International Journal of Science, Engineering and Technology Research (IJSETR)
Volume 6, Issue 4, April 2017, ISSN: 2278 -7798

Static Contactless Charging System Using Inductive Coupling Method

Gum Hkawng Tu Raw[1], Wai Phyo Ei[2]

***Abstract*— In this paper, static contactless charging system is demonstrated by using the method of inductive coupling. Although conductive charging technology has been widely used in many electrical industries such as mobile phones, electric toothbrushes, battery-used electric devices till today, inductive charging technology is going to be another option to choose for consumers in not very far time. It is because inductive charging can give more reliable and flexible benefits since it can be used without a charging cord to plug-in. In this project, oscillator circuit converts DC energy to AC energy in order to transmit magnetic field from transmitter coil to receiver coil by passing frequency and then mutual induction (inductive coupling) occurs between the two coils without any core material except air medium. This system is based on coupling magnetic field, then designed and constructed as two parts. There are two parts in this system and they are transmitter part and receiver part. The transmitter coil (transmitter part) transmits coupling magnetic field to receiver coil (receiver part) by passing frequency at about 30 kHz. The system is safe for users and neighboring electronic devices. This paper outlines the proposed development of a contactless inductive charging system for small electrical device such as mobile phone, small battery car, etc. The project aims to develop contactless charging technology and it is also intended to give a message that how useful the static contactless charging is by creating a proof of concept for inductive charging.**

***Index Terms*—Inductive coupling, oscillator, receiver, transmitter.**

1) INTRODUCTION

Contactless power transfer (CPT) technology is a new kind of power transmission technology which based on Faraday-Lenz electromagnetic induction principle, and it can solve the problem of mobile devices wireless and flexible power supply (2). This technology is safer, more reliable and flexible than traditional technology. And broader application prospects than traditional power transmission technology (1). It was demonstrated firstly by MIT using inductive coupling during the summer 2007 (6, 7). In 2008, Intel also achieved contactless power through inductive coupling. This project can be charged several different handheld devices, such as battery-used small electronic devices, toothbrushes, cellular phones and MP3 player (like 5V charging adapter) (3, 4, 5). It can be charged on the surface of the transmitter coil by putting receiving coil at the device. Contactless power transfer means the power supply is not plugged into the device being charged (close proximity or physical contact) (8).

Manuscript received April, 2017.
Gum Hkawng Tu Raw[1] *is currently pursuing master degree program in mechatronic engineering in Mandalay Technological University, Mandalay, Myanmar, Mobile Phone No: +959797103793.*
Wai Phyo Ei[2] *is a university lecturer of Department of Mechatronic Engineering in Mandalay Technological University, Mandalay, Myanmar, Mobile Phone No: +9595035693.*

In this project, power supply 12V DC drives oscillator circuit as push-pull driver to operate transmitter coil. Then, the transmitter coil transmits coupling magnetic field by passing frequency at about 30 kHz. In this state, the receiver coil receives coupling magnetic field as AC voltage. DC level stabilizer converts AC to DC voltage again to charge the battery of device (small-power electric car).

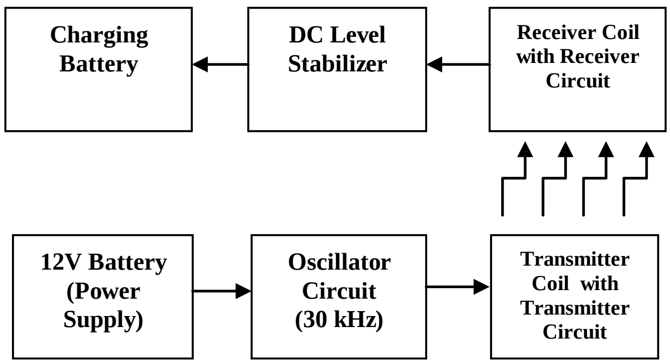


Fig. 1 Block diagram of static contactless power transfer system

2) THEORETICAL BACKGROUND

ICPT technology is a new kind of power transmission technology which based on Faraday-Lenz's electromagnetic induction principle, and it can solve the problem of electric devices' principle wireless and flexible power supply.

