

**36-75 V**  
Input

**12 V**  
Output

**336 W**  
Power

**2000 Vdc**  
Isolation

**Quarter-brick**  
DC Bus Converter

The BusQor® SQ60120QPA28 bus 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. The SQ BusQor series provides an isolated step down voltage from 48 V to a semi-regulated 12 V intermediate bus. BusQor converters are ideal for customers who need multiple outputs and wish to build or buy point of load converters to work with a 12 V rail. RoHS Compliant (see last page).

## BusQor®

Bus Converter



SQ60120QPA28 Module

### Operational Features

- Ultra-high efficiency, 95% at full rated load current
- Delivers up to 28 A (336 W) of output current (power) with minimal derating - no heatsink required
- Input voltage range: 36 – 75 V
- Fixed frequency switching provides predictable EMI performance

### Mechanical Features

- Industry standard quarter-brick bus converter pin-out ("S" Feature Set)
- Industry standard size: 1.45" x 2.3" (36.8 x 58.4 mm)
- Total height only 0.483" (12.27 mm), permits better airflow and smaller card pitch
- Total weight: 1.5 oz. (42 grams)

### Control Features

- On/Off control referenced to input side

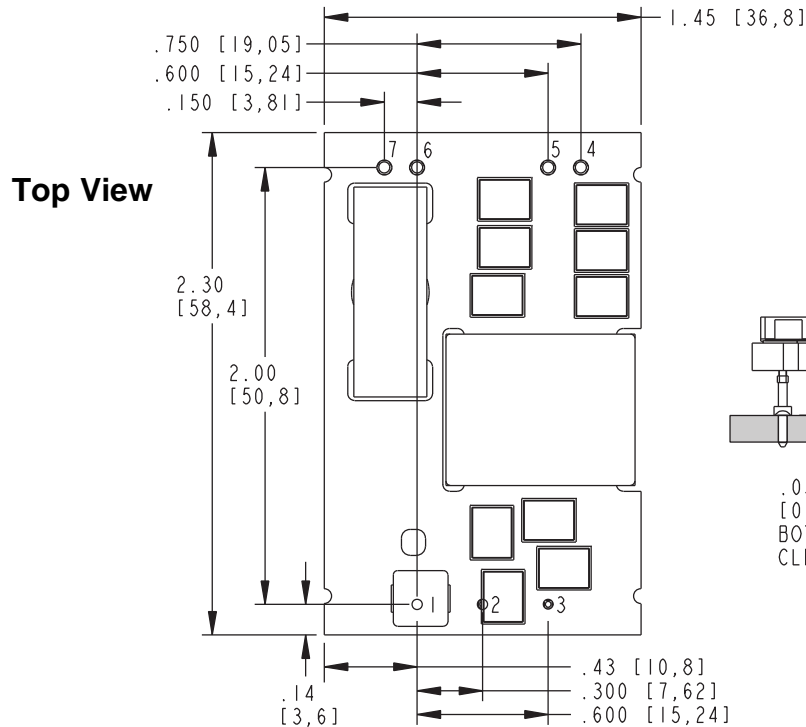
### Protection Features

- Input under-voltage lockout and over-voltage shutdown protects against abnormal input voltages
- Output current limit and short circuit protection
- Output over-voltage protection
- Thermal shutdown

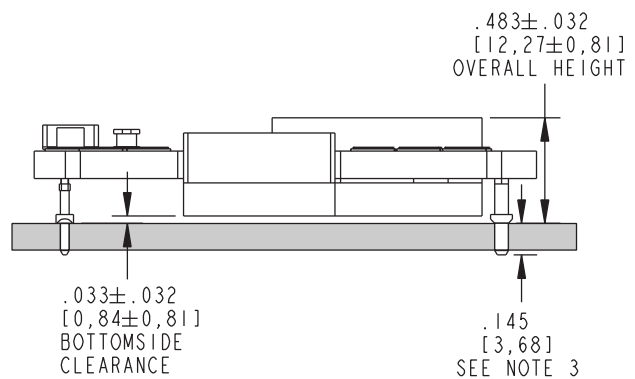
### Safety Features

- 2000V, 30 MΩ input-to-output isolation
- UL/cUL 60950-1 recognized (US & Canada), basic insulation rating
- TUV certified to EN60950-1
- Meets 72/23/EEC and 93/68/EEC directives
- Meets UL94V-0 flammability requirements

### MECHANICAL DIAGRAM



### Side View



### NOTES

- 1) Pins 1-3 are 0.040" (1.02mm) diameter with 0.080" (2.03 mm) diameter standoff shoulders.
- 2) Pins 4-7 are 0.062" (1.57 mm) diameter with 0.100" (2.54 mm) diameter standoff shoulders.
- 3) Other pin lengths available. Recommended pin length is 0.03" (0.76mm) greater than the PCB thickness.
- 4) All Pins: Material - Copper Alloy  
Finish (RoHS 6/6) - Matte Tin over Nickel plate
- 5) Undimensioned components are shown for visual reference only.
- 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) Weight: 1.5 oz. (42 g) typical
- 8) Workmanship: Meets or exceeds IPC-A-610C Class II
- 9) UL/TUV standards require a clearance of 0.04" (1.02mm) around primary areas of the module.

### PIN DESIGNATIONS

Pin No.	Name	Function
1	Vin(+)	Input Positive (36V - 75V)
2	ON/OFF	Logic control input to turn converter on and off.
3	Vin(-)	Input Negative
4	<i>Vout(+)</i>	<i>Output Positive</i>
5	Vout(-)	Output Negative
6	Vout(+)	Output Positive
7	<i>Vout(-)</i>	<i>Output Negative</i>

*Pins in Italics Shaded text are Optional*

### SQ60120QPA28 ELECTRICAL CHARACTERISTICS

T<sub>A</sub>=25°C, airflow rate=300 LFM, V<sub>in</sub>=48Vdc unless otherwise noted; full operating temperature range is -40°C to +100°C ambient temperature with appropriate power derating. Specifications subject to change without notice.

