Description

The AEM30330 evaluation board is a printed circuit board (PCB) featuring all the needed components to operate the AEM30330 integrated circuit (IC).

The AEM30330 evaluation board allows users to test the e-peas IC and analyze its performances in a laboratory-like setting.

It allows easy connections to the energy harvester, the storage element and the load. It also provides all the configuration access to set the device in any one of the modes described in the datasheet. The control and status signals are available on standard pin headers, allowing users to wire for any usage scenario and evaluate the relevant performances.

The AEM30330 evaluation board is a plug and play, intuitive and efficient tool for making the appropriate decisions (component selection, operating modes, etc.) for the design of a highly efficient subsystem in your target application.

More detailed information about AEM30330 features can be found in the datasheet.

Appearance

Features

Five two-way screw terminals
- Source of energy (DC).
- Source of energy (AC low frequency).
- Source of energy (AC medium frequency).
- Load.
- ZMPP configuration.

One three-way screw terminal
- Energy storage element (battery or (super)capacitor).

One 2-pin “Shrouded Header”
- Alternative connector for the storage element.

3-pin headers
- Maximum power point ratio (R_MPP) configuration.
- Maximum power point timing (T_MPP) configuration.
- Storage element voltage configuration.
- Load voltage configuration.
- Dual-cell supercapacitor configuration.
- Modes configuration.

Provision for seven resistors
- Custom mode configuration.
- ZMPP configuration.

Configuration by 0 Ω resistors
- Cold start input configuration.

Four 1-pin headers
- Access to status pins.

Device Information

<table>
<thead>
<tr>
<th>Part Number</th>
<th>Dimensions</th>
</tr>
</thead>
<tbody>
<tr>
<td>2AAEM30330C001</td>
<td>76 mm x 50 mm</td>
</tr>
</tbody>
</table>
1. Connections Diagram

Figure 1: Connection Diagram
### 1.1. Signals Description

<table>
<thead>
<tr>
<th><strong>NAME</strong></th>
<th><strong>FUNCTION</strong></th>
<th><strong>CONNECTION</strong></th>
<th>If used</th>
<th>If not used</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Power signals</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SRC</td>
<td>Connection to the harvested energy source.</td>
<td>Connect the source element.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>STO</td>
<td>Connection to the energy storage element.</td>
<td>Connect the storage element in addition to CSTO (150 µF).</td>
<td></td>
<td>Do not remove CSTO.</td>
</tr>
<tr>
<td>BAL</td>
<td>Connection to mid-point of the dual-cell supercapacitor.</td>
<td>Connect balancing and place a jumper shorting “BAL” and “ToCN”.</td>
<td></td>
<td>Use a jumper to connect “BAL” to “GND”.</td>
</tr>
<tr>
<td>LOAD</td>
<td>Connection to the load (Application).</td>
<td>Connect a load.</td>
<td></td>
<td>Leave floating.</td>
</tr>
<tr>
<td>LF</td>
<td>Connection to the AC harvested energy source. (Low frequency).</td>
<td>Connect the source element.</td>
<td></td>
<td>Leave floating.</td>
</tr>
<tr>
<td>MF</td>
<td>Connection to the AC harvested energy source. (Medium frequency).</td>
<td>Connect the source element.</td>
<td></td>
<td>Leave floating.</td>
</tr>
<tr>
<td><strong>Debug signals</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VINT</td>
<td>Internal voltage supply.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BUFSRC</td>
<td>Connection to an external capacitor buffering the buck-boost converter input.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Configuration signals</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ZMPP</td>
<td>Configuration of the constant impedance MPP.</td>
<td>Use resistor RZMPP.</td>
<td></td>
<td>Leave floating.</td>
</tr>
<tr>
<td><strong>Control signals</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EN_HP</td>
<td>Enabling pin for the high-power mode.</td>
<td>Connect jumper.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>STO_PRIO</td>
<td>Pin for the storage/load priority.</td>
<td>Connect jumper.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>EN_STO_FT</td>
<td>Enabling pin for the feed-through feature.</td>
<td>Connect jumper.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>EN_STO_CH</td>
<td>Enabling pin for the storage charging.</td>
<td>Connect jumper.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>EN_SLEEP</td>
<td>Enabling pin for the sleep mode.</td>
<td>Connect jumper.</td>
<td></td>
<td>Can’t be left floating.</td>
</tr>
<tr>
<td><strong>Status Signals</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ST_LOAD</td>
<td>Logic output. Asserted when the LOAD voltage rises above the $V_{LOAD,TYP}$ threshold. Reset when the LOAD voltage drops below $V_{LOAD,MIN}$ threshold. High level is $V_{LOAD}$.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ST_STO</td>
<td>Logic output. Asserted when the storage device voltage rises above the $V_{CHRDY}$ threshold. Reset when the storage device voltage drops below $V_{OVDIS}$ threshold. High level is $V_{STO}$.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ST_STO_RDY</td>
<td>Logic output. Asserted when the storage element is above $V_{CHRDY}$. High level is $V_{LOAD}$.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ST_STO_OVDIS</td>
<td>Logic output. Asserted when the storage element voltage $V_{STO}$ drops below $V_{OVDIS}$. High level is $V_{LOAD}$.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 1: Signals Description
2. General Considerations

