**TEXAS INSTRUMENTS**

# TL431, TL432 Precision Programmable Reference

## 1 Features

- Reference voltage tolerance at 25°C
  - 0.5% (B grade)
  - 1% (A grade)
  - 2% (Standard grade)
- Adjustable output voltage: $V_{ref}$ to 36 V
- Operation from −40°C to 125°C
- Typical temperature drift (TL43xB)
  - 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

## 2 Applications

- Rack server power
- Industrial AC/DC
- AC inverter & VF drives
- Servo drive control module
- Notebook PC power adapter design
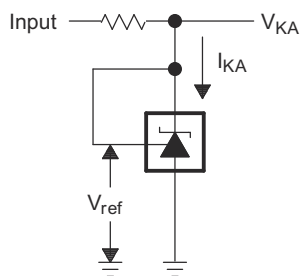


**Simplified Schematic**

## 3 Description

The TL431 and TL432 devices 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. 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 on-board regulation, adjustable power supplies, and switching power supplies. The TL432 device has exactly the same functionality and electrical specifications as the TL431 device, but has different pinouts for the DBV, DBZ, and PK 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 versus 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.

**Device Information**

| PART NUMBER [1] | PACKAGE (PIN) | BODY SIZE (NOM) |
|---|---|---|
| TL43x | SOT-23-3 (3) | 2.90 mm × 1.30 mm |
| | SOT-23-5 (5) | 2.90 mm × 1.60 mm |
| | SOIC (8) | 4.90 mm × 3.90 mm |
| | PDIP (8) | 9.50 mm × 6.35 mm |
| | SOP (8) | 6.20 mm × 5.30 mm |

(1) For all available packages, see the orderable addendum at the end of the data sheet.

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# 4 Revision History

## 5 Device Comparison Table

| DEVICE PINOUT | INITIAL ACCURACY | OPERATING FREE-AIR TEMPERATURE ($T_A$) |
|---|---|---|
| TL431<br>TL432 | B: 0.5%<br>A: 1%<br>(Blank): 2% | C: 0°C to 70°C<br>I: -40°C to 85°C<br>Q: -40°C to 125°C |

Product Folder Links: *TL431 TL432*

# 6 Pin Configuration and Functions

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

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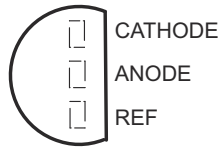
TL431A, TL431B . . . DCK (SC-70) PACKAGE
(TOP VIEW)

CATHODE | 1 | 6 | ANODE
NC | 2 | 5 | NC
REF | 3 | 4 | NC

NC − No internal connection
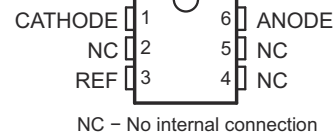
TL431, TL431A, TL431B . . . D (SOIC) PACKAGE
(TOP VIEW)

CATHODE | 1 | 8 | REF
ANODE | 2 | 7 | ANODE
ANODE | 3 | 6 | ANODE
NC | 4 | 5 | NC

NC − No internal connection
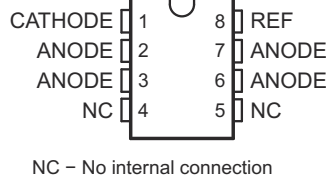
TL431, TL431A, TL431B . . . P (PDIP), PS (SOP),
OR PW (TSSOP) PACKAGE
(TOP VIEW)

CATHODE | 1 | 8 | REF
NC | 2 | 7 | NC
NC | 3 | 6 | ANODE
NC | 4 | 5 | NC

NC − No internal connection
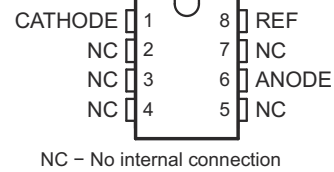
TL431, TL431A, TL431B . . . PK (SOT-89) PACKAGE
(TOP VIEW)

ANODE
CATHODE
ANODE
REF
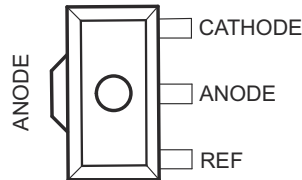
TL432, TL432A, TL432B . . . PK (SOT-89) PACKAGE
(TOP VIEW)

ANODE
REF
ANODE
CATHODE
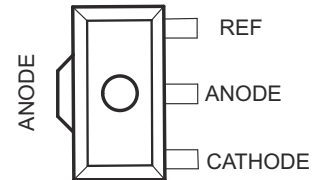
TL431, TL431A, TL431B . . . DBV (SOT-23-5) PACKAGE
(TOP VIEW)

NC | 1 | 5 | ANODE
† | 2 |
CATHODE | 3 | 4 | REF

NC − No internal connection
† Pin 2 is attached to Substrate and must be
   connected to ANODE or left open.
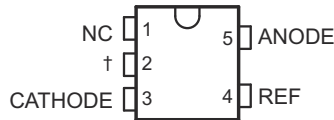
TL432, TL432A, TL432B . . . DBV (SOT-23-5) PACKAGE
(TOP VIEW)

NC | 1 | 5 | REF
ANODE | 2 |
NC | 3 | 4 | CATHODE

NC − No internal connection
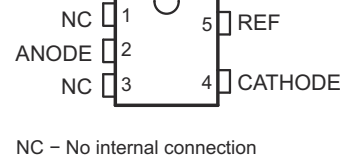
TL431, TL431A, TL431B . . . DBZ (SOT-23-3) PACKAGE
(TOP VIEW)

CATHODE | 1 |
| | 3 | ANODE
REF | 2 |

TL432, TL432A, TL432B . . . DBZ (SOT-23-3) PACKAGE
(TOP VIEW)

REF | 1 |
| | 3 | ANODE
CATHODE | 2 |

**Table 6-1. Pin Functions**

| NAME | PIN | | | | | | | | | | TYPE | DESCRIPTION |
|------|-----|---|---|---|-----|----|-----|------|------|----|------|-------------|
| | TL431x | | | | | | | TL432x | | | | |
| | DBZ | DBV | PK | D | P, PS PW | LP | DCK | DBZ | DBV | PK | | |
| CATHODE | 1 | 3 | 3 | 1 | 1 | 1 | 1 | 2 | 4 | 1 | I/O | Shunt Current/Voltage input |
| REF | 2 | 4 | 1 | 8 | 8 | 3 | 3 | 1 | 5 | 3 | I | Threshold relative to common anode |
| ANODE | 3 | 5 | 2 | 2, 3, 6, 7 | 6 | 2 | 6 | 3 | 2 | 2 | O | Common pin, normally connected to ground |

# 7 Specifications

## 7.1 Absolute Maximum Ratings

over operating free-air temperature range (unless otherwise noted)[1]

|  |  |  | MIN | MAX | UNIT |
|---|---|---|---|---|---|
| $V_{KA}$ | Cathode Voltage[2] |  |  | 37 | V |
| $I_{KA}$ | Continuos Cathode Current Range |  | −100 | 150 | mA |
| $I_{I(ref)}$ | Reference Input Current |  | −0.05 | 10 | mA |
| $T_J$ | Operating Junction Temperature Range |  |  | 150 | °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, which do not imply functional operation of the device at these or any other conditions beyond those indicated under *Recommended Operating Conditions*. 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.

## 7.2 ESD Ratings

|  |  |  | VALUE | UNIT |
|---|---|---|---|---|
| $V_{(ESD)}$ | Electrostatic discharge | Human body model (HBM), per ANSI/ESDA/JEDEC JS-001pins[1] | ±2000 | V |
|  |  | Charged-device model (CDM), per JEDEC specification JESD22-C101 [2] | ±1000 | |

(1)   JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process. Manufacturing with less than 500-V HBM is possible with the necessary precautions.

(2)   JEDEC document JEP157 states that 250-V CDM allows safe manufacturing with a standard ESD control process. Manufacturing with less than 250-V CDM is possible with the necessary precautions.

## 7.3 Thermal Information

| THERMAL METRIC[1] | | TL43xx | | | | | | | | | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  | P | PW | D | PS | DCK | DBV | DBZ | LP | PK | |
|  |  | 8 PINS | | | | 6 PINS | 5 PINS | 3 PINS | | | |
| $R_{\theta JA}$ | Junction-to-ambient thermal resistance | 85 | 149 | 97 | 95 | 259 | 206 | 206 | 140 | 52 | °C/W |
| $R_{\theta JC(top)}$ | Junction-to-case (top) thermal resistance | 57 | 65 | 39 | 46 | 87 | 131 | 76 | 55 | 9 | °C/W |

(1)   For more information about traditional and new thermal metrics, see the *IC Package Thermal Metrics* application report (SPRA953)

## 7.4 Recommended Operating Conditions

See [1]

|  |  |  | MIN | MAX | UNIT |
|---|---|---|---|---|---|
| $V_{KA}$ | Cathode Voltage |  | $V_{ref}$ | 36 | V |
| $I_{KA}$ | Continuous Cathode Current Range |  | 1 | 100 | mA |
| $T_A$ | Operating Free-Air Temperature | TL43xxC | 0 | 70 | °C |
|  |  | TL43xxI | −40 | 85 | |
|  |  | TL43xxQ | −40 | 125 | |

(1)   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.

## 7.5 Electrical Characteristics, TL431C, TL432C

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

| PARAMETER | | TEST CIRCUIT | TEST CONDITIONS | | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|---|
| $V_{ref}$ | Reference Voltage | See Figure 8-1 | $V_{KA} = V_{ref}$, $I_{KA}$ = 10 mA | | 2440 | 2495 | 2550 | mV |
| $V_{I(dev)}$ | Deviation of reference input voltage over full temperature range [1] | See Figure 8-1 | $V_{KA} = V_{ref}$, $I_{KA}$ = 10 mA | SOT23-3 and TL432 devices | | 6 | 16 | mV |
| | | | | All other devices | | 4 | 25 | mV |
| $\Delta V_{ref}$ / $\Delta V_{KA}$ | Ratio of change in reference voltage to the change in cathode voltage | See Figure 8-2 | $I_{KA}$ = 10 mA | $\Delta V_{KA}$ = 10 V - $V_{ref}$ | | −1.4 | −2.7 | mV/V |
| | | | | $\Delta V_{KA}$ = 36 V - 10 V | | −1 | −2 | mV/V |
| $I_{ref}$ | Reference Input Current | See Figure 8-2 | $I_{KA}$ = 10 mA, R1 = 10kΩ, R2 = ∞ | | | 2 | 4 | µA |
| $I_{I(dev)}$ | Deviation of reference input current over full temperature range [1] | See Figure 8-2 | $I_{KA}$ = 10 mA, R1 = 10kΩ, R2 = ∞ | | | 0.4 | 1.2 | µA |
| $I_{min}$ | Minimum cathode current for regulation | See Figure 8-1 | $V_{KA} = V_{ref}$ | | | 0.4 | 1 | mA |
| $I_{off}$ | Off-state cathode current | See Figure 8-3 | $V_{KA}$ = 36 V, $V_{ref}$ = 0 | | | 0.1 | 1 | µA |
| $|Z_{KA}|$ | Dynamic Impedance [2] | See Figure 8-1 | $V_{KA} = V_{ref}$, f ≤ 1 kHz, $I_{KA}$ = 1 mA to 100 mA | | | 0.2 | 0.5 | Ω |

(1) 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. For more details on $V_{I(dev)}$ and how it relates to the average temperature coefficient, see Temperature Coefficient.

