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DESIGN AND SIMULATION OF REMOTE POWER TRANSFER FOR CHARGING RECHARGEABLE MOBILE PHONES

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Abstract

The goal of this paper is to design and simulate an efficient wireless charging system for rechargeable battery. The method adopted in the implementation of this project is called resonance transformer coupling. This phenomenon works on the principle of resonance. One coil was made to be supplying power at 20KHz frequency which generates magnetic field at a particular frequency. Another coil at a distance which has the same natural frequency is tuned with the frequency of the first coil then electromagnetic waves are transferred and we get electricity. This wireless power transfer system consists of two modules: the transmitter module and the receiver module. The transmitter module consists of a direct current power supply connected to an oscillator circuit and a tuned transmitting coil circuit, which generates oscillating magnetic field for power transfer. The receiver module comprises of a tuned receiving coil circuit, the bridge voltage rectifier, light-emitting diodes (LEDs), and voltage regulator. The designed coil structure has two magnetic dipole coils, a primary one (transmitting coil) to induce a magnetic field and a secondary (receiving coil) to receive electric power. The high frequency alternating current of the primary winding (transmitting coil) generates a magnetic field, and then the linkage magnetic flux induces the voltage at the secondary winding (receiving coil). The oscillator oscillates at a resonant frequency of 20 KHz in a short distance range to charge a battery with the use of magnetic field resonance. The simulation result of voltage and distance of coverage are recorded and the graph plotted to show the variation of voltage against distance

Keywords: Design, Simulation, Remote, Power Transfer, Rechargeable, Mobile Phones

1. Introduction

The transfer of energy from a source to a receiver has traditionally necessitated the use of a physical connection. Indeed, electrical grids and power outlets span nearly the entire globe and deliver power to billions of people worldwide. Recently, there has been much interest into the area of wireless power transfer (WPT), that is, the transmission of power without the need for a physical connection [Settapong Malisuwan, Noppadol Tiamnara, 2017]. Presently the use of electronic devices is increasing exponentially and operation of most of these devices necessitates the use of battery. One of the most common devices is cell phone battery which is extensively used by growing number of people across the globe. Battery is the heart of any cell phone which requires frequent recharging. Ordinary battery chargers include rectifier, filter and Universal Serial Bus (USB) cable of fixed length, which indirectly reduces the mobility of the mobile during charging. Wireless charging has many benefits. Firstly, it improves user-friendliness as the inconvenience from connecting cables is removed [Takehiro lmura, Yoichi Hori,(2009)]. Secondly, it provides better product durability (e.g., waterproof and dustproof) for contact-free devices [Ricketts, D. S., M. J. Chabalko and A. Hillenius, (2013)]. Thirdly, it enhances flexibility, especially for any devices that requires replacing of batteries. Fourthly, wireless charging can provide on-demand power, avoiding an overcharging problem and minimizing energy costs

[Kusaka, S. Miyawaki, J. Itoh, (2010)].Wireless charging may one day replace plugs and wires, similar to how Bluetooth and Wi-Fi have modernized personal communication. The concept rests on inductive coupling using an electromagnetic field that transfers energy from the transmitter to the receiver. Wireless transfer of power is not new. In 1831, Michael Faraday discovered induction by sending electromagnetic force through space [Awai I., Komori T, 2010]. In the late 1800s and the early 1900s, Nicola Tesla demonstrated wireless broadcasting and power transmission [Rosnah Mohd Zin, et al (2017)]. Tesla wanted to prove that electrical power could be transmitted without wires, but lack of funding halted the project [Paing, T *et al.*,(2007)].It was not until the 1920s that public broadcasting began. Europe built massive transmitters that covered many countries. The station at Beromünster in Switzerland could have transmitted radio signals at 600kW, but legislation on electro-smog and protests from the local population limited the power to 180kW. Smaller FM stations have since replaced these large national transmitters; cellular repeaters and Wi-Fi stations transmit at a fraction of this power and many are in single watt digits [Chen .R *et al (2009)*]. This project will improve the concept of wireless charger networking which will in turn facilitate data communication and information transfer functions among the communications systems. With this wireless charger, the cost of user-charger is eliminated.

