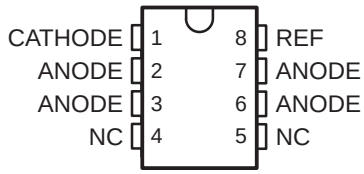
TL431, TL431A, TL431B, TL432, TL432A, TL432B
ADJUSTABLE PRECISION SHUNT REGULATORS

SLVS543A – AUGUST 2004 – REVISED AUGUST 2004

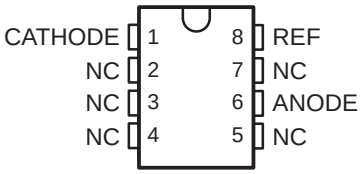
- **Operation From −40°C to 125°C**
  - **0.5% . . . B Grade**
  - **1% . . . A Grade**
  - **2% . . . Standard Grade**
- **Typical Temperature Drift (TL431B)**
  - **6 mV (C Temp)**
  - **14 mV (I Temp, Q Temp)**
- **Low Output Noise**
- **0.2-Ω Typical Output Impedance**
- **Sink-Current Capability . . . 1 mA to 100 mA**
- **Adjustable Output Voltage . . . V_{ref} to 36 V**

TL431, TL431A, TL431B . . . D (SOIC) PACKAGE
(TOP VIEW)



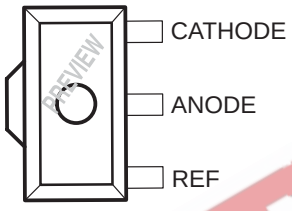
NC − No internal connection

TL431, TL431A, TL431B . . . P (PDIP), PS (SOP), OR PW (TSSOP) PACKAGE
(TOP VIEW)

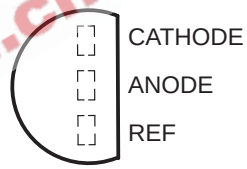


NC − No internal connection

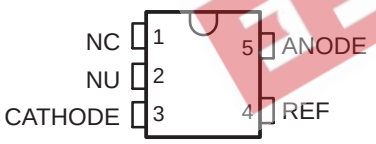
TL431, TL431A, TL431B . . . PK (SOT-89) PACKAGE
(TOP VIEW)



TL431, TL431A, TL431B . . . LP (TO-92/TO-226) PACKAGE
(TOP VIEW)

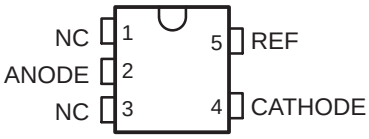


TL431, TL431A, TL431B . . . DBV (SOT23-5) PACKAGE
(TOP VIEW)



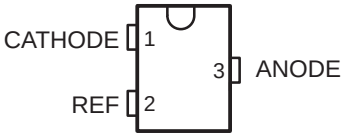
NC − No internal connection
NU − Make no external connection

TL432, TL432A, TL432B . . . DBV (SOT23-5) PACKAGE
(TOP VIEW)

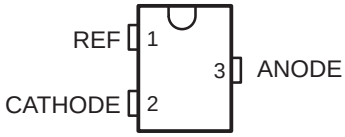


NC − No internal connection

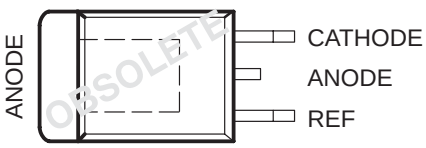
TL431, TL431A, TL431B . . . DBZ (SOT23-3) PACKAGE
(TOP VIEW)



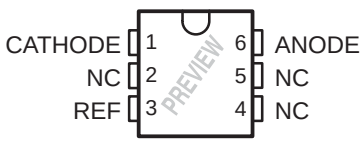
TL432, TL432A, TL432B . . . DBZ (SOT23-3) PACKAGE
(TOP VIEW)



TL431 . . . KTP (PowerFLEX™/TO-252) PACKAGE
(TOP VIEW)



TL431A, TL431B . . . DCK (SC-70) PACKAGE
(TOP VIEW)



NC − No internal connection

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description/ordering information

The TL431 and TL432 are three-terminal adjustable shunt regulators, with specified thermal stability over applicable automotive, commercial, and military temperature ranges. The output voltage can be set to any value between V_{ref} (approximately 2.5 V) and 36 V, with two external resistors (see Figure 17). These devices have a typical output impedance of 0.2 Ω. Active output circuitry provides a very sharp turn-on characteristic, making these devices excellent replacements for Zener diodes in many applications, such as onboard regulation, adjustable power supplies, and switching power supplies. The TL432 has exactly the same functionality and electrical specifications as the TL431, but has different pinouts for the DBV and DBZ packages.

Both the TL431 and TL432 devices are offered in three grades, with initial tolerances (at 25°C) of 0.5%, 1%, and 2%, for the B, A, and standard grade, respectively. In addition, low output drift vs temperature ensures good stability over the entire temperature range.

The TL43xxC devices are characterized for operation from 0°C to 70°C, the TL43xxI devices are characterized for operation from −40°C to 85°C, and the TL43xxQ devices are characterized for operation from −40°C to 125°C.

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description/ordering information (continued)

V_{ref} TOLERANCE (25°C) = 2%
TL431, TL432 ORDERING INFORMATION

T_A	PACKAGE†		ORDERABLE PART NUMBER	TOP-SIDE MARKING‡
0°C to 70°C	PDIP (P)	Tube of 50	TL431CP	TL431CP
	SOIC (D)	Tube of 75	TL431CD	TL431C
		Reel of 2500	TL431CDR	
	SOP (PS)	Reel of 2000	TL431CPSR	T431
	SOT-23-5 (DBV)	Reel of 3000	TL431CDBVR	T3C_
		Reel of 250	TL431CDBVT	
		Reel of 3000	TL432CDBVR	TAB_
		Reel of 250	TL432CDBVT	
	SOT-23-3 (DBZ)	Reel of 3000	TL431CDBZR	TAC_
		Reel of 250	TL431CDBZT	
		Reel of 3000	TL432CDBZR	TAB_
		Reel of 250	TL432CDBZT	
	SOT-89 (PK)	Reel of 1000	TL431CPK	43
	TO-226/TO-92 (LP)	Bulk of 1000	TL431CLP	TL431C
		Ammo of 2000	TL431CLPM	
		Reel of 2000	TL431CLPR	
	TSSOP (PW)	Tube of 150	TL431CPW	T431
		Reel of 2000	TL431CPWR	
−40°C to 85°C	PDIP (P)	Tube of 50	TL431IP	TL431IP
	SOIC (D)	Tube of 75	TL431ID	TL431I
		Reel of 2500	TL431IDR	
	SOT-23-5 (DBV)	Reel of 3000	TL431IDBVR	T3I_
		Reel of 250	TL431IDBVT	
		Reel of 3000	TL432IDBVR	T4A_
		Reel of 250	TL432IDBVT	
	SOT-23-3 (DBZ)	Reel of 3000	TL431IDBZR	TAI_
		Reel of 250	TL431IDBZT	
		Reel of 3000	TL432IDBZR	T4A_
		Reel of 250	TL432IDBZT	
	SOT-89 (PK)	Reel of 1000	TL431IPK	3I
	TO-226/TO-92 (LP)	Bulk of 1000	TL431ILP	TL431I
		Reel of 2000	TL431ILPR	

† Package drawings, standard packing quantities, thermal data, symbolization, and PCB design guidelines are available at www.ti.com/sc/package.
‡ DBV/DBZ: The actual top-side marking has one additional character that designates the assembly/test site.

description/ordering information (continued)

V_{ref} TOLERANCE (25°C) = 2%
TL431, TL432 ORDERING INFORMATION

T_A	PACKAGE†		ORDERABLE PART NUMBER	TOP-SIDE MARKING‡
−40°C to 125°C	SOT-23-5 (DBV)	Reel of 3000	TL431QDBVR	TBD
		Reel of 250	TL431QDBVT	
		Reel of 3000	TL432QDBVR	TBD
		Reel of 250	TL432QDBVT	
	SOT-23-3 (DBZ)	Reel of 3000	TL431QDBZR	TBD
		Reel of 250	TL431QDBZT	
		Reel of 3000	TL432QDBZR	TBD
		Reel of 250	TL432QDBZT	

† Package drawings, standard packing quantities, thermal data, symbolization, and PCB design guidelines are available at www.ti.com/sc/package.
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V_{ref} TOLERANCE (25°C) = 1%
TL431A, TL432A ORDERING INFORMATION

T_A	PACKAGE†		ORDERABLE PART NUMBER	TOP-SIDE MARKING‡
0°C to 70°C	PDIP (P)	Tube of 50	TL431ACP	TL431ACP
	SC-70 (DCK)	Reel of 3000	TL431ACDCKR	TBD
		Reel of 250	TL431ACDCKT	
	SOIC (D)	Tube of 75	TL431ACD	431AC
		Reel of 2500	TL431ACDR	
	SOP (PS)	Reel of 2000	TL431ACPSR	T431A
	SOT-23-5 (DBV)	Reel of 3000	TL431ACDBVR	TAC_
		Reel of 250	TL431ACDBVT	
		Reel of 3000	TL432ACDBVR	TAB_
		Reel of 250	TL432ACDBVT	
	SOT-23-3 (DBZ)	Reel of 3000	TL431ACDBZR	TAC_
		Reel of 250	TL431ACDBZT	
		Reel of 3000	TL432ACDBZR	TAB_
		Reel of 250	TL432ACDBZT	
	SOT-89 (PK)	Reel of 1000	TL431ACPK	4A
	TO-226/TO-92 (LP)	Bulk of 1000	TL431ACLP	TL431AC
		Ammo of 2000	TL431ACLPM	TL431AC
		Reel of 2000	TL431ACLPR	
	TSSOP (PW)	Tube of 150	TL431ACPW	T431A
		Reel of 2000	TL431ACPWR	

† Package drawings, standard packing quantities, thermal data, symbolization, and PCB design guidelines are available at www.ti.com/sc/package.
‡ DBV/DBZ/DCK: The actual top-side marking has one additional character that designates the assembly/test site.

description/ordering information (continued)

V_{ref} TOLERANCE (25°C) = 1%
TL431A, TL432A ORDERING INFORMATION

T_A	PACKAGE†		ORDERABLE PART NUMBER	TOP-SIDE MARKING‡
−40°C to 85°C	PDIP (P)	Tube of 50	TL431AIP	TL431AIP
	SC-70 (DCK)	Reel of 3000	TL431AIDCKR	TBD
		Reel of 250	TL431AIDCKT	
	SOIC (D)	Tube of 75	TL431AID	431AI
		Reel of 2500	TL431AIDR	
	SOT-23-5 (DBV)	Reel of 3000	TL431AIDBVR	TAI_
		Reel of 250	TL431AIDBVT	
		Reel of 3000	TL432AIDBVR	T4A_
		Reel of 250	TL432AIDBVT	
	SOT-23-3 (DBZ)	Reel of 3000	TL431AIDBZR	TAI_
		Reel of 250	TL431AIDBZT	
		Reel of 3000	TL432AIDBZR	T4A_
		Reel of 250	TL432AIDBZT	
	SOT-89 (PK)	Reel of 1000	TL431AIPK	4B
	TO-226/TO-92 (LP)	Bulk of 1000	TL431AILP	TL431AI
		Ammo of 2000	TL431AILPM	
		Reel of 2000	TL431AILPR	
−40°C to 125°C	SOT-23-5 (DBV)	Reel of 3000	TL431AQDBVR	TBD
		Reel of 250	TL431AQDBVR	
		Reel of 3000	TL432AQDBVR	TBD
		Reel of 250	TL432AQDBVT	
	SOT-23-3 (DBZ)	Reel of 3000	TL431AQDBZR	TBD
		Reel of 250	TL431AQDBZT	
		Reel of 3000	TL432AQDBZR	TBD
		Reel of 250	TL432AQDBZT	

† Package drawings, standard packing quantities, thermal data, symbolization, and PCB design guidelines are available at www.ti.com/sc/package.
‡ DBV/DBZ/DCK: The actual top-side marking has one additional character that designates the assembly/test site.

description/ordering information (continued)

V_{ref} TOLERANCE (25°C) = 0.5%
TL431B, TL432B ORDERING INFORMATION

T_A	PACKAGE†		ORDERABLE PART NUMBER	TOP-SIDE MARKING‡
0°C to 70°C	PDIP (P)	Tube of 50	TL431BCP	TL431BCP
	SC-70 (DCK)	Reel of 3000	TL431BCDCKR	TBD
		Reel of 250	TL431BCDCKT	
	SOIC (D)	Tube of 75	TL431BCD	T431B
		Reel of 2500	TL431BCDR	
	SOP (PS)	Reel of 2000	TL431BCPSR	TL431B
	SOT-23-5 (DBV)	Reel of 3000	TL431BCDBVR	T3G_
		Reel of 250	TL431BCDBVT	
		Reel of 3000	TL432BCDBVR	TBC_
		Reel of 250	TL432BCDBVT	
	SOT-23-3 (DBZ)	Reel of 3000	TL431BCDBZR	T3G_
		Reel of 250	TL431BCDBZT	
		Reel of 3000	TL432BCDBZR	TBC_
		Reel of 250	TL432BCDBZT	
	SOT-89 (PK)	Reel of 1000	TL431BCPK	4C
	TO-226/TO-92 (LP)	Bulk of 1000	TL431BCLP	TL431B
		Ammo of 2000	TL431BCLPM	
		Reel of 2000	TL431BCLPR	
	TSSOP (PW)	Tube of 150	TL431BCPW	T431B
		Reel of 2000	TL431BCPWR	
−40°C to 85°C	PDIP (P)	Tube of 50	TL431BIP	TL431BIP
	SC-70 (DCK)	Reel of 3000	TL431BIDCKR	TBD
		Reel of 250	TL431BIDCKT	
	SOIC (D)	Tube of 75	TL431BID	Z431B
		Reel of 2500	TL431BIDR	
	SOT-23-5 (DBV)	Reel of 3000	TL431BIDBVR	T3F_
		Reel of 250	TL431BIDBVT	
		Reel of 3000	TL432BIDBVR	T4F_
		Reel of 250	TL432BIDBVT	
	SOT-23-3 (DBZ)	Reel of 3000	TL431BIDBZR	T3F_
		Reel of 250	TL431BIDBZT	
		Reel of 3000	TL432BIDBZR	T4F_
		Reel of 250	TL432IBDBZT	
	SOT-89 (PK)	Reel of 1000	TL431BIPK	4I
	TO-226/TO-92 (LP)	Bulk of 1000	TL431BILP	Z431B
		Reel of 2000	TL431BILPR	

† Package drawings, standard packing quantities, thermal data, symbolization, and PCB design guidelines are available at www.ti.com/sc/package.
‡ DBV/DBZ/DCK: The actual top-side marking has one additional character that designates the assembly/test site.

