

TL431, TL431A ADJUSTABLE PRECISION SHUNT REGULATORS

SLVS0050 – JULY 1978 – REVISED JUNE 2002

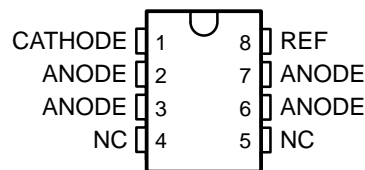
- Equivalent Full-Range Temperature Coefficient . . . 30 ppm/°C
- 0.2-Ω Typical Output Impedance
- Sink-Current Capability . . . 1 mA to 100 mA
- Low Output Noise
- Adjustable Output Voltage . . . V_{ref} to 36 V
- Available in a Wide Range of High-Density Packages

description

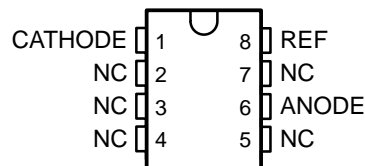
The TL431 and TL431A are three-terminal adjustable shunt regulators with specified thermal stability over applicable automotive, commercial, and military temperature ranges. The output voltage can be set to any value between V_{ref} (approximately 2.5 V) and 36 V, with two external resistors (see Figure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

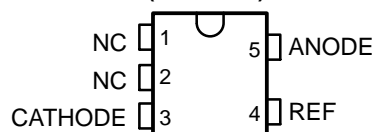
**D PACKAGE
(TOP VIEW)**



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

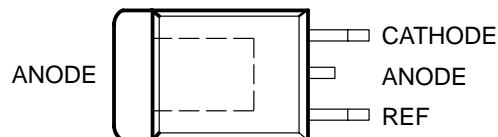


**DBV PACKAGE
(TOP VIEW)**

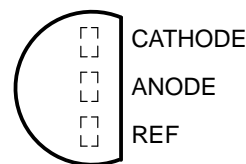


NC – No internal connection

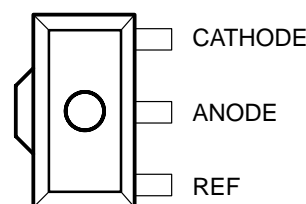
**KTP PACKAGE
(TOP VIEW)**



**LP PACKAGE
(TOP VIEW)**



**PK PACKAGE
(TOP VIEW)**



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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

ADJUSTABLE PRECISION SHUNT REGULATORS

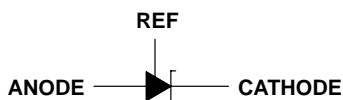
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AVAILABLE OPTIONS

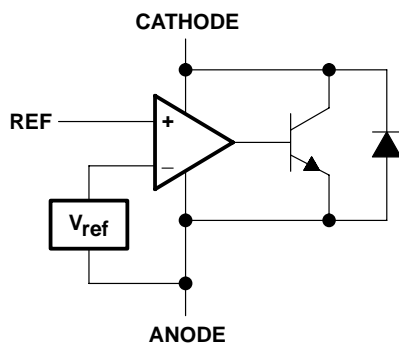
T _A	PACKAGE						
	SMALL OUTLINE (D, PS)	SOT-23 (DBV)	PLASTIC FLANGE MOUNT (KTP)	TO-226AA (LP)	PLASTIC DIP (P)	PLASTIC SHRINK SMALL OUTLINE (PW)	SOT-89 (PK)
0°C to 70°C	TL431CD TL431CPSR TL431ACD TL431ACPSR	TL431CDBVR	TL431CKTPR	TL431CLP TL431ACL	TL431CP TL431ACP	TL431CPWR TL431ACPWR	TL431CPK
-40°C to 85°C	TL431ID TL431AID	TL431IDBVR		TL431ILP TL431AILP	TL431IP TL431AIP		TL431IPK

The D package is available taped and reeled. Add the suffix R to the device type (e.g., TL431CDR). The DBV, KTP, PK, PS, and PW packages are only available taped and reeled (do not add the suffix R to the PK device type). The LP package also is available in ammo pack. Add the suffix M to the device type (e.g., TL431CLPM).

symbol



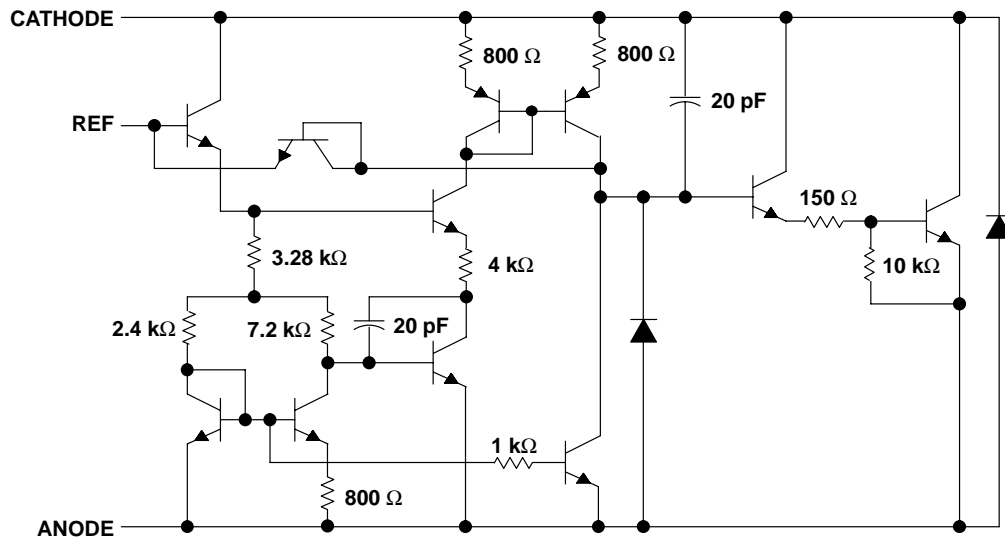
functional block diagram



TL431, TL431A ADJUSTABLE PRECISION SHUNT REGULATORS

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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 μ A to 10 mA
Package thermal impedance, θ_{JA} (see Notes 2 and 4): DBV package	206°C/W
(see Notes 2 and 3): KTP package	28°C/W
(see Notes 2 and 4): LP package	156°C/W
(see Notes 2 and 4): P package	85°C/W
(see Notes 2 and 4): PK package	52°C/W
(see Notes 2 and 4): PS package	95°C/W
(see Notes 2 and 4): PW package	149°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. 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 affect reliability.
 3. The package thermal impedance is calculated in accordance with JESD 51-5.
 4. The package thermal impedance is calculated in accordance with JESD 51-7.

