

LM431 Adjustable Precision Zener Shunt Regulator

Check for Samples: [LM431](#)

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

DESCRIPTION

The LM431 is a 3-terminal adjustable shunt regulator with ensured 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.

Connection Diagram

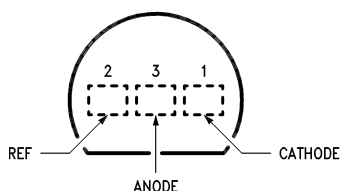


Figure 1. TO-92: Plastic Package Top View

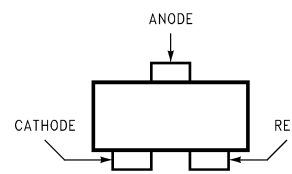


Figure 2. SOT-23: 3-Lead Small Outline Top View

A. Note: NC = Not internally connected.

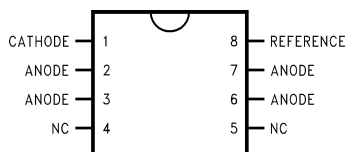
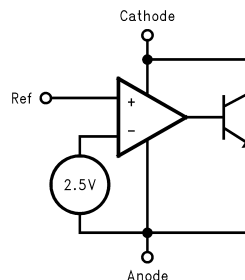
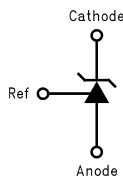


Figure 3. SOIC: 8-Pin Surface Mount Top view

Symbol and Functional Diagrams



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DC Test Circuits

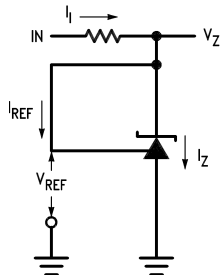


Figure 4. Test Circuit for $V_Z = V_{REF}$

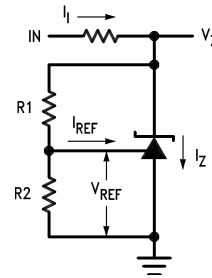


Figure 5. Test Circuit for $V_Z > V_{REF}$

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

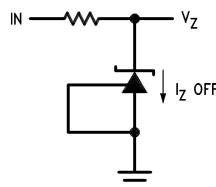


Figure 6. Test Circuit for Off-State Current



These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

Absolute Maximum Ratings⁽¹⁾⁽²⁾

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
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 ⁽³⁾⁽⁴⁾	TO-92 Package	0.78W
	SOIC Package	0.81W
	SOT-23 Package	0.28W

- (1) 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.
- (2) If Military/Aerospace specified devices are required, please contact the TI Sales Office/ Distributors for availability and specifications.
- (3) $T_{J \text{ Max}} = 150^\circ\text{C}$.
- (4) Ratings apply to ambient temperature at 25°C. Above this temperature, derate the TO-92 at 6.2 mW/°C, the SOIC at 6.5 mW/°C, the SOT-23 at 2.2 mW/°C.

Operating Conditions

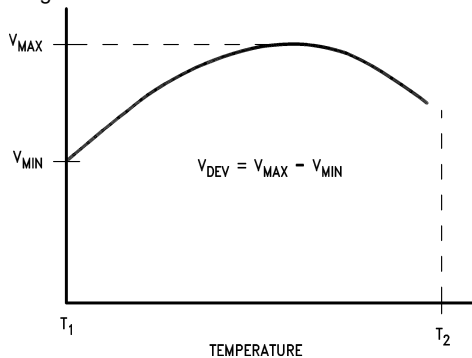
	Min	Max
Cathode Voltage	V_{REF}	37V
Cathode Current	1.0 mA	100 mA

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 4)	2.440	2.495	2.550	V
		V _Z = V _{REF} , I _I = 10 mA LM431B (Figure 4)	2.470	2.495	2.520	V
		V _Z = V _{REF} , I _I = 10 mA LM431C (Figure 4)	2.485	2.500	2.510	V
V _{DEV}	Deviation of Reference Input Voltage Over Temperature ⁽¹⁾	V _Z = V _{REF} , I _I = 10 mA, T _A = Full Range (Figure 4)		8.0	17	mV
ΔV _{REF} /ΔV _Z	Ratio of the Change in Reference Voltage to the Change in Cathode Voltage	I _Z = 10 mA (Figure 5)	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 kΩ, R ₂ = ∞, I _I = 10 mA (Figure 5)		2.0	4.0	μA
αI _{REF}	Deviation of Reference Input Current over Temperature	R ₁ = 10 kΩ, R ₂ = ∞, I _I = 10 mA, T _A = Full Range (Figure 5)		0.4	1.2	μA
I _{Z(MIN)}	Minimum Cathode Current for Regulation	V _Z = V _{REF} (Figure 4)		0.4	1.0	mA
I _{Z(OFF)}	Off-State Current	V _Z = 36V, V _{REF} = 0V (Figure 6)		0.3	1.0	μA
r _Z	Dynamic Output Impedance ⁽²⁾	V _Z = V _{REF} , LM431A, Frequency = 0 Hz (Figure 4)			0.75	Ω
		V _Z = V _{REF} , LM431B, LM431C Frequency = 0 Hz (Figure 4)			0.50	Ω

- (1) Deviation of reference input voltage, V_{DEV}, is defined as the maximum variation of the reference input voltage over the full temperature range.



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

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

Where:

T₂ - T₁ = full temperature change (0-70°C).

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

Example: V_{DEV} = 8.0 mV, V_{REF} = 2495 mV, T₂ - T₁ = 70°C, slope is positive.

