UNIVERSITI TEKNIKAL MALAYSIA MELAKA

CORDLESS CHARGING FOR VARIOUS DEVICE

This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree in Engineering Technology (Industrial Electronic) (Hons.)

by

MUHAMMAD HANAFI BIN MOHD NAJIB
B071110385
901124115271

FACULTY OF ENGINEERING TECHNOLOGY
2015

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

BORANG PENGESAHAN STATUS LAPORAN PROJEK SARJANA MUDA

TAJUK: **CORDLESS CHARGING FOR VARIOUS DEVICE**

SESI PENGAJIAN: **2014/15 Semester 2**

Saya **MUHAMMAD HANAFI BIN MOHD NAJIB**

mengaku membenarkan Laporan PSM ini disimpan di Perpustakaan Universiti Teknikal Malaysia Melaka (UTeM) dengan syarat-syarat kegunaan seperti berikut:

1. Laporan PSM adalah hak milik Universiti Teknikal Malaysia Melaka dan penulis.
2. Perpustakaan Universiti Teknikal Malaysia Melaka dibenarkan membuat salinan untuk tujuan pengajian sahaja dengan izin penulis.
3. Perpustakaan dibenarkan membuat salinan laporan PSM ini sebagai bahan pertukaran antara institusi pengajian tinggi.
4. **Sila tandakan (✓)

☐	SULIT	(Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysia sebagaimana yang termaktub dalam AKTA RAHSIA RASMI 1972)
☐	TERHAD	(Mengandungi maklumat TERHAD yang telah ditentukan oleh organisasi/badan di mana penyelidikan dijalankan)
☑	TIDAK TERHAD	

Disahkan oleh:

_____ _____

Alamat Tetap:
LOT 283 KM 8,
KAMPUNG ALAI,
75460 MELAKA.

Cop Rasmi:

Tarikh: _____ Tarikh: _____

** Jika Laporan PSM ini SULIT atau TERHAD, sila lampirkan surat daripada pihak berkuasa/organisasi berkenaan dengan menyatakan sekali sebab dan tempoh laporan PSM ini perlu dikelaskan sebagai SULIT atau TERHAD.

DECLARATION

I hereby, declared this report entitled “Cordless Charging for Various Device” is the results of my own research except as cited in references.

Signature	:	…….
Author’s Name	:	……
Date	:	……

APPROVAL

This report is submitted to the Faculty of Engineering Technology of UTeM as a partial fulfillment of the requirements for the degree of Bachelor of Engineering Technology (Industrial Electronic) (Hons.). The member of the supervisory is as follow:

……

(Project Supervisor)

ABSTRAK

Dengan perkembangan teknologi yang semakin pesat, bateri adalah masalah utama bagi elektronik pengguna mudah alih, kita masih terhad dengan membawa alat pengecas berwayar dengan hanya satu peranti setiap pengecas. Dengan semua peranti mudah alih yang kita bawa, bateri perlu dicas semula. Penyelesaian sementara bagi masalah ini adalah dengan menggunakan Powerbank. Penyelesaian sementara ini juga menggunakan bateri. Melalui inovasi alat pengecasan induktif tanpa wayar, pengguna peranti elektronik dapat untuk menyelesaikan masalah mengecas peranti secara serentak tanpa kerumitan menggunakan alat pengecas yang berbeza untuk setiap peranti yang berlainan dan tanpa wayar yang berserabut.

ABSTRACT

With the fast pace development of technology, battery is still the main problem for consumer mobile electronic, we are still limited to the old fashion of carrying a wired charging port with only one device per port. With all portable devices that we carried, batteries will need to be recharge. The alternative solution for this problem is by using "Powerbank". Although this alternative way can charge the device, it is still using battery and need to be recharge. Through this innovation of cordless inductive charging, this could be the next big thing in consumer electronic to solve the problem charging multiple devices simultaneously without the hassle of carrying different charging for different devices plus eliminate the need of messy cables.

ACKNOWLEDGEMENT

First and foremost, I would like to take this opportunity to express my sincere acknowledgement to my supervisor En. Tg Mohd Faisal Bin Tengku Wook from the Faculty of Engineering Technology (FTK) for her essential supervision, support and encouragement towards the completion of this thesis.

I am highly indebted to En. Tg Mohd Faisal Bin Tengku Wook for his guidance and constant supervision as well as for providing necessary information regarding the project & also for his support in completing the project.

