# Technical Specification

**Half Brick** ***48V$_{in}$ 15V$_{out}$ 10A$_{out}$***

# High Efficiency, No Heatsink, Isolated DC/DC Converter

***The PQ48150HNA10 PowerQor™ converter is a next-generation, board-mountable, isolated, fixed switching frequency dc/dc converter that uses synchronous rectification to achieve extremely high conversion efficiency. The power dissipated by the converter is so low that a heatsink is not required, which saves cost, weight, height, and application effort. All of the power and control components are mounted to the multi-layer PCB substrate with high-yield surface mount technology. Since the PowerQor converter has no explicit thermal connections, the PowerQor converter is very reliable.***

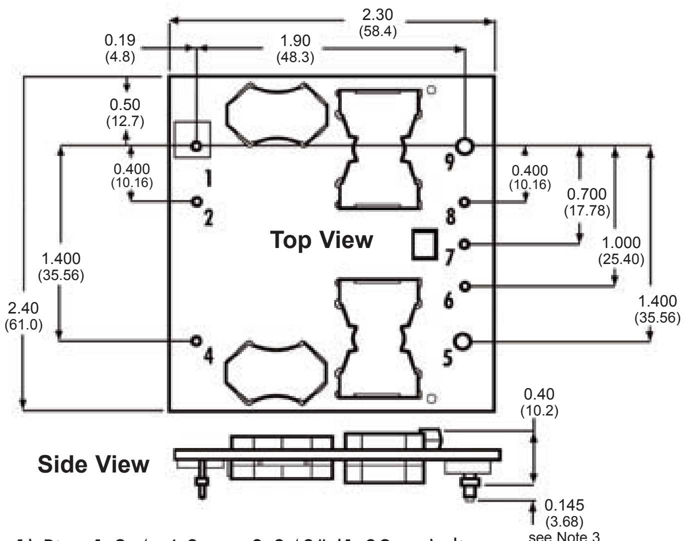
*PQ48150HNA10 Module*

## Features

- Ultra-high efficiency, over 90% at full rated load
- Industry standard pin-out configuration (pin for pin compatible with Lucent JW150 series)
- Industry standard size: 2.3″ x 2.4″
- Total height only 0.40″
- Total weight: 58 grams (2.0 oz.)
- Wide input voltage range: 36V – 75V
- On/Off control referenced to input side (positive and negative logic options are available)
- Remote sense for the output voltage
- Output voltage trim: +10%/-20%
- Input under-voltage lockout and over-voltage shutdown
- Output current limit and short ciruit protection
- Output over-voltage protection
- Thermal shutdown
- 2000V, 10 MΩ input-to-output isolation
- UL 1950 recognized (US & Canada) basic insulation rating, TUV certified to EN60950
- Meets 72/23/EEC and 93/68/EEC directives

## Benefits

- Reduces dissipated heat; saves energy
- Pin and feature compatible with older dc/dc converters
- Small footprint saves board space
- Extremely low profile permits better airflow and smaller card pitch in the rack
- Greatly reduces vibration and shock problems
- Meets or exceeds all 48V bus standards
- Converter turn-on/off can be sequenced
- Compensates for output distribution drops
- Permits custom voltages and voltage margining
- Protects against input system instability and input system induced failure
- Protects the converter against excessive load current or a short circuit condition
- Protects the load from a damaging voltage
- Protects the converter against abnormal environmental conditions
- Provides input/output ground separation
- Provides a Safety Extra Low Voltage output and non-flammability
- Facilitates CE Marking in user's end product




Shown Actual Size

1) Pins 1,2,4, 6-8 are 0.040" (1.02mm) dia. with 0.080" (2.03mm) dia. standoff shoulders.
2) Pins 5 and 9 are 0.080" (2.03 mm) dia. with 0.125" (3.18mm) dia. standoff shoulders.
3) Other pin extension lengths available. All pins are Brass with Tin/Lead plating over Nickel
4) Undimensioned components for visual reference only.
5) Weight: 2.0 oz. (58 g)
6) All dimensions in inches (mm)
   Tolerances: x.xx +/-0.02 in. (x.x +/-0.5mm)
   x.xxx +/-0.010 in. (x.xx +/-0.25mm)
7) Workmanship: Meets or exceeds IPC-A-610B Class II

| Pin No. | Name | Function |
|---|---|---|
| 1 | Vin(+) | Positive terminal for the +48V input bus |
| 2 | ON/OFF | Logic signal to turn converter on and off, referenced to Vin(-). Positive and negative logic versions available. |
| 4 | Vin(-) | Return terminal for the +48V input bus |
| 5 | Vout(-) | Return terminal for the 15V output voltage |
| 6 | SENSE(-) | Return remote sense |
| 7 | TRIM | Output voltage trim |
| 8 | SENSE(+) | Positive remote sense |
| 9 | Vout(+) | Positive terminal for the 15V output voltage |

## ABSOLUTE MAXIMUM RATINGS

Input Voltage:
- Non-Operating: 100V continuous
- Operating: 80V continuous

Input/Output Isolation Voltage: 2000V
Storage Temperature: -55°C to +125°C
Operating Temperature: -40°C to +115°C
Voltage at ON/OFF input pin: +18V / -4V

## OPTIONS

The PQ48150HNA10 comes in two versions that differ by the sense of the logic used for the ON/OFF control signal. The PQ48150HNA10P (default option) version uses positive logic; that is, the converter is on when the ON/OFF signal (Pin 2) is high. The PQ48150HNA10N version uses negative logic; the converter is on when the ON/OFF signal is low.

**Patents**: SynQor is protected under various patents, including but not limited to U.S. Patent # 5,999,417.

## SAFETY

The PQ48150HNA10 series of converters are UL 1950 recognized (US & Canada) with basic insulation rating and TUV certified to EN60950 requirements.

The converters also meet 72/23/EEC and 93/68/EEC directives as well as 94V-0 flammability requirements for board and plastic components.

An external input fuse must always be used to meet these safety requirements.

