pH BASED FOOD ANALYZER

By

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FINAL PROJECT REPORT

Submitted to the Electrical & Electronics Engineering Programme
in Partial Fulfillment of the Requirements
for the Degree
Bachelor of Engineering (Hons)
(Electrical & Electronics Engineering)

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CERTIFICATION OF APPROVAL

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Approved:

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Project Supervisor

UNIVERSITI TEKNOLOGI PETRONAS
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December 2009

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

Nurhazrina binti Zakaria

ABSTRACT

The objective of this study is to design and construct a prototype for pH Based Food Analyzer which is easy to use by anyone without extensive training. This sensor is used in determining the pH level in food. The chemical reaction that occurred can produce contaminant or spoilage in food and can affect the pH level. With this pH Based Food Analyzer, the pH level of food can be monitored. This project includes the study on chemical reaction and also on sensor circuit. It is divided into three parts ; recognition element, transducer and signal processor. Throughout this project, electrochemical transducer with ionic recognition is used. The sensor used is connected to amplifier in order to amplify the voltage produced. The amplifier then connected to computer through data acquisition (DAQ) card. The result of pH level is displayed using software LabView.

ACKNOWLEDGEMENTS

Throughout this year there are many great people have helped me during my time doing this project. It is a pleasure for me to convey my gratitude in a humble acknowledgement.

First and foremost, I would like to express my gratitude to my supervisor, Assoc. Prof. Dr. Josefina Barnachea Janier who has supported me throughout this project. She has been contributing her knowledge and patience while allowing me did the project in my own way. She has been supportive in guiding me during my hard times. Thousands of appreciation is not enough to show her my gratitude.

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Last but not least, my family and my great friends. They are the one that gave me an endless moral support for me to never give up. My parents have given me a full support throughout my study. I am indebted to them more than they know. To my friends, they have been a teacher, a good advisor and loyal listener to me. Thank you all.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

DAQ	Data Acquisition
PBFA	pH Based Food Analyzer

Chapter 1

INTRODUCTION

1.1 Background of Study

As a human being, our tongue can detect four tastes which are saltiness, sweetness, sourness and bitterness. However, Japanese scientist had found the fifth taste; umami or savoury[1]. The components that contribute to sweetness are saccharin, alcohols and some amino acids. For sour taste, it was from acids which from dissociation of H^+ ions in any solution. While for saltiness is from metal ions (eg. NaCl) and bitterness is from the existence of alkaloids and non-alkaloids. Lastly, the umami taste is from amino acids (glutamate). However, our tongue cannot detect the pH level in our food. This project will help in determining the pH level in our food.

Nowadays, there are plenty of cases which involve food contamination. Many students have become the victims of this case. Some undergo bad stomach-ache and there are also who died because of food contamination. Apart from pH level, we also cannot detect any contamination in our food. Most of rotten food can be identified from its appearance, smell and structure of the food itself. However, some contamination cannot be identified through appearance or smell of the food. There are numerous sources for contamination to occur. Normally, the contamination occurred in the raw food like fish, in water, hygiene and also some chemical reactions during the cooking. These contaminations can become poison in the food.

There are a few applications used sensor technique in the market. Most of them are used in the pharmacies or in the food industry. For example, the Medisense ‘ExacTech’ [2] biosensors which used to determine glucose level in blood. The similar example with the project is the Electronic Tongue which used to identify chemical composition in drugs, wine and many more.

1.1 Problem Statement

Students are the majority who undergo health's problems due to food contamination. Most of them are still naive in determining either good or bad food. Their decisions in choosing food are mostly affected by the appearance and taste. However, as contamination cannot be detected visually, students tend to consume the spoiled food. By detecting the contamination in the food before it being consumed, it can safe someone life and maintaining the health's level.

Fruits flavour is affected by its condition and also its aroma. People who has stuffy nose cannot distinguish the fruit properly. Even the ripe fruit tastes different from the immature one. Other than that, fruit sometimes can be dangerous. Most of citrus fruit has high level of acids. By detecting the phase of acidity and alkalinity, it can helps in maintaining people's health.

1.2 Objectives and Scope of Study

The overall objective of this project is to design and construct a prototype for pH Based Food Analyzer (PBFA). This PBFA will be used in detecting pH level in food. It can determine the phase of acidity and alkalinity and help in determining whether the fruits are suitable to be eaten or not. The main objective is to design and construct PBFA which is easy to use by anyone at any location and without extensive training in laboratory techniques. The PBFA will be used to ensure the food is safe for consumption in a short period of time.

The scope of study is to find the relationship between food's pH and the amount of voltage induced by its pH level.

Chapter 2

LITERATURE REVIEW AND THEORY

2.1 Theory

This project can be divided into several parts. First part is the chemical detection element, followed by transducer and the signal processor. The detection element is the contact between prototype and the studied solution. Similar to human's tongue, the working principle start when the element detects chemical compounds of flavour. Then the taste identified by tongue's receptor is sent to brain. Alike for the sensor, the signal from detection element is then transferred to transducer. The transducer will convert the signal into electric signal. Output from the transducer will then be interpreted by signal processor which the result can be read and understood by human being.

There are a few aspects of sensor [2] that need to be considered. They are the recognition elements, the transducer and the method of immobilization. The recognition element is vital as they response to the food or studied solution that is being tested. There are a few types of method that can be used in the recognition element [2]. For this project, ionic recognition is used where the element used is only interacting with certain ion being tested. The particular ion will be sensed by ion-selective electrodes and when the interaction occurs, voltage is induced and detected by potentiometer.

Ion-selective electrodes are connected to transducer. The transducer used in detecting the change occurred when the recognition element interact with the studied solution [2]. It will convert the change into a readable signal. In this project, electrochemical transducer is chosen to detect the voltage induced.

Immobilization [2] is a method where the recognition element has contact with studied solution. The contact will allow some chemical reaction to occur on the sensor. The method used is adsorption on to a surface of sensor.

2.2 Working Principle

This pH Based Food Analyzer consists of two electrodes and also pH meter. The electrodes are the reference electrode and also glass electrode. Both of the electrodes are connected to the pH meter through wire. The working principle is basically similar with battery.

The electrodes will be immersed in tested solution. Some chemical reaction will occur between the glass electrode and tested solution. This reaction will induce voltage which will be transfered to the pH meter. The reference electrode produces a constant voltage. It uses as a reference voltage. Voltage from the glass electrode will be compared to the reference electrode to determine the voltage induced from the chemical reaction.

The outcome voltage will be transferred to pH meter to be interpreted as pH reading instead of voltage reading.

2.3 Basic Electrochemical Cell

This project is based on basic electrochemical cell [2], as shown in Figure 1. The electrochemical cell is used in measuring the voltage induced when reaction takes place between the electrode and ions in solution.

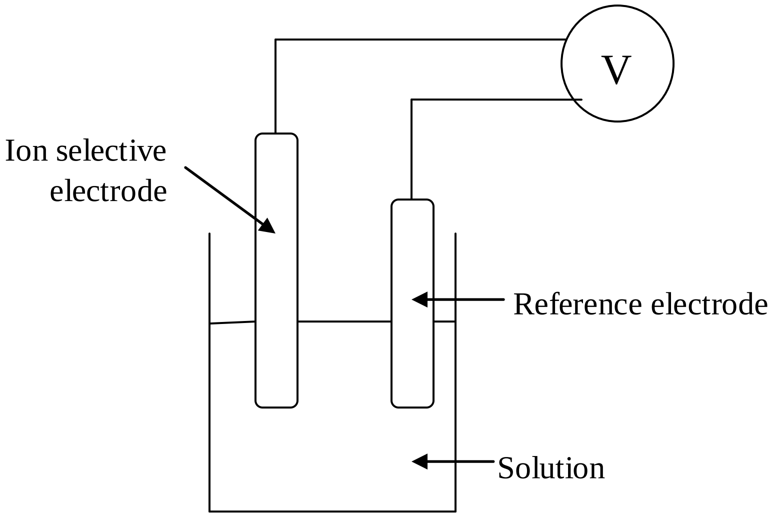

Figure 1 : Basic Electrochemical Cell

When ion selective electrode is immersed in the solution, certain chemical reactions will take place. This reaction produces some voltage which detected by voltmeter. For this project, the same idea used in electrochemical cell is applied.

