AEM10900 Evaluation Board User Guide

Description

The AEM10900 evaluation kit (EVK) is a printed circuit board (PCB) featuring all the required components to operate the AEM10900 integrated circuit (IC) in QFN28 package.

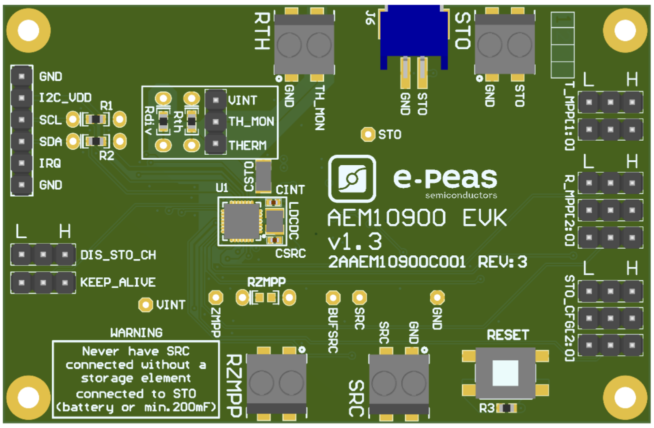
The AEM10900 evaluation board allows users to test the e-peas IC and analyze its performances in a laboratory-like setting or in product mock-ups.

It allows easy connections to an energy harvester (e.g. a single element PV cell) and a storage element. It also provides all the configuration access to set the device in any of the modes described in the datasheet. The control and status signals are available on standard pin headers or through an I²C bus communication, allowing users to override preconfigured board settings through host MCU and evaluate the IC performances.

The AEM10900 EVK is a plug and play, intuitive and efficient tool to optimize the AEM10900 configuration, allowing users to design a highly efficient subsystem for the desired target application. Component replacement and operating mode switching is convenient and easy.

More detailed information about AEM10900 features can be found in the datasheet.

Appearance



Features

Two-way screw terminals

- Source of energy (DC).
- ZMPP configuration.
- Energy storage element (battery).
- Thermistor used for thermal monitoring.

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.
- Energy storage element threshold configuration.
- Mode configuration.
- Thermal monitoring configuration.

6-pin header

- I²C communication pins.

Applications

Wearable Electronics	Keyboards
Remote Control Units	Electronic Shelf Labels
Smart Buildings	Indoor Sensors

