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Wireless power transfer using the concept of magnetic coil resonant system

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Abstract

Long life lithium ion batteries and methanol fuel cells have been persuaded as ways to make the electrical components more mobile, consumers' expectations are still far from being met due to the added weight and expenses for battery replacement. The discovery of wireless power is transfered as a new option, and holds great promise to leave the oversized battery. The design of wireless power transfer applies the concept of magnetic coil resonant system (MCRS). The concept of MCRS is similar with a function of an antenna to transfer the power from one point to another. Simulation process is used to produce the output wave on the virtual oscilloscope and to obtain the reading of output voltage from the multimeter. The transmitter side contains power supply, transmitter oscillator circuit and transmitter magnetic coil. Transmitter circuit convert DC to AC waveform and the receiver circuit convert AC to DC voltage. The DC Source that connected to transmitter was provided by the DC source regulator acts as DC source to adjust voltage and current separately. The project show the efficiency of the wireless power transfer with different coil diameter and a distance between the transmitter and receiver coil. At a distance of 15 cm, power is successfully transmitted as it is indicated by the LED light to turn on. The increment of size in coil diameter has given a higher power and longer coverage distance for wireless transfer power.

Keywords*: magnetic coil, resonant system, wireless power transfer*

1. Introduction

Wireless power transfer has been a dream of human beings. Many scientists have researched it uninterruptedly but very little progress has been made. They have been studied very deeply and used in each daily life, such as electric toothbrushes, cordless home phones and so on [1-3]. However, the researcher did not provide a design-oriented model for such wireless power transfer systems, suitable for designing or validating a design. Efficiency of non-contact electromagnetic induction can reach to 80% but it is in a very short distance i.e. 1 cm [4]. Wireless power transfer of resonant coupling can transfer energy in 5 cm and its efficiency reaches 40%. A coil ring with an oscillating current works as resonant system to transfer a power [5, 6]. This generate an oscillating magnetic field [7-9].

The prototype of wireless power transfer (WPT) has four main parts. The first part is DC input voltage which is the input is using DC source. The second part is transmitter which is used to transmit the power by using the magnetic coil resonance system (MCRS) [10-12]. The third part is a receiver circuit that functions as a receiver to receive the power from the transmitter. The last part is a load; this project used only LED as an output or load.

2. Proposed Method

WPT is the process where electrical energy is transmitted from a power source to an electrical load across an air gap using induction coils [10]. These coils produce an electromagnetic field which sends energy from a charging base station (transmitter) to a coil on a portable device (receiver) with complete galvanic isolation [5, 11]. The receiver coil takes power from the electromagnetic field and converts it into electrical power [8, 12]. Figure 1 shows the block diagram for the whole project. Inductive or magnetic coupling works on the principle of electromagnetism [13]. When a wire is proximity to a magnetic field, it induces a magnetic field in that wire [14-16]. Transferring energy between wires through magnetic field is inductive coupling.

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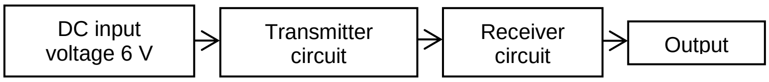

Figure 1. Block diagram of wireless power transfer

Figure 2 shows how the magnetic coil resonant system work. Depending on the distance between the transmitter and receiver coils, only a fraction of the magnetic flux generated by the transmitter coil penetrates the receiver coil and contributes to the power transmission [16]. The more flux reaches the receiver, the better the coils are coupled [17]. Figure 3 shows longer distance between transmitter and receiver coils. In loosely coupled systems, only a fraction of the transmitted flux is captured in the receiver [18-20]. Theoretically, less distance between transmit and receive coils are more efficient and less heat which is an advantage to the products with tight budgets such as modern smartphones.

