Benha University
Faculty Of Engineering (Shoubra)
Communications And Computer Engineering

WIRELESS POWER TRANSFER

Prepared by:

231903633	جورج اميل صادق ساويرس
231903549	كنزي وليد سرور حسانين
231903614	لجين أحمد يوسف محمد
231903753	زياد عبدالحكيم عبدالمقصود عبد الرازق

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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 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 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

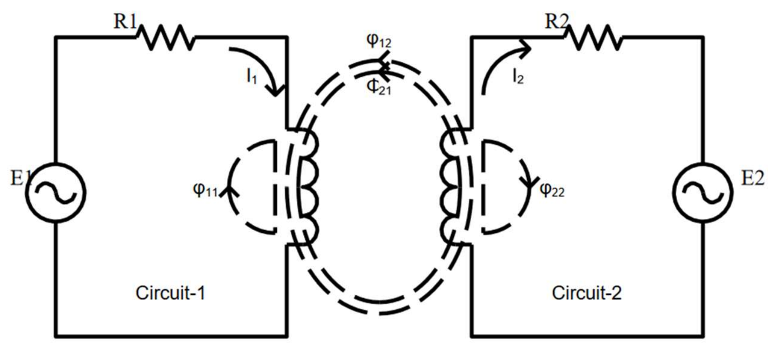
1) Inductive Coupling

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.

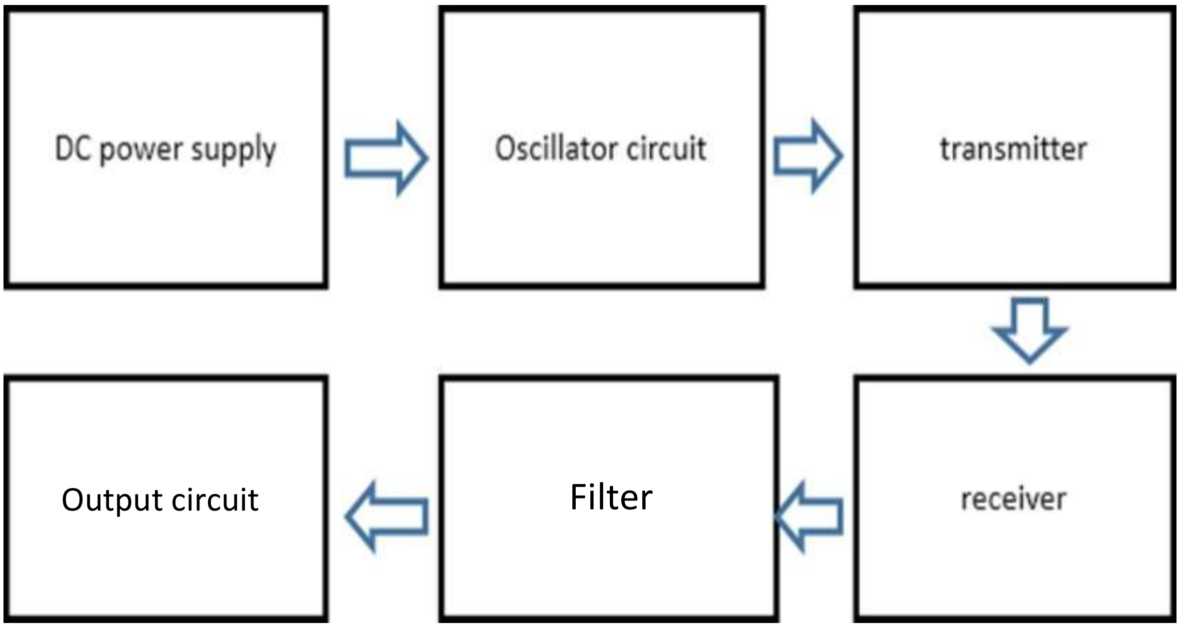
2) Inductive Charging

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.

