TL1431-Q1
PRECISION PROGRAMMABLE REFERENCE
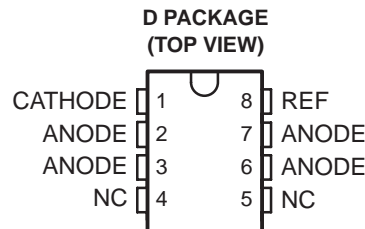
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- **Qualified for Automotive Applications**
- **0.4% Initial Voltage Tolerance**
- **0.2-Ω Typical Output Impedance**
- **Fast Turnon . . . 500 ns**
- **Sink Current Capability . . . 1 mA to 100 mA**
- **Low Reference Current (REF)**
- **Adjustable Output Voltage . . . $V_{I(ref)}$ to 36 V**

D PACKAGE
(TOP VIEW)

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

NC – No internal connection
ANODE terminals are connected internally.

description/ordering information

The TL1431 is a precision programmable reference with specified thermal stability over the automotive temperature range. The output voltage can be set to any value between $V_{I(ref)}$ (approximately 2.5 V) and 36 V with two external resistors (see Figure 16). This device has a typical output impedance of 0.2 Ω. Active output circuitry provides a very sharp turnon characteristic, making the device an excellent replacement for Zener diodes and other types of references in applications such as onboard regulation, adjustable power supplies, and switching power supplies.

The TL1431Q is characterized for operation over the full automotive temperature range of –40°C to 125°C.

ORDERING INFORMATION†

T_A	PACKAGE‡		ORDERABLE PART NUMBER	TOP-SIDE MARKING
–40°C to 125°C	SOIC (D)	Reel of 2500	TL1431QDRQ1	1431Q1

† 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

REF

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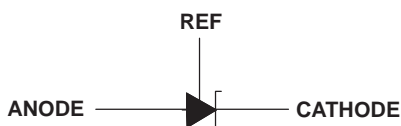
Please be aware that an important notice concerning availability, standard warranty, and use in critical applications of Texas Instruments semiconductor products and disclaimers thereto appears at the end of this data sheet.

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TEXAS INSTRUMENTS

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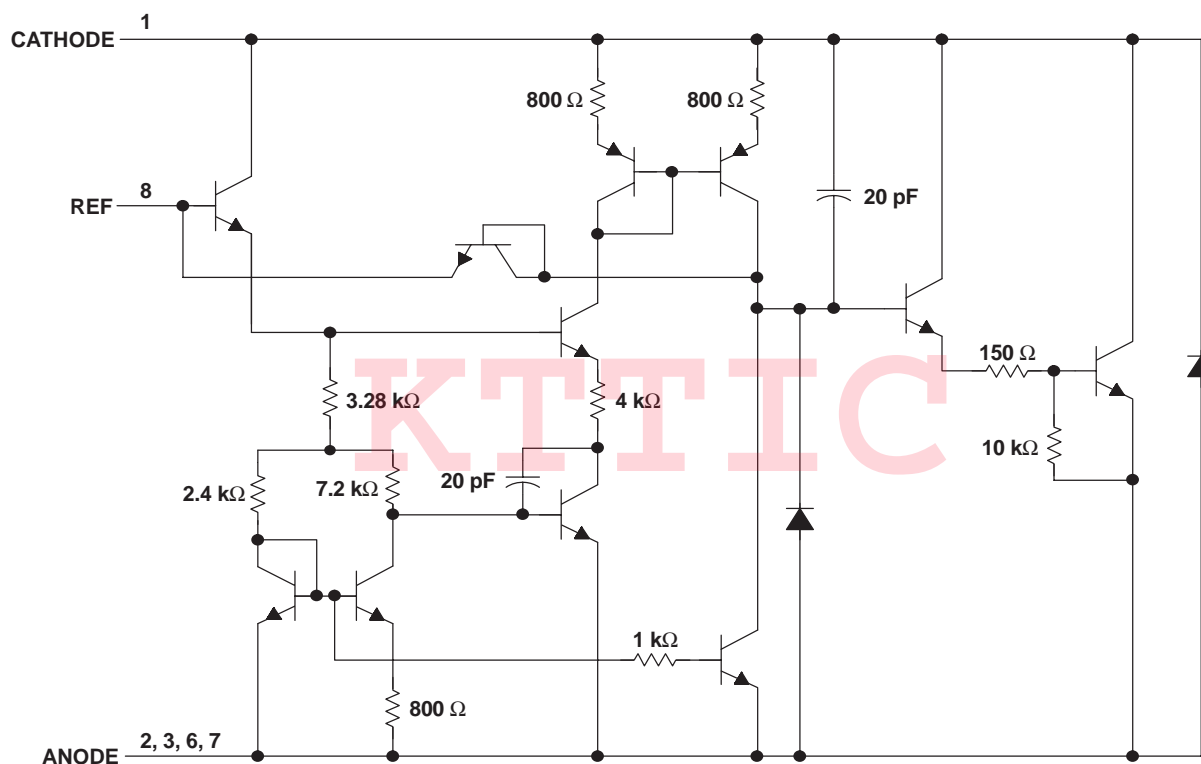
http://www.kttic.com

1

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functional block diagram
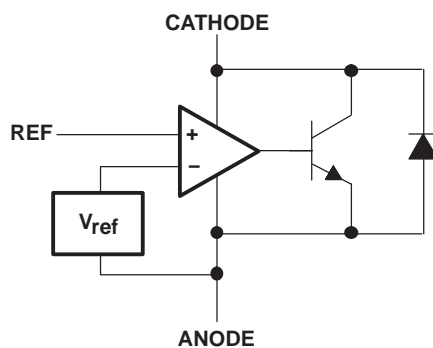
equivalent schematic†

† All component values are nominal.

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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, $I_{I(ref)}$ . . . . −50 μA to 10 mA
Package thermal impedance, θ_{JA} (see Notes 2 and 3) . . . . 97°C/W
Operating virtual junction temperature, T_J . . . . 150°C
Continuous total power dissipation . . . . See Dissipation Rating Table
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds . . . . 260°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.
NOTES: 1. All voltage values are with respect to ANODE, unless otherwise noted.
         2. Temperature and/or supply voltages must be limited to ensure that the maximum dissipation rating is not exceeded.
         3. The package thermal impedance is calculated in accordance with JESD 51-7.

