



APPLICATION NOTE

AEM15820 APM Calibration Procedure



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1. Introduction

The AEM15820 Average Power Monitoring (APM) functionality allows the user to determine the power flowing in and out of the storage element connected to the **STO** pin:

- From the harvester connected to the **SRC** pin (boost converter)
- To the application circuit connected to the **LOAD** pin (buck converter)
- From the 5 V charger connected to the **5V_IN** pin.

The core principle of the calibration is to determine, for a given hardware implementation and for a given AEM15820 specimen, the factor that allows for converting the values read in the APM data registers (APMxBSTLP, APMxBSTHP, APMxLOAD and APMxCHG5V) to instantaneous electrical power, as seen by the storage element. This parameter is referred in the datasheet as the α parameter for the boost and buck converters, subscripted with the corresponding DCDC converter. The α factor is dimensionless.

Please note that the APM data can be integrated for determining the energy that the corresponding DCDC converter has transferred during a period of time. To do so with accuracy, the APM window must be determined by the applicative circuit, typically by measuring the time between two rising edges of the **IRQ** pin.

It is recommended that calibration is performed once per specimen at room temperature. Temperature affects the precision with which the APM measures power/energy.

The content of this document assumes that the reader has read the AEM15820 datasheet.

2. Equipment

The following equipment is needed for the described calibrations:

2.1. Source Measurement Unit (SMU)

A Source Measurement Unit (SMU) is a high-precision, 4-quadrant laboratory instrument that tightly integrates the capabilities of a precision power supply and a high-performance digital multimeter. It operates in two primary modes:

- **Voltage Source Mode:** The SMU regulates a precise voltage across the Device Under Test (DUT) by dynamically sourcing or sinking current. A user-defined current compliance (limit) is set to protect the circuit. The SMU maintains voltage regulation as long as the current demanded by the DUT remains below this compliance limit.
- **Current Source Mode:** The SMU forces a precise, constant current through the DUT by dynamically adjusting the output voltage. A user-defined voltage compliance (limit) is set to prevent overvoltage conditions. The SMU maintains current regulation as long as the resulting voltage across the DUT - dictated by its impedance ($V = I \times R$) - does not exceed this compliance limit.

2.2. Power Supply Unit (PSU)

Some of the tests described in this document require a power supply that provides a regulated voltage output with sufficient current capability to perform the tests described. It can be either a proper laboratory Power Supply Unit (PSU), or the output of a voltage regulator.

3. LP boost converter APM calibration

3.1. Calibration output

The output of the LP boost converter calibration is the $\alpha_{LP\ BOOST}$ factor, which is the factor that allows for converting the APM data - read in the AEM15820 APMxBSTLP register - to an electrical power value, as shown below:

$$P_{STO,LP\ BOOST} = \alpha_{LP\ BOOST} \cdot APM_{LP\ BOOST}$$

- $P_{STO,LP\ BOOST}$ is the power extracted from SRC and provided to STO by the LP boost converter.
- $APM_{LP\ BOOST}$ is the APM data value read in the AEM15820 register APMxBSTLP.

3.2. Hardware setup

The calibration of the LP boost converter APM requires the following equipment:

- 1 computer with Windows OS running the AEM15820 Configuration GUI.
- 1 circuit with the AEM15820 and its external components:
 - The calibration must be done for each circuit specimen.
 - The harvester, storage element and application circuit must be disconnected from the AEM15820 circuit.
- 1 Source Measurement Unit (SMU). Using the SMU in four-wire mode is optional but leads to more accurate results.
- 1 Power Supply Unit (PSU).
- 1 resistor, whose value is determined in Section 3.3.

Wire the equipment as shown in Figure 1.

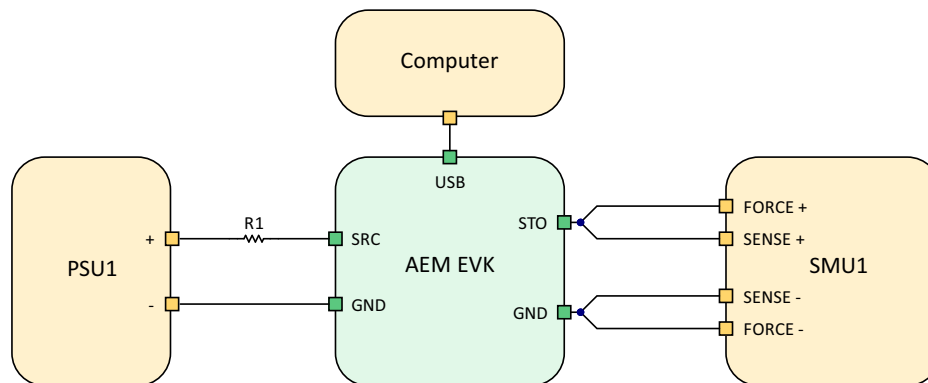


Figure 1: LP boost converter APM calibration base setup

The calibration process begins with both SMU1 and PSU1 switched OFF.

