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INDEX

Research Paper Engineering

Instrumentation system for amperometric biosensor

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ABSTRACT

Biosensors are special chemical sensors based on biochemical mechanism. The biological recognition system usually consists of a receptor protein, antibody and enzyme which translate the information from the biochemical domain into a physical output signal. There are different types of biosensors.One of the widely used is the amperometric type of biosensor which are based on the measurements of current which is proportional to the analyte concentration. The work entitled in this paper involves in designing an instrumentation system for measuring amperometric biosensors which processes on the current signal obtained from a dummy cell which simulate as amperometric biosensor and it is based on the cyclic voltamettry principle.

Keywords : Amperometric, cyclic voltamettry, Dummy cell, Potentiostat

1. INTRODUCTION

There is an increased demand for rapid and accurate methods of detecting pathogenic bacteria, viruses, and other disease causing agents.In response to these demands biosensors are developed which are fully automated or semi-automated and in miniaturized form. The sensors that use electrochemical detection principle have become more popular such as amperometric type of biosensor and are widely utilized in many applications, such as disease diagnosis, environmental monitoring, and food inspection due to their fast analysis, high selectivity, high sensitivity, and simplicity.An amperometric sensor acts as a transducer which converts the chemical quantity of analytes within a given solution into electrical signal. In general two forms of output signal are generated namely potential and current.Each requiring its own readout circuit. Amperometric sensorswhich generate a current signal utilize a potentiostat as an interface circuit during the gathering of signals. Potentiometric electrochemical sensors generate a potential signal utilize an instrumentation amplifier (IA) as the readout circuit. A back-end circuit system is necessary for acquiring sensor information and transmitting the acquired data as in Fig1.Amperometric biosensors basically relay on the principle of cyclic voltamettry, which is electrochemical technique which measures the current that develops at amperometric biosensor. The resulting current at the cell is due to the redox reactions of solution species and the current generated is proportional the concentration of the analytes. The redox reaction (reversible) taking place in the solution can be represented as: $O + ne^{-}R$. Where O and R are the oxidized and reduced forms of the redox couple respectively.

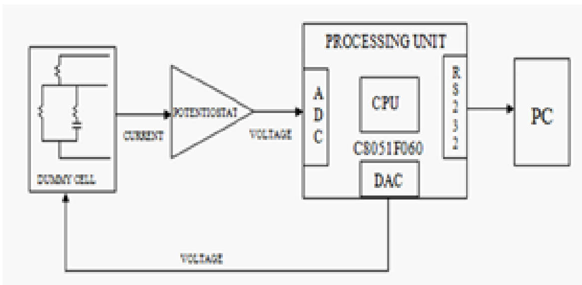
Fig1.Back-end circuit system

2.METHODS AND MATERIALS

A. The Proposed Instrumentation System

In Fig2 the schematization of the realized instrumentation System is reported.

Fig2. Block diagram of Instrumentation System



The sensible element (the dummy cell) constitutes RC network, which generates current. The conditioning circuit converts the current signal in a voltage signal which is measurable by the processing unit. The acquired voltage is processed to obtain cyclic voltagram. A microcontroller interacts with both user and instrumentation system for displaying measured results and helping the user manage the procedure.

B. Dummy cell (Amperometric Biosensor)

The equivalent circuit corresponding to the amperometric biosensor is as shown in the Fig3. Each interface of electrode can be realized by combination of resistors and capacitor network. The potential is applied between the reference electrode and the working electrode of dummy cell and the current is measured at the working electrode of dummy cell.

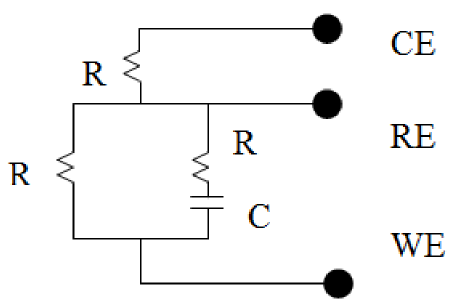


Fig 3. Block diagram of Dummy Cell

C. The Potentiostat Circuit
Potentiostat is an amplifier used to control a voltage between two electrodes, a working electrode and a reference electrode to a constant value. The potentiostat will perform the following two tasks:

1. Measure the potential difference between working electrode and reference electrode without polarizing the reference electrode
2. Compare the potential difference to a preset voltage and force a current through the counter electrode towards the working electrode in order to counteract the difference between preset voltage and existing working electrode potential.

Potentiostat can be realized by using a bipolar operational amplifier (OpAmp), Fig 4 shows the potentiostat with dummy cell.It consists of the Control Circuit, The Reference Circuit and Current Measuring Circuit.

