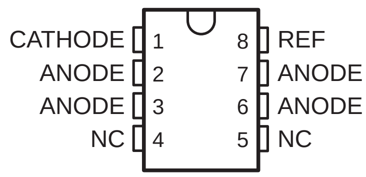
- **Equivalent Full-Range Temperature Coefficient . . . 30 ppm/°C**
- **0.2-Ω Typical Output Impedance**
- **Sink-Current Capability . . . 1 mA to 100 mA**
- **Low Output Noise**
- **Adjustable Output Voltage . . . V_{ref} to 36 V**
- **Available in a Wide Range of High-Density Packages**

description

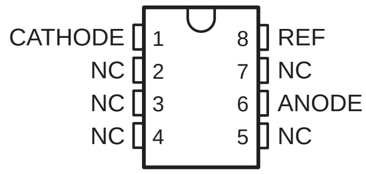
The TL431 and TL431A are three-terminal adjustable shunt regulators with specified thermal stability over applicable automotive, commercial, and military temperature ranges. The output voltage can be set to any value between V_{ref} (approximately 2.5 V) and 36 V with two external resistors (see Figure 17). These devices have a typical output impedance of 0.2 Ω. Active output circuitry provides a very sharp turn-on characteristic, making these devices excellent replacements for Zener diodes in many applications, such as onboard regulation, adjustable power supplies, and switching power supplies.

The TL431C and TL431AC are characterized for operation from 0°C to 70°C, and the TL431I and TL431AI are characterized for operation from –40°C to 85°C.

D PACKAGE
(TOP VIEW)

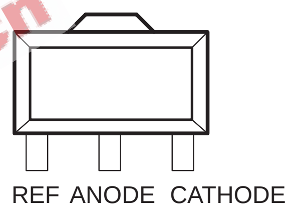


P OR PW PACKAGE
(TOP VIEW)

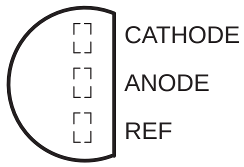


NC – No internal connection

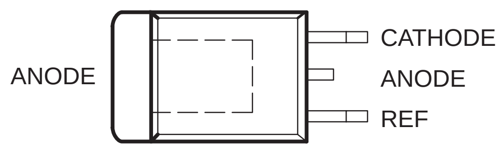
PK PACKAGE
(TOP VIEW)



LP PACKAGE
(TOP VIEW)



KTP PACKAGE
(TOP VIEW)



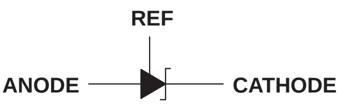
Please be aware that an important notice concerning availability, standard warranty, and use in critical applications of Texas Instruments semiconductor products and disclaimers thereto appears at the end of this data sheet.

AVAILABLE OPTIONS

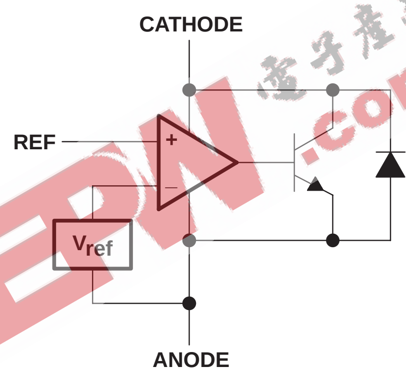
T_A	PACKAGED DEVICES						CHIP FORM (Y)
	SMALL OUTLINE (D)	PLASTIC FLANGE MOUNT (KTP)	TO-226AA (LP)	PLASTIC DIP (P)	SOT-89 (PK)	SHRINK SMALL OUTLINE (PW)	
0°C to 70°C	TL431CD TL431ACD	TL431CKTPR	TL431CLP TL431ACLP	TL431CP TL431ACP	TL431CPK	TL431CPW	TL431Y
–40°C to 85°C	TL431ID TL431AID		TL431ILP TL431AILP	TL431IP TL431AIP	TL431IPK		

The D and LP packages are available taped and reeled. The KTP and PK packages are only available taped and reeled. Add the suffix R to device type (e.g., TL431CDR). Chip forms are tested at T_A = 25°C.

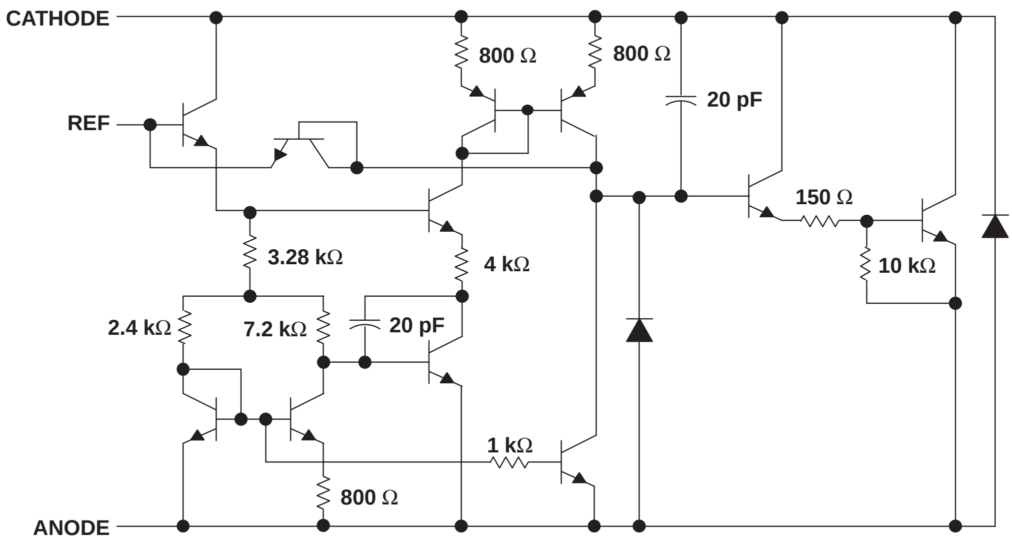
symbol



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 . . . . . –50 μA to 10 mA
Package thermal impedance, θ_{JA} (see Notes 2 and 3): D package . . . . . 97°C/W
LP package . . . . . 156°C/W
KTP package . . . . . 28°C/W
P package . . . . . 127°C/W
PK package . . . . . 52°C/W
PW package . . . . . 149°C/W
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: D, P, or PW package . . . . . 260°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: LP or PK package . . . . . 300°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. Voltage values are with respect to the anode terminal 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, except for through-hole packages, which use a trace length of zero.