2. Techniques for Wireless Charging System

There are three major techniques for wireless charging. They are *Inductive Coupling Approach*, *Electromagnetic Radiation Approach* and *Magnetic Resonant Coupling Approach*. Inductive coupling-based Wireless Power Transfer makes use of magnetic field induction. It is a typical near-field transmission technique. The state-of-the-art technologies can support transmission distance in mm or cm (Xiaolin Mou, 2015). Electromagnetic radiation approach requires a microwave source, a waveguide, a transmitting antenna, and a receiving antenna. The energy is transmitted from the microwave source to the waveguide and then to the receiver. It is capital intensive. A typical magnetic resonant coupling system consists of two electromagnetic subsystems with the same natural resonance frequency, enabling efficient power transfer (Jonah and Georgakopoulos, 2013). When the transmitter coil is excited by the source, the transmitter and the receiver coils are magnetically coupled.

3. Methodology

The wireless power transfer system consists of two modules or units: the transmitter unit and the receiver unit. The transmitter unit, which consists of a direct current (DC) power supply connected to an oscillator circuit and a tuned transmitting coil circuit, which generates oscillating magnetic field for power transfer. The receiver unit comprises the tuned receiving coil circuit, the bridge voltage rectifier, light-emitting diodes (LEDs), and voltage regulator. Figure 1, shows the block diagram representing the wireless power transfer system.

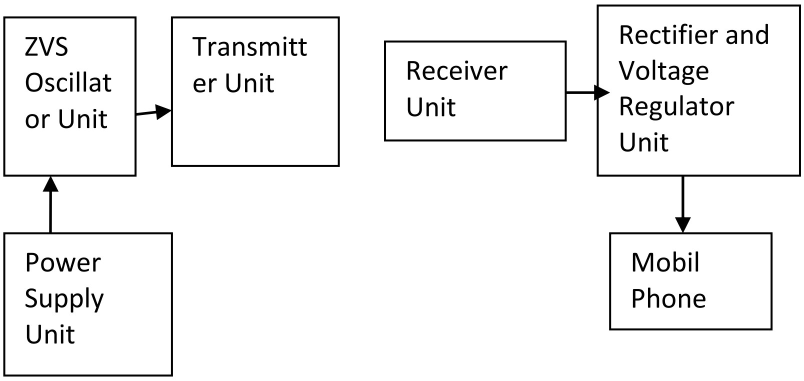

Figure 1: Proposed Wireless Power Transmission System Block Diagram

3.1. The Transmitter Unit:

This section was designed in such a way that the transmitter unit consists of a direct current (DC) power supply connected to an oscillator circuit with tuned transmitting coil circuit, which generates oscillating magnetic field for power transfer. The power supply unit is made up of step down transformer, ac to dc rectifier unit that can supply 2 – 3 amps and up to 24Vdc output voltage. The main reason was to limit the excess current the circuit is capable of drawing. Figure 2 shows the circuit diagram of transmitter unit.

3.2 The Oscillator

The oscillator circuit was designed in accordance with a zero voltage switching (ZVS) circuit developed by Vladimiro Mazzilli. Mazzilli's zero voltage switching is a derivative of the LC MOS oscillator and it is well known for its simplicity. Mazilli ZVS driver is a self-resonant, push-pull, free running oscillator that uses a transformer to generate high voltage [Odeyemi .k, Akande . D, and Ogunti E (2011)]. In this work, the Mazillis driver circuit was used with slight modification of the circuit design to improve efficiency and reliability. The transformer in zero voltage switching circuit was removed and replaced with LC circuit and transmitting coil for efficient performance. This was done in order to achieve Zero power "Lossless" during switching transitions and to achieve high efficiency with high voltage inputs at any frequency.

