

TL431, TL431A

ADJUSTABLE PRECISION SHUNT REGULATORS

SLVS005J – JULY 1978 – REVISED JULY 1999

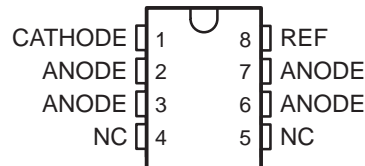
- Equivalent Full-Range Temperature Coefficient . . . 30 ppm/°C
- 0.2-Ω Typical Output Impedance
- Sink-Current Capability . . . 1 mA to 100 mA
- Low Output Noise
- Adjustable Output Voltage . . . V_{ref} to 36 V
- Available in a Wide Range of High-Density Packages

description

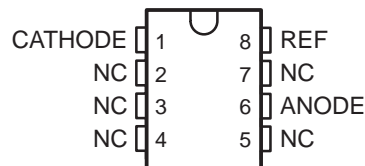
The TL431 and TL431A are three-terminal adjustable shunt regulators with specified thermal stability over applicable automotive, commercial, and military temperature ranges. The output voltage can be set to any value between V_{ref} (approximately 2.5 V) and 36 V with two external resistors (see Figure 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)**

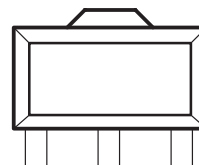


**P OR PW PACKAGE
(TOP VIEW)**



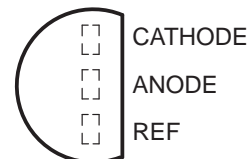
NC – No internal connection

**PK PACKAGE
(TOP VIEW)**

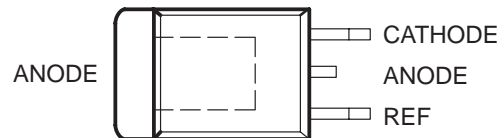


REF ANODE CATHODE

**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.

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**

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TL431, TL431A

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AVAILABLE OPTIONS

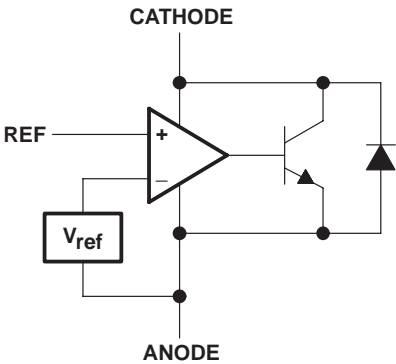
T _A	PACKAGED DEVICES						CHIP FORM (Y)
	SMALL OUTLINE (D)	PLASTIC FLANGE MOUNT (KTP)	TO-226AA (LP)	PLASTIC DIP (P)	SOT-89 (PK)	SHRINK SMALL OUTLINE (PW)	
0°C to 70°C	TL431CD TL431ACD	TL431CKTPR	TL431CLP TL431ACL	TL431CP TL431ACP	TL431CPK	TL431CPW	TL431Y
–40°C to 85°C	TL431ID TL431AID		TL431ILP TL431AILP	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.

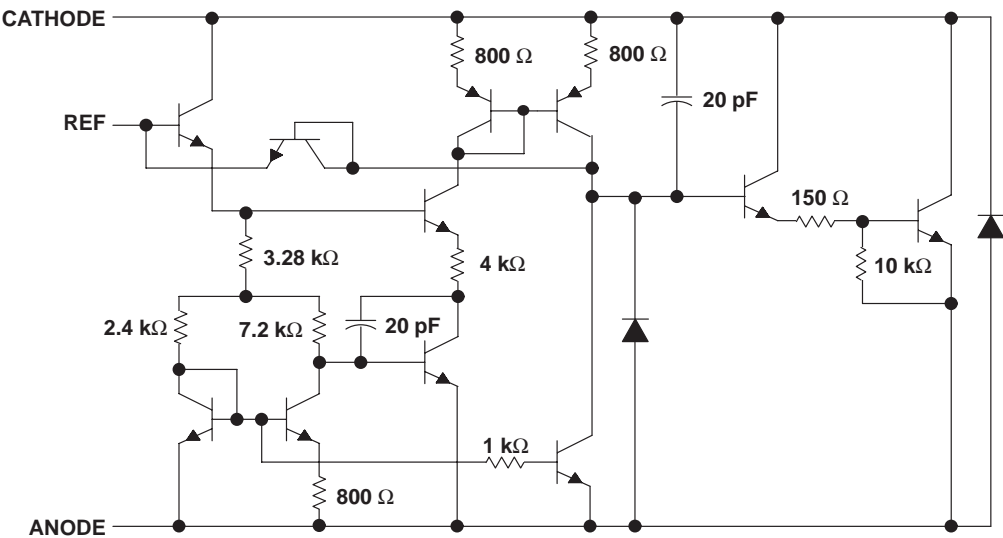
symbol



functional block diagram



equivalent schematic†



† All component values are nominal.

