A WIRELESS POWERED MOBILE PHONE CHARGING SYSTEM

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Abstract

The design and construction of a wireless powered mobile phone charging system is one of such attempts to transmit power wirelessly via the principle of magnetic coupling. This project is basically made up of two parts: the transmitting unit which comprises the oscillator and the transmitting coil and the receiving unit which comprises the receiving coil and the rectifying circuit. The oscillator converts the DC voltage to AC and generates the transmitting frequency needed to induce voltage to the receiving coil. The receiving coil receives the induced voltage and sends it to the rectifying circuit which converts it to DC voltage, after which it is regulated to the 5V required for charging the mobile phone battery.

KEYWORDS: *Wireless power transmission, magnetic coupling, inductive coupling, astable, monostable.*

I. INTRODUCTION

In electrical power arrangements, the supply of electrical energy is incomplete until the generated electrical power has been transmitted and efficiently distributed to consumers for use.Generally transmission of electrical energy has to do with the transfer of electrical energy from a source to a load over a given distance. This is usually done using cables and wires which vary in size, physical construction, length and other dimensions with regards to the nature of power transferred and transmission distance.

But, recent developments seeks to develop methods of achieving power transmission without the use of wires thereby eliminating some of the constraints related to power transmission using wires. Wireless power transmission is the transfer of electrical energy from a source to a load without the use of wires and cables or any physical construction between the two points. This improvement in electrical energy transmission has led to the design of charging systems that are capable of wireless power transfer. This means that the power supply cord is not plugged to the device been charged (though it may be in close proximity).

Wireless power transfer technology has existed for a long time, however recent advances have allowed it to become more practical, and recent interest in consumer market has brought it to the centre of attention. Also, owing to the immense importance attached to electricity and intense demand for convenient and cost effective ways of generating, transmitting and distributing electrical energy at increased efficiency, scientists and engineers now look for ways to cut cost while delivering the required service[1, 2]. The wireless powered mobile phone charging system is a means of transmitting electrical energy from a source to a mobile device without the use of wires.

The concept of wireless power transmission was pioneered by the work of Nikola Tesla when he carried out his famous experiment in 1891 – The Colorado spring experiment. From his experimental station he was able to light a bulb through a resonant circuit grounded at one end using the Tesla coil [5].Since then, efforts have been made to make wireless power transmission more efficient and convenient. To this end, the use of magneto plated wires (copper wire with magnet plated circumference) has been used to improve transmitter and receiver efficiency [6] though at a small distance. In [3], reference was made to experiment at MIT in 2012 where two copper coils each, a self-resonant system were used. The coil attached to the power source is referred to as the sending unit. The sending unit produced a magnetic field oscillating at MHz (10MHz) frequencies. A power exchange occurred between the sending and receiving units which is specially designed to resonate at the same frequency as the sending unit.

The means or methods of achieving wireless power transmission [7] are classified into different categories depending on the:

a. Technology applied
b. Range of transmission
c. The type of antenna used

A. Based on technology applied

Wireless power transmission systems based on technology applied are divided into:

i. Inductive coupled system:
The systems transfer power between coils of wires by a magnetic field.This system uses the transformer principles but over a distance.

ii. Resonant inductive coupled systems:
This is form of inductive coupling but the difference between it and other forms of inductive coupling is that in this case, the transmitter and the receiver coils are designed to be at resonance.

iii. Capacitive coupled systems:
In this type of wireless power transfer systems, the principle of electrostatic induction is used. Hence, power is transferred by electrical fields between electrodes such as metal plates.

iv. Magneto-dynamically coupled systems:
In this type, armatures, one rotating and the other coupled by a magnetic field and rotating synchronously are used to transfer power from the source to the load.

v. Microwaves:
Here electrical energy is beamed as microwave and converted back to electrical energy at the receiver and through the use of antennas.

B. Based on range i.e. Distance of transmission:

Wireless power transmission systems are classified by range into three, depending on the distance between the transmitter and receiver coils. The divisions are:

i. Short
ii. Medium and
iii. Long range wireless transmission systems.

