DESIGN AND PERFORMANCE ANALYSIS OF WIRELESS POWER TRANSFER

This thesis report is submitted in partial fulfillment of the requirements for the Degree of Bachelor of Science in Electrical and Electronic Engineering

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DECLERATION

We hereby declare that the thesis titled “DESIGN AND PERFORMANCE ANALYSIS OF WIRELESS POWER TRANSFER”, a thesis submitted to the Department of Electrical and Electronic Engineering of BRAC University in partial fulfillment of the requirements for the degree of Bachelor of Science in Electrical and Electronic Engineering is our own work. The work has not been presented elsewhere for assessment. Where material has been used from other sources it has been properly acknowledged / referred. The presentation of the work was held on…

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Dedicated

To

Our Parents and Teachers

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LIST OF ABBREVIATIONS

DC	Direct Current
AC	Alternating Current.
LED	Light Emitting Diode
ADC	Analog-to-Digital Converter
WPT	Wireless Power Transfer
DWPT	Dynamic Wireless Power Transfer
EMF	Electromagnetic Force
MMF	Magnetomotive Force
IC	Integrated Circuit
MMC	Multi Mini Capacitor
PCB	Printed Circuit Board
NST	Neon Sign Transformer
AWG	American Wired Gauge
IMF	International Monetary Fund
EV	Electric Vehicle
MIT	Massachusetts Institution of Technology
MRC	Magnetic Resonance Coupling
LC	Inductor-Capacitor Circuit
RMS	Root Mean Square

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First of all, we express our heartiest thanks and gratefulness to almighty Allah for divine blessing makes us possible to complete this thesis successfully. We are grateful and wish our profound our indebtedness to Assistant Professor Dr. Md. Rezwanul Ahsan, Department of Electrical and Electronics Engineering, Daffodil International University, Dhaka. Deep theoretical and hardware knowledge and keen interest of our supervisor in this field influenced us to carry out this thesis. His endless patience, scholarly guidance, continual encouragement, constant and energetic supervision, constructive criticism, valuable advice, reading many inferior drafts and correcting them at all stage have made it possible to complete this research.

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ABSTRACT

Wireless force transmission (WPT) has been creating in a wide range of subject in different field and furthermore become an exceptionally dynamic research zone due to their potential in giving high innovation to our day by day lives. It is an exceptionally efficient and a method for saving our natural resources intending to modernize these fuel free transports. This paper is about to design wireless power system and performance analysis like; charging for EV and sun-oriented vehicles, share potential with no wire. The reason for this postulation is planning and usage of a framework to improve the exhibition of remote force move framework and to lessen the utilization of wires by utilizing Tesla coil as a transmitter to create high frequency, high voltage with low exchanging flow so as to deliver high density flux to move electric power. Power is transferred wirelessly by magnetic field which is made by direct enlistment followed by resonant magnetic induction which is a type of inductive coupling where the carried flux can be caught by inductive coil at the receiver that coupled to the primary coil. This tesla coil is included to transfer power a way off to a load or an electrical hardware that should be charged or fueled wirelessly. This system is grown in order to decrease the utilization of wire, spare characteristic assets, power for electric vehicle and wireless charging. We present a far-reaching review of wireless charging procedures, the improvements in specialized standard and their ongoing development in arrange application. Particularly with respect to organize applications, we survey the static charger planning systems, versatile charger dispatch procedures, portable charger dispatch methodologies and remote charger advancement techniques. We talk about open issues and difficulties, in actualizing remote charging, advances. Eventually we imagine some down to earth future system use of wireless charging.

CHAPTER 1

INTRODUCTION

1.1 Introduction

These days, we can't envision our existence without electricity. From the earliest starting point of humanity, there consistently has been the need of power, which carried us to the invention of fire, steam motor and in particular, electricity. Larger part of the present habitation and business structures are controlled by alternating current (AC) from the power grid. This AC current is very necessary for our daily life, for example; lights, fans, kitchen applications, chargers, and so on.

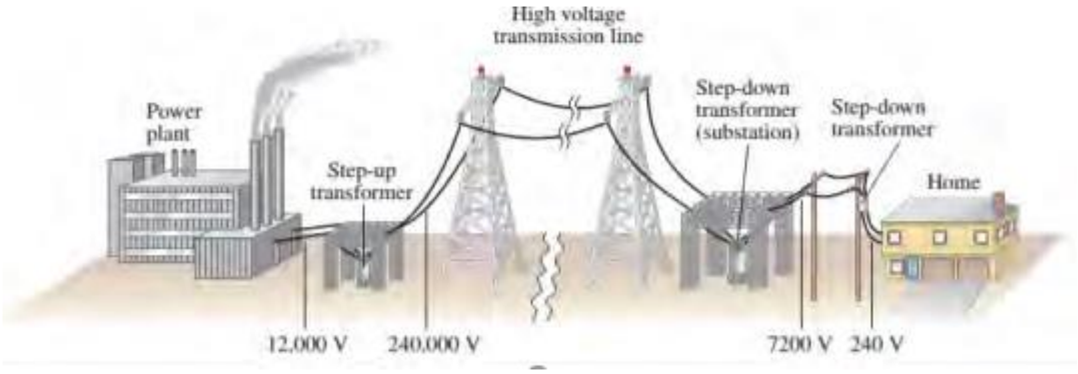

Fig 1.1 Power transmission from Power station

Power stations generate AC electricity that is delivered to load centers through high voltage transmission lines and steps transformers with core losses. At the distribution end the voltage is step down for efficient distribution of transmitted power and the consumers consume at its desire low voltage level. Almost all components are operated with electrical wires. Wires carries within countries even outsides the country. But, complexity is wire or cord like; short circuited, burning wires, plug in or out, twisting etc. From the ordinary transmission framework, wireless power transmission is progressively effective, modern and truly required innovation to be created [3].

1.2 Introduction of Wireless Power Transmission

Wireless power transfer (WPT) makes it possible to supply power through an air gap, without the need for current carrying wires. It can provide power form an AC source to compatible batteries or devices without physical connectors or wires.

Fig. 1.2 Wired Charging System [2]

WPT system can recharge mobile phone and tablet, drone, cars, even transportation equipment. It may even be possible to wirelessly transmit power gathered by solar-panel array in space. WPT has been an exciting development in consumer electronics, replacing wired chargers. WPT utilizes fields made by charged particles to convey vitality among transmitters and beneficiaries over an air gap. The air gap is spanned by changing over the energy into a structure that can go through the air. The energy is changed over to a wavering field, transmitted over the air, and afterward changed over into usable electrical flow by a receiver.

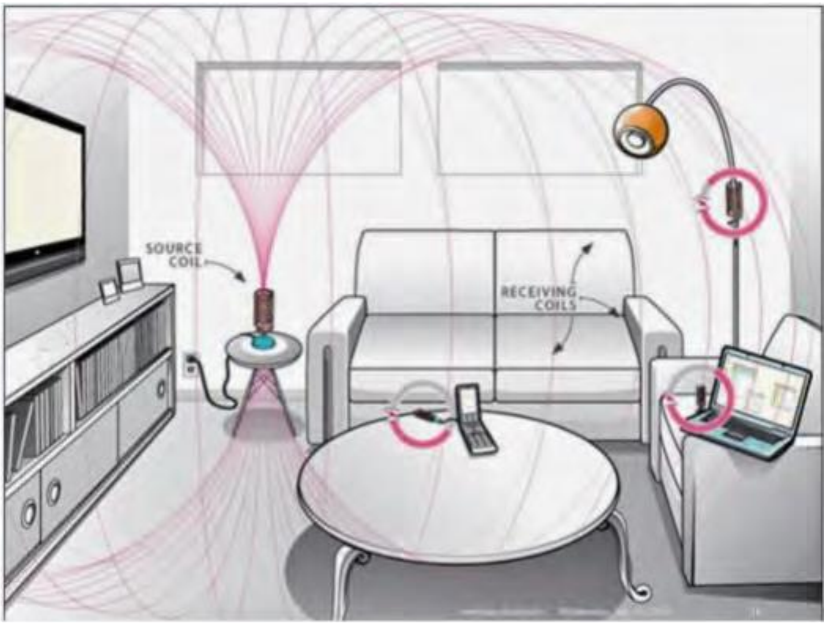

Fig. 1.3 Wires Power System [3]

Contingent upon the power and separation, vitality can be viably moved through an electric field, a magnetic field, or electromagnetic waves, for example, radio waves, microwaves, or even light.

1.3 Invention of WPT

The concept of transferring power without wires was invented in late 1890s. Nicola Tesla is mostly famous in case of wireless power transfer. Nicola Tesla successfully lighted electric bulbs wirelessly at his Colorado Spring Lab. In his experiment he used electrodynamics induction which is also known as resonant inductive coupling. While he was doing his own experiment in the lab, he invented an electrical resonating transformer in the year 1891. The transformer was also known was the Tesla Coil or Tesla's Coil.

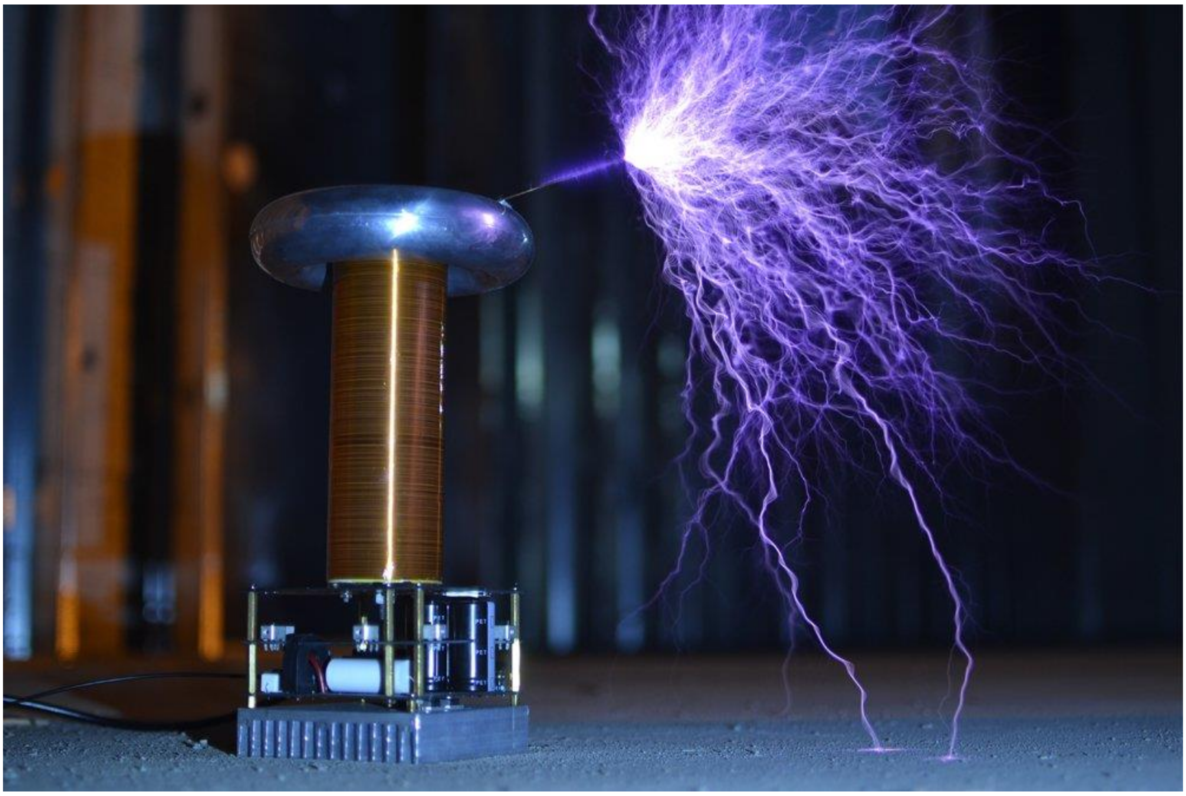

Fig. 1.4 Tesla Coil

Nikola Tesla was confident that his transformer would convey power without the connection of wires. At the Pikes Peak, North America the climate was somewhat harsh. Lightning storms was normal there. Tesla watched the normal lightning and investigated how it acted. He additionally analyzed how the lightning travel out to the ground. He found that soon after the lightning the air stays charged for certain minutes. At that point he tried different things with his transformer and saw how the charges were reflected. He really found an extra-ordinary outcome even with a little tesla coil. In spite of the fact that he was trying with the little one, yet in addition he fabricated probably the biggest coil at any point assembled. The entrancing issue is, the releases from the huge loop in Colorado Spring Lab could be seen from a long separation.

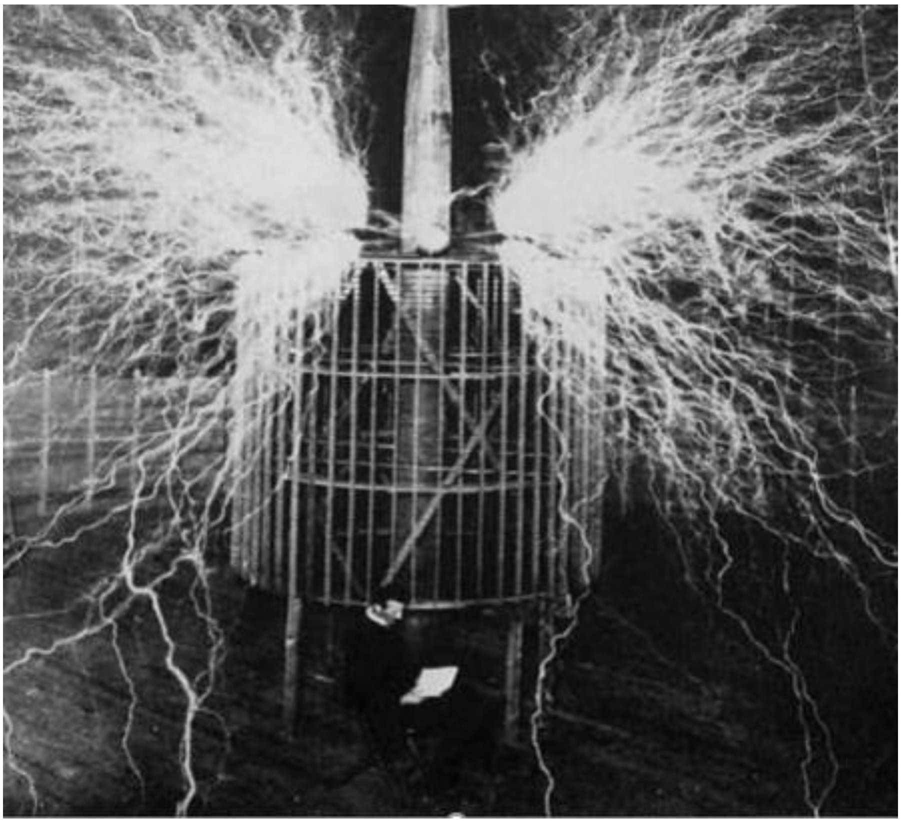

Fig. 1.5 Nicola Tesla’s Experiment

1.4 Motivation

After Nikola Tesla had presented the idea of remote power move, and tested for related innovation patent in 1902. From that point forward, numerous researchers have done research on it. Some of them had the option to increase a few accomplishments in acceptance control transmission at short proximity. For our situation, the principle reason for our investigation was to accomplish a more brilliant yield and hence adding to the transmission of wireless power transfer. So as to keep pace with the advanced advances, the idea of wireless power transfer is should have been exposed which was another explanation for picking this concept. In modern times, no one wants to use the wire or cord in case of charging any device and there comes the necessity of WPT.

According to the IMF, Bangladesh's economy is the second fastest growing major economy of 2016 [8]. With the development of economy, the ways of life are getting higher step by step. All things considered, the use of smart devices are getting very popular these days. The smart gadgets have different highlights however the transmission of power into them wirelessly in one of the spectacular features in recent time. Individuals are a lot of partial to utilizing gadgets that doesn't require the association through wires or strings. It has been mentioned earlier that, to get rid of the annoying wires, WPT is the perfect solution. This paper describes about the design and performance of wireless power transfer using tesla coil technique.

Recent in Bangladesh, there are a few producers who have presented electric bikes (otherwise called E-Cycles). There are additionally simple bicycles (otherwise called Electric Rickshaw) which ordinarily drive inside a fixed region. These vehicles run by rechargeable batteries. To energize them, wires are should have been associated from the divider attachment to the batteries. WPT can be an improved recharging system in such manner.

