

See discussions, stats, and author profiles for this publication at: <https://www.researchgate.net/publication/290192630>

Wireless Power Transfer

Thesis · October 2015

DOI: 10.13140/RG.2.1.2501.1288

CITATIONS

0

READS

81,916

1 author:



Gautam Navapara

Dharmsinh Desai University

1 PUBLICATION 0 CITATIONS

SEE PROFILE

Some of the authors of this publication are also working on these related projects:



Improve accuracy of open source OCR engine [View project](#)



Wireless Power Transfer [View project](#)

PROJECT REPORT ON
WIRELESS POWER TRANSFER

By
NAVAPARA GAUTAM B.

Under Supervision of
PROF. KEYUR M. PATEL



Department of Electronics and Communication
Faculty of Technology, Nadiad
October, 2015

DEPARTMENT OF ELECTRONICS AND COMMUNICATION



CERTIFICATE

This is to certify that the term work carried out in the subject of TERM PROJECT and recorded in this report is the bonafide work of Mr. GAUTAM NAVAPARA. Roll No.: (EC-060) of B.Tech semester 5TH in the branch of ELECTRONICS & COMMUNICATION during the academic year 2015-2016.

Staff in Charge

Head of the Department

Date:

Date:23/10/2015

ACKNOWLEDGEMENT

We hereby, completing this project, would like to express our very great appreciation to Prof. K.M.Patel for providing required guidance and his valuable and constructive suggestions during our project work. His willingness to give his time so generously has been very much appreciated.

We would also like to thank our friends for their timely help comment and suggestions. Their suggestions and comments had really given me new direction to think on project.

We also thank Prof. Dr. N.J. Kothari for giving us the opportunity to carry out a thesis of our choice.

Lastly, we would like to extend our gratitude to authors of the papers and information sources without which this project would not have been possible.

The Faculty of technology of Dharmsinh Desai University- Nadiad has provided us with the knowledge and assistance that constructed the foundation required in us to initiate and follow through a project such as this, and for that we are grateful to all the teachers, officers, and staff of the ECE Department.

Finally, we would like to express our gratefulness towards our parents and Almighty for being there with us through thick and thin.

INDEX

Title	Page no.
1. Abstract	01
2. Introduction	02
3. Basic concept of wireless power transfer	03
4. Inductance of Coil and Coil Design	05
5. Block diagram	07
6. Circuit diagram	08
7. Transmitter	10
8. Receiver	12
9. PCB layout	14
10. Output	15
11. Conclusion	16
12. Application and future work	17
13. Advantages and disadvantage	19
14. Biography	20
15. Appendix	21

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 Tesla. Wireless power transfer can make a remarkable change in the field of the electrical engineering which eliminates the use conventional copper cables and current carrying wires.

Day by day new technologies are making our life simpler. Wireless charging through resonance could be one of the next technologies that bring the future nearer. In this project it has been shown that it is possible to charge low power devices wirelessly via inductive coupling. It minimizes the complexity that arises for the use of conventional wire system. In addition, the project also opens up new possibilities of wireless systems in our other daily life uses.

INTRODUCTION

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 charge 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 device has its own design for the charging port. At this point a question might arise. —What if a single device can be used to charge these devices simultaneously without the use of wires and not creating a mess in the process? We gave it a thought and came up with an idea. The solution to all these dilemma lies with inductive coupling, a simple and effective way of transferring power wirelessly.

Wireless Power Transmission (WPT) is the efficient transmission of electric power from one point to another through 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 power can be transmitted using Inductive coupling for short range, Resonant Induction for mid-range and Electromagnetic wave power transfer for high range. WPT is a technology that can transport power to locations, which are otherwise not possible or impractical to reach. Charging low power devices and eventually mid power devices by means of inductive coupling could be the next big thing.

The objective of this project is to design and construct a method to transmit wireless electrical power through space and charge a designated low power device. The system will work by using resonant coils to transmit power from an AC line to a resistive load. Investigation of various geometrical and physical form factors evaluated in order to increase coupling between transmitter and receiver.

A success in doing so would eliminate the use of cables in the charging process thus making it simpler and easier to charge a low power device. It would also ensure the safety of the device since it would eliminate the risk of short circuit.

The objective also includes the prospect of charging multiple low power devices simultaneously using a single source which would use a single power outlet.

