Ultra Efficient Battery Charger with Constant Voltage and MPPT Source Regulation

Features and Benefits

Single source input
- Conversion efficiency up to 97 %.
- Harvest from 120 mV up to the storage element voltage after cold start.
- Up to 135 mA current extracted.

Maximum Power Point Tracking
- Configurable source regulation mode to either constant voltage or open-circuit voltage ratio to match various PV cells.
- Selectable input regulation voltage for constant voltage mode.
- Configurable MPPT ratio ranging from 35% to 90%.
- Configurable MPPT sensing timing and period.

Cold start from 275 mV / 1.5 µW input
- Startup at ultra-low power from harvesting source input.

Configurable overdischarge & overcharge protection
- Supports various rechargeable storage elements types (LiC, Li-ion, LiPo...) with preset protection levels or custom mode configuration.

System configuration by GPIO
- System settings dynamically configurable through GPIO.

Shipping mode
- Storage element charge and discharge disabling during shipment.

Applications

Smart home	Industrial sensor
Smart building	Retail
Edge IoT	PC accessories

Description

The AEM11900 is a fully integrated and compact power management circuit that extracts DC power from a harvesting source to store energy in a rechargeable storage element. This compact and ultra-efficient battery charger allows for extending battery lifetime and eliminating the primary energy battery in a large range of applications.

The AEM11900 implements both constant voltage regulation and open circuit ratio source regulation, allowing for harvesting the maximum power available from various sources to charge the storage element.

With its unique cold-start circuit, it can start operating with an input voltage as low as 275 mV (min. 1.5 µW power).

Configurable protection levels, set by presets or custom mode, define the storage element voltage protection thresholds to prevent overdischarging and overcharging.

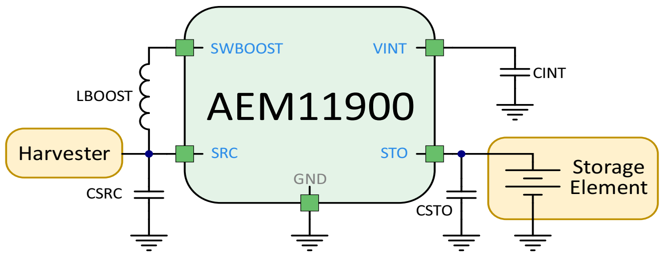
A shipping mode is available to prevent charging and discharging of the storage element during shipping or storage.

Device Information

Part Number	Package	Body size
10AEM11900A0000	QFN 24-pin	4 x 4 mm

Evaluation Board

Part number
2AAEM11900A001



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1. Pin Configuration and Functions

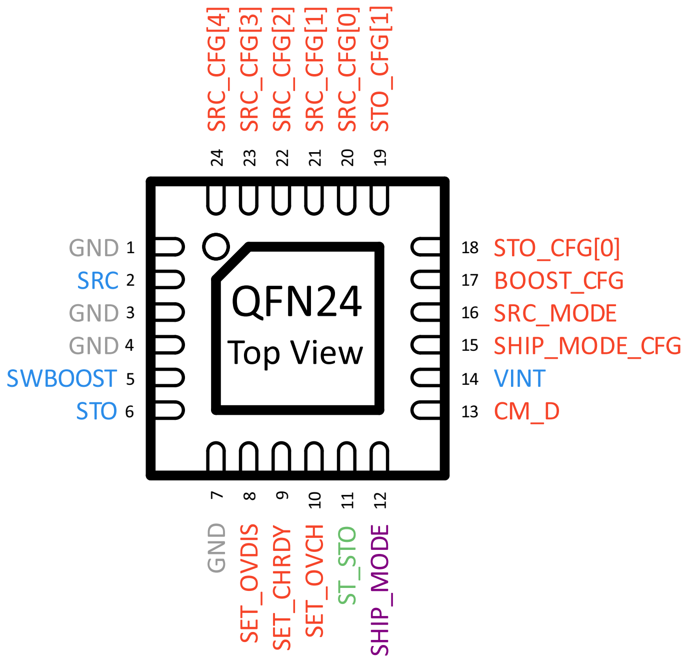


Figure 1: Pinout diagram

NAME	PIN NUMBER	FUNCTION
Power Pins		
SRC	2	Connection to the energy source harvested by the boost converter.
SWBOOST	5	Switching node of the boost converter.
STO	6	Connection to the energy storage element (rechargeable battery).
VINT	14	Connection for C_{INT} buffering capacitor. AEM11900 internal power supply (do not connect any external circuit on VINT).

Table 1: Pins description (part 1)

<table>
<tr><th rowspan="2">NAME</th><th rowspan="2">PIN NUMBER</th><th colspan="2">LOGIC LEVEL</th><th rowspan="2">FUNCTION</th></tr>
<tr><th>LOW</th><th>HIGH</th></tr>
<tr><td colspan="5">Control Pin</td></tr>
<tr><td>SHIP_MODE</td><td>12</td><td>GND</td><td>STO</td><td>Used to configure the shipping mode.
- If SHIP_MODE is LOW (shipping mode disabled):
  - Normal operation.
- If SHIP_MODE is HIGH (shipping mode enabled):
  - Minimum consumption from the storage element.
  - Storage element charge disabled (boost converter disabled).
  - VINT only supplied from SRC if energy available.
Floating state depends on the setting of the SHIP_MODE_CFG pin.</td></tr>
<tr><td colspan="5">Configuration Pins</td></tr>
<tr><td>SRC_MODE</td><td>16</td><td>GND</td><td>VINT</td><td>Used to configure the source voltage regulation mode:
- LOW: constant voltage mode.
- HIGH: MPPT ratio mode (open-circuit voltage ratio).
Read as HIGH if left floating.</td></tr>
<tr><td>SRC_CFG[4]</td><td>24</td><td rowspan="5">GND</td><td rowspan="5">VINT</td><td rowspan="5">Used to configure the SRC regulation voltage.
- If SRC_MODE is LOW (constant voltage mode):
  - SRC_CFG[4:0] are used to set SRC constant regulation voltage.
- If SRC_MODE is HIGH (MPPT ratio mode):
  - SRC_CFG[2:0] are used to set SRC MPPT ratio.
  - SRC_CFG[4:3] are used to set SRC MPPT timings.
Read as HIGH if left floating.</td></tr>
<tr><td>SRC_CFG[3]</td><td>23</td></tr>
<tr><td>SRC_CFG[2]</td><td>22</td></tr>
<tr><td>SRC_CFG[1]</td><td>21</td></tr>
<tr><td>SRC_CFG[0]</td><td>20</td></tr>
<tr><td>STO_CFG[1]</td><td>19</td><td rowspan="2">GND</td><td rowspan="2">VINT</td><td rowspan="2">Used to configure the storage element voltage thresholds (see Section 5.4).
Read as HIGH if left floating.</td></tr>
<tr><td>STO_CFG[0]</td><td>18</td></tr>
<tr><td>BOOST_CFG</td><td>17</td><td>GND</td><td>VINT</td><td>Used to configure the boost converter timings (see Section 5.5).
Read as HIGH if left floating.</td></tr>
<tr><td>SET_OVDIS</td><td>8</td><td colspan="2" rowspan="4">Analog Pin</td><td rowspan="4">(Optional) Used to configure the storage element voltage thresholds when in custom mode (see Section 5.4.2).
If the custom mode is not used, connect all four pins to GND.</td></tr>
<tr><td>SET_CHRDY</td><td>9</td></tr>
<tr><td>SET_OVCH</td><td>10</td></tr>
<tr><td>CM_D</td><td>13</td></tr>
<tr><td>SHIP_MODE_CFG</td><td>15</td><td>GND</td><td>VINT</td><td>Used to configure the floating state of the SHIP_MODE pin.
- If SHIP_MODE_CFG is LOW:
  - SHIP_MODE pin is read HIGH when floating.
- If SHIP_MODE_CFG is HIGH:
  - SHIP_MODE pin is read LOW when floating.
Read as HIGH if left floating.</td></tr>
</table>

Table 2: Pins description (part 2)

NAME	PIN NUMBER	LOGIC LEVEL		FUNCTION
		LOW	HIGH	
Status Pin				
ST_STO	11	GND	STO	Logic output. - HIGH when in SUPPLY STATE and SLEEP STATE. - LOW in every other states. See Section 4.4.4 for more information.
Other pins				
GND	Thermal Pad, 1, 3, 4, 7			Thermal pad and pin 4 must be strongly tied to the PCB ground plane, as these are the main GND connections of the AEM11900.

Table 3: Pins description (part 3)

2. Specifications

2.1. Absolute Maximum Ratings

Parameter		Min	Max	Unit
Operating junction temperature T_J		-40	85	°C
Storage temperature T_{stg}		-65	150	°C
Input voltage	STO, SRC[1], SWBOOST, SET_OVDIS, SET_CHRDY, SET_OVCH, CM_D, SHIP_MODE, ST_STO.	-0.3	5.50	V
	VINT, BOOST_CFG, STO_CFG[1:0], SRC_CFG[4:0], SHIP_MODE_CFG, SRC_MODE.	-0.3	2.75	V

Table 4: Absolute maximum ratings

1. Always make sure that the voltage on SRC is lower than the voltage on STO.

2.2. ESD Ratings

Parameter		Value	Unit
Electrostatic discharge V_{ESD}	Human-Body Model (HBM)[1]	± 2000	V
	Charged-Device Model (CDM)[2]	± 1000	V

Table 5: ESD ratings

1. ESD Human-Body Model (HBM) value tested according to JEDEC standard JS-001-2023.
2. ESD Charger-Device Model (CDM) value tested according to JEDEC standard JS-002-2022.

