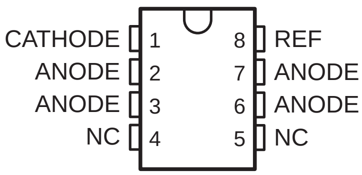
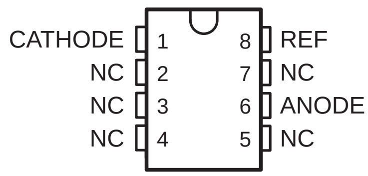
- **0.4% Initial Voltage Tolerance**
- **0.2-Ω Typical Output Impedance**
- **Fast Turnon . . . 500 ns**
- **Sink Current Capability . . . 1 mA to 100 mA**
- **Low Reference Current (REF)**
- **Adjustable Output Voltage . . . $V_{I(ref)}$ to 36 V**

D PACKAGE
(TOP VIEW)



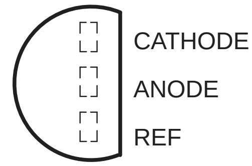
NC – No internal connection
ANODE terminals are connected internally.

JG OR PW PACKAGE
(TOP VIEW)

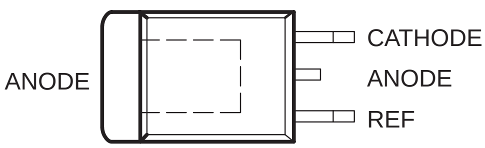


NC – No internal connection

LP PACKAGE
(TOP VIEW)

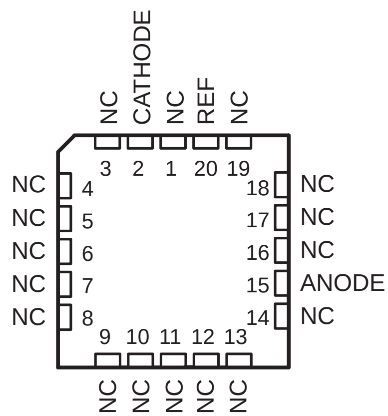


KTP PACKAGE
(TOP VIEW)



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

FK PACKAGE
(TOP VIEW)



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 $V_{I(ref)}$ (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.

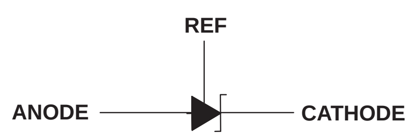
description/ordering information (continued)

ORDERING INFORMATION

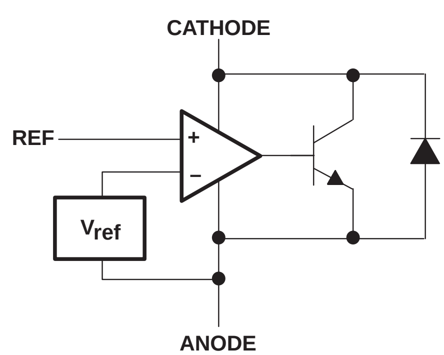
T_A	PACKAGE†		ORDERABLE PART NUMBER	TOP-SIDE MARKING
0°C to 70°C	POWER-FLEX (KTP)	Reel of 3000	TL1431CKTPR	TL1431C
	SOIC (D)	Tube of 75	TL1431CD	1431C
		Reel of 2500	TL1431CDR	
	TO-226 / TO-92 (LP)	Bulk of 1000	TL1431CLP	TL1431C
		Reel of 2000	TL1431CLPR	
	TSSOP (PW)	Tube of 150	TL1431CPW	T1431
		Reel 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	
–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.

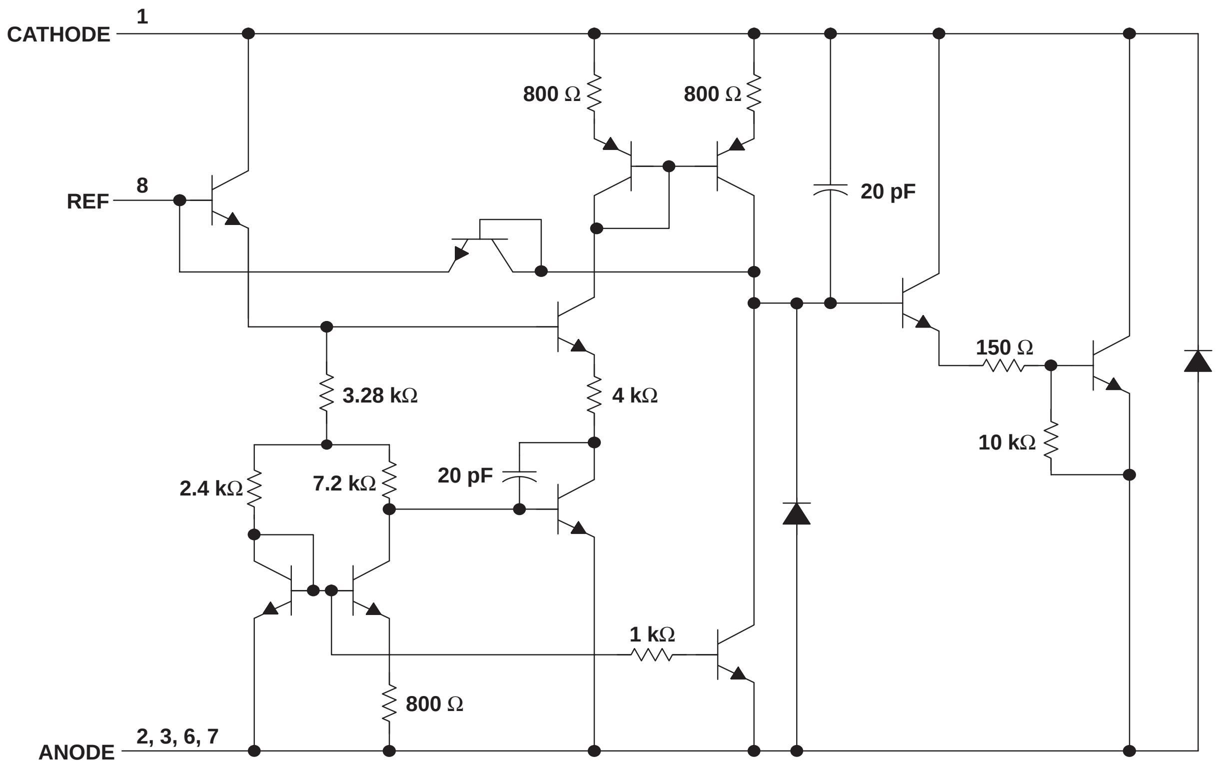
symbol



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 µA 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.

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	°C
		TL1431M	–55	125	°C

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

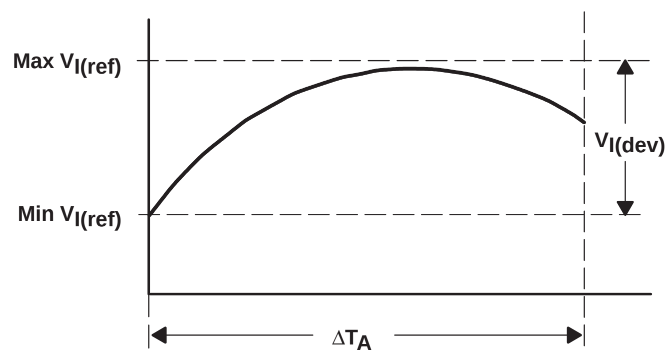
PARAMETER		TEST CONDITIONS	T_A†	TEST CIRCUIT	TL1431C MIN	TL1431C TYP	TL1431C MAX	UNIT
$V_{I(ref)}$	Reference input voltage	$V_{KA} = V_{I(ref)}$	25°C	Figure 1	2490	2500	2510	mV
			Full range		2480		2520	
$V_{I(dev)}$	Deviation of reference input voltage over full temperature range‡	$V_{KA} = V_{I(ref)}$	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	ΔV_{KA} = 3 V to 36 V	Full range	Figure 2		–1.1	–2	mV/V
$I_{I(ref)}$	Reference input current	R1 = 10 kΩ, R2 = ∞	25°C	Figure 2		1.5	2.5	µA
			Full range				3	
$I_{I(dev)}$	Deviation of reference input current over full temperature range‡	R1 = 10 kΩ, R2 = ∞	Full range	Figure 2		0.2	1.2	µA
I_{min}	Minimum cathode current for regulation	$V_{KA} = V_{I(ref)}$	25°C	Figure 1		0.45	1	mA
I_{off}	Off-state cathode current	V_{KA} = 36 V, $V_{I(ref)}$ = 0	25°C	Figure 3		0.18	0.5	µA
			Full range				2	
$\lvert z_{KA} \rvert$	Output impedance§	$V_{KA} = V_{I(ref)}$, f ≤ 1 kHz, I_{KA} = 1 mA to 100 mA	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:

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

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: $\left|z_{KA}\right| = \frac{\Delta V_{KA}}{\Delta I_{KA}}$

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 $\left|z_{KA}\right|\left(1 + \frac{R1}{R2}\right)$.

