



ISSN: 2757-8828

SELCUK UNIVERSITY JOURNAL OF ENGINEERING SCIENCES

Journal homepage: <http://sujes.selcuk.edu.tr>International
Open Access Volume 22
Issue 03

December, 2023

Research Article**Development of an inductive wireless charger for mobile phones**

Olumide Samuel Odeyemi^a , **Nazmat Toyin Surajudeen-Bakinde^a** , **Frederick Ojiemhende Ehiagwina^{* a,b}** , **Akindele Segun Afolabi^a** , **Ayodele Isqeel Abdullateef^a** 

^aDepartment of Electrical and Electronics Engineering, University of Ilorin, Ilorin, Kwara State, Nigeria^bDepartment of Electrical/Electronics Engineering, The Polytechnic Offa, Offa, Kwara State, Nigeria**ARTICLE INFO***Article history:*

Received 11 May 2023

Accepted 28 December 2023

Keywords:

Inductive Charging

Mobile Devices

Wireless Charging

Wireless Power Transmission
(WPT)**ABSTRACT**

This research focuses on designing and constructing a wireless charger for mobile phones. The wireless charging technique used is the inductive technique, which involves designing and constructing a power supply unit, an oscillator circuit, the transmitter and receiver coils, and rectification and filtering circuits. The oscillator circuit converts the 9 V DC voltage from the power supply unit to an oscillating magnetic field of high frequency (about 200 kHz) on the transmitter coil. This time-varying magnetic field induces EMF on the receiver coil according to the principles of mutual inductance. The induced voltage on the receiver coil is then passed through the required circuits for rectification, filtering, and regulation. The output of the receiver unit is used to charge a mobile phone. ATMEGA328P microcontroller is also embedded in the wireless charger to detect and display the working state of the wireless charger through the 16 x 2 LCD to make the device more user-friendly and easier to use. Based on the design, the wireless charger can produce up to 5 V voltage and 450 mA current at the output of the receiver circuit, which are the minimum requirements for charging a mobile phone. Also, the wireless charger can charge a mobile phone effectively at a distance of 6 cm. The embedded microcontroller unit also enhances the interaction between the wireless charger and the users.

This is an open access article under the CC BY-SA 4.0 license.
(<https://creativecommons.org/licenses/by-sa/4.0/>)

1. Introduction

Wireless power transmission refers to the transfer of electrical energy from one point to another without using wire or any other material as a form of physical link [1–2]. It was first experimented with in the 19th century by Nikola Tesla, who proposed the wireless transfer of electrical energy through ionized air [2]. Since its inception, wireless power transmission has evolved from mere theories to standard features of modern smart devices and has found its application in diverse fields, including the Internet of Things, general power distribution, underwater applications, and electrical power systems [1], [3], [4], [5].

Wireless charging involves the transfer of electric power to a device through an air gap to replenish the energy of that device. It offers a number of advantages, such as improving user-friendliness by doing away with the hassle of connecting wires, providing excellent device longevity for contact-free devices, increasing customization for devices

that frequently have battery replacement issues, and lowering energy costs and overcharging issues [6–7]. This evolving technology is being adopted worldwide by various technology companies to enhance the efficiency of their products [6]. It also enables smart Internet of Things (IoT) devices to receive electric power wirelessly at a designated distance [8].

The three major wireless charging techniques are inductive charging, resonance charging, and microwave radiation [7]. Inductive charging and resonance charging are classified as near-field, where the generated magnetic field from the transmitter is effective in the region close to the transmitter [9], [10]. Microwave radiation is classified as far-field, where the electromagnetic wave is transmitted over a far distance [9], [11]. Wireless charging standards, which include the Qi standard, the Power Matter Alliance (PMA) and the Alliance for Wireless Power (A4WP), are based on the three different wireless charging techniques, namely

* Corresponding author. E-mail address: frederick.ehiagwina@fedpoffaonline.edu.ng

Inductive Charging, Resonance Charging and Microwave Radiation [7]. The inductive charging technique is the most applicable for effectively charging portable devices like mobile phones. The Qi wireless charger supplies power to portable devices via inductive charging [7], [9].

Inductive wireless charging offers several advantages compared to other wireless charging technologies, contributing to its widespread adoption and use in various consumer and industrial applications. The key advantages of inductive wireless charging over other wireless charging technologies are discussed as follows. **Ubiquitous Adoption:** The Qi standard, which enables inductive wireless charging, has gained significant acceptance as a wireless charging standard in consumer electronics, especially for smartphones and other portable devices. Due to its extensive use, inductive wireless charging is now easily accessible in a variety of settings, including public areas, workplaces, automobiles, and homes. **Compatibility and Standardisation:** A wide range of products from different manufacturers are highly compatible with inductive wireless charging, particularly when it comes to the Qi standard. By enabling customers to utilize common chargers across a variety of devices, the standardization of inductive charging technologies promotes inclusivity and convenience. **Convenience and Usability:** The procedure of charging with inductive wireless charging is straightforward. Users can do away with the necessity for exact alignment or physical connections by just placing their devices on a charging pad or surface. Increased user acceptance and smooth integration into daily activities may result from this. **Flexibility and Spatial Freedom:** While inductive wireless charging strikes a balance between usability and flexibility, resonant wireless charging also gives flexibility in space. This combination enables efficient charging at short distances while preserving a dependable and useful user experience. **Safety and Reliability:** Safety and efficiency are given top priority in inductive wireless charging standards, which frequently include functions like temperature control, foreign object recognition, and overcharging prevention. Users can expect a dependable and secure charging experience thanks to these safety precautions. While other wireless charging technologies—such as microwave, RF, ultrasonic, and resonant coupling—have their advantages, inductive wireless charging—especially in the form of the Qi standard—has become more well-known due to its established infrastructure, compatibility, and ease of use. This makes it the technology of choice for many consumer and business applications [12,13].