Parameter	Min.	Typ.	Max.	Units	Notes & Conditions
<b>ABSOLUTE MAXIMUM RATINGS</b>					
Input Voltage					
Non-Operating	0		100	V	Continuous
Operating	36	48	75	V	Continuous
Operating Transient Protection			100	V	100 ms
Isolation Voltage (input to output)			2000	V	Basic insulation, Pollution Degree 2
Operating Temperature	-40		100	°C	
Storage Temperature	-55		125	°C	
Voltage at ON/OFF input pin	-2		18	V	
<b>INPUT CHARACTERISTICS</b>					
Operating Input Voltage Range	36	48	75	V	
Input Under-Voltage Lockout					
Turn-On Voltage Threshold	31		34	V	
Turn-Off Voltage Threshold	28		32	V	
Lockout Voltage Hysteresis	2		4	V	
Input Over-Voltage Shutdown					
Turn-Off Voltage Threshold		105		V	V <sub>in</sub> when unit will shut down
Turn-On Voltage Threshold		95		V	V <sub>in</sub> when unit turns on after shutdown event
Maximum Input Current			12	A	100% Load, 35 V <sub>in</sub>
No-Load Input Current			130	mA	
Disabled Input Current			8.5	mA	
Input Reflected-Ripple Current		7.5	14.0	mA	RMS through 10µH inductor; Figures 12 & 14
Input Terminal-Ripple Current		600	1000	mA	RMS, full load; Figures 12 & 1
Recommended Input Fuse <sup>1</sup>			15	A	Fast blow external fuse recommended
Input Filter Component Values (C\I)		6.6\0.22		µF\µH	Internal values
Recommended External Input Capacitance		47		µF	Typical ESR 0.1-0.2Ω; see Figure 12
<b>OUTPUT CHARACTERISTICS</b>					
Output Voltage Set Point		12.35		V	48V <sub>in</sub> , no load
Output Voltage Regulation					
Over Line		+0.48\ -1.8		V	Figure 4
Over Load		+0\ -0.6		V	Figure 4
Over Temperature		±300		mV	Figure 4
Total Output Voltage Range	10.6		12.7	V	Over sample, line, load, temperature & life
Output Voltage Ripple and Noise <sup>2</sup>					20MHz bandwidth; Figures 12 & 15
Peak-to-Peak		150	300	mV	Full Load; see Figures 12 & 15
RMS		40	100	mV	Full Load; see Figures 12 & 15
Operating Output Current Range	0		28	A	Subject to thermal derating; Figures 5 - 8
Output DC Current-Limit Inception		35		A	Output Voltage 10% Low; Figure 16
Output DC Current-Limit Shutdown Voltage		7		V	
Back-Drive Current Limit while Disabled		50		mA	Negative current drawn from output
Maximum Output Capacitance			3,000	µF	12V <sub>out</sub> at 28A Resistive Load
<b>DYNAMIC CHARACTERISTICS</b>					
Output Voltage during Load Current Transient					
For a Step Change in Output Current (0.1A/µs)		1500	2250	mV	50% to 75% to 50% lout max; Figure 11
Settling Time		250	350	µs	To within 1% V <sub>out</sub> nom
Turn-On Transient					
Turn-On Time		8	10	ms	Full load, V <sub>out</sub> =90% nom.; Figures 9 & 10
Start-Up Inhibit Time		200		ms	-40°C to +125°C; Figure E
Output Voltage Overshoot		0		%	3 mF load capacitance, lout = 0A
<b>EFFICIENCY</b>					
100% Load		95		%	Figure 1
50% Load		95		%	Figure 1
<b>TEMPERATURE LIMITS FOR POWER DERATING CURVES</b>					
Semiconductor Junction Temperature			125	°C	Package rated to 150°C
Board Temperature			125	°C	UL rated max operating temp 130°C
Transformer Temperature			125	°C	See Figures 5 - 8 for derating curves
<b>ISOLATION CHARACTERISTICS</b>					
Isolation Voltage (dielectric strength)		2000		V	
Isolation Resistance		30		MΩ	
Isolation Capacitance <sup>3</sup>			470	pF	

Note 1: UL's product certification tests were carried out using 15A fast blow fuse. Fuse interruption characteristics have to be taken into account while designing input traces. User should ensure that Input trace is capable of withstanding fault currents until fuse blows.

Note 2: For applications requiring reduced output voltage ripple and noise, consult SynQor applications support (e-mail: support@synqor.com)

Note 3: Higher values of isolation capacitance can be added external to the module.

### ELECTRICAL CHARACTERISTICS (Continued)

Parameter	Min.	Typ.	Max.	Units	Notes & Conditions
<b>FEATURE CHARACTERISTICS</b>					
Switching Frequency	260	300	340	kHz	
ON/OFF Control (Option P)					Figure B
Off-State Voltage	-1.0		0.8	V	
On-State Voltage	2.4		18	V	
ON/OFF Control (Option N)					Figure B
Off-State Voltage	2.4		18	V	
On-State Voltage	-1.0		0.8	V	
Output Over-Voltage Protection		16		V	Over full temp range; no load
Over-Temperature Shutdown	140		150	°C	Average PCB Temperature
Over-Temperature Shutdown Restart Hysteresis		10		°C	
<b>RELIABILITY CHARACTERISTICS</b>					
Calculated MTBF (Telcordia)		2.6		10 <sup>6</sup> Hrs.	TR-NWT-000332; 80% load, 300LFM, 40°C T <sub>a</sub>
Calculated MTBF (MIL-217)		2.1		10 <sup>6</sup> Hrs.	MIL-HDBK-217F; 80% load, 300LFM, 40°C T <sub>a</sub>
Field Demonstrated MTBF				10 <sup>6</sup> Hrs.	See our website for details

### STANDARDS COMPLIANCE

Parameter	Notes
<b>STANDARDS COMPLIANCE</b>	
UL/cUL 60950-1	File # E194341, Basic insulation & pollution degree 2
EN60950-1	Certified by TUV
72/23/EEC	
93/68/EEC	
Needle Flame Test (IEC 695-2-2)	Test on entire assembly; board & plastic components UL94V-0 compliant
IEC 61000-4-2	ESD test, 8kV - NP, 15kV air - NP (Normal Performance)
GR-1089-CORE	Section 7 - electrical safety, Section 9 - bonding/grounding

- An external input fuse must always be used to meet these safety requirements. Contact SynQor for official safety certificates on new releases or download from the SynQor website.

### QUALIFICATION TESTING

Parameter	# Units	Test Conditions
<b>QUALIFICATION TESTING</b>		
Life Test	32	95% rated V <sub>in</sub> and load, units at derating point, 1000 hours
Vibration	5	10-55Hz sweep, 0.060" total excursion, 1 min./sweep, 120 sweeps for 3 axis
Mechanical Shock	5	100g minimum, 2 drops in x and y axis, 1 drop in z axis
Temperature Cycling	10	-40°C to 100°C, unit temp. ramp 15°C/min., 500 cycles
Power/Thermal Cycling	5	Toperating = min to max, V <sub>in</sub> = min to max, full load, 100 cycles
Design Marginality	5	T <sub>min</sub> -10°C to T <sub>max</sub> +10°C, 5°C steps, V <sub>in</sub> = min to max, 0-105% load
Humidity	5	85°C, 85% RH, 1000 hours, 2 minutes on and 6 hours off
Solderability	15 pins	MIL-STD-883, method 2003 and JESD22-B102D

- Extensive characterization testing of all SynQor products and manufacturing processes is performed to ensure that we supply robust, reliable product. Contact the factory for official product family qualification documents.

