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Development of a Wireless Power Transfer Circuit Based on Inductive Coupling

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Abstract

Wireless electrical energy transfer has many advantages over the same through conducting cables. This research focusses on developing wireless power transfer circuitusing inductive coupling. The experiment has been done by changing the number of turns and the diameter of the wire of a coil with the aim of finding the maximum power and the longest distancethat the energy can be transferred through wireless means. The power source is connected to a series of electronics components and a copper coil which form the primary source for the transmitter the power receiver consists of a copper coil, a rectifier and the load. In a system with the diameter of the wires of the two coils is0.5 mm, and the number of turns is 26 at the frequency of 470KHz the efficiency of power transfer about 1.51% at a distance of 1 cm. The transferred energy by wireless means could operate a 1 Watt LED at 1 cm.

Keywords*: wireless power transfer, inductive coupling, transmitter circuit, receiver circuit*

1. Introduction

Today's technological developments have progressed very rapidly. Along with the increasing human needs of the day is the need for a technology that can support the human needs. In everyday life man now can not be separated from the need for electrical equipment. Almost in all aspects of human need electrical power. In general, the electrical power transfer that we use is to use an intermediate medium in the form of copper wires. Copper is used as an electrical transfer medium because the material is composed of many electrons that can move freely. When copper wire is connected to a power source the flow of electrons can move freely on the material. But along with the development of technology today has developed wireless power transfer. In addition to increasing the practicality of this also can be a savings on materials for the manufacture of cables as a medium of power distribution.

Wireless power transfer (WPT) is a way to transmit electrical energy without using wires. Currently there are several wireless power transfer technologies that no one uses electric fields, magnetic, and electromagnetic fields. This wireless power transmission is useful for powering electrical devices where the cables used are uncomfortable, dangerous, or impossible. Wireless power transfer techniques fall into two categories areradiative and non-radiative [1]. In the near-field technique or a non-radiation, power transferred by magnetic fields using inductive coupling between the coils of wire, or electric field using capasitive coupling between metal electrodes [2].

Inductive coupling is the most widely used wireless technology. Applications include charging handheld devices such as phones [3] and electric toothbrushes, RFID/NFC tags [4] and [5], and chargers for implantable medical devices such as artificial pacemaker, or electric vehicles. In the far-field techniques or radiation, also called power beam, the power transferred by electromagnetic radiation, such as microwaves or laser signal. This technique can remotely transfer energy but should be directed to the receiver. The application proposal for this technique is solar powered satellites and unmanned aircraft vehicle (drone) [6] and [7]. Electric power delivery without passing through a cable will greatly assist in the use of electronic equipment because it will be more effective and efficient, but the wireless power delivery system should also pay attention to exposure to electromagnetic fields are potentially harmful to living things themselves. In this study developed a wireless power transfer circuit with inductive coupling. Wireless power transfer by inductive coupling has been developed another researcher

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in [8], [9] and [10]. Other research in the field of wireless charging, among others, is done by [11] and [12].

2. Research Method
2.1. Inductive Coupling Principle
Inductive coupling principle can be seen in

Figure *1*. Inductive coupling is the electromagnetic coupling between two coils, namely the primary and secondary coils. In this design the primary coil and the secondary coil must be considered several things that may affect the power transfer process itself, such as the wire used, the number of turns, the diameter of the wire (AWG), the diameter of the coil and the shape of the winding.

From

Figure *1*(a) the primary coil receives the DC input and is processed so that it becomes a magnetic field for power transfer, and for the secondary coil of

Figure *1*(b) receives the magnetic field produced by the secondary coil and converted into an AC signal. There are two mechanisms in which the harmonic current can cause heating in a conductor greater than the expected current value. The first mechanism is due to the distribution of current in the conductor, including skin effect and proximity effect.

