AEM13921 Evaluation Kit User Guide

Description

The AEM13921 evaluation kit (EVK) is a printed circuit board (PCB) featuring all the required components to operate the AEM13921 integrated circuit (IC) in QFN 40-pin package.

The AEM13921 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 one or two energy harvesters (e.g. an indoor PV cell and an outdoor PV cell), an optional 5 V power source, a storage element and an application circuit. It also provides all the configuration accesses 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 over-ride preconfigured board settings through any I²C master device and evaluate the IC performances. Furthermore, the on-board USB-to-I²C converter and e-peas' "I²C Configuration Tool" simplify I²C communication.

The AEM13921 EVK is a plug and play, intuitive and efficient tool to optimize the AEM13921 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 AEM13921 features can be found in the datasheet.

Applications

Smart home	Industrial sensor
Smart building	Retail
Edge IoT	PC accessories

Features and Benefits

Two-way screw terminals

- Two DC sources of energy (SRCx).
- ZMPP configuration.
- Energy storage element (STO).
- Application circuit (LOAD).
- 5 V DC power input (5V_IN).

3-pin headers

- Sources voltage regulation configuration.
- Storage element protection thresholds configuration.
- Load voltage regulation configuration.
- I²C enable/disable.
- Thermal monitoring enable/disable.
- Shipping mode enable/disable.

2-pin headers

- 5 V power input max. current presets.

7-pin header

- I²C communication with application circuit.

USB connector

- 5 V DC power input (max. 5.5 V peak).
- Connection to the on-board USB to I²C converter.

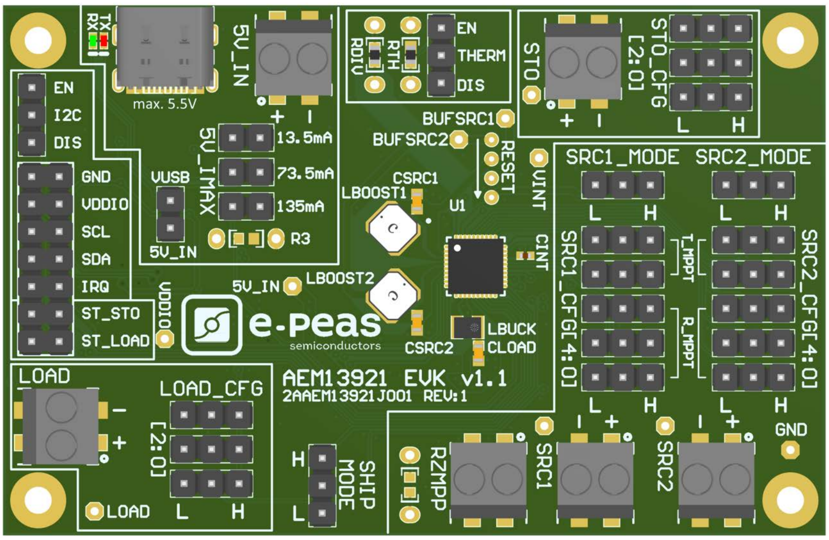
Evaluation Kit Information

Part number	Dimensions
2AAEM13921J001 REV:1	76 mm x 49 mm

Device Information

Part Number	Package	Body size
10AEM13921J0000	QFN 40-pin	5 x 5 mm

Appearance



1. EVK Connection Diagram

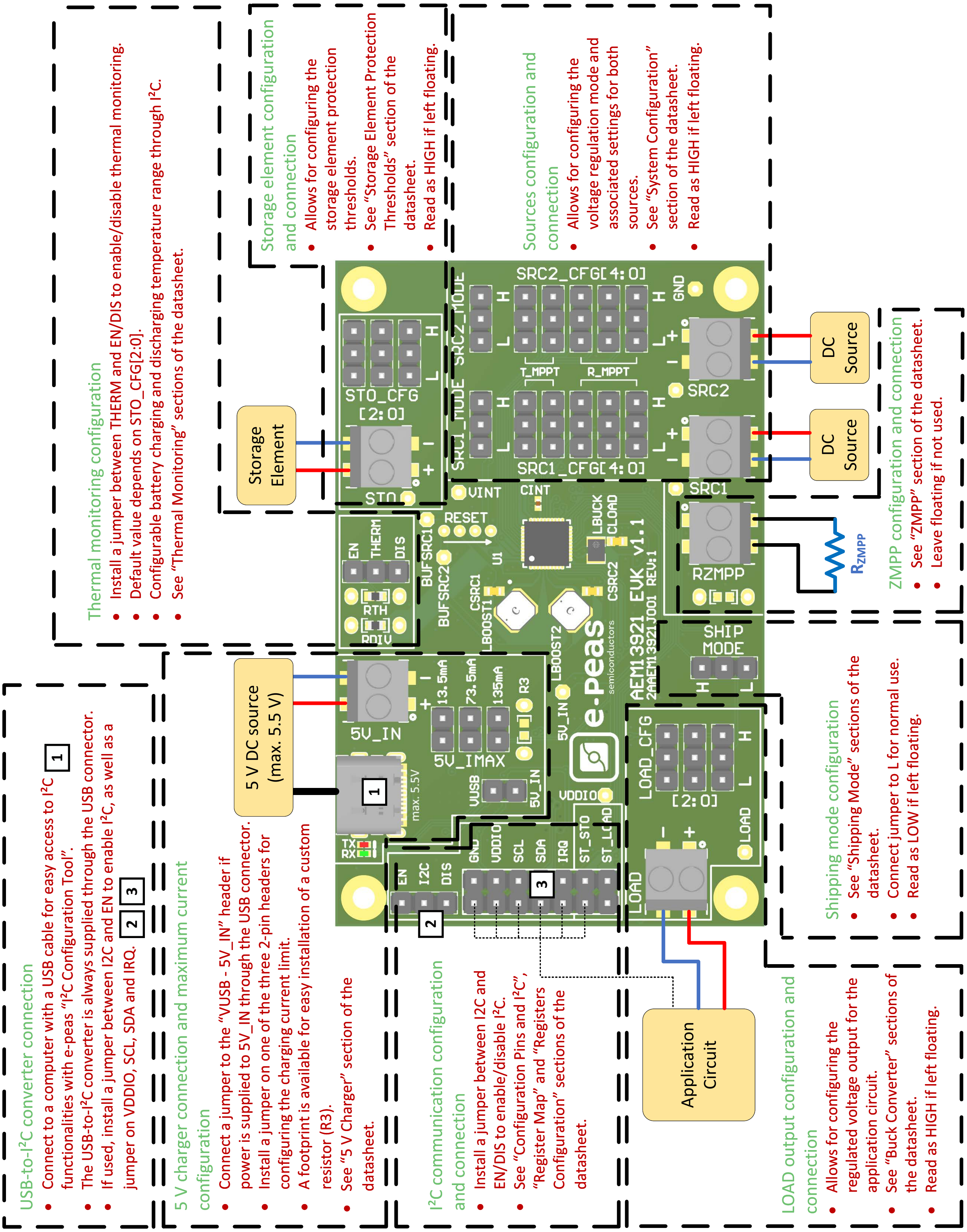


Figure 1: EVK connection diagram

2. Pin Configuration and Functions

NAME	FUNCTION	CONNECTION	
		If used	If not used
Power Pins			
SRC SRC2	Connection to the energy source harvested by the boost converter #1 and #2 respectively.	Connect the harvester(s).	Can be left floating or connected to GND.
ZMPP	Connection for R_{ZMPP}.	Connect R_{ZMPP} resistor.	Leave floating.
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[2:0] pins or BUCKCFG.VLOAD register field 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.
VDDIO	Voltage reference for the I²C interface, as well as for the IRQ pin.	Connect to a external DC power supply and place a jumper between I2C and EN.	Connect to GND by placing a jumper between VDDIO and GND in the communication header.
Control Pin			
SHIP_MODE	When HIGH: - Minimum consumption from the storage element. - Storage element charge is disabled (Boost converters are disabled). - Buck (LOAD) is disabled. - Only VINT is charged if energy is available on SRC or SRC2.	Connect a jumper to H.	Connect a jumper to L or leave floating. Read as LOW if left floating.

