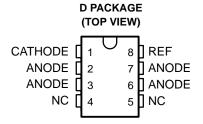
- 0.4% Initial Voltage Tolerance
- 0.1-Ω Typical Output Impedance
- Fast Turn On . . . 500 ns
- Sink Current Capability . . . 1 mA to 100 mA
- Low REF Current
- Adjustable Output Voltage . . . V<sub>ref</sub> to 36 V
- Available In Two High-Density Packaging Options:
  - Small Outline (D)
  - TO-226AA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

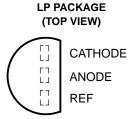
## description

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  $\Omega$ . 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.

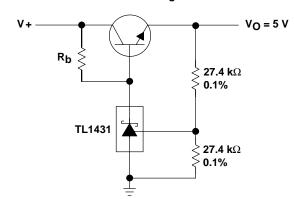


NC – No internal connection ANODE terminals are internally connected.



## application schematic

#### 5-V Precision Regulator



NOTE A:  $R_b$  should provide cathode current  $\geq$  1-mA to the

#### **AVAILABLE OPTIONS**

PA	CHIP FORM		
TA	SMALL OUTLINE (D)	TO-226AA (LP)	(Y)
0°C to 70°C	TL1431CD	TL1431CLP	TL1431Y
-40°C to 125°C	TL1431QD	TL1431QLP	1614311

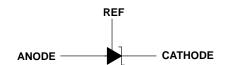
The D and LP packages are available taped and reeled. Add R suffix to device type (e.g., TL1431CDR). Chip forms are tested at 25°C.

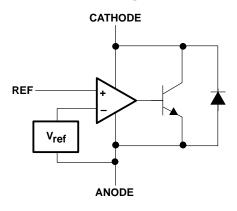


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### symbol

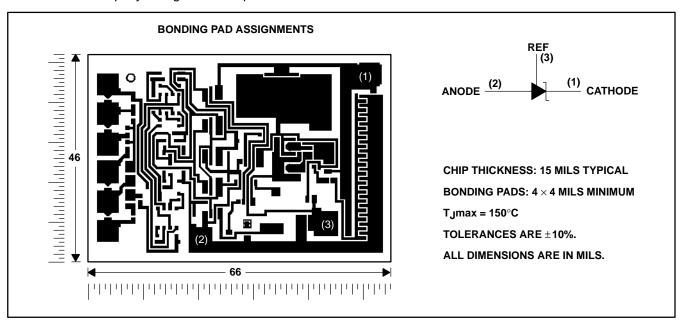
## functional block diagram



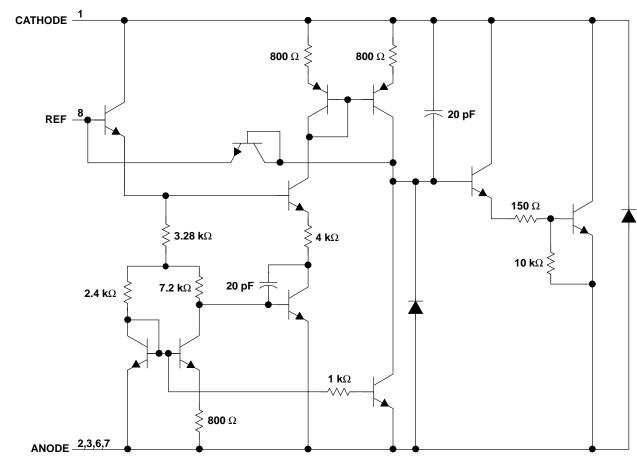


## **TL1431Y chip information**

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.



# equivalent schematic



NOTE A: All component values are nominal.

# TL1431C, TL1431Q, TL1431Y PRECISION PROGRAMMABLE REFERENCES

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

cathode voltage, V <sub>KA</sub> (see Note 1)	37 V
Continuous cathode current range, I <sub>KA</sub>	
Reference input current range, I <sub>I(REF)</sub>	
Continuous total power dissipation	See Dissipation Rating Table
Operating free-air temperature range, T <sub>A</sub> : C suffix	0°C to 70°C
Q suffix	40°C to 125°C
Storage temperature range, T <sub>Stq</sub>	–65°C to 150°C
Lead temperature 1.6 mm (1/16 inch) from case for 10 seconds	260°C

<sup>†</sup> 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.

