Design of a Multi-Voltage Wireless Charging Pad for Small Household Electrical Appliances

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***Abstract*—A variety of small household electrical appliances (SHEA) are operated by means of rechargeable batteries. In addition, wireless chargers are also increasing. But most chargers can only charge a fixed voltage of small household electrical appliances. Therefore this design develops a multi-voltage wireless charging pad with a MCU which can not only automatically identify the RFID tag for small household electrical appliances, but also can automatically supply four voltage levels, such as 12V, 9V, 5V, and 3.3V as required by small household electrical appliances voltages, to charge the rechargeable battery.**

Keywords—Wireless Charging; RFID; Small Household Electrical Appliances

I. INTRODUCTION

Due to electronic technological progress in recent years, many people use some small household electrical appliances (SHEA). For example: handheld mobile phones, remote controllers, electronic watches, and Walkmans which use rechargeable batteries with different voltages. Some small household electrical appliances use different voltages, such as 12V, 9V, 5V and 3.3V. Therefore we have designed and implemented a multi-voltage wireless charging pad which can charge a variety of small household electrical appliances.

To identify the rechargeable battery voltages of small household electrical appliances, the RFID and NFC technology can be used [1] [2]. This multi-voltage wireless charging pad integrates RFID technology which can identify small household electrical appliances. The charging pad reader module senses the RFID tags of each appliance before charging. Different RFID tags represent the different rechargeable voltages of small household appliances. According to the RFID tag sensing, the MCU will determine the voltage values to be supplied for small household electrical appliances.

II. HARDWARE ARCHITECTURE

The multi-voltage wireless charging pad as shown in Fig. 1 is made up of two parts: the transmitting part and the receiving part. The transmitting part consists of the transmitting coil and the transmitting pad and the receiving part consists of the receiving coil and the receiving pad. The multi-voltage wireless charging pad has an RFID tag which can be used to identify the class of small household electrical appliances with the specific operation voltage.

As the receiving pad has an RFID tag, the MCU can identify the operation voltage in the receiving part, and then match the operation voltage with each small household electrical appliance.

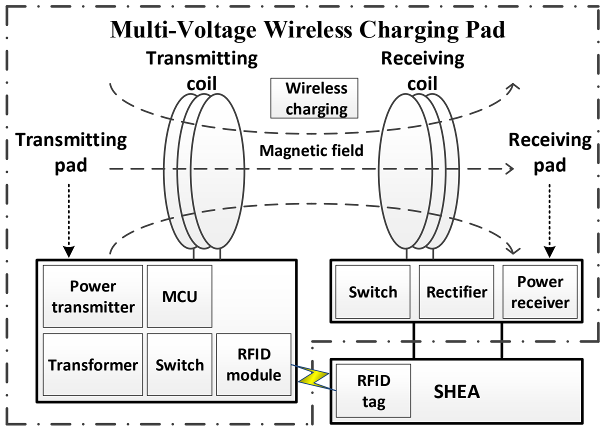

Fig. 1. The multi-voltage wireless charging pad architecture.

III. SOFTWARE ARCHITECTURE

Fig. 2 shows the software flowchart for a multi-voltage wireless charging pad. When any small household electrical appliance runs out of power, this appliance can be placed on a wireless charging pad to charge the rechargeable battery. When the transmitting pad transmits the RFID to the RFID tag, the MCU will discern the charging voltage of any small household electrical appliance. When the launching RFID tag is read into the charging pad, the MCU will determine the RFID tag and the operation voltage. If the operation voltage is 12V, the flowchart will remain at 12V and then enter the next phase of procedure C. If the operation voltage is 9V, 5V, or 3.3V, it will enter procedure B. The flowchart will reduce the voltage to the required voltage of any small household electrical appliance and then enter procedure C. If none of the above situations are present this design will immediately stop charging so as to avoid any dangerous charging. Procedure C judges whether any small household electrical appliance is using full power or not. If the rechargeable battery of any small household electrical appliance is full it will then stop charging. Otherwise, the pad will keep charging until it is 100% charged and then stop charging.

If a small household electrical appliance has no RFID tag but the user knows its charging voltage, the user can manually adjust the voltage for charging.