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

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

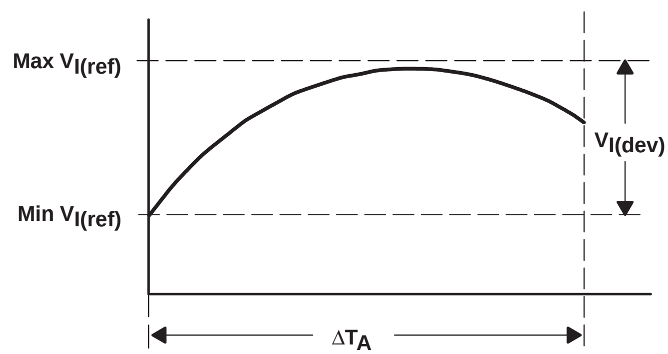
*On products compliant to MIL-PRF-38535, this parameter is not production tested.

† 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 $V_{I(dev)}$ 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:

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

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 $|z_{KA}|\left(1 + \frac{R1}{R2}\right)$.

PARAMETER MEASUREMENT INFORMATION

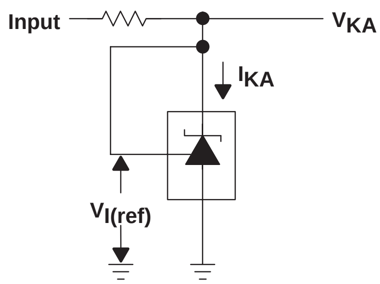


Figure 1. Test Circuit for $V_{(KA)} = V_{ref}$

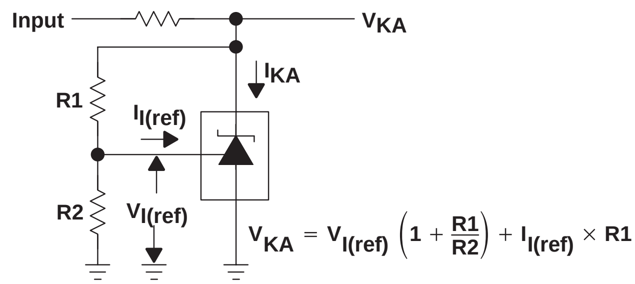


Figure 2. Test Circuit for $V_{(KA)} > V_{ref}$

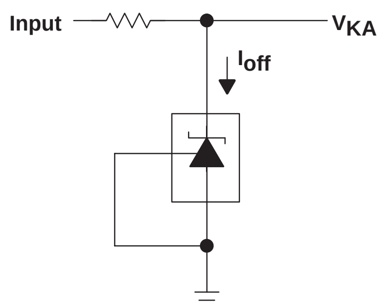


Figure 3. Test Circuit for I_{off}

TYPICAL CHARACTERISTICS

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Reference voltage vs Free-air temperature	4
Reference current vs Free-air temperature	5
Cathode current vs Cathode voltage	6, 7
Off-state cathode current vs Free-air temperature	8
Ratio of delta reference voltage to delta cathode voltage vs Free-air temperature	9
Equivalent input-noise voltage vs Frequency	10
Equivalent input-noise voltage over a 10-second period	11
Small-signal voltage amplification vs Frequency	12
Reference impedance vs Frequency	13
Pulse response	14
Stability boundary conditions	15