1.5 Contribution of this research

We are attempting to improve the efficiency of the WPT. For instance, we increase the separation the induced voltage to the load reduces, however we are attempting to accomplish a specific measure of voltage inside a fixed range, with the goal that the heap can be worked from a specific separation wirelessly. It will facilitate the lifestyle in wording or family unit tasks as well as in regard of transportation like vehicle charging. In this research, we have prevailing to charge a cell phone wirelessly by a load coil which is around 2 cm from the secondary coil.

1.6 Research objective

Previously, the individuals who have worked looked into on WPT have faced numerous difficulties. The limitation that the researcher and specialists are energizing batteries, continuation of supplied power, managing moving points, enhancing the sensors, etc. In spite of the fact that these difficulties still exist, step by step the restrictions and issues are getting limited due to the nonstop research going on WPT. The purpose behind our research was to contribute to minimize the limitation of the transmission of power wirelessly.

1.7 Advantage of wireless power transmission

The advantages of wireless power transfer are too many to be describe. Some of them are mentioned below:

- WPT relieves us from using annoying wire connections.
- WPT is a safe, durable form of power transmission.
- Wireless technology really allows a network to reach locations that could not be achieved by using a network cable.
- It allows power transfer system to become portable.
- The cost of transmission and distribution becomes less and the cost of electrical energy for the consumer also can be reduced.
- Loss of transmission is at negligible level in the WPT. However, the efficiency of this method is very much higher than the wired transmission.
- The power failure due to short circuit and fault on cables will never exist in the power transmission system and power theft will not be possible at all.
- One of the major benefits is, wireless power allows a highly expandable power range.
- WPT increase the product life of a device.

1.8 Overview of the research

At first, we needed to build the effectiveness of the wireless power transmission system. This implies, in the event that we increment the separation between the load coil and the secondary coil, the load will perform relatively better in the most possible range.

1.9 Summary of the following chapters

- The 1st chapter describes about the basics of wireless power transfer (WPT), the historical background of the invention of WPT and the reason behind choosing this topic for our thesis. It also gives a clear idea about our contribution to this research and purpose of our research. Moreover, the advantages and disadvantages of wireless power are being described here.
- The 2nd chapter explains the basic concepts of wireless power transfer. For example: Ampere's law, Faraday's law of induction, Lenz's law. It also describes about the two main types of WPT and they are i) Far field and ii)

Near field WPT. The basic differences between wired and wireless power transfer are mentioned here properly. Efficiency of WPT is discussed in the last part of this chapter.

- The 3rd chapter is titled as “Existing improvements on Wireless Power Transfer”. Here three techniques of power transmission is described; which are i) inductive coupling, ii) mix-inductive coupling and iii) microwave. At the end of this chapter, some limitations and problems of WPT are being described with explanation.
- The 4th chapter of our thesis is mainly focused on the fundamentals of tesla coil, the components that must be required to build an efficient tesla coil. The basic designing of tesla coil is also shown here. This designing includes: neon sign transformer, primary coil, primary capacitor, spark gap, secondary coil and top load. Lastly in this chapter, an overview of the overall system is provided.
- The 5th chapter briefly describes about our project implementation. The name of the components and their functions and discussion about the connections among the components are given there. The components include step down transformer, oscillator circuit, primary coil, secondary coil and load coil.
- The 6th chapter is completely focuses on the Oscillator circuit. The reason behind putting this component in a separate chapter is to describe the basic functions of this circuit are vast. The uses of oscillator in tesla coil, designing of it, the analysis of the output of the oscillator, the result from simulation are also mentioned here.
- The 7th chapter is all about “Result”. The analysis of the result we got and the calculated value of efficiency of the system is properly mention in this chapter. The power calculation is also provided here along with necessary values. There is also a description about how the efficiency can be further improved in the last part of this chapter.

- The 8th chapter which is certainly the last one puts in the conclusion part. This chapter tells about the summary of the whole research. There were some limitations which he had faced during this research are also described here. There is also a discussion on the future work that can be done on this research later on.

CHAPTER 2
WIRELESS POWER TRANSFER

2.1 Introduction

Wireless power transmission (WPT) is not a new technology. Nicola Tesla first invented the basic concept of wireless power transfer in 19^{th} century. Throughout the years, a few researchers continue with their chips away at it. The major advantages of wireless power transfer are low efficiency. Thus, analysts are attempting to improve the efficiency utilizing a few kinds of procedures. The benefits of wireless power transfer are numerous that there has been a increasing enthusiasm for wireless power transfer innovation. Wireless power transfer innovation can take out all the charging inconvenient. It can make our day by day life so smooth and simple. The fundamental distinction among wired and wireless power transfer is the link. The conventional wireless power transfer has the issues of power loss, harming wire, electric flash, etc. Meanwhile, it is hard to use cable to transmit power in some extraordinary events. All things considered, wireless power transfer technology is an answer.

2.2 Basic concept of wireless power transfer

Wireless power transfer is where electric energy is transmitted from control source to an electrical load with no wire association. Wireless power transfer depends on the magnetic resonance and close to handle coupling of two circle resonators was accounted for by Nicola tesla a century back. Power is wirelessly move when magnetic field is moved over short distance. The magnetic field is made utilizing inductive coupling between loops of wire or electric fields utilizing capacitive coupling between terminals. The concept of inductive coupling and magnetic field originates from the following principles [9].

2.2.1 Ampere's law

According to Ampere's law, when current is passed through a closed loop of conductor or coil a magnetic field is created around it. The magnetic field created by the current is proportional to the size of that current with a constant of proportionality equal to the permeability of free space.

2.2.2 Faraday's law of induction

Faraday's law states that the instantaneous force (EMF) or voltage induced in a circuit due to changing magnetic field is directly proportional to the change of that magnetic field.

2.2.3 Lenz's law

Lenz's law of electromagnetic induction states that the direction of the current induced in a conductor by a changing magnetic field (as per Faraday's law of electromagnetic induction) is such that the magnetic field created by the induced current opposes the initial changing magnetic field which produced it.

In wireless power transfer system, these standards are embraced. In for the most part a WPT framework consist of a transmitter associated with power source and a receiver which gets the power and deliver it to load. In the transmitter side, there is a primary coil and in the recipient side there is a secondary loop. At the point when the power is associated with the primary coil a current went through it and a magnetic field is conformed to it. At the point when the secondary coil is carried near the primary coil a voltage induced in the secondary coil which generates a current that causes another magnetic field around the secondary coil. The current delivered in the secondary coil is utilized by any load with no physical connection [10].

2.3 Types of wireless power transfer

There are mainly two types of wireless power transfer, radiative and non-radiative. Radiative are for far field and non-radiative are for near field.

2.3.1 Far field or radiative region

In far field or radiative region, microwave or laser pillars is utilized to transmit power wirelessly. These procedures can move high power over distances. In any case, a direct line of transmission way is required as high level radiation transmits from transmitter to receiver. In microwave radiation system, frequency is very high so the antennas should be large enough to satisfy the power density limits. This system is generally utilized in space and military applications, for example, sunlight based power satellite [9].

2.3.2 Near field or non-radiative region

In close to field or non-radiative region, there are a few procedures to move power wirelessly. They are inductive coupling, resonant inductive coupling, capacitive coupling, full capacitive coupling and magneto dynamic coupling. In inductive coupling, power is moved between coils of wire by a magnetic field. From two coils, one is in the transmitter side and another is in the receiver side. This is the most seasoned and most generally utilized wireless power innovation. It is utilized to charge telephones battery, electric vehicles battery, oscillating brush battery and turn on a bulb. This strategy is profoundly effective when two coils are near one another. In resonant inductive coupling, power is moved between two full circuits by magnetic fields. One circuit is in the transmitter side and another circuit is in the receiver side. Each resonant circuit comprises of coil of wire associated with a capacitor. The resonant between the loops can exceptionally build coupling and power move. It is generally productive than inductive coupling technique. Power can be moved over more separations with high proficiency. These days it is generally caught up in present day wireless power systems. In capacitive coupling, power is moved by electric field between terminals, for example, metal plates. In this procedure, a capacitor is formed between the transmitter and receiver electrode. The capacitive coupling has confinement on charging electric vehicles because of too little coupling capacitance. Along these lines, it is essentially utilized in a low power application. In full capacitive coupling, resonance is utilized with capacitive coupling to expand the range. In magneto-dynamic coupling, power is moved between two rotating armatures. One armature is in the transmitter side and another is in the recipient side and both rotate synchronously. Both coils are coupled together by an magnetic field generate by permanent magnets on the armatures. It is an alternative procedure of inductive power transfer for non-contact charging of electric vehicles. It is asserted that this strategy can move power over separations of 10 to 15 cm (4 to 6 inches) with high productivity, over 90% [9].

2.4 Function difference between wired and wireless power transfer

Wired is the term that refers to any physical association consisting of cables. The cables are copper wire, twisted pair or fiber optic and so on. Wired power transfer is the transmission of power through cables. Then again, wireless is the term that refers to the medium that is made of electromagnetic waves. All the wireless gadgets including reception apparatus or sensors. Wireless power transfer is a strategy for transmitting energy starting with one physical gadget then onto the next with no physical association. The fundamental contrast among wireless and wired association is the physical medium between two gadgets. For instance, the cables can be harmed and require fix or substitution. The expense for the substitution or fix can be high. When compared with cables wireless is anything but difficult to introduce and no need to worry about the damage of cables. Utilizing wire, we can move power starting with one gadget then onto the next. In wireless power transfer, one can without much of a stretch transfer power from one gadget to various gadgets. In wired association, there is an opportunity of intensity disappointment or power misfortune because of short out due to the presence of cables. Some of the time it is difficult to deal with the interconnecting wires between devices in wired association. Wireless systems are similarly support free and if upkeep gets vital, they are anything but difficult to keep up [11].

2.5 Efficiency

Wireless power transfer (WPT) technology is growing quickly and its efficiency expanding step by step. It is profoundly effective now and again. Using this technology, one can turn on more than each bulb at a time. It is also possible to charge a few batteries simultaneously without using any cable. Many working groups have experimented WPT technology using various sorts of strategies. In 1983, Donaldson's research demonstrated that the ideal electromagnetic coupling coefficient of the transmitter and receiver can be accomplished by using the S/P capacitance compensation technique. The transmission productivity can arrive at half. In 2009, KAIST tried on the SUV vehicle and got 17 kw control at the yield with a separation of 170mm. The effectiveness arrived at 71%. In 2010, University of Auckland tried on private vehicles and accomplished 3kW power for charging the vehicles battery remotely [12]. The effectiveness was 85% a good way off of 180mm among source and load. A group from MIT has tested and had the option to illuminate a 60W light from a power source a way off of 2m. The effectiveness of this examination was 40%. Moreover, they found that it is possible to build the effectiveness by shorten the separation.

Analysts had the able to power a 60W light at generally 90% efficiency a way off of 3 feet. In 2010, MIT WiTricity tried on private vehicles and accomplished 3.3kW power for charging the vehicle's battery a way off of 180 mm. The efficiency was 90%. In WPT innovation, separation is a major issue and we became more acquainted with this through these tested outcomes. The efficiency of WPT relies upon the separation.

The efficiency is higher if there is shorter separation between power source and load. The efficiency is lower if the separation between power source and load is longer. Then again, the efficiency likewise relies upon the strategy [13].

CHAPTER 3
EXISTING IMPROVEMENTS OF WIRELESS POWER TRANSFER

3.1 Introduction

Communication technologies are giving universal and cable free communication to the user but users gadgets are still battery restricted and need wires to charge them. The ongoing advances are promising to charge gadgets without the help of wires or battery replacement. These days, wireless power transfer is being used in IC cards, portable telephones and electric automobiles [14]. It is important to improve the quality factor of the receiving coil and the transmitting coil for high efficiency and long separation transmission [14]. Many researches are occurring to improve the efficiency and distance simultaneously. Nikola Tesla has designed tesla coil to move power wireless in 1891. He was somewhat over driven as he imagined to have a wireless power grid. At present, wireless power transfer is occurring in charging electric vehicles, mobiles and different gadgets. In this field, the contribution of Nikola Tesla is irreplaceable. Modern technology of transferring power wirelessly incorporates tesla coil. With the progression of time, the development of tesla coil is changed. In spite of the fact that it will be only a fantasy to have a wireless power grid in future, be that as it may, wireless charging system is building up everywhere throughout the world. Wireless power system is costly, but it is safe. It will eliminate the loss of the wires, it will prevent users from electrocution.

3.2 Overview

Wireless power transmission technologies use time-varying electric, magnetic, or electromagnetic fields [9]. Wireless transmission is helpful to power electrical gadgets where interconnecting wires are inconvenient, hazardous, or are not possible [9]. It is more secure for people. As the system gets wireless, individuals will have no physical contacts with the transmission procedure. In this way, it will be more secure for individuals. Besides, it will be efficient, simple for individuals as it doesn't require any cable association. It is especially easy to use as gadgets will be charged simultaneously when they are being used. Besides it saves time.

Different research group used a Litz Magneto Plated wire (LMW) structures as transmission coils for wireless power transmission in electric vehicle charging system [15]. Litz wire is commonly used to decrease the AC resistance because of skin impact of a coil [14]. However, the decrease in AC opposition brought about by the nearness impact is troublesome, and there is a farthest point in expanding the quality factor utilizing a Litz wire [14].

In wireless power transfer, there are for the most part two classifications, radiative and non-radiative. Non-radiative method is utilized to deliver power wireless in close to fields. This procedure utilizes magnetic fields made by inductive coupling between coils of wire, or by electric fields using capacitive coupling using metal electrodes. Non-radiative strategy is used to deliver power wireless in far fields. In this system, power is transferred by light emissions radiation, similar to microwave or laser beams.

3.3 Inductive coupling

The coupling between two wires can be expanded by winding them into coils and putting them near one another on a common axis, so the magnetic field of one loop goes through the other coil [16]. The mutual inductance of two conductor is used to measure the amount of inductive coupling between them. The coupling between two wires can be increased by winding them into coils and setting them near one another on a common axis, so the magnetic field of one coil goes through the other coil [16]. The two coils might be physically contained in a single unit, as in the primary and secondary windings of a transformer, or might be separated. Coupling might be intentional or unintentional. Intentional inductive coupling can make signals from one circuit be induced into a nearby circuit, this is called cross-talk, and is a type of electromagnetic interference [16].

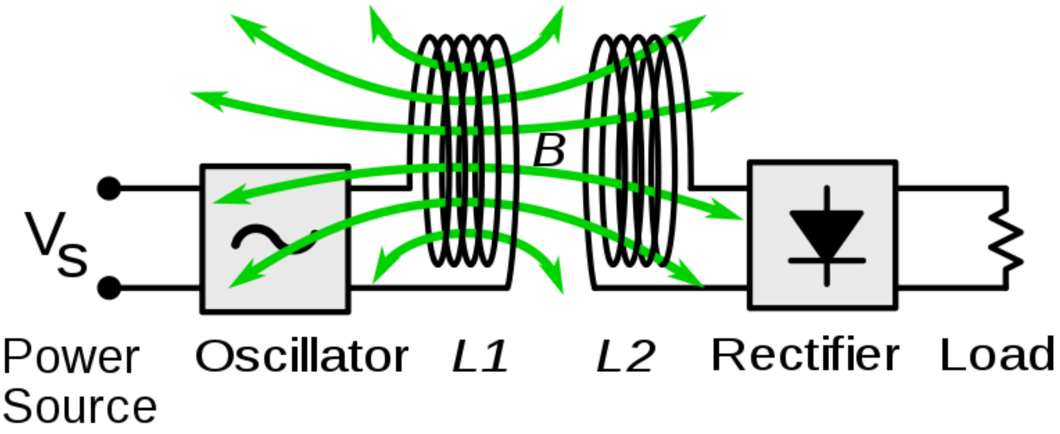

Fig. 3.1: Inductive Coupling [17]

3.4 Mix Inductive Coupling

Wireless power transfer system by means of magnetic resonance coupling (WPT/MRC) is used for its higher efficiency, longer range and more prominent power output [18]. Up to now, various circuit structures are broadly used in wireless power transfer system [18]. There are four essential topologies: series-series, series-parallel, parallel-parallel, parallel-series. Tesla coil follows the mechanism of magnetic resonance coupling. Direct induction followed by magnetic resonance induction is used for wireless power transmission. The flux created from the primary coil is gotten by the coupled secondary coil and voltage is actuated in the secondary coil. The general method is utilizing magnetic field, so the primary coil ought to have a sufficiently high frequency, high flux density. Thus, the tesla coil is used as a transmitter to create high voltage, high, low alternating current and flux density.