(2) The dynamic impedance is defined by $|Z_{KA}| = \Delta V_{KA}/\Delta I_{KA}$. For more details on $|Z_{KA}|$ and how it relates to $V_{KA}$, see Dynamic Impedance.

Product Folder Links: *TL431 TL432*

## 7.6 Electrical Characteristics, TL431I, TL432I

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

| | PARAMETER | TEST CIRCUIT | TEST CONDITIONS | | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|---|
| $V_{ref}$ | Reference Voltage | See Figure 8-1 | $V_{KA} = V_{ref}$, $I_{KA} = 10$ mA | | 2440 | 2495 | 2550 | mV |
| $V_{I(dev)}$ | Deviation of reference input voltage over full temperature range [1] | See Figure 8-1 | $V_{KA} = V_{ref}$, $I_{KA} = 10$ mA | SOT23-3 and TL432 devices | | 14 | 34 | mV |
| | | | | All other devices | | 5 | 50 | mV |
| $\Delta V_{ref}$ / $\Delta V_{KA}$ | Ratio of change in reference voltage to the change in cathode voltage | See Figure 8-2 | $I_{KA} = 10$ mA | $\Delta V_{KA} = 10$ V - $V_{ref}$ | | −1.4 | −2.7 | mV/V |
| | | | | $\Delta V_{KA} = 36$ V - 10 V | | −1 | −2 | mV/V |
| $I_{ref}$ | Reference Input Current | See Figure 8-2 | $I_{KA} = 10$ mA, R1 = 10kΩ, R2 = ∞ | | | 2 | 4 | µA |
| $I_{I(dev)}$ | Deviation of reference input current over full temperature range [1] | See Figure 8-2 | $I_{KA} = 10$ mA, R1 = 10kΩ, R2 = ∞ | | | 0.8 | 2.5 | µA |
| $I_{min}$ | Minimum cathode current for regulation | See Figure 8-1 | $V_{KA} = V_{ref}$ | | | 0.4 | 1 | mA |
| $I_{off}$ | Off-state cathode current | See Figure 8-3 | $V_{KA} = 36$ V, $V_{ref} = 0$ | | | 0.1 | 1 | µA |
| $|Z_{KA}|$ | Dynamic Impedance [2] | See Figure 8-1 | $V_{KA} = V_{ref}$,  f ≤ 1 kHz, $I_{KA} = 1$ mA to 100 mA | | | 0.2 | 0.5 | Ω |

(1)    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. For more details on $V_{I(dev)}$ and how it relates to the average temperature coefficient, see Temperature Coefficient.

(2)    The dynamic impedance is defined by $|Z_{KA}| = \Delta V_{KA}/\Delta I_{KA}$.  For more details on $|Z_{KA}|$ and how it relates to $V_{KA}$, see Dynamic Impedance.

Product Folder Links: TL431 TL432

## 7.7 Electrical Characteristics, TL431Q, TL432Q

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

| PARAMETER | | TEST CIRCUIT | TEST CONDITIONS | | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|---|
| $V_{ref}$ | Reference Voltage | See Figure 8-1 | $V_{KA} = V_{ref}$, $I_{KA}$ = 10 mA | | 2440 | 2495 | 2550 | mV |
| $V_{I(dev)}$ | Deviation of reference input voltage over full temperature range [1] | See Figure 8-1 | $V_{KA} = V_{ref}$, $I_{KA}$ = 10 mA | | | 14 | 34 | mV |
| $\Delta V_{ref}$ / $\Delta V_{KA}$ | Ratio of change in reference voltage to the change in cathode voltage | See Figure 8-2 | $I_{KA}$ = 10 mA | $\Delta V_{KA}$ = 10 V - $V_{ref}$ | | −1.4 | −2.7 | mV/V |
| | | | | $\Delta V_{KA}$ = 36 V - 10 V | | −1 | −2 | mV/V |
| $I_{ref}$ | Reference Input Current | See Figure 8-2 | $I_{KA}$ = 10 mA, R1 = 10kΩ, R2 = ∞ | | | 2 | 4 | µA |
| $I_{I(dev)}$ | Deviation of reference input current over full temperature range [1] | See Figure 8-2 | $I_{KA}$ = 10 mA, R1 = 10kΩ, R2 = ∞ | | | 0.8 | 2.5 | µA |
| $I_{min}$ | Minimum cathode current for regulation | See Figure 8-1 | $V_{KA} = V_{ref}$ | | | 0.4 | 1 | mA |
| $I_{off}$ | Off-state cathode current | See Figure 8-3 | $V_{KA}$ = 36 V, $V_{ref}$ = 0 | | | 0.1 | 1 | µA |
| $|Z_{KA}|$ | Dynamic Impedance [2] | See Figure 8-1 | $V_{KA} = V_{ref}$,  f ≤ 1 kHz, $I_{KA}$ = 1 mA to 100 mA | | | 0.2 | 0.5 | Ω |

(1)     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. For more details on $V_{I(dev)}$ and how it relates to the average temperature coefficient, see Temperature Coefficient.

(2)     The dynamic impedance is defined by $|Z_{KA}| = \Delta V_{KA}/\Delta I_{KA}$.  For more details on $|Z_{KA}|$ and how it relates to $V_{KA}$, see Dynamic Impedance.

Product Folder Links: *TL431 TL432*

## 7.8 Electrical Characteristics, TL431AC, TL432AC

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

| PARAMETER | | TEST CIRCUIT | TEST CONDITIONS | | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|---|
| $V_{ref}$ | Reference Voltage | See Figure 8-1 | $V_{KA} = V_{ref}$, $I_{KA}$ = 10 mA | | 2470 | 2495 | 2520 | mV |
| $V_{I(dev)}$ | Deviation of reference input voltage over full temperature range [1] | See Figure 8-1 | $V_{KA} = V_{ref}$, $I_{KA}$ = 10 mA | SOT23-3 and TL432 devices | | 6 | 16 | mV |
| | | | | All other devices | | 4 | 25 | mV |
| $\Delta V_{ref}$ / $\Delta V_{KA}$ | Ratio of change in reference voltage to the change in cathode voltage | See Figure 8-2 | $I_{KA}$ = 10 mA | $\Delta V_{KA}$ = 10 V - $V_{ref}$ | | −1.4 | −2.7 | mV/V |
| | | | | $\Delta V_{KA}$ = 36 V - 10 V | | −1 | −2 | mV/V |
| $I_{ref}$ | Reference Input Current | See Figure 8-2 | $I_{KA}$ = 10 mA, R1 = 10kΩ, R2 = ∞ | | | 2 | 4 | µA |
| $I_{I(dev)}$ | Deviation of reference input current over full temperature range [1] | See Figure 8-2 | $I_{KA}$ = 10 mA, R1 = 10kΩ, R2 = ∞ | | | 0.8 | 1.2 | µA |
| $I_{min}$ | Minimum cathode current for regulation | See Figure 8-1 | $V_{KA} = V_{ref}$ | | | 0.4 | 0.6 | mA |
| $I_{off}$ | Off-state cathode current | See Figure 8-3 | $V_{KA}$ = 36 V, $V_{ref}$ = 0 | | | 0.1 | 0.5 | µA |
| $\lvert Z_{KA}\rvert$ | Dynamic Impedance [2] | See Figure 8-1 | $V_{KA} = V_{ref}$, f ≤ 1 kHz, $I_{KA}$ = 1 mA to 100 mA | | | 0.2 | 0.5 | Ω |

(1)  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. For more details on $V_{I(dev)}$ and how it relates to the average temperature coefficient, see Temperature Coefficient.

(2)  The dynamic impedance is defined by $\lvert Z_{KA}\rvert = \Delta V_{KA}/\Delta I_{KA}$. For more details on $\lvert Z_{KA}\rvert$ and how it relates to $V_{KA}$, see Dynamic Impedance.

## 7.9 Electrical Characteristics, TL431AI, TL432AI

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

| PARAMETER | | TEST CIRCUIT | TEST CONDITIONS | | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|---|
| $V_{ref}$ | Reference Voltage | See Figure 8-1 | $V_{KA} = V_{ref}$, $I_{KA}$ = 10 mA | | 2470 | 2495 | 2520 | mV |
| $V_{I(dev)}$ | Deviation of reference input voltage over full temperature range [1] | See Figure 8-1 | $V_{KA} = V_{ref}$, $I_{KA}$ = 10 mA | SOT23-3 and TL432 devices | | 14 | 34 | mV |
| | | | | All other devices | | 5 | 50 | mV |
| $\Delta V_{ref} / \Delta V_{KA}$ | Ratio of change in reference voltage to the change in cathode voltage | See Figure 8-2 | $I_{KA}$ = 10 mA | $\Delta V_{KA}$ = 10 V - $V_{ref}$ | | −1.4 | −2.7 | mV/V |
| | | | | $\Delta V_{KA}$ = 36 V - 10 V | | −1 | −2 | mV/V |
| $I_{ref}$ | Reference Input Current | See Figure 8-2 | $I_{KA}$ = 10 mA, R1 = 10kΩ, R2 = ∞ | | | 2 | 4 | μA |
| $I_{I(dev)}$ | Deviation of reference input current over full temperature range [1] | See Figure 8-2 | $I_{KA}$ = 10 mA, R1 = 10kΩ, R2 = ∞ | | | 0.8 | 2.5 | μA |
| $I_{min}$ | Minimum cathode current for regulation | See Figure 8-1 | $V_{KA} = V_{ref}$ | | | 0.4 | 0.7 | mA |
| $I_{off}$ | Off-state cathode current | See Figure 8-3 | $V_{KA}$ = 36 V, $V_{ref}$ = 0 | | | 0.1 | 0.5 | μA |
| $|Z_{KA}|$ | Dynamic Impedance [2] | See Figure 8-1 | $V_{KA} = V_{ref}$, f ≤ 1 kHz, $I_{KA}$ = 1 mA to 100 mA | | | 0.2 | 0.5 | Ω |

(1) 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. For more details on $V_{I(dev)}$ and how it relates to the average temperature coefficient, see Temperature Coefficient.

(2) The dynamic impedance is defined by $|Z_{KA}| = \Delta V_{KA}/\Delta I_{KA}$. For more details on $|Z_{KA}|$ and how it relates to $V_{KA}$, see Dynamic Impedance.