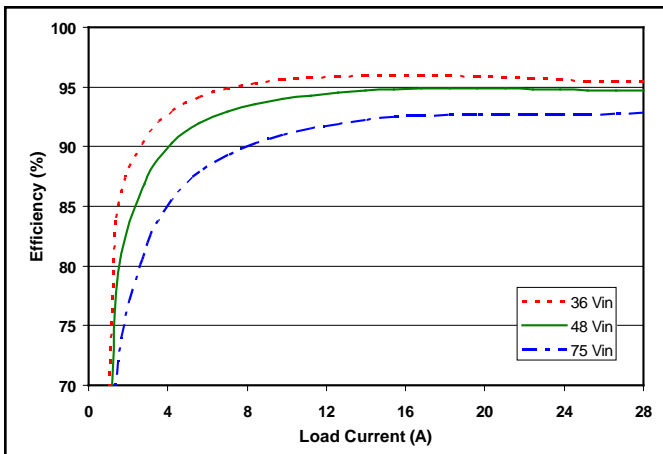


Figure 1: Efficiency at nominal output voltage vs. load current for minimum, nominal, and maximum input voltage at 25°C.

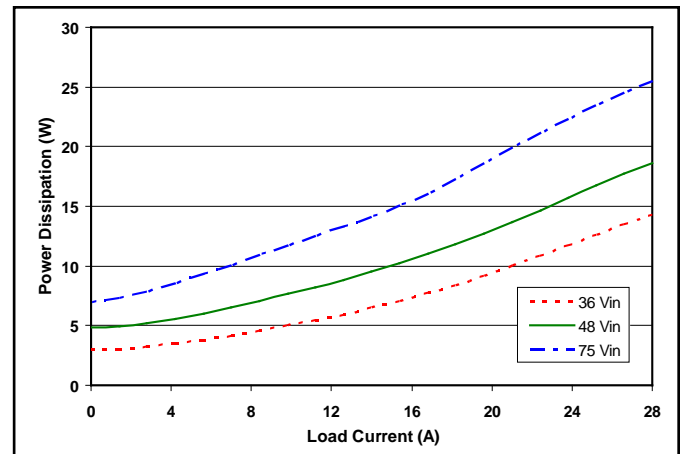


Figure 2: Power dissipation at nominal output voltage vs. load current for minimum, nominal, and maximum input voltage at 25°C.

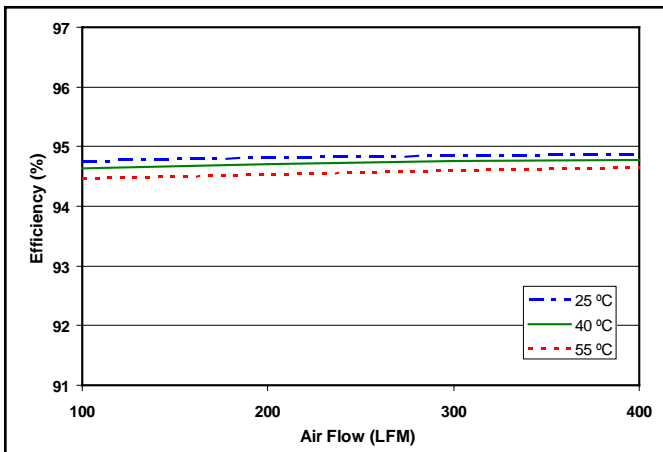


Figure 3: Efficiency at nominal output voltage and 60% rated power vs. airflow rate for ambient air temperatures of 25°C, 40°C, and 55°C (nominal input voltage).

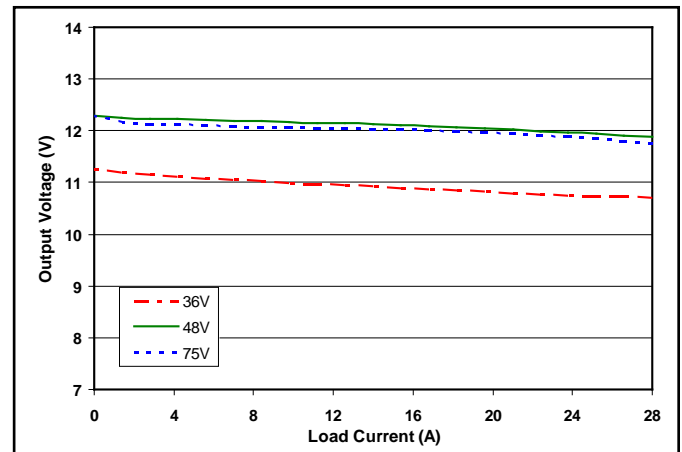


Figure 4: Output voltage regulation vs. load current for minimum, nominal, and maximum input voltage at 25°C.

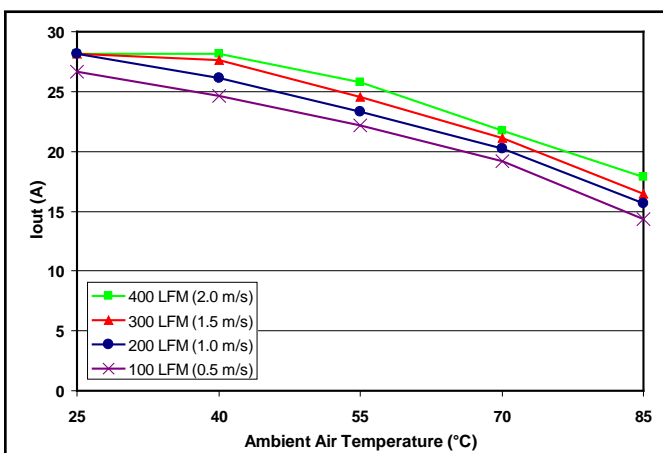


Figure 5: Maximum output power derating curves vs. ambient air temperature for airflow rates of 0 LFM through 400 LFM with air flowing from pin 3 to pin 1 (nominal input voltage).

