EE1200 - Electrical Circuits Lab
Solar Wireless Mobile Charger

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Abstract

This project presents the development of a solar-powered wireless mobile charger, designed to provide convenient and environmentally sustainable charging solutions for mobile devices. Utilizing photovoltaic cells, the charger harnesses solar energy to replenish its internal battery, enabling it to wirelessly charge compatible devices such as smartphones and tablets. The system incorporates efficient power management and wireless charging technologies to ensure optimal charging performance. Through this innovation, users can access reliable charging capabilities on-the-go, while reducing reliance on traditional grid power sources and minimizing environmental impact.

This innovation not only offers users the convenience of on-the-go charging but also contributes to reducing carbon footprints by promoting renewable energy adoption in everyday technology usage.

Generally a wireless charging system consists of two parts:

- *Transmitter*
- *Receiver*

In this Project, we have discussed about the working model of both the circuits - Transmitter and Receiver circuit.

Contents

1 THEORY

1.1 ELCTROMAGNETIC INDUCTION

Ørsted was able to demonstrate that electric currents can produce magnetic fields by setting up a compass through a wire carrying an electric current.

This observation paved the way for the discovery that an electromotive force and current are produced in a nearby circuit by a change in the magnetic field. James Clerk Maxwell eventually mathematically analyzed this process, known as electromagnetic induction, which led to the development of Faraday's Law.

Faraday's Law states that the amount of voltage induced in a coil is directly proportional to the rate of change of the magnetic flux with respect to the coil, $\frac{d\phi}{dt}$ and to the number of turns of wire in the coil (N). The formula that represents Faraday's Law is:

$$V = N\,\frac{d\phi}{dt}$$

1.2 INDUCTIVE COUPLING

When two conductors are arranged so that an electromagnetic induction causes a voltage to be generated at the ends of one wire when a change in current flows through the other, the two conductors are said to be inductively or magnetically connected.

Ampere's circuit law states that a fluctuating current flowing through the first wire produces a fluctuating magnetic field surrounding it. According to Faraday's law of induction, a change in the magnetic field causes an electromotive force, also known as voltage, to occur in the second wire. The mutual inductance of two conductors indicates the degree of inductive coupling between them. When two wires are wound into coils and positioned near to one another on a common axis, the magnetic fields of the two coils pass through one another, increasing the coupling between them. A magnetic core made of ferromagnetic material, such as iron or ferrite, placed inside the coils can help improve coupling by raising the magnetic flux.

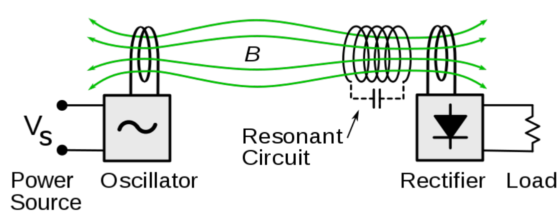


Figure 1: Simplified Circuit Illustrating Inductive Coupling

Think about a coil that receives a current. As a result, the magnetic field surrounding it changes. A second coil will generate an induced voltage when it is exposed to a main coil's fluctuating magnetic field, magnetically connecting the two coils. The following formula can be used to compute the voltage induced in the second coil as a function of mutual inductance:

$$L_M = k\sqrt{L_1 L_2}$$

where, k is the coupling coefficient.

An inductor and a resistor (R_p) are connected to the transmitter's AC source in the circuit. (L_1), where the resistor stands for heat-related power loss. When the AC source's fluctuating current flows through inductor 1 (L_1), it produces a magnetic field that induces voltage in L_2. The

The transmitter's fluctuating magnetic field provides power to the reception circuit, which contains L_2, R_s, and R_L. Once more, R_L is the load and R_s is the inductor's power loss.

Increasing the coil's number of turns, current strength, cross-sectional area, and radial magnetic field strength can all improve the inductive coupling's efficiency of power transfer. Because magnetic fields weaken fast, inductive coupling is only useful over very short distances. Attempts have been made to decrease inductive coupling's transfer loss. There are several approaches that could be used to improve drive electronics, frequencies, and ultra-thin coils. The efficiency of the other two ways is still being looked into for potential improvements, however when higher frequency induction is used to deliver high power, the efficiency approaches 86%.