DISSIPATION RATING TABLE

PACKAGE	$T_A \leq 25°C$ POWER RATING	DERATING FACTOR ABOVE $T_A = 25°C$	$T_A = 70°C$ POWER RATING	$T_A = 85°C$ POWER RATING	$T_A = 125°C$ POWER RATING
D	1102 mW	10.3 mW/°C	638.5 mW	484 mW	72.1 mW

recommended operating conditions

		MIN	MAX	UNIT
V_{KA}	Cathode voltage	$V_{I(ref)}$	36	V
I_{KA}	Cathode current	1	100	mA
T_A	Operating free-air temperature	−40	125	°C
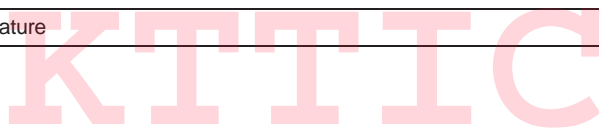
![TEXAS INSTRUMENTS]

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

|	PARAMETER	TEST CONDITIONS	T_A†	TEST CIRCUIT	MIN	TYP	MAX	UNIT
$V_{I(ref)}$	Reference input voltage	V_{KA} = $V_{I(ref)}$	25°C	Figure 1	2490	2500	2510	mV
			Full range		2470		2530	
$V_{I(dev)}$	Deviation of reference input voltage over full temperature range‡	V_{KA} = $V_{I(ref)}$	Full range	Figure 1		17	55	mV
$\dfrac{\Delta V_{I(ref)}}{\Delta V_{KA}}$	Ratio of change in reference input voltage to the change in cathode voltage	ΔV_{KA} = 3 V to 36 V	Full range	Figure 2		−1.1	−2	mV/V
$I_{I(ref)}$	Reference input current	R1 = 10 kΩ, R2 = ∞	25°C	Figure 2		1.5	2.5	μA
			Full range				4	
$I_{I(dev)}$	Deviation of reference input current over full temperature range‡	R1 = 10 kΩ, R2 = ∞	Full range	Figure 2		0.5	2	μA
I_{min}	Minimum cathode current for regulation	V_{KA} = $V_{I(ref)}$	25°C	Figure 1		0.45	1	mA
I_{off}	Off-state cathode current	V_{KA} = 36 V, $V_{I(ref)}$ = 0	25°C	Figure 3		0.18	0.5	μA
			Full range				2	
$|z_{KA}|$	Output impedance§	V_{KA} = $V_{I(ref)}$, f ≤ 1 kHz, I_{KA} = 1 mA to 100 mA	25°C	Figure 1		0.2	0.4	Ω

† Full range is −40°C to 125°C for Q-suffix devices.

‡ The deviation parameters $V_{I(dev)}$ and $I_{I(dev)}$ are defined as the differences between the maximum and minimum values obtained over the rated temperature range. The average full-range temperature coefficient of the reference input voltage $\alpha_{V_{I(ref)}}$ is defined as:

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

where:

ΔT_A is the rated operating temperature range of the device.
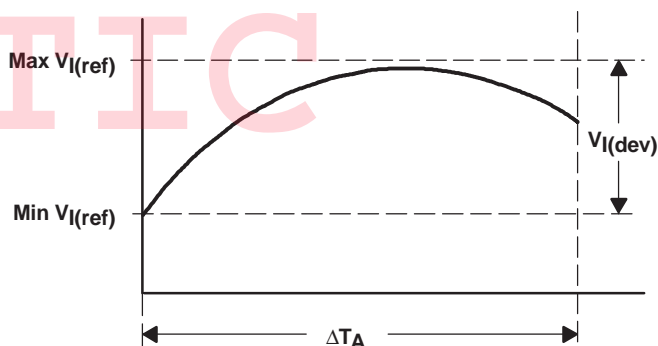
$\alpha_{V_{I(ref)}}$ is positive or negative, depending on whether minimum $V_{I(ref)}$ or maximum $V_{I(ref)}$, respectively, occurs at the lower temperature.

§ The output impedance is defined as: $|z_{KA}| = \dfrac{\Delta V_{KA}}{\Delta I_{KA}}$

When the device is operating with two external resistors (see Figure 2), the total dynamic impedance of the circuit is given by: $|z'| = \dfrac{\Delta V}{\Delta I}$, which is approximately equal to $|z_{KA}|\left(1 + \dfrac{R1}{R2}\right)$.

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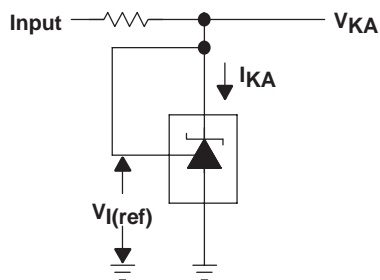
PARAMETER MEASUREMENT INFORMATION

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

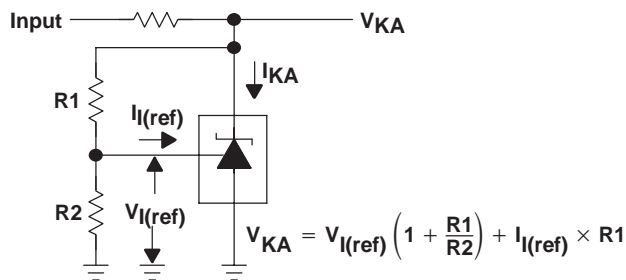$$V_{KA} = V_{I(ref)}\left(1 + \frac{R1}{R2}\right) + I_{I(ref)} \times R1$$

Figure 2. Test Circuit for V$_{(KA)}$ > V$_{ref}$
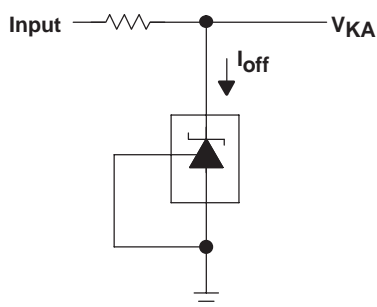
Figure 3. Test Circuit for I$_{off}$

TYPICAL CHARACTERISTICS

Table of Graphs

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Reference voltage vs Free-air temperature	4
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Cathode current vs Cathode voltage	6, 7
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Ratio of delta reference voltage to delta cathode voltage vs Free-air temperature	9
Equivalent input-noise voltage vs Frequency	10
Equivalent input-noise voltage over a 10-second period	11
Small-signal voltage amplification vs Frequency	12
Reference impedance vs Frequency	13
Pulse response	14
Stability boundary conditions	15