recommended operating conditions

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



TL431, TL431A

ADJUSTABLE PRECISION SHUNT REGULATORS

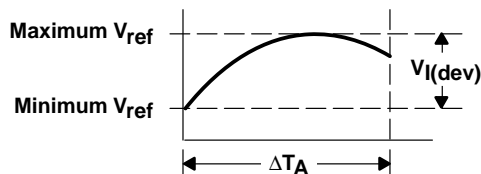
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electrical characteristics over recommended operating conditions, $T_A = 25^\circ\text{C}$ (unless otherwise noted)

PARAMETER	TEST CIRCUIT	TEST CONDITIONS	TL431C			UNIT
			MIN	TYP	MAX	
V_{ref} Reference voltage	2	$V_{\text{KA}} = V_{\text{ref}}, I_{\text{KA}} = 10 \text{ mA}$	2440	2495	2550	mV
$V_{\text{I(dev)}}$ Deviation of reference voltage over full temperature range (see Figure 1)	2	$V_{\text{KA}} = V_{\text{ref}}, I_{\text{KA}} = 10 \text{ mA}, T_A = 0^\circ\text{C to } 70^\circ\text{C}$		4	25	mV
$\frac{\Delta V_{\text{ref}}}{\Delta V_{\text{KA}}}$ Ratio of change in reference voltage to the change in cathode voltage	3	$I_{\text{KA}} = 10 \text{ mA}$		-1.4	-2.7	$\frac{\text{mV}}{\text{V}}$
				-1	-2	
I_{ref} Reference current	3	$I_{\text{KA}} = 10 \text{ mA}, R_1 = 10 \text{ k}\Omega, R_2 = \infty$		2	4	μA
$I_{\text{I(dev)}}$ Deviation of reference current over full temperature range (see Figure 1)	3	$I_{\text{KA}} = 10 \text{ mA}, R_1 = 10 \text{ k}\Omega, R_2 = \infty, T_A = 0^\circ\text{C to } 70^\circ\text{C}$		0.4	1.2	μA
I_{min} Minimum cathode current for regulation	2	$V_{\text{KA}} = V_{\text{ref}}$		0.4	1	mA
I_{off} Off-state cathode current	4	$V_{\text{KA}} = 36 \text{ V}, V_{\text{ref}} = 0$		0.1	1	μA
$ z_{\text{KA}} $ Dynamic impedance (see Figure 1)	1	$I_{\text{KA}} = 1 \text{ mA to } 100 \text{ mA}, V_{\text{KA}} = V_{\text{ref}}, f \leq 1 \text{ kHz}$		0.2	0.5	Ω

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

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



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

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

$$|z'| = \frac{\Delta V}{\Delta I} \approx |z_{\text{KA}}| \left(1 + \frac{R_1}{R_2} \right)$$

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	TL4311			UNIT
			MIN	TYP	MAX	
V_{ref} Reference voltage	2	$V_{\text{KA}} = V_{\text{ref}}, I_{\text{KA}} = 10 \text{ mA}$	2440	2495	2550	mV
$V_{\text{I(dev)}}$ Deviation of reference voltage over full temperature range (see Figure 1)	2	$V_{\text{KA}} = V_{\text{ref}}, I_{\text{KA}} = 10 \text{ mA}, T_A = -40^\circ\text{C} \text{ to } 85^\circ\text{C}$		5	50	mV
$\frac{\Delta V_{\text{ref}}}{\Delta V_{\text{KA}}}$ Ratio of change in reference voltage to the change in cathode voltage	3	$I_{\text{KA}} = 10 \text{ mA}$	$\Delta V_{\text{KA}} = 10 \text{ V} - V_{\text{ref}}$	-1.4	-2.7	$\frac{\text{mV}}{\text{V}}$
			$\Delta V_{\text{KA}} = 36 \text{ V} - 10 \text{ V}$	-1	-2	
I_{ref} Reference current	3	$I_{\text{KA}} = 10 \text{ mA}, R_1 = 10 \text{ k}\Omega, R_2 = \infty$		2	4	μA
$I_{\text{I(dev)}}$ Deviation of reference current over full temperature range (see Figure 1)	3	$I_{\text{KA}} = 10 \text{ mA}, R_1 = 10 \text{ k}\Omega, R_2 = \infty, T_A = -40^\circ\text{C} \text{ to } 85^\circ\text{C}$		0.8	2.5	μA
I_{min} Minimum cathode current for regulation	2	$V_{\text{KA}} = V_{\text{ref}}$		0.4	1	mA
I_{off} Off-state cathode current	4	$V_{\text{KA}} = 36 \text{ V}, V_{\text{ref}} = 0$		0.1	1	μA
$ z_{\text{KA}} $ Dynamic impedance (see Figure 1)	2	$I_{\text{KA}} = 1 \text{ mA} \text{ to } 100 \text{ mA}, V_{\text{KA}} = V_{\text{ref}}, f \leq 1 \text{ kHz}$		0.2	0.5	Ω

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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	$V_{\text{KA}} = V_{\text{ref}}, I_{\text{KA}} = 10 \text{ mA}$	2470	2495	2520	mV
$V_{\text{I(dev)}}$ Deviation of reference voltage over full temperature range (see Figure 1)	2	$V_{\text{KA}} = V_{\text{ref}}, I_{\text{KA}} = 10 \text{ mA}, T_A = 0^\circ\text{C to } 70^\circ\text{C}$		4	25	mV
$\frac{\Delta V_{\text{ref}}}{\Delta V_{\text{KA}}}$ Ratio of change in reference voltage to the change in cathode voltage	3	$I_{\text{KA}} = 10 \text{ mA}$		-1.4	-2.7	$\frac{\text{mV}}{\text{V}}$
				-1	-2	
I_{ref} Reference current	3	$I_{\text{KA}} = 10 \text{ mA}, R_1 = 10 \text{ k}\Omega, R_2 = \infty$		2	4	μA
$I_{\text{I(dev)}}$ Deviation of reference current over full temperature range (see Figure 1)	3	$I_{\text{KA}} = 10 \text{ mA}, R_1 = 10 \text{ k}\Omega, R_2 = \infty, T_A = 0^\circ\text{C to } 70^\circ\text{C}$		0.8	1.2	μA
I_{min} Minimum cathode current for regulation	2	$V_{\text{KA}} = V_{\text{ref}}$		0.4	0.6	mA
I_{off} Off-state cathode current	4	$V_{\text{KA}} = 36 \text{ V}, V_{\text{ref}} = 0$		0.1	0.5	μA
$ z_{\text{KA}} $ Dynamic impedance (see Figure 1)	1	$I_{\text{KA}} = 1 \text{ mA to } 100 \text{ mA}, V_{\text{KA}} = V_{\text{ref}}, f \leq 1 \text{ kHz}$		0.2	0.5	Ω

