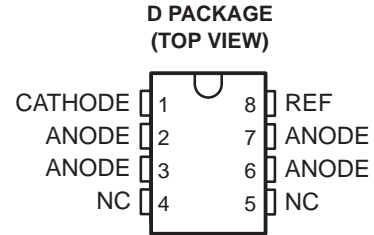


- **0.4% Initial Voltage Tolerance**
- **0.2-Ω Typical Output Impedance**
- **Fast Turnon . . . 500 ns**
- **Sink Current Capability . . . 1 mA to 100 mA**
- **Low Reference Current (REF)**
- **Adjustable Output Voltage . . .  $V_{I(ref)}$  to 36 V**

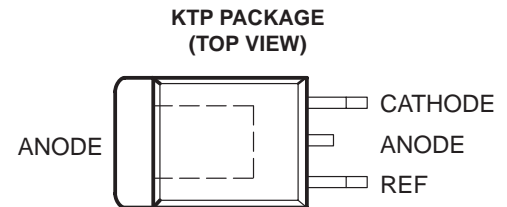
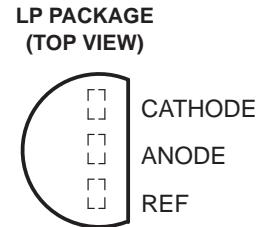
## description

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.

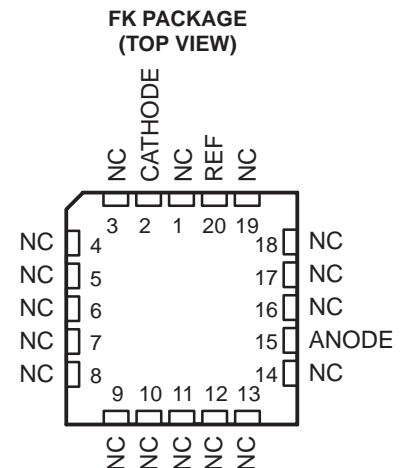
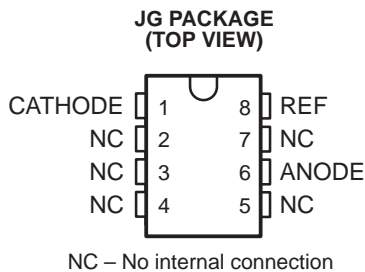
The TL1431C is characterized for operation over the commercial temperature range of 0°C to 70°C. The TL1431Q is characterized for operation over the full automotive temperature range of -40°C to 125°C. The TL1431M is characterized for operation over the full military temperature range of -55°C to 125°C.



NC – No internal connection  
ANODE terminals are connected internally.



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



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.

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  
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# TL1431 PRECISION PROGRAMMABLE REFERENCE

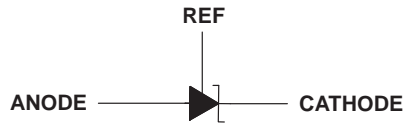
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## AVAILABLE OPTIONS

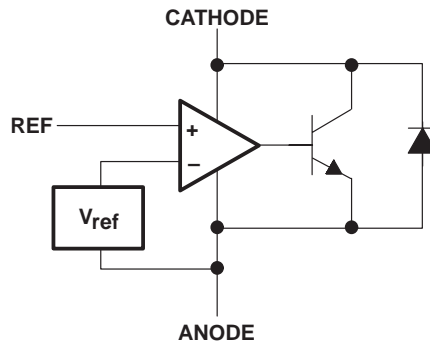
T <sub>A</sub>	PACKAGED DEVICES					CHIP FORM (Y)
	SMALL OUTLINE (D)	PLASTIC FLANGE MOUNTED (KTP)	TO-226AA (LP)	CHIP CARRIER (FK)	CERAMIC DIP (JG)	
0°C to 70°C	TL1431CD	TL1431CKTPR	TL1431CLP	–	–	TL1431Y
–40°C to 125°C	TL1431QD	–	TL1431QLP	–	–	
–55°C to 125°C	–	–	–	TL1431MFK	TL1431MJG	

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.