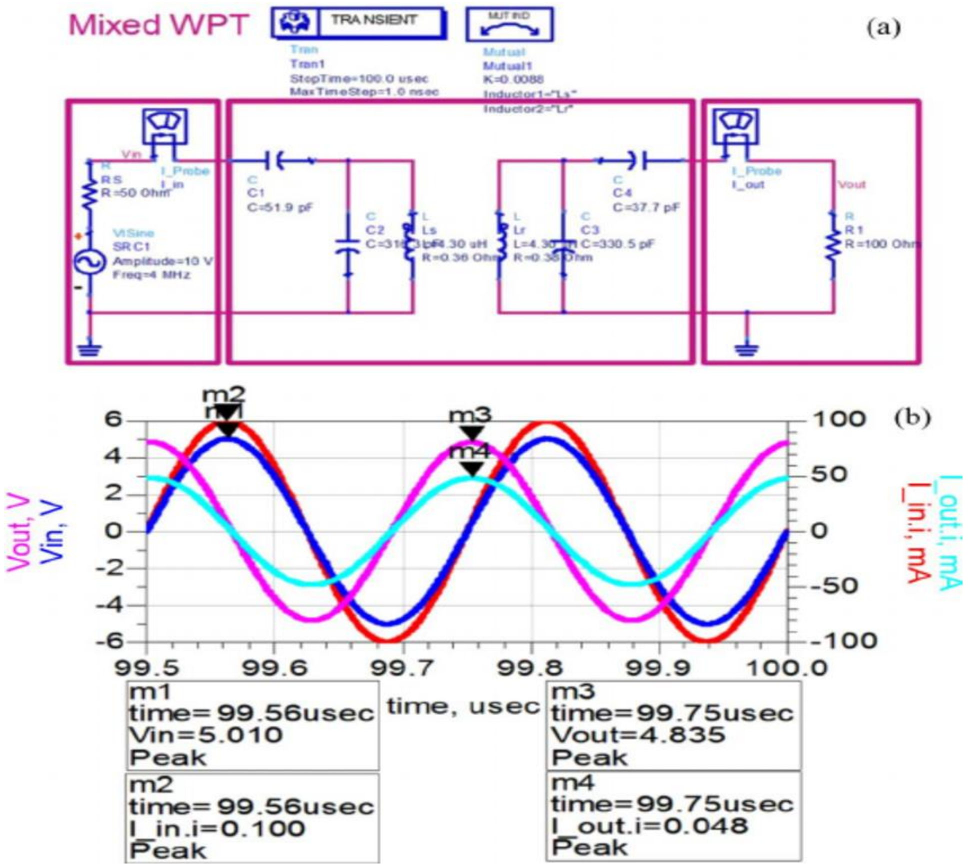

Fig. 3.2: Mix Resonant Coupling Circuits [19]

3.5 Microwave

Power transmission by means of radio waves can be made more directional, allowing longer-distance power beaming, with shorter wavelengths of electromagnetic radiation, ordinarily in the microwave range [09]. A rectenna might be used to change over the microwave energy once more into electricity. Rectenna change efficiencies surpassing 95% have been figured it out. Power beaming using microwaves has been proposed for the transmission of energy from orbiting solar power base power satellites to Earth and the beaming of power to spacecraft leaving orbit has been considered [09]. For earthbound applications, a large area 10 km diameter getting array permits huge all out power levels to be used while working at the low power levels recommended for human electromagnetic exposure security [09]. Wireless power transmission using microwaves is very much demonstrated. Investigations during the several kilowatts have been performed at Goldstone in California in 1975 [09].

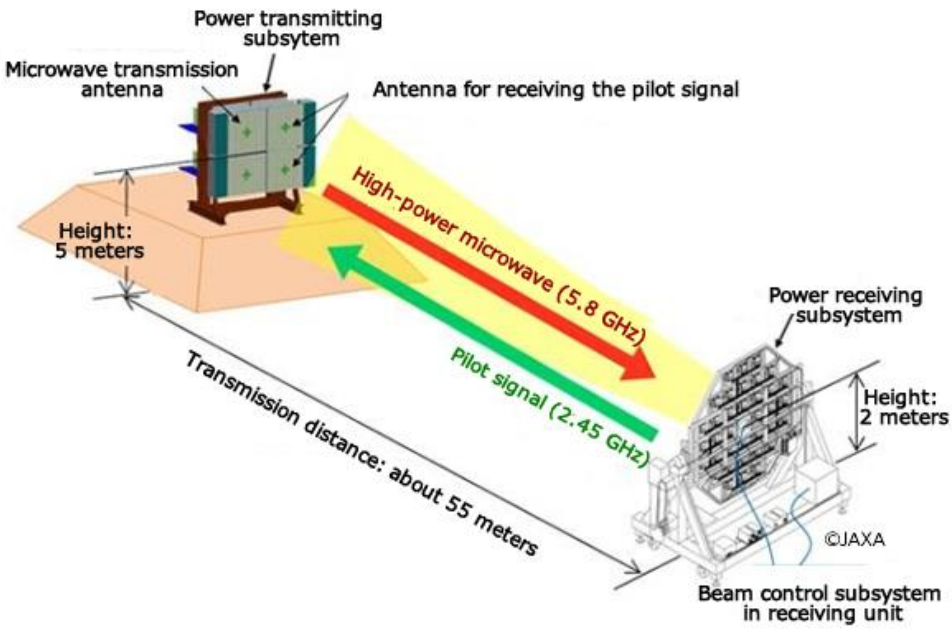

Fig. 3.3: Microwave wireless power transfer [20]

Tesla coil additionally pursues the component of magnetic resonance coupling. Direct induction followed by magnetic resonance induction is used for wireless power transmission. The transition delivered from the primary coil is gotten by the coupled secondary coil and voltage is induced in the secondary coil. The general strategy is using magnetic field, so the primary coil ought to have a sufficiently high frequency, high flux density. Along these lines, the tesla coil is used as a transmitter to create high voltage, high, low alternative current and high flux density [21].

3.6 Limitations and Problems

At the point when wireless power transfer is in band with data transfer, there will be break in connectivity. The wireless power density is difficult to estimate and control. The radio introduction can be over the limit because of reflection and refraction of the signal originated from different wireless devices. Guaranteeing safety where end-users are permitted to send new power transmission and change the areas of existing energy transmission and energy recipient at run-time is difficult. The more ETs are sent, end users may be presented to more radiation. Determining a power move plan for ETs so as to expand power transfer and guarantee EMR safety is a difficult issue. In such dynamic system, one should ensure the exposure security considering run-time impact of unpredictable end-user actions. For scenarios where ERs are wearable, body movements may prompt unpredictable exposure influence on various parts of the body.

Wireless power transfer through microwave includes biological impacts because of high resonance [22]. Besides, it will be very much costly. The transmission of electric power through this strategy is vulnerable to security risk like cyber warfare [22].

CHAPTER 4
WIRELESS POWER TRANSFER USING TESLA COIL

4.1 Introduction

In 1891 Nikola Tesla invented his Tesla Coil so as to transmit power through air, without a doubt he spent majority of his profession lifetime attempting to accomplish his ultimate goal of wireless power transmission [23]. At whatever point power was required one would require a receiver coil to convert over the power into a useful form as per individual needs [01]. Nikola Tesla had some achievement around there however the financial specialists thought that it was illogical and refused to support in further research, so he has to stop this research. His research on wireless power transfer was not a loss as he used tesla coil to analyze in radio transmission, build death ray and other wild inventions [01]. So motivated from his tests, we chose to used tesla coil for wireless power transmission and to materialize his dream of move power wirelessly. For wireless power transfer, tesla coil is used as a transmitter where tesla coil is used high voltage, high frequency transformer. Working method and structuring of a tesla coil will be described later the parts.

4.2 Working principle of Tesla Coil

To put this in a nutshell, a Tesla Coil is a radio frequency oscillator that drives a double-tuned resonant transformer to produce high voltages with low currents. Now, to better understand what a radio frequency oscillator is, let's take one further step back to first understand an electronic oscillator. An electronic oscillator is primarily an electronic circuit that produces an osmicating electrical signal, which is often a sine wave or a square wave. Oscillators convert direct current from a power supply to an alternating current signal. An electronic oscillator that produces signals in the radio frequency range (100kHz to 100GHz) is called a radio frequency oscillator. A resonant transformer works on the concept of resonant inductive coupling, where the secondary coil in the transformer is loosely coupled, so it resonates. The special aspect of the resonant transformer is that either one or both the circuits present in the transformer consists of a capacitor connected in parallel to it. This coupling of the transformer circuit and the capacitor turns it into a tuning circuit. A tuning circuit or LC circuit is used either for generating signals at a particular frequency or picking out a signal at a particular frequency from a more complex signal, which is also known as a bandpass filter. Whether you compare the first patented model or the more modern ones, there is one commonality that you will find in all of them—the spark gap. The functionality of the spark gap is to excite the oscillated electrical signal from the resonant circuit. The unique design of the coil ensures that there are low resistive energy losses at high voltages, which the Tesla Coil produces.

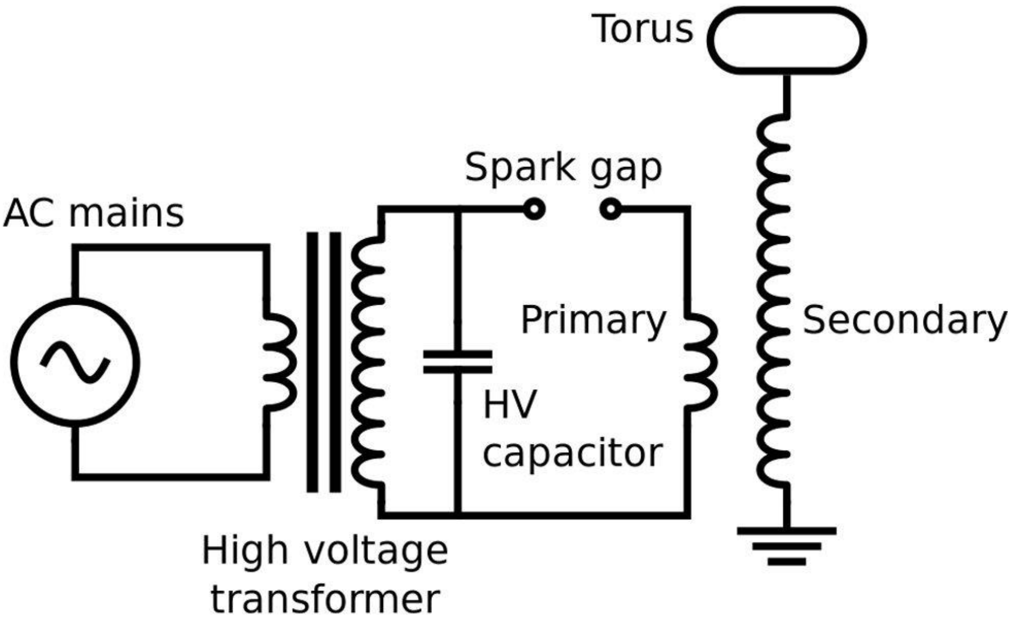

Fig. 4.1: Operation of the Tesla Coil [24]

Now that we understand the different components of such a coil, we can delve into the operation of the Tesla Coil in its entirety. First, the resonant transformer steps up the voltage to a very high level, to the point where high voltage begins jumping across the spark gap. The typical voltages are between 5 and 30 kilovolts. The capacitor in the circuit forms a tuned circuit with the primary winding L1 of the apparatus. The spark gap plays the role of the switch in the primary circuit. The Tesla Coil (L1, L2) together with the spark gap, generates a high output of voltage when coupled together.

4.3 Mathematical nuances of the Tesla Coil

There are three important mathematical nuances or foundations upon which the operation of the Tesla Coil is built. The two main features are the oscillating frequency and the output voltage. First, let's take a look at the oscillating frequency. To produce the largest amount of voltage possible from a Tesla Coil, it must be ensured that the primary and secondary circuits of the resonance transformer are tuned to resonate with each other. The resonant frequencies of the primary and secondary circuits are defined by *f1* and *f2*. Usually, the secondary circuit frequency (*f*2) cannot be adjusted. However, the primary can be adjusted with the help of a tap. The conditions for resonance are given below:

$$f1 = (1/2\pi) * \sqrt{(1/L1C1)}$$

$$F2 = (1/2\pi) * \sqrt{(1/L2C2)}$$

Unlike conventional transformers, the output voltage of the resonance transformer is not directly proportional to the number-of-turns ratio, as in the case of an ordinary transformer. It can be calculated through the conservation of energy. When the cycle begins, and the spark starts all of the energy from the primary circuit, $\mathbf{W_1}$ is stored in the capacitor $\mathbf{C_1}$. If $\mathbf{V_1}$ is the voltage at which the spark gap breaks down, which is usually close to the peak output voltage of the supply transformer ***T***, this energy is:

$$V2 = V1\sqrt{(C1/C2)} = V1\sqrt{(L2/L1)}$$

Once the energy level crosses 85% capacity, it transfers over to the secondary circuit. At the peak energy level of the system, the voltage on the secondary side is $\mathbf{V_2}$, the energy stored is $\mathbf{W_2}$, and the capacitor on the secondary circuit is $\mathbf{C_2}$. Assuming that no energy losses occur, $\mathbf{W_1}$ and $\mathbf{W_2}$ will be equal. This shows that the loss of energy by transmitting it wirelessly could have theoretically been kept to a minimum [24].

4.4 Advantages of using Tesla Coil

In direct electromagnetic induction, it conveys power at 10 cm with 80% productivity alongside 20 cm with 45% proficiency, which isn't sufficient. In addition to that there was low flux density which brings about low induced voltage in the primary coil just as the secondary coil. A Massachusetts Institute of Technology (MIT) report which says, in urban areas the electric vehicles will get charged while going through the streets. For this situation, the streets are working in as the primary coil, this procedure is known as Dynamic Wireless Power Transfer (DWPT). In developing nations like

Bangladesh, it is practically difficult to fabricate this sort of road. Wireless power transfer depends on electromagnetic acceptance among primary and secondary coil where induction relies upon the change of flux and the change of flux relies upon the flow of current. From the fundamental idea of induction, we know the Faraday's law about the electromotive power (EMF) which relies upon the change of flux which is essentially the basic idea of an typically transformer which induced voltage is corresponding to the rate of change of flux linkage. This implies if the coil is stationary comparative with the magnetic field, no emf is induced rather to induced emf, either the coil or magnetic field must move. Faraday's law is mentioned bellow,

$$\varepsilon = -N \frac{\delta\varphi}{8t}$$

If we integrate both side of the formula and rearrange in term of ϕ we would find that the flux depends upon the integral of the voltage. This implies it will induce a magnetic field if we put an emf over the coil. The tesla coil also works at this guideline, the more the emf the more the induced magnetic field and the more the magnetic field the more voltage induced in the secondary side. Tesla coil is a kind of transformer but not the typical transformer which functions as a transmitter in wireless power transmission. In tesla coil, the density of induced magnetic field is so high and the induced voltage is also so high that has the more efficiency in transmission of power. Tesla coil works on resonant coupling, so the frequency is also so high. In tesla coil the induced magnetic field in an inductor captured by another inductor coil and as this system utilize magnetic field to move energy that is the reason the flux that is delivered in the primary side must be in high density with high frequency. This is one of the fundamental problems to transfer electric power wirelessly with a good efficiency rate. Along these lines, tesla coil is used as a transmitter to deliver high frequency, high voltage with low alternating current so as to create high density of flux for a superior transmission of wireless power [25]. Another perspective is to be in getting looked at that having a unusually high frequency, high voltage, tesla coil has no health hazards when they goes through a body don't cause any painful situation and muscle compression of electric shock, as low frequency AC/DC current do. The nervous system is insensitive toward currents with frequencies more than 10 - 20 kHz [26].