recommended operating conditions

		MIN	MAX	UNIT
Cathode voltage, V_{KA}		V_{ref}	36	V
Cathode current, I_{KA}		1	100	mA
Operating free-air temperature range, T_A	TL431C, TL431AC	0	70	°C
	TL431I, TL431AI	–40	85	

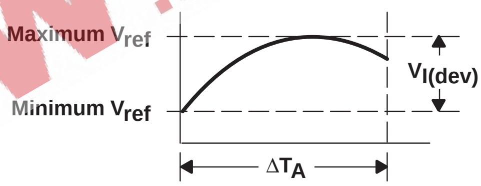
electrical characteristics over recommended operating conditions, T_A = 25°C (unless otherwise noted)

PARAMETER		TEST CIRCUIT	TEST CONDITIONS		TL431C			UNIT
					MIN	TYP	MAX	
V_{ref}	Reference voltage	2	$V_{KA} = V_{ref}$,	I_{KA} = 10 mA	2440	2495	2550	mV
$V_{I(dev)}$	Deviation of reference voltage over full temperature range (see Figure 1)	2	$V_{KA} = V_{ref}$, I_{KA} = 10 mA, T_A = full range†			4	25	mV
$\frac{\Delta V_{ref}}{\Delta V_{KA}}$	Ratio of change in reference voltage to the change in cathode voltage	3	I_{KA} = 10 mA	ΔV_{KA} = 10 V – V_{ref}		–1.4	–2.7	$\frac{mV}{V}$
				ΔV_{KA} = 36 V – 10 V		–1	–2	
I_{ref}	Reference current	3	I_{KA} = 10 mA, R1 = 10 kΩ, R2 = ∞			2	4	µA
$I_{I(dev)}$	Deviation of reference current over full temperature range (see Figure 1)	3	I_{KA} = 10 mA, R1 = 10 kΩ, R2 = ∞, T_A = full range†			0.4	1.2	µA
I_{min}	Minimum cathode current for regulation	2	$V_{KA} = V_{ref}$			0.4	1	mA
I_{off}	Off-state cathode current	4	V_{KA} = 36 V,	V_{ref} = 0		0.1	1	µA
$\lvert z_{KA}\rvert$	Dynamic impedance (see Figure 1)	1	I_{KA} = 1 mA to 100 mA, $V_{KA} = V_{ref}$, f ≤ 1 kHz			0.2	0.5	Ω

† Full range is 0°C to 70°C for the TL431C.

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

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



where:

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

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

Example: maximum V_{ref} = 2496 mV at 30°C, minimum V_{ref} = 2492 mV at 0°C, V_{ref} = 2495 mV at 25°C, ΔT_A = 70°C for TL431C

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

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

Calculating Dynamic Impedance

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

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

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

Figure 1. Calculating Deviation Parameters and Dynamic Impedance

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

PARAMETER		TEST CIRCUIT	TEST CONDITIONS		TL431I MIN	TL431I TYP	TL431I MAX	UNIT
V_{ref}	Reference voltage	2	$V_{KA} = V_{ref}$, I_{KA} = 10 mA		2440	2495	2550	mV
$V_{I(dev)}$	Deviation of reference voltage over full temperature range (see Figure 1)	2	$V_{KA} = V_{ref}$, I_{KA} = 10 mA, T_A = full range†			5	50	mV
$\frac{\Delta V_{ref}}{\Delta V_{KA}}$	Ratio of change in reference voltage to the change in cathode voltage	3	I_{KA} = 10 mA	ΔV_{KA} = 10 V – V_{ref}		–1.4	–2.7	$\frac{mV}{V}$
				ΔV_{KA} = 36 V – 10 V		–1	–2	
I_{ref}	Reference current	3	I_{KA} = 10 mA, R1 = 10 kΩ, R2 = ∞			2	4	µA
$I_{I(dev)}$	Deviation of reference current over full temperature range (see Figure 1)	3	I_{KA} = 10 mA, R1 = 10 kΩ, R2 = ∞, T_A = full range†			0.8	2.5	µA
I_{min}	Minimum cathode current for regulation	2	$V_{KA} = V_{ref}$			0.4	1	mA
I_{off}	Off-state cathode current	4	V_{KA} = 36 V, V_{ref} = 0			0.1	1	µA
$\lvert z_{KA} \rvert$	Dynamic impedance (see Figure 1)	2	I_{KA} = 1 mA to 100 mA, $V_{KA} = V_{ref}$, f ≤ 1 kHz			0.2	0.5	Ω

† Full range is –40°C to 85°C for the TL431I.

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

PARAMETER		TEST CIRCUIT	TEST CONDITIONS		TL431AC MIN	TL431AC TYP	TL431AC MAX	UNIT
V_{ref}	Reference voltage	2	$V_{KA} = V_{ref}$, I_{KA} = 10 mA		2470	2495	2520	mV
$V_{I(dev)}$	Deviation of reference voltage over full temperature range (see Figure 1)	2	$V_{KA} = V_{ref}$, I_{KA} = 10 mA, T_A = full range†			4	25	mV
$\frac{\Delta V_{ref}}{\Delta V_{KA}}$	Ratio of change in reference voltage to the change in cathode voltage	3	I_{KA} = 10 mA	ΔV_{KA} = 10 V – V_{ref}		–1.4	–2.7	$\frac{mV}{V}$
				ΔV_{KA} = 36 V – 10 V		–1	–2	
I_{ref}	Reference current	3	I_{KA} = 10 mA, R1 = 10 kΩ, R2 = ∞			2	4	µA
$I_{I(dev)}$	Deviation of reference current over full temperature range (see Figure 1)	3	I_{KA} = 10 mA, R1 = 10 kΩ, R2 = ∞, T_A = full range‡			0.8	1.2	µA
I_{min}	Minimum cathode current for regulation	2	$V_{KA} = V_{ref}$			0.4	0.6	mA
I_{off}	Off-state cathode current	4	V_{KA} = 36 V, V_{ref} = 0			0.1	0.5	µA
$\lvert z_{KA} \rvert$	Dynamic impedance (see Figure 1)	1	I_{KA} = 1 mA to 100 mA, $V_{KA} = V_{ref}$, f ≤ 1 kHz			0.2	0.5	Ω

‡ Full range is 0°C to 70°C for the TL431AC.

