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

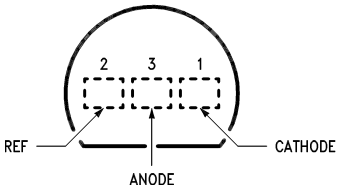


Figure 1. TO-92: Plastic Package
Top View

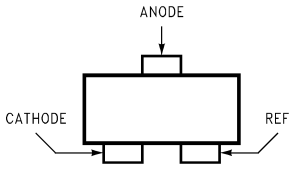


Figure 2. SOT-23: 3-Lead Small Outline
Top View

A. Note: NC = Not internally connected.

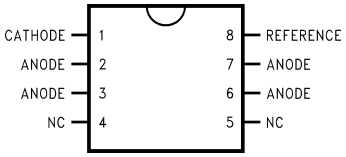
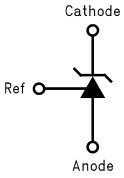
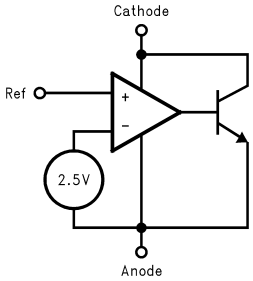


Figure 3. SOIC: 8-Pin Surface Mount
Top view

Symbol and Functional Diagrams





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DC Test Circuits

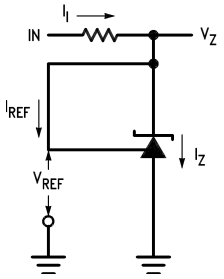
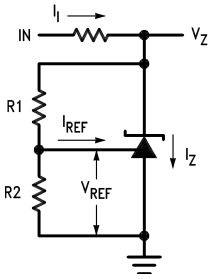


Figure 4. Test Circuit for $V_Z = V_{REF}$



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

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

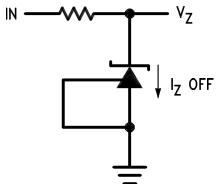


Figure 6. Test Circuit for Off-State Current

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) $T_{J\ Max}$ = 150°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

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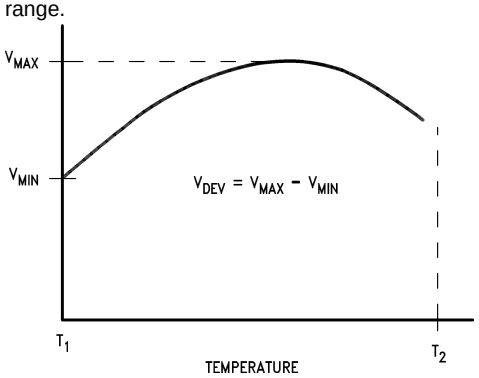
LM431 Electrical Characteristics

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
$\Delta V_{REF}/\Delta V_Z$	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
$\propto I_{REF}$	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, $\propto V_{REF}$, is defined as:

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

Where:
$T_2 - T_1$ = 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, $T_2 - T_1$ = 70°C, slope is positive.

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

(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:

$$r_Z = \frac{\Delta V_Z}{\Delta I_Z} \cong \left[r_Z\left(1 + \frac{R1}{R2}\right)\right]$$

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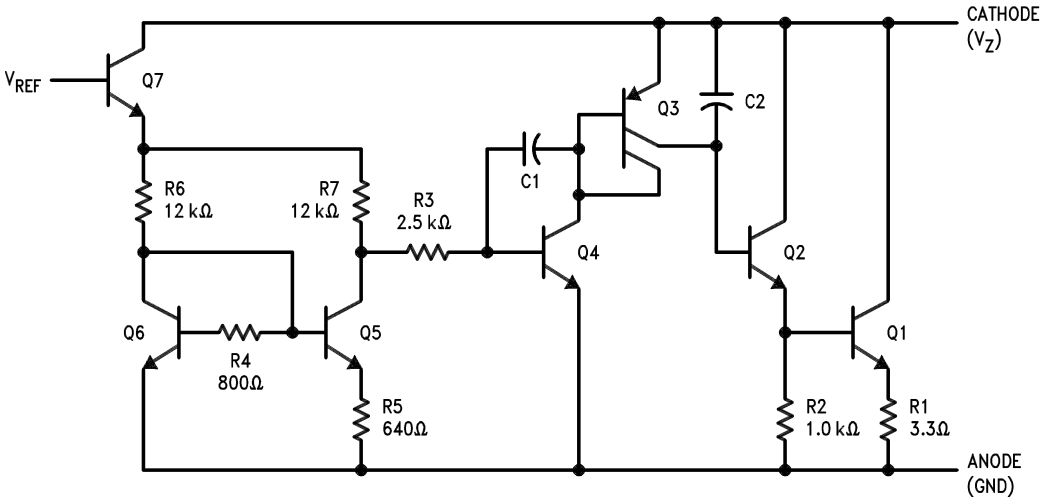
Equivalent Circuit



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Typical Performance Characteristics

Input Current vs V_Z

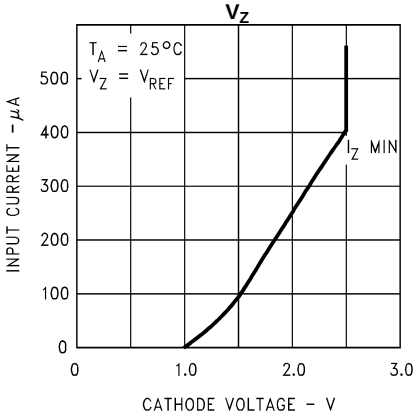


Figure 7.

