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PC based system for conductivity measurement

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ABSTRACT

A PC based system for conductivity measurement has been designed and developed for chemical rate determination. A precise operational amplifier (LM308) is used as amplifier for measuring conductivity of electrolytic system. The temperature measurement is also provided in the system since the conductivity of the solution varies with temperature. The paper deals with the hardware and software details.

INTRODUCTION

Electrolytic conductivity is a measure of the ability of a solution to carry an electrical current[1]. Traditionally, the measurement of electrolytic conductance has been one of the most accurate and precise of all electrochemical techniques. Conduction of an electric current through an electrolyte solution involves migration of positively charged species toward the cathode and negatively charged ones toward the anode. The conductance, which is a measure of the current that results from the application of a given electrical force, is directly dependent upon the number of charged particles in the solution. All ions contribute to the conduction process, but the fraction of current carried by any given species is determined by its relative concentration and its inherent mobility in the medium.

The conductance of a solution is the reciprocal[2-3] of the electrical resistance and has the units of ohm^{-1}, i.e., C = 1/R, where R is the resistance in ohms.

Conductance is directly proportional to the cross sectional area A and inversely proportional to the length "l" of a uniform conductor. Thus,

C = G*(A/l)

where G is proportionality constant called the specific conductance or conductivity. 'A' and 'I' are numerically equal, the specific conductance becomes the conductance and hence it can be measured in terms of conductance.

Instrumentation

The block diagram of the system is shown in the figure 1. The functional blocks of the system are given below.

1. Conductivity Cell
2. Sine wave generator
3. Unity gain amplifier
4. Temperature measurement and compensation
5. Electronic relay (OMRON G6A274P)
6. RMS to DC convector (MAX636)
7. 12-bit A/D convector (ICL7109)
8. PC interface (PC and 8255 PCI Card)

The complete photograph of PC based system for conductivity measurement is shown in figure 2. The salient features of the individual blocks of the system follow.

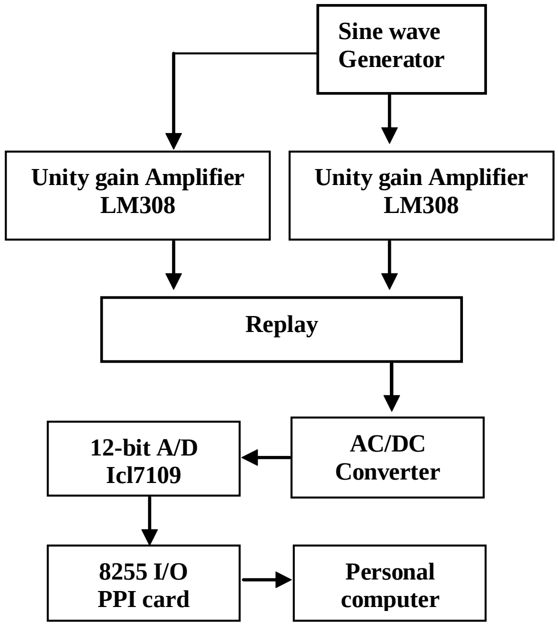

Figure 1: Block diagram of PC based system for conductivity measurement

Figure 2: The complete photograph of PC based system for conductivity measurement.

1. Conductivity cell

The conductivity cell consists of a pair of electrodes that are firmly located in a constant geometry and which are immersed in an electrolytic solution whose conductivity is to be measured. The cell used in the present study consists of two platinum electrodes of $1cm^2$ cross sectional area that are separated by a distance of 1cm. The cell constant of the cell used in the present study is 1.01.

2. Sine wave generator

A.C source consists of function generator, buffer and transformer. A function generator[4] is designed using IC8038 to generate sinusoidal signal for the excitation of the cell. Since it's excellent amplitude and frequency stability it has been chosen in the present study. The amplitude and frequency of generator is exactly adjusted to 1V and 1 KHz respectively. To avoid the loading effects, the sinusoidal signal from the function generator is applied to cell through an isolation transformer[5]. As the output signal of the function generator cannot be given to transformer directly, an emitter follower is employed to drive the transformer.

