● **Qualified for Automotive Applications**
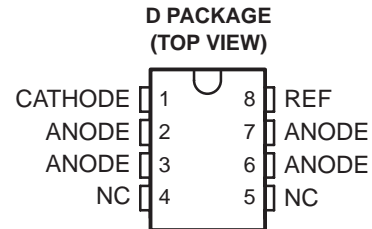
● **0.4% Initial Voltage Tolerance**

● **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.

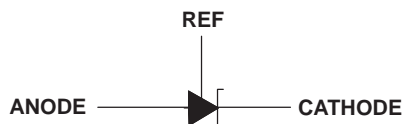The TL1431Q is characterized for operation over the full automotive temperature range of –40°C to 125°C.

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**

TEXAS INSTRUMENTS

POST OFFICE BOX 655303 ● DALLAS, TEXAS 75265

1

functional block diagram
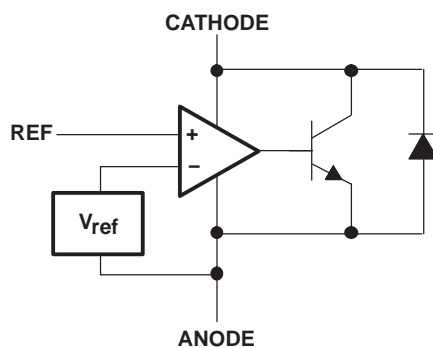
equivalent schematic†
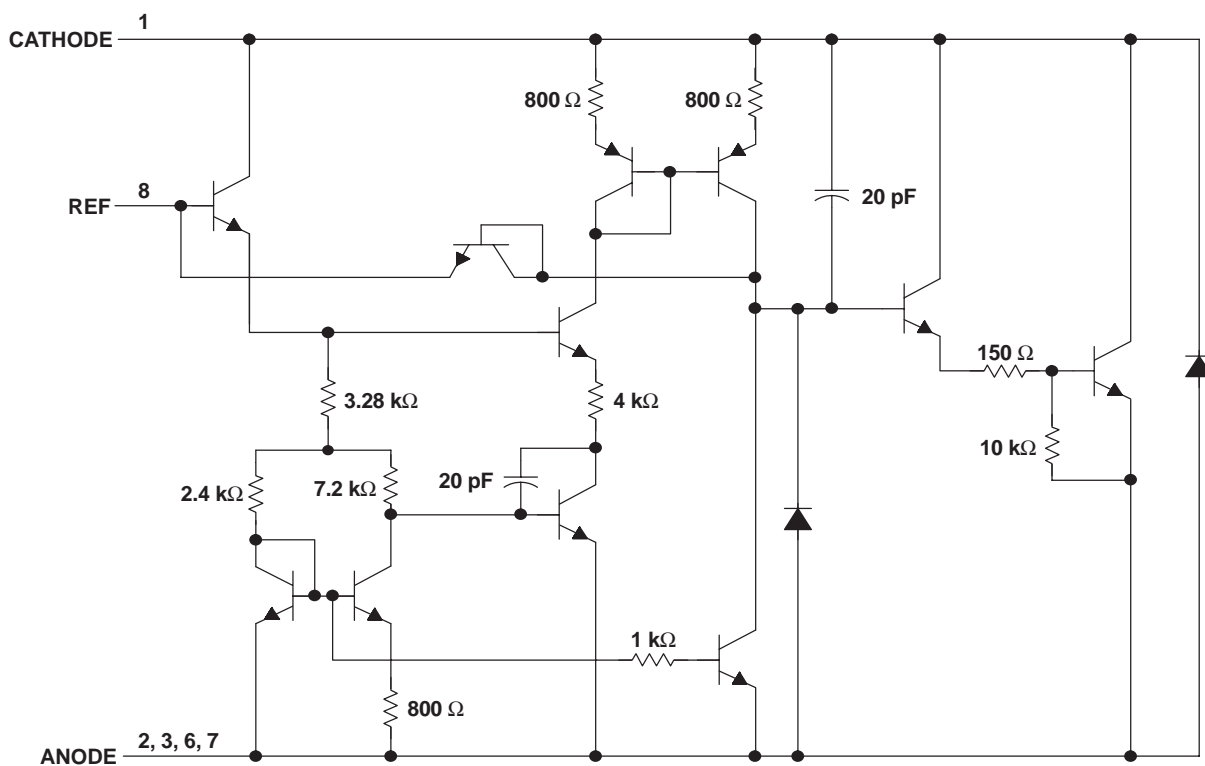
† All component values are nominal.

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, $I_{I(ref)}$	−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

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:

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

where:

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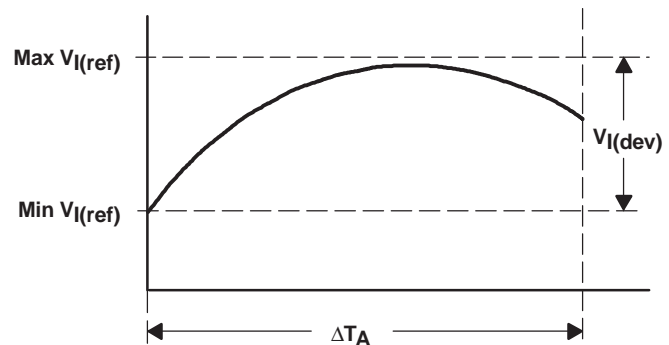
$\alpha_{V_{I(ref)}}$ is positive or negative, depending on whether minimum $V_{I(ref)}$ or maximum $V_{I(ref)}$, respectively, occurs at the lower temperature.

§ 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 $|z_{KA}| \left(1 + \dfrac{R1}{R2} \right)$.
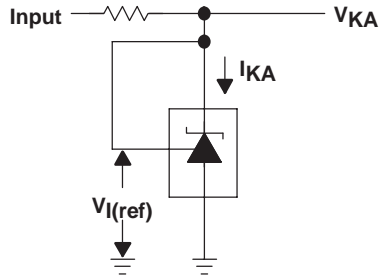
TEXAS
INSTRUMENTS

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PARAMETER MEASUREMENT INFORMATION

