DEVELOPMENT OF WIRELESS POWER TRANSFER (WPT) TECHNOLOGY FOR MINI AQUARIUM USING CAPACITIVE POWER TRANSFER (CPT) APPROACH

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ABSTRACT

Since long time ago, electrical appliances in the aquarium use wired technologies to power up the devices and this causes unpleasant view at power outlets and risk for short circuit to be present in the water. To avoid those problems, Wireless Power Transfer (WPT) technology using capacitive approach is applied on the aquarium for this project as the main objective. The scopes of this project are that the project is using Class E inverter due to better efficiency compare to other class especially in wireless power transfer, 1MHz as operating frequency to transfer 1W of power and the load used is LED strip with 12V input. Once the system is developed, the system performance is analysed and achieved 72.6% efficiency in term of distance and 23.6% efficiency for plate misalignment with fixed distance that is 2mm, acrylic thickness. In the end, the WPT system is successful to be applied in the aquarium using capacitive approach as well as there are potentials for improvement so that the product can be marketed to meet the consumers' demand.

ABSTRAK

Sejak dahulu lagi, barangan elektrik di dalam akuarium menggunakan teknologi wayar untuk menghidupkannya sekaligus menjadikan pemandangan yang tidak selesa di tempat plag dan wujud risiko untuk kejadian lintar pintas dalam air. Bagi mengelakkan masalah tersebut, teknologi pemindahan kuasa tanpa wayar menggunakan kaedah kapasitif telah diaplikasikan ke dalam akuarium telah menjadi objektif utama dalam projek ini. Skop bagi projek ini adalah menggunakan Kelas E inverter untuk mendapatkan kecekapan yang terbaik berbanding kelas-kelas yang lain, 1MHz sebagai frekuensi operasi untuk pemindahan kuasa 1W, dan beban yang digunakan adalah lampu jalur LED dengan kemasukan 12V. Setelah sistem berjaya dilaksanakan, prestasi sistem telah dianalis dan berjaya mendapatkan 72.6% kecekapan bagi analisis jarak dan kecekapan 23.6% bagi analisis ketidakjajaran plat dengan jarak yang tetap iaitu 2mm, ketebalan akrilik. Akhir sekali, sistem WPT ini berjaya untuk diaplikasikan ke dalam akuarium menggunakan pendekatan kapasitif dan mempunyai potensi untuk penambahbaikan supaya boleh dipasarkan dengan kadar segera.

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LIST OF ABBREVIATIONS

WPT	-	Wireless Power Transfer
IPT	-	Inductive Power Transfer
CPT	-	Capacitive Power Transfer
APT	-	Acoustic Power Transfer
MPT	-	Microwave Power Transfer
LPT	-	Light Power Transfer
ZVS	-	Zero Voltage Switching
DC	-	Direct Current
MOSFET	-	Metal Oxide Semiconductor Field Effect Transistor
PWM	-	Pulse Width Modulation
IC	-	Integrated Circuit

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CHAPTER I

INTRODUCTION

The first chapter of this thesis explains about project background, project objectives, problem statement of the project, scope of the project, overview of methodology and lastly project outline.

1.1 Project Background

Electronic power transfer is commonly have connections between metal part of plug and socket or commonly known as wired technology [1]. Currently, the researchers in the world as well as manufacturers of electronics products are attempting to replace the wired technology to wireless technology for power transfer on electrical and electronics appliances. This is because the technology could lead to better environment by reducing usage of non-renewable energy; i.e. petroleum for

mobile vehicles can be substitute with electrical vehicles. By having this technology, cables and connectors, elimination in circuitry could be possible and thus increase reliability and maintenance-free operation for critical field such as medical field and military field. The advantages of WPT on cable elimination and maintenance free operation are also helpful especially for underwater electronics devices to power up aside common electronics devices that we use every day. .

Therefore, the classification of WPT is divided into two categories that are near-field power transfer and far-field power transfer. In near-field power transfer, the inductive power transfer (IPT) is the favourite power transfer type used for real world applications compared to capacitive power transfer (CPT) and acoustic power transfer (APT). Last year, IKEA has released a new product that is a small table that able to charge electronics gadgets by placing the item at a certain spot and has introduced the WPT technology to the consumers in worldwide and eliminate cable [2]. Besides IPT, CPT and APT, microwave power transfer (MPT) and light power transfer (LPT) are under the far-field power transfer category respectively [3]. For this project, WPT is applied in the aquarium; using near field technique with CPT approach for WPT is chosen. This is because CPT is capable to transmit through metal objects unlike IPT and has higher efficiency than APT. Therefore, application of WPT in water for instance, aquarium is interesting topic to be done because multiple devices are usually used in the aquarium so the fishes can live comfortably although there are some obstacles need to overcome to achieve perfect result.

