UNIVERSITI TEKNIKAL MALAYSIA MELAKA

DETECTION OF DIELECTRIC MATERIAL USING MINIATURE TWO-PLATE ELECTRICAL CAPACITANCE SENSOR

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

by

MOHD ALIF BIN MOHD TAH

B071310205

91040301 - 01 - 6641

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TAJUK: **DETECTION OF DIELECTRIC MATERIAL USING MINIATURE TWO-PLATE ELECTRICAL CAPACITANCE**

SESI PENGAJIAN: **2016/17 Semester 1**

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Alif

Alamat Tetap:

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Signature	:	Alif
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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 Electrical Engineering Technology (Industrial Electronic) with Honours. The member of the supervisory is as follow:

Wan Norhisyam
(Project Supervisor)

ABSTRAK

Penderia kemuatan elektrik untuk mengesan bahan dielektrik dibina dan dibentangkan dalam kerja ini. Projek ini memberi tumpuan kepada bagaimana untuk mereka bentuk dan melaksanakan sistem untuk mengesan jenis bahan dielektrik menggunakan ujian kemuatan elektrik. Penderia kemuatan Elektrik direka dengan menggunakan perisian Comsol Multiphysics untuk melihat medan elektrik dan kontur potensi elektrik. Nilai kemuatan dari perisian diukur berdasarkan konsep litar ulang alik. Arus dari penderia mengalir ke litar pengesan cas dimana nilai voltan ialah berpadanan dengan nilai kemuatan antara sepasang elektrod. Voltan dari litar pengesan cas telah dikuatkan oleh litar penguat sebelum menghantar kepada litar penapis untuk menolak isyarat yang tidak diingini dan untuk mendapatkan keluaran arus terus yang bersih dari isyarat masukan ulang alik. Voltan daripada litar penapis telah ditukar daripada analog kepada isyarat digital menggunakan perisian LabVIEW melalui litar Arduino Uno. Perisian LabVIEW digunakan untuk memaparkan jenis bahan dielektrik atau bahan komposit sama ada kertas, plastik, papan litar FR4 di dalam sistem komputer.

ABSTRACT

Electrical Capacitance Sensor for detect the dielectric material is constructed and presented in this work. This project focuses on how to design and implement the system to detect the type of dielectric material using non – destructive of Electrical Capacitance test concept. The miniature two-plate of Electrical Capacitance Sensor (ECS) is designed by using Comsol Multiphysics Software to see the electric field and contour of electric potential of the system. The capacitance 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 capacitance between electrodes pair. The voltage from the charge detector circuit has been amplified by amplifier circuit before sending to the low - pass filter for rejecting unwanted signal of the fringe effect and to get the clean DC output from AC input signal. The voltage from filter circuit has been converted from the analog to digital signal using labVIEW interface software via the Arduino Uno module circuit. The labVIEW software is used as graphical user interface (GUI) to display the type of dielectric material or composite material of paper, plastic, FR4 Circuit Board respectively in the computer system.

DEDICATION

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

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A lot thanks to Allah the Almighty give me this opportunity to finish my final Degree project. Indeed, the lessons learnt gained my knowledge and opened me up to new perspectives. In the name of Allah, most benevolent, ever-merciful, all praises be to Allah, Lords of all the worlds. Thank you Allah.

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LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURE

AC	-	Alternating Current
ADC	-	Analog to digital converter
DAS	-	Data acquisition system
ECT	-	Electrical Capacitance Tomography
ECS	-	Electrical Capacitance Sensor
GUI	-	Graphical User Interface
mm	-	millimetres
Op-amp	-	Operational amplifier
PC	-	Personal Computer
PCB	-	Printed Circuit Board
USB	-	Universal Serial Bus
Vp-p	-	Voltage peak-to-peak
A/D	-	Analog to Digital
f	-	Frequency
Cx	-	Unknown standing capacitance
d	-	Distance between of two plates
ε_0	-	Permittivity of free space
ε_r	-	Relative Permittivity
ε_p	-	Permittivity of plastic
ε_{fr4}	-	Permittivity of FR4
ε_{paper}	-	Permittivity of paper

CHAPTER 1
INTRODUCTION

1.0 Background of project

Electrical Capacitance Sensor (ECS) is a type of a non- destructive testing technique. This system is adopted from the Electrical Capacitance Tomography (ECT) concept which is become utmost mature between various tomography modalities. The concept operation of the system is to measure the variations of capacitance between two plates of electrodes representative the permittivity distribution and hence the material distribution (Yang & Peng, 2013). Any two adjacent conductors can be considering as a capacitor and different dielectric properties between conductors will create a different capacitance value (Mohamad et al. 2011).

. Each of the dielectric material has different permittivity value so it will result the different capacitance value. This system consists of three main parts which are electrode capacitance sensor, a capacitance measuring unit and a host of computer as shown in figure 1.1. The capacitance measuring circuit or known as signal conditioning circuit is used to collect data and convert the measuring reading to digital (Mohamad, 2012) before the computer manipulate and display the results.

