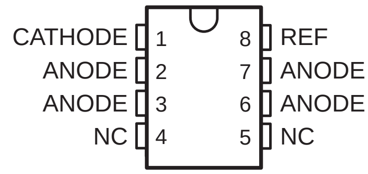
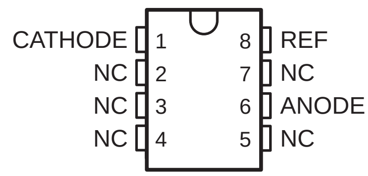
- **Equivalent Full-Range Temperature Coefficient . . . 30 ppm/°C**
- **0.2-Ω Typical Output Impedance**
- **Sink-Current Capability . . . 1 mA to 100 mA**
- **Low Output Noise**
- **Adjustable Output Voltage . . . V_{ref} to 36 V**
- **Available in a Wide Range of High-Density Packages**

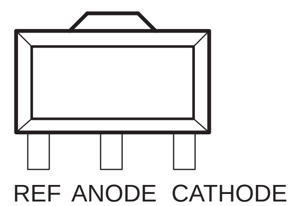
D PACKAGE (TOP VIEW)



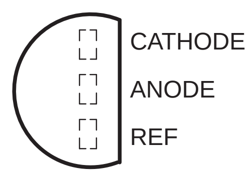
JG, P, OR PW PACKAGE (TOP VIEW)



PK PACKAGE (TOP VIEW)



LP PACKAGE (TOP VIEW)

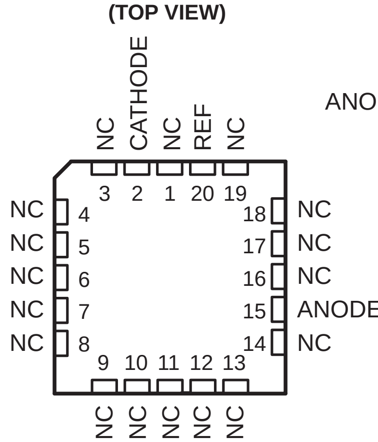


description

The TL431 and TL431A are 3-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 on-board regulation, adjustable power supplies, and switching power supplies.

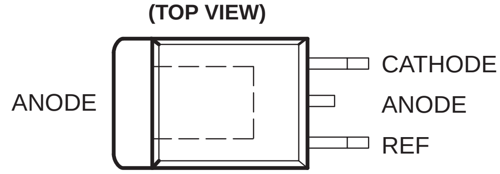
The TL431C and TL431AC are characterized for operation from 0°C to 70°C, and the TL431I and TL431AI are characterized for operation from –40°C to 85°C. The TL431M is characterized for operation over the full military temperature range of –55°C to 125°C.

FK PACKAGE (TOP VIEW)



NC – No internal connection

KTP PACKAGE (TOP VIEW)

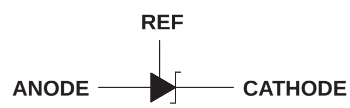


AVAILABLE OPTIONS

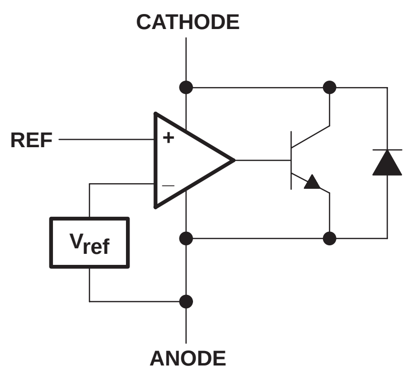
T_A	PACKAGED DEVICES								CHIP FORM (Y)
	SMALL OUTLINE (D)	CHIP CARRIER (FK)	CERAMIC DIP (JG)	PLASTIC FLANGE MOUNT (KTP)	TO-226AA (LP)	PLASTIC DIP (P)	SOT-89 (PK)	SHRINK SMALL OUTLINE (PW)	
0°C to 70°C	TL431CD TL431ACD			TL431CKTPR	TL431CLP TL431ACLP	TL431CP TL431ACP	TL431CPK	TL431CPW	
–40°C to 85°C	TL431ID TL431AID				TL431ILP TL431AILP	TL431IP TL431AIP	TL431IPK		TL431Y
–55°C to 125°C		TL431MFK	TL431MJG						

