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COMPUTERIZED SETUP FOR THE DC POLARIZATION TEST

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ABSTRACT

With various investigations of electrolytes materials, it is very import to identify their various behavior patterns and properties. As far as electrolytes are concerned, their conductivity is a special feature to be studied and also the nature of conductivity whether ionic or electronic or mixed is of prime importance. Transference number measurement is one of the simplest methods of evaluating nature of conductivity. For measurement of transference number, DC polarization test is commonly used. In this study, it was attempted to design a computerized system to DC polarization test. The features that were given priority in the designing are cost effectiveness, better data acquisition and compatibility with most of the PCs and laptops. This system has been designed using ADS1110 (16 bit AD converter with self-calibrating) and pic 16f877a for monitoring the slowly varying signals. Firmware was written in CCS C v.4 compiler and burnt to the microcontroller by using PICkit2 programmer. Another program was also developed in Matlab R1012a which allows to display the graph of current vs. time. From the data represent on the graph we can clearly separate the materials as ionic or electronic.

Keywords: *Electrolytes, transference number, DC polarization test*

1.0 INTRODUCTION

Solid electrolytes are solid-state materials that possess an electric conductivity partially or wholly due to ionic displacements.[1] When solid electrolytes possess conductivity due to both ionic and electronic transport, it is necessary to know the fraction of the conductivity due to ions and electrons.[2]

The parameter that is used to describe the contributions of individual species (ionic or electronic) in a solid or liquid on conductivity is the transference number. This is defined as the fraction of the total electrical current that is carried by a particular species when an electrical potential difference is imposed upon the adjacent electrodes. The transference number of ions as t_i, and electrons as t_e, can be defined as;

$$t_i = i_i / i_T \quad (1)$$

and

$$t_e = i_e / i_T \quad (2)$$

where $i_T = i_i + i_e$[3] (3)

In most of the liquid / aqueous electrolytes as well as ion conducting polymer electrolytes, cations and anions both contribute significantly to the total ionic conductivity and the electron /hole conduction is negligibly small. Hence, separate cationic/anionic transference numbers are also important parameters which can be mathematically calculated by following equations:

$$t_+ = \sum I_+ / \sum (I_+ + I_-) \quad (4)$$

$$t_- = \sum I_- / \sum (I_+ + I_-) \quad (5)$$

where t_+ is cationic transference number, t_- is anionic transference number and Σ (I+ + I-) is the total current expressed as the sum of the partial currents due to mobile cations and anions present in the electrolyte.[4]

Several techniques have been used for measuring the transference numbers of various electrolyte systems. Among them, DC polarization is a widely used method. D.C. polarization technique was used for the first time by Wagner [1975] to determine transference number of ions and electrons separately. A d.c. electric potential is applied across the sample sandwiched between two blocking electrodes and the current is monitored as a function of time. A typical 'current vs. time' plot is shown in Fig. 1.

