



# Guidelines for Testing SynQor DC-DC Converters



## Summary

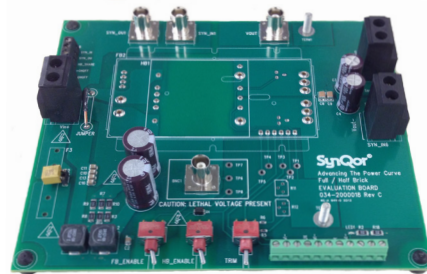
This application note provides brief descriptions and guidelines for electrical evaluation tests of DC-DC converters.

## Introduction

This application note provides guidelines for testing many features of SynQor DC-DC converters. These tests can be facilitated by use of SynQor evaluation boards, available for purchase. Please refer to the specific application note for each evaluation board for detailed information about connections, schematic, component placement, and parts list.

The following is a list of evaluation tests discussed in this document.

- A) Initial Power-up
- B) Input Under-Voltage Turn-On Threshold
- C) Input Under-Voltage Turn Off Threshold
- D) Input Lockout Hysteresis Voltage
- E) Input Voltage Range
- F) No Load Input Current
- G) Disabled Input Current
- H) Line Regulation
- I) Load Regulation
- J) Output Ripple
- K) Output DC Current-Limit Inception
- L) Output Voltage Deviation and Response Time Due to Step Change in Input Voltage
- M) Output Voltage Deviation and Response Time Due to Step Change in Load Current
- N) Soft Start Turn-On Time
- O) Efficiency



**Safety and ESD:** When setting up and operating electrical equipment, ensure standard safety and ESD guidelines are followed.

**Shock Warning:** There are areas of SynQor evaluation boards that have exposed access to high voltage. Exercise caution to avoid contact with those voltages. Also note that the evaluation board may retain high voltage temporarily after input power has been removed. Exercise caution when handling.

**Application of Input Power:** Never apply input power to a converter with a switch closure, such as a knife switch or circuit breaker. That type of action applies input voltage with an uncontrolled very high rate of rise (dV/dt) that could be damaging to the converter and to external components before the converter. Instead, apply input voltage with a controlled rate of rise. Also, ensure input voltage is off before inserting or removing a converter module from the evaluation board.

**Sockets:** Please note that SynQor evaluation boards typically use sockets to provide the option of testing multiple converters. These sockets are not rated for continuous high currents. Short-term testing is fine, but be aware of this limitation for longer-term testing. The spring fingers in the sockets will add resistance in the power path, which will cause voltage drops at higher currents that could contribute significant errors in regulation and efficiency measurements. (This limitation is compensated for on some evaluation boards with Kelvin connections.) These spring fingers also do not provide the thermal cooling path from the module pins to PCB routing that is enabled by soldered connections. This may contribute to higher converter temperatures and error when performing thermal evaluations. For longer-term testing, thermal testing, and permanent installations use soldered connections.

**Thermal Considerations:** When testing converters on an evaluation board, ensure adequate cooling. Apply cooling air with a fan blowing across the converter or across a heatsink attached to the converter. Monitor the converter temperature to ensure it doesn't exceed the maximum rated per the datasheet specification.

**Kelvin Connections:** Power module input voltage and output voltage measurements should always be measured at the power module pins using Kelvin connections. They should not be measured at the evaluation board connectors or at the pin sockets. Measuring module input or output voltage other than at Kelvin connection test points will result in measurement error.

**BNC Caution:** BNC test connectors may not have common grounds. Refer to the evaluation board information to determine BNC ground connections to avoid shorting out connections on your evaluation board through the oscilloscope probes.