Thermal Information

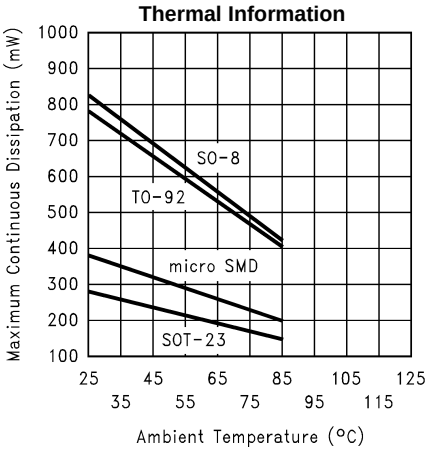


Figure 8.

Input Current vs V_Z

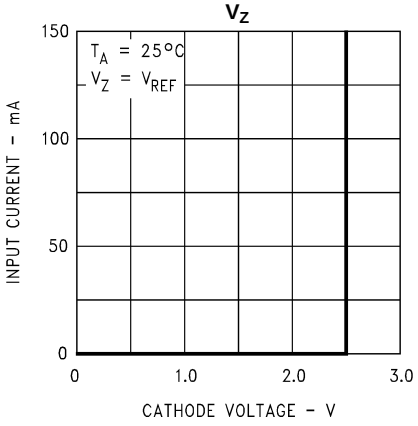


Figure 9.

Dynamic Impedance vs Frequency

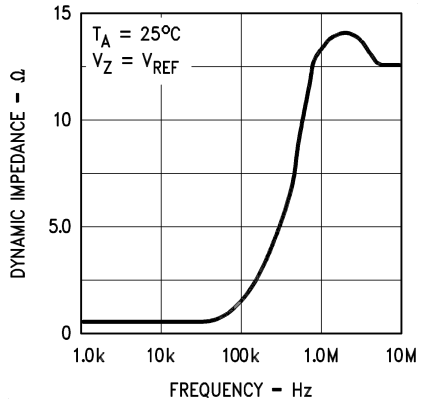
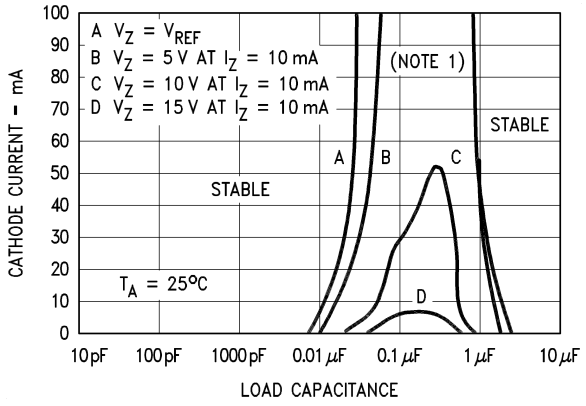


Figure 10.

Stability Boundary Conditions



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.

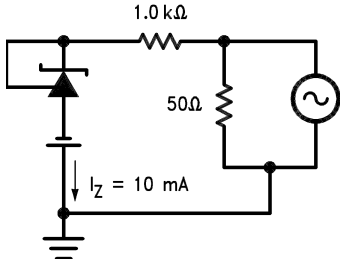


Figure 12.

Typical Performance Characteristics (continued)

Test Circuit for Curve A Above

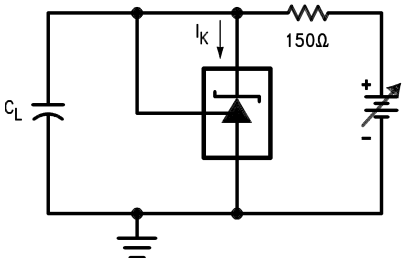


Figure 13.

Test Circuit for Curves B, C and D Above

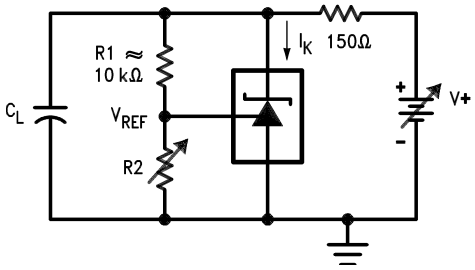


Figure 14.