3. Unity gain amplifier

LM308[6] used as input unity gain amplifier for both sample (Conductivity cell) and reference. Both are connected in non-inverting mode with unity gain and with selectable feedback resistor network, for the selection of input. The output of the amplifiers is given to an electric (OMRON male) relay, which can be controlled through PC. The output of AC signal converted to DC with MAX636. Which is a RMS to DC converter. The conductance can be calculated by using the formula.

$$V_0 = R_f / R_i + R_c$$

where R_f = Feedback resistance, R_i = Input resistance, R_c = Resistance of the conductivity cell, and 1/RC is the conductance of the electrolytic solution.

4. Temparature measurement and compensation

Accurate conductivity measurement depends on temperature compensation[7]. Hence, an integrated circuit temperature sensor LM335 is used in the present study to measure temperature of the solution[8]. The LM335 is Kelvin's sensor i.e., its output is 2.73±V/°C. In order to get the temperature in degree Celsius, the voltage 2.73 must be subtracted from the output of the sensor. Operational amplifier produces a reference voltage of 2.73V, which is subtracted from the output of the sensor using an operational amplifier in differential mode. The differential amplifier produces a change

10mV/°C. The output of differential amplifier is given to the personal computer through a relay.

5. Electronic relay

An electronic relay of OMRAON G6A274P is used in the present study to select the outputs of sample and reference amplifier outputs given to RMS to DC converter by controlling through PC using Portc.1. It requires for its operation +5v dc power supply.

6. RMS to dc converter (Max636)

The output of the op-amp is an AC signal. For processing this through PC have to converted in to DC, for which in the present study MAX636[9] RMS to DC converter used that can accepts upto 200mv ac as max input.

7. Analog to digital converter

The analog to digital converter is the core of any data-acquisition system designed to transform data in the form of continuous analog variable into a discrete binary code suitable for digital processing. First and foremost, the required resolution of the converter must be determined. This will determine the number of recognizable quantization intervals in the ADC transfer function.

Intersil's 12-bit A/d converter ICL7109[10] is used to digitize the analog voltage. The 12-bit binary plus polarity and over-range outputs can be directly interfaced to a microprocessor bus. The computer through the 8255 programmable peripheral interface controls the ICL7109. The features are a true differential input, the ability to measure both positive and a negative input voltage, and anon-chip reference voltage generator.

The data conversion equation is

$$\textbf{Data out} = 4096 \times V_{in}/2 \times V_{ref}$$

An input of +1 V will generate the same 12-bit data output as an input of -1v. However, the POL pin will be at logic high for positive input and at logic low for negative. When the run/hold input is tied high, the ICL7109 continuously performs A/D conversion with a fixed length of 8192 clock cycles per conversion. The status pin indicates the end of conversion.

8. PC interface

The personal computer is used in the present study. The ADC card using the ICL7109 (12-bit A/D converter) is developed and interfaced with the computer through the ports of 8255 of I/O card, which is inserted in the I/O slot of the motherboard of the computer.

The addresses of the ports used are as follows

Port	Address
A	D080h
B	D081h
C	D082h
CR	D083h

The port-A is connected to the low-order data bits of the ADC. The Port-B is connected to the high-order data bits of the ADC. The Port-c is used to control pins of the ADC and Multiplexer. The D25 connector is used to connect the I/O card to ADC card. The necessary software written in C language is used to implement the analog to digital conversion.

The measurement of conductivity using a personal computer conceptually described when the conductivity cell is dipped in the acquirers solution .The excitation for the conductivity cell is a sine wave, generated by a function generated IC 8038.Its frequency is adjusted to 1KHZ with 150mv amplitude. The conductance amplifier is wide band high gain operational amplifier, in which the difference feedback resistance can be selected to obtain different conductance range between 0.2 and 10-7 ohms this is followed by a AC to DC converter of max 636.

