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## INDEX

Sr. No.	Title	Author	Subject	Page No.
1	Antioxidant activity of opuntia stricta	S. Jasmine Mary, Dr. A .John Merina	Chemistry	1-3
2	Consumers Perception and Attitude Towards Consumerism	Dr. M. Dhanabhakym, M. Kavitha	Commerce	4-6
3	Foreign Direct Investment In India & Indian Economy	Dr. M. K. Maru	Commerce	7-8
4	Service Marketing: An Imperative Ideology for Attracting Customers	Dr. Vipul Chalotra	Commerce	9-10
5	“An Evaluation of Human Resource Accounting Disclosure Practices in Indian Companies”	Dr. Nidhi Sharma Hitendra Shukla	Commerce	11-13
6	Changing Products of Life Insurance Corporation of India After Liberalization-an Overview	Dr. Niranjan Kakati	Commerce	14-16
7	Consumer Behaviour And Marketing Actions	Dr.A.Jayakumar K.Kalaiselvi	Commerce	17-19
8	Corporate Social Responsibility & Ethics in Marketing	Manojkumar Mohanbhai Parmar	Commerce	20-22
9	Regulated Market – an Overview	S. Ravi Dr.K.Uthaiyasuriyan	Commerce	23-25
10	A Socio-Economic And Statutory Approach Towards Right To Life	Manish Parshuram Pawar Dr. Ashok Pawar	Economics	26-27
11	An Analysis of the Impact of Power Sector Reforms in Haryana on the Generation, Transmission and Distribution	Dr. Pardeep S. Chauhan	Economics	28-30
12	Professional Education And Employment Of Banjara and Dhangar Community in India	Dr.Pawar Ashok S Naik Priti A. Dr. Rathod Sunita J.	Economics	31-33
13	Educational condition of Banjara and Vanjari Communities in India: An Over view	Dr.Pawar Ashok S. Tidke Atish S. Dr. Ambhore Shankar B.	Economics	34-36
14	Socio-economic Conditions of Tea Plantation Workers in Bangladesh: A Case Study on Sreemongal	Shapan Chandra Majumder Sanjay Chandra Roy	Economics	37-40
15	The impact of Yoga on Anxiety of Secondary School Students	Dr. D. Hassan	Education	41-45
16	Portfolio Writing: An innovative reflective learning strategy in Teacher Education	Dr.K.Chellamani	Education	46-48
17	Instrumentation system for amperometric biosensor	Chethan .G, Saurav Pratap Singh, Dr. Padmaja .K.V, Dr. Prasanna kumar .S.C.	Engineering	49-51
18	“Performance Analysis of WiMAX Physical Layer Using Different Code Rates & Modulation Schemes”	Harish Prajapati Mrs. B.Harita Mr. Rajinder Bhatia	Engineering	52-55
19	Design Dual-Axis Solar Tracker using Microcontroller	Jigesh R. Shah V. S. Jadhav	Engineering	56-57
20	BER Performance of DS-CDMA System Over a Communication Channel	Rahul Parulkar Rupesh Dubey Angeeta Hirwe Prabhat Pandey	Engineering	58-60

21	Effect of Strain Hardening Rate on The Clamp Load Loss Due to an Externally Applied Separating Force In Bolted Joints	Ravi Sekhar V.S.Jadhav	Engineering	61-63
22	Advances In Derivative Free Mobile Robot Position Determination	Swapnil Saurav	Engineering	64-66
23	Mechanical Behavior of A Orthodontic Retraction Loop : A Analytical And Experimental Study	Swati Gunjal V.S.Jadhav	Engineering	67-69
24	Enhancement of Surface Finish and Surface Hardness of Burnishing Process Using Taguchi Method	V. N. Deshmukh S. S. Kadam	Engineering	70-72
25	Design & Structural Analysis of an Automobile Independent Suspensions type Mac-Pherson Shock Absorber	Vandana Y. Gajjar, Nihit Soni, Chauhan Sagar, Shaikh EzazAhmed, Surti Pratik	Engineering	73-80
26	A survey on secure file synchronization in distributed system	Chhaya Nayak Deepak Tomar	Engineering	81-82
27	Design of Road Side Drainage	Mehul I. Patel Prof. N.G.Raval	Engineering	83-85
28	Study on Relation Between CBR Value of Subgrade Soil and Moisture Content	Mehul I. Patel Prof. N.G.Raval	Engineering	86-87
29	Design and Optimatization, Weight Reduction of Rear Axle Banjo Housing for Light Weight Vechicle.	S Surya Narayana	Engineering	88-90
30	Product-Mix Strategy of Jammu and Kashmir Co-operatives Supply and Marketing Federation Limited in Jammu District of J&K State	TARSEM LAL	Engineering	91-93
31	Micro Finance: A Study of Semi Urban Women Workers	Soheli Ghose	Finance	94-98
32	"Real Estate Investment Trusts (REITs): An overview of Structure & Legislative Framework"	Mr. Rohit Arora	Finance	99-101
33	Title: "Real Estate Investment Trusts (REITs): Development in India"	Mr. Rohit Arora	Finance	102-103
34	An Assessment of Relationship between Crop Production and Climatic Elements: A Case Study of Karveer Tehsil	Mr. Prashant Tanaji Patil Miss. Mugade Nisha Ramchandra, Miss. Mane madhuri maruti	Geography	104-107
35	Measuring The Performance Of Hypothetical Ltd. Using Z-Score Model	Dr. Prameela S. Shetty Dr.Devaraj K	Management	108-110
36	A Study on Factors Affecting Buying Decision of Garments in Surat City	Dr. Hormaz Dali Patel Dr. Mehul P. Desai.	Management	111-115
37	Hutchinson Essar - Vodafone – A Case Study	Vukka Narendhra	Management	116-118
38	To Study The Effect of Basement with Retaining Walls and The Behavior of The Structure	Patel Shailesh Prof. P. G. Patel	Management	119-121
39	AIDA model of Advertising Strategy	Prof.Arvind Rathod	Management	122-125
40	"A Balanced Corporate Responsibility"	Simon Jacob C	Management	126-127
41	Study and analysis Trend and Progress of Banking in India	Triveni Singh, Prof. (Dr) Sanjeev Bansal, Dr. Amit Kumar Pandey	Management	128-131
42	"Marketing Communication-an Inevitable Part of Business Activity"	Dr. Rakeshkumar R.Jani	Marketing	132-136
43	Users' Opinion Regarding Advertisements on Social Networking Siteswith Special Reference to Facebook	Priyanka Patel	Marketing	137-139

