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PC CONTROLLED ON-LINE pH MEASUREMENT AND CONTROL SYSTEM USING INDIGENOUS pH TRANSMITTER

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Abstract

An indigenous pH transmitter has been developed to use with an industrial grade pH electrode. It has an output of 4-20mA corresponding to 0-14pH. Present paper describes the design aspects of the transmitter and its use in a PC based on-line measurement/ control system.

1.0 INTRODUCTION

Hydrogen ion concentration is an important parameter in all chemical and electrochemical processes. It indicates whether a solution is acidic, neutral or alkaline. pH is defined as the negative logrithm of hydrogen ion concentration. Mathematically it is represented by the following equation

$$pH = -\log_{10}[H^+]$$

Even though there are many reports on the development of pH meters [1-5], based on analog as well as digital circuits using microprocessors, microcontrollers and personal computers, much attention has not been given to the development of pH transmitters which are vital in industrial atmospheres. These transmitters are used where the signal is to be transported over a long distance. They are more important in industrial sites with significant interference from electrical sources. This communication discusses the design and development aspects of a pH transmitter and its use to monitor/control the pH using a personal computer.

2.0 PRINCIPLE OF MEASUREMENT

pH is sensed using a glass electrode with a special type of glass membrane which is sensitive to hydrogen ions. When the glass electrode, along with a reference electrode is dipped in a solution, a potential is developed proportional to the hydrogen ion concentration in the solution. In general the glass electrode develops 59.1 mV/pH at 25°C. A normal glass electrode develops a voltage of 413.7 mV at zero pH, 0 mV at 7 pH and -413.7mV at 14 pH. The voltage output of the electrode is also temperature dependent. The normal drift in voltage is about 0.2 mV/°C/pH and is almost linear from 0 to 100°C. So, for accurate measurement of pH, temperature correction must be given.

3.0 HARDWARE

Fig.1 shows the complete block diagram of the PC based pH measurement and control system. It mainly consists of a buffer amplifier, a signal conditioning circuit, a transmitter, a receiver (1-V converter), an add-on card and the personal computer system. The buffer amplifier receives the pH signal from the sensor. The output from the buffer amplifier is temperature compensated and signal conditioned to raise the signal level to a value suitable for the transmitter input. A current to voltage converter receives the transmitter output and converts it to an equivalent voltage, which is fed to the personal computer through an ADC and I/O card. Then the computer calculates and displays the pH value.

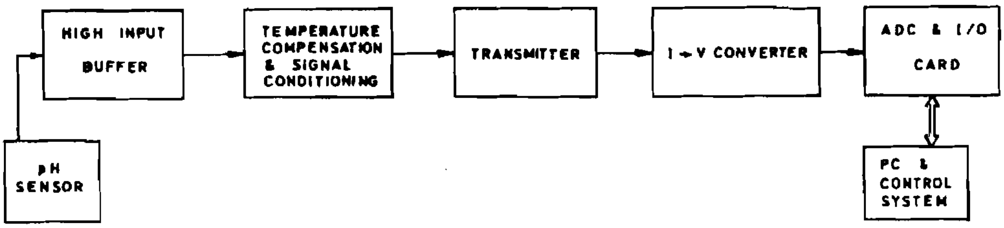

Fig.1 Block diagram of PC based pH measurement and control system

3.1 Transmitter

Fig.2 shows the block diagram of the transmitter. The pH is sensed by an industrial grade epoxy combination electrode whose output is fed to a voltage follower circuit which has got a very high input impedance. As the internal resistance of the electrode is of the order of 10^8 to 10^9 ohms, the buffer amplifier stage has been designed to receive the signal from the sensor. The developed circuit uses the integrated circuit CA 3140 as buffer which has an input impedance of 10^{12} ohms. As the output of the voltage follower varies from positive to negative polarity, [+413.7 mV to – 413,7mV when pH changes from 0 to 14 at 25°C] an unipolar generator has been designed to convert the bipolar voltage into an unipolar voltage. The output of the unipolar generator varies linearly from 0-140mV when the pH changes from 0 to 14pH. The temperature compensation is applied in the differential amplifier stage. The transmitter also has a built in circuit for temperature measurement for the purpose of temperature compensation. This circuit is designed for an optional temperature sensor based on IC AD590. This IC is a temperature transducer with a linear current output of 1 mA/K. The sensor has a wide temperature range of – 55°C to +150°C and an excellent linearity of 0.3°C over full range. It can be operated on wide power supply range of +4V to +30V. The sensor output is signal conditioned and scaled up to a value of 10mV/°C. This signal is made use of for temperature compensation at the differential amplifier stage. The output of this stage is further conditioned and scaled up to vary from 0 to 5V when the sensed pH varies from 0-14. This signal is fed to the transmitter. In the designed circuit Burr-Brown IC XTR 110 has been used as transmitter. It is a precision voltage-to-current converter designed for analog signal transmission. It has 0.005% maximum linearity and can be operated on a wide supply range of 13.5V to 40V. The transmitter has been designed to accept input of 0 to 5 Volts giving a corresponding output of 4 to 20mA. Following are the specifications of the developed transmitter.