Product Folder Links: *TL431 TL432*

## 7.10 Electrical Characteristics, TL431AQ, TL432AQ

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

| PARAMETER | | TEST CIRCUIT | TEST CONDITIONS | | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|---|
| $V_{ref}$ | Reference Voltage | See Figure 8-1 | $V_{KA}$ = $V_{ref}$, $I_{KA}$ = 10 mA | | 2470 | 2495 | 2520 | mV |
| $V_{I(dev)}$ | Deviation of reference input voltage over full temperature range [1] | See Figure 8-1 | $V_{KA}$ = $V_{ref}$, $I_{KA}$ = 10 mA | | | 14 | 34 | mV |
| $\Delta V_{ref}$ / $\Delta V_{KA}$ | Ratio of change in reference voltage to the change in cathode voltage | See Figure 8-2 | $I_{KA}$ = 10 mA | $\Delta V_{KA}$ = 10 V - $V_{ref}$ | | −1.4 | −2.7 | mV/V |
| | | | | $\Delta V_{KA}$ = 36 V - 10 V | | −1 | −2 | mV/V |
| $I_{ref}$ | Reference Input Current | See Figure 8-2 | $I_{KA}$ = 10 mA, R1 = 10kΩ, R2 = ∞ | | | 2 | 4 | µA |
| $I_{I(dev)}$ | Deviation of reference input current over full temperature range [1] | See Figure 8-2 | $I_{KA}$ = 10 mA, R1 = 10kΩ, R2 = ∞ | | | 0.8 | 2.5 | µA |
| $I_{min}$ | Minimum cathode current for regulation | See Figure 8-1 | $V_{KA}$ = $V_{ref}$ | | | 0.4 | 0.7 | mA |
| $I_{off}$ | Off-state cathode current | See Figure 8-3 | $V_{KA}$ = 36 V, $V_{ref}$ = 0 | | | 0.1 | 0.5 | µA |
| $|Z_{KA}|$ | Dynamic Impedance [2] | See Figure 8-1 | $V_{KA}$ = $V_{ref}$, f ≤ 1 kHz, $I_{KA}$ = 1 mA to 100 mA | | | 0.2 | 0.5 | Ω |

(1) 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. For more details on $V_{I(dev)}$ and how it relates to the average temperature coefficient, see Temperature Coefficient.

(2) The dynamic impedance is defined by $|Z_{KA}|$ = $\Delta V_{KA}/\Delta I_{KA}$. For more details on $|Z_{KA}|$ and how it relates to $V_{KA}$, see Dynamic Impedance.

## 7.11 Electrical Characteristics, TL431BC, TL432BC

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

| | PARAMETER | TEST CIRCUIT | TEST CONDITIONS | | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|---|
| $V_{ref}$ | Reference Voltage | See Figure 8-1 | $V_{KA}$ = $V_{ref}$, $I_{KA}$ = 10 mA | | 2483 | 2495 | 2507 | mV |
| $V_{I(dev)}$ | Deviation of reference input voltage over full temperature range [1] | See Figure 8-1 | $V_{KA}$ = $V_{ref}$, $I_{KA}$ = 10 mA | | | 6 | 16 | mV |
| $\Delta V_{ref}$ / $\Delta V_{KA}$ | Ratio of change in reference voltage to the change in cathode voltage | See Figure 8-2 | $I_{KA}$ = 10 mA | $\Delta V_{KA}$ = 10 V - $V_{ref}$ | | −1.4 | −2.7 | mV/V |
| | | | | $\Delta V_{KA}$ = 36 V - 10 V | | −1 | −2 | mV/V |
| $I_{ref}$ | Reference Input Current | See Figure 8-2 | $I_{KA}$ = 10 mA, R1 = 10kΩ, R2 = ∞ | | | 2 | 4 | µA |
| $I_{I(dev)}$ | Deviation of reference input current over full temperature range [1] | See Figure 8-2 | $I_{KA}$ = 10 mA, R1 = 10kΩ, R2 = ∞ | | | 0.8 | 1.2 | µA |
| $I_{min}$ | Minimum cathode current for regulation | See Figure 8-1 | $V_{KA}$ = $V_{ref}$ | | | 0.4 | 0.6 | mA |
| $I_{off}$ | Off-state cathode current | See Figure 8-3 | $V_{KA}$ = 36 V, $V_{ref}$ = 0 | | | 0.1 | 0.5 | µA |
| $|Z_{KA}|$ | Dynamic Impedance [2] | See Figure 8-1 | $V_{KA}$ = $V_{ref}$,  f ≤ 1 kHz, $I_{KA}$ = 1 mA to 100 mA | | | 0.2 | 0.5 | Ω |

(1) 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. For more details on $V_{I(dev)}$ and how it relates to the average temperature coefficient, see Temperature Coefficient.

(2) The dynamic impedance is defined by $|Z_{KA}| = \Delta V_{KA}/\Delta I_{KA}$.  For more details on $|Z_{KA}|$ and how it relates to $V_{KA}$, see Dynamic Impedance.

## 7.12 Electrical Characteristics, TL431BI, TL432BI

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

| PARAMETER | | TEST CIRCUIT | TEST CONDITIONS | | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|---|
| $V_{ref}$ | Reference Voltage | See Figure 8-1 | $V_{KA} = V_{ref}$, $I_{KA}$ = 10 mA | | 2483 | 2495 | 2507 | mV |
| $V_{I(dev)}$ | Deviation of reference input voltage over full temperature range [1] | See Figure 8-1 | $V_{KA} = V_{ref}$, $I_{KA}$ = 10 mA | | | 14 | 34 | mV |
| $\Delta V_{ref} / \Delta V_{KA}$ | Ratio of change in reference voltage to the change in cathode voltage | See Figure 8-2 | $I_{KA}$ = 10 mA | $\Delta V_{KA}$ = 10 V - $V_{ref}$ | | −1.4 | −2.7 | mV/V |
| | | | | $\Delta V_{KA}$ = 36 V - 10 V | | −1 | −2 | mV/V |
| $I_{ref}$ | Reference Input Current | See Figure 8-2 | $I_{KA}$ = 10 mA, R1 = 10kΩ, R2 = ∞ | | | 2 | 4 | µA |
| $I_{I(dev)}$ | Deviation of reference input current over full temperature range [1] | See Figure 8-2 | $I_{KA}$ = 10 mA, R1 = 10kΩ, R2 = ∞ | | | 0.8 | 2.5 | µA |
| $I_{min}$ | Minimum cathode current for regulation | See Figure 8-1 | $V_{KA} = V_{ref}$ | | | 0.4 | 0.7 | mA |
| $I_{off}$ | Off-state cathode current | See Figure 8-3 | $V_{KA}$ = 36 V, $V_{ref}$ = 0 | | | 0.1 | 0.5 | µA |
| $|Z_{KA}|$ | Dynamic Impedance [2] | See Figure 8-1 | $V_{KA} = V_{ref}$, f ≤ 1 kHz, $I_{KA}$ = 1 mA to 100 mA | | | 0.2 | 0.5 | Ω |

(1) 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. For more details on $V_{I(dev)}$ and how it relates to the average temperature coefficient, see Temperature Coefficient.

(2) The dynamic impedance is defined by $|Z_{KA}| = \Delta V_{KA}/\Delta I_{KA}$. For more details on $|Z_{KA}|$ and how it relates to $V_{KA}$, see Dynamic Impedance.

## 7.13 Electrical Characteristics, TL431BQ, TL432BQ

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

| PARAMETER | | TEST CIRCUIT | TEST CONDITIONS | | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|---|
| $V_{ref}$ | Reference Voltage | See Figure 8-1 | $V_{KA} = V_{ref}$, $I_{KA}$ = 10 mA | | 2483 | 2495 | 2507 | mV |
| $V_{I(dev)}$ | Deviation of reference input voltage over full temperature range [1] | See Figure 8-1 | $V_{KA} = V_{ref}$, $I_{KA}$ = 10 mA | | | 14 | 34 | mV |
| $\Delta V_{ref}$ / $\Delta V_{KA}$ | Ratio of change in reference voltage to the change in cathode voltage | See Figure 8-2 | $I_{KA}$ = 10 mA | $\Delta V_{KA}$ = 10 V - $V_{ref}$ | | −1.4 | −2.7 | mV/V |
| | | | | $\Delta V_{KA}$ = 36 V - 10 V | | −1 | −2 | mV/V |
| $I_{ref}$ | Reference Input Current | See Figure 8-2 | $I_{KA}$ = 10 mA, R1 = 10kΩ, R2 = ∞ | | | 2 | 4 | µA |
| $I_{I(dev)}$ | Deviation of reference input current over full temperature range [1] | See Figure 8-2 | $I_{KA}$ = 10 mA, R1 = 10kΩ, R2 = ∞ | | | 0.8 | 2.5 | µA |
| $I_{min}$ | Minimum cathode current for regulation | See Figure 8-1 | $V_{KA} = V_{ref}$ | | | 0.4 | 0.7 | mA |
| $I_{off}$ | Off-state cathode current | See Figure 8-3 | $V_{KA}$ = 36 V, $V_{ref}$ = 0 | | | 0.1 | 0.5 | µA |
| $|Z_{KA}|$ | Dynamic Impedance [2] | See Figure 8-1 | $V_{KA} = V_{ref}$, f ≤ 1 kHz, $I_{KA}$ = 1 mA to 100 mA | | | 0.2 | 0.5 | Ω |

(1) 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. For more details on $V_{I(dev)}$ and how it relates to the average temperature coefficient, see Temperature Coefficient.

(2) The dynamic impedance is defined by $|Z_{KA}| = \Delta V_{KA}/\Delta I_{KA}$. For more details on $|Z_{KA}|$ and how it relates to $V_{KA}$, see Dynamic Impedance.