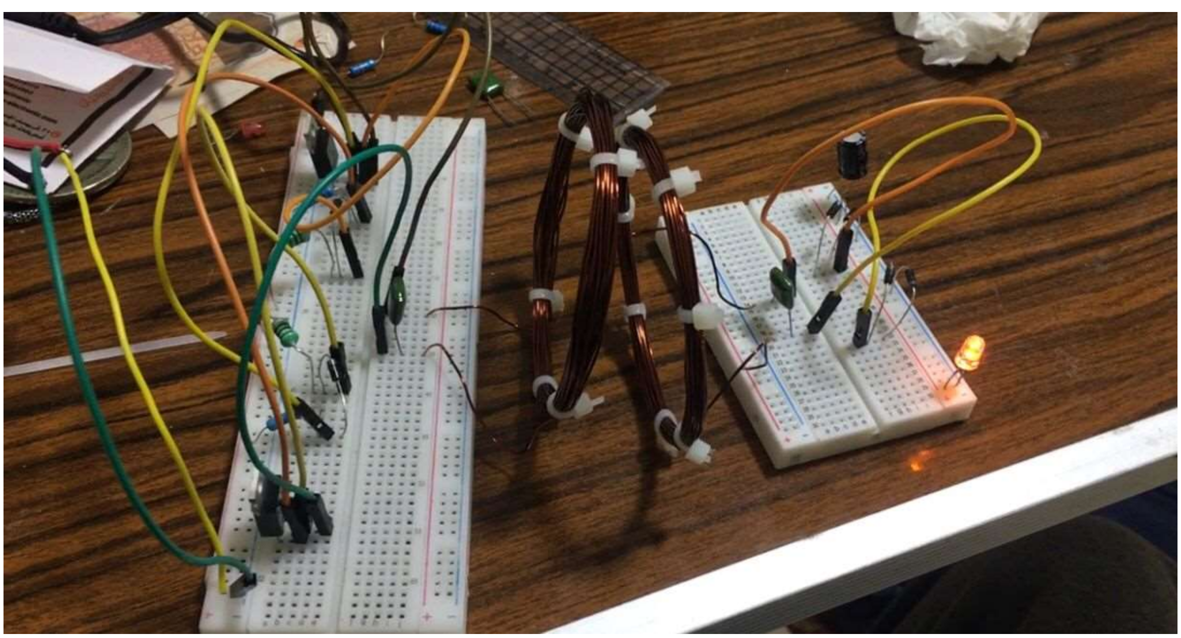
Greater distances can be achieved when the inductive charging system uses resonant inductive coupling.

Block diagram:



Schematic capture and test board trial:

