

Design and Development of Microcontroller Based Digital Soil pH Meter

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Abstract: Microcontroller based digital soil pH meter is an electronic device that can measure the acidity or alkalinity of soil and is used for soil measurements in agriculture. In this work, a portable, inexpensive microcontroller based soil pH meter has been designed and developed using a resistive sensor, a buffer circuit and an ATMEGA328 microcontroller. A low voltage power supply has also been designed to operate the buffer circuit, sensor as well as microcontroller. The buffer circuit was used to obtain the output voltage of the sensor and a summing amplifier has been used to raise the output voltage of the sensor. The output of the summing amplifier was then allowed to send the microcontroller as input. A C++ programming language and Arduino IDE software have been developed to control the function of the microcontroller. The output of the microcontroller is displayed as a pH value by the 16×2 keypad shield LCD display. The developed system has been tested several ways and found satisfactory results.

Keywords: Digital soil pH meter, microcontroller, buffer circuit, summing amplifier and Arduino IDE software

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I. Introduction

The pH of the soil is the single most important chemical property of the soil which represents a measure of the acidity or basicity of soil. It influences some physical processes as well as most of the chemical and biological processes occurring in soil including supply and availability of essential elements, growth of soil organisms of all kinds, nitrification of ammonia and rock weathering [1, 2]. Plants nutrient is also affected by pH of the soil availability by controlling the chemical forms of the different nutrients and influencing the chemical reactions they undergo. The optimum pH range of soil for most plants is between 5.5 and 7.5 where many plants have seemed to thrive at pH values outside this range [3, 4]. The pH of a natural soil depends not only in the mineral composition of the parent material of the soil but also in the weathering reactions in that parent material. Parent material is the underlying geological material. Parent material forms soil horizons form. Soil gets a great deal of structure and minerals from their parent material, which is classified based upon their contents. They can be classified as consolidated or unconsolidated mineral material. These materials had undergone some degree of physical or chemical weathering and the mode by which the materials were most recently transported [5-7]. In warm, humid environments, soil acidification occur and because of the produce of weathering are leached by the flow of water through the soil. In dry climates, soil weathering and leaching are less intense. Soil pH is often neutral and alkaline in dry climate [8]. 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. Thus, it is important to check soil pH before designing or planting a new garden and hence by 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 [9, 10]. A low cost microcontroller based digital pH meter was designed and implemented by Mashud et al. [11] using a fast response microcontroller PIC16F876 and obtained results were compared with the actual result and found satisfactory. In year 2011, the author M.A.A. Mashud et al. [12] explained a digital pH meter using microcontroller to measure the pH of blood. This design system is simple and clinically applicable. The developed system was tested among 15 patients and obtained results were sound. A pH meter measuring the gastric of patients was designed and its operation was explained by D. Meiners et al. [13]. S.J. Taylor et al. [14] demonstrated how to test a pH for a nasogastric tube. Levine et al. [15] and Baghaie et al. [16] used pH probes

to measure the intragastric of patients. However the above systems are quite expensive and complex and involve long fabrication processes.

In this work, a digital soil pH meter was designed and developed using a fast response Arduino microcontroller. An assembly language program has been developed to control the function of microcontroller using PROTEUS7 software. The output of the microcontroller was displayed by two LCD display.

II. Principle of Operation

To design the system, the first attempt has been taken is to design the block diagram of the desired system. The block diagram of the complete units consists of several blocks, including the sensor circuit, low voltage power supply, buffer amplifier, summing amplifier, microcontroller unit, and display circuit and blocks are connected by arrows as shown in Fig. 1. The designed low voltage power supply generates low voltage (+5 V and -5V) for the buffer amplifier circuit, summing amplifier and microcontroller. The low signal obtained from pH electrode is fed to the summing amplifier via buffer circuit. The output voltage of the summing amplifier acts as input of the microcontroller. The output of the microcontroller operates the display circuit (LCD display). The simplified block diagram of the designed and developed portable soil pH meter is shown Fig. 1.