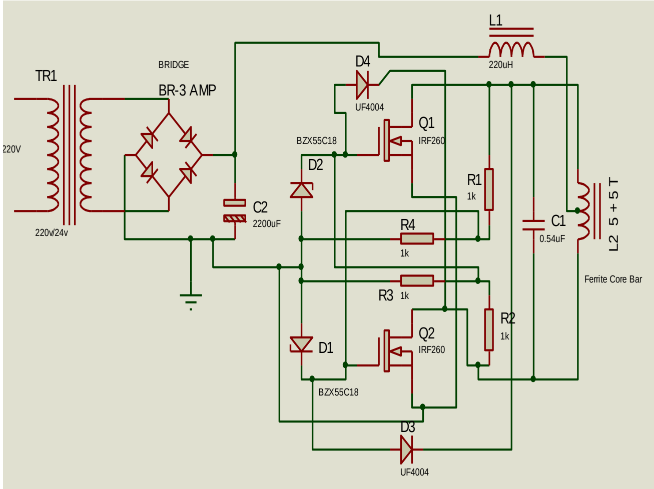

Figure 2: The transmitter circuit

The switching circuit consists of two IRF260 MOSFETs and two 18V Zener diodes (D1 and D2) that regulate the base voltage of the MOSFETs in other not to exceed maximum voltage of 20V. The base resistor 1k-ohms voltage divider and 10k-Ohms pull down resistor are for biasing the MOSFET. R1- R4 voltage divider network reduces the gate voltage and also limits the current to avoid damaging the MOSFET. The MOSFET bias arrangement prevents the use of high Watt resistor as in the case of Mazilli driver and also prevents latch which prevent startup of oscillation. R5 and R6 of 10k are voltage pull down resistors to keep both

MOSFETS in off state before power is applied to the circuit. D3 and D4 ensure that the corresponding MOSFET is in off state; that is its gate voltage is down to ground when the voltage on the opposite leg of the tank circuit is connected to ground. A 220µH inductor that is in series to the transmitting coil limits the current flowing in the circuit. The 0.54uF capacitor across the transmitting coil forms an LC resonance tank circuit. The MOSFETs used need a voltage rating about 4 times higher than the supply voltage and an R(ds)on - resistance below 150 milli-ohms to reduce heating in the system. The circuit was simulated using Proteus software before actual hardware implementation of the circuit.

3. Design of Transmitting and Receiving Coils

The transmitter and receiver circuit combined is called the resonant coupling circuit. It is the heart of the entire system as the actual wireless power transfer is carried out here. The efficiency of the coupling circuit determines the amount of power available for the receiver system. Making the transmitting coil and the receiving coil is experimental. To make the coil for the transmitter, take 14 wire gauge (2.5mm^2); and wind ten (10) turns center tapped (5 + 5) transmitting coil windings at the middle of a ferrite core rod with windings at the center. The windings are suitable for voltages between 12 to 36 vdc; at higher voltages additional windings will be needed. Experimenting with the number of windings will improve performance. Too few windings will result in excessive heating and too many will result in reduced power output. Then, get some masking tape, and wrap it around the coil. This makes sure that the coils stay in place. To make the receiving coil, basically repeat the process above; just leave out the center tapping part and wind five (5) turns on another ferrite core rod for the receiver coil. Figure 3 below shows the schematic of the receiver unit

4.1. The Receiver Unit

The receiving coil is as described above which also forms an LC tuned circuit with the capacitor in parallel and of same value with the one in transmitter unit.