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

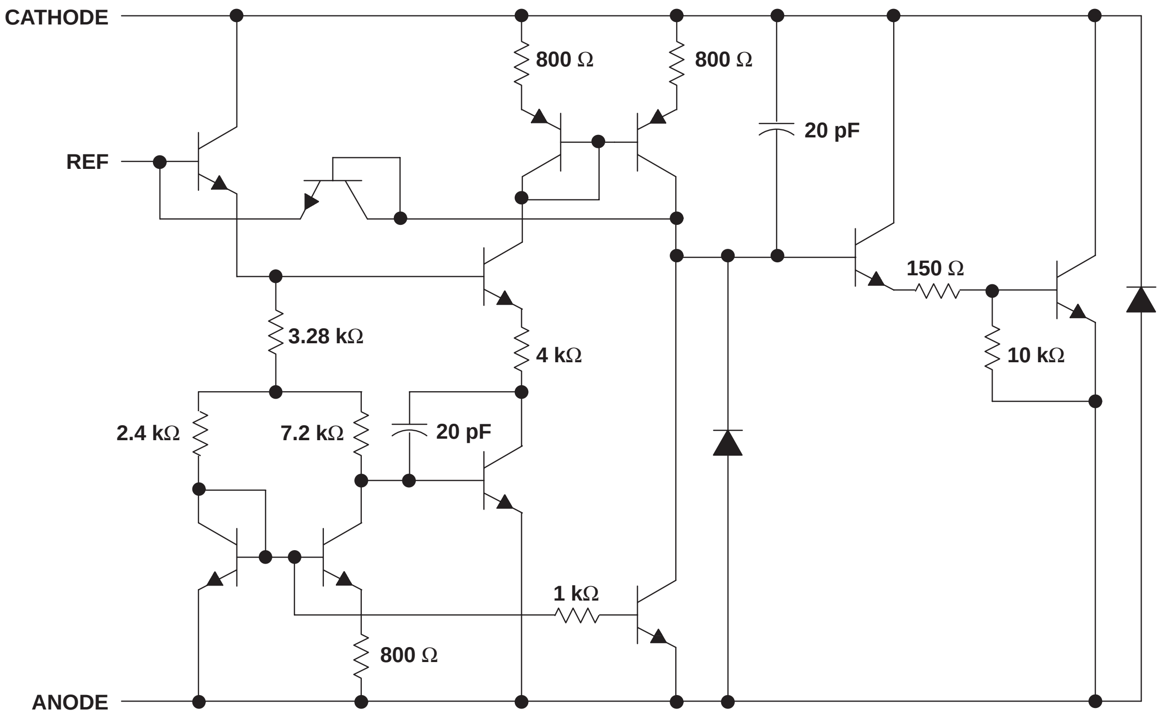
symbol



functional block diagram



equivalent schematic†

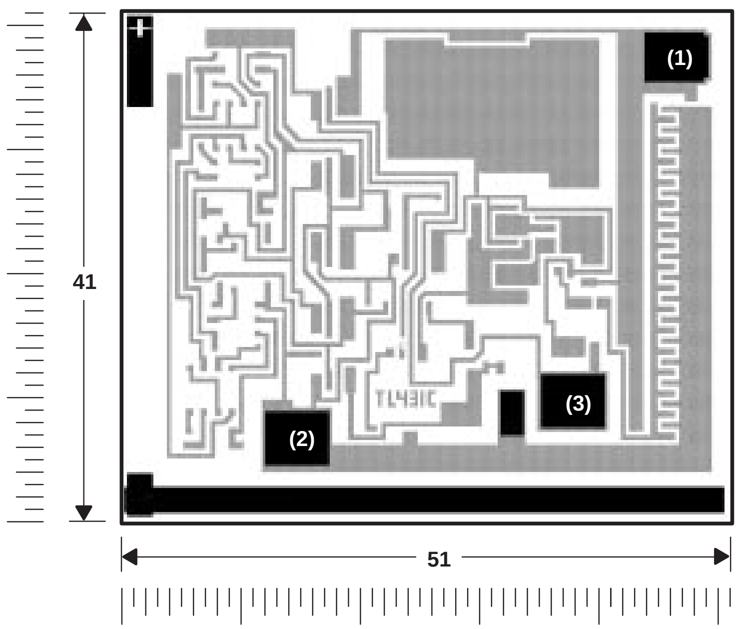


† All component values are nominal.

TL431Y chip information

This chip, when properly assembled, displays characteristics similar to those of the TL431C. Thermal compression or ultrasonic bonding can be used on the doped-aluminum bonding pads. The chip can be mounted with conductive epoxy or a gold-silicon preform.

Bonding Pad Assignments



Chip Thickness: 15 Mils Typical
Bonding Pads: 4 × 4 Mils Minimum
T_J(max) = 150°C
Tolerances Are ±10%.
All Dimensions Are in Mils.
Pins 2, 3, 6, and 7 Are Connected Together.
Pins 4 and 5 Are Not Connected.

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
Continuous total power dissipation . . . . See Dissipation Rating Tables 1 and 2
Storage temperature range, T_{stg} . . . . –65°C to 150°C
Case temperature for 60 seconds: FK package . . . . 260°C
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: JG, LP, or PK package . . . . 300°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.

NOTE 1: Voltage values are with respect to the anode terminal unless otherwise noted.

DISSIPATION RATING TABLE 1 – FREE-AIR TEMPERATURE

PACKAGE	T_A = 25°C POWER RATING	DERATING FACTOR ABOVE T_A = 25°C	T_A = 70°C POWER RATING	T_A = 85°C POWER RATING	T_A = 125°C POWER RATING
D	725 mW	5.8 mW/°C	464 mW	377 mW	—
FK	1375 mW	11 mW/°C	880 mW	715 mW	275 mW
JG	1050 mW	8.4 mW/°C	672 mW	546 mW	210 mW
KTP	1800 mW	14.5 mW/°C	1147 mW	943 mW	—
LP	775 mW	6.2 mW/°C	496 mW	403 mW	—
P	1000 mW	8 mW/°C	640 mW	520 mW	—
PK	500 mW	4 mW/°C	320 mW	260 mW	—
PW	525 mW	4.2 mW/°C	336 mW	—	—

DISSIPATION RATING TABLE 2 – CASE TEMPERATURE

PACKAGE	T_C = 25°C POWER RATING	DERATING FACTOR ABOVE T_C = 25°C	T_C = 70°C POWER RATING	T_C = 85°C POWER RATING
PK	3125 mW	25 mW/°C	2000 mW	1625 mW

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	C suffix	0	70	°C
	I suffix	–40	85	
	M suffix	–55	125	

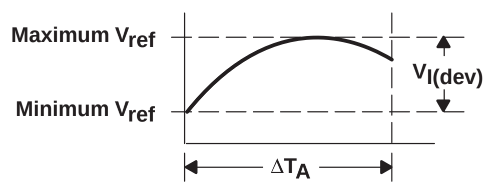
electrical characteristics over recommended operating conditions, T_A = 25°C (unless otherwise noted)