2.1. Safety Information

Always connect the elements in the following order:

1. Reset the board: Short VINT, LOAD, STO and SRC test points to GND.
2. Completely configure the PCB (jumpers/resistors):
   - MPP configuration (Ratio/Timing).
   - Battery configuration.
   - Load voltage configuration.
   - Balancing circuit configuration.
   - Mode configuration.
3. Connect the storage elements on STO.
4. Connect the Load on LOAD.
5. Connect the source (DC or AC) to the SRC connector.

To avoid damaging the board, users are required to follow this procedure.
The pins “BAL” and EN_SLEEP cannot remain floating.

2.2. Basic Configurations

<table>
<thead>
<tr>
<th>Configuration pins</th>
<th>Storage element threshold voltages</th>
<th>Typical use</th>
</tr>
</thead>
<tbody>
<tr>
<td>STO_CFG[3:0]</td>
<td>V_OVDIS</td>
<td>V_CHRDY</td>
</tr>
<tr>
<td>L</td>
<td>3.00 V</td>
<td>3.50 V</td>
</tr>
<tr>
<td>L</td>
<td>2.80 V</td>
<td>3.10 V</td>
</tr>
<tr>
<td>L</td>
<td>1.85 V</td>
<td>2.40 V</td>
</tr>
<tr>
<td>L</td>
<td>0.20 V</td>
<td>1.00 V</td>
</tr>
<tr>
<td>L</td>
<td>0.20 V</td>
<td>1.00 V</td>
</tr>
<tr>
<td>L</td>
<td>1.00 V</td>
<td>1.20 V</td>
</tr>
<tr>
<td>L</td>
<td>1.85 V</td>
<td>2.30 V</td>
</tr>
<tr>
<td>L</td>
<td>1.10 V</td>
<td>1.25 V</td>
</tr>
<tr>
<td>H</td>
<td>2.20 V</td>
<td>2.50 V</td>
</tr>
<tr>
<td>H</td>
<td>1.45 V</td>
<td>2.00 V</td>
</tr>
<tr>
<td>H</td>
<td>1.00 V</td>
<td>1.20 V</td>
</tr>
<tr>
<td>H</td>
<td>2.00 V</td>
<td>2.30 V</td>
</tr>
<tr>
<td>H</td>
<td>3.00 V</td>
<td>3.50 V</td>
</tr>
<tr>
<td>H</td>
<td>2.60 V</td>
<td>2.70 V</td>
</tr>
<tr>
<td>H</td>
<td>2.60 V</td>
<td>3.50 V</td>
</tr>
</tbody>
</table>

Table 2: Storage Element Configuration Pins
### Configuration pins - MPPT ratio

<table>
<thead>
<tr>
<th>R_MPP[2:0]</th>
<th>$V_{MPP}$ / $V_{OC}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>L L L</td>
<td>35%</td>
</tr>
<tr>
<td>L L H</td>
<td>50%</td>
</tr>
<tr>
<td>L H L</td>
<td>60%</td>
</tr>
<tr>
<td>L H H</td>
<td>65%</td>
</tr>
<tr>
<td>H L L</td>
<td>70%</td>
</tr>
<tr>
<td>H L H</td>
<td>75%</td>
</tr>
<tr>
<td>H H L</td>
<td>80%</td>
</tr>
<tr>
<td>H H H</td>
<td>ZMPP</td>
</tr>
</tbody>
</table>

