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 µW input

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

Constant input voltage mode

- Optimized for constant voltage PV cells.
- Selectable input regulation voltage.
- Up to 110 mA current extracted from the harvester.

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

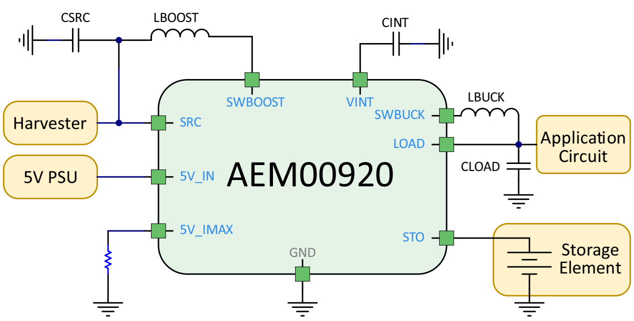
- Disables charging and discharging of the battery during shipment.

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.

Applications

Remote Controls	Wireless Keyboards



Description

The AEM00920 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.

The AEM00920 implements constant voltage regulation of the source, allowing for harvesting the maximum power available from the source to charge the storage element.

With its unique cold-start circuit, it can start operating with an input voltage as low as 275 mV (min. 5 µW 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
10AEM00920A0000	QFN 24-pin	4x4mm

Evaluation Board

Part number
2AAEM00920Axxxx

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1. Pin Configuration and Functions

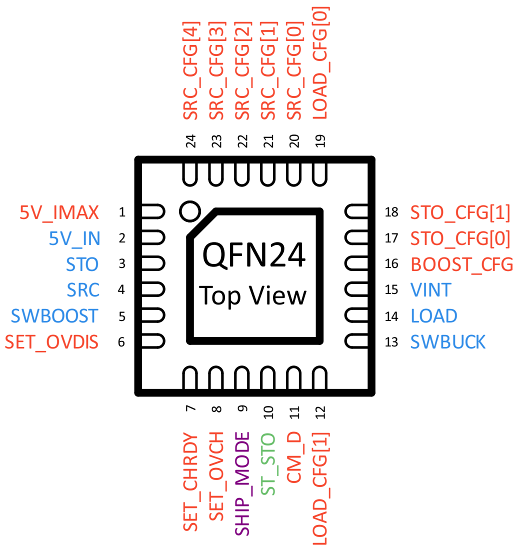


Figure 1: Pinout diagram

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. AEM00920 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: - 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				
SRC_CFG[4]	24	GND	VINT	Used for the configuration of SRC regulation voltage. SRC_CFG[4:0] are all read as HIGH when left floating.
SRC_CFG[3]	23	GND	VINT	
SRC_CFG[2]	22	GND	VINT	
SRC_CFG[1]	21	GND	VINT	
SRC_CFG[0]	20	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: - Connect CM_D to GND. - Connect SET_OVDIS / SET_CHRDY / SET_OVCH either to any voltage between 0 V (GND) and V_{STO}, or leave them floating.
SET_CHRDY	7			
SET_OVCH	8			
CM_D	11			
Status Pin				
ST_STO	10	GND	STO	Logic output. - 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 AEM00920.

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	θJA	θJC	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
$V_{SRC,REG}$	Target regulation voltage of the source, depending on SRC_CFG[4:0] configuration.		0.25		3.20	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 V		51		µW
		V_{5V_IN} = 5.50 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 AEM00920 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 AEM00920 does not extract power from the source. Voltages down to GND voltage does not damage the AEM00920 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 AEM00920 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			
SRC_CFG[4:0]	Boost source voltage regulation 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

