

Designing a pH Data Acquisition and Logging Device using an Inexpensive Microcontroller

Chaitanya S. Misal

University of North Carolina at Charlotte
csmisal@uncc.edu

James M. Conrad

University of North Carolina at Charlotte
jmconrad@uncc.edu

Abstract

Accurate measurement and analysis of pH data is required for a multitude of applications ranging from the agricultural sector to clinical laboratories. In many of these applications an inexpensive hand-held unit is needed. This paper describes a low cost and low power pH sensing and data logging system using a Renesas microcontroller and pH sensor. This paper describes the sensor data acquisition and data logging system including details of its construction, capabilities and applications.

1. Introduction

A pH value is the function of the Hydrogen ion concentration in a solution. Many important properties of a solution can be determined from accurate measurement of pH, including acidity of the solution and the extent of reaction in the solution [6]. The pH scale ranges from 0 to 14 with pH 7 as neutral, pH 0 as highly acidic, and pH 14 as highly basic.

1.1 Motivation

Accurate measurement and analysis is very important for many applications ranging from industrial operations to biological processes. Many of these applications demand a low power, low cost portable device. Some of the prominent applications include [1]:

- Biochemistry.
- Agronomy: The availability of nutrients for plant, depend upon the pH content of the soil as well as the activity of soil bacteria. Knowledge of the pH value helps determine the necessary measures to be taken to ensure the health of plants.
- Food Science: Food products need to have an optimum pH level; hence knowledge of pH will help in maintaining quality of food products.
- Chemical Research and Engineering: Researchers use the knowledge of pH to determine and thus understand the chemical reaction rate. Engineers use this information to develop practical commercial processes (i.e. nuclear plants, process industries).
- Environmental Research and Pollution Control: pH knowledge of a lake or a river is important to maintain proper ecological balance. Extremes in pH can affect

the flora and fauna adversely. Also, protecting our waterways requires constant monitoring of industrial effluent. pH measurements are used as a guide to the proper neutralization of these industrial wastes, as well as to monitor the final effluent quality.

Therefore, accurate pH measurement helps with proper management of cost saving techniques.

Any developed system would also need to be cost effective compared to similar products available in the market from YSI Corporation (current cost: \$380) [3]. However, the existing product does not have storage capability.

1.2 System Overview

This system provides a small, inexpensive, and easily deployable pH data acquisition and data logging system. Figure 1 summarizes the components and functionality of the designed system.

The pH sensor measures a solution and gives an output in the form of millivolts (positive voltage for pH above 7 and negative voltage for pH below 7). This small voltage is fed to signal conditioning circuit which was designed to account for both positive and negative voltages and give a corresponding output from 0 to 5 Volts. Further, it is fed as input to a 10-bit Analog-to-Digital converter which is an integrated peripheral on the Renesas M16C/62P microcontroller chip. The converted digital value is used by a C code program which performs a table look-up to obtain the equivalent pH value. The pH value is displayed on the LCD display and logged on to the 4Kb on-chip flash

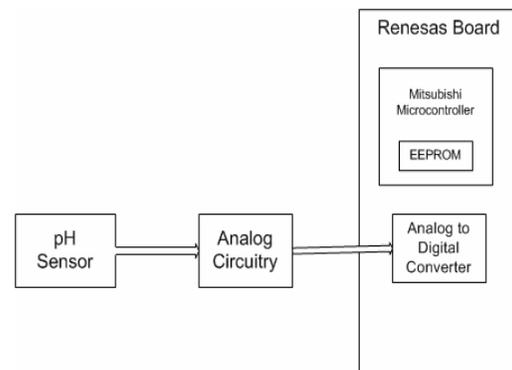


Fig. 1: System Block Diagram

memory block (non-volatile data logging). Use of the on-chip memory's (EEPROM) reserved area helps to save the cost of having external memory and also reduces the size of the system.

The timers are set in the system to take readings at regular intervals and log the data in the memory. The timer period can be set to longer intervals to improve system power consumption. This data can be observed in real time as well as offline by downloading the EEPROM memory. The distribution of pH values over a period of time can be plotted for further analysis and study.