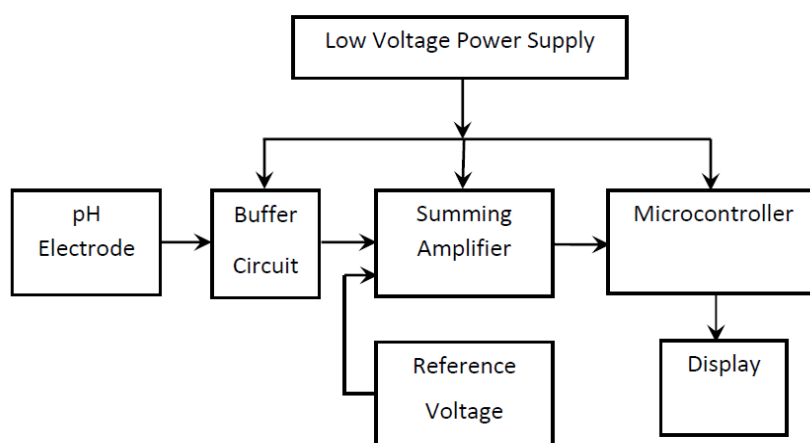


Fig. 1: The simplified block diagram of the designed soil pH meter.

III. Design and Circuit Description

3.1. Low voltage power supply

All electronic components including microcontroller require power and in our case microcontrollers, buffer circuit, and summing amplifier uses dc voltages of +5V and -5V. Therefore, a highly stable regulated dc power supply was designed using a step down transformer, four crystal diodes, two capacitors, and two (IC7805 and IC7905) [17-21]. The circuit diagram of the designed low voltage power supply and its voltage regulation curves are illustrated in Fig. 2, Fig. 3 and Fig. 4, respectively.

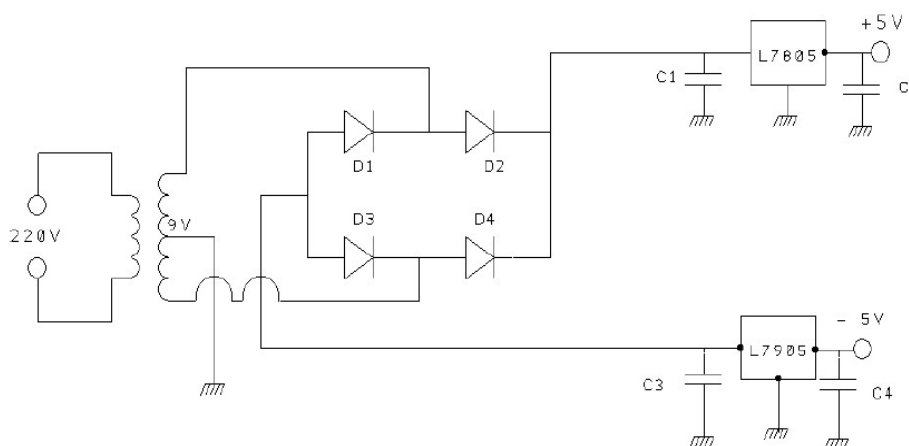


Fig. 2: Circuit diagram of low voltage power supply.

