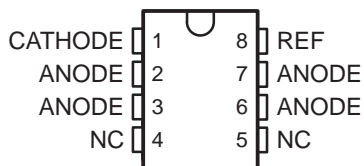


TL431, TL431A, TL431B, TL432, TL432A, TL432B ADJUSTABLE PRECISION SHUNT REGULATORS

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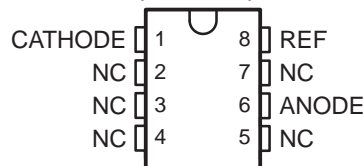
- Operation From -40°C to 125°C
 - 0.5% . . . B Grade
 - 1% . . . A Grade
 - 2% . . . Standard Grade
- Typical Temperature Drift (TL431B)
 - 6 mV (C Temp)
 - 14 mV (I Temp, Q Temp)
- Low Output Noise
- 0.2- Ω Typical Output Impedance
- Sink-Current Capability . . . 1 mA to 100 mA
- Adjustable Output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

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



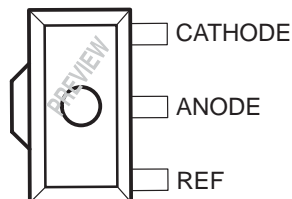
NC – No internal connection

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

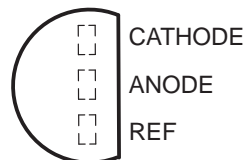


NC – No internal connection

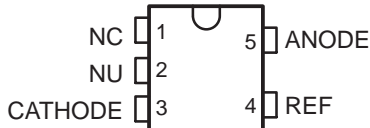
TL431, TL431A, TL431B . . . PK (SOT-89) PACKAGE
(TOP VIEW)



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

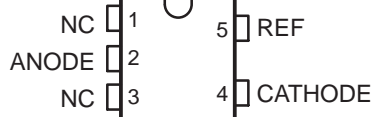


TL431, TL431A, TL431B . . . DBV (SOT23-5) PACKAGE
(TOP VIEW)



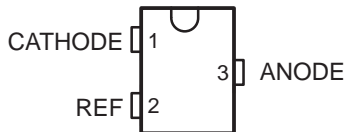
NC – No internal connection
NU – Make no external connection

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

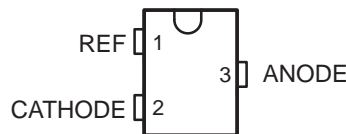


NC – No internal connection

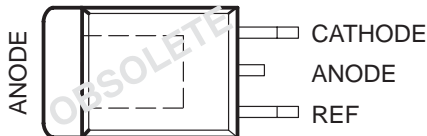
TL431, TL431A, TL431B . . . DBZ (SOT23-3) PACKAGE
(TOP VIEW)



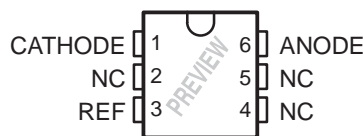
TL432, TL432A, TL432B . . . DBZ (SOT23-3) PACKAGE
(TOP VIEW)



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



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



NC – No internal connection



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

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

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description/ordering information (continued)

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

| TA | 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 | TAB_ |
| | | Reel of 3000 | TL432CDBZR | |
| | | Reel of 250 | TL432CDBZT | |
| | SOT-89 (PK) | Reel of 1000 | TL431CPK | |
| | 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 | T4A_ |
| | | Reel of 3000 | TL432IDBZR | |
| | | Reel of 250 | TL432IDBZT | |
| | SOT-89 (PK) | Reel of 1000 | TL431IPK | |
| | 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.

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

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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‡ |
|----------------|----------------|--------------|-----------------------|-------------------|
| -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.

‡ DBV/DBZ: The actual top-side marking has one additional character that designates the assembly/test site.

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 | TL431ACL | 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.



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

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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.

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

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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 | TL432BIDBZT | |
| | 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.



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

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description/ordering information (continued)

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

| TA | 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 | |
| | | Reel of 3000 | TL432BQDBVR | T4H_ |
| | | | Reel of 250 | |
| | SOT-23-3 (DBZ) | Reel of 3000 | TL431BQDBZR | T3H_ |
| | | | Reel of 250 | |
| | | Reel of 3000 | TL432BQDBZR | T4H_ |
| | | | Reel of 250 | |
| | 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 | | |

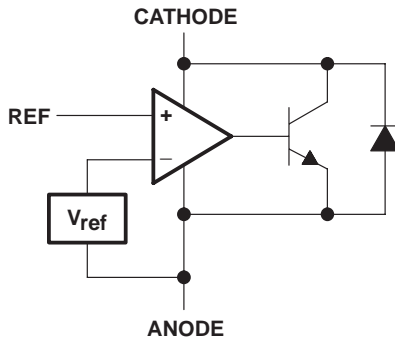
† Package drawings, standard packing quantities, thermal data, symbolization, and PCB design guidelines are available at www.ti.com/sc/package.

‡ DBV/DBZ: The actual top-side marking has one additional character that designates the assembly/test site.

symbol



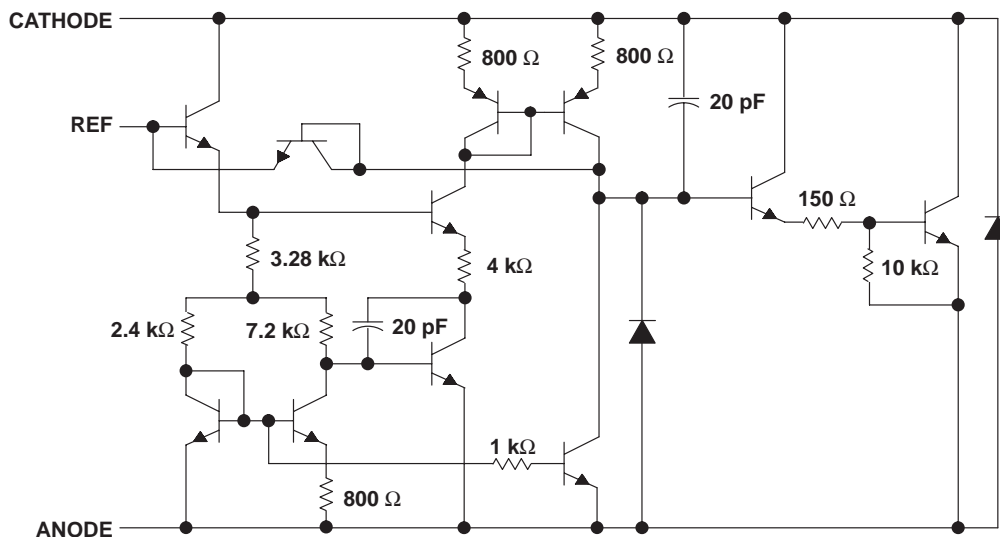
functional block diagram



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

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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 μ A 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.

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

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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 | |

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

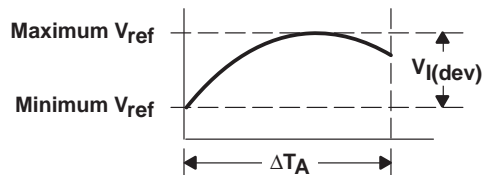
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electrical characteristics over recommended operating conditions, $T_A = 25^\circ\text{C}$ (unless otherwise noted)

| PARAMETER | TEST CIRCUIT | TEST CONDITIONS | TL431C, TL432C | | | UNIT | |
|--|--------------|---|---|------|------|------|------------------------------|
| | | | MIN | TYP | MAX | | |
| V_{ref} Reference voltage | 2 | $V_{\text{KA}} = V_{\text{ref}}$, $I_{\text{KA}} = 10\text{ mA}$ | 2440 | 2495 | 2550 | mV | |
| $V_{\text{I(dev)}}$ Deviation of reference voltage over full temperature range (see Figure 1) | 2 | $V_{\text{KA}} = V_{\text{ref}}$, $I_{\text{KA}} = 10\text{ mA}$, $T_A = 0^\circ\text{C}$ to 70°C | SOT23-3 and TL432 devices | | 6 | 16 | mV |
| | | | All other devices | | 4 | 25 | |
| $\frac{\Delta V_{\text{ref}}}{\Delta V_{\text{KA}}}$ Ratio of change in reference voltage to the change in cathode voltage | 3 | $I_{\text{KA}} = 10\text{ mA}$ | $\Delta V_{\text{KA}} = 10\text{ V} - V_{\text{ref}}$ | | -1.4 | -2.7 | $\frac{\text{mV}}{\text{V}}$ |
| | | | $\Delta V_{\text{KA}} = 36\text{ V} - 10\text{ V}$ | | -1 | -2 | |
| I_{ref} Reference current | 3 | $I_{\text{KA}} = 10\text{ mA}$, $R_1 = 10\text{ k}\Omega$, $R_2 = \infty$ | | | 2 | 4 | μA |
| $I_{\text{I(dev)}}$ Deviation of reference current over full temperature range (see Figure 1) | 3 | $I_{\text{KA}} = 10\text{ mA}$, $R_1 = 10\text{ k}\Omega$, $R_2 = \infty$, $T_A = 0^\circ\text{C}$ to 70°C | | | 0.4 | 1.2 | μA |
| I_{min} Minimum cathode current for regulation | 2 | $V_{\text{KA}} = V_{\text{ref}}$ | | | 0.4 | 1 | mA |
| I_{off} Off-state cathode current | 4 | $V_{\text{KA}} = 36\text{ V}$, $V_{\text{ref}} = 0$ | | | 0.1 | 1 | μA |
| $ z_{\text{KA}} $ Dynamic impedance (see Figure 1) | 1 | $I_{\text{KA}} = 1\text{ mA}$ to 100 mA , $V_{\text{KA}} = V_{\text{ref}}$, $f \leq 1\text{ kHz}$ | | | 0.2 | 0.5 | Ω |

The deviation parameters $V_{\text{ref(dev)}}$ and $I_{\text{ref(dev)}}$ 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, $\alpha_{V_{\text{ref}}}$, is defined as:

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



where:

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

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

Example: maximum $V_{\text{ref}} = 2496\text{ mV}$ at 30°C , minimum $V_{\text{ref}} = 2492\text{ mV}$ at 0°C , $V_{\text{ref}} = 2495\text{ mV}$ at 25°C , $\Delta T_A = 70^\circ\text{C}$ for TL431C

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

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

Calculating Dynamic Impedance

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

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

$$|z'| = \frac{\Delta V}{\Delta I} \approx |z_{\text{KA}}| \left(1 + \frac{R_1}{R_2} \right)$$

