

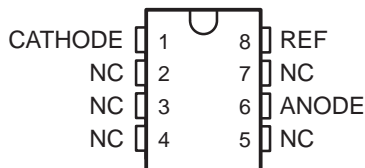
- 0.4% Initial Voltage Tolerance
- 0.2-Ω Typical Output Impedance
- Fast Turnon . . . 500 ns
- Sink Current Capability . . . 1 mA to 100 mA
- Low Reference Current (REF)
- Adjustable Output Voltage . . . $V_{I(\text{ref})}$ to 36 V

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 $V_{I(\text{ref})}$ (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.

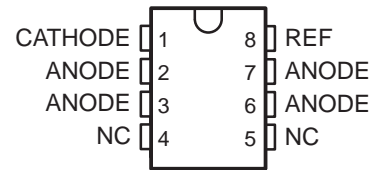
The TL1431C is characterized for operation over the commercial temperature range of 0°C to 70°C. The TL1431Q is characterized for operation over the full automotive temperature range of –40°C to 125°C. The TL1431M is characterized for operation over the full military temperature range of –55°C to 125°C.

**JG PACKAGE
(TOP VIEW)**



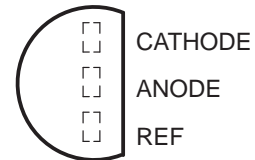
NC – No internal connection

**D PACKAGE
(TOP VIEW)**

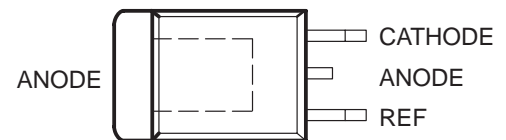


NC – No internal connection
ANODE terminals are connected internally.

**LP PACKAGE
(TOP VIEW)**

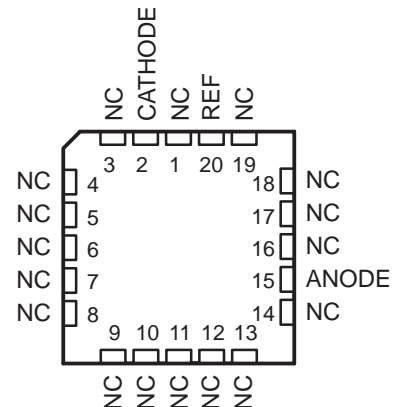


**KTP PACKAGE
(TOP VIEW)**



The ANODE terminal is in electrical contact with the mounting base.

**FK PACKAGE
(TOP VIEW)**



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.

PRODUCTION DATA information is current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.

**TEXAS
INSTRUMENTS**

POST OFFICE BOX 655303 • DALLAS, TEXAS 75265

Copyright © 2000, Texas Instruments Incorporated
On products compliant to MIL-PRF-38535, all parameters are tested unless otherwise noted. On all other products, production processing does not necessarily include testing of all parameters.

TL1431

PRECISION PROGRAMMABLE REFERENCE

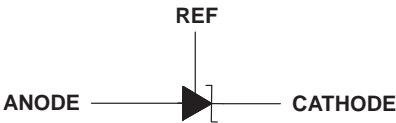
SLVS062F – DECEMBER 1991 – REVISED JANUARY 2000

AVAILABLE OPTIONS

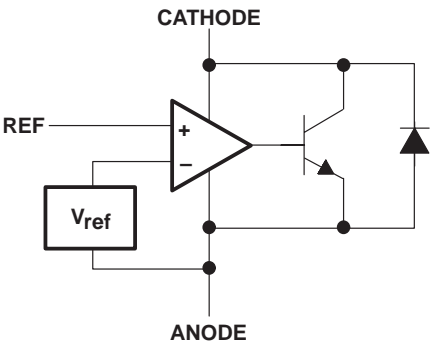
T _A	PACKAGED DEVICES					CHIP FORM (Y)
	SMALL OUTLINE (D)	PLASTIC FLANGE MOUNTED (KTP)	TO-226AA (LP)	CHIP CARRIER (FK)	CERAMIC DIP (JG)	
0°C to 70°C	TL1431CD	TL1431CKTPR	TL1431CLP	–	–	TL1431Y
–40°C to 125°C	TL1431QD	–	TL1431QLP	–	–	
–55°C to 125°C	–	–	–	TL1431MFK	TL1431MJG	

The D and LP packages are available taped and reeled. The KTP package is only available taped and reeled. Add the suffix R to the device type (e.g., TL1431CDR). Chip forms are tested at 25°C.

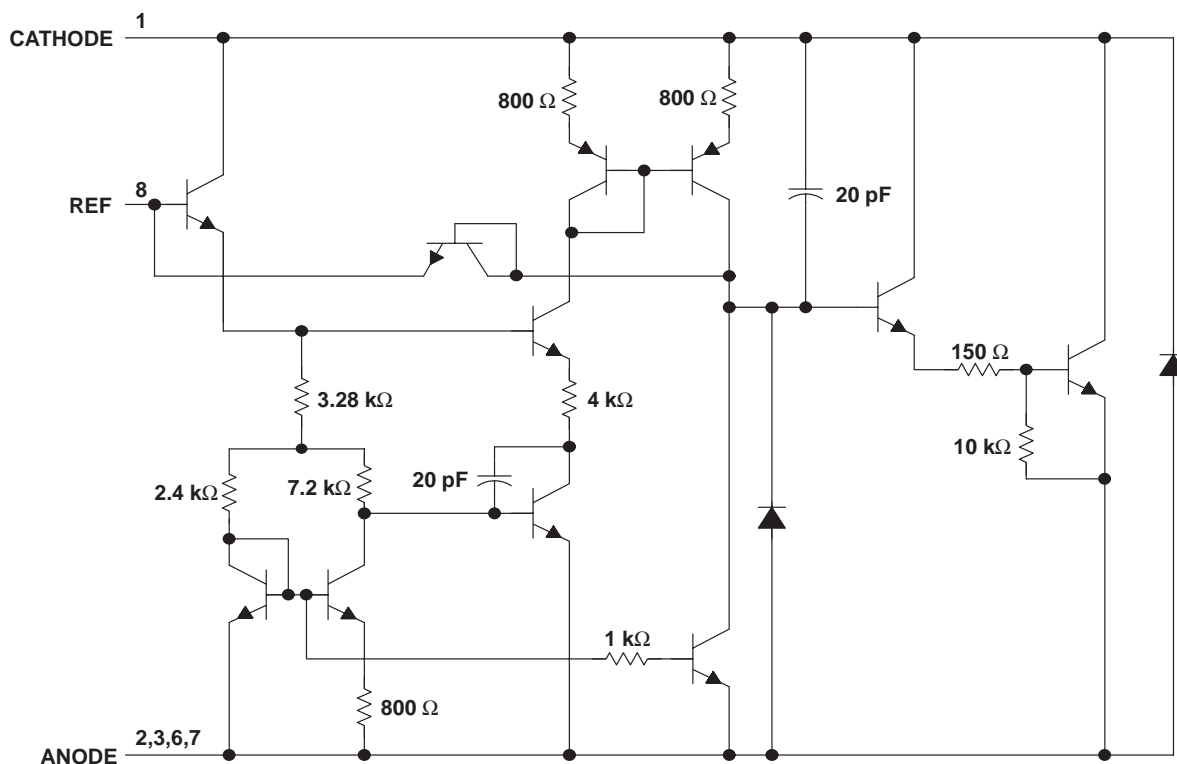
logic symbol



functional block diagram



equivalent schematic†



† All component values are nominal.
Pin numbers shown are for the D package.

