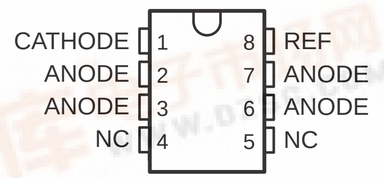
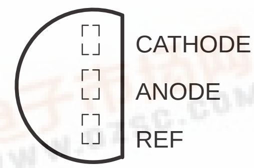
- **0.4% Initial Voltage Tolerance**
- **0.2-Ω Typical Output Impedance**
- **Fast Turnon . . . 500 ns**
- **Sink Current Capability . . . 1 mA to 100 mA**
- **Low Reference Current (REF)**
- **Adjustable Output Voltage . . . $V_{I(ref)}$ to 36 V**

D PACKAGE (TOP VIEW)

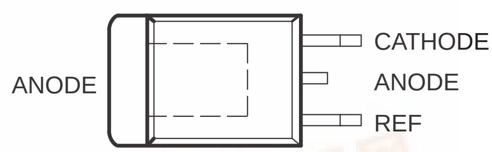


NC – No internal connection
ANODE terminals are connected internally.

LP PACKAGE (TOP VIEW)



KTP PACKAGE (TOP VIEW)



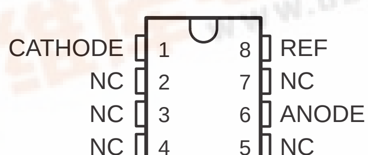
The ANODE terminal is in electrical contact with the mounting base.

description

The TL1431 is a precision programmable reference with specified thermal stability over automotive, commercial, and military temperature ranges. The output voltage can be set to any value between $V_{I(ref)}$ (approximately 2.5 V) and 36 V with two external resistors (see Figure 16). This device has a typical output impedance of 0.2 Ω. Active output circuitry provides a very sharp turnon characteristic, making the device an excellent replacement for zener diodes and other types of references in applications such as onboard regulation, adjustable power supplies, and switching power supplies.

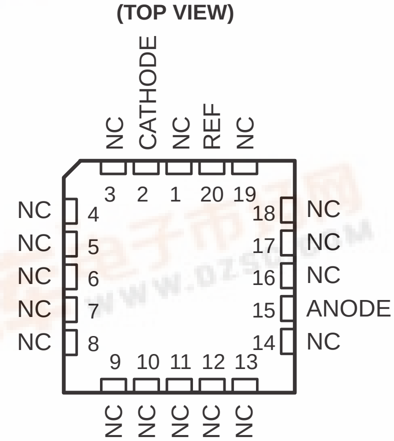
The TL1431C is characterized for operation over the commercial temperature range of 0°C to 70°C. The TL1431Q is characterized for operation over the full automotive temperature range of –40°C to 125°C. The TL1431M is characterized for operation over the full military temperature range of –55°C to 125°C.

JG PACKAGE (TOP VIEW)



NC – No internal connection

FK PACKAGE (TOP VIEW)



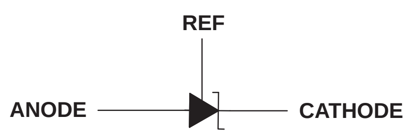
Please be aware that an important notice concerning availability, standard warranty, and use in critical applications of Texas Instruments semiconductor products and disclaimers thereto appears at the end of this data sheet.

AVAILABLE OPTIONS

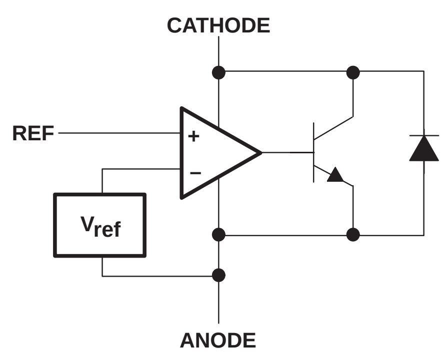
T_A	PACKAGED DEVICES					CHIP FORM (Y)
	SMALL OUTLINE (D)	PLASTIC FLANGE MOUNTED (KTP)	TO-226AA (LP)	CHIP CARRIER (FK)	CERAMIC DIP (JG)	
0°C to 70°C	TL1431CD	TL1431CKTPR	TL1431CLP	–	–	TL1431Y
–40°C to 125°C	TL1431QD	–	TL1431QLP	–	–	
–55°C to 125°C	–	–	–	TL1431MFK	TL1431MJG	