A. *Laws of Electromagnetic Induction*

(i) Faraday's Law of Electromagnetic Induction

Electromagnetic induction is the process by which a current can be induced to flow due to a changing magnetic field. According to the Faraday's law of electromagnetic induction, the magnitude of induced EMF is directly proportional to the rate of change of magnetic flux linked with a conductor or coil. This can be stated mathematically as:

$$\varepsilon = \frac{d\phi}{dt} \text{ (Volts)} \quad (1)$$

(ii) Lenz's Law of Electromagnetic Induction

While Faraday's law tell us the magnitude of the EMF produced, Lenz's law tell us the direction that current will flow.

Lenz's law is typically incorporated into Faraday's law with a minus sign, the inclusion of which allows the same coordinate system to be used for both the flux and EMF.

$$\varepsilon = -\frac{d\phi}{dt} \text{ (Volts)} \quad (2)$$

(iii) Faraday-Lenz's law of Electromagnetic Induction

In practice, it is often considered that deals with magnetic induction in multiple coils of wire, each of which contributes the same EMF. For this cause, an additional term N representing the number of turns, is often included, i.e.,

$$\varepsilon = -N\frac{d\phi}{dt} \text{ (Volts)} \quad (3)$$

Where,

- ε is the electromotive force (EMF),
- N is the number of turns,
- $\frac{d\phi}{dt}$ is the rate of change of magnetic flux with time.

The minus sign shows that, the direction of the induced EMF and the direction of change in magnetic fields have opposite signs.

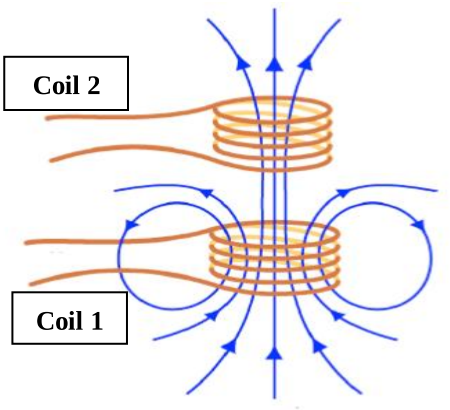


Fig. 2 Changing current in coil1 produces changing magnetic flux in coil2

B. Magnetic Field

Magnetic fields are produced by electric currents, which can be macroscopic currents in wires, or microscopic currents associated with electrons in atomic orbits. Magnetic fields occur whenever charge is in motion. As more charge is put in more motion, the strength of a magnetic field increases.

Except along the axis, the magnetic field of a circular coil cannot be expressed in closed form. Along the coil axis, if the origin of the coordinates is taken at the center of the coil and if the z axis is taken along the coil axis, the magnitude of the magnetic field B, which points in the z direction, is given by

$$B = \frac{\mu_0 N a^2 I}{2(a^2 + z^2)^{3/2}} \quad (4)$$

Where,

- N is the number of turns of the field coil,
- I is the magnitude of the electric current (Ampere, A),
- a is the radius of the coil (meter, m),
- z is the axial distance from the center of the coil (meter, m),
- SI unit of B is the Tesla (T),
- $\mu_0 = 4\pi \times 10^{-7}$ is the permeability of free space (Tm/A).

C. Magnetic Flux

Magnetic flux is a measurement of the total magnetic field which passes through a given area. The magnetic field through a loop can be changed either by changing the magnitude of the field or changing the area of the loop.

For a loop of area A in the presence of a uniform magnetic field B, the magnetic flux is defined as

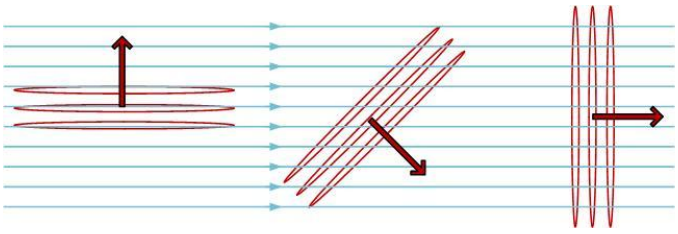
$$\phi = NBA\cos\theta \quad (5)$$

Where,

- ϕ is the angle between B and the normal to A,
- A is the area of the loop,
- B is the magnetic field ,
- SI unit of ϕ is the Weber (Wb).

