AN4396
Application note

STEVAL-ISV021V1, energy harvesting system based on SPV1050, PV panel and battery

Domenico Ragonese

Introduction

The STEVAL-ISV021V1 is a demonstration kit which consists of a complete energy harvesting module based on the SPV1050 ULP energy harvester and battery charger, having the purpose to show the electrical performance of the power converter and many other fundamental electrical quantities related to the overall system.

The SPV1050 power manager is configured as a buck-boost converter, fitting the electrical characteristics of the mounted PV panel and battery.

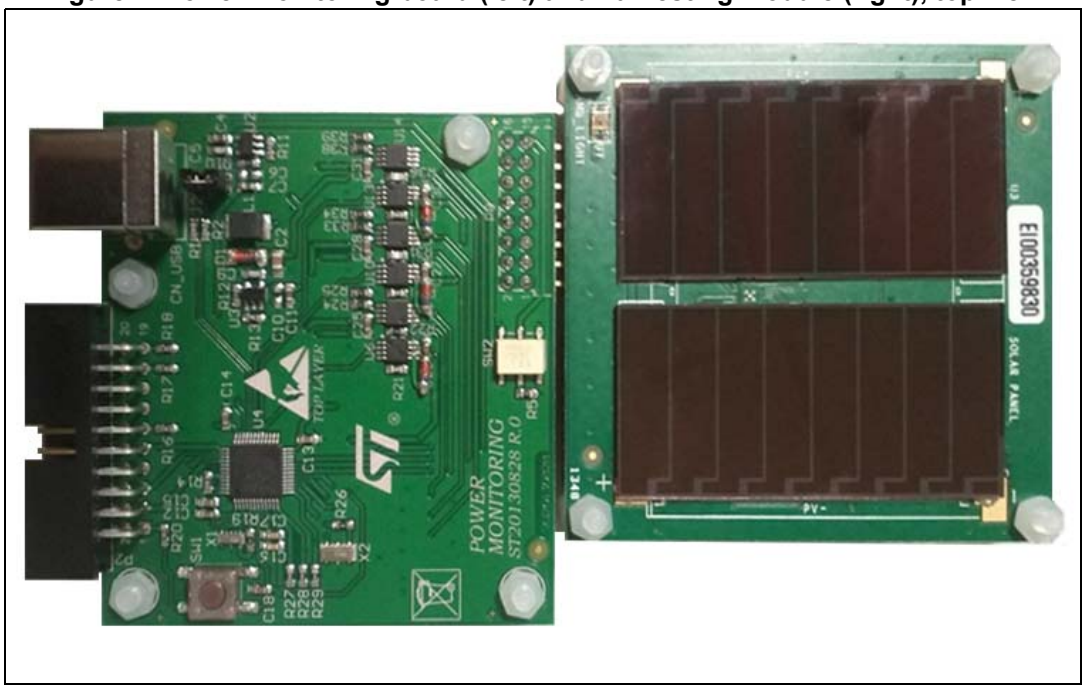
A power monitoring board along with a software GUI are used to monitor and to graph both of the PV panel and battery voltage and current, and system performances, like MPPT accuracy and conversion efficiency.

The STEVAL-ISV021V1 represents the standalone harvesting module that can be interfaced with a wireless sensor node to provide the microcontroller, transmitter and sensors with the energy scavenged and stored into the battery.

Furthermore, the STEVAL-ISV021V1 harvesting module embeds an extension connector to interface and to monitor of some of the SPV1050 input and output signals through a microcontroller based board.

The complete STEVAL-ISV021V1 kit is shown in *Figure 1*.

Figure 1. Power monitoring board (left) and harvesting module (right), top view



Contents

1 Schematic and bill of material

The schematic, bill of material and gerber files can be downloaded from the Design resources tab of the STEVAL-ISV021V1 product folder on *www.st.com*.