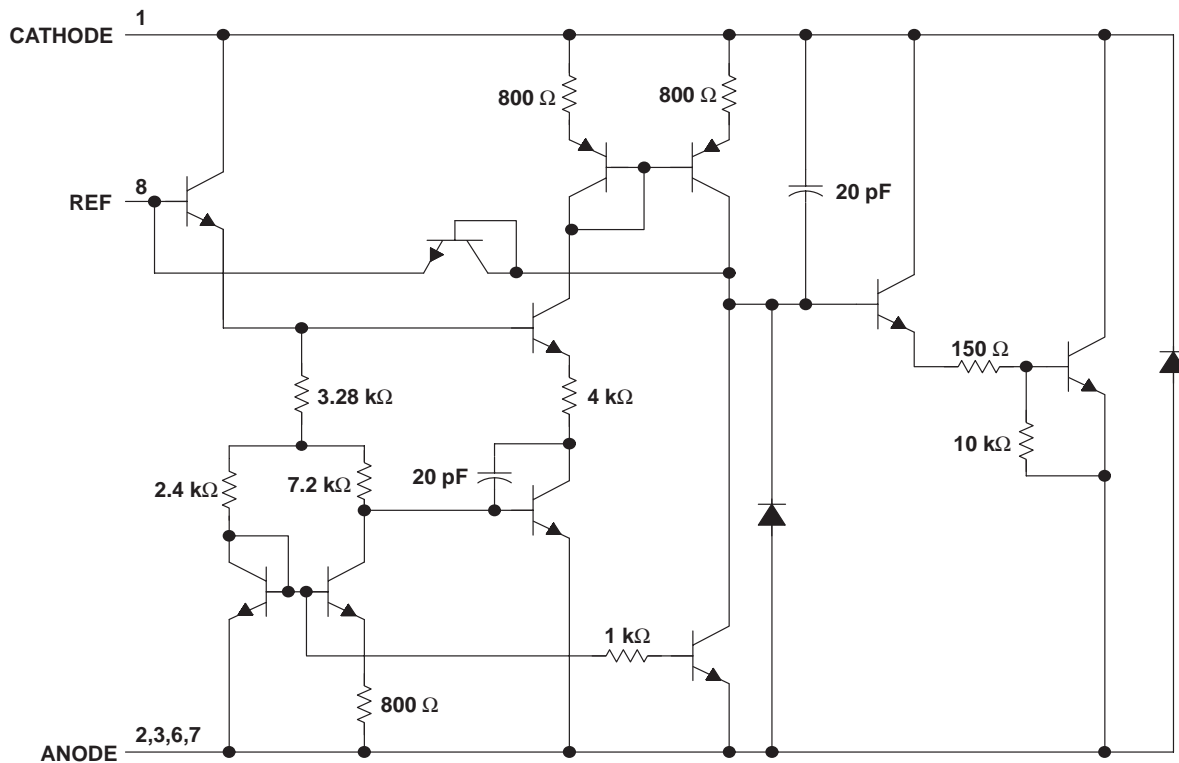
## logic symbol



## functional block diagram



equivalent schematic†



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

# TL1431 PRECISION PROGRAMMABLE REFERENCE

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## 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 $\mu$ A to 10 mA
Package thermal impedance, $\theta_{JA}$ (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:
- All voltage values are with respect to ANODE unless otherwise noted.
  - Maximum power dissipation is a function of  $T_J(max)$ ,  $\theta_{JA}$ , 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.
  - The package thermal impedance is calculated in accordance with JESD 51.

