

## Highly Versatile Buck-Boost Ambient Energy Manager Battery Charger with Source Voltage Level Configuration

### Feature

#### Ultra-low power start-up

- Cold start from 275 mV input voltage and 3  $\mu$ W input power (typical).

#### Constant input voltage regulation

- Optimized for intermittent and pulse power.
- Selectable operating input voltage from 140 mV to 4.5 V.

#### Adaptive and smart energy management

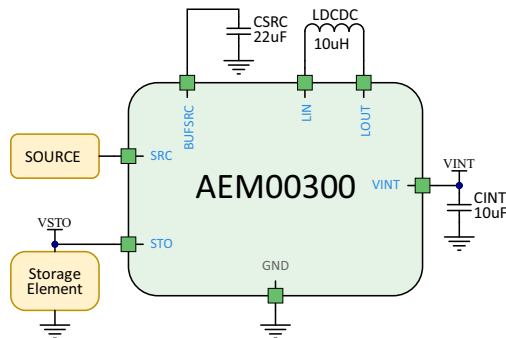
- DCDC switches automatically between boost, buck-boost and buck operation, according to input and output voltages, to maximize energy transfer.

#### Battery protection features

- Selectable over-charge and over-discharge protection for any type of rechargeable battery or (super-)capacitor.
- Fast super-capacitor charging.
- Dual cell super-capacitor balancing circuit.

#### Smallest footprint, smallest BOM

- Only three external components are required.
- One 10  $\mu$ H inductor.
- Two capacitors: one 10  $\mu$ F and one 22  $\mu$ F.



### Description

The AEM00300 is an integrated energy management circuit that extracts DC power from an ambient energy harvesting source to store energy in a storage element. The AEM00300 allows to extend battery lifetime and ultimately eliminates the primary energy storage element in a large range of applications.

Thanks to its selectable operating input voltage, it is possible to set a voltage at which the AEM00300 operates. This voltage is between 140 mV and 4.5 V.

With its unique cold start circuit, the AEM00300 can start harvesting with an input voltage as low as 275 mV and from an input power of 3  $\mu$ W. The preset protection levels determine the storage element voltages protection thresholds to avoid over-charging and over-discharging the storage element and thus avoiding damaging it. Those are set through configuration pins. Moreover, custom threshold voltages can be obtained at the expense of a few configuration resistors.

The chip integrates all active elements for powering a typical wireless sensor. Only two capacitors and one inductor are required.

### Applications

Door access systems      Smart wearable sensors  
 Smart switches home/building      Point-of-sales (POS)

### Device Information

| Part Number     | Package    | Body size [mm] |
|-----------------|------------|----------------|
| 10AEM00300C0000 | QFN 28-pin | 4x4mm          |

### Evaluation Board

| Part Number    |
|----------------|
| 2AAEM00300C001 |

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## 1. Introduction

Figure 1: Simplified Schematic View

The AEM00300 is a full-featured energy efficient power management circuit able to harvest energy from an energy source (connected to **SRC**) to charge a storage element (connected to **STO**). This is done with a minimal bill of material: only 2 capacitors and one inductor are needed for a basic setup.

The heart of the AEM00300 is a regulated switching DCDC converter with high power conversion efficiency.

At first start-up, as soon as a required cold-start voltage of 275 mV and a sparse amount of power of at least 3  $\mu$ W is available at the source, the AEM00300 coldstarts. After the cold start, the AEM extracts the power available from the source if the working input voltage is higher than  $V_{SRC,REG}$ .

Through four configuration pins (**STO\_CFG[3:0]**), the user can select a specific operating mode out of 15 modes that cover most application requirements without any dedicated external component. Those operating modes define the protection levels of the storage element. If none of those 15 modes fit the user's storage element, a custom mode is also available to allow the user to define a mode with custom specifications.

Status pin **ST\_STO** provides information about the voltage levels of the storage element. **ST\_STO** is HIGH when the voltage of the storage element  $V_{STO}$  is above  $V_{CHRDY}$  and is reset when the voltage drops below  $V_{OVDIS}$ .

Depending on the harvester and the application, the source regulation voltage,  $V_{SRC,REG}$ , can be configured thanks to six configuration pins (**SRC\_LVL\_CFG[5:0]**).

The AEM00300's DCDC converter can work in two modes: **LOW POWER MODE** and **HIGH POWER MODE**, each one of these being optimized for a power range on **SRC**.

The charging of the storage element can be prevented by pulling **EN\_STO\_CH** to GND, typically to protect the storage element if the temperature is too low/high to safely charge it.

## 2. Pin Configuration and Functions

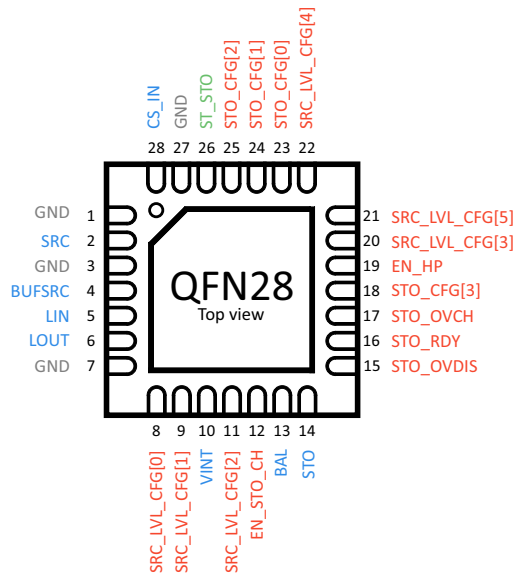


Figure 2: Pinout Diagram QFN 28-pin

| NAME               | PIN NUMBER | FUNCTION  |                 |   |
|--------------------|------------|---|-----------------|---|
| <b>Power Pins</b>  |            |   |                 |   |
| CS_IN              | 28         | Input for the eternal cold start circuit.   |                 |   |
| SRC                | 2          | Connection to the harvested energy source.  |                 |   |
| BUFSRC             | 4          | Connection to an external capacitor buffering the DCDC converter input.   |                 |   |
| LIN                | 5          | DCDC inductance connection.   |                 |   |
| LOUT               | 6          | DCDC inductance connection.   |                 |   |
| VINT               | 10         | Internal voltage supply.  |                 |   |
| BAL                | 13         | Connection to mid-point of a dual-cell supercapacitor (optional). Must be connected to GND if not used.   |                 |   |
| STO                | 14         | Connection to the energy storage element - battery or (super-)capacitor. Cannot be left floating. Must be connected to a minimum capacitance of 100 $\mu$ F or to a rechargeable battery. |                 |   |
| <b>Status Pins</b> |            |   |                 |   |
| ST_STO             | 26         | Logic Output  | HIGH: $V_{STO}$ | HIGH when the storage device voltage $V_{STO}$ rises above $V_{CHRDY}$ threshold. LOW when $V_{STO}$ drops below the $V_{OVDIS}$ threshold. |

Table 1: Power and Status Pins

| NAME                      | PIN NUMBER  | HIGH LEVEL   | FLOATING STATE | FUNCTION   |
|---------------------------|-------------|--|----------------|--|
| <b>Configuration Pins</b> |             |  |                |  |
| SRC_LVL_CFG[0]            | 8           | V <sub>VINT</sub>  | HIGH           | Used for the configuration of the source voltage level.<br>Read as HIGH when left floating.  |
| SRC_LVL_CFG[1]            | 9           |  |                |  |
| SRC_LVL_CFG[2]            | 11          |  |                |  |
| SRC_LVL_CFG[3]            | 20          |  |                |  |
| SRC_LVL_CFG[4]            | 22          |  |                |  |
| SRC_LVL_CFG[5]            | 21          |  |                |  |
| STO_CFG[0]                | 23          | V <sub>VINT</sub>  | HIGH           | Used for the configuration of the threshold voltages for the energy storage element V <sub>OVDIS</sub> , V <sub>CHRDY</sub> and V <sub>OVCH</sub> .<br>Read as HIGH when left floating.                  |
| STO_CFG[1]                | 24          |  |                |  |
| STO_CFG[2]                | 25          |  |                |  |
| STO_CFG[3]                | 18          |  |                |  |
| STO_OVCH                  | 17          | Used for the configuration of the threshold voltages (V <sub>OVDIS</sub> , V <sub>CHRDY</sub> and V <sub>OVCH</sub> ) for the energy storage element when STO_CFG[3:0] are set to custom mode (optional). Must be left floating if not used. |                |  |
| STO_RDY                   | 16          |  |                |  |
| STO_OVDIS                 | 15          |  |                |  |
| EN_STO_CH                 | 12          | V <sub>LOAD</sub>  | HIGH           | <ul style="list-style-type: none"> <li>- Pulled up to <b>LOAD</b> or floating: enables the charging of the battery</li> <li>- Pulled down to <b>GND</b>: disables the charging of the battery</li> </ul> |
| EN_HP                     | 19          | V <sub>VINT</sub>  | HIGH           | <ul style="list-style-type: none"> <li>- Pulled up to <b>VINT</b> or floating: <b>HIGH POWER MODE</b> enabled</li> <li>- Pulled down to <b>GND</b>: <b>HIGH POWER MODE</b> disabled</li> </ul>           |
| <b>Other</b>              |             |  |                |  |
| GND                       | 1, 3, 7, 27 | Ground connection, best possible connection to PCB ground plane.   |                |  |
|                           | Exposed pad |  |                |  |

Table 2: Configuration and Ground Pins

### 3. Absolute Maximum Ratings

| Parameter  | Value            |
|--|------------------|
| Voltage on <i>STO</i> , <i>SRC</i> , <i>BUFSRC</i> , <i>LIN</i> , <i>LOUT</i> , <i>BAL</i> , <i>CS_IN</i>  | -0.3 V to 5.5 V  |
| Voltage on <i>VINT</i> , <i>SRC_LVL_CFG[5:0]</i> , <i>STO_CFG[3:0]</i> , <i>STO_OVCH</i> , <i>STO_OVDIS</i> , <i>STO_RDY</i> , <i>EN_HP</i> , <i>EN_STO_CH</i> | -0.3 V to 2.75 V |
| Operating junction temperature   | -40 °C to 125 °C |
| Storage temperature  | -65 °C to 150 °C |
| ESD HBM voltage  | > 2000 V         |
| ESD CDM voltage  | > 500 V          |

Table 3: Absolute Maximum Ratings

### 4. Thermal Resistance

| Package    | $\theta_{JA}$ | $\theta_{JC}$ | Unit |
|------------|---------------|---------------|------|
| QFN 28-pin | TBD           | TBD           | °C/W |