3.3. Determine the operating conditions

Best results are achieved when the user calibrates the α_{LP_BOOST} factor as close as possible to the expected system operating conditions described in the current section.

Storage element calibration voltage

The storage element voltage range is defined by setting the following parameters of the AEM15820:

- V_{OVDIS} is the minimum voltage below which the storage element is considered to be fully discharged.
- V_{OVCH} is the maximum voltage above which the storage element is considered to be fully charged.

The calibration voltage $V_{STO,CALIB}$ on **STO** is then determined as follows:

$$V_{STO,CALIB} = \frac{V_{OVCH} + V_{OVDIS}}{2}$$

Source calibration voltage

The source voltage range is to be determined from the specifications of the harvester.

- $V_{MPP,MIN}$ is the harvester's minimum Maximum Power Point (MPP) voltage, typically obtained when the harvester is under the lowest ambient energy (e.g. for a PV cell, the lowest considered luminosity).
- $V_{MPP,MAX}$ is the harvester's maximum MPP voltage, typically obtained when the harvester is under the highest ambient energy (e.g. for a PV cell, the highest considered luminosity).

The calibration voltage $V_{SRC,CALIB}$ on **SRC** is determined as follows:

$$V_{SRC,CALIB} = \frac{V_{MPP,MAX} + V_{MPP,MIN}}{2}$$

Source series resistance and PSU voltage

Select a source series resistance **R1** between 100 Ω and 1 k Ω and the PSU voltage V_{PSU1} as follows, to obtain a source current of roughly 10 mA:

$$V_{PSU1} = R1 \cdot 10 \times 10^{-3} + V_{SRC,CALIB}$$

$$V_{PSU1} < V_{STO}$$

Please note that the exact value of the source current is not critical as only the current on **STO** matters for determining the α_{LP_BOOST} factor. Any source current between 5 mA and 15 mA is fine for calibrating the APM, but V_{PSU1} must be configured so that its voltage is below V_{STO} .



3.4. Calibration protocol

3.4.1. Step 1: Supply STO

Referring to Figure 1, configure SMU1 as follows:

- **Mode:** Voltage source.
- **Voltage:** Set the voltage of SMU1 to $V_{STO,CALIB}$ as determined in Section 3.3.
- **Current compliance:** Set the current compliance to 100 mA.
- **Measurement mode:** Four-wire measurement mode is preferred for best measurement accuracy. Two-wire mode works as well if four-wire mode is not available.

Switch ON SMU1.

3.4.2. Step 2: Supply SRC

Referring to Figure 1, configure PSU1 as follows:

- **Voltage:** Set the voltage of PSU1 V_{PSU1} so that it is at least 500 mV above $V_{SRC,CALIB}$ as determined in Section 3.3. Also make sure that $V_{SRC,CALIB}$ is below the storage element voltage $V_{STO,CALIB}$.
- **Current compliance:** Set the current compliance to 100 mA (at least higher than I_{R1}).
- Place **R1** - as determined in Section 3.3 - between PSU1 positive terminal and the AEM15820 EVK **SRC** terminal.

Switch ON PSU1.

Wait a few seconds for the AEM15820 to coldstart. Cold start is finished when **VINT** reaches its 2.2 V regulation voltage.



3.4.3. Step 3: Configure the AEM15820 registers through I²C communication

Use the AEM15820 Configuration GUI, that can be downloaded from *e-peas website*.