Evaluation Kit Information

Part Number	Dimensions
2AAEM10900C001 REV:3	76 mm x 50 mm

Device Information

Part Number	Package	Body size
10AEM10900C0000	QFN 28-pin	4x4mm

1. Connections Diagram

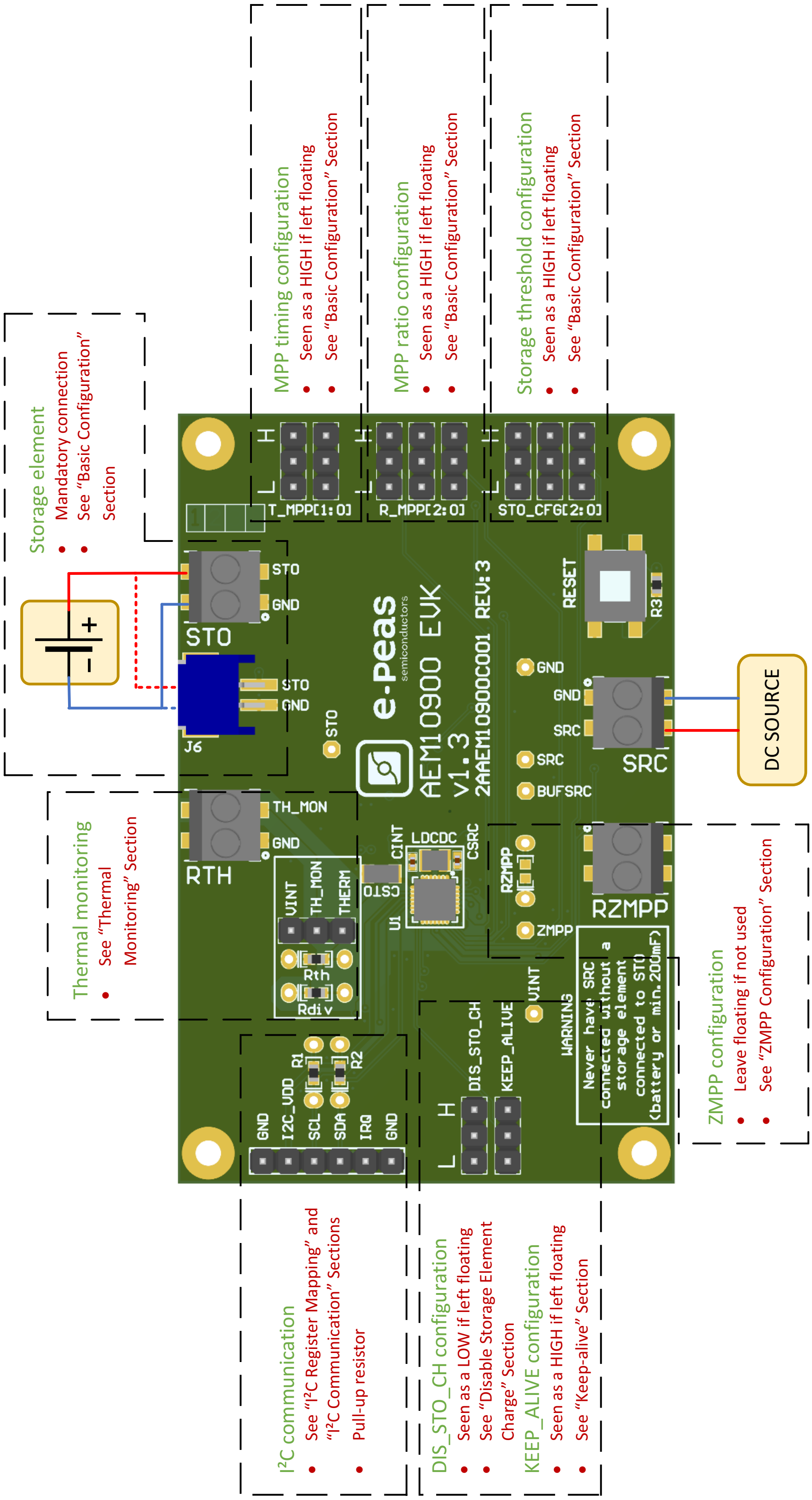


Figure 1: Connection diagram

1.1. Signals Description

NAME	FUNCTION	CONNECTION	
		If used	If not used
Power signals			
SRC	Connection to the harvested energy source.	Connect the source element.	Can be left floating.
STO	Connection to the energy storage element.	Cannot be left floating, voltage must always be above 2.8 V.	
I^2C _VDD	Connection to I^2C voltage supply.	Connect to I^2C supply.	Connect to GND.
ZMPP	Configuration of the constant impedance MPP.	Connect R_{ZMPP} resistor.	Leave floating.
VINT	AEM Internal voltage supply.		
BUFSRC	AEM connection to a capacitor buffering the boost converter input (no connector on EVK).		
Configuration signals			
R_MPP[2:0]	Configuration of the MPP ratio.	Connect jumpers.	Read as high if left floating.
T_MPP[1:0]	Configuration of the MPP timing.	Connect jumpers.	Read as high if left floating.
STO_CFG[2:0]	Configuration of the threshold voltages for the energy storage element.	Connect jumpers.	Read as high if left floating.
TH_MON	Configuration of the thermal monitoring.	Connect a thermistor.	Connect to VINT.
Control signals			
DIS_STO_CH	Disabling pin for the storage charging.	Connect jumper (see Section 2.5.2).	Read as low if left floating.
KEEP_ALIVE	Enabling pin to supply internal circuitry from the storage element if no power on SRC.	Connect jumper (see Section 2.5.2).	Read as low if left floating.
I^2C signals			
SDA	Bidirectional data line.	Connect to host I^2C bus.	Connect I^2C _VDD to GND (SDA and SCL will be pulled down by R_1 and R_2).
SCL	Unidirectional serial clock.		
IRQ	Interrupt request.	Connect to host GPIO.	Leave floating.

