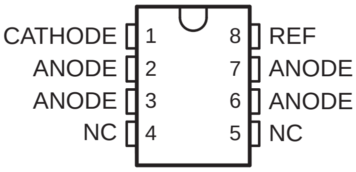
## FEATURES

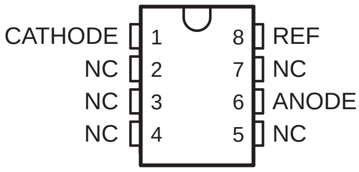
- **0.4% Initial Voltage Tolerance**
- **0.2-Ω Typical Output Impedance**
- **Fast Turnon…500 ns**
- **Sink Current Capability…1 mA to 100 mA**
- **Low Reference Current (REF)**
- **Adjustable Output Voltage…$V_{I(ref)}$ to 36 V**

**D PACKAGE**
**(TOP VIEW)**



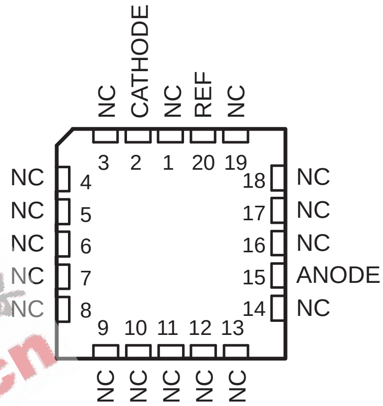

NC – No internal connection
ANODE terminals are connected internally

**JG OR PW PACKAGE**
**(TOP VIEW)**

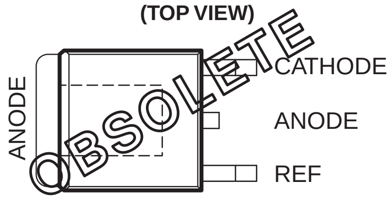



NC – No internal connection

**FK PACKAGE**
**(TOP VIEW)**




**KTP PACKAGE**
**(TOP VIEW)**




**LP 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.

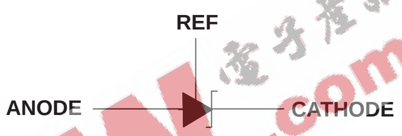
The TL1431C is characterized for operation over the commercial temperature range of 0°C to 70°C. The TL1431Q is characterized for operation over the full automotive temperature range of –40°C to 125°C. The TL1431M is characterized for operation over the full military temperature range of –55°C to 125°C.

## ORDERING INFORMATION(1)

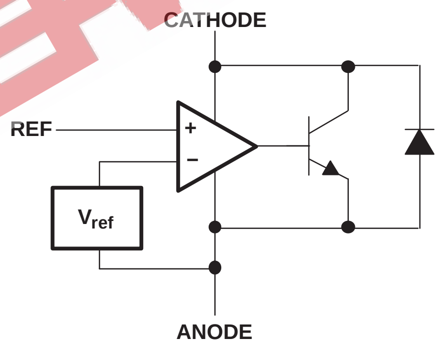
| $T_A$ | PACKAGE | | ORDERABLE PART NUMBER | TOP-SIDE MARKING |
|---|---|---|---|---|
| 0°C to 70°C | PowerFLEX™ – KTP | Reel of 3000 | TL1431CKTPR | OBSOLETE |
| | SOIC – D | Tube of 75 | TL1431CD | 1431C |
| | | Reel of 2500 | TL1431CDR | |
| | TO-226 / TO-92 – LP | Bulk of 1000 | TL1431CLP | TL1431C |
| | | 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 | |
| | 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 |

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

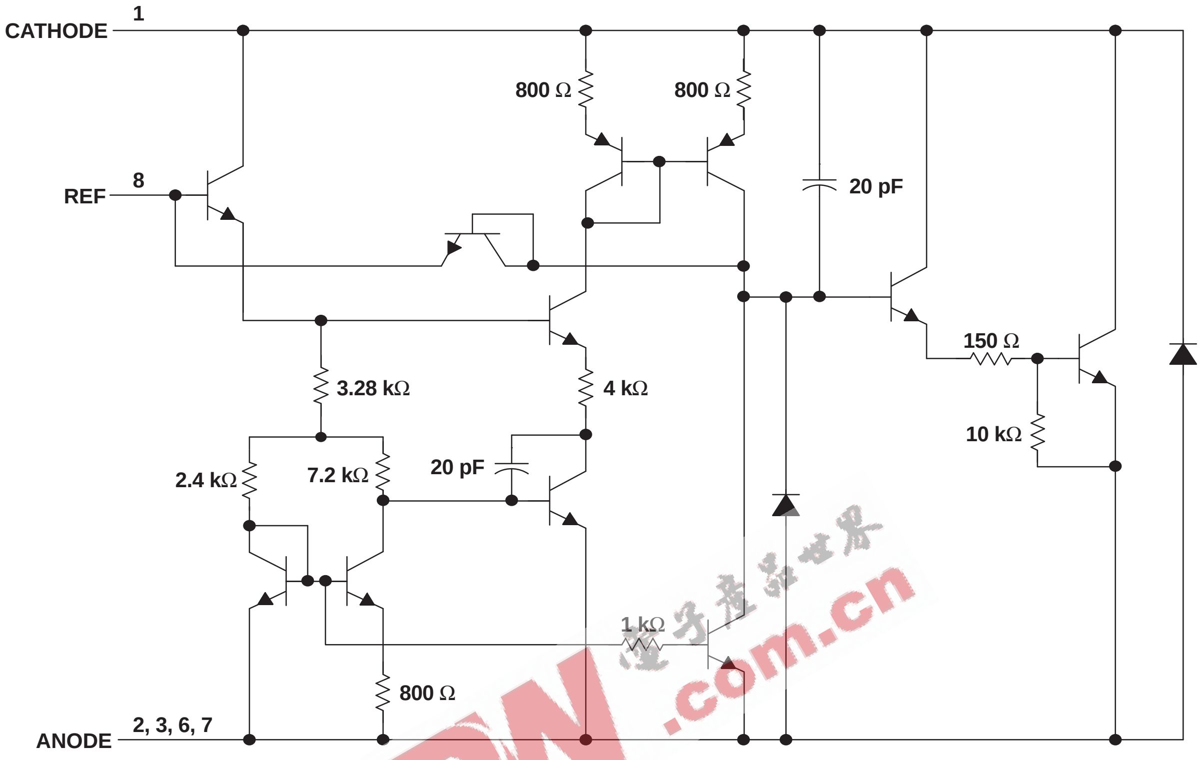
## SYMBOL




## FUNCTIONAL BLOCK DIAGRAM



## EQUIVALENT SCHEMATIC




A. All component values are nominal.

B. Pin numbers shown are for the D package.



## Absolute Maximum Ratings[1]

over operating free-air temperature range (unless otherwise noted)

| | | | MIN | MAX | UNIT |
|---|---|---|---|---|---|
| $V_{KA}$ | Cathode voltage[2] | | | 37 | V |
| $I_{KA}$ | Continuous cathode current range | | –100 | 150 | mA |
| $I_{I(ref)}$ | Reference input current range | | –50 | 10 | mA |
| $\theta_{JA}$ | Package thermal impedance[3][4] | D package | | 97 | °C/W |
| | | LP package | | 140 | |
| | | PW package | | 149 | |
| $\theta_{JC}$ | Package thermal impedance[5][6] | FK package | | 5.61 | °C/W |
| | | JG package | | 14.5 | |
| $T_J$ | Operating virtual junction temperature | | | 150 | °C |
| | Lead temperature | 1,6 mm (1/16 in) from case for 10 s | | 260 | °C |
| $T_{stg}$ | Storage temperature range | | –65 | 150 | °C |

(1) 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.

(2) All voltage values are with respect to ANODE, unless otherwise noted.

(3) Maximum power dissipation is a function of $T_{J(max)}$, $\theta_{JA}$, 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.

(4) The package thermal impedance is calculated in accordance with JESD 51-7.

(5) Maximum power dissipation is a function of $T_{J(max)}$, $\theta_{JC}$, 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 | |
| | | TL1431M | –55 | 125 | |

## Electrical Characteristics

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

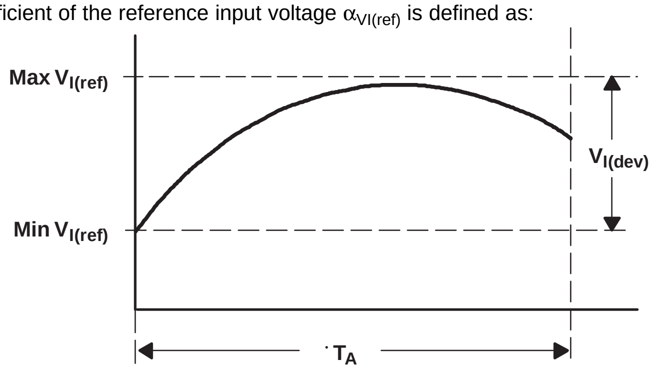
| PARAMETER | | TEST CONDITIONS | $T_A$ (1) | TEST CIRCUIT | TL1431C | | | UNIT |
|---|---|---|---|---|---|---|---|---|
| | | | | | MIN | TYP | MAX | |
| $V_{I(ref)}$ | Reference input voltage | $V_{KA} = V_{I(ref)}$ | 25°C | Figure 1 | 2490 | 2500 | 2510 | mV |
| | | | Full range | | 2480 | | 2520 | |
| $V_{I(dev)}$ | Deviation of reference input voltage over full temperature range (2) | $V_{KA} = V_{I(ref)}$ | 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 | $\Delta V_{KA}$ = 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 (2) | 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 (3) | $V_{KA} = V_{I(ref)}$, f ≤ 1 kHz, $I_{KA}$ = 1 mA to 100 mA | 25°C | Figure 1 | | 0.2 | 0.4 | Ω |

(1) Full range is 0°C to 70°C for C-suffix devices.