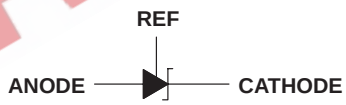
description/ordering information (continued)

V_{ref} TOLERANCE (25°C) = 0.5%
TL431B, TL432B ORDERING INFORMATION (CONTINUED)

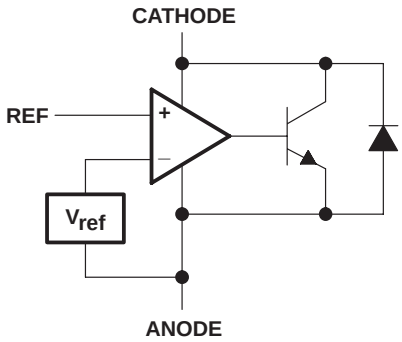
T_A	PACKAGE†		ORDERABLE PART NUMBER	TOP-SIDE MARKING‡
−40°C to 125°C	SOIC (D)	Tube of 75	TL431BQD	T431BQ
		Reel of 2500	TL431BQDR	
	SOT-23-5 (DBV)	Reel of 3000	TL431BQDBVR	T3H_
		Reel of 250	TL431BQDBVT	
		Reel of 3000	TL432BQDBVR	T4H_
		Reel of 250	TL432BQDBVT	
	SOT-23-3 (DBZ)	Reel of 3000	TL431BQDBZR	T3H_
		Reel of 250	TL431BQDBZT	
		Reel of 3000	TL432BQDBZR	T4H_
		Reel of 250	TL432BQDBZT	
	SOT-89 (PK)	Reel of 1000	TL431BQPK	3H
	TO-226/TO-92 (LP)	Bulk of 1000	TL431BQLP	T431BQ
		Ammo of 2000	TL431BQLPM	
		Reel of 2000	TL431BQLPR	

† Package drawings, standard packing quantities, thermal data, symbolization, and PCB design guidelines are available at www.ti.com/sc/package.
‡ DBV/DBZ: The actual top-side marking has one additional character that designates the assembly/test site.

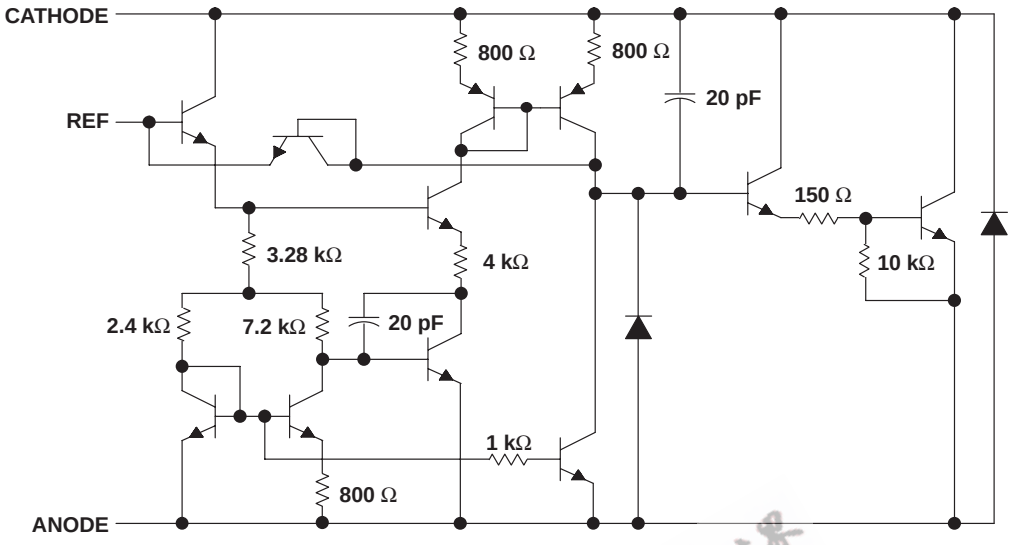
symbol



functional block diagram



equivalent schematic†



† All component values are nominal.

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 . . . . . −50 μA to 10 mA
Operating virtual junction temperature, T_J . . . . . 150°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.

NOTE 1: Voltage values are with respect to the ANODE terminal, unless otherwise noted.

package thermal data (see Note 2)

PACKAGE	BOARD	θ_{JC}	θ_{JA}
PDIP (P)	High K, JESD 51-7	57°C/W	85°C/W
SOIC (D)	High K, JESD 51-7	39°C/W	97°C/W
SOP (PS)	High K, JESD 51-7	46°C/W	95°C/W
SOT-89 (PK)	High K, JESD 51-7	9°C/W	52°C/W
SOT-23-5 (DBV)	High K, JESD 51-7	131°C/W	206°C/W
SOT-23-3 (DBZ)	High K, JESD 51-7	TBD	TBD
TO-92 (LP)	High K, JESD 51-7	55°C/W	140°C/W
TSSOP (PW)	High K, JESD 51-7	65°C/W	149°C/W

NOTE 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.

recommended operating conditions

			MIN	MAX	UNIT
V_{KA}	Cathode voltage		V_{ref}	36	V
I_{KA}	Cathode current		1	100	mA
T_A	Operating free-air temperature range	TL43xxC	0	70	°C
		TL43xxI	−40	85	
		TL43xxQ	−40	125	

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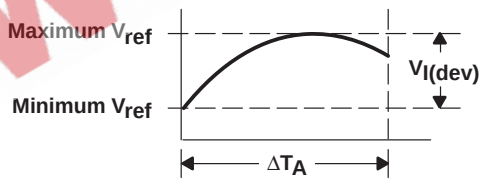
electrical characteristics over recommended operating conditions, T_A = 25°C (unless otherwise noted)

PARAMETER		TEST CIRCUIT	TEST CONDITIONS		TL431C, TL432C			UNIT
					MIN	TYP	MAX	
V_{ref}	Reference voltage	2	V_{KA} = V_{ref}, I_{KA} = 10 mA		2440	2495	2550	mV
$V_{I(dev)}$	Deviation of reference voltage over full temperature range (see Figure 1)	2	V_{KA} = V_{ref}, I_{KA} = 10 mA, T_A = 0°C to 70°C	SOT23-3 and TL432 devices		6	16	mV
				All other devices		4	25	
$\frac{\Delta V_{ref}}{\Delta V_{KA}}$	Ratio of change in reference voltage to the change in cathode voltage	3	I_{KA} = 10 mA	ΔV_{KA} = 10 V − V_{ref}		−1.4	−2.7	$\frac{mV}{V}$
				ΔV_{KA} = 36 V − 10 V		−1	−2	
I_{ref}	Reference current	3	I_{KA} = 10 mA, R1 = 10 kΩ, R2 = ∞			2	4	µA
$I_{I(dev)}$	Deviation of reference current over full temperature range (see Figure 1)	3	I_{KA} = 10 mA, R1 = 10 kΩ, R2 = ∞, T_A = 0°C to 70°C			0.4	1.2	µA
I_{min}	Minimum cathode current for regulation	2	V_{KA} = V_{ref}			0.4	1	mA
I_{off}	Off-state cathode current	4	V_{KA} = 36 V, V_{ref} = 0			0.1	1	µA
$\|z_{KA}\|$	Dynamic impedance (see Figure 1)	1	I_{KA} = 1 mA to 100 mA, V_{KA} = V_{ref}, f ≤ 1 kHz			0.2	0.5	Ω

The deviation parameters $V_{ref(dev)}$ and $I_{ref(dev)}$ are defined as the differences between the maximum and minimum values obtained over the recommended temperature range. The average full-range temperature coefficient of the reference voltage, α_{Vref}, is defined as:

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



where:
ΔT_A is the recommended operating free-air temperature range of the device.

$\alpha_{V_{ref}}$ can be positive or negative, depending on whether minimum V_{ref} or maximum V_{ref}, respectively, occurs at the lower temperature.

Example: maximum V_{ref} = 2496 mV at 30°C, minimum V_{ref} = 2492 mV at 0°C, V_{ref} = 2495 mV at 25°C, ΔT_A = 70°C for TL431C

$$\left|\alpha_{V_{ref}}\right| = \frac{\left(\frac{4\ mV}{2495\ mV}\right) \times 10^6}{70°C} \approx \frac{23\ ppm}{°C}$$

Because minimum V_{ref} occurs at the lower temperature, the coefficient is positive.

Calculating Dynamic Impedance

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

When the device is operating with two external resistors (see Figure 3), the total dynamic impedance of the circuit is given by:

$$|z'| = \frac{\Delta V}{\Delta I} \approx |z_{KA}| \left(1 + \frac{R1}{R2}\right)$$

Figure 1. Calculating Deviation Parameters and Dynamic Impedance

electrical characteristics over recommended operating conditions, T_A = 25°C (unless otherwise noted)

PARAMETER		TEST CIRCUIT	TEST CONDITIONS		TL431I, TL432I			UNIT
					MIN	TYP	MAX	
V_{ref}	Reference voltage	2	V_{KA} = V_{ref},	I_{KA} = 10 mA	2440	2495	2550	mV
$V_{I(dev)}$	Deviation of reference voltage over full temperature range (see Figure 1)	2	V_{KA} = V_{ref}, I_{KA} = 10 mA, T_A = −40°C to 85°C	SOT23-3 and TL432 devices		14	34	mV
				All other devices		5	50	
$\frac{\Delta V_{ref}}{\Delta V_{KA}}$	Ratio of change in reference voltage to the change in cathode voltage	3	I_{KA} = 10 mA	ΔV_{KA} = 10 V − V_{ref}		−1.4	−2.7	$\frac{mV}{V}$
				ΔV_{KA} = 36 V − 10 V		−1	−2	
I_{ref}	Reference current	3	I_{KA} = 10 mA, R1 = 10 kΩ, R2 = ∞			2	4	µA
$I_{I(dev)}$	Deviation of reference current over full temperature range (see Figure 1)	3	I_{KA} = 10 mA, R1 = 10 kΩ, R2 = ∞, T_A = −40°C to 85°C			0.8	2.5	µA
I_{min}	Minimum cathode current for regulation	2	V_{KA} = V_{ref}			0.4	1	mA
I_{off}	Off-state cathode current	4	V_{KA} = 36 V,	V_{ref} = 0		0.1	1	µA
$\|z_{KA}\|$	Dynamic impedance (see Figure 1)	2	I_{KA} = 1 mA to 100 mA, V_{KA} = V_{ref}, f ≤ 1 kHz			0.2	0.5	Ω

electrical characteristics over recommended operating conditions, T_A = 25°C (unless otherwise noted)

PARAMETER		TEST CIRCUIT	TEST CONDITIONS		TL431Q, TL432Q			UNIT
					MIN	TYP	MAX	
V_{ref}	Reference voltage	2	V_{KA} = V_{ref},	I_{KA} = 10 mA	2440	2495	2550	mV
$V_{I(dev)}$	Deviation of reference voltage over full temperature range (see Figure 1)	2	V_{KA} = V_{ref}, I_{KA} = 10 mA, T_A = −40°C to 125°C			14	34	mV
$\frac{\Delta V_{ref}}{\Delta V_{KA}}$	Ratio of change in reference voltage to the change in cathode voltage	3	I_{KA} = 10 mA	ΔV_{KA} = 10 V − V_{ref}		−1.4	−2.7	$\frac{mV}{V}$
				ΔV_{KA} = 36 V − 10 V		−1	−2	
I_{ref}	Reference current	3	I_{KA} = 10 mA, R1 = 10 kΩ, R2 = ∞			2	4	µA
$I_{I(dev)}$	Deviation of reference current over full temperature range (see Figure 1)	3	I_{KA} = 10 mA, R1 = 10 kΩ, R2 = ∞, T_A = −40°C to 125°C			0.8	2.5	µA
I_{min}	Minimum cathode current for regulation	2	V_{KA} = V_{ref}			0.4	1	mA
I_{off}	Off-state cathode current	4	V_{KA} = 36 V,	V_{ref} = 0		0.1	1	µA
$\|z_{KA}\|$	Dynamic impedance (see Figure 1)	2	I_{KA} = 1 mA to 100 mA, V_{KA} = V_{ref}, f ≤ 1 kHz			0.2	0.5	Ω

electrical characteristics over recommended operating conditions, T_A = 25°C (unless otherwise noted)

PARAMETER		TEST CIRCUIT	TEST CONDITIONS		TL431AC, TL432AC			UNIT
					MIN	TYP	MAX	
V_{ref}	Reference voltage	2	V_{KA} = V_{ref}, I_{KA} = 10 mA		2470	2495	2520	mV
$V_{I(dev)}$	Deviation of reference voltage over full temperature range (see Figure 1)	2	V_{KA} = V_{ref}, I_{KA} = 10 mA, T_A = 0°C to 70°C	SOT23-3, SC-70, and TL432 devices		6	16	mV
				All other devices		4	25	
$\frac{\Delta V_{ref}}{\Delta V_{KA}}$	Ratio of change in reference voltage to the change in cathode voltage	3	I_{KA} = 10 mA	ΔV_{KA} = 10 V − V_{ref}		−1.4	−2.7	$\frac{mV}{V}$
				ΔV_{KA} = 36 V − 10 V		−1	−2	
I_{ref}	Reference current	3	I_{KA} = 10 mA, R1 = 10 kΩ, R2 = ∞			2	4	µA
$I_{I(dev)}$	Deviation of reference current over full temperature range (see Figure 1)	3	I_{KA} = 10 mA, R1 = 10 kΩ, R2 = ∞, T_A = 0°C to 70°C			0.8	1.2	µA
I_{min}	Minimum cathode current for regulation	2	V_{KA} = V_{ref}			0.4	0.6	mA
I_{off}	Off-state cathode current	4	V_{KA} = 36 V, V_{ref} = 0			0.1	0.5	µA
$\|z_{KA}\|$	Dynamic impedance (see Figure 1)	1	I_{KA} = 1 mA to 100 mA, V_{KA} = V_{ref}, f ≤ 1 kHz			0.2	0.5	Ω

electrical characteristics over recommended operating conditions, T_A = 25°C (unless otherwise noted)

PARAMETER		TEST CIRCUIT	TEST CONDITIONS		TL431AI, TL432AI			UNIT
					MIN	TYP	MAX	
V_{ref}	Reference voltage	2	V_{KA} = V_{ref}, I_{KA} = 10 mA		2470	2495	2520	mV
$V_{I(dev)}$	Deviation of reference voltage over full temperature range (see Figure 1)	2	V_{KA} = V_{ref}, I_{KA} = 10 mA, T_A = −40°C to 85°C	SOT23-3, SC-70, and TL432 devices		14	34	mV
				All other packages		5	50	
$\frac{\Delta V_{ref}}{\Delta V_{KA}}$	Ratio of change in reference voltage to the change in cathode voltage	3	I_{KA} = 10 mA	ΔV_{KA} = 10 V − V_{ref}		−1.4	−2.7	$\frac{mV}{V}$
				ΔV_{KA} = 36 V − 10 V		−1	−2	
I_{ref}	Reference current	3	I_{KA} = 10 mA, R1 = 10 kΩ, R2 = ∞			2	4	µA
$I_{I(dev)}$	Deviation of reference current over full temperature range (see Figure 1)	3	I_{KA} = 10 mA, R1 = 10 kΩ, R2 = ∞, T_A = −40°C to 85°C			0.8	2.5	µA
I_{min}	Minimum cathode current for regulation	2	V_{KA} = V_{ref}			0.4	0.7	mA
I_{off}	Off-state cathode current	4	V_{KA} = 36 V, V_{ref} = 0			0.1	0.5	µA
$\|z_{KA}\|$	Dynamic impedance (see Figure 1)	2	I_{KA} = 1 mA to 100 mA, V_{KA} = V_{ref}, f ≤ 1 kHz			0.2	0.5	Ω

electrical characteristics over recommended operating conditions, T_A = 25°C (unless otherwise noted)