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

2.3. Thermal Resistance

Package	θJA	θJC	Unit
QFN-24	60	6	°C/W

Table 6: Thermal data

2.4. Electrical Characteristics at 25 °C

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
Power conversion						
$P_{SRC,CS}$	Minimum source power required for cold start.			1.5		µW
$V_{SRC,CS}$	Minimum source voltage required for cold start.			0.275		V
$V_{SRC,REG}$	Constant voltage mode: target regulation voltage of the source, depending on SRC_CFG[4:0] configuration.		0.25		3.18[1]	V
V_{MPP}	MPPT ratio mode: target regulation voltage of the source determined dynamically. V_{MPP} defined thanks to SRC_CFG[2:0] configuration and the source open-circuit voltage V_{OC}.		0.12		0.90 x V_{OC}	V
$V_{SRC,LOW}$	SRC target regulation voltage below which the AEM11900 switches to SLEEP STATE (SRC in MPPT ratio mode).			0.12		V
V_{OC}	Open-circuit voltage of the source.		0.00[2]		V_{STO}	V
$I_{SRC,MAX}$	Maximum current extracted from the SRC pin, with the following BOOST_CFG and L_{BOOST} configuration for achieving maximum current capability: - BOOST_CFG = LOW and L_{BOOST} = 3.3 µH. - BOOST_CFG = HIGH and L_{BOOST} = 10 µH.			135		mA
Timing						
T_{CRIT}	In SUPPLY STATE, the AEM11900 waits for T_{CRIT} before switching to OVDIS STATE when V_{STO} drops below V_{OVDIS}.			1.86		s
$T_{GPIO,MON}$	GPIO reading rate.			1.86		s
$T_{STO,MON}$	Storage element voltage monitoring rate.			116		ms
$T_{MPPT,PERIOD}$	MPPT V_{OC} evaluations period.	SRC_MODE = HIGH (MPPT ratio mode)	15[3]		25[4]	s
$T_{MPPT,WAIT}$	Wait time before V_{OC} measurement begins during MPP evaluations.	SRC_MODE = HIGH (MPPT ratio mode)	0.25[5]		0.50[6]	s
$T_{MPPT,MEASURE}$	Duration of V_{OC} measurement during MPP evaluations.	SRC_MODE = HIGH (MPPT ratio mode)		1.36		ms

Table 7: Electrical characteristics (part 1)

1. To harvest energy from the source, $V_{SRC,REG}$ must remain below V_{OC}.
2. When the open-circuit voltage is below the source regulation voltage, the AEM11900 does not extract power from the source. Voltages down to GND do not damage the AEM11900.
3. Typical value when SRC_CFG[4] is LOW, see Section 5.3.
4. Typical value when SRC_CFG[4] is HIGH, see Section 5.3.
5. Typical value when SRC_CFG[3] is LOW, see Section 5.3.
6. Typical value when SRC_CFG[3] is HIGH, see Section 5.3.

Symbol	Parameter	Conditions	Min	Typ.	Max	Unit
Storage element						
V_{STO}	Voltage on the storage element.		2.40[1]		4.59[2]	V
V_{OVDIS}	Voltage below which the storage element is considered to be fully depleted, and must not be discharged any further (see Section 4.4).	Configured by STO_CFG[1:0].	2.51		3.51	V
		Configured by custom mode.	2.40		4.39	V
V_{CHRDY}	In START STATE, voltage required on the storage element to switch to SUPPLY STATE (see Section 4.4).	Configured by STO_CFG[1:0].	2.61		3.60	V
		Configured by custom mode.	2.51		4.50	V
V_{OVCH}	Voltage above which the storage element is considered to be fully charged, and must not be charged any further (see Section 4.4).	Configured by STO_CFG[1:0].	3.79		4.35	V
		Configured by custom mode.	2.61		4.59	V
Internal supply & quiescent current						
V_{INT}	Internal voltage supply.			2.25		V
$V_{INT,CS}$	Minimum voltage on VINT to allow the AEM11900 to switch from RESET STATE to SENSE STO STATE.			2.30		V
$V_{INT,RESET}$	Minimum voltage on VINT before switching to RESET STATE (from any other state).			2.00		V
$I_{Q,SUPPLY}$	Quiescent current on STO in SUPPLY STATE.[3]			270		nA
$I_{Q,SLEEP}$	Quiescent current on STO in SLEEP STATE.[3]			205		nA
$I_{Q,SHIP}$	Quiescent current drawn from the storage element when the AEM11900 is in shipping mode (SHIP_MODE is HIGH) with or without energy available on SRC.			10		nA
$I_{Q,RESET}$	Quiescent current on STO when the AEM11900 is in RESET STATE.					

Table 8: Electrical characteristics (part 2)

1. As set by the storage element lowest configurable overdischarge threshold.
2. As set by the storage element highest configurable overcharge threshold.
3. When the boost converter is not running.

2.5. Recommended Operating Conditions

Symbol	Parameter	Condition	Min[1]	Typ	Max[1]	Unit
External components						
L_{BOOST}	Boost converter inductor.	BOOST_CFG = L	3.3	10[2]		µH
		BOOST_CFG = H	9.9	33[2]		µH
C_{SRC}	SRC terminal decoupling capacitor.			10		µF
C_{INT}	VINT terminal decoupling capacitor.		5	10		µF
C_{STO}	STO terminal decoupling capacitor.		5	47[3]		µF
R_T	Optional - Total resistance value for setting the battery threshold voltages in custom mode ($R_T = R_1 + R_2 + R_3 + R_4$). See Section 5.4.2.		100		400	kΩ

Table 9: Recommended external components

1. All minimum and maximum values are effective components values, taking into account tolerances, derating, temperatures, voltages and any operating conditions (special care must be taken with capacitor derating).
2. Typical values recommended for best efficiency/current capability trade-off.
3. Recommended value for optimal efficiency, particularly with high-ESR storage elements. If using a smaller value, ensure it meets the minimum requirement.

2.5.1. External Inductor Information

The AEM11900 operates with an external miniature inductor (L_{BOOST}). This inductor must support a minimum switching frequency of 10 MHz. Using an inductor with low equivalent series resistance (ESR) improves the power conversion efficiency of the boost converter.

With the recommended operating conditions (10 µH inductor with BOOST_CFG = L or 33 µH inductor with BOOST_CFG = H), the boost inductor L_{BOOST} must support a minimum peak current of 135 mA.

2.5.2. External Capacitors Information

The AEM11900 operates with three external miniature capacitors to ensure stable operation of the boost converter input, storage element output, and internal supply. Each capacitor serves as a local energy buffer that limits voltage fluctuations caused by switching activity.

To maintain optimal performances and minimized quiescent current, all capacitors must exhibit a low leakage current and follow the recommended nominal values listed in Table 9, with a tolerance of ± 20 %.

2.6. Typical Characteristics

2.6.1. Boost Converter Conversion Efficiency

Figure 2 shows the AEM11900 boost efficiency with:

- L_{BOOST} = 33 µH (Coilcraft LPS4018-333MRB).
- BOOST_CFG = H (x3).

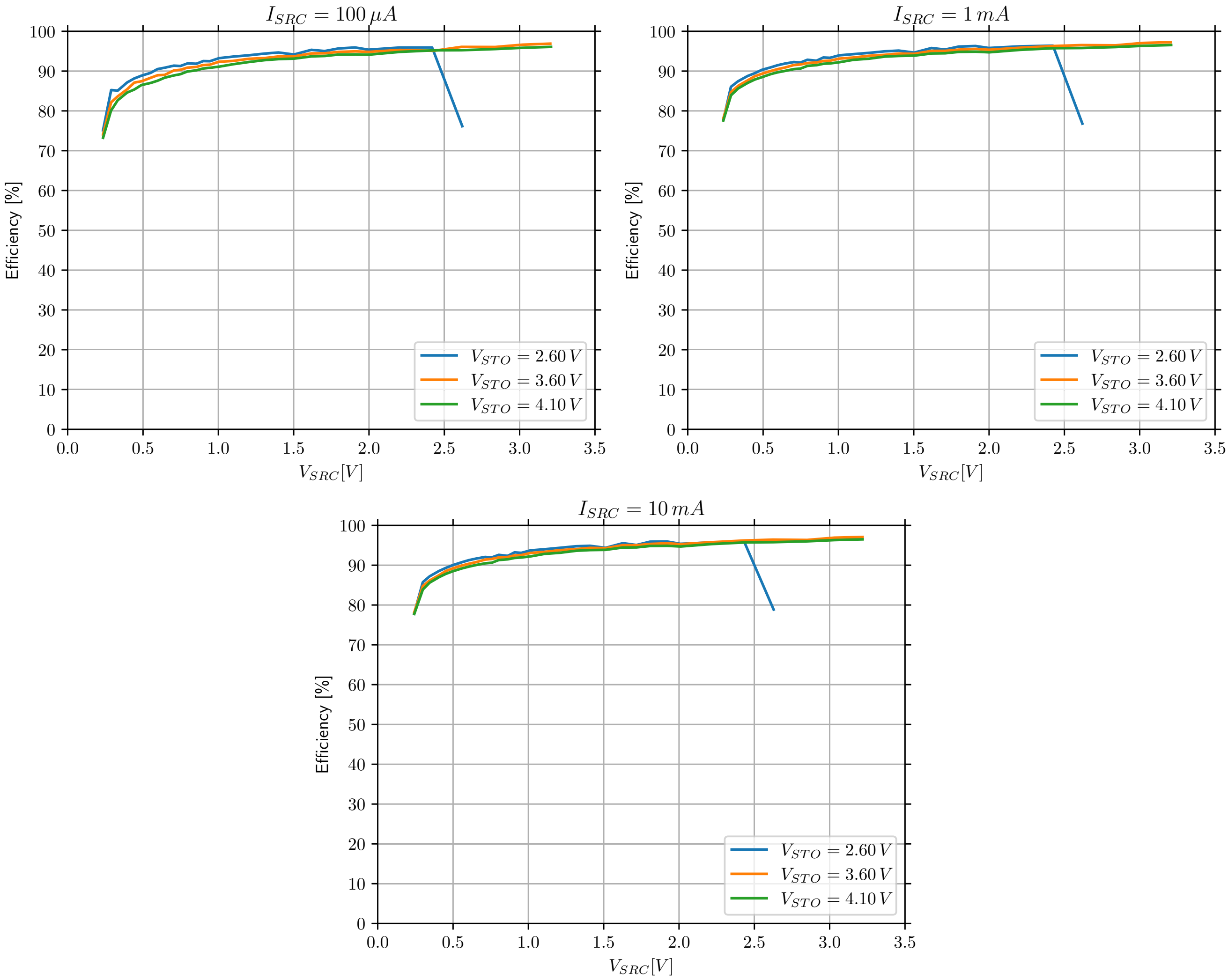


Figure 2: Preliminary boost converter efficiency

NOTE: The boost efficiency data presented in Figure 2 includes the AEM11900 quiescent current.

