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DEVELOPMENT OF A CONTACT-LESS CHARGING DEVICE FOR WIRELESS POWER TRANSFER

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Abstract: This Project provides a comprehensive overview of contactless charging devices, exploring its principles, forms, Types, applications, advantages, and challenges. it focuses on designing and building a wireless charging device that can be powered by a battery source, also known as a contactless charging device. The transmitter unit (input) and the receiver unit (output) make up this gadget. The device receives a 220V AC mains signal as input, which is rectified or converted to a DC signal. The gadget thus has two power sources (battery and mains). The backup batteries are then charged with this DC signal, which is also fed into a 48 kHz oscillating circuit. This circuit uses a square wave signal to create an alternating signal, which is then passed through an induction coil to create an electromagnetic field that transfers power. This is electromagnetic induction's basic idea. The coil at the receiver, which is placed in the path of this field is induced with the alternating current (AC) which is then rectified again to DC before it's passed through a 5V bulk converter circuit which regulates the output of the device to 5V which can be able to power different portable devices efficiently. Additionally, the device is noiseless and the output is taken through the USB port provided.

Keywords: Contact-less Charging, Transmitter, Receiver, Batteries, Power, DC Signal

I. BACKGROUND OF STUDY

The study of the design and construction of a mobile contactless charging device is a topic that falls under the broader field of wireless power transfer. Contactless charging devices involve the transfer of electrical power from a device called the transmitter to another device called the receiver without using cables. Nikola Tesla was the first to undertake Wireless Power Transfer tests. Wireless energy transfer, also known as wireless power transmission, is the process of transmitting electrical energy from a power source to an electrical load without the need for cables [1].

When rapid or continuous energy transfer is required yet linking cables is cumbersome, dangerous, or impossible, wireless transmission is a viable option. Wireless power transmission can revolutionize electrical and electronic engineering by removing the need for traditional copper connections and current-carrying wires. The idea is based on this notion and is designed to transmit electricity over a shortdistance.

For example, if you have an electronic device, such as a cell phone, and you need to charge the battery, you will most likely need to purchase a charger and connect the phone to the cable. What if you could charge it without needing to connect it to a power source? That is to say,power will be sent wirelessly. The thought of a laptop that people could use indefinitely and never run out of power, and that could be powered entirely by a wireless charger, sounds like something out of a science fiction film, but it's possible because of inductive coupling. Wireless charging, also known as wireless power transfer, is a technique that allows a power source to send electromagnetic energy through an air gap to an electrical load without the use of cables. This technology is attracting a diverse set of uses.

II. LITERATURE REVIEW

(Wei et al., 2024) Aiming at the situation that the wired charger for inspection equipment has electrodes that are prone to rust and corrosion, poor contact, and inspection equipment cannot enter and exit the charging dock normally, this paper designs a set of non-contact charging systems. The system consists of two parts, the transmitter board, and the receiver board, mainly including power factor correction, high-frequency inverter, resonant circuit, charging control, circuit protection, and other modules.

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The transmitter board first converts the utility power into 60 kHz AC power and then transmits it to the receiver board through the resonant network. The receiving board charges the battery through the charging control circuit.

The test results show that the wireless charger works stably and reliably, has perfect protection functions, and has a maximum output power of 150 W, which can meet the charging needs of most inspection equipment.

(Aurongjeb et al., 2025) Electric vehicles (EVs) wireless charging is enabled by inductive power transfer (IPT) technology, which eliminates the need for physical connections between the vehicle and the charging station, allowing power to be transmitted without the use of cables. However, in the present wireless charging equipment, the power transfer still needs to be improved. In this work, we present a power transfer structure using a unique “DD circular (DDC) power pad”, which mitigates the two major obstacles of wireless EV charging, due to the mitigating power of electromagnetic field (EMF) leakage emissions and the increase in misalignment tolerance. We present a DDC power pad structure, which integrates features from both double D(DD) and circular power pads. We first build a three-dimensional electromagnetic model based on the DDC structure. A detailed analysis is performed of the electromagnetic characteristics, and the device parameters regarding the power transfer efficiency, coupling coefficient, and mutual inductance are also presented to evaluate the overall performance. Then, we examine the performance of the DDC power pad under various horizontal and vertical misalignment circumstances. The coupling coefficients and mutual inductance, as two essential factors for effective power transmission under dynamic circumstances, are investigated. The findings of misalignment effects on coupling efficiency indicate that the misalignment does not compromise the DDC pad’s robust performance. Therefore, our DDC power pad structure has a better electromagnetic characteristic and a higher misalignment tolerance than conventional circular and DD pads. In general, the DDC structure we present makes it a promising solution for wireless EV charging systems and has good application prospects.

(Kamble & Gohokar, 2024) In the current age of wireless communication among multiple devices, including mobile phones, laptops, wireless speakers, and more, the power supply for these devices remains predominantly reliant on wired connections or energy storage solutions such as batteries. These batteries, in turn, necessitate contact-based chargers for recharging. This paper presents a foundational exploration and blueprint for a contactless battery charger that facilitates bidirectional energy transfer for electric vehicle (EV) applications. The proposed design incorporates renewable energy sources and grid power, which feed into a voltage-to-voltage converter responsible for transmitting power through a wireless air gap using a Tesla coil. This transmitted flux is subsequently harnessed by a receiving Tesla coil and converted back into voltage, facilitating the charging or energy storage of batteries [15]. This contactless charging mechanism holds immense potential across a spectrum of applications, including EV charging stations, wearable contactless jackets, mobile EV charging for roadsters in transit, military border deployments, contactless propulsion systems, and more. It offers the advantage of obviating the need for heavy and cumbersome batteries, along with the associated bulky wiring and high installation costs. The system design encompasses variable power transfer capabilities ranging from 12 volts to 100 volts, with a current capacity of up to 5 amperes and a minimum operating distance of 1 meter.