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

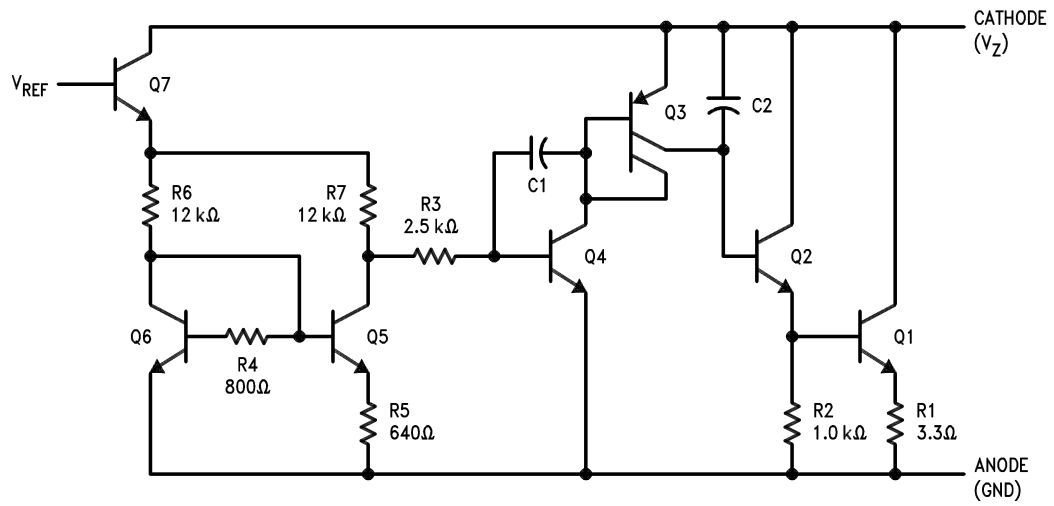
- (2) The dynamic output impedance, r_Z, is defined as:

$$r_Z = \frac{\Delta V_Z}{\Delta I_Z}$$

When the device is programmed with two external resistors, R₁ and R₂, (see Figure 5), 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



Typical Performance Characteristics

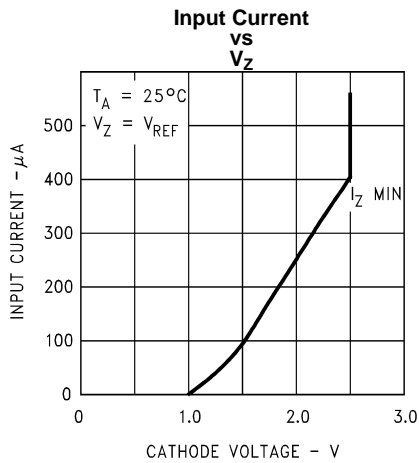


Figure 7.

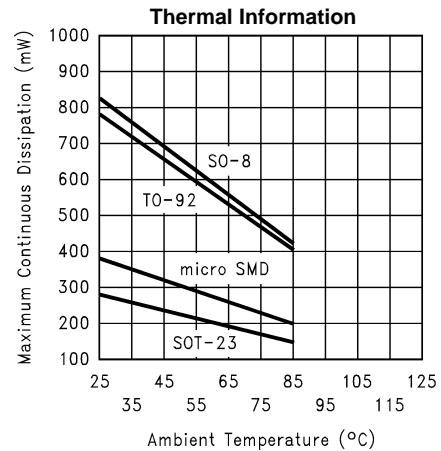


Figure 8.

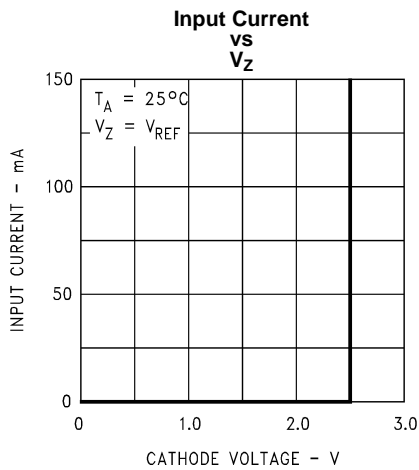


Figure 9.

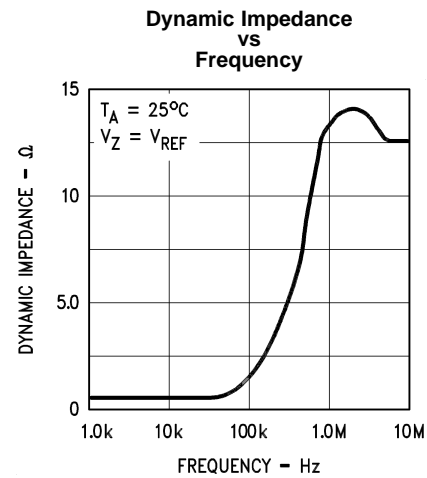
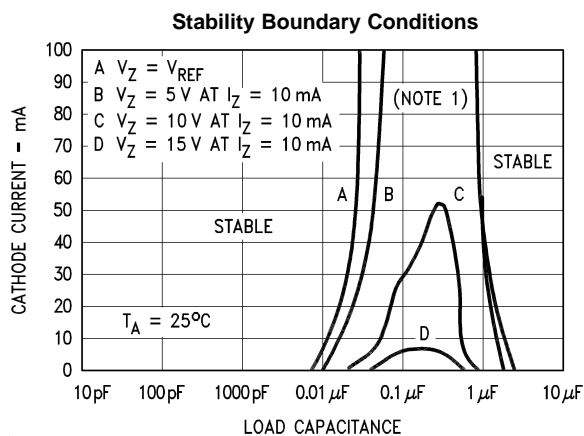


Figure 10.



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 V_Z and I_Z conditions with C_L = 0. V⁺ and C_L were then adjusted to determine the ranges of stability.

Figure 11.