Table 4: Thermal Resistance

#### ESD CAUTION



#### ESD (ELECTROSTATIC DISCHARGE) SENSITIVE DEVICE

These devices have limited built-in ESD protection and damage may thus occur on devices subjected to high-energy ESD. Therefore, proper ESD precautions should be taken to avoid performance degradation or loss of functionality



## 5. Typical Electrical Characteristics at 25 °C

| Symbol   | Parameter  | Conditions   | Min   | Typ   | Max       | Unit    |
|--|--|--|---|-------|-----------|---------|
| <b>Power Conversion</b>                        |  |  |   |       |           |         |
| $P_{SRC,CS}$                                   | Source power required for cold start   | $V_{STO} > V_{chr dy}$   |   | 3     |           | $\mu W$ |
|  |  | $V_{STO} < V_{chr dy}$   |   | 6     |           | $\mu W$ |
| $V_{SRC}$                                      | Input voltage of the energy source   | During cold start  |   | 0.275 | 4.5       | V       |
|  |  | After cold start   | 0.14  |       | 4.5       | V       |
| $V_{SRC,REG}$ $V_{SRC,REG}$                    | Regulation voltage of the source   | See Table 9  | Depends on $SRC\_LVL\_CFG[5:0]$ configuration |       |           | V       |
| <b>Storage element</b>                         |  |  |   |       |           |         |
| $V_{OVCH}$                                     | Maximum voltage accepted on the storage element before disabling its charging  | see Table 8  | Depends on $STO\_CFG[3:0]$ configuration      |       |           | V       |
| $V_{CHRDY}$                                    | Minimum voltage required on the storage element before asserting the $ST\_STO$ |  |   |       |           | V       |
| $V_{OVDIS}$                                    | Minimum voltage accepted on the storage element before resetting $ST\_STO$     |  |   |       |           | V       |
| <b>Internal supply &amp; Quiescent Current</b> |  |  |   |       |           |         |
| $V_{VINT}$                                     | Internal voltage supply  |  |   | 2.2   |           | V       |
| $I_Q$  | Quiescent current on $STO$   | $V_{STO} = 3.7V$<br>$V_{LOAD} = 2.5V$<br>$EN\_SLEEP = L$<br>$EN\_HP = L$ |   | 5.9   |           | nA      |
| Symbol   | Logic Level  | LOW  |   |       | HIGH      |         |
| <b>Logic output pins</b>                       |  |  |   |       |           |         |
| $ST\_STO$                                      | Logic output levels on the status $STO$ pin                                    | GND  |   |       | $V_{STO}$ |         |

Table 5: Typical Electrical Characteristics

## 6. Recommended Operation Conditions

| Symbol                     | Parameter  | Min              | Typ         | Max  | Unit             |
|----------------------------|--|------------------|-------------|------|------------------|
| <b>External Components</b> |  |                  |             |      |                  |
| $L_{DCDC}$                 | Inductor of the DCDC converter   |                  | 10          |      | $\mu\text{H}$    |
| $C_{SRC}$                  | Capacitor decoupling the SRC terminal  | 13 <sup>1</sup>  | 22          |      | $\mu\text{F}$    |
| $C_{INT}$                  | Capacitor decoupling the VINT terminal   | 5 <sup>1</sup>   | 10          |      | $\mu\text{F}$    |
| $C_{STO}$                  | Optional - Capacitor on STO if no storage element is connected (see Section 9.6.1) | 100 <sup>1</sup> |             |      | $\mu\text{F}$    |
| STO_OVCH                   | Configuration of $V_{OVCH}$ in custom mode   | 1                | Section 9.3 | 100  | $\text{M}\Omega$ |
| STO_OVDIS                  | Configuration of $V_{OVDIS}$ in custom mode  |                  |             |      |                  |
| STO_RDY                    | Configuration of $V_{CHRDY}$ in custom mode  |                  |             |      |                  |
| Symbol                     | Logic Level  | LOW              |             | HIGH |                  |
| <b>Logic input pins</b>    |  |                  |             |      |                  |
| SRC_LVL_CFG[5:0]           | Configuration pins for the SRC voltage level                                       | GND              |             | VINT |                  |
| STO_CFG[3:0]               | Configuration pins for the STO voltage   | GND              |             | VINT |                  |
| EN_STO_FT                  | Configuration pin for the controller   | GND              |             | VINT |                  |
| EN_STO_CH                  | Configuration pin for the controller   | GND              |             | VINT |                  |
| EN_HP                      | Configuration pin for the controller   | GND              |             | VINT |                  |

Table 6: Recommended Operation Conditions

1. Consider all component tolerance and deratings. Typically, DC-bias derating has a major impact on capacitance on ceramic capacitors.

## 7. Functional Block Diagram

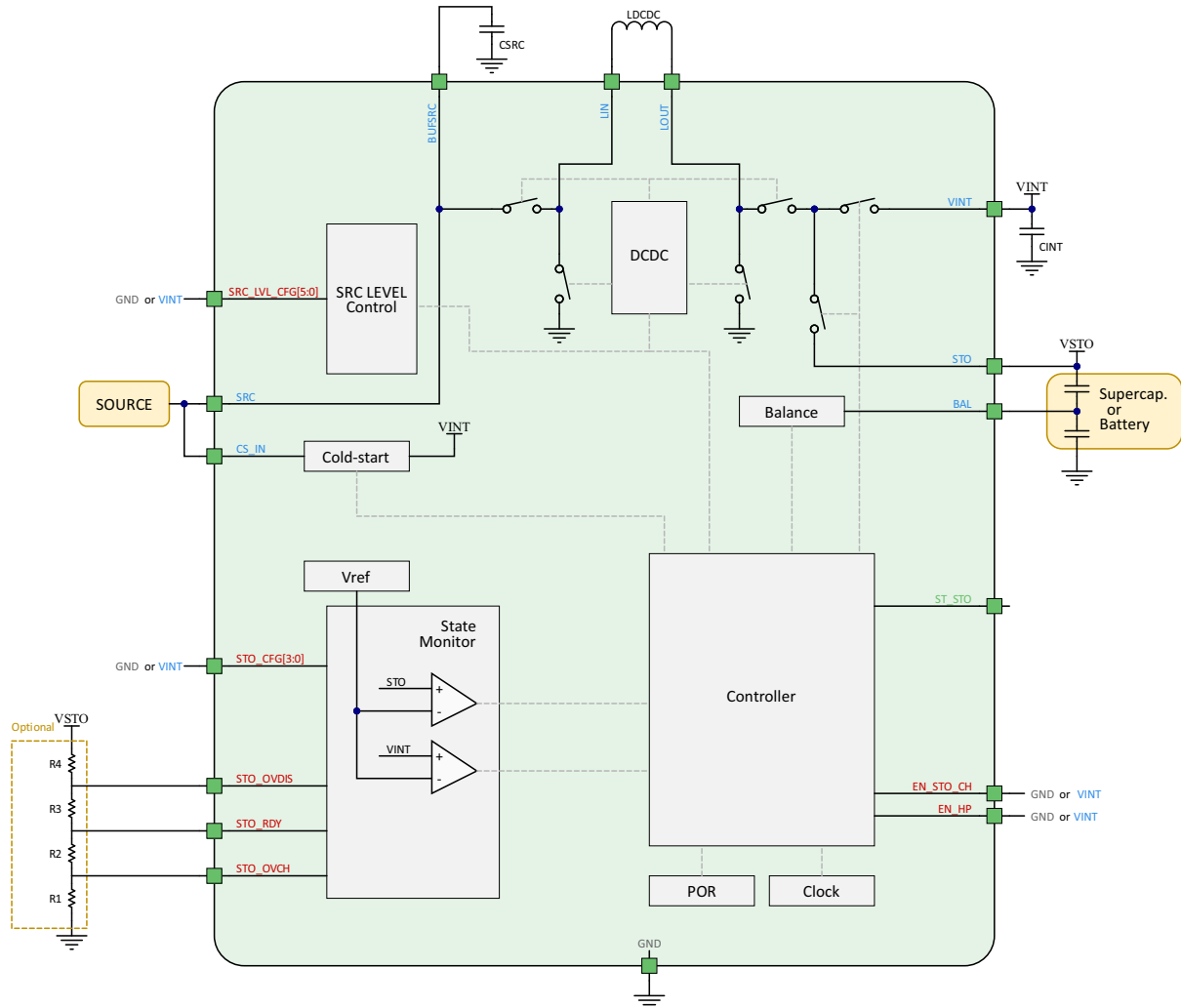


Figure 3: Functional Block Diagram

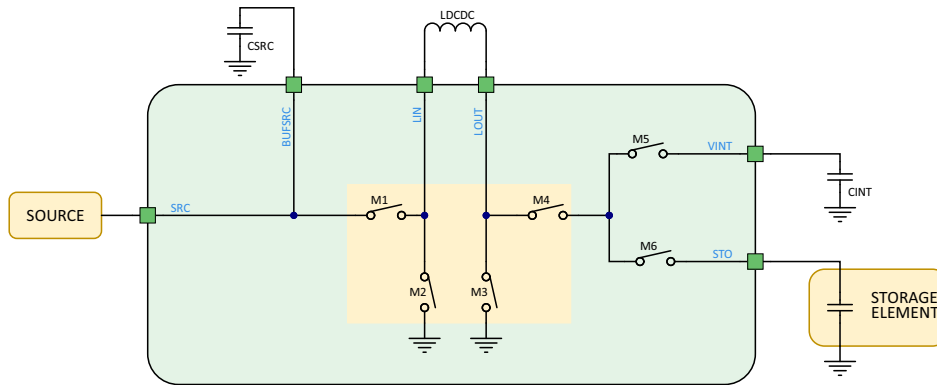


Figure 4: Simplified Schematic View of the AEM00300

## 8. Theory of Operation

### 8.1. DCDC Converter

The DCDC converter converts the voltage available at **BUFSRC** to a level suitable for charging the storage element **STO** or to regulate the internal supply **VINT**. The switching transistors of the DCDC converter are M1, M2, M3 and M4. Thanks to M5 and M6, the controller selects between **VINT** and **STO** respectively as the converter output. **STO** is selected as an output only when **VINT** does not need to be supplied.

The reactive power component of this converter is the external inductor  $L_{DCDC}$ .  $V_{SRC}$  is regulated to  $V_{SRC,REG}$  configured by **SRC\_LVL\_CFG[5:0]**. **BUFSRC** is decoupled by the capacitor  $C_{SRC}$ , which smooths the voltage against the current pulses pulled by the DCDC converter. The storage element is connected to the **STO** pin.

