Redox Reaction Detection Using Potentiostat and Mbed Microcontroller as Data Acquisition

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Abstract—**This project is to design a system to detect redox reaction and to design data acquisition to save data into Microsoft excel. The method to detect redox reaction is by using potentiostat. The potentiostat is a device consists of reference electrode, working elecrtrode and control electrode. The data acquisition is a device to receive digital data so that user can measure any electrical voltage, current, temperature, sound by using a computer. Data acquisition used in this project is made by using Mbed Microcontroller cortex-M3. This project successfully able to runs redox reaction however, it does not yet able to save accurate data of redox reaction.**

Keywords- Redox Reaction; potentiostat; Mbed microcontroller; Data Acquisition

I. INTRODUCTION

Redox reaction comes from the words reduction-oxidation reaction. It is a reaction associate with the transfer of electrons between two species of atom, molecule or ion [1]. If atom, molecule or ion receives or gain electrons, it is said as an oxidizing agent because it gives oxygen to another species, while if atom, molecule or ion loss electron, it is said as an act of reducing agent because it reduces oxygen at another species [2]. Redox reaction typically happens in our surrounding such as photosynthesis, extraction of metal from its ore, respiratory of human body, combustion, electrochemical cell used in vehicles or dry cell and etc. [3]. Redox reaction has helped human body to live but it also the causes of human body to suffer. Human body suffers from aging, cancer, hardening of arteries and rheumatoid arthritis and it is mainly happening because of oxidation reaction [4]. This project is to detect redox reaction by using potentiostat where it can measure and controls the voltage difference between working electrode and reference electrode. Potentiostat consist of three electrodes namely working electrode, reference electrode and control electrode [5]. The data receive from the potetiostat needs to be recorded to analyse. In order to record the data, another device is required. This device must collect data and save the data so that it can be analysed. This device is known as data acquisition. According to National Instrument, data acquisition (DAQ) is the process of measuring an electrical or physical phenomenon such as voltage, current, temperature, pressure, or sound with a computer. DAQ hardware acts as the interface between a computer and signals produce by the potentiostat. Since the potentiostat send a data in analogue form, it is compulsory to have a DAQ to digitizes the incoming signal produce by potentiostat [6]. The DAQ uses in this project is Mbed microcontroller cortex-M3. The Mbed microcontroller also use to give a specific signal to the potentiostat. This project objectives are to detect redox reaction and using Mbed Microcontroller as DAQ.

II. DESIGN METHODOLOGY

A. Transducer

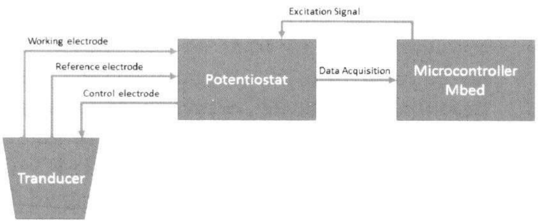

Figure 1. Block diagram of this project

This project consists of three parts. The first part is transducer, second is potentiostat and lastly is a microcontroller. The first part is use to convert biological response into electrical signal. This is where redox reaction takes place. The biosensor consists of FeCN solution which act as a medium, silver or silver chloride (Ag/AgCl) as reference electrode, gold (Au) plate as working electrode and platinum wire as control electrode.

B. Potentiostat

Potentiostat is made up operational amplifers (op-amp) with different configuration. The configurations use in this project are voltage amplifier, summing amplifier, current-to-voltage amplifier and voltage follower (buffer).

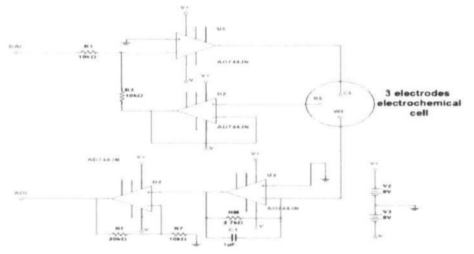

Figure 2. Op-amps use in potentiostat

First, the summing amplifier is use to sum the voltage applied that is from the microcontroller with voltage that is produced by buffer. The output of the summing amplifier will be the control electrode that will be dipped into FeCN solution. Second, the buffer is use to receive voltage that is produce inside the FeCN solution. The buffer also block the current from following into it so that only voltage will be measured and be added by the summing amplifier. The current produce by FeCN solution will flow to current-to-voltage. The current-to-voltage amplifier is to convert current to voltage so that the microcontroller can read the signal it receive. The voltage from the current-to-voltage amplifier is then amplified using voltage amplifier. The output of voltage amplifier is then connected to the microcontroller to be recorded as data acquisiton (DA Q).