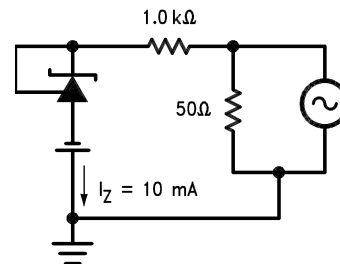


Figure 12.

Typical Performance Characteristics (continued)

Test Circuit for Curve A Above

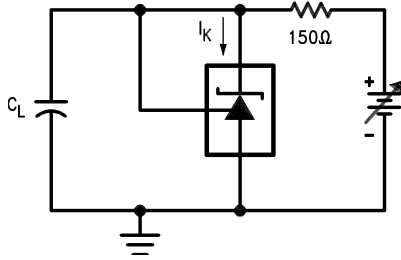


Figure 13.

Test Circuit for Curves B, C and D Above

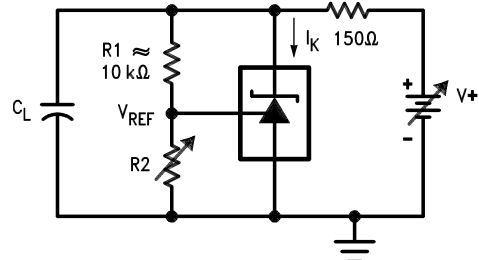


Figure 14.

Typical Applications

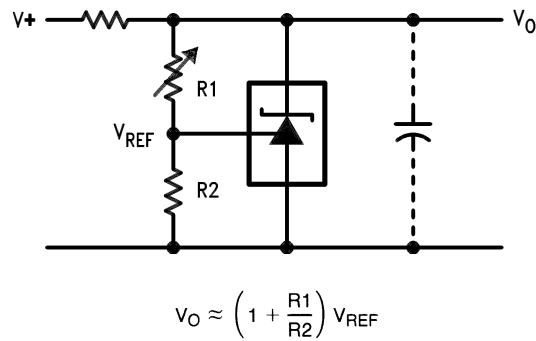


Figure 15. Shunt Regulator

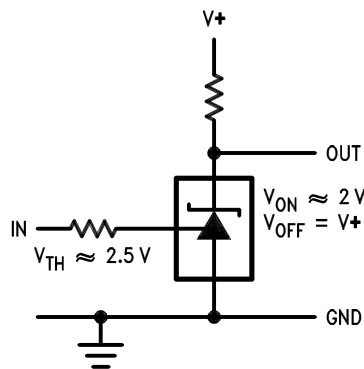


Figure 16. Single Supply Comparator with Temperature Compensated Threshold

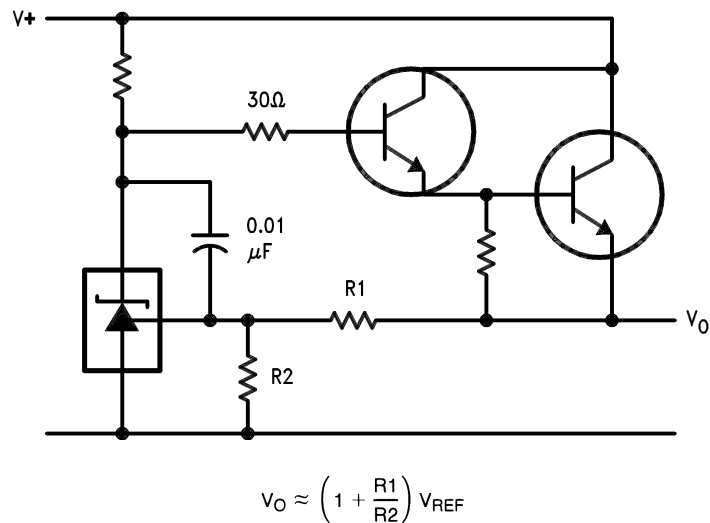
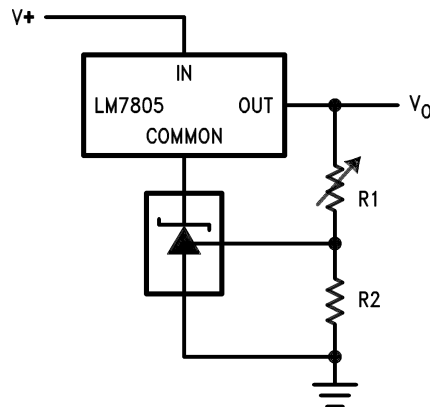