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
$\|z_{KA}\|$	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 temperature 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	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 temperature 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		TL431M MIN	TL431M TYP	TL431M MAX	UNIT
V_{ref}	Reference voltage	2	$V_{KA} = V_{ref}$,	I_{KA} = 10 mA	2400	2495	2600	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†			22		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	–3	mV/V
				ΔV_{KA} = 36 V – 10 V		–1	–2.3	
I_{ref}	Reference current	3	I_{KA} = 10 mA, R1 = 10 kΩ, R2 = ∞			2	8*	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‡			1		µA
I_{min}	Minimum cathode current for regulation	2	$V_{KA} = V_{ref}$			0.4	1.5	mA
I_{off}	Off-state cathode current	4	V_{KA} = 36 V,	V_{ref} = 0		0.1	3	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	0.9*	Ω

* On products compliant to MIL-PRF-38535, this parameter is not production tested.
‡ Full temperature range is –55°C to 125°C for the TL431M.

electrical characteristics over recommended operating conditions, T_A = 25°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	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 temperature 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	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 temperature 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 MIN	TL431Y TYP	TL431Y MAX	UNIT
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

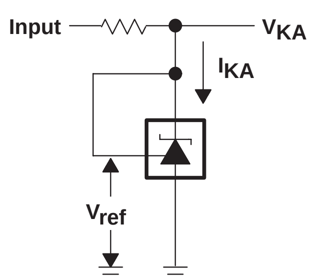


Figure 2. Test Circuit for $V_{KA} = V_{ref}$

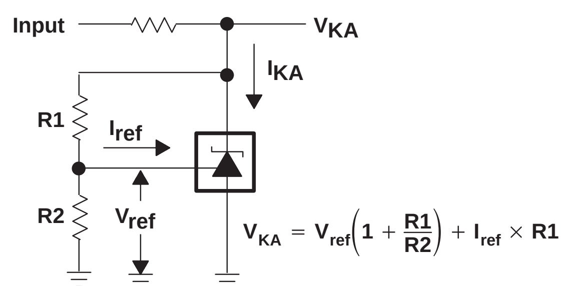


Figure 3. Test Circuit for $V_{KA} > V_{ref}$

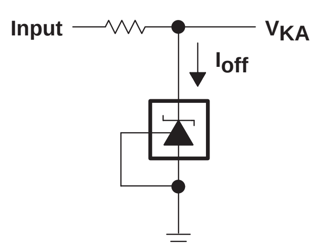


Figure 4. Test Circuit for I_{off}

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
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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 3-terminal fixed regulator	20
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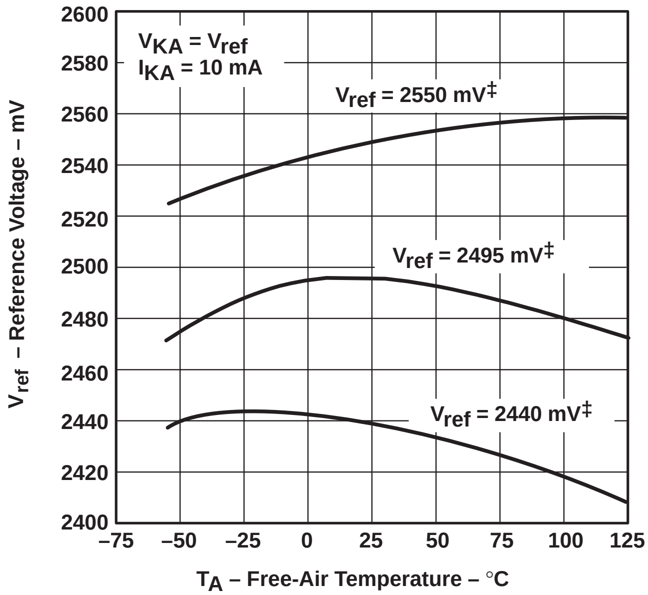
PWM converter with reference	25
Voltage monitor	26
Delay timer	27
Precision current limiter	28
Precision constant-current sink	29

TYPICAL CHARACTERISTICS

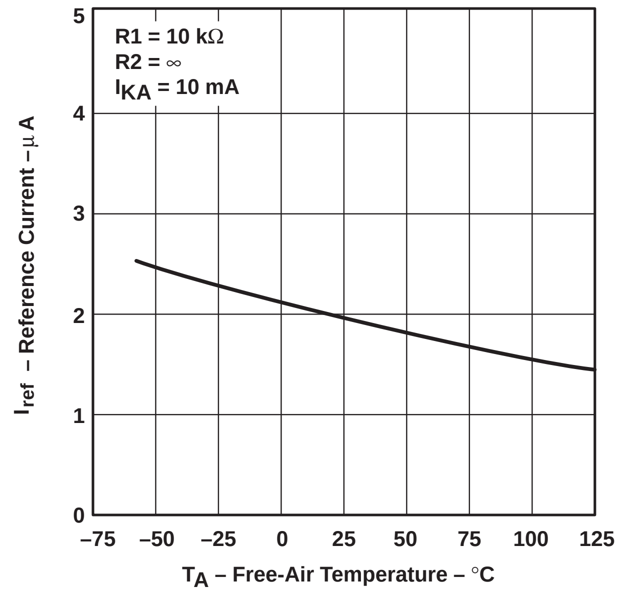
REFERENCE VOLTAGE vs FREE-AIR TEMPERATURE†



† Data is applicable only within the recommended operating free-air temperature ranges of the various devices.
‡ 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†



† Data is applicable only within the recommended operating free-air temperature ranges of the various devices.

