Design and Development of a Capacitive Power Transfer for Contactless Charging of Low Power Devices

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Abstract *—In this technically advanced era, technology isthe cornerstoneof civilization.The importance of technology bringsintofocus the value ofchargingtechnologies. The scope of the industry is moving towards Wireless Charging as this allows for easier charging without the use of wires and is extremely convenient. Wireless chargers that exist currently are inductively coupled. Inductive coupling tends to cause electromagnetic disruption in most of the devices that is sensitive to electromagnetic interference. This design which is based on capacitive coupling overcomes the disadvantage of any interference with other devices as it is based on Electrostatic Coupling. Thisdesign is able to charge a low device through contactless charging efficiently.*

The designed wireless charger unit was simulated in Proteus8 Professional Suite. A transformer is used to step down the supply voltage to the requisite value. The H-Bridge circuit is used to convert dc to a con the Transmitter side and the Rectifier circuit is used to convert ac back to dc in theReceiver side of the device. An LED which is a low powered device is connected to the receiver side of the circuit as a load. Power is transferred to the circuit via the plates which are separated by a dielectric medium.

A wireless charger was built, however, the size and the weight are two very important criteria in the design of any charger and these factors are affected by the effective plate size of the coupling capacitors and must be taken into consideration for the design of a charger.

Keywords:*Capacitive Coupling, Proteus 8, Microcontroller, LED.*

I. INTRODUCTION

The world has advanced to a stage where technology is an extremely vital part of our daily lives. As the dependency on technology increased, the need for more efficient, more compact, smaller and lighter devices are required. The technology used in present charging systems for these devices are outdated and inept. The commonly used wired chargers lack flexibility in movement and lack efficiency in charging of multiple devices simultaneously. Wireless Power Transfer is gaining increasing attention for charging of low powered devices like smart phones, cameras and laptops. Present Wireless Chargers are based on an inductive interface between the transmitter and receiver. Both the transmitter and receiver are fitted with electrical coils. When brought close to each other, power is transferred from the transmitter to the receiver. An alternate approach using a capacitive interface rather than inductive interface is used to deliver the power. Electrostatic field is confined between the plates in this approach, dispelling the need for flux guiding and shielding components used in inductively coupled systems which not only add bulk but also increase the overall cost of said systems.

Generally, a transformer which consists of two coils is used for transfer power keeping in mind the need to achieve isolation in circuits. Similarly, capacitors can be used for isolation, but the method of common-mode rejection is different. These signals do not induce flux in the transformer core. However, practically, finite capacitive coupling from the primary to the secondary leads to common mode feed through. This is not a feasible outcome. It is because the signals are limited to low frequencies and their harmonics. The impedance of capacitors at low frequencies is high, limiting the common mode current that passes through. Thus capacitances can also be used to isolation, and power can be delivered at much higher frequencies.

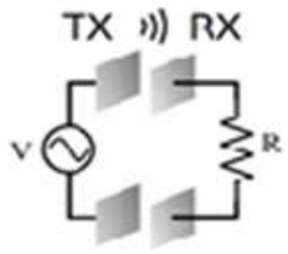

Figure 1-1 Capacitively Coupled Power Transfer [1]

Figure 1-1 shows the capacitively coupled power transfer circuit by parallel plates. The concept of high frequency power transfer has been in practice with magnetic solutions for decades, it allows reduction of the size and cost of the transformer.

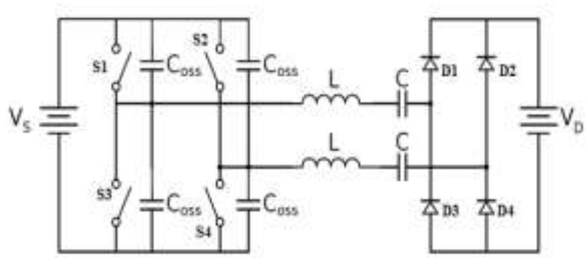

Figure 1-2 Schematic Diagram of a Series Resonant Converter Circuit [1]

Figure 1-2 explains how the power is transferred from V_S to V_D through the two coupling capacitors C.These two capacitors are in series, so the effective capacitance between transmitter and receiver is C/2. An H-bridge driver converts V_s into an AC voltage to enable current to flow through the capacitors. Inductors L are placed in series with the coupling capacitance to enable soft-switching. A diode rectifier converts the AC voltage back to DC.

II. LITERATURE REVIEW

Research on Inductively Coupled Wireless Charging has been conducted on new Multi Layered printed Circuit Board winding matrices of hexagonal structures that can generate magnetic flux of almost even magnitude over the surface of winding arrays were developed for a multi device charging board. The author's design deals with the construction of a new type of charging platform where multiple devices can be charged simultaneously regardless of position and orientation. The principle and structure of the charging platform are explained and the feasibility has been confirmed with various practical measurements. The proposed universal charging platform was successfully used for charging various devices. The feasibility and the drawbacks of a Inductively coupled design were surveyed with this paper. [2]

Wireless Power Transfer through Capacitive coupling was explored wherein the author proposed that using a capacitive, rather than inductive interface for wireless power delivery is gaining increasing attention for powering and charging portable devices including smart phones, cameras, and laptop computers. The simplicity and low cost of capacitive interfaces makes them very attractive for wireless charging stations. Major benefits include low electromagnetic radiation and the amenability of combined power and data transfer over the same interface. He presents a capacitive power transfer circuit using series resonance that enables efficient high frequency, moderate voltage operation through soft switching. An included analysis predicts fundamental limitations on the maximum achievable efficiency for a given amount of coupling capacitance. Automatic tuning loops ensure the circuit operates at the optimum frequency and maximum efficiency over a wide range of coupling capacitance and load conditions. His design and analysis were instrumental in developing the the circuit and to affirm that the wireless power transfer was achieved. [1]