(2) 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 $\alpha_{VI(ref)}$ is defined as:

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

where:
$\Delta T_A$ is the rated operating temperature range of the device.




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

(3) The output impedance is defined as: $\lvert z_{KA}\rvert = \frac{\Delta V_{KA}}{\Delta I_{KA}}$

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

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

## Electrical Characteristics

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

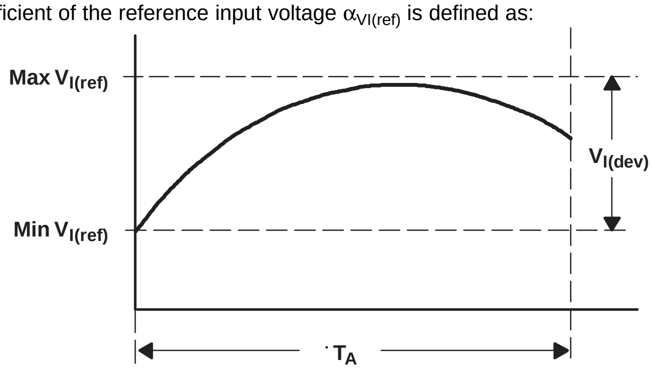
| PARAMETER | | TEST CONDITIONS | $T_A$ (1) | TEST CIRCUIT | TL1431Q MIN | TL1431Q TYP | TL1431Q MAX | TL1431M MIN | TL1431M TYP | TL1431M MAX | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $V_{I(ref)}$ | Reference input voltage | $V_{KA} = V_{I(ref)}$ | 25°C | Figure 1 | 2490 | 2500 | 2510 | 2475 | 2500 | 2540 | mV |
| | | | Full range | | 2470 | | 2530 | 2460 | | 2550 | |
| $V_{I(dev)}$ | Deviation of reference input voltage over full temperature range (2) | $V_{KA} = V_{I(ref)}$ | Full range | Figure 1 | | 17 | 55 | | 17 | 55 (3) | mV |
| $\frac{\Delta V_{I(ref)}}{\Delta V_{KA}}$ | Ratio of change in reference input voltage to the change in cathode voltage | $\Delta V_{KA}$ = 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 (2) | R1 = 10 kΩ, R2 = ∞ | Full range | Figure 2 | | 0.5 | 2 | | 0.5 | 3 (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 (4) | $V_{KA} = V_{I(ref)}$, f ≤ 1 kHz, $I_{KA}$ = 1 mA to 100 mA | 25°C | Figure 1 | | 0.2 | 0.4 | | 0.2 | 0.4 | Ω |

(1) Full range is –40°C to 125°C for Q-suffix devices and –55°C to 125°C for M-suffix devices.

(2) 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 $\alpha_{VI(ref)}$ is defined as:

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

where:
$\Delta T_A$ is the rated operating temperature range of the device.




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

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

(4) 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

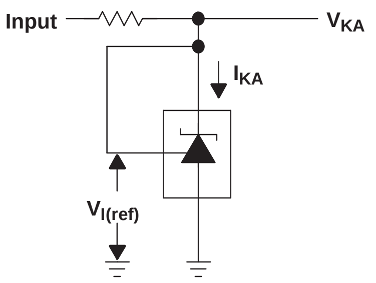



Figure 1. Test Circuit for $V_{(KA)} = V_{ref}$

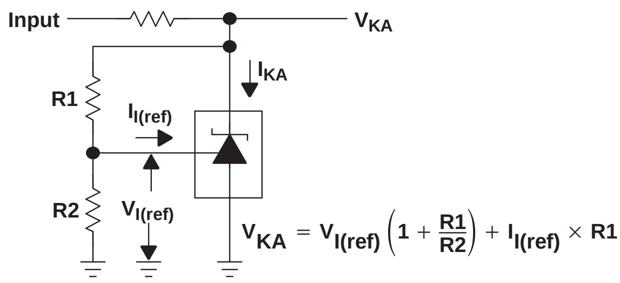



Figure 2. Test Circuit for $V_{(KA)} > V_{ref}$

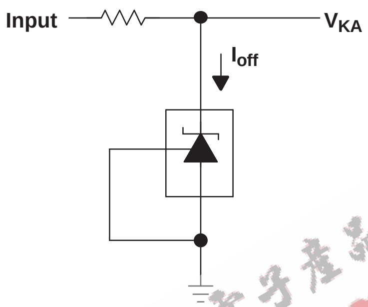



Figure 3. Test Circuit for $I_{off}$

## TYPICAL CHARACTERISTICS

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

### Table of Graphs

| GRAPH | FIGURE |
|---|---|
| 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 |

REFERENCE VOLTAGE
vs
FREE-AIR TEMPERATURE

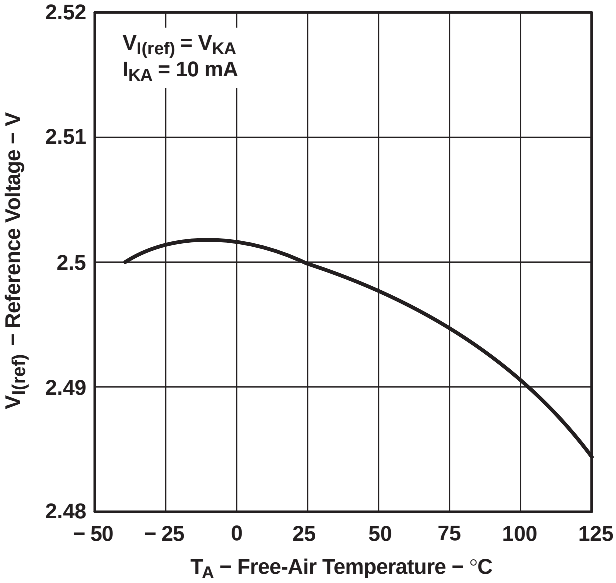



Figure 4.

REFERENCE CURRENT
vs
FREE-AIR TEMPERATURE

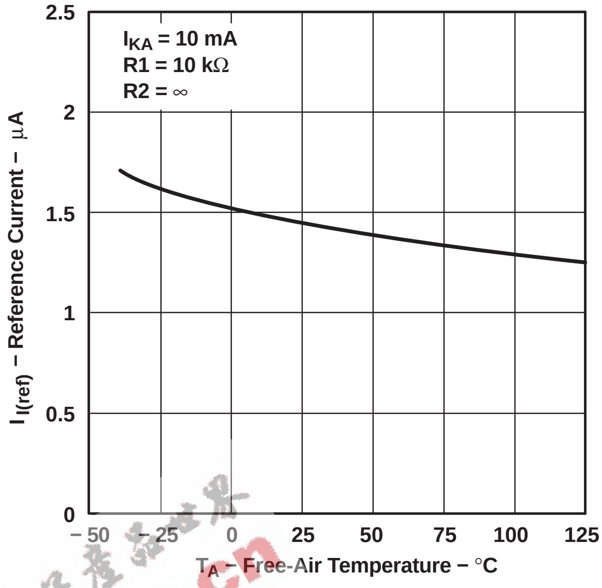



Figure 5.

CATHODE CURRENT
vs
CATHODE VOLTAGE

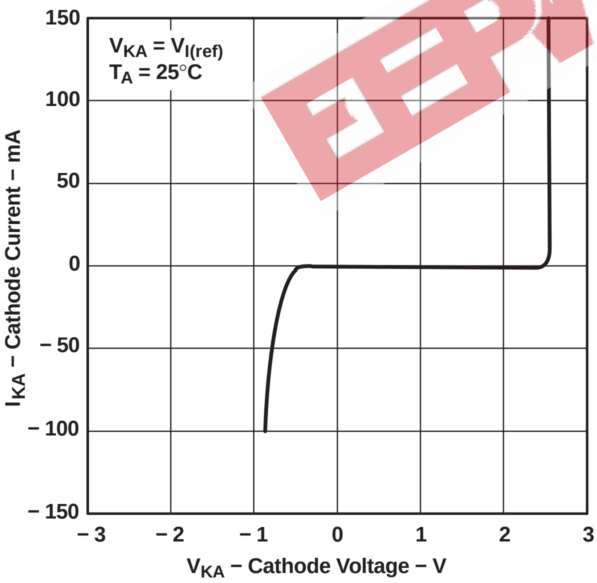



Figure 6.

CATHODE CURRENT
vs
CATHODE VOLTAGE

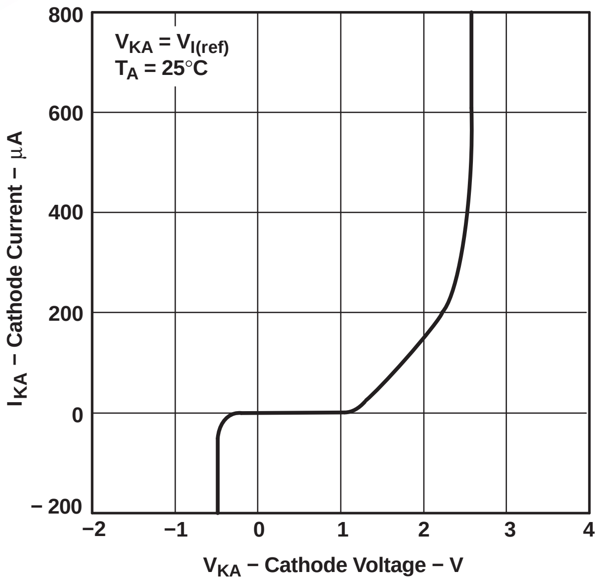



Figure 7.