Figure 6

CATHODE CURRENT vs CATHODE VOLTAGE

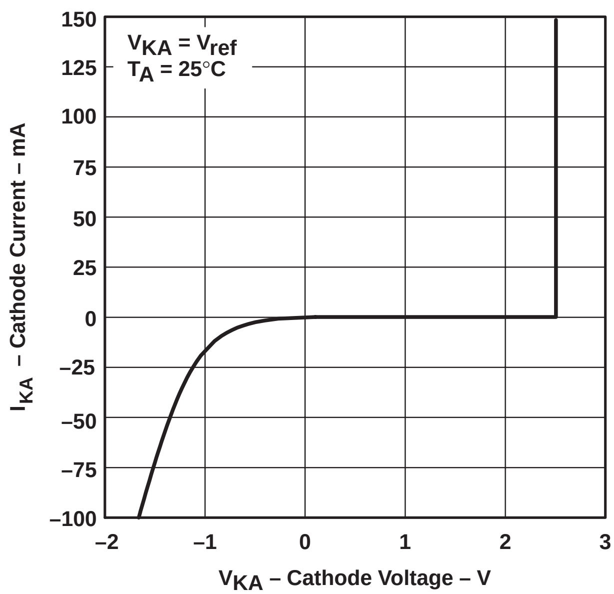


Figure 7

CATHODE CURRENT vs CATHODE VOLTAGE

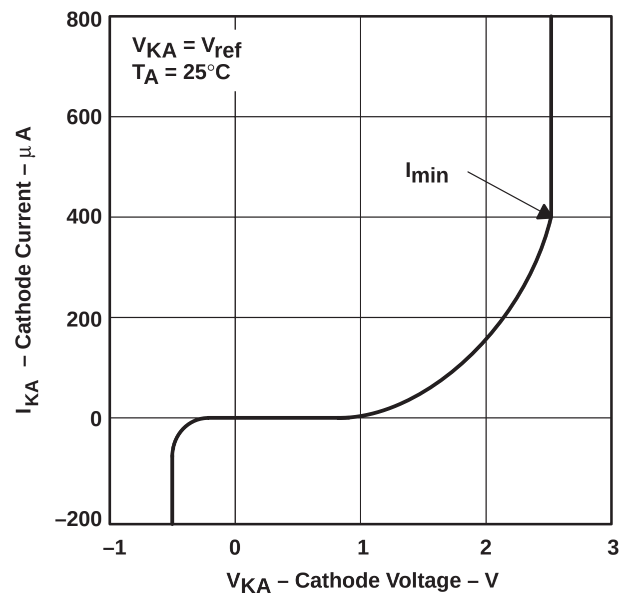
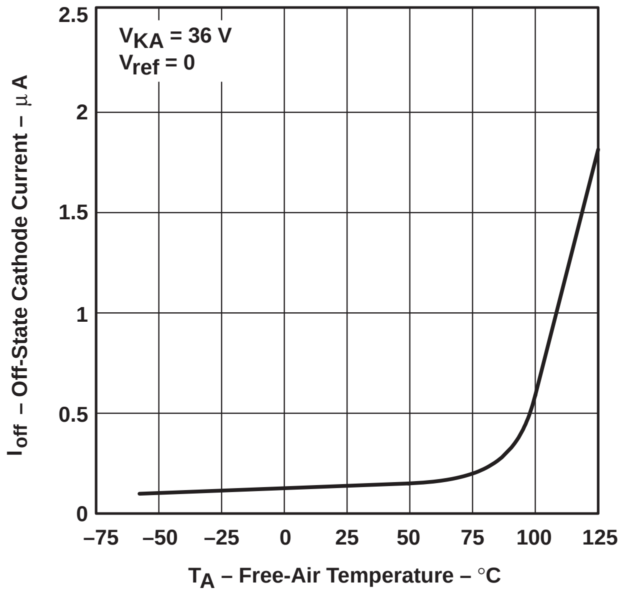


Figure 8

TYPICAL CHARACTERISTICS

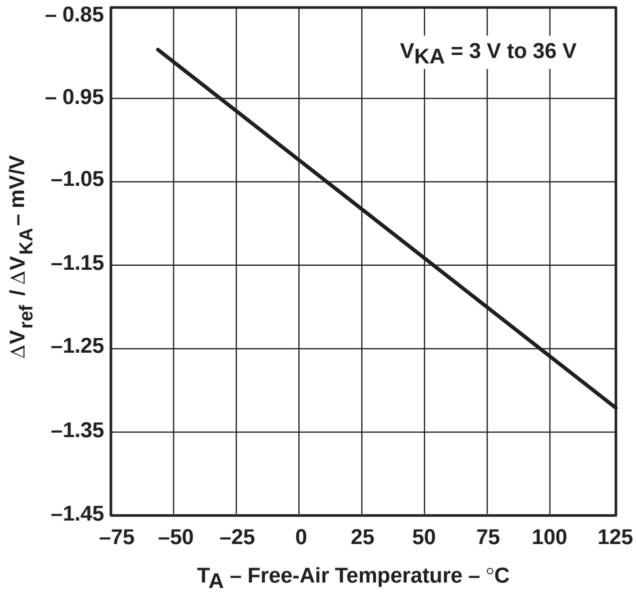
OFF-STATE CATHODE CURRENT vs FREE-AIR TEMPERATURE†



† Data is applicable only within the recommended operating free-air temperature ranges of the various devices.

Figure 9

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



† Data is applicable only within the recommended operating free-air temperature ranges of the various devices.