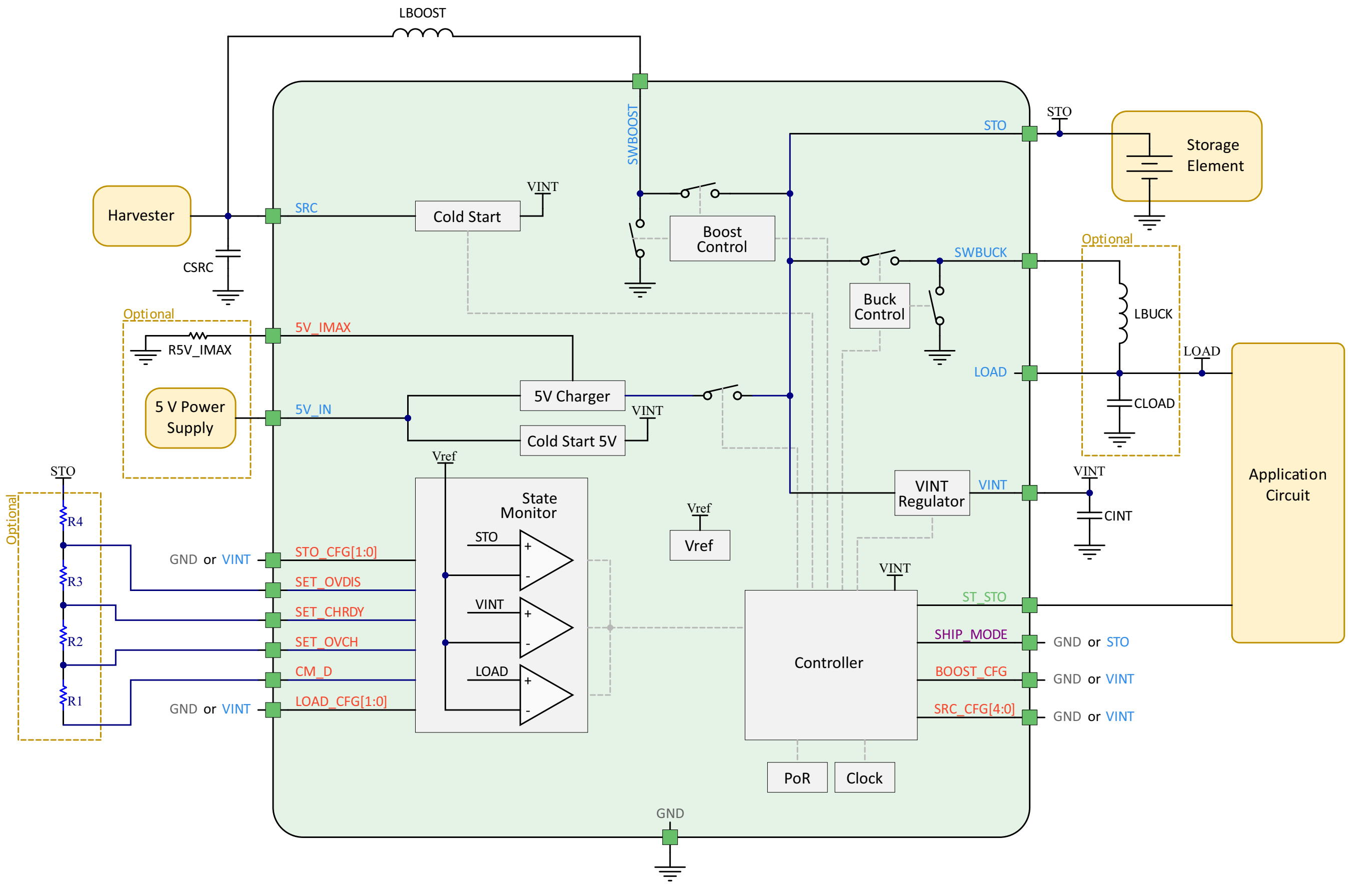


Figure 2: Functional block diagram

7. Theory of Operation

7.1. Cold-Start Circuits

The AEM00920 is able to coldstart from SRC or from 5V_IN. The cold-start circuits supply the AEM00920 internal circuit (connected to VINT) when the device is in RESET STATE, SENSE STO STATE or OVDIS STATE.

7.2. Boost Converter

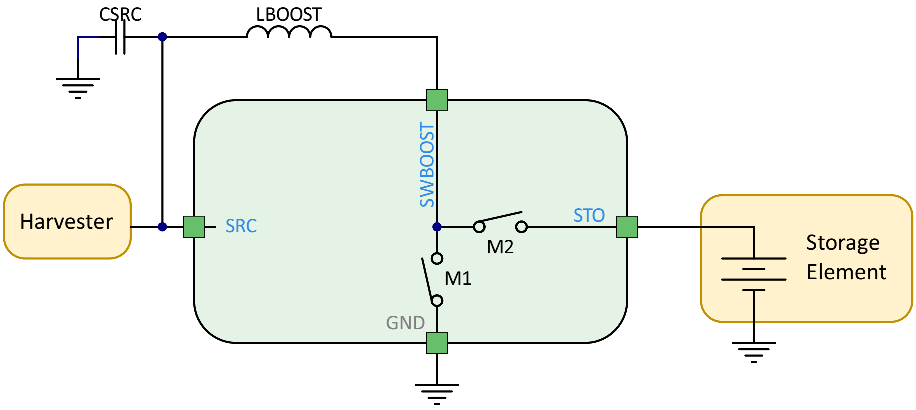


Figure 3: Simplified schematic view of the boost converter

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 constant voltage regulation setting (SRC_CFG[4:0]).

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. Source Voltage Regulation

During START STATE, OVDIS STATE and SUPPLY STATE, the voltage on SRC is regulated to a voltage configured by the user. The AEM00920 offers a wide choice of values for the source regulation voltage $V_{SRC,REG}$.

The AEM00920 behaves as follows:

- If the open-circuit voltage V_{OC} of the harvester is lower than $V_{SRC,REG}$, the AEM00920 does not extract power from the source.
- If SRC voltage is higher than $V_{SRC,REG}$, the AEM00920 regulates V_{SRC} to $V_{SRC,REG}$ and thus extracts power from the source.

7.3. 5V Charger

The AEM00920 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.