In this study, a wireless charger for mobile phones is designed and constructed based on the inductive charging technique to allow for compactness and mobility. This study redefines the standards for wireless charging and makes a

notable contribution to the existing works. The contributions include:

1. Achievement of a 6 cm transmission range, which enhances the usability of the wireless charger for users.
2. Integration of microcontroller unit to allow communication features and enable effective monitoring of the charger's operating condition. This improves control and engagement with the charging process by making the charger smarter and easier to use.

These contributions pave the way for more intelligent and adaptable wireless charging solutions. It establishes a new standard for efficiency, user experience, and the possibility of further applications in diverse settings

2. Related Works

Continuous research and experiments have been conducted on ways of integrating wireless power transmission into our daily lives. Hence, wireless power transmission and its various applications are fast becoming the new normal.

Oyeleke *et al.* [14] developed a prototype wireless charging system based on the inductive charging technique. The transmitter and receiver in the system include resonator circuits, which utilize an LC resonator and a high-efficiency push-pull amplifier to convert a DC voltage into a 50–70 kHz signal. Through mutual induction, energy is wirelessly transmitted from the LC resonator to the receiver. The induced EMF in the receiver is rectified, filtered, and regulated to produce sufficient output for charging a mobile phone. However, the system requires a wire to transmit power from the receiver to the mobile phone.

Similarly, Flores-Garcia *et al.* [15] presented a simple wireless charger circuit intended for mobile phones without integrated wireless charging capability, with the use of a series-series resonant converter and a half-bridge inverter as the drivers. The approach's viability was demonstrated by the experimental findings, which verified the analysis and the design. Also, Kumar *et al.* [16] developed an inductive wireless power transmission system specifically for electric vehicle battery charging applications. The study used a series-series (SS) compensated Inductive Power Transfer (IPT) mechanism to construct a 2 kW wireless power charger; the implementation was done in MATLAB Simulink.

In [17], Zable *et al.* evaluated the performance of a Wireless Power Transfer (WPT) circuit intended for wireless charging with the goal of comprehending and resolving the increasing charging distances beyond those of existing mobile chargers. The study incorporated variations in coil diameter with different coil sizes using an impedance-based quality factor

tuning method. To improve transfer efficiency and extend the distance between the device and the charging pad, adjustments were made to the coupling coefficient and inductor turn ratio. The results showed that when the coupling coefficient was adjusted to 0.1, the circuit could produce a 3V DC voltage.

Zhang [18] proposed an intelligent wireless charger based on the Internet of Things (IoT). This study used mathematical analysis and wireless charging technologies to investigate a smart wireless charger linked to the IoT. In order to create a workable wireless charging system, the study included a thorough analysis and computation of the control, transmit, and receive circuits within the wireless charger. Resonance methods, radio wave transmission, and electromagnetic field sensing were used to maximize charging efficiency and avoid overheating or damage during charging. The experimental findings showed that this IoT-based smart wireless charger could successfully replace wired chargers for 99% of small appliances and significantly increase charging efficiency for larger devices, such as desktop computers, by 1.4 to 1.6 times. Though it provides improved charging efficiency, this technology is rather expensive and complex.

Lai *et al.* [19] developed an IoT-based wireless charging service for public use called "AnyCharge," consisting of five key components: a Wi-Fi-enabled wireless charger, an IoT gateway, a cloud-based management platform, a secure Wi-Fi auto-connection algorithm, and a mobile app. The charger was connected to an IoT gateway via Wi-Fi using a secure auto-connection method, and the gateways were linked to a cloud server through message queue telemetry transport. While Android and iOS applications allow users to quickly locate free chargers at the closest charging locations, the administrators could monitor and control chargers through the management platform. More than 200 chargers were installed in a variety of settings, including restaurants, hotels, telecom stores, and hospitals, as part of a large-scale deployment. Statistics from this deployment highlighted a robust demand for public charging services.

3. Design Methodology

Figure 1 illustrates the block diagram of the wireless charger. It is divided into four units: the power supply unit, the transmitter unit, the microcontroller unit, and the receiver unit.

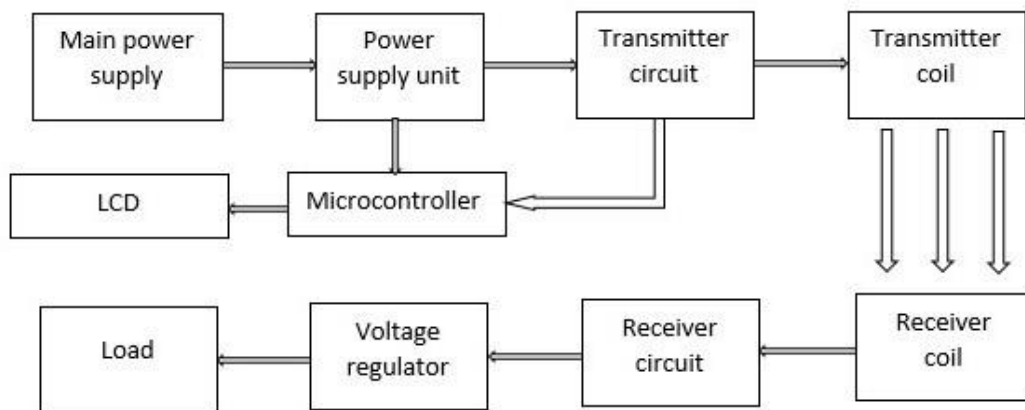


Figure 1. Block diagram of a wireless charger

3.1. Power Supply Unit

The power supply unit is depicted in Figure 2. It comprises 12 V, 2 A power adapter, LM317T and LM7805 voltage regulators. Its main function is to provide the required DC.

