Ultra Efficient Energy Manager with MPPT Voltage Regulation, Regulated Buck Output and 5 V Charger

Features and Benefits

Harvester source input
- Efficiency above 90 % on the source.
- Harvest from 120 mV after cold start.
- Up to 135 mA current extracted from the harvester.

Maximum Power Point Tracking
- Open circuit voltage ratio regulation method.
- 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 120 mV up to the storage element voltage.

Cold start from 275 mV / 1.5 µW input
- Startup at ultra-low power from harvesting source input.

Selectable overdischarge and overcharge protection
- Supports various types of rechargeable batteries (LiC, Li-ion, LiPo...).
- Custom mode configuration.

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 100 mA.

System configuration by GPIO
- All settings are dynamically configurable through GPIO.

Shipping mode
- Disables charging and discharging the battery during shipment.

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

Applications

Smart home	Industrial sensor
Smart building	Retail
Edge IoT	PC accessories

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 storage element and supply an application circuit. A 5 V input can also be used to charge the storage element (e.g. if it gets depleted). This compact and ultra-efficient battery charger allows for extending battery lifetime and eliminating the primary energy storage element 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. 1.5 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 the storage element during shipping or storage.

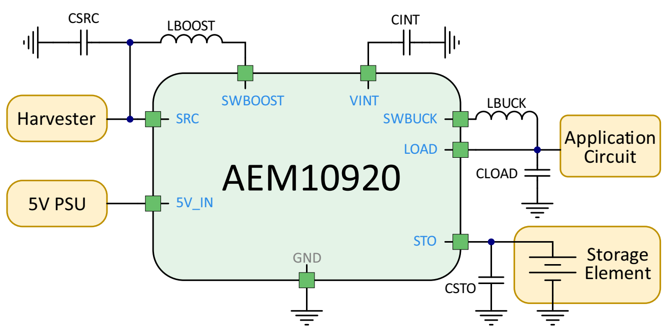
A buck regulator with selectable output voltage allows an application circuit to be supplied with high efficiency.

Device Information

Part Number	Package	Body size
10AEM10920A0001	QFN 24-pin	4x4mm

Evaluation Board

Part number
2AAEM10920A001



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1. Pin Configuration and Functions

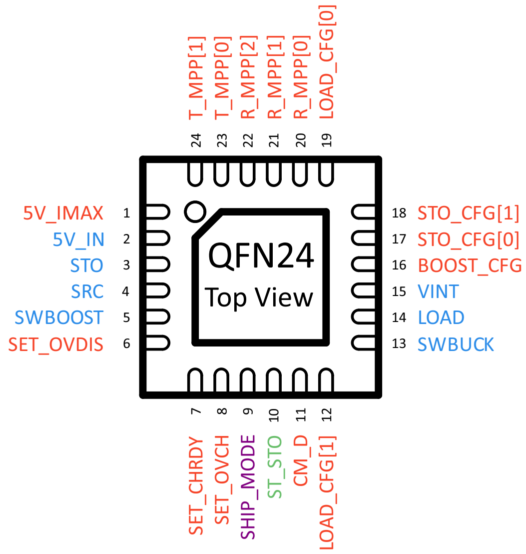


Figure 1: Pinout diagram

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. 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	Used to configure the shipping mode. 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				
R_MPP[2]	22	GND	VINT	Used to configure the MPPT 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 to configure the MPPT 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 protection 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 5.4. Read as HIGH if left floating.
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 to configure the storage element protection thresholds when in custom mode (optional). If the custom mode is not used, connect all four pins to GND.
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 only GND connection of the AEM10920.

Table 2: Pins description (part 2)

2. Specifications

2.1. Absolute Maximum Ratings

Parameter		Min	Max	Unit
Operating junction temperature T_J		-40	85	°C
Storage temperature T_{stg}		-65	150	°C
Input voltage	5V_IN, STO, SRC, SWBOOST, SWBUCK, LOAD, 5V_IMAX, LOAD_CFG[1], SET_OVDIS, SET_CHRDY, SET_OVCH, CM_D, SHIP_MODE, ST_STO	-0.3	5.50	V
	VINT, LOAD_CFG[0], BOOST_CFG, STO_CFG[1:0], R_MPP[2:0], T_MPP[1:0]	-0.3	2.75	V

Table 3: Absolute maximum ratings

2.2. ESD Ratings

Parameter		Value	Unit
Electrostatic discharge V_{ESD}	Human-Body Model (HBM)[1]	± 2000	V
	Charged-Device Model (CDM)[2]	± 1000	V

Table 4: ESD ratings

1. ESD Human-Body Model (HBM) value tested according to JEDEC standard JS-001-2023.
2. ESD Charger-Device Model (CDM) value tested according to JEDEC standard JS-002-2022.

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

2.3. Thermal Resistance

Package	θJA	θJC	Unit
QFN-24	60	6	°C/W

Table 5: Thermal data

2.4. Electrical Characteristics at 25 °C

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
Power conversion						
$P_{SRC,CS}$	Minimum source power required for cold start.			1.5		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		0.90 x V_{OC}	V
$V_{SRC,LOW}$	V_{SRC} threshold below which the AEM10920 switches to SLEEP STATE.			0.113		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 [2]		5.50	V
$I_{5V,CC}$	Maximum charging current of 5 V charger programmed by the resistor on the 5V_IMAX pin.		13.50		135	mA
$T_{5V,RISE}$	Minimum rise time from 0 V to 5 V on the 5V_IN pin.			50		µs
Timing						
T_{CRIT}	When V_{STO} drops below V_{OVDIS} in SUPPLY STATE, the AEM10920 waits for T_{CRIT} before switching to OVDIS STATE and disabling the LOAD output.			2.50		s
$T_{CRIT,ST}$	When V_{STO} drops below V_{OVDIS} in SUPPLY STATE, the AEM10920 waits for $T_{CRIT,ST}$ before setting ST_STO LOW.			1.86		s
$T_{GPIO,MON}$	GPIO reading rate.			1.86		s
$T_{STO,MON}$	Storage element voltage monitoring rate.	In SUPPLY STATE, START STATE, or OVDIS STATE with the buck converter and the 5 V charger disabled.		116		ms
		In SLEEP STATE, with the buck converter disabled.		931		ms
		When the buck converter is enabled (any state).		15		ms
		When the 5 V charger is enabled (any state except SLEEP STATE).		15		ms
$T_{MPPT,PERIOD}$	Time between two MPP evaluations (see Table 9).		15		25	s
$T_{MPPT,WAIT}$	Wait time before V_{OC} measurement begins during MPP evaluations (see Table 9).		0.25		0.50	s
$T_{MPPT,MEASURE}$	Duration of V_{OC} measurement during MPP evaluations.			1.36		ms

Table 6: 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 do not damage the AEM10920.
2. For the 5 V charger to operate, the voltage on 5V_IN must be greater than or equal to 3.5 V and at least 200 mV higher than the voltage on STO.

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[3].	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[3].	2.50		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[3].	2.70		4.59	V
Internal supply & quiescent current						
V_{INT}	Internal voltage supply.			2.25		V
$V_{INT,CS}$	Minimum voltage on VINT to allow the AEM10920 to switch from RESET STATE to SENSE STO STATE.			2.30		V
$V_{INT,RESET}$	Minimum voltage on VINT before switching to RESET STATE (from any other state).			2.00		V
$I_{Q,SUPPLY}$	Quiescent current on VINT in SUPPLY STATE.[4]	LOAD disabled.		270		nA
		LOAD enabled.[5]		480		
$I_{Q,SLEEP}$	Quiescent current on VINT in SLEEP STATE.[4]	LOAD disabled.		205		nA
		LOAD enabled.[5]		415		
$I_{Q,SHIP}$	Quiescent current drawn on the storage element when the AEM10920 is in shipping mode (SHIP_MODE is HIGH) with or without energy available on SRC.			10		nA
$I_{Q,RESET}$	Quiescent current on STO when the AEM10920 is in RESET STATE.					

Table 7: Electrical characteristics (part 2)

1. *As set by the battery overdischarge threshold configuration.*
2. *As set by the battery overcharge threshold configuration.*
3. *For configuring the custom mode, please make sure to meet the constraints explained in Section 5.3.2.*
4. *When neither the boost converter nor the buck converter are running.*
5. *V_{LOAD} set to 2.2 V and LOAD pin left floating.*

2.5. Recommended Operating Conditions

Symbol	Parameter	Condition	Min[1]	Typ	Max[1]	Unit
External components						
L_{BOOST}	Inductor of the boost converter.	BOOST_CFG = L	3.3	10[2]		µH
		BOOST_CFG = H	9.9	33[2]		µH
C_{SRC}	Capacitor decoupling the SRC terminal.			10		µF
L_{BUCK}	Inductor of the buck converter.		3.3	10[2]		µH
C_{LOAD}	Capacitor of the buck converter.		10	22		µF
C_{INT}	Capacitor decoupling the VINT terminal.		5	10		µF
C_{STO}	Capacitor decoupling the STO terminal.		5	47[3]		µF
R_{5V_IMAX}	Resistor for configuring the 5V charger maximum current. (Optional)		0.37		3.7	kΩ
R_T	Optional - Total resistor value for setting the battery threshold voltages in custom mode (R_T = R_1 + R_2 + R_3 + R_4 + 800).		100		400	kΩ

Table 8: 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).
2. L_{BOOST} and L_{BUCK} typical values recommended for best trade-off between boost/buck efficiency and current capability.
3. Recommended value for optimal efficiency, particularly with high-ESR storage elements. If using a smaller value, ensure it meets the minimum requirement.

2.5.1. External Inductors Information

The AEM10920 operates with two external miniature inductors. For both inductors, the switching frequency must be at leasts 10 MHz. Low equivalent series resistance (ESR) favors the power conversion efficiency of the boost and buck converters.