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	$V_{\text{KA}} = V_{\text{ref}}, I_{\text{KA}} = 10 \text{ mA}$	2470	2495	2520	mV
$V_{\text{I(dev)}}$ Deviation of reference voltage over full temperature range (see Figure 1)	2	$V_{\text{KA}} = V_{\text{ref}}, I_{\text{KA}} = 10 \text{ mA}, T_A = -40^\circ\text{C to } 85^\circ\text{C}$		5	50	mV
$\frac{\Delta V_{\text{ref}}}{\Delta V_{\text{KA}}}$ Ratio of change in reference voltage to the change in cathode voltage	3	$I_{\text{KA}} = 10 \text{ mA}$		-1.4	-2.7	$\frac{\text{mV}}{\text{V}}$
				-1	-2	
I_{ref} Reference current	3	$I_{\text{KA}} = 10 \text{ mA}, R_1 = 10 \text{ k}\Omega, R_2 = \infty$		2	4	μA
$I_{\text{I(dev)}}$ Deviation of reference current over full temperature range (see Figure 1)	3	$I_{\text{KA}} = 10 \text{ mA}, R_1 = 10 \text{ k}\Omega, R_2 = \infty, T_A = -40^\circ\text{C to } 85^\circ\text{C}$		0.8	2.5	μA
I_{min} Minimum cathode current for regulation	2	$V_{\text{KA}} = V_{\text{ref}}$		0.4	0.7	mA
I_{off} Off-state cathode current	4	$V_{\text{KA}} = 36 \text{ V}, V_{\text{ref}} = 0$		0.1	0.5	μA
$ z_{\text{KA}} $ Dynamic impedance (see Figure 1)	2	$I_{\text{KA}} = 1 \text{ mA to } 100 \text{ mA}, V_{\text{KA}} = V_{\text{ref}}, f \leq 1 \text{ kHz}$		0.2	0.5	Ω



PARAMETER MEASUREMENT INFORMATION

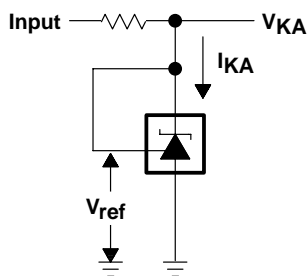


Figure 2. Test Circuit for $V_{KA} = V_{ref}$

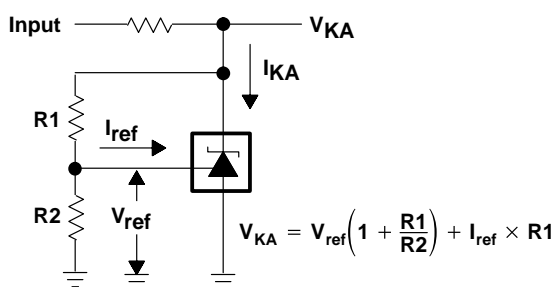


Figure 3. Test Circuit for $V_{KA} > V_{ref}$

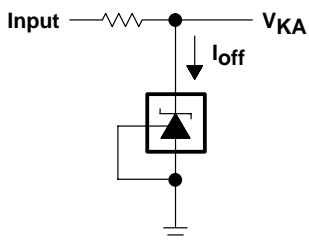


Figure 4. Test Circuit for I_{off}

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TYPICAL CHARACTERISTICS

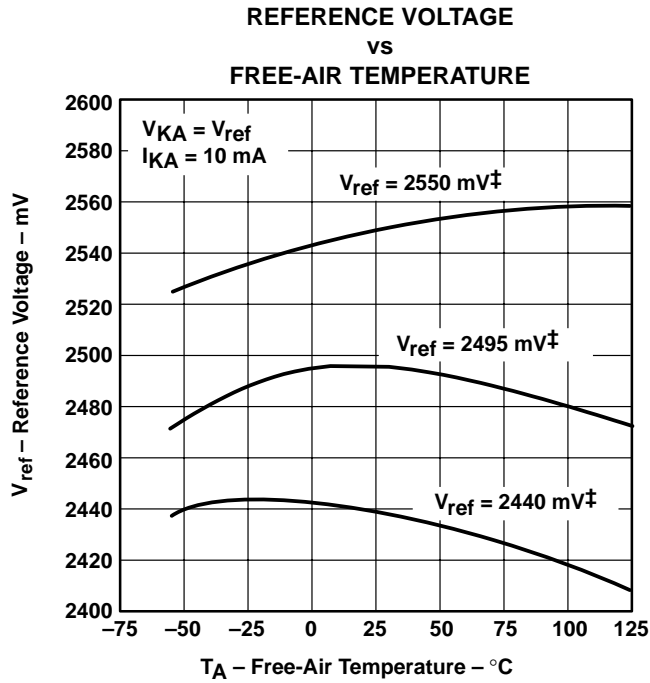
Table 1. Graphs

	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
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
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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
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Precision 5-V 1.5-A regulator	23
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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

