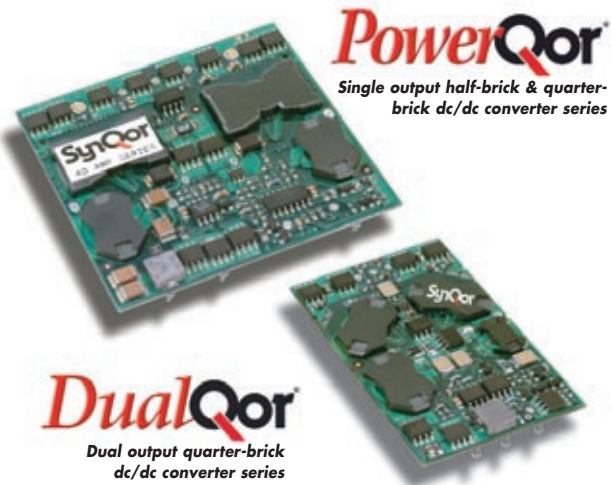# Evaluation Procedure for SynQor converters

IMPORTANT: *This document will guide you through the evaluation process to fully qualify any PowerQor or DualQor module(s). Before you begin, you must do the following:*

1. Obtain the data sheet(s) for the unit(s) you are qualifying in order to validate your test results. All data sheets are available from the company website www.synqor.com.

2. Determine which evaluation board you are using: standard eval board (accepts standard half-bricks and quarter-bricks), full feature eval board (accepts full feature half-bricks used in parallel applications), dual output eval board (accepts DualQor series). Section I provides information on applicable documents and methods for cooling the converter modules. Section II covers testing of a single converter on a standard or full feature board and dual output quarter-bricks on a DualQor eval board. Section III covers testing multiple units on a full feature board. The procedures are mainly written with the single output modules in mind but where relevant, differences in testing of a dual output converter will be addressed on a test-by-test basis.

Single output half-brick & quarter-brick dc/dc converter series

Dual output quarter-brick dc/dc converter series

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Evaluation Procedure
*Power*Qor & *Dual*Qor Series

SECTION I - GENERAL INFORMATION

1.0   Purpose

The purpose of this document is to help the reader to perform electrical measurements on one or more *Power*Qor DC/DC Converter(s). This procedure is written to cover all SynQor dc/dc converters regardless of package size, feature set, input voltage, output voltage or current rating. This document contains detailed instructions on how to test most of the electrical parameters specified in the technical data sheet. Section I covers general documentation and procedures that you will need for testing any type of converter. Section II outlines testing for a single dc/dc converter. Section III outlines additional testing, which you can perform with the full feature units used in paralleled operation.

2.0   Applicable Documents

The following documents and/or general knowledge contain information relevant to this evaluation procedure.

Technical Data Sheet(s)	(Available at www.synqor.com)
*Power*Qor Standard Evaluation Board Schematic	(Appendix A)
*Power*Qor Standard Evaluation Board Layout	(Appendix B)
*Dual*Qor Evaluation Board Schematic	(Appendix C)
*Dual*Qor Evaluation Board Layout	(Appendix D)
*Power*Qor Parallel Evaluation Board Schematic	(Appendix E)
*Power*Qor Parallel Evaluation Board Layout	(Appendix F)
General Test and Safety Procedures	
ESD Protection	

3.0   Cooling of the Converters

SynQor's *Power*Qor and *Dual*Qor DC/DC converters are so efficient that they do not need heatsinks. They will produce some heat, however (for example, approximately 11 Watts for a 3.3Vout PQ48033HMA30 half brick at room temperature when the converter is delivering 30 Amps, or 100 Watts). It is important to blow air on the converters to keep the components cool in this situation. In a normal room temperature environment, only 300 linear feet per minute (LFM) of airflow is required. This airflow rate can be easily achieved or exceeded with a small cooling fan. It is important to make sure this fan is turned on and its airflow is directed along the top surfaces of the converters when electrical tests are conducted. If it is not, the converter components can get too hot and the over-temperature protection circuitry will then enable and turn the converters off.

SECTION II - PERFORMANCE VERIFICATION OF A SINGLE CONVERTER

This section of the document explains in detail how to use either the *Power*Qor (single output Standard or Full Feature) or *Dual*Qor (dual output) Evaluation Boards to verify the electrical characteristics of a single converter. Section III outlines additional requirements to test multiple converters on the *Power*Qor Full Feature Evaluation Board.

4.0   Equipment Required

4.1	(1)	*Power*Qor Standard Evaluation Board or *Power*Qor Full Feature Evaluation Board for single output converters or a *Dual*Qor Evaluation Board for dual output quarter-brick converters.
4.2	(1)	0 - 100 volts, DC @ 0 - 20 Ampere Power Supply; Sorenson DCR 80-37 or Equivalent. The power supply should be sized for the maximum power required by the converter(s).
4.3	(1)	4 channel, 100MHz oscilloscope; Tektronix TDS640A or Equivalent
4.4	(6)	3 1/2 Digit Multimeter (to be called DVM1, DVM2, DVM3, DVM4, DVM5 and DVM6);

Hewlett-Packard 3458A or Equivalent

4.5   (2)   400 Watt Electronic Load or Resistive Load; Kikusui PLZ1003W or Equivalent. The load should be sized for the maximum power produced by the converter(s).

4.6   (1)   EMPRO HA 10-100 Current Shunt or Equivalent, in this document to be called RSIN. (10 A, 100 mV shunt)

4.7   (1)   EMPRO H 100-100 Current Shunt or Equivalent, to be called RSOUT. (100A, 100 mV shunt). The *Dual*Qor Evaluation Board incorporates the output current shunts for both output RSOUT1 and RSOUT2 in the eval board. 1mOhm shunts are used in the *Dual*Qor eval board to measure the output current from each output.

4.8   (4)   BNC cables; increase quantity to (6) if testing with the *Dual*Qor Evaluation Board

        (2)   BNC T-Adapters; increase quantity to (3) if testing with the *Dual*Qor Evaluation Board

        (4)   BNC-to-Banana Adapters; increase quantity to (6) if testing with the *Dual*Qor Evaluation Board

        (2)   Twisted-pair cables with Banana plugs on one end; decrease quantity to (1) if testing with the *Dual*Qor Evaluation Board

5.0   Equipment Set-Up and Description

If using a *Power*Qor Standard Evaluation Board, go to section 5.0(a).
If using a *Dual*Qor Evaluation Board, go to Section 5.0(b).
If using a *Power*Qor Full Feature Evaluation Board, go to Section 5.0(c).

5.0(a)   Setting Up With a *Power*Qor Standard Evaluation Board

5.1(a)   Connect a wire from the negative (-) output terminal of the power supply to the negative (-) terminal of the power input jack JI of the Standard Evaluation Board.

