ADVANCED WIRELESS CHARGING SYSTEM FOR PORTABLE ELECTRIC DEVICES

A Senior Scholars Thesis

by

JIANYANG LIU

Submitted to Honors and Undergraduate Research
in partial fulfillment of the requirements for the designation as

UNDERGRADUATE RESEARCH SCHOLAR

May 2012

Major: Electrical Engineering

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ABSTRACT

Advanced Wireless Charging System for Portable Electric Devices.
(May 2012)

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This paper presents a wireless charging system for portable electric devices. The important impacts of wireless charging systems on the global environment are first examined, and the two basic methods for wireless charging are then explained. The feasibility of applying each method to the wireless charging system is also analyzed. In order to achieve a high efficiency and more precise control for the wireless power transfer, the technology of a contactless charging board is used in this research. Because the experiments operated base on an induction cooker, the basic structure of the induction cooker are explained. Then the strategy of controling the output power is given. Finally, comprehensive experiments with efficiency tests, effective distance tests, and how the location of the coil would affect those important factors are given. The result shows that the method of contactless charging board is reliable for portable electric devices to achieve a relatively high charging efficiency and an acceptable charging distance.

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CHAPTER I

INTRODUCTION

With the development of technology, people's life is becoming easier and more convenient nowadays. It changes people's way of living and saves time and energy. Wireless is one of the most beneficial technologies among them. However, the application of wireless charging has not been widely accepted in the industry yet due to the low efficiency and low effective distance. There are two ways of wireless energy transfer. One is based on the traditional induction coil coupling (like the Contactless Charging Board), by using this kind of technology we could achieve high efficiency for energy transfer over a short distance [1]. The other way is called Witricity by using the technology of magnetic resonant coupling to transfer energy wirelessly. This technology is applied to the project by one of the professors in MIT [2], and could gain relatively high transfer efficiency (forty five percent) over a long distance. The traditional induction coil coupling is chosen in the research because the Witricity technology is always used for high power. A basic contact charging board is designed in the research period as the wireless charging system for small electric devices like cell phone. An induction cook top is used in the experiment as a source to generate high frequency magnetic field. Then a circuit is designed to transfer the energy to portable electric devices like cell phones.

This thesis follows the style of *IEEE Transactions on Power Electronics.*

CHAPTER II

METHOD

On the first stage of the research, an advanced wireless charging system is designed and implemented. The main equipment used in this period is an induction cooker, which is used as an electromagnetic field generator, then the electromagnetic field is used to transform into the wireless power supply for the electric devices. The transformation processes contain methods of Power Electronics, and resonance for the Electromagnetic Field.

The charging system used in this research is composed of three parts besides the induction cooker. The first part is a secondary side of the coil which is designed to get the magnetic flux generated from the induction cooktop. In this project, the coil is made as in the same shape and size as the coil inside the induction cooktop so as to maximize the effective distance by the charging system.

After the secondary side of the coil gets the time varying magnetic flux generated from the induction cooktop, it would generate an AC voltage. Since most electric devices need a DC voltage to charge their batteries, a full bridge rectifier is connected to the secondary side of the coil. The rectifier chip used in this project is TP202 TCI, and in order to stabilize the DC voltage, two capacitor of 2200uf is connected in parallel after the output of the rectifier circuit.

The last part of the project is a buck converter, because the voltage generated from the rectifier circuit is larger than most electric devices could accept and the most efficient way to step down the voltage will be a buck converter. The buck converter consists of a MOSFET in order to control the duty cycle of the circuit, a function generator to generate the square wave signal, a gate drive integrated circuit in order to amplify the signal generated from the function generator so that a MOSFET could use, an Inductor to maintain the current, and a capacitor to keep the voltage ripple small. The load (Electric Devices) is connected directly at the output of the buck converter, in order to get the power generated from the induction cooktop.

In this research process, the main result is concluded by comparing the effective distance of the circuit with different locations of the secondary side of the coil. The efficiency is calculated by dividing the output power from the input power. The Output power is the power written on electric device’s instruction manual (Normally 5 watts), and the input power is calculated from the principle of ohms law which is to multiply the input current with the input voltage.

The main tools used in the research process are the multimeter and oscilloscope. By using the multimeter, the input and the output current and voltage could be measured. Thus, the input and the output power could be calculated by multiply current and voltage measured. By using the oscilloscope the waveform for the input and output could also be measured, in order to get a better understanding of the result.