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

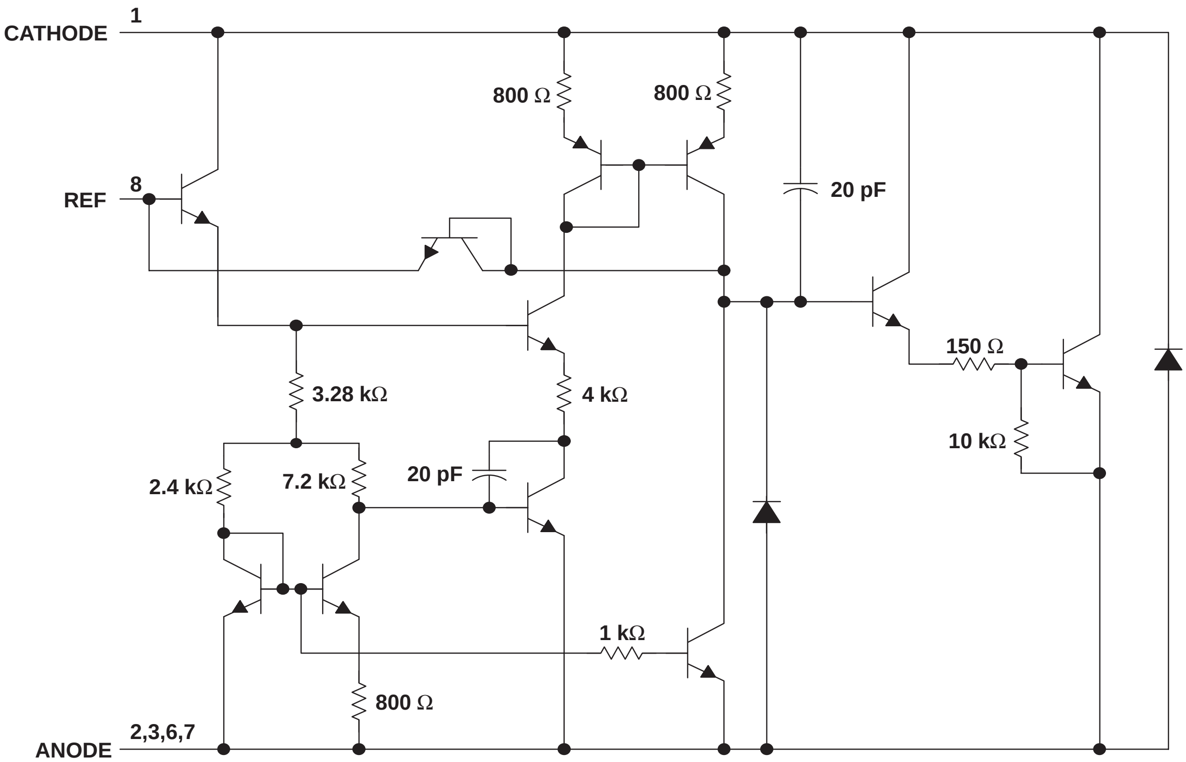
logic symbol



functional block diagram



equivalent schematic†



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

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

Cathode voltage, V_{KA} (see Note 1) . . . . 37 V
Continuous cathode current range, I_{KA} . . . . –100 mA to 150 mA
Reference input current range, $I_{I(ref)}$ . . . . –50 µA to 10 mA
Package thermal impedance, θ_{JA} (see Notes 2 and 3): D package . . . . 97°C/W
KTP package . . . . 28°C/W
LP package . . . . 156°C/W
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds . . . . 260°C
Storage temperature range, T_{stg} . . . . –65°C to 150°C

† Stresses beyond those listed under "absolute maximum ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under "recommended operating conditions" is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

NOTES: 1. All voltage values are with respect to ANODE unless otherwise noted.
2. Maximum power dissipation is a function of T_J(max), θ_{JA}, and T_A. The maximum allowable power dissipation at any allowable ambient temperature is $P_D = (T_J(max) – T_A)/\theta_{JA}$. Operating at the absolute maximum T_J of 150°C can impact reliability.
3. The package thermal impedance is calculated in accordance with JESD 51.

POWER DISSIPATION RATING TABLE – FREE-AIR TEMPERATURE

PACKAGE	T_A = 25°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
FK	1375 mW	11.0 mW/°C	880 mW	715 mW	275 mW
JG	1050 mW	8.4 mW/°C	672 mW	546 mW	210 mW

recommended operating conditions

			MIN	MAX	UNIT
V_{KA}	Cathode voltage		$V_{I(ref)}$	36	V
I_{KA}	Cathode current		1	100	mA
T_A	Operating free-air temperature	TL1431C	0	70	°C
		TL1431Q	–40	125	
		TL1431M	–55	125	

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

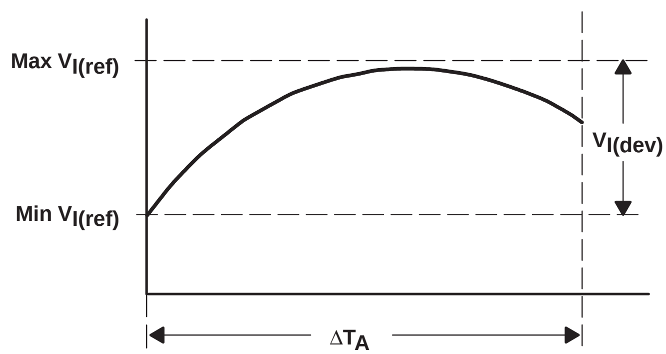
PARAMETER		TEST CONDITIONS	T_A†	TEST CIRCUIT	TL1431C MIN	TL1431C TYP	TL1431C MAX	UNIT
$V_{I(ref)}$	Reference input voltage	$V_{KA} = V_{I(ref)}$	25°C	Figure 1	2490	2500	2510	mV
			Full range		2480		2520	
$V_{I(dev)}$	Deviation of reference input voltage over full temperature range‡	$V_{KA} = V_{I(ref)}$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

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

‡ The deviation parameters $V_{I(dev)}$ and $I_{I(dev)}$ are defined as the differences between the maximum and minimum values obtained over the rated temperature range. The average full-range temperature coefficient of the reference input voltage $\alpha_{V_{I(ref)}}$ is defined as:

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

where:
ΔT_A is the rated operating temperature range of the device.



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

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

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

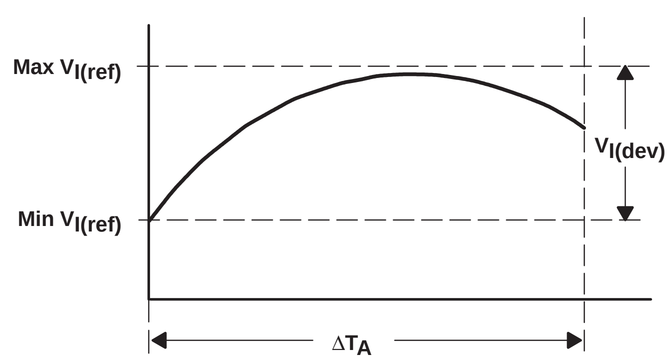
electrical characteristics at specified free-air temperature, I_{KA} = 10 mA (unless otherwise noted)

PARAMETER		TEST CONDITIONS	T_A†	TEST CIRCUIT	TL1431Q			TL1431M			UNIT
					MIN	TYP	MAX	MIN	TYP	MAX	
$V_{I(ref)}$	Reference input voltage	$V_{KA} = V_{I(ref)}$	25°C	Figure 1	2490	2500	2510	2475	2500	2540	mV
			Full range		2470		2530	2460		2550	
$V_{I(dev)}$	Deviation of reference input voltage over full temperature range‡	$V_{KA} = V_{I(ref)}$	Full range	Figure 1		17	55		17	55*	mV
$\frac{\Delta V_{I(ref)}}{\Delta V_{KA}}$	Ratio of change in reference input voltage to the change in cathode voltage	ΔV_{KA} = 3 V to 36 V	Full range	Figure 2		–1.1	–2		–1.1	–2	mV/V
$I_{I(ref)}$	Reference input current	R1 = 10 kΩ, R2 = ∞	25°C	Figure 2		1.5	2.5		1.5	2.5	μA
			Full range				4			5	
$I_{I(dev)}$	Deviation of reference input current over full temperature range‡	R1 = 10 kΩ, R2 = ∞	Full range	Figure 2		0.5	2		0.5	3*	μA
	Minimum cathode current for regulation	$V_{KA} = V_{I(ref)}$ to 36 V	25°C	Figure 1		0.45	1		0.45	1	mA
I_{off}	Off-state cathode current	V_{KA} = 36 V, $V_{I(ref)}$ = 0	25°C	Figure 3		0.18	0.5		0.18	0.5	μA
			Full range				2			2	
$\lvert z_{KA} \rvert$	Output impedance§	$V_{KA} = V_{I(ref)}$, f ≤ 1 kHz, I_{KA} = 1 mA to 100 mA	25°C	Figure 1		0.2	0.4		0.2	0.4	Ω