#### **DISSIPATION RATING TABLE**

PACKAGE	T <sub>A</sub> ≤ 25°C POWER RATING	DERATING FACTOR ABOVE T <sub>A</sub> = 25°C	T <sub>A</sub> = 70°C POWER RATING	T <sub>A</sub> = 105°C POWER RATING	T <sub>A</sub> = 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	UNIT
cathode voltage, V <sub>KA</sub>	V <sub>I(ref)</sub>	36	V <sub>I(ref)</sub>	36	V
cathode current, IKA	1	100	1	100	mA
Operating free-air temperature, T <sub>A</sub>	0	70	-40	125	°C

NOTE 1: All voltage values are with respect to ANODE unless otherwise noted.

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

PARAMETER		TEST CONDITIONS	<b>T.</b> †	TEST	Т	L14310	;	Т	L14310	)	UNIT
	PARAMETER	1EST CONDITIONS	T <sub>A</sub> †	CIRCUIT	MIN	TYP	MAX	MIN	TYP	MAX	UNIT
			25°C		2490	2500	2510	2490	2500	2510	
V <sub>I(ref)</sub>	Reference input voltage	$V_{KA} = V_{I(ref)}$	Full range	1	2480		2520	2470		2530	mV
V <sub>I(dev)</sub>	Deviation of reference input voltage over full temperature range‡	V <sub>K</sub> A = V <sub>I</sub> (ref)	Full range	1		4	20		17	55	mV
ΔV <sub>I(ref)</sub> ΔVKA	Ratio of change in reference input voltage to the change in cathode voltage	$\Delta V_{KA} = 3 \text{ V to } 36 \text{ V}$	Full range	2		-1.1	-2		-1.1	-2	mV/V
			25°C			1.5	2.5		1.5	2.5	
II(ref)	Reference input current	R1 = 10 k $\Omega$ , R2 = $\infty$	Full range	2			3			3	μΑ
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	μА
	Minimum cathode current for regulation	$V_{KA} = V_{I(ref)}$ to 36 V	25°C	1		0.45	1		0.45	1	mA
	Off-state cathode		25°C			0.18	0.5		0.18	0.5	
l <sub>off</sub>	current	$V_{KA} = 36 \text{ V},  V_{I(ref)} = 0$	Full range	3			2			2	μΑ
Izkal	Output impedance§	$V_{KA} = V_{I(ref)}$ , $f \le 1$ kHz, $I_{KA} = 1$ mA to 100 mA	25°C	1		0.1	0.2		0.1	0.2	Ω

$$\left|\alpha_{\text{VI(ref)}}\right| \left(\frac{\text{ppm}}{^{\circ}\text{C}}\right) = \frac{\left(\frac{\text{V}_{\text{I(dev)}}}{\text{V}_{\text{I(ref)}} \text{ at } 25^{\circ}\text{C}}\right) \times 10^{6}}{\Delta \text{T}_{\text{A}}} \qquad \qquad \text{Max V}_{\text{I(ref)}} = \frac{1}{2} \left(\frac{\text{Max V}_{\text{I(ref)}}}{\text{Max V}_{\text{I(ref)}}}\right) = \frac{1}{2} \left(\frac{\text{Max V}_{\text{I(ref)}}}{\text{Max V}_{\text{I(ref)}}}\right) \times 10^{6}}{\Delta \text{T}_{\text{A}}}$$

where  $\Delta T_{\mbox{\scriptsize A}}$  is the rated operating temperature range of the device. Min VI(ref)



 $\alpha_{Vref}$  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:  $|z_{KA}| = \frac{\Delta V_{KA}}{\Delta I_{KA}}$ .

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  $|z_{KA}| \left(1 + \frac{R1}{R2}\right)$ .

<sup>†</sup> 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<sub>I(dev)</sub> and I<sub>I(dev)</sub> 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:

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

PARAMETER		TEST CONDITIONS	TEST	TL1431Y			UNIT	
	PARAMETER	TEST CONDITIONS	CIRCUIT	MIN	TYP	MAX	L	
V <sub>I(ref)</sub>	Reference input voltage	V <sub>KA</sub> = V <sub>I(ref)</sub>	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	$\Delta V_{KA} = 3 \text{ V to } 36 \text{ V}$	2		-1.1	-2	mV/V	
I <sub>I(ref)</sub>	Reference input current	R1 = 10 k $\Omega$ , R2 = $\infty$	2		1.44	2.5	μΑ	
IKAmin	Minimum cathode current for regulation	$V_{KA} = V_{I(ref)}$ to 36 V	1		0.45	1	mA	
I <sub>off</sub>	Off-state cathode current	$V_{KA} = 36 \text{ V},  V_{ref} = 0$	3		0.18	0.5	μΑ	
z <sub>K</sub> A	Output impedance†	$V_{KA} = V_{I(ref)}$ , $f \le 1 \text{ kHz}$ , $I_{KA} = 1 \text{ mA to } 100 \text{ mA}$	1		0.1	0.2	Ω	