POWER DISSIPATION RATING TABLE – FREE-AIR TEMPERATURE

PACKAGE	$T_A = 25^\circ\text{C}$ POWER RATING	DERATING FACTOR ABOVE $T_A = 25^\circ\text{C}$	$T_A = 70^\circ\text{C}$ POWER RATING	$T_A = 85^\circ\text{C}$ POWER RATING	$T_A = 125^\circ\text{C}$ 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,  $I_{KA} = 10 \text{ mA}$  (unless otherwise noted)**

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

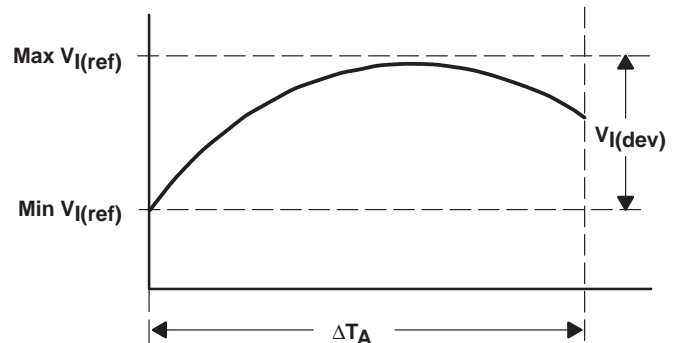
† Full range is 0°C to 70°C for C-suffix devices.

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

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

where:

$\Delta T_A$  is the rated operating temperature range of the device.



$\alpha_{V_{I(\text{ref})}}$  is positive or negative depending on whether minimum  $V_{I(\text{ref})}$  or maximum  $V_{I(\text{ref})}$ , 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  $|z_{KA}| \left( 1 + \frac{R1}{R2} \right)$ .

# TL1431 PRECISION PROGRAMMABLE REFERENCE

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

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

\*On products compliant to MIL-PRF-38535, this parameter is not production tested.

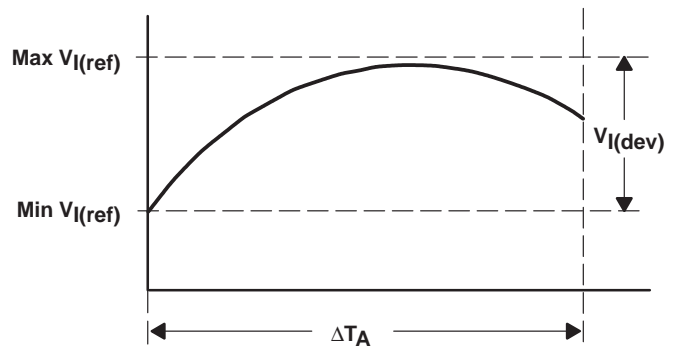
† Full range is  $-40^\circ\text{C}$  to  $125^\circ\text{C}$  for Q-suffix devices, and  $-55^\circ\text{C}$  to  $125^\circ\text{C}$  for M-suffix devices.

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

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

where:

$\Delta T_A$  is the rated operating temperature range of the device.



$\alpha_{V_{I(\text{ref})}}$  is positive or negative depending on whether minimum  $V_{I(\text{ref})}$  or maximum  $V_{I(\text{ref})}$ , 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  $|z_{KA}| \left( 1 + \frac{R1}{R2} \right)$ .

**electrical characteristics at  $I_{KA} = 10 \text{ mA}$ ,  $T_A = 25^\circ\text{C}$**

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

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

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

**PARAMETER MEASUREMENT INFORMATION**

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

where:  
 $\Delta T_A$  is the rated operating temperature range of the device.

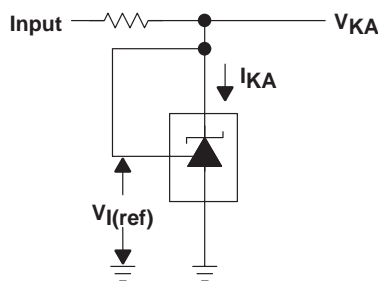
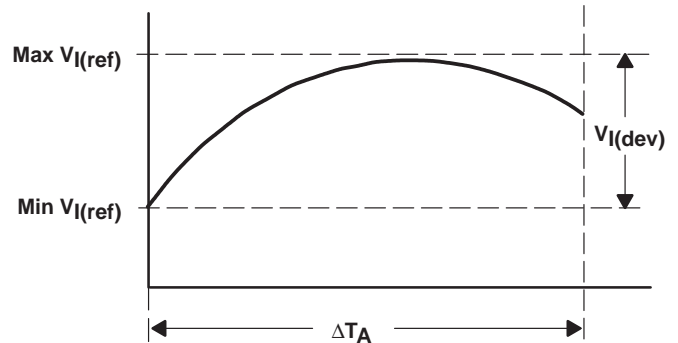