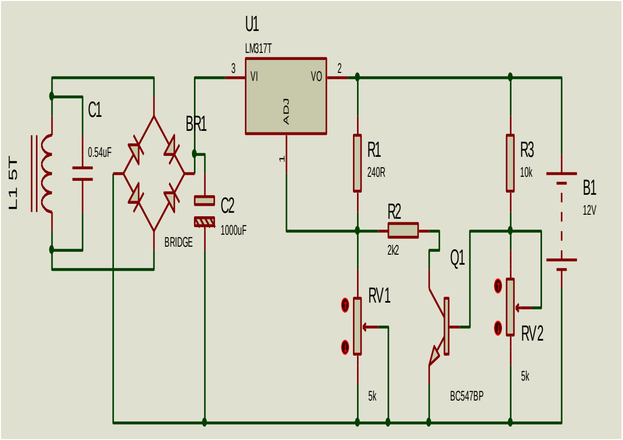

Figure 3: The receiver circuit

4.2 Voltage Rectifier

Rectifier circuit was needed to rectify the AC voltage received from the receiver coil to charge the battery. The bridge rectifier was used as a rectifying diodes connected in a closed loop "bridge" configuration. The smoothing capacitor connected to the bridge circuit converts the full-wave rippled output of the rectifier into a smooth DC output voltage. Since the diode rectifies sinusoidal signals of high frequency, schottky diode of 2-3Amps was used for the bridge rectifier circuit.

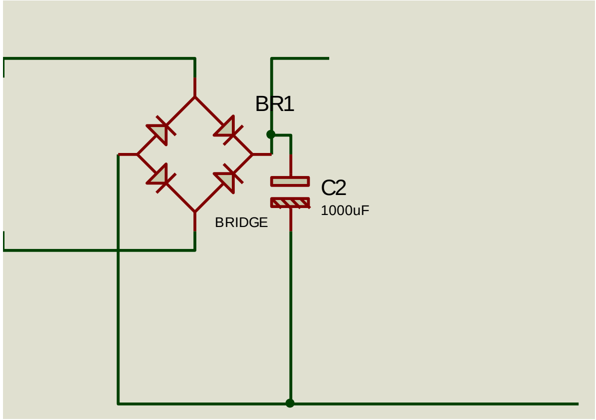

Figure 4: Rectifier Circuit

4.3 The Voltage regulator:

The Voltage regulator was used as battery charging operation. Variable voltage regulator (LM317) was used to set a wide range of voltages. This was done by constructing a resistance divider at the output and varying one resister to obtain the desired DC output. This voltage regulator **take** in a voltage as high as +40V and as low as +3V.

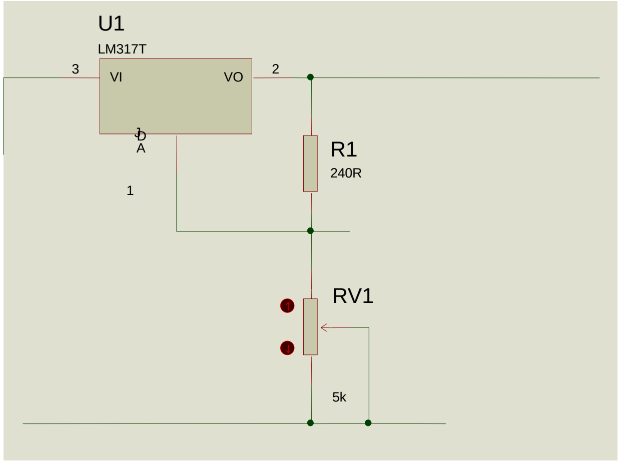

Figure 5: The LM317 Regulator Circuit

The voltage between V_{out} and ADJ was fixed and the value was 1.25V as standard. Control of output voltage was possible by the value of R_2. Output voltage (V_{out}) was calculable by the following equation.

$$V_{out} = 1.25\,(1 + R_2/R_1) + I_{ADJ}(R_2)\text{---}1$$

I_{ADJ} is current which flows from an Adj pin and it was 10µA. Therefore, this was considered negligible value. Vref = 1.25V, R_1 = 240Ω, Iadj = 50-100µA. Lastly, R_2 was either raised to create a larger output voltage or lowered to create a lower output voltage. Since the value of I_{adj} is very low, it is considered insignificant;

