A Light Energy Harvester with Wireless Power Transfer Capability in 0.5μm CMOS Process

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ABSTRACT

This paper presents a system comprising a light energy harvester with MPPT and wireless power transfer with adaptive output power control. Both have integrated circuits (ICs) fabricated by a 0.5μm CMOS process, thereby making the system low cost and small size. Measured results show the system achieves not only high tracking and conversion efficiencies, but also a wide output power range.

1. INTRODUCTION

Light energy is an important renewable energy resource since it is clean, non-polluting, and inexhaustible. With the evolution of semiconductor and power electronics technologies, combining a light energy harvester and a wireless power transfer (WPT) system with ICs to supply electronic products or charge storage units can increase the availability of electricity and decrease the wiring of a building. In order to harvest the maximum power from a photovoltaic (PV) module’s nonlinear output under different environmental conditions, this work implements a control IC with maximum power point tracking (MPPT) [1] for a boost harvester. In addition, to reduce power loss and transmit appropriate power to a wireless power receiver (RX), a WPT transmitter (TX) IC is also implemented.

Fig. 1 shows the architecture of a light energy harvester with WPT system. As illustrated, it comprises a PV module, a light energy harvester with MPPT, and a DC bus loaded with a WPT system. The DC bus can also be loaded with a battery management system (BMS) and/or converters. A 48V DC bus is chosen due to its high conversion efficiency for battery backup and selectable load voltages (Vload) of converters, such as 24V, 19V and 12V for electronic products. This system uses a 320W PV module as the input source and is controlled by a small MPPT IC that eliminates certain discrete components, thereby reducing cost and size. The WPT TX adaptively adjusts the transmitted power under different load conditions for higher efficiency.

2. CIRCUIT IMPLEMENTATION

This section introduces the light energy harvester and the WPT system, respectively.

2.1. Light energy harvester

The perturb and observe (P&O) MPPT method is used in this work due to its ease of implementation [1]. Fig. 2 shows the proposed boost-type light energy harvester with MPPT IC. The sensed PV module output voltage, Vpv, and current,Ipv, are converted by a high voltage to low voltage (HV-LV) interface circuit and are delivered into an analog multiplier (MU), the output of which is connected to the sample and hold (S/H) circuit. This circuit samples the adjacent Vpv and Ipv and then outputs them to a comparator. The comparator output is then sent to the accumulator (ACC) to determine the moving direction of the reference voltage, Vref. If the present PV power is larger than the previous one, Vref moves in the same direction; otherwise, it moves in the opposite direction. In addition, a digital-to-analog converter (DAC) is used for high tracking efficiency. Vpv and Vref are entered into a compensator and are modulated to the PWM code to determine the duty ratio of the power MOSFET, MN.

2.2. Wireless power transfer

Fig. 3 shows the proposed WPT system, which includes a WPT TX and a WPT RX. In the system, energy is wirelessly coupled from LP to LS, and the switching frequency, fsw, of the full-bridge inverter is selected to equal the resonant frequencies of the LP-CP and LS-CS resonant tanks. The transmitted power is controlled by dynamic scaling of VDVS and regulating the peak value of IP, IP(pk) via the IP(pk) regulation loop. IP is sensed from the derivative of the CP voltage VCP according to (1) instead of using a current-sense resistor, thereby reducing power loss.

\[ IP = CP \cdot \frac{dV_{CP}}{dt} \]  

The IP sensor comprises a level-down shifter, a differentiator, and a low-pass filter to implement (1). The level-down shifter scales VCP down, the differentiator implements the derivative operator in (1), and the low-pass filter filters high-frequency noises induced in the differentiator.
3. MEASUREMENT RESULTS

This section shows the chip photos and measurement results. Figs. 4(a) and (b) show the chip photos of the proposed MPPT IC and WPT TX IC, respectively. Both are fabricated in 0.5μm CMOS process and occupy 0.66mm² and 6.1mm², respectively.

Fig. 5 shows the tracking efficiency ηtrack and conversion efficiency ηconv of the light energy harvester, the definitions of which are reported in [2]. The peak ηtrack and peak ηconv of this work are 99.9% and 97%, respectively.

Fig. 6(a) shows the measured waveforms of the PV module voltage V_pv, current I_pv and power P_pv. Fig. 6(b) presents the measured waveforms of the WPT system, in which fsw=100kHz, Lp=6.3μH, Ls=12.5μH, and VIp(pk) is regulated under different Iload and reset to 0V every fsw. As Iload changes from 400mA to 900mA, then back to 400mA, VIp(pk) is regulated while VRECT is changed from 4.3V to 5.3V, and then back to 4.3V with transient times of 1ms and 1.2ms, respectively. If VRECT is connected to a DC-DC converter, a fine regulated voltage can be obtained.

![Fig. 5. Measured ηtrack and ηconv of the light energy harvester.](image)

4. CONCLUSION

This work implements a light energy harvester and a WPT system including a 0.66mm² MPPT IC and a 6.1mm² WPT TX IC. The light energy harvester achieves 99.9% peak tracking efficiency, 97% peak conversion efficiency and 10~300W output power range. The WPT system achieves 70.4% peak conversion efficiency and 5W output power. Accordingly, it offers a low cost and small size solution to improve the availability of electricity and reduce the wiring in a building.

5. REFERENCES