Table 1: Pin description

2. General Considerations

2.1. Safety Information

Always connect the elements in the following order:

1. Reset the board: push the “RESET” (SW2) switch during 5 seconds minimum.
2. Completely configure the PCB (jumpers/resistors):
   - Battery configuration.
   - Mode configuration.
   - Thermal monitoring configuration.
3. Connect I2C_VDD:
   - To GND if I²C is not used (SDA and SCL will also be connected to GND through their pull up resistors).
   - To a power supply if I²C is used (1.5 V to 2.2 V).
4. Connect the storage elements on STO with a voltage higher than 2.8 V.
5. Connect the source to the SRC connector (open circuit voltage lower than 2.0 V).

2.2. Basic Configurations

Configuration	Availability Through Pins		MPPT ratio
R_MPP[3:0]	I²C Interface[a]	Configuration pins[b]	V_{MPP} / V_{OC}
LLLL	yes	yes	ZMPP
LLLH	yes	yes	90%
LLHL	yes	yes	65%
LLHH	yes	yes	60%
LHLL	yes	yes	85%
LHLH	yes	yes	75%
LHHL	yes	yes	70%
LHHH	yes	yes	80%
HLLL	yes	no	35%
HLLH	yes	no	50%

Table 2: Configuration of R_{MPPT}

a. For I²C configuration, R_MPP[3:0] value is set thanks to the MPPTCFG[3:0] register.
b.Only R_MPP[2:0] settings are available by GPIO configuration (R_MPP[3] = L in that case).

Configuration	Availability Through Pins		MPP Timing	
T_MPP[2:0]	I²C Interface[a]	Configuration pins[b]	Sampling duration T_{VOC} [ms]	Sampling period T_{MPPT} [ms]
LLL	yes	no	2	64
LLH	yes	no	256	16384
LHL	yes	no	64	4096
LHH	yes	no	8	1024
HLL	yes	yes	4	256
HLH	yes	yes	2	128
HHL	yes	yes	4	512
HHH	yes	yes	2	256

Table 3: Configuration of T_{MPPT}

a. For I²C configuration, T_MPP[2:0] value is set thanks to the MPPTCFG[6:4] register (see Table 5).
b. Only T_MPP[1:0] settings are available by GPIO configuration (T_MPP[2] = H in that case).

Configuration	**Availability Through Pins**		**Storage Element Threshold Voltage**	
STO_CFG[2:0]	I²C Interface	Configuration pins	V_{OVCH}	V_{OVDIS}
LLL	yes	yes	4.50 V	3.30 V
LLH	yes	yes	4.00 V	2.80 V
LHL	yes	yes	3.63 V	2.80 V
LHH	yes	yes	3.90 V	2.80 V
HLL	yes	yes	3.90 V	3.50 V
HLH	yes	yes	3.90 V	3.01 V
HHL	yes	yes	4.35 V	3.01 V
HHH	yes	yes	4.12 V	3.01 V

Table 4: Usage of STO_CFG[2:0]

