AEM10920 Evaluation Kit User Guide

Description

The AEM10920 evaluation kit (EVK) is a printed circuit board (PCB) featuring all the required components to operate the AEM10920 integrated circuit (IC) in QFN 24-pin package.

AEM10920 evaluation kit allows users to test 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, an optional 5 V power source, a storage element and an application circuit. Thanks to headers and resistors, it also provides all configuration options to set the device in any of the modes described in the datasheet. A status signal is available on a standard pin header.

AEM10920 EVK is an easy-to-use, intuitive and efficient tool to optimize AEM10920 configuration, allowing users to design a highly efficient subsystem for the desired target application. Component replacement and operating mode switching is convenient and easy.

Detailed information about AEM10920 features can be found in the datasheet.

Applications

Remote Controls	Wireless Keyboards

Features and Benefits

Very high conversion efficiency
- Average 93% from source to storage element.
- Average 92% from storage element to application.

Two-way screw terminals
- DC source of energy (SRC).
- Energy storage element (STO).
- Application circuit (LOAD).
- 5 V DC power input (5V_IN).

3-pin headers
- Source voltage regulation mode configuration.
- Storage element voltage thresholds configuration.
- Load voltage regulation configuration.
- Shipping mode enable/disable.
- Boost configuration.

2-pin headers
- 5 V power input max current presets.

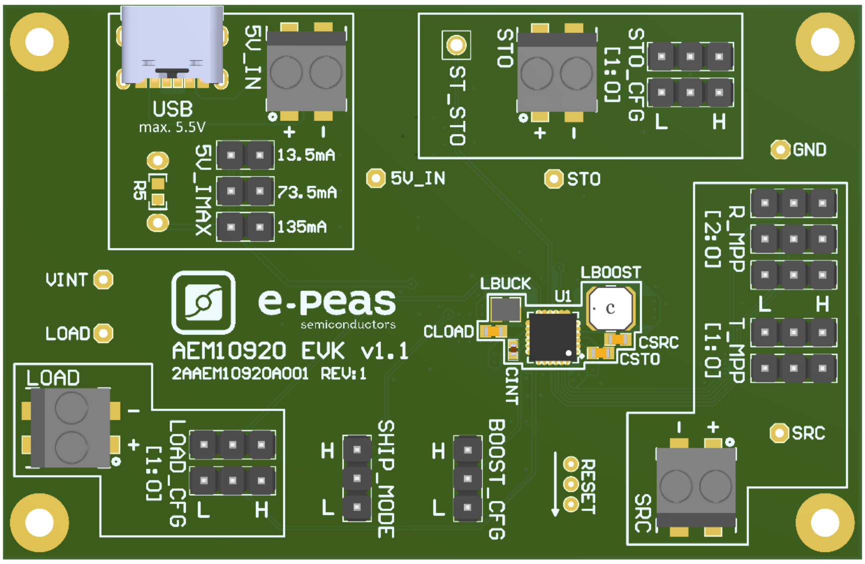
USB connector
- 5 V DC power input (max. 5.5 V peak).

