Wireless Power Transfer By High Frequency Resonating Coils And Mosfet

Supritha S B, Sushmitha P C, Ujwala Kini H, Vidya M , Dr.Rajendra R. Patil
Department of Electronics & Communication Engineering
GSSS Institute of Engineering & Technology For Women,
Mysuru

***Abstract*—The transmission of electrical energy from source to load for a distance without any conducting wire or cables is called Wireless Power Transmission. The concept of wireless power transfer was realized by Nikola Telsa. Wireless power transfer can make a remarkable change in the field of the electrical engineering which eliminates the use of conventional copper cables and current carrying wires.**

I. INTRODUCTION

1.1 Overview

We live in a world of technological advancement. New technologies emerge each and every day to make our life simpler. Despite all these, we still rely on the classical and conventional wire system to change our everyday use low power devices such as mobile phones, digital camera etc. and even mid power devices such as laptops. The conventional wire system creates a mess when it comes to charging several devices simultaneously. It also takes up a lot of electric sockets and not to mention the fact that each devices has its own design for the charging port.

Wireless Power Transmission (WPT) is the efficient transmission of electric power from one point to another trough vacuum or an atmosphere without the use of wire or any other substance. This can be used for applications where either an instantaneous amount or a continuous delivery of energy is needed, but where conventional wires are unaffordable, inconvenient, expensive, hazardous, unwanted or impossible.

The idea of wireless power transfer originated from the inconvenience of having too many wires sharing a limited amount of power sockets. We believe that many people have the same experience of lacking enough sockets for their electronic devices. Thus by creating a wireless power transfer system, it would help clean up the clutter of wires around power sockets making the space more tidy and organized. The technology for wireless power transmission or wireless power transfer (WPT) is in the forefront of electronic development. Applications involving microwaves, solar cells, lasers, and resonance of electromagnetic waves have had the most recent success with WPT. The main function of wireless power transfer is to allow electrical devices to be continuously charged and lose the constraint of a power cord. Although the idea is only a theory and not widely implemented yet, extensive research dating back to the 1850's has led to the conclusion that WPT is possible. Wireless Power Transmission, Transfer the three main systems used for WPT are microwaves, resonance, and solar cells.

1.2 Objectives

The main objective of this project is to develop a concept of wireless power transfer for multiple applications and can also charge a rechargeable battery or a cell phone wirelessly suitably modified for the purpose. The study will look into the methods that are currently in use and seek to improve on the areas where the performance is low. The hardware system will involve the design and construction of a transmitter and receiver modules. Below figure 1 shows how WPT place a major role in connecting home appliances.

Figure 1: Home appliances connected via WPT

II. LITERATURE SURVEY

A large part of the energy sent out by the generating plant must arrive at the receiver or receivers to make the system economical. From the referred paper "Wireless Power Transmission Using Resonance Inductive Coupling" published in the year 2014. The most common form of wireless power transmission is carried out using direct induction followed by resonant magnetic induction. Other methods under consideration are electromagnetic radiation in the form of microwaves or lasers and electrical conduction through natural media. Transmitting power as magnetic waves from one place to another in order to reduce the transmission and distribution losses. This concept is known as Resonating Inductive Coupling (RIC).

Electromagnetic field inductance between two coils that are tuned to resonate at the same frequency. From the paper "Wireless Power Transmission System Based on Magnetic Inductive Resonance of Couple Circuit". This type of method has a high quality factor (Q) and consist of air cored to avoid iron losses. For energy harvesting wireless or battery less sensors can be used and possible to store in capacitors. One of the methods of wireless power transmission scheme is microwave power transmission, where for data transmission and acquisition can easily possible by magnetic inductive resonance.

Numerical data are presented for power transfer efficiency of both receivers. From the paper "Design and Construction of wireless power transfer system using magnetic resonant coupling". Electromagnetic induction method has short range. Since magnetic field coupling is a non-radiative power transfer method, it has higher efficiency. However, power transfer range can be increased by applying magnetic coupling with resonance phenomenon. A magnetic field is generated when electric charge moves through space or within an electrical conductor.

