

LM431

Adjustable Precision Zener Shunt Regulator

General Description

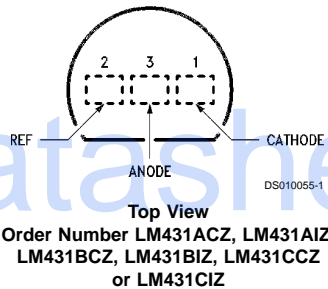
The LM431 is a 3-terminal adjustable shunt regulator with guaranteed temperature stability over the entire temperature range of operation. The output voltage may be set at any level greater than 2.5V (V_{REF}) up to 36V merely by selecting two external resistors that act as a voltage divided network.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

Features

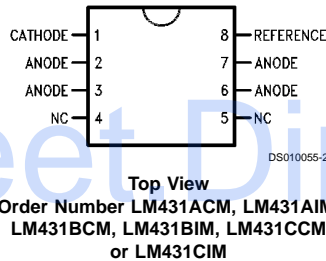
- Average temperature coefficient 50 ppm/°C
- Temperature compensated for operation over the full temperature range
- Programmable output voltage
- Fast turn-on response
- Low output noise

Connection Diagrams

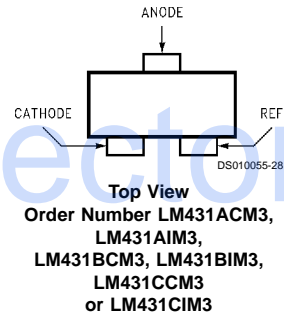
TO-92: Plastic Package



SO-8: 8-Pin Surface Mount



SOT-23: 3-Lead Small Outline



Ordering Information (Note 1)

Package	Typical Accuracy			Temperature Range
	0.5%	1%	2%	
TO-92	LM431CCZ LM431CIZ	LM431BCZ LM431BIZ	LM431ACZ LM431AIZ	0°C to +70°C -40°C to +85°C
SO-8	LM431CCM LM431CIM	LM431BCM LM431BIM	LM431ACM LM431AIM	0°C to +70°C -40°C to +85°C
SOT-23	LM431CCM3 LM431CIM3	LM431BCM3 LM431BIM3	LM431ACM3 LM431AIM3	0°C to +70°C -40°C to +85°C

Note 1: See Table 1 for package marking for SOT-23.

Absolute Maximum Ratings (Note *NO TARGET FOR FNxref NS0108*)

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 (LM431xI)	-40°C to +85°C
Commercial (LM431xC)	0°C to +70°C
Lead Temperature	
TO-92 Package/SO-8 Package/SOT-23 Package (Soldering, 10 sec.)	265°C
Internal Power Dissipation (Note 2) (Note 3)	
TO-92 Package	0.78W

SO-8 Package	0.81W
SOT-23 Package	0.28W
Cathode Voltage	37V
Continuous Cathode Current	-10 mA to +150 mA
Reference Voltage	-0.5V
Reference Input Current	10 mA
Operating Conditions	Min Max
Cathode Voltage	V _{REF} 37V
Cathode Current	1.0 mA 100 mA

Note 2: T_{J Max} = 150°C.

Note 3: 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, and the SOT-23 at 2.2 mW/°C.

