit diagram of soil hygrometer sensor

F. Real Time Clock

Real time clock (RTC) is a computer clock which keeps track of current time. In data acquisition and data logging application the actual time of the acquired signal is required. Therefore, RTC is used to keep track of current time. DS1307 is an I2C protocol based RTC which is used in this application to keep track of current time. Fig. 3 illustrates the circuit diagram of real time clock.

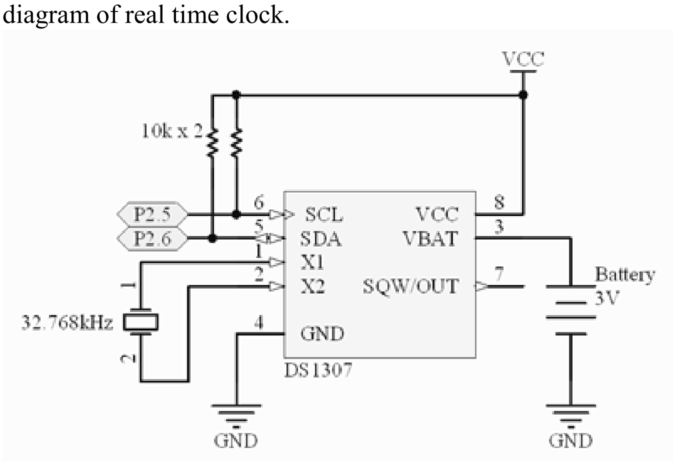

Fig. 3. Circuit diagram of Real Time Clock

G. Microcontroller

ATmega328 microcontroller has 14 digital input/output pins from which 6 pins can be used for pulse width modulation (PWM) purpose. There are 6 analog inputs, 16 MHz ceramic resonator, USB connector and has a operating voltage of 5V. It has 32 kB flash memory, 2 kB SRAM and 1 kB EEPROM. In Atmega328 microcontroller, Inter Integrated Circuit (I2C) bus and Serial Peripheral Interface (SPI) bus are available. I2C bus consists of two pins such as Standard Clock Line (SCL) and Standard Data line (SDA). SCL speed for I2C protocol is up to 100 kHz. All I2C addresses are either 7 bits or 10 bits. SPI is a master-slave protocol. SPI bus consists of 3 pins (SCLK, MISO and MOSI). SCLK stands for serial clock, MOSI stands for Master Output, Slave Input and MISO stands for Master Input, Slave Output. The pinout of ATmega328 microcontroller is shown in Fig. 4.

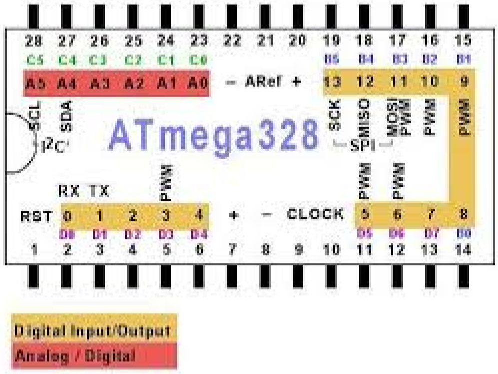

Fig. 4. Pinout of ATmega328 microcontroller

The schematic connection diagram of I2C bus and SPI bus are illustrated in Fig. 5 and Fig. 6 respectively.

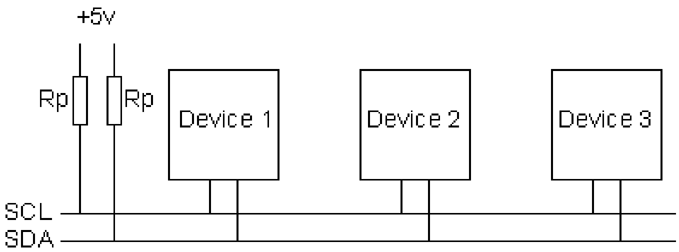

Fig. 5. I2C protocol

Fig. 6. SPI protocol

III. INTERFACING MICROCONTROLLER WITH NI-LABVIEW

The data transmitted from serial port of microcontroller is interfaced with NI-LabVIEW using VISA protocol. VISA stands for Virtual Instrument Software Architecture developed by VXI Plug and Play Systems Alliance. It is a standard for configuring, programming, and troubleshooting instrumentation systems comprising GPIB, VXI, PXI, Serial, Ethernet, and/or USB interfaces. VISA provides the programming interface between the hardware and development environments. The basic operations of VISA are

- Establish link with VISA driver
- Open a communication channel
- Communicate with the instrument
- Terminate the session
- Close the link with VISA driver

The microcontroller communicates via its USB port to the PC but this is presented to the LabVIEW as a COM port. VISA collects the data from the COM port and displays the data in the LabVIEW front panel.

