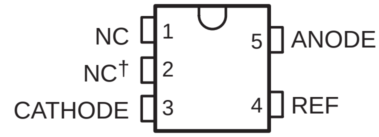
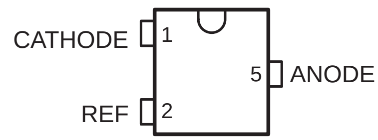
- Qualified for Automotive Applications
- Operation From −40°C to 125°C
- Reference Voltage Tolerance at 25°C
  - 1% . . . A Grade
  - 0.5% . . . B Grade
- Typical Temperature Drift
  - 14 mV (Q Temp)
- Low Output Noise
- 0.2-Ω Typical Output Impedance
- Sink-Current Capability = 1 mA to 100 mA
- Adjustable Output Voltage = V_{ref} to 36 V

DBV (SOT-23-5) PACKAGE
(TOP VIEW)



NC − No internal connection
† Pin 2 is connected internally to ANODE (die substrate) and should be floating or connected to ANODE.

TL431, TL431A, TL431B
DBZ (SOT-23-5) PACKAGE
(TOP VIEW)



description

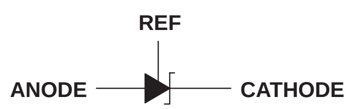
The TL431 is a three-terminal adjustable shunt regulator with specified thermal stability over applicable automotive temperature ranges. The output voltage can be set to any value between V_{ref} (approximately 2.5 V) and 36 V, with two external resistors (see Figure 17). This device has a typical output impedance of 0.2 Ω. Active output circuitry provides a sharp turn-on characteristic, making this device an excellent replacement for Zener diodes in many applications, such as onboard regulation, adjustable power supplies, and switching power supplies.

Ordering Information†

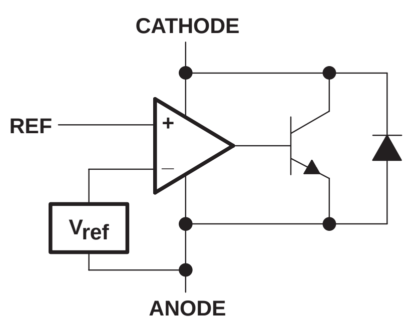
T_A	PACKAGE‡		ORDERABLE PART NUMBER	TOP-SIDE MARKING
−40°C to 125°C	SOT-23-5 (DBV)	Reel of 3000	TL431AQDBVRQ1	TACQ
	SOT-23-3 (DBZ)	Reel of 3000	TL431BQDBZRQ1	T3FU
	SOT-23-5 (DBV)	Reel of 3000	TL431QDBVRQ1	T3QU
	SOT-23-3 (DBZ)	Reel of 3000	TL431AQDBZRQ1	TAQU

† For the most current package and ordering information, see the Package Option Addendum at the end of this document, or see the TI web site at http://www.ti.com.
‡ Package drawings, thermal data, and symbolization are available at http://www.ti.com/packaging.

symbol



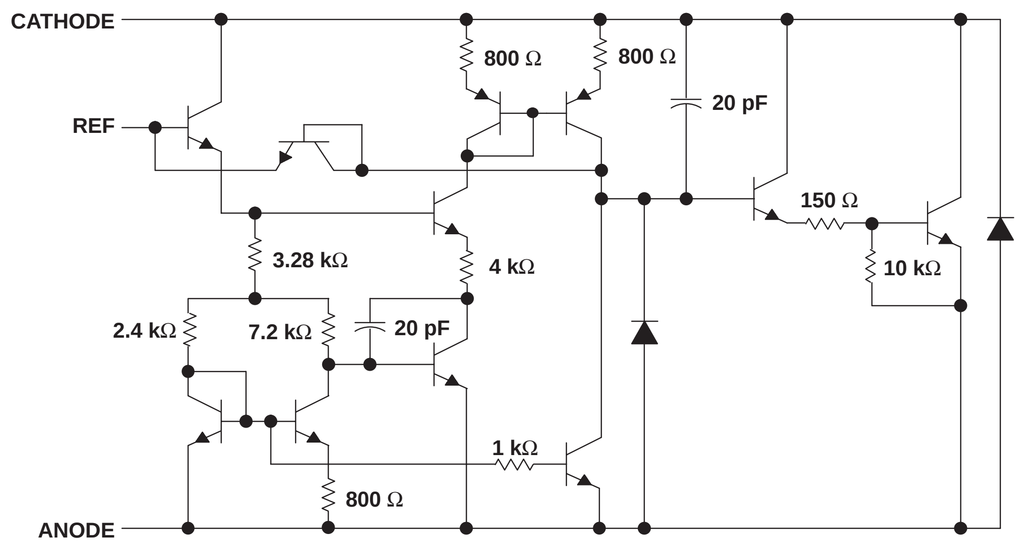
functional block diagram



Please be aware that an important notice concerning availability, standard warranty, and use in critical applications of Texas Instruments semiconductor products and disclaimers thereto appears at the end of this data sheet.

PowerFLEX is a trademark of Texas Instruments.

equivalent schematic†



† All component values are nominal.

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)‡

Cathode voltage, V_{KA} (see Note 1) . . . . 37 V
Continuous cathode current range, I_{KA} . . . . −100 mA to 150 mA
Reference input current range . . . . −50 μA to 10 mA
Operating virtual junction temperature, T_J . . . . 150°C
Storage temperature range, T_{stg} . . . . −65°C to 150°C
ESD protection level (see Note 2): HBM . . . . (H2) 2.5 kV
CDM . . . . (C4) 1 kV
MM . . . . (M2) 200 V

‡ 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.