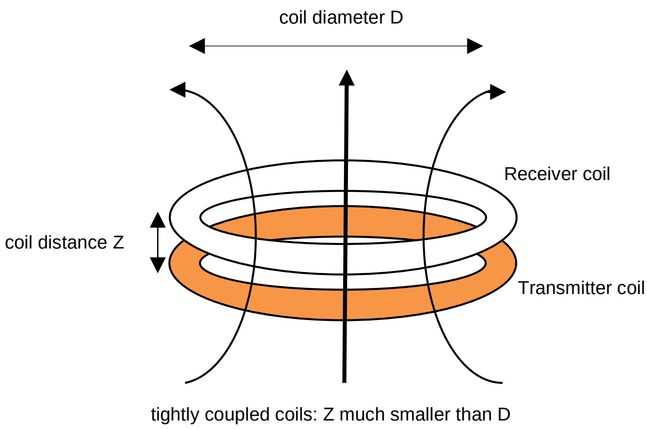

Figure 2. The short coil distance

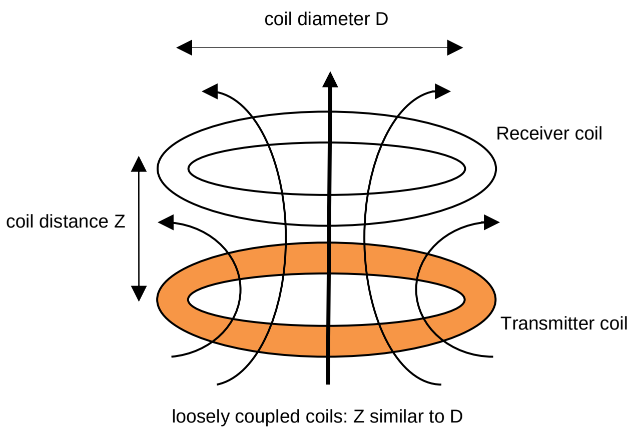

Figure 3. The long coil distance

Figure 4 shows a simple WPT circuit, the left side is called transmitting side, and the right side is called receiving side; u is a sinusoidal input for WPT [21, 22]. R_1, R_2, C_1, C_2 are parasitic factors of the circuit. L_1 and L_2 are self inductances, and M is the mutual inductance between L_1 and L_2. R_L is a load resistance which consumes energy [23-25], while v_1 and v_2 are the voltage of C_1 and C_2, and i_1 and i_2 are the current of L_1 and L_2.

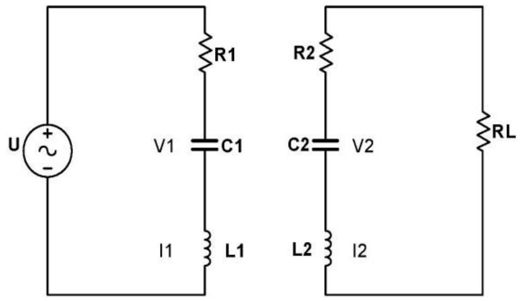

Figure 4. A simple WPT circuit

3. Research Method

This section gives the process of project experiment in 3 part namely simulation process, testing process and hardware preparation.

3.1. Simulation

Figure 5 shows the simulation for the wireless power transfer circuit. This simulation process is used to produce the output wave on the virtual oscilloscope and to obtain the reading of output voltage from the multimeter. For the transmitter part, it contains DC source transmitter circuit and magnetic coil. Transmitter circuit convert DC voltage to AC form, then receiver circuit convert AC to DC form, that compatible for low power device.