### Equipment Required

- Evaluation Board
- Power Supply (voltage & current range depends on which converter is being tested)
- Oscilloscope and probes
- Digital Voltmeters (DVM)
- Load, electronic or resistive
- Current shunts
- BNC cables and adapters
- Fan(s)

## Set-up

- Size wire connections according to maximum dc current.
- Connect the positive lead of the input power supply source to Vin+ on the evaluation board input connector.
- Connect the return lead of the input power supply source to Vin-.
- Connect Vout+ from the evaluation board output to a current shunt. Connect the other side of this current shunt to the positive lead of the load. Connect Vout- from the board output to the return lead of the load.
- Connect an external switch or control to the Enable control terminal at the board connector. Otherwise, leave the connector terminal open and use the On/Off switch provided on the evaluation board.
- Put output voltage trim switch in desired position for no trim, trim up, or trim down. If trimming, set the trim pot to the desired position.
- If the evaluation board is configured with remote sense jumpers, then decide on a remote or local sense configuration and connect jumpers as needed. If using the remote-sense feature to sense at the load use a twisted-wire pair to make the connection from the evaluation board remote-sense output connector to the load sense location.
- Use Kelvin connections for Digital Volt Meter (DVM) measurements of module input voltage and module output voltage.

## A) Initial Power-up

- 1) Ensure the Enable signal or switch (external or evaluation board switch) is in the off position.
- 2) Turn on the fan(s).
- 3) Turn on the input source power supply and increase its voltage until the desired value is reached.
- 4) Enable the converter using the Enable signal or switch.
- 5) Verify the proper output voltage is present on the power converter output with a DVM, oscilloscope, or both.
- 6) The converter can also be turned on by first putting the Enable signal or switch in the “on” state and then either turning on the power supply by ramping up its voltage manually from zero to the desired value, or by presetting the power supply to the desired voltage and rise time and then switching it on.

**CAUTION:** Do not use a knife switch, circuit breaker, or similar device to apply input voltage to the converter with a fast rise time. Fast rise times are not normal equipment operation and can cause damage to the converter and other circuits on the input of the converter.

- 7) Toggle the Enable signal or switch to the “off” position, remove input power, turn off the fan(s).

## B) Input Under-Voltage Turn-On Threshold

The input under-voltage turn-on threshold is defined as the input voltage at which the pre-enabled converter first turns on as the input voltage is increased from zero.

- 1) Set the input voltage source to zero.
- 2) Turn on the fan(s).
- 3) Enable the converter using the Enable signal or switch.
- 4) Slowly increase the input voltage from zero while monitoring the input voltage and output voltage with a DVM and/or oscilloscope. Continue increasing the input voltage until the output voltage appears. Record the input voltage. The input voltage should be within the range given in the datasheet at “Input Characteristics”, “Input Under-Voltage Lockout”, “Turn-On Voltage Threshold”.
- 5) Toggle the Enable signal or switch to the “off” position, remove input power, turn off the fan(s).

## C) Input Under-Voltage Turn-Off Threshold

The input under-voltage turn-off threshold is defined as the input voltage at which the properly operating converter turns itself off as the input voltage is decreased below the operating range.

- 1) Disable the converter using the Enable signal or switch.
- 2) Set the input voltage source to the minimum input voltage specified in the datasheet.
- 3) Turn on the fan(s).
- 4) Enable the converter using the Enable signal or switch.
- 5) Verify that the output voltage is present.
- 6) Slowly reduce the input voltage until the converter turns off. Record the input voltage at this point. The input voltage should be within the range given in the datasheet at “Input Characteristics”, “Input Under-Voltage Lockout”, “Turn-Off Voltage Threshold”.
- 7) Toggle the Enable signal or switch to the “off” position, remove input power, turn off the fan(s).

## D) Input Lockout Hysteresis Voltage

The input lockout hysteresis voltage is the difference between the input voltage at which the converter turns on (input under-voltage turn-on threshold) and that at which it turns off (input under-voltage turn-off threshold) with the Enable signal or switch already in the “on” position.