Figure 1. Calculating Deviation Parameters and Dynamic Impedance

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electrical characteristics over recommended operating conditions, $T_A = 25^\circ\text{C}$ (unless otherwise noted)

| PARAMETER | TEST CIRCUIT | TEST CONDITIONS | TL431I, TL432I | | | UNIT | |
|--|--------------|---|---|------|------|------|------------------------------|
| | | | MIN | TYP | MAX | | |
| V_{ref} Reference voltage | 2 | $V_{\text{KA}} = V_{\text{ref}}$, $I_{\text{KA}} = 10\text{ mA}$ | 2440 | 2495 | 2550 | mV | |
| $V_{\text{I(dev)}}$ Deviation of reference voltage over full temperature range (see Figure 1) | 2 | $V_{\text{KA}} = V_{\text{ref}}$, $I_{\text{KA}} = 10\text{ mA}$, $T_A = -40^\circ\text{C}$ to 85°C | SOT23-3 and TL432 devices | | 14 | 34 | mV |
| | | All other devices | | 5 | 50 | | |
| $\frac{\Delta V_{\text{ref}}}{\Delta V_{\text{KA}}}$ Ratio of change in reference voltage to the change in cathode voltage | 3 | $I_{\text{KA}} = 10\text{ mA}$ | $\Delta V_{\text{KA}} = 10\text{ V} - V_{\text{ref}}$ | | -1.4 | -2.7 | $\frac{\text{mV}}{\text{V}}$ |
| | | | $\Delta V_{\text{KA}} = 36\text{ V} - 10\text{ V}$ | | -1 | -2 | |
| I_{ref} Reference current | 3 | $I_{\text{KA}} = 10\text{ mA}$, $R_1 = 10\text{ k}\Omega$, $R_2 = \infty$ | | | 2 | 4 | μA |
| $I_{\text{I(dev)}}$ Deviation of reference current over full temperature range (see Figure 1) | 3 | $I_{\text{KA}} = 10\text{ mA}$, $R_1 = 10\text{ k}\Omega$, $R_2 = \infty$, $T_A = -40^\circ\text{C}$ to 85°C | | | 0.8 | 2.5 | μA |
| I_{min} Minimum cathode current for regulation | 2 | $V_{\text{KA}} = V_{\text{ref}}$ | | | 0.4 | 1 | mA |
| I_{off} Off-state cathode current | 4 | $V_{\text{KA}} = 36\text{ V}$, $V_{\text{ref}} = 0$ | | | 0.1 | 1 | μA |
| $ z_{\text{KA}} $ Dynamic impedance (see Figure 1) | 2 | $I_{\text{KA}} = 1\text{ mA}$ to 100 mA , $V_{\text{KA}} = V_{\text{ref}}$, $f \leq 1\text{ kHz}$ | | | 0.2 | 0.5 | Ω |

electrical characteristics over recommended operating conditions, $T_A = 25^\circ\text{C}$ (unless otherwise noted)

| PARAMETER | TEST CIRCUIT | TEST CONDITIONS | TL431Q, TL432Q | | | UNIT | |
|--|--------------|--|---|------|------|------|------------------------------|
| | | | MIN | TYP | MAX | | |
| V_{ref} Reference voltage | 2 | $V_{\text{KA}} = V_{\text{ref}}$, $I_{\text{KA}} = 10\text{ mA}$ | 2440 | 2495 | 2550 | mV | |
| $V_{\text{I(dev)}}$ Deviation of reference voltage over full temperature range (see Figure 1) | 2 | $V_{\text{KA}} = V_{\text{ref}}$, $I_{\text{KA}} = 10\text{ mA}$, $T_A = -40^\circ\text{C}$ to 125°C | | | 14 | 34 | mV |
| | | | | | | | |
| $\frac{\Delta V_{\text{ref}}}{\Delta V_{\text{KA}}}$ Ratio of change in reference voltage to the change in cathode voltage | 3 | $I_{\text{KA}} = 10\text{ mA}$ | $\Delta V_{\text{KA}} = 10\text{ V} - V_{\text{ref}}$ | | -1.4 | -2.7 | $\frac{\text{mV}}{\text{V}}$ |
| | | | $\Delta V_{\text{KA}} = 36\text{ V} - 10\text{ V}$ | | -1 | -2 | |
| I_{ref} Reference current | 3 | $I_{\text{KA}} = 10\text{ mA}$, $R_1 = 10\text{ k}\Omega$, $R_2 = \infty$ | | | 2 | 4 | μA |
| $I_{\text{I(dev)}}$ Deviation of reference current over full temperature range (see Figure 1) | 3 | $I_{\text{KA}} = 10\text{ mA}$, $R_1 = 10\text{ k}\Omega$, $R_2 = \infty$, $T_A = -40^\circ\text{C}$ to 125°C | | | 0.8 | 2.5 | μA |
| I_{min} Minimum cathode current for regulation | 2 | $V_{\text{KA}} = V_{\text{ref}}$ | | | 0.4 | 1 | mA |
| I_{off} Off-state cathode current | 4 | $V_{\text{KA}} = 36\text{ V}$, $V_{\text{ref}} = 0$ | | | 0.1 | 1 | μA |
| $ z_{\text{KA}} $ Dynamic impedance (see Figure 1) | 2 | $I_{\text{KA}} = 1\text{ mA}$ to 100 mA , $V_{\text{KA}} = V_{\text{ref}}$, $f \leq 1\text{ kHz}$ | | | 0.2 | 0.5 | Ω |



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electrical characteristics over recommended operating conditions, $T_A = 25^\circ\text{C}$ (unless otherwise noted)

| PARAMETER | TEST CIRCUIT | TEST CONDITIONS | TL431AC, TL432AC | | | UNIT | |
|--|--------------|---|---|------|------|------|------------------------------|
| | | | MIN | TYP | MAX | | |
| V_{ref} Reference voltage | 2 | $V_{\text{KA}} = V_{\text{ref}}$, $I_{\text{KA}} = 10\text{ mA}$ | 2470 | 2495 | 2520 | mV | |
| $V_{\text{I(dev)}}$ Deviation of reference voltage over full temperature range (see Figure 1) | 2 | $V_{\text{KA}} = V_{\text{ref}}$, $I_{\text{KA}} = 10\text{ mA}$, $T_A = 0^\circ\text{C}$ to 70°C | SOT23-3, SC-70, and TL432 devices | | 6 | 16 | mV |
| | | | All other devices | | 4 | 25 | |
| $\frac{\Delta V_{\text{ref}}}{\Delta V_{\text{KA}}}$ Ratio of change in reference voltage to the change in cathode voltage | 3 | $I_{\text{KA}} = 10\text{ mA}$ | $\Delta V_{\text{KA}} = 10\text{ V} - V_{\text{ref}}$ | | -1.4 | -2.7 | $\frac{\text{mV}}{\text{V}}$ |
| | | | $\Delta V_{\text{KA}} = 36\text{ V} - 10\text{ V}$ | | -1 | -2 | |
| I_{ref} Reference current | 3 | $I_{\text{KA}} = 10\text{ mA}$, $R_1 = 10\text{ k}\Omega$, $R_2 = \infty$ | | | 2 | 4 | μA |
| $I_{\text{I(dev)}}$ Deviation of reference current over full temperature range (see Figure 1) | 3 | $I_{\text{KA}} = 10\text{ mA}$, $R_1 = 10\text{ k}\Omega$, $R_2 = \infty$, $T_A = 0^\circ\text{C}$ to 70°C | | | 0.8 | 1.2 | μA |
| I_{min} Minimum cathode current for regulation | 2 | $V_{\text{KA}} = V_{\text{ref}}$ | | | 0.4 | 0.6 | mA |
| I_{off} Off-state cathode current | 4 | $V_{\text{KA}} = 36\text{ V}$, $V_{\text{ref}} = 0$ | | | 0.1 | 0.5 | μA |
| $ z_{\text{KA}} $ Dynamic impedance (see Figure 1) | 1 | $I_{\text{KA}} = 1\text{ mA}$ to 100 mA , $V_{\text{KA}} = V_{\text{ref}}$, $f \leq 1\text{ kHz}$ | | | 0.2 | 0.5 | Ω |

electrical characteristics over recommended operating conditions, $T_A = 25^\circ\text{C}$ (unless otherwise noted)

| PARAMETER | TEST CIRCUIT | TEST CONDITIONS | TL431AI, TL432AI | | | UNIT | |
|--|--------------|---|---|------|------|------|------------------------------|
| | | | MIN | TYP | MAX | | |
| V_{ref} Reference voltage | 2 | $V_{\text{KA}} = V_{\text{ref}}$, $I_{\text{KA}} = 10\text{ mA}$ | 2470 | 2495 | 2520 | mV | |
| $V_{\text{I(dev)}}$ Deviation of reference voltage over full temperature range (see Figure 1) | 2 | $V_{\text{KA}} = V_{\text{ref}}$, $I_{\text{KA}} = 10\text{ mA}$, $T_A = -40^\circ\text{C}$ to 85°C | SOT23-3, SC-70, and TL432 devices | | 14 | 34 | mV |
| | | | All other packages | | 5 | 50 | |
| $\frac{\Delta V_{\text{ref}}}{\Delta V_{\text{KA}}}$ Ratio of change in reference voltage to the change in cathode voltage | 3 | $I_{\text{KA}} = 10\text{ mA}$ | $\Delta V_{\text{KA}} = 10\text{ V} - V_{\text{ref}}$ | | -1.4 | -2.7 | $\frac{\text{mV}}{\text{V}}$ |
| | | | $\Delta V_{\text{KA}} = 36\text{ V} - 10\text{ V}$ | | -1 | -2 | |
| I_{ref} Reference current | 3 | $I_{\text{KA}} = 10\text{ mA}$, $R_1 = 10\text{ k}\Omega$, $R_2 = \infty$ | | | 2 | 4 | μA |
| $I_{\text{I(dev)}}$ Deviation of reference current over full temperature range (see Figure 1) | 3 | $I_{\text{KA}} = 10\text{ mA}$, $R_1 = 10\text{ k}\Omega$, $R_2 = \infty$, $T_A = -40^\circ\text{C}$ to 85°C | | | 0.8 | 2.5 | μA |
| I_{min} Minimum cathode current for regulation | 2 | $V_{\text{KA}} = V_{\text{ref}}$ | | | 0.4 | 0.7 | mA |
| I_{off} Off-state cathode current | 4 | $V_{\text{KA}} = 36\text{ V}$, $V_{\text{ref}} = 0$ | | | 0.1 | 0.5 | μA |
| $ z_{\text{KA}} $ Dynamic impedance (see Figure 1) | 2 | $I_{\text{KA}} = 1\text{ mA}$ to 100 mA , $V_{\text{KA}} = V_{\text{ref}}$, $f \leq 1\text{ kHz}$ | | | 0.2 | 0.5 | Ω |



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electrical characteristics over recommended operating conditions, $T_A = 25^\circ\text{C}$ (unless otherwise noted)

| PARAMETER | TEST CIRCUIT | TEST CONDITIONS | TL431AQ, TL432AQ | | | UNIT |
|--|--------------|--|---|------|------|------------------------------|
| | | | MIN | TYP | MAX | |
| V_{ref} Reference voltage | 2 | $V_{\text{KA}} = V_{\text{ref}}$, $I_{\text{KA}} = 10\text{ mA}$ | 2470 | 2495 | 2520 | mV |
| $V_{\text{I(dev)}}$ Deviation of reference voltage over full temperature range (see Figure 1) | 2 | $V_{\text{KA}} = V_{\text{ref}}$, $I_{\text{KA}} = 10\text{ mA}$, $T_A = -40^\circ\text{C}$ to 125°C | | 14 | 34 | mV |
| $\frac{\Delta V_{\text{ref}}}{\Delta V_{\text{KA}}}$ Ratio of change in reference voltage to the change in cathode voltage | 3 | $I_{\text{KA}} = 10\text{ mA}$ | $\Delta V_{\text{KA}} = 10\text{ V} - V_{\text{ref}}$ | -1.4 | -2.7 | $\frac{\text{mV}}{\text{V}}$ |
| | | | $\Delta V_{\text{KA}} = 36\text{ V} - 10\text{ V}$ | -1 | -2 | |
| I_{ref} Reference current | 3 | $I_{\text{KA}} = 10\text{ mA}$, $R_1 = 10\text{ k}\Omega$, $R_2 = \infty$ | | 2 | 4 | μA |
| $I_{\text{I(dev)}}$ Deviation of reference current over full temperature range (see Figure 1) | 3 | $I_{\text{KA}} = 10\text{ mA}$, $R_1 = 10\text{ k}\Omega$, $R_2 = \infty$, $T_A = -40^\circ\text{C}$ to 125°C | | 0.8 | 2.5 | μA |
| I_{min} Minimum cathode current for regulation | 2 | $V_{\text{KA}} = V_{\text{ref}}$ | | 0.4 | 0.7 | mA |
| I_{off} Off-state cathode current | 4 | $V_{\text{KA}} = 36\text{ V}$, $V_{\text{ref}} = 0$ | | 0.1 | 0.5 | μA |
| $ z_{\text{KA}} $ Dynamic impedance (see Figure 1) | 2 | $I_{\text{KA}} = 1\text{ mA}$ to 100 mA , $V_{\text{KA}} = V_{\text{ref}}$, $f \leq 1\text{ kHz}$ | | 0.2 | 0.5 | Ω |