2.3. I²C Register Map

Address	Name	Bit	Field Name	Access	RESET	Description
0x00	VERSION	[3:0]	MINOR	R	-	Chip ID
		[7:4]	MAJOR	R	-	
0x01	MPPTCFG	[3:0]	RATIO	R/W	0x07 (80%)	MPPT ratios
		[6:4]	TIMING	R/W	0x07 (2ms/ 256ms)	MPPT timings
0x02	VOVDIS	[5:0]	THRESH	R/W	0x2D (3.05V)	Overdischarge level of the storage element
0x03	VOVCH	[5:0]	THRESH	R/W	0x33 (4.1V)	Overcharge level of the storage element
0x04	TEMPCOLD	[7:0]	THRESH	R/W	0x8F (0°C)	Cold temperature level
0x05	TEMPHOT	[7:0]	THRESH	R/W	0x2F (45°C)	Hot temperature level
0x06	PWR	[0:0]	KEEPALEN	R/W	0x01	Keepalive enable
		[1:1]	HPEN	R/W	0x01	High power mode enable
		[2:2]	TMONEN	R/W	0x01	Temperature monitoring enable
		[3:3]	STOCHDIS	R/W	0x00	Battery charging disable
0x07	SLEEP	[0:0]	EN	R/W	0x01	Sleep mode enable
		[3:1]	THRESH	R/W	0x00	Sleep threshold
0x08	STOMON	[2:0]	RATE	R/W	0x00	ADC rate
0x09	APM	[0:0]	EN	R/W	0x00	APM enable
		[1:1]	RSVD1	R/W	0x00	Write 0x01 when APM is used.
		[3:2]	RSVD2	R/W	0x00	Write 0x00 when APM is used.
0x0A	IRQEN	[0:0]	I2CRDY	R/W	0x01	IRQ serial interface ready enable
		[1:1]	VOVDIS	R/W	0x00	IRQ STO OVDIS enable
		[2:2]	VOVCH	R/W	0x00	IRQ STO OVCH enable
		[3:3]	SLPTHRESH	R/W	0x00	IRQ SRC LOW enable
		[4:4]	TEMP	R/W	0x00	IRQ temperature enable
		[5:5]	APMDONE	R/W	0x00	IRQ APM done enable
0x0B	CTRL	[0:0]	UPDATE	R/W	0x00	Load I²C registers configuration
		[2:2]	SYNCBUSY	R	0x00	Synchronization busy flag
0x0C	IRQFLG	[0:0]	I2CRDY	R	0x00	IRQ serial interface ready flag
		[1:1]	VOVDIS	R	0x00	IRQ STO OVDIS flag
		[2:2]	VOVCH	R	0x00	IRQ STO OVCH flag
		[3:3]	SLPTHRESH	R	0x00	IRQ SRC LOW flag
		[4:4]	TEMP	R	0x00	IRQ temperature flag
		[5:5]	APMDONE	R	0x00	IRQ APM done flag
0x0D	STATUS	[1:1]	VOVDIS	R	0x00	Status STO OVDIS
		[2:2]	VOVCH	R	0x00	Status STO OVCH
		[3:3]	SLPTHRESH	R	0x00	Status SRC LOW
		[4:4]	TEMP	R	0x00	Status temperature
		[6:6]	CHARGE	R	0x00	Status STO Charge
0x0E	APM0	[7:0]	DATA	R	0x00	APM data 0
0x0F	APM1	[7:0]	DATA	R	0x00	APM data 1
0x10	APM2	[7:0]	DATA	R	0x00	APM data 2
0x11	TEMP	[7:0]	DATA	R	0x00	Temperature data
0x12	STO	[7:0]	DATA	R	0x00	Storage element voltage
0x13	SRC	[7:0]	DATA	R	0x00	SRC ADC value

Table 5: Register summary

2.4. I²C Communication

The device address on the I²C bus is 0x41. All information about the I²C communication is available in the AEM10900 datasheet, "System configuration" Section.

I2C_VDD must be connected to an external power supply which voltage is within the 1.5 V to 2.2 V range. On the Evaluation Board, 1 kΩ pull-up on SDA and SCL (R1 and R2) to I2C_VDD are provided.

In case one or more configurations are set by I²C communication, none of the configuration pins (GPIOs) will be taken into account anymore. Thus, applying the default values to any registers that have not been explicitly configured by I²C.

2.5. Advanced Configurations

A complete description of the system constraints and configurations is available in Section "System configuration" of the AEM10900 datasheet.

2.5.1. ZMPP Configuration

If ZMPP configuration is chosen (see Table 2), the AEM10900 regulates V_{SRC} at a voltage equals to the product of R_{ZMPP} times the current available at the source SRC.

