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Abstract

FOCV-MPPT Power Management Unit for Submilliwatt Indoor PV Cells †

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Abstract: This work proposes and experimentally characterizes a low-power circuit to track the maximum power point (MPP) of submilliwatt photovoltaic (PV) cells intended for indoor applications. The circuit relies on a low-power conventional indirect tracking technique: the fractional open circuit voltage (FOCV). The experimental results presented herein show that power losses due to the tracking inaccuracy of the FOCV technique are much lower (at least a factor of 10) than those due to the ensuing micropower DC/DC converter. Accordingly, the application of more accurate yet more power-demanding tracking techniques seems unnecessary in such scenarios, since they could incur even higher power losses.

Keywords: autonomous sensors; energy harvesting; indoor applications; MPPT; PV cells

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1. Introduction

Using energy harvesters to power autonomous sensors offers advantages in terms of sustainability and maintenance costs [1]. In order to extract the maximum power, the energy transducers have to operate around the MPP, which depends on the environmental conditions. For example, in a PV cell, the MPP depends on both the irradiance and temperature. For this reason, energy transducers are usually connected to a power management unit (PMU) that, among other tasks, tracks the MPP. Many MPP tracking (MPPT) techniques have been proposed in the literature [2,3], especially for PV cells. These techniques are mainly classified into two groups [2]: conventional and novel (e.g., based on artificial neural networks), the latter being smarter but also more power-demanding than the former. Within the conventional group, there are two subgroups [2]: indirect (e.g., FOCV) and direct (e.g., perturb and observe) methods, the latter being more accurate but also more power-demanding than the former. Indirect conventional methods do not track the MPP the best, but they do offer the lowest power consumption, which is crucial indoors since the output power of the cells is in the submilliwatt range. In such a context, this work proposes and experimentally characterizes a FOCV-based PMU for a low-power indoor PV cell.

2. Materials and Method

The considered energy transducer is a low-cost amorphous PV cell (Panasonic AM1454) intended for indoors, with an active area of around 11 cm^2. The cell is tested at different levels of illuminance (from 100 to 1500 lux) coming from a cold white LED at a constant temperature of 25 °C. The cell output is then connected to a commercial PMU (bq25570 from Texas Instruments), as shown in Figure 1a, which applies the FOCV-MPPT technique with a K factor of 0.75; K corresponds to the ratio of the operating voltage with respect to the open circuit voltage (V_{oc}) of the cell. The internal micropower boost DC/DC converter regulates the operating point of the cell around $K \cdot V_{oc}$, and also transfers the energy to a rechargeable battery. The power at the output of both the cell and the PMU were measured using a source and measurement unit (Agilent B2901A).

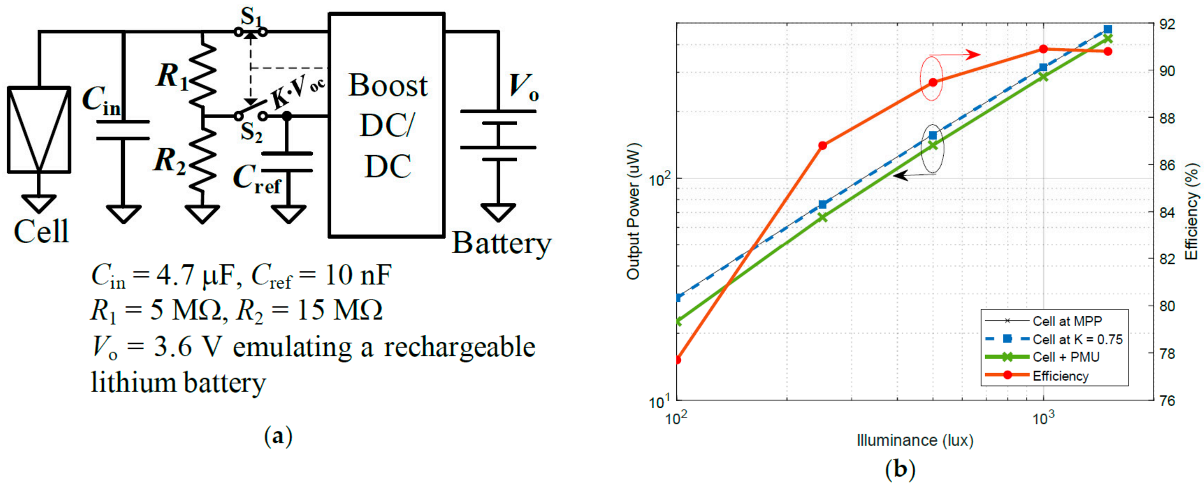

Figure 1. (**a**) Proposed PMU for a low-power PV cell applying the FOCV-MPPT method. (**b**) Experimental results obtained when characterizing the circuit in Figure 1a.

3. Experimental Results and Discussion

Figure 1b shows the main results obtained during the experimental characterization. First, it shows (in black) the power at the output of the cell for different levels of illuminance assuming that it operates at the MPP. The higher the illuminance, the higher the output power, as expected. The power ranges from tens to hundreds of microwatts since this is a low-power cell under low indoor lighting conditions. Second, Figure 1b shows (in blue) the power at the output of the cell considering that the FOCV is applied and, hence, the cell operates at a voltage of $K{\cdot}V_{oc}$. Although a simple MPPT technique is applied, the power losses due to the tracking inaccuracy are less than 1%. Third, Figure 1b shows (in green) the power at the PMU output. Comparing the results in blue and green, the power losses due to the PMU are equal to 21%, 12%, 10%, 9%, and 9% at 100, 250, 500, 1000, and 1500 lux, respectively. Finally, Figure 1b also shows (in red) the overall efficiency (i.e., data in green over data in black), which ranges from 78% to 91%. Such a calculation of efficiency includes the effects of (i) operating at a point not exactly equal to the MPP, (ii) disconnecting the cell (for 256 ms every 16 s by means of switches S1 and S2 in Figure 1a) so as to determine $K{\cdot}V_{oc}$, and (iii) using a non-ideal DC/DC converter. The effects of the latter have been determined to be the most predominant. So, in such scenarios, it seems unnecessary to apply more accurate yet more power-demanding tracking methods.

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