Evaluation Kit Information

Part number	Dimensions
2AAEM10920A001 REV:0	76 mm x 49 mm

Device Information

Part Number	Package	Body size
10AEM10920A0000	QFN 24-pin	4x4mm



1. EVK Connection Diagram

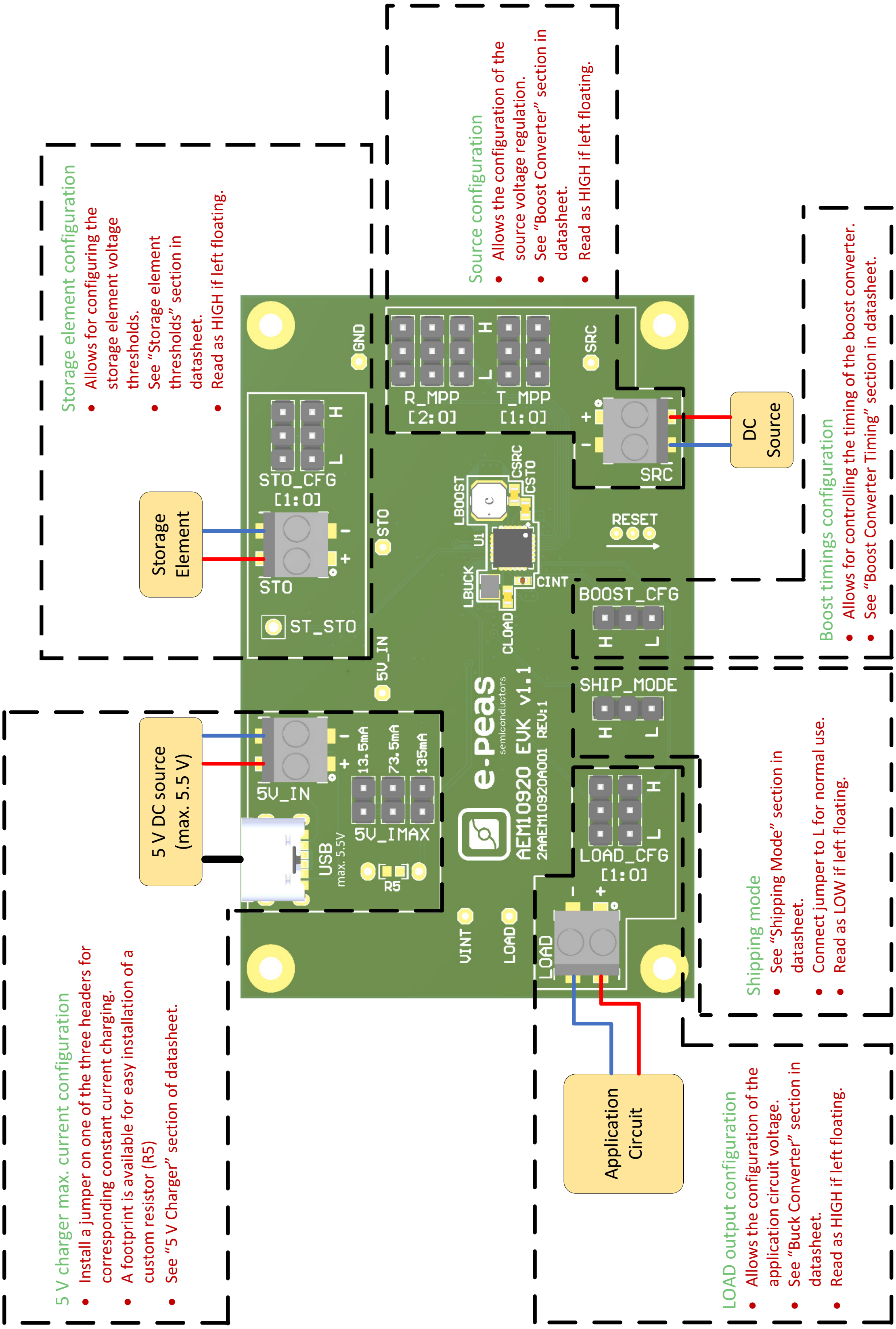


Figure 1: AEM10920 EVK connection diagram

2. Pin Configuration and Functions

NAME	FUNCTION	CONNECTION	
		If used	If not used
Power Pins			
SRC	Connection to the energy source harvested by the boost converter.	Connect the source element.	Can be left floating or connected to GND.
STO	Connection to the energy storage element (rechargeable battery or LiC).	Connect the storage element.	Leave floating. If left floating, storage element is on-board capacitor C_{STO}, which may be too small for most applications.
LOAD	Output voltage of the buck converter to supply an application circuit.	Connect the application circuit.	Disable buck converter through LOAD_CFG[1:0] pins and leave the LOAD pin floating.
5V_IN	Input of the 5 V DC power supply.	Connect a 5 V DC power source.	Leave floating.
Control Pin			
SHIP_MODE	Logic input. When HIGH: - Minimum consumption from the storage element. - Storage element charge is disabled (boost converter is disabled). - Buck (LOAD) is disabled. - Only VINT is charged if energy is available on SRC.	Connect jumper to H.	Read as LOW if left floating.
Configuration Pins			
R_MPP[2:0]	Used for the configuration of SRC Maximum Power Point Tracking (MPPT) ratio $R_{MPPT} = V_{MPP} / V_{OC}$.	Connect jumpers.	Read as HIGH if left floating.
T_MPP[1:0]	Used for the configuration of SRC Maximum Power Point Tracking (MPPT) period $T_{MPPT,PERIOD}$ and sampling duration $T_{MPPT,SAMPLING}$.	Connect jumpers.	Read as HIGH if left floating.
STO_CFG[1:0]	Used to configure the storage element voltage thresholds.	Connect jumpers.	Read as HIGH if left floating.
LOAD_CFG[1:0]	Used to configure the LOAD output regulation voltage.	Connect jumpers.	Read as HIGH if left floating.
BOOST_CFG	Used to configure the boost converter timings.	- Connect jumper to L for timings x1. - Connect jumper to H for timings x3.	Read as HIGH if left floating.
5V_IMAX	Connection to an external resistor to set the charging current from the 5V_IN supply to STO.	Connect jumper on one of the three 2-pin headers or connect a resistor on R5.	Leave floating if 5V_IN is not used.
Status Pin			
ST_STO	Logic output. - HIGH when in SUPPLY STATE or in SLEEP STATE. - LOW otherwise.	Connect to application circuit. HIGH level is STO.	Leave floating.

Table 1: Signals description

3. General Considerations

3.1. Safety Information

Always connect the elements in the following order:

1. Reset the board by temporally connecting the “RESET” pads to GND, from top to bottom (as shown on PCB) silkscreen.

2. Completely configure the PCB (jumpers/resistors):

    - Sources voltage regulation mode (SRC_LVL_CFG[4:0]).
    - Storage element voltage thresholds (STO_CFG[1:0]).
    - Load output regulation voltage (LOAD_CFG[1:0]).
    - Boost converter timings configuration (BOOST_CFG).
    - 5 V charger maximum current.

4. Connect a storage element on the STO screw connector.

5. Connect the application circuit on the LOAD screw connector.

6. Connect the harvester to the source.

3.2. AEM10920 Reset

The following procedure must be followed to properly reset the AEM10920:

- Connect a wire to GND.
- Use this wire to short the “Reset” pads to GND from top to bottom, as indicated on the EVK silkscreen.

3.3. Configurations

3.3.1. Source MPPT Configuration

Configuration pins		Period [s]	Sampling duration [ms]
T_MPP[1:0]		$T_{MPPT,PERIOD}$	$T_{MPPT,SAMPLING}$
L	L	15	250
L	H	15	500
H	L	25	250
H	H	25	500

Configuration pins			MPPT Ratio [%]
R_MPP[2:0]			R_{MPPT}
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%

Table 2: MPPT ratio and timings configuration with R_MPP[2:0] and T_MPP[1:0]

3.3.2. Storage Element Configuration

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	2.50	2.55	3.80	Lithium-ion Super Capacitor (LiC)
L	H	3.00	3.20	4.12	Lithium-ion
H	L	3.00	3.20	4.35	Lithium Polymer (LiPo)
H	H	3.50	3.55	3.90	Lithium-ion (ultra-long life)

Table 3: Storage element configuration with STO_CFG[1:0]

3.3.3. Load Configuration

Configuration pins		LOAD voltage [V]
LOAD_CFG[1:0]		V_{LOAD}
L	L	Buck disabled
L	H	2.2
H	L	2.5[1]
H	H	2.8[2]

Table 4: Configuration of LOAD voltage with LOAD_CFG[1:0]

1. This configuration is only available if V_{OVDIS} > 2.5 V.
2. This configuration is only available if V_{OVDIS} > 2.8 V.

