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System for automated solar cells characterization, SPICE modelling and simple energy harvester module application

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Abstract:
The work is about automated system that allows characterization of solar cells for low energy applications. The system is suited for small solar cells that can be used for indoor energy harvesting. These solar cells differ from standard solar cells in its ability to provide enough voltage level also at low levels of ambient light. This simplifies circuit for energy harvesting for wireless sensors application. Specialized solar cell of dimensions 2.5 × 2.5 cm^2 was tested and the measured characteristics are compared with SPICE model that can be used for simulations. The solar cell was applied with energy harvester module EH300 at different light conditions. The testing proved that the developed system can provide enough energy for wireless and battery-less measurement even at light levels below 20 lx. The presented system thus can be used for various indoor IoT applications.

INTRODUCTION

Energy harvesting allows operate electronic devices without battery or support the battery to increase its lifetime. It is suitable mainly for places where the standard powering cannot be applied. One of the most popular source of energy is the solar cell (or PV - photovoltaic panel) that is converting the light to the electrical energy. Standard solar cells are applicable only when the high light intensities are available. This paper compares standard solar cell with specialized photovoltaic panel SOLEMS that is able to harvest also at very low light environment. It keeps high voltage even at light levels below 20 lx. This simplifies the energy harvesting circuit and simple harvesting setup can be build.

CHARACTERIZATION TEST BENCH

Typical way of manual characterization the solar panel is presented in fig. 1 [2]. The panel is exposed to a constant illumination and it is loaded by the variable resistor. The voltages and currents are registered for different R_L values to form the IV characteristics (fig. 2). The manual measurement can be used for single characterization but it is time consuming and the precision is affected by the human factor. The automated system was developed to overcome this.

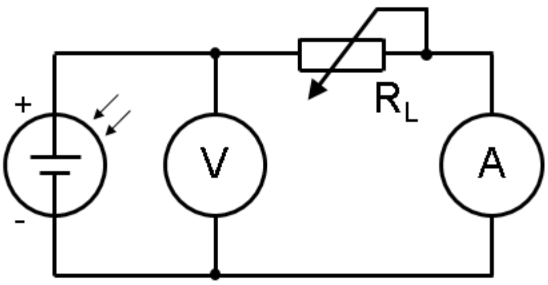

Fig. 1: Typical way of manual PV cell characterization

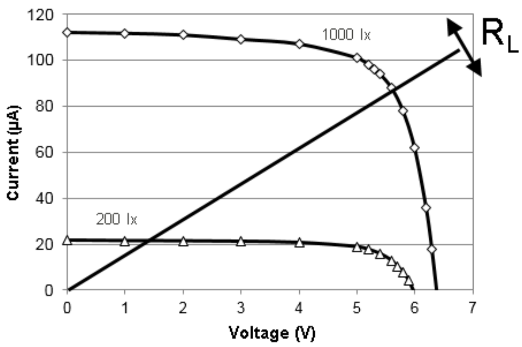

Fig. 2: IV curves of the PV cell and loading resistor curve

The automated characterization system consists of hardware part that allows defined light intensity setting and automated setting of the loading current (fig. 3). Figure 4 shows schematic of the analogue circuit that is used for automated setting of the current through the PV cell. Driving voltage (V_IBIAS=0..1V) is generated by D/A converter and is converted to the current via R52. Voltage on the panel is then sensed by A/D converter (V_PV+). Signal (V_PV-) is also checked by the A/D converter to be sure the solar cell is loaded properly. The measurement is correct when (V_PV-) is the same as (V_IBIAS=0..1V).