Voltage for the system. It takes 220 V AC from the supply mains and supplies 5 V DC to the microcontroller unit through the LM7805 and 9 V DC to the transmitter unit through the LM317T. The regulated DC power supply remains unchanged irrespective of the quantity of current drawn from it [20].

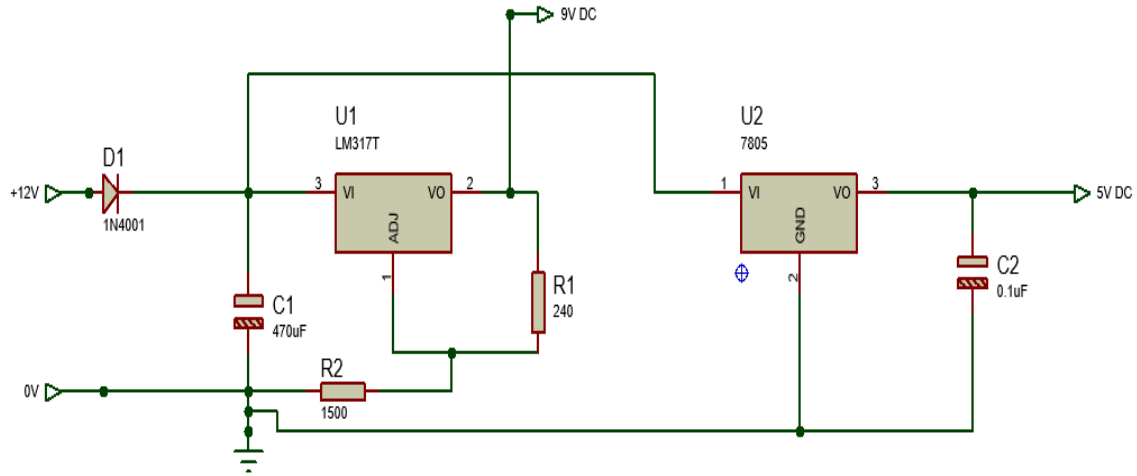


Figure 2. Circuit diagram of the power supply unit

3.2. Transmitter Unit

The transmitter unit is designed to transmit voltage wirelessly by converting the regulated DC voltage from the power supply unit to AC voltage at high frequency, which is then converted to a magnetic field when passed through the transmitter coil [21]. The transmitter unit consists of a Hartley oscillator circuit and the transmitter coil.

3.2.1. The Hartley Oscillator Circuit

The basic function of the oscillator circuit in the transmitter unit is to convert the regulated DC voltage supplied by the voltage regulator to an AC voltage at a high frequency [14]. The Hartley oscillator circuit consists of a tank circuit comprising two series-connected inductors placed across a common capacitor, and the centre of the inductors is tapped [22]. The oscillator circuit is shown in Figure 3.

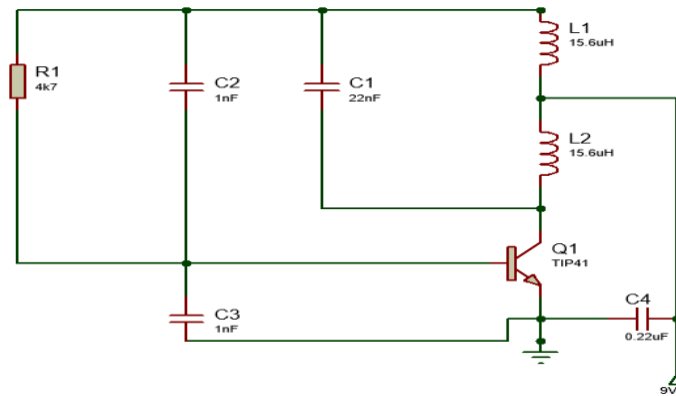


Figure 3. Circuit diagram of Hartley Oscillator

3.2.2. Transmitter Coil

The transmitter coil induces a magnetic field when current passes through it. A coil of Standard Wire Gauge (SWG) 21 (0.813 mm), a diameter of 8 cm, and a thickness of 6.5 mm was used. The transmitter coil is centre-tapped, with coil turns of 4 on both sides.

The inductance of the coil is given as follows:

$$L = \mu_0 N^2 \frac{A}{l} \quad (1)$$

where L is the coil's inductance, A is the area of the coil, μ_0 is the permeability of free space, N is the number of turns, and l is the coil's thickness.

Given $\mu_0 = 4\pi \times 10^{-7} \text{ H/m}$

$$A = \pi r^2 \quad (2)$$

Therefore,

$$L = 4\pi \times 10^{-7} \times 4^2 \times \frac{5.03 \times 10^{-3}}{6.5 \times 10^{-3}} = 15.6 \mu H$$

The oscillator circuit's frequency of oscillation is equal to the resonant frequency, and it is given as:

$$f = \frac{1}{2\pi\sqrt{LC}} \quad (3)$$

$$L = L_1 + L_2 \quad (4)$$

where:

C = capacitance of the capacitor.

L₁ and L₂ = Inductance of the coils.