The basic principle of WPT is that two self resonators that have the same resonant frequency can transfer energy over mid-range distance. From the paper "An Innovative Design of Wireless Power Transfer by High Frequency Resonant Coupling" published in the year 2015. A number of researches have been conducted on WPT including equivalent model and analysis of WPT system using circuit theory. A magnetically coupled resonance WPT system uses an intermediate self-resonator coil to extend the coverage of wireless power transfer that is coaxially arranged with both transmitter and receiver self-resonant coils. It was also reported that magnetically coupled resonance WPT has several valuable advantages, such as efficient midrange power transfer, non-radiative, and nearly Omni-directional.

WPT is an interesting and challenging field attracting contributions from several areas including material science and nanotechnology, power electronics, applied electromagnetics, and RF and microwave electronics. From the paper "Wireless Power Transmission".

III. METHODOLOGY

AC 230V ,50 Hz mains is stepped down to low voltage ac by conventional 50 Hz iron cored transformer which is then rectified by a bridge rectifier to develop around 14 volt DC. This DC is again made to ac by a PWM inverter using half bridge concept comprising of 2 MOSFETs and 2 capacitors being switched at 40 KHz which is then fed to a resonating high frequency coil acting as primary of an air core transformer. Another matching resonating coil formed as secondary drives a lamp load of 10 watts spaced at an air distance of 20 CMs. The overall efficiency of the power transfer in this case is more than 90% for perfectly coupled and matched series resonators. However, practically resonators with a Q of 1,000 should be able to send power over a distance 9 times the radius of the devices with an efficiency of 10%. The secondary coil develops a voltage of 40 KHz at 12volt while it is kept spaced from the primary coil where air is used as the core. The output of the secondary can also be given to a high frequency bridge rectifier that can deliver DC which could then be regulated to maintain a constant voltage to a DC motor or current to feed to rechargeable battery or a cell phone. However, the overall efficiency of the power transfer shall be less than 50% for all such weakly coupled series resonators. Figure 2 shows the block diagram of WPT.

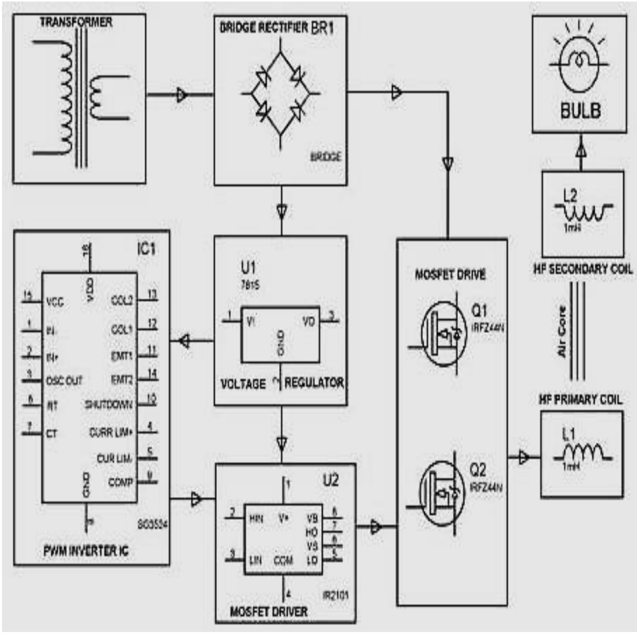

Figure 2: Block diagram of WPT

The main circuit diagram comprises of five functional blocks namely

1. Power Supply Block with Rectifier and Voltage regulator
2. SG3524 Regulating Pulse-Width Modulator
3. High speed MOSFET Driver
4. IRZ44 MOSFET Operation
5. Primary Coil

3.1 Circuit Operation

i. 230 Volts AC is fed to the HF transforming which is a step down transformer converts 230V AC to 18V~24V AC.

ii. 18V~24V AC will form an input to Full wave rectifier which is formed by IN 5408 and the output of 15 V.

iii. 15V is connected to Voltage Regulator 7815 after smoothing through 1000µf capacitor. In this project voltage requirement is 15V so 7815 is used and it has following feature.