TYPICAL CHARACTERISTICS†

REFERENCE VOLTAGE vs FREE-AIR TEMPERATURE

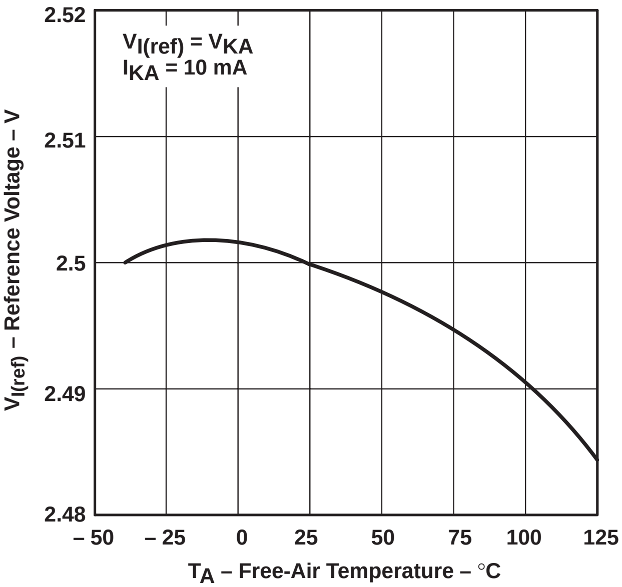


Figure 4

REFERENCE CURRENT vs FREE-AIR TEMPERATURE

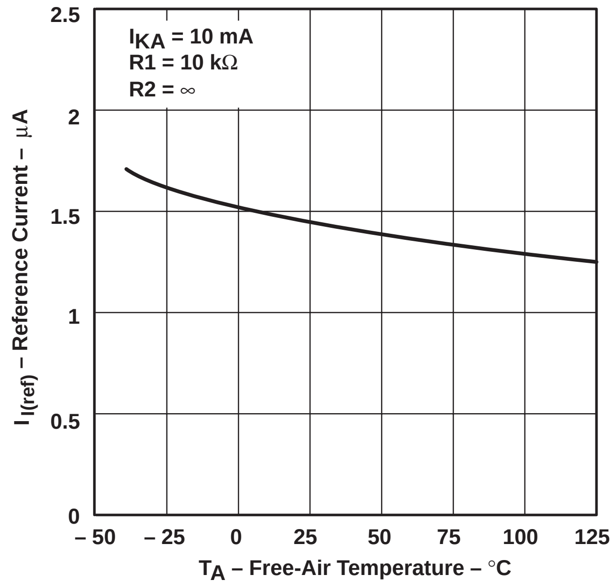


Figure 5

CATHODE CURRENT vs CATHODE VOLTAGE

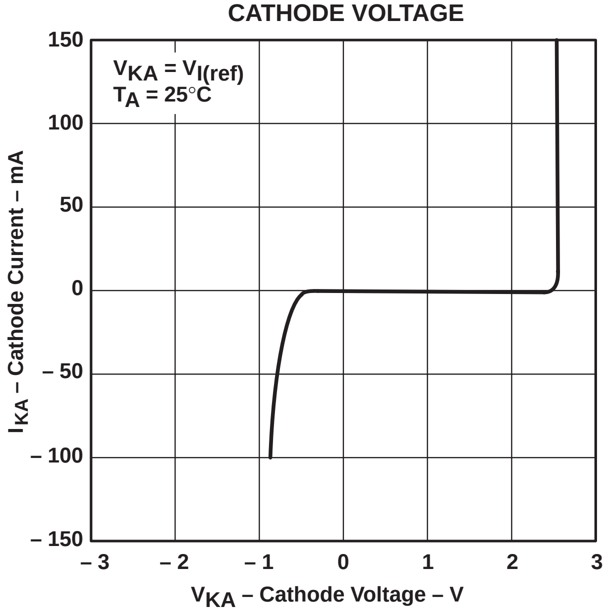


Figure 6

CATHODE CURRENT vs CATHODE VOLTAGE

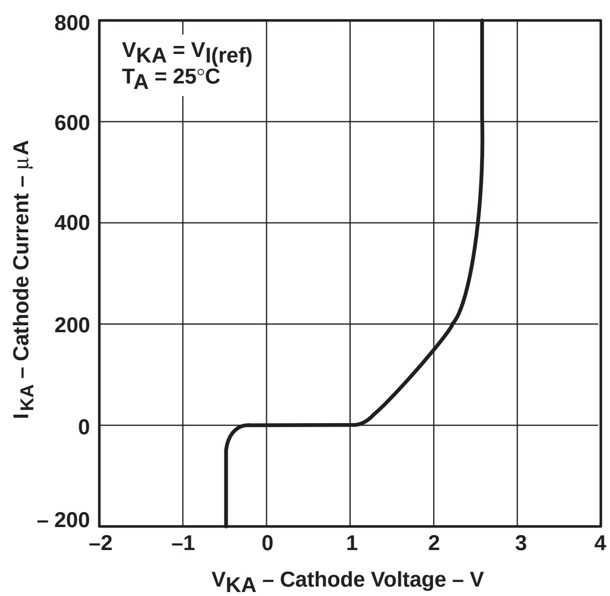


Figure 7

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

TYPICAL CHARACTERISTICS†

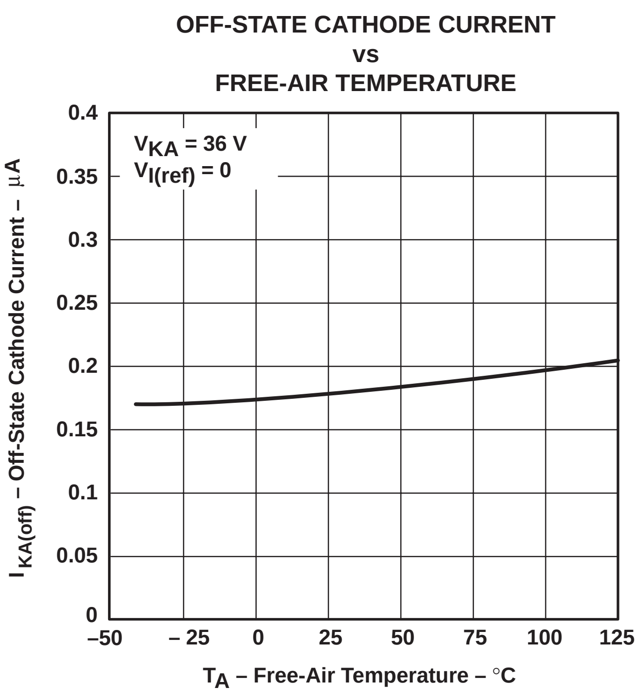


Figure 8

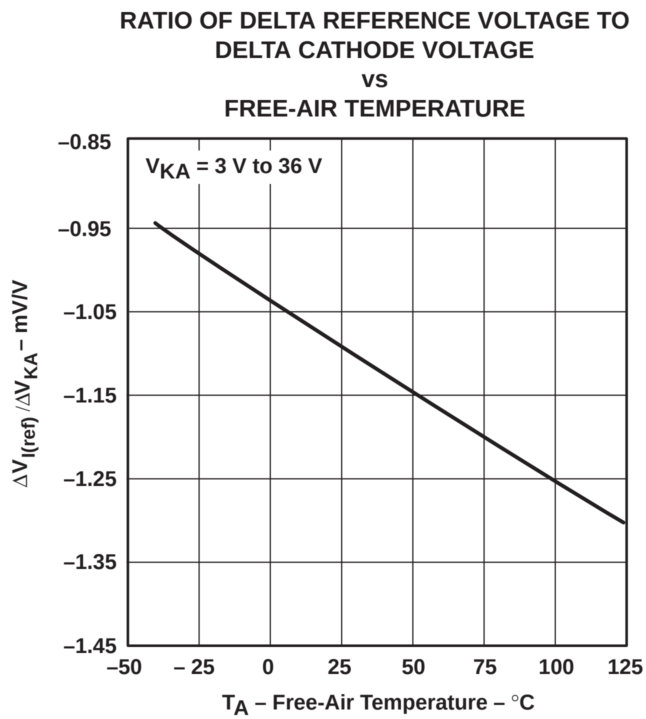


Figure 9

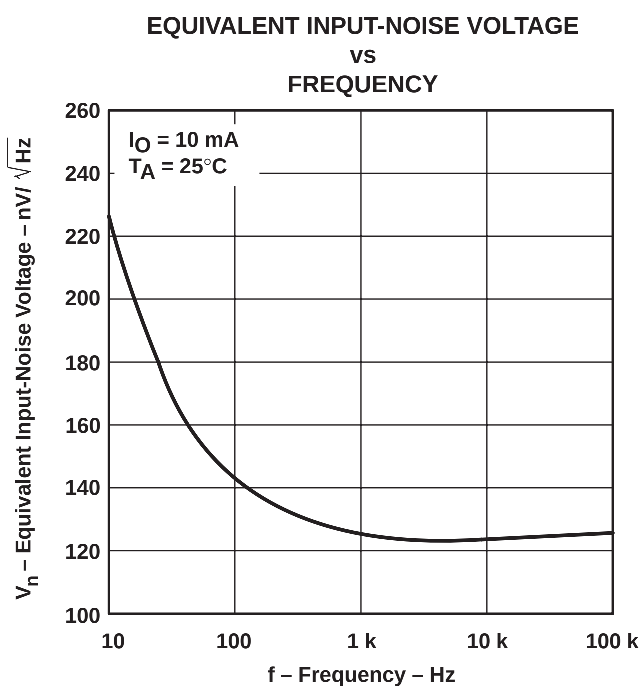
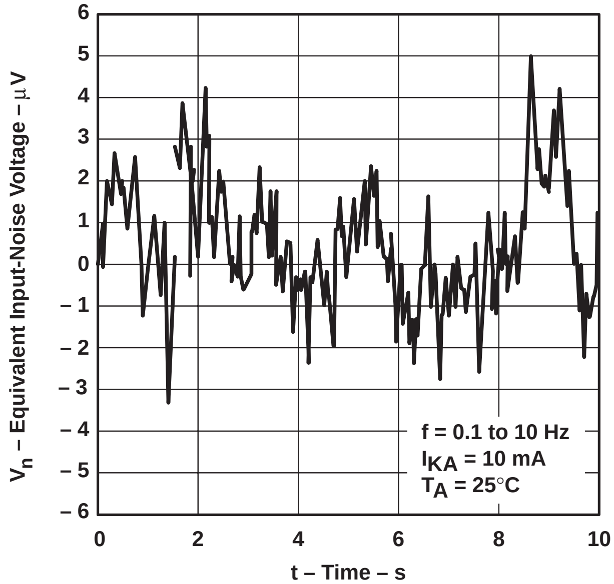
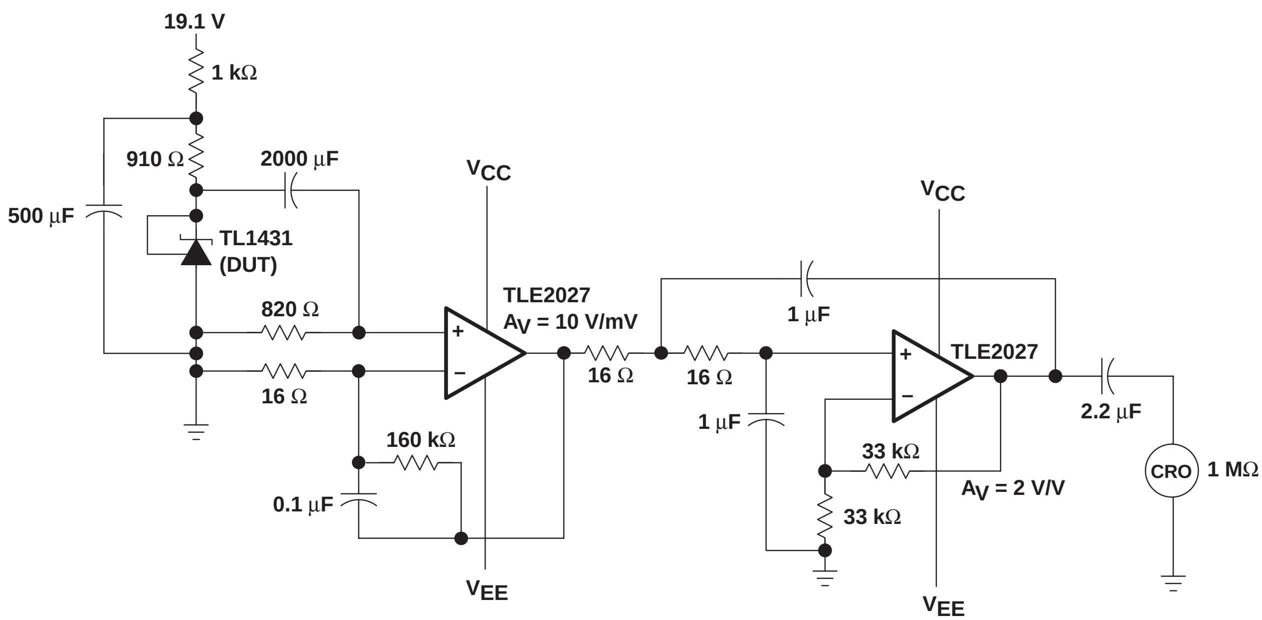


Figure 10

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

TYPICAL CHARACTERISTICS



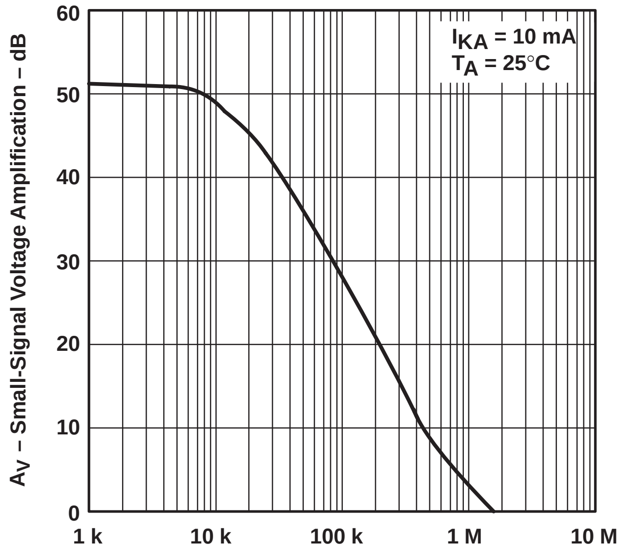


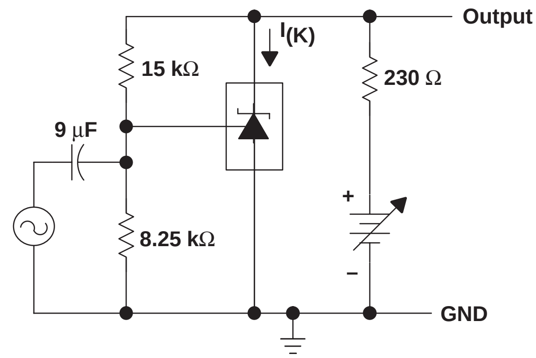
TEST CIRCUIT FOR 0.1-Hz TO 10-Hz EQUIVALENT INPUT-NOISE VOLTAGE