IV. PROBLEM FORMULATION

The proposed data acquisition system consists of five sensors and a RTC module. The five sensors are soil hygrometer, light intensity sensor, temperature sensor, humidity sensor and pressure sensor. Soil hygrometer is connected to A0, light intensity sensor is connected with A2 and temperature sensor is connected to A3. Humidity sensor is connected to digital port D4. Pressure sensor and RTC module are interfaced with I2C bus of ATmega328 microcontroller. Fig. shows the block diagram representation of the proposed data acquisition system.

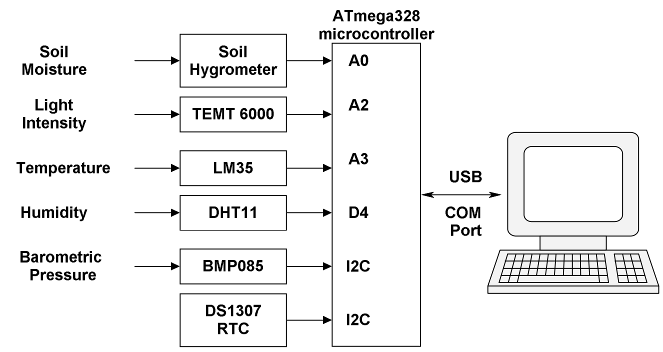

Fig. 7. Block diagram representation of the proposed data acquisition system

Fig. 8 shows the circuit diagram for interfacing of different sensors with ATmega328 microcontroller. The sensor data is read at 2 sec interval and the resultant data is shown in the serial port of the microcontroller. The baud rate of serial port is 9600.

V. EXPERIMENTAL RESULTS

The low cost data acquisition system is designed and tested in real world environment. The data is displayed with proper time stamp. Fig. 8 presents the hardware developed for data acquisition and data logging application.

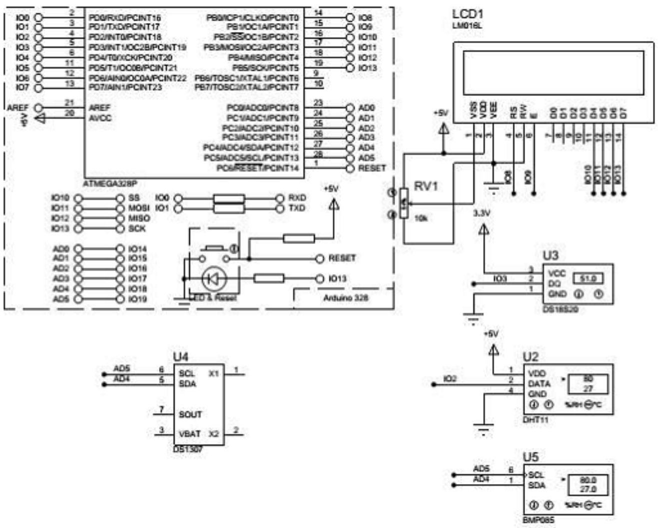

Fig. 8. Circuit diagram of microcontroller and sensor interface

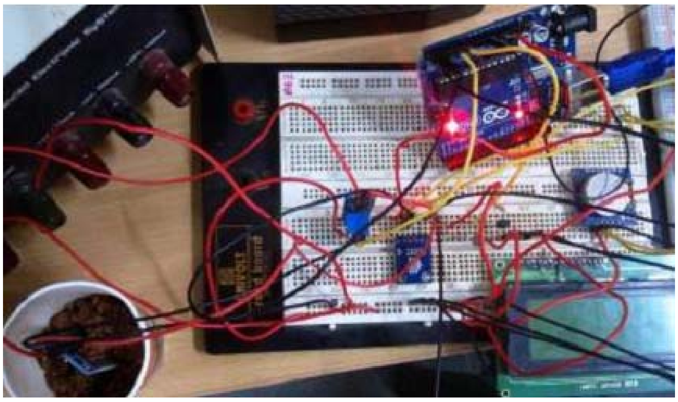

Fig. 9. Hardware developed for data acquisition and data logging

The data of microcontroller is sent to LabVIEW via serial port using VISA protocol. A LabVIEW application is developed for serial communication using VISA. The front panel of the above application is shown in Fig. 10. The LabVIEW application has data storage capacity and a graphic user interface.