NOTE 2: ESD Protection Level per AEC Q100 Classification

package thermal data (see Note3)

PACKAGE	BOARD	θ_{JC}	θ_{JA}
SOT-23-5 (DBV)	High K, JESD 51-7	131°C/W	206°C/W
SOT-23-3 (DBZ)	High K, JESD 51-7	76°C/W	206°C/W

NOTE 3: Maximum power dissipation is a function of T_J(max), θ_{JA}, and T_A. The maximum allowable power dissipation at any allowable ambient temperature is $P_D = (T_J(max) - T_A)/\theta_{JA}$. Operating at the absolute maximum T_J of 150°C can affect reliability.

recommended operating conditions

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

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

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

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

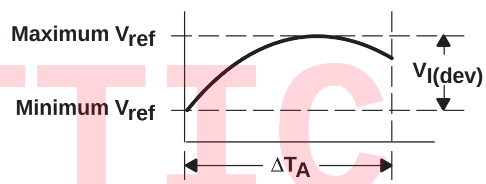
PARAMETER		TEST CIRCUIT	TEST CONDITIONS		TL431AQ MIN	TL431AQ TYP	TL431AQ MAX	UNIT
V_{ref}	Reference voltage	2	$V_{KA} = V_{ref}$, I_{KA} = 10 mA		2470	2495	2520	mV
$V_{I(dev)}$	Deviation of reference voltage over full temperature range (see Figure 1)	2	$V_{KA} = V_{ref}$, I_{KA} = 10 mA, T_A = −40°C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

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

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

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

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



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

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

Example: maximum V_{ref} = 2496 mV at 30°C, minimum V_{ref} = 2492 mV at 0°C, V_{ref} = 2495 mV at 25°C, ΔT_A = 70°C for TL431

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

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

Calculating Dynamic Impedance

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

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

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

Figure 1. Calculating Deviation Parameters and Dynamic Impedance

PARAMETER MEASUREMENT INFORMATION

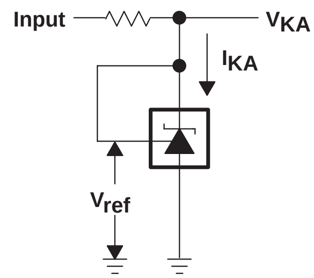


Figure 2. Test Circuit for $V_{KA} = V_{ref}$

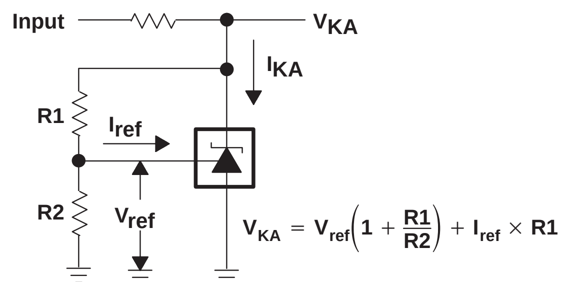


Figure 3. Test Circuit for $V_{KA} > V_{ref}$

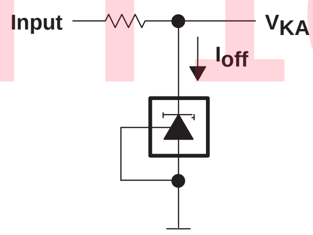


Figure 4. Test Circuit for I_{off}

TYPICAL CHARACTERISTICS

Table 1. Graphs

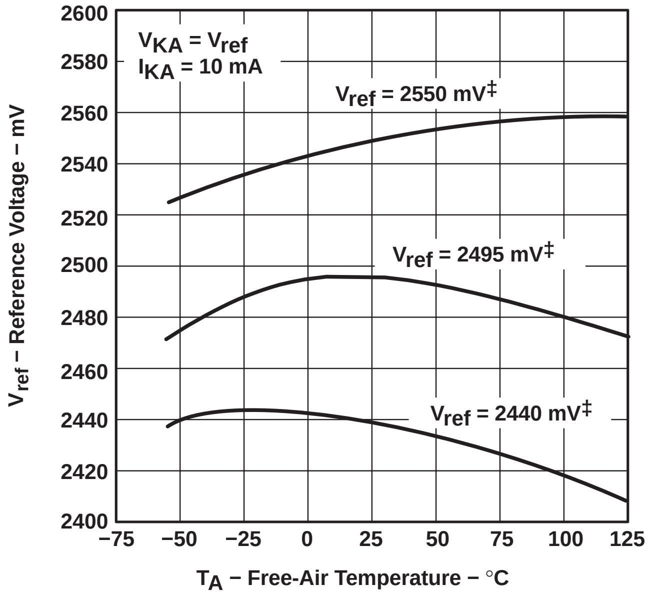
	FIGURE
Reference voltage vs Free-air temperature	5
Reference current vs Free-air temperature	6
Cathode current vs Cathode voltage	7, 8
OFF-state cathode current vs Free-air temperature	9
Ratio of delta reference voltage to delta cathode voltage vs Free-air temperature	10
Equivalent input noise voltage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

