# UNIVERSITI TEKNIKAL MALAYSIA MELAKA

## DEVELOPMENT OF FOREIGN MATERIAL IN FOOD DETECTION SENSOR USING RESISTANCE CONCEPT

This report is submitted in accordance with the requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor of Electronics Engineering Technology (Telecommunications) with Honours.

by

**NUR FARHANA INTAN SUHAILA BT RIZALMAN**

**B071410447**

**950529105080**

FACULTY OF ENGINEERING TECHNOLOGY

2017

# UNIVERSITI TEKNIKAL MALAYSIA MELAKA

## BORANG PENGESAHAN STATUS LAPORAN PROJEK SARJANA MUDA

TAJUK: **DEVELOPMENT OF FOREIGN MATERIAL IN FOOD DETECTION SENSOR USING RESISTANCE CONCEPT**

SESI PENGAJIAN: **2017/2018**

Saya **NUR FARHANA INTAN SUHAILA BT RIZALMAN**

mengaku membenarkan Laporan PSM ini disimpan di Perpustakaan Universiti Teknikal Malaysia Melaka (UTeM) dengan syarat-syarat kegunaan seperti berikut:

1. Laporan PSM adalah hak milik Universiti Teknikal Malaysia Melaka dan penulis.
2. Perpustakaan Universiti Teknikal Malaysia Melaka dibenarkan membuat salinan untuk tujuan pengajian sahaja dengan izin penulis.
3. Perpustakaan dibenarkan membuat salinan laporan PSM ini sebagai bahan pertukaran antara institusi pengajian tinggi.
4. **Sila tandakan (✓)

| | | |
|---|---|---|
| ☐ | SULIT | (Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysia sebagaimana yang termaktub dalam AKTA RAHSIA RASMI 1972) |
| ☐ | TERHAD | (Mengandungi maklumat TERHAD yang telah ditentukan oleh organisasi/badan di mana penyelidikan dijalankan) |
| ☐ | TIDAK TERHAD | |

Disahkan oleh:

_____ _____

Alamat Tetap:

PLB NO 2 JALAN PUSAT DESA

KG BUKIT BADONG 45600

BESTARI JAYA SELANGOR

Cop Rasmi:

Tarikh: _____ Tarikh: _____

** Jika Laporan PSM ini SULIT atau TERHAD, sila lampirkan surat daripada pihak berkuasa/organisasi berkenaan dengan menyatakan sekali sebab dan tempoh laporan PSM ini perlu dikelaskan sebagai SULIT atau TERHAD.

# DECLARATION

I hereby, declared this report entitled “Development of Foreign Material in Food Detection Sensor Using Resistance Concept” is the results of my own research except as cited in references.

Signature : …….

Author‟s Name : NUR FARHANA INTAN SUHAILA BT RIZALMAN

Date : 20 DECEMBER 2017

# APPROVAL

This report is submitted to the Faculty of Engineering Technology of UTeM as a partial fulfillment of the requirements for the degree of Bachelor of Electronics Engineering Technology (Telecommunications) with Honours. The member of the supervisory is as follow:

……

(Project Supervisor)

# ABSTRAK

Sensor Rintangan Elektrik untuk mengesan bahan asing dalam sensor pengesanan makanan dibina dan dibentangkan dalam kerja ini. Projek ini memberi tumpuan kepada bagaimana untuk merekabentuk dan melaksanakan sistem untuk mengesan dan membezakan antara makanan dan bahan asing menggunakan konsep rintangan. Plat elektrod Sensor Rintangan Elektrik (SRE) direka bentuk menggunakan perisian Comsol Multiphysics untuk melihat medan elektrik dan kontur potensi elektrik sistem. Nilai rintangan dari sensor diukur berdasarkan konsep Litar AC. Arus bolak dari sensor mengalir ke litar pengesan pengecasan yang memberikan voltan sepadan dengan rintangan antara elektrod. Voltan dari litar pengesan caj telah ditinggikan oleh litar penguat untuk memperoleh output DC dari isyarat input AC. Litar bentuk voltan telah ditukar dari analog ke isyarat digital menggunakan Aplikasi Elektronik Bluetooth melalui Arduino Uno melalui modul Bluetooth HC-05. Aplikasi Elektronik Bluetooth digunakan sebagai antara muka pengguna grafik (GUI) untuk memaparkan keadaan bahan yang diuji termasuk makanan dan bahan asing untuk telefon pintar.