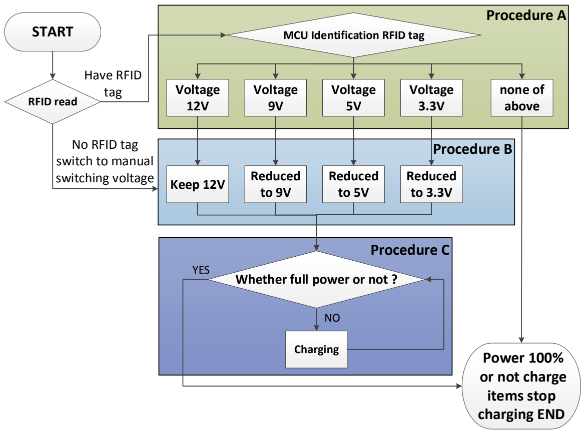

Fig. 2. The multi-voltage wireless charging pad software flowchart.

IV. Experimental Results And Comparison

The comparison of this design with other designs is as shown in Table I. Design A has a single voltage for charging. Design B is able to charge a variety of products, but it cannot recognize any RFID tag. This design can recognize a RFID tag and can also convert the voltage of the rechargeable battery of the small household electrical appliances.

TABLE I. Comparison of This Design And Other Designs

	Design A	Design B	This Design
Recognition Charge Items (RFID tag)	Yes	No	Yes
Charge Various Household Electrical Appliances	No	Yes	Yes
Charge Various Voltages	No	No	Yes

Table II shows the power consumption of each module of the wireless charging pad. When the receiving pad does not read the RFID tag, the MCU stays in sleep mode so that this design can save the power consumption. Of all the wireless charging pad modules, the coil consumes the highest power, because the coil is used to transmit the power. The RFID module is always on, because it determines whether or not the SHEA has different charging current, so as to make sure that the charging voltage is the correct one to be used.

TABLE II. The Power Consumption of Each Module

	Power consumption of each module	
	Standby	***Operation***
RFID Module	123mW	123mW
MCU	164mW	233mW
Transmitting Coil	0W	3.24W

The definition of the wireless charging efficiency is as follows: Eq. (1)

$$Effciency\% = \frac{V_{out} \times I_{out}}{V_{in} \times I_{in}} \qquad (1)$$

Fig. 3 shows the measurement circuit for the wireless charging efficiency. When the power supplies currents and the input voltage V_{in} and the current I_{in} after supplying the incoming transmitter coils of transformers, the power is transferred through a magnetic field to the receiving pad. The receiving pad output uses the rectifier output voltage V_{out} and the current I_{out} power input that are required for the rechargeable battery.

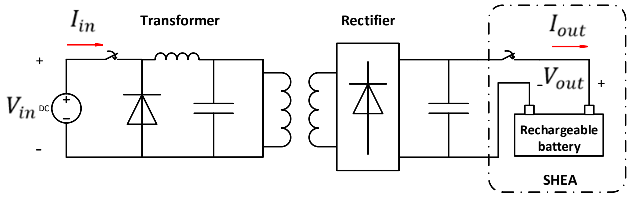

Fig. 3. Wireless charging efficiency measurement circuit.

Table III shows the wireless charging efficiency of this design. The test transmitting pad and the coil is connected to a power supply and measures the output efficiency of the receiving pad. With a 12V current of 0.27A, the receiver can receive a 12.0V current of 0.25A. The wireless charging efficiency is about 67%. When the 9V current is of 0.33A, the receiver can receive a 9.0V current of 0.33A current. The wireless charging efficiency is about 64%. When the 5V current is 0.45A, the receiver can receive a 5V current of 0.30A. The wireless charging efficiency is about 67%. When the 5V current of the receiver is 0.24A, the receiver can receive a 3.3V current of 0.24A. The wireless charging efficiency is about 60%.

TABLE III. The Power Consumption of Each Module

	Input Voltage			
	12V	***9V***	***5V***	***3.3V***
Efficiency	67%	64%	67%	60%

V. Conclusion

This wireless charging pad senses the RFID tag to identify small household electrical appliances and select the voltages. It outputs four different charging voltages for different rechargeable batteries. Not only is it more convenient to use, it can also reduce the use of disposable batteries and to make the result more environmentally friendly. In the future we will add more charging voltages, increase the power rating for various larger electronics, and enhance this pad's wireless charging efficiency.

References

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