5.2(a)   Connect a wire from the positive (+) terminal of the power supply to one terminal of current shunt RSIN. Connect the other terminal of the shunt to the (+) terminal of J1. Use 16 AWG wire or the equivalent for all the connections between the power supply and the power input jack

5.3(a)   Using a twisted-pair cable, connect a multimeter, henceforth referred to as DVM1, to shunt RSIN to monitor the voltage of the shunt.

5.4(a)   Connect a BNC T-adapter to the J3 BNC connector which monitors the input voltage. Connect a BNC cable from the adapter to a multimeter DVM2 through a BNC-to-banana adapter. Connect another BNC cable from the adapter to channel 1 of the oscilloscope.

5.5(a)   Connect a BNC T-adapter to the J4 BNC connector which monitors the output voltage. Connect a BNC cable from the adapter to a multimeter DVM3 through a BNC-to-banana adapter. Connect another BNC cable from the adapter to channel 2 of the oscilloscope.

5.6(a)   Connect a wire from the negative (-) terminal of the electronic load (or to one terminal of a resistive load) to the negative (-) output terminal Vout- of the Evaluation Board.

5.7(a)   Connect a wire from the positive (+) terminal of the electronic load (or to the other terminal of the resistive load) to one terminal of current shunt RSOUT. Connect the other terminal of the shunt to the (+) output terminal Vout+ of the Evaluation Board. To minimize the impedances of the connector cables, use 8 AWG wire or the equivalent for all the connections between the output of the converter and the load. The thicker the conductors used the better, especially in the low output voltage units, which are less tolerant to voltage drops due to connection impedances.

5.8(a)   Using a twisted-pair cable, connect a multimeter DVM4 to shunt RSOUT to monitor the voltage across the shunt. After setting up the *Power*Qor Standard Evaluation Board go to Section 6.

5.0(b)   Setting Up With a *Dual*Qor Evaluation Board

5.1(b)   Connect a wire from the negative (-) output terminal of the power supply to the negative (-) terminal of the

power input jack JIN1 of the *Dual*Qor Evaluation Board.

5.2(b) Connect a wire from the positive (+) terminal of the power supply to one terminal of current shunt RSIN. Connect the other terminal of the shunt to the (+) terminal of JIN1. Use 16 AWG wire or the equivalent for all the connections between the power supply and the power input jack

5.3(b) Using a twisted-pair cable, connect a multimeter, henceforth referred to as DVM1, to shunt RSIN to monitor the voltage of the shunt.

5.4(b) Connect a BNC T-adapter to the JIN2 BNC connector which monitors the input voltage. Connect a BNC cable from the adapter to a multimeter DVM2 through a BNC-to-banana adapter. Connect another BNC cable from the adapter to channel 1 of the oscilloscope.

5.5(b) Connect a BNC T-adapter to the JOUT3 BNC connector which monitors output voltage #1. Connect a BNC cable from the adapter to a multimeter DVM3 through a BNC-to-banana adapter. Connect another BNC cable from the adapter to channel 2 of the oscilloscope.

5.6(b) Connect a BNC T-adapter to the JOUT9 BNC connector which monitors output voltage #2. Connect a BNC cable from the adapter to a multimeter DVM5 through a BNC-to-banana adapter. Connect another BNC cable from the adapter to channel 3 of the oscilloscope.

5.7(b) Connect a wire from the negative (-) terminal of electronic load #1 (or to one terminal of a resistive load #1) to the negative (-) output terminal Vout- (connector J01 pins 4,5,6) of the Evaluation Board. To minimize the impedances of the connector cables, use 8 AWG wire or multiple strands of 12 AWG wire for all connections between the load and evaluation board. A lower impedance on these connections is better, especially for the low output voltages, which are less tolerant to voltage drops due to connecting impedances.

5.8(b) Connect a wire from the positive (+) terminal of electronic load #1 (or the other terminal of resistive load #1) to the positive (+) output terminal Vout2+ (connector J01 pins 1,2,3) of the Evaluation Board.

5.9(b) Connect a wire from the negative (-) terminal of electronic load #2 (or to one terminal of a resistive load #2) to the negative (-) output terminal Vout- (connector J02 pins 1,2,3) of the Evaluation Board. Connect a wire from the positive (+) terminal of electronic load #2 (or the other terminal of resistive load #2) to the positive (+) output terminal Vout1+ (connector J02 pins 4,5,6) of the Evaluation Board.

5.10(b) Connect a BNC cable to multimeter DVM4 to RSOUT2 (JOUT4) to monitor the voltage across the shunt, which is proportional to the load current delivered by output #2.

5.11(b) Connect a BNC cable to multimeter DVM6 to RSOUT1 (JOUT6) to monitor the voltage across the shunt, which is proportional to the load current delivered by output #1. After setting up the *Dual*Qor Evaluation Board go to Section 6.

Note: Because the outputs of dual output quarter bricks share the return line (Vout-), the shunts used to measure the output currents are placed on the positive rail of each output. Please note that you should never try to connect the signal coming from the output current shunts to the oscilloscope if you are already monitoring the output voltages because this will short the output of the module. The module will go into its short circuit protection operation.

5.0(c) Setting Up With a *PowerQor* Full Feature Evaluation Board

5.1(c) Connect a wire from the negative (-) output terminal of the power supply to the negative (-) terminal of the power input jack JIN1 of the Full Feature Evaluation Board.

5.2(c) Connect a wire from the positive (+) terminal of the power supply to one terminal of current shunt RSIN. Connect the other terminal of the shunt to the (+) terminal of JIN1. Use 16 AWG wire or the equivalent for all the connections between the power supply and the power input jack.

5.3(c) Using a twisted-pair cable, connect a multimeter, henceforth referred to as DVM1, to shunt RSIN to monitor the voltage across the shunt.

5.4(c) Connect a BNC T-adapter to the "VIN" BNC connector which monitors the input voltage. Connect a BNC

cable from the adapter to a multimeter DVM2 through a BNC-to-banana adapter. Connect another BNC cable from the adapter to channel 1 of the oscilloscope.

5.5(c)   Connect a BNC T-adapter to the "VOUT" BNC connector which monitors the output voltage. Connect a BNC cable from the adapter to a multimeter DVM3 through a BNC-to-banana adapter. Connect another BNC cable from the adapter to channel 2 of the oscilloscope.

5.6(c)   Connect a wire from the negative (-) terminal of the electronic load (or to one terminal of a resistive load) to the negative (-) output terminal Vout- of the Evaluation Board.

5.7(c)   Connect a wire from the positive (+) terminal of the electronic load (or to the other terminal of the resistive load) to one terminal of current shunt RSOUT. Connect the other terminal of the shunt to the (+) output terminal Vout+ of the Evaluation Board. To minimize the impedances of the connector cables, use 8 AWG wire or the equivalent for all the connections between the output of the converter and the load. The thicker the conductors used the better, especially in the low output voltage units, which are less tolerant to voltage drops due to connection impedances.