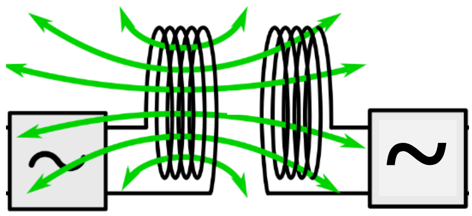
a. primary b. secondary

Figure 1. Inductive coupling principle

Skin effect is caused by the distribution of surface current greater than in the conductor, so that effective resistance increases. Skin effects increase with increasing frequency and conductor diameter. While the proximity effect due to the conductor magnetic field disrupts the current distribution in adjacent carriers. Inductance value can calculate using equation 1.

$$L = \frac{r^2 \times N^2}{8r + 11d} \quad (1)$$

Where:
L = Inductance of coil (μH)
N= Number of turns in wire coil
r = Mean radius of coil (inches)
d = thickness of coil (inches)

2.2. Block Diagram
The system developed can be illustrated in the block diagram as shown in Figure 2. The system consists of a power supply with 12V output, an oscillator, the primary coil or coils sender, the secondary coil or the receiver coil, and rectifier. This wireless power transfer works using the principle of electromagnetic induction. To generate the electron magnetic field required 2 pieces of coils that serve as a magnetic field producer that is the primary coil and magnetic field catcher is the secondary coil. The magnetic field will only appear if given the resources back and forth therefore necessary oscillator circuit that works as a modifier of the direct current generated by the power supply into an alternating current. After that process the alternating current is passed to the primary coil in the form of the inductor component L and

generates the magnetic field to be transferred to the secondary coil in the same component of the inductor.

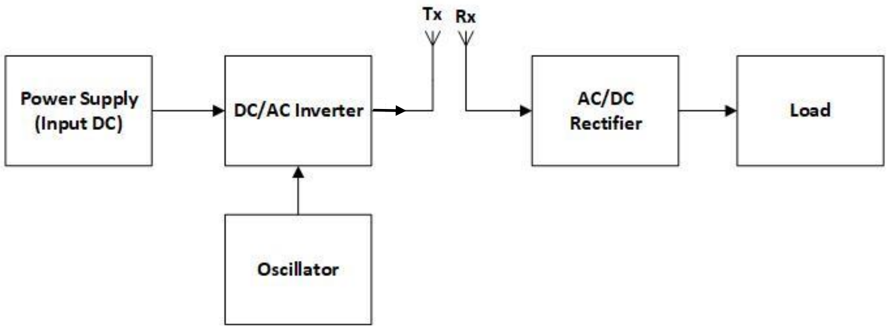

Figure 2. Block Diagram

After the magnetic field is captured by the next secondary coil from the magnetic field it changes into alternating current according to Faraday's law. Next the alternating current goes into the rectifier circuit so that its current becomes direct current. The result of the rectification is used to provide the power supply to the load to be used ie the lamp or electronic devices.

2.3. Electronic Design

Electronic circuit to be designed consists of a full-bridge inverter circuit, Tx and Rx antenna, and rectifier circuit.In the full-bridge inverter circuit used 2 pieces of IR2110 MOSFET driver, 4 pieces MOSFET IRFP250N, and oscillator IC 555 [13]. The main component of the rectifier circuit is 4 FR204 diodes as a rectifier and regulator 7805 as the output voltage regulator. For Tx and Rx antennas are made using email wire. The wire is entwined by using design forms spiderweb coil windings. This design is used to minimize the losses caused by the skineffect and proximityeffect.

3. Results and Analysis

3.1. Testing Effect of Coil Wire Diameter

In this test important section of a sender and receiver circuit in the form of a coil size of 0.5 mm for the first test and 0,75mm for the second test. Based on Table 1 and 2 it is seen that for the diameter of 0.75 mm wire and the distance of 1 cm, there is a voltage of 2.6 volts at the Vregulator point. Whereas for 0.5 mm wire diameter obtained voltage 2.1 volts. For lamp conditions, 0.5 mm wire diameter and 2 cm distance of the lights have begun to fade while for 0.75 mm wire diameter the lights begin to fade at a distance of 2.5 cm. Maximum power transfer generated amounted to 67.6 mWusing a 0.75 mm diameter wire. Whereas for 0.5 mm wire diameter the maximum power that can be generated is 44.1 mW. For optimal power transfer using 0.75 mm diameter wire because at a distance of 1 cm to 2 cm bright light conditions and the resulting voltage is quite large when compared with 0.5 mm wire diameter.