On the other hand, the effective distance is much easier to measure than the efficiency of the circuit. Since the contactless charging board is chosen as the primary research method because of a relatively higher efficiency. As a result, the effective distance for the contactless charging board (normally within 4 cm) is relatively short compared with other technology. In this experiment, a wood ruler is used as a tool to measure the effective distance by different shape of coils.

CHAPTER III

RESULTS

Fig.1 shows the induction cooker used in this experiment, the output RMS value of current has been measured by the multimeter, which is about 8.9 A (Fig.2). The output voltage is shown on the oscilloscope and the RMS value is about 150 Volts (Fig.3). Thus the output power for the induction cooker is 1335 watts. The induction cooker is used as the primary side of the whole circuit. And on the secondary side of the circuit, the coil is made as in the same shape and size as the primary side, in order to keep the highest effective distance and efficiency.

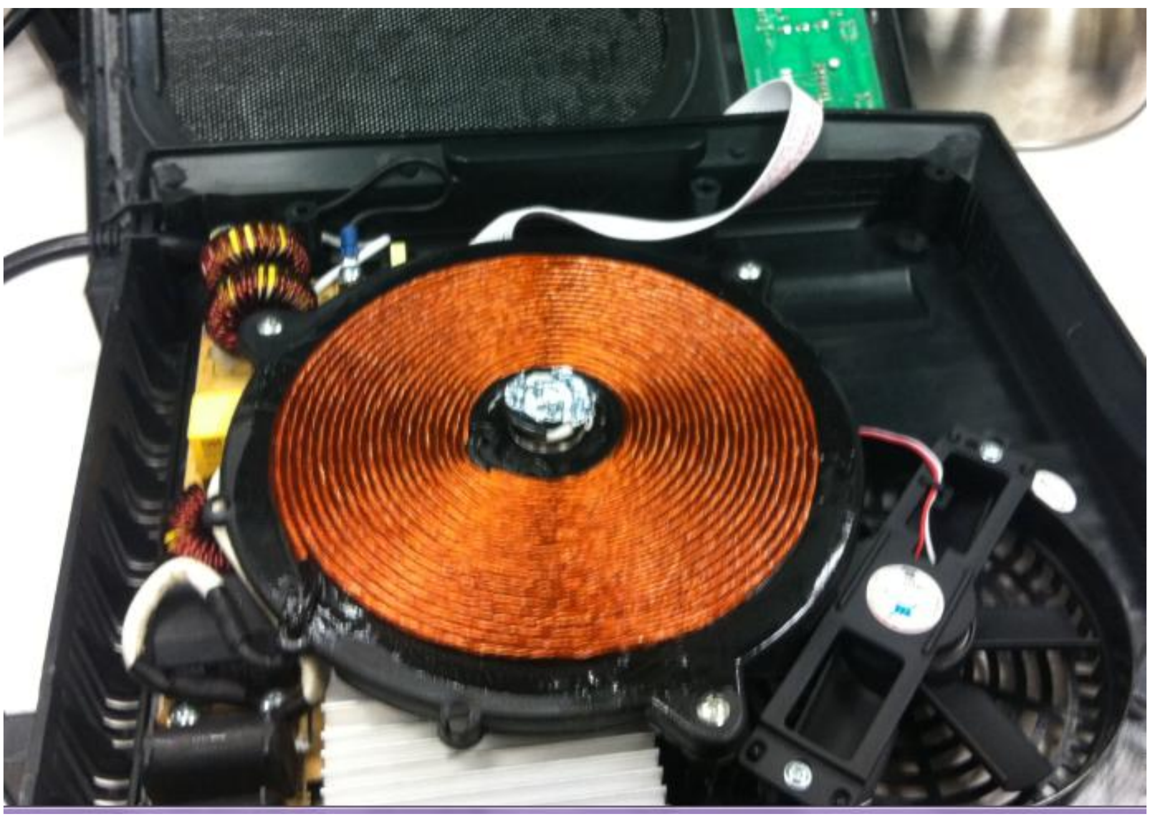

Fig.1.Induction Cooker.

Fig.2. Output Current

The RMS value for the AC output voltage is also measured by the multymeter which is 7.9 Volts; but for electric devices they cannot use a AC voltage directly. As a result, the coil in the secondary side of the circuit is connected directly to a rectifier shown on Fig.4. The rectifier consists of two pairs of diodes and two 2200uF capacitors in order to generate a smooth DC Voltage. The voltage ripple after the rectifier circuit is around 1 percent.