(Zheng, 2024) Magnetic coupled resonant radio energy transmission (WPT) technology utilizes the coupling of the magnetic fields of the transmitting and receiving coils and wirelessly transmits energy through electromagnetic induction, greatly expanding the applications of power equipment in special environments. The technology uses the magnetic field coupling between the transmitting coil and the receiving coil to realize the wireless transmission of energy through electromagnetic induction. This method breaks the limitation of traditional wire transmission and greatly expands the application potential of power equipment in various special environments. In this paper, an efficient, stable and long-distance wireless charging device is designed and realized. In order to improve transmission efficiency, two-coil configuration with series-series structure is adopted, and its equivalent circuit model is established by circuit theory and Kirchhoff's law. Therefore, a new radio energy transmission device based on single chip microcomputer is designed, including PWM signal generator, level matching circuit, high frequency inverter circuit and other key parts. Expressions for transmission efficiency and output power are derived from equation analysis and power-on experiments performed on a physical device. In addition, the effects of transmission frequency, load impedance and transmission distance on the performance are investigated.

III. SYSTEM DESIGN

The different methods (the use of microwaves, and lasers) exist for transmitting power wirelessly. In this project, we adopted the inductive technique of wireless power transfer. We considered this method the best based on the achievable efficiency which ranges from 75% to 85% with the present technology available [1].

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Transmitting power via lasers and microwaves has efficiency higher than inductive coupling, and this is based on the fact that they are highly directive. However, the problem with these techniques is that their high-efficiency capability is lost during conversion back to electrical energy.

So, because the bulk of energy transmitted through the air needs to get to the receiving end, it becomes necessary to use the inductive technique. A comprehensive review has been done for this wireless transfer system's analysis, modeling, design, implementation/testing, verification, and operation. The wireless charging platform still requires a cable linking between the receiver and the phone. Therefore, the transmitter is activated upon the trigger from a light-emitting diode specifying that the receiver has been dropped on the platform, then coupling takes place, after which rectification follows, and then DC is sent to the mobile phone.

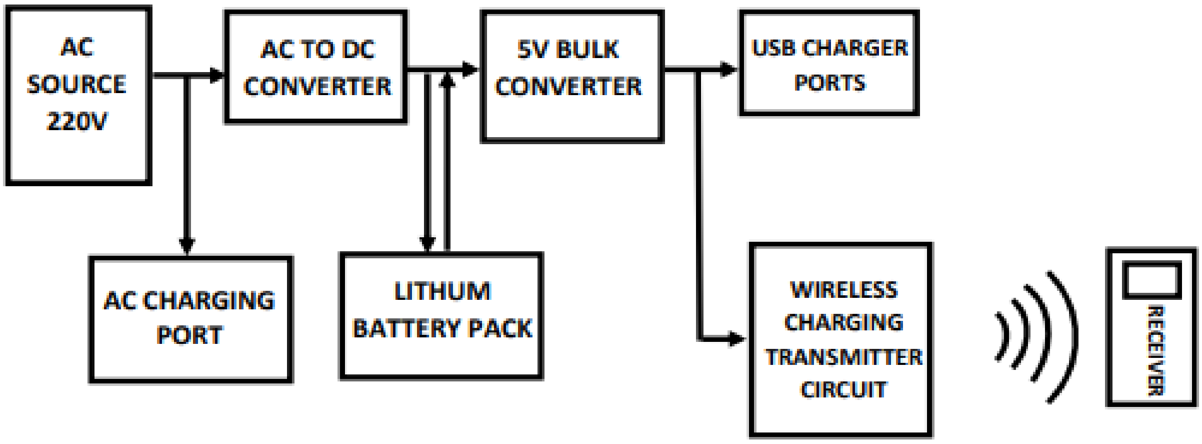

Figure 3.1: Block Diagram of a Contactless Charging Device.