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

$$V_{KA} = V_{I(ref)} \left(1 + \frac{R1}{R2} \right) + I_{I(ref)} \times R1$$
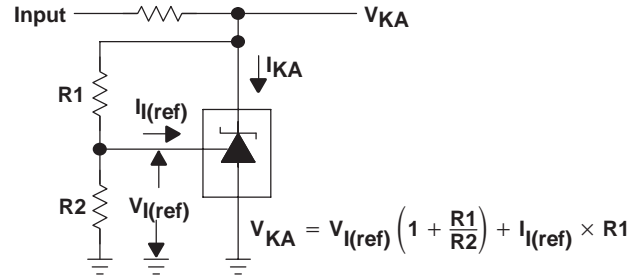
Figure 2. Test Circuit for $V_{(KA)} > V_{ref}$
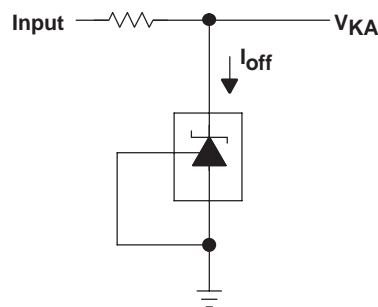
Figure 3. Test Circuit for I_{off}

TYPICAL CHARACTERISTICS

Table of Graphs

	FIGURE
Reference voltage vs Free-air temperature	4
Reference current vs Free-air temperature	5
Cathode current vs Cathode voltage	6, 7
Off-state cathode current vs Free-air temperature	8
Ratio of delta reference voltage to delta cathode voltage vs Free-air temperature	9
Equivalent input-noise voltage vs Frequency	10
Equivalent input-noise voltage over a 10-second period	11
Small-signal voltage amplification vs Frequency	12
Reference impedance vs Frequency	13
Pulse response	14
Stability boundary conditions	15

TYPICAL CHARACTERISTICS†

REFERENCE VOLTAGE
vs
FREE-AIR TEMPERATURE

$V_{I(ref)} = V_{KA}$
$I_{KA} = 10$ mA

Figure 4

REFERENCE CURRENT
vs
FREE-AIR TEMPERATURE

$I_{KA} = 10$ mA
R1 = 10 kΩ
R2 = ∞

Figure 5

CATHODE CURRENT
vs
CATHODE VOLTAGE

$V_{KA} = V_{I(ref)}$
$T_A = 25°C$

Figure 6

CATHODE CURRENT
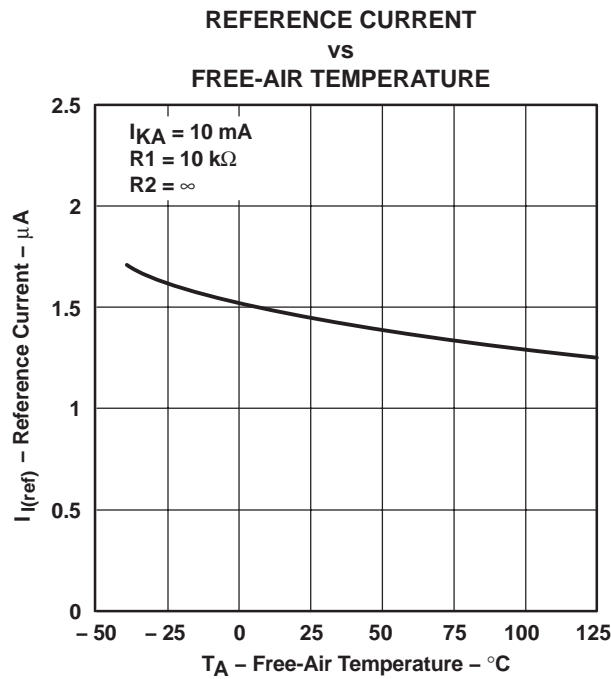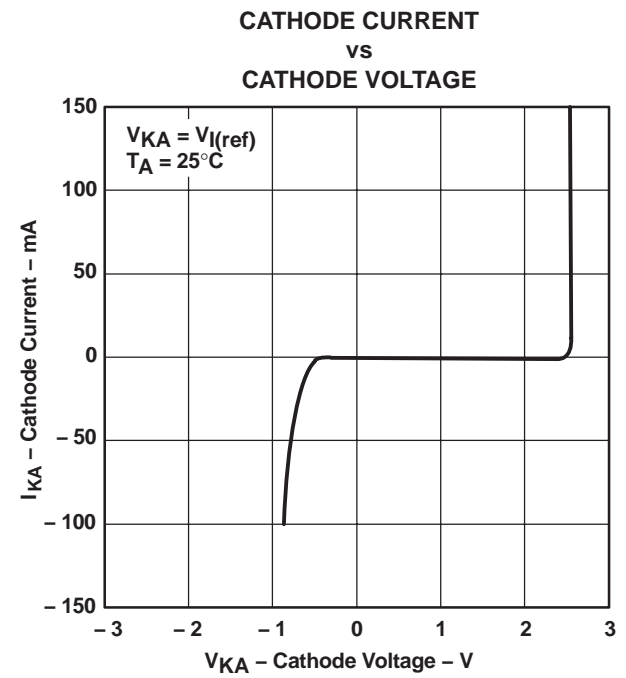**vs**
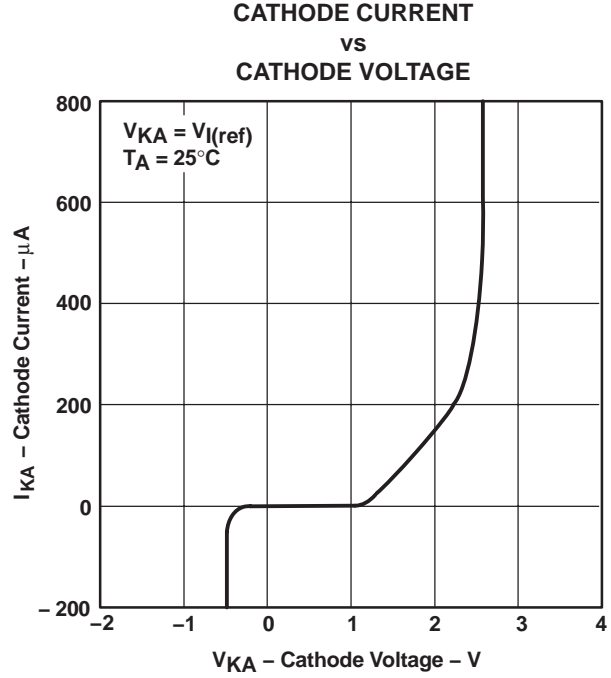**CATHODE VOLTAGE**