# PQ48150HNA10 ELECTRICAL CHARACTERISTICS

($T_A$=25°C, airflow rate=300 LFM, $V_{in}$=48Vdc unless otherwise noted; full operating temperature range is -40°C to +100°C with appropriate power derating.)

| PARAMETER | NOTES and CONDITIONS | PQ48150HNA10 | | | |
|---|---|---|---|---|---|
| | | Min. | Typ. | Max. | Units |
| **INPUT CHARACTERISTICS** | | | | | |
| Operating Input Voltage Range | | 36 | 48 | 75 | V |
| Input Under-Voltage Lockou | Figure 11 | | | | |
| Turn-On Voltage Threshold | | 33.2 | 34.5 | 35.5 | V |
| Turn-Off Voltage Threshold | | 30.2 | 31.5 | 33 | V |
| Lockout Hysteresis Voltage | | 2.9 | 3 | 3.1 | V |
| Input Over-Voltage Shutdown | Figure 12 | | | | |
| Turn-Off Voltage Threshold | | 77 | 78.5 | 79.5 | V |
| Turn-On Voltage Threshold | | 76 | 77 | 78 | V |
| Shutdown Hysteresis Voltage | | 1.4 | 1.5 | 1.6 | V |
| Maximum Input Current | 100% Load | | | 4.8 | A |
| No-Load Input Current | | | 70 | 80 | mA |
| Off Converter Input Current | | | 1.6 | 3 | mA |
| Inrush Current Transient Rating | | | .01 | | $A^2s$ |
| Input Reflected-Ripple Current | RMS; see Figure 10 | | 5 | | mA |
| **OUTPUT CHARACTERISTICS** | | | | | |
| Output Voltage Set Point | 50% load | 14.8 | 15.0 | 15.2 | V |
| Output Voltage Regulation | | | | | |
| Over Load | | | ±10 | ±30 | mV |
| Over Line | | | ±15 | ±30 | mV |
| Over Temperature | | | ±50 | ±100 | mV |
| Total Output Voltage Range | | 14.64 | | 15.36 | V |
| Output Voltage Ripple and Noise | 20MHz bandwidth; see Figure 9 | | | | |
| Peak-to-Peak | | | 50 | 100 | mV |
| RMS | | | 15 | 30 | mV |
| Operating Output Current Range | | 0 | | 10 | A |
| Output DC Current-Limit Inception | Output Voltage 10% Low | | 11 | | A |
| Output DC Current-Limit Shutdown Voltage | | | 11 | | V |
| Output Short-Term Shutdown Current-Limit | | | 100 | | A |
| Short-Circuit Surge Current Transient Rating | | | 0.25 | | $A^2s$ |
| **DYNAMIC CHARACTERISTICS** | | | | | |
| Input Voltage Ripple Rejection | 120 Hz; Figure 16 | | 40 | | dB |
| Output Voltage Current Transient | See Figures 7 & 8 | | | | |
| Positive Step Change in Output Current | 50% Io to 75% Io | | 800 | | mV |
| Negative Step Change in Output Current | 75% Io to 50% Io | | 800 | | mV |
| Settling Time to 1% | | | 300 | | μs |
| Turn-On Transient | | | | | |
| Turn-On Time | See Figures 5 & 6 | | 4 | | ms |
| Output Voltage Overshoot | 10mF load capacitance, Iout = 0A | | | 0 | % |
| **EFFICIENCY** | | | | | |
| 100% Load | Figure 1 | | 90.2 | | % |
| 80% Load | | | 91.1 | | % |
| 60% Load | | | 91.2 | | % |
| 40% Load | | | 90.5 | | % |
| **TEMPERATURE LIMITS FOR POWER DERATING CURVE** | | | | | |
| Semiconductor Junction Temperature | Package rated to 150°C | | | 125 | °C |
| Board Temperature | Board rated to 165°C | | | 125 | °C |
| Transformer Temperature | Figure 3 | | | 125 | °C |
| **ISOLATION CHARACTERISTICS** | | | | | |
| Isolation Voltage | | 2000 | | | V |
| Isolation Resistance | | 10 | | | MΩ |
| Isolation Capacitance | | | 3300 | | pF |
| **FEATURE CHARACTERISTICS** | | | | | |
| Switching Frequency | | 180 | 200 | 220 | kHz |
| ON/OFF Control (Option P) | | | | | |
| Off-State Voltage | | 0 | | 0.8 | V |
| On-State Voltage | | 2.7 | | 15 | V |
| ON/OFF Control (Option N) | | | | | |
| Off-State Voltage | | 2.7 | | 15 | V |
| On-State Voltage | | 0 | | 0.8 | V |
| ON/OFF Control (Either Option) | | | | | |
| Pull-Up Voltage | | | Vin/6 | 15 | V |
| Pull-Up Resistance | | | 20 | | kΩ |
| Output Voltage Trim Range | Across Pins 9 & 5; Figures 17 & 18 | -20 | | +10 | % |
| Output Voltage Remote Sense Range | Across Pins 9 & 5 | | | +10 | % |
| Output Over-Voltage Protection | | | 125 | | % |
| Over-Temperature Shutdown | Average PCB Temperature | | 115 | | °C |

Specifications subject to change without notice.

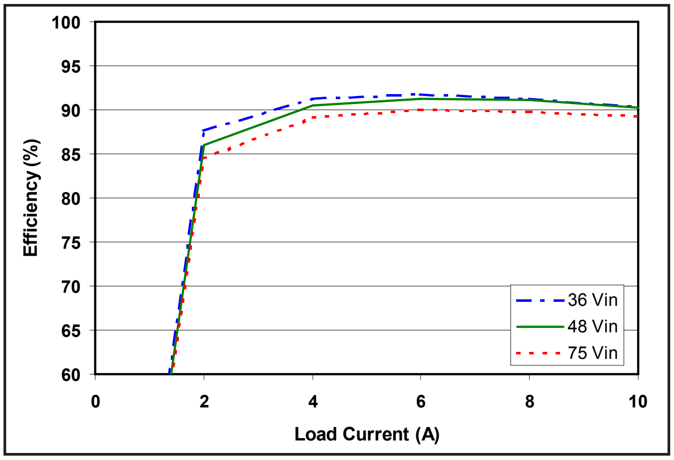



***Figure 1:*** *Efficiency vs. load current for minimum, nominal, and maximum input voltage with 25°C air flowing at the rate of 300 LFM.*

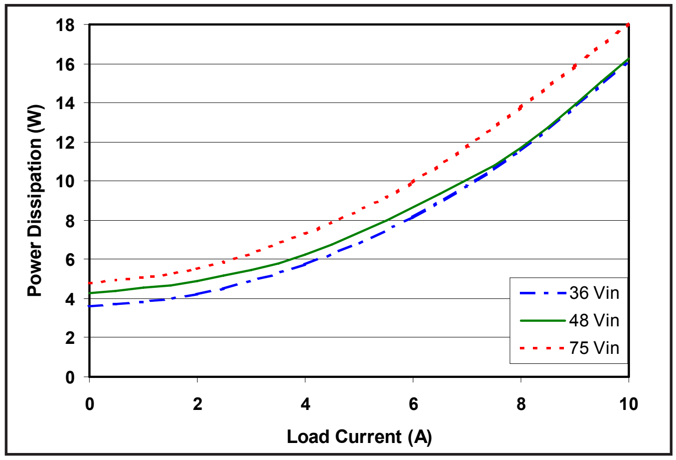



***Figure 2:*** *Power dissipation vs. load current for minimum, nominal, and maximum input voltage with 25°C air flowing at the rate of 300 LFM.*