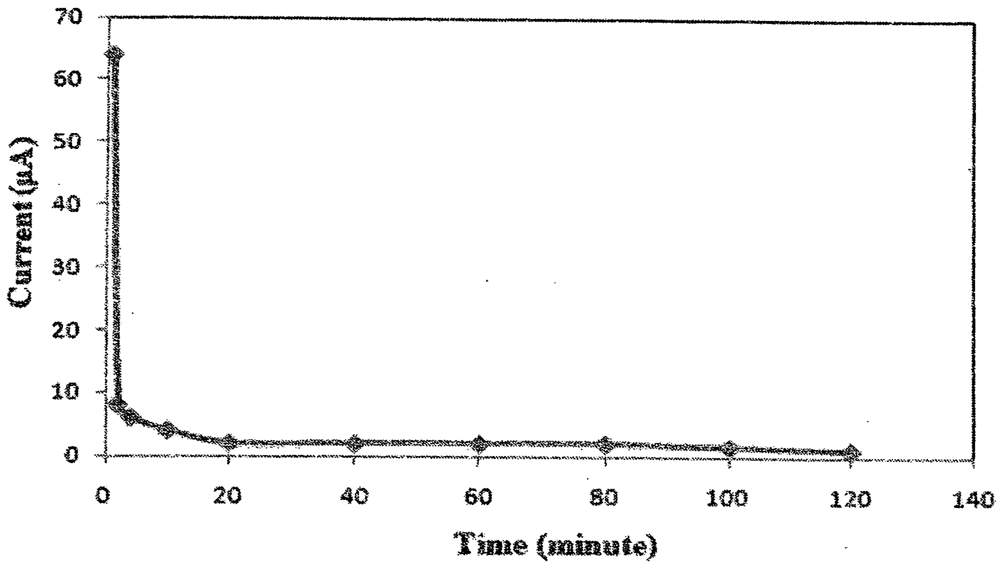

Figure 1: Current vs. time plot obtained by DC polarization test

The peak current obtained initially decreases rapidly with time due to polarization of mobile ions at the electrode / electrolyte interface. Afterwards, the current either approaches zero (for pure ion conductor) or attains a residual constant value (for mixed ionic/electronic conductor). If the sample is a pure electronic conductor, there will be no current reduction. The initial total current (I_T) is either due to ions solely or as a result of combined ionic and electronic conduction, while the constant residual current is only due to electron conduction. From the 'current vs. time' plot the ionic (t_i) and electron (t_e) transport numbers can be determined using equations 1, 2 and 3[4].

Nowadays various methods are used in DC polarization technique. But they are time consuming because parameters resulting from three independent measurements have to be combined for evaluating a single transference number[5]. Also there are advanced systems for transference number measurement such as Autolab potentiostat/galvanostat analyzer. But its maintenance and repair costs are quite high.

The objective of this study is to design a simple computerized system to carryout DC polarization test. It is a cost effective simple system for measuring of the voltage across a shunt resister and converting of analog data into a digital value. An ADS1110 was used to do the analog to digital conversion and a pic microcontroller to get digital values from the ADS1110 via I^2C communication system and they were sent to the serial port. For microcontroller programming, PIC C was used, Matlab R2012a version was used for graph plotting part. This application responds quickly and automatically to active at the port, without having to waste time checking.

2.0 EXPERIMENTAL

2.1 Data acquisition unit

An ADS1110, 16f877a pic microcontroller, a MAX232 &a RS 232 serial port were used to design the data acquisition unit.ADS 1110 is a continuously self-calibrating, precision analog to digital converter IC with differential inputs and upto 16 bits of resolution. The ADS1110 uses an I^2C – compatible serial interface and consists of an onboard programmable gain amplifier, which offers gains up to 8, allows smaller signals to be measured with high resolution. Two edges of shunt resistor (R_s) was connected to pin no.1 (Vin+) and pin no.6 (Vin-) of ADS1110 and then it read the voltage across the R_s and converted it into a 16 bit binary number. Then pin no. 3 (SCL) and pin no.4 (SDA) were connected to pic16f877a's pin 18(SCL) and pin no. 23 (SDA) respectively. Pic16f877a is a 40 pin DIP microcontroller which reads the output of ADS1110 as two separate bytes, and then it sent them through the serial port (RS232). It also has I^2C facilities inside the chip itself which allows communicating with ADS1110. These operations were controlled by the firmware. Pin no. 25 (Tx) of pic16f877a was used to send the serial data to the PC through the MAX232 driver. The mAX232 converted the TTL signal from the microcontroller into RS232 voltage level.