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absolute maximum ratings over operating free-air temperature range (unless otherwise noted)†

Cathode voltage, V_{KA} (see Note 1)	37 V
Continuous cathode current range, I_{KA}	–100 mA to 150 mA
Reference input current range	–50 μ A 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 JEDEC 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	



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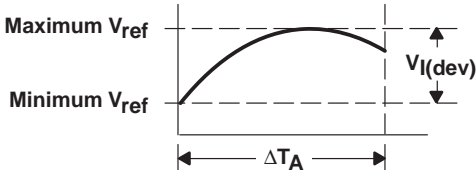
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electrical characteristics over recommended operating conditions, $T_A = 25^\circ\text{C}$ (unless otherwise noted)

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

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

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

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


where:

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

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

Example: maximum $V_{\text{ref}} = 2496\text{ mV}$ at 30°C , minimum $V_{\text{ref}} = 2492\text{ mV}$ at 0°C , $V_{\text{ref}} = 2495\text{ mV}$ at 25°C , $\Delta T_A = 70^\circ\text{C}$ for TL431C

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

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

Calculating Dynamic Impedance

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

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

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

Figure 1. Calculating Deviation Parameters and Dynamic Impedance

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electrical characteristics over recommended operating conditions, $T_A = 25^\circ\text{C}$ (unless otherwise noted)

PARAMETER		TEST CIRCUIT	TEST CONDITIONS		TL431I			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†			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	$\frac{\text{mV}}{\text{V}}$	
				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
z _{KA}	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, $T_A = 25^\circ\text{C}$ (unless otherwise noted)

PARAMETER		TEST CIRCUIT	TEST CONDITIONS		TL431AC			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†			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	$\frac{\text{mV}}{\text{V}}$	
				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
z _{KA}	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.



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electrical characteristics over recommended operating conditions, $T_A = 25^\circ\text{C}$ (unless otherwise noted)

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

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

electrical characteristics over recommended operating conditions, $T_A = 25^\circ\text{C}$ (unless otherwise noted)

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

‡ Calculating dynamic impedance:

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

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

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

PARAMETER MEASUREMENT INFORMATION

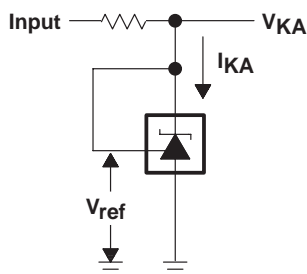


Figure 2. Test Circuit for $V_{KA} = V_{ref}$

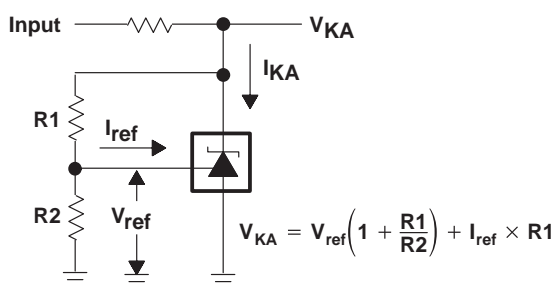


Figure 3. Test Circuit for $V_{KA} > V_{ref}$

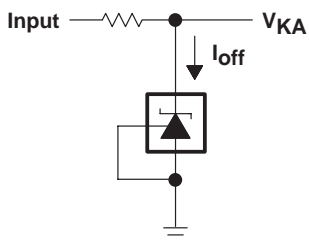


Figure 4. Test Circuit for I_{off}

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TYPICAL CHARACTERISTICS

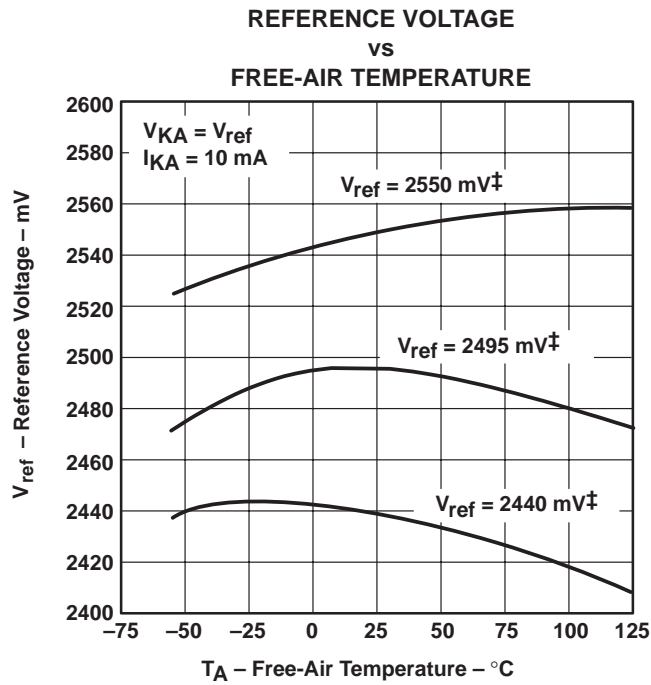
Table 1. Graphs

	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
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Pulse response	15
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Table 2. Application Circuits

	FIGURE
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Single-supply comparator with temperature-compensated threshold	18
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Output control of a three-terminal fixed regulator	20
High-current shunt regulator	21
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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†



† Data is for devices having the indicated value of V_{ref} at $I_{KA} = 10 \text{ mA}$, $T_A = 25^\circ\text{C}$.