Product Folder Links: *TL431 TL432*

## 7.14 Typical Characteristics

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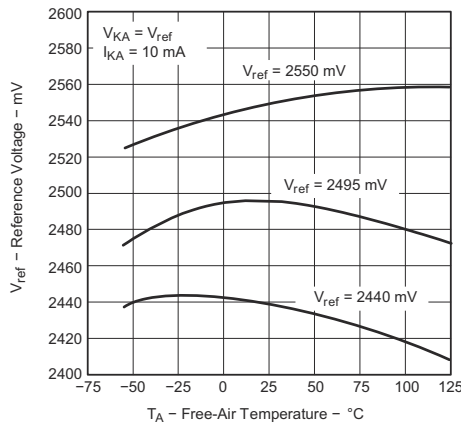


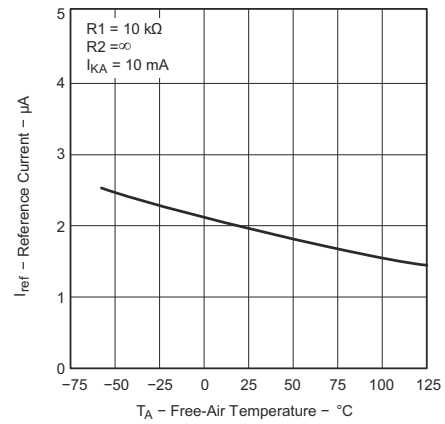**Figure 7-1. Reference Voltage vs Free-Air Temperature**



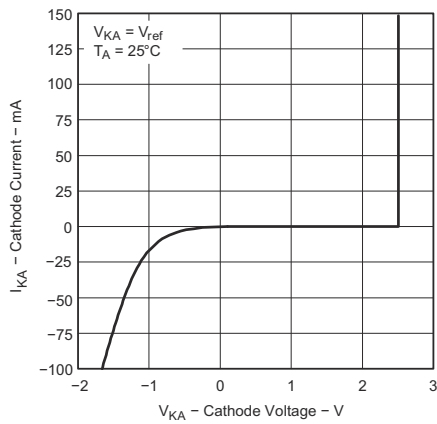**Figure 7-2. Reference Current vs Free-Air Temperature**



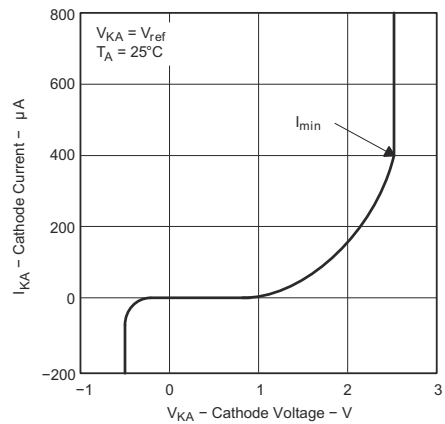**Figure 7-3. Cathode Current vs Cathode Voltage**
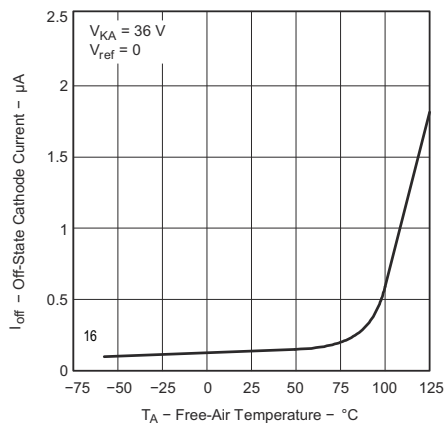


**Figure 7-4. Cathode Current vs Cathode Voltage**
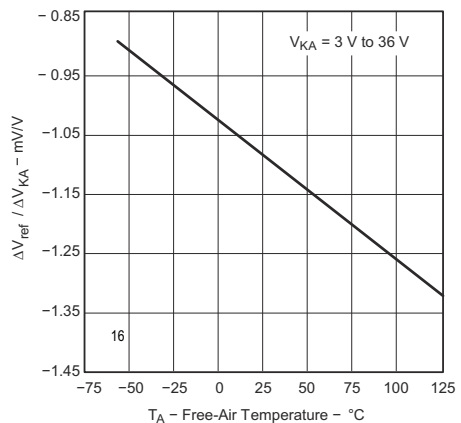


**Figure 7-5. Off-State Cathode Current vs Free-Air Temperature**



**Figure 7-6. Ratio of Delta Reference Voltage to Delta Cathode Voltage vs Free-Air Temperature**

Product Folder Links: *TL431 TL432*
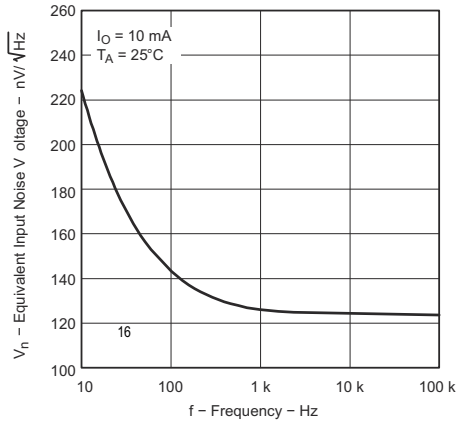
**Figure 7-7. Equivalent Input Noise Voltage vs Frequency**
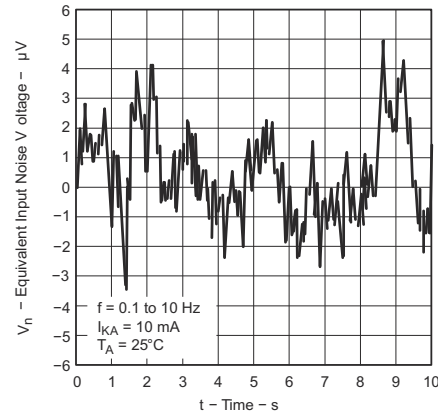


**Figure 7-8. Equivalent Input Noise Voltage Over a 10-S Period**
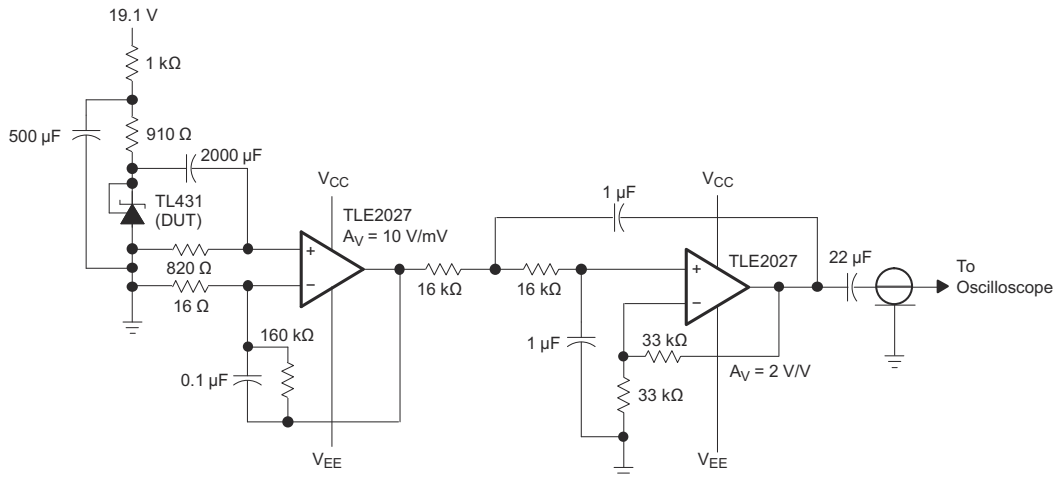


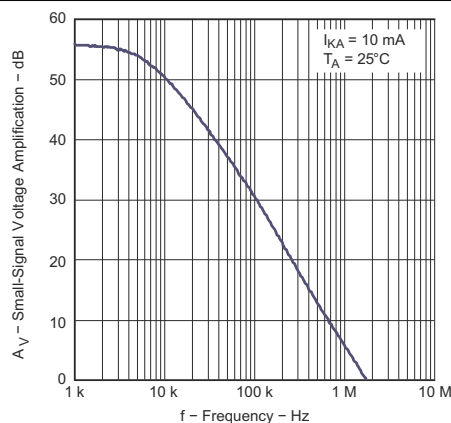**Figure 7-9. Test Circuit for Equivalent Input Noise Voltage Over a 10-S Period**



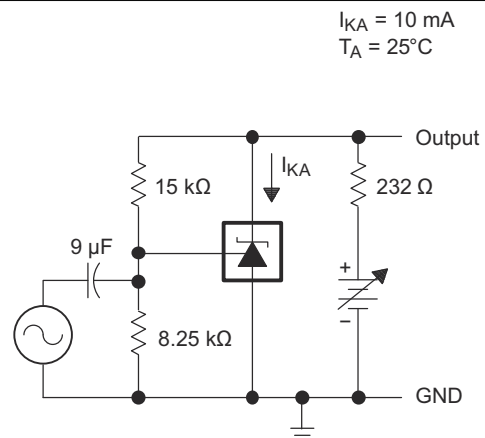**Figure 7-10. Small-Signal Voltage Amplification vs Frequency**
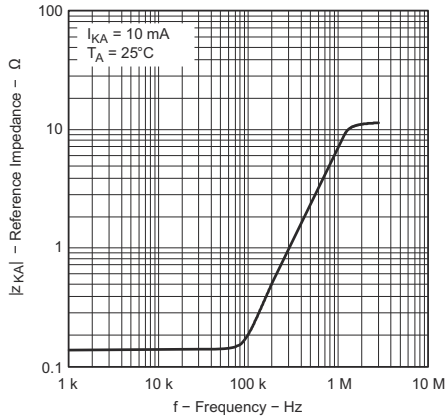


**Figure 7-11. Test Circuit for Voltage Amplification**

Product Folder Links: *TL431 TL432*

**Figure 7-12. Reference Impedance vs Frequency**
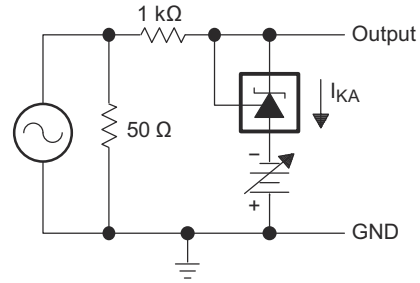


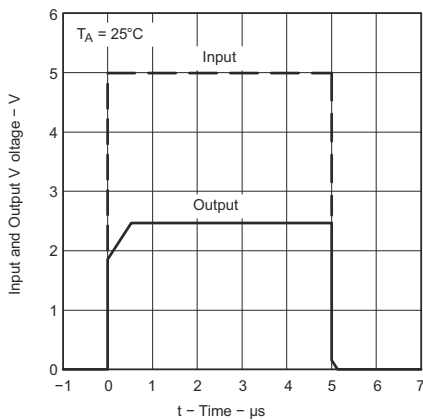**Figure 7-13. Test Circuit for Reference Impedance**
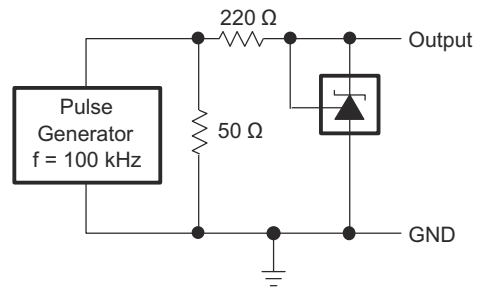


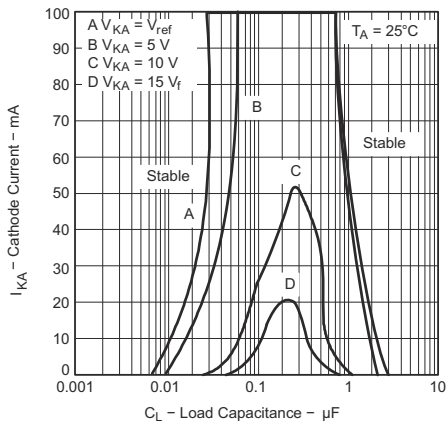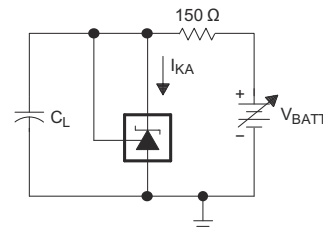**Figure 7-14. Pulse Response**
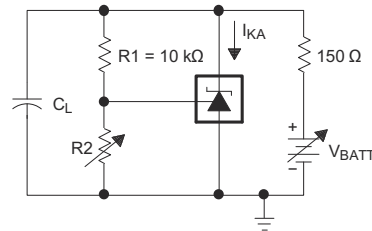


**Figure 7-15. Test Circuit for Pulse Response**



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. VBATT and $C_L$ then are adjusted to determine the ranges of stability.

