

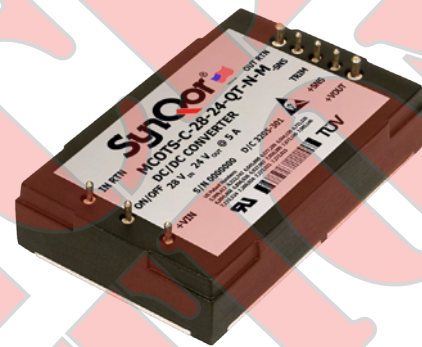
## MILITARY COTS DC/DC CONVERTER

<b>16-40V</b> Continuous Input	<b>16-50V</b> Transient Input	<b>24V</b> Output	<b>5A</b> Output	<b>90% @ 2.5A / 90% @ 5A</b> Efficiency
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Full Power Operation: -55°C to +100°C

The MilQor series of MIL-COTS DC/DC converters brings SynQor's field proven high-efficiency synchronous rectification technology to the Military/Aerospace industry. SynQor's ruggedized encased packaging approach ensures survivability in demanding environments. Compatible with the industry standard format, these converters operate at a fixed frequency, and follow conservative component derating guidelines. They are designed and manufactured to comply with a wide range of military standards

## Mil-COTS



Designed and Manufactured in the USA

### Operational Features

- High efficiency, 90% at full rated load current
- Operating input voltage range: 16-40 V
- Fixed frequency switching provides predictable EMI
- No minimum load requirement

### Mechanical Features

- Industry standard quarter-brick pin-out configuration
- Size: 1.54" x 2.39" x 0.50"  
(39.0 x 60.6 x 12.7mm)
- Total weight: 3 oz (85 g)

### Control Features

- On/Off control referenced to input side
- Remote sense for the output voltage
- Output voltage trim range of -20%, +10%

### Safety Features

- 2250 V, 30 MΩ input-to-output isolation
- Certified 60950-1 requirements for basic insulation (see Standards and Qualifications page)
- CE Marked
- RoHS compliant

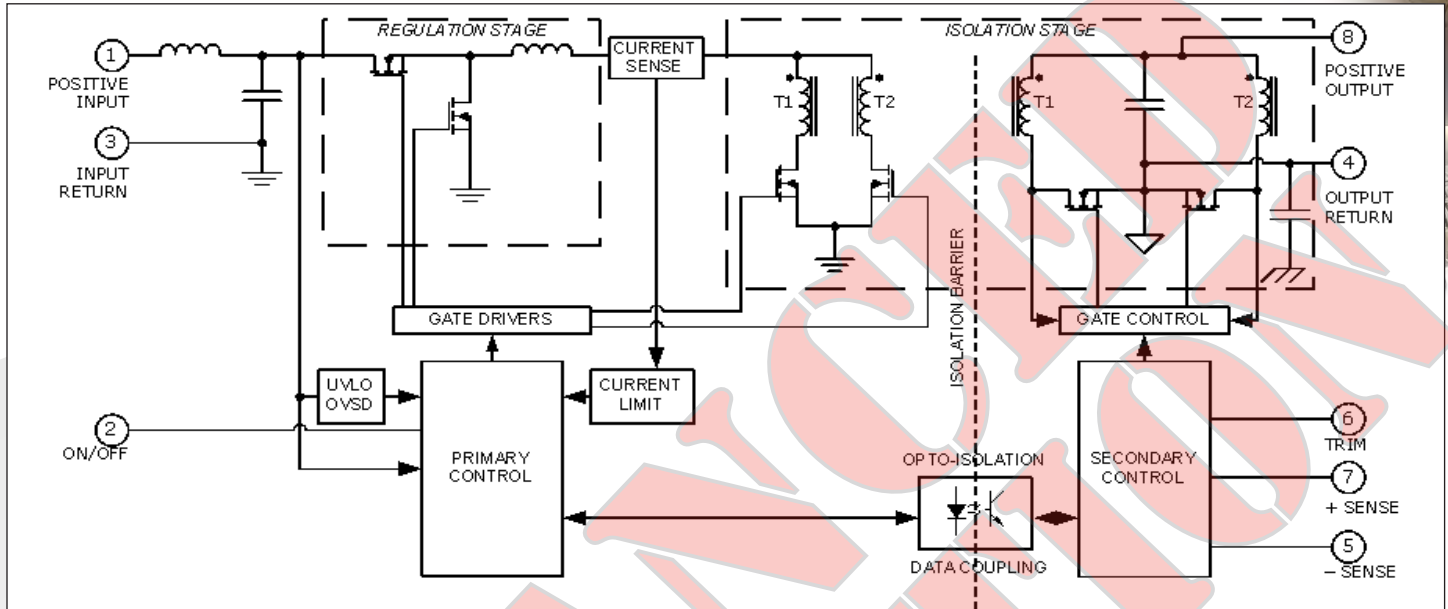
### Protection Features

- Input under-voltage lockout
- Output current limit and short circuit protection
- Active back bias limit
- Output over-voltage protection
- Thermal shutdown