$V_{KA} = V_{I(ref)}$
$T_A = 25°C$
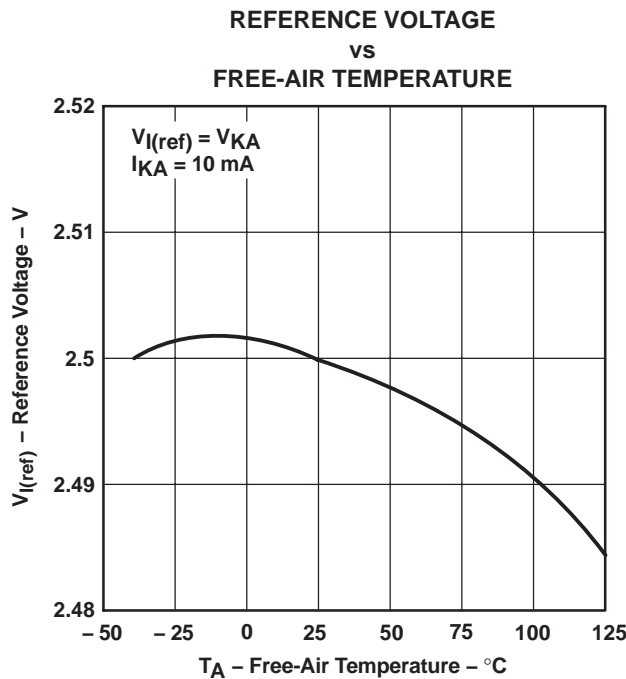
Figure 7

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

![Texas Instruments logo]
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TYPICAL CHARACTERISTICS[†]

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

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

Y-axis: $I_{KA(off)}$ – Off-State Cathode Current – µA
X-axis: T_A – Free-Air Temperature – °C

Figure 8

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

$V_{KA} = 3$ V to 36 V

Y-axis: $\Delta V_{I(ref)} / \Delta V_{KA}$ – mV/V
X-axis: T_A – Free-Air Temperature – °C

Figure 9

**EQUIVALENT INPUT-NOISE VOLTAGE
vs
FREQUENCY**

$I_O = 10$ mA
$T_A = 25$°C

Y-axis: V_n – Equivalent Input-Noise Voltage – nV/$\sqrt{Hz}$
X-axis: f – Frequency – Hz

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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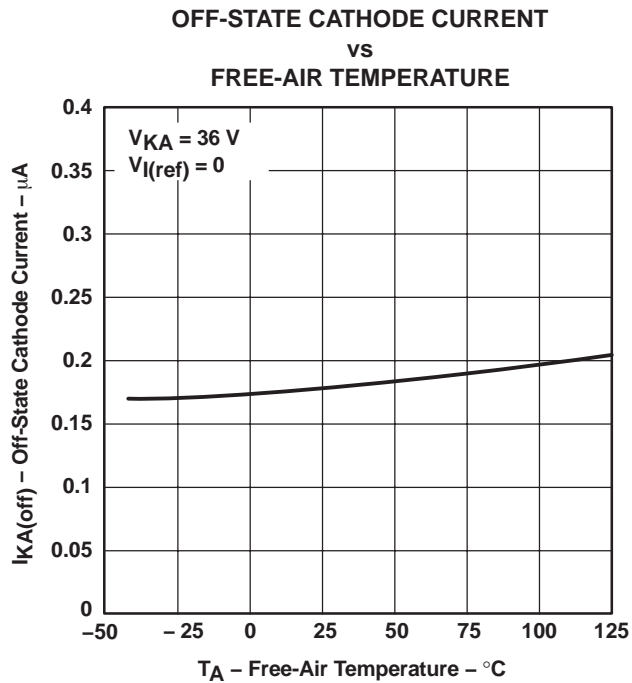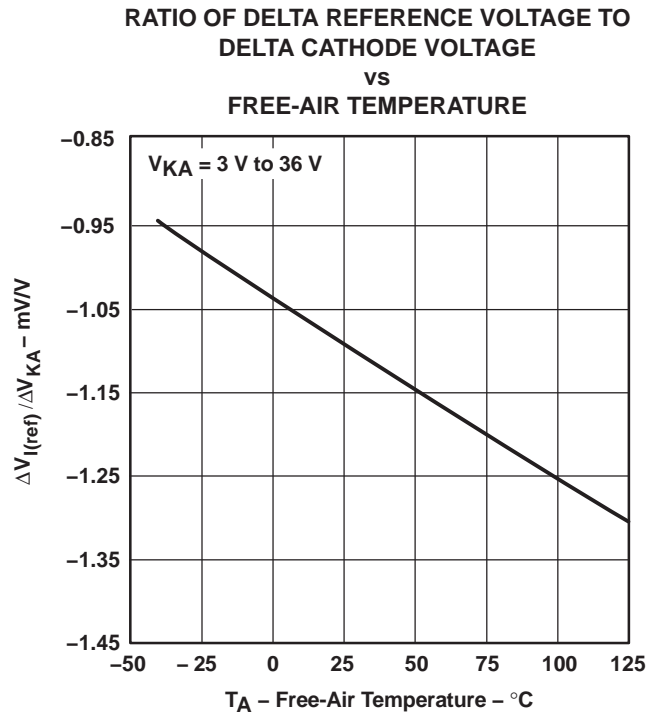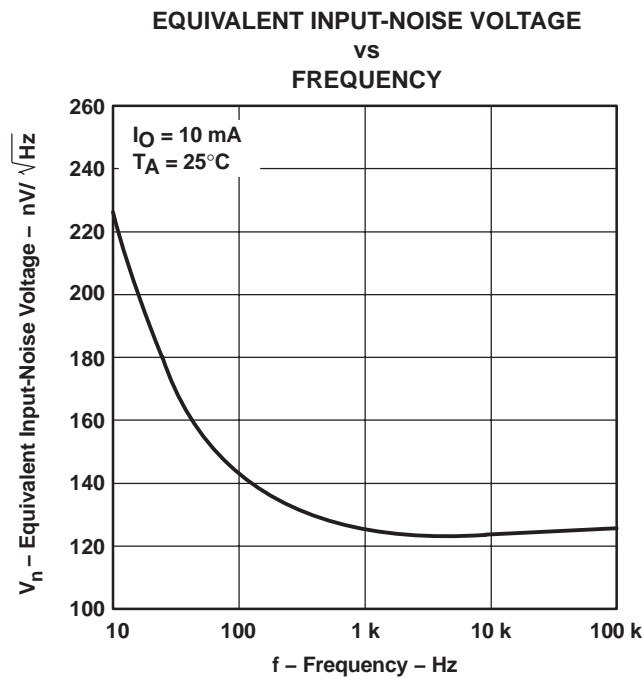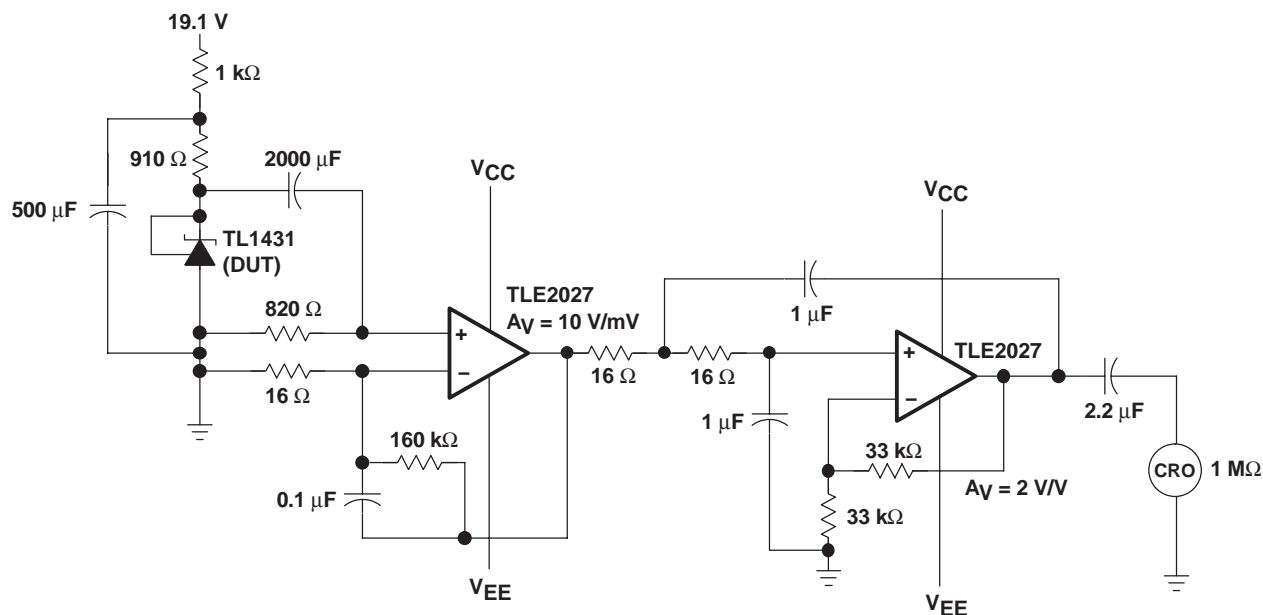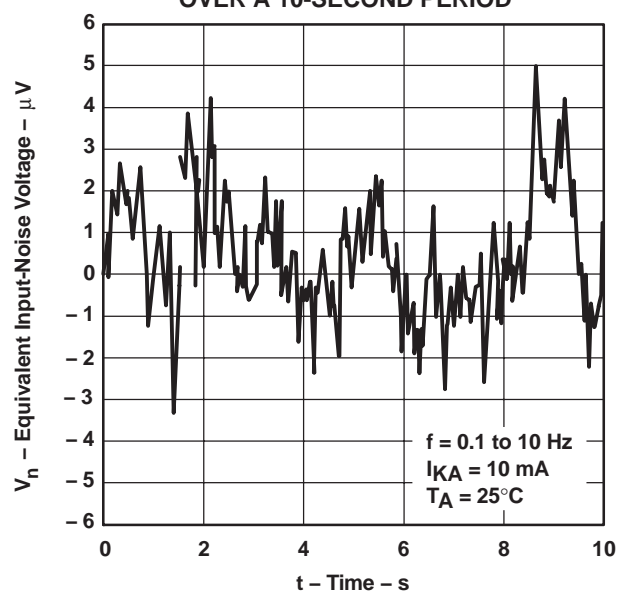## TYPICAL CHARACTERISTICS

