NEH2000BY

Energy harvesting PMIC

Rev. 4.0 — 16 August 2023 Product data sheet

1. General description

NEH2000BY is a high-performance energy harvesting solution for low-power applications. The NEH2000BY harvests energy generated by a photo-voltaic (PV) cell. The energy charges a rechargeable battery.

Nexperia's advanced Maximum Power Point Tracking (MPPT) uses an embedded hill-climbing algorithm to deliver the maximum power to the load. The MPPT is designed to be independent of specific characteristics of the harvesters, therefore any harvester that fits the specifications of the chip can be used. Moreover, the MPPT circuit can detect the maximum power point with an interval of 0.7 second resulting in maximum efficiency in various environments where energy can rapidly change over time.

The NEH2000BY is available in a Plastic 16 terminal Quad Flat package, 3 mm x 3 mm.

2. Features and target applications

Features and benefits

- High-efficiency low-power 2x boosting DC-to-DC converter
- Harvesting power range from 35 μW to 2 mW
- Advanced MPPT to maximize efficiency
- Ultra fast MPPT interval of 0.7 second
- Small BOM with no external inductor required
- Compatible with various types of rechargeable batteries

Applications

- Wireless IoT devices
- Smart remote controls
- Electronic shelf labels
- Wearable devices
- Industrial and environmental monitoring
- Consumer electronics
- Beacons

3. Typical application

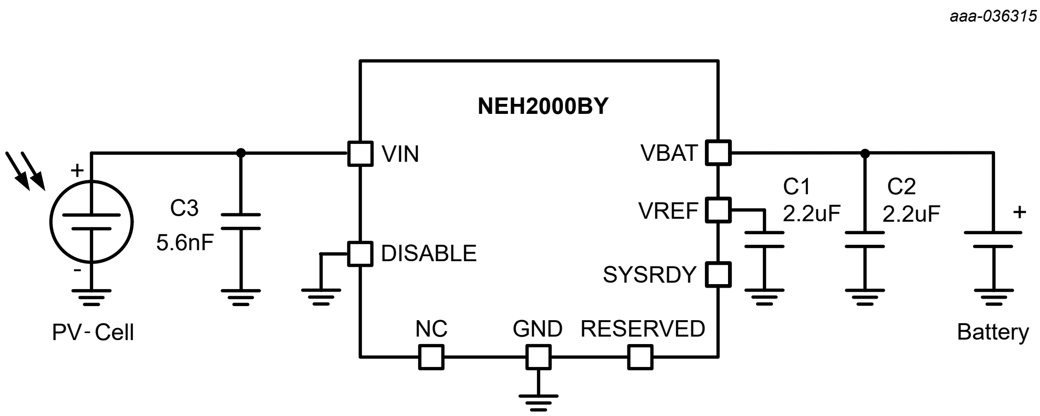


Fig. 1. Typical PV-Cell application

4. Pinning information

Package Diagram

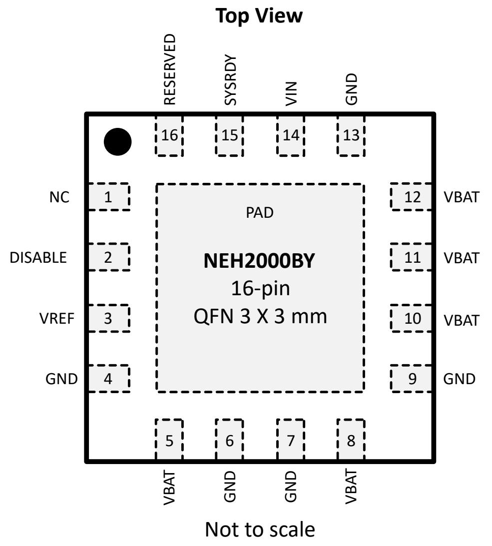


Fig. 2. QFN16 3 mm x 3 mm package

Table 1. Pinning information

Pin	Symbol	Description
1	NC	not connected; can be floating or grounded
2	DISABLE	Disable pin. Harvester is active when connected to GND. This pin can be used to deactivate harvesting in case battery is full
3	VREF	decoupling for internal supply generation; no external load supported
4	GND	ground
5	VBAT	output of the energy harvester and device supply
6	GND	ground
7	GND	ground
8	VBAT	connect to V_{BAT}
9	GND	ground
10	VBAT	connect to V_{BAT}
11	VBAT	connect to V_{BAT}
12	VBAT	output of the energy harvester and device supply
13	GND	ground
14	VIN	DC input of energy harvester
15	SYSRDY	System Ready output; indicates (HIGH) when start-up of device is ready
16	RESERVED	reserved; should be left floating
PAD	GND	ground