C. Based on type of antenna used:

The different technologies used in the transmission of wireless power systems require different antenna configurations e.g. Microwave technologies employ rectennas while inductive and resonant technologies make use of coils. These put together affect the design of any wireless power transmission system.

This project is focused on the design and construction of a wireless powered mobile phone charging system using inductive coupling to cover a short distance.Inductive coupling is based on magnetic field induction that delivers electric energy between two coils. Inductive power transfer (IPT) happens when a primary coil of an energy transmitter generates predominantly varying magnetic field across the secondary coil of the energy receiver within the field. The near field magnetic power then induces voltage/current across the secondary coil of the energy receiver within the field. This voltage can be used for charging a wireless device or storage system. The operating frequency of inductive coupling is typically in the kilo Hertz range. The secondary coil should be tuned at the operating frequency to enhance efficient charging [8]. The quality factor is usually designed in small values (e.g. below 10) [9], because the transferred power attenuates quickly for large quality values [10]. Due to lack of compensation of high quality factor, the effective charging distance is generally within 20cm [11]. The advantages of magnetic inductive coupling include ease of implementation, convenient operation, high efficiency in close distance, and safety.

II. DEVELOPMENT OF BLOCK DIAGRAM

The block diagram of the inductively coupled wireless mobile phone charging system is as shown in figure 1.0

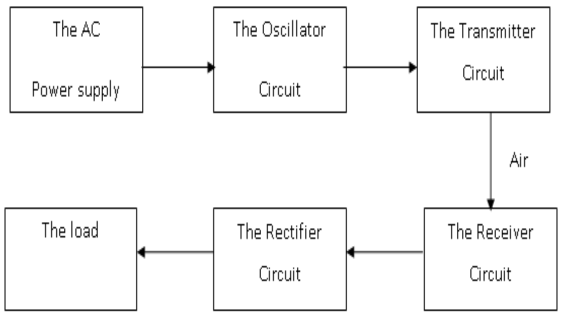

Figure 1.0: Block diagram of wireless mobile phone charging system.

The AC power source is drawn from the mains supply (220V/50Hz) from the wall socket. The voltage is reduced to 15V using a step down transformer. It is then converted to DC voltage with the help of a rectifier before it is sent to the oscillator circuit. The oscillator circuit is a circuit arrangement set up to convert direct current signals to alternating current signals. The function of the oscillator is to generate the needed transmission frequency. The oscillator circuit used is CD4047BCM IC. The IC has 14 pins and can operate either in monostable or astable mode. The IC was configured to operate in astable mode. The output from the oscillator is then transferred to the transmitter circuit. This is the heart of the circuit since it is where the actual transmission of power takes place. The transmitter is made of two MOSFETs and a copper coil.In wireless mobile phone charging system, the receiver circuit generally drives a rectifier [12] through which the induced high frequency voltage is converted to DC for use in powering a mobile phone.This rectifier operates with the same principle as the rectifier used in the power supply block but differs in the sense that the rectifier here must be able to operate at high frequencies. It converts the high frequency output of the receiver to a DC signal which can be used to power a mobile phone. The output is connected to a mobile phone for testing.