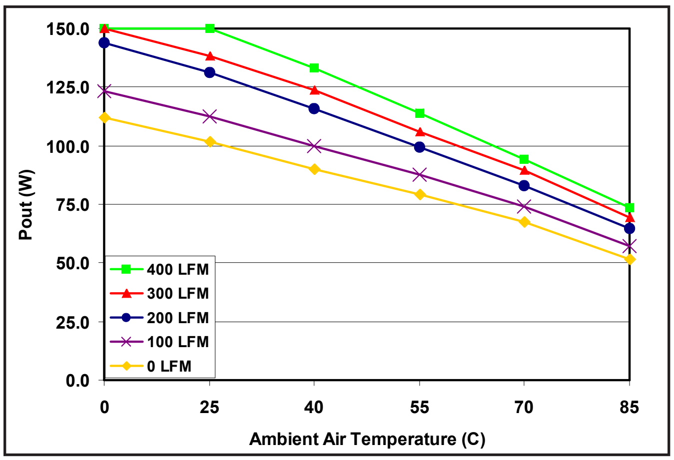



***Figure 3:*** *Maximum output power-derating curves vs. ambient air temperature for airflow rates of 0 LFM through 400 LFM with air flowing from input to output and nominal input voltage.*

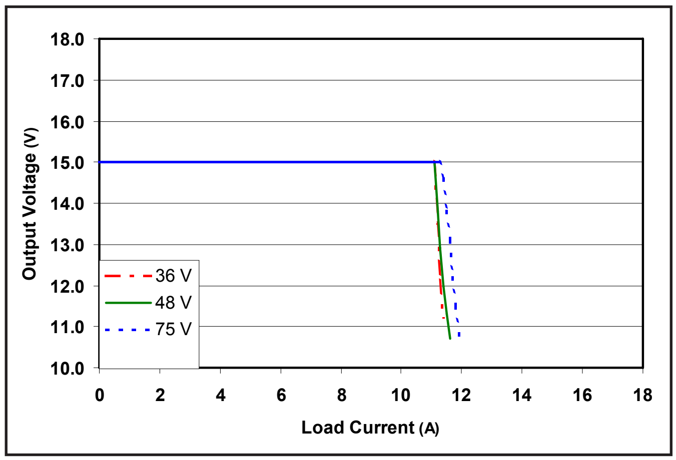



***Figure 4:*** *Output voltage vs. load current showing typical current limit curves and converter shutdown points.*

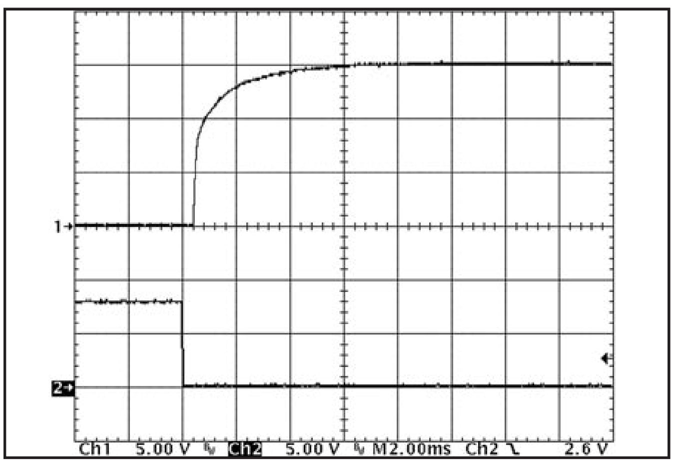



***Figure 5:*** *Turn-on transient at full rated load current (resistive load)*
*Top Trace: Vout; 5V/div*
*Bottom Trace: ON/OFF; 5V/div*

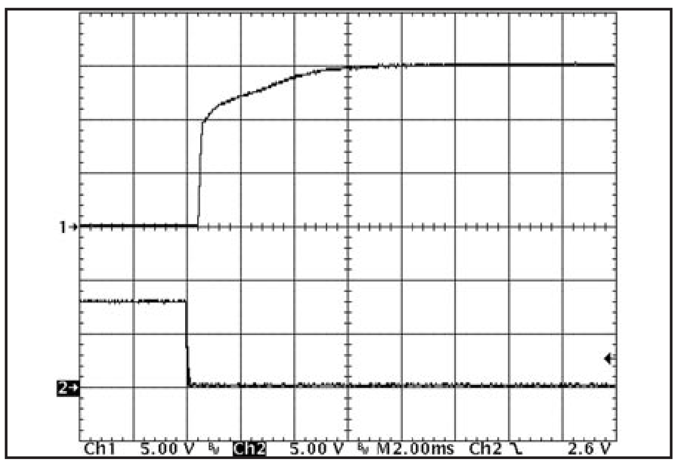



***Figure 6:*** *Turn-on transient at zero load current.*
*Top Trace: Vout; 5V/div*
*Bottom Trace: ON/OFF; 5V/div*

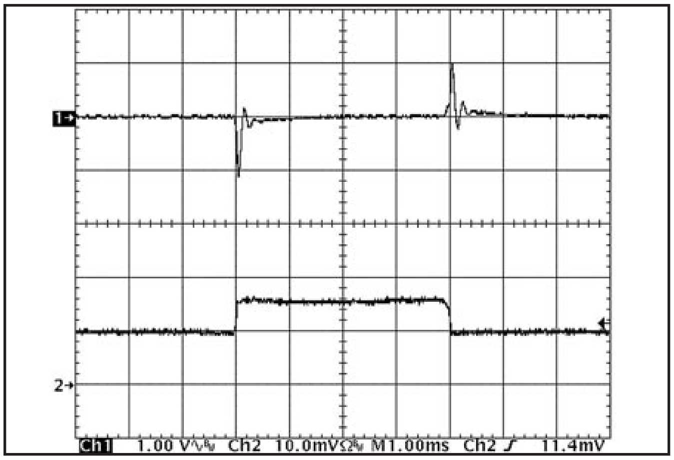



***Figure 7:*** *Output voltage response (1V/div) to a step-change in load current (50% - 75% - 50% of Imax; dI/dt = 0.1A/µs). Load capacitance: 15µF, 450 mΩ ESR tantalum capacitor and 1µF ceramic capacitor.*

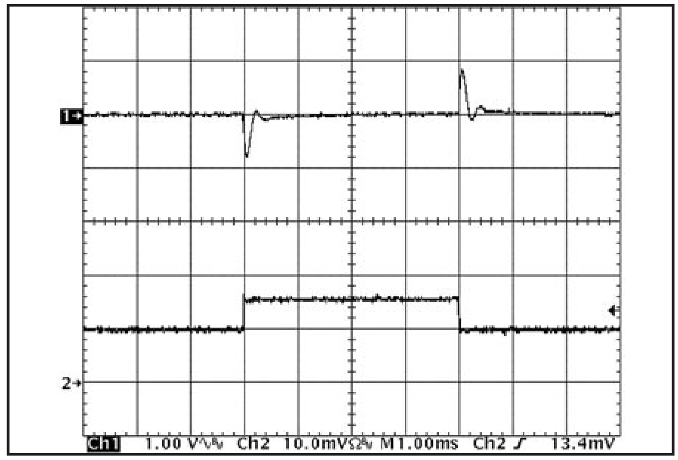



***Figure 8:*** *Output voltage response (1V/div) to a step-change in load current (50% - 75% - 50% of Imax: dI/dt = 1A/µs). Load capacitance: 100µF, 125 mΩ ESR tantalum capacitor and 1µF ceramic capacitor.*