TYPICAL CHARACTERISTICS†

**REFERENCE VOLTAGE
vs
FREE-AIR TEMPERATURE**

Figure 4

**REFERENCE CURRENT
vs
FREE-AIR TEMPERATURE**

Figure 5

**CATHODE CURRENT
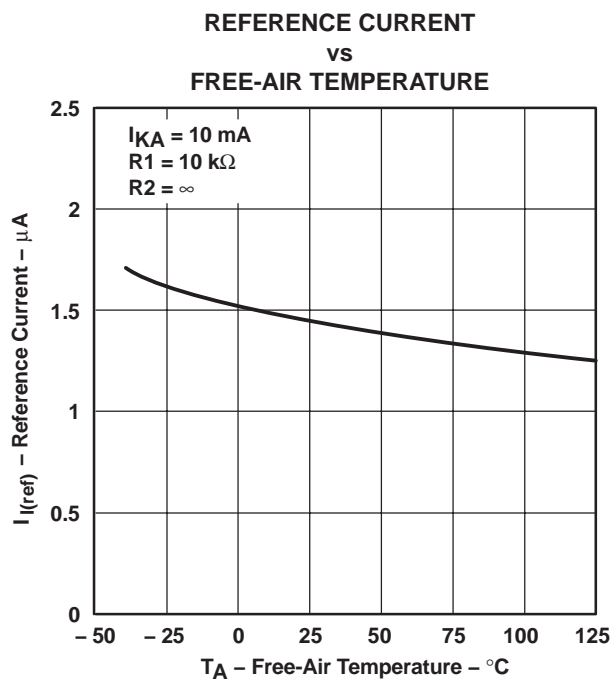vs
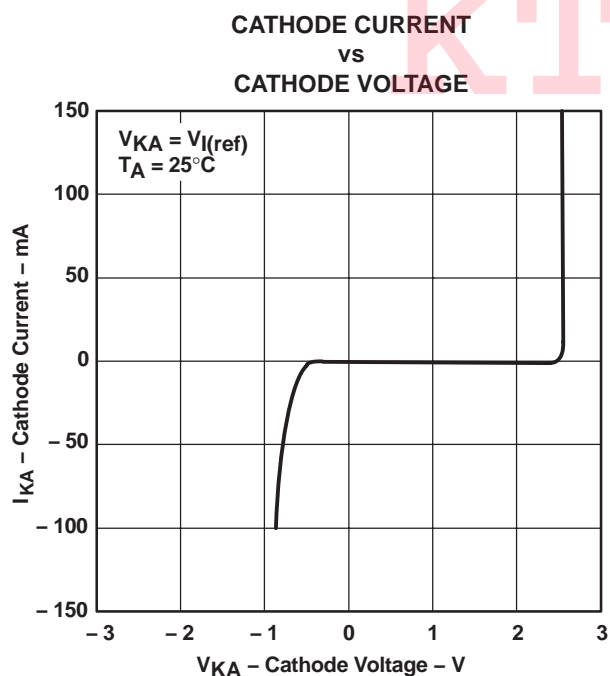CATHODE VOLTAGE**

Figure 6
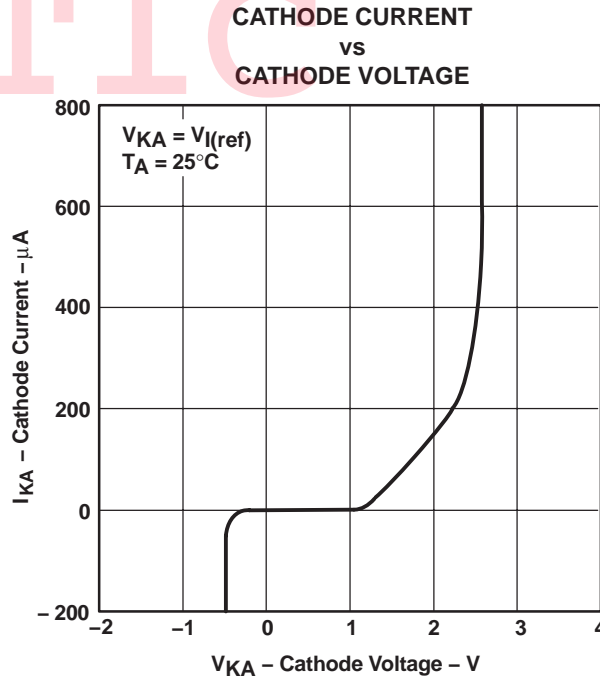
**CATHODE CURRENT
vs
CATHODE VOLTAGE**
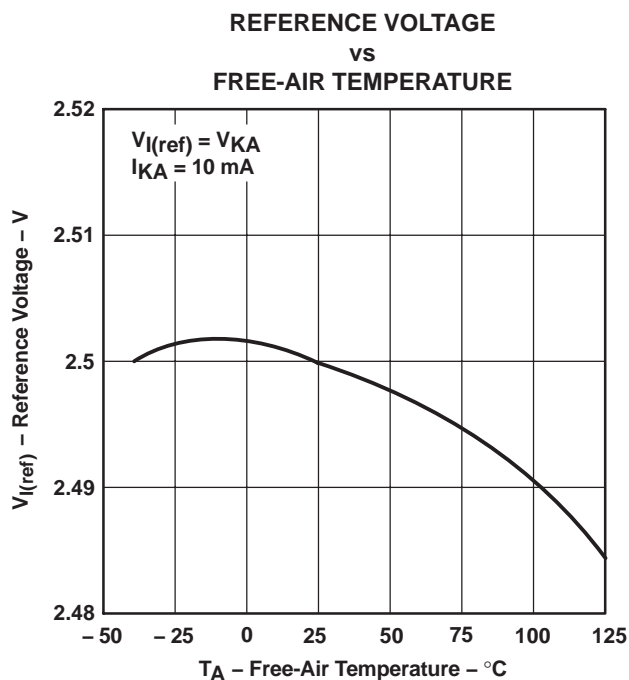
Figure 7

