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Wireless Power for Mobile Battery Charger

M. Fitra*, Elvy S
Department of Electrical Engineering, Faculty of Engineering, University of Muhammadiyah Sumatera Utara. (UMSU) Indonesia
*Corresponding author, e-mail: mhdfitra@umsu.ac.id

Abstract

This Wireless Mobile Battery Charger project is using technique of inductive coupling. The basic concept of his technique was applied in transformer construction. With this technique, the power from AC or DC can be transfer through the medium of magnetic field or air space. In this project, the method is divided into two major activities which is to purpose circuit construction and to fabricate the prototype. The result is to evaluate the distance of power that can be transferred using technique of inductive coupling.

Keywords: *Wireless power transfer, Wireless mobile battery charger*

1. Introduction

Today's worlds demand a continuous power consumption in daily business increase [1]. Users more interested for technologies that can make their business convenience [2]. Wireless Mobile Battery Charger is wireless energy transfer that process whereby electrical energy is transmitted from power source to an electrical load that does not have to built-in power source or without the use of interconnecting wires.

Whereas the battery charger is device use to put energy into a secondary cell or rechargeable battery. Battery charger works by forcing an electric current through it. The idea of wireless mobile battery charger is using mutual inductance or also known as inductive coupling [6]. This technique is one of the effective way to transfer power wirelessly [3].

The transmission of electrical energy is from one point to another point without using wire but through air space is called as inductive charging [4]. An inductive charging uses concept of inductive coupling to transfer energy between two circuits through electromagnetic field as it basic operation.

The wireless mobile battery charger is design to eliminate wired traditional system of charging. Even better, the wireless charger is an alternative to carrying collection of devices specific charger because the existed various type of charger now day.

This project used mutual inductance working principle to transmit the power [7]. Wireless mobile battery charger can be divided into 3 major part of components, which is transmitter side, receiver side and inductive coupling [5]. Basically wireless mobile battery charger idea come into block diagram as shows in Figure 1.

Figure 1. Block Diagram of Wireless Power Transfer

This Wireless Mobile Battery Charger project need several circuit such as oscillator circuit (transmitter), charging circuit (receiver), and a couple of coils (act like an antenna), a power supply (input) and output from phone battery (low power device) [11]. The basic block diagram of Wireless Power Transfer as Figure 1 then is expend into one system of Wireless Mobile Battery Charger as shown as Figure 2.

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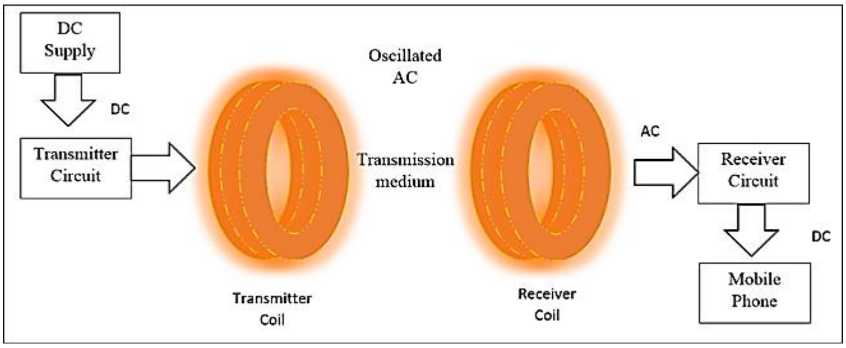


Figure 2. Block diagram of Wireless Mobile Battery Charger

Figure 2 simply explain from the input of wireless mobile battery charger till the output implemented at mobile phone. The overall functioning of Wireless Mobile Battery Charger is briefly explain through the consume block diagram, it required a wireless power transmitter and a wireless power receiver sections [3, 4].

For the transmitter section, it contain power supply, transmitter circuit and transmitter coil. Transmitter section will convert DC voltage to AC form then receiver will convert AC to DC form that compatible for low power device. Whereas, at receiver section containing with receiver coil, receiver rectifier circuit, voltage regulator IC and mobile phone battery.

The transmitter coil in this wireless Mobile Battery Charger transmitter section converts the DC power from an oscillator to a high frequency AC power signal. This high frequency alternating current, which is linked with the wireless power transmitting coil, would create an alternating magnetic field in the coil due to induction, to transmit energy [10]. When the transmitting and receiving coils are equivalent with or not significantly smaller than their separation distance between the two coils [13].