**Figure 7-16. Stability Boundary Conditions for All TL431 and TL431A Devices (Except for SOT23-3, SC-70, and Q-Temp Devices)**
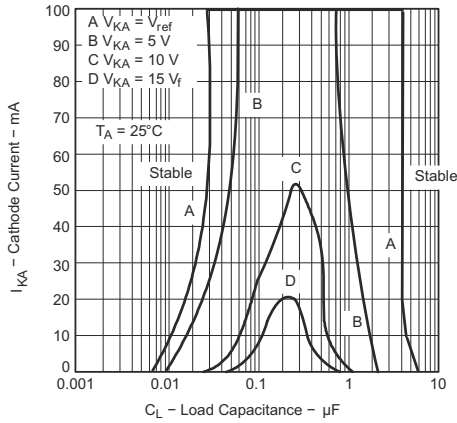


TEST CIRCUIT FOR CURVE A

TEST CIRCUIT FOR CURVES B, C, AND D

**Figure 7-17. Test Circuits for Stability Boundary Conditions**

Product Folder Links: *TL431 TL432*

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. VBATT and $C_L$ then are adjusted to determine the ranges of stability.

**Figure 7-18. Stability Boundary Conditions for All TL431B, TL432, SOT-23, SC-70, and Q-Temp Devices**



TEST CIRCUIT FOR CURVE A
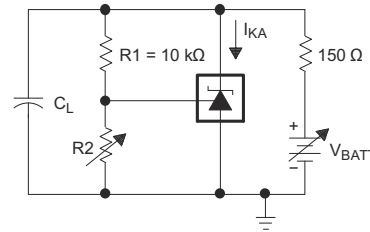
TEST CIRCUIT FOR CURVES B, C, AND D

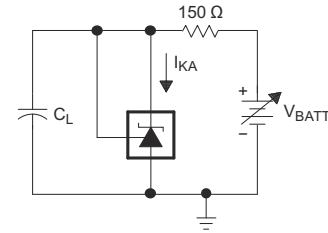**Figure 7-19. Test Circuit for Stability Boundary Conditions**

Product Folder Links: *TL431 TL432*
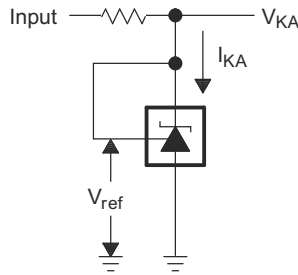
# 8 Parameter Measurement Information



**Figure 8-1. Test Circuit for $V_{KA} = V_{ref}$**



$$V_{KA} = V_{ref}\left(1 + \frac{R1}{R2}\right) + I_{ref} \times R1$$
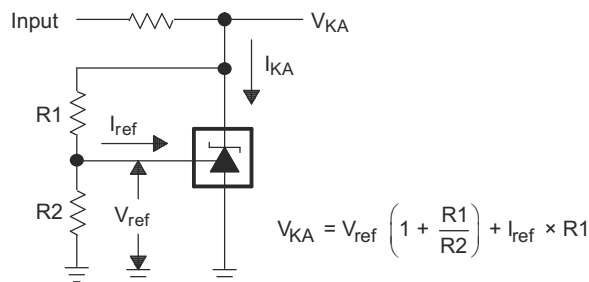
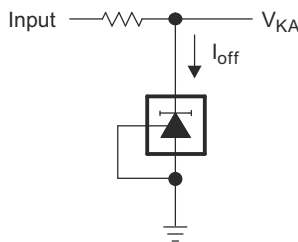**Figure 8-2. Test Circuit for $V_{KA} > V_{ref}$**



**Figure 8-3. Test Circuit for $I_{off}$**

## 8.1 Temperature Coefficient

The deviation of the reference voltage, $V_{ref}$, over the full temperature range is known as $V_{I(dev)}$. The parameter of $V_{I(dev)}$ can be used to find the temperature coefficient of the device. The average full-range temperature coefficient of the reference input voltage, $\alpha_{Vref}$, is defined as:

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

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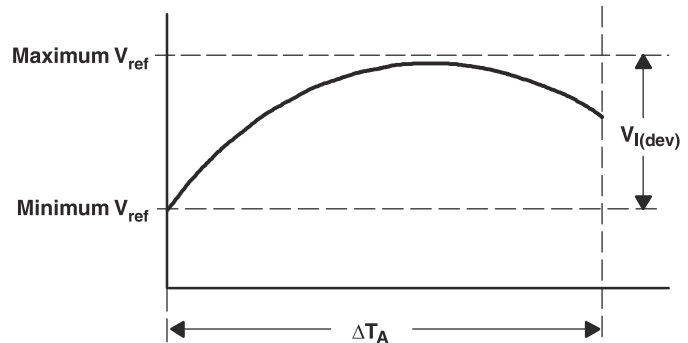


$\alpha_{Vref}$ is positive or negative, depending on whether minimum $V_{ref}$ or maximum $V_{ref}$, respectively, occurs at the lower temperature. The full-range temperature coefficient is an average and therefore any subsection of the rated operating temperature range can yield a value that is greater or less than the average. For more details on temperature coefficient, refer to the *Voltage Reference Selection Basics White Paper*.

## 8.2 Dynamic Impedance

The dynamic impedance is defined as $|Z_{KA}| = \dfrac{\Delta V_{KA}}{\Delta I_{KA}}$ . When the device is operating with two external resistors (see Figure 7-13), the total dynamic impedance of the circuit is given by $|z'| = \dfrac{\Delta V}{\Delta I}$ , which is approximately equal to $|Z_{KA}|\left(1 + \dfrac{R1}{R2}\right)$ .

The $V_{KA}$ of the device can be affected by the dynamic impedance. The device test current $I_{test}$ for $V_{KA}$ is specified in the *Electrical Characteristics*. Any deviation from $I_{test}$ can cause deviation on the output $V_{KA}$. Figure 8-4 shows the effect of the dynamic impedance on the $V_{KA}$.
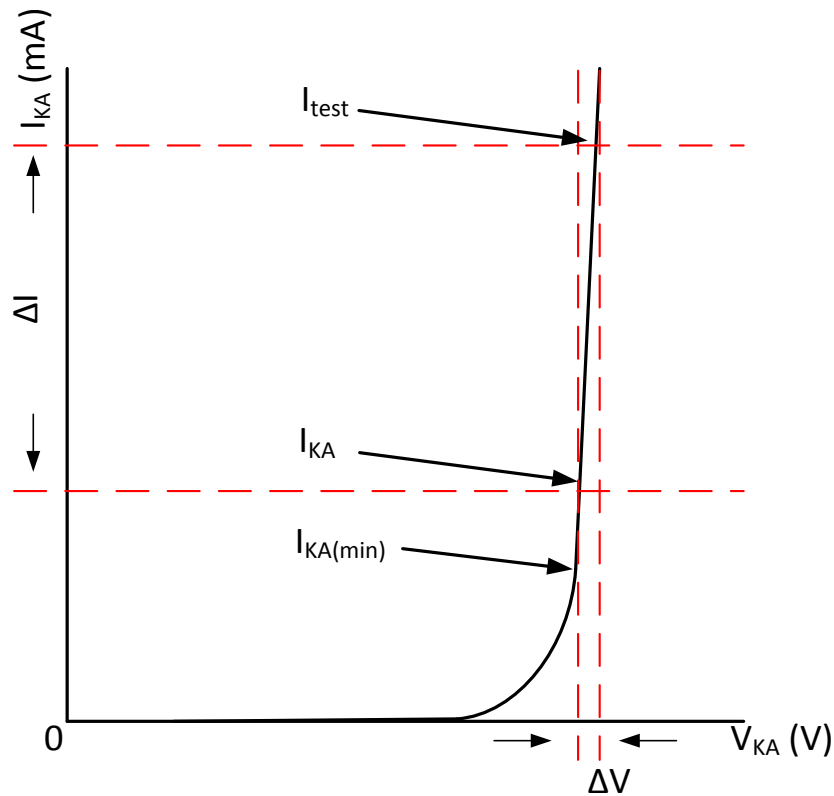


**Figure 8-4. Dynamic Impedance**

# 9 Detailed Description

## 9.1 Overview

This standard device has proven ubiquity and versatility across a wide range of applications, ranging from power to signal path. This is due to its key components containing an accurate voltage reference & opamp, which are very fundamental analog building blocks. TL43xx is used in conjunction with its key components to behave as a single voltage reference, error amplifier, voltage clamp or comparator with integrated reference.

TL43xx can be operated and adjusted to cathode voltages from 2.5V to 36V, making this part optimum for a wide range of end equipments in industrial, auto, telecom & computing. In order for this device to behave as a shunt regulator or error amplifier, >1mA ($I_{min}$(max)) must be supplied in to the cathode pin. Under this condition, feedback can be applied from the Cathode and Ref pins to create a replica of the internal reference voltage.

Various reference voltage options can be purchased with initial tolerances (at 25°C) of 0.5%, 1%, and 2%. These reference options are denoted by B (0.5%), A (1.0%) and blank (2.0%) after the TL431 or TL432. TL431 & TL432 are both functionaly, but have separate pinout options.