PARAMETER		TEST CIRCUIT	TEST CONDITIONS		TL431AQ, TL432AQ			UNIT
					MIN	TYP	MAX	
V_{ref}	Reference voltage	2	V_{KA} = V_{ref}, I_{KA} = 10 mA		2470	2495	2520	mV
$V_{I(dev)}$	Deviation of reference voltage over full temperature range (see Figure 1)	2	V_{KA} = V_{ref}, I_{KA} = 10 mA, T_A = −40°C to 125°C			14	34	mV
$\frac{\Delta V_{ref}}{\Delta V_{KA}}$	Ratio of change in reference voltage to the change in cathode voltage	3	I_{KA} = 10 mA	ΔV_{KA} = 10 V − V_{ref}		−1.4	−2.7	$\frac{mV}{V}$
				ΔV_{KA} = 36 V − 10 V		−1	−2	
I_{ref}	Reference current	3	I_{KA} = 10 mA, R1 = 10 kΩ, R2 = ∞			2	4	µA
$I_{I(dev)}$	Deviation of reference current over full temperature range (see Figure 1)	3	I_{KA} = 10 mA, R1 = 10 kΩ, R2 = ∞, T_A = −40°C to 125°C			0.8	2.5	µA
I_{min}	Minimum cathode current for regulation	2	V_{KA} = V_{ref}			0.4	0.7	mA
I_{off}	Off-state cathode current	4	V_{KA} = 36 V, V_{ref} = 0			0.1	0.5	µA
$\|z_{KA}\|$	Dynamic impedance (see Figure 1)	2	I_{KA} = 1 mA to 100 mA, V_{KA} = V_{ref}, f ≤ 1 kHz			0.2	0.5	Ω

electrical characteristics over recommended operating conditions, T_A = 25°C (unless otherwise noted)

PARAMETER		TEST CIRCUIT	TEST CONDITIONS		TL431BC, TL432BC			UNIT
					MIN	TYP	MAX	
V_{ref}	Reference voltage	2	V_{KA} = V_{ref}, I_{KA} = 10 mA		2483	2495	2507	mV
$V_{I(dev)}$	Deviation of reference voltage over full temperature range (see Figure 1)	2	V_{KA} = V_{ref}, I_{KA} = 10 mA, T_A = 0°C to 70°C			6	16	mV
$\frac{\Delta V_{ref}}{\Delta V_{KA}}$	Ratio of change in reference voltage to the change in cathode voltage	3	I_{KA} = 10 mA	ΔV_{KA} = 10 V − V_{ref}		−1.4	−2.7	$\frac{mV}{V}$
				ΔV_{KA} = 36 V − 10 V		−1	−2	
I_{ref}	Reference current	3	I_{KA} = 10 mA, R1 = 10 kΩ, R2 = ∞			2	4	µA
$I_{I(dev)}$	Deviation of reference current over full temperature range (see Figure 1)	3	I_{KA} = 10 mA, R1 = 10 kΩ, R2 = ∞, T_A = 0°C to 70°C			0.8	1.2	µA
I_{min}	Minimum cathode current for regulation	2	V_{KA} = V_{ref}			0.4	0.6	mA
I_{off}	Off-state cathode current	4	V_{KA} = 36 V, V_{ref} = 0			0.1	0.5	µA
$\|z_{KA}\|$	Dynamic impedance (see Figure 1)	1	I_{KA} = 1 mA to 100 mA, V_{KA} = V_{ref}, f ≤ 1 kHz			0.2	0.5	Ω

electrical characteristics over recommended operating conditions, T_A = 25°C (unless otherwise noted)

PARAMETER		TEST CIRCUIT	TEST CONDITIONS		TL431BI, TL432BI			UNIT
					MIN	TYP	MAX	
V_{ref}	Reference voltage	2	V_{KA} = V_{ref},	I_{KA} = 10 mA	2483	2495	2507	mV
$V_{I(dev)}$	Deviation of reference voltage over full temperature range (see Figure 1)	2	V_{KA} = V_{ref}, I_{KA} = 10 mA, T_A = −40°C to 85°C			14	34	mV
$\frac{\Delta V_{ref}}{\Delta V_{KA}}$	Ratio of change in reference voltage to the change in cathode voltage	3	I_{KA} = 10 mA	ΔV_{KA} = 10 V − V_{ref}		−1.4	−2.7	$\frac{mV}{V}$
				ΔV_{KA} = 36 V − 10 V		−1	−2	
I_{ref}	Reference current	3	I_{KA} = 10 mA, R1 = 10 kΩ, R2 = ∞			2	4	µA
$I_{I(dev)}$	Deviation of reference current over full temperature range (see Figure 1)	3	I_{KA} = 10 mA, R1 = 10 kΩ, R2 = ∞, T_A = −40°C to 85°C			0.8	2.5	µA
I_{min}	Minimum cathode current for regulation	2	V_{KA} = V_{ref}			0.4	0.7	mA
I_{off}	Off-state cathode current	4	V_{KA} = 36 V,	V_{ref} = 0		0.1	0.5	µA
$\|z_{KA}\|$	Dynamic impedance (see Figure 1)	2	I_{KA} = 1 mA to 100 mA, V_{KA} = V_{ref}, f ≤ 1 kHz			0.2	0.5	Ω

electrical characteristics over recommended operating conditions, T_A = 25°C (unless otherwise noted)

PARAMETER		TEST CIRCUIT	TEST CONDITIONS		TL431BQ, TL432BQ			UNIT
					MIN	TYP	MAX	
V_{ref}	Reference voltage	2	V_{KA} = V_{ref},	I_{KA} = 10 mA	2483	2495	2507	mV
$V_{I(dev)}$	Deviation of reference voltage over full temperature range (see Figure 1)	2	V_{KA} = V_{ref}, I_{KA} = 10 mA, T_A = −40°C to 125°C			14	34	mV
$\frac{\Delta V_{ref}}{\Delta V_{KA}}$	Ratio of change in reference voltage to the change in cathode voltage	3	I_{KA} = 10 mA	ΔV_{KA} = 10 V − V_{ref}		−1.4	−2.7	$\frac{mV}{V}$
				ΔV_{KA} = 36 V − 10 V		−1	−2	
I_{ref}	Reference current	3	I_{KA} = 10 mA, R1 = 10 kΩ, R2 = ∞			2	4	µA
$I_{I(dev)}$	Deviation of reference current over full temperature range (see Figure 1)	3	I_{KA} = 10 mA, R1 = 10 kΩ, R2 = ∞, T_A = −40°C to 125°C			0.8	2.5	µA
I_{min}	Minimum cathode current for regulation	2	V_{KA} = V_{ref}			0.4	0.7	mA
I_{off}	Off-state cathode current	4	V_{KA} = 36 V,	V_{ref} = 0		0.1	0.5	µA
$\|z_{KA}\|$	Dynamic impedance (see Figure 1)	1	I_{KA} = 1 mA to 100 mA, V_{KA} = V_{ref}, f ≤ 1 kHz			0.2	0.5	Ω

PARAMETER MEASUREMENT INFORMATION

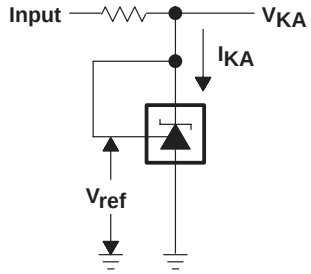


Figure 2. Test Circuit for $V_{KA} = V_{ref}$

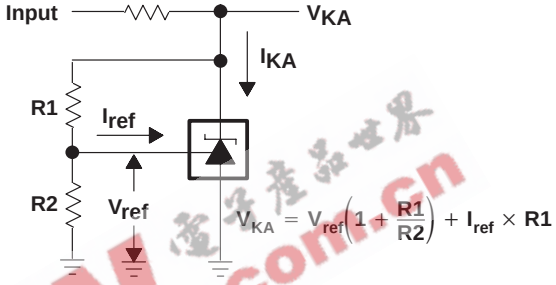


Figure 3. Test Circuit for $V_{KA} > V_{ref}$

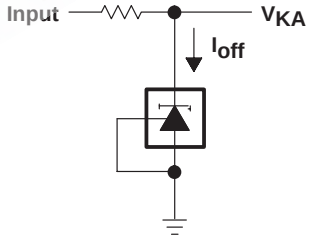


Figure 4. Test Circuit for I_{off}

TYPICAL CHARACTERISTICS

Table 1. Graphs

	FIGURE
Reference voltage vs Free-air temperature	5
Reference current vs Free-air temperature	6
Cathode current vs Cathode voltage	7, 8
OFF-state cathode current vs Free-air temperature	9
Ratio of delta reference voltage to delta cathode voltage vs Free-air temperature	10
Equivalent input noise voltage vs Frequency	11
Equivalent input noise voltage over a 10-s period	12
Small-signal voltage amplification vs Frequency	13
Reference impedance vs Frequency	14
Pulse response	15
Stability boundary conditions	16

Table 2. Application Circuits

	FIGURE
Shunt regulator	17
Single-supply comparator with temperature-compensated threshold	18
Precision high-current series regulator	19
Output control of a three-terminal fixed regulator	20
High-current shunt regulator	21
Crowbar circuit	22
Precision 5-V 1.5-A regulator	23
Efficient 5-V precision regulator	24
PWM converter with reference	25
Voltage monitor	26
Delay timer	27
Precision current limiter	28
Precision constant-current sink	29

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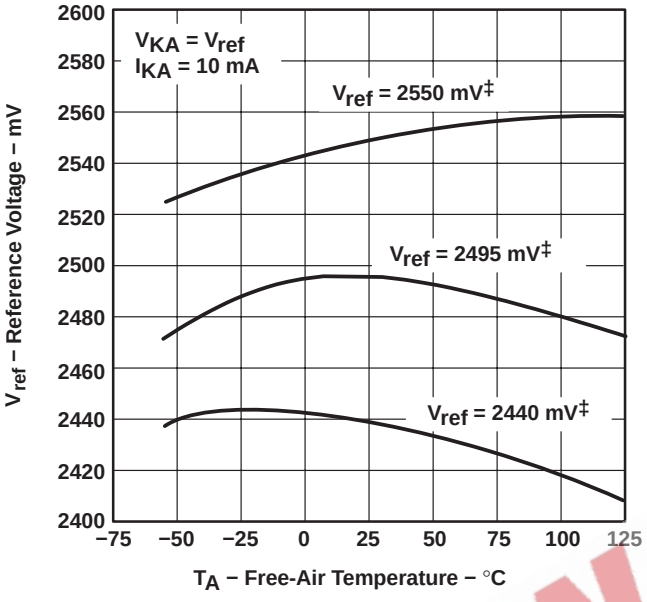
TYPICAL CHARACTERISTICS†

REFERENCE VOLTAGE
vs
FREE-AIR TEMPERATURE



‡ Data is for devices having the indicated value of V_{ref} at I_{KA} = 10 mA, T_A = 25°C.