In the wireless mobile battery charger receiver section, the receiver coils receives that energy as an induced alternating voltage due to induction in its coil and a rectifier in the wireless power receiver section converts that AC voltage to a DC voltage. Finally this rectified DC voltage would be feed to the load through a voltage controller section. That is, the wireless mobile battery charger receiver section’s main function is to charge a low power mobile battery through inductive coupling [9]. In Wireless Power Transmission (WPT) systems, the proportion of energy received by the load is critical and the efficiency is the more significant parameter [14].

2. Research Method

This section covers the steps taken of the project Wireless Mobile Battery Charger flow process in simulation using MULTISIM, circuit construction using PROTEOUS, circuit testing on breadboard and hardware implementation.

2.1. Multisim Simulation

Before fabrication process start, the circuit need to construct to get better resonant frequency as desired. The MULTISIM software is used to construct receiver and transmitter circuit of Wireless Mobile Battery Charger and simulate the frequency resonant of transmitter circuit. During this circuit simulation using MULTISIM, the parameter used is assume in ideal state.

Figure 3 shows the simulation for the transceiver circuit by using the Multisim 13.0 software. This simulation process is used to produce the output waveform by using the virtual oscilloscope and to obtain the reading of output voltage from the virtual probes.

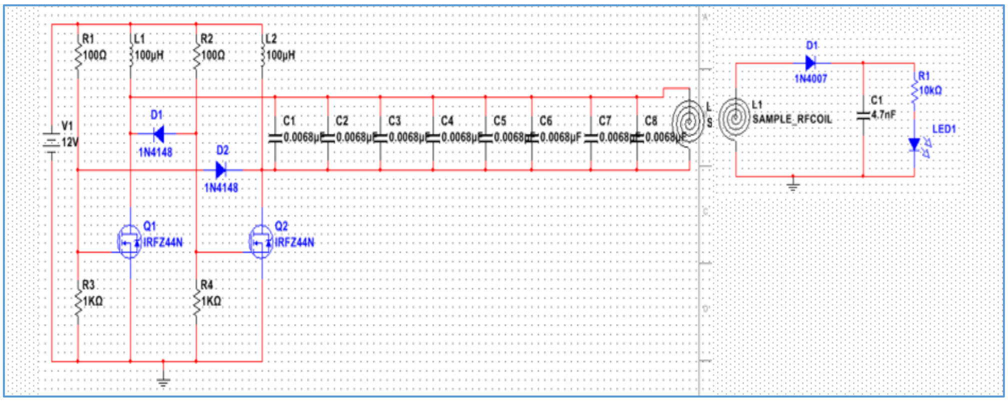


Figure 3. Wireless Mobile Battery Charger Circuit using MULTISIM Simulation

2.2. Proteous Simulation

The PCB foot-print layout is designed using PROTEOUS software before transferred onto PCB board. Simulation using PROTEOUS software is divided into three major task, which is schematic construction using ISIS PROTEOUS, PCB layout using ARES PROTEOUS, and 3D visualizer using Gerber generated/Exelon files viewer. To fabricate transmitter circuit on PCB board, firstly footprint of the circuit should draw. Figure 4 below simply shows the procedure using ROTEOUS in making the PCB layout.

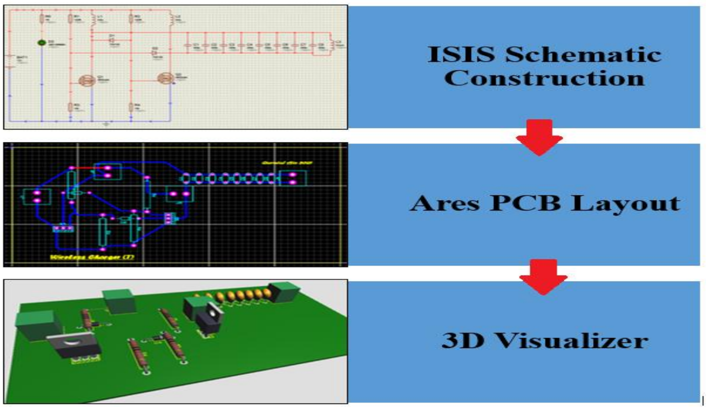


Figure 4. Flow Process to make Wireless Mobile Battery Charger using PROTEOUS Simulation

There were several design rules that need to be set before proceed to use the software. To draw a standard PCB layout, there are rules for every interconnection from components to VIA and route connection. Using PROTEOUS, the standard rules can be created with desired rules for electrical clearance, routing width, routing corner degree, VIA holes size and component clearance.