- ➢ 7815 voltage regulator IC does not require any component to balance or saturate their output voltage.
- ➢ The 7815 IC has a built-in protection from the high current. There is a heat-sink with the common ground connected with which is helpful in order to prevent our regulator IC from overheating and short-circuits making it uncompromising in the most application.

iv. The output after 1000µf capacitor is taken to MOSFET and the output after 7815 voltage regulator is taken to SG3524 for VCC and V+ of IR2101 as both requires steady and stable regulated voltage source, so 10µf capacitor is used to further smoothing of 15V regulated power supply.

v. 1K resistance along with RED LED D2 is connected across the 7815 voltage regulator for indication of availability of power supply.

vi. 15V regulated power supply will input for SG 3524 which generates +5 V power supply required for internal operation of the IC. It has got three parts

- To generate the pulses of +2.5V/-2.5V as logical output for the pin 11 & 14 alternatively whose frequency decided by C3, R4 and RV across RT and CT of the IC.
- +5 volts generated will be feed to pin No. 1 and 2 i.e. IN- and IN + for which acts as comparator with the reference voltage feed to non-inverting input IN+ with V_{ref} =2.5V
- RT and CT of PIN Number 6&7, basically these pin outs are connected with an external resistor and a capacitor for setting up the frequency of the inbuilt oscillator stage or circuit. CT must be attached with a calculated capacitor while the RT pin with a resistor for optimizing the frequency of the IC the frequency is tuned around 1.8 Hz for tuning adjustable resistor RV is connected along with R4.
- Pin#11 and #14 (EMT1 & EMT2): These are the two outputs of the IC which operate in a totem pole configuration or simply in a flip flop or push pull manner. External devices which are intended for controlling the converter transformers are integrated with these pin outs for implementing the final operations

vii. The Output of 11 and 14 is connected to pin Number 2 & 3(HIN and LIN) of IR2101 MOSFET Driver.15 Volts regulated output from the 7815 is connected to pin Number 1 (V+)

viii. Pin No 1, 4 and 8 (COMM, V+ and Vb) are connected through 2.2µf and D1 diode of IN4007 which will be connected to pin no. Vs also through C4 and C5 which together acts as bootstrap capacitor for the output is connected to output load terminal of MOSFET Q1 and Q4.

ix. When PIN HIN gets high logic from SG 3524 voltage from V+ is fed to HO Which through R1 resistor is feed to gate of Q1 which will be more than the threshold voltage of 8V and is more positive then the drain of the MOSFET Q1 and LO output is low as LIN is Low logic makes gate of Q2 less than the threshold voltage 8V so MOSFET Q2 will not conducts and current will flow through MOSFET Q1 and Primary coil, capacitor C6 and C8 to drain.

x. When PIN LIN gets high logic from SG 3524 voltage from V+ is fed to LO Which through R10 resistor is feed to gate of Q2 which will be more than the threshold voltage of 8V and is more positive then the drain of the MOSFET Q2 and HO output is low as HIN is Low logic makes gate of Q1 less than the threshold voltage 8V so MOSFET Q1 will not conducts6 and current will flow through capacitor C7, C6, primary coil MOSFET Q2 to drain.

xi. The current will flow through the primary coil which in turn generates EMF and induced in to secondary as the number of turns and resonance frequency of both primary and secondary are same. Sufficient magnetic flus will be there for the gap of around 7cm.

xii. Two secondary coil are designed with the same dimension to demonstrate multipurpose application of the project.

xiii. One secondary is to conned to florescent bulb and second is conned to AC to converter PCB which will be used for charging mobile, power supply speaker and DC fan …

3.2. Calculation

In this project 45Gauge Copper wire is used and made the coil of 11cm radius Diameter of the coil (D) = 22cm Radius of the coil (r) = 11cm Radius of the cross-section (a) = 0 .004572cm Number of Turns (N) = 15 turns 120 Strands Permeability of free space: μ_0=1.2566*10^{-7} P = Resistivity of Copper = 1.796x10^{-8}

