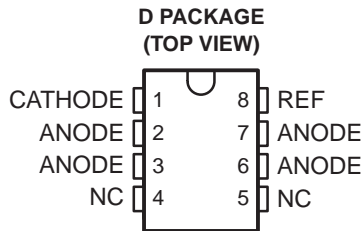


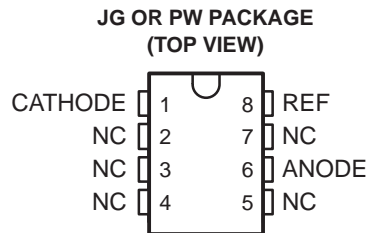
TL1431 PRECISION PROGRAMMABLE REFERENCE

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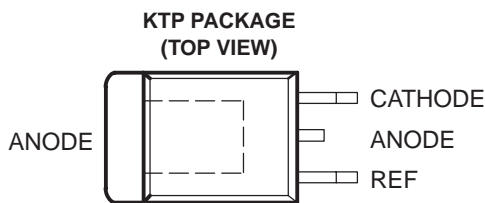
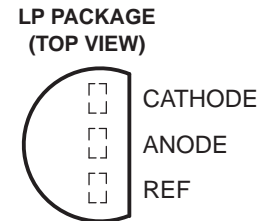
- 0.4% Initial Voltage Tolerance
- 0.2-Ω Typical Output Impedance
- Fast Turnon . . . 500 ns
- Sink Current Capability . . . 1 mA to 100 mA
- Low Reference Current (REF)
- Adjustable Output Voltage . . . $V_{I(\text{ref})}$ to 36 V



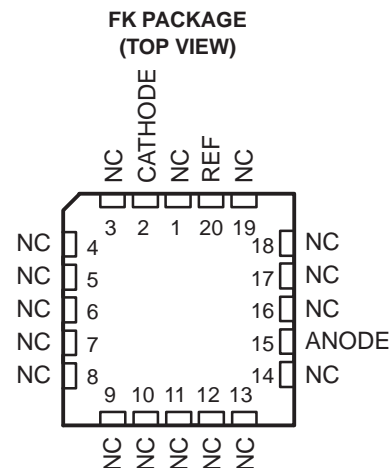
NC – No internal connection
ANODE terminals are connected internally.



NC – No internal connection



The ANODE terminal is in electrical contact with the mounting base.



description/ordering information

The TL1431 is a precision programmable reference with specified thermal stability over automotive, commercial, and military temperature ranges. The output voltage can be set to any value between $V_{I(\text{ref})}$ (approximately 2.5 V) and 36 V with two external resistors (see Figure 16). This device has a typical output impedance of 0.2 Ω. Active output circuitry provides a very sharp turnon characteristic, making the device an excellent replacement for Zener diodes and other types of references in applications such as onboard regulation, adjustable power supplies, and switching power supplies.

The TL1431C is characterized for operation over the commercial temperature range of 0°C to 70°C. The TL1431Q is characterized for operation over the full automotive temperature range of –40°C to 125°C. The TL1431M is characterized for operation over the full military temperature range of –55°C to 125°C.



Please be aware that an important notice concerning availability, standard warranty, and use in critical applications of Texas Instruments semiconductor products and disclaimers thereto appears at the end of this data sheet.

PRODUCTION DATA information is current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.

**TEXAS
INSTRUMENTS**

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On products compliant to MIL-PRF-38535, all parameters are tested unless otherwise noted. On all other products, production processing does not necessarily include testing of all parameters.

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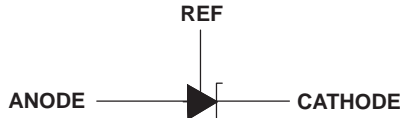
description/ordering information (continued)

ORDERING INFORMATION

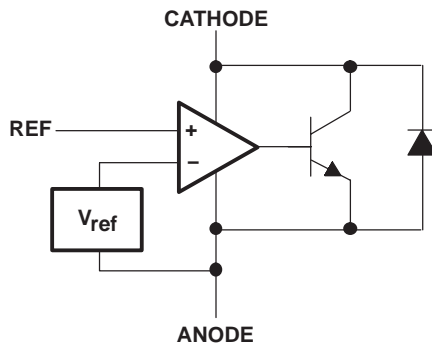
TA	PACKAGE†		ORDERABLE PART NUMBER	TOP-SIDE MARKING
0°C to 70°C	POWER-FLEX (KTP)	Reel of 3000	TL1431CKTPR	TL1431C
	SOIC (D)	Tube of 75	TL1431CD	1431C
		Reel of 2500	TL1431CDR	
	TO-226 / TO-92 (LP)	Bulk of 1000	TL1431CLP	TL1431C
		Reel of 2000	TL1431CLPR	
	TSSOP (PW)	Tube of 150	TL1431CPW	T1431
Reel of 2000		TL1431CPWR		
-40°C to 125°C	SOIC (D)	Tube of 75	TL1431QD	TL1431QD
		Reel of 2500	TL1431QDR	
	TO-226 / TO-92 (LP)	Bulk of 1000	TL1431QLP	TL1431QLP
		Reel of 2000	TL1431QLPR	
	TSSOP (PW)	Tube of 150	TL1431QPW	T1431QPW
		Reel of 2000	TL1431QPWR	
-55°C to 125°C	CDIP (JG)	Tube of 50	TL1431MJG	TL1431MJG
	LCCC (FK)	Tube of 55	TL1431MFK	TL1431MFK

† Package drawings, standard packing quantities, thermal data, symbolization, and PCB design guidelines are available at www.ti.com/sc/package.

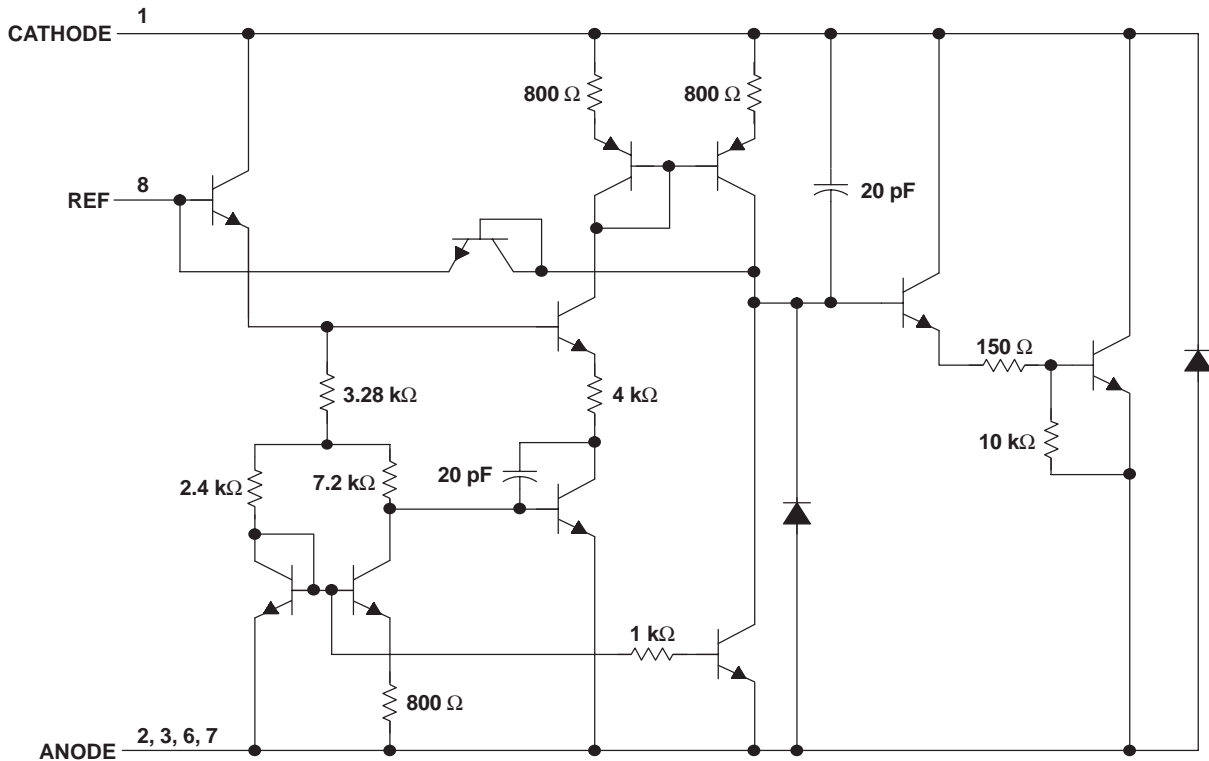
symbol



functional block diagram



equivalent schematic†



† All component values are nominal.
Pin numbers shown are for the D package.

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)‡

Cathode voltage, V_{KA} (see Note 1)	37 V
Continuous cathode current range, I_{KA}	-100 mA to 150 mA
Reference input current range, $I_{I(ref)}$	-50 μ A to 10 mA
Package thermal impedance, θ_{JA} (see Notes 2 and 3): D package	97°C/W
(see Notes 2 and 4): KTP package	28°C/W
(see Notes 2 and 3): LP package	140°C/W
(see Notes 2 and 3): PW package	149°C/W
Package thermal impedance, θ_{JC} (see Notes 5 and 6): FK package	5.61°C/W
JG package	14.5°C/W
Operating virtual junction temperature, T_J	150°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds	260°C
Storage temperature range, T_{stg}	-65°C to 150°C

‡ Stresses beyond those listed under “absolute maximum ratings” may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under “recommended operating conditions” is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

- NOTES:
1. All voltage values are with respect to ANODE, unless otherwise noted.
 2. Maximum power dissipation is a function of $T_J(max)$, θ_{JA} , and T_A . The maximum allowable power dissipation at any allowable ambient temperature is $P_D = (T_J(max) - T_A)/\theta_{JA}$. Operating at the absolute maximum T_J of 150°C can affect reliability.
 3. The package thermal impedance is calculated in accordance with JESD 51-7.
 4. The package thermal impedance is calculated in accordance with JESD 51-5.
 5. Maximum power dissipation is a function of $T_J(max)$, θ_{JC} , and T_C . The maximum allowable power dissipation at any allowable case temperature is $P_D = (T_J(max) - T_C)/\theta_{JC}$. Operating at the absolute maximum T_J of 150°C can affect reliability.
 6. The package thermal impedance is calculated in accordance with MIL-STD-883.

