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Wireless Mobile Charging Using Inductive Coupling

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Abstract

Wireless charging technology is revolutionizing the way electronic devices are powered, offering convenience and flexibility. This project focuses on the design and implementation of a high-efficiency wireless mobile charging system using inductive coupling, capable of delivering 22W power to modern fast-charging smartphones. The system operates at a resonant frequency of 150 kHz, leveraging optimized transmitter and receiver coils to ensure maximum energy transfer efficiency. The design incorporates 555 timer, IRF540N MOSFET, LC resonant circuits and optimized coil alignment to enhance efficiency. Schottky rectifiers, and XL6009 buck converter, ensure stable output with safety mechanisms. Simulation and experimental results confirm effective energy transfer, even in the presence of alignment challenges and EMI (electromagnetic interference), making this system a promising solution for next-generation mobile charging. Thermal management strategies and robust safety features, such as overcurrent and overvoltage protection, ensure reliable and secure operation.

Keywords: *Wireless power transfer, inductive coupling, Resonant frequency, mobile charging, Optimized coil alignment.*

1. Introduction

The increasing dependency on mobile devices necessitates rapid advancements in charging technologies. Wireless power transfer (WPT) systems based on inductive coupling have gained popularity for their convenience and reliability. In this paper, we explore the design and implementation of a wireless mobile charging system capable of transferring over 22W of power, making it suitable for fast mobile charging applications. The circuit uses readily available components and offers a low-cost yet efficient solution. Traditional wired charging systems often face issues such as cable wear and tear, port damage. Inductive coupling technology eliminates the need for physical connectors, providing a more durable and user-friendly alternative. Wireless charging through inductive coupling involves close-range energy transfer via magnetic fields generated by current-carrying coils. By matching the resonant frequency of the transmitter and receiver coils, energy transfer can be maximized. However, this technique also presents design challenges related to coil design, frequency tuning, and power regulation, which this paper addresses in detail [1].

2. Principle of Operation

Inductive coupling relies on magnetic resonance to transfer power between a primary (transmitting) and secondary (receiving) coil. When alternating current flows through the primary coil, a varying magnetic field is generated, which induces a voltage in the secondary coil [2]. This principle is governed by Faraday’s law of electromagnetic induction, which states that the induced electromotive force (EMF) in a coil is proportional to the rate of change of magnetic flux through it. The system's efficiency depends on resonance frequency matching, coil alignment, and switching performance of the driver circuit [3].

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2.1 Block Diagram

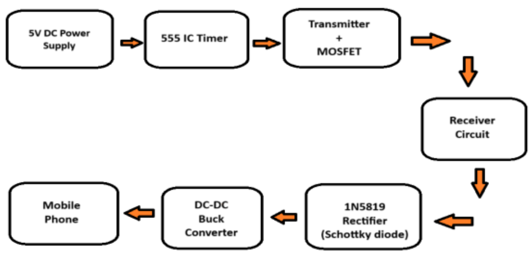

Figure 1 Block Diagram

Specifications

Input supply : 5V,3A

555 timer : 4.5 – 15V, 200mA, frequency = 150Khz

IRF540N MOSFET : VGS = 4V, VDS = 5V, ID = 2.5A

Transmitter coil : coil length = 2.2m, coil diameter = 4.5cm
No.of turns = 15
Inductance = 50uH
capacitance = 1nF

Receiver coil : coil length = 2.9m, coil diameter = 4.5cm
No.of turns = 20
Inductance = 60uH
capacitance = 1nF

Bridge rectifier : 2.6V, 150mA

DC-DC buck converter : 2V to 5V,9V,15V,30V and max current > 2A. Figure 1 shows Block Diagram.