4.5 Designing of a Tesla Coil

In direct electromagnetic induction, the power is transmitted by electromagnetic coupling but this procedure requires a short proximity between the transmitter and receiver so as to couple. To broaden the separation between the transmitter and receiver, tesla coil is the best arrangement. Tesla coil is used as a transmitter to deliver high voltage, high frequency, low alternating current to create high flux density. An additional element of using Tesla coil is, that isn't unsafe for human body [27]. So as to deliver high voltage, high frequency and high flux density with low alternating current in the secondary coil, flux created in the primary coil must be in high density with frequency.

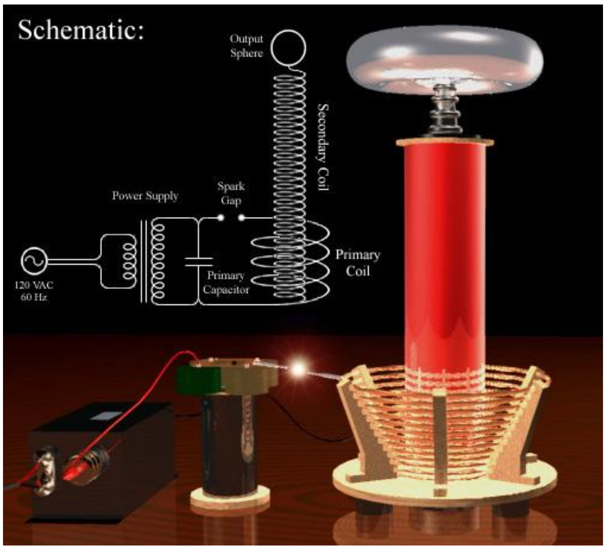

Fig. 4.2: Schematic diagram of Tesla Coil

The standard voltage ratio between the primary and secondary coil is 1:100. The two coils should have the equivalent resonant frequency coupled to form a great output. The formula of resonant frequency is:

$$f_r = \frac{1}{2\Pi\sqrt{(LC)}}$$

Depend upon the value of L and C, we get a full resonant frequency at the primary side that must be identical to the secondary resonant frequency. To maintain a strategic distance from abuse of electrical energy, parallel resonant can be used. In parallel resonant, the inductance and the capacitance are in parallel so the impedance of the combination rises to greatest the resonant frequency. Magnetomotive force (MMF) increase when the quantity of turns and current increase.

$$mmf, f_m = N*1$$

After saturation, however the quantity of turns is increased, the MMF will never again increase just as the flux. There is a few equipment that is important to assemble a tesla coil as it isn't only a regular transformer or a simple transmitter. Tesla coil is bit complicated electric hardware which needs some complex working conditions and component just as to deliver perfect output. On the off chance that any of the types of equipment get missing or destroyed making or faulty construction can make every one of the things wrecked which can cause an extraordinary threat. In this way, it is a difficult job to structure a tesla coil and one should be cautious about it and some most significant things must be remember which should be in under consideration at to develop a tesla coil. All the hardware and their functions are described in detail with their average qualities in the following below [27].

4.5.1 Neon Sign Transformer (NST)

A neon sign transformer is slightly not the same as the regular transformers which convert

Fig 4.3: Neon Sign Transformer

line voltages in the scope of 2-15 kV and supply between 18-30 mA and 60 mA. If there should arise an occurrence of picking the NST, we should guarantee that transformer supplies at any rate 5 kV, else we may have problems with the spark gap not firing. A power factor correction (PFC) can be wired over the NST input terminal to address the

AC power phase and increase efficiency. PFC shift the VA rating of the transformer closer to actual input and output watts and reduces input current needed. Considering each one of those papers and some Tesla coil designing sites, we thought of a few estimated values and Tesla Map software shows typical values for designing NST. In the table given below, typical NST values are mentioned using Tesla Map [27].

Table 4.1: NST input and output in Tesla Map

NST Input		**NST Output**	
Optimum PFC Cap	17.8uF	Input Voltage	220V
NST Watts	280W	Input Frequency	50Hz
Max Arc Length	28.4 in	Output Voltage	9kV
MMC Cap for Static Spark Gap	17.2nF	Output Current	30mA

4.5.2 Primary Coil

The basic functionality of primary coil is to couple to the secondary coil to transfer power form the primary to secondary circuits. It takes the output from the NST and step up the voltage with 1:100 proportion in the secondary coil. In the primary side the flux density must be sufficiently high, so the

Fig. 4.4: Primary coil of Tesla Coil [29]

coil AWG must be low. Generally, 0.25in diameter of copper tube is utilized to frame the primary coil. There must be a spacing of 0.25in between turns. Primary coil can be developed in various shapes like pancake, conical or helix. To frame conical shape, the coil angle must be under 45 degree. Helical coils are twisted into a helix of equivalent distance across. We are utilizing pancake formed primary coil since it is anything but difficult to develop and it is wanted to utilize pancake for medium and large size Tesla coil. We designed estimate primary coil utilizing Tesla Map. Tesla Map shows typical value for designing. For coil wire diameter and wire spacing regular values are 0.06in to 0.25in. Center hole diameter measured between inside the innermost turns are 2in bigger than the secondary coil width. The values are given bellow [27].

Table. 4.2: Primary coil input and output in Tesla Map

Primary Inputs		**Primary Outputs**				
		Turns	**Diameter**	**Height**	**Length**	**Inductance**
Coil wire diameter	0.25 in	1	9 in	0.25in	2.36 ft	0.457uH
Coil wire spacing	0.25 in	2	10 in	0.25in	4.97 ft	1.72uH
Coil hole diameter	8.0 in	3	11 in	0.25in	7.85 ft	3.73uH
Coil incline angle	0 in	4	12 in	0.25in	11 ft	6.45uH

4.5.3 Primary Capacitor

Primary capacitor is significant part for construction of tesla coil. The primary coil gets input through the primary capacitor as power cannot be provided directly to the primary coil of a tesla coil since it won't work until the resonant frequency matches. Basically, to make a primary LC circuit primary capacitor is used. This primary capacitor isn't only the ceramic or cylindrical shaped capacitors that are utilized is lab works rather it is made of a few dozen of capacitors wired in series and parallel setup making a variety of capacitors, this kind of designed capacitors are called Multi-Mini capacitors (MMC). The benefit of utilizing MMC for primary coil is, it is easy to replace if any of those fails to work. To construct an array of capacitors it is recommended to utilize production line capacitors as they are named with an ideal capacitance and simple to get desired capacitance and sheltered just as this capacitor presented to high voltage and short

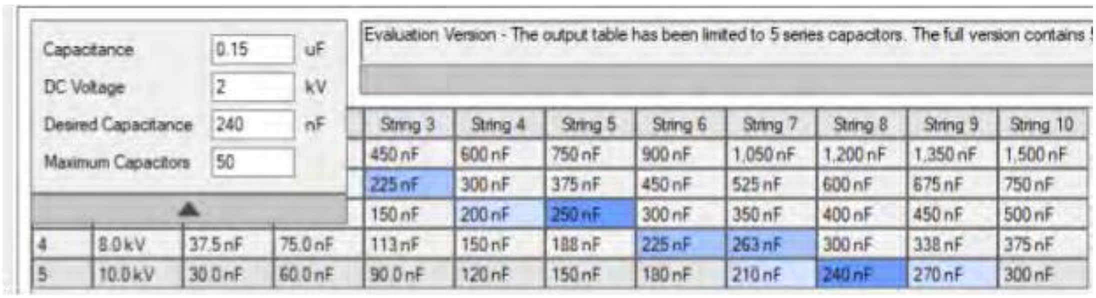

Fig. 4.5: MMC designing in Tesla Map

charge/release process times and this factory capacitors have a high tolerance level. This capacitor is picked with the VDC rating as it requires short charged and discharged time and VAC is overlooked. Typically, 1.6 kV to 2 kV capacitors are utilized to make a MMC array wiring a few capacitors series and parallel association with give an ideal voltage rating [27].

Primary capacitors are picked relying upon the rating of the NST like, if 15 kV rating RMS power supply the capacitors are chosen 40 - 60 kV voltage rating which is 2 - 3 times the peak voltage of the NST. A typical MMC will have a dozen of capacitors in every series string, it is better to compute the strings and the number of capacitors with rows and columns with certain valued capacitors [27]. Tesla Map can be used to calculate and designing of the MMC array. Fig. 4.3 is a normal MMC calculation in Tesla Map with some ordinary qualities for medium measured tesla coil.

Fig. 4.6: Typical MMC array [30]

Here it shows 2 kV VDC rating maximum 50 capacitors with 0.15 uF capacitance combing in strings, desired 240 nF can be acquired. In Fig. 4.4 is a typical primary capacitor exhibit.

4.5.4 Spark Gap

The spark gap is really a switch that quickly associated the primary capacitor to the primary coil. It is fundamentally two conductors separated in a box loaded up with inert gas. At the point when the capacitor is sufficiently charged to fire the spark gap, it shorted between the primary coil and capacitor. It is important to coordinate the resonant frequency of the two LC circuits of primary and secondary side. It is of two types, one is static gap and another is rotary gap. A spark gap is an absolute necessity for large and medium sized tesla coil [27]. Fig. 4.5 demonstrated a typical static spark.

Fig. 4.7: Static spark gap [30]

4.5.5 Secondary Coil

The secondary coil is coupled with primary coil. It is really a white PVC pipe covered by a lot of enamel wire. One side is connected with ground and high voltage gets through the opposite side. PVC pipe standard size is about 4.4-6.6in. Two flanges (Flat rim) are needed in two sides of the secondary coil. 22 AWG to 28 AWG enameled copper wire is expected to form winding. Greater than 28 AWG is considered loss. The magnet wire is normally sold by weight. Magnet wire is copper wire with slender polish protection. Both wires are same by conduct, but the magnet copper wire is specially covered with thin and high heat absorbing material. There must not be any spaces between winding wires and no overlapping as well. Height to width ratio of secondary coil is 5:1 for small, 4:1 for average sized, and 3:1 for large Tesla coil. The common value of the winding are 800-1200 turns. We designed estimated secondary coil utilizing Tesla Map. It shows ordinary values for designing [27].

Table 4.3: Secondary coil input output data in Tesla Map

Secondary coil inputs		**Secondary coil outputs**	
Magnet wire AWG	22	Secondary coil turns	923
Coil winding weight	26 in	Secondary H/W ratio	4.7:1
Coil form diameter	5.5 in	Secondary wire length	1330 ft
		Secondary wire weight	1.17 kg
		Optimal top load cap	22.4pF

4.5.6 Top Load

It is a metallic item at the highest point of the secondary coil. It gives a capacitance to the Tesla coil. Top load is favored doughnut or toroid shaped. To construct a top load, there must be aluminum duct, a flange and wires. The flange is covered by the aluminum duct. There are two different ways to construct it. The first way is to twist the wire to bring the two edges of the aluminum duct as close as could be expected under the circumstances. The wire must be inside the toroid. The other way is to utilize craft glue to include the aluminum duct and the rib together. In the wake of calculating the value of the primary and secondary coil in the Tesla Map, we found that the ideal value of the ideal top load capacitance is 22.4 pF [27]. Fig. 4.6 is a typical top load.

Fig 4.8: Top Load [27]

4.6 Overview

Here in this chapter the considerable number of segments of tesla coil with their functions are described. The typical values and measurement are also given for a medium sized tesla coil construction. In the later chapters, the execution of tesla coil utilized in our project will be portrayed with solid values, measurement and specifications.

CHAPTER 5
PROJECT IMPLEMENTATION

5.1 Introduction

Tesla coil is extremely risky as we know it requires high voltage to drive and it step up voltage at the secondary side with a 1:100 ratio. It is extremely dangerous and need skills to deal with cautiously, really specialists are expected to deal with this tesla coil. It is simpler to deal with a smaller than normal or little measured tesla coil rather than the typical or medium sized tesla coil as in this mini sized tesla coil, the info is low voltage with a higher frequency. The development of the primary and the secondary coil will likewise be diverse similarly as with a lower turns, diameter, height and furthermore different parameters will have different ratio. Fundamentally, the designing of the entire tesla coil will be slightly different however the main intension and essential properties will continue as before. In typical tesla coil, input is provider through NST however we cannot utilize it as it gives output of 15 kV (ordinarily) which is high voltage and dangerous to handle. NST step up the voltage with a high frequency that goes to the primary coil through a high voltage capacitor exhibit and a spark gap. For our situation, we cannot utilize any of them in view of the dangerousness and unavailability in commercial sectors. To maintain a strategic distance from the danger issues, we utilized low input voltage with high frequency as is it required to initiate more voltage in the secondary side so as to get efficient voltage. So as to build voltage an oscillator circuit must be built with a low voltage. That is the reason we have built an oscillator circuit which creates a high frequency and that is provided to the primary loop the tesla coil through a capacitor. The tesla coil gets power from the oscillator circuit output. Then from the primary coil, voltage induced in the secondary coil which supply power wirelessly in air. Electromagnetic waves are noticeable all around and a load coil is there to induced voltage in it then it is changed over to a usable form. Fig. 5.1 shows the entire progression of the undertaking in a block diagram. This is the basic idea of our construction and in the following parts all the equipment,

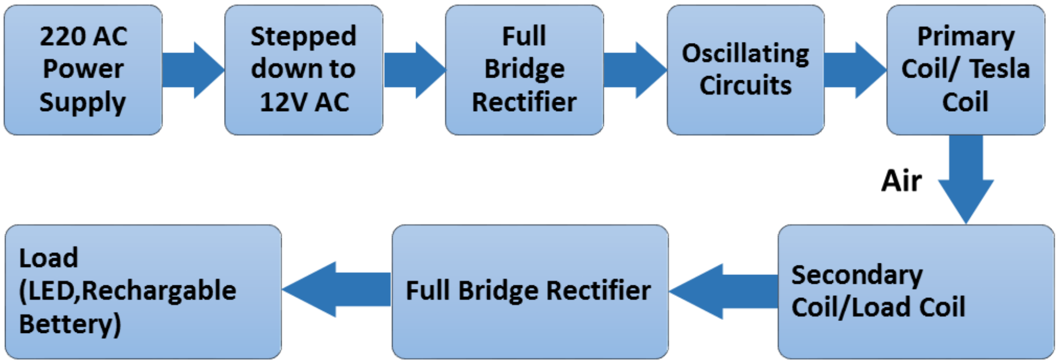

Fig. 5.1: Block Diagram of the Overall process

design and functionality will be described in detail. Here we will portray the construction of the entire experimental arrangement with appropriate measurement of the coil, determination of types of equipment is utilized. The designing of the coils and the entire procedure will be described in this chapter.

5.2 Step Down Transformer

A transformer that decreases voltage from primary to secondary is known as a step-down transformer. In a step-down transformer, primary turns are higher than secondary transformer. The transformer converts high voltage, low current power into low voltage high current power. The more details about step down transformer are talked about in part 6. Fig. 6.1 shows the step-down transformer utilized in our transformer. In our thesis project, we have utilized step-down transformer to convert over 220V AC voltage to 12V AC. Step-down transformers output is directly connected with the full bridge rectifier to convert 12V AC to 12V DC. The output of the rectifier is associated with oscillating circuit. The 220V AC can harm or consumed the oscillating circuit. This is the explanation we picked a step-down transformer to avoid the danger of the harm.

5.3 Oscillator Circuit

An oscillator circuit is an electronic circuit that makes a periodic signal often a sine wave or square wave. Oscillator circuit convert DC voltage to AC voltage. It likewise produces high frequency. The fundamental reason for utilizing an oscillator circuit is to produce a high frequency voltage. We have given 220V AC as contribution with 50Hz frequency. In making of Tesla coil, the primary coil resonant frequency should be approximately 20 kHz to 100KHz or more. To increase the frequency from 50Hz to higher, we used an oscillator circuit. In our thesis project, we made the circuit utilizing resistors, capacitors and a NE555P Timer IC. Fig. 6.6 and Fig. 6.8 shows the schematic and practical implementation of the oscillator circuit utilized in our project. The details of the oscillator circuit and the working of that circuit will be portrayed in part 6. We have utilized 46ohm, 21ohm and 547ohm resistors, and 0.001uF, 0.02uF, 0.1uF capacitors. We effectively got 123 kHz frequency with 6V peak at the output of the oscillator circuit. The output voltage was a square wave but we required a pure sinusoidal wave. To convert the square wave to a sinusoidal wave, we included a low pass filter with the oscillator circuit appeared in Fig. 6.13. The activity of the low pass filter is to pass the sinusoidal waveform of the pulse wave. The low pass filter is a RLC circuit. We have utilized 300 mH inductor, 15ohm resistor and 15nF capacitor in series connection. After connecting the low pass filter with the oscillator output, we got a pure sinusoidal wave with a frequency of 121kHz. The peak voltage of the sinusoidal wave was 8.35V in our oscillator circuit which perfectly worked. There is a slight distinction between simulation and practical implementation. In simulation, we got 100 kHz frequency at the output of the filter though in practical its 121 kHz. This happened in light of the fact that we made 15ohm resistor utilizing a few resisters associated in series-parallel association and furthermore is for capacitors. Afterward, the output of the oscillator circuit with low pass filter was associated with the primary coil capacitor.