2 OVERVIEW OF COMPONENTS

The hardware components required to design the proposed system of Solar Wireless Mobile Charger.

Component	**Quantity**
Copper wire (25 gauge)	2 (30 rounds each)
IRFZ44N Mosfet	1
Solar Panel (12V)	1
IC4007 Diode	5
Breadboard	3
1000 μF capacitor	1
LM7805	1
KA7809	1
1 kΩ resistor	3
100 Ω resistor	2
100 μF capacitor	1
LED	1
4.7nF capacitor	1
1nF Capacitor	2
220nF capacitor	1
ICR18650 Rechargable cells	2

Table 1: Components List

2.1 IRFZ44N MOSFET

The term metal-oxide semiconductor field-effect transistors is abbreviated as MOSFET. It has a drain, a gate, and a source. A MOSFET has a gate that is isolated from the channel. As a result, the MOSFET is sometimes referred to as an IGFET, or insulated-gate field effect transistor. MOSFETs are voltage-controlled devices, as opposed to transistors, meaning that the necessary Gate threshold voltage (V$_{GS}$) can be supplied to switch them on or off.

The IRFZ44N is an N-channel enhancement type MOSFET that contributes to higher switching circuit efficiency. It has a low R_{ds} value of 17.5 mΩ and a high drain current of 49A. Additionally, the MOSFET has a low threshold voltage of 4V, at which point it will begin to conduct. For this reason, it is frequently used to drive at 5V with micro-controllers. The pulsed drain current (ID-peak) is 160A, the gate-source voltage (V_{GS}) is ±20V (max), the maximum drain-source voltage (V_{DS}) is 55V, and the minimum gate threshold voltage (V_{GS-th}) is 2V.

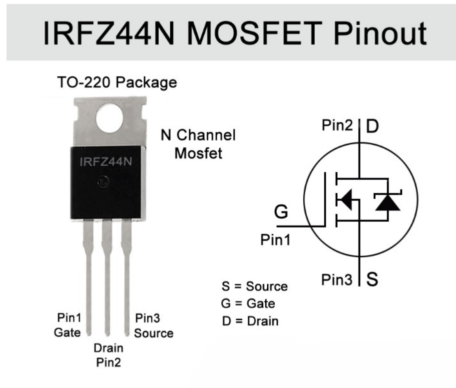


Figure 2: Pinout configuration of IRFZ44N

PIN no.	PIN name	Description
1	gate	Controls the biasing of the MOSFET
2	Drain	Current flows through Drain
3	Source	urrent flows out through Source

Table 2: Pinout table of IRFZ44N

2.2 LM7805

A popular voltage regulator that is utilized in the majority of electronics applications is the 7805 Voltage Regulator IC. It gives a fluctuating input voltage supply a steady +5V output value. An iconic regulator IC that is used in the majority of projects is the 7805 IC. The terms "78" and "05" in the name 7805 indicate that it is a positive voltage regulator and that its output value is 5 volts. 7805 will therefore generate an output voltage of +5V. This integrated circuit has a 1.5A maximum output current. However, it loses a lot of heat. Thus, it is typically advised to use a heat sink for projects requiring a higher current consumption. It can accept input voltages as low as 7V and as high as 25V.

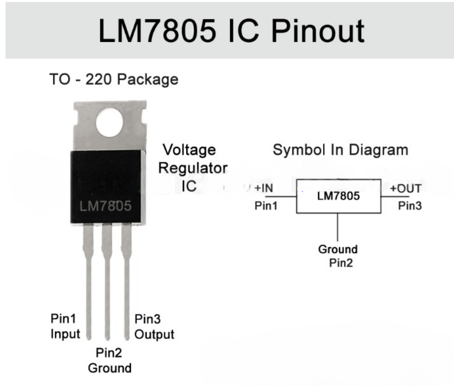


Figure 3: Pinout configuration of LM7805

PIN no.	PIN name	Description
1	Input(V+)	Unregulated Input Voltage
2	Ground(Gnd)	Connected to Ground
3	Output (V_o)	Output Regulated +5V