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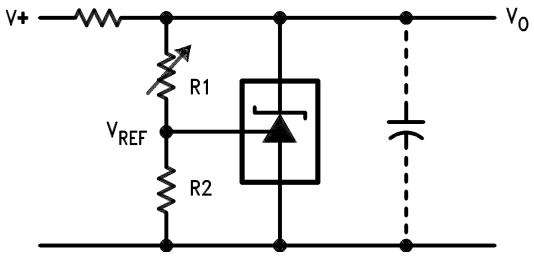
Typical Applications



$$V_O \approx \left(1 + \frac{R1}{R2}\right) V_{REF}$$

Figure 15. Shunt Regulator

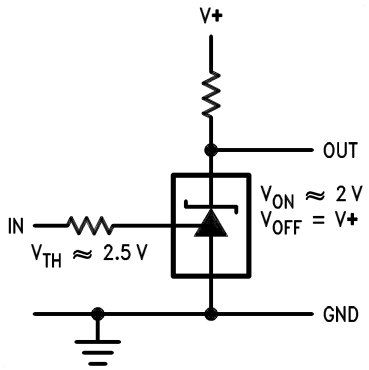
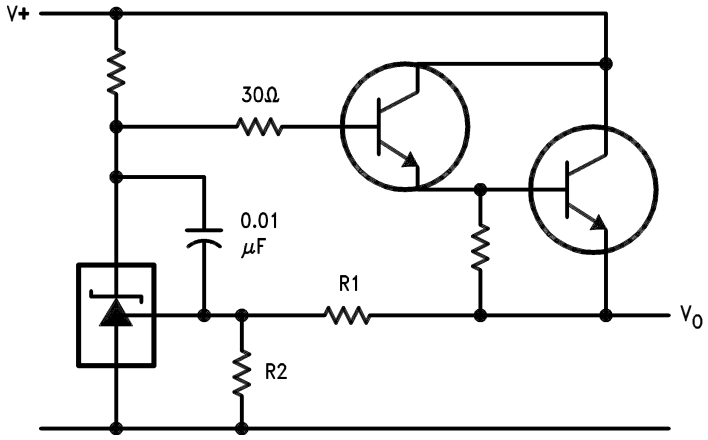


Figure 16. Single Supply Comparator with Temperature Compensated Threshold



$$V_O \approx \left(1 + \frac{R1}{R2}\right) V_{REF}$$

Figure 17. Series Regulator

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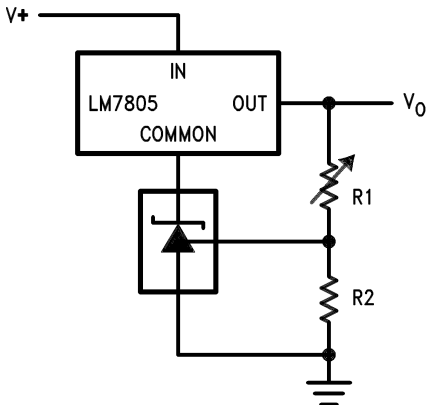
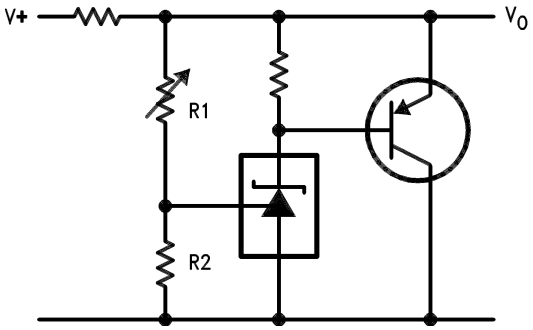


$$V_O = \left(1 + \frac{R1}{R2}\right) V_{REF}$$

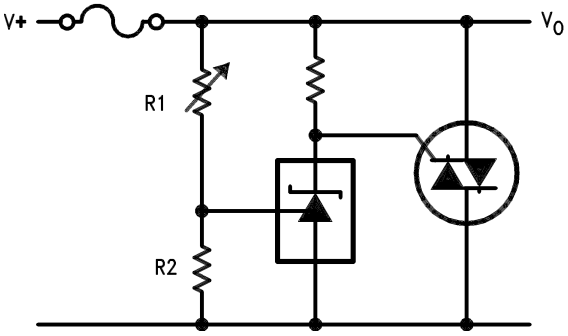
$$V_{O\ MIN} = V_{REF} + 5V$$

Figure 18. Output Control of a Three Terminal Fixed Regulator



$$V_O \approx \left(1 + \frac{R1}{R2}\right) V_{REF}$$

Figure 19. Higher Current Shunt Regulator



$$V_{LIMIT} \approx \left(1 + \frac{R1}{R2}\right) V_{REF}$$

Figure 20. Crow Bar

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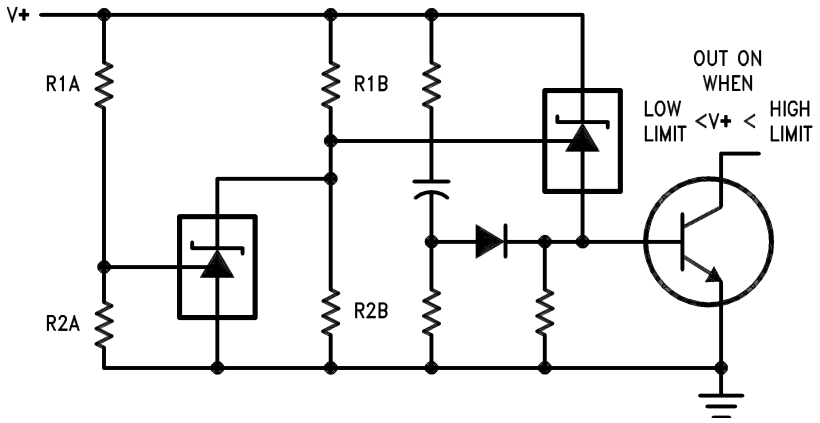
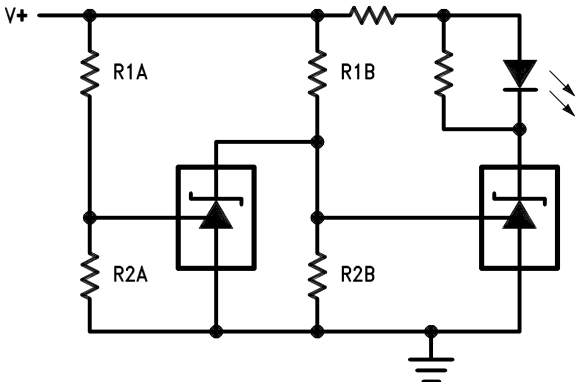


