A DEVELOPMENT OF WIRELESS POWER TRANSFER USING CAPACITIVE METHOD FOR MOUSE CHARGING APPLICATION

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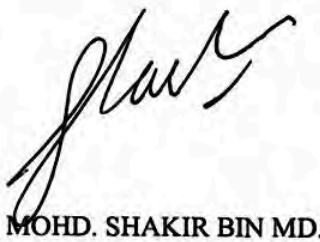
Signature : 

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To my beloved friends and family. Thank you my supervisor and all lecturers who guide me, and to all my friends for giving me mentally and moral support during process of finish final year project.

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ABSTRACT

Wireless power transfer (WPT) is a non-contact power transfer within a distance. With the advantage of not-contact concept, WPT enhances the flexibility movement of the devices. Basically, there are three types of the WPT which are inductive power transfer (IPT), Capacitive Power Transfer (CPT) and Acoustic Power Transfer (APT). Among these, capacitive power transfer (CPT) has the advantages of confining electric field between coupled plates, metal penetration ability and also the simplicity in circuit topologies. Therefore, we focus on the capacitive method in this project. This project aims to develop a wireless mouse charging system using capacitive based method. This method enables wireless power transmission from mouse pad to wireless mouse. Hence, no battery requires to power up the mouse. To be more specific, a high efficiency Class-E converter is designed to convert the DC source to AC and the compensation circuit of resonant tank is also designed in the transmitter part in order to improve the efficiency. In the end, a prototype is developed to prove the developed method. The performances analysis of the developed prototype is discussed and the future recommendation of this technique is also presented.

Keywords: Wireless Power Transfer (WPT), Capacitive Power Transfer (CPT), wireless mouse charging, low power applications.

ABSTRAK

Pemindahan kuasa tanpa wayar (WPT) ialah pemindahan kuasa tanpa sebarang sentuhan dalam linkungan sesuatu jarak. Dengan kelebihan konsep tanpa sentuhan wayar, WPT dapat meningkatkan pergerakan sesuatu alat dengan lebih fleksibel. Pada asasnya, terdapat tiga jenis WPT yang mana ialah pemindahan kuasa secara beraruhan (IPT), pemidahan kuasa secara berkemuatan (CPT) dan pemindahan tenaga melalui bunyi (AET). Antara jenis pemindahan kuasa tersebut, pemindahan kuasa secara berkemuatan (CPT) mempunyai banyak kebaikan iaitu medan elektrik antara gandingan plat-plat, keupayaan penembusan logam dan juga kesederhanaan di topologi litar. Justeru, kami fokus pada pemindahan kuasa secara berkemuatan dalam projek ini. Projek ini bertujuan untuk mencipta sistem pengecasan tetikus tanpa wayar dengan menggunakan kaedah pemindahan kuasa secara berkemuatan. Kaedah ini membolehkan penghantaran kuasa tanpa wayar dari pad tetikus ke tetikus. Maka, tiada penggunaan bateri diperlukan untuk menghidupkan kuasa tetikus itu. Untuk lebih terperinci lagi, penukar kelas E yang kecekapan tinggi direka bentuk untuk menukar sumber DC kepada AC dan litar pampasan tangki bersalunan juga direka dalam bahagian pemancar supaya kecekapan dapat ditingkatkan. Akhirnya, sebuah prototaip dicipta untuk membuktikan kaedah tersebut. Analisis keadaaan prototaip yang dicipta telah dibincangkan dan cadangan akan datang teknik ini juga dibentangkan.

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LIST OF ABBREVIATION

WPT	**-**	**Wireless Power Transfer**
IPT	**-**	**Inductive Power Transfer**
APT	**-**	**Acoustic Power Transfer**
CPT	**-**	**Capacitive Power Transfer**
EMI	**-**	**Electromagnetic Interference**
AC	**-**	**Alternating Current**
DC	**-**	**Direct Current**
USB	**-**	**Universal Serial Bus**
EV	**-**	**Electric Vehicle**
MOSFET	**-**	**Metal-Oxide-Semiconductor Field Effect Transistor**
ZVS	**-**	**Zero Voltage Switching**
ZCS	**-**	**Zero Current Switching**
PWM	**-**	**Pulse Width Modulation**
LED	**-**	**Light-Emitting Diode**

CHAPTER I

INTRODUCTION

In this chapter, wireless power transfer (WPT) will be discussed and the types of the techniques of WPT will be explained. A summary and the aim of this project will also be presented and discussed in this section.