5.8(c)   Using a twisted-pair cable, connect a multimeter DVM4 to shunt RSOUT to monitor the voltage across the shunt.

6.0   Test Set-Up For a Single Converter

6.1   Initial Set-Up

1) Insert a converter into the Evaluation Board. If using the Full Feature Evaluation Board, insert the converter into either of the positions PQ1 or PQ2. It will be assumed here that the PQ1 position is used.

2) If using the Full Feature Evaluation Board: Leave ONOFF_COM permanently in the closed position. (All the switches ONOFF_COM, ONOFF1 and ONOFF2 are closed when the actuator, or arm, is facing in the direction toward the corner of the board containing components QS1, RS2, RS4, etc., and are open when the arm is facing toward the input connector JIN1.)

3) Set multimeters (DVM1, DVM2, DVM3, DVM4, DVM5 and DVM6) as follows:

      Voltage   =   Autorange   (DVM5 and DVM6 used only in *Dual*Qor test set-up))

4) Set oscilloscope as follows:

      Timebase   =   1 ms/Div
      Trigger   =   Auto
    Channel 1
      Volts   =   nearest sensitivity to (Vin nominal/4) V/Div
      Coupling   =   DC
    Channel 2
      Volts   =   nearest sensitivity to (Vout/4) V/Div
      Coupling   =   DC
    Channel 3 (only for *Dual*Qor test set-up)
      Volts   =   nearest sensitivity to (Vout2 nominal / 4) V / Div
      Coupling   =   DC

These oscilloscope settings can be adjusted as necessary during testing to improve the clarity of the waveforms and the accuracy of the results. In particular, when it is desired to reproduce specific waveforms on the datasheet the settings should be adjusted to match those on the oscillograms being replicated.

5) Electronic load(s)

Turn on the electronic load(s) and adjust the current level(s) to a value below the rated output current(s) of the converter, which is given in the "Output Characteristics: Operating Output Current Range" line in the "Electrical Characteristics" section of the datasheet for the converter. For Dual output modules the maximum output power rating can be supplied by either output but not at the same time. Make sure that the combined load supplied by both outputs does not exceed the power rating of the converter.

6.2   Initial Power Up

1) Turn on the fan.

2) Turn on the power supply and increase its voltage (using DVM2 to monitor the input voltage) until the desired value is reached.

3) Toggle the on/off switch to the "on" position to enable the DC/DC converter. For a unit with positive on/off logic, the "on" position is with the switch open. For a unit with negative on/off logic, the "on" position is with the switch closed.

4) The converter is now operating, which can be verified by observing DVM3 (DVM5) and channel 2 (channel 3) of the oscilloscope. The reading of DVM3 (DVM5) and the oscilloscope should fall within the range given in the "Output Characteristics: Output Voltage Set Point" line of the datasheet. At this point the sensitivity of channel 2 (3) of the oscilloscope can be adjusted to give the best-looking trace for the output voltage of the unit being tested.

5) The converter can also be turned on by first toggling the on/off switch to the "on" position and then either

      i. turning on the power supply by ramping up its voltage manually from zero to the desired value

      or

      ii. presetting the power supply to the desired voltage and then switching it on.

Toggle the on/off switch to the "off" position after each test is performed to disable the DC/DC converter.

7.0 Test and Evaluation: Input Characteristics

The *Power*Qor families of converters operate over wide input voltage ranges. For example, under all load conditions, the PQ48 and PQ60 families will operate from 35 to 75 volts and the PQ24 family will operate from 18 to 36 V. The PQ60 families can also safely withstand transient input voltages of up to 100V for 100ms. All the converters have an input under-voltage protection feature that will not allow them to start up until the input voltage exceeds a certain minimum threshold voltage.

7.1 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.

Test

1) Turn on the fan.

2) Disable the converter using the on/off switch.

3) Set the input voltage source to zero.

4) Enable the converter using the on/off switch.

5) Slowly increase the input voltage from zero while monitoring DVM2 and channel 1 of the oscilloscope (input voltage), DVM3 (DVM5) and channel 2 (3) of the oscilloscope (output voltage 1, and output voltage 2 if testing dual output converter), until the output voltage(s) of the converter just rises to its steady-state value(s) as given in the "Output Characteristics: Output Voltage Set Point" line in the datasheet. Record the input voltage. The input voltage should lie within the range given by the "Input Characteristics: Turn-On Voltage Threshold" line of the datasheet.

6) Leave the converter running for the test that follows.

7.2 Input Under Voltage Turn Off Threshold

The input under voltage turn-on 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.

Test

1) Slowly reduce the input voltage until the converter turns off. Record the input voltage at this point. It should lie within the limits given in the "Input Characteristics: Turn-Off Voltage Threshold" line of the datasheet.

7.3 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 on/off switch already in the "on" position.

Test

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

7.4 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.

Test

1) Disable the converter using the on/off switch.

2) Make sure the load current is set to a value equal to or less than the rated current of the unit. For a dual output converter, make sure that the total power delivered by both outputs is equal or less than the power rating of the module.

3) Set the input voltage to any value within the operating range.

4) Enable the converter with the on/off switch and make sure that the output voltage(s) is (are) at its correct voltage.

5) Monitoring DVM2, DVM3 (DVM5) and the oscilloscope, vary the input voltage over the range given and verify that the output voltage(s) stays at its correct value for all input voltages lying within the range given in the "Operating Input Voltage Range" line of the datasheet.

7.5 Input Over Voltage Turn-Off Threshold

The input over voltage turn-off threshold is defined as the voltage at which the converter turns itself off as the input voltage is increased above the operating range. Please note that this feature is only present on the PQ48 half-brick models.

Test

1) Set the load current to a value equal to or less than the rated current of the converter.

2) Set the input voltage to any value within the operating range.

3) Enable the converter with the on/off switch and make sure that the output voltage is at its correct value.

4) Monitoring DVM2, DVM3 (DVM5) and the oscilloscope, increase the input voltage slowly until the converter just turns off. The input voltage at which turn-off occurs should lie within the range given in the "Input Over-Voltage Shutdown: Turn-Off Threshold" line of the datasheet. Leave the input voltage above the turn-off threshold for the next test.

7.6 Input Over Voltage Turn-On Threshold

The input over voltage threshold is defined as the voltage at which the converter turns itself back on as the input voltage is lowered from above the operating range.

Test

1) While monitoring DVM2, DVM3 (DVM5) and the oscilloscope, reduce the input voltage slowly until the converter turns on again. The input voltage at which turn-on occurs should lie within the range given in the "Input Over-Voltage Shutdown: Turn-On Threshold" line of the datasheet.

