Wireless Power Transfer

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Abstract—**Wireless charging of gadgets is one of the new emerging technologies in the world at the moment. The most common method used at the moment is wireless power transfer (WPT) by resonant inductive coupling. Wireless power transfer is one of the simplest and inexpensive ways of charging as it eliminate the use of conventional copper cables and current carrying wires. In this paper write up, a methodology and principle of operation are devised for wireless power transfer through resonant inductive coupling, and a feasible design is modeled accordingly. The resonant inductive coupling technique is used since currently it's the easiest method of wireless power transfer because of high efficiency and large amount of the energy transferred. In the paper results of experiments done to check wireless working will be shown. Also to further show its versatility and range of applications the power transferred will be used to charge a battery with the aid of additional circuitry. This paper work focuses on the study of wireless power transfer for the purpose of transferring energy at maximum efficiency within a small range or in the near field region.**

Key Words— **WPT, Resonant inductive coupling, Charger.**

I. INTRODUCTION

IF you are using an electronic device perhaps a mobile phone and you need to recharge the battery then you will probably have to get a charger and connect the phone to the wire. But what if you could charge it without having to connect it to wire? Meaning power will be transferred wirelessly. This is possible through a concept called Wireless Power Transfer (WPT). Research and studies have been done ever since the 19th century but it is only recently that this concept has begun to be implemented.Currently engineers are trying to discover how to increase the efficiency of power transmitted wirelessly and also methods that are safe to human beings and the environment and notwithstanding, methods that are cheaper and hence can be commercially viable. Though still in the early stages, several electronic companies are beginning to roll out devices that can wirelessly transmit power . During the past 20 years, improvements in wireless technologies have led to a revival of related research. Public interest in wireless power has also increased with the application of Nikola Tesla ideas and inventions [1]. As a result of this, the feasibility of technological implementation merits examination. Various scientists and inventors contributed to the development of wireless power. Examining their backgrounds reveals the sources of their motivation and the methods by which they conducted research. The inventions developed during this time were more advanced than anything that had been seen before, solving challenging problems and developing the basic theories that yielded modern technology. These inventors' patents, papers, and experiments effectively describe the practicality and utility of wireless power propagation. Three prominent forms of power transmission are conduction, induction, and radiation. There are various formulas that explain how electrical power can be transmitted without the use of a physical conductor. Each mode of power transport has theories that govern how the electromagnetic waves carry power from a transmitter to a receiver [2]. The importance of WPT is no wire ,no e-waste, need for battery eliminated, efficient and harmless, low maintenance cost, more effective (when the transmitting and receiving points are along a line of sight), can reach the places which are remote, Maintains battery life, and if it happened short circuit in the receiver circuit ,the transmitter circuit not affected . The overall goal of this paper is to design and successfully implement a wireless power transmission system for residential purpose, and the major objective is to achieve Wireless power transfer inductive coupling between the transmitting and receiving coils in the near field.

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II. WIRELESS POWER TRANSFER TECHNIQUES

For WPT systems, power can be transferred from the transmitter to the receiver through EM fields. Thus, WPT can be classified to radiative and non radiative techniques according to the form of the EM fields and the operational distance between the transmitter and the receiver. Radiative power, for which case the operational distance is far beyond the wavelength of carrier wave, can be emitted from a transmitting antenna in the form of EM waves propagating over a long distance. The amount of power emitted as EM waves by an antenna depends on the ratio of the antenna's size to the wavelength. Thus, to transmit the power to a long distance the antenna's size should be in the order of or higher than the wavelength. Moreover, the antenna employed in the radiative power transfer should be highly directive; otherwise, a big portion of energy will be dissipated and lost out of the system. Non-radiative WPT, for which case the operational distance is much less than the wavelength, can be achieved through the near field coupling. Power can be transferred via electric fields in capacitive power transfer (CPT) systems by capacitive coupling between metal electrodes [3][4] or via magnetic fields by inductive coupling between coils. By working mechanisms, WPT systems based on magnetic coupling can be further classified into two types. One type is based on magnetic induction and called inductive coupling power transfer (IPT), where Biot-Savart's Law and Faraday's Law are the governing principles. The modern IPT systems support only short-range transmission (less than the dimension of the resonator), which is usually at millimeter to centimeter level. Regarding IPT. The other type is magnetic resonant coupling power transfer (MRPT), where the energy can be transferred between two magnetically coupled resonant devices with the same resonance frequency. In this paper we focused on near field techniques[5].