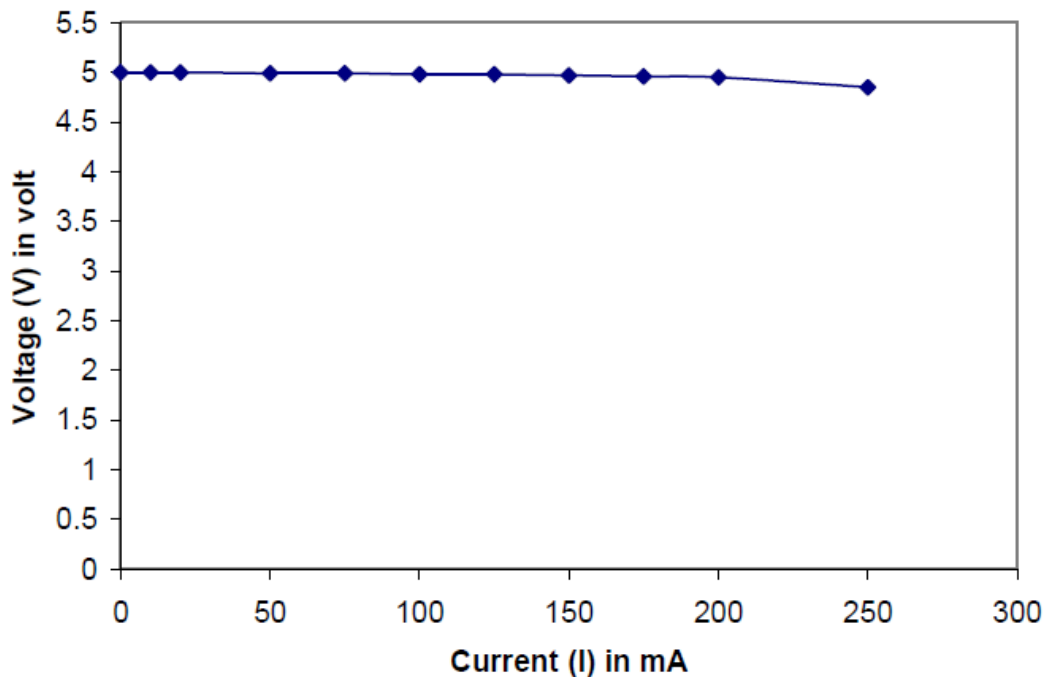


Fig. 3: Voltage regulation curve for +5V power supply.

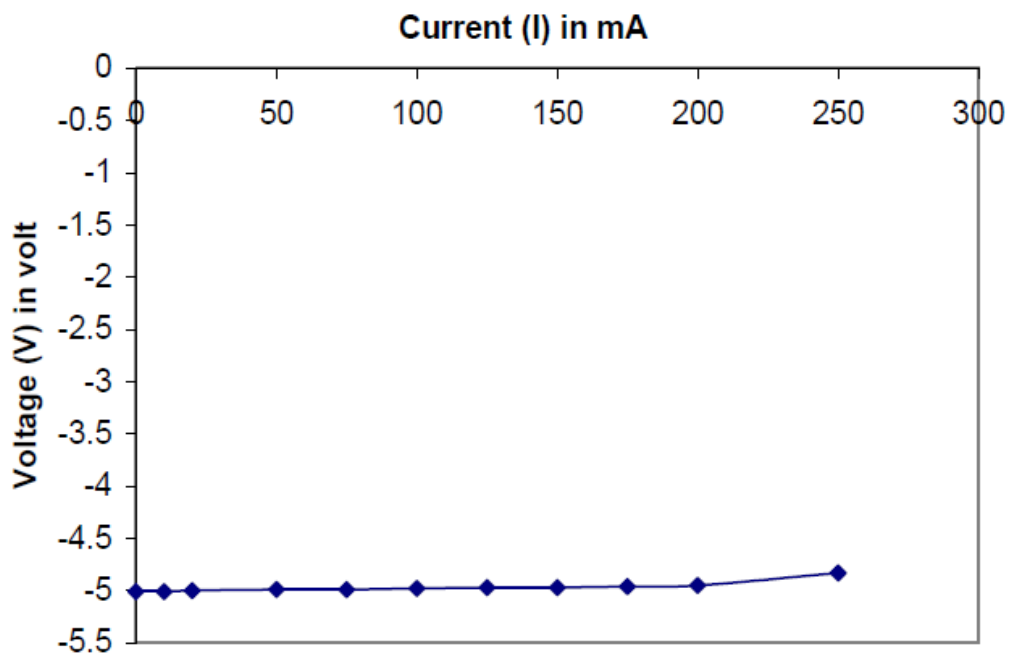


Fig. 4: Voltage regulation curve for -5V power supply.

