AN INTELLIGENT POWER MANAGER WITH SOLAR AND WIRELESS ENERGY HARVESTING FOR INTERNET OF THINGS APPLICATIONS

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Abstract - An intelligent power manager with solar and wireless energy harvesting for internet of things (IoT) applications has been realized. The intelligent power manager can detect the power consumption of the appliances and upload it to the database through the Wi-Fi module. The power consumption can be accessed on the written apps of the portable devices. The solar energy harvesting can charge the appliances all the time for saving power. The wireless energy harvesting uses the antennae for extending the wireless power transmission distance. The measured power consumption of the proposed intelligent power manager is 190 mW.

Index Terms - Intelligent power manager, solar and wireless energy harvesting, CMOS, internet of things.

I. INTRODUCTION

Recently, the internet of things (IoT) has drawn a lot of attention [1]. Appliances can communicate with each other through the internet for sharing information. Power management is one of the important topics in IoT. Sometimes, appliances consuming a lot of power should be adjusted properly for saving energy if the users can monitor the power consumption. Hence, an intelligent power manager for IoT has been proposed in this paper. The intelligent power manager can detect the power consumption of the appliances and uploads it to the data base through the Wi-Fi. And then users can access the power consumption through the internet by using the written application (app) of the portable devices as shown in Fig. 1. In addition, multi-source energy harvesting is a popular topic on energy saving [2]. The renewable energy includes solar, wind, thermal, vibrational, piezoelectric energies, and so on. In the solar energy technology, the photons hit the solar panels and the current is induced and stored in the batteries [3]. Although the efficiency of this technology may be not particularly high, it still is a useful method for power saving. Therefore, the technology has been used in the proposed intelligent power manager. Furthermore, wireless charging also is in vogue because of the convenience that appliances can be charged without connecting wires [4]. The wireless power transfer generally should use inductive coils or antennae as transmission media. The inductive coils can deliver the wireless power in near-field distance with the magnetic coupling [5]. The antennae can radiate wireless power in far-field distance with the form of electromagnetic wave [6]. In order to extend the distance of the wireless power transmission, the wireless charging with the antennae have been utilized in the proposed manager. In a word, an intelligent power manager with solar and wireless energy harvesting for IoT applications has been proposed in this paper. The following sections are organized as below. Section II illustrates the system architecture and design consideration. The measurement results are described in section III. Section IV concludes this paper.

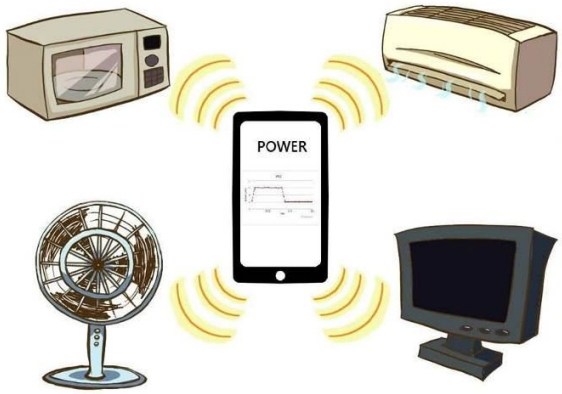


Fig. 1. Schematic of the proposed intelligent power manager with multi-source energy harvesting.

II. SYSTEM ARCHITECTURE AND DESIGN CONSIDERATION

The proposed intelligent power manager consists of a solar charging circuit, a wireless charging circuit, a voltage limiter, and an intelligent power management unit as shown in Fig. 2. The solar panel of the solar charging circuit converts the sunlight to the current which passes through a diode and the voltage limiter. And then the current will be stored in the battery or directly be used the appliances. The diode can avoid the inverse current from the voltage limiter. The voltage limiter (M_5-M_8, and R) can restrict the voltage of the battery. If the voltage on the battery is from low to high, the voltage on R will also be from low to high and M_8 will be turned on. Hence, the current of M_8