D. Strength of Magnetic Flux

The strength of magnetic flux mainly depends on the distance and the position of the receiver coil. Figure. 2 shows the three different position of the receiver coil.



$\theta = 90^\circ$ $\qquad$ $\theta = 45^\circ$ $\qquad$ $\theta = 0^\circ$

$\phi = 0$ $\qquad$ $\phi = \frac{1}{\sqrt{2}} BA$ $\qquad$ $\phi = BA$

Fig. 3 Three different positions of the receiver coil

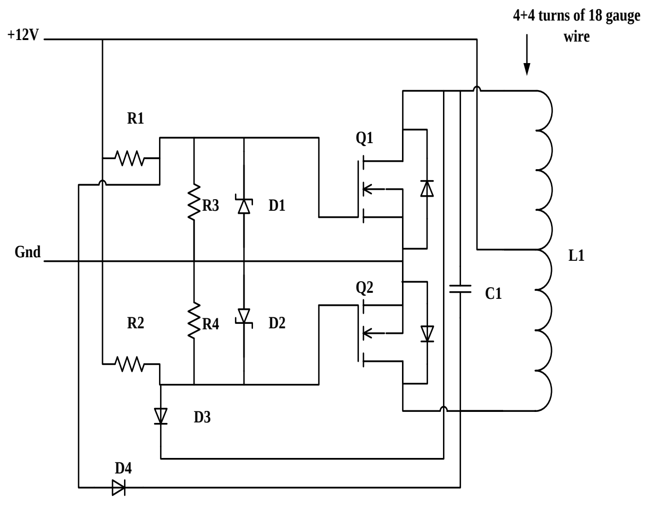
3) Operations of The Entire System

The overall operation of the system can be divided into two different sections:

- Transmission section and
- Receiving section.

A. Transmission section

In transmission section, oscillation circuit operates as push-pull devices to transmit magnetic field to the receiving coil. The system uses coupled magnetic fields as a frequency to transfer electromagnetic energy from the transmitter coil to receiver coil. Fig.4 shows the transmitter circuit.



R1 = R2 = 470Ω (5W), R3 = R4 = 10kΩ (0.25W)

D1 = D2 = 12V (Zener Diode – 1N4742) , D1 = D2 = 1000V 1A (Diode - 1N4007)

Q1 = Q2 = FHP3205 (N – Channel MOSFET)

C1 = 1µF (Non – Electrolyte)

L1 = 27.6µH (203mm Diameter, 8 turns, 5mm Thickness)

Fig. 4 Transmitter circuit

Power Supply 12V battery (DC voltage) is used in this project and it supplies 12 V to operate the control circuit. The DC power source provides a constant DC voltage to the input of the transmitter circuit. By using 12V battery, circuit diagram receives stable voltage and current. Therefore, it is suitable for the circuit of wireless charging system by using inductive coupling.

The transmitter coil, energized by the high frequency AC current, produces an alternating magnetic field. In this project, wire gauge 18 is used and the number of turns of the transmitter coil is eight turns.

Transmitter circuit receives a constant DC voltage from the DC power supply. There, this DC power is converted to a high frequency AC power and is supplied to the transmitter coil. Components of the transmitter circuit are Field Effect Transistor, Diodes, Inductor, Capacitor and Resistors. Figure.5 shows the transmitter circuit with the transmitter coil.

