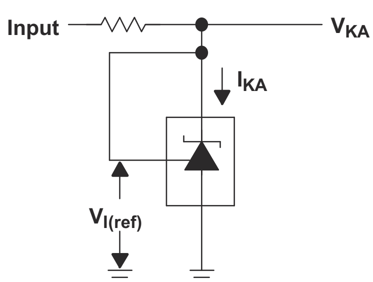
TL1431-SP Class V, Precision Programmable Reference

1 Features

- QMLV qualified to 100-krad(Si) RHA, 5962R99620
- 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

2 Applications

- Adjustable voltage and current referencing
- Secondary side regulation in flyback SMPSs
- Zener replacement
- Voltage monitoring
- Comparator with integrated reference
- Command and data handling (C&DH)
- Optical imaging payload
- Radar imaging payload
- Satellite electrical power system (EPS)



Simplified Schematic

3 Description

The TL1431 is a precision programmable reference with specified thermal stability over automotive, commercial, and military temperature ranges. The output voltage can be set to any value between $V_{I(ref)}$ (approximately 2.5 V) and 36 V with two external resistors. 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 TL1431 is characterized for operation over the full military temperature range of –55°C to 125°C.

Device Information

PART NUMBER(1)	GRADE	PACKAGE
5962R9962001VPA	Flight grade RHA 100 krad(Si)	8-pin JG Weight 0.87 g(2)
5962-9962001VPA	Flight grade class V	
5962R9962001VHA	Flight grade RHA 100 krad(Si)	10-pin U Weight 0.2 g(2)
TL1431U/EM	Engineering samples(3)	EVM

(1) For all available packages, see the orderable addendum at the end of the data sheet.
(2) Weight is accurate to ±10%.
(3) These units are intended for engineering evaluation only. They are processed to a noncompliant flow (that is, no burn in, and so forth) and are tested to a temperature rating of 25°C only. These units are not suitable for qualification, production, radiation testing or flight use. Parts are not warranted for performance over the full MIL specified temperature range of –55°C to 125°C or operating life.

Table of Contents

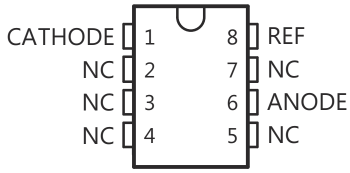
4 Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

Changes from Revision B (September 2013) to Revision C (November 2020) — **Page**

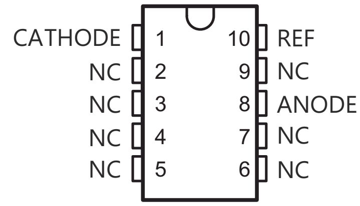
- Added *Applications* section, Pin Functions table, *ESD Ratings* table, *Thermal Information* table, *Detailed Description* section, *Application and Implementation* section, *Power Supply Recommendations* section, *Layout* section, *Device and Documentation Support* section, and *Mechanical, Packaging, and Orderable Information* section.... 1
- Updated the numbering format for tables, figures, and cross-references throughout the document....1
- Updated Device Information table.... 1
- Added U package pinout drawing....3

5 Pin Configuration and Functions



NC - No internal connection

Figure 5-1. JG Package 8-Pin CDIP Top View



NC - No internal connection

Figure 5-2. U Package 10-Pin CFP Top View

Table 5-1. Pin Functions

PIN			I/O	DESCRIPTION
NAME	JG	U		
ANODE	6	—	O	Common pin, normally connected to ground
CATHODE	1	—	I/O	Shunt current/voltage input
REF	8	—	I	Threshold relative to common ground
NC	2,3,4,5,7	2,3,4,5,6,7,9	—	No internal connection

6 Specifications

6.1 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}	Continuous cathode current		–100	150	mA
$I_{I(ref)}$	Reference input current		–0.05	10	mA
T_J	Operating virtual junction temperature			150	°C
	Lead temperature	1.6 mm (1/16 in) from case for 10 s		260	°C
T_{stg}	Storage temperature		–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.

6.2 ESD Ratings

			VALUE	UNIT
$V_{(ESD)}$	Electrostatic discharge	Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001[(1)]	±2000	V

(1) JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process.

6.3 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	–55	125	°C

6.4 Thermal Information

THERMAL METRIC[(1)]		TL1431-SP		UNIT
		JG (CDIP)	U (CFP)	
		8 PINS	10 PINS	
$R_{\theta JC}$	Junction-to-case thermal resistance [(2)] [(3)]	14.5	19.1	°C/W

(1) For more information about traditional and new thermal metrics, see the *Semiconductor and IC Package Thermal Metrics* application report, SPRA953.
(2) Maximum power dissipation is a function of $T_{J(max)}$, $R_{\theta JC}$, and T_C. The maximum allowable power dissipation at any allowable case temperature is $P_D = (T_{J(max)} – T_C) / R_{\theta JC}$. Operating at the absolute maximum T_J of 150°C can affect reliability.
(3) The package thermal impedance is calculated in accordance with MIL-STD-883.

6.5 Electrical Characteristics

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

PARAMETER		TEST CONDITIONS	T_A [(2)]	TEST CIRCUIT	MIN	TYP	MAX	UNIT
$V_{I(ref)}$	Reference input voltage	$V_{KA} = V_{I(ref)}$	25°C	Figure 7-1	2475	2500	2540	mV
			Full range		2460		2550	
$V_{I(dev)}$	Deviation of reference input voltage over full temperature range[(3)]	$V_{KA} = V_{I(ref)}$	Full range	Figure 7-1		17	55[(1)]	mV
$\frac{\Delta V_{I(ref)}}{\Delta V_{KA}}$	Ratio of change in reference input voltage to the change in cathode voltage	ΔV_{KA} = 3 V to 36 V	Full range	Figure 7-2		–1.1	–2	mV/V
$I_{I(ref)}$	Reference input current	R1 = 10 kΩ, R2 = ∞	25°C	Figure 7-2		1.5	2.5	µA
			Full range				5	
$I_{I(dev)}$	Deviation of reference input current over full temperature range[(3)]	R1 = 10 kΩ, R2 = ∞	Full range	Figure 7-2		0.5	3[(1)]	µA
I_{min}	Minimum cathode current for regulation	$V_{KA} = V_{I(ref)}$	25°C	Figure 7-1		0.45	1	mA
I_{off}	Off-state cathode current	V_{KA} = 36 V, $V_{I(ref)}$ = 0	25°C	Figure 7-3		0.18	0.5	µA
			Full range				2	
$\lvert z_{KA} \rvert$	Output impedance[(4)]	$V_{KA} = V_{I(ref)}$, f ≤ 1 kHz, I_{KA} = 1 mA to 100 mA	25°C	Figure 7-1		0.2	0.4	Ω

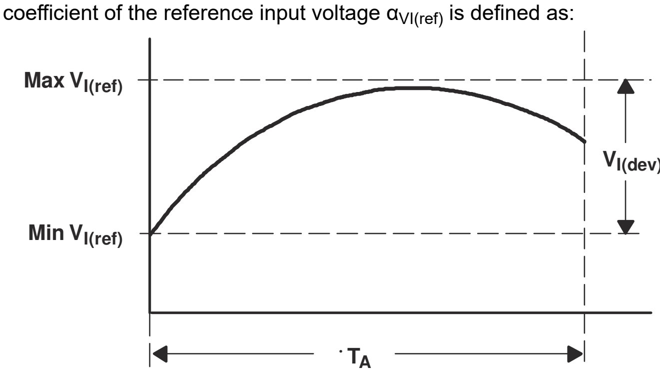
(1) On products compliant to MIL-PRF-38535, this parameter is not production tested.

(2) Full range is –55°C to 125°C.