Table 3: MPP Ratio Configuration Pins

### Configuration pins - MPPT timing

<table>
<thead>
<tr>
<th>T_MPP[1:0]</th>
<th>Sampling duration</th>
<th>Sampling period</th>
</tr>
</thead>
<tbody>
<tr>
<td>L L</td>
<td>3.83 ms</td>
<td>18.28 ms</td>
</tr>
<tr>
<td>L H</td>
<td>5.1 ms</td>
<td>280 ms</td>
</tr>
<tr>
<td>H L</td>
<td>71.6 ms</td>
<td>1.12 s</td>
</tr>
<tr>
<td>H H</td>
<td>1.12 s</td>
<td>71.7 s</td>
</tr>
</tbody>
</table>

Table 4: MPP Timing Configuration Pins

### Configuration pins - LOAD output voltage

<table>
<thead>
<tr>
<th>LOAD_CFG[2:0]</th>
<th>$V_{LOAD,MIN}$</th>
<th>$V_{LOAD,MID}$</th>
<th>$V_{LOAD,TYP}$</th>
<th>$V_{LOAD,MAX}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>L L L</td>
<td>3.15 V</td>
<td>3.23 V</td>
<td>3.28 V</td>
<td>3.34 V</td>
</tr>
<tr>
<td>L L H</td>
<td>2.35 V</td>
<td>2.47 V</td>
<td>2.50 V</td>
<td>2.53 V</td>
</tr>
<tr>
<td>L H L</td>
<td>1.64 V</td>
<td>1.75 V</td>
<td>1.79 V</td>
<td>1.82 V</td>
</tr>
<tr>
<td>L H H</td>
<td>1.14 V</td>
<td>1.16 V</td>
<td>1.20 V</td>
<td>1.23 V</td>
</tr>
<tr>
<td>H L L</td>
<td>1.39 V</td>
<td>1.56 V</td>
<td>1.61 V</td>
<td>2.63 V</td>
</tr>
<tr>
<td>H L H</td>
<td>1.39 V</td>
<td>1.56 V</td>
<td>1.61 V</td>
<td>4.65 V</td>
</tr>
<tr>
<td>H H L</td>
<td>Reserved, do not use.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>H H H</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 5: Load Configuration Pins
2.3. Advanced Configurations

A complete description of the system constraints and configurations is available in the AEM30330 datasheet “System Configuration” Section.

A reminder on how to calculate the configuration resistors value is provided below. Calculation can be made with the help of the spreadsheet found on the e-peas website.

2.3.1. Custom Mode

In addition to the pre-defined protection levels, the custom mode allows users to define their own levels via resistors R1 to R4, according to the following equations:

\[
\begin{align*}
R_1 &= R_2 + R_3 + R_4 \\
10 \Omega &\leq R_1 &\leq 100 \Omega \\
R_1 &= \frac{1V}{V_{OVCH}} \\
R_2 &= R_1 \times \left( \frac{1V}{V_{CHRDY}} - \frac{1V}{V_{OVCH}} \right) \\
R_3 &= R_1 \times \left( \frac{1V}{V_{OVDIS}} - \frac{1V}{V_{CHRDY}} \right) \\
R_4 &= R_1 \times \left( 1 - \frac{1V}{V_{OVDIS}} \right)
\end{align*}
\]

User must ensure that the protection levels satisfy the following conditions:

\[
\begin{align*}
V_{CHRDY} + 0.05V &\leq V_{OVCH} \leq 4.5V \\
V_{OVDIS} + 0.05V &\leq V_{CHRDY} \leq V_{OVCH} - 0.05V \\
1V &\leq V_{OVDIS}
\end{align*}
\]

If unused, leave the resistor footprints (R1 to R4) empty.

2.3.2. ZMPP Configuration

If this configuration is chosen (see Table 3), the AEM30330 regulates \(\text{V}_{\text{SRC}}\) at a voltage equals to the product of \(R_{\text{ZMPP}}\) times the current available at the source \(\text{SRC}\).

\[
10 \Omega \leq R_{\text{ZMPP}} \leq 1 \Omega
\]

If unused, leave the resistor footprint \(R_{\text{ZMPP}}\) empty.

2.3.3. Balancing Circuit Configuration

When using a dual-cell supercapacitor (that does not already include a balancing circuit), enable the balancing circuit configuration to ensure equal voltage on both cells. To do so:

- Connect the node between the two supercapacitor cells to \(\text{BAL}\) (on \(\text{STO}\) connector).
- Use a jumper to connect “BAL” to “ToCN”.

If unused, use a jumper to connect “BAL” to “GND”.