electrical characteristics over recommended operating conditions, $T_A = 25^\circ\text{C}$ (unless otherwise noted)

| PARAMETER | TEST CIRCUIT | TEST CONDITIONS | TL431BC, TL432BC | | | UNIT |
|--|--------------|---|---|------|------|------------------------------|
| | | | MIN | TYP | MAX | |
| V_{ref} Reference voltage | 2 | $V_{\text{KA}} = V_{\text{ref}}$, $I_{\text{KA}} = 10\text{ mA}$ | 2483 | 2495 | 2507 | mV |
| $V_{\text{I(dev)}}$ Deviation of reference voltage over full temperature range (see Figure 1) | 2 | $V_{\text{KA}} = V_{\text{ref}}$, $I_{\text{KA}} = 10\text{ mA}$, $T_A = 0^\circ\text{C}$ to 70°C | | 6 | 16 | mV |
| $\frac{\Delta V_{\text{ref}}}{\Delta V_{\text{KA}}}$ Ratio of change in reference voltage to the change in cathode voltage | 3 | $I_{\text{KA}} = 10\text{ mA}$ | $\Delta V_{\text{KA}} = 10\text{ V} - V_{\text{ref}}$ | -1.4 | -2.7 | $\frac{\text{mV}}{\text{V}}$ |
| | | | $\Delta V_{\text{KA}} = 36\text{ V} - 10\text{ V}$ | -1 | -2 | |
| I_{ref} Reference current | 3 | $I_{\text{KA}} = 10\text{ mA}$, $R_1 = 10\text{ k}\Omega$, $R_2 = \infty$ | | 2 | 4 | μA |
| $I_{\text{I(dev)}}$ Deviation of reference current over full temperature range (see Figure 1) | 3 | $I_{\text{KA}} = 10\text{ mA}$, $R_1 = 10\text{ k}\Omega$, $R_2 = \infty$, $T_A = 0^\circ\text{C}$ to 70°C | | 0.8 | 1.2 | μA |
| I_{min} Minimum cathode current for regulation | 2 | $V_{\text{KA}} = V_{\text{ref}}$ | | 0.4 | 0.6 | mA |
| I_{off} Off-state cathode current | 4 | $V_{\text{KA}} = 36\text{ V}$, $V_{\text{ref}} = 0$ | | 0.1 | 0.5 | μA |
| $ z_{\text{KA}} $ Dynamic impedance (see Figure 1) | 1 | $I_{\text{KA}} = 1\text{ mA}$ to 100 mA , $V_{\text{KA}} = V_{\text{ref}}$, $f \leq 1\text{ kHz}$ | | 0.2 | 0.5 | Ω |



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electrical characteristics over recommended operating conditions, $T_A = 25^\circ\text{C}$ (unless otherwise noted)

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

electrical characteristics over recommended operating conditions, $T_A = 25^\circ\text{C}$ (unless otherwise noted)

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



PARAMETER MEASUREMENT INFORMATION

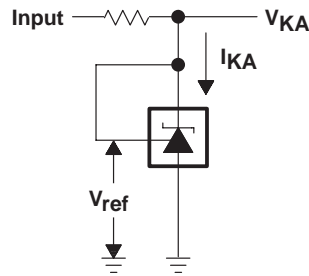


Figure 2. Test Circuit for $V_{KA} = V_{ref}$

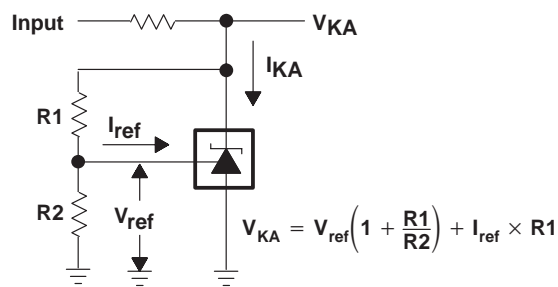


Figure 3. Test Circuit for $V_{KA} > V_{ref}$

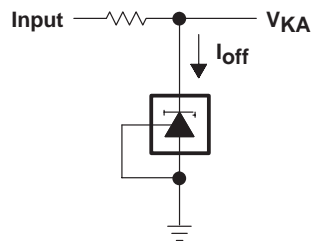


Figure 4. Test Circuit for I_{off}

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TYPICAL CHARACTERISTICS

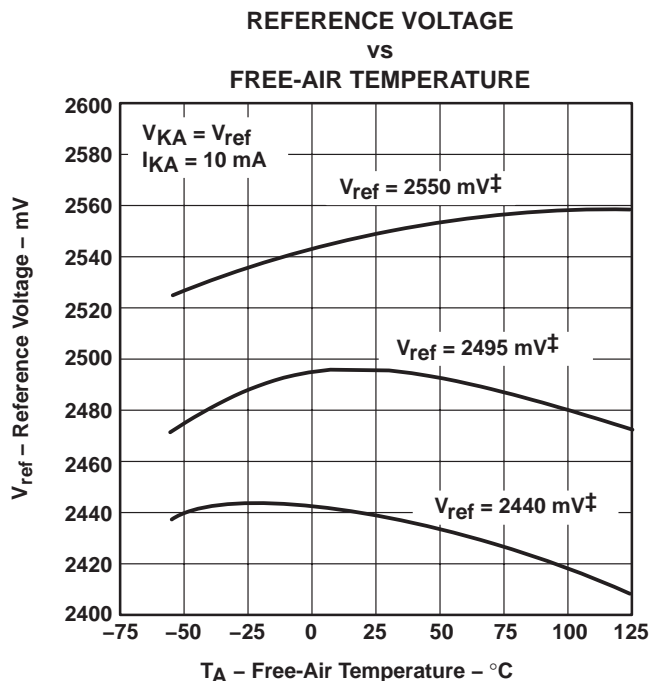
Table 1. Graphs

| | 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 |

TYPICAL CHARACTERISTICS†



† Data is for devices having the indicated value of V_{ref} at $I_{KA} = 10 \text{ mA}$, $T_A = 25^\circ\text{C}$.

