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IMPLEMENTATION OF A WIRELESS CHARGING SYSTEM FOR MOBILE DEVICES

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ABSTRACT

This work describes the implementation of an RF based wireless charging system using RF transmitting and receiving modules. The objective of this work is to implement a system that has the ability to interact and communicate wirelessly within short range. This mobile wireless charging switching system consists of two sections, the transmitting and the receiving section. Each section was interfaced to 433MHz transmitting and receiving modules. The transmitter section of the wireless mobile charging system sends bursts of 433MHz signal through push button switch which is used in the initiation of the charging process to the receiver; when this signal is received by the receiver, it activates a relay which in turn switches on the internal power that comprises the backup battery, DC-to DC converter via a Universal Serial Bus (USB) port to the mobile device to begin charging. This work was able to achieve a wireless transfer of power for distance of about one metre between the transmitter and the receiver.

KEYWORDS: wireless charging, radio frequency radiation, electromagnetic induction, inductive coupling, microcontroller,

INTRODUCTION

Wireless power transfer makes it possible to charge mobile devices wirelessly through a concept called Wireless Power Transmission (WPT). WPT operates using electromagnetic induction principles. Here a primary coil generates a predominantly magnetic field and induces current on a secondary coil within the field. In wireless power transfer, range (distance between the charging device and the mobile device to be charged) is a big issue due to the amount of power required for electromagnetic induction.

Copper wires used in the transmission of electrical energy can sometimes spark, get short circuited and even give electrical shock. Regular use of these wires can also sometimes make them less reliable. Wireless power transfer technology can overcome these.

Wireless Power Transmission (WPT) mainly uses three main systems such as microwaves, solar cells and resonance. Its advantages include, ability to charge multiple devices; high charging speeds; charging cords are eliminated thereby providing for watertight and compact devices vital in some applications ; there is freedom between power source and the device; since there are no mechanical connectors and therefore no sparking and corrosion; minimizes mechanical connections. However WPT charging systems charge more slowly, are less efficient and more expensive than the wire type.

Research and studies have been done since the 19th century but it is only recently that this concept has begun to be implemented. Currently inroads have been made on ways to increase the efficiency of power transmitted wirelessly and making sure that this is done safely, cheaply and is commercially viable. Several electronic companies are rolling out devices that can wirelessly transmit power.

Many chargers are not suitable for use for mobile devices due to the charging technology involved. Another problem associated with such charging systems is overcharging which may cause thermal run-away and battery explosion. There is also variation in battery technology. Though most charging systems now incorporate wireless technology making remote charging possible, incorporating certain protective functionality is still a concern in the charging system design.

This work tries to implement a simple wireless charging system that utilises locally available materials and components and can be used to demonstrate wireless charging to students. This system eliminates the complicated design and implementation procedures undertaken by the giant electronic companies. It can also be of interest to electronic buffs.

Although Tesla (1914) demonstrated wireless power transfer over a century ago, the subject was not well investigated until researchers at Los-Alamos National Laboratory developed the first passive Radio-

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Identification (RFID) tag (Landt, 1998). The RFID tag is passive because the chip inside it is powered by the signal that incidents on it. By 2006, a senior design project group at Illinois had completed a project entitled “Wireless Power Adapter for Rechargeable Devices” (Schuler, 1996). In the work, the group successfully demonstrated that a cell phone could be wirelessly charged.

In 2007, the research group at Massachusetts Institute of Technology (MIT) demonstrated the wireless powering of a light bulb thereby boosting work in this area (Techtalk, 2007). Constazo *et.al* (2014) beamed more light on electromagnetic energy harvesting and wireless power transmission. Also, Lu *et.al* (2015) carried out a contemporary survey on wireless RF energy harvesting. Bi *et.al* (2015) looked at the opportunities and challenges in wireless power communication.