I would like to express my gratitude towards my parents of for their kind co-operation and encouragement which help me in completion of this project report. My thanks and appreciations also go to my peers who have willingly helped me out with their abilities.

TABLE OF CONTENT

Abstrak		i
Abstract		ii
Dedication		iii
Acknowledgement		iv
Table of Content		v
List of Tables		vi
List of Figures		vii
List Abbreviations, Symbols and Nomenclatures		viii
CHAPTER 1: INTRODUCTION		**1**
1.1	Project Introduction	1
1.2	Problem Statement	2
1.3	Objective	2
1.4	Project Scope	2
CHAPTER 2: LITERATURE REVIEW		**3**
2.1	Introduction	3
2.2	Wireless Power Transmission	3
	2.2.1 Short Transmission	4
	2.2.1.1 Circuit Design	5
	2.2.1.2 Induction	5
	2.2.1.3 Electrodynamic Induction	7
	2.2.2 Medium Transmission	7
	2.2.2.1 Benefits of Resonant Coupling	8
	2.2.2.2 Coupling Coefficient	9
	2.2.2.3 Power Transfer and Efficiency	9
	2.2.2.4 Ultrasonic	10

2.2.3 High Transmission 10
2.2.3.1 Radio Wave 11
2.2.3.2 Laser 12
2.2.4 Comparison 13
2.3 Oscillator 14
2.3.1 Harmonic Oscillator 15
2.3.2 Relaxation Oscillator 15
2.4 Transmitter and Receiver Circuit 15
2.4.1 Transmitter Circuit 16
2.4.1.1 Power Transmitter 16
2.4.2 Receiver Circuit 17
2.4.2.1 Power Receiver 17

CHAPTER 3: METHODOLOGY 19
3.1 Introduction 19
3.2 Project Built 21
3.2.1 Project Model 22

CHAPTER 4: RESULT AND DISCUSSION 25
4.1 Introduction 25
4.2 Theoretical 25
4.2.1 Resonant Circuit 26
4.2.1.1 Push Pull Converter 28
4.2.2 Qi Circuit 28
4.3 Actual Analysis 30
4.3.1 Resonant Circuit Analysis 30
4.3.2 Qi Circuit Analysis 42

CHAPTER 5: CONCLUSION & FUTURE WORK 44
5.1 Introduction 44
5.2 Conclusion 44
5.3 Future Work 45

REFERENCES **46**

APPENDICES **47**

APPENDIX A IRF510 Datasheet 47

LIST OF TABLES

2.1	Advantage and Disadvantage for WPT Laser Method	12
2.2	Comparison between All Method of WPT	13
4.1	Value comparison between theory, calculation and simulation	30
4.2	Bill of Materials	32
4.3	Pre-Testing Circuit Measurement Value	33
4.4	Transmitter Circuit	35
4.5	Energy Transfer with Air Gap	36
4.6	40kHz Receiver Circuit Analysis	38
4.7	40kHz Receiver Circuit Analysis Between Parameter	39
4.8	Energy measurement for small resonant circuit	41
4.9	Qi Result Analysis	43

LIST OF FIGURES

2.1	Wireless Power Transfer	4
2.2	Inductive Coupling	5
2.3	Inductive Coupling Circuit Design	5
2.4	Inductive Power Transfer	6
2.5	Two electrode plate configuration in capacitive coupling	7
2.6	Resonant Coupling	7
2.7	Ultrasonic WPT	10
2.8	Radio wave Conversion by Using Rectenna	11
2.9	WPT Laser Method	12
2.10	Power Transmitter	16
2.11	Power Receiver	17
2.12	Full-Wave Rectifier	18
3.1	Project Flowchart	20
3.2	Cordless Charging Flowchart	21
3.3	Base Station for Wireless Charging	22
3.4	Mobile Phone Recharging On Top Of Base Station	23
3.5	Notebook wireless Charging Setup	24
4.1	Resonant Transmitter Circuit	26
4.2	Resonant Transmitter Circuit Frequency	27
4.3	Switching cycle in the push-pull converter	28
4.4	Qi system overview	29
4.5	Transmitter circuit for WPT	30
4.6	Resonant Frequency Transmission	31
4.7	Push-Pull Frequency	31
4.8	Pre-testing at breadboard	32
4.9	Factors that can decrease charging time	33
4.10	PCB Design Transmitter Circuit	34