Figure 5

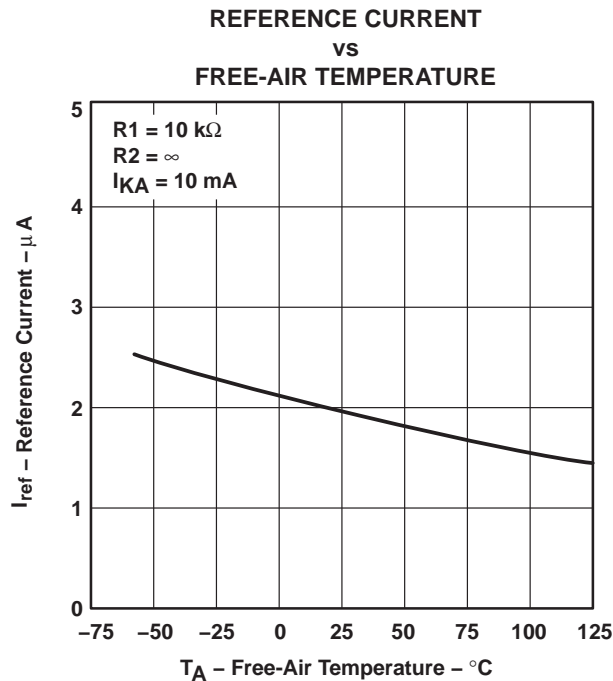


Figure 6

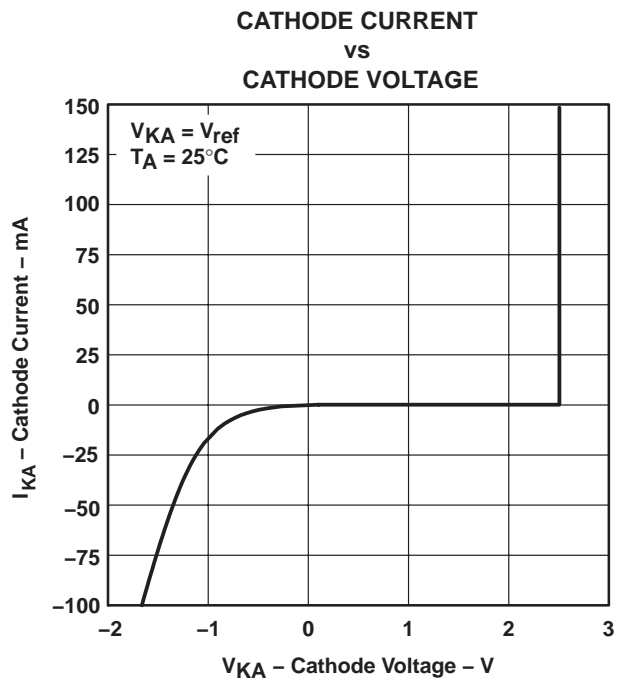


Figure 7

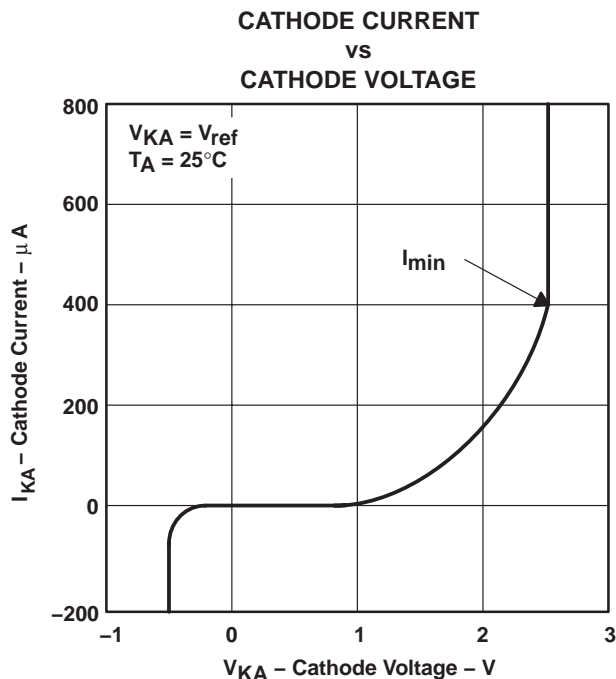


Figure 8

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

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TYPICAL CHARACTERISTICS†

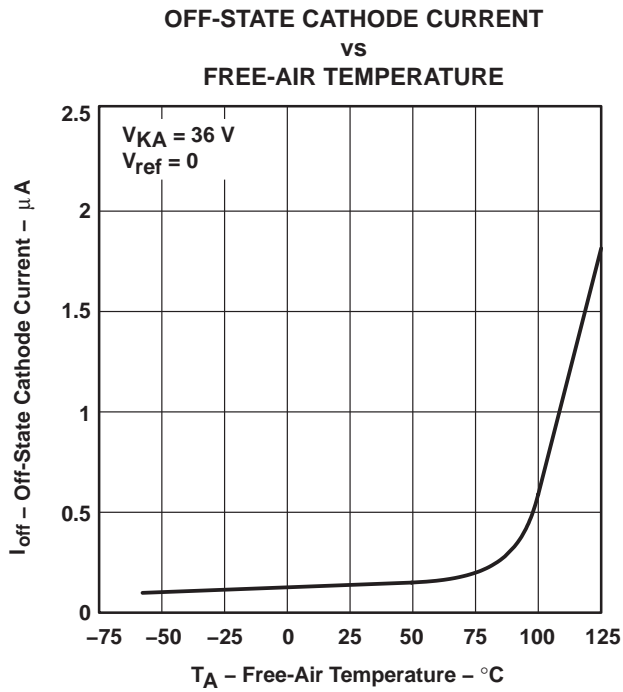


Figure 9

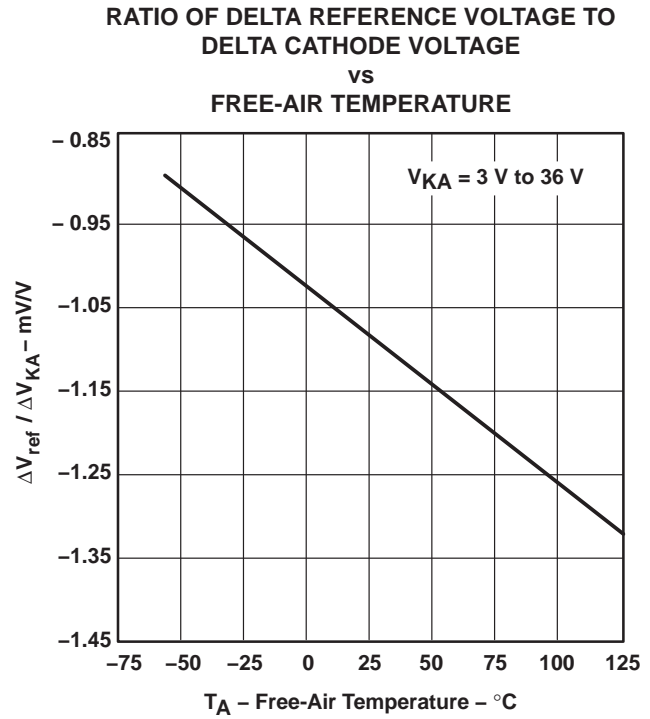


Figure 10

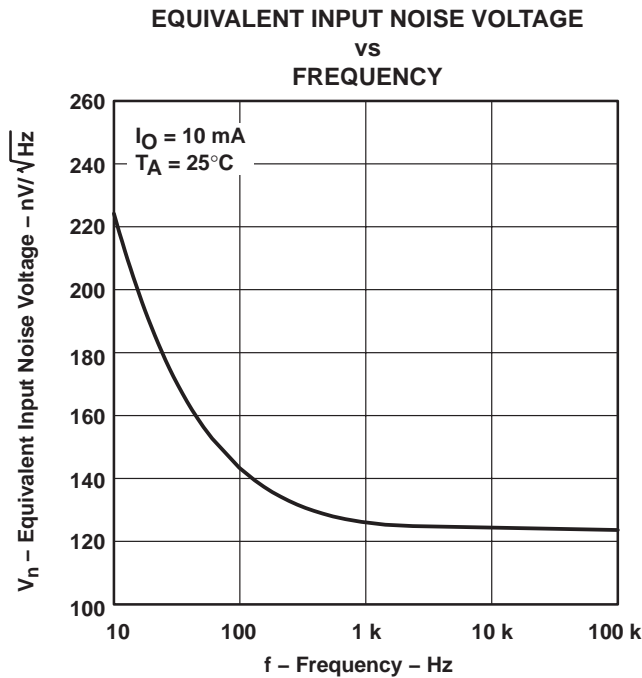


Figure 11

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

TYPICAL CHARACTERISTICS

EQUIVALENT INPUT NOISE VOLTAGE
OVER A 10-S PERIOD

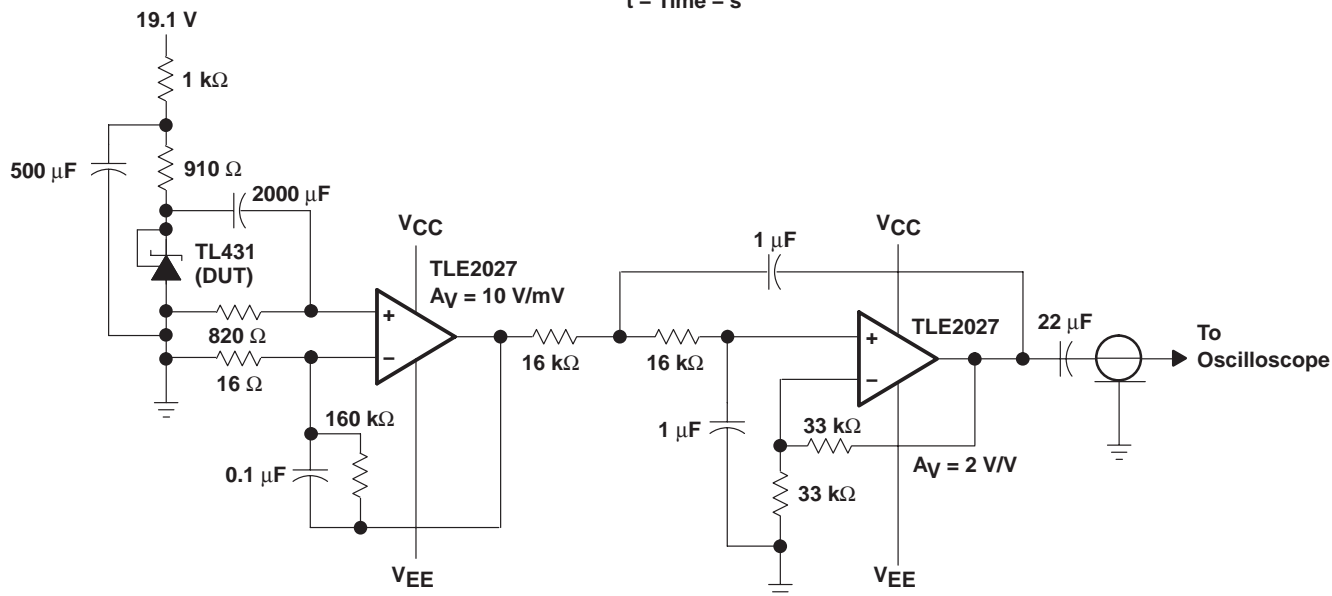
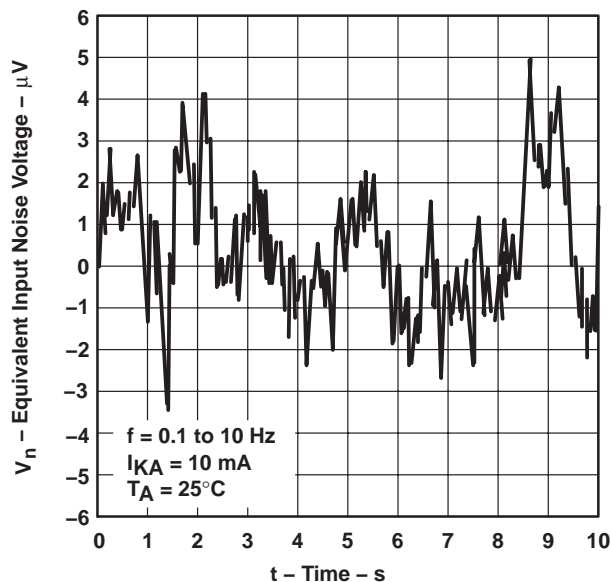


