

LM431

Adjustable Precision Zener Shunt Regulator

General Description

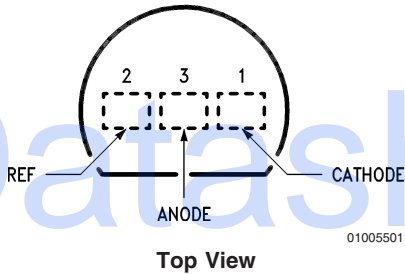
The LM431 is a 3-terminal adjustable shunt regulator with guaranteed temperature stability over the entire temperature range of operation. It is now available in a chip sized package (4-Bump micro SMD) using National's micro SMD package technology. The output voltage may be set at any level greater than 2.5V (V_{REF}) up to 36V merely by selecting two external resistors that act as a voltage divided network. Due to the sharp turn-on characteristics this device is an excellent replacement for many zener diode applications.

Features

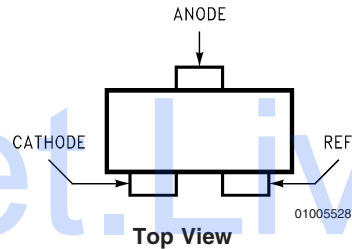
- Average temperature coefficient 50 ppm/°C
- Temperature compensated for operation over the full temperature range
- Programmable output voltage
- Fast turn-on response
- Low output noise
- LM431 in micro SMD package
- See AN-1112 for micro SMD considerations

Connection Diagrams

TO-92: Plastic Package



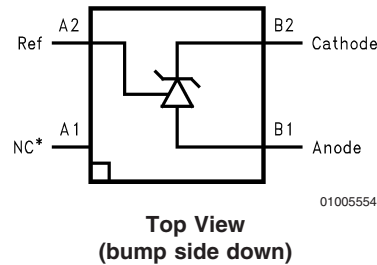
SOT-23: 3-Lead Small Outline



SO-8: 8-Pin Surface Mount



4-Bump micro SMD



Note: *NC = Not internally connected. Must be electrically isolated from the rest of the circuit for the microSMD package.

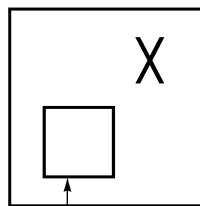
Ordering Information

| Package | Typical Accuracy Order Number/Package Marking | | | Temperature Range | Transport Media | NSC Drawing |
|-----------|---|-----------------------|-------------------------------------|-------------------|---|-------------|
| | 0.5% | 1% | 2% | | | |
| TO-92 | LM431CCZ/ LM431CCZ | LM431BCZ/ LM431BCZ | LM431ACZ/ LM431ACZ | 0°C to +70°C | Rails | Z03A |
| | LM431CIZ/ LM431CIZ | LM431BIZ/ LM431BIZ | LM431AIZ/ LM431AIZ | -40°C to +85°C | | |
| SO-8 | LM431CCM/ 431CCM | LM431BCM/ 431BCM | LM431ACM/ LM431ACM | 0°C to +70°C | Rails | M08A |
| | LM431CCMX/ 431CCM | LM431BCM/ 431BCM | LM431ACMX/ LM431ACM | | Tape & Reel | |
| | LM431CIM/ 431CIM | LM431BIM/ 431BIM | LM431AIM/ LM431AIM | -40°C to +85°C | Rails | |
| | LM431CIMX/ 431CIM | LM431BIMX/ 431BIM | LM431AIMX/ LM431AIM | | Tape & Reel | |
| SOT-23 | LM431CCM3/ N1B | LM431BCM3/ N1D | LM431ACM3/ N1F | 0°C to +70°C | Rails | MF03A |
| | LM431CCM3X/ N1B | LM431BCM3X/ N1D | LM431ACM3X/ N1F | | Tape & Reel | |
| | LM431CIM3 N1A | LM431BIM3 N1C | LM431AIM3 N1E | -40°C to +85°C | Rails | |
| | LM431CIM3X N1A | LM431BIM3X N1C | LM431AIM3X N1E | | Tape & Reel | |
| micro SMD | - | - | LM431AIBP LM431AIBPX (Note 1) | -40°C to +85°C | 250 Units Tape and Reel 3k Units Tape and Reel | BPA04AFB |