*On products compliant to MIL-PRF-38535, this parameter is not production tested.
† Full range is –40°C to 125°C for Q-suffix devices, and –55°C to 125°C for M-suffix devices.
‡ The deviation parameters $V_{I(dev)}$ and $I_{I(dev)}$ are defined as the differences between the maximum and minimum values obtained over the rated temperature range. The average full-range temperature coefficient of the reference input voltage $\alpha_{V_{I(ref)}}$ is defined as:

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

where:
ΔT_A is the rated operating temperature range of the device.



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

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

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

electrical characteristics at I_{KA} = 10 mA, T_A = 25°C

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

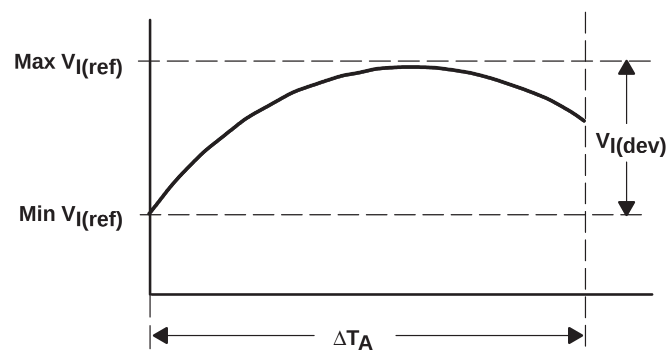
† The output impedance is defined as: $\lvert z' \rvert = \frac{\Delta V}{\Delta I}$

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

PARAMETER MEASUREMENT INFORMATION

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

where:
ΔT_A is the rated operating temperature range of the device.



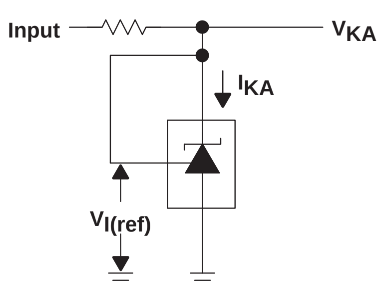


Figure 1. Test Circuit for $V_{(KA)} = V_{ref}$

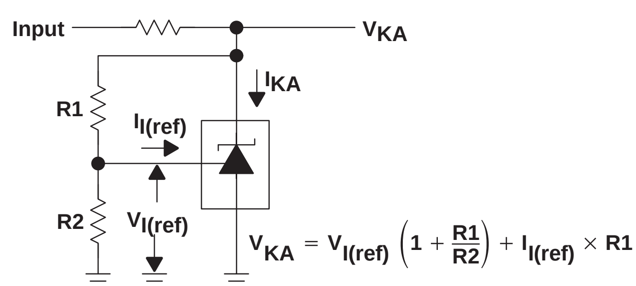


Figure 2. Test Circuit for $V_{(KA)} > V_{ref}$

PARAMETER MEASUREMENT INFORMATION

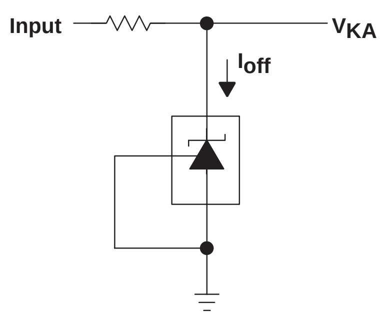


Figure 3. Test Circuit for I_{off}

TYPICAL CHARACTERISTICS

Table of Graphs

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Equivalent input-noise voltage vs Frequency	10
Equivalent input-noise voltage over a 10-second period	11
Small-signal voltage amplification vs Frequency	12
Reference impedance vs Frequency	13
Pulse response	14
Stability boundary conditions	15