3. System Design

3.1 Components Used

- TP4056 (Battery charging module) / Input adapter cable
- 555 Timer IC (Astable mode for frequency generation)
- IRF540N MOSFET (Switching control
- Resistors: 100 ohm, 1K ohm, 5.6K ohm
- Capacitors: 1nF, 1Uf
- 22AWG Copper wire (Transmitter and receiver coils)
- 1N5819 Diodes (Flyback protection)
- XL6009 (DC-DC converters for voltage regulation)
- 33W USB-C charger (5V, 3A output)

3.2 Transmitter Circuit

A 555 timer is configured in a stable mode to produce a square wave of 150kHz. The output drives the gate of the IRF540N MOSFET [4]. The drain is connected to one end of the transmitter coil, while the other end is connected to the 12V supply. A fly back diode protects the MOSFET from voltage spikes. The source is connected to the common ground. Figure 3 shows Represents Above Simulation Result.

3.3 Receiver Circuit

The receiver coil induces an AC voltage, which is rectified using a full-bridge rectifier made of 1N4007 diodes. The output is filtered and fed into the XL6009 or MT3608 boost converter, depending on the output requirements. The TP4056 module is used to safely charge a lithium-ion battery or power the mobile device. Figure 2 shows Transmitter and Receiver Circuit.

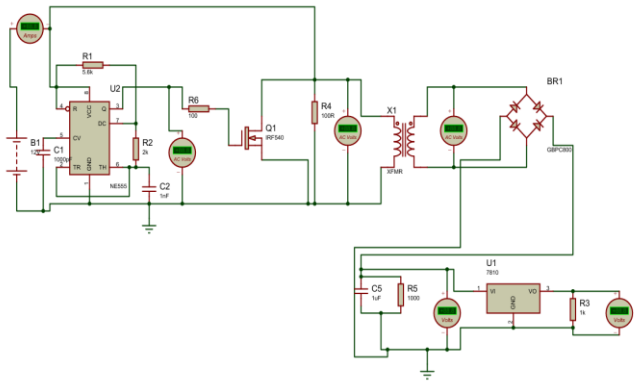

Figure 2 Transmitter and Receiver Circuit

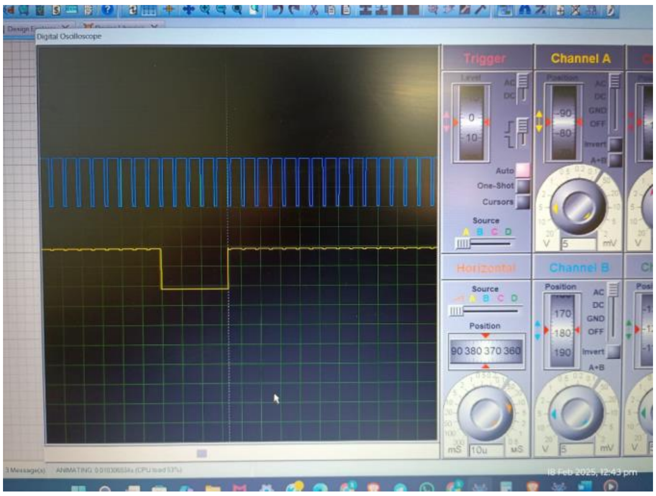

Figure 3 Represents Above Simulation Result

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4. Design Calculations

$T = (0.693 * (R_1+2R_2) C)$

$T_{ON} = 0.693 * (R_1+R_2) C$

$T_{OFF} = 0.693 * (R_2) C$

$f = 1.44/(R_1+2R_2) C$

Assuming **f=150Khz, C=1nF**

- $150 * 10^3 = 1.44/(R_1+2R_2) * 10^{-9}$
- (R1+2R2) * 10-9 = 1.44 * 10-3 /150
- R1+2R2 = 1440/150 Kilo Ohm
- R1+R2 = 9.6 K Ohm