7.7 100V Input Voltage Transient Withstand Capability

The input over voltage turn-on and turn-off threshold tests must not be performed on the converters (such as the PQ60 families) designed to withstand 100V input voltage transients. These converters have a turn

off threshold greatly in excess of 100V, and will be damaged by attempts to raise the input high enough to test for this threshold.

These units are instead checked for proper operation at input voltages not exceeding 100V.

Test

1) Set the load current(s) to a value equal to or less than the rated current (power rating) of the converter.

2) Set the input voltage to any value within the operating range.

3) Enable the converter with the on/off switch and make sure that the output voltage(s) is (are) at its correct value.

4) Monitoring DVM2, DVM3 (DVM5) and the oscilloscope, increase the input voltage to 100V. The converter should continue to operate and produce the correct output voltage(s) for all input voltages higher than the under voltage turn-on threshold voltage up to and including 100V.

7.8   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(s).

Test

1) Remove the output load(s) (either the electronic or the resistive load(s)).

2) Enable the converter using the on/off switch.

3) Adjust the input power supply to the particular operating point of interest.

4) Read and record the input current from current shunt RSIN as measured by voltmeter DVM1. 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.

7.9   Disabled Input Current

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

Test

1) Disable the converter using the on/off switch.

2) Adjust the input power supply to the particular voltage of interest.

3) Read and record the input current from current shunt RSIN as measured by voltmeter DVM1. 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: Off Converter Input Current" line.

8.0   Test and Evaluation: Output Characteristics

8.1   Line Regulation

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

Test

1) Turn on fan.

2) Enable the converter using the on/off switch.

3) Turn on the power supply and set the output power level to the desired operating point.

4) While observing the output voltage(s) on meter DVM3 (DVM5), adjust the input power supply voltage across the converter's input operating voltage range. Record the output voltage(s) at each input voltage. Calculate the mean output voltage as:

$$V_{O\_MN\_1} = V_{O1\_1} + V_{O1\_2} + ... + V_{O1\_N} / N$$

$$V_{O\_MN\_2} = V_{O2\_1} + V_{O2\_2} + ... + V_{O2\_N} / N$$

where V_{Oi_1}, V_{Oi_2}, V_{Oi_3}, etc., are the N output voltages recorded for the *i*-th output. The +/- deviation of any measured value of output voltage (say the *j*-th measurement) from the mean value can be defined as:

$$\Delta V_{O\_1} = V_{O1\_j} - V_{O\_MN\_1}$$

$$\Delta V_{O\_2} = V_{O2\_j} - V_{O\_MN\_2}$$

If the load current(s) is (are) 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.

8.2   Load Regulation

Load regulation is defined as the percentage change in output voltage caused by varying the output load current(s) over the specified range (0 amperes to full load) with the input voltage and ambient temperature remaining constant.

Test
1) Turn on fan.
2) Enable the converter using the on/off switch.
3) Turn on the power supply and set the input voltage level to the desired operating point.
4) While observing the output voltage(s) (DVM3, DVM5), adjust the load across the converter's operating load range (0 amperes to full load). For dual output converters with one output at no load, adjust the load current of the second output from 0 amperes to full load, then set the second output to no load and proceed to adjust the first output from 0 amperes to full load. For calculating the mean output voltage and deviations as in the "Line Regulation test" section above, record maximum +/- deviation of the output voltage(s) from its mean value over the full range of the input voltage. 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: Over Load" line.

8.3   Output Ripple

Output ripple is defined as the periodic AC component at the DC/DC converter's output voltage(s). 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.

Test
1) Turn on the fan.
2) Enable the converter using the on/off switch.
3) Turn on the power supply and set the input voltage and the output load(s) to the desired operating point.
4) Set the timebase of the oscilloscope to 2.5 µs/Div, set channel 2 (3) to AC coupling at 20mV/Div, and limit the bandwidth to 20 MHz. If the oscilloscope has the capability, set it to calculate the peak-to-peak and RMS ripple voltages.

For best results the BNC cable connected to channel 1 should be disconnected during this test. This will minimize the common mode noise that can couple to the output voltage ripple measurement.

The oscillograms of the output ripple should be similar to those in the Output Voltage Ripple Figure in the datasheet, and 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. If testing a dual output converter using the *DualQor* Evaluation board you will need to add a 15 uF D case tantalum capacitor in locations COUT17 and COUT18. SynQor does not populate these capacitors because the evaluation board can be used with converters with two positive outputs (ie. 5.0/3.3V dual output quarter-brick) or converters that have a positive and a negative output (ie. +/- 12V dual output quarter-brick) and tantalum type

capacitors are polarity sensitive. Therefore when adding these capacitors make sure you place them with the correct polarity.

8.4   Output DC Current-Limit Inception

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

Test

1) Turn on the fan.
2) Enable the converter using the on/off switch.
3) Turn on the power supply and set the input voltage to the desired operating point and the load(s) to a value just below the rated power of the converter.
4) While monitoring DVM3 (DVM5) (the output voltage(s)), increase the load current slowly beyond the rated power. For a dual output converter set the current of output #1 to zero and set the current of output #2 to its rated load current. The current at which the converter loses regulation, and the output voltage(s) fall to 90 % of its steady state value, is the current limit inception point. On dual output converters there is a current limit inception point for each output. This current should be greater than the rated current and should be the same as the current given in the "Output Characteristics: Output DC Current-Limit Inception" line of the datasheet.

9.0   Test and Evaluation: Dynamic Characteristics

9.1   Output Voltage Deviation and Response Time Due to 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.

Test

1) Turn on fan.
2) Enable the converter using the on/off switch.
3) Turn on the power supply and set its voltage to the desired operating point.
4) Adjust channel 2 (3) on the oscilloscope to be AC coupled and to 100 mV/Div. Adjust the Timebase to 1 ms/Div, and the trigger to normal and adjust the trigger point for a negative going pulse at approximately 50 mV.
5) Using the electronic load in pulse mode, set it for the desired load transient.
6) If the transient test conditions are set per the Output Voltage Response Figures in the datasheet, the resulting maximum output voltage deviation and response time should be the same as the values given in the "Dynamic Characteristics: Output Voltage Current Transient" section of the datasheet and their corresponding figures.

9.2   Soft Start Turn-On Time

Soft Start Turn-On Time is defined as the time it takes for the output(s) 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 and to eliminate any overshoot in the output voltage(s).

Test

1) Turn on the fan.
2) Disable the converter using the on/off switch.
3) Turn on the power supply and set its voltage to the desired operating point.
4) Connect a probe to channel 4 of the oscilloscope.
5) Connect the probe to the ON/OFF pin of the converter. Ground the probe to the Vin(-) pin of the converter.