TL1431

PRECISION PROGRAMMABLE REFERENCE

SLVS062F – DECEMBER 1991 – REVISED JANUARY 2000

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 μ A to 10 mA
Package thermal impedance, θ_{JA} (see Notes 2 and 3): D package	97°C/W
KTP package	28°C/W
LP package	156°C/W
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. 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 impact reliability.
 3. The package thermal impedance is calculated in accordance with JESD 51.

POWER DISSIPATION RATING TABLE – FREE-AIR TEMPERATURE

PACKAGE	$T_A = 25^\circ\text{C}$ POWER RATING	DERATING FACTOR ABOVE $T_A = 25^\circ\text{C}$	$T_A = 70^\circ\text{C}$ POWER RATING	$T_A = 85^\circ\text{C}$ POWER RATING	$T_A = 125^\circ\text{C}$ POWER RATING
FK	1375 mW	11.0 mW/°C	880 mW	715 mW	275 mW
JG	1050 mW	8.4 mW/°C	672 mW	546 mW	210 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	TL1431C	0	70
		TL1431Q	–40	125
		TL1431M	–55	125



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

PARAMETER	TEST CONDITIONS	T_A †	TEST CIRCUIT	TL1431C			UNIT
				MIN	TYP	MAX	
$V_{I(\text{ref})}$ Reference input voltage	$V_{KA} = V_{I(\text{ref})}$	25°C	Figure 1	2490	2500	2510	mV
		Full range		2480		2520	
$V_{I(\text{dev})}$ Deviation of reference input voltage over full temperature range‡	$V_{KA} = V_{I(\text{ref})}$	Full range	Figure 1		4	20	mV
$\frac{\Delta V_{I(\text{ref})}}{\Delta V_{KA}}$ Ratio of change in reference input voltage to the change in cathode voltage	$\Delta V_{KA} = 3 \text{ V to } 36 \text{ V}$	Full range	Figure 2		–1.1	–2	mV/V
$I_{I(\text{ref})}$ Reference input current	$R1 = 10 \text{ k}\Omega, R2 = \infty$	25°C	Figure 2		1.5	2.5	μA
		Full range				3	
$I_{I(\text{dev})}$ Deviation of reference input current over full temperature range‡	$R1 = 10 \text{ k}\Omega, R2 = \infty$	Full range	Figure 2		0.2	1.2	μA
Minimum cathode current for regulation	$V_{KA} = V_{I(\text{ref})} \text{ to } 36 \text{ V}$	25°C	Figure 1		0.45	1	mA
I_{off} Off-state cathode current	$V_{KA} = 36 \text{ V}, V_{I(\text{ref})} = 0$	25°C	Figure 3		0.18	0.5	μA
		Full range				2	
$ z_{KA} $ Output impedance§	$V_{KA} = V_{I(\text{ref})}, f \leq 1 \text{ kHz}, I_{KA} = 1 \text{ mA to } 100 \text{ mA}$	25°C	Figure 1		0.2	0.4	Ω

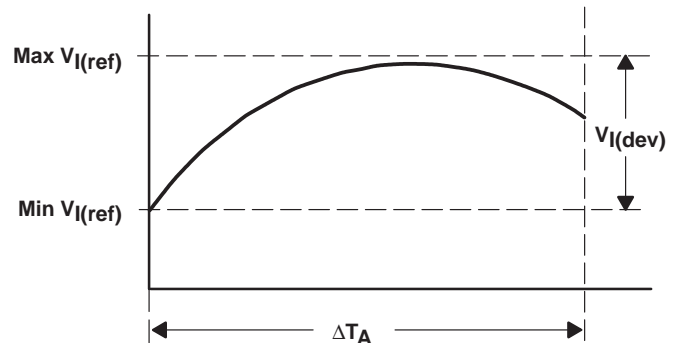
† Full range is 0°C to 70°C for C-suffix devices.

‡ The deviation parameters $V_{I(\text{dev})}$ and $I_{I(\text{dev})}$ 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 $\alpha_{V_{I(\text{ref})}}$ is defined as:

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

where:

ΔT_A is the rated operating temperature range of the device.



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

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

When the device is operating with two external resistors (see Figure 2), the total dynamic impedance of the circuit is given by: $|z'| = \frac{\Delta V}{\Delta I}$,

which is approximately equal to $|z_{KA}| \left(1 + \frac{R1}{R2} \right)$.

TL1431

PRECISION PROGRAMMABLE REFERENCE

SLVS062F – DECEMBER 1991 – REVISED JANUARY 2000

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

PARAMETER	TEST CONDITIONS	T_A †	TEST CIRCUIT	TL1431Q			TL1431M			UNIT
				MIN	TYP	MAX	MIN	TYP	MAX	
$V_{I(ref)}$ Reference input voltage	$V_{KA} = V_{I(ref)}$	25°C	Figure 1	2490	2500	2510	2475	2500	2540	mV
		Full range		2470		2530	2460		2550	
$V_{I(dev)}$ Deviation of reference input voltage over full temperature range‡	$V_{KA} = V_{I(ref)}$	Full range	Figure 1		17	55		17	55*	mV
$\frac{\Delta V_{I(ref)}}{\Delta V_{KA}}$ Ratio of change in reference input voltage to the change in cathode voltage	$\Delta V_{KA} = 3$ V to 36 V	Full range	Figure 2		–1.1	–2		–1.1	–2	mV/V
$I_{I(ref)}$ Reference input current	$R1 = 10$ k Ω , $R2 = \infty$	25°C	Figure 2		1.5	2.5		1.5	2.5	μ A
		Full range				4			5	
$I_{I(dev)}$ Deviation of reference input current over full temperature range‡	$R1 = 10$ k Ω , $R2 = \infty$	Full range	Figure 2		0.5	2		0.5	3*	μ A
Minimum cathode current for regulation	$V_{KA} = V_{I(ref)}$ to 36 V	25°C	Figure 1		0.45	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		0.18	0.5	μ A
		Full range				2			2	
$ z_{KA} $ Output impedance§	$V_{KA} = V_{I(ref)}$, $f \leq 1$ kHz, $I_{KA} = 1$ mA to 100 mA	25°C	Figure 1		0.2	0.4		0.2	0.4	Ω

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

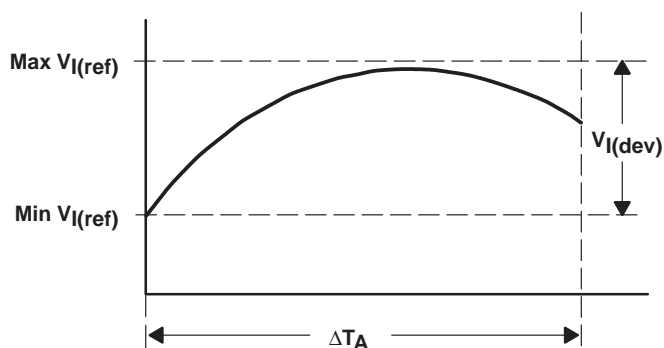
† Full range is –40°C to 125°C for Q-suffix devices, and –55°C to 125°C for M-suffix devices.