1.2 Project objectives

The objectives of the project are:

1. To develop wireless power transfer (WPT) system using capacitive approach for mini aquarium system.
2. To design Class E inverter as power converter to improve efficiency of such system.
3. To analyse the performance of the developed system in term of output efficiency.

1.3 Problem statement

In order to raise fishes at home, an aquarium needs several electrical appliances in the tank. To provide better environment for new habitat of these fishes, air pump, water pump, and lights are some necessary electrical appliances used in the aquarium [4]. Thus, this situation leads into presence of plug extensions use for power up multiple devices as well as presence of a lot of wires that might cause unpleasant sight and risk of short circuit. By having WPT technology replaces the wired technology, the wires usage as well as power outlets can be reduced for these devices. Besides that, cleaning the aquarium becomes less hassle if WPT is implemented to the aquarium. Due to incapability of inductive approach to wirelessly transfer power through metal shielding environment and acoustic approach to have lowest efficiency amongst the near field approach, capacitive approach is selected to be the most suitable for WPT system in the aquarium. Yet, the capacitive approach have issues need to be solved to have a good performance in transferring power that are plate distance and misalignment. So, the WPT implementation using capacitive approach in the aquarium and the system performance are done for the project.

1.4 Scope of Project

The first scope of the project is having capacitive power transfer as the approach for wireless power transfer. Next, Class E inverter is used as power converter for the project. To represent a mini scale of usual aquarium, the size of aquarium that is used for this project is 300mm x 210mm x 210mm. The required specification that need to be fulfilled for the project are the operating frequency must be 1MHz, duty cycle 50% because larger frequency causes parasitic capacitance value to be higher while lower frequency causes the components value become larger and therefore 1MHz is an optimum frequency. As for the desired power output, 1W is used so that

power is capable to power up the load and each capacitor plate size used must be under 130mm width and 180mm length in order two plates can be placed as receiver of CPT at the bottom of the aquarium. Finally, the distance between a pair of capacitor plate is fixed to 2mm, which is the thickness of medium, acrylic.

1.5 Overview of Methodology

There are several processes are essential to be completed for this project to be successful. The processes that are involved in the project are designing circuits involved in prototype based on requirement desired by calculating component values needed, simulate the circuits based on calculated values, testing the circuits using value of components that nearest to successful simulate circuitry done, board fabrication and assembling process , troubleshooting the circuits until the circuits function properly, and lastly analyse the performance of the prototype by comparing to simulation result. Figure 1.1 illustrates the steps in finishing the project.

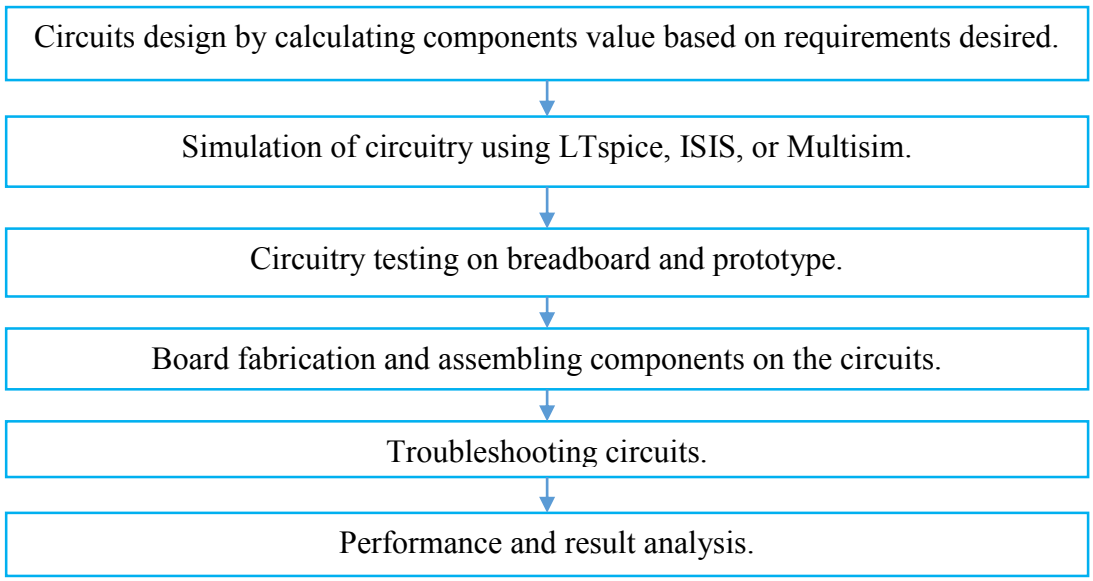

Figure 1.1 Steps in completing the project.

1.6 Project Outline

In Chapter I, the chapter introduces the project background, the problem statement of the project, the objectives of the project, the scope of the project as well as the project outlines. This chapter purposely gives the readers a clear view on the purpose of the project and brief version of this thesis is all about.