### OFF-STATE CATHODE CURRENT vs FREE-AIR TEMPERATURE

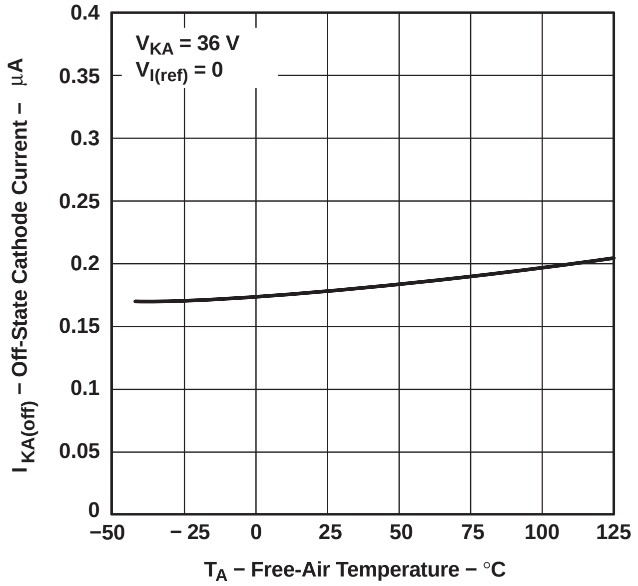



**Figure 8.**

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

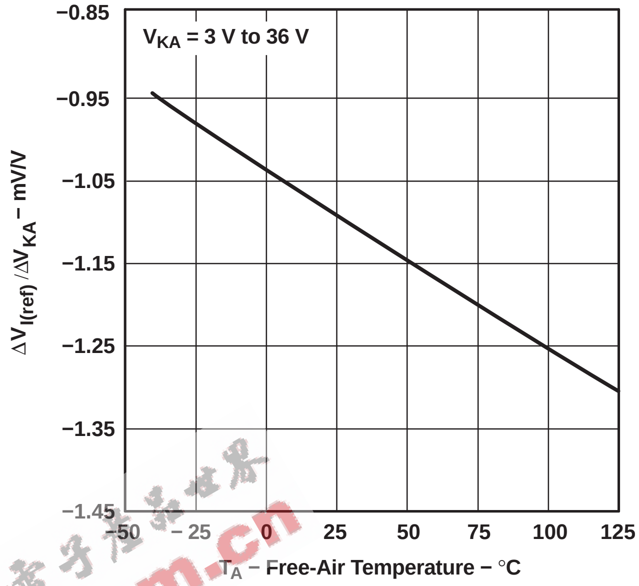



**Figure 9.**

### EQUIVALENT INPUT-NOISE VOLTAGE vs FREQUENCY

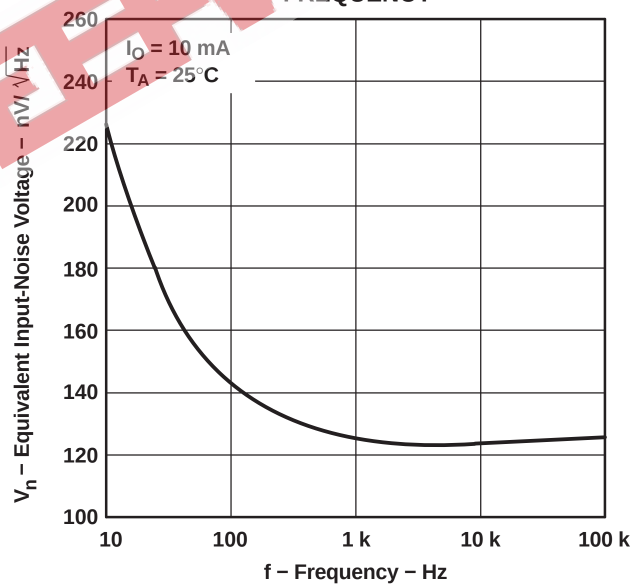
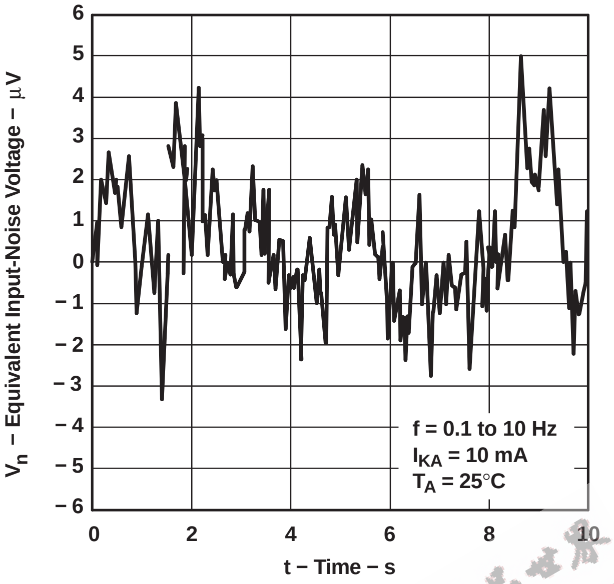
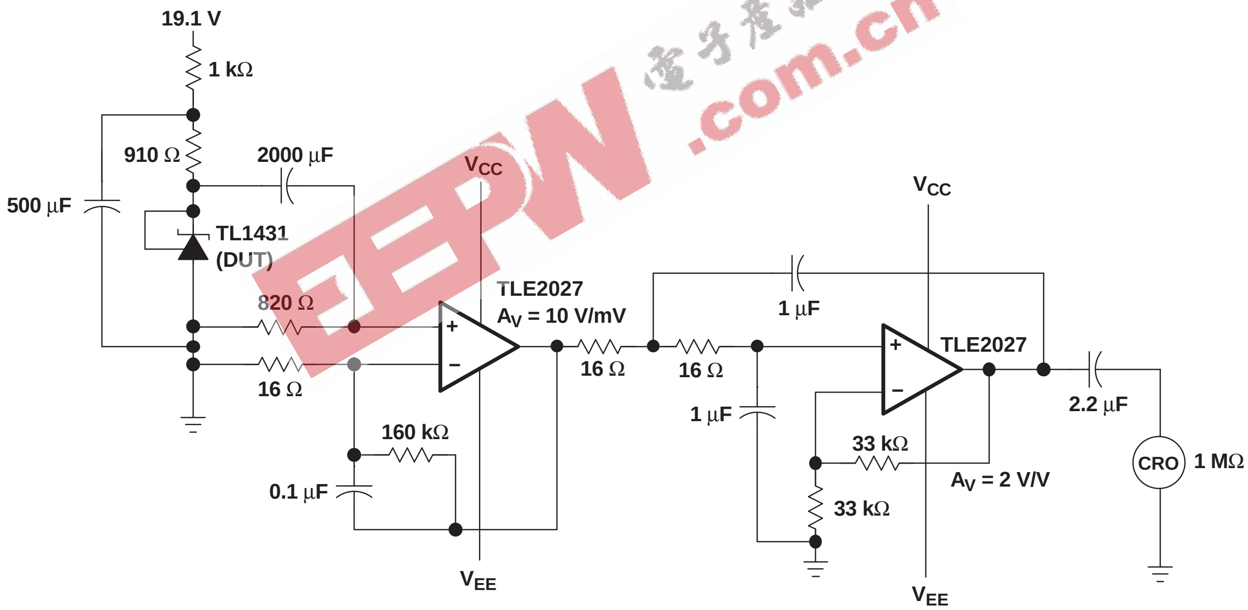



**Figure 10.**

EQUIVALENT INPUT-NOISE VOLTAGE
OVER A 10-SECOND PERIOD




TEST CIRCUIT FOR 0.1-Hz TO 10-Hz EQUIVALENT INPUT-NOISE VOLTAGE
Figure 11.

SMALL-SIGNAL VOLTAGE AMPLIFICATION
vs
FREQUENCY

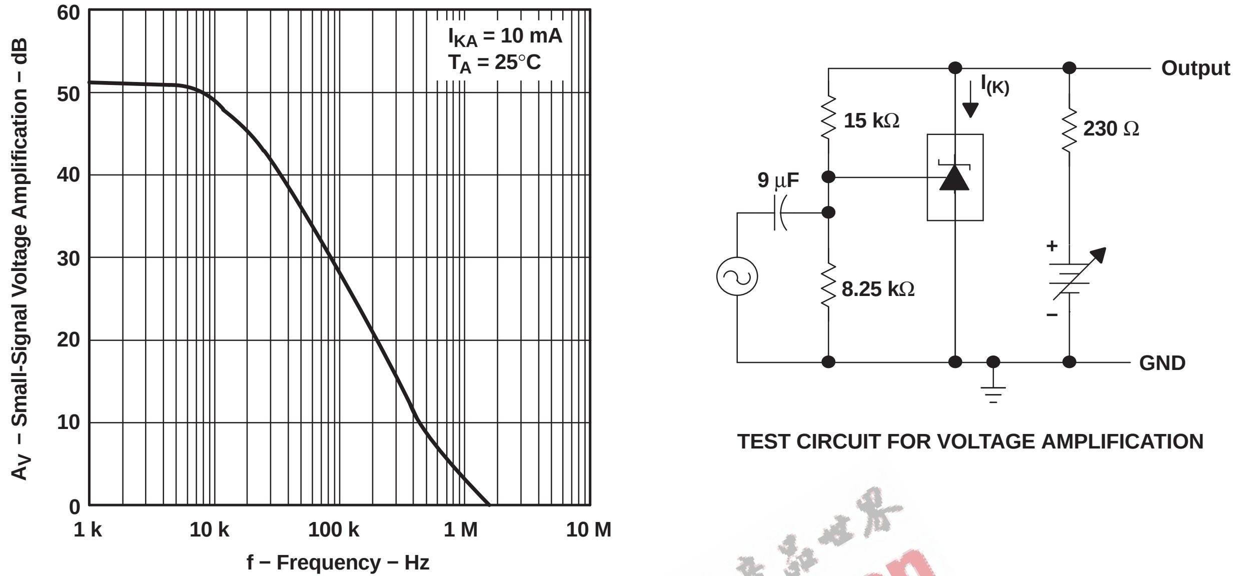



Figure 12.

