ISSN: 2278 – 909X
International Journal of Advanced Research in Electronics and Communication Engineering (IJARECE)
Volume 6, Issue 7, July 2017

WIRELESS POWER TRANSFER BY RESONANT INDUCTIVE COUPLING

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Abstract—*An investigation into the feasibility of wireless power transmission through inductive coupling is carried out using transmission and receiving coils as the coupling antennas. The coilsare in the form of closed loops to both transmit and receive power. To transmit power, an alternating current must be passed through a closed loop coil. The alternating current will create a time varying magnetic field. The flux generated by the time varying magnetic field will then induce a voltage on a receiving coil closed loop system. This seemingly simple system outlines the major principle that our research investigated. The primary benefits to using inductive coupling are the simplicity of the transmission and receiving antennas, additionally for small power transmission this is a much safer means of conveyance. Experimenting on the developed system, effect of frequency and distance between transmitter and receiver coils on the power transmitted were analysed. The significance of resonant inductive coupling in terms of reliability and efficiency is discussed.*

***Index Terms*—Wireless Power transfer, Resonant Inductive Coupling, Induction, Witricity.**

I. INTRODUCTION

Wireless power transfer technology can be applied to a wide variety of applications and environments. The ability to transfer power safely, efficiently, and over distance can improve products by making them more convenient, reliable, and environmentally friendly.This technology is widely termed as Witricity(derived from wireless Electricity). This document details the need and usefulness of wireless power transmission and furthermore feasibility of using inductive coupling as the means for wireless power transmission. The report will outline the design process and the logical steps that were taken in the experimentation and design of the final unit.The entire system integrationand determinationof its performance for the feasibility of wireless power transfer through inductive coupling is analysed.

II. SYSTEM DESIGN AND SIMULATION

The most common form of wireless power transmission is carried out using direct induction followed by resonant magnetic induction.Resonant inductive coupling or electrodynamicinduction is the near field wireless transmission of electrical energy between two coils that are tuned to resonate at the same frequency. The equipment to do this is sometimes called a resonant or resonance transformer.

A. DESIGN

Overall system consists of power supply, Oscillator, transmitter coil, receiver coil, rectifier and an electrical load. Schematic block diagram of the system is as shown below:

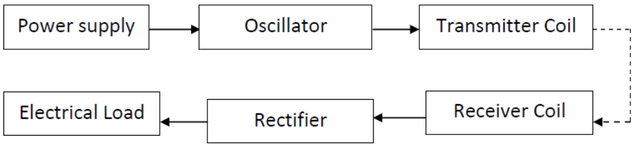


Fig 1. *Schematic block diagram of the Wireless Power Transmission System*

The transmitter circuit is driven from a +12 V regulated DC power supply. The supply should have high current rating for reliable operation of the circuit. Provisions like short circuit protection and overload protection are also desirable. Switched Mode Power Supply (SMPS) fulfills all the necessary requirements and is the best choice as the power supply.

The oscillator circuit is designed to feed the antenna with electrical energy at required frequency. It forms the heart of the transmitter. The circuit of choice was a slightly modified form of royer oscillator, such as popularly used in CCFL inverters and flyback drivers. Schematic arrangement of the circuit is shown in figure 2.

The circuit feeds a parallel LC tank circuit which would take feedback from the tank circuit itself, hence always driving it at its resonant frequency. Large reactive currents circulate within the tank while only real power is drawn from the supply. This sets up a magnetic field alternating at the resonant frequency of the tank circuit in the inductor which is used for power transfer.

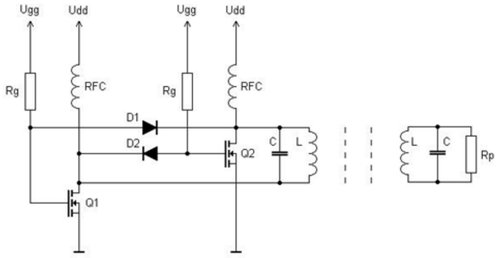


Fig 2. Schematic Diagram of oscillator circuit

The transmitter coil forms the inductor in the LC tank circuit of the oscillator. Electromagnetic radiation is generated due to high frequency oscillations in the transmitter coil. The transmitter coil induces an emf in a receiver coil. The emf generated is alternating in nature with the same frequency as that of the transmitter section. The Received signal is rectified, filtered and fed to a voltage regulator.Different coils are designed to conduct the experiment with different frequencies

The alternating voltage induced in the receiver is rectified using a bridge rectifier. After rectification it is filtered and output voltage is regulated using IC7805.