Figure 11

TYPICAL CHARACTERISTICS

SMALL-SIGNAL VOLTAGE AMPLIFICATION
vs
FREQUENCY

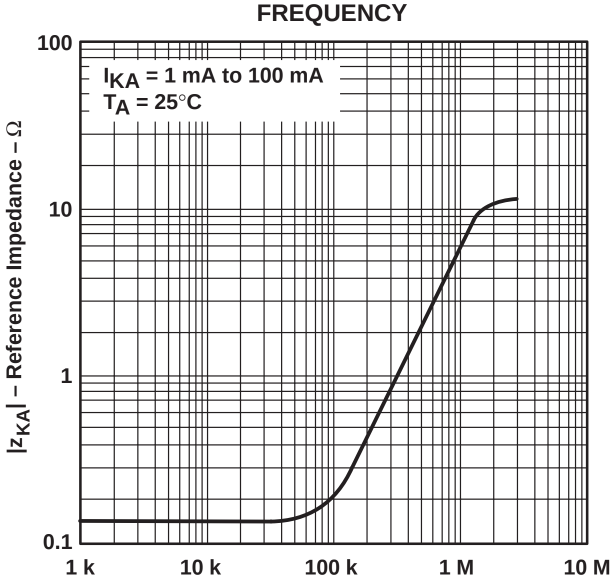


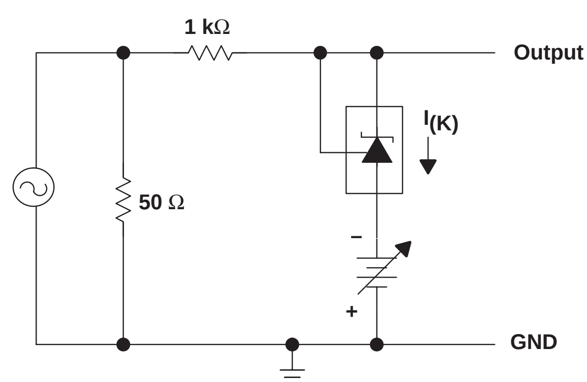


TEST CIRCUIT FOR VOLTAGE AMPLIFICATION

Figure 12

REFERENCE IMPEDANCE
vs
FREQUENCY

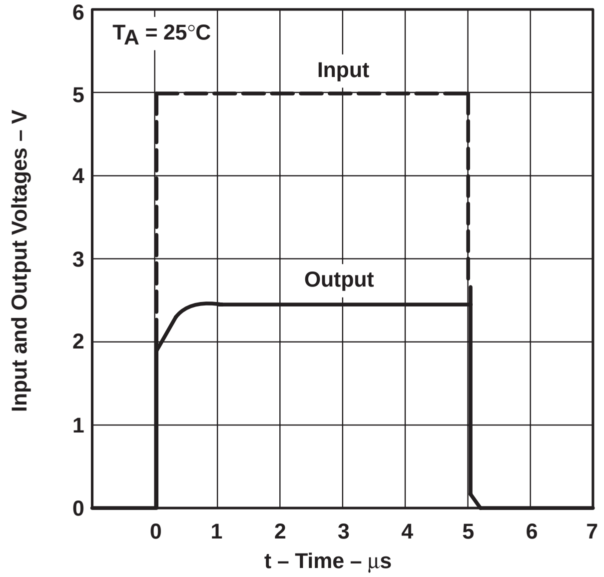


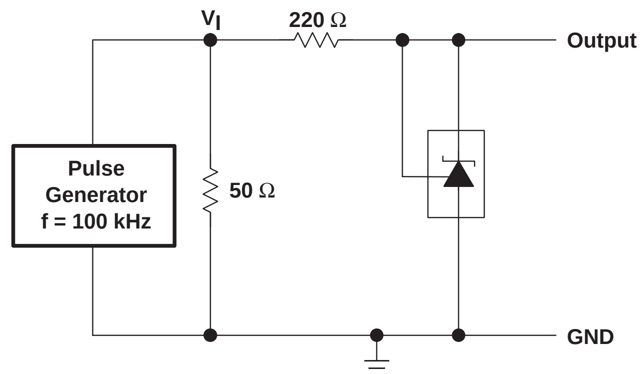


TEST CIRCUIT FOR REFERENCE IMPEDANCE

Figure 13

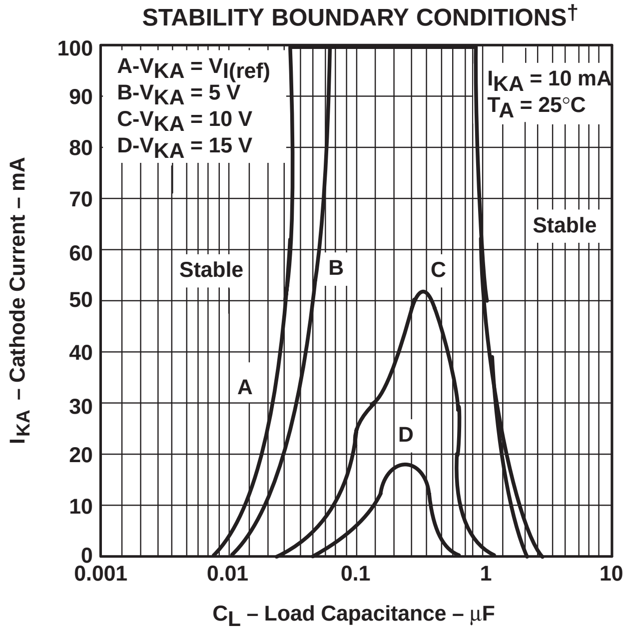
TYPICAL CHARACTERISTICS



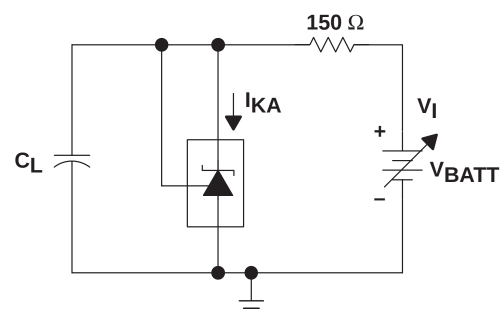


TEST CIRCUIT FOR PULSE RESPONSE

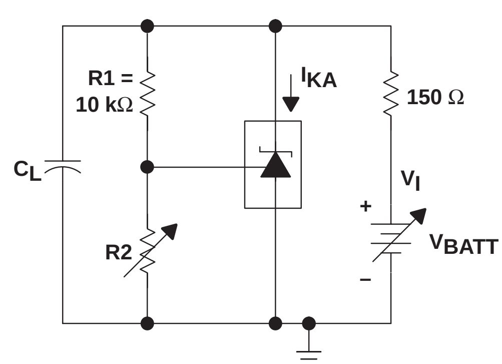
Figure 14



† The areas under the curves represent conditions that may cause the device to oscillate. For curves B, C, and D, R2 and V+ are adjusted to establish the initial V_{KA} and I_{KA} conditions, with $C_L = 0$. V_{BATT} and C_L then are adjusted to determine the ranges of stability.



TEST CIRCUIT FOR CURVE A



TEST CIRCUIT FOR CURVES B, C, AND D

Figure 15

APPLICATION INFORMATION

Table of Application Circuits

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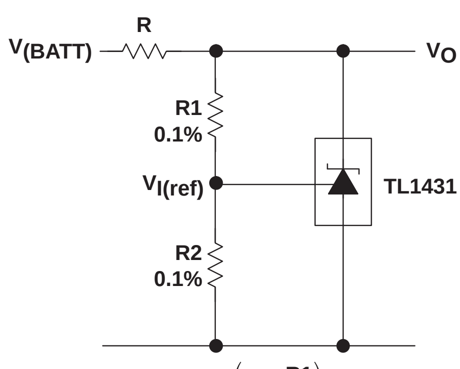
Crowbar	21
Precision 5-V, 1.5-A, 0.5% regulator	22
5-V precision regulator	23
PWM converter with 0.5% reference	24
Voltage monitor	25
Delay timer	26
Precision current limiter	27
Precision constant-current sink	28