2. Data Acquisition

Data acquisition includes the process of extracting, transforming and transporting data from the source system and external data sources to the microcontroller for storage.

2.1. pH Sensor

The sensor selected was a Sensorex general purpose epoxy pH electrode (S200C) [8]. It is a standard laboratory-use electrode which, when inserted in a solution, produces a small voltage (mV) proportional to Hydrogen ion concentration [4]. The output voltage for known standard pH values were measured for the Sensorex electrode and compared with a known standard pH meter. The recorded values were used to build the look-up table used to pH meter operation.

2.2. Analog Circuitry

Figure 2 shows the analog circuit used to condition the small voltage signal. The zener diode provides constant voltage at the pin2 of operational amplifier, while pin3 measures the output from the sensor. The amplifier is used in an inverting configuration with a gain of 10. The design is such that when the solution is neutral (i.e. pH 7) the output voltage is 2.5 Volts (range is 0-5 Volts). The designed circuit is inexpensive, accurate and reliable.

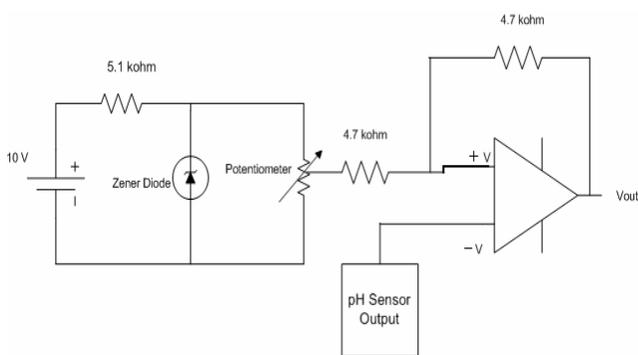


Fig. 2: Signal Conditioning Circuit (“Analog Circuitry” in Figure 1)

2.3 Renesas Microcontroller (M16C/62P)

The Renesas M30626P microcontroller is a single-chip 16bit CMOS microcomputer. It operates using sophisticated instructions featuring a high level of instruction efficiency. The M30626P has a 1 Mbytes address space and is capable of executing instructions at up to 24MHz. It has a multiplier and DMAC which combined with fast instruction processing capability makes it suitable for communication and industrial equipment which require high speed arithmetic/ logic operation [6]. The pH sensing system was built using a Renesas SKP16C/62P Evaluation Board (Figure 3).

The Renesas microcontroller has a 10-bit analog to digital converter which takes input through port 10. The converted digital data is fed to the microcontroller. C code is written to calibrate the digital raw value to an equivalent pH value.

The C-code performs the write operation of the processed data for data logging in to the reserved memory.

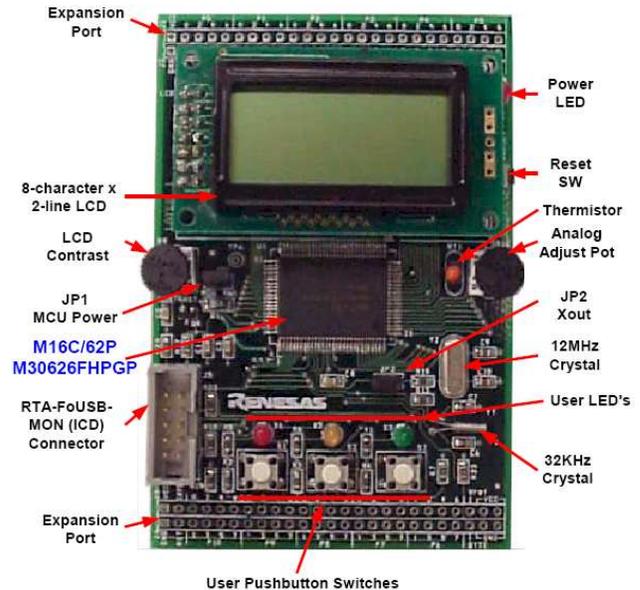


Fig. 3: SKP16C/62P Evaluation Board [7]

3. Data Logging

Data logging is a very common measurement application. In the most basic form data logging is the measurement and recording of physical or electrical parameters over a period of time. The data can be temperature, pressure, acceleration, current, voltage, displacement, or any wide range of parameters [2]. Real-world data logging applications, such as pH measurements, require some combination of online analysis, offline analysis, report generation, and data sharing.

