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**AUTOMOTIVE GRADE MICROPOWER CURRENT MONITOR**

**Description**

The ZXCT1009Q is a micropower high side current sense monitor.

This device eliminates the need to disrupt the ground plane when sensing a load current.

It takes a high side voltage developed across a current shunt resistor and translates it into a proportional output current. A user defined output resistor scales the output current into a ground-referenced voltage.

The wide input voltage range of 20V down to as low as 2.5V make it suitable for a range of applications. A minimum operating current of just 4μA, combined with a SOT23 package make it a unique solution for portable battery equipment.

The ZXCT1009Q has been qualified to AEC-Q100 Grade 3 and is Automotive Grade supporting PPAPs.

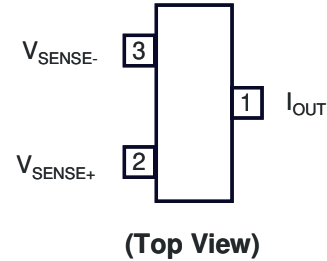
**Features**

- Low cost, accurate high-side current sensing
- Output voltage scaling
- Up to 2.5V sense voltage
- 2.5V to 20V supply range
- 4μA quiescent current
- 1% typical accuracy
- SOT23
  - **Totally Lead-Free & Fully RoHS Compliant (Notes 1 & 2)**
  - **Halogen and Antimony Free. "Green" Device (Note 3)**
- Automotive Grade
  - **Qualified to AEC-Q100 Standards for High Reliability**
  - **PPAP Capable (Note 4)**

- Notes:
1. No purposely added lead. Fully EU Directive 2002/95/EC (RoHS) & 2011/65/EU (RoHS 2) compliant.
  2. See [http://www.diodes.com/quality/lead\\_free.html](http://www.diodes.com/quality/lead_free.html) for more information about Diodes Incorporated's definitions of Halogen- and Antimony-free, "Green" and Lead-free.
  3. Halogen- and Antimony-free "Green" products are defined as those which contain <900ppm bromine, <900ppm chlorine (<1500ppm total Br + Cl) and <1000ppm antimony compounds.
  4. Automotive products are AEC-Q100 qualified and are PPAP capable. Automotive, AEC-Q100 and standard products are electrically and thermally the same, except where specified. For more information, please refer to [http://www.diodes.com/quality/product\\_compliance\\_definitions/](http://www.diodes.com/quality/product_compliance_definitions/).

**Pin Assignments**

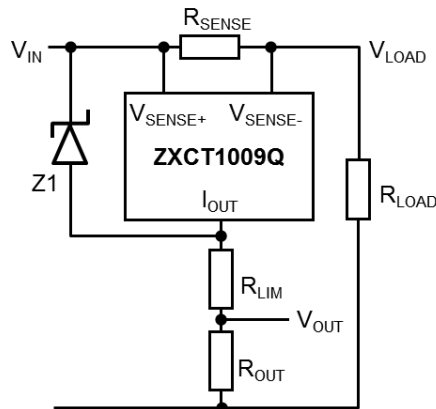
**SOT23**  
**Package Suffix - F**



**Applications**

- Automotive Current Measurement
- Automotive DC Motor Stall Detection
- Over Current Monitor

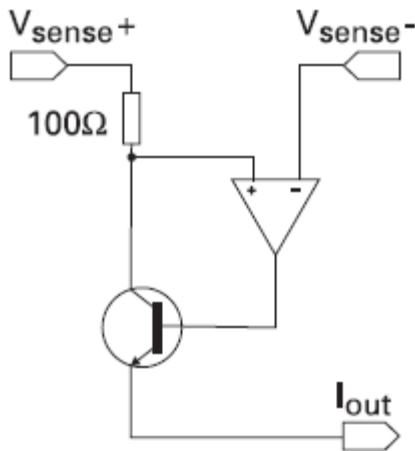
**Typical Application Circuit**



## Pin Descriptions

| Pin Name            | Pin Function                                     |
|---------------------|--|
| V <sub>SENSE+</sub> | Connection to supply voltage                     |
| V <sub>SENSE-</sub> | Connection to load                               |
| I <sub>OUT</sub>    | Output current, proportional to measured current |