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

PARAMETER		TEST CIRCUIT	TEST CONDITIONS		TL431AI			UNIT
					MIN	TYP	MAX	
V_{ref}	Reference voltage	2	$V_{KA} = V_{ref}$,	I_{KA} = 10 mA	2470	2495	2520	mV
$V_{I(dev)}$	Deviation of reference voltage over full temperature range (see Figure 1)	2	$V_{KA} = V_{ref}$, I_{KA} = 10 mA, T_A = full range†			5	50	mV
$\frac{\Delta V_{ref}}{\Delta V_{KA}}$	Ratio of change in reference voltage to the change in cathode voltage	3	I_{KA} = 10 mA	ΔV_{KA} = 10 V – V_{ref}		–1.4	–2.7	$\frac{mV}{V}$
				ΔV_{KA} = 36 V – 10 V		–1	–2	
I_{ref}	Reference current	3	I_{KA} = 10 mA, R1 = 10 kΩ, R2 = ∞			2	4	μA
$I_{I(dev)}$	Deviation of reference current over full temperature range (see Figure 1)	3	I_{KA} = 10 mA, R1 = 10 kΩ, R2 = ∞, T_A = full range†			0.8	2.5	μA
I_{min}	Minimum cathode current for regulation	2	$V_{KA} = V_{ref}$			0.4	0.7	mA
I_{off}	Off-state cathode current	4	V_{KA} = 36 V,	V_{ref} = 0		0.1	0.5	μA
$\lvert z_{KA}\rvert$	Dynamic impedance (see Figure 1)	2	I_{KA} = 1 mA to 100 mA, $V_{KA} = V_{ref}$, f ≤ 1 kHz			0.2	0.5	Ω

† Full range is –40°C to 85°C for the TL431AI.

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

PARAMETER		TEST CIRCUIT	TEST CONDITIONS		TL431Y			UNIT
					MIN	TYP	MAX	
V_{ref}	Reference voltage	2	$V_{KA} = V_{ref}$,	I_{KA} = 10 mA		2495		mV
$\frac{\Delta V_{ref}}{\Delta V_{KA}}$	Ratio of change in reference voltage to the change in cathode voltage	3	I_{KA} = 10 mA	ΔV_{KA} = 10 V – V_{ref}		–1.4		$\frac{mV}{V}$
				ΔV_{KA} = 36 V – 10 V		–1		
I_{ref}	Reference input current	3	I_{KA} = 10 mA, R1 = 10 kΩ, R2 = ∞			2		μA
I_{min}	Minimum cathode current for regulation	2	$V_{KA} = V_{ref}$			0.4		mA
I_{off}	Off-state cathode current	4	V_{KA} = 36 V,	V_{ref} = 0		0.1		μA
$\lvert z_{KA}\rvert$	Dynamic impedance‡	2	I_{KA} = 1 mA to 100 mA, $V_{KA} = V_{ref}$, f ≤ 1 kHz			0.2		Ω

‡ Calculating dynamic impedance:

The dynamic 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 3), the total dynamic impedance of the circuit is given by:

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

PARAMETER MEASUREMENT INFORMATION

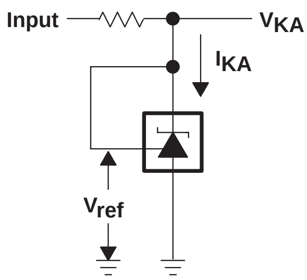


Figure 2. Test Circuit for $V_{KA} = V_{ref}$

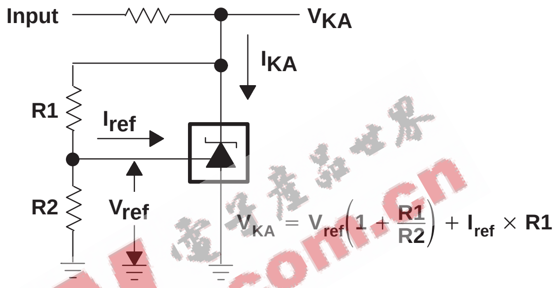


Figure 3. Test Circuit for $V_{KA} > V_{ref}$

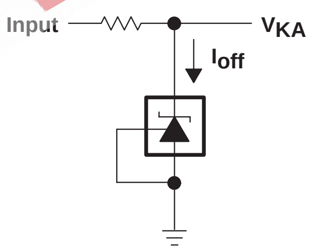


Figure 4. Test Circuit for I_{off}

TYPICAL CHARACTERISTICS

Table 1. Graphs

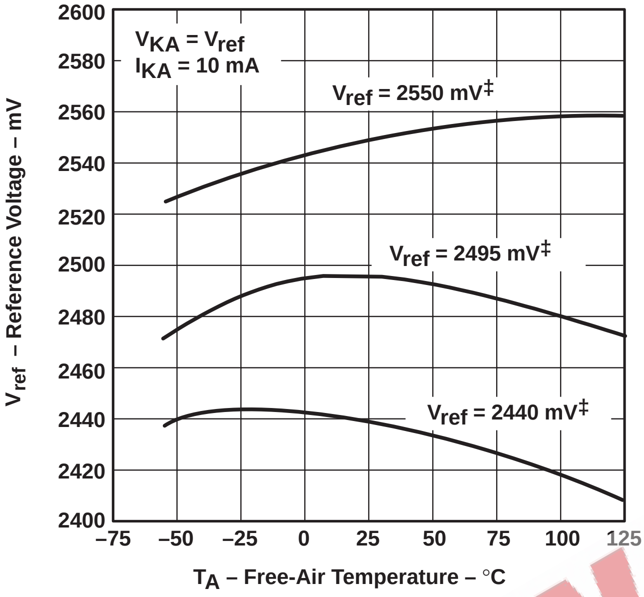
	FIGURE
Reference input voltage vs Free-air temperature	5
Reference input current vs Free-air temperature	6
Cathode current vs Cathode voltage	7, 8
Off-state cathode current vs Free-air temperature	9
Ratio of delta reference voltage to change in cathode voltage vs Free-air temperature	10
Equivalent input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