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recommended operating conditions

		MIN	MAX	UNIT	
V _{KA}	Cathode voltage	V _{I(ref)}	36	V	
I _{KA}	Cathode current	1	100	mA	
T _A	Operating free-air temperature	TL1431C	0	70	°C
		TL1431Q	-40	125	
		TL1431M	-55	125	

electrical characteristics at specified free-air temperature, I_{KA} = 10 mA (unless otherwise noted)

PARAMETER	TEST CONDITIONS	T _A †	TEST CIRCUIT	TL1431C			UNIT
				MIN	TYP	MAX	
V _{I(ref)}	Reference input voltage	25°C	Figure 1	2490	2500	2510	mV
		Full range		2480		2520	
V _{I(dev)}	Deviation of reference input voltage over full temperature range‡	Full range	Figure 1		4	20	mV
$\frac{\Delta V_{I(ref)}}{\Delta V_{KA}}$	Ratio of change in reference input voltage to the change in cathode voltage	Full range	Figure 2		-1.1	-2	mV/V
I _{I(ref)}	Reference input current	25°C	Figure 2		1.5	2.5	µA
		Full range				3	
I _{I(dev)}	Deviation of reference input current over full temperature range‡	Full range	Figure 2		0.2	1.2	µA
I _{min}	Minimum cathode current for regulation	25°C	Figure 1		0.45	1	mA
I _{off}	Off-state cathode current	25°C	Figure 3		0.18	0.5	µA
		Full range				2	
z _{KA}	Output impedance§	25°C	Figure 1		0.2	0.4	Ω

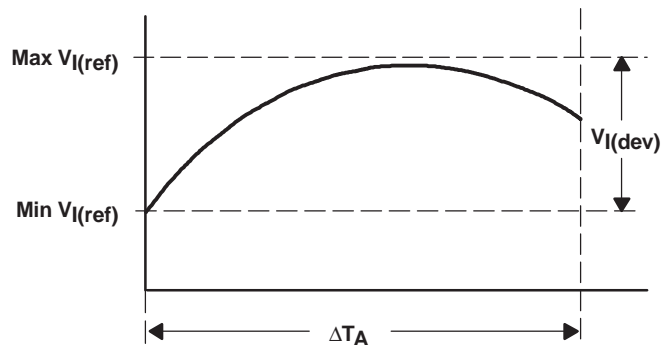
† Full range is 0°C to 70°C for C-suffix devices.

‡ The deviation parameters V_{I(dev)} and I_{I(dev)} are defined as the differences between the maximum and minimum values obtained over the rated temperature range. The average full-range temperature coefficient of the reference input voltage $\alpha_{V_{I(ref)}}$ is defined as:

$$|\alpha_{V_{I(ref)}}| \left(\frac{\text{ppm}}{^{\circ}\text{C}} \right) = \frac{\left(\frac{V_{I(dev)}}{V_{I(ref) \text{ at } 25^{\circ}\text{C}}} \right) \times 10^6}{\Delta T_A}$$

where:

ΔT_A is the rated operating temperature range of the device.



$\alpha_{V_{I(ref)}}$ is positive or negative, depending on whether minimum V_{I(ref)} or maximum V_{I(ref)}, respectively, occurs at the lower temperature.

§ The output impedance is defined as: $|z_{KA}| = \frac{\Delta V_{KA}}{\Delta I_{KA}}$

When the device is operating with two external resistors (see Figure 2), the total dynamic impedance of the circuit is given by: $|z'| = \frac{\Delta V}{\Delta I}$,

which is approximately equal to $|z_{KA}| \left(1 + \frac{R1}{R2} \right)$.



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electrical characteristics at specified free-air temperature, $I_{KA} = 10 \text{ mA}$ (unless otherwise noted)

PARAMETER	TEST CONDITIONS	T_A †	TEST CIRCUIT	TL1431Q			TL1431M			UNIT
				MIN	TYP	MAX	MIN	TYP	MAX	
$V_{I(\text{ref})}$ Reference input voltage	$V_{KA} = V_{I(\text{ref})}$	25°C	Figure 1	2490	2500	2510	2475	2500	2540	mV
		Full range		2470		2530	2460		2550	
$V_{I(\text{dev})}$ Deviation of reference input voltage over full temperature range ‡	$V_{KA} = V_{I(\text{ref})}$	Full range	Figure 1		17	55		17	55*	mV
$\frac{\Delta V_{I(\text{ref})}}{\Delta V_{KA}}$ Ratio of change in reference input voltage to the change in cathode voltage	$\Delta V_{KA} = 3 \text{ V to } 36 \text{ V}$	Full range	Figure 2		-1.1	-2		-1.1	-2	mV/V
$I_{I(\text{ref})}$ Reference input current	$R1 = 10 \text{ k}\Omega, R2 = \infty$	25°C	Figure 2		1.5	2.5		1.5	2.5	μA
		Full range				4			5	
$I_{I(\text{dev})}$ Deviation of reference input current over full temperature range ‡	$R1 = 10 \text{ k}\Omega, R2 = \infty$	Full range	Figure 2		0.5	2		0.5	3*	μA
I_{min} Minimum cathode current for regulation	$V_{KA} = V_{I(\text{ref})}$	25°C	Figure 1		0.45	1		0.45	1	mA
I_{off} Off-state cathode current	$V_{KA} = 36 \text{ V}, V_{I(\text{ref})} = 0$	25°C	Figure 3		0.18	0.5		0.18	0.5	μA
		Full range				2			2	
$ z_{KA} $ Output impedance §	$V_{KA} = V_{I(\text{ref})}, f \leq 1 \text{ kHz}, I_{KA} = 1 \text{ mA to } 100 \text{ mA}$	25°C	Figure 1		0.2	0.4		0.2	0.4	Ω

*On products compliant to MIL-PRF-38535, this parameter is not production tested.

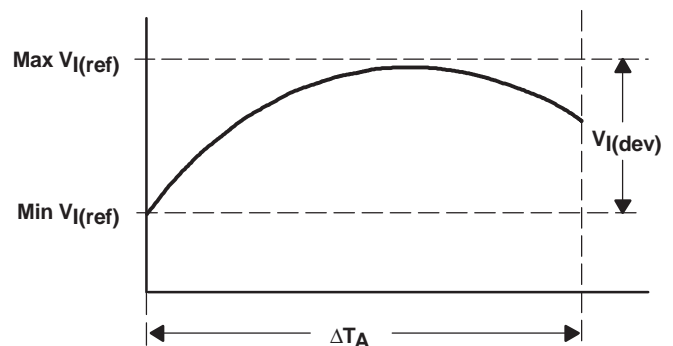
† Full range is -40°C to 125°C for Q-suffix devices and -55°C to 125°C for M-suffix devices.

‡ The deviation parameters $V_{I(\text{dev})}$ and $I_{I(\text{dev})}$ are defined as the differences between the maximum and minimum values obtained over the rated temperature range. The average full-range temperature coefficient of the reference input voltage $\alpha_{V_{I(\text{ref})}}$ is defined as:

$$|\alpha_{V_{I(\text{ref})}}| \left(\frac{\text{ppm}}{^\circ\text{C}} \right) = \frac{\left(\frac{V_{I(\text{dev})}}{V_{I(\text{ref}) \text{ at } 25^\circ\text{C}}} \right) \times 10^6}{\Delta T_A}$$

where:

ΔT_A is the rated operating temperature range of the device.



$\alpha_{V_{I(\text{ref})}}$ is positive or negative, depending on whether minimum $V_{I(\text{ref})}$ or maximum $V_{I(\text{ref})}$, respectively, occurs at the lower temperature.

§ The output impedance is defined as: $|z_{KA}| = \frac{\Delta V_{KA}}{\Delta I_{KA}}$

When the device is operating with two external resistors (see Figure 2), the total dynamic impedance of the circuit is given by: $|z'| = \frac{\Delta V}{\Delta I}$,

which is approximately equal to $|z_{KA}| \left(1 + \frac{R1}{R2} \right)$.