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.
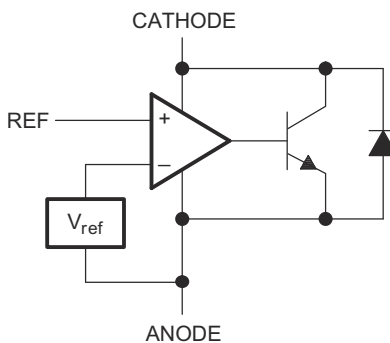
## 9.2 Functional Block Diagram



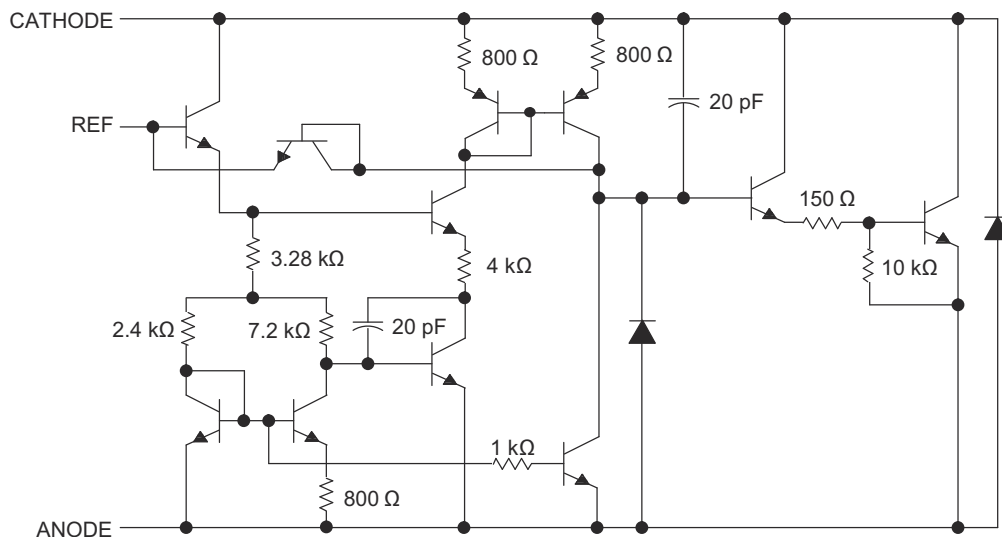**Figure 9-1. Equivalent Schematic**



**Figure 9-2. Detailed Schematic**

## 9.3 Feature Description

TL43xx consists of an internal reference and amplifier that outputs a sink current base on the difference between the reference pin and the virtual internal pin. The sink current is produced by the internal Darlington pair, shown in the above schematic (Figure 9-2). A Darlington pair is used in order for this device to be able to sink a maximum current of 100 mA.

When operated with enough voltage headroom (≥ 2.5 V) and cathode current ($I_{KA}$), TL431 forces the reference pin to 2.5 V. However, the reference pin can not be left floating, as it needs $I_{REF}$ ≥ 4 µA (please see *Electrical Characteristics, TL431C, TL432C*). This is because the reference pin is driven into an npn, which needs base current in order operate properly.

When feedback is applied from the Cathode and Reference pins, TL43xx behaves as a Zener diode, regulating to a constant voltage dependent on current being supplied into the cathode. This is due to the internal amplifier and reference entering the proper operating regions. The same amount of current needed in the above feedback situation must be applied to this device in open loop, servo or error amplifying implementations in order for it to be in the proper linear region giving TL43xx enough gain.

Unlike many linear regulators, TL43xx is internally compensated to be stable without an output capacitor between the cathode and anode. However, if it is desired to use an output capacitor Figure 7-18 can be used as a guide to assist in choosing the correct capacitor to maintain stability.

## 9.4 Device Functional Modes

### 9.4.1 Open Loop (Comparator)

When the cathode/output voltage or current of TL43xx is not being fed back to the reference/input pin in any form, this device is operating in open loop. With proper cathode current (Ika) applied to this device, TL43xx will have the characteristics shown in Figure 10-2. With such high gain in this configuration, TL43xx is typically used as a comparator. With the reference integrated makes TL43xx the prefered choice when users are trying to monitor a certain level of a single signal.

### 9.4.2 Closed Loop

When the cathode/output voltage or current of TL43xx is being fed back to the reference/input pin in any form, this device is operating in closed loop. The majority of applications involving TL43xx use it in this manner to regulate a fixed voltage or current. The feedback enables this device to behave as an error amplifier, computing a portion of the output voltage and adjusting it to maintain the desired regulation. This is done by relating the output voltage back to the reference pin in a manner to make it equal to the internal reference voltage, which can be accomplished via resistive or direct feedback.

# 10 Applications and Implementation

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**Note**

Information in the following applications sections is not part of the TI component specification, and TI does not warrant its accuracy or completeness. TI's customers are responsible for determining suitability of components for their purposes. Customers should validate and test their design implementation to confirm system functionality.

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## 10.1 Application Information

As this device has many applications and setups, there are many situations that this datasheet can not characterize in detail. The linked application notes will help the designer make the best choices when using this part.

Application note *Understanding Stability Boundary Conditions Charts in TL431, TL432 Data Sheet* (SLVA482) will provide a deeper understanding of this devices stability characteristics and aid the user in making the right choices when choosing a load capacitor. Application note *Setting the Shunt Voltage on an Adjustable Shunt Regulator* (SLVA445) assists designers in setting the shunt voltage to achieve optimum accuracy for this device.

## 10.2 Typical Applications

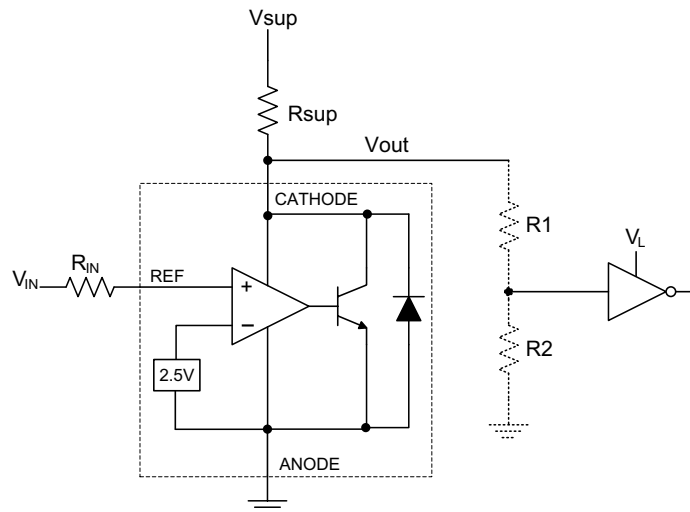### 10.2.1 Comparator With Integrated Reference



**Figure 10-1. Comparator Application Schematic**

### 10.2.1.1 Design Requirements

For this design example, use the parameters listed in *Table 10-1* as the input parameters.

**Table 10-1. Design Parameters**

| DESIGN PARAMETER | EXAMPLE VALUE |
|---|---|
| Input Voltage Range | 0 V to 5 V |
| Input Resistance | 10 kΩ |
| Supply Voltage | 24 V |
| Cathode Current (Ik) | 5 mA |
| Output Voltage Level | ~2 V – $V_{SUP}$ |
| Logic Input Thresholds VIH/VIL | $V_L$ |

### 10.2.1.2 Detailed Design Procedure

When using TL431 as a comparator with reference, determine the following:

- Input Voltage Range
- Reference Voltage Accuracy
- Output logic input high and low level thresholds
- Current Source resistance

**10.2.1.2.1 Basic Operation**

In the configuration shown in Figure 10-1 TL431 will behave as a comparator, comparing the $V_{REF}$ pin voltage to the internal virtual reference voltage. When provided a proper cathode current ($I_K$), TL43xx will have enough open loop gain to provide a quick response. This can be seen in Figure 10-2, where the $R_{SUP}$=10 kΩ ($I_{KA}$=500 µA) situation responds much slower than $R_{SUP}$=1 kΩ ($I_{KA}$=5 mA). Operation near and below $I_{min}$ could result in low gain, leading to a slow response.

**10.2.1.2.1.1 Overdrive**

Slow or inaccurate responses can also occur when the reference pin is not provided enough overdrive voltage. This is the amount of voltage that is higher than the internal virtual reference. The internal virtual reference voltage will be within the range of 2.5 V ±(0.5%, 1.0% or 1.5%) depending on which version is being used. The more overdrive voltage provided, the faster the TL431 will respond.

For applications where TL431 is being used as a comparator, it is best to set the trip point to greater than the positive expected error (i.e. +1.0% for the A version). For fast response, setting the trip point to >10% of the internal $V_{REF}$ should suffice.

For minimal voltage drop or difference from Vin to the ref pin, it is recommended to use an input resistor <10kΩ to provide Iref.

**10.2.1.2.2 Output Voltage and Logic Input Level**

In order for TL431 to properly be used as a comparator, the logic output must be readable by the receiving logic device. This is accomplished by knowing the input high and low level threshold voltage levels, typically denoted by $V_{IH}$ & $V_{IL}$.

As seen in Figure 10-2, TL431's output low level voltage in open-loop/comparator mode is ~2 V, which is typically sufficient for 5V supplied logic. However, would not work for 3.3 V & 1.8 V supplied logic. In order to accomodate this a resistive divider can be tied to the output to attenuate the output voltage to a voltage legible to the receiving low voltage logic device.

TL431's output high voltage is equal to $V_{SUP}$ due to TL431 being open-collector. If $V_{SUP}$ is much higher than the receiving logic's maximum input voltage tolerance, the output must be attenuated to accomadate the outgoing logic's reliability.

When using a resistive divider on the output, be sure to make the sum of the resistive divider (R1 & R2 in Figure 10-1) is much greater than $R_{SUP}$ in order to not interfere with TL431's ability to pull close to $V_{SUP}$ when turning off.

**10.2.1.2.2.1 Input Resistance**

TL431 requires an input resistance in this application in order to source the reference current ($I_{REF}$) needed from this device to be in the proper operating regions while turing on. The actual voltage seen at the ref pin will be $V_{REF}=V_{IN}-I_{REF}*R_{IN}$. Since $I_{REF}$ can be as high as 4 μA it is recommended to use a resistance small enough that will mitigate the error that $I_{REF}$ creates from $V_{IN}$.
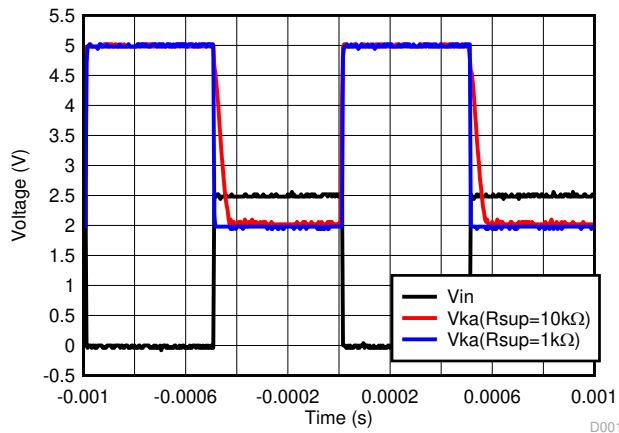
**10.2.1.3 Application Curve**



**Figure 10-2. Output Response With Various Cathode Currents**
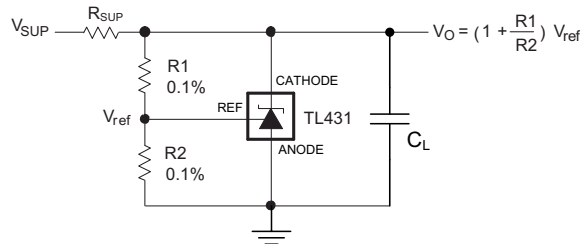
## 10.2.2 Shunt Regulator/Reference



**Figure 10-3. Shunt Regulator Schematic**

### 10.2.2.1 Design Requirements

For this design example, use the parameters listed in Table 10-1 as the input parameters.