Figure 5

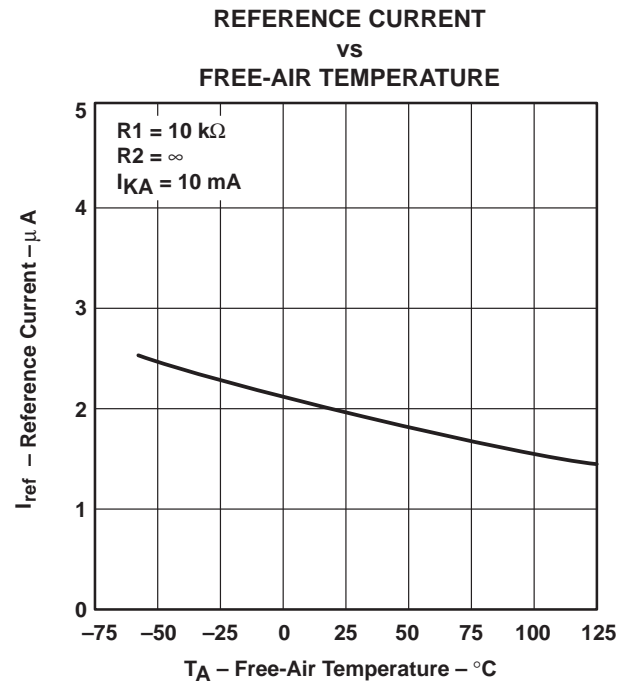


Figure 6

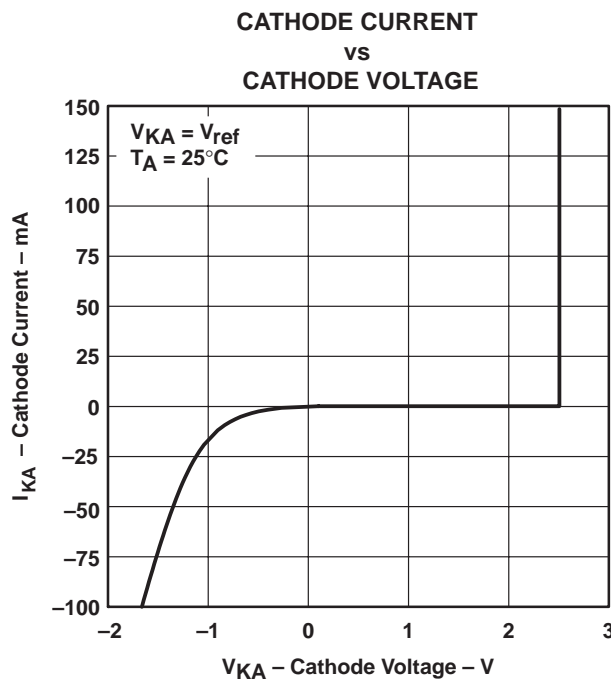


Figure 7

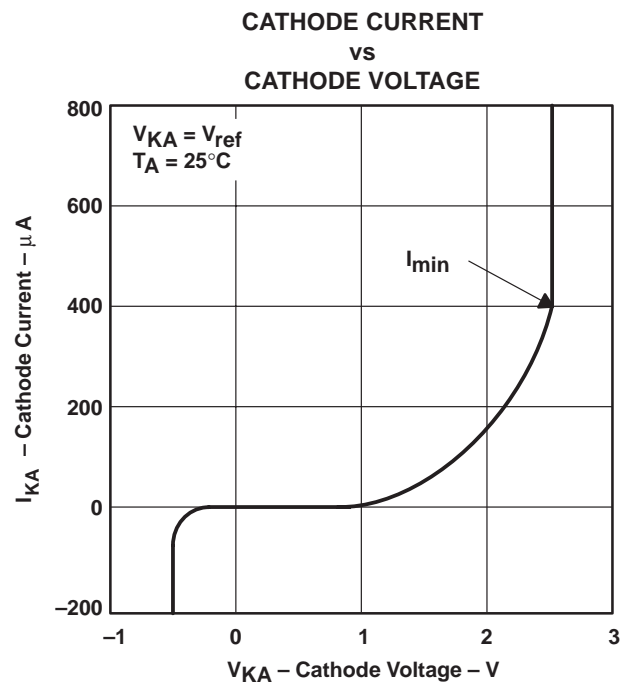


Figure 8

† 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†

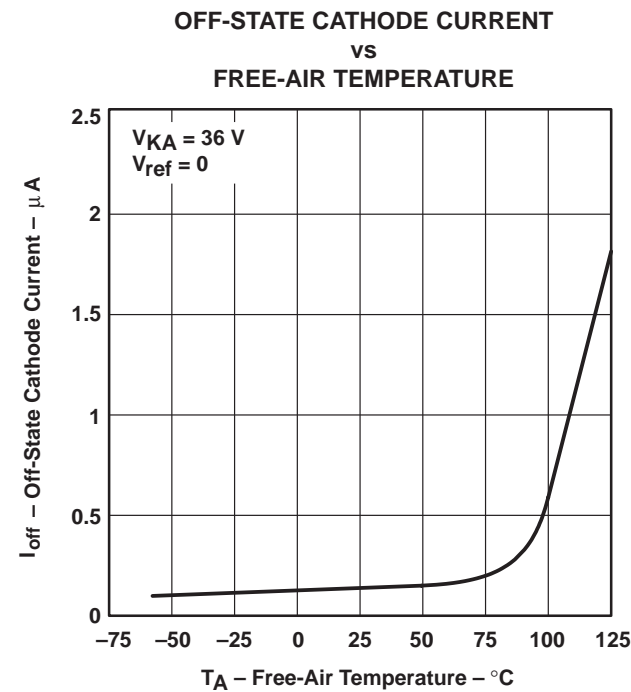


Figure 9