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3.1 System Flowchart

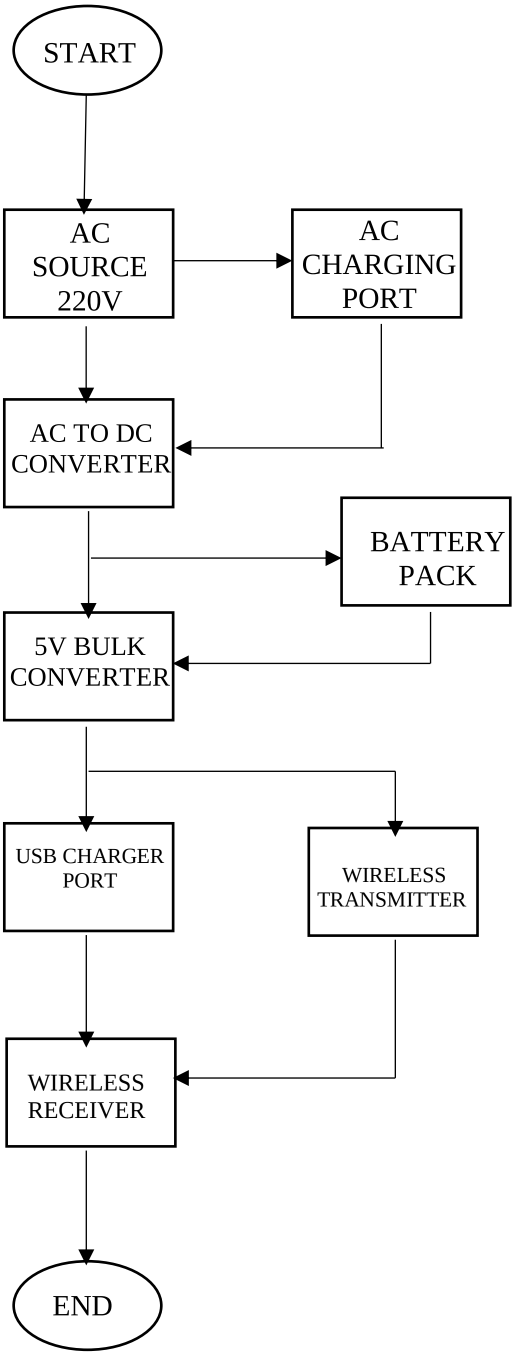

Figure 3.2: Flowchart Diagram of the Project

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3.2 System Subsystems

The process of designing a wireless charger can be complex; it does become easier when broken down into its component steps. The following sections detail each component within the project, as well as how each section is constructed and interacts with other blocks to result in the production of a 5V DC voltage for wireless charging. For better design and construction, the system has been divided into six major subsystems.These subsystems perform major tasks relevant to the project. These are:

- DC Power Supply Subsystem
- Oscillating Subsystem
- Battery Subsystem
- 5V Bulk Converter
- Transmitter Subsystem
- Receiver Subsystem.

3.2.1 DC Power Supply Subsystem

This subsystem's function encompasses the supply of power in the whole system, in other to maintain a level of reliability we developed the system to have two different power supplies in other to tackle the issue of irregular power supply we have in our country Nigeria, these power supply units include both Mains and Battery.

- Mains: This refers to the electrical power supply obtained directly from the Power Holding Company of Nigeria (PHCN). This power is of the AC type of 230V/50HZ and must be rectified to DC and stepped down to 15v to enable it to power the entire system. This was accomplished using a rectifier.

- BATTERY: This refers to the power supplied by the backup battery, the system switches to this backup battery when there is a power failure. [2]

3.2.2 Oscillating Subsystem

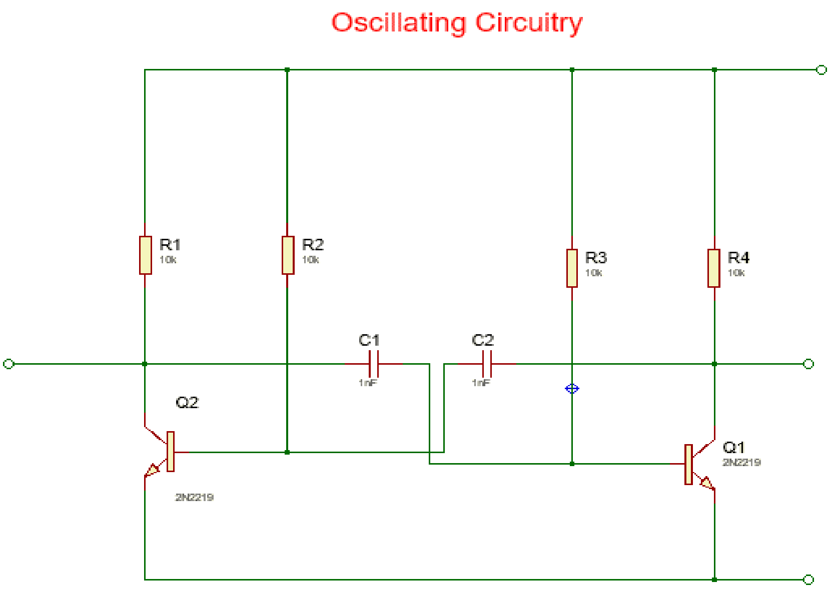

Figure 3.3: Block Diagram of the Oscillating Circuit

In this project, the energy from a D.C. source is required to be transferred through electromagnetic induction, but at D.C. electromagnetic induction does not take place. Hence there is a need to convert the existing DC to AC by using an oscillating circuit. To design an oscillating circuit, certain parameters such as oscillating frequency and the type of waveform have to be known. For this project, the oscillating frequency was chosen to be as high as 48 kHz since the energy transfer is through an air core and also above the audible frequency range.

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A square waveform was also chosen based on its simplicity of generation. The circuit above shows an astable multivibrator circuit on which the oscillating circuit design will be based upon.

$$F = \frac{0.7}{RC} \quad (3.1)$$

Where R = R2 = R3 = R4 and C =C1 = C2

For F = 48 KHz

C = 0.1µF

$$R = \frac{0.7}{FC}$$

$$R = \frac{0.7}{4.8 \times 10^{-3} \times 0.1 \times 10^{-6}}$$

R = 145.83 Ω

3.2.3 The Battery Subsystem

This subsystem encompasses mainly the backup battery used in the system as an alternative power supply unit. To power our system, we decided to use a deep-cycle battery. A deep cycle battery is a battery designed to be regularly and deeply discharged using most of its capacity. The amperage of this battery will determine how long the battery system can be used as a backup.Mathematically, [3].