# ABSTRACT

Electrical Resistance Sensor for detect the foreign material in food detection sensor is constructed and presented in this work. This project focuses on how to design and implement the system to detect and distinguish between food and foreign material using resistance concept. The electrode plate of Electrical Resistance Sensor (ERS) is designed using Comsol Multiphysics Software to see the electric field and contour of the electric potential of the system. The resistance value from the sensor is measured based on AC Circuit concept. The alternating current from the sensor flows to the charge detector circuit providing the voltage corresponding to the resistance between the electrode pair. The voltage from the charge detector circuit has been amplified by amplifier circuit to obtained DC output from AC input signal. The voltage form circuit has been converted from the analog to digital signal using Bluetooth Electronics Application via Arduino Uno through HC-05 Bluetooth module. The Bluetooth Electronics Application is used as graphical user interface (GUI) to display the condition of the material tested including food and foreign material to smartphone.

# DEDICATION

Special dedicated to
my beloved parents and siblings as well as my friends, who have encourage, guided and supported me throughout my study.

# ACKNOWLEDGEMENT

All praise is due to Allah the Almighty, The Beneficent, the Merciful for the strengths and His blessing and for giving me this opportunity to finish my final Degree project. Alhamdulillah, I have learnt so many things in order to improve my knowledge and skills and lead to completion of this project.

First and foremost, I'm eternally grateful and thankful to my supervisor, En. Wan Norhisyam Bin Abd Rashid for his supervision, continuous guidance, meticulous suggestions, patience and constant support. I consider myself very fortunate for being able to work with a very considerate, understanding and encouraging lecturer like him. His invaluable help of constructive comments and suggestions throughout the experimental and thesis works have contributed to the success of this project. Without his offering to accomplish this project, I would not be able to finish my study at UTeM.

My deepest gratitude goes to my beloved mother; Jumilah Bt Jumat, my uncle and my aunty; Amir Bin Basiron and Junaini Bt Jumat and as well as my sisters; Siti Nadzirah Bt Amir and Nur Farhanny Intan Suraya Bt Rizalman for their endless love, prayers and encouragement, and for always there cheering me up and stood by me through the good times and bad. Gazillion thanks to all lecturers and my friends who directly or indirectly contributed in this project, as their kindness means a lot to me. Thank you very much.

# TABLE OF CONTENT

# LIST OF TABLES

# LIST OF FIGURES

# CHAPTER 1
# INTRODUCTION

## 1.0 Background of project

Electrical Resistance Sensor (ERS) is used as a novel concept of detection of foreign material in food. Resistance idea itself is the measure of opposition to electric current. At the point when an electric current of one ampere passes through a component across which a potential difference voltage of one volt exists, then the resistance of that component is one ohm. The only law that applied in this concept is Ohm‟s Law. It states that current is directly proportional to the voltage and inversely proportional to the resistance. For that reason, the measure of voltage is equal to the measure of current multiplied by the measure of resistance, V=IR (Rosenberg, 2005).

Electrical resistance is the easiest electrical property to be measured accurately over a wide range at moderate cost. There are many classifications of resistive sensors based on their sensing principle but this project focused on using photoresistive which it decrease in resistance when light strikes a photo-conductive material (Du, 2015). A few materials, like copper is used as the electrode in this project as it has a very low resistance to the flow of electricity. Others, for example glass or rubber have a very high resistance to the flow of electricity. This fairly clearly is the reason copper is used as electrical conductors and why we use rubber and plastic to insulate those electrodes.

The system is adopted from Electrical Resistance Tomography (ERT) concept because of its advantages of being low cost, suitable for various kinds and sizes of pipes and vessels, having no radiation hazard, and being non-intrusive (Aw

et al, 2014). ERT usually carried out with multi-electrode resistivity and measure the resistivity distribution of the subsurface materials (Saad et al, 2012). The electrodes can be set in 8, 16 or 32 electrode groups but this project only used only two electrodes. ERT is used to determine resistivity by making measurement of voltage around the electrode. ERT used to measure resistivity by comparing the resistivity values collected.