2.4 Definition of pH

The pH value of a solution is the negative log of its hydrogen ion activity (α), which is the product of hydrogen ion concentration [H^+] and the activity coefficient of hydrogen ($\gamma_H{}^+$) at that concentration [6].

$$\mathbf{pH = -log\ \alpha = -log\ \gamma_H{}^+[H^+]} \ \ldots\ldots (1)$$

In pure water and in dilute solutions, the H^+ activity can be considered the same as the H^+ concentration [6].

$$\mathbf{pH = -log\ gH^+[H^+] = -log\ [H^+]} \ \ldots\ldots (2)$$

Most pH readings range from 0 to 14. Solutions with a lower pH than 7 are acidic while solutions with a greater than pH 7 are basic or alkaline. Figure 2 is the diagram of pH level [6].

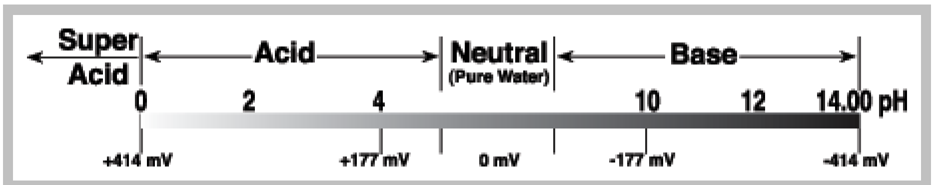

Figure 2 : Diagram of pH level

From the diagram, the characteristics and voltage induced is shown with respect to each pH level.

2.5 pH Electrode

In this system, two electrodes are used. First is reference electrode and another is glass electrode. For reference electrode, it provides a stable and zero-voltage connection to liquid solution so that a complete circuit can be made to measure the glass electrode's voltage. Below is the construction of reference electrode [7].

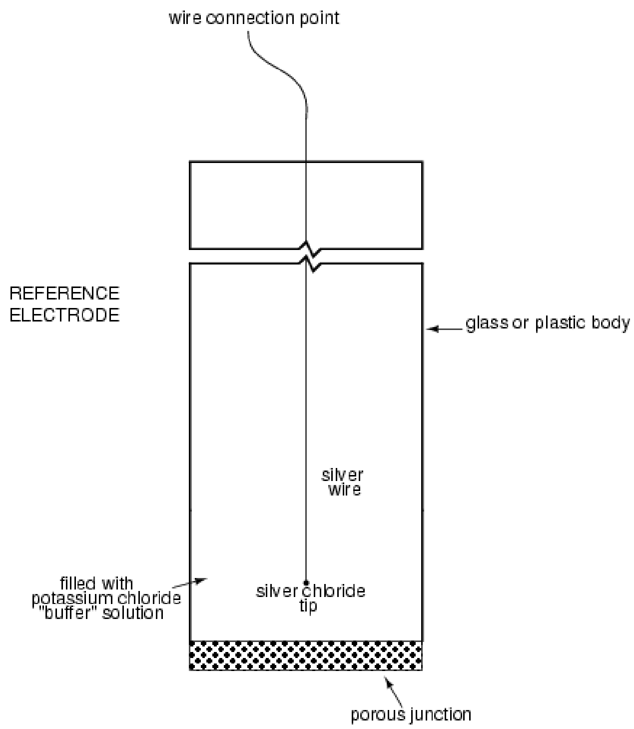

Figure 3 : Diagram of Reference Electrode [7]

In the electrode is silver wire coating with silver chloride immersed with potassium chloride solution. The reaction between wire and solution will produce constant voltage which used as reference potential.

The other electrode is the glass electrode and it has similar construction. Figure 4 shows the diagram of glass electrode [7].

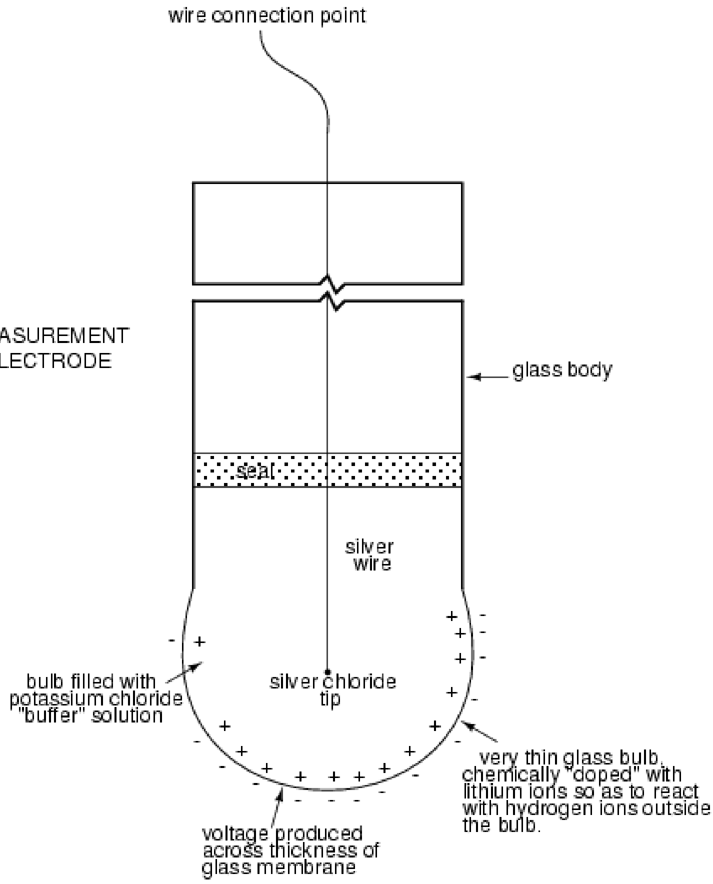

Figure 4 : Diagram of Glass Electrode [7]

The glass electrode is made of glass and consists of a thin wall glass bulb. The bulb filled with potassium chloride solution [7]. The bulb is doped with lithium ions in order to react with hydrogen ions in a tested solution. The glass bulb is ion-selective in order to filter the hydrogen ions from tested solution. In the electrode the silver wire is immersed in potassium chloride solution which is used to ensure a constant voltage on the inner surface of the glass membrane.

For simplicity, both of the electrodes are combined into one electrode. Both reference and glass electrode contain in the same rod. However, the chemical solution for reference electrode is separated in order for reference electrode to have constant voltage and not affected by tested solution.

2.6 pH meter

The pH meter is actually a voltmeter that measures the voltage induced at the electrodes. The voltage measured then converted into pH reading as the output. Figure 5 shows the circuit diagram of pH meter [8].

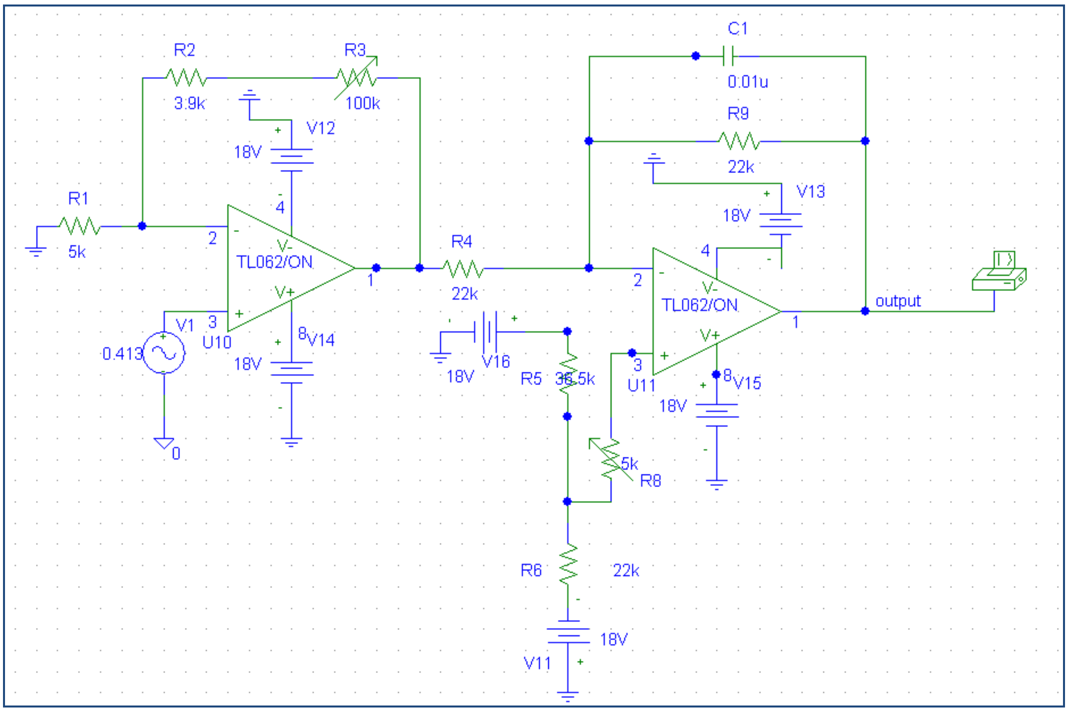

Figure 5: Diagram of circuit for pH meter

This circuit consists of two parts; first is an amplifier and second is an integrator.

