EXA40 SERIES

Application Note 101 Rev. 01 - Feb. 1999

NEW Product

- **Ultra high efficiency topology, 91% typical at 5V**
- **Operating ambient temperature of -40°C to +70°C (natural convection)**
- **Approved to EN60950, UL1950, CSA C22.2 No. 234/950**
- **Complies with ETS 300 019-1-3/2-3**
- **Complies with ETS 300 132-2 input voltage and current requirements**
- **Fully compliant with ETS 300 386-1**

1. Introduction

The EXA40 Series is a new generation of DC/DC converters which were designed in response to the growing need for low operating voltage and higher efficiencies. They offer unprecedented efficiency figures and the greatest range of low output voltages on the market.

In addition the automated manufacture methods and use of planar magnetics together with an extensive qualification program have produced one of the most reliable range of converters.

2. Models and Features

The EXA40 comprises eight separate models as shown in Table 1. All popular integrated circuit operating voltages are covered by the entire range.

Model	Input Voltage	Output Voltage
EXA40-24S05	18-36VDC	4.5 to 5.5V
EXA40-24S3V3	18-36VDC	3.0 to 3.6V
EXA40-24S2V75	18-36VDC	2.5 to 3.0V
EXA40-24S1V8	18-36VDC	1.5 to 2.0V
EXA40-48S05	36-75VDC	4.5 to 5.5V
EXA40-48S3V3	36-75VDC	3.0 to 3.6V
EXA40-48S2V75	36-75VDC	2.5 to 3.0V
EXA40-48S1V8	36-75VDC	1.5 to 2.0V

Table 1 - EXA40 Models

Features
- Overtemperature shutdown
- Optional latching OVP
- Primary remote On/Off
- Output voltage adjustability
- Continuous short circuit protection
- Overcurrent limiting

3. General Description

Electrical Description
The EXA40 is a resonant reset Forward converter with synchronous rectification. A simplified schematic is shown in Figure 1. The significant gain in efficiency has been achieved by optimum driving of the synchronous rectifiers.

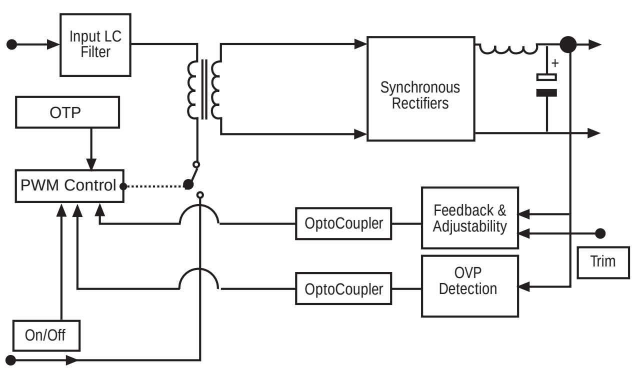

Figure 1 - Simplified Schematic

The DC input is filtered by an LC filter before it reaches the main transformer. A PWM controller is used to regulate the output. The main power switch is a MOSFET running at a control frequency of 300KHz.

The output is sensed and compared with a secondary side reference and an error signal is fed back via an optocoupler to the PWM controller. The trim pin on the secondary side allows the output to be adjusted by connecting a resistor between trim and either the positive or negative output depending on whether you wish to trim up or down.

The optional latching Over-Voltage Protection (OVP) circuit sends back a signal to the PWM controller to turn off if the output rises above a pre-determined limit for longer than 1ms. OVP transients less than this are eliminated through the use of an output TVS. More details on the OVP section can be found in the applications section. The controller latches off until the power is re-cycled or the remote pin is toggled.

An Over-Temperature Protection (OTP) circuit on the primary side shuts down the PWM controller if the converter is in danger of being damaged. Unlike the OVP circuit the OTP circuit does not latch off the controller. There is however a considerable amount of thermal hysteresis which is used to protect the unit.

The output synchronous rectifiers are controlled by circuitry on the secondary side which optimise the driving scheme.

Physical Construction
The EXA40 is constructed using a single multi-layer FR4 PCB. SMT components are placed on both sides of the PCB and in general, the heavier power components are mounted on the top side in order to optimise heat dissipation.

The converter is sold as an open-frame product and no case is required. 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. In addition open frame converters are more easily re-cycled.
- **Reliability:** Open Frame modules are more reliable for a number of reasons.

A separate paper discussing the benefits of “open frame low to medium DC/DC converters” Design Note 102 is available from Artesyn Technologies. The effective elimination of potting and a case has been made possible by the use of modern automated manufacturing techniques and in particular the 100% use of SMT components, the use of planar magnetics and the exceptionally high efficiencies.

4. Features and Functions

Overvoltage Protection
A TVS is used across all models to clamp all transients of short duration that may occur. The levels of these transients are given in Table 2.

Output Voltage	TVS Value
5V	6.8V
3.3V	4.0V
2.75V	4.0V
1.8V	4.0V

Table 2 - Output TVS Clamping Voltages

The maximum duration of these pulses and their peak power is dependent on a number of factors. Appendix 2 contains details of the output TVS ratings. For a single Pulse the maximum Peak Power at 1ms is 600W at 25°C (see Figure A2-1). As the ambient temperature increases so the Peak Pulse power derates as shown in Figure A2-2.

Repetitive Pulses are not as straightforward and an extra derating chart is supplied in Figure A2-3. The derating is expressed here as a function of the pulse duty cycle and pulse width. Note that these derating factors are quoted at 25°C and must be further derated for temperature by referring to Figure A2-2.

The OVP function is an optional function that is used to protect the users circuitry from damage should the converter fail or if an externally induced transient occurs on the output. The trip points are set quite accurately at 125% of Vout nominal and are given in Table 3.

The OVP function has a discrimination circuit to prevent it tripping due to small duration transients. This filter eliminates any pulses of between 500µs and 1ms duration over the trip point level.

Output Voltage	TVS Value
5V	6.2V
3.3V	4.2V
2.75V	3.6V
1.8V	2.5V

Table 3 - OVP Trip Point

When the unit trips the PWM controller shuts down the output within 1ms.

Over Temperature Protection
This feature is included as standard in order to protect the converter and the circuitry it powers from overheating in the event of a runaway thermal condition such as a fan failure at high temperatures. or continuous operation above Tmax at full power.