If L₁ = 15.6 μH and L₂ = 15.6 μH

$$\therefore L = 15.6 \mu H + 15.6 \mu H = 31.2 \mu H$$

For a capacitor of 22 nF, the frequency of oscillation is calculated as follows:

$$f = \frac{1}{2\pi\sqrt{31.2 \times 10^{-6} \times 22 \times 10^{-9}}} = 192.1 \text{ kHz}$$

3.3. Microcontroller Unit

The basic function of the microcontroller unit is to detect and display the working state of the entire system. It provides an interface for the user to control the system's operation and display the working state of the device for the user's assessment. It comprises an Atmega328P microcontroller interfaced with 16×2 LCD, LDR, and LED. Figure 4 shows the Flowchart of the microcontroller unit.

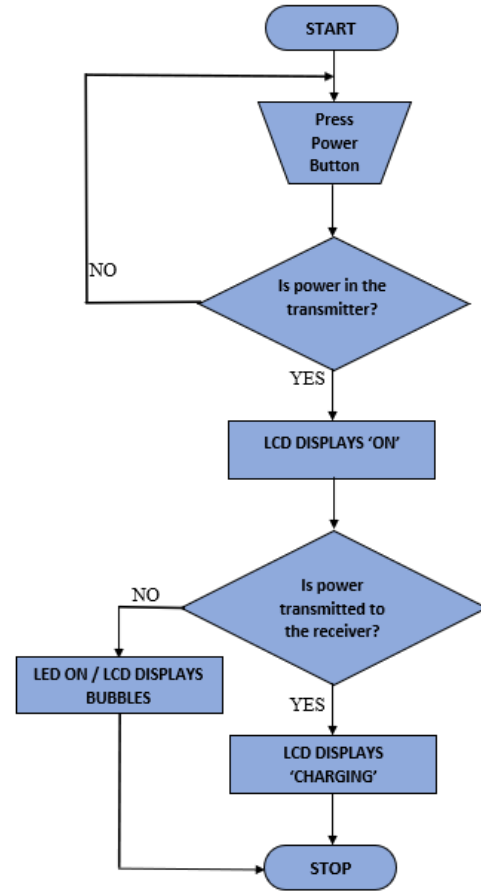


Figure 4. Flowchart of the microcontroller unit

Figure 5 shows the circuit diagram of the transmitter section, consisting of the power supply unit, the oscillator circuit, and the microcontroller unit.