Note 1: The micro SMD package marking is a 1 digit manufacturing Date Code only

micro SMD Top View Marking Example

X = Date Code



Pin A1 Identifier

01005556

Symbol and Functional Diagrams



DC Test Circuits



FIGURE 1. Test Circuit for $V_Z = V_{REF}$



Note: $V_Z = V_{REF} (1 + R1/R2) + I_{REF} \cdot R1$

FIGURE 2. Test Circuit for $V_Z > V_{REF}$



Test Circuit for Off-State Current

Absolute Maximum Ratings (Note 2)

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/Distributors for availability and specifications.

| | |
|-----------------------------|-----------------|
| Storage Temperature Range | -65°C to +150°C |
| Operating Temperature Range | |
| Industrial (LM431xl) | -40°C to +85°C |
| Commercial (LM431xC) | 0°C to +70°C |

Soldering Information

| | |
|----------------------------------|--------------------|
| Infrared or Convection (20 sec.) | 235°C |
| Wave Soldering (10 sec.) | 260°C (lead temp.) |
| Cathode Voltage | 37V |
| Continuous Cathode Current | -10 mA to +150 mA |

| | |
|---|-------|
| Reference Voltage | -0.5V |
| Reference Input Current | 10 mA |
| Internal Power Dissipation (Notes 3, 4) | |
| TO-92 Package | 0.78W |
| SO-8 Package | 0.81W |
| SOT-23 Package | 0.28W |
| micro SMD Package | 0.30W |

Operating Conditions

| | Min | Max |
|-----------------|-----------|--------|
| Cathode Voltage | V_{REF} | 37V |
| Cathode Current | 1.0 mA | 100 mA |

LM431

Electrical Characteristics

$T_A = 25^\circ\text{C}$ unless otherwise specified

| Symbol | Parameter | Conditions | Min | Typ | Max | Units |
|-------------------------------------|---|--|-----------------------------|-------|-------|---------------|
| V_{REF} | Reference Voltage | $V_Z = V_{REF}$, $I_I = 10\text{ mA}$ LM431A (Figure 1) | 2.440 | 2.495 | 2.550 | V |
| | | $V_Z = V_{REF}$, $I_I = 10\text{ mA}$ LM431B (Figure 1) | 2.470 | 2.495 | 2.520 | V |
| | | $V_Z = V_{REF}$, $I_I = 10\text{ mA}$ LM431C (Figure 1) | 2.485 | 2.500 | 2.510 | V |
| V_{DEV} | Deviation of Reference Input Voltage Over Temperature (Note 5) | $V_Z = V_{REF}$, $I_I = 10\text{ mA}$, $T_A = \text{Full Range}$ (Figure 1) | | 8.0 | 17 | mV |
| $\frac{\Delta V_{REF}}{\Delta V_Z}$ | Ratio of the Change in Reference Voltage to the Change in Cathode Voltage | $I_Z = 10\text{ mA}$ (Figure 2) | V_Z from V_{REF} to 10V | -1.4 | -2.7 | mV/V |
| | | | V_Z from 10V to 36V | -1.0 | -2.0 | |
| I_{REF} | Reference Input Current | $R_1 = 10\text{ k}\Omega$, $R_2 = \infty$, $I_I = 10\text{ mA}$ (Figure 2) | | 2.0 | 4.0 | μA |
| ∞I_{REF} | Deviation of Reference Input Current over Temperature | $R_1 = 10\text{ k}\Omega$, $R_2 = \infty$, $I_I = 10\text{ mA}$, $T_A = \text{Full Range}$ (Figure 2) | | 0.4 | 1.2 | μA |
| $I_{Z(MIN)}$ | Minimum Cathode Current for Regulation | $V_Z = V_{REF}$ (Figure 1) | | 0.4 | 1.0 | mA |
| $I_{Z(OFF)}$ | Off-State Current | $V_Z = 36\text{V}$, $V_{REF} = 0\text{V}$ (Figure *NO TARGET FOR fi*) | | 0.3 | 1.0 | μA |
| r_Z | Dynamic Output Impedance (Note 6) | $V_Z = V_{REF}$, LM431A, Frequency = 0 Hz (Figure 1) | | | 0.75 | Ω |
| | | $V_Z = V_{REF}$, LM431B, LM431C Frequency = 0 Hz (Figure 1) | | | 0.50 | Ω |

Note 2: Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Electrical specifications do not apply when operating the device beyond its rated operating conditions.

Note 3: $T_{J\text{ Max}} = 150^\circ\text{C}$.