Table 2. Application Circuits

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

TYPICAL CHARACTERISTICS†

**REFERENCE VOLTAGE
vs
FREE-AIR TEMPERATURE**



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

Figure 5

**REFERENCE CURRENT
vs
FREE-AIR TEMPERATURE**

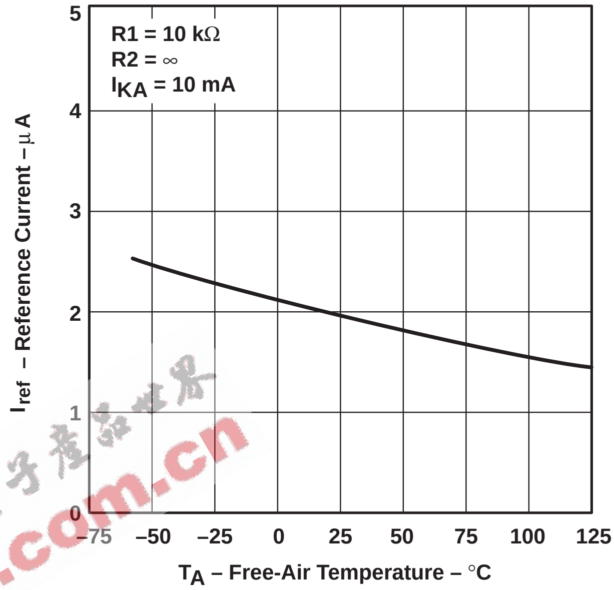


Figure 6

**CATHODE CURRENT
vs
CATHODE VOLTAGE**

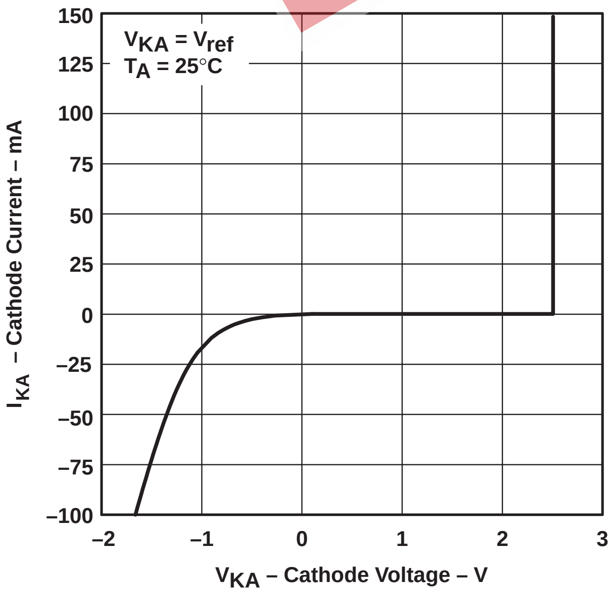


Figure 7

**CATHODE CURRENT
vs
CATHODE VOLTAGE**

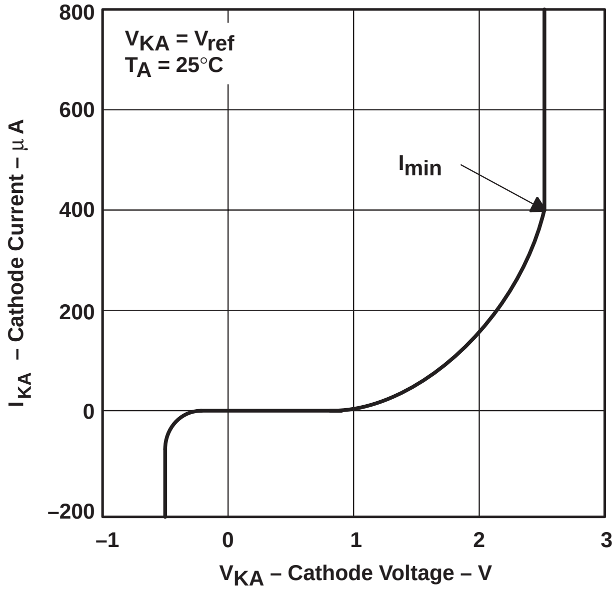


Figure 8

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

TYPICAL CHARACTERISTICS†

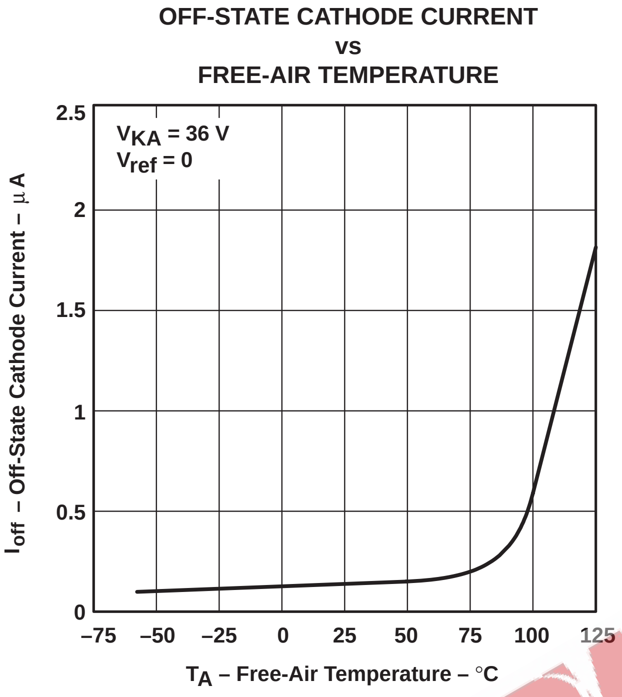


Figure 9

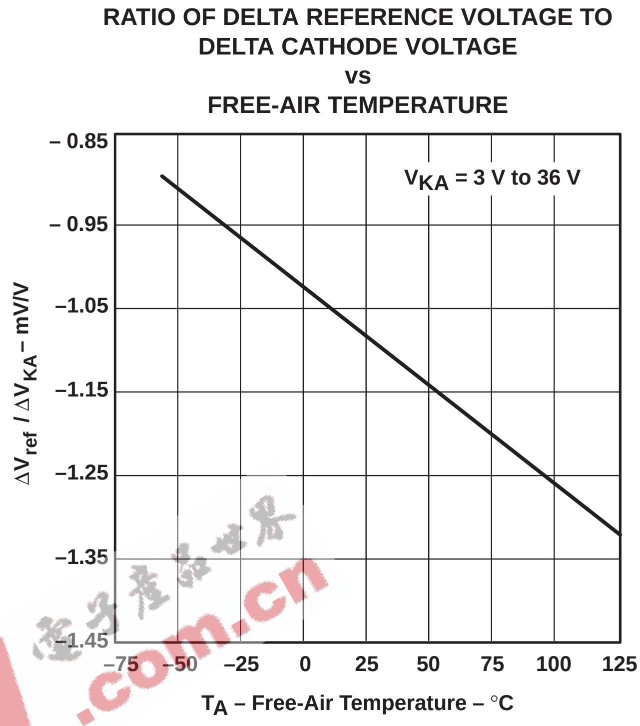


Figure 10

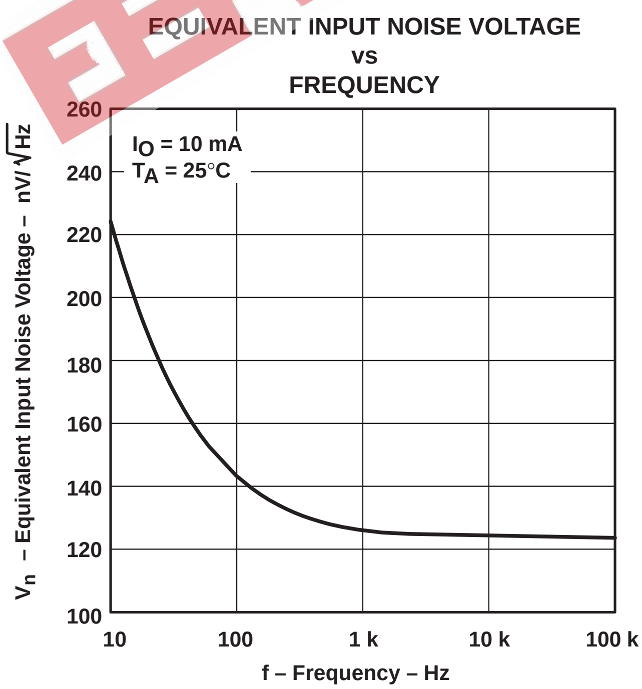
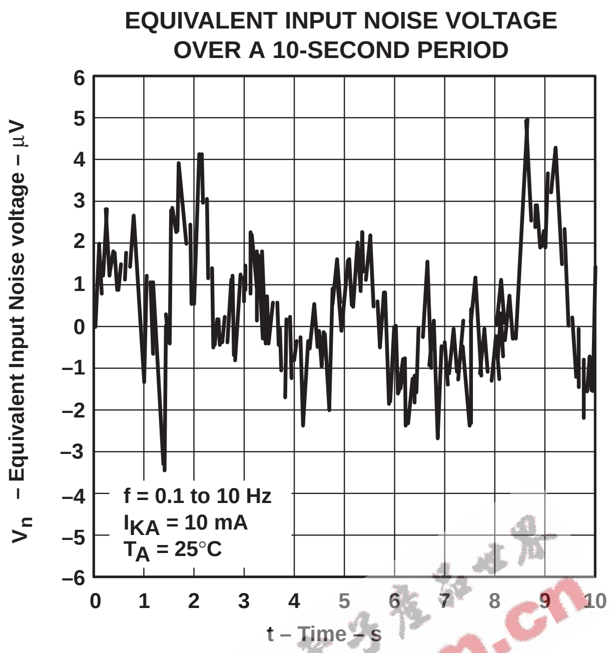