5. Ordering information

Table 2. Ordering information

Type number	Package		
	Name	Description	Version
NEH2000BY	SOT8076-1	Plastic Quad Flat package, no leads; 16 terminals: 0.5 mm pitch 3 mm x 3 mm x 0.75 mm body	1.0

6. Block Diagram

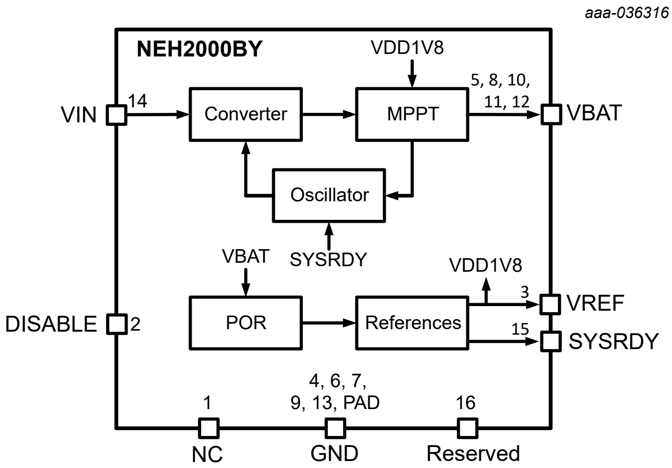


Fig. 3. NEH2000BY block diagram

7. Limiting values

Table 3. Limiting values

In accordance with the Absolute Maximum Rating System (IEC 60134). Voltages are referenced to GND (ground = 0 V).

Symbol	Parameter	Conditions	Min	Max	Unit
V_{IN}	input voltage [1]		-0.3	V_{BAT} + 0.3	V
			-0.3	5	V
V_{BAT}	battery voltage		-0.3	5	V
$V_{DISABLE}$	DISABLE input voltage		-0.3	5	V
I_{IN}	input current		-	100	mA
T_j	junction temperature		-50	+125	°C
T_{stg}	storage temperature		-65	+150	°C

[1] To prevent damage to the device, do not apply V_{IN} > 2 V in case no battery connected.

7.1. ESD ratings

Table 4. ESD ratings

Symbol	Parameter	Conditions	Value	Unit
V_{ESD}	electrostatic discharge voltage	HBM: ANSI/ESDA/JEDEC JS-001	± 2000	V
		CDM: ANSI/ESDA/JEDEC JS-002	± 1000	V

8. Recommended operating conditions

Table 5. Recommended operating conditions

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
V_{BAT}	battery voltage		2.5	-	4.5	V
T_{amb}	ambient temperature		-40	-	+85	°C

9. Thermal characteristics

Table 6. Thermal characteristics

Symbol	Parameter	SOT8076-1	Unit
$R_{\theta(j\text{-}a)}$	junction-to-ambient thermal resistance	97	K/W
$R_{\theta(j\text{-}top)}$	junction-to-case (top) thermal resistance	88	K/W
$\Psi_{(j\text{-}top)}$	junction-to-case (top) thermal characterization parameter	60	K/W

10. Characteristics

Table 7. Characteristics

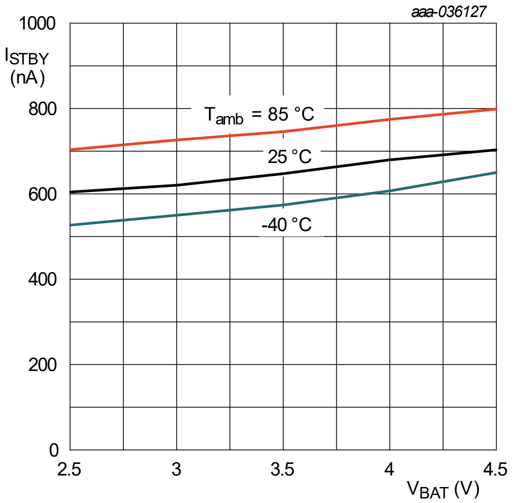
V_{BAT} = 3 V, V_{OC} = 3 V. Typical values specified at T_{amb} = 25 °C, Min and Max values specified at T_{amb} = –40 °C to 85 °C. Voltages are referenced to GND (ground = 0 V).