The amplifier is connected directly to pH electrode through the third pin of TL062. The voltage detected through the electrode will flow through the op-amp and will be amplified. The amplifier has gain value in the range of 0.39 to 10.39 depending on the impedance of pH electrode. The output of this stage would be between -7V and +7V with -7V being pH of 14 and +7V represents 0 pH.

The second part is the integrator. Its function is to invert and offset the output voltage from the amplifier. Capacitor in the integrator will be fully charged and produce constant potential difference. The integrator is combined with differential op-amp. The differential op-amp will compare the voltage from amplifier with a power supply set from the potentiometer. This will result in positive or negative voltage depending on voltage input from pH electrode.

2.7 pH Measurement

In acidic or alkaline solutions, voltage will be induced on the glass bulb surface. This voltage is proportional to changes in H^+ ions. The changes of H^+ ions in tested solutions are compared to changes in reference electrode. More changes occurred in the tested solution, a higher voltage will be induced. This relationship is described by Nernst equation [6]:

$$\mathbf{E = E^\circ + \frac{2.3RT}{nF} \log \frac{unknown\ [H^+]}{internal\ [H^+]}} \qquad \ldots\ldots(3)$$

where : **E** = total potential difference (measured in mV)

E° = reference potential

R = gas constant, 8.314volt.coulomb / ^{o}K.mol

T = temperature in Kelvin

n = number of electrons, 1 for H^+ ion.

F = Faraday's constant, 96490 coulombs/mol

[H^+] = hydrogen ion concentration

As shown from the equation 3, the voltage induced is affected by temperature of the solution. This temperature dependence is compensated by R1 in the circuit. At room temperature, 25^{o}C, the electrode potentials are referred to standard hydrogen electrode which H^+=1 and E^o=0 [6].

$$\frac{\mathbf{2.3RT}}{\mathbf{nF}} = \frac{2.3(8.314)(298.1)}{(1)(96490)}$$

which lead to : **pH = E / 0.05915.**

As shown from the calculation, this means that in room temperature (25^{o}C), every 0.05915V indicates a pH in the solution. Acidic pH will induce negative voltage while alkaline pH will produce positive voltage. However, at neutral which is pH 7 the voltage induced is 0V. By using this equation and calculation, we can estimate the pH level in the tested solution by calculating the voltage induced. Figure 6 shows the relationship between voltage induced per pH at different temperature.[9]

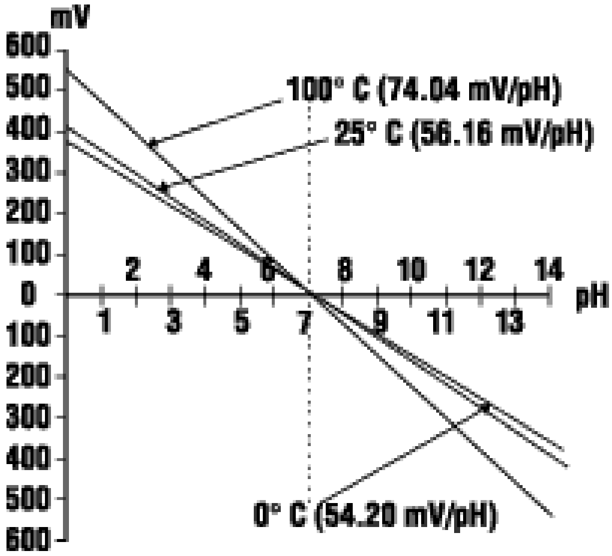

Figure 6 : Relationship between voltage and pH at different temperature

2.8 Food Contamination

Food contaminants considered are the major substances not intentionally added to food but that can be found in the food as a result of the general and the local environment (e.g storage and packaging) through which the food progresses, from primary plant or animal production, through various stages of handling, processing, packaging, storage, distribution and sale, to preparation, cooking and consumption [10]. Other than that, food spoilage also builds up dangerous contaminant in food.

During food spoilage, microbes such as bacteria, fungi and yeast grow which derive energy from the breakdown of food carbohydrates, proteins and fat [11]. Microbes involved in spoilage of food products are primarily bacteria, yeasts and fungi [11]. For example, aerobic bacteria microbes, such as Salmonella, are involved in the spoilage of a variety of chicken or egg related products such as mayonnaise [11].

Chemical reactions that occurred during food spoilage due to microbial spoilage will produce acid as the output. For example, during milk products spoilage, lactic acid is produced as the result of bacteria reactions. The resultant acid can be detected using pH electrode which the output signal sent to pH meter. The changes in pH in food can be indicating microbial reaction had occurred and the food is not suitable to be consumed.

Chapter 3

METHODOLOGY

3.1 Procedure Identification

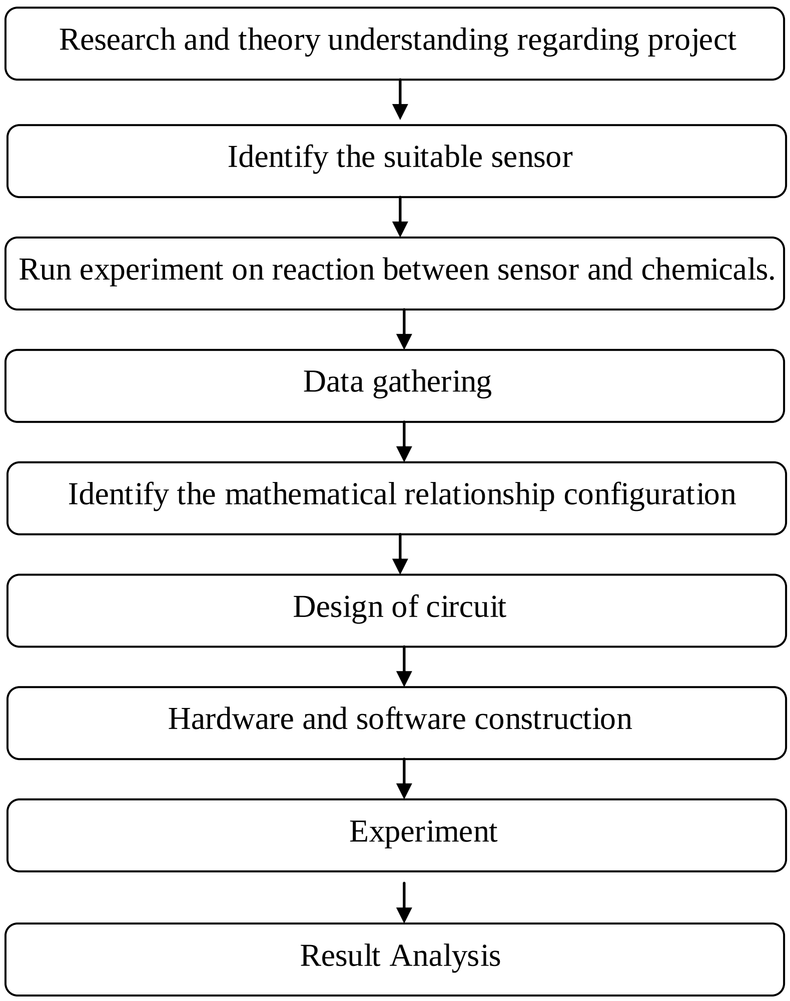

Figure 7 : Project's workflow

3.1.1 Research and theory understanding regarding project

Research about the project has been done and all the aspects of project are being identified. Theory of each aspect is being identified and mastered.