## Functional Block Diagram



## Absolute Maximum Ratings (@T<sub>A</sub> = +25°C, unless otherwise specified.)

| Description   | Rating               | Unit  |
|---|----------------------|-------|
| Voltage on any pin (relative to I <sub>OUT</sub> )    | -0.6 to 20           | V     |
| Continuous output current, I <sub>OUT</sub>           | 25                   | mA    |
| Continuous sense voltage, V <sub>SENSE</sub> (Note 5) | -0.5 to +5           | V     |
| Operating temperature, T <sub>A</sub>                 | -40 to +85           | °C    |
| Storage temperature                                   | -55 to +125          | °C    |
| <b>ESD Susceptibility</b>                             |                      |       |
| HBM   | Human Body Model     | 2 kV  |
| MM  | Machine Model        | 300 V |
| CDM   | Charged Device Model | 1 kV  |

Caution: Stresses greater than the 'Absolute Maximum Ratings' specified above, may cause permanent damage to the device. These are stress ratings only; functional operation of the device at these or any other conditions exceeding those indicated in this specification is not implied. Device reliability may be affected by exposure to absolute maximum rating conditions for extended periods of time.

Semiconductor devices are ESD sensitive and may be damaged by exposure to ESD events. Suitable ESD precautions should be taken when handling and transporting these devices.

## Package Thermal Data

| Package | θ <sub>JA</sub> | P <sub>DIS</sub><br>T <sub>A</sub> = +25°C, T <sub>J</sub> = +150°C |
|---------|-----------------|---|
| SOT23   | 280°C/W         | 450mW   |

**Electrical Characteristics** (@T<sub>A</sub> = +25°C, V<sub>IN</sub> = 5V, R<sub>OUT</sub> = 100Ω, unless otherwise specified.)

| Symbol              | Parameter   | Conditions   | Limits |       |       | Units |
|---------------------|---|--|--------|-------|-------|-------|
|                     |   |  | Min    | Typ   | Max   |       |
| V <sub>IN</sub>     | V <sub>CC</sub> range                                     |  | 2.5    |       | 20    | V     |
| I <sub>OUT</sub>    | Output Current (Note 6)                                   | V <sub>SENSE</sub> = 0V (Note 5)   | 1      | 4     | 15    | μA    |
|                     |   | V <sub>SENSE</sub> = 10mV  | 90     | 104   | 120   | μA    |
|                     |   | V <sub>SENSE</sub> = 100mV   | 0.975  | 1.002 | 1.025 | mA    |
|                     |   | V <sub>SENSE</sub> = 200mV   | 1.95   | 2.0   | 2.05  | mA    |
|                     |   | V <sub>SENSE</sub> = 1V  | 9.6    | 9.98  | 10.2  | mA    |
| V <sub>SENSE</sub>  | Sense Voltage (Note 5)                                    |  | 0      |       | 2500  | mV    |
| I <sub>SENSE-</sub> | V <sub>SENSE-</sub> Input Current                         |  |        |       | 100   | nA    |
| ACC                 | Accuracy  | R <sub>SENSE</sub> = 0.1Ω<br>V <sub>SENSE</sub> = 200mV                  | -2.5   |       | 2.5   | %     |
| G <sub>M</sub>      | Transconductance,<br>I <sub>OUT</sub> /V <sub>SENSE</sub> |  |        | 10000 |       | μA/V  |
| BW                  | Bandwidth   | V <sub>SENSE(DC)</sub> = 10mv, RF P <sub>IN</sub> = -40dBm (Note 7)      |        | 300   |       | kHz   |
|                     |   | V <sub>SENSE(DC)</sub> = 100mv, RF P <sub>IN</sub> = -20dBm <sup>‡</sup> |        | 2     |       | MHz   |

Notes: 5. V<sub>SENSE</sub> is defined as the differential voltage between V<sub>SENSE+</sub> and V<sub>SENSE-</sub> pins.

$$\begin{aligned} V_{SENSE} &= V_{SENSE+} - V_{SENSE-} \\ &= V_{IN} - V_{LOAD} \\ &= I_{LOAD} \times R_{SENSE} \end{aligned}$$