4.11	Transmitter Circuit	34
4.12	Receiver Circuit	35
4.13	Charging Times	36
4.14	Air gap and current relationship	37
4.15	40kHz Receiver Circuit Analysis	38
4.16	40kHz Receiver Circuit AC Voltage Test	38
4.17	Low power resonant circuit	40
4.18	Qi Receiver Pad	41
4.19	Mobile phone charging using Qi	41
4.20	Qi Transmission Pad	42

LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURE

WPT	-	Wireless Power Transmission
AC	-	Alternate Current
DC	-	Direct Current
EMF	-	Electromagnetic Field
RF	-	Radio Frequency
RC	-	Resistor Capacitor
LC	-	Inductor Capacitor
WBS	-	Wireless Base Station
LED	-	Light Emitting Diode
mAh	-	Miliampere per hour
Tx	-	Transmitter
Rx	-	Receiver
π	-	Pi
μ	-	Micro
Ω	-	Ohm

CHAPTER 1
INTRODUCTION

We live in a world of technological advancement. New technologies emerge each and every day to make our life simpler. Despite all these, we still rely on the classical and conventional wire system to charge our everyday use such as mobile phones, digital camera etc. and even devices such as laptops. The conventional wire system creates a mess when it comes to charging several devices simultaneously. It also takes up a lot of electric sockets and not to mention the fact that each device has its own design for the charging port. For this project, cordless charger is designed to introduce an alternative source where it is allows users to charge the phone and other various devices wireless without connected a power cord the electric power port for each devices. Wireless Power Transmission (WPT) is the transmission of sending an electrical energy from one point to another without the use of wire or any other medium. Where conventional wires is inconvenient and dangerous, this WPT can transmit electrical energy through inductive coupling and can charge low and mid power devices. This inductive coupling could be the next big thing in technology advancement.

1.1 Problem Statement

With the advancement of today electronic technology, almost all devices that exist use a power cord to power up the device. As of today most consumer at least carried with them at least two devices with them all the time in their daily life. This will create numerous problem. Such problem that prone to occur is the problem that having to carry one charging adapter for each one of the devices.

Another problem arise is that with many charging adapter that need to be plug, this will take up spaces at the power socket. With many charging adapter plugged in, safety is a problem due to the so many wired that connected to each one of the devices.

1.2 Objective

(a) To study about the wireless power transmission (WPT).
(b) To implement wireless power transmission technology.
(c) To design project according to the wireless power transmission technology.

1.3 Project Scope

Throughout this project, several guideline and specification must be followed to make sure the project the project is within the project:

(a) The scope of this project is to develop a cordless charging system by using electromagnetic induction that generate through coil.
(b) The concept of how the electrical energy is transmitted must be studied and understand and find out the limit of wireless electrical energy.
(c) Find out through studied the effect of electromagnetic to other electronic components.

CHAPTER 2
LITERATURE REVIEW

This chapter will covers on the related work of this project with details explanation about the technologies that been used in this project and the depiction of the project including the build and the components. In the wireless power transmission, there are a lot of method that can achieve the same result that is transfer power from one point to another point. This chapter will cover all the method in wireless power transfer and it can be seen throughout this chapter to get better understanding of this technology and it uses and purposes for each one of the method.

2.1 Wireless Power Transmission

WPT or Wireless power transmission is a form of electrical transmission without the need of wires or medium for electrical charges to flow from point A to Point B. WPT can be used to transfer power whether continuously or instantaneously. This type of transmission is most needed where wires are inconvenient, dangerous or unwanted. WPT transmission is divided into 3 main types, Short transmission, medium transmission and long transmission and others method that include Radio Wave, Laser and Ultrasonic each with its own practicality and function based on the type of transmission the user needed. Through WPT, low to medium powered devices could be charge without the need of wires to carry the electrical charges to the devices.

