Automated Intelligent Charging of Portable Devices using Resonant Inductive Coupling

Aishwarya Joy[1], Neha Kadam[2], Tushar Supe[3]
Department of Electronics and Telecommunication,
Fr. Conceicao Rodrigues Institute of Technology affiliated with University of Mumbai,
Navi Mumbai, India.

Abstract

The field of Wireless Power Transfer (WPT) has been revitalized since the development of resonant inductive coupling. It is essentially the transfer of power without any physical connections by the use of resonant inductive coupling. This concept brings great promise to the development of gadgets being able to charge themselves by rather simply being placed within range of the transmitter. Also, this process can be made even more efficient and convenient by the implementation of communication modules in the transmitter and the portable device to be charged, which gives real time feedback and charge control for the system. Power wastage is thus reduced by only transferring power when required. This paper proposes such a system which is a hassle free and innovative way to ensure that our portable devices remain charged.

1. Introduction

Traditionally, charging of mobile devices is all wired. However, using wired charging techniques has certain disadvantages or limitations. With the advancement in technology, these problems can now be addressed. Wireless charging is more convenient. Rather than having to connect a power cable, the device can be simply placed next to the transmitter.

The use of a wireless charger will make the device hardware durable as, without the need to constantly plug and unplug the device, there is significantly less wear and tear on the socket of the device and the attaching cable. Wireless charging gives a protected connection. This offers no corrosion as the electronics are all enclosed, away from water or oxygen in the atmosphere.

This paper aims at providing an automated system which detects when a portable device equipped with the appropriate receiver enters its vicinity. When a device as such is detected, the charge on the device is determined and communicated to the transmitter. If the charge on the device is within certain pre-defined values (i.e. it requires charging), the device is then wirelessly charged.

2. Literature Review

Common methods of wireless transfer are using a traditional inductive (non-resonant) charging, capacitive power transfer and the novel resonant inductive coupling. The efficiency obtained at a distance of about 5 cm from the transmitter coil, was about 15% for the traditional inductive charging and about 75% for the novel resonant charging method under similar testing conditions [1]. The efficiency for capacitive power transfer was found to be about 45% in a prototype system [2]. Also, the magnetic fields utilized for the power transfer interact very weakly with biological beings and are considered to be safe [3]. The use of optics to transmit and receive power wirelessly provides a higher efficiency for large distances compared to the other methods, however for smaller distances the efficiency is found to be low [4].

Also the transfer of information is possible using the same technology, however the bandwidth required for the same is very high, about 8.5MHz [5]. The use of magnetic induction for transfer of information with various devices thus proves infeasible.

The current status of devices in the market equipped with such this technology is not much and the transition of this technology from the research stage to the industrial stage is still in progress [6].

3. Technology Used

3.1. Resonant Inductive Coupling

This is a method of Wireless Power Transfer where the transmitter and receiver coils are maintained at resonance at the same frequency.

This ensures that the coupling factor between the transmitter and receiver coils is between 0.7 – 0.9 even when the distance between the two is increased [1]. The range of operation is within the non-radiative near field region around the transmitter coil. This region is very small for frequencies in the kHz range and thus this concept can be utilized ideally in the MHz range.

The transmitter and receiver are essentially an inductive coil and a capacitor placed in parallel, to resonate at a frequency in the MHz range. When the receiver coil is brought in the vicinity of the transmitter, the mutual inductance (M) between the two causes the transfer of power to the receiver. Therefore to maximize the transfer of power, the value of M should be maximized and the values of self-inductances of the coils should be minimized.

The above mentioned concept can be implemented at microwave frequencies if the self-inductance values are very low [7].

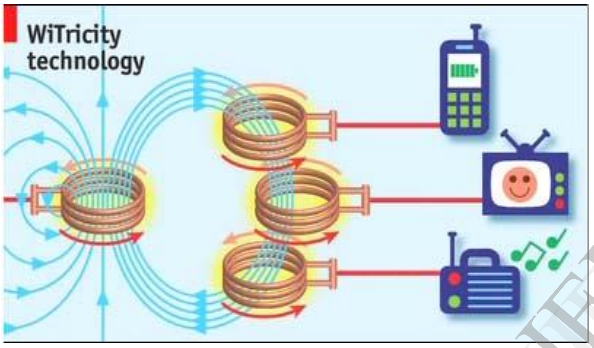

Figure 1. WPT using Resonant Inductive Coupling [8]

3.2. Current Based State of Charge (SOC) Estimation

The energy contained in an electric charge is measured in Coulombs and is equal to the integral over time of the current which is delivered to the charge. The remaining capacity in a cell can be calculated by measuring the current entering (charging) or leaving (discharging) the cells and integrating (accumulating) this over time. In other words the charge transferred in or out of the cell is obtained by accumulating the current drain over time. The calibration reference point is a fully charged cell, not an empty cell, and the SOC is obtained by subtracting the net charge flow from the charge in a fully charged cell. This method, known as Coulomb counting, provides higher accuracy than most other SOC measurements since it measures the charge flow directly. However it still needs compensation to allow for the operating conditions [10].

3.3. Battery Management System and State of Health (SOH) Determination

Managing the external battery parameters can increase the battery life. Therefore, a battery management system (BMS) is required taking the special demands of the battery technology into account [11].