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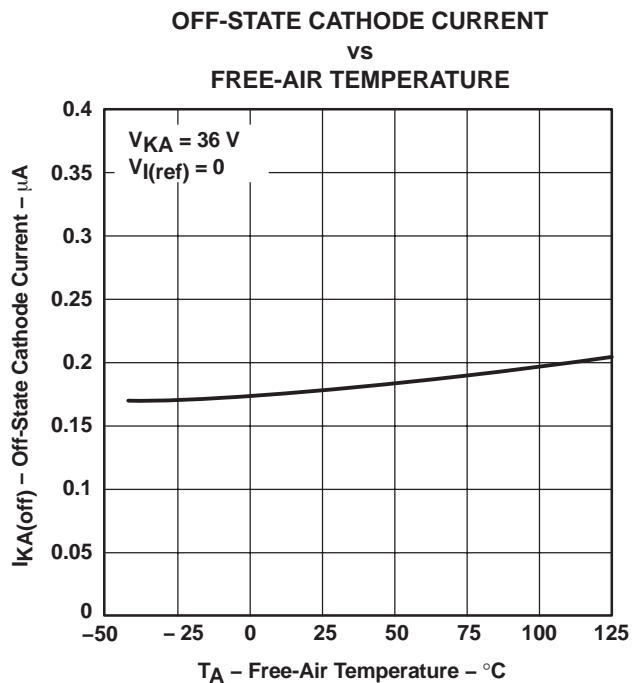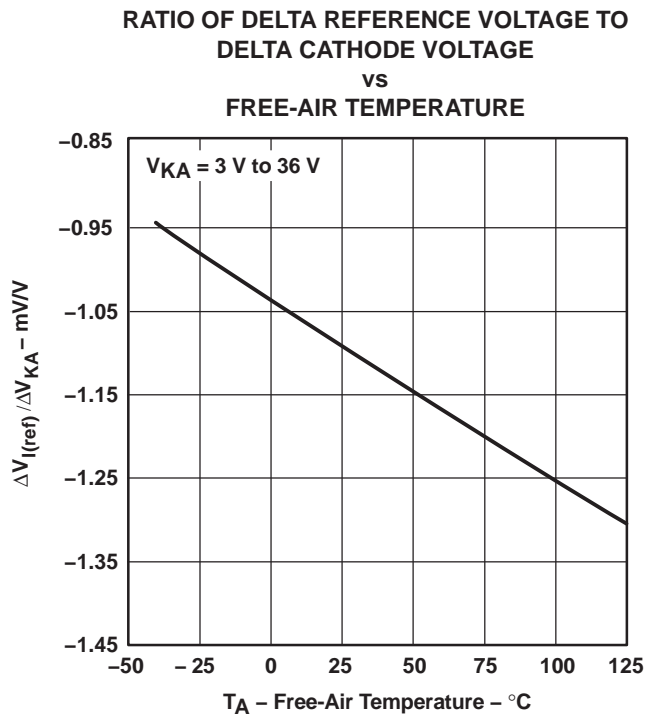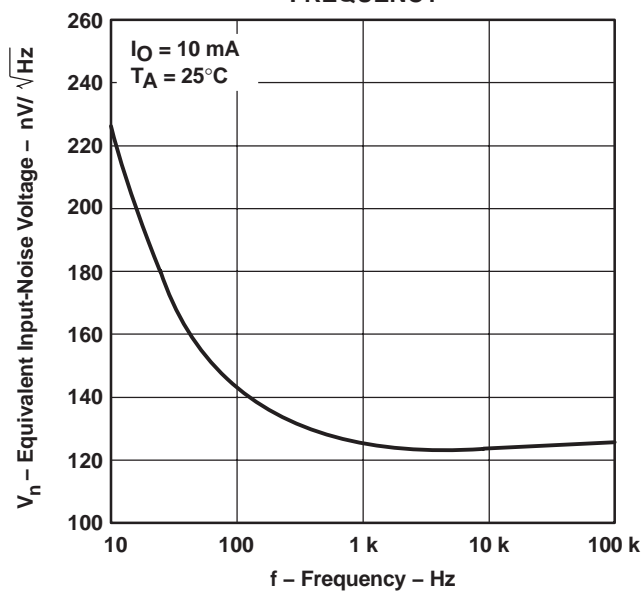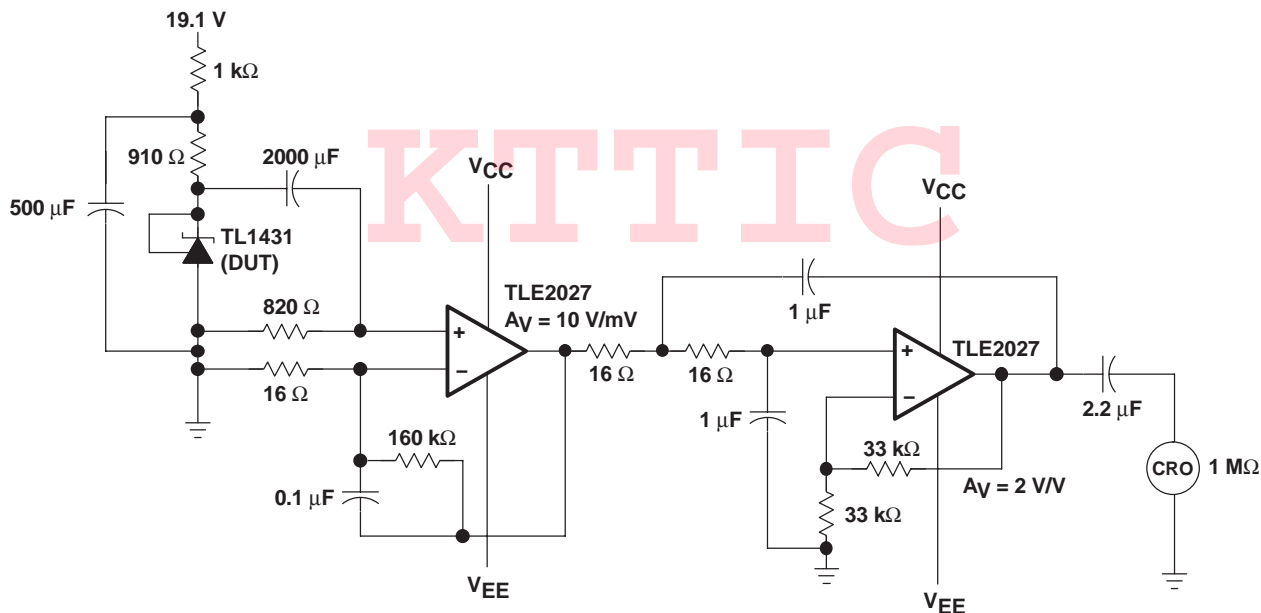
TYPICAL CHARACTERISTICS†

OFF-STATE CATHODE CURRENT
vs
FREE-AIR TEMPERATURE

V_{KA} = 36 V
$V_{I(ref)}$ = 0

Figure 8

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

V_{KA} = 3 V to 36 V

Figure 9

EQUIVALENT INPUT-NOISE VOLTAGE
vs
FREQUENCY

I_O = 10 mA
T_A = 25°C

Figure 10
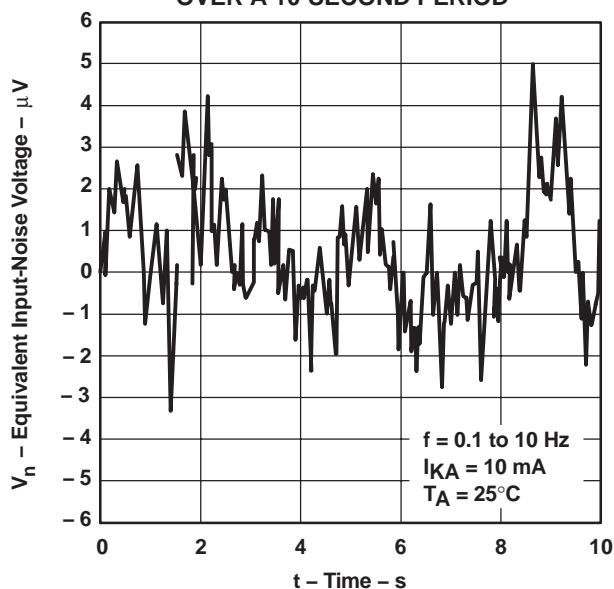
† Data at high and low temperatures are applicable only within the recommended operating free-air temperature ranges of the various devices.