- $10\ \Omega \leq R_{ZMPP} \leq 100\ k\Omega$

If unused, leave both the R_{ZMPP} resistor footprint and screw connector empty.

2.5.2. Mode Configuration

DIS_STO_CH

Enabling/disabling battery charging can be done by setting a jumper on the corresponding 3-pin header.

- Use a jumper to connect the DIS_STO_CH to H to disable the charge of the storage element.
- Use a jumper to connect the DIS_STO_CH to L to enable the charge of the storage element.

KEEP_ALIVE

The KEEP_ALIVE feature allows to supply the internal circuitry from the storage element when no power is available on the source terminal.

- Use a jumper to connect the KEEP_ALIVE to H to enable the feature.
- Use a jumper to connect the KEEP_ALIVE to L to disable the feature.

2.5.3. Thermal Monitoring

The thermal monitoring feature protects the battery by disabling the battery charging when ambient temperature is outside a specified range. The higher and lower thresholds are configurable using the I²C communication (see datasheet).

- Place a jumper between TH_MON and VINT to disable the feature.
- Place a jumper between TH_MON and THERM to enable the feature.

3. Functional Tests

This section presents a few simple tests that allow users to understand the functional behavior of the AEM10900. 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 measurements use the following equipment:

- Two Source Measurement Units (SMU, four-quadrant power supply).
- One 2-channel oscilloscope.

The following functional tests were made using the following setup:

- EVK jumpers configuration:
  - R_MPP[2:0] = HHL (70%).
  - T_MPP[1:0] = HH (2 ms / 256 ms).
  - STO_CFG[2:0] = HHH (3.01 V - 4.12 V).
  - DIS_STO_CH = L.
  - KEEP_ALIVE = H.
  - Place the jumper to connect TH_MON with VINT.
- Place a jumper to connect I²C_VDD and GND if the I²C communication is not used.

Users can adapt the setup to match the use case system as long as the input limitations are respected, as well as the minimum storage voltage and cold-start constraints (see "Introduction" Section of AEM10900 datasheet).

3.1. Start-up

The following example allows users to observe the start-up behavior of the AEM10900.

Setup

- Place oscilloscope probes on VINT and STO.
- Referring to Figure 1, follow steps 1 to 5 explained in Section 2.1 "Safety Information".
- STO: SMU set as a 3.0 V voltage source with 1 mA current compliance.
- SRC: SMU set as a 1 mA or 100 µA current source with 0.8 V voltage compliance.

Observations and measurements

- VINT: voltage rises to 2.2 V.
- STO: observe the current absorbed by the SMU as power is transferred from SRC to STO.

3.2. Shutdown

This test allows users to observe the behavior of the AEM10900 when the system is running out of energy. This test is to be done when the AEM10900 has already started, as at the end of the test described in Section 3.1.

Setup

- Disable the KEEP_ALIVE feature (KEEP_ALIVE = L).
- Place the oscilloscope probe on VINT.
- 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).
- Disconnect the SMU from SRC.

Observations and measurements

- VINT: voltage falls to GND.
- STO: no leakage from STO (probe impedance considered).

3.3. Cold Start

The following test allows users to observe the minimum voltage required to coldstart the AEM10900. To prevent current leakage caused by the probe impedance, users should avoid probing any unnecessary node. Make sure to properly reset the board to observe the cold-start behavior.

Setup

- Place oscilloscope probe on SRC.
- Referring Figure 1, follow steps 1 to 5 explained in Section 2.1.
- SRC: SMU set as 20 µA current source with 0.3 V voltage compliance.
- STO: SMU as 3.0 V voltage source with 100 µA current compliance.

Observations and measurements

- SRC voltage clamped at the cold-start voltage during the cold-start phase and then regulated at the selected MPPT percentage of Voc configured thanks to R_MPP when cold start is over. The duration of the cold-start phase decreases as the input power increases. Select the input power accordingly to be able to observe the cold-start phase.
- STO: SMU starts absorbing current sourced by the STO pin once the cold-start phase is completed.

