# Measurement of Power Consumption by Various Components in an Embedded System

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***Abstract:*** **The Accurate measurement and analysis of pH data is necessary for various applications from agriculture sector to clinical laboratories. Preferably an inexpensive hand-held unit is needed for these applications. This paper presents development of embedded systems for measurement of pH using 8051 microcontroller. In Battery operated embedded systems, power saving is of paramount importance without compromising performance. It is proposed to measure power consumed by various components of an Embedded System. Once the power consumption is known, methods of its minimization can be implemented.**

***Keywords— Microcontroller, pH sensor, Power measurement.***

## I. INTRODUCTION

The pH meter has innumerable applications in industry and R&D laboratories. Although several attempts have been made to design analog and digital pH meters, it suffer from limitations like compactness, complexity in design, lack of storage and serial communication facilities etc., which are very important for research applications. Then microcontroller 8051 based pH meter overcomes the above difficulties. The Hydrogen ion concentration in the solution is measured as pH. The pH scale ranges from 0 to 14. A solution with pH 7 is considered as neutral and with pH 0 as highly acidic and with pH 14 is considered as highly basic. 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. The microcontroller computes mV readings from the ADC chip and converts it to pH scale. Energy efficiency is one of the main factors to be considered in designing an Embedded System. Estimation of Power Consumed by an Embedded System plays vital role while development of battery powered equipments. Lesser power consumption results in longer delay between successive recharges. Also it reduces amount of heat dissipation, resulting in lower packaging cost, cooling and increase in reliability. Once the power consumption is known, various techniques can be used to minimize it.

## II. EXPERIMENTAL SETUP

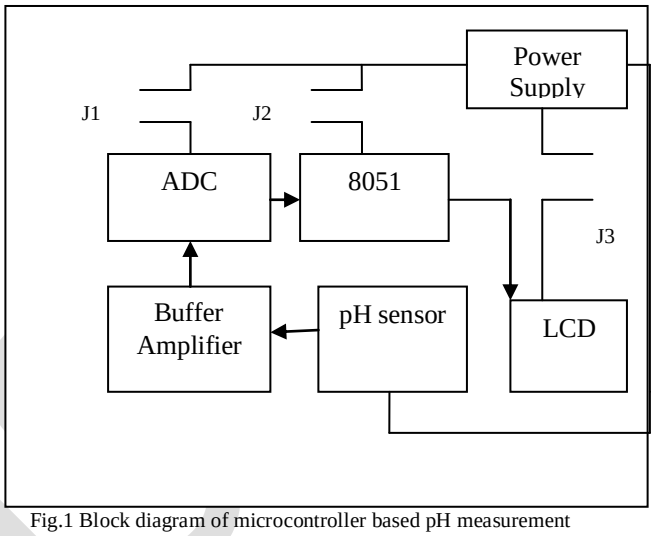


Fig.1 Block diagram of microcontroller based pH measurement

The proposed setup is shown above. J1-J3 is used to measure current. They are shorted when measurement is not required.

*1. pH probe –*

The meter is designed to read the DC potential of + 1.0000 full scales. The glass electrode for pH measurement produces approx. +414mV output for pH 0-14. This makes the meter is able to use with many types of electrodes. The specification is as follows.

- Measurement range: 0.00-14.00 pH
- Resolution: 0.01 pH
- Accuracy: ± 0.05 pH
- Operating temperature: 0ºC-50ºC
- Dimensions: 150mm
- Cable length: 1.2m (3.93ft)

Fig.2 pH probe

*2. MICROCONTROLLER 8051 –*

The 8051 microcontroller is an 8-bit microcontroller introduced by Intel Corporation. this microcontroller has 128 bytes of Random Access Memory(RAM), 4K bytes of on-chip Ream Only Memory(ROM), two timers, one serial port and four port(each 8-bits wide) all on a single chip. The Central Processing Unit (CPU) can work only on 8-bit of data at a time. The 8051 has four I/O ports, each 8-bit wide.

*3. ADC 0808 –*

Analog-to-digital converters are among the most widely used devices for data acquisition. We need an analog to digital converter to translate he analog signals to digital numbers so that the microcontroller can read and process them.

## III. CIRCUIT DIAGRAM

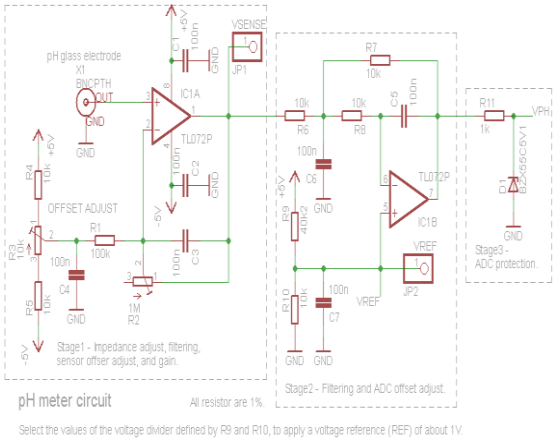


Fig.3 pH measurement

The electrode is placed inside the beaker filled with a solution whose pH is to be measured. The glass bulb welded at the end of the measurement electrode consists of lithium ions doped to it which makes it act as an ion selective barrier and allows the hydrogen ions from the unknown solution to migrate through the barrier and interacts with the glass, developing an electrochemical potential related to the hydrogen ion concentration. The measurement electrode potential thus changes with the hydrogen ion concentration. On the other hand, the reference electrode potential doesn't changes with the hydrogen ion concentration and provides a stable potential against which the measuring electrode is compared. It consists of a neutral solution which is allowed to exchange ions with the unknown solution through a porous separator, thus forming low resistance connection to complete the whole circuit. The potential difference between the two electrodes gives a direct measurement of the hydrogen ion concentration or pH of the system and is first preamplifier to strengthen it and then given to the analog to digital converter , in which the analog data is converted into specified digital signal and then gives corrective digital signal to the 8051 microcontroller. In 8051 microcontroller signal coming from ADC 0808 compared with the data stored in the log or in memory and find out exact result and displayed on the LCD.

