

## Power Operational Amplifiers

### FEATURES

- HIGH POWER BANDWIDTH — 350kHz
- HIGH SLEW RATE — 20V/ $\mu$ s
- FAST SETTLING TIME — 600ns
- LOW CROSSOVER DISTORTION — Class A/B
- LOW INTERNAL LOSSES — 1.2V at 2A
- HIGH OUTPUT CURRENT —  $\pm$ 5A PEAK
- LOW INPUT BIAS CURRENT — FET Input
- ISOLATED CASE — 300 VDC

### APPLICATIONS

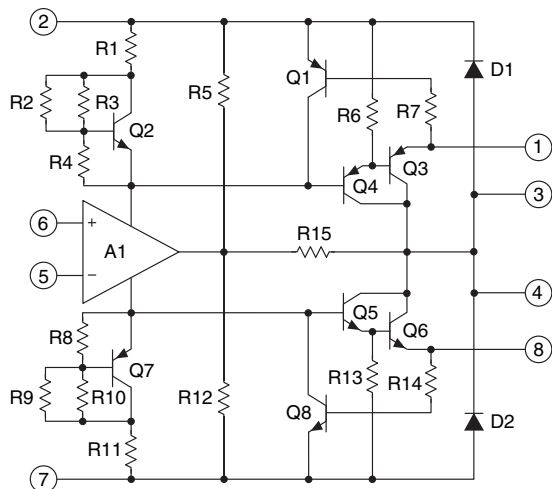
- MOTOR, VALVE AND ACTUATOR CONTROL
- MAGNETIC DEFLECTION CIRCUITS UP TO 5A
- POWER TRANSDUCERS UP TO 350 kHz
- AUDIO AMPLIFIERS UP TO 30W RMS

### DESCRIPTION

The PA02 and PA02A are wideband, high output current operational amplifiers designed to drive resistive, inductive and capacitive loads. Their complementary “collector output” stage can swing close to the supply rails and is protected against inductive kickback. For optimum linearity, the output stage is biased for class A/B operation. The safe operating area (SOA) can be observed for all operating conditions by selection of user programmable, current limiting resistors (down to 10mA). Both amplifiers are internally compensated but are not recommended for use as unity gain followers. For continuous operation under load, mounting on a heatsink of proper rating is recommended.

These hybrid integrated circuits utilize thick film (cermet) resistors, ceramic capacitors and semiconductor chips to maximize reliability, minimize size and give top performance. Ultrasonically bonded aluminum wires provide reliable interconnections at all operating temperatures. The 8-pin TO-3 package is hermetically sealed and electrically isolated. Isolation washers are not recommended. The use of compressible thermal washers and/or improper mounting torque will void the product warranty. Please see “General Operating Considerations”.

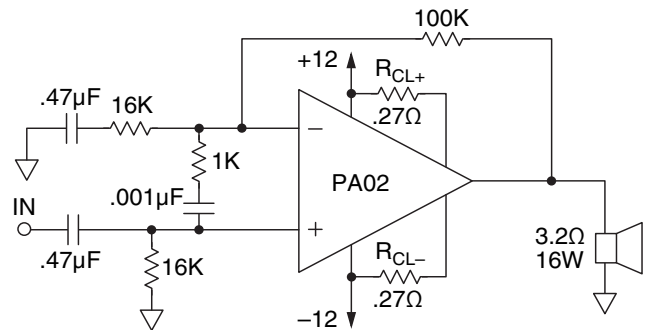
### EQUIVALENT SCHEMATIC



8-PIN TO-3  
PACKAGE STYLE CE

### TYPICAL APPLICATION

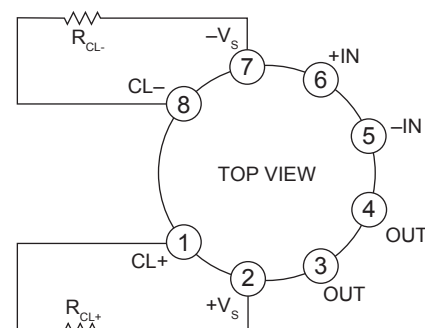
#### Vehicular Sound System Power Stage



### LOW INTERNAL LOSS MAXIMIZES EFFICIENCY

When system voltages are low and power is at a premium, the PA02 is a natural choice. The circuit above utilizes not only the feature of low internal loss of the PA02, but also its very low distortion level to implement a crystal clear audio amplifier suitable even for airborne applications. This circuit uses AC coupling of both the input signal and the gain circuit to render DC voltage across the speaker insignificant. The resistor and capacitor across the inputs form a stability enhancement network. The 0.27 ohm current limit resistors provide protection in the event of an output short circuit.

