Faculty of Electrical and Electronic Engineering Technology

LOW COST HAND-MADE POTENTIOSTAT USING RASPBERRY-PI

DHARMINDRAN A/L MUNIANDY

Bachelor of Electronics Engineering Technology with Honours

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A project report submitted
in partial fulfillment of the requirements for the degree of
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I declare that this project report entitled "LOW COST HAND-MADE POTENTIOSTAT USING RASPBERRY-PI" is the result of my own research except as cited in the references. The project report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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I hereby declare that I have checked this project report and in my opinion, this project report is adequate in terms of scope and quality for the award of the degree of Bachelor of Electronics Engineering Technology with Honours.

Signature : 

Supervisor Name : NAJMIAH RADIAH BINTI MOHAMAD

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DEDICATION

My gratitude goes out to my beloved family, relatives, and colleagues who seem to be around for me and assisted me complete my project work smoothly. More than that , I credit this project to my respectable supervisor, Pn. Najmiah Radiah Binti Mohamad, whom had instructed me including how to conduct this suggested project and assisted me in finishing the study appropriately. I also dedicate my achievement to UTeM, who provided me all the resources I require to accomplish this effort. My gratitude also extends to everyone who has assisted me in carrying out this effort with care and utmost sympathy in which were fundamental to the successful outcome. I'm really pleased where I would would like to convey my gratefulness to everyone for the time, commitment, and faith in my ability to achieve my objectives on conducting this project.

ABSTRACT

While the world works to enhance water cleanliness, some sections of the world continue to suffer severe water purity problems. Lead traces exceeding the legal limit have been found in many drinking water systems. Excessive lead in drinking water are causing cardiovascular problems, blood pressure and hypertension increment, low kidney functionality and reproductive issues (in both men and women). Corrosion or solder joints in pipes are the most common problems of lead pollution, which can result in deaths in victims. In order to develop a cost-effective and precise solution, a unique approach had been determined for detecting lead in water sources with a low-cost portable device with high accuracy. A three-electrode potentiostat is wired to a Trans-Impedance Amplifier, Low Pass Filter (LPF), and the signal is then read through a 12-bit ADC. The circuit was put into the test with two different value of resistance representing a dummy cell. To examine peaks at the voltage potential of resistor, the dummy cell is scanned with a cyclic voltammetry where three common wire used as the three electrode cell (working electrode, counter electrode and reference electrode) while the voltage and the current is monitored. The difference of resistance representing concentration of heavy metal in the dummy is determined by the maximum value of voltage potential measured.

ABSTRAK

Walaupun dunia berusaha untuk meningkatkan kebersihan air, beberapa bahagian di dunia terus mengalami masalah ketulenan air yang teruk. Kesan plumbum yang melebihi had undang-undang telah ditemui dalam banyak sistem air minuman. Plumbum yang berlebihan dalam air minuman menyebabkan masalah kardiovaskular, tekanan darah dan peningkatan hipertensi, kefungsian buah pinggang yang rendah dan masalah pembiakan (dalam lelaki dan wanita). Kakisan atau sambungan pateri dalam paip adalah masalah pencemaran plumbum yang paling biasa, yang boleh mengakibatkan kematian kepada mangsa. Untuk membangunkan penyelesaian yang kos efektif dan tepat, pendekatan unik telah ditentukan untuk mengesan plumbum dalam sumber air dengan peranti mudah alih kos rendah dengan ketepatan yang tinggi. Potentiostat tiga elektrod disambungkan ke Penguat Trans-Impedans, Penapis Lulus Rendah (LPF), dan isyarat kemudian dibaca melalui ADC 12-bit. Litar telah dimasukkan ke dalam ujian dengan dua nilai rintangan berbeza yang mewakili sel dummy. Untuk memeriksa puncak pada potensi voltan perintang, sel dummy diimbas dengan voltammetri kitaran di mana tiga wayar biasa digunakan sebagai tiga sel elektrod (elektrod kerja, elektrod pembilang dan elektrod rujukan) manakala voltan dan arus dipantau. Perbezaan rintangan yang mewakili kepekatan logam berat dalam dummy ditentukan oleh nilai maksimum potensi voltan yang diukur.