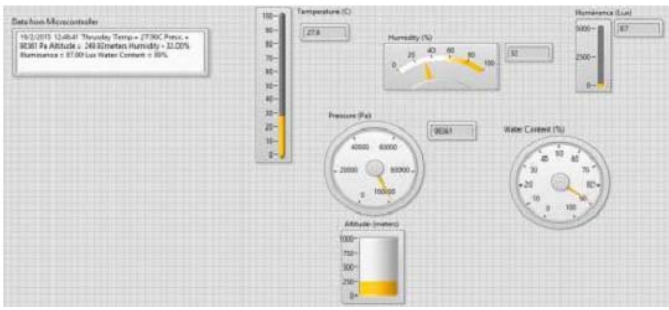

Fig. 10. LabVIEW front panel for data logging system

Fig.11 illustrates the sensors data displayed at ther serial port of PC. The acuired data at a particular instant is summarized in Table IV.

VI. Conclusion

This paper discusses the design of a low cost data acquisition and data logging system for meterological application. Different physical parameters such as ambient temperature, barometric pressure, altitude, humidity, moisture content and illuminance are acquired from environment using ATmega328 microcontroller. The instantaneous data is displayed in the serial port of microcontroller with 9600 baud rate. The microcontroller serial communication port is interfaced with NI-LabVIEW using VISA protocol. The LabVIEW based application has a proper graphic user interface and data storing facility which is helpful to the end user. The hardware setup is experimentally tested in different environmental condition and it provides satisfactory results.

Acknowledgment

The authors would like to thank Department of Science and Technology, Government of India for the financial support under FIST program (Grant No. SR/FST/ETI-020/2010) to setup Virtual and Intelligent Instrumentation Laboratory in the Department of Electronics and Communication Engineering, National Institute of Technology, Rourkela in which the research work has been carried out.

References

[1] S. Rosiek, and F.J. Batlles, “A microcontroller-based data-acquisition system for meteorological station monitoring,” *Energy Conversion and Management*, vol. 49, no. 12, pp. 3746-3754, 2008.

[2] M. Benghanem, “Measurement of meteorological data based on wireless data acquisition system monitoring,” *Applied Energy*, vol. 86, pp. 2651-2660, 2009.

[3] M. Benghanem, “A low cost wireless data acquisition system for weather station monitoring,” *Renewable Energy*, vol. 35, pp. 862-872, 2010.

[4] Farihah Shariff, Nasrudin Abd Rahim, Hew Wooi Ping, ``Zigbee based data acqusition system for online monitoring of grid connected photovolatic system," *Expert Systems with Applications*, vol. 42, pp. 1730-1742, 2015.

[5] M. Fuentes, M. Vivar, J.M. Burgos, J. Aguilera, J.A. Vacas, ``Design of an accurate, low cost autonomous data logger for PV system monitoring using Arduino that complies with IEC standards," *Solar Energy Materials and Solar Cells*, vol. 130, pp. 529-543, 2014.

[6] Mohammad Haroon Waseem, Muhammad Alamzeb, Basir Mustafa, Fahad Malik, Mustafa Shakir and Mahmood Ashraf Khan, ``Design of low cost underwater wireless sensor network for water quality measurement," *IETE J. Research*, vol. 59, no. 5, pp. 523-534, Sep. 2013.

[7] S. Ameur, M. Laghrouche, A. Adane, ``Monitoring a greenhouse using a microcontroller based meteorological data acquistion system," *Renewable Energy*, vol. 24, pp. 19-30, 2001.

[8] Zhenqiang Su, Johannes Huschle, Stephen Redfield, Frank Liu, ``High-speed Real-time Multi-channel Data-acquisition Unit: Challenges and Results," in Proc. *11th Annual IEEE CCNC-Mobile device platform and communication*, 2014, pp. 105-112.

[9] Hongmin Wang, Zhu jie, Xufei Nie and Dandan Li, ``Design of PIC microcontroller based high capacity multichannel data acquisition module," in Proc. *2012 International Conference on Measurement, Infromation and Control*, 2012, pp. 685-688.

[10] Subhransu Padhee, Yaduvir Singh, ``Data logging and supervisory control of process using LabVIEW," in Proc. *IEEE Student’s Technology Symposium*, 2011, pp. 329-334.

[11] Li Lixin and Ding Diankuan, ``Design of multi-channel high precision data acquisition system based on AD574A," in Proc. *IEEE Conf. Mechanic automation and control engineering*, 2011, pp. 1199-1201.