(3) 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 $\alpha_{VI(ref)}$ is defined as:

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

where:
ΔT_A is the rated operating temperature range of the device.



$\alpha_{VI(ref)}$ is positive or negative, depending on whether minimum $V_{I(ref)}$ or maximum $V_{I(ref)}$, respectively, occurs at the lower temperature.

(4) The output impedance is defined as: $\lvert z_{KA} \rvert = \frac{\Delta V_{KA}}{\Delta I_{KA}}$
When the device is operating with two external resistors (see Figure 7-2), the total dynamic impedance of the circuit is given by:
$\lvert z' \rvert = \frac{\Delta V}{\Delta I}$, which is approximately equal to $\lvert z_{KA} \rvert \left(1 + \frac{R1}{R2}\right)$.

6.6 Typical Characteristics

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

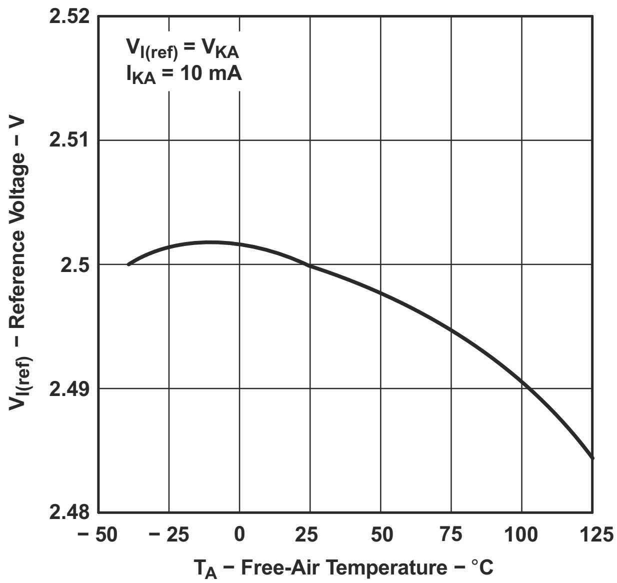


Figure 6-1. Reference Voltage vs Free-Air Temperature

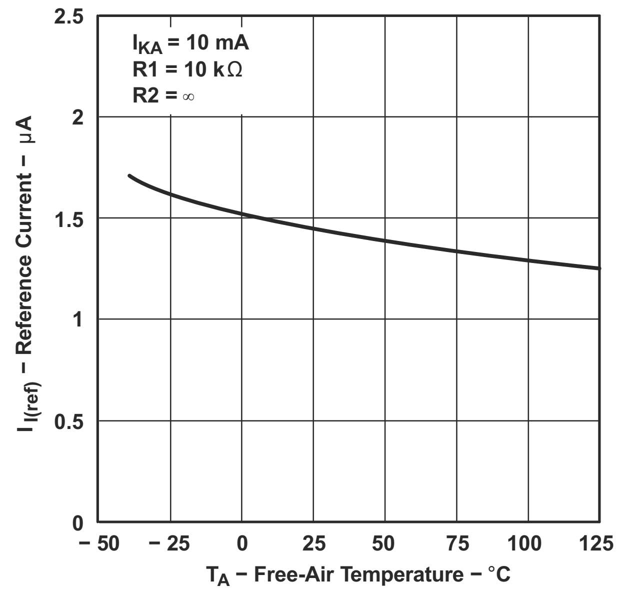


Figure 6-2. Reference Current vs Free-Air Temperature

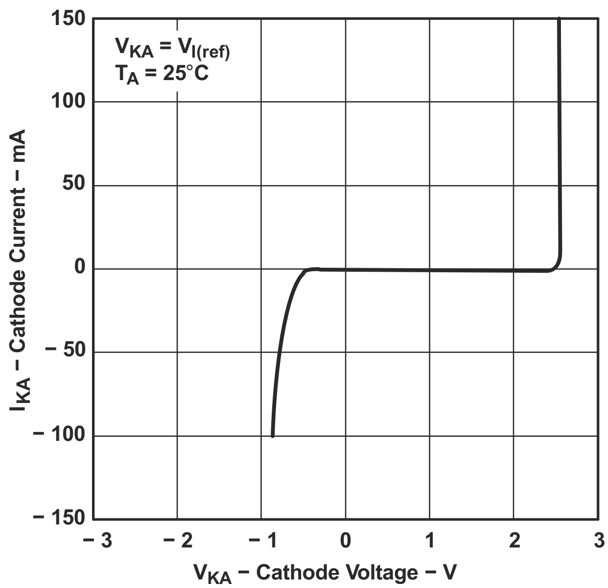


Figure 6-3. Cathode Current vs Cathode Voltage

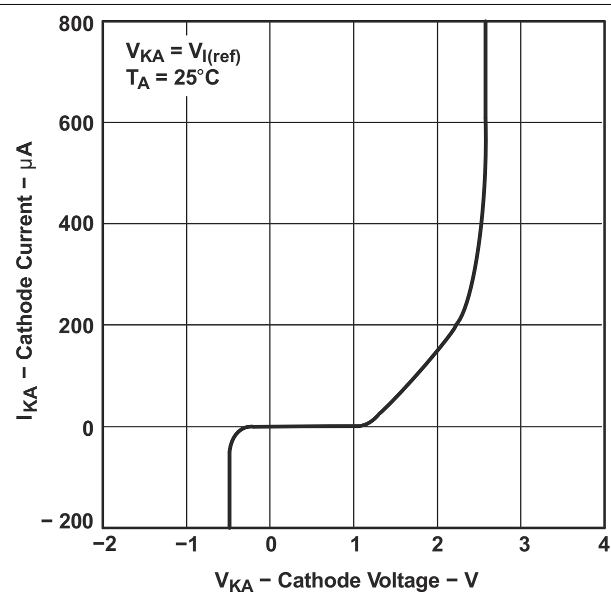


Figure 6-4. Cathode Current vs Cathode Voltage

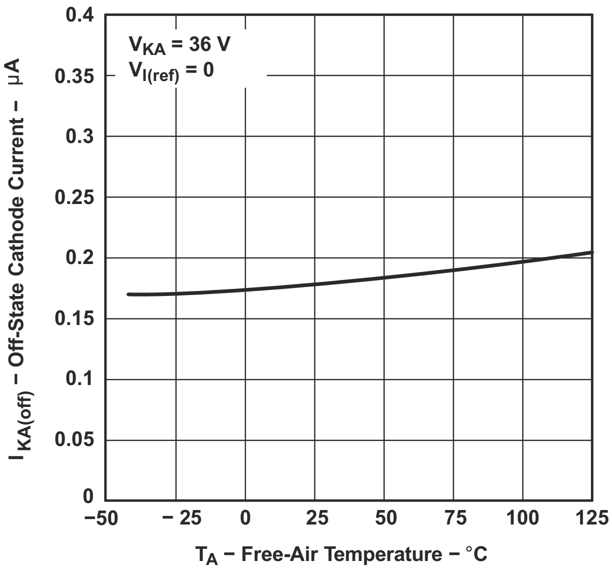


Figure 6-5. Off-State Cathode Current vs Free-Air Temperature

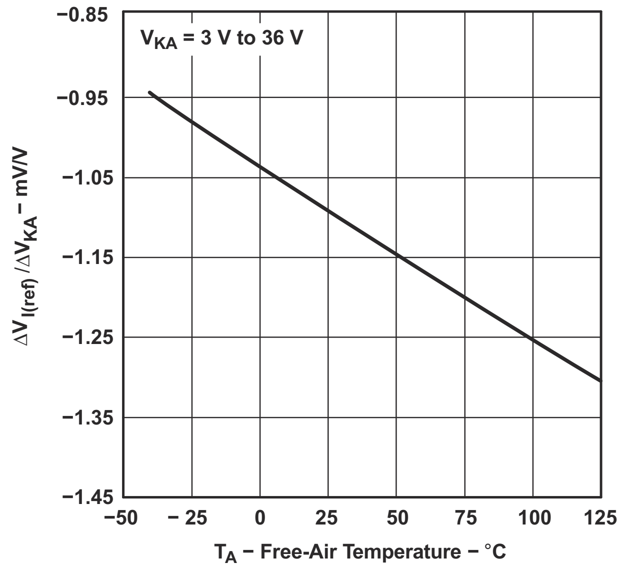


Figure 6-6. Ratio of Delta Reference Voltage to Delta Cathode Voltage vs Free-Air Temperature