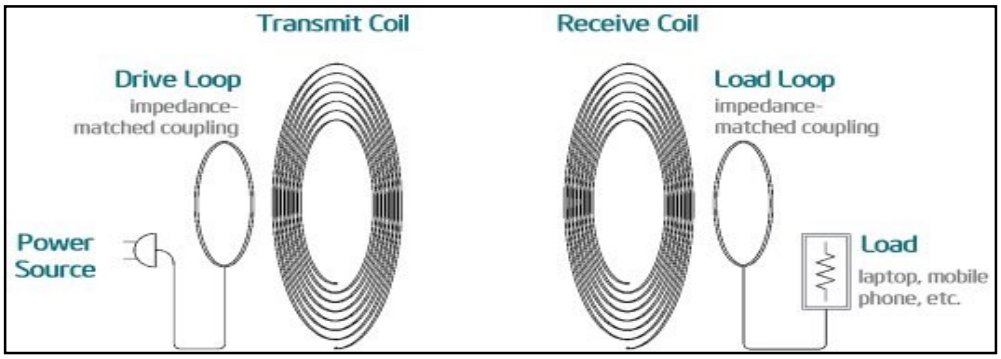

Figure 2.1: Wireless Power Transfer

The three main parts of WPT is the distance to transfer the power to the intended devices. Short transmission use inductance and inductive coupling to transfer power, while medium transmission use Resonant induction and long range use electromagnetic wave power transfer to transfer electrical energy, all of this transmission is without the need of a medium. For radio wave method, this method will send electrical signal by using the radio signal just like WI-FI. Laser method will transmit power that is embedded into the laser beam and the last method is to transfer power by using ultrasonic method that is composed of components that have its own purposes to send and receive the signal and change the signal to DC power.

2.1.1 Short Transmission

For short transmission, the Inductance and Inductive coupling is the simplest method of all the method due to it only have a supply, primary winding(transmitter), secondary winding(receiver) and load. For inductance system, it is almost the same system as a transformer with primary and secondary winding.

For transformer primary winding generate electrical signal and for secondary winding it is up to manufacturer to make it a step-up (increase) or a step-down (decrease). The system of inductance and inductive power transmission is as follow:

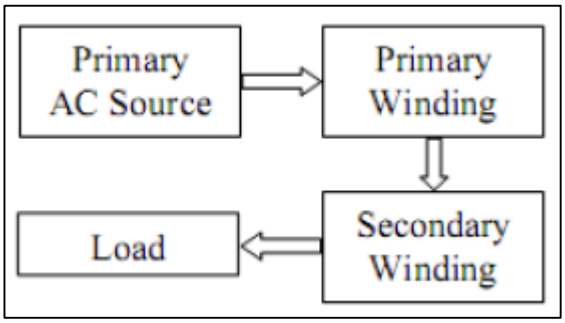

Figure 2.2: Inductive Coupling

This system of inductive coupling is widely use, due to the multiple advantages such as high efficiency of 80% to 86%. This system is also have less risk to have an electrical shock accident and the advantage of near field to charge the devices without connecting wires to the devices itself. The old ways connecting the power cable is then be replace with the device is place on or near to a charging plate is more convenient than connecting to a power cable (Naim, et al., 2012).

2.1.1.1 Circuit Design

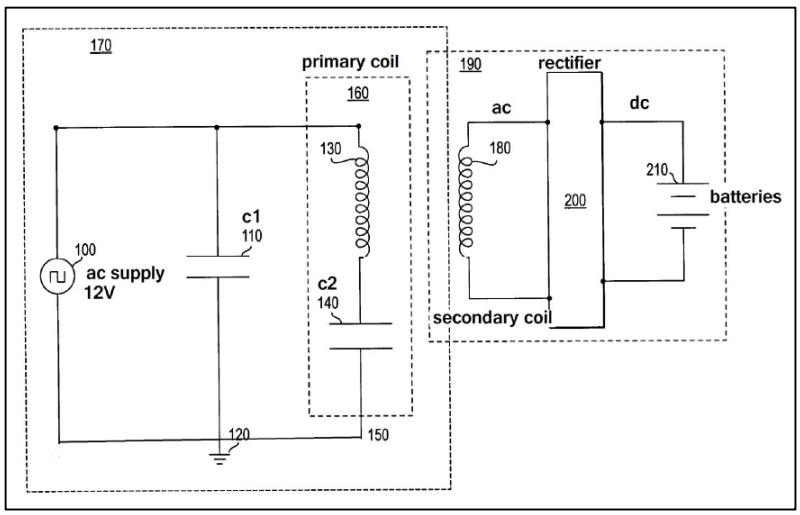

Figure 2.3: Inductive Coupling Circuit Design

The working principle of an inductive coupling wireless power transmission is based on the same principle of a transformer. The power transfers from the transformer from one circuit to the other circuit is through an inductive conductor or the coil winding at the transformer itself (Basharat, 2013). The current that flow at the winding

coil will create magnetic field (EMF) that generate voltage, this effect of power transmission is called *mutual induction*.