Table 1. Measurement of Power Transfer with 0.5mm Wire Diameter

AWG 0.5mm				
Load 100 ohm				
Distance (cm)	Vunregulator (Volt)	Vregulator (Volt)	Power	Lamp
1	5.8	2.1	44.1 mW	Bright
1.5	4.4	1.8	32.4 mW	Bright
2	3.4	1	10 mW	Dim
2.5	2.8	0.07	49 uW	Die
3	2.6	0.01	1 uW	Die
3.5	2.4	0	0	Die
4	2	0	0	Die
4.5	1.6	0	0	Die

5	1,2	0	0	Die

Table 2. Measurement of Power Transfer with 0.75mm Wire Diameter

AWG 0.75mm				
Load 100 ohm				
Distance (cm)	Vunregulator (Volt)	Vregulator (Volt)	Pow er	Lamp
1	6.2	2.6	67.6 mW	Bright
1.5	4.8	2	40.5 mW	Bright
2	4	1,2	14.4 mW	Bright
2.5	3.4	0.4	1.6 mW	Dim
3	2.9	0.07	49 uW	Die
3.5	2.4	0.01	1 u	Die
4	2	0	0	Die
4.5	1.5	0	0	Die
5	1,2	0	0	Die

Graph comparison voltage and power to the coil wire diameter of 0, 5 mm and 0.75 mm can be seen in Figure 3.

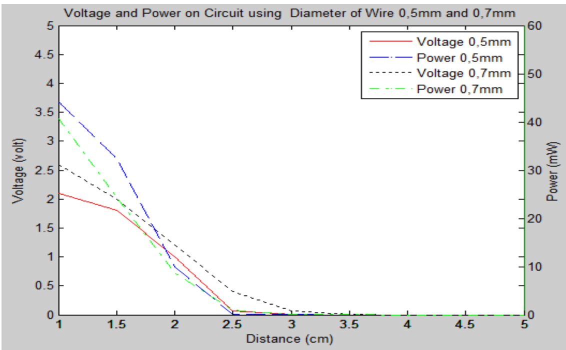

Figure 3. Comparison of voltage and power with 0.5mm and 0.75mm coil wire diameters

3.2. Frequency Impact Testing

Experimental results with varying frequency can be seen in Table 3. In Table 3 the voltage is inversely proportional to the frequency change. The greater the frequency generated the smaller the voltage generated. At 490KHz frequency has decreased the value of voltage and for testing the next frequency of 500KHz to 600KHz seen the voltage obtained did not really affect the value of the other voltage. The smallest voltage obtained at 4.3V is at a frequency of 600KHz. For setting the frequency with the result that the maximum voltage is obtained at a frequency of 470KHz and 480KHz as shown in Table 3.

Table 3. Voltage Measurement Data on Frequency Changes

Distance 1 cm		
AWG 0.75mm		
Frequency (KHz)	Vunregulator (Volt)	Vregulator (Volt)
470	6	5
480	6	5
490	5.6	4.7
500	5.5	4.6
510	5.4	4.5
520	5.5	4.6
530	5.4	4.5
540	5.3	4.4
550	5.4	4.5
560	5.5	4.6

570	5.5	4.6
580	5.3	4.4
590	5.4	4.5
600	5.2	4.3

3.3. Testing the Influence of the Number of Turns

Test results with different number of turn can be seen in Tables 4 and 5. From the two experimental results in Tables 4 and 5 the result of maximum voltage of 2.7 V the power obtained for 72.9 mW using 26 turns at a distance of 1 cm. For the first experiment (13 turns) the lamp condition at 2 cm has begun to fade. In the second experiment (the number of turn of 26X) the light conditions begin to fade at a distance of 2.5 cm. So the more the number of windings the more optimal the power transfer generated. Furthermore, by using winding 26X measured circuit efficiency in power transfer. The result of measurement and efficiency calculation can be seen in Table 6. Comparison of voltage and power to the coil windings 13X and 26X can be seen in Figure 4.