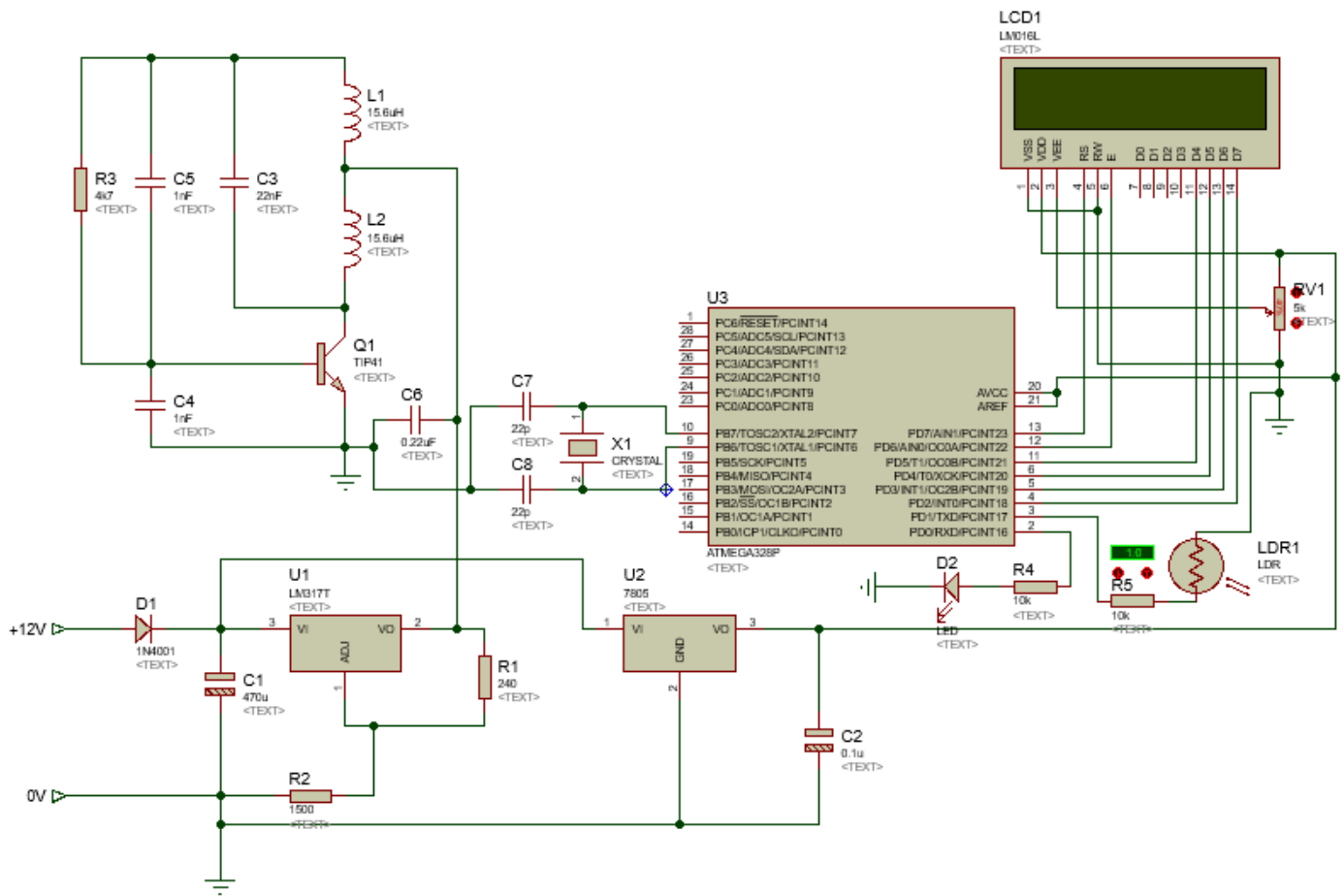


Figure 5. Circuit diagram of the transmitter section

3.4. Receiver Unit

The receiver unit is part of the system that receives the induced magnetic field from the transmitter unit through the receiver coil and converts it to a regulated DC voltage required for charging the mobile phone [21]. The receiver

unit consists of the receiver coil, the rectifier circuit, the filter, and the voltage regulator. The output of the voltage regulator provides the regulated 5 V DC required to charge the mobile phone. Figure 6 shows the circuit diagram of the receiver unit.

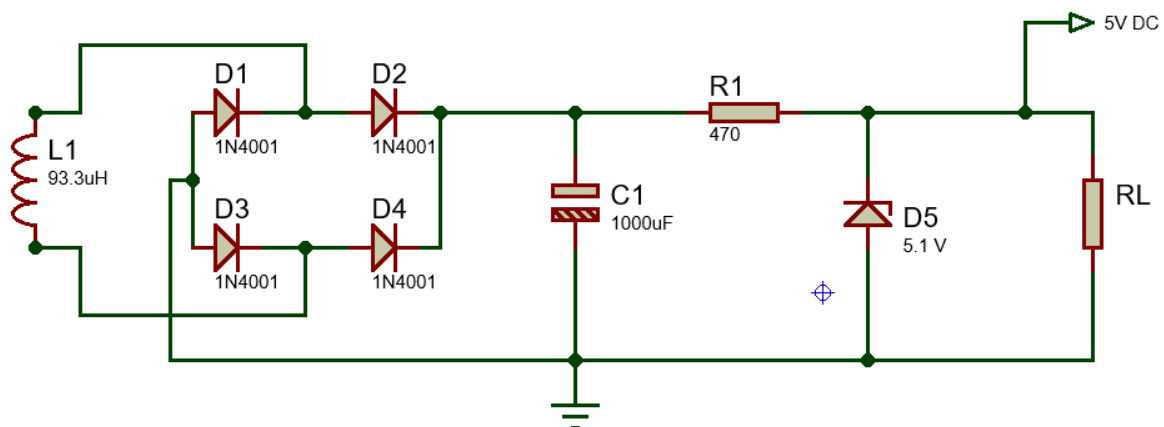


Figure 6. Circuit diagram of the receiver unit

3.4.1. The Bridge Rectifier

The bridge rectifier circuit converts the AC voltage induced in the receiver coil into DC voltage [23]. The AC input voltage is rectified using a full-wave bridge diode rectifier,

which produces DC in both the positive and negative halves of the cycle.

Root mean square voltage induced in the receiver coil, $V_{r.m.s} = 15 \text{ V}$

Peak voltage is given as:

$$V_m = \sqrt{2} \times V_{r.m.s} \quad (5)$$

$$V_m = \sqrt{2} \times 15 = 21.2 \text{ V}$$

The Peak Inverse Voltage (PIV) is given as:

$$PIV = 2V_m \quad (6)$$

$$PIV = 2 \times 21.2 = 42.4 \text{ V}$$

Since the PIV = 42.4 V, 1N4001 diode with PIV of 50 V is selected.

3.4.2. The Filter Capacitor

The filter capacitor removes the ripple content from the output of the bridge rectifier.

The voltage drop from the diode, $V_d = 2 \times 0.7 = 1.4 \text{ V}$

The output of the bridge rectifier, V_o :

$$V_o = V_m - V_d \quad (7)$$

$$V_o = 21.2 \text{ V} - 1.4 \text{ V} = 19.8 \text{ V}$$

The average value of DC output voltage, V_{dc} :

$$V_{dc} = \frac{2V_m}{\pi} \quad (8)$$

Ripple voltage, V_r :

$$V_r = V_o - V_{dc} \quad (9)$$

$$V_r = 6.31 \text{ V}$$

Capacitance of the filtering capacitor, C:

$$C = \frac{I_{dc} \times t}{V} \quad (10)$$

where I_{dc} = Load Current, which is given as 500 mA

Time, t:

$$t = \frac{1}{2 \times f} \quad (11)$$

where f = Frequency

$$C = \frac{I_{dc}}{2 \times f \times V_r} = 792 \mu\text{F}$$

Therefore, a capacitor of 1000 μF is selected for filtering.

3.4.3. Voltage Regulator

A 5.1 V Zener diode is used as a voltage regulator to supply a regulated output of 5 V DC to the load. Resistor R1 is selected to be 470 Ω , which protects the voltage regulator from inrush current.

4. System Implementation, Testing, Result and Discussion

The implementation of various units of the wireless charger is based on the design and calculation shown in the previous sections. It is ensured that each component used

is selected based on the values from the designs and calculations.

Each circuit is first implemented on a breadboard for testing and further analysis before being transferred permanently to a Printed Circuit Board (PCB). The components are fixed permanently on the PCB using the soldering iron and soldering lead. Pictures of the implemented circuits on the PCB and the transmitter and receiver coils are shown in Figures 7, 8, and 9, while the completed device is shown in Figure 10.