Range 4 to 20mA	0.00 to 14.00 pH
Accuracy ±0.02 mA	±0.02pH

Resolution ±0.01 mA	±0.01pH
Temperature compensation	Adjustable from 0 to 100°C
Calibration	Independent trimmers for offset & slope
Sensor	Industrial grade combination electrode
Power supply	230V, 50Hz

Fig.3 shows a detailed schematic diagram of the pH measurement and control system using the indigenous transmitter. The current output received from the transmitter is converted to corresponding voltage using Burr-Brown IC RCV 420. This integrated circuit is a precision current-loop receiver designed to convert a 4-20mA input signal into a 0-5V output signal. This has got a 0.1% overall conversion accuracy and a high noise immunity. The output of the receiver is fed to the input of a PC add-on card. A PC add- on card has been developed for this purpose with address selection facility, a 12-bit analog to digital converter, a programmable peripheral interface with I/O lines and relay driver circuits for activation of solenoids. Digital I/O lines are used in the pH control mode. As per the set limit of pH, I/O lines activate the driver circuits and the solenoid valve opens facilitating the addition of buffer solution to adjust pH of the bath.

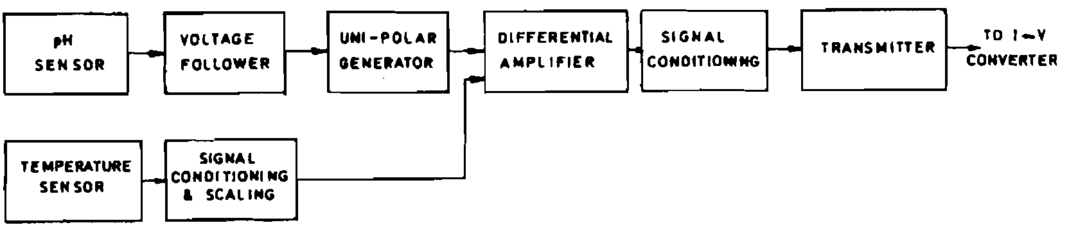

Fig.2 Block diagram of the pH transmitter

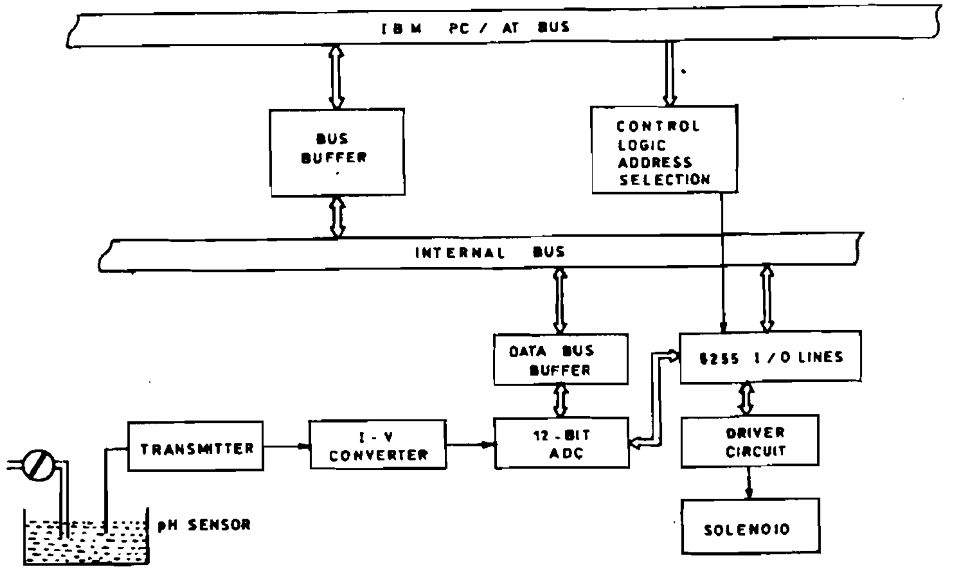

Fig.3 Detailed schematic diagram of the PC based pH measurement and control system