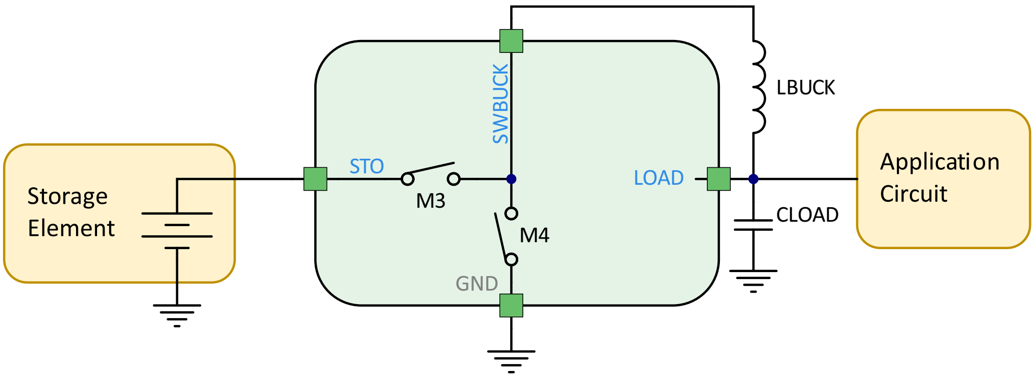


Figure 4: Simplified schematic view of the buck converter

7.5. State Machine Description

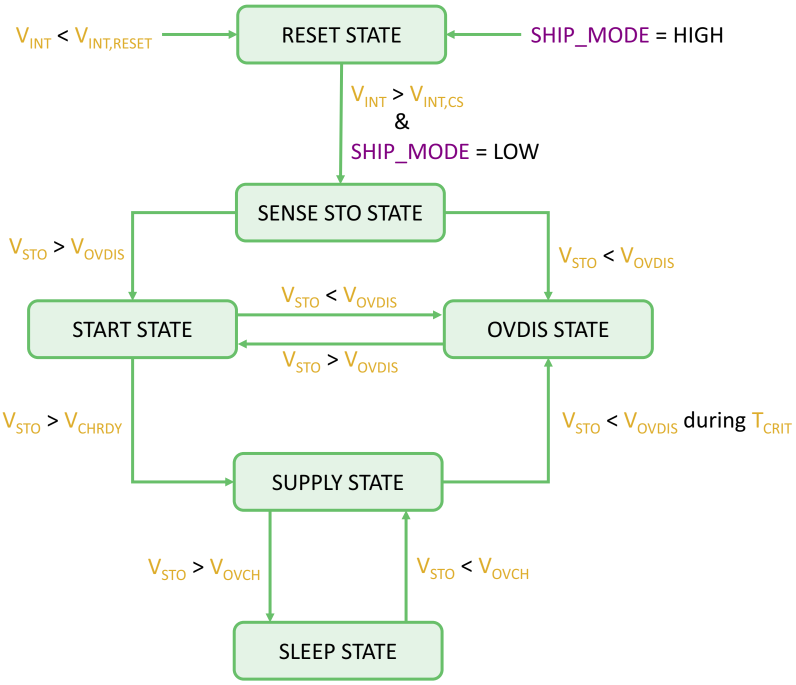


Figure 5: AEM00920 state machine

7.5.1. Reset State

The AEM00920 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 AEM00920 behaves as follows:

- The AEM00920 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 µW).
  - 5V_IN (V_{5V_IN} > 3.5 V).
- The AEM00920 internal circuit, connected on VINT, is supplied by SRC or 5V_IN. No current is drawn from the battery.
- ST_STO is LOW.

The AEM00920 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 AEM00920 reads the value on all configuration pins and switches to SENSE STO STATE.
- If shipping mode is enabled (SHIP_MODE is HIGH), the AEM00920 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 AEM00920 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 AEM00920.

- If V_{STO} > V_{OVDIS}, the AEM00920 switches to START STATE.
- If V_{STO} < V_{OVDIS}, the AEM00920 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 AEM00920 switches to START STATE if V_{STO} is above V_{OVDIS}.

In START STATE, the AEM00920 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 AEM00920 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 AEM00920 switches to SUPPLY STATE if V_{STO} is above V_{CHRDY}.

In SUPPLY STATE, the AEM00920 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 AEM00920 switches to SLEEP STATE if the following condition is met:

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

In SUPPLY STATE, the AEM00920 switches to OVDIS STATE if the following condition is met:

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

7.5.5. OVDIS State

The AEM00920 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 AEM00920 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 AEM00920 internal circuit, connected on VINT, is supplied by SRC or 5V_IN. If not enough power is available on either of those pins, the AEM00920 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 AEM00920 internal circuit consumption when the battery is fully charged. Thus, battery discharging is kept minimal.

In SLEEP STATE, the AEM00920 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 AEM00920 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 AEM00920 switches back to SUPPLY STATE if $V_{STO} < V_{OVCH}$.

8. System Configuration

8.1. Configuration Pins Reading

After a cold start, the AEM00920 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. Source Voltage Regulation

User can set the regulation voltage with SRC_CFG[4:0] (see Table 9).

Configuration pins					Voltage [V]	Configuration pins					Voltage [V]
SRC_CFG[4:0]					$V_{SRC,REG}$	SRC_CFG[4:0]					$V_{SRC,REG}$
L	L	L	L	L	0.25	H	L	L	L	L	1.10
L	L	L	L	H	0.30	H	L	L	L	H	1.20
L	L	L	H	L	0.35	H	L	L	H	L	1.30
L	L	L	H	H	0.40	H	L	L	H	H	1.40
L	L	H	L	L	0.45	H	L	H	L	L	1.50
L	L	H	L	H	0.50	H	L	H	L	H	1.60
L	L	H	H	L	0.55	H	L	H	H	L	1.70
L	L	H	H	H	0.60	H	L	H	H	H	1.80
L	H	L	L	L	0.65	H	H	L	L	L	1.90
L	H	L	L	H	0.70	H	H	L	L	H	2.00
L	H	L	H	L	0.75	H	H	L	H	L	2.20
L	H	L	H	H	0.80	H	H	L	H	H	2.40
L	H	H	L	L	0.85	H	H	H	L	L	2.60
L	H	H	L	H	0.9	H	H	H	L	H	2.80
L	H	H	H	L	0.95	H	H	H	H	L	3.00
L	H	H	H	H	1.00	H	H	H	H	H	3.20

Table 9: Configuration of the source constant regulation voltage with SRC_CFG[4:0] pins

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_{OVCH}, 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:

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

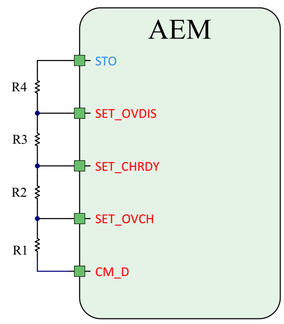


Figure 6: Custom configuration resistors

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 AEM00920.

