THE DEVELOPMENT OF WIRELESS POWER TRANSFER TECHNOLOGIES FOR MOBILE CHARGING IN VEHICLES USING INDUCTIVE APPROACH

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To my beloved mother and father.

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ABSTRACT

The rapid growth of technology has seen many changes in terms of devices manufactured. However, even though massive improvements are made, the current conventional method used for powering up devices still remain through wired connections. From hand held devices such as mobile devices need at least a backup power source to remain powered up. Thus, these scenarios have been overcome by the introduction of portable power banks and also portable chargers. However, these devices still depend on physical connections between the mobile device and the mentioned chargers. Thus, this project is to develop a wireless charger for a mobile device which can be used in a vehicle. Wireless Power Transfer (WPT) method is much safer compared to wired connections, as they eliminate the need of wired connections from the charger to the mobile device. The selected method is through Inductive Power Transfer (IPT), due to its advantages where it can transfer power wirelessly with a higher efficiency in a short range. To make this work, a Class E inverter will be designed to convert a direct current (DC) supply into alternating current (AC) supply at a higher frequency with a higher efficiency. To validate its efficiency, analysis on the gap distance between the two magnetic coils, transmitter and receiver, is performed. At the end of this project, the designed prototype is able to yield approximately 70 % in terms of efficiency.

Keywords: Wireless Power Transfer (WPT), Inductive Power Transfer (WPT), Class E Inverter circuit, wireless mobile charger in vehicles, magnetic coils.

ABSTRAK

Pertumbuhan pesat teknologi telah menyaksikan banyak perubahan dari segi alat peranti yang dikilangkan. Walaupun peningkatan yang drastik dapat dilihat, pengunaan kaedah konvensional masih lagi digunakan untuk menghidupkan sesuatu alat peranti melalui sambungan berwayar. Daripada peranti tangan seperti telefon mudah alih memerlukan sekurang-kurangnya sumber kuasa sandaran untuk digunakan sepanjang waktu. Oleh itu, senario ini telah diatasi dengan pengenalan Power Bank mudah alih dan juga pengecas mudah alih. Walau bagaimanapun, peranti ini masih bergantung kepada sambungan fizikal antara telefon mudah alih dan pengecas tersebut. Oleh itu, projek ini akan membangunkan satu pengecas tanpa wayar untuk telefon mudah alih yang boleh digunakan di dalam kenderaan. Kaedah yang digunakan adalah melalui kaedah Pemindahan Kuasa Tanpa Wayar dimana ia lebih selamat berbanding dengan sambungan berwayar, kerana mereka menghapuskan keperluan sambungan berwayar dari pengecas ke telefon mudah alih. Teknik yang dipilih adalah melalui Inductive Transfer Power (IPT), kerana kelebihannya di mana ia boleh memindahkan kuasa secara tanpa wayar dengan kecekapan yang tinggi pada jarak yang pendek. Oleh itu, penukar Kelas E akan direka untuk menukar arus terus (DC) ke arus ulang alik (AC) pada frekuensi yang lebih tinggi dengan kecekapan yang baik. Untuk mengesahkan kecekapan kaedah ini, analisis kepada jarak antara kedua-dua gegelung, pemancar dan penerima, dilakukan. Pada akhir projek ini, prototaip yang direka mampu menghasilkan kira-kira 70% dari segi kecekapan.

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LIST OF ABBREVIATION

WPT	-Wireless Power Transfer
NFWPT	-Near Field Wireless Power Transfer
FFWPT	-Far Field Wireless Power Transfer
AC	-Alternating Current
DC	-Direct Current
ZVS	-Zero Voltage Switching
IPT	-Inductive Power Transfer
CPT	-Capacitive Power Transfer
AET	-Acoustic Energy Transfer
μH	-Microhenry
pF	-Pico Farad
V	-Voltage
mA	-Milli Ampere
PCB	-Printed Circuit Board
ARES	- Advance Routing and Editing Software

LIST OF APPENDICES

CHAPTER I

INTRODUCTION

1.0 Overview

This chapter gives an overall overview regarding on the research title of "The Development of Wireless Power Transfer Technologies for Mobile Charging in Vehicles using Inductive Approach". A brief explanation on the concepts of wireless power transfer and the involved techniques are described. The problem statement, project objectives, scope of work and the structure of the report are also discussed here.

1.1 Project Introduction

Wireless Power Transfer Technology [1], [2] is trending itself as an actual solution for transmitting energy for devices at remote distances through an air gap, without the need for current-carrying wires. This technology is to be said that could change the concept of to either charge or even power up electronic devices wirelessly. The number of publications on wireless power has increase by at least 1200% over the past 10 years [3], [4]. The idea of this wireless power transfer technology is to conveniently transmit power from a power source to a load, in this case, a mobile device which will be achieved through an air gap, thus eliminating the need of wired connections. This WPT technology was actually developed in the late 19^{th} and early 20^{th} century, where electromagnetic research were deeply researched back then. These researches are the core to today's development in the transportation of electrical power.