3.2. Buffer amplifier

The buffer circuit is one kind of emitter follower and is generally used for impedance matching. Our designed buffer circuit consists of one 741 IC (IC4) and a 10 KΩ resistor (R6). The signal from the pH electrode is connected to the non-inverting terminal of IC4 [22].

3.3. Summing Amplifier

The output voltage of pH electrode is very much low. The amount of voltage is required to operate the operational amplifier used in the system cannot given by the pH electrode and hence a summing amplifier is designed to sum up and increase the voltage of pH electrode using a 741 IC (IC3), a 2 KΩ resistor (R4), a 10 KΩ resistor (R3), and a 10 KΩ variable resistor (VR1) [23]. The obtained output voltage of the summing amplifier is used as a microcontroller's input.

3.4. Microcontroller Atmega328

Atmega328 is a low power CMOS 8-bit microcontroller which is based on the AVR enhanced RISC architecture. It achieves throughputs close to 1 MIPS per MHz and empowers system designed so that it can optimize the device for power consumption versus processing speed. In our designed system, the output of the summing amplifier is connected to the Atmega328 Microcontroller [24-27]. The microcontroller converts data from analogue to digital, analyses data and displays data. Pin diagrams of Atmega328 Microcontroller are shown in Fig. 5.

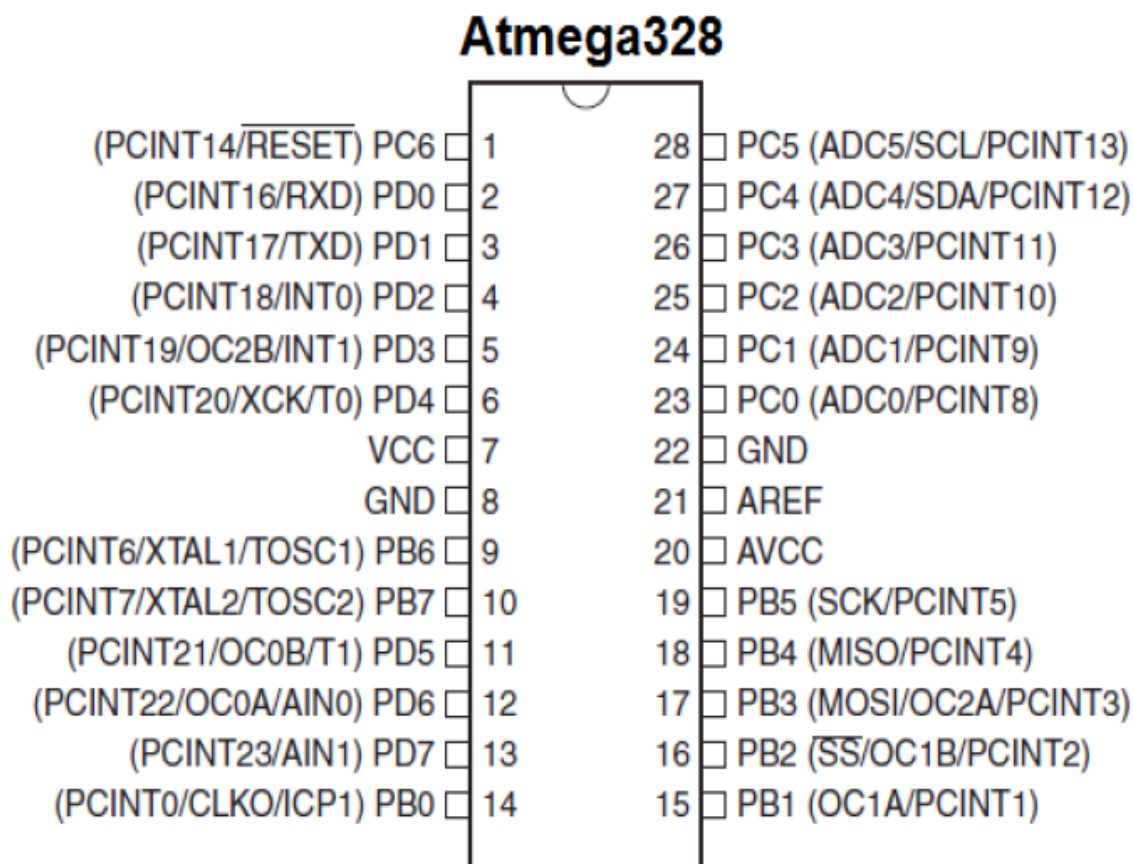


Fig. 5: Pin diagrams of Atmega328 Microcontroller.