Make sure to set the following parameters according to the operating conditions defined in Section 3.3:

- Boost settings:
 - Set the boost timing multiplier according to the target application requirements.
- Source settings:
 - Set **SRC** mode to constant voltage.
 - Set the constant voltage level to $V_{\text{SRC,CALIB}}$.
- Storage element threshold voltages:
 - Set V_{OVDIS} at least 300 mV below $V_{\text{STO,CALIB}}$.
 - Set V_{CHRDY} at least 200 mV below $V_{\text{STO,CALIB}}$.
 - Set V_{OVCH} at least 200 mV above $V_{\text{STO,CALIB}}$.
- Disable the **LOAD** buck converter.
- APM configuration:
 - Enable the APM for the LP boost converter.
 - Set the APM mode to “power”.
 - Set the APM window to the one required by the application (generally the longest available).
 - Set the APM accumulator to 1.
- Disable the thermal protection.
- Write the configuration to the AEM15820 and make sure writing is successful.



3.4.4. Step 4: Run the measurement and determine the $\alpha_{LP\ BOOST}$ factor

In the Configuration GUI:

- Navigate to the “Monitoring” tab.
- Set the “ALPHA” parameter of the LP boost converter to 1.
- Click on the “Start Monitoring” button to start reading the APM.
- Click on “Reset Power Averaging”.

On SMU1, read the power that is provided from SRC to STO. For best accuracy, use the averaging capability of the SMU and read the averaged value.

Let the measure run for about a minute and determine the $\alpha_{LP\ BOOST}$ factor as follows:

$$\alpha_{LP\ BOOST} = \frac{I_{STO,SMU} \cdot V_{STO,CALIB}}{APM_{LP\ BOOST,AVERAGE}} = \frac{P_{STO,SMU}}{APM_{LP\ BOOST,AVERAGE}}$$

- $APM_{LP\ BOOST,AVERAGE}$ is the average APM value as read on the AEM15820 Configuration GUI “APM Average [W]”.
- $I_{STO,SMU}$ is the (average) current read on SMU1.
- $P_{STO,SMU}$ is the (average) power read on SMU1.

3.4.5. Step 5: Apply the calibration result

Configuration GUI

Apply the previously determined $\alpha_{LP\ BOOST}$ factor to the configuration GUI field.

The power/energy results displayed when running the “Monitoring Mode” should be consistent with those transferred to the STO pin.

Application firmware

The values read from the APMxSRC registers can now be converted to power (watts) by multiplying them by the $\alpha_{LP\ BOOST}$ factor. The energy (in Joules) can then be calculated by multiplying the power value by the duration of the APM window, ideally as measured by the application circuit.

4. HP boost converter APM calibration

Please note that the calibration of the HP boost converter relies on the results of the calibration of the LP boost converter ($\alpha_{LP\ BOOST}$ is needed to determine $\alpha_{HP\ BOOST}$). Thus, it must be done after the calibration of the LP boost converter.

4.1. Calibration output

The output of the HP boost converter calibration is the $\alpha_{HP\ BOOST}$ factor, which is the factor that allows for converting the APM data - read in the AEM15820 APMxBSTHP register - to an electrical power value, for a given couple of SRC and STO voltages (V_{SRC} , V_{STO}), as shown below:

$$P_{STO,HP\ BOOST}(V_{SRC}, V_{STO}) = \alpha_{HP\ BOOST}(V_{SRC}, V_{STO}) \cdot APM_{HP\ BOOST}$$

- $P_{STO,HP\ BOOST}(V_{SRC}, V_{STO})$ is the power extracted from SRC and provided to STO by the HP boost converter, at a given (V_{SRC} , V_{STO}) voltage couple.
- $APM_{HP\ BOOST}$ is the APM data value read in the AEM15820 APMxBSTHP register.

The use of external components for the HP boost converter switching does not allow for internal compensation as for the LP boost converter, so the values given above are all depending on V_{SRC} and V_{STO} . Nevertheless, to streamline the process of calibrating the $\alpha_{HP\ BOOST}$ factor, the calibration is performed at $V_{SRC,CALIB}$ and $V_{STO,CALIB}$, and then each measure is extrapolated from those values as follows:

$$P_{STO,HP\ BOOST}(V_{SRC}, V_{STO}) = \alpha_{HP\ BOOST,CALIB} \cdot APM_{HP\ BOOST} \cdot \frac{V_{STO} \cdot (V_{STO,CALIB} - V_{SRC,CALIB})}{V_{STO,CALIB} \cdot (V_{STO} - V_{SRC})}$$

- $\alpha_{HP\ BOOST,CALIB}$ is the factor obtained by calibrating the HP boost converter at $V_{SRC,CALIB}$ and $V_{STO,CALIB}$.
- $V_{SRC,CALIB}$ is the SRC voltage at which the calibration has been done.
- $V_{STO,CALIB}$ is the STO voltage at which the calibration has been done.
- $APM_{HP\ BOOST}$ is the value read in the HP boost converter APM data register APMxBSTHP.
- V_{SRC} is the current voltage on the SRC pin, that can be read from the AEM15820 SRC register.
- V_{STO} is the current voltage on the STO pin, that can be read from the AEM15820 STO register.