The actual ambient temperature it trips at is dependent on quite a number of factors The airflow over the unit is the most dominant parameter. The trip point is also affected by the input voltage, output trim voltage, user PCB layout, output load and model.

For all models under full load conditions the trip point will be at a minimum of 75°C in still air using the recommended layout in the Applications section. Still Air or natural convection is defined as 0.1m/s airflow.

As the load is decreased and the unit is operated at higher temperatures, the trip point also rises. This trip point will at all times protect the unit and will be a minimum of 5°C away from the safe operating temperature of the device.

Current Limit and Short Circuit
All models of the EXA40 have a built in current limit function and full continuous short circuit protection.

The current limit inception point is dependent on the input voltage, ambient temperature and has a parametric spread also. For all models the inception point is typically 140% or 11.2A. It may go as high as 180% or as low as 100% over all operating conditions and the lifetime of the product.

None of the specifications are guaranteed when the unit is operated in an overcurrent condition. The unit will not be damaged in an overcurrent condition as it will protect itself through the use of the OTP function before any damage occurs. However the lifetime of the unit will be reduced.

In short circuit the unit enters a ‘hiccup’ foldback current mode and may be operated continuously in this condition. The duty cycle of this hiccup is dependent on input voltage, temperature etc. The RMS value of the short circuit current is guaranteed to be a maximum of 12A RMS over all operating conditions and the lifetime of the product. While the unit is specified to operate into a continuous short circuit, extended or frequent short circuits will reduce the lifetime of the converter.

A short circuit is defined as a resistance of 20mΩ or less.

Remote On/Off
The remote On/Off function allows the unit to be controlled by an external signal which puts the module into a low power dissipating sleep mode. Methods of applying are given in the applications section.

Output Voltage Adjustment
The output voltage on all models except for the 1.8V output is trimmable by ±10%. The 1.8V output is asymmetrically trimmable by +13% and -18%. Details on how to do trim all models are provided in the applications section.

5. Safety

Isolation
The EXA40 has been submitted to independent safety agencies and has EN60950 and UL1950 Safety approvals. Basic insulation is provided and the unit is approved for use between the classes of circuits listed in Table 4.

Insulation	
Between	And
TNV-1 Circuit	Earthed SELV Circuit Unearthed SELV Circuit
TNV-2 Circuit TNV-3 Circuit	Earthed SELV Circuit Unearthed SELV Circuit or or TNV-1 Circuit
Earthed or Unearthed Hazardous Voltage Secondary Circuit	Earthed SELV Circuit ELV Circuit Unearthed Hazardous Voltage Secondary Circuit TNV-1 Circuit

Table 4 Insulation categories for Basic

The TNV or Telecommunication Voltage definitions are given in Table V.1 of IEC950 from which EN60950 and UL1950 are derived.

The EXA40 has an approved insulation system that satisfies the requirements of the safety standards.

In order for the user to maintain the insulation requirements of these safety standards it is necessary for the required creepage and clearance distances to be maintained between the input and output.

Creepage is the distance along a surface such as a PCB and for the EXA40 the creepage requirement between primary and secondary is 1.4mm or 55 thou. Clearance is the distance through air and the requirement is 0.7mm or 27 thou.

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 then the fuse may be in either input line.

For the 48V input models a 2A Anti-Surge Fuse should be used and for the 24V models a 3.15A Anti-Surge fuse is required. High Rupture Capacity (HRC) fuses are recommended.

6. EMC

The EXA40 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. Following is the list of standards which apply and which it has complied with.

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 (FCC Part 15) is very difficult to do as 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 from 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. The EXA40 is primarily intended for PCB mounting in Telecommunication Rack systems.

For the purpose of the radiated test the unit was mounted on a 6U high PCB with a 40W load on board and connections to the remote on/off and trim pins. The recommended PCB layouts were used on the test PCB. The unit was then mounted in an ETSI standard 19” rack system and the position of the card was varied to achieve maximum emissions.

There was a 4µF capacitor connected across the input and the ground plane was connected to the output (pin 7). However the difference between the ground plane being connected to the input or output is minimal. Details of the capacitor and optimum groundplane can be found in later sections.

The test results for the 48S05 and 24S05 models are shown in tables 5 and 6 below as these are the models with the highest switching voltages and currents. The testing was carried out by an independent test house and a copy of the report is available on request.

Frequency (MHz)	Response (dBµV/m)
30.00	14.80
102.53	23.75
108.50	21.80
109.09	22.85
110.67	23.00

Table 5 - Radiated Emissions on EXA40-48S05

Frequency (MHz)	Response (dBµV/m)
30.00	14.80
108.56	15.80
108.81	16.85
110.62	19.00
111.50	21.20

Table 6 - Radiated Emissions on EXA40-24S05

In both cases the unit passed the Class B limit which is 30 dBV/m with a significant margin.

Conducted emissions
The required standard for conducted is EN55022 Class A (FCC Part 15). The EXA40 has quite a substantial LC filter on board to enable it to meet this standard with just the addition of one external component for the 48V models and two for some of the 24V models.

The conducted noise graphs for the EXA40-48S05 are given in Figure 2 & Figure 3 . The graphs of all other models are available on request.