- **Test board**



➢ **Schematic capture:**

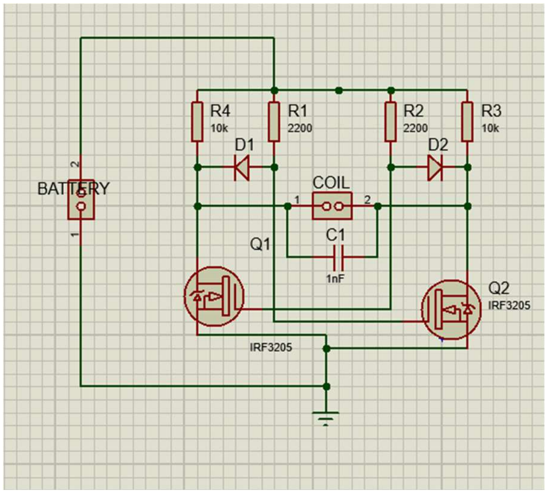


Figure 1: Transmitter circuit

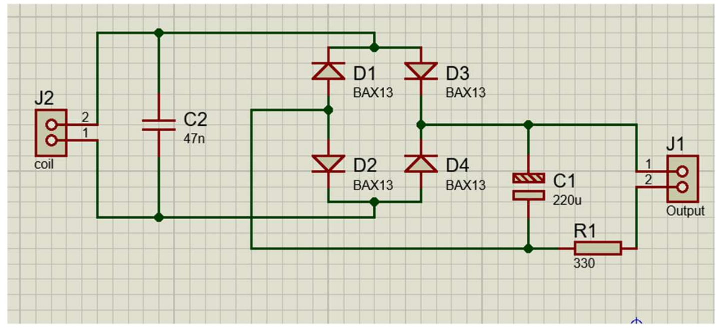


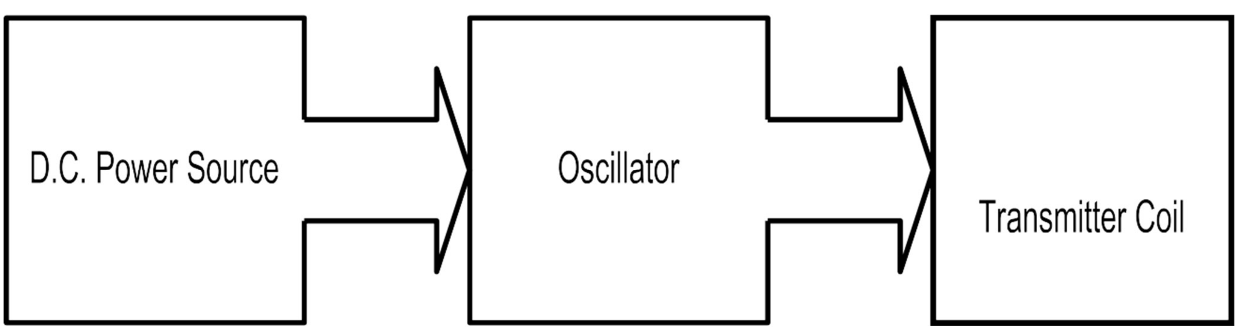
Figure 2: Receiver circuit

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 L1 and L2, two semiconductors (Here N-channel Enhancement power-MOSFETS) labeled Q1 and Q2, a resonating capacitor labeled C1 and an inductor (here the transmitter coil) . Cross-coupled feedback is provided via the diodes D1 and D2. R1 and R2 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 Q1 turned on first, the voltage at the drain of Q1's will be clamped to near ground while the voltage at Q2'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, D1 will be forward bias by more voltage than D2 and hence it will turn on Q2 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 60 mm diameter, 25 swg copper wire and 25 turns. From the equation of inductance of a single layer air core coil, we get inductance $L = (d^2 * n^2) / (18d + 40l)$

$L = (6^2 * 25^2) / (18 * 6 + 40 * 1.5)$

$L = (36 * 625) / (108 + 60)$

$L = 22500 / 168$

$L \approx 133.93\ \mu H$

1. **The components of the transmitter circuit:**

- 2-IRF3205
- 2-100uH inductors
- 2-2.2k ohm/0.5watt resistors
- 2- 1N4007 diodes
- 1-47nF capacitor
- 1-transmetting coil (**6 cm diameter, 25 turns, copper wire with 0.3 mm diameter**

2. Components roles:

1. IRF3205 MOSFETs: act as the heart of the wireless power transfer circuit, converting the DC input from the power source into the oscillating magnetic field that transmits power wirelessly. Their efficient operation and proper control are essential for achieving high power transfer efficiency and reliable operation.
2. 100uH inductors: These inductors store energy in the magnetic field that is used to transfer power to the receiver coil.
3. 2.2k ohm resistors: These resistors are used to limit the current that flows through the MOSFETs.
4. 1N4007 diodes: These diodes are used to protect the circuit from reverse voltage spikes.
5. 1-47nF capacitor: This capacitor is connected in parallel with the coil to form a resonant circuit. The resonant circuit helps to maximize the efficiency of the power transfer.
6. Coil: This coil is used to generate the oscillating magnetic field that transfers power to the receiver coil.

Receiver

1. The components of the receiver circuit:

- Receiving coil (6 cm diameter, 25 turns, copper wire with 0.3 mm diameter)
- 47nF capacitor
- Bridge of 4 1N4007 diodes
- 220uF /25volt polarized capacitor
- Resistor and LED

2. Components roles:

1. Receiving coil: This coil has the same parameters as the transmitter coil and is used to receive the oscillating magnetic field and convert it into electrical energy. The coil is designed to have a high inductance and a low resistance. This helps to maximize the efficiency of the power transfer.

