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](image-url)
4. Pinning information

Package Diagram

![NEH2000BY 16-pin QFN 3 x 3 mm package](image)

**Fig. 2.** QFN16 3 mm x 3 mm package

**Table 1. Pinning information**

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

Table 2. Ordering information

<table>
<thead>
<tr>
<th>Type number</th>
<th>Package</th>
<th>Description</th>
<th>Version</th>
</tr>
</thead>
<tbody>
<tr>
<td>NEH2000BY</td>
<td>SOT8076-1</td>
<td>Plastic Quad Flat package, no leads; 16 terminals: 0.5 mm pitch 3 mm x 3 mm x 0.75 mm body</td>
<td>1.0</td>
</tr>
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</table>

6. Block Diagram

![NEH2000BY block diagram](image)

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).

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Conditions</th>
<th>Min</th>
<th>Max</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>VIN</td>
<td>input voltage [1]</td>
<td>-0.3</td>
<td>VBAT+0.3</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>-0.3</td>
<td>5</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>VBAT</td>
<td>battery voltage</td>
<td>-0.3</td>
<td>5</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>VDISABLE</td>
<td>DISABLE input voltage</td>
<td>-0.3</td>
<td>5</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>IIN</td>
<td>input current</td>
<td>-</td>
<td>100</td>
<td>mA</td>
<td></td>
</tr>
<tr>
<td>Tj</td>
<td>junction temperature</td>
<td>-50</td>
<td>+125</td>
<td>°C</td>
<td></td>
</tr>
<tr>
<td>Tstab</td>
<td>storage temperature</td>
<td>-65</td>
<td>+150</td>
<td>°C</td>
<td></td>
</tr>
</tbody>
</table>

[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

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Conditions</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>VESD</td>
<td>electrostatic discharge voltage</td>
<td>HBM: ANSI/ESDA/JEDEC JS-001</td>
<td>± 2000</td>
<td>V</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CDM: ANSI/ESDA/JEDEC JS-002</td>
<td>± 1000</td>
<td>V</td>
</tr>
</tbody>
</table>
8. Recommended operating conditions

Table 5. Recommended operating conditions

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Conditions</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_{\text{BAT}}$</td>
<td>battery voltage</td>
<td></td>
<td>2.5</td>
<td>-</td>
<td>4.5</td>
<td>V</td>
</tr>
<tr>
<td>$T_{\text{amb}}$</td>
<td>ambient temperature</td>
<td></td>
<td>-40</td>
<td>-</td>
<td>+85</td>
<td>°C</td>
</tr>
</tbody>
</table>

9. Thermal characteristics

Table 6. Thermal characteristics

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>SOT8076-1</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>$R_{\text{j(a)}}$</td>
<td>junction-to-ambient thermal resistance</td>
<td>97</td>
<td>K/W</td>
</tr>
<tr>
<td>$R_{\text{j(top)}}$</td>
<td>junction-to-case (top) thermal resistance</td>
<td>88</td>
<td>K/W</td>
</tr>
<tr>
<td>$\psi_{\text{j(top)}}$</td>
<td>junction-to-case (top) thermal characterization parameter</td>
<td>60</td>
<td>K/W</td>
</tr>
</tbody>
</table>

10. Characteristics

Table 7. Characteristics

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

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Conditions</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_{\text{BAT}}$</td>
<td>battery voltage</td>
<td></td>
<td>-</td>
<td>2.5</td>
<td>2.7</td>
<td>V</td>
</tr>
<tr>
<td>$V_{\text{IN}}$</td>
<td>harvester input voltage</td>
<td>after startup SYSRDY is high</td>
<td>1.9</td>
<td>-</td>
<td>-</td>
<td>V</td>
</tr>
<tr>
<td>$I_{\text{STBY}}$</td>
<td>standby current</td>
<td></td>
<td>-</td>
<td>625</td>
<td>1150</td>
<td>nA</td>
</tr>
<tr>
<td>$V_{\text{REF}}$</td>
<td>internally generated supply</td>
<td></td>
<td>1.6</td>
<td>1.8</td>
<td>2</td>
<td>V</td>
</tr>
<tr>
<td>$t_{\text{start}}$</td>
<td>start-up time</td>
<td></td>
<td>-</td>
<td>50</td>
<td>-</td>
<td>ms</td>
</tr>
</tbody>
</table>