1.1 Project Background

Wireless Power Transfer also known as WPT is a process of transferring power between two or more physically unconnected electric circuits or devices [1]. This innovative technology has created new possibilities to supply electronic devices with electrical energy by eliminating of wires, connectors and slip-rings. The potential application of WPT can range from a low power office or home appliances to a high power industrial systems. This concept has been first demonstrated by Nikola Tesla in the 1980s by powering up fluorescent lamps 25 miles from the power source without using wires [2]. Since then, various techniques based on WPT have been established which is shown in Figure 1.1. Generally, it can be divided according to the medium used for power

transmission, which are acoustic-based WPT, light-based WPT, capacitive-based WPT and the inductively coupled WPT.

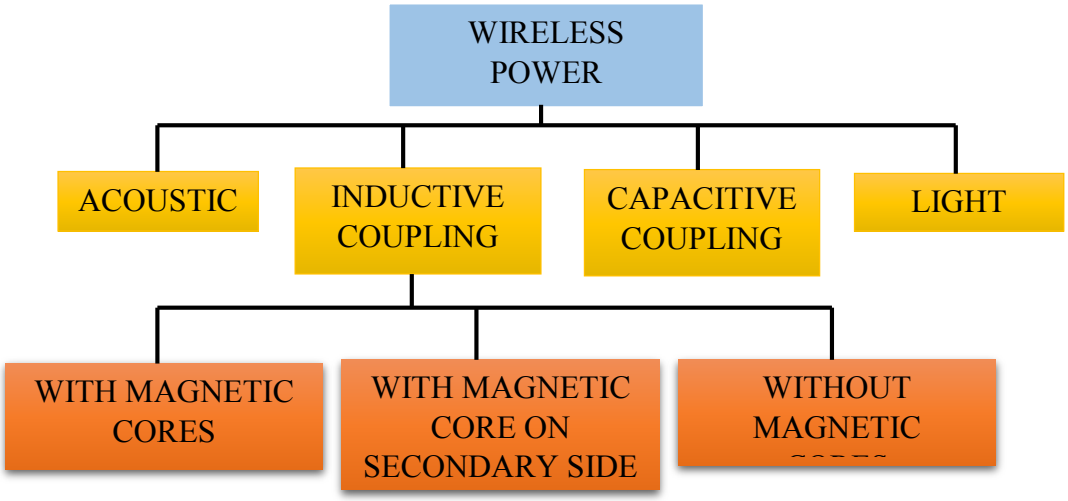

Figure 1.1: Classification of WPT [3].

The most well-known technique in the WPT technology is inductive coupling between transmitter and receiver which is widely applied to most of the applications nowadays [3]. The concept of the inductive power transfer (IPT) is the power is being transmitted to the receiver by electromagnetic induction via inductive coupling [4]. However, the major drawback of IPT is ferromagnetic interference which is the flux cannot pass through the magnetisable material.

Meanwhile, the acoustic power transfer is comparatively new which optimizing the vibration or ultrasonic propagation wave rather than electromagnetic fields for power transmission. On the other hand, the working principles of light wireless power transfer system are similar to far-field electromagnetic waves or microwave energy transfer. An optical power beam which is generated by laser diode is converted back to electrical power by photovoltaic diodes before supply to the receiver. Although light-based systems able to supply a great amount of power, its diffraction losses have directly influenced the efficiency over a great distance [5], [6].

As compared to popular inductive power transfer, both of the APT and CPT have the advantages over IPT. For APT, the efficiency of the power transmission is higher when the distance of the transmitter and receiver is much larger. While, capacitive have to ability of metal penetration and the potential to reduce electromagnetic interference (EMI) that will overcome the problems in IPT. Although the APT could overcome the metal barrier issue and the distance limitation, the difficulties of the large acoustic impedance mismatch of the transmitter and receiver with the medium could lead to a severe limit on the efficiency of power transfer. Hence, the capacitive approach will be used in this project. The basic operating principles of the capacitive-based WPT will be discussed in the following Chapter.

1.2 Project Overview

In this project, we focus on the capacitive based method due to its advantages over the IPT and APT. The ability of metal penetration could solve the issue that faced in the IPT. However, the misalignment of the both transmitter and receiver plates could directly influence the power efficiency and this will limit the power transmission and the efficiency. This phenomenon is also concerned in the APT techniques which is cause by its large acoustic impedance mismatch. But, in this project, CPT technique is preferable over APT due to the flexibility in movement. Besides, the simplicity in circuit topologies, low standing power, as well as low EMI are the advantages for choosing CPT technique over IPT [7]. This project aims to develop a wireless computer mouse charging system using a capacitive based method. This method enables wireless power transmission from a mouse pad to a wireless computer mouse. Hence, no battery requires to power up the mouse. To be more specific, at the transmitter side, a converter is designed to convert the DC source to AC while the compensation circuit is also designed to improve the efficiency of the system. A prototype is developed to prove the proposed method. Finally, at the end of this project, a prototype of wireless computer mouse charging via capacitive

coupling is developed and the efficiency performance analysis of the developed prototype is completed.