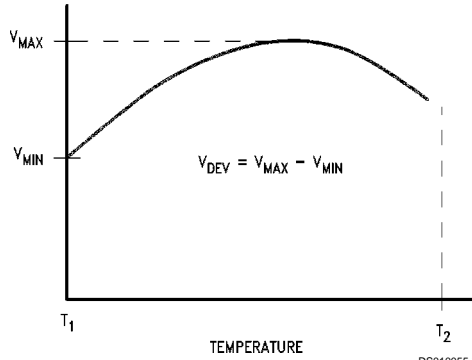
LM431
Electrical Characteristics

T_A = 25°C unless otherwise specified

Symbol	Parameter	Conditions	Min	Typ	Max	Units
V _{REF}	Reference Voltage	V _Z = V _{REF} , I _I = 10 mA LM431A (Figure 1)	2.440	2.495	2.550	V
		V _Z = V _{REF} , I _I = 10 mA LM431B (Figure 1)	2.470	2.495	2.520	V
		V _Z = V _{REF} , I _I = 10 mA LM431C (Figure 1)	2.485	2.500	2.510	V
V _{DEV}	Deviation of Reference Input Voltage Over Temperature (Note 4)	V _Z = V _{REF} , I _I = 10 mA, T _A = 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 mA V _Z from V _{REF} to 10V (Figure 2)		-1.4	-2.7	mV/V
		V _Z from 10V to 36V		-1.0	-2.0	
I _{REF}	Reference Input Current	R ₁ = 10 kΩ, R ₂ = ∞, I _I = 10 mA (Figure 2)		2.0	4.0	μA
<5I _{CREF}	Deviation of Reference Input Current over Temperature	R ₁ = 10 kΩ, R ₂ = ∞, I _I = 10 mA, T _A = 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 = 36V, V _{REF} = 0V (Figure 3)		0.3	1.0	μA
r _Z	Dynamic Output Impedance (Note 4)	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 4: 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)



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

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

Where:

$T_2 - T_1$ = full temperature change.

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

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

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

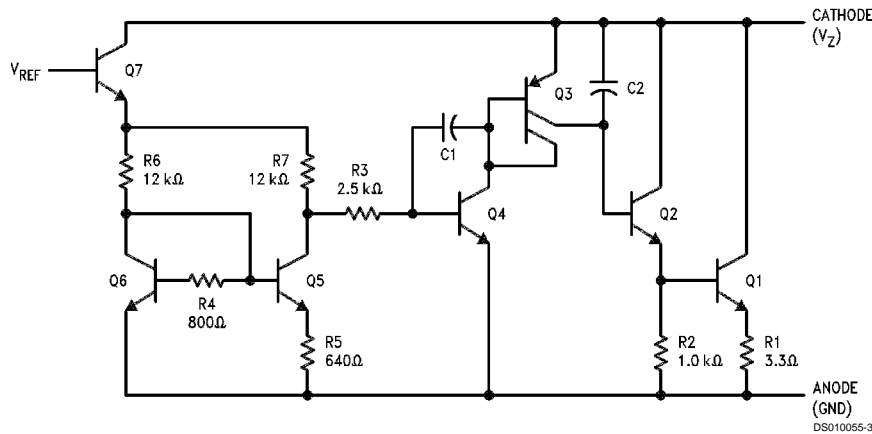
The dynamic output impedance, r_z , is defined as:

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

When the device is programmed with two external resistors, R_1 and R_2 , (see Figure 2), the dynamic output impedance of the overall circuit, r_z , is defined as:

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

Equivalent Circuit



DC Test Circuits

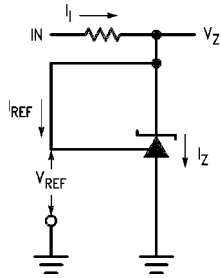
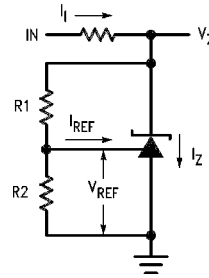


FIGURE 1. Test Circuit for $V_Z = V_{REF}$

DS010055-4



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

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

DS010055-5

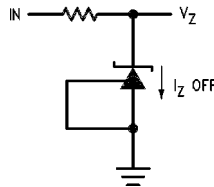
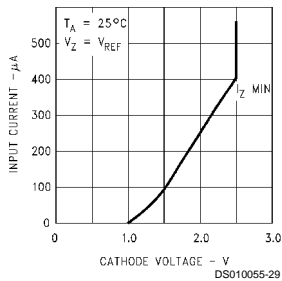


FIGURE 3. Test Circuit for Off-State Current

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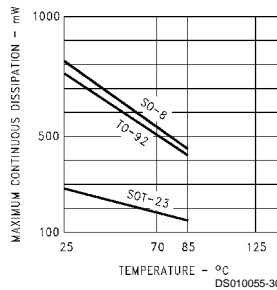
Typical Performance Characteristics

