NEW Product

EXQ50 Single
Application Note

ARTESYN® TECHNOLOGIES

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- **High efficiency topology, typically 90% at 5V, 86.5% at 1.8V**
- **Industry standard footprint**
- **Wide ambient temperature range, -40°C to +90°C**
- **90% to 110% output trim**
- **No minimum load**
- **Overvoltage protection**
- **Remote On/Off**

Features

- Industry standard quarter-brick pin-out and footprint: 57.91 x 36.83 x 10.16mm (2.28 x 1.45 x 0.4 inches)
- Wide operating temperature range (-40°C to +90°C)
- ±10% output voltage adjustability
- No minimum load requirement
- Remote on/off control (primary referenced)
- Remote sense compensation
- Constant switching frequency
- Brickwall over-current protection
- Continuous short-circuit protection
- Non-latching output over-voltage protection (OVP)
- Over-temperature protection (OTP)
- Input under/over-voltage lockout protection (U/OVLO)
- Input under-voltage (UV) and over-voltage (OV) protection

1. Introduction

This application note describes the features and functions of Artesyn Technologies' EXQ50 series of high power density, quarter-brick DC/DC converters. These open-frame, single-output modules are targeted specifically at the fixed and mobile telecommunications, industrial electronics and distributed power markets.

The EXQ50 series offers a wide input voltage range of 33-75VDC and can operate over an ambient temperature range of -40°C to +90°C. Ultra-high efficiency operation is achieved through the use of proprietary synchronous rectification and control techniques. The modules are fully protected against over-current, over-voltage and over-temperature conditions. Standard features include remote on/off and remote sense.

The series was designed primarily for telecommunication applications and complies with ETS 300 386-1 immunity and emission standards for high priority of service class. In addition, the series complies with ETS 300 019-1-3/-2-3 environmental standards (all classes) including shock, vibration, humidity and thermal performance. EN60950 and UL/cUL1950 safety approvals have been obtained, and a high level of reliability has been designed into all models through extensive use of conservative de-rating criteria. Automated manufacturing methods, together with an extensive qualification program, ensure that all EXQ50 series converters are extremely reliable.

2. Models

The EXQ50 series comprises four models, as listed in Table 1.

Model	Input Voltage	Output Voltage	Output Current
EXQ50-48S1V8	33-75VDC	1.8V	20A
EXQ50-48S2V5	33-75VDC	2.5V	20A
EXQ50-48S3V3	33-75VDC	3.3V	15A
EXQ50-48S05	33-75VDC	5.0V	10A

Table 1 - EXQ50 Models

3. General Description

3.1 Electrical Description

A block diagram of the EXQ50 converter is shown in Figure 1. Extremely high efficiency power conversion is achieved through the use of synchronous rectification techniques.

The EXQ50 is implemented using a current-mode controlled interleaved flyback topology. Power is transferred magnetically across the isolation barrier, via isolating power transformers. In all models, the secondary-side rectification stage consists of synchronous rectifiers controlled by proprietary circuitry to optimize the timing for high efficiency power conversion. The regulated voltage on the output pins is governed by the voltage on the module's sense pins, V_{sense+} and V_{sense-}.

The output is adjustable over a range of 90% to 110% of the nominal output voltage, using the TRIM pin (referenced to V_{sense-}).

The converter can be shut down via a remote on/off input that is referenced to the primary side. This input is compatible with popular logic devices; a 'positive' logic input is supplied as standard, with 'negative' logic available as an option. Positive logic implies that the converter is enabled if the remote on/off input is high (or floating), and disabled if it is low. Conversely, negative logic implies that the converter is enabled if the remote on/off input is low, and disabled if it is high (or floating).

The output is monitored for over-voltage conditions. The converter will clamp at the over-voltage set-point if an overvoltage condition is detected at the output.

The converter is also protected against over-temperature conditions. If the converter is overloaded or the ambient temperature gets too high, the converter will shut down until the temperature falls below a minimum threshold. There is a thermal hysteresis of typically 3ºC to 5ºC, to protect the unit.

An internal filter smoothes the input current and reduces conducted and radiated EMI. Further improvement can be achieved through the use of an optional external input filter. See Section 6.1 for further details.

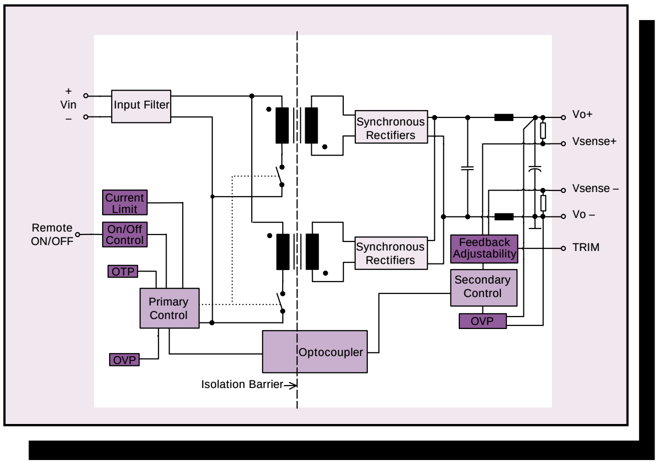


Figure 1 - Electrical Block Diagram

3.2 Physical Construction
The EXQ50 is constructed using a multi-layer FR4 PCB. SMT power components are placed on one side of the PCB, and all low-power control components are placed on the other side. Heat dissipation of the power components is optimized, ensuring that control components are not thermally stressed.