Figure 5

REFERENCE CURRENT
vs
FREE-AIR TEMPERATURE

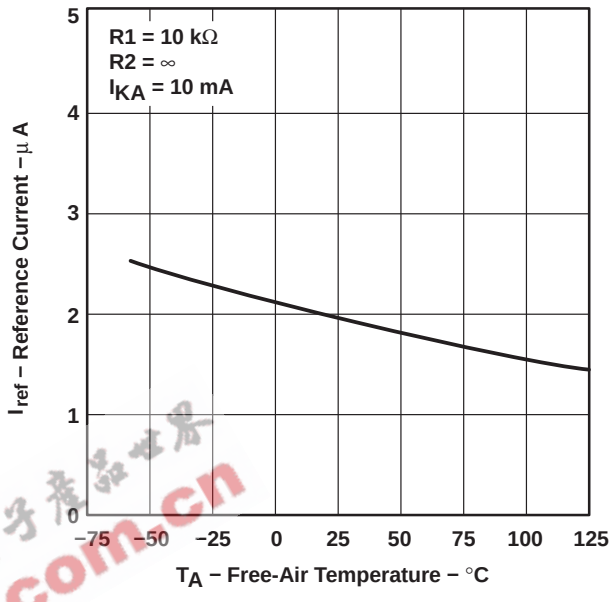


Figure 6

CATHODE CURRENT
vs
CATHODE VOLTAGE

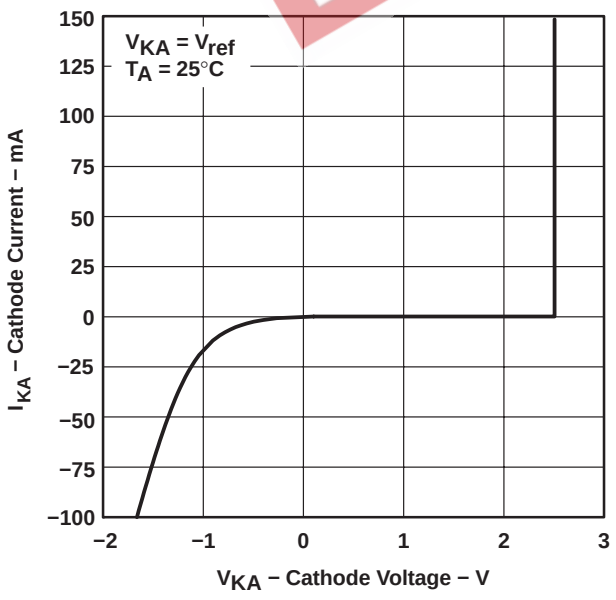


Figure 7

CATHODE CURRENT
vs
CATHODE VOLTAGE

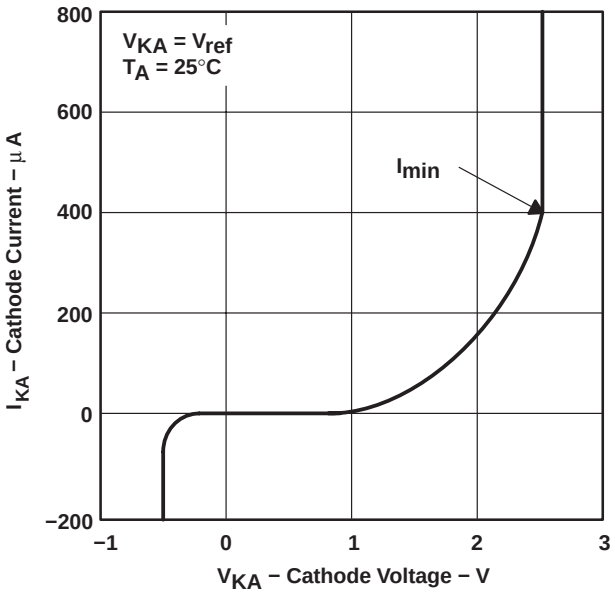


Figure 8

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

TYPICAL CHARACTERISTICS†

OFF-STATE CATHODE CURRENT vs FREE-AIR TEMPERATURE

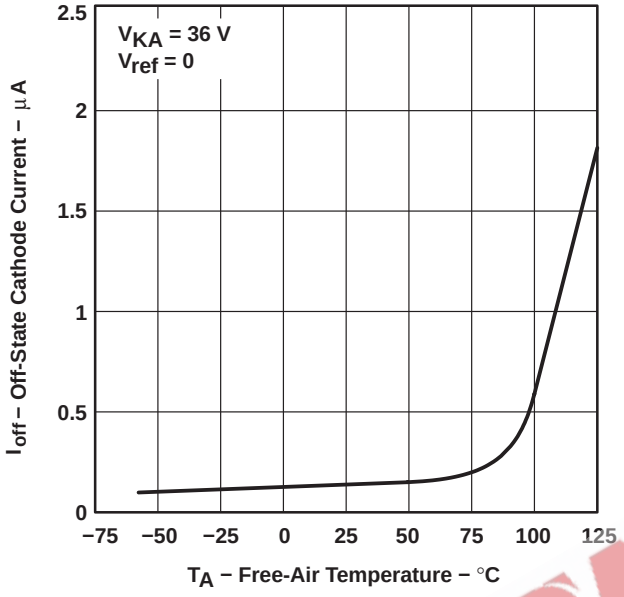


Figure 9

RATIO OF DELTA REFERENCE VOLTAGE TO DELTA CATHODE VOLTAGE vs FREE-AIR TEMPERATURE

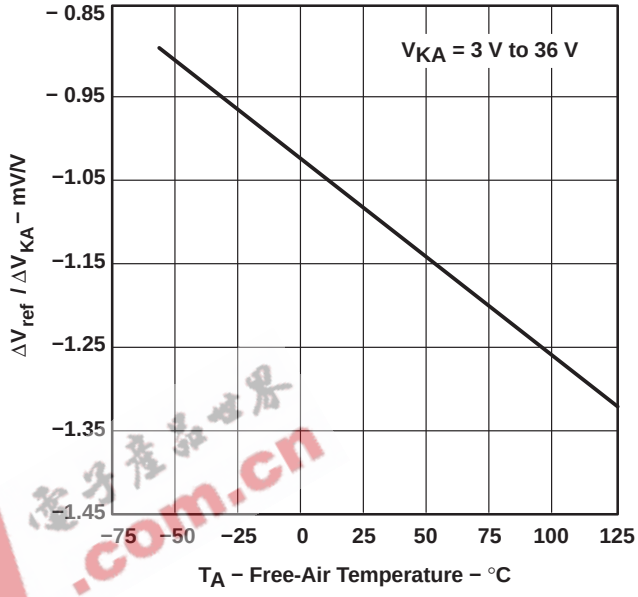


Figure 10

EQUIVALENT INPUT NOISE VOLTAGE vs FREQUENCY

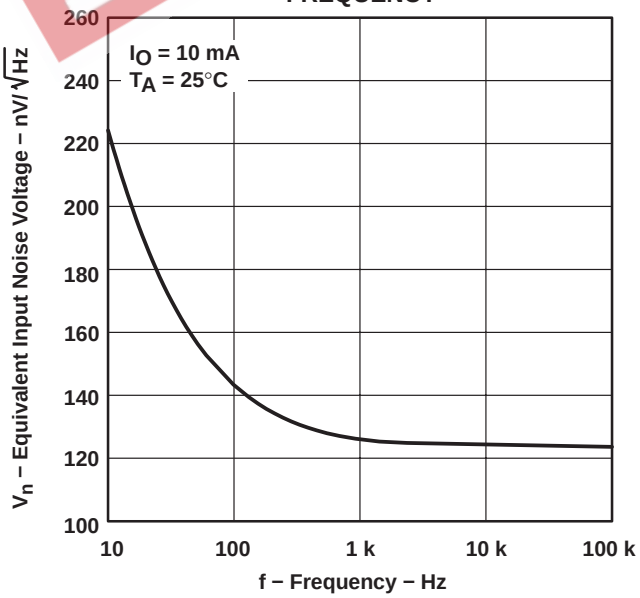


Figure 11

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

TYPICAL CHARACTERISTICS

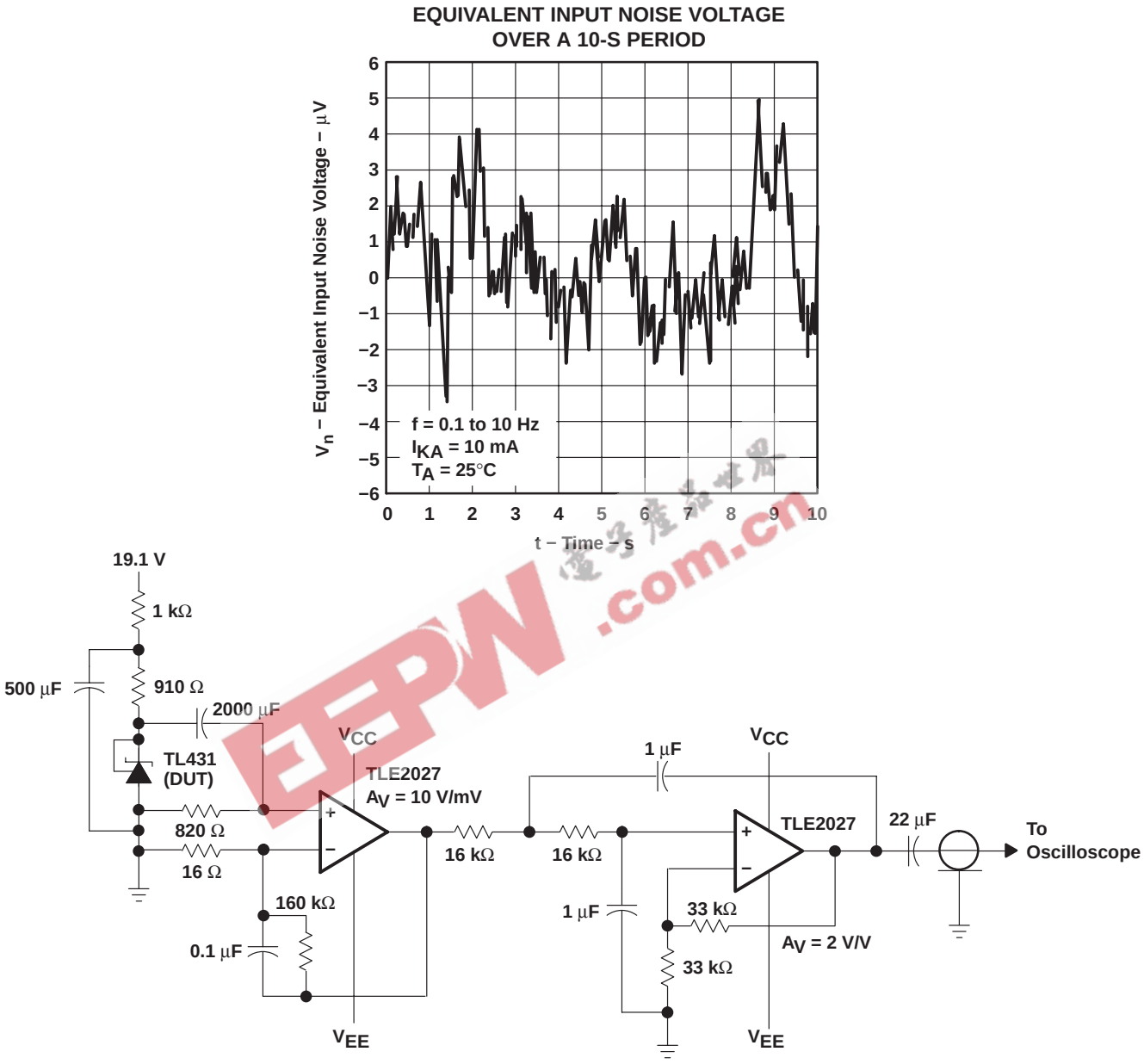
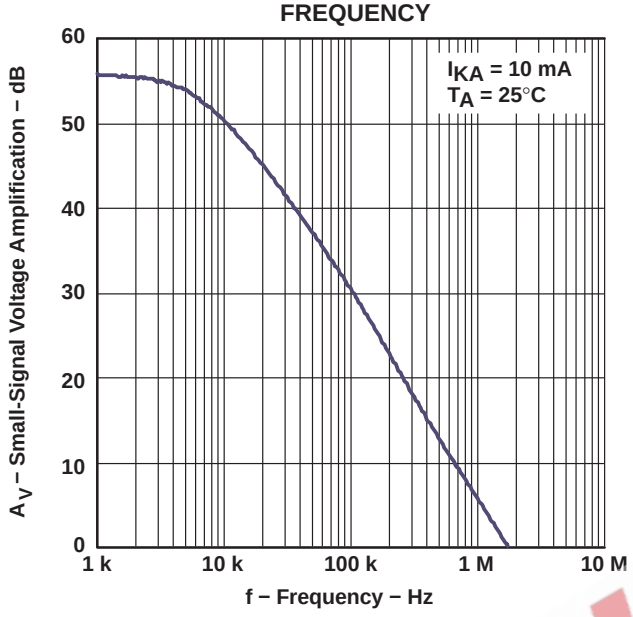


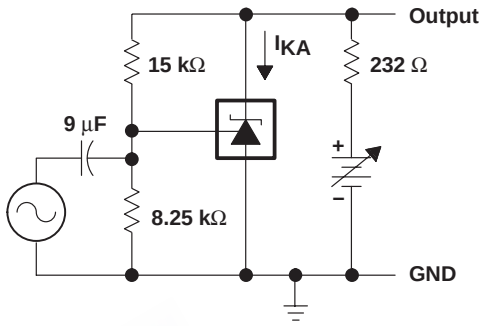
Figure 12. Test Circuit for Equivalent Input Noise Voltage

TYPICAL CHARACTERISTICS

SMALL-SIGNAL VOLTAGE AMPLIFICATION vs FREQUENCY



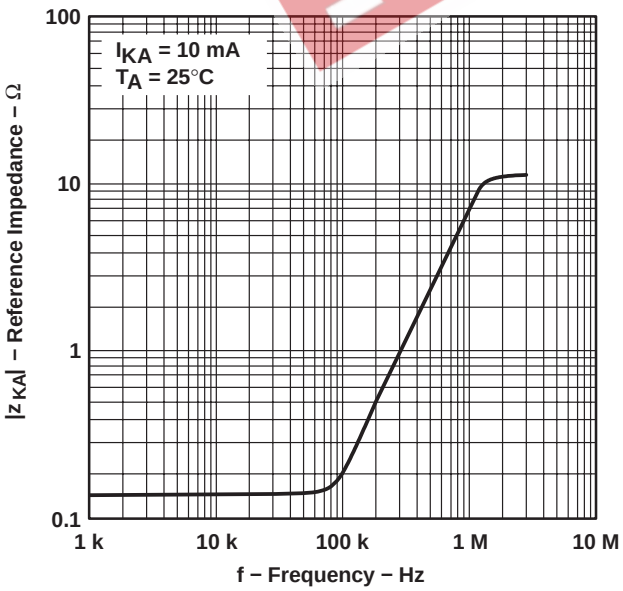
I_{KA} = 10 mA
T_A = 25°C

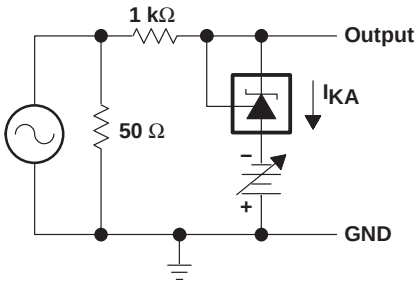


TEST CIRCUIT FOR VOLTAGE AMPLIFICATION

Figure 13

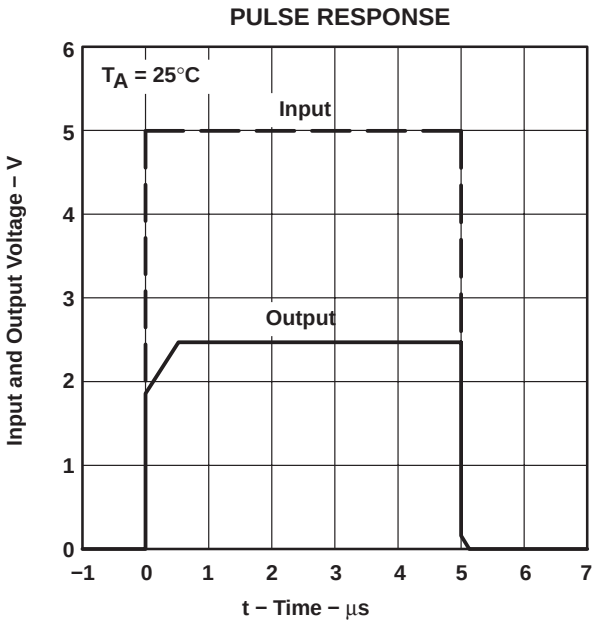
REFERENCE IMPEDANCE vs FREQUENCY

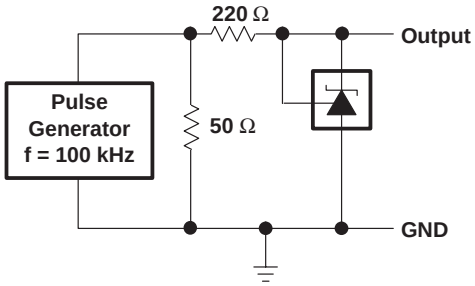




TEST CIRCUIT FOR REFERENCE IMPEDANCE

Figure 14





TEST CIRCUIT FOR PULSE RESPONSE

Figure 15

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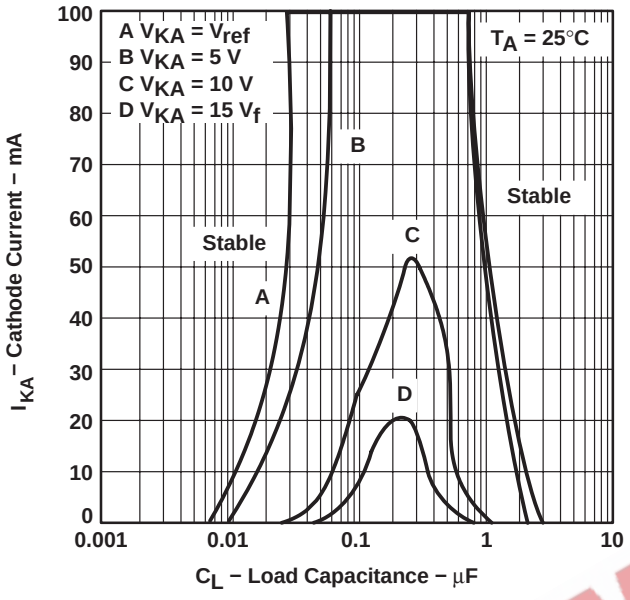
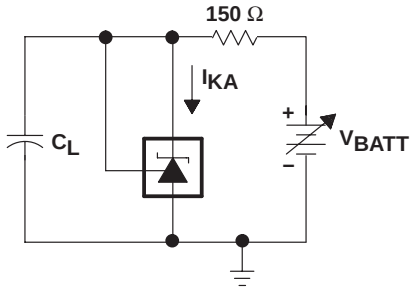
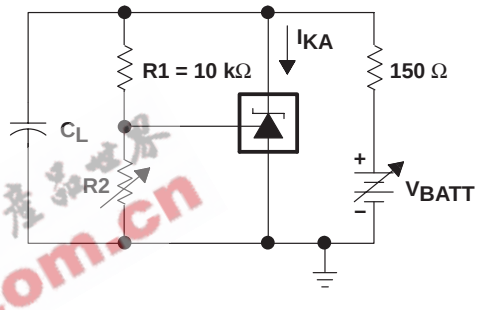
TYPICAL CHARACTERISTICS