$$\text{LOW LIMIT} \approx V_{REF}\left(1 + \frac{R1B}{R2B}\right) + V_{BE}$$

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

Figure 21. Over Voltage/Under Voltage Protection Circuit

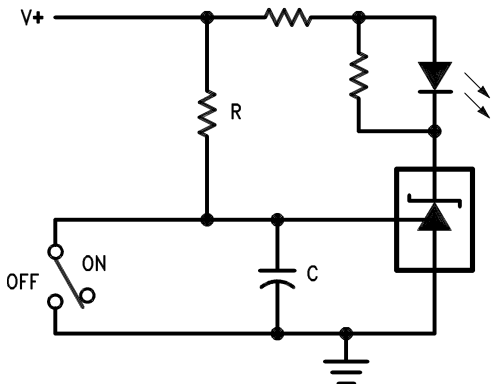


$$\text{LOW LIMIT} \approx V_{REF}\left(1 + \frac{R1B}{R2B}\right)$$

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

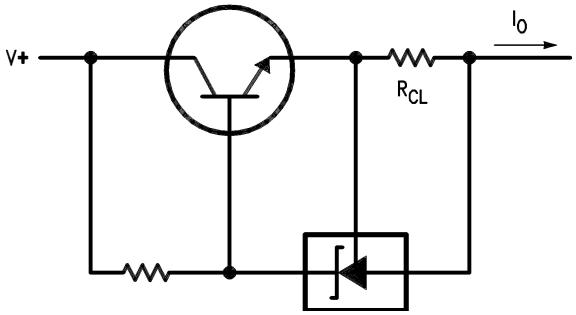
LED ON WHEN LOW LIMIT $< V^{+} <$ HIGH LIMIT

Figure 22. Voltage Monitor



$$DELAY = R \bullet C \bullet \ell n \frac{V+}{(V^+) - V_{REF}}$$

Figure 23. Delay Timer



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

Figure 24. Current Limiter or Current Source

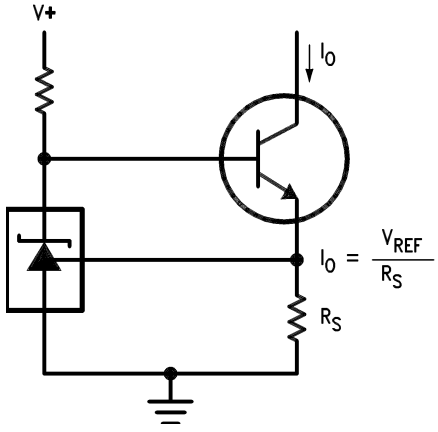


Figure 25. Constant Current Sink

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REVISION HISTORY

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

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PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish	MSL Peak Temp (3)	Op Temp (°C)	Top-Side Markings (4)	Samples
LM431ACM	ACTIVE	SOIC	D	8	95	TBD	Call TI	Call TI	-40 to 85	LM431 ACM	Samples
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	ACTIVE	SOT-23	DBZ	3	1000	TBD	Call TI	Call TI	-40 to 85	N1F	Samples
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	ACTIVE	SOT-23	DBZ	3	3000	TBD	Call TI	Call TI	-40 to 85	N1F	Samples
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	ACTIVE	SOIC	D	8	2500	TBD	Call TI	Call TI	-40 to 85	LM431 ACM	Samples
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)	SNCU	Level-1-NA-UNLIM		LM431 ACZ	Samples
LM431ACZ/LFT4	ACTIVE	TO-92	LP	3	2000	Green (RoHS & no Sb/Br)	SNCU	Level-1-NA-UNLIM		LM431 ACZ	Samples
LM431ACZ/NOPB	ACTIVE	TO-92	LP	3	1800	Green (RoHS & no Sb/Br)	SNCU	Level-1-NA-UNLIM	-40 to 85	LM431 ACZ	Samples
LM431AIM	ACTIVE	SOIC	D	8	95	TBD	Call TI	Call TI	-40 to 85	LM431 AIM	Samples
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	ACTIVE	SOT-23	DBZ	3	1000	TBD	Call TI	Call TI	-40 to 85	N1E	Samples
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	ACTIVE	SOT-23	DBZ	3	3000	TBD	Call TI	Call TI	-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	ACTIVE	SOIC	D	8	2500	TBD	Call TI	Call TI	-40 to 85	LM431 AIM	Samples