Table 3: Pinout table of LM7805

3 PROCEDURE AND WORKING

3.1 Transmitter Circuit

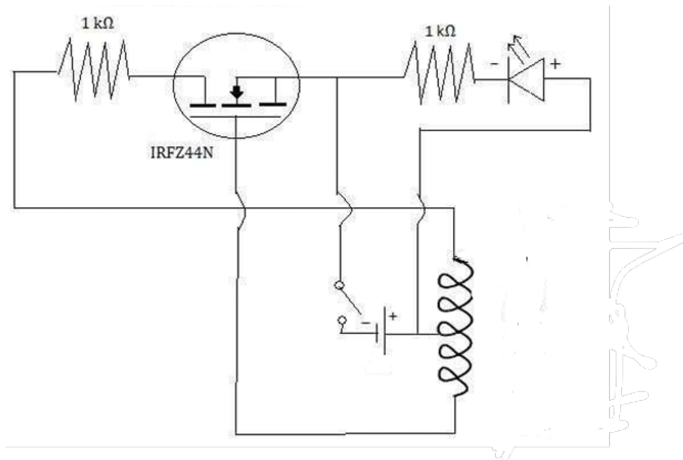


Figure 4: Schematic of Transmitter Circuit

Process of working:
Here we use an inverter circuit involving a Mosfet which is capable of switching rapidly which results in conversion of dc voltage to ac voltage.
When the circuit is fed with input voltage, the voltage starts increasing from 0. It reaches the threshold voltage of the mosfet(3.4V),and when it just crosses the threshold voltage,as we know when $V_{GS} > V_{th}$, the switch closes between drain and source,allowing current to pass trough it.
So when current passes through the coil,an emf is produced in the opposite direction in the coil, which opposes the given voltage, so the voltage starts decreasing and when it becomes less than threshold voltage, the switch between drain and source gets opened.
So the circuit again reaches the initial position.This process repeats continuosly. input voltage also oscillates between 3.4V.In this way continuous switching and converting the dc voltage to ac voltage occurs and the ac voltage passes through the coil to the reciever coil.

Now we added some resistors and cappacitors of suitable values to ensure proper filtering and increasing efficiency.

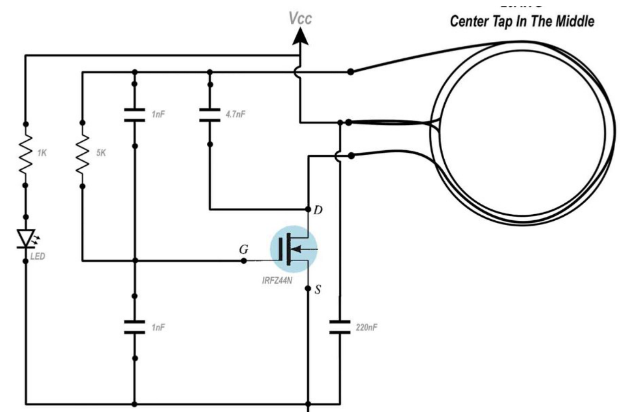


Figure 5

- **5k Resistor and 1nF Capacitor in Parallel (Gate to First End of Coil):** This combination forms a low-pass filter. The resistor helps to limit the current flow into the gate, and the capacitor bypasses high-frequency noise from reaching the gate of the MOSFET. It ensures that only the desired oscillation frequency influences the gate. Use: Prevents high-frequency noise from interfering with the operation of the oscillator, improving stability.
- **4.7nF Capacitor (Between First and Last Ends of Coil):** This capacitor creates an LC tank circuit with the tapped coil. The LC tank circuit determines the resonant frequency of the oscillator. Use: Sets the fundamental frequency of the oscillator by interacting with the inductance of the coil.
- **1k Resistor (Connected to the Tap of the Coil):** This resistor provides a load for the tap of the coil and helps to stabilize the circuit by controlling the current flow at that point. Use: Ensures proper functioning of the oscillator and helps to maintain stability.
- **1nF Capacitor (Connected to the Tap of the Coil):** This capacitor provides additional filtering and stabilization at the tap point of the coil. Use: Filters out high-frequency noise and helps maintain a stable voltage at the tap point.
- **220nF Capacitor (Connected to the Tap of the Coil):** This capacitor further enhances the stability of the tap point by providing additional filtering and decoupling. Use: Ensures a stable voltage at the tap point and helps prevent unwanted oscillations or noise.