C. *Mbed Microcontroller*

There are two purposes of using Mbed microcontroller, first is to give excitation signal to the potentiostat and second is to save data it receives from the potentiostat. The excitation signal use to give voltage to the potentiostat is called Differential Pulse Voltammetry. Voltammetry is a method in which information about analyte can be obtained by measuring current versus voltage applied. This technique allows the elimination of background current from the applied voltage [7]. The microcontroller is programmed to give a fixed scan rate of 0.01V/s, a staircase wave having a step of 0.005V starting at 0.4V to 1.2V. The staircase wave is combined with a pulse of 0.1V.

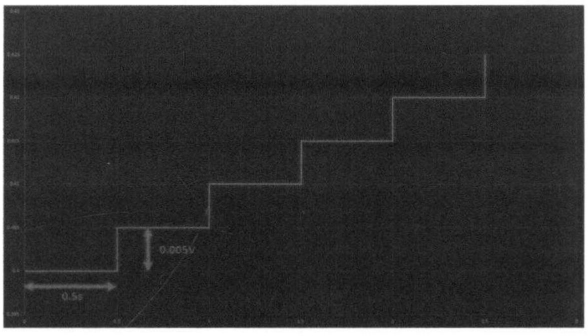

Figure 3. Staircase wave having a step of 0.05V

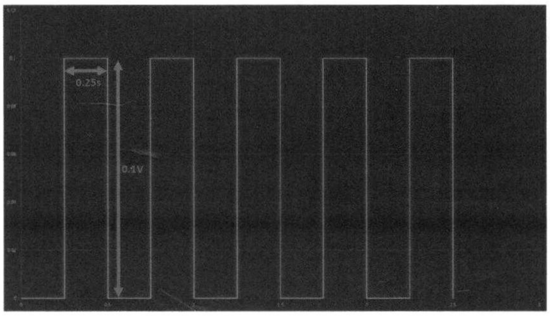

Figure 4. Pulse wave of 0.1V

The combination of the two waves resulting in a new wave that looks like figure 5.

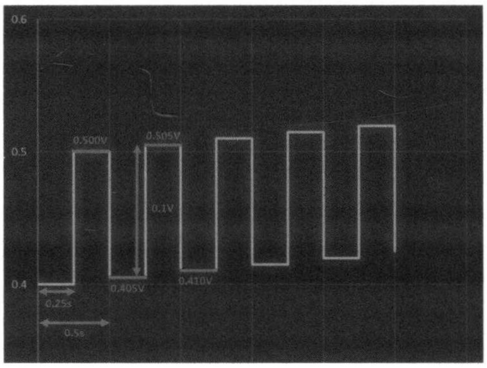

Figure 5. The excitation signal to be fed to the potentiostat

Mbed Cortex-M3 is use in this project. This microcontroller has 10-bit digital to analogue converter which can be used to give excitation signal to the potentiostat. It also has 12-bit analogue to digital converter. Since the potentiostat send a data in analogue form, it is compulsory to have a DAQ to digitizes the incoming signal produce by potentiostat. The microcontroller is able to measure minimum voltage at 0.806mV. Although the current measure is small, the potentiostat was built to convert current to voltage and amplify it so that the microcontroller can read the data it receives and save the data.