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish	MSL Peak Temp (3)	Op Temp (°C)	Top-Side Markings (4)	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)	SNCU	Level-1-NA-UNLIM		LM431 AIZ	Samples
LM431AIZ/NOPB	ACTIVE	TO-92	LP	3	1800	Green (RoHS & no Sb/Br)	SNCU	Level-1-NA-UNLIM	-40 to 85	LM431 AIZ	Samples
LM431BCM	ACTIVE	SOIC	D	8	95	TBD	Call TI	Call TI	-40 to 85	431 BCM	Samples
LM431BCM/NOPB	ACTIVE	SOIC	D	8	95	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	-40 to 85	431 BCM	Samples
LM431BCM3	ACTIVE	SOT-23	DBZ	3	1000	TBD	Call TI	Call TI	-40 to 85	N1D	Samples
LM431BCM3/NOPB	ACTIVE	SOT-23	DBZ	3	1000	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	-40 to 85	N1D	Samples
LM431BCM3X/NOPB	ACTIVE	SOT-23	DBZ	3	3000	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	-40 to 85	N1D	Samples
LM431BCMX	ACTIVE	SOIC	D	8	2500	TBD	Call TI	Call TI	-40 to 85	431 BCM	Samples
LM431BCMX/NOPB	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	-40 to 85	431 BCM	Samples
LM431BCZ/NOPB	ACTIVE	TO-92	LP	3	1800	Green (RoHS & no Sb/Br)	SNCU	Level-1-NA-UNLIM	-40 to 85	LM431 BCZ	Samples
LM431BIM	ACTIVE	SOIC	D	8	95	TBD	Call TI	Call TI	-40 to 85	431 BIM	Samples
LM431BIM/NOPB	ACTIVE	SOIC	D	8	95	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	-40 to 85	431 BIM	Samples
LM431BIM3	ACTIVE	SOT-23	DBZ	3	1000	TBD	Call TI	Call TI	-40 to 85	N1C	Samples
LM431BIM3/NOPB	ACTIVE	SOT-23	DBZ	3	1000	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	-40 to 85	N1C	Samples
LM431BIM3X	ACTIVE	SOT-23	DBZ	3	3000	TBD	Call TI	Call TI	-40 to 85	N1C	Samples
LM431BIM3X/NOPB	ACTIVE	SOT-23	DBZ	3	3000	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	-40 to 85	N1C	Samples
LM431BIMX/NOPB	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	-40 to 85	431 BIM	Samples

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish	MSL Peak Temp (3)	Op Temp (°C)	Top-Side Markings (4)	Samples
LM431CCM/NOPB	ACTIVE	SOIC	D	8	95	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	-40 to 85	431 CCM	Samples
LM431CCM3	ACTIVE	SOT-23	DBZ	3	1000	TBD	Call TI	Call TI	-40 to 85	N1B	Samples
LM431CCM3/NOPB	ACTIVE	SOT-23	DBZ	3	1000	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	-40 to 85	N1B	Samples
LM431CCM3X	ACTIVE	SOT-23	DBZ	3	3000	TBD	Call TI	Call TI	-40 to 85	N1B	Samples
LM431CCM3X/NOPB	ACTIVE	SOT-23	DBZ	3	3000	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	-40 to 85	N1B	Samples
LM431CCZ/NOPB	ACTIVE	TO-92	LP	3	1800	Green (RoHS & no Sb/Br)	SNCU	Level-1-NA-UNLIM	-40 to 85	LM431 CCZ	Samples
LM431CIM	ACTIVE	SOIC	D	8	95	TBD	Call TI	Call TI	-40 to 85	431 CIM	Samples
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	ACTIVE	SOT-23	DBZ	3	1000	TBD	Call TI	Call TI	-40 to 85	N1A	Samples
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	ACTIVE	SOT-23	DBZ	3	3000	TBD	Call TI	Call TI	-40 to 85	N1A	Samples
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)	SNCU	Level-1-NA-UNLIM		LM431 CIZ	Samples
LM431CIZ/NOPB	ACTIVE	TO-92	LP	3	1800	Green (RoHS & no Sb/Br)	SNCU	Level-1-NA-UNLIM	-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) Multiple Top-Side Markings will be inside parentheses. Only one Top-Side 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 Top-Side Marking for that device.