3.1.2 Identify the suitable sensor

The crucial part of the prototype is the sensor. All possible sensors that can be used are being identified. The suitable sensor is identified and chose.

3.1.3 Run experiment on reaction between sensor and chemicals

Experiment is run to confirm the chemical reaction between sensor and also chemicals.

3.1.4 Data gathering

Result of the experiment of interaction between sensor and chemicals is recorded.

3.1.5 Identify the mathematical relationship configuration

Using the data from experiment on reaction between sensor and chemical, a mathematical configuration is built up.

3.1.6 Design of circuit

The sensor needs to be connected to amplifier as it produces low voltage. The circuit of amplifier is designed to meet the system requirement.

3.1.7 Hardware and software construction

After the circuit is designed, the hardware construction is started. Electronics components are gathered and soldered on Veroboard. The sensor is connected to circuit. At the same time, the software is also been constructed to display the output from the circuit.

3.1.8 Experiment

After the prototype is done, experiment is run to test the prototype. Experiment also been done on certain fruits in determining its pH level.

3.1.9 Result analysis

The result from the experiment is analyzed and conclusion is made.

3.2 Tools

There are a number of tools that I have been using throughout the project. The items that are being used can be divided into two; hardware and software.

3.2.1 Hardware

- Sensor : Glass ion-selective electrode
- Circuit : Op-amp TL062, Resistors, Potentiometers
- DAQ card : Low Cost Multifunction I/O PCI-6024E
  Connector Block CB-68LPZ
  Thermocouple Input SCC-TC01

3.2.2 Software

- pSpice : Digital logic simulation software that can stimulate circuits.
- LabView : A platform and development environment for a visual programming language from National Instruments.

Chapter 4
RESULTS AND DISCUSSION

4.1 Prototype Overview

This prototype consist of three parts; sensor, circuit and software. The circuit will be connected to software through DAQ (Data Acquisition) card.

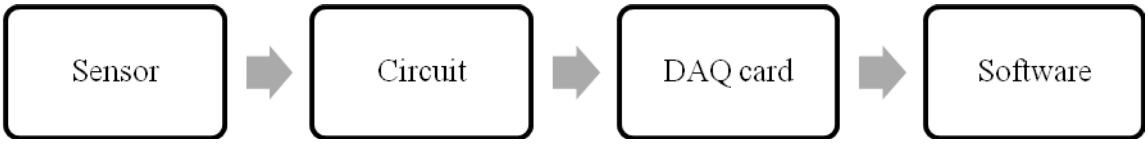

Figure 8 : Overall diagram of prototype

4.2 Sensor

Below are the pictures of sensor used. These pictures are from front view and side view.

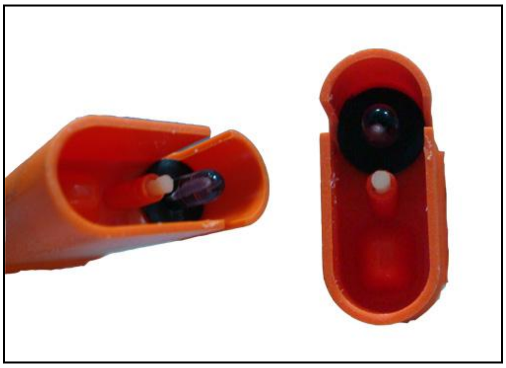

Figure 9 : Pictures of sensor

The specification of this sensor are :

- Operating range : 0 - 14 pH
- Possible error : ± 0.2%
- Calibration : one point at pH 7

4.3 Output from circuit

In order for the circuit to produce output which gives direct pH reading, the amplifier and integrator need to be set up. Firstly is the amplifier. It needs to have gain of 17. This can be done by changing the value of resistance through potentiometer R_3. For the integrator, it needs to set to 7 offset. Similar to amplifier, this can be obtained by changing the value of R_8. Table 1 show the output from the circuit when the amplifier's gain is 17 and integrator has 7 offset values. The input voltage is set at the sensor input which is V1. Refer to laboratory model in Appendix C in gathering the data.

Table 1 : Output of circuit in voltage

pH Value	Voltage Reading (Volts)	Output (Volts)
1	-0.354	0.982
2	-0.295	1.985
3	-0.236	2.988
4	-0.177	3.99
5	-0.118	4.994
6	-0.059	5.997
7	0	7
8	0.059	8.003
9	0.118	9.006
10	0.177	10.009
11	0.236	11.012
12	0.295	12.015

The result showed that the circuit produce output in voltage which is directly indicated the pH level. However, this is only simulation based on circuit without any pH electrode connected. The value easily changed due to electrode's resistance and tested solution's temperature. The output produces more accurate reading after both cases were considered.

4.4 Software Screenshot

This is the interface of the software that used in measuring the pH reading using LabView software.

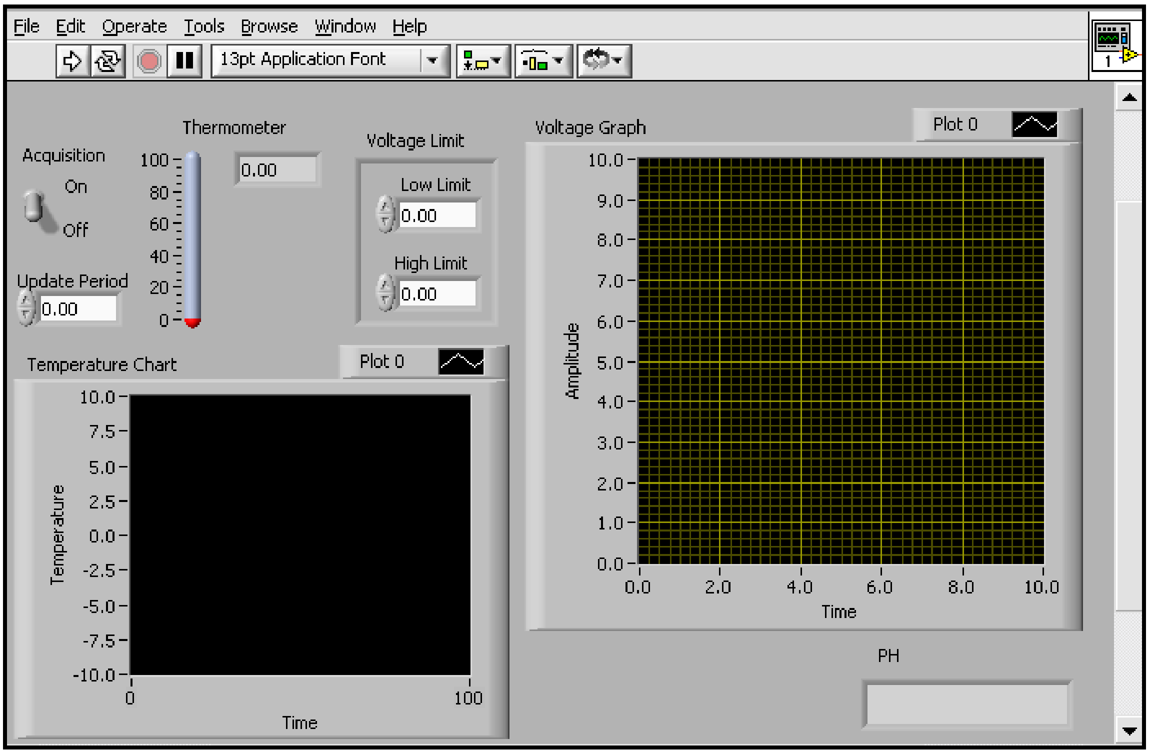

Figure 10 : Software screenshot

As shown in the display above, the software is divided into three sections which are temperature, voltage and pH. The software is supplied with start and stop button in order to begin and terminate data acquisition. The data acquisition starts with detecting current temperature, followed by voltage reading. Voltage produced by pH electrode will be shown in the voltage graph at the right top corner. After the process of data acquisition is terminated, the stable reading will be shown in the voltage box at the bottom. The voltage can determined by the pH value but it also affected by temperature.