5.4 Primary Coil

In our wireless power transfer process, we have utilized tesla coil procedure to move power wirelessly and the tesla coil is system utilized as a transmitter of wireless power transfer. Tesla coil is a kind of transformer but not quite the same as the conventional transformers. As we probably are aware and examined in Chapter 4 about the basic hypothesis of transformer and Faraday's law, transformer is comprised of primary and secondary coils in primary and secondary sides individually. Primary coil remains in primary side which induces voltage in the secondary side through electromagnetic induction. The primary side makes magnetic flux in the primary side and incites secondary coil through transition lines. The primary coil makes electromagnetic flux with the difference in alternating current in a coil. In the secondary coil the voltage is instigated and the incited voltage subordinate upon the pace of progress of transition inside the primary and secondary side. Every one of the recipes and laws are referenced in Chapter 4. We have to know how induction operate to design the coil in which the induction, electromagnetic flux, induced voltage pace of progress of flux depend.

Making slight mistakes or error in the measurement of the construction of coil, the tesla coil won't work. It is exceptionally touchy work that needs to done cautiously. We have talked about before that the primary coil wire must be thicker than the secondary coil wire. That implies, primary coil wire diameter is more than the secondary coil wire diameter. That is the reason we have utilized an exceptionally thick or bigger width wire for primary coil development. Our developed primary coil is appeared in Fig. 5.2. The best use for primary coil is to utilize copper tube

Fig. 5.2: Primary Coil

wire which is thicker and round and hollow shape tube. We have taken 17*12*4 mm measurement copper tube for our primary coil. We made helix molded primary coil as we probably are aware primary coil can be in various shapes. As we were making smaller sized primary coil, it is smarter to utilize helix shape primary coil for better induction in secondary coil. The inner width of the helix essential loop is 68 mm. We have examined in the Chapter 4 about the commonplace turns for the primary coil and spacing between turns. We have taken 5 turns in primary coil with 15 mm dividing between turns. Approximately 1.068 m long copper tube is utilized in the development of the coil. As the coil diameter is 70 mm and 5 turns were utilized in this way, $\pi \times 70 \times 5 = 1.099$ m. Thus, we took approximately 1 m long wire tube length as indicated by the accessibility in the market. All the measurement of the primary coil is given in Table: 5.1.

Table 5.1: Primary coil measurement

Coil diameter	30mm
Number of turns	20
Length of wire	1m

5.5 Secondary Coil

The primary coil induces voltage in the secondary coil to move power wirelessly with a 1:100 proportion. Optional loop stepped up the voltage to a sufficiently high voltage that can be moved keeping up the resonance frequency. The load coil gets power from the primary coil and from the top load of the secondary coil. Tesla coil is an electrical thunderous transformer planned by Nicola Tesla which has both primary and secondary side like other regular transformers. In secondary side, secondary coil is utilized with top burden to make primary LC circuit. It is answerable for creating the exceptionally high voltage in primary side of Tesla loop. In tesla coil strategy as we referenced before that the oscillator circuit offers contribution to the primary coil with an extremely high frequency, magnetic field produce in the middle of primary and secondary coil and this magnetic field actuates an electric flow in the primary coil. This current later produce an induced voltage in the secondary coil and furthermore in the primary coil a magnetic field is initiated in a certain are focusing this primary coil. Along these lines, secondary coil fundamentally makes a range where it can move power to the loads and this voltage changed over to a usable structure is utilized to control gadgets. In the structuring procedure, secondary coil ought to be plan first before planning the primary coil.

Table 5.2: Secondary coil measurement

Coil diameter	20mm
Number of turns	20
Length of wire	2m

5.6 Load Coil

Tesla coil makes magnetic field encompassing in a specific region focusing the secondary coil. Around there are electromagnetic waves with exceptionally high frequency. This high frequency power in electromagnetic structure cannot be utilized in any of the electronic or electric gadgets. So after the transfer of power wirelessly it is obligatory to receive that energy in which structure it is than it is expected to change over in a usable structure. Load coil is such a coil, that receive that energy and induce a voltage than convert it to another form. To develop a load coil for our project to receive power wirelessly from tesla coil, 20 turns of 32 AWG copper wire is taken. It was winded in a plastic of roughly 1inch distance across. The two terminals of the load coil is associated with the full bridge rectifier circuit to convert it into a DC voltage. One terminal goes to the info (positive terminal) of the rectifier circuit and another goes to the ground. Before connecting to the circuit, the terminals of the coil wire is scratched to the coating of the surface for the better conduction. Load coil that is used to catch power wirelessly and power up devices wirelessly. The rectifier circuit gets power from this load coil. Basically, the load coil works as a voltage source for the rectifier circuit.

5.7 AC to DC conversion circuit

As referenced before, electric power is required in a usable structure to drive any electronic or electric gadgets. Tesla coil drives in a high frequency voltage but most our day by day life appliance runs in 50 or 60 Hz of frequency. Tesla coil runs at a high frequency and produces higher frequency to keep up the LC resonance frequency. Whatever the power tesla coil delivers wirelessly cannot be utilized directly to any gadgets rather it is important to change over that gotten capacity to a usable structure. We know from the law of conservation of energy that the summation of the energy is consistent, it simply can be changed starting with one structure then onto the next. This idea is used here moreover. That high frequency electromagnetic power is caught with the load coil and moved to the AC to DC changing over circuit which is the full bridge rectifier. In section 6 the subtleties of the full scaffold rectifier is talked about intricately. Fig. 6.3 is the schematic chart of the full scaffold rectifier and the Fig. 6.5 is the circuit arrangement of the full bridge rectifier which changes over AC voltage to DC voltage. This AC to DC change is utilized multiple times in our undertaking, one in the oscillator circuit and another in the getting side to supply the DC voltage to the load LED.

CHAPTER 6
OSCILLATOR CIRCUIT

6.1 Introduction

There are numerous ways to move power wirelessly with different effectiveness. The kinds of wireless power transfer is talked about before parts with their advantages and disadvantages. Utilization of tesla coil in wireless power transfer was additionally referenced before. Tesla coil is bit complicated to operate through it is sort of transformer dislike a typical transformer. Usefulness of a tesla coil is confused to such an extent that it has exceptionally confounded working conditions and property. The development of a tesla coil is additionally exceptionally confounded and one must be cautious about it else all the difficult work will go futile. A slight blunder in estimation or imprudence in development can pulverize all the work you have done as such far. Working tesla curl is likewise a major issue as it requires many confused and perilous conditions. It requires high voltage, high frequency with low substituting current. Presently the inquiry emerge why it is so entangled and why it requires such a significant number of conditions to work tesla coil. As referenced before, it isn't only an average advance up transformer as it has a lot more turns in the optional side contrasted with the essential side with 1:100 turns proportion. In contrast to a normal transformer, every one of its properties not just rely upon turns proportion rather it relies upon a lot more things like working recurrence, voltage or resounding recurrence. Tesla loop is a high voltage, high recurrence transformer and it needs high recurrence to work. The fundamental working strategy of acceptance as per Faraday's law that instigated voltage relies upon pace of progress of transition linkage, pace of progress of motion relies upon the present stream in per unit time cycle. On the off chance that the frequency is so high, the pace of progress of transition will likewise be high which increment the instigated voltage in the optional side as the information high frequency substituting voltage applied. Based on the rationale or property it is important to give high frequency voltage in the primary side of the tesla coil as it knocks up the voltage surprisingly high with the 1:100 proportion. So on the off chance that one needs a tesla coil to work splendidly fine, the working voltage and frequency must be sufficiently high. This is the reason we constructed a swaying circuit to expand the frequency of the information voltage of the tesla coil. Later in the section the entire wavering circuit will be described with the output diagram of that circuit.

6.2 Use of oscillator circuit in tesla coil

Tesla loop is complicated electrical device which needs a complicated working system. It is a sort of transformer but a path not quite the same as the typical conventional transformer. Normally a typical transformer is either a step up or step-down with some variation in function. Tesla coil is constantly a step-up transformer with unordinary ascent of voltage and frequency. Tesla coil is a resonant transformer containing a primary and secondary LC circuit which is approximately coupled together. A high voltage power is provided to the primary side through a transformer which charges a capacitor and afterward it will release through a spark gap into the primary coil. The energy will oscillate to and fro between the primary capacitor and primary coil inductor at high frequencies (commonly 100 - 300 kHz). As the primary circuit oscillates, power is prompted in the secondary coil where the voltage is multiplied many times. The primary and the secondary LC circuit must oscillate at a similar frequency to achieve the maximum power transfer [27]. The oscillation or resonance frequency depends upon the inductance (L) and the capacitance (C) of both of the primary and secondary side of a tesla coil. The equation for the resonance frequency (f) was mentioned earlier. Presently the inquiry emerges, how to compute and coordinate the resonance frequency for a specific tesla coil. As we probably am aware this resonance frequency depends upon the estimation of L and C, a product name Tesla CAD would do it by the estimation of the inductance, L of the secondary coil by the AWG, number of turns, input voltage and frequency and the diameter of the coil. Here comes the fundamental part, what ought to be the information frequency of the tesla coil and why. The tesla coil takes a shot at the acceptance property, from the primary equation about enlistment, Faraday's law we realize that the actuated voltage is relative to the pace of progress of transition linkage. The more the change of flux, the more the induced voltage. The change of flux depends, on the frequency of the progression of current. The increase in the frequency of the progression of the current, the increment in the change of flux and hence increment in the actuated voltage. For the most part in Bangladesh our AC is in 50Hz however a tesla coil works commonly in 100 - 300 kHz which is actually a high frequency. So it actually a sensitive work which must be done carefully.

6.3 Design of oscillator circuit

Tesla coil to operate it is necessary to increase frequency of the input voltage. The whole process of designing a oscillator circuit can be divided into several parts like,

1. Step down process
2. AC to DC conversion process
3. Oscillating process
4. Filtering process

First of all, AC 220V is stepped down to 12V AC with a stage down transformer. From that point onward, with a full bridge rectifier circuit, 12V AC is changed over into a 12V DC which will be the contribution for the oscillator circuit. The oscillator circuit will give the beat wave with an exceptionally high frequency. At last, with a RLC channel circuit we will get the sinusoidal voltage waveform which will be the contribution of the primary coil of the tesla coil through a capacitor.

The main job is to step down the 220V AC to 12V AC with a little step down transformer which is accessible in the market or one can arrange in the market with their detail. To maintain a strategic distance from a great deal of complicacy it is savvier to utilize an instant transformer accessible in the market with legitimate determination. We purchased a stage down transformer structure the market and its detail is, I/P: 220V ~ 50Hz

O/P: 12Vx2 1000mA

Fig. 6.1: Step-down Transformer [31]

Fig. 6.1 shows the step-down transformer what is utilized during our project. Here 12Vx2 means that we can either get 12V or 24V in the output. With the proper combination of two from the three wires in the output side can give the desire output. For example, if one takes the output from the black and yellow wires, will get 12V AC as an output, if an output is taken from the two black wires, 24V AC they will get. We took 12V AC with the black and yellow combination from the output.

In the wake of getting the ventured down AC voltage, we changed over the AC to DC voltage with the rectifier circuit and smooth is with a capacitor. Fig 6.2 shows a full bridge rectifier circuit which changes over the 12V AC to 12V DC that goes to the oscillator input. A full extension rectifier is comprised

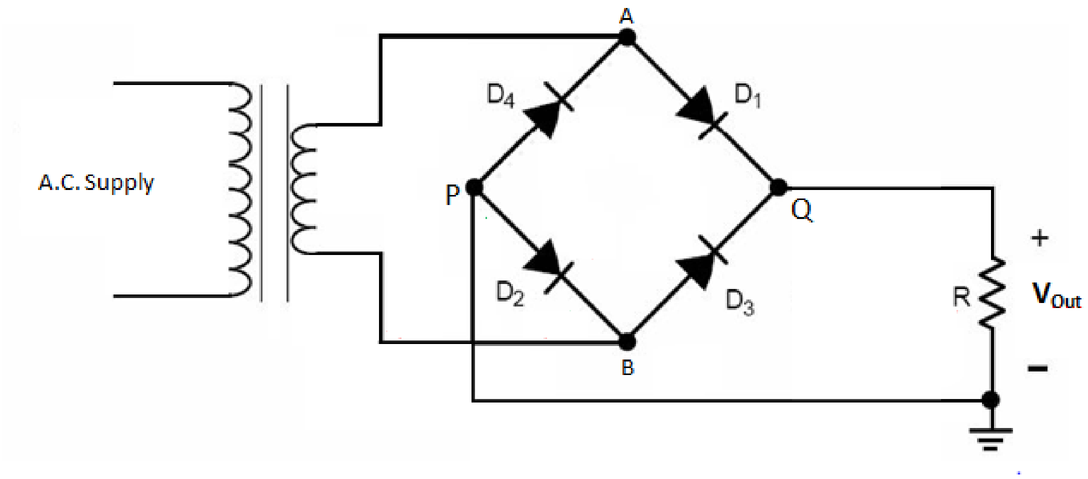

Fig.6.2: Full bridge rectifier [32]

of four diodes which changes over both of the cycles of an AC voltage into an unadulterated DC voltage. The four diodes are associated in arrangement sets with just two diodes directing during every half cycle. During the positive half cycle the diodes marked D1 and D2 (Fig. 6.2) are leading in arrangement association while different diodes are backward one-sided and current is streaming toward a path. During the negative half cycle, the diodes D3 and D4 are leading in arrangement association while different diodes are backward one-sided and the current is streaming a similar way as in the past. As the present moving through the heap is unidirectional, the voltage created over the heap is likewise unidirectional. Anyway actually, every diode drops 0.7V, so during each push current courses through two diodes, so the sufficiency of the yield voltage is two voltage drops (2X0.7V = 1.4V) not exactly the info voltage Vmax plentifulness. There is additionally a capacitor parallel to the heap. This capacitor is known as the smoothing capacitor as it smooths the yield DC voltage to an unadulterated DC voltage. The smoothing capacitor diminishes the AC variety of the redressed yield. This smoothing capacitor changes over the full wave DC swell voltage into an increasingly smooth DC voltage. We should be cautious picking the ideal capacitor. On the off chance that the capacitance esteem is too low has the little impact on the yield voltage. On the off chance that the smoothing capacitance esteem is adequately huge enough, the yield voltage is as smooth as unadulterated DC [33].

We have constructed our full bridge rectifier circuit to convert 12v AC to 12 V DC voltage.

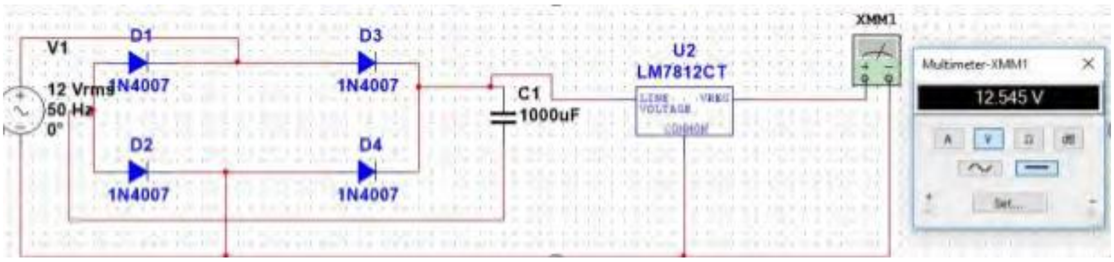

Fig.6.3: Schematic diagram of full bridge rectifier

voltage regulator IC LM7812CT is used to regulate voltage. **Fig. 6.3** shows our full bridge rectifier circuit simulated in oscilloscope. In our rectifier circuit 1N4007 series four diodes are used along with smoothing 1000µF capacitor. In each half cycle there is a drop of 1.4V as two diodes are in series in different combination (D1 & D2 or D3 & D4) in every cycle. IC LM7812CT is a voltage regulator to maintain the 12V DC at the output side of the oscillator circuit.