**Table 10-2. Design Parameters**

| DESIGN PARAMETER | EXAMPLE VALUE |
|---|---|
| Reference Initial Accuracy | 1.0 % |
| Supply Voltage | 24 V |
| Cathode Current (Ik) | 5 mA |
| Output Voltage Level | 2.5 V - 36 V |
| Load Capacitance | 10 µF |
| Feedback Resistor Values and Accuracy (R1 & R2) | 10 kΩ |

### 10.2.2.2 Detailed Design Procedure

When using TL431 as a Shunt Regulator, determine the following:

- Input Voltage Range
- Temperature Range
- Total Accuracy
- Cathode Current
- Reference Initial Accuracy
- Output Capacitance

#### 10.2.2.2.1 Programming Output/Cathode Voltage

In order to program the cathode voltage to a regulated voltage a resistive bridge must be shunted between the cathode and anode pins with the mid point tied to the reference pin. This can be seen in Figure 10-3, with R1 & R2 being the resistive bridge. The cathode/output voltage in the shunt regulator configuration can be approximated by the equation shown in Figure 10-3. The cathode voltage can be more accuratel determined by taking in to account the cathode current:

$$V_o = (1 + R1/R2) * V_{REF} - I_{REF} * R1$$

In order for this equation to be valid, TL43xx must be fully biased so that it has enough open loop gain to mitigate any gain error. This can be done by meeting the Imin spec denoted in *Electrical Characteristics, TL431C, TL432C*.

Product Folder Links: *TL431 TL432*

#### 10.2.2.2.2 Total Accuracy

When programming the output above unity gain ($V_{KA}$=$V_{REF}$), TL43xx is susceptible to other errors that may effect the overall accuracy beyond $V_{REF}$. These errors include:

- R1 and R2 accuracies
- $V_{I(dev)}$ - Change in reference voltage over temperature
- $\Delta V_{REF}$ / $\Delta V_{KA}$ - Change in reference voltage to the change in cathode voltage
- $|z_{KA}|$ - Dynamic impedance, causing a change in cathode voltage with cathode current

Worst case cathode voltage can be determined taking all of the variables in to account. Application note *Setting the Shunt Voltage on an Adjustable Shunt Regulator* (SLVA445) assists designers in setting the shunt voltage to achieve optimum accuracy for this device.

#### 10.2.2.2.3 Stability

Though TL43xx is stable with no capacitive load, the device that receives the shunt regulator's output voltage could present a capacitive load that is within the TL43xx region of stability, shown in Figure 7-16 and Figure 7-18. Also, designers may use capacitive loads to improve the transient response or for power supply decoupling. When using additional capacitance between Cathode and Anode, refer to Figure 7-16 and Figure 7-18. Also, application note *Understanding Stability Boundary Conditions Charts in TL431, TL432 Data Sheet* (SLVA482) will provide a deeper understanding of this devices stability characteristics and aid the user in making the right choices when choosing a load capacitor.

#### 10.2.2.2.4 Start-Up Time

As shown in Figure 10-4, TL43xx has a fast response up to ~2 V and then slowly charges to its programmed value. This is due to the compensation capacitance (shown in Figure 7-18) the TL43xx has to meet its stability criteria. Despite the secondary delay, TL43xx still has a fast response suitable for many clamp applications.
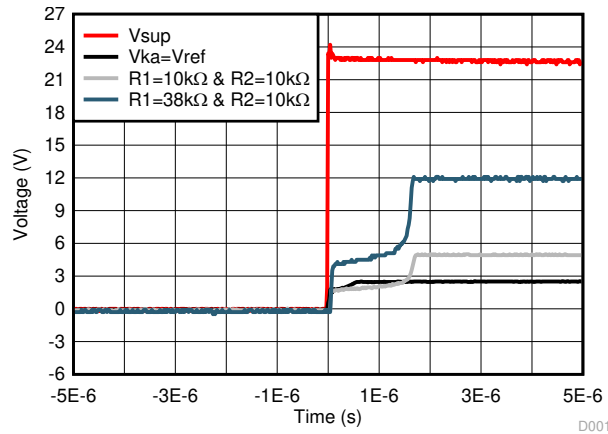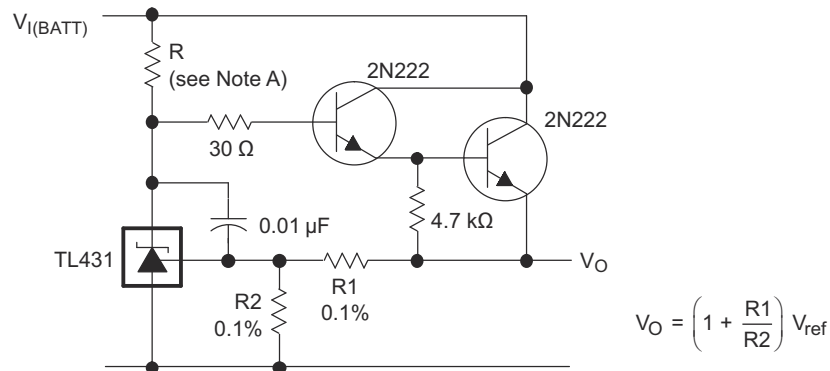
### 10.2.2.3 Application Curve



**Figure 10-4. TL43xx Start-Up Response**

## 10.3 System Examples



A.    R should provide cathode current ≥1 mA to the TL431 at minimum $V_{(BATT)}$.
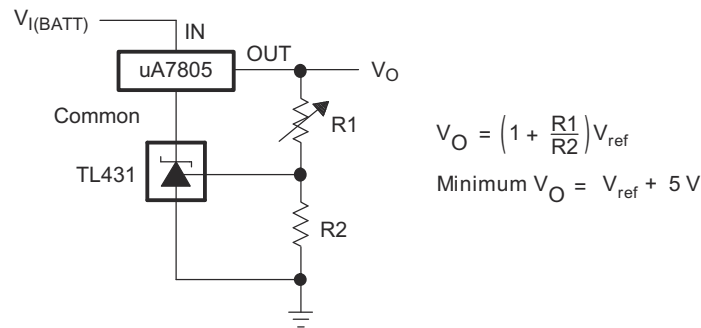
**Figure 10-5. Precision High-Current Series Regulator**



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

$$\text{Minimum } V_O = V_{ref} + 5\text{ V}$$

**Figure 10-6. Output Control of a Three-Terminal Fixed Regulator**



$$V_O = \left(1 + \frac{R1}{R2}\right)V_{ref}$$
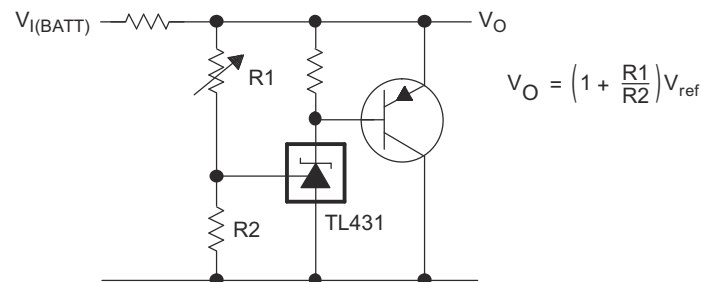
**Figure 10-7. High-Current Shunt Regulator**
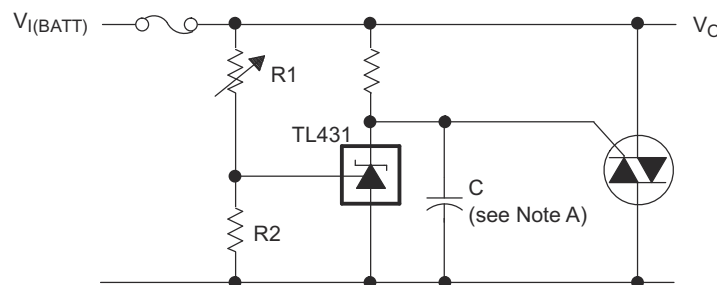


A.    Refer to the stability boundary conditions in Figure 7-16 and Figure 7-18 to determine allowable values for C.

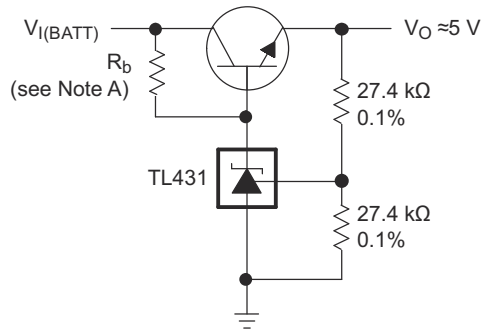**Figure 10-8. Crowbar Circuit**
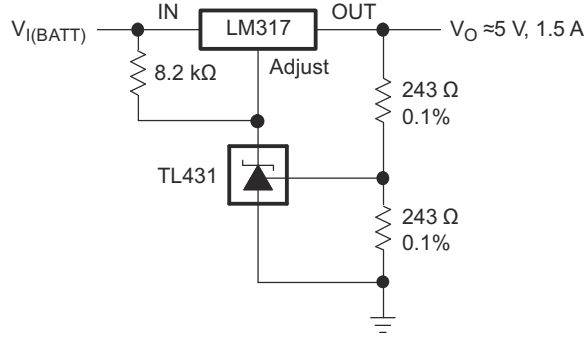
**Figure 10-9. Precision 5-V, 1.5-A Regulator**



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

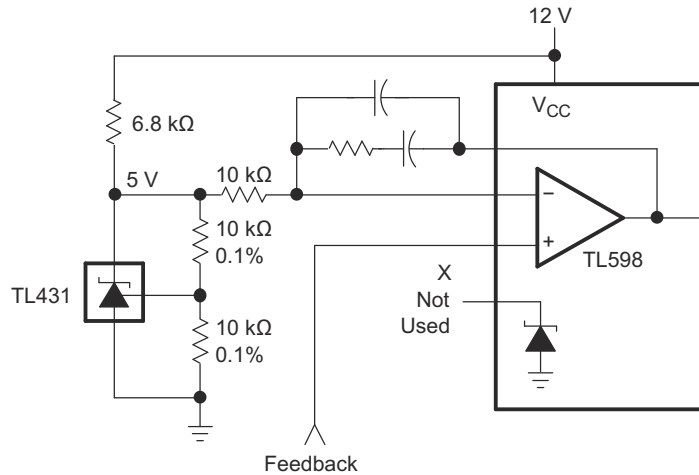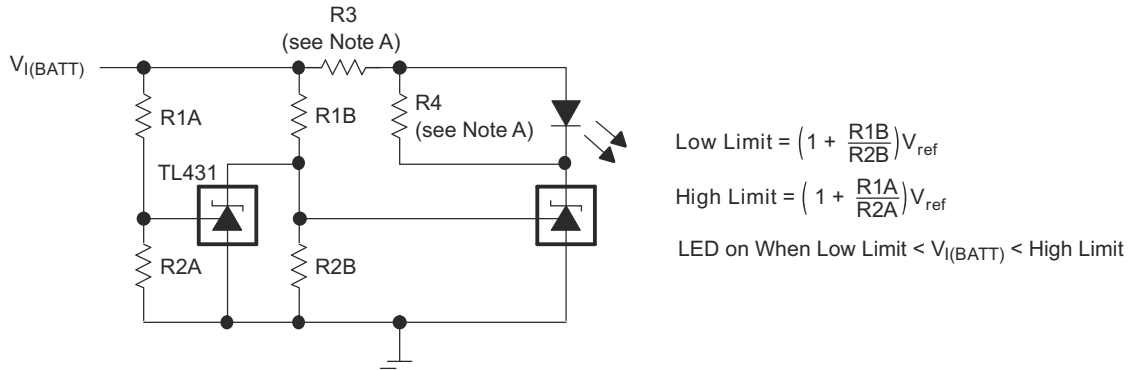**Figure 10-10. Efficient 5-V Precision Regulator**