**STABILITY BOUNDARY CONDITIONS†
FOR ALL TL431 AND TL431A DEVICES
(EXCEPT FOR SOT23-3, SC-70, AND Q-TEMP DEVICES)**



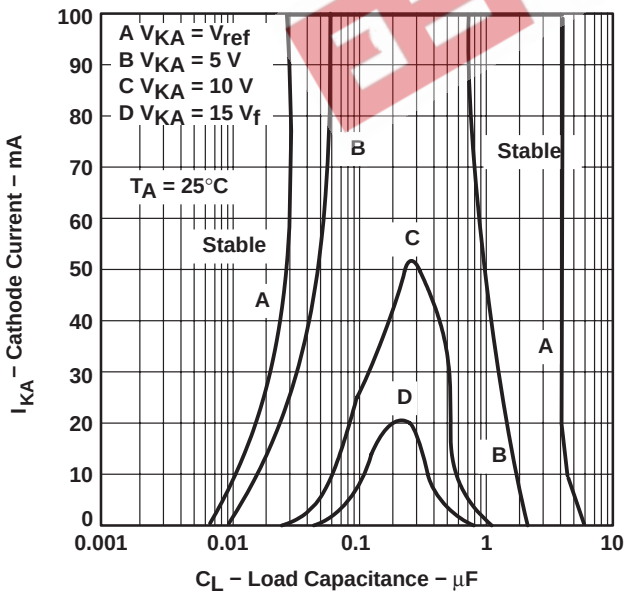


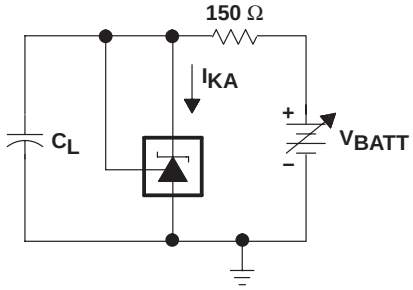
TEST CIRCUIT FOR CURVE A



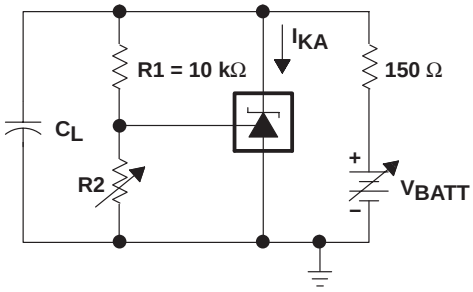
TEST CIRCUIT FOR CURVES B, C, AND D

**STABILITY BOUNDARY CONDITIONS†
FOR ALL TL431B, TL432, SOT-23, SC-70, AND Q-TEMP DEVICES**





TEST CIRCUIT FOR CURVE A

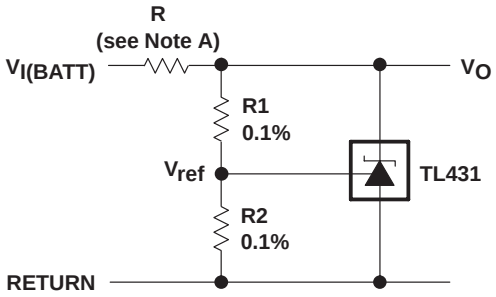


TEST CIRCUIT FOR CURVES B, C, AND D

† 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_{KA} and I_{KA} conditions with C_L = 0. V_{BATT} and C_L then were adjusted to determine the ranges of stability.

Figure 16

APPLICATION INFORMATION



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

NOTE A: R should provide cathode current ≥1 mA to the TL431 at minimum $V_{I(BATT)}$.

Figure 17. Shunt Regulator

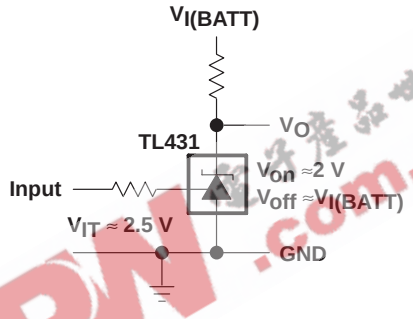
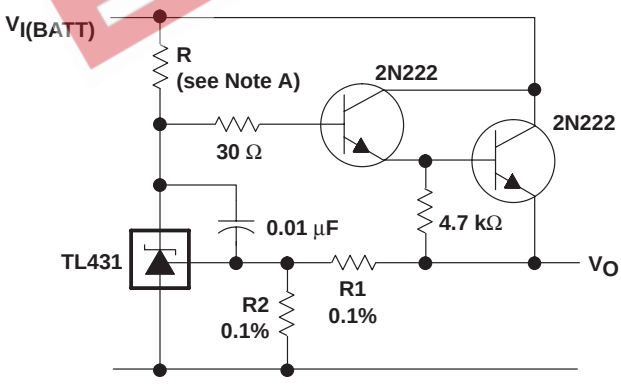


Figure 18. Single-Supply Comparator With Temperature-Compensated Threshold



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

NOTE A: R should provide cathode current ≥1 mA to the TL431 at minimum $V_{I(BATT)}$.

Figure 19. Precision High-Current Series Regulator

APPLICATION INFORMATION

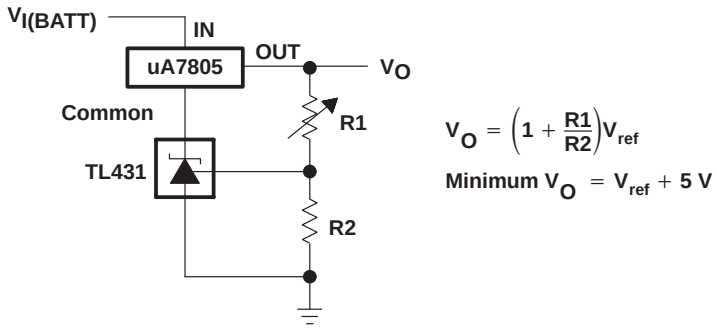


Figure 20. Output Control of a Three-Terminal Fixed Regulator

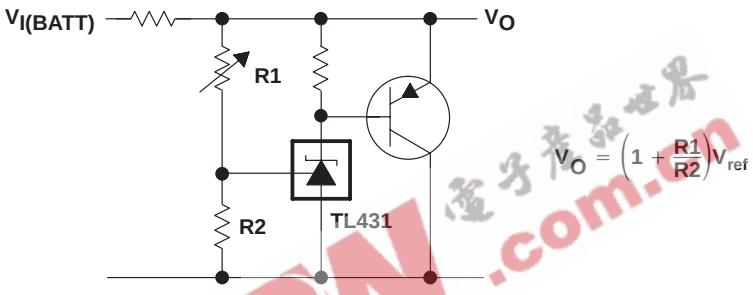
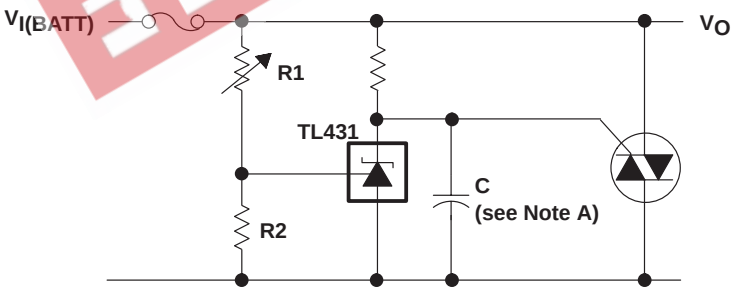


Figure 21. High-Current Shunt Regulator



NOTE A: Refer to the stability boundary conditions in Figure 16 to determine allowable values for C.

Figure 22. Crowbar Circuit

APPLICATION INFORMATION

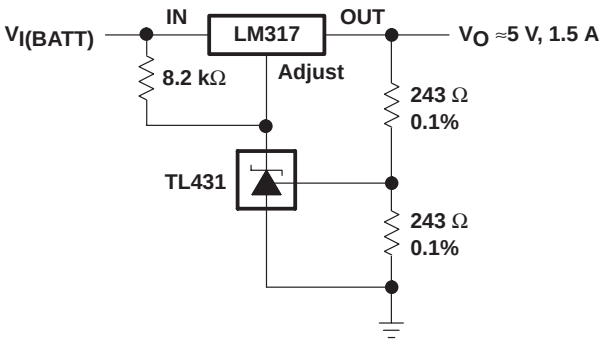
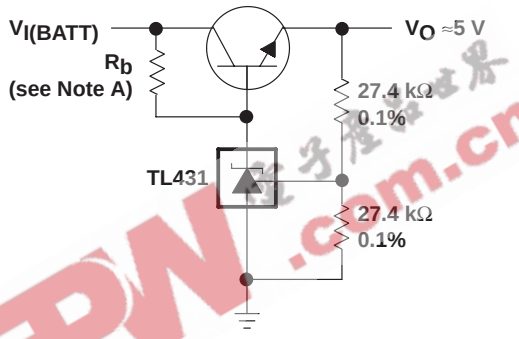


Figure 23. Precision 5-V 1.5-A Regulator



NOTE A: R_b should provide cathode current ≥1 mA to the TL431.

Figure 24. Efficient 5-V Precision Regulator

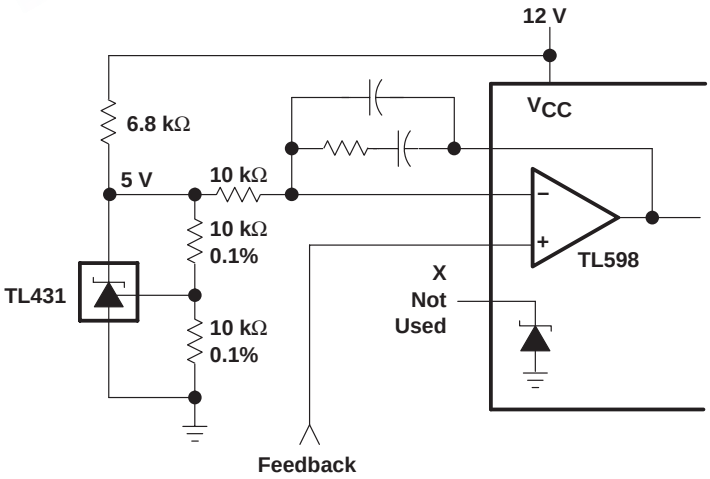
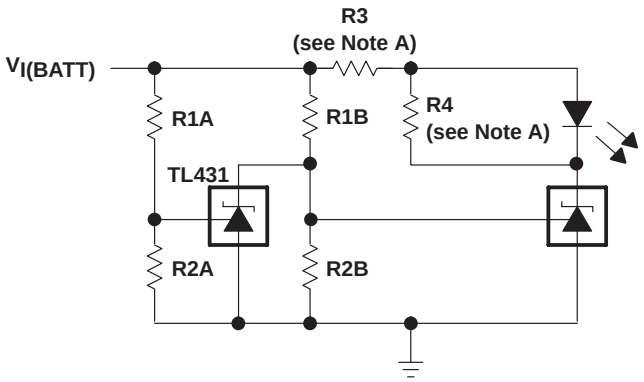


Figure 25. PWM Converter With Reference

APPLICATION INFORMATION



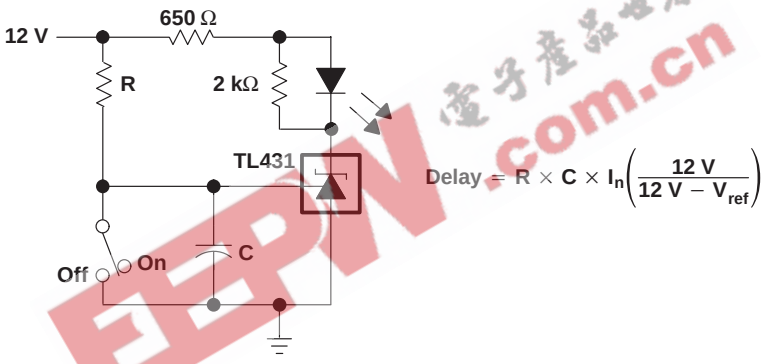
$$\text{Low Limit} = \left(1 + \frac{R1B}{R2B}\right)V_{ref}$$

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

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

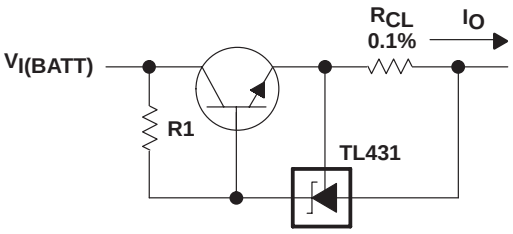
NOTE A: R3 and R4 are selected to provide the desired LED intensity and cathode current ≥1 mA to the TL431 at the available $V_{I(BATT)}$.

