

Ultra Efficient Energy Manager with Constant Voltage, Regulated Buck Output and 5 V CC/CV Charger

Features and Benefits

Cold start from 275 mV / 5 μ W input

- Startup at ultra-low power from harvesting source input.

Maximum Power Point Tracking

- Matches various single/dual elements PV cells.
- Configurable MPPT ratios ranging from 35% to 90%.
- Configurable MPPT sensing timing and period.
- MPPT voltage operation range from 110 mV up to the storage element voltage.

Selectable overdischarge and overcharge protection

- Supports various types of rechargeable batteries (LiC, Li-ion, LiPo...).

Regulated output for application circuit

- Buck regulator with efficiency above 90 %.
- Selectable output voltage (2.2 V, 2.5 V or 2.8 V).
- Output current up to 135 mA.

System configuration by GPIO

- All settings are dynamically configurable through GPIO.

Shipping mode

- Disables charging and discharging of the battery during shipment.

External 5 V charging capability

- Extra charging input for 5 V power supplies.
- CC/CV charging with configurable current limit in CC mode (max. 135 mA).
- Provides a fast charging alternative when no source is available for a long time.

Description

The AEM10920 is a fully integrated and compact power management circuit that extracts DC power from a harvesting source to store energy in a rechargeable battery and supply an application circuit. A 5 V input can also be used to charge the battery (e.g. if the battery gets depleted). This compact and ultra-efficient battery charger allows for extending battery lifetime and eliminating the primary energy storage in a large range of applications.

Thanks to a Maximum Power Point Tracking and a ultra-low power boost converter, the AEM10920 harvests the maximum available power from a source to charge a storage element.

With its unique cold-start circuit, it can start operating with an input voltage as low as 275 mV (min. 5 μ W power).

The configurable protection levels determine the storage element voltage protection thresholds to avoid overcharging and overdischarging the storage element and thus damaging it.

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

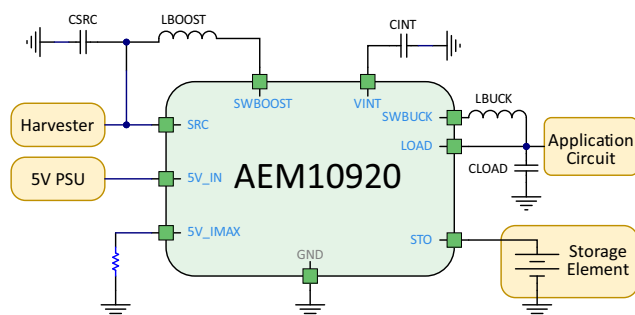
A buck regulator with selectable output voltage allows an application circuit to be supplied with high efficiency.

Device Information

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

Applications

Remote Controls Wireless Keyboards



Evaluation Board

Part number
2AAEM10920Axxxx

Table of Contents

1. Pin Configuration and Functions	5
2. Absolute Maximum Ratings	7
3. Thermal Resistance	7
4. Typical Electrical Characteristics at 25 °C	8
5. Recommended Operation Conditions	10
6. Functional Block Diagram	11
7. Theory of Operation	12
7.1. Cold-Start Circuits	12
7.2. Boost Converter	12
7.2.1. Operation Principle	12
7.2.2. Maximum Power Point Tracking	12
7.3. 5V Charger	13
7.4. Buck Converter	13
7.5. State Machine Description	14
7.5.1. Reset State	14
7.5.2. Sense STO State	14
7.5.3. Start State	15
7.5.4. Supply State	15
7.5.5. OVDIS State	15
7.5.6. Sleep State	15
8. System Configuration	16
8.1. Configuration Pins Reading	16
8.2. MPPT Configuration	16
8.3. Storage Element Thresholds	17
8.3.1. Configuration Pins	17
8.3.2. Custom mode	17
8.4. Boost Converter Timings	18
8.5. LOAD Output Voltage	18
8.6. 5 V Charger	18
9. Typical Application Circuit	19
9.1. Example Circuit 1	19
9.2. Example Circuit 2	20
10. Performances	21
10.1. Boost Converter Conversion Efficiency	21
10.2. Buck Converter Conversion Efficiency	22
11. Minimum BOM	23
12. Layout	24
12.1. Guidelines	24
12.2. Example	24
13. Package Information	25
13.1. Package Dimensions	25
14. Revision History	26

List of Figures

Figure 1: Pinout diagram	5
Figure 2: Functional block diagram	11
Figure 3: Simplified schematic view of the boost converter	12
Figure 4: Simplified schematic view of the buck converter	13
Figure 5: AEM10920 state machine	14
Figure 6: Custom configuration resistors	17
Figure 7: Typical application circuit 1	19
Figure 8: Typical application circuit 2	20
Figure 9: Boost converter efficiency	21
Figure 10: Buck (LOAD) converter efficiency	22
Figure 11: Layout example for the AEM10920 with associated passive components	24
Figure 12: QFN 24-pin 4x4mm drawing (all dimensions in mm)	25

List of Tables

Table 1: Pins description (part 1)	5
Table 2: Pins description (part 2)	6
Table 3: Absolute maximum ratings	7
Table 4: Thermal data	7
Table 5: Electrical characteristics (part 1)	8
Table 6: Electrical characteristics (part 2)	9
Table 7: Recommended external components	10
Table 8: Logic input pin connections	10
Table 9: Configuration of MPP ratio and timings	16
Table 10: Storage element configuration with STO_CFG[1:0] pins	17
Table 11: Boost converter timings configuration	18
Table 12: Configuration of LOAD voltage with LOAD_CFG[1:0] pins	18
Table 13: Typical resistor values for setting 5 V charger max. current	18
Table 14: Minimum BOM	23
Table 15: Revision History	26

1. Pin Configuration and Functions

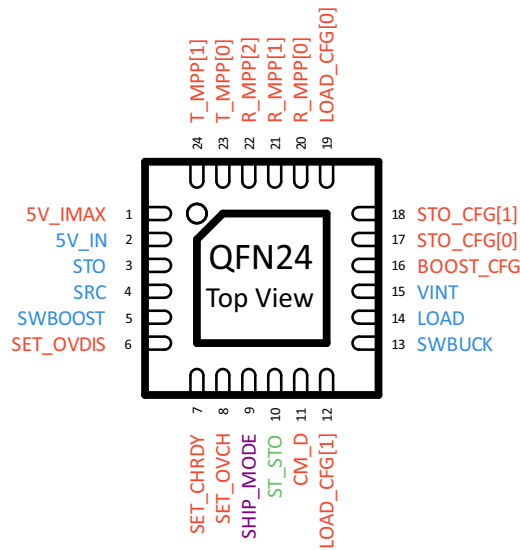


Figure 1: Pinout diagram

NAME	PIN NUMBER	FUNCTION
Power Pins		
SRC	4	Connection to the energy source harvested by the boost converter.
SWBOOST	5	Switching node of the boost converter.
STO	3	Connection to the energy storage element (rechargeable battery).
SWBUCK	13	Switching node of the buck converter.
LOAD	14	Output voltage of the buck converter to supply an application circuit.
5V_IN	2	Input of the 5 V DC power supply. (optional) Leave floating if not used.
VINT	15	Connection for C_{INT} buffering capacitor. AEM10920 internal power supply (do not connect any external circuit on VINT).