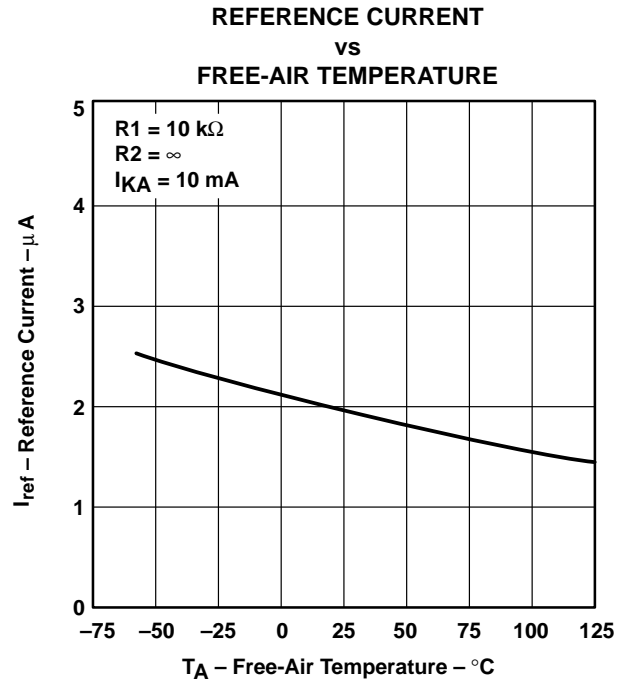


Figure 6

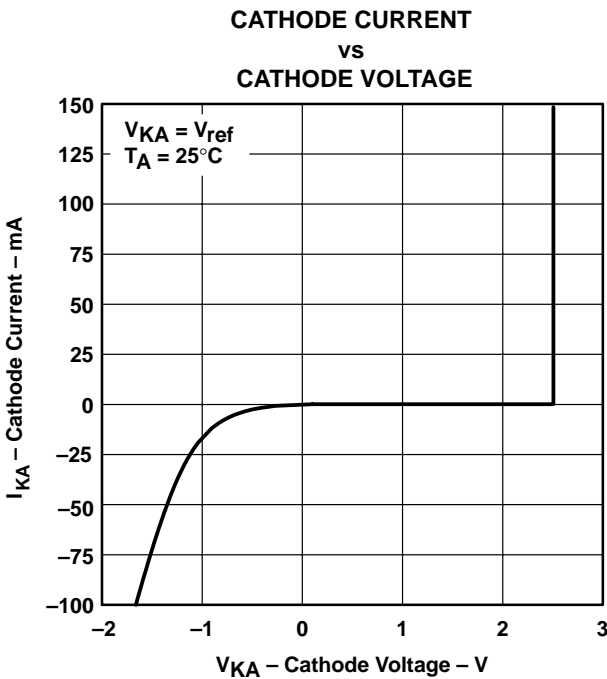


Figure 7

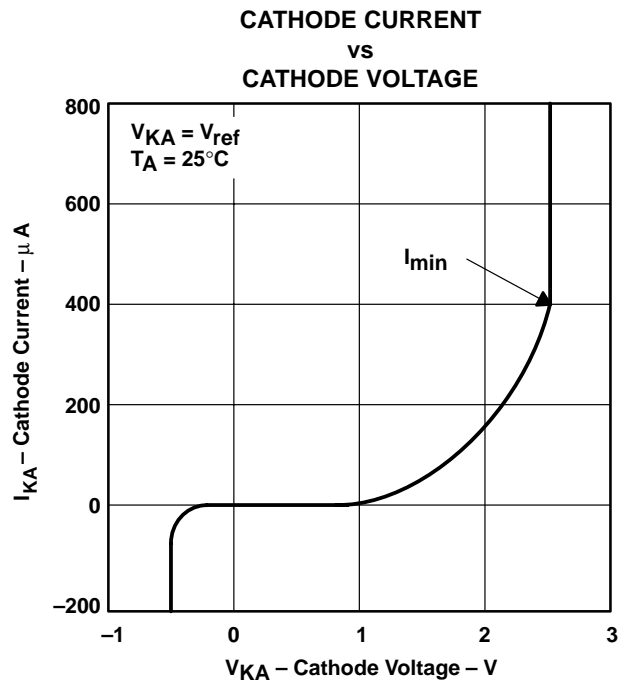


Figure 8

† 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†

OFF-STATE CATHODE CURRENT
vs
FREE-AIR TEMPERATURE

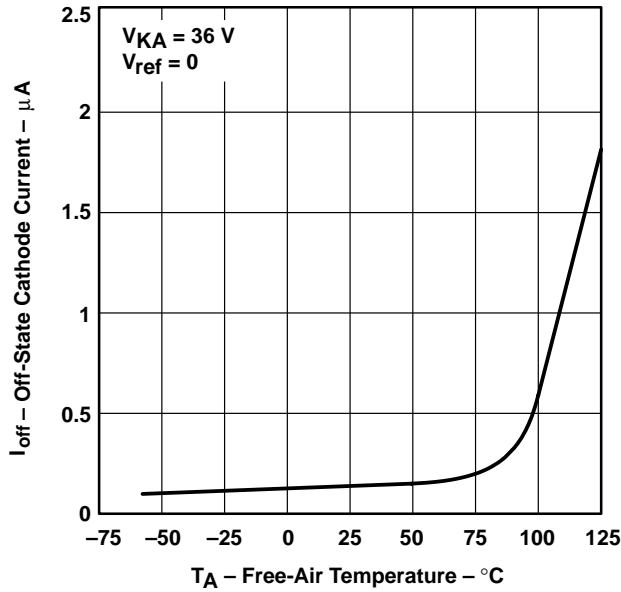


Figure 9

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