Depending on its input voltage and its output voltage, the DCDC converter will work as a boost converter, a buck converter or a buck-boost converter. The maximum power that can be harvested and supplied to the output depends on the power mode (**HIGH POWER MODE** or **LOW POWER MODE**), which is configured through the **EN\_HP** pin (see Section 9.1).

| DCDC Converter Mode | Input Voltage / Output Voltage                                 |
|---------------------|--|
| Boost               | $V_{IN} < V_{OUT} - 250 \text{ mV}$                            |
| Buck                | $V_{IN} > V_{OUT} + 250 \text{ mV}$                            |
| Buck - Boost        | $V_{OUT} - 250 \text{ mV} < V_{IN} < V_{OUT} + 250 \text{ mV}$ |

Table 7: DCDC Converter Modes

### 8.2. Cold-Start Circuit

The AEM00300 is able to coldstart if the voltage on **CS\_IN** is above 0.275 V. The minimum available power is:

- 3  $\mu\text{W}$  if  $V_{STO}$  is above  $V_{CHRDY}$ .
- 6  $\mu\text{W}$  if  $V_{STO}$  is below  $V_{CHRDY}$ .

**CS\_IN** is typically connected to **SRC** to allow the AEM00300 to coldstart from the energy available on the harvester. Nevertheless, any other energy source can be connected to **CS\_IN** as long as it meets the electrical specifications constraints described in Sections 5 and 6.

### 8.3. AEM00300 States Description

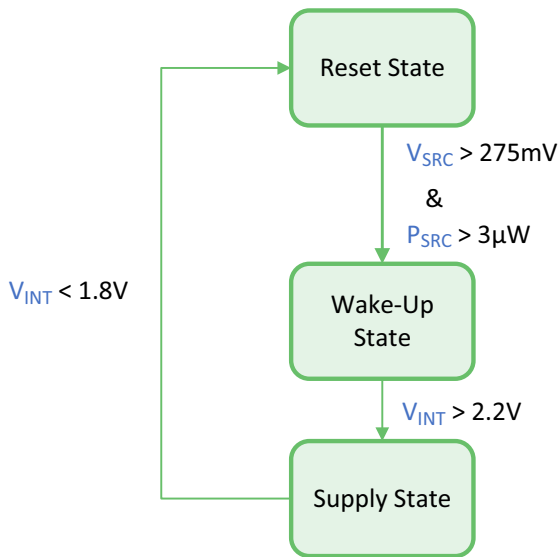


Figure 5: Diagram of the AEM00300 States

#### 8.3.1. Reset and Wake Up States

The **RESET STATE** is a state where all nodes are deeply discharged and there is no available energy to be harvested. As soon as the required cold start voltage of 275 mV and a sparse amount of power of just 3  $\mu\text{W}$  become available on **CS\_IN** (usually connected to **SRC**), the AEM00300 switches to **WAKE-UP STATE**, and energy is extracted from **SRC** to make  $V_{\text{VINT}}$  rise to 2.2 V. When  $V_{\text{VINT}}$  reaches those 2.2 V, the AEM00300 switches to **SUPPLY STATE**.

#### 8.3.2. Supply State

In **SUPPLY STATE**, three scenarios are possible:

- There is enough power provided by the source (**SRC**) to keep  $V_{\text{VINT}}$  at 2.2 V. The excessive power is used to charge the storage element on **STO**. In that case, the circuit remains in **SUPPLY STATE**. If **STO** is fully charged, the DCDC converter is disabled to prevent over-charging the storage element, and the **SRC** pin is set to high impedance.
- Due to a lack of power from the source,  $V_{\text{STO}}$  falls below  $V_{\text{OVDIS}}$ . In this case, the circuit enters **RESET STATE** as explained in Section 8.3.1.
- There is no power on **SRC**. It is therefore not possible to maintain  $V_{\text{VINT}}$  to 2.2 V. In this case, the circuit enters in **RESET STATE**.

The AEM00300 internal circuit current consumption causes  $C_{\text{INT}}$  to discharge. When the voltage on **VINT** falls below its 2.2 V regulation set point, the DCDC converter switches its output to recharge  $C_{\text{INT}}$  from **SRC**, thus keeping **VINT** regulated. If no sufficient power is available on **SRC** to keep **VINT** regulated, the AEM00300 switches to **RESET STATE**.

### 8.4. Source Voltage Regulation

During **SUPPLY STATE**, the voltage on **SRC** is regulated to a voltage configured by the user. The AEM00300 offers a choice of fifty-nine values for the source voltage. If the open-circuit voltage of the harvester is lower than  $V_{\text{SRC,REG}}$ , the AEM00300 does not extract the power from the source. If the **SRC** voltage is higher, the AEM00300 regulates  $V_{\text{SRC}}$  to  $V_{\text{SRC,REG}}$  and extracts power.

### 8.5. Balancing for Dual-Cell Supercapacitor

The balancing circuit allows the user to balance the internal voltage of the dual-cell supercapacitor connected to **STO** in order to avoid damaging the supercapacitor because of excessive voltage on one cell.

If **BAL** is connected to **GND**, the balancing circuit is disabled. This configuration must be used if a battery, a capacitor or a single-cell supercapacitor is connected on **STO**.

If **BAL** is connected to the node between both cells of a supercapacitor, the balancing circuit compensates for any mismatch of the two cells that could lead to the over-charge of one of two cells. The balancing circuit ensures that **BAL** remains close to  $V_{\text{STO}}/2$ . This configuration must be used if a dual-cell supercapacitor is connected to **STO**, and that this supercapacitor requires cells balancing.

The balancing circuit works as follows, with  $V_{\text{BAL}}$  the voltage on the **BAL** pin:

- $V_{\text{BAL}} > \frac{V_{\text{STO}}}{2}$ : the AEM00300 enables a switch between **BAL** and **GND** to discharge the bottom supercapacitor cell to **GND** (up to 20 mA).
- $V_{\text{BAL}} < \frac{V_{\text{STO}}}{2}$ : the AEM00300 enables a switch between **STO** and **BAL** to discharge the top supercapacitor cell to the bottom supercapacitor cell (up to 20 mA).

*NOTE: the balancing feature is optimized for supercapacitors, for use with other storage elements (batteries, etc.), please contact e-peas support.*

## 9. System Configuration

### 9.1. High Power / Low Power Mode

When **EN\_HP** is pulled to **VINT**, the DCDC converter is configured to **HIGH POWER MODE**. This allows higher currents to be extracted from the DCDC converter input (**SRC**) to the DCDC converter output (**STO**).

### 9.2. Storage Element Configuration

Through four configuration pins (**STO\_CFG[3:0]**), the user can set a particular operating mode from a range that covers most application requirements, without any dedicated external component as shown in Table 8. The three threshold levels are defined as:

- **V<sub>OVCH</sub>**: maximum voltage accepted on the storage element before disabling its charging.
- **V<sub>CHRDY</sub>**: minimum voltage required on the storage element before **ST\_STO** is HIGH.
- **V<sub>OVDIS</sub>**: minimum voltage accepted on the storage element before setting **ST\_STO** LOW.

| Configuration pins  |   |   |   | Storage element threshold voltages                               |                          |                         | Typical use  |
|---------------------|---|---|---|--|--------------------------|-------------------------|--|
| <b>STO_CFG[3:0]</b> |   |   |   | <b>V<sub>OVDIS</sub></b>   | <b>V<sub>CHRDY</sub></b> | <b>V<sub>OVCH</sub></b> |  |
| L                   | L | L | L | 3.00 V   | 3.50 V                   | 4.05 V                  | LiCoO <sub>2</sub> battery, Li-Po battery, Lithium Titanate (3.8 V) battery (long life). |
| L                   | L | L | H | 2.80 V   | 3.10 V                   | 3.60 V                  | LiFePO <sub>4</sub> battery, Lithium capacitor (LiC).                                    |
| L                   | L | H | L | 1.85 V   | 2.40 V                   | 2.70 V                  | Dual-cell NiMH battery, Lithium-Titanate (2.4V) battery.                                 |
| L                   | L | H | H | 0.20 V   | 1.00 V                   | 4.65 V                  | Dual-cell supercapacitor.  |
| L                   | H | L | L | 0.20 V   | 1.00 V                   | 2.60 V                  | Single-cell supercapacitor.  |
| L                   | H | L | H | 1.00 V   | 1.20 V                   | 2.95 V                  | Single-cell supercapacitor.  |
| L                   | H | H | L | 1.85 V   | 2.30 V                   | 2.60 V                  | Lithium-Titanate battery (2.4V).   |
| L                   | H | H | H | Custom Mode (single-cell NiMH battery, LiC, etc.) <sup>1</sup> . |                          |                         |  |
| H                   | L | L | L | 1.10 V   | 1.25 V                   | 1.50 V                  | Ni-Cd single-cell battery.   |
| H                   | L | L | H | 2.20 V   | 2.50 V                   | 3.00 V                  | Ni-Cd dual-cell battery.   |
| H                   | L | H | L | 1.45 V   | 2.00 V                   | 4.65 V                  | Dual-cell supercapacitor.  |
| H                   | L | H | H | 1.00 V   | 1.20 V                   | 2.60 V                  | Single-cell supercapacitor.  |
| H                   | H | L | L | 2.00 V   | 2.30 V                   | 2.60 V                  | Solid State battery.   |
| H                   | H | L | H | 3.00 V   | 3.50 V                   | 4.35 V                  | LiCoO <sub>2</sub> battery, Li-Po battery, Lithium Titanate (3.8 V) battery.             |
| H                   | H | H | L | 2.60 V   | 2.70 V                   | 4.00 V                  | Tadiran TLI.   |
| H                   | H | H | H | 2.60 V   | 3.50 V                   | 3.90 V                  | Tadiran HLC.   |

Table 8: Storage Element Configuration Pins

1. An example of a single-cell NiMH batteries optimized custom mode setting can be found at Section 10.2.

### 9.3. Custom Mode Configuration

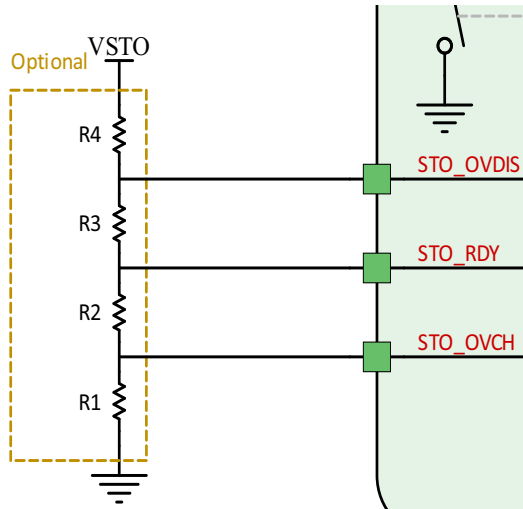


Figure 6: Custom Mode Settings

When `STO_CFG[3:0] = LHHH`, the custom mode is selected and all four configuration resistors must be wired as shown in Figure 6.