Figure 11

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

TYPICAL CHARACTERISTICS



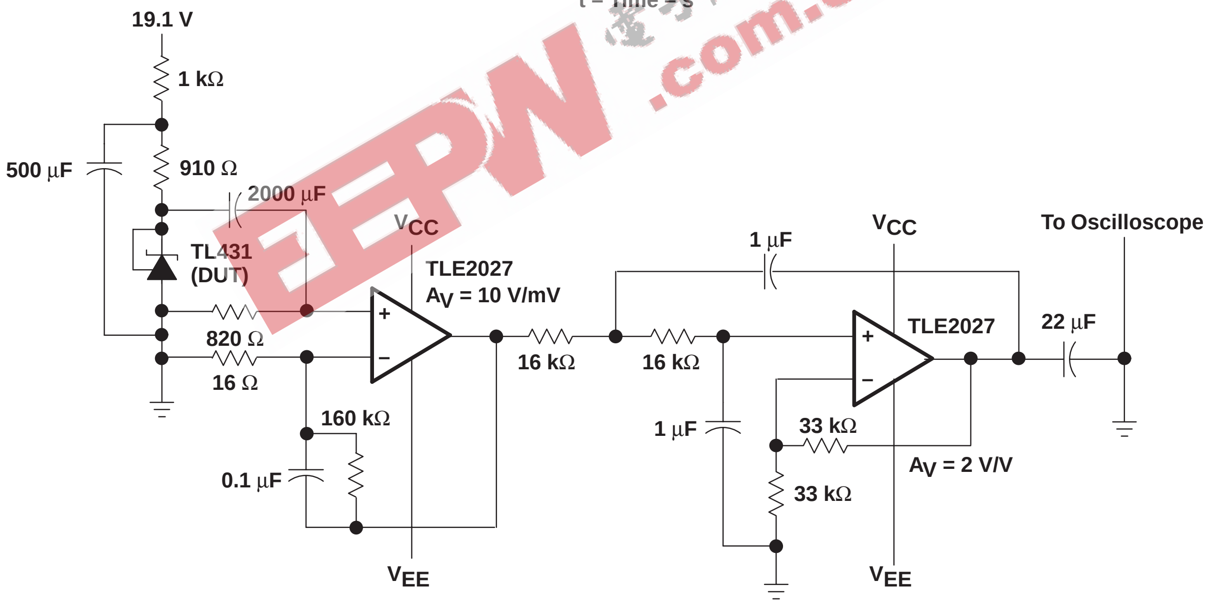
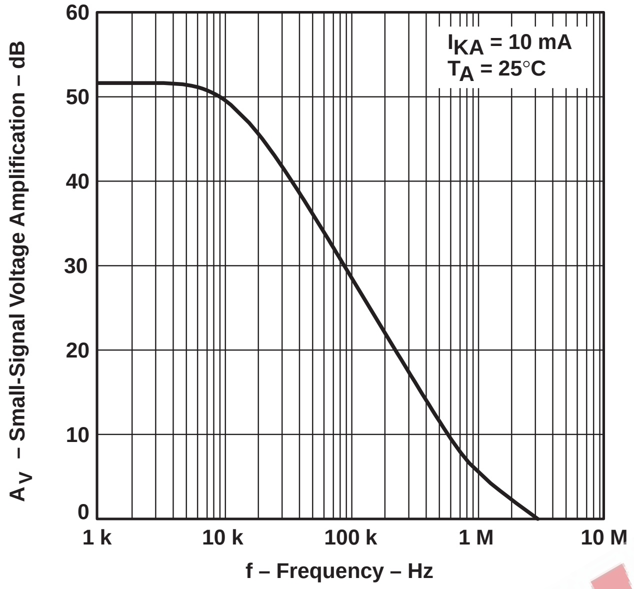
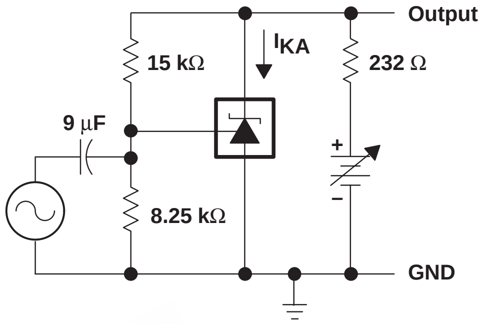