Symbol	Parameter	Conditions		Min	Typ	Max	Unit
Supplies and start-up							
V_{BAT}	battery voltage	to startup SYSRDY becomes high		-	2.5	2.7	V
		after startup SYSRDY is high	[1]	1.9	-	-	V
V_{IN}	harvester input voltage		[2]	-	1.65	-	V
I_{STBY}	standby current			-	625	1150	nA
V_{REF}	internally generated supply		[3]	1.6	1.8	2	V
t_{start}	start-up time	time for SYSRDY to become high after applying V_{BAT}; -20 °C < T_{amb} < 85 °C		-	50	-	ms
Power converter							
$P_{IN(low)}$	input power range, low-end	efficiency = 70%		-	35	-	μW
$P_{IN(high)}$	input power range, high-end	efficiency = 70%		-	2	-	mW
t_{MPPT}	MPPT interval			-	0.7	-	s
t_{MPPT_OPT}	MPPT optimization time			-	10	-	ms
$f_{CONV(low)}$	frequency at low-end power	P_{in} = 35 μW		-	50	-	kHz
$f_{CONV(high)}$	frequency at high-end power	P_{in} = 2 mW		-	1.8	-	MHz
Control							
V_{IL}	logic low level for DISABLE			-	-	0.1 × V_{BAT}	V
V_{IH}	logic high level for DISABLE			0.9 × V_{BAT}	-	-	V

[1] Reduced performance to be expected for V_{BAT} < 2.5 V.
[2] To prevent battery charging directly from the PV-cell take care that V_{OC} is lower than V_{BAT} plus a diode voltage (~0.5 V).
[3] Do not use/load V_{REF} in the application.

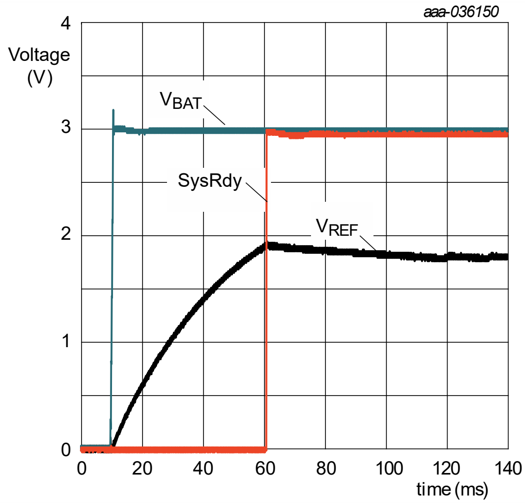
10.1. Typical performance characteristics

V_{BAT} = 3 V, V_{OC} = 3 V, T_{amb} = 25 °C, unless otherwise specified.



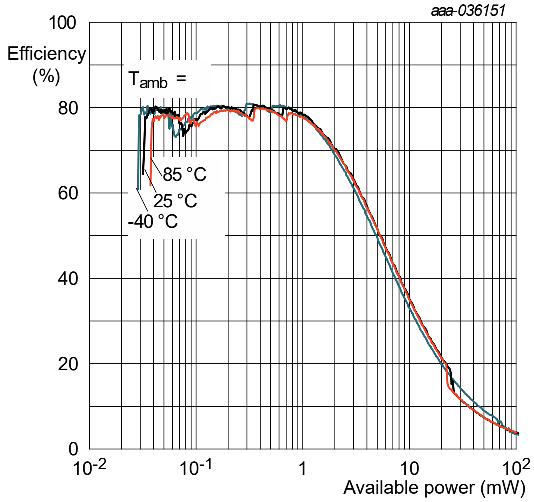
T_{amb}= 85 °C, 25 °C, -40 °C

Fig. 4. Stand-by current as a function of V_{BAT}



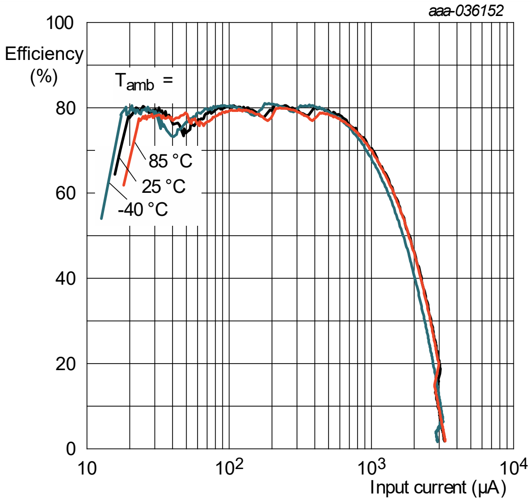
DISABLE = LOW

Fig. 5. Start-up sequence; V_{REF}, V_{BAT} and SysRdy as a function of time



T_{amb}= 85 °C, 25 °C, -40 °C

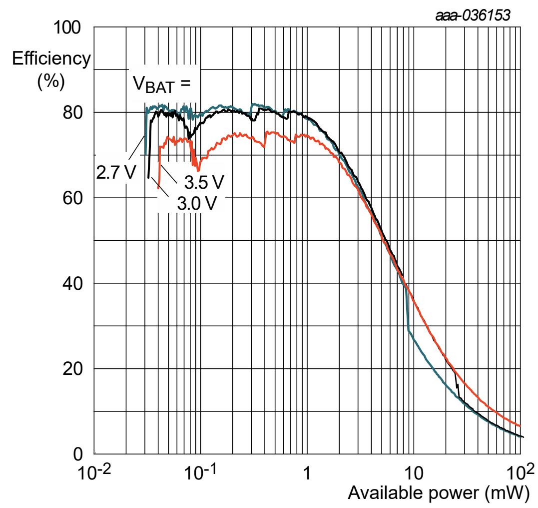
Fig. 6. Efficiency as a function of available power