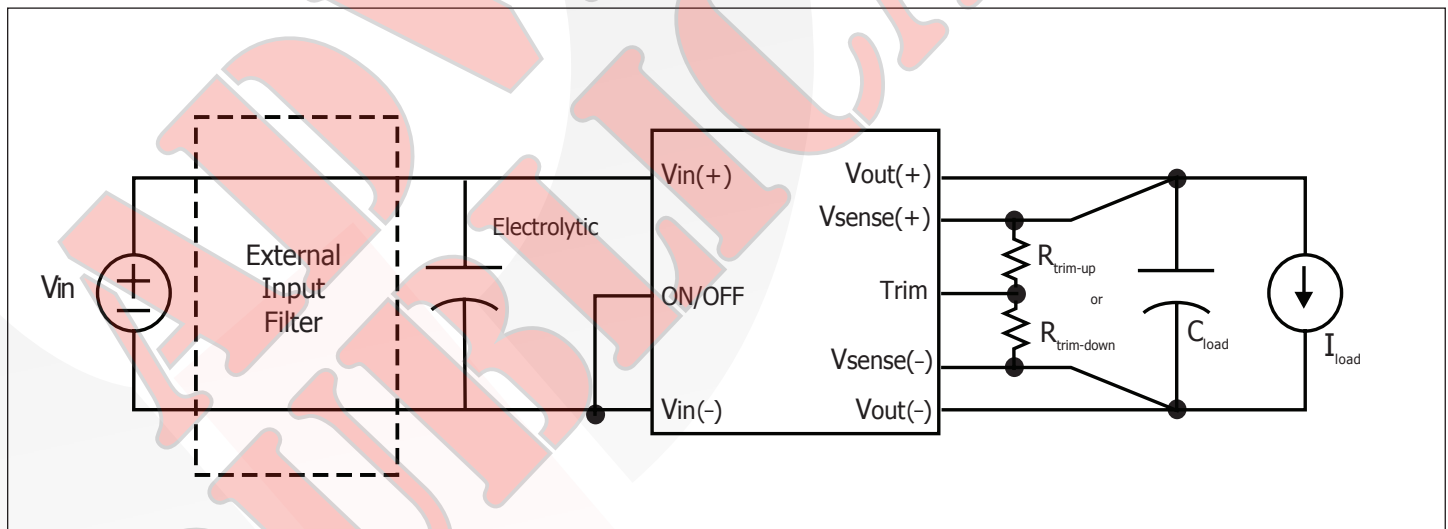
### Screening/Qualification

- AS9100 and ISO 9100:2000 certified facility
- Qualification consistent with MIL-STD-883
- Available with standard or military grade screening
- Pre-cap inspection per IPC-610, Class III
- Temperature cycling per MIL-STD-883, Method 1010, Condition B, 10 cycles
- Burn-In at 100°C baseplate temperature
- Final visual inspection per MIL-STD-2008
- Full component traceability

### BLOCK DIAGRAM



### TYPICAL CONNECTION DIAGRAM



### MCOTS-C-28-48-QT ELECTRICAL CHARACTERISTICS

Ta = 25 °C, airflow rate = 300 LFM, Vin = 28Vdc unless otherwise noted; full operating temperature range is -40 °C to +100 °C baseplate 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			60	V	Continuous
Operating			40	V	Continuous
Operating Transient Protection			50	V	1s transient, square wave
Isolation Voltage					
Input to Output			2250	V dc	
Input to Base-Plate			2250	V dc	
Output to Base-Plate			2250	V dc	
Operating Temperature	-40		100	°C	Baseplate temperature
Storage Temperature	-55		125	°C	
Voltage at ON/OFF input pin	-2		18	V	
<b>INPUT CHARACTERISTICS</b>					
Operating Input Voltage Range	16	28	40	V	50V transient for 1 s
Input Under-Voltage Lockout					
Turn-On Voltage Threshold	15.1	15.4	15.7	V	
Turn-Off Voltage Threshold	14.2	14.5	14.8	V	
Lockout Voltage Hysteresis		0.9		V	
Recommended External Input Capacitance		100		µF	Typical ESR 0.1-0.2 Ω
Input Filter Component Values (L/C)		1.0/6.6		µH/µF	Internal values; see Figure E
Maximum Input Current			11.0	A	Vin min; trim up; in current limit
No-Load Input Current		140	180	mA	
Disabled Input Current		2	4	mA	
Response to Input Transient		0.6		V	See Figure 6
Input Terminal Ripple Current		400		mA	RMS
Recommended Input Fuse			TBD	A	Fast acting external fuse recommended
<b>OUTPUT CHARACTERISTICS</b>					
Output Voltage Set Point	23.76	24	24.24	V	
Output Voltage Regulation					
Over Line		±0.1	±0.3	%	
Over Load		±0.1	±0.3	%	
Over Temperature	-360		360	mV	
Total Output Voltage Range	23.40		24.60	V	Over sample, line, load, temperature & life
Output Voltage Ripple and Noise					20 MHz bandwidth; see Note 1
Peak-to-Peak	0	55	110	mV	Full load
RMS		15	30	mV	Full load
Operating Output Current Range	0		5	A	Subject to thermal derating
Output DC Current-Limit Inception	5.5	6.0	6.5	A	Output voltage 10% Low
Output DC Current-Limit Shutdown Voltage		13		V	
Back-Drive Current Limit while Enabled		0.22		A	Negative current drawn from output
Back-Drive Current Limit while Disabled		TBD		mA	Negative current drawn from output
Maximum Output Capacitance			400	µF	Vout nominal at full load (resistive load)
Output Voltage during Load Current Transient					
Step Change in Output Current (0.1 A/µs)		700		mV	50% to 75% to 50% Iout max
Settling Time		100		µs	To within 1% Vout nom
Output Voltage Trim Range	-20		10	%	Across Pins 8&4; Common Figures 3-5; see Note 2
Output Voltage Remote Sense Range			10	%	Across Pins 8&4
Output Over-Voltage Protection	28.08	29.28	30.48	V	Over full temp range
<b>DYNAMIC CHARACTERISTICS</b>					
Turn-On Transient					
Turn-On Time		9		ms	Full load, Vout=90% nom.
Start-Up Inhibit Time	200	230	250	ms	-40 °C to +125 °C; Figure F
Output Voltage Overshoot		0		%	Maximum Output Capacitance
<b>EFFICIENCY</b>					
100% Load		90		%	See Figure 1 for efficiency curve
50% Load		90		%	See Figure 1 for efficiency curve



# Technical Specification

**MCOTS-C-28-24-QT**  
**Output: 24V**  
**Current: 5A**

## MCOTS-C-28-48-QT ELECTRICAL CHARACTERISTICS (cont.)

Ta = 25 °C, airflow rate = 300 LFM, Vin = 28Vdc unless otherwise noted; full operating temperature range is -40 °C to +100 °C baseplate temperature with appropriate power derating. Specifications subject to change without notice.