Figure 12. Test Circuit for Equivalent Input Noise Voltage

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TYPICAL CHARACTERISTICS

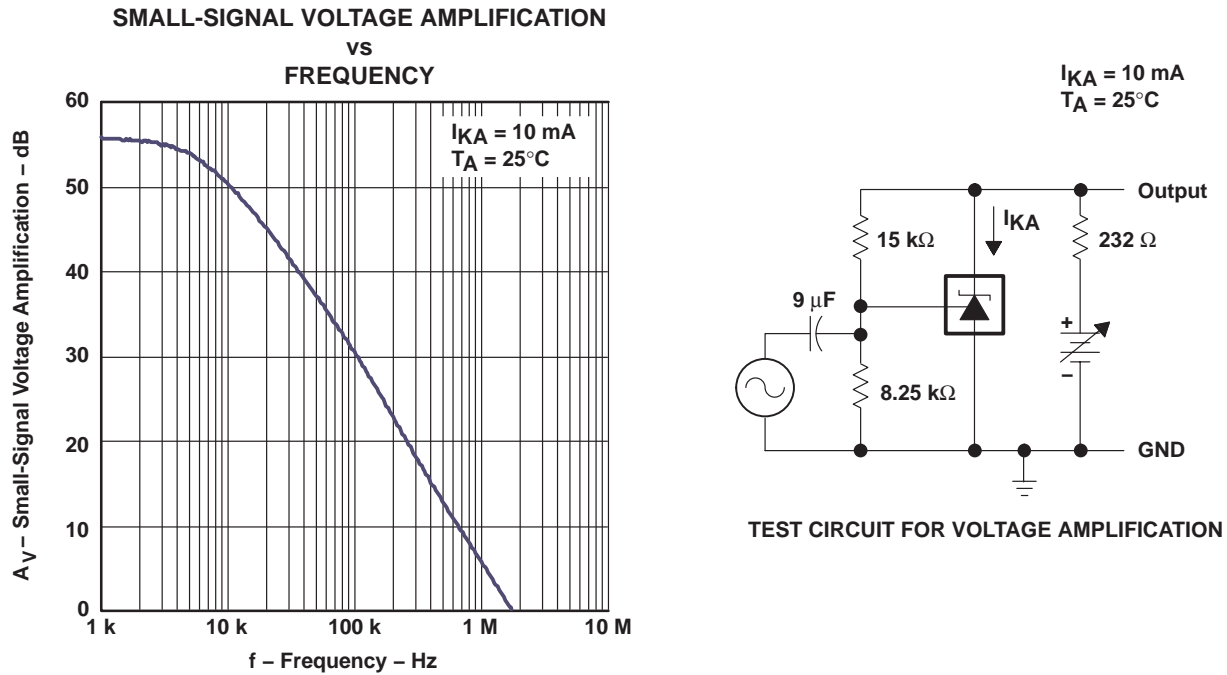


Figure 13

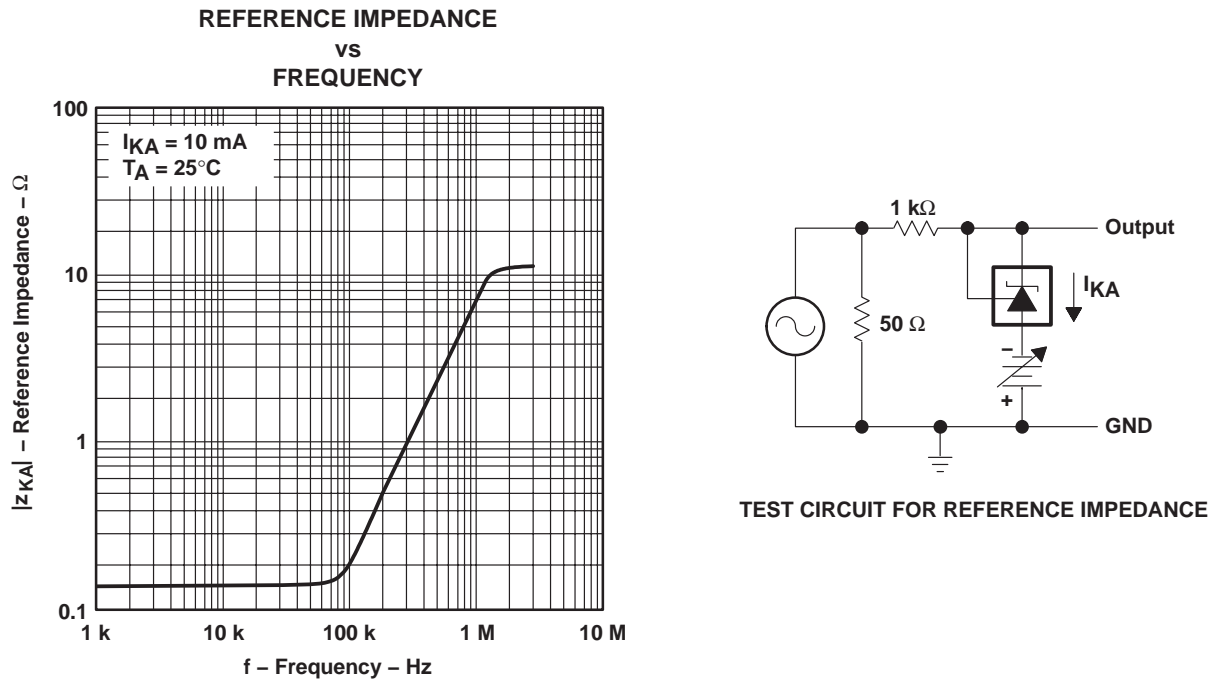


Figure 14

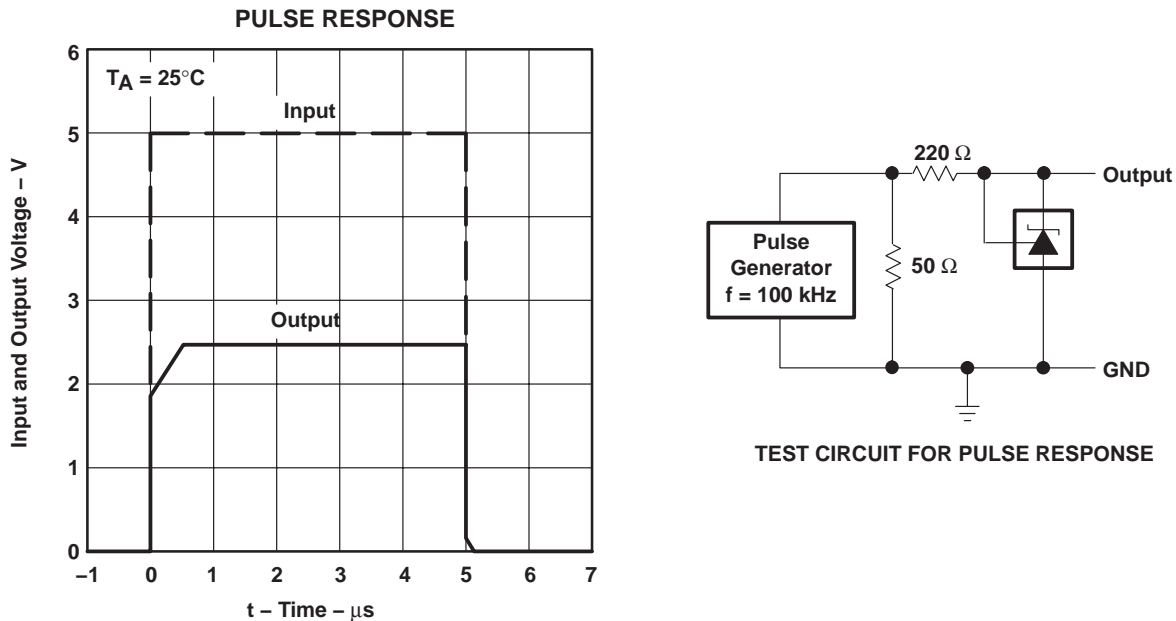


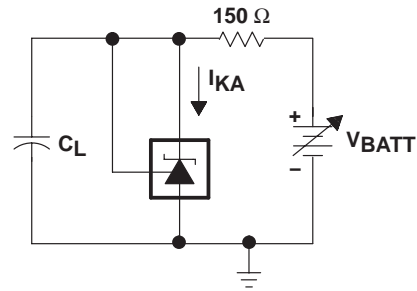
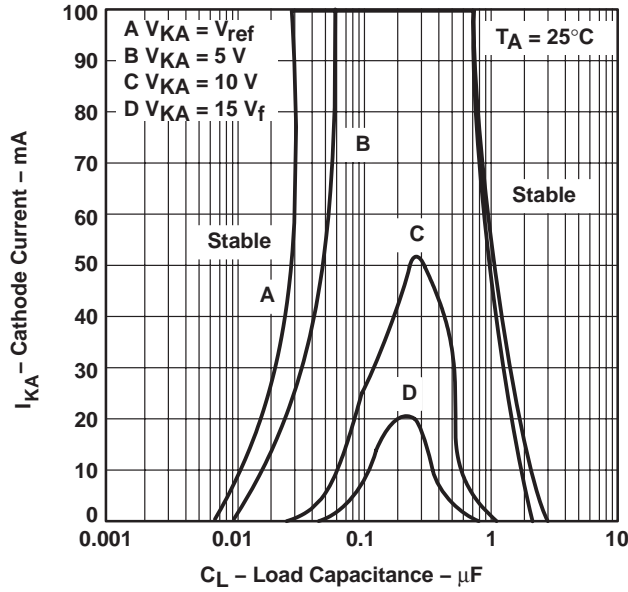
Figure 15

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

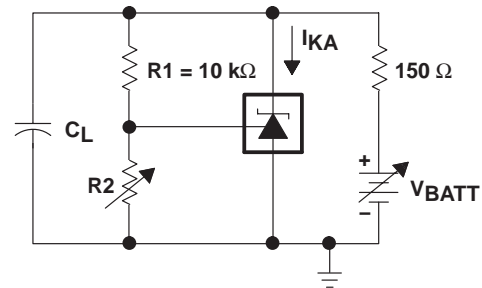
SLVS543A – AUGUST 2004 – REVISED AUGUST 2004

TYPICAL CHARACTERISTICS

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

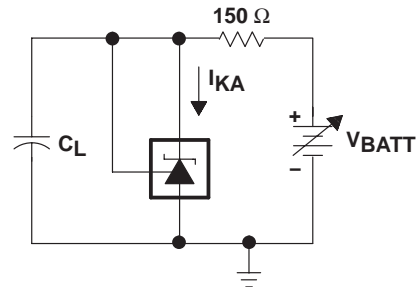
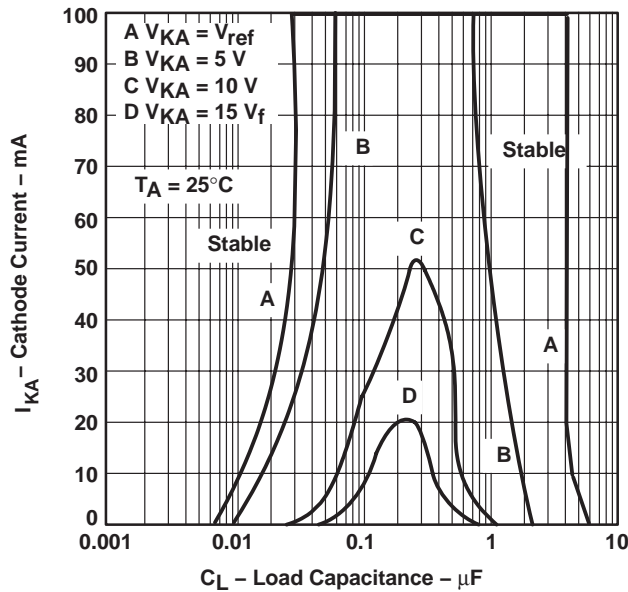


TEST CIRCUIT FOR CURVE A

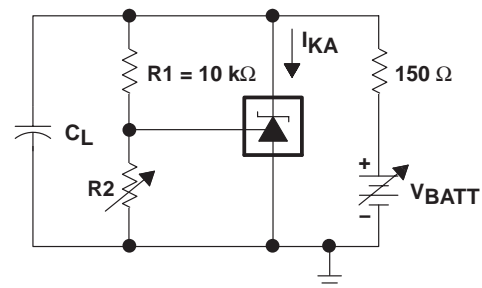


TEST CIRCUIT FOR CURVES B, C, AND D

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



TEST CIRCUIT FOR CURVE A

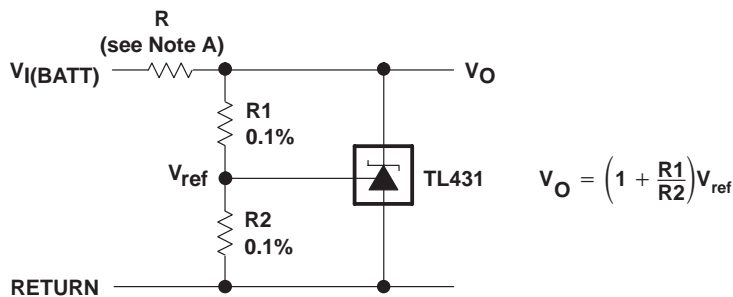


TEST CIRCUIT FOR CURVES B, C, AND D

† 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



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

Figure 17. Shunt Regulator

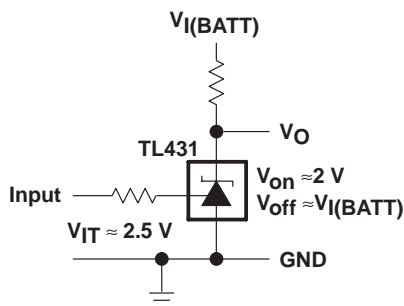
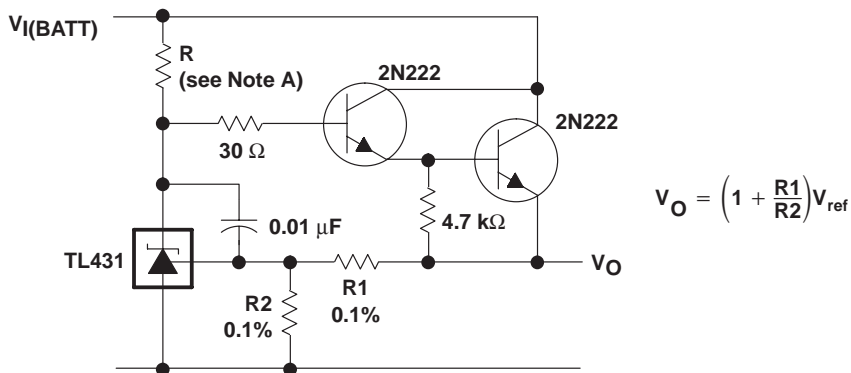


Figure 18. Single-Supply Comparator With Temperature-Compensated Threshold



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

Figure 19. Precision High-Current Series Regulator

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

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APPLICATION INFORMATION

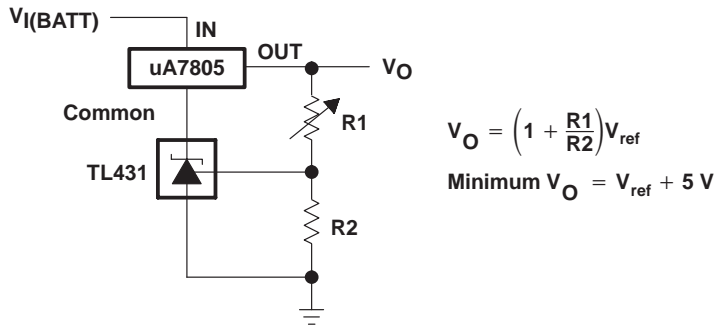


Figure 20. Output Control of a Three-Terminal Fixed Regulator

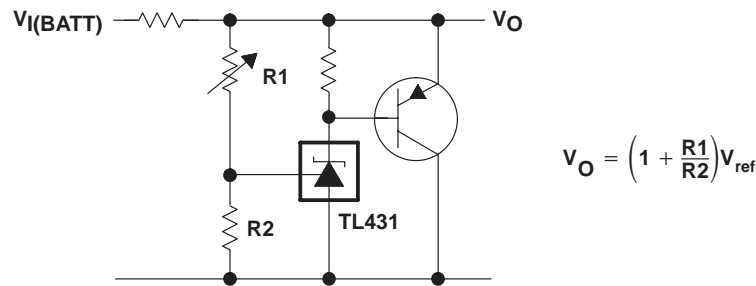
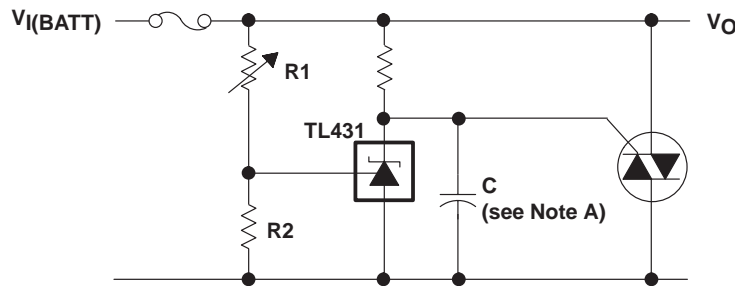