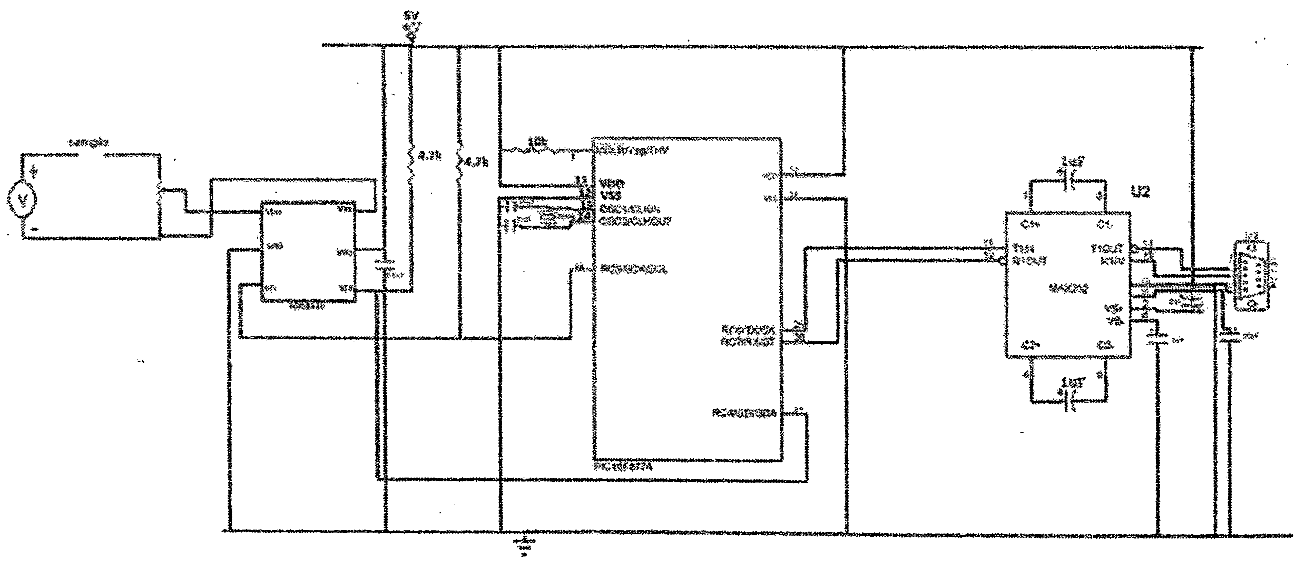

Figure 2: Hardware design of the system

The MAX232 driver IC uses some external capacitors to enhance the voltage level to RS232 level. A DB9 connector was used to connect to the COM port of the PC. The circuit was made into a PCB using TRAX MAKER 2000 software.

2.2 Software implementation

For the proper functioning of the data acquisition system, a firmware was developed and written to the microcontroller and an application program was also developed in Matlab R2012a for data representation.

2.2.1 Programming the pic 16f877a

A simple program was written in CCS C v.4 compiler for proper ADC conversion at a fixed sampling rate in ADS1110 and for sending the digitized data serially. The program was compiled to make HEX file. The generated HEX file was programmed to the pic 16f877a microcontroller using PICkit2 programmer.

The flow chart of the developed pic program is shown in Figure 3.

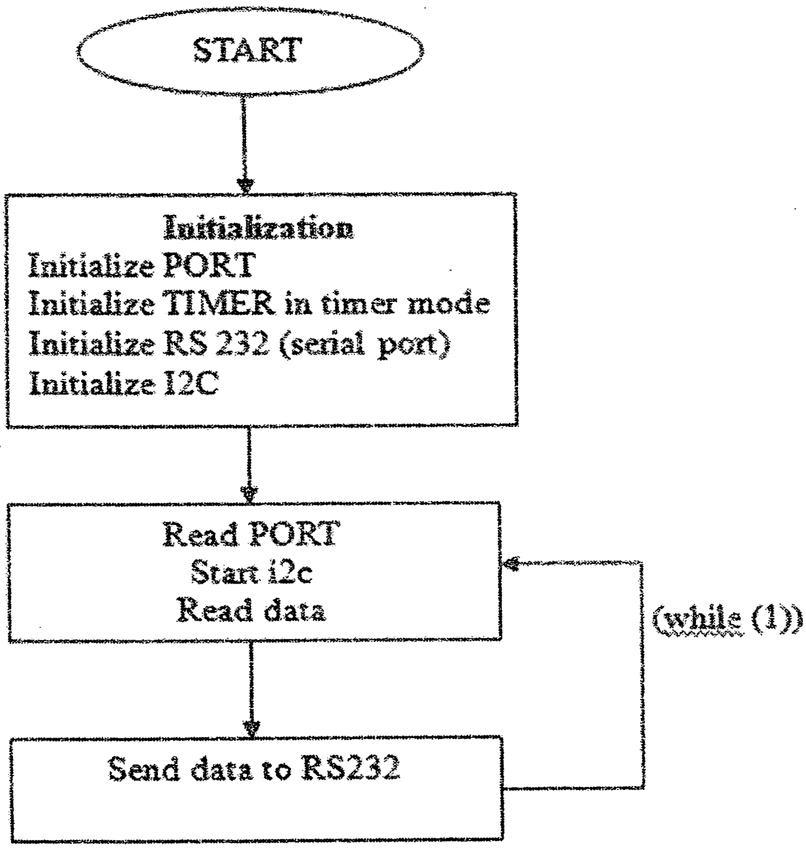

Figure 3: Flow chart of the pic program

2.2.2 *Programming in matlab*

For graphical display of acquired data with time, a program was developed in Matlab R2012a. It reads the output of the pic 16f877a microcontroller through RS232 serial port. The acquired data then was converted into a decimal value since microcontroller outputs the value as two bytes. According to the given commands a graph was plotted.

3.0 Results and Discussion

For each 20 ms, ADS 1110 converts a value into 16 bit binary number. Then the pic 16f877a microcontroller reads these digital values for every 4 s. the acquired values has been displayed graphically in a graph against time. According to the graph, it is possible to identify correctly and easily whether the new materials are ionic or electronic.

4.0 CONCLUSION

The design is a low cost, simple and compatible to PCs and laptops, as serial port is very common these days. This will be very useful in research and practical laboratories where acquisition of slowly varying conditions are required for measuring, monitoring, analysis and graphical representation of data. It can also be developed with more features and interfaced to the commonly available USB port of a PC or a laptop.

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