As shown below in Figure 11 the temperature section for the program. The program started using acquisition button. The program will be updated in seconds depending on update period. The update period can be adjusted depending on the use of program. The current temperature will be read from the thermometer and will be displayed in the box on the right. The program will detect and record the temperature when the program starts and stop when the program terminated. The temperature's history will be displayed in the temperature chart.

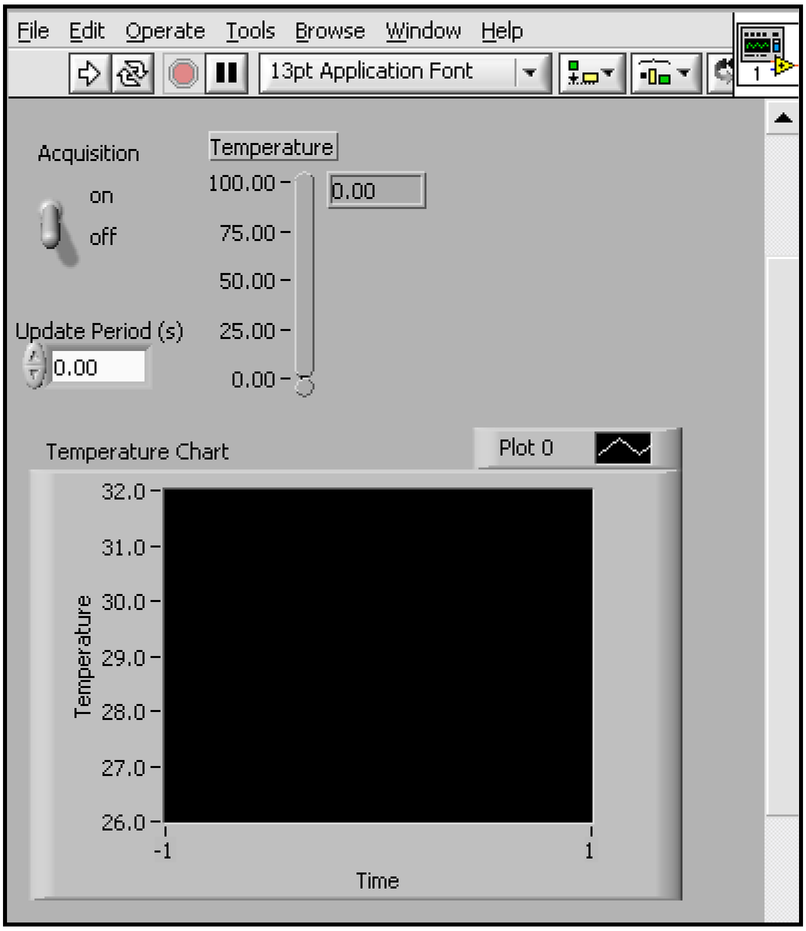

Figure 11 : Screenshot for temperature part of the program

Next figure is the block diagram of the temperature part using LabView. The temperature is detected from the DAQ card and converted into Celcius. The reading then is displayed in the temperature chart.

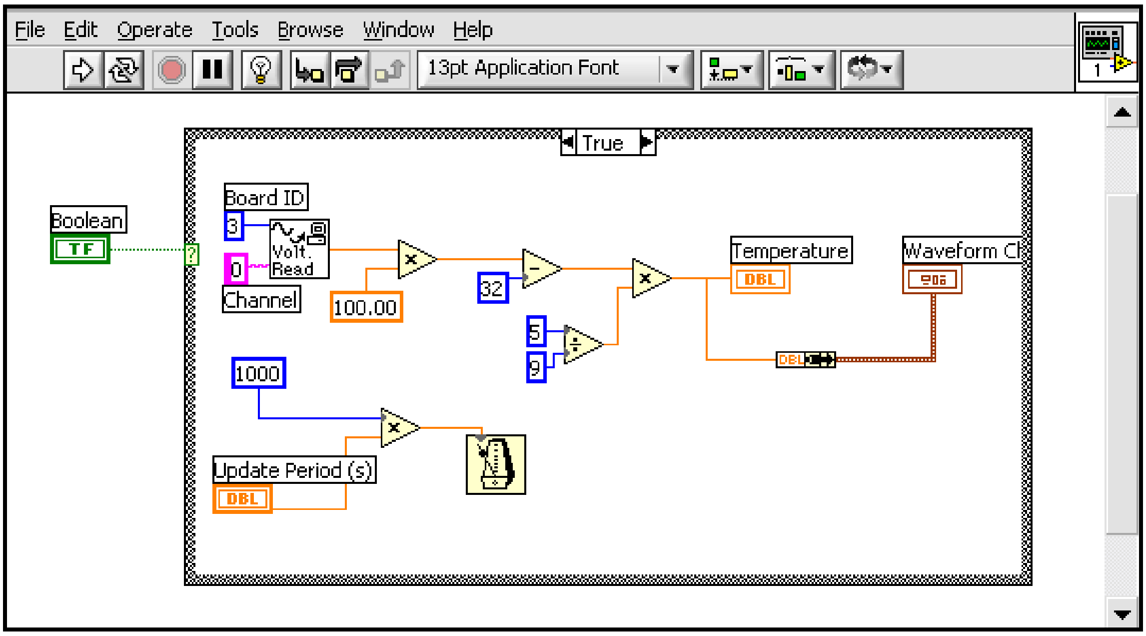

Figure 12 : Block diagram of temperature part

Figure 13 below is the voltage part of the program. Voltage that induced from the sensor is transferred to DAQ card and detected through the program. The average reading is calculated and displayed as pH value.

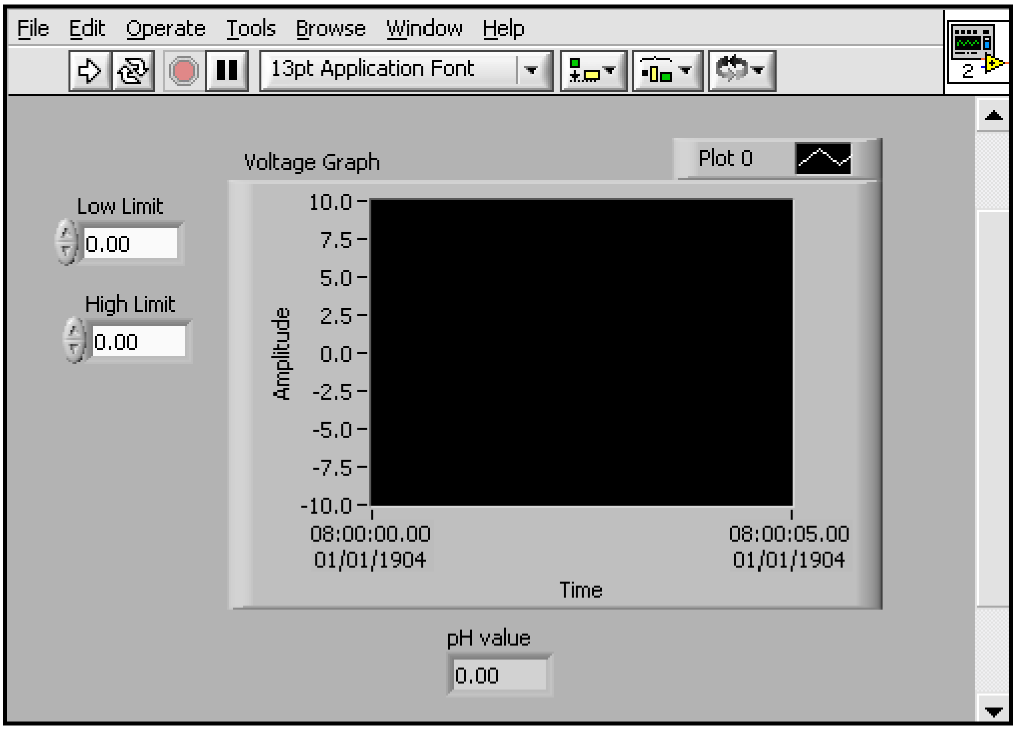

Figure 13 : Screenshot for voltage part of the program

The block diagram of the voltage part is shown as below. The connection is made from the DAQ channel and displayed to voltage graph.