The author proposes a non-contact charging system using a resonant converter in this paper, where the efficiency is improved by connecting a parallel capacitor in the secondary side of the transformer. Another approach proposed a system scale design that uses capacitive coupling for power and signal isolation. These papers gave an insight into the design of Wireless Capacitor Charging and they describe a system prototype which can carry out effective charging along with bidirectional data transfer. [3]-[4]

A novel contactless battery charging system using capacitive power transfer (CPT) technology with the aim being to achieve an intervention-free energy replenishment system for soccer playing robots was proposed. It was surmised from his paper that although Inductive Power Transfer (IPT) technology has been investigated for such an application, the CPT technology provides a new solution which can transfer power across metal barriers and reduce electromagnetic interference (EMI). This paper covers system design of a power converter for high frequency electric field generation, proper coupling between the primary circuit and the power pick-up on board the robot, as well as the pick-up battery charging. This paper also gave an understanding of the effective range of such a charger as well as the design criteria to maintain a sustained output at the load. [5]

III. OBJECTIVES AND METHODOLOGY

A. Objectives

The objectives of project are given below:

1) To study the existing circuit that can wirelessly transfer power to a circuit.

2) To arrive at a design specifications for the wireless charger aiming at higher efficiency with least amount of coupling capacitance.

3) To test the wireless charger to meet the design specifications.

4) To develop the transmitter and receiver hardware units.

B. Methodology Adopted:

Methodology for Objective-1:

Literature Survey will be made to understand the designs and developments made in capacitive power transfer wireless charger technology.

Methodology for Objective-2:

• Pre-requisite data for the design specifications of wireless chargers is extracted from the available reference journal publications meeting the desired specifications.

• The designed wireless charger unit will be simulated in Proteus and circuit component values are obtained.

• The capacitive power transfer circuit will be designed to meet USB level power specifications.

• The design will be refined to get the optimum circuit component values and retested using Proteus.

Methodology for Objective-3:

• The Transmitter and Receiver Blocks will be developed with discrete components on Printed Circuit board after choosing the appropriate components to match the obtained design as closely as possible.

Methodology for Objective-4:

• The capacitive interface is implemented with Transmitter and Receiver circuit and its functioning is tested against the expected outcome.

IV. EXPERIMENTAL WORK

The circuit was built onto a wooden board for stability. All the connections were made and soldered so as to maintain a proper stable circuit connection. The Aluminium plates used for the Coupling Capacitors are ensured to be straight metal sheets without any dents or bends. The Transmitter circuit has two plates and the Receiving circuit has two plates. One plate of each block is placed on top of each other with air and paper as dielectric in place. Dielectrics like air and paper are used to check the efficiency of the circuit in each case. In each case, the LED on the Receiving Circuit is used to check for transfer of power across the capacitor plates. The same is repeated with Capacitor plates of different sizes and the results are tabulated. On turning the power supply off, the LED must glow due to the power stored in the batteries.

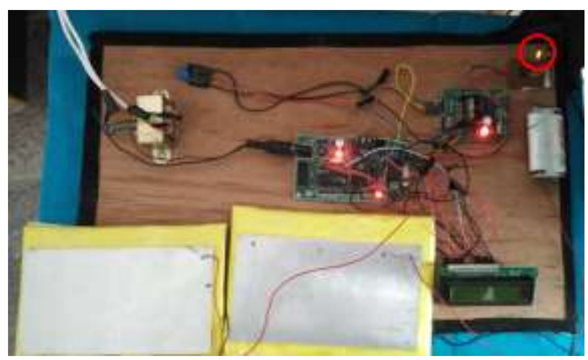

Figure 1-3 Working Model of the Circuit

Capacitor Plate Area (cm^2)	Maximum Distance Between Plates in Air (cm)
5*8	76
8*8	138
10*8	165
15*8	241

Table 1-1 Maximum distance between Capacitor Plates in Air for Various Plate Dimensions

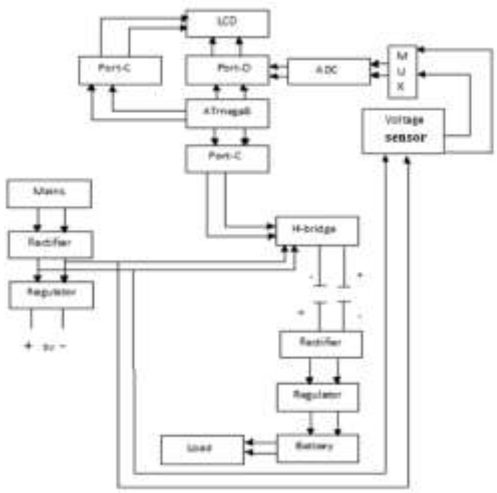

Figure 1-4 Block Diagram of the Circuit

V. CONCLUSION

Literature review on various wireless power transmission system and capacitive coupling gave an idea on WPT systems. Based on the experimental result, the study on wireless power transfer using capacitive coupling has much aspect in terms distance of primary and secondary plates, thickness of plates, area of the plates. A miniature model demonstration with power getting transferred from primary to secondary is achieved with air as a dielectric. The same concept could be adopted with scaling features in wireless chargers.

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