AH = (Current x Time) (3.2)

Considering two (2) mobile devices.Using 1.97A = 1970mA
Therefore 2 phones will yield 2 x 1970 = 3940mA = 4A
For about 5hrs back up/discharges assuming ideal conditions i.e. at no losses

2 x 5 = 10AH.

In our design we noted that we should not draw the 10A from the battery because of the depth ofdischarge (DoD), If we draw the entire 10A we will make the charging process irreversible thereby damaging the battery. We tested a lead-acid deep-cycle battery, this had an inverse correlation between the depth of discharge (DoD) of the battery and the number of charge and discharge cycles it can perform. DOD is measured in percentage (%) and a lead-acid deep-cyclebattery has an average DoD of 50%. A DoD of 50% means that out of 10AH we could only use 20AH before the battery shuts down. Upon further testing, we discovered that most deep-cycle batteries can discharge up to 80% DoD. [7] [8]

Therefore, 80% of 10A

$$= \frac{80}{100\%}$$

= 8AH

3.2.4 Transmitter Subsystem.

This subsystem encompasses the transmitter section of the system which operates on the principles of electromagnetic induction. Inductive charging also Known as (wireless charging orcordless charging) is a type of wireless charging that uses an electromagnetic field to transfer energy between two objects using electromagnetic induction which is the production of electricity across a magnetic field. Inductive charging is usually done with a charging station or inductive pad (transmitter). [3] [4] [5] Energy is sent through this transmitter which in turn delivers this energy to a receiver wirelessly which then utilizes this energy to charge batteries or run electronic devices. Induction chargers use an induction coil to create an alternating electromagnetic field from within a charging base, and a second induction coil

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(receiver) in the portable device takes the power from the EM field and converts it back into electric current to charge batteries. The two coils in proximity combine to form an electrical transformer. It should be noted that the greater the distance between the two coils the lower the power received. Although greater distances between transmitter and receiver can be achieved using resonant inductive coupling, our project adapts the inductive coupling method of wireless power transfer. Also, the transmitter is interfaced with an SG3525 oscillator which is a 16-pin IC we configured this IC in astable mode to generate constant clock pulses. [6]

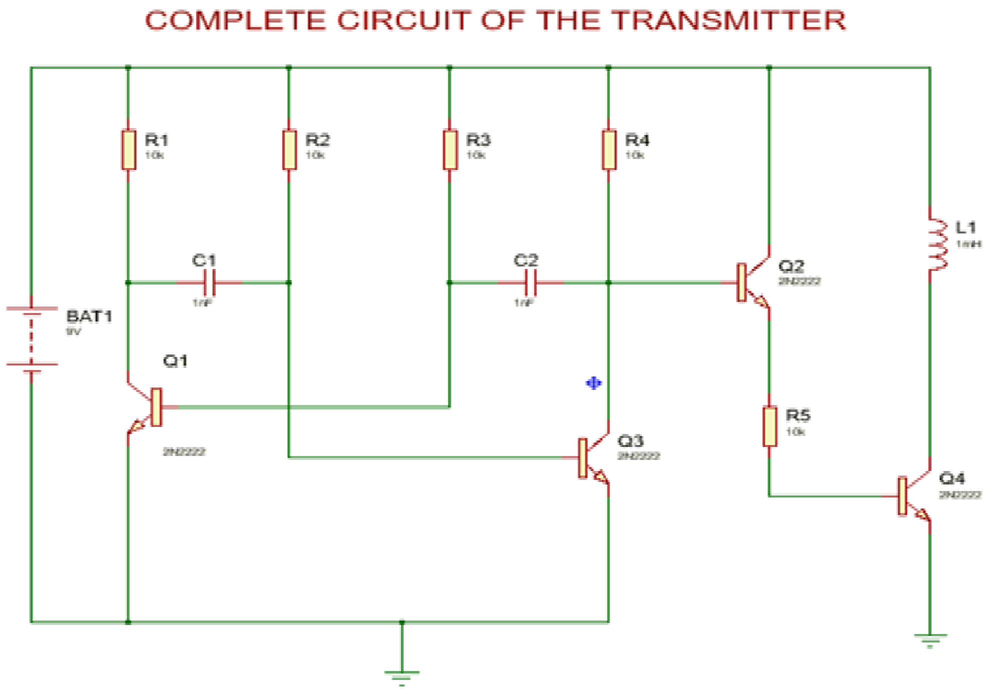

Figure 3.4: Circuit diagram of the transmitter.

