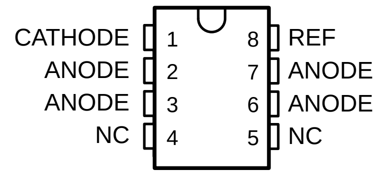
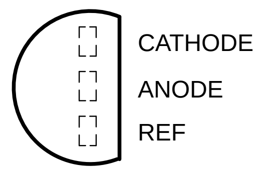
- **0.4% Initial Voltage Tolerance**
- **0.1-Ω Typical Output Impedance**
- **Fast Turn On . . . 500 ns**
- **Sink Current Capability . . . 1 mA to 100 mA**
- **Low REF Current**
- **Adjustable Output Voltage . . . V_{ref} to 36 V**
- **Available In Two High-Density Packaging Options:**
  - **Small Outline (D)**
  - **TO-226AA (LP)**

D PACKAGE
(TOP VIEW)



NC – No internal connection
ANODE terminals are internally connected.

LP PACKAGE
(TOP VIEW)



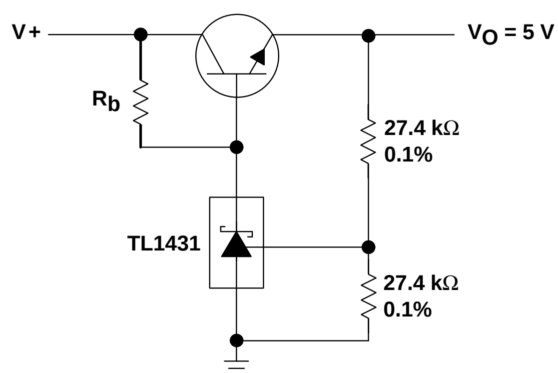
description

The TL1431 is a precision programmable reference with specified thermal stability over applicable automotive and commercial temperature ranges. The output voltage may be set to any value between $V_{I(ref)}$ (approximately 2.5 V) and 36 V with two external resistors (see Figure 16). These devices have a typical output impedance of 0.1 Ω. Active output circuitry provides a very sharp turn-on characteristic, making these devices excellent replacements for zener diodes and other types of references in applications such as on-board regulation, adjustable power supplies, and switching power supplies.

The TL1431 is offered in a wide variety of high-density packaging options. It is also available in both the automotive temperature range and the commercial temperature range. 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 automotive temperature range of –40°C to 125°C.

application schematic

5-V Precision Regulator



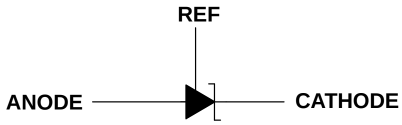
NOTE A: R_b should provide cathode current ≥ 1-mA to the TL1431.

AVAILABLE OPTIONS

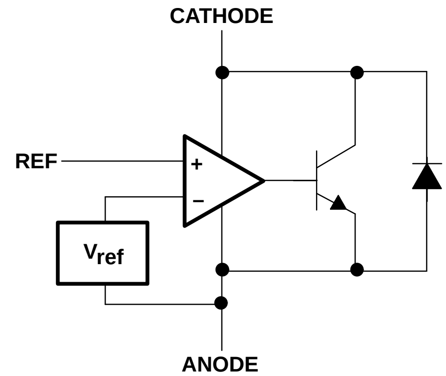
PACKAGED DEVICES			CHIP FORM (Y)
T_A	SMALL OUTLINE (D)	TO-226AA (LP)	
0°C to 70°C	TL1431CD	TL1431CLP	TL1431Y
–40°C to 125°C	TL1431QD	TL1431QLP	

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

symbol



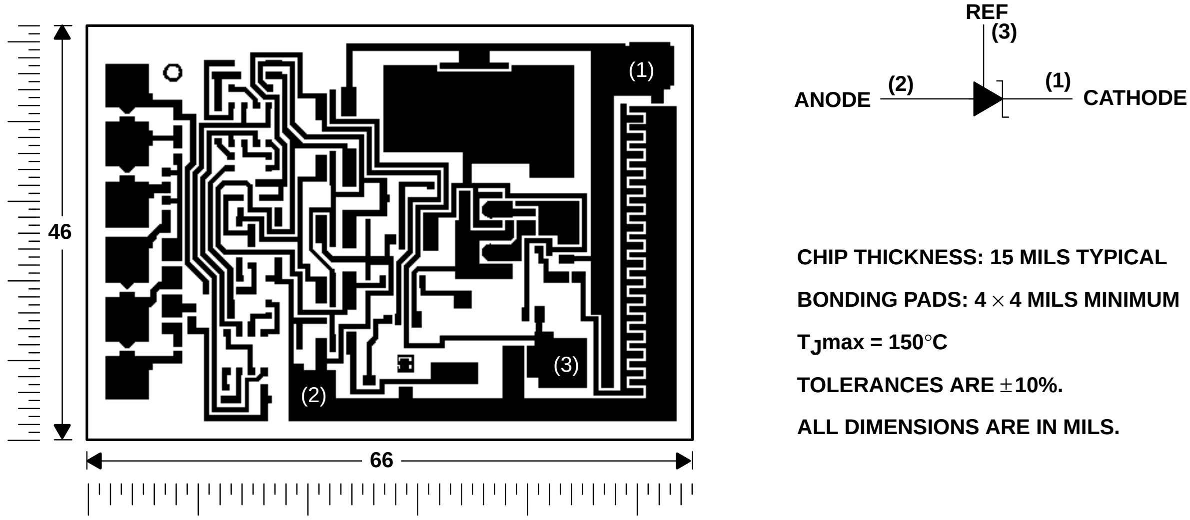
functional block diagram



TL1431Y chip information

This chip, when properly assembled, displays characteristics similar to the TL1431. Thermal compression or ultrasonic bonding may be used on the doped aluminum bonding pads. The chip may be mounted with conductive epoxy or a gold-silicon preform.