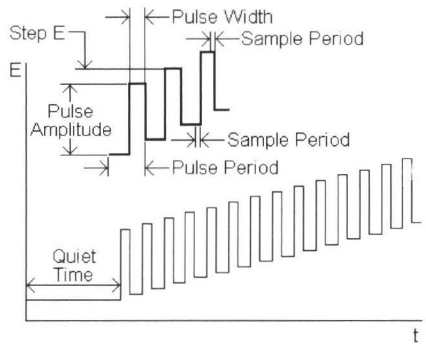

Figure 6. Excitation signal

The data recorded for analysis is taken before and after pulse change ($\Delta I = I_1 - I_2$). Since the current receive has been converted into voltage, the equation becomes ($\Delta V = V_1 - V_2$).

D. Flowchart of project

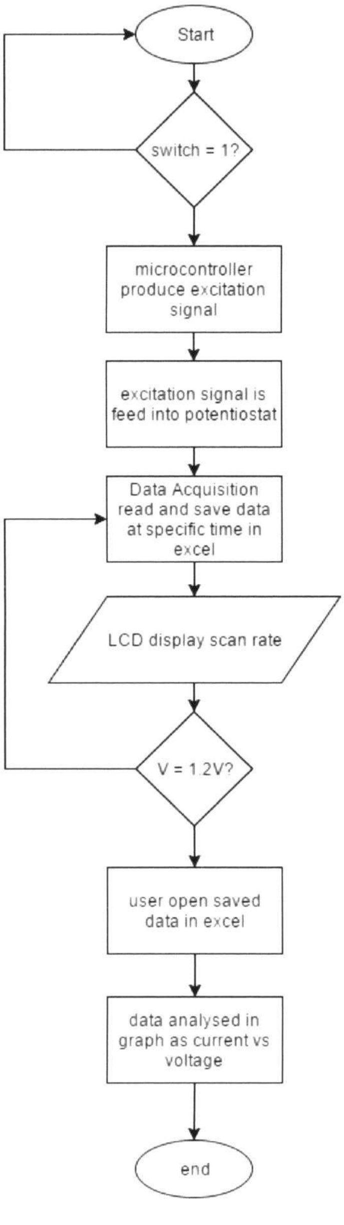

Figure 7. The flowchart of this project

Figure 7 explain the process of this project starting with user pressing a switch to start feeding the potentiostat with an excitation signal. The process proceeds to data acquisitioning to be saved in Microsoft excel and at the same time the LCD display will provide information to the user about scan rate and voltages applied to the potentiostat at a specific time. The maximum voltage applied is 1.2V. As the voltage reach 1.2V, the microcontroller stop sending excitation signal and user can then open Microsoft excel to analyse the data obtained.

E. Coding of the project

```
for(float i = (0.5/3.3); i < (1.2/3.3); i += (0.005/3.3f))
{
    if(i>=1.19/3.3)
    {
        led1saya=1;
        led2saya=0;
        fclose(fp);
        t.stop();
    }
    aout=(i - (pulseamplitude/3.3));
    fprintf(fp,"%.4f,%.8f,%.2f\n",aout.read()*3.3,ain.read()/660,t.read());
    wait(0.25);
    aout=i;
    lcd.locate(0,1);
    lcdprintnum(aout.read()*3.3);
    lcd.printf(" V");
    fprintf(fp,"%.4f,%.8f,%.2f\n",aout.read()*3.3,ain.read()/660,t.read());
    wait(0.25);
}
```

Figure 8. Coding of Mbed microcontroller

In section C, the sample period is sample before pulse rise and before pulse fall. The period before the pulse rise and fall is approximately 0.25s. During 0.25s is where microcontroller sample the data it receives and save it.

The coding command the microcontroller to send signal of 0.4V to the potentiostat at a period of 0.25s. During 0.25s, the microcontroller will sample the data it receive from the potentiostat and save the data. After reaching 0.25s, the microcontroller will start to fall down by 0.1V and the signal is given at a period of 0.25s. Again at this period of time, the microcontroller will start sampling and save the data. The data it receive will be sampled and the signal will keep continue to rise and fall as long as the voltage supplied does not reach 1.2V. when the voltage supplied reach 1.2V, the microcontroller will stop sending signal and also stop receiving data. The microcontroller can now be access to open microsoft excel for further research the data collected.