3.3.4. 5 V Charger Configuration

Resistor [Ω]	Maximum Charging Current [mA]
R_{5V_IMAX}	$I_{5V,CC}$
370	135.0
680	73.5
1500[1]	33.3
3700	13.5

Table 5: Typical resistor values for setting 5 V charger max. current

1. Can be obtained by installing a 1.5 kΩ resistor on R5 and leaving all 3 headers without jumpers.

Three 2-pin headers corresponding to three current presets are available on the EVK. Install a jumper on the corresponding header to enable a preset.

Furthermore, R5 allows users for an easy installation of a custom resistor, either in through-hole or in SMD 0603 package. In that case, do not install any jumper on the three preset headers and install a resistor on R5 footprint.

3.3.5. Shipping Mode

The shipping mode feature allows for forcing the AEM10920 in RESET STATE (see datasheet), thus disabling all AEM10920 functionalities including the boost converter, the buck converter and the 5 V charger. Only VINT is charged from SRC if energy is available from it. The battery is no longer charged or discharged.

Shipping mode is enabled by installing a jumper to HIGH on the EVK dedicated header. To disable it, connect a jumper to LOW or leave it floating.

4. Functional Tests

This section presents a few simple tests that allow users to understand the functional behavior of the AEM10920. To avoid damaging the board, follow the procedure found in Section 3.1. If a test has to be restarted, make sure to properly reset the system to obtain reproducible results.

Users can adapt the setup to match the use case system as long as the source limitations are respected, as well as the minimum storage voltage and cold-start constraints (see "Typical Electrical Characteristics at 25 °C" Section of AEM10920 datasheet).

In the following sections, when a "power supply" is required, it can be either a standard one quadrant positive voltage / positive current laboratory power supply with regulated voltage, or an SMU set as voltage source with current compliance.

4.1. Start up

4.1.1. Description

The following example allows users to observe the start-up behavior of the AEM10920.

4.1.2. Setup

- Oscilloscope:
    - Channel 1: STO.
    - Channel 2: VINT (may be probed on H pin on STO_CFG[1] header for example).
- SRC (2 alternatives, initially disconnected):
    - 1 V / 10 mA power supply with a 100 Ω resistor in series (I_{SRC} = 2.5 mA with R_{MPPT} = 75%.
    - SMU set as 2.5 mA current source with 1 V compliance.
- R_MPP[2:0] = HLL
    - R_{MPPT} = 75%.
    - $I_{SRC} = \frac{1V - 75\% \cdot 1V}{100\Omega} = 2.5mA$ (PSU).
    - $I_{SRC} = 2.5mA$ (SMU).
- T_MPP[1:0] = HH.
    - $T_{MPPT,PERIOD}$ = 25 s.
    - $T_{MPPT,SAMPLING}$ = 500 ms.
- 1000 µF capacitor connected to STO as storage element.
- 3 V power supply or SMU connected to STO beforehand.
- STO_CFG[1:0] = LH.
    - V_{OVDIS} = 3.00 V.
    - V_{CHRDY} = 3.20 V.
    - V_{OVCH} = 4.12 V.
- LOAD is floating.
- LOAD_CFG[1:0] = LL.
    - LOAD disabled.

4.1.3. Measurements

- Reset the AEM10920 as described in Section 3.2.
- Start with:
  - 3 V power supply connected to STO so that C_{STO} is charged to 3.0 V beforehand.
  - No source connected to SRC.
- Disconnect the power supply from STO.
- Connect the 1 V / 100 Ω PSU or the 2.5 mA current source SMU to SRC.
- Observe V_{INT} rise up to 2.2 V and be regulated at that voltage.
- Energy is transferred from SRC to STO: V_{STO} rises from its initial 3.0 V voltage to V_{OVCH} (4.12 V).
- V_{STO} is regulated to V_{OVCH} (4.12 V) as the AEM10920 prevents the storage element to be charged any further.
- 5V_IN left floating.

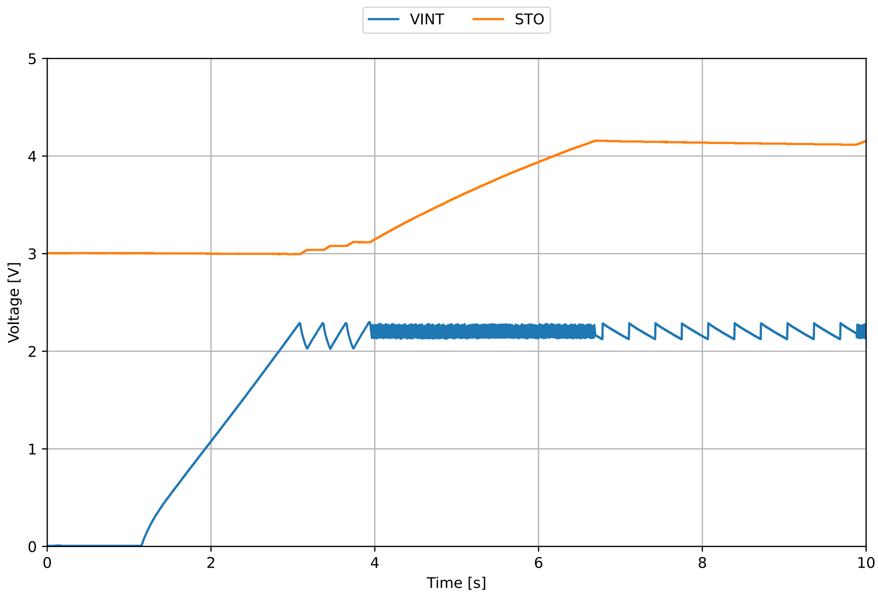


Figure 2: AEM10920 start-up behavior

4.2. Cold-Start

4.2.1. Description

The following example allows users to observe the cold-start behavior of the AEM10920.