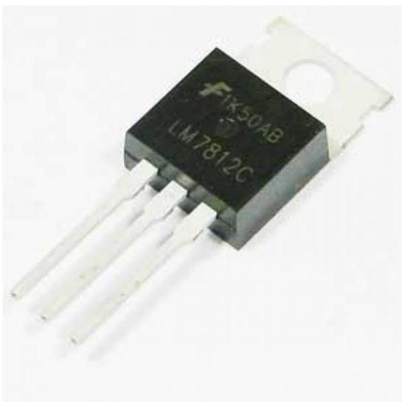

Fig.6.4: IC LM7812CT [34]

6.4 Result

To drive the coil it is essential to increase the input frequency of the voltage because a typical medium sized tesla coil requires at least 100-300 kHz frequency and mini or small sized tesla coil requires at least 80-100 kHz frequency. But for our projected device we need a fix 50 Hz frequency. In the simulation process for the oscillator circuit in project we got 50 Hz frequency with peak RMS voltage of the pulse wave is 4.9V and approximately 5V with the help of a voltage booster. All the result we got in simulation and practical is mentioned down in the table 6.5.

Table 6.1: Simulation vs Practical result of oscillator circuit

Simulation result	Practical result
Frequency 50Hz	Frequency 50Hz
Voltage Peak 1.60V	Voltage Peak 5V

CHAPTER 7

RESULTS AND DISCUSSION

7.1 Introduction

Tesla coil is utilized for wirless power transfer everywhere throughout the world. In any case, to make it work, the frequency must be in excess of 50 kHz, else it won't work. There are numerous approaches to incrase the frequency. For enormous tesla coil and huge output power, Neon Sign Transformer (NST) is utilized. The output voltage of NST is 20-30 kV which is utilized as the contribution of the primary coil through an primary capacitor. We worked with the smaller than expected tesla coil and for little tesla coil, the info voltage is extremely low with a high frequency. Along these lines, we utilized oscillation circuit to increase the frequecy. The possibility of our task-based theory is to transfer power wirelessly, and to get a thought of effectiveness. The point by point result is examined in area 7.2.

7.2 Result analysis

The frequency of our smaller than normal coil model was 50Hz. To measure the output voltage of the secondary voltage, we couldn't utilize multimeter, in light of the fact that multimeter doesn't work when the frequency is so high. It gives a voltage rating which fluctuates between 0 - 1V. Thus, we made a receiver coil which was associated with a full bridge rectifier circuit, to change over the AC output to DC. At that point we estimated the DC output voltage with a multimeter shifting the separation of the receiver coil from the secondary coil. We got output voltage up to 20mm (milimeter) separation. After that the voltage drops to zero. The voltage we got from the receiver circuit at various separations are given bellow in the Table 7.1.

Table 7.1: DC output voltage at different height

Height (mm)	O/P Voltage
1	4.9
5	4.3
10	4.1
15	3.8
20	2.9
25	0

Table 7.2: DC output voltage at different distances from right side

Right Side Distance (mm)	O/P Voltage
1	4.5
5	3.6
10	2.7

Table 7.3: DC output voltage at different distances from left side

Left Side Distance (mm)	O/P Voltage
1	4.3
5	3.3
10	2.4

From the table, we can see that the output voltage is inversely proportional with distance. As the distance, the output voltage decrease. At zero distance, the output voltage is maximum. It remains constant up to

7.3 Power calculation

In our proposed wireless power transfer system, the input is given through a step-down transformer. So the input power must be determined from the transformer. We know from the fundamental idea of transformer that is the force is steady in the both of the sides of transformer. In transformer the voltage is stepped up or down adjusting the current. From the power calculation formula,

$$P = VI \cos\theta$$

That implies, voltage, V is inversely proportional to the current, I. Along these lines, in step down transformer the voltage is stepped down and rising the current to keep up the force consistent. The force in the primary side is equivalent to the force in the secondary side regardless of whether the voltage is either stepped up or down. Thus, if anyone want to calculate power for a transformer, they can either quantify power from the primary side or from the secondary side, both of the cases they will get the precisely same outcome and whichever way is right. We determined the info power from the

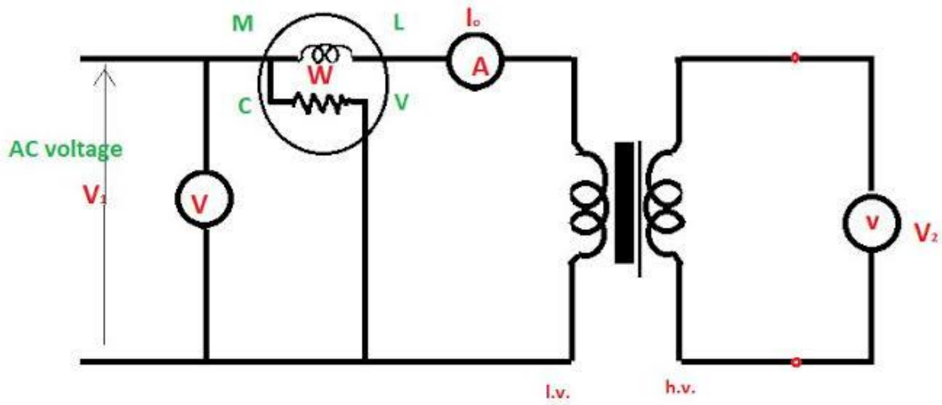

Fig.7.1: Wattmeter connection to the transformer [35]

Primary side of the transformer. We connected the wattmeter in the primary side of thr transformer like in **Fig 7.2**. The wattmeter was shorted as required before connecting to the transformer. The wattmeter gave the reading of Pin = 2watt power at the input side. The reading of the wattmeter measuring the input power. We measured the output voltage from the receiver circuit, across the LED connected to the full wave rectifier circuit. We measured the current across the LED as well. The maximum output voltage we got is 4.9. So, with 4.9V DC the LED draws 10mA of current. The DC ammeter reading of the output current drawn by LED at the full bridge rectifier. The maximum output power we got is

Output power = VI

= 4.9*0.01

= 0.049 watt

So, the maximum output power we got wirelessly is 0.049 watt. The output power is very low, as there is a power loss in the receiver coil, across the diodes used in the rectifier circuit. There is a power loss across each component of the oscillator circuit as well. As a result, we got very low output power, just enough to light up LEDs. The maximum power loss is through the air during the transmission wirelessly. Tn large scale wireless power transfer system, large tesla coil is used where oscillating circuit is replaced by neon sign transformer. As a result, no power loss across the neon sign transformer. So the output power is much higher.

7.4 Efficiency

Effectiveness implies the proportion of the valuable work performed by a machine or in a procedure to the all out energy used or heat taken in [31]. In our proposed remote force move framework, productivity demonstrates how well we could convey power wirelessly.

Our information power was 2 watt and the yield power from the recipient circuit was 0.02803 watt.

Along these lines, the general effectiveness is**,**

N = (0.049/2) * 100

=2.45%

The effectiveness we got from our proposed wireless power transfer system is exceptionally low. Yet, there are a few different ways which we discovered from the exploration and useful trial. Most importantly, the info power we utilized is exceptionally low. As we worked with the small-scale tesla coil, we utilized wavering circuit to increase the frequency. There is a misfortune in each hardware of the swaying circuit. In any case, in the event that we go for huge scale wireless force, we need to make a huge tesla coil. In enormous tesla loop, neon sign transformer is utilized, and the output voltage of the transformer which is utilized as the contribution to the primary tesla coil. All the more critically, no force misfortune happens over the transformer [35]. Besides, in huge tesla loop, sparkle hole is utilized in the middle of the neon sign transformer and primary coil of the tesla coil [35]. Capacitor bank is additionally utilized with the primary loop. Topload functions as the secondary loop capacitor to coordinate resonance [35]. We didn't utilize of this things in our smaller than usual tesla coil circuit. Another significant parameter is the turns proportion. For enormous tesla coil, higher turns are utilized in the secondary loop. The proportion of the primary coil and secondary loop is regularly 1:100 [35].

Also, we estimated the output over the LED from the rectifier circuit which was associated with the secondary coil. Subsequently, there was power misfortune over every segment of the secondary circuit, an air misfortune in the middle of the secondary coil of the tesla loop and the receiver loop.

For large scale wireless power transfer, we have to make the whole circuit in different way, and the large tesla coil circuit diagram is given below:

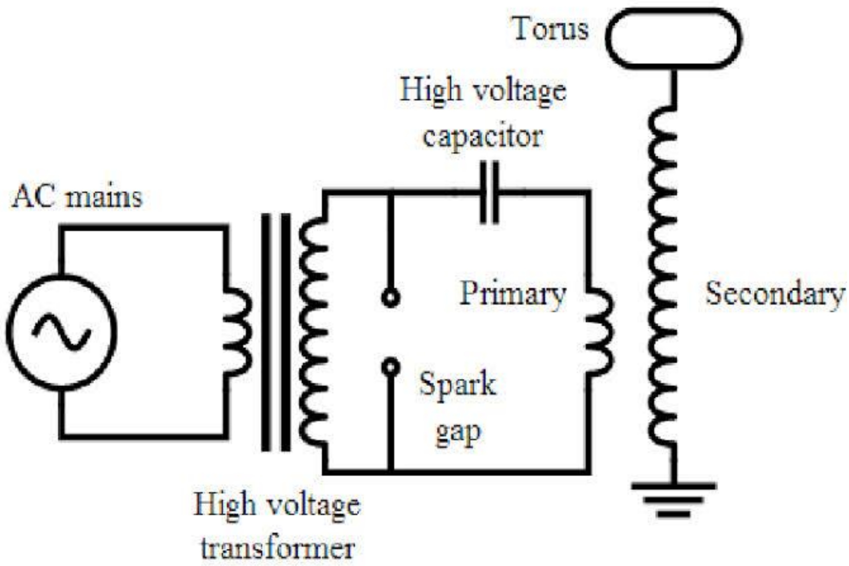

Fig. 7.2: Large tesla coil diagram [37]

This is the circuit diagram of the large tesla coil, with a higher efficiency and higher range as well. In this way, we will develop our design and increase the efficiency.

CHAPTER 8
CONCLUSION AND SUMMARY

8.1 Introduction

The proposed wireless power transfer utilizing tesla coil indicated a promising outcome as our primary goal was to build up a wireless power transfer system. We got some output voltage to the receiver coil a good way off up to 20 millimeter which drops at 4.9. We changed over the output power from AC to DC lastly had the option to charge a cell phone battery. We utilized step down tesla coil for this experience and found that it is conceivable to move more capacity to a more drawn out range utilizing enormous tesla coil. The oscillating circuit was the principle part of this experience. We need to increase the frequency in excess of 50 kHz to make the tesla coil work. The effectiveness of wireless power supply generally relies upon the capacitor estimations of the wavering circuit. The simulation part shows that, on the off chance that we change the capacitor esteem, the frequency changes and with higher frequency, we can move more power wirelessly to higher distance. This shows the proficiency and the range can be improved.

8.2 Limitation

The major problem of wireless power transfer utilizing tesla coil is, the efficiency is inversely relative to the distance. Therefore, it can transfer extremely low force at higher distance. Thus, the general efficiency is low. Estimating the output voltage is another issue we faced. As the frequency is in excess of 50 kHz, the multimeter doesn't work appropriately. The output voltage rating from the multimeter varies from zero to one volt. The principle issue is that, the output is beat. In this way, utilizing an oscilloscope won't be fitting. Utilizing a voltage divider, we can get the yield from the oscilloscope or multimeter [38]. The receiver coil ought to be in appropriate arrangement to get greatest force at the load.

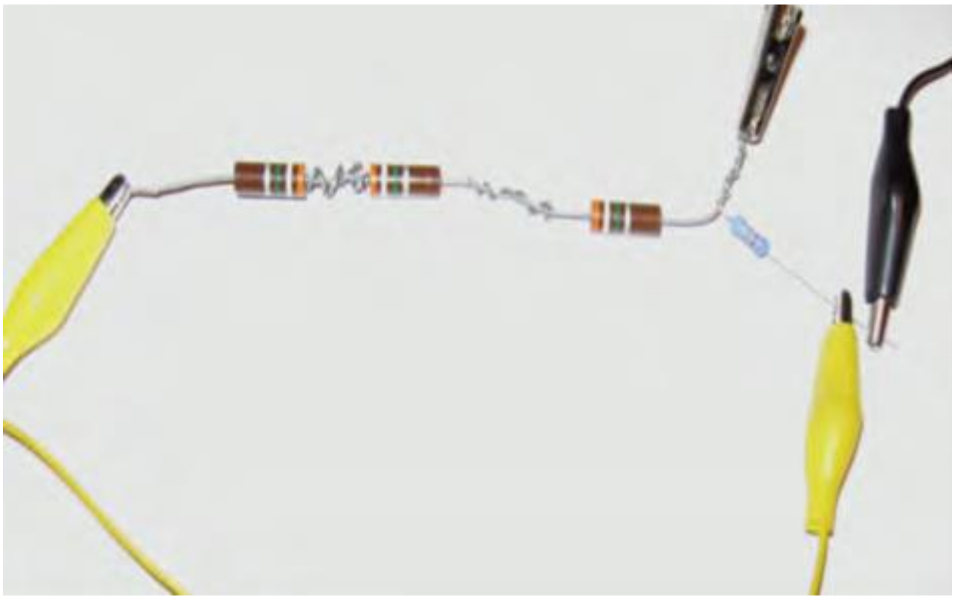

Fig. 8.1: Output measurement using voltage divider [38]

Another major problem of wireless power transfer is, all devices, which are in the range of the tesla coil, will go about as a receiver and draw a load. Each gadget, which will be charged wirelessly, ought to have worked in over current security as the current noticeable all around will be sufficiently high to move power effectively [39]. The wireless system is simple and safe, contrasting with the previous framework. However, it is exorbitant. Our body can resist to low frequency voltages which can hurt us our life to death. As tesla coil works at an exceptionally high frequency and delivers significantly progressively higher frequency which our body cannot avoid and doesn't unsafe by any stretch of the imagination. So it tends to be said that tesla coil has no wellbeing danger.

8.3 Future work

Wireless power transfer has a promising future. We will be over ambitious in the event that we state that wireless power transfer will be utilized in the transmission framework since, most importantly, it will cost a great deal to plant this framework. Also, keeping up transmission timetable of wireless power transfer will be extreme. Thirdly, all gadgets ought to have worked in security. Be that as it may, soon, on street remote charging for electric vehicles will be presented. Electric vehicles will get energized while traveling through the street. There will be a recipient at the base of the electric vehicle, which will get power through attractive enlistment from the street and the street will be adjusted so that it will convey power from the tesla curl. Another method for this on street charging is, remote force will be moved from bars, which will be situated along the edge of the street. This time, the collector will be put at the highest point of the electric vehicle. Each shaft has its range. At the point when an electric vehicle comes in the scope of a pillar, the receiver of that vehicle will get power from that bar. The beam will be put so that, when an electric-vehicles moves out of the range of a pillar, it will be in the range of another. Along these lines, it will get power reliably through the road.

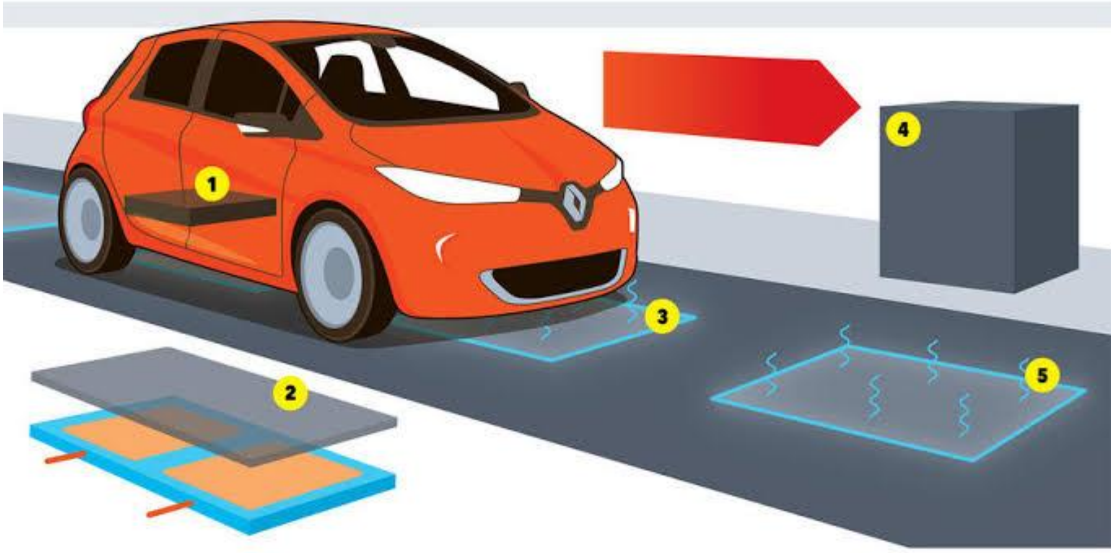

Fig. 8.2: On road charging electric vehicle

Device like mobiles and laptops will get charged up while being used. People do not have to be tensed about the charging issue of these devices anyone. It will be time saving and less hazardous for people. Moreover, the charging will be faster.