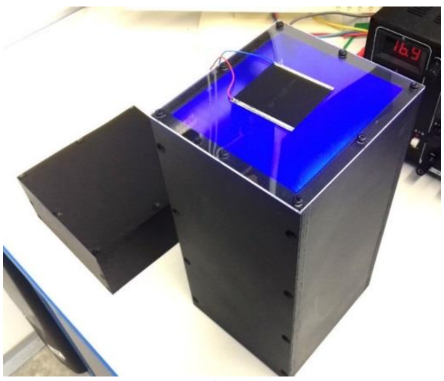

Fig. 3: Hardware part of the characterization system

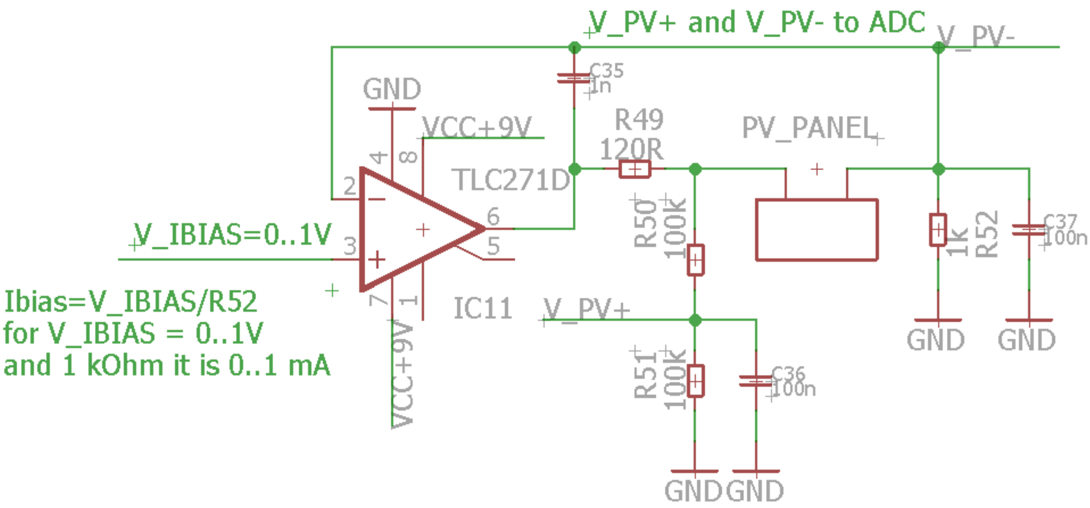

Fig. 4: Hardware part of the characterization system

The system was tested with different small solar cells. Figures 6 and 7 show measured characteristics of two representative PV cells from fig. 5.

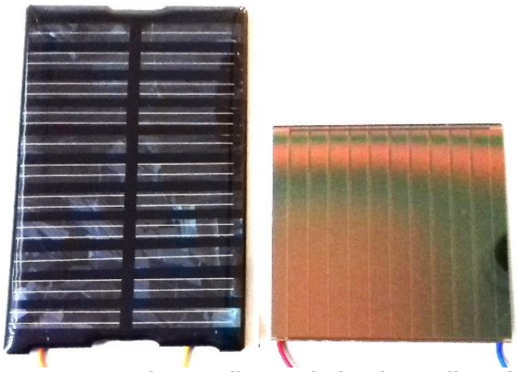
Fig. 5: Two tested PV cells: standard polycrystalline (left), specialized amorphous panel SOLEMS [1] (right)

It is evident from the fig. 7 that SOLEMS PV cell can be used for energy harvesting also at low light intensities without any additional DC/DC converter. It can be connected directly to the energy harvesting circuit EH300 [8]. Standard polycrystalline PV cell (Fig. 6) has too low voltage at low illuminance to be harvested without additional converter.