Figure 21. High-Current Shunt Regulator



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

Figure 22. Crowbar Circuit

APPLICATION INFORMATION

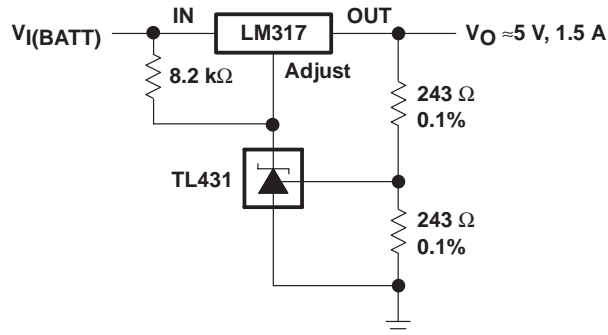
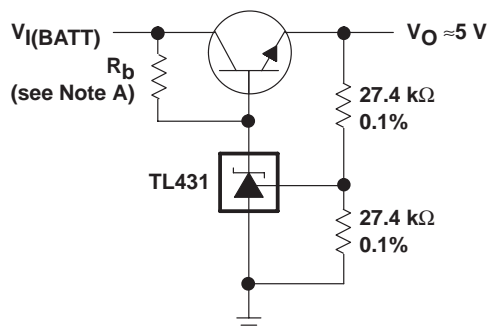


Figure 23. Precision 5-V 1.5-A Regulator



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

Figure 24. Efficient 5-V Precision Regulator

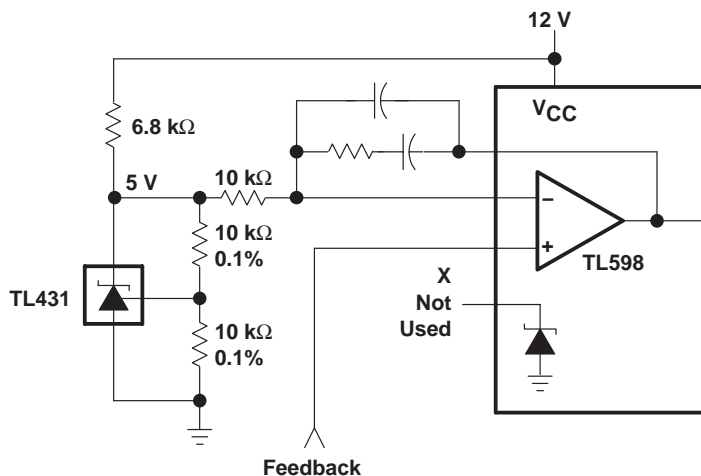
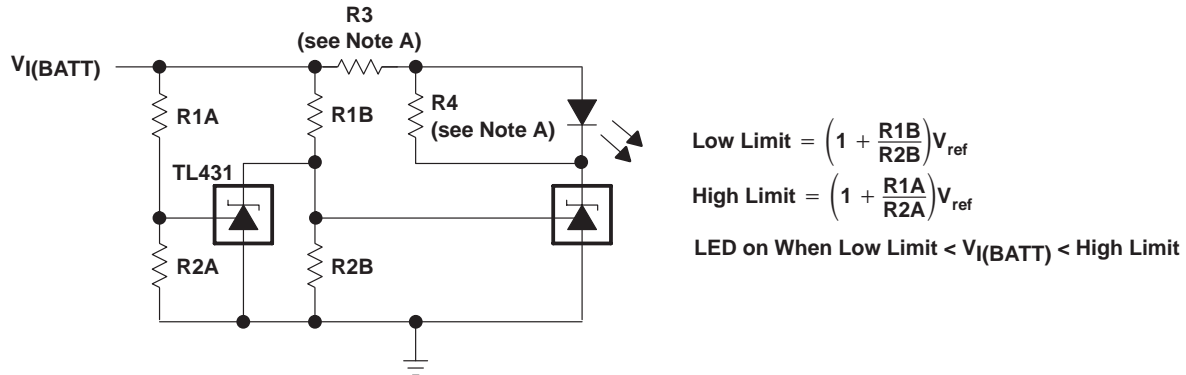


Figure 25. PWM Converter With Reference

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

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APPLICATION INFORMATION



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

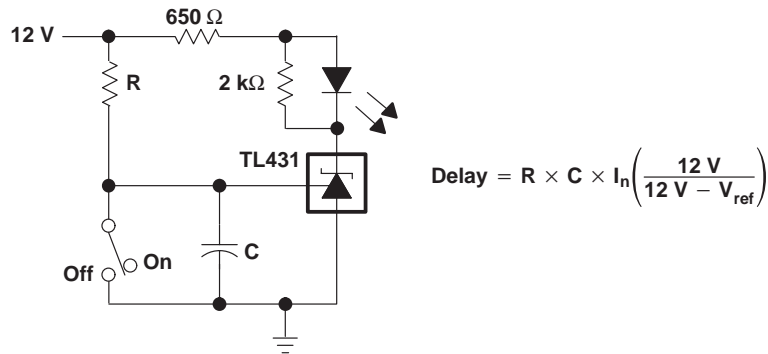


Figure 27. Delay Timer

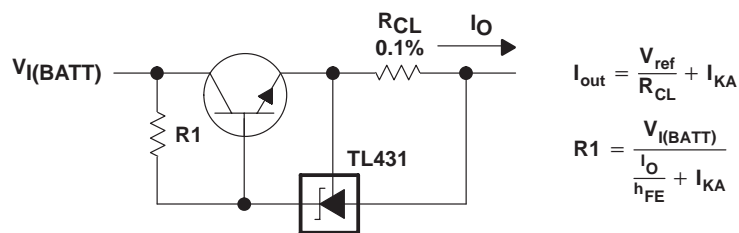


Figure 28. Precision Current Limiter

APPLICATION INFORMATION

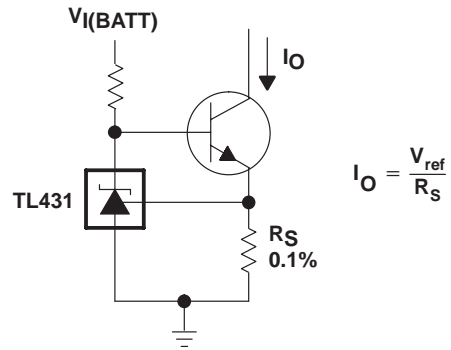


Figure 29. Precision Constant-Current Sink

JG (R-GDIP-T8)

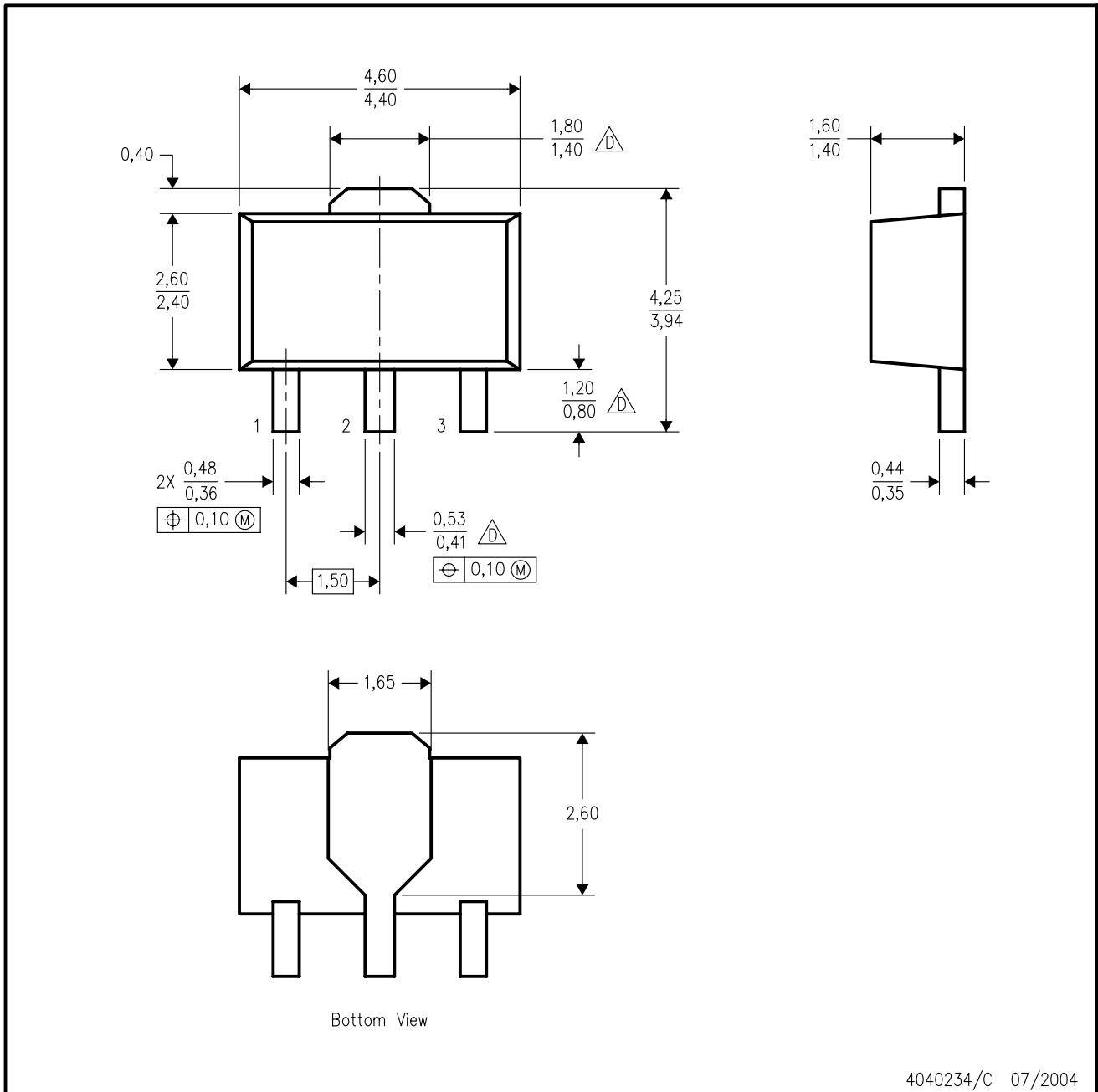
CERAMIC DUAL-IN-LINE




- 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

PK (R-PSSO-F3)

PLASTIC SINGLE-IN-LINE PACKAGE



- 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.
-  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



- 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

P (R-PDIP-T8)