1.3 Motivation

The growing popularity of battery-powered electronics and communication devices has provided a great benefit to human society. From an ordinary computer mouse to a tailless computer mouse, wireless mouse, it is obviously much more convenient to use. This shows the main benefit of WPT as well as in reducing the hassle of wires. However, each of this battery-powered electronic device comes along with its own charger, batteries and, consequently resulting in an increasing electronic waste issue and it brings up the environmental concerns among the society. Most of the commercialized wireless computer mouse are powered up by the batteries and bring up a few problems. Inconvenience of battery replacement, the cost of the battery replacement and the environmental issue associated with the battery disposal are the main drawbacks of the battery-powered wireless computer mouse. Therefore, in this project, a battery-less wireless mouse is suggested and will be developed based on the CPT concept. By replacing the battery in the wireless computer mouse, the capacitive-based approach will be designed based on the a few considerations that would affect the efficiency performance of a wireless computer mouse. The consideration is stated and discussed in the scope of work section. A battery-less mouse is definitely become ideal since the battery is eliminated and replaced by the charging method using the capacitive coupling power transfer method. Besides, a battery-less mouse could be commercialized due to the increased convenience of this device as opposed to consistently having to change the batteries in a regular wireless mouse or even using a wired computer mouse.

1.4 Problem Statement

In wireless power transfer (WPT), there are various techniques are established based on the WPT concept. One of the most well-known technique among those techniques is inductive power transfer (IPT). IPT is widely dominating the electronic devices nowadays. One of the perhaps most popular examples of low power devices that uses IPT method are the Sonicare electrical toothbrush by Philips [1]. This inductive approach is using the magnetic fields from a coil to induce a current in another coupled coil so that there is a flow of current wirelessly. Also, there is existing wireless mouse charger known as "Magic Charger" that using induction charging. Obviously, IPT technique is popular and commonly used in the most application. However, IPT has few drawbacks and one of that is the coil heating effect. During the charging process, the coil may be heating up and this will cause the efficiency of power transfer to drop in the process of charging. While, another drawback of IPT is the metal interference. The metal interference will disturb the magnetic flux and directly limit the implementation of IPT on the wider range of application. Therefore, the CPT is proposed in this project because CPT could overcome those problems. In CPT, there is no overheating issues and stay constant or stable without efficiency drop over a period of charging. Unlike IPT, the CPT is not affected by the ferromagnetic material interference neither in E-field nor H-field. On the other hand, there is also APT technique can be considered in this project. APT is a very new technique and APT also can be employed in various transmission types from sound wave to light wave. Although APT can be used in different types of transmission, it could be a difficulty in choosing the best transmission method for this project. Normally, APT is meant for a long range transmission while in this project the transmission range is in a short range so the APT technique is not quite suitable to be used. Besides, the APT have the issue of mismatch impedance. The mismatch in the APT could lead to a severe drop in the efficiency of power transfer. Thus, the CPT technique is the most appropriate method for this wireless mouse charging project. By applying CPT, the limitation in the APT and IPT could be overcome. As mentioned, the "Magic Charger" on the market is using the IPT method to charge up but usually the "Magic Charger" comes in a set of

rechargeable battery and charger station and bring up the battery issue. Although by using the rechargeable battery would definitely reduce the battery disposal issue, but it would be great if there is no battery being implanted in the wireless mouse and yet it still can be powered up. Therefore, in this project, CPT will be employed to power up the wireless mouse to eliminate the usage of the battery. Apart from that, there is a common limitation of these commercialized products. When the devices need to be charged up, it requires to be placed on top of its own charging station (transmitter) or charging socket of the charger. In other words, a precise aligned is needed for the transmitter and receiver which will limit the positioning flexibility of the receiver. Especially for the wireless mouse, this limitation will bring a lot of inconvenience such as the wireless mouse need to be leave on it charging station for a period of for charging. Therefore, in this project, a wireless computer mouse charging system is proposed. This system uses the capacitive power transfer based approach to solve this issue. Capacitive approach is being chosen over the IPT and APT techniques because the CPT could overcome the problems of metal barrier, coil heating effects and precise in alignment which are mentioned earlier. The proposed capacitive based wireless mouse charging system is able to charge the mouse while the mouse is in its use. Another saying, the mouse is still in charging mode even a user is using it as long as the mouse is in the effective area of charging (mouse pad). However, the movement of the mouse along the x-axis is preferable in due to achieve fully coupled condition to contribute a higher efficiency of power transfer.