Next, Chapter II is about literature review of the project. This chapter is actually covers the previous works completed by other researchers. The previous works done by the researchers includes wireless power transfer (WPT), inductive power transfer (IPT), capacitive power transfer (CPT), acoustic power transfer (APT), Class E inverter and zero voltage switching.

Chapter III describes thoroughly the methodology used in completing the project and the process flow of the project. The approaches that are used for simulation and completing the prototype part by part are well explained in this Chapter III.

Finally yet importantly, Chapter IV presents the result on simulation as well as the experiment. The results obtained, later, discussed and analysed for the performance done and the expenses for the project also presented briefly.

Finally, Chapter V deduces project conclusions based on the result achieved and objectives desired. Recommendation on future works or improvements that can be made for the project are also suggested as one of the part in the chapter.

CHAPTER II

LITERATURE REVIEW

For the second chapter, previous works and findings by other researchers that are related to the project are reviewed and discussed. Background of Wireless Power Transmission (WPT), structure of Inductive Power Transfer (IPT), Capacitive Power Transfer (CPT), Acoustic Power Transfer (APT). Class E amplifier, Zero Voltage Switching (ZVS) are thoroughly explained in this chapter.

2.1 Literature overview

WPT technology is technology that has been a hit trend in the past five years among the researchers and developers and thus led to quite number of articles and journals have been published in IEEE site [6-20]. In 1891, Nikola Tesla is one of the earliest person who demonstrated the concept of this technology by powering florescent lamps that is 25 miles away from power source without wires [5]. By

inventing rectenna that converts microwaves energy into DC current in early 1960s and demonstrated the ability with powering up helicopter in 1964, author in [5] stated that William C. Brown has also contributed in the development of wireless power transmission through microwaves as medium.

For WPT technology to transfer smoothly from transmitter to receiver part, there are several components need to be done. The block diagram of basic WPT system is illustrated in Figure 2.1.

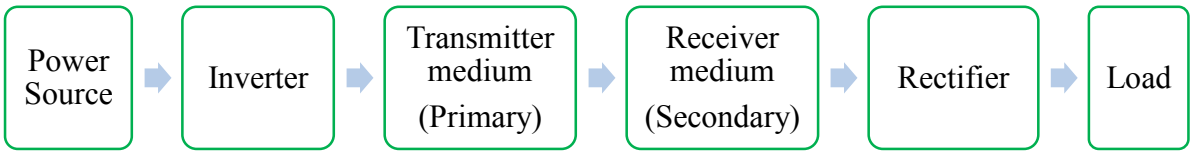

Figure 2.1 Block diagram of WPT

Based on Figure 2.1, direct current (DC) source from power source is converted into AC by inverter circuit. Then, the converted power must be in AC form so that the power can be transmitted from primary medium to secondary medium. Then, at secondary medium, AC power will be converted to DC power by rectifier for load usage such as electronic appliances i.e. mobile phones.

Generally, wireless power transfer can be classified into two categories; near field WPT and far field WPT. These categorizations have considered three factors; 1. The distance of transmission from the source, 2. The characteristics of the electromagnetic field change and 3. Methods in achieving WPT. In this chapter, both categories will be thoroughly explained to understand variety of WPT scheme.

Besides WPT, Class E inverter is also studied because the amplifier is chosen as inverter circuit in this work. Class E amplifier is the power amplifier that has high efficiency and simple structure that can be used in fast switching. S. Liu states that the Class E circuit will have nearly 100% efficiency theoretically as the circuit satisfies zero voltage switching (ZVS) condition and have fixed load [6]. Before ending the second chapter, the condition of ZVS is explained entirely as the condition plays significant role in achieving high efficiency.

2.2 Wireless Power Transfer (WPT)

A process of transmitting energy from one circuit onto another without passing through any manmade conductive elements interconnecting them is known as WPT [7]. By using WPT technology, several advantages, disadvantages, and challenges should be known in using the system. Authors in [8] describe advantages and disadvantages of WPT in their article in details.

One of advantages of WPT that is described in [8] is power transmission line cables between source and consumers are eliminated in WPT. Not only the problem with faulty cable or short circuit can be eliminated, the risk of electricity being stolen also can be reduced. With elimination of cables, loss of transmission can be negligible and therefore theoretically the efficiency is expected to be higher compared to wired transmission. On top of that, the cost for power transmission and distribution will become less and cost of electrical energy is reduced for consumer since no resistance in wireless transmission. Furthermore, places that are impossible to reach with wired transmission can easily be reached using WPT system. Lastly, the freedom in choosing transmitter and receiver in the system is more varied for WPT system.

Even though there are many advantages of WPT system, every system must have even slight drawback. The major drawbacks for the system are a very high capital cost for practical implementation are needed for the system as well as probability of external interference present when transferring power in the system.