Table 2. Application Circuits

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

TYPICAL CHARACTERISTICS†

REFERENCE VOLTAGE vs FREE-AIR TEMPERATURE



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

Figure 5

REFERENCE CURRENT vs FREE-AIR TEMPERATURE

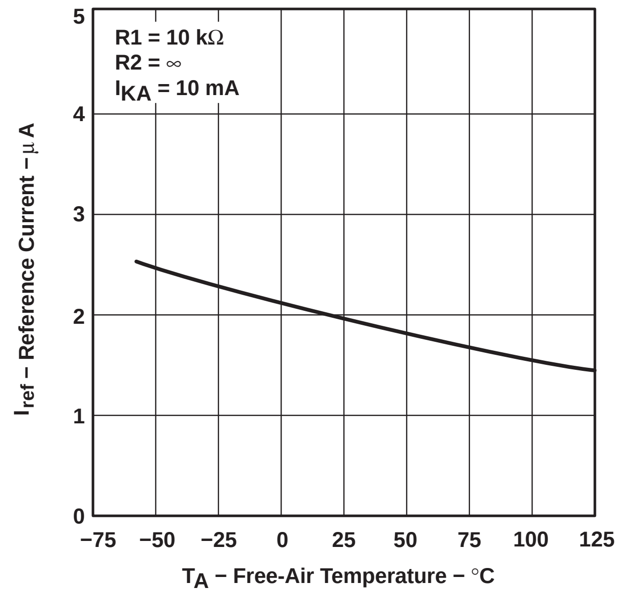


Figure 6

CATHODE CURRENT vs CATHODE VOLTAGE

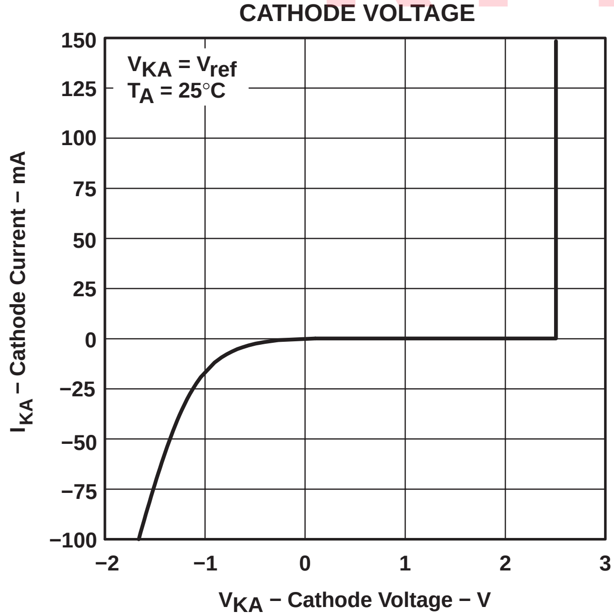


Figure 7

CATHODE CURRENT vs CATHODE VOLTAGE

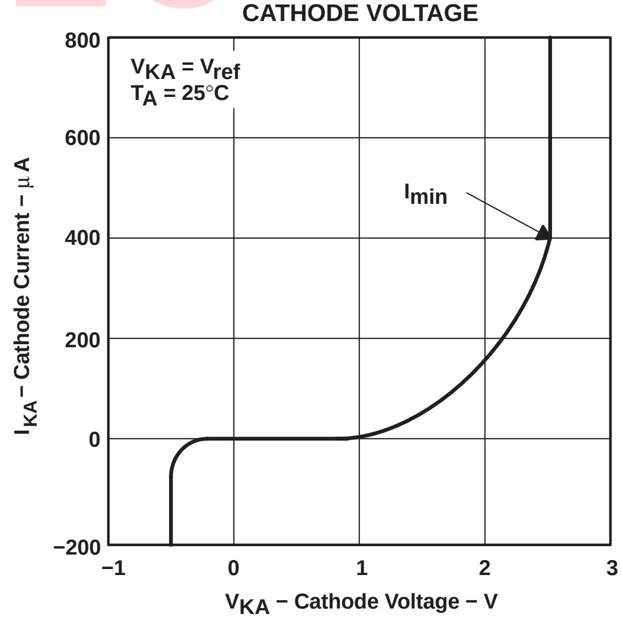


Figure 8

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

TYPICAL CHARACTERISTICS†

OFF-STATE CATHODE CURRENT
vs
FREE-AIR TEMPERATURE

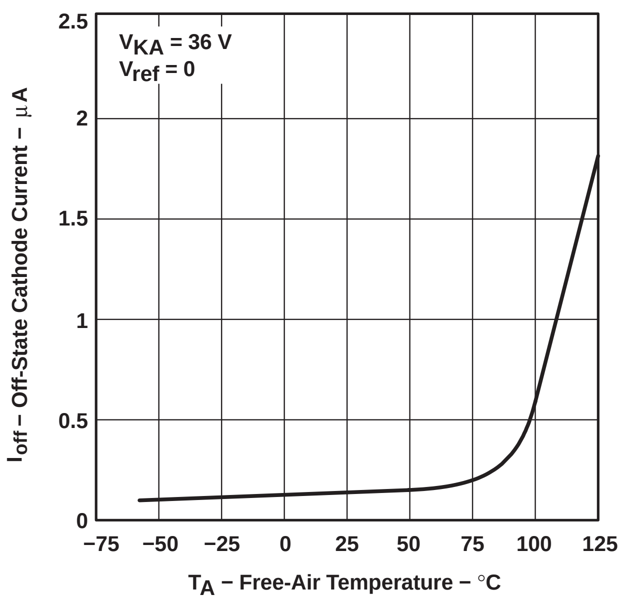


Figure 9

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

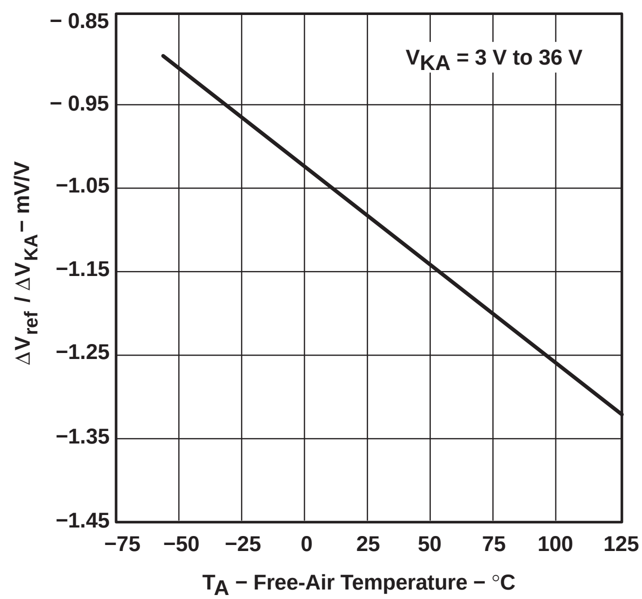


Figure 10

EQUIVALENT INPUT NOISE VOLTAGE
vs
FREQUENCY

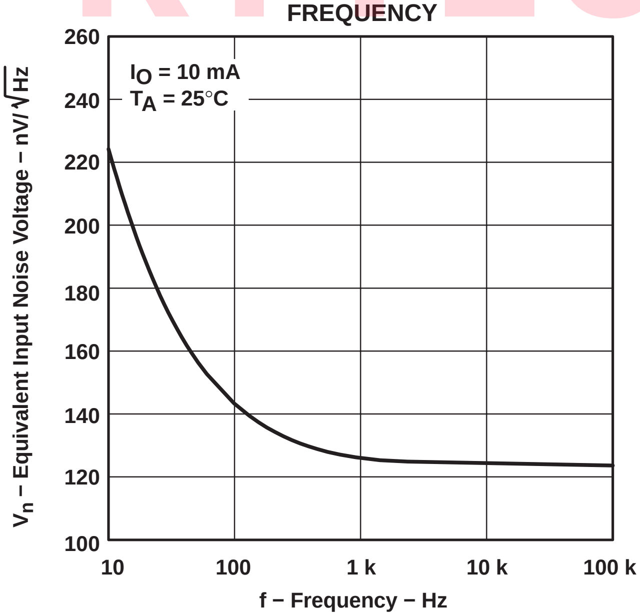
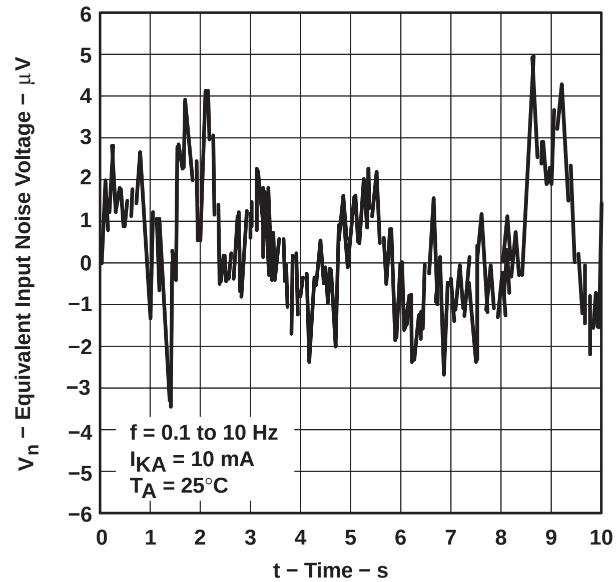