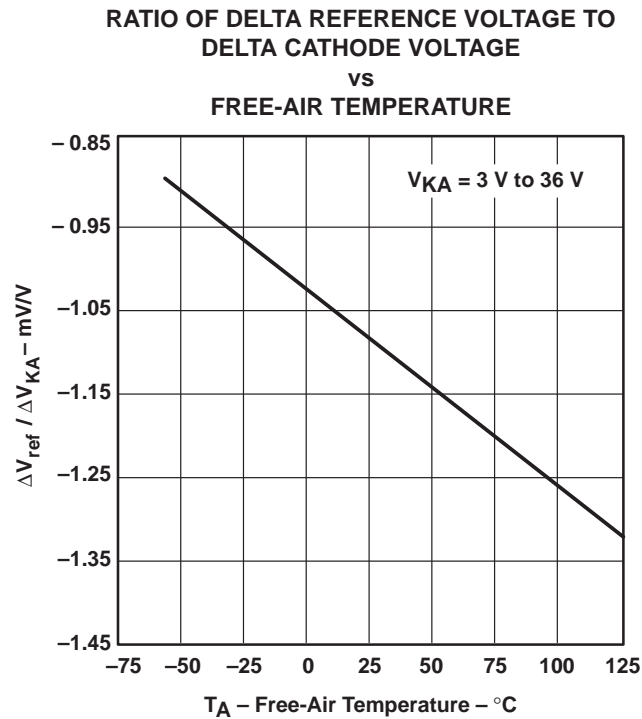


Figure 10

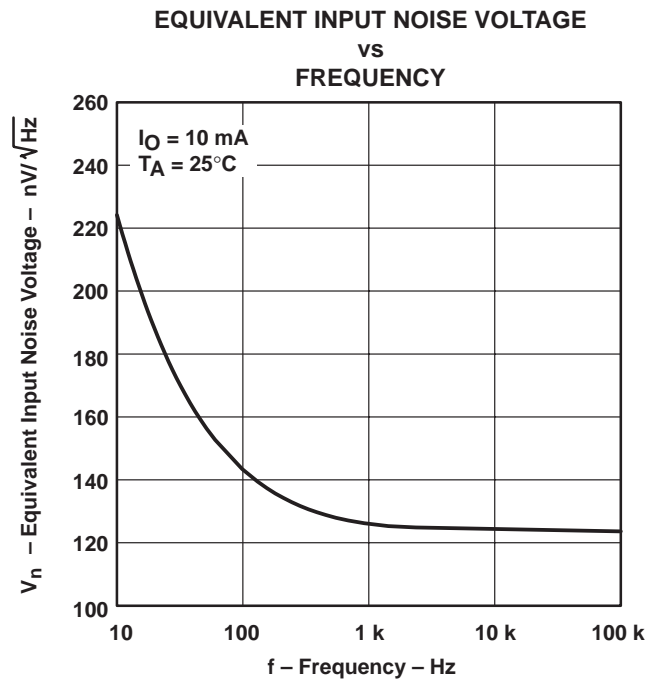


Figure 11

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

TYPICAL CHARACTERISTICS

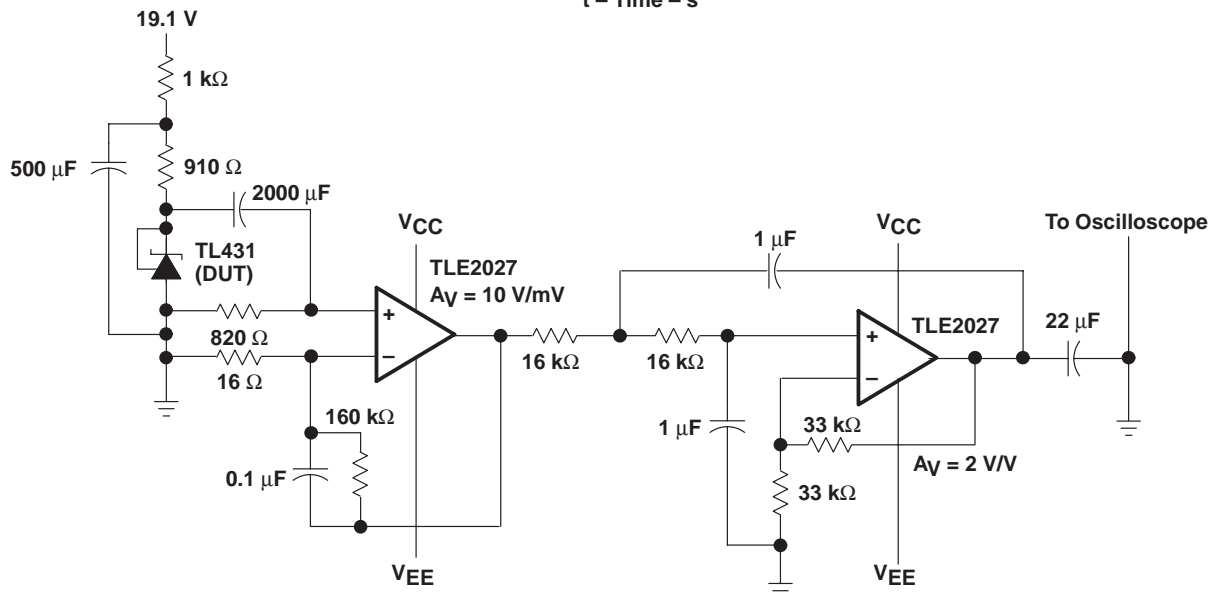
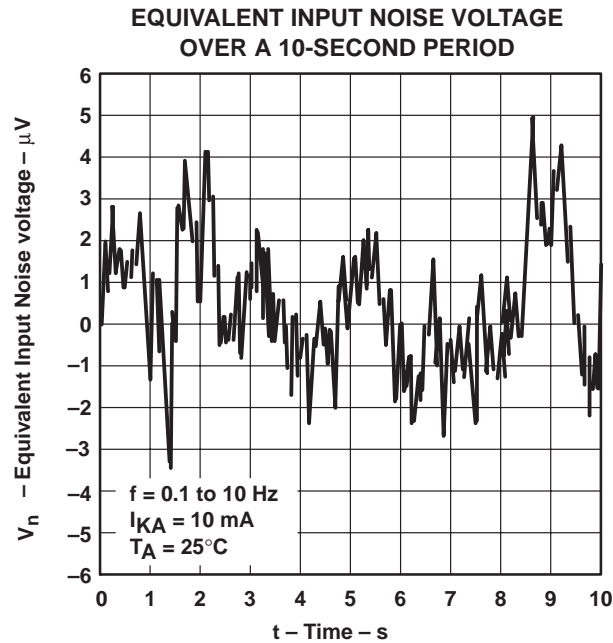