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 AEM00920 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

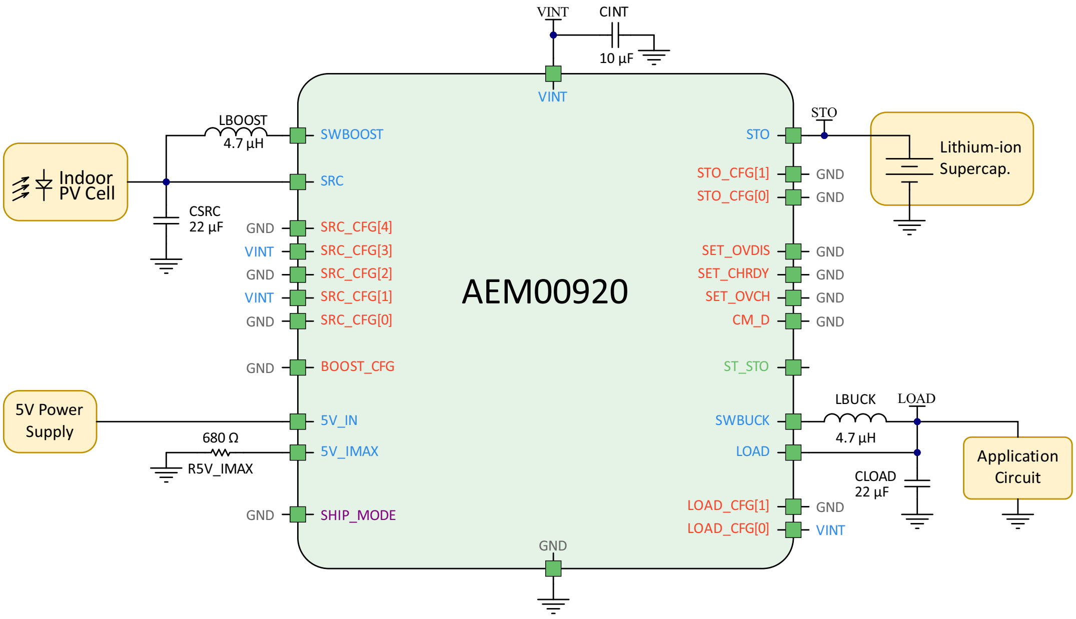


Figure 7: Typical application circuit 1

Figure 7 shows a typical application circuit of the AEM00920.

Configuration of SRC

The second energy source is an indoor PV cell which has a constant 0.75 V MPP voltage. SRC is thus configured as follows:

- SRC_CFG[4:0] = LHLHL (0.75 V regulation).
- BOOST_CFG = L: x1 boost timing.
- L_{BOOST} = 4.7 µH 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 µH 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 Ω.
- $I_{5V,CC}$ = 73.5 mA.

Shipping mode

Shipping mode is not used.

- SHIP_MODE is connected to GND.

9.2. Example Circuit 2

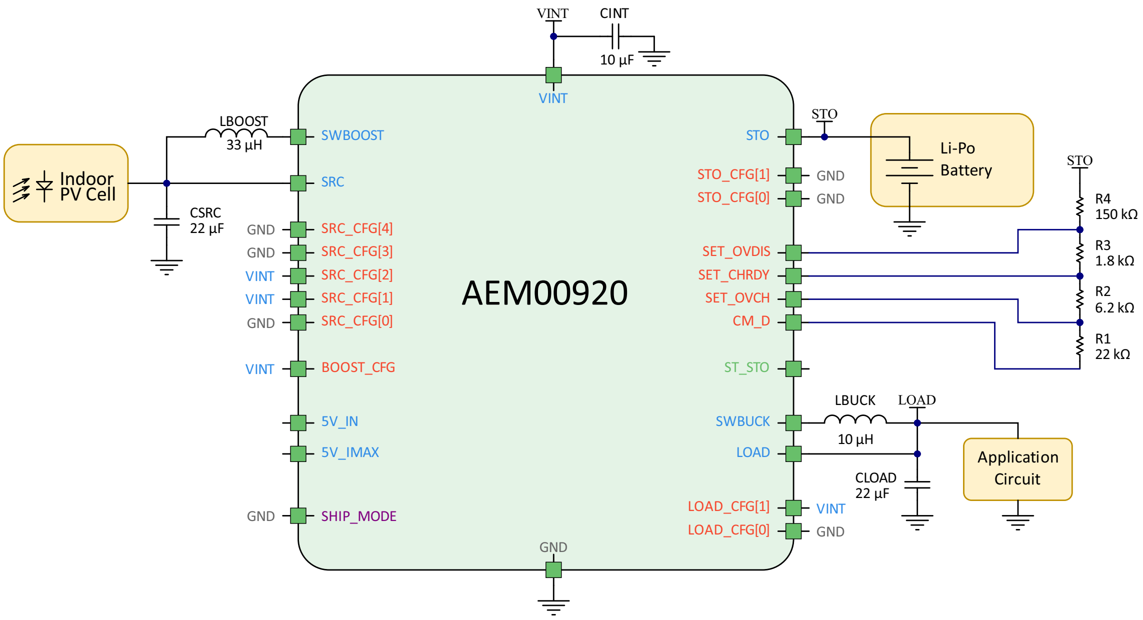


Figure 8: Typical application circuit 2

Figure 8 shows a typical application circuit of the AEM00920.