Mung *et.al* (2010) successfully designed and constructed a wireless charging system using inductive coupling. They used Biot- Savat and Faraday’s laws to calculate the inductive coupling within the transmitter and receiver coils. In this work, there was a transfer of about 7.4W of energy when the transmitter and receiver were about 1.3 inches apart. They made a suggestion of possibly improving on this design by changing the power rating of the Metal Oxide Semiconductor Field Effect Transistor (MOSFET).

Salat *et.al* (2013) presented innovative receiver architecture. In this work, a wireless power transfer between a transmitter and a receiver using magnetic coupling was implemented. This innovative receiver design greatly improved the power conversion efficiency. According to them, the efficiency was between 96.5% and 99.9% over the entire range of operating condition.

Kurs *et.al* (2007) experimentally demonstrated an efficient non radiative power transfer over a distance up to eight times the radius of the induction coils. They were able to transfer 60W of power with 40% efficiency over a distance of two meters.

Chiu *et.al* (2006) worked on retro directive array of radio frequency identification and microwave tracking beacon applications while Zhai *et.al* (2010) showed a practical charging system based on an ultra-wideband retro reflective beam forming.

There are different types of battery charging systems namely: Simple, trickle, timer-based, intelligent, fast, pulse, USB-based, solar, inductive type battery chargers. All these systems have their modes of operation.

2.0 MATERIALS

Components used include Peripheral Interface Controller (PIC) microcontroller (PIC12F675) which is an 8-bit microcontroller that comes in an 8 pin Dual Inline (DIL) package with 8K of flash memory, and 256 bytes of EEPROM data memory. It is an extremely affordable device for the numerous features that it contains.

Radio Frequency (RF) wireless modules commonly known as 433MHz data transceivers which operate on the 433.050MHz to 434.790MHz band, at a power level of 25mW were also used. The transmitter was an Amplitude Shift Keying (ASK) transmitter module designed specifically for remote control, wireless mouse and car alarm system operating at 315/433.92MHz.

2.1 DESIGN METHODOLOGY

There are several methods associated with wireless power transfer system. According to Shinohara (2014) wireless power system falls into two categories: non-radiative and radiative. The method adopted for this work is the non-radiative approach with slight modification to support mobile devices that have no support for wireless charging. Using this method, two separate units comprising a transmitter and receiver were constructed with the transmitter being the switching and activating source and the receiver being the powering and the charging source. In conventional wireless charging systems, non-radiative or radiative technique is used depending on the device support feature.

This mobile wireless charging switching system consists of two sections, the transmitting and the receiving sections. Each section was interfaced to 433MHz transmitting and receiving modules. The transmitter section of the wireless mobile charging system sends burst of 433MHz signal through push button switch which is used in the initiation of the charging process to the receiver. When this signal is received by the receiver, it activates a relay which in turn switches on the internal power that comprises the backup battery, DC-to DC converter via a Universal Serial Bus (USB) port to the mobile device to begin charging. Being an intelligent design, the inbuilt microcontroller ensures that the receiver knows and recognizes that it is the transmitter that sent the signal. The receiver is based on a PIC12F675-I/P microcontroller chip which interprets the data signal that is received from the 433MHz receiver module. If the signal from the transmitter is sent successfully, it turns on the output to activate the charging process through a relay.

2.2 THE TRANSMITTER AND ITS OPERATION

In conventional wireless charging systems, the transmitter emits an alternating current via a transmitter coil, which then induces a voltage in the receiver coil found in the device. Due to the fact that most mobile devices do not support this technology, a less expensive and simple approach was adopted for this work. Here the described wireless charging switching system makes use of switching and control method to activate the charging process. The described system comprises a transmitter and a receiver with inbuilt battery bank modified in order to become completely wireless.

The charging process was initiated to the phone to be charged by a pair of 433MHz RF modules (transmitter, receiver). The receiver consists of a charging system that is made up of backup battery, DC-to-DC converter, a rectifying diode bridge with a regulator in order to produce the required DC voltage (5V at 1A) required by the load. The transmitted signal was used in controlling the receiver in order to deliver the needed power that was used in charging the mobile device.