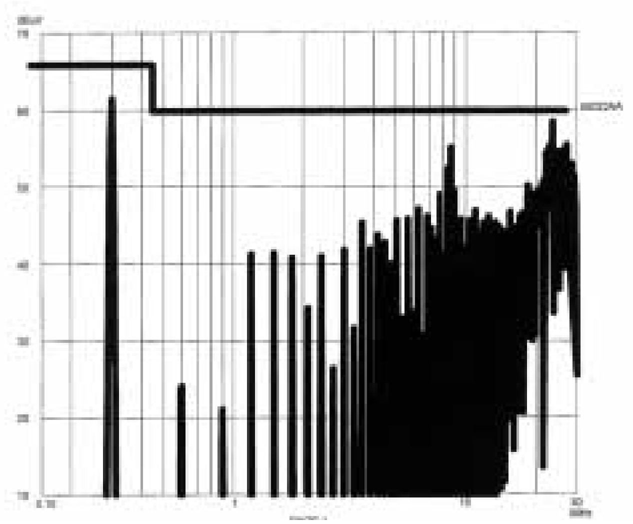

Figure 2 - EXA40-48S05 Class A Conducted Noise

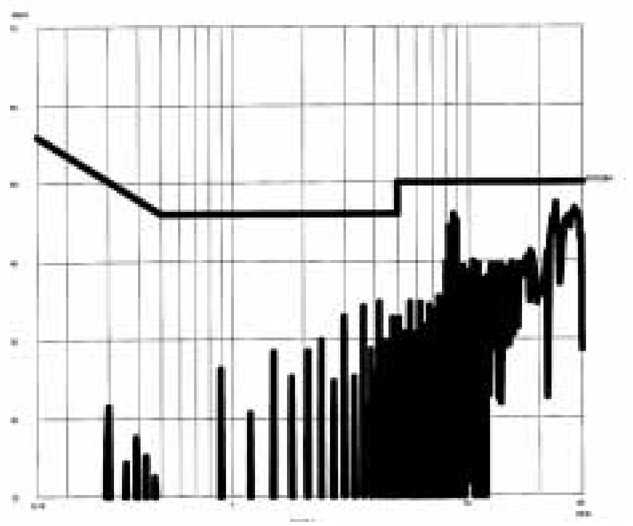

Figure 3 - EXA40-48S05 Class B Conducted Noise

The required Filters to meet Class A & Class B for all models shown in Figure 4 to Figure 7. Table 7 is a cross-reference which indicates which filter is required for which model.

Model	Class A	Class B
48S1V8	Filter A	Filter C
48S2V75	Filter A	Filter C
48S3V3	Filter A	Filter C
48S05	Filter A	Filter B
24S1V8	Filter A	Filter C
24S2V75	Filter B	Filter C
24S3V3	Filter B	Filter C
24S05	Filter B	Filter D

Table 7 - Model/Filter cross-reference

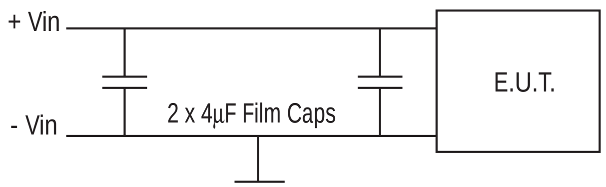

Figure 4 - Filter A

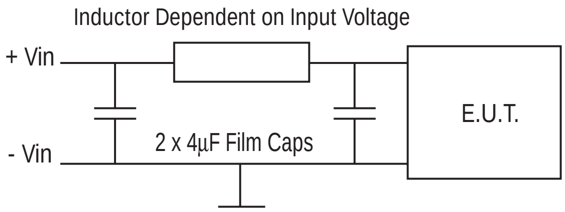

Figure 5 - Filter B

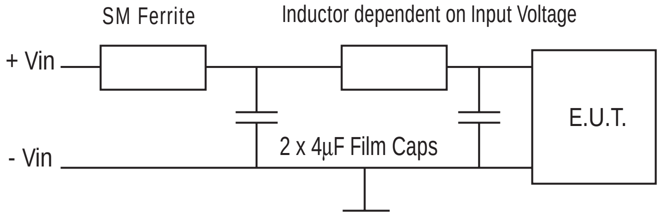

Figure 6 - Filter C

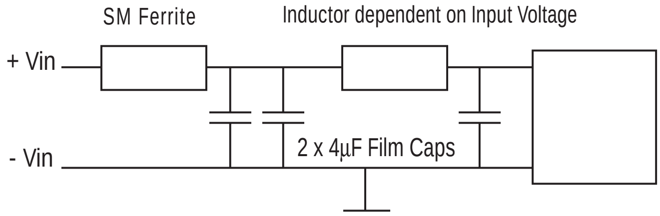

Figure 7 - Filter D

The part numbers of the parts used in each case are given below.

Film Capacitor ITW Paktron part number 405K100CS4G.

Surface Mount Ferrite Bead part no; MMG DS52-9K3F-R1ES2.

24Vin models use 10µH TDK inductor part no; SLF10145T-100M2R5.

48Vin models use 47µH TDK inductor part no; SLF10145T-470M1R4.

7. Use in a Manufacturing Environment

Resistance to Soldering Heat
The EXA40 is intended for PCB mounting. Artesyn has determined how well it can resist the temperatures associated with the 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 the applications section. A soldering iron set to 350°C ± 10°C was applied to each terminal for 5 seconds. The UUT was then removed from the test PCB and was examined under a microscope for any reflow of the pin solder or physical change to the terminations. None was found.

For the wave soldering test the UUT was again mounted on a test PCB. The unit was wave soldered using the conditions shown in Table 8.

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

Table 8 Wave Solder Test Conditions

The UUT was inspected after soldering and no physical change on pin terminations was found.

Water Washing
The EXA40 is suitable for water washing as it doesn't have any pockets where water may congregate long-term. The user should ensure that a sufficient drying process and period is available to remove the water from the unit after washing

ESD Control
The EXA40's 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 an approved ESD control procedures. Failure to do so could affect the lifetime of the converter.

8. Applications

Optimum PCB Layout
The recommended PCB layout for a double and single sided PCB's are given in Appendix 3. At a minimum 2oz/ft^2 or 70µm copper should be used. The PCB acts as a heatsink and draws heat from the unit via conduction through the pins and radiation. The two layers also act as EMC shields.

If 2oz/ft^2 copper or the recommended layout isn't used then the user needs to ensure that the unit always operates within correct temperature limits by measuring the hotspots indicated in the thermal section.

For a double-sided PCB Figure A3-1 and Figure A3-2 should be used Figure A3-4 should be used for single-sided PCB's. Figure A3-5 show locations where via should not be placed on the user application to avoid solder mounds causing isolation problems.

Optimum Thermal Performance
All models of the EXA40 except the EXA40-24S05 can operate in still air up to a maximum ambient temperature of 70°C using the recommended PCB layout shown in the previous section. The EXA40-24S05 is limited to 60°C without airflow. Still air which is sometimes called natural convection is defined as 0.1m/s airflow. Above 70°C the output power may be derated so that the maximum ambient operating temperature can be extended to 100°C as shown in Figure 8 and Figure 9.