6) Adjust channel 4 of the oscilloscope to be DC coupled and to a vertical sensitivity of 5V/Div.

7) Adjust channel 2 (3) of the oscilloscope to be DC coupled and to the vertical sensitivity nearest to (Vout/4) V/Div. For example, for a converter with an output voltage of 3.3V, the horizontal sensitivity of the oscilloscope would be set at 1V/Div.

8) Adjust the timebase of the oscilloscope to 10 ms/Div.

9) Adjust the oscilloscope trigger to a one time event and adjust the trigger level for a positive going pulse at approximately Vout/2 on channel 2 (for a 3.3V output, the trigger level would be about 1.5V).

10) Enable the converter with the on/off switch and note the waveforms captured on channels 2, 3 and 4 of the oscilloscope.

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.

The soft start waveform should be the same as those in the Turn-On Figures in the datasheet. The comparison can be facilitated by changing the oscilloscope voltage and timebase settings to those in the corresponding Figures. Note that channels 2, 3 and 4 in this test correspond to channels 1, 2 and 3 respectively in the datasheet Figures. 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.

10.0 Test and Evaluation: Thermal Characteristics

10.1 Efficiency

Efficiency is defined as the ratio of the output power ($P_{OUT} = V_{OUT} \times I_{OUT}$) to the input power ($P_{IN} = V_{IN} \times I_{IN}$) expressed as a percentage under specified conditions. For dual output converters the output power is defined as the addition of the power delivered by each output ($P_{OUT} = V_{OUT\_1} \times I_{OUT\_1} + V_{OUT\_2} \times I_{OUT\_2}$). To accurately measure efficiency in the converter, high accuracy current shunts RSIN and RSOUT are used to accurately measure the input and output currents. The *Dual*Qor evaluation board incorporates the current shunts for both outputs RSOUT1 and RSOUT2. RSOUT1 and RSOUT2 are 1 mOhm shunts.

Test

1) Turn on the fan.

2) Enable the converter using the on/off switch.

3) Turn on the power supply and set the input voltage level to the desired operating point.

4) Adjust the electronic load(s) to the desired operating point.

5) Read and record the output voltage V_{OUT} (DVM3) and input voltage V_{IN} (DVM2). When measuring efficiency on a dual output converter record output voltage #1 (DVM3) and output voltage #2 (DVM5).

6) Read and record the input current I_{IN} (DVM1) and the output current I_{OUT} (DVM4). For a dual output converter record the input current I_{IN_1} (DVM1), the output current I_{OUT_1} (DVM4), and I_{OUT_2} (DVM6). Make sure to convert the voltage readings of the meters to the correct currents according to the conversion factors between the meters and their respective shunts.

7) Calculate the converter's efficiency η with the following formula:

$$\eta = \frac{P_{OUT}}{P_{IN}} \times 100\%$$

The calculated efficiency should be the same as that from the Efficiency Figure in the datasheet.

10.2 Power Dissipation

The power dissipated by the converter is:

$$P_D = P_{IN} - P_{OUT}$$

and should accord with that shown in the Power Dissipation Figure in the datasheet.

SECTION III - PERFORMANCE VERIFICATION OF TWO PARALLELED CONVERTERS

This section of the document explains how to use the Full Feature Evaluation Board to test the electrical characteristics of two paralleled *Power*Qor converters. Note that the paralleled converters do not have to be identical, but can be different members of a family of the same output voltage and input voltage range. For example, the 48Vin to 1.5Vout half-brick family currently has four members: Tera, Giga, Mega and Kilo rated respectively at 60, 40, 30 and 20A. An arbitrary combination of any two of these can be paralleled and can therefore be tested according to the procedures that follow. See the Full Feature Application Note on the SynQor website for more information.

11.0   Additional Applicable Documents

The following additional documents and/or general knowledge contain information relevant to the Full Feature evaluation procedure for paralleled converters.

Full Feature Application Note   (Available at www.synqor.com)

12.0   Additional Equipment Required

You will need all the equipment used to verify the performance of a single unit listed in section 4.0, plus the following:

12.1	(2)	4 1/2 Digit Multimeter (DVM5 and DVM6)
12.2	(1)	EMPRO HA 20-100 Current Shunt or equivalent to be called RSIN. The 20 A, 100 mV shunt replaces HA 10-100 from section 4 to give more current measuring capability
12.3	(1)	EMPRO H 200-100 Current Shunt or equivalent to be called RSOUT. The 200A, 100 mV shunt replaces HA 100-100 in section 4 to give more current measuring capability
12.4	(2)	BNC cables
	(2)	BNC-to-Banana Adapters

13.0 Equipment Set-Up and Description

As already outlined in Section 5.0(c), with the following substitutions and additions.

13.1   In the test fixture, replace the shunt of Section 4.6 with that of Section 12.2.

13.2   Similarly, replace the shunt of Section 4.7 with that of Section 12.3. The purpose of the substitutions from smaller to larger current shunts is to make it possible to measure the larger currents associated with paralleled converters. The bigger shunts could have been used for the tests on the single converter, but the accuracy, especially of the efficiency tests, might have been compromised.

13.3   Through a BNC-to-banana adapter, connect a BNC cable from DVM5, to the BNC jack IOUT1 to monitor the output current of the converter in the PQ1 position.

13.4   Through a BNC-to-banana adapter, connect a BNC cable from DVM6, to the BNC jack IOUT2 to monitor the output current of the converter in the PQ2 position.

13.5   Insert two converters into the Full Feature Evaluation board in the PQ1 and PQ2 positions.

14.0   Parallel Characteristics

When converters are paralleled, the system behavior is very similar to that of a stand-alone converter. Most of the tests will give results that are virtually identical to those from a stand-alone converter. These tests are listed below

together with the section in the test procedures for a stand-alone converter where they are described. Follow the previously described procedures if you wish to repeat these tests.

> Input Under Voltage Turn-On Threshold (same as Section 7.1)
> Input Under Voltage Turn-Off Threshold (same as Section 7.2)
> Input Lockout Hysteresis Voltage (same as Section 7.3)
> Input Voltage Range (same as Section 7.4)
> Input Over Voltage Turn-Off Threshold (same as Section 7.5)
> Input Over Voltage Turn-On Threshold (same as Section 7.6)
> 100V Operation (same as Section 7.7)

The input current tests will give double the numerical results of the corresponding tests on a stand-alone converter (because the current shunt measures the combined current of the units). The test procedures are again as previously described.

> No Load Input Current (twice the result of Section 7.8)
> Disabled Input Current (twice the result of Section 7.9)

The regulation and ripple tests, while not giving exactly the same numbers as those of a stand-alone unit, will give results that are comparable to, and within the limits given for them in the stand-alone case. The test procedures are again as previously described.