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LIST OF SYMBOLS

Cd	-	Cadmium
Pb	-	Lead
Hg	-	Mercury
As	-	Arsenic
KCl	-	Potassium Chloride
TIA	-	Trans-Impedance Amplifier
ADC	-	Analog to Digital Converter
DAC	-	Digital to Analog Converter
V	-	Voltage
USB	-	Universal Serial Bus
WE	-	Working Electrode
CE	-	Counter Electrode
RE	-	Reference Electrode
SPE	-	Screen-Printed Electrode

CHAPTER 1

INTRODUCTION

1.5 Background

According to chemistry, metals are “elements that conduct electricity, have a matte texture, are insoluble in water, generate hydroxide ions, and have basic oxides.” Heavy metals can be found in the environment from both natural/geogenic/lithogenic and anthropogenic sources. Two natural or geological sources of heavy metals in the environment are weathering of metal-bearing rocks and volcanic eruptions. Global trends of industrialisation and urbanisation on Earth have resulted in a rise in the anthropogenic contribution of heavy metals to the environment [1]. Metals are used in a wide variety of applications and are vital in today's industrialised world. Metals play important physiological and biochemical roles in biological systems, and their absence or excess can lead to metabolic and biochemical issues. Lead is a dangerous element that naturally occurs in the Earth's crust. Environmental contamination is caused by the mining, smelting, manufacturing, and recycling industries, as well as the continued use of leaded paint, gasoline, and aviation fuel in some countries. More than three-quarters of the world's lead usage comes from the production of lead-acid batteries for automobiles.

Lead, on the other hand, can be found in pigments, paints, solder, stained glass, lead crystal glassware, ammunition, ceramic glazes, jewellery, toys, some cosmetics, and traditional cures. According to health experts, there is no such thing as a safe level of lead exposure. Despite the fact that some heavy metals, referred to as necessary heavy metals, play important roles in biological systems, they are generally hazardous to living beings, depending on the quantity and duration of exposure. It is a well-known fact in

toxicology that too much of anything is bad. Non-essential heavy metals (Cd, Pb, and Hg) and metalloids (As, etc.) can cause harm even in little amounts. Heavy metals are necessary in minute levels in the body, but when concentrations reach certain limitations or thresholds, they become toxic. For some elements, the essentiality and toxicity window is quite narrow. Cancer, mutagenesis, and teratogenic consequences have all been related to heavy metals. As a result, they cause the generation of reactive oxygen species (ROS) and oxidative stress. Oxidative stress in organisms causes a variety of illnesses and abnormal states. Heavy metals can wreak havoc on the body's metabolic system. The interaction of heavy metals with sulfhydryl (SH) enzyme systems results in the inhibition of enzymes involved in cellular energy production, resulting in toxicity[2]. Lead poisoning affects a large number of people worldwide each year, according to the World Health Organization. Approximately a single year, lead poisoning caused in 140,000 deaths and 600,000 mental disabilities.

Taking all this into concern, monitoring metals in water should be a must using device such as potentiostats. In a multiple electrode electrochemical cell, a potentiostat is an analytical device used to manage the potential of the working electrode. The potentiostat has numerous internal circuits that enable it to do this purpose. Potentials and currents are generated and measured by the circuits. The potentiostat circuit is connected to the electrodes of the electrochemical cell via external wires in a cell cable. On one end, the cell cable connects to the working, counter (auxiliary), and reference electrodes, and on the other end, it connects to the potentiostat cell cable connection in a traditional three-electrode cell. The applied signal is controlled by the potentiostat's internal circuitry.