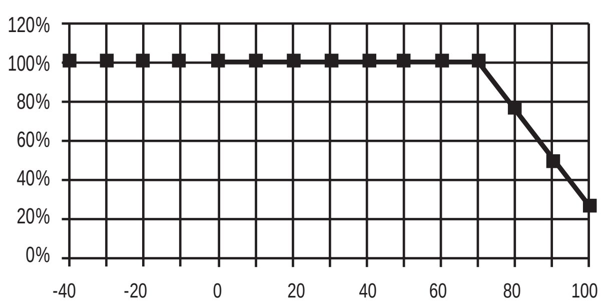

Figure 8 - Output Power versus Ambient Temperature in natural Convection

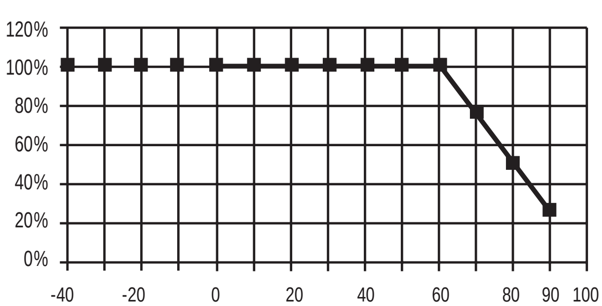

Figure 9 - Output Power versus Ambient Temperature in natural Convection for the EXA40-24S05

If forced air cooling is used then the converter may be used up to 95°C at full output power dependent on the airflow. Figure 10 is a graph of the maximum allowed ambient temperature at full power versus the airflow across the converter.

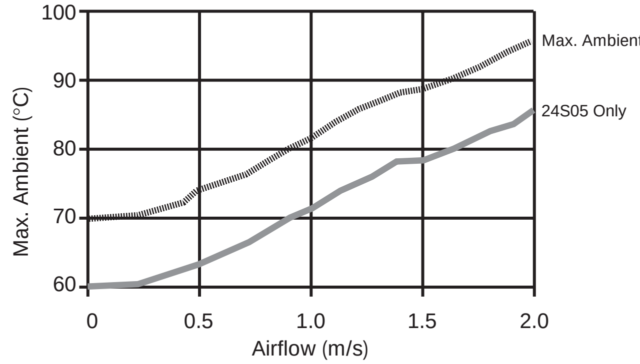

Figure 10 - Max. Ambient Temperature at full Power with Forced Airflow

If the unit is operated with forced airflow then it may be operated to 100°C with linear derating from the maximum ambient specified in Figure 10. Figure 11 shows the derating for a converter operating with 1.5m/s forc
ed airflow for all models except the EXA40-24S05.

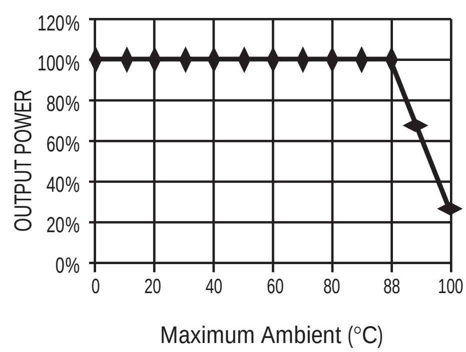

Figure 11 - Thermal Derating for 1.5m/s Forced Airflow.

Figure 12 shows the derating for an EXA40-24S05

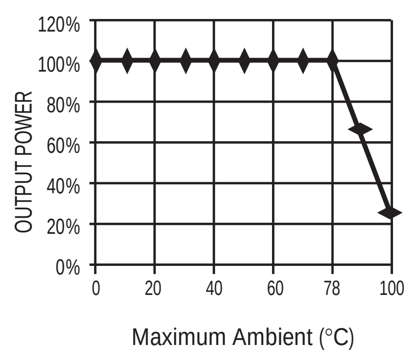

Figure 12 - Thermal Derating for 1.5m/s Forced Airflow.

The most accurate method of ensuring that the converter is operating within its guidelines in a chosen application is to measure the temperature of a hot-spot. There are three such spots on the EXA40 and which is the hottest is dependent on the input line voltage, output load and the ambient temperature. In general they will be within 10°C of each other.

These hot spots are shown in Figure 13. They are the main primary switch and the two secondary synchronous rectifiers, each of which is a D2PAK.

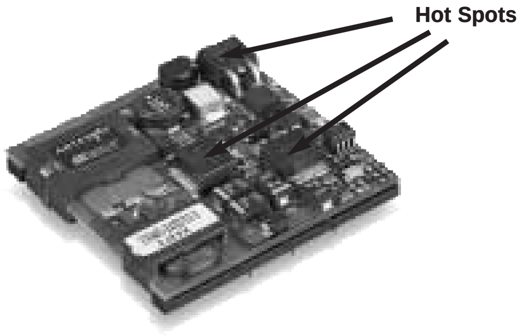

Figure 13 Hot Spot Locations

When measuring the temperature of these points the thermocouple should be mounted as closely as possible to the tab of the device. In order to maintain the Artesyn Derating criteria the temperatures of the devices should never exceed 120°C.

Remote On/Off Control
The remote On/Off control is a primary referenced function which allows the converter to be put into a low power dissipating sleep mode. The maximum current taken by unit during this mode is 2mA over all line and temperature conditions.

The remote On/Off pin can source typically 70µA of current into the collector of a transistor and can be directly connected to an optocoupler open collector output. The following three figures provide details of methods of connecting to the remote on/off pin.