Input Current vs V_Z



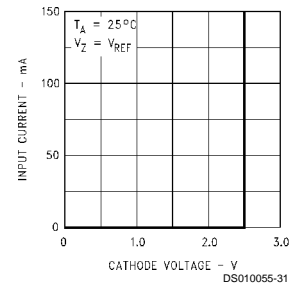
DS010055-29

Thermal Information



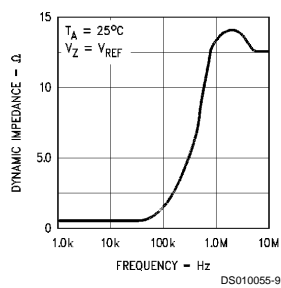
DS010055-30

Input Current vs V_Z

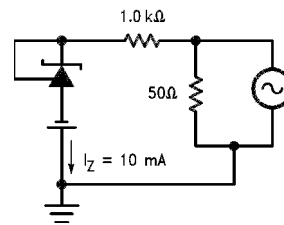


DS010055-31

Dynamic Impedance vs Frequency



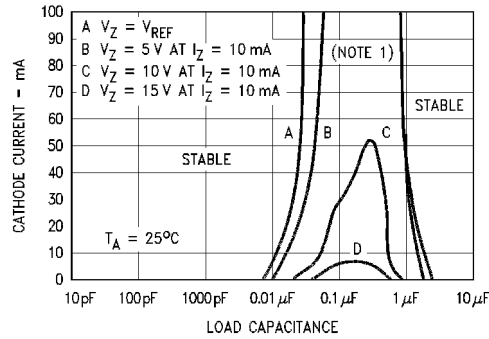
DS010055-9



DS010055-10

Typical Performance Characteristics (Continued)

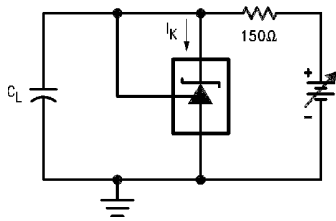
Stability Boundary Conditions



DS010055-11

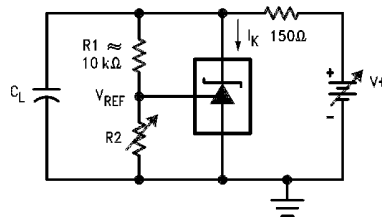
Note 1: The areas under the curves represent conditions that may cause the device to oscillate. For curves B, C, and D, R_2 and V^+ were adjusted to establish the initial V_Z and I_Z conditions with $C_L = 0$. V^+ and C_L were then adjusted to determine the ranges of stability.

Test Circuit for Curve A Above



DS010055-12

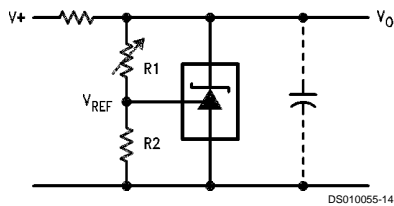
Test Circuit for Curves B, C and D Above



DS010055-13

Typical Applications

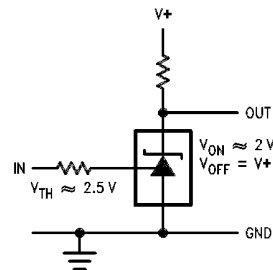
Shunt Regulator



DS010055-14

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

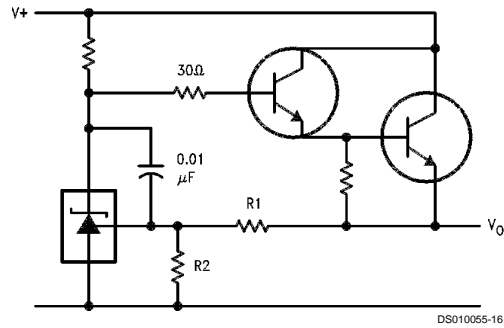
Single Supply Comparator with Temperature Compensated Threshold



DS010055-15

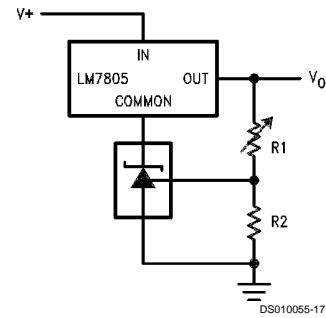
Typical Applications (Continued)