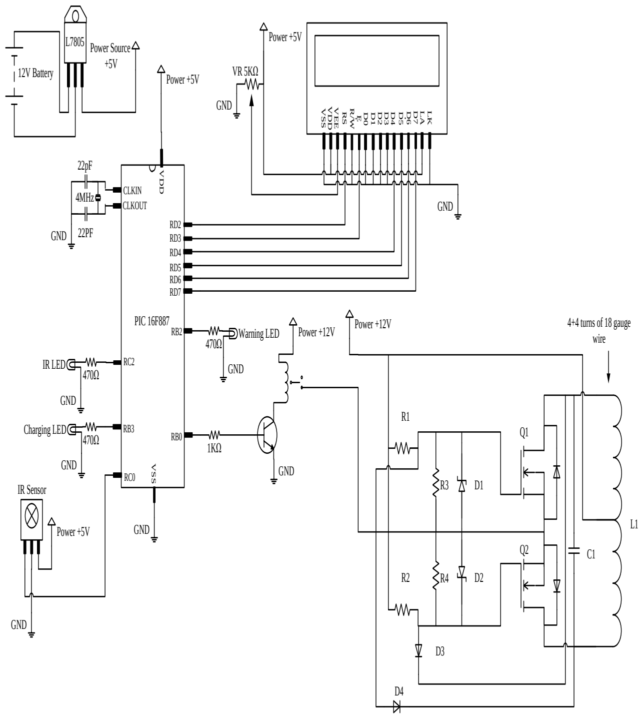


Fig. 5 Circuit diagram of transmission section

A. Receiving Section

In the receiver coil, it receives magnetic field induced from the transmitter coil. In this state, it is AC level and it needs to convert DC level for charging the battery of electric device. The wire gauge and turns of the coil are the same as the transmitter coil.

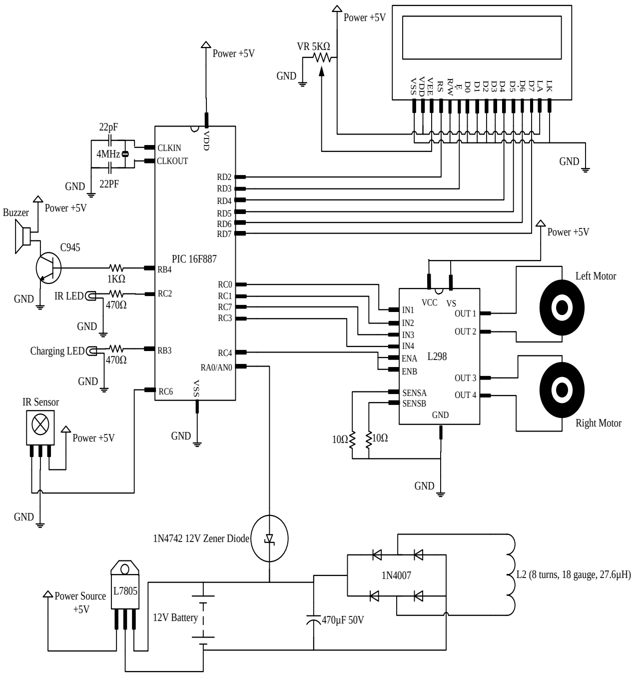


Fig. 6 Circuit diagram of receiving section

When the battery car is in the motion over the inductive charging surface, the transmitter coil induced the magnetic field to the receiver coil. The rectifier rectifies the induced voltage from AC to DC level. When the green LED (charging LED) is on, the battery of the device is started to charge.

In this project, DC 6 volts battery is used to drive the motor of small battery car. The battery receives the power from the receiver coil.

4) Calculations of the System Design

A. *Calculation of Magnetic Field (B)*

From equation (4),

$$B = \frac{\mu_0 N a^2 I}{2(a^2 + z^2)^{3/2}}$$

Where, a = 101.6 mm = 0.1016 m,
z = 5 cm = 0.05 m,
I =1.13 A,
μ_0 = 4π x 10^{-7} Tm/A,
N = 8 turns.

Then, B = 40.38 x 10^{-6} T = 40.38 μ T.

B. *Calculation of Magnetic Flux (ϕ)*

From equation (5),

$$\phi = NBA\cos\theta$$

Where, N = 8turns,
B = 40.38 μ T,
r = 0.1016 m,
A = πr^2 = 0.032 m^2,
θ = 0°, 45°, 90°,…

At θ = 0° position, ϕ = 10.47 μ Tm^2.
At θ = 45° position, ϕ = 5.503 μ Tm^2.
At θ = 90° position, ϕ = 0 Tm^2.