Basic concept of wireless power transfer

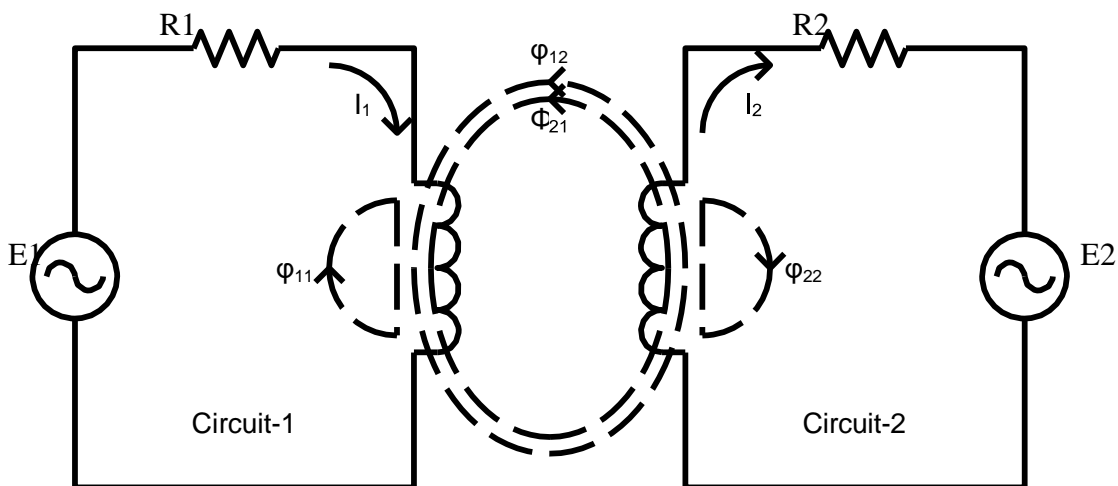
1) Inductive Coupling

Inductive or Magnetic coupling works on the principle of electromagnetism. When a wire is proximity to a magnetic field, it generates a magnetic field in that wire. Transferring energy between wires through magnetic fields is inductive coupling.

If a portion of the magnetic flux established by one circuit interlinks with the second circuit, then two circuits are coupled magnetically and the energy may be transferred from one circuit to the another circuit.

This energy transfer is performed by the transfer of the magnetic field which is common to the both circuits.

In electrical engineering, two conductors are referred to as mutual-inductively coupled or magnetically coupled when they are configured such that change in current flow through one wire induces a voltage across the end of the other wire through electromagnetic induction. The amount of inductive coupling between two conductors is measured by their mutual inductance.



Inductive Coupling with Four Component Fluxes

Power transfer efficiency of inductive coupling can be increased by increasing the number of turns in the coil, the strength of the current, the area of cross-section of the coil and the strength of the radial magnetic field. Magnetic fields decay quickly, making inductive coupling effective at a very short range.

2) **Inductive Charging**

Inductive charging uses the electromagnetic field to transfer energy between two objects. A charging station sends energy through inductive coupling to an electrical device, which stores the energy in the batteries. Because there is a small gap between the two coils, inductive charging is one kind of short-distance wireless energy transfer.

Induction chargers typically use an induction coil to create an alternating electromagnetic field from within a charging base station, and a second induction coil in the portable device takes power from the electromagnetic field and converts it back into electrical current to charge the battery. The two induction coils in proximity combine to form an electrical transformer.

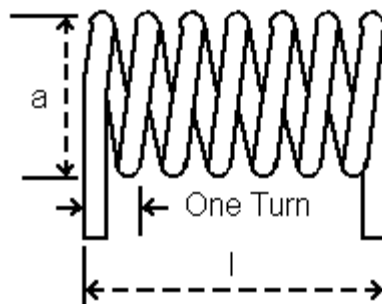
Greater distances can be achieved when the inductive charging system uses resonant inductive coupling.

Inductance of Coil and Coil Design

Introduction

An ideal inductor has inductance, but no resistance or capacitance, and does not dissipate or radiate energy. However, real inductors have resistance (due to the resistance of the wire and losses in core material), and parasitic capacitance (due to the electric field between the turns of wire which are at slightly different potentials). At high frequencies the capacitance begins to affect the inductor's behavior; at some frequency, real inductors behave as resonant circuits, becoming self-resonant. At frequencies above this the capacitive reactance becomes the dominant part of the impedance. Energy is dissipated by the resistance of the wire, and by any losses in the magnetic core due to hysteresis. At high currents, iron core inductors also show gradual departure from ideal behavior due to nonlinearity caused by magnetic saturation. At higher frequencies, resistance and resistive losses in inductors grow due to skin effect in the inductor's winding wires. Core losses also contribute to inductor losses at higher frequencies

Single Layer Coil



Single Layer Coil

A single layer coil, as shown in figure, has two advantages. Firstly, like all air core coils, it is free from iron losses and the non-linearity mentioned above. Secondly, single layer coils have the additional advantage of low self-capacitance and thus high self-resonant frequency.

In the simple case of a single layer solenoidal coil the inductance may be calculated as follows:

$$L = (d^2 n^2) / (l + 0.45d) [\mu\text{H}]$$

Where L is the inductance, d is the coil diameter in meters, l is the coil length in meters and n is the number of turns.