$V_{OVCH}$ ,  $V_{CHRDY}$  and  $V_{OVDIS}$  are defined thanks to R1, R2, R3 and R4, which can be determined within the following constraints:

- $R_T = R_1 + R_2 + R_3 + R_4$
- $1\text{M}\Omega \leq R_T \leq 100\text{M}\Omega$
- $R_1 = R_T \cdot \frac{1\text{V}}{V_{OVCH}}$

- $R_2 = R_T \cdot \left( \frac{1\text{V}}{V_{CHRDY}} - \frac{1\text{V}}{V_{OVCH}} \right)$
- $R_3 = R_T \cdot \left( \frac{1\text{V}}{V_{OVDIS}} - \frac{1\text{V}}{V_{CHRDY}} \right)$
- $R_4 = R_T \cdot \left( 1 - \frac{1\text{V}}{V_{OVDIS}} \right)$

The resistors should have high values to make the additional power consumption negligible. Moreover, the following constraints must be respected to ensure the functionality of the chip:

- $V_{CHRDY} + 0.05\text{V} \leq V_{OVCH} \leq 4.5\text{V}$
- $V_{OVDIS} + 0.05\text{V} \leq V_{CHRDY} \leq V_{OVCH} - 0.05\text{V}$
- $1\text{V} \leq V_{OVDIS}$

### 9.4. Disable Storage Element Charging

Pulling down `EN_STO_CH` pin to GND disables the charging of the storage element connected to `STO`. This can be done for example to protect the storage element when the system detects that the environment temperature is too low or too high to safely charge the storage element.

While `EN_STO_CH` is pulled down, `VINT` can still be supplied from `SRC`.

To enable charging the storage element on `STO`, `EN_STO_CH` must be pulled up to `VINT` or left floating (pin is pulled up internally).

## 9.5. Source Level Configuration

Six dedicated configuration pins, **SRC\_LVL\_CFG[5:0]**, allow selecting the  $V_{\text{SRC,REG}}$  at which the source regulates its voltage.

| Configuration pins |   |   |   |   |   | Voltage Level        |
|--------------------|---|---|---|---|---|----------------------|
| SRC_LVL_CFG[5:0]   |   |   |   |   |   | $V_{\text{SRC,REG}}$ |
| L                  | L | L | L | L | L | 0.14 V               |
| L                  | L | L | L | L | H | 0.17 V               |
| L                  | L | L | L | H | L | 0.20 V               |
| L                  | L | L | L | H | H | 0.23 V               |
| L                  | L | L | H | L | L | 0.26 V               |
| L                  | L | L | H | L | H | 0.30 V               |
| L                  | L | L | H | H | L | 0.34 V               |
| L                  | L | L | H | H | H | 0.39 V               |
| L                  | L | H | L | L | L | 0.43 V               |
| L                  | L | H | L | L | H | 0.48 V               |
| L                  | L | H | L | H | L | 0.52 V               |
| L                  | L | H | L | H | H | 0.57 V               |
| L                  | L | H | H | L | L | 0.61 V               |
| L                  | L | H | H | L | H | 0.66 V               |
| L                  | L | H | H | H | L | 0.70 V               |
| L                  | L | H | H | H | H | 0.75 V               |
| L                  | H | L | L | L | L | 0.80 V               |
| L                  | H | L | L | L | H | 0.84 V               |
| L                  | H | L | L | H | L | 0.89 V               |
| L                  | H | L | L | H | H | 0.95 V               |
| L                  | H | L | H | L | L | 1.05 V               |
| L                  | H | L | H | L | H | 1.14 V               |
| L                  | H | L | H | H | L | 1.23 V               |
| L                  | H | L | H | H | H | 1.32 V               |
| L                  | H | H | L | L | L | 1.41 V               |
| L                  | H | H | L | L | H | 1.50 V               |
| L                  | H | H | L | H | L | 1.59 V               |
| L                  | H | H | L | H | H | 1.68 V               |
| L                  | H | H | H | L | L | 1.77 V               |
| L                  | H | H | H | L | H | 1.86 V               |
| Configuration pins |   |   |   |   |   | Voltage Level        |
| SRC_LVL_CFG[5:0]   |   |   |   |   |   | $V_{\text{SRC,REG}}$ |
| L                  | H | H | H | H | L | 1.95 V               |
| L                  | H | H | H | H | H | 2.05 V               |
| H                  | L | L | L | L | L | 2.14 V               |
| H                  | L | L | L | L | H | 2.23 V               |
| H                  | L | L | L | H | L | 2.32 V               |
| H                  | L | L | L | H | H | 2.41 V               |
| H                  | L | L | H | L | L | 2.50 V               |
| H                  | L | L | H | L | H | 2.59 V               |
| H                  | L | L | H | H | L | 2.68 V               |
| H                  | L | L | H | H | H | 2.77 V               |
| H                  | L | H | L | L | L | 2.86 V               |
| H                  | L | H | L | L | H | 2.95 V               |
| H                  | L | H | L | H | L | 3.05 V               |
| H                  | L | H | L | H | H | 3.14 V               |
| H                  | L | H | H | L | L | 3.23 V               |
| H                  | L | H | H | L | H | 3.32 V               |
| H                  | L | H | H | H | L | 3.41 V               |
| H                  | L | H | H | H | H | 3.50 V               |
| H                  | H | L | L | L | L | 3.59 V               |
| H                  | H | L | L | L | H | 3.68 V               |
| H                  | H | L | L | H | L | 3.77 V               |
| H                  | H | L | L | H | H | 3.86 V               |
| H                  | H | L | H | L | L | 3.95 V               |
| H                  | H | L | H | L | H | 4.05 V               |
| H                  | H | L | H | H | L | 4.14 V               |
| H                  | H | L | H | H | H | 4.23 V               |
| H                  | H | H | L | L | L | 4.32 V               |
| H                  | H | H | L | L | H | 4.41 V               |
| H                  | H | H | L | H | L | 4.50 V               |

Table 9: Source regulation configuration pins



## 9.6. External Components

Refer to Figure 14 to have an illustration of the external components wiring.

### 9.6.1. Storage Element Information

The energy storage element of the AEM00300 can be a rechargeable battery, a supercapacitor or a capacitor. The size of the storage element must be determined so that its voltage does not fall below  $V_{OVDIS}$  even during current peaks pulled by the application. If the internal resistance of the storage element cannot sustain this voltage limit, it is advisable to decouple the battery with a capacitor.

If the application expects a disconnection of the battery (e.g. because of a user removable connector), the PCB should include a capacitor  $C_{STO}$  of at least 100  $\mu\text{F}$  connected between **STO** and **GND**. The leakage current of the storage element should be small as leakage currents directly impact the quiescent current of the whole subsystem.

### 9.6.2. External Inductor Information

The AEM00300 operates with one standard miniature inductor.  $L_{DCDC}$  must sustain a peak current of at least 1 A and a switching frequency of at least 10 MHz. Low equivalent series resistance (ESR) favors the power conversion efficiency of the DCDC converter. The recommended value is 10  $\mu\text{H}$ .

### 9.6.3. External Capacitors Information

#### 9.6.3.1. $C_{SRC}$

This capacitor acts as an energy buffer at the input of the DCDC converter. It prevents large voltage fluctuations when the DCDC converter is switching. The recommended nominal value is 22  $\mu\text{F}$ .

#### 9.6.3.2. $C_{INT}$

This capacitor acts as an energy buffer for the internal voltage supply. The recommended nominal value is 10  $\mu\text{F}$ .

## 10. Typical Application Circuits

### 10.1. Example Circuit 1

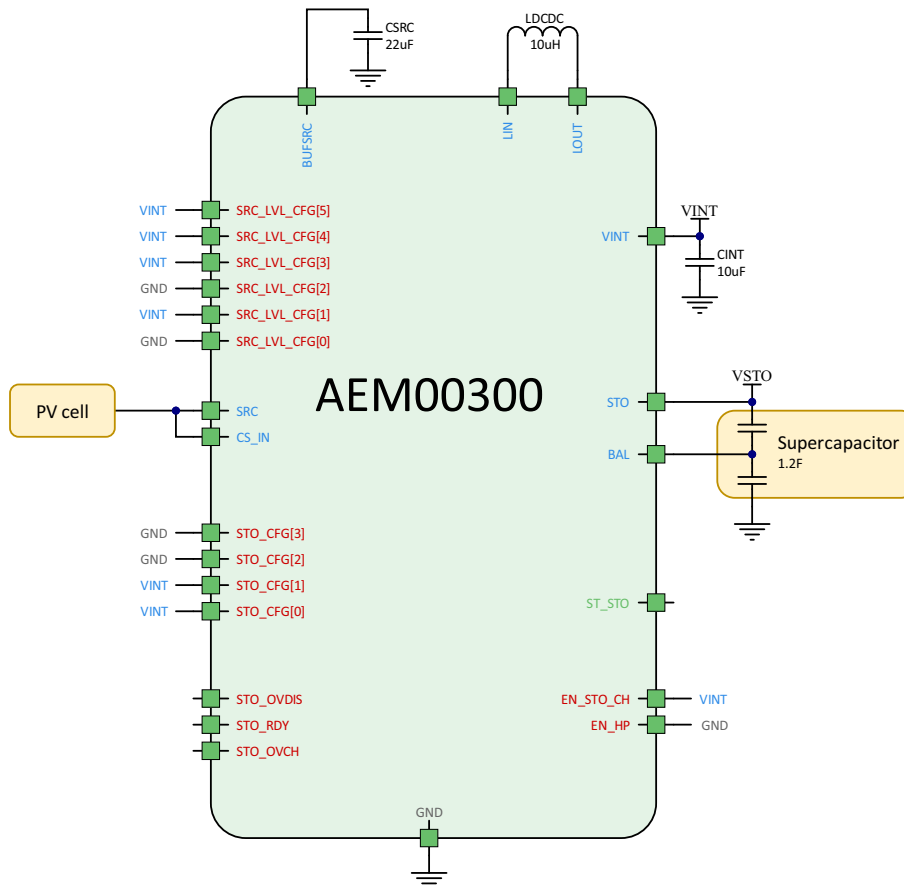


Figure 7: Typical Application Circuit 1

The circuit is an example of a system with solar energy harvesting. It uses a pre-defined operating mode that uses standard components, and a supercapacitor as energy storage.

- Energy source: PV cell.
- **SRC\_LVL\_CFG[5:0] = LLHHHH**: the AEM00300 starts to extract power from 0.75 V and regulates  $V_{SRC}$  to 0.75 V.

- **STO\_CFG[3:0] = LLHH**: the storage element is a dual-cell supercapacitor, with:
  - $V_{OVCH} = 4.65$  V
  - $V_{CHRDY} = 1.00$  V
  - $V_{OVDIS} = 0.20$  V
- The balancing pin of the dual-cell supercapacitor is connected to **BAL**.
- **EN\_STO\_CH** is connected to **VINT**: the charging of the storage element on **STO** is enabled.
- **EN\_HP** is connected to **GND**: the DCDC converter is in **LOW POWER MODE**.