**Figure 10-11. PWM Converter With Reference**

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

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

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

A.    Select R3 and R4 to provide the desired LED intensity and cathode current ≥1 mA to the TL431 at the available $V_{I(BATT)}$.
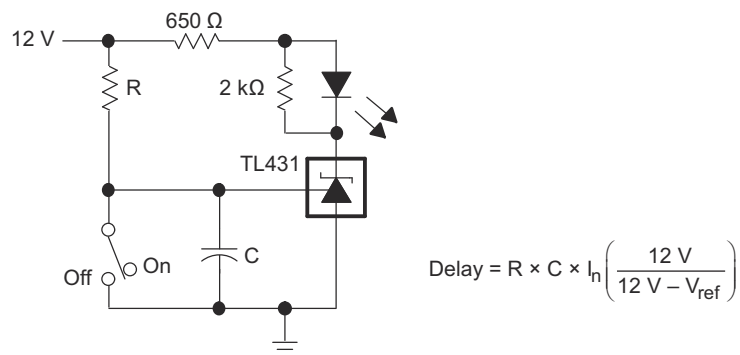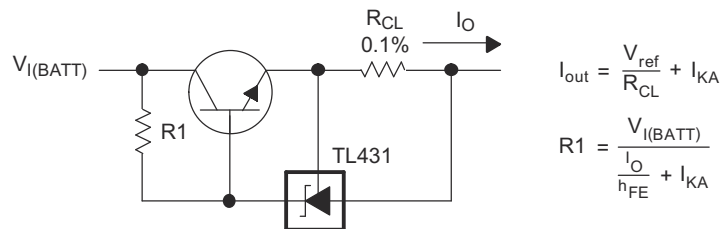
**Figure 10-12. Voltage Monitor**

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

**Figure 10-13. Delay Timer**

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

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

**Figure 10-14. Precision Current Limiter**

$$I_O = \frac{V_{ref}}{R_S}$$
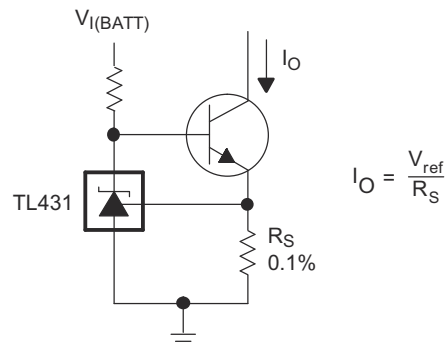
**Figure 10-15. Precision Constant-Current Sink**

Product Folder Links: *TL431 TL432*

## 10.4 Power Supply Recommendations

When using TL43xx as a Linear Regulator to supply a load, designers will typically use a bypass capacitor on the output/cathode pin. When doing this, be sure that the capacitance is within the stability criteria shown in Figure 7-16 and Figure 7-18.

In order to not exceed the maximum cathode current, be sure that the supply voltage is current limited. Also, be sure to limit the current being driven into the Ref pin, as not to exceed its absolute maximum rating.

For applications shunting high currents, pay attention to the cathode and anode trace lengths, adjusting the width of the traces to have the proper current density.

## 10.5 Layout

### 10.5.1 Layout Guidelines

Bypass capacitors should be placed as close to the part as possible. Current-carrying traces need to have widths appropriate for the amount of current they are carrying; in the case of the TL43xx, these currents will be low.
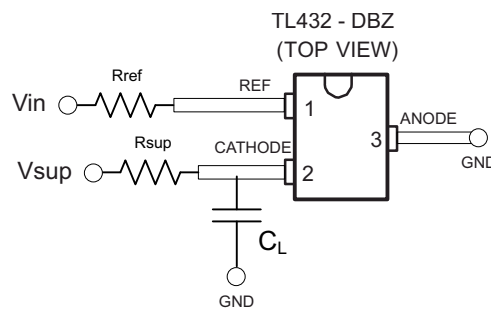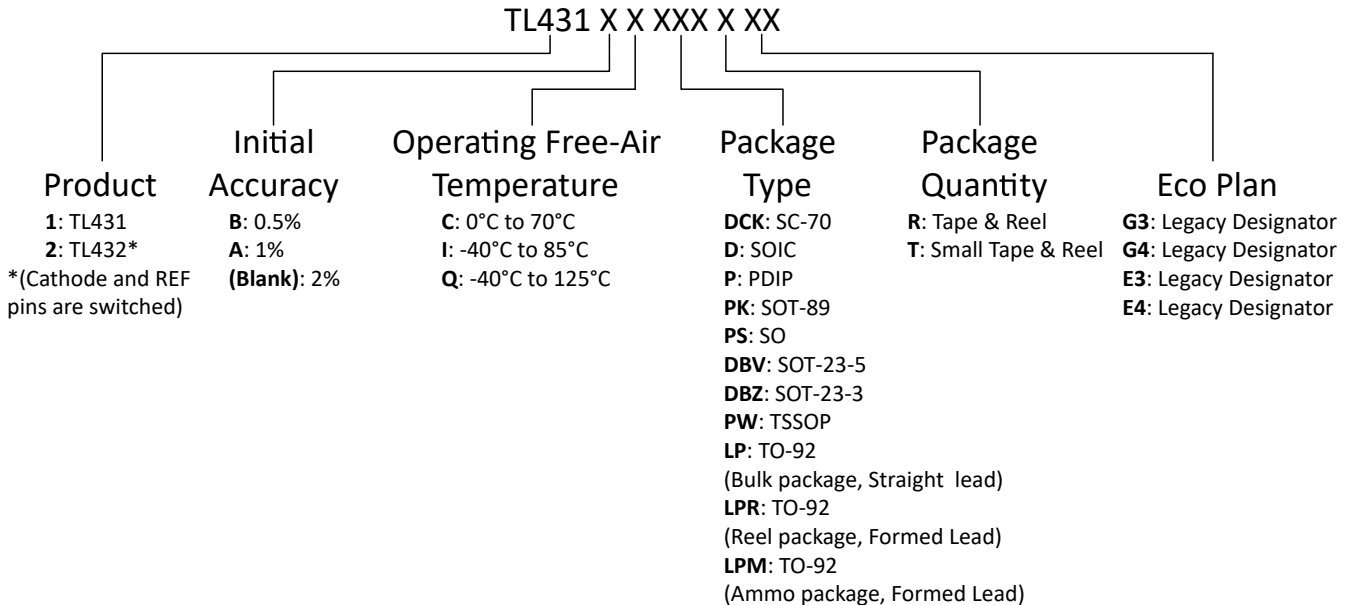
### 10.5.2 Layout Example



**Figure 10-16. DBZ Layout Example**

# 11 Device and Documentation Support

## 11.1 Device Nomenclature

TI assigns suffixes and prefixes to differentiate all the combinations of the TL43x family. The Eco Plan designator is a legacy designator that was used to differentiate Pb-free and Green devices. More details and possible orderable combinations are located on the Package Option Addendum in Mechanical, Packaging, and Orderable Information.

TL431 X X XXX X XX

**Product**
**1**: TL431
**2**: TL432*
*(Cathode and REF pins are switched)

**Initial Accuracy**
**B**: 0.5%
**A**: 1%
**(Blank)**: 2%

**Operating Free-Air Temperature**
**C**: 0°C to 70°C
**I**: -40°C to 85°C
**Q**: -40°C to 125°C

**Package Type**
**DCK**: SC-70
**D**: SOIC
**P**: PDIP
**PK**: SOT-89
**PS**: SO
**DBV**: SOT-23-5
**DBZ**: SOT-23-3
**PW**: TSSOP
**LP**: TO-92
(Bulk package, Straight lead)
**LPR**: TO-92
(Reel package, Formed Lead)
**LPM**: TO-92
(Ammo package, Formed Lead)

**Package Quantity**
**R**: Tape & Reel
**T**: Small Tape & Reel

**Eco Plan**
**G3**: Legacy Designator
**G4**: Legacy Designator
**E3**: Legacy Designator
**E4**: Legacy Designator

## 11.2 Related Links

The table below lists quick access links. Categories include technical documents, support and community resources, tools and software, and quick access to sample or buy.

**Table 11-1. Related Links**

| PARTS | PRODUCT FOLDER | SAMPLE & BUY | TECHNICAL DOCUMENTS | TOOLS & SOFTWARE | SUPPORT & COMMUNITY |
|-------|----------------|--------------|---------------------|------------------|---------------------|
| TL431 | Click here | Click here | Click here | Click here | Click here |
| TL432 | Click here | Click here | Click here | Click here | Click here |

## 11.3 Receiving Notification of Documentation Updates

To receive notification of documentation updates, navigate to the device product folder on ti.com. Click on *Notifications* to register and receive a weekly digest of any product information that has changed. For change details, review the revision history included in any revised document.

## 11.4 Support Resources

TI E2E™ support forums are an engineer's go-to source for fast, verified answers and design help — straight from the experts. Search existing answers or ask your own question to get the quick design help you need.

Linked content is provided "AS IS" by the respective contributors. They do not constitute TI specifications and do not necessarily reflect TI's views; see TI's Terms of Use.

## 11.5 Trademarks

TI E2E™ is a trademark of Texas Instruments.
All trademarks are the property of their respective owners.

## 11.6 Electrostatic Discharge Caution

This integrated circuit can be damaged by ESD. Texas Instruments recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

## 11.7 Glossary

TI Glossary          This glossary lists and explains terms, acronyms, and definitions.

## 12 Mechanical, Packaging, and Orderable Information

The following pages include mechanical packaging and orderable information. This information is the most current data available for the designated devices. This data is subject to change without notice and revision of this document. For browser based versions of this data sheet, refer to the left hand navigation.

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Product Folder Links: *TL431 TL432*