2.3.4. Mode Configuration

**EN_HP**

When \(\text{EN}_\text{HP}\) is pulled up to \(\text{VINT}\), the DCDC converter is set to HIGH POWER MODE. This allows higher currents to be extracted from the buck-boost input (\(\text{SRC}\) or \(\text{STO}\)) to the buck-boost output (\(\text{LOAD}\), \(\text{STO}\) or \(\text{VINT}\)).

- Use a jumper to connect \(\text{EN}_\text{HP}\) to H to enable the high-power mode.
- Use a jumper to connect \(\text{EN}_\text{HP}\) to L to disable the high-power mode.

**STO_PRIO**

It is possible to define a priority between \(\text{STO}\) and \(\text{LOAD}\).

- Use a jumper to connect the \(\text{STO}_\text{PRIO}\) to H to supply the storage element to \(V_{\text{CHRDY}}\) before start supplying the \(\text{LOAD}\).
- Use a jumper to connect the \(\text{STO}_\text{PRIO}\) to L to supply in the first place the \(\text{LOAD}\), charging the storage element with the remaining energy.

**EN_STO_CH**

To disable battery charging, the 3-pin header is available.

- Use a jumper to connect the \(\text{EN}_\text{STO}_\text{CH}\) to H to enable the charge of the storage element.
- Use a jumper to connect the \(\text{EN}_\text{STO}_\text{CH}\) to L to disable the charge of the storage element.

An internal pull-up resistor is setting the \(\text{EN}_\text{STO}_\text{CH}\) at H by default.

**EN_SLEEP**

The SLEEP STATE reduces the AEM30330 quiescent current by ceasing the energy extraction from the \(\text{SRC}\) and reducing \(V_{\text{LOAD}}\) and \(V_{\text{VIN}}\) monitoring period.

- Use a jumper to connect the \(\text{EN}_\text{SLEEP}\) to H to activate the feature.
- Use a jumper to connect the \(\text{EN}_\text{SLEEP}\) to L to disable the feature.

Do not leave \(\text{EN}_\text{SLEEP}\) floating, doing so could damage the AEM.

**EN_STO_FT**

To disable the source to storage element feed-through, the 3-pin header is available.

- Use a jumper to connect the \(\text{EN}_\text{STO}_\text{FT}\) to H to enable the feature.
- Use a jumper to connect the \(\text{EN}_\text{STO}_\text{FT}\) to L to disable the feature.
2.3.5. Rectifier Use

When a rectifier is used, it is recommended to use the ZMPP configuration. With a MPP ratio, the voltage level of the MPPT will not be the right one. In fact, due to the rectifier capacitor, the open-circuit evaluation will not be done correctly.
3. Functional Tests

This section presents a few simple tests that allow the user to understand the functional behavior of the AEM30330. To avoid damaging the board, follow the procedure found in Section 2.1 “Safety Information”. If a test has to be restarted make sure to properly reset the system to obtain reproducible results.

The following functional tests were made using the following setup:

- \( R_{MPP}[2:0] = LLL \).
- \( T_{MPP}[1:0] = LH \).
- \( STO_{CFG}[3:0] = LLLL \).
- \( EN_{HP} = H \).
- \( STO_{PRI} = H \).
- \( EN_{STO_{FT}} = L \).
- \( EN_{STO_{CH}} = H \).
- \( EN_{SLEEP} = L \).
- Storage element: Capacitor (4.7 mF + CSTO).
- Load: 10kOhm on LOAD.
- SRC: current source (1mA or 100uA) with voltage compliance (4V).

Setup can be adapted to match user’s system as long as the input and cold-start constraints are met (see the AEM30330 datasheet “Introduction” Section).

3.1. Start-up

The following example allows the user to observe the behavior of the AEM30330 in Wake-up state.

**Setup**

- Place the probes on the nodes to be observed.
- Referring to Figure 1, follow steps 1 to 5 explained in Section 2.1 “Safety Information”.

**Observations and Measurements**

- \( STO \): Voltage rises as the power provided by the source is transferred to the storage element.
- \( LOAD \): Regulated when voltage on \( STO \) first rises above \( V_{CHRDY} \).
- \( ST_{LOAD} \): Asserted when \( LOAD \) is supplied.
- \( ST_{STO} \) and \( ST_{STO_{RDY}} \): Asserted when the voltage on \( STO \) rises above \( V_{CHRDY} \).

3.2. Shutdown

This test allows users to observe the behavior of the AEM30330 when the system is running out of energy.