L_{BOOST}

With the recommended operating conditions (10 µH inductor with BOOST_CFG = L or 33 µH inductor with BOOST_CFG = H), the boost inductor L_{BOOST} must support a minimum peak current of 135 mA.

L_{BUCK}

With the recommended operating condition (10 µH inductor), the buck inductor L_{BUCK} must support a minimum peak current of 135 mA.

2.5.2. External Capacitors Information

The AEM10920 operates with four external miniature capacitors to ensure stable operation of the boost converter input, buck converter output, storage element output, and internal supply. Each capacitor serves as a local energy buffer that limits voltage fluctuations caused by switching activity or dynamic load transition.

To maintain optimal performances and minimized quiescent current, all capacitors must exhibit a low leakage current and follow the recommended nominal values listed in Table 8, with a tolerance of ± 20 %.

2.6. Typical Characteristics

2.6.1. Boost Converter Conversion Efficiency

Figure 2 shows the AEM10920 boost efficiency with:

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

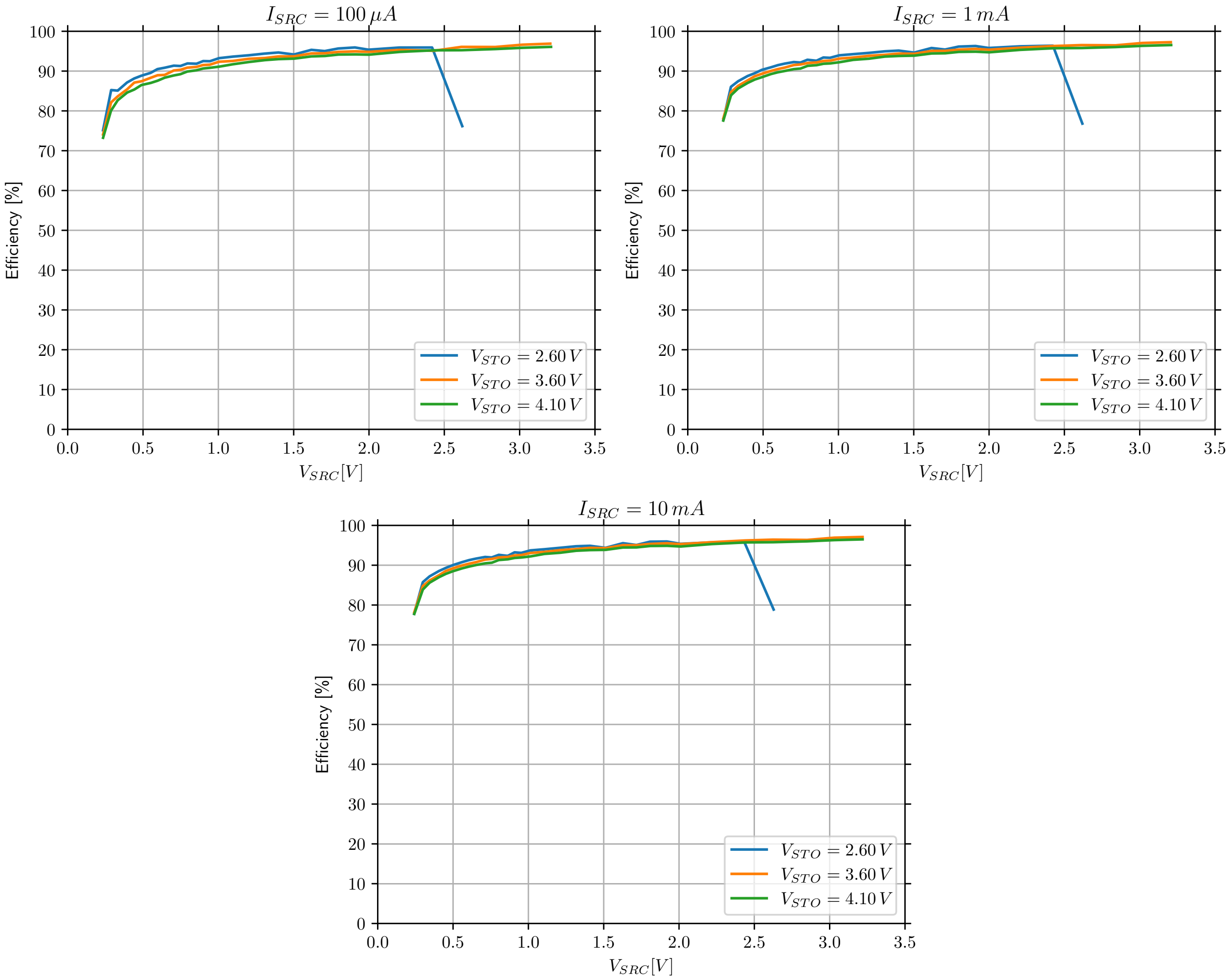


Figure 2: Boost converter efficiency

NOTE: The boost efficiency data presented in Figure 2 include the AEM10920 quiescent current.

2.6.2. Buck Converter Conversion Efficiency

Figure 3 shows the AEM10920 buck efficiency with L_{BUCK} = 10 µH (TDK VLS252012CX-100M-1).

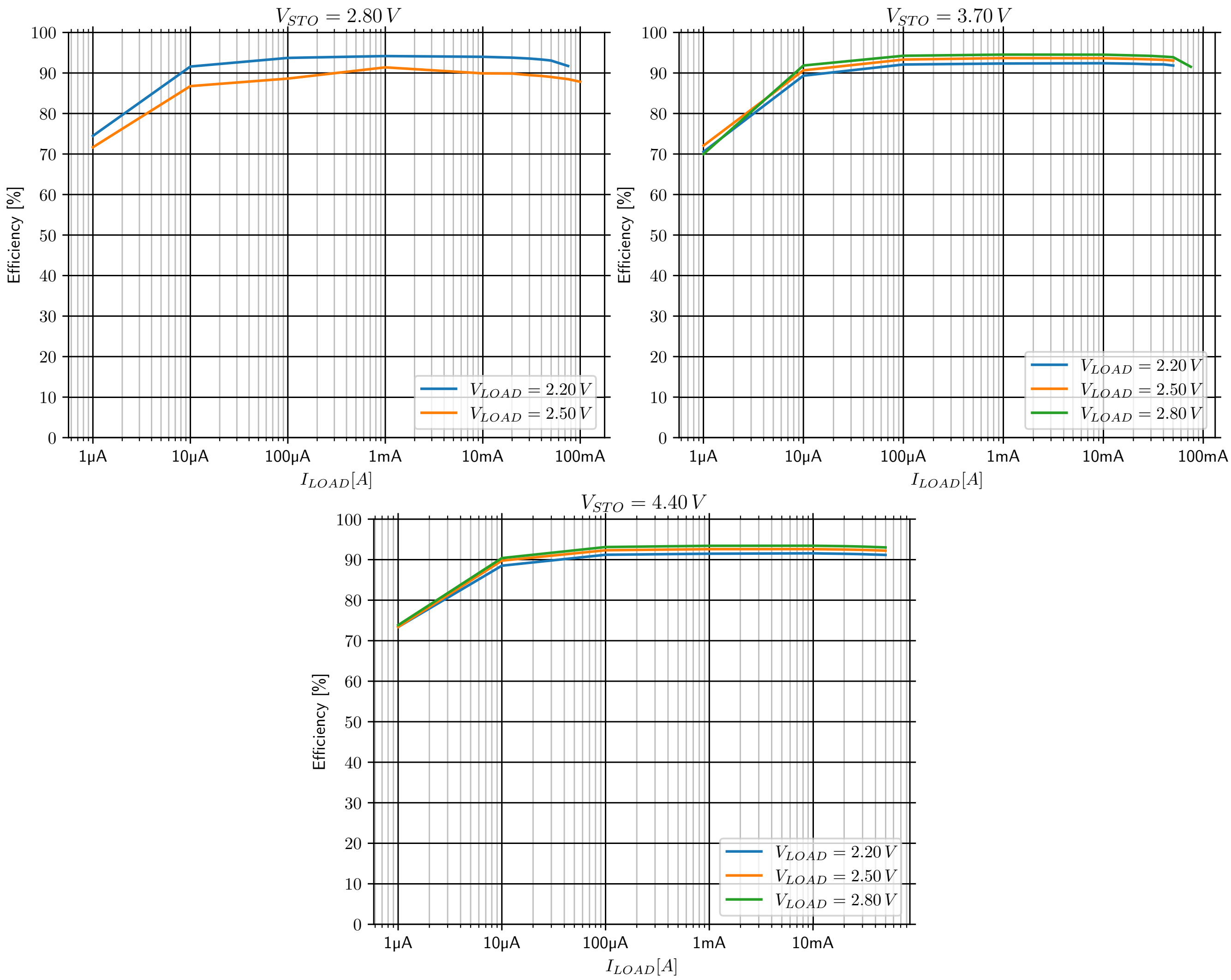


Figure 3: Buck (LOAD) converter efficiency

NOTE: The quiescent current of the AEM10920 is not included in the buck efficiency data presented in Figure 3, as it has already been included in the boost efficiency data shown in Section 2.6.1. This quiescent current has been measured with the boost converter in SLEEP STATE and the buck converter switched off.