1.5 Problem Statement

Environmental contamination is one of the most pressing issues affecting modern society. Heavy metal pollution and poisoning of the environment is a severe hazard to the environment. Heavy metal contamination has occurred as a result of rapid industrialisation and urbanisation. Metal concentrations beyond permissible level also does have an impact water microbiology and can impair fertility. In concern of all this harmful effects caused ny metals, finding a highly sensitive and selective approach for determining trace amounts of heavy metals in the environment is critical. The determination of lead in environmental samples has been reported using a variety of approaches. Resonance light scattering[3] and spectrophotometric approaches[4] are two of these methods. Spectroscopic approaches, particularly graphite furnace atomic adsorption spectroscopy, and inductively coupled plasma mass spectrometry (ICP-MS)[5] were utilised for trace lead analysis. These approaches offer high sensitivity and selectivity, but they are time consuming to analyse and require very expensive apparatus. As a result, a easy, and exact approach for determining metals in ambient samples is proposed. The method uses a potentiostat, raspberry-pi and wired electrodes to conduct electrochemical analysis on any resistance to represent heavy metal. The potentiostat device is mainly proposed based on the simple method of constructing this device and low in cost.

1.5 Project Objective

The primary objective of this project is to present a device or design of low cost hand held potentiostat with utmost accuracy. Particularly, the objectives are as follows:

a) To design a relatively low cost alternative electrochemical instrument to conduct electroanalytical experiments using raspberry-pi.

b) To design a potentiostat circuit embedded with a mini-computer (Raspbian OS) in order to provide entirely portable device.

c) To study the operation of a trans-impedance amplifier (TIA) in a potentiostat to perform current to voltage conversion, as well as a reference current circuit that can provide relatively stable current sources to the differential amplifier's two inputs with measuring and analyzing redox reaction from varying resistance in a aqueos solution.

1.5 Scope of Project

The scope of this research is to design a potentiostat system to determine the presence of lead. This potentiostat is designed by only using simple potentiostat circuitry in which can take in a small current signal and convert it to voltage, as well as a linear and amplified voltage signal at the potentiostat's output for integration with an ADC circuit. The Raspberry-pi is used in combination with LCD Waveshare 3.5 inch as a device in whole. The measurements of different concentration for the device is obtained from the output terminal of potentiostat by cyclic voltammetry. Despite the existance of potentiostat that can observe output in various ways, the output of this circuit will be observed on mini device with LCD screen using Raspbian OS[6].

CHAPTER 2

LITERATURE REVIEW

2.5 Introduction

A potentiostat is a device that controls and measures voltage. It has an electrical circuit that regulates the voltage between two electrodes dipped in an electrochemical cell, namely the Working Electrode and the Reference Electrode. Current is injected through a third electrode, the Counter Electrode, to achieve this control. The Working Electrode current is measured and analyzed afterwards. We use it to demonstrate the detection of heavy metal presence in solution, and it will be used to determine whether they are above the permissible level in the future.

2.5 Voltammetry

By applying a voltage across an electrochemical cell and monitoring the current, it is an electroanalytical method for detecting traces of metals in a solution. Voltammograms are graphs that show the current vs the applied potential. This diagram depicts the reaction that took place in the solution. The type of voltammetry is determined by the pattern of the applied potential. Depending on the analyte to be analysed in the solution, different forms of voltammetry are applied[7]. Cyclic Voltammetry, Linear Voltammetry, and differential pulse Voltammetry are examples of frequent forms. Here, we're conducting using cyclic voltammetry. In the chapters of analytical electrochemistry, cyclic voltammetry is possibly the most important and commonly used technique. An abundance of quantitative information on surface electrochemical events can be gained by measuring the current through an electrochemical cell when the cell potential is cycled.[8]