> Line Regulation (similar to Section 8.1)
> Load Regulation (similar to Section 8.2)
> Output Ripple (similar to Section 8.3)

15.0 Set-Up For Additional Tests on Two Paralleled Converters

As already outlined in Section 6.0, with the following additions.

15.1   Initial Set-Up
1) Double the thickness of all the connector wires (relative to the wire thickness used to qualify a single converter) between the evaluation board and the load. This can be done by paralleling the existing wires with an equal number of wires of the same thickness.
2) Double the thickness of all the connector wires between the input power supply and the evaluation board
3) Insert a converter into the Full Feature Evaluation Board in the PQ2 position.
4) Set multimeters (DVM5 and DVM6) as follows:
> Voltage   =   Autorange

16.0 Test and Evaluation: Parallel Characteristics

The following tests are also performed at room temperature (+25°C)

16.1   Static Current Share Accuracy
For two equally rated paralleled converters, the static current share deviation ΔI_{OUT}, a measure of the static current share accuracy, is defined as the percentage ratio of the difference between their output currents I_{OUT1} and I_{OUT2} to the rated current I_{RATED} of one converter, as shown below:

$$\Delta I_{OUT} = \frac{\left| I_{OUT1} - I_{OUT2} \right|}{I_{RATED}} \times 100\%$$

Since paralleled converters with unequal current limits share the current in proportion to their ratings, the static current share deviation is also measured relative to the rated currents of the converters. In this case the equation is as follows:

$$\Delta I_{OUT} = \left|\left(\frac{I_{OUT1}}{I_{RATED1}} - \frac{I_{OUT2}}{I_{RATED2}}\right)\right| \times 100\%$$

Test
1) Turn on the fan
2) Turn on the power supply and set its voltage to the desired value.
3) Turn on the load and set it to a current less than the full load current of one converter.
4) Enable the converters using ONOFF1 and ONOFF2. Check DVM5 and DVM6 to see that both converters are on and sharing the load current.
5) Now increase the load current (if necessary) to the desired value.
6) Read the output currents I_{OUT1} (on DVM5) and I_{OUT2} (on DVM6) of the two paralleled converters, making the appropriate conversions from the voltage reading of the meters to the currents through their corresponding shunts. Calculate the current share deviation ΔI_{OUT} according to the appropriate formula above. The deviation should not exceed the limits given in the "Output Characteristics: Current Share Accuracy" line of the datasheet. For unequally rated converters deviation is not controlled as tightly.

17.0   Test and Evaluation: Thermal Characteristics

17.1   Efficiency (same as in Section 10.1)

Efficiency is defined and measured as previously explained. Because shunts RSIN and RSOUT respectively measure the total system input and output currents the result will give the total system efficiency. The test procedures are again as previously described. The total calculated efficiency of the paralleled system should be the same as that of any single converter within that system operating at the same input voltage and load current. For example, the system efficiency for two (2) 3.3Vout, 48Vin Tera half-bricks providing 50A each (for 100A total) should equal that of a single 3.3Vout Tera half-brick at 50A load.

17.2   Power Dissipation

The total power dissipated by the two converters is calculated as before:

$$P_{DT} = P_{INT} - P_{OUTT}$$

with the total system input and output powers being used in the equation.
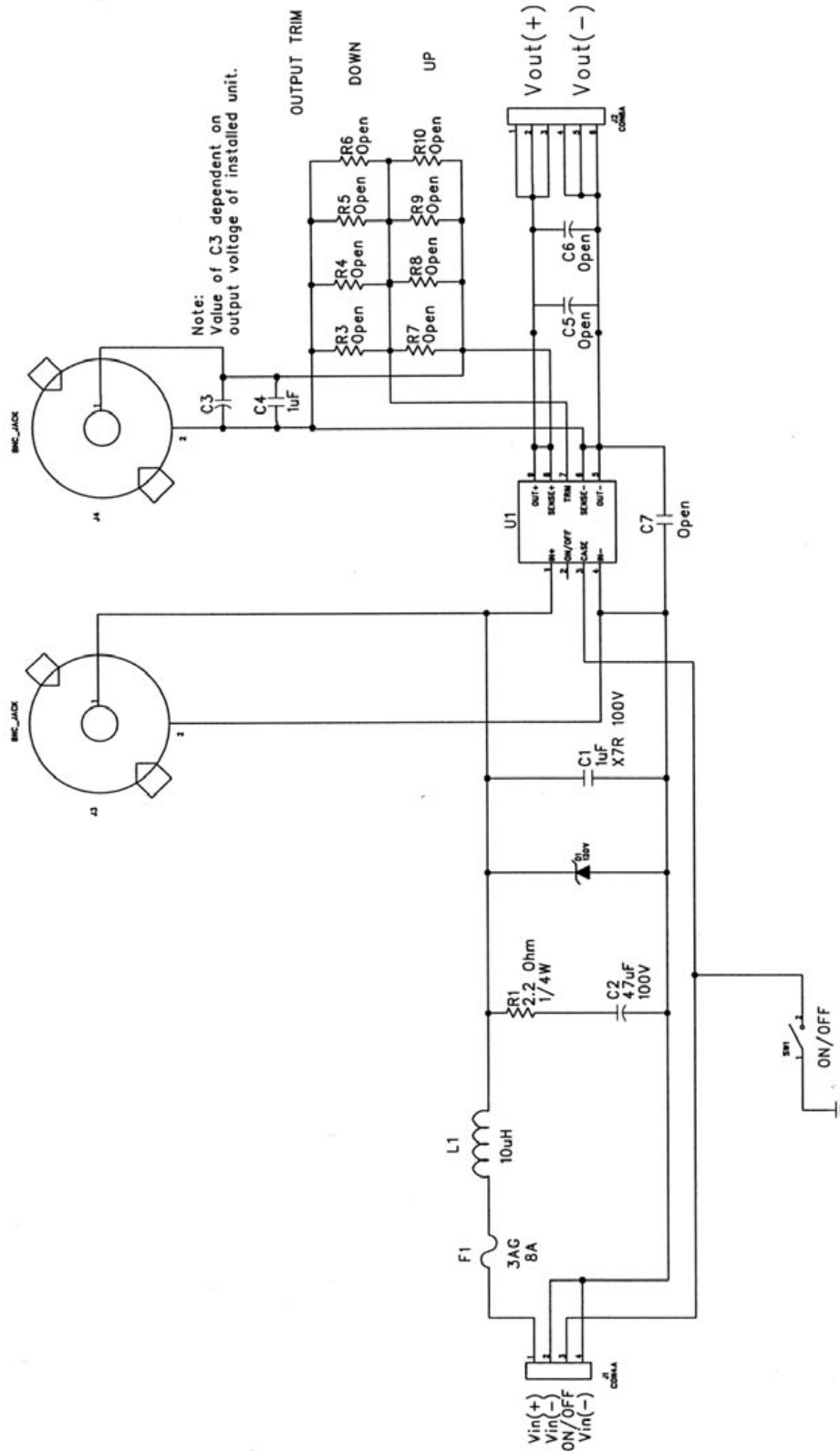
18.0 Appendices