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PARAMETER MEASUREMENT INFORMATION

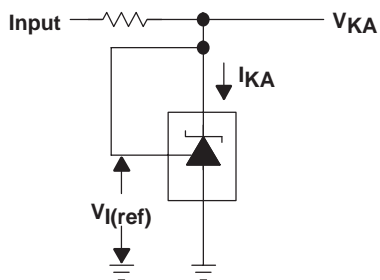


Figure 1. Test Circuit for $V_{(KA)} = V_{ref}$

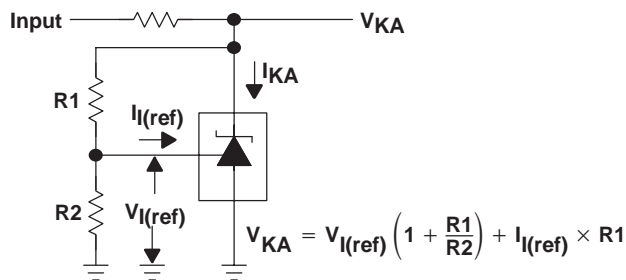


Figure 2. Test Circuit for $V_{(KA)} > V_{ref}$

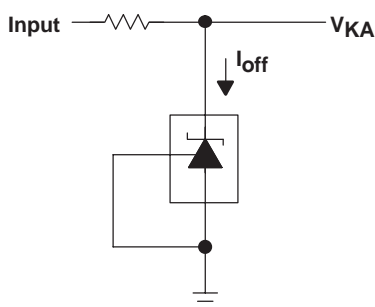


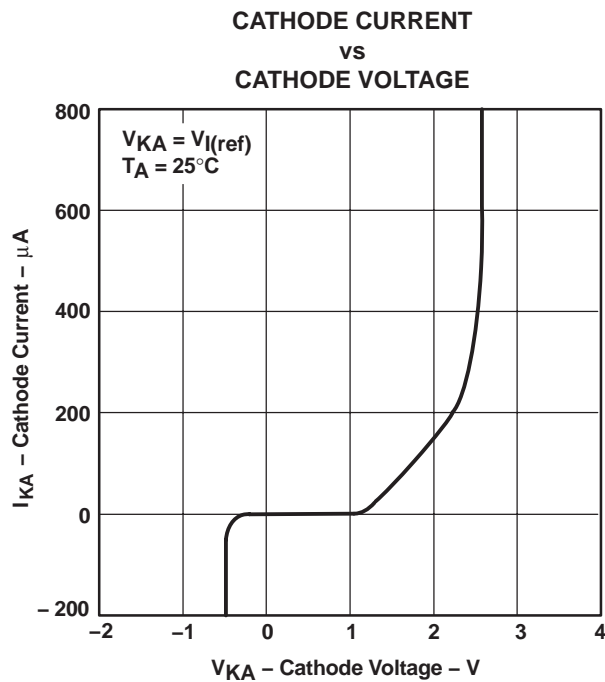
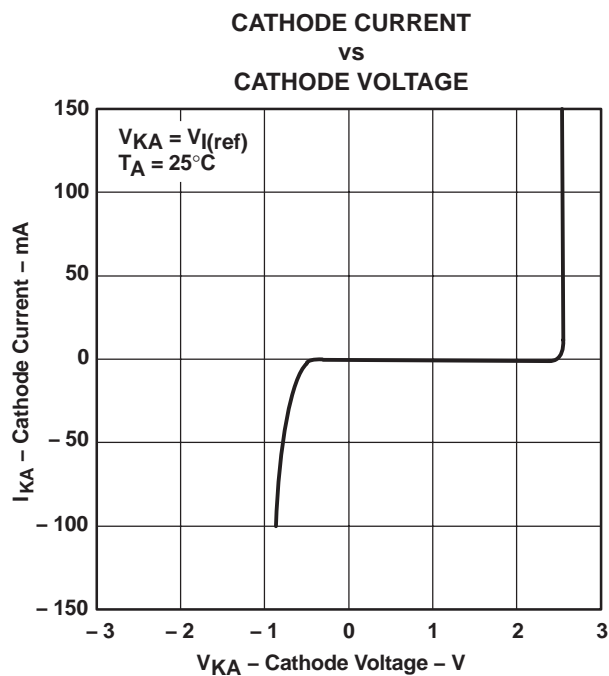
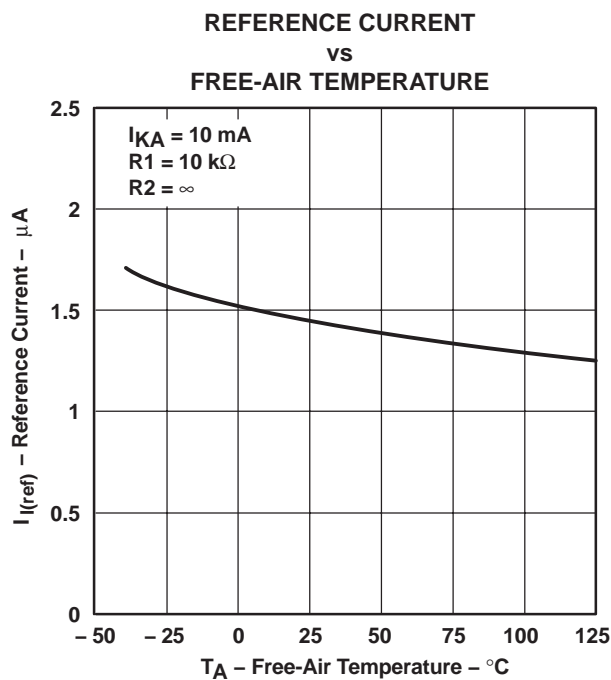
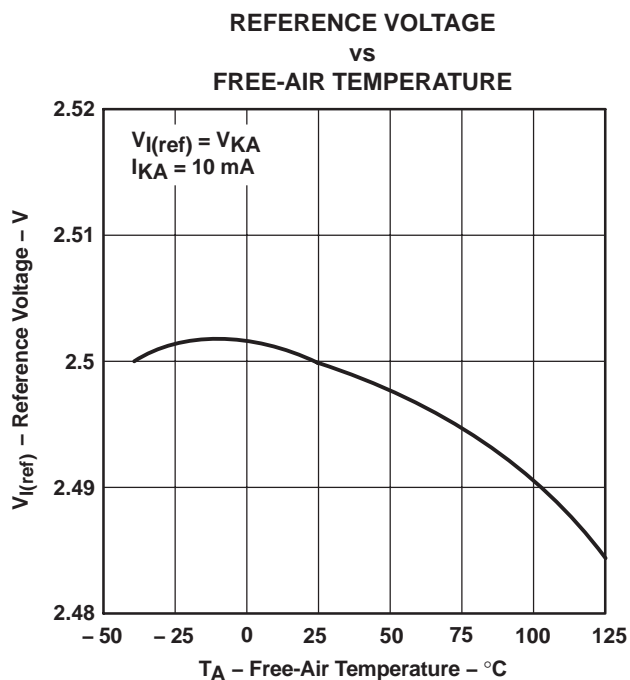
Figure 3. Test Circuit for I_{off}

TYPICAL CHARACTERISTICS

Table of Graphs

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Reference voltage vs Free-air temperature	4
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Equivalent input-noise voltage vs Frequency	10
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Small-signal voltage amplification vs Frequency	12
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Pulse response	14
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TYPICAL CHARACTERISTICS†



† Data at high and low temperatures are applicable only within the recommended operating free-air temperature ranges of the various devices.