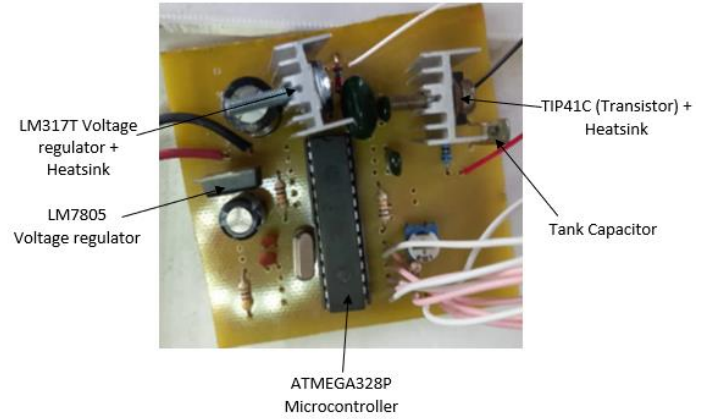


Figure 7. The transmitter circuit on a PCB

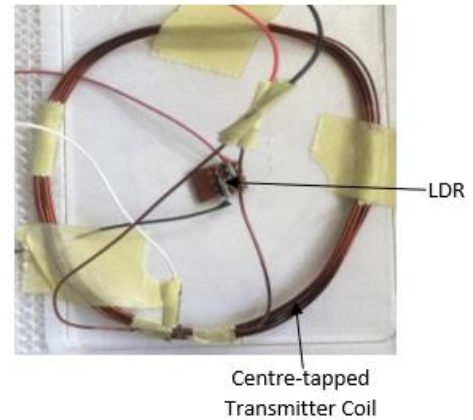
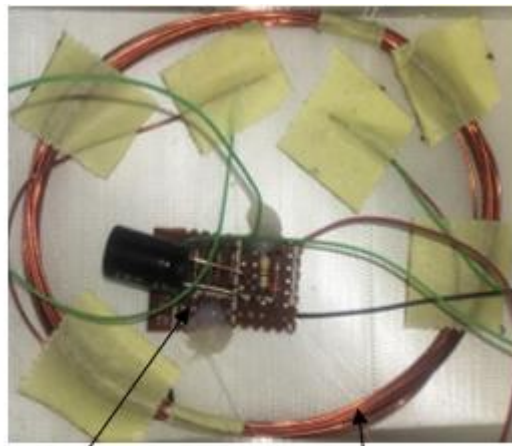


Figure 8. The transmitter coil



Receiver Circuit Receiver Coil

Figure 9. The receiver circuit and the receiver coil

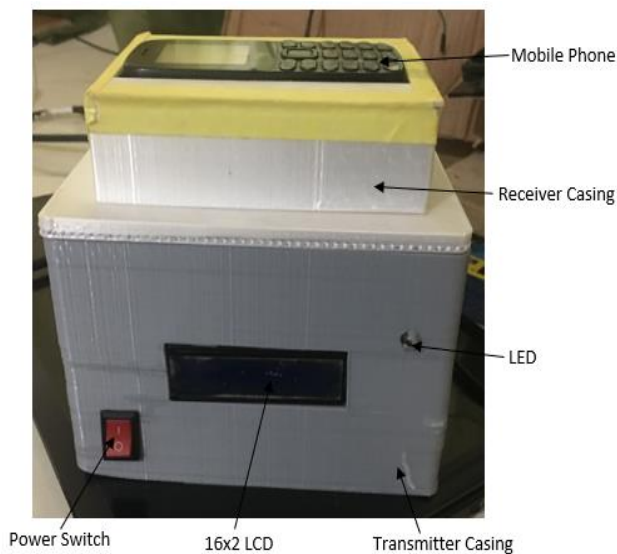


Figure 10. The completed work

The testing process involves testing the performance of the transmitter and measuring the voltage induced in the receiver unit with respect to the range of power transmission, that is, the distance between the transmitter and the receiver.

4.1. Transmitter Performance Testing

The transmitter's performance depends on the voltage supplied to the transmitter section and the output of the transmitter coil. Therefore, measurements are carried out at the power adapter input, the oscillator's input, which is the output of the LM317T voltage regulator, and the oscillator's output using a multimeter. The values obtained are then compared with the design or calculated values. Table 1 shows the results of the transmitter performance tests.

Table 1. Measurement results of the transmitter performance

Parameter	Voltage Type	Theoretical Value (V)	Actual Value (V)
Adapter Output	DC	12.0	12.32
Oscillator input	DC	9.06	10.0
Oscillator output	AC	10.0	9.98

4.2. Transmission Range Measurement

The transmission range of the wireless charger is determined by varying the distance between the transmitter and the receiver at 3 cm intervals and taking measurements of the induced voltage in the receiver unit at each distance. Figure 11 illustrates the transmission distance with respect to the induced voltage at the receiver.