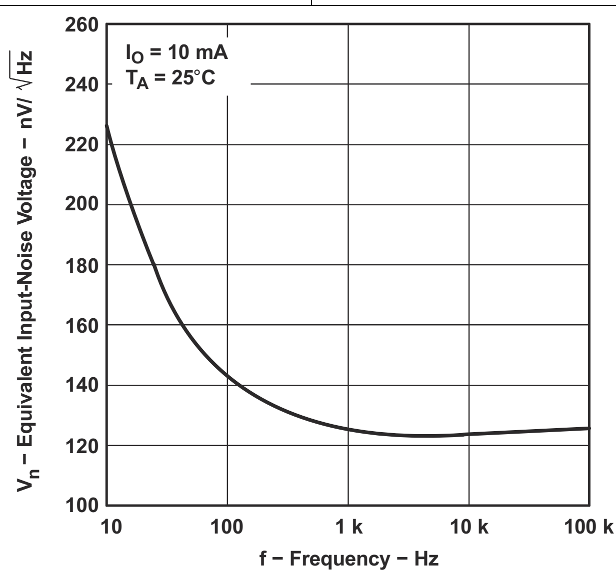


Figure 6-7. Equivalent Input-Noise Voltage vs Frequency

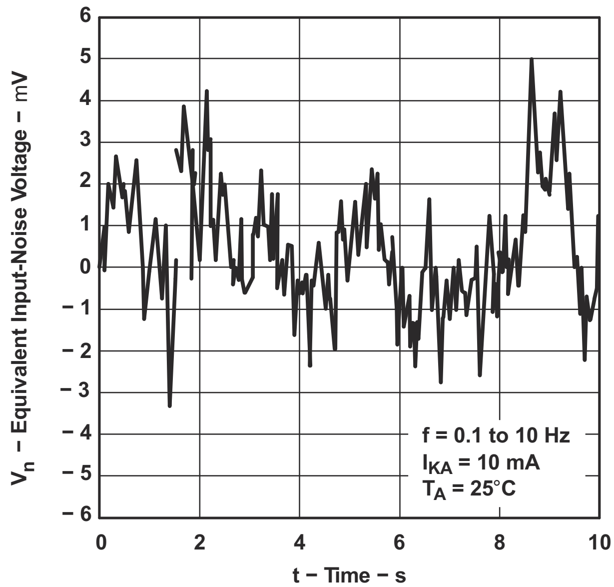


Figure 6-8. Equivalent Input-Noise Voltage Over a 10-s Period

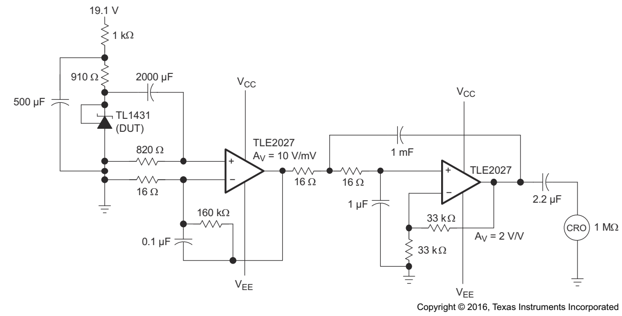


Figure 6-9. Test Circuit for 0.1-Hz to 10-Hz Equivalent Input-Noise Voltage

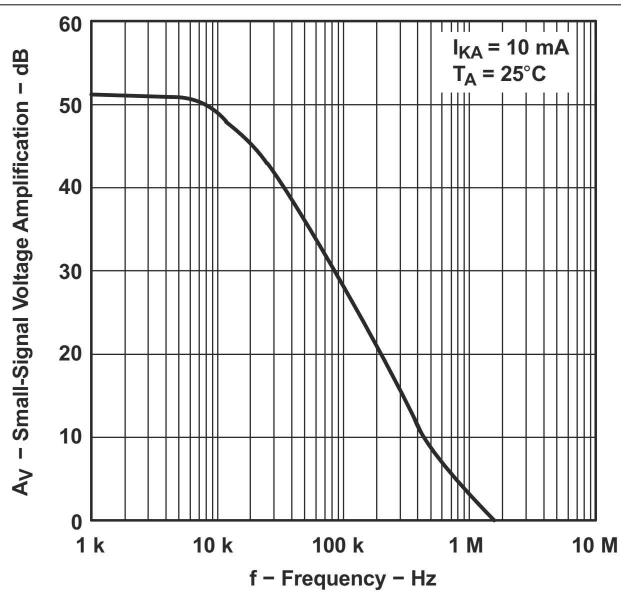


Figure 6-10. Small-Signal Voltage Amplification vs Frequency

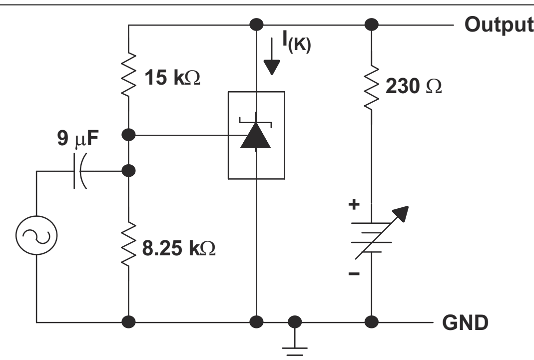


Figure 6-11. Test Circuit for Voltage Amplification

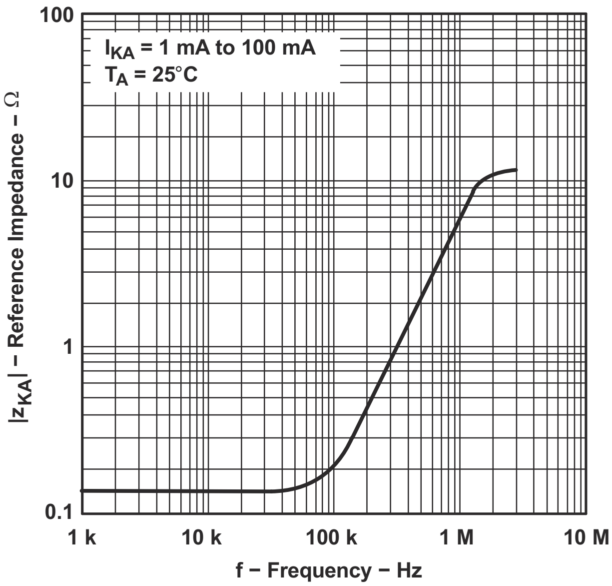


Figure 6-12. Reference Impedance vs Frequency

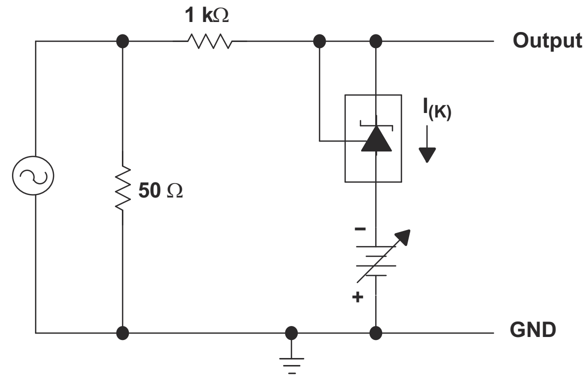


Figure 6-13. Test Circuit for Reference Impedance

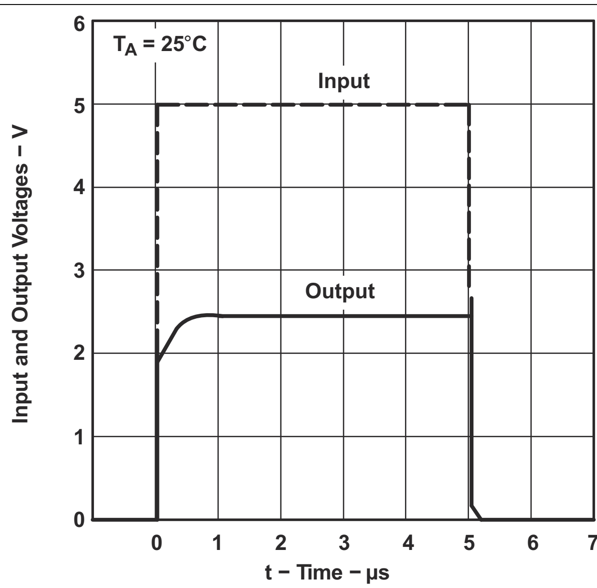


Figure 6-14. Pulse Response

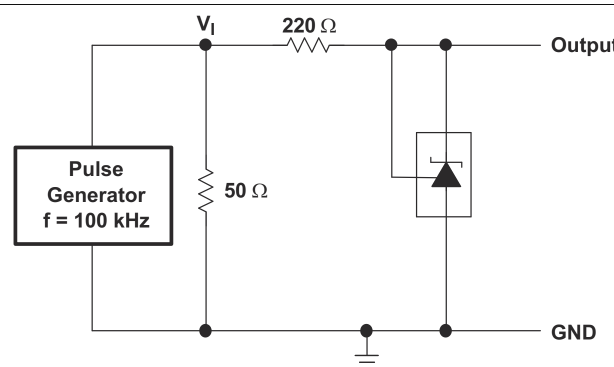
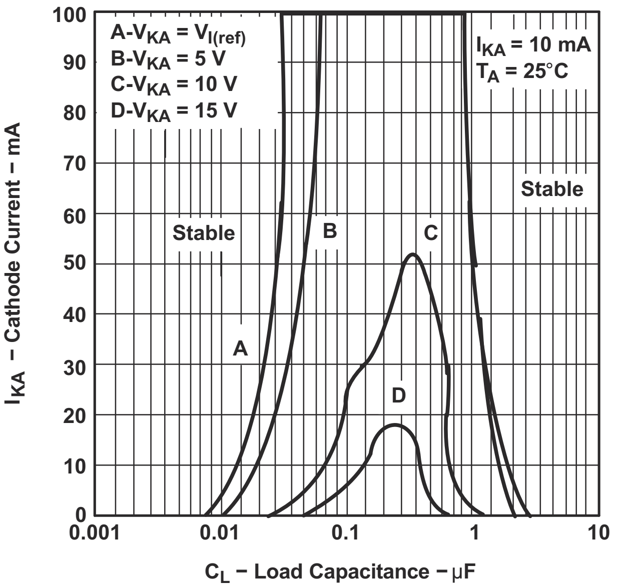
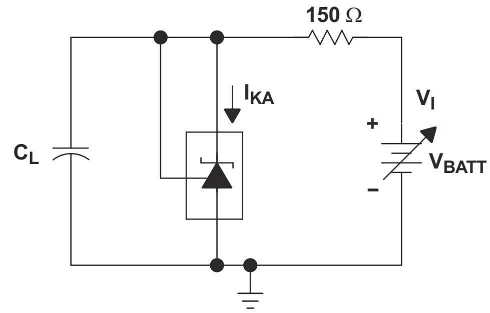


Figure 6-15. Test Circuit for Pulse Response

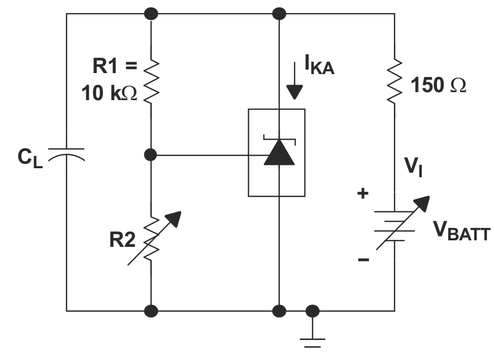


A. The areas under the curves represent conditions that may cause the device to oscillate. For curves B, C; and D, R2; and V+ are adjusted to establish the initial V_{KA} and I_{KA} conditions, with C_L = 0. V_{BATT} and C_L then are adjusted to determine the ranges of stability.