<b>ISOLATION CHARACTERISTICS</b>					
Isolation Voltage (dielectric strength)					See Absolute Maximum Ratings
Isolation Resistance		30		MΩ	
Isolation Capacitance (input to output)		1000		pF	See Note 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	
Maximum Baseplate Temperature, Tb			100	°C	
<b>FEATURE CHARACTERISTICS</b>					
Switching Frequency	230	250	270	kHz	For both input and isolation stage
ON/OFF Control					
Off-State Voltage	2.4		18	V	
On-State Voltage	-2		0.8		
ON/OFF Control					Application notes Figures A & B
Pull-Up Voltage		5		V	
Pull-Up Resistance		50		kΩ	
Over-Temperature Shutdown OTP Trip Point		125		°C	Average PCB Temperature
Over-Temperature Shutdown Restart Hysteresis		10		°C	
<b>RELIABILITY CHARACTERISTICS</b>					
Calculated MTBF (Telcordia) TR-NWT-000332		TBD		106 Hrs.	80% load, 200LFM, 40 °C Ta
Calculated MTBF (MIL-217) MIL-HDBK-217F		TBD		106 Hrs.	80% load, 200LFM, 40 °C Ta
Field Demonstrated MTBF				106 Hrs.	See our website for details

Note 1: Higher values of isolation capacitance can be added external to the module.

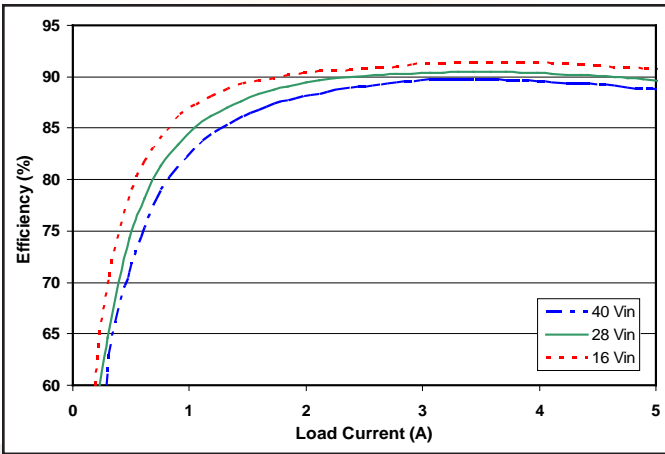


Figure 1: Efficiency at nominal output voltage vs. load current for minimum, nominal, and maximum input voltage at 25°C.

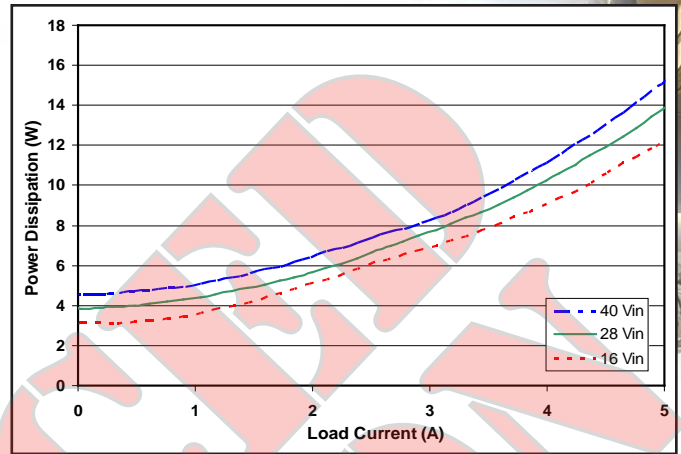


Figure 2: Power dissipation at nominal output voltage vs. load current for minimum, nominal, and maximum input voltage at 25°C.

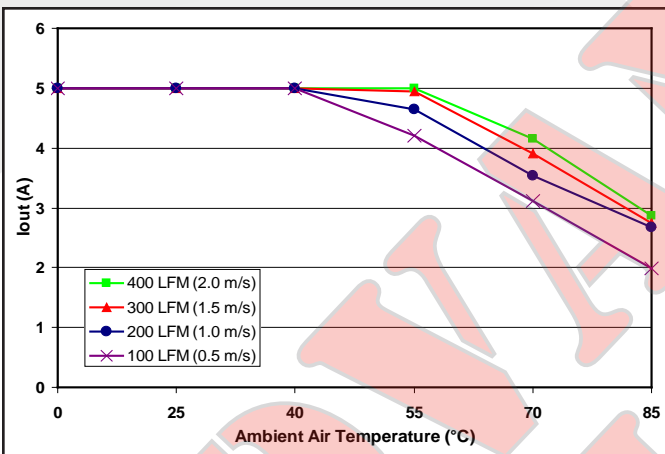


Figure 3: Encased converter (without heatsink) max. output power derating vs. ambient air temperature for airflow rates of 100 LFM through 400 LFM. Air flows across the converter from pin 3 to pin 1 (nominal input voltage).

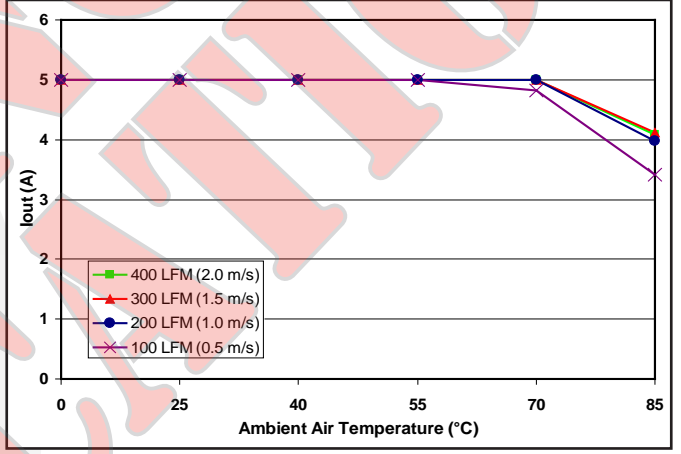


Figure 4: Encased converter (with 1/4" heatsink) max. output power derating vs. ambient air temperature for airflow rates of 100 LFM through 400 LFM. Air flows across the converter from pin 3 to pin 1 (nominal input voltage).