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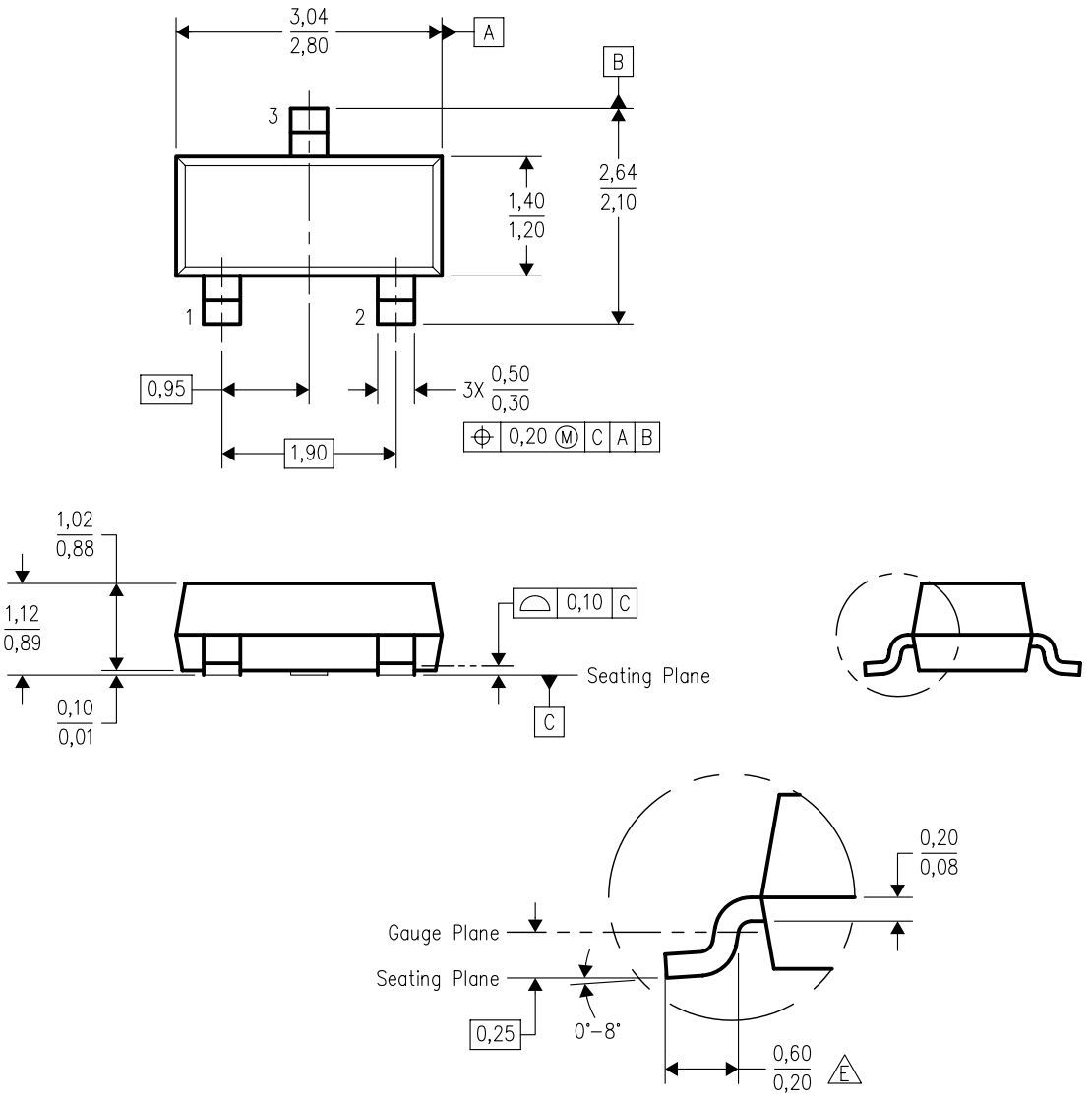
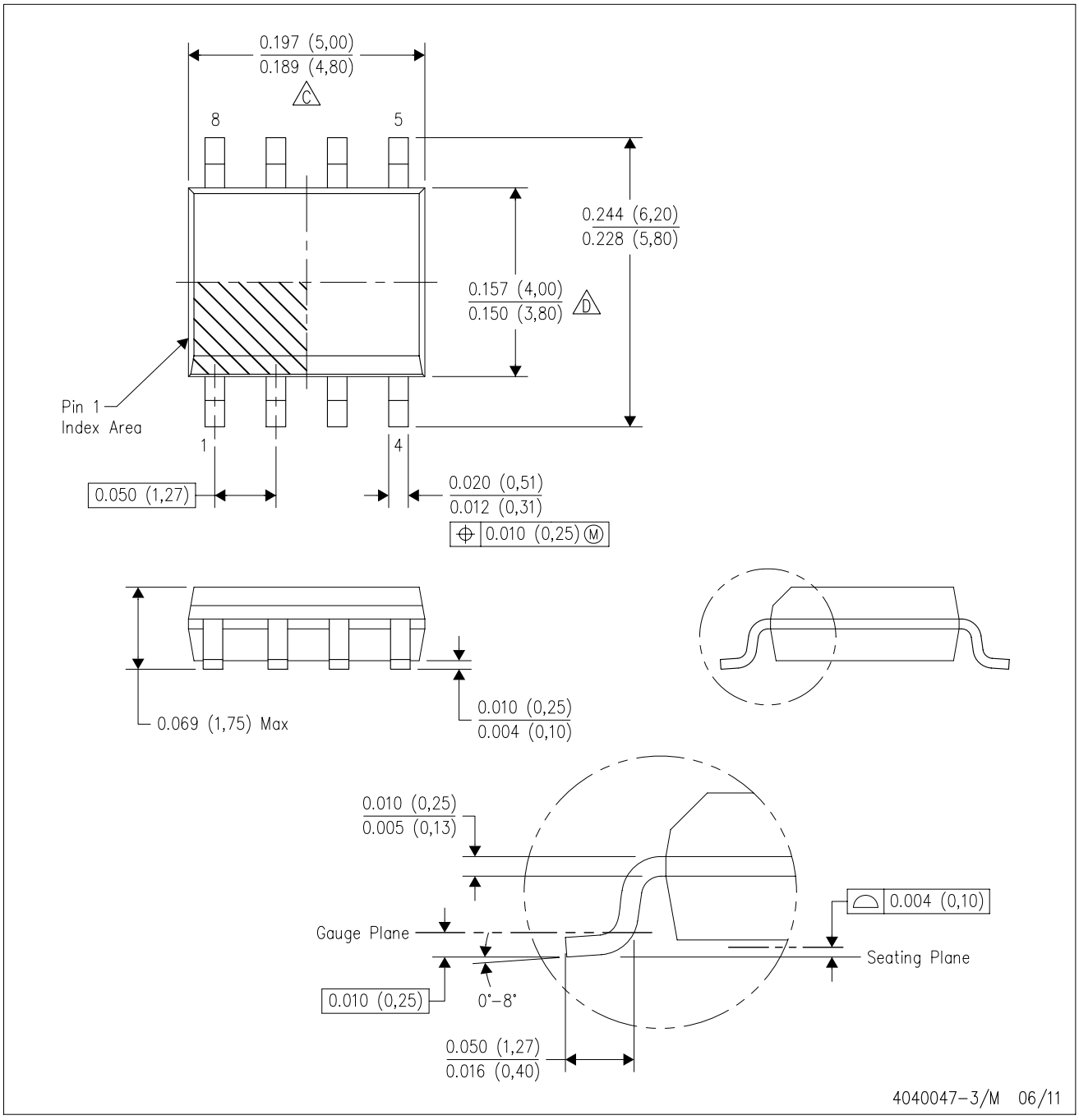
DBZ (R–PDSO–G3) PLASTIC SMALL–OUTLINE