Figure 26. Voltage Monitor



$$\text{Delay} = R \times C \times \ln\left(\frac{12\ V}{12\ V - V_{ref}}\right)$$

Figure 27. Delay Timer



$$I_{out} = \frac{V_{ref}}{R_{CL}} + I_{KA}$$

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

Figure 28. Precision Current Limiter

APPLICATION INFORMATION

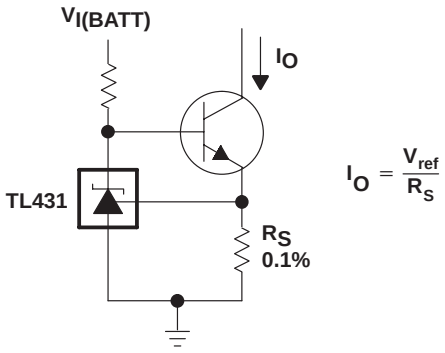
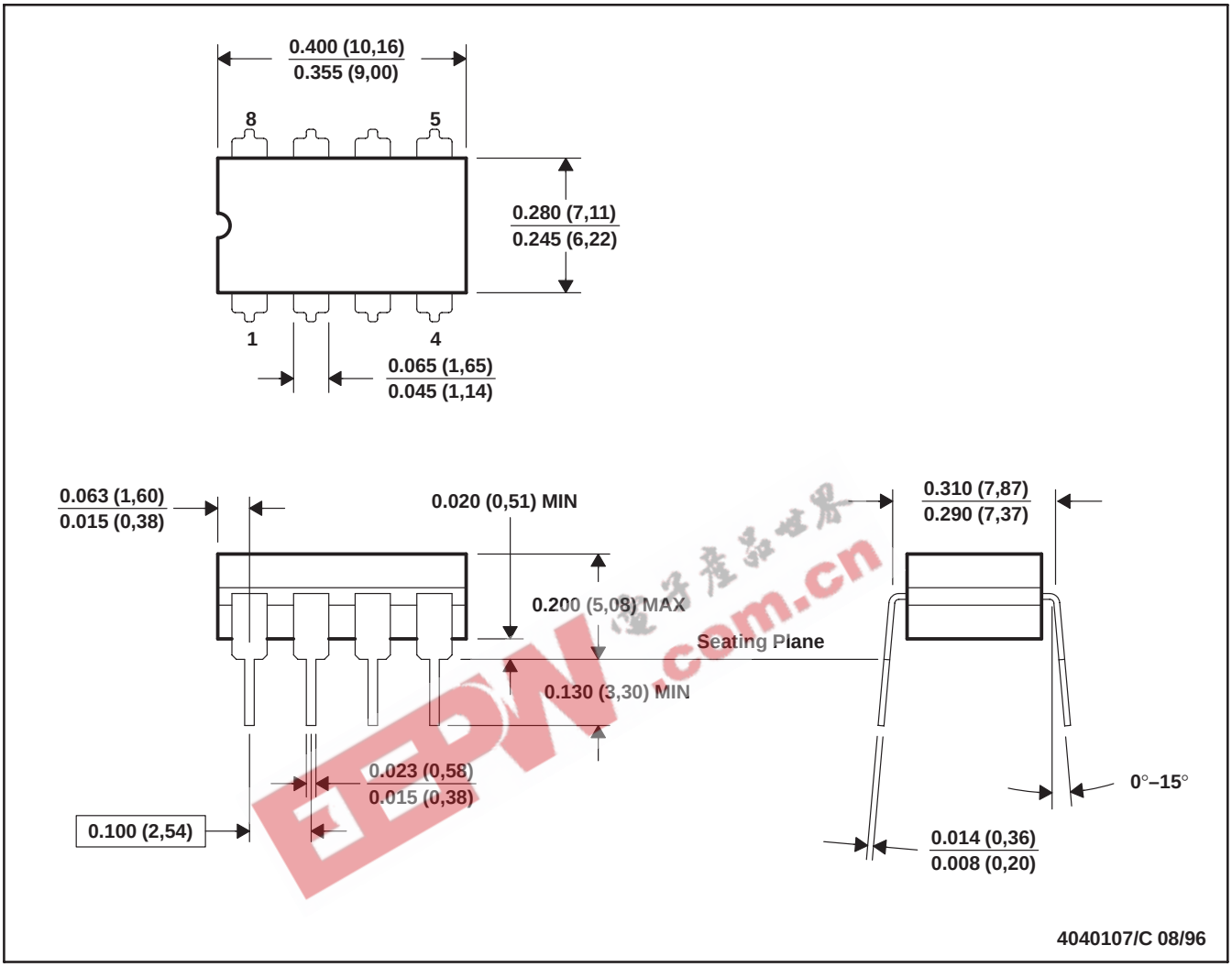


Figure 29. Precision Constant-Current Sink

EEPW .com.cn

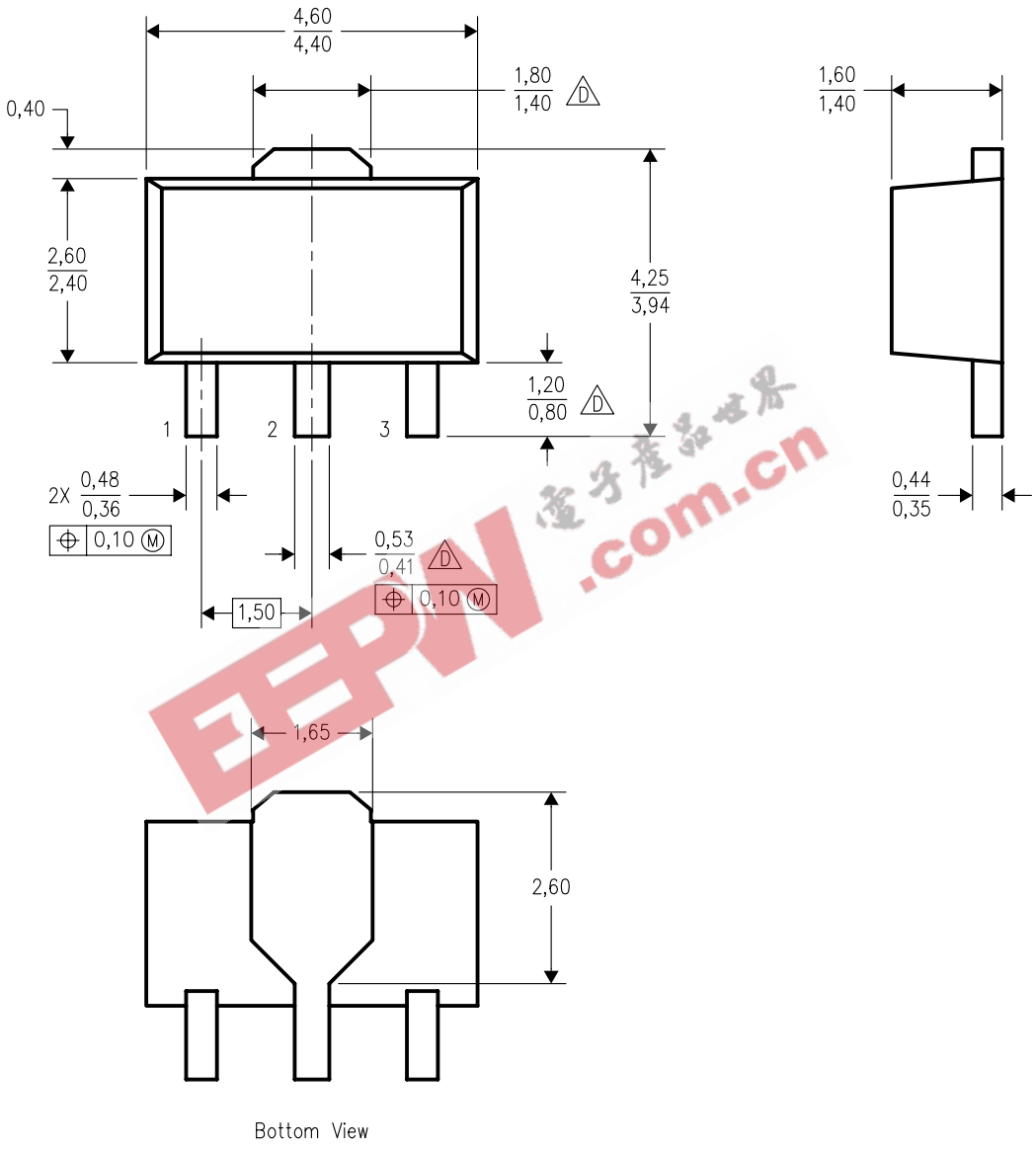
MCER001A – JANUARY 1995 – REVISED JANUARY 1997

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

PK (R–PSSO–F3) PLASTIC SINGLE–IN–LINE PACKAGE



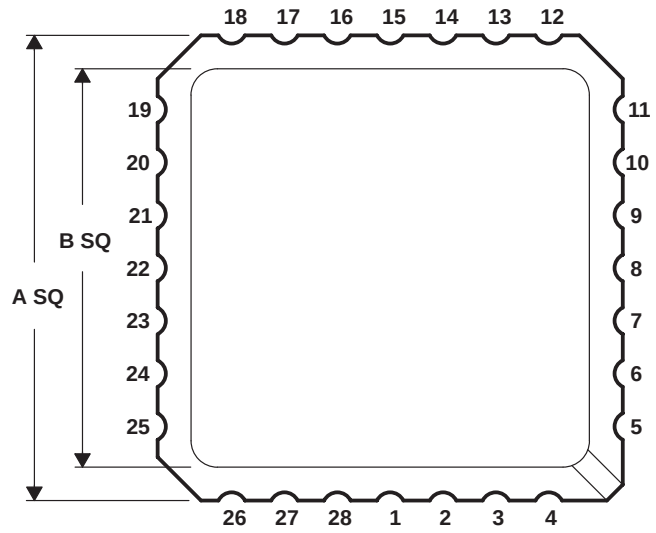
4040234/C 07/2004

NOTES:
A. All linear dimensions are in millimeters. Dimensioning and tolerancing per ASME Y14.5–1994.
B. This drawing is subject to change without notice.
C. The center lead is in electrical contact with the tab.
D. Falls within JEDEC TO–243 variation AA, except minimum lead length, pin 2 minimum lead width, and minimum tab width.

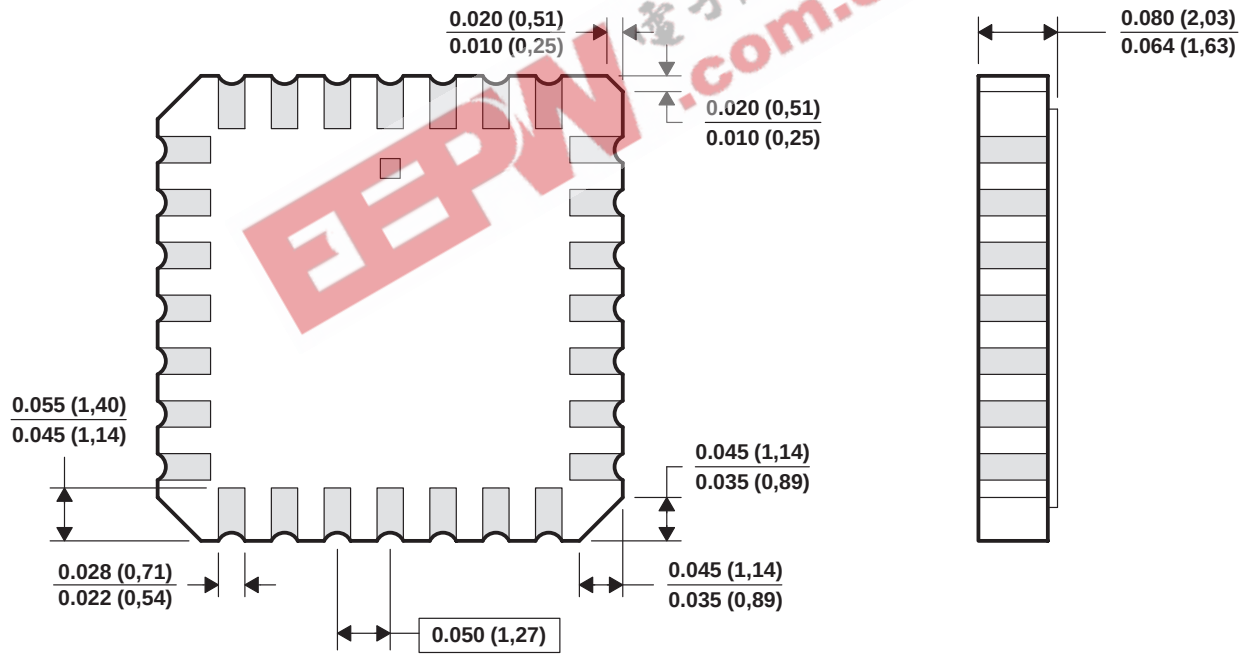
FK (S-CQCC-N**)

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)