Table 1: Pins description (part 1)



NAME	PIN NUMBER	LOGIC LEVEL		FUNCTION
		LOW	HIGH	
Control Pin				
SHIP_MODE	9	GND	STO	Logic input. When HIGH: <ul style="list-style-type: none">- Minimum consumption from the storage element.- Storage element charge is disabled (boost converter is disabled).- Buck (LOAD) is disabled.- VINT is charged only if energy is available on SRC. Read as LOW if left floating.
Configuration Pins				
R_MPP[2]	22	GND	VINT	Used for the configuration of the MPP ratio. Read as HIGH when left floating.
R_MPP[1]	21	GND	VINT	
R_MPP[0]	20	GND	VINT	
T_MPP[1]	24	GND	VINT	Used for the configuration of the MPP timings. Read as HIGH when left floating.
T_MPP[0]	23	GND	VINT	
STO_CFG[1]	18	GND	VINT	Used to configure the storage element voltage thresholds. Read as HIGH if left floating.
STO_CFG[0]	17	GND	VINT	
LOAD_CFG[1]	12	GND	VINT	Used to configure the LOAD output regulation voltage. Read as HIGH if left floating.
LOAD_CFG[0]	19	GND	VINT	
BOOST_CFG	16	GND	VINT	Used to configure the boost converter timings, as described in Section 8.4.
5V_IMAX	1	Analog Pin		Connection to an external resistor to set the charging current from the 5V_IN supply to STO. Leave floating if the 5V_IN power supply is not used.
SET_OVDIS	6	Analog Pin		Used for the configuration of the threshold voltages for the energy storage element when in custom mode (optional). If the custom mode is not used: <ul style="list-style-type: none">- Connect CM_D to GND.- Connect SET_OVDIS / SET_CHRDY / SET_OVCH either to any voltage between 0 V (GND) and VSTO, or leave them floating.
SET_CHRDY	7			
SET_OVCH	8			
CM_D	11			
Status Pin				
ST_STO	10	GND	STO	Logic output. <ul style="list-style-type: none">- HIGH when in SUPPLY STATE and SLEEP STATE.- LOW otherwise.
Other pins				
GND	Thermal pad			The thermal pad must be strongly tied to the PCB ground plane, as it is the main GND connection of the AEM10920.

Table 2: Pins description (part 2)

2. Absolute Maximum Ratings

Parameter	Value
Operating junction temperature	TBD
ESD HBM voltage	TBD
ESD CDM voltage	TBD

Table 3: Absolute maximum ratings

3. Thermal Resistance

Package	θ_{JA}	θ_{JC}	Unit
TBD	TBD	TBD	°C/W

Table 4: Thermal data

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



4. Typical Electrical Characteristics at 25 °C

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
Power conversion						
$P_{SRC,CS}$	Minimum source power required for cold start.			5		μW
$V_{SRC,CS}$	Minimum source voltage required for cold start.			0.275		V
V_{MPP}	Dynamically determined target regulation voltage of the source. V_{MPP} depends on $R_{MPP}[2:0]$ configuration and on the open-circuit voltage of the source V_{OC} .		0.12		V_{STO}	V
V_{OC}	Open-circuit voltage of the source.		0.00 ¹		V_{STO}	V
V_{5V_IN}	Voltage on the $5V_IN$ pin to allow for charging the battery.		3.50		5.50	V
$P_{5V_IN,MIN}$	Minimum power on $5V_IN$ to start charging the battery.	$V_{5V_IN} = 3.50\text{ V}$		51		μW
		$V_{5V_IN} = 5.50\text{ V}$		80		
$I_{5V,CC}$	Maximum charging current of 5 V charger when in constant current (CC) mode. This is programmed by the resistor on the $5V_IMAX$ pin.		13.50		135	mA
Timing						
T_{CRIT}	In SUPPLY STATE , the AEM10920 waits for T_{CRIT} before switching to OVDIS STATE when V_{STO} drops below V_{OVDIS} .			2.50		s
$T_{GPIO,MON}$	GPIO reading rate.			1.85		s

Table 5: Electrical characteristics (part 1)

1. When the open-circuit voltage is below the source regulation voltage, the AEM10920 does not extract power from the source. Voltages down to GND voltage does not damage the AEM10920 though.



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}	Minimum voltage accepted on the storage element before stopping to supply LOAD .	Configured by STO_CFG[1:0] or by the custom mode.	2.40		3.58	V
V _{CHRDY}	Voltage required on the storage element to start supplying LOAD in START STATE .	Configured by STO_CFG[1:0] or by the custom mode.	2.46		3.64	V
V _{OVCH}	Maximum voltage accepted on the storage element before disabling its charging.	Configured by STO_CFG[1:0] or by the custom mode.	2.7		4.59	V
Internal supply & quiescent current						
V _{INT}	Internal voltage supply.		2.20	2.25	2.30	V
V _{INT,RESET}	Minimum voltage on VINT before switching to RESET STATE (from any other state).			2.0		V
V _{INT,CS}	Minimum voltage on VINT to allow the AEM10920 to switch from RESET STATE to SENSE STO STATE .			2.3		V
I _{QSUPPLY}	Quiescent current on VINT in SUPPLY STATE . ³			TBD		nA
I _{QSLEEP}	Quiescent current on VINT in SLEEP STATE . ³			TBD		nA
I _{QSHIP,SRC}	Quiescent current on STO when the shipping mode functionality is enabled (SHIP_MODE set HIGH).	Energy on SRC .		10		nA

Table 6: Electrical characteristics (part 2)

1. As set by the battery overdischarge threshold configuration.
2. As set by the battery overcharge threshold configuration.
3. When neither the boost converter nor the buck converter are running.



5. Recommended Operation Conditions

Symbol	Parameter	Min ¹	Typ	Max ¹	Unit
External components					
L _{BOOST}	Inductor of the boost converter.	4.7		33	μH
C _{SRC}	Capacitor decoupling the SRC terminal.		10		μF
L _{BUCK}	Inductor of the buck converter.	3.75	15		μH
C _{LOAD}	Capacitor of the buck converter.	TBD			μF
C _{INT}	Capacitor decoupling the VINT terminal.	5	10		μF
R _{5V_IMAX}	Resistor for configuring the 5V charger current when in constant current mode (CC). (Optional)	0.37		3.7	kΩ
R _T	Optional - Resistor for setting threshold voltage of the battery in custom mode	0.1		0.4	MΩ

Table 7: Recommended external components

1. All minimum and maximum values are real components values, taking into account tolerances, derating, temperatures, voltages and any operating conditions (special care must be taken with capacitor derating).

Symbol	Parameter		
Logic input pins			
R_MPP[2:0] T_MPP[1:0]	Boost source MPPT settings.	Logic LOW (L)	Connect to GND.
		Logic HIGH (H)	Connect to VINT.
STO_CFG[1:0]	Storage element voltage thresholds configuration.	Logic LOW (L)	Connect to GND.
		Logic HIGH (H)	Connect to VINT.
LOAD_CFG[1:0]	Configuration of the LOAD buck output voltage regulation.	Logic LOW (L)	Connect to GND.
		Logic HIGH (H)	Connect to VINT.
SHIP_MODE	Shipping mode enable.	Logic LOW (L)	Connect to GND.
		Logic HIGH (H)	Connect to STO.