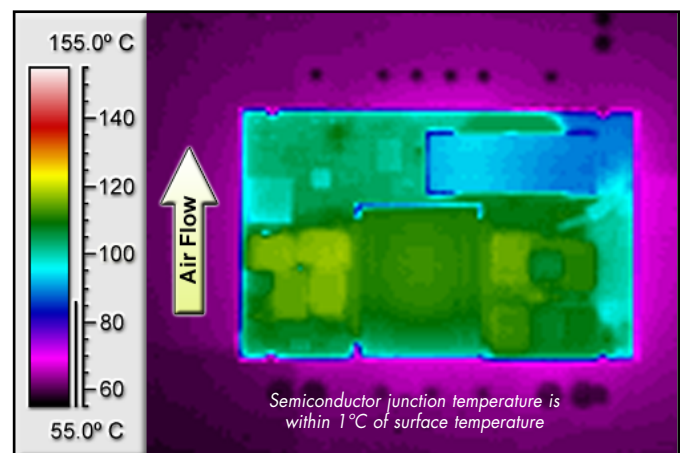
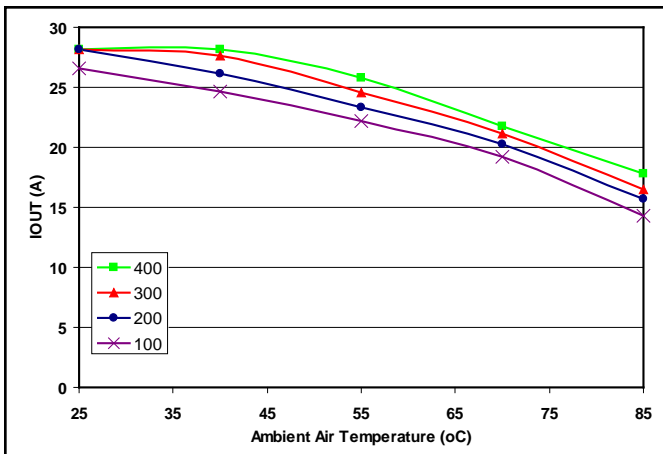
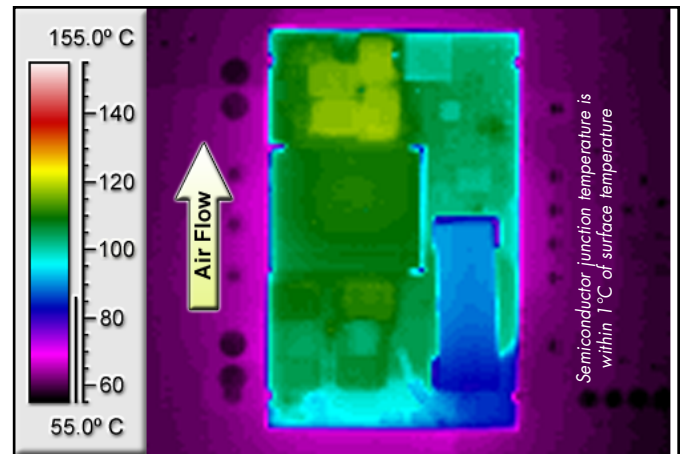


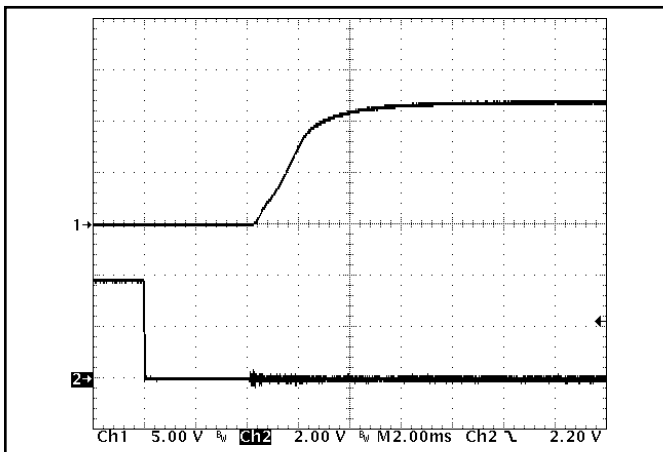
Figure 6: Thermal plot of converter at 23.3 amp load current (279.6W) with 55°C air flowing at the rate of 200 LFM. Air is flowing across the converter from pin 3 to pin 1 (nominal input voltage).



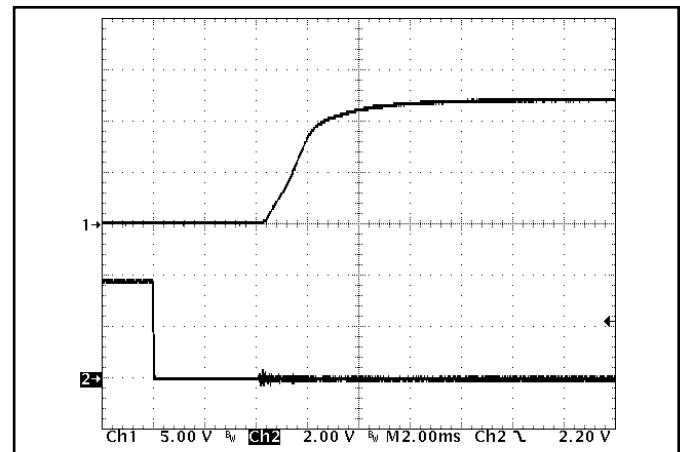
**Figure 7:** Maximum output power derating curves vs. ambient air temperature for airflow rates of 0 LFM through 400 LFM with air flowing from output to input (nominal input voltage).



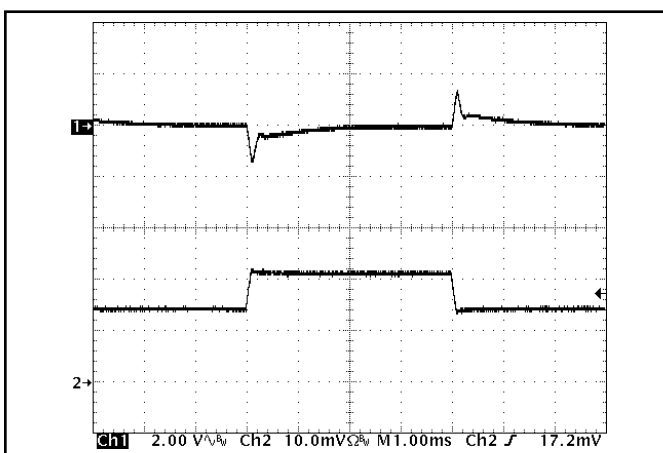
**Figure 8:** Thermal plot of converter at 21.9 amp load current (262.8W) with 55°C air flowing at the rate of 200 LFM. Air is flowing across the converter from output to input (nominal input voltage).