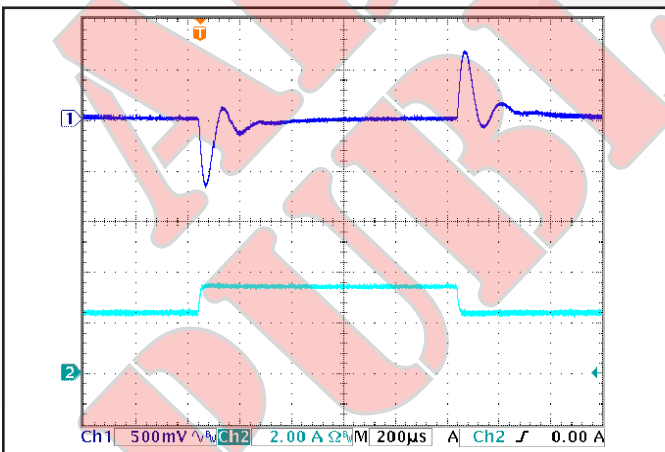


Figure 5: Output voltage response to step-change in load current (50%-75%-50% of Iout(max); dI/dt = 0.1 A/ $\mu$ s). Load cap: 1  $\mu$ F ceramic and 15  $\mu$ F tantalum capacitors. Ch 1: Vout (500mV/div), Ch 2: Iout (2A/div).

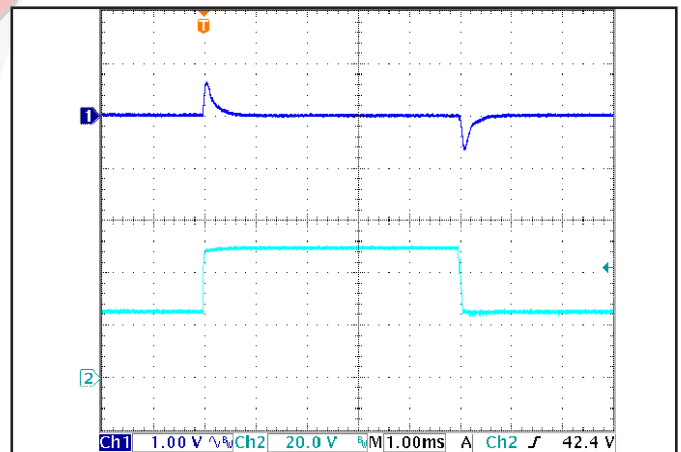


Figure 6: Output voltage response to step-change in input voltage (500 V/ms). Load cap: 100  $\mu$ F, electrolytic output capacitance. Ch 1: Vout (1V/div), Ch 2: Vin (20V/div).

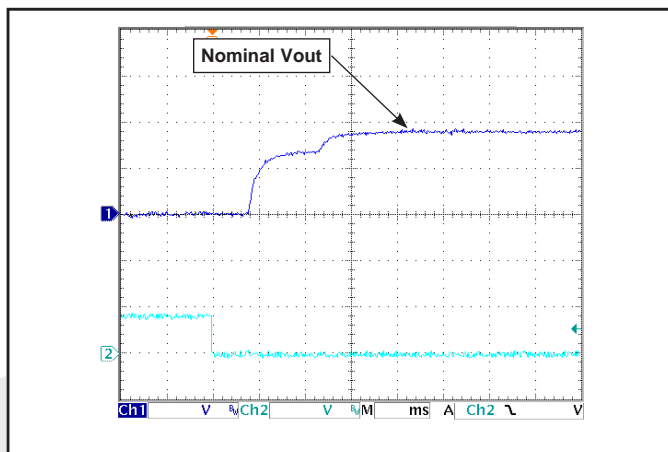


Figure 7: Typical startup waveform. Input voltage pre-applied, ON/OFF Pin on Ch 2.

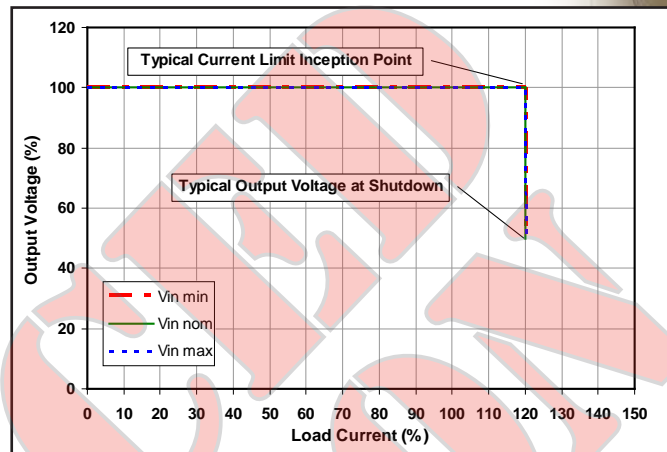


Figure 8: Output voltage vs. load current showing typical current limit curves and converter shutdown points.

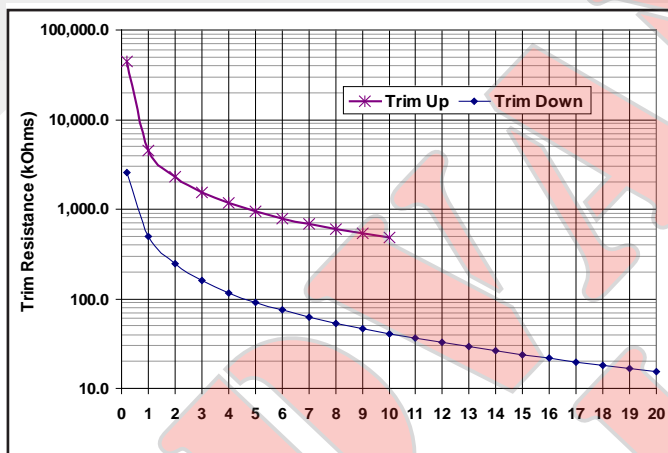


Figure 9: Trim graph for trim-up, trim down.