This near field technique is non-radioactive type of transmission, by transmitting energy wirelessly, energy will likely losses its power. Wireless transmission technique can be classified as three type of resistive losses (Basharat, 2013).

(a) Induction
(b) Electro Dynamic Induction
(c) Electrostatic Induction

2.1.1.2 Induction

This effect of mutual induction can be seen at the electric toothbrush that oral-b Company develop to charge their electric toothbrush products. The primary and secondary circuits are not connected directly to one another. The action of transferring energy is though electromagnetic coupling between transmitter coil and receiver coil (Basharat, 2013).

For this inductive coupling method, the receiver must be place near to the transmitter for the coupling to be properly working and thus make the power transfer (voltage) to happen.

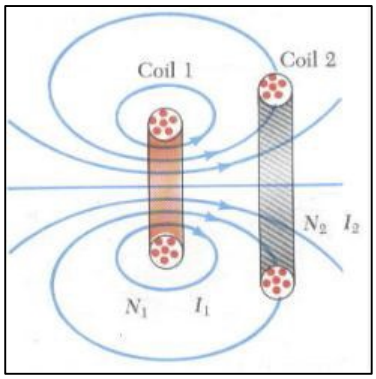

Figure 2.4: Inductive Power Transfer

2.1.1.3 Electro Dynamic Induction

Electrostatic induction or capacitive coupling is a method that involving high frequency alternating current (AC) transmitting over two electrode plate. This changing of magnetic flux can be used to transfer energy to a receiving device (Basharat, 2013).

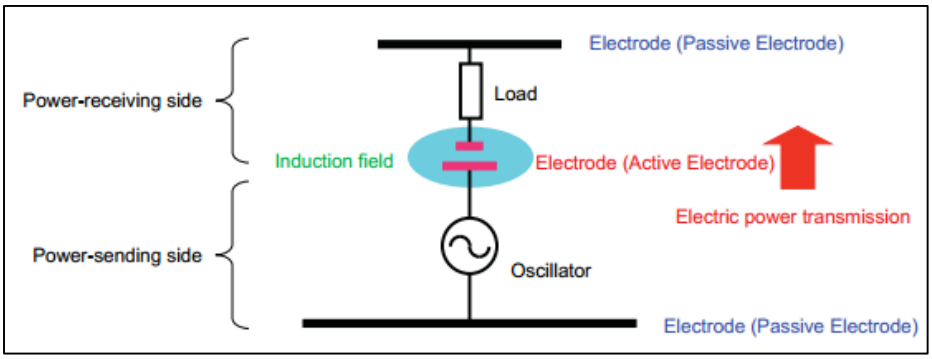

Figure 2.5: Two electrode plate configuration in capacitive coupling

2.1.2 Medium Transmission

Resonant is a phenomenon in which when the material is disturb it will oscillate to its same natural frequencies, example of this is a violin, the thicker the violin string the lower the resonant it oscillate. This type of phenomenon can be used in wireless power transmission by using resonant coupling or Electro dynamic induction.

Resonant coupling work by tuning the frequency of the transmitter and receiver to it natural frequency and when it resonate the energy will be transfer between two mutual circuits.

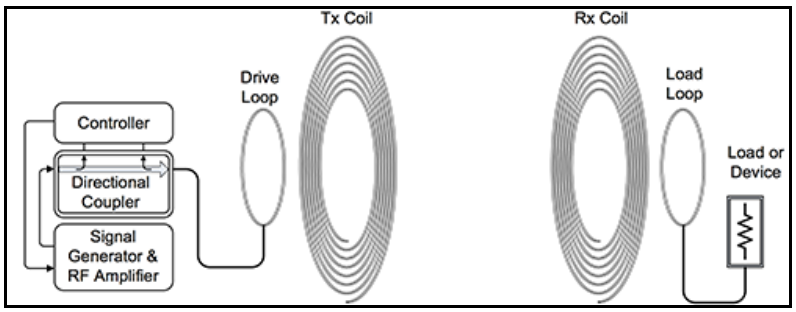

Figure 2.6: Resonant Coupling

2.1.2.1 Benefits of Resonant Coupling

When Resonant coupling come into the market of wireless power transfer, it struck many eye due to its benefits, such as this technology can eliminate the need of power cord for charging, this also make the devices more reliable by replacing components that is highly prone to damage(over-time use) such as cable and connector (Dr.Morris, 2013).