3.2.5 Factors that affect the transmitter coil.

Coil Shape: The shape of the coil used as an antenna will determine the area to which the power will be transmitted.[7]
Coil Impedance: Maximum power will be transmitted if the transmitting coil's impedance is equal to the receiving coil's impedance which could be achieved by resonating both sending and receiving coils at a similar resonating frequency. [7]
Distance between coils: The total distance between two coils i.e. sending and receiving coils also affects the power transmitted too. Usually, the transmitted power reduces inversely proportional to the increase in distance. [7]
Number of coils: The number of coils used as transmitter and receiver affects the transmitted power directly. With the increase in coils used, the complexity of the circuit also increases.
Intermediate Coils: if any Intermediate coils are used, it must be perfectly matched with the impedance of the transmitting andreceiving coil impedance, thus providing the potential to increase the distance vastly.
Area of coils turn: The area of the coil's turn will affect the power transmitted directly as with the increase in the coil's area,its range will also improve.
Coil Alignment: The alignment of the transmitter/receiver coil would affect the power transmitted from one end tothe other. Two different forms of misalignment could occur
Lateral misalignment: Coils are in parallel, but their centers do not meet horizontally orvertically.
Angular misalignment: Centers of both transmitter and receiver coil are well aligned butthe coils are turned by an angle [8].

3.2.6 Receiver Subsystem.

This subsystem consists of the receiver coil component of the charging system, this subsystem takes the transmitted power induced wirelessly from the transmitter and converts the alternatingcurrent back to direct current. The receiver subsystem has a rectifier interfaced to it which doesthis conversion of currents.

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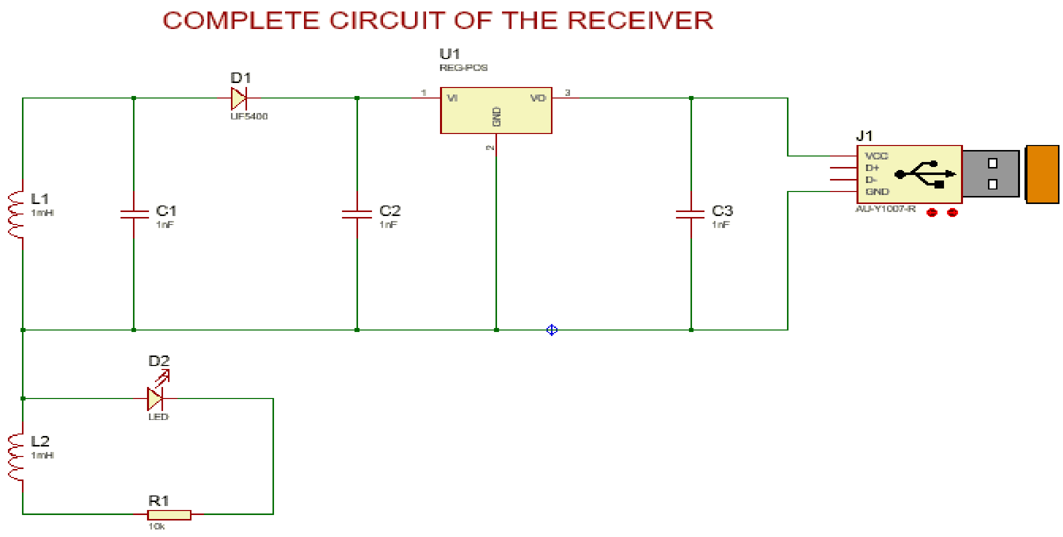

Figure 3.5: Schematic Diagram of the Receiver.

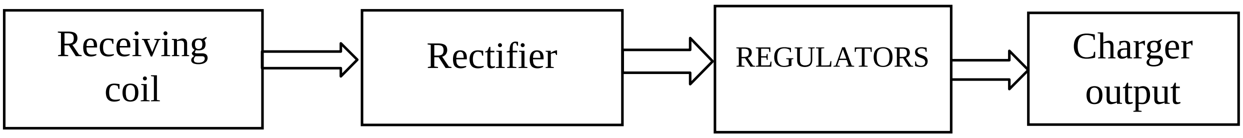

Figure 3.6: Block Diagram of the Transceiver unit. [8]

3.2.7 AC-TO-DC CONVERTER

The primary function of the AC-to-DC converter is to rectify the incoming AC power and convert it into a stable DC voltage. This process ensures compatibility with the requirements of the wireless charging system and the electronic device being charged. The converter typically employs diodes, capacitors, and other components to perform the rectification and smoothing of the AC waveform.

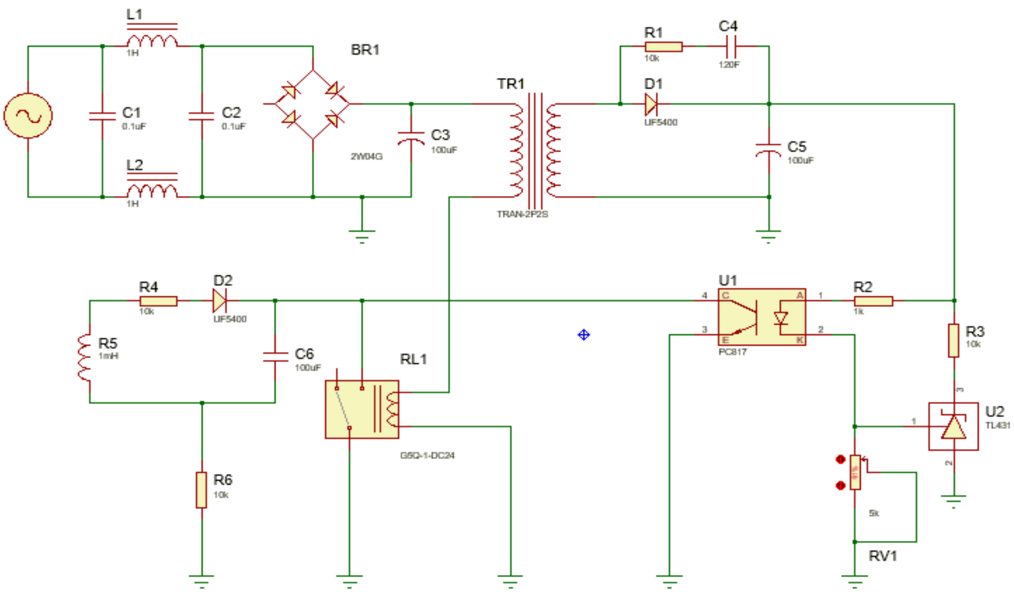

Figure 3.7: Schematic Diagram of the AC-TO-DC Converter

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3.2.8 5 Volts Bulk Converter