Note 4: Ratings apply to ambient temperature at 25°C. Above this temperature, derate the TO-92 at 6.2 mW/°C, the SO-8 at 6.5 mW/°C, the SOT-23 at 2.2 mW/°C and the micro SMD at 3mW/°C.

Note 5: Deviation of reference input voltage, V_{DEV} , is defined as the maximum variation of the reference input voltage over the full temperature range.

LM431

Electrical Characteristics (Continued)



01005507

The average temperature coefficient of the reference input voltage, αV_{REF} , is defined as:

$$\alpha V_{REF} \frac{\text{ppm}}{^{\circ}\text{C}} = \frac{\pm \left[\frac{V_{\text{Max}} - V_{\text{Min}}}{V_{REF}(\text{at } 25^{\circ}\text{C})} \right] 10^6}{T_2 - T_1} = \frac{\pm \left[\frac{V_{\text{DEV}}}{V_{REF}(\text{at } 25^{\circ}\text{C})} \right] 10^6}{T_2 - T_1}$$

Where:

$T_2 - T_1$ = full temperature change (0-70°C).

αV_{REF} can be positive or negative depending on whether the slope is positive or negative.

Example: $V_{DEV} = 8.0 \text{ mV}$, $V_{REF} = 2495 \text{ mV}$, $T_2 - T_1 = 70^{\circ}\text{C}$, slope is positive.

$$\alpha V_{REF} = \frac{\left[\frac{8.0 \text{ mV}}{2495 \text{ mV}} \right] 10^6}{70^{\circ}\text{C}} = +46 \text{ ppm}/^{\circ}\text{C}$$

Note 6: The dynamic output impedance, r_z , is defined as:

$$r_z = \frac{\Delta V_z}{\Delta I_z}$$

When the device is programmed with two external resistors, R1 and R2, (see Figure 2), the dynamic output impedance of the overall circuit, r_z , is defined as:

$$r_z = \frac{\Delta V_z}{\Delta I_z} \cong \left[r_z \left(1 + \frac{R_1}{R_2} \right) \right]$$

Equivalent Circuit



01005503

Typical Performance Characteristics

Input Current vs V_Z



01005529

Thermal Information



01005530

Input Current vs V_Z



01005531

Dynamic Impedance vs Frequency



01005509

Typical Performance Characteristics (Continued)

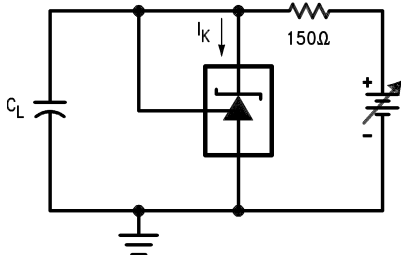
Stability Boundary Conditions



01005510

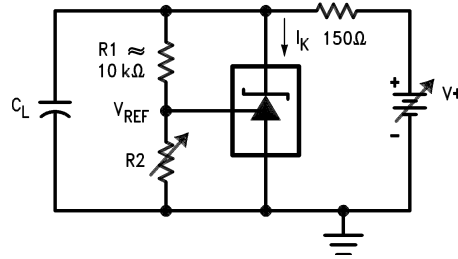
Note: The areas under the curves represent conditions that may cause the device to oscillate. For curves B, C, and D, R2 and V+ were adjusted to establish the initial Vz and Iz conditions with CL = 0. V+ and CL were then adjusted to determine the ranges of stability.

Test Circuit for Curve A Above



01005512

Test Circuit for Curves B, C and D Above



01005513

Typical Applications

Shunt Regulator



01005514

$$V_O \approx \left(1 + \frac{R_1}{R_2}\right) V_{REF}$$

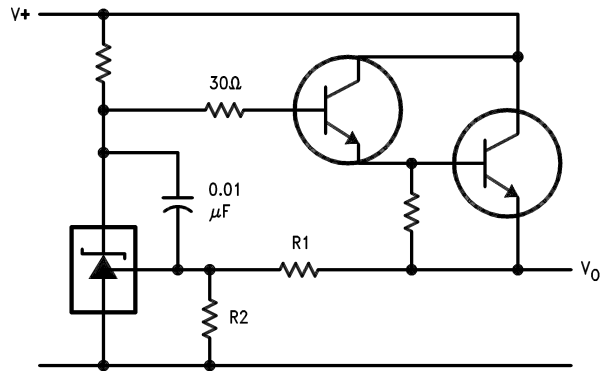
Single Supply Comparator with Temperature Compensated Threshold



01005515

Typical Applications (Continued)