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TYPICAL CHARACTERISTICS

EQUIVALENT INPUT-NOISE VOLTAGE
OVER A 10-SECOND PERIOD

f = 0.1 to 10 Hz
I_{KA} = 10 mA
T_A = 25°C

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

Figure 11

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TYPICAL CHARACTERISTICS

SMALL-SIGNAL VOLTAGE AMPLIFICATION
vs
FREQUENCY

$I_{KA} = 10$ mA
$T_A = 25°C$

TEST CIRCUIT FOR VOLTAGE AMPLIFICATION

Figure 12

REFERENCE IMPEDANCE
vs
FREQUENCY

$I_{KA} = 1$ mA to 100 mA
$T_A = 25°C$

TEST CIRCUIT FOR REFERENCE IMPEDANCE

Figure 13

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TYPICAL CHARACTERISTICS
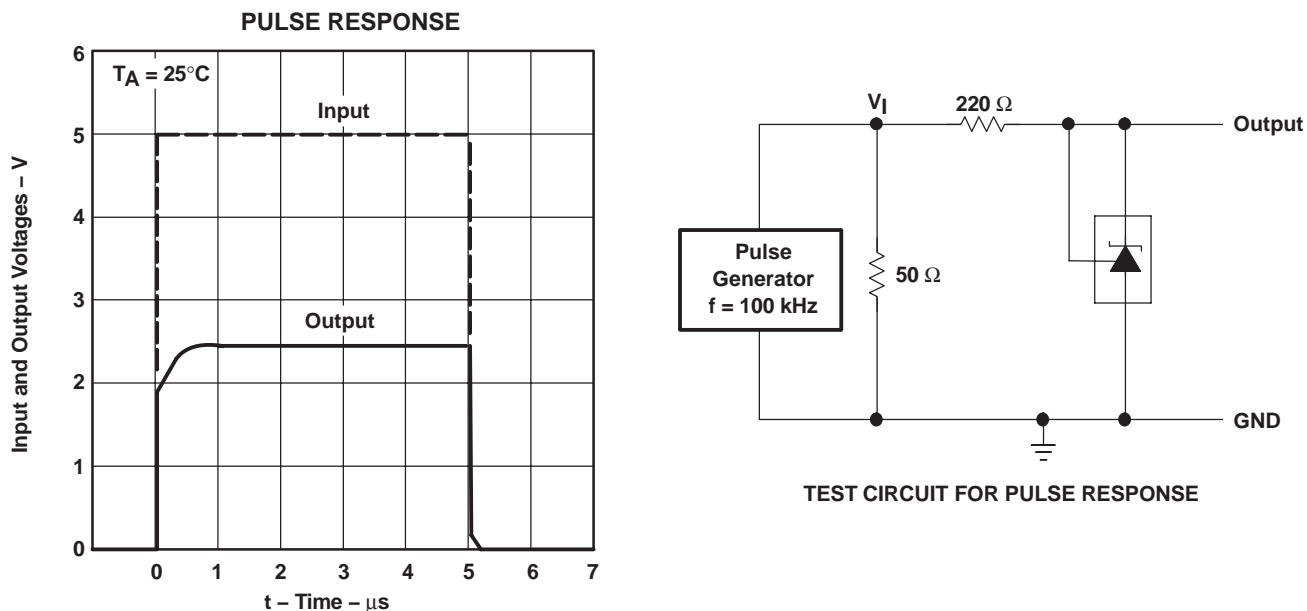
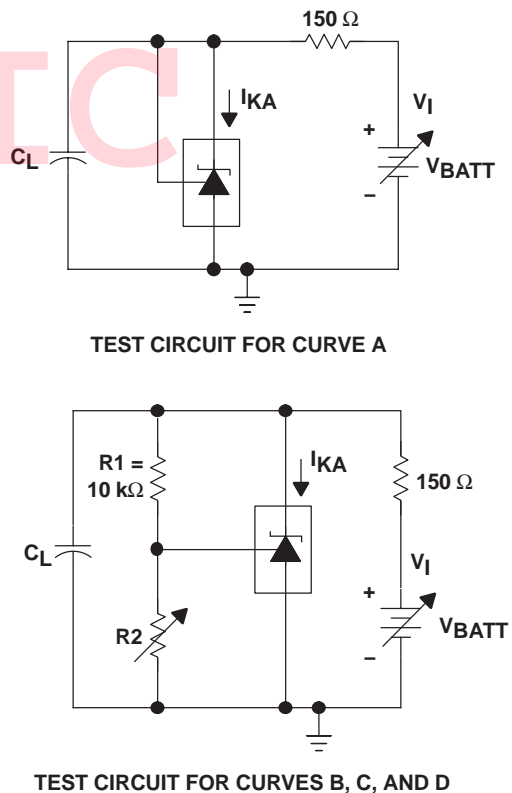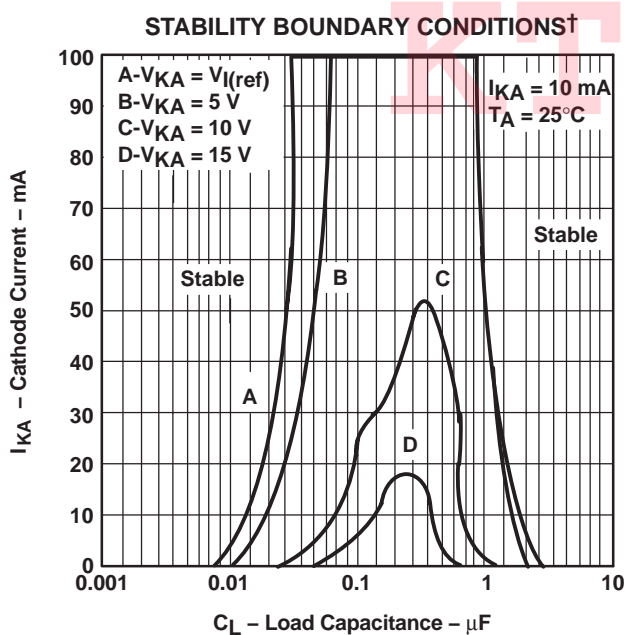## PULSE RESPONSE