Figure 12. Test Circuit for Equivalent Input Noise Voltage

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TYPICAL CHARACTERISTICS

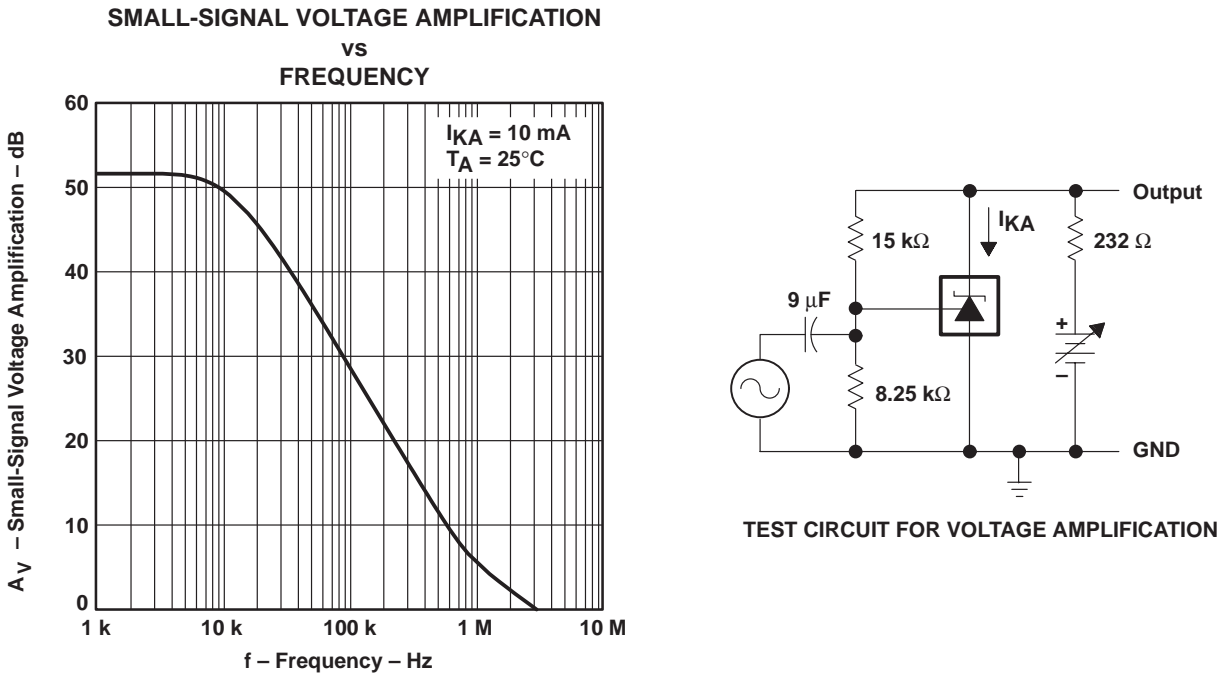


Figure 13

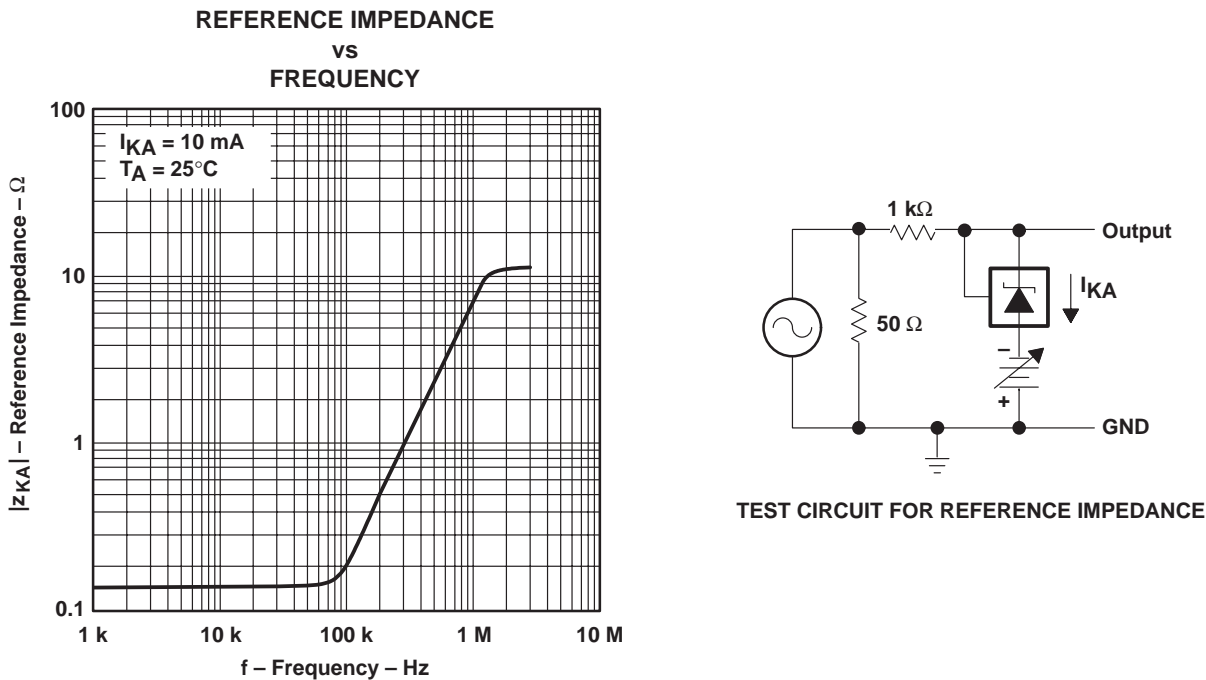


Figure 14

TYPICAL CHARACTERISTICS

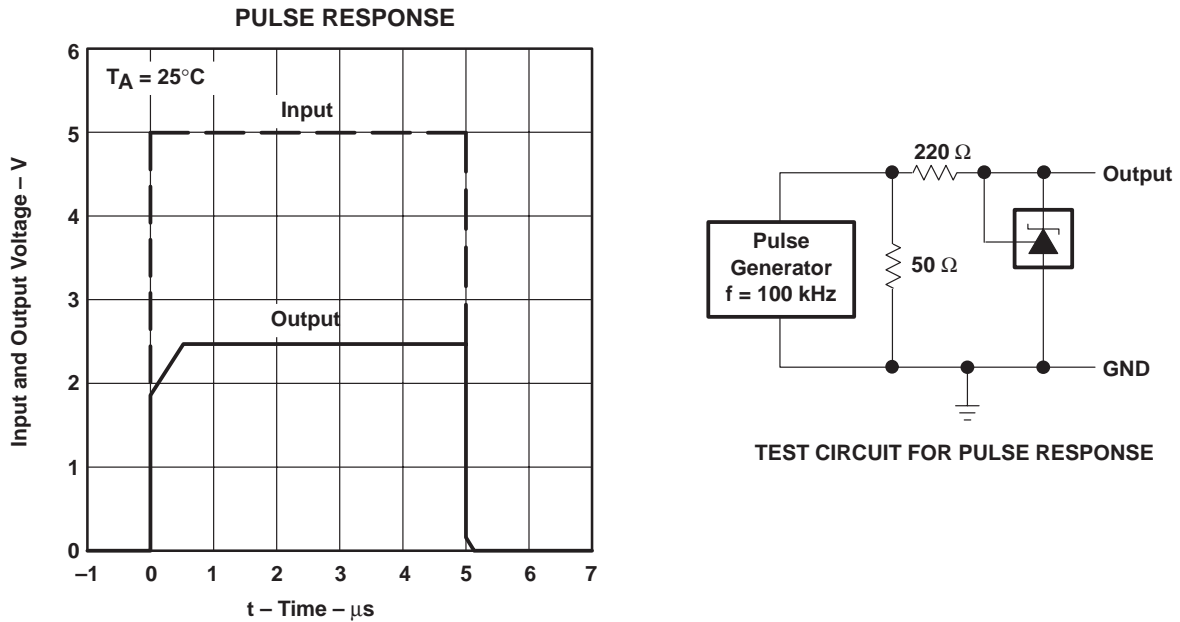


Figure 15

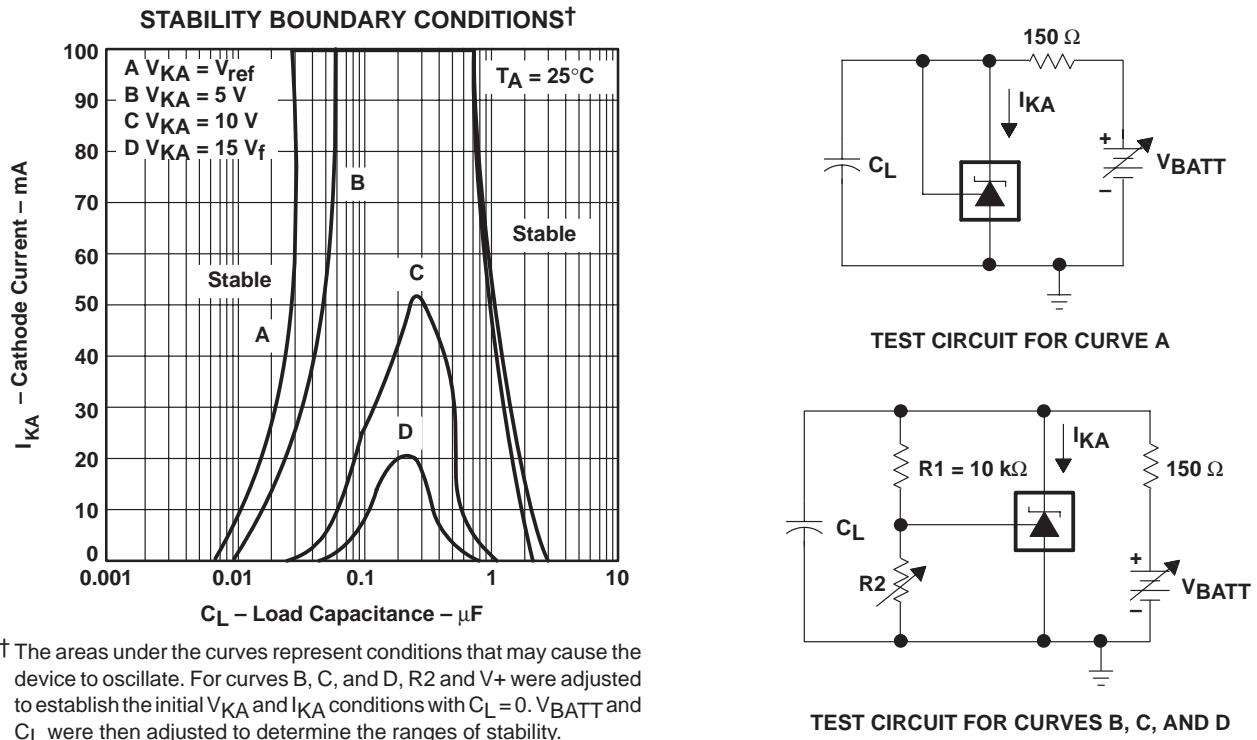


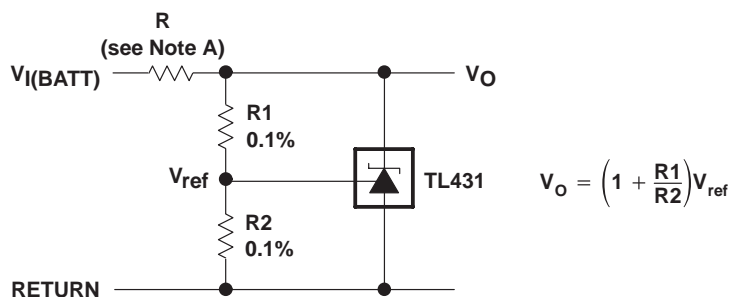
Figure 16

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APPLICATION INFORMATION