C. *Calculation by Digital Oscilloscope*

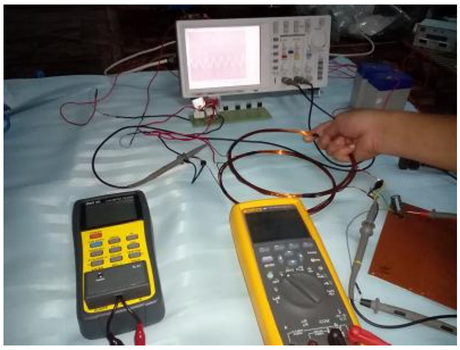


Fig. 7 Waveform of the two coils testing by oscilloscope

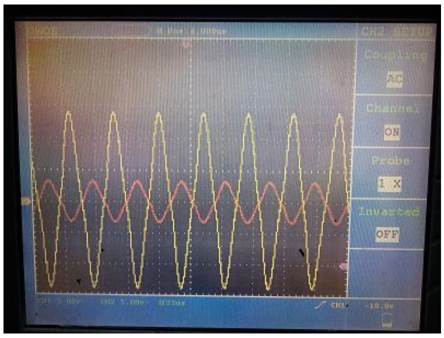


Fig. 8 Waveform of primary coil (channel-2, yellow color)
Vp = 14V, time T = 35µs, frequency f = 1/T =28.571 kHz

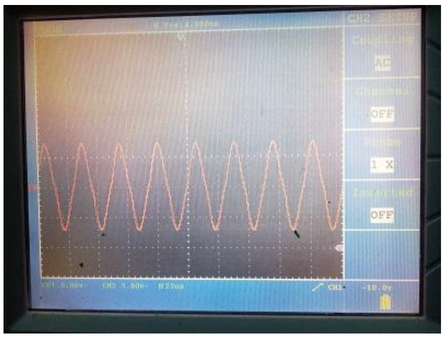


Fig. 9 Waveform of secondary coil (channel-1, red color)
Vs = 8.4V, time T = 35µs, frequency f = 1/T =28.571 kHz

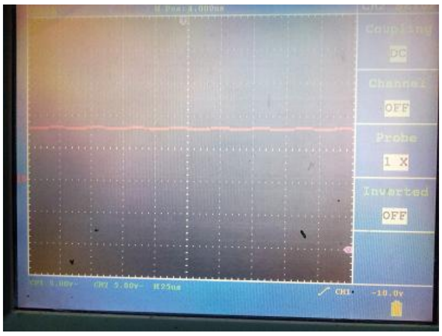


Fig. 10 DC voltage of secondary coil (8.4V)

D. Calculation by Digital Voltmeter

Fig. 11 DC Voltage and Ampere of Transmission Section
(Distance between transmitter and receiver = 5 cm)
P = VI = 12.801 × 9.869 = 126.333 W

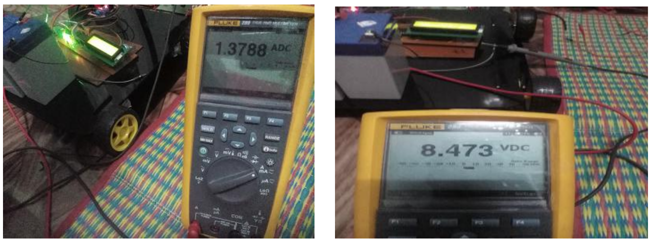


Fig. 12 DC Voltage and Ampere of Receiving Section
(Distance between transmitter and receiver = 5 cm)
P = VI = 8.473 × 1.3788 = 11.683 W