PLASTIC DUAL-IN-LINE



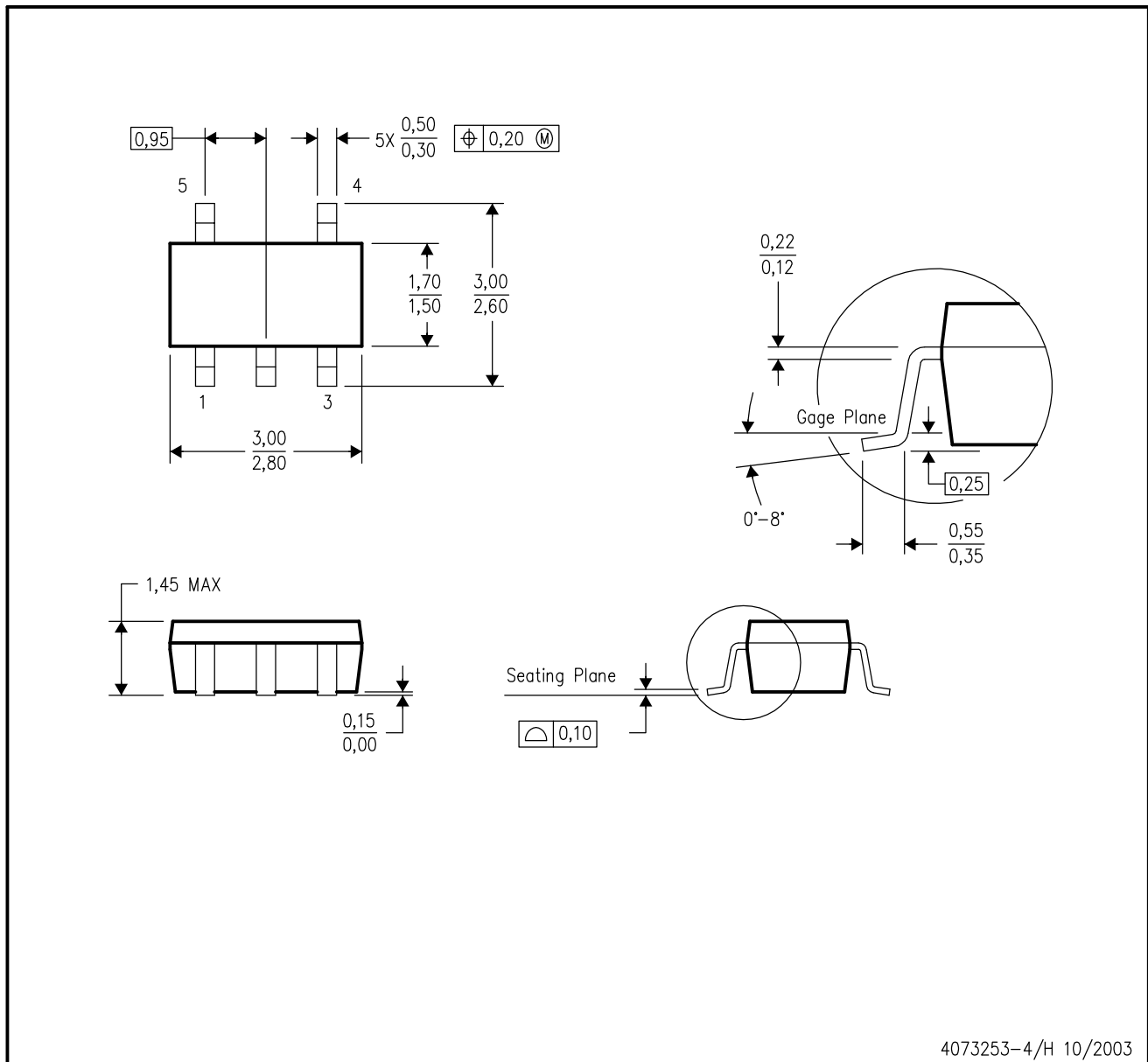
- NOTES: A. All linear dimensions are in inches (millimeters).
 B. This drawing is subject to change without notice.
 C. Falls within JEDEC MS-001

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



DBV (R-PDSO-G5)

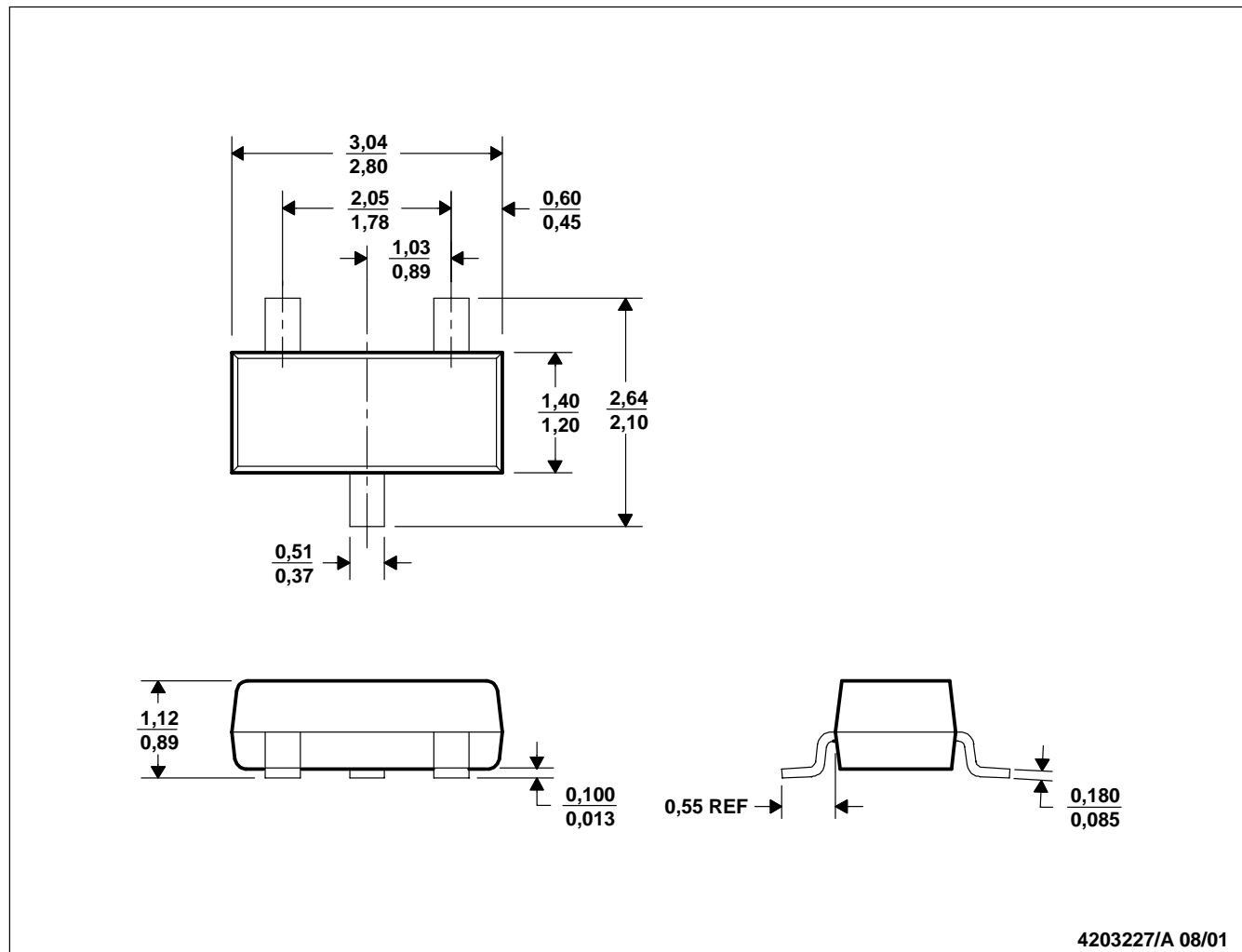
PLASTIC SMALL-OUTLINE PACKAGE



- 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)

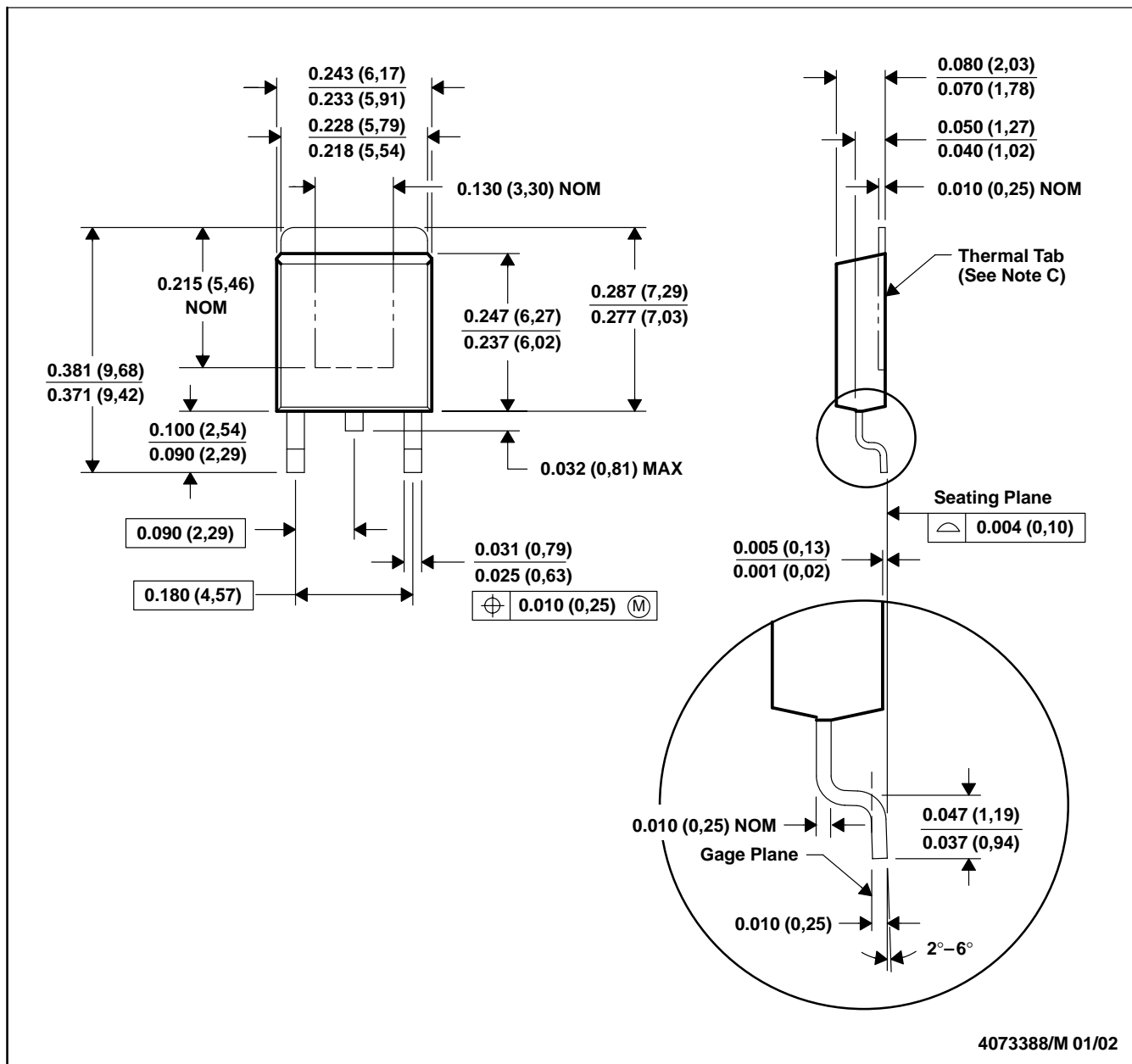
PLASTIC SMALL-OUTLINE



- 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.