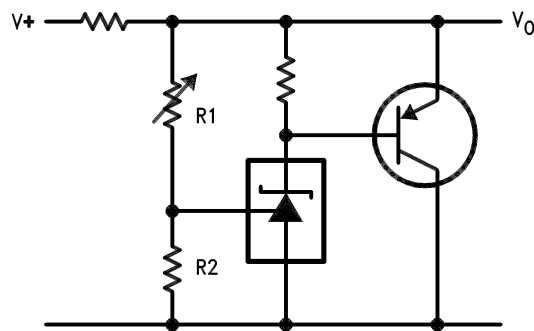
Figure 17. Series Regulator



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

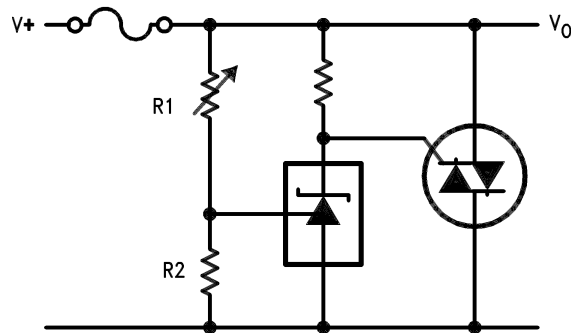
$$V_{O\ MIN} = V_{REF} + 5V$$

Figure 18. Output Control of a Three Terminal Fixed Regulator



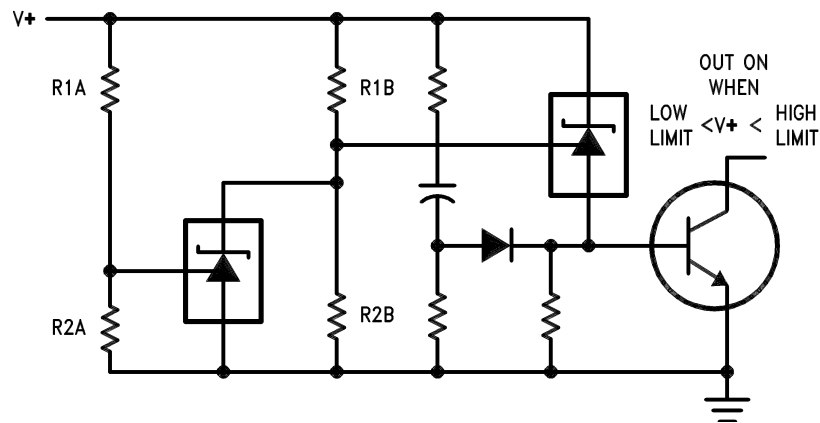
$$V_O \approx \left(1 + \frac{R_1}{R_2}\right) V_{REF}$$

Figure 19. Higher Current Shunt Regulator



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

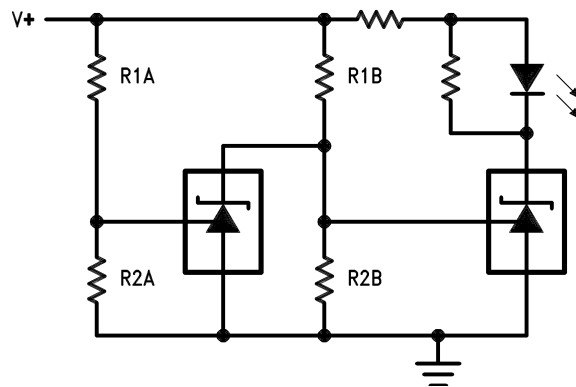
Figure 20. Crow Bar



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

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

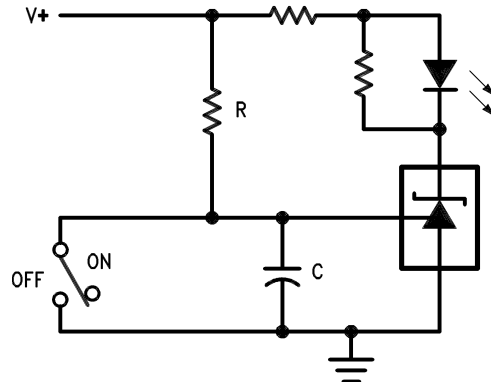
Figure 21. Over Voltage/Under Voltage Protection Circuit



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

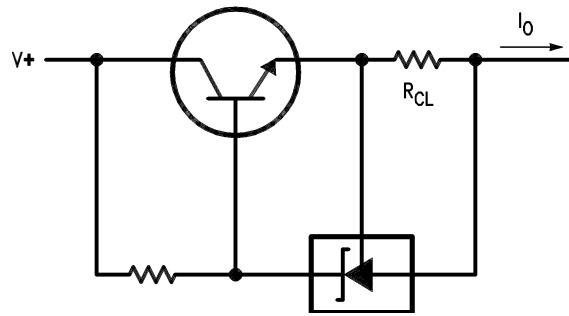
$$\text{HIGH LIMIT} \approx V_{\text{REF}} \left(1 + \frac{R1A}{R2A} \right)$$

Figure 22. Voltage Monitor



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

Figure 23. Delay Timer



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

Figure 24. Current Limiter or Current Source

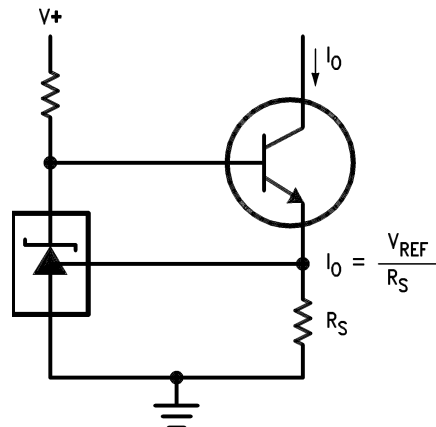


Figure 25. Constant Current Sink

REVISION HISTORY

Changes from Revision F (April 2013) to Revision G	Page
• Changed layout of National Data Sheet to TI format	10

PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
LM431ACM	NRND	SOIC	D	8	95	TBD	Call TI	Call TI	-40 to 85	LM431 ACM	
LM431ACM/NOPB	ACTIVE	SOIC	D	8	95	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	-40 to 85	LM431 ACM	Samples
LM431ACM3	NRND	SOT-23	DBZ	3	1000	TBD	Call TI	Call TI	-40 to 85	N1F	
LM431ACM3/NOPB	ACTIVE	SOT-23	DBZ	3	1000	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	-40 to 85	N1F	Samples
LM431ACM3X	NRND	SOT-23	DBZ	3	3000	TBD	Call TI	Call TI	-40 to 85	N1F	
LM431ACM3X/NOPB	ACTIVE	SOT-23	DBZ	3	3000	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	-40 to 85	N1F	Samples
LM431ACMX	NRND	SOIC	D	8	2500	TBD	Call TI	Call TI	-40 to 85	LM431 ACM	
LM431ACMX/NOPB	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	-40 to 85	LM431 ACM	Samples
LM431ACZ/LFT3	ACTIVE	TO-92	LP	3	2000	Green (RoHS & no Sb/Br)	CU SN	N / A for Pkg Type		LM431 ACZ	Samples
LM431ACZ/LFT4	ACTIVE	TO-92	LP	3	2000	Green (RoHS & no Sb/Br)	CU SN	N / A for Pkg Type		LM431 ACZ	Samples
LM431ACZ/NOPB	ACTIVE	TO-92	LP	3	1800	Green (RoHS & no Sb/Br)	CU	N / A for Pkg Type	-40 to 85	LM431 ACZ	Samples
LM431AIM	NRND	SOIC	D	8	95	TBD	Call TI	Call TI	-40 to 85	LM431 AIM	
LM431AIM/NOPB	ACTIVE	SOIC	D	8	95	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	-40 to 85	LM431 AIM	Samples
LM431AIM3	NRND	SOT-23	DBZ	3	1000	TBD	Call TI	Call TI	-40 to 85	N1E	
LM431AIM3/NOPB	ACTIVE	SOT-23	DBZ	3	1000	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	-40 to 85	N1E	Samples
LM431AIM3X/NOPB	ACTIVE	SOT-23	DBZ	3	3000	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	-40 to 85	N1E	Samples
LM431AIMX/NOPB	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	-40 to 85	LM431 AIM	Samples
LM431AIZ/LFT1	ACTIVE	TO-92	LP	3	2000	Green (RoHS & no Sb/Br)	CU SN	N / A for Pkg Type		LM431 AIZ	Samples

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
LM431CIM	NRND	SOIC	D	8	95	TBD	Call TI	Call TI	-40 to 85	431 CIM	
LM431CIM/NOPB	ACTIVE	SOIC	D	8	95	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	-40 to 85	431 CIM	Samples
LM431CIM3	NRND	SOT-23	DBZ	3	1000	TBD	Call TI	Call TI	-40 to 85	N1A	
LM431CIM3/NOPB	ACTIVE	SOT-23	DBZ	3	1000	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	-40 to 85	N1A	Samples
LM431CIM3X	NRND	SOT-23	DBZ	3	3000	TBD	Call TI	Call TI	-40 to 85	N1A	
LM431CIM3X/NOPB	ACTIVE	SOT-23	DBZ	3	3000	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	-40 to 85	N1A	Samples
LM431CIZ/LFT1	ACTIVE	TO-92	LP	3	2000	Green (RoHS & no Sb/Br)	CU SN	N / A for Pkg Type		LM431 CIZ	Samples
LM431CIZ/NOPB	ACTIVE	TO-92	LP	3	1800	Green (RoHS & no Sb/Br)	CU SN	N / A for Pkg Type	-40 to 85	LM431 CIZ	Samples

(1) The marketing status values are defined as follows:

ACTIVE: Product device recommended for new designs.

LIFEBUY: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.

NRND: Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.

PREVIEW: Device has been announced but is not in production. Samples may or may not be available.

OBSOLETE: TI has discontinued the production of the device.

(2) Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check <http://www.ti.com/productcontent> for the latest availability information and additional product content details.

TBD: The Pb-Free/Green conversion plan has not been defined.

Pb-Free (RoHS): TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.

Pb-Free (RoHS Exempt): This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.

Green (RoHS & no Sb/Br): TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

(3) MSL, Peak Temp. - The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

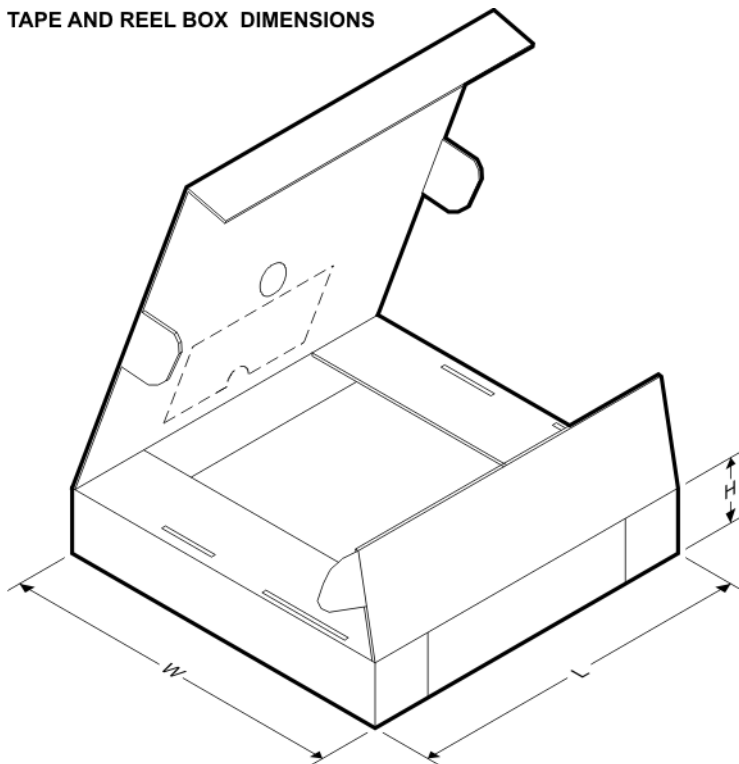
⁽⁵⁾ Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "-" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

⁽⁶⁾ Lead/Ball Finish - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead/Ball Finish values may wrap to two lines if the finish value exceeds the maximum column width.

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In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.

Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
LM431BIM3X/NOPB	SOT-23	DBZ	3	3000	178.0	8.4	3.3	2.9	1.22	4.0	8.0	Q3
LM431BIMX/NOPB	SOIC	D	8	2500	330.0	12.4	6.5	5.4	2.0	8.0	12.0	Q1
LM431CCM3/NOPB	SOT-23	DBZ	3	1000	178.0	8.4	3.3	2.9	1.22	4.0	8.0	Q3
LM431CCM3X	SOT-23	DBZ	3	3000	178.0	8.4	3.3	2.9	1.22	4.0	8.0	Q3
LM431CCM3X/NOPB	SOT-23	DBZ	3	3000	178.0	8.4	3.3	2.9	1.22	4.0	8.0	Q3
LM431CIM3	SOT-23	DBZ	3	1000	178.0	8.4	3.3	2.9	1.22	4.0	8.0	Q3
LM431CIM3/NOPB	SOT-23	DBZ	3	1000	178.0	8.4	3.3	2.9	1.22	4.0	8.0	Q3
LM431CIM3X	SOT-23	DBZ	3	3000	178.0	8.4	3.3	2.9	1.22	4.0	8.0	Q3
LM431CIM3X/NOPB	SOT-23	DBZ	3	3000	178.0	8.4	3.3	2.9	1.22	4.0	8.0	Q3

TAPE AND REEL BOX DIMENSIONS


*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
LM431ACM3	SOT-23	DBZ	3	1000	210.0	185.0	35.0
LM431ACM3/NOPB	SOT-23	DBZ	3	1000	210.0	185.0	35.0
LM431ACM3X	SOT-23	DBZ	3	3000	210.0	185.0	35.0
LM431ACM3X/NOPB	SOT-23	DBZ	3	3000	210.0	185.0	35.0
LM431ACMX	SOIC	D	8	2500	367.0	367.0	35.0
LM431ACMX/NOPB	SOIC	D	8	2500	367.0	367.0	35.0
LM431AIM3	SOT-23	DBZ	3	1000	210.0	185.0	35.0
LM431AIM3/NOPB	SOT-23	DBZ	3	1000	210.0	185.0	35.0

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
LM431AIM3X/NOPB	SOT-23	DBZ	3	3000	210.0	185.0	35.0
LM431AIMX/NOPB	SOIC	D	8	2500	367.0	367.0	35.0
LM431BCM3	SOT-23	DBZ	3	1000	210.0	185.0	35.0
LM431BCM3/NOPB	SOT-23	DBZ	3	1000	210.0	185.0	35.0
LM431BCM3X/NOPB	SOT-23	DBZ	3	3000	210.0	185.0	35.0
LM431BCM3X	SOIC	D	8	2500	367.0	367.0	35.0
LM431BCM3X/NOPB	SOIC	D	8	2500	367.0	367.0	35.0
LM431BIM3	SOT-23	DBZ	3	1000	210.0	185.0	35.0
LM431BIM3/NOPB	SOT-23	DBZ	3	1000	210.0	185.0	35.0
LM431BIM3X	SOT-23	DBZ	3	3000	210.0	185.0	35.0
LM431BIM3X/NOPB	SOT-23	DBZ	3	3000	210.0	185.0	35.0
LM431BIM3X/NOPB	SOIC	D	8	2500	367.0	367.0	35.0
LM431CCM3/NOPB	SOT-23	DBZ	3	1000	210.0	185.0	35.0
LM431CCM3X	SOT-23	DBZ	3	3000	210.0	185.0	35.0
LM431CCM3X/NOPB	SOT-23	DBZ	3	3000	210.0	185.0	35.0
LM431CIM3	SOT-23	DBZ	3	1000	210.0	185.0	35.0
LM431CIM3/NOPB	SOT-23	DBZ	3	1000	210.0	185.0	35.0
LM431CIM3X	SOT-23	DBZ	3	3000	210.0	185.0	35.0
LM431CIM3X/NOPB	SOT-23	DBZ	3	3000	210.0	185.0	35.0

DBZ (R-PDSO-G3)