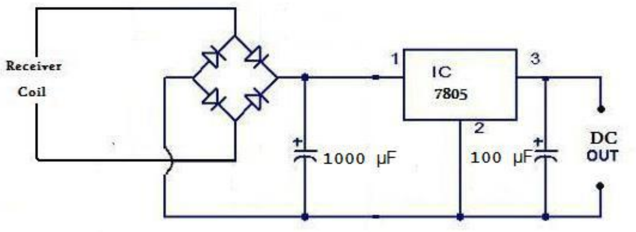


Fig.3 Rectifier and regulator circuit

The circuit is used to charge a mobile phone battery. Li-ion battery (3.7V, 1110mAh) is used as the load.

B. SIMULATION

Simulation tests were performed using the software 'NI Multisim'. From simulation, for primary coil inductance of 1mH and reciever coil inductance of 10mH an output of 2.8Vp-p under coupling of 0.1 was obtained.

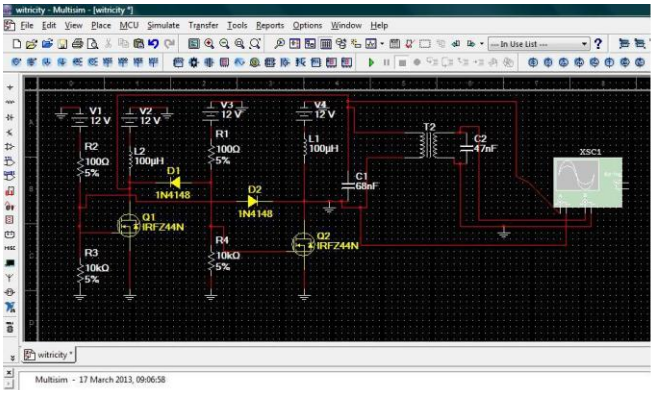
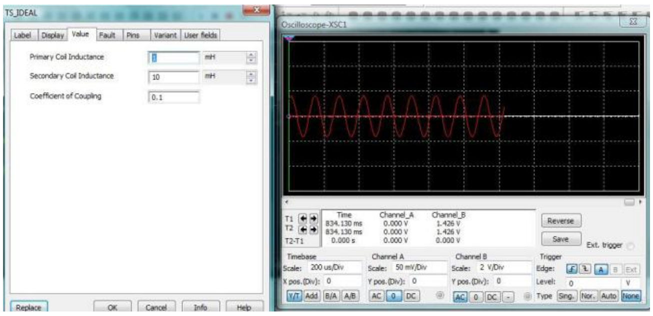


Fig 4. Circuit Diagram Simulation

It was observed that for reciver inductance in the range of nano-henry no output was received, which is in agreement with the tests performed. From simulation, it was understood that as the receiver coil inductance is increased, the o/p voltage increases but current decreases significantly.



Primary Coil Inductance: 1 mH
Secondary Coil Inductance: 10 mH
Coefficient of Coupling: 0.1

	Time	Channel_A	Channel_B
T1	834.130 ms	0.000 V	1.426 V
T2	834.130 ms	0.000 V	1.426 V
T2-T1	0.000 s	0.000 V	0.000 V

Timebase Scale: 200 us/Div; X pos.(Div): 0
Channel A Scale: 50 mV/Div; Y pos.(Div): 0
Channel B Scale: 2 V/Div; Y pos.(Div): 0
Trigger Level: 0 V

Fig 5. Simulation Output

C. ENCLOSURE

The Enclosure design is relatively simple. The transmitter was designed as a box large enough to carry most components on the bottom of the box and screw them to the base. In addition, there is sufficient room for additional circuits if necessary. The construction of the box included a connector and a switch to turn on the system. The enclosure cover is made using glass piece of 6x4 inches.

Fig 5.The system enclosure

III. RESULTS AND DISCUSSIONS

The feasibility of wireless power transfer is a definite reality as this project has demonstrated. The major point of the research was to evaluate whether or not inductive coupling was a feasible solution. While it is possible to transmit and receive power using inductive coupling it has some definite drawbacks. A long distance inductive coupling is far too inefficient in its current state. But wireless power transfer can be efficiently used for short distance power transfer.