T_{amb}= 85 °C, 25 °C, -40 °C

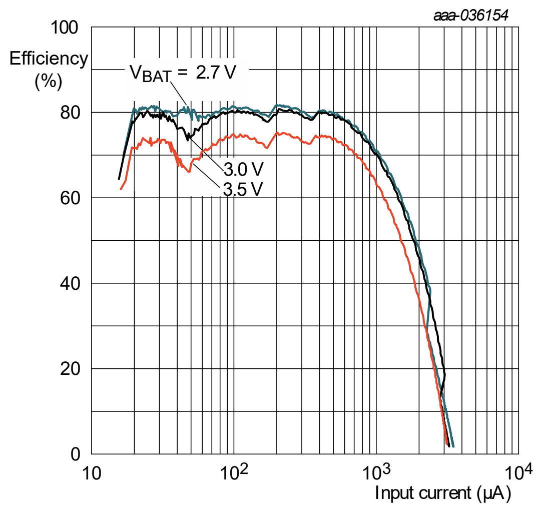
Fig. 7. Efficiency as a function of input current

V_{BAT} = 3 V, V_{OC} = 3 V, T_{amb} = 25 °C, unless otherwise specified.



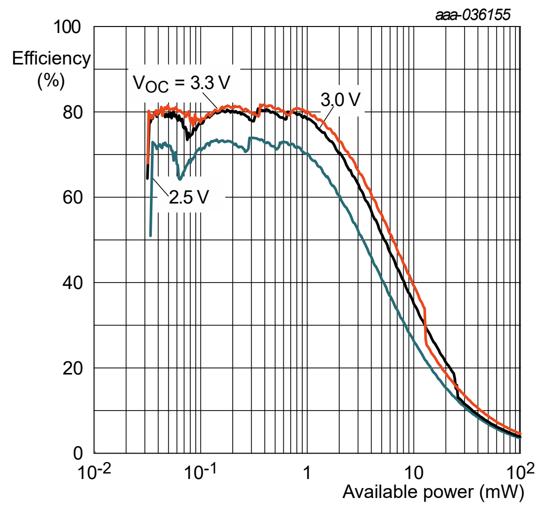
battery voltage = 2.7 V, 3.0 V, 3.5 V

Fig. 8. Efficiency as a function of available power



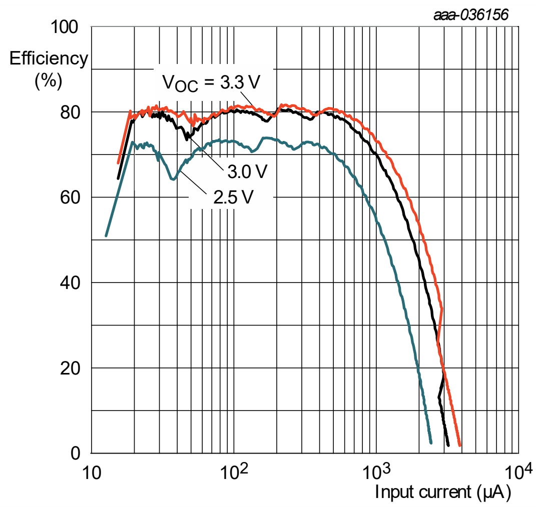
battery voltage = 2.7 V, 3.0 V, 3.5 V

Fig. 9. Efficiency as a function of input current



V_{OC} = 2.5 V, 3.0 V, 3.3 V

Fig. 10. Efficiency as a function of available power



V_{OC} = 2.5 V, 3.0 V, 3.3 V

Fig. 11. Efficiency as a function of input current

11. Application information

11.1. Typical application

A typical PV-cell application is shown in Fig. 12. Table 8 lists the Bill of Materials.