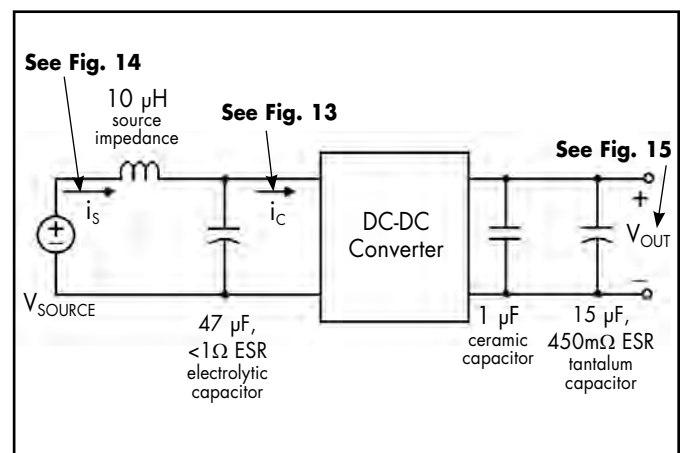
**Figure 9:** Turn-on transient at half load (resistive load) and 3mF output capacitance (2.0 ms/div). Input voltage pre-applied. Channel 1: V<sub>out</sub> (5V/div). Channel 2: ON/OFF input (2V/div).



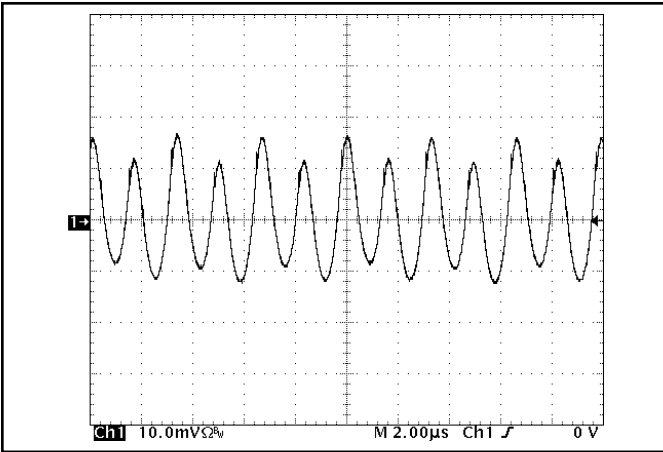
**Figure 10:** Turn-on transient at zero load and 3mF output capacitance (2.0ms/div). Input voltage pre-applied. Channel 1: V<sub>out</sub> (5V/div). Channel 2: ON/OFF input (2V/div).



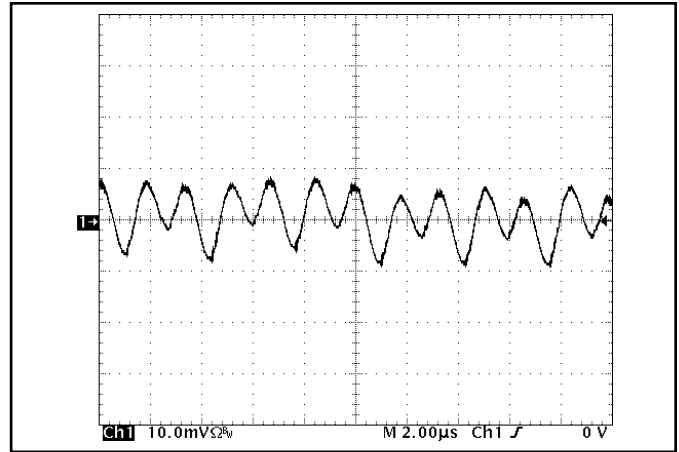
**Figure 11:** Output voltage response to step-change in load current (50%-75%-50% of I<sub>out</sub>(max); dI/dt = 0.1A/μs). Load cap: 100μF, 100 mΩ ESR tantalum cap. Top trace: V<sub>out</sub> (2V/div), Bottom trace: I<sub>out</sub> (10A/div).



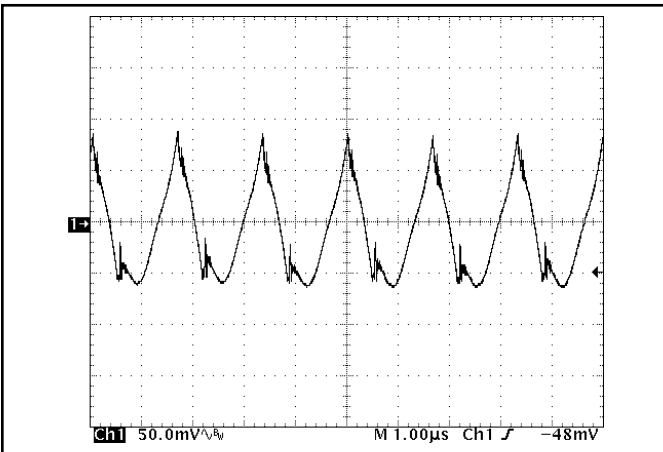
**Figure 12:** Test set-up diagram showing measurement points for Input Terminal Ripple Current (Figure 13), Input Reflected Ripple Current (Figure 14) and Output Voltage Ripple (Figure 15).



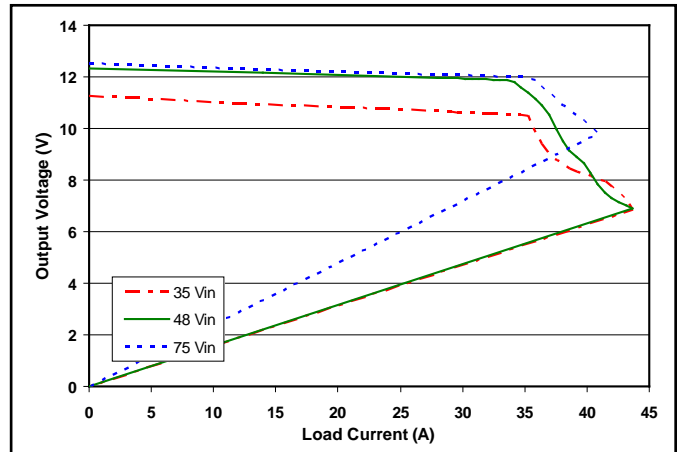
**Figure 13:** Input Terminal Ripple Current,  $i_c$ , at full rated output current and nominal input voltage with  $5\mu\text{H}$  source impedance and  $47\mu\text{F}$  electrolytic capacitor (500mA/div). See Figure 12.



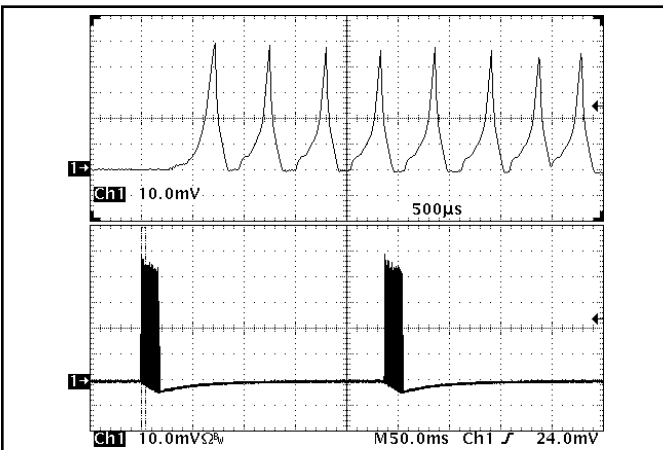
**Figure 14:** Input reflected ripple current,  $i_s$ , through a  $5\mu\text{H}$  source inductor at nominal input voltage and rated load current (10mA/div). See Figure 12.