will increase and the voltage on the battery

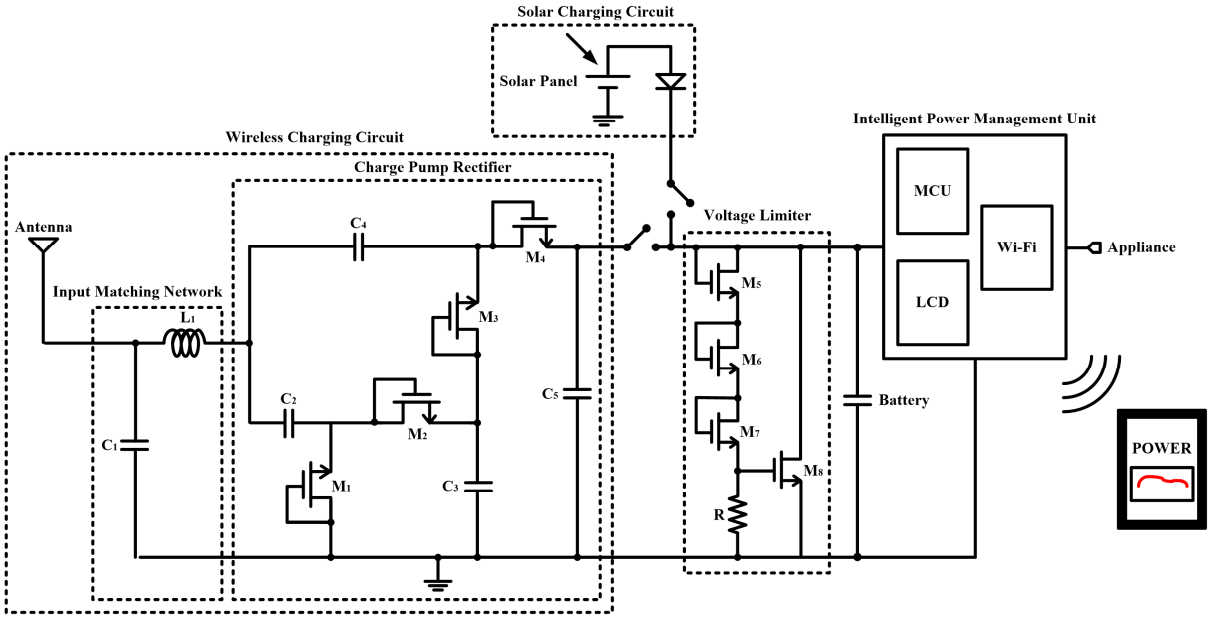


Fig. 2. The system block diagram of the proposed intelligent power manager.

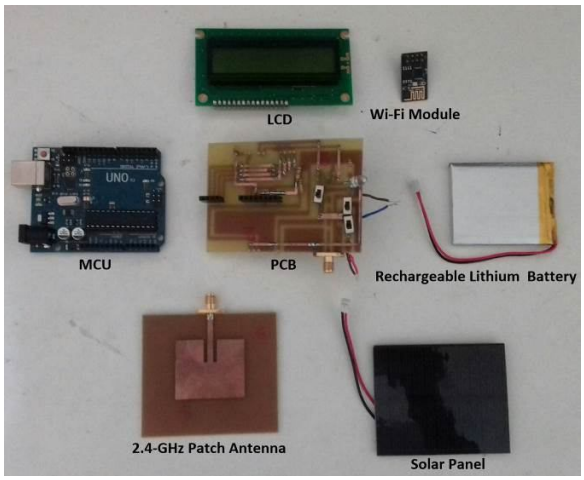


Fig. 3. All components of the proposed intelligent power manager.

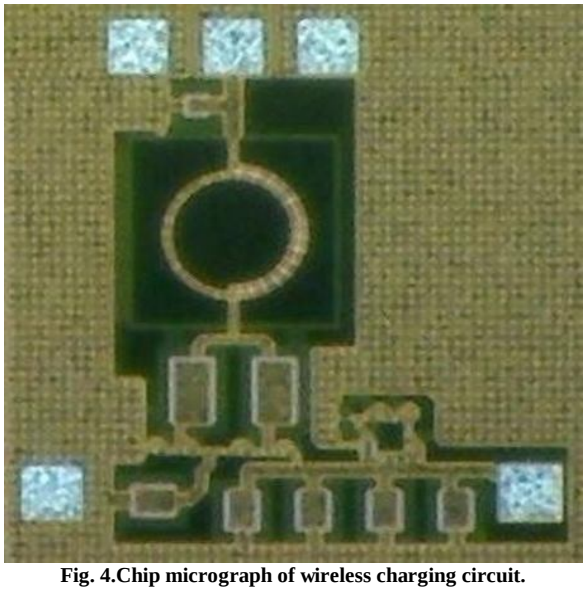


Fig. 4.Chip micrograph of wireless charging circuit.

will reduce. The wireless charging circuit contains an antenna, an input matching network and a charge-pump rectifier. The wireless charging circuit is designed for rectifying 2.4-GHz wireless signals to a DC voltage. In the wireless charging circuit, a patch antenna has been fabricated by using a FR4 printed circuit board (PCB). The input matching network (L_1 and C_1) can reduce the wireless signal reflection and increase the power transmission efficiency. The real and imaginary parts of its input impedance should be 50 Ω and zero, respectively.

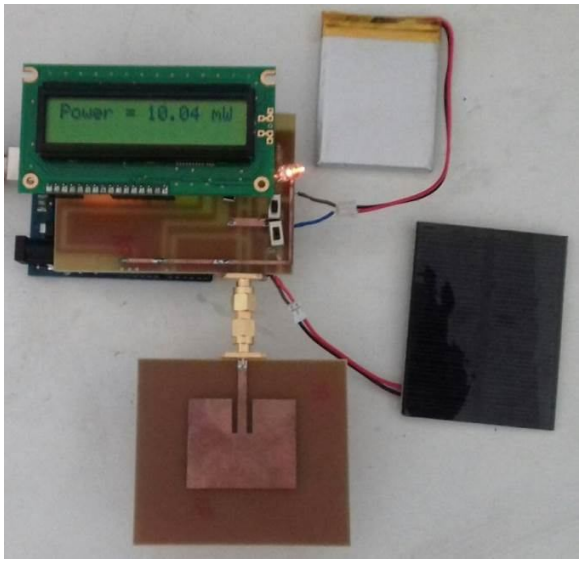


Fig. 5. The measurement setup of the intelligent power manager.