III. PROPOSED SYSTEM DESIGN

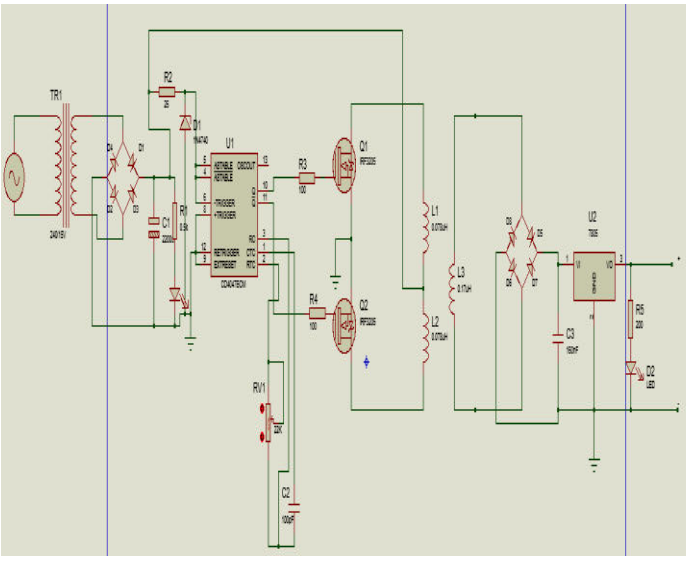

Figure 2.0: complete circuit diagram of the wireless mobile phone charger

The wireless powered mobile phone charging system is capable of operating in either astable or monostable mode. Here it has been configured to operate in the astable mode. The capacitor C_2 andRV_1 forms a tank network to provide the operating frequency of the system. The variable resistor RV_1 is provided for adjusting the output frequency. The time period of the oscillation is given by$T = 4.4\ (RC)$. Theoutput pins $Q$are$\bar{Q}$are complementary to each other and produces square wave pulse with 50% duty cycle used to drive the gate of the MOSFET Switches.

When the output at the pin 10 goes low, pin 11 will be high at this point Q_2 will turn ON and current flows through the lower winding inductor L_2 thereby transforming energy to the secondary winding L_3 and positive half cycle voltage output is obtained. Similarly, when the output at pin 10 goes high, pin 11 goes low, Q_1 turns ON and the current flows through the upper winding inductor L_1 thereby transferring energy to the secondary winding which is rectified and negative half cycle voltage is obtained. The continuous switching ON and OFF of the two MOSFETS produces a quasi-square wave across the secondary winding which is rectified by the bridge diode and subsequently filtered by the output filter C_3. UA7805 regulator keeps the output voltage at the constant value of 5V.

IV.CIRCUIT CALCULATIONS

1. Design of the Oscillator Unit

The oscillator circuit is designed using CD4047BCM integrated circuit (IC). The IC is configured to operate in astable mode.

The switches Q_1 and Q_2 must turn ON and OFF at the frequency given by

$$f = \frac{1}{4.4(RC)} ------------- (1)$$

From the datasheet of CD4047BCM at 10KHz, $C_1 = 100pF \text{and} RV_1 = 22K\Omega$

$$f = \frac{1}{4.4(C_1 \times RV_1)} = \frac{1}{4.4(22K\Omega \times 100pF)} = 10330Hz$$

$RV_1$is adjusted to produce $10KHz$

2. Design of the Transmitter Coil

Since inductance of air core inductor is given by

$$L_2 = \frac{(d^2 \times n^2)}{18d + 40l)} ------------ (2)$$

Where L = inductance of primary winding in μH

d = coil diameter = 11.8 inches

l = coil length in inches = 39.4 inches

n = number of turns.

Since the required inductance is $1.114\mu H$, we substitute the values of d, l, and L in equation (2) to find the number of turns 'n'.

From equation (2),

$$L(18d+40l)=d^2\times n^2$$

$$\Rightarrow n^2=\frac{L(18d+40l)}{d^2}$$

$$=\frac{1.114(18\times11.8+40\times39.4)}{11.8^2}$$

$$=\frac{1.114(1788.4)}{139.24}=14.31$$

$$n=\sqrt{14.31}=3.783$$

$$n=3.8$$

We then choose

$$N_1=4\ turns.$$

3. Design of the Receiver Coil

Induced voltage in the secondary winding can be obtained from the following equation

$$\frac{N_2}{N_1}=\frac{V_2}{V_1}----------------(3)$$

Where;

$V_1 = primary\ winding\ voltage$

$V_2 = secondary\ winding\ voltage$

$N_1 = no.\ of\ turns\ of\ the\ primary\ winding$

$N_2 = no.\ of\ turns\ of\ the\ secondary\ winding$

Therefore;

$$V_2=\frac{N_2}{N_1}\times V_1--------------(4)$$

The required output from the system is 5.0V

$$\therefore 5=\frac{N_2}{N_1}\times V_1$$

Where;