Figure 11

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

TYPICAL CHARACTERISTICS

EQUIVALENT INPUT NOISE VOLTAGE
OVER A 10-S PERIOD



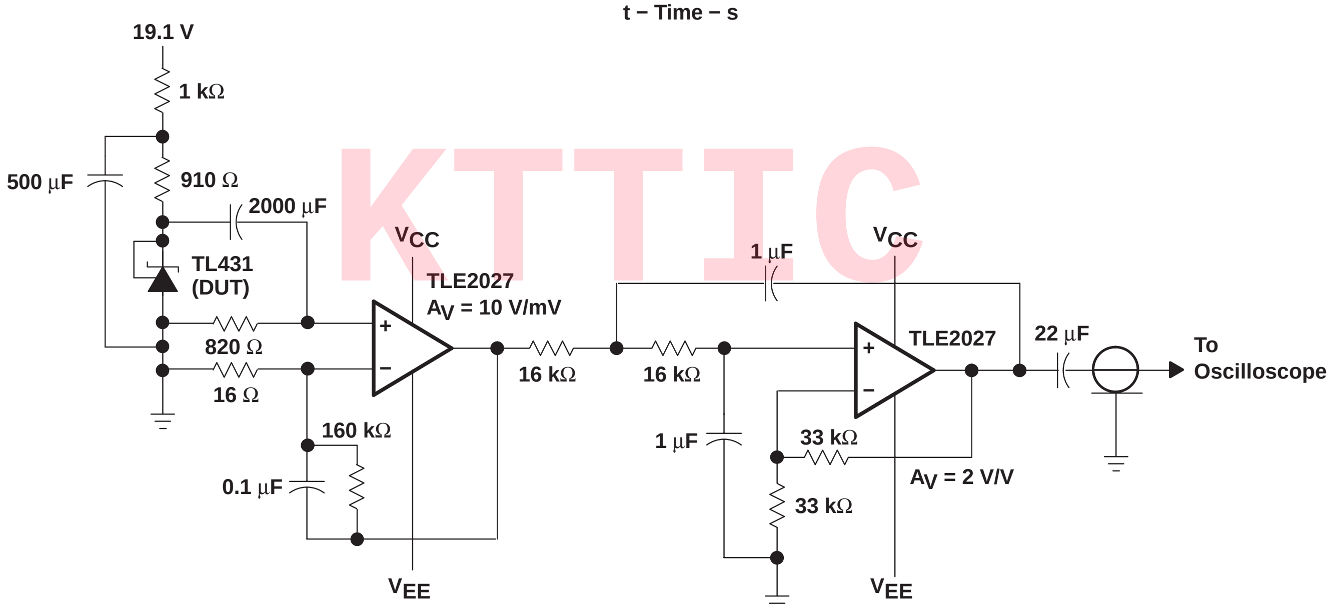
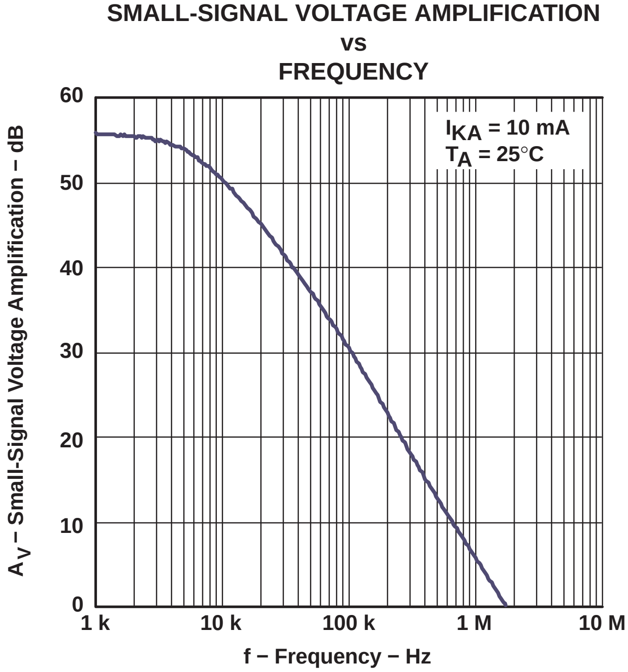


Figure 12. Test Circuit for Equivalent Input Noise Voltage

TYPICAL CHARACTERISTICS



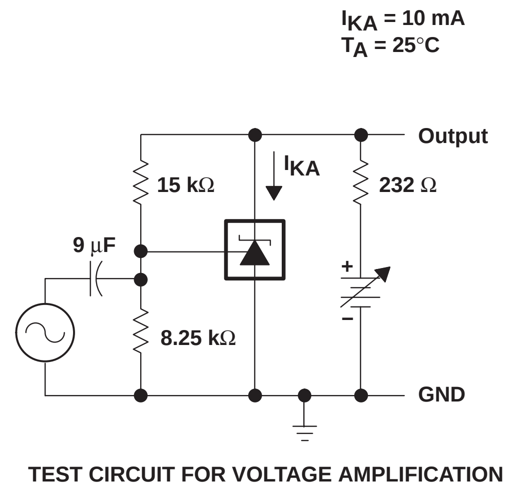
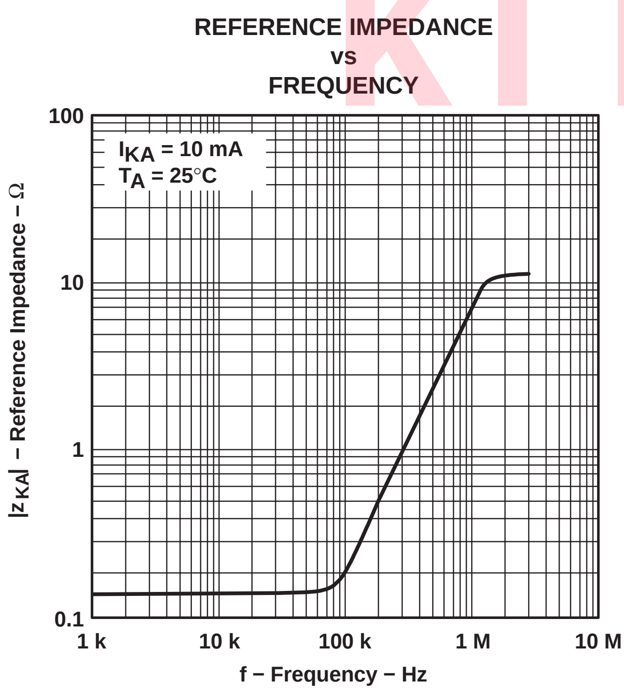