Figure 6-16. Stability Boundary Conditions



Test Circuit for Curve A



Test Circuit for Curves B, C, and D

Figure 6-17. Test Circuits for Curves A Through D

7 Parameter Measurement Information

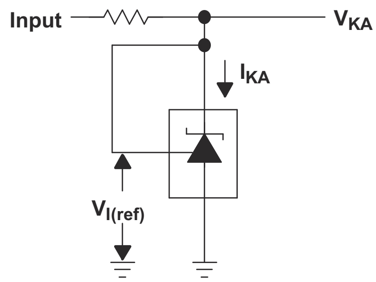


Figure 7-1. Test Circuit for $V_{(KA)} = V_{ref}$

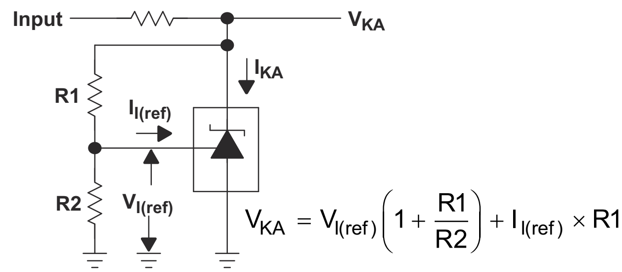


Figure 7-2. Test Circuit for $V_{(KA)} > V_{ref}$

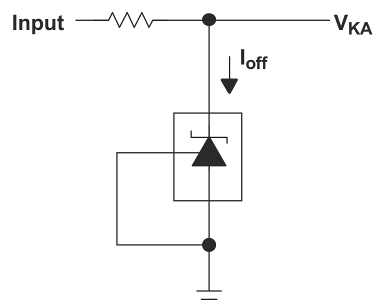


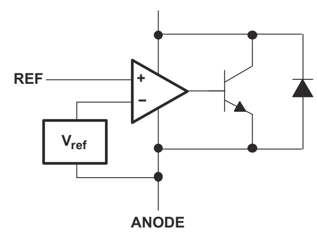
Figure 7-3. Test Circuit for I_{off}

8 Detailed Description

8.1 Overview

The TL1431 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 and op amp, which are very fundamental analog building blocks. TL1431 is used in conjunction with its key components to behave as a single voltage reference, error amplifier, voltage clamp, or comparator with integrated reference. TL1431 can be operated and adjusted to cathode voltages from 2.5 V to 36 V, making this part optimum for a wide range of end equipments in aerospace, industrial, auto, telecom, and computing. In order for this device to behave as a shunt regulator or error amplifier, > 1 mA (Imin(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. The TL1431-SP devices are characterized for operation from –55°C to 125°C.