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

Figure 12

REFERENCE IMPEDANCE
vs
FREQUENCY
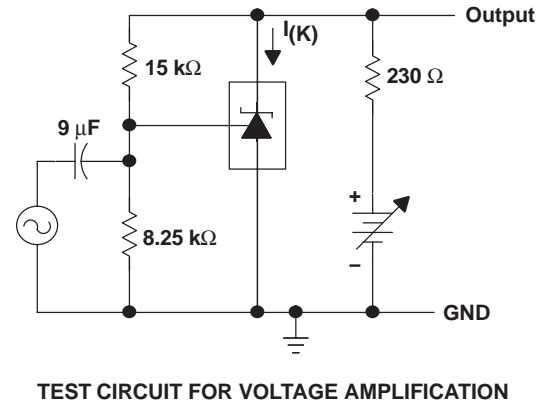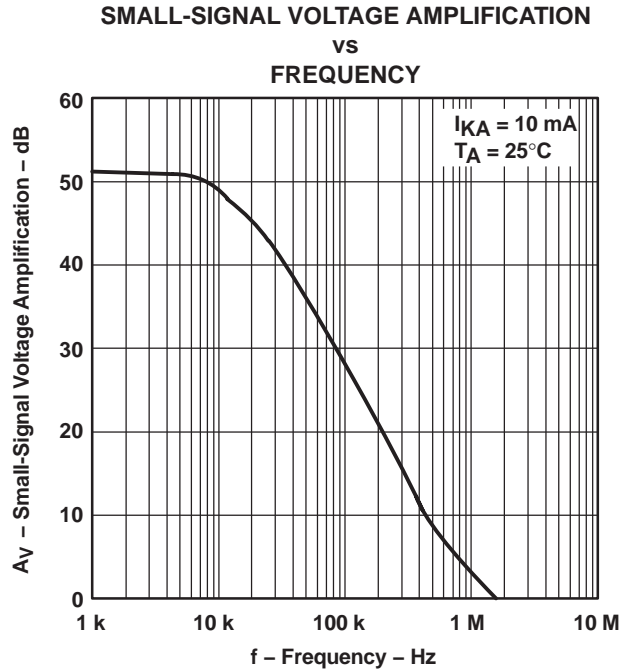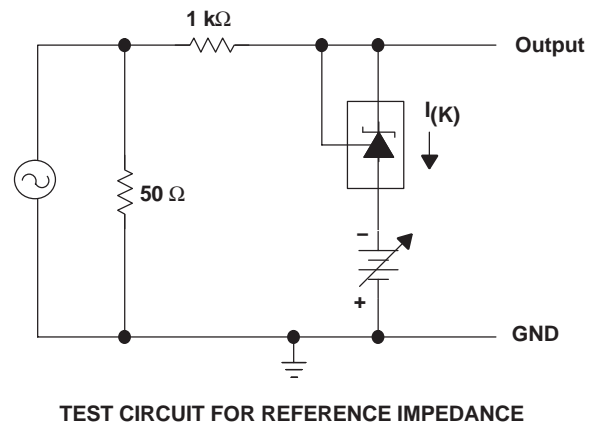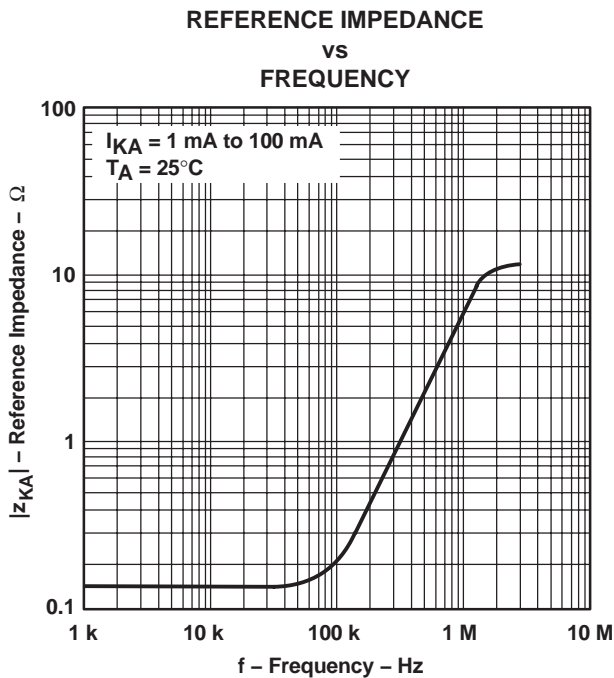
Figure 13