The transmitter circuit diagram is shown in figure 1 with its operation.

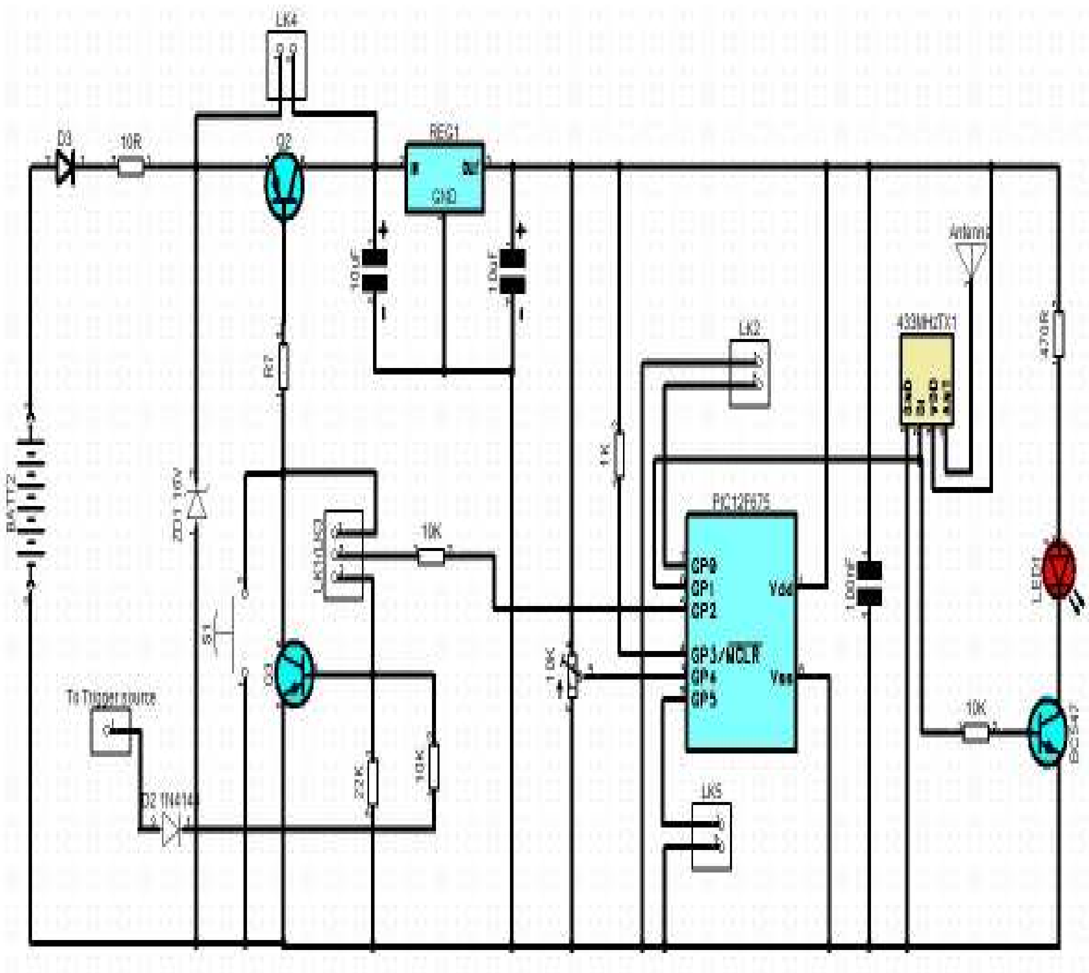

Figure 1: Circuit Diagram of the Transmitter for the Wireless Switching System

The circuit was designed to run from a power supply between 7V and 12V with very low power drain, suitable for battery use. In the current design specification, a 9V battery was used; the system could also be wired into a vehicle's 12V supply. 12 V batteries are the most common battery available. Absolutely no power was drawn when the transmitter was in its standby state – that is, when the transmit switch had not been pressed.