REFERENCE IMPEDANCE
vs
FREQUENCY

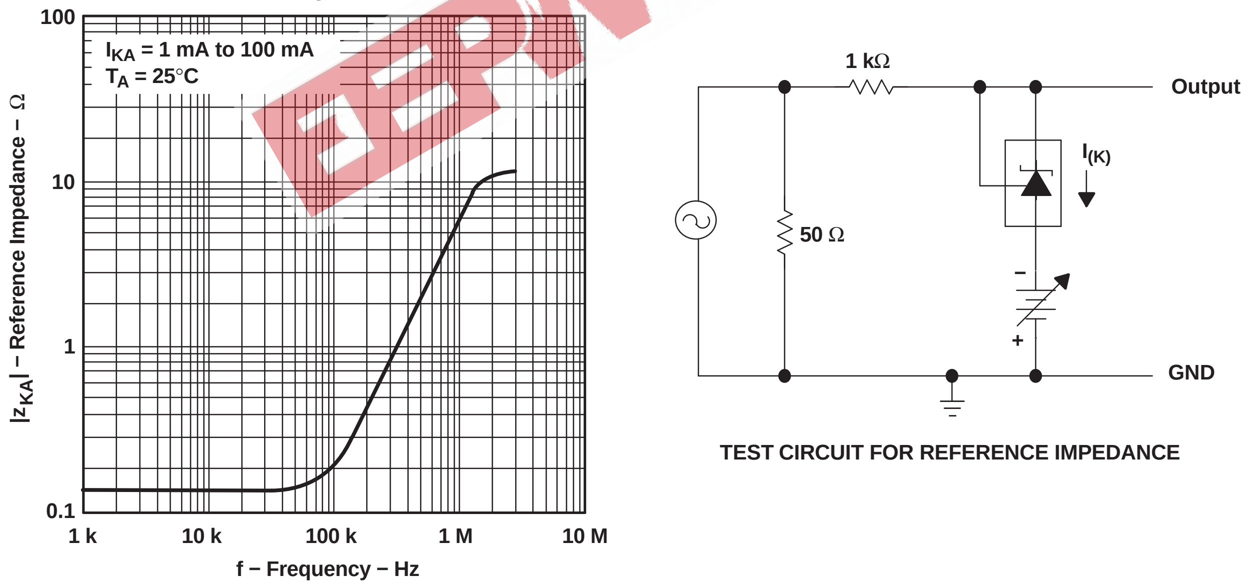



Figure 13.

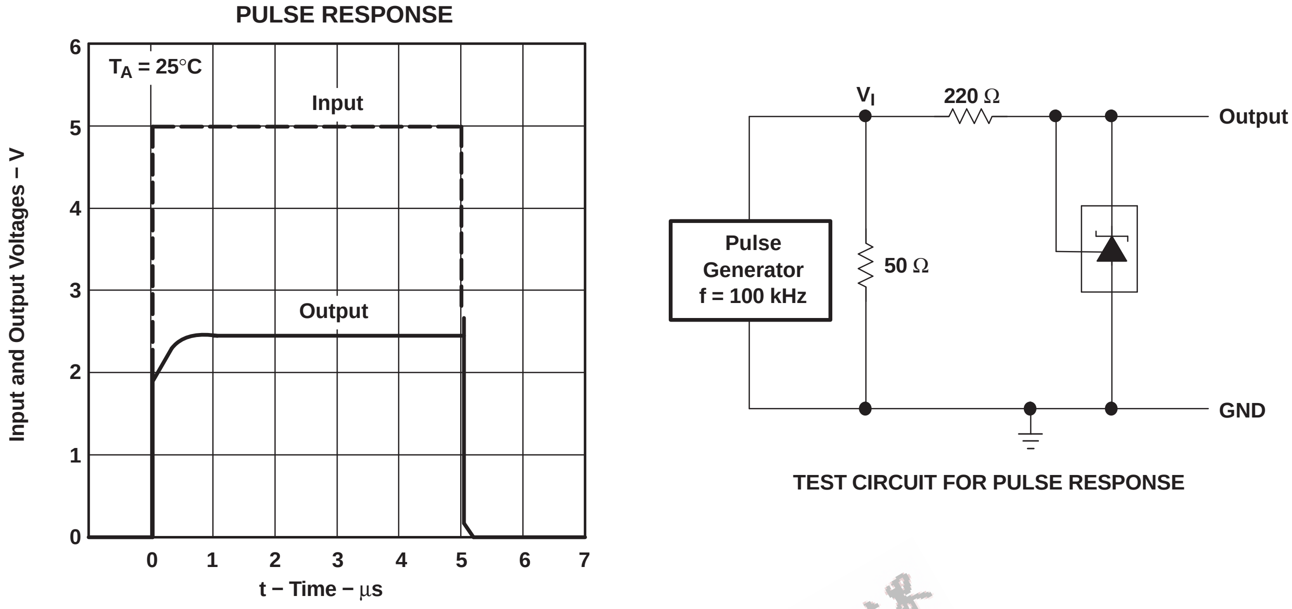
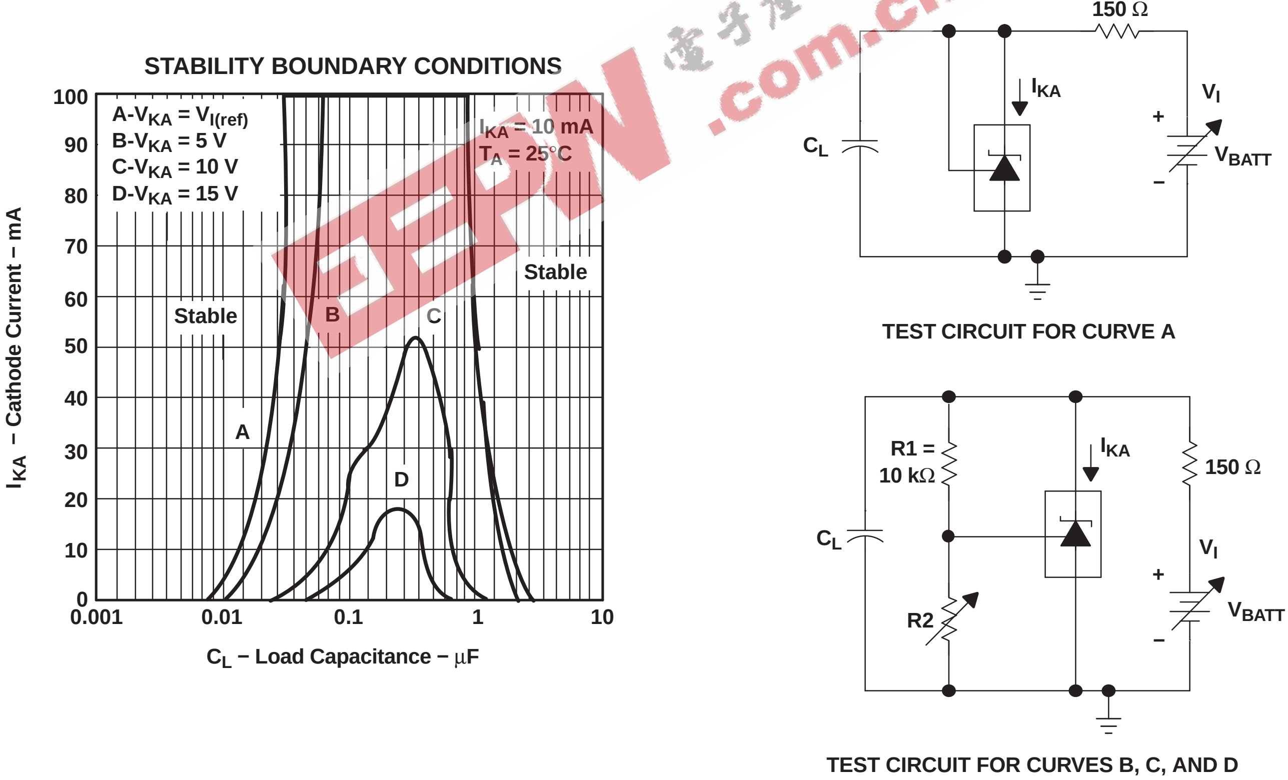



Figure 14.