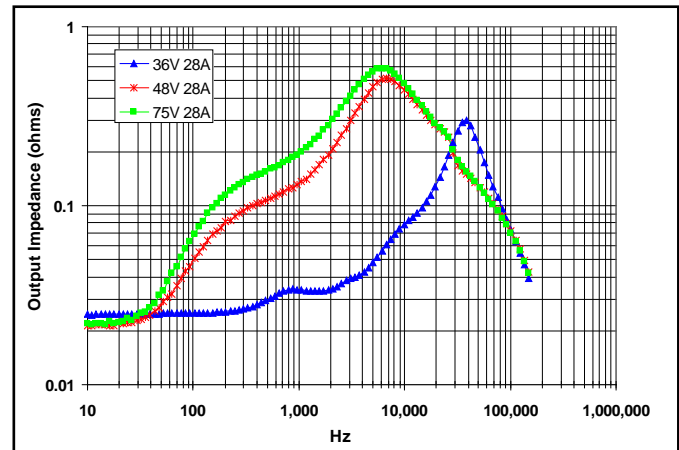
**Figure 15:** Output voltage ripple at nominal input voltage and rated load current (50mV/div). Load capacitance:  $1\mu\text{F}$  ceramic capacitor and  $15\mu\text{F}$  tantalum capacitor. Bandwidth: 20MHz. See Figure 12.



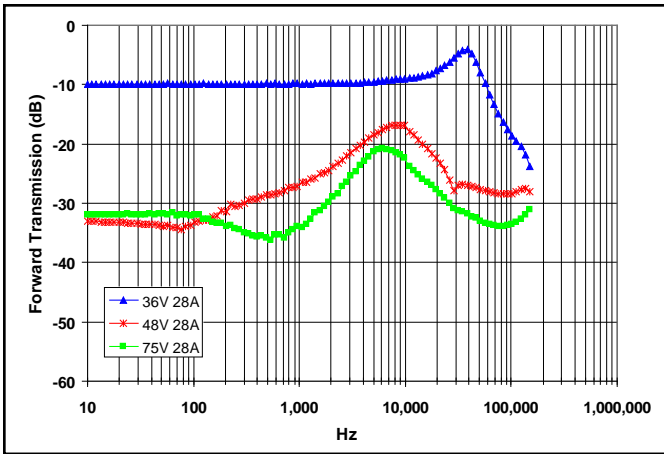
**Figure 16:** Output voltage vs. load current showing typical current limit curves and converter shutdown points.



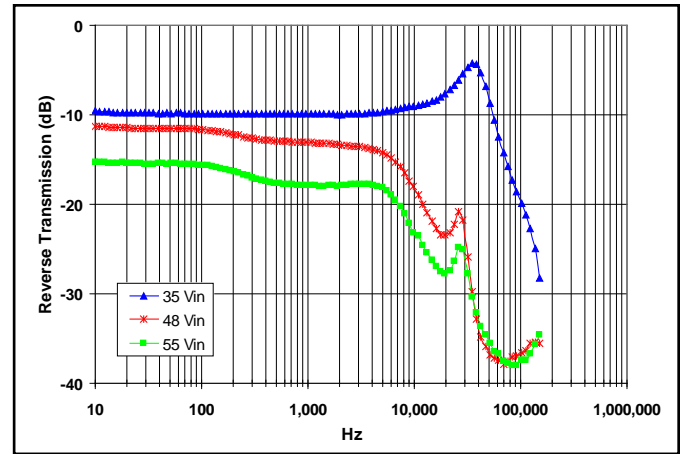
**Figure 17:** Load current (10A/div) as a function of time when the converter attempts to turn on into a  $1\text{m}\Omega$  short circuit. Top trace (500µs/div) is an expansion of the on-time portion of the bottom trace.



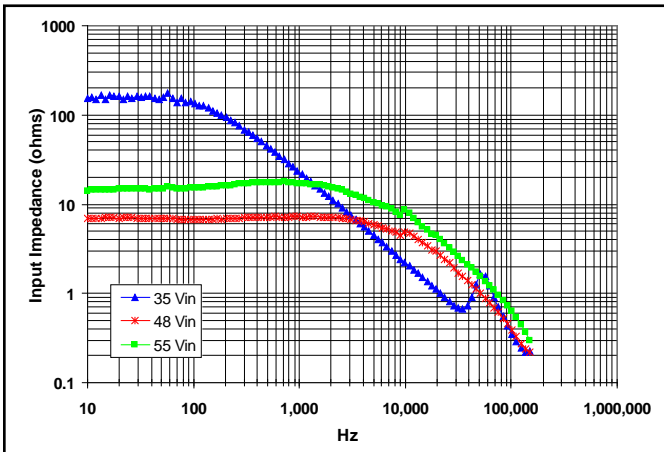
**Figure 18:** Magnitude of incremental output impedance ( $Z_{out} = v_{out}/i_{out}$ ) for minimum, nominal, and maximum input voltage at full rated power.



**Figure 19:** Magnitude of incremental forward transmission ( $FT = v_{out}/v_{in}$ ) for minimum, nominal, and maximum input voltage at full rated power.



**Figure 20:** Magnitude of incremental reverse transmission ( $RT = i_{in}/i_{out}$ ) for minimum, nominal, and maximum input voltage at full rated power.



**Figure 21:** Magnitude of incremental input impedance ( $Z_{in} = v_{in}/i_{in}$ ) for minimum, nominal, and maximum input voltage at full rated power.

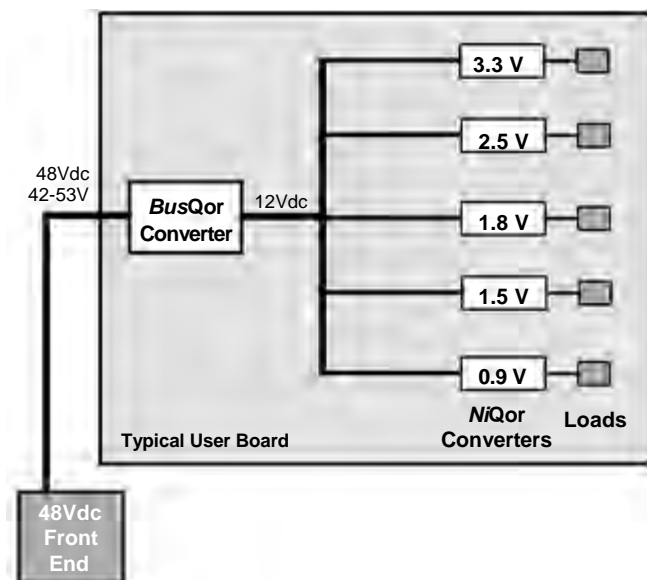
### BASIC OPERATION AND FEATURES

With voltages dropping and currents rising, the economics of an Intermediate Bus Architecture (IBA) are becoming more attractive, especially in systems requiring multiple low voltages. IBA systems separate the role of isolation and voltage scaling from regulation and sensing. The *BusQor* series bus converter provides isolation and a coarse voltage step down in one compact module, leaving regulation to simpler, less expensive non-isolated converters.