Figure 14

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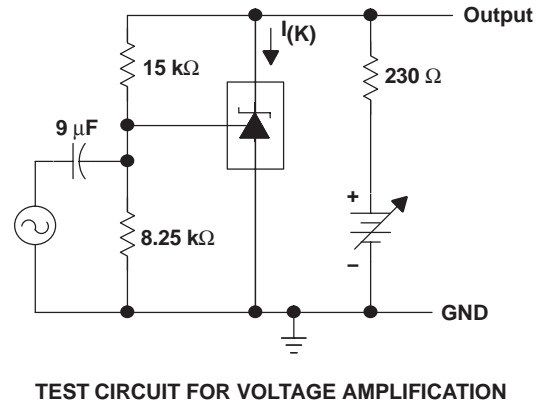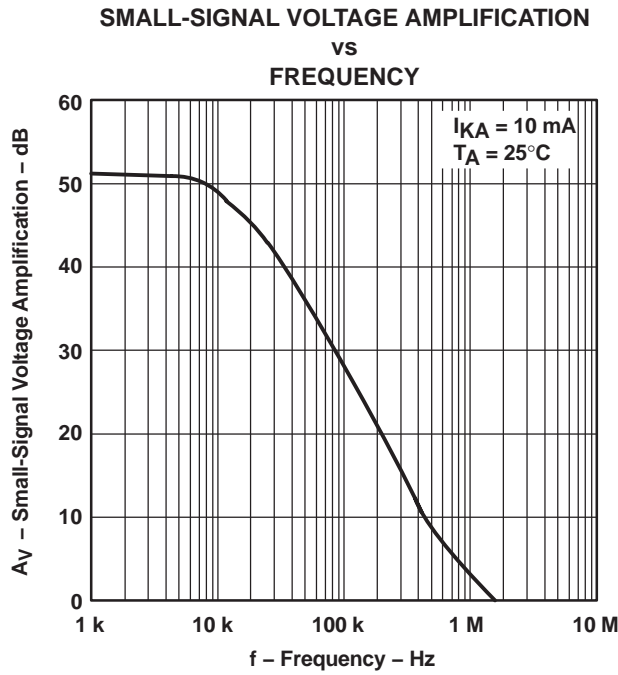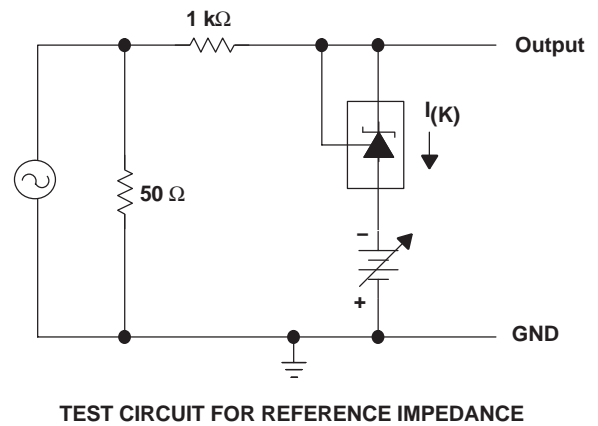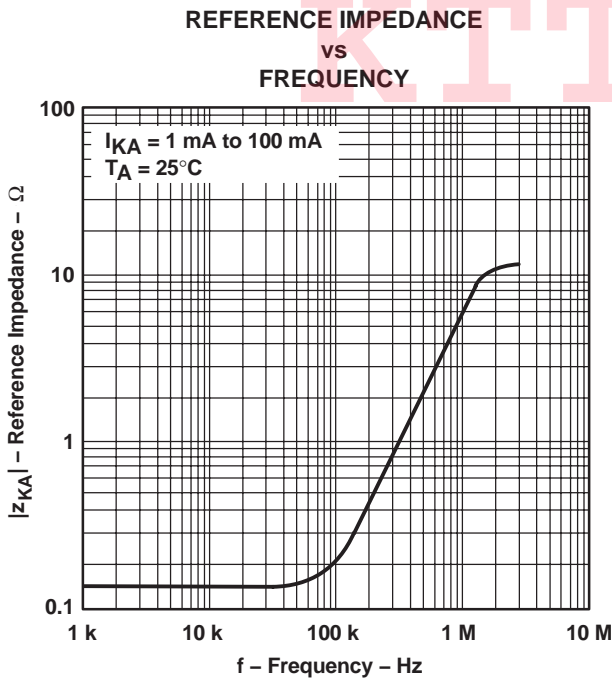
† The areas under the curves represent conditions that may cause the device to oscillate. For curves B, C, and D, R2 and V+ are adjusted to establish the initial V_{KA} and I_{KA} conditions, with $C_L = 0$. V_{BATT} and C_L then are adjusted to determine the ranges of stability.

Figure 15

TEST CIRCUIT FOR PULSE RESPONSE

TEST CIRCUIT FOR CURVE A

TEST CIRCUIT FOR CURVES B, C, AND D

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APPLICATION INFORMATION

Table of Application Circuits

APPLICATION	FIGURE
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Higher-current shunt regulator	20
Crowbar	21
Precision 5-V, 1.5-A, 0.5% regulator	22
5-V precision regulator	23
PWM converter with 0.5% reference	24
Voltage monitor	25
Delay timer	26
Precision current limiter	27
Precision constant-current sink	28

$$V_O = \left(1 + \frac{R1}{R2}\right)V_{I(ref)}$$
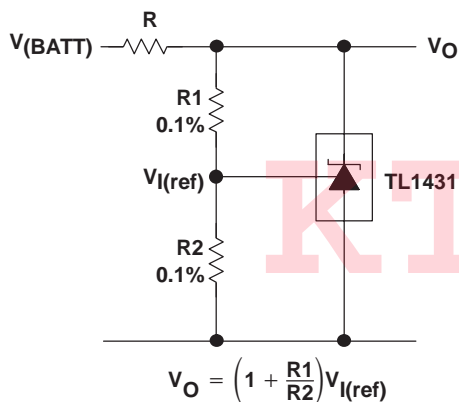
NOTE A: R should provide cathode current ≥1 mA to the TL1431 at minimum $V_{(BATT)}$.

Figure 16. Shunt Regulator
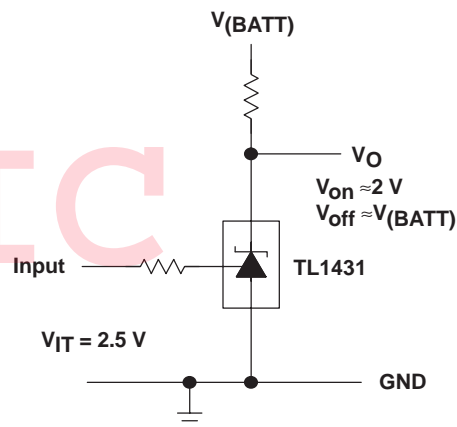
**Figure 17. Single-Supply Comparator
With Temperature-Compensated Threshold**

APPLICATION INFORMATION

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

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

Figure 18. Precision High-Current Series Regulator

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

Min V = $V_{I(ref)}$ + 5 V
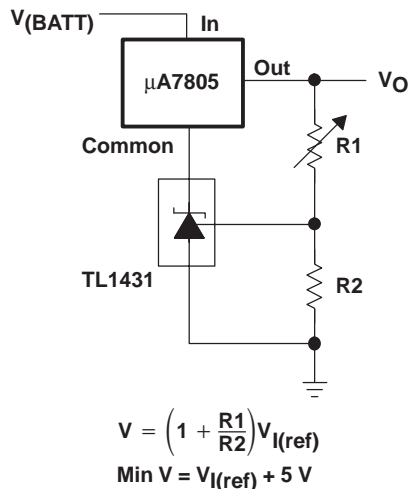
**Figure 19. Output Control of a
Three-Terminal Fixed Regulator**