The charge-pump rectifier (M_1-M_4, and C_2-C_5) can convert the incoming wireless signal to a DC rectified current which also passes through the voltage limiter and is stored in the battery [7]. The structure of

charge-pump rectifier can increase the rectified voltages and perform good conversion efficiency. The input matching circuit and voltage limiter are fabricated by using UMC 0.18 um CMOS technology. The solar and wireless charging circuits can be switched if necessary. The intelligent power management unit includes a micro-control unit (MCU), a liquid crystal display (LCD), a Wi-Fi module, and a portable app. The MCU detects the power consumption of the appliances and displays it on the LCD. The power consumption can be uploaded and stored in the database through the Wi-Fi module simultaneously. The power consumption in the database can be accessed through the apps on the portable devices. The appliances can be shut down or activated through the apps far away for saving power in the future.

Technology	UMC 0.18 um CMOS and PCB	
Wireless charging	Rectifier efficiency (%)	23
Solar charging*	Solar panel size (cm^2)	38.5
	Efficiency (%)	17
	Maximum output power (W)	0.5
Intelligent power management	MCU power controlling LCD data revealing Portable app monitoring	
Power consumption (mW)	190	

***The efficiency and maximum output depend on the chosen size of the solar panel.**

Table I Performance summary of the proposed intelligent power manager.

III. MEASUREMENT RESULTS

The wireless charging circuit and voltage limiter are realized in UMC 0.18 um CMOS process and are integrated with the solar charging circuit and intelligent power management unit by using a PCB. The patch antenna has a size of 10.8 mm^2 and a directivity of 6 dB. The measured conversion efficiency of the rectifier is 23 %. In this paper, a size of 38.5 cm^2 for the solar panel has been chosen for measurement. Its maximum output power is about 0.5 W. The maximum output power of the solar panel can be improved by increasing its size. The conversion efficiency of the solar panel is 17 %. The intelligent power management unit chooses a module called Arduino Uno as its MCU for controlling the LCD and the Wi-Fi module. According to the required display types and reaction speeds in the written program code of the MCU, the power consumption can be displayed on the LCD and uploaded to the database through the Wi-Fi Module. The used LCD module is 1602. The Wi-Fi module using a circuit named ESP-8266 which has a function of the universal asynchronous receiver/transmitter (UART) can execute the data transmission between the MCU and the portable devices. All components of the proposed intelligent power manager are shown in Fig. 3. The wireless charging circuit occupies a chip area of 0.26 cm^2 as shown in Fig. 4. For simplifying the measurement processes, a LED circuit with input impedance of 1500 Ω is used instead of the appliance. Besides, a rechargeable lithium battery is utilized instead of the battery of the appliance. The measurement setup of the intelligent power manager is shown in Fig. 5. As you can see, the measured power coemption of the LED circuit is about 10.04 mW. In the meantime, the measured power consumption has been uploaded and stored in the database through the Wi-Fi module. The written app of the portable device displays the measured power consumption versus time as shown in Fig. 6. The power consumption of the proposed intelligent power manager is 190 mW. Table I shows the performance summary of the proposed intelligent power manager.

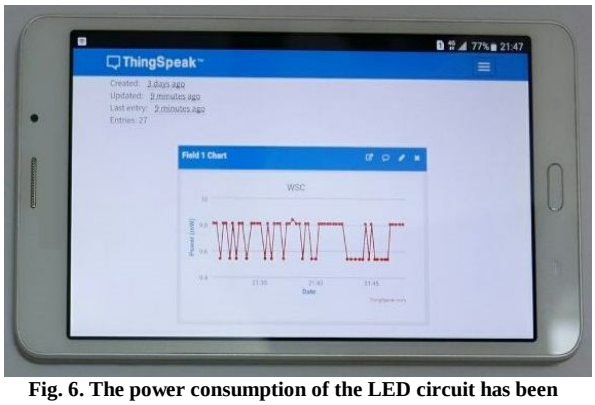


Fig. 6. The power consumption of the LED circuit has been uploaded to the data base and accessed on the written app of the portable device.

CONCLUSION

An intelligent power manager with solar and wireless energy harvesting has been realized in UMC 0.18 um CMOS technology on the PCB. The proposed intelligent power manager can detect the power consumption of the appliances and upload it to the database through the Wi-Fi module. The power consumption can be accessed on the written apps of the portable devices and the LCD. The solar energy harvesting can charge the appliances all the time for saving power. Its performance can be improved by increasing the size of the solar panel. The antennae has been used in the wireless energy harvesting for extending the wireless power transmission distance. The measured conversion efficiency is 23 %. The measured power consumption of the proposed intelligent power manager is 190 mW. The proposed intelligent power manager is suitable for IoT applications.

ACKNOWLEDGEMENT

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