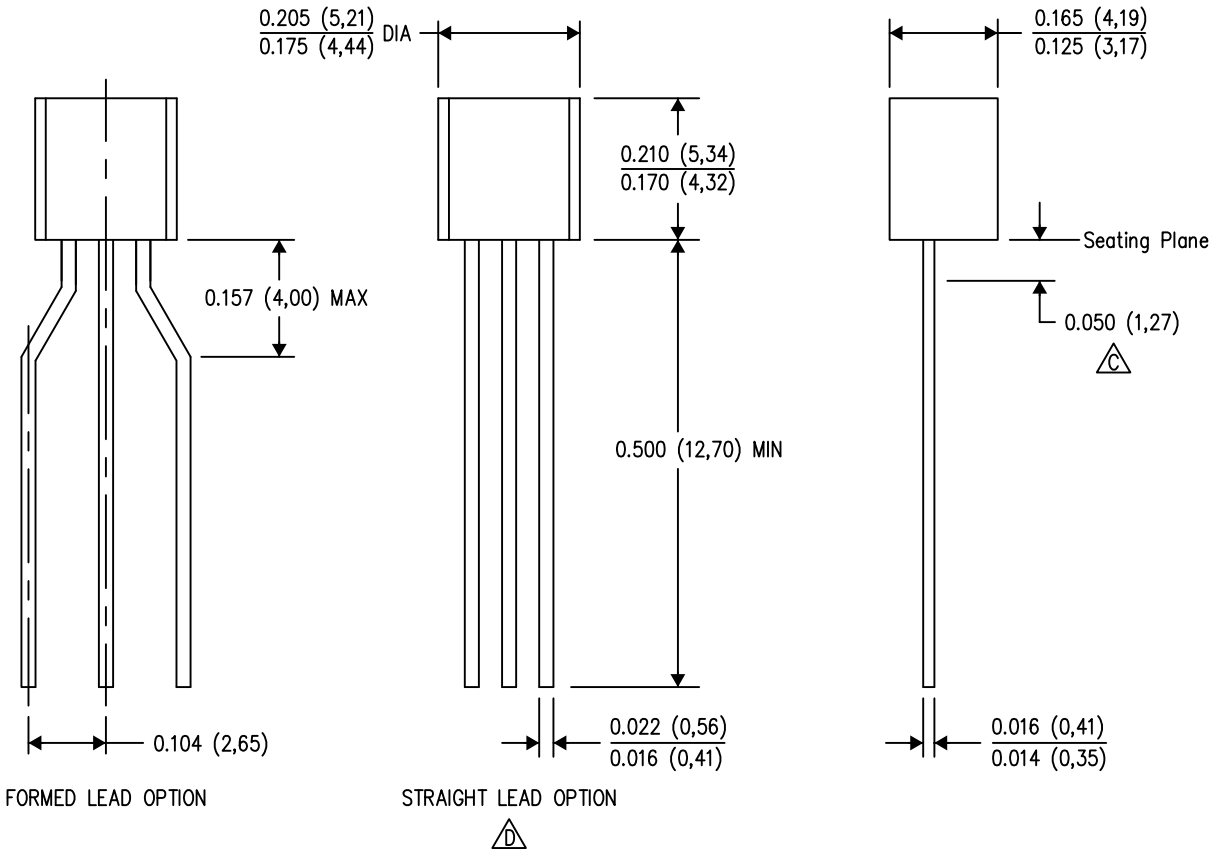
NOTES:
A. All linear dimensions are in millimeters. Dimensioning and tolerancing per ASME Y14.5M–1994.
B. This drawing is subject to change without notice.
C. Lead dimensions are inclusive of plating.
D. Body dimensions are exclusive of mold flash and protrusion. Mold flash and protrusion not to exceed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