1.2 Problem Statement

Problem Statement 1

In recent years, portable devices has made a huge impact on almost every humans, making it a compulsory device to be owned due to its portability and functionality. The explosive growth of mobile computing has led to a faster and more powerful portable devices such as mobile phones. However, the usage of hand-held devices has its own deficiency in terms of its battery's lifespan. These days, the manufactured mobile devices are extremely powerful in a way that even its' battery storage capability is not sufficient enough to last for a single day usage. Thus, in the short term, the usage of wired-adapters in cars for mobile charging were introduced. An adapter would be plugged into the cigarette lighter port, drawing a steady power source to charge these devices. However, the usage of these wired-charger, is to be said not safe especially

when it is tangled. To untangle these wires during driving in a tight space could prove costly to the driver's safety. In addition to these wired-charging, Power Banks were also used to support one device's battery lifespan. However, in today's market, the safety protocols on these devices are often taken lightly especially those manufactured from companies that produces clone devices. Besides that, cost wise, they are much cheaper due to the lesser quality of components used in manufacturing clone devices. In recent events, several cases of Power Banks exploded in one's pocket or even in a vehicle due to direct exposure to sunlight has questioned the integrity of these Power Banks. Thus, the idea of introducing wireless power transfer (WPT) technology would certainly bring less harm to humans especially if installed in a car.

Problem Statement 2

Wireless Power Transfer is considered to be the next "big-thing" in transferring power through a contactless medium. As explained earlier, the inductive method is the best technique in terms of it efficiency, its cost and also based on its transmission range. However, in previous experimental researches on this inductive power transfer, a Class D amplifier is used to realize the transmitters but it is said to require at least 2 MOSFETS to achieve a zero voltage switching condition (ZVS), thus increasing the cost of the products and also introduces yielding process problems. Therefore, in this project, a Class-E power amplifier will be used which is also a switching type amplifier. It is said to consist of fewer components with high reliability and a low-cost advantage, with also a theoretical efficiency of 100%. This Class-E will be built together with an impedance matching network between the power amplifier and the transmitter coil in an effort to maximize the power transferring rate.

1.3 Objectives

The following are the objectives of this project:

a) To design and develop a wireless power transfer charger for mobile devices that can be used in a car while travelling through inductive method.
b) To design an Class E power amplifier circuit with a high efficiency output power generated at a minimum of 70% efficiency
c) To analyze the performance of the proposed method in terms of output efficiency.

1.4 Scope of Work

The Figure 1.1 shows the scope of work of this project in terms of block diagram. Meanwhile, the details on the scope of this project are as follows:

a) Inductive coupling approach is used
b) One load is used; i.e. standard mobile phone for testing purposes
c) The project specifications are as follows:-
    - Input voltage : 12Vdc – determined based on the specifications of the load
    - Operating Frequency : 1MHz – in order to design a small scale system and low power losses
    - Output Power : 5 Watts – determined based on the selected mobile phone for testing purposes
    - Operating Distances : 1-2cm – pre-determined distance between the load and transmitter for charging purposes.

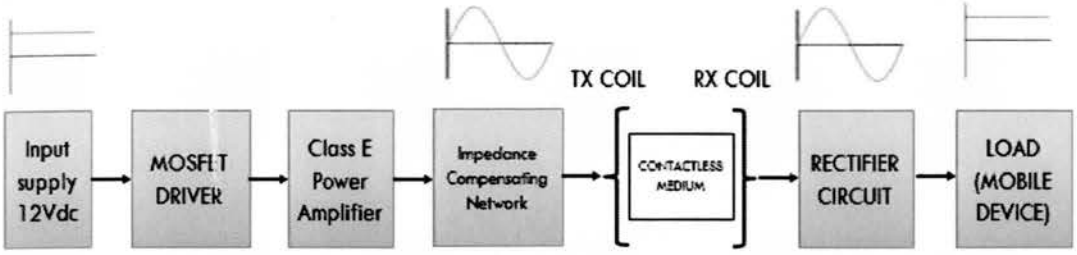

Figure 1.1 : General block diagram of project

1.5 Structure of Report

This report consist of 5 main chapters. The first chapter is the introduction for this project. Together with the introduction part, there will be the project's problems statements and its objectives. Scope of the project is also mentioned in this chapter.

Chapter 2 is basically regarding the literature review for this project. Previous research and experimental works are reviewed on and are used as the core for this project.

Chapter 3 discusses on the methodology used in completing this project. In this chapter, several design equations and the circuit designs are included.

In Chapter 4, the results and discussion of this project's output are explained. The results will be divided into two parts, one through simulation process and the second is through experimental work. To validate the performance of the system, analysis will be conducted.

Lastly, Chapter 5 will be to conclude the project and also a recommendation part for future additional work which can be added to this project

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CHAPTER II

LITERITURE REVIEW

2.0 Overview

This chapter discusses regarding the previous researches which relates to this project's title which is Wireless Power Transfer Technologies. This gives a detailed background study on previous findings and ways to improve them.

2.1 History of Wireless Power Transfer

As written in previous researches, Nikola Tesla is to be considered as the father to the development of WPT technology [5]. He was able to demonstrate the illumination of