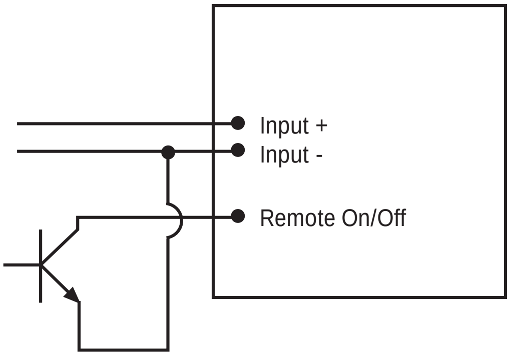

Figure 14 Implementation of Remote On/Off with a single Transistor

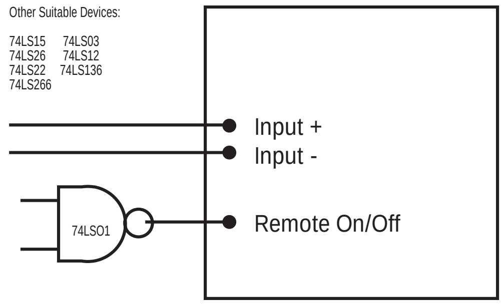

Figure 15 Implementation of Remote On/Off with TTL Devices

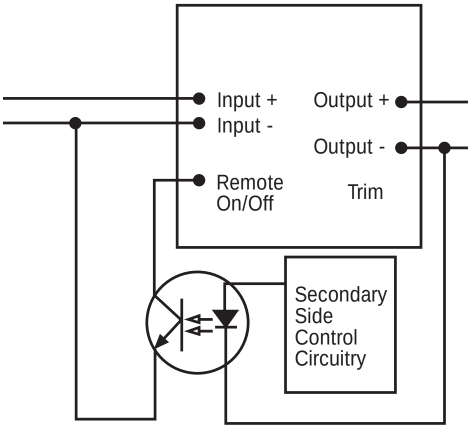

Figure 16 Secondary Side control of Remote On/Off

Output Voltage Adjust
The output voltage can be adjusted by connecting a resistor between the output trim pin and either the output high or low pin. For the 2.75V, 3.3V and 5V outputs the trim function has a range of approximately ±10%. For the 1.8V output the trim range is typically +13%/-18%. The following three figures show how the output may be trimmed either high or low while Appendix 1 contains graphs which plot the output voltage against the trim resistor for all models.