8.2 Functional Block Diagram



8.3 Feature Description

TL1431 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 Detailed Schematic. 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 (IKA), TL1431 forces the reference pin to 2.5 V. However, the reference pin can not be left floating, as it needs IREF ≥ 5 μA (see *Electrical Characteristics – TL1431-SP*). This is because the reference pin is driven into an npn, which needs base current to operate properly. When feedback is applied from the cathode and reference pins, TL1431 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 TL1431 enough gain. Unlike many linear regulators, TL1431 is internally compensated to be stable without an output capacitor between the cathode and anode. However, if desired an output capacitor can be used as a guide to assist in choosing the correct capacitor to maintain stability.

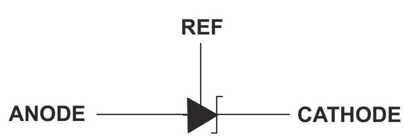


Figure 8-1. Symbol

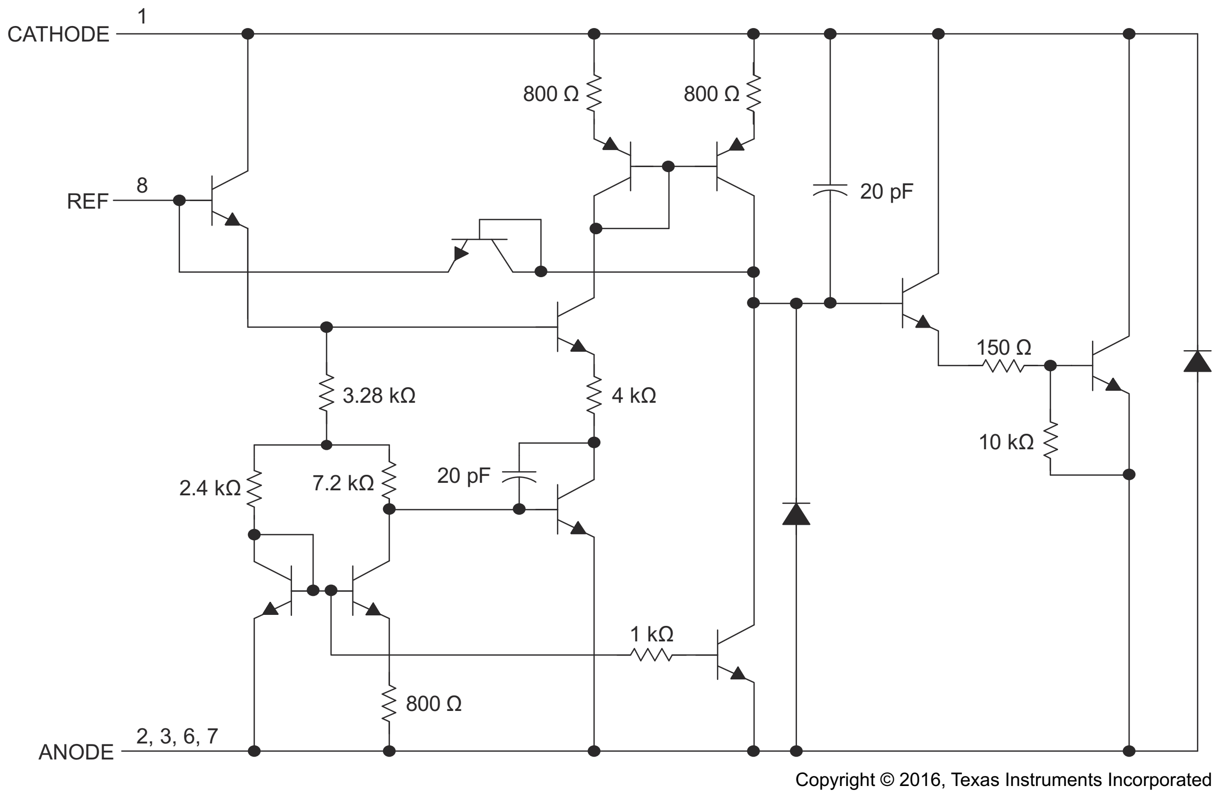


Figure 8-2. Equivalent Schematic

8.4 Device Functional Modes

8.4.1 Open Loop (Comparator)

When the cathode or output voltage or current of TL1431 is not being fed back to the reference or input pin in any form, this device is operating in open loop. With proper cathode current (I_{KA}) applied to this device, TL1431 has the characteristics shown in Figure 9-1. With such high gain in this configuration, TL1431 is typically used as a comparator. With the reference integrated makes TL1431 the preferred choice when users are trying to monitor a certain level of a single signal.

8.4.2 Closed Loop

When the cathode or output voltage or current of TL1431 is being fed back to the reference or input pin in any form, this device is operating in closed loop. The majority of applications involving TL1431 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 through resistive or direct feedback.

9 Application and Implementation

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.

9.1 Application Information

As the TL1431 device has many applications and setups, there are many situations that this datasheet cannot characterize in detail. The linked application notes help the designer make the best choices when using this part. *Understanding Stability Boundary Conditions Charts in TL431, TL432 Data Sheet* (SLVA482) provides a deeper understanding of this devices stability characteristics and aid the user in making the right choices when choosing a load capacitor. *Setting the Shunt Voltage on an Adjustable Shunt Regulator* (SLVA445) assists designers in setting the shunt voltage to achieve optimum accuracy for this device.

9.2 Typical Application

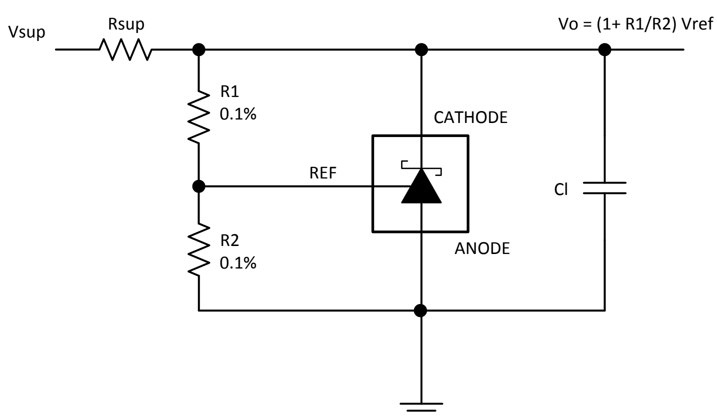


Figure 9-1. Comparator Application Schematic

9.2.1 Design Requirements

For this design example, use the parameters listed in Table 9-1 as the input parameters.

Table 9-1. Design Parameters

PARAMETER	VALUE
Reference initial accuracy	0.4%
Supply voltage	48 V
Cathode current (I_K)	50 µA
Output voltage level	2.5 V to 36 V
Load capacitance	1 nF
Feedback resistor values and accuracy (R1 and R2)	10 kΩ

9.2.2 Detailed Design Procedure

When using TL1431 as a shunt regulator, determine the following:

- Input voltage range
- Temperature range
- Total accuracy

- Cathode current
- Reference initial accuracy
- Output capacitance

9.2.3 Programming Output/Cathode Voltage

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 9-1, with R1 and R2 being the resistive bridge. The cathode/output voltage in the shunt regulator configuration can be approximated by the equation shown in Figure 9-1. The cathode voltage can be more accurately determined by taking in to account the cathode current with Equation 1.

$$Vo = (1 + R1 / R2) \times V_{REF} - I_{REF} \times R1 \quad (1)$$

For this equation to be valid, TL1431 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 specification denoted in Section 6.5.

9.2.4 Total Accuracy

When programming the output above unity gain (V_{KA}=V_{REF}), TL1431 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
- ΔV_{REF} / ΔV_{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.

9.2.5 Stability

Though TL1431 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 TL1431 region of stability, shown in Figure 6-16. 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 6-16.