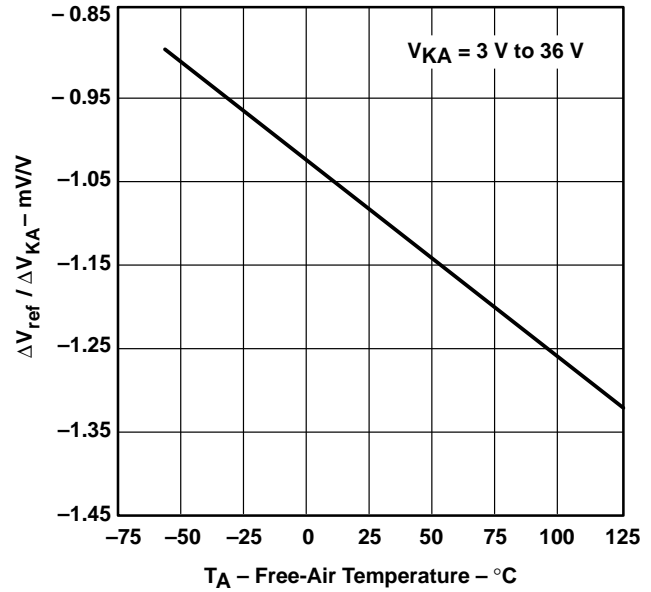


Figure 10

EQUIVALENT INPUT NOISE VOLTAGE
vs
FREQUENCY

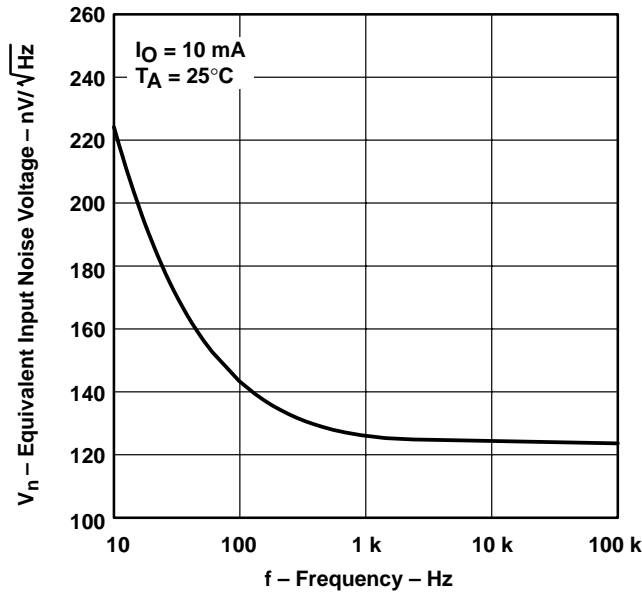


Figure 11

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



TYPICAL CHARACTERISTICS

EQUIVALENT INPUT NOISE VOLTAGE
 OVER A 10-SECOND PERIOD

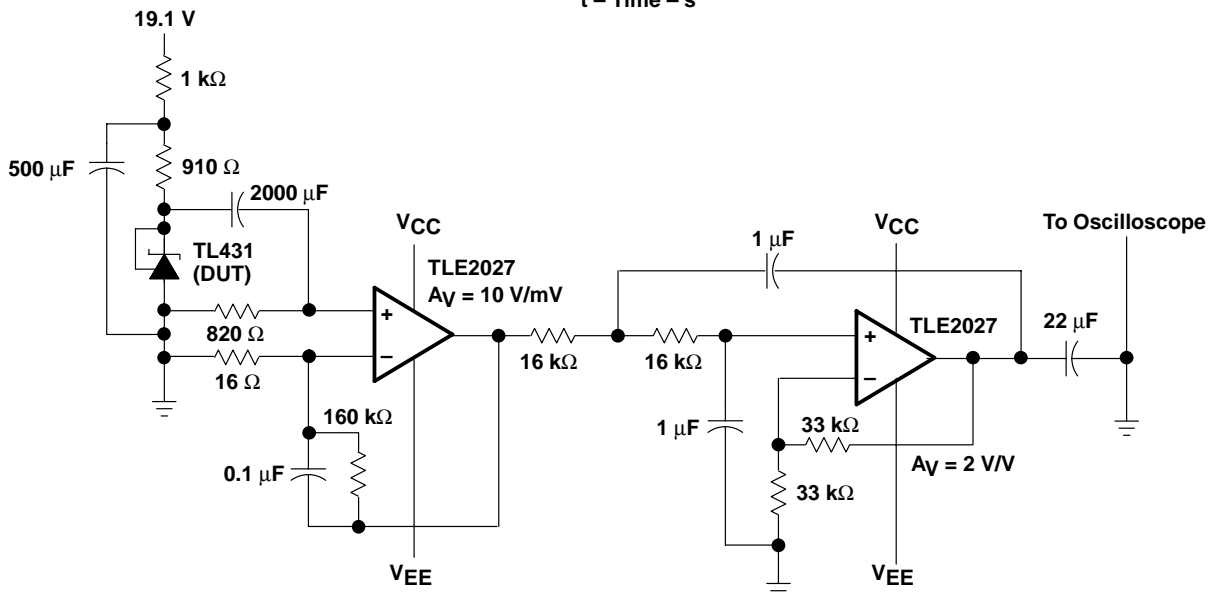
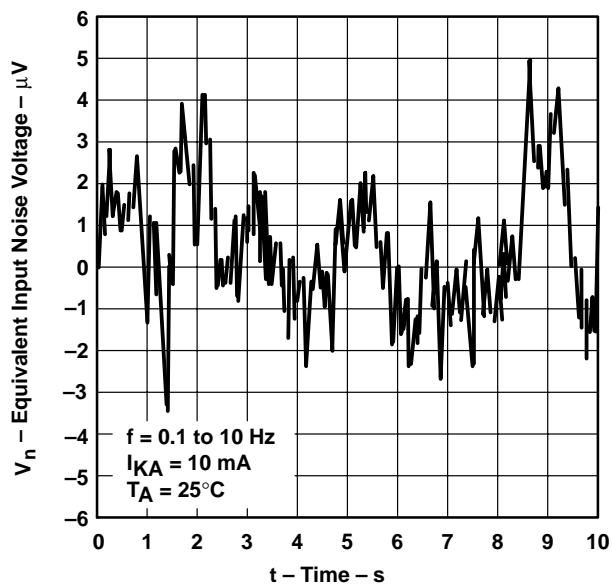