## 10.2. Example Circuit 2

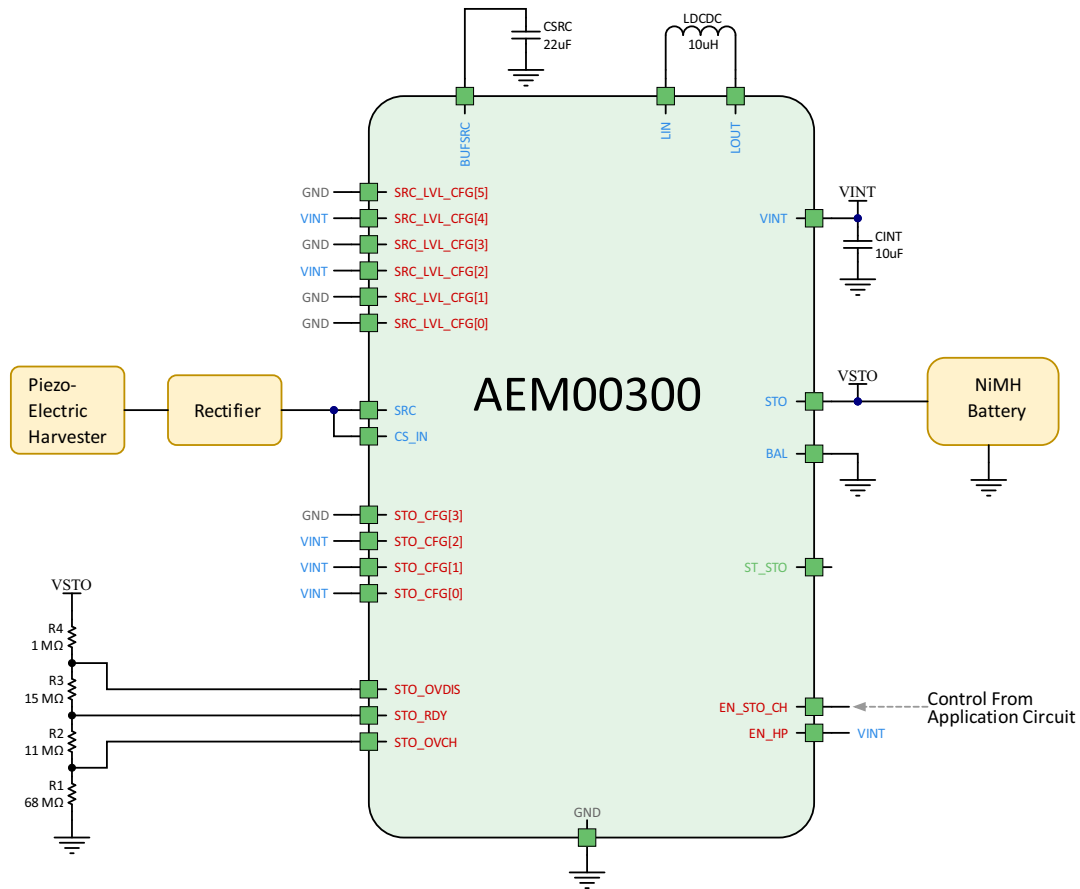


Figure 8: Typical Application Circuit 2

The circuit is an example of a system with vibration energy harvesting. It uses a rechargeable NiMH battery as storage element. The voltage thresholds are set by the custom mode.

- Energy source: piezoelectric vibration harvester.
- **SRC\_LVL\_CFG[5:0]** = LHLHLL: the AEM00300 starts to extract power from 1.05 V and regulates  $V_{SRC}$  to 1.05 V.
- **STO\_CFG[3:0]** = LHHH: the storage element is a NiMH rechargeable battery, used with custom mode:
  - $V_{OVDIS} = 1.00\text{ V}$
  - $V_{CHRDY} = 1.20\text{ V}$
  - $V_{OVCH} = 1.40\text{ V}$
- Custom mode resistor divider calculations (values have been chosen to match E24 series value):
  - $R_T = 95\text{ M}\Omega$
  - $R_1 = R_T \cdot \frac{1\text{ V}}{V_{OVCH}} \approx 68\text{ M}\Omega$
  - $R_2 = R_T \cdot \left( \frac{1\text{ V}}{V_{CHRDY}} - \frac{1\text{ V}}{V_{OVCH}} \right) \approx 11\text{ M}\Omega$

$$- R_3 = R_T \cdot \left( \frac{1\text{ V}}{V_{OVDIS}} - \frac{1\text{ V}}{V_{CHRDY}} \right) \approx 15\text{ M}\Omega$$

$$- R_4 = R_T \cdot \left( 1 - \frac{1\text{ V}}{V_{OVDIS}} \right) \approx 1\text{ M}\Omega$$

- **BAL** is not used (not a dual-cell storage element) so it is connected to GND.
- **EN\_STO\_CH**: the charging of the storage element present on **STO** is controlled by the application circuit, typically by a micro-controller GPIO output.
- **EN\_HP** is connected to **VINT**: the DCDC converter is in **HIGH POWER MODE**.

*NOTE: for LiC (Lithium-ion Capacitor) storage elements, or others that would not be covered by **STO\_CFG[3:0]** presets, please apply the same equations as in the above example to determine custom mode resistors values. E24 series values for typical storage elements can be found in the AEM00300 Configuration Tool spreadsheet, to be downloaded on e-peas website.*

## 11. Circuit Behavior

### 11.1. Wake-up state and Supply state

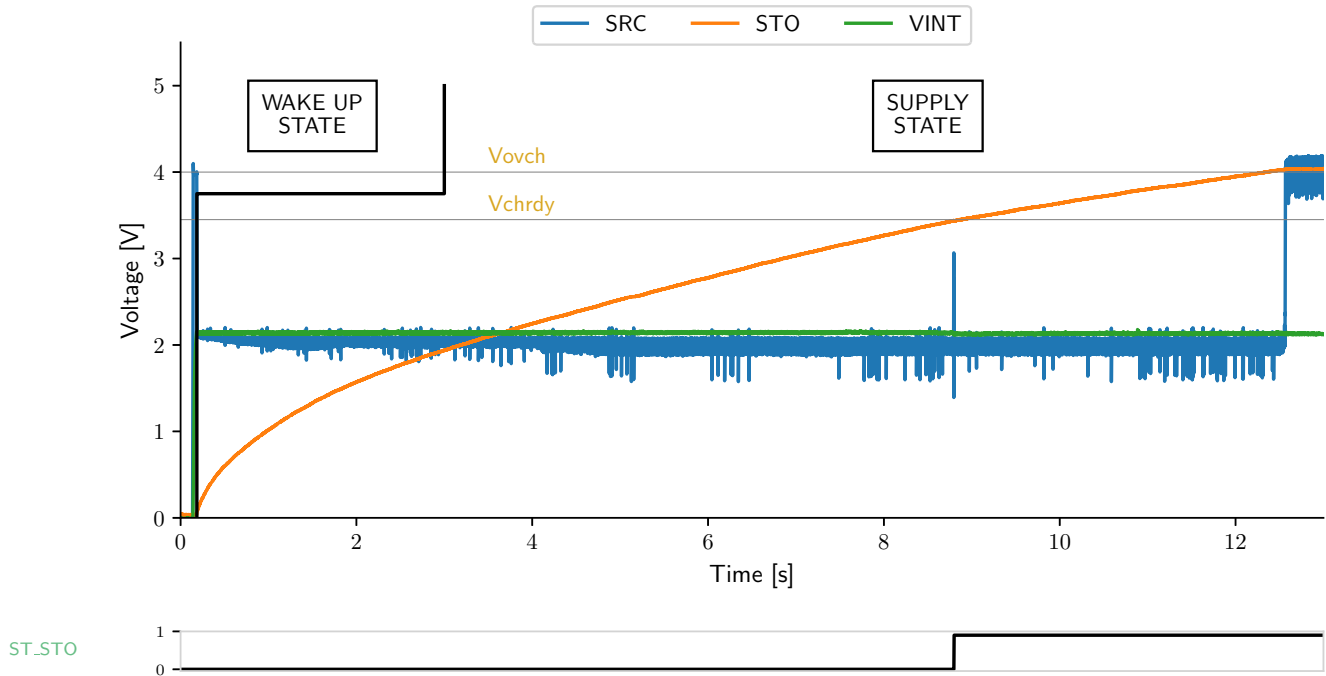
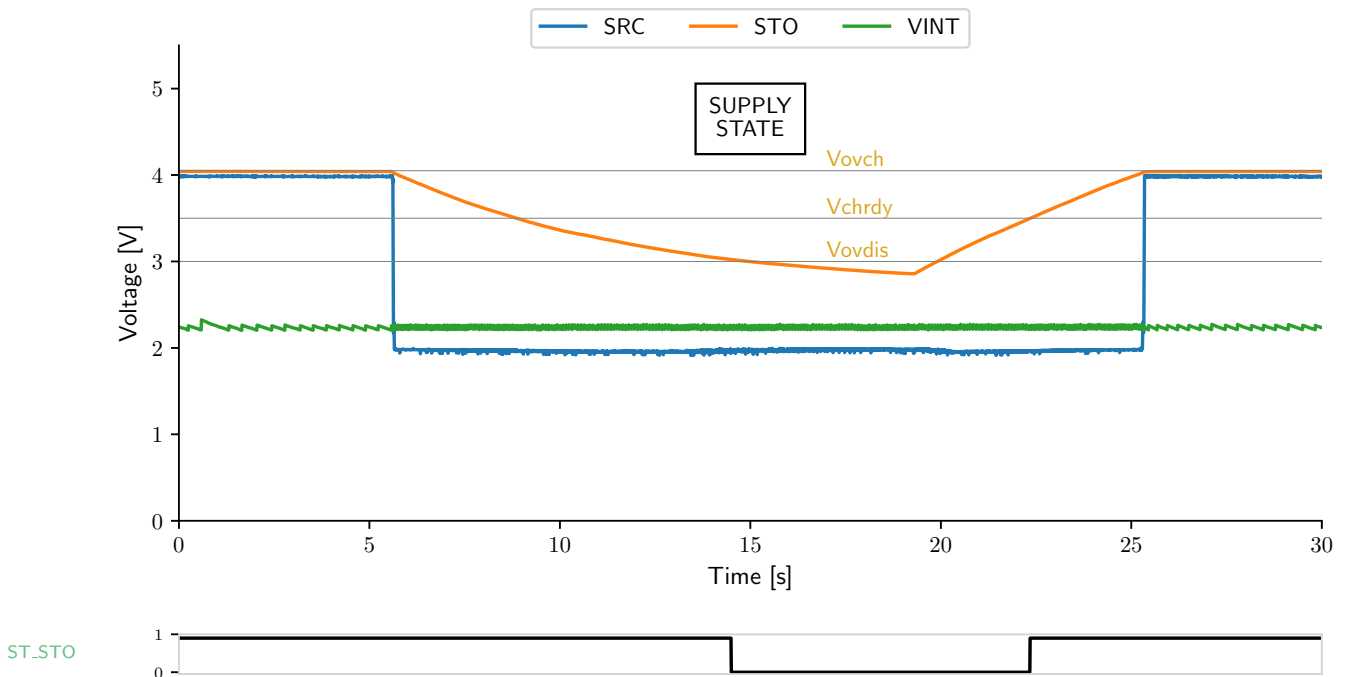