The 5 Volts Bulk Converter is a critical component within wireless charging systems, responsible for transforming the incoming electrical power into a stable 5-volt direct current (DC) output. This converter is essential for ensuring compatibility with a wide range of electronic devices, as 5 volts is a common charging voltage for smartphones, tablets, and other gadgets. The primary function of the 5 Volts Bulk Converter is to rectify the incoming alternating current (AC) from a power source and convert it into a continuous 5-volt DC output. This conversion process is crucial for meeting the power requirements of various electronics.

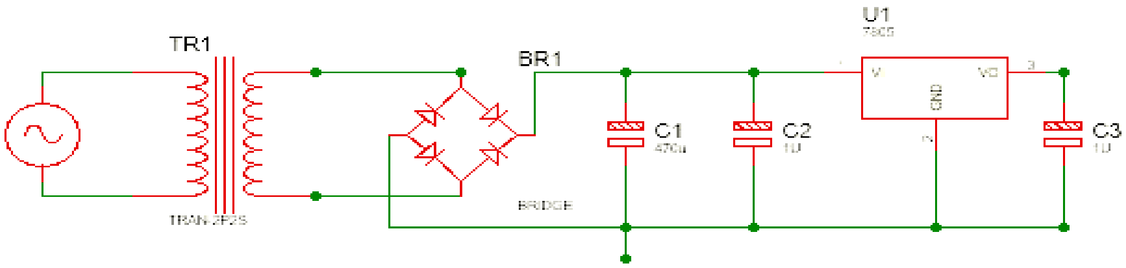

Figure 3.8 Schematic Diagram of the 5 Volts Bulk Converter

3.3 Working Principle

From the requirements specification analysis and design, a working principle of the system has been deduced as follows:- This wireless charging device is a device that leverages the working principles of electromagnetic induction to implement a system of wireless power transfer with an emphasis on resonant coupling. From the block diagrams above, we note that the system has two different power supplies connected to a control circuitry. When power is sent to the transmitters, they radiate the power outwards at a particular intensity and diameter based on our calculations, determined by the number of turns and the coil diameter. Consequently, the receiver circuits when placed near the outward electromagnetic radiations of the transmitter, couples/completes the circuit, and thus power willbe transferred from the transmitter and subsequently received by the receiver wirelessly. This received power which is an alternating current AC will then be rectified and regulated to a 5v DC which will be used to charge mobile devices.

IV. DC SUPPLY SUBSYSTEM IMPLEMENTATION AND UNIT TESTING

4.1 Implementation

1. Circuit components are connected accurately according to the schematic design.
2. Turn On the system by applying an AC power source.
3. The control sub-system is ready to be integrated with other subsystems.

Table 4.1: Unit testing

Test	Steps	Expected Result	Actual result
On/off	Switch on the Circuitry by interfacing a power Supply unit to it.	The AC-to-DC converter and the 5v bulk converter are on as current passes through the attached Components	Success
Response to all Peripherals	Plug and unplug Peripherals	Peripherals are detected	Success

4.2 Tests and Measurements

Several tests were done to check the operations of the system since efficiency is an important part of the system's operation, corresponding measurements were carried out. The measurement data is presented in Table 4.2 and the efficiency curve is shown in Figure 4.1.

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Table 4.2: Custom 30W WPT Table System Efficiency Measurement Data.

TX voltage, V	TX current, A	TX Power W	RX Power W	Efficiency %
14.5	0.77	11.16	6.81	61.02
14.5	0.85	12.32	7.86	63.8
14.5	1.18	17.11	11.01	64.35
14.5	1.39	20.15	13.78	68.39
14.5	1.50	21.75	15.88	73.01
14.5	1.63	23.63	17.85	75.54
14.5	1.75	25.37	19.96	78.68
14.5	1.97	28.56	23.51	82.32

The test was carried out using Array 3711A programmable DC electronic load. TX voltage is the voltage supplied to the transmitter module and RX power is the total power that sinks in the load on a constant current mode.