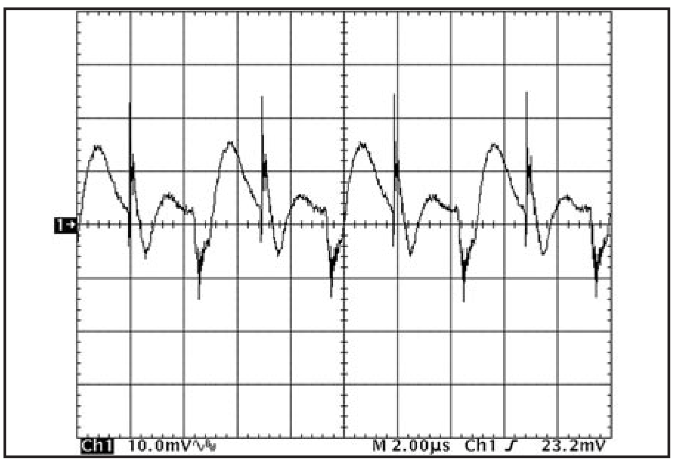



***Figure 9:*** *Output voltage ripple at nominal input voltage and rated load current (10 mV/div). Load Capacitance: 15µF, 450mΩ ESR tantalum capacitor and 1µF ceramic capacitor, 20 MHz bandwidth.*

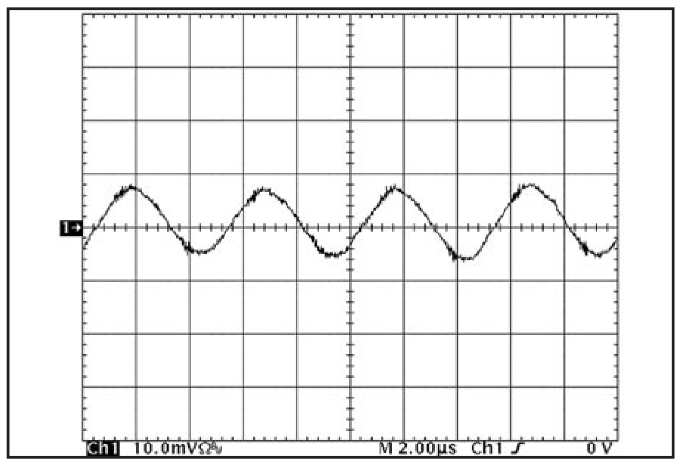



***Figure 10:*** *Input reflected ripple current through a 10 µH source inductor at nominal input voltage and rated load current (5 mA/div).*

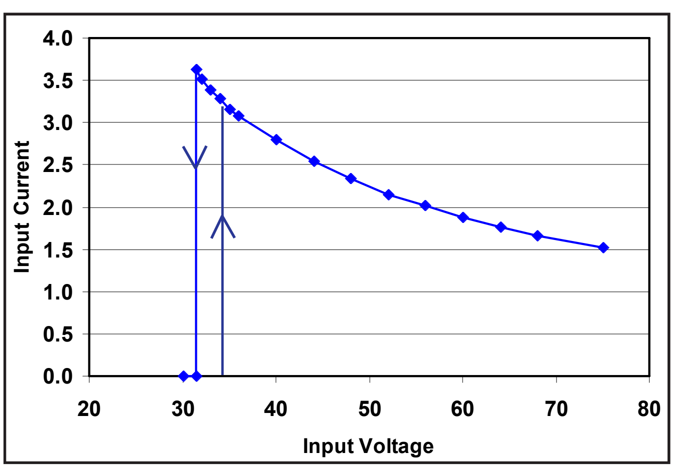



***Figure 11:*** *Input voltage vs. input current at full load showing input undervoltage lockout feature.*

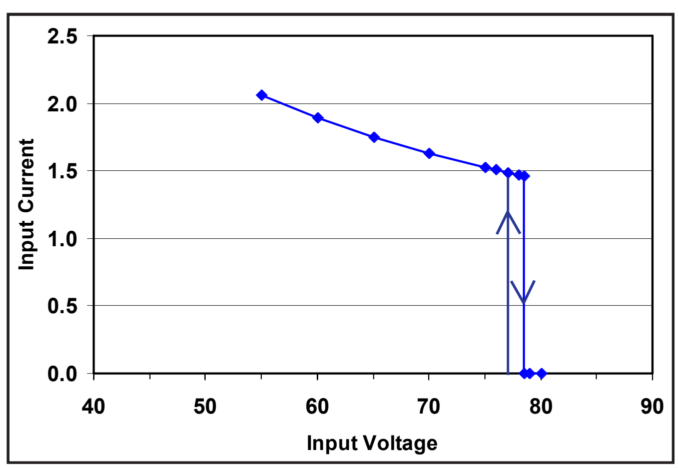



***Figure 12:*** *Input voltage vs. input current at full load showing input overvoltage shutdown feature.*

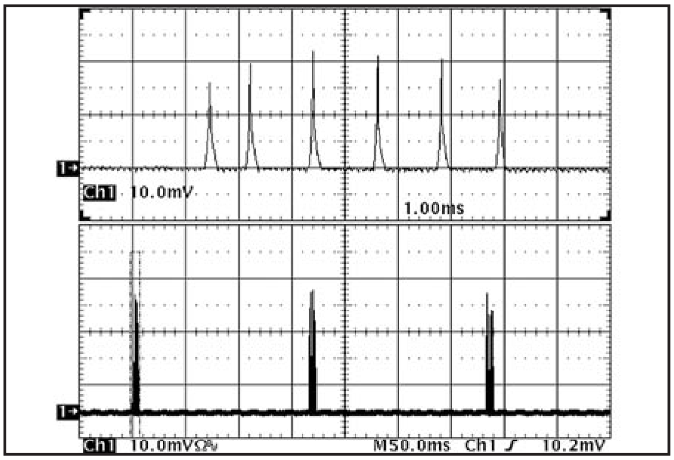



***Figure 13:*** *Load current (10A/div) as a function of time when the converter attempts to turn on into a 10 mΩ short circuit. Top trace is an expansion of the on-time portion of the bottom trace.*