1.5 Objectives

a) To develop a wireless mouse charging prototype using capacitive power transfer method.
b) To design a compensation circuit to improve the efficiency of such circuits.
c) To analyze the efficiency performance of the developed prototype.

1.6 Scope of Work

This prototype is designed in a small scale low power model up to 5V and wireless power transmission range effective is within 1cm gap. The issue that always affects the efficiency of the power transmission in CPT is the alignment of the transmitter plates and the receiver plates. Hence, in this project, the both plates on the wireless computer mouse and mouse pad are to be designed in an aligned fixed position as shown in the Figure 1.2 while the Figure 1.3 shows the misalignment situation of the both plates [8]. As can be seen, when the misalignment situation occurred, there are uncoupled areas between the transmitter and receiver which will lead to the consequences in affecting the efficiency performance of the system. The plate effective area is highlighted on the mouse pad. In this prototype, a fully aligned situation is desirable.

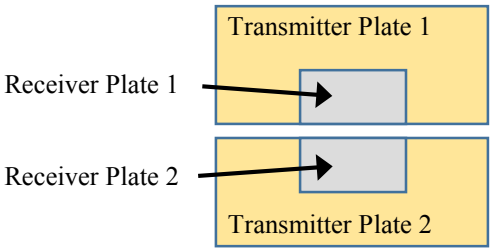

Figure 1.2: Fully Aligned and Coupled Situation [8].

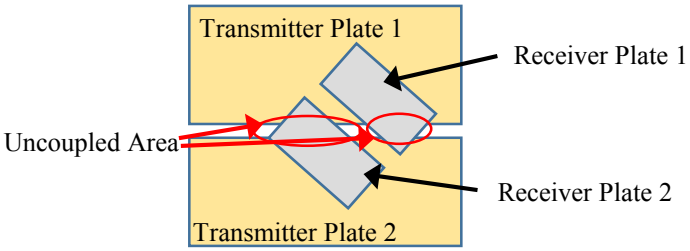

Figure 1.3: Misaligned Situation [8].

In a CPT system, a high frequency voltage is desired to drive the electric field coupler so that the alternating current can flow through it to provide the load with the required power. Therefore, a Class-E converter is designed as the high frequency converter at the transmitter to convert DC source to AC. The best converter is selected

based on the performance analysis and then implemented at the transmitter part. On the other hand, the problem of power loss during the charging process is overcome by designating capacitor compensation circuits at the transmitter and receiver part. The basic conceptual design of the prototype is shown in Figure 1.4. From the figure, first, a DC source from the USB port is supplied to the primary circuit also known as the transmitter. At the transmitter part, there is a high frequency converter is designed to convert the DC source to a high frequency of AC voltage and then an alternating electric field is generated and pass through the capacitive coupling plate to the receiver part of the system which is the secondary pick-up (receiver plates) attached in the wireless computer mouse.

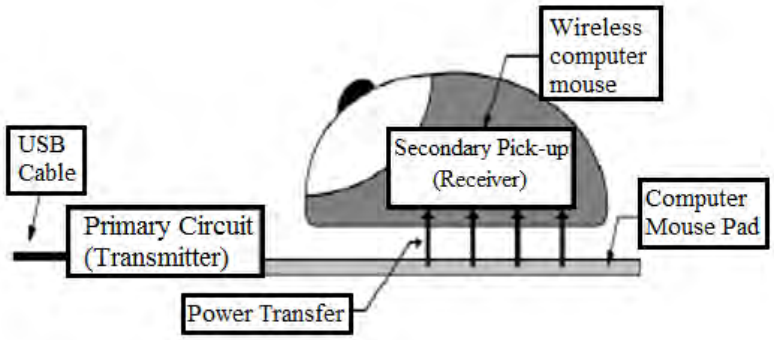

Figure 1.4: Conceptual Design of Wireless Mouse Charging Prototype [9].

1.7 Project Planning

In project planning, the flow of project is essential in completing the project step by step. The flow of the designing this project is based on the problem statement, objectives of the work and the scope of work. Therefore, a gantt chart is constructed for the progress of this project.