Table 1: Signals description (part 1)

NAME	FUNCTION	CONNECTION	
		If used	If not used
Configuration Pins			
SRCx_MODE	Used to configure the SRCx voltage regulation strategy: - LOW: constant voltage mode. - HIGH: MPPT mode (ratio or ZMPP).	Connect jumper.	Read as HIGH if left floating.
SRCx_CFG[4:0]	Used to configure the SRCx regulation voltage. SRCx_MODE = LOW (constant voltage mode): - SRCx_CFG[4:0] are used to set SRCx constant regulation voltage. SRCx_MODE = HIGH (MPPT ratio mode): - SRCx_CFG[2:0] are used to set SRCx MPPT ratio. - SRCx_CFG[4:3] are used to set SRCx MPPT timings.	Connect jumpers.	Read as HIGH if left floating.
STO_CFG[2:0]	Used to configure the storage element protection thresholds.	Connect jumpers.	Read as HIGH if left floating.
LOAD_CFG[2:0]	Used to configure the LOAD output regulation voltage.	Connect jumpers.	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 place a resistor on R3.	Leave floating if 5V_IN is not used.
TH_MON	Connection for thermistor voltage divider mid-point, used to configure the thermal monitoring feature.	Connect jumper between THERM and EN.	Connect jumper between THERM and DIS.
I²C Pins			
SDA SCL	Serial data/clock for I²C communication.	Pull-up to VDDIO by installing a jumper between I2C and EN. Connect to I²C master device.	Connect to GND by installing a jumper between I2C and DIS.

Table 1: Signals description (part 2)

NAME	FUNCTION	CONNECTION	
		If used	If not used
Status Pin			
ST_STO	Logic output. - HIGH when in SUPPLY STATE or in SLEEP STATE. - LOW otherwise.	Connect to the application circuit. High logic level is STO.	Leave floating.
ST_LOAD	Logic output, this signal is available if V_{LOAD} configuration is ≥ 1.2 V. ST_LOAD is set HIGH if the buck converter is enabled, the temperature is within the thermal protection range, and: - V_{STO} rises above $V_{CHRDY,BUCK}$ when the 5 V charger is not connected, or - V_{STO} rises above $V_{OVDIS,BUCK}$ when the 5 V charger is connected. ST_LOAD is set LOW if: - The buck converter is disabled, or - The temperature is outside of the range, or - V_{STO} remains below $V_{OVDIS,BUCK}$ for $T_{CRIT,ST}$.	Connect to the application circuit. High logic level is LOAD.	Leave floating.
Various			
USB connector	Serves two purposes: - USB to I²C converter: allows for connecting the EVK to a computer for easy access to I²C functionalities with e-peas “I²C Configuration Tool”. - Supply the 5V_IN pin from USB. To do so, place a jumper on the “5V_IN-VUSB” header.	Connect a USB cable to a computer (I²C or 5V_IN) or to a USB charger (5V_IN only).	Do not connect.

Table 1: Signals description (part 3)

3. General Considerations

3.1. Safety Information

Always perform the following steps in the correct 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 regulation (SRCx_CFG[4:0] and SRCx_MODE).
    - Storage element protection thresholds (STO_CFG[2:0]).
    - Load output regulation voltage (LOAD_CFG[2:0]).
    - Thermal monitoring.
    - 5 V charger maximum current.
    - I^2C enable/disable.
3. Connect a power supply on VDDIO if the I^2C bus / IRQ pin are used.
4. Connect a storage element on the STO screw connector.
5. Connect the application circuit on the LOAD screw connector.
6. Connect at lease one of the following:
    - The harvester(s) on the SRC(s) screw connector(s).
    - A 5 V power supply to the 5V_IN screw connector.
    - A USB charger or a computer to the USB connector with a jumper placed on the “5V_IN-VUSB” header.

3.2. AEM13921 Reset

The following procedure must be followed to properly reset the AEM13921:

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

3.3. Basic Configurations

3.3.1. Source Configuration

3.3.1.1. Constant Voltage Mode (SRCx_MODE = L)

Configuration pins					Voltage [V]
SRCx_CFG[4:0]					$V_{SRCx,REG}$
L	L	L	L	L	0.25
L	L	L	L	H	0.30
L	L	L	H	L	0.35
L	L	L	H	H	0.41
L	L	H	L	L	0.45
L	L	H	L	H	0.50
L	L	H	H	L	0.56
L	L	H	H	H	0.60
L	H	L	L	L	0.65
L	H	L	L	H	0.71
L	H	L	H	L	0.75
L	H	L	H	H	0.80
L	H	H	L	L	0.86
L	H	H	L	H	0.90
L	H	H	H	L	0.95
L	H	H	H	H	1.01

Configuration pins					Voltage [V]
SRCx_CFG[4:0]					$V_{SRCx,REG}$
H	L	L	L	L	1.10
H	L	L	L	H	1.20
H	L	L	H	L	1.31
H	L	L	H	H	1.40
H	L	H	L	L	1.50
H	L	H	L	H	1.59
H	L	H	H	L	1.70
H	L	H	H	H	1.79
H	H	L	L	L	1.90
H	H	L	L	H	1.99
H	H	L	H	L	2.19
H	H	L	H	H	2.41
H	H	H	L	L	2.59
H	H	H	L	H	2.82
H	H	H	H	L	3.00
H	H	H	H	H	3.18

Table 2: Source constant regulation voltage configuration with SRCx_CFG[4:0] pins

3.3.1.2. MPPT Ratio Mode (SRCx_MODE = H)

Configuration pins			MPPT ratio [%]
SRCx_CFG[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	ZMPP (SRC) 100 % (SRC2)

Configuration pins		MPPT wait time [ms]	MPPT period [ms]
SRCx_CFG[4:3]		$T_{MPPT,WAIT}$ [1]	$T_{MPPT,PERIOD}$
L	L	1.8	116 [2]
L	H	7.3	465
H	L	29	1862
H	H	233	14895

Table 3: MPPT ratio and timings configuration with SRCx_CFG[4:0] pins

1.The total time spent in open-circuit is the sum of $T_{MPPT,WAIT}$ (configurable, see table above) and $T_{MPPT,MEASURE}$ (fixed, see "Electrical Characteristics" table in the datasheet).
2.If $T_{MPPT,PERIOD}$ is set to 116 ms for any of the two SRCx, the APM WINDOW will automatically be set to 116 ms by the AEM13921 for the two boost converters, the buck converter, and the 5 V charger APM modules.

3.3.2. Storage Element Configuration

The STO_CFG[2:0] pins are used to configure the storage element protection thresholds (V_{OVDIS}, V_{CHRDY} and V_{OVCH}), the charge ready buck threshold depending on V_{LOAD} ($V_{CHRDY,BUCK}$) and the temperature thresholds (TEMPCOLDCH, TEMPHOTCH, TEMPCOLDDIS and TEMPHOTDIS). See tables below.

Configuration pins			**Overdischarge voltage [V]**	**Charge ready voltage [V]**	**Overcharge voltage [V]**	**Storage element type**
STO_CFG[2:0]			V_{OVDIS}	V_{CHRDY}	V_{OVCH}	
L	L	L	2.51	2.61	3.79	Lithium-ion Super Capacitor (LiC)
L	L	H	2.51	2.61	3.49	Lithium-ion Super Capacitor 85 °C (LiC)
L	H	L	3.00	3.21	4.13	Lithium-ion
L	H	H	3.00	3.21	3.90	Lithium-ion (long life)
H	L	L	3.51	3.60	3.90	Lithium-ion (super long life)
H	L	H	3.00	3.60	4.35	Lithium Polymer (LiPo), NiMH
H	H	L	2.81	3.11	3.62	Lithium Iron Phosphate (LiFePO4)
H	H	H	2.61	2.70	3.90	Tadiran HLC1020

Table 4: Storage element configuration with STO_CFG[2:0] pins

Configuration pins			**Buck charge ready voltage [V]**				**Storage element type**
STO_CFG[2:0]			$V_{CHRDY,BUCK}$ for $V_{LOAD} \leq 2.5$ V	$V_{CHRDY,BUCK}$ for $V_{LOAD} = 2.8$ V	$V_{CHRDY,BUCK}$ for $V_{LOAD} = 3.0$ V	$V_{CHRDY,BUCK}$ for $V_{LOAD} = 3.3$ V	
L	L	L	2.61	2.91	3.11	3.41	Lithium-ion Super Capacitor (LiC)
L	L	H	2.61	2.91	3.11	3.41	Lithium-ion Super Capacitor 85 °C (LiC)
L	H	L	3.21	3.21	3.21	3.51	Lithium-ion
L	H	H	3.21	3.21	3.21	3.51	Lithium-ion (long life)
H	L	L	3.60	3.60	3.60	3.60	Lithium-ion (super long life)
H	L	H	3.60	3.60	3.60	3.60	Lithium Polymer (LiPo), NiMH
H	H	L	3.11	3.11	3.21	3.41	Lithium Iron Phosphate (LiFePO4)
H	H	H	2.70	2.91	3.11	3.41	Tadiran HLC1020

Table 5: Charge ready buck thresholds with STO_CFG[2:0] pins configuration depending on LOAD voltage

Configuration pins			Minimum charging temperature [°C]	Maximum charging temperature [°C]	Minimum discharging temperature [°C]	Maximum discharging temperature [°C]	Storage element type
STO_CFG[2:0]			TEMPCOLDCH	TEMPHOTCH	TEMPCOLDDIS	TEMPHOTDIS	
L	L	L	-15	60	-15	60	Lithium-ion Super Capacitor (LiC)
L	L	H	-25	85	-25	85	Lithium-ion Super Capacitor 85 °C (LiC)
L	H	L	0	45	0	45	Lithium-ion
L	H	H	0	45	0	45	Lithium-ion (long life)
H	L	L	0	45	0	45	Lithium-ion (super long life)
H	L	H	0	45	0	45	Lithium Polymer (LiPo), NiMH
H	H	L	0	45	0	45	Lithium Iron Phosphate (LiFePO4)
H	H	H	-40	85	-40	85	Tadiran HLC1020

Table 6: Default temperature thresholds depending on STO_CFG[2:0] configuration with the recommended RDIV and RTH

DISCLAIMER: Storage element protection thresholds and temperature thresholds provided for each storage element type 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.