Figure 2. Harvesting module schematic

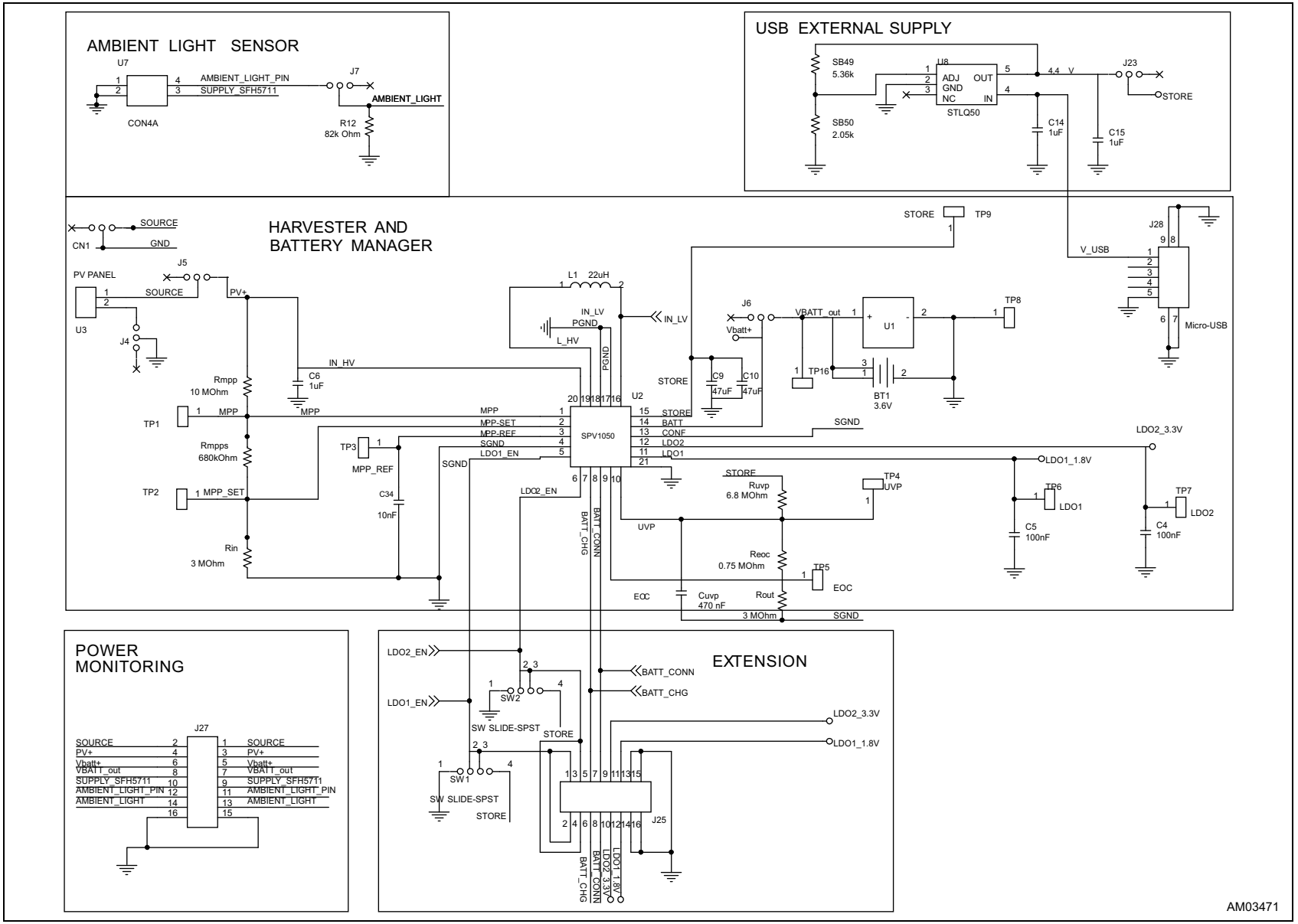


Table 1. Harvesting module BOM

Sect.	Item	Qty.	Ref.	Part/value	Tolerance (%)	Voltage current	Watt	Technol. info.	Package	Manufacturer	Manufacturer code	More information
Battery	1	1	BT1	Support for Li-Ion battery					SMD	Keystone	3008	
	2	1	J6	SMD jumper				Pitch 100 mils	SMD	FCI	95293-101-03LF	This jumper allows the connection of the STORE pin to the voltage regulator U4 in case the external sampling is OFF
Supply	3	2	U3	Flexible PV panel					SMD	SANYO	AM-1801	2 PV panels connected in series
	5	1	J4	SMD jumper				Pitch 100 mils	SMD	FCI	95293-101-03LF	This jumper disconnects the PV panel U3 in case an alternative supply is required and connected to CN1
	6	1	J5	3-way switch				Pitch 100 mils	SMD	FCI	95293-101-03LF	This jumper allows the connection of the source to the harvester U1 in case the external sampling is OFF
	7	1	CN1	2-way conn.				Pitch 100 mils	SMD	FCI	95293-101-03LF	Input connector for external PV panel or TEG

Table 1. Harvesting module BOM (continued)