An analog to digital convector converts the analog information into corresponding digital information. Some additional electronic circuitry acts as interface between A/C circuit and the personal computer .The program executing on the computer with direct the computer when to the digital data from the interface peripheral, how to process the values and how to display final information.

Software

The role of the software in the present study is given below.

a. To initialize the ports of 8255
b. To read digital data through A/D converter.

The flowchart of the program is presented in the figure 3. The detailed program is written in the C language.

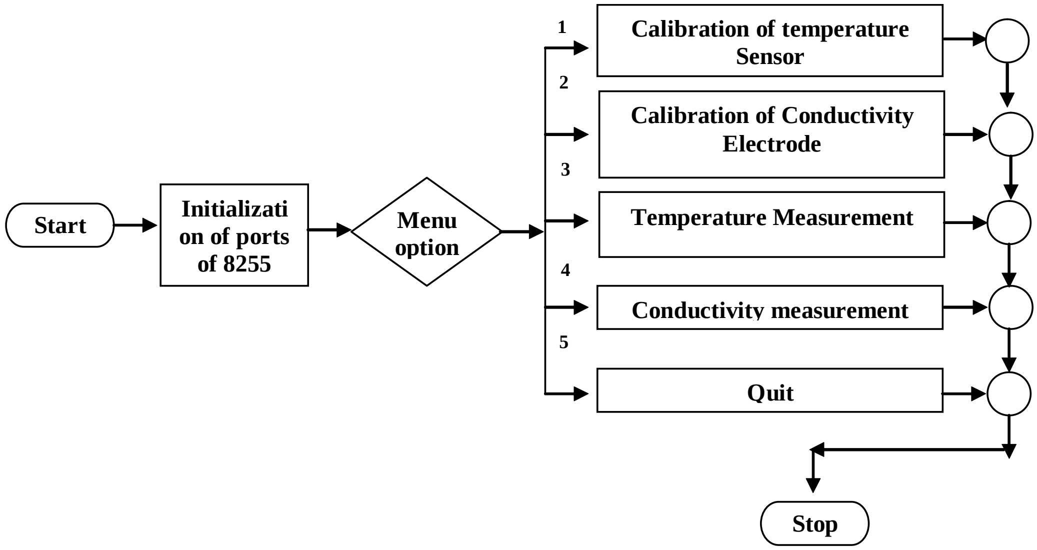

Figure 3: Flowchart of PC based system for conductivity measurement

TABLE 1: Equivalent conductance at 25°C in Ω^{-1} cm^2

S. no	Resistor/ Solution	Solution normality	Specific conductance at 25°C (10^{-3}mhos cm^{-1}) present study	Specific conductance at 25°C (10^{-3}mhos cm^{-1}) literature values[11]
1	500 Ω	-	1.9989	2.0000
2	1000 Ω	-	0.9992	1.0000
3	10.0 KΩ	-	0.0993	0.1000
		N	12.849	12.856
4	KCL	N	1.4090	1.4087
		1N	111.3435	111.347
		N	10.865	10.878
5	$AgNO_3$	N	12.479	12.476
		1N	94.1473	94.2602
		N	10.873	10.878
6	Nacl	N	1.1916	1.1924
		1N	94.2167	94.2600

Concentration	Eletrolytic solution	ystronix	Radio Meter[11]	Present study
0.001M	HCL	422.61	422.74	422.27
	KCL	147.87	147.81	147.56
	NAOH	246.32	246.13	245.94

RESULTS AND DISCUSSION

After making the appropriate adjustments both in the hardware and software and also following the calibration procedures as mentioned earlier, the instrument is tested with standard solutions for conductance measurements. The results of measurements are presented in TABLE 1. The values of these measurements agree with the standard values. The instrument is quite successful in measuring the conductance with an accuracy of $\pm$0.5%. Measuring the conductance of the solution continuously for a period of 24 hours, which is extremely good, tests the stability of the system. Automatic temperature compensation of conductance is also incorporated in the design of the system. The real time measurement with a provision to store the results is also tested.

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