3.4. Thermal Monitoring

The following test allows users to observe the thermal monitoring functionality.

Setup

- Place a 10 kΩ NTC thermistor with β = 3380 on R_{th}.
- Place a 22 kΩ pull-up resistor on R_{DIV}.
- Place the jumper to connect TH_MON with THERM.
- Place the probes on the nodes to be observed.
- Referring to Figure 1, follow steps 1 to 5 as explained in Section 2.1 “Safety Information”. Configure the board in the desired state and start the system (see Section 3.1).

Observations and measurements

- If the temperature is lower than 0°C, the charge of the storage element is disabled.
- If the temperature is higher than 45°C, the charge of the storage element is disabled.
- If the temperature is between 0°C and 45°C, the charge of the storage element is enabled.

3.5. Keep-alive

The KEEP_ALIVE feature sets the behavior of the AEM10900 when no power is available on SRC.

Setup

- Place the oscilloscope probe on VINT.
- 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).
- Enable the KEEP_ALIVE feature (connect KEEP_ALIVE to H).
- Disconnect the SMU from the SRC pin.

Observations and measurements

- VINT: the internal circuitry is supplied by the storage element (V_{VINT} does not drop).

3.6. Disable Storage Element Charge

The DIS_STO_CH feature allows to disable the storage element charge.

Setup

- Use a jumper to connect DIS_STO_CH to H to disable the charge of the storage element.
- STO: SMU set as a 3.0 V voltage source with 1 mA current compliance.
- 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).

Observations and measurements

- STO: observe that no current is absorbed by the SMU on STO when power is applied on SRC.

3.7. I²C Communication

This test allows users to change a configuration through the I²C communication.

Setup

- Place the oscilloscope probe on SRC.
- 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).
- Connect I²C _VDD to the I²C supply (between 1.8 V and 2.2 V).
- Write ‘0010 0011’ (0x23) on the MPPTCFG register (0x01):
  - V_{MPP} / V_{OC} = 60%.
  - 64 ms V_{OC} sampling duration.
  - 4 s V_{OC} sampling period.
- Write ‘1’ to the CTRL register (0x0B) to load the I²C register configuration (at startup the AEM10900 load its configurations from the pins settings).

Observations and measurements

- SRC: observe that the voltage regulation switches to 60% of the open circuit voltage V_{OC} as defined by the SRC SMU voltage compliance, when the register value is loaded.
- SRC: observe that the timing between two MPP evaluation is 4 s and the duration of the MPP is 64 ms.

3.8. Efficiency

This test allows users to reproduce the efficiency graphs of the boost converter (see "DCDC Conversion Efficiency" Section in the AEM10900 datasheet).

Setup

- 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).
- STO: connect SMU configured as a 4.7 V voltage source with a 100 mA current compliance.
- SRC: connect SMU configured as a source current with a voltage compliance of 1.0 V to ensure the AEM10900 coldstarts.

Manipulations

- STO: set the SMU to the desired voltage, between V_{OVDIS} and V_{OVCH}. Make sure the SMU integration time is as long as possible.
- SRC: sweep the voltage compliance of the SMU from 0.12 V to 1.5 V to let the AEM10900 set V_{MPP} according to the MPP ratio.

Observations and measurements

- For each data point of the SRC voltage sweep, note the SRC SMU voltage and current, as well as the STO SMU voltage and current. Repeat the measurement for each data point a copious number of times to ensure capturing current peaks.
- The efficiency η in percent is computed by applying the following formula:

$$\eta = 100 \cdot \frac{V_{STO} \cdot I_{STO}}{V_{SRC} \cdot I_{SRC}}$$

NOTE: to ensure optimal efficiency, make sure a minimal decoupling capacitance of 22 µF is present on the STO pin.