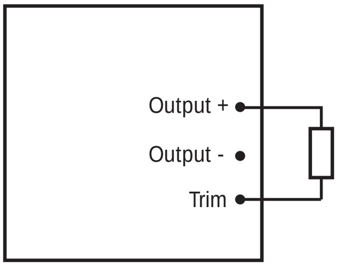

Figure 17 Output Trim Low using a Fixed resistor or Potentiometer

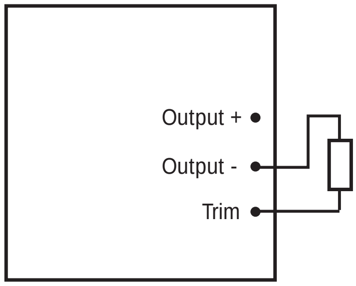

Figure 18 Output Trim High using a Fixed resistor or Potentiometer

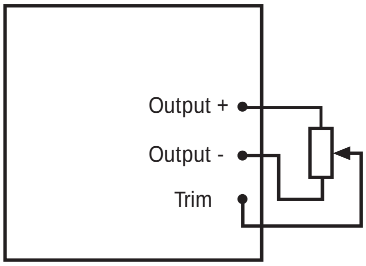

Figure 19 Variable Output Trim using a Potentiometer

Appendix 1 Output Voltage Trim Curves

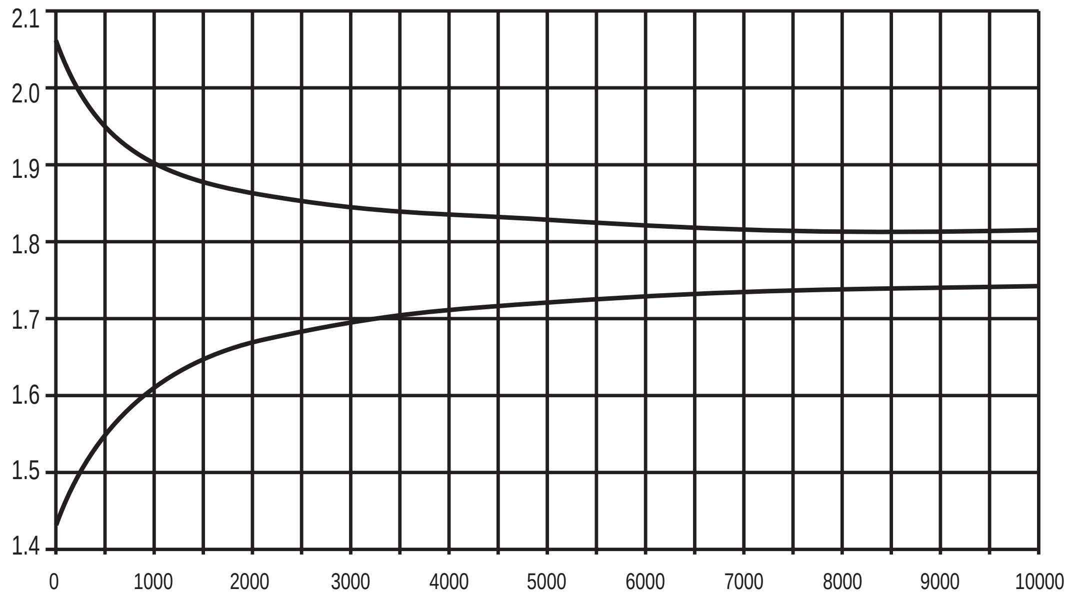

Figure A1-1 - 1.8V Output Voltage vs. Trim Resistor Value

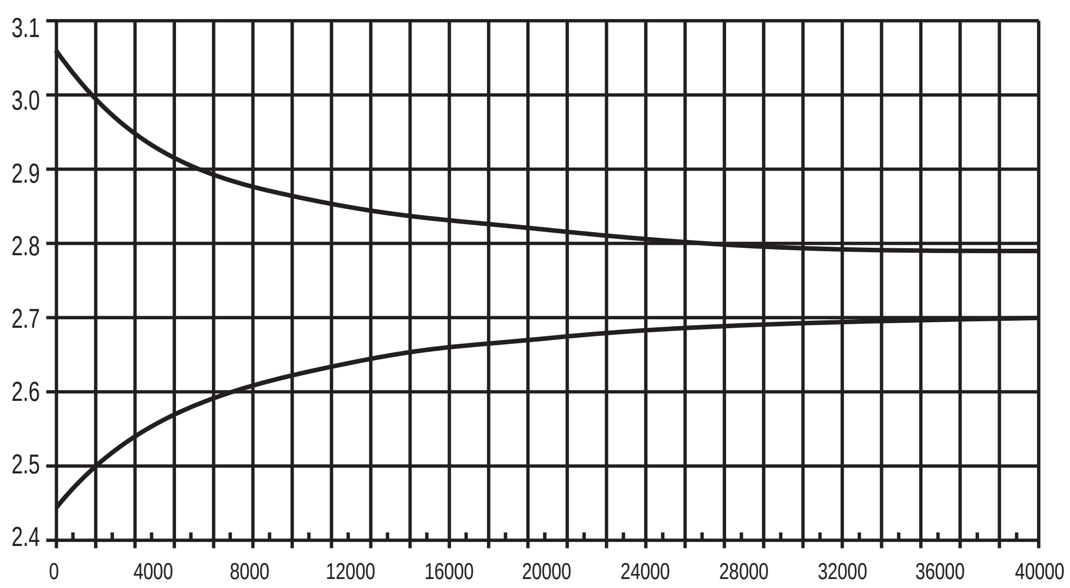

Figure A1-2 - 2.75V Output Voltage vs. Trim Resistor Value