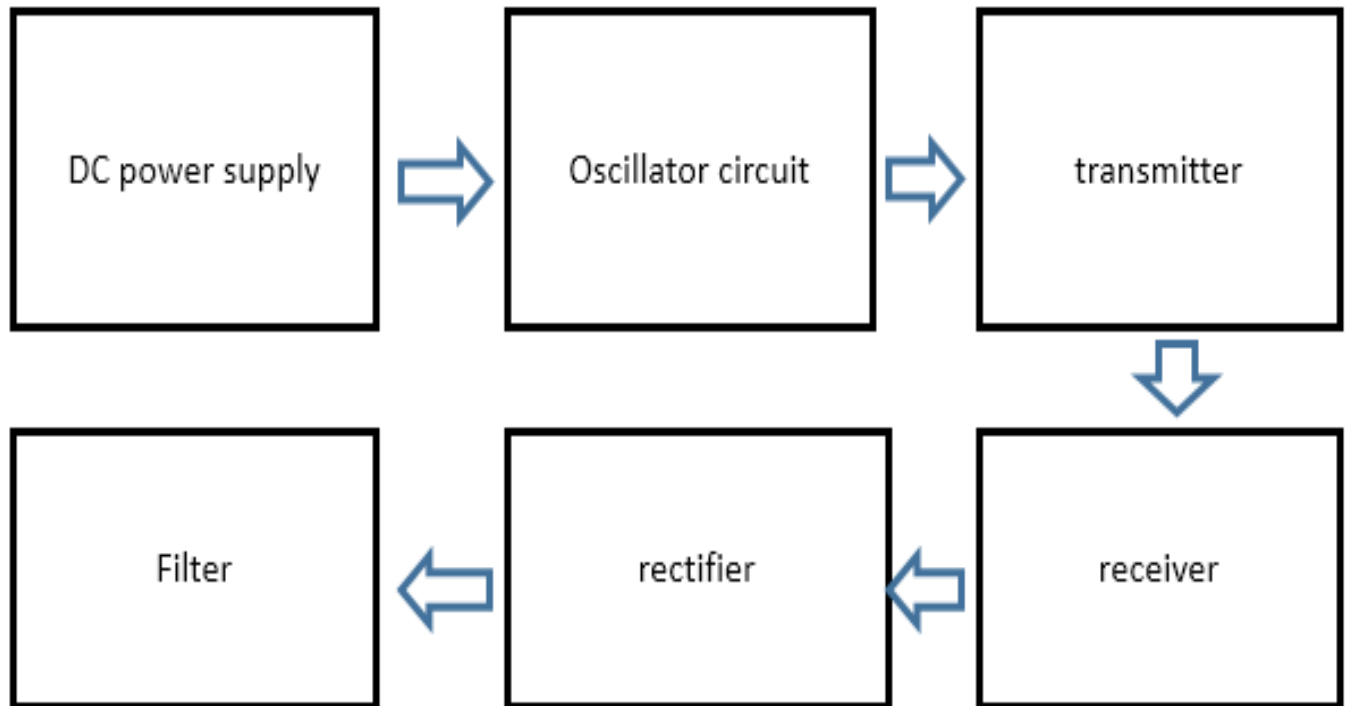
Losses in coil:

At high frequencies, particularly radio frequencies (RF), inductors have higher resistance and other losses. In addition to causing power loss, in resonant circuits this can reduce the Q factor of the circuit, broadening the bandwidth. In RF inductors, which are mostly air core types, specialized construction techniques are used to minimize these losses. The losses are due to these effects:

I. **Skin effect:** The resistance of a wire to high frequency current is higher than its resistance to direct current because of skin effect. Radio frequency alternating current does not penetrate far into the body of a conductor but travels along its surface. Therefore, in a solid wire, most of the cross sectional area of the wire is not used to conduct the current, which is in a narrow annulus on the surface. This effect increases the resistance of the wire in the coil, which may already have a relatively high resistance due to its length and small diameter.

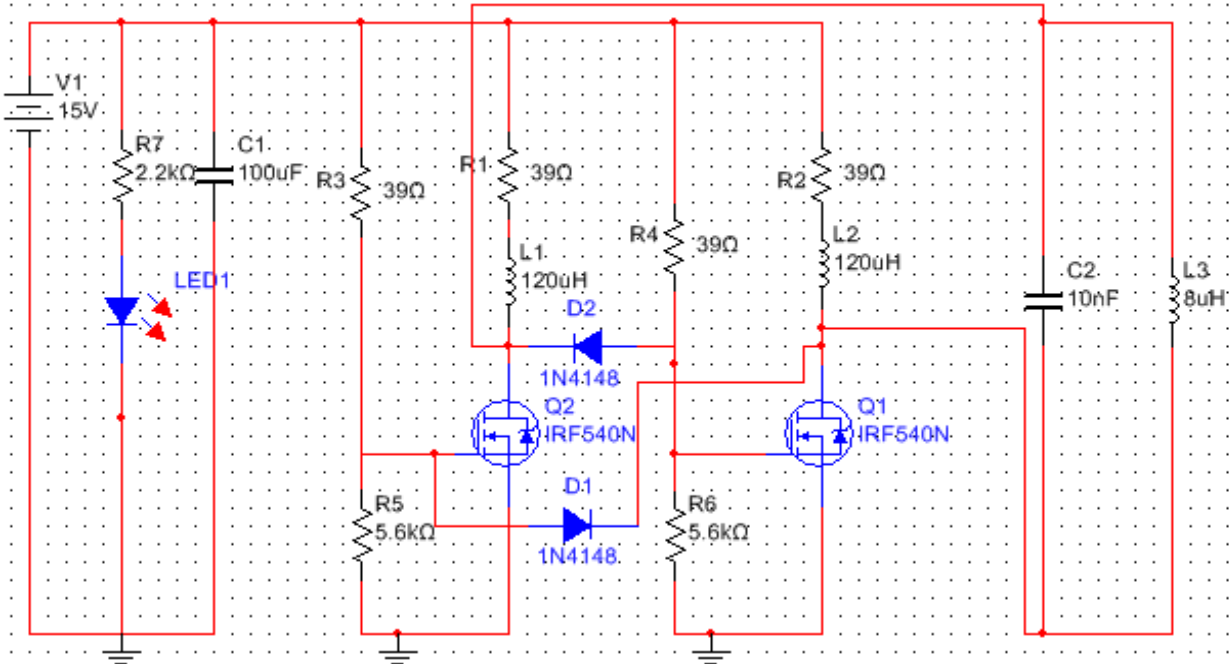
II. **Parasitic capacitance:** The capacitance between individual wire turns of the coil, called parasitic capacitance, does not cause energy losses but can change the behavior of the coil. Each turn of the coil is at a slightly different potential, so the electric field between neighboring turns stores charge on the wire. So the coil acts as if it has a capacitor in parallel with it. At a high enough frequency this capacitance can resonate with the inductance of the coil forming a tuned circuit, causing the coil to become self-resonant.