TL1431-Q1
PRECISION PROGRAMMABLE REFERENCE

TYPICAL CHARACTERISTICS

PULSE RESPONSE

TEST CIRCUIT FOR PULSE RESPONSE

Figure 14

STABILITY BOUNDARY CONDITIONS†

A-V_{KA} = $V_{I(ref)}$
B-V_{KA} = 5 V
C-V_{KA} = 10 V
D-V_{KA} = 15 V

I_{KA} = 10 mA
T_A = 25°C

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+ 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

TEXAS INSTRUMENTS
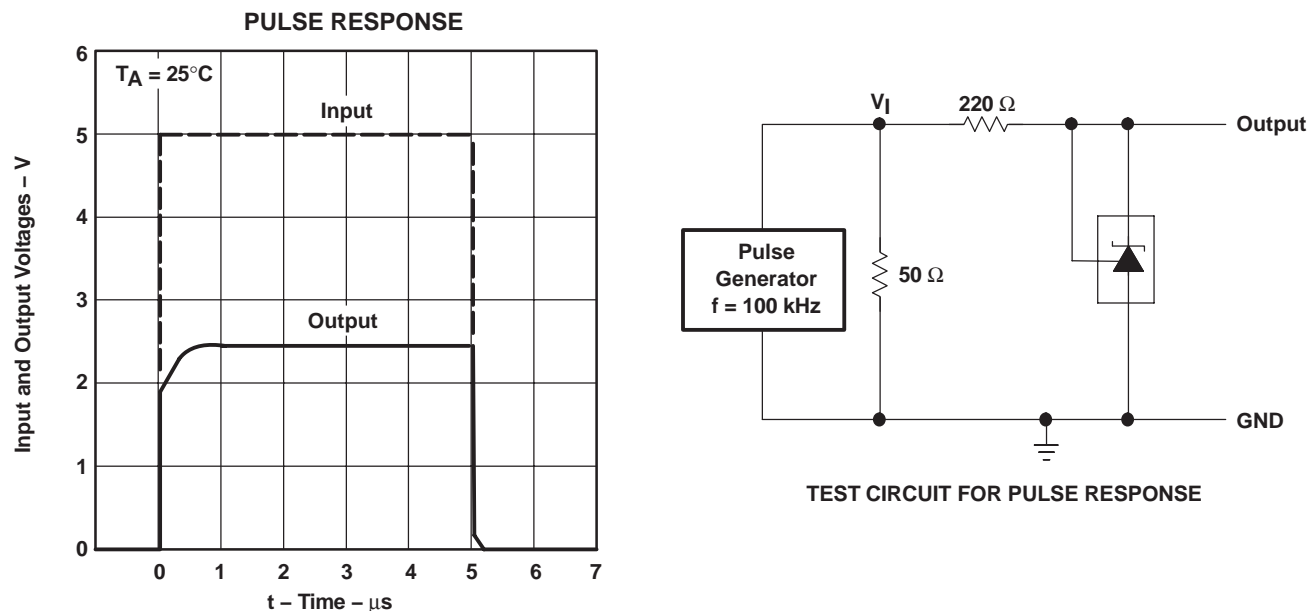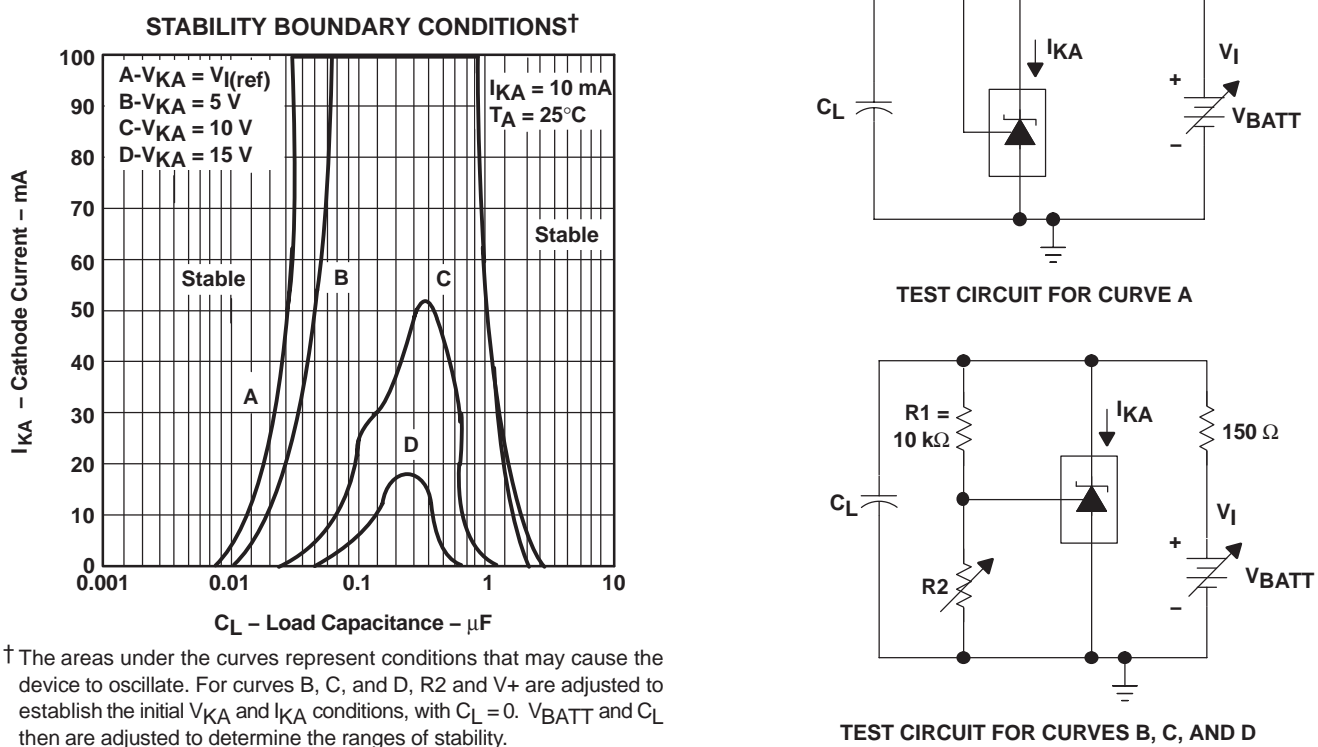
APPLICATION INFORMATION