Different coil combinations are used as the transmitter and receiver to study the effect of frequency on power transmitted. Experiment is conducted by varying the distance between transmitter and receiver coils to study the relationship between distance and power transmitted. The observations are tabulated. Based on the tabulation, the most efficient and reliable coil combinations were selected and Wireless power transfer using resonant inductive coupling was accomplished and a mobile phone was charged

For parallel resonance,

$$f = \frac{1}{2\pi\sqrt{LC}}\ \text{Hz} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Let,

L1 =225 nH (single turn copper tube of 5.5 mm diameter with circumference of the coil 65cm)
L2=90 nH (single turn copper tube of 5.5 mm diameter with circumference of the coil 19cm)
L3=200µH (36 turns of 26 gauge copper conductor with 9cm coil diameter)
L4=12.5µH (9 turns parallel to 9 turns of 26 gauge copper conductor with 9cm coil diameter)
f = Frequency of oscillations
V_1= DC Supply voltage = 12V
I_1= DC current from SMPS
V_2= Output voltage across load
I_2= Output current
d= Normal distance between transmitter and receiver
d_{max}= Maximum normal distance between transmitter and receiver with output.

A. *Case 1*

Using L1 as transmitter and L3 as receiver. Readings are taken at different distances. Voltage is measured by open circuiting the secondary and then current at the same distance is measured by short circuiting the secondary. Maximum distance for which a noticeable output is obtained is also noted.

f=799.8 kHz

	V_1 (V)	I_1 (mA)	V_2 (V)	I_2 (mA)
d=0	12	560	74.5	114
d=5cm	12	550	66	40
d=10 cm	12	550	29.2	34
d=15 cm	12	570	14.1	33
dmax=51cm	12	570	0.5	0.05

Table 1

B. *Case II*

Using L2 as transmitter and L3 as receiver. Readings are taken at different distances. Voltage is measured by open circuiting the secondary and then current at the same distance is measured by short circuiting the secondary. Maximum distance for which a noticeable output is obtained is also noted.

f= 1.63 MHz

	V_1 (V)	I_1 (mA)	V_2 (V)	I_2 (mA)
d=0	12	1.07	48	29.2
d=5cm	12	1.08	73	4.2
d=10 cm	12	1.06	72.5	1.8
d=65 cm	12	1.02	1.3	0.01

Table 2

C. *Case III*

Using L4 as transmitter and L3 as receiver. Secondary voltage is rectified and filtered. 12V dc fan is used as the load.

f= 175.7 kHz

	V_1 (V)	I_1 (mA)	V_2 (V)	I_2 (mA)
d=0	12	1.29	19.8	253
d=2 cm	12	0.536	9.4	169
d=5 cm	12	0.3	2	24.5
d=10 cm	12	0.3	1	0.2
dmax=15cm	12	0.3	0.7	0.1

Table 3

IV. OBSERVATIONS AND CONCLUSIONS

From the experimentation results it can be found that power can be transmitted over greater distance by increasing the frequency of oscillations. However at higher frequency, the bandwidth at which resonant condition occurs decreases significantly and tuning became difficult .Hence to achieve resonance, a lower frequency was selected .This also avoided the possibility of interference with communication circuit, Also if single turn primary is used the current output at the secondary would be very low due to high transformation ratio by basic transformer principle, hence a multi turn coil was used.

The combination using L4 as transmitter and L3 as receiver (f=175.7 kHz) was chosen to realize the coupling circuit which would be driving the charging unit.

Inductive coupling has a definite future in the short range transmission distance. This particularly has medical implementations to transmit a few inches to power a remote sensor implanted in the human body.

There are several improvements that can be made to the system to increase its overall performance. By varying the resonant frequency of the circuit over a wider range the effects of frequency on transmission can be better analysed and optimum transmission frequency can be selected. A gang capacitor can be used in the tank circuit for fine tuning of circuit performance. Fine tuning of the circuit for better resonance will also boost the system efficiency and reduce power requirement of the circuit.Alternate coil designs aiming to reduce size of the receiver can be attempted so that the receiver can be integrated as a module in the cell phone itself.

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