When the transmit switch (S1) was pressed, the power drawn was less than 20mA and this was only for a short period while the switch was held closed and the unit was transmitting. Power was applied to the circuit via diode D3 and a 10Ω resistor to the emitter of transistor Q2. The diode provided reverse polarity protection (essential when used with a 9V battery) whiles the 10Ω resistor in conjunction with the 16V Zener diode (ZD1) protected against transient voltages. Transient voltages were not likely when used with a battery supply, but the protection was included since the circuit was powered from an automotive 12V supply (car battery).

Pressing switch S1 connected the base (B) of transistor Q1 to ground (0V) via the 1kΩ resistor. This allowed current to flow from the emitter to base, and so the transistor was switched on. Power was then connected to the input of regulator REG1, which supplied +5V to in the diagram represents the pressure sensor, Pressing S1 was not the only way to trigger the transmitter – other methods are available to suit many different applications. For example, connecting the two 'external' inputs together will turn transistor Q2 on, having the same effect as if switch S1 is closed. A further alternative is to apply a voltage (as low as 1.8V) to the anode (A) of diode D2 to trigger Q2. The input current at 1.8V was 60μA. When power was connected to the transmitter system, the written program in the microcontroller began to run, making Port GP2 pin 5 of the microcontroller to turn high (+5V). This condition at the same time turned port GP1 high to drive the data line of the 433MHz module and transistor Q2 via the 10kΩ resistor that was connected to the base of the transistor; transistor Q2 switched on to allow LED to activate and to indicate that transmission was going on. Power to the circuit could be maintained, even when the switch was released.

2.3 THE RECEIVER AND ITS OPERATION

The receiver was a miniature module that receives On-off-keyed (OOK) modulation signal and demodulated to digital signal for the next decoder stage, with low

up of Phase Lock Loop (PLL) structure. The receiver was designed specifically for remote control and wireless security receiver operating at 315/433.92MHz.
The receiver circuit shown in Fig. 2 also used a PIC12F675-I/P microcontroller, which worked in conjunction with the 433MHz RF receiver module. The circuit was powered from the internal power that comprised a DC-to-DC converter and backup battery. The design was intended to be DC powered using external conventional cell phone charger capable of delivering up to 1Amp for use in recharging back of the internal battery back-up. DC power used in recharging of the internal backup battery was to be responsible for providing power to power other circuit components including the microcontroller and the transmitter module. In operation, the DC from the internal battery was fed to a DC-to-DC converter whose output DC was smoothened by capacitors C2 and C3 to further reduce DC ripple. The same DC voltage from the DC to DC converter was fed to regulator REG2 to produce the required +5V DC that was used to power low voltage components. Overall current consumption was around 7mA with the LED off and 14mA with the LED on. More current was required from the supply to enable the switching circuit that was connected to the output function properly.