4.2. Hardware setup

The calibration of the HP boost converter APM requires the following equipment:

- 1 computer with Windows OS running the AEM15820 Configuration GUI.
- 1 circuit with the AEM15820 and its external components:
 - The calibration must be done for each circuit specimen.
 - The harvester, storage element and application circuit must be disconnected from the AEM15820 circuit.
- 1 Source Measurement Unit (SMU). Using the SMU in four-wire mode is optional but leads to more accurate results.
- 1 Power Supply Unit (PSU).
- 1 resistor, whose value is determined in Section 4.3.

Wire the equipment as shown in Figure 2.

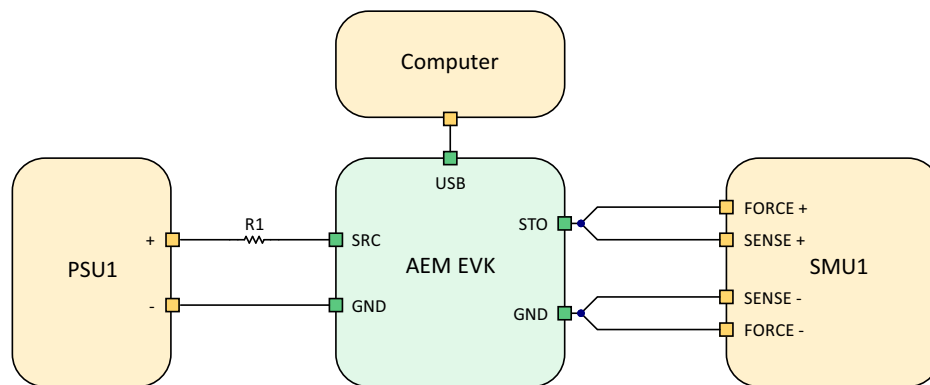


Figure 2: HP boost converter APM calibration base setup

The calibration process begins with both SMU1 and PSU1 switched OFF.

4.3. Determine the operating conditions

Best results are achieved when the user calibrates both the $\alpha_{LP\ BOOST}$ and the $\alpha_{HP\ BOOST}$ factors as close as possible to the expected system operating conditions:

Storage element calibration voltage

Determine the storage element voltage for calibration $V_{STO,CALIB}$ as described in Section 3.3.

Source calibration voltage

The source voltage for HP boost converter calibration $V_{SRC,CALIB}$ is the same as the one for the LP boost converter, whose value is determined in Section 3.2.

Source series resistance and PSU voltage

Select a source series resistance $R1$ between 5 Ω and 50 Ω and the PSU voltage V_{PSU1} as follows, to obtain a source current of roughly 200 mA:

$$V_{PSU1} = R1 \cdot 200 \times 10^{-3} + V_{SRC,CALIB}$$

$$V_{PSU1} < V_{STO}$$

Please note that the exact value of the source current is not critical as only the current on **STO** matters for determining the $\alpha_{LP\ BOOST}$ factor. Any source current between 150 mA and 250 mA is fine for calibrating the APM, but V_{PSU1} must be configured so that its voltage is below V_{STO} .

Please note that the resistance power rating P_{R1} must be sufficient to stand this current I_{R1} without overheating:

$$P_{R1} > R1 \cdot I_{R1}^2$$

For instance, with 10 Ω at 200 mA, $R1$ must be rated more than 0.4 W.



4.4. Calibration protocol

4.4.1. Step 1: Supply STO

Referring to Figure 2, configure SMU1 as follows:

- **Mode:** Voltage source.
- **Voltage:** Set the voltage of SMU1 to $V_{STO,CALIB}$ as determined in Section 4.3.
- **Current compliance:** Set the current compliance to 1 A.
- **Measurement mode:** Considering the currents involved with the HP boost converter, four-wire measurement mode is highly recommended for best measurement accuracy.

Switch ON SMU1.