Table 8: Logic input pin connections



6. Functional Block Diagram

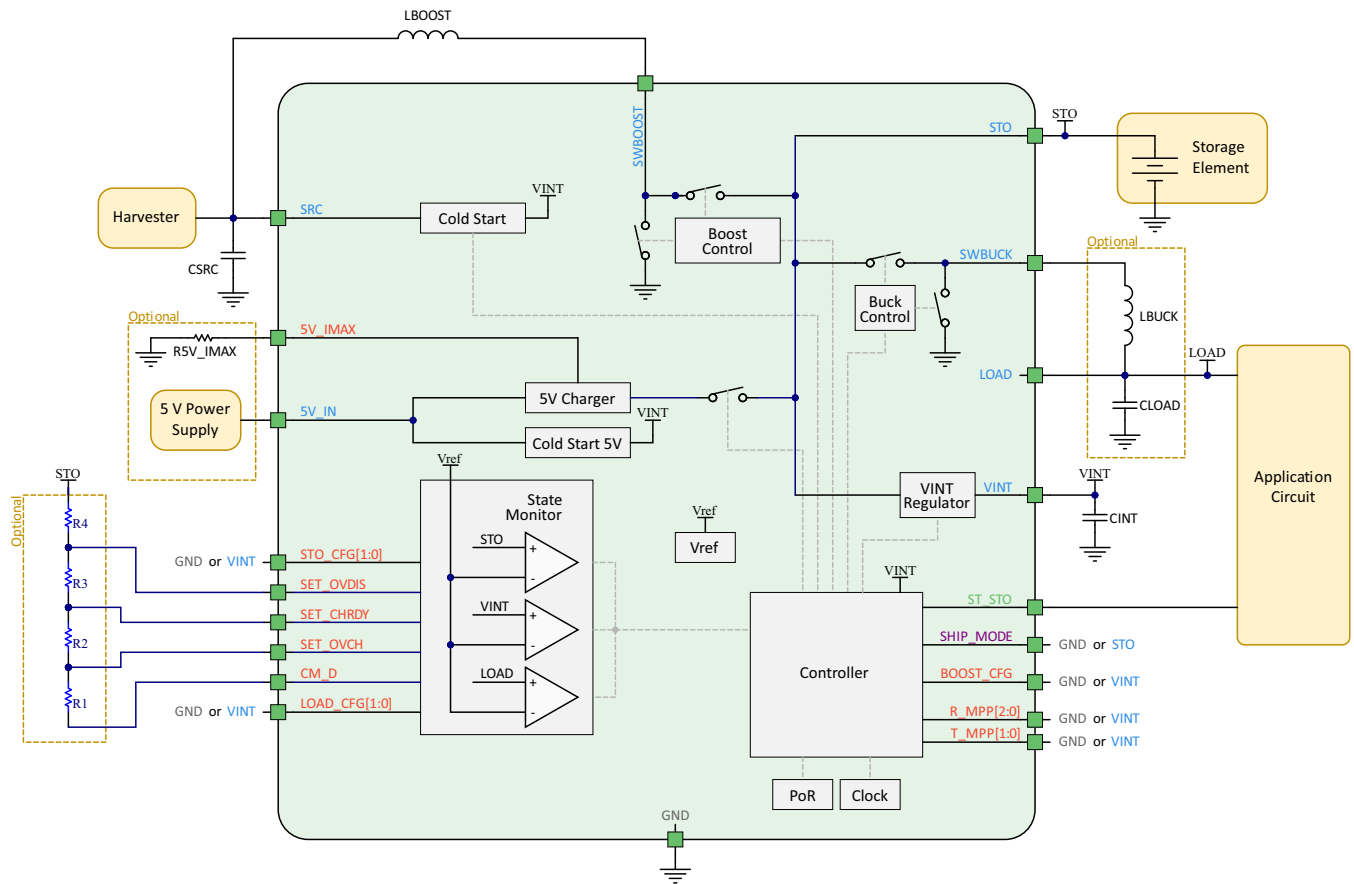


Figure 2: Functional block diagram

7. Theory of Operation

7.1. Cold-Start Circuits

The AEM10920 is able to coldstart from **SRC** or from **5V_IN**. The cold-start circuits supply the AEM10920 internal circuit (connected to **VINT**) when the device is in **RESET STATE**, **SENSE STO STATE** or **OVDIS STATE**.

7.2. Boost Converter

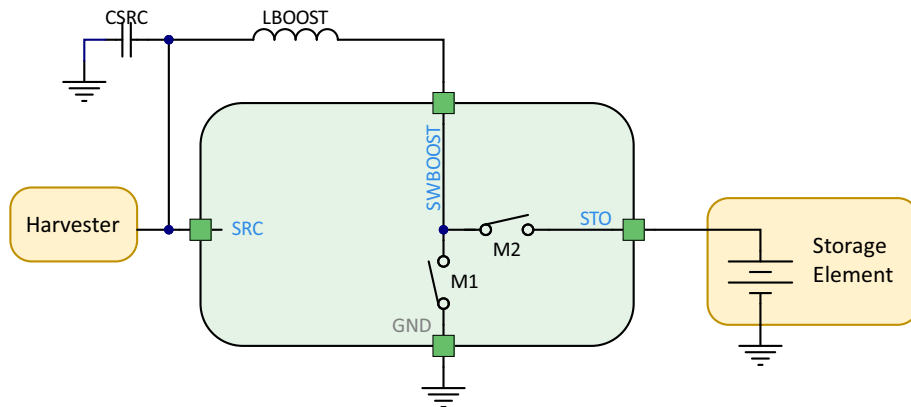


Figure 3: Simplified schematic view of the boost converter

7.2.1. 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 is determined by the source voltage regulation (dynamically determined by the MPPT module).

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, which voltage is V_{STO} . This node is linked to the output of the boost converter through transistor M2. When energy harvesting is occurring, the converter charges the battery.

The maximum current supplied to the **STO** pin depends on the value of L_{BOOST} and on the **BOOST_CFG** settings (see Section 8.4).

7.2.2. Maximum Power Point Tracking

The AEM10920 has a Maximum Power Point Tracking (MPPT) module, that 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, that means that V_{MPP} / V_{OC} is constant for any lighting conditions, even though both voltages increase when luminosity increase.

The MPP ratio (V_{MPP} / V_{OC}) differs from one harvester model to the other. User must set the MPP ratio to match the specifications of the harvester model used and thus maximize power extraction. This ratio is set with the configuration pins **R_MPP[2:0]** according to Table 9.

The MPPT module evaluates the open circuit voltage V_{OC} periodically to ensure optimal power extraction at any time. The sampling period $T_{MPPT,PERIOD}$ and sampling duration $T_{MPPT,SAMPLING}$ of the evaluation of V_{OC} are set according to Table 9 with the configuration pins **T_MPP[1:0]**. Every $T_{MPPT,PERIOD}$, the AEM10920 stops extracting power from the source, waits during $T_{MPPT,SAMPLING}$ for the source to rise to its open circuit voltage V_{OC} , and measures V_{OC} .

The AEM10920 supports multiple V_{MPP} levels in the range from 0.11 V to V_{STO} . It offers a choice of eight values for the V_{MPP} / V_{OC} fraction.

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

7.3. 5V Charger

The AEM10920 is equipped with a 5 V charger for fast charging of the battery connected on the **STO** pin. When a voltage higher than 3.5 V and V_{STO} is detected on the **5V_IN** pin, the charger starts charging the battery, implementing a constant current / constant voltage operation (CC/CV):

- Constant current (CC) operation:
 - When V_{STO} is not close to V_{OVCH} .
 - Battery charging current $I_{5V,CC}$ is configured by the value of the R_{5V_IMAX} resistor connected to the **5V_IMAX** pin (see Section 8.6 for further details about R_{5V_IMAX} configuration). $I_{5V,CC}$ range is from 13.5 mA to 135 mA.
- Constant voltage (CV) operation:
 - When V_{OVCH} is close to V_{OVCH} .
 - The charging current $I_{5V,CV}$ gradually decreases to zero as the V_{STO} reaches V_{OVCH} .

Using the 5 V charger is not mandatory. When not used, leave both **5V_IN** and **5V_IMAX** pins floating.

7.4. Buck Converter

The buck (step-down) converter transfers energy from the battery connected on **STO** to the regulated **LOAD** output. The switching transistors of the buck converter are M3 and M4. The reactive power component of this converter is the external inductor L_{BUCK} . **LOAD** is decoupled by the capacitor C_{LOAD} , which smooths the voltage against the current pulses induced by the consumption of the external circuit connected to **LOAD**.

Setting the **LOAD** regulation voltage V_{LOAD} is done through **LOAD_CFG[1:0]** pins.

After cold start, the buck converter starts once V_{STO} is higher than V_{CHRDY} . It stays enabled, and thus regulates V_{LOAD} , until V_{STO} drops below V_{OVDIS} longer than T_{CRIT} .

When the difference between V_{STO} and V_{LOAD} is smaller than 0.25V, it switches to “bang-bang” controlled converter mode:

- When V_{LOAD} is too low, a switch connects **STO** directly to **LOAD**, making V_{LOAD} rise.
- When V_{LOAD} is too high, the controller disconnects **STO** and **LOAD** so that V_{LOAD} decreases.