Figure 10

EQUIVALENT INPUT NOISE VOLTAGE vs FREQUENCY

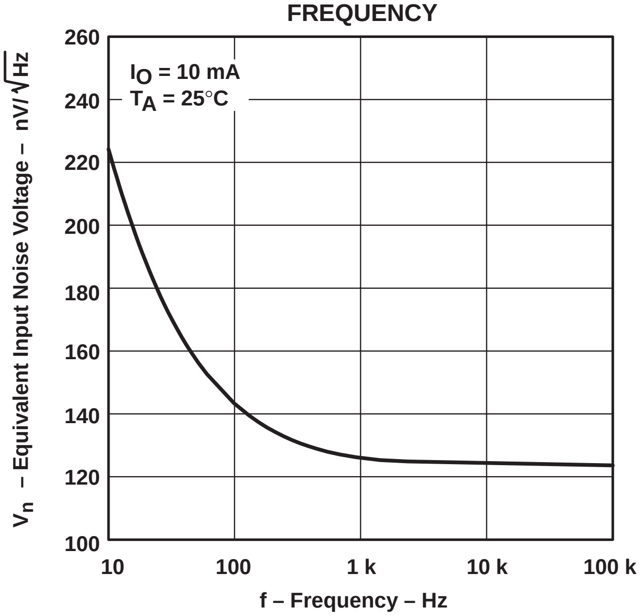
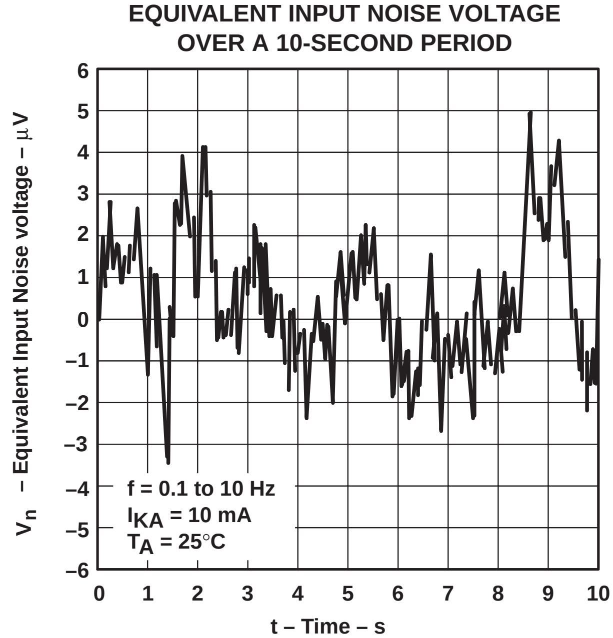


Figure 11

TYPICAL CHARACTERISTICS



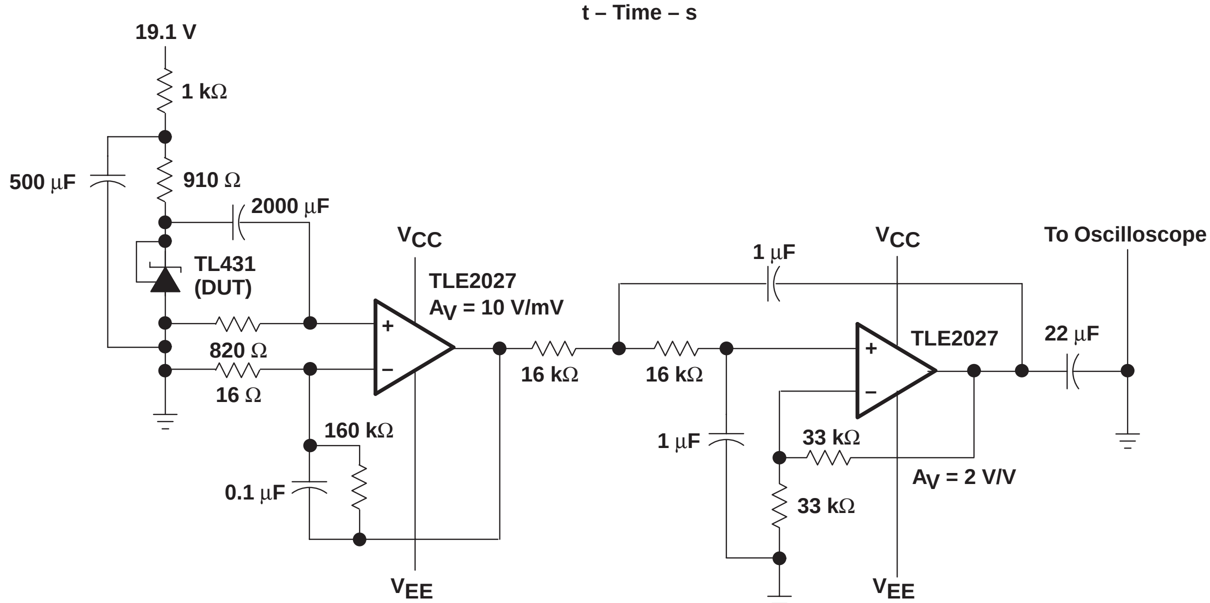
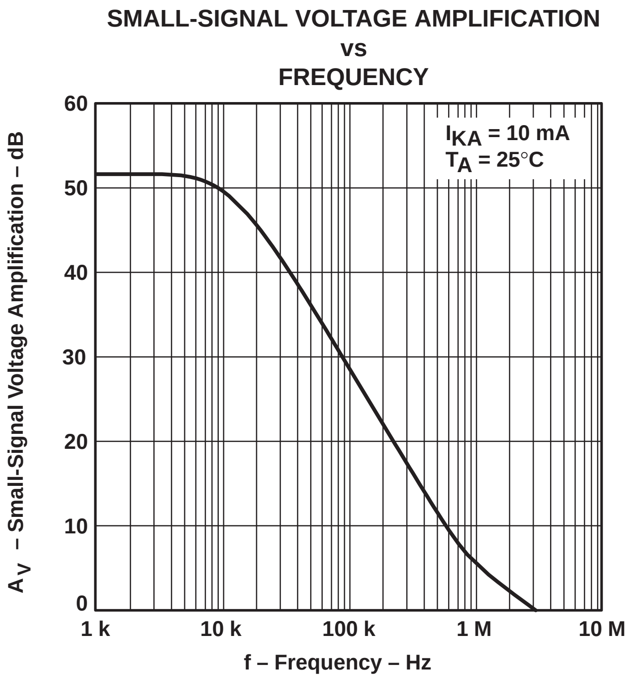
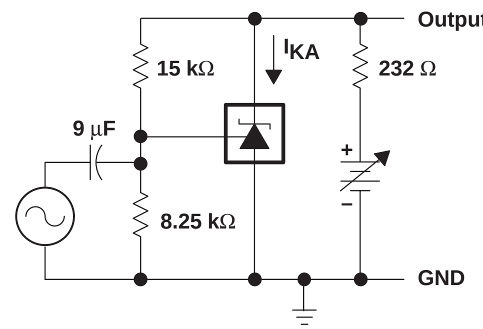