Figure 1. Test Circuit for  $V_{(KA)} = V_{\text{ref}}$

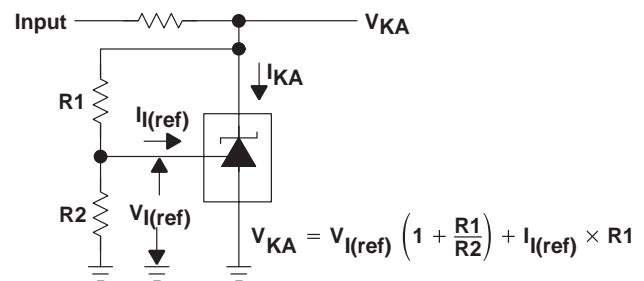
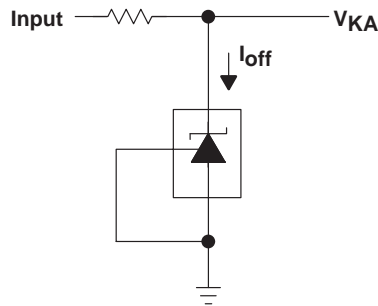


Figure 2. Test Circuit for  $V_{(KA)} > V_{\text{ref}}$

**PARAMETER MEASUREMENT INFORMATION**



**Figure 3. Test Circuit for  $I_{off}$**

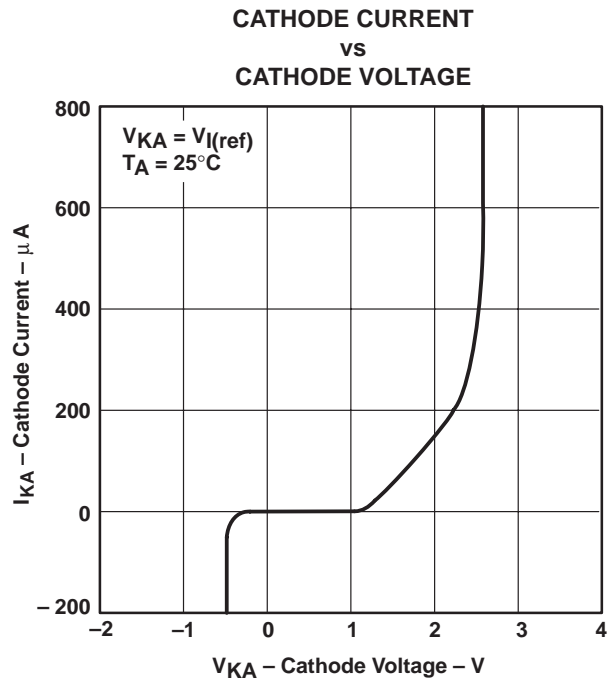
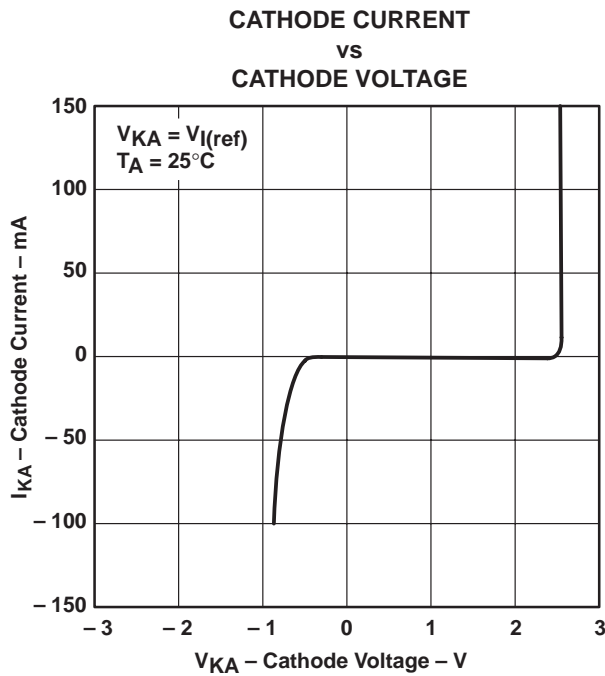
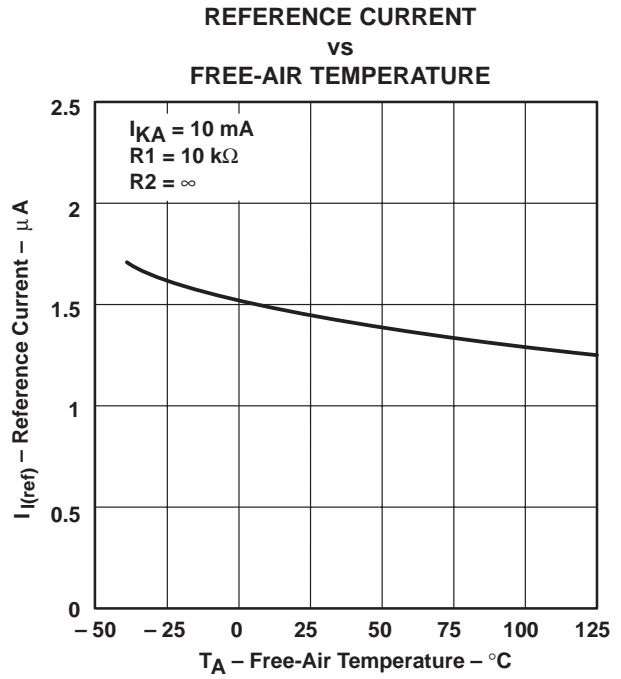
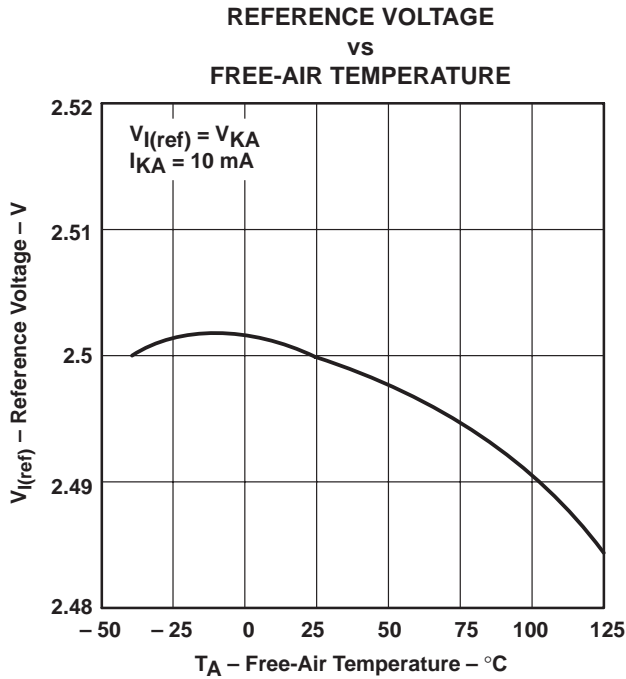
**TYPICAL CHARACTERISTICS**