This project will discuss on how the resistance concept is used as a detection sensor on determining foreign material in food. The whole system was designed to detect the presence of unwanted foreign materials in different types of food product which applies the tomographic imaging to it. As for food detection, there were many other techniques used to detect presence of foreign material in food such as metal detection, optical techniques, X-ray food inspection, electrostatic techniques, microwave techniques and etc. but this will use a novel method of ERT. The food such as a food in a container for example will be detected by the sensor and from that the final result will be displayed be Bluetooth Electronics Application.

## 1.1 Problem Statement

Food inspection has been a serious matter in the food industry as the contamination by foreign materials such as metals, bone, plastics and glass in food plays a major impact in the industry. In spite of a great deal of effort to prevent mixing foreign bodies in food materials, food manufacturers have still not been able to detect them. Some of the food products are poorly in condition without inspection of the supplier which may reduce the quality of the food makes many consumers feel unpleasant plus it is hard to distinguish between food itself and the foreign material contains in it. So, improvements in the food inspection need to be taken in the food industry itself.

## 1.2 Objective of project

At the completion of tasks project, I will able:

i. To develop a sensor that able to detect the presence foreign material of food products.
ii. To make an inspection for the food products.
iii. To distinguish between foreign material and food during the detection process.

## 1.3 Scope of Study

The focus of the project will be on:

i. Develop a sensor to detect any foreign material in the food product.
ii. Using GUI for inspection whether the food contains any foreign material or not.
iii. Construct a signal conditioning circuit to distinguish between food and foreign material in it.

## 1.4 Thesis Outline

The report is divided into five chapters where each of the chapter is briefly described as follow:

First chapter is describing the background of project, problem statement, objectives of the project and scopes of study.

Second chapter presents the literature review of the project. It discussed about the types of design of sensors, Electrical Resistance Tomography Concept, food detection and some previous research paper related to the project.

The third chapter explains about the methodology of the project. The project consist both types of process flows for simulation and hardware part. The simulation part describes the methods how Electrical Resistance Sensor is designed using Comsol software up to the hardware part and development Bluetooth Electronics Application as graphical human interface (GUI).

The fourth chapter describes data analysis and explanation about the results and discussions for software and hardware of this project.

The fifth chapter is describing the conclusions of finding results and suggestions for future work.

# CHAPTER 2
# LITERATURE REVIEW

## 2.0 Introduction

Electrical resistance is a numerical factor that used to calculate voltage as well as current. Sensing takes of changing in resistance to infer changes in others physical measurements. It is important to understand where resistance do changes due of material or geometry changes. Specifically, electrical resistivity tomography (ERT) is the method used in order to determine resistivity by making measurement of voltage around the periphery of a vessel. In other word, it used to measure resistivity by comparing resistivity values collected. The arrangement for ERT usually consists of electrodes array and the measured is the resistance itself (or impedance) (York, 2001). The whole system include sensors, measurement electronics, switching electronics, signal conditioning circuit, analogue to digital converter, communication and a host computer control as well as a data processing.

## 2.1 Studies on previous paper

There was previous review about the applications ERT as proposed by Beck (1998) which were;

Table 2.1: Previous reported applications of ERT

| Process | status |
|---|---|
| Nuclear waste site characterisation | Field test |
| Waste storage ponds | Field test |
| Subsurface resistivity | Field test |
| Leaks in buried pipes | Field test |
| Multi-phase flow | Laboratory test |
| Hydrocyclone monitoring | Industrial process |

This short listed were some of the applications that have been done in the developed in the specific areas which have been mentioned before. The main component during the process is the design of the sensor, specifically on the electrode part. Usually, the maximum number of electrodes used the in the design of the sensor is 16 but in my project will only involve 2.

## 2.2 Design

As for Andrew J. Wilkinson (2005), he did a development of a design of a pulse-based high speed with 1000 frames/s ERT system with real-time visualisation. This is because it much simpler than any sinusoidal-based system and it is capable of very high frame rates. The targeted area was for the mixing phenomena and also for slurry pipe-line flow. Some of the 16-electrodes were built in one current source which multiplexed to the drive electrodes and the electrode pairs multiplexed to one detector amplifier. This design was implemented using low cost and readily available components.

Another new method for two-phase flow measurement has been proposed by Xiang Deng (2010) where the sensing electrodes need to be in contact with the conductive solution so that the field can be established. At the meantime, this system

use ac impedance which also known as contact impedance will be useful and important to the design application where in a way it can produce the same response signal as the actual system. The electrodes must own a good conductive performance and the value of the electrode surface area influences the measured voltage as it helpful to the uniform distribution of the exciting current density.