Power converter

$P_{\text{IN(low)}}$ input power range, low-end efficiency = 70%

$P_{\text{IN(high)}}$ input power range, high-end efficiency = 70%

$T_{\text{MPPT}}$ MPPT interval

$T_{\text{MPPT OPT}}$ MPPT optimization time

$f_{\text{CONV(low)}}$ frequency at low-end power $P_{\text{IN}} = 35$ μW

$f_{\text{CONV(high)}}$ frequency at high-end power $P_{\text{IN}} = 2$ mW

Control

$V_{\text{IL}}$ logic low level for DISABLE

$V_{\text{IH}}$ logic high level for DISABLE

[1] Reduced performance to be expected for $V_{\text{BAT}} < 2.5$ V.

[2] To prevent battery charging directly from the PV-cell take care that $V_{\text{OC}}$ is lower than $V_{\text{BAT}}$ plus a diode voltage (≈0.5 V).

[3] Do not use/load $V_{\text{REF}}$ in the application.
10.1. Typical performance characteristics

\( V_{\text{BAT}} = 3 \, V, \, V_{\text{OC}} = 3 \, V, \, T_{\text{amb}} = 25 \, ^{\circ}C, \, \text{unless otherwise specified.} \)

- **Fig. 4.** Stand-by current as a function of \( V_{\text{BAT}} \)

\[ T_{\text{amb}} = 85 \, ^{\circ}C, \, 25 \, ^{\circ}C, \, -40 \, ^{\circ}C \]

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

\( \text{DISABLE} = \text{LOW} \)

- **Fig. 6.** Efficiency as a function of available power

\[ T_{\text{amb}} = 85 \, ^{\circ}C, \, 25 \, ^{\circ}C, \, -40 \, ^{\circ}C \]

- **Fig. 7.** Efficiency as a function of input current

\[ T_{\text{amb}} = 85 \, ^{\circ}C, \, 25 \, ^{\circ}C, \, -40 \, ^{\circ}C \]
\[ V_{BAT} = 3 \text{ V}, \quad V_{OC} = 3 \text{ V}, \quad T_{amb} = 25 \degree C, \text{ unless otherwise specified.} \]

**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**

- Battery voltage = 2.7 V, 3.0 V, 3.5 V

**Fig. 10. Efficiency as a function of available power**

- \( V_{OC} = 2.5 \text{ V}, 3.0 \text{ V}, 3.3 \text{ V} \)

**Fig. 11. Efficiency as a function of input current**

- \( V_{OC} = 2.5 \text{ V}, 3.0 \text{ V}, 3.3 \text{ V} \)
11. Application information

11.1. Typical application

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

![Typical PV-Cell application](image)

**Fig. 12. Typical PV-Cell application**

<table>
<thead>
<tr>
<th>Reference designator</th>
<th>Description</th>
<th>Type</th>
<th>Value</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>U1</td>
<td>PMIC</td>
<td>NEH2000BY</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>C1, C2</td>
<td>capacitor</td>
<td>X7R / 6.3 V</td>
<td>2.2 µF</td>
<td>2</td>
</tr>
<tr>
<td>C3</td>
<td>capacitor</td>
<td>X7R / 6.3 V</td>
<td>5.6 nF</td>
<td>1</td>
</tr>
</tbody>
</table>

11.2. Harvesting efficiency

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

- $\text{Eff}_{\text{converter}}$: The efficiency of the power converter in the NEH2000BY
- $\text{Eff}_{\text{match}}$: The matching efficiency between the NEH2000BY and the PV-cell

$$\text{Eff}_{\text{total}} = \text{Eff}_{\text{converter}} \times \text{Eff}_{\text{match}}$$  \hspace{1cm} (1)

![Matching and converter efficiency](image)

**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:

\[
\text{Eff}_{\text{converter}} = \frac{P_{OUT}}{P_{IN}} \times 100 \%
\]  

(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

\[
\text{Eff}_{\text{match}} = \frac{P_{IN}}{P_{\text{available}}} \times 100 \%
\]  

(3)

Where $P_{IN}$ is the actual power at the input of the power converter and $P_{\text{available}}$ 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:

\[
V_{IN} = \frac{V_{BAT}}{\text{Boosting factor}}
\]  