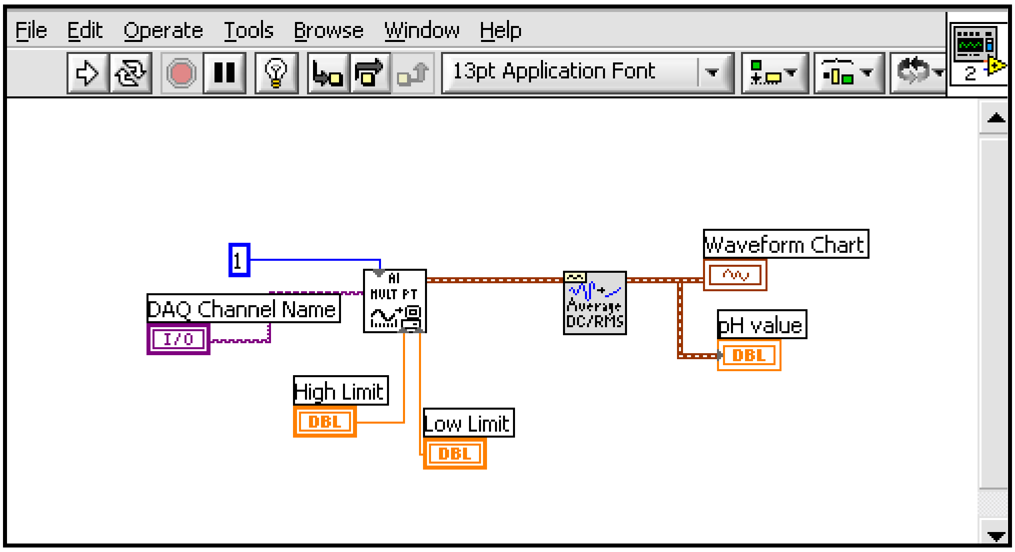

Figure 14 : Block diagram of voltage part

4.5 Work Test

The prototype is tested first using liquid, which is the mineral water. Theoretically the pH level of mineral water is 6.8 [13]. By running the software, the result is shown in Figure 15.

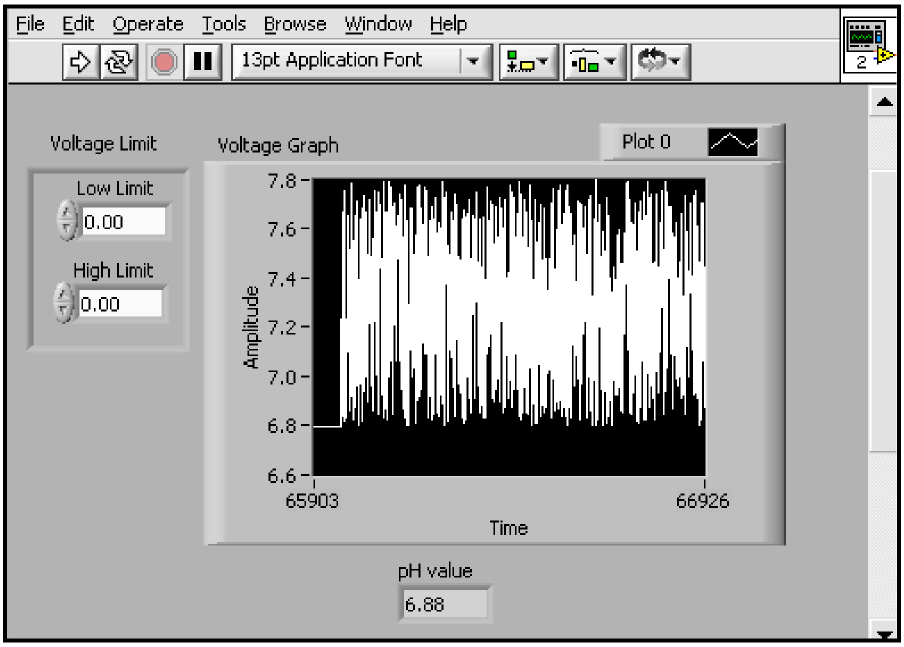

Figure 15 : Result for mineral water

The voltage limit is not set so that the graph can record a suitable range of voltage induced. As shown in Figure 15, the sensor induced voltage in random manner. To obtain the pH value, the average of the graph is calculated and displayed in pH value box.

Next test is being done for tomato juice in room temperature. Normal pH for tomato juice is 4.2 [13]. The sensors are immersed in the juice and the voltage induced is recorded. The result is as shown in Figure 16.

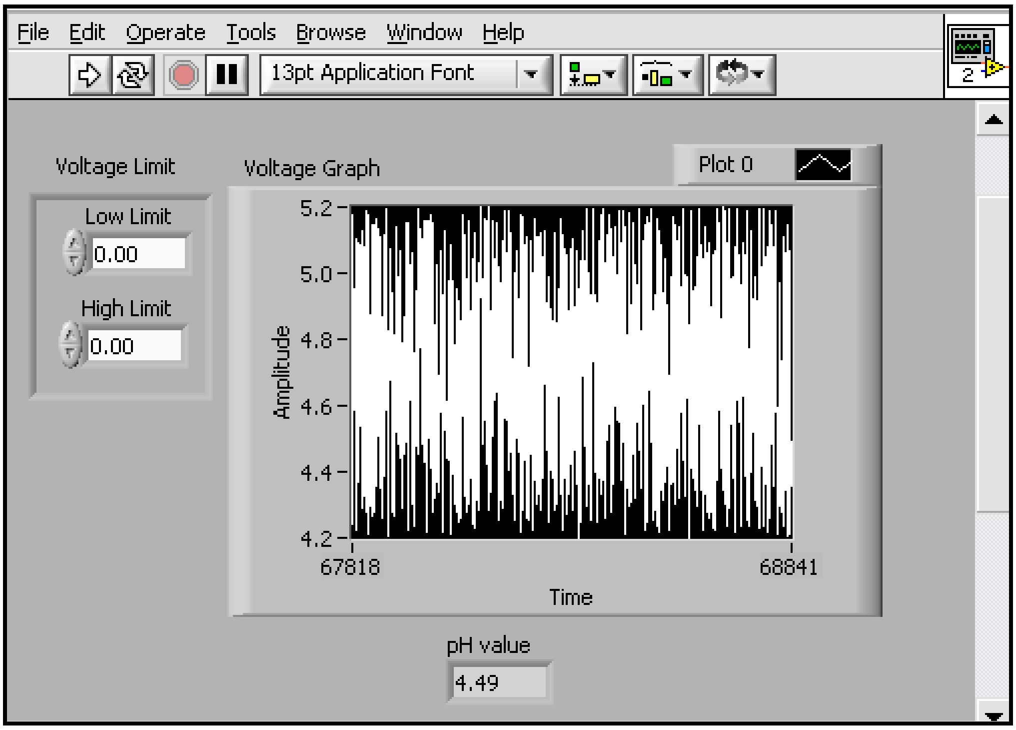

Figure 16 : Result for tomato's juice

The result showed that pH for tomato’s juice is 4.49.The result is acceptable as the value is closed to normal pH which is 4.2. Test also has been done to over ripe tomato. The pH level of over ripe tomato is expected to be different and more acidic. The result of the test is shown in Figure 17.