Series Regulator



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

Output Control of a Three Terminal Fixed Regulator

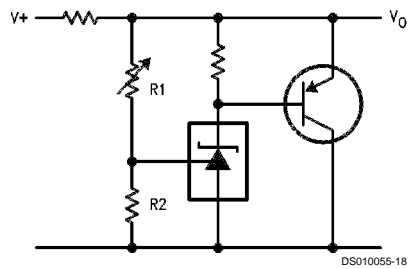


$$V_O = \left(1 + \frac{R_1}{R_2}\right) V_{REF}$$

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

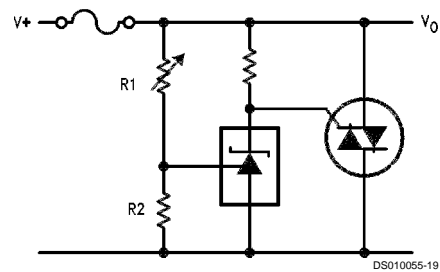
$$V_{O \text{ MIN}} = V_{REF} + 5V$$

Higher Current Shunt Regulator



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

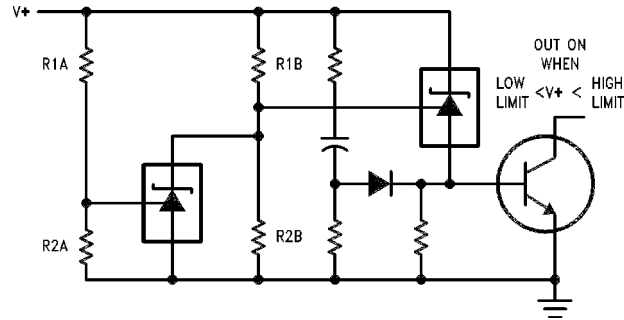
Crow Bar



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

Typical Applications (Continued)

Over Voltage/Under Voltage Protection Circuit

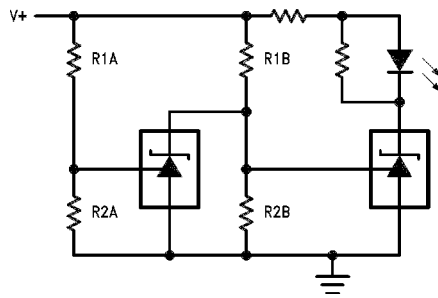


DS010055-20

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

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

Voltage Monitor

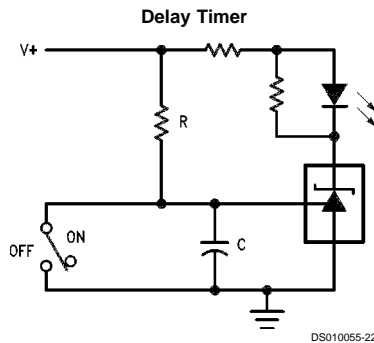


DS010055-21

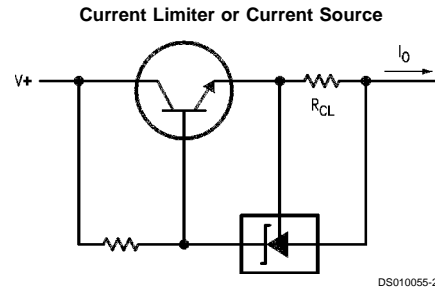
$$\text{LOW LIMIT} \approx V_{\text{REF}} \left(1 + \frac{R1B}{R2B} \right) \quad \text{LED ON WHEN LOW LIMIT} < V^+ < \text{HIGH LIMIT}$$

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

Typical Applications (Continued)

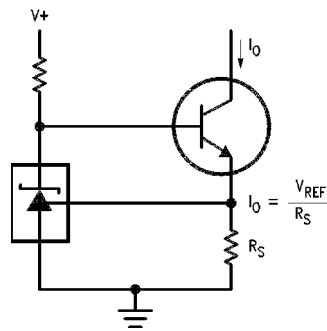


$$\text{DELAY} = R \cdot C \cdot \ln \frac{V^+}{(V^+) - V_{REF}}$$



$$I_o = \frac{V_{REF}}{R_{CL}}$$

Constant Current Sink



Recommended Solder Pads for SOT-23 Package

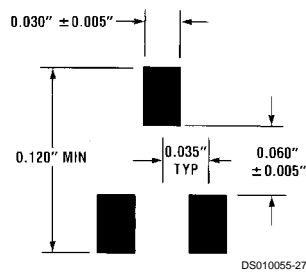
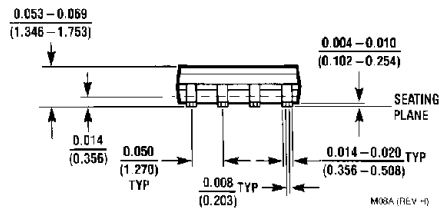
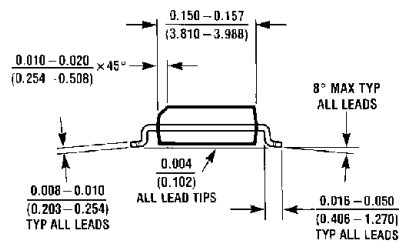
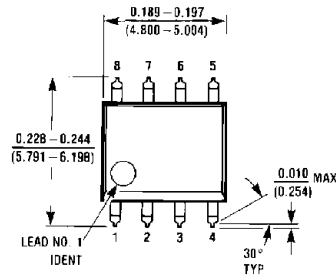