BONDING PAD ASSIGNMENTS



CHIP THICKNESS: 15 MILS TYPICAL

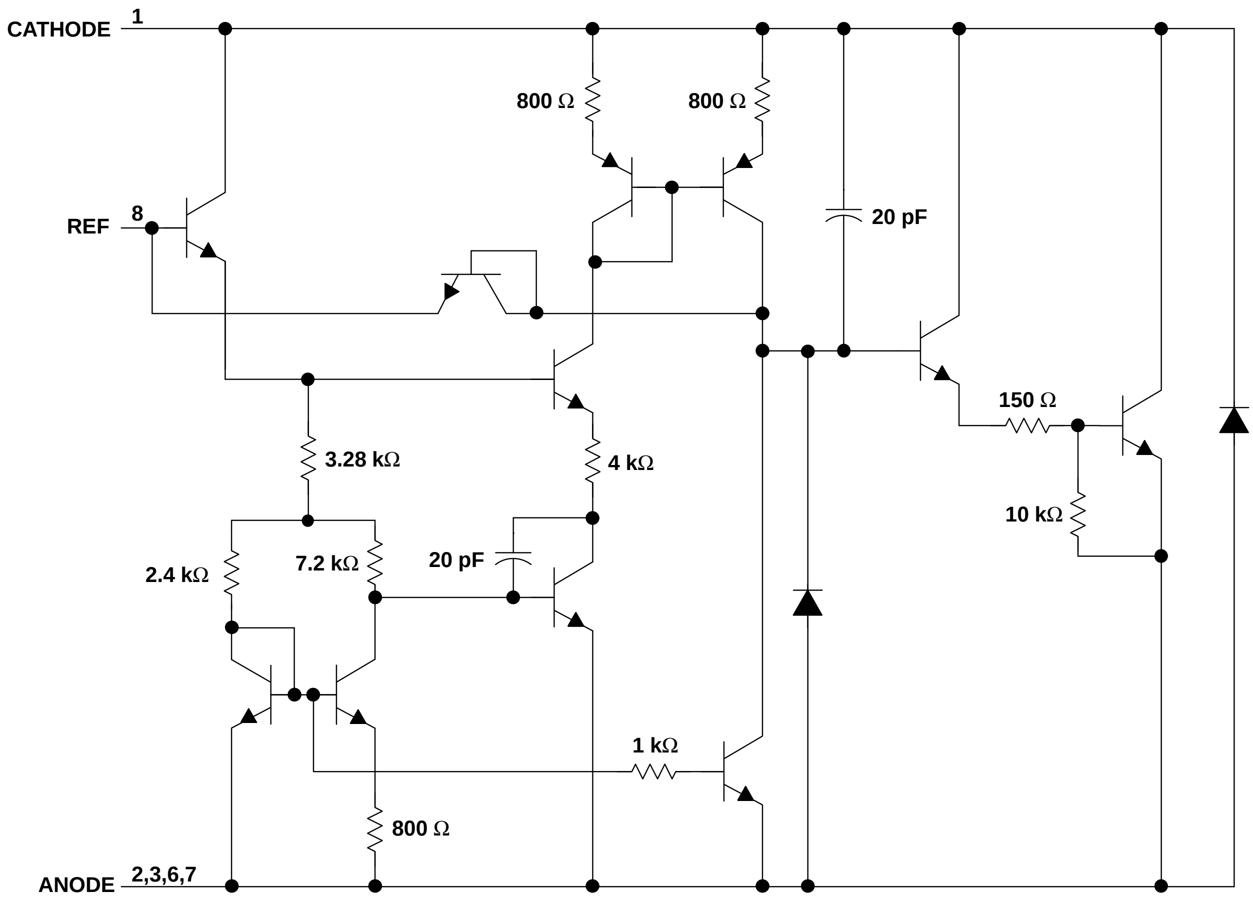
BONDING PADS: 4 × 4 MILS MINIMUM

$T_J$max = 150°C

TOLERANCES ARE ±10%.

ALL DIMENSIONS ARE IN MILS.

equivalent schematic



NOTE A: 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, $I_{I(REF)}$		–50 µA to 10 mA
Continuous total power dissipation		See Dissipation Rating Table
Operating free-air temperature range, T_A:	C suffix	0°C to 70°C
	Q suffix	–40°C to 125°C
Storage temperature range, T_{stg}		–65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds		260°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: All voltage values are with respect to ANODE unless otherwise noted.

DISSIPATION RATING TABLE

PACKAGE	$T_A \le 25°C$ POWER RATING	DERATING FACTOR ABOVE $T_A = 25°C$	$T_A = 70°C$ POWER RATING	$T_A = 105°C$ POWER RATING	$T_A = 125°C$ POWER RATING
D	725 mW	5.8 mW/°C	464 mW	261 mW	145 mW
LP	775 mW	6.2 mW/°C	496 mW	279 mW	155 mW

recommended operating conditions

	C SUFFIX		Q SUFFIX		UNIT
	MIN	MAX	MIN	MAX	
cathode voltage, V_{KA}	$V_{I(ref)}$	36	$V_{I(ref)}$	36	V
cathode current, I_{KA}	1	100	1	100	mA
Operating free-air temperature, T_A	0	70	–40	125	°C

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

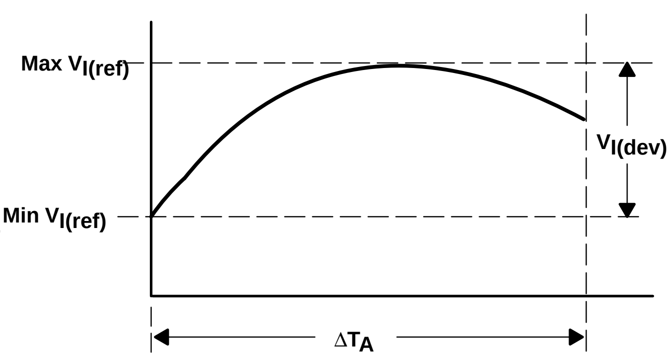
PARAMETER		TEST CONDITIONS	T_A†	TEST CIRCUIT	TL1431C			TL1431Q			UNIT
					MIN	TYP	MAX	MIN	TYP	MAX	
$V_{I(ref)}$	Reference input voltage	$V_{KA} = V_{I(ref)}$	25°C	1	2490	2500	2510	2490	2500	2510	mV
			Full range		2480		2520	2470		2530	
$V_{I(dev)}$	Deviation of reference input voltage over full temperature range‡	$V_{KA} = V_{I(ref)}$	Full range	1		4	20		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	2		–1.1	–2		–1.1	–2	mV/V
$I_{I(ref)}$	Reference input current	R1 = 10 kΩ, R2 = ∞	25°C	2		1.5	2.5		1.5	2.5	µA
			Full range				3			3	
$I_{I(dev)}$	Deviation of reference input current over full temperature range‡	R1 = 10 kΩ, R2 = ∞	Full range	2		0.2	1.2		0.5	1.2	µA
	Minimum cathode current for regulation	$V_{KA} = V_{I(ref)}$ to 36 V	25°C	1		0.45	1		0.45	1	mA
I_{off}	Off-state cathode current	V_{KA} = 36 V, $V_{I(ref)}$ = 0	25°C	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	1		0.1	0.2		0.1	0.2	Ω