**Table of Graphs**

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TYPICAL CHARACTERISTICS†



† 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†

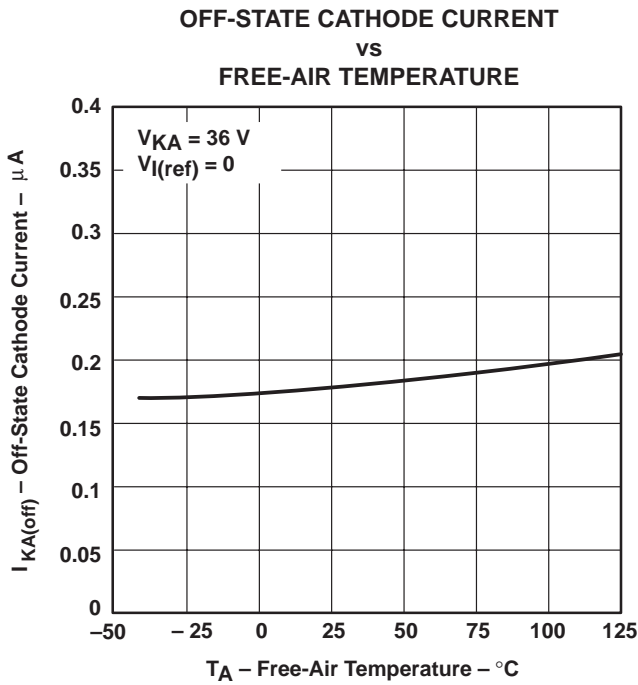