In Figure A below, the *BusQor* module provides the isolation stage of the IBA system. The isolated bus then distributes power to the non-isolated buck regulators to generate the required voltage levels at the point of load. In this case, the bucks are represented with SynQor's *NiQor* series of non-isolated dc-dc converters. In many applications requiring multiple low voltage outputs, significant savings can be achieved in board space and overall system costs.

When designing an IBA system with bus converters, the designer can select from a variety of bus voltages. While there is no universally ideal bus voltage, most designs employ one of the following: 12V, 9V, 7.5V, 5V, or 3.3V. Higher bus voltages can lead to lower efficiency for the buck regulators but are more efficient for the bus converter and provide lower board level distribution current. Lower bus voltages offer the opposite trade offs.

SynQor's SQ *BusQor* modules accept the full 48/60V telecom bus voltage and have a narrow output voltage range compatible with many non-isolated point of load converters. When used in IBA systems, the output variation of the *BusQor* must be in accordance with the input voltage range of the non-isolated converters being employed.

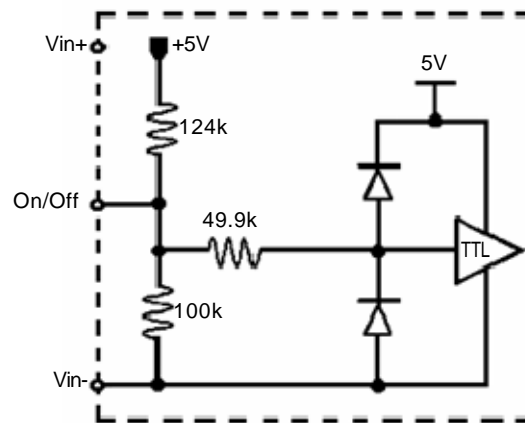


**Figure A:** Example of Intermediate Bus Architecture using *BusQor* bus converter and *NiQor* non-isolated converters

### CONTROL FEATURES

**REMOTE ON/OFF (Pin 2):** 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 input bus,  $V_{in(-)}$ . There are two versions of the converter that differ by the sense of the logic used for the ON/OFF input.

In the positive logic version, the ON/OFF input is active high (meaning that a high turns the converter *on*). In the negative logic version, the ON/OFF signal is active low (meaning that a low turns the converter *on*). Figure B is a detailed look of the internal ON/OFF circuitry.

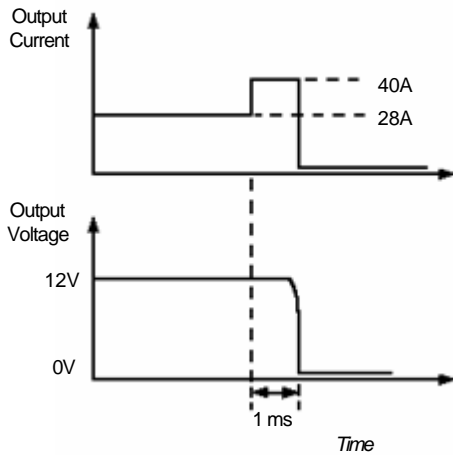


**Figure B:** Internal ON/OFF pin circuitry

### 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 in the application note titled "Input System Instability" available on the SynQor website. The lockout circuitry is a comparator with DC hysteresis. When the input voltage is rising, it must exceed the typical Turn-On Voltage Threshold value (listed on the specification page) before the converter will turn on. Once the converter is on, the input voltage must fall below the typical Turn-Off Voltage Threshold value before the converter will turn off. Also see Figure E.

**Output Current Limit:** The output of the *BusQor* module is electronically protected against output overloads. When an overload current greater than the "DC Current-Limit Inception" specification is drawn from the output, the output of the *BusQor* will shutdown to zero volts after the 1 ms have elapsed (see Figure C). The shutdown period lasts for a typical period of 200 ms (Figure D) after which the *BusQor* tries to power up again. If the overload persists, the output voltage will go through

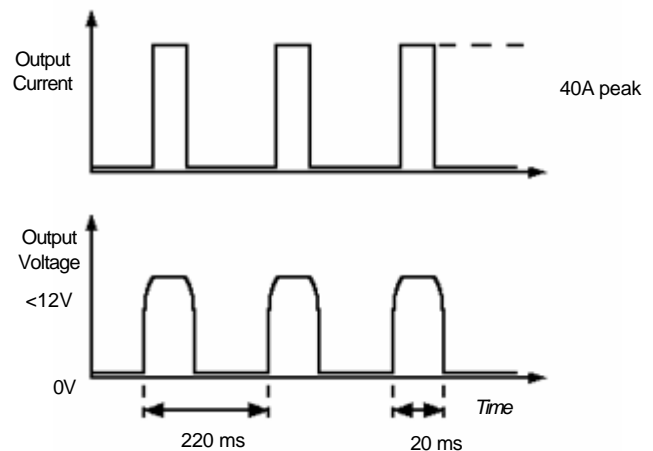


**Figure C:** Output Overload protection diagram (not to scale)

repeated cycles of shutdown and restart with a duty cycle of 20 ms (On) and 200 ms (Off) respectively. The *BusQor* module returns (auto resetting) to normal operation once the overload is removed. The *BusQor* is designed to survive in this mode indefinitely without damage and without human intervention.

**Output Short Circuit Protection:** When the output of the *BusQor* module is shorted, a peak current of typically 40 A will flow into the short circuit for a time of about 1 ms. The output of the *BusQor* will shutdown to zero volts after the 1 ms have elapsed (Figure D). The shutdown period lasts for a time of 200 ms, at the end of which the *BusQor* module tries to power up again. If the short circuit persists, the output voltage will go through repeated cycles of shutdown and restart with a duty cycle of 20 ms (On) and 200 ms (Off) respectively. The *BusQor* module returns (auto resetting) to normal operation once the short circuit is removed. The *BusQor* is designed to survive in this mode indefinitely without damage and without human intervention.

