Design and Implementation of Microcontroller Based Digital Soil pH Meter

M.A. A. Mashud, M. H. Uddin and Md. Serajul Islam

Dept. of Applied Physics, Electronics & Communication Engineering
Islamic University, Kushtia-7003, Bangladesh.
Email: ms.mashud@yahoo.com

Dept. of Applied Chemistry & Chemical Technology
Islamic University, Kushtia-7003, Bangladesh.

Dept. of Medical Physics & Biomedical Engineering Engineering
Gono Bishwabidyalay, Savar, Dhaka, Bangladesh.

Abstract— A state-of-the-art-technology was used to design a digital soil pH meter. This paper focuses on the measurement of the value of pH (soil). The very simple circuitry was employed in this design. To do this, a low cost microcontroller PIC16F876 was used to control the function of the system. A system software was developed using C programming language. A common anode display was used to display the output ranges from 00.00 to 99.99 by the four seven-segment display.

Keywords— Microcontroller, soil pH, digital, PCWH and low-cost

Manuscript received on 5 July 2014 and accepted for publication on 18 August 2014.

1 INTRODUCTION

SOIL pH is the single most important chemical property of the soil like soil texture is to the physical properties. Soil pH influences most chemical and biological processes occurring in soil and some physical processes. These include supply and availability of essential elements, growth of soil organisms of all kinds, nitrification of ammonia and rock weathering. The pH of soil is an important factor in determining which plants will grow because it controls which nutrients are available for the plants to use. Knowing the pH of the soil will quickly allow user to determine if the soil is suitable for plant growth and what nutrients will be most limiting.

Soils influenced the composition of forest stand and ground cover, rate of tree growth, vigour of natural reproduction and other silviculturally important factors [1]. Physico-chemical characteristics of forest soils vary in space and time because variation in topography, climate, weathering processes, vegetation cover, microbial activities [2] and several other biotic and abiotic factors. Vegetation also plays an important role in soil formation [3]. The yearly contribution of surface vegetation to soil, in the form of needles, leaves, cones, pollen, branches and twigs, gradually decomposes and becomes a part of the soil [4]. The nutrient thus, returned in the soil, exerts a strong feedback on the ecosystem processes [5]. Plant tissues (above and below ground litter) are the main source of soil organic matter, which influences the physico-chemical characteristics of soil such as, texture, water holding capacity, pH and nutrients availability [6]. Nutrients supply varies widely among ecosystems [7], resulting in differences in plant community structure and its production [8].

The nature of soil profile, pH and nutrient cycling between the soils and crops are the important dimensions to determine the site quality. The vegetation influences the physico-chemical properties of the soil to a great extent. It improves the soil structure, infiltration rate and WHC, hydraulic conductivity and aeration [9,10].

Soil pH is a measure of the relative acidity or basicity of a given soil. The pH scale (0-14) is a logarithmic expression of hydrogen ion activity. A pH of 7.0 is neutral, and soils above or below this value are either alkaline or acidic, respectively. A soil with a pH of 6.0 is ten times more acidic than a soil of pH 7.0. Changes in soil pH dramatically affect the availability of nutrients to growing crops. The pH meter is the preferred method for determination of soil pH.

In year 2011, the author M.A.A. Mashud et. al, [11] explained a digital pH meter using microcontroller to measure the pH of blood. This design system is simple and clinically applicable. The developed system is tested among 15 patients and found sound result. In this work

microcontroller PIC12F675 is used with watch-dog mode to avoiding the external oscillator circuit and MC14511B is used as a buffer and driver circuit.

Now, the author developed a digital pH meter to measure the pH of soil using a fast response microcontroller PIC16F876. In this work for better performance external oscillator circuit is used. For quickly real time display MC14511B is avoided and common cathode display is used.

2 Design Consideration

The system is divided into six parts: the low voltage power supply, sensor circuit, buffer amplifier, summing amplifier, microcontroller unit and display circuit. Low voltage power supply produces 5 volts for the buffer amplifier circuit, summing amplifier and microcontroller. A LM336 is used to produce 2.5V. The signal from pH electrode goes to the buffer amplifier circuit. The amplified signal is the input of the summing amplifier, which goes to the microcontroller. The output of the microcontroller operates the display circuit. The block diagram and the complete circuit diagram of the developed system are shown in Figure 1 and Figure 2 respectively.