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

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

Figure 16. Shunt Regulator

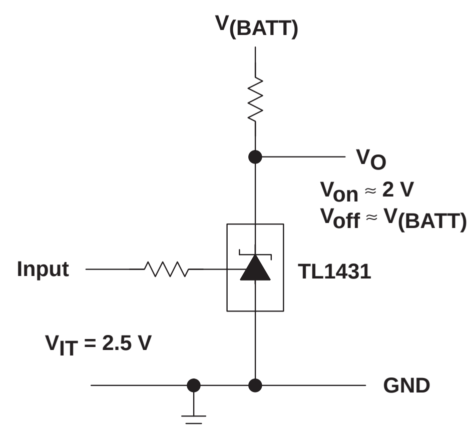
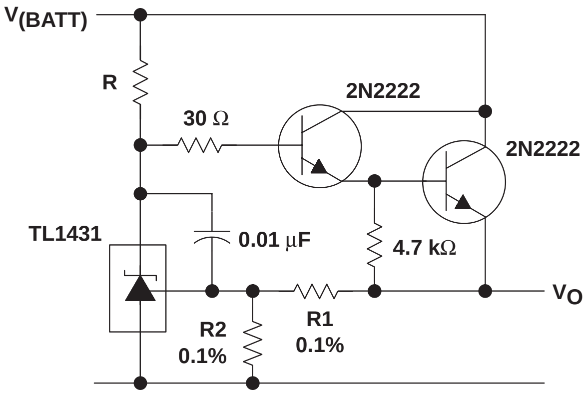


Figure 17. Single-Supply Comparator With Temperature-Compensated Threshold

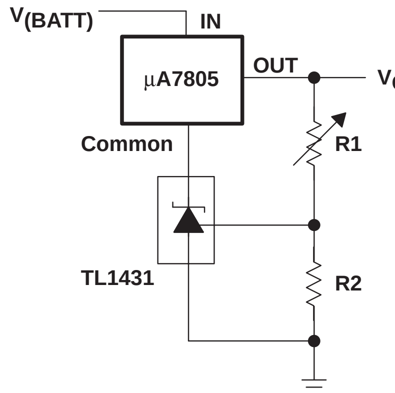
APPLICATION INFORMATION



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

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

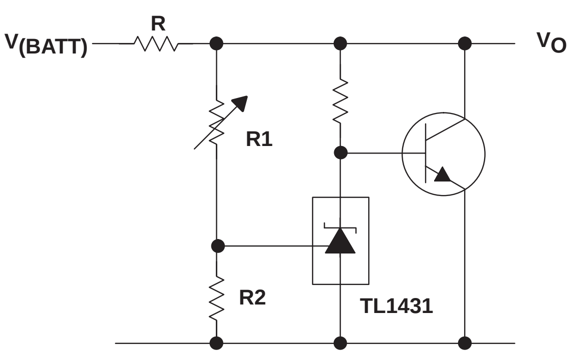
Figure 18. Precision High-Current Series Regulator



$$V = \left(1 + \frac{R1}{R2}\right)V_{I(ref)}$$

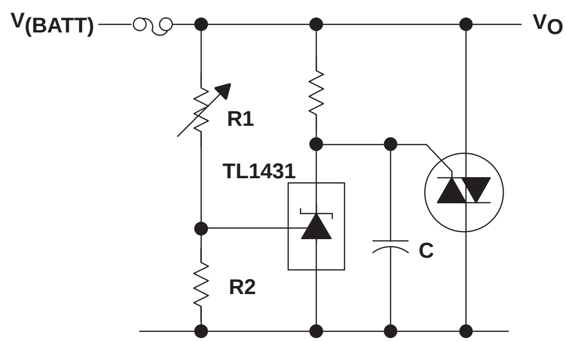
$$\text{Min } V = V_{I(ref)} + 5\text{ V}$$

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



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

Figure 20. Higher-Current Shunt Regulator



$$V_{trip} = \left(1 + \frac{R1}{R2}\right)V_{I(ref)}$$

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

Figure 21. Crowbar

APPLICATION INFORMATION

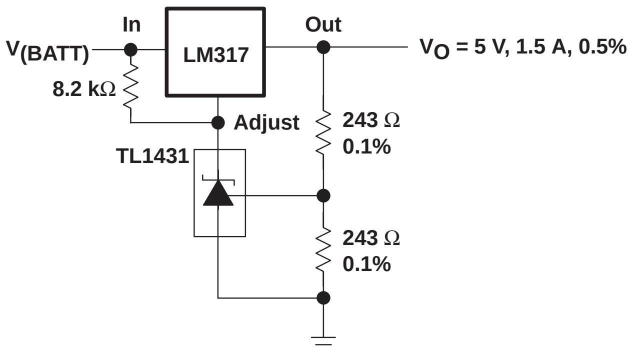
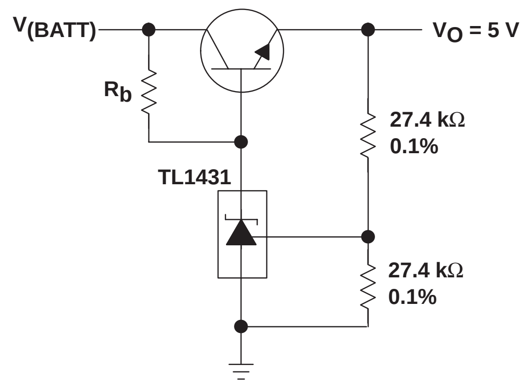


Figure 22. Precision 5-V, 1.5-A, 0.5% Regulator



NOTE A: R_b should provide cathode current ≥1 mA to the TL1431.

Figure 23. 5-V Precision Regulator

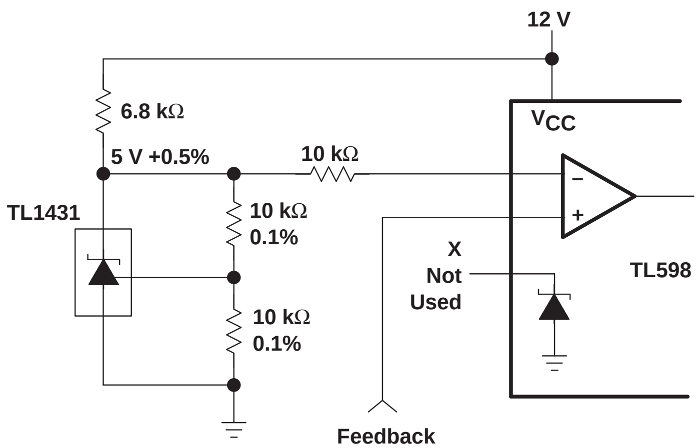
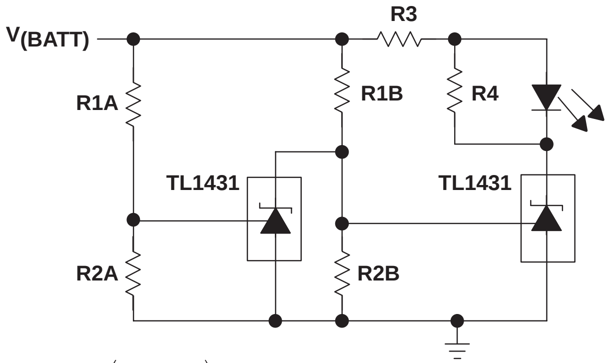


Figure 24. PWM Converter With 0.5% Reference

APPLICATION INFORMATION



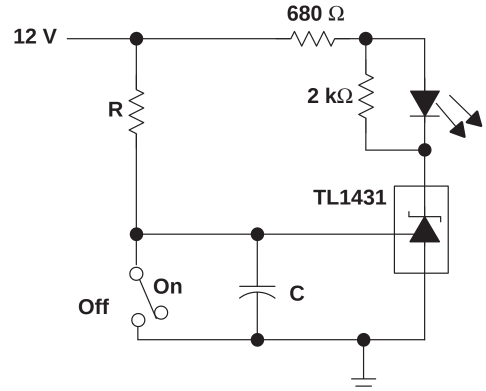
$$\text{Low Limit} = \left(1 + \frac{R1B}{R2B}\right)V_{I(ref)}$$

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

LED on When
Low Limit < $V_{(BATT)}$ < High Limit

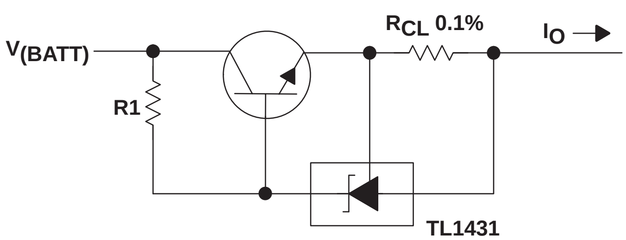
NOTE A: Select R3 and R4 to provide the desired LED intensity and cathode current ≥1 mA to the TL1431.