Figure 13



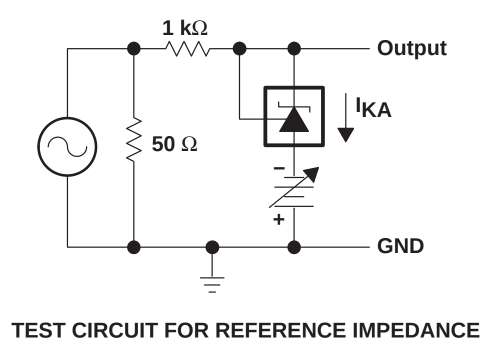
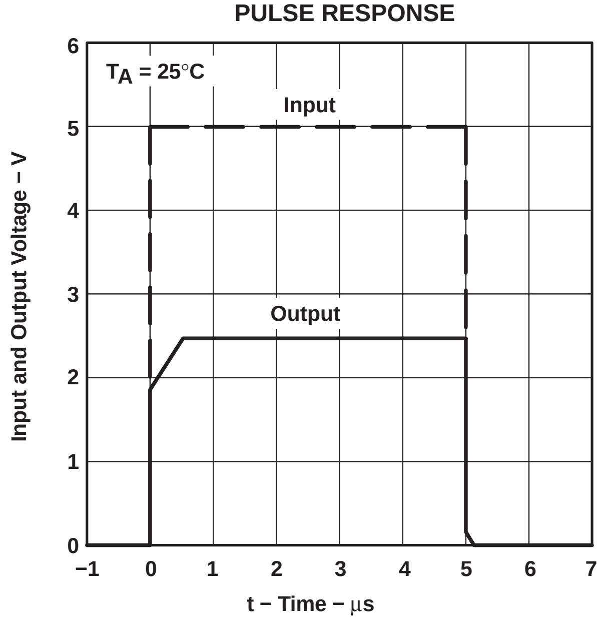
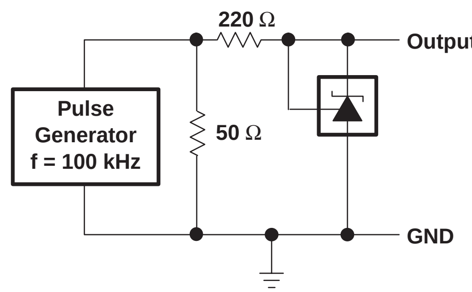