3.3.3. Load Configuration

Configuration pins			LOAD voltage [V]
LOAD_CFG[2:0]			V_{LOAD}
L	L	L	Buck disabled
L	L	H	1.2
L	H	L	1.8
L	H	H	2.2
H	L	L	2.5
H	L	H	2.8
H	H	L	3.0
H	H	H	3.3

Table 7: LOAD voltage configuration with LOAD_CFG[2:0] pins

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	33.3[1]
3700	13.5

Table 8: Typical resistor values for setting 5 V charger max. current

1. Could be obtained by installing a 1.5 kΩ resistor on R3 and leaving all 3 headers open.

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, R3 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 R3 footprint.

3.4. I²C Configuration

3.4.1. I²C Communication

The device address on the I²C bus is 0x51. All information about the I²C communication is available in the AEM13921 datasheet “System Configuration” Section.

VDDIO must be connected to an external power supply which voltage is within the 1.5 V to 5.0 V range. On the evaluation board, 1 kΩ pull-up resistors on SDA and SCL (RSDA and RSCL) to VDDIO are provided.

In case the AEM13921 configurations are set by I²C communication, the configuration pins will not be taken into account anymore (except the SHIP_MODE pin).

The AEM13921 evaluation board provides a 14-pin, 2x7 header that supports two methods for accessing the I²C interface:

- Direct I²C access: The left row of the header (closest to the board edge) is directly connected to the AEM13921 I²C signals (VDDIO, SCL, SDA, and IRQ).
- On-board USB-to-I²C converter: The right row of the header is connected to the integrated USB-to-I²C converter on the evaluation board. To communicate with the AEM13921 through USB, four jumpers must be installed, each linking the corresponding left-side pin to right-side pin for VDDIO, SCL, SDA, and IRQ. See Section 3.4.2.

3.4.2. USB to I²C Converter

The AEM13921 has an on-board USB-to-I²C converter. When a computer is connected to the USB connector and the four jumpers for VDDIO, SCL, SDA, and IRQ are placed, it is recognized as a serial (COM) port, and is intended for use with e-peas “I²C Configuration Tool”, which can be downloaded from e-peas website, along with all necessary information about how to use it.

3.4.3. Register Map

All the register descriptions are provided in the AEM13921 datasheet.

Address	Name	Bit	Field Name	Access	Reset	Description
0x00	VERSION	[7:0]	VERSION	R	-	AEM13921 version number.
0x01	SRC1REGU0	[0:0]	MODE	R/W	0x01	SRC regulation mode.
		[3:1]	CFG0	R/W	0x00	SRC regulation mechanism configuration.
0x02	SRC1REGU1	[2:0]	CFG1	R/W	0x00	
		[5:3]	CFG2	R/W	0x00	
0x03	SRC2REGU0	[0:0]	MODE	R/W	0x01	SRC2 regulation mode.
		[3:1]	CFG0	R/W	0x00	SRC2 regulation mechanism configuration.
0x04	SRC2REGU1	[2:0]	CFG1	R/W	0x00	
		[5:3]	CFG2	R/W	0x00	
0x05	VOVDIS	[5:0]	THRESH	R/W	0x06	Storage element overdischarge threshold.
0x06	VCHRDY	[6:0]	THRESH	R/W	0x05	Storage element charge ready threshold.
0x07	VOVCH	[6:0]	THRESH	R/W	0x3A	Storage element overcharge threshold.
0x08	BST1CFG	[0:0]	EN	R/W	0x01	Boost SRC enable.
		[1:1]	HPEN	R/W	0x01	Boost SRC high-power mode enable.
		[4:2]	TMULT	R/W	0x01	Boost SRC current configuration.

Table 9: Register map (part 1)

Address	Name	Bit	Field Name	Access	Reset	Description
0x09	BST2CFG	[0:0]	EN	R/W	0x01	Boost SRC2 enable.
		[1:1]	HPEN	R/W	0x01	Boost SRC2 high-power mode enable.
		[4:2]	TMULT	R/W	0x01	Boost SRC2 current configuration.
0x0A	BUCKCFG	[3:0]	VLOAD	R/W	0x00	Buck output voltage configuration.
		[6:4]	TMULT	R/W	0x03	Buck current configuration.
0x0B	VCHRDYBUCK	[6:0]	THRESH	R/W	0x05	Storage element charge ready buck threshold.
0x0C	CHG5V	[0:0]	EN	R/W	0x01	5 V charger enable.
		[1:1]	CVEN	R/W	0x00	Constant voltage (CV) mode enable.
		[6:2]	THRESH	R/W	0x00	5 V charger stop voltage threshold.
0x0D	TEMPCOLDCH	[7:0]	THRESH	R/W	0xD1	Cold temperature threshold for storage element charging.
0x0E	TEMPHOTCH	[7:0]	THRESH	R/W	0x18	Hot temperature threshold for storage element charging.
0x0F	TEMPCOLDDIS	[7:0]	THRESH	R/W	0xD1	Cold temperature threshold for storage element discharging.
0x10	TEMPHOTDIS	[7:0]	THRESH	R/W	0x18	Hot temperature threshold for storage element discharging.
0x11	TEMPPROTECT	[0:0]	EN	R/W	0x01	Thermal protection enable.
0x12	SRCLOW	[2:0]	SRC1THRESH	R/W	0x00	V_{SRCLOW} threshold for SRC.
		[5:3]	SRC2THRESH	R/W	0x00	V_{SRCLOW} threshold for SRC2.
0x13	APM	[0:0]	SRC1EN	R/W	0x00	APM SRC enable.
		[1:1]	SRC2EN	R/W	0x00	APM SRC2 enable.
		[2:2]	LOADEN	R/W	0x00	APM LOAD enable.
		[3:3]	CHG5VEN	R/W	0x00	APM 5 V charger enable.
		[4:4]	MODE	R/W	0x00	APM mode.
		[5:5]	WINDOW	R/W	0x00	APM window.
0x14	APMACC	[7:0]	CFG	R/W	0x00	Number of APM window accumulations.
0x15	IRQEN0	[0:0]	I2CRDY	R/W	0x01	IRQ serial interface ready enable.
		[1:1]	VOVDIS	R/W	0x00	IRQ VOVDIS enable.
		[2:2]	VCHRDY	R/W	0x00	IRQ VCHRDY enable.
		[3:3]	VOVCH	R/W	0x00	IRQ VOVCH enable.
		[4:4]	SRCLOW	R/W	0x00	IRQ source low threshold (SRCx) enable.
		[5:5]	TEMPCH	R/W	0x00	IRQ temperature charge enable.
		[6:6]	TEMPDIS	R/W	0x00	IRQ temperature discharge enable.
		[7:7]	CHG5VCONN	R/W	0x00	IRQ 5 V charger connected enable.
0x16	IRQEN1	[0:0]	SRC1MPPTSTART	R/W	0x00	IRQ MPPT start (SRC) enable.
		[1:1]	SRC1MPPTDONE	R/W	0x00	IRQ MPPT done (SRC) enable.
		[2:2]	SRC2MPPTSTART	R/W	0x00	IRQ MPPT start (SRC2) enable.
		[3:3]	SRC2MPPTDONE	R/W	0x00	IRQ MPPT done (SRC2) enable.
		[4:4]	STODONE	R/W	0x00	IRQ STO measurement done enable.
		[5:5]	TEMPDONE	R/W	0x00	IRQ temperature measurement done enable.
		[6:6]	APMDONE	R/W	0x00	IRQ APM done enable.
		[7:7]	APMERR	R/W	0x00	IRQ APM error enable.