Sect.		Item	Qty.	Ref.	Part/value	Tolerance (%)	Voltage current	Watt	Technol. info.	Package	Manufacturer	Manufacturer code	More information
Harvester/DC-DC controller section		8	1	U2	SPV1050						ST		Harvester and thin film battery manager
	MPPT section	9	1	C6	1 µF	15%	25 V		X5R	0603	Murata	GRM188R61E105KA12D	Input capacitance
		10	1	Rmpp	10 MΩ	1%		0.1		0603	VISHAY	CRCW060310M0FKEA	Resistor partitioning for MPP track
		11	1	Rmpps	680 kΩ	1%		0.1		0603	TE Connectivity	CRG0603F680K	Resistor partitioning for MPP setting
		12	1	Rin	3 MΩ	0.01				0603	VISHAY	CRCW06033M00FKEA	Input resistor partitioning
		13	1	C34	10 nF	15%	16 V		X7R	0603	Murata	GRM188R71C103KA01D	Voltage sampling time constant capacitance
		14	1	L1	22 µH	20%					Coilcraft	LPS4018-223ML_ LPS5010-223ML_ XFL2006-223ME_	DC-DC inductor
	LDO1	15	1	SW1	3-way switch				Pitch 100 mils	SMD	FCI	95293-101-04LF	Close 1 - 2, LDO1 is disabled Close 2 - 3, LDO1 controlled by external signal
		16	1	C5	100 nF	10%	6.3 V		X5R	0402	AVX	04026D104KAT2A	
	LDO2	17	1	SW2	3-way switch				Pitch 100 mils	SMD	FCI	95293-101-04LF	Close 1 - 2, LDO2 is disabled Close 2 - 3, LDO2 controlled by external signal
		18	1	C4	100 nF	10%	6.3 V		X5R	0402	AVX	04026D104KAT2A	

Table 1. Harvesting module BOM (continued)

Sect.	Item	Qty.	Ref.	Part/value	Tolerance (%)	Voltage current	Watt	Technol. info.	Package	Manufacturer	Manufacturer code	More information
Battery management section	19	2	C9, C10	47 µF	20%	6.3 V		X5R	0805	KEMET	C0805C476M9PAC7800	Capacitor on STORE net
	21	1	Cuvp	470 nF	15%	10 V		X5R	0603	Murata	GRM188R71A474KA61D	UVP voltage sampling delay time constant capacitance
	22	1	Ruvp	6.8 MΩ	1%				0603	VISHAY	CRCW06036M80FKEA	VEOC = 4.15 V VUVP = 3.75 V
	23	1	Reoc	0.75 MΩ	1%				0603	VISHAY	CRCW0603750KFKEA	
	24	1	Rout	3 MΩ	1%				0603	VISHAY	CRCW06033M00FKEA	
Ambient light	25	1	U7	SFH5711					SMD	OSRAM	SFH 5711	Ambient light sensor: place on the same solder side of the PV panel (U3)
	26	1	R12	80 kΩ	1%		0.1		0603	VISHAY	CRCW060382K0FKEA	
	27	1	J7	SMD jumper				Pitch 100 mils	SMD	FCI	95293-101-03LF	
External supply from USB	28	1	U8	STLQ50C-R					SOT323-5L	ST	STLQ50C-R	
	29	1	SB49	5.36 kΩ			0.1		0603	Panasonic	ERA3AEB5361V	
	30	1	SB50	2.05 kΩ	±1%		0.1		0603	VISHAY	CRCW06032K05FKEA	
	31	2	C14, C15	1 µF	15%	25 V		X5R	0603	Murata	GRM188R61E105KA12D	
	33	1	J23	SMD jumper				Pitch 100 mils	SMD	FCI	95293-101-03LF	Disable charging from USB

Table 1. Harvesting module BOM (continued)

Sect.	Item	Qty.	Ref.	Part/value	Tolerance (%)	Voltage current	Watt	Technol. info.	Package	Manufacturer	Manufacturer code	More information
External connections	34	1	J28	Micro-USB					SMD	Molex	47346-0001	External charge from USB
	35	1	J25	16-pin conn.				2.54 mm	SDM	Samtec	SMH-108-02-G-D	Connector for future extensions
	36	1	J27	16-pin conn.				2.54 mm	SMD	Samtec	SMH-108-02-G-D	Connector for power monitoring board
Spacers + nuts	37	4	Screw support							RS	325-687 and 525-701	

2 Harvesting module layout

Figure 3 and *Figure 4* show the component placement and the layout (top and bottom views) of the harvesting module.