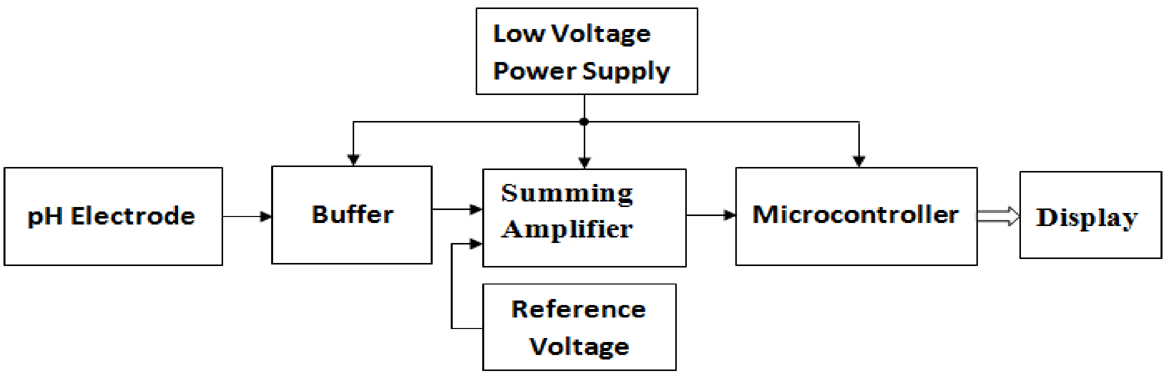

Figure 1: Block diagram of the designed system

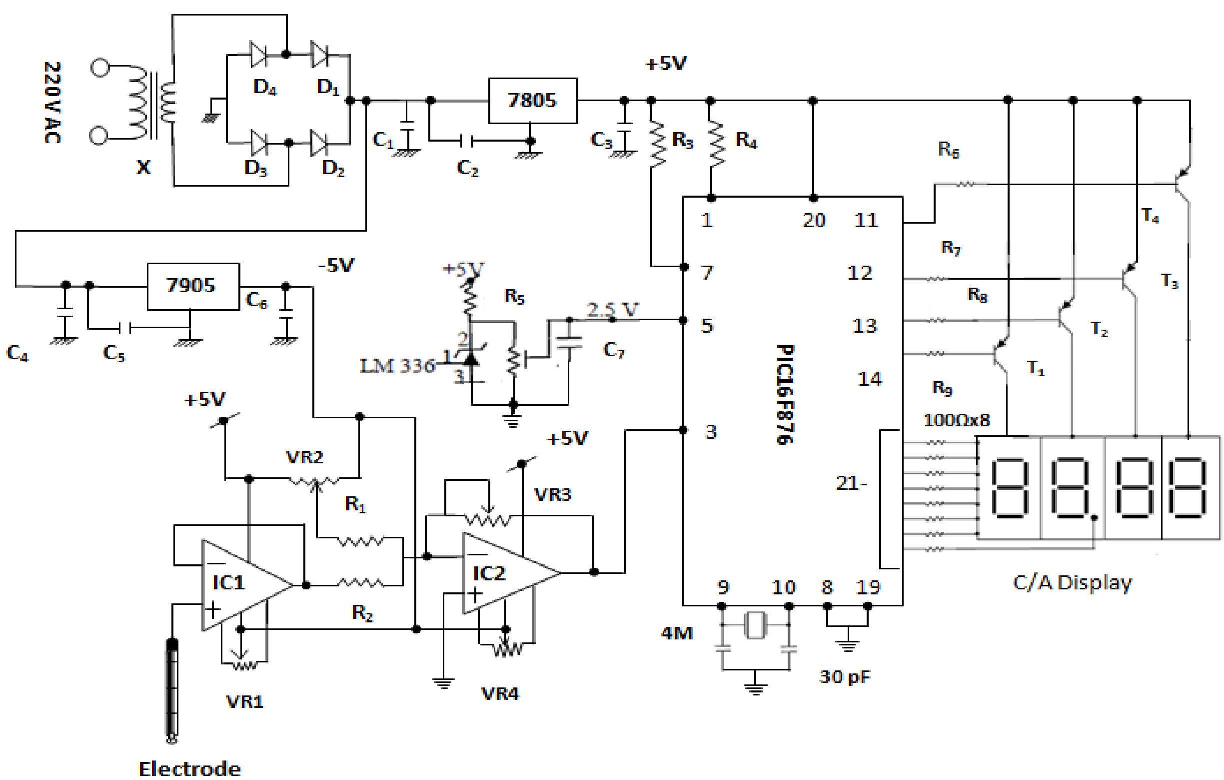

Figure 2: Complete circuit diagram of the designed system

2.1 Low Voltage Power Supply

The microcontroller and al electronic components are used in designing the complete pH meter require a dc voltage (+5v & -5v). A highly stable regulated dc power supply was designed for this purpose. The complete circuit of a regulated dc power supply is shown in Figure 2, using IC7805 and IC7905 as a voltage-regulating device [12]. It contains four diodes, D_1, D_2, D_3 and D_4, which are connected to the a.c. supply [13] for +5V.

2.2 Buffer Amplifier

The buffer amplifier [14] circuit consists of IC1 and VR1. The signal from the pH electrode is connected to non-inverting terminal of IC1. VR1 is connected between pin 1and 5 for a null setting.

2.3 Summing Amplifier

The summing amplifier [15] consists of IC2, VR2, VR3, VR4, R_1 and R_2. The output of the summing amplifier is used as a microcontroller's input. This system uses two input summing amplifiers with inverting configuration

2.4 Microcontroller Unit