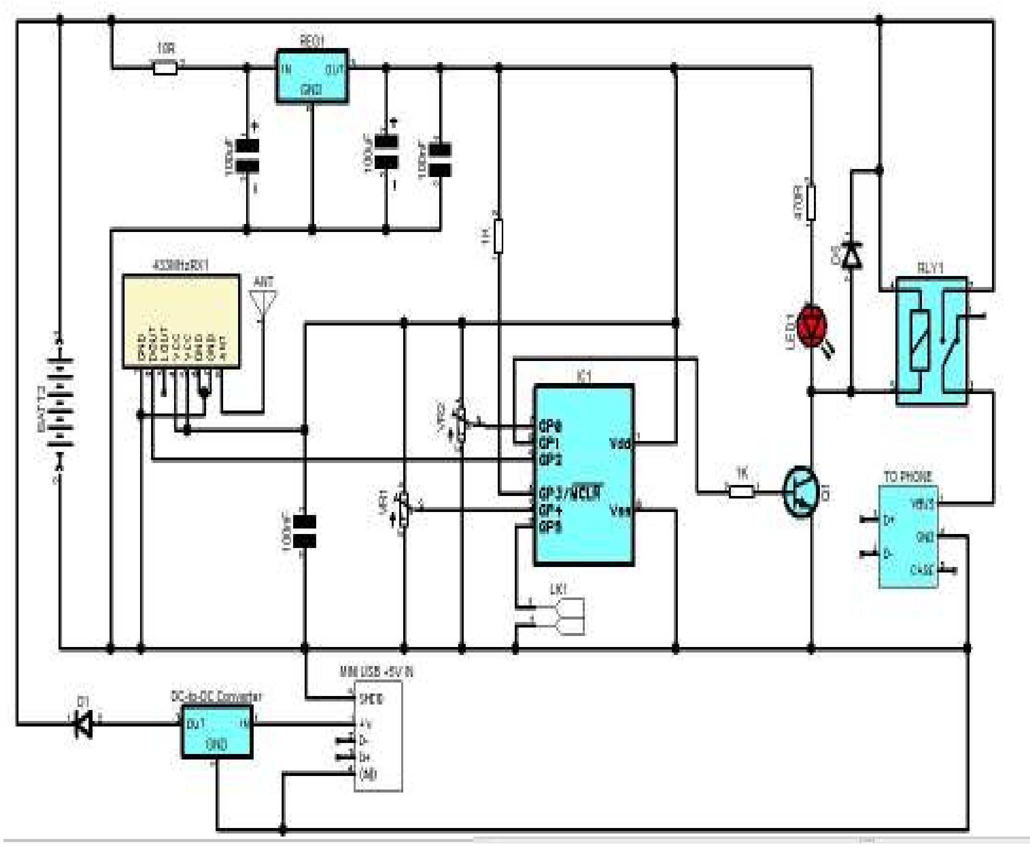

Figure 2: Circuit Diagram of the Receiver for the Wireless Switching System

Both IC1 and the 433MHz module had their supply decoupled by a 100nF capacitor close to the supply pins for each. IC1 had two analogue inputs (AN0 and AN3) to monitor the voltage set by potentiometer VR1 and VR2. The voltages at each input were converted to a digital value within IC1. VR1 set the identity, and this was adjusted to match the identity of the transmitter. VR2 set the timeout period of the output when it was set for momentary action. Data from the UHF receiver module was monitored by the GP2 input port of IC1. When it received a signal it compared the values embedded in the internal written code with the identity value set by VR1 and for the correct on/off and stop bit codes. If the values were correct, it sent its GP1 output high, which turned on transistor Q1.
With Q1's collector low, LED1 was connected virtually across the 5V supply (via 470Ω current-limiting resistor), so the LED lights to indicate that signal had been received from the transmitter. Q1's collector (C) was connected to one of the output terminals. This was used in driving the switching circuit comprising of a 12V relay connected across the output terminals. Diode D5 protected Q1 from any voltage spike that could likely occur when the relay switched off. The output can be either momentary or toggled, which can be selected by using link LK1. When LK1 was out, operation was momentary and Q1 was initially turned on only when it received a valid transmission data from the transmitter. It stayed turned on for a period set by potentiometer VR2. Timeout periods could be set from 0.2s through to about 50s. If the transmitter was set to retransmit, then Q1 could be held on for as long as the transmitter switch was held down. The timeout needs to be set long enough so that Q1 does not momentarily switch off between each retransmission of signal from the transmitter. Q1 switched off when the transmitter switch was released and after the timeout period.