Block Diagram

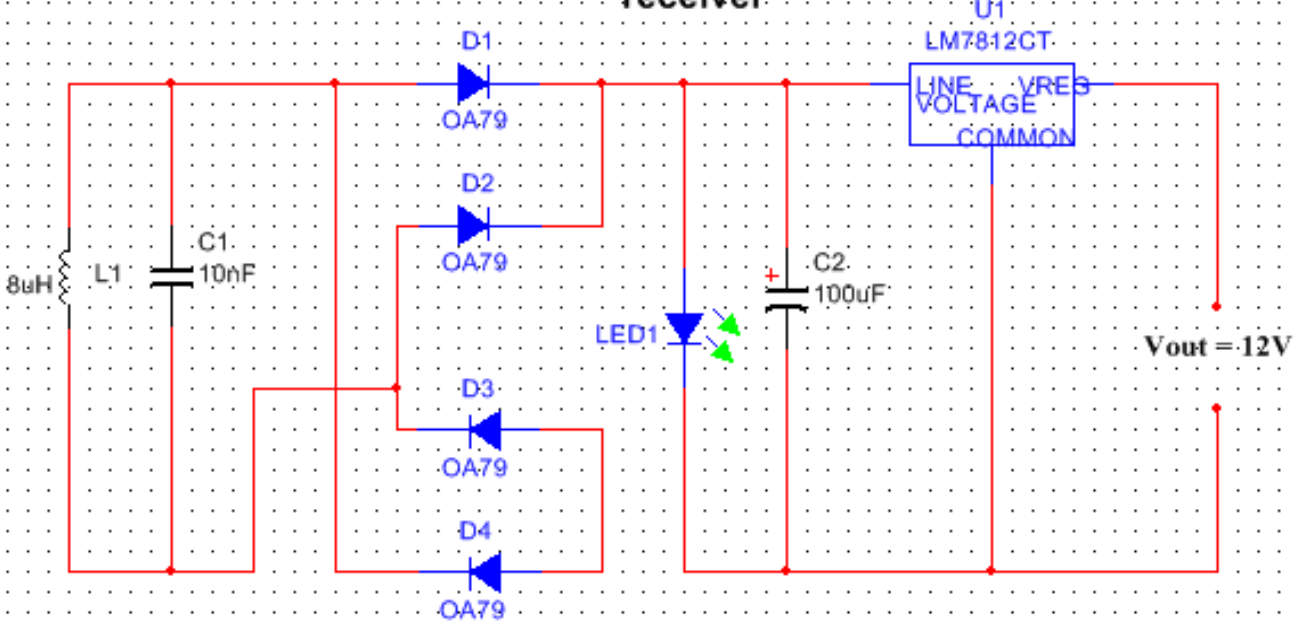


Circuit Diagram

transmitter



receiver



Components used in transmitter:

Component's Name	Component's Value or code
Voltage Source, V_{dc}	15V
Capacitor, C	10nF
Resistor, R_1	39 ohm, 5watt
Resistor, R_2	39 ohm, 5watt
Resistor, R_3	39 ohm, 5watt
Resistor, R_4	39 ohm, 5watt
Resistor, R_5	5.6k ohm
Resistor, R_6	5.6k ohm
Diode, D_1	1N4148
Diode, D_2	1N4148
MOSFET, Q_1	IRF540
MOSFET, Q_2	IRF540
Radio Frequency Choke, L_1	120 μ H
Radio Frequency Choke, L_2	120 μ H
Transmitter coil, L	8 μ H

Components used in receiver:

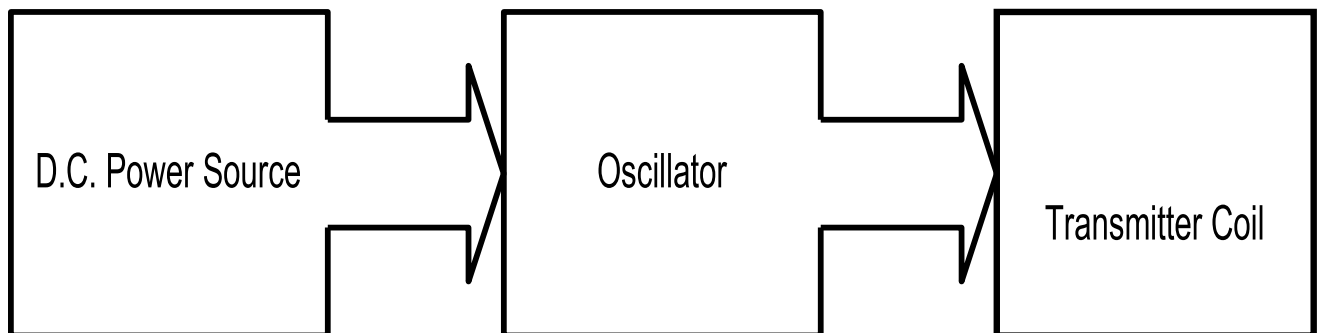
Component's Name	Component's Value or code
Diode, D_1	OA79
Diode, D_2	OA79
Diode, D_3	OA79
Diode, D_4	OA79
Capacitor, C_1	10 Nf
Capacitor, C_2	100 μ F
Voltage Regulator IC	IC LM 7812
Receiver coil, L	8 μ H

Transmitter

Working of transmitter circuit:

The transmitter module of our project is made up of a D.C. power source, an oscillator circuit (commonly known as an inverter) and a transmitter coil.

