

# **Neural Network Algorithm Development For Ion Sensitive Field Effect Transistor (ISFET) Sensor**

This thesis is represented in partial of fulfillment for the award of the

**Bachelor of Engineering (Hons.) in Electronic Engineering**

**UNIVERSITI TEKNOLOGI MARA**

**(SEPT 2012 – JULY 2013)**



**MUHAMMAD NASRUL HAKIM B. ADENAN (2010860744)  
FACULTY OF ELECTRICAL ENGINEERING  
UNIVERSITI TEKNOLOGI MARA  
40450 SHAH ALAM SELANGOR  
MALAYSIA**

## ACKNOWLEDGEMENT

*In the name of ALLAH S.W.T the most Merciful and the most Gracious*

All praises to Allah for His Kindness, I able to complete this project. However, it would not have been possible without the kind support and help of many individuals and organizations.

In such a great opportunity, I would like to thank my supervisor, madam Maizatul Zolkapli for her support, advices, motivation and guidance in completing the project.

Thanks and appreciation to Dr. Wan Fazlida Hanim Abdullah for her kind co-operation and encouragement and for providing necessary information regarding the project which helps in completion of this project.

I would like to express my special gratitude and thanks to master student, Nor Hakimah for giving me such attention and time for discussions and sharing informations. I also would like to express my gratitude towards my family and friends for their kind co-operation and encouragement which help in completion of this project. My thanks and appreciations also go to people who have willingly helped me out with their abilities.

## **ABSTRACT**

Ion Sensitive Field-Effect Transistor, which later in this paper will refer as ISFET is a kind of sensor that able to differentiate the ion by replacing the gate of the FET with electrode and the membrane. Membrane acts as selector for the ions. The sensor detects the ions and converts it into electrical signal. However the sensor has weakness to detect main ion from the interfering ion in the mixed solution when the ions have same characteristic. For this project, potassium ion ( $K^+$ ) and ammonium ion ( $NH_4^+$ ) will be used as the sample as both ions have similar size. To overcome the problem, the sensor needs to be trained for pre-calibrate and pre-process by developing a model of Artificial Neural Networks (ANN). The ANN makes the model learn the pattern by the sample of inputs and outputs to estimate results or to get more accurate data. Backpropagation is used as the learning method of ANN model. The algorithm will be developed in MATLAB. The objective of this project is to develop ANN model for ISFET sensor that able to estimate the main ion in mixed solution by learning the pattern of the input and output of the sensor. The ANN model performance can be optimized by altering certain parameters in the learning algorithm. The results show that the model is able to predict with 97% accuracy and has strong and precise estimation ability with R-factor of 91.55%.

## TABLE OF CONTENTS

<b>ACKNOWLEDGEMENT</b>	<b>IV</b>
<b>ABSTRACT</b>	<b>V</b>
<b>LIST OF FIGURES</b>	<b>VII</b>
<b>LIST OF TABLES</b>	<b>VIII</b>
<b>CHAPTER 1: INTRODUCTION</b>	<b>1</b>
1.1 PROJECT BACKGROUND	1
1.2 PROBLEM STATEMENT	2
1.3 OBJECTIVES	3
1.4 SCOPE OF WORK	4
1.5 STRUCTURE OF THESIS	4
<b>CHAPTER 2: LITERATURE REVIEW</b>	<b>6</b>
2.1 ISFET AS SENSOR	6
2.2 ARTIFICIAL INTELLIGENCE	7
2.2.1 ARTIFICIAL NEURAL NETWORK	8
2.2.2 FUZZY LOGIC	9
2.2.3 GENETIC ALGORITHM	9
2.2.4 APPLICATION OF ARTIFICIAL INTELLIGENCE	10
2.3 ARTIFICIAL NEURAL NETWORK BASIC CONSTRUCTION	11
2.4 ACTIVATION FUNCTIONS	12
2.5 LEARNING METHOD	14
2.6 PARAMETERS FOR BACKPROPAGATION	15
2.7 MATLAB	16
<b>CHAPTER 3: METHODOLOGY</b>	<b>17</b>
3.1 STRUCTURE OF ISFET SENSOR SYSTEM	17
3.2 NEURAL NETWORK ARCHITECTURE	18
3.3 TRAINING AND TESTING NEURAL NETWORK	20
3.4 IMPROVE BACKPROPAGATION DESIGN	20
3.5 DESCRIPTION OF BACKPROPAGATION PROCESS FLOW	22
<b>CHAPTER 4: RESULTS AND DISCUSSION</b>	<b>24</b>
4.1 EFFECT OF ACTIVATION FUNCTIONS	24
4.2 EFFECT OF PARAMETERS TO THE PERFORMANCE OF ANN	26
4.2.1 HIDDEN NEURON OPTIMIZATION	27
4.2.2 LEARNING RATE OPTIMIZATION	29
4.2.3 MOMENTUM OPTIMIZATION	31
4.3 OVERALL PERFORMANCE CHECK	33
<b>CHAPTER 5: CONCLUSION</b>	<b>36</b>
<b>CHAPTER 6: RECOMMENDATION</b>	<b>37</b>
<b>LIST OF REFERENCES</b>	<b>39</b>
<b>APPENDICES</b>	<b>41</b>

# **CHAPTER 1**

## **INTRODUCTION**

### **1.1 PROJECT BACKGROUND**

The ISFET sensor is MOSFET based sensor that detects ions by their sizes [1]. The sensor functions by sensing the ions that pass through the membrane. The ions that pass through the membrane will change the voltage threshold of the FET [2]. The output produced of this ISFET is in Drain Current value that will be converted to voltage value by readout circuit. The complications to differentiate the ions with same characteristics are the main concern and motivation to develop the learning algorithm for this ISFET. The output produced will show as the mixed ions instead of single separated ions. In order to overcome this problem, the ISFET needs to learn how to differentiate the ions with same characteristics.

The neural network is one of the artificial intelligence that able to demonstrate the learning ability same as brain [7]. The neural network will be applied as the learning algorithm to improve the selectivity of ions for this ISFET. By implementing this model to the ISFET, the sensor is expected to have better classification ability in classifying solutions of its pH value.