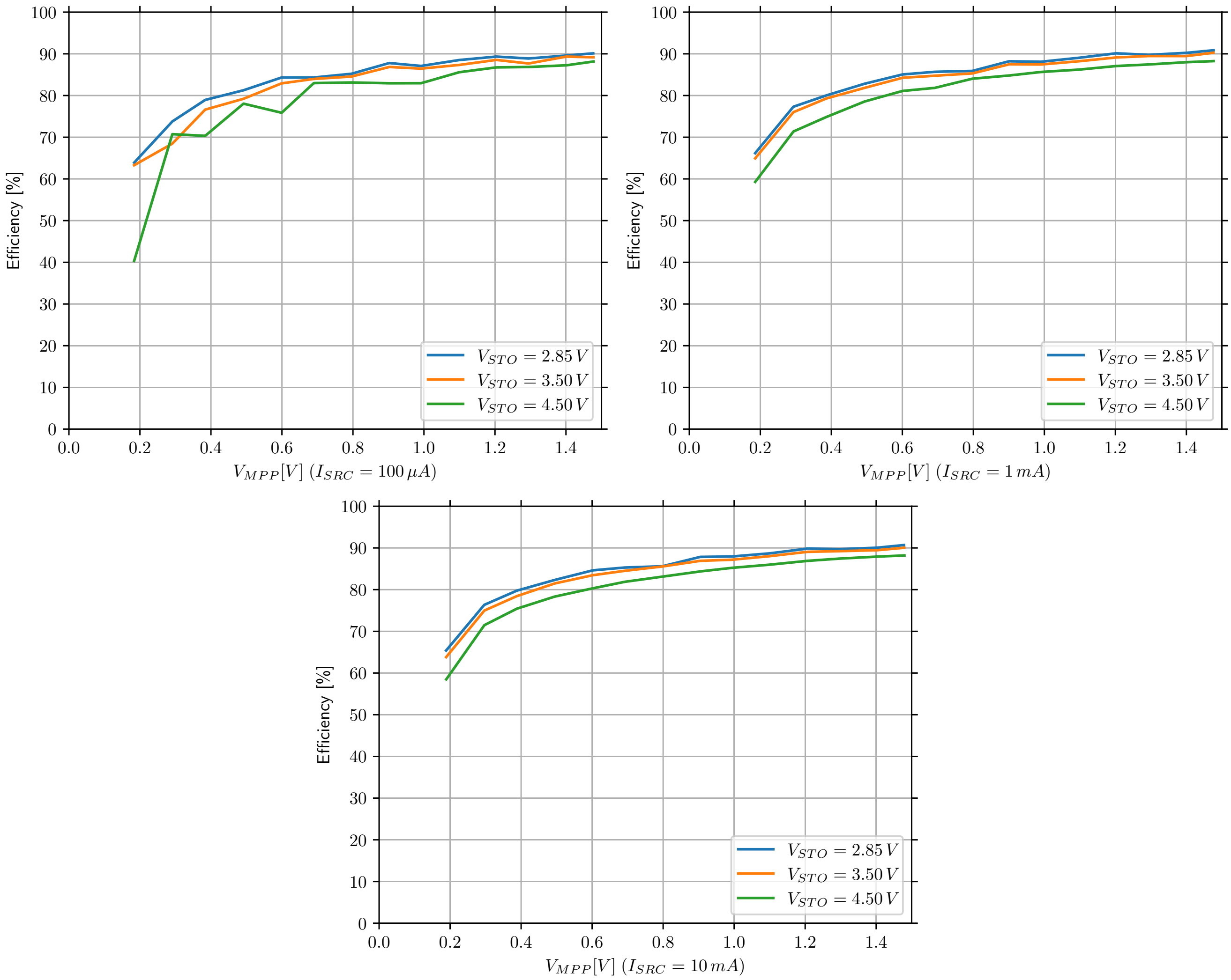


Figure 2: AEM10900 efficiency (LDCDC: TDK VLS252012HBX-6R8M-1)