Figure 3. Harvesting module - top view

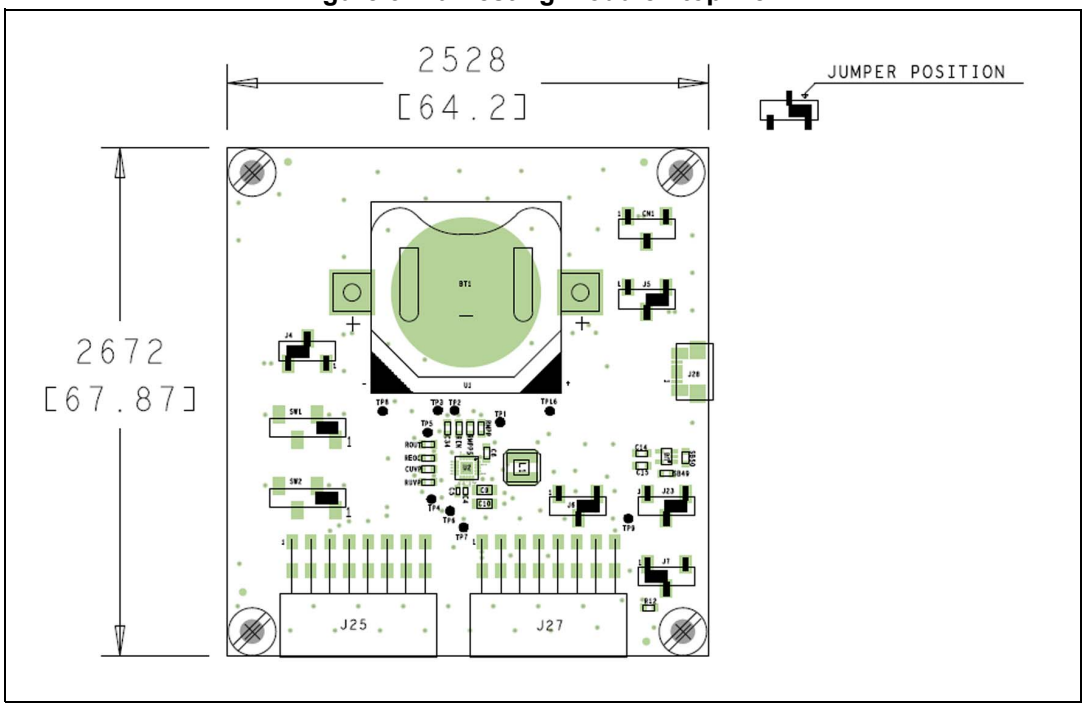
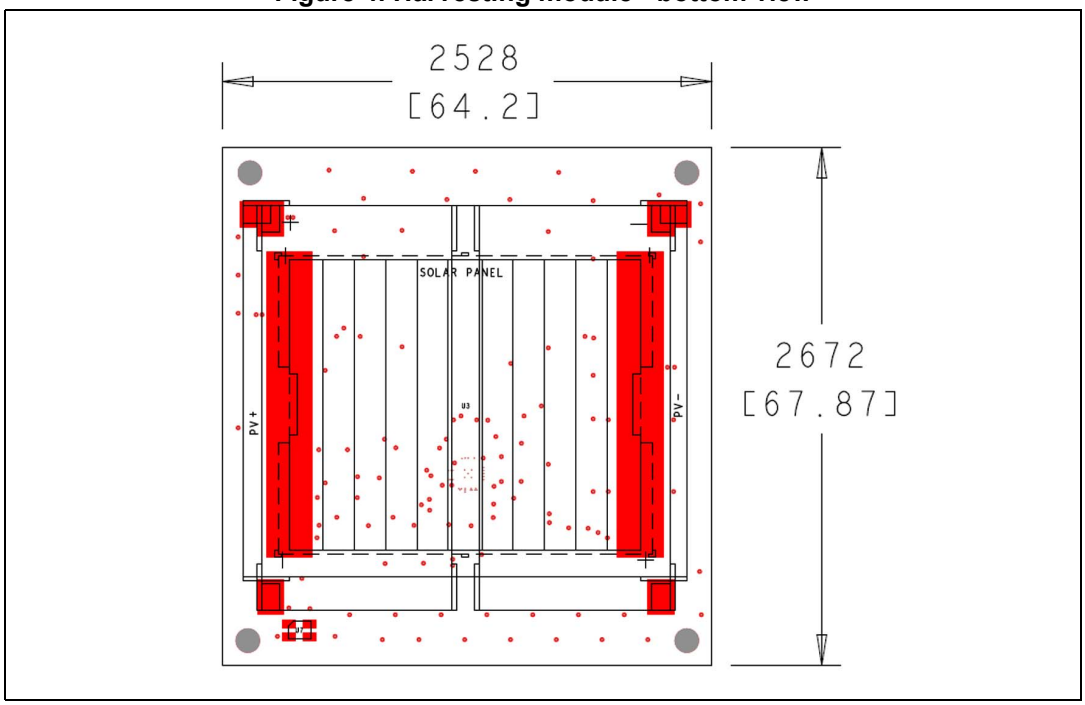


Figure 4. Harvesting module - bottom view



In order to ensure a proper noise rejection that could impact the SPV1050 device performance, the following indications must be followed in the PCB routing:

- The exposed pad and the pins PGND and GND must be connected to the same ground plane.
- The capacitor on the STORE pin must be placed as closest as possible to the related pin.
- The capacitors on the LDO1 and LDO2 pins must be placed as closest as possible to the related pins.