‡ 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:

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

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: $|z_{KA}| = \frac{\Delta V_{KA}}{\Delta I_{KA}}$

When the device is operating with two external resistors (see Figure 2), the total dynamic impedance of the circuit is given by: $|z'| = \frac{\Delta V}{\Delta I}$,

which is approximately equal to $|z_{KA}| \left(1 + \frac{R1}{R2} \right)$.

electrical characteristics at $I_{KA} = 10 \text{ mA}$, $T_A = 25^\circ\text{C}$

PARAMETER	TEST CONDITIONS	TEST CIRCUIT	TL1431Y			UNIT
			MIN	TYP	MAX	
$V_{I(\text{ref})}$ Reference input voltage	$V_{KA} = V_{I(\text{ref})}$	Figure 1	2490	2500	2510	mV
$\frac{\Delta V_{I(\text{ref})}}{\Delta V_{KA}}$ Ratio of change in reference input voltage to the change in cathode voltage	$\Delta V_{KA} = 3 \text{ V to } 36 \text{ V}$	Figure 2		-1.1	-2	mV/V
$I_{I(\text{ref})}$ Reference input current	$R1 = 10 \text{ k}\Omega$, $R2 = \infty$	Figure 2		1.44	2.5	μA
$I_{KA\text{min}}$ Minimum cathode current for regulation	$V_{KA} = V_{I(\text{ref})}$ to 36 V	Figure 1		0.45	1	mA
I_{off} Off-state cathode current	$V_{KA} = 36 \text{ V}$, $V_{\text{ref}} = 0$	Figure 3		0.18	0.5	μA
$ z_{KA} $ Output impedance†	$V_{KA} = V_{I(\text{ref})}$, $f \leq 1 \text{ kHz}$, $I_{KA} = 1 \text{ mA to } 100 \text{ mA}$	Figure 1		0.2	0.4	Ω

† The output impedance is defined as: $|z'| = \frac{\Delta V}{\Delta I}$

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

PARAMETER MEASUREMENT INFORMATION

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

where:

ΔT_A is the rated operating temperature range of the device.

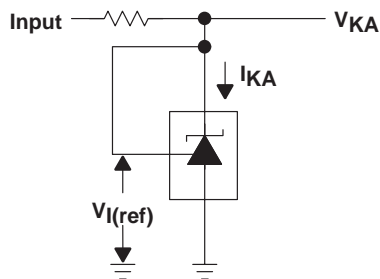
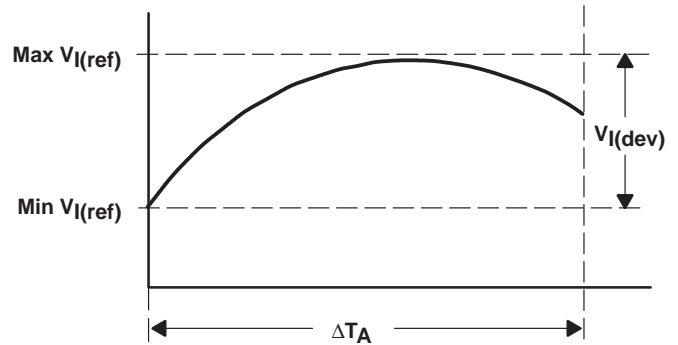