3. Functional Block Diagram

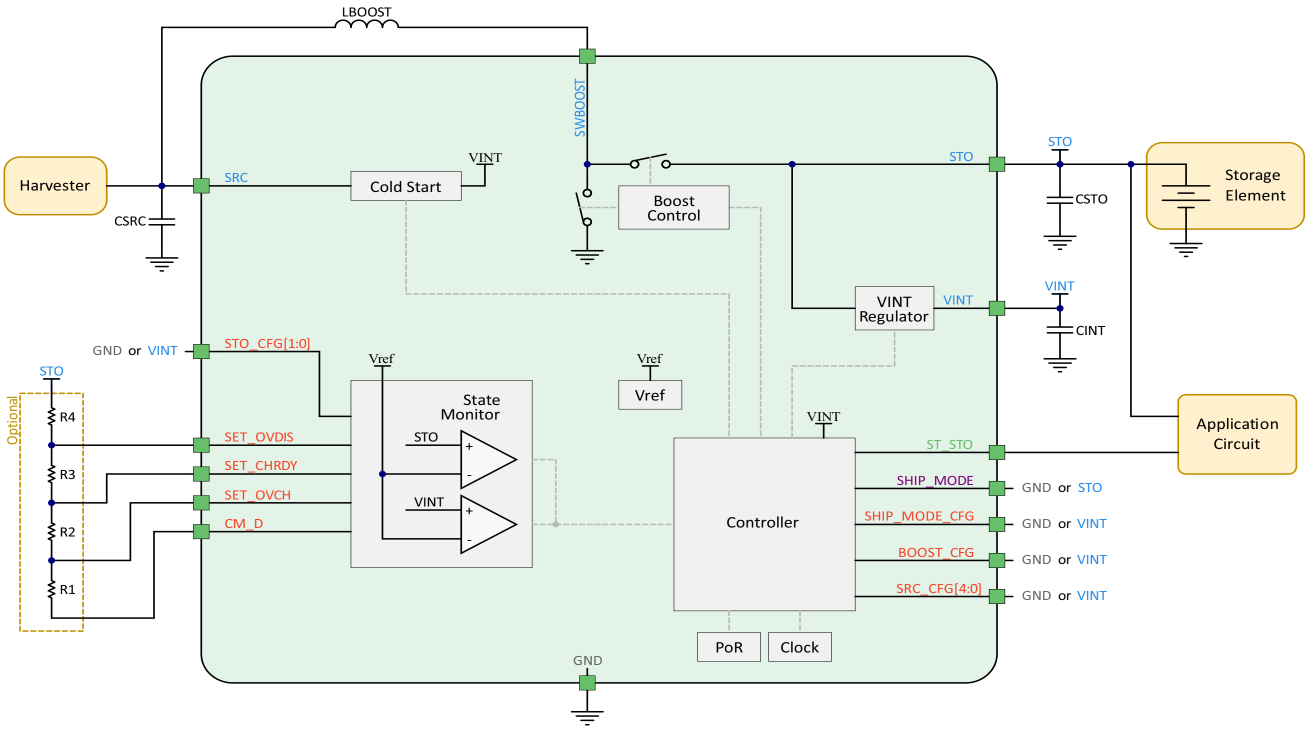


Figure 3: Functional block diagram

4. Theory of Operation

4.1. Cold-Start Circuit

The AEM11900 is able to coldstart from SRC. The cold-start circuit provides energy to the AEM11900 internal supply (VINT) when the device is in RESET STATE, SENSE STO STATE or OVDIS STATE.

4.2. Boost Converter

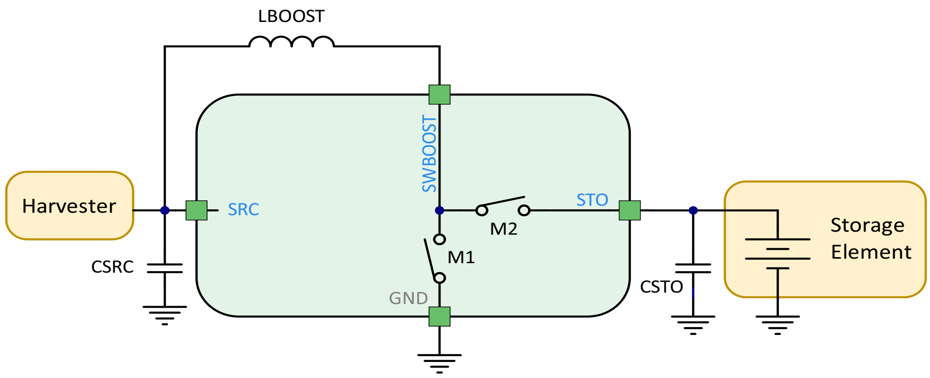


Figure 4: Simplified schematic view of the boost converter

4.2.1. Operation Principle

The boost (step-up) converter raises the voltage available at SRC to a level suitable for charging the storage element, in the range of 2.40 V to 4.59 V, according to the system configuration. The switching transistors of the boost converter are M1 and M2. The reactive power component of this converter is the external inductor L_{BOOST}.

Target source regulation voltage can be determined by:

- The constant voltage regulation setting when SRC_MODE is LOW (see Section 4.2.2).
- The MPPT module setting (ratio of open-circuit voltage) when SRC_MODE is HIGH (see Section 4.2.3).

SRC is decoupled by the capacitor C_{SRC}, which smooths the voltage against the current pulses induced by the boost converter.

The storage element is connected to the STO pin. This node is linked to the output of the boost converter.

The maximum current supplied to the STO pin depends on the value of L_{BOOST} and on the BOOST_CFG settings (see Section 5.5).

4.2.2. Source Constant Voltage Regulation

Constant voltage regulation mode can be selected by setting SRC_MODE to LOW.

In this mode, during START STATE, OVDIS STATE and SUPPLY STATE, V_{SRC} is regulated to a fixed voltage configured by the user (see Section 5.2).

The AEM11900 behaves as follows:

- If the open-circuit voltage V_{OC} of the harvester is lower than $V_{SRC,REG}$, the AEM11900 does not extract power from the source.
- If V_{OC} is higher than $V_{SRC,REG}$, the AEM11900 regulates V_{SRC} to $V_{SRC,REG}$ and thus, extracts power from the source.

4.2.3. Maximum Power Point Tracking

Maximum power point tracking mode can be selected by setting SRC_MODE to HIGH.

The AEM11900 Maximum Power Point Tracking (MPPT) module relies on the fact that, for several models of harvesters (typ. solar cells), the ratio between the maximum power point voltage (V_{MPP}) and the open-circuit voltage (V_{OC}) is constant for a wide range of harvesting conditions. For a solar cell, this means that V_{MPP} / V_{OC} is constant for any lighting conditions, even though both voltages increase when luminosity increases.

The maximum power point ratio (V_{MPP} / V_{OC}) differs from one harvester model to the other. The user must set the MPPT ratio to match the specifications of the harvester model used and thus maximize power extraction. This ratio is set through the configuration pins SRC_CFG[2:0] according to Table 11.

The MPPT module evaluates the open-circuit voltage V_{OC} periodically with the following sequence to ensure optimal power extraction at any time:

- The AEM11900 stops extracting power from the SRC during $T_{MPPT,WAIT}$ to allow the SRC voltage to rise to V_{OC}.
- Once this delay elapses, the AEM11900 performs the measurement of V_{OC} during $T_{MPPT,MEASURE}$ and determines V_{MPP} based on the configured MPPT ratio R_{MPPT} (see Table 11).
- After the measurement, the AEM11900 resumes power extraction by regulating the SRC voltage to the newly determined V_{MPP}.
- This MPPT evaluation is repeated every $T_{MPPT,PERIOD}$.

$T_{MPPT,WAIT}$ and $T_{MPPT,PERIOD}$ are set through the configuration pins SRC_CFG[4:3] (see Table 11) while $T_{MPPT,MEASURE}$ is constant for any configuration (see Table 7).

The AEM11900 offers a choice of eight different MPPT ratio values to support multiple V_{MPP} levels in the range from 0.12 V to 90 % of V_{OC}.

The MPPT module is active during START STATE, OVDIS STATE, SUPPLY STATE and SLEEP STATE.

4.3. Shipping Mode

The shipping mode feature allows to force the AEM11900 in RESET STATE (see Section 4.4), to disable the boost converter and therefore to prevent the charge of the storage element. Only VINT is charged from SRC if V_{SRC} is above $V_{SRC,CS}$.