Figure 14

TYPICAL CHARACTERISTICS



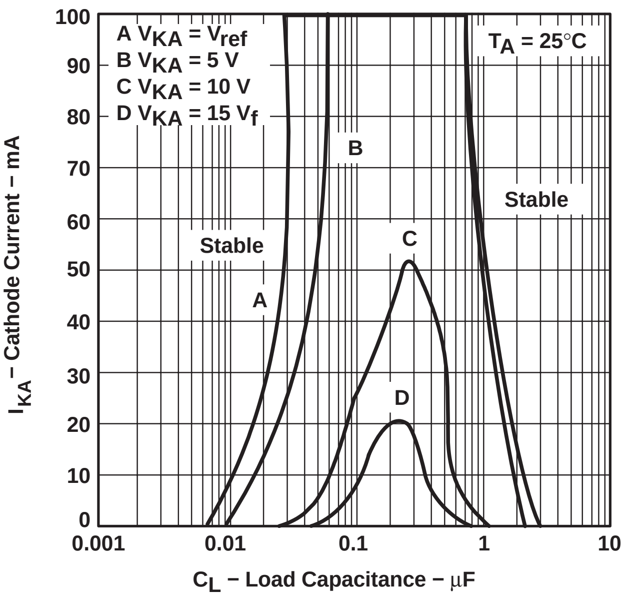


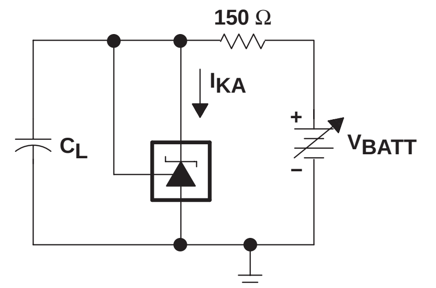
TEST CIRCUIT FOR PULSE RESPONSE

Figure 15

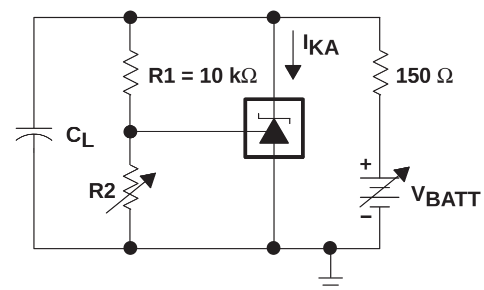
TYPICAL CHARACTERISTICS

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



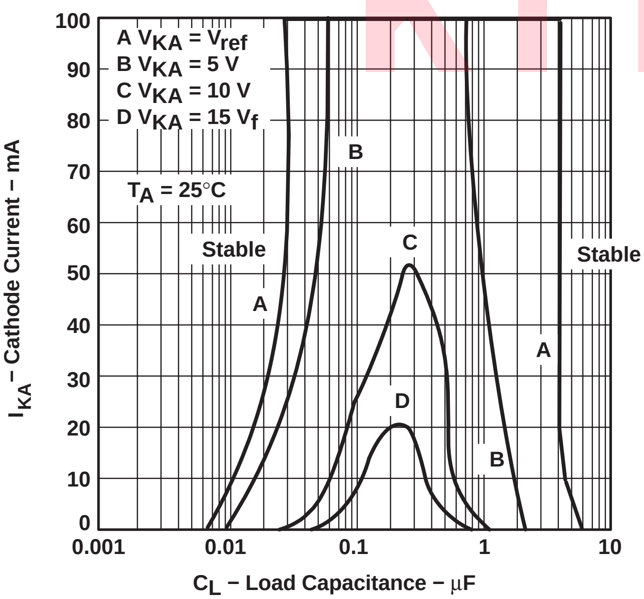


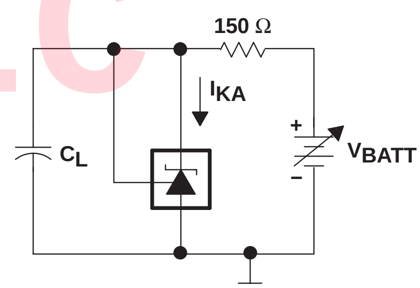
TEST CIRCUIT FOR CURVE A



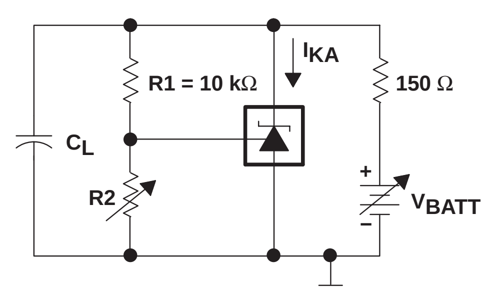
TEST CIRCUIT FOR CURVES B, C, AND D

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





TEST CIRCUIT FOR CURVE A

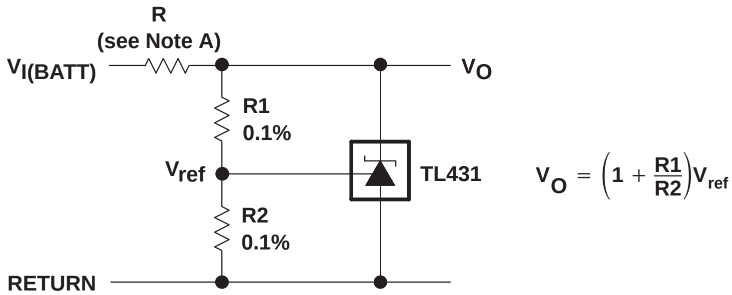


TEST CIRCUIT FOR CURVES B, C, AND D

† 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

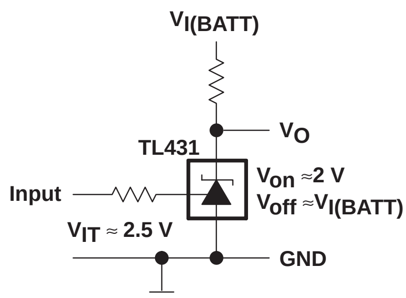
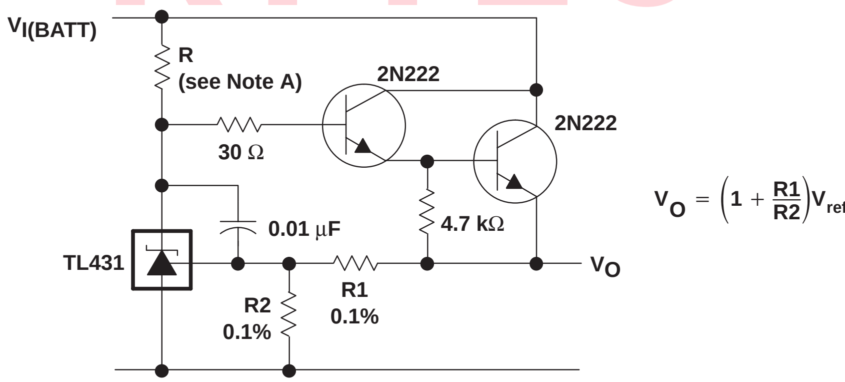


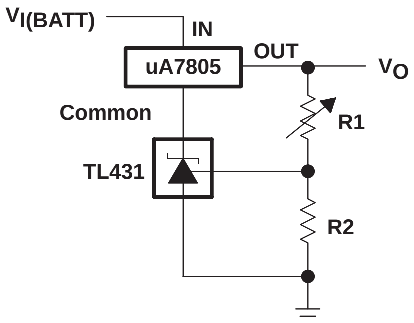
Figure 18. Single-Supply Comparator With Temperature-Compensated Threshold



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

Figure 19. Precision High-Current Series Regulator

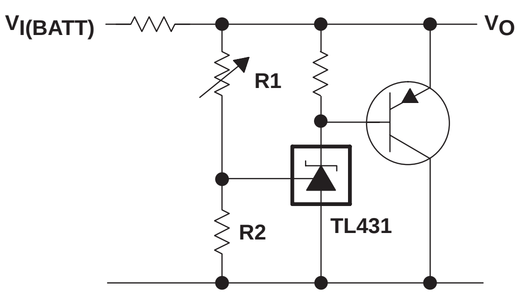
APPLICATION INFORMATION



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

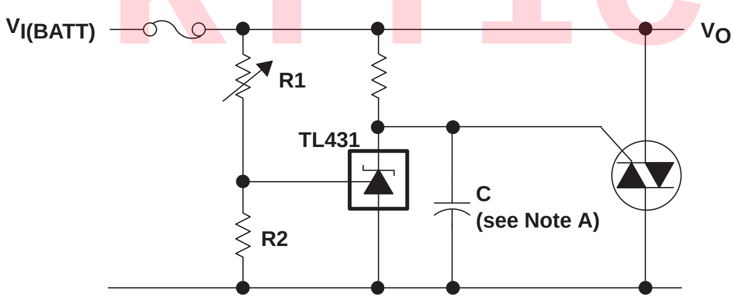
$$\text{Minimum } V_O = V_{ref} + 5\ V$$

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



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

Figure 21. High-Current Shunt Regulator



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

Figure 22. Crowbar Circuit

APPLICATION INFORMATION

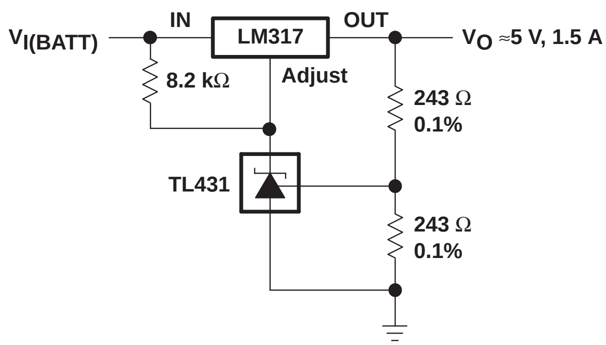
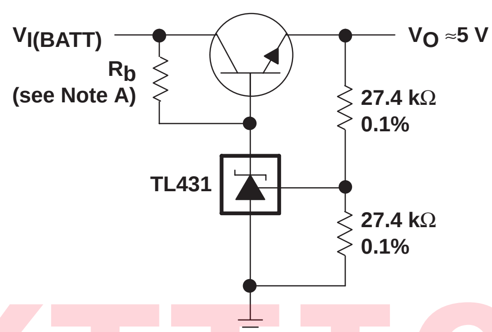