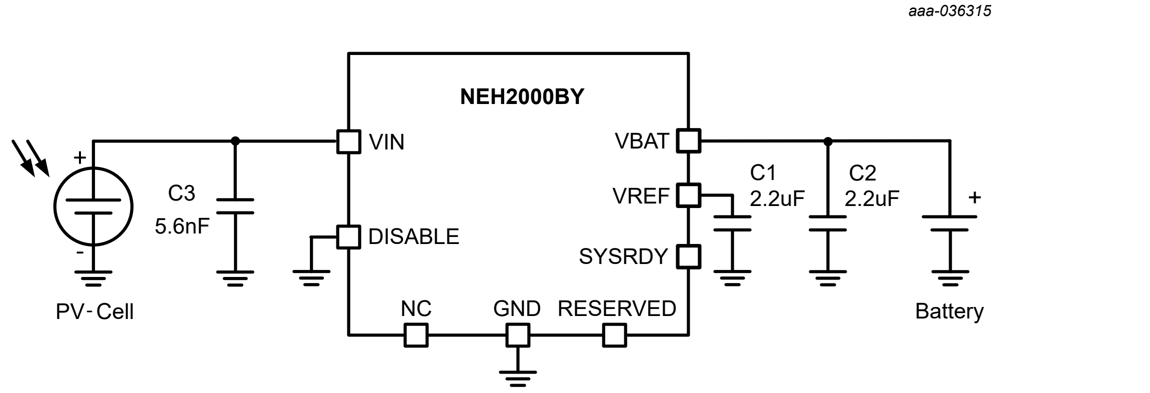


Fig. 12. Typical PV-Cell application

Table 8. Bill of Materials

Reference designator	Description	Type	Value	Quantity
U1	PMIC	NEH2000BY	-	1
C1, C2	capacitor	X7R / 6.3 V	2.2 µF	2
C3	capacitor	X7R / 6.3 V	5.6 nF	1

11.2. Harvesting efficiency

The overall efficiency (Eff_{total}) of the NEH2000BY in combination with a PV-cell comprises two components (see Fig. 13):

- $Eff_{converter}$: The efficiency of the power converter in the NEH2000BY
- Eff_{match} : The matching efficiency between the NEH2000BY and the PV-cell

$$Eff_{total} = Eff_{converter} \times Eff_{match} \quad (1)$$

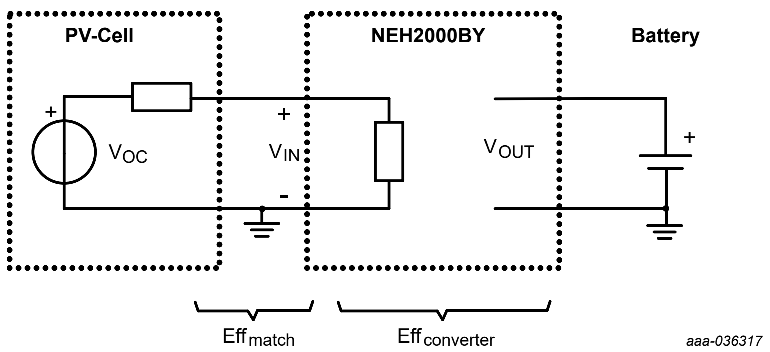


Fig. 13. Matching and converter efficiency

11.3. Power converter efficiency

In practice, a power converter has losses from input power (P_{IN}) to output power (P_{OUT}). The ratio of the output power and input power, is typically referred to as the power-converter efficiency:

$$Eff_{converter} = \frac{P_{OUT}}{P_{IN}} \times 100\ \% \qquad (2)$$

For common inductive and capacitive power converters this efficiency is in the range of 80% to 95%. Several characteristics can have an impact on this efficiency, such as: ratio of the output voltage and input voltage; quality and size of the converter capacitors / inductors, fully integrated or external components, etc. The NEH2000BY has a fully integrated power converter. In its targeted power range the converter efficiency is about 82%.

11.4. Matching efficiency

In general, power transfer between components is optimized by matching the receiving input impedance with the transmitting output impedance. In a harvesting system it is also important to transfer power from harvester to the power converter in the most efficient manner to minimize loss of harvested energy. How optimal power transfer between PV-cell and power converter is, can be expressed by matching efficiency.

The matching efficiency is defined as

$$Eff_{match} = \frac{P_{IN}}{P_{available}} \times 100\ \% \qquad (3)$$

Where P_{IN} is the actual power at the input of the power converter and $P_{available}$ is the maximum power that can be achieved at the input (which is at 100% matching).

From the graphs in Section 10.1, (Fig. 8 to Fig. 11), it can be seen that the matching efficiency (as part of the overall efficiency) has a dependency on the ratio of V_{OC} and V_{BAT}. Both relate in a certain way to the power converter's input. The V_{BAT} relation can be understood from the perspective that the capacitive power converter has a given boost factor between input and output:

$$V_{IN} = \frac{V_{BAT}}{\text{Boosting factor}} \qquad (4)$$

Where the actual boosting factor of the NEH2000BY is about 1.8 (unloaded boosting is 2).

