

“I hereby declare that I have read through this report entitle “The Construction of Crosstalk’s Testing Apparatus for Teaching and Learning” and found that it has comply the partial fulfillment for awarding the degree of Bachelor of Electrical Engineering (Industrial Power)”

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Date : 27 May 2013

**THE CONSTRUCTION OF CROSSTALK'S TESTING APPARATUS FOR
TEACHING AND LEARNING**

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**A report submitted in partial fulfillment of the requirements for the degree of
Bachelor of Electrical Engineering (Industrial Power)**

Faculty of Electrical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

May 2013

I declare that this report entitle “The Construction of Crosstalk’s Testing Apparatus for Teaching and Learning” is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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“To my beloved family, especially my parents Hj Ismail Bin Kasim
and Hajah Hasnah Bt Abdullah”

Thank you for all the support

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ABSTRACT

The unintentional interference in one system is always discussed for electrical and electronic circuit. This is caused by generation, transmission and reception of electromagnetic energy in systems. This unintentional interference, or referred as disturbance will cause the system itself affected, even disrupt the other system. The crosstalk issues is one of electromagnetic problem that caused unintentional interference occur in a system. This crosstalk problem is very important to discuss as for designing, implementing and maintaining of the electrical and electronic systems. Furthermore, the understanding of crosstalk issue is not understandable, as there is no such apparatus to demonstrate all the crosstalk criteria. Hence, to understand and analyze the crosstalk problem, it's crucial to have the crosstalk's testing apparatus. This project is focused on construction of the crosstalk's testing apparatus for the teaching and learning, based on theory of crosstalk. This crosstalk's testing apparatus will be use to study, examine and investigate the crosstalk problem such as capacitive coupling and inductive coupling .Moreover, the best method to overcome crosstalk problem are suggested after analyzed data is gathered. As a result, the form, characteristic, and feature of the capacitive and inductive coupling are performed through result obtained. . In addition, the problem resulting crosstalk is explained through experiment so that the objective of this project is successfully achieved. As recommendation, this project can be upgrade for further research by considering impedance coupling through experiment. Besides, the crosstalk testing's apparatus can be redesign to vary the orientation ($\cos \theta$) of two conductor wires, as it also can caused the crosstalk effect.

ABSTRAK

Gangguan yang tidak disengajakan didalam satu sistem selalu dibincangkan, terutamanya berkenaan dengan litar elektrik dan elektronik. Gangguan ini disebabkan oleh penjanaan, penghantaran, dan penerimaan tenaga elektromagnet didalam sistem. Gangguaan yang tidak disengajakan ini akan menjejaskan sistem itu sendiri, malahan mengganggu sistem yang lain. Isu *crosstalk* ini adalah satu masalah elektromagnet yang menyebabkan terhasilnya gangguan yang tidak disengajakan didalam sistem. Masalah *crosstalk* ini amat penting untuk dibincangkan apabila mahu mereka-bentuk, melaksana, dan menyelenggara sistem elektrik dan elektronik. Tambahan lagi, pemahaman tentang isu *crosstalk* ini tidak jelas, apabila tiada sebarang radas untuk mempamerkan kesemua kriteria *crosstalk*. Jadi, untuk pemahaman dan analisis terhadap masalah *crosstalk*, ia amat penting untuk memiliki radas ujikaji *crosstalk*. Projek ini akan memberi tumpuan kepada pembinaan radas ujikaji *crosstalk* untuk pengajaran dan pembelajaran, mengikut teori *crosstalk*. Radas ujikaji *crosstalk* ini akan digunakan untuk pembelajaran, penelitian dan penyiasatan terhadap masalah *crosstalk* seperti gandingan kapasitif dan gandingan induktif. Selain itu, kaedah terbaik untuk mengatasi masalah *crosstalk* ini dicadangkan selepas analisis data dikumpulkan. Hasil keputusan, bentuk, sifat, dan elemen gandingan kapasitif dan induktif dijelmakan dari keputusan yang telah dapat. Tambahan lagi, masalah *crosstalk* ini telah diterangkan melalui eksperimen, oleh itu objektif projek ini berjaya dicapai. Sebagai cadangan, projek ini boleh ditambah baik untuk kajian akan datang, dengan mengambil kira gandingan *impedance* didalam eksperimen. Antara lain, radas ujikaji *crosstalk* boleh diubahsuai untuk mengubah paksi ($\cos \theta$) terhadap dua wayar, kerana ia juga boleh menyebabkan efek *crosstalk*.