Series Regulator



01005516

$$V_O \approx \left(1 + \frac{R_1}{R_2}\right) V_{REF}$$

Output Control of a Three Terminal Fixed Regulator



01005517

$$V_O = \left(1 + \frac{R_1}{R_2}\right) V_{REF}$$

$$V_{O\ MIN} = V_{REF} + 5V$$

Higher Current Shunt Regulator



01005518

$$V_O \approx \left(1 + \frac{R_1}{R_2}\right) V_{REF}$$

Crow Bar

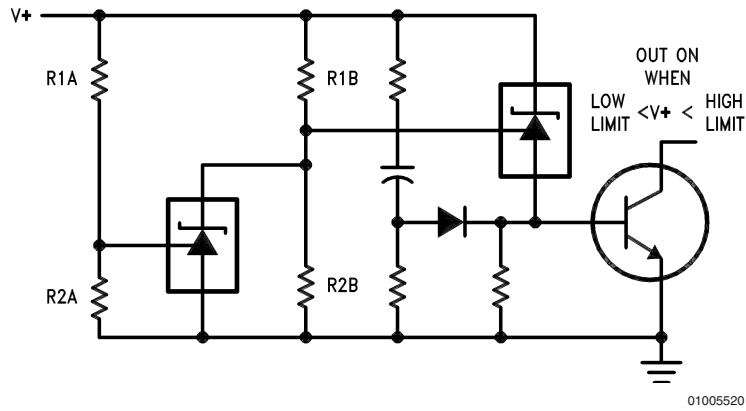


01005519

$$V_{LIMIT} \approx \left(1 + \frac{R_1}{R_2}\right) V_{REF}$$

Typical Applications (Continued)

Over Voltage/Under Voltage Protection Circuit

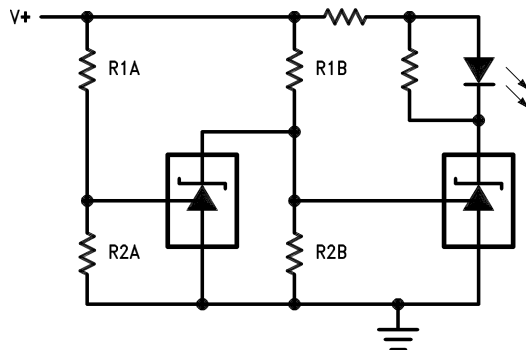


01005520

$$\text{LOW LIMIT} \approx V_{\text{REF}} \left(1 + \frac{R1B}{R2B} \right) + V_{\text{BE}}$$

$$\text{HIGH LIMIT} \approx V_{\text{REF}} \left(1 + \frac{R1A}{R2A} \right)$$

Voltage Monitor



01005521

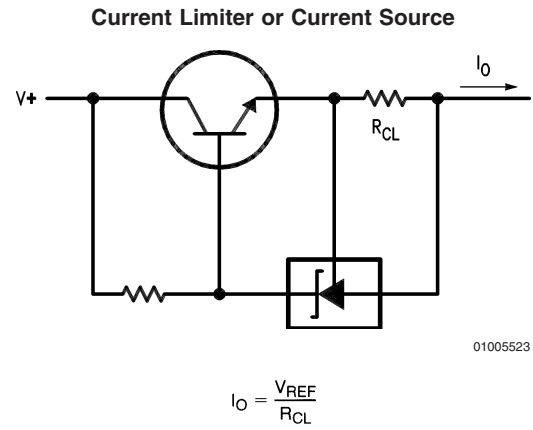
$$\text{LOW LIMIT} \approx V_{\text{REF}} \left(1 + \frac{R1B}{R2B} \right) \quad \text{LED ON WHEN LOW LIMIT} < V^+ < \text{HIGH LIMIT}$$

$$\text{HIGH LIMIT} \approx V_{\text{REF}} \left(1 + \frac{R1A}{R2A} \right)$$

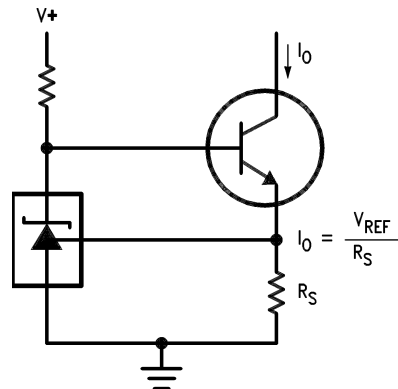
Typical Applications (Continued)