A. Inductive Coupling Power Transfer (IPT)

Two conductors are referred to as mutual-inductively coupled as shown in figure 1 when they are configured such that change in current flow through one wire induces a voltage across the ends of the other wire through electromagnetic induction. In wireless transfer, a portion of the magnetic flux established by one circuit interlinks with the second circuit, then two circuits are coupled magnetically and the energy is transferred from one circuit to the another circuit, the basics of this process is the transmitter and receiver coils are inductively coupled [6]. Oscillators are used in transmitters to convert DC current to AC current. The AC current passed in the transmitter coil generates magnetic field, which induces a voltage in receiver coil Magnetic Field is concentrated in small volume between transmitter and receiver. The receiver has a rectifier that convert AC back into DC for use. The voltage regulator is meant to maintain a constant voltage. The effect of inductance can be magnified or amplified through coiling the wire. Inductive coupling energy transfer carries a far lower risk of electrical shock, when compared with conductive charging, because there are no exposed conductors The main disadvantages of this method is its lower efficiency and increased resistive heating in comparison to direct contact. Inductive charging also requires drive electronics and coils that increase manufacturing complexity and cost. Wireless charging pad, electric brush, transformer inverts work based on this concept [7].

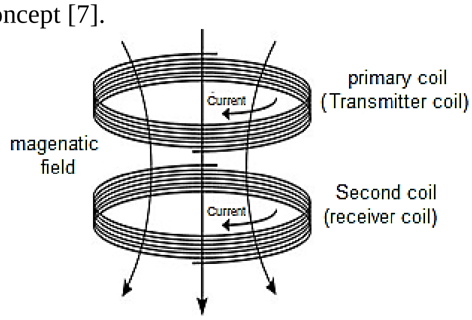


Fig. 1 Inductive Coupling

B. magnetic resonant coupling power transfer (MRPT)

Magnetic resonant coupling power transfer (MRPT) is transmitting power between two coils as shown in figure 2 that are tuned to resonate at the same frequency. Resonance occurs when the self-resonant frequency of coils equal to the frequency of AC power supply, when the equivalent circuits of coils in high frequency have the minimum impedance [8]. Then, the most energy will be transferred from the resonant path Resonant transfer works by making a capacitive loaded primary coil ring with an oscillating current. This generates an oscillating magnetic field. Because the coil is highly resonant, any energy placed in the coil dies away relatively slowly over very many cycles, but if a second coil is brought near it, the coil can pick up most of the energy before it is lost, even if it is some distance away. The fields used are predominately non-radiate Magnetic resonant coupling can also be used to deliver power from a large source coil to one or many small load coils with lumped capacitors at the coil terminals providing a simple means to match resonant frequencies for the coils In this method, losses occur due to ohm resistance and radiation[9].

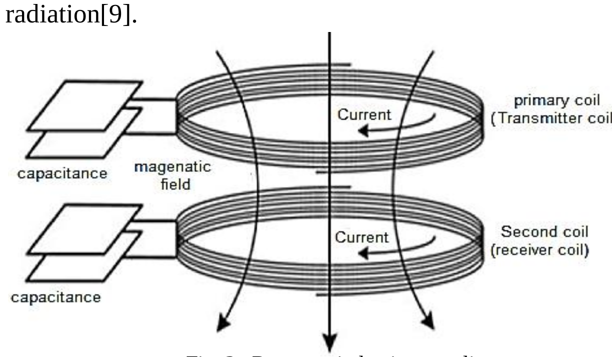


Fig. 2. Resonant inductive coupling

The frequency at which resonant occurs is determined by

$$f_{r=}\frac{1}{2\pi\sqrt{LC}} \quad (1)$$

The parallel resonant LC circuit is often called a tank circuit, The stored energy is transferred back and forth between the capacitor and the coil as shown in figure 3 and figure4 [10].