The converter is an open-frame product and has no case or case pin. The open-frame design has several advantages over encapsulated closed devices. Among these advantages are:

- **Cost:** no potting compound, case or associated process costs involved
- **Thermals:** the heat is removed from the heat generating components without heating more sensitive, less tolerant components such as opto-couplers
- **Environmental:** some encapsulants are not kind to the environment and create problems in incinerators. Furthermore, open-frame converters are more easily re-cycled
- **Reliability:** open-frame modules are more reliable for a number of reasons, including improved thermal performance and reduced TCE stresses

A separate paper discussing the benefits of open-frame DC/DC converters (Design Note 102) is available at www.artesyn.com

4. Features and Functions

4.1 Wide Operating Temperature Range
The EXQ50's ability to accommodate a wide range of ambient temperatures is the result of its extremely high power conversion efficiency and resultant low power dissipation, combined with the excellent thermal performance of the PCB substrate. The maximum output power that the module can deliver depends on a number of parameters, primarily:

- Input voltage range (application dependent)
- Output load current
- Air velocity (forced or natural convection)
- Mounting orientation of target application PCB, i.e. vertical/horizontal mount, or mechanically tied down (especially important in natural convection conditions)
- Target application PCB design, especially ground planes. These can be effective heatsinks for the converter

The EXQ50 can be operated from -40ºC to a maximum ambient temperature of +90ºC. A number of design graphs are included in Figures 12, 13, 14 and 15 to simplify the design task and allow the power system designer to determine the maximum output current at which the EXQ50 module may be operated for a given ambient temperature and airflow.

4.2 Over-Temperature Protection (OTP)
The EXQ50 is equipped with non-latching over-temperature protection. A temperature sensor monitors the temperature of the main substrate. If the temperature exceeds a threshold of 115°C (typical) the converter will shut down, disabling the output. When the substrate temperature has decreased by between 3ºC and 5°C the converter will automatically restart.

The EXQ50 might experience over-temperature conditions during a persistent overload on the output. Overload conditions can be caused by external faults. OTP might also be entered due to a loss of control of the environmental conditions (e.g. an increase in the converter's ambient temperature due to a failing fan).

4.3 Output Voltage Adjustment
The output voltage on all models is trimmable from 90% to 110% of the nominal voltage setpoint. Details on how to trim all models are provided in Section 8.4.

4.4 Output Over-Voltage Protection
The clamped over-voltage protection (OVP) feature is used to protect the module and the user's circuitry in the event that a fault occurs in the main control loop. Faults of this type include optocoupler failure, an open-circuit sense resistor or error amplifier failure. The unit is also protected in the event of the output being trimmed above the recommended maximum specification.

The OVP circuit consists of an auxiliary control loop running in parallel to the main control loop. However, unlike the main loop, the OVP loop senses the voltage at the output power terminals of the module. The sensed voltage is compared to a separate OVP reference and a compensated error signal is generated such that the output voltage is regulated to the OVP clamp level. Note that an optocoupler is not required during operation of the OVP clamp circuit. OVP clamp levels are typically set at 120-125% of the nominal output voltage setpoint for all models.

4.5 Safe Operating Area
The Safe Operating Area (SOA) of the EXQ50 converter is shown in Figure 2. Assuming the converter is operated within its thermal limits it can deliver rated output current I_{rated}. Note, however, that when the unit is trimmed up, the output current may need to be derated so that the output power does not exceed 50W. The module will still deliver I_{rated} when trimmed down.

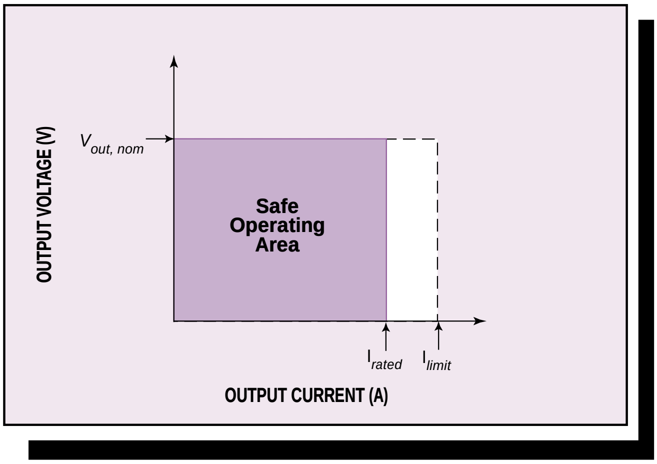


Figure 2 - Maximum Output Current Safe Operating Area

It should be noted that the SOA shown in Figure 2 is valid only if the converter is operated within its thermal specification. See Section 8.2 for more details.

4.6 Brickwall Current Limit and Short-Circuit Protection

All EXQ50 models have a built-in brickwall current limit function and full continuous short-circuit protection. Thus the V–I characteristic in current limit, as indicated by the dashed line in Figure 2, will be almost vertical at the current limit inception point, I_{limit}. This means that the output current should be almost constant irrespective of the output voltage during overload. The current limit inception point is influenced by the ambient temperature and line voltage, and also has a parametric spread. The inception point is typically 120% of rated full load for all models. The brickwall current limit scheme has many advantages, including increased capacitive load start-up capability (see Section 8.7).

Note that none of the module specifications is guaranteed when the unit is operated in an overcurrent condition. The unit will not be damaged in an overcurrent condition because it will be protected by the OTP function, but the converter's lifetime may be reduced.

4.7 Remote On/Off

The remote on/off input allows external circuitry to put the EXQ50 converter into a low dissipation sleep mode. Active-high remote on/off is available as standard and active-low logic can be specified as an option by adding the suffix '-R' to the part number.