3 Harvesting module connectors

The STEVAL-ISV021V1 provides a set of connectors for the input sources which are described below:

- **CN1 (2-pin connector)**

This connector is provided to supply the SPV1050 device by a supply source alternative to the on-board PV panel.

Table 2. CN1 connector

	CN1 pin number	
	1	2
Signal	SOURCE +	SOURCE -

The J4 must be open before an external source is connected to the CN1. For the proper selection of the external source, please refer to the datasheet of the SPV1050 device.

- **J25 (16-pin extension connector).**
  It can be used to connect the harvesting module to an external load such as a wireless sensor node module.

Table 3. J25 connector

	J25 pin number						
	1 - 2	3 - 4	5 - 6	7 - 8	9 - 10	11 - 12	13 - 16
SPV1050 pin signal	LDO1_EN CONTROL	LDO2_EN CONTROL	$\overline{\text{BATT\_CHG}}$	$\overline{\text{BATT\_CONN}}$	LDO2	LDO1	GND

  - **LDO1_EN CONTROL** (input): it provides the connection to an external signal that controls the LDO1_EN pin. In this case the SW1 must be left open. If the LDO1 is not used, the LDO1_EN pin has to be connected to ground.
  - **LDO2_EN CONTROL** (input): it provides the connection to an external signal that controls the LDO2_EN pin. In this case the SW2 must be left open. If the LDO2 is not used, the LDO2_EN pin has to be connected to ground.
  - **$\overline{\text{BATT\_CHG}}$** (output): battery charge status pin.
    This is an open drain pin that has to be pulled up by a resistor (10 MΩ typical) to V_{STORE} voltage rail.
  - **$\overline{\text{BATT\_CONN}}$** (output): battery connection status pin.
    This is an open drain pin that has to be pulled up by a resistor (10 MΩ typical) to V_{STORE} voltage rail.
  - **LDO2:** LDO2 (3.3 V) output voltage pin.
  - **LDO1:** LDO1 (1.8 V) output voltage pin.
  - **GND:** ground pin of the extension board.

- **J27 (16-pin monitoring connector)**
  It provides the connection to the power monitoring board.

Table 4. J27 connector

	J27 pin number							
	1 - 2	**3 - 4**	**5 - 6**	**7 - 8**	**9 - 10**	**11 - 12**	**13 - 14**	**15 - 16**
Signal	SOURCE	PV+	Vbatt+	VBATT_OUT	SUPPLY_ SFH5711	AMBIENT_ LIGHT_PIN	AMBIENT_ LIGHT	GND

- **SOURCE, PV+:** Harvesting source current sensing pin.
  If the power monitoring board is used, then the jumper J5 must be left open; otherwise pins 1 and 2 of the J5 must be shorted.
- **VBATT+, VBATT_OUT:** Battery current sensing pin.
  If the power monitoring board is used, then the jumper J6 must be left open; otherwise pins 1 and 2 of the J6 must be shorted.
- **SUPPLY_SFH5711:** Power supply of the ambient light sensor pin (placed on the top side of the board).
- **AMBIENT_LIGHT, AMBIENT_LIGHT_PIN:** Ambient light current sensing pin.
  If the power monitoring board is used, then the jumper J7 must be left open.
- **GND:** Ground pin.

4 Jumpers and switches

Table 5. J4 jumper

	J4
Function	CLOSE 1 - 2: harvesting board supplied by the on-board PV panel OPEN 1 - 2: enables an alternative source from the CN1

Table 6. J5 jumper

	J5
Function	CLOSE 1 - 2: bypasses power monitoring sense and supply directly the SPV1050 OPEN 1 - 2: power monitoring enabled from the power monitoring board

Table 7. J6 jumper

	J6
Function	CLOSE 1 - 2: bypasses power monitoring sense and connects the battery to the BATT pin OPEN 1 - 2: enables sensing from the monitoring board

Table 8. J7 jumper

	J7
Function	CLOSE 1 - 2: not used OPEN 1 - 2: enables ambient light sensing from the monitoring board

Table 9. J23 jumper

	J23
Function	CLOSE 1 - 2: STORE pin supplied by the USB cable OPEN 1 - 2: STORE pin supplied by the energy harvesting source

Table 10. SW1 and SW2

	SW1	SW2
Function	CLOSE 1-3: LDO1 DISABLED CLOSE 2-3: LDO1 ENABLED FLOATING: EXTERNAL CONTROL BY J25	CLOSE 1-3: LDO2 DISABLED CLOSE 2-3: LDO2 ENABLED FLOATING: EXTERNAL CONTROL BY J25