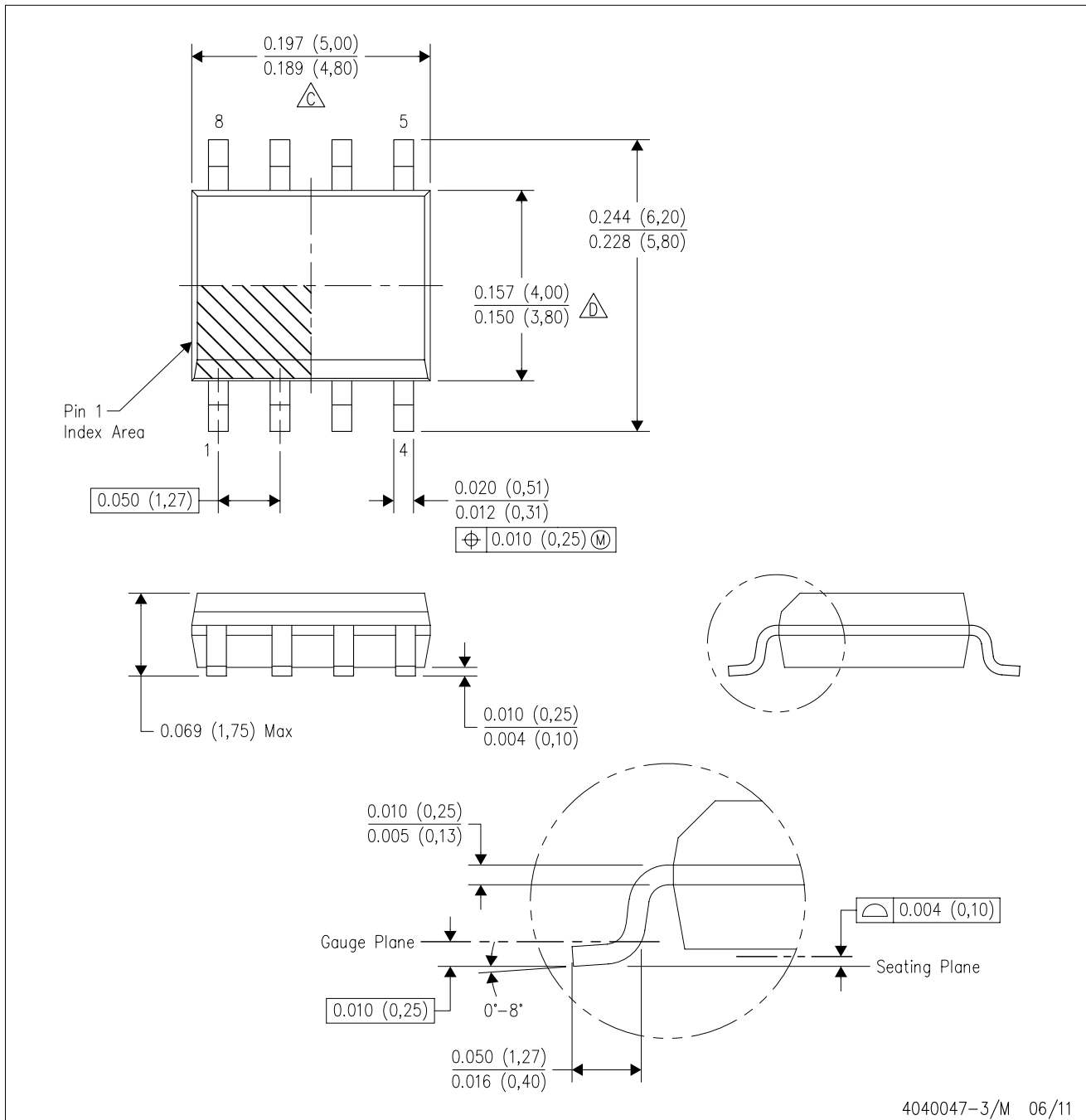
PLASTIC SMALL-OUTLINE



- NOTES:
- A. All linear dimensions are in millimeters. Dimensioning and tolerancing per ASME Y14.5M-1994.
 - B. This drawing is subject to change without notice.
 - C. Lead dimensions are inclusive of plating.
 - D. Body dimensions are exclusive of mold flash and protrusion. Mold flash and protrusion not to exceed 0.25 per side.
 - $\triangle E$ Falls within JEDEC TO-236 variation AB, except minimum foot length.

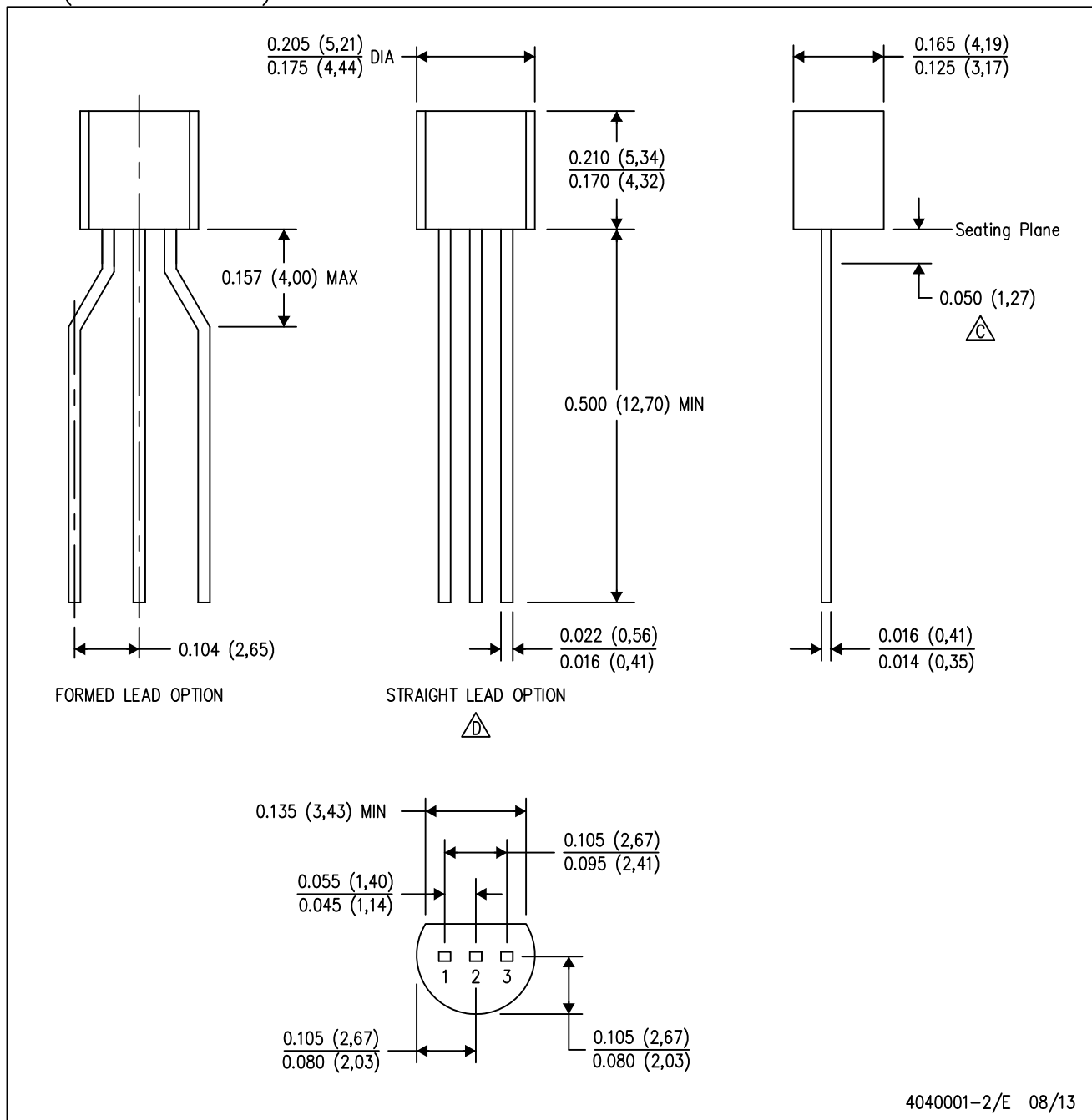
D (R-PDSO-G8)