2. 47nF capacitor: This capacitor is connected in parallel with the receiving coil to form a resonant circuit. The resonant circuit helps to maximize the efficiency of the power transfer.
3. Bridge of 4 1N4007 diodes: This Bridge rectifies the alternating current (AC) from the receiving coil and converts it into direct current (DC). The diodes are arranged in a bridge configuration to provide full-wave rectification. This means that the bridge outputs a positive DC voltage regardless of the polarity of the AC input voltage.
4. 220uf /25volt polarized capacitor: This capacitor helps in smoothing out the rectified DC signal, reducing any ripple or fluctuations.
5. Resistor and LED for detection: The resistor and LED are likely used for detecting the presence of a received power signal. The resistor limits the current flowing through the LED, and when power is received, the LED lights up as an indication

➢ **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.

➢ **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:**

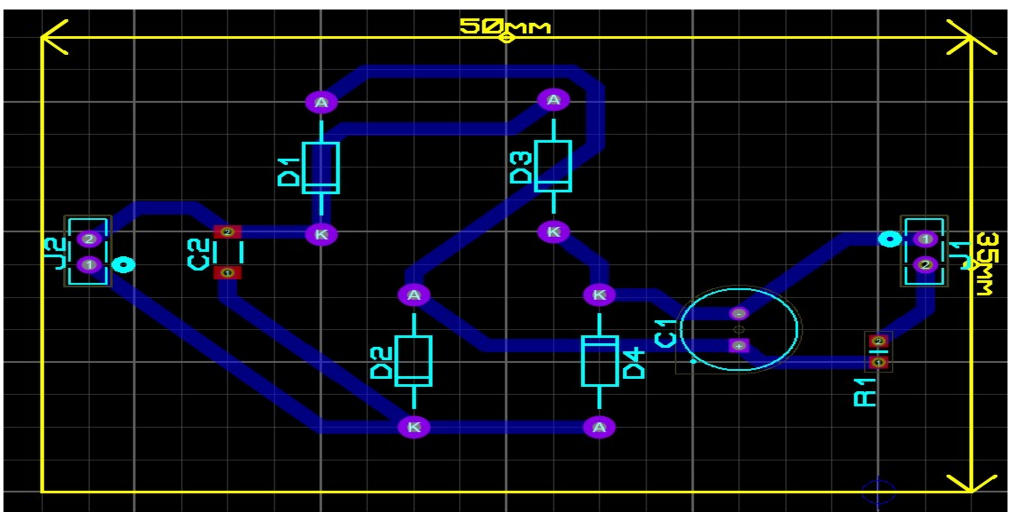
During the Positive half cycle of the input AC waveform diodes D1 and D3 are forward biased and D2 and D4 are reverse biased. When the voltage, more than the threshold level of the diodes D1 and D3, starts conducting – the load current starts flowing through it.

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.

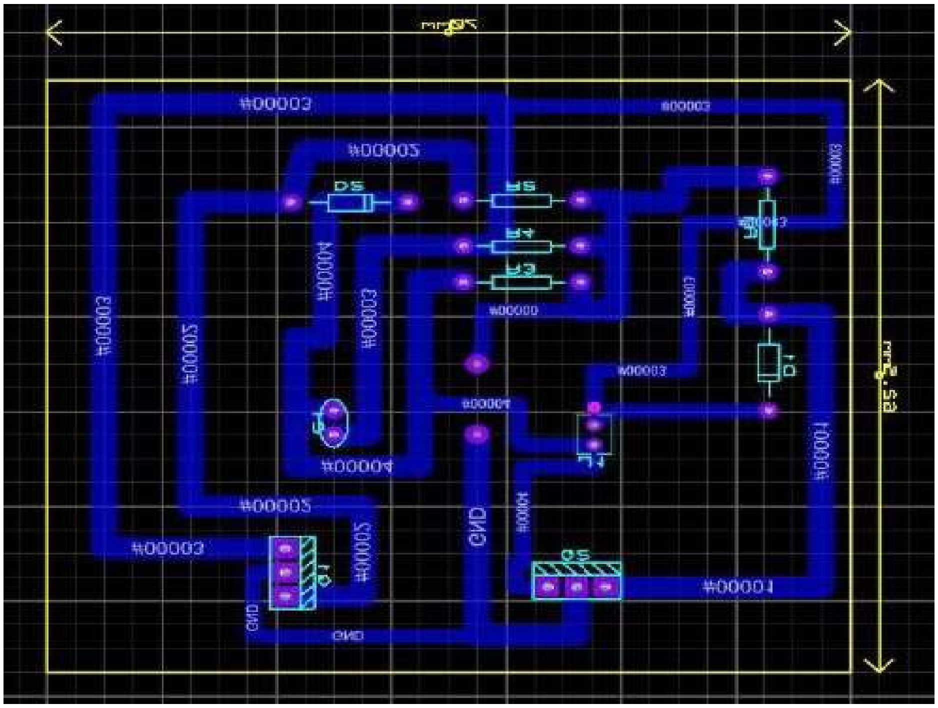
Further we can use capacitor filter to remove ripples present in output of bridge rectifier. After capacitor filter.