Figure 12. Test Circuit for Equivalent Input Noise Voltage

TYPICAL CHARACTERISTICS

SMALL-SIGNAL VOLTAGE AMPLIFICATION
vs
FREQUENCY

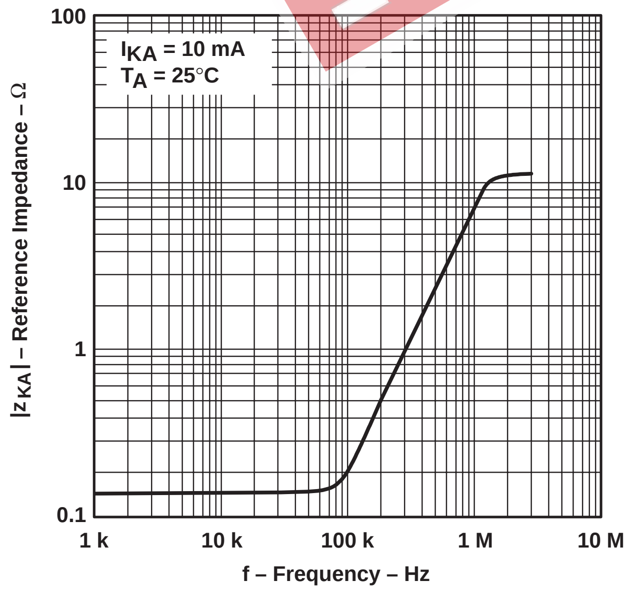


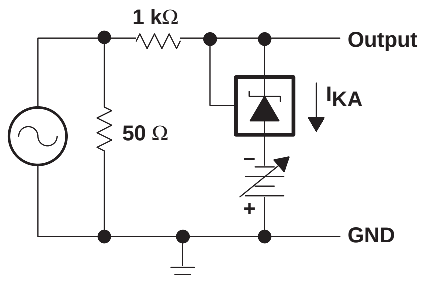


TEST CIRCUIT FOR VOLTAGE AMPLIFICATION

Figure 13

REFERENCE IMPEDANCE
vs
FREQUENCY



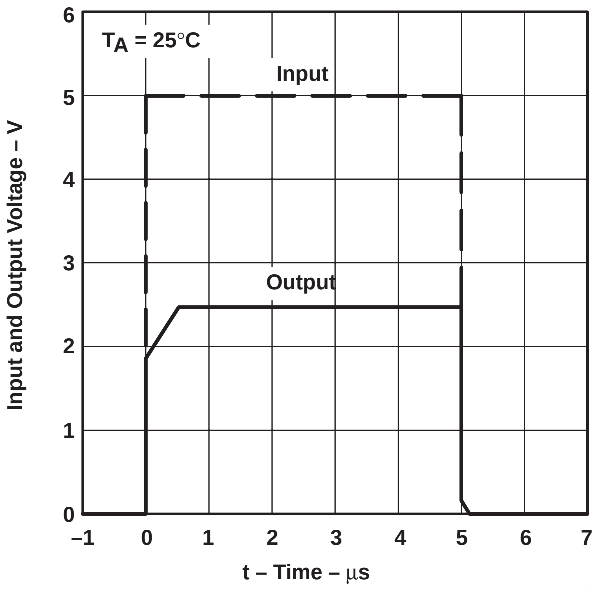


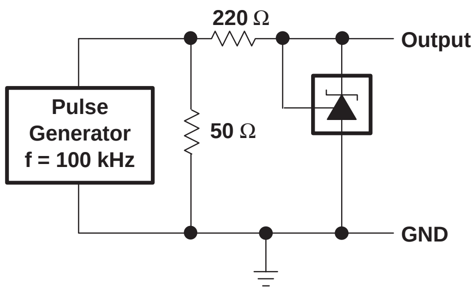
TEST CIRCUIT FOR REFERENCE IMPEDANCE

Figure 14

TYPICAL CHARACTERISTICS

PULSE RESPONSE

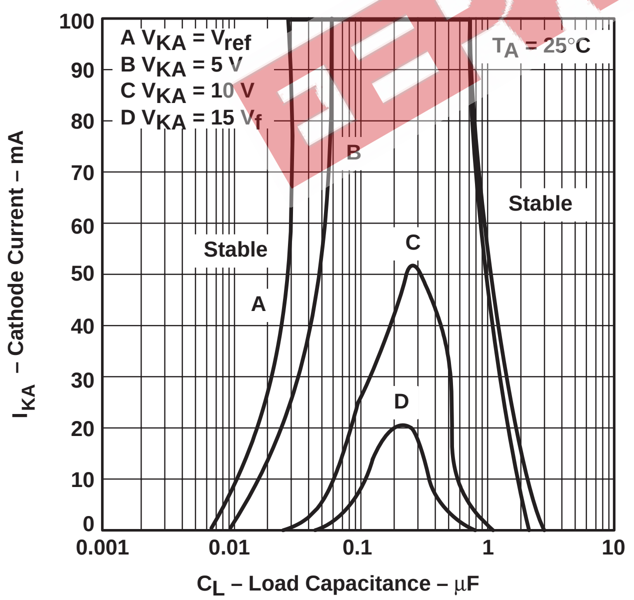


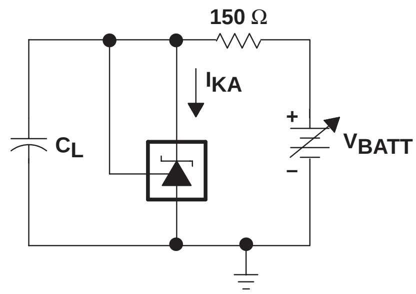


TEST CIRCUIT FOR PULSE RESPONSE

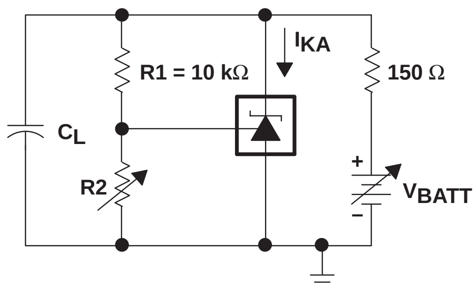
Figure 15

STABILITY BOUNDARY CONDITIONS†





TEST CIRCUIT FOR CURVE A

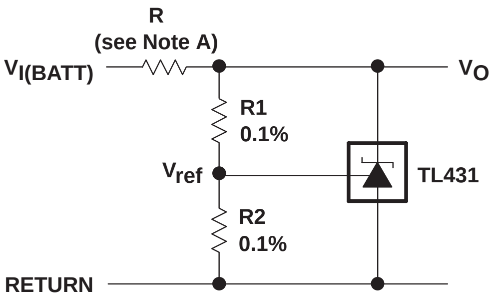


TEST CIRCUIT FOR CURVES B, C, AND D