This powerful (200 nanosecond instruction execution) and easy-to-program (only 35 single word instructions) CMOS FLASH-based 8-bit microcontroller packs Microchip's powerful Programmable Interface Controller (PIC) architecture into a 28-pin package and is compatible with the PIC16C5X, PIC12CXXX and PIC16C7X devices [16,17]. The PIC's Console Command Processor (CCP) which is capture/compare/pulse-width module can also detect rising or falling edges every four or 16 pulses [18]. PIC16F876 features 256 bytes of electrically erasable programmable read-only memory (EEPROM) data memory, self programming, 5 channels of 10-bit Analog-to-Digital (A/D) converter, 2 additional timers, 2 capture/compare/PWM functions, the synchronous serial port can be configured as either 3-wire Serial Peripheral Interface (SPI) or the 2-wire Inter-Integrated Circuit (IIC) bus and a Universal Asynchronous Receiver Transmitter (USART). All of these features make it ideal for an advanced level A/D applications in automotive, industrial appliances and consumer applications. Pin diagrams of microcontroller PIC16F876 are shown in Figure 3.

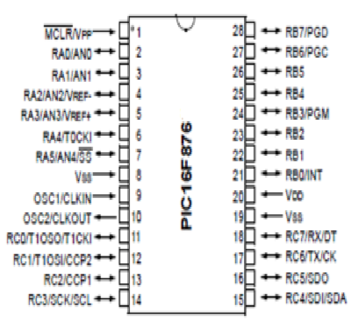

Figure 3: Pin diagram of microcontroller PIC16F876

3 SYSTEEM PROGRAM

The software has been developed for controlling the whole system. The software is divided into different sub routines and main routines. The compiler PCWH is used to develop the software [19]. The flow chart of the program is depicted in Figure 4.