Figure 1. Test Circuit for $V_{KA} = V_{\text{ref}}$

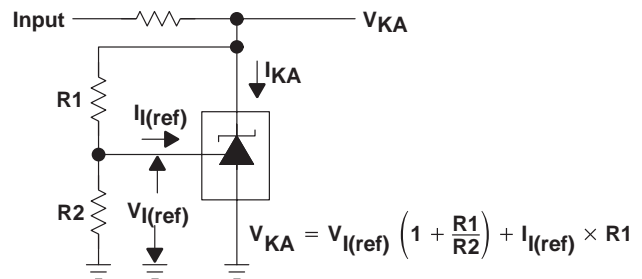


Figure 2. Test Circuit for $V_{KA} > V_{\text{ref}}$

PARAMETER MEASUREMENT INFORMATION

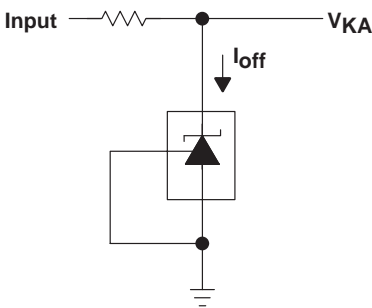


Figure 3. Test Circuit for I_{off}

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†

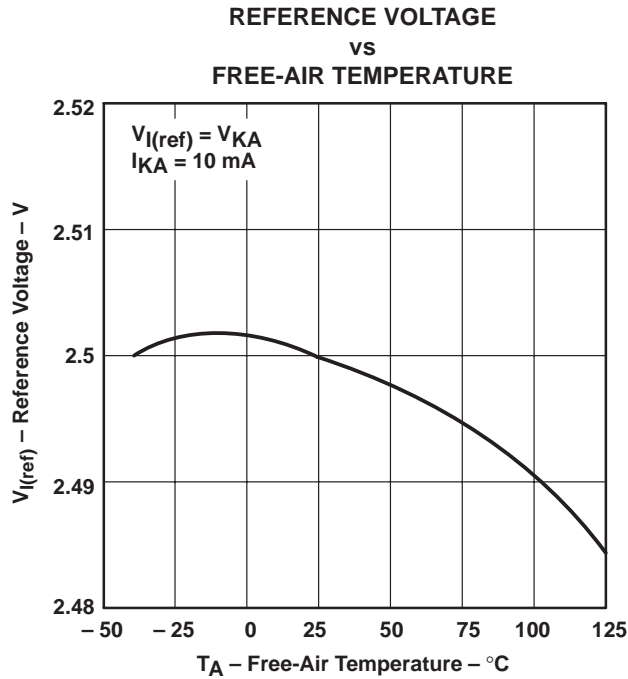


Figure 4

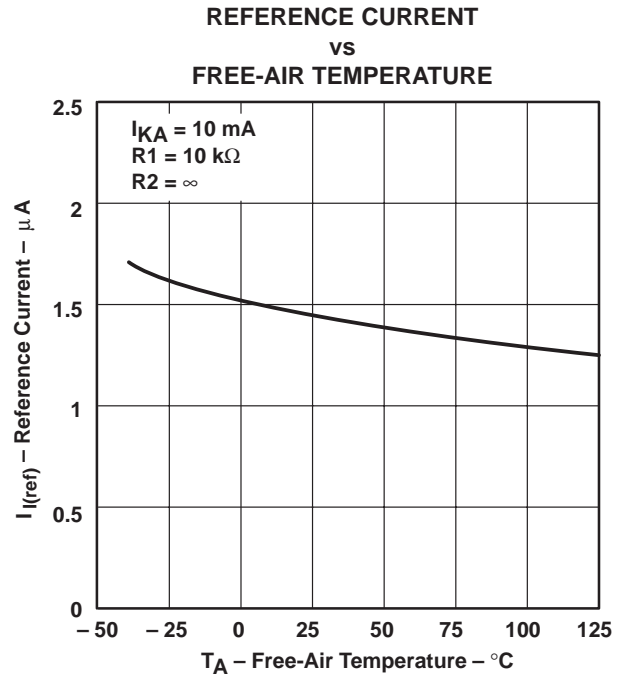


Figure 5

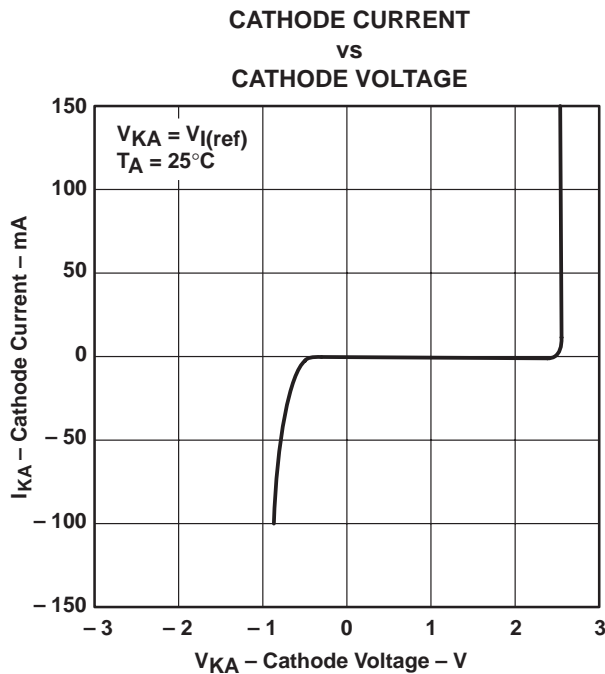


Figure 6

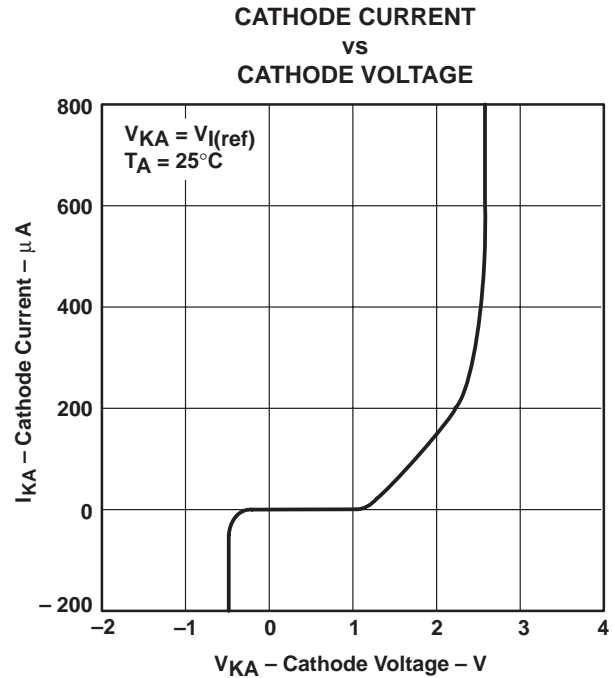


Figure 7

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