3. Functional Block Diagram

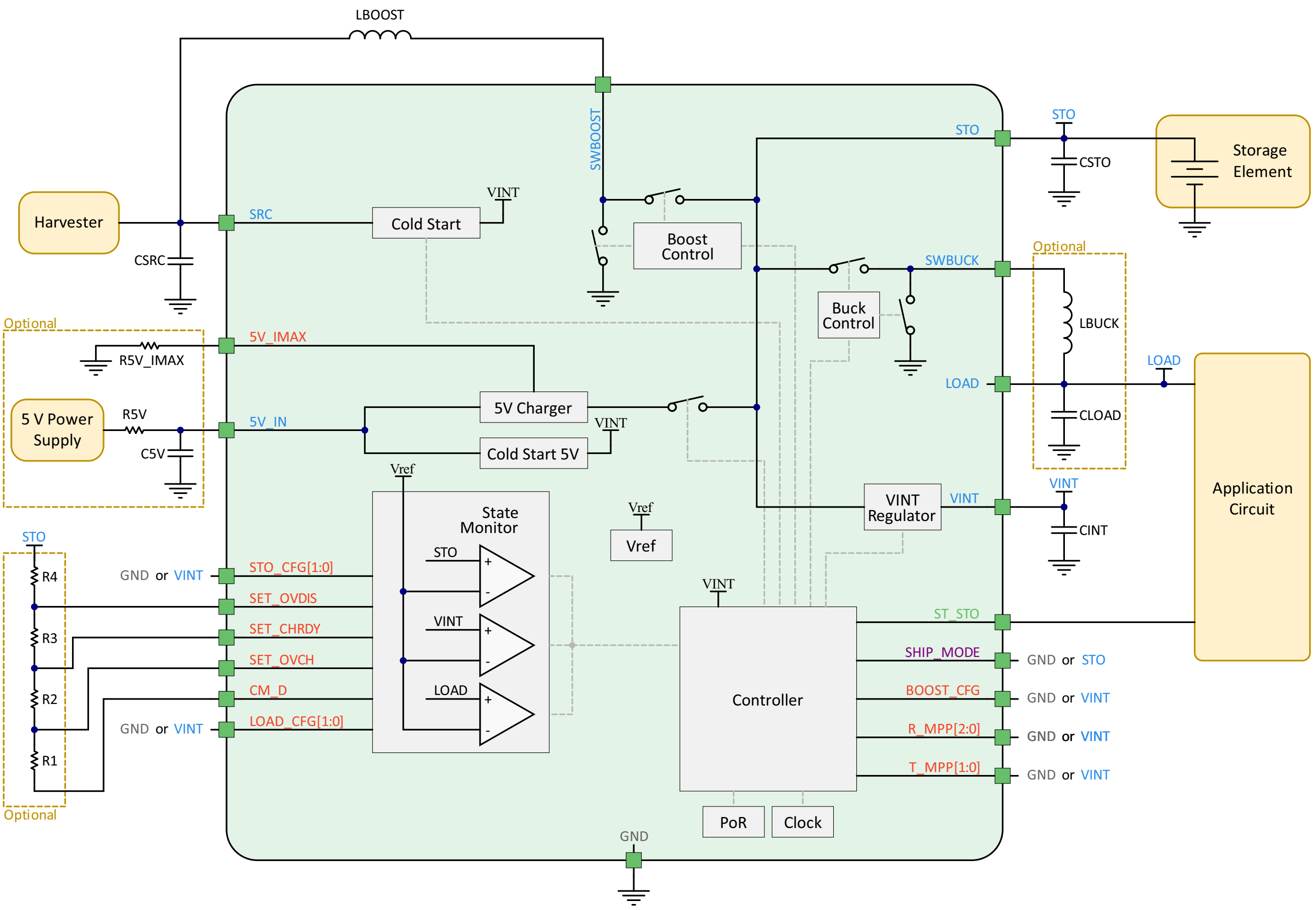


Figure 4: Functional block diagram

4. Theory of Operation

4.1. 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.

4.2. Boost Converter

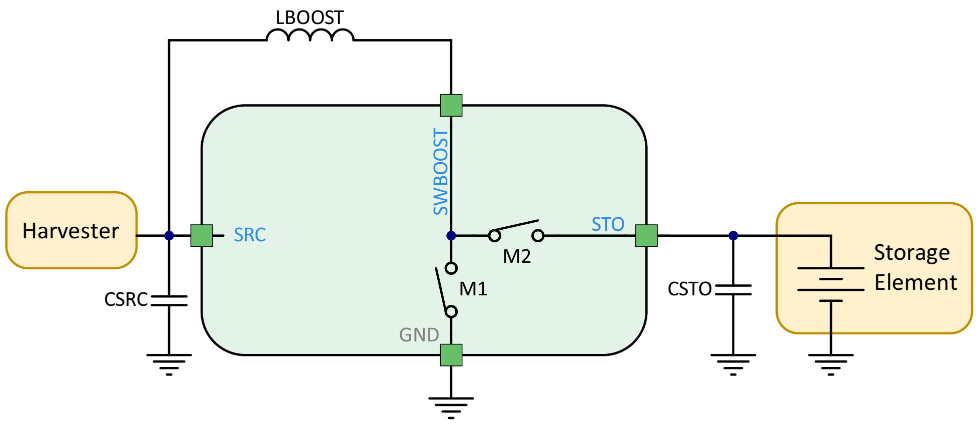


Figure 5: Simplified schematic view of the boost converter

4.2.1. 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 5.4).

4.2.2. 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. The 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 with the following sequence to ensure optimal power extraction at any time:

- The AEM10920 stops extracting power from the SRC during $T_{MPPT,WAIT}$ to allow the SRC voltage to rise to V_{OC}.
- Once this delay elapses, the AEM10920 performs the measurement of V_{OC} during $T_{MPPT,MEASURE}$ and determines V_{MPP} based on the configured MPPT ratio (R_{MPPT}).
- After the measurement, the AEM10920 resumes power extraction by regulating the SRC voltage to the newly determined V_{MPP}.
- The MPPT evaluation is repeated every $T_{MPPT,PERIOD}$.

$T_{MPPT,WAIT}$ and $T_{MPPT,PERIOD}$ are set with the configuration pins T_MPP[1:0] (see Table 9) while $T_{MPPT,MEASURE}$ is constant for any configuration (see Table 6).

The AEM10920 offers a choice of eight different MPPT ratio values (see Table 9) to support multiple V_{MPP} levels in the range from 0.12 V to 90 % of V_{OC}.

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

4.3. 5 V Charger

The AEM10920 is equipped with a 5 V charger for fast charging of the battery connected on the STO pin.

The 5 V charger can be used when the following conditions are met:

- $V_{5V\_IN} \geq 3.5$ V
- $V_{5V\_IN} \geq V_{STO} + 200$ mV

The maximum charging current is configured in a range from 13.5 mA to 135 mA by the value of R_{5V_IMAX} resistor connected to the 5V_IMAX pin (see Section 5.6 for further details about R_{5V_IMAX} configuration).

With the 5 V charger, the storage element is charged by implementing a constant current / constant voltage operation (CC/CV):

- When V_{STO} is not close to V_{OVCH}, the AEM10920 operates in constant current (CC) mode. In this mode, the storage element is charged from the 5V_IN input with the configured maximum charging current ($I_{5V,CC}$).
- When V_{STO} approaches V_{OVCH}, the AEM10920 switches to a constant voltage (CV) operation. The AEM10920 gradually reduces the effective charge current down to zero. This reduction is performed digitally using a PWM-based scheme where the configured $I_{5V,CC}$ is applied intermittently to achieve a controlled tapering of the average charge current.

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

Please note that the rise time of the voltage applied on the 5V_IN must not be too short. See Section 5.6 for more information and Section 6.1 for a design example.

4.4. Buck Converter

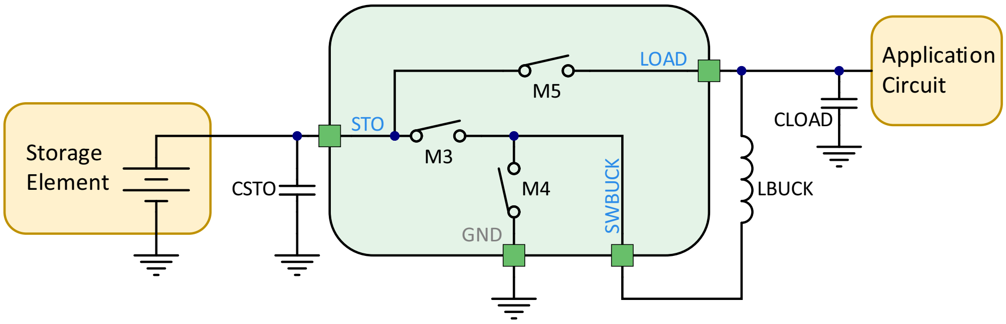


Figure 6: Simplified schematic view of the buck converter

The buck (step-down) converter transfers energy from the storage element 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 buck converter and by the external circuit connected to LOAD.

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

After cold start, if the buck converter has been enabled, the LOAD output starts to be supplied when:

- V_{STO} rises above V_{CHRDY}, if the 5 V charger is not charging, or
- V_{STO} rises above V_{OVDIS}, if the 5 V charger is charging.

NOTE: When using the 5 V charger, make sure the configured $I_{5V,CC}$ is high enough to supply the circuit connected on LOAD. If not, once V_{STO} rises above V_{OVDIS}, the LOAD is directly enabled, and the current drained on the storage element could directly discharge V_{STO} below V_{OVDIS}, thus, disabling the LOAD output.

When V_{STO} drops below V_{OVDIS} for longer than $T_{CRIT,ST}$, the AEM10920 sets ST_STO LOW, to notify that the system is about to shutdown, and waits for the end of T_{CRIT} to disable the LOAD output.

Using the buck converter is not mandatory. If not used, the user must do the following:

- Connect all LOAD_CFG[1:0] to GND (LOW) to disable the buck converter.
- Leave SWBUCK and LOAD pins floating.