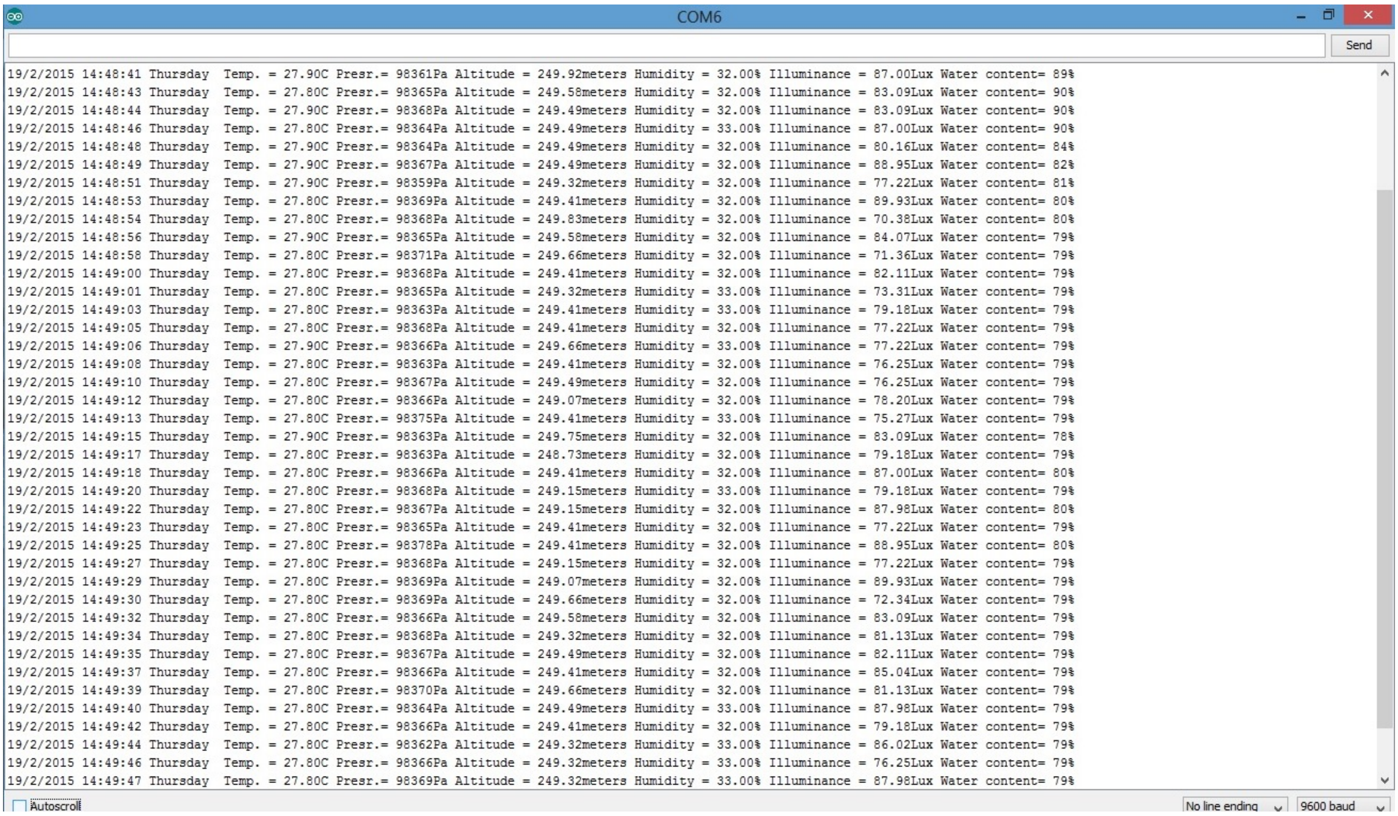

Fig. 11. Sensors acquired data displayed in serial port of PC

TABLE IV. DATA ACQUISITION VIA SERIAL PORT

Date	Time	Day	Temp (°C)	Pressure (Pa)	Altitude (m)	Humidity (%)	Illumination (Lux)	Water Content (%)
19/2/2015	14:48:41	Thursday	27.9	98361	249.92	32	87	89
19/2/2015	14:48:43	Thursday	27.8	98365	249.58	32	83.09	90
19/2/2015	14:48:46	Thursday	27.9	98368	249.49	32	83.09	90
19/2/2015	14:48:48	Thursday	27.8	98364	249.49	32	87	90
19/2/2015	14:48:51	Thursday	27.9	98367	249.32	32	80.16	84
19/2/2015	14:48:53	Thursday	27.8	98359	249.41	32	88.95	82