$$U = E_{pH} - E_{ref}$$

$E_{pH}$ – Voltage potential of measurement electrode

$E_{ref}$ – Voltage potential of reference electrode

The pH is calculated based on the Nerns't equation which states that change in total potential for every change in pH is

U = -kTpH

k- Boltzmann's constant, T- temperature

## IV. POWER MEASUREMENT

There is always great demand for technology which brings energy efficiency resulting in more work with lesser amount of energy. Focus is to reduce power consumption without affecting Quality of Service (QoS). In this era of information technology, usage of high tech gadgets like computers, mobile phones, video games and other embedded electronic devices is increasing rapidly. According to a formula based on the Arrhenius Law, component life expectancy decreases 50% for every $10^0$C temperature increase. Thus, reducing a component's operating temperature by the same amount (consuming less energy), doubles its life expectancy. Embedded power consumption estimation can be classified into two methods, measurement-based and simulation-based. In the simulation-based approach a simulation model of the target hardware is used to run the applications and calculate the energy consumption of each part of the system. This approach needs the simulation model of all hardware modules that are mostly unavailable or very expensive. Measurement-based methods use data obtained from a physical target device. The main advantage of measurement-based methods is high accuracy in the energy estimation due to the real values obtained from the target platform. Figure 4 shows experimental setup used.

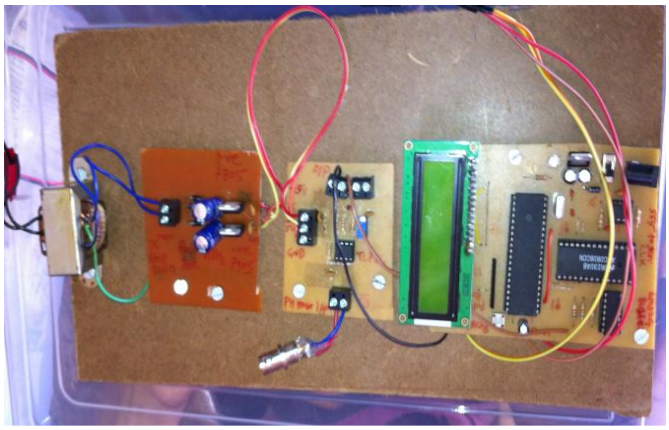

Fig.4. Experimental setup for pH measurement.

## V. RESULTS AND DISCUSSION

The readings obtained by the setup are compared with standard values of buffer solutions. Table 1 shows the

reading obtained and standard values. It is observed that fairly good results can be obtained with proposed method.

| Sr.no | Solution | Standard pH value | Reading obtained | % error |
|---|---|---|---|---|
| 1 | Std. buffer sol. | 4.2 | 3.94 | 6.1 |
| 2 | Standard buffer sol. | 9.3 | 8.96 | 6.5 |
| 3 | Distilled water | 7 | 6.43 | 8.14 |

Table no- 1. pH measurement

After measuring pH values, the current taken by various components are measured. The experimental setup is shown in figure 5. The power consumed by various components is calculated and is compared with values given in data sheet. Table 2 shows the readings obtained and values obtained from data sheet.

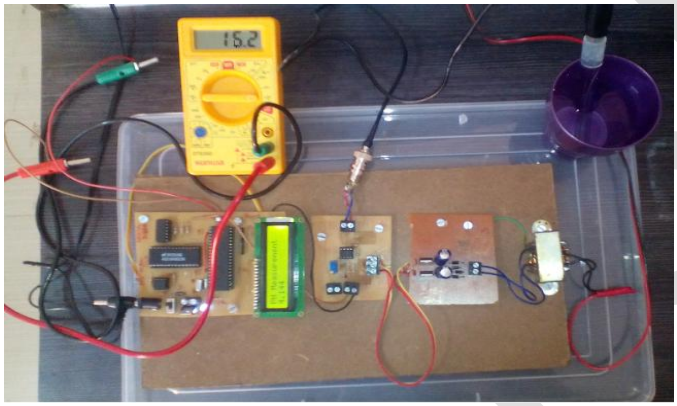

Fig.5. Experimental setup for power measurement.

| Sr. No. | Module | Standard value watt | Measure value watt | %error |
|---|---|---|---|---|
| 1 | Entire circuit | | 0.132 | |
| 2 | 8051 | 0.074 | 0.081 | -8 |
| 3 | ADC | 0.03 | 0.035 | -16.6 |
| 4 | LCD | 0.012 | 0.016 | -6.66 |

Table No.-2. Measurement Power consumption

## VI. CONCLUSION AND FUTURE WORK

Once the power consumption is known, different techniques to save power in battery operated system can be developed. Power saving modes of 8051 viz, Idle mode and Power down mode can be used to further save power. Power can further be saved by proper selection of display.

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