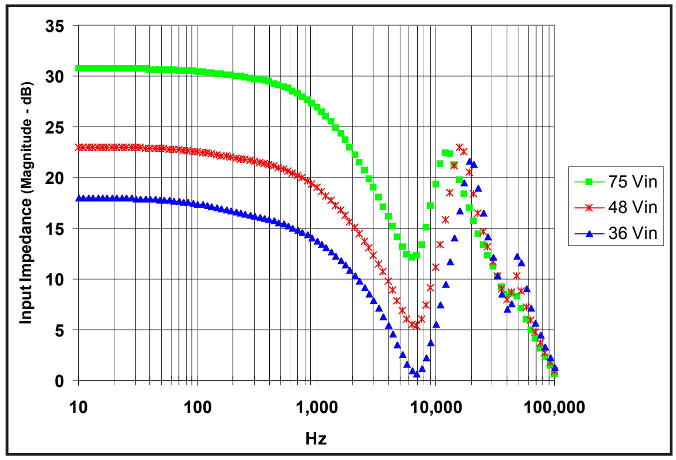



***Figure 14:*** *Input impedance ($Z_{in} = V_{in}/I_{in}$) for minimum, nominal, and maximum input voltage at full rated power.*

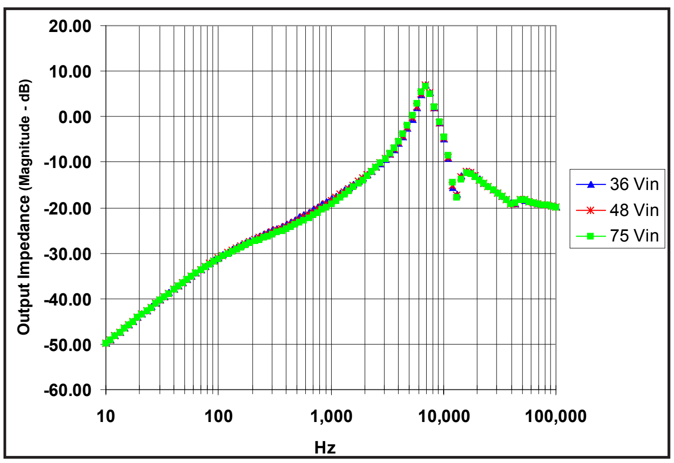



***Figure 15:*** *Output impedance ($Z_{out} = V_{out}/I_{out}$) for minimum, nominal, and maximum input voltage at full rated power.*

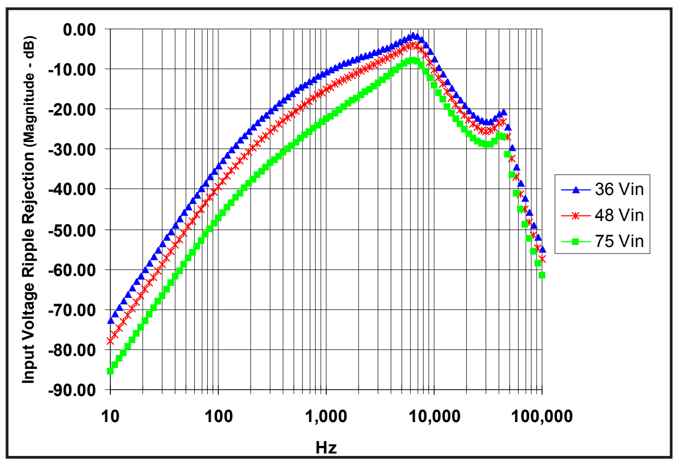



***Figure 16:*** *Input voltage ripple rejection (IVRR = $V_{out}/V_{in}$) for minimum, nominal, and maximum input voltage at full rated power.*

# BASIC OPERATION AND FEATURES

The *Power*Qor series converter uses a two-stage power circuit topology. The first stage is a buck-converter that keeps the output voltage constant over variations in line, load, and temperature. The second stage uses a transformer to provide the functions of input/output isolation and voltage step-down to achieve the low output voltage required.

Both the first stage and the second stage switch at a fixed frequency of 200 kHz. The fundamental frequency of the ripple in the voltage and current waveforms at the converter's input and output terminals is therefore 200 kHz, as well.

Rectification of the transformer's output is accomplished with synchronous rectifiers. These devices, which are MOSFETs with a very low on-state resistance, dissipate far less energy than Schottky diodes used in conventional dc/dc converters. This is the primary reason that the *Power*Qor converter has such high efficiency—even at very low output voltages and very high output currents.

Dissipation throughout the converter is so low that the **PowerQor converter requires no heatsink** to deliver a greater level of power than can be delivered by a conventional, Schottky-diode-based dc/dc converter with a 0.5″ high heatsink. At equivalent ambient air temperature, airflow rate, and output power level, the hottest semiconductor junction temperature and the hottest PCB temperature within the *Power*Qor converter are cooler than those found in conventional dc/dc converters with a 0.5″ high heatsink attached.

Since a heatsink is not required, the *Power*Qor converter does not need a metal baseplate or potting material to help conduct the dissipated energy to the heatsink. The *Power*Qor converter can thus be built more simply using conventional surface mount techniques on a PCB substrate.

Unlike conventional dc/dc converters, which have critical thermal connections between the power components and the baseplate, and between the baseplate and the heatsink, the *Power*Qor converter has no explicit, failure-prone thermal connections.

Compared to a conventional Schottky-diode-based dc/dc converter with a 0.5″ high heatsink, the *Power*Qor converters are more efficient and dissipate as little as half the energy. For example, the 3.3Vout *Power*Qor converter is 10% more efficient than a conventional converter (89% vs. 79% at full load) and dissipates less than half the energy. Additionally, because the *Power*Qor converter is thinner (0.4″ vs. 1.0″), the board-to-board pitch in a rack can be much smaller, and cooling airflow is less impeded by the converter. Because the *Power*Qor converter is much lighter (54 grams vs. 140 grams for a conventional converter with an attached heatsink), vibration and shock-induced problems are greatly reduced. Moreover, due to the lack of failure-prone explicit thermal connections and the lack of potting material the *Power*Qor converter is more reliable than conventional dc/dc converters.

The *Power*Qor series converters use the industry standard pin-out configuration used by other vendors of comparably sized and rated dc/dc converters. The units are pin for pin compatible with the Lucent JW150 series.

The *Power*Qor converter has many control and protection features:

- An **ON/OFF** input permits the user to control when the converter is *on* and *off* in order to properly sequence different power supplies and to reduce power consumption during a standby condition.

- **Positive and negative remote sense** inputs permit the user to maintain an accurate voltage at the load despite distribution voltage drops between the converter's output and the load.

- An **output voltage trim** input permits the user to trim the output voltage up or down to achieve a custom voltage level or to do voltage margining.

- An **input under-voltage lockout** and an **input over-voltage shutdown** insure that the converteroperates only when the input voltage is within its prescribed range. The under-voltage lockout avoids input system instability problems while the input voltage is rising, and the over-voltage shutdown protects the converter from damage if the input voltage is too high.

- The **output current limit** protects both the converter and the board on which it is mounted against a short circuit condition.
- An **output over-voltage limit** circuit controls how high the output voltage can get. This circuit senses when the output voltage exceeds a prescribed value and pulls down the output voltage below its nominal value for a brief period of time.
- A sensor located in a central spot of the PCB provides a **PCB temperature limit**. If, due to an abnormal condition, this spot gets too hot, the converter will turn off. Once the converter has cooled, it will automatically turn on again without the need to recycle the input power.