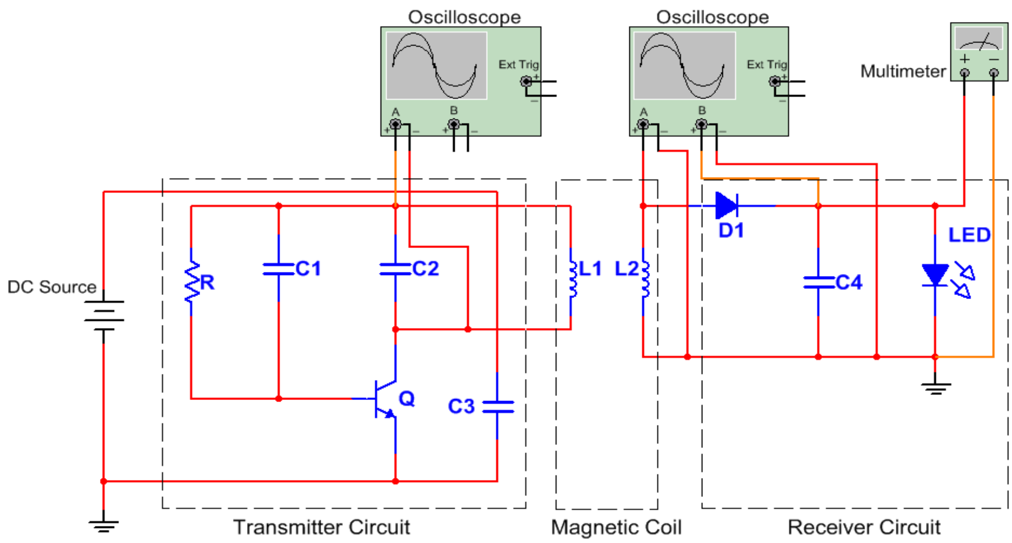

Figure 5. Wireless power transfer circuit simulation

3.2. Testing Process

The experimental has been setup on PCB kit board for the transmitter and receiver circuit. The LED has been used as a load and connected at the receiver side and magnetic coil. The electric source for this experiment is variable DC power supply. Figure 6 shows the testing the circuit on PCB kit board when both of coils areput at very close distance i.e. 0 cm. As the experiment is carried out by turning on the DC supply, the LED is lighted up clearly with 3 V on its terminal side. It is also recorded that the output voltage is 3 V. Figure 7 shows the experiment as the coils are placed at longer distance i.e. 5 cm. The experimental result shows that the LED is dimmed at 2.5 V. The output voltage decreases to 2.5 V. The experiment is repeated with different diameter size of the coil to get the data measurement for each coil.

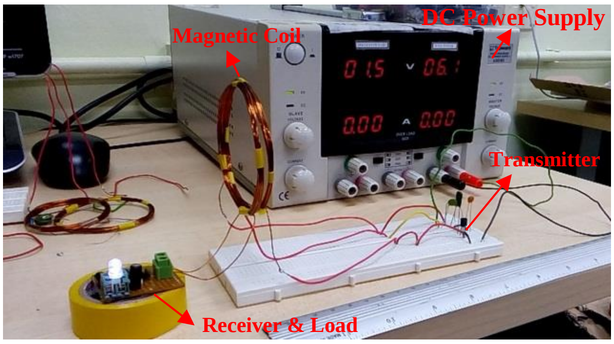

Figure 6. The experiment for WPT magnetic coil with distance of 0 cm

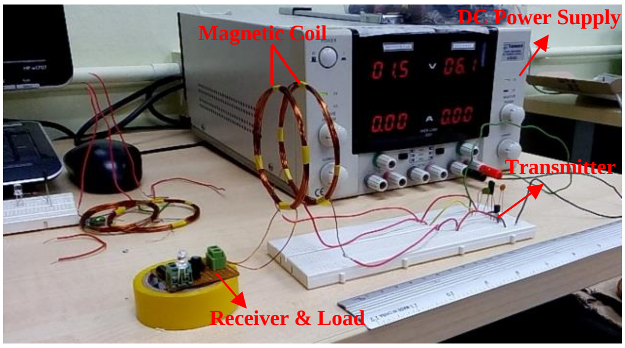

Figure 7. The experiment for WPT magnetic coil with distance of 5 cm

3.3. Hardware Process

At the last process of experiment, the circuit is set up permanently at the printed circuit board as the final prototype of WPT. The DC source for WPT prototype is fixed and it is supplied by 6 V batteries. Figure 8 shows the hardware set up for the prototype. During experiment, the electric power remains to be transferred although the distance between transmitter and receiver coil is more than 15 cm. The bright of LED is clear to be observed.

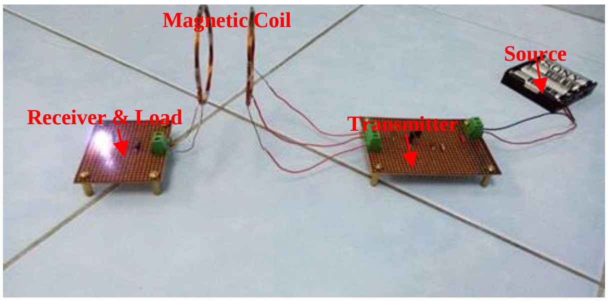

Figure 8. Hardware circuit

4. Results and Discussion

The experiment applied 5 types coil with different diameter, i.e. 6–10 cm respectively. Every coil has fixed 10 turn for both transmitter and receiver coil. Table 1 shows the result of the output voltage with the several distance variables between the transmitter and receiver coil. The maximum distance is obtained at 15 cm when the LED remains on which gives indication that the power is transferred to the load.