Table of Application Circuits

APPLICATION	FIGURE
Shunt regulator	16
Single-supply comparator with temperature-compensated threshold	17
Precision high-current series regulator	18
Output control of a three-terminal fixed regulator	19
Higher-current shunt regulator	20
Crowbar	21
Precision 5-V, 1.5-A, 0.5% regulator	22
5-V precision regulator	23
PWM converter with 0.5% reference	24
Voltage monitor	25
Delay timer	26
Precision current limiter	27
Precision constant-current sink	28

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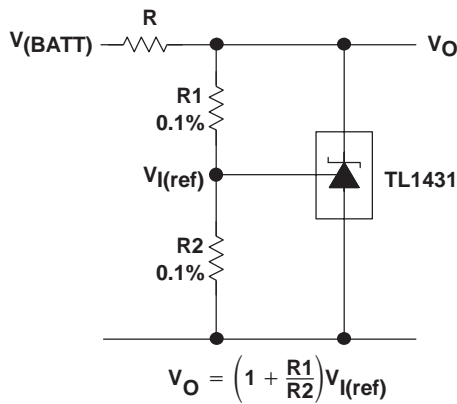
NOTE A: R should provide cathode current ≥1 mA to the TL1431 at minimum $V_{(BATT)}$.

Figure 16. Shunt Regulator

$V_{on} \approx 2\ V$
$V_{off} \approx V_{(BATT)}$

$V_{IT} = 2.5\ V$
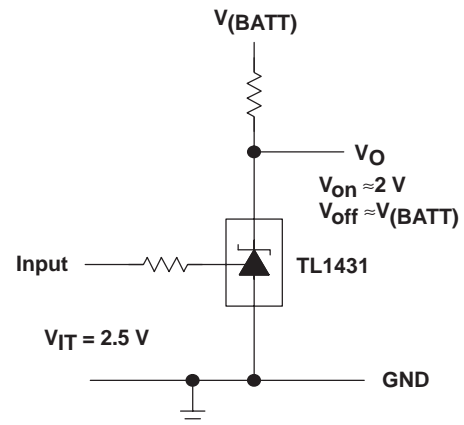
**Figure 17. Single-Supply Comparator
With Temperature-Compensated Threshold**

APPLICATION INFORMATION

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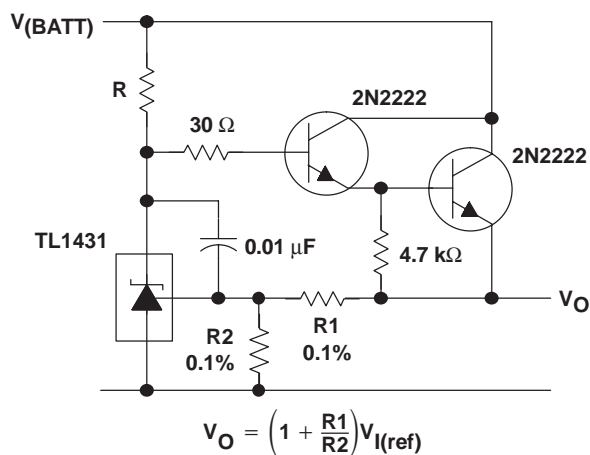
NOTE A: R should provide cathode current ≥1 mA to the TL1431 at minimum $V_{(BATT)}$.

Figure 18. Precision High-Current Series Regulator

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

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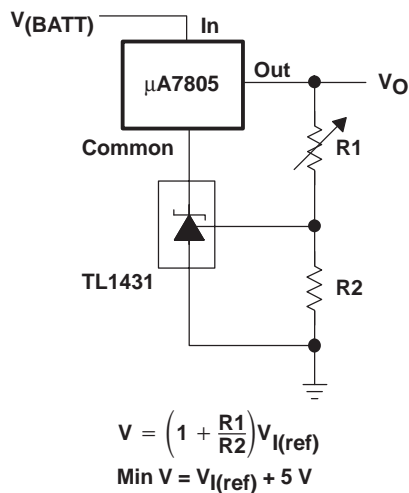
**Figure 19. Output Control of a
Three-Terminal Fixed Regulator**

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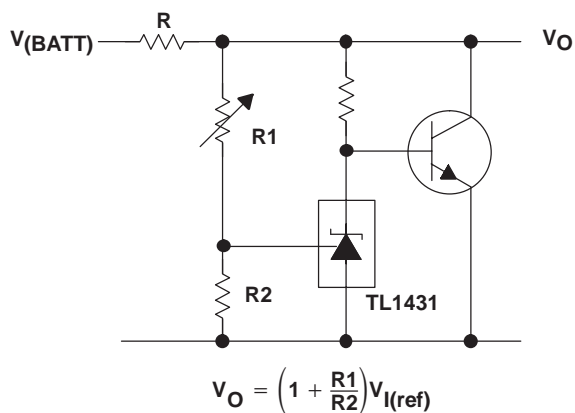
Figure 20. Higher-Current Shunt Regulator

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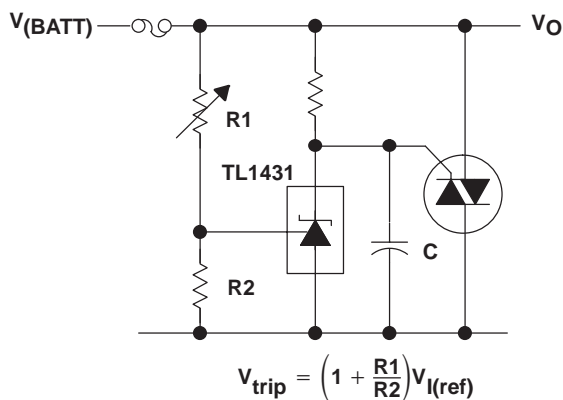
NOTE A: Refer to the stability boundary conditions in Figure 15 to determine allowable values for C.