E. Calculation of System Efficiency

Efficiency is defined as

$$\eta = \frac{P(receiving)}{P(transmitting)} \times 100 \tag{6}$$

P(receiving) = 11.683 W,
P(transmitting) = 126.333 V,

Then, efficiency, η = 0.0925 = 9.25%

5) SIMULATION AND TEST RESULTS

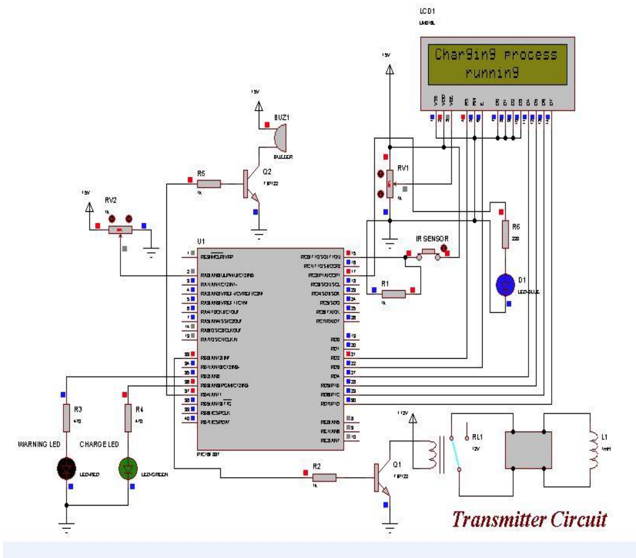


Fig. 13 Simulation result for transmission section

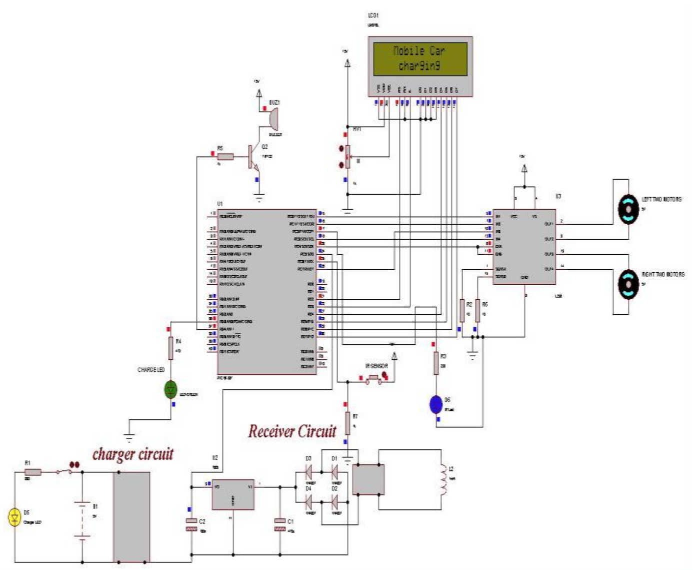
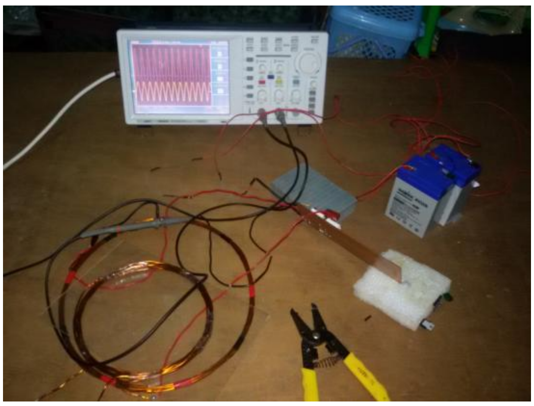


Fig. 14 Simulation result for receiving section



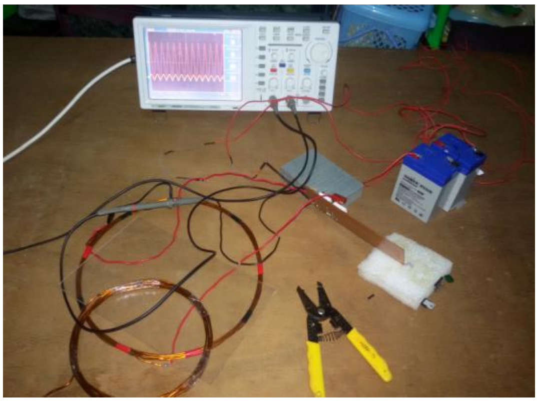


Fig. 15 Test Results

6) Conclusion

In this paper, contactless charging system by using inductive coupling method is designed and constructed. There are many kinds of methods in contactless charging system such as Inductive Coupling, Magnetic Resonance Coupling, Microwave Radiation, Radio Frequency Energy Harvesting and Laser power beaming. Among them, inductive coupling method is chosen to use in this paper. Contactless charging system by using inductive coupling method is safety and more efficiency than other methods of contactless power transfer. Contactless charging method can increase efficiency by changing the design of coil and the circuit design.