# Technical Specification

**MCOTS-C-28-24-QT**

**Output: 24V**

**Current: 5A**

## MIL-COTS Qualification

Test Name	Details	#Tested (# Failed)	Consistent with MIL-STD-883F Method	Consistent with MIL-STD-883F Method 5005
Life Testing	Visual, mechanical and electrical testing before, during and after 1000 hour burn-in @ full load	15 (0)	Method 1005.8	
Shock-Vibration	Visual, mechanical and electrical testing before, during and after shock and vibration tests	5 (0)		MIL-STD-202, Method 1
Humidity	+85°C, 85%RH, 1000 hours, 2 minutes on/6 hours off	8 (0)	Method 1004.7	
Temperature Cycling	500 cycles of -40°C to +100°C (30 minute dwell at each temperature)	10 (0)	Method 1010.8	Condition A
Solderability	15 pins	15 (0)	Method 2003	
DMT	-65°C to +110°C across full line and load specifications in 5°C steps	7 (0)		

## MIL-COTS Screening

Screening	Process Description	Standard	Military (MIL Grade)
Baseplate Operating Temperature		-55°C to +100°C	-55°C to +100°C
Storage Temperature		-65°C to +135°C	-65°C to +135°C
Pre-Cap inspection	IPC-610, Class III	•	•
Temperature Cycling	Method 1010, Condition B, 10 Cycles		•
Burn-In	100°C Baseplate	12 Hours	96 Hours
Final Electrical Test	100%	25°C	-55°C, +25°C, +100°C
Final Visual Inspection	MIL-STD-2008	•	•

## BASIC OPERATION AND FEATURES

This MIL-COTS converter series uses a two-stage power conversion 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-up or step-down to achieve the output voltage required.

Both the first stage and the second stage switch at a fixed frequency for predictable EMI performance. 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. This is the primary reason that the converter has such high efficiency, even at very low output voltages and very high output currents.

These converters are offered totally encased to withstand harsh environments and thermally demanding applications. Dissipation throughout the converter is so low that it does not require a heatsink for operation in many applications; however, adding a heatsink provides improved thermal derating performance in extreme situations.

This series of converters use the industry standard footprint and pin-out configuration.

## 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, Vin(-). The ON/OFF signal is active low (meaning that a low turns the converter on). Figure A details four possible circuits for driving the ON/OFF pin. Figure B is a detailed look of the internal ON/OFF circuitry.

**REMOTE SENSE(±) (Pins 7 and 5):** The SENSE(±) inputs correct for voltage drops along the conductors that connect the converter's output pins to the load.

Pin 7 should be connected to Vout(+) and Pin 5 should be connected to Vout(-) at the point on the board where regulation is desired. A remote connection at the load can adjust for a voltage drop only as large as that specified in this datasheet, that is

$$[V_{out(+)} - V_{out(-)}] - [V_{sense(+)} - V_{sense(-)}] \leq \text{Sense Range \%} \times V_{out}$$

Pins 7 and 5 must be connected for proper regulation of the output voltage. If these connections are not made, the converter will deliver an output voltage that is slightly higher than its specified value.

**Note:** the output over-voltage protection circuit senses the voltage across the output (pins 8 and 4) to determine when it should trigger, not the voltage across the converter's sense leads (pins 7 and 5). Therefore, the resistive drop on the board should be small enough so that output OVP does not trigger, even during load transients.

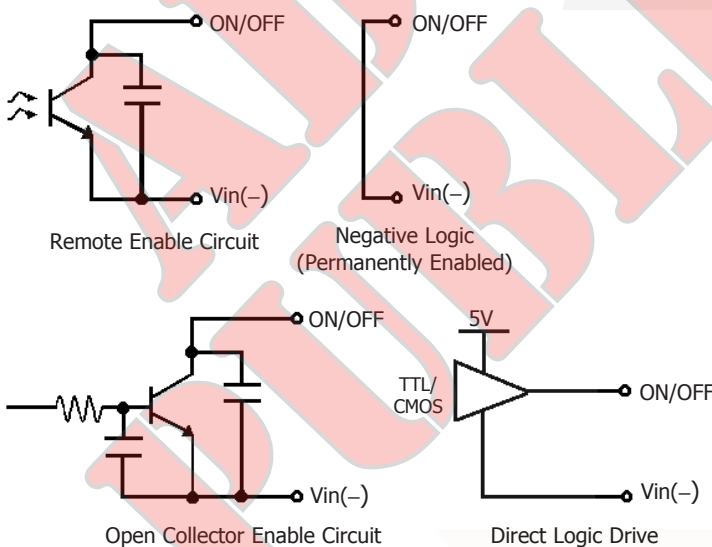


Figure A: Various circuits for driving the ON/OFF pin.

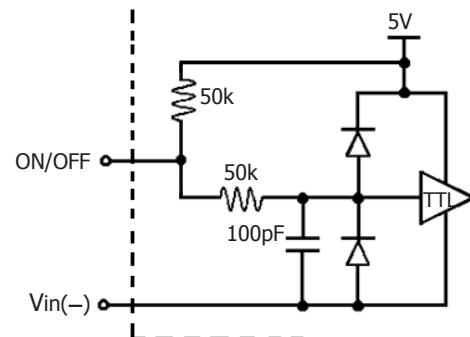


Figure B: Internal ON/OFF pin circuitry



**OUTPUT VOLTAGE TRIM (Pin 6):** The TRIM input permits the user to adjust the output voltage across the sense leads up or down according to the trim range specifications.