† Full range is 0°C to 70°C for C-suffix devices and –40°C to 125°C for Q-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 $\alpha_{VI(ref)}$ is defined as:

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

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



α_{Vref} 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:

$|z'| = \frac{\Delta V}{\Delta I}$, 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	$V_{KA} = V_{I(ref)}$	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	2		–1.1	–2	mV/V
$I_{I(ref)}$	Reference input current	R1 = 10 kΩ, R2 = ∞	2		1.44	2.5	µA
$I_{KA}min$	Minimum cathode current for regulation	$V_{KA} = V_{I(ref)}$ to 36 V	1		0.45	1	mA
I_{off}	Off-state cathode current	V_{KA} = 36 V, V_{ref} = 0	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	1		0.1	0.2	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

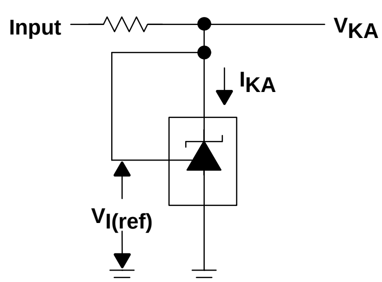


Figure 1. Test Circuit for $V_{(KA)} = V_{ref}$

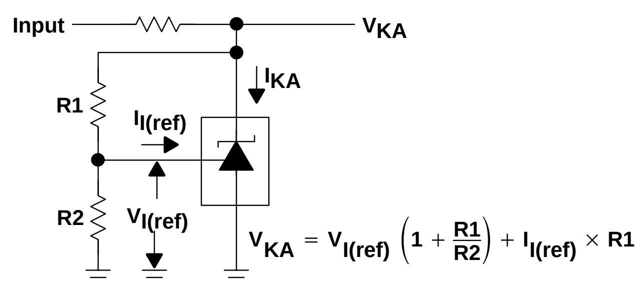


Figure 2. Test Circuit for $V_{(KA)} > V_{ref}$

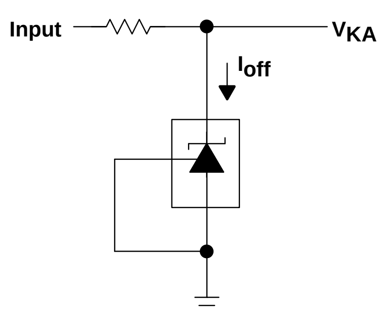


Figure 3. Test Circuit for I_{off}

TYPICAL CHARACTERISTICS

Table of Graphs

			FIGURE
$V_{I(ref)}$	Reference voltage	vs Free-air temperature	4
$I_{I(ref)}$	Reference current	vs Free-air temperature	5
I_{KA}	Cathode current	vs Cathode voltage	6, 7
$I_{KA(off)}$	Off-state cathode current	vs Free-air temperature	8
$\Delta V_{I(ref)}$	Ratio of delta reference voltage to delta cathode voltage	vs Free-air temperature	9
V_n	Equivalent input noise voltage	vs Frequency	10
		Over a 10-second time period	11
A_V	Small-signal voltage amplification	vs Frequency	12
$\|z_{KA}\|$	Reference impedance	vs Frequency	13
	Pulse response		14
	Stability boundary conditions		15