6. Includes input offset voltage contribution  
7. -20dBm = 63mV<sub>PP</sub> into 50Ω.

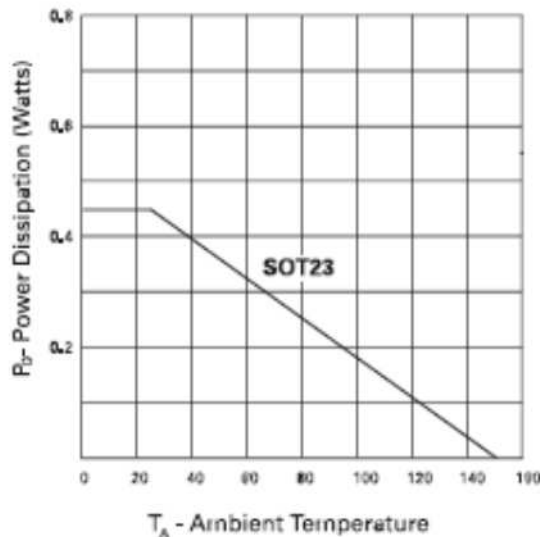
**Power Dissipation**

The maximum allowable power dissipation of the device for normal operation (P<sub>MAX</sub>), is a function of the package junction to ambient thermal resistance (θ<sub>JA</sub>), maximum junction temperature (T<sub>JMAX</sub>), and ambient temperature (T<sub>AMB</sub>), according to the expression:

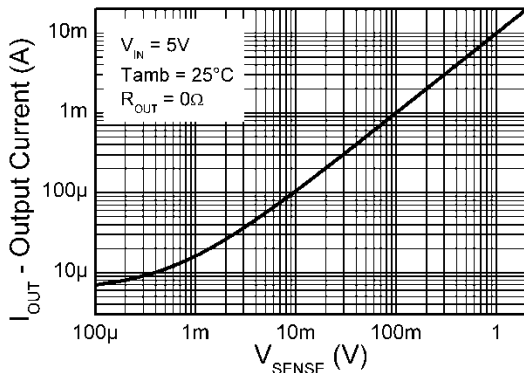
$$P_{MAX} = (T_{JMAX} - T_{AMB}) / \theta_{JA}$$

The device power dissipation, P<sub>D</sub> is given by the expression:

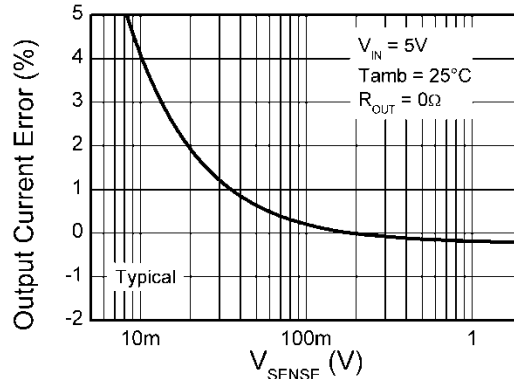
$$P_D = I_{OUT} \times (V_{IN} - V_{OUT}) \text{ W}$$