4. Schematics

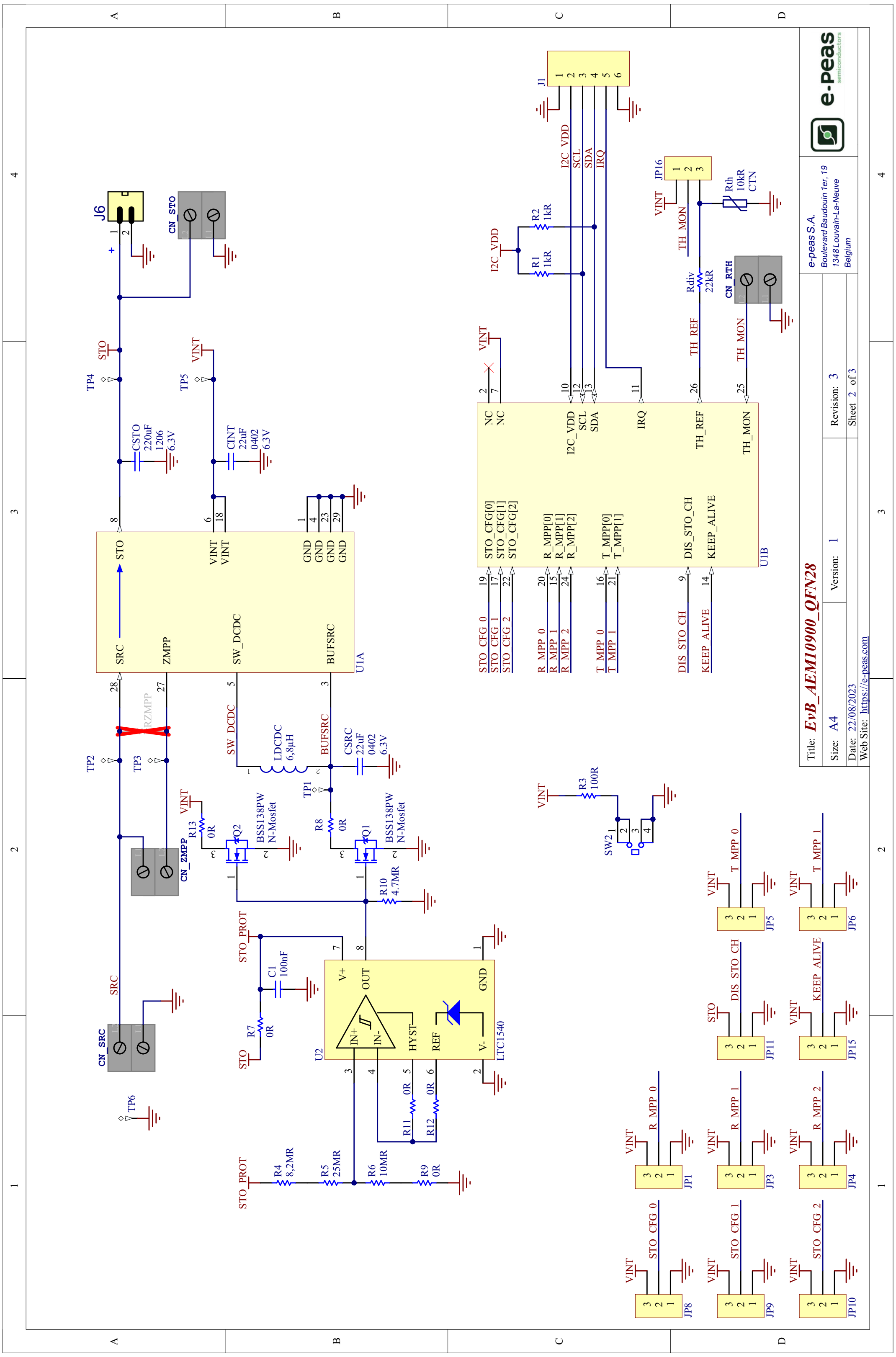


Figure 3: AEM10900 Evaluation Board Schematic

5. Revision History

EVK Version	User Guide Revision	Date	Description
Up to 1.2	0.9	February, 2022	Creation of the document.
1.3	1.0	September, 2023	Fixed some inconsistencies and updated images.
1.3	1.1	February, 2024	Corrected typos and aesthetic modifications.

Table 6: Revision History