Figure 5 shows the transmitter and receiver schematic circuit was simulate using ISIS PROTEOUS before transferred onto PCB layout then generated to CAM file. PROTEOUS software is simple intelligent software where it will give sign indication if components are too near to each other's. Because the size of component has to be considered where it may cause troublesome in soldering session if component are put too near.

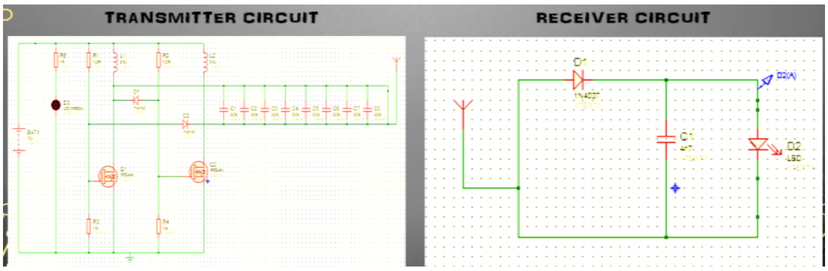


Figure 5. Schematic Circuit Simulation using PROTEOUS

2.3. Testing Process

In early stage of project, the proposed circuit of transmitter is tested on breadboard before being transferred to PCB. The experimental laboratories setup has been studied for the transmitter and receiver circuit. In this experiment, the input use is DC power supply. Yet practically, the charger is used as supply of Wireless Mobile Battery Charger. Then the LED is consider as an output in this experiment testing.

Figure 6 shows the set-up of testing process for proposed circuit on breadboard. This process to make sure the circuit connection and component been used is functioned. After the construction of transmitter and receiver circuit undergo functionality process testing using multi-meter to test the board continuity as shown as Figure 7.

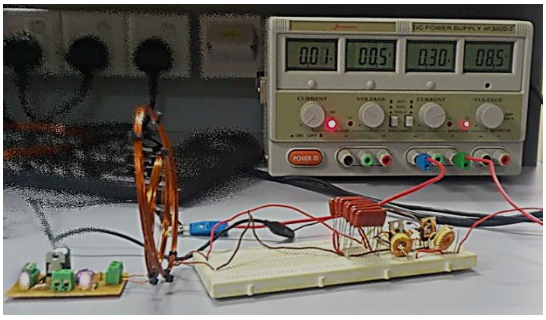


Figure 6. Experimental Set-up of proposed circuit

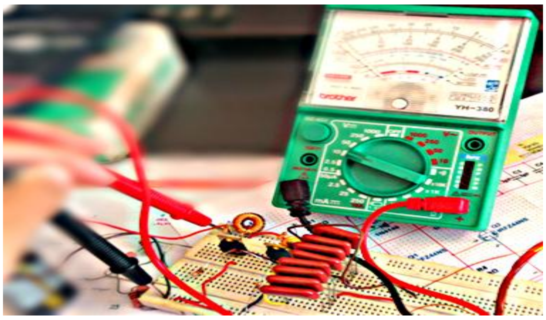


Figure 7. Testing Circuit on Breadboard using Multimeter

2.4. Hardware Implementation

The implemented of transmitter and receiver circuit on project of Wireless Mobile Battery Charger to the application of mobile phone is the last process in this project. Figure 8 shows the Wireless Mobile Battery Charger with LED load.

While Figure 9 show the Wireless Mobile Battery Charger proposed circuit implemented to mobile phone battery.

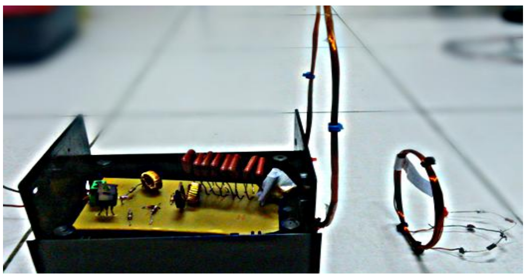


Figure 8. Hardware Implementation Circuit to LED

Figure 9. Hardware Implementation Proposed Circuit to Mobile Phone.

3. Results and Analysis

Several circuit is proposed in the circuit (transmitter and receiver) construction. This result achieve using MULTISIM simulation. The output of produced waveform is observed. Figure 10 show the circuit of transmitter proposed.

Unfortunately, this proposed circuit show the unstable result. Which is the output waveform of this circuit fluctuated and has transient at the beginning of it switching time. This can give bad impact to device. The Table 1 below shows the waveform result from this circuit.