Subtract the result of the “Input Under-Voltage Turn-Off Threshold” test from that of the “Input Under-Voltage Turn On Threshold” test. The result is the hysteresis, which should lie within the range given in the “Input Characteristics”, “Input Under-Voltage Lockout”, “Lockout Voltage Hysteresis” line of the datasheet.

## E) Input Voltage Range

The input voltage range is the span of input voltages within which the converter is designed to operate in order to produce the correct output voltage.

- 1) Disable the converter using the Enable signal or switch.
- 2) Ensure the load current is set to a value equal to or less than the rated current of the unit.
- 3) Turn on the fan(s).
- 4) Set the input voltage to any value within the operating range.
- 5) Enable the converter with the Enable signal or switch.
- 6) Ensure that the output voltage is at its correct voltage.
- 7) Vary the input voltage over the range given in the “Operating Input Voltage Range” line of the datasheet while monitoring the input and output voltage with a DVM and/or oscilloscope. Verify that the output voltage stays at its correct value for all input voltages within the range given in the datasheet.
- 8) Toggle the Enable signal or switch to the “off” position, remove input power, turn off the fan(s).

## F) No Load Input Current

The no load input current is the current that the converter draws from the input voltage supply when it is running with no load connected to its output.

- 1) Remove the output load.
- 2) Enable the converter using the Enable signal or switch.
- 3) Adjust the input power supply to the particular operating point of interest.
- 4) Read and record the input current from the input-side current shunt as measured by a DVM. If the input voltage is set at the value given in the datasheet the reading should not exceed the maximum value given there in the “Input Characteristics”, “No-Load Input Current” line.
- 5) Toggle the Enable signal or switch to the “off” position, remove input power, turn off the fan(s).

## G) Disabled Input Current

The disabled input current is the current that the converter draws from the input voltage supply while the converter is in the “off” state.

- 1) Disable the converter using the Enable signal or switch.
- 2) Adjust the input power supply to the particular voltage of interest.
- 3) Read and record the input current from input-side current shunt with a DVM. If the input voltage is set at the value given in the datasheet the reading should not exceed the maximum value given in the “Input Characteristics”, “Disabled Input Current” line.
- 4) Toggle the Enable signal or switch to the “off” position, remove input power, turn off the fan(s).

## H) Line Regulation

Line regulation is defined as the percentage change in output voltage caused by varying the input voltage over the specified operating range with the output load and temperature remaining constant.

- 1) Turn on the fan(s).
- 2) Enable the converter using the Enable signal or switch.
- 3) Turn on the input power supply and set the module output current level to the desired operating point.
- 4) While observing the output voltage on the DVM adjust the input power supply voltage across the converter’s input operating voltage range. Record the output voltage at each input voltage.
- 5) Toggle the Enable signal or switch to the “off” position, remove input power, turn off the fan(s).

Calculate the mean output voltage as

$$V_{oMEAN} = VO1 + VO2 + \dots + VON / N$$

where VO1, VO2, VO3, etc., are each of the N output voltages recorded.

The +/- deviation of any measured value of output voltage (the j-th measurement) from the mean value can be defined as  $V_{oj} - V_{oMEAN}$

If the load current is within the operating range of the converter, the deviation should not exceed the maximum limits given in the “Output Characteristics”, “Output Voltage Regulation”, “Over Line” value in the datasheet.



## I) Load Regulation

Load regulation is defined as the percentage change in output voltage caused by varying the output load current over the specified range (minimum load to full load) with the input voltage and ambient temperature remaining constant.

- 1) Turn on the fan(s).
- 2) Enable the converter using the Enable signal or switch.
- 3) Turn on the input power supply and set the input voltage level to the desired operating point.
- 4) While observing the output voltage on a DVM, adjust the load across the converter's operating load range (minimum load to full load). Record the output voltage at each load current setting.
- 5) Toggle the Enable signal or switch to the "off" position, remove input power, turn off the fan(s).

To calculate the mean output voltage and deviations use the equations shown in the Line Regulation test section.