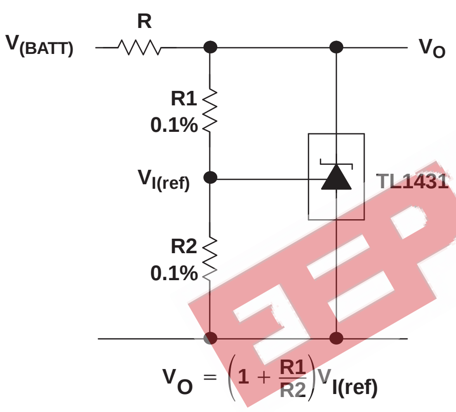

A. The areas under the curves represent conditions that may cause the device to oscillate. For curves B, C, and D, R2 and V+ are adjusted to establish the initial $V_{KA}$ and $I_{KA}$ conditions, with $C_L$ = 0. $V_{BATT}$ and $C_L$ then are adjusted to determine the ranges of stability.

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 |
| Higher-current shunt regulator | 20 |
| 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 |




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

**Figure 16. Shunt Regulator**

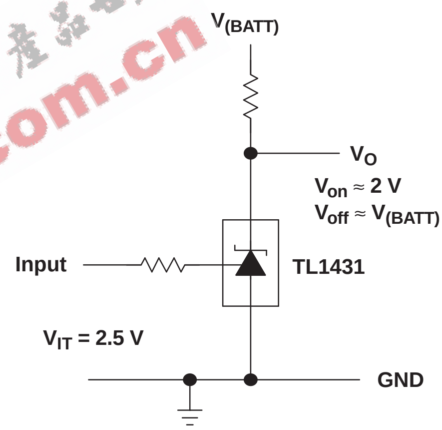
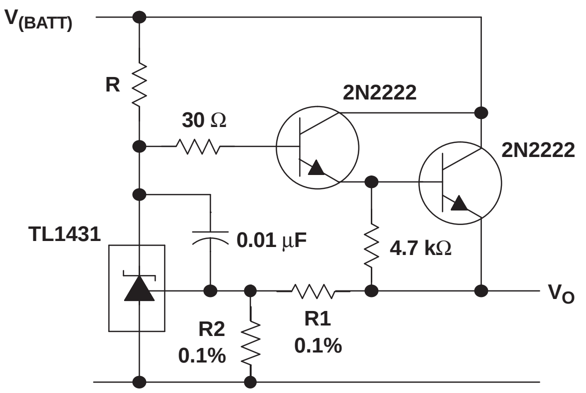


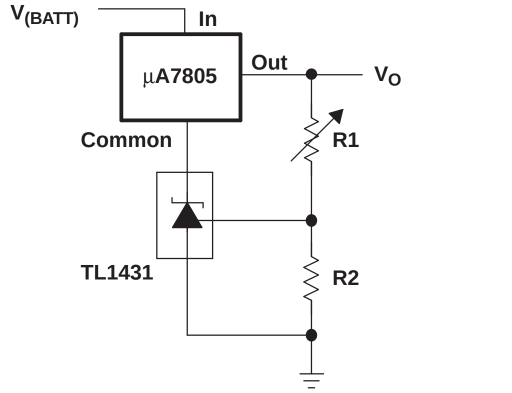

**Figure 17. Single-Supply Comparator With Temperature-Compensated Threshold**




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

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

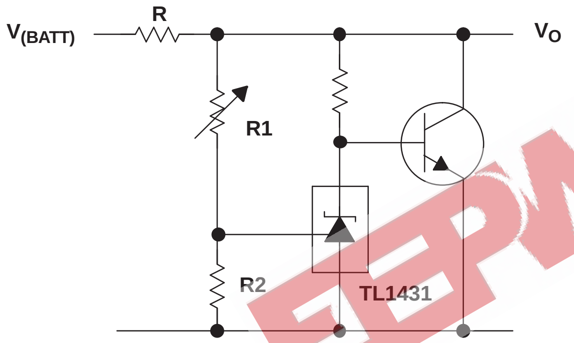
**Figure 18. Precision High-Current Series Regulator**




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

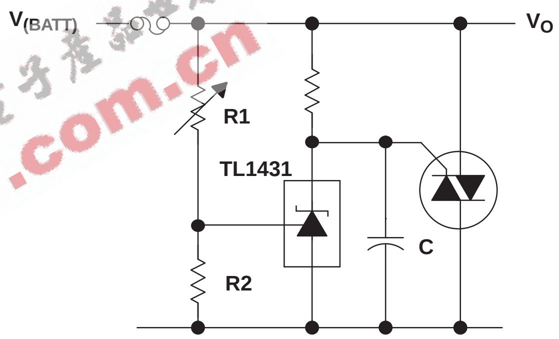
$$\text{Min } V = V_{I(ref)} + 5\ V$$

**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**




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

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

**Figure 21. Crowbar**



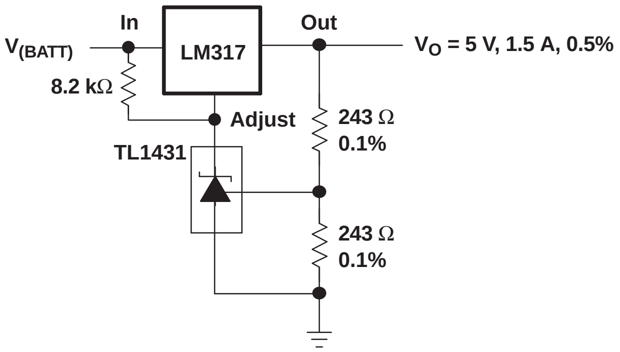
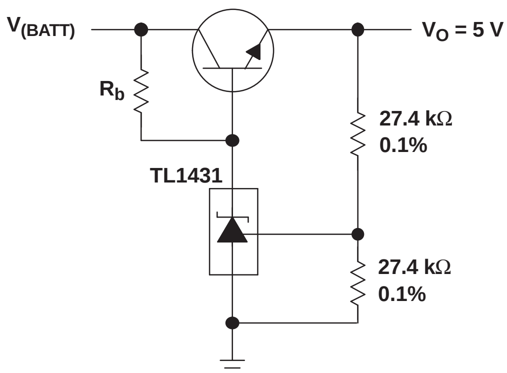



**Figure 22. Precision 5-V, 1.5-A, 0.5% Regulator**




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

**Figure 23. 5-V Precision Regulator**

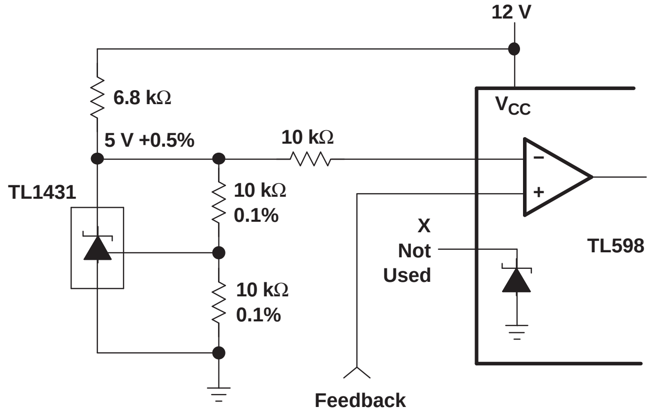
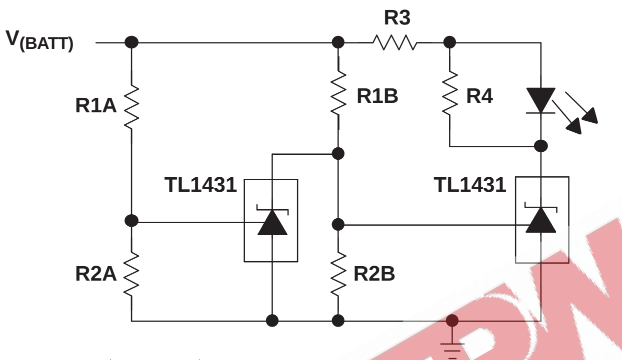



Figure 24. PWM Converter With 0.5% Reference



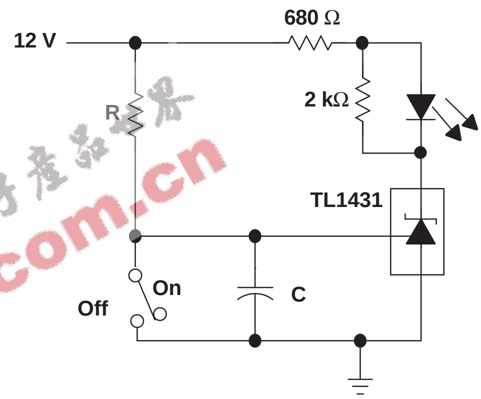

$$\text{Low Limit} = \left(1 + \frac{R1B}{R2B}\right) V_{I(ref)}$$

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

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

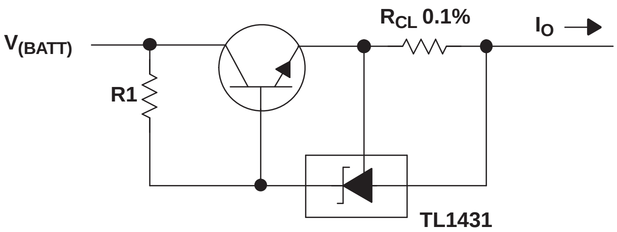
A. Select R3 and R4 to provide the desired LED intensity and cathode current ≥1 mA to the TL1431.