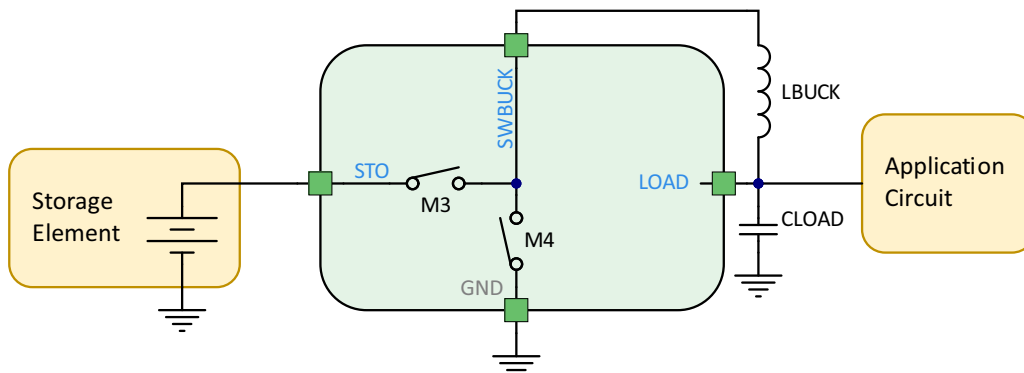


Figure 4: Simplified schematic view of the buck converter

7.5. State Machine Description

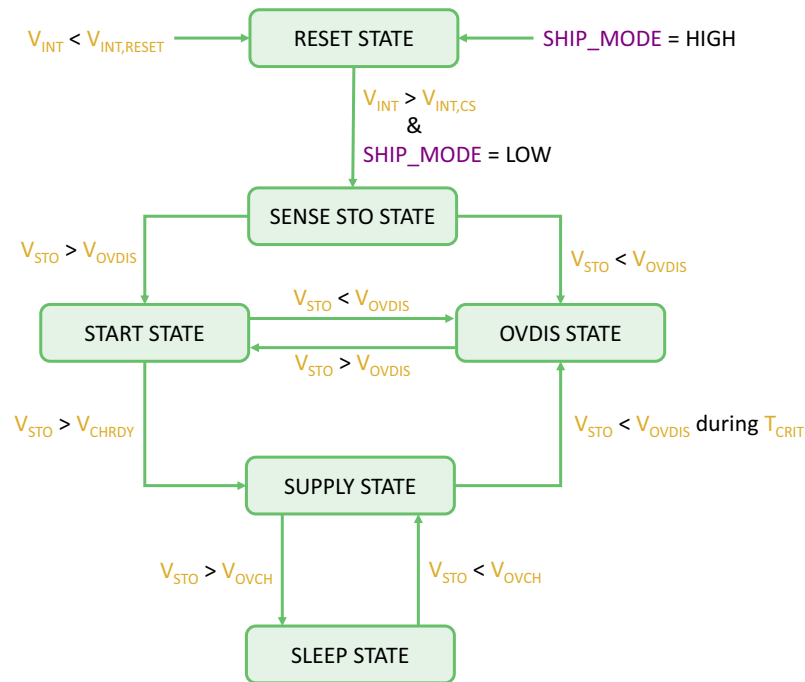


Figure 5: AEM10920 state machine

7.5.1. Reset State

The AEM10920 enters **RESET STATE** if one of the following is true:

- V_{INT} is below 2 V.
- shipping mode is enabled (**SHIP_MODE** is HIGH).

In **RESET STATE**, the AEM10920 behaves as follows:

- The AEM10920 is performing a cold start to make V_{INT} rise to 2.3 V. Cold start can be done from any of the following energy sources:
 - **SRC** ($V_{SRC} > 0.275$ V and $P_{SRC,CS} > 5$ μ W).
 - **5V_IN** ($V_{5V_IN} > 3.5$ V).
- The AEM10920 internal circuit, connected on **VINT**, is supplied by **SRC** or **5V_IN**. No current is drawn from the battery.
- **ST_STO** is LOW.

The AEM10920 stays in **RESET STATE** until the power available on either **SRC** meets the cold-start requirements long enough to make V_{INT} reach 2.3 V (see Table 5). Then:

- If shipping mode is disabled (**SHIP_MODE** is LOW), the AEM10920 reads the value on all configuration pins and switches to **SENSE STO STATE**.
- If shipping mode is enabled (**SHIP_MODE** is HIGH), the AEM10920 stays in **RESET STATE** until shipping mode is disabled by setting **SHIP_MODE** LOW. **SHIP_MODE** is read every $T_{GPIO,MON}$.

Please note that, from any state, the AEM10920 will switch to **RESET STATE** if V_{INT} drops below 2 V.

7.5.2. Sense STO State

In **SENSE STO STATE**, a first measure of V_{STO} is performed by the AEM10920.

- If $V_{STO} > V_{OVDIS}$, the AEM10920 switches to **START STATE**.
- If $V_{STO} < V_{OVDIS}$, the AEM10920 switches to **OVDIS STATE**.
- **ST_STO** is LOW.

In **SENSE STO STATE**, none of the DCDC converters are running.

7.5.3. Start State

When in **SENSE STO STATE**, the AEM10920 switches to **START STATE** if V_{STO} is above V_{OVDIS} .

In **START STATE**, the AEM10920 behaves as follows:

- The battery connected on **STO** is charged by the boost converter or by the 5 V charger, until V_{STO} reaches V_{CHRDY} .
- The AEM10920 internal circuit connected on **VINT** is supplied by the battery regardless of the power available on **SRC** or **5V_IN**.
- The buck converter (**LOAD**) is disabled.
- **ST_STO** is LOW.

7.5.4. Supply State

When in **START STATE**, the AEM10920 switches to **SUPPLY STATE** if V_{STO} is above V_{CHRDY} .

In **SUPPLY STATE**, the AEM10920 behaves the same as when in **START STATE**, but with the following differences:

- The buck converter driving **LOAD** is enabled (if enabled by the user).
- **ST_STO** is HIGH.

When in **SUPPLY STATE**, the AEM10920 switches to **SLEEP STATE** if the following condition is met:

- $V_{STO} > V_{OVCH}$.

In **SUPPLY STATE**, the AEM10920 switches to **OVDIS STATE** if the following condition is met:

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

7.5.5. OVDIS State

The AEM10920 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 AEM10920 behaves as follows:

- The battery connected on **STO** is charged by the boost converter or by the 5 V charger, until V_{STO} exceeds V_{OVDIS} .
- The AEM10920 internal circuit, connected on **VINT**, is supplied by **SRC** or **5V_IN**. If not enough power is available on either of those pins, the AEM10920 switches to **RESET STATE**. No current is drawn from the battery.
- The buck converter (**LOAD**) is disabled.
- **ST_STO** is LOW.

7.5.6. Sleep State

SLEEP STATE allows for reducing the AEM10920 internal circuit consumption when the battery is fully charged. Thus, battery discharging is kept minimal.

In **SLEEP STATE**, the AEM10920 behaves as follows:

- The battery connected on **STO** is not charged by **SRC**, allowing for reducing the quiescent current on **VINT** and thus on **STO**.
- The AEM10920 internal circuit connected on **VINT** is supplied by the battery regardless of the power available on **SRC** or **5V_IN**.
- The buck converter (**LOAD**) is enabled.
- **ST_STO** is HIGH.

When in **SLEEP STATE**, the AEM10920 switches back to **SUPPLY STATE** if $V_{STO} < V_{OVCH}$.

8. System Configuration

8.1. Configuration Pins Reading

After a cold start, the AEM10920 reads the configuration pins. Those are then read periodically every $T_{GPIO,MON}$. The configuration pins can be changed on-the-fly. The floating configuration pins are read as HIGH, except **SHIP_MODE** which is read as LOW.

8.2. MPPT Configuration

Two parameters are necessary to configure the Maximum Power Point Tracking (MPPT). The first parameter is the MPP tracking ratio, which is selected according to the characteristics of the input power source. This parameter is set by the configuration pins **R_MPP[2:0]**.

The second parameter allows configuring the duration of the evaluation of V_{OC} and the time between two MPP evaluations. This configuration is set by the configuration pins **T_MPP[1:0]**.

Configuration			Function
R_MPP[2:0]			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	
T_MPP[1:0]		$T_{MPPT,PERIOD}$ [s]	$T_{MPPT,SAMPLING}$ [s]
L	L	15	0.25
L	H	15	0.50
H	L	25	0.25
H	H	25	0.50

Table 9: Configuration of MPP ratio and timings

8.3. Storage Element Thresholds

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

- Configuration through the $STO_CFG[2:0]$ pins as described in Section 8.3.1.
- Configuration using the custom mode as described in Section 8.3.2.