See Section 5.6 for shipping mode configuration.

4.4. State Machine Description

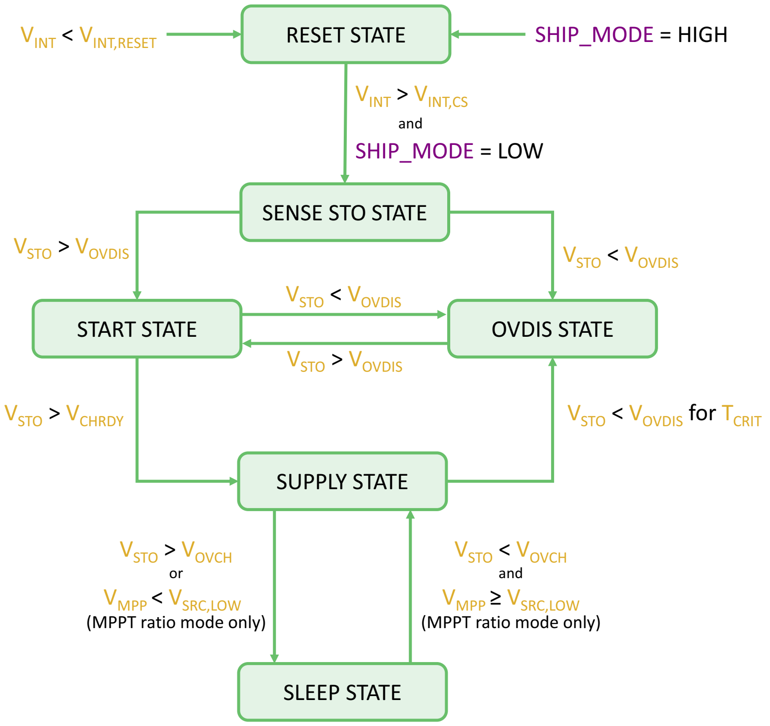


Figure 5: State machine

4.4.1. RESET STATE

The AEM11900 enters RESET STATE if one of the following is true:

- V_{INT} is below $V_{INT,RESET}$.
- Shipping mode is enabled (SHIP_MODE is HIGH).

In RESET STATE, the AEM11900 behaves as follows:

- The boost converter is disabled.
- The AEM11900 internal circuit VINT is supplied by SRC.
- Only $I_{Q,RESET}$ is drawn from the storage element connected to STO.
- ST_STO is LOW.

The AEM11900 stays in RESET STATE until the power available on SRC meets the cold-start requirements long enough to make V_{INT} reach $V_{INT,CS}$ (see Table 8).

Then:

- If shipping mode is disabled, the AEM11900 reads the value on all configuration pins and switches to SENSE STO STATE.
- If shipping mode is enabled, the AEM11900 stays in RESET STATE until shipping mode is disabled.

See Section 5.6 for how to configure the shipping mode.

Furthermore, from any state, the AEM11900 will switch to RESET STATE if V_{INT} drops below $V_{INT,RESET}$.

4.4.2. SENSE STO STATE

In SENSE STO STATE, the AEM11900 behaves as follows:

- A first measure of V_{STO} is performed by the AEM11900.
- The boost converter is not running.
- ST_STO is LOW.

From SENSE STO STATE, the AEM11900 switches to:

- START STATE if $V_{STO} > V_{OVDIS}$.
- OVDIS STATE if $V_{STO} < V_{OVDIS}$.

4.4.3. START STATE

When in SENSE STO STATE, the AEM11900 switches to START STATE if V_{STO} is above V_{OVDIS}.

In START STATE, the AEM11900 behaves as follows:

- The storage element connected to STO is charged by the boost converter until V_{STO} reaches V_{CHRDY}.
- The VINT internal supply energy is provided by the storage element regardless of the power available on SRC.
- ST_STO is LOW.

From START STATE, the AEM11900 switches to:

- SUPPLY STATE if $V_{STO} > V_{CHRDY}$.
- OVDIS STATE if $V_{STO} < V_{OVDIS}$.

4.4.4. SUPPLY STATE

When in START STATE, the AEM11900 switches to SUPPLY STATE if V_{STO} rises above V_{CHRDY}.

In SUPPLY STATE, the AEM11900 behaves the same as when in START STATE, but ST_STO is HIGH.

When in SUPPLY STATE, the AEM11900 switches to SLEEP STATE if one of the following conditions is met:

- $V_{STO} > V_{OVCH}$
- $V_{MPP} < V_{SRC,LOW}$ (for MPPT ratio mode only)

NOTE: In constant voltage mode, $V_{SRC,REG}$ cannot be set below $V_{SRC,LOW}$. SLEEP STATE is triggered only when V_{STO} rises above V_{OVCH}.

From SUPPLY STATE, the AEM11900 switches to OVDIS STATE if the following condition is met:

- $V_{STO} < V_{OVDIS}$ for T_{CRIT}

4.4.5. OVDIS STATE

The AEM11900 switches to OVDIS STATE if:

- V_{STO} is below V_{OVDIS} when in SENSE STO STATE or START STATE.
- V_{STO} remains below V_{OVDIS} for more than T_{CRIT} when in SUPPLY STATE.

In OVDIS STATE, the AEM11900 behaves as follows:

- The storage element connected to STO is charged by the boost converter until V_{STO} rises above V_{OVDIS}.
- The VINT internal supply energy is provided by SRC.
- ST_STO is LOW.

From OVDIS STATE, the AEM11900 switches to:

- START STATE if V_{STO} rises above V_{OVDIS}.
- RESET STATE if not enough power is available on SRC to maintain V_{INT} above $V_{INT,RESET}$. STO pin is set to high impedance, so that virtually no current is drawn from the storage element connected to STO ($I_{Q,RESET}$ as defined in Section 2.4).

4.4.6. SLEEP STATE

SLEEP STATE allows for reducing the AEM11900 internal circuit consumption, and thus, keeping storage element discharge to a minimum.

The AEM11900 switches from SUPPLY STATE to SLEEP STATE if one of the following conditions is true:

- The battery is fully charged ($V_{STO} > V_{OVCH}$).
- The source regulation voltage V_{MPP} is lower than $V_{SRC,LOW}$ (for MPPT ratio mode only).

In SLEEP STATE, the AEM11900 behaves as follows:

- The battery connected to STO is not charged by SRC, allowing for reducing the quiescent current on VINT and thus, on STO.
- The VINT internal supply energy is provided by the storage element regardless of the power available on SRC.
- ST_STO is HIGH.

From SLEEP STATE, the AEM11900 switches back to SUPPLY STATE if the following conditions are true:

- $V_{STO} < V_{OVCH}$
- $V_{MPP} \geq V_{SRC,LOW}$ (for MPPT ratio mode only)

5. System Configuration

5.1. Configuration Pins Reading

After a cold start, the AEM11900 reads the configuration pins. Those are then read periodically every $T_{GPIO,MON}$.

The configuration pins can be changed on-the-fly, except for the custom mode configuration pins (CM_D, SET_OVDIS, SET_CHRDY, and SET_OVCH), which are read only at startup.

The floating state of the configuration pins is HIGH, except for the SHIP_MODE pin, whose floating state is set by SHIP_MODE_CFG (see Table 3), and the custom mode configuration pins, which cannot be left floating (see Section 5.4.2).

5.2. Source Constant Voltage Regulation Configuration

When source regulation is configured to constant voltage mode (SRC_MODE is LOW), the regulation voltage can be configured with SRC_CFG[4:0] (see Table 10).

Configuration pins					Voltage [V]	Configuration pins					Voltage [V]
SRC_CFG[4:0]					$V_{SRC,REG}$	SRC_CFG[4:0]					$V_{SRC,REG}$
L	L	L	L	L	0.25	H	L	L	L	L	1.10
L	L	L	L	H	0.30	H	L	L	L	H	1.20
L	L	L	H	L	0.35	H	L	L	H	L	1.31
L	L	L	H	H	0.41	H	L	L	H	H	1.40
L	L	H	L	L	0.45	H	L	H	L	L	1.50
L	L	H	L	H	0.50	H	L	H	L	H	1.61
L	L	H	H	L	0.56	H	L	H	H	L	1.70
L	L	H	H	H	0.60	H	L	H	H	H	1.79
L	H	L	L	L	0.65	H	H	L	L	L	1.90
L	H	L	L	H	0.71	H	H	L	L	H	1.99
L	H	L	H	L	0.75	H	H	L	H	L	2.19
L	H	L	H	H	0.80	H	H	L	H	H	2.41
L	H	H	L	L	0.86	H	H	H	L	L	2.59
L	H	H	L	H	0.90	H	H	H	L	H	2.82
L	H	H	H	L	0.95	H	H	H	H	L	3.00
L	H	H	H	H	1.01	H	H	H	H	H	3.18

Table 10: Configuration of the source constant regulation voltage with SRC_CFG[4:0] pins

5.3. MPPT Configuration

When SRC voltage regulation is set to MPPT mode (SRC_MODE is HIGH), two parameters must be configured:

- The first parameter is the MPP tracking ratio R_{MPPT}, which is selected according to the characteristics of the input power source. This parameter is set by the configuration pins SRC_CFG[2:0].
- The second parameter allows for configuring the wait time before V_{OC} measurement begins for each MPP evaluation ($T_{MPPT,WAIT}$) and the MPP evaluations period ($T_{MPPT,PERIOD}$). This configuration is set by the configuration pins SRC_CFG[4:3].