Assuming **R_1 = 2 K Ohm, R_2 = 5.6 K Ohm**

Duty Cycle = $T_{ON}/T * 100$

$= (R_1+R_2)/ (R_1+2R_2) * 100 = (2+5.6)/(5.6+4) *100$

= 7.6/9.6 *100 = 0.79 *100 ~ 80 %

Output Voltage (V_{OUT}) = V_{in} * Duty Cycle
= 5 * 80% = 4 V

Theoretically, V_{OUT} = 4V

Resonant frequency, f = $\frac{1.44}{(R_1+2R_2)} \cdot \frac{1}{c}$

R1 = 5.6 Kohms, R2 = 2 Kohms, C = 1 Nf, f = 150 kHz

To Calculate the size of the air – core coil, the distance between transmitter and receiver was assumed 3cm

$a= (2)^{1/2} Z$, Z=3 cm

Radius of coil a =4.24 cm

Gauge of Copper wire coil:

Skin depth $\delta = 1/(\pi f \mu \sigma)^{1/2}$

δ =0.356 mm

AWG =22

Number of turns of coil:

$L = \mu_0 N^2 A/l$

$N = ((L * l)/\mu_0 * A)^{1/2}$

l = length of coil

A = Area of cross section of wire

μ_0 = Permeability of free space ($4\pi * 10^{-7}$ μ/m)

N = No. of turns of coil

For **l = 2.5 m**

$N = ((5*10^{-7} *0.5)/(4\pi*10^{-7}*56.47*10^{-4}))^{1/2}$

$N = (2.5/709.72*10^{-5})^{1/2}$

$= (2.5/0.71)^{1/2} * 10$ = 18.7 turns

N=15 turns

For **l = 2.8 m**

$N = ((5*10^{-6}*1)/ (4\pi*10^{-7} * 56.47*10^{-4}))^{1/2}$

$N = (5/0.71)^{1/2} *10$ = 26.5 turns

N = 20 turns

Now, for **L=10μH and l=2.5m**

$N = ((10* 10^{-6} * 0.5)/ (4\pi * 10^{-7} * 56.47 * 10^{-4}))^{1/2}$

$N = (5/0.71)^{1/2} *10$

N=26 turns

For **L=10μH, l =2.8m**

$N = ((10*10^{-6}*1)/ (4\pi * 10^{-7} * 56.47*10^{-4}))^{1/2}$

$N = (10/0.71)^{1/2} * 10$

N=37 turns

Details of Transmitting Coil:

Radius of the transmitting coil (r) = 2.25cm,

Number of transmitting coil Turns (N) = 15 turns Coil wire size= 22 gauge

Diameter= 4.5cm

Details of Receiving Coil:

Radius of the receiving coil (r) = 2.25cm ,

Number of receiving coil Turns (N) = 19, Coil wire size= 22 gauge

Diameter= 4.5cm

Inductance of transmitter coil = N2μ0 A/l

= 152 x 4π x 10-7 x π (4.5/2*10-2) 2/0.00966

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= 46.5uH

Inductance of receiver coil = N2μ0 A/l

= 192 x 4π x 10-7 x 1.59 x 10-3)/0.012236

= 58.98uH

5. Experimental Setup

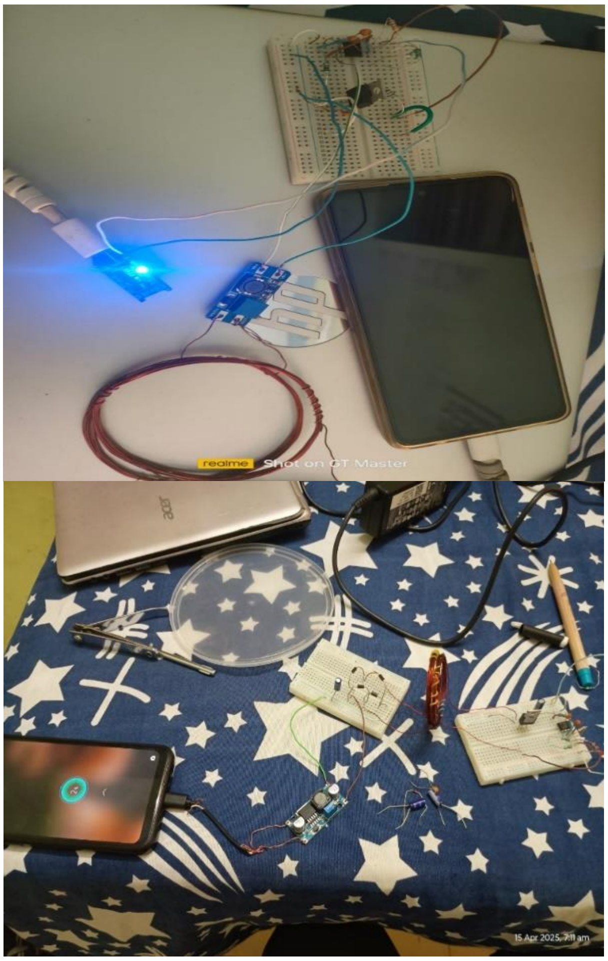

Figure 4 Represents Charging of Mobile at Supply Of 5V – 2.5A Rating

6. Results

The wireless charging system generates a stable 5V DC output using a Schottky rectifier and voltage regulator. Achieving 300 mA to 500 mA, it ensures reliable power delivery for mobile devices under optimal coil alignment. Table 1 shows Denotes The Variation Between Coil Alignment And Output Voltage. Though slightly slower than wired charging, it offers a practical solution for low-power electronics. Figure 5 shows Performance of Coils.

Table 1 Denotes The Variation Between Coil Alignment And Output Voltage

Distance between Coils	Output Voltage
0 cm	8 v
1 cm	7.5 v
2 cm	7 v
3 cm	5.5 v
4 cm	3 v
5 cm	1.5 v
6 cm	0.9 v

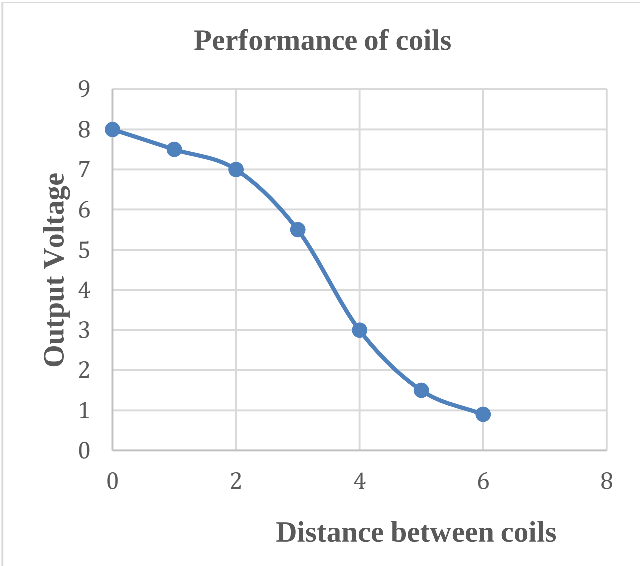

Figure 5 Performance Of Coils

The wireless charging system maintains effective output (≥5V) up to 2–3 cm separation, beyond which efficiency drops sharply due to weak magnetic coupling. Experimental results confirm that precise coil alignment and minimal distance are crucial for stable and reliable wireless energy transfer. Figure 4 shows Represents Charging of Mobile at Supply Of 5V – 2.5A Rating [5].

Conclusion

The proposed system successfully demonstrates inductive power transfer using a MOSFET-driven transmitter and 555 timer-based pulse generation. It offers a connector-free, durable, and convenient charging solution for portable electronics. While the current design is effective, future enhancements could target higher efficiency, extended range, and improved EMI control. Further developments may enable compatibility with multiple devices and advance the system toward commercial-grade applications.

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