Table 9: Register map (part 2)

Address	Name	Bit	Field Name	Access	Reset	Description
0x17	CTRL	[0:0]	UPDATE	R/W	0x00	Load I²C registers configuration.
		[1:1]	-	R	-	Reserved.
		[2:2]	SYNCBUSY	R	0x00	Synchronization busy flag.
0x18	IRQFLG0	[0:0]	I2CRDY	R	0x00	IRQ serial interface ready flag.
		[1:1]	VOVDIS	R	0x00	IRQ VOVDIS flag.
		[2:2]	VCHRDY	R	0x00	IRQ VCHRDY flag.
		[3:3]	VOVCH	R	0x00	IRQ VOVCH flag.
		[4:4]	SRCLOW	R	0x00	IRQ source low threshold (SRCx) flag.
		[5:5]	TEMPCH	R	0x00	IRQ temperature (charge) flag.
		[6:6]	TEMPDIS	R	0x00	IRQ temperature (discharge) flag.
		[7:7]	CHG5VCONN	R	0x00	IRQ 5 V charger connected flag.
0x19	IRQFLG1	[0:0]	SRC1MPPTSTART	R	0x00	IRQ MPPT start (SRC) flag.
		[1:1]	SRC1MPPTDONE	R	0x00	IRQ MPPT done (SRC) flag.
		[2:2]	SRC2MPPTSTART	R	0x00	IRQ MPPT start (SRC2) flag.
		[3:3]	SRC2MPPTDONE	R	0x00	IRQ MPPT done (SRC2) flag.
		[4:4]	STODONE	R	0x00	IRQ STO measurement done flag.
		[5:5]	TEMPDONE	R	0x00	IRQ temperature measurement done flag.
		[6:6]	APMDONE	R	0x00	IRQ APM done flag.
		[7:7]	APMERR	R	0x00	IRQ APM error flag.
0x1A	STATUS0	[0:0]	VOVDIS	R	0x00	Status VOVIDS.
		[1:1]	VCHRDY	R	0x00	Status VCHRDY.
		[2:2]	VOVCH	R	0x00	Status VOVCH.
		[3:3]	SRC1LOW	R	0x00	Status source low threshold (SRC).
		[4:4]	SRC2LOW	R	0x00	Status source low threshold (SRC2).
		[5:5]	CHG5VCONN	R	0x00	Status 5 V charger connected.
0x1B	STATUS1	[0:0]	TEMPCOLDCH	R	0x00	Status cold temperature (charge).
		[1:1]	TEMPHOTCH	R	0x00	Status hot temperature (charge).
		[2:2]	TEMPCOLDDIS	R	0x00	Status cold temperature (discharge).
		[3:3]	TEMPHOTDIS	R	0x00	Status hot temperature (discharge).
0x1C	APM0SRC1	[7:0]	DATA	R	0x00	APM data 0 (SRC).
0x1D	APM1SRC1	[7:0]	DATA	R	0x00	APM data 1 (SRC).
0x1E	APM2SRC1	[7:0]	DATA	R	0x00	APM data 2 (SRC).
0x1F	APM0SRC2	[7:0]	DATA	R	0x00	APM data 0 (SRC2).
0x20	APM1SRC2	[7:0]	DATA	R	0x00	APM data 1 (SRC2).
0x21	APM2SRC2	[7:0]	DATA	R	0x00	APM data 2 (SRC2).
0x22	APM0LOAD	[7:0]	DATA	R	0x00	APM data 0 (LOAD).
0x23	APM1LOAD	[7:0]	DATA	R	0x00	APM data 1 (LOAD).
0x24	APM2LOAD	[7:0]	DATA	R	0x00	APM data 2 (LOAD).
0x25	APM0CHG5V	[7:0]	DATA	R	0x00	APM data 0 (CHG5V).
0x26	APM1CHG5V	[7:0]	DATA	R	0x00	APM data 1 (CHG5V).

Table 9: Register map (part 3)

Address	Name	Bit	Field Name	Access	Reset	Description
0x27	APMERR	[0:0]	SRC1OV	R	0x00	APM counter overflow SRC.
		[1:1]	SRC1NVLD	R	0x00	APM counter corrupted SRC.
		[2:2]	SRC2OV	R	0x00	APM counter overflow SRC2.
		[3:3]	SRC2NVLD	R	0x00	APM counter corrupted SRC2.
		[4:4]	LOADOV	R	0x00	APM counter overflow LOAD.
		[5:5]	LOADNVLD	R	0x00	APM counter corrupted LOAD.
		[6:6]	CHG5VLIM	R	0x00	5 V charger current limited due to overdischarged storage element.
0x28	TEMP	[7:0]	DATA	R	0x00	Temperature monitoring value.
0x29	STO	[7:0]	DATA	R	0x00	STO monitoring value.
0x2A	SRC1	[7:0]	DATA	R	0x00	SRC monitoring value.
0x2B	SRC2	[7:0]	DATA	R	0x00	SRC2 monitoring value.
...	RSVD	-	-	R	-	Reserved.
0xE0	PN0	[7:0]	DATA	R	0x31	Part number 0 data.
0xE1	PN1	[7:0]	DATA	R	0x32	Part number 1 data.
0xE2	PN2	[7:0]	DATA	R	0x39	Part number 2 data.
0xE3	PN3	[7:0]	DATA	R	0x33	Part number 3 data.
0xE4	PN4	[7:0]	DATA	R	0x31	Part number 4 data.

Table 9: Register map (part 4)

3.5. Advanced Configurations

A complete description of the system constraints and configurations is available in Section "System configuration" of the AEM13921 datasheet.

3.5.1. Shipping Mode

The shipping mode feature allows forcing the AEM13921 in RESET STATE (see datasheet), thus, disabling all AEM13921 functionalities including both boost converters, the buck converter and the 5 V charger. Only VINT is charged from SRCx if energy is available from it. The storage element is no longer charged or discharged.

Shipping mode is enabled by installing a jumper in HIGH position on the EVK dedicated header. It is disabled if a jumper is connected to LOW or if SHIP_MODE pin is left floating.

3.5.2. ZMPP

The ZMPP feature allows the AEM13921 to regulate the input of the SRC to match the resistance R_{ZMPP} connected to the ZMPP pin. See the "Theory of Operations" section from the AEM13921 datasheet for more information about the ZMPP mode.

R_{ZMPP} must comply with the following formula:

$$33\ \Omega < R_{ZMPP} < 100\ k\Omega$$

R_{ZMPP} can be connected either on the dedicated screw connector or soldered on the RZMPP footprint next to it.

If unused, leave the resistor footprint RZMPP empty and do not connect a resistor to the screw connector.

3.5.3. Temperature Monitoring and Thermal Protection

The temperature monitoring feature allows to measure the ambient temperature.

To use the temperature monitoring, R_{DIV} and R_{TH} must be mounted and THERM connected to EN, done by placing a jumper between THERM and EN on the EVK dedicated header. To disable the feature place a jumper between THERM and DIS.

The thermal protection feature allows to protect the storage element by disabling its charge from SRC, SRC2 and 5V_IN and its discharge through LOAD when the ambient temperature is outside the configured temperature thresholds. The cold and hot thresholds for charging and discharging default values depend on STO_CFG[2:0] pins and are configurable through the I²C communication (see datasheet).

To use the thermal protection, the temperature monitoring must be enabled (as explained above), and TEMPPROTECT.EN field set to 1 (default value). The thermal protection uses the configured temperature thresholds to protect the storage element.

4. Functional Tests

This section presents a few simple tests that allow the user to understand the functional behavior of the AEM13921. 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.

The user 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 "Electrical Characteristics at 25 °C" Section of AEM13921 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 the user to observe the start-up behavior of the AEM13921, showing that the AEM13921 starts charging the storage element as soon as VINT reaches its 2.2 V regulation voltage. The energy source can be connected either on SRC or SRC2 (named SRCx).

4.1.2. Setup

- Oscilloscope:
  - Channel 1: STO.
  - Channel 2: VINT (may be probed on H pin on SRC2_CFG[0] header for example).
- SRCx (2 alternatives, initially disconnected):
  - 1 V / 10 mA power supply with a 100 Ω resistor in series (I_{SRCx} = 2.5 mA with R_{MPPT} = 75%).
  - SMU set as 2.5 mA current source with 1 V voltage compliance.
- SRCx_MODE = H.
  - MPPT ratio mode.
- SRCx_CFG[2:0] = HLL.
  - R_{MPPT} = 75%.
- $I_{SRCx} = \frac{1\,V - 0.75\,V}{100\,\Omega} = 2.5\,mA$ (PSU)
- $I_{SRCx} = 2.5\,mA$ (SMU)
- SRCx_CFG[4:3] = LH.
  - $T_{MPPT,PERIOD}$ = 465 ms.
  - $T_{MPPT,WAIT}$ = 7.3 ms.
- 1000 µF capacitor connected to STO as storage element.
- 3 V power supply or SMU connected to STO beforehand.
- STO_CFG[2:0] = LHL.
  - V_{OVDIS} = 3.00 V.
  - V_{CHRDY} = 3.21 V.
  - V_{OVCH} = 4.13 V.
  - $V_{CHRDY,BUCK}$ = 3.21 V.
- LOAD_CFG[2:0] = LLL.
  - LOAD disabled.
- LOAD is floating.
- 5V_IN left floating.
- Jumper between I2C and DIS and between VDDIO and GND.
  - I²C disabled.
- Jumper between THERM and DIS.
  - Thermal monitoring disabled.
- Nothing connected to R_{ZMPP} screw terminal.