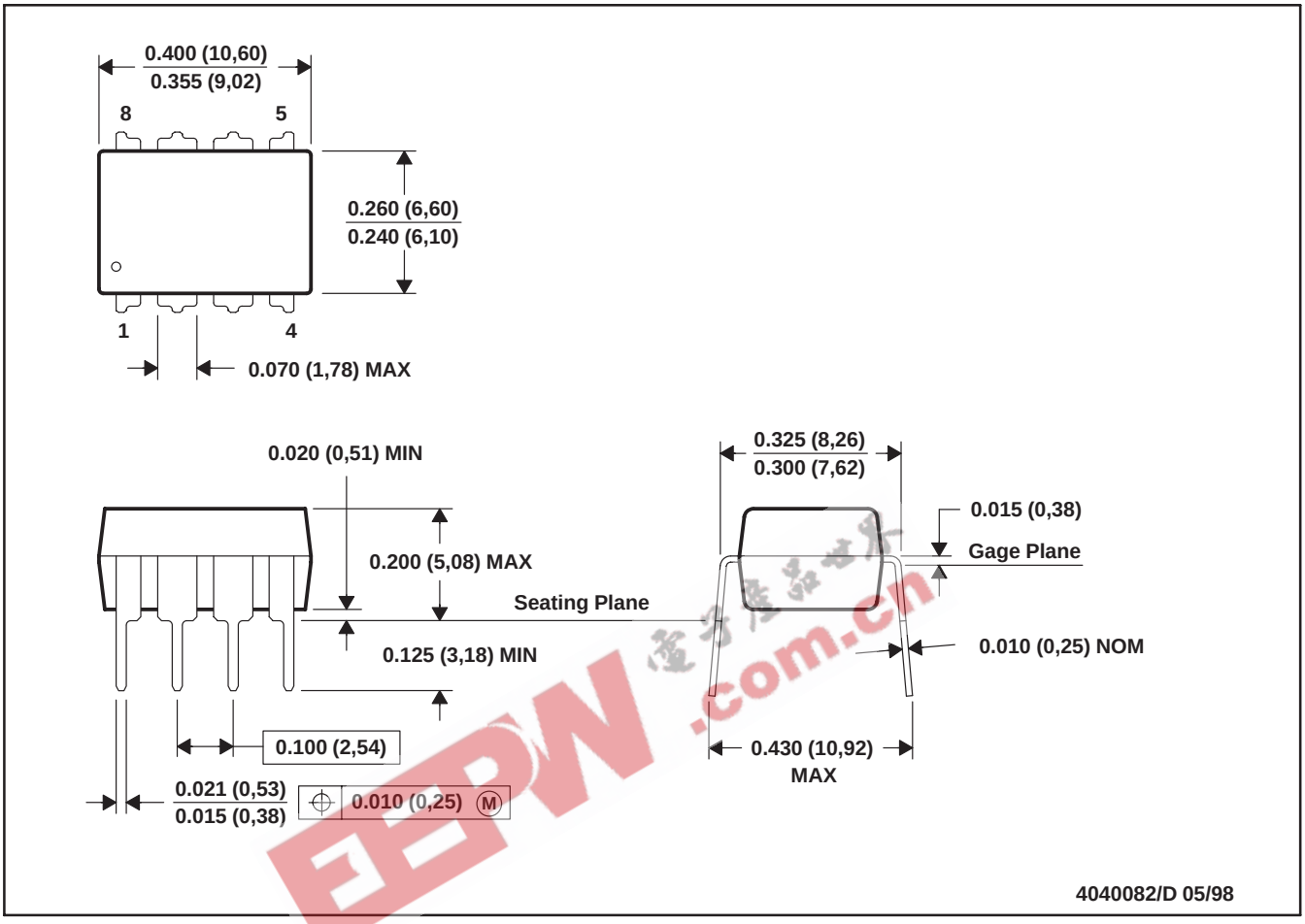


4040140/D 10/96

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

MPDI001A – JANUARY 1995 – REVISED JUNE 1999

P (R-PDIP-T8) **PLASTIC DUAL-IN-LINE**

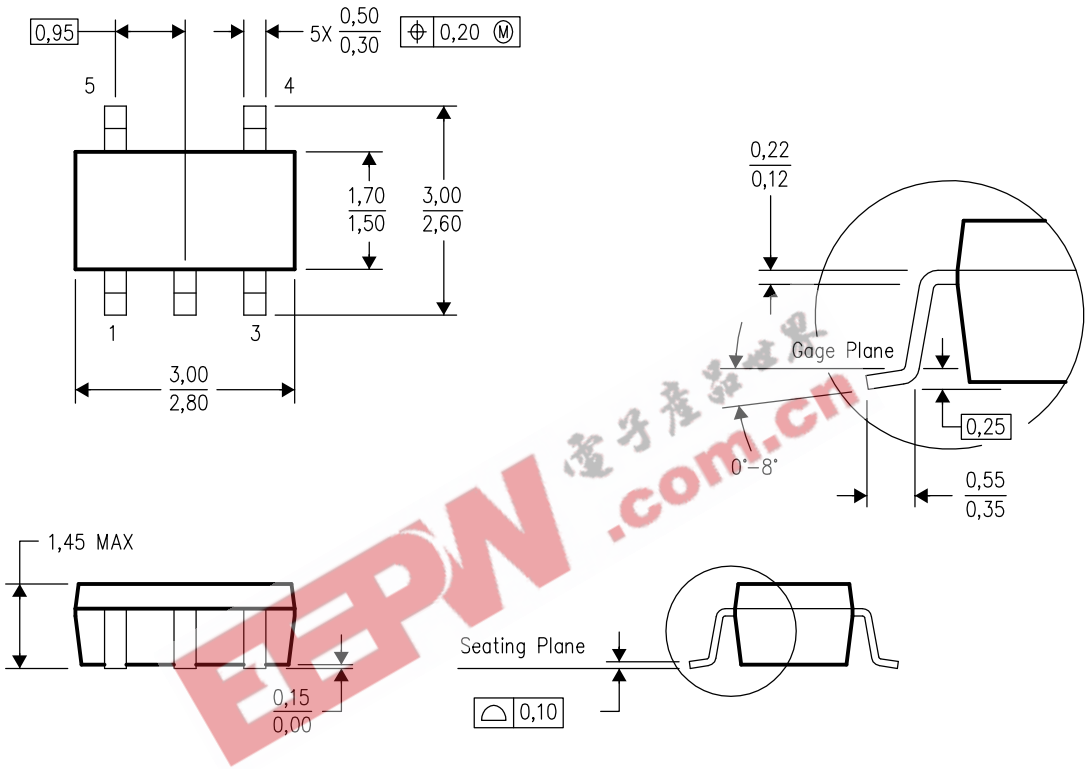


NOTES: A. All linear dimensions are in inches (millimeters).
B. This drawing is subject to change without notice.
C. Falls within JEDEC MS-001

EEPW .com.cn

For the latest package information, go to http://www.ti.com/sc/docs/package/pkg_info.htm

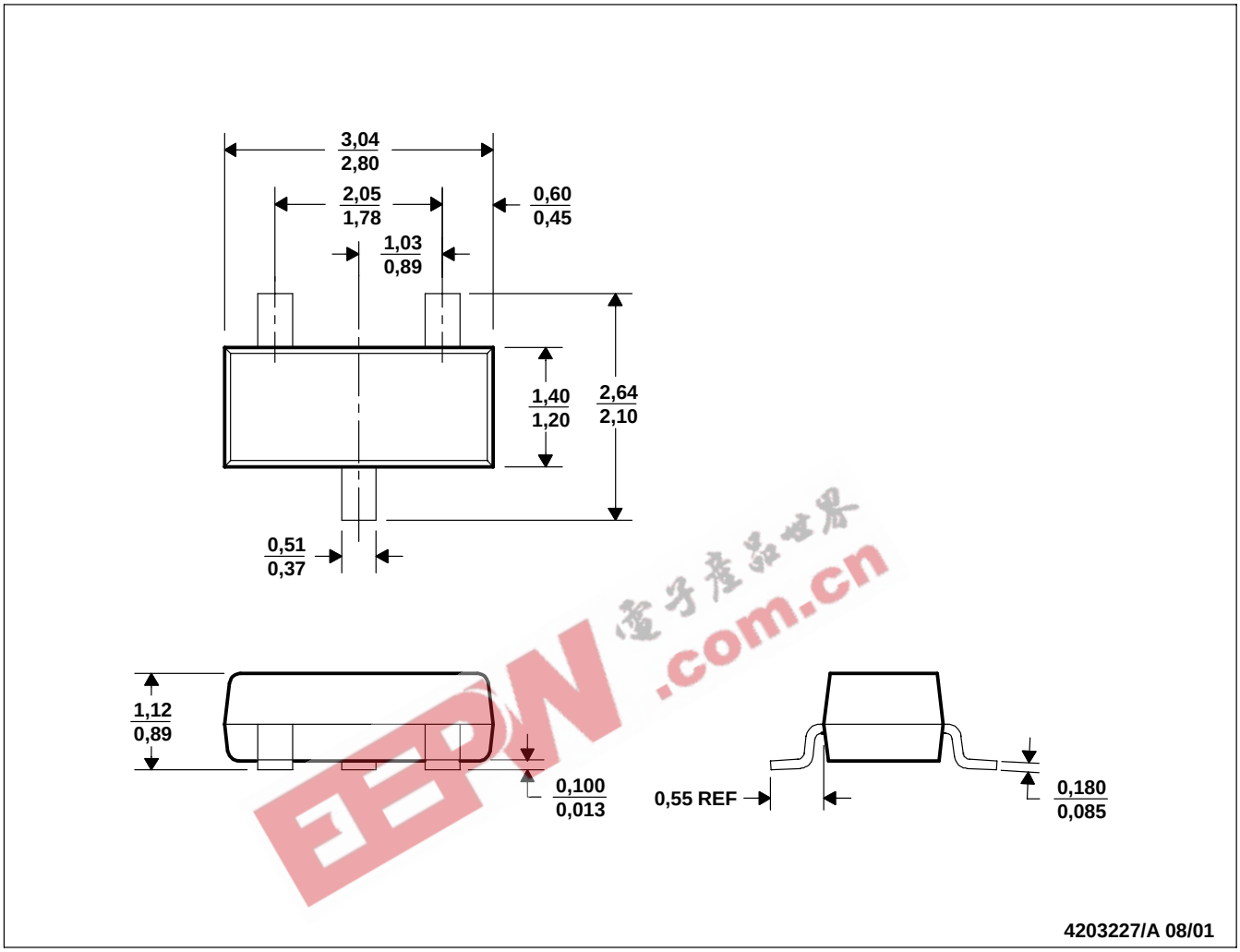
DBV (R–PDSO–G5) PLASTIC SMALL–OUTLINE PACKAGE



4073253–4/H 10/2003

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.
D. Falls within JEDEC MO–178 Variation AA.

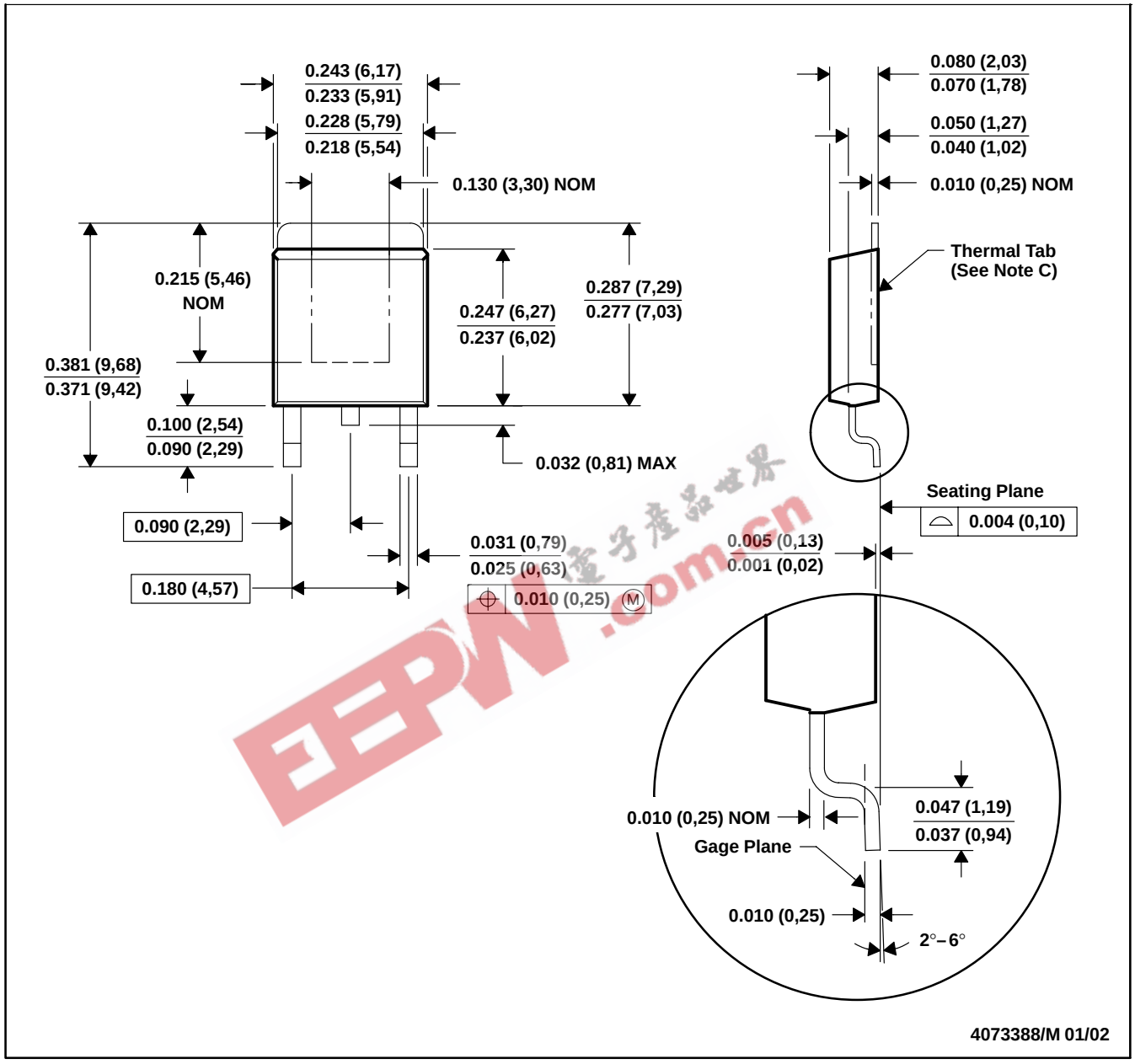
DBZ (R-PDSO-G3) **PLASTIC SMALL-OUTLINE**



NOTES: A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Dimensions are inclusive of plating.
D. Dimensions are exclusive of mold flash and metal burr.

MPSF001F – JANUARY 1996 – REVISED JANUARY 2002

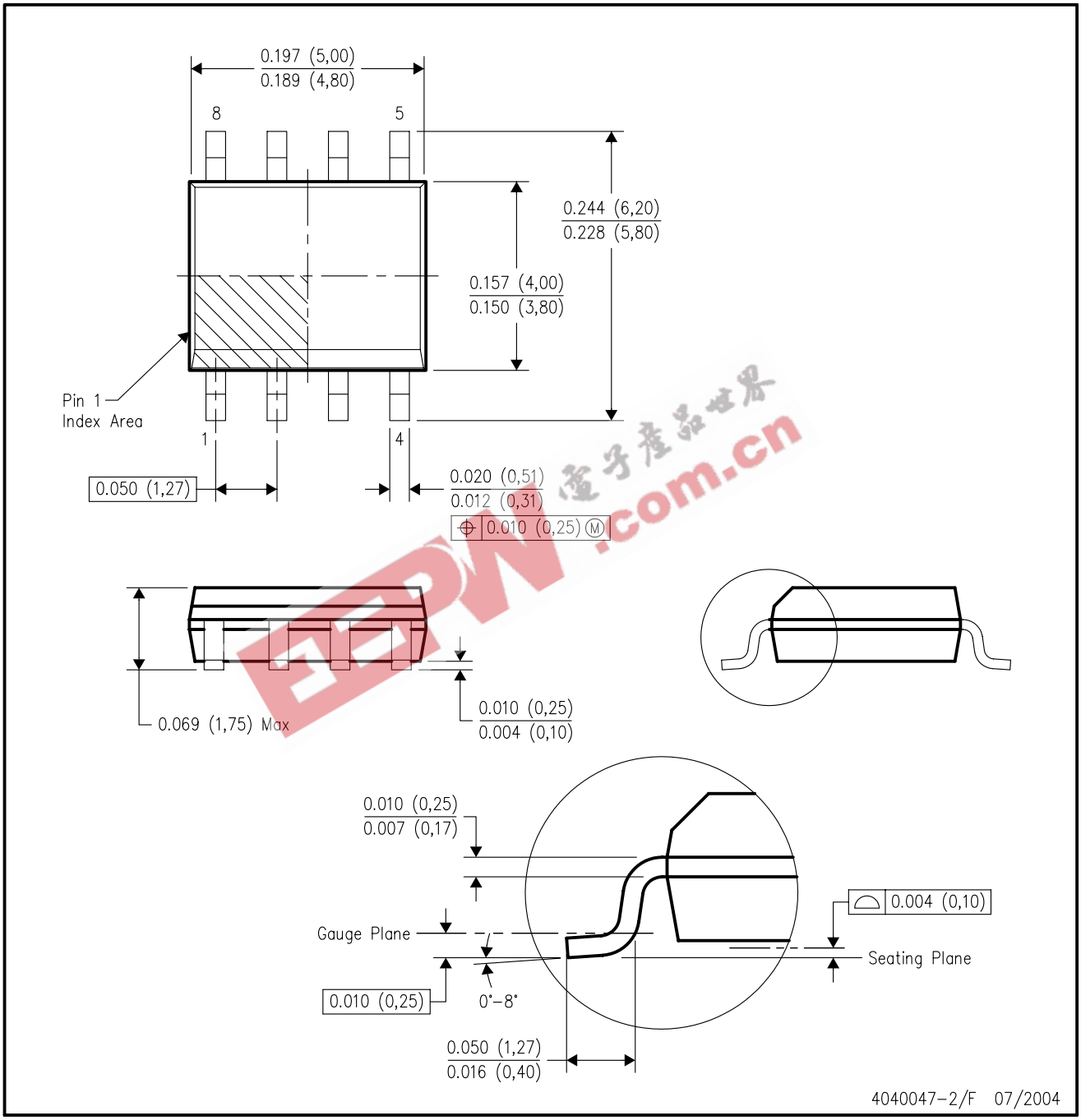
KTP (R-PSFM-G2) PowerFLEX™ PLASTIC FLANGE-MOUNT PACKAGE



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.