4.4.2. Step 2: Supply SRC

Referring to Figure 2, configure PSU1 as follows:

- **Voltage:** Set the voltage of PSU1 V_{PSU1} so that it is at least 500 mV above $V_{SRC,CALIB}$ as determined in Section 4.3. Also make sure that $V_{SRC,CALIB}$ is below the storage element voltage $V_{STO,CALIB}$.
- **Current compliance:** Set the current compliance to 1 A (at least higher than I_{R1}).
- Place **R1** - as determined in Section 4.3 - between PSU1 positive terminal and the AEM15820 EVK **SRC** terminal.

Switch ON PSU1.

Wait a few seconds for the AEM15820 to coldstart. Cold start is finished when **VINT** reaches its 2.2 V regulation voltage.



4.4.3. Step 3: Configure the AEM15820 registers through I²C communication

Use the AEM15820 Configuration GUI, that can be downloaded from *e-peas website*.

Make sure to set the following parameters according to the operating conditions defined in Section 4.3:

- Boost settings:
 - Set the boost timing multiplier according to the target application requirements.
- Source settings:
 - Set **SRC** mode to constant voltage.
 - Set the constant voltage level to $V_{\text{SRC,CALIB}}$.
- Storage element threshold voltages:
 - Set V_{OVDIS} at least 300 mV below $V_{\text{STO,CALIB}}$.
 - Set V_{CHRDY} at least 200 mV below $V_{\text{STO,CALIB}}$.
 - Set V_{OVCH} at least 200 mV above $V_{\text{STO,CALIB}}$.
- Disable the **LOAD** buck converter.
- APM configuration:
 - Enable the APM for both the LP boost converter and the HP boost converter.
 - Set the APM mode to “power”.
 - Set the APM window to the one required by the application (generally the longest available).
 - Set the APM accumulator to 1.
- Disable the thermal protection.
- Write the configuration to the AEM15820 and make sure writing is successful.

4.4.4. Step 4: Run the measurement and determine the $\alpha_{\text{HP BOOST}}$ factor

In the Configuration GUI:

- Navigate to the “Monitoring” tab.
- Set the “ALPHA” parameter of the LP boost converter to the value determined in Section 3.
- Set the “ALPHA” parameter of the HP boost converter to 1.
- Set the “VSRC [V] (calibration)” parameter to $V_{\text{SRC,CALIB}}$.
- Set the “VSTO [V] (calibration)” parameter to $V_{\text{STO,CALIB}}$.
- Click on the “Start Monitoring” button to start reading the APM.
- Click on “Reset Power Averaging”.

On SMU1, read the power that is provided from SRC to STO. For best accuracy, use the averaging capability of the SMU and read the averaged value.

Let the measure run for about a minute and determine the $\alpha_{\text{HP BOOST}}$ factor as follows, removing the participation of the LP boost converter to isolate the one of the HP boost converter:

$$\alpha_{\text{HP BOOST}} = \frac{I_{\text{STO,SMU}} \cdot V_{\text{STO,CALIB}} - \text{APM}_{\text{LP BOOST,AVERAGE}} \cdot \alpha_{\text{LP BOOST}}}{\text{APM}_{\text{HP BOOST,AVERAGE}}}$$
$$\alpha_{\text{HP BOOST}} = \frac{P_{\text{STO,SMU}} - \text{APM}_{\text{LP BOOST,AVERAGE}} \cdot \alpha_{\text{LP BOOST}}}{\text{APM}_{\text{HP BOOST,AVERAGE}}}$$

- $\text{APM}_{\text{LP BOOST,AVERAGE}}$ is the average APM value for the LP boost converter as read on the AEM15820 Configuration GUI “APM Average [W]”.
- $\alpha_{\text{LP BOOST}}$ is the factor for the LP boost converter as determined in Section 3.
- $\text{APM}_{\text{HP BOOST,AVERAGE}}$ is the average APM value for the HP boost converter as read on the AEM15820 Configuration GUI “APM Average [W]”.
- $I_{\text{STO,SMU}}$ is the (average) current read on SMU1.
- $P_{\text{STO,SMU}}$ is the (average) power read on SMU1.

4.4.5. Step 5: Apply the calibration result

Configuration GUI

Apply the previously determined $\alpha_{\text{HP BOOST,CALIB}}$ factor to the configuration GUI field, as well as the SRC and STO calibration voltages $V_{\text{SRC,CALIB}}$ and $V_{\text{STO,CALIB}}$.