Table1. The Experimental Result

Diameter (cm)	Distance (cm)	Output Voltage (V)
6.0	0	3.0
	5	2.8
	10	2.6
	15	2.5
7.0	0	3.4
	5	3.32
	10	3.2
	15	3.0
8.0	0	3.8
	5	3.71
	10	3.52
	15	3.1
9.0	0	4.1
	5	3.81
	10	3.74
	15	3.5
10.0	0	4.85
	5	4.69
	10	4.54
	15	4.15

Figure 9 shows the graph of output voltage as the function of distance. The curves are drawn based on recorded data at Table 1 and theygives the relationship that the output voltage remains constant until the distance is set above 15 cm. The maximum decrement of output voltage reach 4.15 V as the distance is set at 15 cm. The lower output voltage is occurred because the receiver coil cannot receive the power from the transmitter coil.

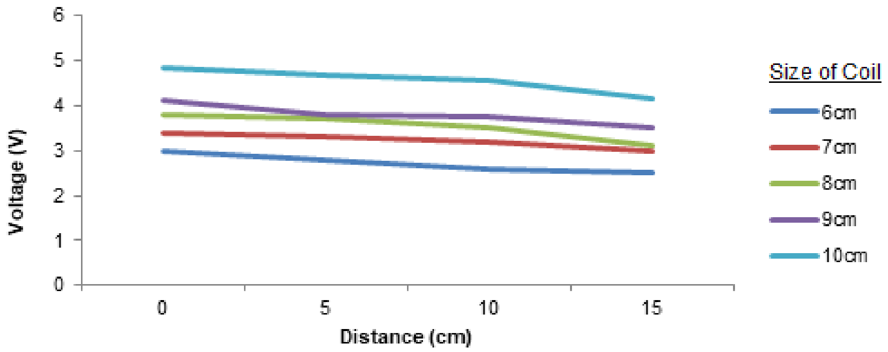

Figure 9. Graph of output voltage vs distance

Figure 10 shows the output waveform from the oscilloscope. The waveform shows the sinusoidal wave with frequency 468.8 kHz and 70.4 V peak to peak voltages as the transmitter and receiver coil distance is 15 cm. Figure 11 shows the output waveform from the oscilloscope. The waveform shows the sinusoidal wave with frequency 451 kHz and 83.2 V peak to peak voltages as the transmitter and receiver coil distance is 0 cm. The amplitude of output voltage is considerably high at 4.85 V, although the waveform has ripples.

The result shows that the output voltage are in the range of 4.15 to 4.85 V and the output current at load side are in the range of 0.3 to 0.85 A. Those output voltage and current provide 1.23 to 3.48 W when the recorded output voltage and current are calculated. The power delivered at output side of receiver coil has the opportunity as the electric source for any gadget or product. The increment of coil diameter has affected the higher power while the longer distance between the coils has reduced the ability of WPT to transfer the electric power.

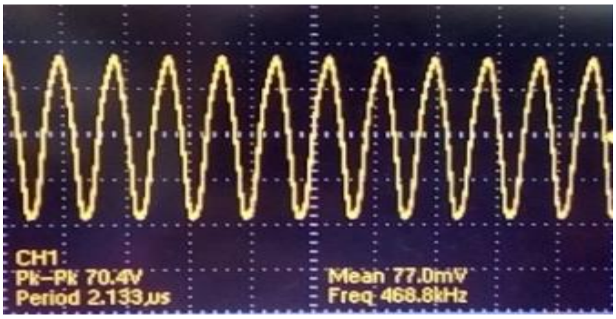

Figure 10. Sinusoidal output waveform for the distance of 15 cm

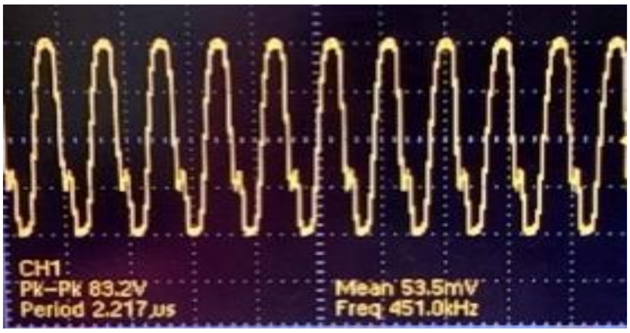

Figure 11. Sinusoidal output waveform for the distance of 0 cm

5. Conclusions

From the overall experiment conducted from this prototype of wireless power transfers using the concept of magnetic coil resonant conclusions are deducted. Based on experimental result, the study on wireless power transfer using MCRS has much aspect in terms distance and size of diameter coil. The maximum distance is obtained at 15 cm when the LED remains on which gives indication that the power is transferred to the load.

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