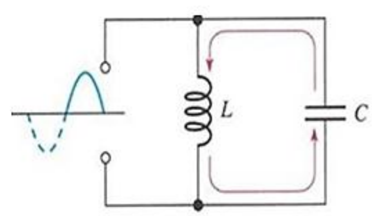


Fig. 3. Tank circuit (The coil de energizes as the capacitor charge)

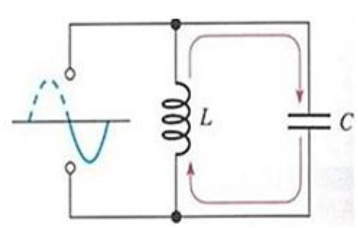


Fig. 4. Tank circuit (The capacitor discharges as the coil energizes)

III. Experimental work

The block diagram of near field techniques of WPT is shown in figure 5.

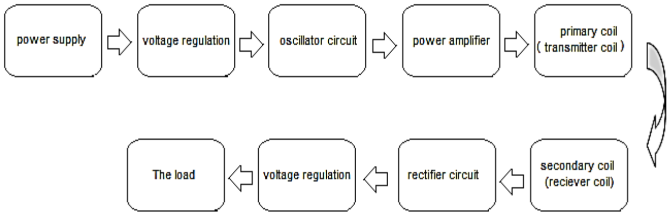


Fig. 5. Block diagram of transmitter and reciever wireless power transfer

1) *Power Supply*: Power supply is used to supply the transmitter circuit of WPT which is contain oscillator circuit, power amplifier, and transmitter coil by DC voltage.
2) *Voltage Regulation*: ICs regulator is mainly used in the circuit to maintain the exact voltage which is followed by the power supply. A regulator is mainly employed with the capacitor connected in parallel to the input terminal and the output terminal of the IC regulator. For the checking of gigantic alterations in the input as well as in the output filter, capacitors are used. While the bypass capacitors are used to check the small period spikes on the input and output level. Bypass capacitors are mainly of small values that are used to bypass the small period pulses straightly into the Earth.
3) *Oscillator Circuit*: The oscillator is circuit that converts DC signal to AC signal with a desired frequency, in this paper we used the timer 555 as oscillator. The NE555 monolithic timing circuit is a highly stable controller capable of producing accurate time delays, or oscillation. In the time delay mode of operation, the time is precisely controlled by one external resistor and capacitor. For a stable operation as an oscillator, the free running frequency and the duty cycle are both accurately controlled with two external resistors and one capacitor. The circuit may be triggered and reset on falling waveforms, and the output structure can source or sink up to 200mA.
4) *Power Amplifier*: The power amplifier is used to amplify the ac signal from oscillator circuit to drive the transmitter coil. IRF 540 N-Channel Power MOSFET was used as power amplifier, it had the following specification 33A, 100V and 0.040 Ohm.
5) *Transmitter Coil*: An electromagnetic coil is an electrical conductor such as a wire in the shape of a coil, spiral or helix. A current through any conductor creates a circular magnetic field around the conductor due to Ampere's law as shown in figure 6. The advantage of using the coil shape is that it increases the strength of magnetic field produced by a given current. The magnetic fields generated by the separate turns of wire all pass through the center of the coil and add (superpose) to produce a strong field there. The more turns of wire, the stronger field produced and pass to receiver coil [11].
6) *Receiver Coil*: A changing external magnetic flux induces a voltage in a conductor such as a wire, due to Faraday's law of induction as shown in figure 1. The induced voltage can be increased by winding the wire into a coil, because the field lines intersect the circuit multiple times.
7) *Rectifier Circuit*: Rectifier circuit rectified AC voltage into DC voltage to supply the load.