When using the MPPT ratio regulation mode, the total capacitance connected to the SRC pin of the AEM11900 must be selected based on the characteristics of the energy harvester and on the available source power. The source capacitor (C_{SRC}) charging time up to the open-circuit voltage (V_{OC}) during the Maximum Power Point (MPP) evaluations must remain shorter than the configured $T_{MPPT,WAIT}$. This will ensure an accurate measurement of V_{OC} and thus, an accurate source voltage regulation.

Configuration			Function
SRC_CFG[2:0]			$R_{MPPT} = V_{MPP} / V_{OC}$
L	L	L	35 %
L	L	H	50 %
L	H	L	65 %
L	H	H	70 %
H	L	L	75 %
H	L	H	80 %
H	H	L	85 %
H	H	H	90 %

Configuration		Function	
SRC_CFG[4:3]		$T_{MPPT,PERIOD}$ [s]	$T_{MPPT,WAIT}$ [s]
L	L	15	0.25
L	H	15	0.50
H	L	25	0.25
H	H	25	0.50

Table 11: Configuration of MPPT ratio and timings

5.4. Storage Element Protection Thresholds

Two methods are available to configure the storage element protection thresholds V_{OVDIS}, V_{CHRDY} and V_{OVCH}:

- Configuration through STO_CFG[1:0] pins as described in Section 5.4.1.
- Configuration using the custom mode as described in Section 5.4.2.

5.4.1. Configuration Pins

The storage element protection thresholds V_{OVDIS}, V_{CHRDY} and V_{OVCH}, can be configured through STO_CFG[1:0] pins as shown in Table 12.

Configuration pins		Overdischarge voltage [V]	Charge ready voltage [V]	Overcharge voltage [V]	Storage element type
STO_CFG[1:0]		V_{OVDIS}	V_{CHRDY}	V_{OVCH}	
L	L	2.51	2.61	3.79	Lithium-ion Super Capacitor (LiC)
L	H	3.00	3.21	4.13	Lithium-ion battery
H	L	3.00	3.21	4.35	LiPo battery
H	H	3.51	3.60	3.90	Li-ion battery (ultra long life)

Table 12: Storage element configuration with STO_CFG[1:0] pins

DISCLAIMER: storage element thresholds provided in the table above are indicative to support a wide range of storage element variants. They are provided as is to the best knowledge of e-peas's application laboratory. They should not replace the actual values provided in the storage element manufacturer's specifications and datasheet.

5.4.2. Custom Mode

The storage element protection thresholds V_{OVDIS}, V_{CHRDY} and V_{OVCH}, can be configured through the custom mode.

During startup, when exiting RESET STATE, the AEM11900 reads the CM_D pin along with the other configuration pins. If CM_D is not connected to GND, the custom mode is selected regardless of the state of STO_CFG[1:0] pins. The CM_D pin is read only at this moment and cannot be modified dynamically.

When the custom mode is enabled, the storage element protection thresholds are defined during SENSE STO STATE through all four configuration resistors wired as shown in Figure 6.

CAUTION: If the custom mode is not used, make sure to connect CM_D to GND, as this pin cannot be left floating.

V_{OVDIS}, V_{CHRDY} and V_{OVCH} defined by R_1, R_2, R_3 and R_4 are calculated as follows:

- $R_T = R_1 + R_2 + R_3 + R_4$
- $100\ k\Omega \le R_T \le 400\ k\Omega$
- $R_1 = R_T \cdot \frac{0.5\ V}{V_{OVCH}}$
- $R_2 = R_T \cdot \left(\frac{0.5\ V}{V_{CHRDY}} - \frac{0.5\ V}{V_{OVCH}}\right)$
- $R_3 = R_T \cdot \left(\frac{0.5\ V}{V_{OVDIS}} - \frac{0.5\ V}{V_{CHRDY}}\right)$
- $R_4 = R_T - (R_1 + R_2 + R_3)$

The following constraints must be met to ensure the functionality of the chip:

- $2.40\ V \le V_{OVDIS} \le 4.39\ V$
- $2.51\ V \le V_{CHRDY} \le 4.50\ V$
- $2.61\ V \le V_{OVCH} \le 4.59\ V$
- $V_{CHRDY} + 100\ mV < V_{OVCH}$
- $V_{OVDIS} + 100\ mV < V_{CHRDY}$

NOTE: If the threshold voltages are set below the minimum or above the maximum allowed values, the thresholds will be forced to the closest valid value (minimum or maximum).

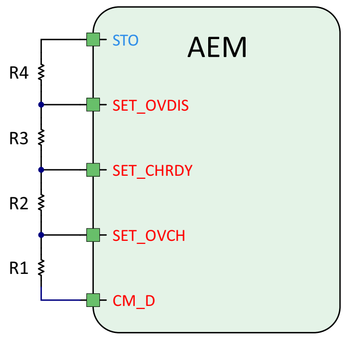


Figure 6: Custom mode configuration resistors

5.5. Boost Converter Timings

The BOOST_CFG pin allows for modifying the peak current of the boost inductor by multiplying the on/off timings of the boost converter, as shown in Table 13. The larger the timing multiplier, the larger the boost inductor peak current, and thus, the larger the average source current pulled from SRC to STO.

The peak current in the inductor also depends on the value of the inductor. Table 13 shows the minimum inductor value to be implemented for each timing value. Lower value may cause damage to the AEM11900.

Configuration pin	Function		
BOOST_CFG	Timing multiplier factor	Minimum L_{BOOST} [µH]	Recommended[1] L_{BOOST} [µH]
L	x1	3.3	10
H	x3	9.9	33

Table 13: Boost converter timings configuration

1. Recommended L_{BOOST} for the best efficiency/current capability trade-off according to the tests carried out in e-peas laboratory.

5.6. Shipping Mode

The shipping mode, described in Section 4.3, can be configured as follows:

The SHIP_MODE pin controls the shipping mode state:

- If SHIP_MODE is LOW, the shipping mode is disabled.
- If SHIP_MODE is HIGH, the shipping mode is enabled.

If SHIP_MODE is left floating, its state depends on the SHIP_MODE_CFG pin:

- If SHIP_MODE_CFG is LOW, SHIP_MODE is interpreted as HIGH if left floating.
- If SHIP_MODE_CFG is HIGH, SHIP_MODE is interpreted as LOW if left floating.

The SHIP_MODE and SHIP_MODE_CFG pins are read every $T_{GPIO,MON}$.

SHIP_MODE_CFG pin state	SHIP_MODE pin state	Shipping Mode Functionality
LOW	LOW	Disabled
	floating	Enabled
	HIGH	Enabled
HIGH	LOW	Disabled
	floating	Disabled
	HIGH	Enabled

Table 14: Shipping mode configuration

6. Typical Application Circuit

6.1. Example Circuit 1

Figure 7 shows a typical application circuit of the AEM11900.

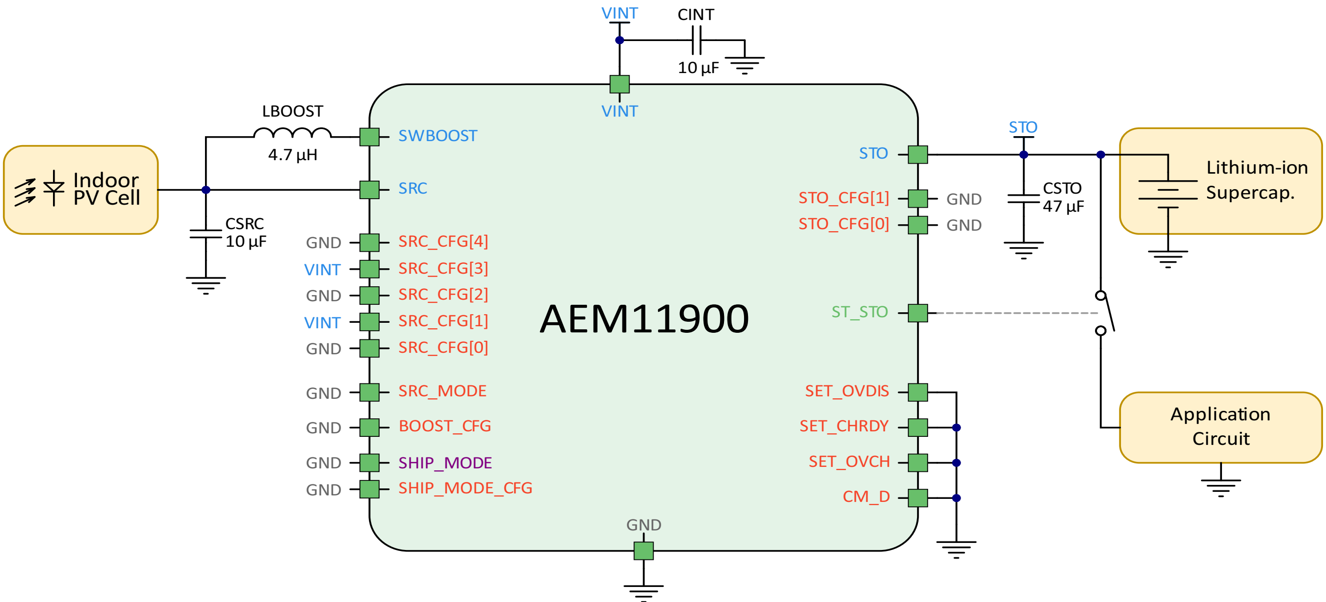


Figure 7: Typical application circuit 1

Configuration of SRC

The energy source is an indoor PV cell which provides the maximum power at 0.75 V. SRC is configured as follows:

- SRC_MODE = L (constant voltage regulation mode).
- SRC_CFG[4:0] = LHLHL (0.75 V regulation).
- BOOST_CFG = L: x1 boost timing.
- L_{BOOST} = 4.7 µH for high current capability with x1 boost timing (see Section 5.5) and low-cost inductor.