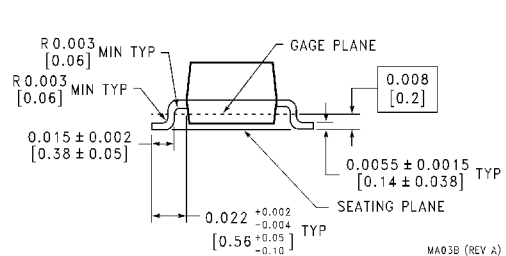
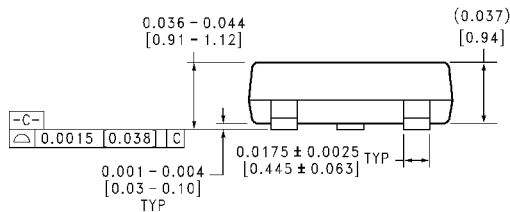
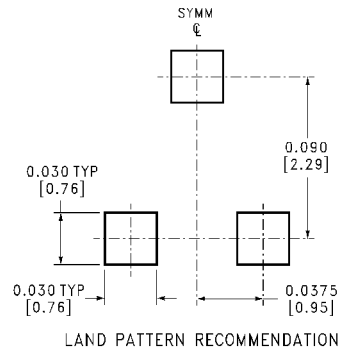
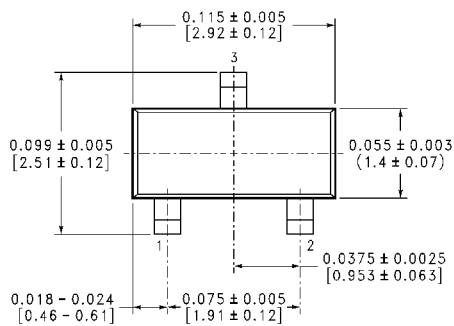
TABLE 1. Package Marking for SOT-23

Order Number	Top Mark
LM431ACM3	N1F
LM431AIM3	N1E
LM431BCM3	N1D
LM431BIM3	N1C
LM431CCM3	N1B
LM431CIM3	N1A

Physical Dimensions inches (millimeters) unless otherwise noted

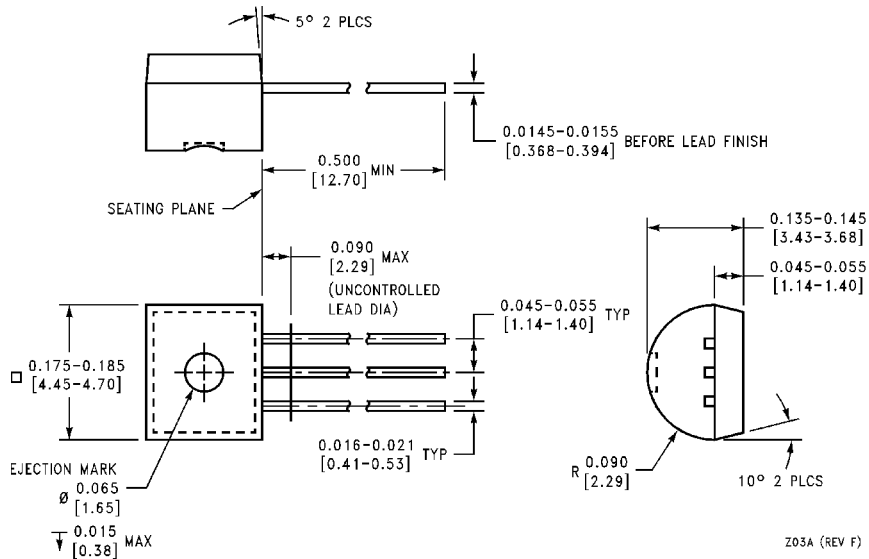


Order Number LM431ACM or LM431AIM
NS Package Number M08A



SOT-23 Molded Small Outline Transistor Package (M3)
Order Number LM60BIM3 or LM60CIM3
NS Package Number MA03B

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




Order Number LM431ACZ or LM431AIZ
NS Package Number Z03A

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