To decrease the output voltage, the user should connect a resistor between Pin 6 and Pin 5 (SENSE(-) input). For a desired decrease of the nominal output voltage, the value of the resistor should be

$$R_{\text{trim-down}} = \left( \frac{511}{\Delta\%} \right) - 10.22 \text{ (k}\Omega\text{)}$$

where

$$\Delta\% = \left| \frac{V_{\text{nominal}} - V_{\text{desired}}}{V_{\text{nominal}}} \right| \times 100\%$$

To increase the output voltage, the user should connect a resistor between Pin 6 and Pin 7 (SENSE(+) input). For a desired increase of the nominal output voltage, the value of the resistor should be

$$R_{\text{trim-up}} = \left( \frac{5.11V_{\text{OUT}} \times (100 + \Delta\%)}{1.225\Delta\%} - \frac{511}{\Delta\%} - 10.22 \right) \text{ (k}\Omega\text{)}$$

where  $V_{\text{out}}$  = Nominal Output Voltage

Trim graphs show the relationship between the trim resistor value and  $R_{\text{trim-up}}$  and  $R_{\text{trim-down}}$ , showing the total range the output voltage can be trimmed up or down.

**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, particularly during transients.

It is not necessary for the user to add capacitance at the Trim pin. The node is internally bypassed to eliminate noise.

**Total DC Variation of  $V_{\text{OUT}}$ :** For the converter to meet its full specifications, the maximum variation of the dc value of  $V_{\text{OUT}}$ , due to both trimming and remote load voltage drops, should not be greater than that specified for the output voltage trim range.

## 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" on our 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 specifications 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.

**Output Current Limit:** The maximum current limit remains constant as the output voltage drops. However, once the impedance of the load across the output is small enough to make the output voltage drop below the specified Output DC Current-Limit Shutdown Voltage, the converter turns off.

The converter then enters a "hiccup 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. This prevents excessive heating of the converter or the load board.

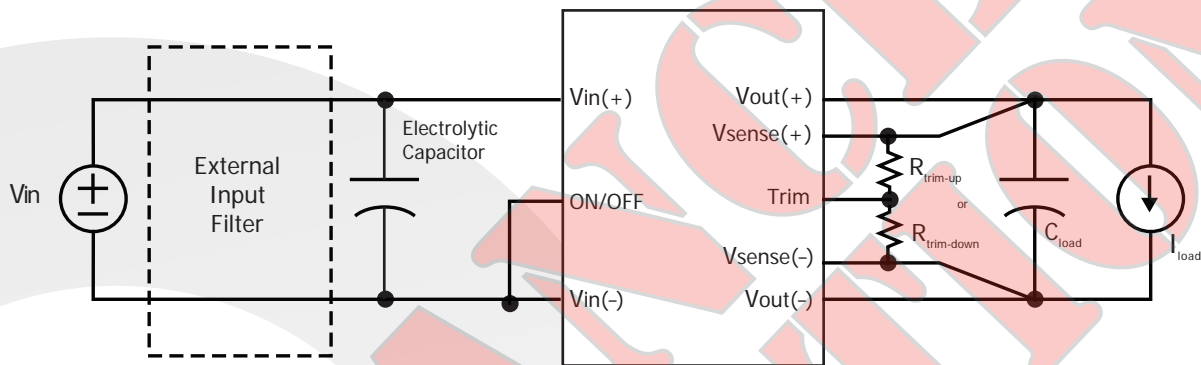
**Output Over-Voltage Limit:** If the voltage across the output pins exceeds the Output Over-Voltage Protection threshold, the converter will immediately stop switching. This prevents damage to the load circuit due to 1) excessive series resistance in output current path from converter output pins to sense point, 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. After 200 ms the converter will automatically restart.

**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

**Input System Instability:** This condition can occur because any dc-dc converter appears incrementally as a negative resistance load. A detailed application note titled "Input System Instability" is available on the SynQor website which provides an understanding of why this instability arises, and shows the preferred solution for correcting it.

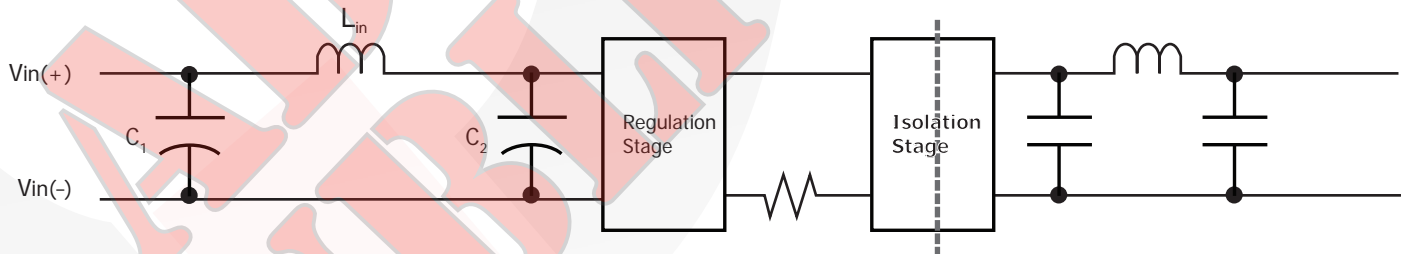
**Application Circuits:** Figure C provides a typical circuit diagram which details the input filtering and voltage trimming.



*Figure C: Typical application circuit (negative logic unit, permanently enabled).*

**Input Filtering and External Capacitance:** Figure D provides a diagram showing the internal input filter components. This filter dramatically reduces input terminal ripple current, which otherwise could exceed the rating of an external electrolytic input capacitor.

The recommended external input capacitance is specified in the Input Characteristics section on the Electrical Characteristics page. More detailed information is available in the application note titled "EMI Characteristics" on the SynQor website.