The open-circuit voltage (V_{OC}) of a PV-cell relates to power converters input via the maximum power-point tracking voltage (V_{MPPT}). This is the voltage on the power converter's input where most power is delivered by the PV-cell:

$$V_{MPPT} = 0.7 \ldots 0.9 \times V_{OC} \qquad (5)$$

The typical MPPT ratio (V_{MPPT}/V_{OC}) of a PV-cell is 0.8.

Combining equations (4) and (5), the following guideline for V_{OC} applies:

$$V_{OC} = \frac{V_{BAT}}{\text{Boosting factor} \times \text{MPPT ratio}}$$
$$V_{OC} = 0.69 \times V_{BAT} \qquad (6)$$

Thus, for optimal matching efficiency a PV-cell should be chosen with a V_{OC} that is 0.69 × V_{BAT}.

11.5. Guideline for PV-cell selection

In this section a guideline is given for the selection of a PV-cell in an NEH2000BY application. Following this guideline will yield the best overall efficiency for the energy harvesting of the application. It is based on the optimum matching efficiency as described in the previous section.

Taking into account that the maximum-power point of a PV cell is about 0.8 × V_{OC}, the following guideline for the PV-cell applies:

$$V_{OC} = 0.5 \ldots 0.8 \times V_{BAT} \quad (7)$$

11.6. Enhanced low input power operation

In case operation at very low input power levels is desired, the NEH2000BY can be configured for operation starting at 10 μW input power. In this case, the power range shifts down by about a factor of 2. Please contact Nexperia for the appropriate configuration.

11.7. Full battery protection

In general, a battery should not be over-charged. Continue charging in that case can damage the battery. An energy harvester, like the NEH2000BY should therefore stop harvesting once the battery is fully charged. This can be implemented by adding an over-voltage protection device (OVP) to the harvester (see Fig. 14).

Detecting whether a battery is fully charged or not can be done by observing the battery voltage. Each battery type has it own maximum allowed voltage. An OVP device can monitor the battery voltage V_{BAT}. Once the maximum allowed battery voltage is detected the OVP device will assert its output and by that disable the harvester. Once the V_{BAT} level drops below the release voltage of the OVP device, harvesting commences again.

OVP devices are available in many different types. The OVP device should have an over-voltage detection level that corresponds to the maximum allowed battery voltage. The output logic of the OVP should be chosen such that the output is high when the maximum battery voltage is at or above the allowed level.