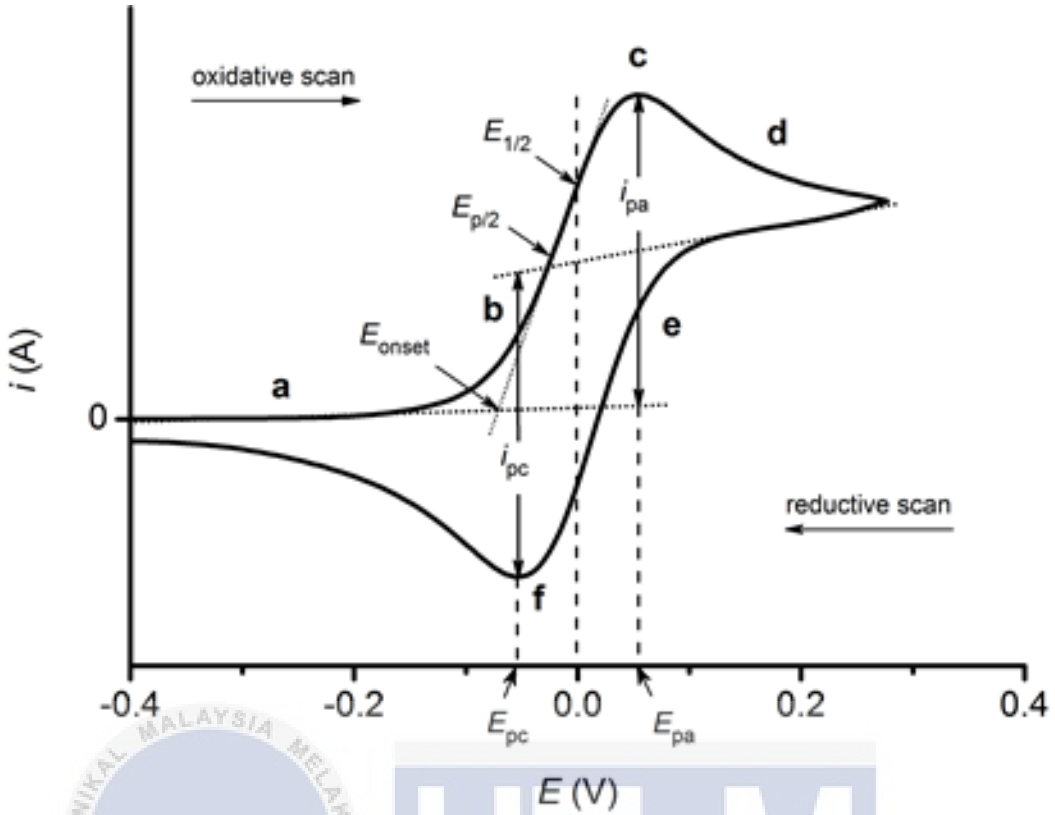

Figure 2.2.1 Example of Cyclic Voltammetry[9]

2.5 3-Electrode System

1) Refference Electrode

The Working electrode uses this electrode as a voltage reference. This means that the voltage measurements are taken against this electrode rather than against ground. As a result, it proves to be an essential component of the tests. It is meant to maintain a steady voltage while allowing no current to flow through it. Since, this electrode is only used for one purpose, its stability is much better, and 3-electrode systems provide better operation and measurements.

2) Working Electrode

In electrochemical investigations, this electrode is the focal point. By adjusting the potential and producing a reaction in the solution of interest across this electrode, current can be measured. As a result, the substance employed for this electrode is generally inert in order to avoid any reactive changes. A transimpedance amplifier is also attached to the working electrode. This converts the observed current to voltage, allowing for filtering, transmission, and analysis of the data.

3) Counter Electrode

The circuit is completed by this electrode. This electrode conducts the current that enters the solution through the working electrode. It's generally constructed of the same material as the working electrode. This electrode is used to change the applied voltage.