*Figure D: Internal Input Filter Diagram (component values listed on the specifications page).*

**Startup Inhibit Period:** The Startup Inhibit Period ensures that the converter will remain off for approximately 200 ms when it is shut down for any reason. When an output short is present, this generates a 5 Hz "hiccup mode," which prevents the converter from overheating. In all, there are seven ways that the converter can be shut down, initiating a Startup Inhibit Period:

- Input Under-Voltage Lockout
- Input Over-Voltage Shutdown
- Output Over-Voltage Protection
- Over Temperature Shutdown
- Current Limit
- Short Circuit Protection
- Turned off by the ON/OFF input

Figure E shows three turn-on scenarios, where a Startup Inhibit Period is initiated at  $t_0$ ,  $t_1$ , and  $t_2$ :

Before time  $t_0$ , 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 Startup Inhibit Period is initiated. At the end of this delay, the ON/OFF pin is evaluated, and since it is active, the unit turns on.

At time  $t_1$ , the unit is disabled by the ON/OFF pin, and it cannot be enabled again until the Startup Inhibit Period has elapsed.

When the ON/OFF pin goes high after  $t_2$ , the Startup Inhibit Period has elapsed, and the output turns on within the typical Turn-On Time.

**Thermal Considerations:** The maximum operating base-plate temperature,  $T_B$ , is 100 °C. As long as the user's thermal system keeps  $T_B \leq 100$  °C, the converter can deliver its full rated power.

A power derating curve can be calculated for any heatsink that is attached to the base-plate of the converter. It is only necessary to determine the thermal resistance,  $R_{THBA}$ , of the chosen heatsink between the base-plate and the ambient air for a given airflow rate. This information is usually available from the heatsink vendor. The following formula can be used to determine the maximum power the converter can dissipate for a given thermal condition if its base-plate is to be no higher than 100 °C.

$$P_{diss}^{max} = \frac{100 \text{ }^\circ\text{C} - T_A}{R_{THBA}}$$

This value of power dissipation can then be used in conjunction with the data shown in Figure 2 to determine the maximum load current (and power) that the converter can deliver in the given thermal condition.

For convenience, power derating curves for an encased converter without a heatsink and with a typical heatsink are provided for each output voltage.

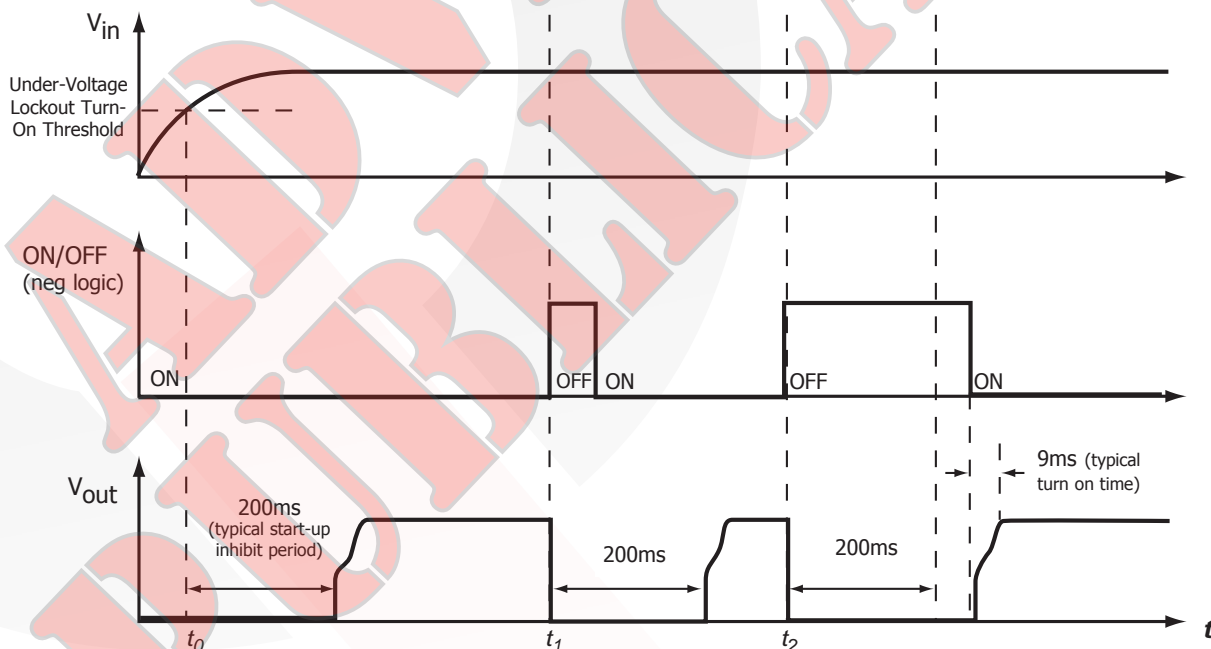
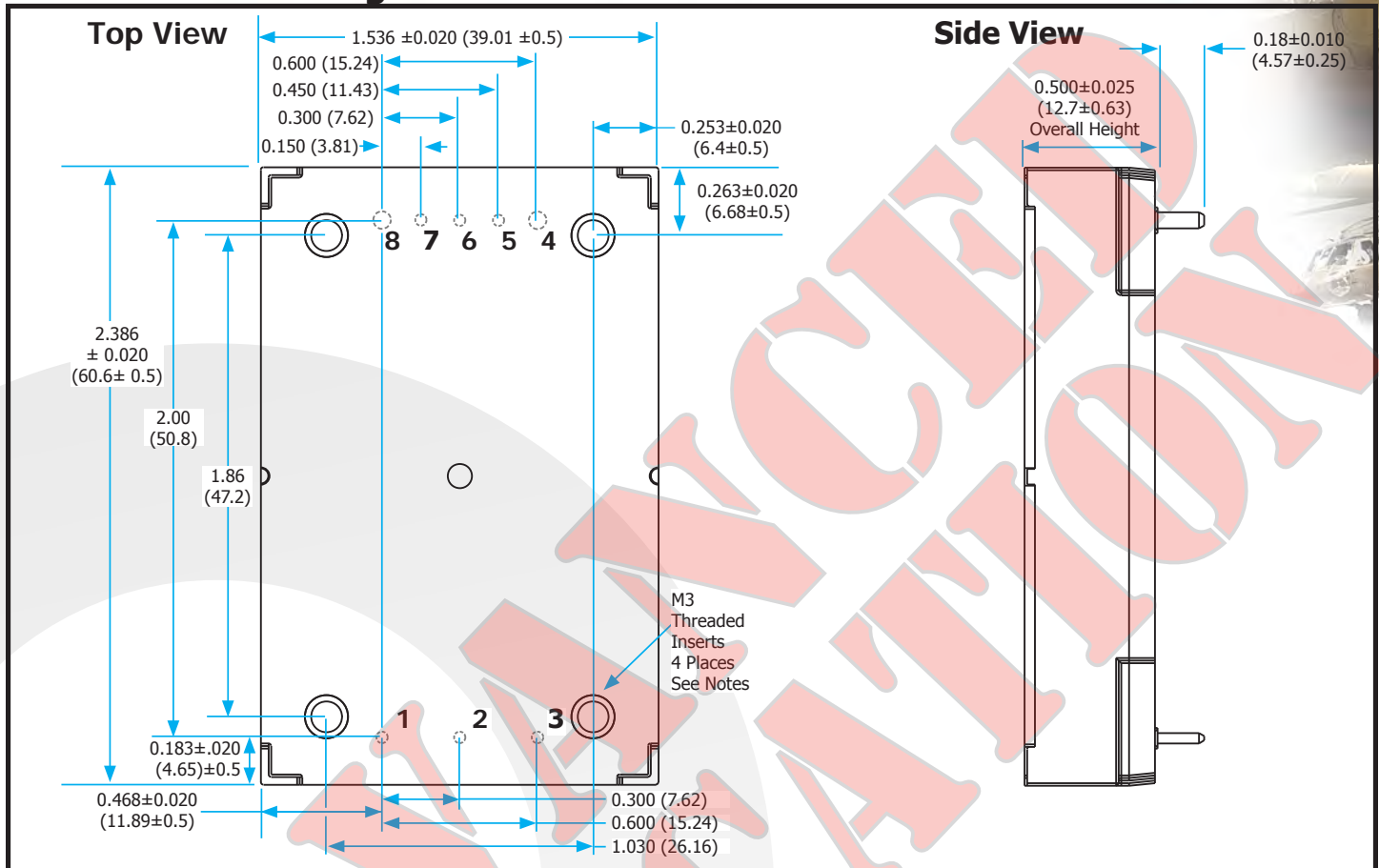