### EXTERNAL CONNECTIONS



**ABSOLUTE MAXIMUM RATINGS**

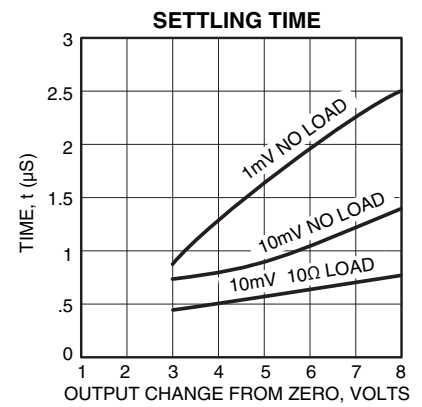
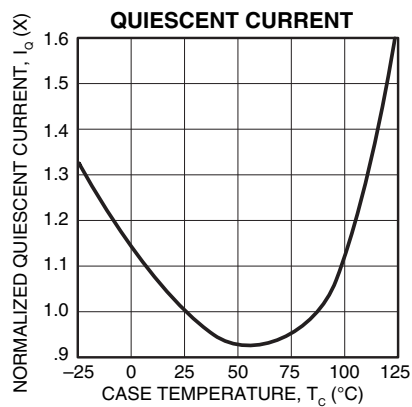
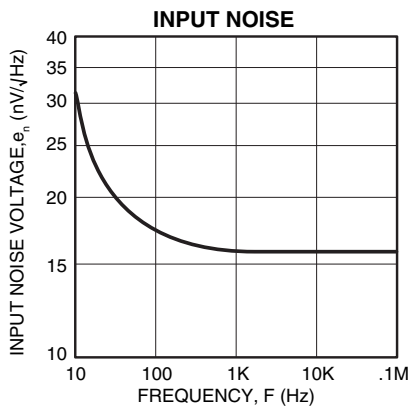
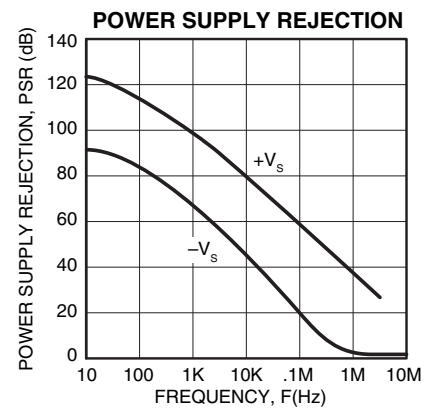
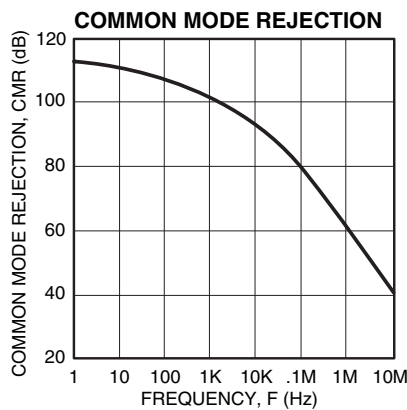
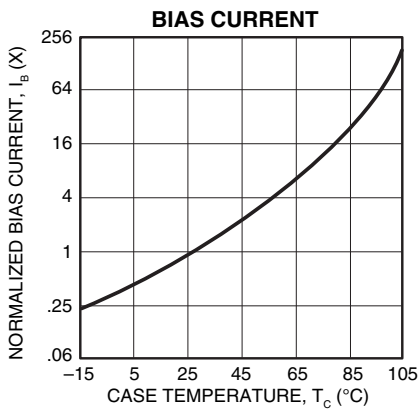
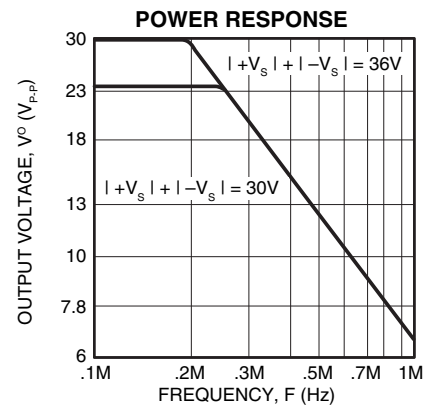
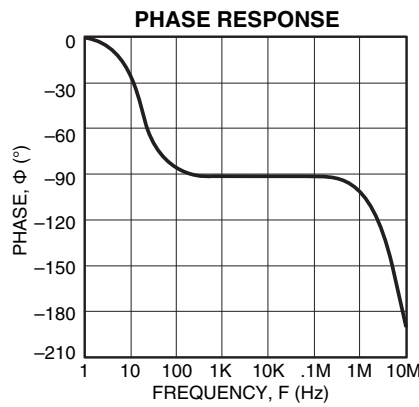
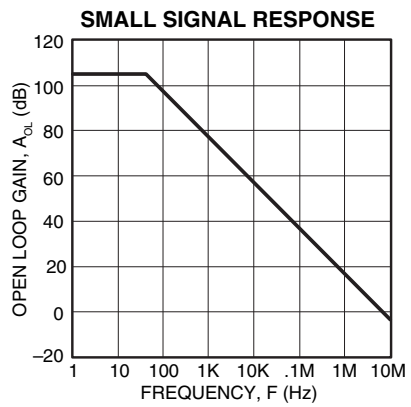
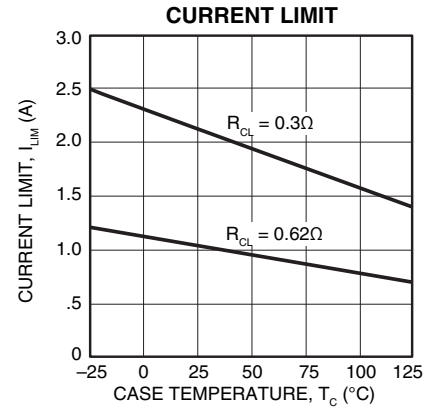
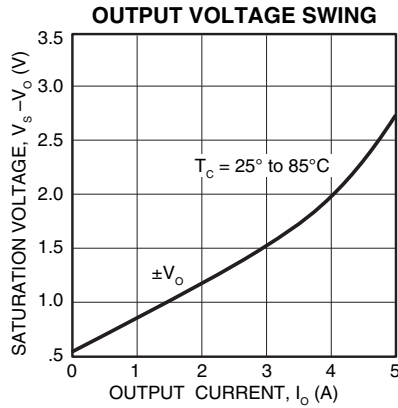
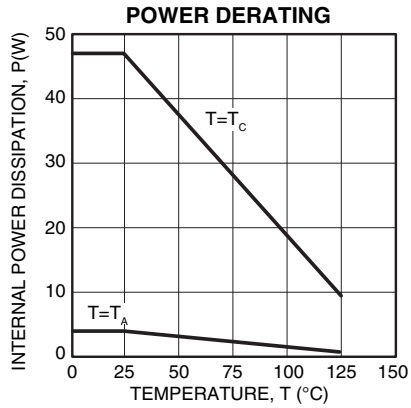
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|--|--|
| SUPPLY VOLTAGE, +V <sub>s</sub> to -V <sub>s</sub> | 38V  |
| OUTPUT CURRENT, within SOA                         | 5A   |
| POWER DISSIPATION, internal <sup>1</sup>           | 48W  |
| INPUT VOLTAGE, differential                        | ±30V                                       |
| INPUT VOLTAGE, common mode                         | -V <sub>s</sub> +2V to +V <sub>s</sub> -2V |
| TEMPERATURE, pin solder - 10s                      | 350°C                                      |
| TEMPERATURE, junction <sup>1</sup>                 | 150°C                                      |
| TEMPERATURE RANGE, storage                         | -65 to +150°C                              |
| OPERATING TEMPERATURE RANGE, case                  | -55 to +125°C                              |