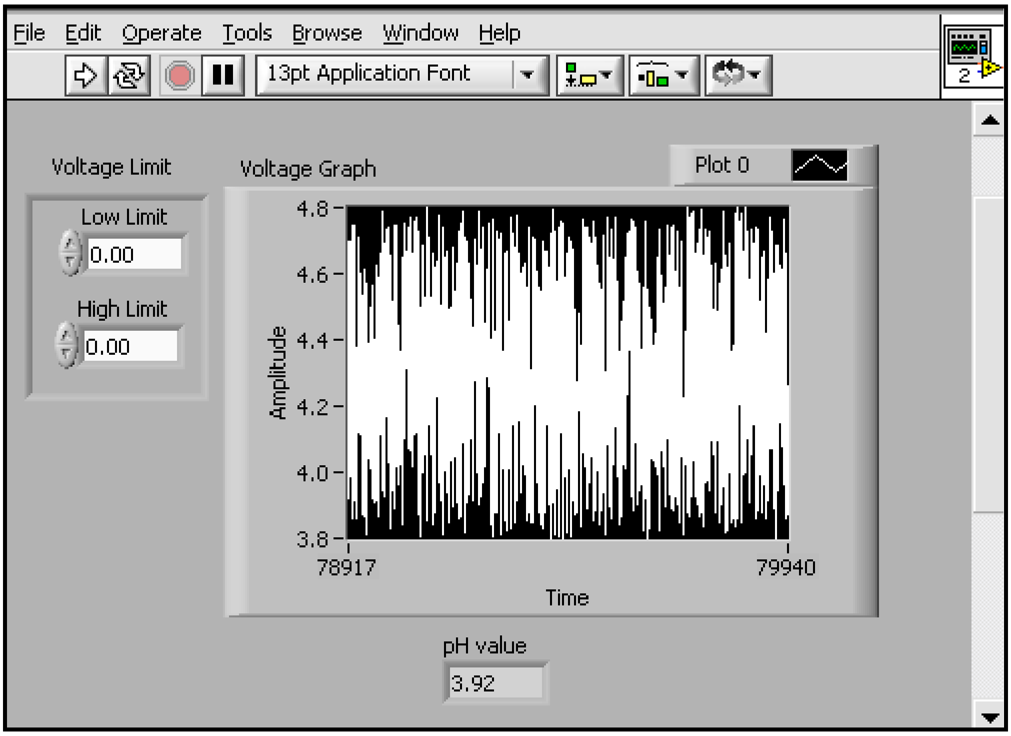

Figure 17 : Result for over ripe tomato

From the result it showed that the pH level for over ripe tomato is lower than to tomato in normal condition. This is proved that fruits have a different pH value for its different condition. The over ripe fruit has more acidic pH value than fruit in its optimal condition. By knowing the pH value that we are consuming, this can protect our health from any disease.

Chapter 5
CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The findings showed that the pH Based Food Analyzer (PBFA) can be used in determining the pH level in fruits. The most suitable is using ion-selective electrodes with electrochemical transducer since it's effective to a specific chemical compound especially H^+ ions and the signal can be transferred easily.

The principle of ion-selective electrodes is it reacted with specific type of ions and induced certain amount of voltage. The amount of voltage induced is the identification of H^+ ions contained in the tested solution. This voltage will be interpreted to determine the pH level.

5.2 Recommendation

This project can be improved more in terms of few aspects. Improvement for this project is to have temperature compensation for pH reading. The pH value got from the voltage reading is in room temperature. Different temperature will give different pH value. By covering this aspect, the pH value got from the software can be more accurate.

Second is to have the prototype that is small and portable size. The pH Based Food Analyzer is connected to DAQ card which is very difficult to carry around and it needs to connect to a computer. To solve this problem, this PBFA can be built in portable size so that it can be carried around easily and also can attract customer in industry based.

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APPENDICES

APPENDIX A

GANTT CHART FOR FYP1

No.	Detail/ Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	Selection of Project Topic															
2	Preliminary Research Work															
3	Submission of Preliminary Report				•											
4	Research on chemical compound															
5	Research on recognition element															
6	Research on transducer															
7	Submission of Progress Report								•							
8	Gathering the material and construct prototype (hardware and software)															
9	Submission of Interim Report Final Draft														•	
10	Submission of Interim Report															•

Gantt chart for FYP1

APPENDIX B

GANTT CHART FOR FYP 2

No.	Detail/ Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	Circuit construction and simulation	■	■	■	■											
2	Submission of Progress Report				●											
3	Software construction				■	■	■	■	■	■	■	■	■	■		
4	Seminar											●				
5	Experiment											■	■	■	■	
6	Poster exhibition										●					
7	Submission of Dissertation (soft bound)												●			
8	Oral Presentation														●	
9	Submission of Dissertation (hard bound)															●

Gantt chart for FYP2

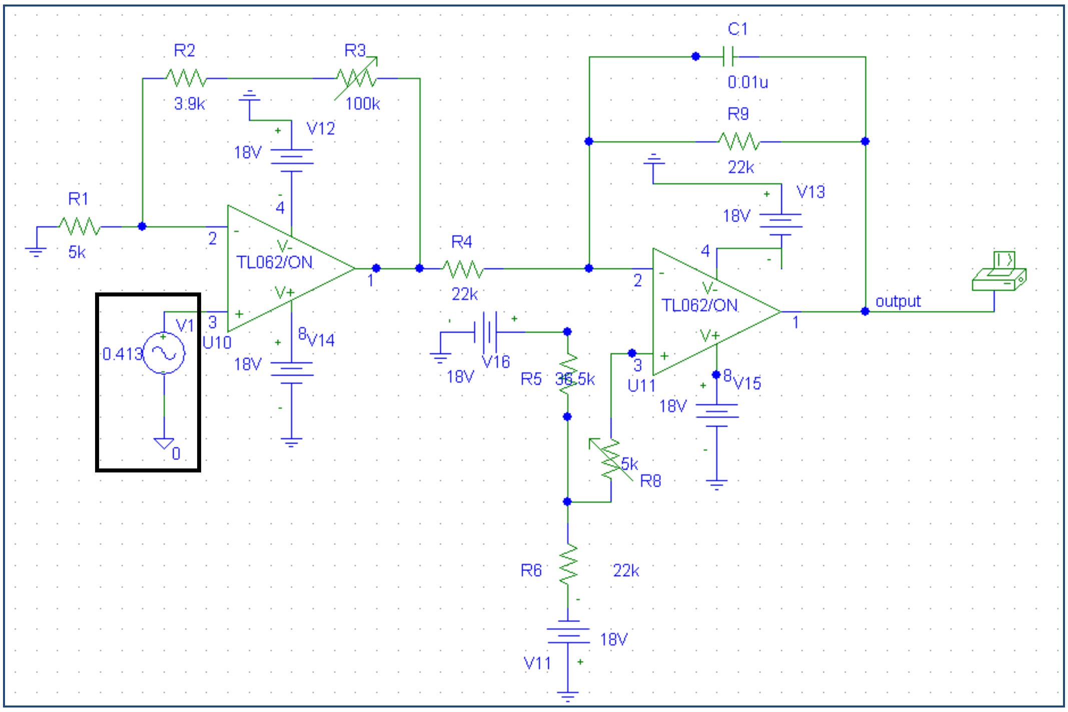
APPENDIX C

LABORATORY MODEL

Laboratory Model in Simulating Circuit using pSpice

First step : Create simulation profile

All the components are placed according to circuit diagram and connected to wire. Figure below shows the complete connection.



Second step : Stimulate design

To stimulate the design, need to replace the sensor's input with voltage supply, V1. V1 is an analog voltage supply as sensor produce analog voltage. V1 is replaced with induced voltage with respect to each pH level.

pH Value	Voltage Reading (Volts)
1	-0.354
2	-0.295
3	-0.236
4	-0.177
5	-0.118
6	-0.059

7	0
8	0.059
9	0.118
10	0.177
11	0.236
12	0.295

To stimulate the design, the setting is changed. From the pSpice, the Setup is clicked under Analysis tab. Another window pops up. From this window, enable AC Sweep and Bias Point Detail.