Hence, $V_{out} = 1.25(1+R_2/R_1)\text{-------}2$

5. The System Operation

In operation, the oscillator circuit converts the dc output of the power supply into a high frequency alternating current (ac) current while the transmitting coil generates an oscillating magnetic field, then the linkage magnetic flux induces the voltage at receiving coil thus wireless power transfer is achieved. When power is applied to the transmitting circuit, the modified ZVS driver begins by oscillating at the frequency range of 17 – 20 KHz. Current flows through the transmitting coil to both sides of the MOSFET's drains. One of the MOSFETs turns on faster than the other and more current draws to this MOSFET, thus turning off the other MOSFET since they are in ZVS arrangement. Then voltage starts to rise and fall sinusoidally that is when Q1 is on then Q2 will be off and vice versa. When Q1 turns on, the voltage at drain of Q1 will be ground while voltage at source of Q2 rises to a peak and drops back down during the one half cycle of LC tank. As voltage of the source of Q2 drops to zero, the gate current to Q1 is also removed and as a result, Q1 turns off. This causes the drain voltage of Q1 to rise and Q2 turns on. The MOSFETs switch when there is least power induced (ZVS). This same process repeats continually as long as there is power in the circuit. To prevent the oscillator from drawing huge peak currents and causing excess heating and components failure, an inductor, L1 is placed in series with the power supply functioning as a choke to limit current surge.

6. Result and Discussion

The waveform of resonance was observed when the circuit was simulated (figure 6). Due to resonance, the voltage swings in the tank circuit (between the 5 + 5 coil and the 0.54uF capacitor) are much higher than what the input voltage was. Resonance helps with transmission distance, and also, as a result, when the MOSFETS was turn on, we observed what is called Zero Voltage Switching, where MOSFETS turn on and off when the voltage across them is zero. However, due to on-state resistance, they still make a little bit of heat. The reason was that the principle of its power transmission was by magnetism. As the coil oscillates, it sends an alternating magnetic field through the air, which was picked up by the receiving coil (and again, due to resonance, the voltage rises upwards) and thus, power was transmitted through air.

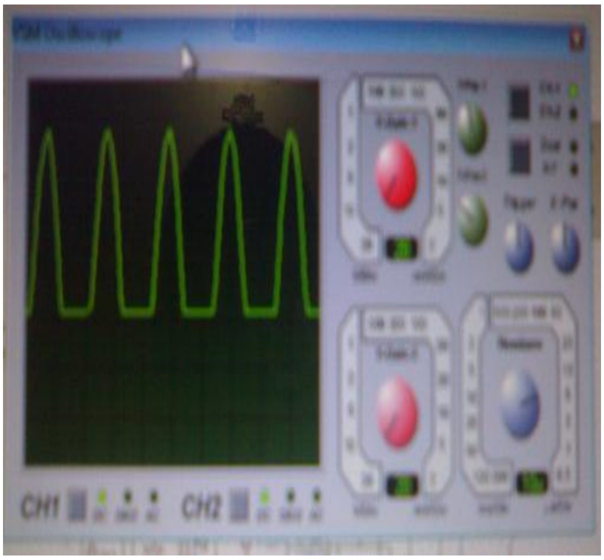

Figure 6: Transmitting Unit Resonance Waveform

During testing, the transmitting range was measured by separating the receiver circuit away from the transmitting circuit at intervals measured with a meter tape and a voltmeter was used for measuring the received resonant voltage. At a distance of 0 cm between the two coils, it was able to transmit maximum power, to charge a 12V/7AH battery. As the coils were separated the charge rate changed. As the distance of separation between the coils increased, the rate of charge reduces further until at a distant point the charger can no longer charge the battery. It was evident that the power transferred was related to the distance of separation between the coils. A measurement starting at a distance of 0 cm between the coils in 10 cm increments up to a distance of 1 m of separation was taken. Based upon the data collected, the following graph shows voltage as against distance between the coils.