  Overall, the added capacitors and resistors in the circuit serve to improve stability, filter out noise, set the oscillation frequency, and ensure proper functioning of the oscillator. Each component plays a specific role in shaping the behavior of the circuit and contributing to its overall performance.

3.2 Receiver Circuit

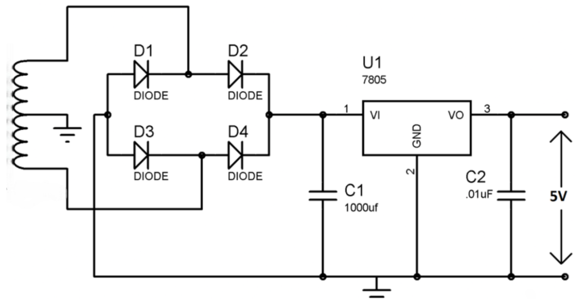


Figure 6: Schematic of Receiver Circuit

Here the input is an AC Voltage (output of the transmitter circuit).

- **Rectification**
  The method of rectifying an alternate current (AC) is to take out its negative component, which results in a partial DC. Four diodes can be used to accomplish this. Diodes restrict the direction in which current can flow. Diodes D1 and D4 are reverse biased in the second half of the AC cycle (negative half), while D2 and D3 are forward biased in the first half of the cycle and D1 and D4 are reverse biased. The negative half cycle is changed to a positive cycle by this combination.

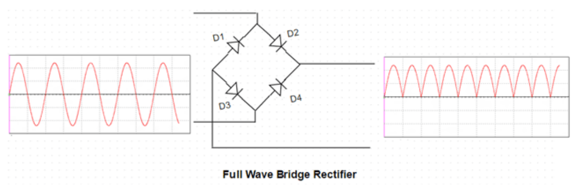


Figure 7: Full-Wave Bridge Rectifier

- **Filtration**
  The output after the Rectification is not a proper DC, it is oscillation output and has a very high ripple factor. We don't need that pulsating output, for this we use Capacitor. Capacitor charge till the waveform goes to its peak and discharge into Load circuit when waveform goes low. So when output is going low, capacitor maintains the proper voltage supply into the Load circuit, hence creating the DC.

- **Voltage Regulation**
  A regulated 5 volt DC is produced using a voltage regulator, IC 7805. The IC can operate in the input voltage range of 7–20V, however for optimal operation, the input voltage must be two volts higher than the rated output voltage, or at least 7V. All the circuitry needed to produce a well regulated DC is contained within voltage regulators. To remove noise caused by brief voltage fluctuations, a 0.01μF capacitor needs to be attached to the 7805's output.

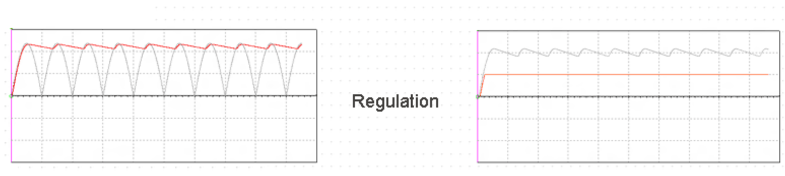


Figure 8: Regulation

3.3 Power Bank Circuit

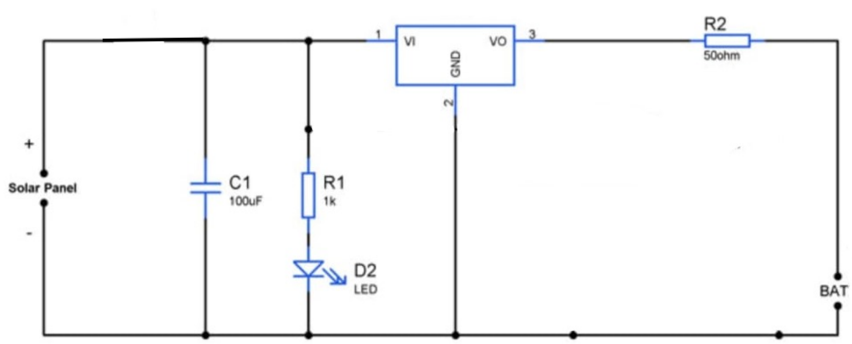


Figure 9

The working of the above circuit is similar to the receiver circuit. During days, the circuit works normally with the solar panel. In the absence of sunlight, the battery (charged during day) can be used for the same. Instead of IC 7805, we used IC 7809 to get an output of 9V so that it can charge the battery.