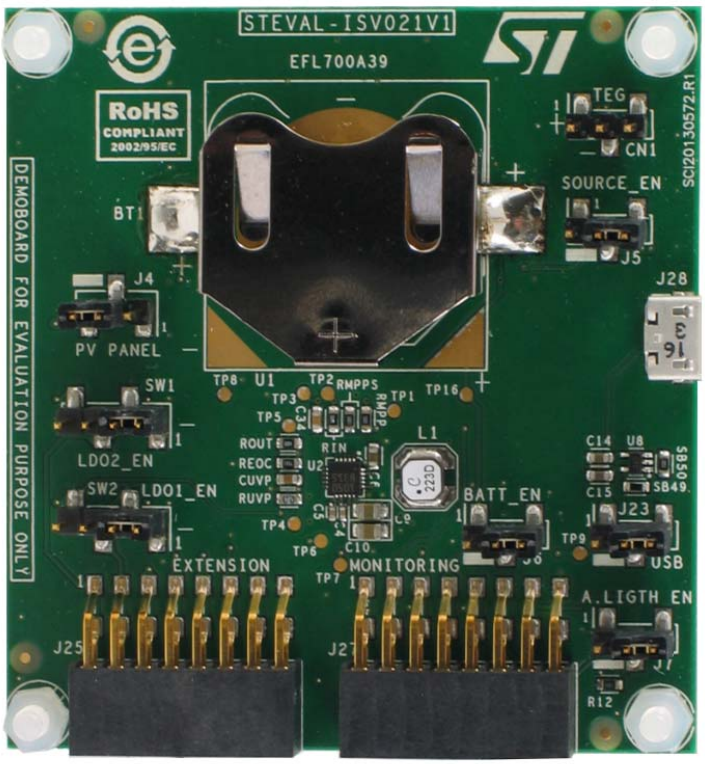
5 Harvesting module and power monitoring board

The harvesting module can be used both: as a standalone device or with the power monitoring board.

In the standalone mode, leave the CN1 open and connect the jumpers as described below:

- Close pins 2 - 3 of the J4 and close pins 1 - 2 of the J5 in order to supply the SPV1050 device by the on-board PV panel.
- Close pins 1 - 3 of the J6 in order to connect the on-board battery.

Figure 5. Jumper configuration for harvester module in stand-alone mode



It is possible to monitor the system behavior and efficiency by following the listed steps:

- Place a voltmeter between pins 1 - 2 of the CN1 (V_{IN})
- Replace the short on the J5 by an ammeter (I_{IN})
- Place a voltmeter between the TP16 and TP8 (V_{BATT})
- Replace the short on the J6 by an ammeter (I_{BATT})

The STEVAL-ISV021V1 kit includes the power monitoring board, and the related GUI which runs on the Windows® XP and Windows 7 OSs.

The power monitoring board and the related GUI allow a quick and intuitive way to monitor the system performances.

Before to connect the harvester module to the power monitoring board, set the jumpers as described below:

- Close pins 2 - 3 of the J4 in order to supply the SPV1050 device by the on-board PV panel
- Close pins 2 - 3 of the J5 in order to allow the power monitoring to sense the input voltage and current.
- Close pins 2 - 3 of the J6 in order to allow the power monitoring to sense the battery voltage and current.
- Close pins 2 - 3 of the J7 in order to allow the power monitoring to sense the ambient light on the PV panel.

Figure 6. Jumper configuration for harvester module connected to power monitoring board