$N_2 = ?$

$N_1 = 4\ turns$

$V_1 = 12.6V$`

$$\Rightarrow N_2=\frac{5N_1}{V_1}=\frac{5\times4}{12.6}=\frac{20}{12.6}=1.59$$

$$N_2\approx 2\ turns.$$

Hence;

$N_1 = 4\ turns$

$N_2 = 2\ turns$

Therefore the induced voltage can be calculated as thus;

$$V_2=\frac{N_2}{N_1}\times V_1$$

$$\Rightarrow V_2={}^2/_4\times12.6$$

$$\therefore V_2=6.3V$$

V. HARDWARE IMPLEMENTATION

The implementation of the wireless powered mobile phone charger involves the design and construction of two major parts which are the transmitting unit and the receiving unit. The transmitting unit comprises the oscillator circuit and the transmitting coil. It is responsible for generating the electromagnetic field that is transferred to receiving coil via the principle of inductive coupling.The receiving circuit is responsible for receiving the electromagnetic field. The voltage received is an AC voltage which is then converted to DC by the rectifier in order to make it suitable for charging a mobile phone.

VI. DISCUSSION OF RESULTS

The result obtained at the receiver unit varied with the distance of separation between the transmitter and the receiver. The farthest distance of separation that could be achieved was about 15cm, with a measured voltage of about 0.8V. The results are shown in table 1.0

Table 1.0: Measured result at the receiver

Distance from the transmitter (cm)	Voltage received (V_{DC})
1	7.2
3	6.3
5	5.8
7	4.3
9	3.4
11	2.5
13	1.8
15	0.8

Since the voltage required to charge the mobile phone battery is 5V, it means that the mobile phone can only charge when the separation distance between the transmitter and the receiver is about 6cm. This is a deviation from the intended design as the highest distance at which energy was transferred and received was not up to 20cm.This deviation in the design intention was as a result of the challenge posed by switching frequency of the solid state electronic devices used in the design.

Over a distance of 15cm, the received voltage was at 0.8V. But the transmitted voltage was 12.6V. We can thus give the efficiency of the system in terms of the voltage transmitted and received as

$$\text{Efficiency, } \eta = \frac{outputvoltage}{inputvoltage} \times 100 --- (5)$$

$$= \frac{received\ voltage}{transmitted\ voltage} \times 100$$

$$= \frac{7.2}{12.6} \times 100$$

$$= 57.1\%$$

Table 2.0: Voltage transfer efficiency

Distance from the transmitter (cm)	Voltage received (V_{DC})	Efficiency
1	7.2	57.1%
3	6.3	50.0%
5	5.8	46.0%
7	4.3	34.1%
9	3.4	27.0%
11	2.5	19.8%
13	1.8	14.3%
15	0.8	6.3%

The highest efficiency of power transfer (57.1%) is obtained when the distance between the transmitter and the receiver coil is 1cm. The system is still able to work effectively when the distance is up to 5 cm since the minimum voltage for charging required is 5V.

VII. CONCLUSION

The design and construction of a wireless powered mobile phone charging system is described in this report. The voltage needed to charge the mobile phone battery (5V) is induced on the receiving coil when the separation distance between the transmitter and the receiver is about 6cm. This is however not up to the intended separation distance of 15 cm. The major reason for the deviation in result is because the designed circuit operating frequency was limited by the switching frequency of the MOSFETs used. Since the transmission distance is directly proportional to the system frequency of operation, this reduced the transmission distance greatly. The system was observed to overheat which implied great loss of useful energy in the form of heat through the MOSFETs and this caused a reduction in the energy available for transmission. We hereby recommend that subsequent works be attempted using external oscillator devices, efforts should be made to harmonize the system operating frequency with the switching frequency of the solid state devices in order to increase transmission distance and magneto-plated coils be used instead of copper wire (coil).

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