4 OBSERVATIONS

- Below are the results obtained for the Transmitter Circuit.

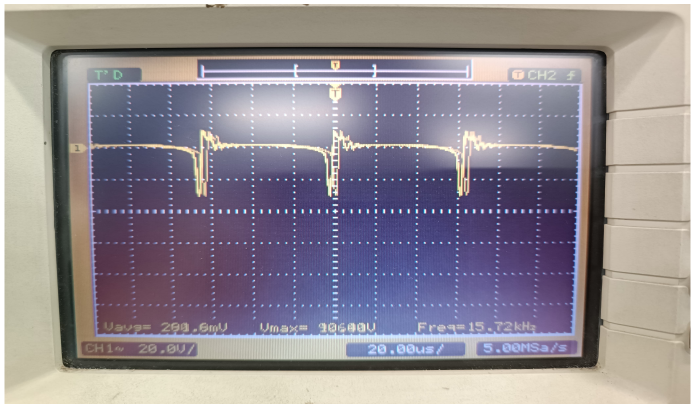


Figure 10: Results obtained from Oscilloscope

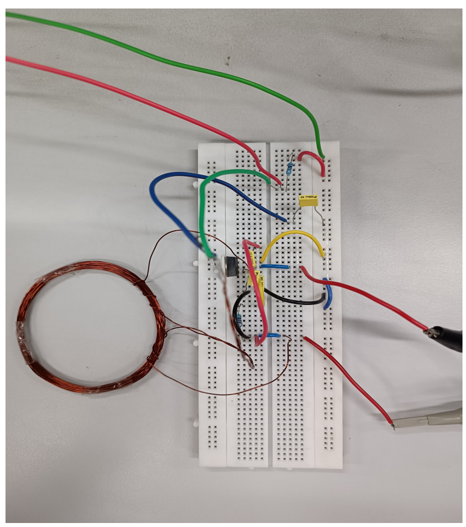


Figure 11

- Below are the results obtained for the Receiver circuit.

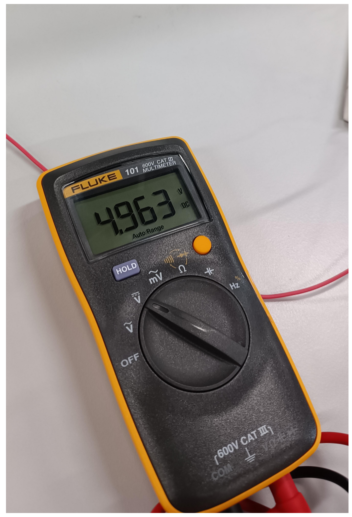


Figure 12: Output Voltage measured using multi-meter

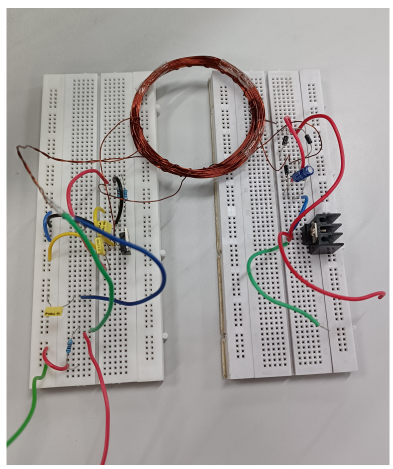


Figure 13

- Output Voltage for Different Values of Distance Between the Coils.