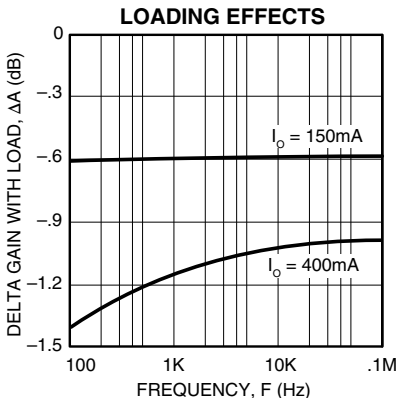
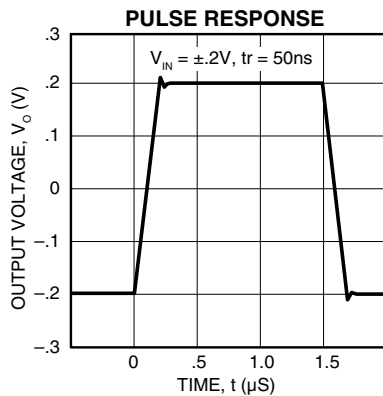
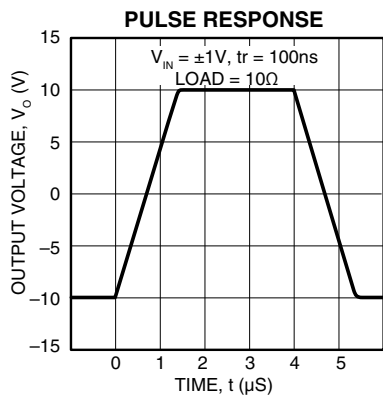
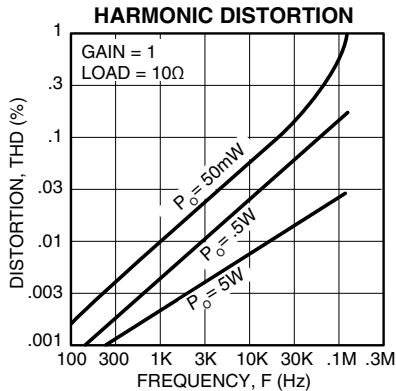
**SPECIFICATIONS**