Figure E: Startup Inhibit Period (turn-on time not to scale)

## Mechanical Drawing



## NOTES

- M3 screws used to bolt unit's baseplate to other surfaces (such as a heatsink) must not exceed 0.100" (2.54 mm) depth below the surface of the baseplate.
- Applied torque per screw should not exceed 6in-lb. (0.7 Nm).
- Baseplate flatness tolerance is 0.004" (.10mm) TIR for surface.
- Pins 1-3, 5-7 are 0.040" (1.02mm) diameter, with 0.080" (2.03mm) diameter standoff shoulders.
- Pins 4 and 8 are 0.062" (1.57 mm) diameter with 0.100" (2.54 mm) diameter standoff shoulders.
- All Pins: Material - Copper Alloy- Finish (RoHS 6/6) - Matte Tin over Nickel plate
- Undimensioned components are shown for visual reference only.
- Weight: 3.02 oz. (85.7 g) typical
- All dimensions in inches (mm)  
Tolerances: x.xx +/-0.02 in. (x.x +/-0.5mm)  
x.xxx +/-0.010 in. (x.xx +/-0.25mm)
- Workmanship: Meets or exceeds IPC-A-610C Class II
- Recommended pin length is 0.03" (0.76mm) greater than the PCB thickness.

## PIN DESIGNATIONS

Pin	Name	Function
1	Vin(+)	Positive input voltage
2	ON/OFF	TTL input to turn converter on and off, referenced to Vin(-), with internal pull up.
3	Vin(-)	Negative input voltage
4	Vout(-)	Negative output voltage
5	SENSE(-)	Negative remote sense <sup>1</sup>
6	TRIM	Output voltage trim <sup>2</sup>
7	SENSE(+)	Positive remote sense <sup>3</sup>
8	Vout(+)	Positive output voltage

### Notes:

- SENSE(-) should be connected to Vout(-) either remotely or at the converter.
- Leave TRIM pin open for nominal output voltage.
- SENSE(+) should be connected to Vout(+) either remotely or at the converter.



# Technical Specification

**MCOTS-C-28-24-QT**

**Output: 24V**  
**Current: 5A**

## Ordering Information/ Part Numbering

Family	Product	Input Voltage	Output Voltage	Package	Heatsink Option	Screening Level
MCOTS	C: Converter F: Filter	28: 16-40V 48: 34-75V 270: 155-400V	1R2: 1.2V 1R5: 1.5V 1R8: 1.8V 2R5: 2.5V 3R3: 3.3V 05: 5V 07: 7V 12: 12V 15: 15V 24: 24V 28: 28V 40: 40V 48: 48V P: Passive T: Active	FT: Full Brick HP: Half Brick Peta HZ: Half Brick Zeta QT: Quarter Brick EG: Eighth Brick SM: Sixteenth Brick	N: Normal F: Flanged	S: Standard M: M-Grade

Example MCOTS-C-28-24-QT-N-S

### 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 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](mailto:rohs@synqor.com).

### 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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#### Warranty

SynQor offers a two (2) year limited warranty. Complete warranty information is listed on our website or is available upon request from SynQor.

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