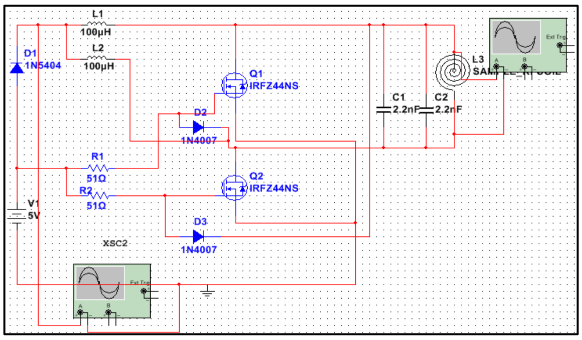
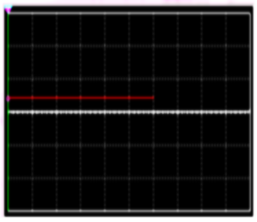
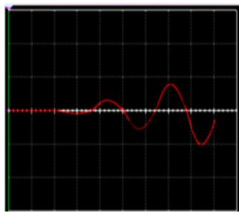


Figure 10. Transmitter Circuit

Table 1. Output Waveform

Input waveform	Output waveform
	

Then to improve the performance of circuit the idea in construction transmitter circuit is modified from Royer oscillator circuit. This oscillator circuit incredibly simple yet a very powerful design. This statement because it can operate in very high oscillating current with depending on semiconductor component only. In order to make this circuit operate in high frequency, power MOSFET is used. Moreover it is very fast in switching. Figure 11 shows the construction of transmitter oscillator circuit using MULTISIM software.

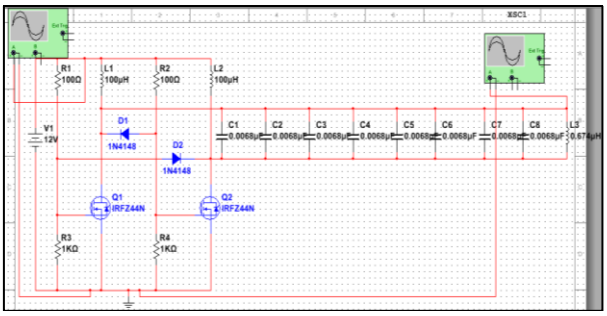


Figure 11. Transmitter Circuit

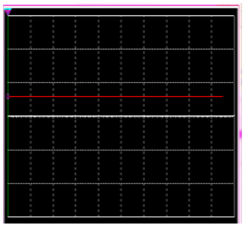
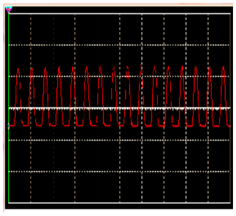
DC source allow current to flows through inductor labelled L1 and L2 as in Figure 4.5 and through drain terminal of MOSFET labelled Q1 and Q2. At that same time, the voltage appear at gate terminal of MOSFET. As it behaviour, MOSFET will turning ON when achieve +12V at Vg-s terminal. Voltage appear at both MOSFET Q1 and Q2 but only one will turn ON per-time. It's depend the fastness MOSFET receive voltage. Let say Q1 turn ON first, voltage at drain Q1 will clamped to near ground. Instantly MOSFET2 will be less conductive state or in OFF-state and make it voltage achieve maximum voltage then start to fall due to tank circuit form by capacitor through one half cycle [5]. The resonant frequency oscillated at transmitter coil circuit can be determined by formula as;

$$\mathrm{fr} = \frac{1}{\left(2\pi\left(\sqrt{LC}\right)\right)} \qquad (1)$$

Generally, N-channel power MOSFET (IRFZ44N- Q1 and Q2) act as switching devices. Two choke of inductor toroid (L1 and L2) used to give energy of high oscillating frequency. Then capacitor (C) works as a resonating capacitor which store energy. Diode (D1 and D2) provide cross coupled feedback and resistors (R1-R4) works as biasing network for Q1 and Q2. In this simulation, sample RF coil is used. This type of coil transferring energy due magnetic field flux [8]. The result when using all component listed in this transmitter circuit rapidly high than basic RC oscillator circuit and basic LC oscillator circuit.

The output waveform of this circuit oscillate in steady state as show in Table 2. The input waveform in DC and the output produce in high oscillating frequency AC form.