Fig 4. Dummy cell with potentiostat

Control Circuit: The control circuit consists of the control amplifier to provide current to the counter electrode (CE) to balance the current required by the working electrode (WE).

Reference Circuit: The reference electrode (RE) is used to maintain a fixed potential across the working electrode.To ensure that current does not flow into or out of the reference electrode (RE), its potential is buffered with a voltage follower.

Current Measuring Circuit: The measuring circuit has a single stage OPAMP .As the working electrode (WE) i.e. the biosensor responds to the target analyte, a current flow is created, proportional to the concentration of the analyte. This current is then reflected across as output voltage

D. Processing Unit
The signal acquisition, conversion and processing is carried out by a C8051F060 microcontroller, that is featured with both on board analog to digital (ADC) and digital to analog (DAC)converters. The specifications of the C8051F060 are: High-Speed pipelined 8051-compatible CIP-51 microcontroller core (up to 25 MIPS); In-system, full-speed, non-intrusive debug interface on-chip10-bit 200 ksps ADC with PGA and 8-channel analog multiplexer; Two 12-bit DACs with programmable update scheduling; 64 kB in-system programmable Flash memory; 4352 (4096 + 256) bytes of on-chip RAM; External Data Memory Interface with 64 kB direct address space; UART serial interfaces implemented in hardware; Five general purpose 16-bit Timers; Programmable Counter/Timer Array with six capture/compare modules.

E. The Software
The microcontroller software module has the following main tasks: acquiring, generating and processing. The PC software is developed using Silicon Laboratories IDE, consisting of drivers for different peripherals such as LCD to display the required values, keypad acts as user interface to provide input to the system, ADC to convert the input analog signal to the module in to digital output signal and an DAC to generate a triangular waveform of required potential that is applied to the biosensor(Dummy cell). The software is very user friendly. The host via RS232 receives the data transmitted by instrumentation system and analysis of data can be done on the PC.

3. METHODOLOGY
The three electrodes of the potentiostat namely working (WE), reference (RE) and counter (CE) were connected to a dummy cell, press start button from keypad, Required input potential is generated by on board DAC of MCU and applied to dummy cell .The current generated in response to applied voltage is measured at current measuring amplifier, Obtained current signal is converted in to voltage then applied to on board ADC of MCU to obtain digital readings of applied analog voltage(current)signal. The host receives the data transmitted via RS232 by the MCU (current, applied voltage), a graph is plotted for the obtained data from serial port and graph is then investigated to obtain required results. Fig 4. Shows algorithm of the methodology

4. RESULTS AND DISCUSSION
The three electrodes of the dummy cell namely working (WE), reference (RE) and counter (CE) were connected to apotentiostat. An output triangular waveform generated from the DAC of MCU for voltage ranging from 0V to + 2.4V was applied as input as in Fig 4(a). The output across current measuring amplifier of potenstiostat were observedand cyclic voltagram for Dummy cell is plotted as in Fig 4(b)

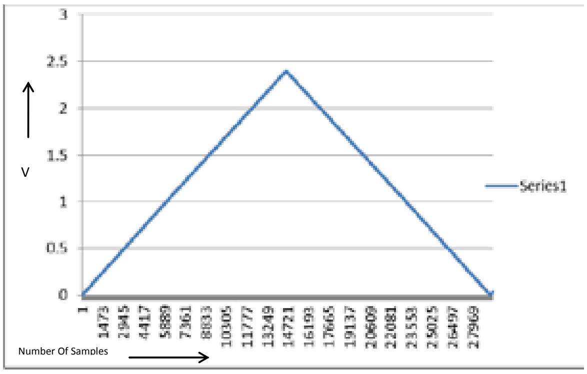


Fig 4 (a) Input voltage waveform generated from DAC of MCU

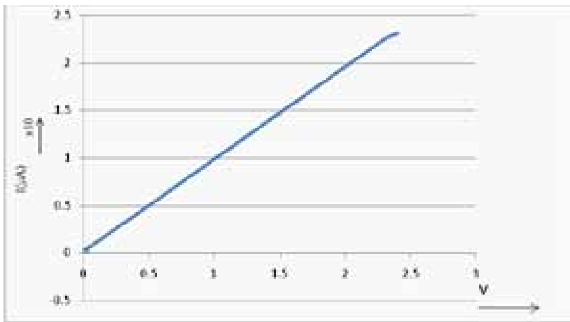


Fig 4 (b) Cyclic voltagram for Dummy cell

5. CONCLUSION
The paper presents a microcontroller based instrumentation-system for measuring current from amperometric-biosensor with the equivalent circuit for amperometric biosensor called as dummy cell, we can test the voltage range from 0v to +2.4V, which can generate current ofμA range. The necessary software to acquire, process and display the results has also been developed.

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