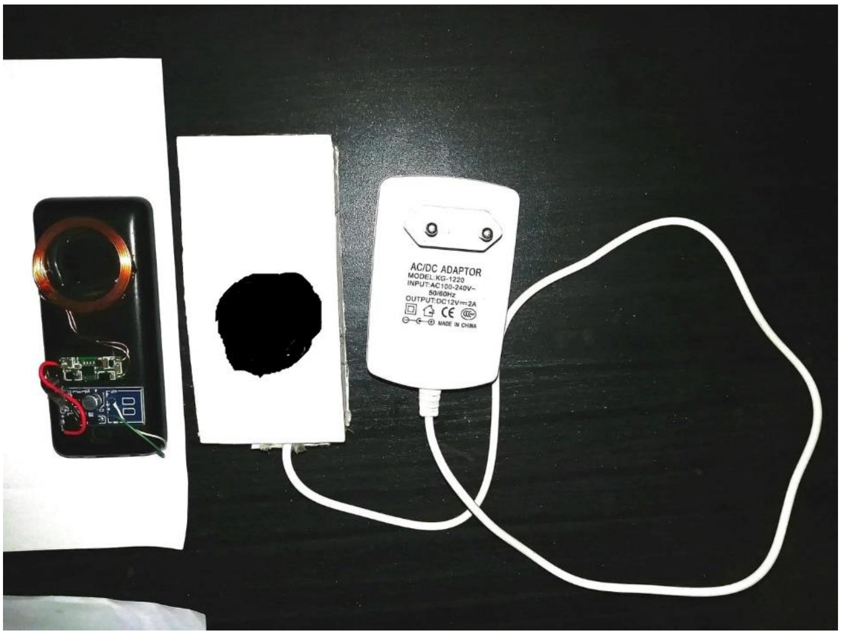

Fig.8.3: Wireless mobile charger

8.4 Conclusion

The proposed thesis on the based project was to convey power wirelessly. Our examination and handy execution indicated positive outcomes. We had the option to transfer power wirelessly and the proficiency was 2.45% which is low. In any case, from the exploration, we found that, the productivity can be expanded. As the output power is contrarily relative with the separation, it is particularly testing to improve the productivity. Many researches are proceeding to improve the efficiency.

This task demonstrates numerous promises to the efficient power vitality framework. In any case, to do as such, we need to increase the efficiency first. On the off chance that we can develop this structure to get a sufficiently high efficiency, we may be going for the huge scale wireless power transmission grid, which was the fantasy of Nikola Tesla when he originally developed tesla coil. In spite of the fact that it appeared that, he was somewhat over aspiring around then, late research results show that, it very well may be possible.

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APPENDIX A

BLOCK DIAGRAM

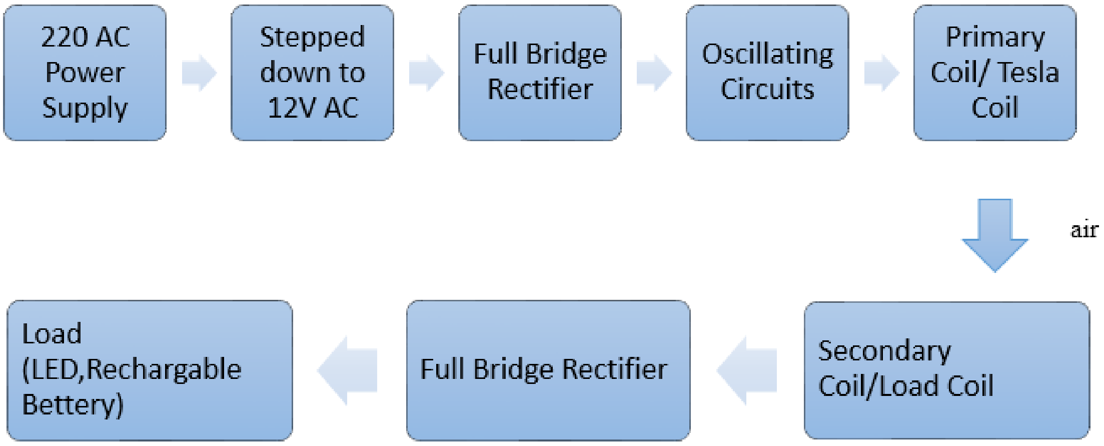


Fig. Block diagram of overall system

APPENDIX B

SCHEMATIC DIAGRAM

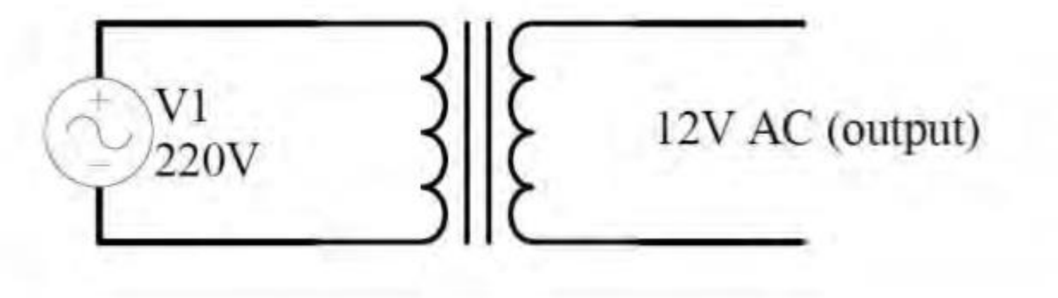


Fig. Step-down transformer

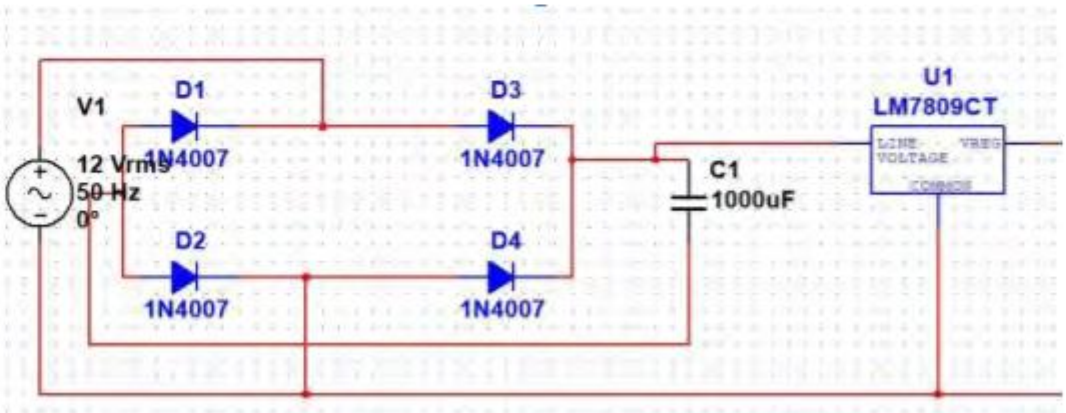


Fig. Full bridge rectifier

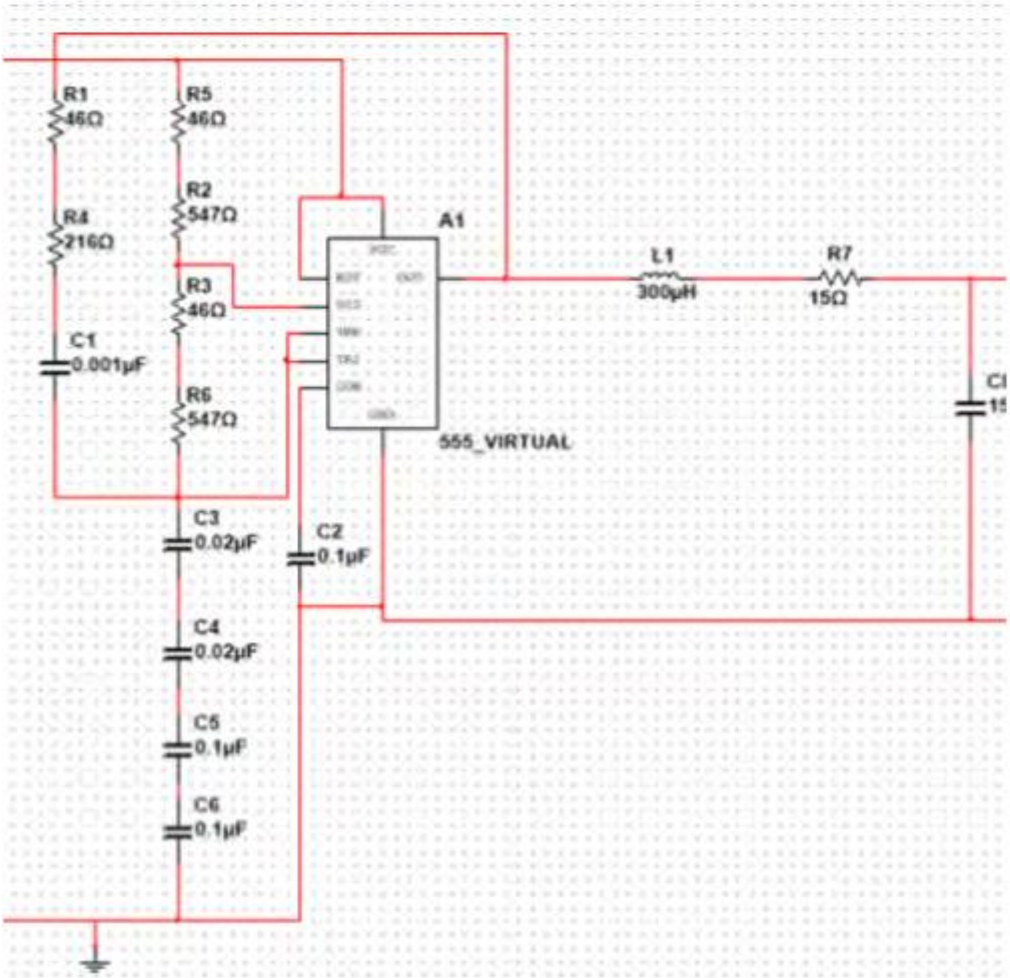


Fig. Oscillator circuit with low pass filter

Fig. Primary capacitor

Fig. Mini coil

Fig. Air medium

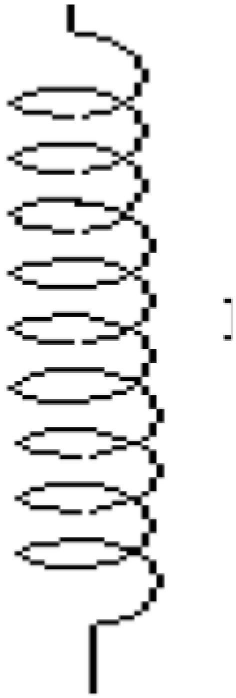


Fig. Load coil

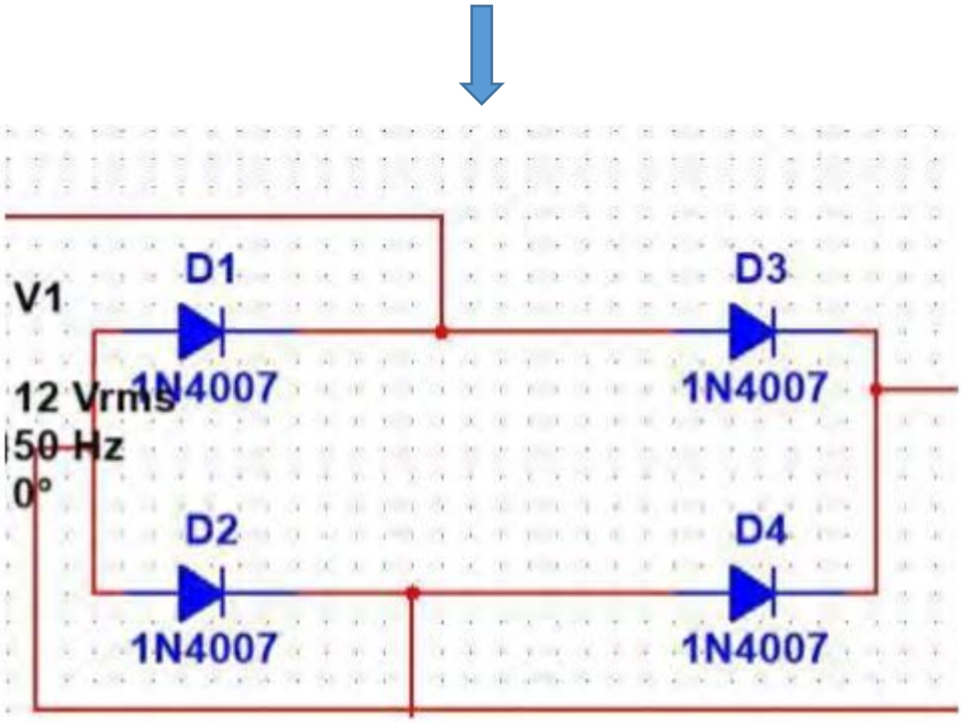


Fig. Full bridge rectifier

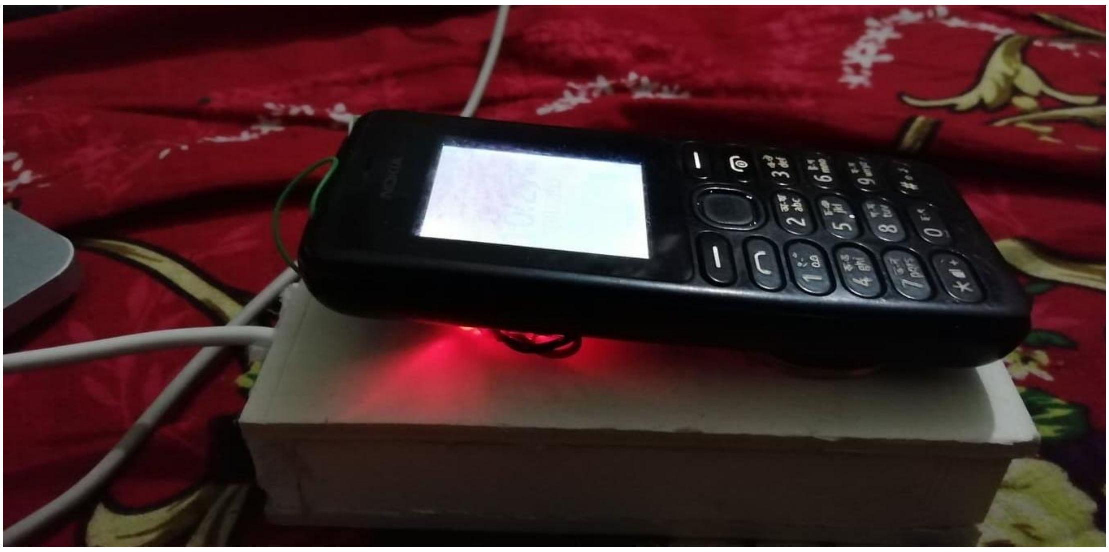


Fig. Wireless charging

APPENDIX C

COMPONENT

Step-down transformer

Fig. Step down transformer

Step down transformer has been used to convert the 220V ac into 12V ac. One black wire is connected to the oscillator circuit and yellow wire is connected to ground. It supplies 12V ac voltage to the oscillator circuit.