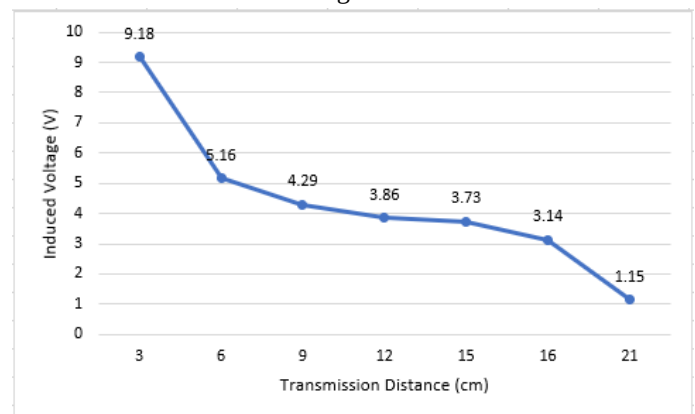


Figure 11. Transmission distance with respect to the induced voltage at the receiver

4.3. Discussion of Results

The results obtained from the transmitter performance test show that the theoretical values used for the design calculations and circuit analysis are almost the same as the actual values of the parameters when measured. The oscillator's output voltage is important to determine the efficiency of the wireless charger. The result shows a difference of 0.02 V between the theoretical and actual values, which results in an efficiency of 99.8%. This implies that the calculated values in the circuit analysis and design calculations perfectly determine the overall performance and efficiency of the wireless charger. As shown in Figure 11, the transmission range measurement results show that the receiver's induced voltage varies inversely with the transmission distance. This is because the magnetic flux around the transmitter coils gets weaker as the distance increases and consequently induces less voltage on the receiver coil. Hence, the wireless charger will function at its highest efficiency when the receiver is closest to the transmitter, and the efficiency reduces as the transmission distance increases. The minimum voltage requirement for charging a mobile phone is 5 V, and the

graphical illustration of the transmission range measurement shows that 5.16 V is induced at the receiver at a distance of 6 cm. This implies that at a distance farther than 6 cm, the voltage induced is lower than 5 V and will not be enough to charge a mobile phone. Hence, the transmission range of the wireless charger is 6 cm, beyond which the wireless charger becomes inefficient.

Furthermore, it should be noted that a certain amount of errors is considered when taking measurements of the transmitter performance and the transmission range, as the readings taken from the multimeter are liable to precision errors. Also, the limitation in transmission range is generic to the inductive technique of wireless charging due to the components' limitations. An attempt to increase the transmission range of the wireless charger will involve changing the components and the technique of wireless charging, which is beyond the scope of this research. However, the efficiency of the wireless charger and the transmission range achieved in this research is appreciable and satisfies the aim and objectives of the research.

Figures 12 and 13 depict the working state of the wireless charger. The microcontroller unit is responsible for sensing and displaying the working states of the wireless charger,

as explained earlier. When the receiver is not in range, the LCD on the transmitter displays bubbles, and the LED turns ON. Also, when the receiver is within the transmission range, the LED turns OFF, and the LCD displays "Charging Device Wirelessly."



Figure 12. When the receiver is not in range



Figure 13. When the receiver is within the transmission range

5. Conclusion

In this study, a wireless charger for a mobile phone was developed using the inductive wireless charging technique. The procedure involved designing and constructing the power supply unit, the transmitter unit, which comprises the oscillator circuit and the transmitter coil; the microcontroller unit; and the receiver unit, which comprises the receiver coil, rectification circuit, filtering circuit, and voltage regulator.

The wireless charger's design allows it to generate up to 5 V of voltage and 450 mA of current at the receiver circuit's

output, which is sufficient to charge a mobile phone. Additionally, a mobile phone can be efficiently charged by the wireless charger up to a distance of 6 cm, and the embedded microcontroller unit further improves the user's interface with the wireless charger. It is to be noted that the efficiency of the wireless charger decreases as the transmission distance increases.

The achievement of this study on the development of an inductive wireless charger with a transmission range of 6 cm is consistent with existing research on proximity charging at short distances. Additionally, the idea stands

out due to the addition of a microcontroller unit, which improves the user interface and charger intelligence. This is consistent with current advancements in wireless charging technologies that prioritize intelligent features for enhanced device compatibility and user experience. The utilization of the microcontroller's capabilities and the use of inductive coupling for wireless charging make this project relevant to the advancement of wireless charging technology and highlight its potential for wider applications in the field of mobile electronic devices. However, in future research, the transmission range of the inductive wireless charging technique can be improved to allow for more flexibility. Also, other wireless charging techniques can be explored for charging mobile devices.

Author contributions

Conceptualization: [Olumide Samuel Odeyemi, Nazmat Toyin Surajudeen-Bakinde]; Methodology: [Olumide Samuel Odeyemi, Nazmat Toyin Surajudeen-Bakinde]; Formal analysis and investigation: [Olumide Samuel Odeyemi, "Nazmat Toyin Surajudeen-Bakinde, Frederick Ojiemhende Ehiagwina, Akindele Segun Afolabi", Ayodele Isqeel Abdullateef]; Writing - original draft preparation: [Olumide Samuel Odeyemi, Nazmat Toyin Surajudeen-Bakinde]; Writing - review and editing: [Olumide Samuel Odeyemi, Nazmat Toyin Surajudeen-Bakinde, Frederick Ojiemhende Ehiagwina, Akindele Segun Afolabi", Ayodele Isqeel Abdullateef]; Funding acquisition: [Olumide Samuel Odeyemi]; Resources: [Olumide Samuel Odeyemie]; Supervision: [Nazmat Toyin Surajudeen-Bakinde]

Conflicts of interest/Competing interests

No one or anything we know has a conflict of interest or a shared interest that could influence our work.