TYPICAL CHARACTERISTICS†

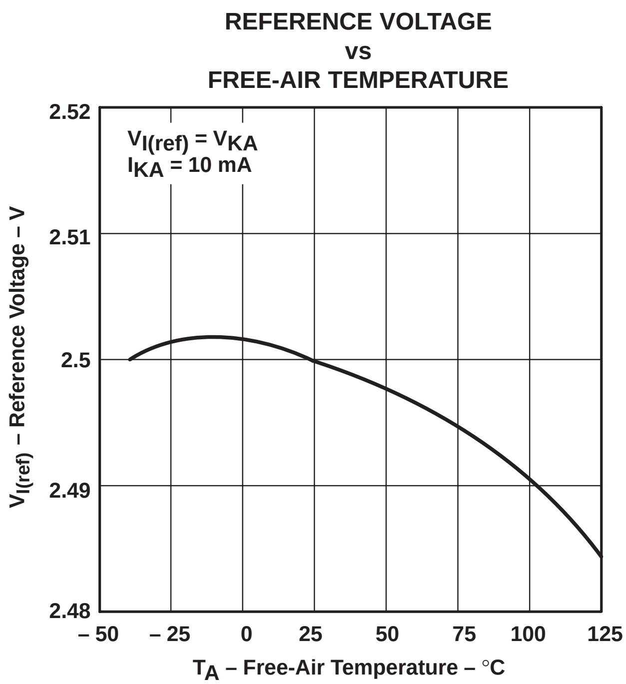


Figure 4

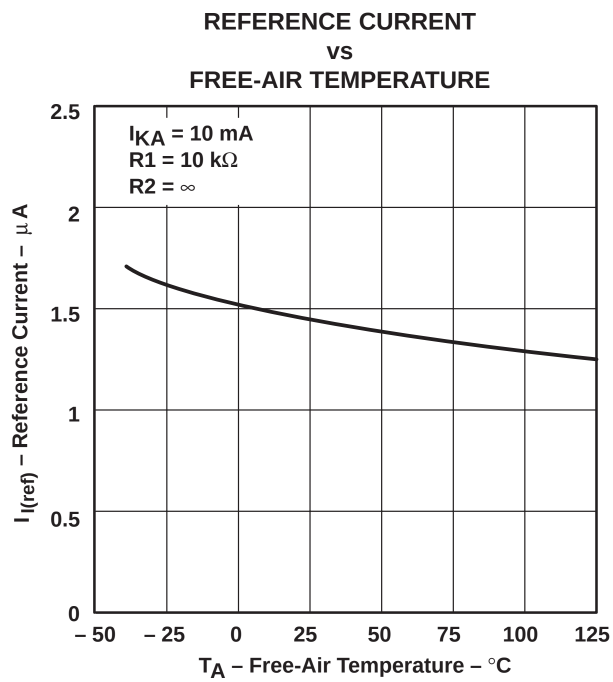


Figure 5

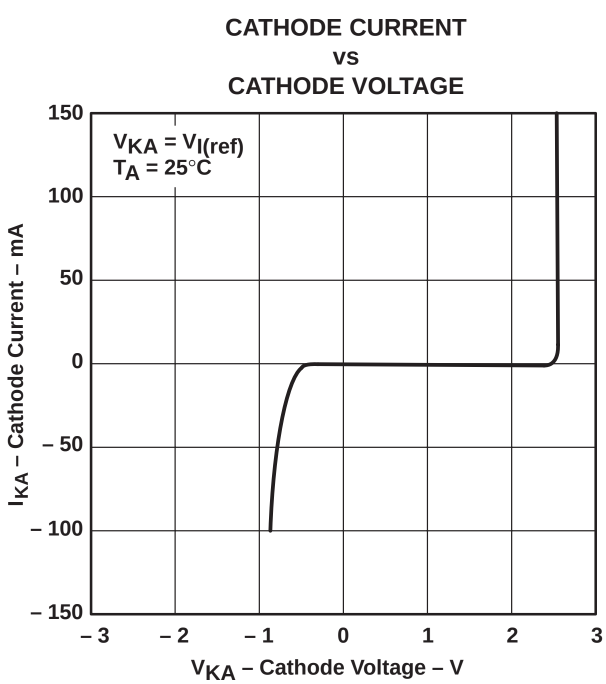


Figure 6

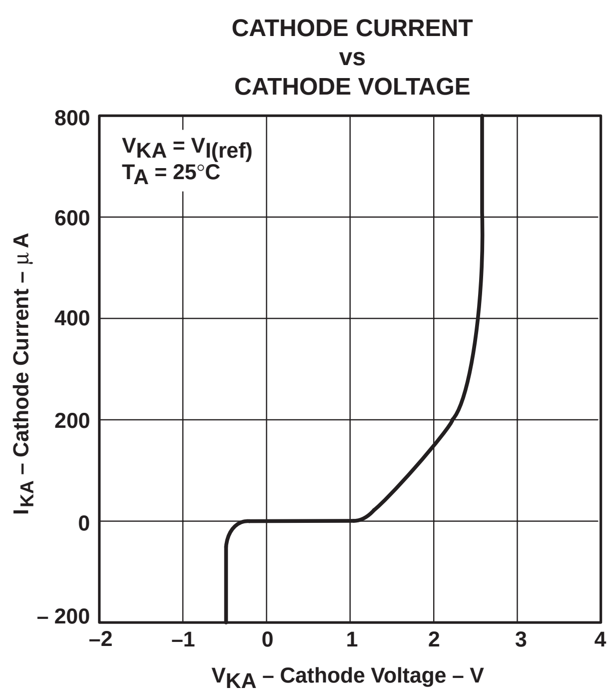


Figure 7