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LIST OF SYMBOLS

A	–	Area
B	–	Magnetic Field (Magnetic Flux per Area)
C12	–	Capacitance Crosstalk Between Conductor Wire
Cr	–	Capacitance Crosstalk Between Conductor to Ground Plane
E	–	Electric Field Intensity (Strength) V/m
F	–	Force
I	–	Current
k	–	Constant of $\sim 9 \times 10^9$ m/F
M	–	Mutual Inductance Between Frequency
Q	–	Charges
R	–	Resistance / Distance
V	–	Voltage
X	–	Reactance
Z	–	Impedance
ω	–	2π X Frequency

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CHAPTER 1

INTRODUCTION

1.1 Motivation

Unintentional interference of electromagnetic in electrical or electronic circuit may cause the system not function well, or even failure in the system. The examples of electromagnetic interference problem are, voice leaked at telecommunication line from other people's connection, interference on television display when vacuum cleaner is working, and others. This project will contributed enough to analyze and examine the unintentional interference caused by crosstalk problem. Moreover, the analyzed data can be use to suggest a best method to prevent the crosstalk problem. This project can be use for better understanding in learning and teaching process. As the crosstalk problem can clearly understand and solve, problem of signal interference caused by crosstalk problem can be reduce, or the system even immune to the unintentional interference.

1.2 Problem Statement

In principle, the crosstalk issue is very important aspect for designing, implementing and maintaining for the electrical and electronic systems. The crosstalk problem in the circuit could lead the circuit error. Moreover, the understanding of crosstalk issue is not understandable if there is no such apparatus to demonstrate all the crosstalk criteria, which are capacitive and inductive coupling. Therefore, it is crucial to have the crosstalk's testing apparatus for learning and teaching process. As having the crosstalk's testing apparatus, the

problem of unintentional interference can be perform and the action can be taken to reduce the crosstalk problem as well.

1.3 Objectives

The main purposes of this project are:

- To construct the crosstalk's testing apparatus for the teaching and learning based on theory of the crosstalk.
- To analyze and investigate the crosstalk problem, such as capacitive coupling and inductive coupling
- To find out the best method to overcome the crosstalk problems on the tested conductor wires.

1.4 Scope

In this project, the scope is limited to construct the crosstalk's apparatus by using the theory of electromagnetic coupling of the conductor. The crosstalk's testing apparatus will only perform the crosstalk problem which are capacitive coupling and inductive coupling and its only limit to perform crosstalk in electrical small circuit (small scale). Moreover, the apparatus is only to test crosstalk problem between two conductor wires, which are the wires of the source circuit and the wires of the victim circuit. This crosstalk's apparatus will only use aluminum as reference ground plane. At the end, the data will be measure and record by using oscilloscope at the victim circuit for analysis.

CHAPTER 2

LITERATURE REVIEW

2.1 Problem of Electromagnetic Interference (EMI)

Travelling of electromagnetic energy during generation, transmission, reception of electrical and electronic circuit can caused the unintentional interference to the other system. As an example, the receiving of radio signal can be interrupt when the radio is placed near to the computer, or any electronic equipment which having high frequency. The computer circuit will produce electromagnetic field which is catch up by radio antenna, and then processed by circuit of radio, and consequently caused unintelligible sound. [1, 4]

Electromagnetic interference (EMI) and electromagnetic compatibility (EMC) is related to each other. EMC can be defined as ability of devices or equipment that can function well in electromagnetic surroundings without creating electromagnetic disturbances to others system in those surroundings.

2.2 Electromagnetic Compatibility (EMC)

The aggressiveness of using electronic circuits for computation, communication, laboratory equipments and other purpose makes the need to diversity the system to operate at close range of each other. EMI is the main problem in designing an electronic circuit, and it's become important criteria need to be consider. The neglecting of EMI factor possibly caused the circuit not function well in electromagnetic environment, and also the electromagnetic field generated by it will affect the disturbance to other electrical and electronic system. [2, 4]

Furthermore, at the current situation, the usage of integrated circuit and large-scale integration has reduced dimension of electric equipment. As the circuits become smaller and compact, the diversity of circuit and components are placed in a small space, which will contribute to unintentional interference [2]. Moreover, the clock frequencies in certain electronic equipment have aggressively increased annually, example a computer having clock speed more than 2GHz. The EMC problem can be decomposed in three main parts, which are source of emission (emitter), transfer of emission (coupling path) and reception of emission (receiver or victim).[4]

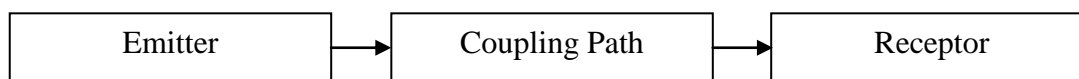


Figure 2.1: Basic decomposition of EMC problem

2.3 Electric and Magnetic Fields

The main elements in the electromagnetic interference are electric field and magnetic field, and they actually related to each other. Both elements are source of electromagnetic and caused the production of signal interference to other systems [5]. The relation of electricity and magnetism is explained thru Maxwell's equation. The electric charges containing positive and negative charge are attracting to each other, and they are repelled when in the same polarity. The force of attracting and repulsion of charges produced electric fields, and its can be referred as voltage. In addition, the movement of group of electric charge in same direction is called electric current. Sometimes, a moving group of negative charges is also called as electron. As a straight conductor wire allowing the current flow, it will produce and generate magnetic field over the conductor wire in circular form, according to the right hand rule [5, 9].