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TYPICAL CHARACTERISTICS†

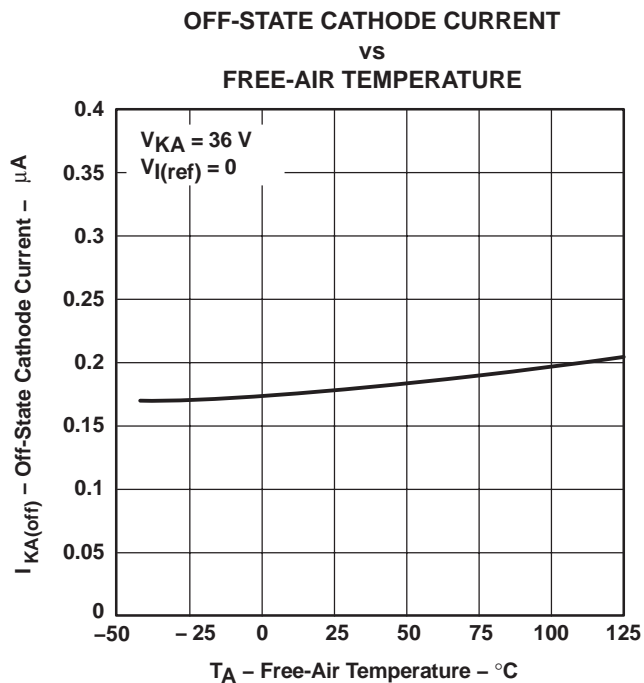


Figure 8

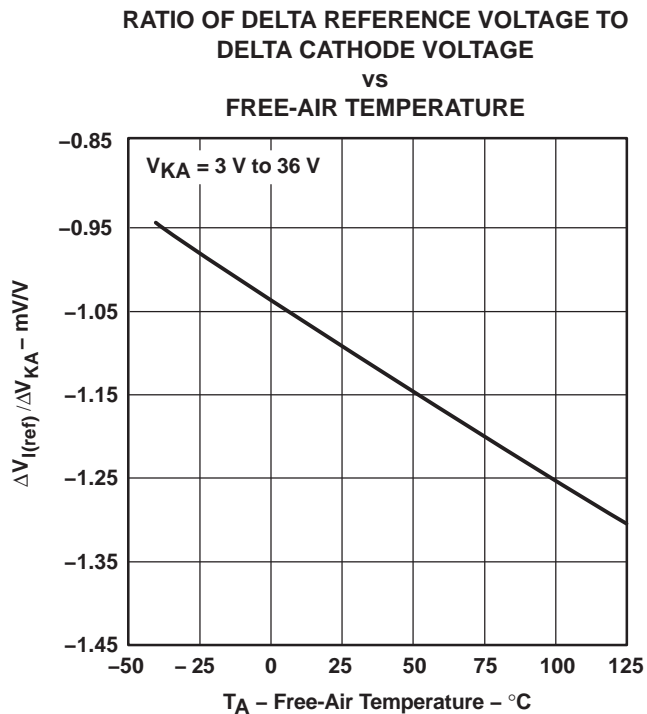


Figure 9

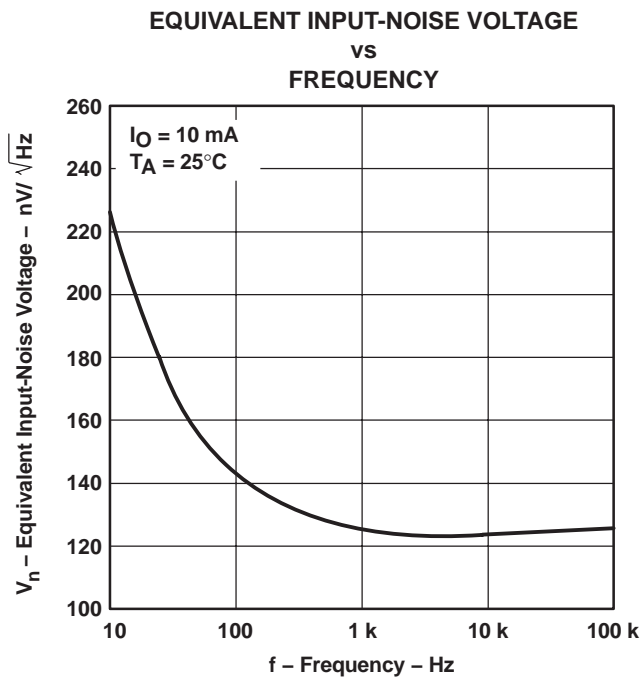


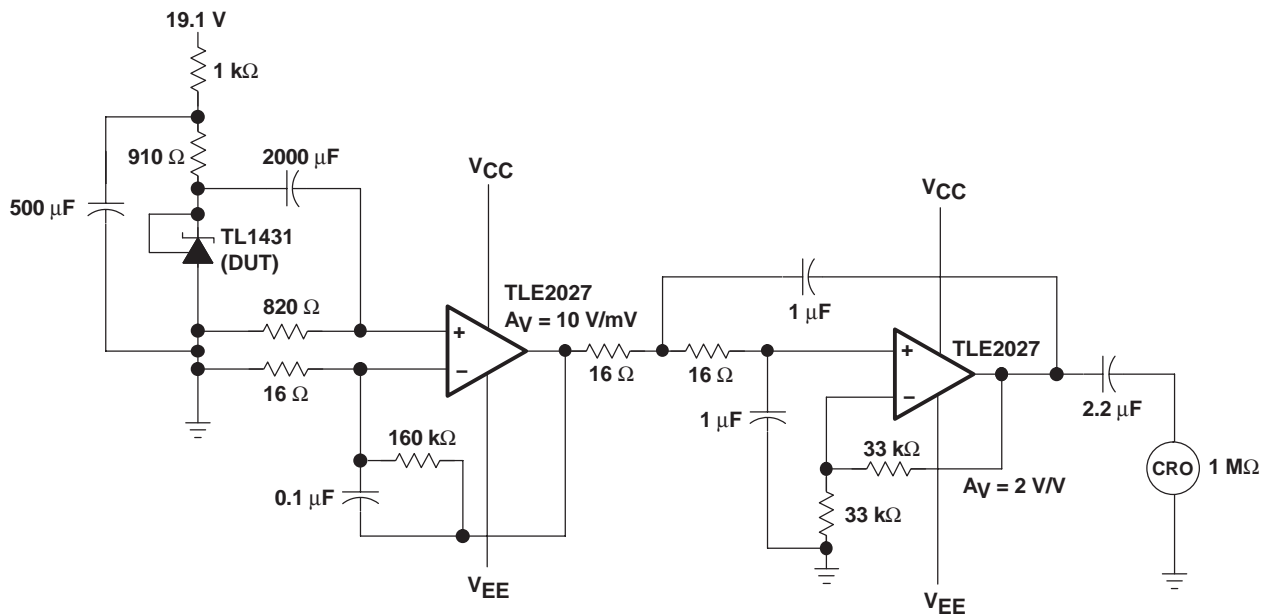
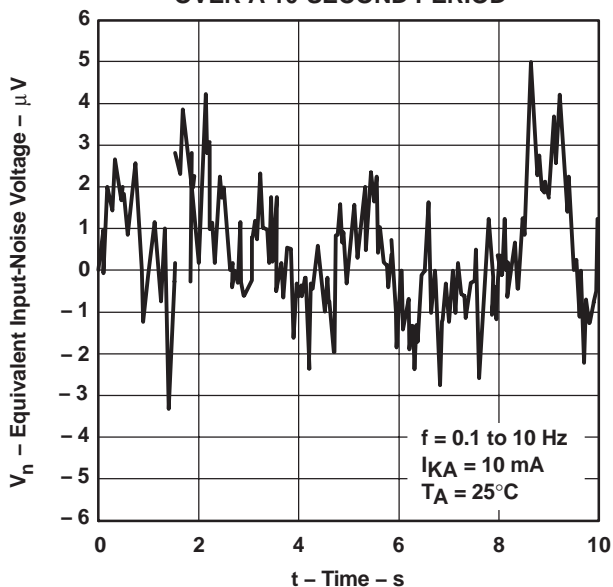
Figure 10

† Data at high and low temperatures are applicable only within the recommended operating free-air temperature ranges of the various devices.