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

TYPICAL CHARACTERISTICS†

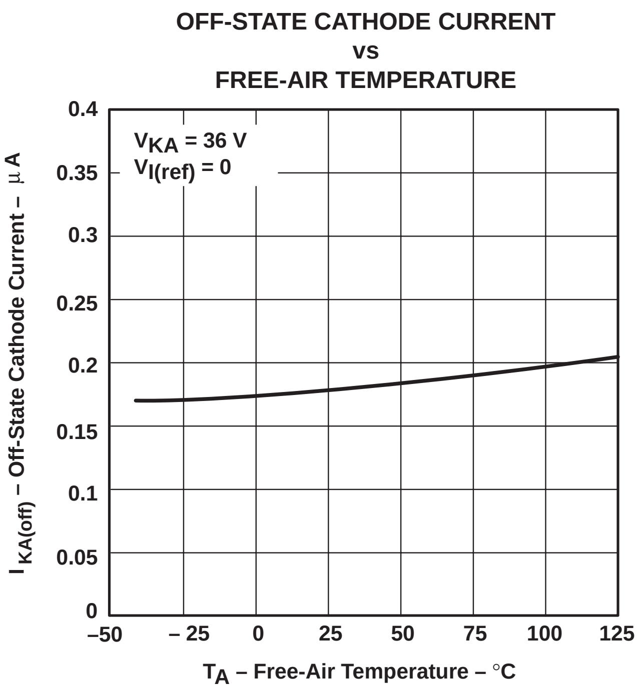


Figure 8

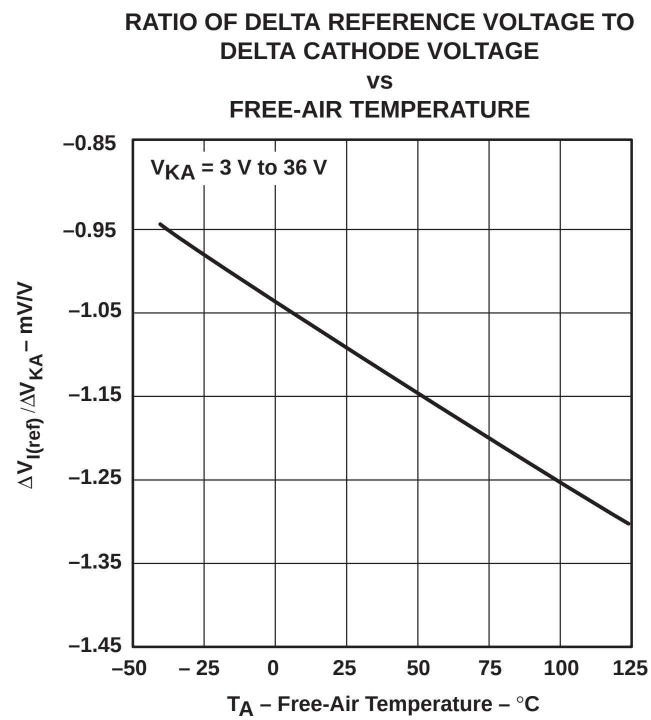


Figure 9

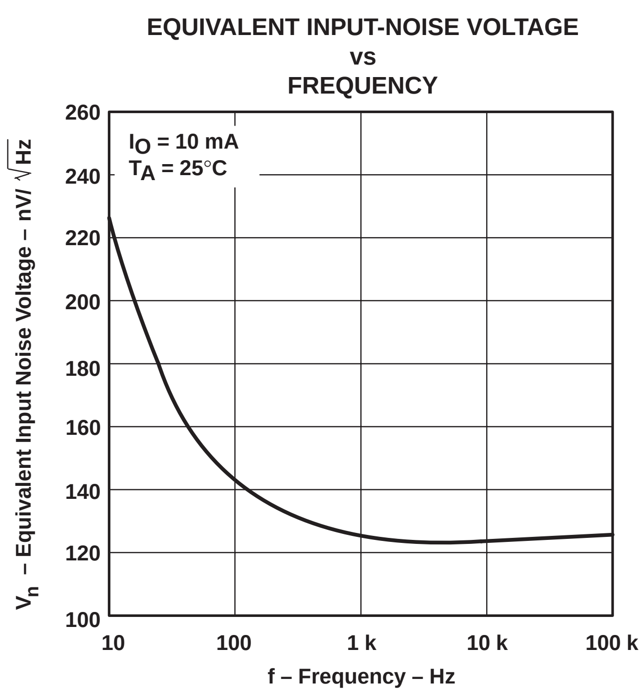
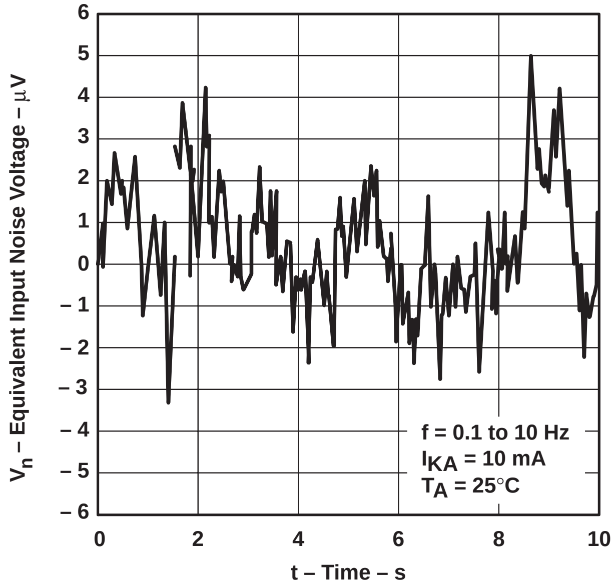