Figure 23. Precision 5-V 1.5-A Regulator



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

Figure 24. Efficient 5-V Precision Regulator

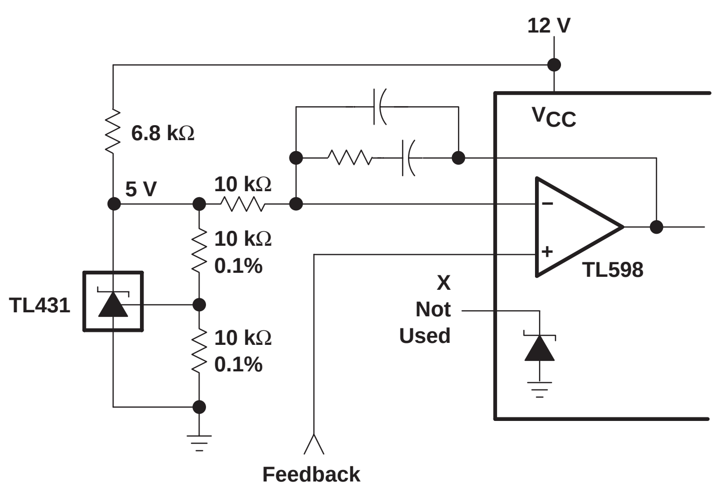
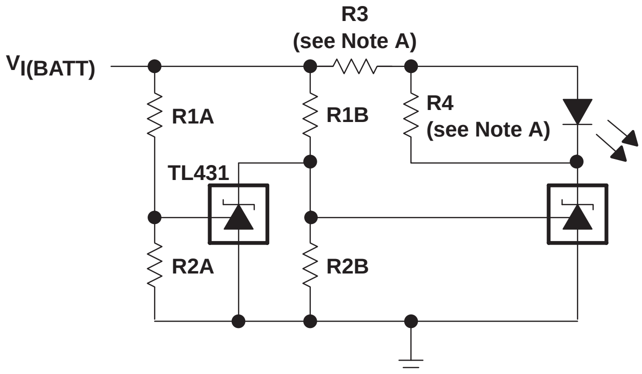


Figure 25. PWM Converter With Reference

APPLICATION INFORMATION



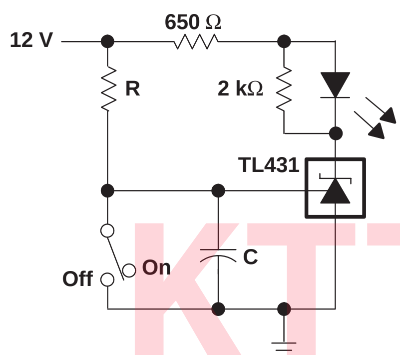
$$\text{Low Limit} = \left(1 + \frac{R1B}{R2B}\right)V_{ref}$$

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

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

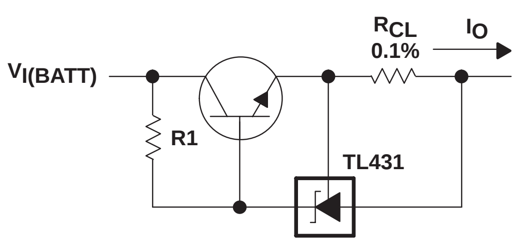
NOTE A: R3 and R4 are selected to provide the desired LED intensity and cathode current ≥1 mA to the TL431 at the available $V_{I(BATT)}$.

Figure 26. Voltage Monitor



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

Figure 27. Delay Timer



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

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

Figure 28. Precision Current Limiter

APPLICATION INFORMATION

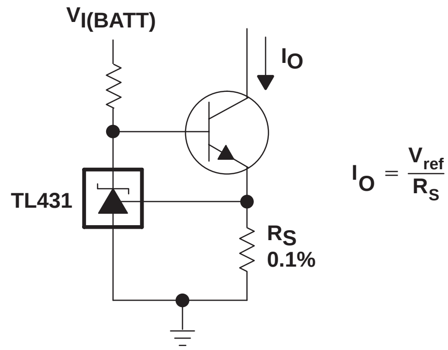


Figure 29. Precision Constant-Current Sink

PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish	MSL Peak Temp (3)
TL431AQDBVRQ1	ACTIVE	SOT-23	DBV	5	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TL431AQDBZRQ1	ACTIVE	SOT-23	DBZ	3	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TL431BQDBZRQ1	ACTIVE	SOT-23	DBZ	3	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM

(1) The marketing status values are defined as follows:
ACTIVE: Product device recommended for new designs.
LIFEBUY: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.
NRND: Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.
PREVIEW: Device has been announced but is not in production. Samples may or may not be available.
OBSOLETE: TI has discontinued the production of the device.

(2) Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check http://www.ti.com/productcontent for the latest availability information and additional product content details.
TBD: The Pb-Free/Green conversion plan has not been defined.
Pb-Free (RoHS): TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.
Pb-Free (RoHS Exempt): This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.
Green (RoHS & no Sb/Br): TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