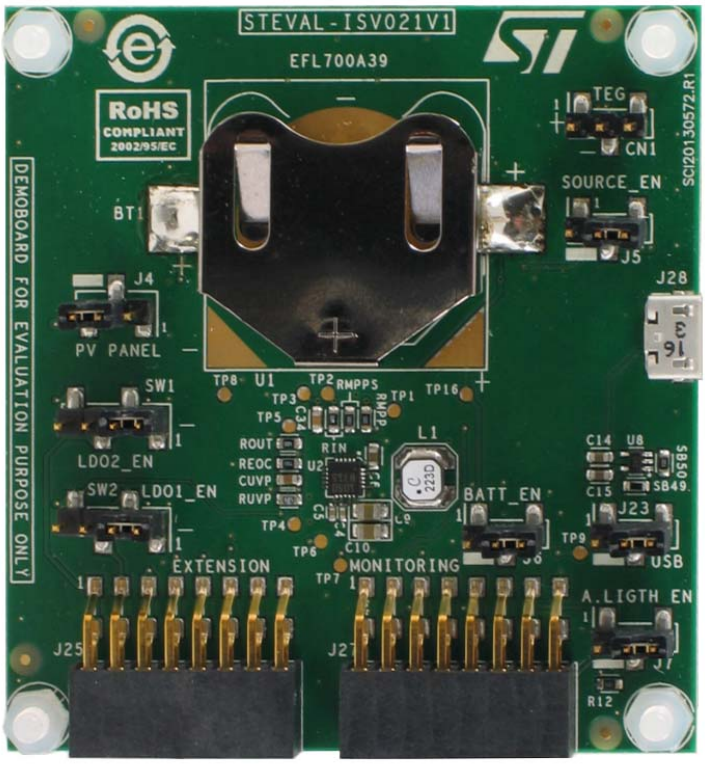
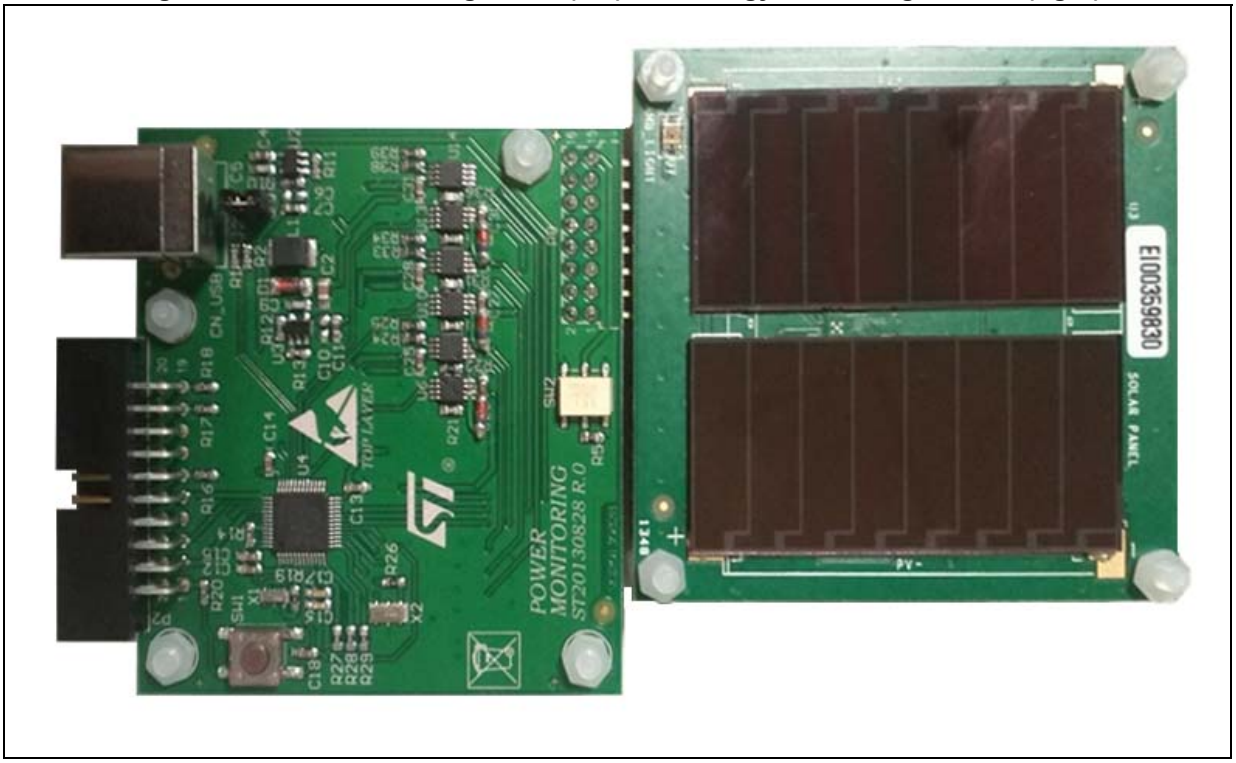


Figure 7 shows the connection of the harvesting module and the power monitoring board of the STEVAL-ISV021V1 kit.

Figure 7. Power monitoring board (left) and energy harvesting module (right)



The power monitoring board allows to measure up to three voltage-current pairs when connected to a generic DUT. This board can acquire up to 12800 samples per second when a single channel is active. For multi-channel acquisition the available bandwidth is split among the three channels. Two channels can acquire currents in the range 1 μA - 15 mA, while the third one works in the range 1 μA - 1 mA. This board can be used as a general purpose measurement board, and in this case is a part of the STEVAL-ISV021V1 kit. The ambient light irradiation, the input supply operating points (the input voltage and current of the harvested source) and the output stage operating points (the battery voltage and current) are sampled.

The sampled parameters can be displayed by the GUI once the monitoring board is connected to a PC or laptop through the dedicated USB cable.