The D.C. power source provides a constant D.C. voltage to the input of the oscillator circuit. There, this D.C. power is converted to a high frequency A.C. power and is supplied to the transmitter coil. The transmitter coil, energized by the high frequency A.C. current, produces an alternating magnetic field.



DC supply:

The D.C. Power Source consists of a simple step down transformer and a rectifier circuit. The transformer steps down the voltage to a desired level and the rectifier circuit convert the A.C. voltage to D.C.

Oscillator circuit:

The prototype oscillator Circuit designed for the project is a modified Royer oscillator. This oscillator circuit is incredibly simple yet a very powerful design. Very high oscillating current can be achieved with this circuit depending on the semiconductor used. Here high current is necessary to increase the strength of the magnetic field.

Working of oscillator circuit:

The circuit consists of with two chokes labeled L_1 and L_2 , two semiconductors (Here N-channel Enhancement power-MOSFETS) labeled Q_1 and Q_2 , a resonating capacitor labeled C_2 and an inductor (here the transmitter coil) labeled L_3 . Cross-coupled feedback is provided via the diodes D_1 and D_2 . R_1 , R_3 and R_2 , R_4 are the biasing network for MOSFETS.

When power is applied, DC current flows through the two sides of the coil and to the transistors' drain. At the same time the voltage appears on both gates and starts to turn the transistors on. One transistor is invariably a little faster than the other and will turn on more. The current would continue to increase until the coil (transformer) saturates. The resonating capacitor C causes the voltage across the primary to first rise and then fall in a standard sine wave pattern.

Assuming that Q_1 turned on first, the voltage at the drain of Q_1 's will be clamped to near ground while the voltage at Q_2 's drain rises to a peak and then falls as the tank formed by the capacitor and the coil primary oscillator through one half cycle. After that, D_1 will be forward bias by more voltage than D_2 and hence it will turn on Q_2 and cycle repeats.

The oscillator runs at the frequency determined by the inductance of the coil, the capacitor value and to a lesser extent, the load applied to the secondary (Source coil).

The operating frequency is the familiar formula for resonance,

$$F = 1/2 \times \pi \times \sqrt{LC}$$

Transmitter coil:

For this project the transmitter coil was constructed with 92 mm diameter, 17 swg copper wire and 7 turns.

From the equation of inductance of a single layer air core coil, we get inductance $L = 8.1 \mu\text{H}$.

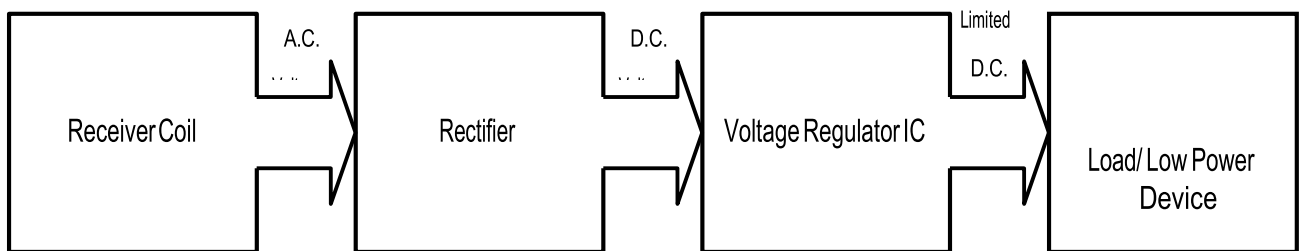
Receiver

Working of Receiver:

The receiver module of our project is made up of a receiver coil, a rectifier circuit and a voltage regulator IC. And additional buck converter to get more current by decreasing output voltage to 5 volt.

An A.C. voltage is induced in the receiver coil. The rectifier circuit converts it to D.C. and the voltage regulator IC helps to maintain a constant limited voltage at the load.

The following block diagram gives a general idea of the receiver module:



Block Diagram of the Receiver Module

Receiver coil:

Receiver coil for our project is designed same as transmitter coil with same value.

Rectifier:

A diode bridge is an arrangement of four (or more) diodes in a bridge circuit configuration that provides the same polarity of output for either polarity of input. When used in its most common application, for conversion of an alternating current (AC) input into direct current a (DC) output, it is known as a bridge rectifier. The essential feature of a diode bridge is that the polarity of the output is the same regardless of the polarity at the input.

Operation of bridge rectifier:

During the Positive half cycle of the input AC waveform diodes D1 and D3 are forward biased and D2 and D4 are reverse biased. When the voltage, more than the threshold level of the diodes D1 and D3, starts conducting – the load current starts flowing through it.

During the negative half cycle of the input AC waveform, the diodes D2 and D4 are forward biased, and D1 and D3 are reverse biased. Load current starts flowing through the D2 and D4 diodes.

Further we can use capacitor filter to remove ripples present in output of bridge rectifier. After capacitor filter, smooth DC voltage is present at the input of voltage regulator.

Voltage regulator IC:

A voltage regulator is an electrical regulator designed to automatically maintain a constant voltage level. It may use an electromechanical mechanism, or electronic components. Depending on the design, it may be used to regulate one or more AC or DC voltages.