Figure 8

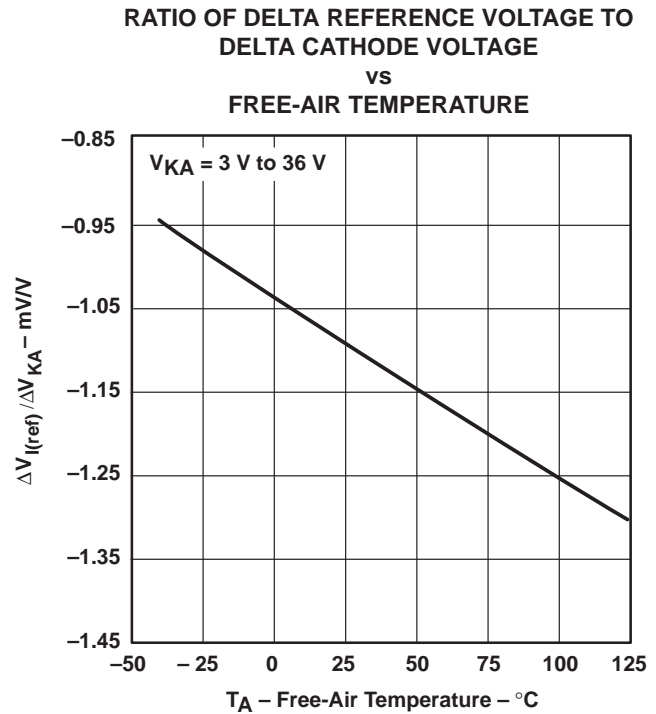


Figure 9

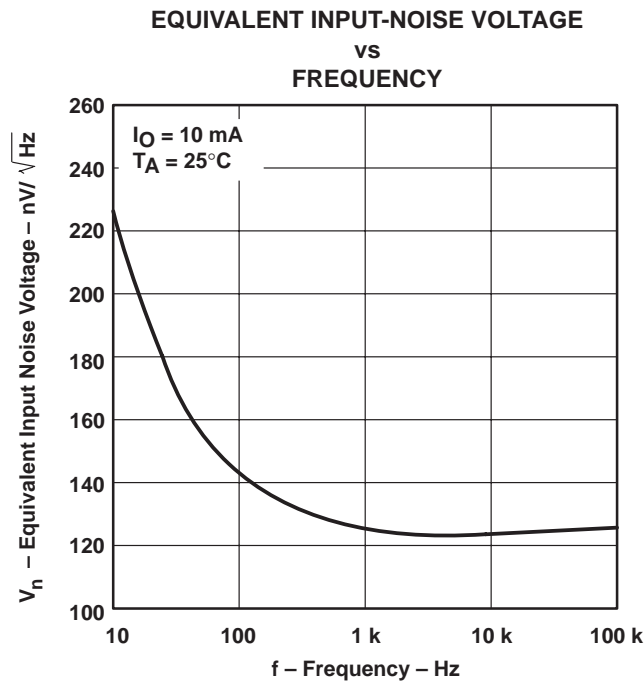


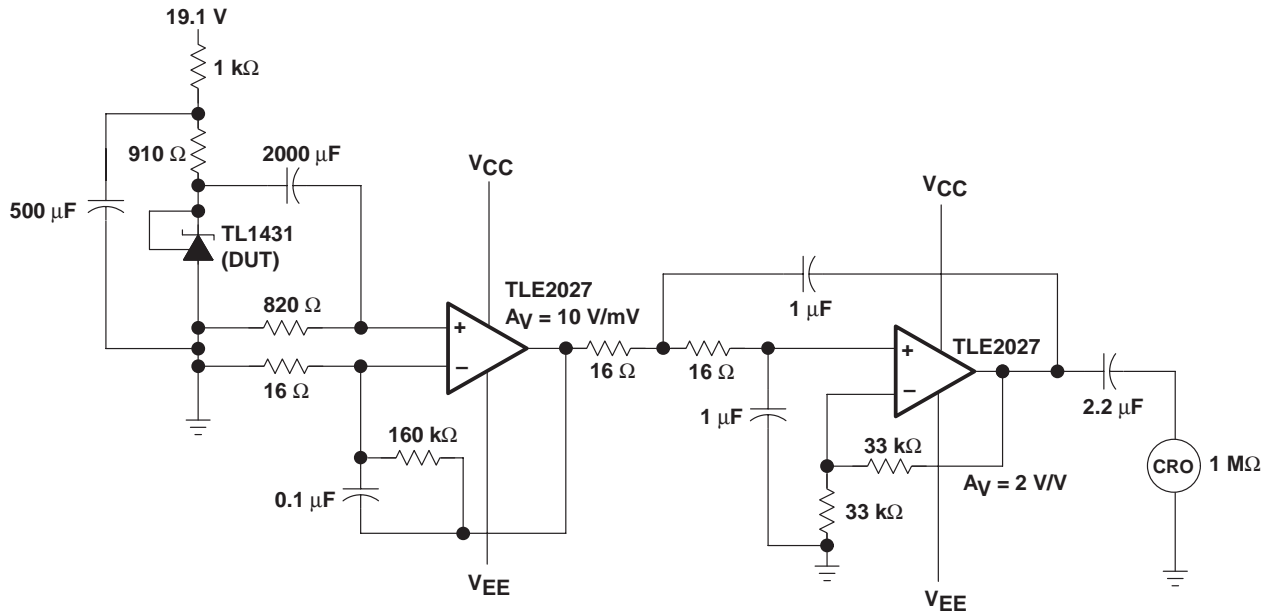
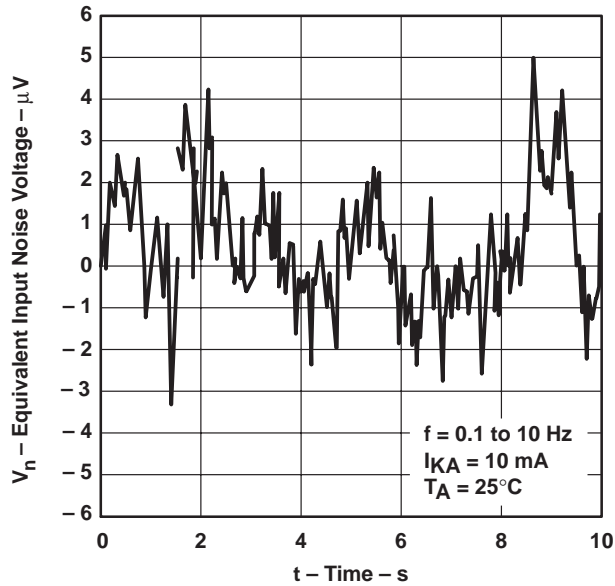
Figure 10