PCB LAYOUT

- **Receiver:**



➢ **Transmitter:**



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.

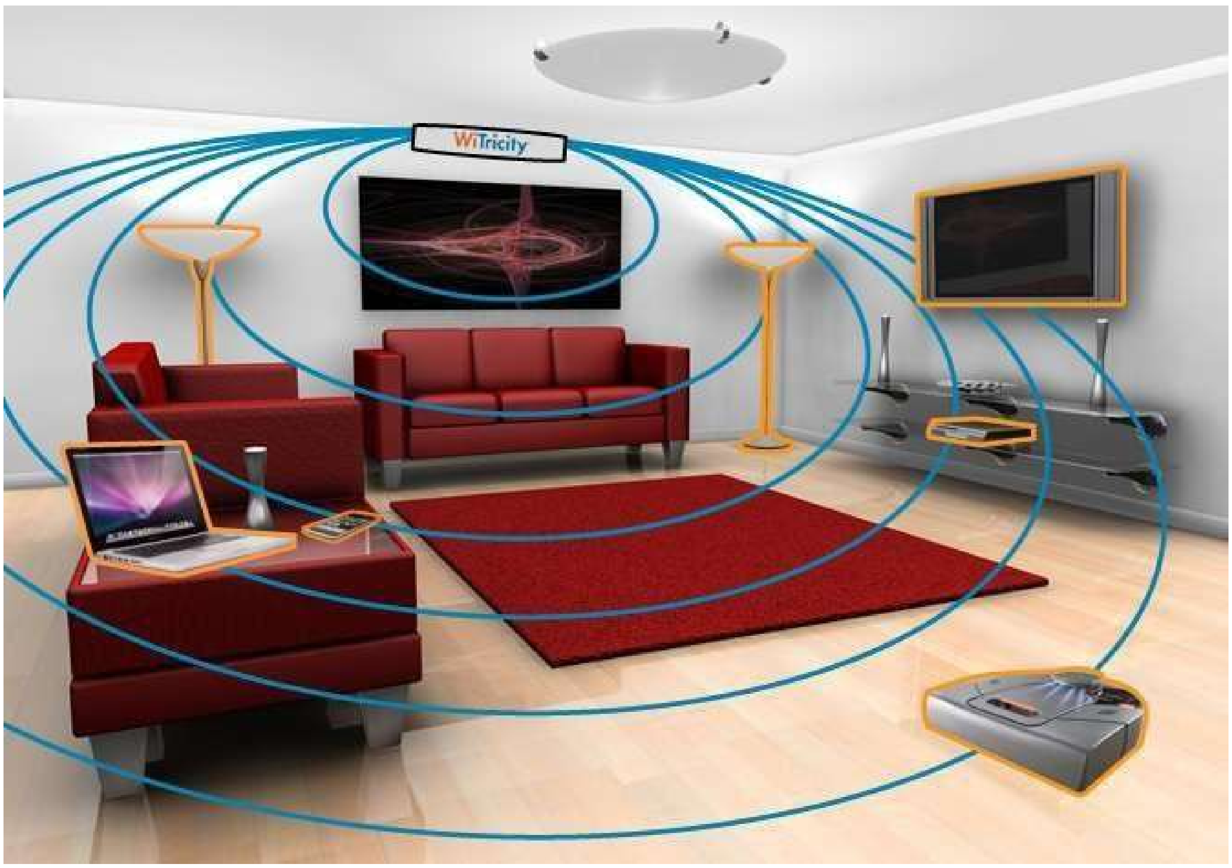
➢ **Future work:**

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.

CONCLUSION

The goal of this project was to design and implement a wireless power transfer 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.

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