Theoretical Calculation:

1. Inductance of the Winding:

Inductance of a circular coil = N2μ_0 r (ln (8r/a) – 1.75)

= 15*15 x 4π x10^{-7} x 11 x (ln ((8x11)/0.00457) -1.75)

= 7.87 mH

2. Resistance of the Winding: Resistance of the Winding (R) = ρl/A Length of the coil (l) = Circumference of coil x N= 2π x 11x15= 1036.2cm A = 2πr(r+h), where, h= width of the winding (0.5cm) = 794.42cm P = Resistivity of Copper = 1.796x10-8 R = 2.3426x10-8 Ω 3. Resistance of Leakage path:

R = ρl/A

P = Resistivity of Air = 106, l = length of air gap = 6.5 cm (Distance to be transmitted) A = Area of air gap (Area between two coils) R = 2.62 MΩ

4. Resonant Frequency:

f = 1/2π sqrt of LC

L = 9.742 mH

C = 0.1nF (Capacitor Used)

f = 1.8 MHz Resonance Condition: For Resonance to occur, XL = XC XL = Inductive reactance (Reactance of Coil) XC = Capacitive Reactance XL = 2π x f x L = 88.86K Ω XC = 1/2π x f x C = 88789 Ω = 88.79 KΩ

Thus, XL = XC and so Resonance occurs resulting in transfer of power wirelessly.

IV. APPLICATIONS

- Industrial Applications: The primary applications include wireless sensors on rotating shafts, wireless equipment charging and powering, and safe and watertight equipment through eliminating charging cords
- Subsea applications: though subsea vehicles can self-navigate, human assistance is still required for power supply. Due to the rough terrain, as well as the distance, cabled conductors can prove to be a challenge. WPT comes in handy in these instances.
- Charging mobile devices, unmanned aircraft, home appliances and electric vehicles: The charging system

the smaller gadgets comes in the form of a charging pad and power benches, where the user places the device such as a mobile phone and electric toothbrushes.

- Charging and operating medical implants such as subcutaneous drug supplies, pacemakers, and other implants. WPT, especially with high resonance allows convenient continual charging of these implants without the need for frequent surgeries and the inclusion of external charging ports.

V. ADVANTAGES

- More Reliable/Less Costly
  - Never run out of battery power in wireless zones
  - Power transfers more efficiently than through wires
- More Convenient
  - No more changing batteries
  - No messy cords
- Environmentally Friendly
  - Reduces the use of disposable batteries
  - Reduces energy loss

VI. RESULTS AND DISCUSSIONS

- Figure 3 indicates the model of primary coil of WPT
- Figure 4 indicates the model of secondary coil of WPT which is connected to bulb. The primary coil transmits the power to secondary coil through air core of distance 12cm which glows the bulb.
- Figure 5 and 6 indicates the model of secondary coil of WPT which is connected to USB port which is used for multiple applications like charging the mobile, air cooler, hand fan etc.