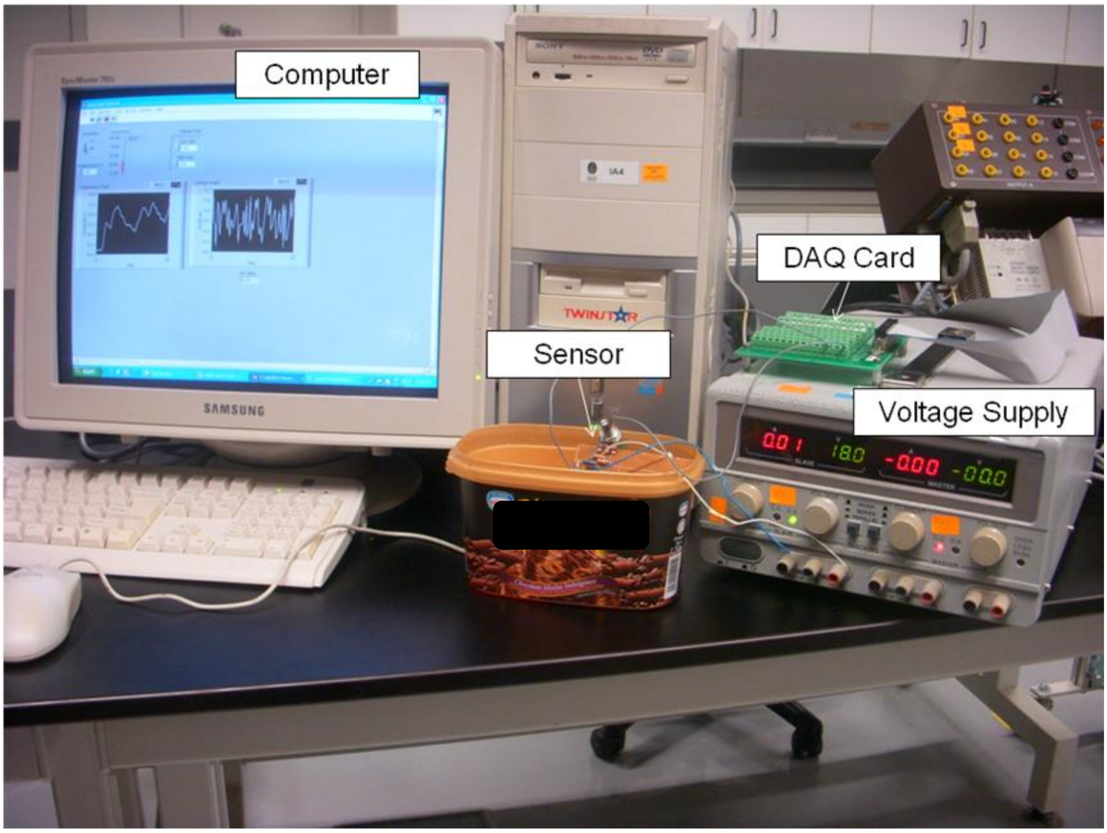
After changed the setting, the circuit is ready to be stimulated. To stimulate the design, click Analysis – Stimulate. The result is showed from the graph.

Third step : Analyze result

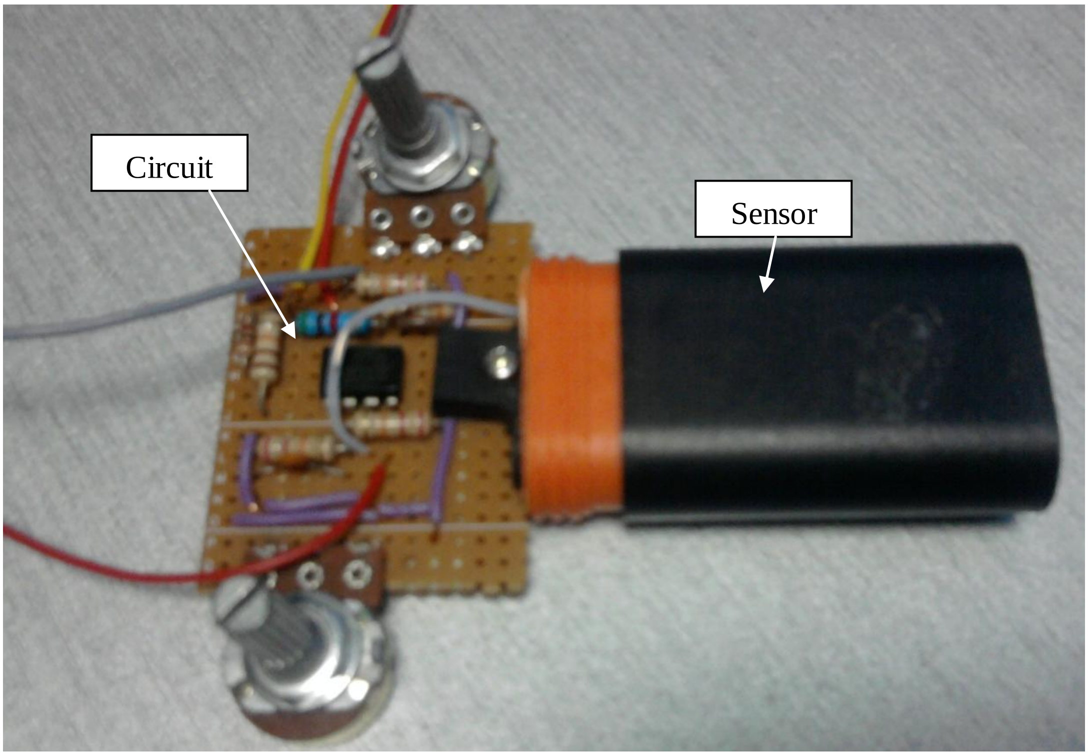
All the results obtained from the stimulation is recorded and tabulated. The result is compared to theoretical value of induced voltage and also pH value.

APPENDIX D

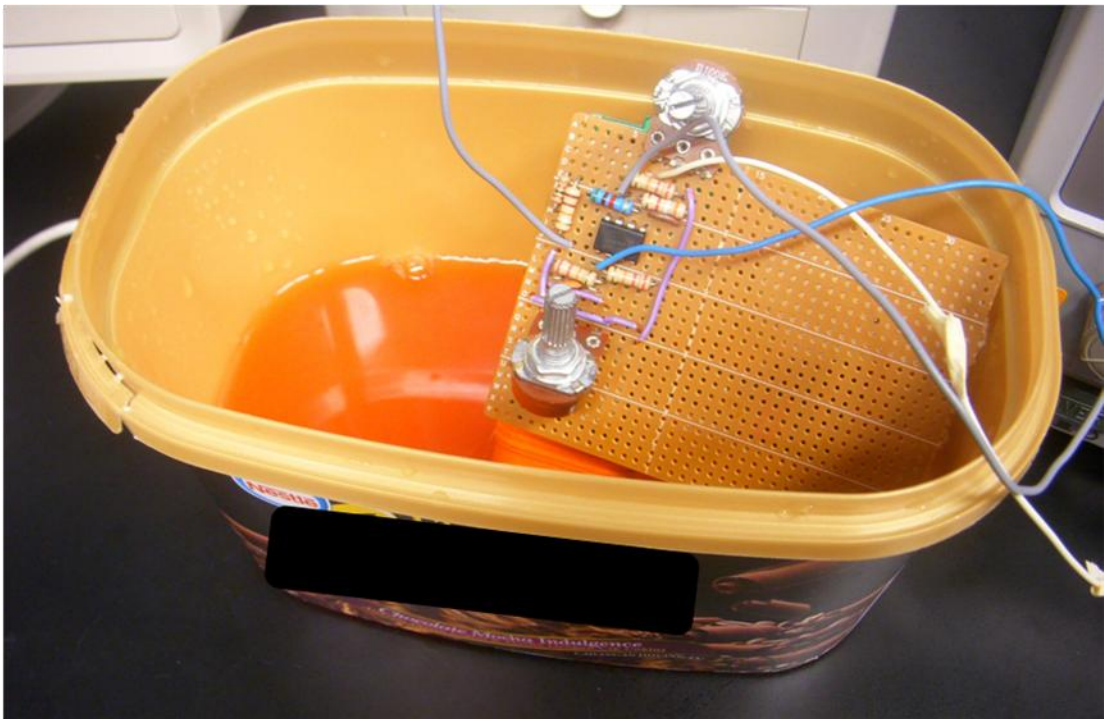
PROTOTYPE



Overall picture of prototype connected to computer and voltage supply



Picture of prototype



Picture of prototype being tested with tomato juice

APPENDIX E

DATASHEET OF TL062