44	Bilateral Accessory Peroneal Muscle - A Case Report	Dr. Renuka B. Adgaonkar, Dr. Archana Shekokar	Medical Science	140-141
45	Decentralization and Dilemmas in Development: A Debate	Dr. N. M. Sali	Political Science	142-143
46	Study of Microstylolites from Carbonate Rocks of Kurnool Group, Andhra Pradesh, South India.	P.Madesh, P.Lokesh Bharani , S.Baby Shwetha	Science	144-147
47	Evolution Of Rural Tourism and Its Prosperity	Joysingha Mishra,	Tourism	148-150



## 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 voltammetry principle.

**Keywords : Amperometric, cyclic voltammetry, 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 sensors which 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 rely on the principle of cyclic voltammetry, 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:  $O + ne^- \rightleftharpoons R$ . Where O and R are the oxidized and reduced forms of the redox couple respectively.



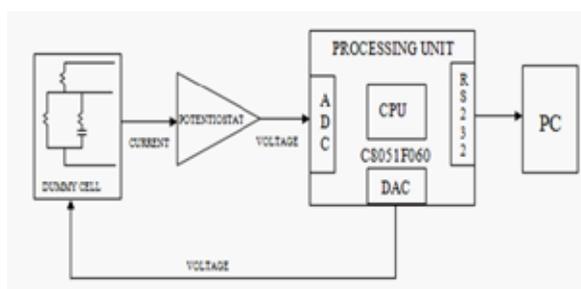
Fig1. Back-end circuit system

### 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 voltamgram. 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.

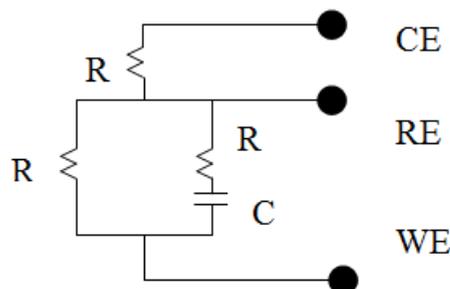


Fig 3. Block diagram of Dummy Cell

**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-chip 10-bit 200 kbps 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 in-

put 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 a potentiostat. 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 potentiostat were observed and cyclic voltogram for Dummy cell is plotted as in Fig 4(b)

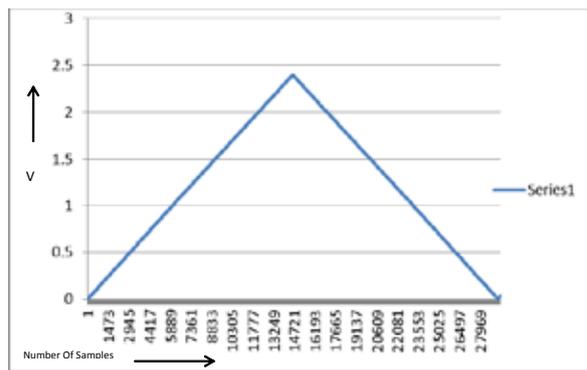


Fig 4 (a) Input voltage waveform generated from DAC of MCU

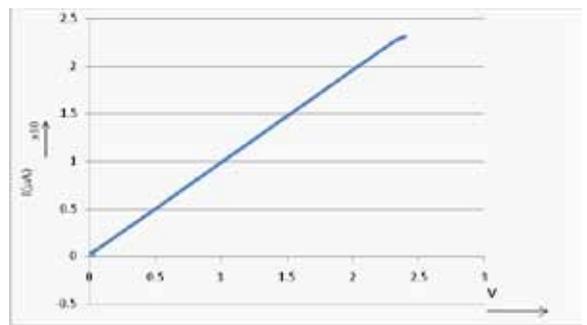


Fig 4 (b) Cyclic voltogram for Dummy cell

**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 of μA range. The necessary software to acquire, process and display the results has also been developed.

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