Active-high units of the EXQ50 series are turned on if the remote on/off pin is high (or floating). Pulling the pin low will turn off the unit. Active-low units of the EXQ50 series are turned on if the remote on/off pin is low. Pulling the pin high (or leaving it floating) will turn off the unit. The signal level of the remote on/off input is defined with respect to Vin–.

To simplify the design of the external control circuit, logic signal thresholds are specified over the full temperature range. The maximum remote on/off input open circuit voltage, as well as the acceptable leakage currents, are specified in the EXQ50 Long Form Datasheet. The remote on/off input can be driven in a variety of ways as shown in Figures 3, 4 and 5. If the remote on/off signal originates on the primary side, the remote on/off input can be driven through a discrete device (e.g. a bipolar signal transistor) or directly from a logic gate output. The output of the logic gate may be an open-collector (or open-drain) device. If the drive signal originates on the secondary side, the remote on/off input can be isolated and driven through an optocoupler.

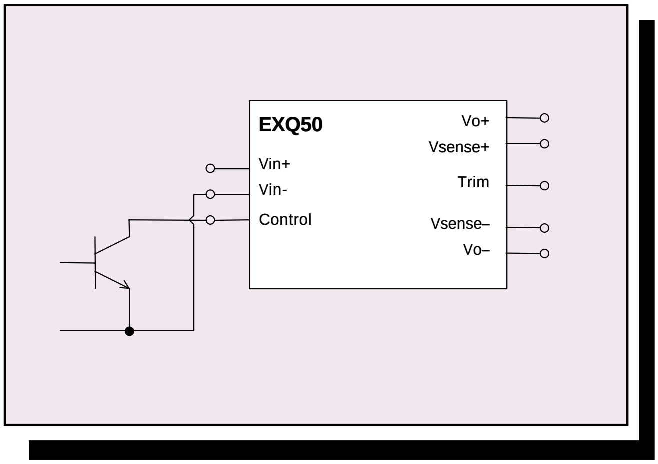


Figure 3 - Remote on/off Input Drive Circuit for Non-Isolated Bipolar

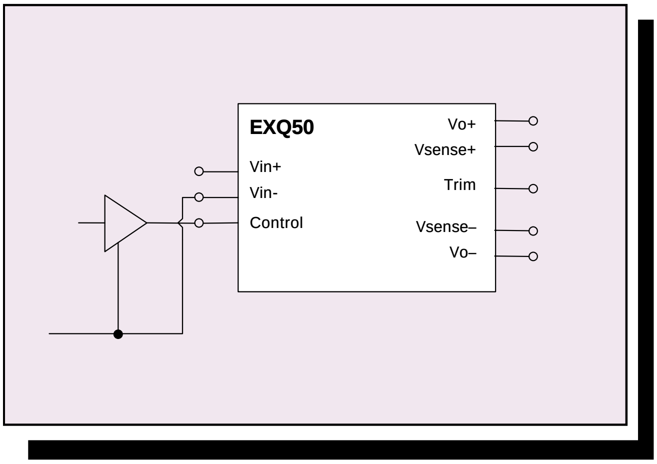


Figure 4 - Remote on/off Input Drive Circuit for Logic Driver

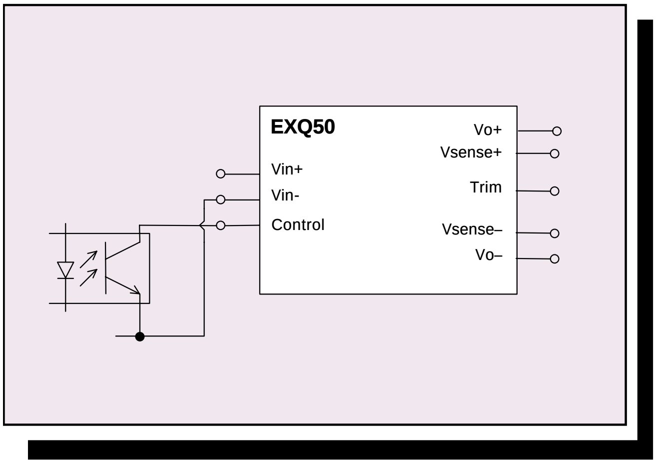


Figure 5 - Remote on/off Input Drive Circuit using an Optocoupler to maintain the isolation barrier from primary to secondary

5. Safety

5.1 Isolation
The EXQ50 series has been designed in accordance with EN60950, CAN/CSA-C22.2 No. 60950-00 and UL60950 'Safety of Information Technology Equipment'.

The EXQ50 DC/DC converter is intended for inclusion in other equipment and the installer must ensure that it is in compliance with all the requirements of the end application.

For many applications, models with operational insulation will be sufficient, provided that one pole of the output is connected to protective earth. Units with operational isolation are less costly and will have 1-2% higher efficiency than the equivalent model with basic isolation.

The galvanic isolation is verified in an electric strength test during production; the test voltage between input and output is 1.5kVDC. Also, note that the flammability ratings of the terminal support header blocks and internal plastic constructions meet UL94V-0.

5.2 Input Fusing
In order to comply with safety requirements, the user must provide a fuse in the unearthed input line if an earthed input is used. The reason for putting the fuse in the unearthed line is to avoid earth being disconnected in the event of a failure. If an earthed input is not being used, the fuse can be placed in either input line.

A 3.15 Amp slow-blow/anti-surge 200V HRC (High Rupture Capacity) fuse should be used for all models.

6. EMC

The EXQ50 has been designed to comply with the EMC requirements of ETSI 300 386-1. It meets the most stringent requirements of Table 5; 'public telecommunications equipment, locations other than telecommunication centres, high priority of service'.

