Data Collection for Modelling Power Chargers in Energy Harvesting

Mojtaba Masoudinejad
Lehrstuhl für Förder- und Lagerwesen
Technische Universität Dortmund
mojtaba.masoudinejad@tu-dortmund.de

An energy harvesting (EH) module is able to empower an embedded device and increase its life span. Such a system requires a charging module in addition to the harvester and energy storage. However, adding this structure increases the design complexity and requires detailed modelling. This paper provides a data collection and analysis process for state of the art charger devices. This collection enables data-based modelling of chargers.

1 Introduction

Non-stationary embedded devices will establish the future computing [4]. In spite of growing number of these devices [5], their power supply is still a challenging implementation aspect. Although increasing the storage size helps some applications, others such as an intelligent warehouse [1], cannot rely only on batteries. Logistics application [2] require device deployment in large scale, long life span with no maintenance costs.

Using EH expands devices' life cycle. However, it adds complexities to the hardware design. From one side dynamic voltage of the harvester has to be continuously matched to the battery's voltage. on the other hand, a control system has to keep both operational points near the optimum [3]. A solution including all these functionalities is mostly called a charger, which its overview is shown in Fig.1. Developing such charger with of-the-shelf components is possible. However, energy losses forces most implementations to use monolithic solutions. Currently, there are three chips from the BQ255XX series made by Texas Instruments (TI) and SPV1050 from ST available for this purpose. TI's BQ25505 and BQ25570 chips promise higher efficiency and have dominated the market.

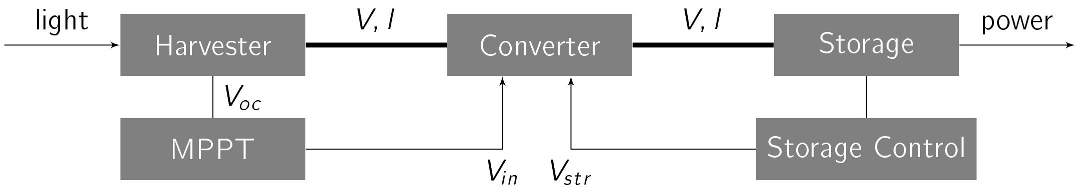

Figure 1: Complete power supply chain for a PV EH powered device

Any large-scale deployment necessitates a detailed power analysis of the whole system. Designer has to balance harvested energy with system's load using modelling and simulation. However, available knowledge from monolithic chargers is limited. Consequently, black-box modelling principle would be easier to avoid internal complexities. These techniques require only system's input/output at different operational conditions.

2 State of the Art

Reliable data collection requires understanding of possible operational conditions of the system. The overall operational state machine of these chips is presented in Fig. 2 [3] In a balanced system this device would be mostly working in the *NO* state. Therefore, data collection in this state has the highest priority.

From transitions in Fig.2 can be seen that the storage voltage (V_{str}) has to be larger than 1.8 V and smaller than the over-voltage limit which is 4.2 V for TI's evaluation boards. These boards are used to assure same design and setup as proposed by manufacturer.

3 Measurement

Two Source Measurement Units (SMU) from *Keysight* are connected to evaluation boards, responsible to emulate the harvester and storage. Measurement precision of both devices is 10 fA and 100 nV. One channel acting as a current source replicates a

Figure 2: A simplified state machine representing charger's operational states

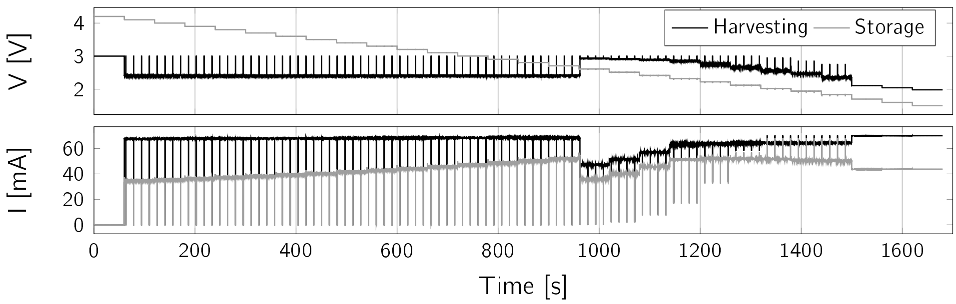

Figure 3: signals measured from TI BQ25505 at I_{in} =70 mA and V_{oc} =3.5 V

photovoltaic harvester with its open circuit voltage as voltage compliance. Simultaneously, another channel acts as a voltage source representing the battery. Voltage and current of both channels is measured concurrently.

For a proper modelling, two sets of independent data are required. One set will be used for developing the model, While the other set is used for its evaluation.

3.1 Modelling experiments

For collecting modelling data, input parameters (including I_{EH} and V_{oc}) are constant while V_{str} changes. V_{str} begins from 4.2 V and reduces to 1.5 V. An example of such data is presented in Fig. 3.

To cover all possible operational points, this process is automated. SMU is connected to a PC running a MATLAB program. This program communicates with the device using SCPI commands. It initializes the system, sets parameter values and acquires collected data from the device. Using this process, 540 datasets for each charger are collected.

3.2 Evaluation experiment

In addition to the cross validation during modelling, a secondary dataset is required here for validation. For this propose, a secondary experiment is proposed. In contrast to the modelling experiment with a static working condition during each time period, the evaluation experiment includes dynamics and is able to cover more operational points. During this experiment the I_{EH} changes over time as the variable parameter. This sinusoid signal starts at 50 mA, increases to 100 mA; then, reduces to zero and again to the initial value of 50 mA. This form uncovers possible hidden memory effects which causes different behaviours according to the signal derivation.

While input current changes during the experiment, V_{oc} and V_{str} are constant. An example of collected data for such experiment is shown in Fig. 4. The MPPT measurement periods

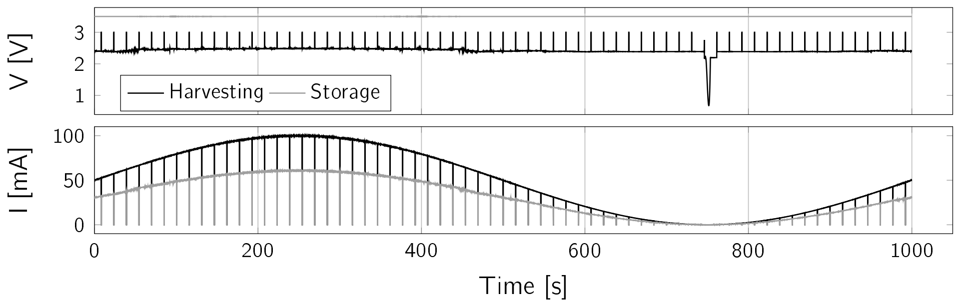

Figure 4: Example PSS signals measured from TI BQ25570 with a sinusoidal input current, 3 V open circuit voltage and a constant 3.5 V storage voltage

can be seen in these data as well. Using the automated collection process, 280 set of evaluation datasets are collected for each charger as well.

4 Sum up

This report addressed necessity of modelling energy harvesting based power supply. Two state-of-the-art monolithic power charger for this purpose are presented. Specification of two different data collection scenarios for modelling them is proposed.

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