Figure 9: Wake-up state and Supply state

- $STO\_CFG[3:0] = LLLL$
- $V_{OVDIS} = 3.00\text{ V}$
- $V_{CHRDY} = 3.50\text{ V}$
- $V_{OVCH} = 4.05\text{ V}$
- $SRC\_LVL\_CFG[5:0] = LHHHHH$  ( $V_{SRC,REG} = 2.05\text{ V}$ )
- $C_{STO} = 10\text{ mF}$
- $SRC$ : 5 mA current source with 4 V voltage compliance
- $EN\_HP = H$  (high power mode)
- $EN\_STO\_CH = H$  (storage element charge enabled)

## 11.2. Supply state



- **STO\_CFG[3:0]** = LLLL
- $V_{OVDIS}$  = 3.00 V
- $V_{CHRDY}$  = 3.50 V
- $V_{OVCH}$  = 4.05 V
- **SRC\_LVL\_CFG[5:0]** = LHHHHH ( $V_{SRC,REG}$  = 2.05 V)
- $C_{STO}$  = 10 mF
- **SRC**: 5 mA current source with 4 V voltage compliance
- **EN\_HP** = H (high power mode)
- **EN\_STO\_CH** = H (storage element charge enabled)
- 1 k $\Omega$  between **STO** and **GND**, connected between 5.5 s and 19 s (no load on **STO** the rest of the time)

### 11.3. Supply state and Reset state

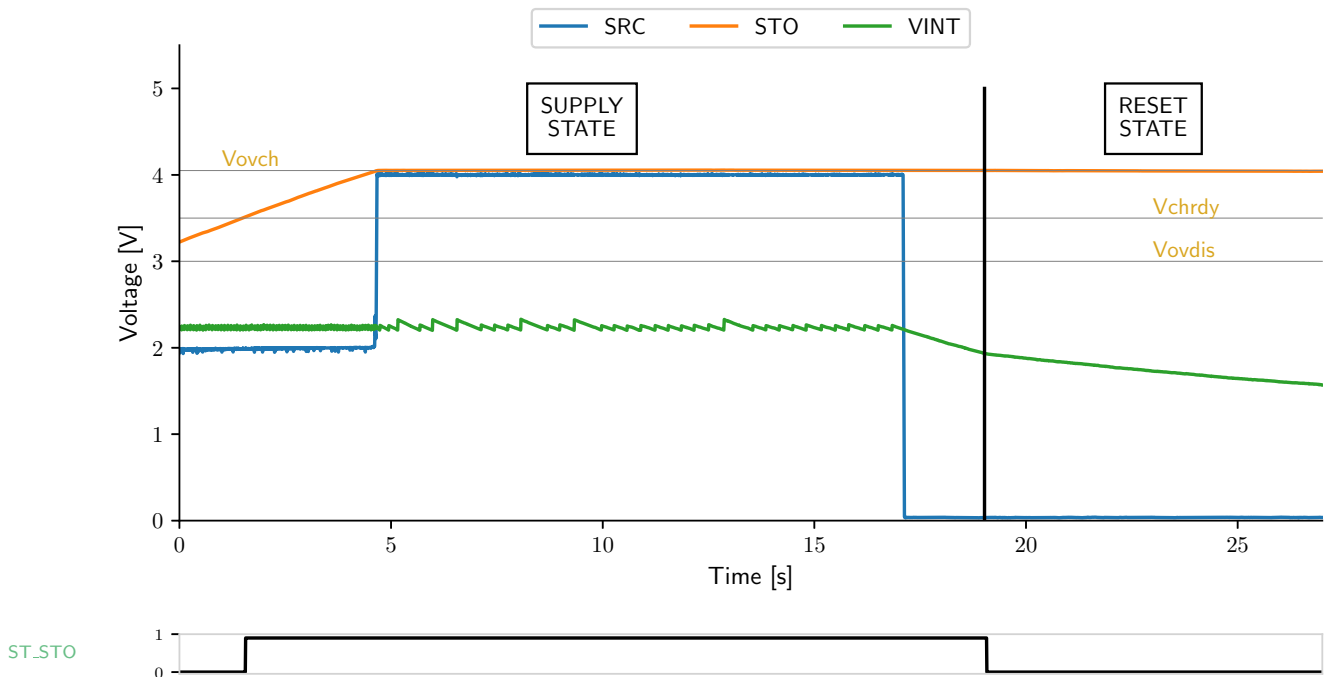


Figure 11: Supply state and Reset state

- $STO\_CFG[3:0] = LLLL$
- $V_{OVDIS} = 3.00\text{ V}$
- $V_{CHRDY} = 3.50\text{ V}$
- $V_{OVCH} = 4.05\text{ V}$
- $SRC\_LVL\_CFG[5:0] = LHHHHH$  ( $V_{SRC,REG} = 2.05\text{ V}$ )
- $C_{STO} = 10\text{ mF}$
- SRC: 5 mA current source with 4 V voltage compliance (stopped after 17 seconds)
- $EN\_HP = H$  (high power mode)
- $EN\_STO\_CH = H$  (storage element charge enabled)