3.5. Programming of Arduino Uno

The Arduino Uno is a microcontroller board which is based on the Atmega328. It has 14 digital input/output pins where 6 pins can be used as PWM outputs, and 6 analog inputs. The Atmega328 also support 12C (TWI) and SPI communication. The Arduino software includes a Wire library to simplify use of 12C bus. The Arduino Uno can be programmed with the Arduino software. The Arduino language is based on C/C++. The software has been developed for controlling the whole system and the flow chart of the program is shown in Fig. 6.

3.6. Display System

The Arduino LCD Keypad shield has been developed for Arduino which includes a 16×2 LCD display. It has 6 momentary push buttons. Pins 4, 5, 6, 7, 8, 9 and 10 are used to interface with the LCD. On the board, LED indicates power on. Fig. 7 shows LCD display for Arduino. The entire circuit diagram of the designed and developed digital soil pH meter is shown in Fig. 8.

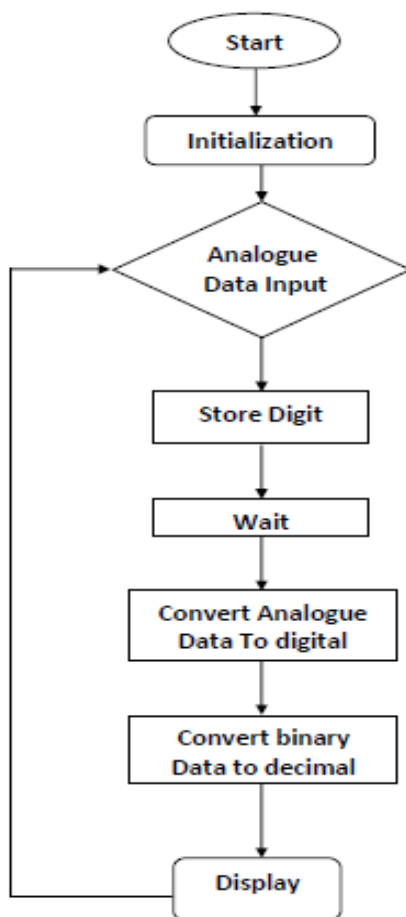


Fig. 6: Flow chart of the designed soil pH meter.