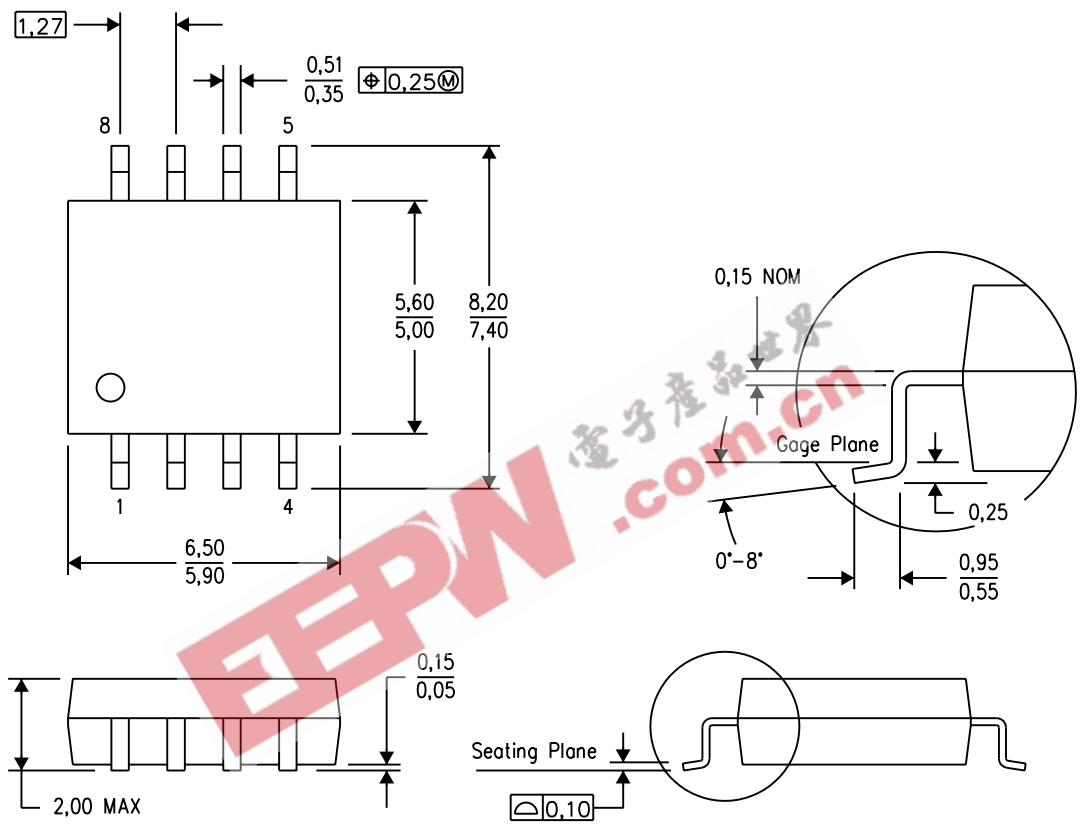
D (R–PDSO–G8) PLASTIC SMALL–OUTLINE PACKAGE



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 variation AA.

MECHANICAL DATA

PS (R-PDSO-G8) **PLASTIC SMALL-OUTLINE PACKAGE**

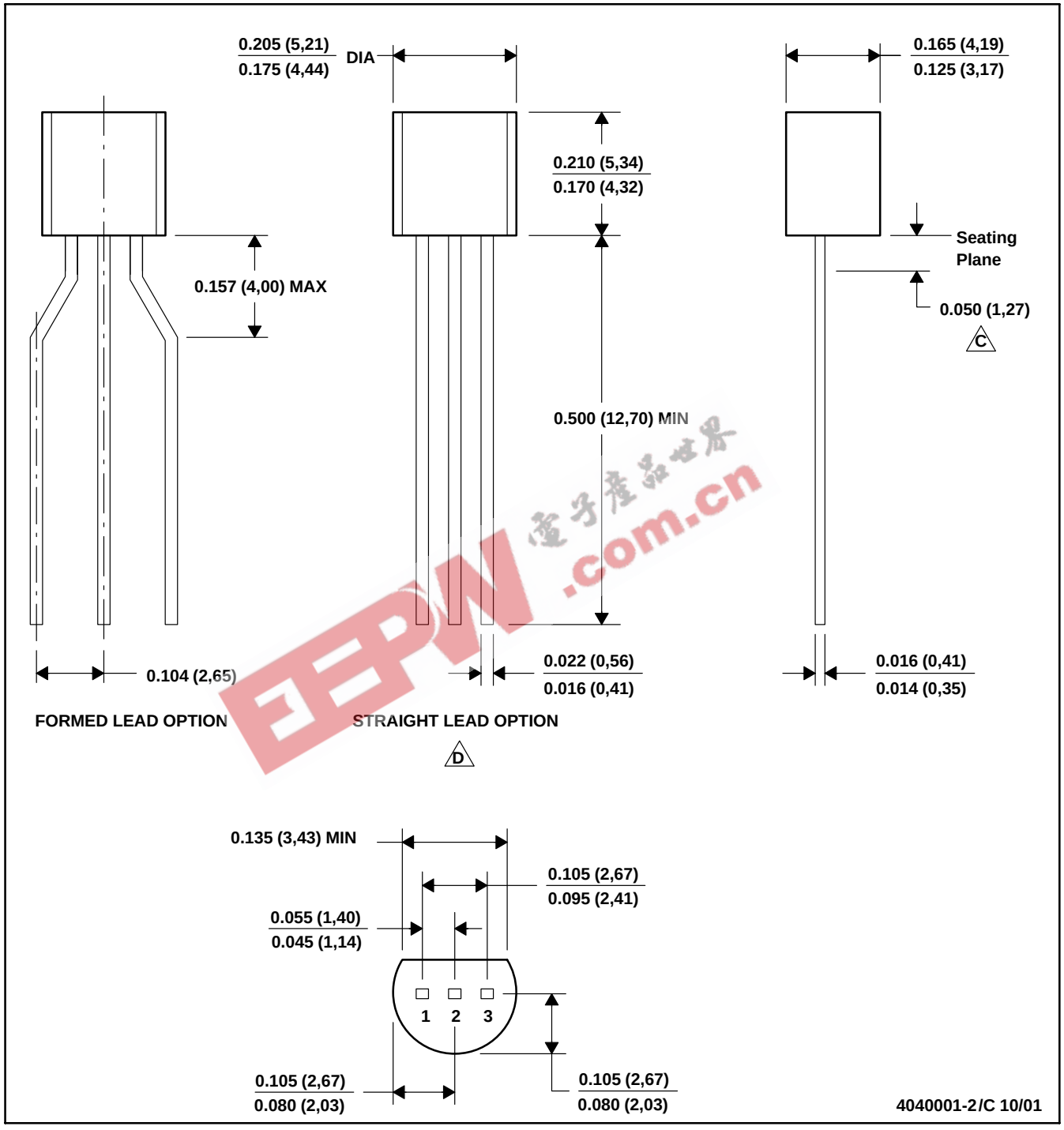


4040063/C 03/03

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.

MSOT002A – OCTOBER 1994 – REVISED NOVEMBER 2001

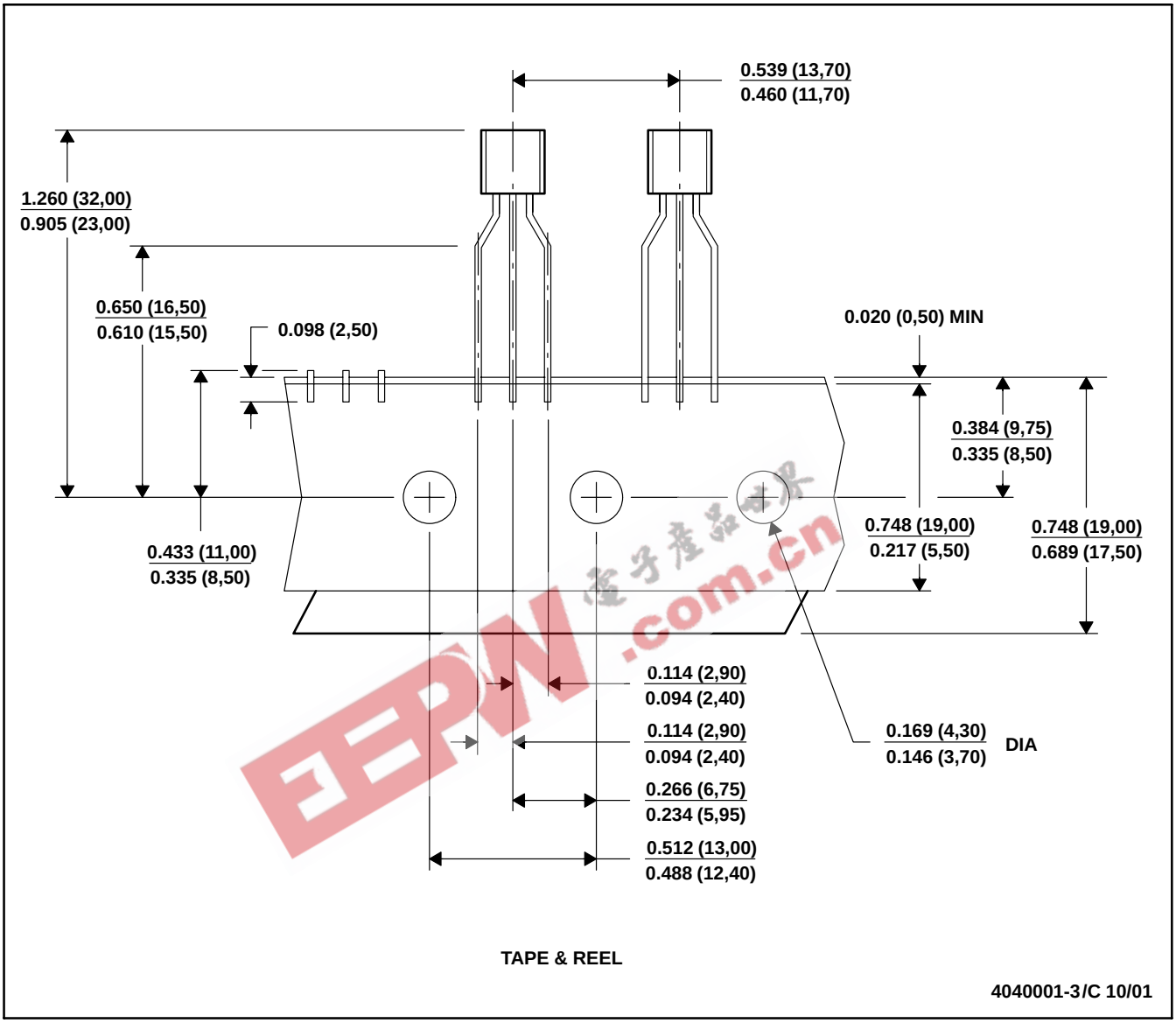
LP (O-PBCY-W3) **PLASTIC CYLINDRICAL PACKAGE**



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.

MECHANICAL DATA

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

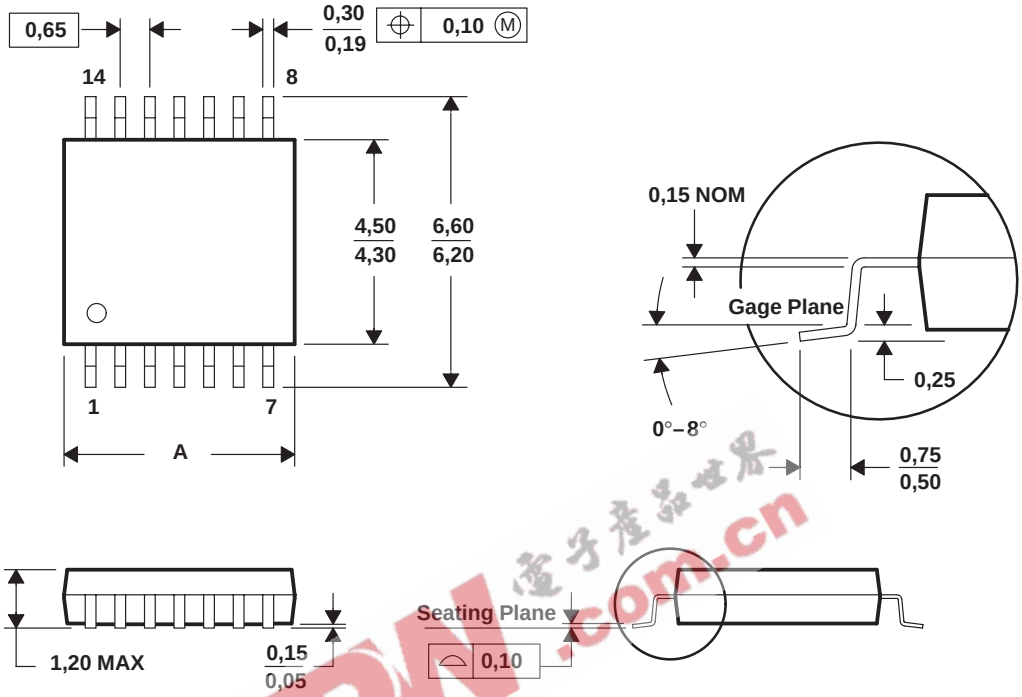


NOTES: A. All linear dimensions are in inches (millimeters).
B. This drawing is subject to change without notice.
C. Tape and Reel information for the Format Lead Option package.

MTSS001C – JANUARY 1995 – REVISED FEBRUARY 1999

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

14 PINS SHOWN



DIM \ PINS **	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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