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

- When V_{LOAD} is too low, the switch M5 connects STO directly to LOAD, making V_{LOAD} rise.
- When V_{LOAD} is too high, M5 disconnects STO and LOAD so that V_{LOAD} decreases.

4.5. Shipping Mode

The shipping mode feature allows to force the AEM10920 in RESET STATE (see Section 4.6), to disable the boost converter and therefore to prevent the charge of the storage element. Only VINT is charged from SRC if V_{SRC} is above $V_{SRC,CS}$.

See Section 5.7 for shipping mode configuration.

4.6. State Machine Description

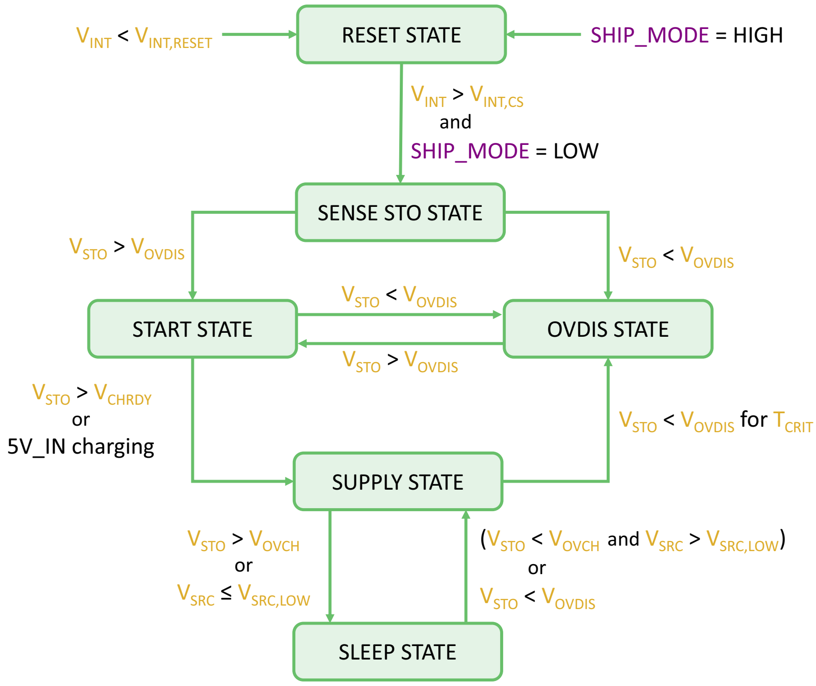


Figure 7: AEM10920 state machine

4.6.1. Reset State

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

- V_{INT} is below $V_{INT,RESET}$.
- 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 $P_{SRC,CS}$ > 1.5 µW).
  - 5V_IN (V_{5V_IN} > 3.5 V & V_{5V_IN} > V_{STO} + 0.2 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 SRC or on 5V_IN meets the cold-start requirements long enough to make V_{INT} reach $V_{INT,CS}$ (see Table 7). 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 $V_{INT,RESET}$.

4.6.2. 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.

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

4.6.4. Supply State

When in START STATE, the AEM10920 switches to SUPPLY STATE if one of the following conditions is true:

- V_{STO} is above V_{CHRDY}.
- The 5 V charger is charging.

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 one of the following conditions is met:

- $V_{STO} > V_{OVCH}$
- $V_{SRC} \leq V_{SRC,LOW}$

If V_{STO} falls below V_{OVDIS} when the AEM10920 is in SUPPLY STATE:

- ST_STO is set LOW after 1.86 s ($T_{CRIT,ST}$).
- the AEM10920 switches to OVDIS STATE and disables the LOAD output after 2.5 s (T_{CRIT}).

4.6.5. 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 storage element.
- The buck converter (LOAD) is disabled.
- ST_STO is LOW.

4.6.6. Sleep State

SLEEP STATE allows for reducing the AEM10920 internal circuit consumption, and thus, keeping storage element discharge to the minimum.

The AEM10920 switches from SUPPLY STATE to SLEEP STATE if one of the following conditions is true:

- the battery is fully charged ($V_{STO} > V_{OVCH}$).
- the source voltage is equal to or lower than $V_{SRC,LOW}$.

In SLEEP STATE, the AEM10920 behaves as follows:

- The storage element 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 storage element 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 one of the following conditions is true:

- $V_{STO} < V_{OVCH}$ & $V_{SRC} > V_{SRC,LOW}$
- $V_{STO} < V_{OVDIS}$

5. System Configuration

5.1. 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.

5.2. MPPT Configuration

Two parameters are necessary to configure the Maximum Power Point Tracking (MPPT). The first parameter is the MPP tracking ratio R_{MPPT}, 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 wait time before V_{OC} measurement begins for each MPP evaluation ($T_{MPPT,WAIT}$) and the MPP evaluations period ($T_{MPPT,PERIOD}$). This configuration is set by the configuration pins T_MPP[1:0].

NOTE: The total capacitance connected to the SRC pin of the AEM10920 must be selected based on the characteristics of the energy harvester and on the available source power. The source capacitor (C_{SRC}) charging time up to the open-circuit voltage (V_{OC}) during the MPP evaluations must remain shorter than the configured $T_{MPPT,WAIT}$. This will ensure an accurate measurement of V_{OC} and thus, an accurate source voltage regulation.

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]	$T_{MPPT,WAIT}$ [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

5.3. 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 5.3.1.
- Configuration using the custom mode as described in Section 5.3.2.

5.3.1. Configuration Pins

The storage element protection thresholds V_{OVDIS}, 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	2.51	2.55	3.79	Lithium-ion Super Capacitor (LiC)
L	H	3.00	3.21	4.12	Lithium-ion battery
H	L	3.00	3.21	4.35	LiPo battery
H	H	3.51	3.56	3.90	Li-ion battery (ultra long life)

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

DISCLAIMER: storage element thresholds provided 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.

DISCLAIMER: For STO_CFG[1:0] configurations LL and HH, the small difference between V_{CHRDY} and V_{OVDIS} may lead to a confusion between the two thresholds due to factors such as battery ESR, leading to enabling and disabling LOAD output and ST_STO unexpectedly. This behavior will no longer occur once the storage element voltage rise above V_{CHRDY}.

5.3.2. Custom Mode

During startup, when exiting RESET STATE, the AEM10920 reads the CM_D pin along with the other configuration pins. If CM_D is not connected to GND, the custom mode is selected regardless of the state of STO_CFG[1:0] pins. The CM_D pin is read only at this moment and cannot be modified dynamically.

When the custom mode is enabled, the storage element protection thresholds are defined during SENSE STO STATE through all four custom mode configuration resistors wired as shown in Figure 8.

CAUTION: If the custom mode is not used, make sure to connect CM_D to GND, as this pin cannot be left floating.

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

- $R_T = R_1 + R_2 + R_3 + R_4 + 800$
- $100\text{k}\Omega \le R_T \le 400\text{k}\Omega$
- $R_1 = R_T \cdot \frac{0.5V}{V_{OVCH}} - 800$
- $R_2 = R_T \cdot \left(\frac{0.5V}{V_{CHRDY}} - \frac{0.5V}{V_{OVCH}}\right)$
- $R_3 = R_T \cdot \left(\frac{0.5V}{V_{OVDIS}} - \frac{0.5V}{V_{CHRDY}}\right)$
- $R_4 = R_T - (R_1 + R_2 + R_3 + 800)$

When using the custom mode, the following constraints must be met to ensure the functionality of the chip:

- 2.40 V ≤ V_{OVDIS} ≤ 3.58 V
- 2.50 V ≤ V_{CHRDY} ≤ 3.64 V
- 2.70 V ≤ V_{OVCH} ≤ 4.59 V
- V_{OVCH} > V_{CHRDY} + 100 mV
- V_{CHRDY} > V_{OVDIS} + 100 mV
- V_{OVDIS} > V_{LOAD} + 100 mV

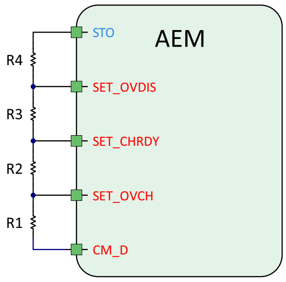


Figure 8: Custom configuration resistors

5.4. 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	Timing multiplier	L_{BOOST} [µH]	
BOOST_CFG	Value	**Minimum**	**Recommended**[1]
L	x1	3.3	10
H	x3	9.9	33

Table 11: Boost converter timings configuration

1. The recommended values provide the best efficiency/current capability trade-off according to the tests carried out in the e-peas laboratory.

5.5. 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[1]
L	H	2.2
H	L	2.5
H	H	2.8

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

1. When using the 5 V charger, do not disable the LOAD output even if not used. In this situation, configure any V_{LOAD} value, connect the LOAD pin to the STO pin, and leave the SWBUCK pin floating.

NOTE: The buck voltage (V_{LOAD}) cannot be selected higher than the configured V_{OVDIS}. In such situation, the AEM10920 will not start the buck converter.

5.6. 5 V Charger

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

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

R_{5V_IMAX} must be chosen so that $I_{5V,CC}$ complies to the range defined in Table 6. Example values can be found in the following table:

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

NOTE: when using the 5 V charger, please make sure to leave the buck converter enabled (LOAD_CFG[1:0] not configured to LL), connect the LOAD pin to STO and leave SWBUCK floating.

The rise time of the voltage applied on 5V_IN must not be too short. Thus, it is recommended to add a RC circuit in series with the 5V_IN pin which matches the following, with R_{5V} in series and C_{5V} between 5V_IN and GND:

$$R_{5V} \cdot C_{5V} > T_{5V,RISE}$$

- $T_{5V,RISE}$ is the rise time from 0 V to 5 V of the voltage on the 5V_IN pin (see Table 2.4). Comparing this to the RC constant adds a margin as the RC constant defines 63% of the final voltage.
- R_{5V} must be determined so that, for the configured $I_{5V,CC}$, the voltage on the 5V_IN pin is:
  - above 3.5 V.
  - above V_{STO} + 200 mV.
- C_{5V} is determined from the value of R_{5V} using the equation above. A low charging current allows for high R_{5V} value and thus for a low C_{5V} value.