Figure 12. Test Circuit for Equivalent Input Noise Voltage

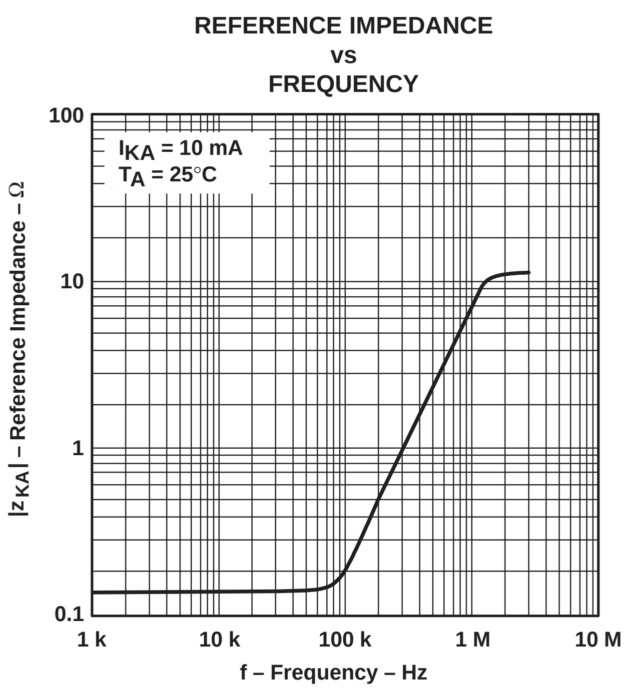
TYPICAL CHARACTERISTICS

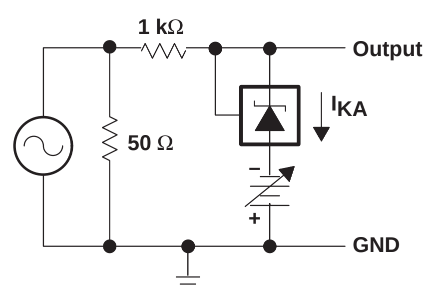




TEST CIRCUIT FOR VOLTAGE AMPLIFICATION

Figure 13



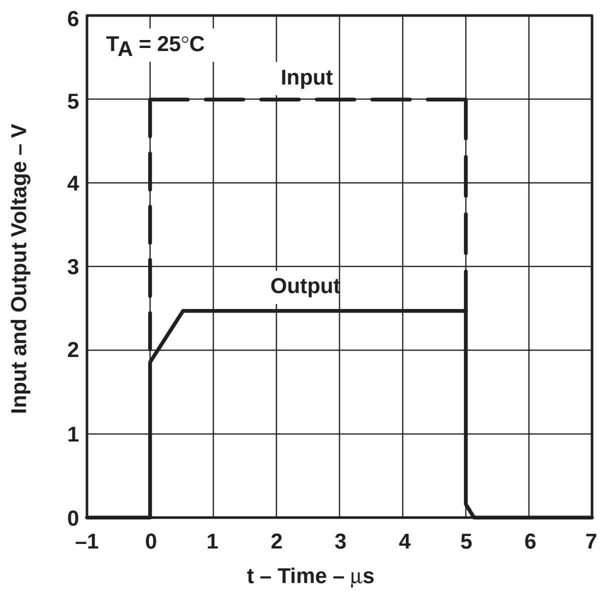


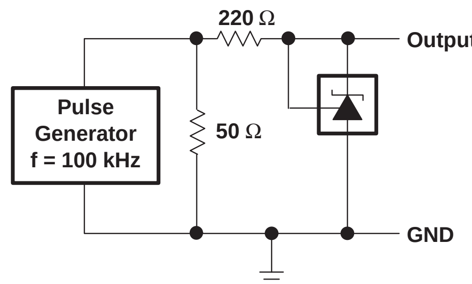
TEST CIRCUIT FOR REFERENCE IMPEDANCE

Figure 14

TYPICAL CHARACTERISTICS

PULSE RESPONSE

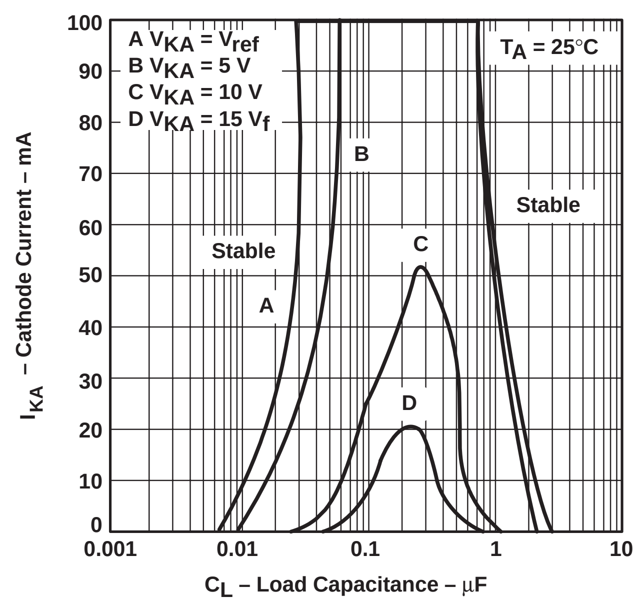




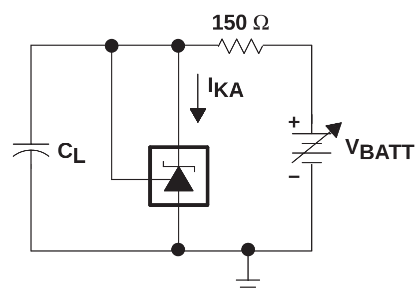
TEST CIRCUIT FOR PULSE RESPONSE

Figure 15

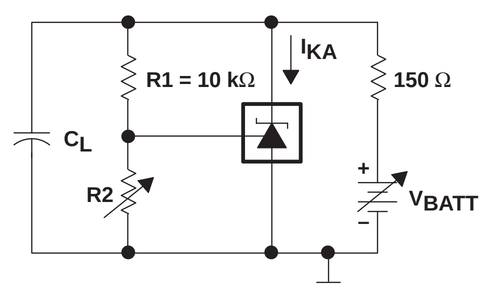
STABILITY BOUNDARY CONDITIONS†



† 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.



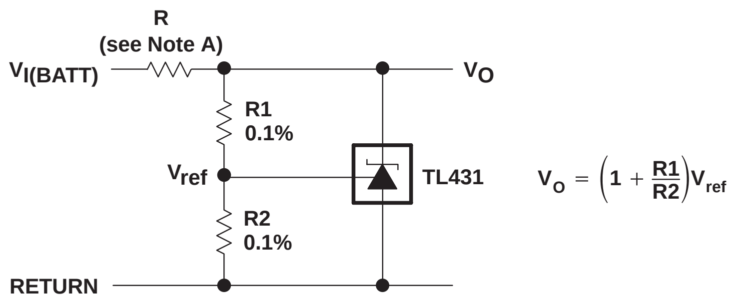