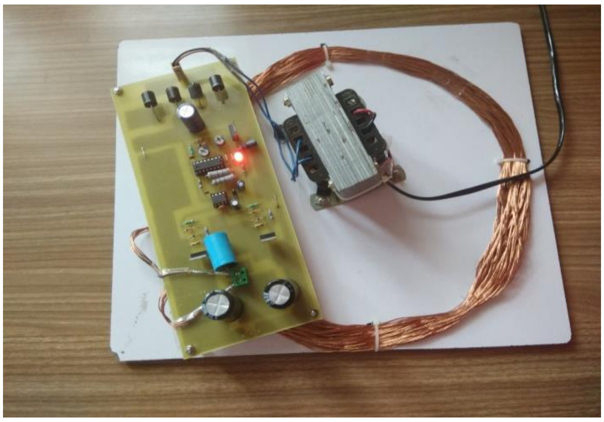

Figure 3: Primary coil of WPT

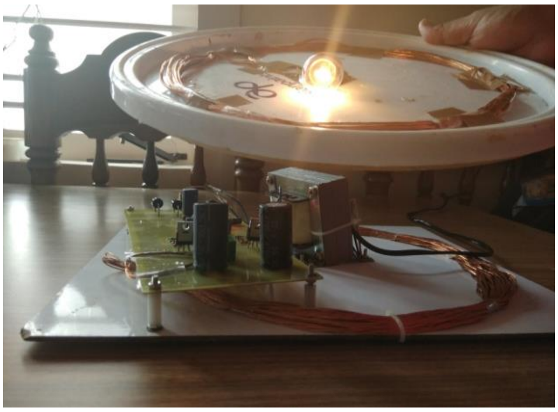

Figure 5: Secondary coil connected to USB port

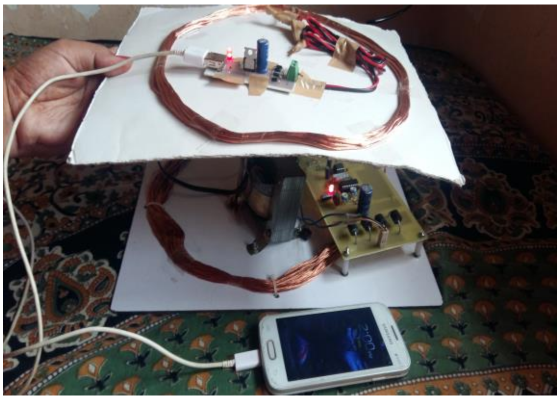

figure 6: Secondary coil connected to mobile via USB port

VII. CONCLUSION

The goal of this project was to design and implement a wireless power transfer and wireless charger for low power devices via resonant inductive coupling. After analyzing the whole system step by step for optimization, a circuit was designed and implemented. Experimental results showed that significant improvements in terms of power-transfer efficiency have been achieved.

It was described and demonstrated that resonant inductive coupling can be used to deliver power wirelessly from a source coil to a load coil and charge a low power device. The Wireless Power Transmission would replace the conventional technology.

REFERENCES

[1] Liguang Xie; Yi Shi; Hou, Y.T.; Lou, A., "Wireless power transfer and applications to sensor networks," Wireless Communications, IEEE, vol.20, no.4, pp.140,145, August 2013.

[2] Pawade, Sourabh, Tushar Nimje, and Dipti Diwase. "goodbye wires: approach to wireless power Transmission." Int. journal of emerging technology and advanced engineering. ISSN: 2250-2459.

[3] Schneider, D., "Wireless power at a distance is still far away [Electrons Unplugged]," Spectrum, IEEE, vol.47, no.5, pp.34,39, May 2010.

[4] Gozalvez, J., "WiTricity-The Wireless Power Transfer [Mobile Radio]," Vehicular Technology Magazine, IEEE, vol.2, no.2, pp.38,44, June 2007.

[5] Teck Chuan Beh; Kato, M.; Imura, T.; Sehoon Oh; Hori, Y., "Automated Impedance Matching System for Robust Wireless Power Transfer via Magnetic Resonance Coupling," Industrial Electronics, IEEE Transactions on, vol.60, no.9, pp.3689,3698, Sept. 2013.

[6] Kurs, Andre; Moffatt, Robert; Soljacic, Marin, "Simultaneous mid-range power transfer to multiple devices," Applied Physics Letters, vol.96, no.4, pp.044102, 044102-3, Jan 2010.

[7] Kurs, Andre, et al. "Wireless power transfer via strongly coupled magnetic resonances." science 317.5834 (2007): 83-86.

[8] Waffenschmidt, E., "Wireless power for mobile devices," Telecommunications Energy Conference (INTELEC), 2011 IEEE 33rd International, vol., no., pp.1,9, 9-13 Oct. 2011.