Figure 25. Voltage Monitor



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

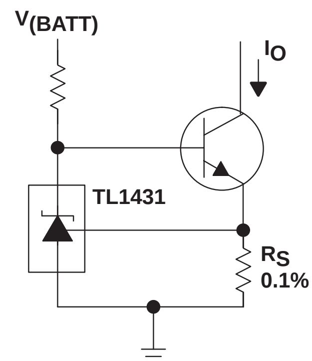
Figure 26. Delay Timer



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

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

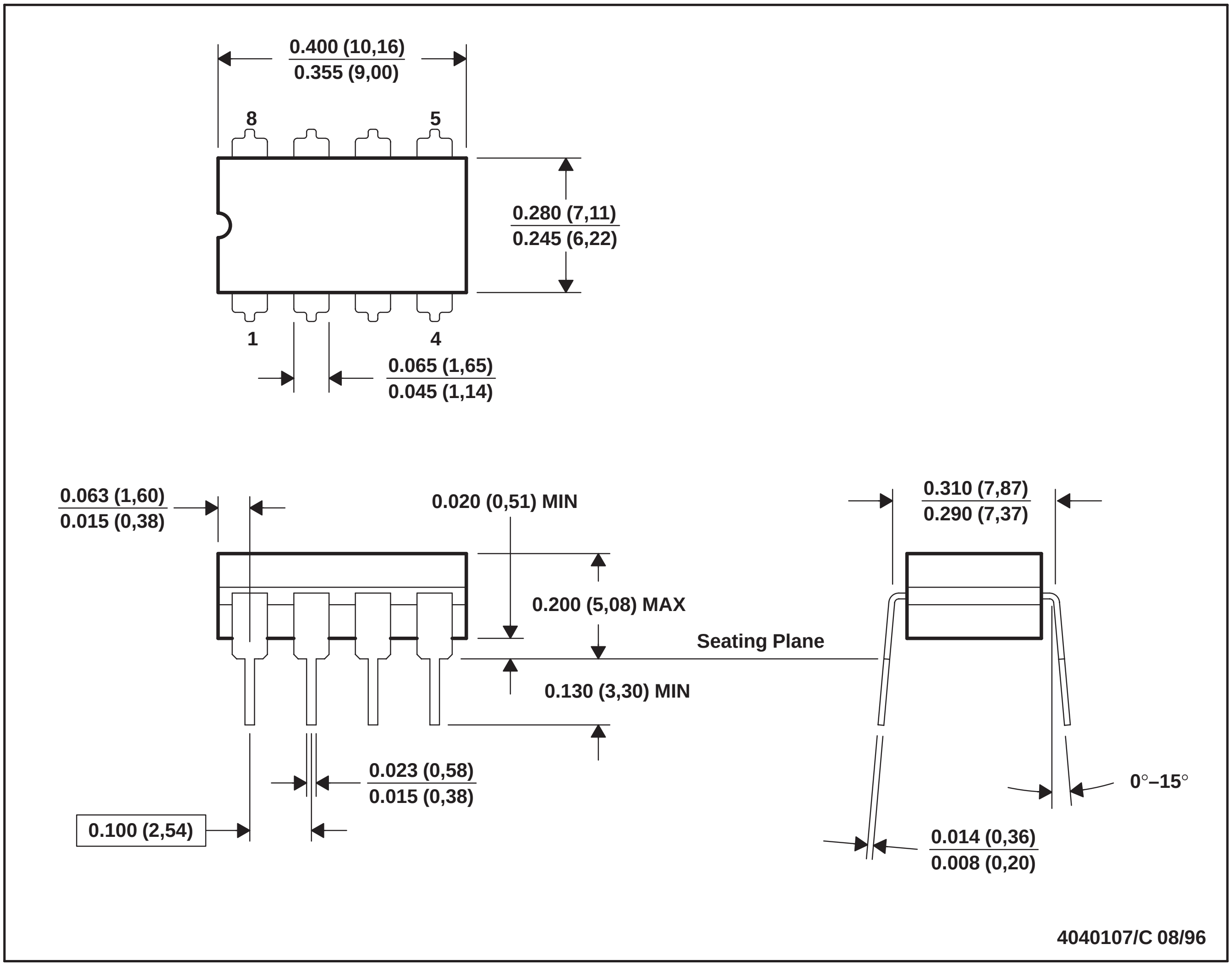
Figure 27. Precision Current Limiter



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

Figure 28. Precision Constant-Current Sink

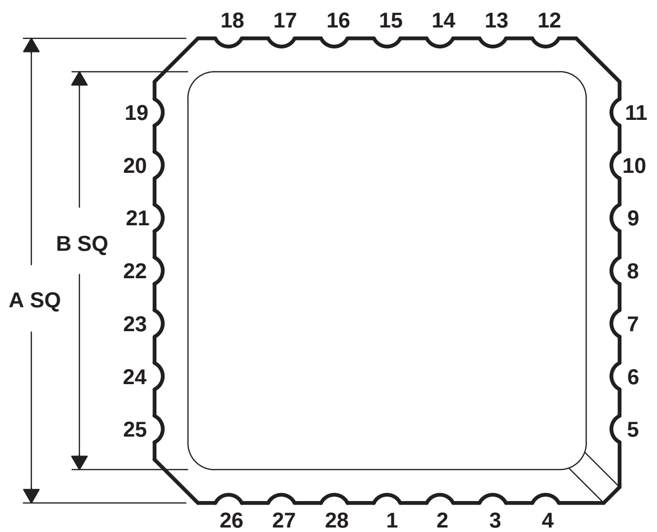
JG (R-GDIP-T8) **CERAMIC DUAL-IN-LINE**



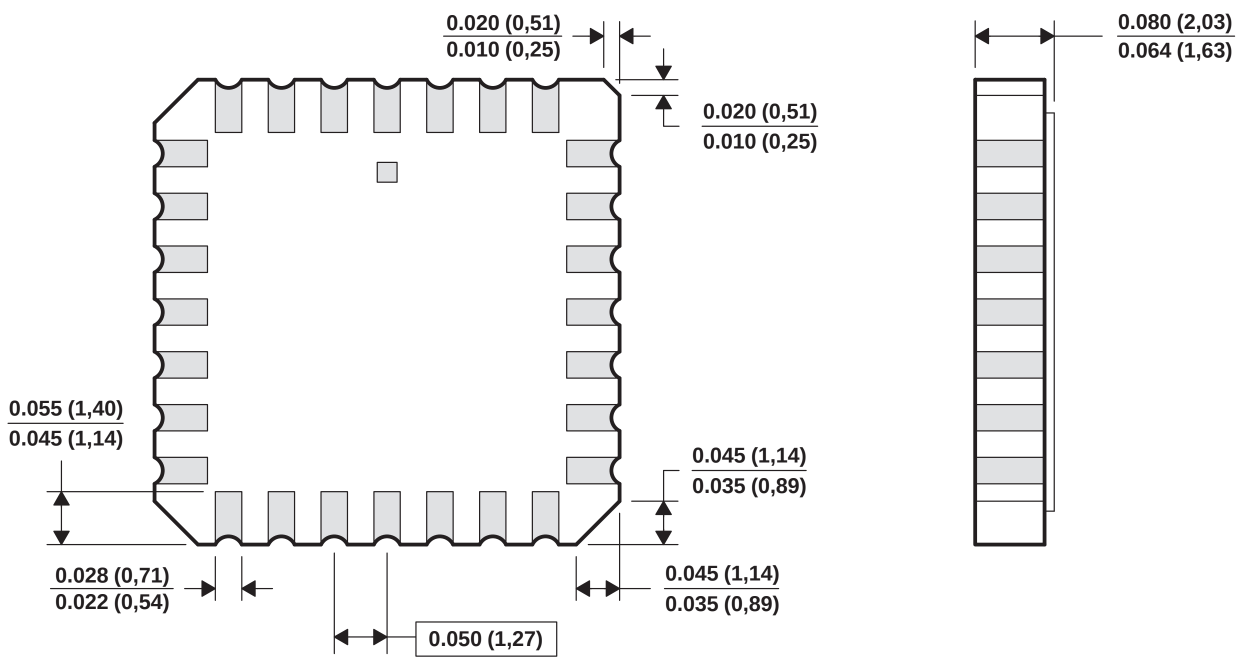
NOTES: A. All linear dimensions are in inches (millimeters).
B. This drawing is subject to change without notice.
C. This package can be hermetically sealed with a ceramic lid using glass frit.
D. Index point is provided on cap for terminal identification.
E. Falls within MIL STD 1835 GDIP1-T8