In the Auto resetting mode, also referred to as “Hiccup” mode, the power drawn from the 48 V input is about 5 Watts, most of which is dissipated into the external fault. It is important that copper traces and pads from the output circuit be designed to withstand the short term peaks, although the average current into the fault may be as low as 50 mA typical. See Figure 17 for appropriate waveform.



**Figure D:** Output Short Circuit and Auto-Resetting protection diagram (not to scale)

**Over-Temperature Shutdown:** A temperature sensor on the converter senses the average temperature of the module. The thermal shutdown circuit is designed to turn the converter off when the temperature at the sensed location reaches the Over-Temperature Shutdown value. It will allow the converter to turn on again when the temperature of the sensed location falls by the amount of the Over-Temperature Shutdown Restart Hysteresis value.

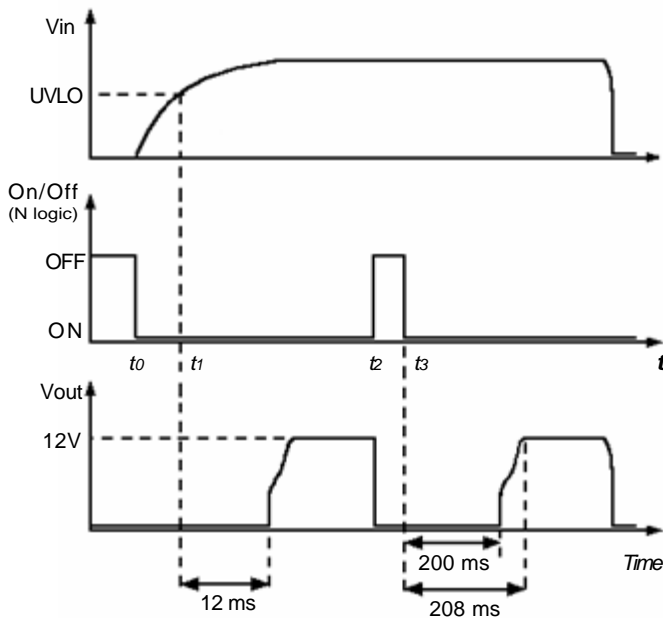
## APPLICATION CONSIDERATIONS

**Start-Up Inhibit Period:** Figure E details the Start-Up Inhibit Period for the *BusQor* module when  $V_{in}$  is applied with the On/Off pin asserted (enabled). Before time  $t_1$ , when the input voltage is below the UVL threshold, the unit is disabled by the Input Under-Voltage Lockout feature. When the input voltage rises above the UVL threshold, the Input Under-Voltage Lockout is released, and a typical Startup Inhibit Period of 8 ms from a  $V_{in}$  start-up. Once the module recognizes it should be on it waits an additional 4 ms before it starts. When starting from an on/off event the module has an inhibit time of 200 ms like our standard products. The output builds up to 90% or higher of the nominal voltage and stabilizes to its nominal output voltage in a total time of 8 ms typical. The the module has a  $V_{out}$  rise time of 4 ms typically.

At time  $t_2$ , when the On/Off pin is de-asserted (disabled), the *BusQor* module stops switching immediately. Fall time from 12 V to 0 V is dependent on output capacitance load current, and any parasitic trace inductance in the output load circuit.

At time  $t_3$ , when the On/Off pin is re-asserted (enabled), the *BusQor* module output begins to build up after the inhibit period of 200 ms typical.

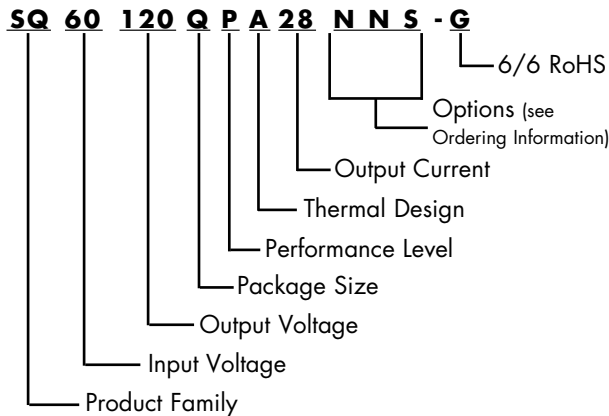
Refer to the Control Features section of the data sheet for details on enabling and disabling methods for N and P logic type modules.



**Figure E:** Power Up/Down Diagram (not to scale) showing Start-Up Inhibit Period.

### PART NUMBERING SYSTEM

The part numbering system for SynQor's BusQor DC bus converters follows the format shown in the example below.



The first 12 characters comprise the base part number and the last 3 characters indicate available options. Although there are no default values for enable logic and pin length, the most common options are negative logic and 0.145" pins. These part numbers are more likely to be readily available in stock for evaluation and prototype quantities. A "-G" suffix indicates the product is 6/6 RoHS compliant.

### PATENTS

SynQor holds the following patents, one or more of which might apply to this product:

5,999,417	6,222,742	6,545,890	6,577,109
6,594,159	6,731,520	6,894,468	6,896,526
6,927,987	7,050,309	7,072,190	7,085,146
7,119,524	7,269,034	7,272,021	7,272,023

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 USA

### ORDERING INFORMATION

The tables below show the valid model numbers and ordering options for converters in this product family. When ordering SynQor converters, please ensure that you use the complete 15 character part number consisting of the 12 character base part number and the additional 3 characters for options. A "-G" suffix indicates the product is 6/6 RoHS compliant.

Model Number	Input Voltage	Output Voltage	Max Output Current
SQ60120QPA28xyz-G	36 - 75 V	12 V	28 A

The following option choices must be included in place of the x y z spaces in the model numbers listed above.

Options Description: x y z		
Enable Logic*	Pin Length	Feature Set
P - Positive N - Negative	K - 0.110" N - 0.145" R - 0.180" Y - 0.250"	S - Standard 2 Pin 4 - Two sets of Output Pins

### Application Notes

A variety of application notes and technical white papers can be downloaded in pdf format from our website.

**RoHS Compliance:** The EU led RoHS (Restriction of Hazardous Substances) Directive bans the use of Lead, Cadmium, Hexavalent Chromium, Mercury, Polybrominated Biphenyls (PBB), and Polybrominated Diphenyl Ether (PBDE) in Electrical and Electronic Equipment. This SynQor product is available as 6/6 RoHS compliant. For more information please refer to SynQor's RoHS addendum available at our RoHS Compliance / Lead Free Initiative web page or e-mail us at rohs@synqor.com.

#### Warranty

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

Information furnished by SynQor is believed to be accurate and reliable. However, no responsibility is assumed by SynQor for its use, nor for any infringements of patents or other rights of third parties which may result from its use. No license is granted by implication or otherwise under any patent or patent rights of SynQor.