TYPICAL CHARACTERISTICS†

REFERENCE VOLTAGE vs FREE-AIR TEMPERATURE

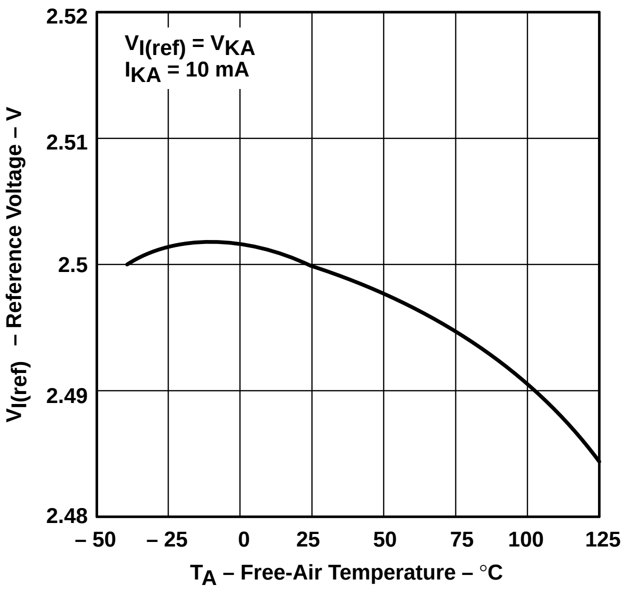


Figure 4

REFERENCE CURRENT vs FREE-AIR TEMPERATURE

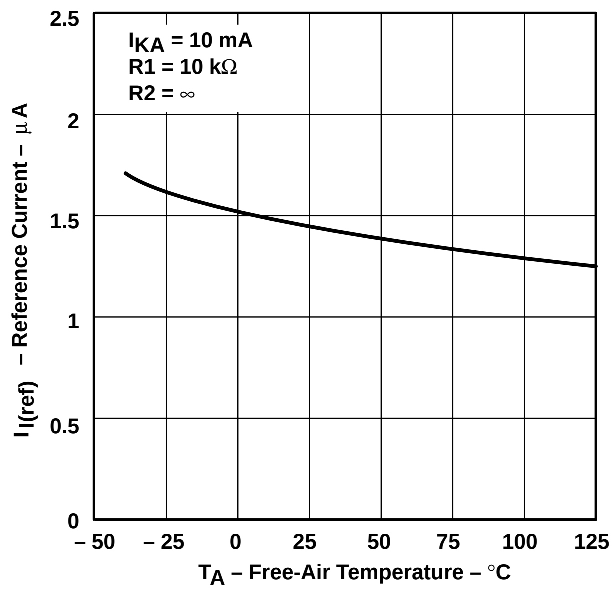


Figure 5

CATHODE CURRENT vs CATHODE VOLTAGE

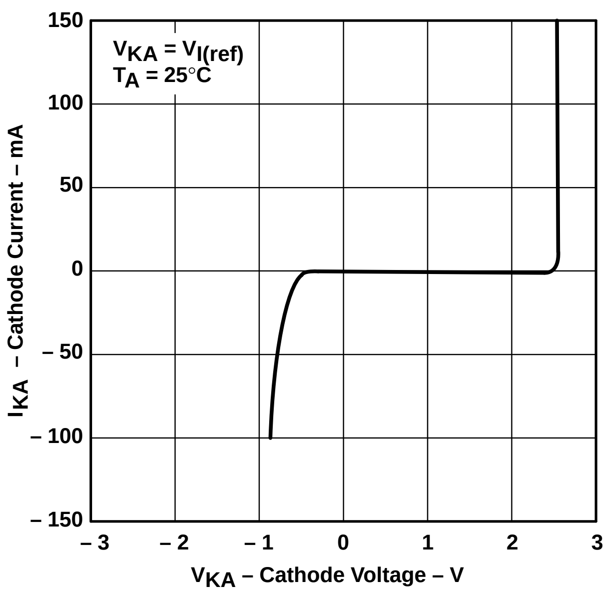


Figure 6

CATHODE CURRENT vs CATHODE VOLTAGE

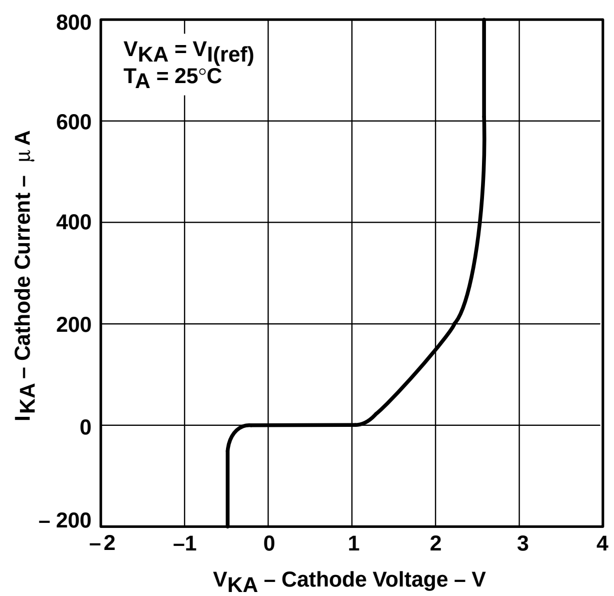


Figure 7

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