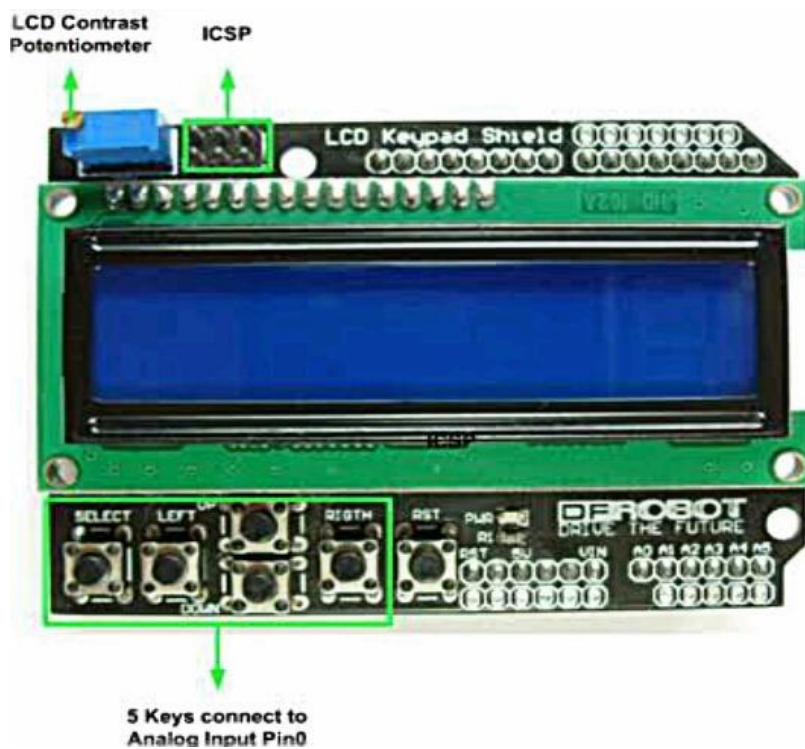


Fig. 7: LCD Keypad shield

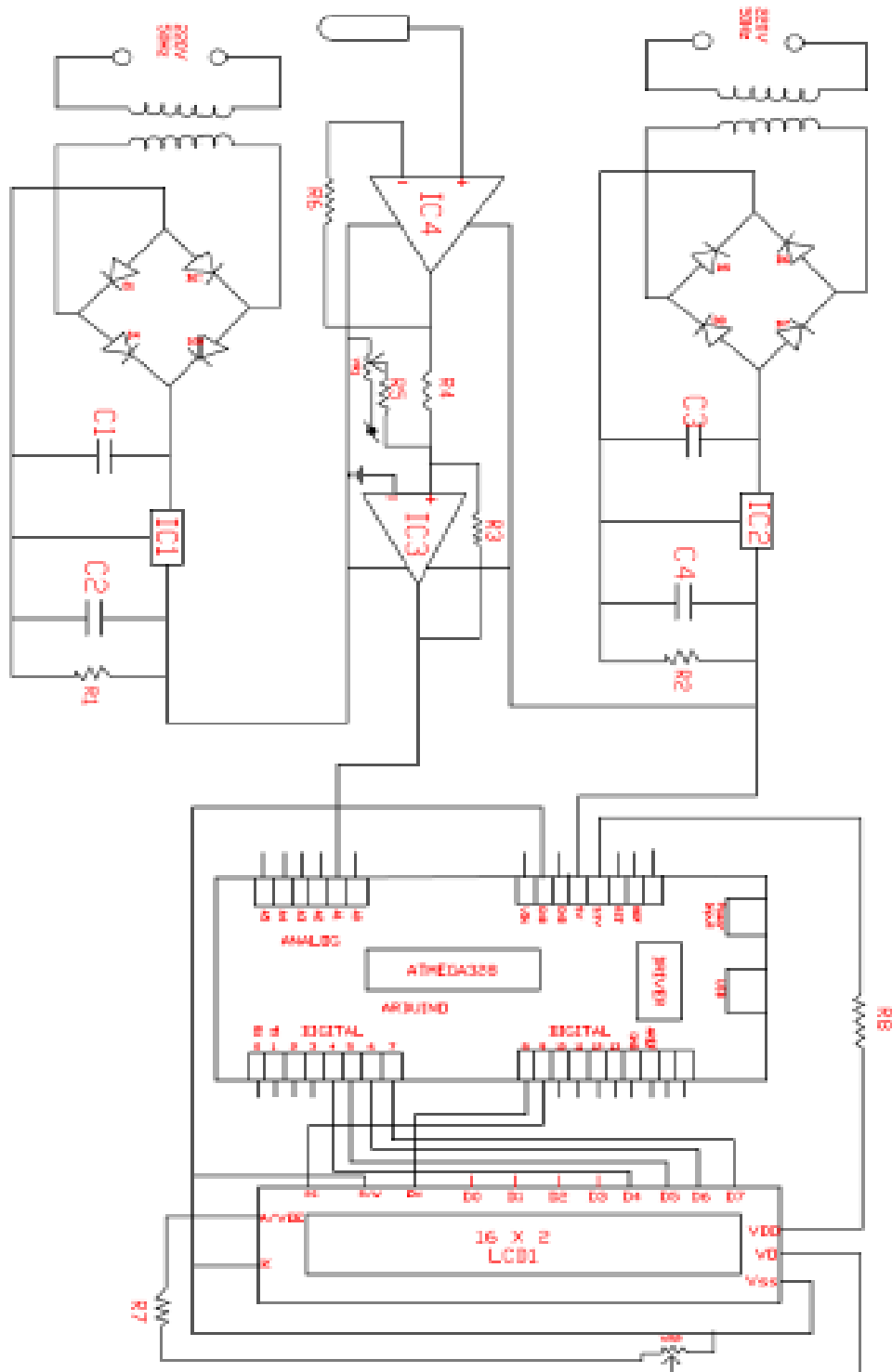


Fig. 8: The full circuit diagram of the designed and developed digital soil pH meter.

IV. Results and discussion

The Atmega328 microcontroller based digital soil pH meter was successfully designed and developed, and its performance was tested with actual pH meter and found satisfactory. The obtained results of pH were compared with the actual results obtained from laboratory pH meter, PHM83, with an accuracy of $\pm 0.1\%$. A graphic representation of the comparison between the designed system and the laboratory pH meter is shown in Fig. 9. It is observed from Fig. 9 that the developed system represents sound stability and accuracy [11, 12].