TYPICAL CHARACTERISTICS

EQUIVALENT INPUT-NOISE VOLTAGE
OVER A 10-SECOND PERIOD



TEST CIRCUIT FOR 0.1-Hz TO 10-Hz EQUIVALENT INPUT-NOISE VOLTAGE

Figure 11

TYPICAL CHARACTERISTICS

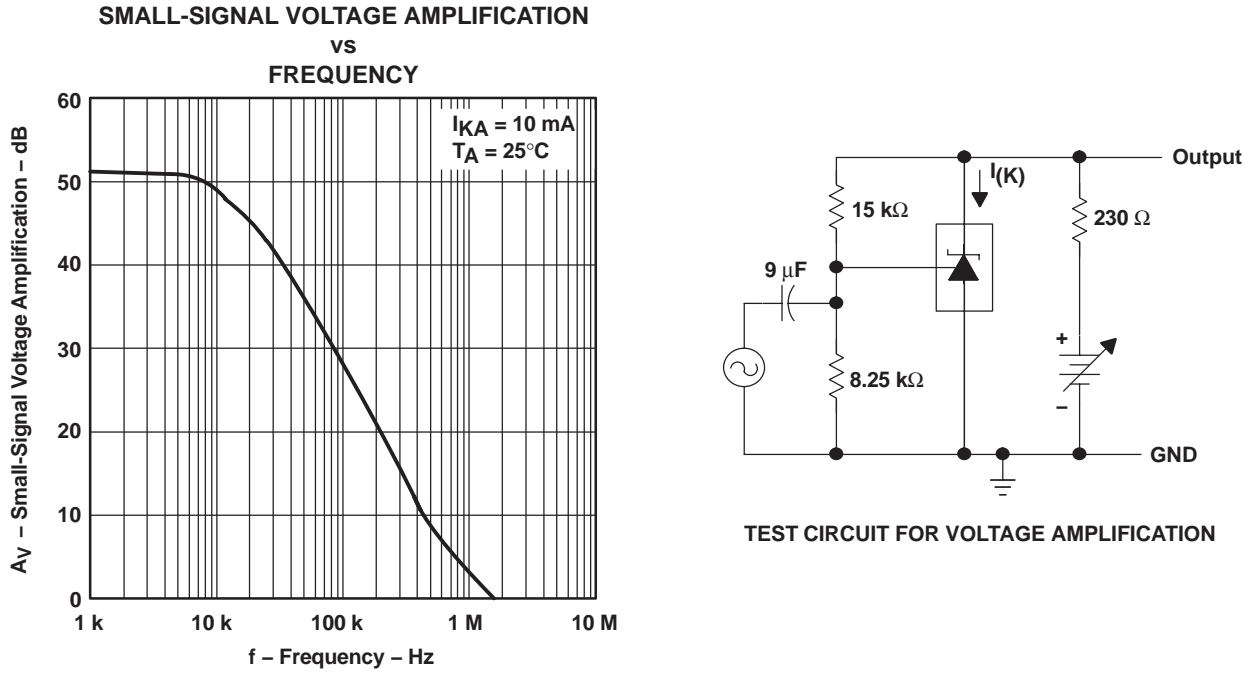


Figure 12

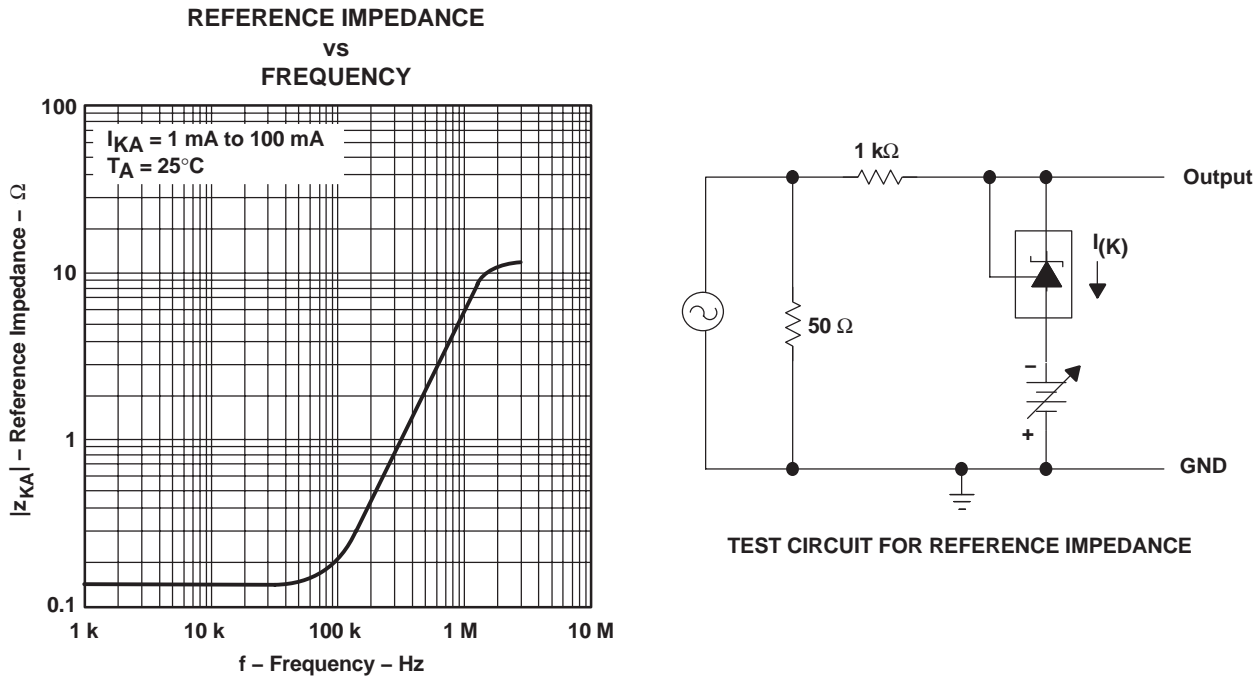


Figure 13

TYPICAL CHARACTERISTICS

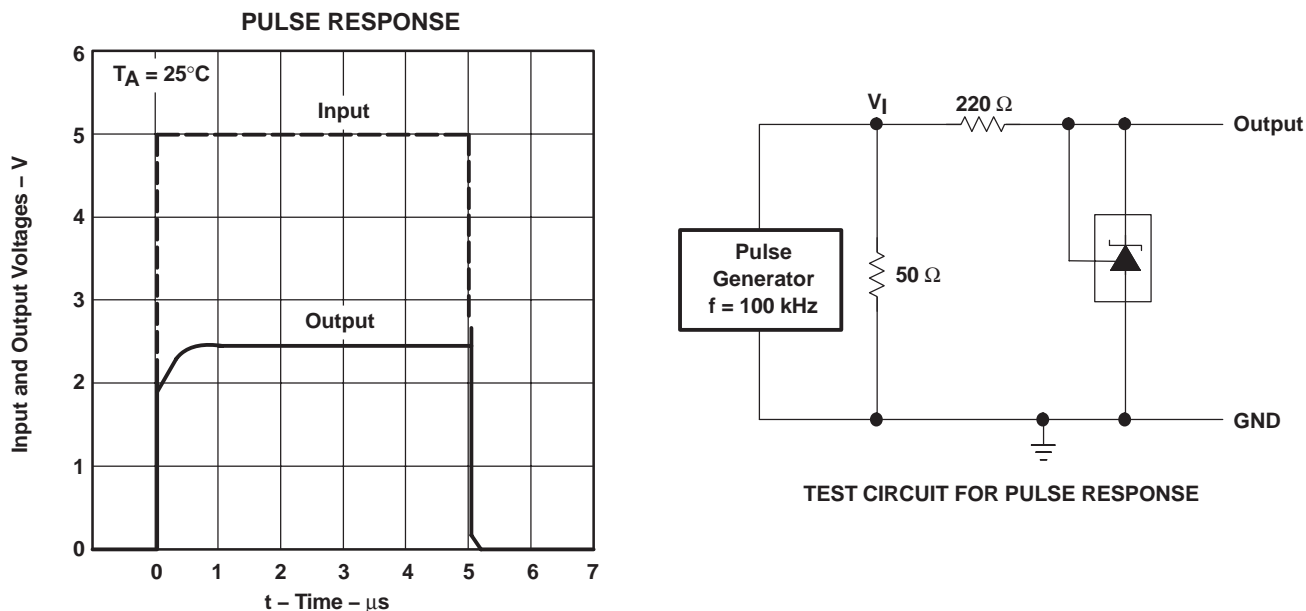


Figure 14

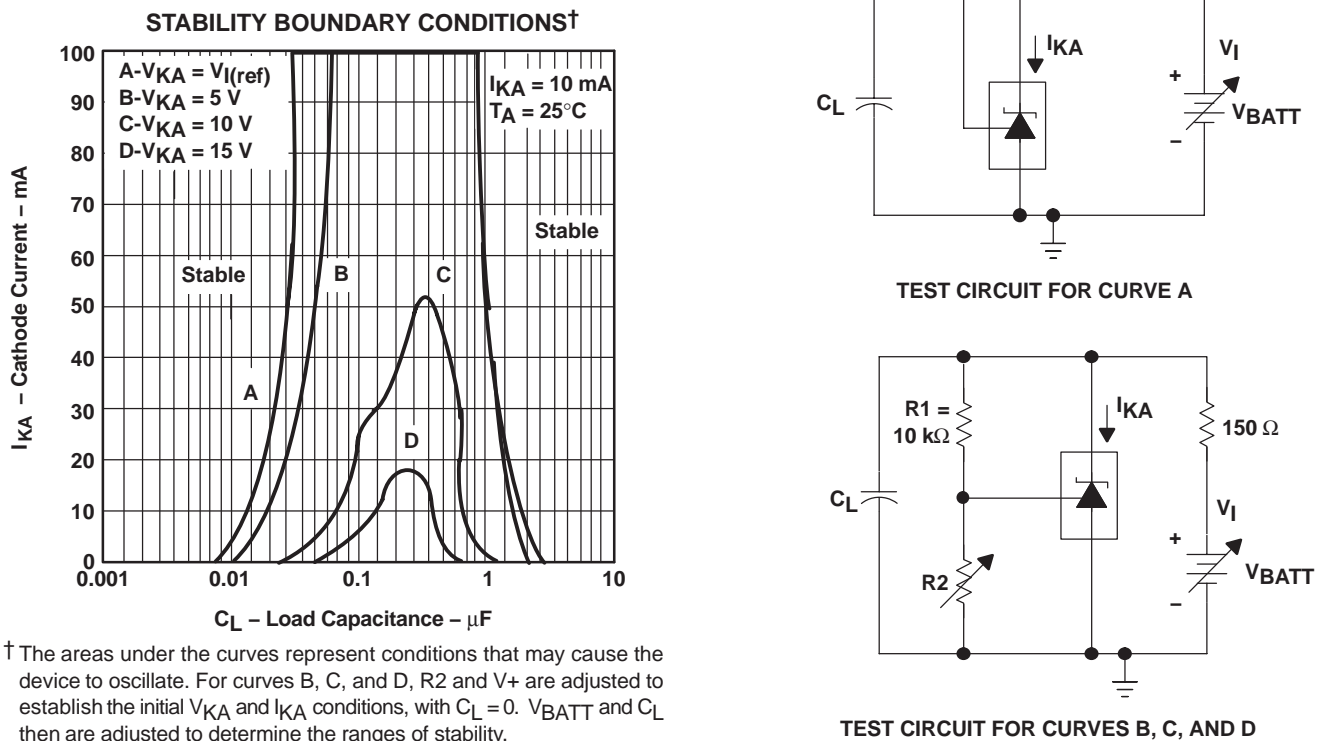
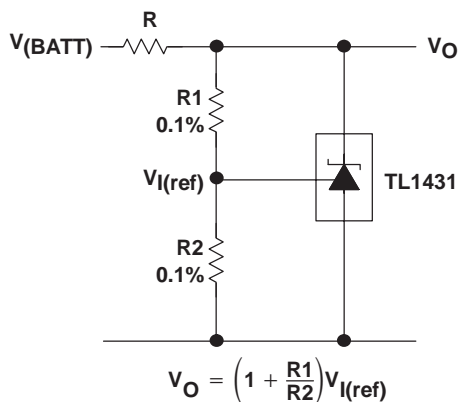


Figure 15

APPLICATION INFORMATION

Table of Application Circuits

APPLICATION	FIGURE
Shunt regulator	16
Single-supply comparator with temperature-compensated threshold	17
Precision high-current series regulator	18
Output control of a three-terminal fixed regulator	19
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Crowbar	21
Precision 5-V, 1.5-A, 0.5% regulator	22
5-V precision regulator	23
PWM converter with 0.5% reference	24
Voltage monitor	25
Delay timer	26
Precision current limiter	27
Precision constant-current sink	28



NOTE A: R should provide cathode current ≥ 1 mA to the TL1431 at minimum $V_{(BATT)}$.

Figure 16. Shunt Regulator

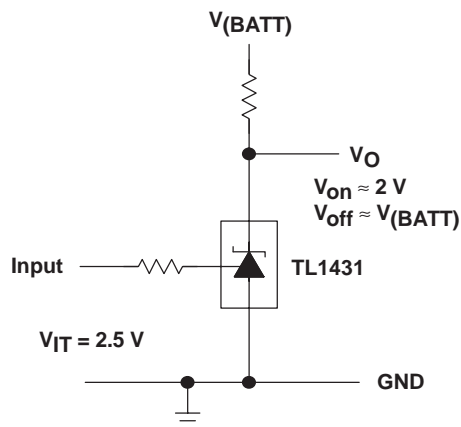
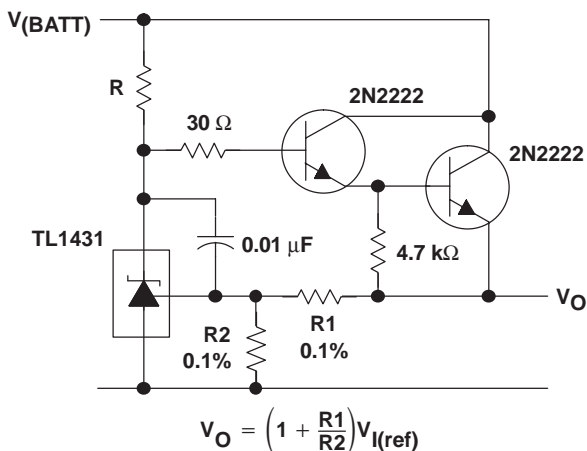


Figure 17. Single-Supply Comparator With Temperature-Compensated Threshold

APPLICATION INFORMATION



NOTE A: R should provide cathode current ≥ 1 mA to the TL1431 at minimum $V(BATT)$.