If the input voltage is set at the value given in the datasheet, the deviation should not exceed the maximum limits given in the "Output Characteristics", "Output Voltage Regulation", "Over Load" line.

## J) Output Ripple

Output ripple is defined as the periodic AC component at the DC-DC converter's output voltage. It is harmonically related to the converter's switching frequency. It is measured in two ways: peak-to-peak and RMS, both done at a specified bandwidth.

For the best accuracy when measuring ripple and noise, please refer to SynQor's application note "Vout Ripple Measurement".

- 1) Set the time base of the oscilloscope to a value that will allow the switching frequency, as indicated in the datasheet, to be viewed. Limit the bandwidth to 20MHz. If the oscilloscope has the capability, set it to calculate the peak-peak and RMS ripple voltages.
- 2) Connect the oscilloscope to the power module output voltage BNC test connector according to the instructions found in SynQor's application note "Vout Ripple Measurement".

[http://www.synqor.com/documents/appnotes/appnt\\_Vout\\_Ripple\\_Measurement.pdf](http://www.synqor.com/documents/appnotes/appnt_Vout_Ripple_Measurement.pdf)

- 3) Turn on the fan(s).
- 4) Enable the converter using the Enable signal or switch.
- 5) Turn on the power supply and set the input voltage and the output load to the desired operating point.
- 6) Measure the output ripple on the oscilloscope. The peak-to-peak and RMS ripple magnitudes should not exceed the values given in the "Output Voltage Ripple and Noise" section of the datasheet.
- 7) Toggle the Enable signal or switch to the "off" position, remove input power, turn off the fan(s).

## K) Output DC Current-Limit Inception

The output current limit inception point is defined as the current where the converter begins to enter current limit.

- 1) Turn on the fan(s).
- 2) Enable the converter using the Enable signal or switch.
- 3) Turn on the power supply and set the input voltage to the desired operating point and the load current to a value just below the maximum rated output current of the converter.
- 4) While monitoring the output voltage, increase the load current slowly beyond the rated maximum. The current at which the converter loses regulation, and the output voltage falls to 90% of its steady state value, is the current limit inception point. This current should be greater than the rated current and should be similar to the current given in the “Output Characteristics”, “Output DC Current-Limit Inception” line of the datasheet.
- 5) Toggle the Enable signal or switch to the “off” position, remove input power, turn off the fan(s).

## L) Output Voltage Deviation and Response Time Due to Step Change in Input Voltage

The output voltage of the converter may have a temporary deviation due to a step change in input voltage or output current. This section tests the response of the converter due to a step change in input voltage.

The transient response of the converter is characterized by two parameters: the maximum output voltage deviation, and the response time.

The output voltage deviation is defined as the response of the converter to a step change in the input voltage. The response time is the length of time it takes for the output voltage to return to within 1% of its final value after a transient.

This section is intended to test transient input voltages within the specifications of the power converter module. This section does not test the input transient voltage protection capabilities of transient protection components or circuits that may exist on the evaluation board or final system design.

- 1) Attach an oscilloscope probe to the output. Set the oscilloscope channel to AC couple. Adjust the oscilloscope to the settings in the “Output Voltage Response to Step Change in Input Voltage” Figure in the datasheet.
- 2) Turn on the fan(s).
- 3) Enable the converter using the Enable signal or switch.
- 4) Turn on the power supply and set its voltage to the desired operating point.
- 5) Set desired input voltage transient using the input source supply in pulse mode, or a custom test configuration.
- 6) When set to the same conditions, the maximum output voltage deviation and response time should be similar to that seen in the “Output Voltage Response to Step-Change in Input Voltage” Figure in the datasheet.
- 7) Toggle the Enable signal or switch to the “off” position, remove input power, turn off the fan(s).



## M) Output Voltage Deviation and Response Time Due to Step Change in Load Current

The output voltage of the converter may have a temporary deviation due to a step change in input voltage or output current. This section tests the response due to a step change in load current.