4.1.3. Measurements

- Reset the AEM13921 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 SRCx.
- Disconnect the power supply from STO.
- Connect the power supply or the SMU to SRCx.
- Observe V_{INT} rise up to 2.2 V and be regulated at that voltage.
- Energy is transferred from SRCx to STO: V_{STO} rises from its initial 3.0 V voltage to V_{OVCH} (4.13 V).
- V_{STO} is regulated to V_{OVCH} (4.13 V) as the AEM13921 prevents the storage element to be charged any further.

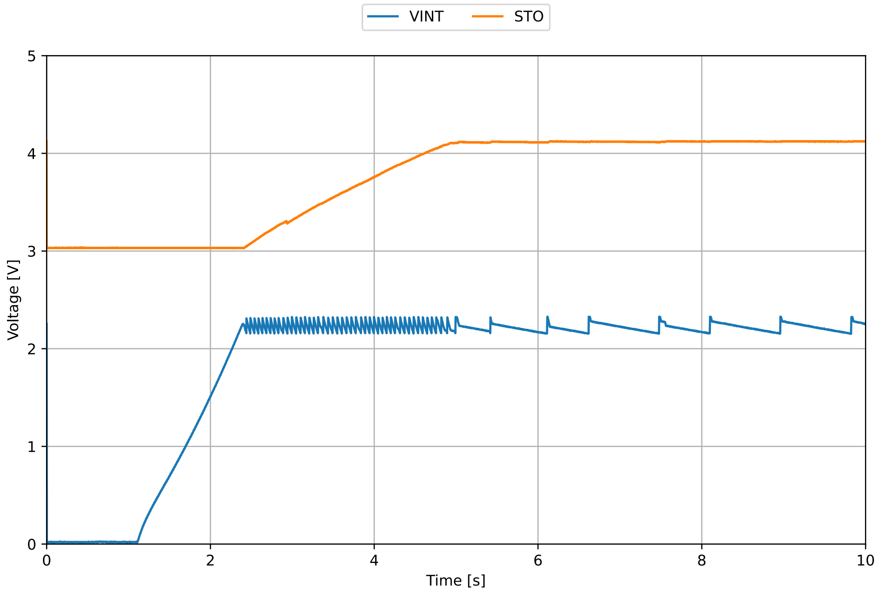


Figure 2: Start-up behavior

4.2. Cold start

4.2.1. Description

The following example allows the user to observe the cold-start behavior of the AEM13921, showing the behavior of SRC and VINT when the AEM13921 coldstarts. The energy source can be connected either on SRC or SRC2 (named SRCx) .

4.2.2. Setup

- Oscilloscope:
  - Channel 1: SRCx.
  - Channel 2: VINT (may be probed on H pin on SRC2_CFG[0] header for example).
  - Note than the oscilloscope probes will have an impact in the minimum input cold-start power due to their input impedance.
- SRCx (2 alternatives, initially disconnected):
  - 1 V / 10 mA power supply with a 68 kΩ resistor in series (I_{SRCx} = 10 µA with source voltage clamped to 0.3 V during cold start). 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 voltage compliance. Using an SMU allows for validating the minimum cold-start power as well as the minimum cold-start voltage.
  - Note that the AEM13921 is able to cold start at lower power than used in this example.
- SRCx_MODE = H.
  - MPPT ratio mode.
- SRCx_CFG[2:0] = HLL.
  - R_{MPPT} = 75%.
- $I_{SRCx} = \frac{1\,V - 0.3\,V}{68\,k\Omega} = 10\,\mu A$ (PSU)
- $I_{SRCx} = 10\,\mu A$ (SMU)
- SRCx_CFG[4:3] = LH.
  - $T_{MPPT,PERIOD}$ = 465 ms
  - $T_{MPPT,WAIT}$ = 7.3 ms.
- 1000 µF capacitor connected to STO as storage element.
- 3 V power supply connected to STO beforehand.
- STO_CFG[2:0] = LHL.
  - V_{OVDIS} = 3.00 V.
  - V_{CHRDY} = 3.21 V.
  - V_{OVCH} = 4.13 V.
  - $V_{CHRDY,BUCK}$ = 3.21 V.
- LOAD_CFG[2:0] = LLL.
  - LOAD disabled.
- LOAD is floating.
- 5V_IN left floating.
- Jumper between I2C and DIS and between VDDIO and GND.
  - I²C disabled.
- Jumper between THERM and DIS.
  - Thermal monitoring disabled.
- Nothing connected to R_{ZMPP} screw terminal.

4.2.3. Measurements

- Reset the AEM13921 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 SRCx.
- Disconnect the power supply from STO.
- Connect the power supply or SMU to SRCx.
- Cold-start phase:
  - Observe V_{SRCx} 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 AEM13921 performs a first V_{OC} evaluation on SRCx.
- Then, the AEM13921 extracts energy from SRCx, regulating V_{SRCx} to 75 % of V_{OC} (about 750 mV).
- V_{OC} is re-evaluated every 465 ms.

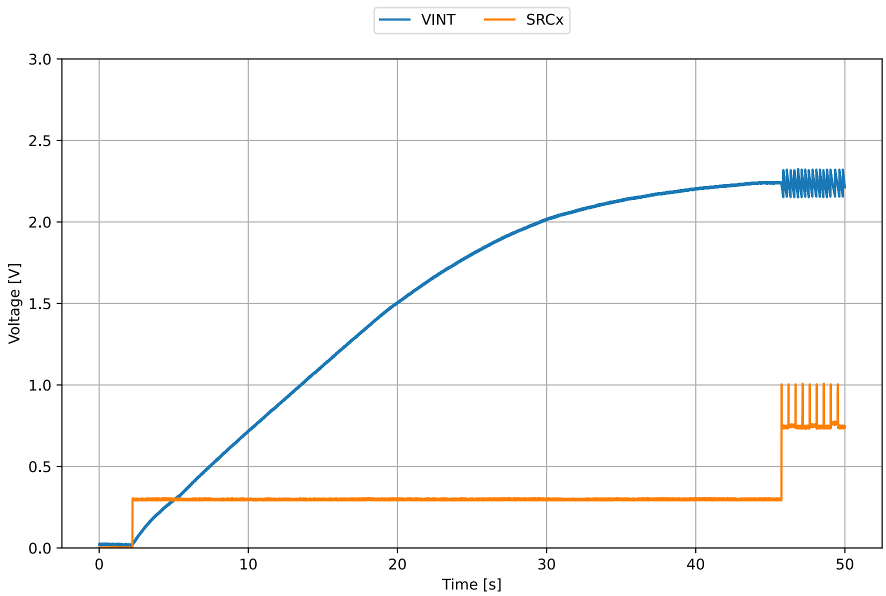


Figure 3: Cold-start behavior

4.3. Load

4.3.1. Description

The following example allows the user to observe how the AEM13921 switches ON and OFF the buck converter supplying the LOAD pin. The energy source can be connected either on SRC or SRC2 (named SRCx).

4.3.2. Setup

- Oscilloscope:
  - Channel 1: STO.
  - Channel 2: LOAD.
- SRCx (2 alternatives, initially disconnected):
  - 1 V / 10 mA power supply with a 100 Ω resistor in series (I_{SRCx} = 2.5 mA with R_{MPPT} = 75%).
  - SMU set as 2.5 mA current source with 1.0 V voltage compliance.
- SRCx_MODE = H.
  - MPPT ratio mode.
- SRCx_CFG[2:0] = HLL.
  - R_{MPPT} = 75%.
- $I_{SRCx} = \frac{1V - 0.75V}{100\Omega} = 2.5mA$ (PSU)
- $I_{SRCx} = 2.5mA$ (SMU)
- SRCx_CFG[4:3] = LH.
  - $T_{MPPT,PERIOD}$ = 465 ms
  - $T_{MPPT,WAIT}$ = 7.3 ms.
- 1000 µF capacitor connected to STO as storage element.
- Power supply connected to STO beforehand with a voltage below V_{OVDIS}, 2.8 V in this example.
- STO_CFG[2:0] = LHL.
  - V_{OVDIS} = 3.00 V.
  - V_{CHRDY} = 3.21 V.
  - V_{OVCH} = 4.13 V.
  - $V_{CHRDY,BUCK}$ = 3.21 V.
- LOAD_CFG[2:0] = LHL.
  - LOAD is regulated at 1.8 V.
- LOAD: 5 kΩ resistor connected between LOAD and GND.
  - I_{LOAD} = 360 µA.
- 5V_IN left floating.
- Jumper between I2C and DIS and between VDDIO and GND.
  - I²C disabled.
- Jumper between THERM and DIS.
  - Thermal monitoring disabled.
- Nothing connected to R_{ZMPP} screw terminal.