6.1 Conducted Emissions
The applicable standard for conducted emissions is EN55022 (FCC Part 15). Conducted noise can appear as both differential mode and common mode noise currents. Differential mode noise is measured between the two input lines, with the major components occurring at the converter's fundamental switching frequency and its harmonics. Common mode noise, a contributor to both radiated emissions and input conducted emissions, is measured between the input lines and system ground and can be broadband in nature. The EXQ50 series of converters bypasses common mode noise internally by using two paralleled 1nF, 2kV capacitors between Vin- and Vo+. Common mode noise currents flowing in the application circuitry will therefore be greatly minimized. Furthermore, the EXQ50 has a substantial filter on-board to enable it to meet the EN55022 Class B standard using the external filter depicted in Figure 6. A similar filter can be derived for Class A compliance using the same component set.

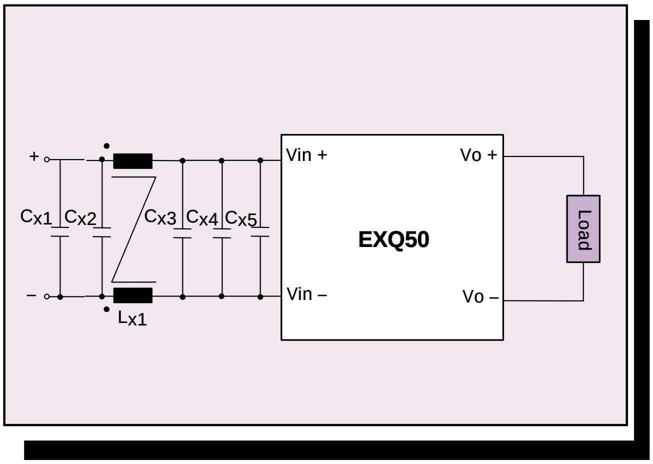


Figure 6 - Recommended Filter for Class B Compliance

The components and manufacturers' part numbers used in the above filter are as follows:

C_{x1}, C_{x2}, C_{x4}, C_{x5}, 1.5µF, 100V Marcon, THCR50E2A155ZT
C_{x3}, ITW Paktron 4µF, 100V, SMT film capacitor, 405K100CS4
L_{x1}, Pulse Eng PO351

The recommended PCB layout of the specified filter is shown in Figure 7.

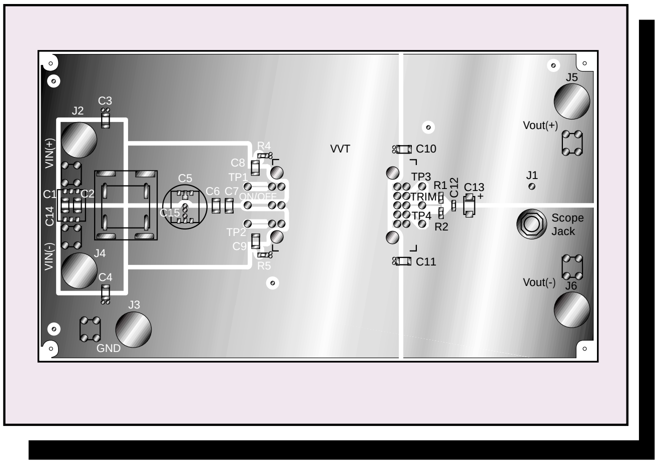


Figure 7 - Conducted EMI Filter Recommended Layout Guidelines

A typical conducted emission measurement result for the EXQ50-48S3V3 is shown in Figure 8. The results were obtained using the recommended external Class B filter.

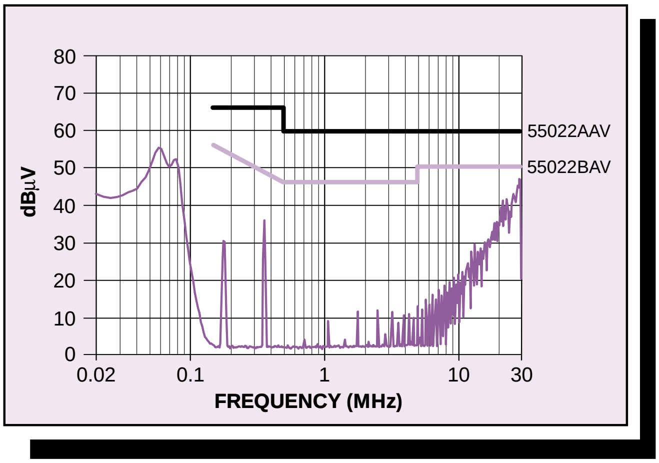


Figure 8 -Typical Spectrum of the EXQ50-48S3V3 Level B

6.2 Radiated Emissions
The applicable standard is EN55022 Class B (FCC Part 15). Testing DC/DC converters as a stand-alone component to the exact requirements of EN55022 is very difficult, because the standard calls for 1m leads to be attached to the input and output ports and aligned such as to maximise the disturbance. In such a set-up, it is possible to form a perfect dipole antenna that very few DC/DC converters could pass.

However, the standard also states that 'An attempt should be made to maximise the disturbance consistent with the typical application by varying the configuration of the test sample'. In addition, ETS 300 386-1 states that the testing should be carried out on the enclosure. For most applications, the signal input lines to the converter should be less than 3 meters long and this is sufficient to meet the requirements of the standard.

Typical radiated emission results are shown in Figure 9.