TYPICAL CHARACTERISTICS†

OFF-STATE CATHODE CURRENT vs FREE-AIR TEMPERATURE

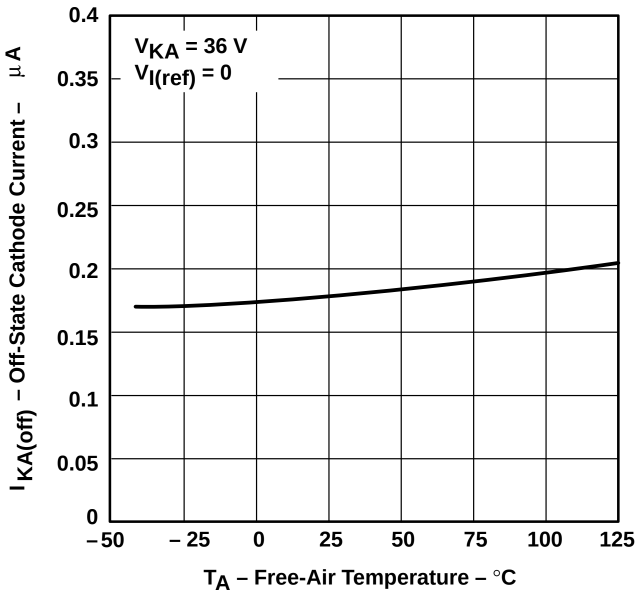


Figure 8

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

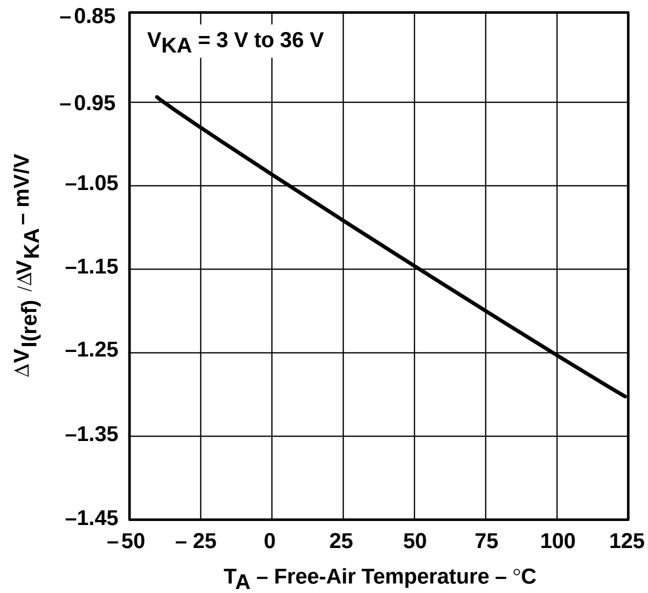


Figure 9

EQUIVALENT INPUT NOISE VOLTAGE vs FREQUENCY

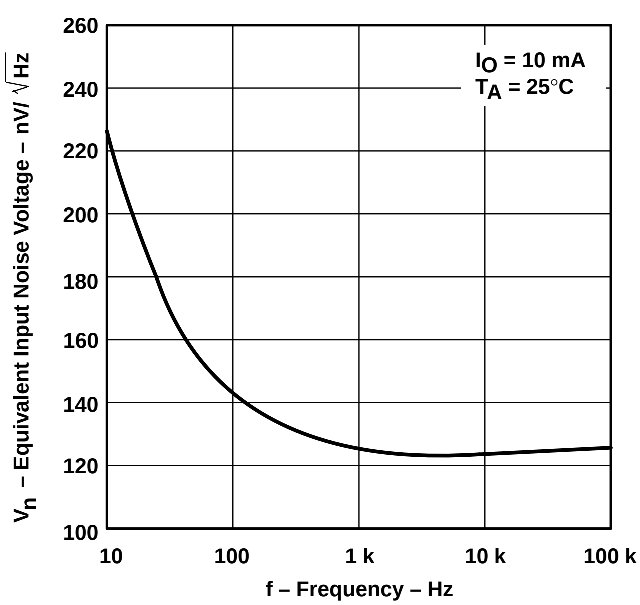
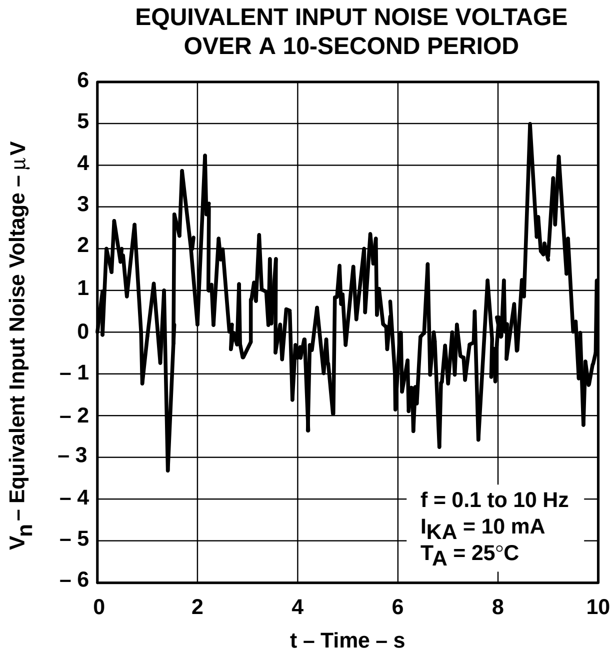
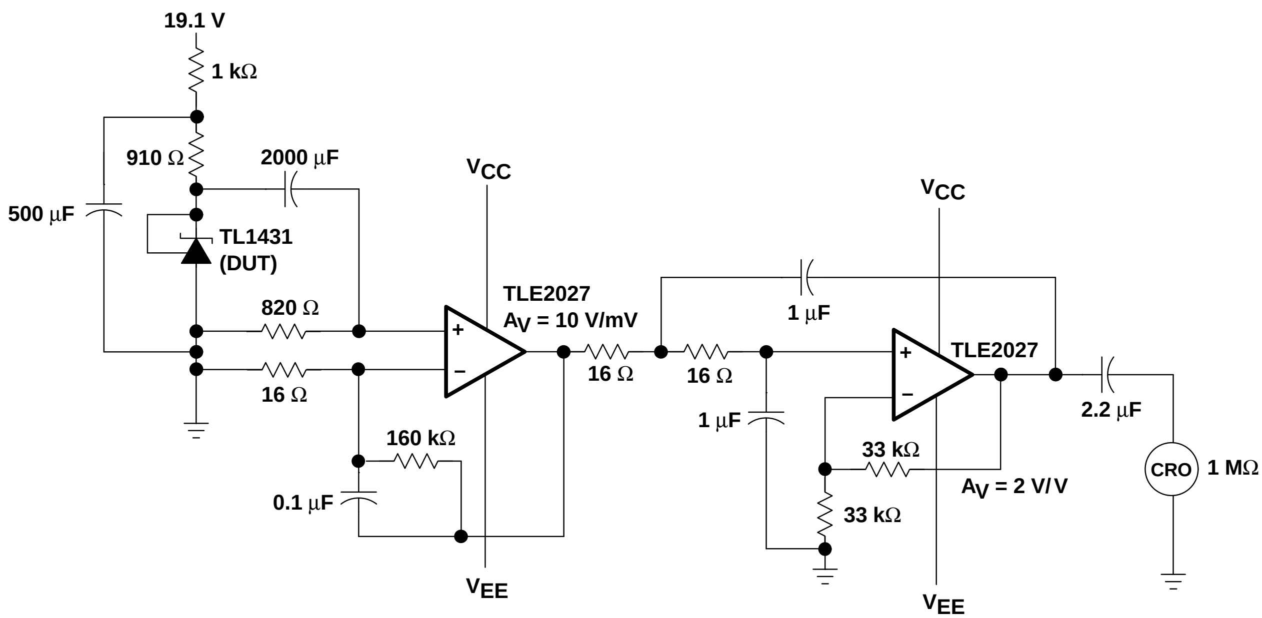