Configuration of SRC

The second energy source is an indoor PV cell which has a constant 0.55 V MPP voltage. SRC is thus configured as follows:

- SRC_CFG[4:0] = LLHHL (0.55 V regulation).
- BOOST_CFG = H: x3 boost timing.
- L_{BOOST} = 33 µH 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: AEM00920 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:
  - $R_T = R_1 + R_2 + R_3 + R_4 = 180\text{k}\Omega$
  - $R_1 = R_T \cdot \frac{0.5\text{V}}{V_{OVCH}} = 22\text{k}\Omega$
  - $R_2 = R_T \cdot \left(\frac{0.5\text{V}}{V_{CHRDY}} - \frac{0.5\text{V}}{V_{OVCH}}\right) = 6.2\text{k}\Omega$
  - $R_3 = R_T \cdot \left(\frac{0.5\text{V}}{V_{OVDIS}} - \frac{0.5\text{V}}{V_{CHRDY}}\right) = 1.8\text{k}\Omega$
  - $R_4 = R_T - (R_1 + R_2 + R_3) = 150\text{k}\Omega$

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 µH 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 AEM00920 boost efficiency with:

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

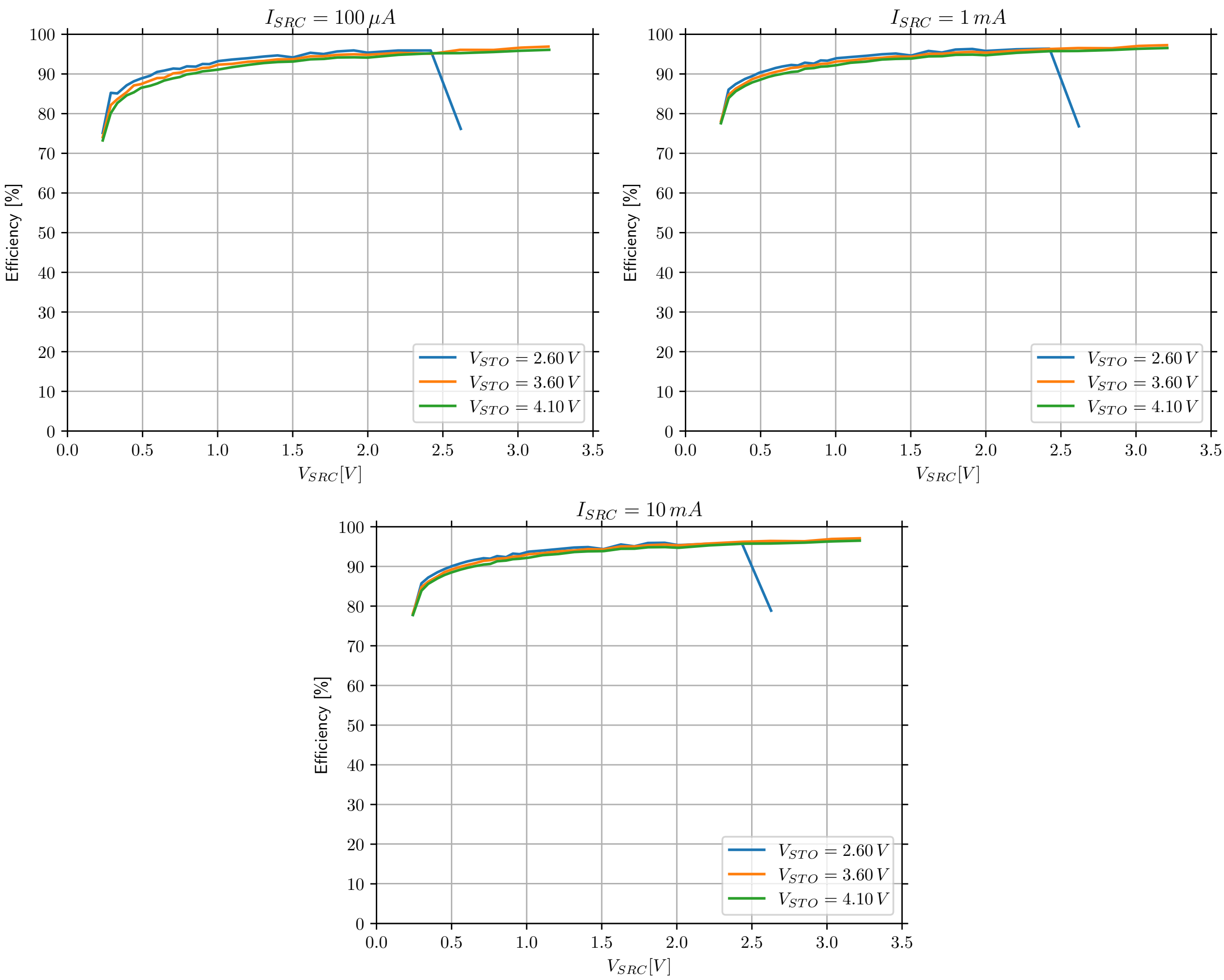


Figure 9: Boost converter efficiency

10.2. Buck Converter Conversion Efficiency

Figure 10 shows the AEM00920 buck efficiency with L_{BUCK} = 10 µH (TDK VLS252012CX-100M-1).