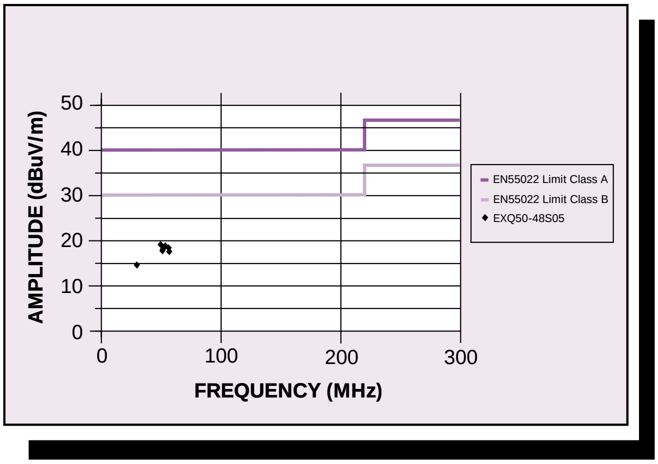


Figure 9 - Typical Radiated Emission EXQ50 (Vin=48V, Io nom)

7. Use in a Manufacturing Environment

7.1 Resistance to Solder Heat

EXQ50 series connverters are intended for PCB mounting. Artesyn Technologies has determined how well the product can resist the temperatures associated with soldering of PTH components without affecting its performance or reliability. The method used to verify this is MIL-STD-202 method 210D. Within this method two test conditions were specified, Soldering Iron condition A and Wave Solder Condition C.

For the soldering iron test, the UUT was placed on a PCB with the recommended PCB layout pattern shown in Section 8. A soldering iron set to 350ºC±10ºC was applied to each terminal for 5 seconds. The UUT was then removed from the test PCB and examined under a microscope for any reflow of the pin solder or physical change to the terminations. None was found.

For the wave solder test, the UUT was again mounted on a test PCB. The unit was wave soldered using the conditions shown in Table 2. The UUT was inspected after soldering and no physical change was found on the pin terminations.

Temperature	Time	Temperature Ramp
260°C±5°C	10sec±1	Preheat 4°C/sec to 160°C. 25mm/sec rate

Table 2 - Wave Solder Test Conditions

7.2 Water Washing

Where possible, a no-clean solder paste system should be used for solder attaching the EXQ50 product onto application boards. The EXQ50 is suitable for water washing applications, because it does not have entrapment areas where water and residues may become trapped long term. However, the user must ensure that the drying process is sufficient to remove all water from the converter after washing - never power the converter unless it is fully dried. The user's process must clean the soldered assembly in accordance with ANSI/J-STD-001.

7.3 ESD Control

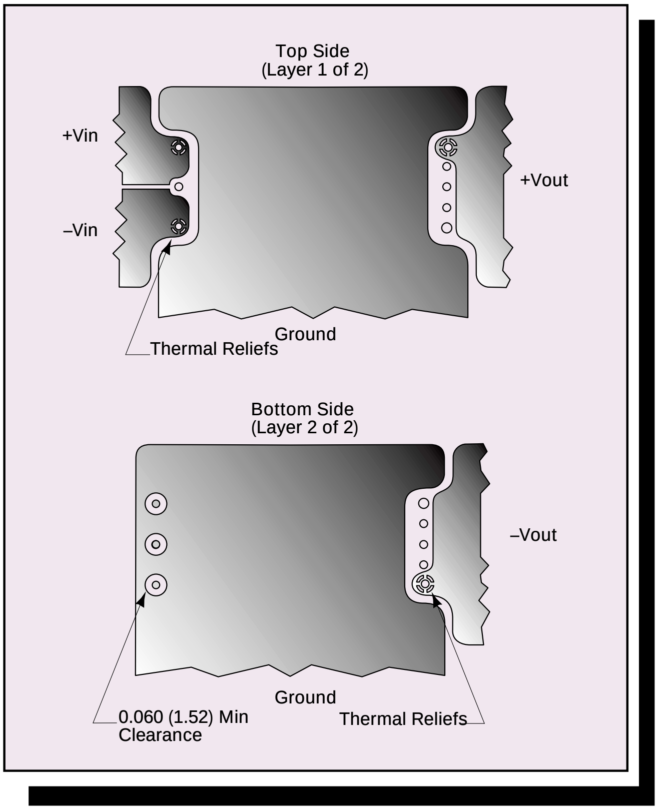
EXQ50 units are manufactured in an ESD controlled environment and supplied in conductive packaging to prevent ESD damage occurring before or during shipping. It is essential that they are unpacked and handled using approved ESD control procedures. Failure to do so could affect the lifetime of the converter.

8. Applications

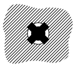
8.1 Optimum PCB Layout

The PCB acts as a heat sink and draws heat from the unit via conduction through the pins and through radiation. It is recommended that power and return planes be used. A three-wire system including a chassis or system ground is also possible, and a ground plane is beneficial. These planes act as EMC shields (note that the recommended layout shown in Figure 7 does not guarantee system EMC compliance since this depends on the end application). A recommended layout for an end user's double-sided PCB that maintains the creepage and clearance requirements discussed in the safety section of this application note, is presented in Figure 10. However the end user must ensure that other components and metal in the vicinity of the EXQ50 meet the spacing requirements to which the system is approved. Low resistance and low inductance PCB layout traces should be used where possible, particularly when high currents are flowing (e.g. the output side).