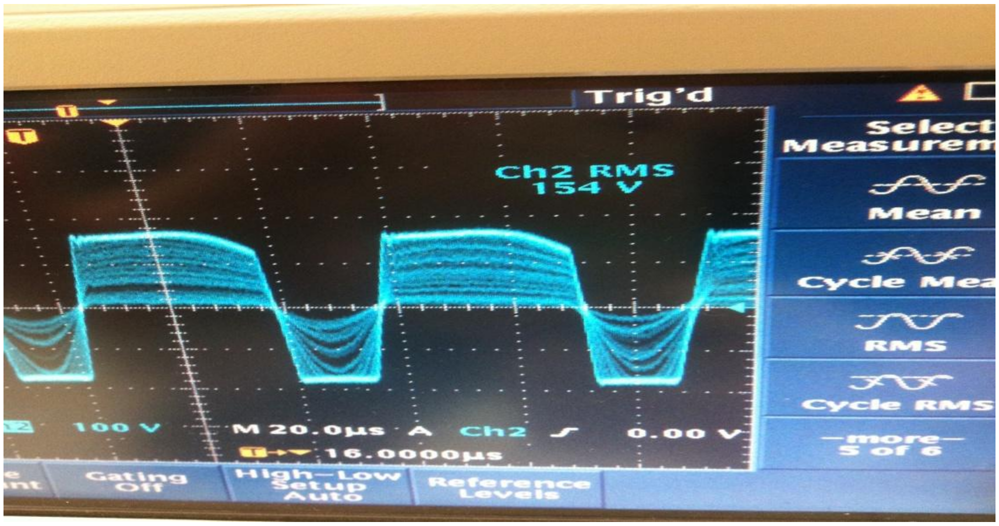

Fig.3. Output Voltage

Fig.4 shows the circuit in the secondary side, it is a full bridge rectifier circuit in order to transform the AC voltage into the DC voltage which the electric devices could use. The diodes used in this circuit work in pair, whenever two of diodes are activated, the other two are closed. After the rectifier circuit the output DC voltage is 4.69 Volts due to the voltage drop across the diodes.

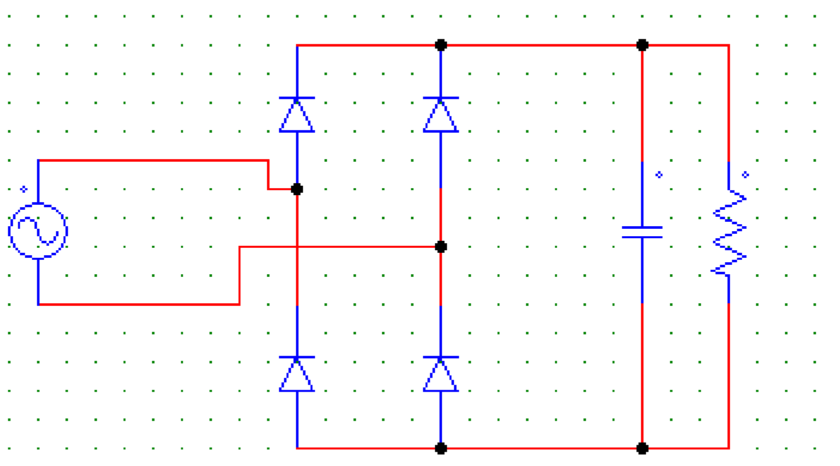

Fig.4.Rectifier Circuit.

Fig.5 is a buck converter connected to the circuit on Fig.4; it is used in order to stabilize the voltage and decrease the voltage by the rectifier circuit. The functional generator used in this project generates a 100 kHz square wave to control the MOSFET's duty cycle, when the duty cycle of the MOSFET is changed, the output voltage also changes. The reason why such a high frequency is used is to keep the output voltage ripple as small as possible.