Figure 10

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

TYPICAL CHARACTERISTICS

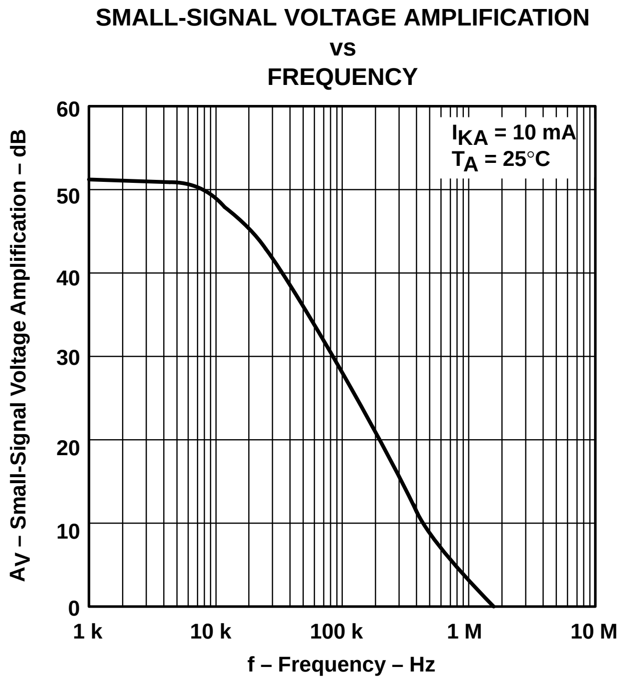


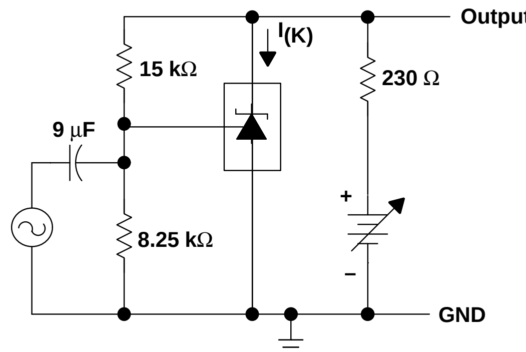


TEST CIRCUIT FOR 0.1-Hz TO 10-Hz EQUIVALENT INPUT NOISE VOLTAGE

Figure 11

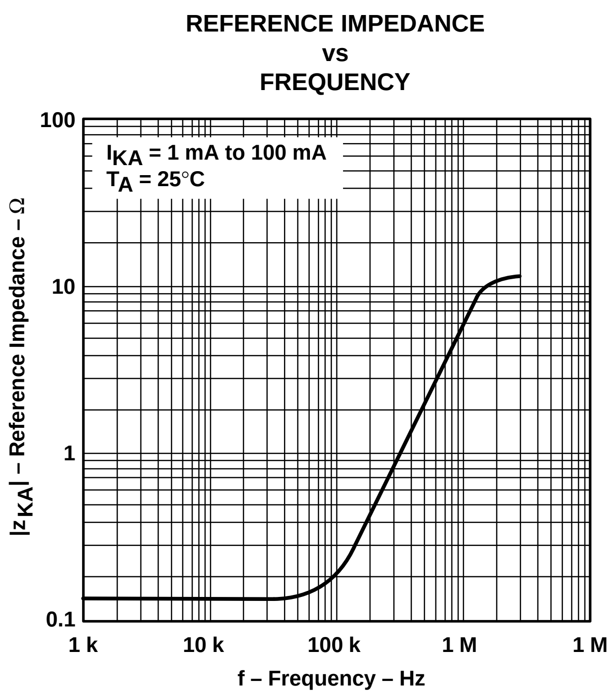
TYPICAL CHARACTERISTICS

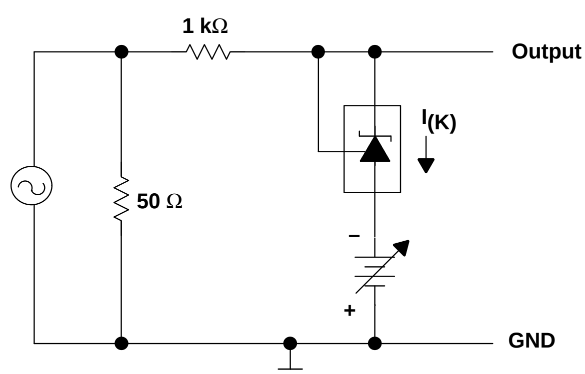




TEST CIRCUIT FOR VOLTAGE AMPLIFICATION

Figure 12



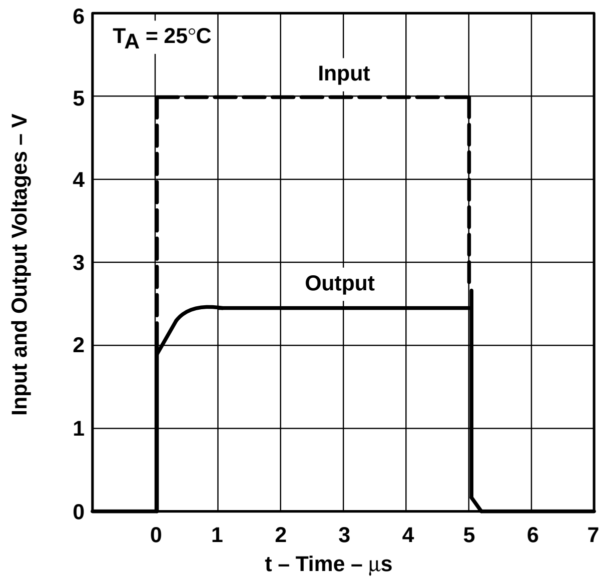


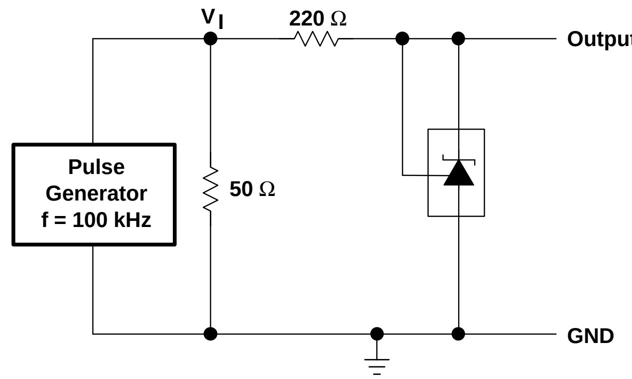
TEST CIRCUIT FOR REFERENCE IMPEDANCE

Figure 13

TYPICAL CHARACTERISTICS

PULSE RESPONSE

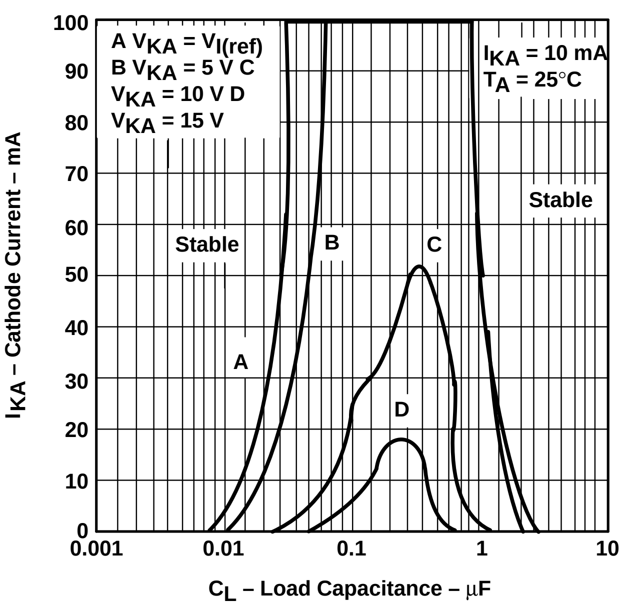




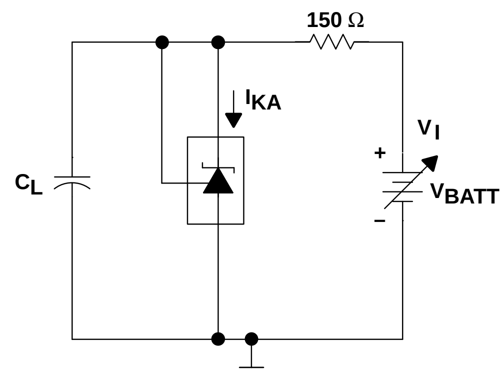
TEST CIRCUIT FOR PULSE RESPONSE

Figure 14

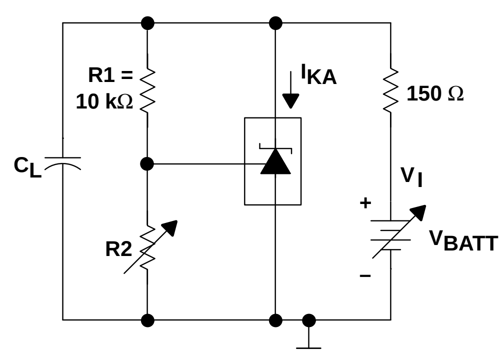
STABILITY BOUNDARY CONDITIONS†



† 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



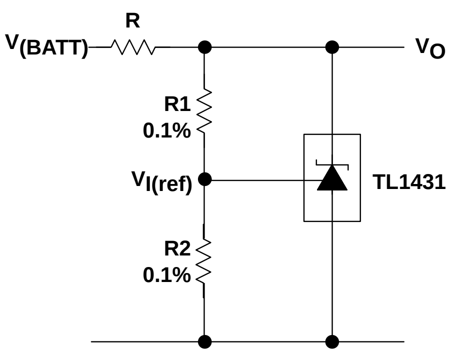
TEST CIRCUIT FOR CURVES B, C, AND D

Figure 15

APPLICATION INFORMATION

Table of Application Circuits

APPLICATION	FIGURE
Shunt regulator	16
Single-supply comparator with temperature-compensated threshold	17
Precision high-current series regulator	18