<sup>†</sup> The output impedance is defined as:  $|z'| = \frac{\Delta V}{\Delta l}$ 

When the device is operating with two external resistors (see Figure 2), the total dynamic impedance of the circuit is given by

$$\left|z_{KA}\right| = \frac{\Delta V_{KA}}{\Delta I_{KA}} \ \, , \text{which is approximately equal to} \ \, \left|z_{KA}\right| \left(1 \, + \frac{R1}{R2}\right) \, .$$

#### PARAMETER MEASUREMENT INFORMATION

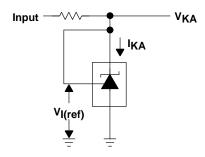


Figure 1. Test Circuit for  $V_{(KA)} = V_{ref}$ 

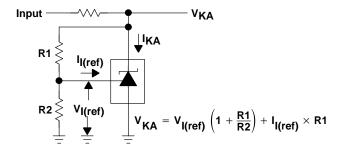


Figure 2. Test Circuit for  $V_{(KA)} > V_{ref}$ 

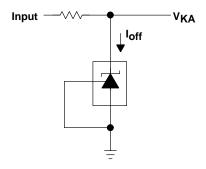


Figure 3. Test Circuit for Ioff

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## **TYPICAL CHARACTERISTICS**

# **Table of Graphs**

			FIGURE
V <sub>I(ref)</sub>	Reference voltage	vs Free-air temperature	4
I <sub>I(ref)</sub>	Reference current	vs Free-air temperature	5
IKA	Cathode current	vs Cathode voltage	6, 7
I <sub>KA(off)</sub>	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	Faulty plant input poins yelfogs	vs Frequency	10
V <sub>n</sub>	Equivalent input noise voltage	Over a 10-second time period	11
Ay	Small-signal voltage amplification	vs Frequency	12
z <sub>KA</sub>	Reference impedance	vs Frequency	13
	Pulse response		14
	Stability boundary conditions		15

#### TYPICAL CHARACTERISTICS<sup>†</sup>

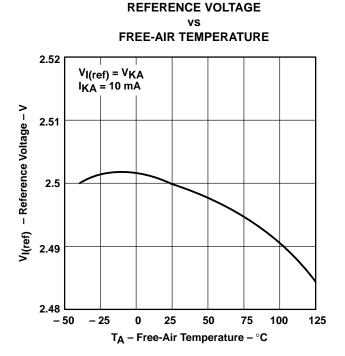
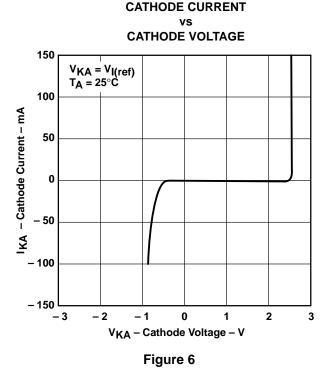


Figure 4



REFERENCE CURRENT vs FREE-AIR TEMPERATURE

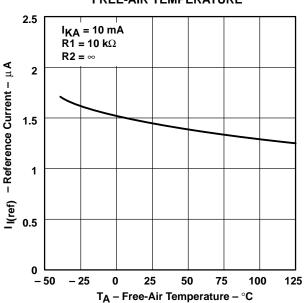


Figure 5

# **CATHODE CURRENT CATHODE VOLTAGE**

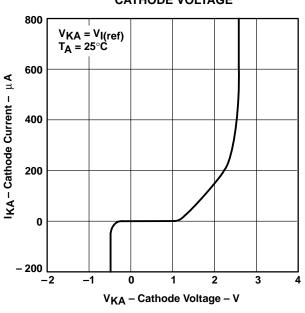


Figure 7

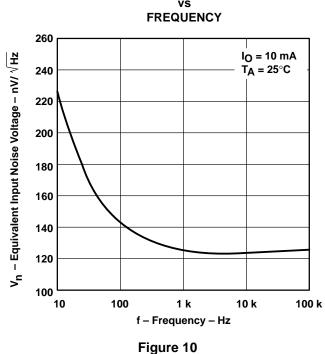
<sup>†</sup> Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.