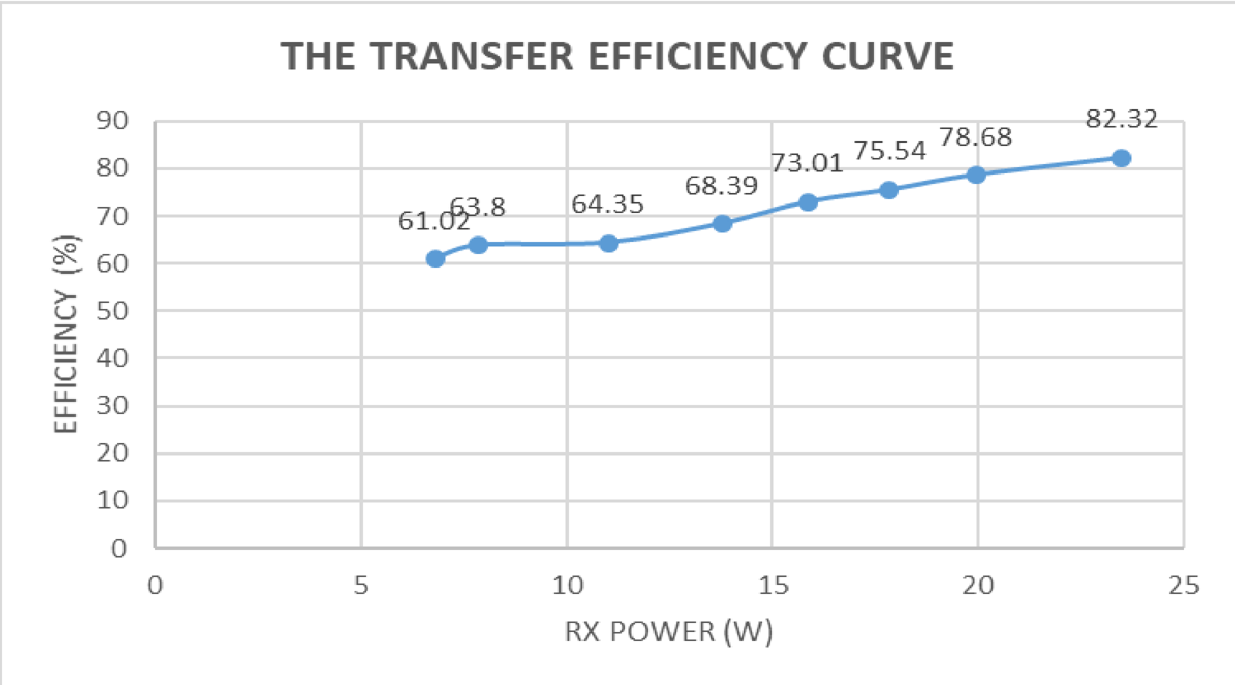

Figure 4.1: Graph to measure the transfer efficiency curve.

As can be seen from the graph the efficiency rises drastically but exceeds 70% only after ~2.25 W. In addition, the maximum achieved distance is 5 mm through different materials including linoleum, carpet and rubber and Perspex which was eventually thematerial we used for our covering.

The system was proven to be working as expected. However, a strict limitation to maximum of 5 W power output, tight alignment of the coils and too short range (onlyup to 1 cm) were the main drawbacks. They prevented the system from being “truly wireless” and provide a considerable advantage over traditional wires.

4.2.1 Charging Capacity Evaluation

This evaluation was carried out using a wireless earbuds at the receiver with 250mAH.

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Table 4.3: Charging Capacity Evaluation using a 250mAH wireless earbuds

RX Power W	Time Taken to charge from 0% - 25% Minutes	Time Taken to charge from 0% - 50% Minutes	Time Taken to charge from 0%-75% Minutes	Time Taken to charge from 0%-100% Minutes
6.81	7 mins 10 Sec	14 Mins 15 Sec	20 Mins 30 Sec	27 Mins 24 Sec
7.86	6 Mins 57 Sec	11 Mins 26 Sec	17 Mins 3 Sec	23 Mins 40 Sec
11.01	6 Mins 10 Sec	11 Mins 1 Sec	16 Mins 50 Sec	23 Mins 2 Sec
13.78	5 Mins 43 Sec	10 Mins 40 Sec	16 Mins 10 Sec	22 Mins 50 Sec
15.88	5 Mins 2 Sec	10 Mins 20 Sec	15 Mins 30 Sec	21 Mins 45 Sec
17.85	4 Mins 45 Sec	9 Mins 1 Sec	14 Mins 30 Sec	21 Mins 3 Sec
19.96	4 Mins 10 Sec	8 Mins 40 Sec	12 Mins 2 Sec	18 Mins 45 Sec
23.51	3 Mins 1 Sec	7 Mins 50 Sec	11 Mins 45 Sec	18 Mins 3 Sec

It was observe that as the Receiving Power increases the charging time decreases.