4.3.3. Measurements

- Reset the AEM13921 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 SRCx.
- Disconnect the power supply from STO.
- Connect the power supply or SMU to SRCx.
- After cold start, observe the storage element charging.
- When $V_{STO} > V_{CHRDY,BUCK}$, the buck converter is enabled and the LOAD starts being regulated to 1.8 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 or SMU from SRCx (done at about 9 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 $V_{STO} < V_{OVDIS,BUCK}$ ($V_{OVDIS,BUCK} = V_{OVDIS}$ in this example), the AEM13921 waits for T_{CRIT} (2.56 s) and then switches OFF the buck converter. LOAD is no longer regulated and drops down to 0 V.

Please note that, 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}.

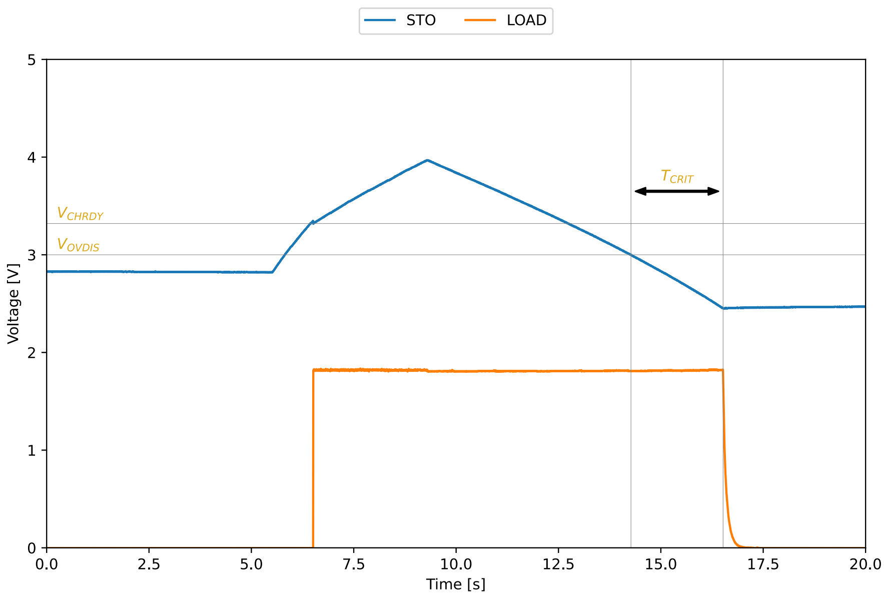


Figure 4: LOAD output behavior

4.4. 5 V Charger

4.4.1. Description

The following example allows the user to observe how the AEM13921 coldstarts and charges the storage element from the 5 V charger.

4.4.2. Setup

- Oscilloscope:
  - Channel 1: STO.
  - Channel 2: 5V_IN.
- SRCx 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.
- Power supply connected to STO beforehand with a voltage below V_{OVDIS}, 2.8 V in this example.
- STO_CFG[2:0] = LHL.
  - V_{OVDIS} = 3.00 V.
  - V_{CHRDY} = 3.21 V.
  - V_{OVCH} = 4.13 V.
  - $V_{CHRDY,BUCK}$ = 3.21 V.
- LOAD_CFG[2:0] = LLL.
  - LOAD is disabled.
- LOAD left floating.
- Jumper between I2C and DIS and between VDDIO and GND.
  - I²C disabled.
- Jumper between THERM and DIS.
  - Thermal monitoring disabled.
- Nothing connected to R_{ZMPP} screw terminal.

4.4.3. Measurements

- Reset the AEM13921 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} (4.13 V).

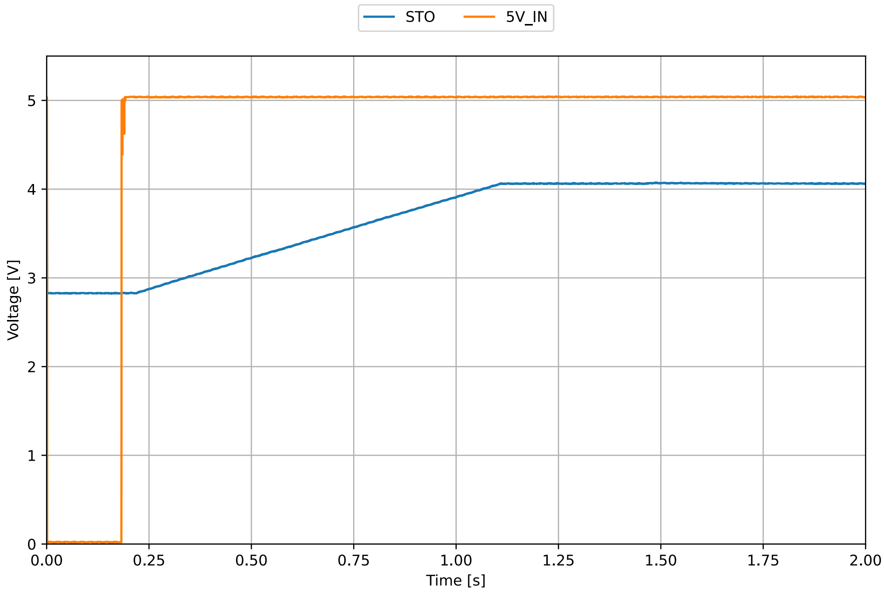


Figure 5: Cold-start and storage element charge from 5V_IN

4.5. Thermal Protection

4.5.1. Description

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

4.5.2. Setup

- Use a heat source to increase the thermistor R_{TH} temperature. In the following example, an SMD hot air rework station has been used, with temperature set to +100°C with moderate air flow.
- Oscilloscope:
  - Channel 1: SRCx.
  - Channel 2: STO.
- SRCx: 1 V / 10 mA power supply with a 3 kΩ resistor in series (I_{SRCx} = 83 µA with R_{MPPT} = 75%).
- SRCx_MODE = H.
  - MPPT ratio mode.
- SRCx_CFG[2:0] = HLL.
  - R_{MPPT} = 75%.
- $I_{SRCx} = \frac{1V - 0.75V}{3k\Omega} = 83\mu A$
- SRCx_CFG[4:3] = HL.
  - $T_{MPPT,PERIOD}$ = 1862 ms.
  - $T_{MPPT,WAIT}$ = 29 ms.
- 1000 µF capacitor connected to STO as storage element.
- 3 V power supply connected to STO beforehand.
- STO_CFG[2:0] = LHL.
  - V_{OVDIS} = 3.00 V.
  - V_{CHRDY} = 3.21 V.
  - V_{OVCH} = 4.13 V.
  - $V_{CHRDY,BUCK}$ = 3.21 V.
- LOAD_CFG[2:0] = LLL.
  - LOAD is disabled.
- LOAD left floating.
- 5V_IN left floating.
- Jumper between I2C and DIS and between VDDIO and GND.
  - I²C disabled.
- Jumper between THERM and EN.
  - Thermal monitoring enabled.
  - 10 kΩ NTC thermistor with β = 3380 on R_{TH} (default on EVK).
  - 22 kΩ pullup resistor on R_{DIV} (default on EVK).
  - Storage element charging and discharging disabled below 0°C.
  - Storage element charging and discharging disabled above +45°C.
- Nothing connected to R_{ZMPP} screw terminal.

4.5.3. Measurements

- Reset the AEM13921 as described in Section 3.2.
- Start with:
  - 3 V power supply connected to STO so that C_{STO} is charged to 3 V beforehand.
  - SRCx left floating.
- Disconnect the power supply from STO.
- Connect the power supply or SMU to SRCx.
- After cold start, observe the storage element charging.
- Start flowing hot air on the thermistor R_{TH}.
- When R_{TH} is hot enough, above 45°C (near 7 s on Figure 6), the AEM13921 thermal protection is triggered:
  - No more energy is extracted from the source connected on SRCx, which rises to its open circuit voltage V_{OC}.
  - The storage element is no longer charged (V_{STO} stops rising) even though V_{STO} is below V_{OVCH}, and thus, is protected.
  - The LOAD would stop being supplied if enabled.
  - VINT is still supplied from SRCx.