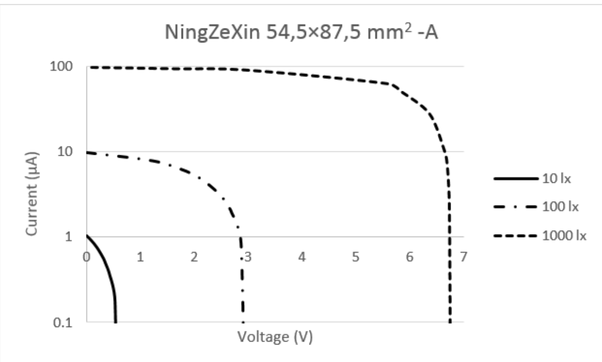

Fig. 6: IV characteristics of standard polycrystalline cell

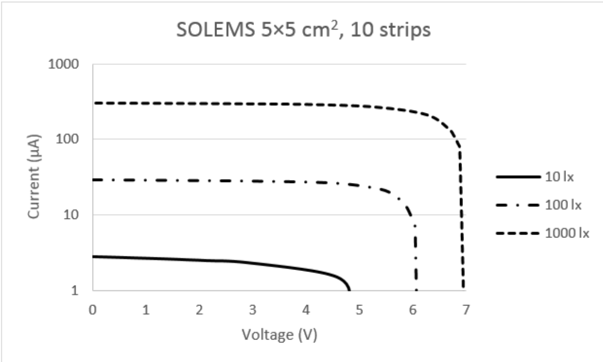

Fig. 7: IV characteristics of amorphous solar cell SOLEMS

SPICE MODEL

Measured IV characteristics are transferred via UART to the second (software) part of the system, where the SPICE parameters are calculated. The application analyzes the data and returns the basic parameters of the solar cell according the equivalent circuit (fig. 8) [3-7]. Simulated data can be compared with real measurement.

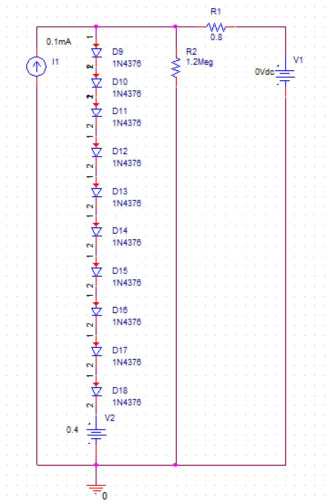

Fig. 8: OrCAD Spice model of the solar cell used for modelling the SOLEMS PV cell

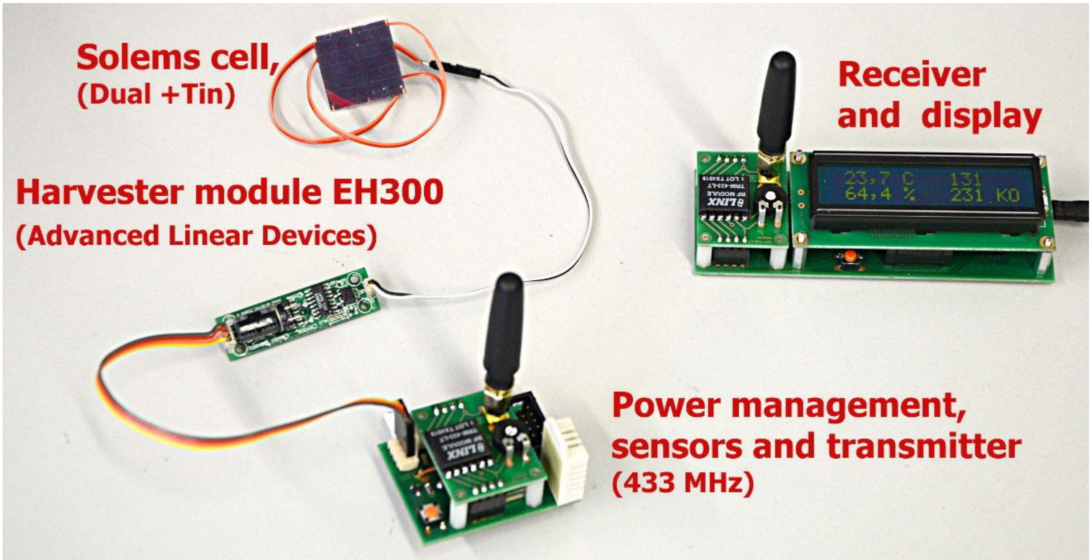

Fig. 9: Testing device for wireless and battery less measurement with energy harvester module EH300

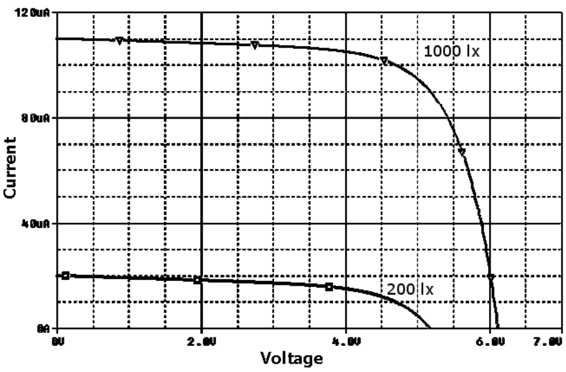

Fig. 10: Spice simulation of the model with parameters suited to the SOLEMS PV cell

Figure 10 presents the SPICE simulation result of the circuit according the fig. 8 where the parameters were set in order to approximate the SOLEMS PV cell measurement (compare with fig. 7). The SPICE model is good for higher illuminations. For low illuminations the open circuit voltage is underestimated. This can be corrected by voltage source V2 in the model.