## 12. Performance Data

### 12.1. DCDC Conversion Efficiency From SRC to STO in Low Power Mode

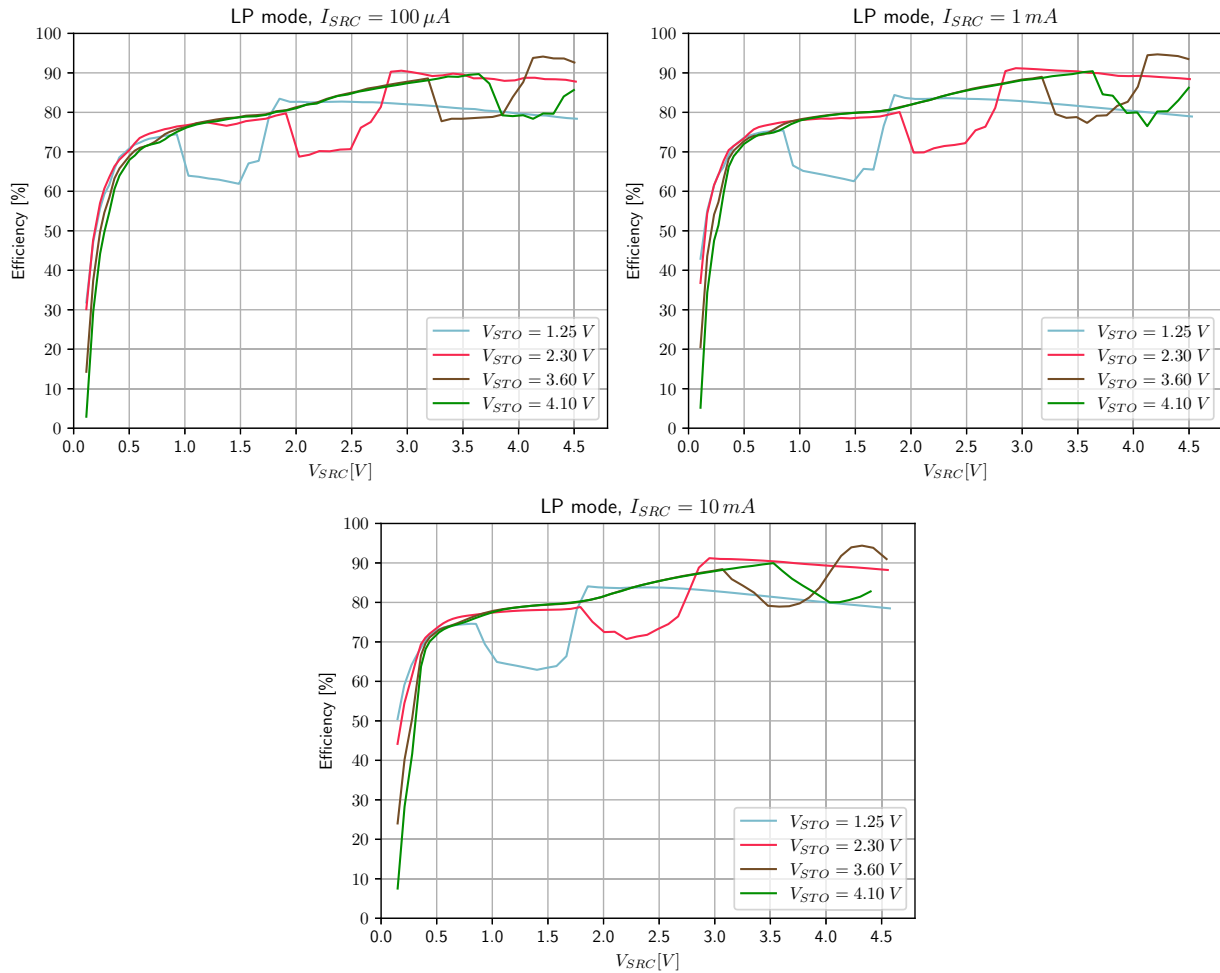


Figure 12: DCDC Efficiency from SRC to STO for 1 mA and 10 mA in Low Power Mode

## 12.2. DCDC Conversion Efficiency From SRC to STO in High Power Mode

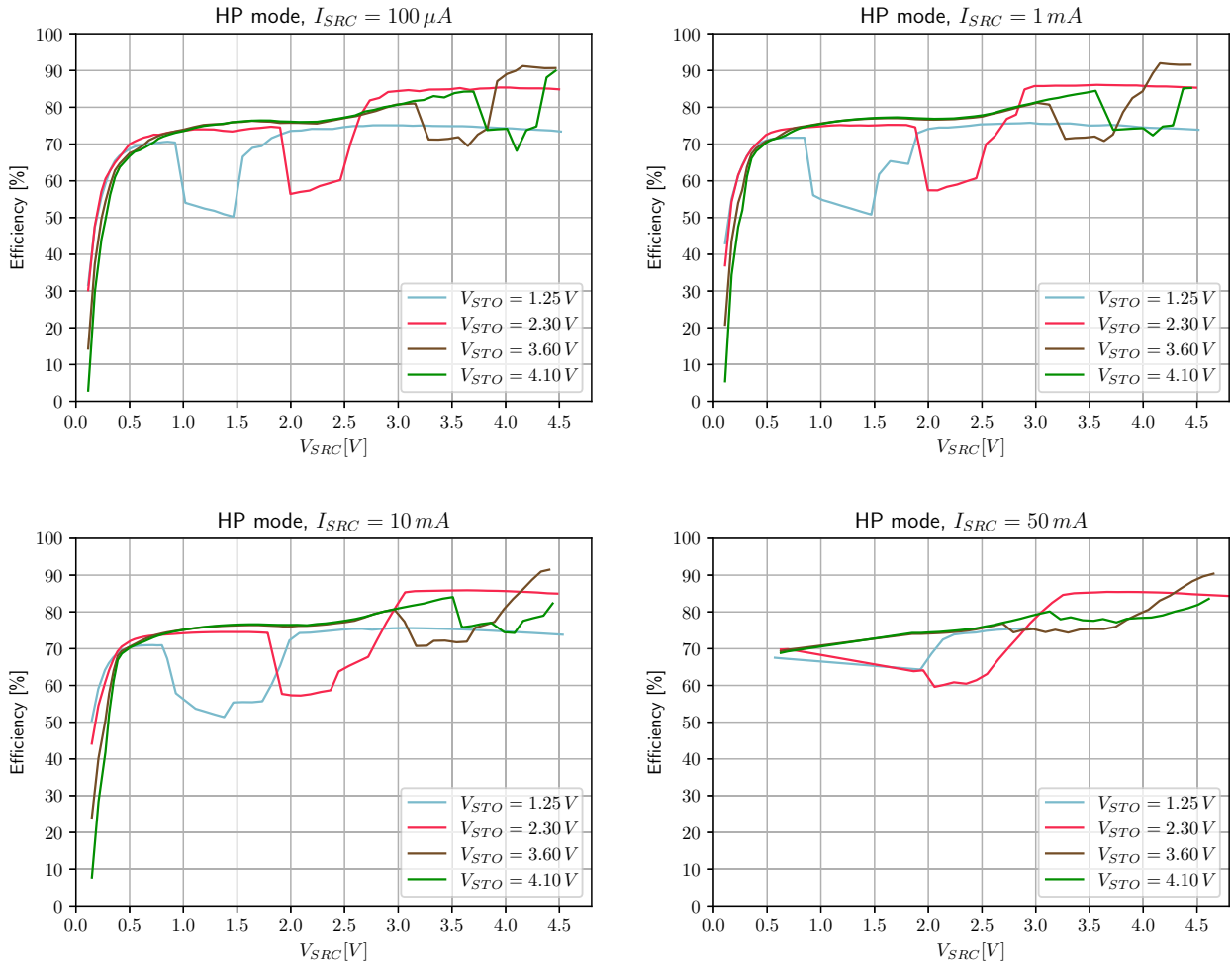


Figure 13: DCDC Efficiency from SRC to STO for 10 mA and 50 mA in High Power Mode



### 13. Schematic

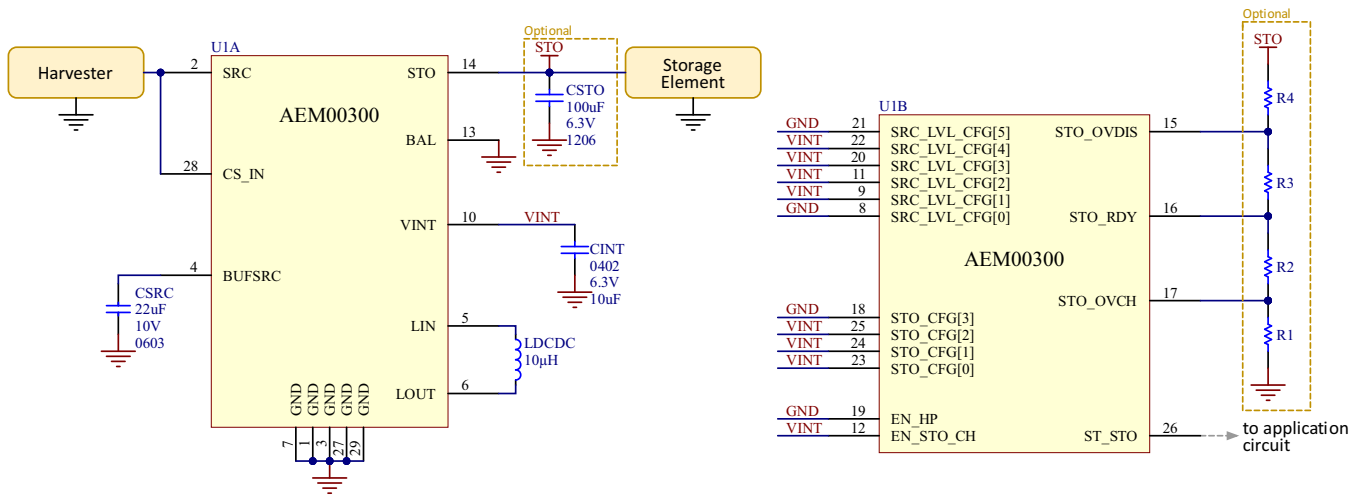


Figure 14: Schematic Example

| Designator                  | Description                             | Quantity | Manufacturer | Link                      |
|-----------------------------|---|----------|--------------|---------------------------|
| U1                          | AEM00300 - Symbol QFN 28-pin            | 1        | e-peas       | order at sales@e-peas.com |
| L <sub>DCDC</sub>           | Power inductor 10 µH - 1.76A            | 1        | Murata       | DFE252010F-100M           |
| C <sub>INT</sub>            | Ceramic Cap 10 µF, 6.3V, 20%, X5R 0402  | 1        | Murata       | GRM155R60J106ME15         |
| C <sub>SRC</sub>            | Ceramic Cap 22 µF, 10V, 20%, X5R 0603   | 1        | Murata       | GRM188R61A226ME15D        |
| C <sub>STO</sub> (optional) | Ceramic Cap 100 µF, 6.3V, 20%, X5R 1206 | 1        | TDK          | C3216X5R1A107M160AC       |

Table 10: Minimal Bill of Materials

## 14. Layout

### 14.1. Guidelines

Good layout practices are mandatory in order to obtain good stability and best efficiency with the AEM00300. It also allows for minimizing electromagnetic interferences generated by the AEM00300 DCDC converter.

The following list, while not exhaustive, shows the main attention points when routing a PCB with the AEM00300:

- The switching nodes (**LIN** and **LOUT**) must be kept as short as possible, with minimal track resistance and minimal track capacitance. Low resistance is obtained by keeping track length as short as possible and track width as large as possible between  $L_{DCDC}$  and the AEM00300 pins. Minimal capacitance is obtained by keeping distance between **LIN/LOUT** and other signals. We recommend removing the ground plane, the power plane and the bottom layer ground pour under  $L_{DCDC}$  footprint, as well as adding distance between **LIN/LOUT** and the top ground pour, as shown on Figure 15.
- The DCDC decoupling capacitors ( $C_{SRC} - C_{STO}$ ) must be placed as close as possible to the AEM00300, with direct connection and minimum track resistance for the corresponding power nodes (**BUFSRC** and **STO**).
- The **GND** return path between the DCDC decoupling capacitors ( $C_{SRC} - C_{STO}$ ) and the AEM00300 thermal pad, which is the AEM00300 main **GND** connection, must be as direct and short as possible. This is preferably done on the top layer when possible, otherwise by internal/bottom plane, using low resistance vias to decrease layer-to-layer connection resistance.
- The external DC power connections (**SRC** and **STO**) must be connected to the AEM00300 with low resistance tracks.
- Connection between **VINT** and  $C_{INT}$  must be moderately short for AEM00300 stability, even though this pins does not carry large currents. Same for connection between  $C_{INT}$  to **GND**.
- The **BAL** pin connection track must be able to handle at least 40 mA.
- The custom mode setting pins **STO\_OVDIS**, **STO\_RDY** and **STO\_OVCH** are high impedance analog inputs typically connected to a resistive divider with high resistor values, making those three nodes prone to pickup noise. Thus it is recommended to keep those as short as possible and as far as possible to noise sources such as DCDC switching nodes.
- The configuration pins and the status pins have minimal layout restrictions. **CS\_IN** maximum current is below 1 mA, so its layout restrictions are minimal as well.