FK (S-CQCC-N)** **LEADLESS CERAMIC CHIP CARRIER**

28 TERMINAL SHOWN



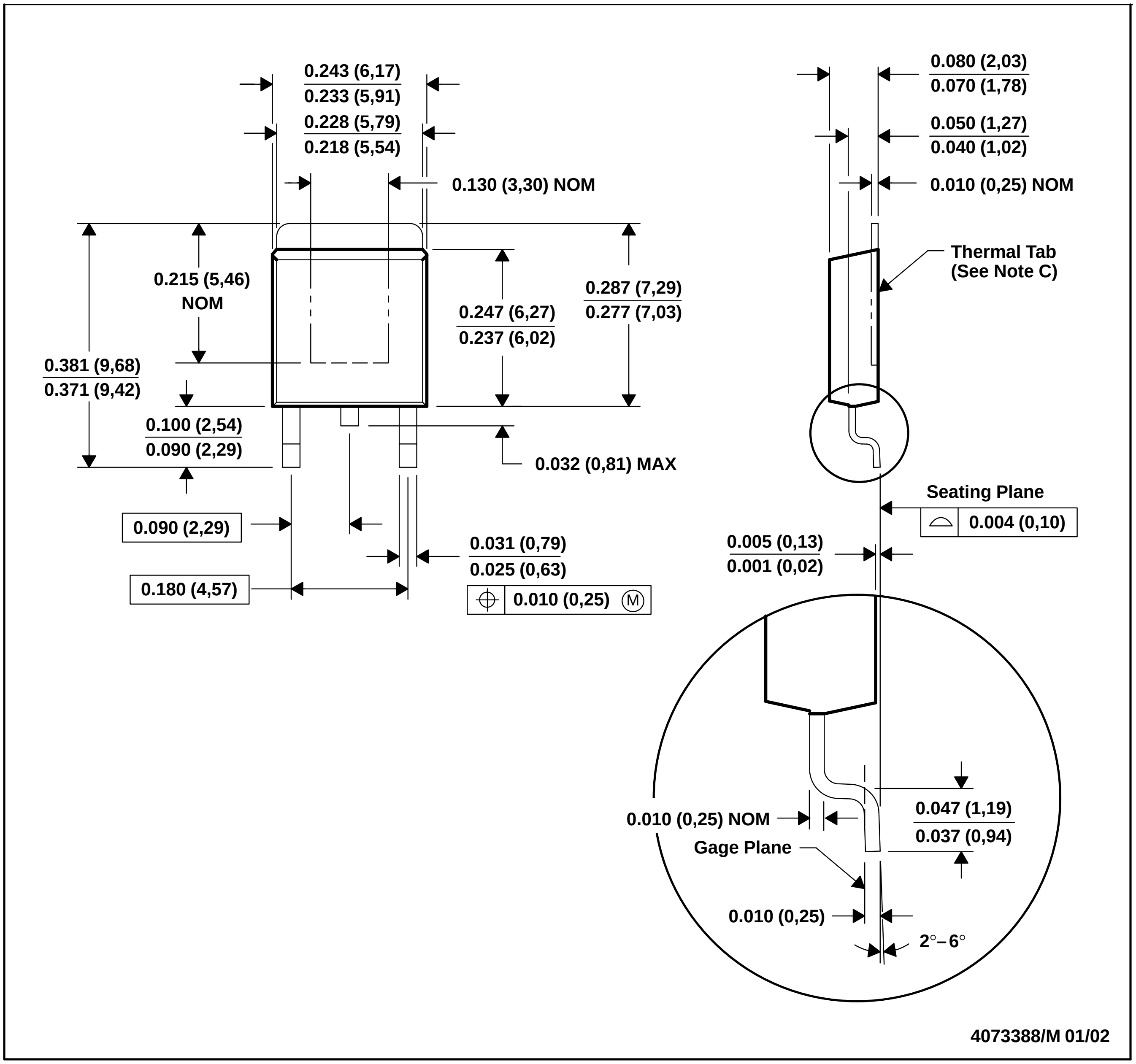
NO. OF TERMINALS **	A		B	
	MIN	MAX	MIN	MAX
20	0.342 (8,69)	0.358 (9,09)	0.307 (7,80)	0.358 (9,09)
28	0.442 (11,23)	0.458 (11,63)	0.406 (10,31)	0.458 (11,63)
44	0.640 (16,26)	0.660 (16,76)	0.495 (12,58)	0.560 (14,22)
52	0.739 (18,78)	0.761 (19,32)	0.495 (12,58)	0.560 (14,22)
68	0.938 (23,83)	0.962 (24,43)	0.850 (21,6)	0.858 (21,8)
84	1.141 (28,99)	1.165 (29,59)	1.047 (26,6)	1.063 (27,0)



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**

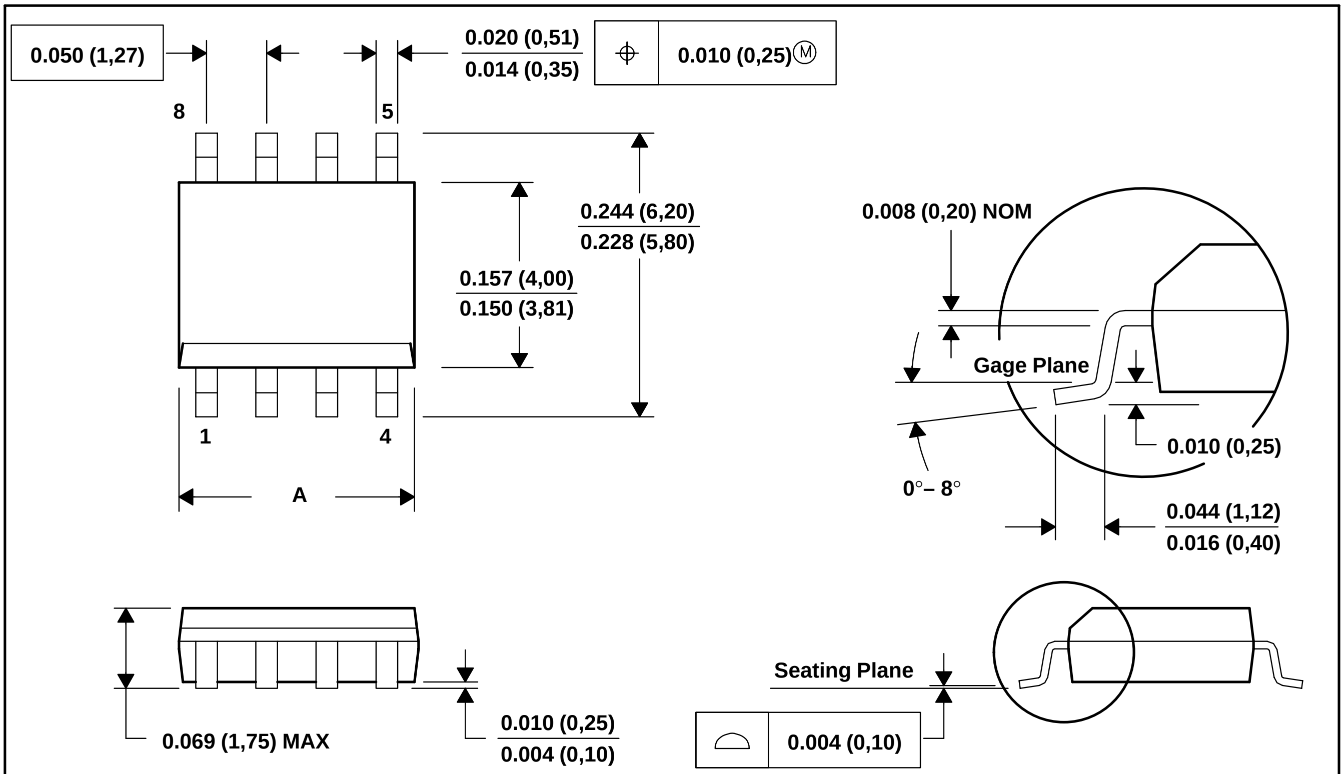


NOTES:
A. All linear dimensions are in inches (millimeters).
B. This drawing is subject to change without notice.
C. The center lead is in electrical contact with the thermal tab.
D. Dimensions do not include mold protrusions, not to exceed 0.006 (0,15).
E. Falls within JEDEC TO-252 variation AC.

PowerFLEX is a trademark of Texas Instruments.