Output control of a 3-terminal fixed regulator	19
Higher-current shunt regulator	20
Crowbar	21
Precision 5-V, 1.5-A, 0.5% regulator	22
Efficient 5-V precision regulator	23
PWM down converter with 0.5% reference	24
Voltage monitor	25
Delay timer	26
Precision current limiter	27
Precision constant-current sink	28



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

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

Figure 16. Shunt Regulator

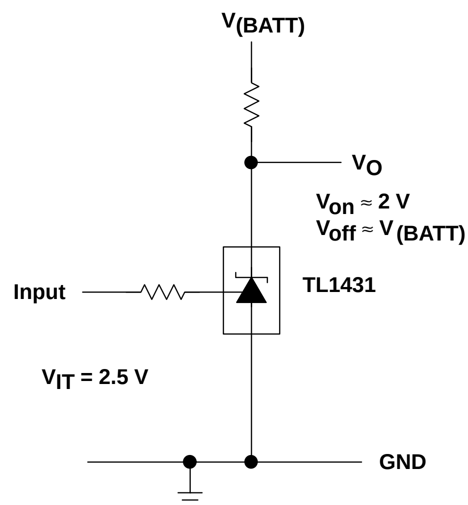
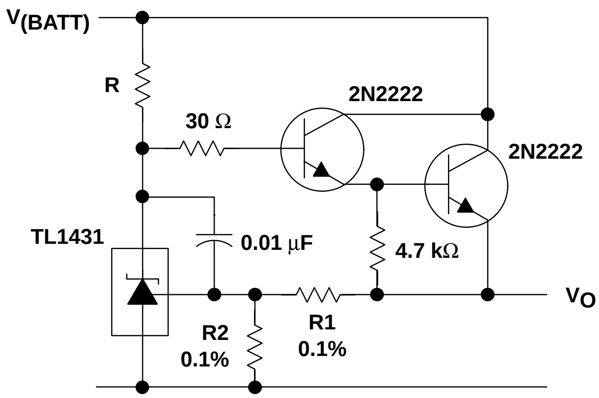


Figure 17. Single-Supply Comparator With Temperature-Compensated Threshold

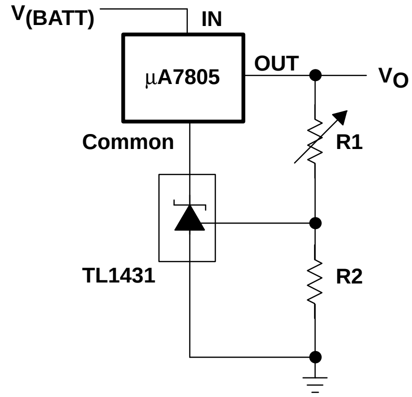
APPLICATION INFORMATION



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

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

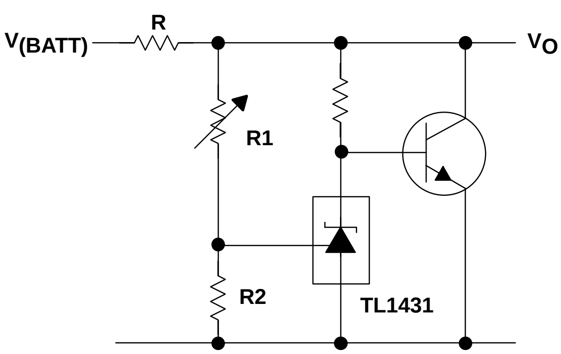
Figure 18. Precision High-Current Series Regulator



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

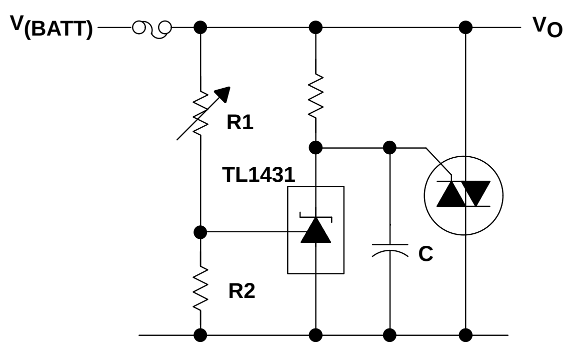
Min $V = V_{I(ref)} + 5$ V

Figure 19. Output Control of a 3-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 on Figure 15 to determine allowable values for the capacitor.