[9] Tianjia Sun; Xiang Xie; Guolin Li; Yingke Gu; Yangdong Deng; Zhihua Wang, "A Two-Hop Wireless Power Transfer System With an Efficiency-Enhanced Power Receiver for Motion-Free Capsule Endoscopy Inspection,"Biomedical Engineering, IEEE Transactions on, vol.59, no.11, pp.3247,3254, Nov. 2012.

[10] Radiom, S., Baghaei-Nejad, M., Aghdam, K., Vandenbosch, G. A., Zheng, L. R., and Gielen, G. G. (2010). Far-Field On-Chip Antennas Monolithically Integrated in a Wireless-Powered 5.8-GHz Downlink/UWB Uplink RFID Tag in 0.18-Standard CMOS. Solid-State Circuits, IEEE Journal of, 45(9), 1746-1758.

[11] Shouyin, Z. (2000, September). Development of quasi-optical microwave transmission lines in microwave diagnostics systems on Hefei tokamaks. InInfrared and Millimeter Waves, 2000. Conference Digest. 2000 25th International Conference on (pp. 89-90). IEEE.

[12] Feng, G., Wang, Q., Yang, P., Zhang, J., Wang, Z., and Liu, F. (2011, July). Diagnostic technology for temporal-spatial distribution of far-field high power laser beam profile. In Electronics and Optoelectronics (ICEOE), 2011 International Conference on (Vol. 2, pp. V2-30). IEEE.

[13]Ying Fu; Wang, T.; Johan Liu, "Microwave-transmission, heat and temperature properties of electrically conductive adhesive," Components and Packaging Technologies, IEEE Transactions on, vol.26, no.1, pp.193,198, March 2003

[14] Whitehurst, L. N., Lee, M. C., and Pradipta, R. (2013). Solar-Powered Microwave Transmission for Remote Sensing and Communications. IEEE Transactions on Plasma Science, 41(3), 606-612.

[15] Gutierrez-Martinez, C.; Santos-Aguilar, J.; Torres-Fortiz, J.A.; Morales-Diaz, A., "Using photonic filters for tuning dispersion-indused microwave transmission windows on radio over fiber schemes," Microwave and Optoelectronics Conference, 2007. IMOC 2007. SBMO/IEEE MTT-S International, vol., no., pp.450,453, Oct. 29 2007-Nov. 1 2007

[16] Huang, H., and Castillo, E. (2012, May). Wireless interrogation of microwave transmission line for distributed sensing. In Millimeter Waves (GSMM), 2012 5th Global Symposium on (pp. 135-138). IEEE.

[17] Lin, J.C., "Wireless Power Transfer for Mobile Applications, and Health Effects [Telecommunications Health and Safety]," Antennas and Propagation Magazine, IEEE, vol.55, no.2, pp.250,253, April 2013.

[18] Van Wageningen, D.; Staring, T., "The Qi wireless power standard," Power Electronics and Motion Control Conference (EPE/PEMC), 2010 14th

[19] Hui, S.Y., "Planar Wireless Charging Technology for Portable Electronic Products and Qi," Proceedings of the IEEE, vol.101, no.6, pp.1290,1301, June 2013.

[20] Galizzi, M.; Caldara, M.; Re, V.; Vitali, A., "A novel Qi-standard compliant full-bridge wireless power charger for low power devices," Wireless Power Transfer (WPT), 2013 IEEE, vol., no., pp.44,47, 15-16 May 2013

[21] Caldara, M.; Colleoni, C.; Galizzi, M.; Guido, E.; Re, V.; Rosace, G.; Vitali, A., "Low power textile-based wearable sensor platform for pH and temperature monitoring with wireless battery recharge," Sensors, 2012 IEEE, vol., no., pp.1,4, 28-31 Oct. 2012

[22] Tseng, R.; von Novak, B.; Shevde, S.; Grajski, K.A., "Introduction to the alliance for wireless power loosely-coupled wireless power transfer system specification version 1.0," Wireless Power Transfer (WPT), 2013 IEEE, vol., no., pp.79,83, 15-16 May 2013.

[23] Kesler, M. (2013). Highly Resonant Wireless Power Transfer: Safe, Efficient, and over Distance