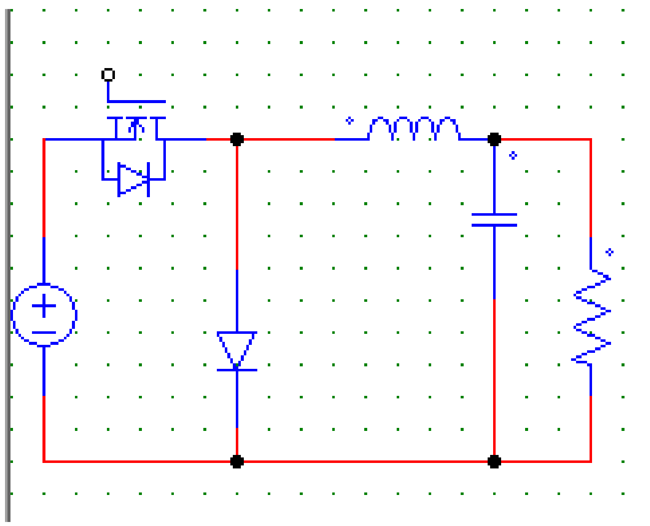

Fig.5. Buck Converter

The voltage on the load side has been measured as 3.3 Volts as shown in Fig.6, which is equal to the required input voltage for the electric devices. According to the whole charging system in Fig.7, the electric device charges its battery successfully.

Fig.6. DC Output

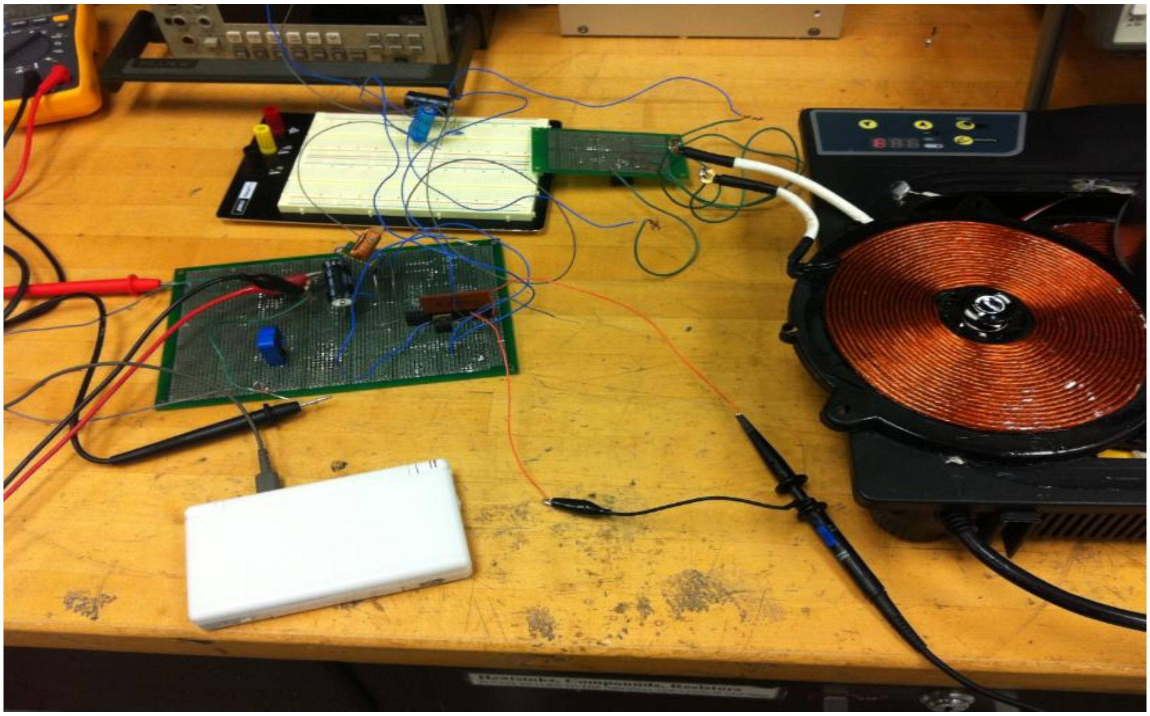

Fig.7. Whole System When Working

CHAPTER IV

SUMMARY AND CONCLUSIONS

The wireless charging pad works well and can be used for charging small electric devices like cell phones.

Firstly, the induction cooktop is used as a power supply in the whole charging system; this is because it could generate steady sinusoidal wave output in a relatively high frequency (15-20k Hz). By keeping the frequency high, the effective distance and the efficiency for the whole system will increase.

Secondly, in order to receive the power as large as possible, the coil in the secondary side of the circuit is built as in the same shape and same size as the primary side of the circuit. The real testing shows that the whole system provides enough power for the whole charging system.

Finally, this project not only makes the author formulate the concept of power electronics but also helps him to learn how to apply what he has learned to practice. The process of building a real charging system is a great experience which will benefit his academic career in the future.

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