5.7. Shipping Mode

The shipping mode, described in Section 4.5, can be configured as follows with the SHIP_MODE pin:

Configuration pin	Feature state
SHIP_MODE	**Shipping mode**
L	Disabled
H	Enabled

Table 14: Shipping mode configuration

6. Typical Application Circuit

6.1. Example Circuit 1

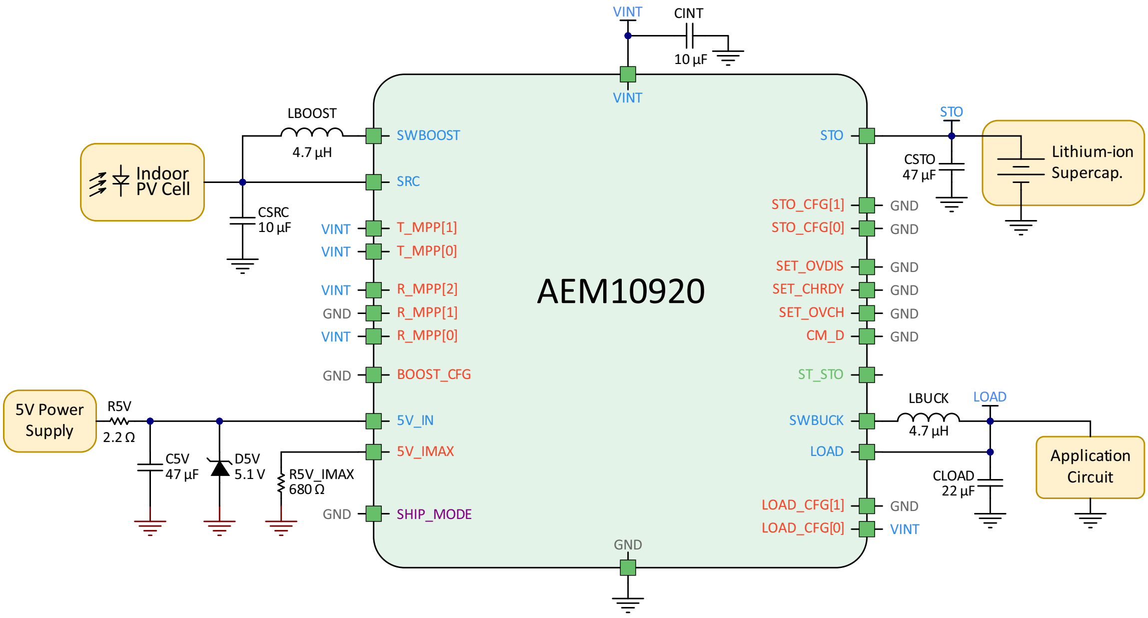


Figure 9: Typical application circuit 1

Figure 9 shows a typical application circuit of the AEM10920.

Configuration of SRC

The 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:
  - $T_{MPPT,PERIOD}$ = 25 s.
  - $T_{MPPT,WAIT}$ = 0.5 s.
- BOOST_CFG = L: x1 boost timing.
- L_{BOOST} = 4.7 µH for high current capability with x1 boost timing (see Section 5.4) 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} = 2.51 V.
  - V_{CHRDY} = 2.55 V.
  - V_{OVCH} = 3.79 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.

Shipping mode

Shipping mode is not used.

- SHIP_MODE is connected to GND.

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.

The RC filter, which role is to slow down the rise time of the 5 V source, can be determined with the following steps.

R_{5V} is calculated so that its voltage drop across it ensures a voltage on 5V_IN higher than V_{OVCH} + 200 mV:

$$I_{5V,CC} \cdot R_{5V} < 5V - V_{OVCH} - 0.2V$$

$$R_{5V} < \frac{5V - V_{OVCH} - 0.2V}{I_{5V,CC}} \quad \Leftrightarrow \quad R_{5V} < \frac{5V - 3.79V - 0.2V}{73.5 \times 10^{-3}}$$

$$R_{5V} < 13.74\Omega$$

C_{5V} is calculated so that the 5V_IN voltage rise time remains below $T_{5V,RISE}$:

$$R_{5V} \cdot C_{5V} > T_{5V,RISE}$$

$$R_{5V} \cdot C_{5V} > 50\mu s$$

To meet these two conditions, the following component values have been selected:

- R_{5V} = 2.2 Ω
- C_{5V} = 47 µF

The 5 V source is expected to have ripple and/or over voltages up to 5.5 V, so a 5.1 V zener diode D_{5V} is added to prevent those to damage the AEM10920.

The minimum power rating of D_{5V} is computed as follows, from its maximum reverse current I_{D5V}, its voltage V_{D5V}, and the resistor R_{5V}:

$$P_{D5V} \geq I_{D5V} \cdot V_{D5V} \quad \Leftrightarrow \quad P_{D5V} \geq \frac{5.5V - 5.1V}{R_{5V}} \cdot 5.1V$$

$$P_{D5V} \geq \frac{5.5V - 5.1V}{2.2} \cdot 5.1V \quad \Leftrightarrow \quad P_{D5V} \geq 927mW$$

R_{5V} dissipated power $P_{R5V,idle}$ when the 5V charger does not pull any current to charge the storage element is determined as follows:

$$P_{R5V,idle} = \frac{(5.5V - 5.1V)^2}{R_{5V}} \Leftrightarrow P_{R\_5V,idle} = \frac{(5.5V - 5.1V)^2}{2.2}$$

$$P_{R\_5V,idle} = 73mW$$

Furthermore, R_{5V} dissipated power $P_{R5V,CC}$ at $I_{5V,CC}$ current (73.5 mA) is determined as follows:

$$P_{R\_5V,CC} = R_{5V} \cdot I_{5V,CC}^2 = 2.2\Omega \cdot (73.5mA)^2 = 12mW$$

The minimum required power rating of R_{5V} is the maximum of $P_{R5V,idle}$ and $P_{R5V,CC}$, thus, 73 mW.

6.2. Example Circuit 2

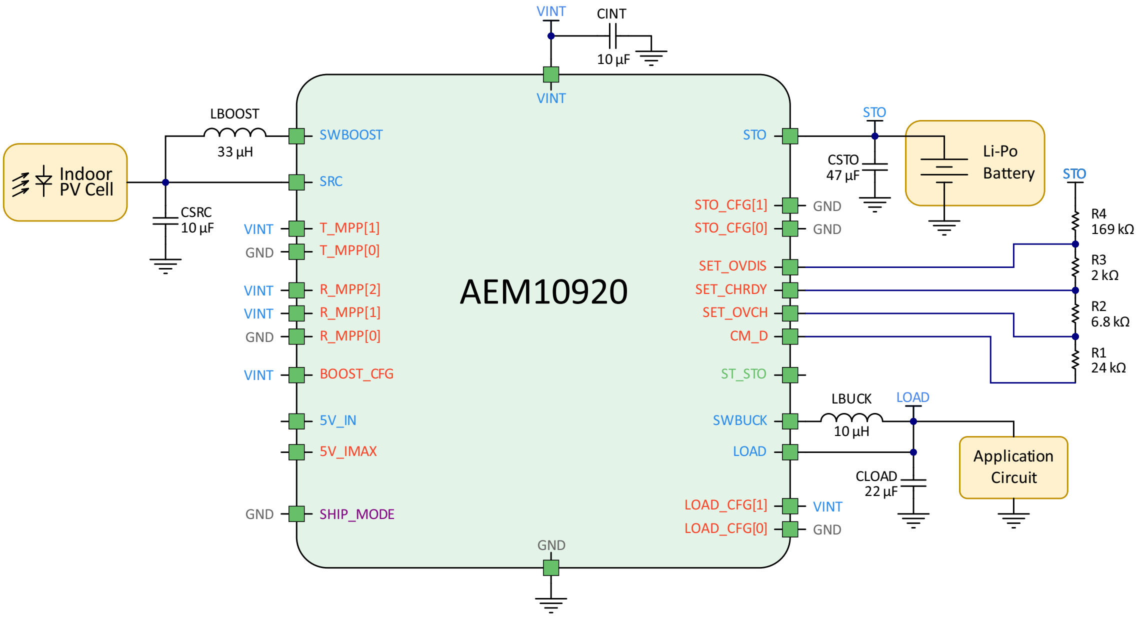


Figure 10: Typical application circuit 2

Figure 10 shows a typical application circuit of the AEM10920.

Configuration of SRC

The 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:
  - $T_{MPPT,PERIOD}$ = 25 s.
  - $T_{MPPT,WAIT}$ = 0.25 s.
- BOOST_CFG = H: x3 boost timing.
- L_{BOOST} = 33 µH for best trade-off between efficiency and current capability with x3 boost timing (see Table 8).

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} = 3.00 V.
  - V_{CHRDY} = 3.20 V.
  - V_{OVCH} = 4.10 V.
- Custom mode resistors are configured as follows:
  - $R_T = R_1 + R_2 + R_3 + R_4 + 800 = 202.6k\Omega$
  - $R_1 = R_T \cdot \frac{0.5V}{V_{OVCH}} - 800 = 24k\Omega$
  - $R_2 = R_T \cdot \left(\frac{0.5V}{V_{CHRDY}} - \frac{0.5V}{V_{OVCH}}\right) = 6.8k\Omega$
  - $R_3 = R_T \cdot \left(\frac{0.5V}{V_{OVDIS}} - \frac{0.5V}{V_{CHRDY}}\right) = 2k\Omega$
  - $R_4 = R_T - (R_1 + R_2 + R_3 + 800) = 169k\Omega$

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 tradeoff between efficiency and maximum current (see Table 8).