9.2.6 Start-up Time

As shown in Figure 9-2, TL1431 has a fast response up to approximately 2 V and then slowly charges to its programmed value. This is due to the compensation capacitance the TL1431 has to meet its stability criteria. Despite the secondary delay, TL1431 still has a fast response suitable for many clamp applications.

9.2.7 Application Curve

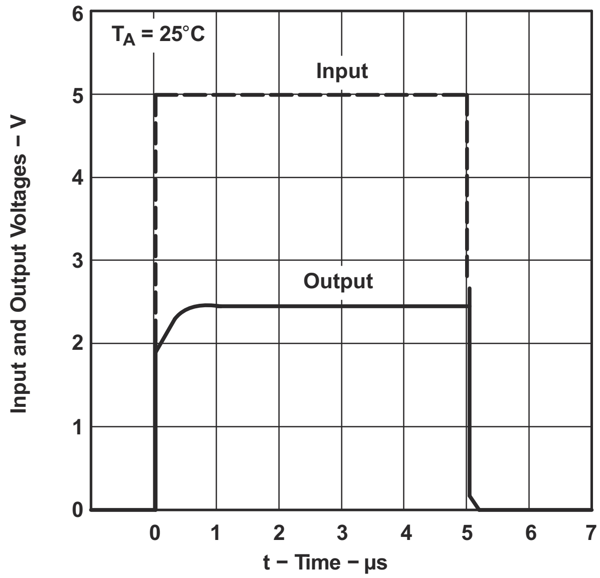


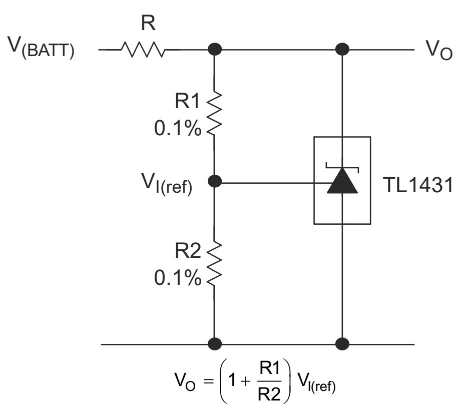
Figure 9-2. TL1431 Start-up Response

9.2.8 System Examples

Table 9-2 lists example circuits of the TL1431.

Table 9-2. Table of Example Circuits

APPLICATION	FIGURE
Shunt regulator	Figure 9-3
Single-supply comparator with temperature-compensated threshold	Figure 9-4
Precision high-current series regulator	Figure 9-5
Output control of a three-terminal fixed regulator	Figure 9-6
Higher-current shunt regulator	Figure 9-7
Crowbar	Figure 9-8
Precision 5-V, 1.5-A, 0.5% regulator	Figure 9-9
5-V precision regulator	Figure 9-10
PWM converter with 0.5% reference	Figure 9-11
Voltage monitor	Figure 9-12
Delay timer	Figure 9-13
Precision current limiter	Figure 9-14
Precision constant-current sink	Figure 9-15



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

Figure 9-3. Shunt Regulator

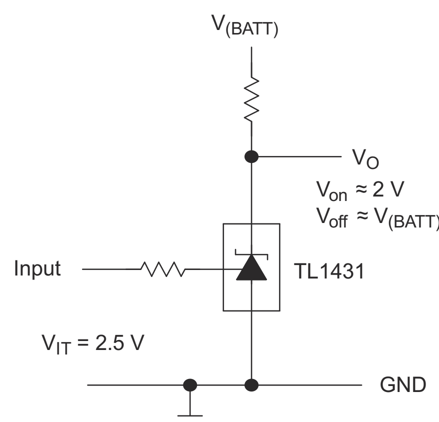
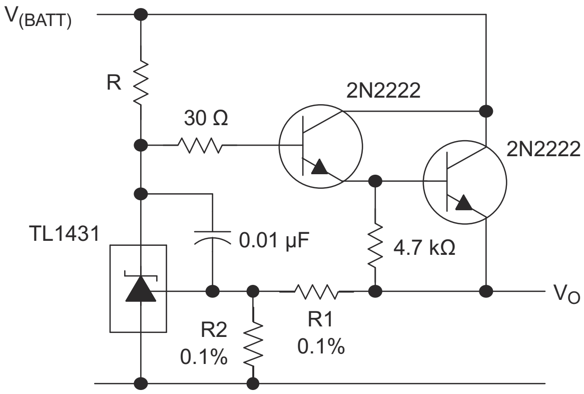


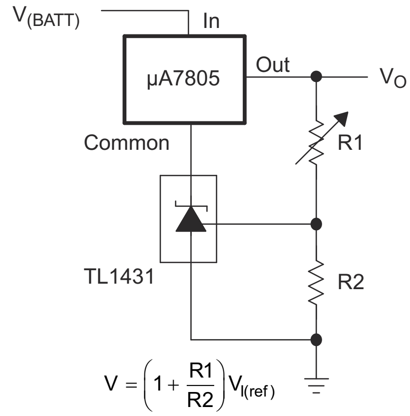
Figure 9-4. Single-Supply Comparator With Temperature-Compensated Threshold



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

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

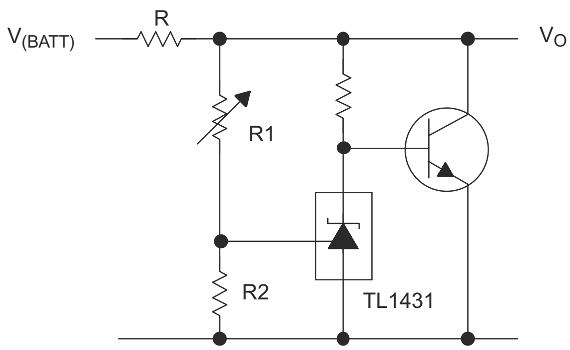
Figure 9-5. Precision High-Current Series Regulator



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

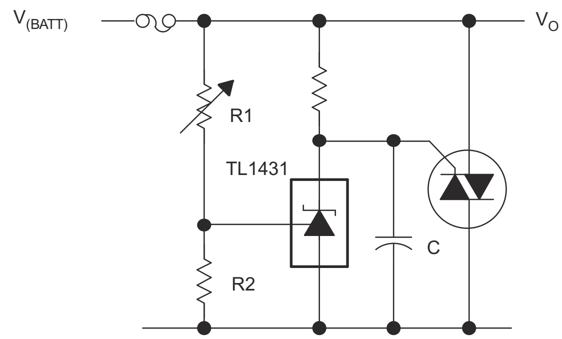
$$\text{Min } V = V_{I(ref)} + 5\ V$$

Figure 9-6. Output Control of a Three-Terminal Fixed Regulator



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

Figure 9-7. Higher-Current Shunt Regulator



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

See the stability boundary conditions in Figure 6-16 to determine allowable values for C.

Figure 9-8. Crowbar

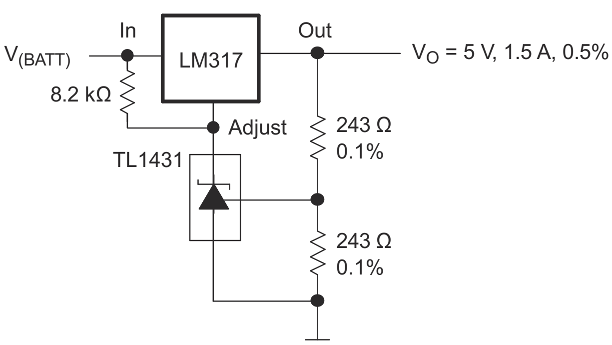
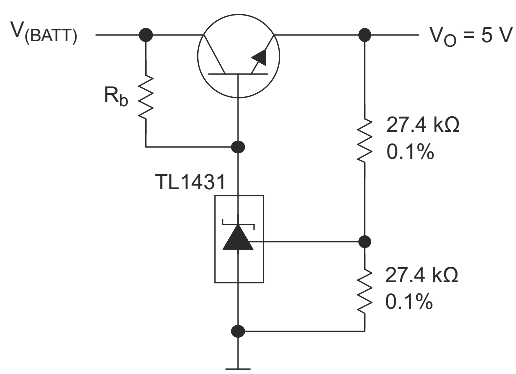


Figure 9-9. Precision 5-V, 1.5-A, 0.5% Regulator



R_b must provide cathode current ≥1 mA to the TL1431.