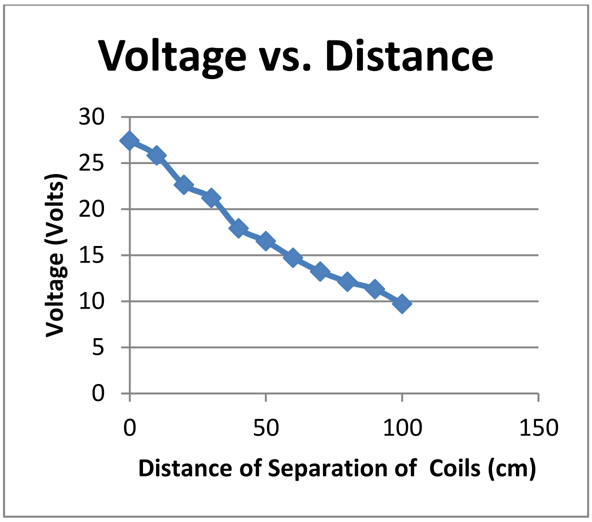

Figure 7: Graph of Voltage against Distance

7. Conclusion

In this work, the development of wireless battery charger was performed. The Voltage of power transfer system was found to be 27.5V when the coils are at zero distance to each other. On increasing the distance between coils, the power transfer efficiency is found to decrease. Thus the variation of distance between the two coils was done until power transfer efficiency is at maximum and that occur at resonance frequency.

Reference

Awai I., Komori T, (2010). "*A Simple and Versatile Design Method of Resonator-Coupled Wireless Power Transfer System*," Communications, Circuits and Systems (ICCCAS), Int. Conf., pp. 616-620.

Rosnah Mohd Zin, et al (2017). *Zero voltage switching driver and flyback transformer for generation of atmospheric pressure plasma jet*; American Institute of Physic, AIP Conference Proceedings.

Settapong Malisuwan, Noppadol Tiamnara (2017). *Design of Antennas for a Rectenna System of Wireless Power Transfer in the LTE/WLAN Frequency Band. Journal of Clean Energy Technologies, Vol. 5, No. 1 Pages 42-46.*

Paing , T *et al.*,(2007). "*Wirelessly-powered wireless sensor platform,*" in *Proc. European Conference on Wireless Technologies*, pp. 241-244.

Takehiro lmura, Yoichi Hori,(2009). "*Wireless power transfer using electromagnetic resonant coupling*", The Journal of the Institute of Electrical Engineers of Japan, Vol. 129, No. 7, pp. 414-417.

Ricketts, D. S., M. J. Chabalko and A. Hillenius,(2013). ''*Experimental demonstration of the equivalence of inductive and strongly coupled magnetic resonance wireless power transfer,*'' Appl Phys Lett, vol. 102, 053904 , doi: 10.1063/1.4788748.

Kusaka, S. Miyawaki, J. Itoh, (2010). "*A Experimental Evaluation of a SiC Schotky Barrier Rectifier with a Magnetic Resonant Coupling for Contactless Power Transmission as a Power Supply*", Annual Conference of IEE of Japan Industry Applications Society (IEEJ JIASC), pp.323-326,(in Japanese).

Chen .R *et al (2009).* "*Design and experiment of a loop rectenna for RFID wireless power transmission and data communication applications, Progress in Electromagnetics Research Proceeding.*

Xiaolin Mou, (2015). *Wireless Powe Transfer;* Published in Proceedings of IEEE VTC Spring Workshop on ICT4SG.

Jonah and Georgakopoulos, (2013). *Wireless power transfer in concrete via strongly coupled magnetic resonance*," IEEE Transactions on Antennas and Propagation, vol. 61, no. 3, pp. 1378–1384.

Odeyemi .k, Akande . D, and Ogunti E (2011): "*Design of an S-band rectangular microstrip patch antenna*," European Journal of Scientific Research, vol. 55, pp. 72-79.