III. RESULT AND DISCUSSION

The data acquisition is an instrument that process a measurement of an electrical or physical phenomenon such as voltage, current, temperature, pressure, or sound with a computer. The DAQ used by Mbed microcontroller can be said successful since it does record data. Figure 9 shows the prove that this microcontroller can act as DAQ. Figure 10 show the result from recording excitation signal.

VOLTAGE	CURRENT	TIME
0	1.0371	0
0	0.9122	0.25
0.1	0.7994	0.25
0.1	0.901	0.5
0.003	0.7366	0.5
0.003	0.8558	0.75
0.103	0.7527	0.76
0.103	0.855	1.01

Figure 9. Some of data receives from potentiostat

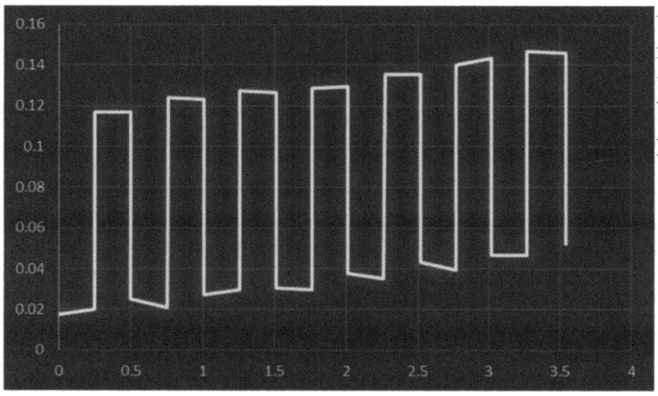

Figure 10. Data from recording the excitation signal

The result obtained is the same the theory, but does this result will help in achiving the result of reodx reaction? The expected result for current to voltage follower is as figure 11. The figure was taken from last semester project.

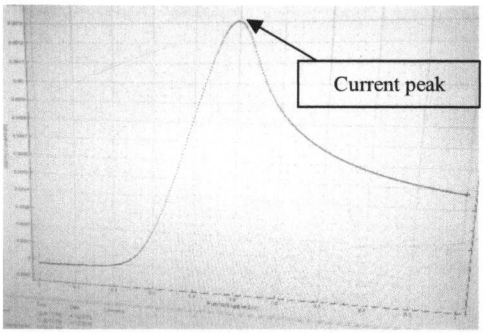

Figure 11. Data from recording the excitation signal

Figure 11 shows the result obtained from [9]. The wave shown by figure 11 has a peak current. The peak current tells that there is a concentration of current at the working electrode. This means that the redox reaction is occurring mostly at a voltage where the current is maximum. We can also look at the solution to see whether this experiment works or not by looking at control electrode.

Figure 12. Bubble acumulating around control electrode

The bubble surrounding the control electrode as shown in figure 12 means that the control electrode is having oxygen. The oxidation is occurring at the control electrode while the reduction is occurring at working electrode. By having these bubbles also means that this project is working well in terms of transducer and potentiostat. The comparison between last semester result (figure 11) and this projects result is figure 13 below.

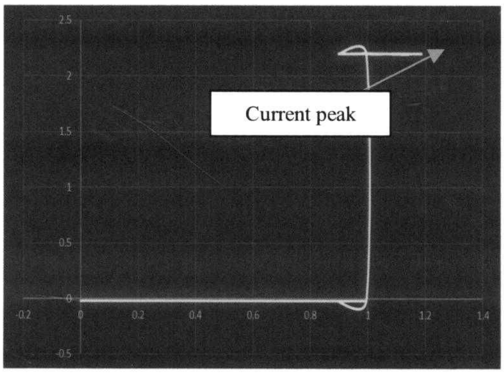

Figure 13. Results obtained by using Mbed Microcontroller

Figure 13 shows the result obtained in this project. Clearly this is a failure and needs to be repaired. Further research is needed in order to repair this DAQ.

IV. CONCLUSION

A redox reaction design using potentiostat can be said succesfull and the tranducers also showing positive result by showing bubble accumulating around the control electrode. DAQ however showing a negative result.

It is highly recommended that this project focus more to DAQ and compare it with existing DAQ so that this project can see what is missing with self-made DAQ and industrial DAQ.

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