TYPICAL CHARACTERISTICS†

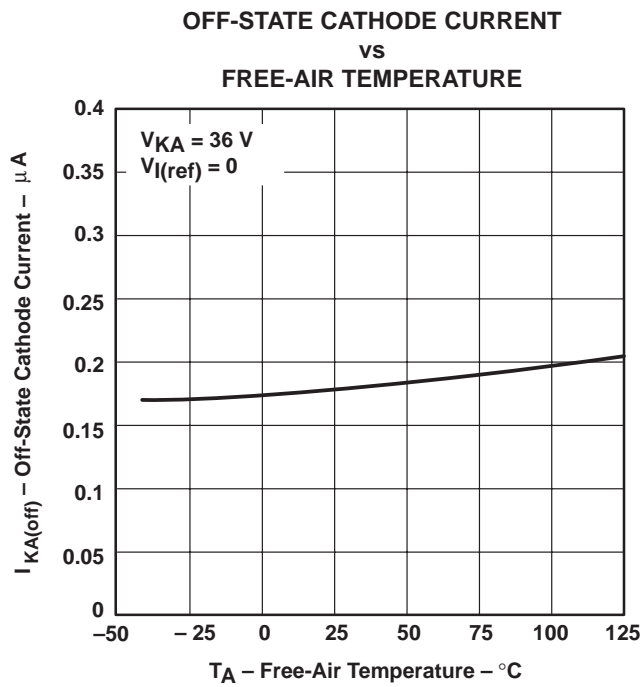


Figure 8

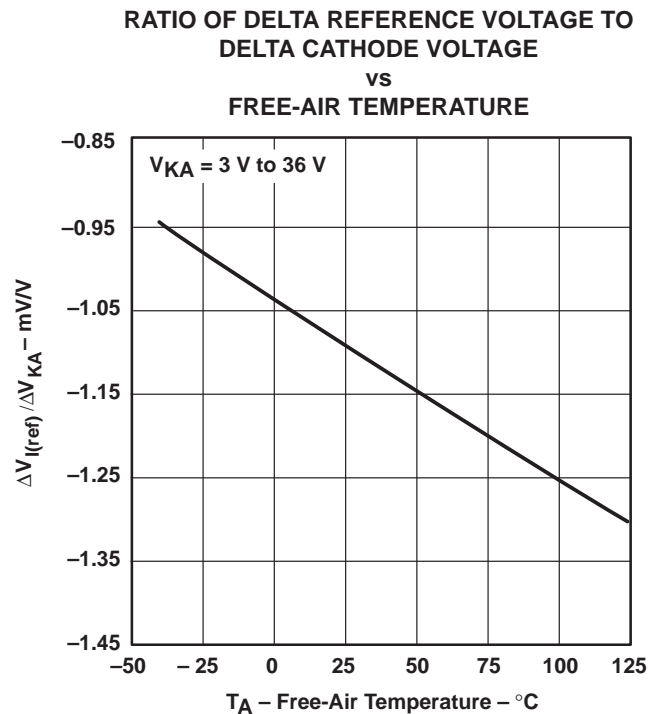


Figure 9

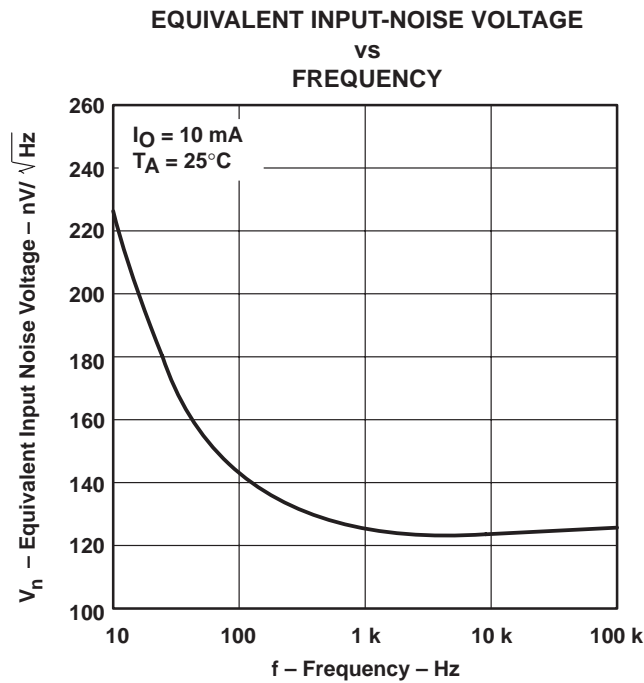
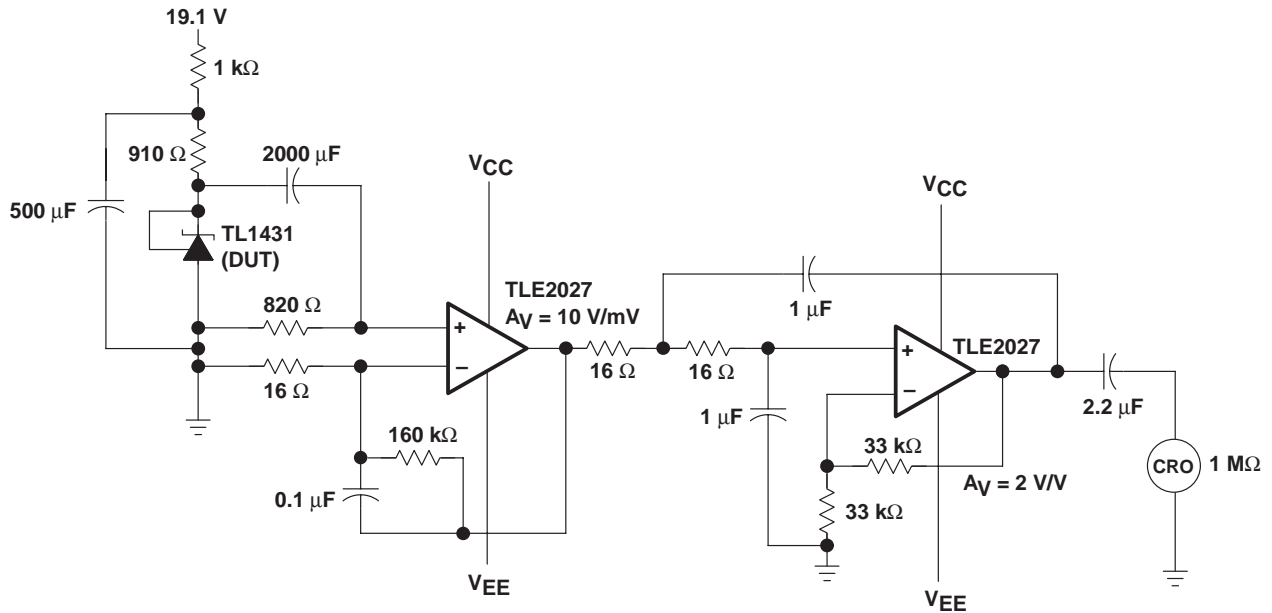
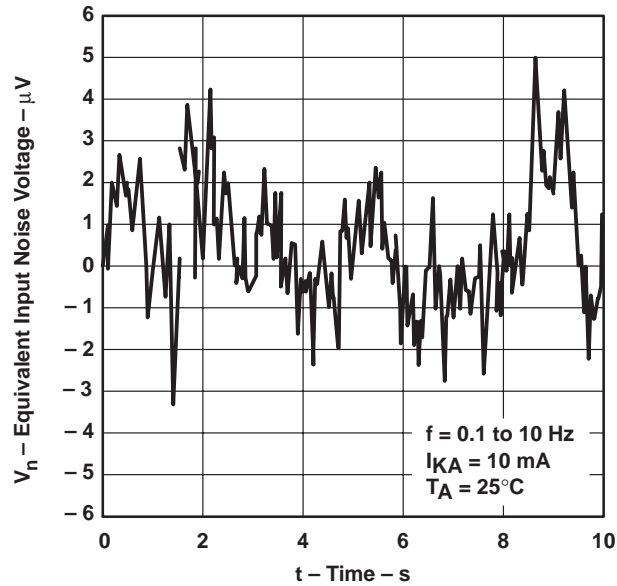


Figure 10

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

TYPICAL CHARACTERISTICS

EQUIVALENT INPUT-NOISE VOLTAGE
OVER A 10-SECOND PERIOD



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

Figure 11

TYPICAL CHARACTERISTICS

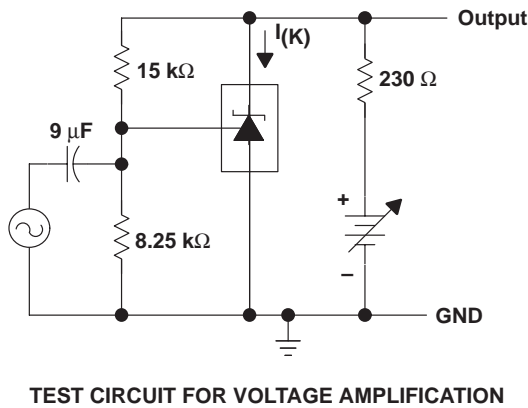
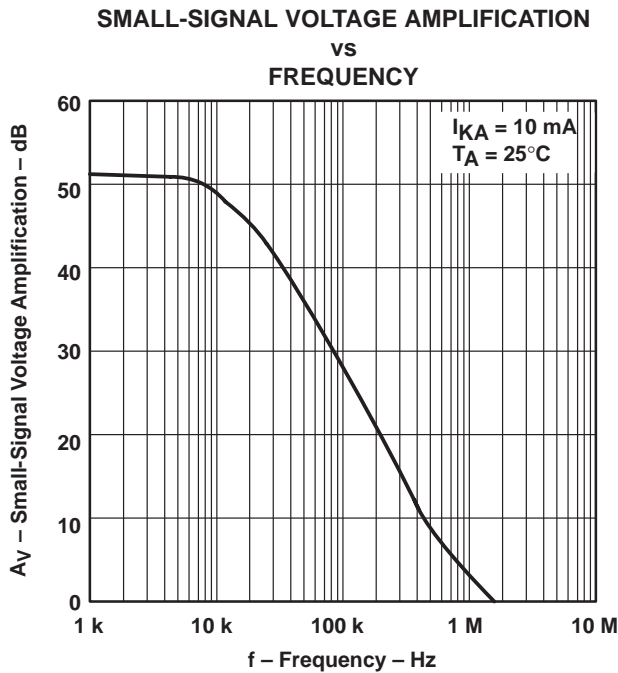