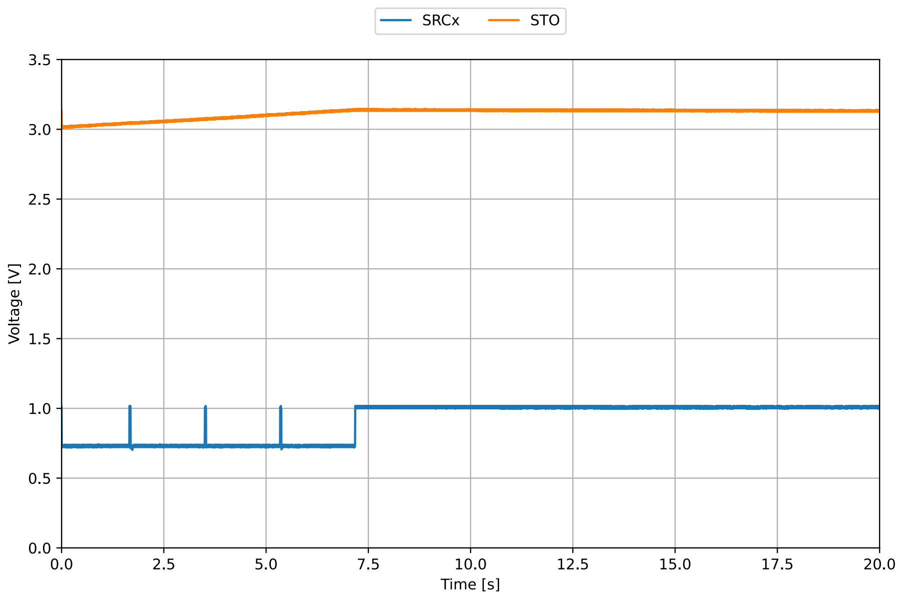


Figure 6: Storage element thermal protection behavior

5. Performance Tests

This section presents the tests to reproduce the performance graphs found in the AEM13921 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 AEM13921 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 Converters Efficiency

5.1.1. Description

The boost converter efficiency is determined for a fixed set point of the AEM13921:

- Fixed SRCx voltage V_{SRCx}.
- Fixed SRCx current I_{SRCx}.
- Fixed STO voltage V_{STO}.
- Fixed inductor value L_{BOOSTx}. Please note that the inductor model has a subsequent influence on the efficiency.
- Fixed boost timing. Use the I²C bus to configure the AEM13921 timing if not using the default value.

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

The following apply for both SRC and SRC2 (noted SRCx).

Please note that, to avoid any leakage that would affect the measurement, no probe or voltmeter should be connected to the AEM13921 pins while measuring the boost efficiency.

5.1.2. Setup

- SRCx_MODE = L.
  - Constant voltage mode.
- SRCx_CFG[4:0] set according to the desired V_{SRCx} set point (see Table 2).
- SRCx: SMU set as current source.
  - Current source set to the desired I_{SRCx}.
  - Voltage compliance set to 0.5 V above the desired $V_{SRCx,REG}$ set point.
- 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 than the power of the SMU connected to SRCx (V_{SRCx} x I_{SRCx}). Do not lower the current compliance lower than 100 µA.
- Optional: a device able to act as an I²C master and send I²C commands to the AEM13921. Only useful when testing settings that are not accessible through the configuration pins, such as boost timings. Please note that, the results shown on Figure 7 are with x3 boost timing, which is the default value when not configuring the AEM13921 though the I²C registers, but must be configured if the I²C is used.

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, the user must make sure that V_{STO} does not drop below V_{OVDIS} between measurements.

- Start with both SMU switched OFF.
- Reset the AEM13921.
- STO SMU: set the voltage to 5.0 V and switch ON, to make sure that V_{STO} is above V_{OVCH}.
- SRCx SMU: set the current source to 1 mA with the voltage compliance to 1.0 V to trigger the AEM13921 cold start.
- Wait for V_{INT} to rise to its 2.2 V regulation voltage.
- The AEM13921 is now ready to perform an efficiency measurement. Do not lower V_{STO} below V_{OVDIS} from that point to avoid the AEM13921 going to OVDIS STATE. Keep STO SMU current compliance to at least 100 µA.

Efficiency measurement

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

- Set SRCx SMU to the desired voltage and current set point.
- Set STO SMU to the desired voltage and adapted current range.
- 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:

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

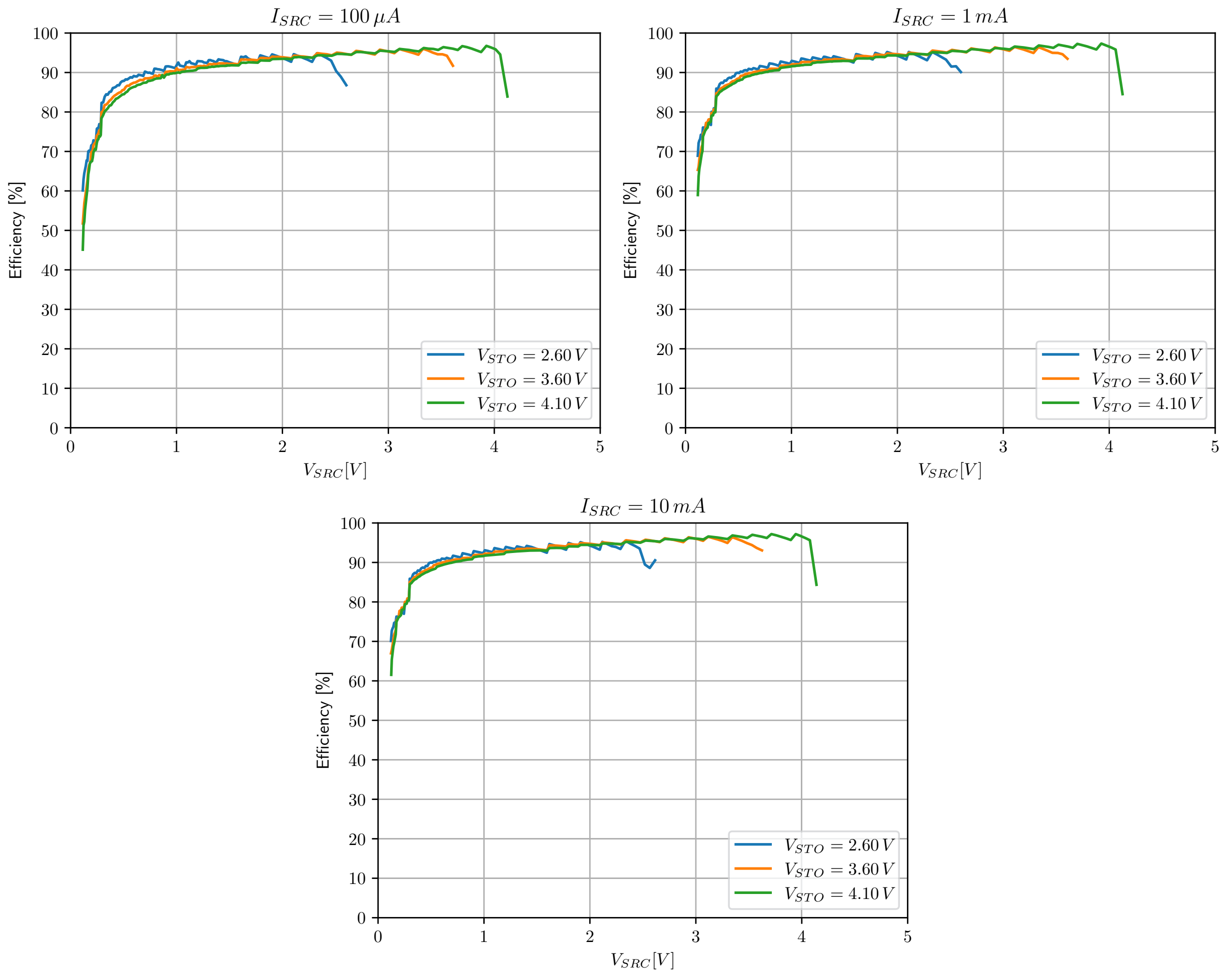


Figure 7: Boost converter efficiency with L_{BOOSTx} = 33 µH (Coilcraft LPS4018-333MRB), BSTxCFG.TMULT = 0x02 (x3)

5.2. Buck Converter Efficiency

5.2.1. Description

The buck converter efficiency is determined on a fixed set point of the AEM13921:

- 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.
- Fixed buck timing. Use the I²C bus to configure the AEM13921 timing if not using the default value.

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 should be connected to the AEM13921 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}.
- SRCx: any power supply with voltage higher than $V_{SRCx,CS}$ and lower than 5.0 V (1 V / 1 mA is typically fine).
- Optional: a device able to act as an I²C master and send I²C commands to the AEM13921. Only useful when testing settings that are not accessible through the configuration pins, such as buck timings. Please note that the results shown on Figure 8 are with buck timing x2, that is the default value when not configuring the AEM13921 though the I²C registers. If using the I²C bus, the default value of the BUCKCFG register is 0x03 (timing x4).