8.3.1. Configuration Pins

The storage element protection thresholds V_{OVCH} , V_{CHRDY} and V_{OVDIS} , can be configured through the $STO_CFG[1:0]$ pins as shown in Table 10.

Configuration pins		Overdischarge voltage [V]	Charge ready voltage [V]	Overcharge voltage [V]	Battery 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 battery
H	L	3.00	3.20	4.35	LiPo battery
H	H	3.50	3.55	3.90	Li-ion battery (ultra long life)

Table 10: Storage element configuration with $STO_CFG[1:0]$ pins

8.3.2. Custom mode

When CM_D is not connected to GND, the custom mode is selected regardless of $STO_CFG[1:0]$ pins and all four configuration resistors shown in Figure 6, must be wired as follows:

V_{OVCH} , V_{CHRDY} and V_{OVDIS} are defined thanks to R_1 , R_2 , R_3 and R_4 . Defining R_T as follows, R_1 , R_2 , R_3 and R_4 are calculated as:

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

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

- $2.40V < V_{OVDIS} < 3.58V$
- $2.46V < V_{CHRDY} < 3.64V$
- $2.70V < V_{OVCH} < 4.59V$
- $V_{CHRDY} + 0.05V < V_{OVCH} < 4.59V$
- $V_{OVDIS} + 0.05V < V_{CHRDY} < V_{OVCH} - 0.05V$
- $V_{OVDIS} > V_{LOAD}$

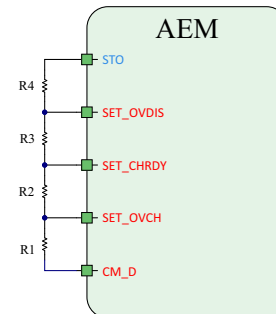


Figure 6: Custom configuration resistors



8.4. 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 11. The higher the timing multiplier, the higher the boost inductor peak current, and thus the higher the average source current pulled from **SRC** to **STO**.

The peak current in the inductor also depends on the value of the inductor. Table 11 shows the minimum inductor value to be implemented for each timing value. Lower value may lead to damaging the AEM10920.

Configuration pin	Function	
BOOST_CFG	Timing multiplication factor	Minimum L_{BOOST} inductance [μH]
L	x1	4
H	x3	12

Table 11: Boost converter timings configuration

8.5. LOAD Output Voltage

Table 12 shows how to configure the regulated voltage on **LOAD** output with the **LOAD_CFG[1:0]** pins.

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

Table 12: Configuration of **LOAD** voltage with **LOAD_CFG[1:0]** pins

The buck voltage cannot be selected smaller than V_{OVDIS} . In such situation, the AEM10920 will not start the buck converter.

8.6. 5 V Charger

The 5 V charger implements CC/CV operation. When in CC, the maximum charging current $I_{5V,CC}$ can be set by connecting a resistor R_{5V_IMAX} between **5V_IMAX** and **GND**:

$$I_{5V,CC} = \frac{50}{R_{5V_MAX}}$$

Please note that R_{5V_IMAX} must be chosen so that $I_{5V,CC}$ complies to the range defined in Table 5. Example values can be found in Table 13:

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

Table 13: Typical resistor values for setting 5 V charger max. current

9. Typical Application Circuit

9.1. Example Circuit 1

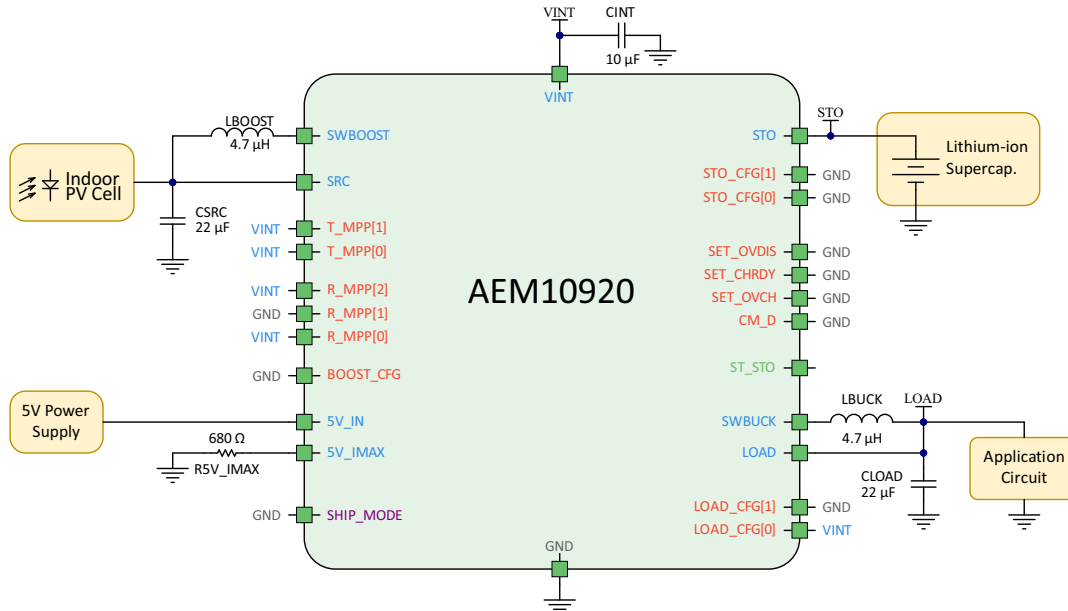


Figure 7: Typical application circuit 1

Figure 7 shows a typical application circuit of the AEM10920.

Configuration of SRC

The second energy source is an indoor PV cell which has an 80% MPP ratio. SRC is thus configured as follows:

- $R_MPP[2:0] = HLH$: 80% ratio.
- $T_MPP[1:0] = HH$:
 - $T_{MPPT,PERIOD} = 25s$.
 - $T_{MPPT,SAMPLING} = 0.5s$.
- $BOOST_CFG = L$: x1 boost timing.
- $L_{BOOST} = 4.7 \mu H$ for best efficiency with x1 boost timing (see Section 8.4) and low-cost inductor.

Configuration of STO

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

- $STO_CFG[1:0] = LL$.
 - $V_{OVDIS} = 2.5 V$.
 - $V_{CHRDY} = 2.55 V$.
 - $V_{OVCH} = 3.8 V$.
- Custom mode is not used so CM_D , SET_OVDIS , SET_CHRDY and SET_OVCH are connected to GND.

Configuration of LOAD

The application circuit is supplied with 2.2 V with current peaks up to 40 mA. The buck converter is configured as follows:

- $LOAD_CFG[1:0] = LH$ (2.2 V)
- $L_{BUCK} = 4.7 \mu H$ for high current capability and low cost inductor.

Configuration of 5V_IN

The maximum allowed current to charge the storage element is 75 mA. Closest standard series resistor is 680 Ω, which leads to a 73.5 mA maximum current.

- $R_{5V_IMAX} = 680 \Omega$.
- $I_{5V,CC} = 73.5 mA$.

Shipping mode

Shipping mode is not used.

- $SHIP_MODE$ is connected to GND.