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

Figure 16

APPLICATION INFORMATION



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

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

Figure 17. Shunt Regulator

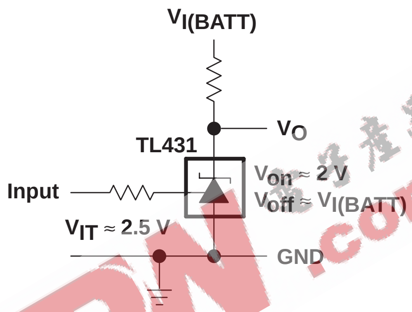
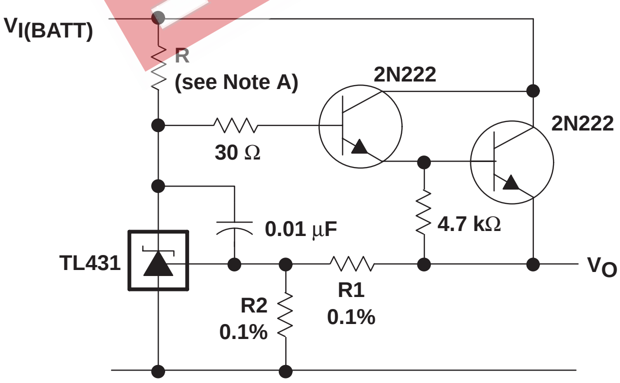


Figure 18. Single-Supply Comparator With Temperature-Compensated Threshold



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

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

Figure 19. Precision High-Current Series Regulator

APPLICATION INFORMATION

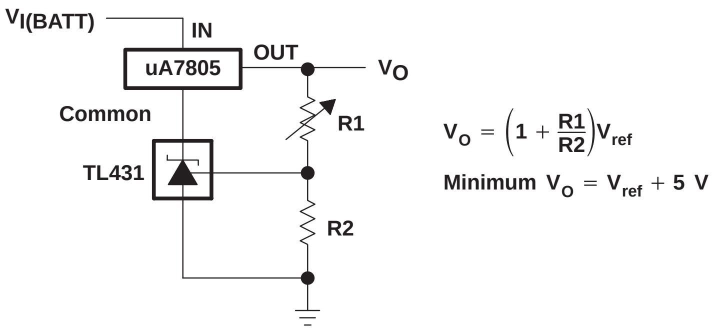


Figure 20. Output Control of a Three-Terminal Fixed Regulator

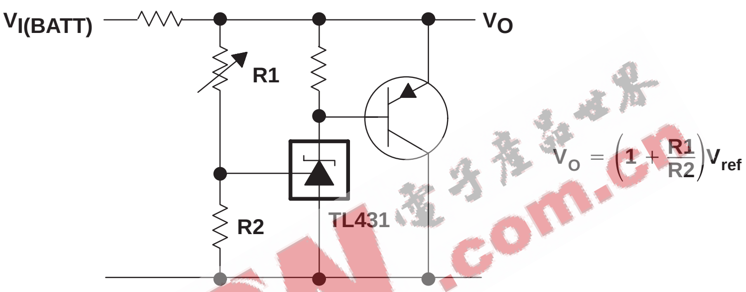
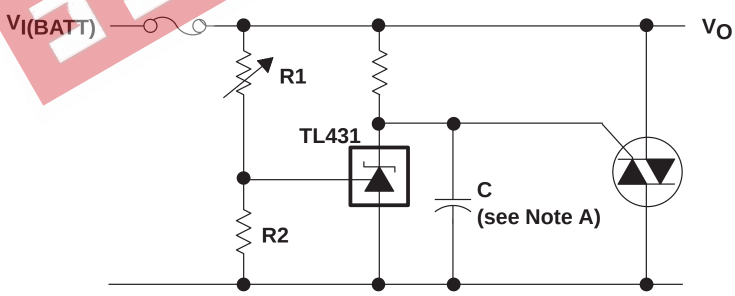