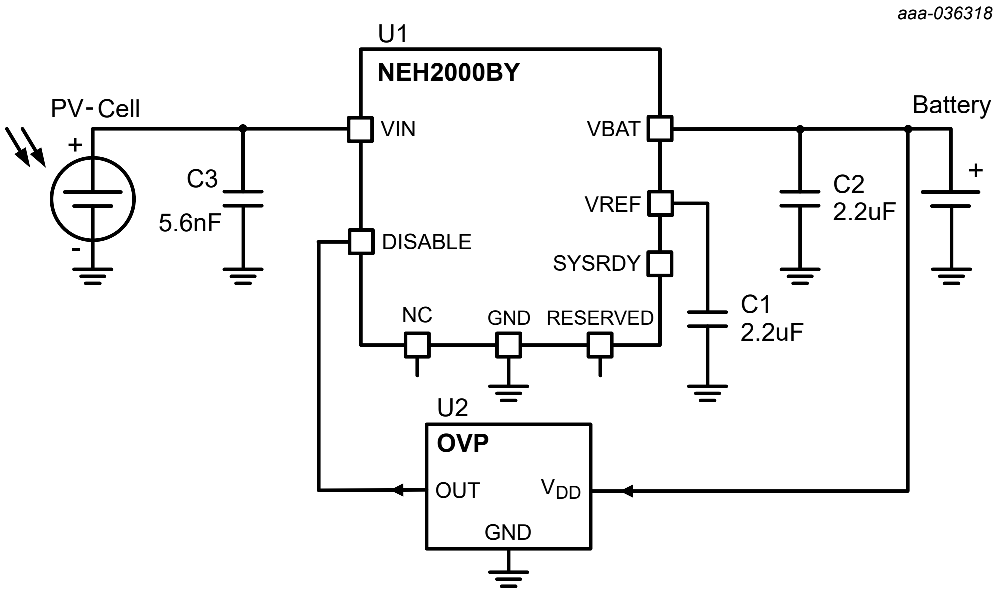
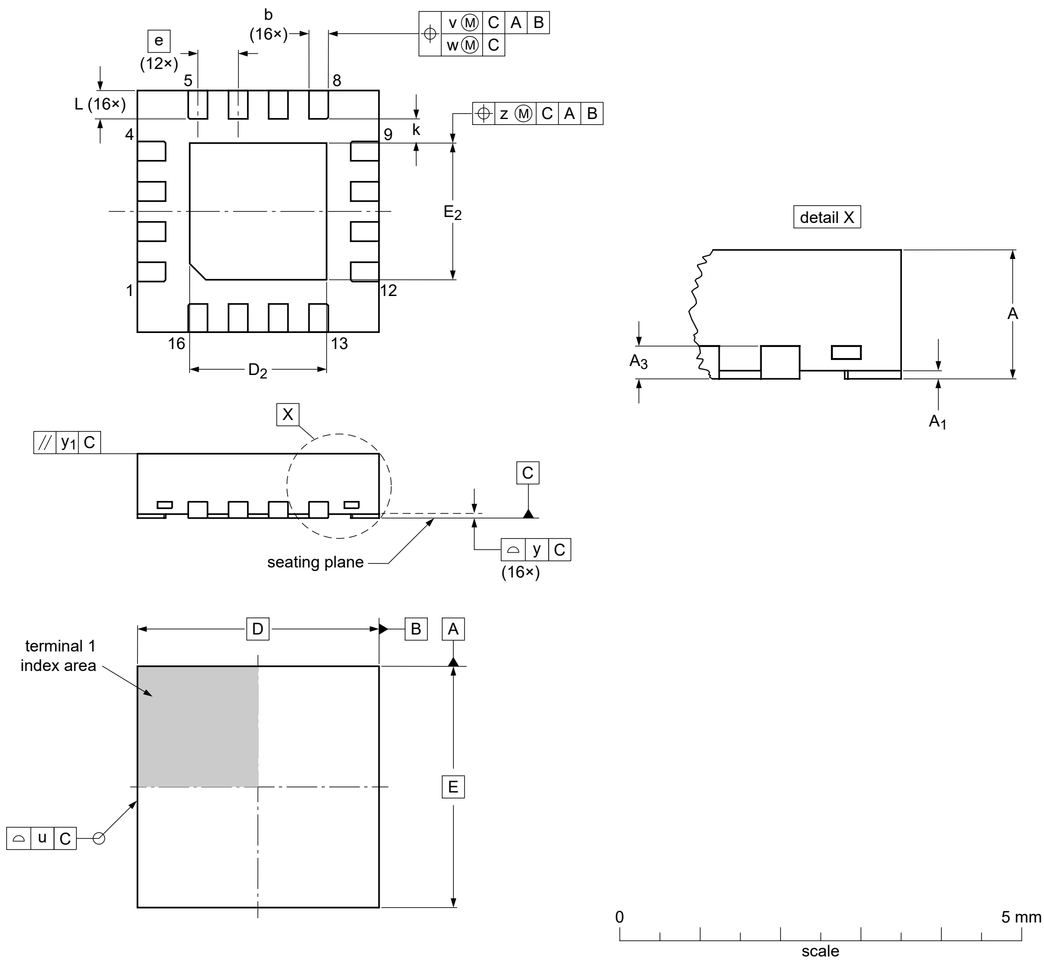


Fig. 14. Application with maximum battery-voltage protection

12. Package outline

HWQFN16: plastic thermal enhanced very very thin Quad Flat packages; no leads; 16 terminals; 0.5 mm pitch; 3.0 × 3.0 × 0.75 mm body **SOT8076-1**



Dimensions (mm are the original dimensions)

Unit(1)		A	A_1	A_3	b	D	D_2	E	E_2	e	k	L	u	v	w	y	y_1	z
mm	max	0.80	0.05		0.30		1.75		1.75			0.40						
	nom	0.75	0.02	0.20 REF	0.24	3.00 BSC	1.70	3.00 BSC	1.70	0.50 BSC	0.30 REF	0.35	0.15	0.10	0.05	0.08	0.10	0.10
	min	0.70	0		0.18		1.65		1.65			0.30						

sot8076-1_po

Outline version	References: IEC	References: JEDEC	References: JEITA		European projection	Issue date
SOT8076-1		MO-220 (WEED-4)				23-03-20