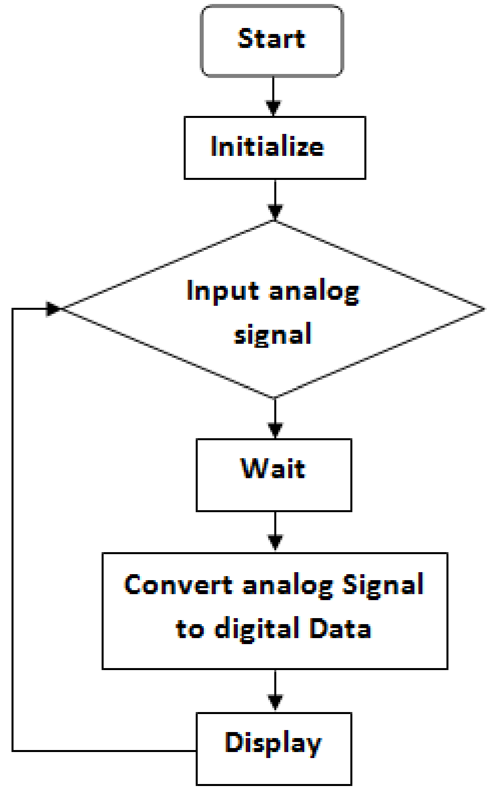

Figure 4: Flow chart of the developed system program

4 RESULTS AND DISCUSSION

The microcontroller based digital soil pH meter was successfully designed and developed, as its performance was strong. The result of pH is compared with the actual result. The model of the laboratory pH meter is PHM83, with an accuracy of +/-0.1%. Figure 5 provides a graphic representation of the comparison between the designed system and the laboratory pH meter. The graph illustrates that the developed system has sound stability and accuracy. Our designed pH meter was tested and compared with standard pH value. The result is shown in table 1. The results showed that the designed system can be used for measuring pH [20, 21].

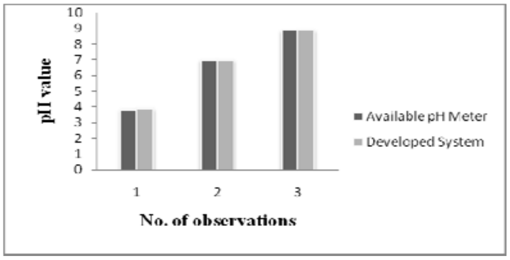

Figure 5: Comparative study of developed system and available pH meter

TABLE 1
COMPARISON OF DIFERENT VALUES WITH STANDARD VALUE

Standard (pH)	1	3	5	7	9	11
The first measurement(pH)	1.01	2.98	5.06	7.01	9.03	11.05
The second measurement(pH)	1.03	2.92	5.09	7.05	9.08	11.08
The third measurement(pH)	1.02	2.95	5.06	7.04	9.10	11.04
The fourth measurement(pH)	1.04	3.02	5.07	7.03	9.07	11.03
The fifth measurement(pH)	1.02	2.96	5.04	7.04	9.09	11.02
Average(pH)	1.02	2.97	5.06	7.03	9.07	11.04
Average error quantity (pH)	0.05					

Clay soil has a lower pH than pasture soil because clay soil is found in lower plains, it is exposed to excessive amounts of water and nutrients. Therefore, lowering the pH as seen in the results. A lot of water moving through soils requires fertilization for good crops and tends to be more acidic (pH < 7). At lower pH's there is more aluminums in the soils which can be toxic to plant and animal growth. Most soils target pH is 6.5. Nutrients are easily provided for plant growth and development at this pH. A pH of 6.5 also promotes growth of beneficial microorganisms within the soil itself. Therefore the soil pH meter is essential for measuring the value of pH. We seems that our designed pH meted be beneficial for the developing countries because of low cost.

4 CONCLUSION

The price of electronic equipments has fallen significantly in recent times, though the cost of equipment in Bangladesh remains expensive. However due to the rapid development of micro electronics, all the designed component and instruments are available at a lower price. The device is reliable in operation and it costs approximately U$100 for fabrication, whereas the price of a similar instrument in the international market is no less than U$500. Moreover, the comparison of the features of the presently used system shows that the developed system is a better choice in terms of cost, portability and design. Therefore, the opportunity to use the designed instruments will be open to many users, particularly in developing countries.

REFERENCES

[1] Bhatnagar HP. Soils from different quality sal (*Shorea robusta*) forests of Uttar Pradesh.Tropical Ecology 1965; 6: 56-62

[2] Paudel S. Sah JP. Physiochemical characteristics of soil in tropical sal (*Shorea robusta* Gaertn.) forests in eastern Nepal. Himalayan Journal of Sciences 2003; 1(2)107-110

[3] Champan JL, Reiss MJ. *Ecology Principles and Application*. Ca bridge; Cambridge University Press 1992; 294 p.