Figure 12

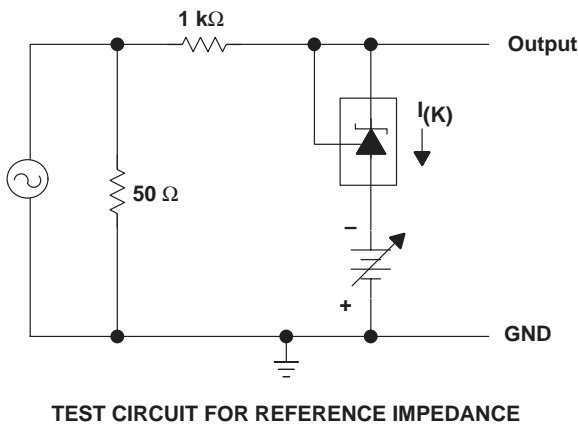
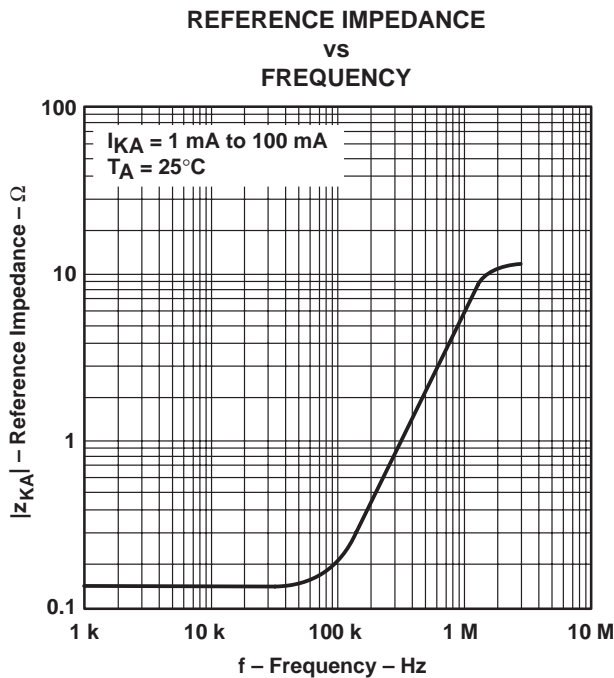


Figure 13

TYPICAL CHARACTERISTICS

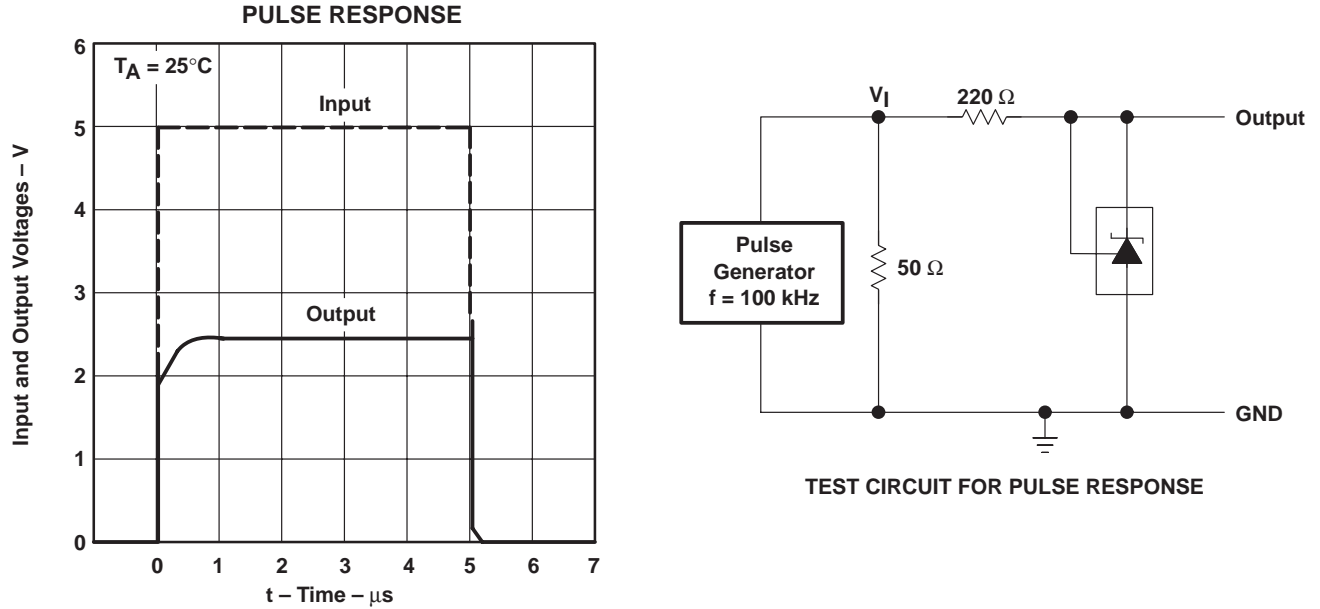


Figure 14

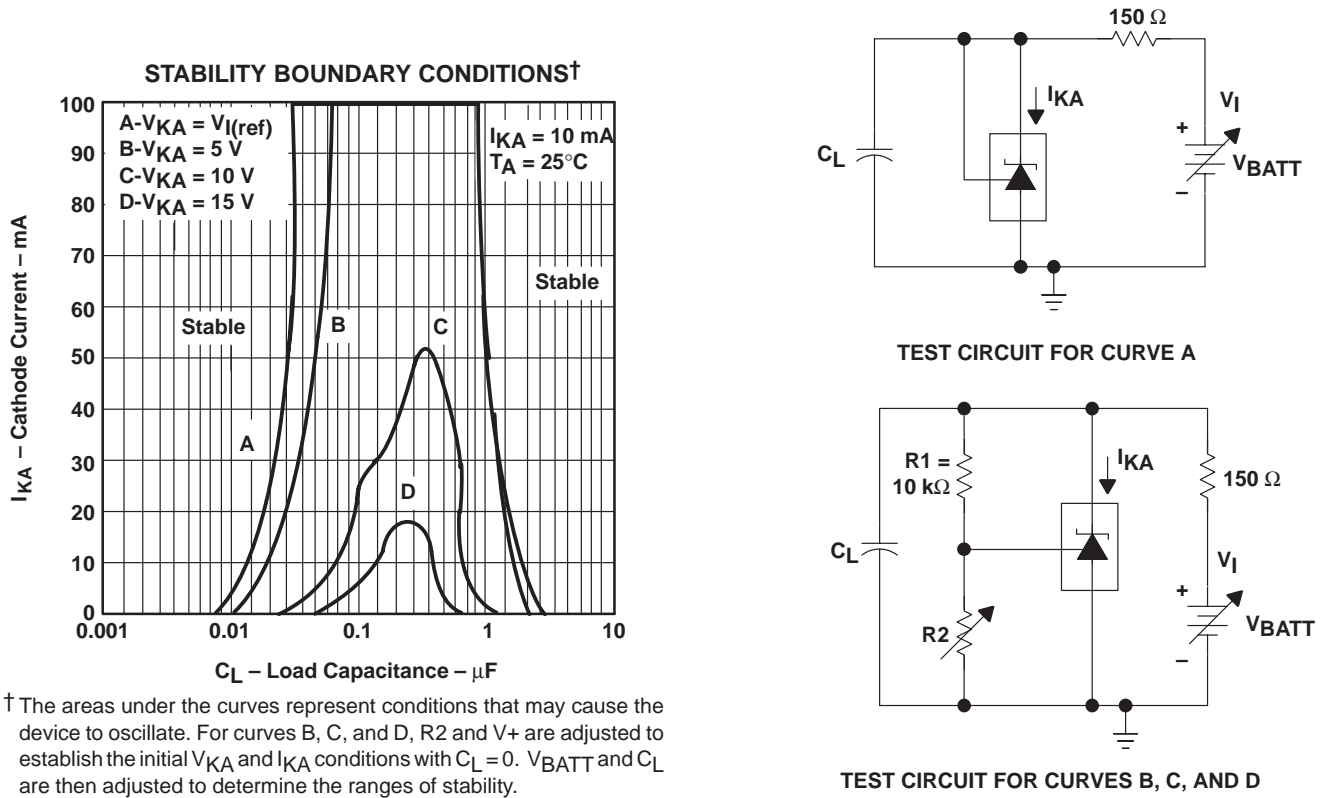
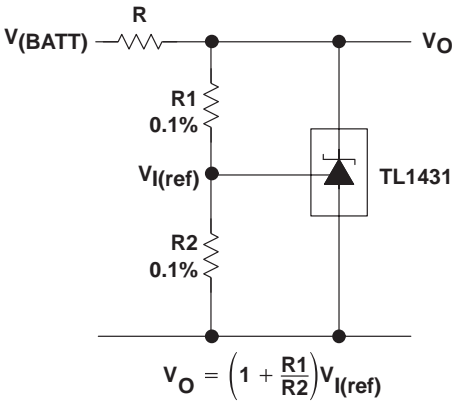