Colin D. Christy and Stephen A. Dyer (2002) did a method where of using 4-electrode array that effect in both resistance as well as contact resistance. These will lead to additional current and voltage measurement as it used two electrodes to inject current and the other two to measure resulting voltage drop just like in figure 1. It works when the measurement of resistance are taken during the system is moving across the ground. This method took place so that the bad measurements can be strained out and resistivity and contact resistance can be measured instantaneously.

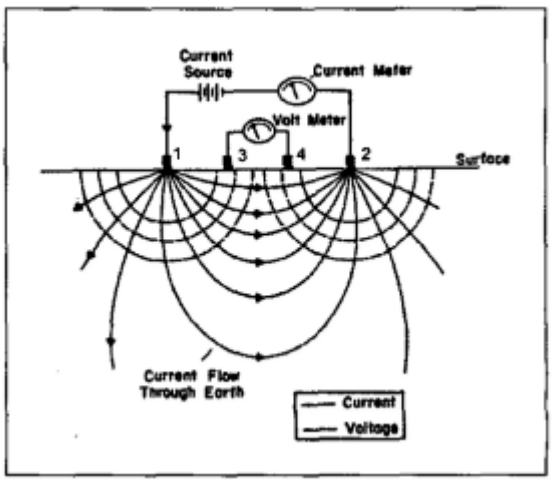


Figure 2.1: Schematic of a four-electrode resistivity measurement.

Another design of a sensor can be expended range of semiconductor resistance sensor (Guan, 2010) in order to improve measurement accuracy which eventually leads to good feasibility. Semiconductor resistance sensor is commonly used in the industry because of speed small volume, high sensitivity, light weight and easy integration as well as improves measurement accuracy.

ERT has been created for a considerable length of time as one of the fundamentals procedure of tomography which took places especially in the industry. Before, the previous ERT system which happened the metal electrodes are in contact with the liquid directly (Wang, 2013) and lead to electrode corrosion and limitation of applications of ERT in the industry itself. In order to overcome the situation, a new method has been proposed by B. Wang (2013) where using capacitively coupled contactless conductivity detection ($C^4D$) as a solution for that problem. An axial arrangement of $C^4D$ was introduced in 1998 and independently was made a meaningfully involvement to it. Then, it was simplified to 2 electrodes pattern in order to make sure the easier technique is used to measure the resistance of a liquid between electrodes without directly contacted within the liquid where it can be avoided of chemical reactions of the electrodes. Plus, it is used because the technique can be implemented without difficulty and has high sturdiness. This model is more specified on measurement of conductivity distribution of two-phase flow.

## 2.3 Other Applications

Flow rate measurement of two-phase flow is an unresolved problem in industrial and it is still on-going. So, the speed can be measured in the two-phase flows, via two sets axially parted sensors with the cross-correlation technique. A paper has discussed the way to extract the character from a certain voltage data for measuring correlation velocity with normalized cross-correlation method. In this paper, the dual-plane ERT system has been used, which takes the adjacent exciting mode alternately in dual planes and used 15frames/sec·plane, 16 titanium electrodes installed equally on each plane, which can obtained 208 voltage data in the exciting model.

Deng et al. (2012) have proposed a fusions research of electrical tomography with conventional sensors provide possibilities to improve two-phase flow accurate measurement. Based on their studies in the paper, fusions of ERT with electromagnetic (EM), electrical capacitance tomography (ECT) with ERT and ECT with electrostatic sensor are introduced and the theoretical support for the multi-

sensor fusion for two-phase flow measurement were discussed. In industry, tomography process has a potential in measurement of two-phase flows but it is hard to get precise measurement by tomography itself. It is possible to get precise measurement by fusion of industrial tomography with conventional sensors. Faraday‟s law of electromagnetic induction is used as the primer principle of EM flow meter in order to apply ERT with EM flow meter to realize the accurate measurement in gas or conductive liquid two-phase flow.