Configuration of STO

The storage element is a Lithium-ion supercapacitor. Storage element threshold voltages are set as follows:

- STO_CFG[1:0] = LL.
  - V_{OVDIS} = 2.51 V.
  - V_{CHRDY} = 2.61 V.
  - V_{OVCH} = 3.79 V.
- Custom mode is not used so CM_D, SET_OVDIS, SET_CHRDY and SET_OVCH are connected to GND.

Shipping mode

Shipping mode is not used.

- SHIP_MODE is connected to GND.
- SHIP_MODE_CFG is connected to GND.

Status pin

The ST_STO pin is used to control a switch that disconnects the application circuit from the storage element, so that:

- The application circuit is powered only once V_{STO} rises above V_{CHRDY}.
- The application circuit power consumption does not discharge further the storage element when it is overdischarged.

6.2. Example Circuit 2

Figure 8 shows a typical application circuit of the AEM11900.

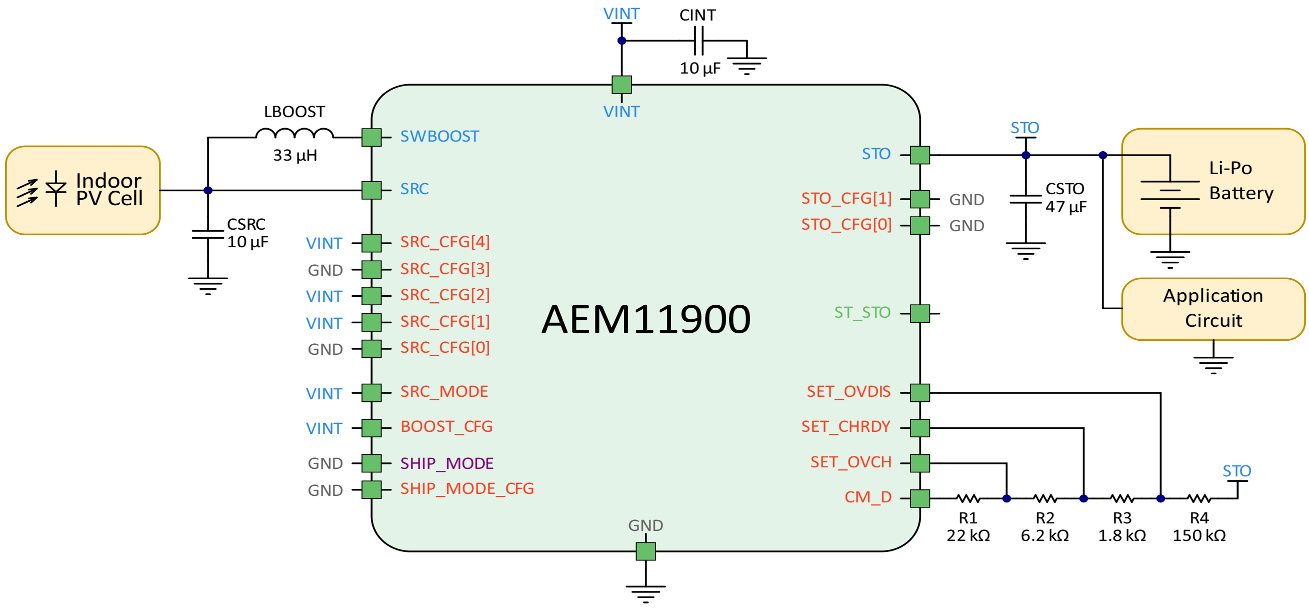


Figure 8: Typical application circuit 2

Configuration of SRC

The energy source is an indoor PV cell which has an 85% MPPT ratio. SRC is configured as follows:

- SRC_MODE = H (MPPT mode).
- SRC_CFG[2:0] = HHL: 85 % ratio.
- SRC_CFG[4:3] = HL:
  - $T_{MPPT,PERIOD}$ = 25 s.
  - $T_{MPPT,WAIT}$ = 0.25 s.
- BOOST_CFG = H: x3 boost timing.
- L_{BOOST} = 33 µH for best trade-off between efficiency and maximum current with x3 boost timing (see Section 5.5).

Shipping mode

Shipping mode is not used.

- SHIP_MODE is connected to GND.
- SHIP_MODE_CFG is connected to GND.

Configuration of STO

The storage element is a Lithium-Polymer (Li-Po) battery used with custom voltage thresholds set as follows:

- STO_CFG[1:0] = LL: AEM11900 ignores STO_CFG[1:0] settings as CM_D is not set to GND (custom mode is used).
- Target storage element protection thresholds are the following:
  - V_{OVDIS} = 3.00 V.
  - V_{CHRDY} = 3.20 V.
  - V_{OVCH} = 4.10 V.
- Custom mode resistors are configured as follows:
  - $R_T = R_1 + R_2 + R_3 + R_4 = 180\ k\Omega$
  - $R_1 = R_T \cdot \frac{0.5\ V}{V_{OVCH}} = 22\ k\Omega$
  - $R_2 = R_T \cdot \left(\frac{0.5\ V}{V_{CHRDY}} - \frac{0.5\ V}{V_{OVCH}}\right) = 6.2\ k\Omega$
  - $R_3 = R_T \cdot \left(\frac{0.5\ V}{V_{OVDIS}} - \frac{0.5\ V}{V_{CHRDY}}\right) = 1.8\ k\Omega$
  - $R_4 = R_T - (R_1 + R_2 + R_3) = 150\ k\Omega$

7. Minimum BOM

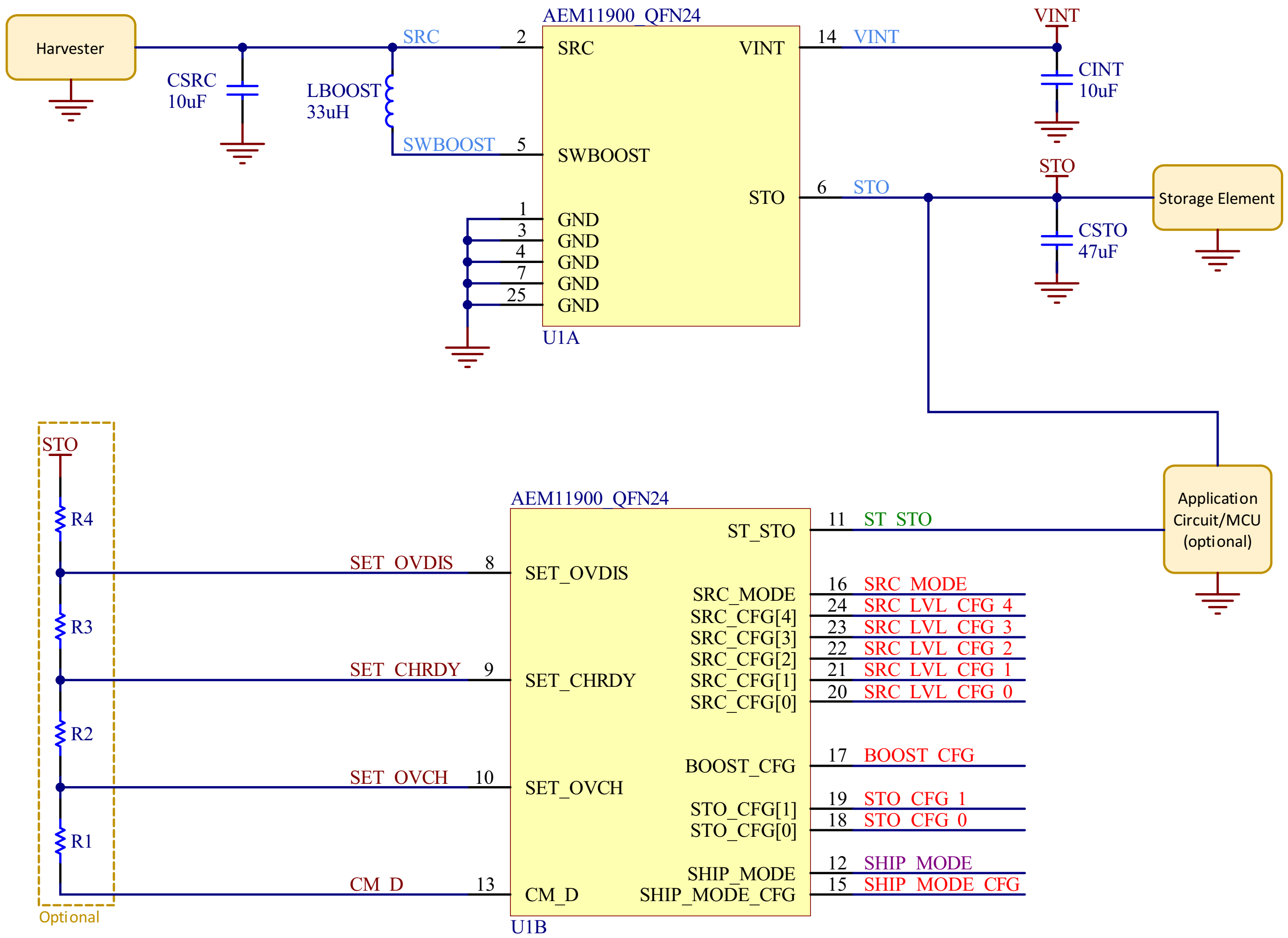


Figure 9: Schematic with minimum BOM

	Designator	Description	Quantity	Manufacturer	Part Number
Mandatory	U1	AEM11900	1	e-peas	order at sales@e-peas.com
	CSRC	Ceramic Capacitor 10 µF, 10 V, 20 %, X5R, 0603	1	Murata	GRM188R61A106ME69D
	LBOOST	Power Inductor 33 µH, 0.68 A, LPS4018	1	Coilcraft	LPS4018-333MRB
	CINT	Ceramic Capacitor 10 µF, 6.3 V, 20 %, X5R, 0402	1	Murata	GRM155R60J106ME44D
	CSTO[1]	Ceramic Capacitor 47 µF 6.3 V, 20 %, X5R, 0603	1	Murata	GRM188R60J476ME15D
Optional	R1	Resistors (to be defined)	1	To be defined (see Section 5.4.2)	
	R2		1		
	R3		1		
	R4		1		

Table 15: Minimum BOM

1. Recommended CSTO for optimal efficiency, particularly with high-ESR storage elements. If using a smaller value, ensure it meets the minimum requirement (see Table 9).