The transient response of the converter is characterized by two parameters: the maximum output voltage deviation, and the response time.

The output voltage deviation is defined as the response of the converter to a step change in the load current. The response time is the length of time it takes for the output voltage to return to within 1% of its final value after a transient.

- 1) Attach an oscilloscope probe to the output. Set the oscilloscope channel to AC couple. Adjust the oscilloscope to the settings in the “Output Voltage Response to Step Change in Load Current” Figure in the datasheet.
- 2) Turn on the fan(s).
- 3) Enable the converter using the Enable signal or switch.
- 4) Turn on the power supply and set its voltage to the desired operating point.
- 5) Set the desired load transient using the electronic load in pulse mode, or using a custom test configuration.
- 6) The maximum output voltage deviation and response time should be similar to or better than the values given in the “Output Characteristics”, “Output Voltage during Load Current Transient” section of the datasheet and the corresponding “Output Voltage Response to Step-Change in Load Current” Figure in the datasheet.
- 7) Toggle the Enable signal or switch to the “off” position, remove input power, turn off the fan(s).

## N) Soft Start Turn-On Time

Soft Start Turn-On Time is defined as the time it takes for the output to rise to 90% of its final value from the time the converter is enabled. This rise time is deliberately made relatively slow to reduce the inrush current to the output capacitors and to eliminate any overshoot in the output voltage.

- 1) Disable the converter using the Enable signal or switch.
- 2) Connect an oscilloscope probe to the ON/OFF (Enable) pin of the converter. Ground the probe to the Vin-pin of the converter.
- 3) Connect an oscilloscope probe to the output voltage.
- 4) Adjust the time base of oscilloscope to a slow setting (i.e. ms / div.) to capture the entire start-up waveform.
- 5) Set the oscilloscope trigger to the probe monitoring the Enable signal, and set the trigger mode to single-shot (one-time event).
- 6) Turn on the fan(s).
- 7) Turn on the input power supply and set its voltage to the desired operating point.
- 8) Enable the converter. Measure the waveforms captured on the oscilloscope.
- 9) Toggle the Enable signal or switch to the “off” position, remove input power, turn off the fan(s).

The soft-start turn-on time measured should not exceed the interval given in the “Dynamic Characteristics”, “Turn-On Transient”, “Turn-On Time” line of the datasheet.

Note: Different electronic loads can give dramatically different results on soft start due to their input characteristics during turn-on. If the turn-on appears abnormal, substitute an actual resistive load of the appropriate value.

## O) Efficiency

Efficiency is defined as the ratio of the output power  $P(\text{out}) = V(\text{out}) \times I(\text{out})$  to the input power  $P(\text{in}) = V(\text{in}) \times I(\text{in})$  expressed as a percentage, under specified operating conditions.

To accurately measure the efficiency of the converter, high accuracy current shunts on the input and output must be used to measure the input and output currents.

Also, the input and output voltages must be measured with Kelvin connections at the module pins, not on the pin sockets or other locations away from the module. Kelvin test points may already be provided on the evaluation board.

- 1) Turn on the fan(s).
- 2) Enable the converter using the Enable signal or switch.
- 3) Turn on the power supply and set the input voltage level to the desired operating point.
- 4) Adjust the load to the desired operating point.
- 5) Read and record the input voltage  $V(\text{in})$ , the input current  $I(\text{in})$ , the output voltage  $V(\text{out})$ , and the output current  $I(\text{out})$ .
- 6) Toggle the Enable signal or switch to the “off” position, remove input power, turn off the fan(s).

Calculate the converter’s efficiency with the following formula:

$$\% \text{ Efficiency} = P(\text{out}) * 100 / P(\text{in})$$

The calculated efficiency should be similar to or better than that shown in the Efficiency Figure in the data-sheet.

The power dissipation of the converter module is  $P(\text{in})$  minus  $P(\text{out})$ .