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

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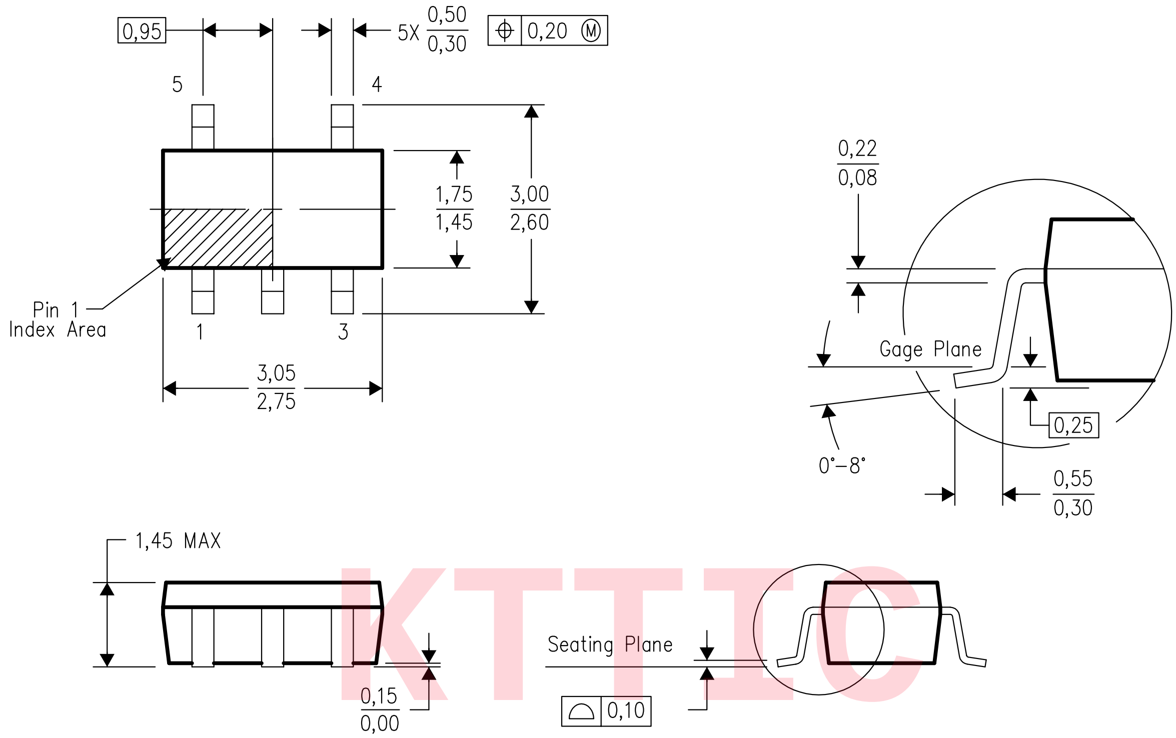
OTHER QUALIFIED VERSIONS OF TL431A-Q1, TL431B-Q1 :

- Catalog: TL431A, TL431B

NOTE: Qualified Version Definitions:

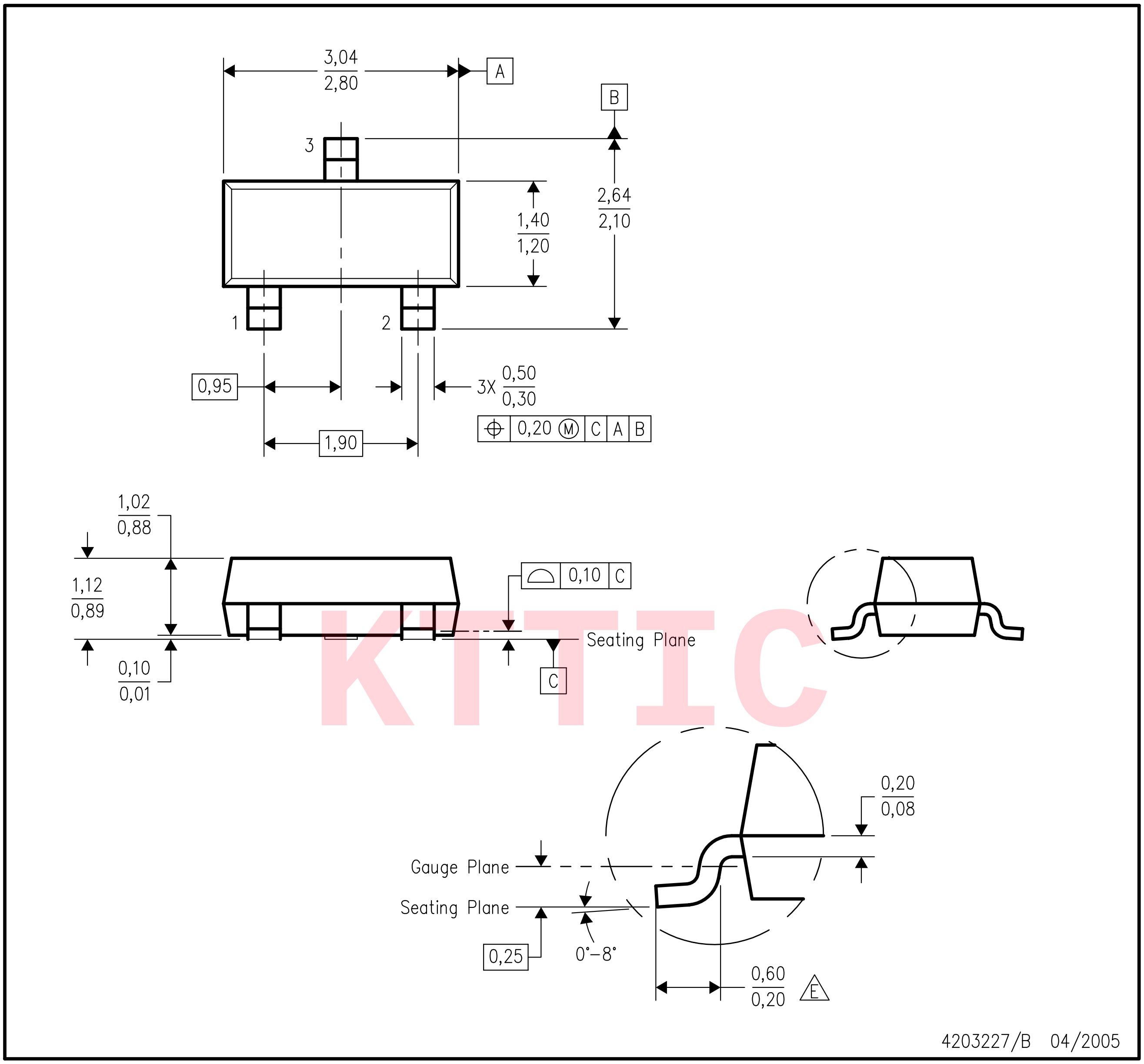
- Catalog - TI's standard catalog product

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. Mold flash and protrusion shall not exceed 0.15 per side.
- D. Falls within JEDEC MO-178 Variation AA.

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



NOTES:
- A. All linear dimensions are in millimeters. Dimensioning and tolerancing per ASME Y14.5M–1994.
- B. This drawing is subject to change without notice.
- C. Lead dimensions are inclusive of plating.
- D. Body dimensions are exclusive of mold flash and protrusion. Mold flash and protrusion not to exceed 0.25 per side.
- E. Falls within JEDEC TO–236 variation AB, except minimum foot length.

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