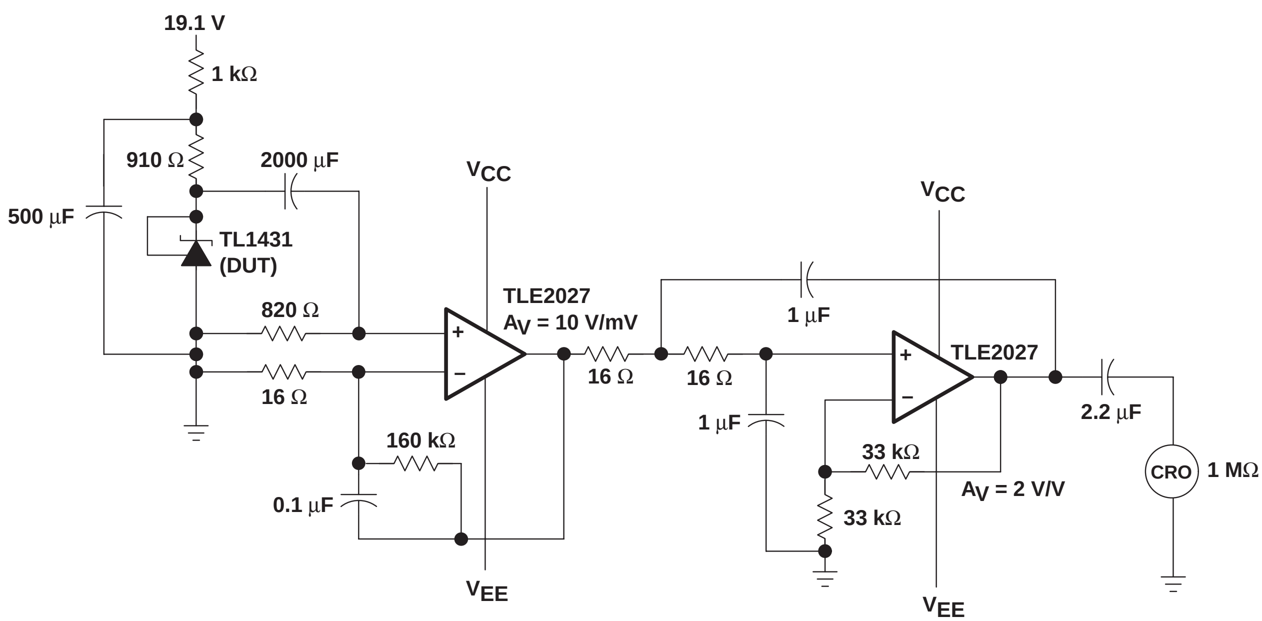
Figure 10

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

TYPICAL CHARACTERISTICS

EQUIVALENT INPUT-NOISE VOLTAGE
OVER A 10-SECOND PERIOD



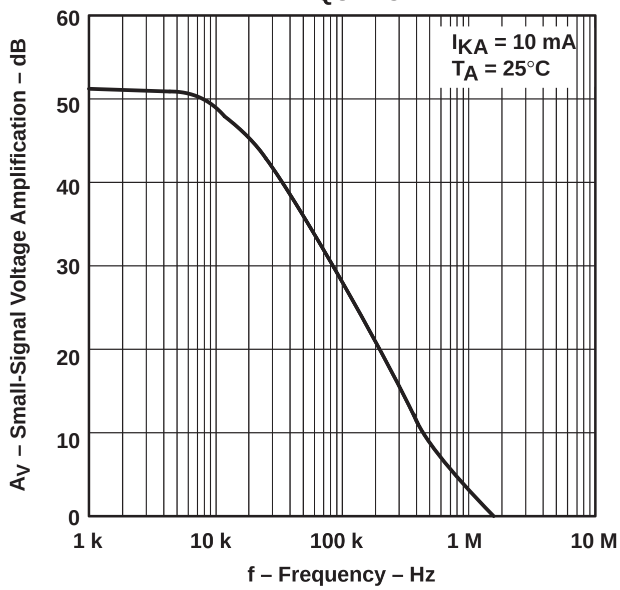


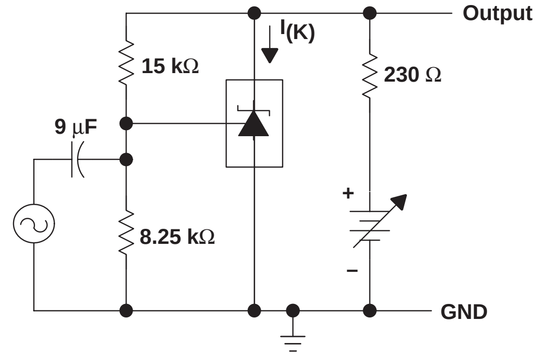
TEST CIRCUIT FOR 0.1-Hz TO 10-Hz EQUIVALENT INPUT-NOISE VOLTAGE