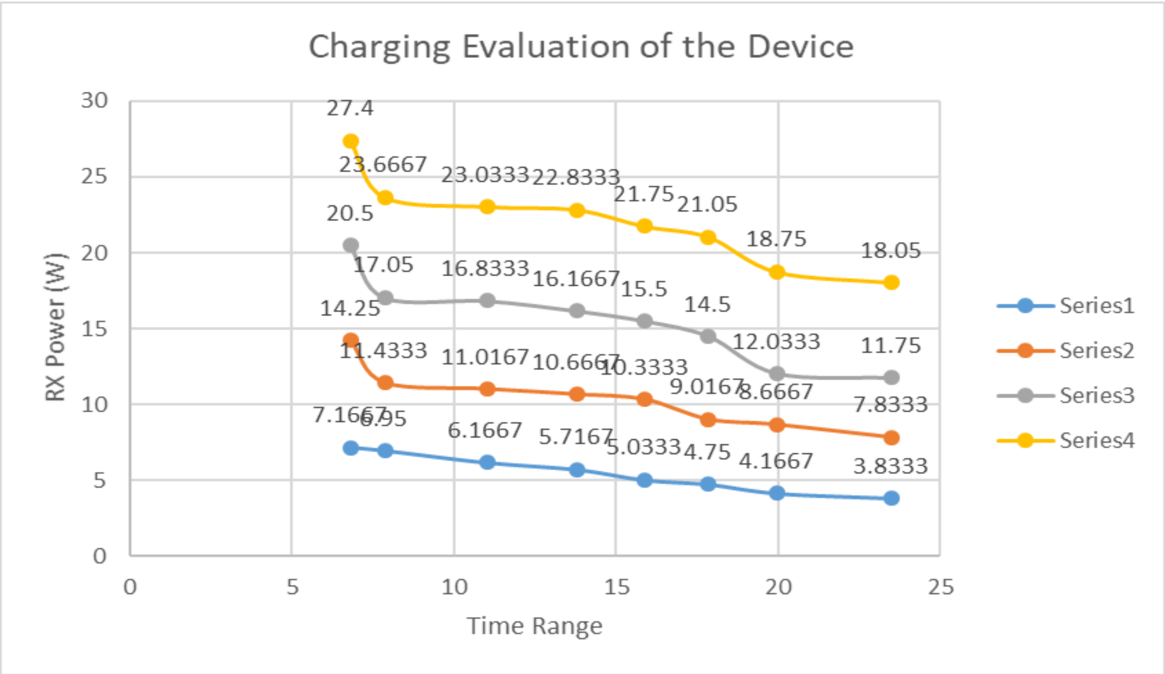

Figure 4.2: Graph for the Charging Capacity Evaluation.

4.3 HARDWARE TESTING

4.3.1 Continuity Test.

In electronics, a continuity test is the process of checking an electric circuit to see if currents flow i.e. if in fact the circuit is accurately connected. We performed a continuity test on our project by placing a small voltage (wired in series with an LED) across each path of the circuit board. If the electron flow is inhabited by broken conductors, damaged components, or excessive resistance, the circuit is said to be "open" and necessary adjustments would be required. [11] [12] We performed this test immediately after the hardware soldering and all configuration has been completed. This test aims at finding any electrical open paths in the circuit after the soldering.

Many a times, the electrical continuity in the circuit is lost due to improper soldering, wrong and rough handling of the PCB, Improper usage of the soldering iron, component failuresand presence of bugs in the circuit programs/diagrams. We used a mustimeter to perform this test. We kept the multimeter in buzzer mode and connected the ground terminal of the multimeter to the ground. We connected both the terminals across the path that needed to be checked. If there is no inhibition to the flow of current hence continuity is achieved, and we willhear the beep sound.

Table 4.4: Unit testing

Test	Steps	Expected Result	Actual result
On/off	Switch on/off button	The LED comes On.	Success

4.3.2 Power ON Test.

This test is performed to check whether the voltage at different terminals is according to the requirement. To perform this test, we took a multimeter and put it in voltage mode. This test wasperformed without IC's because if there is any excessive voltage, this may lead to the damage ofthe IC's. There are two ways to perform this test which are: [12]

[1]. Measuring the AC output to check if we obtain the required 220V AC voltage.
[2]. Checking the output of the fully charged battery using a multi-meter.

Then we applied a given amount of voltage to the power supply circuit. Since our circuit consists of a voltage regulator, we simply measured the input to the voltage regulator to confirm if we were transmitting the required 14.5V since we were using a 7805-voltage regulator IC we got an output of 5V. We also tested the output terminal of the other components of our circuit and we determined that we obtained the required voltage from our circuit.

4.3.3 EMF TEST

In order to check if our system is safe, electromagnetic field (EMF) measurements with SPECTRAN NF5035 pre-Compliance EMC/EMI spectrum analyzer was conducted. According to the test results, our system's exposure at 125 kHz was below both IEEE and ICNRP limits. Nocritical excesses were observed. Different EMF strength values were measured in different distances to the device. The average values of EMF strength were 5.6μT without load and 6μT with the test LED. Obviously, the system complies even with the strict IEEE uncontrolled environment limit.

V. CONCLUSION

Globally, the globe is gradually transitioning toward renewable energy sources to run all of its power-consuming equipment more efficiently. Based on this fact, it is apparent that energy supply must be enhanced and greatly expanded in order to continue to fuel technological developments. There is a need to expand supply and investigate innovative solutions in order for the world's energy system to operate for all of its inhabitants. One excellent solution is wireless power transfer, which, though futuristic and far-fetched, is really achievable. It can be commercially feasible if the necessary conditions and interests are in place.

While the hurdles of implementing wireless power transmission (WPT) are significant, there is no other potential means of increasing energy supply that will be as simple to execute. School students, research institutes, innovation centers, and other groups must work hard to address these issues. Wireless electricity transmission has not been considered seriously, but if electrical energy can be transferred via the air in the same way as Wi-Fi signals and radio waves are, the world will see a significant technological shift. Finally, if we fail to produce and transmit a clean source of energy for any reason, and instead try to survive on existing sources such as what we have now, technological progress prospects are likely to be stymied. Furthermore, we may confront long-term negative changes in the planetary environment that are unfavorable to us. One example is the poisoning of soil and water caused by harmful compounds leaching into the earth from batteries that are disposed of periodically.

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