This technology also can eliminate the sparking hazard when power connection is made to the intended device. If the recharging module is integrated into the devices itself, devices such as mobile phone can be waterproof by eliminate the connection header that can become a hazard to people. This system also can reduce the system cost just by using the same resonator to charge multiple devices at the same time (Dr.Morris, 2013).

With resonant electromagnetic coupling it enable the power to be transfer up to the distance of 2 meter (D.Trace, 2014) and with high scalability of power device range from low to high power devices can be powered by using highly resonant power transfer coupling. This is done by implemented either one or both systems of "Wireless Direct Powering" of a device, which the captured energy is directly connected to a load and any existing battery or energy storage component in the device that is not providing power or is providing back-up power or "Wireless charging" in which where capacitor is charge with the capture energy from the transmitter (Dr.Morris, 2013).

2.1.2.2 Coupling Coefficient

Resonant coupling coefficient (k) is ranging from 0 to 1. This coefficient is tightly relate to the distance of the two coil. Coupling coefficient is divided into 4 categories which is tightly coupled, loosely coupled, critically coupled or over-coupled. When coefficient is around 1(iron -core transformer) the system is a tight-couple. Over-coupled is when the coil is so close together it will breakdown the primary electromagnetic field. To get the optimal power transfer critical coupling is use, the distance for critical coupling is the perfect spot between primary and secondary coil which is not too far or too close together. When the coils is place distant from each other the flux will misses the secondary coil (loosely coupled). The coefficient in tesla coil is around 0.2.

2.1.2.3 Power Transfer and Efficiency

The oscillating energy when place into a primary coil, the coil will form an oscillating magnetic field. The magnetic field will transfer the energy back and forth and this oscillation is determine by gain-bandwidth (Q factor).

$$Q = \frac{1}{r}\sqrt{\frac{L}{C}}$$

When the coils is place at longer distance, the energy of magnetic field will fade quickly the farther the distance between primary and secondary coil. The figure of merit for the efficiency is (Dr.Morris, 2013):

$$U = k\sqrt{Q_1 Q_2}$$

Where Q1 and Q2 is the Q factor of the source and receiver coils. And the maximum achievable efficiency is (Dr.Morris, 2013):

$$efficiency_{opt} = \frac{U^2}{\left(1+\sqrt{1+U^2}\right)^2}$$

2.1.2.4 Ultrasonic

The concept of power transmission by using Ultrasonic is new and still in development. This relatively new method is a method of transmission that uses an ultrasonic air transducers to transfer the power (Jonathan, 2011).

Ultrasonic WPT method is composed of pulse generator and an amplifier, and a horn, transfers the power through the air. A receiver composed of a receiving transducer, a rectifier, and a capacitor, then receives the power and applies it to a circuit (Jonathan, 2011).

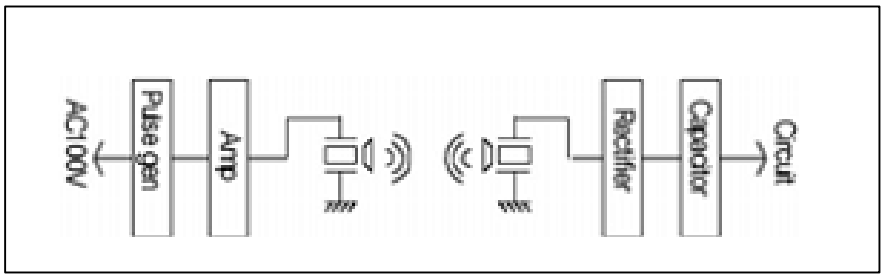

Figure 2.7: Ultrasonic WPT

Although this method of WPT is a breakthrough, it is not being demonstrated and still in development to the hand of the mass consumer. This method show it promising in the future to power up low power devices.

2.1.3 High Transmission

High transmission or far-field transmission is when the energy is transfer at longer range without the need of repeater or any sort of power cable. Far-field technology is still new in wireless power transfer but it can be achieve by using two method that is Radio Wave and Laser. For longer range to work, high directivity antennas or well-collimated laser beam are used to match the shape of the receiving antenna thus delivering power at longer ranges can be achieve.