During the lifetime of a battery, its performance or "health" tends to deteriorate gradually due to irreversible physical and chemical changes which take place with usage and with age until eventually the battery is no longer usable or dead. The SOH is an indication of the point which has been reached in the life cycle of the battery and a measure of its condition relative to a fresh battery.

Any parameter which changes significantly with age, such as cell impedance or conductance, can be used as a basis for providing an indication of the SOH of the cell. Changes to these parameters will normally signify that other changes have occurred which may be of more importance to the user. These could be changes to the external battery performance such as the loss of rated capacity or increased temperature rise during operation or internal changes such as corrosion. In practice, the SOH is estimated from a single measurement of either the cell impedance or the cell conductance [12].

4. Block Diagram of System

4.1. Transmitter

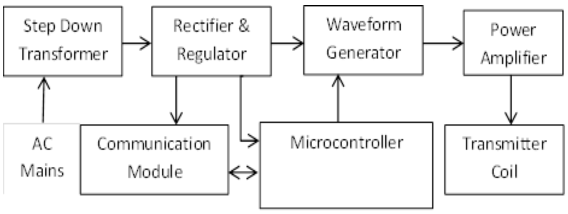

Figure 2. Block Diagram of Transmitter

The block diagram of the transmitter is as shown in Figure 2. The step down transformer is used to bring down the AC mains voltage down to a voltage which is sufficient to drive all the blocks. To get a regulated DC output, the stepped down AC output is then given to the rectifier and regulation block. It is used to generate two voltage levels – one to drive the power amplifier and the other to drive the waveform generator, communication module and microcontroller.

The waveform generator block generates the high frequency sine wave. It may be a simple high frequency oscillator or a waveform generator IC such as the AD9833 by Analog Devices [9]. The output from the waveform generator however, will not be sufficient to be transferred wirelessly and so a power amplifier is used to amplify the power level of the signal. The output is then fed to the transmitter coil which generates magnetic flux used to transfer power.

The communication module is used to communicate with the receivers in its vicinity. The microcontroller is used to control the communication module and the waveform generator.

4.2. Receiver

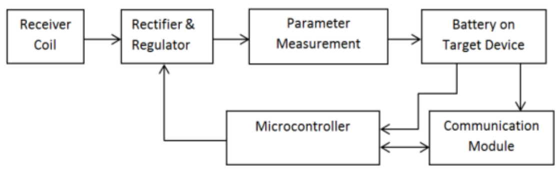

Figure 3. Block Diagram of Receiver

The block diagram of the receiver is as shown in Figure 3. The magnetic flux falls onto the receiver coil and generates a sine wave output. This is then converted to a constant DC using the rectifier and regulation and supplied to the battery on the target device.

The amount of power supplied to the battery is monitored and the SOC of the same is measured and given to the microcontroller. The microcontroller is also used to control the communication module which is used to communicate with the transmitter.

5. Working

When the receiver is not the vicinity of the charger, the transmitter will not generate any magnetic flux. This is controlled by the microcontroller by switching the waveform generator onto the power down mode. The communication module would be programmed to send out a scanning signal on regular time intervals to identify the presence of any receivers in its vicinity. When a receiver is present and receives this scanning signal, it replies with an acknowledgement (ACK). The receiver then computes the SOC on the battery and communicates the same to the transmitter. If these values are found to be within some specified threshold values, the transmitter then begins to charge the device wirelessly.

The transmitter meanwhile, keeps sending out the scanning signal and keeps charging the device as long as it receives the ACK. When the receiver is picked up and is no longer within the vicinity of the transmitter, it sends the Negative Acknowledge Character (NAK) or fails to send anything. In such a case, the transmitter again sets the waveform generator to power down mode and stops transmitting the magnetic flux.

If the devices are equipped with an SOH determination system, the same can communicated to the transmitter. The transmitter can then act as the one interface to notify the user about the SOH of the batteries on all his devices and if any of them need maintenance or need to be replaced.

When there are multiple devices in the vicinity of the transmitter and even if one of them needs to be charged, the transmitter would transmit the magnetic flux for the same. However the others devices which do not need to be charged will also receive the power. Therefore in such a scenario, the transmitter notifies the receiver to disconnect the regulated output from the battery to stop the charging.

6. Advantages

- The user does not have to keep track of the amount of charge on the multiple portable devices that he might be using.
- This is a hassle free method where the user does not have to connect the device to the wired chargers and may just place it near the transmitter and let the system decide whether it needs to be charged.
- It can be used for multiple devices. One such transmitter can be used at one home to be used with the mobile phones and other devices of the entire family.
- This method also ensures there is no wastage of energy when there is no device within the vicinity of the transmitter.
- The user does not have to worry about the health of the batteries of the multiple devices as the one transmitter acts as the interface keeping track of the same for all the devices used with it.

7. Disadvantages

The main disadvantage of the system is that it fails to provide authentication. Any device which does not belong to the user is unable to communicate with the transmitter. However if one or more of the devices of the user are being charged, there is no way to stop the power being transferred to an unauthenticated device tuned at the same frequency.

8. Conclusion

The rapid advancements in technology have led to an increase in the number of portable gadgets and our dependence on it. The need to keep track of the amount of charge on each and to place them to charge is rather inconvenient. Therefore a system as described in this paper provides an ideal solution for the same. One can just simply place his devices on a table equipped with a transmitter and let the system handle everything.

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