Note: Please note, that connecting the harvesting module to the power monitoring board, while this is not powered through the USB cable, causes current draining from the battery, and hence potential damages.

The GUI is arranged in four selectable “tabs”:

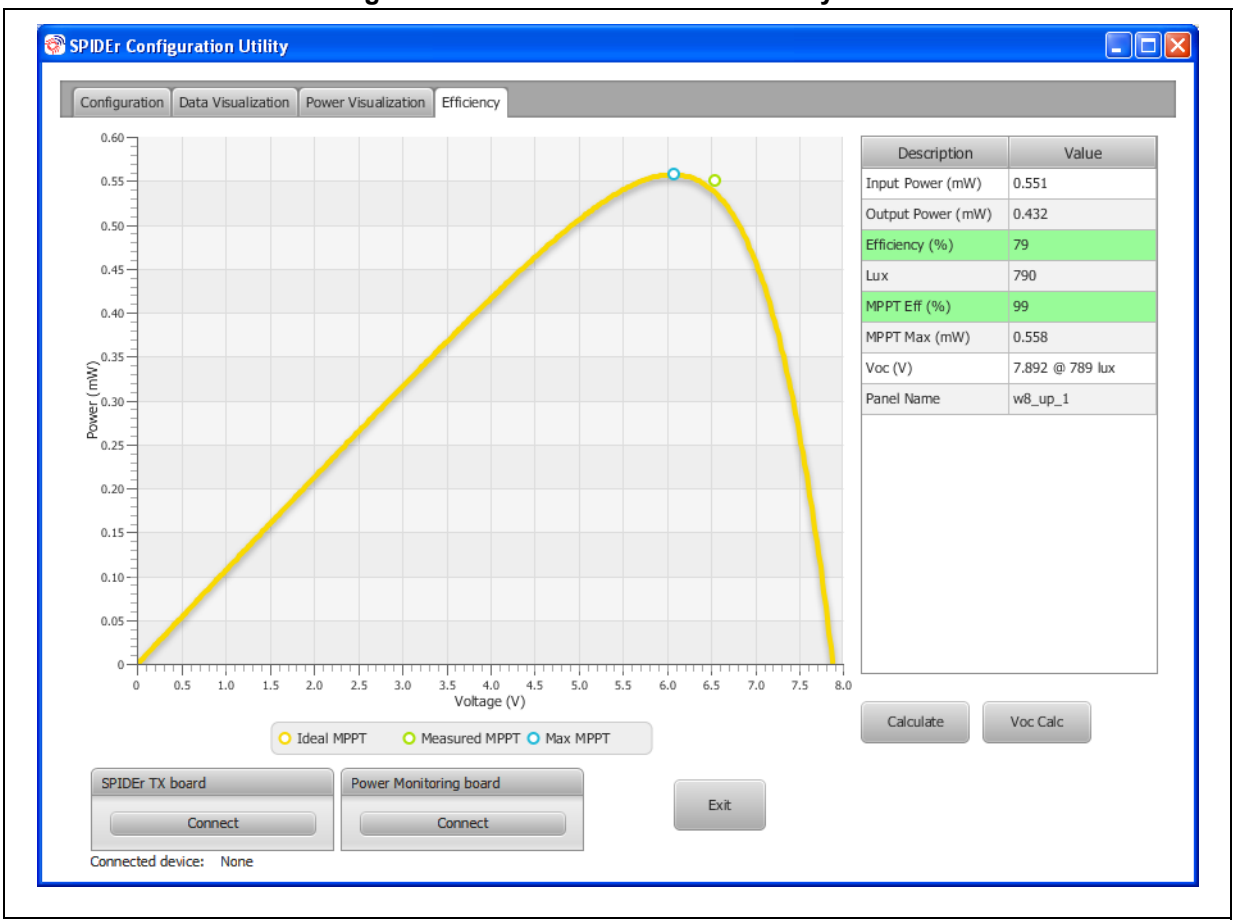
- **Configuration:** allowing the setup of the power monitoring board.
- **Data visualization:** not used with the STEVAL-ISV021V1.
- **Power visualization:** displaying the power sink by the load eventually connected to the “extension” connector J25.
- **Efficiency:** displaying the system performances both in terms of MPPT accuracy and power efficiency.

Just as an example, *Figure 8* the efficiency tab:

- The GUI will show the actual PV panel curve according to the current ambient light conditions.
- On the PV panel curve the green dot indicates the real working point, while the blue dot indicates the maximum power point.
- The table on the top right side of the screen shows the main system parameters and performances.

A detailed description of the GUI is available in the “Software user manual” - UM1752.

Figure 8. STEVAL-ISV021V1 “efficiency” tab



6 Revision history

Table 11. Document revision history

Date	Revision	Changes
03-Jun-2014	1	Initial release.