2.3.1 Coulomb's Law

As the attracting and repelling of the charges, their force between two charges can be expressed with the Coulomb's Law equation. The law is explained about a point of charges is exerts on another charges. The equation as below, [5]

$$F = \frac{k(Q1)(Q2)}{R^2} \quad (2.1)$$

Where, $F =$ Force of two charges (Newton)

$Q1$ and $Q2 =$ Point of charges

$R^2 =$ Distance in meters (m)

$k =$ Constant of $\sim 9 \times 10^9$ m/F

2.3.2 Force of Charged Element

The force, F of moving charges, Q in the Coulomb's Law also can be related with the electric field intensity, E . In others word, the electric field intensity is also called electric field strength. The equation as follows, [5]

$$F = QE \quad (2.2)$$

Where, $F =$ Force (Newton)

$Q =$ Point of charges

$E =$ Electric field intensity or strength (V/m)

2.4 Crosstalk

Crosstalk is the phenomenon that unwanted signals induced to a conductor wire caused by electromagnetic fields of electrical signal on another pair of conductor wires. The main circuit which caused the disturbance referred as source circuit, and the affected circuit referred as victim circuit [1, 2, 4]. When currents and voltages associated with signal transmission apply to the source circuit, the wire of source circuit will have electricity and also magnetic field. These electromagnetic fields will interact to the wire of victim circuit that lay in parallel, and induced the voltages and currents [1, 2].

The coupling process of crosstalk between two wires will occur when the distance of source wires circuit and affected wires is too close to each other. The crosstalk will occur to one system to another in two ways, which are when the system share common impedance and also through electromagnetic (EM) coupling. Commonly, crosstalk will happen by mixture of sharing common impedance and electromagnetic (EM) coupling. The crosstalk caused by electromagnetic (EM) coupling can be categorized in three types, which are capacitive coupling, inductive coupling and the last one is combination of both referred as electromagnetic coupling (radiation)[2, 4].

In theoretical, the crosstalk is easily occurred when the conductor wire is short compare to the wavelength. As the wavelength is long than conductor wire, the coupling circuit can be represented by components of capacitance and inductance. It also can generally said, that the crosstalk is increase with increasing of frequency. The analysis of crosstalk at near end region can consider the magnetic field and electric field separately, however at the far end region the electromagnetic must be consider [1, 2]. The near field region is the region that close to the source of interference, while the far field is reversed [4].