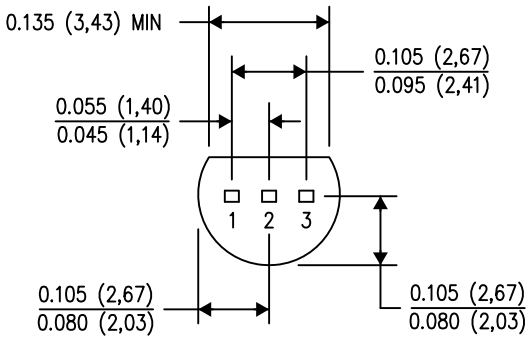
D (R–PDSO–G8) PLASTIC SMALL OUTLINE



NOTES:
A. All linear dimensions are in inches (millimeters).
B. This drawing is subject to change without notice.
C. Body length does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.006 (0,15) each side.
D. Body width does not include interlead flash. Interlead flash shall not exceed 0.017 (0,43) each side.
E. Reference JEDEC MS–012 variation AA.

LP (O–PBCY–W3) PLASTIC CYLINDRICAL PACKAGE

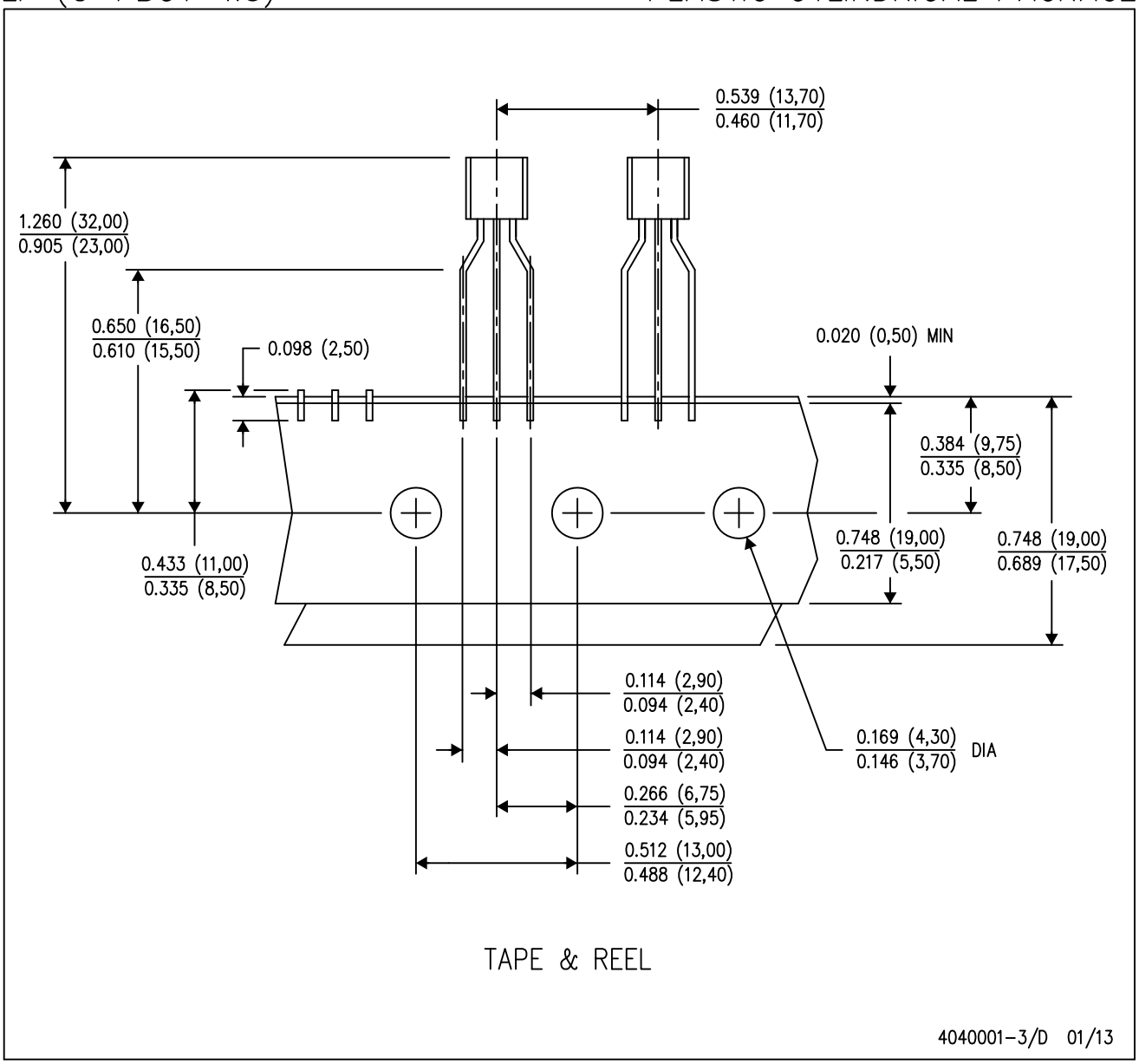




4040001–2/D 01/13

NOTES:
A. All linear dimensions are in inches (millimeters).
B. This drawing is subject to change without notice.
C. Lead dimensions are not controlled within this area.
D. Falls within JEDEC TO–226 Variation AA (TO–226 replaces TO–92).
E. Shipping Method:
Straight lead option available in either bulk pack or tape & reel.
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.

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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