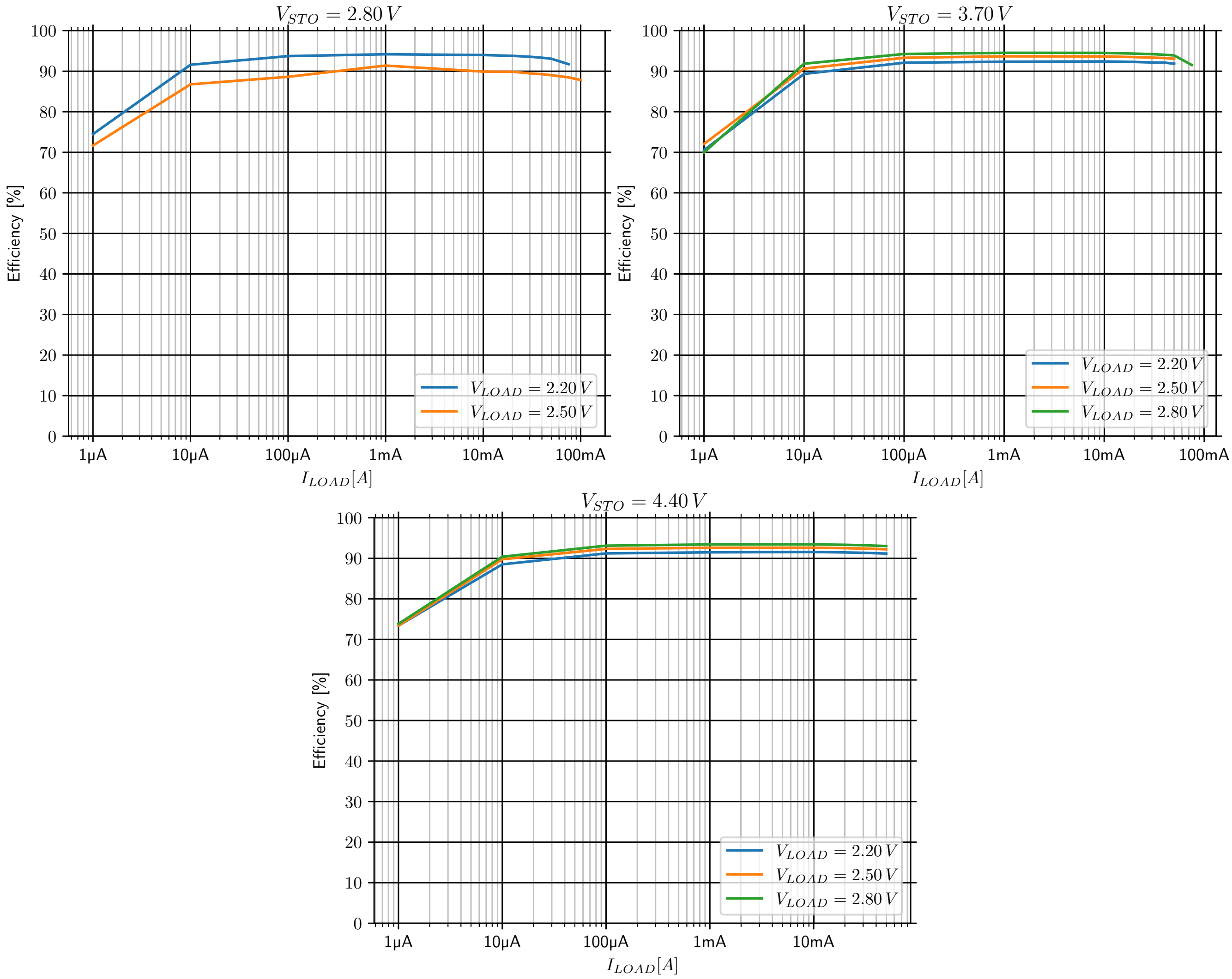
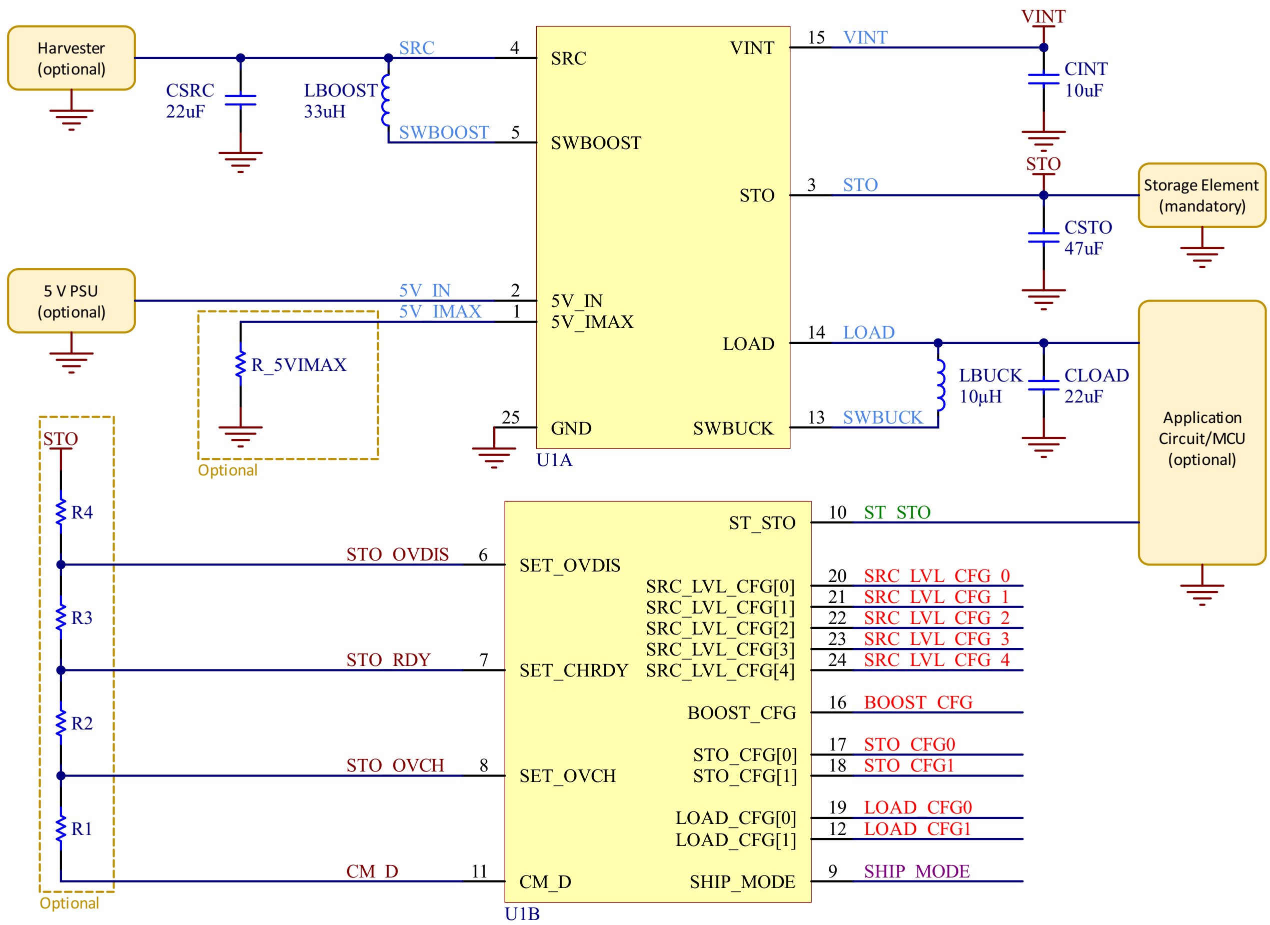