If you have any questions, please contact SynQor technical support at 888-567-9596 or send us an e-mail at support@synqor.com

## Appendix A - *PowerQor* Standard Evaluation Board Schematic

Appendix B - *PowerQor* Standard Evaluation Board Layout & Etches

CAUTION! High Voltage

Fuse rating: 8 Amps 3AG Fast-blow

SynQor™

PowerQor™ Series EVALUATION BOARD

F1

MAXIMUM INPUT VOLTAGE: 100Vdc

J1

Vin(+)
Vin(−)
ON/OFF
Vin(−)

J3

J4

+ Vin −

C7

L1

C8
C4
C3

+ Vout −

OUTPUT TRIM
DOWN   UP

R3 R4 R5 R6   R7 R8 R9 R10

Half Brick Pin 1

Quarter Brick Pin 1

J2

R1 D1 C1

+

C2

C5

C6

Vout(+)

Vout(−)

ON (−P)

ON/OFF

ON (−N)

SW1

EVAL BOARD
034−1000016
REV −

ASSEMBLY
033−1000016

Standard Evaluation Board Front Side Etch

Standard Evaluation Board Back Side Etch

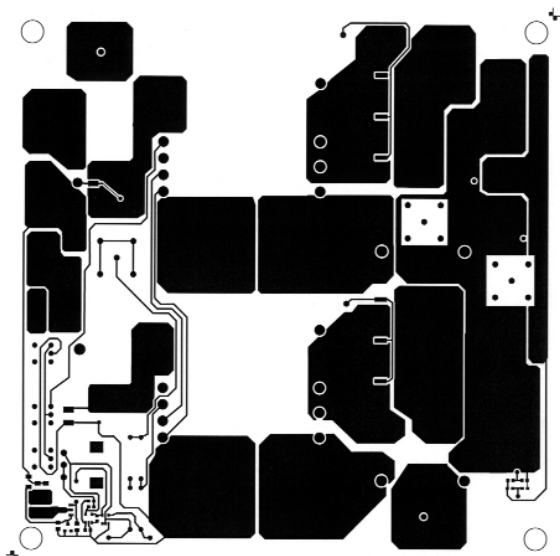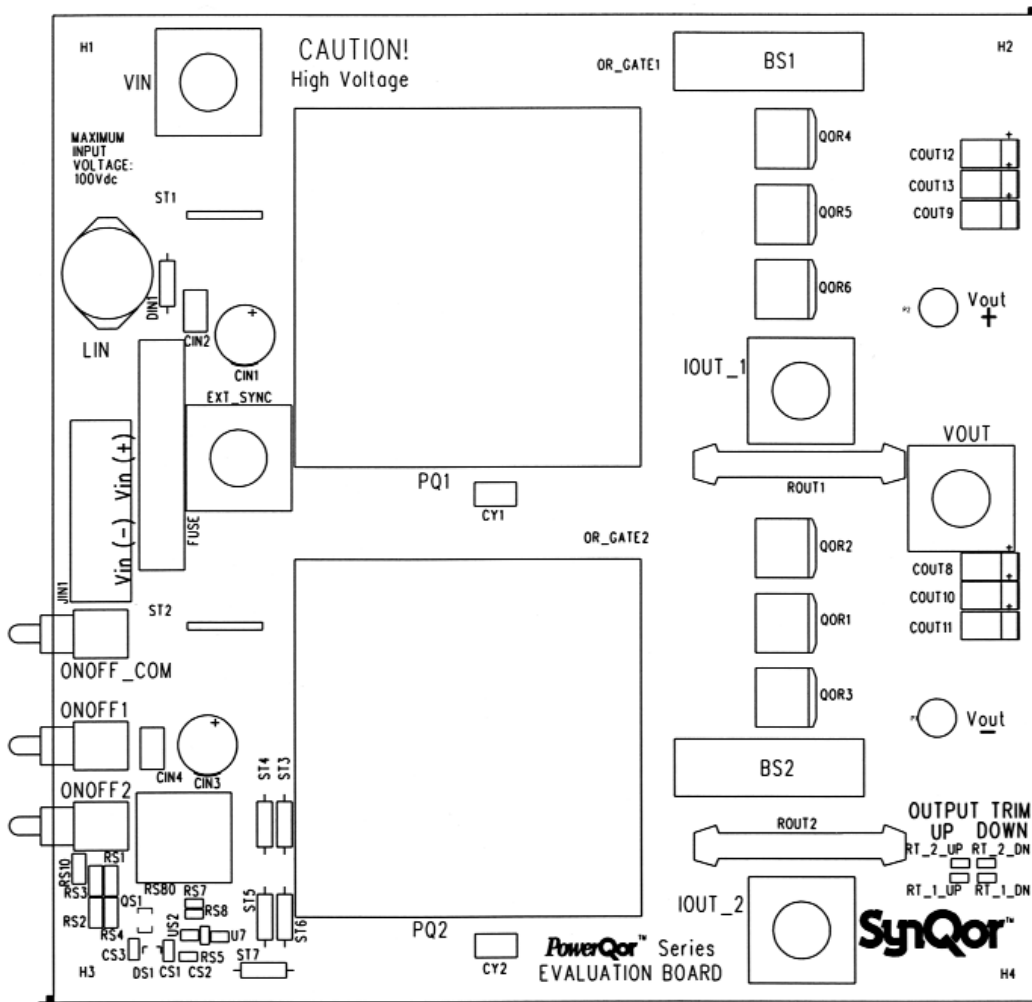## Appendix C - *Dual*Qor Evaluation Board Schematic