The power/energy results displayed when running the “Monitoring Mode” should be consistent with those transferred from the STO pin.

Application firmware

The values read from the APMxSRC registers can now be converted to power (watts) by applying the formula from Section 4.1. The energy (in Joules) can then be calculated by multiplying the power value by the duration of the APM window, ideally as measured by the application circuit.

5. LOAD buck APM calibration

5.1. Calibration output

The output of the **LOAD** buck calibration is the α_{LOAD} factor, which is the factor that allows for converting the APM data - read in the AEM15820 APMxLOAD register - to an electrical power value, as shown below:

$$P_{\text{STO,LOAD}} = \alpha_{\text{LOAD}} \cdot \text{APM}_{\text{LOAD}}$$

- $P_{\text{STO,LOAD}}$ is the power provided by **STO** to **LOAD**.
- APM_{LOAD} is the APM data value read in the AEM15820 APMxLOAD register.

5.2. Hardware setup

The calibration of the **LOAD** APM requires the following equipment:

- 1 computer with Windows OS running the AEM15820 Configuration GUI.
- 1 circuit with the AEM15820 and its external components:
 - The calibration must be done for each circuit specimen.
 - The harvester, storage element and application circuit must be disconnected from the AEM15820 circuit.
- 1 Source Measurement Unit (SMU). Using the SMU in four-wire mode is optional but leads to more accurate results.
- 1 resistor, whose resistance is between 500 Ω and 2 k Ω (resistance precision is not critical).

Wire the equipment as shown in Figure 3. Please note that if the calibration of **LOAD**'s buck converter is done right after the calibration of the LP boost converter (described in Section 3), PSU1 can be left connected to **SRC** to coldstart the AEM15820. Otherwise, the AEM15820 can be coldstarted from the 5V charger as described in Section 5.4.2.

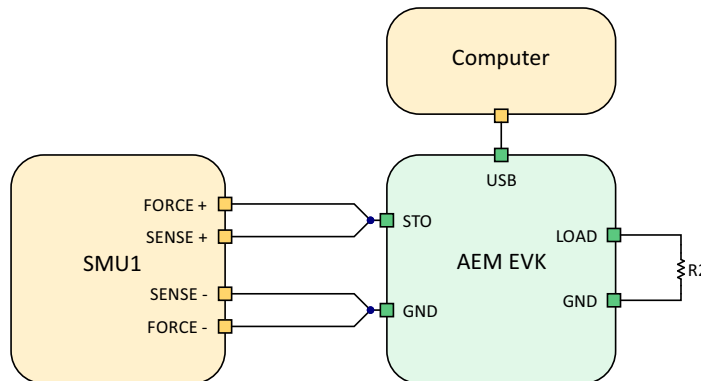


Figure 3: LOAD APM calibration base setup

The calibration process begins with SMU1 switched OFF.



5.3. Determine the operating conditions

Best results are achieved when the user calibrates the α_{LOAD} factor as close as possible to the expected system operating conditions:

Storage element calibration voltage

Determine the storage element voltage for calibration $V_{\text{STO,CALIB}}$ as described in Section 3.3.

LOAD resistance

Configure $R2$ so that a few mA (typically 5 mA) are pulled from the **LOAD** pin, considering the **LOAD** regulation voltage required by the application circuit.

$$R2 = \frac{V_{\text{LOAD}}}{10 \times 10^{-3}}$$

Please note that the exact value of the **LOAD** current is not critical as only the current on **STO** matters for determining the α_{LOAD} factor. Any source current between 1 mA and 15 mA is fine for calibrating the APM.



5.4. Calibration protocol

5.4.1. Step 1: Supply STO

Referring to Figure 3, configure SMU1 as follows:

- **Mode:** Voltage source.
- **Voltage:** Set the voltage of SMU1 to $V_{STO,CALIB}$ as determined in Section 5.3.
- **Current compliance:** Set the current compliance to 100 mA.
- **Measurement mode:** Four-wire measurement mode is preferred for best measurement accuracy. Two-wire mode works as well if four-wire mode is not available.

Switch ON SMU1.