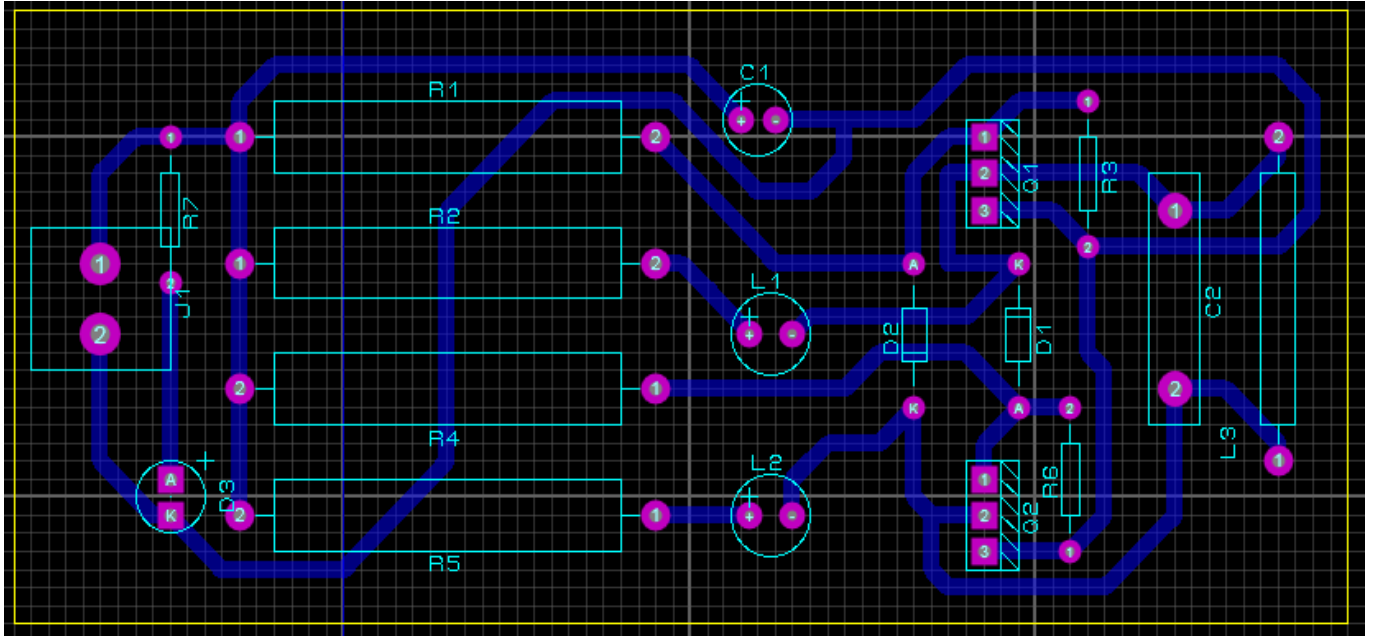
In this project, LM 7812 voltage regulator IC is used since it allowed no more than 12v to the output.

Buck converter:

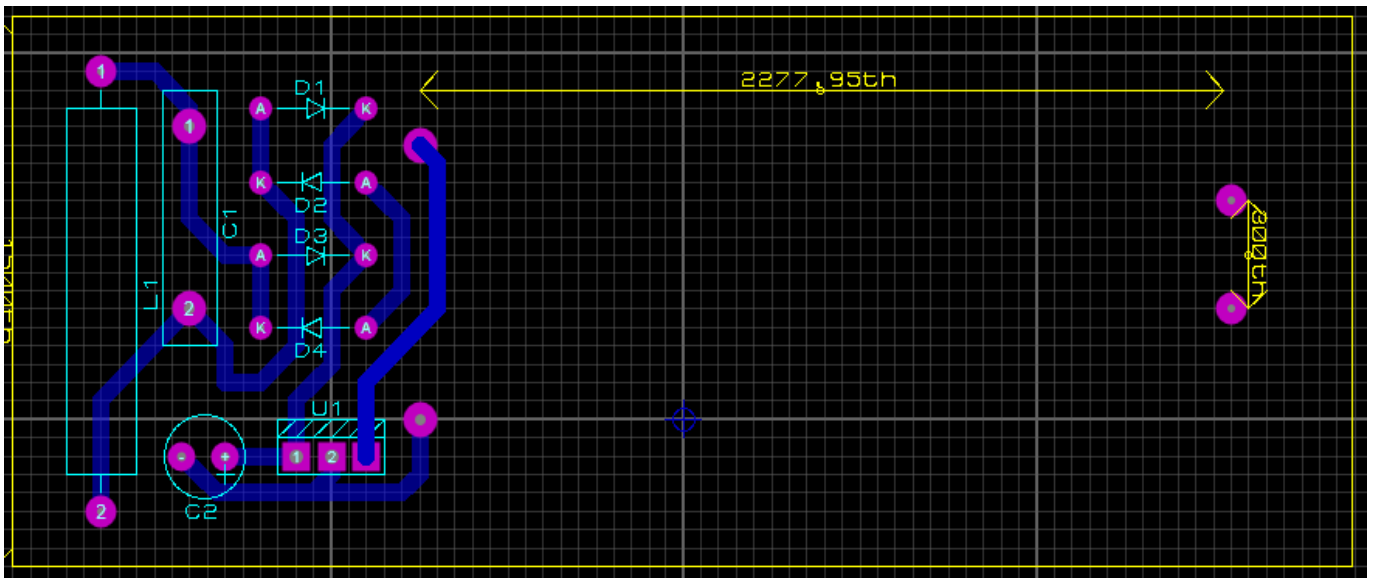
It is totally optional part in receiver circuit. It is used here to increase current at output. Buck converter is DC to DC converter which step down the voltage and according to it, it increase output current. Efficiency of converter is high (near about 98%) and hence very small amount of power loss in this module.