Distance between Coils (mm)	Output Voltage (V)
0	4.966
5	4.653
5.8	4.339
10	4.291
12	4.001
13	3.885
14	3.801
15	3.723
16	3.520
17	3.336
19	3.209
20	3.004

Table 4

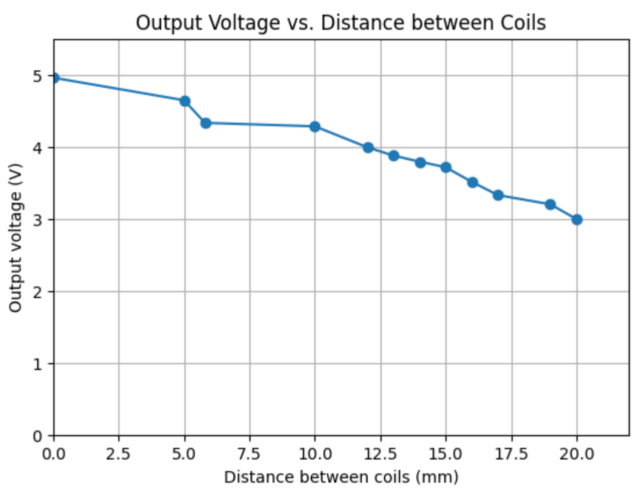
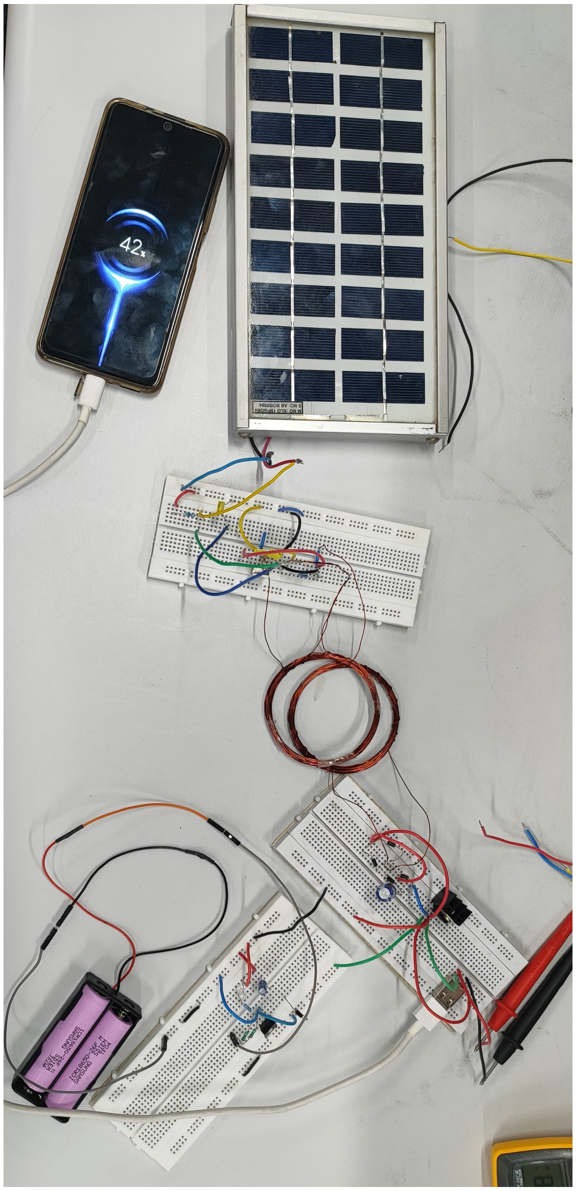


Figure 14: Plot of distance vs Voltage

- The final Result.



5 CONCLUSION

The project demonstrates that the solar wireless mobile charger functions effectively by converting solar energy into electrical energy and delivering it to the mobile device for charging. The consistent output of 5V indicates that the charger is capable of providing the required voltage for charging mobile devices.

The ability of the charger to consistently deliver the expected output voltage affirms its reliability and performance. This is crucial for ensuring that mobile devices are charged efficiently and without interruption, thereby meeting the needs of users in various settings and scenarios.

The successful operation of the charger validates the design choices and selection of components used in the project. It indicates that the chosen solar panels, charging circuitry, and other components are suitable for the intended application and capable of meeting the desired performance criteria.

In conclusion, the successful operation of the solar wireless mobile charger, with the output meeting expectations, highlights its functionality, reliability, and potential for promoting sustainable and convenient mobile charging solutions. It represents a promising step towards addressing the energy needs of mobile devices while embracing renewable energy sources.