5.4.2. Step 2: Coldstart the AEM15820

Two solutions for coldstarting the AEM15820:

- Use PSU1 from the SRC calibration and set the voltage/current of PSU1 above the cold-start voltage/current defined in the datasheet. It is then mandatory to switch off/remove PSU1 for the calibration (PSU1 is not shown on Figure 3).
- Connect a jumper on the "VUSB-5V_IN" header and leave it for 10 seconds. Once the AEM15820 has coldstarted, it is mandatory to remove the jumper to continue with the calibration process.

Please note that the cold start is finished when V_{INT} reaches its 2.2 V regulation voltage.



5.4.3. Step 3: Configure the AEM15820 registers through I²C communication

Use the AEM15820 Configuration GUI, that can be downloaded from *e-peas website*.

Make sure to set the following parameters according to the operating conditions defined in Section 5.3:

- Boost settings:
 - Disable both boost converters.
- Storage element threshold voltages:
 - Set V_{OVDIS} at least 300 mV below $V_{STO,CALIB}$.
 - Set V_{CHRDY} at least 200 mV below $V_{STO,CALIB}$.
 - Set V_{OVCH} at least 200 mV above $V_{STO,CALIB}$.
- **LOAD** buck converter configuration according to the application circuit requirements:
 - Set the buck timing multiplier.
 - Set the **LOAD** voltage.
- APM configuration:
 - Enable the APM for **LOAD**.
 - Set the APM mode to “power”.
 - Set the APM window to the one required by the application (generally the longest available).
 - Set the APM accumulator to 1.
- Disable the thermal protection.
- Write the configuration to the AEM15820 and make sure writing is successful.



5.4.4. Step 4: Run the measurement and determine the α_{LOAD} factor

In the Configuration GUI:

- Navigate to the “Monitoring” tab.
- Set the “ALPHA” parameter of **LOAD** to 1.
- Click on the “Start Monitoring” button to start reading the APM.
- Click on “Reset Power Averaging”.

On SMU1, read the power that is provided from **STO** to **LOAD**. For best accuracy, use the averaging capability of the SMU and read the averaged value.

Let the measure run for about a minute and determine the α_{LOAD} factor as follows:

$$\alpha_{LOAD} = \frac{I_{STO,SMU} \cdot V_{STO,CALIB}}{APM_{LOAD,AVERAGE}} = \frac{P_{STO,SMU}}{APM_{LOAD,AVERAGE}}$$

- $APM_{LOAD,AVERAGE}$ is the average APM value as read on the AEM15820 Configuration GUI “APM Average [W]”
- $I_{STO,SMU}$ is the (average) current read on SMU1.
- $P_{STO,SMU}$ is the (average) power read on SMU1.

5.4.5. Step 5: Apply the calibration result

Configuration GUI

Apply the previously determined α_{LOAD} factor to the configuration GUI field.

The power/energy results displayed when running the “Monitoring Mode” should be consistent with those transferred from the **STO** pin.

Application firmware

The values read from the APMxLOAD registers can now be converted to power (watts) by multiplying them by the α_{LOAD} factor. The energy (in Joules) can then be calculated by multiplying the power value by the duration of the APM window, ideally as measured by the application circuit.

6. 5V_IN (5V charger) APM calibration

6.1. Calibration output

Unlike the boost and buck converters, the 5V charger APM calibration does not produce an alpha factor. Its output is the actual charging current provided to [STO](#).

Along with the APM period and the 5V charger's charging duty cycle (see AEM15820 datasheet), this value allows for calculating the power/energy transferred by the 5V charger to the storage element.

6.2. Hardware setup

The calibration of the 5V charger APM requires the following equipment:

- 1 computer with Windows OS running the AEM15820 Configuration GUI.
- 1 circuit with the AEM15820 and its external components:
 - The calibration must be done for each circuit specimen.
 - The harvester, storage element and application circuit must be disconnected from the AEM15820 circuit.
- 1 Source Measurement Unit (SMU). Using the SMU in four-wire mode is optional but leads to more accurate results.
- Optional: as shown in Figure 4, a PSU can be used as energy source for the 5V charger if the user does not want to pull the charging current USB from the computer.

Wire the equipment as shown in Figure 4.