Figure 18. Precision High-Current Series Regulator

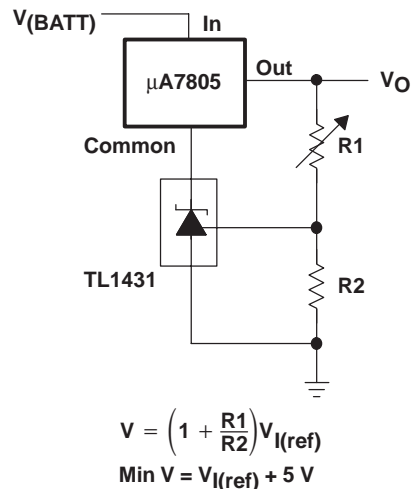


Figure 19. Output Control of a Three-Terminal Fixed Regulator

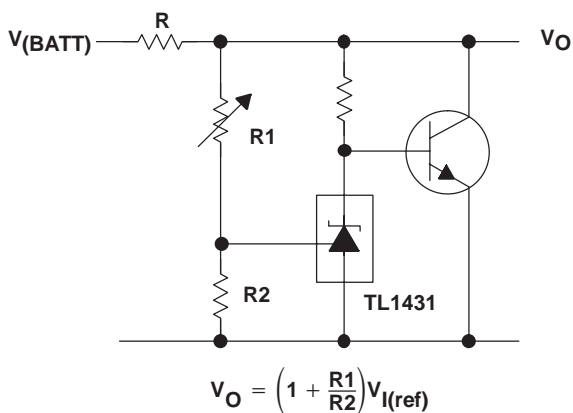
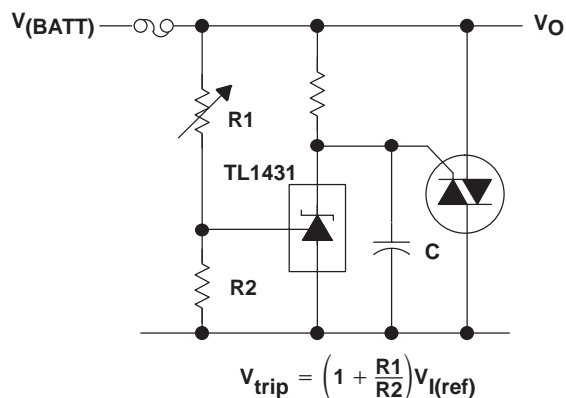


Figure 20. Higher-Current Shunt Regulator



NOTE A: Refer to the stability boundary conditions in Figure 15 to determine allowable values for C.

Figure 21. Crowbar

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APPLICATION INFORMATION

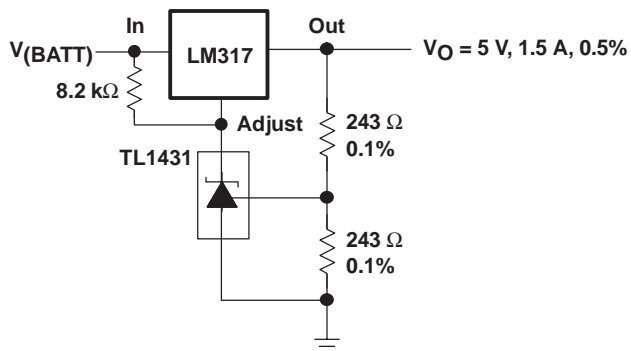
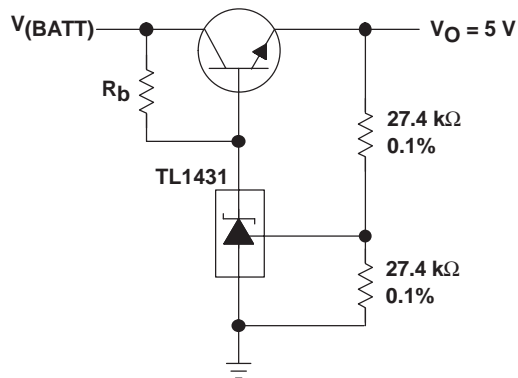


Figure 22. Precision 5-V, 1.5-A, 0.5% Regulator



NOTE A: R_b should provide cathode current $\geq 1\text{ mA}$ to the TL1431.

Figure 23. 5-V Precision Regulator

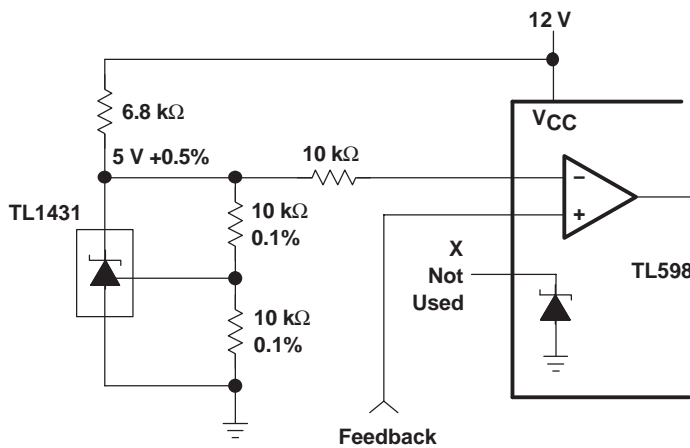
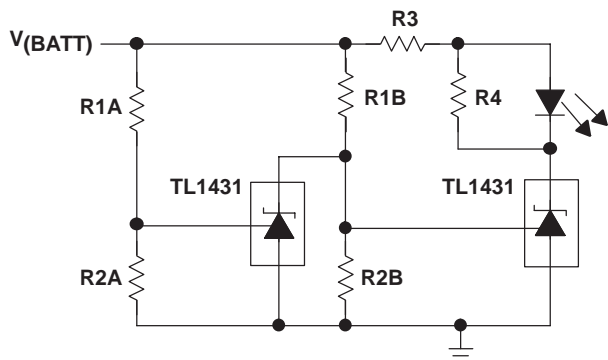


Figure 24. PWM Converter With 0.5% Reference

APPLICATION INFORMATION



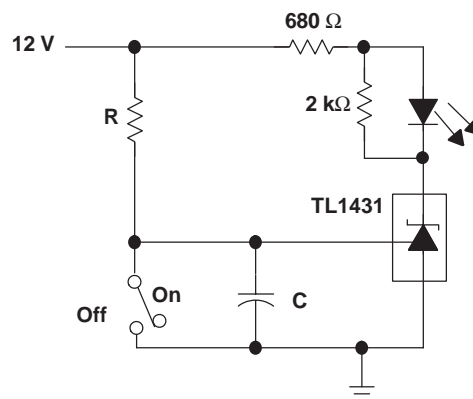
$$\text{Low Limit} = \left(1 + \frac{R1B}{R2B}\right) V_{I(\text{ref})}$$

$$\text{High Limit} = \left(1 + \frac{R1A}{R2A}\right) V_{I(\text{ref})}$$

LED on When
Low Limit < V(BATT) < High Limit

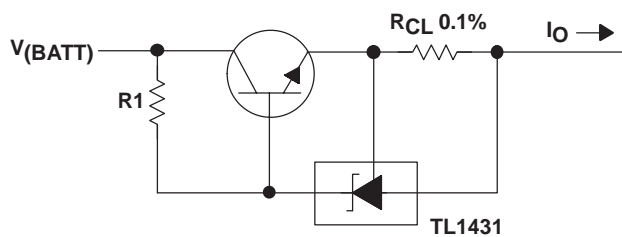
NOTE A: Select R3 and R4 to provide the desired LED intensity and cathode current ≥ 1 mA to the TL1431.