8. Layout

8.1. Guidelines

Figure 10 shows an example of PCB layout with AEM11900.

The following guidelines must be applied for best performances:

- Make sure that ground and power signals are routed with large tracks. If an internal ground plane is used, place via as close as possible to the components, especially for decoupling capacitors.
- Reactive components related to the boost converter must be placed as close as possible to the corresponding pins (SWBOOST, SRC and STO), and be routed with large tracks/polygons.

- PCB track capacitance must be reduced as much as possible on the boost converter switching node SWBOOST. This is done as follows:
  - Keep the connection between the SWBOOST pins and L_{BOOST} short.
  - Remove the ground and power planes under the SWBOOST node. The polygon on the opposite external layer may also be removed.
  - Increase the distance between SWBOOST and the ground polygon on the external PCB layer where the AEM11900 is mounted.

8.2. Example

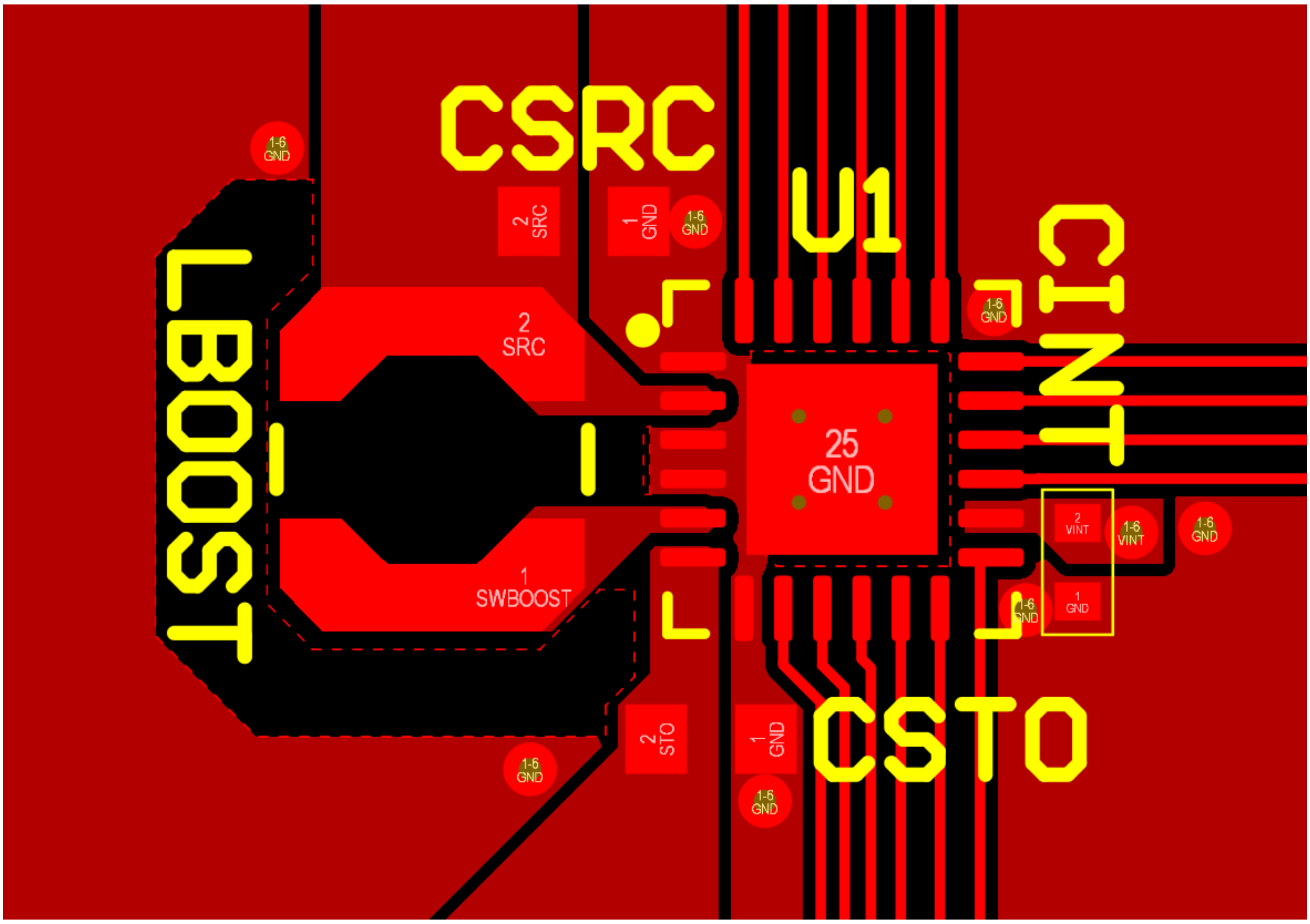


Figure 10: Layout example for the AEM11900 with associated passive components

9. Package Information

9.1. Moisture Sensitivity Level

Package	Moisture Sensitivity Level (MSL)[1]
QFN-24	Level 1

Table 16: Moisture sensitivity level

1. According to JEDEC 22-A113 standard.

9.2. RoHS Compliance

e-peas product complies with RoHS requirement.

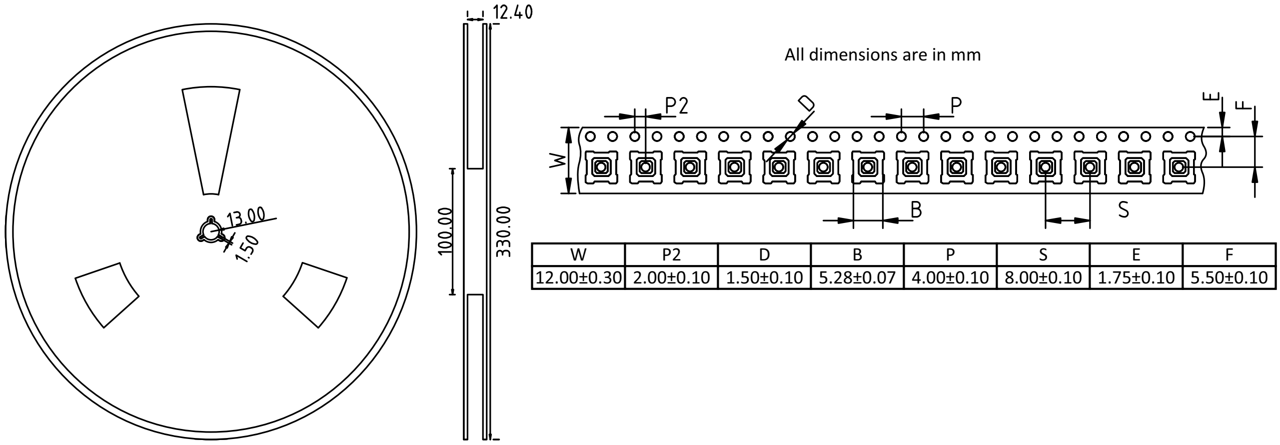
e-peas defines "RoHS" to mean that semiconductor end-products are compliant with RoHS regulation for all 10 RoHS substances.

This applies to silicon, die attached adhesive, gold wire bonding, lead frames, mold compound, and lead finish (pure tin).

9.3. REACH Compliance

The component and elements used by e-peas subcontractors to manufacture e-peas PMICs and devices are REACH compliant. For more detailed information, please contact e-peas sales team.