VIEW IS FROM TOP SIDE



THERMAL RELIEF IN CONDUCTOR PLANES
REFERENCE IPC-D-275 SECTION 5.3.2.3



ALL DIMENSIONS IN INCHES (mm)
ALL TOLERANCES ARE ±0.004 (0.10)

Figure 10 - Recommended Footprints

8.2 Optimum Thermal Performance

The electrical operating conditions of the EXQ50, namely:

- Input voltage, V_{in}
- Output voltage, V_o
- Output current, I_o

determine how much power is dissipated within the converter. The following parameters further influence the thermal stresses experienced by the converter:

- Ambient temperature
- Air velocity
- Thermal efficiency of the end system application
- Parts mounted on system PCB that may block airflow
- Real airflow characteristics at the converter location

The maximum acceptable temperature measured at the thermal reference points is 115ºC. These thermal reference points are shown in Figure 11.

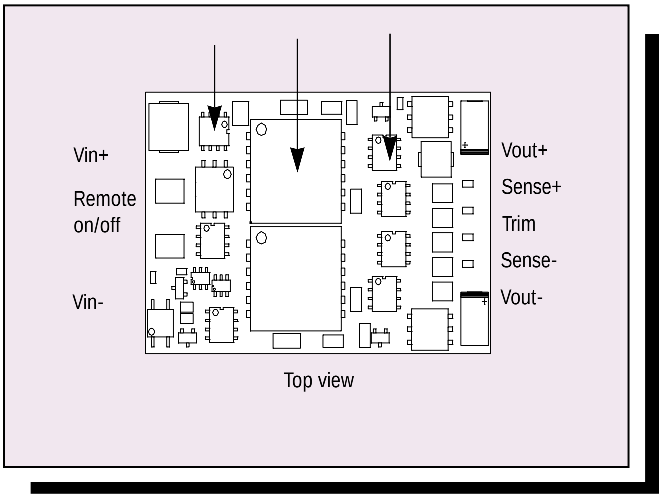


Figure 11 - Thermal Reference Point Locations on EXQ50 Converters

In order to simplify the thermal design, a number of graphs are given in the data sheet and are repeated in Figures 12, 13, 14 and 15. These derating graphs show the load current of the EXQ50 versus the ambient air temperature and forced air velocity. However, since the thermal performance is heavily dependent upon the final system application, the user needs to ensure the thermal reference point temperatures are kept within the recommended temperature rating. It is recommended that the thermal reference point temperatures are measured using a thermocouple or an IR camera. In order to comply with stringent Artesyn derating criteria the ambient temperature should never exceed 90°C. Please contact Artesyn Technologies for further support.

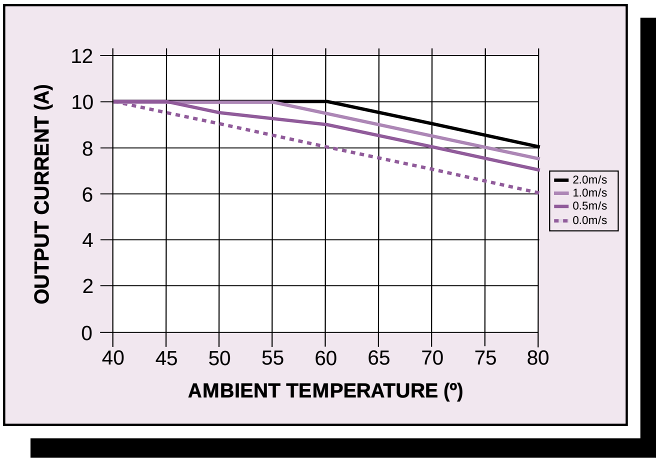


Figure 12 - Maximum Output Current vs. Ambient Temperature and Airflow for EXQ50-48S05

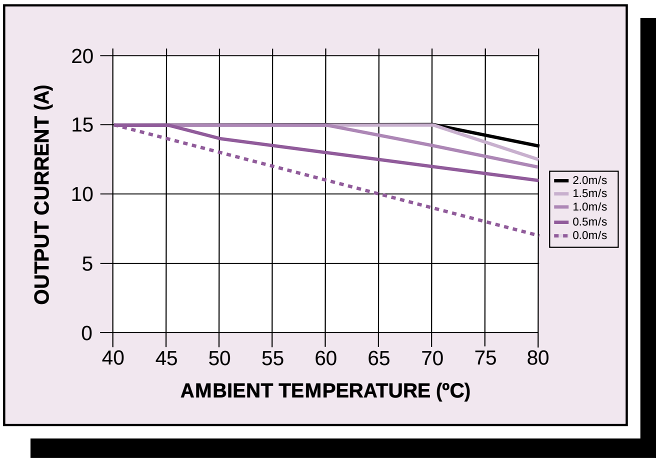


Figure 13 - Maximum Output Current vs. Ambient Temperature and Airflow for EXQ50-48S3V3

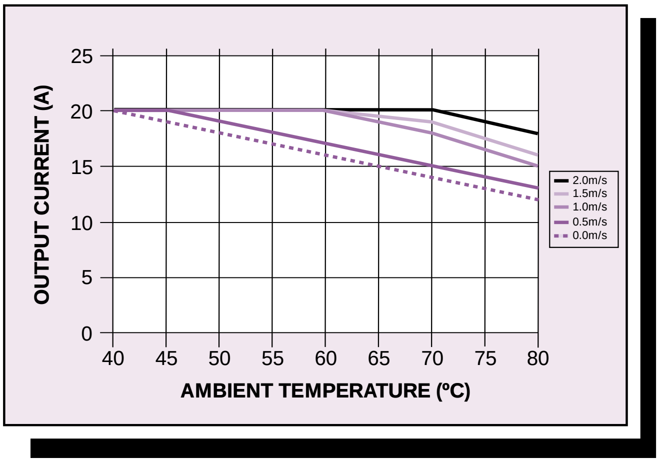


Figure 14 - Maximum Output Current vs. Ambient Temperature and Airflow for EXQ50-48S2V5