Figure 10: Buck (LOAD) converter efficiency

Figure 10 efficiency is shown with the AEM00920 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	AEM00920	1	e-peas	order at sales@e-peas.com
	CSRC	Ceramic Capacitor 22 µF, 10 V, 20%, X5R 0603	1	Murata	GRM188R61A226ME15D
	LBOOST	Power Inductor 33 µH, 0.68 A, LPS4018	1	Coilcraft	LPS4018-333MRB
	CINT	Ceramic Capacitor 10 µF, 6.3 V, 20%, X5R, 0402	1	Murata	GRM155R60J106ME44D
Optional	CSTO[1]	Ceramic Capacitor 47 µF 6.3 V, 20%, X5R, 0603	1	Murata	GRM188R60J476ME15D
	R_5VIMAX[2]	Resistor (to be defined)	1	To be defined	
	LBUCK	Power Inductor 10 µF TDK VLS-CX-1	1	TDK	VLS252012CX-100M-1
	CLOAD	Ceramic Capacitor 22 µF, 10 V, 20%, X5R, 0603	1	Murata	GRM188R61A226ME15D
	R1	Resistors (to be defined)	1	To be defined	
	R2		1		
	R3		1		
	R4		1		

Table 14: Minimum BOM

1. CSTO is not mandatory but ensures high boost converter efficiency with high ESR storage elements.
2. The AEM00920 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 AEM00920.

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 AEM00920 is mounted.