4.2.2. Setup

- Oscilloscope:
  - Channel 1: SRC.
  - Channel 2: VINT (may be probed on H pin on STO_CFG[1] header for example).
- SRC (2 alternatives, initially disconnected):
  - 1 V / 10 mA power supply with a 68 kΩ resistor in series. Please note that using a standard power supply allows for validating the minimum cold-start voltage but does not allow for validating the minimum cold-start power.
  - SMU set as 10 µA current source with 1 V compliance. Using an SMU allows for validating the minimum cold-start power as well as the minimum cold-start voltage.
- R_MPP[2:0] = HLL.
  - R_{MPPT} = 75%.
  - $I_{SRC} = \frac{1V - 0.3V}{68k\Omega} = 10\mu A$ (PSU).
  - $I_{SRC} = 10\mu A$ (SMU).
- T_MPP[1:0] = HH.
  - $T_{MPPT,PERIOD}$ = 25 s
  - $T_{MPPT,SAMPLING}$ = 500 ms.
- 1000 µF capacitor connected to STO as storage element.
- 3 V power supply connected to STO beforehand.
- STO_CFG[1:0] = LH.
  - V_{OVDIS} = 3.00 V.
  - V_{CHRDY} = 3.20 V.
  - V_{OVCH} = 4.12 V.
- LOAD is floating.
- LOAD_CFG[1:0] = LL.
  - LOAD disabled.

4.2.3. Measurements

- Reset the AEM10920 as described in Section 3.2.
- Start with:
  - 3 V power supply connected to STO so that C_{STO} is charged to 3.0 V beforehand.
  - No source connected to SRC.
- Disconnect the power supply from STO.
- Connect the power supply or SMU to SRC.
- Cold-start phase:
  - Observe V_{SRC} clamped to 0.3 V.
  - Observe V_{INT} rise up to 2.2 V and be regulated at that voltage.
- Once V_{INT} has reached its 2.2 V regulation voltage, the AEM10920 performs a first V_{OC} evaluation on SRC.
- Then, the AEM10920 extracts energy from SRC. Note that the source current is too weak to charge CSRC up to the V_{OC} during $T_{MPPT,SAMPLING}$, resulting in a V_{MPP} misevaluation.
- V_{OC} is re-evaluated every 25 s.

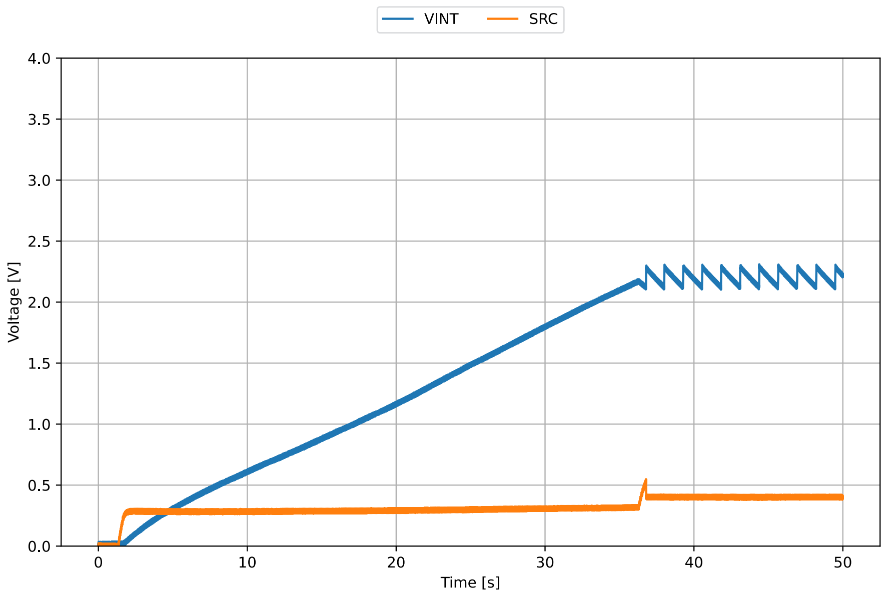


Figure 3: AEM10920 cold-start behavior

4.3. Load

4.3.1. Description

The following example allows users to observe how the AEM10920 switches ON and OFF the buck converter supplying the LOAD pin.

4.3.2. Setup

- Oscilloscope:
  - Channel 1: STO.
  - Channel 2: LOAD.
- SRC (2 alternatives, initially disconnected):
  - 1 V / 10 mA power supply with a 100 Ω resistor in series (I_{SRC} = 2.5 mA with R_{MPPT} = 75%.
  - SMU set as 2.5 mA current source with 1.0 V compliance.
- R_MPP[2:0] = HLL.
  - R_{MPPT} = 75%.

  $$I_{SRCx} = \frac{1V - 75\% \cdot 1V}{100\Omega} = 2.5mA \text{ (PSU)}.$$

  - I_{SRC} = 2.5mA (SMU).
- T_MPP[1:0] = HH.
  - $T_{MPPT,PERIOD}$ = 25 s
  - $T_{MPPT,SAMPLING}$ = 500 ms.
- 1000 µF capacitor connected to STO as storage element.
- 2.8 V power supply connected to STO beforehand.
- STO_CFG[1:0] = LH.
  - V_{OVDIS} = 3.00 V.
  - V_{CHRDY} = 3.20 V.
  - V_{OVCH} = 4.12 V.
- LOAD_CFG[1:0] = LH.
  - LOAD is regulated at 2.2 V.
  - LOAD: a 5 kΩ resistor is connected between LOAD and GND.
  - I_{LOAD} = 440 µA.