Figure 21. Crowbar

APPLICATION INFORMATION

Figure 22. Precision 5-V, 1.5-A, 0.5% Regulator
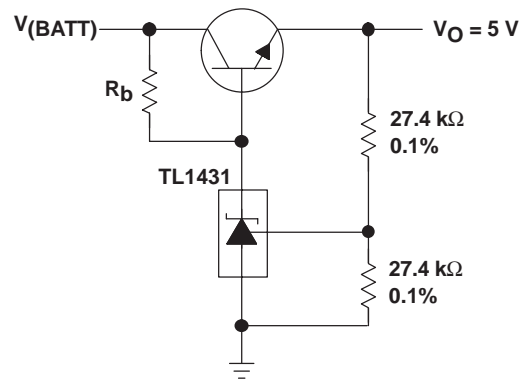
NOTE A: R_b should provide cathode current ≥1 mA to the TL1431.

Figure 23. 5-V Precision Regulator
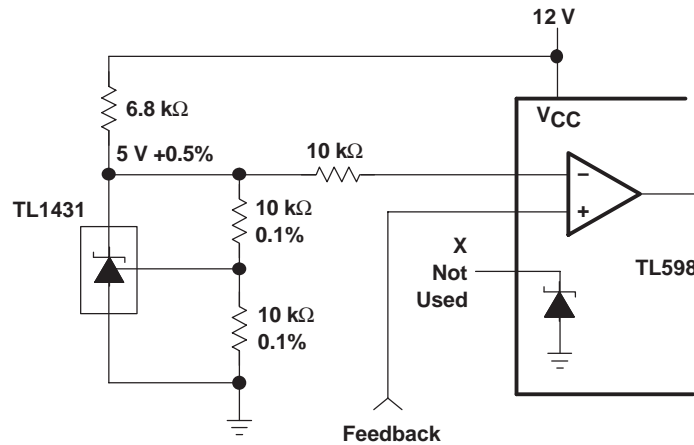
Figure 24. PWM Converter With 0.5% Reference
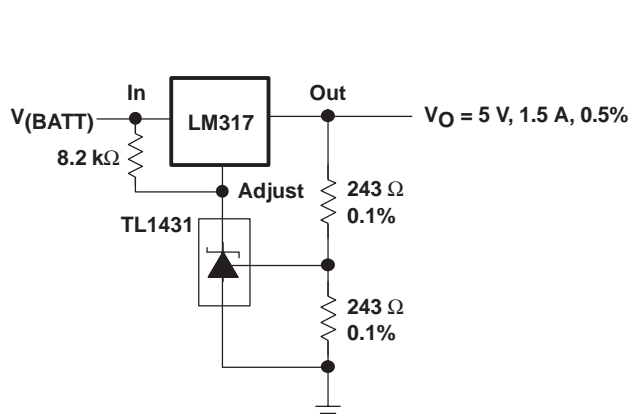
TL1431-Q1
PRECISION PROGRAMMABLE REFERENCE

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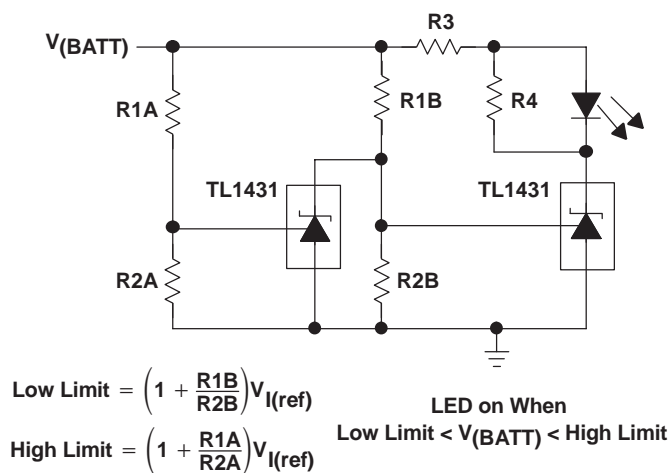
NOTE A: Select R3 and R4 to provide the desired LED intensity and cathode current ≥1 mA to the TL1431.

Figure 25. Voltage Monitor

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

Figure 26. Delay Timer

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

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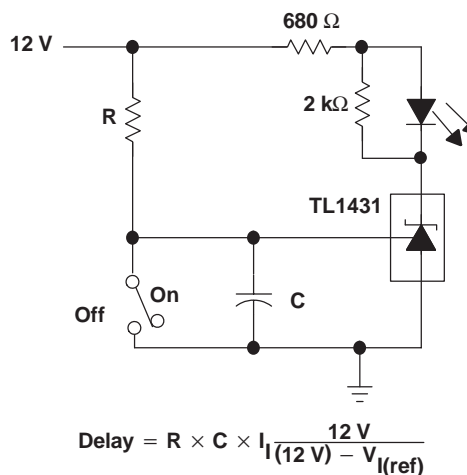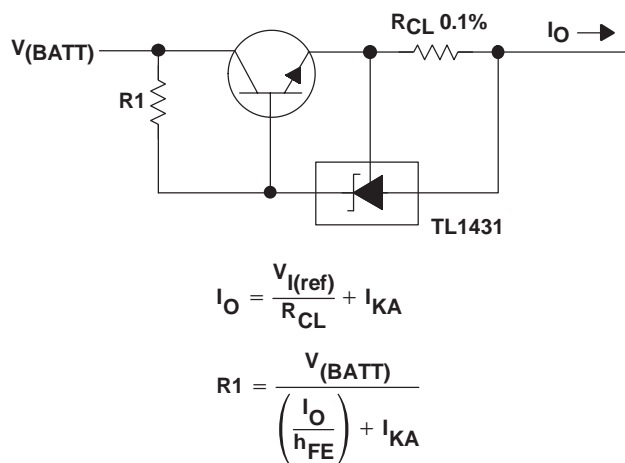
Figure 27. Precision Current Limiter