| PARAMETER                                    | TEST CONDITIONS <sup>2,6</sup>                                     | PA02               |                      |     | PA02A |     |      | UNITS |
|--|--|--------------------|----------------------|-----|-------|-----|------|-------|
|  |  | MIN                | TYP                  | MAX | MIN   | TYP | MAX  |       |
| <b>INPUT</b>                                 |  |                    |                      |     |       |     |      |       |
| OFFSET VOLTAGE, initial                      | T <sub>c</sub> = 25°C  |                    | ±5                   | ±10 |       | ±1  | ±3   | mV    |
| OFFSET VOLTAGE, vs. temperature              | Full temperature range   |                    | ±10                  | ±50 |       | *   | ±25  | μV/°C |
| OFFSET VOLTAGE, vs. supply                   | T <sub>c</sub> = 25°C  |                    | ±10                  |     |       | *   |      | μV/V  |
| OFFSET VOLTAGE, vs. power                    | T <sub>c</sub> = 25°C  |                    | ±6                   |     |       | *   |      | μV/W  |
| BIAS CURRENT, initial                        | T <sub>c</sub> = 25°C  |                    | 50                   | 200 |       | 25  | 100  | pA    |
| BIAS CURRENT, vs. temperature                | T <sub>c</sub> = 85°C  |                    |                      | 200 |       | *   | *    | pA/°C |
| BIAS CURRENT, vs. supply                     | T <sub>c</sub> = 25°C  |                    | .01                  |     |       | *   |      | pA/V  |
| OFFSET CURRENT, initial                      | T <sub>c</sub> = 25°C  |                    | 25                   | 100 |       | 15  | 50   | pA    |
| OFFSET CURRENT, vs. temperature              | T <sub>c</sub> = 85°C  |                    |                      | 100 |       | *   | *    | pA/°C |
| INPUT IMPEDANCE, DC                          | T <sub>c</sub> = 25°C  |                    | 1000                 |     |       | *   |      | GΩ    |
| INPUT CAPACITANCE                            | T <sub>c</sub> = 25°C  |                    | 3                    |     |       | *   |      | pF    |
| COMMON MODE VOLT. RANGE <sup>5</sup> , Pos.  | Full temperature range   | +V <sub>s</sub> -6 | +V <sub>s</sub> -3   |     | *     | *   |      | V     |
| COMMON MODE VOLT. RANGE <sup>5</sup> , Neg.  | Full temperature range   | -V <sub>s</sub> +6 | -V <sub>s</sub> +5   |     | *     | *   |      | V     |
| COMMON MODE REJECTION, DC                    | Full temperature range   | 70                 | 100                  |     | *     | *   |      | dB    |
| <b>GAIN</b>                                  |  |                    |                      |     |       |     |      |       |
| OPEN LOOP GAIN at 10Hz                       | T <sub>c</sub> = 25°C, 1kΩ load                                    |                    | 103                  |     |       | *   |      | dB    |
| OPEN LOOP GAIN at 10Hz                       | Full temp. range, 10kΩ load  | 86                 | 100                  |     | *     | *   |      | dB    |
| GAIN BANDWIDTH PRODUCT at 1MHz               | T <sub>c</sub> = 25°C, 10Ω load                                    |                    | 4.5                  |     |       | *   |      | MHz   |
| POWER BANDWIDTH                              | T <sub>c</sub> = 25°C, 10Ω load                                    |                    | 350                  |     |       | *   |      | kHz   |
| PHASE MARGIN                                 | Full temp. range, 10Ω load   |                    | 30                   |     |       | *   |      | °     |
| <b>OUTPUT</b>                                |  |                    |                      |     |       |     |      |       |
| VOLTAGE SWING <sup>3</sup>                   | T <sub>c</sub> = 25°C, I <sub>o</sub> = 5A, R <sub>CL</sub> = .08Ω | ±V <sub>s</sub> -4 | ±V <sub>s</sub> -3   |     | *     | *   |      | V     |
| VOLTAGE SWING <sup>3</sup>                   | Full temp. range, I <sub>o</sub> = 2A                              | ±V <sub>s</sub> -2 | ±V <sub>s</sub> -1.2 |     | *     | *   |      | V     |
| CURRENT, peak                                | T <sub>c</sub> = 25°C  | 5                  |                      |     | *     | *   |      | A     |
| SETTLING TIME to .1%                         | T <sub>c</sub> = 25°C, 2V step                                     |                    | .6                   |     |       | *   |      | μs    |
| SLEW RATE                                    | T <sub>c</sub> = 25°C  | 13                 | 20                   |     | *     | *   |      | V/μs  |
| CAPACITIVE LOAD                              | Full temp. range, A <sub>v</sub> > 10                              |                    | SOA                  |     |       | *   |      |       |
| HARMONIC DISTORTION                          | P <sub>o</sub> = .5W, F = 1kHz, R <sub>L</sub> = 10Ω               |                    | .004                 |     |       | *   |      | %     |
| SMALL SIGNAL rise/fall time                  | R <sub>L</sub> = 10Ω, A <sub>v</sub> = 1                           |                    | 100                  |     |       | *   |      | ns    |
| SMALL SIGNAL overshoot                       | R <sub>L</sub> = 10Ω, A <sub>v</sub> = 1                           |                    | 10                   |     |       | *   |      | %     |
| <b>POWER SUPPLY</b>                          |  |                    |                      |     |       |     |      |       |
| VOLTAGE                                      | Full temperature range   | ±7                 | ±15                  | ±19 | *     | *   | *    | V     |
| CURRENT, quiescent                           | T <sub>c</sub> = 25°C  |                    | 27                   | 40  |       | *   | *    | mA    |
| <b>THERMAL</b>                               |  |                    |                      |     |       |     |      |       |
| RESISTANCE, AC junction to case <sup>4</sup> | F > 60Hz   |                    | 1.9                  | 2.1 |       | *   | *    | °C/W  |
| RESISTANCE, DC junction to case              | F < 60Hz   |                    | 2.4                  | 2.6 |       | *   | *    | °C/W  |
| RESISTANCE, junction to air                  |  |                    | 30                   |     |       | *   |      | °C/W  |
| TEMPERATURE RANGE, case                      | Meets full range specifications                                    | -25                |                      | +85 | -55   |     | +125 | °C    |