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

Figure 17. Shunt Regulator

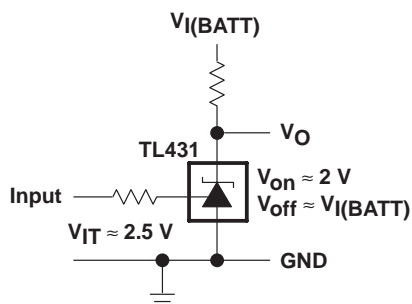
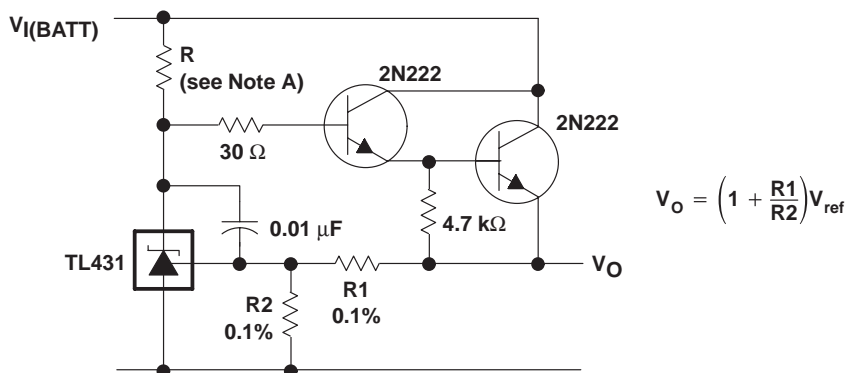


Figure 18. Single-Supply Comparator With Temperature-Compensated Threshold



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

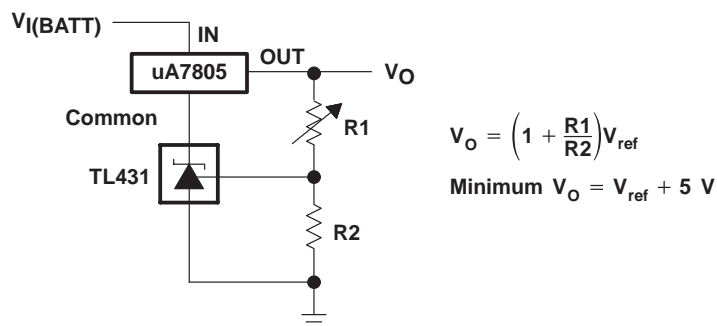


Figure 20. Output Control of a Three-Terminal Fixed Regulator

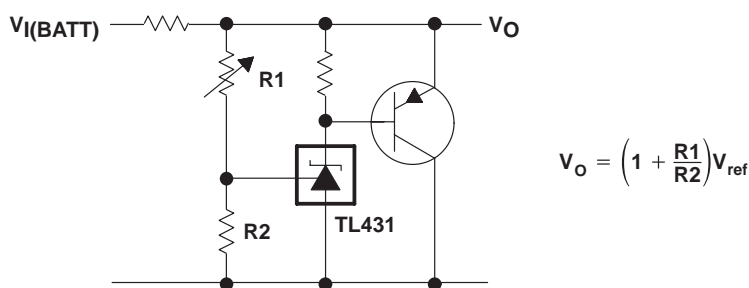