12.2. Example

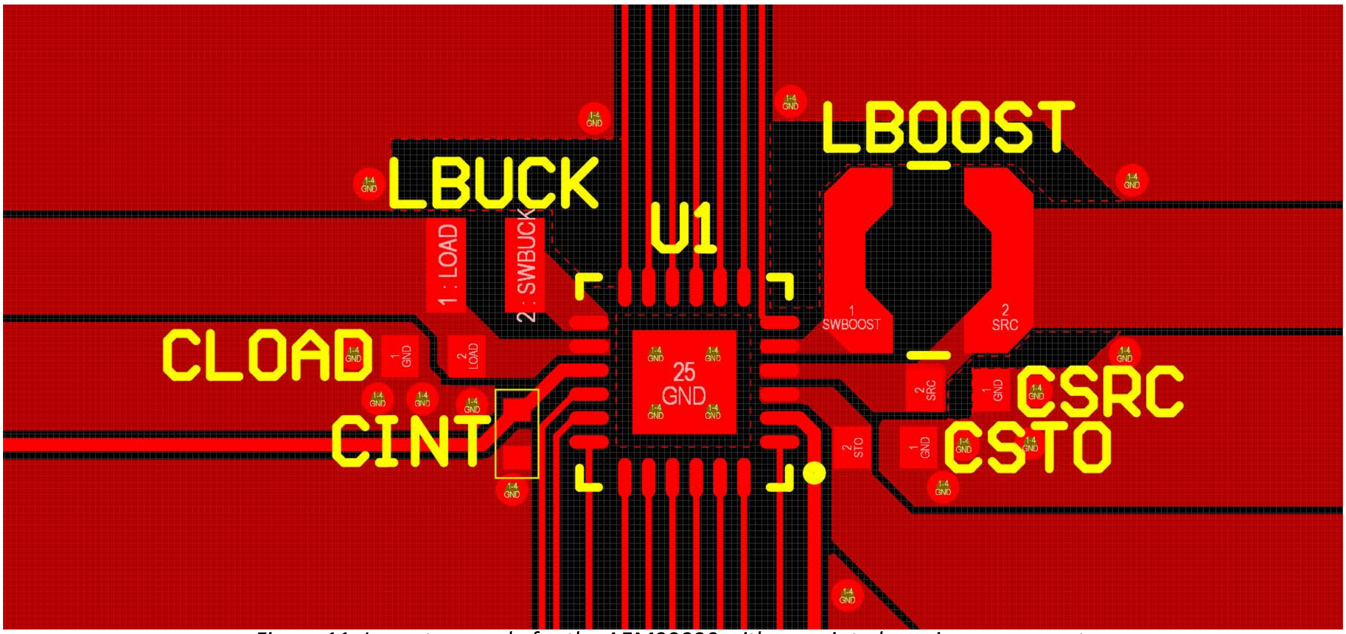


Figure 11: Layout example for the AEM00920 with associated passive components

13. Package Information

13.1. Package Dimensions

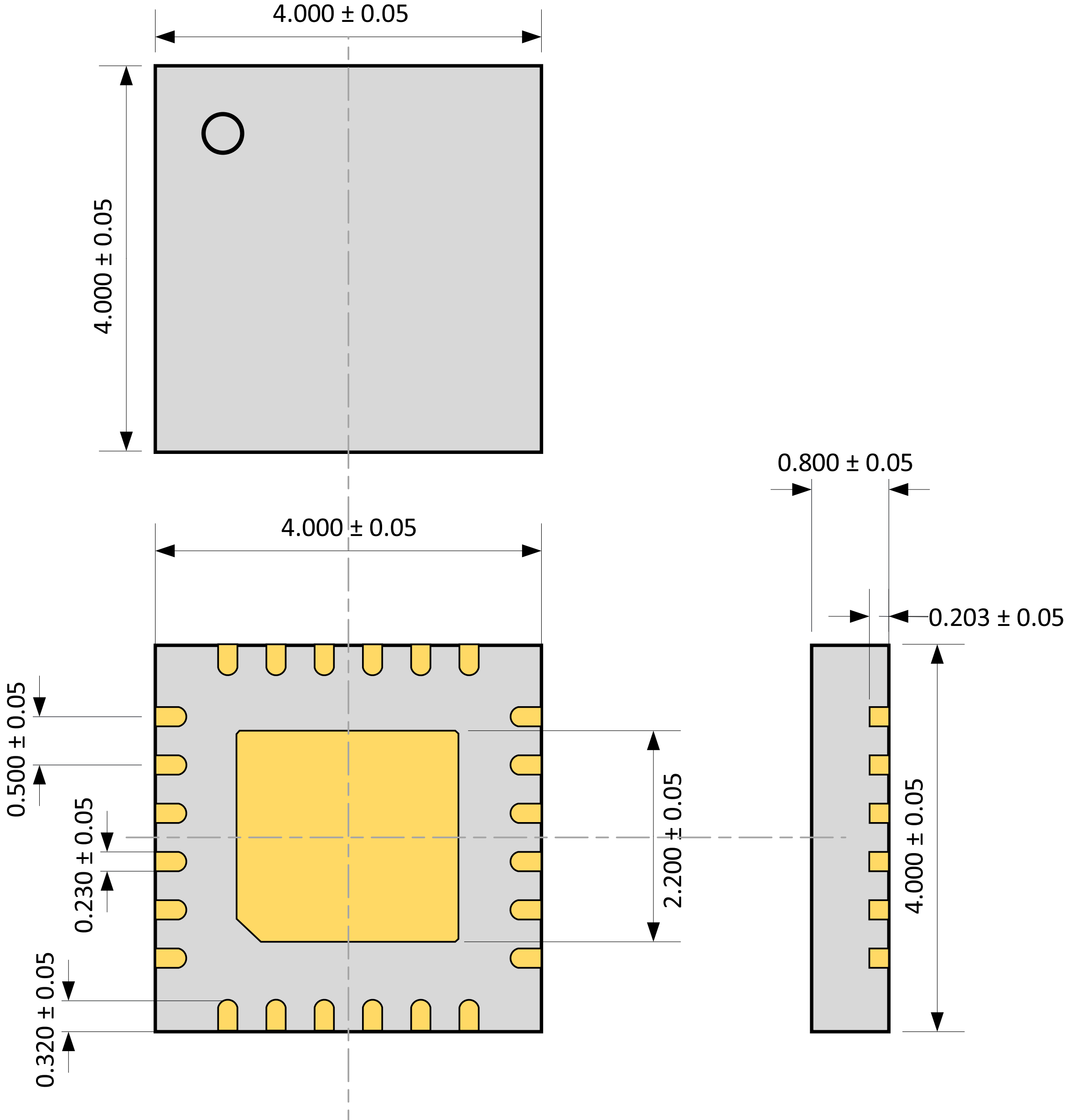


Figure 12: QFN 24-pin 4x4mm drawing (all dimensions in mm)

14. Revision History

Revision	Date	Description
1.0	December, 2023	Creation of the document.
1.1	January, 2024	Added typical application circuits.

Table 15: Revision History