TEST CIRCUIT FOR CURVE A



TEST CIRCUIT FOR CURVES B, C, AND D

Figure 16

APPLICATION INFORMATION



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

Figure 17. Shunt Regulator

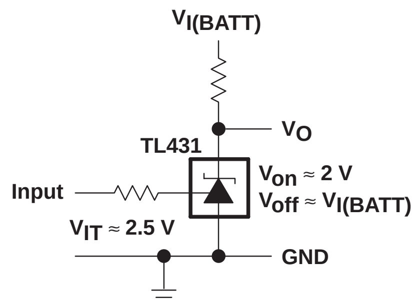
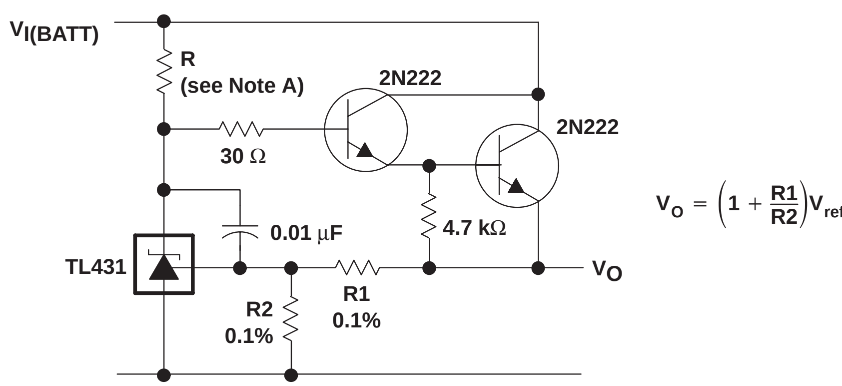


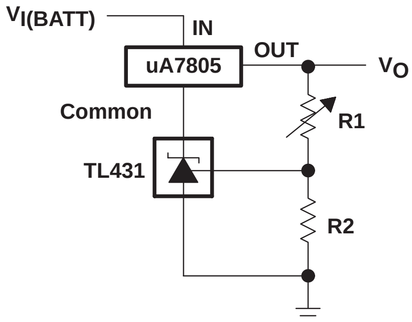
Figure 18. Single-Supply Comparator With Temperature-Compensated Threshold



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

Figure 19. Precision High-Current Series Regulator

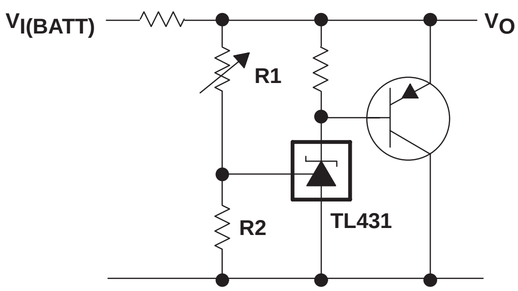
APPLICATION INFORMATION



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

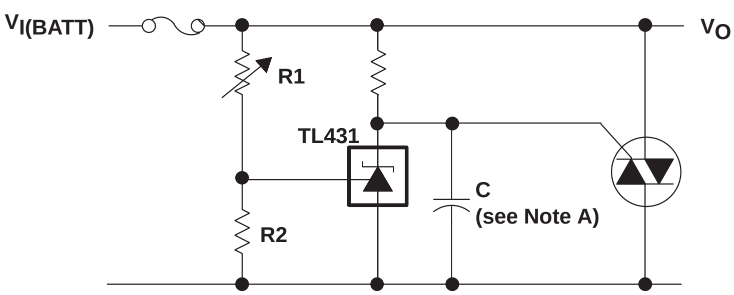
$$\text{Minimum } V_O = V_{ref} + 5\ V$$