D (R-PDSO-G)** **PLASTIC SMALL-OUTLINE PACKAGE**

8 PINS SHOWN



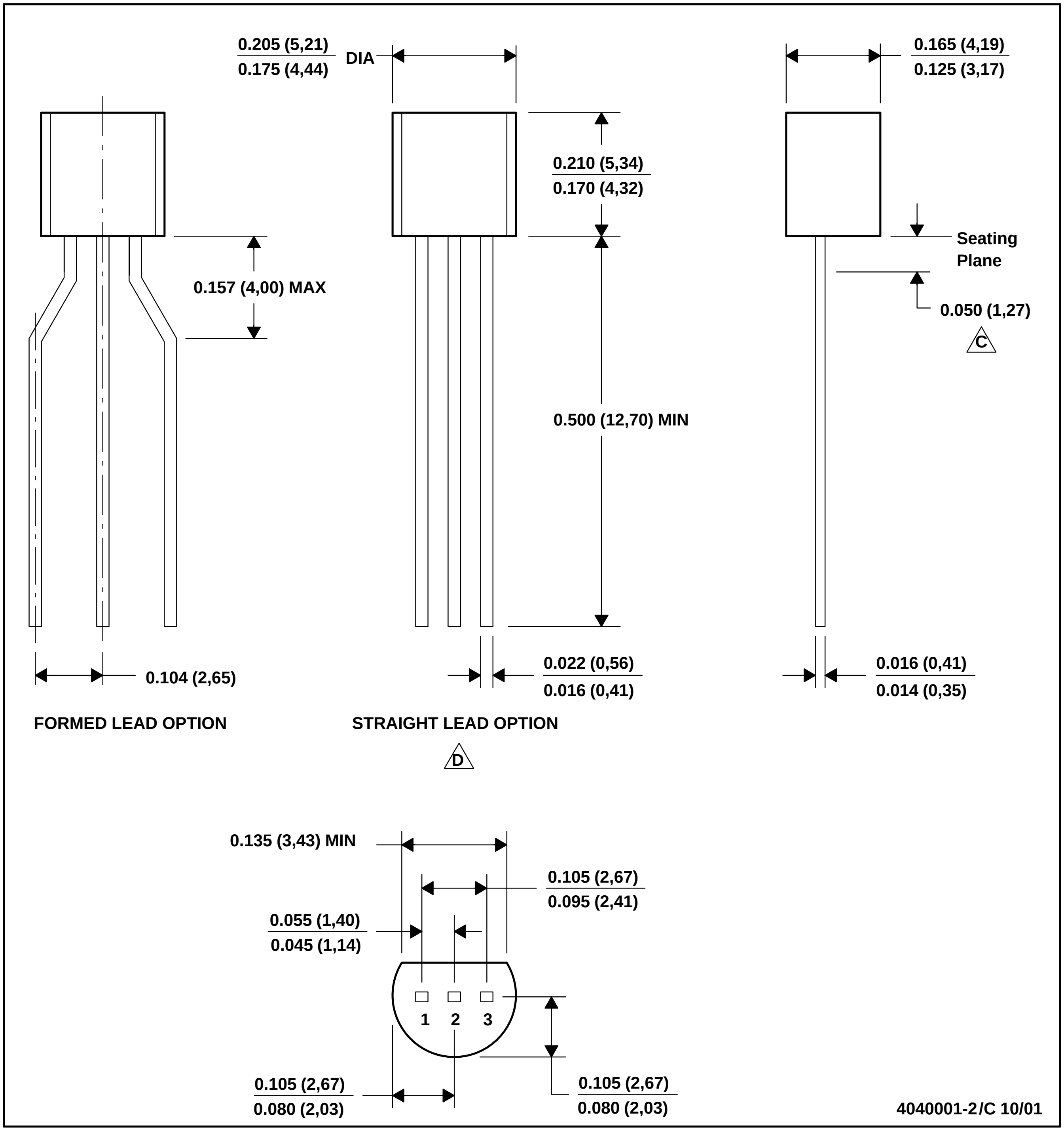
PINS ** / DIM	8	14	16
A MAX	0.197 (5,00)	0.344 (8,75)	0.394 (10,00)
A MIN	0.189 (4,80)	0.337 (8,55)	0.386 (9,80)

4040047/E 09/01

NOTES:
A. All linear dimensions are in inches (millimeters).
B. This drawing is subject to change without notice.
C. Body dimensions do not include mold flash or protrusion, not to exceed 0.006 (0,15).
D. Falls within JEDEC MS-012

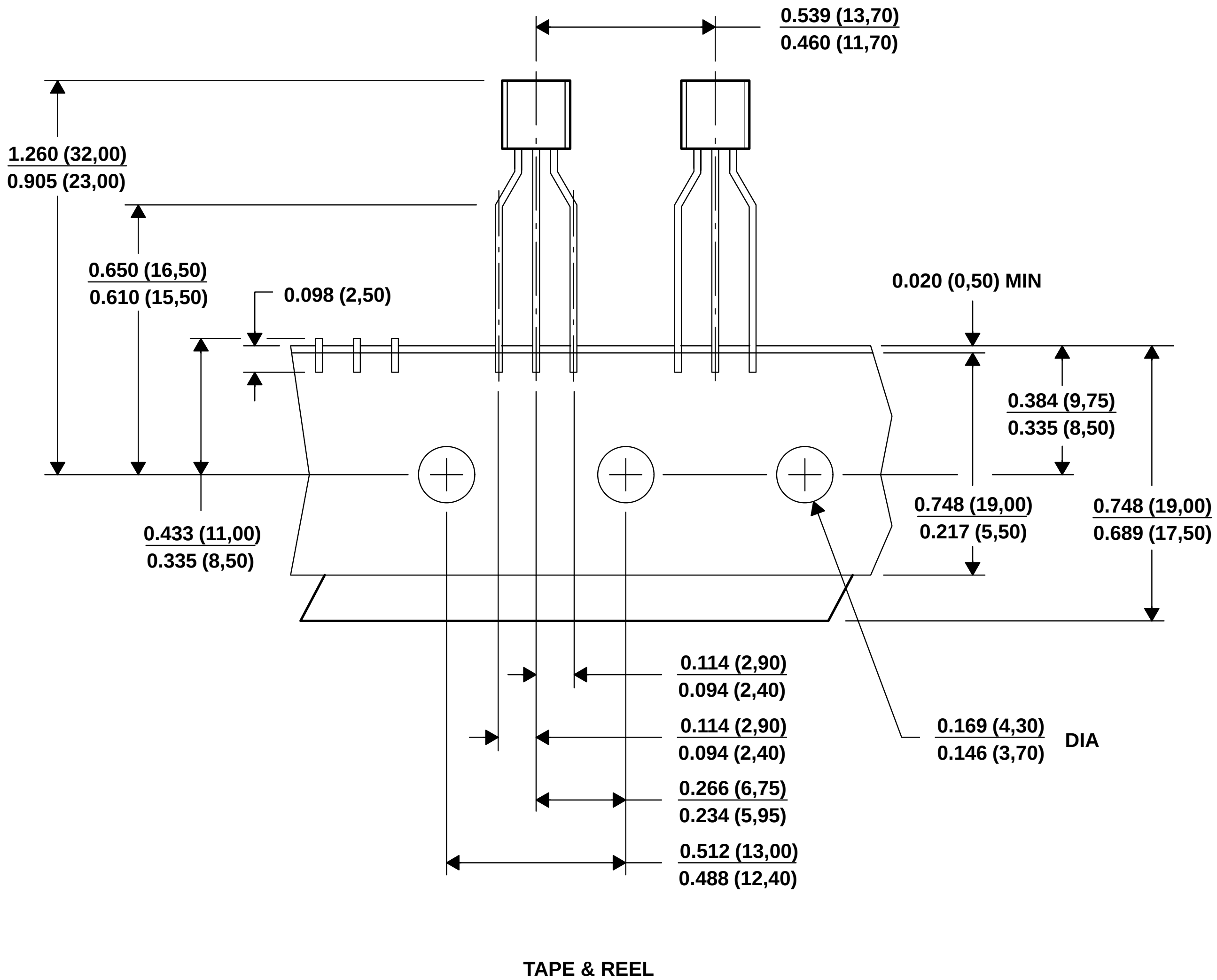
MSOT002A – OCTOBER 1994 – REVISED NOVEMBER 2001

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. 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.

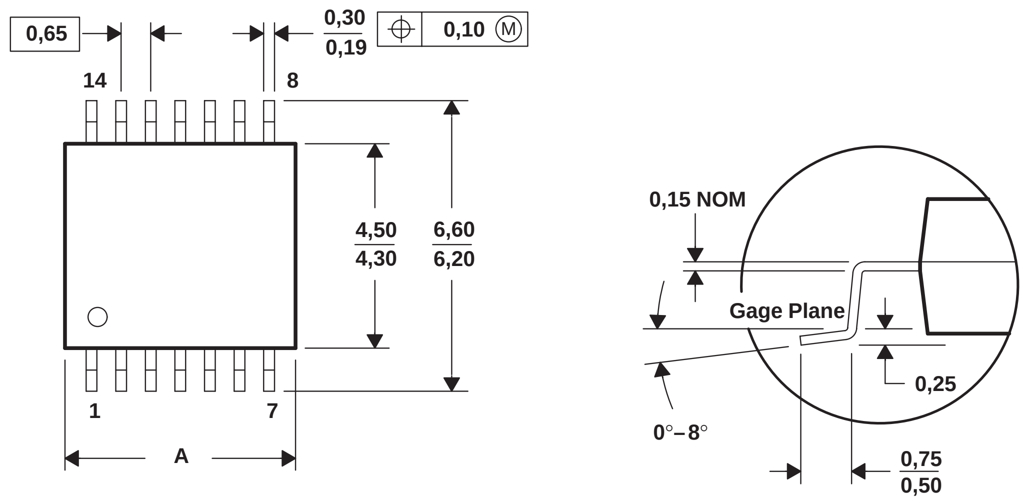
LP (O-PBCY-W3) **PLASTIC CYLINDRICAL PACKAGE**

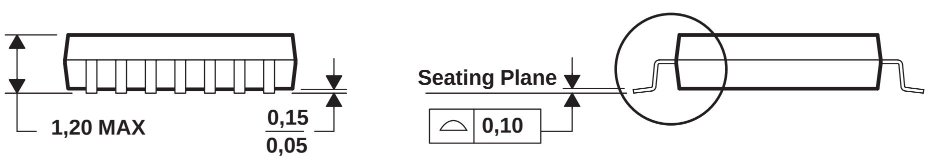


NOTES: A. All linear dimensions are in inches (millimeters).
B. This drawing is subject to change without notice.
C. Tape and Reel information for the Format Lead Option package.

PW (R-PDSO-G)** **PLASTIC SMALL-OUTLINE PACKAGE**

14 PINS SHOWN





PINS ** / DIM	8	14	16	20	24	28
A MAX	3,10	5,10	5,10	6,60	7,90	9,80
A MIN	2,90	4,90	4,90	6,40	7,70	9,60

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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