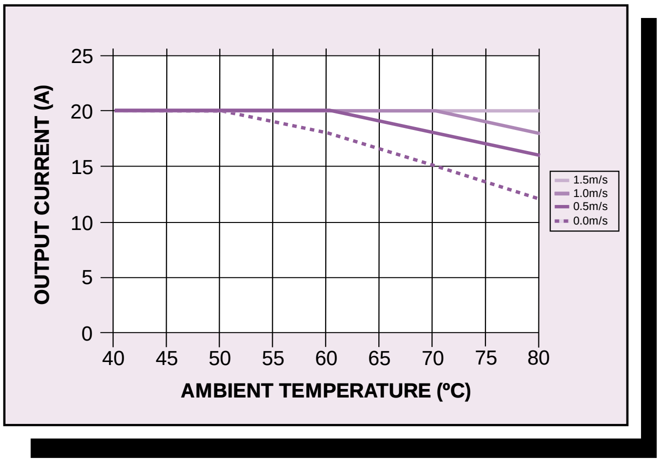


Figure 15 - Maximum Output Current vs. Ambient Temperature and Airflow for EXQ50-48S1V8

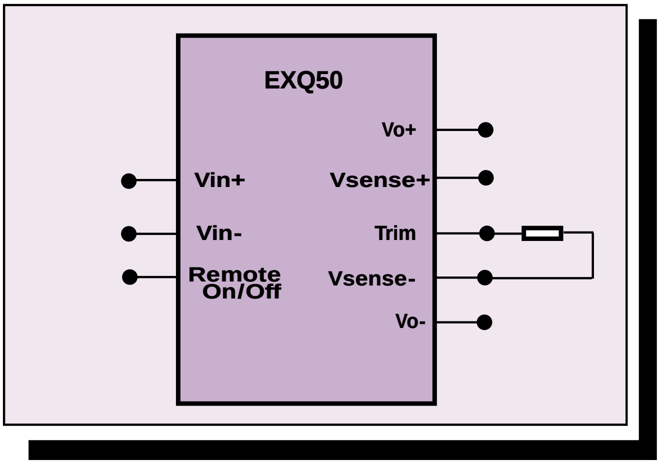


Figure 16 - Trimming Output Voltage - Trim up

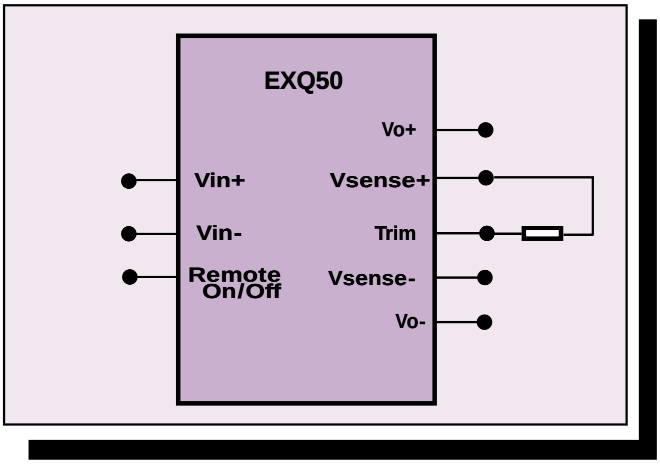


Figure 17 - Trimming Output Voltage - Trim Down

8.3 Remote Sense Compensation

The remote sense compensation feature minimizes the effect of resistance in the distribution system and facilitates accurate voltage regulation at the load terminals or another selected point. The remote sense lines will carry very little current and hence do not require a large cross-sectional area. However, if the sense lines are routed on a PCB, they should be located close to a ground plane in order to minimize any noise coupled onto the lines that might impair control loop stability. A small 100nF ceramic capacitor can be connected at the point of load to decouple any noise on the sense wires. The module will compensate for a maximum drop of 10% of the nominal output voltage. However, if the unit if already trimmed up, the available remote sense compensation range will be correspondingly reduced. Remember that when using remote sense compensation all the resistance, parasitic inductance and capacitance of the distribution system are incorporated into the feedback loop of the power module. This can have an effect on the module's compensation capabilities, affecting its stability and dynamic response.

8.4 Output Voltage Adjustment

The output can be externally trimmed by ±10% by connecting an external resistor between the TRIM pin and either the V_{sense+} or V_{sense-} pin. With an external resistor between TRIM and V_{sense-}, R_{TRIM_UP}, the output voltage setpoint increases. Conversely, connecting an external resistor between TRIM and V_{sense+}, R_{TRIM_DOWN}, the output voltage set point decreases. This is shown in Figures 16 and 17.

The relevant trim equations to derive the appropriate trim resistance for the EXQ50 are as follows:

$$Radj\_down = \left[\frac{(V_{trim\_down} - L)G}{(V_{out,\ nom} - V_{trim\_down})} - H \right] k\Omega$$

$$Radj\_up = \left(\left[\frac{GL}{(V_{trim\_up} - L) - K} \right] - H \right) k\Omega$$

Where,

Vout, nom	is the nominal output voltage of the module
Vtrim-down (or Vtrim-up)	is the desired output voltage
R_{ADJ_DOWN}	is the resistor required to achieve the desired (trimmed down) output voltage
R_{ADJ_UP}	is the resistor required to achieve the desired (trimmed up) output voltage
G,H	are 5110 and 2050 respectively

and the following parameters are defined:

Model	K	L
EXQ50-48S05	2.5	2.5
EXQ50-48S3V3	2.06	1.24
EXQ50-48S2V5	1.29	1.235
EXQ50-48S1V8	0.585	1.232

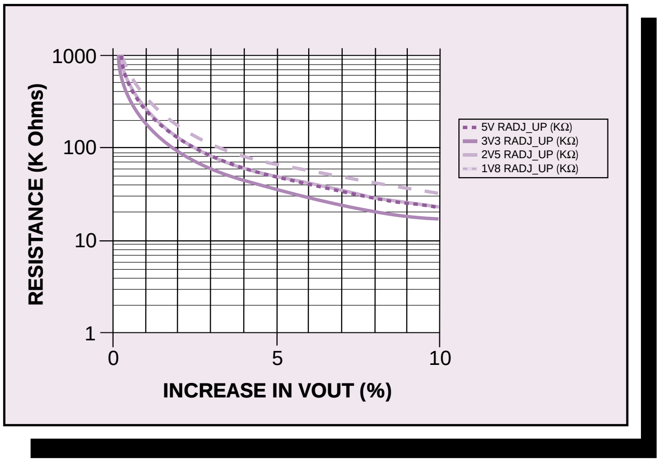


Figure 18 - Typical Trim-Up Curve (resistor from TRIM to V_{sense} -)

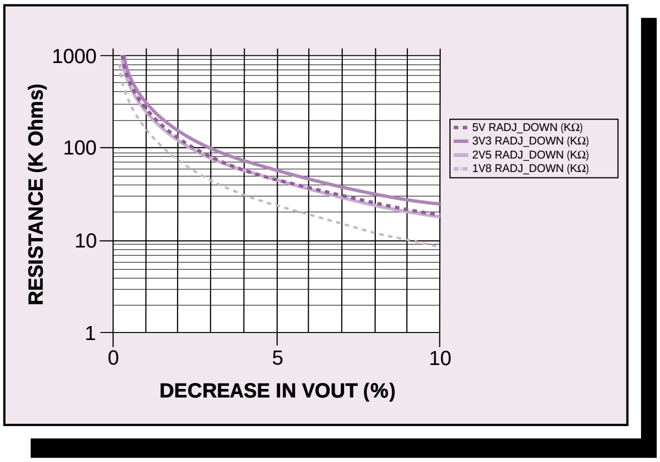


Figure 19 - Typical Trim Down Curve (resistor from TRIM to V_{sense} +)

Note that when the output voltage is trimmed up by a certain percentage, the output current may have to be derated so that the maximum output power rating is not exceeded.

8.5 Parallel and Series Operation

Parallel operation of multiple EXQ50 converters is not recommended. If unavoidable, ORing diodes must be used to decouple the outputs. Droop resistors will support some passive current sharing. It should be noted that both measures will adversely affect power conversion efficiency.

Multiple EXQ50 converters can be connected in series but this may result in an increased level of common mode EMI. Contact your local Artesyn Technologies representative for further information.

8.6 Output Capacitance

The EXQ50 series has been designed for stable operation without the need for external capacitance at the output terminals. However, when powering loads with large dynamic current requirements, improved voltage regulation can be obtained by inserting capacitors as close as possible to the load. The most effective technique is to locate low ESR ceramic capacitors as close to the load as possible, using several capacitors to lower the overall ESR. These ceramic capacitors will handle the short duration high frequency components of the dynamic current requirement. In addition, higher values of electrolytic capacitors should be used to handle the mid-frequency components.

It is equally important to use good design practices when configuring the DC distribution system. Low resistance and low inductance PCB layout traces should be utilized, particularly in the high current output section. Remember that the capacitance of the distribution system and the associated ESR are within the feedback loop of the power module. This can have an effect on the module's compensation capabilities and its resultant stability and dynamic response performance. With large values of capacitance, the stability criteria depend on the magnitude of the ESR with respect to the capacitance. As much of the capacitance as possible should be outside the remote sensing loop and close to the load.

Note that the maximum rated value of output capacitance for all models is 5,000µF. Contact your local Artesyn Technologies representative for further information if larger output capacitance values are required in the application.

8.7 Reflected Ripple Current and Output Ripple & Noise Measurement

The measurement set-up outlined in Figure 21 has been used for both input reflected/terminal ripple current and output voltage ripple and noise measurements on EXQ50 series converters. When measuring output ripple and noise, a 50Ω coaxial cable with a 50Ω termination should be used to prevent impedance mismatch reflections disturbing the noise readings at higher frequencies. The input ripple current measurement setup is compatible with ETS 300 386-1.

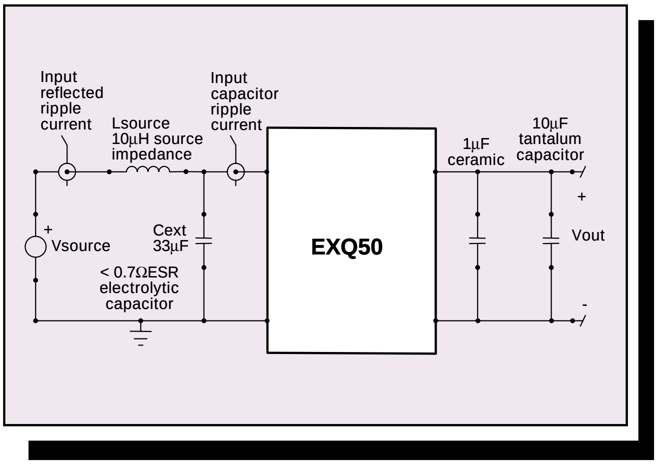


Figure 20 - Input Reflected Ripple/Capacitor Ripple Current and Output Voltage Ripple and Noise Measurement Set-Up