Figure 11

TYPICAL CHARACTERISTICS

SMALL-SIGNAL VOLTAGE AMPLIFICATION vs FREQUENCY

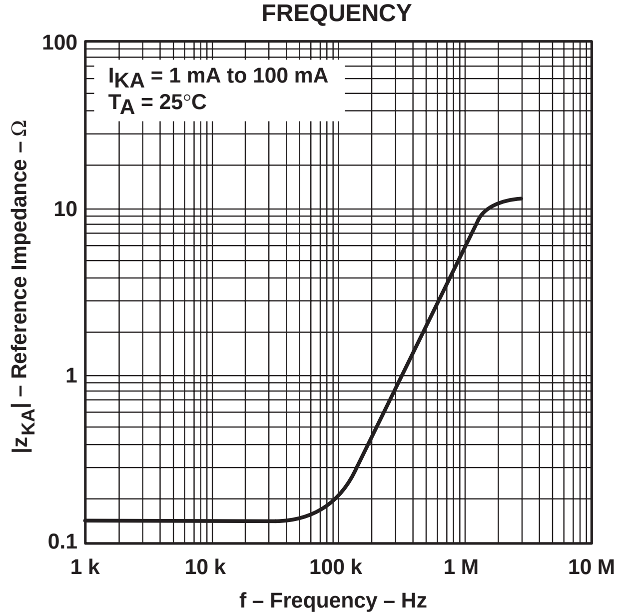


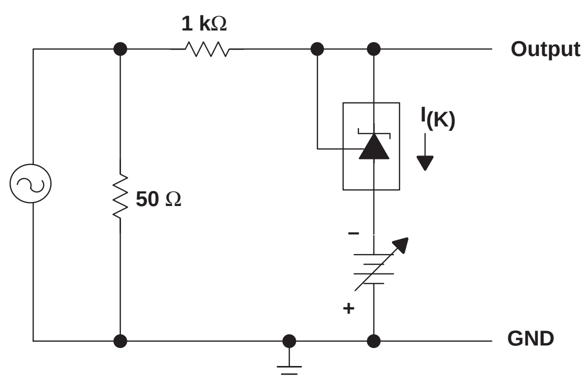


TEST CIRCUIT FOR VOLTAGE AMPLIFICATION

Figure 12

REFERENCE IMPEDANCE vs FREQUENCY



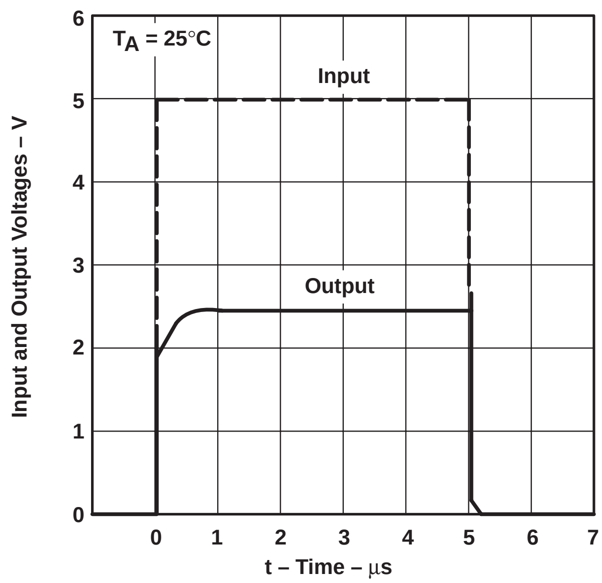


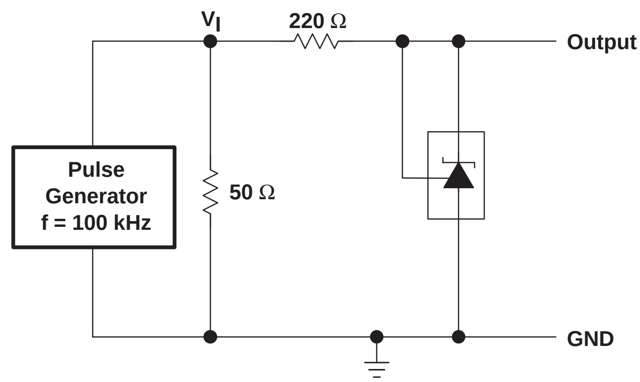
TEST CIRCUIT FOR REFERENCE IMPEDANCE

Figure 13

TYPICAL CHARACTERISTICS

PULSE RESPONSE

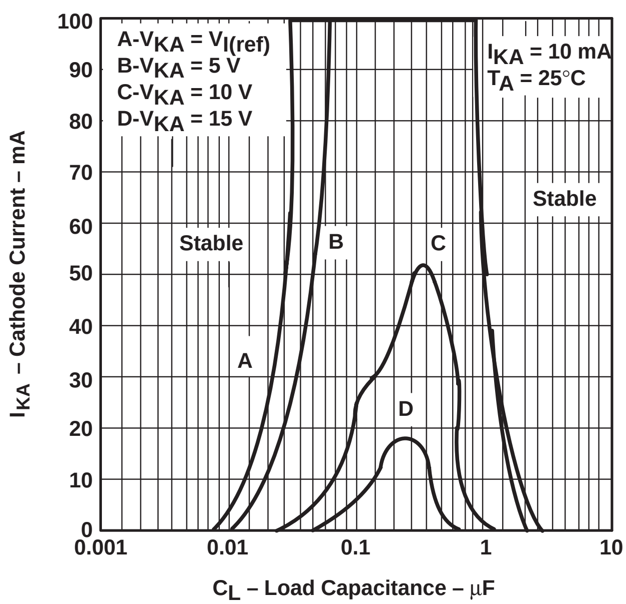




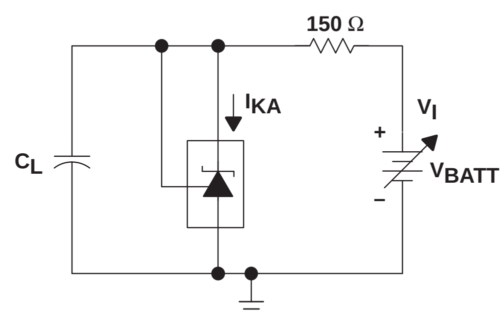
TEST CIRCUIT FOR PULSE RESPONSE

Figure 14

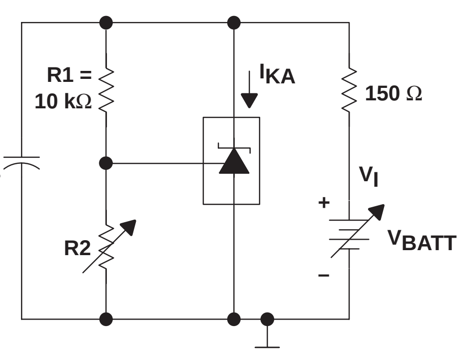
STABILITY BOUNDARY CONDITIONS†



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



TEST CIRCUIT FOR CURVE A



TEST CIRCUIT FOR CURVES B, C, AND D

Figure 15

APPLICATION INFORMATION

Table of Application Circuits

APPLICATION	FIGURE
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Delay timer	26
Precision current limiter	27
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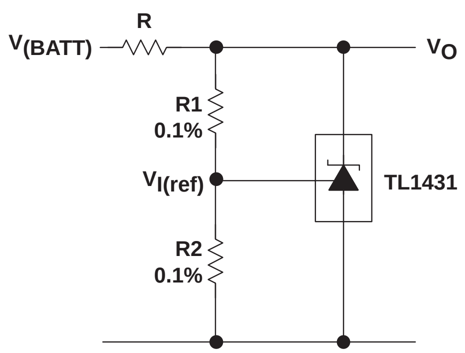


$$V_O = \left(1 + \frac{R1}{R2}\right) V_{I(ref)}$$

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

Figure 16. Shunt Regulator

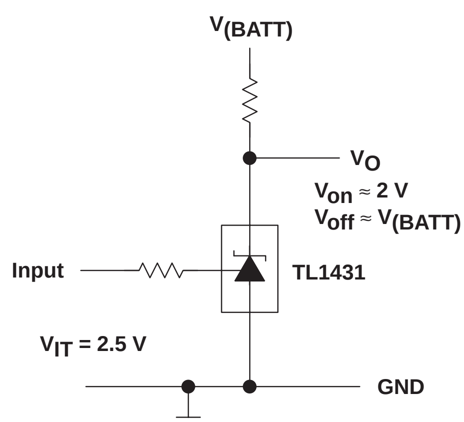
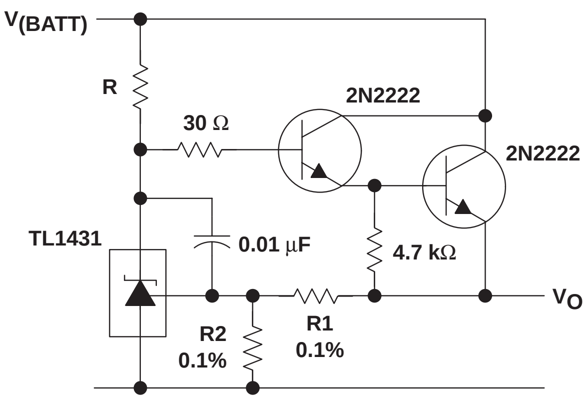


Figure 17. Single-Supply Comparator With Temperature-Compensated Threshold

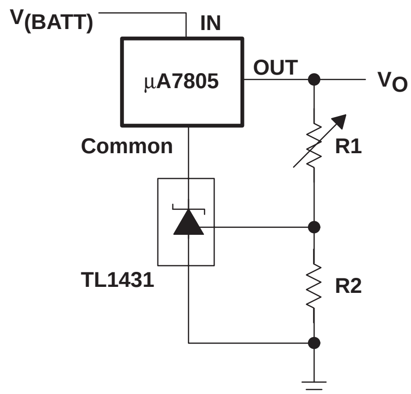
APPLICATION INFORMATION



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

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

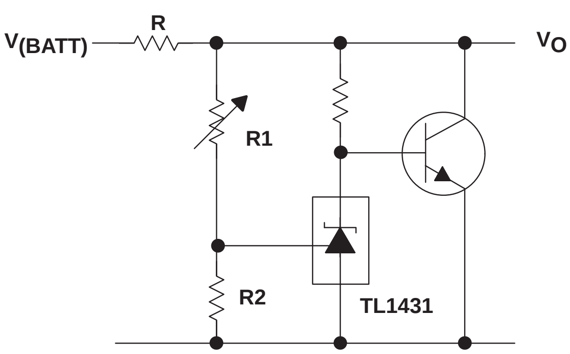
Figure 18. Precision High-Current Series Regulator