Figure 12. Test Circuit for Equivalent Input Noise Voltage

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TYPICAL CHARACTERISTICS

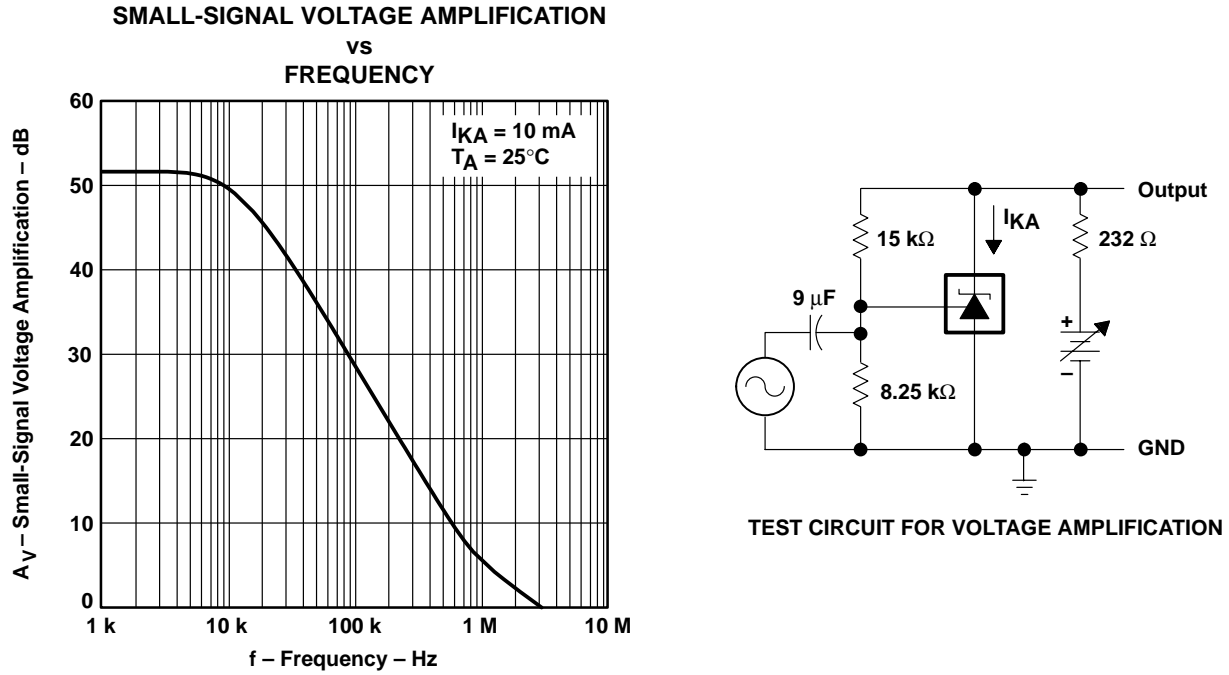


Figure 13

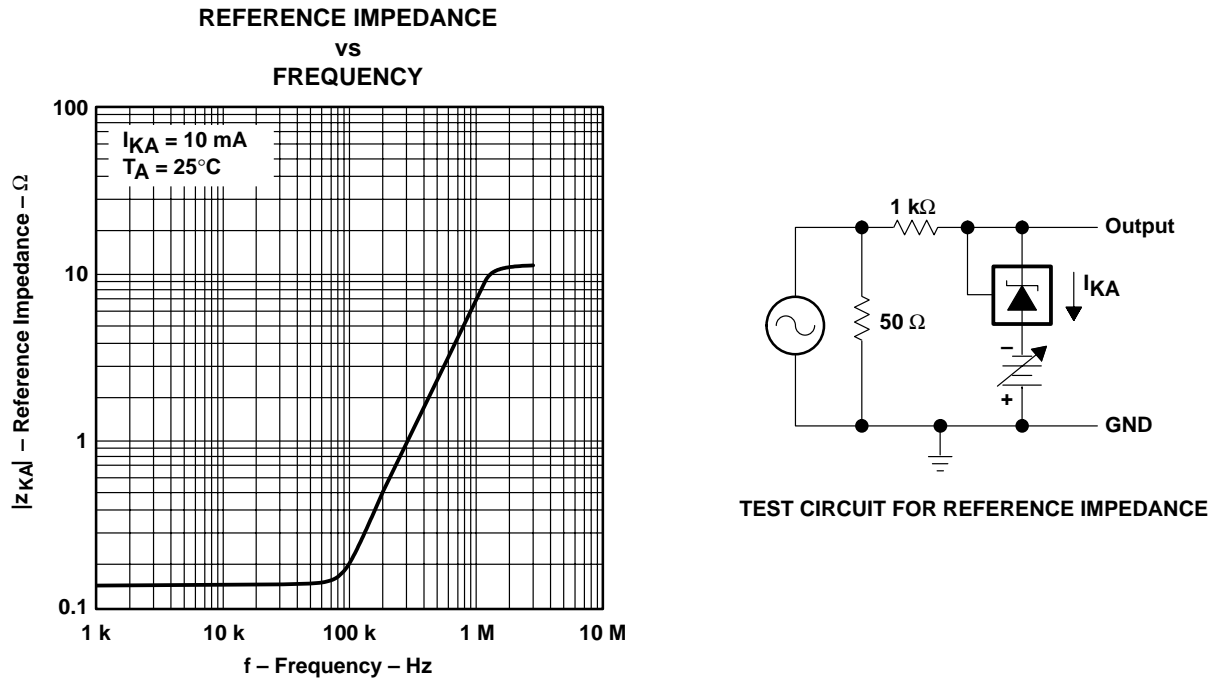


Figure 14

TYPICAL CHARACTERISTICS

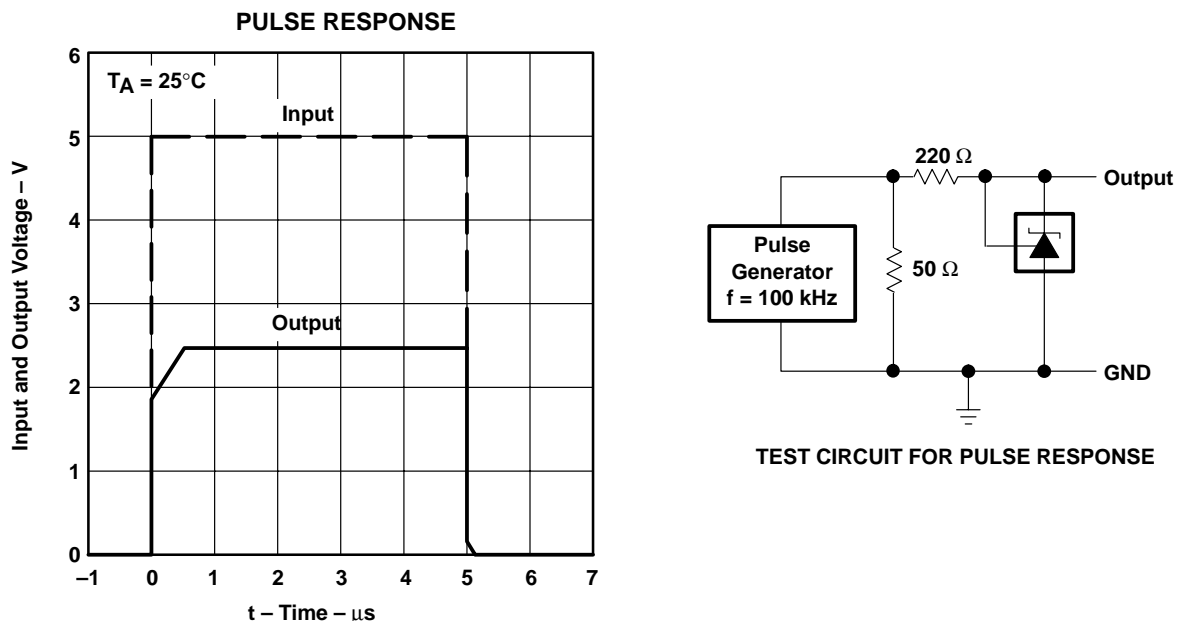


Figure 15

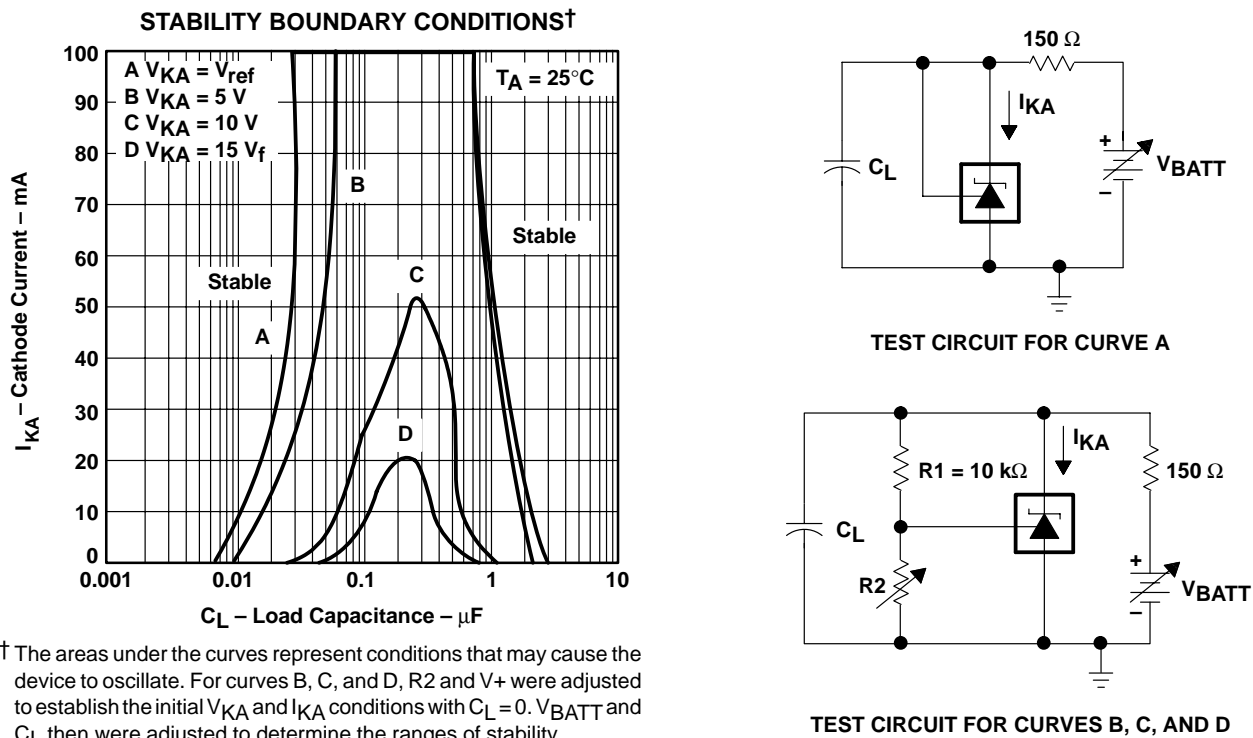
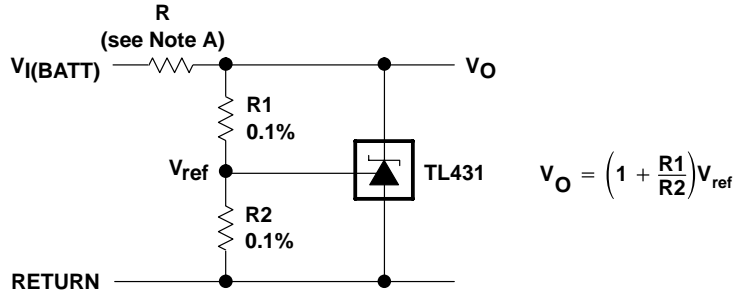


Figure 16