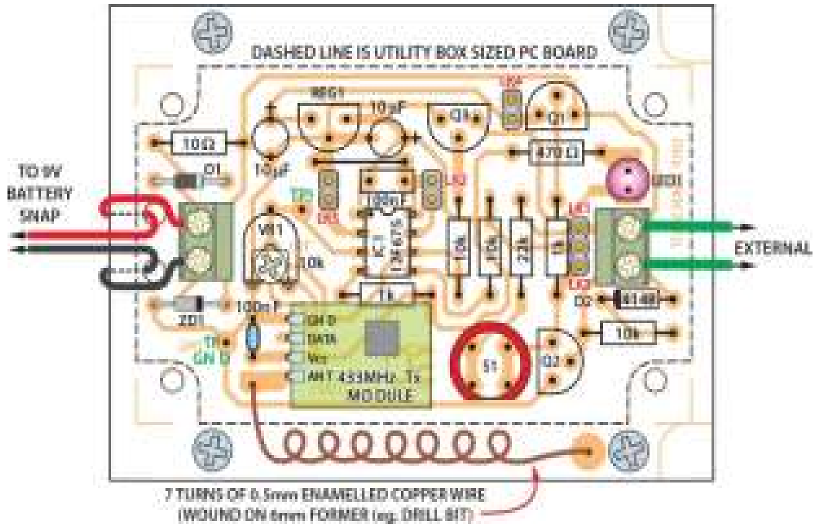

Figure 3: Overlay Diagram for the Transmitter (Multism)

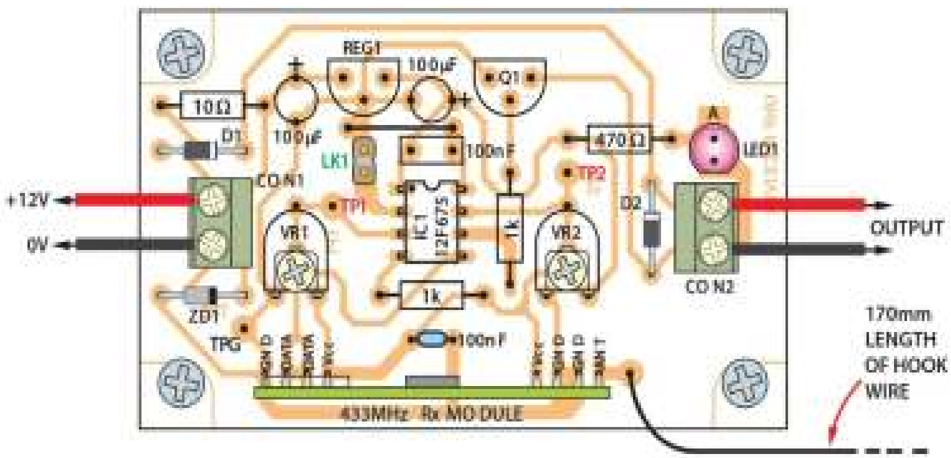

Figure 4: Overlay Diagram for the Receiver (Multism)

3.0 IMPLEMENTATION

The work was implemented and tested and worked properly. It was able to work reliably at a distance of one metre between the transmitter and the receiver. From observation, close up operation was possible when the receiver antenna was disconnected. The momentary delay of the system was also tested by rotating VR2 to mid setting and The LED light for around five seconds. Values that were tested were 200ms, 400ms, 600ms, 800ms, 1s, 1.2s, 1.4s, 1.6s, 1.8s, 2.0s, 2.2s, 2.4s, 3s, 4s, 5s, 6s, 8s, 10s, 12s, 15s, 18s, 21s, 25s, 27s, 30s, 32s, 35s, 38s, 41s, 44s and 50s respectively. These values were spaced about 156mV apart as measured at TP2. The two lowest 156mV settings only gave 200ms period because it was not very easy to set the trim pots below 200mV at the fully anticlockwise end. The upper end adjustment did not access the 41 and 44s position due to the trim pot linearity. In this system toggle mode was chosen so for this reason, jumper plug for LK1 was inserted. The momentary delay did not have any effect on this setting.

Finally, this work was able to be constructed and used for demonstration purposes to enable students The distance between the transmitter and the receiver was about one metre. The aim of this work was definitely achieved.

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