$$V_O = \left(1 + \frac{R1}{R2}\right)V_{I(ref)}$$
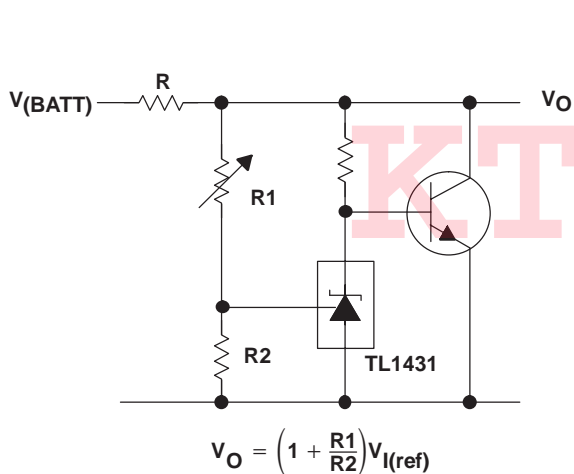
Figure 20. Higher-Current Shunt Regulator

$$V_{trip} = \left(1 + \frac{R1}{R2}\right)V_{I(ref)}$$
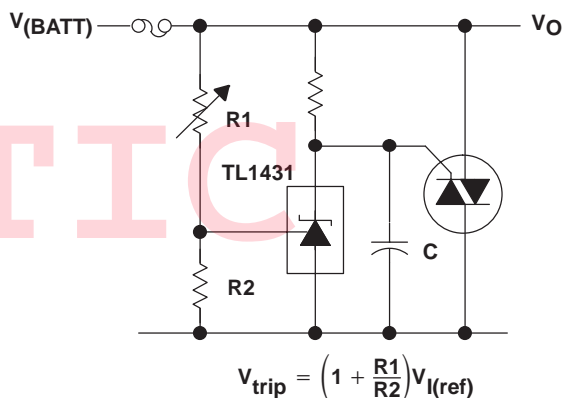
NOTE A: Refer to the stability boundary conditions in Figure 15 to determine allowable values for C.

Figure 21. Crowbar

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APPLICATION INFORMATION

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

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

Figure 23. 5-V Precision Regulator
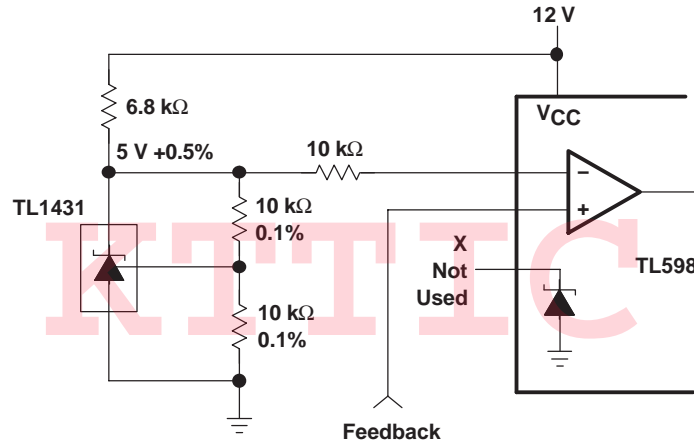
Figure 24. PWM Converter With 0.5% Reference

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APPLICATION INFORMATION

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

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

LED on When
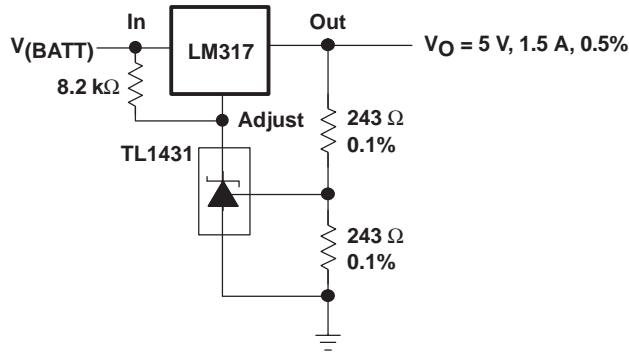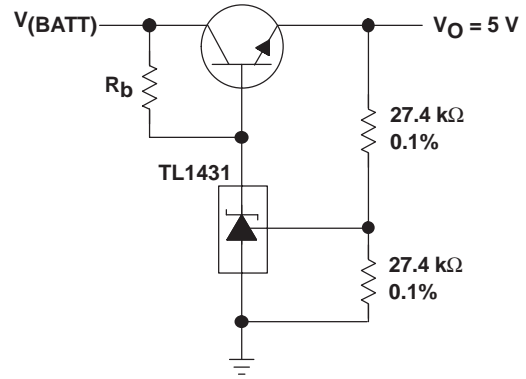**Low Limit < V$_{(BATT)}$ < High Limit**
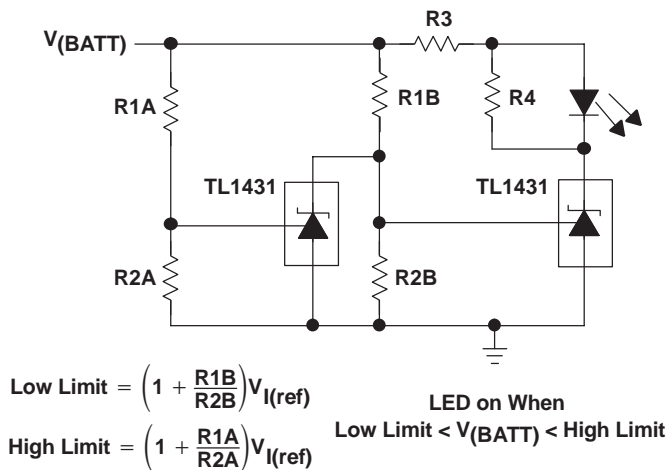
NOTE A: Select R3 and R4 to provide the desired LED intensity and cathode current ≥1 mA to the TL1431.

Figure 25. Voltage Monitor

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

Figure 26. Delay Timer

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

$$R1 = \frac{V_{(BATT)}}{\left(\dfrac{I_O}{h_{FE}}\right) + I_{KA}}$$
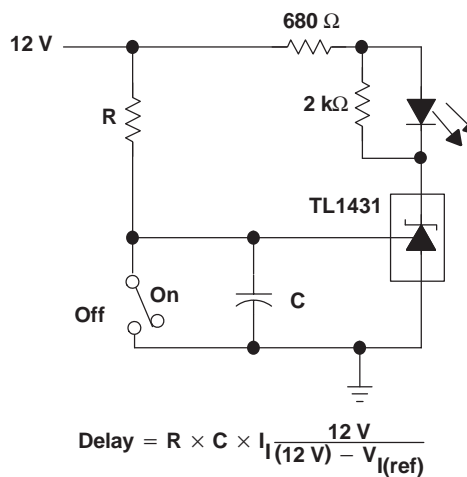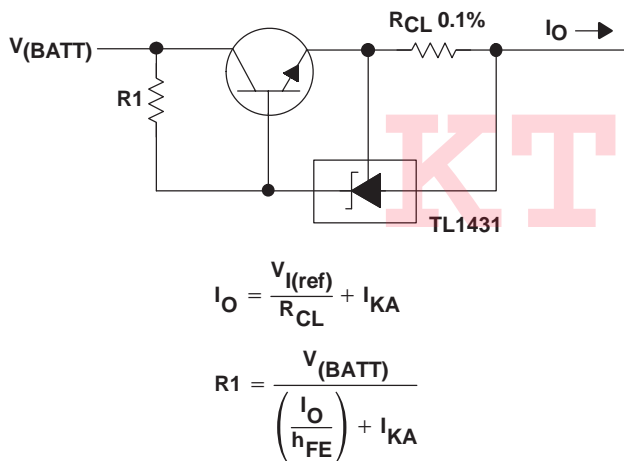
Figure 27. Precision Current Limiter