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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

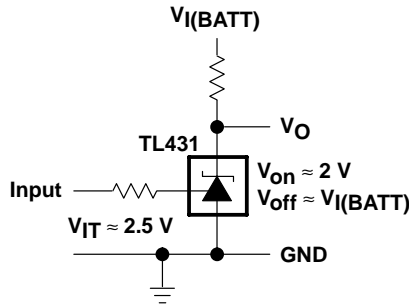
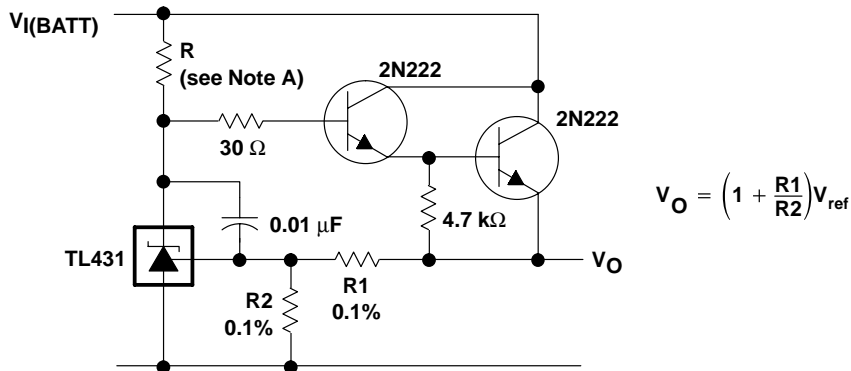


Figure 18. Single-Supply Comparator With Temperature-Compensated Threshold



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

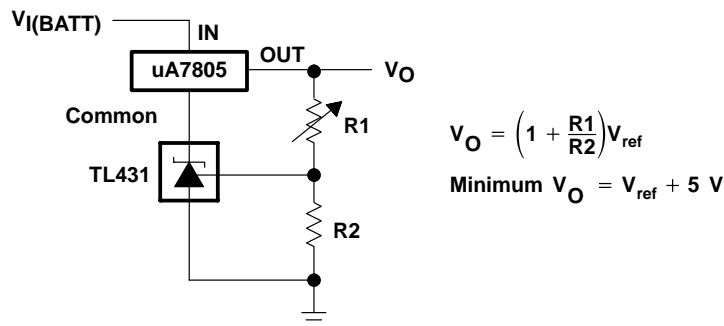


Figure 20. Output Control of a Three-Terminal Fixed Regulator

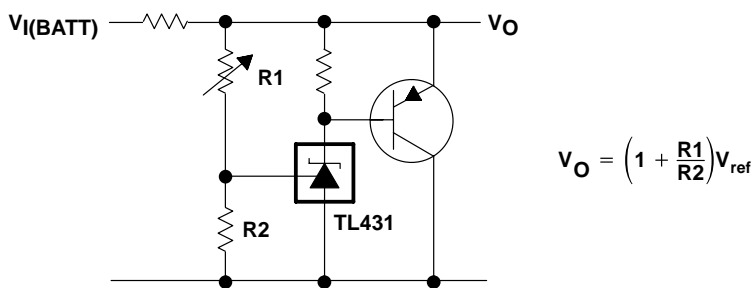
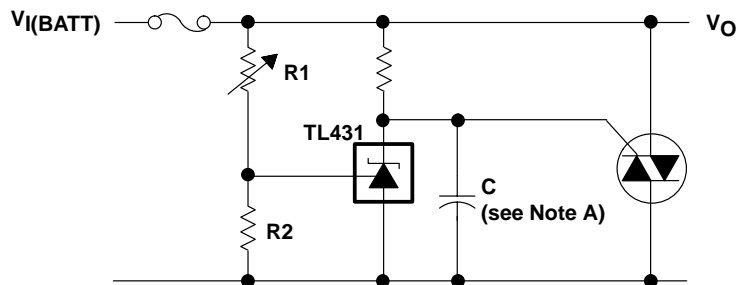