In addition, the system is used guard electrodes at both ends of measurement electrodes as shown in figure 1.2 to permit short measurement electrodes pair to be use (Reinecke & Mewes, 1994). This system has some advantages compared other technique like X-CT and Electrical Resistance Tomography (ERT) which are non-radioactive, non- instructive and non-invasive and low cost (LIU, FU & YANG, 2004). In previous paper, there are a lot of researches related to ECT for industrial

manufacturing application including movement measurement in oil pipelines (Li, 2013),(Xie et al. 1992), wet gas separators, fluidized beds(Liu, Chen & Wang, 2005),(Liu, Yang & Wang, 2011),(Warsito & Fan, 2005),(Warsito & Fan, 2003), pneumatic conveyors and gas/solids cyclones(Wang, Liu, Jiang & Yang, 2006). The purpose of the research is to investigate the output voltage corresponding to the capacitance value of the Electrical capacitance Sensor on dielectric materials test on paper, plastic and FR4 board.

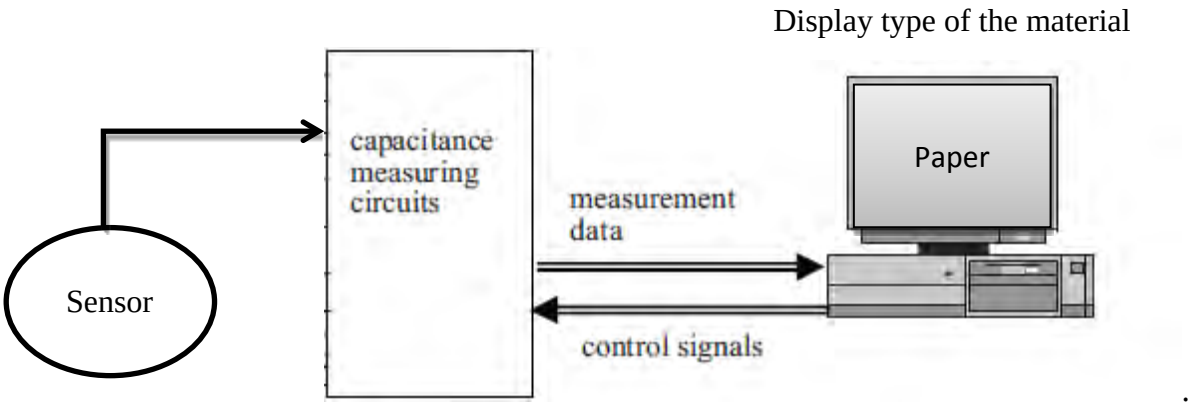

Figure 1.1 Overview of an ECS system

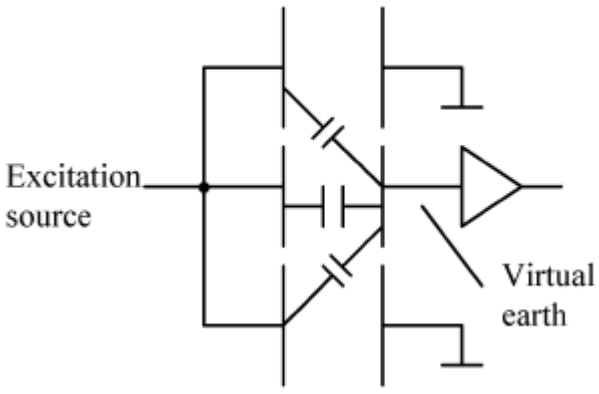

Figure 1.2 Connection of driven guard electrodes

1.2 Problem Statement

The ECS design has been linked to many issues. From that, here are several subjects which were highlighted and discussed as follows:

i. The measurement of internal electrode capacitance with the permittivity distribution and potential distribution is difficult using Laplace Equation. Therefore, by using Finite element method (FEM) simulation package is so much useful.
ii. The sensitivity in dissimilar location between the electrode pair can differ radically where the sensitivity distribution is not uniform. This is because of the evident attribute of soft-field sensing.
iii. To reduce the noise, driven guard electrodes is introduced to eliminate the fringe effect when measure internal electrode capacitance.

1.3 Objectives

At the completion of tasks project, I will able:

i. To design the Electrical Capacitance Sensor (ECS) using Comsol Multiphysics Software
ii. To study the performance of Electrical Capacitance Sensor
iii. To develop an Electrical Capacitance Sensor to detect the type of materials

1.4 Scope of Study

The focus of the project will be on:

i. Design an Electrical Capacitance Sensor in 2D using AC/DC (electrostatics) module in Comsol Multiphysics Software.
ii. The number of 2,4,6,8 electrodes, distance between two plates and the length of electrodes are considered in design of Electrical Capacitance Sensor in Comsol Software to see it performance when detect the dielectric materials.
iii. Development of two electrodes of ECS to test material distribution of FR4, paper and Strip board.

1.5 Thesis outline

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

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

Second chapter presents the literature review of the project. It discussed about the introduction about dielectric material, non- invasive testing method that available used in industry to detect the dielectric material and some previous research paper related to my project.