Fig. 15. Package outline

13. Soldering

Footprint information for reflow soldering of HWQFN16 package **SOT8076-1**

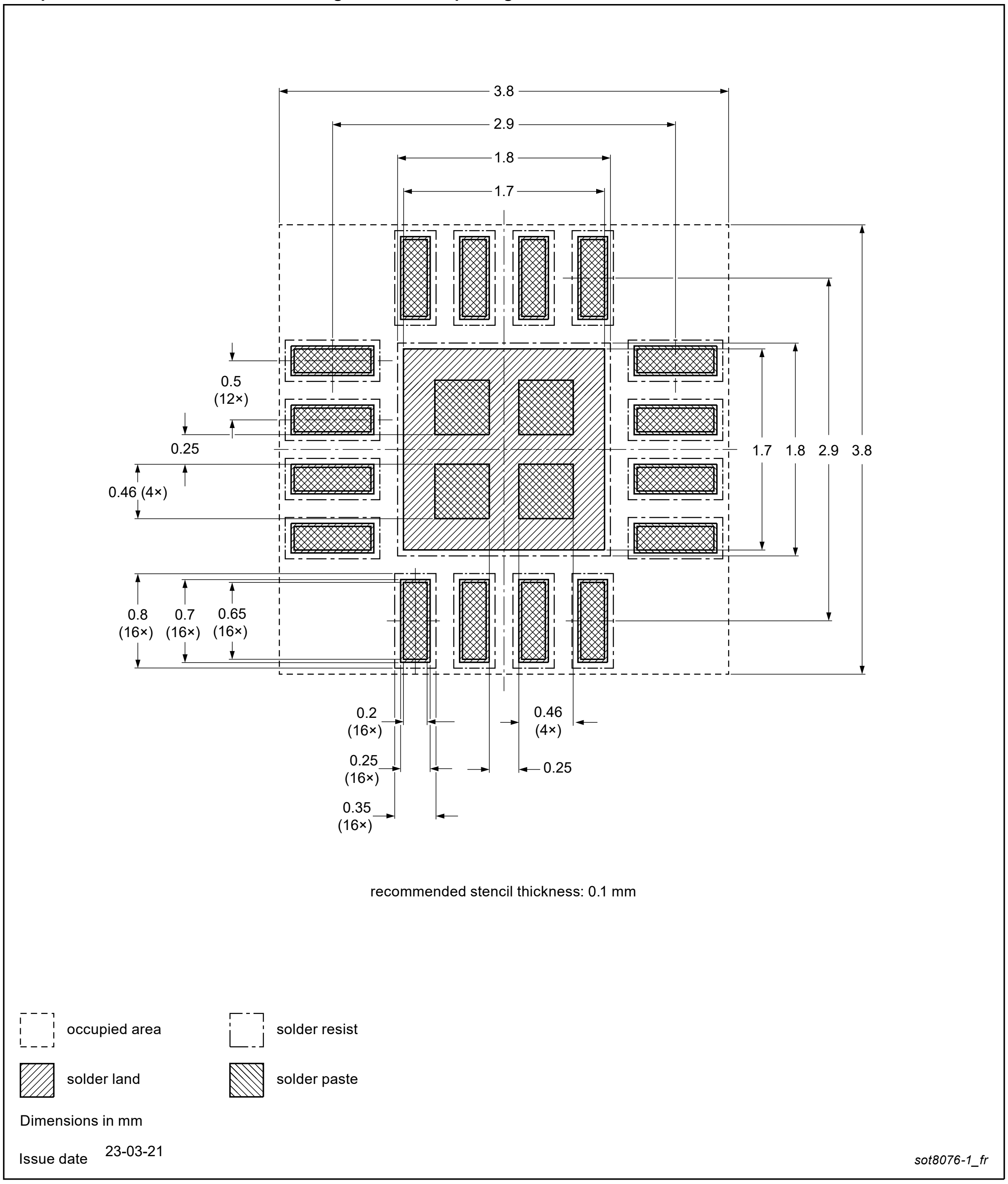


Fig. 16. Soldering footprint

14. Revision history

Table 9. Revision history

Document ID	Release date	Data sheet status	Change notice	Supersedes
NEH2000BY v.4	20230816	Product data sheet	-	NEH2000BY v.3.1
Modifications:	Table 6 and Table 7 updated.			
NEH2000BY v.3.1	20230403	Product data sheet	-	NEH2000BY v.3
Modifications:	Footnote added in Table 3. Table 7 format adjusted.			
NEH2000BY v.3	20230328	Product data sheet	-	NEH2000BY v.2
Modifications:	Pin names updated. Section 11.4, Section 11.5 and Section 12 revised.			
NEH2000BY v.2	20230302	Preliminary data sheet	-	NEH2000BY v.1
Modifications:	Updated to latest Nexperia technical document format			
NEH2000BY v.1 *note: previously named NH2D0245 Revison 1.0*	20221101	Preliminary data sheet	-	-

15. Legal information

Data sheet status

Document status [1][2]	Product status [3]	Definition
Objective [short] data sheet	Development	This document contains data from the objective specification for product development.
Preliminary [short] data sheet	Qualification	This document contains data from the preliminary specification.
Product [short] data sheet	Production	This document contains the product specification.

[1] Please consult the most recently issued document before initiating or completing a design.
[2] The term 'short data sheet' is explained in section "Definitions".
[3] The product status of device(s) described in this document may have changed since this document was published and may differ in case of multiple devices. The latest product status information is available on the internet at https://www.nexperia.com.

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