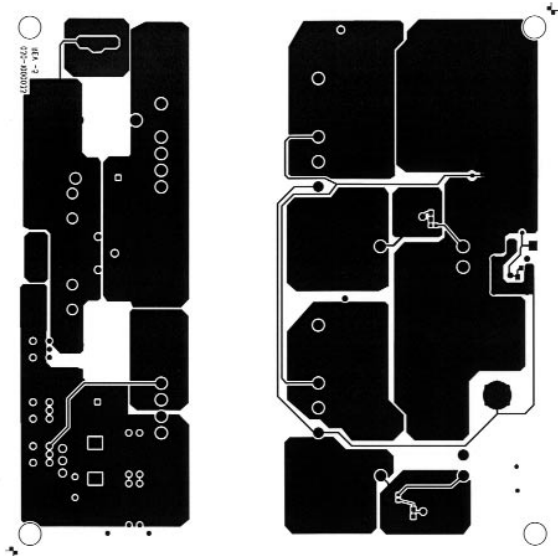## Appendix D - *Dual*Qor Evaluation Board Layout & Etches
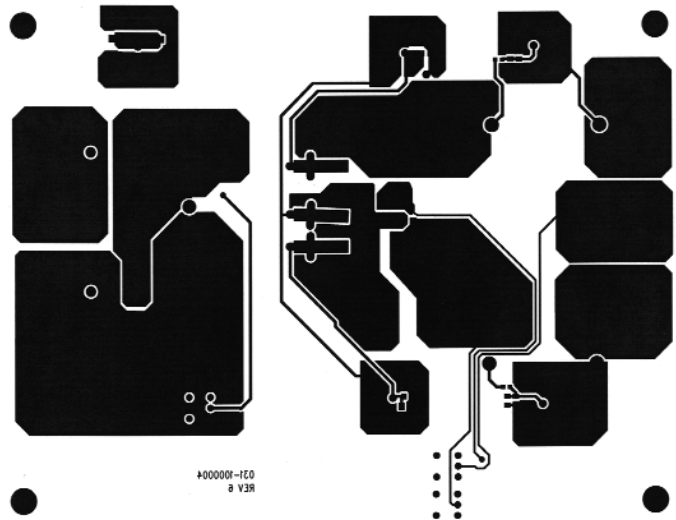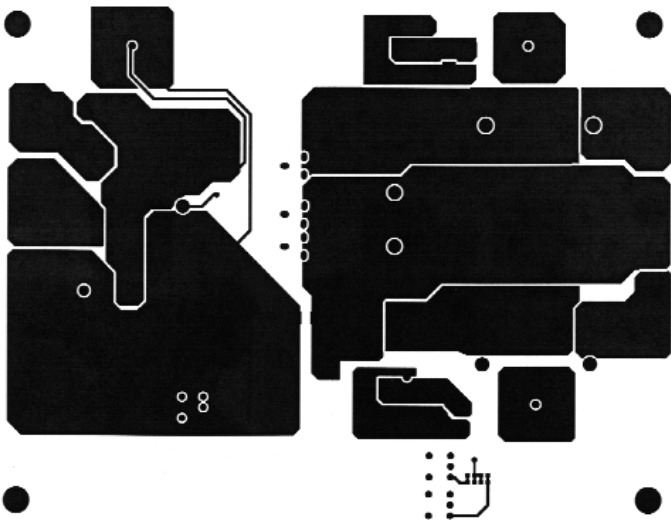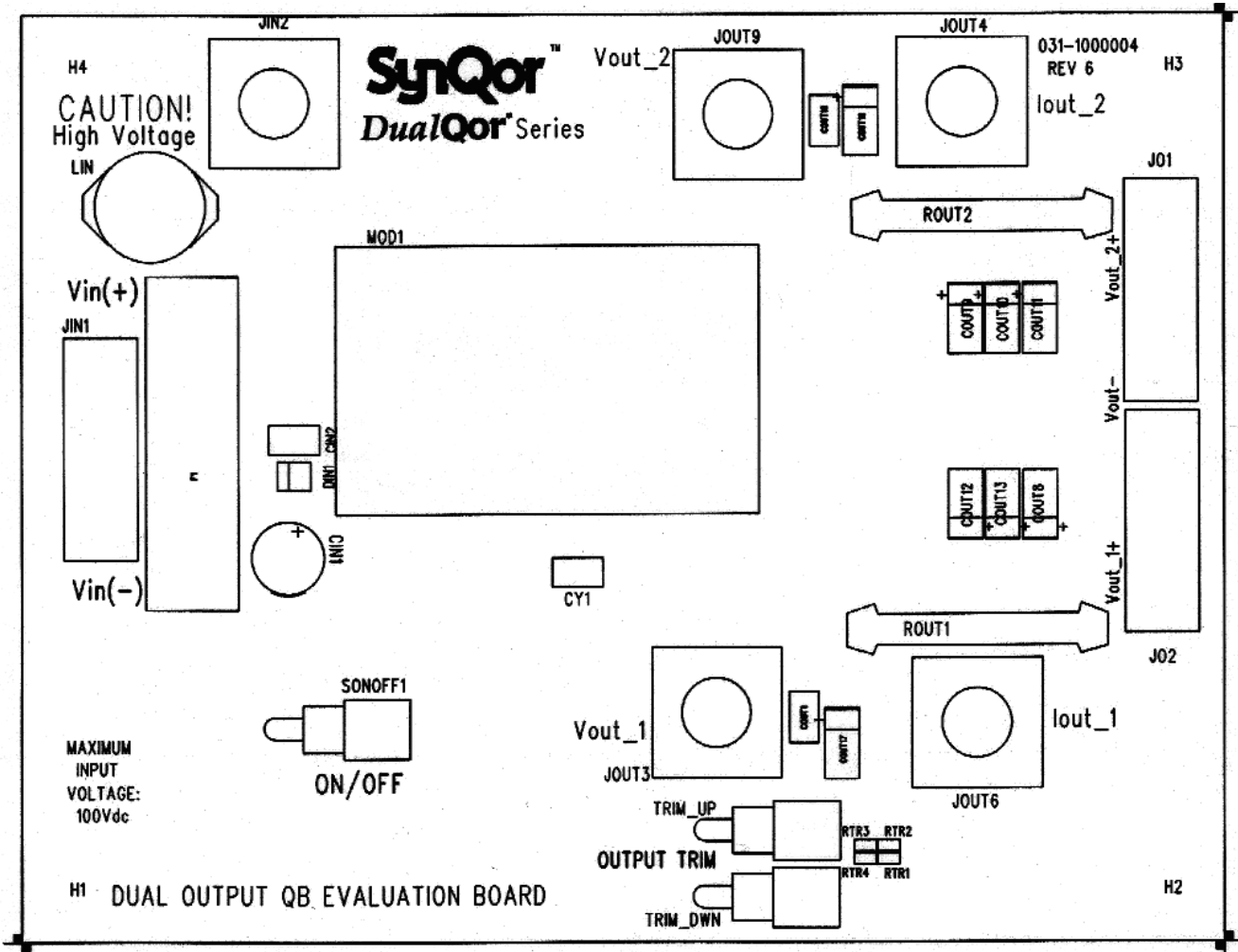
*Dual*Qor Evaluation Board Front Side Etch

*Dual*Qor Evaluation Board Back Side Etch

Appendix E - *Power*Qor Full-Feature Evaluation Board Schematic

Appendix F - *Power*Qor Full-Feature Evaluation Board Layout & Etches

Full-Feature Evaluation Board Front Side Etch

Full-Feature Evaluation Board Back Side Etch