4.3.3. Measurements

- Reset the AEM10920 as described in Section 3.2.
- Start with:
  - 2.8 V power supply connected to STO so that C_{STO} is charged to 2.8 V beforehand.
  - No source connected to SRC.
- Disconnect the power supply from STO.
- Connect the power supply or SMU to SRC.
- After cold start, observe the storage element charging.
- When V_{STO} > V_{CHRDY}, LOAD starts being regulated to 2.2 V, thus providing current to the 5 kΩ resistor. There is more energy harvested than consumed (positive power budget), so the storage element keeps being charged.
- Disconnect the power supply from SRC (done at about 4.75 s on Figure 4).
- The current drawn by the 5 kΩ is now discharging the storage element, as no more energy is harvested to compensate for the load.
- When V_{STO} < V_{OVDIS}, the AEM10920 waits for T_{CRIT} (2.5 s) and then switches OFF the buck converter. LOAD is no longer regulated and drops down to 0 V.

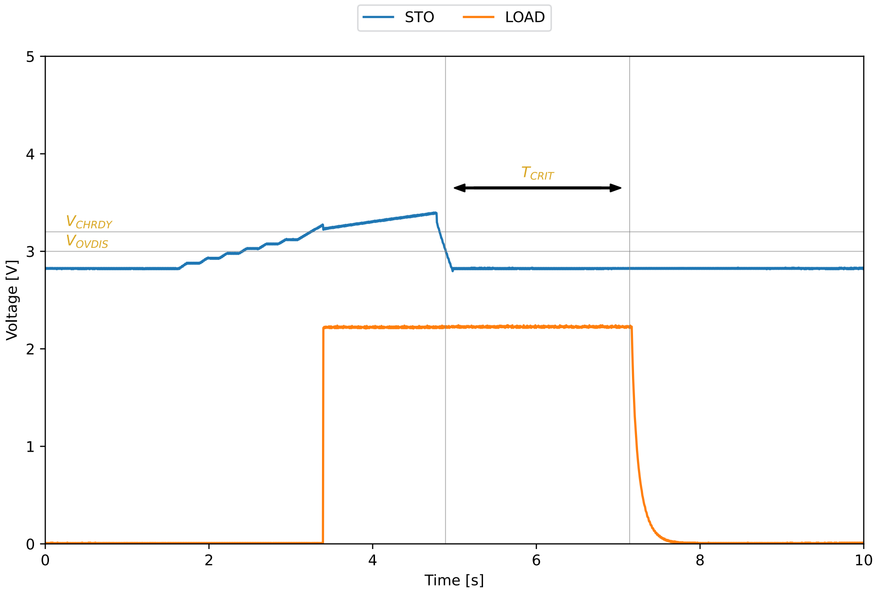


Figure 4: AEM10920 LOAD output behavior

NOTE: in a real application, the storage element would be a battery or a supercapacitor, with much higher stored energy, so that V_{STO} would not drop as low as on Figure 4 during T_{CRIT}.

4.4. 5 V Charger

4.4.1. Description

The following example allows users to observe how the AEM10920 coldstarts and charges the storage element from the 5 V charger.

4.4.2. Setup

- Oscilloscope:
  - Channel 1: STO.
  - Channel 2: 5V_IN.
- SRC left floating.
- 5V_IN: 5.0 V / 200 mA power supply or SMU (initially disconnected).
- 5V_IN constant current set to 13.5 mA by installing a jumper on the corresponding header.
- 10 mF capacitor connected to STO as storage element (1000 µF will also work but STO charging slope will be even steeper).
- 2.8 V power supply connected to STO beforehand.
- STO_CFG[1:0] = LH.
  - V_{OVDIS} = 3.00 V.
  - V_{CHRDY} = 3.20 V.
  - V_{OVCH} = 4.12 V.
- LOAD_CFG[1:0] = LL.
  - LOAD is disabled.
- LOAD left floating.

4.4.3. Measurements

- Reset the AEM10920 as described in Section 3.2.
- Start with:
  - 2.8 V power supply connected to STO so that C_{STO} is charged to 2.8 V beforehand.
  - No source connected to 5V_IN.
- Disconnect the power supply from STO.
- Connect the power supply or SMU to 5V_IN.
- After cold start, observe the storage element charging up to V_{OVCH} (4.12 V).

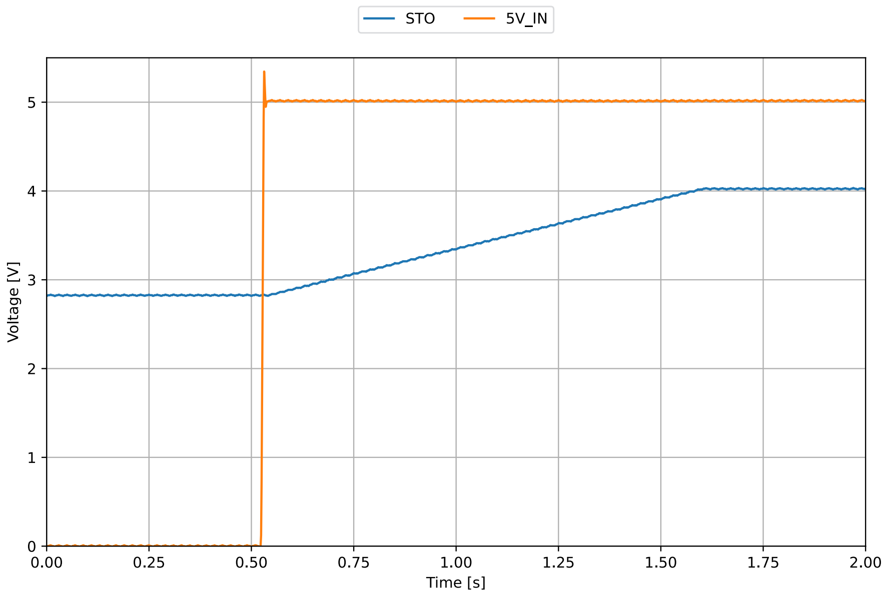


Figure 5: AEM10920 cold start and storage element charge from 5V_IN

5. Performance Tests

This section presents the tests to reproduce the performance graphs found in the AEM10920 datasheet. To be able to reproduce those tests, you will need the following:

- 2 source measure units (SMU, typically Keithley 2450). Those must be set with longest integration time.
- 1 voltage source (only for coldstarting the AEM10920 when performing buck efficiency measurement).