Figure 25. Voltage Monitor



$$\text{Delay} = R \times C \times I_{I(12V) - V_{I(\text{ref})}}$$

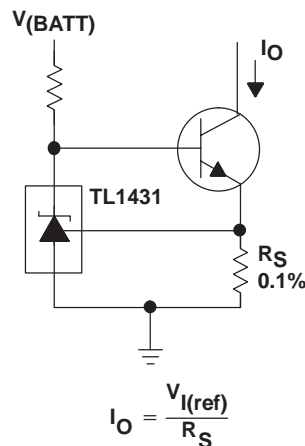
Figure 26. Delay Timer



$$I_O = \frac{V_{I(\text{ref})}}{R_{CL}} + I_{KA}$$

$$R1 = \frac{V_{(BATT)}}{\left(\frac{I_O}{h_{FE}}\right) + I_{KA}}$$

Figure 27. Precision Current Limiter



$$I_O = \frac{V_{I(\text{ref})}}{R_S}$$

Figure 28. Precision Constant-Current Sink

PACKAGING INFORMATION

Orderable Device	Status ⁽¹⁾	Package Type	Package Drawing	Pins	Package Qty	Eco Plan ⁽²⁾	Lead/Ball Finish	MSL Peak Temp ⁽³⁾
5962-9962001Q2A	ACTIVE	LCCC	FK	20	1	TBD	POST-PLATE	Level-NC-NC-NC
5962-9962001QPA	ACTIVE	CDIP	JG	8	1	TBD	A42 SNPB	Level-NC-NC-NC
5962-9962001VPA	ACTIVE	CDIP	JG	8	1	TBD	A42 SNPB	Level-NC-NC-NC
TL1431CD	ACTIVE	SOIC	D	8	75	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TL1431CDE4	ACTIVE	SOIC	D	8	75	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TL1431CDR	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TL1431CDRE4	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TL1431CDRG4	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TL1431CKTPR	OBSOLETE	PFM	KTP	2		TBD	Call TI	Call TI
TL1431CLP	ACTIVE	TO-92	LP	3	1000	TBD	CU SNPB	Level-NC-NC-NC
TL1431CLPM	OBSOLETE	TO-92	LP	3		TBD	Call TI	Call TI
TL1431CLPR	ACTIVE	TO-92	LP	3	2000	TBD	CU SNPB	Level-NC-NC-NC
TL1431CPW	ACTIVE	TSSOP	PW	8	150	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TL1431CPWE4	ACTIVE	TSSOP	PW	8	150	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TL1431CPWR	ACTIVE	TSSOP	PW	8	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TL1431CPWRE4	ACTIVE	TSSOP	PW	8	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TL1431MFK	ACTIVE	LCCC	FK	20	1	TBD	POST-PLATE	Level-NC-NC-NC
TL1431MFKB	ACTIVE	LCCC	FK	20	1	TBD	POST-PLATE	Level-NC-NC-NC
TL1431MJG	ACTIVE	CDIP	JG	8	1	TBD	A42 SNPB	Level-NC-NC-NC
TL1431MJGB	ACTIVE	CDIP	JG	8	1	TBD	A42 SNPB	Level-NC-NC-NC
TL1431QD	ACTIVE	SOIC	D	8	75	Pb-Free (RoHS)	CU NIPDAU	Level-2-250C-1 YEAR/ Level-1-235C-UNLIM
TL1431QDR	ACTIVE	SOIC	D	8	2500	Pb-Free (RoHS)	CU NIPDAU	Level-2-250C-1 YEAR/ Level-1-235C-UNLIM
TL1431QLP	ACTIVE	TO-92	LP	3	1000	TBD	Call TI	Level-1-220C-UNLIM
TL1431QLPR	ACTIVE	TO-92	LP	3	2000	TBD	Call TI	Level-1-220C-UNLIM
TL1431QPWR	ACTIVE	TSSOP	PW	8	2000	TBD	CU NIPDAU	Level-1-250C-UNLIM

⁽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) 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.

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)

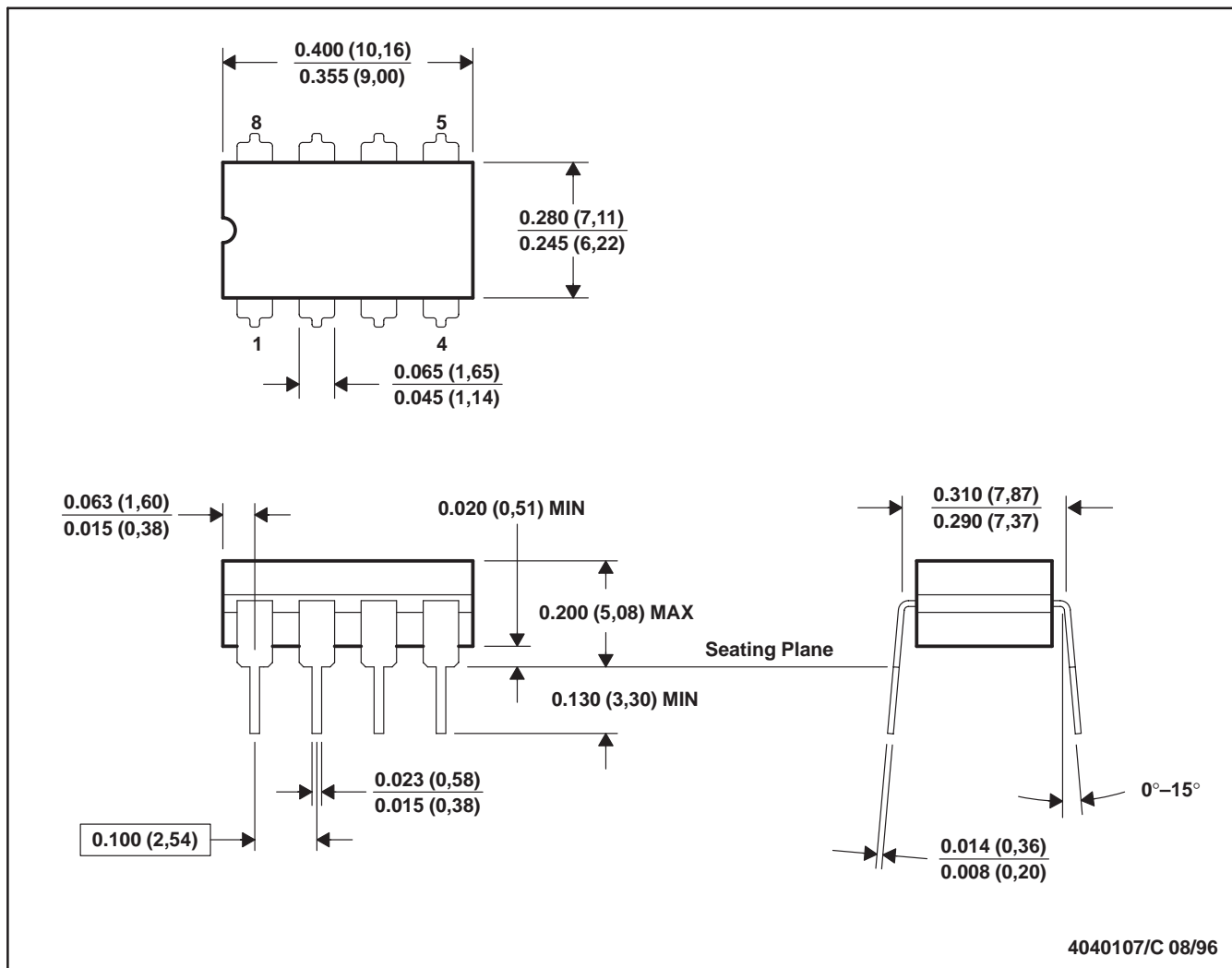
⁽³⁾ MSL, Peak Temp. -- The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

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JG (R-GDIP-T8)

CERAMIC DUAL-IN-LINE



- NOTES: A. All linear dimensions are in inches (millimeters).
 B. This drawing is subject to change without notice.
 C. This package can be hermetically sealed with a ceramic lid using glass frit.
 D. Index point is provided on cap for terminal identification.
 E. Falls within MIL STD 1835 GDIP1-T8

FK (S-CQCC-N**)

LEADLESS CERAMIC CHIP CARRIER

28 TERMINAL SHOWN

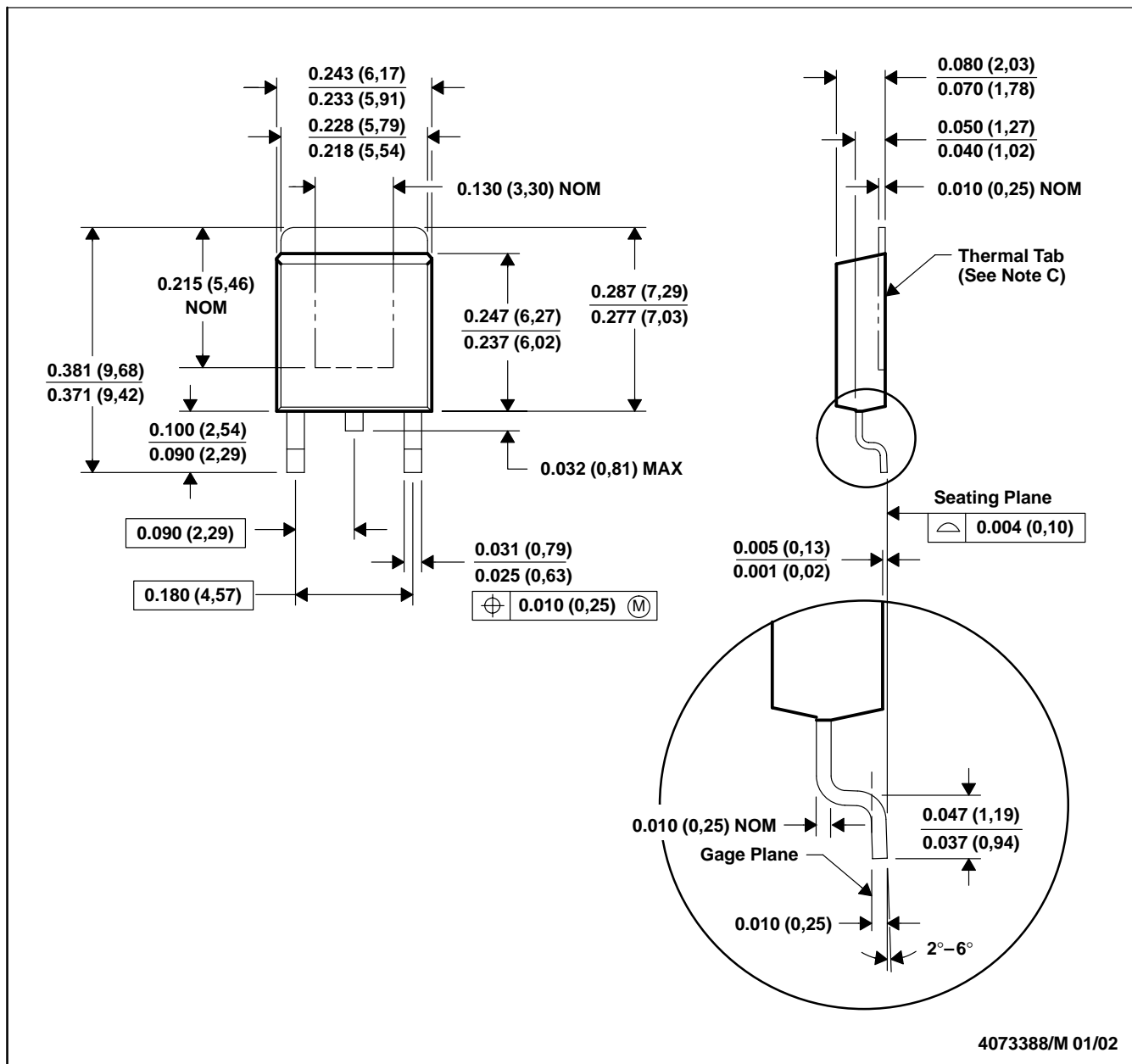


4040140/D 10/96

- NOTES:
- A. All linear dimensions are in inches (millimeters).
 - B. This drawing is subject to change without notice.
 - C. This package can be hermetically sealed with a metal lid.
 - D. The terminals are gold plated.
 - E. Falls within JEDEC MS-004