## CONTROL PIN DESCRIPTIONS

**Pin 2 (ON/OFF)**: The ON/OFF input, Pin 2, permits the user to control when the converter is *on* or *off*. This input is referenced to the return terminal of the 48V input bus. There are two versions of the PowerQor series converter that differ by the sense of the logic used for the ON/OFF input. In the PQxxyyyHNAzzP version, the ON/OFF input is active high (meaning that a high turns the converter *on*). In the PQxxyyyHNAzzN version, the ON/OFF signal is active low (meaning that a low turns the converter *on*).

A low ON/OFF signal is achieved by connecting Pin 2 to Pin 4. A high signal is achieved by releasing Pin 2 so it can be pulled up to an internal voltage (equal to Vin/6) by an internal 20kΩ resistor. It is recommended that an open-collector circuit be used to interface with Pin 2.

The voltage on Pin 2 must be held below 0.8V to be a valid low signal, and the voltage must be allowed to rise above 2.7V to be a valid high signal.

When the 48V input bus is present and the ON/OFF signal makes a transition from its OFF level to its ON level, the converter will turn on with a soft-start transition. Pin 2 must be kept in the OFF-state for at least 2 ms to initiate a full soft-start. Shorter off times will result in a partial soft-start transition.

**Pins 8 and 6 (SENSE(±))**: The SENSE(±) inputs permit the user to correct for voltage drops along the conductors that connect the load to the converter's output pins.

Pin 8 should be connected to Vout(+) and Pin 6 should be connected to Vout(-). These connections can either be made at the output pins of the converter or remotely at the load. A remote connection at the load can adjust for a voltage drop as large as 10% of Vout. That is,

$$\left[\text{Vout}(+) - \text{Vout}(-)\right] - \left[\text{SENSE}(+) - \text{SENSE}(-)\right] \leq 10\%\text{Vout}$$

Pins 8 and 6 must be connected for proper regulation of the output voltage. However, if these connections are not made, nothing catastrophic will happen to the converter under normal operating conditions—the converter will simply deliver an output voltage that is slightly lower than its specified value.

Note: the output over-voltage protection circuit senses the voltage across the sense leads (pins 8 and 6) to determine when it should trigger, not the voltage across the converter's output (pins 9 and 5).

**Pin 7 (TRIM)**: The TRIM input permits the user to adjust the output voltage across the sense leads up or down. To lower the output voltage, the user should connect a resistor between Pin 7 and Pin 6, which is the SENSE(-) input. To raise the output voltage, the user should connect a resistor between Pin 7 and Pin 8, which is the SENSE(+) input.

A resistor connected between Pin 7 and Pin 6 will decrease the output voltage. For a desired decrease of Δ percent of the nominal output voltage, the value of this resistor should be

$$R_{\text{trim-down}} = \left(\frac{100\%}{\Delta}\right) - 2\text{ k}\Omega$$

where

$$\Delta = \left(\frac{\text{Vnominal} - \text{Vdesired}}{\text{Vnominal}}\right) \times 100\%$$

Figure 17 graphs this relationship between Rtrim-down and Δ. The output voltage can be trimmed down as much as 20%.

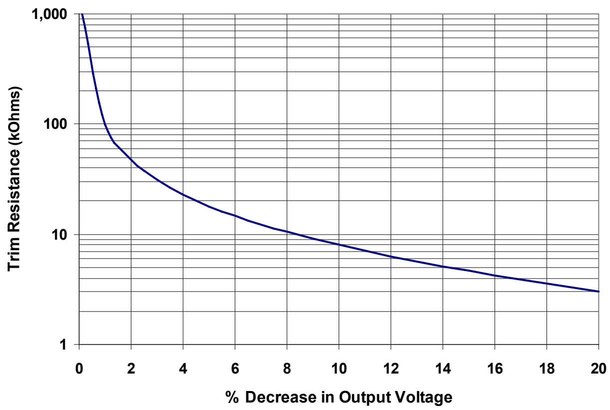



*Figure 17: Trim Down Graph for 15Vout*

A resistor connected between Pin 7 and Pin 8 will increase the output voltage. For a desired increase of Δ percent of the nominal output voltage, the value of this resistor should be

$$R_{trim\text{-}up} = \frac{\left(\frac{V_{NOM}}{V_{REF}} - 2\right) \bullet V_{DES} + V_{NOM}}{V_{DES} - V_{NOM}} \ k\Omega$$

where

$V_{NOM}$ = Nominal Voltage
$V_{DES}$ = Desired Voltage
$V_{REF}$ = 1.225 Volts

Figure 18 graphs this relationship between Rtrim-up and Δ. The output voltage can be trimmed up as much as 10%

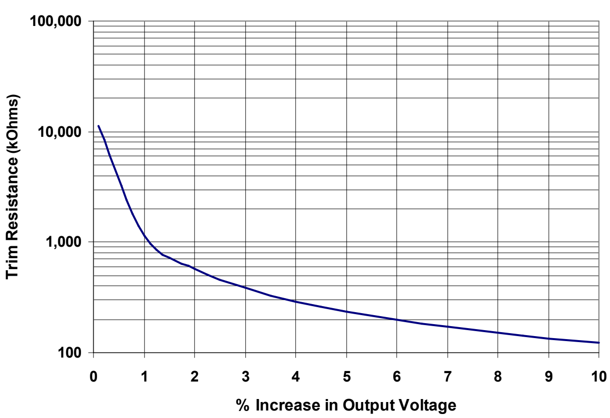



*Figure 18: Trim Up Graph for 15Vout*

Note: the TRIM feature does not affect the voltage at which the output over-voltage protection circuit is triggered. Trimming the output voltage too high may cause the over-voltage protection circuit to engage.

**TOTAL DC VARIATION OF Vout:** For the converter to meet its full specifications, the maximum variation of the dc value of Vout, due to both trimming and remote load voltage drops, should not be greater than +10%/-20%

## PROTECTION FEATURES

**Input Under-Voltage Lockout**: The converter is designed to turn off when the input voltage is too low, helping avoid an input system instability problem, described in more detail below. The lockout circuitry is a comparator with dc hysteresis. When the input voltage is rising, it must exceed a typical value of 34.5V before the converter will turn on. Once the converter is on, the input voltage must fall below a typical value of 31.5V before the converter will turn off.

**Input Over-Voltage Shutdown**: The converter also turns off when the input voltage is too high. This protection feature allows the converter to withstand an input voltage as high as 100V without destruction. The shutdown circuitry is a comparator with dc hysteresis. When the input voltage exceeds a typical value of 78.5V, the converter will turn off. Once the converter is off, it will turn back on when the input voltage falls below a typical value of 77V.