Moreover, we can add to use solar energy via photovoltaic (PV) panels in this current project. Solar energy is one of the top-rank renewable energy resources which cannot be harmful to the natural environment. And also, we can do dynamic contactless charging which is more-advanced technology than the static contactless charging since the battery car has to be charged while moving on the road. However, it is harder to construct, the infrastructure used in the construction are too much expensive, and the cost and gain effects are not fair. Therefore, static contactless charging system is the suitable and reliable technology for consumers who like to use contactless charging technology till today even though dynamic charging system is more-advanced.

Acknowledgment

The author would like to thank specially to his supervisor, Daw Wai Phyo Ei, Lecturer, Department of Mechatronic Engineering, Mandalay Technological University for her giving understanding, helpful guidance, suggestion and directions throughout the preparation of work. The author is also sincerely thankful to all his teachers from Department of Mechatronic Engineering, Mandalay Technological University and his family for their supports and encouragement and also thanks to all his friends.

References

1) Benedikt Schmuelling, Sarp G. Cimen, Thomas Vosshagen, Faical Turki, "Layout and Operation of a Non-Contact Charging System for Electric Vehicles," 15th International Power Electronics and Motion Control Conference, EPE-PEMC 2012 ECCE Europe, Novi Sad, Serbia, 2012.
2) Tao Guobin, Liu Chuang, Diao Ying, Zhang Xiuyan and Pi Boyuan, "Design and Implementation of Inductive Coupling Power Transfer Device Based on Structural Parameters Analysis," http://dx.dol.org/10.14257/ijunesst.2013.6.5.07, 2013.
3) M. Fareq, M. Fitra, M. Irwanto, Syafruddin. HS, N. Gomesh, Farrah. S, M. Rozailan, "Solar Wireless Power Transfer Using Inductive Coupling for Mobile Phone Charger," 2014 IEEE 8th International Power Engineering and Optimization Conference (PEOCO2014), Langkawi, The Jewel of Kedah, Malaysia, March 2014.
4) Syed Khalid Rahman, Omar Ahmed, Md. Saiful Islam, A.H.M. Rafiul Awal, Md. Shariful Islam, "Design and construction of wireless power transfer system using magnetic resonant coupling," American Journal of Electromagnetics and Applications, May 2014.
5) Chun Qiu, K.T.Chau, Tze Wood Ching, and Chunhua Liu, "Overview of Wireless Charging Technologies for Electric Vehicles," Journal of Asian Electric Vehicles, Volume 12, Number 1, June 2014.
6) Xiaolin Mou, Hongjian Sun, "Wireless Power Transfer: Survey and Roadmap," February 2015.
7) Kafeel Ahmed Kalwar, Muhammad Aamir and Saad Mekhilef, "Inductively Coupled Power Transfer (ICPT) for Electric Vehicle Charging-A review," Renewable and Sustainable Energy Reviews 47 (2015) 462-475 www.elsevier.com/locate/rser March, 2015.
8) Amaluddin Zainuddin, Syafeeza Ahmad Radzi, Mazree Ibrahim and Norihan Abdul Hamid, "A Development of Electrical Vehicle Charging System Using Wireless Power Transfer," www.arpnjournals.com, ISSN 1819-6608, May 2016.

Gum Hkawng Tu Raw received the B.Tech (MC) and B.E (MC) degrees both in Mechatronic Engineering from Technological University (Myitkyina) and Technological University (Mandalay) of Kachin State and Mandalay Region, Myanmar in 2012 and 2013, respectively, where he is currently working toward M.E (MC) degree. His research interests include power electronics, control, and their applications in contactless power transfer system.

Wai Phyo Ei received the B.E (MC) and M.E (MC) degrees both in Mechatronic Engineering from Mandalay Technological University (MTU) of Mandalay Region, and Yangon Technological University (YTU) of Yangon Region, Myanmar in 2002 and 2004, respectively. Now, she is currently working as a University Lecturer of Department of Mechatronic Engineering in Mandalay Technological University(MTU). She guides this project and her research interests include control systems, automation designs, and their applications in related systems.