$$I_O = \frac{V_{I(ref)}}{R_S}$$
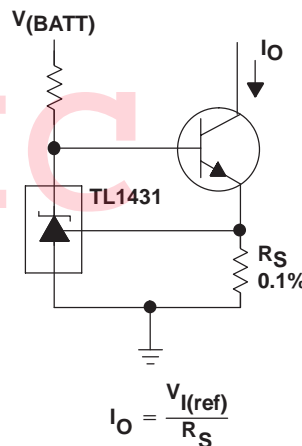
Figure 28. Precision Constant-Current Sink

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PACKAGING INFORMATION

Orderable Device	Status [1]	Package Type	Package Drawing	Pins	Package Qty	Eco Plan [2]	Lead/Ball Finish	MSL Peak Temp [3]
TL1431QDRG4Q1	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TL1431QDRQ1	ACTIVE	SOIC	D	8	2500	Pb-Free (RoHS)	CU NIPDAU	Level-2-250C-1 YEAR/ Level-1-235C-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 TL1431-Q1 :
● Catalog: TL1431
● Enhanced Product: TL1431-EP
● Military: TL1431M
● Space: TL1431-SP

NOTE: Qualified Version Definitions:
    ● Catalog - TI's standard catalog product
    ● Enhanced Product - Supports Defense, Aerospace and Medical Applications
    ● Military - QML certified for Military and Defense Applications
    ● Space - Radiation tolerant, ceramic packaging and qualified for use in Space-based application

MECHANICAL DATA

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

0.197 (5,00)
0.189 (4,80)
Ⓒ

8   5

0.244 (6,20)
0.228 (5,80)

0.157 (4,00)
0.150 (3,80) △D

Pin 1
Index Area

1   4

0.050 (1,27)

0.020 (0,51)
0.012 (0,31)

⊕ 0.010 (0,25) Ⓜ

0.069 (1,75) Max

0.010 (0,25)
0.004 (0,10)

0.010 (0,25)
0.005 (0,13)

0.004 (0,10)

Gauge Plane

Seating Plane

0.010 (0,25)   0°−8°

0.050 (1,27)
0.016 (0,40)

4040047−3/J   09/09
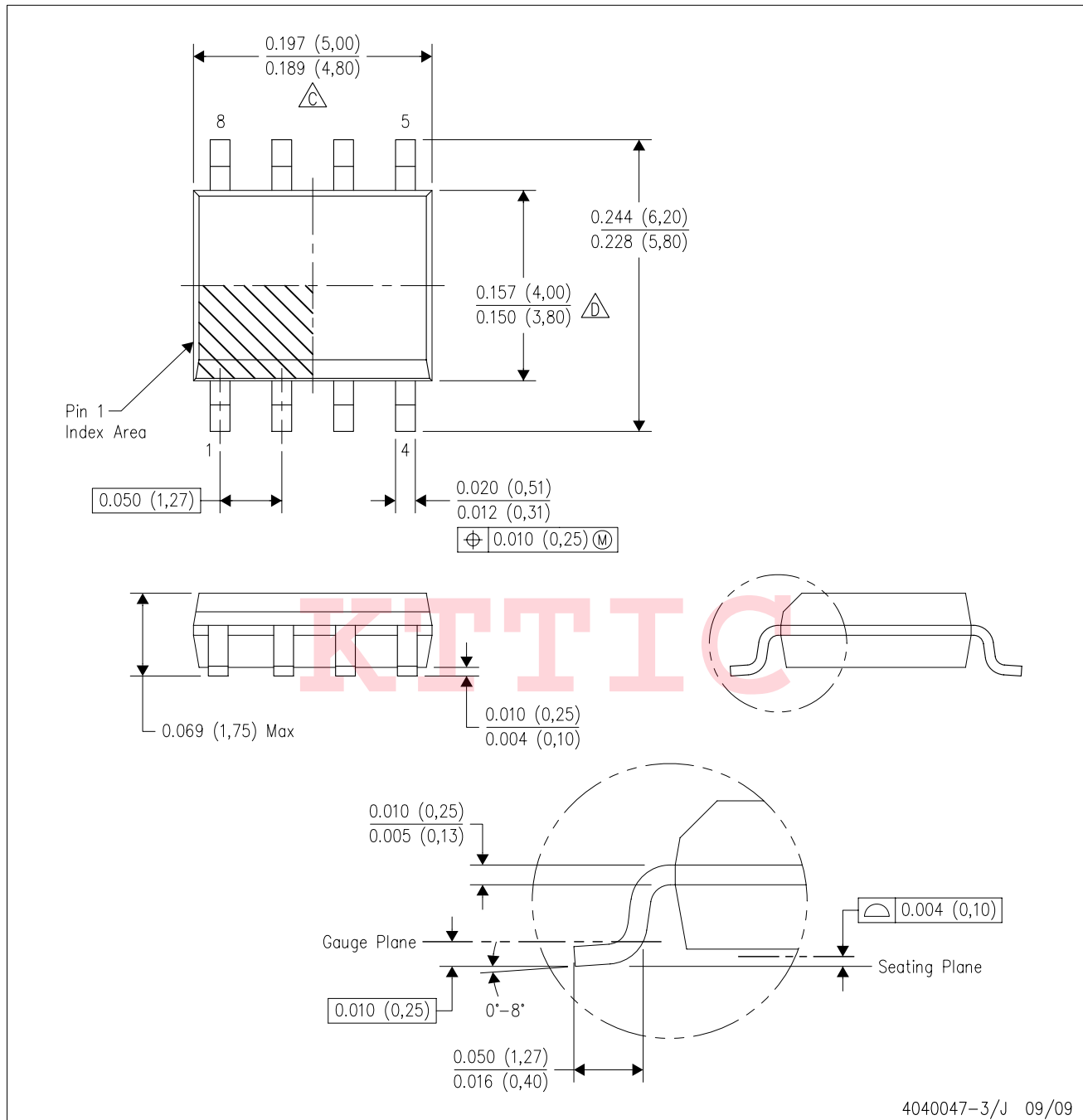
NOTES: A.   All linear dimensions are in inches (millimeters).
          B.   This drawing is subject to change without notice.
         △C   Body length does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall
               not exceed .006 (0,15) per end.
         △D   Body width does not include interlead flash. Interlead flash shall not exceed .017 (0,43) per side.
          E.   Reference JEDEC MS−012 variation AA.

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