**Output Current Limit**: The output current is limited to a typical value of 113% of the rated output current. As shown in Figure 4, this limit does not change appreciably as the output voltage drops. However, once the impedance of the short across the output is small enough to make the output voltage drop below approximately 60% of its nominal value, the converter turns off.

The converter then enters a mode where it repeatedly turns on and off at a 5 Hz (nominal) frequency with a 5% duty cycle until the short circuit condition is removed. During the 8 ms long on-times of these 200 ms long cycles, the converter will repeatedly attempt to bring the output voltage up in a soft-start manner until the converter's output current exceeds the short-term shutdown current-limit. At that point the converter will stop delivering current and initiate another soft-start procedure. These soft-start attempts repeat at approximately a 0.25 ms interval during the 8 ms long on-time.

At the completion of the 8 ms on-time, the converter turns off for 192 ms to avoid excessive heating of the converter or the load board.

If the converter's output is instantly shorted with zero impedance, output current will initially be provided by the discharge of the converter's output capacitors. This current is limited to approximately 80A by the ESR of the capacitors and it will decay with an 8μs time constant. After that, the converter's output current will rise linearly over a 60μs time frame to approximately 80A before the converter stops switching. The load current will then drop to zero over approximately the next 60μs. As a result, the $I^2t$ rating of this short-term current pulse initiated by an instantaneous, zero impedance short-circuit is a very low $0.25A^2s$.

Since a real short-circuit would not be instantaneous, nor would it have zero impedance, the transient rating for a real short-circuit would therefore be less than this value.

**Output Over-Voltage Limit**: The output voltage is limited by an over-voltage protection circuit that senses when the output voltage exceeds its limit and pulls the voltage down below its nominal level. The output voltage then exponentially returns to its nominal value with a 2 ms time constant.

The over-voltage protection circuit is not a "hard clamp"—it does not guarantee the output voltage will always remain below its prescribed limit if, for instance, some portion of the converter fails. However, it does limit the maximum output voltage while the converter recovers from 1) a sudden unloading of the converter, 2) a release of a short-circuit condition, or 3) a release of a current limit condition. Load capacitance determines exactly how high the output voltage will rise in response to these conditions—the higher the capacitance, the lower the voltage limit will be.

**Thermal Shutdown**: The PQ-048033HN30 has a temperature sensor located such that it senses the average temperature of the converter. As explained below in the *Thermal Section*, at full power the hottest MOSFET junction may be 20°C hotter than this point, and the hottest area of the PCB may be 15°C hotter. The thermal shutdown circuit is designed to turn the converter off when the temperature at the sensed location reaches 115°C. It will allow the converter to turn back on when the temperature of the sensed location falls below 110°C. When the converter turns on again, it will do so with a soft-start transition.

# APPLICATION CONSIDERATIONS

### INPUT SYSTEM INSTABILITY

In a distributed power supply architecture, a power source provides power over a bus to many modular dc/dc converters. At low frequencies, these dc/dc converters appear incrementally as *negative* resistance loads. This negative resistance could cause "input system instability" as described below.

**Incremental Negative Resistance**: A modular dc/dc converter is designed to hold its output voltage constant no matter how its input voltage varies. Given a constant load current, the power drawn from the input bus therefore is also a constant. If the input voltage *increases* by some factor, the input current must *decrease* by the same factor to keep the power level constant.

In incremental terms, a positive incremental change in the input voltage results in a negative incremental change in the input current. Incrementally, then, the converter looks like a negative resistor.

The value of this negative resistor at a particular operating point, $V_{IN}$, $I_{IN}$, is:

$$R_N = \frac{-V_{IN}}{I_{IN}}$$

Note that this resistance is a function of the operating point. At full load and low input voltage, the resistance is smallest, while at light load and high input voltage, it is largest.

**Potential Input System Instability**: The preceding analysis assumes dc voltages and currents at the input to the dc/dc converter. However, for ac waveforms the incremental input model for the dc/dc converter must also include the effects of its input filter and control loop dynamics. Figure 19 shows the incremental circuit model when the dc/dc converter is connected to a power source, modeled as a voltage source, $V_S$, in series with an inductor, L, and some positive resistance, $R_P$.

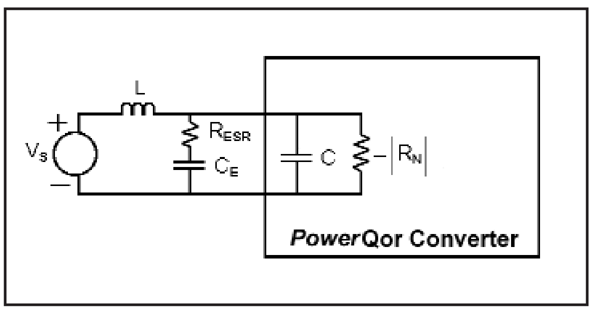



Figure 19

In this figure, C represents the parallel combination of the converter's effective input capacitor and any external ceramic capacitor that is connected across the input terminals. The value of the effective input capacitor can be determined from the converter's input impedance.

The circuit shown in this figure is characterized by the following second-order equation:

$$s^2LC + s\left(\frac{L}{-|R_N|} + R_PC\right) + 1 = 0$$

For power delivery to be efficient, $R_P$ must be very small compared to $|R_N|$. However, for the system to be stable, however, the following relationship must hold:

$$R_P > \frac{L}{C|R_N|}$$

Notice from this result that if L is too large, or if $R_P$ is too small, the system might be unstable. Potential instability would first be observed at low input voltage and full load since the absolute value of $R_N$ is smallest at this operating condition.

If an instability cannot be corrected by changing L or $R_P$, one possible solution is to place additional ceramic capacitors across the converter's input terminals until the relationship shown above is satisfied.

A more common solution is to connect an electrolytic capacitor (with a series resistance) across the input terminals. The capacitor's series resistance, $R_{ESR}$, may be the capacitor's own Equivalent Series Resistance, or it may include an explicit resistor connected in series with the electrolytic capacitor.

The circuit shown in Figure 20 models this approach, where it is assumed that the source resistance, $R_P$, is negligibly small.

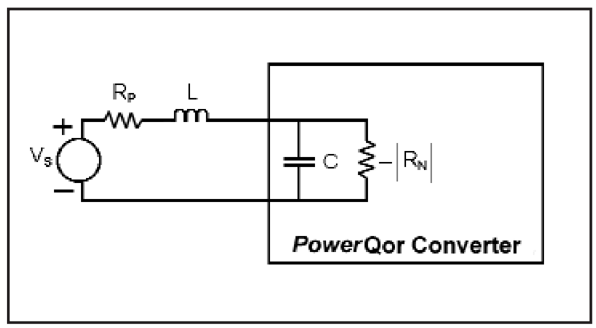



Figure 20

To ensure stability in this system, the following relationships must be satisfied:

$$R_{ESR} > \frac{L}{C_E|R_N|} \quad \text{and} \quad R_{ESR} < |R_N|$$

where it is assumed that $C_E >> C$, which is typically the case.