PCB Layout

Transmitter:

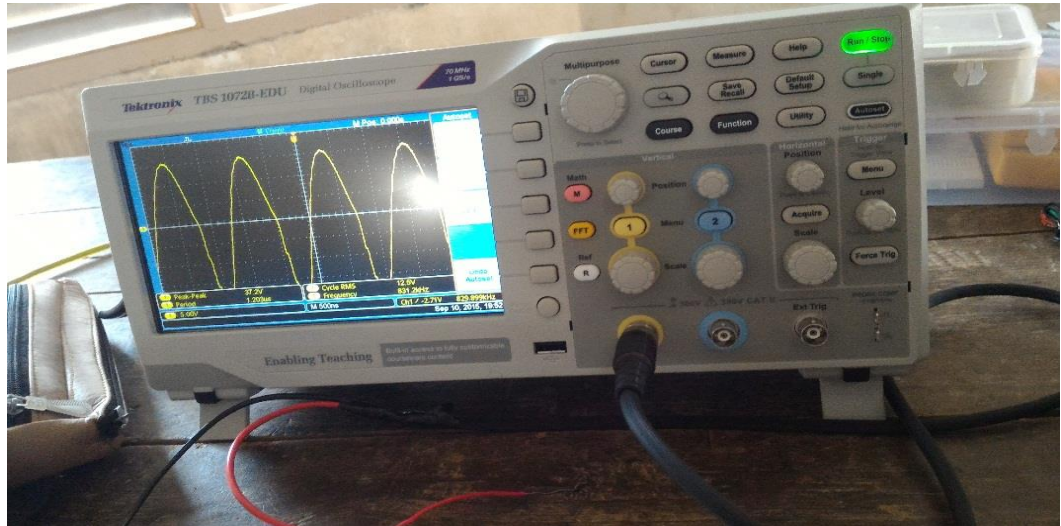


Receiver:

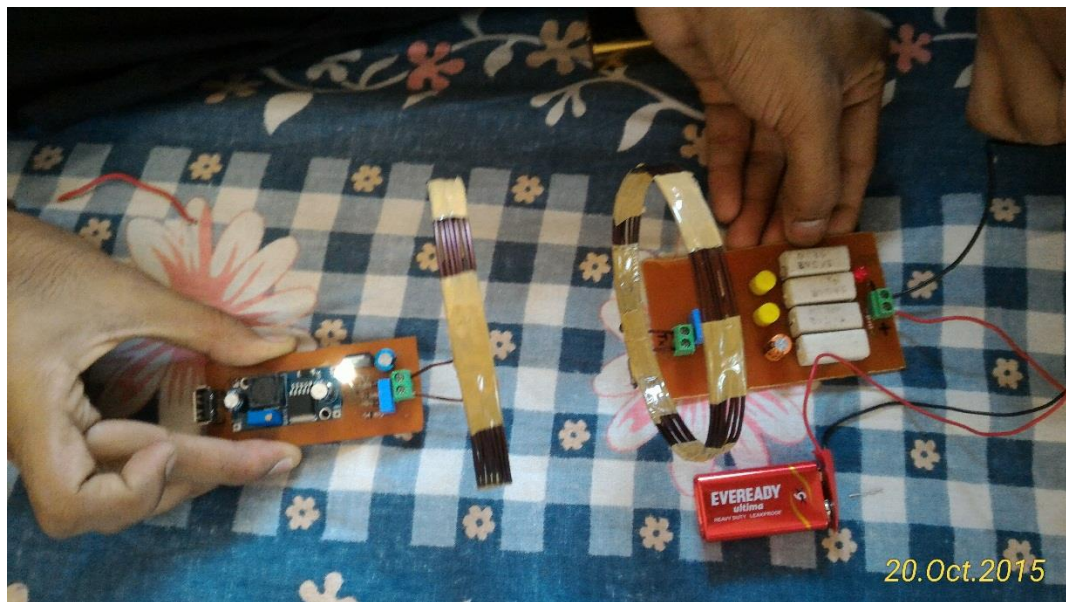


Output

Transmitted signal:-



Receiver output:



Conclusion

The goal of this project was to design and implement a wireless charger for low power devices via resonant inductive coupling. After analysing 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.

As it was mentioned earlier, wireless charging could be the next big thing.

Possible Applications and future work

Applications:

- 1) Smart Phones, Portable Media Players, Digital Cameras and Tablets.
- 2) Public Access Charging Terminal.
- 3) Computer Systems
- 4) Miscellaneous: Wireless chargers are finding its way into anything with a battery inside it. This includes game and TV remotes, cordless power tools, cordless vacuum cleaners, soap dispensers, hearing aids and even cardiac pacemakers. Wireless chargers are also capable of charging super capacitors (super caps), or any device that is traditionally powered by a low-voltage power cable.