9.4. Tape and Reel Dimensions



W	P2	D	B	P	S	E	F
12.00±0.30	2.00±0.10	1.50±0.10	5.28±0.07	4.00±0.10	8.00±0.10	1.75±0.10	5.50±0.10

Figure 11: Tape and reel dimensions

9.5. Package Dimensions

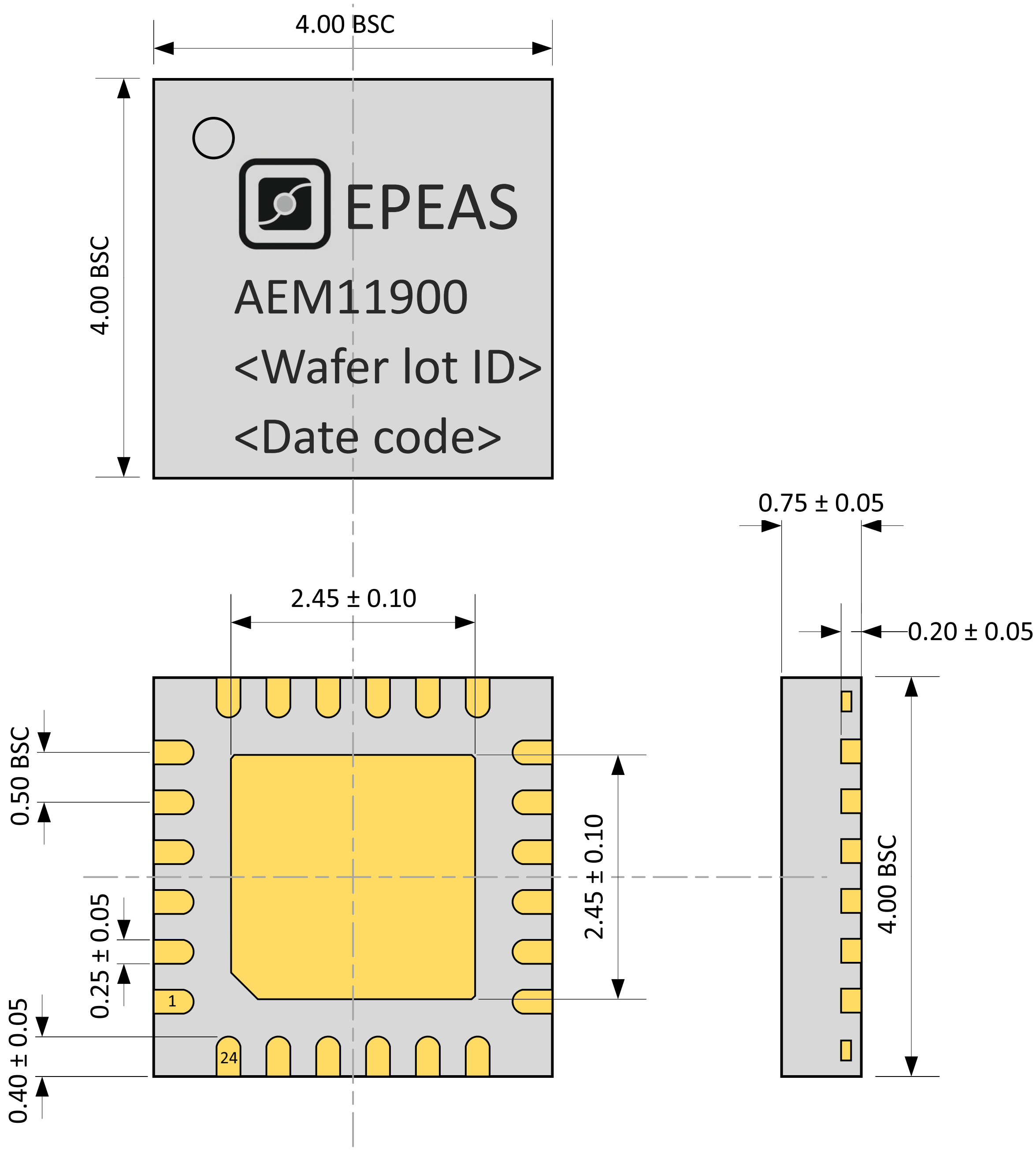


Figure 12: QFN 24-pin 4x4mm drawing (all dimensions in mm)

9.6. Board Layout

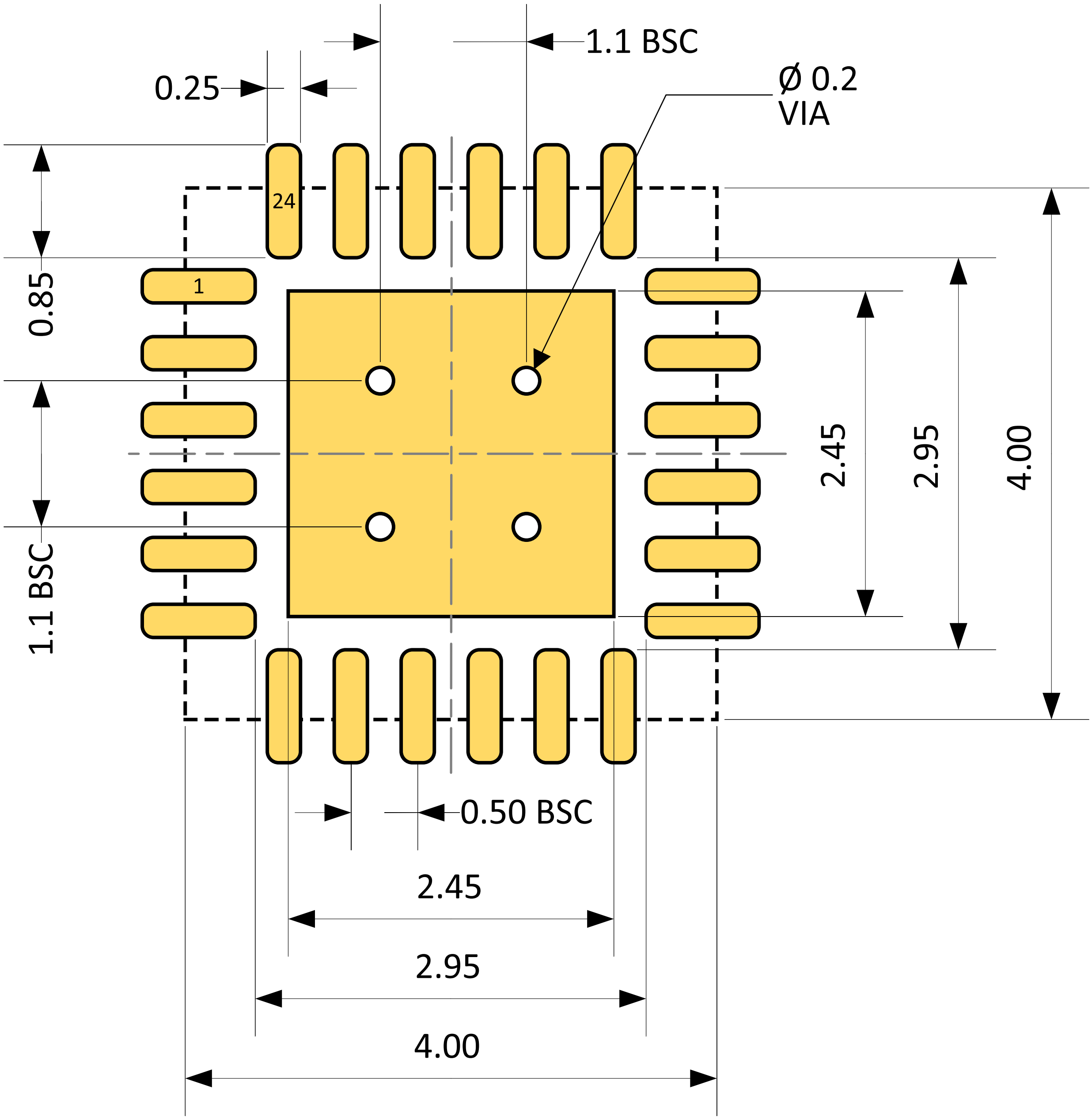


Figure 13: Recommended board layout for QFN24 package (all dimensions in mm)

10. Glossary

C_{INT}
: VINT pin decoupling capacitor.

C_{SRC}
: Boost converter input capacitor.

C_{STO}
: STO pin decoupling capacitor.

$I_{Q,RESET}$
: Quiescent current on STO when the AEM11900 is in RESET STATE.

$I_{Q,SHIP}$
: Quiescent current on STO when the AEM11900 is in shipping mode (SHIP_MODE is HIGH) with or without energy available on SRC.

$I_{Q,SLEEP}$
: Quiescent current on STO in SLEEP STATE.

$I_{Q,SUPPLY}$
: Quiescent current on STO in SUPPLY STATE.

L_{BOOST}
: Boost converter inductor.

$P_{SRC,CS}$
: Minimum power required on SRC to coldstart.

R_1 - R_2 - R_3 - R_4
: Custom mode configuration resistors.

R_{MPPT}
: Ratio of V_{MPP} to V_{OC} (MPPT ratio mode).

R_T
: Sum of the custom mode configuration resistors.

T_{CRIT}
: When V_{STO} drops below V_{OVDIS} in SUPPLY STATE, the AEM11900 waits T_{CRIT} before switching to OVDIS STATE.

$T_{GPIO,MON}$
: GPIO reading rate.

$T_{MPPT,MEASURE}$
: Duration of V_{OC} measurement during MPP evaluations.

$T_{MPPT,PERIOD}$
: MPPT V_{OC} evaluations period (MPPT ratio mode).

$T_{MPPT,WAIT}$
: Wait time before V_{OC} measurement begins during MPP evaluations (MPPT ratio mode).

$T_{STO,MON}$
: Storage element voltage monitoring rate.

V_{CHRDY}
: In START STATE, voltage required on the storage element to switch to SUPPLY STATE (see Section 5.4).

V_{ESD}
: Electrostatic discharge voltage.

V_{INT}
: Voltage on the VINT pin.

$V_{INT,CS}$
: Minimum voltage on VINT to allow the AEM11900 to switch from RESET STATE to SENSE STO STATE.

$V_{INT,RESET}$
: Minimum voltage on VINT before switching to RESET STATE (from any other state).

V_{MPP}
: Target regulation voltage on SRC when extracting power (MPPT ratio mode).

V_{OC}
: Open-circuit voltage of the harvester connected on SRC.

V_{OVCH}
: Maximum voltage accepted on the storage element before disabling its charging (see Section 5.4).

V_{OVDIS}
: Voltage below which the storage element is considered to be fully depleted, and must not be discharged any further (see Section 5.4).

V_{SRC}
: Voltage on the SRC pin.

$V_{SRC,CS}$
: Minimum SRC voltage to coldstart the AEM11900.

$V_{SRC,LOW}$
: V_{SRC} threshold below which the AEM11900 switches to SLEEP STATE (MPPT ratio mode).

$V_{SRC,REG}$
: Source target regulation voltage, set by SRC_CFG[4:0] configuration pins (constant voltage mode).

V_{STO}
: Voltage on the STO pin.

11. Revision History

Revision	Date	Description
1.5	February, 2026	First public release.

Table 17: Revision history