Table 2. Output Waveform

Input waveform	Output waveform
	

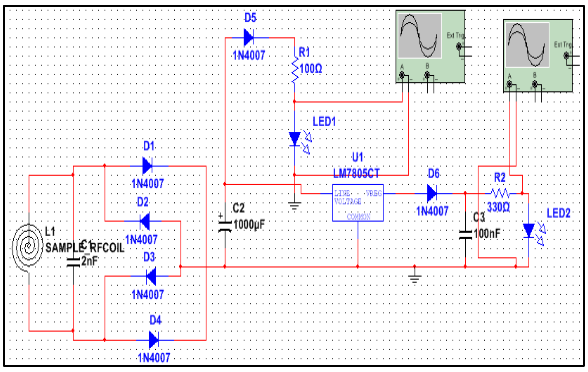


Figure 12. Receiver circuit

Figure 12 shows common receiver circuit construction using MULTISIM. This circuit give two point of output, which can produce 12V and 5V. The operation of circuit is start with an oscillating AC form at receiver coil as supply to the circuit flow to diode D1 and D3 will conduct in series while D2 and D4 in reverse bias. Diode will reversely conduct itself after that. Which means D2 and D4 in series then D1 and D3 is OFF. The capacitor in this circuit act as smoothing component. It will converts full wave ripple produce at rectifier diode during switching to DC output. In this condition, the produced output is 12Vdc. While regulator IC helps to provide a constant limited regulated output voltage which produced 5Vdc to the load before charging the low power devices.

After that, an experiment has been conducted to evaluate the range of distance of the power transfer based on the different coil size of antenna, supply voltage and coil turns [12]. Then to get the result of maximum distance that power can transfer by using the different coil size of antenna, supply voltages and coil turns.

In first experiment, the receiver coil antenna is fixed to 9cm with two mode supply which is 9V and 12V. Transmitter component also varies according to different coil size and number of turns. The result then demonstrated as Table 3 and Table 4 below.

Table 3. Result of 12Vdc Supply

Coil Size (mm)	# turns	Range of Distance (cm)
	10	1
0.1	15	4
	25	12
	10	0
0.54	15	0
	25	1

The experiment is repeated with 6cm diameter of receiver in 9V and 12V. Transmitter component also varies according to different coil size and number of turns. The result then demonstrated as Table 5 and Table 6.

Table 4. Result of 9Vdc supply

Coil Size (mm)	# turns	Range of Distance (cm)
0.1	10	0.5
	15	2.0
	25	8.0
0.54	10	0
	15	0
	25	0

Table 5. Result of 12Vdc supply

Coil Size (mm)	# turns	Range of Distance (cm)
0.1	10	0
	15	0
	25	0
0.54	10	1
	15	3
	25	6

Table 6. Result of 9Vdc supply

Coil Size (mm)	# turns	Range of Distance (cm)
0.1	10	0
	15	0
	25	0
0.54	10	0
	15	0.5
	25	3.0

From the data achieve as shows in all tables indicated the range of distance can be longer if size of transmitter coil is small. Let take one of the best transmission performance in this data; which is transmitter coil size of 0.1cm with higher number of turns of 24 turns give the best result of 12cm of range of distance.

Yet, the smallest transmitter coil size of 0.54mm with 9 turns did not give any result of distance. This is because the transmission resistance become larger when reducing the area size of component (transmitter coil antenna).

The 9cm coil size of receiver (larger) require the smallest coil size of transmitter with higher number of turns to give the best performance power transfer represent in the range of distance as output. Hence in real application this condition is not suitable to apply. Because day by day, the mobile phone size become smaller or friendly user pocket. To implement receiver coil and circuit with mobile phone, the size of both component should match.

So then the second experiment is conducted in order to reducing the receiver coil size. Then the receiver diameter reduce to 6cm. The best result when reduce receiver coil size is transmitter size is bigger with higher number of turns. The large range of distance to transmit power as output.

The analysis can be summarize as the transmission resistance become larger when reducing the area size of antenna (transmitter coil and receiver coil). This situation prove by equation

$$R= \frac{\rho l}{A} \tag{2}$$

The output of power to transmit is;

$$P= I^2 R \tag{3}$$

From table also can observed the output from voltage supply 12Vdc better than 9Vdc. Means that, rectifier AC to DC converter or adapter for transmitter circuit should use the 12Vdc. The maximum distance is until the LED still can light up which is the power still can transfer to the load.

4. Conclusion

This wireless mobile battery charger project was describe and demonstrated that inductive coupling can be used to delivering energy wirelessly from a sources to load to charge mobile phone or any low power device by using coil through air space. This mechanism is potentially robust charging method of charging mobile phone wirelessly

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