$$\text{DELAY} = R \cdot C \cdot \ln \frac{V^+}{(V^+) - V_{REF}}$$



Constant Current Sink



Application Info

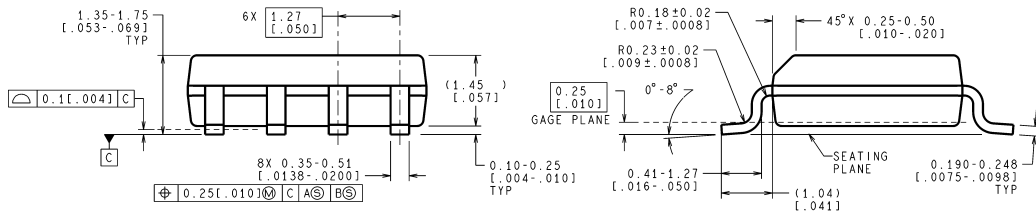
1.0 Mounting

To ensure that the geometry of the micro SMD package maintains good physical contact with the printed circuit board, pin A1 (NC) must be soldered to the pcb. Please see AN-1112 for more detailed information regarding board mounting techniques for the micro SMD package.

2.0 LM431 micro SMD Light Sensitivity

When the LM431 micro SMD package is exposed to bright sunlight, normal office fluorescent light, and other LED's and lasers, it operates within the guaranteed limits specified in the electrical characteristics table.

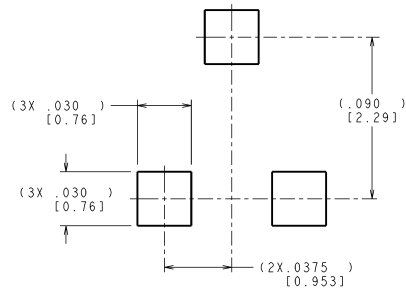
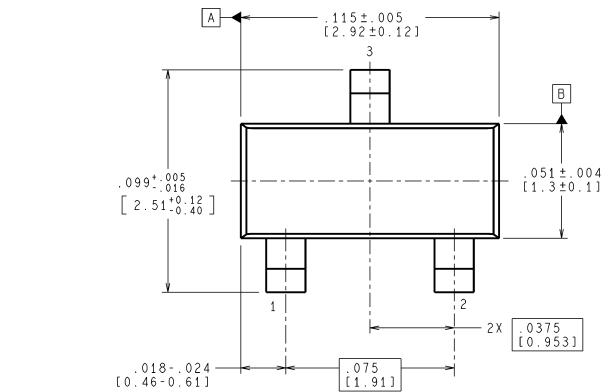
Physical Dimensions inches (millimeters) unless otherwise noted



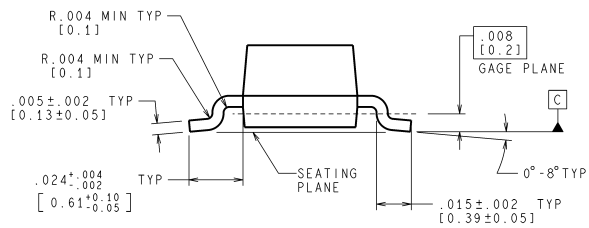
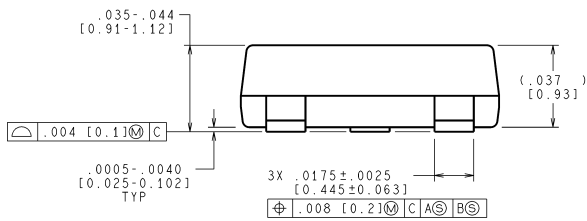
CONTROLLING DIMENSION IS MILLIMETER
VALUES IN [] ARE INCHES
DIMENSIONS IN () FOR REFERENCE ONLY

M08A (Rev K)

**8-Pin SOIC
NS Package Number M08A**



RECOMENDED LAND PATTERN



CONTROLLING DIMENSION IS INCH
VALUES IN [] ARE MILLIMETERS

MF03A (Rev B)

**SOT-23 Molded Small Outline Transistor Package (M3)
NS Package Number MF03A**

Physical Dimensions inches (millimeters) unless otherwise noted (Continued)



DIMENSIONS ARE IN MILLIMETERS

Z03A (Rev G)