Figure 20. Output Control of a 3-Terminal Fixed Regulator



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

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

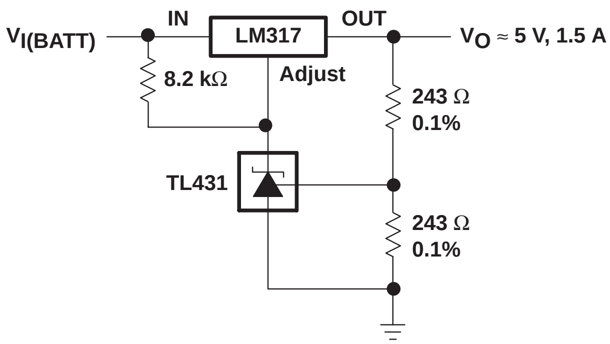
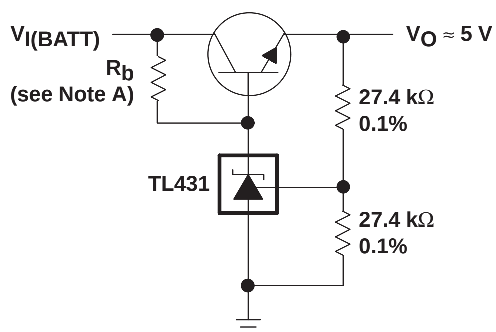


Figure 23. Precision 5-V 1.5-A Regulator



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

Figure 24. Efficient 5-V Precision Regulator

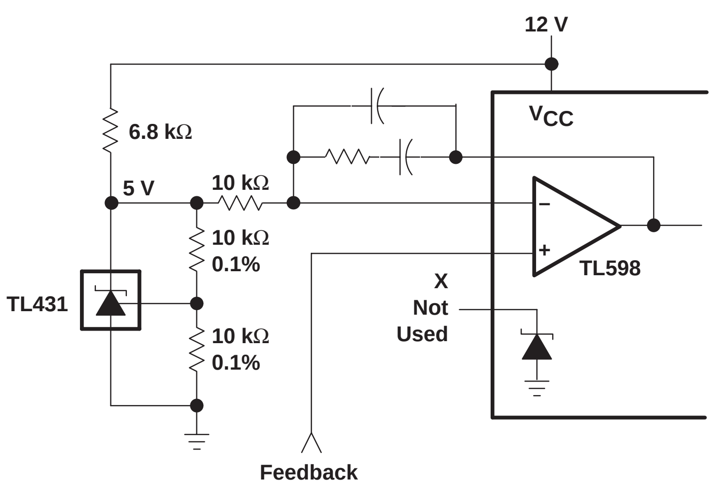
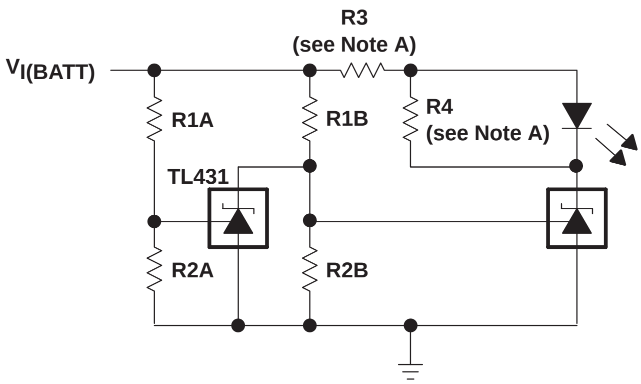


Figure 25. PWM Converter With Reference

APPLICATION INFORMATION



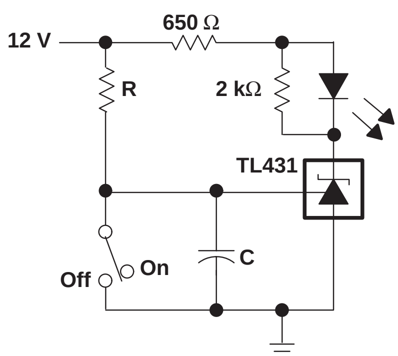
$$\text{Low Limit} = \left(1 + \frac{R1B}{R2B}\right)V_{ref}$$

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

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

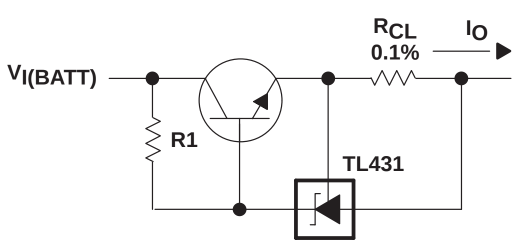
NOTE A: R3 and R4 are selected to provide the desired LED intensity and cathode current ≥1 mA to the TL431 at the available $V_{I(BATT)}$.

Figure 26. Voltage Monitor



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

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

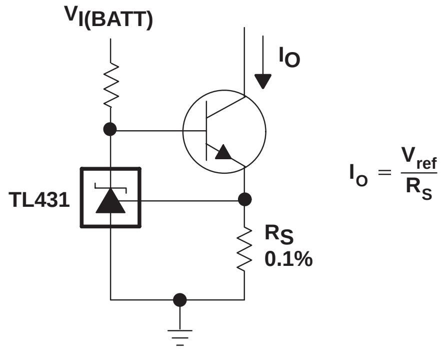


Figure 29. Precision Constant-Current Sink

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