4.0 SOFTWARE

The flow chart of the developed software is shown in Fig.4. The software written in C is versatile and user friendly. It has two modes, one to monitor the pH and the other to monitor and control both. User has the provision to set start time, end time and scan interval in the measurement mode before proceeding to the measurement. In control mode additional provision is provided to set the pH limits. The ADC senses the signal from transmitter through the receiver and the corresponding pH value is directly displayed on the computer terminal. The system senses, calculates and displays pH every one second or any interval set by the user. While monitoring, the software also generates a data file, the hard copy of which can be had on a printer. The data file can be processed in Microsoft Excel to obtain a graph of pH versus time.

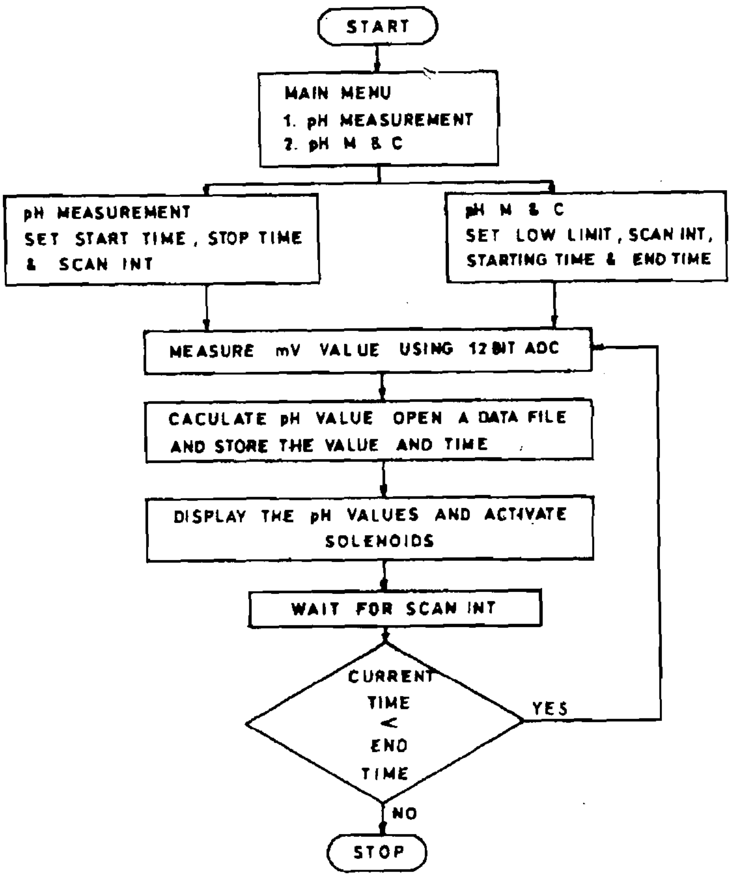

Fig.4 Flow chart of the pH measurement and control system

5.0 RESULTS AND CONCLUSION

Using pH buffers and other solutions and measuring transmitter output the transmitter performance was evaluated. Later the entire PC based system was used to measure the pH of different solutions. The results obtained are presented in Table 1. The first column shows the pH values of three buffers and an experimental bath obtained using a conventional pH meter.

Second column shows the measured values of the transmitter output for same solutions. The output current was measured using HIL 2615 4½ digits multimeter. Third column shows the pH values obtained by calculation from the transmitter current output. Fourth column shows the pH values obtained by measurement as displayed on the computer terminal. It can be seen that the pH values in first and third column closely agree which indicates that the transmitter has excellent performance. Again the pH values in the fourth column indicate that the entire PC based on-line measurement system works quite satisfactorily.

pH by conventional meter	Transmitter output(mA)	mA converted to pH	Display in the computer terminal
4·01	8·56	3·99	3·98
7·00	12·01	7·01	6·98
9·2	14·48	9·17	9·16
8·56	13·79	8·57	8·56

Table 1 Experimental results

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