Figure 9-10. 5-V Precision Regulator

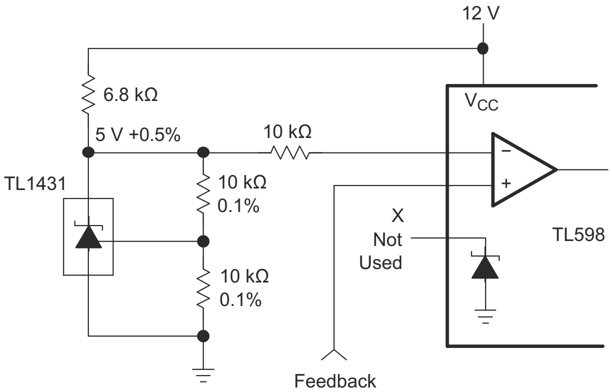
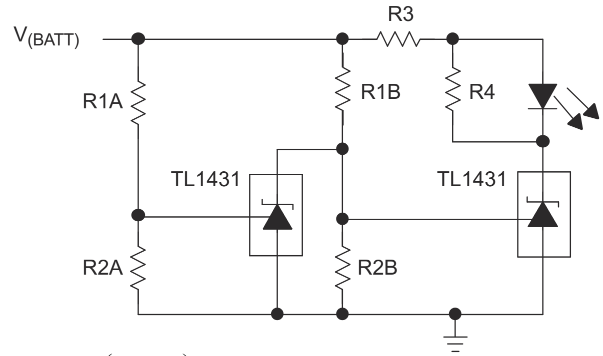


Figure 9-11. PWM Converter With 0.5% Reference



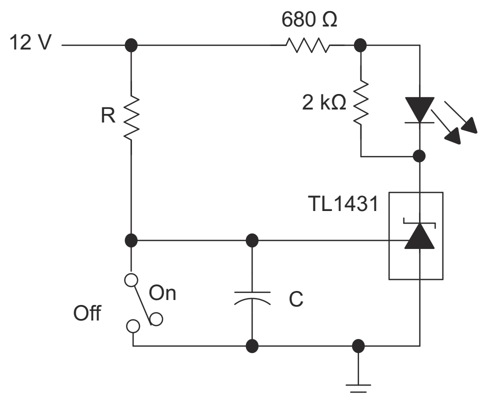
$$\text{Low Limit} = \left(1 + \frac{R1B}{R2B}\right) V_{I(ref)}$$

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

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

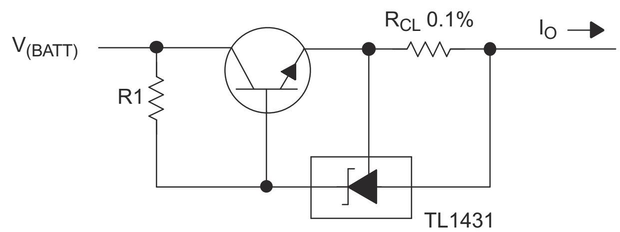
Select R3 and R4 to provide the desired LED intensity and cathode current ≥1 mA to the TL1431.

Figure 9-12. Voltage Monitor



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

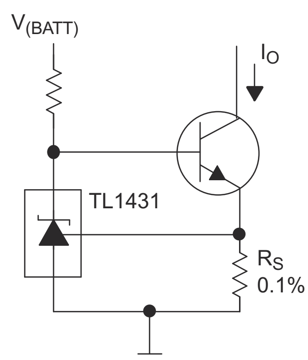
Figure 9-13. Delay Timer



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

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

Figure 9-14. Precision Current Limiter



$$I_O = \frac{V_{I(ref)}}{R_S}$$

Figure 9-15. Precision Constant-Current Sink

10 Power Supply Recommendations

When using TL1431 as a linear regulator to supply a load, designers 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 6-16. To not exceed the maximum cathode current, ensure the supply voltage is current limited. Also, be sure to limit the current being driven into the Ref pin, as not to exceed it's 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.

11 Layout

11.1 Layout Guidelines

Bypass capacitors must 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 TL1431, these currents are low.

11.2 Layout Example

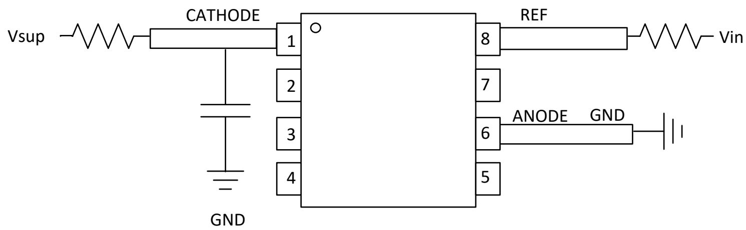


Figure 11-1. 8-Pin JG Layout Example

12 Device and Documentation Support

12.1 Documentation Support

12.1.1 Related Documentation

For related documentation see the following:

- Texas Instruments, *Understanding Stability Boundary Conditions Charts in TL431, TL432 Data Sheet* application report
- Texas Instruments, *Setting the Shunt Voltage on an Adjustable Shunt Regulator* application report

12.2 Receiving Notification of Documentation Updates

To receive notification of documentation updates, navigate to the device product folder on ti.com. Click on *Subscribe to updates* 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.

12.3 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.

12.4 Trademarks

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

12.5 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.

12.6 Glossary

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

13 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.

PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead finish/ Ball material (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
5962-9962001VPA	ACTIVE	CDIP	JG	8	1	Non-RoHS & Green	SNPB	N / A for Pkg Type	-55 to 125	9962001VPA TL1431M	Samples
5962R9962001VHA	ACTIVE	CFP	U	10	1	Non-RoHS & Green	SNPB	N / A for Pkg Type	-55 to 125	R9962001VHA TL1431M	Samples
5962R9962001VPA	ACTIVE	CDIP	JG	8	1	Non-RoHS & Green	SNPB	N / A for Pkg Type	-55 to 125	R9962001VPA TL1431M	Samples
TL1431U/EM	ACTIVE	CFP	U	10	1	Non-RoHS & Green	SNPB	N / A for Pkg Type	25 to 25	TL1431U/EM EVAL ONLY	Samples

(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) **RoHS:** TI defines "RoHS" to mean semiconductor products that are compliant with the current EU RoHS requirements for all 10 RoHS substances, including the requirement that RoHS substance do not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, "RoHS" products are suitable for use in specified lead-free processes. TI may reference these types of products as "Pb-Free".
RoHS Exempt: TI defines "RoHS Exempt" to mean products that contain lead but are compliant with EU RoHS pursuant to a specific EU RoHS exemption.
Green: TI defines "Green" to mean the content of Chlorine (Cl) and Bromine (Br) based flame retardants meet JS709B low halogen requirements of <=1000ppm threshold. Antimony trioxide based flame retardants must also meet the <=1000ppm threshold requirement.

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

(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

(5) Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

(6) Lead finish/Ball material - Orderable Devices 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.