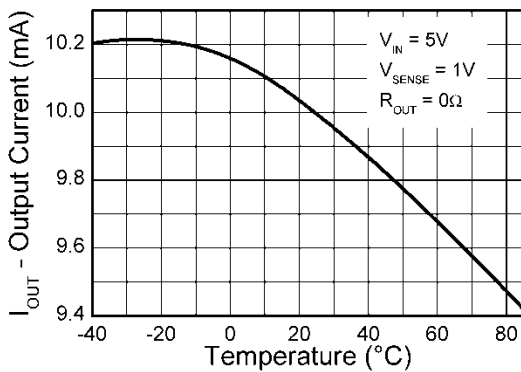
**Typical Characteristics**



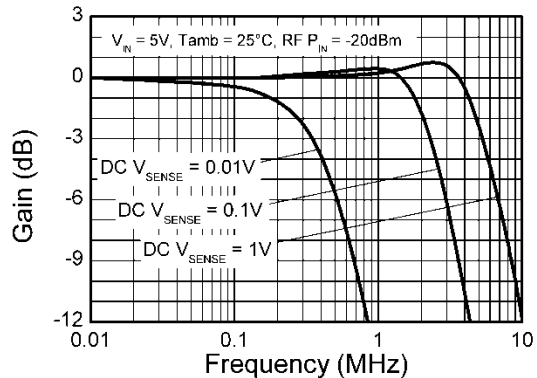
**Typical Output v Sense Voltage**



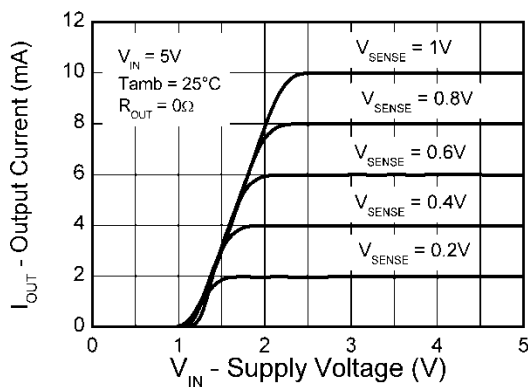
**Error v Sense Voltage**



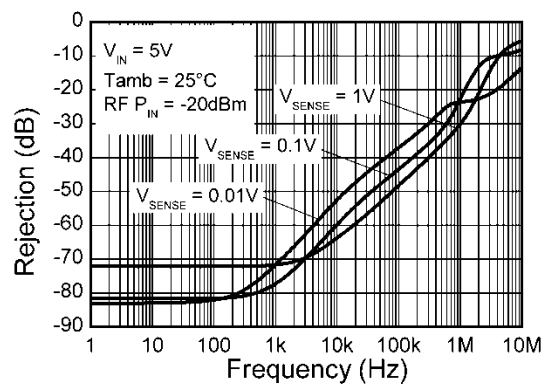
**Output Current v Temperature**



**Frequency Response**

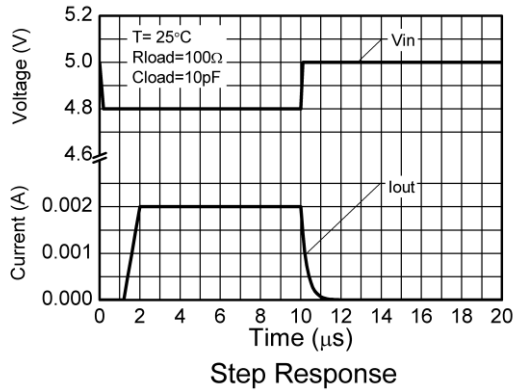


**Transfer Characteristic**



**Common Mode Rejection**

## Typical Characteristics (cont.)



## Application Information

Referring to Figure 1, where  $R_{LOAD}$  represents any load including DC motors, a charging battery or further circuitry that requires monitoring,  $R_{SENSE}$  can be selected on specific requirements of accuracy, size and power rating.

The following text describes how to scale a load current to an output voltage.

Referring to Figure 1.

$$V_{SENSE} = V_{IN} - V_{LOAD}$$

$$= R_{SENSE} \times I_{LOAD}$$

$$I_{OUT} = V_{SENSE} \times 10\text{mA/V}$$

$$V_{OUT} = I_{OUT} \times R_{OUT}$$

Combining (2) and (3)  $V_{OUT}$  can be determined to be:

$$V_{OUT} = 0.01 \times V_{SENSE} \times R_{OUT}$$

Example:

A 1A current is to be represented by a 1V output voltage:

- 1) Choose the value of  $R_{SENSE}$  to give  $50\text{mV} < V_{SENSE} < 500\text{mV}$  at full load.

For example set  $V_{SENSE} = 100\text{mV}$  at 1.0A.

Rearranging (1) gives:

$$R_{SENSE} = \frac{V_{SENSE}}{I_{LOAD}}$$

$$= 0.1/1.0 = 0.1\Omega.$$

- 2) Choose  $R_{OUT}$  to give  $V_{OUT} = 1\text{V}$ , when  $V_{SENSE} = 100\text{mV}$ .

Rearranging (4) for  $R_{OUT}$  gives:

$$R_{OUT} = \frac{V_{OUT}}{V_{SENSE} \times 0.001}$$

$$= \frac{1}{0.1 \times 0.01} = 1\text{k}\Omega$$

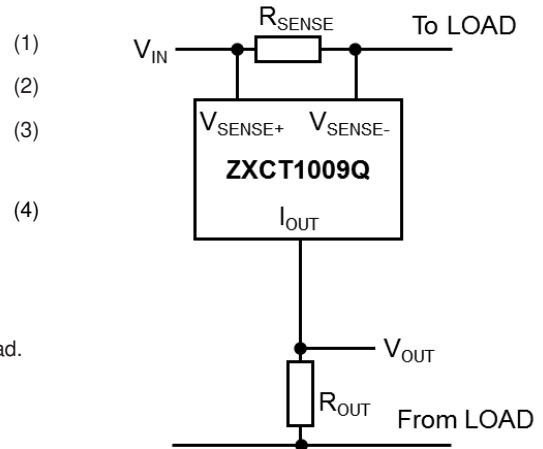
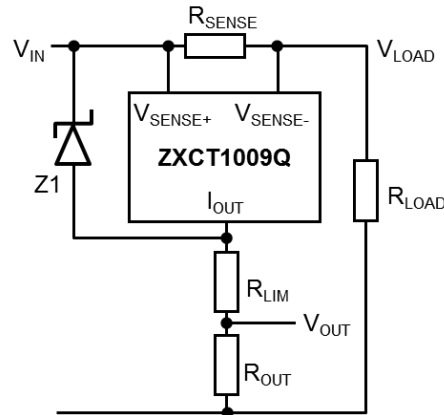


Figure 1: ZXCT1009Q typical circuit

## Application Information (cont.)

### Transient Protection

An additional resistor,  $R_{LIM}$  can be added in series with  $R_{OUT}$  (Figure 2), to limit the current from  $I_{OUT}$ . Any circuit connected to  $V_{OUT}$  will be protected from input voltage transients.



**Figure 2 ZXCT1009Q with Additional Current Limiting Resistor  $R_{LIM}$  and Zener Z1.**

This can be of particular use in automotive applications where load dump and other common transients need to be considered. Adding a Zener diode Z1 provides additional protection for local dump, reverse battery and high voltage transient incidents.

Assuming the worst case condition of  $V_{OUT} = 0V$ ; providing a low impedance to a transient, the minimum value of  $R_{LIM}$  is given by:

$$R_{LIM(min)} = (V_{PK} - V_{MAX}) / I_{PK}$$

Where:

$V_{PK}$  = Peak transient voltage to be withstood

$V_{MAX}$  = Maximum working voltage = 20V

$I_{PK}$  = Peak output current = 40mA

The maximum value of  $R_{LIM}$  is set by  $V_{IN(MIN)}$ ,  $V_{OUT(MAX)}$  and the dropout voltage (see transfer characteristic on page 3) of the ZXCT1009Q:

$$R_{LIM(MAX)} = \frac{R_{OUT} \times [V_{IN(MIN)} - \{V_{DP} + V_{OUT(MAX)}\}]}{V_{OUT(MAX)}}$$

Where:

$V_{IN(MIN)}$  = Minimum Supply Operating Voltage

$V_{DP}$  = Dropout Voltage

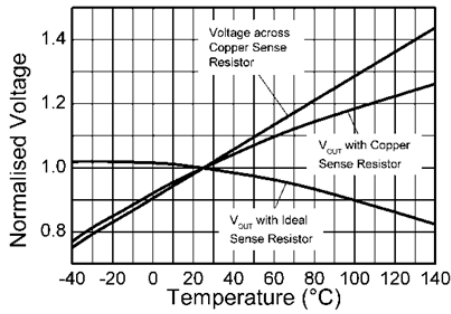
$V_{OUT(MAX)}$  = Maximum Operating Output Voltage

### PCB Trace Shunt Resistor for Low Cost Solution

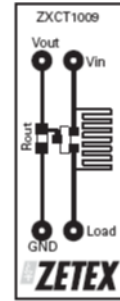
The figure below shows output characteristics of the device when using a PCB resistive trace for a low cost solution in replacement for a conventional shunt resistor. The graph shows the linear rise in voltage across the resistor due to the PTC of the material and demonstrates how this rise in resistance value over temperature compensates for the NTC of the device.

The figure opposite shows a PCB layout suggestion. The resistor section is 25mm x 0.25mm giving approximately 150m $\Omega$  using 1oz copper.

The data for the normalized graph was obtained using a 1A load current and a 100 $\Omega$  output resistor. An electronic version of the PCB layout is available through Diodes applications group.