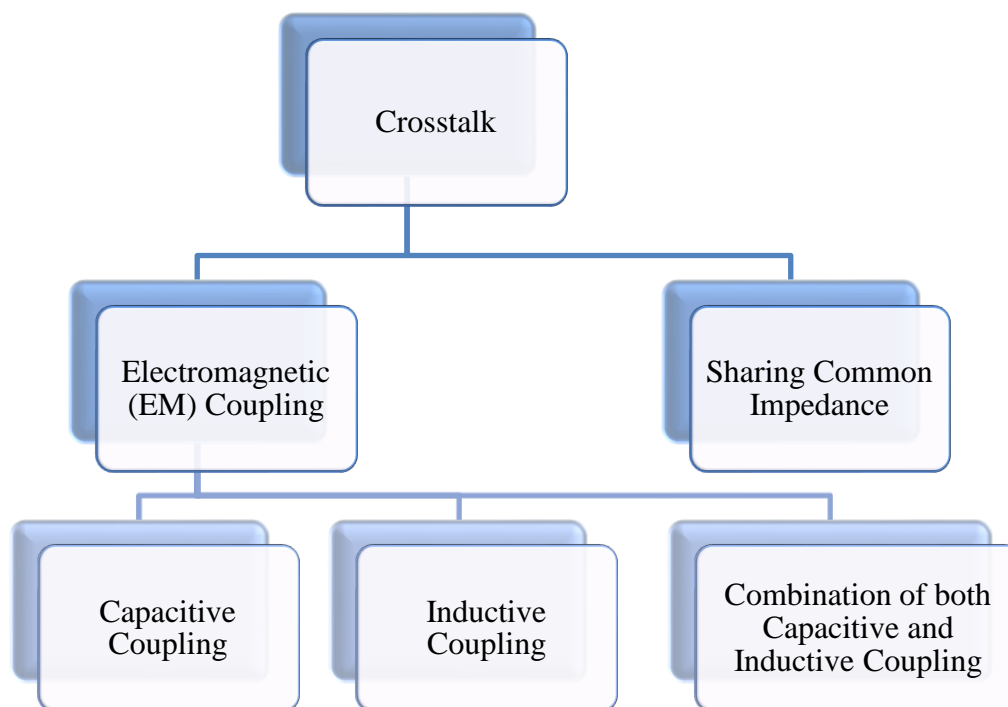


Figure 2.2: The crosstalk tree diagram [4]

2.5 Capacitance Coupling

The electromagnetic field coupling caused by electric field can be referred to as capacitive coupling. When two wires of source and victim circuit lay in parallel, the interaction of electric fields between the circuits will happen. Commonly, the pair of the cable is positioned close to each other. The capacitance will appear in three positions which are, between source circuit conductor wire and victim circuit conductor wire, between source circuit conductor wire to ground plane, and between victim circuit conductor wires to ground plane [3, 7]. The capacitance is not the actual capacitor component, but the stray capacitance caused by electric field. The existence of the stray capacitance will disturb the victim circuit. The closest conductor wire to each other, the high noise voltage will appear on the victim circuit. [2, 3, 7]

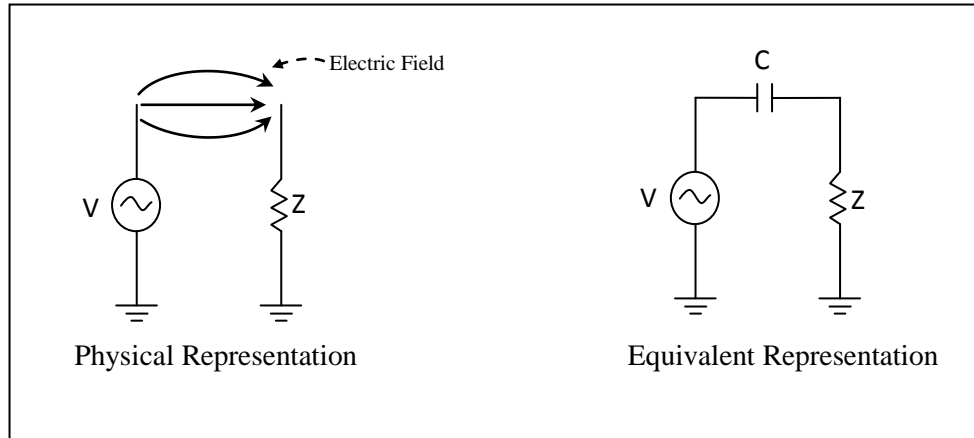


Figure 2.3: If the two circuit are coupled by electric field, the capacitor is represent coupling

[2]

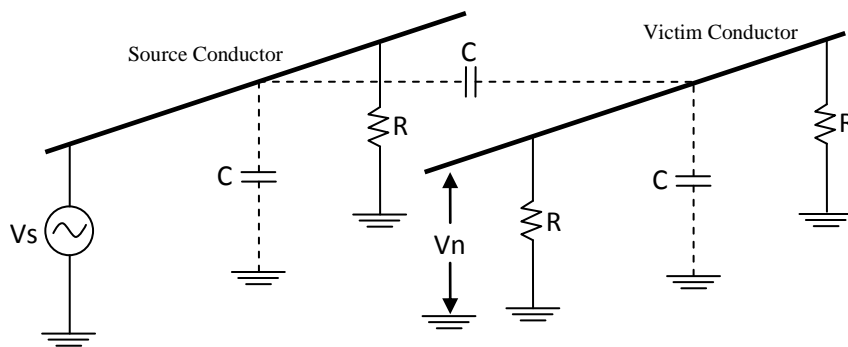


Figure 2.4: Capacitance coupling of two conductors [1, 4]

Based to the circuit above, the equation of capacitance crosstalk can be expressed as below, which noticed that all resistance are matched and equal to R . [4]

$$\frac{V_n}{V_s} \approx \frac{j\omega R(C_{12})}{4 + 4j\omega R(C_{12} + C_r) - \omega^2 R^2 C_r^2 \left(1 + \frac{2(C_{12})}{C_r}\right)} \quad (2.3)$$

Where, V_n = Noise voltage at far end (V)

V_s = Source Voltage (V)

C_{12} = Capacitance crosstalk between conductor (F)

C_r = Capacitance crosstalk between conductor to ground plane (F)

R = Resistor (Ω)