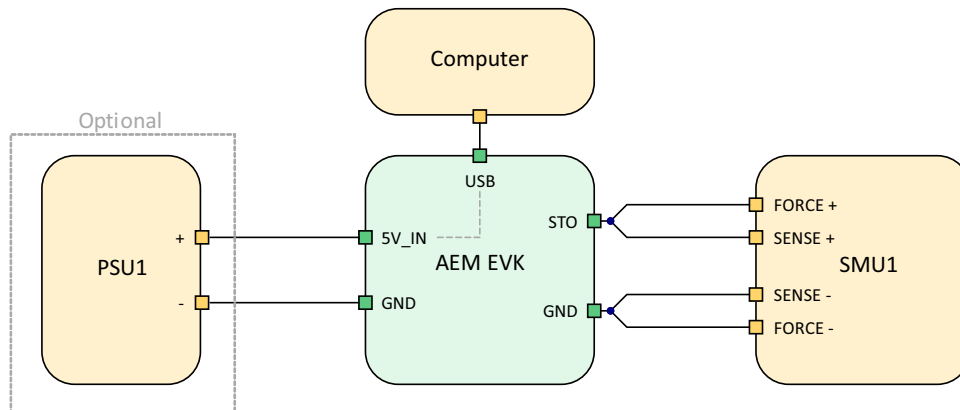


Figure 4: 5V charger APM calibration base setup

The calibration process begins with SMU1 (and optional PSU1) switched OFF.

6.3. Determine the operating conditions

Best results are achieved when the user calibrates the 5V charger current as close as possible to the expected system operating conditions:

Storage element calibration voltage

Determine the storage element voltage for calibration $V_{STO,CALIB}$ as described in Section 3.3.

5V charger current setting

The 5V charger current setting must be set according to the application circuit requirements, typically by the storage element maximum charging current.



6.4. Calibration protocol

6.4.1. Step 1: Supply STO

Referring to Figure 4, configure SMU1 as follows:

- **Mode:** voltage source.
- **Voltage:** set the voltage of SMU1 to $V_{STO,CALIB}$ as determined in Section 3.3.
- **Current compliance:** set the current compliance so that the SMU can absorb at least 1.5x the 5V charger current.
- **Measurement mode:** four-wire measurement mode is preferred for best measurement accuracy. Two-wire mode works as well if four-wire mode is not available.

Switch ON SMU1.

6.4.2. Step 2: Coldstart the AEM15820

Let the AEM15820 coldstart from the energy source connected to the 5V charger $5V_IN$.

Please note that the cold start is finished when V_{INT} reaches its 2.2 V regulation voltage.

6.4.3. Step 3: Configure the AEM15820 registers through I²C communication

Use the AEM15820 Configuration GUI, that can be downloaded from *e-peas website*.

Make sure to set the following parameters according to the operating conditions defined in Section 6.3:

- Boost settings:
 - Disable all boost converters.
- Storage element threshold voltages:
 - Set V_{OVDIS} at least 300 mV below $V_{STO,CALIB}$.
 - Set V_{CHRDY} at least 200 mV below $V_{STO,CALIB}$.
 - Set V_{OVCH} at least 200 mV above $V_{STO,CALIB}$.
- $LOAD$ buck converter settings:
 - Disable the $LOAD$ buck converter.
- 5V charger configuration:
 - Enable the 5V charger.
 - If constant voltage mode is to be enabled, make sure the threshold for constant voltage mode is at least 200 mV higher than $V_{STO,CALIB}$.
- APM configuration:
 - Enable the APM for the 5V charger.
 - Note: the APM mode does not have any impact on the 5V charger APM.
 - Set the APM window to the one required by the application (generally the longest available).
 - Set the APM accumulator to 1.
- Disable the thermal protection.
- Write the configuration to the AEM15820 and make sure writing is successful.



6.4.4. Step 4: Measure the 5V charger current

Read the current $I_{STO,5V,SMU}$ sunk by SMU1, which is the current provided by the 5V charger to **STO**.

6.4.5. Step 5: Apply the calibration result

Configuration GUI

Apply the previously determined $I_{STO,5V,SMU}$ factor to the configuration GUI field.

The power/energy results displayed when running the “Monitoring Mode” should be consistent with those transferred from the **STO** pin.

Application firmware

The values read from the APMxCHG5V registers can now be converted to power (watts) as follows:

$$P_{CHG5V} = D_{CHG} \cdot I_{STO,5V,SMU} \cdot V_{STO}$$

- D_{CHG} is determined as described in the AEM15820 datasheet.
- V_{STO} can be determined by reading the STO register.

To convert the results into energy, multiply the power by the APM window, ideally as measured by the application circuit.



7. Revision history

Revision	Date	Description
1.0	07/09/2026	Creation of the document.

Table 1: Revision history