Figure 21. High-Current Shunt Regulator



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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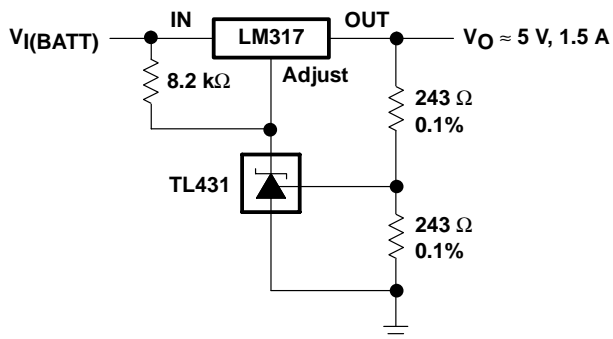
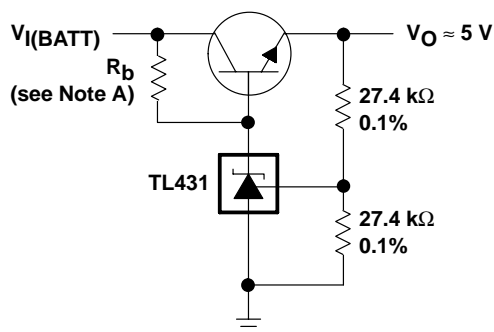


Figure 23. Precision 5-V 1.5-A Regulator



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

Figure 24. Efficient 5-V Precision Regulator

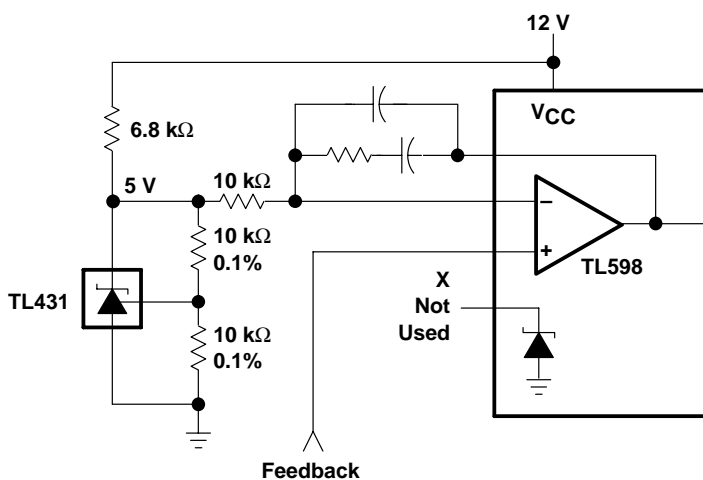
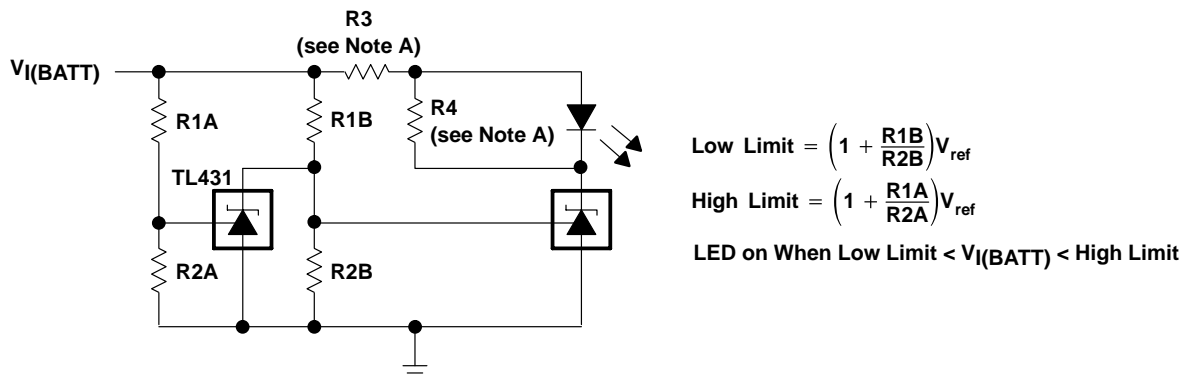


Figure 25. PWM Converter With Reference

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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

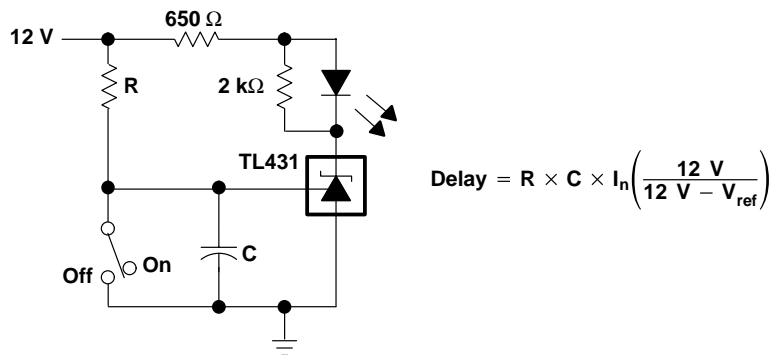


Figure 27. Delay Timer

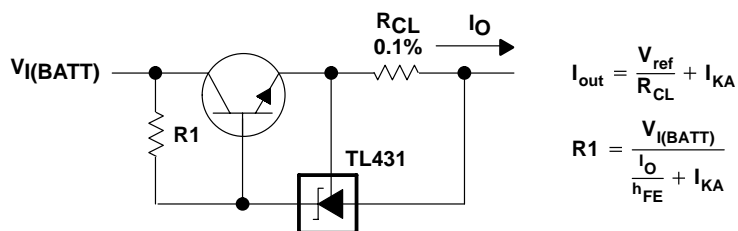


Figure 28. Precision Current Limiter

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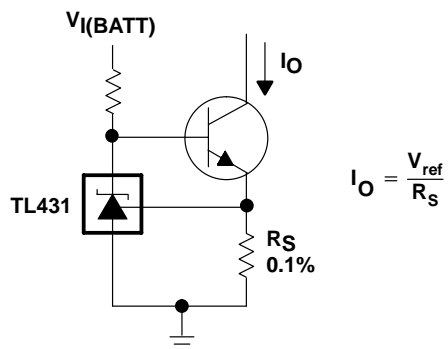


Figure 29. Precision Constant-Current Sink

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