HARVESTER APPLICATION

The SOLEMS PV cell keeps high voltage also at low illuminance which simplifies the energy harvester (no DC/DC converter is needed). The harvester EH300 was chosen to collect the energy from PV cell into the capacitor. It keeps the voltage in the range 1.8 – 3.6 V (see fig. 11 and 12).

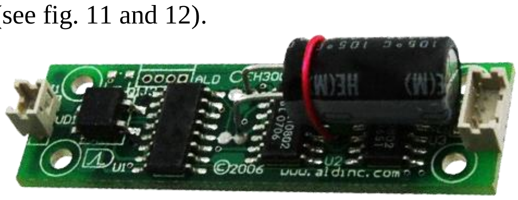

Fig. 11: Energy harvester EH300

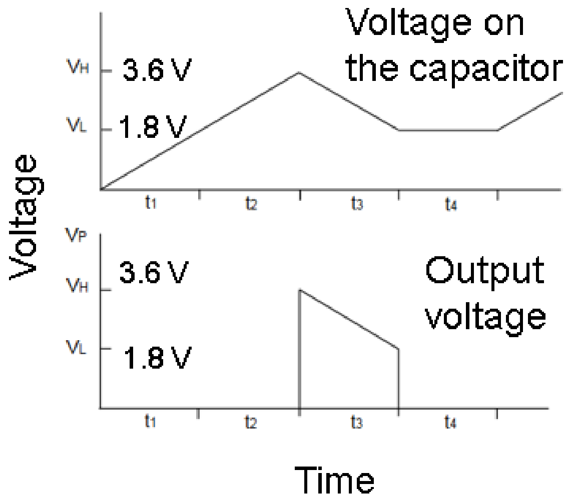

Fig. 12: Energy harvester EH300 working cycle [8]

When there is an internal capacitor of the module charged to 3.6 V, the energy is passed to the output. The energy is available until the voltage on the capacitor drops down to 1.8 V. When the harvester's output is closed the energy from the solar panel can be harvested again. For 1 mF capacitor the energy released in one charging cycle is 4.86 mJ.

Figure 9 presents developed system that is able to wirelessly transmit measured data (temperature and humidity) to the receiver. It uses only the solar energy or it can be also supported by the battery (e.g. for biasing the sensor).

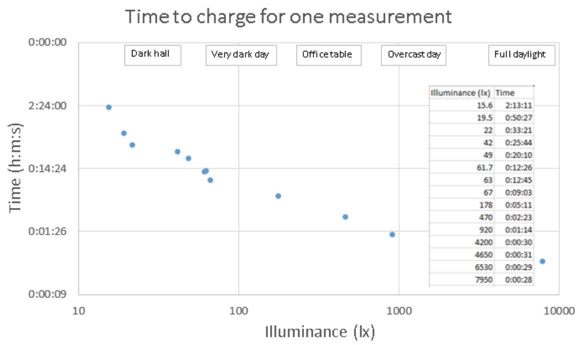

Fig. 13: Example of measured data rate with given solar cell and energy harvester EH300

Figure 13 presents the data transmission rate for PV cell 2.5 × 2.5 cm^2 placed in different environments. The measurement cycles depend on the light intensity. It starts on 28 seconds period for high intensities (8000 lx) and decreases down to 2.25 hours for very dark hall (15 lx). This measurement rates are suitable for most of the IoT indoor applications

CONCLUSIONS

The paper has presented automated system that allows characterization of solar cells for low energy applications. Special PV cell from SOLEMS was measured and compared with standard polycrystalline PV cell. The SPICE model was presented and compared with real measurement. Presented model gives possibilities to improve the match between the simulation and real measurement. Simple application for battery-less environment monitoring was also presented. It is able to operate also at low light environment and thus it is suitable for indoor IoT applications.

ACKNOWLEDGMENTS

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