Figure 25. Voltage Monitor




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

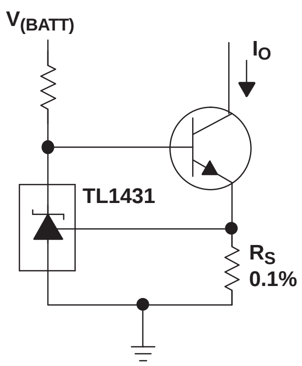
Figure 26. Delay Timer




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

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

Figure 27. Precision Current Limiter




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

Figure 28. Precision Constant-Current Sink

## 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 | N / A for Pkg Type |
| 5962-9962001QPA | ACTIVE | CDIP | JG | 8 | 1 | TBD | A42 SNPB | N / A for Pkg Type |
| 5962-9962001VPA | ACTIVE | CDIP | JG | 8 | 1 | TBD | A42 SNPB | N / A for Pkg Type |
| 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 | Pb-Free (RoHS) | CU SN | N / A for Pkg Type |
| TL1431CLPE3 | ACTIVE | TO-92 | LP | 3 | 1000 | Pb-Free (RoHS) | CU SN | N / A for Pkg Type |
| TL1431CLPM | OBSOLETE | TO-92 | LP | 3 | | TBD | Call TI | Call TI |
| TL1431CLPR | ACTIVE | TO-92 | LP | 3 | 2000 | Pb-Free (RoHS) | CU SN | N / A for Pkg Type |
| TL1431CLPRE3 | ACTIVE | TO-92 | LP | 3 | 2000 | Pb-Free (RoHS) | CU SN | N / A for Pkg Type |
| 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 | N / A for Pkg Type |
| TL1431MFKB | ACTIVE | LCCC | FK | 20 | 1 | TBD | POST-PLATE | N / A for Pkg Type |
| TL1431MJG | ACTIVE | CDIP | JG | 8 | 1 | TBD | A42 SNPB | N / A for Pkg Type |
| TL1431MJGB | ACTIVE | CDIP | JG | 8 | 1 | TBD | A42 SNPB | N / A for Pkg Type |
| 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 | OBSOLETE | TO-92 | LP | 3 | | TBD | Call TI | Call TI |
| TL1431QLPR | OBSOLETE | TO-92 | LP | 3 | | TBD | Call TI | Call TI |
| 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), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check http://www.ti.com/productcontent for the latest availability information and additional product content details.
**TBD:** The Pb-Free/Green conversion plan has not been defined.
**Pb-Free (RoHS):** TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.
**Pb-Free (RoHS Exempt):** This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.
**Green (RoHS & no Sb/Br):** TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

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

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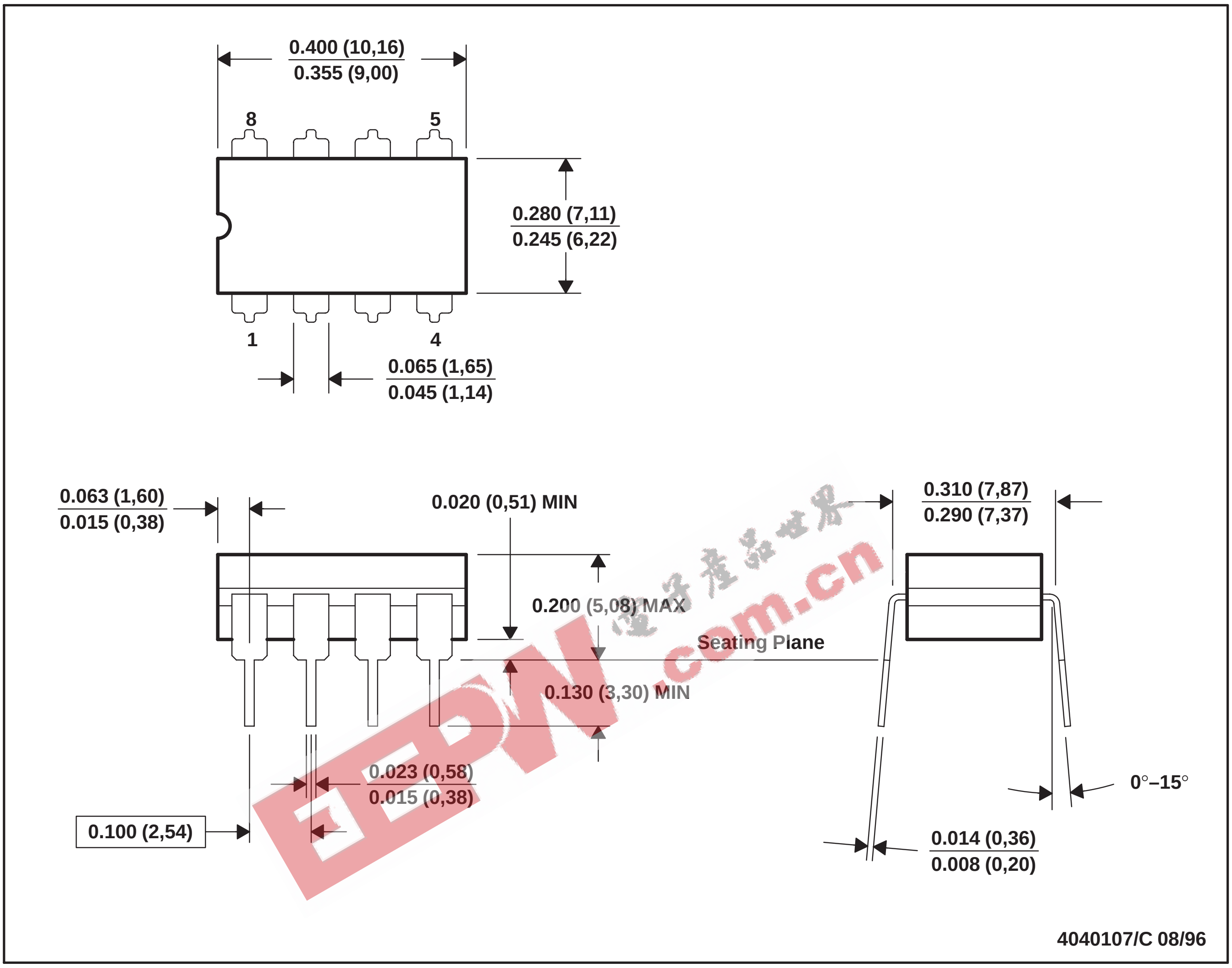
**JG (R-GDIP-T8)** **CERAMIC DUAL-IN-LINE**

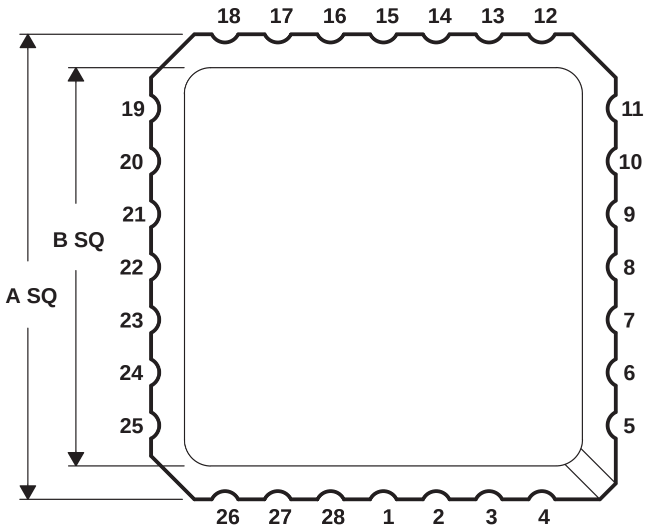



NOTES:
- A. All linear dimensions are in inches (millimeters).
- B. This drawing is subject to change without notice.
- C. This package can be hermetically sealed with a ceramic lid using glass frit.
- D. Index point is provided on cap for terminal identification.
- E. Falls within MIL STD 1835 GDIP1-T8

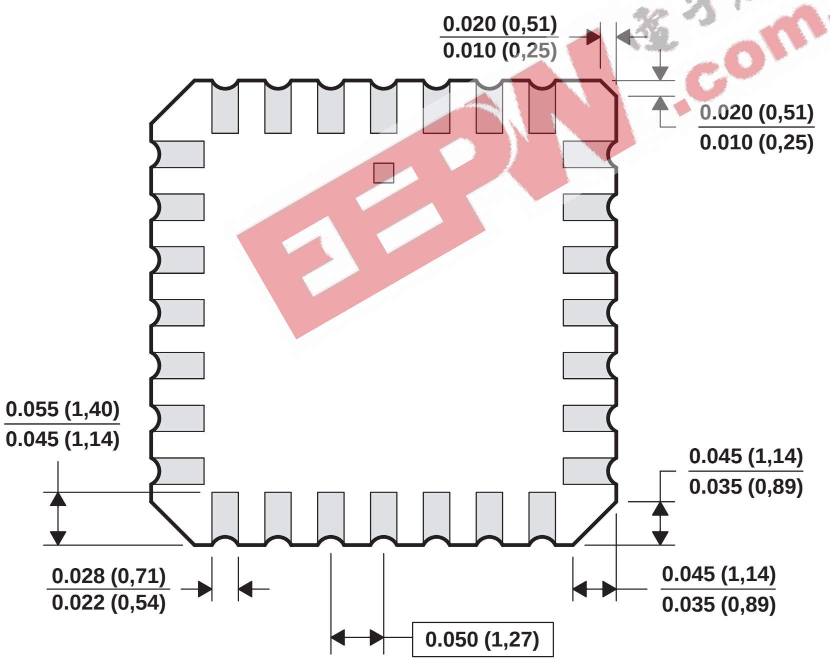
## FK (S-CQCC-N**)