PLASTIC SMALL OUTLINE



LP (O-PBCY-W3)

PLASTIC CYLINDRICAL PACKAGE

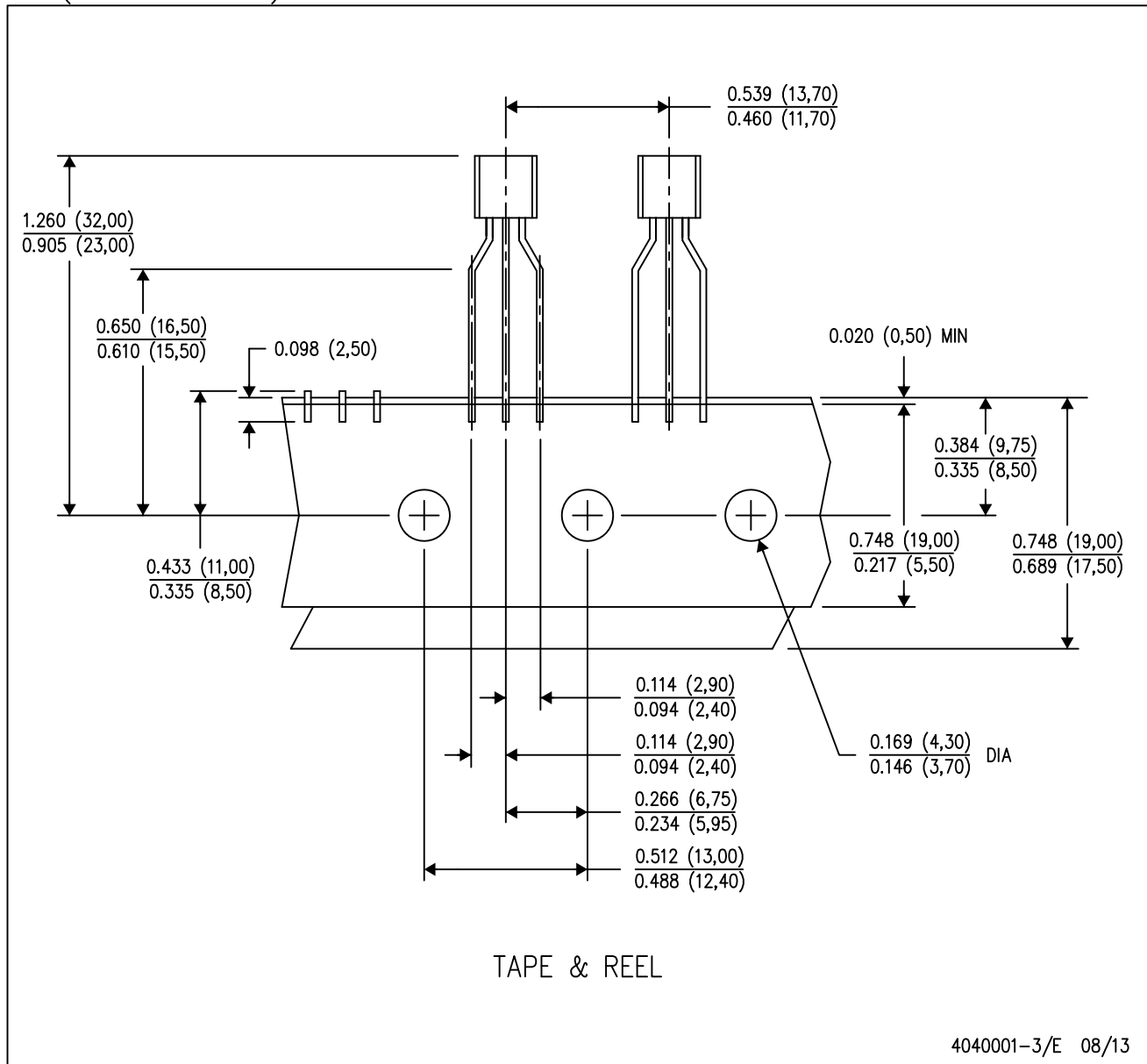


- NOTES:
- A. All linear dimensions are in inches (millimeters).
 - B. This drawing is subject to change without notice.
 - Lead dimensions are not controlled within this area.
 - Falls within JEDEC TO-226 Variation AA (TO-226 replaces TO-92).
 - E. Shipping Method:
 Straight lead option available in bulk pack only.
 Formed lead option available in tape & reel or ammo pack.
 Specific products can be offered in limited combinations of shipping mediums and lead options.
 Consult product folder for more information on available options.

MECHANICAL DATA

LP (O-PBCY-W3)

PLASTIC CYLINDRICAL PACKAGE



- NOTES:
- A. All linear dimensions are in inches (millimeters).
 - B. This drawing is subject to change without notice.
 - C. Tape and Reel information for the Formed Lead Option package.

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