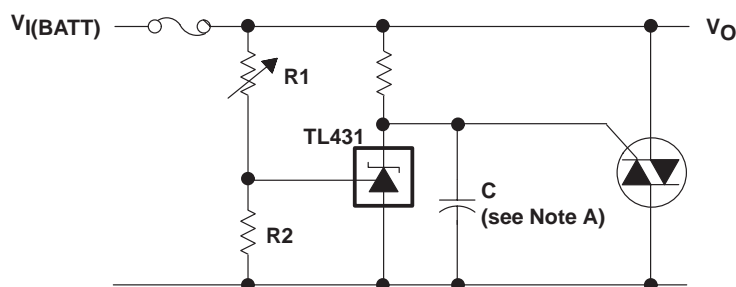


Figure 21. High-Current Shunt Regulator



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

Figure 22. Crowbar Circuit

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APPLICATION INFORMATION

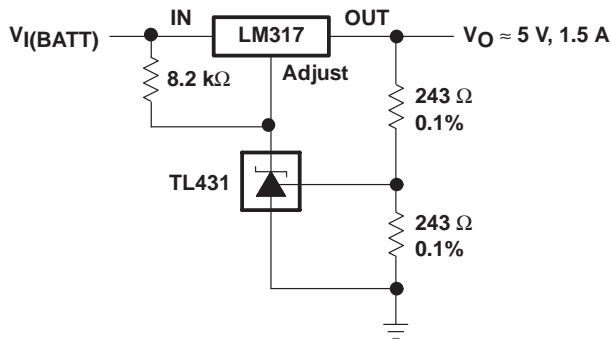
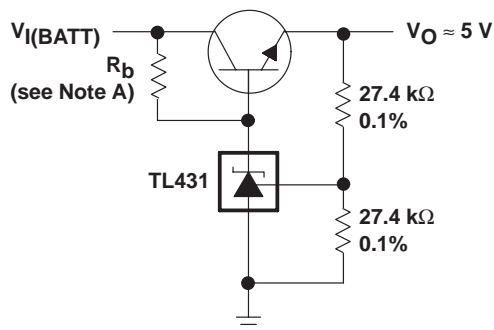


Figure 23. Precision 5-V 1.5-A Regulator



NOTE A: R_b should provide cathode current $\geq 1\text{-mA}$ to the TL431.