Figure 15

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



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

Figure 16. Shunt Regulator

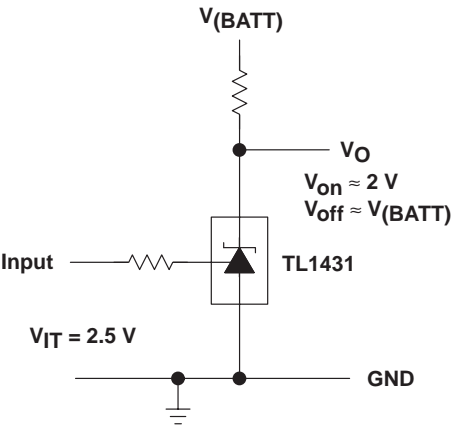
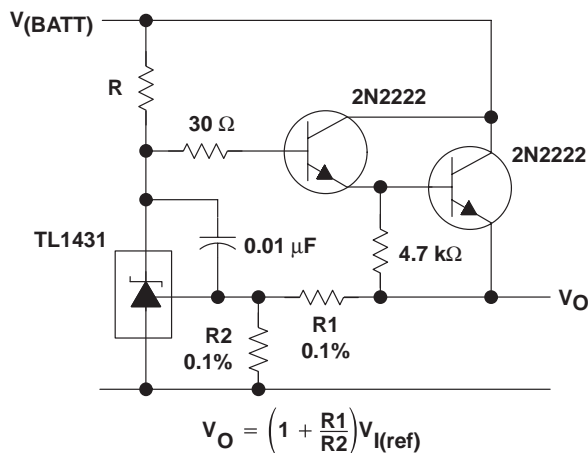


Figure 17. Single-Supply Comparator With Temperature-Compensated Threshold

APPLICATION INFORMATION



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

Figure 18. Precision High-Current Series Regulator

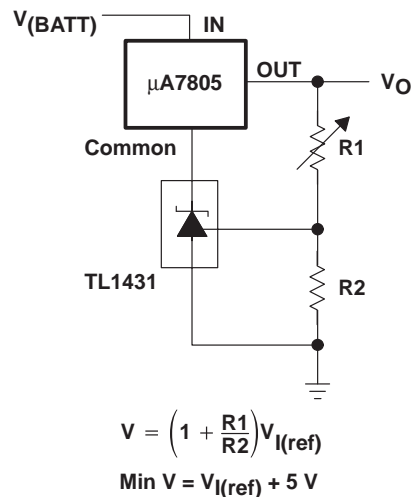


Figure 19. Output Control of a Three-Terminal Fixed Regulator

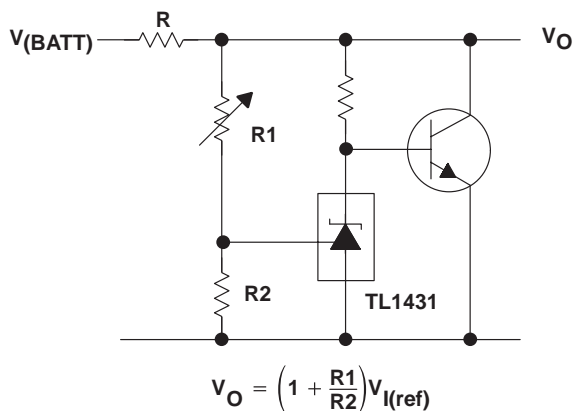
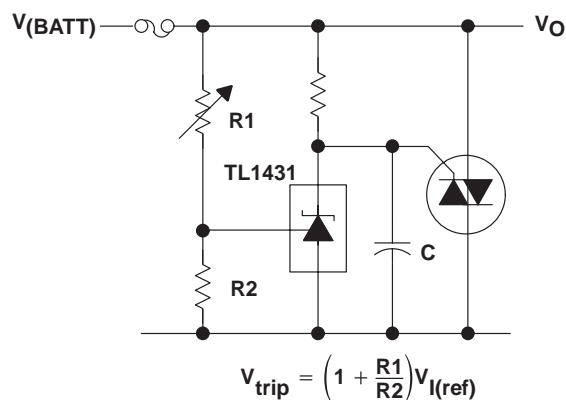


Figure 20. Higher-Current Shunt Regulator



NOTE A: Refer to the stability boundary conditions in Figure 15 to determine allowable values for C.