Figure 21. Crowbar

APPLICATION INFORMATION

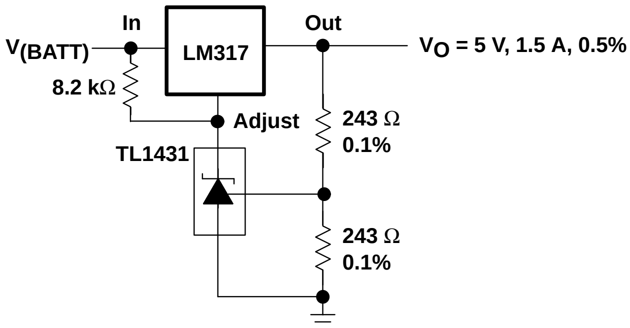
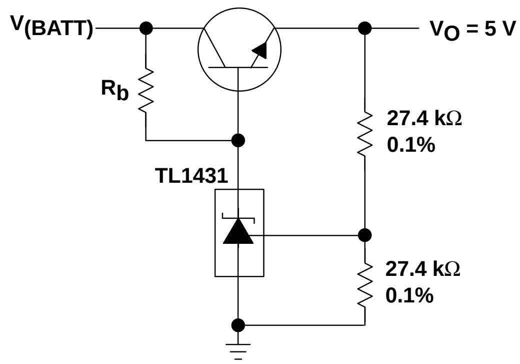


Figure 22. Precision 5-V, 1.5-A, 0.5% Regulator



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

Figure 23. 5-V Precision Regulator

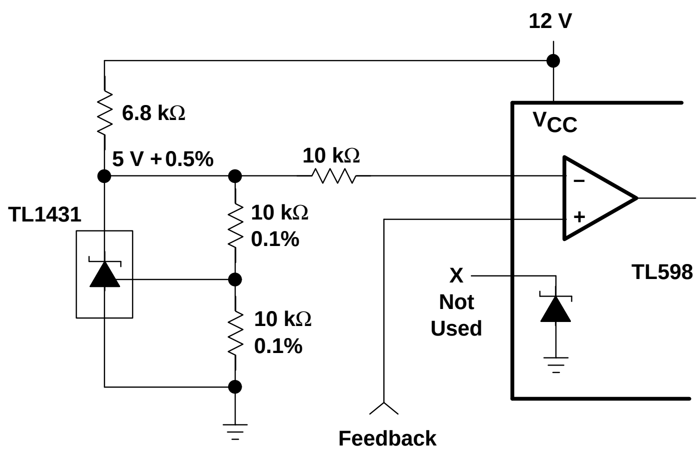
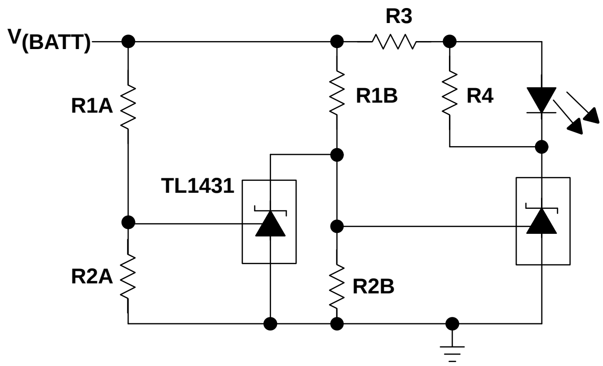


Figure 24. PWM Converter With 0.5% Reference

APPLICATION INFORMATION



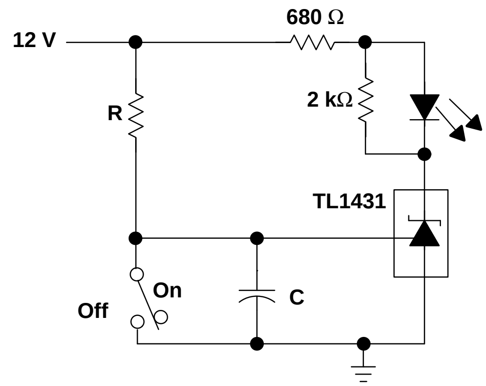
$$\text{Low Limit} = \left(1 + \frac{R1B}{R2B}\right) V_{I(ref)}$$

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

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

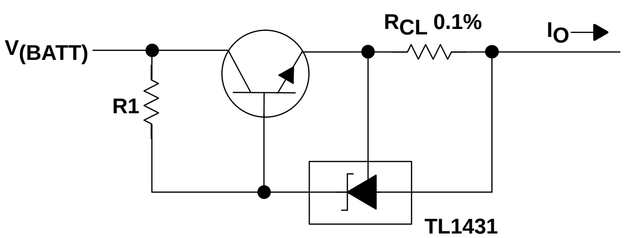
NOTE A: R3 & R4 are selected to provide the desired LED intensity and cathode current ≥ 1 mA to the TL1431.

Figure 25. Voltage Monitor



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

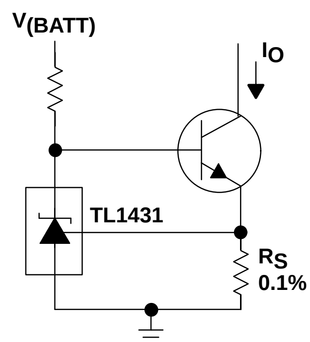
Figure 26. Delay Timer



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

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

Figure 27. Precision Current Limiter



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

Figure 28. Precision Constant-Current Sink