- NOTES: \* The specification of PA02A is identical to the specification for PA02 in applicable column to the left.
1. Long term operation at the maximum junction temperature will result in reduced product life. Derate internal power dissipation to achieve high MTTF.
  2. The power supply voltage for all specifications is the TYP rating unless otherwise noted as a test condition.
  3. +V<sub>s</sub> and -V<sub>s</sub> denote the positive and negative supply rail respectively. Total V<sub>s</sub> is measured from +V<sub>s</sub> to -V<sub>s</sub>.
  4. Rating applies if the output current alternates between both output transistors at a rate faster than 60Hz.
  5. Exceeding CMV range can cause the output to latch.
  6. Full temperature specifications are guaranteed but not 100% tested.
  7. The absolute maximum negative input voltage is equal to the negative power supply voltage plus 1V (-V<sub>s</sub> + 1V).

**CAUTION** The internal substrate contains beryllia (BeO). Do not break the seal. If accidentally broken, do not crush, machine, or subject to temperatures in excess of 850°C to avoid generating toxic fumes.





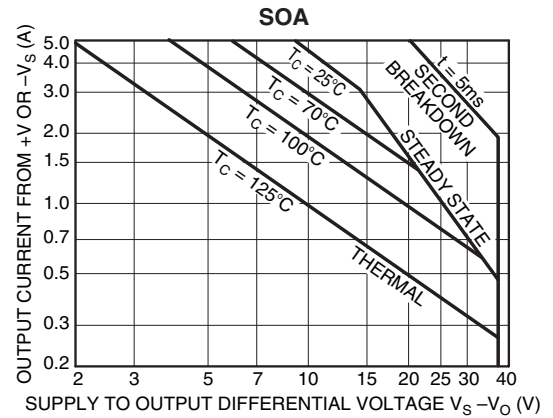
**GENERAL**

Please read Application Note 1 "General Operating Considerations" which covers stability, supplies, heat sinking, mounting, current limit, SOA interpretation, and specification interpretation. Visit [www.apexanalog.com](http://www.apexanalog.com) for design tools that help automate tasks such as calculations for stability, internal power dissipation, current limit; heat sink selection; Apex Microtechnology's complete Application Notes library; Technical Seminar Workbook; and Evaluation Kits.

**SAFE OPERATING AREA**

The SOA curves combine the effect of all limits for this Power Op Amp. For a given application, the direction and magnitude of the output current should be calculated or measured and checked against the SOA curves. This is simple for resistive loads but more complex for reactive and EMF generating loads. The following guidelines may save extensive analytical efforts:

1. Under transient conditions, capacitive and dynamic\* loads up to the following maximums are safe:



**CAPACITIVE LOAD**

| $\pm V_S$ | $I_{LIM} = 2A$ | $I_{LIM} = 5A$ |
|-----------|----------------|----------------|
| 18V       | 2mF            | 0.7mF          |
| 15V       | 10mF           | 2.2mF          |
| 10V       | 25mF           | 10mF           |

**INDUCTIVE LOAD**

| $I_{LIM} = 2A$ | $I_{LIM} = 5A$ |
|----------------|----------------|
| .2H            | 10mH           |
| .7H            | 25mH           |
| 5H             | 50mH           |

\* If the inductive load is driven near steady state conditions, allowing the output voltage to drop more than 8V below the supply rail with  $I_{LIM} = 5A$ , or 17V below the supply rail with  $I_{LIM} = 2A$  while the amplifier is current limiting, the inductor should be capacitively coupled or the current limit must be lowered to meet SOA criteria.

2. The amplifier can handle any EMF generating or reactive load and short circuits to the supply rails or shorts to common if the current limits are set as follows at  $T_C = 85^\circ C$ .

| $\pm V_S$ | SHORT TO $\pm V_S$ | SHORT TO |
|-----------|--------------------|----------|
|           | C, L OR EMF LOAD   | COMMON   |
| 18V       | .5A                | 1.7A     |
| 15V       | .7A                | 2.8A     |
| 10V       | 1.6A               | 4.2A     |

These simplified limits may be exceeded with further analysis using the operating conditions for a specific application.

**CURRENT LIMIT**

Proper operation requires the use of two current limit resistors, connected as shown in the external connection diagram. The minimum value for  $R_{CL}$  is 0.12 ohm, however for optimum reliability it should be set as high as possible.

$$R_{CL} = \frac{0.65}{I_{LIM}}$$

Where:

$I_{LIM}$  is the current limit in amperes  
 $R_{CL}$  is the current limit resistor value in ohms

Refer to the "General Operating Considerations" section of the handbook for current limit adjust details.

## DEVICE MOUNTING

The case (mounting flange) is electrically isolated and should be mounted directly to a heatsink with thermal compound. Screws with Belleville spring washers are recommended to maintain positive clamping pressure on heatsink mounting surfaces. Long periods of thermal cycling can loosen mounting screws and increase thermal resistance.

Since the case is electrically isolated (floating) with respect to the internal circuits it is recommended to connect it to common or other convenient AC ground potential.

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