Figure 21. Crowbar

TL1431

PRECISION PROGRAMMABLE REFERENCE

SLVS062F – DECEMBER 1991 – REVISED JANUARY 2000

APPLICATION INFORMATION

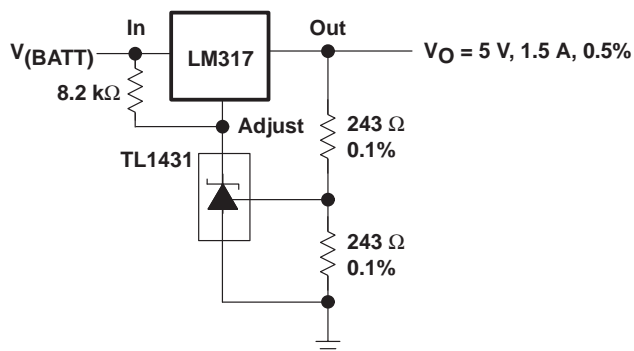


Figure 22. Precision 5-V, 1.5-A, 0.5% Regulator

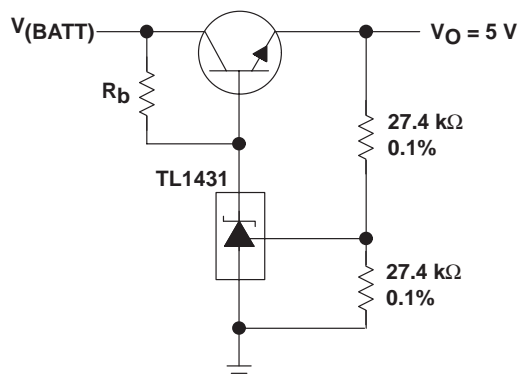


Figure 23. 5-V Precision Regulator

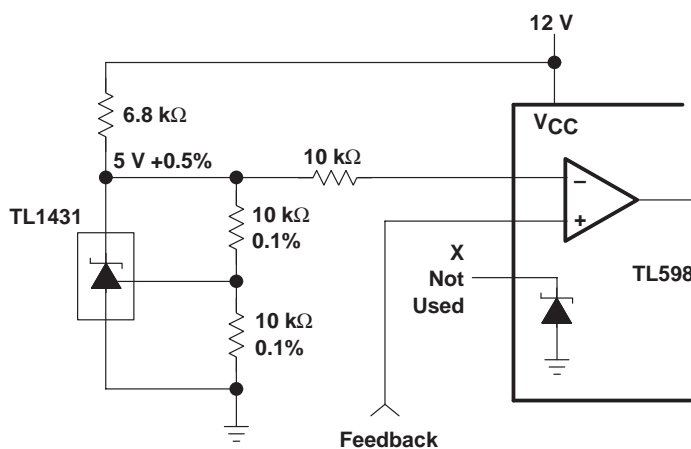


Figure 24. PWM Converter With 0.5% Reference

APPLICATION INFORMATION

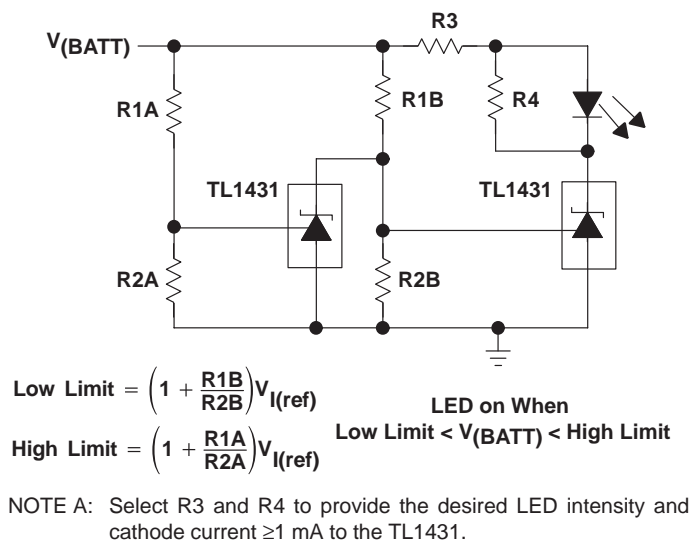


Figure 25. Voltage Monitor

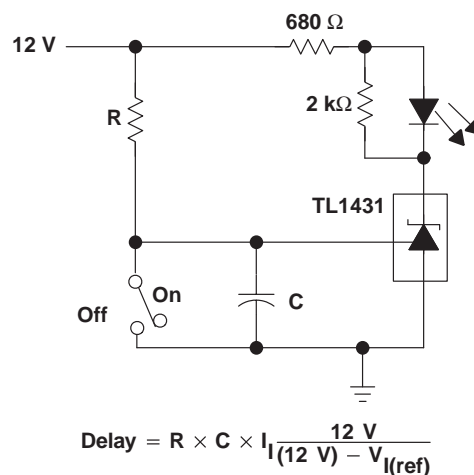


Figure 26. Delay Timer

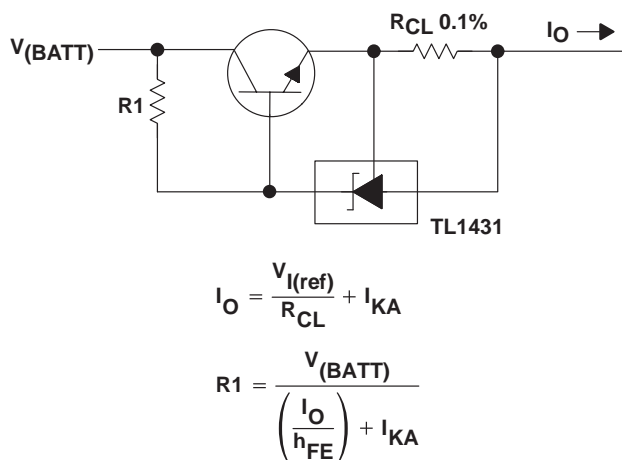


Figure 27. Precision Current Limiter

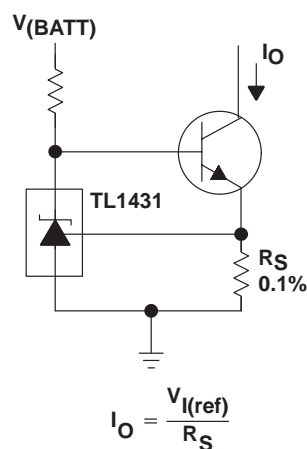


Figure 28. Precision Constant-Current Sink

IMPORTANT NOTICE

Texas Instruments and its subsidiaries (TI) reserve the right to make changes to their products or to discontinue any product or service without notice, and advise customers to obtain the latest version of relevant information to verify, before placing orders, that information being relied on is current and complete. All products are sold subject to the terms and conditions of sale supplied at the time of order acknowledgement, including those pertaining to warranty, patent infringement, and limitation of liability.

TI warrants performance of its semiconductor products to the specifications applicable at the time of sale in accordance with TI's standard warranty. Testing and other quality control techniques are utilized to the extent TI deems necessary to support this warranty. Specific testing of all parameters of each device is not necessarily performed, except those mandated by government requirements.

CERTAIN APPLICATIONS USING SEMICONDUCTOR PRODUCTS MAY INVOLVE POTENTIAL RISKS OF DEATH, PERSONAL INJURY, OR SEVERE PROPERTY OR ENVIRONMENTAL DAMAGE ("CRITICAL APPLICATIONS"). TI SEMICONDUCTOR PRODUCTS ARE NOT DESIGNED, AUTHORIZED, OR WARRANTED TO BE SUITABLE FOR USE IN LIFE-SUPPORT DEVICES OR SYSTEMS OR OTHER CRITICAL APPLICATIONS. INCLUSION OF TI PRODUCTS IN SUCH APPLICATIONS IS UNDERSTOOD TO BE FULLY AT THE CUSTOMER'S RISK.

In order to minimize risks associated with the customer's applications, adequate design and operating safeguards must be provided by the customer to minimize inherent or procedural hazards.

TI assumes no liability for applications assistance or customer product design. TI does not warrant or represent that any license, either express or implied, is granted under any patent right, copyright, mask work right, or other intellectual property right of TI covering or relating to any combination, machine, or process in which such semiconductor products or services might be or are used. TI's publication of information regarding any third party's products or services does not constitute TI's approval, warranty or endorsement thereof.