#### TYPICAL CHARACTERISTICS<sup>†</sup>

#### **RATIO OF DELTA REFERENCE VOLTAGE TO OFF-STATE CATHODE CURRENT DELTA CATHODE VOLTAGE** FREE-AIR TEMPERATURE FREE-AIR TEMPERATURE 0.4 -0.85 V<sub>KA</sub> = 36 V V<sub>KA</sub> = 3 V to 36 V IKA(off) − Off-State Cathode Current − μA $V_{I(ref)} = 0$ 0.35 -0.95 0.3 ∆VI(ref) /∆VKA - mV/V -1.05 0.25 0.2 -1.15 0.15 -1.25 0.1 -1.350.05 0 -1.4525 50 75 100 -50 - 25 0 125 -50 - 25 25 50 75 100 125 T<sub>A</sub> - Free-Air Temperature - °C T<sub>A</sub> - Free-Air Temperature - °C Figure 8 Figure 9

# **EQUIVALENT INPUT NOISE VOLTAGE**

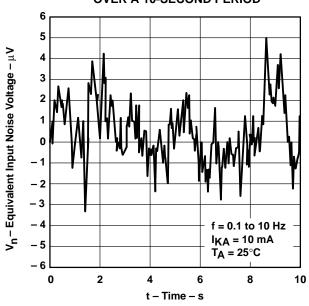


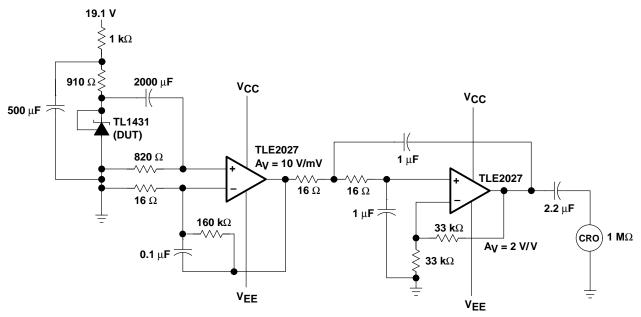
† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.



#### **TYPICAL CHARACTERISTICS**

#### **EQUIVALENT INPUT NOISE VOLTAGE OVER A 10-SECOND PERIOD**



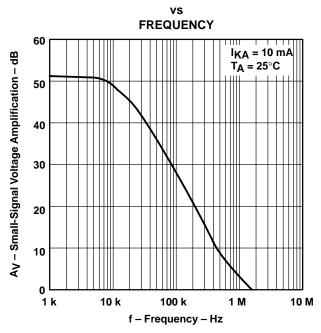


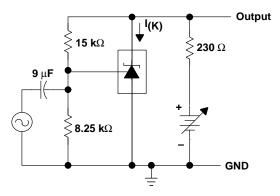
TEST CIRCUIT FOR 0.1-Hz TO 10-Hz EQUIVALENT INPUT NOISE VOLTAGE

Figure 11

#### TYPICAL CHARACTERISTICS

#### **SMALL-SIGNAL VOLTAGE AMPLIFICATION**



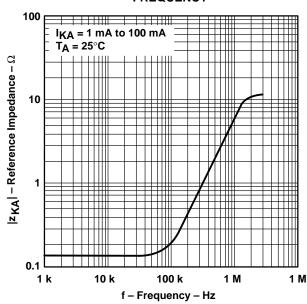


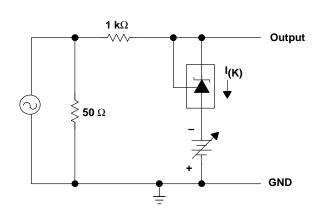
TEST CIRCUIT FOR VOLTAGE AMPLIFICATION

Figure 12

## REFERENCE IMPEDANCE

FREQUENCY



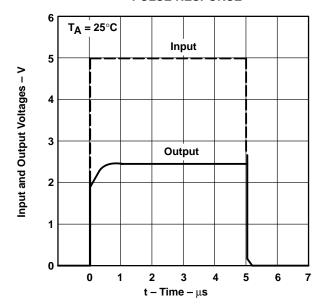


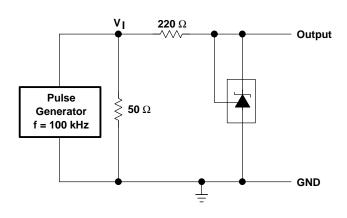
**TEST CIRCUIT FOR REFERENCE IMPEDANCE** 

Figure 13

#### TYPICAL CHARACTERISTICS

#### **PULSE RESPONSE**

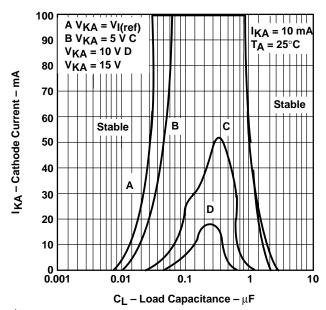




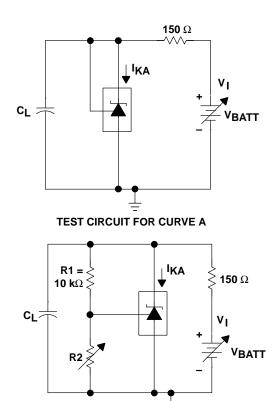
**TEST CIRCUIT FOR PULSE RESPONSE** 

Figure 14

#### STABILITY BOUNDARY CONDITIONS†



<sup>†</sup> 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  $C_L = 0$ .  $V_{BATT} \, \text{and} \, C_L \, \text{are then adjusted to determine the ranges of stability}.$ 