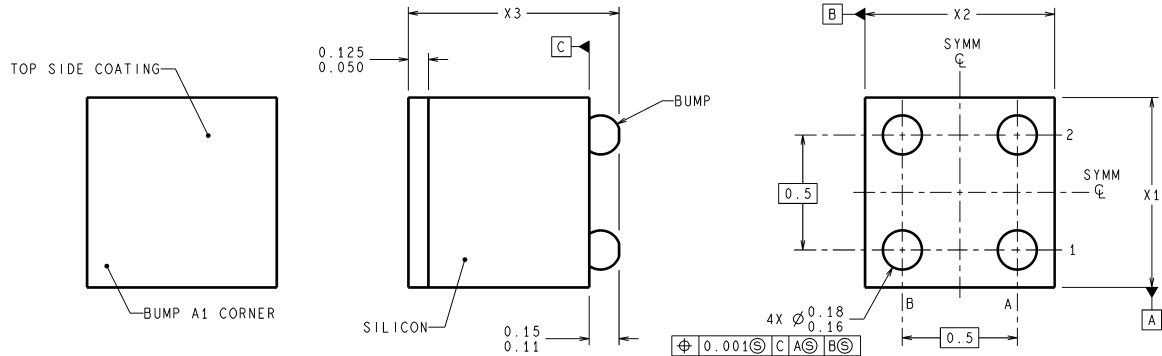
NS Package Number Z03A

Physical Dimensions inches (millimeters) unless otherwise noted (Continued)



DIMENSIONS ARE IN MILLIMETERS
DIMENSIONS IN () FOR REFERENCE ONLY

LAND PATTERN RECOMMENDATION



BPA04XXX (Rev E)

NOTES: UNLESS OTHERWISE SPECIFIED

1. EPOXY COATING
2. 63Sn/37Pb EUTECTIC BUMP
3. RECOMMEND NON-SOLDER MASK DEFINED LANDING PAD.
4. PIN A1 IS ESTABLISHED BY LOWER LEFT CORNER WITH RESPECT TO TEXT ORIENTATION. REMAINING PINS ARE NUMBERED.
5. XXX IN DRAWING NUMBER REPRESENTS PACKAGE SIZE VARIATION WHERE X1 IS PACKAGE WIDTH, X2 IS PACKAGE LENGTH AND X3 IS PACKAGE HEIGHT.
6. REFERENCE JEDEC REGISTRATION MO-211, VARIATION BA.

4-Bump micro SMD
X1 = 0.777 X2 = 0.904 X3 = 0.850
NS Package Number BPA04AFB

National does not assume any responsibility for use of any circuitry described, no circuit patent licenses are implied and National reserves the right at any time without notice to change said circuitry and specifications.

For the most current product information visit us at www.national.com.

LIFE SUPPORT POLICY

NATIONAL'S PRODUCTS ARE NOT AUTHORIZED FOR USE AS CRITICAL COMPONENTS IN LIFE SUPPORT DEVICES OR SYSTEMS WITHOUT THE EXPRESS WRITTEN APPROVAL OF THE PRESIDENT AND GENERAL COUNSEL OF NATIONAL SEMICONDUCTOR CORPORATION. As used herein:

1. Life support devices or systems are devices or systems which, (a) are intended for surgical implant into the body, or (b) support or sustain life, and whose failure to perform when properly used in accordance with instructions for use provided in the labeling, can be reasonably expected to result in a significant injury to the user.
2. A critical component is any component of a life support device or system whose failure to perform can be reasonably expected to cause the failure of the life support device or system, or to affect its safety or effectiveness.

BANNED SUBSTANCE COMPLIANCE

National Semiconductor manufactures products and uses packing materials that meet the provisions of the Customer Products Stewardship Specification (CSP-9-111C2) and the Banned Substances and Materials of Interest Specification (CSP-9-111S2) and contain no "Banned Substances" as defined in CSP-9-111S2.



National Semiconductor
Americas Customer
Support Center
 Email: new.feedback@nsc.com
 Tel: 1-800-272-9959

National Semiconductor
Europe Customer Support Center
 Fax: +49 (0) 180-530 85 86
 Email: europe.support@nsc.com
 Deutsch Tel: +49 (0) 69 9508 6208
 English Tel: +44 (0) 870 24 0 2171
 Français Tel: +33 (0) 1 41 91 8790

National Semiconductor
Asia Pacific Customer
Support Center
 Email: ap.support@nsc.com

National Semiconductor
Japan Customer Support Center
 Fax: 81-3-5639-7507
 Email: jpn.feedback@nsc.com
 Tel: 81-3-5639-7560