9.2. Example Circuit 2

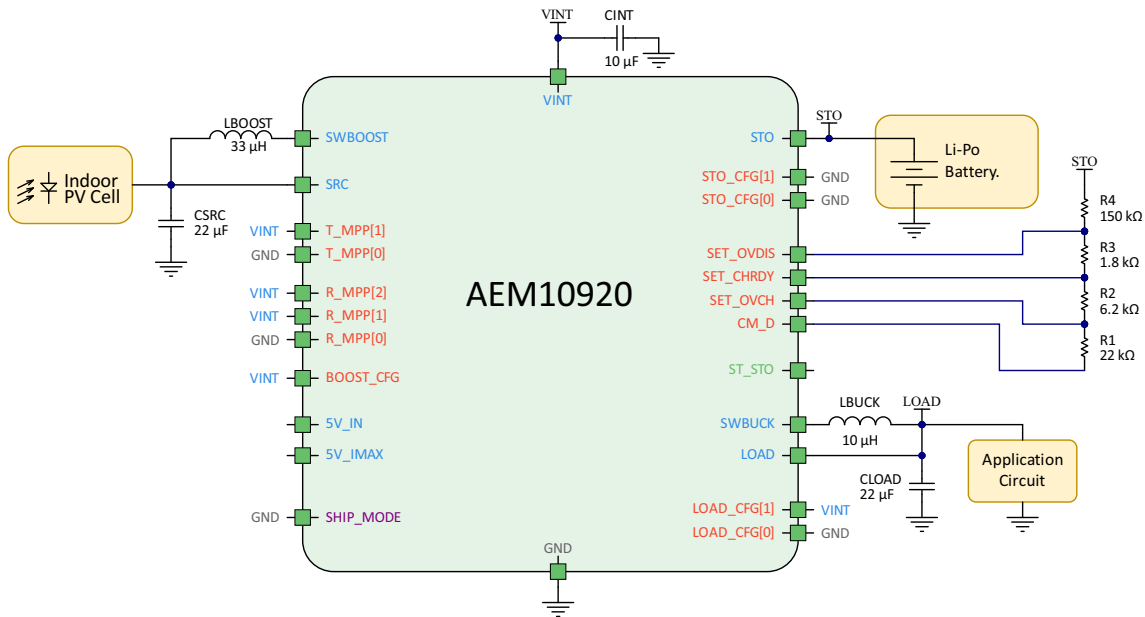


Figure 8: Typical application circuit 2

Figure 8 shows a typical application circuit of the AEM10920.

Configuration of SRC

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

- $R_MPP[2:0]$ = HHL: 85% ratio.
- $T_MPP[1:0]$ = HL:
 - $T_{MPPT,PERIOD} = 25s$.
 - $T_{MPPT,SAMPLING} = 0.25s$.
- $BOOST_CFG$ = H: x3 boost timing.
- $L_{BOOST} = 33 \mu H$ for best efficiency with x3 boost timing (see Section 8.4).

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: AEM10920 ignores $STO_CFG[1:0]$ settings as CM_D is not set to GND (custom mode is used).
- Desired storage element voltage thresholds are the following:
 - $V_{OVDIS} = 3.0 V$.
 - $V_{CHRDY} = 3.2 V$.
 - $V_{OVCH} = 4.1 V$.

- Custom mode resistors are configured as follows:

$$\begin{aligned}
 - R_T &= R_1 + R_2 + R_3 + R_4 = 180k\Omega \\
 - R_1 &= R_T \cdot \frac{0.5V}{V_{OVCH}} = 22k\Omega \\
 - R_2 &= R_T \cdot \left(\frac{0.5V}{V_{CHRDY}} - \frac{0.5V}{V_{OVCH}} \right) = 6.2k\Omega \\
 - R_3 &= R_T \cdot \left(\frac{0.5V}{V_{OVDIS}} - \frac{0.5V}{V_{CHRDY}} \right) = 1.8k\Omega \\
 - R_4 &= R_T - (R_1 + R_2 + R_3) = 150k\Omega
 \end{aligned}$$

Configuration of LOAD

The application circuit is supplied with 2.5 V with current peaks up to 10 mA. The buck converter is configured as follows:

- $LOAD_CFG[1:0]$ = HL (2.5 V)
- $L_{BUCK} = 10 \mu H$ for best efficiency.

Configuration of 5V_IN

5 V charger is not used so both $5V_IN$ and $5V_IMAX$ are left floating.

Shipping mode

Shipping mode is not used.

- $SHIP_MODE$ is connected to GND.

10. Performances

10.1. Boost Converter Conversion Efficiency

Figure 9 shows the AEM10920 boost efficiency with:

- $L_{\text{BOOST}} = 33 \mu\text{H}$ (Coilcraft LPS4018-333MRB).
- BOOST_CFG = H (x3).

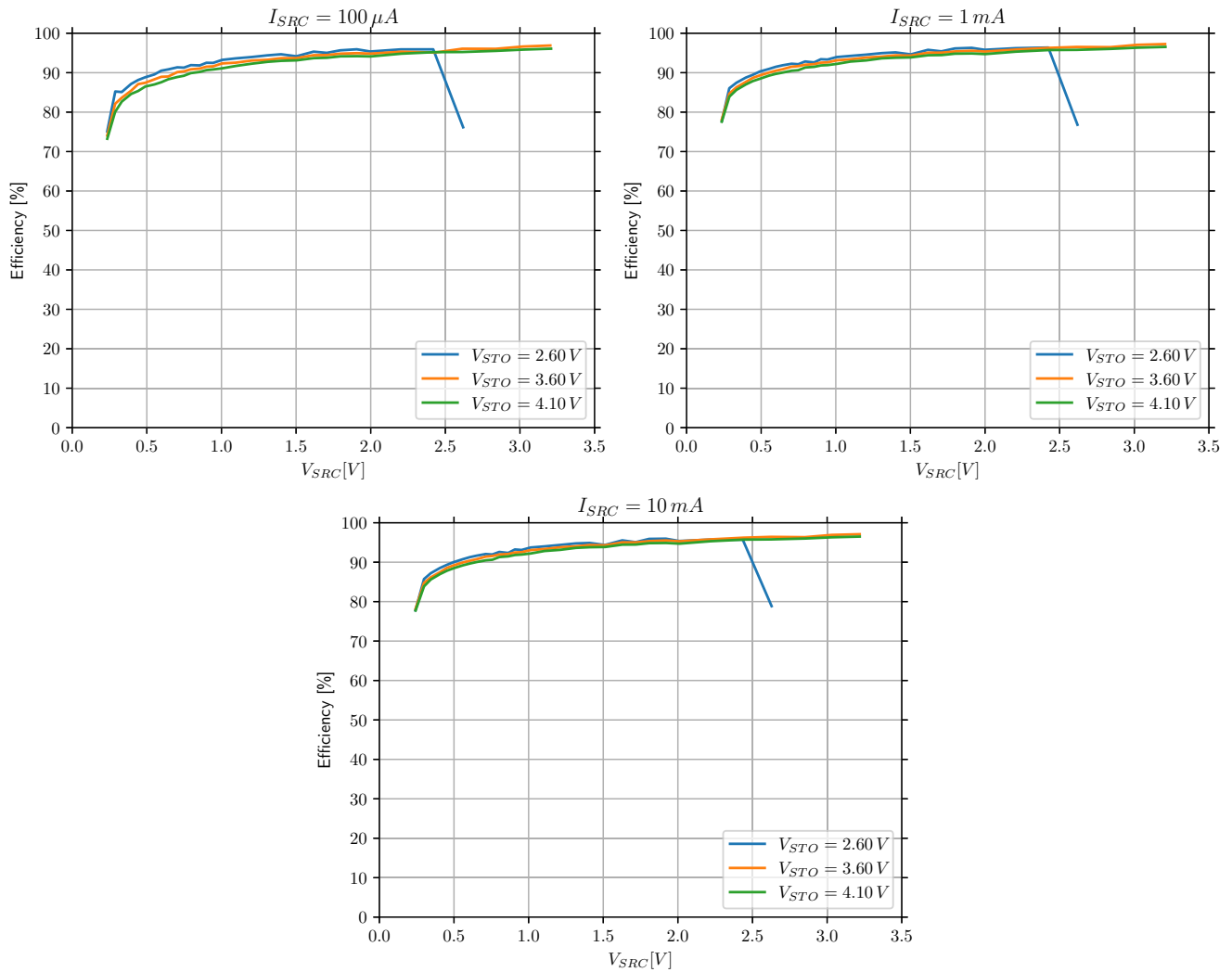


Figure 9: Boost converter efficiency

10.2. Buck Converter Conversion Efficiency

Figure 10 shows the AEM10920 buck efficiency with $L_{BUCK} = 10 \mu\text{H}$ (TDK VLS252012CX-100M-1).