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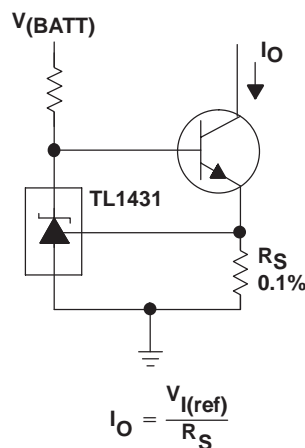
Figure 28. Precision Constant-Current Sink

PACKAGE OPTION ADDENDUM

PACKAGING INFORMATION

Orderable part number	Status (1)	Material type (2)	Package | Pins	Package qty | Carrier	RoHS (3)	Lead finish/ Ball material (4)	MSL rating/ Peak reflow (5)	Op temp (°C)	Part marking (6)
TL1431QDRG4Q1	Active	Production	SOIC (D) | 8	2500 | LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	1431Q1
TL1431QDRG4Q1.A	Active	Production	SOIC (D) | 8	2500 | LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	1431Q1
TL1431QDRQ1	Active	Production	SOIC (D) | 8	2500 | LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	1431Q1
TL1431QDRQ1.A	Active	Production	SOIC (D) | 8	2500 | LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	1431Q1

(1) Status: For more details on status, see our product life cycle.

(2) Material type: When designated, preproduction parts are prototypes/experimental devices, and are not yet approved or released for full production. Testing and final process, including without limitation quality assurance, reliability performance testing, and/or process qualification, may not yet be complete, and this item is subject to further changes or possible discontinuation. If available for ordering, purchases will be subject to an additional waiver at checkout, and are intended for early internal evaluation purposes only. These items are sold without warranties of any kind.

(3) RoHS values: Yes, No, RoHS Exempt. See the TI RoHS Statement for additional information and value definition.

(4) Lead finish/Ball material: Parts may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material values may wrap to two lines if the finish value exceeds the maximum column width.

(5) MSL rating/Peak reflow: The moisture sensitivity level ratings and peak solder (reflow) temperatures. In the event that a part has multiple moisture sensitivity ratings, only the lowest level per JEDEC standards is shown. Refer to the shipping label for the actual reflow temperature that will be used to mount the part to the printed circuit board.

(6) Part marking: There may be an additional marking, which relates to the logo, the lot trace code information, or the environmental category of the part.

Multiple part markings will be inside parentheses. Only one part marking contained in parentheses and separated by a "~" will appear on a part. If a line is indented then it is a continuation of the previous line and the two combined represent the entire part marking for that device.

Important Information and Disclaimer: The information provided on this page represents TI's knowledge and belief as of the date that it is provided. TI bases its knowledge and belief on information provided by third parties, and makes no representation or warranty as to the accuracy of such information. Efforts are underway to better integrate information from third parties. TI has taken and continues to take reasonable steps to provide representative and accurate information but may not have conducted destructive testing or chemical analysis on incoming materials and chemicals. TI and TI suppliers consider certain information to be proprietary, and thus CAS numbers and other limited information may not be available for release.

In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.

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

.228-.244 TYP
[5.80-6.19]

PIN 1 ID AREA

.189-.197
[4.81-5.00]
NOTE 3

1

4

8

5

6X .050
[1.27]

2X
.150
[3.81]

8X .012-.020
[0.31-0.51]

⊕ .010 [0.25] Ⓜ C A B

.150-.157
[3.81-3.98]
NOTE 4

SEATING PLANE

⌒ .004 [0.1] C

4X (0°-15°)

.069 MAX
[1.75]

SEE DETAIL A

4X (0°-15°)

.005-.010 TYP
[0.13-0.25]

.010
[0.25]

0°- 8°

.016-.050
[0.41-1.27]

(.041)
[1.04]

.004-.010
[0.11-0.25]

DETAIL A
TYPICAL

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NOTES:

1. Linear dimensions are in inches [millimeters]. Dimensions in parenthesis are for reference only. Controlling dimensions are in inches.
   Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not
   exceed .006 [0.15] per side.
4. This dimension does not include interlead flash.
5. Reference JEDEC registration MS-012, variation AA.

8X (.061)
[1.55]

SYMM
℄

SEE
DETAILS

1

8

8X (.024)
[0.6]

SYMM
℄

4

5

(R.002) TYP
[0.05]

6X (.050)
[1.27]

(.213)
[5.4]

LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE:8X

METAL

SOLDER MASK
OPENING

SOLDER MASK
OPENING

METAL UNDER
SOLDER MASK

EXPOSED
METAL

EXPOSED
METAL

.0028 MAX
[0.07]
ALL AROUND

.0028 MIN
[0.07]
ALL AROUND

NON SOLDER MASK
DEFINED

SOLDER MASK
DEFINED

SOLDER MASK DETAILS

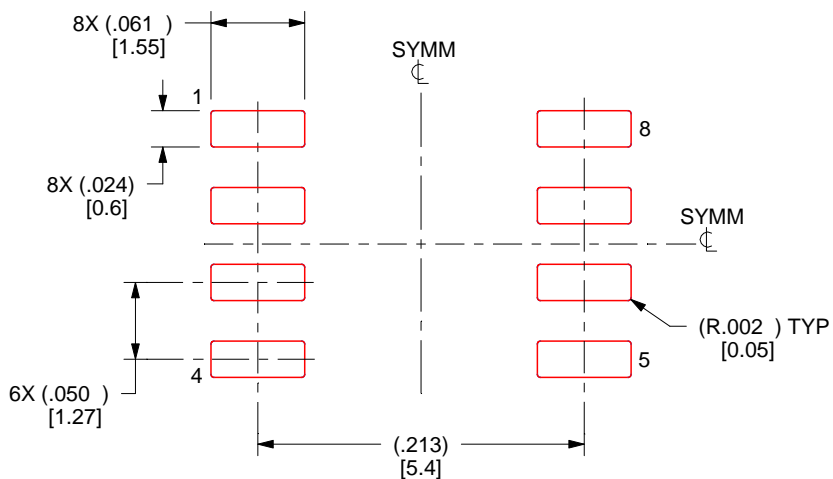4214825/C   02/2019

NOTES: (continued)

6. Publication IPC-7351 may have alternate designs.
7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.

8X (.061)
[1.55]

1

8X (.024)
[0.6]

6X (.050)
[1.27]

4

SYMM
℄

SYMM
℄

8

5

(R.002) TYP
[0.05]

(.213)
[5.4]

SOLDER PASTE EXAMPLE
BASED ON .005 INCH [0.125 MM] THICK STENCIL
SCALE:8X

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NOTES: (continued)

8. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
9. Board assembly site may have different recommendations for stencil design.

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