Figure 21. High-Current Shunt Regulator



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

Figure 22. Crowbar Circuit

APPLICATION INFORMATION

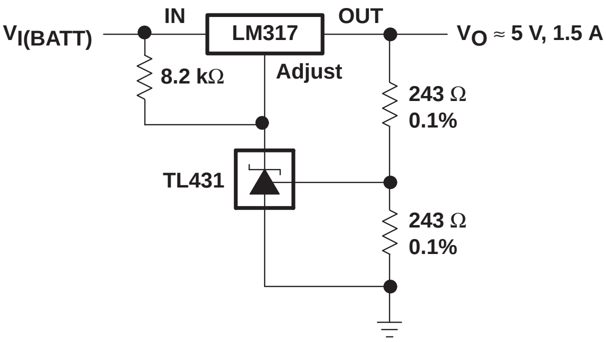
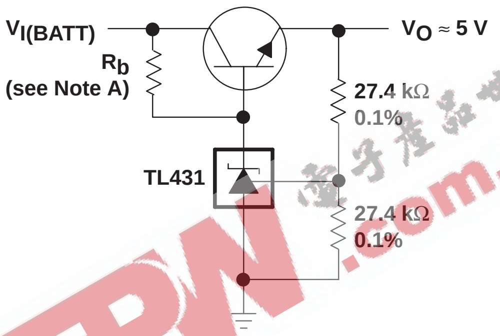


Figure 23. Precision 5-V 1.5-A Regulator



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

Figure 24. Efficient 5-V Precision Regulator

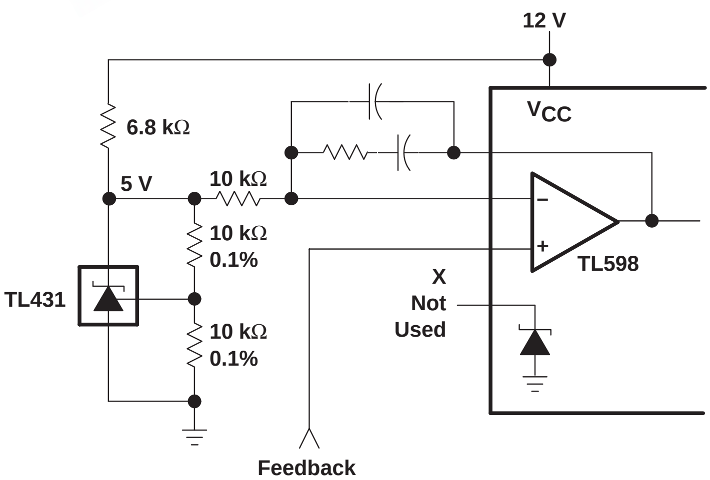
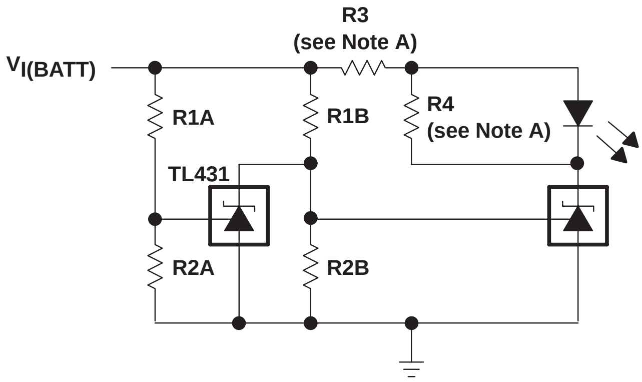


Figure 25. PWM Converter With Reference

TEXAS INSTRUMENTS
POST OFFICE BOX 655303 • DALLAS, TEXAS 75265

APPLICATION INFORMATION



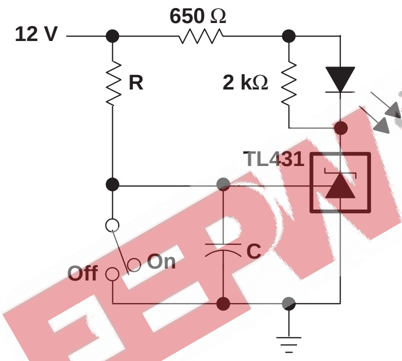
$$\text{Low Limit} = \left(1 + \frac{R1B}{R2B}\right)V_{ref}$$

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

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

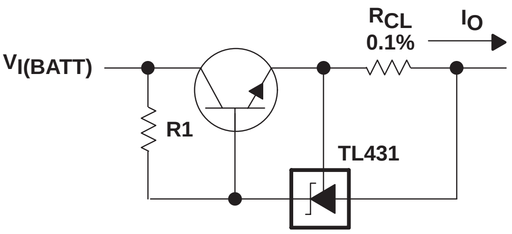
NOTE A: R3 and R4 are selected to provide the desired LED intensity and cathode current ≥1 mA to the TL431 at the available $V_{I(BATT)}$.

Figure 26. Voltage Monitor



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

Figure 27. Delay Timer



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

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

Figure 28. Precision Current Limiter

APPLICATION INFORMATION

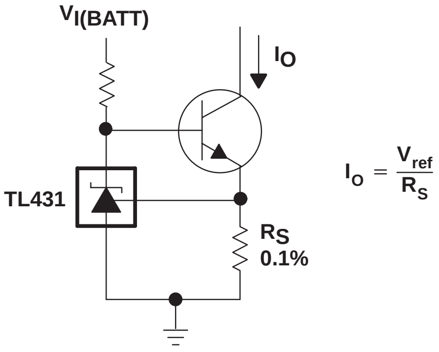


Figure 29. Precision Constant-Current Sink

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.