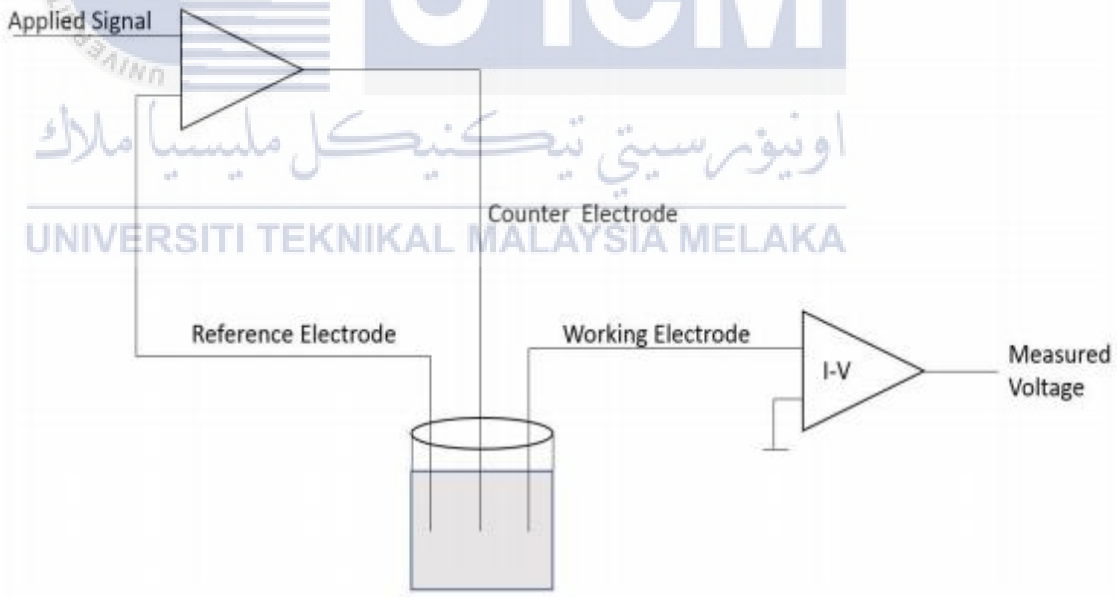

Figure 2.2.2 3-Electrode Cell

2.4 Comparison

There are many researches done and many potentiostat reports are presented on the net today. provided a “low cost potentiostat device” to monitor aqueos solution[10] and many other similar papers. However, these devices uses a PC or laptop to communicate with user which hereby costs nearly RM250 to RM300. The microcontroller used for the data calculation and presentation for such device will me Arduino where external DAC and ADC are not necessary since they have built-in converters as well. There are also many other papers conducted for potentiostat with low cost based on much similar microcontrollers. Anyhow, the method of user interface is not comparable with the device proposed here in which those microcontrollers are not compatible to interact with user in such way. Microcontrollers such as arduino requires external pc or laptop to present the output or data to the user.

Table 1 Literature Review Matrix of 4 Reasearch Papers

Author/ Date	**Theoretical/ Conceptual framework**	**Research Question(s)/ hypothesis**	**Methodology**	**Analysis & Result**	**Conclusion**
(Gupta & Rohella, 1999)	Device used in study of metal corrosion, controlled potential coulmetry as well as in the study of electrochemical process mechanism.	Is it desirable to design and assemble a potentiostat which is handy in operation as well as economically cheap.	Potentiostat that operates with three electrodes in electrolytic cell and its main function is to maintain the potential of working electrode(WE) at preset value with respect to a fixed reference electrode (RE). The instrument does so by passing the necessary current between the working and third	While current flows from the counter electrode, the voltage of the reference electrode (RE) must be adjusted without the necessity for current flow (CE). For the purpose of op-amp A adjustment by amplification R2 is a resistor attached to the inverting circuit at least twice. In order to keep the current flows from getting out of	Performance of the circuit was tested in electrochemical system consisting of Al(WE) in 0.5 N H_2SO_4. Various potential values were recorded and placed in table. The

			electrode called as counter electrode(CE). The potential difference between RE and WE which can be controlled externally is fed to the two inputs of the operational amplifier. The current driven between CE and WE depend upon the voltage difference between RE and WE.	hand, the C op-amp is equipped with a RE electrode. The inverting input receives feedback from the output. As a result, high-power non-inverting circuit amplification frequencies that are higher than the signal frequency. The op-amp is awake and stable. In the case of low frequencies, one seems to be circuit amplification, and the impedance of RE is another. electrode is the	estimated cost to conduct was cheap.

				same as the op-input amp's impedance. As a result, no current enters the reference.	
(Umar et al., 2018)	The device is an alternative electrochemical instrument that can be used to detect heavy metal ions in water.	How can potentiostat identify the heavy duty metals in water with low cost.	The proposed potentiostat is for a three-electrode device with an electronics configuration consisting primarily of an active amplifier and a resistor.	The designed potentiostat was implemented on a breadboard using LM324N Operational Amplifier. The circuit consist of three parts, an ATmega328P Arduino Uno microcontroller for signal generator, parameter control and data acquisition. The second part is a digital and analog converter (DAC)	The purpose of this study is to describe the development of a potentiostat device for the purposed of HMI detection.