Appendix 1 Output Voltage Trim Curves

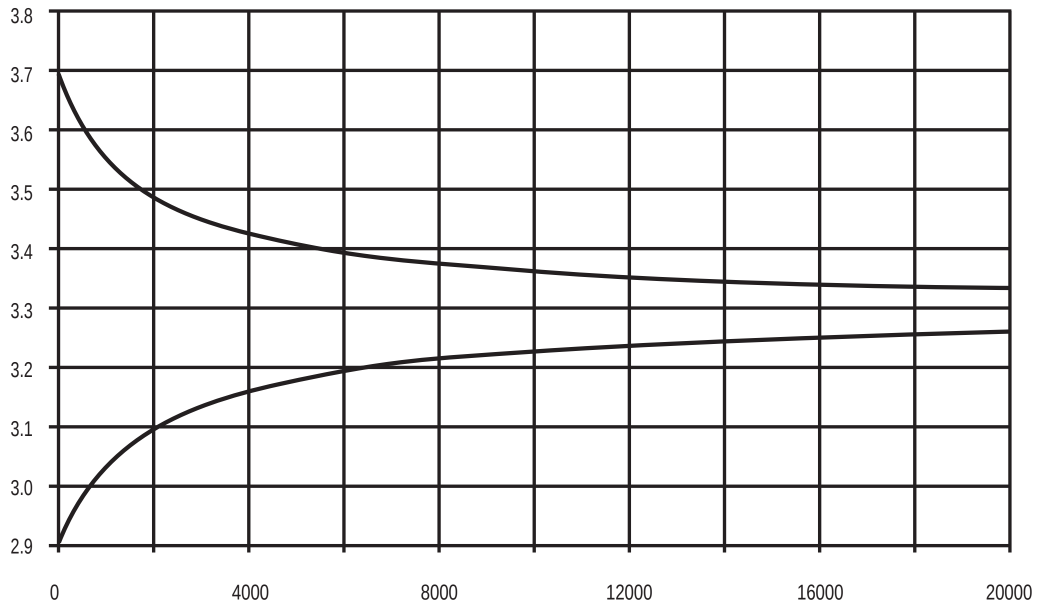

Figure A1-3 - 3.3V Output Voltage vs. Trim Resistor Value

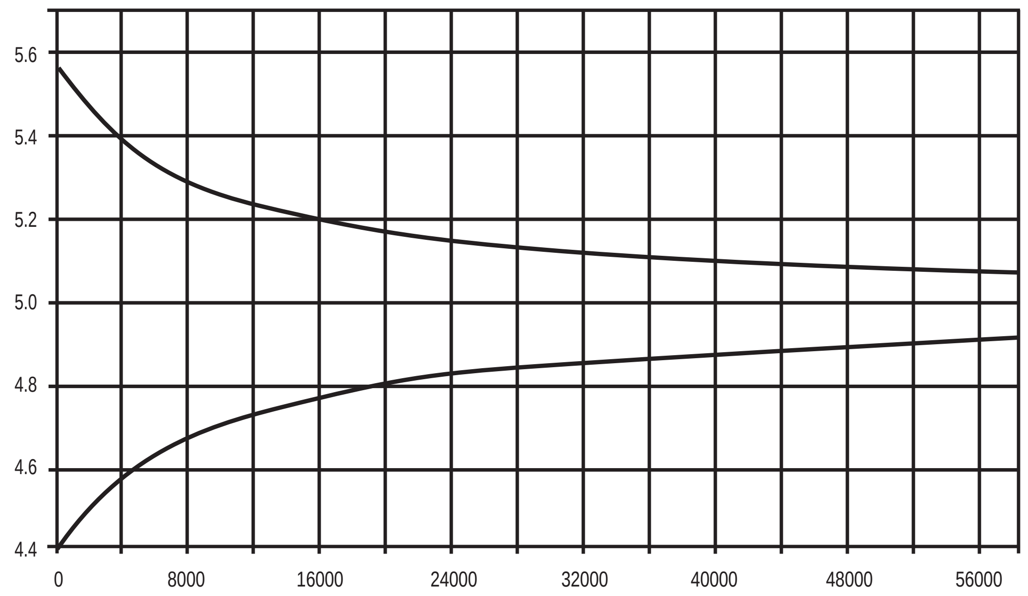

Figure A1-4 - 5V Output Voltage vs. Trim Resistor Value

Appendix 2 Output TVS Rating

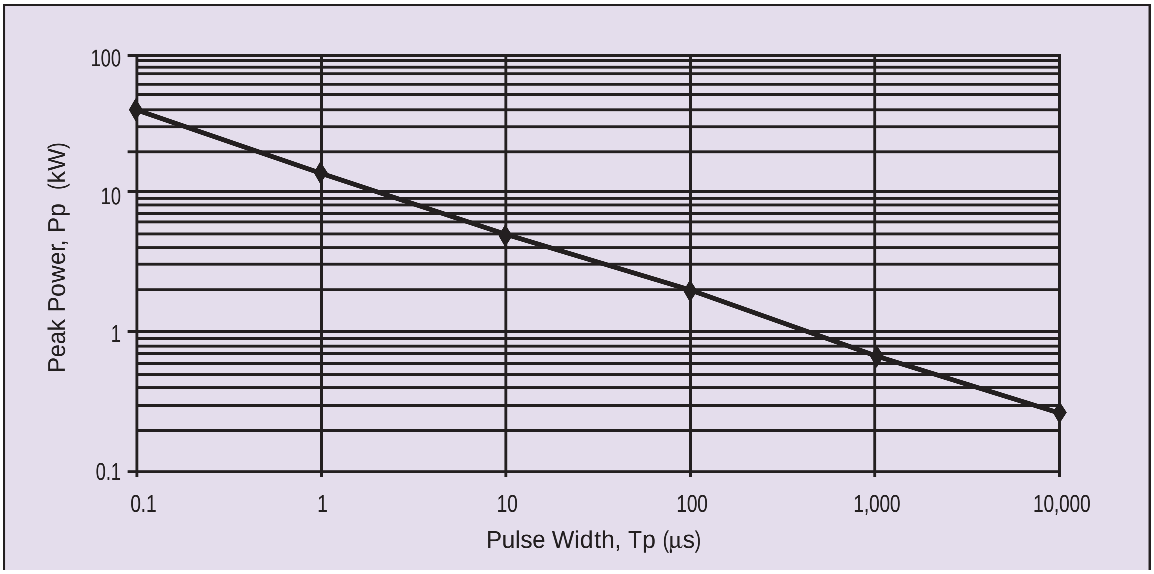

Figure A2-1 - TVS Output Rating vs. Pulse Width @ 25˚C Ambient

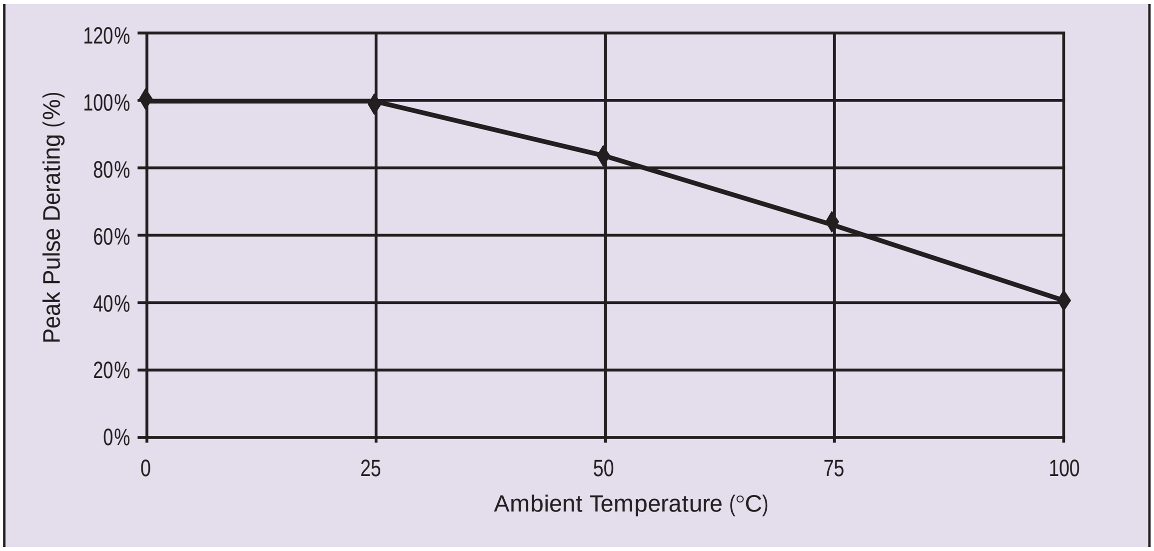

Figure A2-2 - Output TVS Peak Pulse Derating vs. Ambient Temperature

Appendix 2 Output TVS Rating