Note that this second, more common approach to solving the instability problem is consistent with building an input filter to attenuate the ac ripple currents drawn by the dc/dc converter. In this case the inductance L would be an explicit input filter inductor that could be made large since it is divided by a large capacitance, $C_E$, in the relationship shown above.

A detailed application note titled "Input System Instability" is available on the SynQor web site (www.synqor.com).

**THERMAL**

*The values used for the following thermal discussion are derived from the 48V$_{in}$, 3.3V$_{out}$, 30A$_{out}$ PowerQor module (PQ48033HNA30).*

The *Power*Qor PQ48033HNA30 dc/dc converter dissipates less than half the power of a conventional dc/dc converter that uses Schottky diodes. As such, it *does not need a heatsink.* However, just as with any heat producing part in an electronic system, care must be taken to ensure the *Power*Qor converter receives sufficient cooling airflow.

The reason the *Power*Qor converter does not need a heatsink is straightforward. A heatsink increases the surface area exposed to cooling airflow. Typically, a half-inch high heatsink is used, and its fins have 2.5 times the surface area of the baseplate.

However, heat removal is not increased by a factor of 2.5 for two reasons. First, the moving air does not flow freely between the fins, and second, the interface between the baseplate and the heatsink has a significant thermal resistance. Both of these effects reduce the improvement that the heatsink could theoretically provide. In actuality, a half-inch high heatsink generally improves heat removal by only a factor of 1.8 compared to simply blowing air at the same flow rate over the converter's baseplate.

*With less than half as much heat to remove as a conventional dc/dc converter, the PQ48033HNA30 dc/dc converter does not need the factor of 1.8 enhancement of heat-removal provided by a heatsink.*

Moreover, because the *Power*Qor converters have an irregular surface, rather than the smooth surface of a metal baseplate, the thermal resistance between the converter and the air is actually 10% lower than for a conventional dc/dc converter that does not have a heatsink. The irregular surface creates turbulence, rather than laminar flow, bringing more of the cool moving air into direct contact with the *Power*Qor converter and its components.

For example, at an airflow rate of 300 LFM, the average thermal resistance between the PQ48033HNA30 converter and the ambient air is 3.9°C/W, whereas for a conventional dc/dc converter, the thermal resistance between the smooth baseplate and the ambient air is 4.3°C/W. If a half-inch high heatsink is added to the latter, the thermal resistance between the baseplate and the ambient air reduces to 2.4°C/W. However, since the *Power*Qor converter dissipates less than half the heat, its average temperature rise is still 20% lower than that of the conventional converter *with* a heatsink.

Of course, our attention should not be on the average temperature of the *Power*Qor converter, but rather the temperature of the hottest MOSFET junction and the hottest area of the PCB. As shown by the thermal pictures presented in the "Performance Curves" section, at full power the hottest semiconductor junctions are the power MOSFETs and the hottest area of the PCB is near one of the magnetic components.

At full power the hottest MOSFET junction temperature is approximately 20°C above the average temperature of the PQ48033HNA30 converter, while the hottest area of the PCB is approximately 15°C above the converter's average.

By way of comparison, consider a conventional, 79% efficient, 3.3V$_{out}$, 30A$_{out}$ dc/dc converter with a half-inch high heatsink cooled by air flowing at a rate of 300 LFM. The baseplate of this converter would rise 63°C above ambient (26 dissipated watts times 2.4°C/watt). The hottest semiconductor junctions inside this dc/dc converter are 20 degrees hotter than the baseplate, which gives a total temperature rise of 83°C above ambient.

For the PQ48033HNA30 converter operating at full power at 89% efficiency and cooled by 300 LFM air, the average board temperature will rise 48°C above ambient and the hottest junction temperature will be 20°C above that, giving a total temperature rise of 68°C. The result is that the hottest junctions of the *Power*Qor converter *without* a heatsink are 15°C cooler than their counterparts in a conventional dc/dc converter with an attached heatsink operating under the same conditions.

Additionally, the *Power*Qor converter is relatively insensitive to the direction of the flow of the cooling air. Unlike for a conventional converter with a heatsink where the air must flow parallel to the fins of the heatsink, the cooling air can flow over the *Power*Qor converter in any direction. Although different directions *do* affect which semiconductor junctions are the hottest, the maximum temperature rise does not change much.

## POWER DERATING

Figure 3 shows the power derating curves for the PQ48150HNA10 converter. These curves show the maximum output power the converter can deliver while keeping its hottest semiconductor junction below 125°C, the hottest area of the PCB below 125°C, and the hottest temperature of the isolation transformer windings below 125°C. The semiconductors are rated to 150°C and the PCB is rated to 165°C, so these derating curves have significant built-in margins.

Note that, even in a situation where there is no moving air, the PQ48150HNA10 converter can still deliver 77 watts (5.13A at 15V) at 55°C ambient.

It is possible to derive a different set of power derating curves based on lower or higher maximum junction and PCB temperatures.

## MULTIPLE CONVERTERS

When using multiple converters for the same load board, consult SynQor factory for additional application notes.

Other application notes can be found on the SynQor web site or consult a technical support engineer at SynQor.

## PART NUMBERING SYSTEM

The part numbering system for SynQor's *Power*Qor DC/DC converters is shown in the figure below and has the following format:

Example part #: **PQ48033HNA30NNS**

This part number indicates a *Power*Qor converter with 48Vin, 3.3Vout, half-brick size, normal performance level, open air design, 30 amps output current, negative logic, 0.145" pins, and the standard feature set.

When ordering SynQor converters, please ensure that you use the complete 15 character part number. Although there are no default values for logic and pin length, the most common units in inventory have negative logic and N length pins.

**30Amp Half-Brick Product Family and Part Numbering Scheme**

| Product Family | Input Voltage | Output Voltage | Package Size | Performance Series | Thermal Design | "Rated" Output Current | Pos./Neg. Logic | Pin Length | Features |
|---|---|---|---|---|---|---|---|---|---|
| **PQ** | **48** | **033** | **H** | **N** | **A** | **30** | **N** | **N** | **S** |
| PQ - PowerQor | 48 - 35V-75V | 020 - 2.0V | H - Half Brick | N - Normal | A - Open Frame | 30 - 30 Amps | P - Positive | K - 0.110" | S - Standard |
| | | 025 - 2.5V | | | | | N - Negative | N - 0.145" | F - Full Feature |
| | | 033 - 3.3V | | | | | | R - 0.180" | |
| | | 050 - 5.0V | | | | | | Y - 0.250" | |
| | | 120 - 12V | | | | 12 - 12.5 Amps | | | |
| | | 150 - 15V | | | | 10 - 10 Amps | | | |
| *This is the base part number* | | | | | | | *Added to indicate options* | | |

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Warranty
SynQor offers a three (3) year limited warranty. Complete warranty information is listed on our web site or is available upon request from SynQor.