Figure 24. Efficient 5-V Precision Regulator

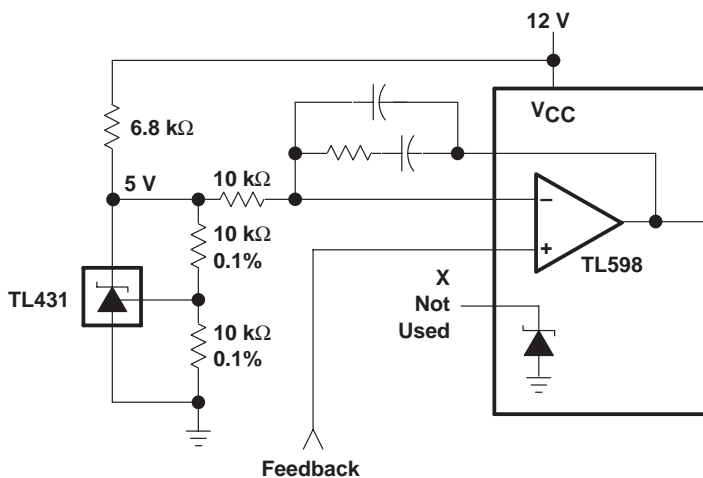
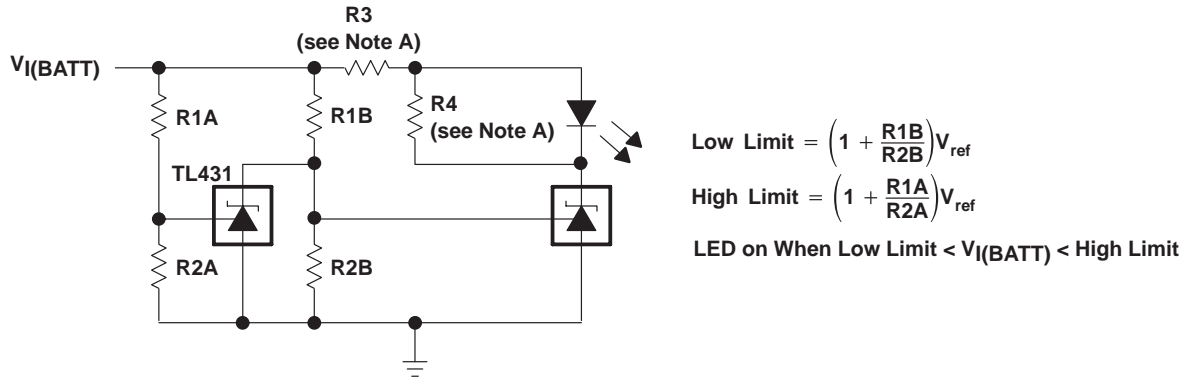


Figure 25. PWM Converter With Reference

APPLICATION INFORMATION



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

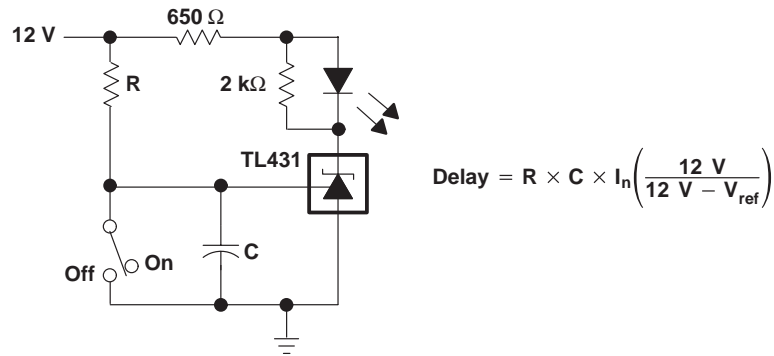


Figure 27. Delay Timer

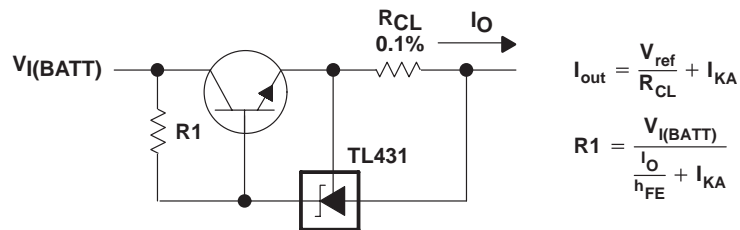


Figure 28. Precision Current Limiter

TL431, TL431A

ADJUSTABLE PRECISION SHUNT REGULATORS

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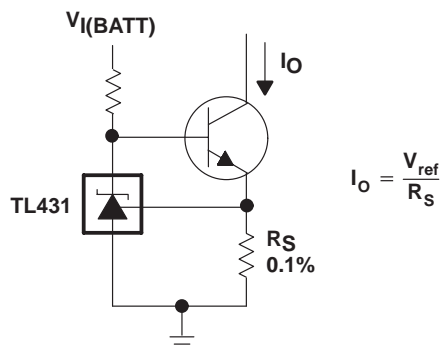


Figure 29. Precision Constant-Current Sink

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