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.

7. Minimum BOM

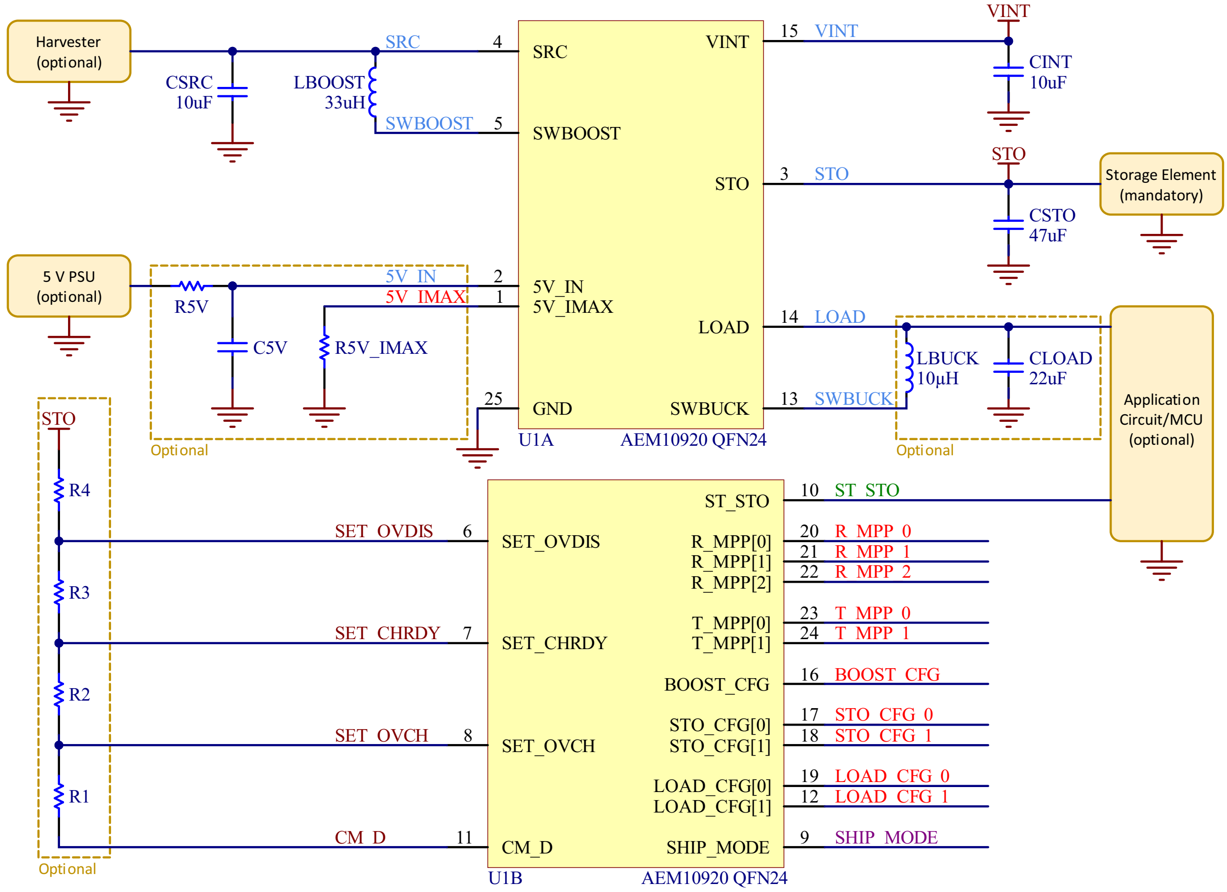


Figure 11: Schematic with minimum BOM

	Designator	Description	Quantity	Manufacturer	Part Number
Mandatory	U1	AEM10920	1	e-peas	order at sales@e-peas.com
	CSRC[1]	Ceramic Capacitor 10 µF, 10 V, 20%, X5R 0603	1	Murata	GRM188R61A106ME69D
	LBOOST[1]	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
	CSTO[2]	Ceramic Capacitor 47 µF, 6.3 V, 20%, X5R, 0603	1	Murata	GRM188R60J476ME15D
Optional	R5V_IMAX[1]	Resistor (to be defined)	1	To be defined	
	C5V[1]	Capacitor (to be defined)	1	To be defined	
	R5V[1]	Resistor (to be defined)	1	To be defined	
	LBUCK	Power Inductor 10 µH 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 15: Minimum BOM

1. The AEM10920 must have at least one energy source to work: boost (SRC), 5 V input (5V_IN) or both.
2. Recommended CSTO for optimal efficiency, particularly with high-ESR storage elements. If using a smaller value, ensure it meets the minimum requirement (see Table 8).

8. Layout

8.1. Guidelines

Figure 12 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.

8.2. Example

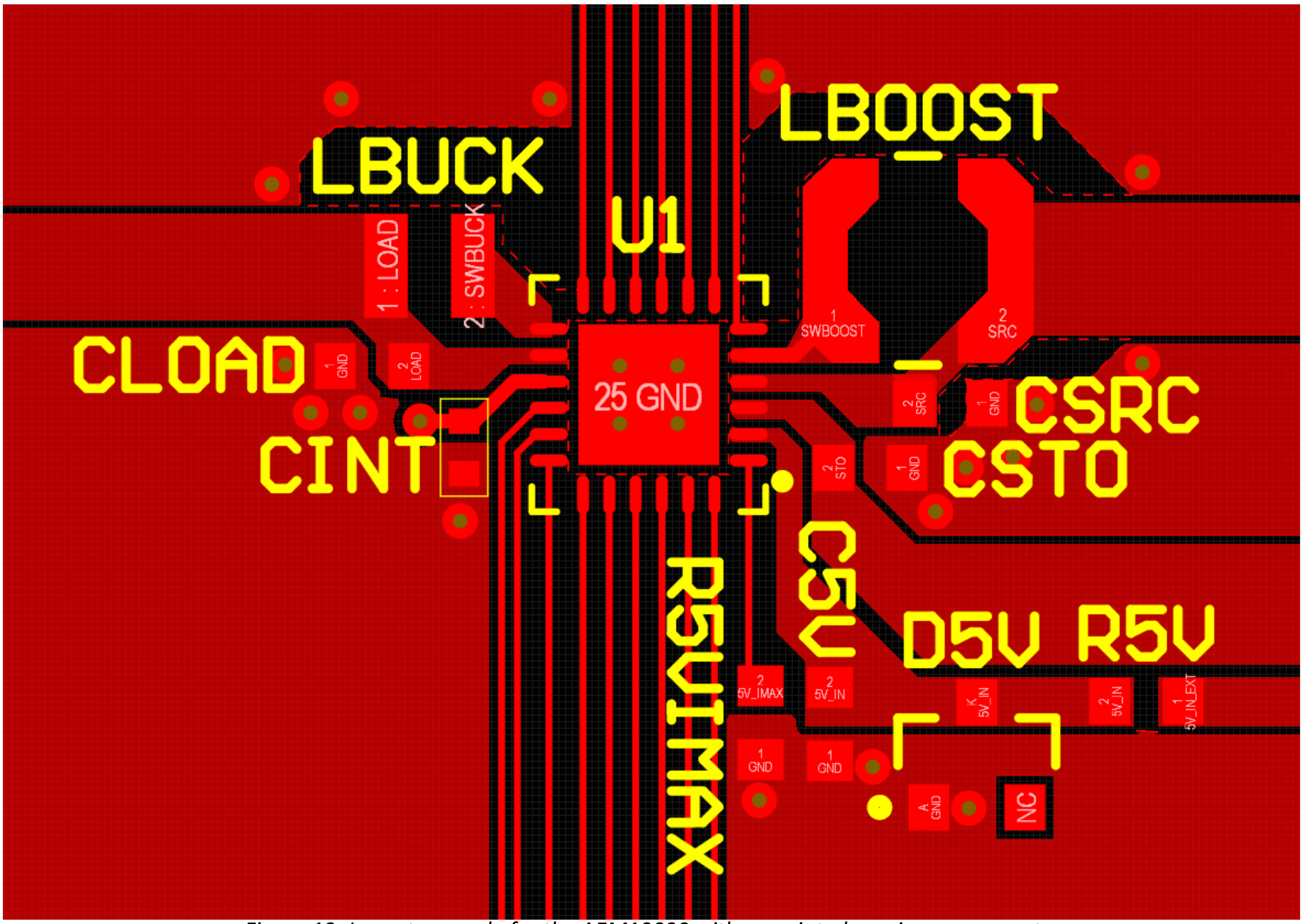


Figure 12: Layout example for the AEM10920 with associated passive components

9. Package Information

9.1. Moisture Sensitivity Level

Package	Moisture Sensitivity Level (MSL)[1]
QFN-24	Level 1

Table 16: Moisture sensitivity level

1. According to JEDEC 22-A113 standard.

9.2. RoHS Compliance

e-peas product complies with RoHS requirement.