KTP (R-PSFM-G2)

PowerFLEX™ PLASTIC FLANGE-MOUNT PACKAGE

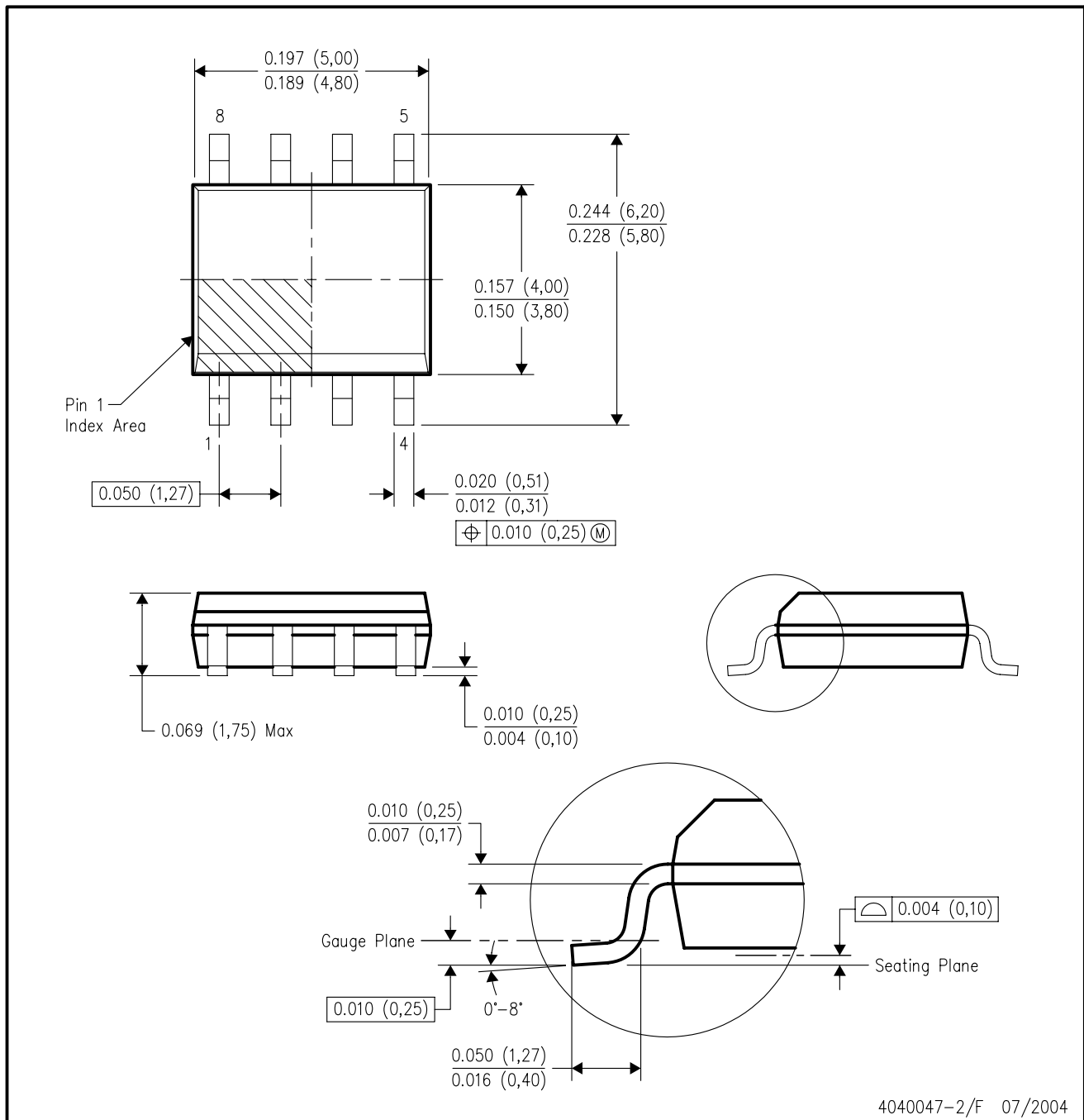


- NOTES: A. All linear dimensions are in inches (millimeters).
 B. This drawing is subject to change without notice.
 C. The center lead is in electrical contact with the thermal tab.
 D. Dimensions do not include mold protrusions, not to exceed 0.006 (0,15).
 E. Falls within JEDEC TO-252 variation AC.

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)

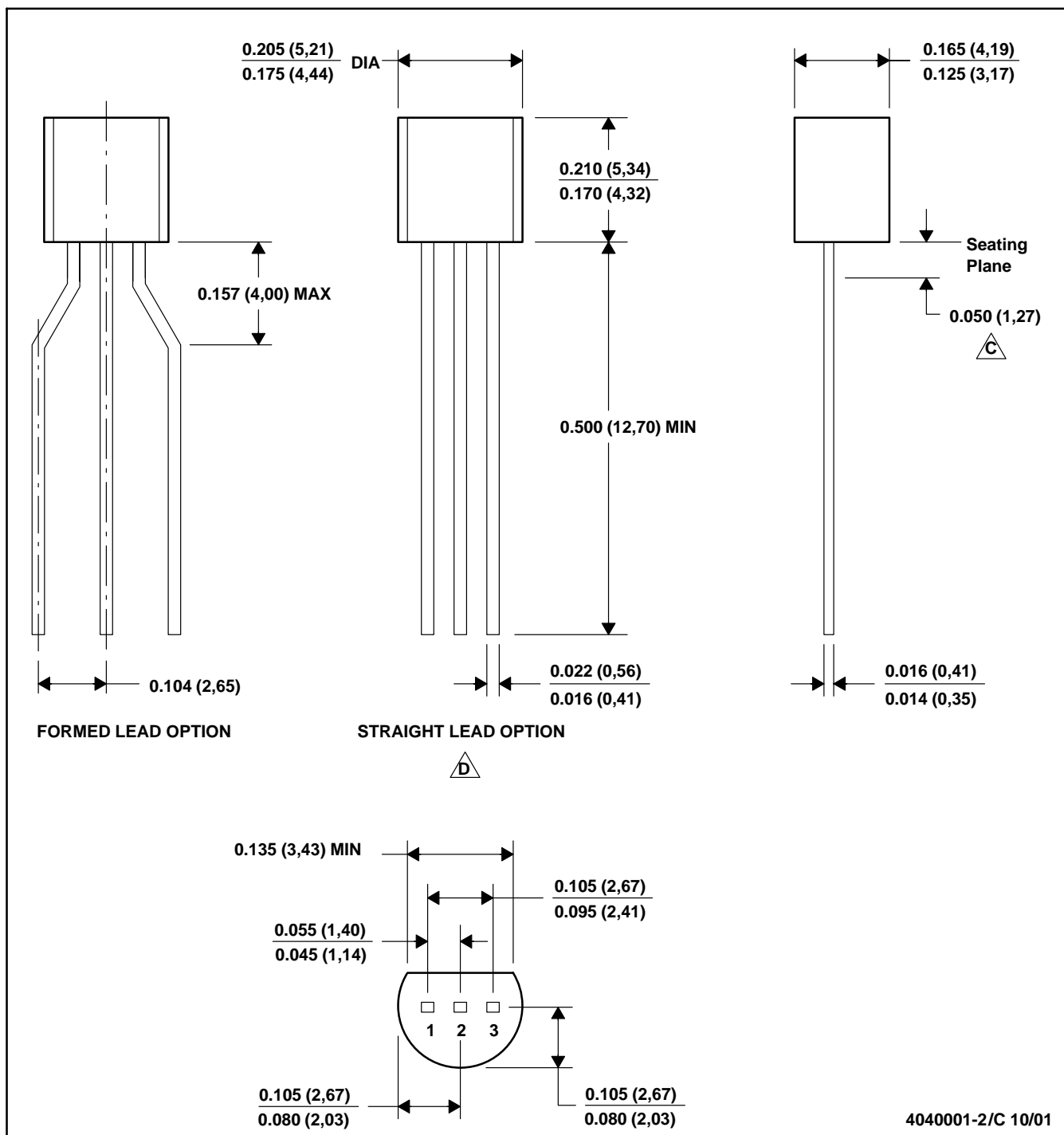
PLASTIC SMALL-OUTLINE PACKAGE



- 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.

LP (O-PBCY-W3)

PLASTIC CYLINDRICAL PACKAGE



4040001-2/C 10/01

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

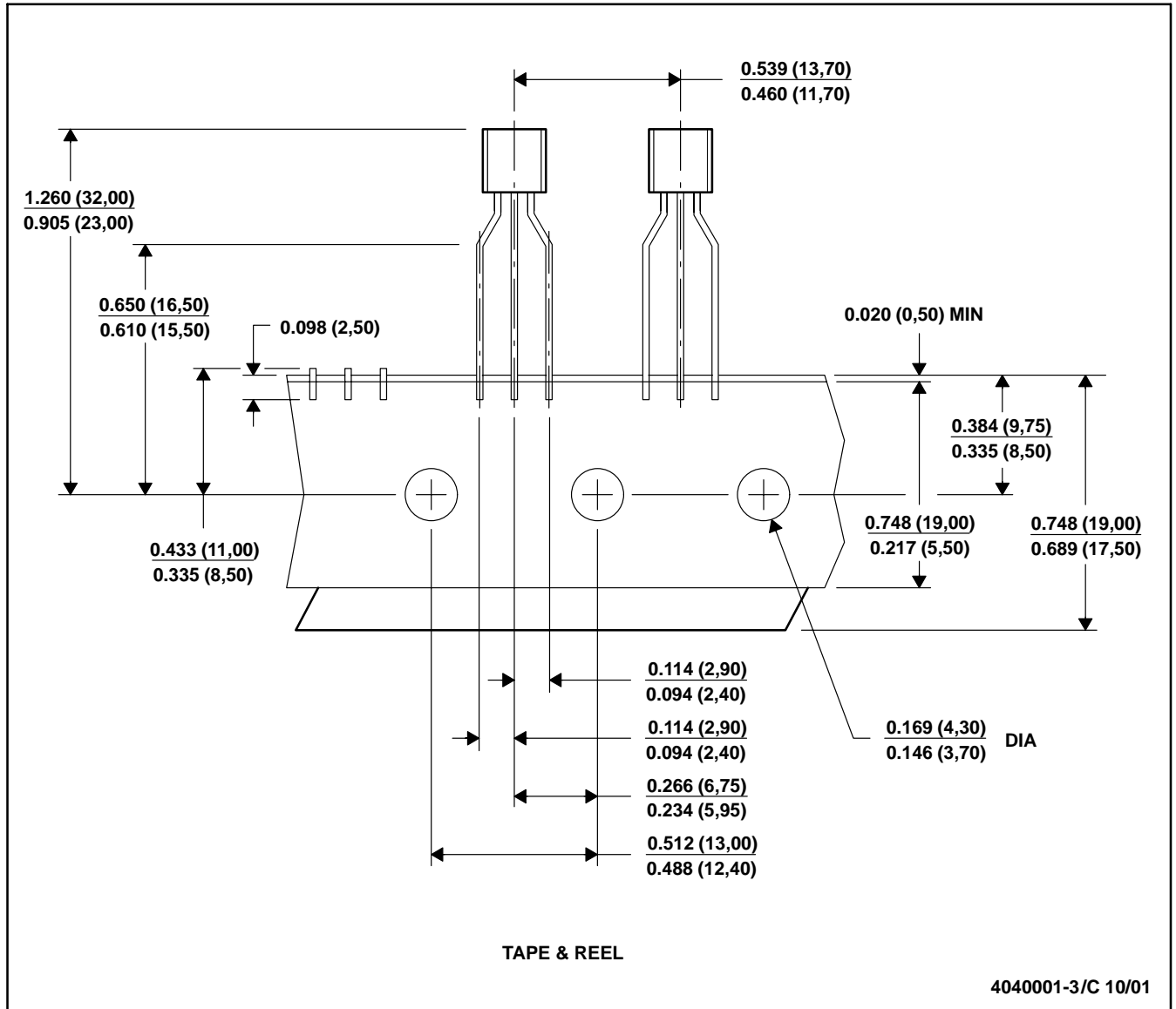


MECHANICAL DATA

MSOT002A – OCTOBER 1994 – REVISED NOVEMBER 2001

LP (O-PBCY-W3)

PLASTIC CYLINDRICAL PACKAGE



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

PW (R-PDSO-G**)

PLASTIC SMALL-OUTLINE PACKAGE

14 PINS SHOWN



4040064/F 01/97

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

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| Logic | logic.ti.com | Military | www.ti.com/military |
| Power Mgmt | power.ti.com | Optical Networking | www.ti.com/opticalnetwork |
| Microcontrollers | microcontroller.ti.com | Security | www.ti.com/security |
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