Table 4. Measurement Results Power Transfer with 13turns

AWG 0.5mm				
Number of turns 13X				
Distance (cm)	Vunregulator (Volt)	Vregulator (Volt)	Pow er	Lamp
1	5.8	2.1	44.1 mW	Bright
1.5	4.4	1.8	32.4 mW	Bright
2	3.4	1	10 mW	Dim
2.5	2.8	0.07	49 uW	Die
3	2.6	0.01	1 uW	Die
3.5	2.4	0	0	Die
4	2	0	0	Die
4.5	1.6	0	0	Die
5	1,2	0	0	Die

Table 5. Measurement Results Power Transfer with the number of turns 26X

AWG 0.5mm				
Number of turns 26X				
Distance (cm)	Vunregulator (Volt)	Vregulator (volt)	Pow er	Lamp
1	7.3	2.7	72.9 mW	Bright
1.5	6.2	2	40 mW	Bright
2	4.7	1.5	22.5 mW	Bright
2.5	3.4	0.4	1.6 mW	Dim
3	2.9	0.05	25 uW	Die
3.5	2.5	0	0	Die
4	2	0	0	Die
4.5	1.6	0	0	Die
5	1,2	0	0	Die

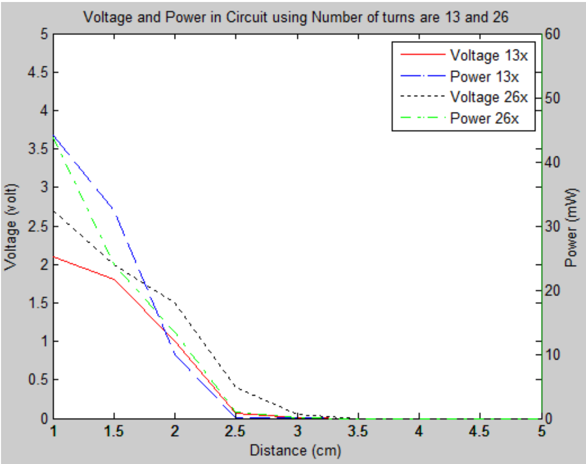

Figure 4. Comparison of voltage and power with coil windings 13X and 26X

Table 6. Transfer Efficiency Calculation

Distance (cm)	V_{input} (V)	I_{input}	P_{nput} (W)	V_{output} (V)	R (Ω)	P_{output} (mW)	η (Efficiency)
1	12	0.4	4.8	2.7	100	72.9	1.52%
1.5	12	0.4	4.8	2	100	40	0.83%
2	12	0.4	4.8	1.5	100	22.5	0.47%
2.5	12	0.4	4.8	0.4	100	1.6	0.03%
3	12	0.4	4.8	0.05	100	0.025	0.0005%
3.5	12	0.4	4.8	0	100	0	0.0%
4	12	0.4	4.8	0	100	0	0.0%
4.5	12	0.4	4.8	0	100	0	0.0%
5	12	0.4	4.8	0	100	0	0.0%

4. Conclusion

The effect of wire diameter (AWG) used is directly proportional to the amount of power that can be transferred. The larger the diameter of the wire used, the greater the power transferred. The effect of the number of turns used is directly proportional to the amount of power that can be transferred. The more the number of windings used the greater the power transferred. The final series used using email wire of 0.5mm diameter, the number of turns 26X, the input frequency of 470KHz. The power efficiency transferred at a distance of 1 cm is about 1.51%. The result of the experiment can turn on 1 Watt LED lamp.

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