To avoid damaging the board, follow the procedure found in Section 3.1 “Safety information”. If a test has to be restarted, make sure to properly reset the system to obtain reproducible results, as shown in Section 3.2.

5.1. Boost Converter Efficiency

5.1.1. Description

The boost converter efficiency is determined for a fixed set point of the AEM10920:

- Fixed SRC voltage V_{SRC}.
- Fixed SRC current I_{SRC}.
- Fixed STO voltage V_{STO}.
- Fixed inductor value L_{BOOST}. Please note that the inductor model has a subsequent influence on the efficiency.

Boost efficiency measurement is about measuring the current provided to STO with all other parameters fixed.

Please note that to avoid any leakage that would affect the measurement, no probe or voltmeter must be connected to the AEM10920 pins while measuring the boost efficiency.

5.1.2. Setup

- R_MPP[2:0] set accordingly to the desired R_{MPPT} ratio (see Table 2).
- SRC: SMU set as current source.
  - Current set to the desired I_{SRC}.
  - Voltage compliance set to V_{MPP}/R_{MPPT}
- STO: SMU set as voltage source:
  - Voltage set to the desired V_{STO} set point.
  - Current compliance set so that the power on STO (V_{STO} x I_{STO}) is at least higher that the power of the SMU connected to SRC (V_{SRC} x I_{SRC}). Do not lower the current compliance lower than 100 µA.

5.1.3. Measurements

Cold start and initialization

This part must only be done for the first efficiency data point measurement. To avoid having to do it between two subsequent set points, users must make sure that V_{STO} does not drop below V_{OVDIS} between measurements.

- Start with both SMU switched OFF.
- Reset the AEM10920.
- STO SMU: set the voltage to 5.0 V and switch ON, to make sure that V_{STO} is above V_{OVCH}.
- SRC SMU: set the voltage source to 1.0 V with 1 mA current compliance to trigger the AEM10920 cold start.
- Wait for V_{INT} to rise to its regulation voltage of 2.2 V.
- The AEM10920 is now ready to perform an efficiency measurement. Do not lower V_{STO} below V_{OVDIS} from that point to avoid the AEM10920 going to OVDIS STATE. Keep STO SMU current compliance at least 100 µA.

Efficiency measurement

The following needs to be done for all desired set points:

- Set SRC SMU to the desired voltage and current set point.
- Set STO SMU to the desired voltage and current set point.
- Clear both SMU buffers.
- Wait for the number of measures of both SMU to be sufficient (the lower the current the higher the necessary number of measures).
- Determine the average currents and voltages from both SMU buffers.
- Determine the boost efficiency with the following formula:

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

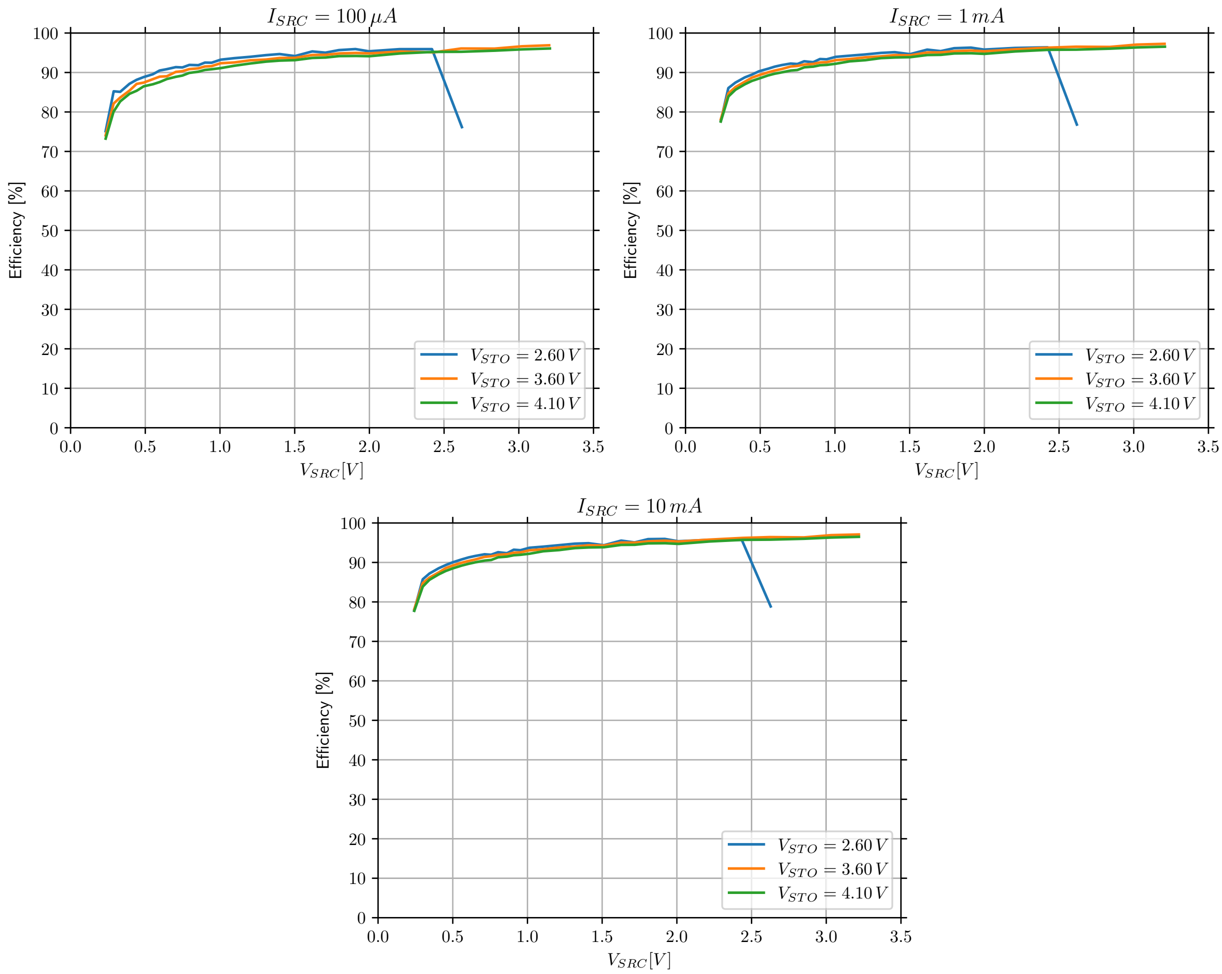


Figure 6: Boost converter efficiency with L_{BOOST} = 33 µH (Coilcraft LPS4018-333MRB) and timings x3

5.2. Buck Converter Efficiency

5.2.1. Description

The buck converter efficiency is determined on a fixed set point of the AEM10920:

- Fixed STO voltage V_{STO}.
- Fixed LOAD voltage V_{LOAD}.
- Fixed LOAD current I_{LOAD}.
- Fixed inductor value L_{BUCK}. Please note that the inductor model has a subsequent influence on the efficiency.

Buck efficiency measurement is about measuring the current that needs to be pulled from STO at a given V_{STO}, to provide a given current/voltage on LOAD, with all other parameters fixed.

Please note that, to avoid any leakage that would affect the measurement, no probe or voltmeter must be connected to the AEM10920 pins while measuring the buck efficiency.

5.2.2. Setup

- STO: SMU set as voltage source:
  - Voltage set to the desired V_{STO} set point.
  - Current compliance set so that the power on STO (V_{STO} x I_{STO}) is at least higher that the power of the SMU connected to LOAD (V_{LOAD} x I_{LOAD}).
- LOAD: SMU set as voltage source.
  - Voltage set to 0.5 V below the desired V_{LOAD} set point, forcing the SMU to pull the compliance current when the buck converter is regulating its output voltage.
  - Current compliance set to the desired I_{LOAD}.

5.2.3. Measurements

Cold start and initialization

This part must only be done for the first efficiency data point measurement. To avoid having to do it between two subsequent set points, users must make sure that STO voltage doesn't drop below V_{OVDIS} between measurements, with at least 100 µA current compliance.

- Start with both SMU switched OFF.
- Reset the AEM10920.
- STO SMU: set the voltage to 5.0 V and switch ON, to make sure that the V_{STO} is above V_{OVCH}.
- Switch ON SRC power supply.
- Wait for V_{INT} to be regulated at 2.2 V.
- Switch OFF SRC power supply.
- The AEM10920 is now ready to perform an efficiency measurement. Do not lower V_{STO} below V_{OVDIS} from that point to avoid the AEM10920 going to OVDIS STATE. Keep the STO SMU current compliance at least 100 µA.

Efficiency measurement

The following needs to be done for all desired set points:

- Set STO SMU to the desired voltage and current set point.
- Set LOAD SMU to the desired voltage and current set point.
- Clear both SMU buffers.
- Wait for the number of measures of both SMU to be sufficient (the lower the current the higher the necessary number of measures).
- Determine the average currents and voltages from both SMU buffers.
- Determine the buck efficiency with the following formula:

$$\eta[\%] = \frac{V_{LOAD} \cdot I_{LOAD}}{V_{STO} \cdot I_{STO}} \cdot 100$$

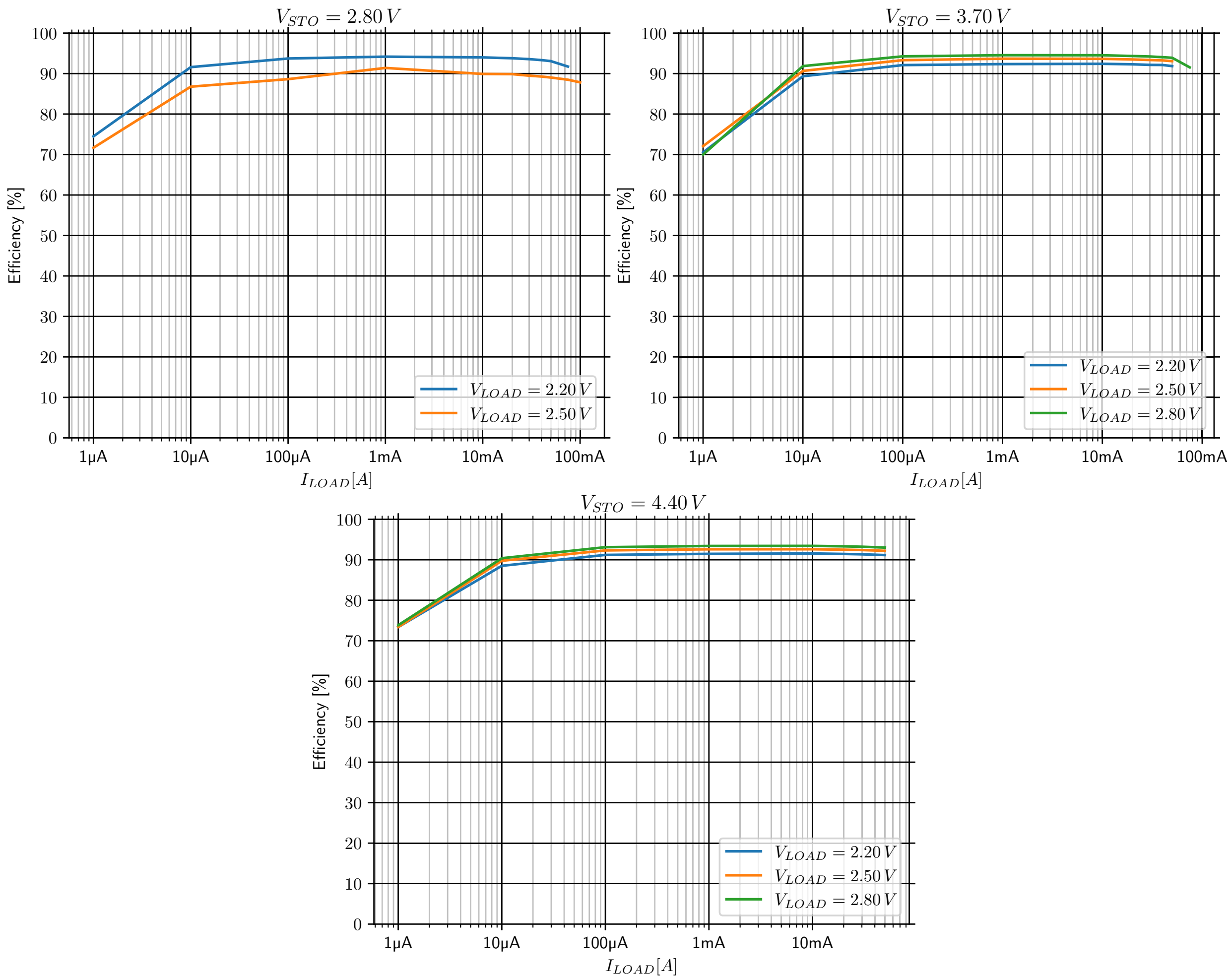


Figure 7: Buck (LOAD) converter efficiency with L_{BUCK} = 10 µH (Coilcraft LPS4018-103MRB)

6. EVK Schematic

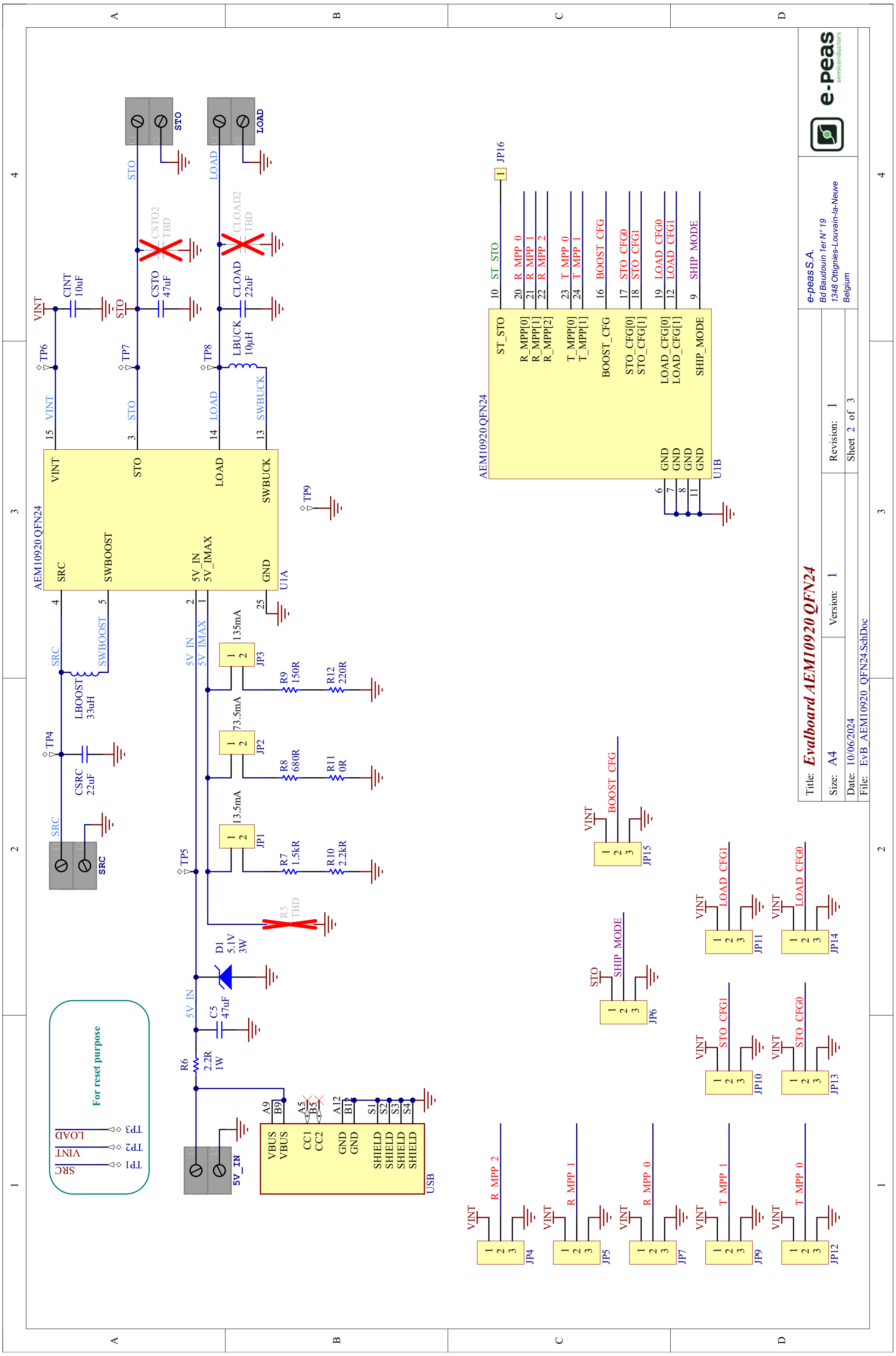


Figure 8: EVK schematic

7. Revision History

EVK Version	User Guide Revision	Date	Description
1.0	1.0	March, 2024	Creation of the document
1.1	1.0	June, 2024	Added average efficiency values on first page.

Table 6: Revision history