(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 ($V_{\text{MPPT}}$). This is the voltage on the power converter’s input where most power is delivered by the PV-cell:

\[
V_{\text{MPPT}} = 0.7 \ldots 0.9 \times V_{OC}
\]  

(5)

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

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

\[
V_{OC} = \frac{V_{BAT}}{\text{Boosting factor} \times \text{MPPT ratio}}
\]  

\[
V_{OC} = 0.69 \times V_{BAT}
\]  

(6)

Thus, for optimal matching efficiency a PV-cell should be chosen with a $V_{OC}$ that is $0.69 \times V_{BAT}$. 
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 $0.8 \times V_{OC}$, the following guideline for the PV-cell applies:

$$V_{OC} = 0.5 \ldots 0.8 \times V_{BAT}$$

(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 thin Quad Flat packages; no leads; 16 terminals; 0.5 mm pitch; 3.0 × 3.0 × 0.75 mm body

![Package outline diagram](image)

Dimensions (mm are the original dimensions)

<table>
<thead>
<tr>
<th>Unit(1)</th>
<th>A</th>
<th>A1</th>
<th>A3</th>
<th>b</th>
<th>D</th>
<th>D2</th>
<th>E</th>
<th>E2</th>
<th>E3</th>
<th>k</th>
<th>L</th>
<th>u</th>
<th>v</th>
<th>w</th>
<th>y1</th>
<th>z</th>
</tr>
</thead>
<tbody>
<tr>
<td>mm max</td>
<td>0.80</td>
<td>0.05</td>
<td>0.20</td>
<td>0.30</td>
<td>0.30</td>
<td>0.30</td>
<td>0.40</td>
<td>0.50</td>
<td>0.65</td>
<td>0.10</td>
<td>0.05</td>
<td>0.08</td>
<td>0.10</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>mm nom</td>
<td>0.75</td>
<td>0.05</td>
<td>0.20</td>
<td>0.24</td>
<td>0.24</td>
<td>0.24</td>
<td>0.30</td>
<td>0.30</td>
<td>0.35</td>
<td>0.15</td>
<td>0.10</td>
<td>0.10</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

![scale X](image)

Fig. 15. Package outline
13. Soldering

Footprint information for reflow soldering of HWQFN16 package

Dimensions in mm

Issue date: 23-03-21

recommended stencil thickness: 0.1 mm

Fig. 16. Soldering footprint
# 14. Revision history

<table>
<thead>
<tr>
<th>Document ID</th>
<th>Release date</th>
<th>Data sheet status</th>
<th>Change notice</th>
<th>Supersedes</th>
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<td>20230816</td>
<td>Product data sheet</td>
<td>-</td>
<td>NEH2000BY v.3.1</td>
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<td>Modifications:</td>
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<tr>
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<td>20230302</td>
<td>Preliminary data sheet</td>
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<td>Updated to latest Nexperia technical document format</td>
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<tr>
<td>NEH2000BY v.1</td>
<td>20221101</td>
<td>Preliminary data sheet</td>
<td>-</td>
<td>-</td>
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<td>note: previously named NH2D0245 Revision 1.0</td>
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### Legal information

#### Data sheet status

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<th>Product status</th>
<th>Definition</th>
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<td>Development</td>
<td>This document contains data from the objective specification for product development.</td>
</tr>
<tr>
<td>Preliminary [short] data sheet</td>
<td>Qualification</td>
<td>This document contains data from the preliminary specification.</td>
</tr>
<tr>
<td>Product [short] data sheet</td>
<td>Production</td>
<td>This document contains the product specification.</td>
</tr>
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</table>

[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

#### Definitions

**Draft** — The document is a draft version only. The content is still under internal review and subject to formal approval, which may result in modifications or additions. Nexperia does not give any representations or warranties as to the accuracy or completeness of information included herein and shall have no liability for the consequences of use of such information.

**Short data sheet** — A short data sheet is an extract from a full data sheet with the same product type (s) and title. A short data sheet is intended for quick reference only and should not be relied upon to contain detailed and full information. For detailed and full information see the relevant full data sheet, which is available on request via the local Nexperia sales office. In case of any inconsistency or conflict with the short data sheet, the full data sheet shall prevail.

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