KTP (R-PSFM-G2)

PowerFLEX™ PLASTIC FLANGE-MOUNT PACKAGE

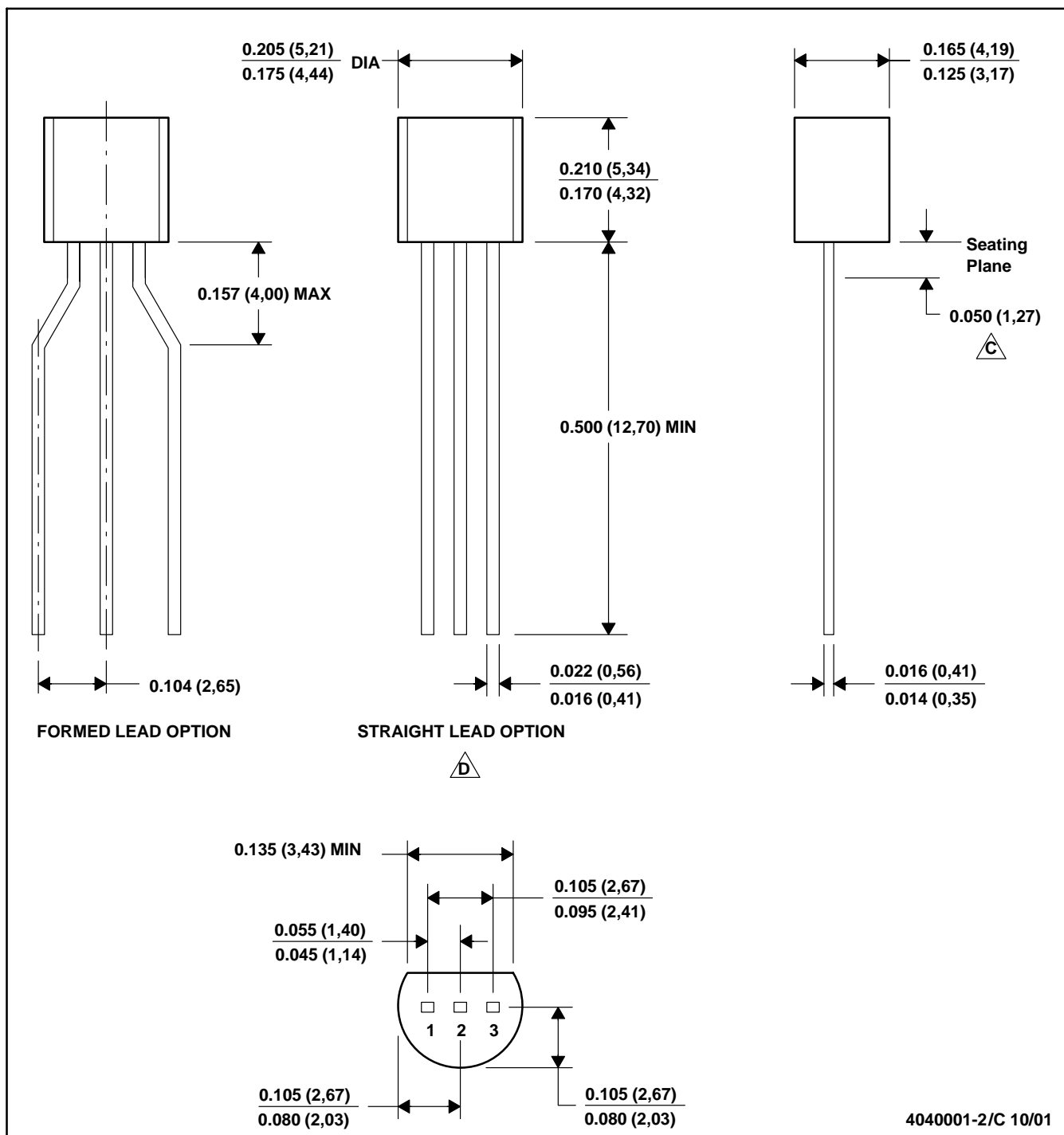


- NOTES: A. All linear dimensions are in inches (millimeters).
 B. This drawing is subject to change without notice.
 C. The center lead is in electrical contact with the thermal tab.
 D. Dimensions do not include mold protrusions, not to exceed 0.006 (0,15).
 E. Falls within JEDEC TO-252 variation AC.

PowerFLEX is a trademark of Texas Instruments.

LP (O-PBCY-W3)

PLASTIC CYLINDRICAL PACKAGE



4040001-2/C 10/01

- 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 bulk pack only.
 Formed lead option available in tape & reel or ammo pack.

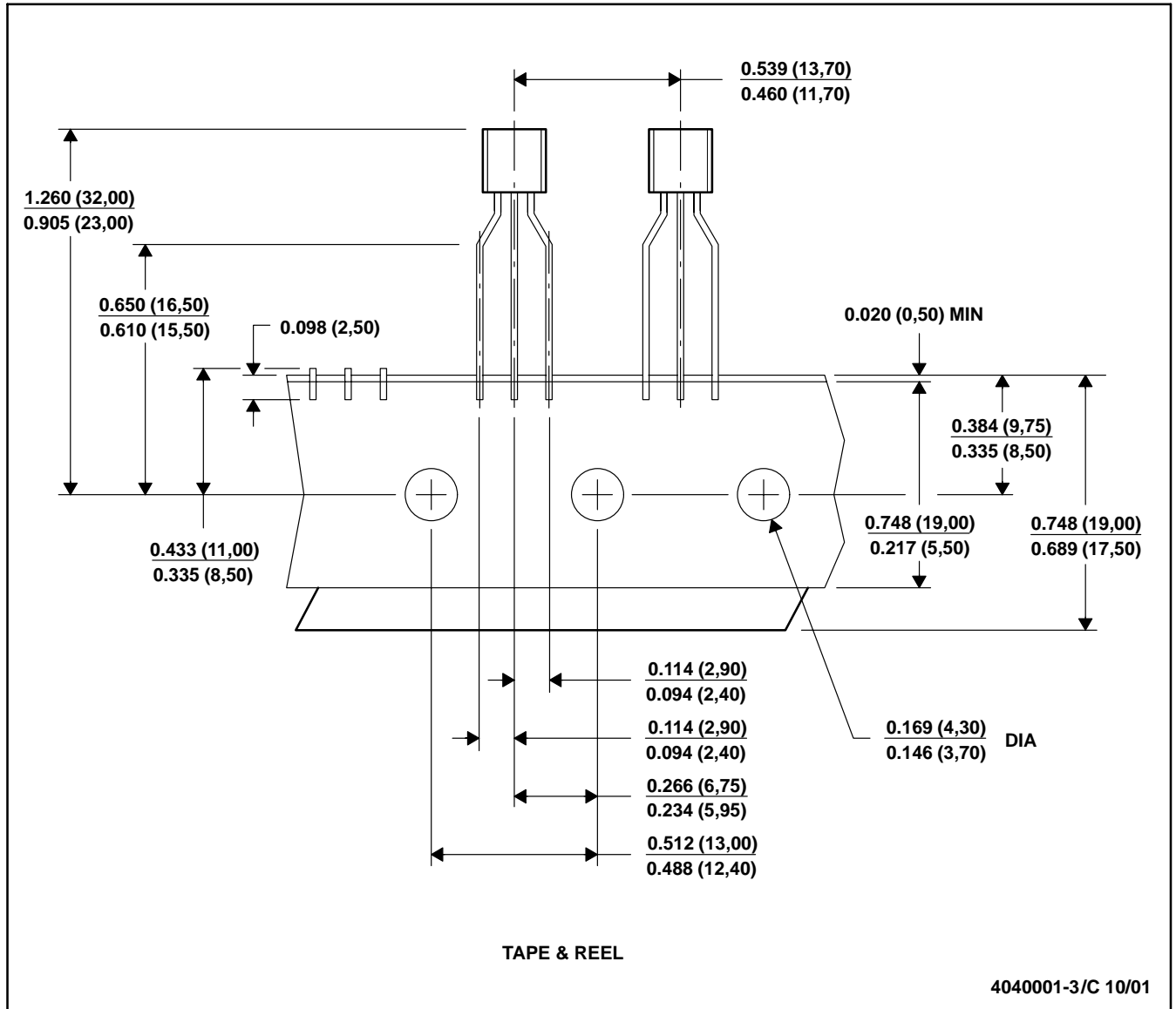


MECHANICAL DATA

MSOT002A – OCTOBER 1994 – REVISED NOVEMBER 2001

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 Format Lead Option package.

PW (R-PDSO-G**)

PLASTIC SMALL-OUTLINE PACKAGE

14 PINS SHOWN



4040064/F 01/97

- NOTES: A. All linear dimensions are in millimeters.
 B. This drawing is subject to change without notice.
 C. Body dimensions do not include mold flash or protrusion not to exceed 0,15.
 D. Falls within JEDEC MO-153

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