[4] Singh RD, Bhatnagar VK. Differences in soil and leaf litter nu trient status under *Pinus, Cedrus and Quercus*. Indian Journal of Forestry. 1997; 147-149p

[5] Pastor J, Aber JD, Mc Clangherty CA, Melillo JM. Above ground production and N and P cycling along a nitrogen mineralization gradient on black hank island,Wisconsin Ecology 1984; 65:256-268

[6] Johnston AE. Soil organic matter; effects on soil and crops. Soil Use Management 1986; 2: 97-105.

[7] Binkley D, Vitousek PM. *Soil Nutrient Availability*. In: Pearey, R.W., J. Ehleringer, N.A., Mooney and Rundel, P.W. (eds) Plant Physiological, Field Methods and Instrumentation London; Champan and Hall. 1989; 75-96.

[8] Ruess JO, Innis GS. A grassland nitrogen flow simulation mode. *Ecology* 1977; 58: 348-429.

[9] Ilorker VM, Totey NG. Floristic diversity and soil studies in Navegaon National Park (Maharashtra). Indian Journal of Fore stry 2001; 24(4): 442-447.

[10] Kumar Munesh, Bhatt VP, Rajwar GS. Plant and soil diversities in a sub-tropical forest of the Garhwal Himalaya. Ghana Journal of Forestry 2006; 19-20:1-19pp

[11] M. A. A. Mashud, M. A. Masud, Md. Serajul Islam. ULAB Joural of Science and Engineering, 2011, vol.4 pp31-34

[12] "Farnell Semiconductor Data CD-ROM," Data sheet 2143.pdf, 7805IC, 7905IC, Issue 7 January 2000.

[13] V.K. MEHTA, "Principles of Electronics," Revised edition, page-150.

[14] R.F. Coughlin and F. F. Driscoll "Operational Amplifiers and Linear Integrated Circuits," Second Edition

[15] R. A. Gayakward, "Op-Amps and Linear Integrated Circuits," Fourth Edition,

[16] M. A. Mazidi, R.M. Kinlay & D. Causey, 2008 "PIC Microcon troller", Prentice Hall Inc.

[17] J. B. Peatman, 1997, "Design with PIC microcontroller", Pren tice Hall Inc.

[18] "Microchip Data sheet" PIC16F876.shtml accessed on 5.8.2010.

[19] PCWH Compiler, version 3.43.

[20] Narain Arora, "Mosfet Modeling for VLSI Simulation", World Scientific Publishing Co. Pte. Ltd., 2007.

[21] A.B.Bhattacharyya, "Compact Mosfet Models for VLSI Design", John Wiley & Sons (Asia) Pte Ltd, 2009.

Md. Abdullah-Al-Mashud was born on Nov.15, 1980 in kushtia, Bangladesh. He received the B.Sc (Hons) degree and M.Sc degree in Applied Physics, Electronics and Communication Engineering (APECE) from Islamic University, Kushtia, Bangladesh in 2003 and 2004 respectively. He works as a faculty member in the department of APECE, Islamic University, Bangladesh. His current interest is microprocessor / microcontroller applications in control, automation, medical instruments, environmental monitoring, low cost electronic systems, Medical Image Processing. His work has produced 13 peer-reviewed scientific International and National Journal papers and also 6 National and International Conf- rences papers.

.

Helal Uddin was born on July.03, 1978 in Jhenidah, Bangladesh. He received the PhD degree fron the Dept. of Applied Physics and Chemistry, Graduate School of Electro-Communications, University of Electro-Communications, 1-5-1 Chofugaoka, Chofu, Tokyo, Japan in 2009. He works as a faculty member in the department of ACCT, Islamic University, Bangladesh. His work has produced 15 peer-reviewed scientific International and National Journal papers. He has published 09 papers in National and International Conf- rences.

Md. Serajul Islam was born in Panchagar, Bangladesh. He received the M.Sc degree in Physics from Rajshahi University, Bangladesh. He was a Chief Scientific Officer and Director in the Institute of Electronics, AERE, Atomic Energy Commission, Savar, Bangladesh. Now he is a professor in the Department of Medical Physics and Biomedical Engineering, Gono Bishwabidyalay. Saver, Bangladesh. His work is design, development and analysis of electronic instruments and reactor control. His work has produced nearly 55 peerreviewed scientific papers and 02 patents.