In this system we present the logged pH data over a period of time to be used for the behavior analysis, and take

preventive measures if required for the specific application. The LCD also displays the real time data for the user.

Exploring the reserved, unused EEPROM in the microcontroller memory for data logging was an important part of building a low-cost system. The ROM in the flash memory area is separated between the user ROM area and the boot ROM area. Figure 4 shows the block diagram of flash memory. The user ROM area has a 4Kb block A, in addition to a program area for microcomputer operation during single chip or memory expansion mode [7].

CPU rewrite mode is used where the user ROM area can be written by executing software commands from the CPU. Thus, the driver provides for the user ROM area to be rewritten directly while the microcomputer is mounted onboard without having to use the ROM programmer [5].

Each pH value needs 2 bytes of memory space, which implies we can have 2048 pH readings logged in the memory. Thus, a large numbers of readings can be obtained

over a long period of time, providing substantial data for analysis. The measurement frequency can be set by adjusting the timers. This avoids the need for the microcontroller to continuously poll for new pH value, thus saving battery life.

4. Conclusions

This paper described the successful implementation of a data acquisition and data logging technique for analysis and data sharing purposes. A low-cost device was built by designing the signal conditioning circuit using inexpensive components and avoiding the use of external memory (i.e. flash card) by exploiting the on-chip and unused flash memory. Power consumption is reduced by using timers to trigger the pH sensing and processing of the data versus using polling for the same operation. The recorded data can prove extremely useful in monitoring soil pH or lake and river water pH. The system can also be used effectively in the fields of food services, chemical research and engineering which require constant pH monitoring and data sharing.

The efficiency of the device can be extended by introducing sleep modes in the microcontroller, thus minimizing the power consumption. Accuracy can be increased by taking into account the variation in sensor output voltage with changes in environment temperature.

5. References

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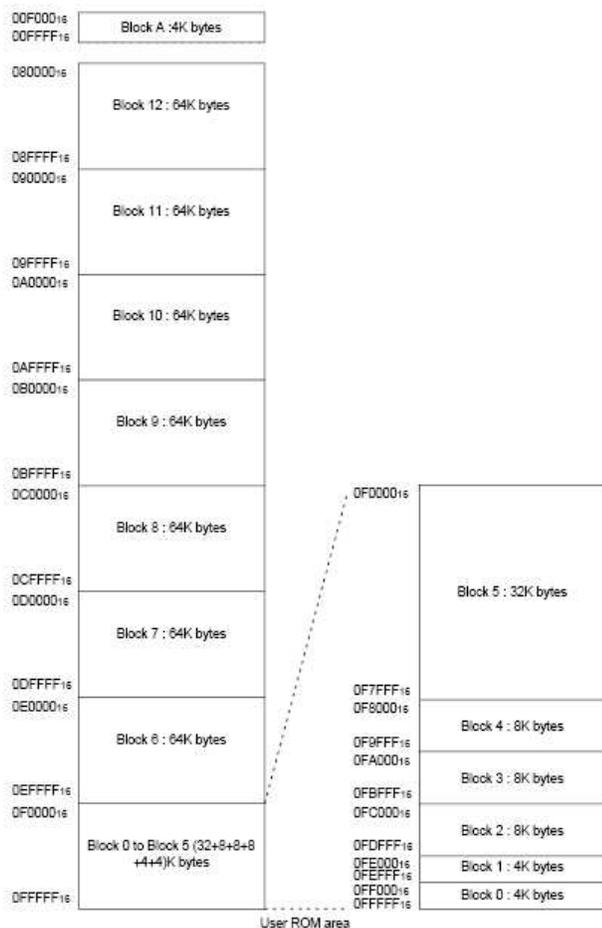


Fig. 4: Flash Memory Block Diagram [7]