References

- [1] S. A. Mohsan *et al.*, "A review on research challenges, limitations and practical solutions for Underwater Wireless Power Transfer," *International Journal of Advanced Computer Science and Applications*, vol. 11, no. 8, 2020. doi:10.14569/ijacsa.2020.0110869
- [2] O. Okoyeigbo, A. A. Olajube, O. Shobayo, A. Aligbe, and A. E. Ibhaze, "Wireless Power Transfer: A Review," *IOP Conference Series: Earth and Environmental Science*, vol. 655, no. 1, p. 012032, 2021. doi:10.1088/1755-1315/655/1/012032
- [3] M. Z. Chaari and S. Al-maadeed, "Wireless Power Transmission for the internet of things (IoT)," *2020 IEEE International Conference on Informatics, IoT, and Enabling Technologies (ICIOT)*, 2020. doi:10.1109/iciot48696.2020.9089547
- [4] J. S. B, P. N. Kalal, P. S. Togare, R. A. Vallamdeshi, and P. P. Waghe, "Wireless Power Transmission Technology," *Journal of Image Processing and Intelligent Remote Sensing*, no. 26, pp. 32–37, 2022. doi:10.55529/jipirs.26.32.37
- [5] B. S. P. S. Manohar, V. V. Gandham, and P. K. Dhal, "An overview of wireless power transmission system and analysis of different methods," *International Journal for Research in Applied Science and Engineering Technology*, vol. 10, no. 3, pp. 1818–1827, 2022. doi:10.22214/ijraset.2022.40987
- [6] S. Gaur, "A Research Paper on Wireless Charging," *Journal of Emerging Technologies and Innovative Research (JETIR)*, vol. 6, no. 5, pp. 648–655, May 2019.
- [7] U. C. Patkar *et al.*, "Wireless charging: Its types, standards and applications," *International Journal on Recent and Innovation Trends in Computing and Communication*, vol. 11, no. 9s, pp. 69–77, 2023. doi:10.17762/ijrctcc.v11i9s.7398
- [8] M. Z. Chaari and S. Al-Maadeed, "Increase the efficiency of IOT devices by using the wireless power transmission in the Industrial Revolution 4.0," *International Journal of Online and Biomedical Engineering (iJOE)*, vol. 17, no. 07, p. 172, 2021. doi:10.3991/ijoe.v17i07.24143
- [9] K. Detka and K. Górecki, "Wireless Power Transfer—a review," *Energies*, vol. 15, no. 19, p. 7236, 2022. doi:10.3390/en15197236
- [10] S. Hussain, Y. Saleem, M. Iftikhar, M. Mian, A. Raza, and U. Farooque, "Parametric Study of Magnetic Resonance Coupling for Mid-Range Wireless Charging of Portable Devices," *Journal of Space Technology*, vol. 1, 2019.
- [11] R. Singh, R. Jain, and D. Shrivastava, "Wireless power transmission technology," *International Journal of Engineering Applied Sciences and Technology*, vol. 4(9), pp. 444–449, 2020.
- [12] Palani G, Sengamalai U. A critical review on inductive wireless power transfer charging system in electric vehicle. *Energy Storage*. 2023; 5(5): e407.
- [13] Feng H, Tavakoli R, OnarOC, Pantic Z. Advances in high-power wireless charging systems: Overview and design considerations. *IEEE Transactions on Transportation Electrification*. 2020; 6(3): 886-919.
- [14] O. D. Oyeleke, T. Sadiq, and P. Nzerem, "Design and construction of a prototype wireless power transfer device," *International Journal of Engineering and Manufacturing*, vol. 9(2), pp. 16-30, 2019.
- [15] E. Flores-Garcia, G. Espinosa-Medina, D. de Leon-Zapata Ramon, A. Diaz de la Rosa-Zapata, and J. Vulfrano Gonzalez-Fernandez, "Analysis and design of a simple wireless charger for mobile phones," *2019 IEEE International Autumn Meeting on Power, Electronics and Computing (ROPEC)*, 2019. doi:10.1109/ropec48299.2019.9057116
- [16] A. Shakya and M. Kumar, "Implementation of Inductive Wireless Power Transmission System for battery charging applications," *2022 Second International Conference on Advances in Electrical, Computing, Communication and Sustainable Technologies (ICAECT)*, 2022. doi:10.1109/icaect54875.2022.9808083
- [17] M. A. H. Zable *et al.*, "Performance evaluation of WPT circuit suitable for wireless charging," *2020 IEEE Symposium on Industrial Electronics & Applications (ISIEA)*, 2020. doi:10.1109/isiea49364.2020.9188073
- [18] X. Zhang, "An intelligent wireless charger based on the internet of things," *Security and Communication Networks*, vol. 2021, pp. 1–12, 2021. doi:10.1155/2021/5558914
- [19] K.-T. Lai *et al.*, "AnyCharge: An IOT-based wireless charging service for the public," *IEEE Internet of Things Journal*, vol. 6, no. 6, pp. 10888–10901, 2019. doi:10.1109/jiot.2019.2943030
- [20] B. L. Theraja and A. K. Theraja, "DC power supplies," in *A Textbook of Electrical Technology*, New Delhi: S. Chand & Company Ltd, 2005; pp: 2129 – 2166.
- [21] T. Agarwal, "Wireless Power Transmission Circuit and its working," *ElProCus*, <https://www.elprocus.com/wireless-power-transfer-circuit-and-working/> (accessed Dec. 2, 2023).
- [22] P. Hrishitha, "The Hartley oscillator using BJT," *International Journal of Scientific Research in Engineering and Management*, vol. 06, no. 03, 2022. doi:10.55041/ijsem11884
- [23] T. Agarwal, "Bridge rectifier: Circuit diagram, types, working & its applications," *ElProCus*, <https://www.elprocus.com/bridge-rectifier-circuit-theory-with-working-operation/> (accessed Dec. 2, 2023).