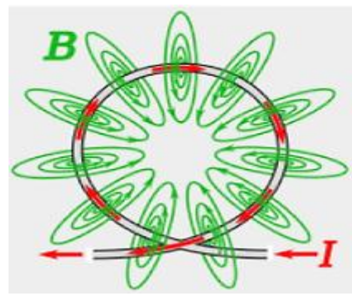


Fig. 6. Current through conductor creates a circular magnetic field

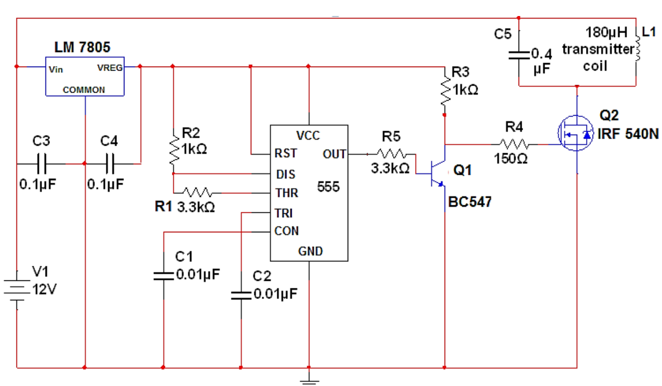
IV. Implementation of WPT circuit

Figure 7 shows the implementation of WPT circuit. The voltage regulator (7805) supplied oscillator circuit with regulated voltage 5 V_{dc} , then a stable multi vibrator oscillator (NE 555) generates a square wave as shown in figure 8 with frequency 18.9 KHz, it can be calculated form the following equation

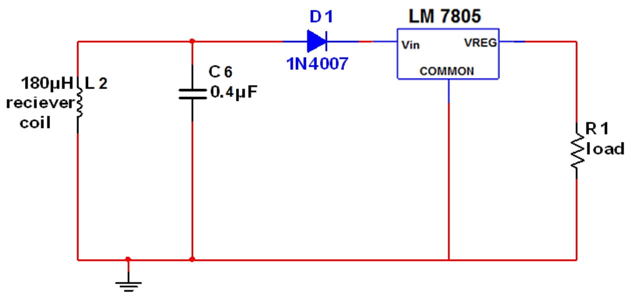
$$f_{t}=\frac{1.44}{(R1+R2)c} \tag{2}$$

$$f_{t}=\frac{1.44}{(1k+2*3.3k)0.01u}=18.9khz \tag{3}$$

The power amplifier consists of transistor Q1(BC547) that is driving the power transistor Q2(IRF540N) which is used to amplify the AC signal with frequency 18.9KHZ to drive the primary coil to induce electromagnetic flux that is transferred to secondary coil in the receiver part of WPT circuit.



(a)



(b)

Fig. 7. Implementation of WPT circuit (a)Transmitter circuit (b)Receiver circuit

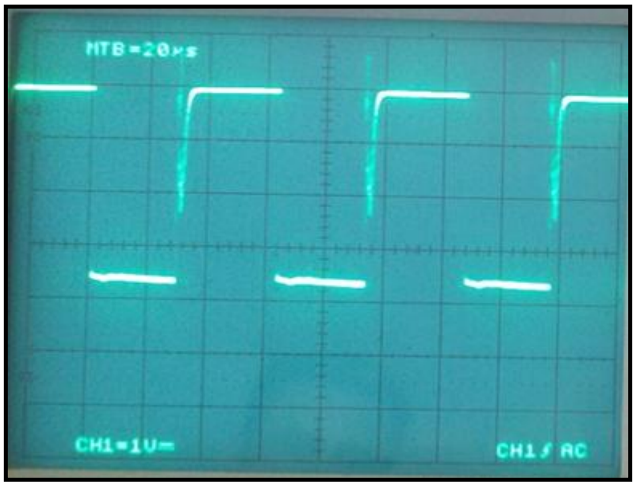


Fig.8. The timer produce square wave with frequency 18.9khz

V. Results and Discussion

Figure 9 shows the practical circuit of WPT, implemented in the circuit laboratory of electrical engineering department. We used WPT circuit to charge the battery of mobile phone (Samsung S1) at different distances between transmitter coil and receiver coil, the output voltage and current of the received circuit measured , the results illustrated in Table I.