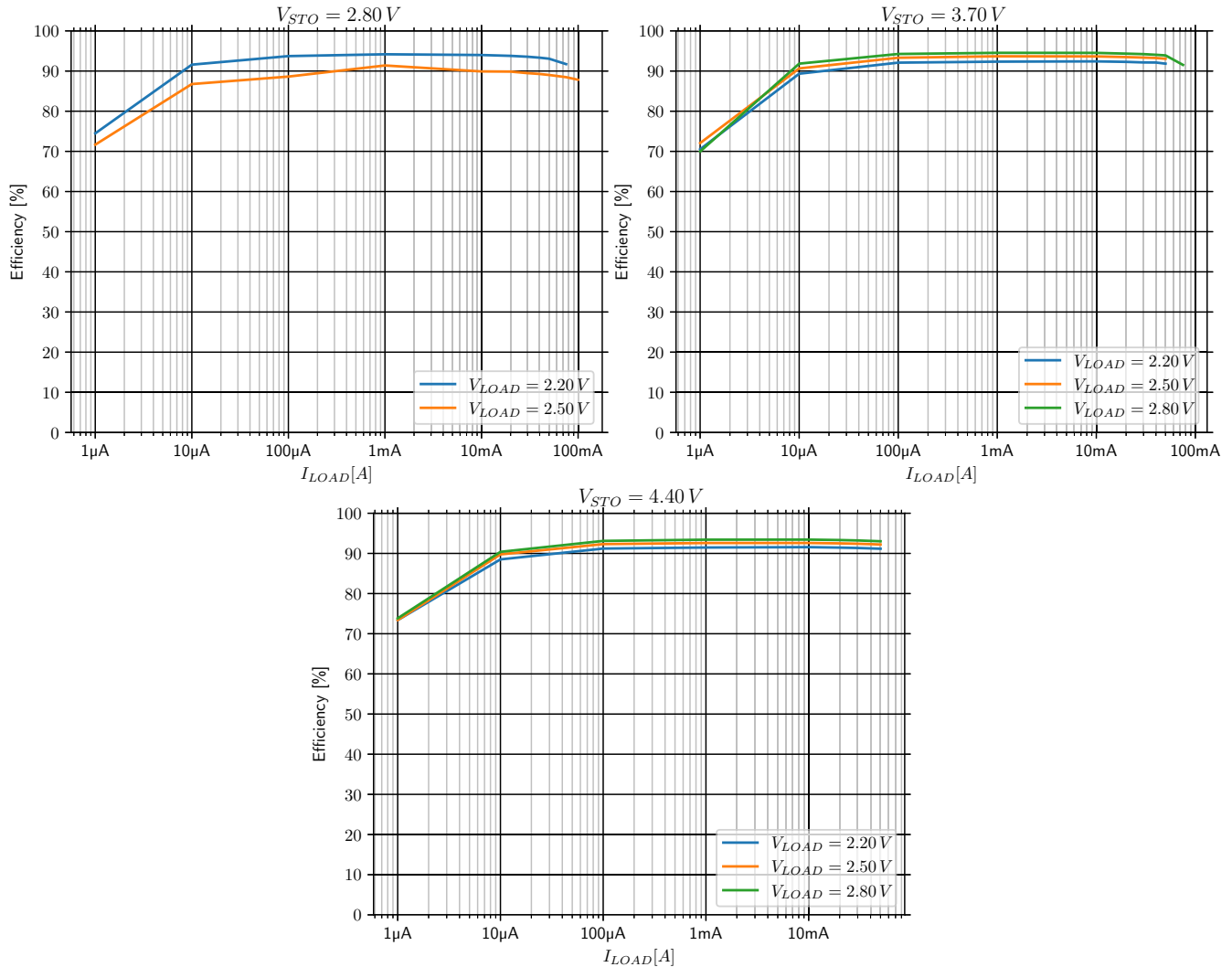


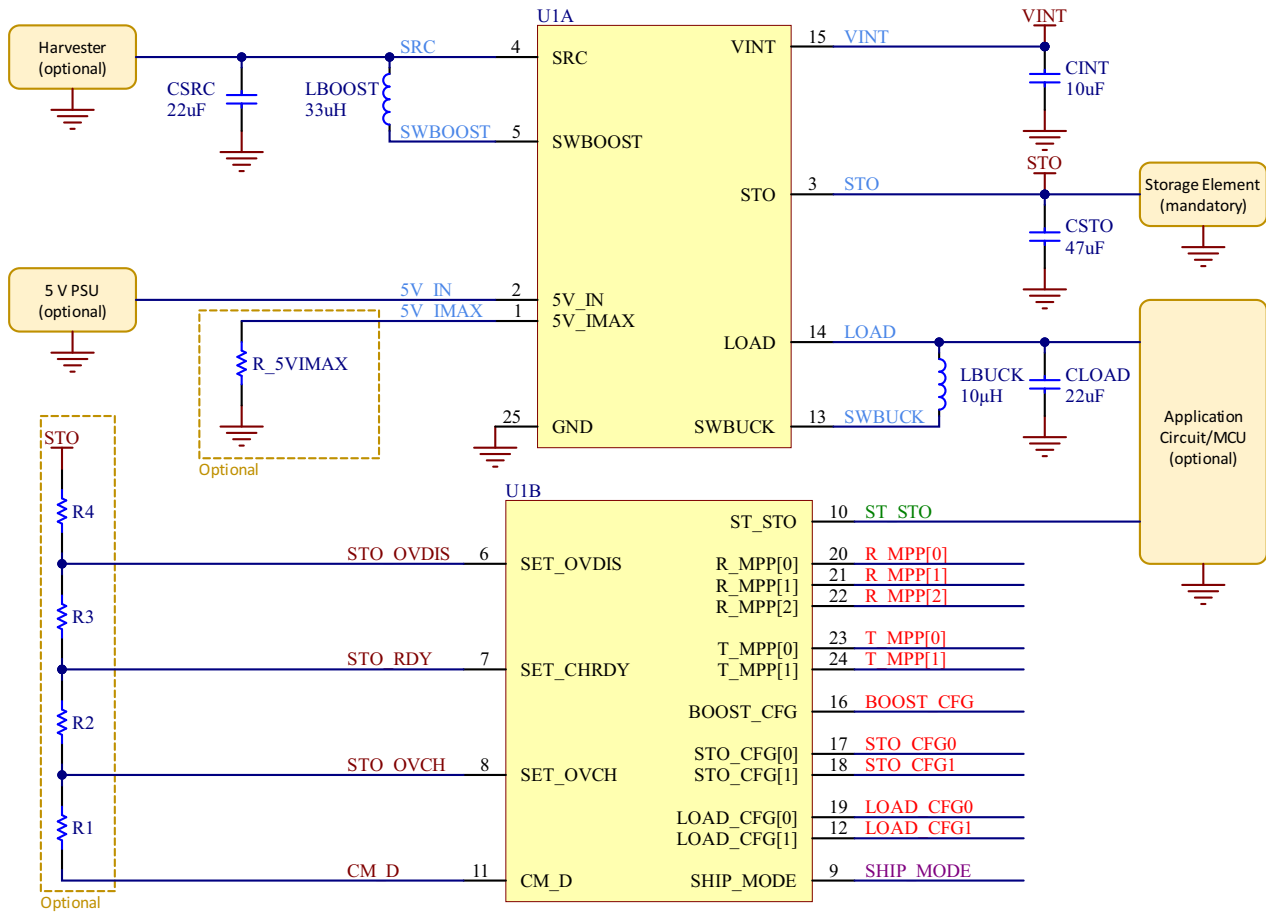
Figure 10: Buck (LOAD) converter efficiency

Figure 10 efficiency is shown with the AEM10920 boost-related quiescent current subtracted from the current provided on STO :

- This quiescent current is measured with the boost converter in **SLEEP STATE** and with the buck converter switched off, so that the current that is necessary to run the buck converter is considered in Figure 10 data.
- It is considered in the boost efficiency data shown in Section 10.1.



11. Minimum BOM



Designator	Description	Quantity	Manufacturer	Part Number
Mandatory	U1	1	e-peas	order at sales@e-peas.com
	CSRC	1	Murata	GRM188R61A226ME15D
	LBOOST	1	Coilcraft	LPS4018-333MRB
	CINT	1	Murata	GRM155R60J106ME44D
Optional	CSTO ¹	1	Murata	GRM188R60J476ME15D
	R_5VIMAX ²	1	To be defined	
	LBUCK	1	TDK	VLS252012CX-100M-1
	CLOAD	1	Murata	GRM188R61A226ME15D
	R1	1	To be defined	
	R2	1		
	R3	1		
	R4	1		

Table 14: Minimum BOM

- CSTO is not mandatory but ensures high boost converter efficiency with high ESR storage elements.
- The AEM10920 must have at least one energy source to work: boost (SRC), 5 V input (5V_IN) or both.