## 14.2. Example

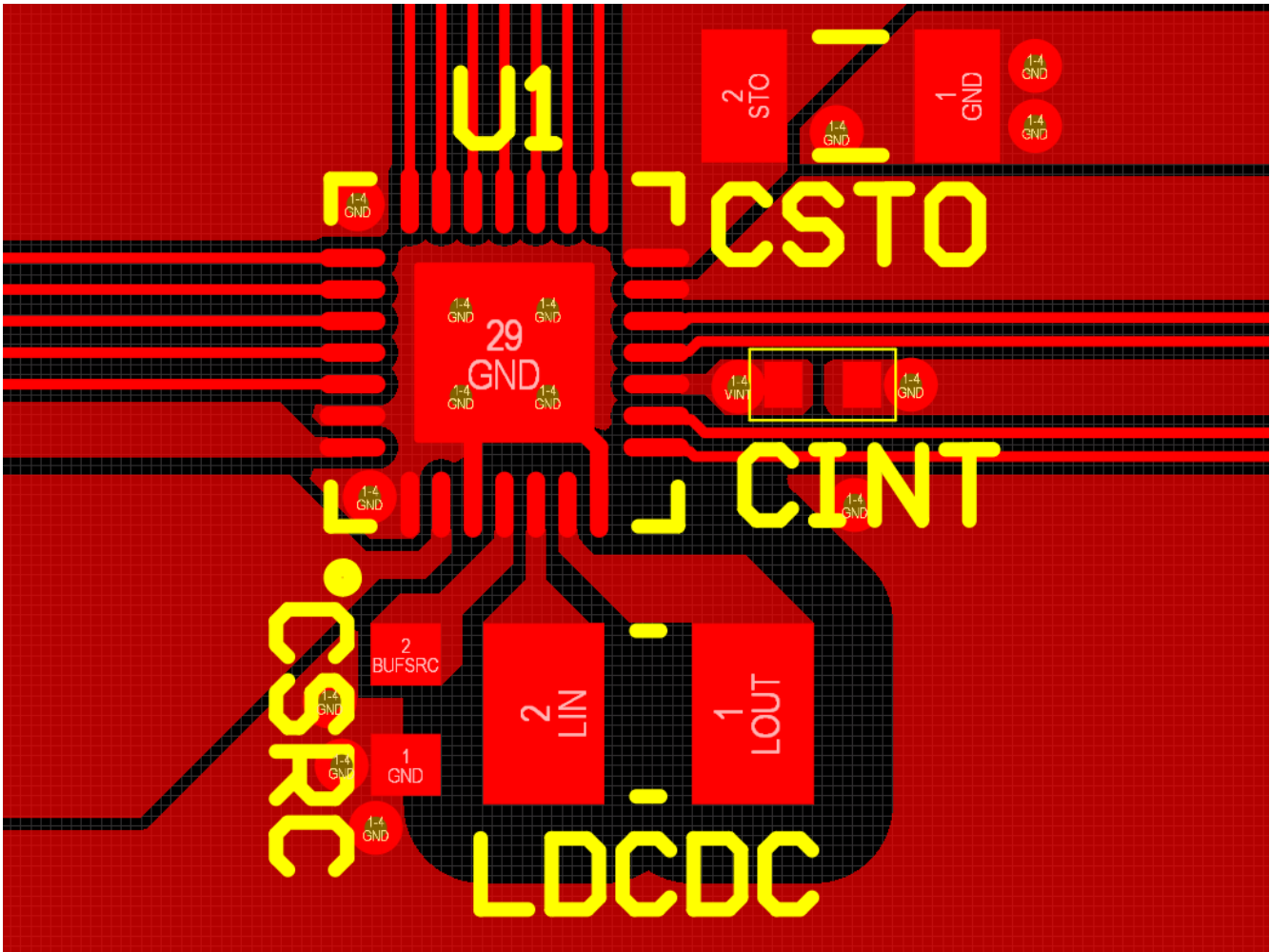


Figure 15: Layout Example for the AEM00300 and its Passive Components

**NOTE:** schematic, symbol and footprint for the e-peas component can be ordered by contacting e-peas support team at [support@e-peas.com](mailto:support@e-peas.com)

## 15. Package Information

### 15.1. Plastic Quad Flatpack No-Lead (QFN 28-pin 4x4mm)

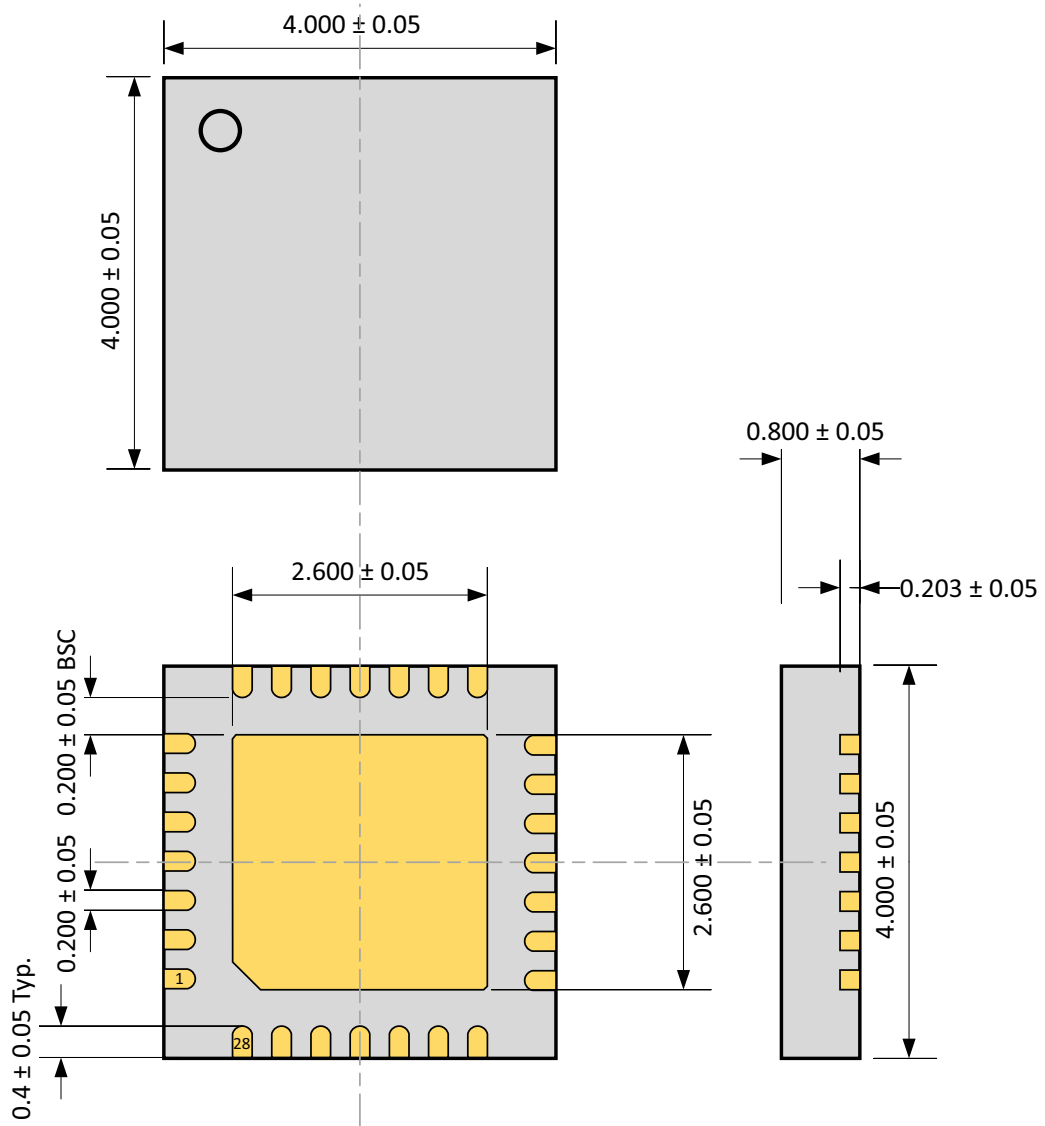


Figure 16: QFN 28-pin 4x4mm Drawing (All Dimensions in mm)

## 15.2. Board Layout

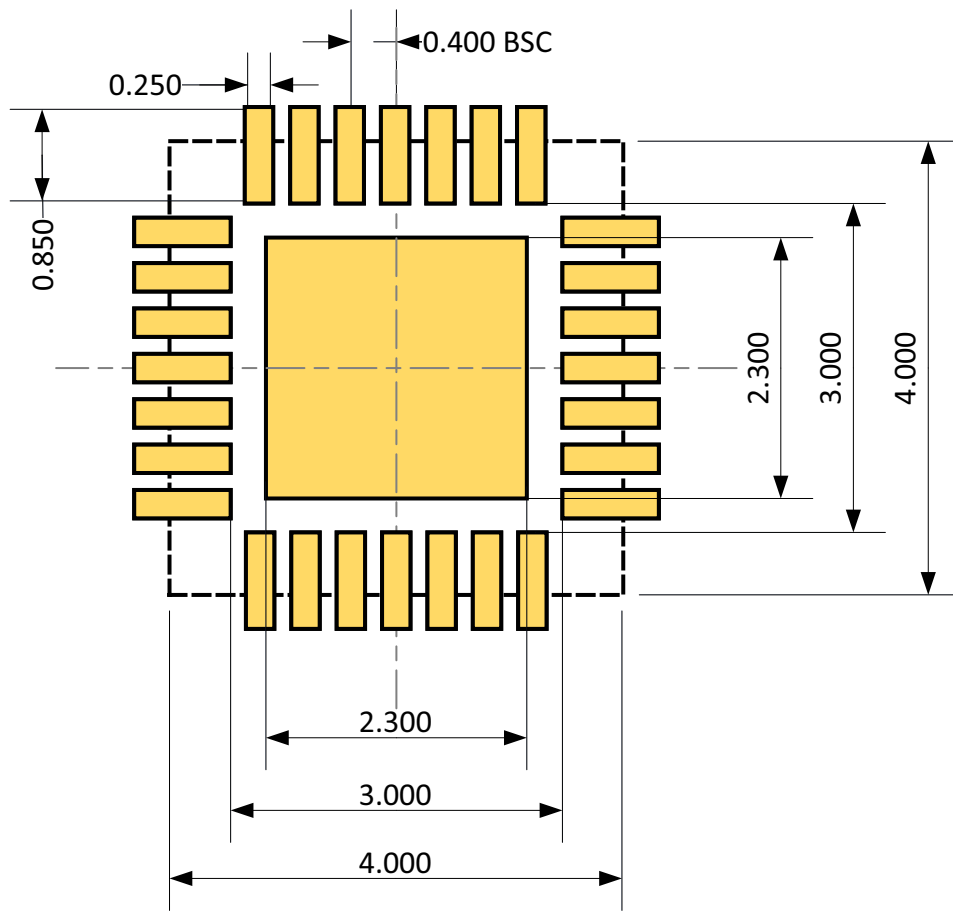


Figure 17: Recommended Board Layout (All Dimensions in mm)

## 16. Revision History

| Revision | Date           | Description  |
|----------|----------------|--|
| 0.0      | January, 2021  | Creation of the document. Preliminary version.   |
| 1.0      | June, 2021     | First version of the document  |
| 1.1      | August, 2021   | Minor modifications  |
| 1.2      | March, 2023    | <ul style="list-style-type: none"> <li>- Various aesthetic improvements.</li> <li>- Explanations about BAL circuit.</li> <li>- Section with precisions about the use of CS_IN.</li> <li>- Fixed state machine graph.</li> <li>- Fixed footprint dimensions</li> <li>- New "behavior" oscilloscope graphs with improved description.</li> <li>- Moved various states description sections as sub-sections of a global section.</li> <li>- Supply State description: explanation about SRC being set to high impedance when all nodes are fully charged.</li> <li>- Updated "Typical use" of storage element vs STO_CFG[3:0] configuration.</li> <li>- Replaced "asserted/de-asserted" by "HIGH/LOW".</li> <li>- Changed CSRC from 15µF/0402 to 22µF/0603.</li> <li>- Updated "Recommended Operation Conditions" with minimum capacitor values including derating and tolerances.</li> <li>- Source in application example 1: replaced RF by PV cell.</li> </ul> |
| 1.3      | November, 2023 | <ul style="list-style-type: none"> <li>- Updated efficiency graphs.</li> <li>- Created section for pinout.</li> <li>- Updated schematics with new symbol.</li> <li>- Digital levels High/Low: replaced 0/1 notation by L/H.</li> <li>- Fixed example circuits errors.</li> <li>- Fixed typos and aesthetic issues.</li> <li>- Added layout guidelines with clearer layout examples.</li> </ul>   |
| 1.4      | February, 2024 | Fixed wrong HIGH level of <b>ST_STO</b> in "Power and Status Pins" table.  |

Table 11: Revision History