555 Timer IC

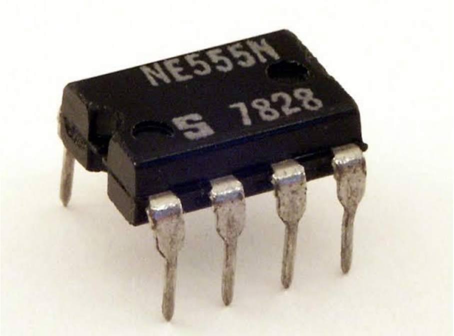


Fig. 555 timer

This IC is used for pulse generated signal. It is an 8pin configuration IC and without this chip, the oscillator circuit cannot perform properly as it will not generate pulse signal. Without these pulse signal, the oscillator circuit will not work. This IC is also known as the driver of the oscillator circuit.

Primary coil

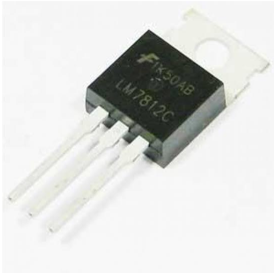
Fig. Primary coil

Secondary coil

Fig. Secondary coil

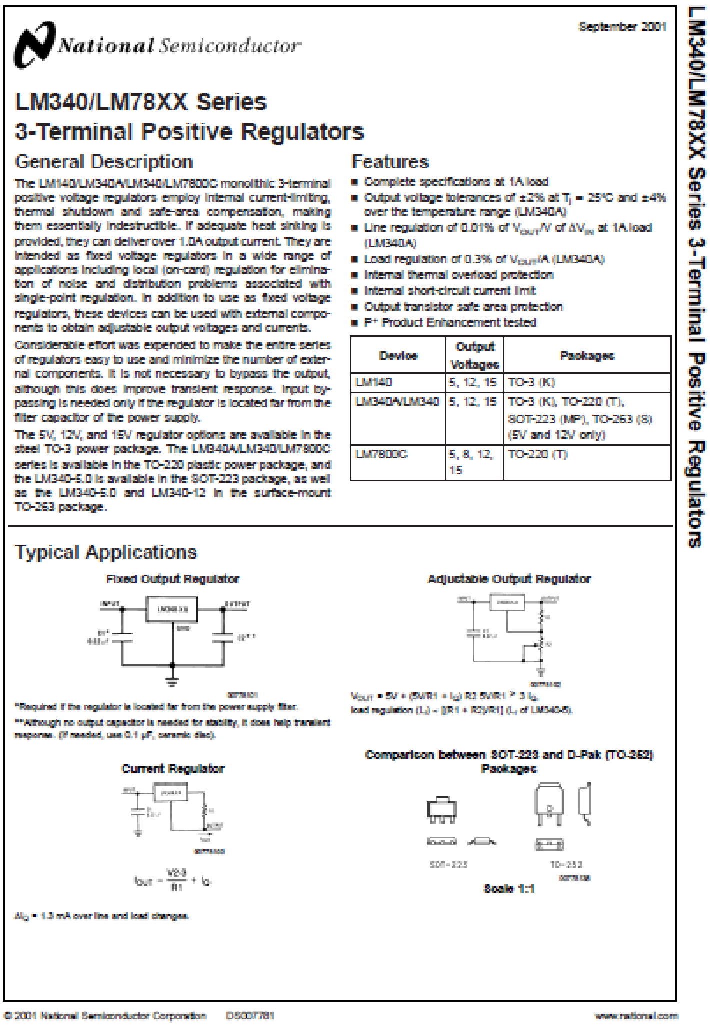
APPENDIX D

DATASHEET



LM78XX Series Voltage Regulator

General Description
The LM78XX series of three terminals



September 2001

National Semiconductor

LM340/LM78XX Series 3-Terminal Positive Regulators

General Description

The LM140/LM340A/LM340/LM7800C monolithic 3-terminal positive voltage regulators employ internal current-limiting, thermal shutdown and safe-area compensation, making them essentially indestructible. If adequate heat sinking is provided, they can deliver over 1.0A output current. They are intended as fixed voltage regulators in a wide range of applications including local (on-card) regulation for elimination of noise and distribution problems associated with single-point regulation. In addition to use as fixed voltage regulators, these devices can be used with external components to obtain adjustable output voltages and currents.

Considerable effort was expended to make the entire series of regulators easy to use and minimize the number of external components. It is not necessary to bypass the output, although this does improve transient response. Input bypassing is needed only if the regulator is located far from the filter capacitor of the power supply.

The 5V, 12V, and 15V regulator options are available in the steel TO-3 power package. The LM340A/LM340/LM7800C series is available in the TO-220 plastic power package, and the LM340-5.0 is available in the SOT-223 package, as well as the LM340-5.0 and LM340-12 in the surface-mount TO-263 package.

Features

- Complete specifications at 1A load
- Output voltage tolerances of ±2% at T_j = 25°C and ±4% over the temperature range (LM340A)
- Line regulation of 0.01% of V_{OUT}/V of ΔV_{IN} at 1A load (LM340A)
- Load regulation of 0.3% of V_{OUT}/A (LM340A)
- Internal thermal overload protection
- Internal short-circuit current limit
- Output transistor safe area protection
- P^+ Product Enhancement tested

Device	Output Voltages	Packages
LM140	5, 12, 15	TO-3 (K)
LM340A/LM340	5, 12, 15	TO-3 (K), TO-220 (T), SOT-223 (MP), TO-263 (S) (5V and 12V only)
LM7800C	5, 8, 12, 15	TO-220 (T)

LM340/LM78XX Series 3-Terminal Positive Regulators

Typical Applications

Fixed Output Regulator

*Required if the regulator is located far from the power supply filter.

**Although no output capacitor is needed for stability, it does help transient response. (If needed, use 0.1 µF, ceramic disc).

Adjustable Output Regulator

V_{OUT} = 5V + (5V/R1 + I_Q) R2 5V/R1 > 3 I_Q,
load regulation (L_r) ≈ [(R1 + R2)/R1] (L_r of LM340-5).

Current Regulator

$I_{OUT} = \frac{V2\text{-}3}{R1} + I_Q$

ΔI_Q = 1.3 mA over line and load changes.

Comparison between SOT-223 and D-Pak (TO-252) Packages

SOT-223 TO-252

Scale 1:1

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Absolute Maximum Ratings (Note 1)

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/ Distributors for availability and specifications.

(Note 5)

DC Input Voltage	
All Devices except LM7824/LM7824C	35V
LM7824/LM7824C	40V
Internal Power Dissipation (Note 2)	Internally Limited
Maximum Junction Temperature	150°C
Storage Temperature Range	−65°C to +150°C
Lead Temperature (Soldering, 10 sec.)	
TO-3 Package (K)	300°C
TO-220 Package (T), TO-263 Package (S)	230°C
ESD Susceptibility (Note 3)	2 kV

Operating Conditions (Note 1)

Temperature Range (T_A) (Note 2)	
LM140A, LM140	−55°C to +125°C
LM340A, LM340, LM7805C, LM7812C, LM7815C, LM7808C	0°C to +125°C

LM340A Electrical Characteristics

I_{OUT} = 1A, −55°C ≤ T_J ≤ +150°C (LM140A), or 0°C ≤ T_J ≤ + 125°C (LM340A) unless otherwise specified (Note 4)

Symbol	Output Voltage		5V			12V			15V			Units
	Input Voltage (unless otherwise noted)		10V			19V			23V			
	Parameter	Conditions	Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	
V_O	Output Voltage	T_J = 25°C	4.9	5	5.1	11.75	12	12.25	14.7	15	15.3	V
		P_D ≤ 15W, 5 mA ≤ I_O ≤ 1A	4.8		5.2	11.5		12.5	14.4		15.6	V
		V_{MIN} ≤ V_{IN} ≤ V_{MAX}	(7.5 ≤ V_{IN} ≤ 20)			(14.8 ≤ V_{IN} ≤ 27)			(17.9 ≤ V_{IN} ≤ 30)			V
ΔV_O	Line Regulation	I_O = 500 mA			10			18			22	mV
		ΔV_{IN}	(7.5 ≤ V_{IN} ≤ 20)			(14.8 ≤ V_{IN} ≤ 27)			(17.9 ≤ V_{IN} ≤ 30)			V
		T_J = 25°C		3	10		4	18		4	22	mV
		ΔV_{IN}	(7.5 ≤ V_{IN} ≤ 20)			(14.5 ≤ V_{IN} ≤ 27)			(17.5 ≤ V_{IN} ≤ 30)			V
		T_J = 25°C			4			9			10	mV
		Over Temperature			12			30			30	mV
		ΔV_{IN}	(8 ≤ V_{IN} ≤ 12)			(16 ≤ V_{IN} ≤ 22)			(20 ≤ V_{IN} ≤ 26)			V
ΔV_O	Load Regulation	T_J = 25°C, 5 mA ≤ I_O ≤ 1.5A		10	25		12	32		12	35	mV
		T_J = 25°C, 250 mA ≤ I_O ≤ 750 mA			15			19			21	mV
		Over Temperature, 5 mA ≤ I_O ≤ 1A			25			60			75	mV
I_Q	Quiescent Current	T_J = 25°C			6			6			6	mA
		Over Temperature			6.5			6.5			6.5	mA
ΔI_Q	Quiescent Current Change	5 mA ≤ I_O ≤ 1A			0.5			0.5			0.5	mA
		T_J = 25°C, I_O = 1A			0.8			0.8			0.8	mA
		V_{MIN} ≤ V_{IN} ≤ V_{MAX}	(7.5 ≤ V_{IN} ≤ 20)			(14.8 ≤ V_{IN} ≤ 27)			(17.9 ≤ V_{IN} ≤ 30)			V
		I_O = 500 mA			0.8			0.8			0.8	mA
		V_{MIN} ≤ V_{IN} ≤ V_{MAX}	(8 ≤ V_{IN} ≤ 25)			(15 ≤ V_{IN} ≤ 30)			(17.9 ≤ V_{IN} ≤ 30)			V
V_N	Output Noise Voltage	T_A = 25°C, 10 Hz ≤ f ≤ 100 kHz		40			75			90		µV
$\frac{\Delta V_{IN}}{\Delta V_{OUT}}$	Ripple Rejection	T_J = 25°C, f = 120 Hz, I_O = 1A	68	80		61	72		60	70		dB
		or f = 120 Hz, I_O = 500 mA, Over Temperature,	68			61			60			dB
		V_{MIN} ≤ V_{IN} ≤ V_{MAX}	(8 ≤ V_{IN} ≤ 18)			(15 ≤ V_{IN} ≤ 25)			(18.5 ≤ V_{IN} ≤ 28.5)			V
R_O	Dropout Voltage	T_J = 25°C, I_O = 1A		2.0			2.0			2.0		V
	Output Resistance	f = 1 kHz		8			18			19		mΩ

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LM340/LM78XX

LM7808C
Electrical Characteristics

0°C ≤ T_J ≤ +150°C, V_I = 14V, I_O = 500 mA, C_I = 0.33 µF, C_O = 0.1 µF, unless otherwise specified

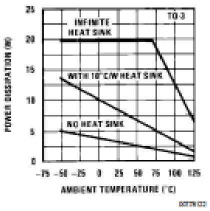
Symbol	Parameter	Conditions (Note 6)	LM7808C Min	LM7808C Typ	LM7808C Max	Units
V_O	Output Voltage	T_J = 25°C	7.7	8.0	8.3	V
ΔV_O	Line Regulation	T_J = 25°C, 10.5V ≤ V_I ≤ 25V		6.0	160	mV
		T_J = 25°C, 11.0V ≤ V_I ≤ 17V		2.0	80	
ΔV_O	Load Regulation	T_J = 25°C, 5.0 mA ≤ I_O ≤ 1.5A		12	160	mV
		T_J = 25°C, 250 mA ≤ I_O ≤ 750 mA		4.0	80	
V_O	Output Voltage	11.5V ≤ V_I ≤ 23V, 5.0 mA ≤ I_O ≤ 1.0A, P ≤ 15W	7.6		8.4	V
I_Q	Quiescent Current	T_J = 25°C		4.3	8.0	mA
ΔI_Q	Quiescent Current Change, With Line	11.5V ≤ V_I ≤ 25V			1.0	mA
	Quiescent Current Change, With Load	5.0 mA ≤ I_O ≤ 1.0A			0.5	
V_N	Noise	T_A = 25°C, 10 Hz ≤ f ≤ 100 kHz		52		µV
$\Delta V_I/\Delta V_O$	Ripple Rejection	f = 120 Hz, I_O = 350 mA, T_J = 25°C	56	72		dB
V_{DO}	Dropout Voltage	I_O = 1.0A, T_J = 25°C		2.0		V
R_O	Output Resistance	f = 1.0 kHz		16		mΩ
I_{OS}	Output Short Circuit Current	T_J = 25°C, V_I = 35V		0.45		A
I_{PK}	Peak Output Current	T_J = 25°C		2.2		A
$\Delta V_O/\Delta T$	Average Temperature Coefficient of Output Voltage	I_O = 5.0 mA		0.8		mV/°C

Note 6: All characteristics are measured with a 0.22 µF capacitor from input to ground and a 0.1 µF capacitor from output to ground. All characteristics except noise voltage and ripple rejection ratio are measured using pulse techniques (t_w ≤ 10 ms, duty cycle ≤ 5%). Output voltage changes due to changes in internal temperature must be taken into account separately.

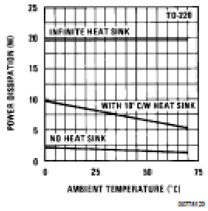
Typical Performance Characteristics

LM340/LM78XX

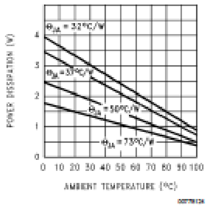
Maximum Average Power Dissipation



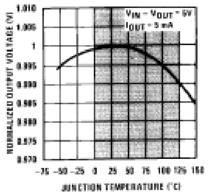
Maximum Average Power Dissipation



Maximum Power Dissipation (TO-263)
(See Note 2)

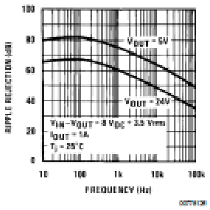


Output Voltage (Normalized to 1V at T_J = 25°C)

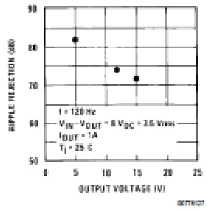


Note: Shaded area refers to LM340A/LM340, LM7805C, LM7812C and LM7815C.

Ripple Rejection



Ripple Rejection



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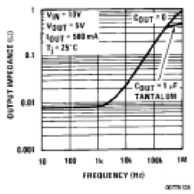
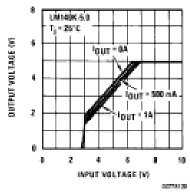
Typical Performance Characteristics (Continued)

LM340/LM78XX

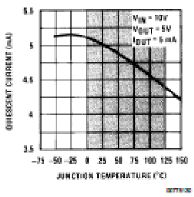
Output Impedance



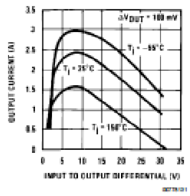
Dropout Characteristics



Quiescent Current

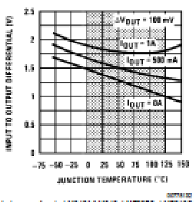


Peak Output Current



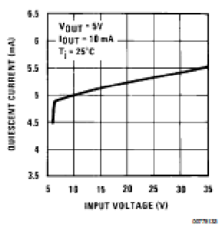
Note: Shaded area refers to LM340A/LM340, LM7805C, LM7812C and LM7815C.

Dropout Voltage



Note: Shaded area refers to LM340A/LM340, LM7805C, LM7812C and LM7815C.

Quiescent Current



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APPENDIX E

SAFETY MEASUREMENT

Careful while using the step-down transformer

Fig. Step down transformer

I/P: 220V ~ 50Hz step down transformer has been used in the making of tesla coil. The input voltage is very high. Anyone can get electric shock while using it. So we have to be very careful while plugged in to the socket. Other thing is the two red wire should not be touched. It can cause a short circuit problem in the transformer and burn the transformer.

Primary and Secondary Coil winding direction

The coil winding direction is very important. If the direction is wrong, then the tesla coil will not be working. Primary and Secondary winding direction should be opposite.

Do not touch the open wire of the winding section

When magnetic coupling happens between primary and secondary coil, one should not touch the open wire. One can get shock while touching the wire as high voltage is present.