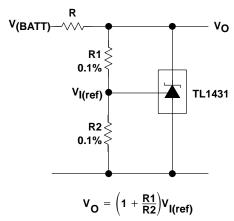


TEST CIRCUIT FOR CURVES B, C, AND D

Figure 15

## **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



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

Figure 16. Shunt Regulator

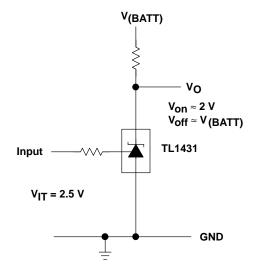
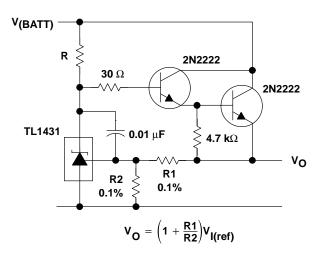


Figure 17. Single-Supply Comparator With Temperature-Compensated Threshold



NOTE A: R should provide cathode current  $\geq$  1-mA to the TL1431 at minimum V(BATT).

Figure 18. Precision High-Current **Series Regulator** 

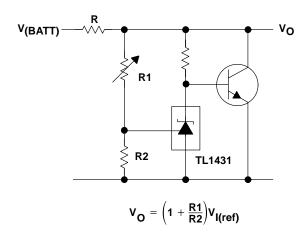


Figure 20. Higher-Current Shunt Regulator

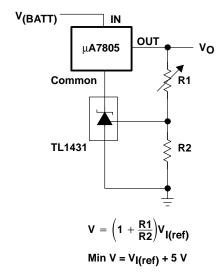
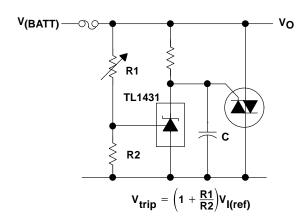


Figure 19. Output Control of a 3-Terminal **Fixed Regulator** 



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

Figure 21. Crowbar

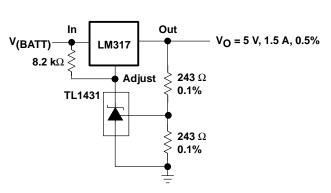
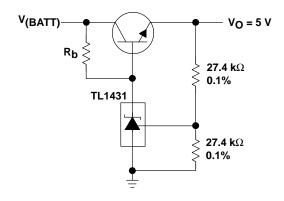


Figure 22. Precision 5-V, 1.5-A, 0.5% Regulator



NOTE A: R<sub>b</sub> should provide cathode current ≥ 1-mA to the TL1431.

Figure 23. 5-V Precision Regulator

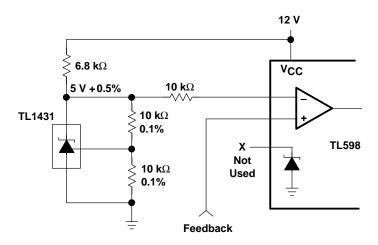
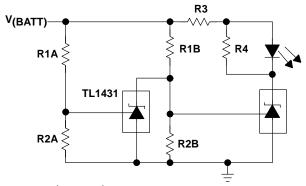


Figure 24. PWM Converter With 0.5% Reference



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

Figure 25. Voltage Monitor

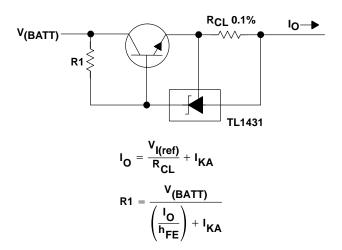


Figure 27. Precision Current Limiter

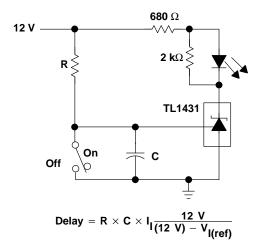


Figure 26. Delay Timer

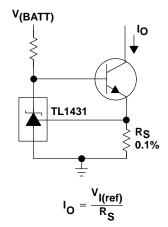


Figure 28. Precision Constant-Current Sink

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