Stanley et al. (2008) on previous studies proposed undertaken using ERT for applications associated to wet particulate processing. University of Manchester has formerly been contributed on the development of electrical tomographic imaging technologies for different modalities together with electro-magnetic, capacitance and resistance tomography. Before, a study has been done with ERT in typical stirred vessel gas-liquid mixing, homogeneous single phase mixing created by different impeller types and an application to the semi-batch feed addition of strong brine – mimicking the semi-batch addition of a feed reactant (Stanley et al., 2005). While Pachowko et al. (2003) mentioned that ERT was used to monitor flow patterns in horizontal slurry transport lines. As usual, the ERT system consist a sensor, a data acquisition system and PC with control and data processing software and the sensor be made up of several electrodes set around or inside the region of interest. Electrodes used for both excitation as well as detection and commonly used as 16 invasive but non-intrusive electrodes as a configuration.

## 2.4 Sensor

In 2009, Gu et al. has proposed another way to develop a new resistance model, obtained from FEM (finite element method). In common, FEM is used to solve the forward problem like calculate the resistance value for a given conductivity distribution and electrodes setup and etc. Electrical resistance sensors when connecting to external discrete resistor networks can be accurately simulated using conventional circuit theories. This enhanced forward model and permits more

flexible sensor configuration and better images achieved, which provides a better foundation for ERT. Few years back, ERT has been established speedily and have been used in many industrial imaging applications up to now. It usually is made up of a set of electrodes evenly mounted around the periphery of the object being imaged. J. Zhao et al (2013) also proposed the electrical field finite element mathematical model of electrical capacitance and resistance dual-modality tomography sensor in 2002. Actually, ERT and ECT have been applied to three-phase flow parameters measurement has a great potential in industrial application as well.

Obrien et al. (2007) implemented a smart Dielectric Elastomer Actuator (DEA) with and integrated extension sensor based on resistance and measurement voltage. The sensor can minimize cost, complexity, and weight compared to external sensor. This project used DEA as actuators and used self-sensing technique instead of any other typical sensing technique where all the electrical characteristics are measured and related to the physical actuator. Obrien et al. (2007) also mentioned that a self-sensor has tolerance to very high voltages, integration with the power electronics and some other requirements. The sensor circuit consists of resistors, DEA and the voltage circuit consist of a resistor ladder and level converting circuitry.

ERS are used as a novel approach to quantify stream flow continuity which means continuous through time and longitudinal connectivity meaning continuous through space across watersheds in USA (Jaeger, 2011). The Continuity and connectivity were quantified based on a strict interpretation of continuous flow at an individual sensor or simultaneous stream flow at multiple sensors. 44 ER sensors were installed at approximately 2-km intervals and the sensor modifications consist two polyvinyl chloride (PVC)-insulated copper wires soldered to the sensor circuit board and protruding from the encased water-proof datalogger throughout eight canyons. Several semi-arid watersheds that are characterized by hydrologically complex flow patterns were accomplished.

Another new invention is from Wu (2015), where it proposed a new design and crosstalk error analysis on resistive sensor array. It was designed to improved crosstalk error among the elements by designed an improved isolated drive feedback

circuit using one op-amp to reduce it by the adjacent column elements. The circuit used the sample resistor connected the networked resistive sensor array to the ground. In the end, the measurement error of the element being tasted has been reduced regularly and it turned out that the less row number and large column number are preferred to be a good performance.

A resistance type sensor was invented by Yang (2016) based on chipless RFID where chip less RFID tags require no RFID transponder or battery and can work for a lifetime as they are not limited by battery life according to Qiao (2014). It usually classified in main categories like temperature sensors (Girbau et al., 2012) and supported by Kubina et al. (2015) where the chip less tag were proposed in. They consisted of an UWB antenna connected to a delay line and loaded with a resistive temperature sensor. It consists of a V-shaped metal scattered on one side of a dielectric substrate. The sensor can make the address information and resistance value transformed into the wireless signal and used directly in an RFID system.

Resistive sensor is the device for the measurement high power microwave pulse (Allampalli et al., 2016). The performance of the resistive sensor based on a well-known electron heating phenomenon in a semiconductor where it is inserted between the thin metal diaphragm and wide wall of the waveguide. This is as a prototype of the sensing element of the resistive sensor. The performance of sensing element is based on electron heating effect of the semiconductor. As the electric fields of the high-power microwave pulse heats electrons in the sample, its resistance changes and by measuring the resistance change the power of the HPM pulse in the waveguide is determined.