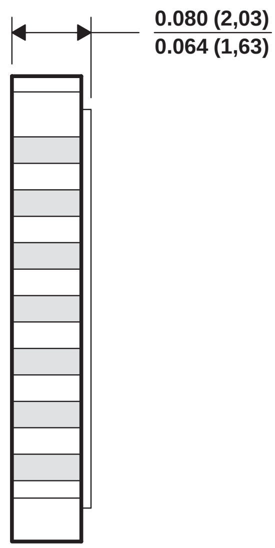
## LEADLESS CERAMIC CHIP CARRIER

**28 TERMINAL SHOWN**




| 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) |

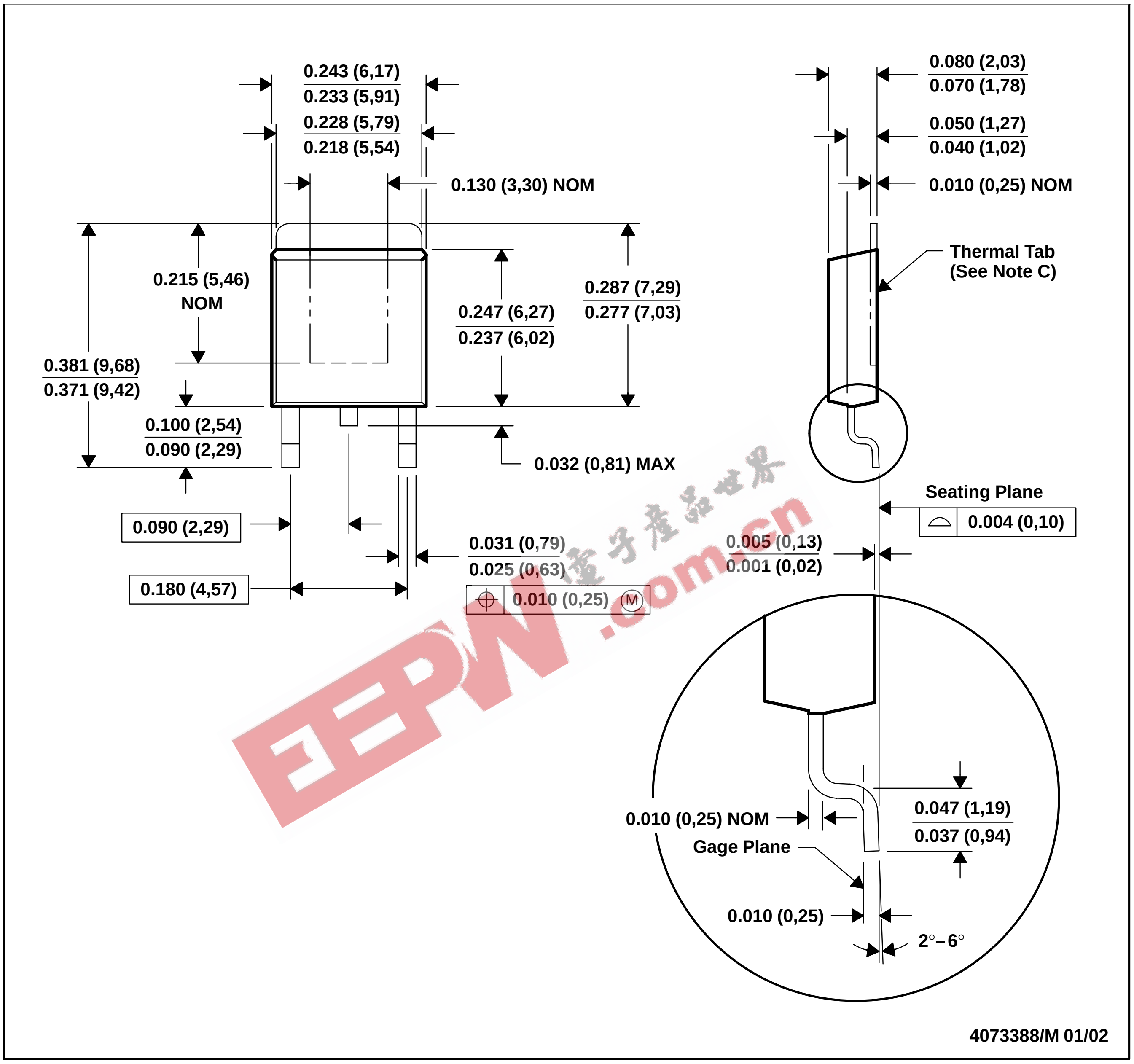



4040140 / D 10/96

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

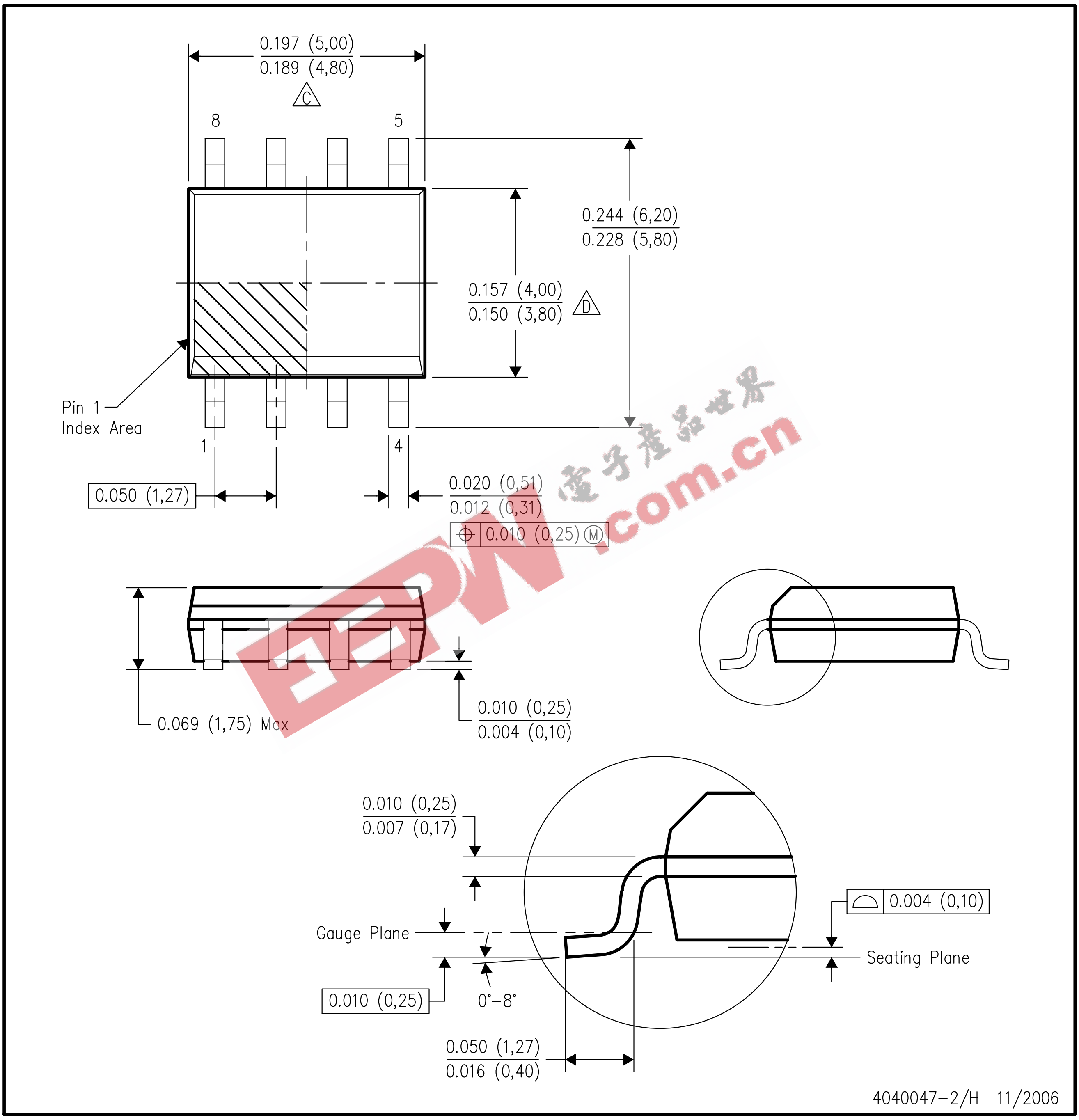
**KTP (R-PSFM-G2)** **PowerFLEX™ PLASTIC FLANGE-MOUNT PACKAGE**




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.