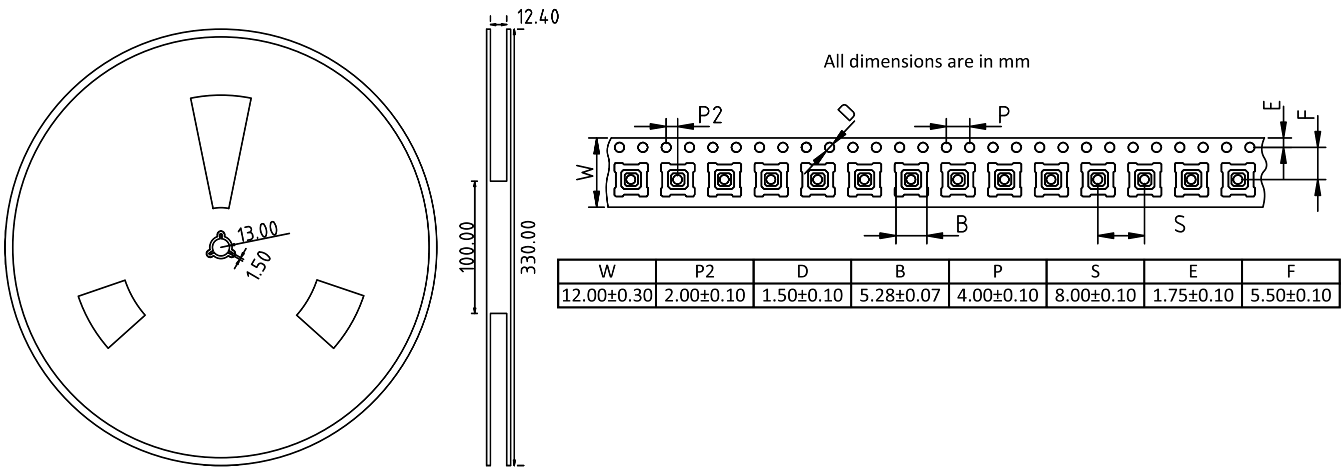
e-peas defines "RoHS" to mean that semiconductor end-products are compliant with RoHS regulation for all 10 RoHS substances.

This applies to silicon, die attached adhesive, gold wire bonding, lead frames, mold compound, and lead finish (pure tin).

9.3. REACH Compliance

The component and elements used by e-peas subcontractors to manufacture e-peas PMICs and devices are REACH compliant. For more detailed information, please contact e-peas sales team.

9.4. Tape and Reel Dimensions



W	P2	D	B	P	S	E	F
12.00±0.30	2.00±0.10	1.50±0.10	5.28±0.07	4.00±0.10	8.00±0.10	1.75±0.10	5.50±0.10

Figure 13: Tape and reel dimensions

9.5. Package Dimensions

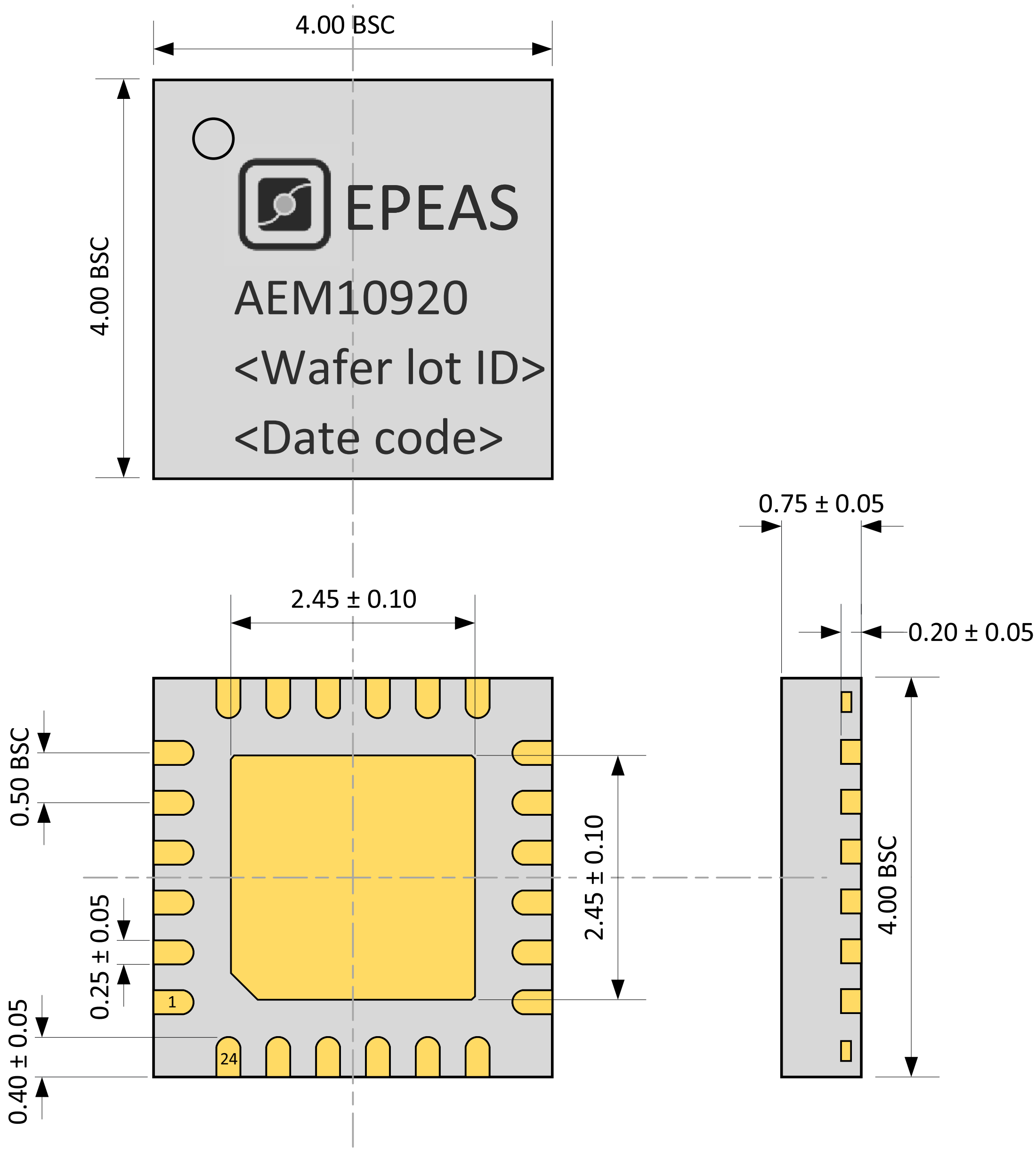


Figure 14: QFN 24-pin 4x4mm drawing (all dimensions in mm)

9.6. Board Layout

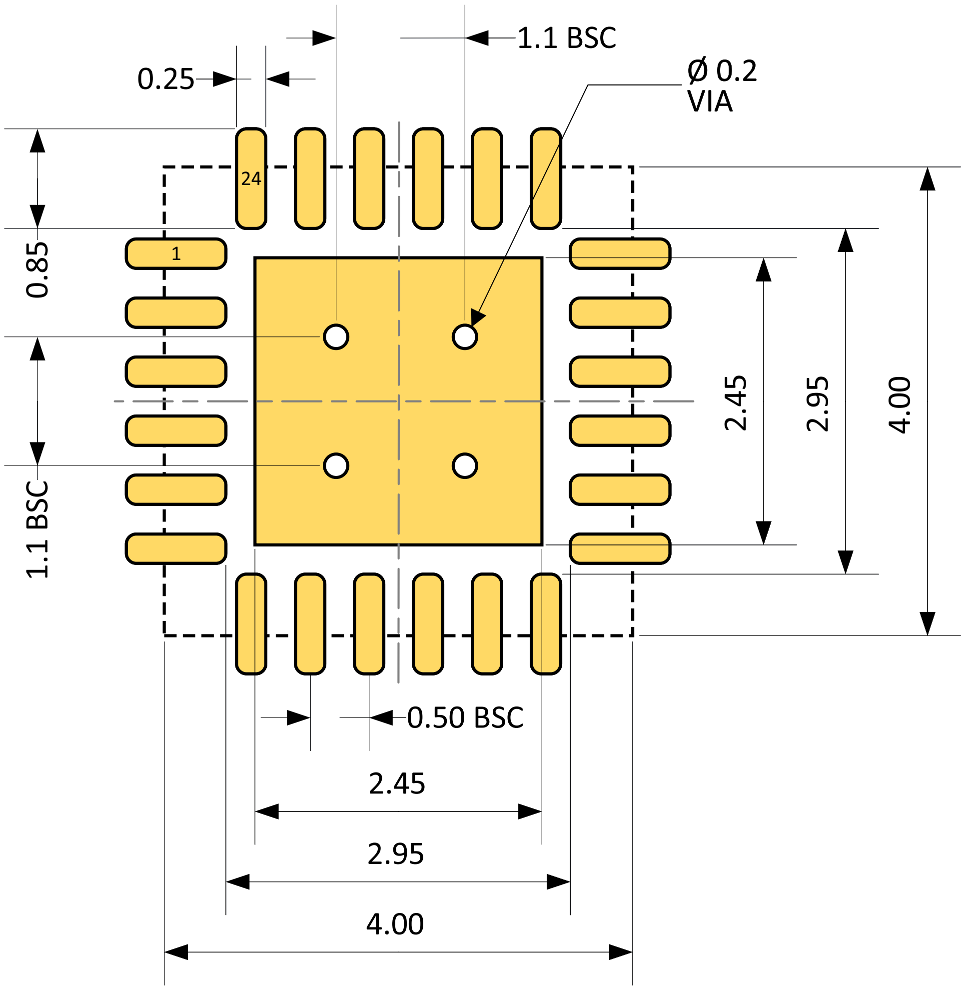


Figure 15: Recommended board layout for QFN24 package (all dimensions in mm)

10. Glossary

C_{5V}

Capacitor creating a RC filter with R_{5V} to slow down the rising time of the voltage on the 5V_IN pin.

C_{INT}

Decoupling capacitor on the VINT pin.

C_{LOAD}

Decoupling capacitor on LOAD pin.

C_{SRC}

Boost converter input capacitor.