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

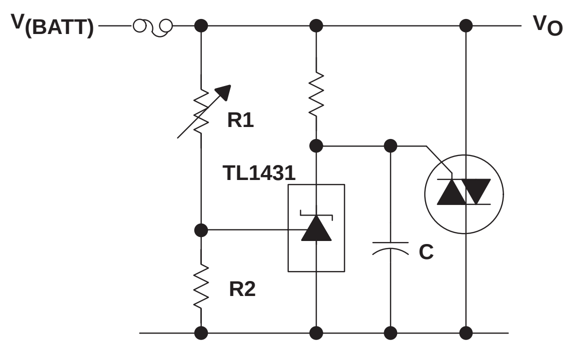
$$\text{Min } V = V_{I(ref)} + 5\ V$$

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



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

Figure 20. Higher-Current Shunt Regulator



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

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

Figure 21. Crowbar

APPLICATION INFORMATION

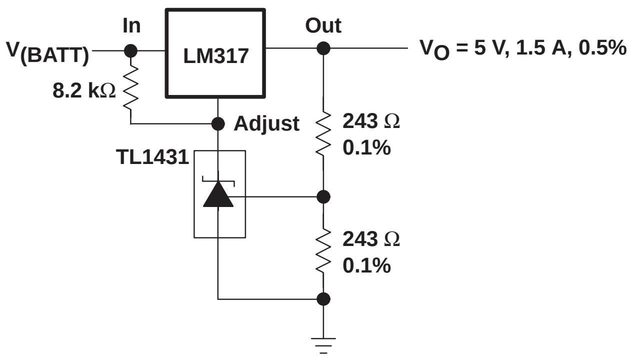
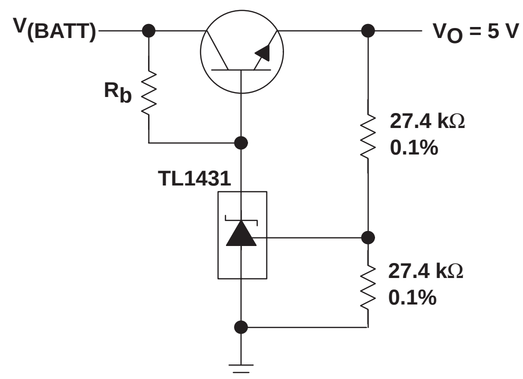


Figure 22. Precision 5-V, 1.5-A, 0.5% Regulator



NOTE A: R_b should provide cathode current ≥1 mA to the TL1431.

Figure 23. 5-V Precision Regulator

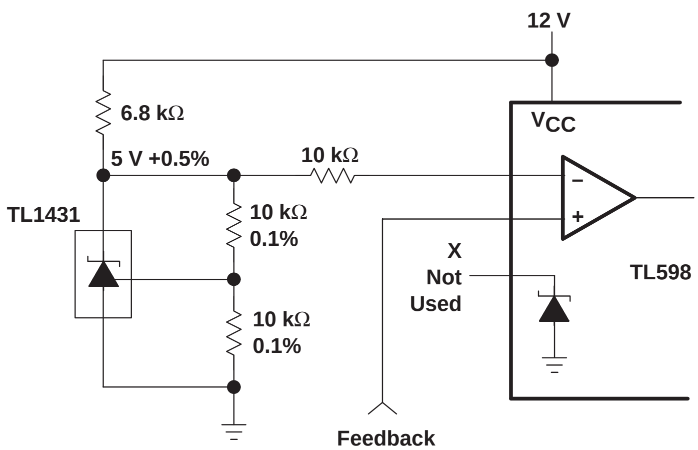


Figure 24. PWM Converter With 0.5% Reference

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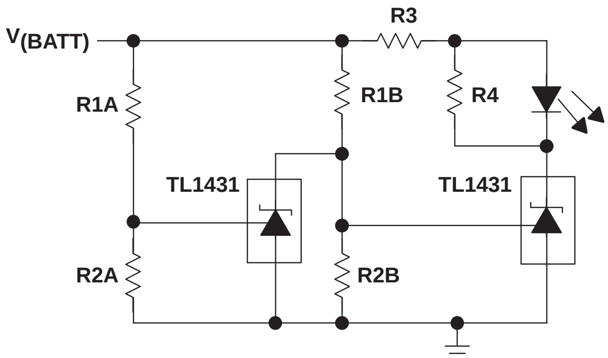


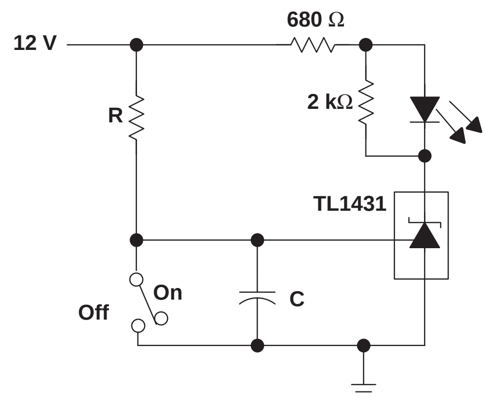
$$\text{Low Limit} = \left(1 + \frac{R1B}{R2B}\right)V_{I(ref)}$$

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

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

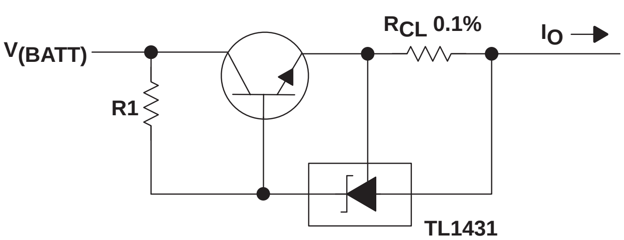
NOTE A: Select R3 and R4 to provide the desired LED intensity and cathode current ≥1 mA to the TL1431.

Figure 25. Voltage Monitor



$$\text{Delay} = R \times C \times \ln \frac{12\ V}{(12\ V) - V_{I(ref)}}$$

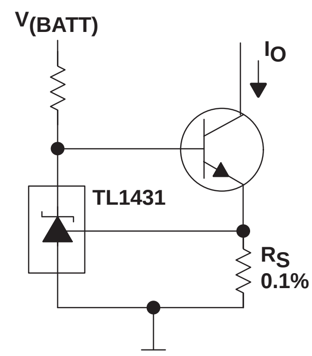
Figure 26. Delay Timer



$$I_O = \frac{V_{I(ref)}}{R_{CL}} + I_{KA}$$

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

Figure 27. Precision Current Limiter



$$I_O = \frac{V_{I(ref)}}{R_S}$$

Figure 28. Precision Constant-Current Sink

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