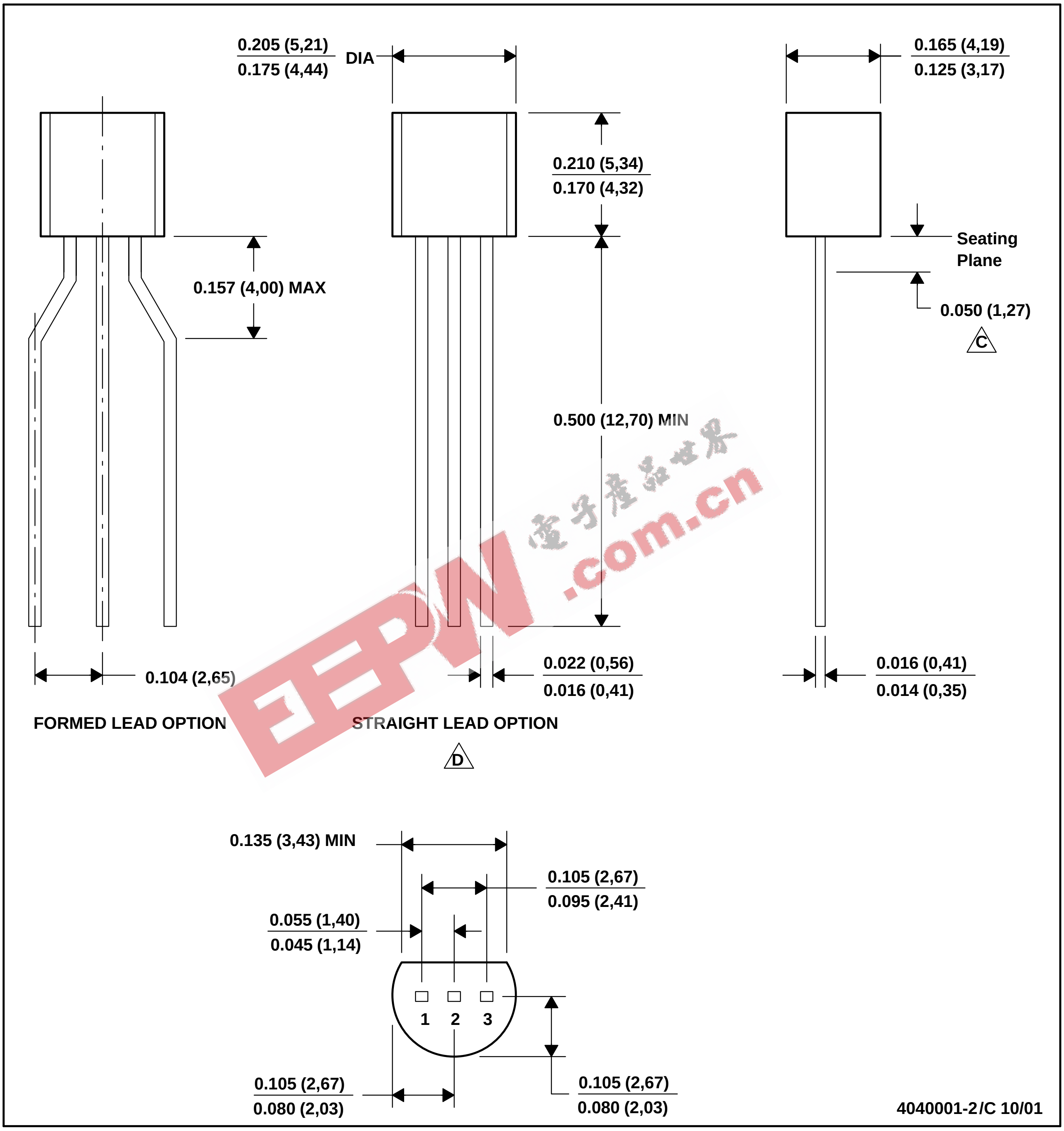
PowerFLEX is a trademark of Texas Instruments.

D (R-PDSO-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 length does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed .006 (0,15) per end.
- D. Body width does not include interlead flash. Interlead flash shall not exceed .017 (0,43) per side.
- E. Reference JEDEC MS-012 variation AA.

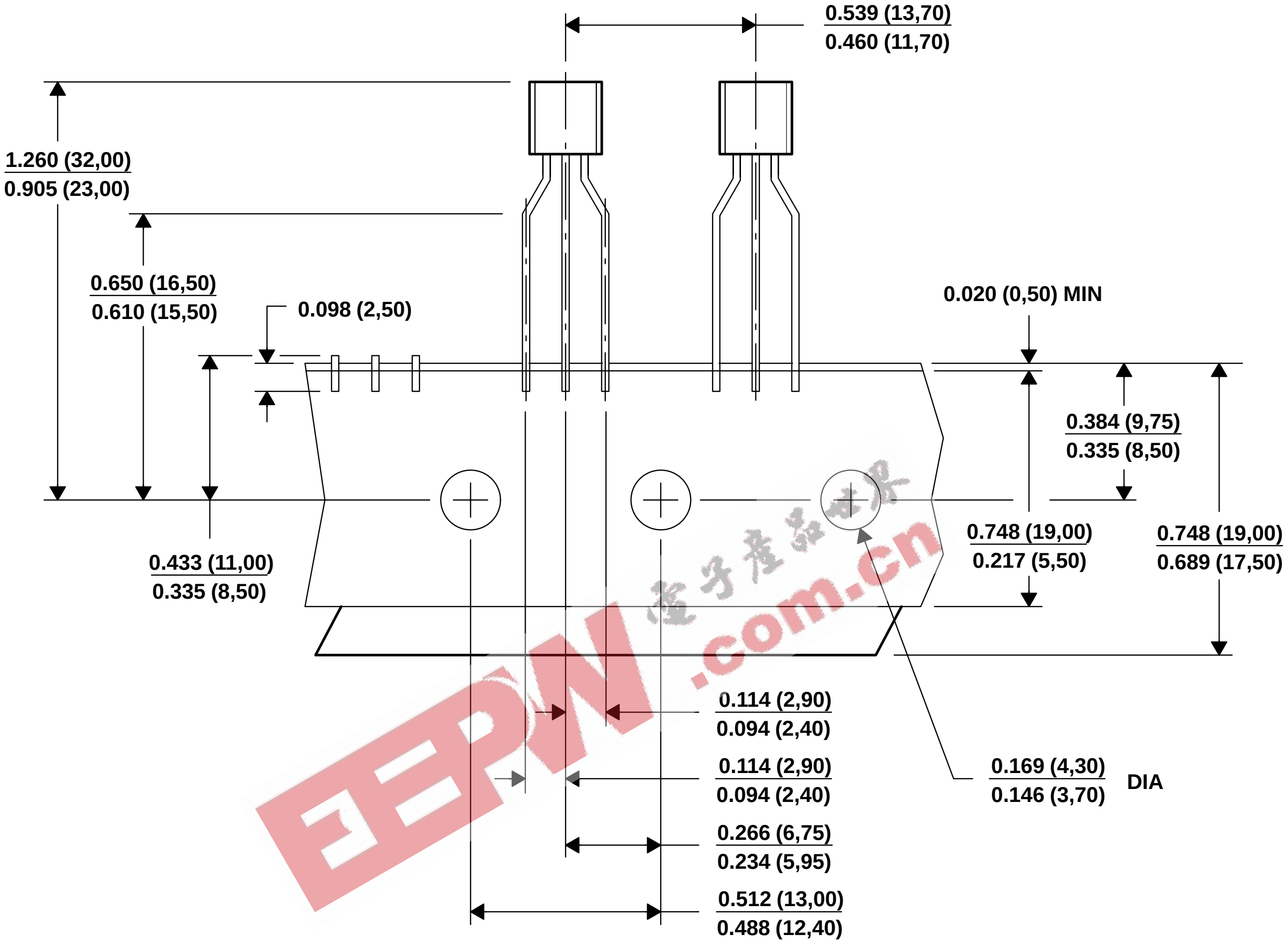
**LP (O-PBCY-W3)** **PLASTIC CYLINDRICAL PACKAGE**






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**



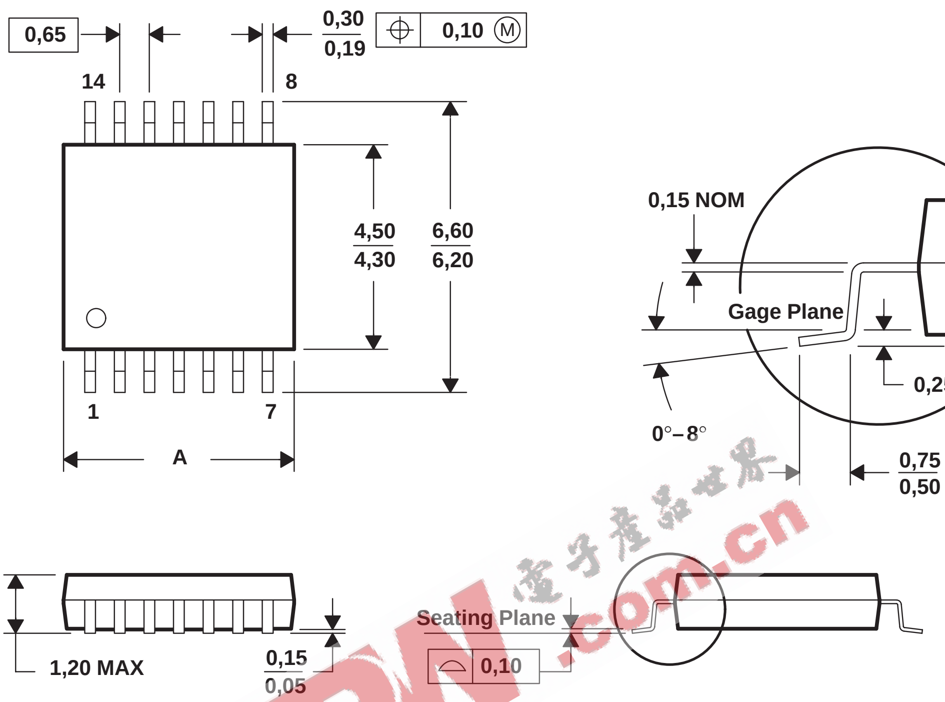

TAPE & REEL

4040001-3/C 10/01

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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