The third chapter explains about the methodology of the project. The project consist two types of process flows for software and hardware part. The software part describes the methods how Electrical Capacitance Sensor is designed using Comsol software and the hardware part consists of overview of internal electrode capacitance

is measured and development labVIEW software as graphical human interface (GUI).

The fourth chapter describes 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

A composite material is a structural material that has two or more combined constituents that are joint at a macroscopic level and are not soluble in each other. Besides that, advanced composite materials that are traditionally available used in the aerospace and another industries commercial as well (Kaw & Group 2006). It is fact that there are inherent flaw in composite material. Manufacturing process like welding, casting, forging, surface treatment and many more industrial applications may cause further flaws or defects.

Therefore, there are several of non - destructive methods (NDT) that can be used to evaluate the materials and at the same time can appraise in term of size, nature and place (International Atomic Energy Agency, 2001). Each of NDT method has advantages and disadvantages for a given application. From that, to select NDT method properly is very important that will give the necessary results.

2.1 Non-destructive Testing Method

Non-destructive method is some of the part quality control and it is complementary to other long established methods (Willcox & Downes, 2000). Non-destructive testing is used to test the materials, used for surface or internal flaws without interfering in any method with the integrity of the material or it is rightness for service. There are many non-destructive testing methods (Atomic & Agency, 2002) to detect the dielectric material in many applications that available used in industry like Radiography, RT, Ultrasonic, UT(Islam et al. 2006), Liquid Penetrant

,PT, Magnetic Particle Inspection, MPI) and Eddy Current Testing, ECT(Kufrin et al. 2010),(Garcia-Martin et al. 2011), (Stubendekova et al. 2014).

2.1.1 Radiography (RT)

2.1.1.1 Fundamental Principle

Radiography is a non-destructive inspection way that used short wavelength electromagnetic radiation passing through the material. This method is useful for the detection of internal defect or flaws in ferrous or lower material density allow more and so that absorb less. In addition, the radiation which reaches the film after passing through the materials becomes a shadow image in a photographic film. The area of low absorption looks dark areas on the developed film, while the area of high absorption looks as light area on the developed film.

2.1.1.2 How it works

Low energy radiation can be either in gamma or X-ray form. Gamma rays are the result of the decay of radioactive isotope while Iridium 192 is a common radioactive source. A gamma source is continuously emitting radiation and must be kept in shielding storage container when not in use. These containers always employ lead or depleted uranium. When electrons travelling at high speed, collide with matter x-ray is produced. The change of electrical energy is accomplished in an evacuated tube. A low of milliamphere (mA) between filament and a target accelerate electrons across this voltage differential.

The act of an electron striking the target produces X-rays which these are produced only voltage is applied to the X-ray tube. Whether using X-rays or gamma sources, the test object for example weld is not radioactive following the inspection. Subsurface discontinuities that are readily discovered by this method are voids instead rounded flaws, metallic and non-metallic inclusion and also favorably aligned incomplete fusion and flaws. Void such as porosity form dark area on the film because they represent a significant loss of a material. Furthermore, metallic inclusions form light area if they are denser than the test object

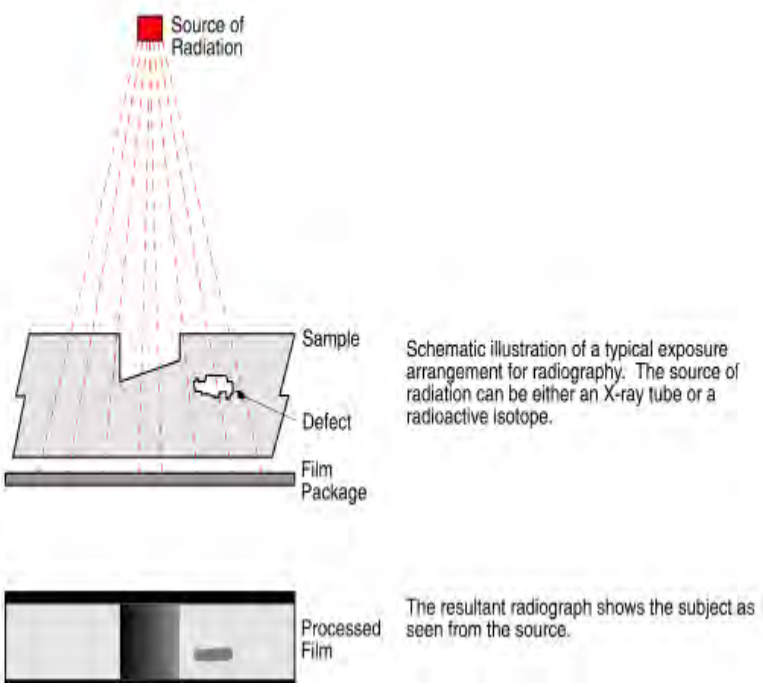

Figure 2.1 Illustration of Radiography Testing

2.1.1.3 Advantages and disadvantages

The advantages of this method are data is presented pictorially and permanent record is created which may be seen at a time and place distant from the test, suitable for thin sections, very