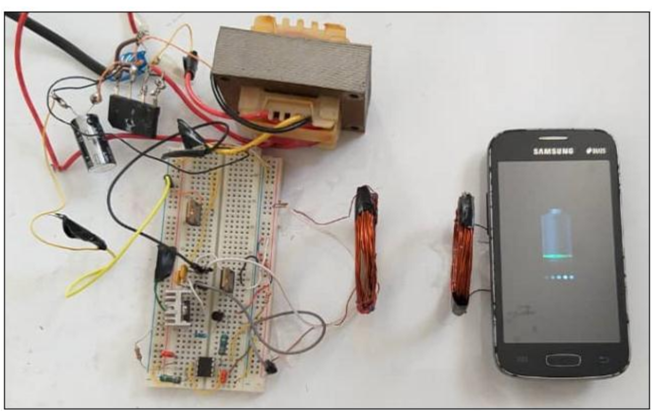


Fig. 9. The practical circuit of WPT in the laboratory

Table I: The output voltages, current, power at different distance between transmitted coil and received coil

Voltage	Current	Power	Distance
4.98v	421mA	2.09w	0
4.9	400mA	1.96w	0.5cm
4.60v	320mA	1.47w	1cm
4.30v	250mA	1.07w	1.5cm
4.10v	220mA	0.90w	2cm
4.02v	160mA	0.64w	2.5cm
4.01v	100mA	0.40w	3cm
3.99v	70mA	0.27w	3.5cm
3.98v	20mA	0.079w	4cm
3.97v	12mA	0.047w	4.5cm
3.96v	1mA	0.0039w	5cm

From Figure 10 we note when the distance between transmitter coil and receiver coil increased the current decreased, this meaning the power lost. The relation between time of charge battery and level of charging illustrated in Figure 11, we got full charging at 140 minutes

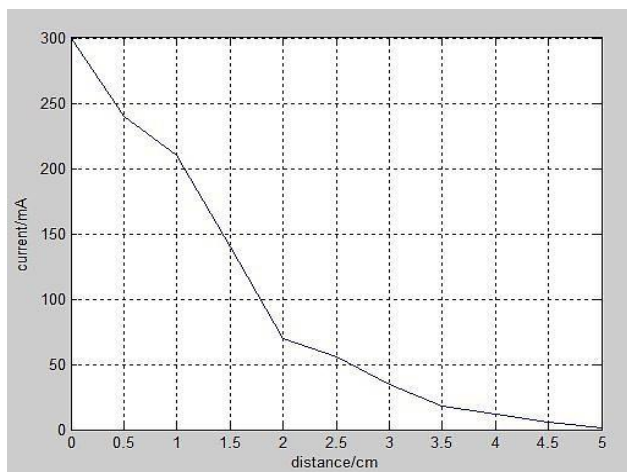


Fig. 10. output current vs. the distance between transmitter and receiver coils

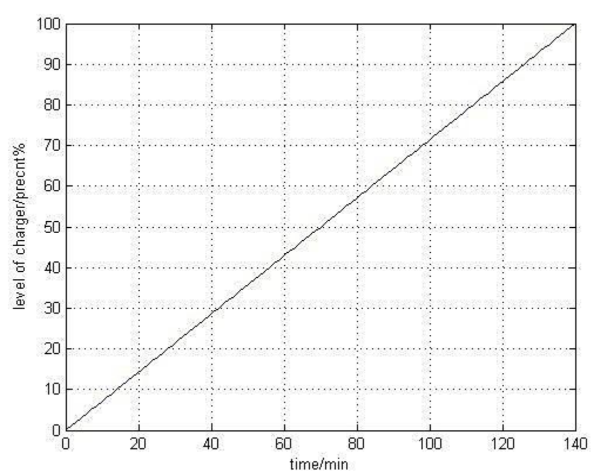


Fig. 11. The relation between time of charge the battery and level of charging

The prototype of near field technique WPT which is designed in the laboratory as shown in figure 12.

Fig. 12. Prototype of near field WPT

VI. CONCLUSION

Based on this study, we can say that the resonant inductive coupling WPT is the most promising technique for powering devices wirelessly with high efficiency over up to few cm. Being safe for humans and environment, resonant inductive coupling WPT can spread to be the standard charging method for most portable devices in the next few years. So, we recommend researchers to focus on this technology. Even though, microwave power transfer is trying to find its way to replace high power transmission lines. Due to health concerns, many researches should be done to find a safe solution that could enable using microwaves for long-distance high power transmission. To summaries, the mains voltage is converted in to an AC signal (alternating current) with high frequency which is then sent to the transmitter coil via the electronic transmitter circuit. The ac current flowing through the transmitter coil induces magnetic field which can extends to receiver coil .The magnetic field then generates a current which flows in coil of the receiving device which is converted into direct current (dc) which can then be used to power the load.

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