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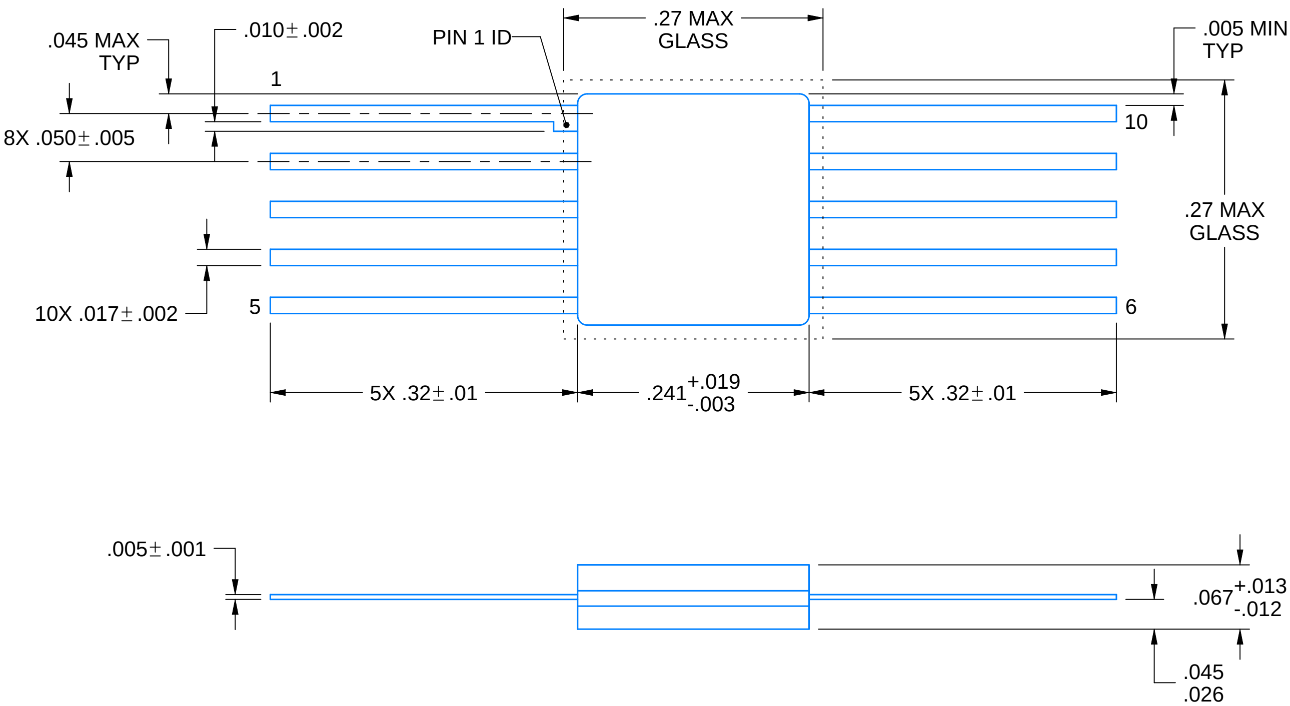
In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.

OTHER QUALIFIED VERSIONS OF TL1431-SP :

- Catalog: TL1431
- Automotive: TL1431-Q1
- Enhanced Product: TL1431-EP
- Military: TL1431M

NOTE: Qualified Version Definitions:

- Catalog - TI's standard catalog product
- Automotive - Q100 devices qualified for high-reliability automotive applications targeting zero defects
- Enhanced Product - Supports Defense, Aerospace and Medical Applications
- Military - QML certified for Military and Defense Applications

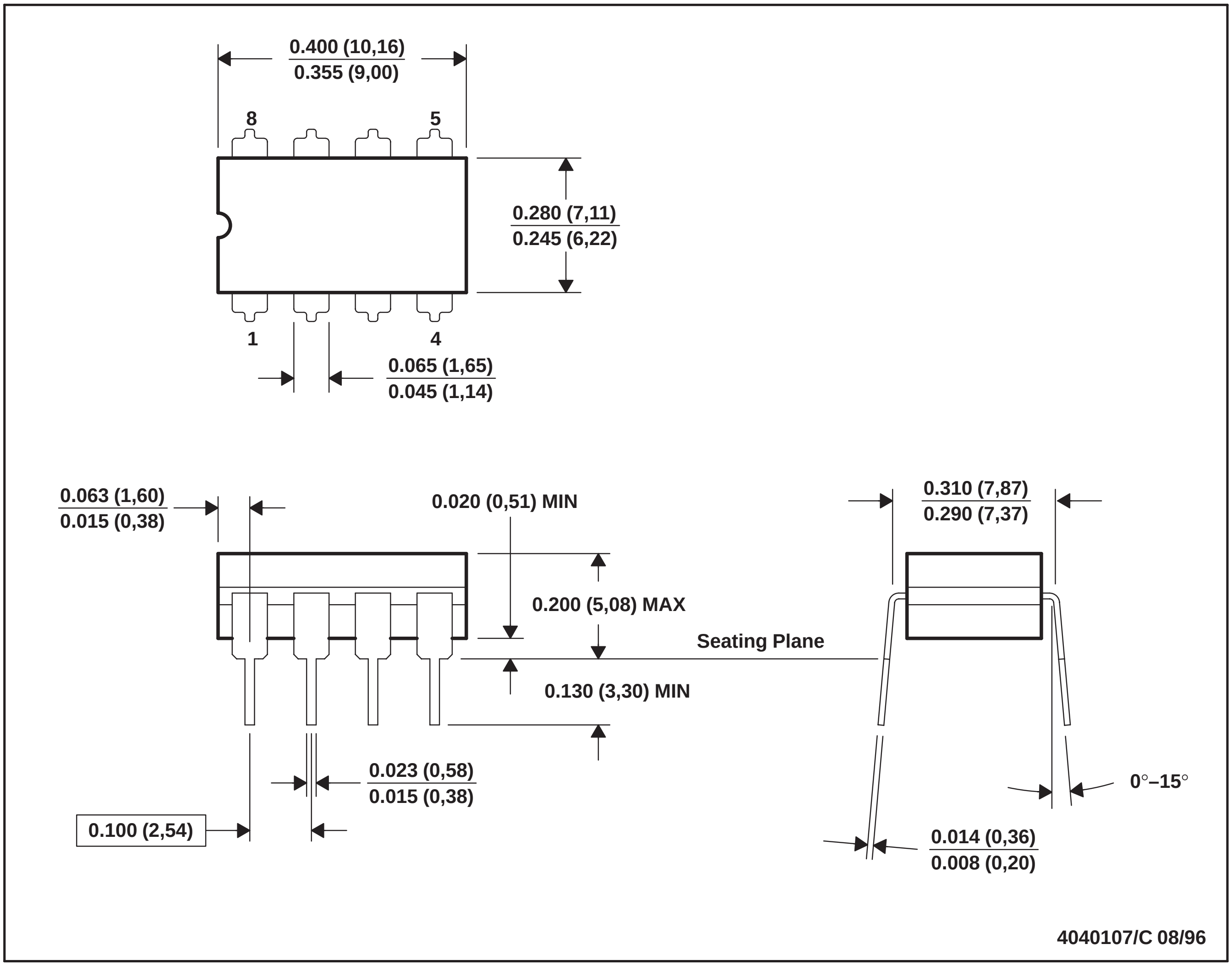


4225582/A 01/2020

NOTES:

1. All linear dimensions are in inches. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.

JG (R-GDIP-T8) **CERAMIC DUAL-IN-LINE**



NOTES:
- A. All linear dimensions are in inches (millimeters).
- B. This drawing is subject to change without notice.
- C. This package can be hermetically sealed with a ceramic lid using glass frit.
- D. Index point is provided on cap for terminal identification.
- E. Falls within MIL STD 1835 GDIP1-T8