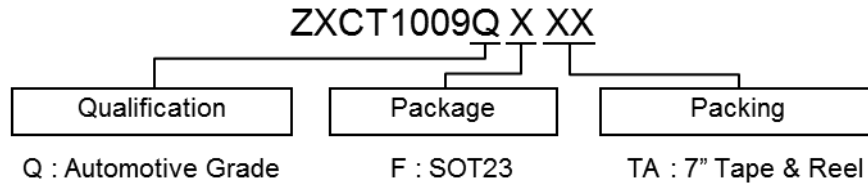


Effect of Sense Resistor Material on Temperature Performance



Layout shows area of shunt resistor compared to SOT23 package. Not actual size.

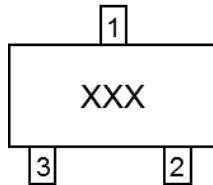
**Ordering Information**



| Device       | Packaging (Note 8) | Package Code | Identification Code | Packing: 7" Tape and Reel |            |                    | Qualification Grade (Note 9) |
|--------------|--------------------|--------------|---------------------|---------------------------|------------|--------------------|------------------------------|
|              |                    |              |                     | Quantity                  | Tape Width | Part Number Suffix |                              |
| ZXCT1009QFTA | SOT23              | F            | 109                 | 3000 Units                | 8mm        | 7"                 | Grade 3                      |

- Note: 8. Pad layout as shown on Diodes Inc. suggested pad layout document AP02001, which can be found on our website at <http://www.diodes.com/datasheets/ap02001.pdf>
9. ZXCT1009Q has been qualified to AEC-Q100 grade 3 and is classified as "Automotive Grade" which supports PPAP documentation. See ZXCT1009 datasheet for commercial qualified version.

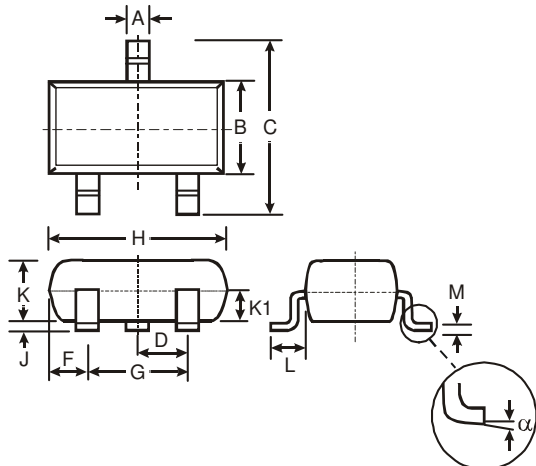
**Marking Information**



XXX : Identification code : 109

**Package Outline Dimensions (All Dimensions in mm)**

Please see AP02001 at <http://www.diodes.com/datasheets/ap02002.pdf> for latest version



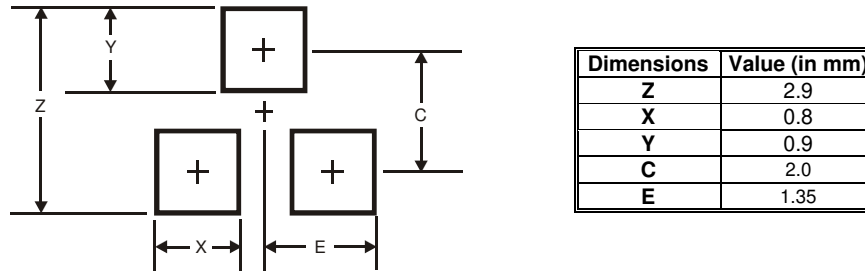
| SOT23 |       |      |       |
|-------|-------|------|-------|
| Dim   | Min   | Max  | Typ   |
| A     | 0.37  | 0.51 | 0.40  |
| B     | 1.20  | 1.40 | 1.30  |
| C     | 2.30  | 2.50 | 2.40  |
| D     | 0.89  | 1.03 | 0.915 |
| F     | 0.45  | 0.60 | 0.535 |
| G     | 1.78  | 2.05 | 1.83  |
| H     | 2.80  | 3.00 | 2.90  |
| J     | 0.013 | 0.10 | 0.05  |
| K     | 0.903 | 1.10 | 1.00  |
| K1    | -     | -    | 0.400 |
| L     | 0.45  | 0.61 | 0.55  |
| M     | 0.085 | 0.18 | 0.11  |
| α     | 0°    | 8°   | -     |

**All Dimensions in mm**



## Suggested Pad Layout

Please see AP02001 at <http://www.diodes.com/datasheets/ap02001.pdf> for latest version.



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