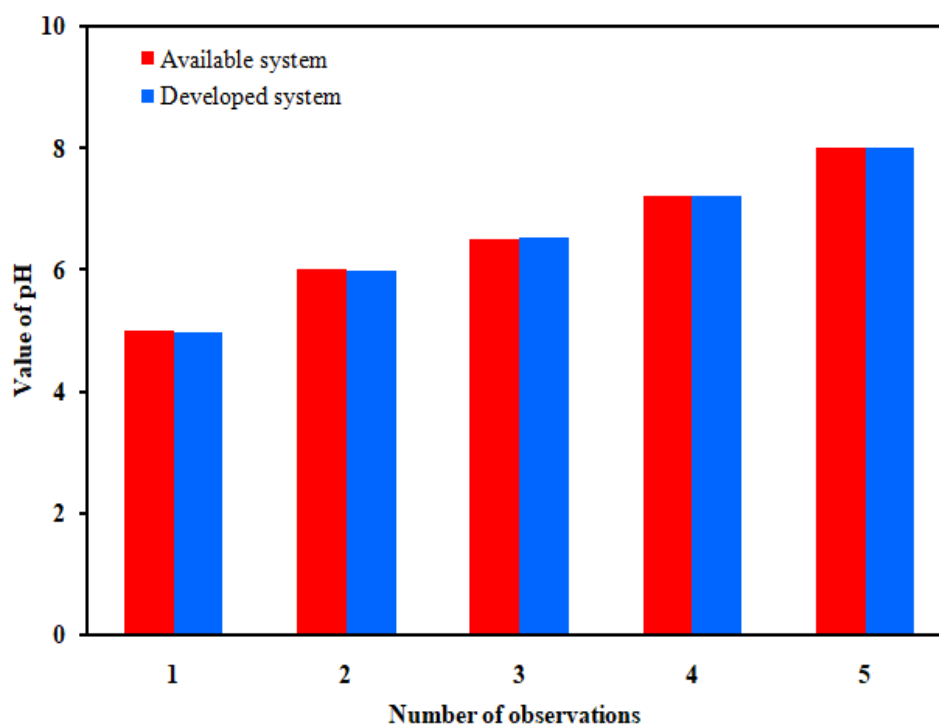


Fig. 9: A comparison between the developed system and the laboratory pH meter.

V. Conclusions

The microcontroller based digital soil pH meter was successfully designed and developed using low voltage power supply, summing amplifier, Atmega328 microcontroller, etc., and its performance was tested, and found very stable and accurate. The device is reliable in operation and inexpensive compared to the similar instrument in the international market. In addition, the comparison of the features of the presently used system shows that the developed system is a much better choice in terms of cost, portability and simplicity of design.

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