D_{5V}

Zener diode that ensures that the voltage on 5V_IN stays below 5.5 V at any time.

$I_{5V,CC}$

Current provided to the storage element by the 5V_IN when in constant current mode.

$I_{Q,RESET}$

Quiescent current on STO when the AEM10920 is in RESET STATE.

$I_{Q,SHIP}$

Quiescent current drawn on the storage element when the AEM10920 is in shipping mode (SHIP_MODE is HIGH) with or without energy available on SRC.

$I_{Q,SLEEP}$

Quiescent current drawn on STO when the AEM10920 is in SLEEP STATE.

$I_{Q,SUPPLY}$

Quiescent current drawn on STO when the AEM10920 is in SUPPLY STATE.

L_{BOOST}

Boost converter inductor.

L_{BUCK}

Buck converter inductor.

$P_{R5V,CC}$

Power dissipated by R_{5V} with the 5 V charger constant current (CC).

$P_{R5V,idle}$

Power dissipated by R_{5V} when no current is pulled by the 5 V charger (current only flowing in the zener protection diode).

$P_{SRC,CS}$

Minimum power required on SRC for the AEM10920 to coldstart.

R_{5V}

Resistor creating a RC filter with C_{5V} to slow down the rising time of the voltage on the 5V_IN pin.

R_{5V_IMAX}

Resistor connected between 5V_IMAX and GND that defines the maximum current provided to the storage element by the 5 V charger (5V_IN pin).

R_{MPPT}

Ratio of V_{MPP} to V_{OC}.

T_{CRIT}

When V_{STO} drops below V_{OVDIS} in SUPPLY STATE, the AEM10920 waits for T_{CRIT} before switching to OVDIS STATE and disabling the LOAD output.

$T_{CRIT,ST}$

When V_{STO} drops below V_{OVDIS} in SUPPLY STATE, the AEM10920 waits for $T_{CRIT,ST}$ before setting ST_STO LOW.

$T_{GPIO,MON}$

GPIO reading rate.

$T_{MPPT,MEASURE}$

Duration of V_{OC} measurement during MPP evaluations

$T_{MPPT,PERIOD}$

Time between two MPP evaluations (see Table 9).

$T_{MPPT,WAIT}$

Wait time before V_{OC} measurmenent begins during MPP evaluations (see Table 9).

$T_{STO,MON}$

Storage element voltage monitoring rate.

V_{5V_IN}
: Voltage the 5V_IN pin.

$V_{5V\_IN,MIN}$
: Minimum voltage on the 5V_IN pin.

V_{CHRDY}
: Minimum voltage accepted on the storage element before starting to supply LOAD in START STATE (see Section 5.3).

V_{ESD}
: Electrostatic discharge voltage.

V_{INT}
: Voltage on the VINT pin.

$V_{INT,CS}$
: Minimum voltage on VINT to allow the AEM10920 to switch from RESET STATE to SENSE STO STATE.

$V_{INT,RESET}$
: Minimum voltage on VINT before switching to RESET STATE (from any other state).

V_{LOAD}
: Voltage on the LOAD pin.

V_{MPP}
: Target regulation voltage on SRC when extracting power.

V_{OC}
: Open circuit voltage of the harvester connected to SRC.

V_{OVCH}
: Maximum voltage accepted on the storage element before disabling its charging (see Section 5.3).

V_{OVDIS}
: Minimum voltage accepted on the storage element before stopping to supply LOAD (see Section 5.3).

V_{SRC}
: Voltage on the SRC pin.

$V_{SRC,CS}$
: Minimum voltage required on SRC for the AEM10920 to coldstart.

$V_{SRC,LOW}$
: V_{SRC} threshold below which the AEM10920 switches to SLEEP STATE.

V_{STO}
: Voltage on the STO pin.

11. Revision History

Revision	Date	Description
1.0	December, 2023	Creation of the document.
1.1	January, 2024	- "Configuration of MPP ratio and timings" table: fixed wrong column title. - Added typical application circuit.
1.2	January, 2024	- Added Glossary. - "LOAD Output Voltage" section: "buck voltage cannot be selected ~~smaller~~*higher* than V_{OVDIS}"
1.3	June, 2024	- L_{BUCK} in BOM in µH instead of µF. - Specified BOOST_CFG state when left floating in "Pin Configuration and Functions" section. - Added BOOST_CFG pin info to "Logic input pin connections" table. - Added cautionary statement about the AEM10920 storage element thresholds presets. - Added $I_{QSUPPLY}$ and I_{QSLEEP} values in "Electrical characteristics" table. - "State Machine Description" section: Added missing transition from START STATE to SUPPLY STATE when 5V charger is enabled.

1.4	June, 2024	- Added REACH and RoHS compliances.
		- Added info about 5 V charger voltage rise time limit and how to handle it.
		- Added cautionary statement along with storage element threshold voltages.
		- Corrected state machine transitions:
		    - From START_STATE to SUPPLY_STATE.
		    - From SUPPLY_STATE to SLEEP_STATE.
		- Pin description table: fixed pin 4 name.
		- Fixed cold start minimum power value.

Table 17: Revision history (part 1)

Revision	Date	Description

1.5	November, 2024	- Reworked of the first page.
		- Corrected the maximum input and output currents on the first page.
		- Modified MPPT voltage operation range minimum value to 120 mV on first page.
		- Added Absolute Maximum Ratings values.
		- Added ESD ratings table.
		- Added Moisture Sensitivity Level section.
		- Moved the RoHS and REACH compliances sections into the “Package Information” section.
		- Renamed “Typical Electrical Characteristics at 25°C” section to “Electrical Characteristics at 25°C”.
		- Modified the typ. minimum source power required for cold start to 1.5 µW.
		- Modified the evaluation board part number on first page.
		- Corrected pin 4 name to SRC in “Pins description” table.
		- Updated V_{MPP} maximum value to 0.90 x V_{STO}.
		- In “Recommended external components” table:
		    - Added BOOST_CFG configuration condition for L_{BOOST} values and the corresponding min. and typ. values.
		    - Modified L_{BUCK} typical value to 10 µH.
		    - Modified L_{BOOST} minimum values.
		    - Added minimum and typical values for C_{LOAD}.
		- In “Boost converter timings configuration” table:
		    - Modified L_{BOOST} minimum values for each boost converter timing.
		    - Added recommended L_{BOOST} values for best efficiency.
		- Added $V_{5V\_IN} \geq V_{STO}$ + 200 mV condition for the 5 V charger to operate in the different 5 V charger sections.
		- Added $V_{SRC,LOW}$ throughout the document.
		- Updated the state machine figure SLEEP STATE input and output conditions and the “Sleep State” section.
		- Modified “Example Circuit 1” section for R5V = 2.2 Ω and C5V = 47 µF.
		- Renamed “Performances” section to “Typical Characteristics” and moved it in “Specifications” section.
		- Updated “Minimum BOM” section to specify CSTO, LBUCK and CLOAD as optional.
		- Updated layout example figure by adding R5V, C5V, D5V and R5V_IMAX.
		- Updated package dimensions and added markings in “QFN 24-pin 4x4mm drawing” figure.
		- Added “Board Layout” section and figure.

1.6	December, 2024	- Updated the part number on first page to 10AEM10920A0001. - Added custom mode feature explanation throughout the document. - Updated the storage element protection threshold values. - Added disclaimer about V_{CHRDY} and V_{OVDIS} thresholds for LL and HH STO_CFG[1:0] configurations. - Removed constant voltage operation mode for 5 V charger. - Added notes to leave the buck converter enabled and to connect LOAD to STO when the 5 V charger is used. - Removed the “Logic input pin connections” table. - Added $T_{CRIT,ST}$ as the delay before setting ST_STO LOW when the storage element falls below V_{OVDIS}.

Table 17: Revision history (part 2)

Revision	Date	Description

1.7	November, 2025	- Added C_{STO} on first page schematic.
		- Renamed SRC_CFG[4:0] pins to SRC_LVL_CFG[4:0].
		- Updated the connection recommendation in the “Pin description” table for the custom mode pins when the custom mode is not used.
		- Updated ESD Charged-Device Model (CDM) value to +- 1000 V.
		- Updated maximum V_{MPP} value to 0.90 x V_{OC}.
		- Removed V_{INT} minimum and maximum values.
		- Removed $P_{5V\_IN,MIN}$ typical values.
		- Removed $I_{QSHIP,SRC}$ from the document.
		- Added $I_{Q,RESET}$ typical value.
		- Updated $T_{CRIT,ST}$ and $T_{GPIO,MON}$ typical values.
		- Added the storage element monitoring rate $T_{STO,MON}$.
		- Updated terminology for MPPT timing parameters throughout the document for improved clarity and consistency:
		  - $T_{MPPT,SAMPLING}$ modified to $T_{MPPT,WAIT}$.
		  - $T_{MPPT,MEASURE}$ added.
		- Updated C_{STO} typical value in the “Recommended external components” table.
		- Added “External Inductors Information” and “External Capacitors Information” sections.
		- Reworked the buck converter section and added M5 switch in the simplified schematic view of the buck converter.
		- Updated minimum V_{CHRDY} value to 2.50 V when using the custom mode.
		- Added the constant voltage operation explanations for the 5 V charger.
		- Updated the recommended L_{BOOST} value for each timing multipliers in the Boost Converter Timings section.
		- Updated figures to show C_{SRC} as 10 µF.
		- Added C_{STO} to multiple figures and applied minor visual adjustments.
		- Added the “Shipping Mode” sections.
		- Updated the “Minimum BOM” section to indicate C_{STO} as a required component.
		- Added tape and reel dimensions figure.
		- Updated package dimensions and board layout recommended dimensions.
		- Listed the glossary items alphabetically instead of by category.

Table 17: Revision history (part 3)