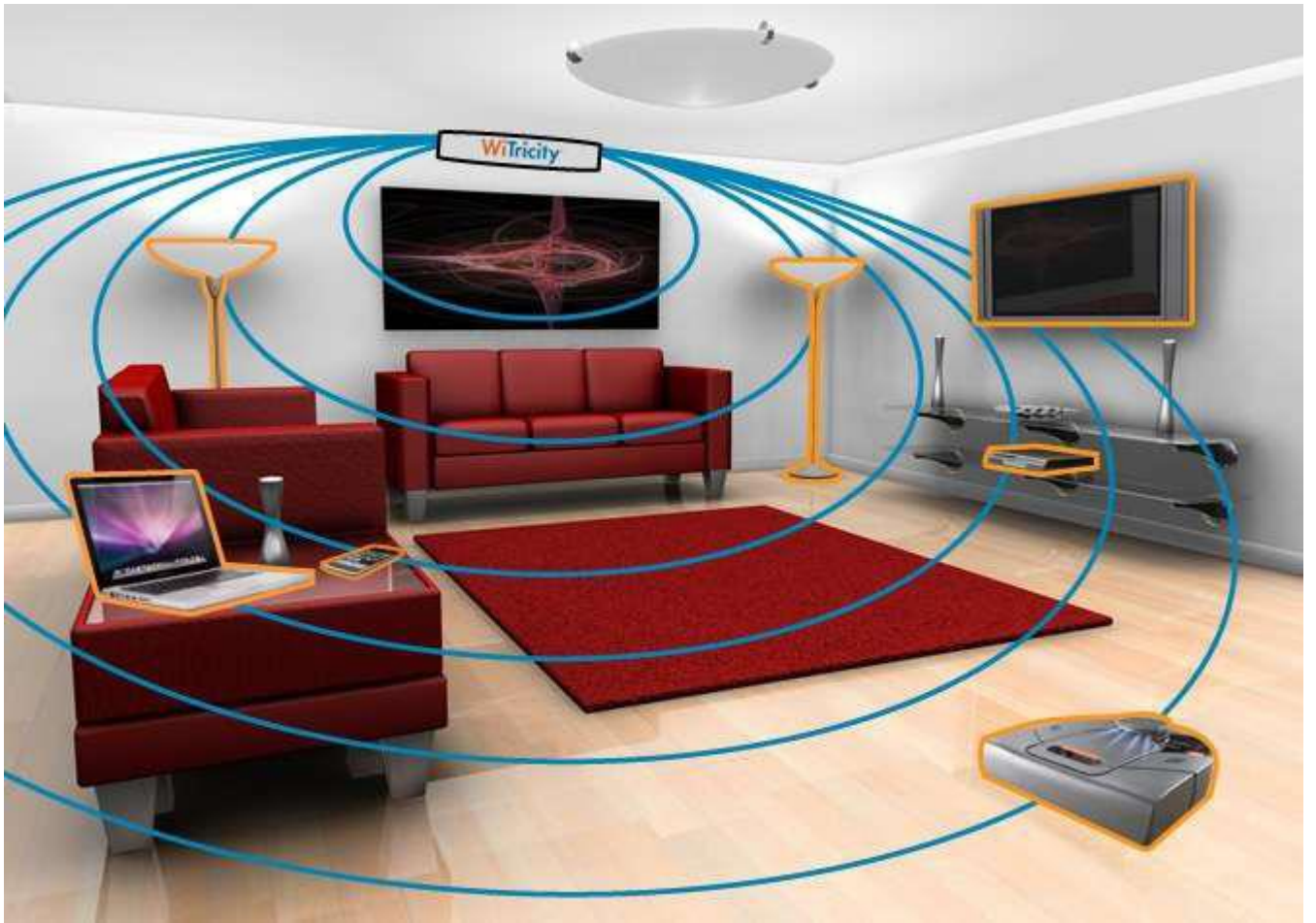
Future work:

To transmit the power to a greater distance, a high power radio frequency amplifier connected with an oscillator is needed. But the construction of the bulky RF power amplifier requires much time and patience.

High power vacuum tube transistor amplifier with high current will make the system more efficient.

A crystal oscillator circuit might be a better option for the transmitter circuit since it can produce a very high frequency A.C. current.

Further effort on this same project can yield some real solutions that can solve the problems of this project. The knowledge of this project will help those who want to design a wireless charging system.



Advantages and disadvantage

Wireless power transfer will be next biggest move in this integrated technologies world because it has numerous advantages and applications.

Advantages:

we don't have need to stick with wires while using any electric device like mobile, laptop, camera etc. complete removal of wires is possible by WPT so system becomes very user friendly and complexity can be reduced. At public places like Malls and stations, complexity of power system can be reduced by WPT.

Disadvantages:

Major disadvantage of wireless power transfer is high power loss for longer distance. So we can transfer power wirelessly from one point to another very efficiently if distance is too small but loss rapidly increases with distance.

Biography

- 1) Jacob Millman and Christos C. Halkias, -Integrated Electronics: Analog and Digital Circuits and Systems
- 2) Muhammad H. Rashid, -Power Electronics: Circuits, Devices, and Applications
- 3) Robert L. Boylestad and Louis Nashelsky, Electronic Devices and Circuit Theory
- 4) William H.Hayt,Jr. and John A.Buck, Engineering Electromagnetics
- 5) https://en.wikipedia.org/wiki/Wireless_power
- 6) <http://www.engineersgarage.com/articles/wireless-power-transmission>

Appendix

- 1) Datasheet of MOSFET IRF540.
- 2) Datasheet of OA79.
- 3) Datasheet of LM7812.