**Setup**

- Place the probes on the nodes to be observed.
- Referring to Figure 1, follow steps 1 to 5 explained in Section 2.1 “Safety Information”. Configure the board in the desired state and start the system (see Section 3.1).
- Let the system reach a steady state (i.e. voltage on \( STO \) between \( V_{CHRDY} \) and \( V_{OVCH} \) and \( ST_{STO} \) asserted).
- Remove your source element and let the system discharge through quiescent current and load.

**Observations and Measurements**

- \( STO \): Voltage decreases as the system consumes the power accumulated in the storage element. The voltage reaches \( V_{OVDIS} \).
- \( ST_{STO_{RDY}} \): De-asserted when the voltage on \( STO \) goes below \( V_{CHRDY} \).
- \( ST_{LOAD} \): De-asserted when the load is no longer available.
- \( ST_{STO_{OVDIS}} \): Asserted for 680 ms when the storage element voltage (\( STO \)) falls below \( V_{OVDIS} \).
- \( ST_{STO} \): De-asserted when the storage element is running out of energy (\( V_{OVDIS} \)).
3.3. Cold Start

The following test allows the user to observe the minimum voltage required to coldstart the AEM30330. To prevent leakage current induced by the probe the user should avoid probing any unnecessary node. Make sure to properly reset the board to observe the cold-start behavior.

Setup
- Place the probes on the nodes to be observed.
- Referring Figure 1, follow steps 1 and 2 explained in Section 2.1. Configure the board in the desired state. Do not plug any storage element in addition to CSTO.
- SRC: Connect your source element.

Observations and Measurements
- SRC: Equal to the cold-start voltage during the cold-start phase. Regulated at the selected MPPT percentage of $V_{OC}$ when cold start is over. Be careful that the cold-start phase time will shorten with the input power. Limit it to ease the observation.
- STO: Starts to charge the storage element when the cold-start phase is over.

3.4. Dual-cell Supercapacitor Balancing Circuit

This test allows users to observe the balancing circuit behavior that maintains the voltage on BAL at half the voltage on STO.

Setup
- Following steps 1 and 2 explained in Section 2.1 and referring to Figure 1, configure the board in the desired state. Plug the jumper linking “BAL” to “ToCN”.
- STO: Connect capacitor C1 between the positive (+) and the BAL pins and a capacitor C2 between BAL and the negative (-) pins. Select C1 and C2 so that:
  - C1 ≠ C2
  - C1 > 1mF
  - C2 > 1mF
  - $\frac{C2 \cdot V_{CHRDY}}{C1} ≥ 0.9V$
- SRC: Plug your source element to start the power flow to the system.

Observations and Measurements
- BAL: Equals to half the voltage on STO.

Do not leave BAL floating, doing so could damage the AEM.

3.5. Source to Storage Element Feed-Through

This example allows users to observe the feed-through feature.

Setup
- Place the probes on the nodes to be observed.
- Referring to Figure 1, follow steps 1 to 5 explained in Section 2.1 “Safety Information”. Configure the board in the desired state and start the system (see Section 3.1).
- Let the system reach a steady state (i.e. voltage on STO between $V_{CHRDY}$ and $V_{OVCH}$ and ST_STO asserted.
- EN_STO_FT: Connect to VINT.
- SRC: current source (1mA or 100uA) with voltage compliance (5V).
- Connect a capacitor (>1mF) on SRC and STO to avoid perturbation due to the SMU behavior.

Observations and Measurements
- STO: The current from the source is transferred directly to the storage element.
4. Schematics

Figure 2: Schematic Part 1
Figure 3: Schematic Part 2
## 5. Revision History

<table>
<thead>
<tr>
<th>EVK Version</th>
<th>User Guide Revision</th>
<th>Date</th>
<th>Description</th>
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<tr>
<td>Up to 1.2</td>
<td>1.0</td>
<td>September, 2021</td>
<td>Creation of the document.</td>
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<td></td>
<td>1.1</td>
<td>November, 2022</td>
<td>Fixed some inconsistencies and updated images.</td>
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<tr>
<td>1.3</td>
<td>1.0</td>
<td>August, 2023</td>
<td>Images and schematics update to EVK v1.3.</td>
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<td>1.3</td>
<td>1.1</td>
<td>December, 2023</td>
<td>- Updated Revision History table to separate EVK version and User Guide version.</td>
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<td></td>
<td></td>
<td></td>
<td>- Replaced 0/1 by L/H.</td>
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Table 6: Revision History