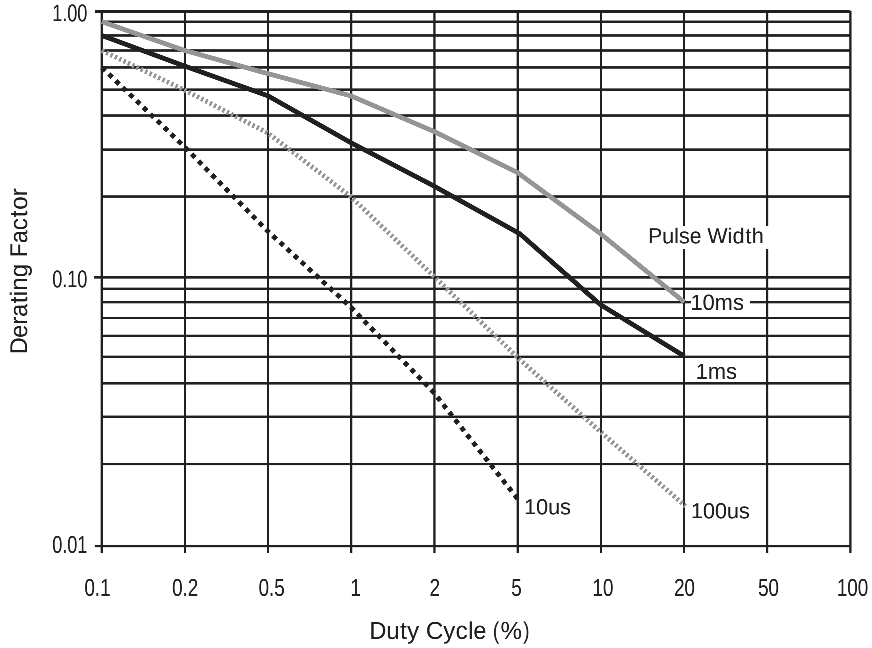

Figure A2-3 3.3V Output Voltage vs. Trim Resistor Value

Appendix 3 Recommended PCB Layouts

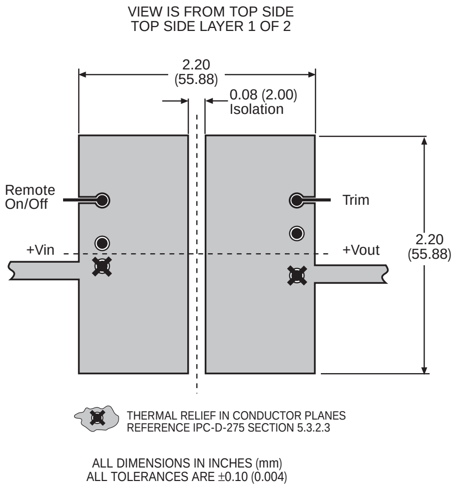

Figure A3-1 - Recommended Top Layer Footprint

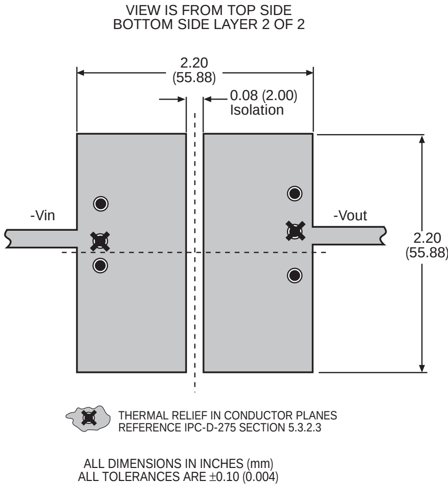

Figure A3-2 - Recommended Bottom Layer Footprint

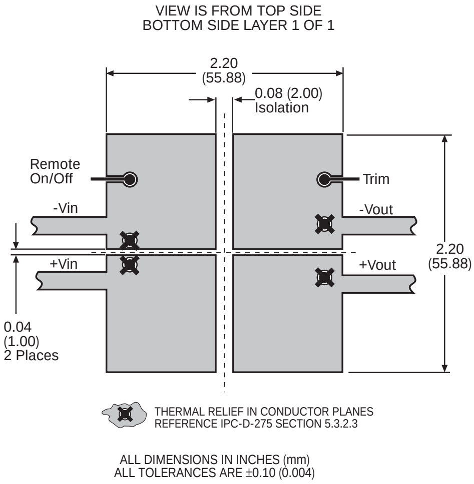

Figure A3-3 - Recommended Single Sided PCB Layout

Appendix 3 Recommended PCB Layouts

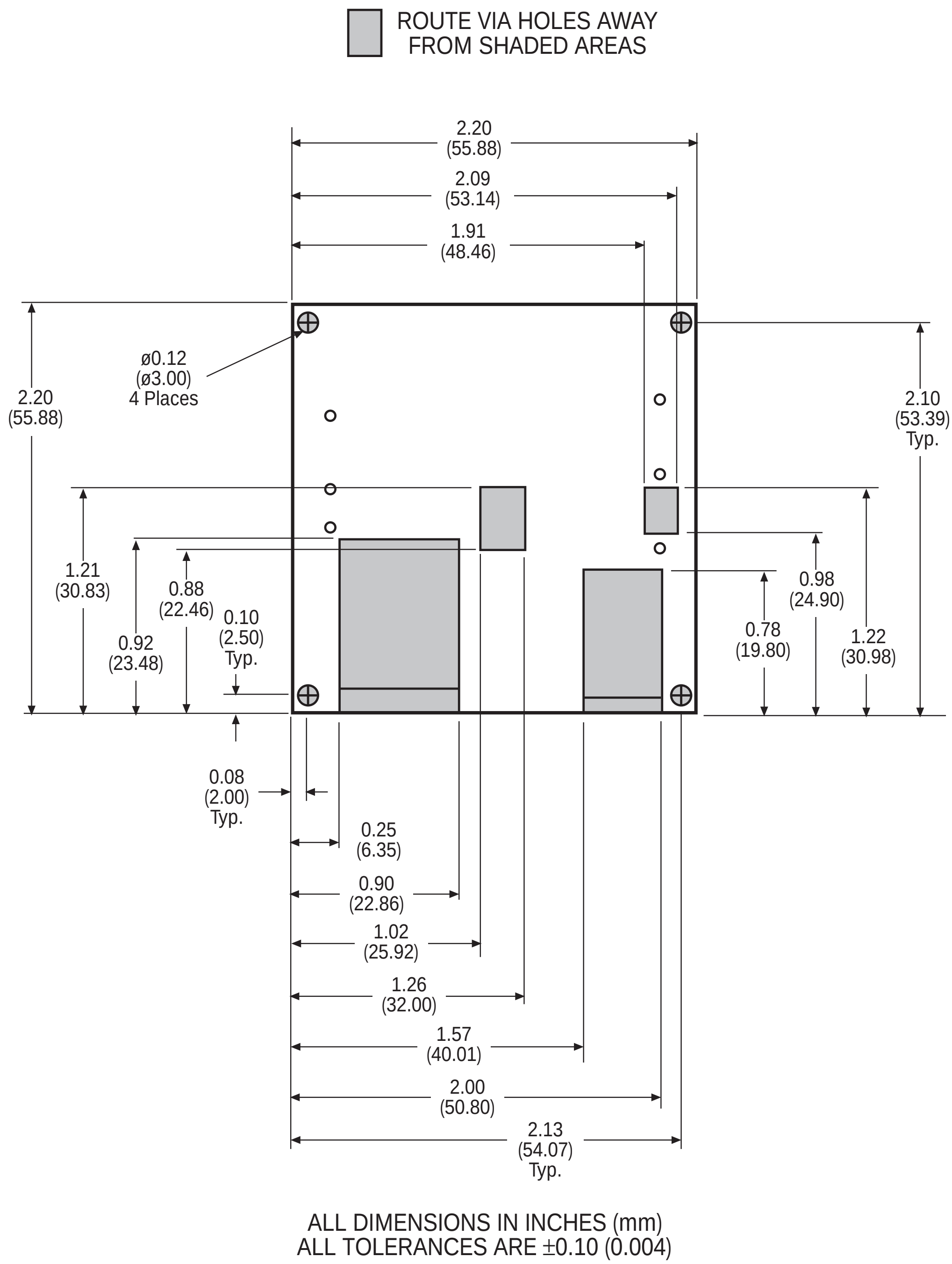

Figure A3-4 Footprint Via Keep-out Areas