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 AEM13921.
- 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 SRCx power supply.
- Wait for V_{INT} to be regulated at 2.2 V.
- Switch OFF SRCx power supply.
- The AEM13921 is now ready to perform an efficiency measurement. Do not lower V_{STO} below V_{OVDIS} from that point to avoid the AEM13921 going to OVDIS STATE. Keep the STO SMU current compliance to 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 adapted current range.
- 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:

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

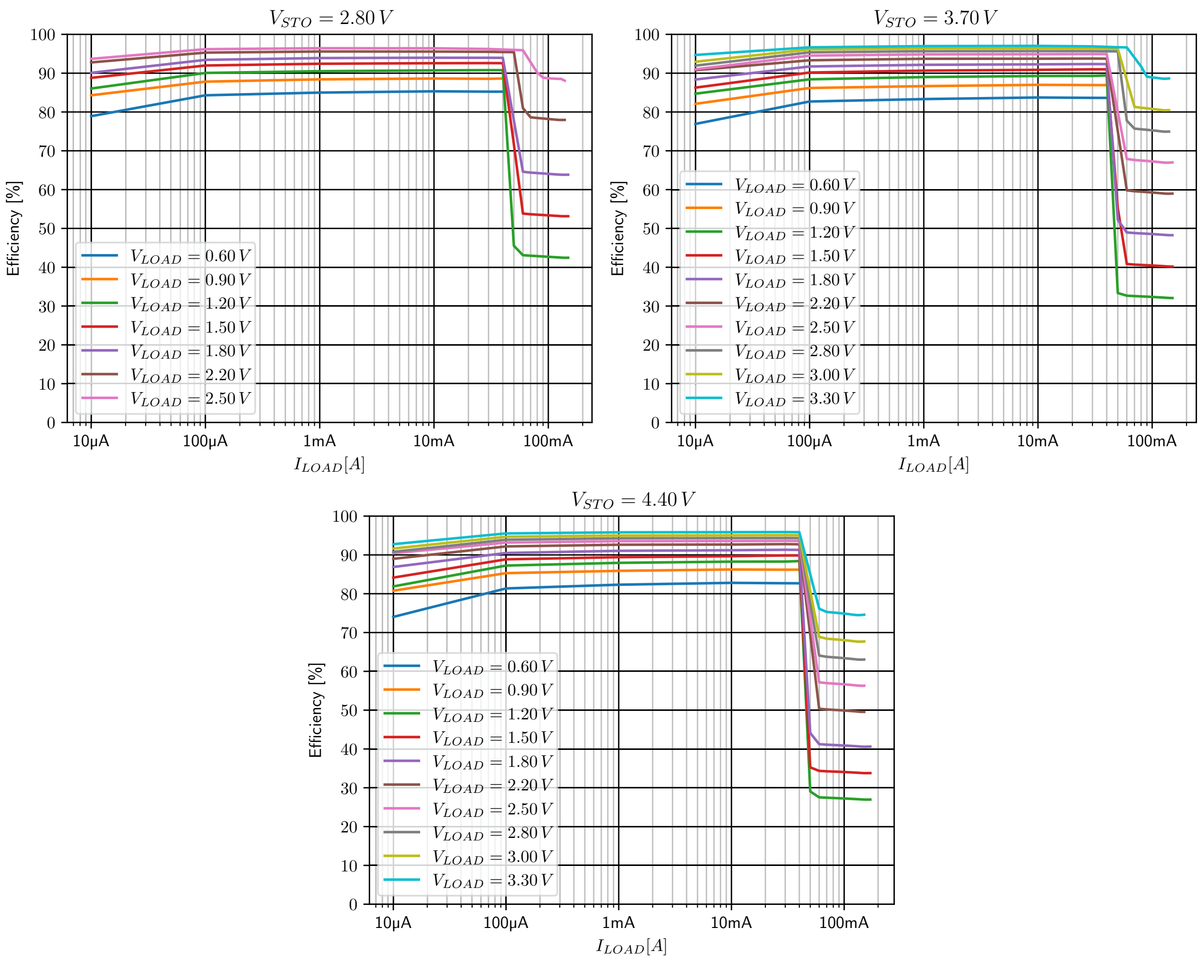


Figure 8: Buck (LOAD) converter efficiency with L_{BUCK} = 10 µH (TDK VLS252012CX-100M-1), T_{MULT} = x2

6. EVK Schematic

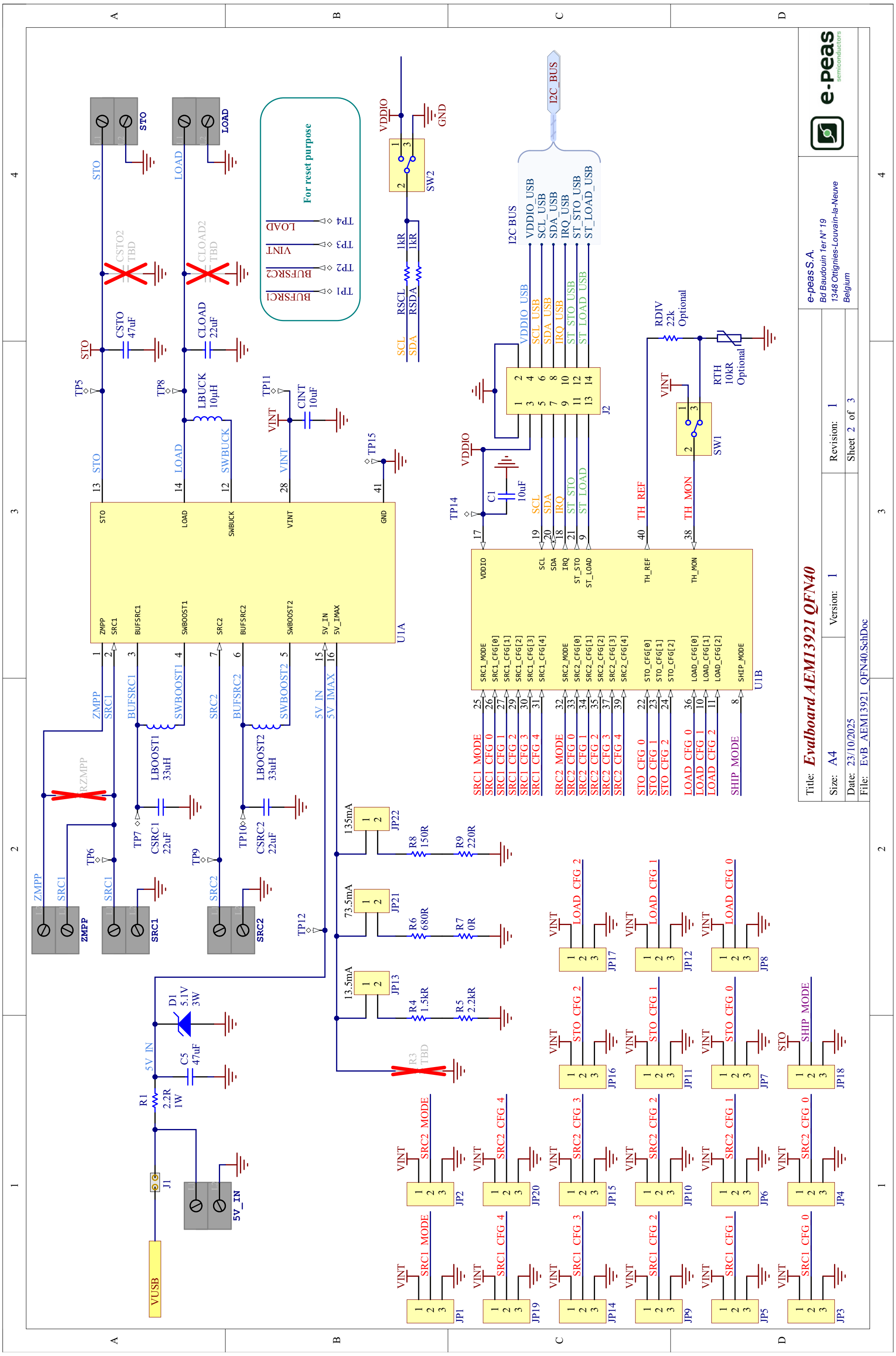


Figure 9: EVK schematic

7. Revision History

EVK Version	User Guide Revision	Date	Description
1.0	1.0	October, 2025	Creation of the document.
1.1	1.0	October, 2025	Update to EVK v1.1: - Added USB-to-I²C converter.
1.1	1.1	December, 2025	Improved I²C interface connection explanations.

Table 10: Revision history