12. Layout

12.1. Guidelines

Figure 11 shows an example of PCB layout with AEM10920.

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/buck converter must be placed as close as possible to the corresponding pins (**SWBOOST**, **SRC**, **STO**, **SWBUCK** and **LOAD**), and be routed with large tracks/polygons.

- PCB track capacitance must be reduced as much as possible on the boost converter switching node **SWBOOST**, as well as on the buck converter switching node **SWBUCK**. This is done as follows:
 - Keep the connection between the **SWBOOST/SWBUCK** pins and the corresponding inductor short.
 - Remove the ground and power planes under the **SWBOOST/SWBUCK** nodes. The polygon on the opposite external layer may also be removed.
 - Increase the distance between **SWBOOST/SWBUCK** and the ground polygon on the external PCB layer where the AEM10920 is mounted.

12.2. Example

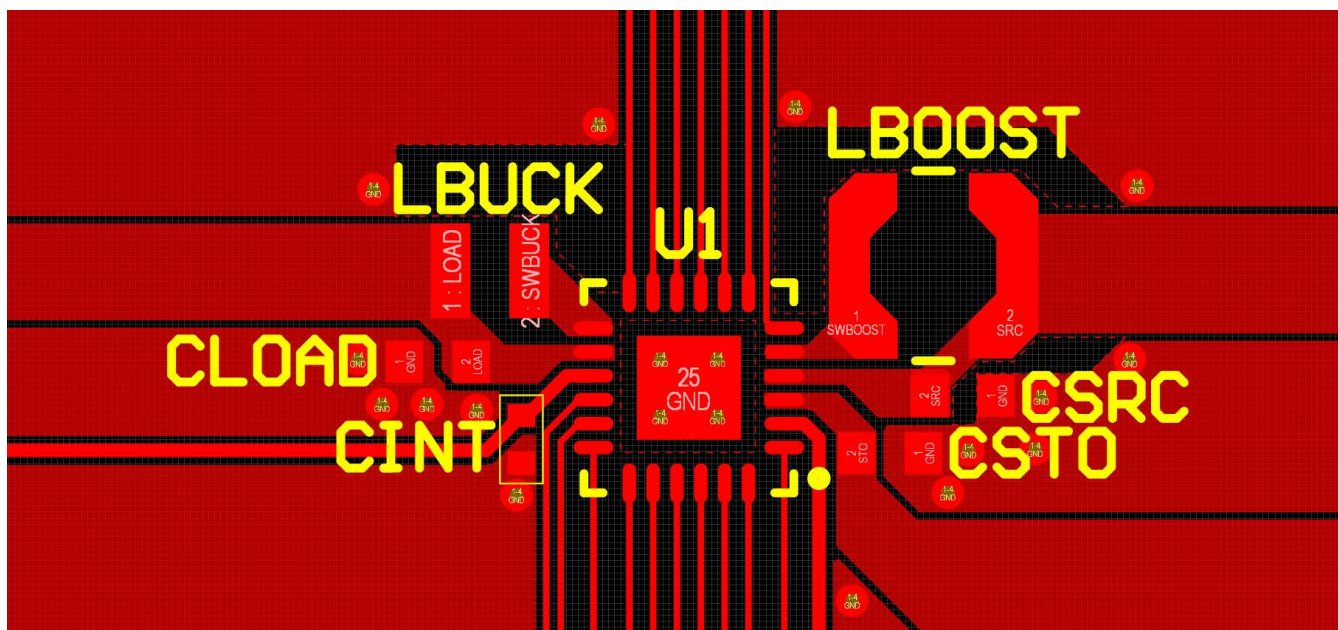


Figure 11: Layout example for the AEM10920 with associated passive components

13. Package Information

13.1. Package Dimensions

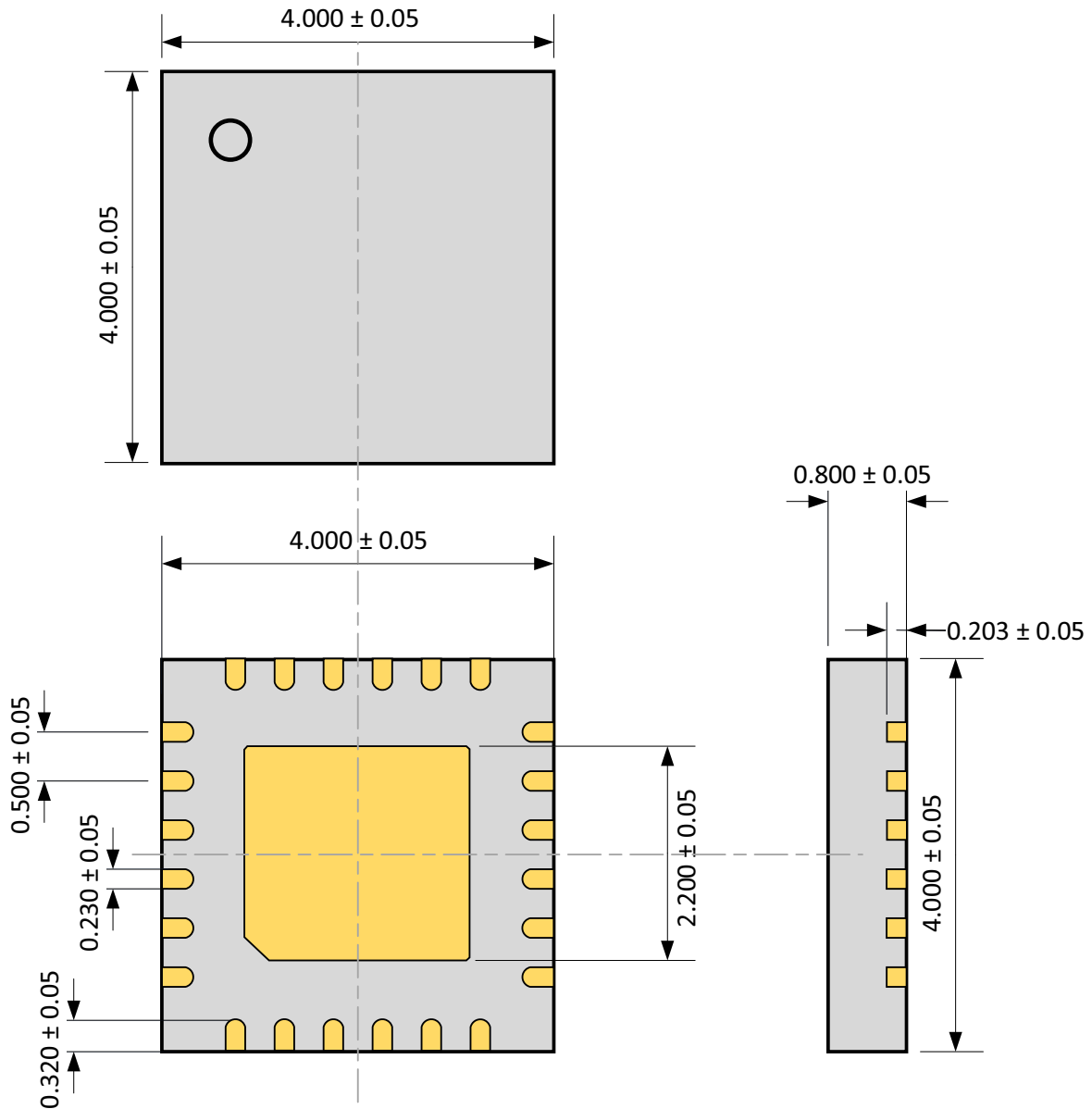


Figure 12: QFN 24-pin 4x4mm drawing (all dimensions in mm)

14. Revision History

Revision	Date	Description
1.0	December, 2023	Creation of the document.
1.1	January, 2024	<ul style="list-style-type: none">- “Configuration of MPP ratio and timings” table: fixed wrong column title.- Added typical application circuit.

Table 15: Revision History