† 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

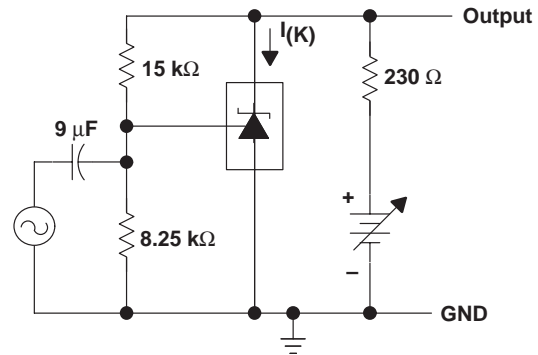
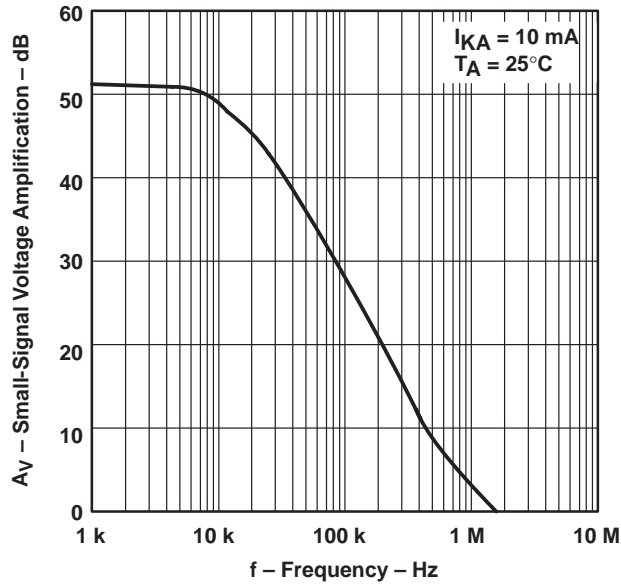


TEST CIRCUIT FOR 0.1-Hz TO 10-Hz EQUIVALENT INPUT-NOISE VOLTAGE

Figure 11

TYPICAL CHARACTERISTICS

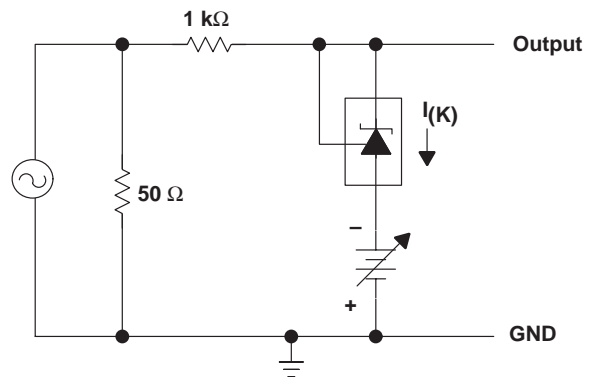
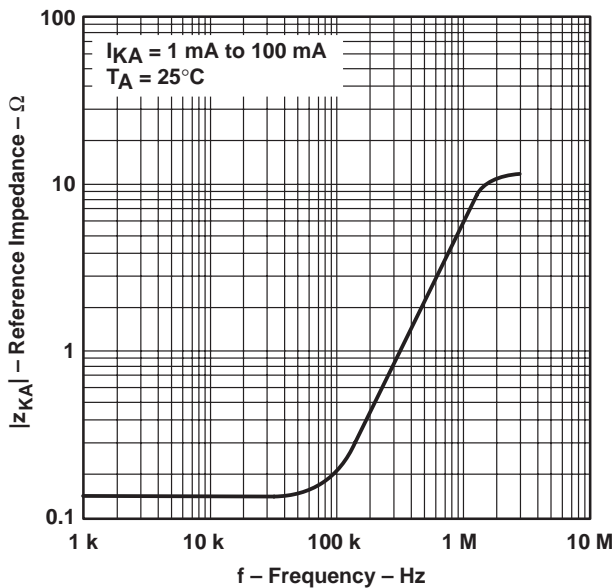
SMALL-SIGNAL VOLTAGE AMPLIFICATION  
VS  
FREQUENCY



TEST CIRCUIT FOR VOLTAGE AMPLIFICATION

Figure 12

REFERENCE IMPEDANCE  
VS  
FREQUENCY



TEST CIRCUIT FOR REFERENCE IMPEDANCE

Figure 13

TYPICAL CHARACTERISTICS

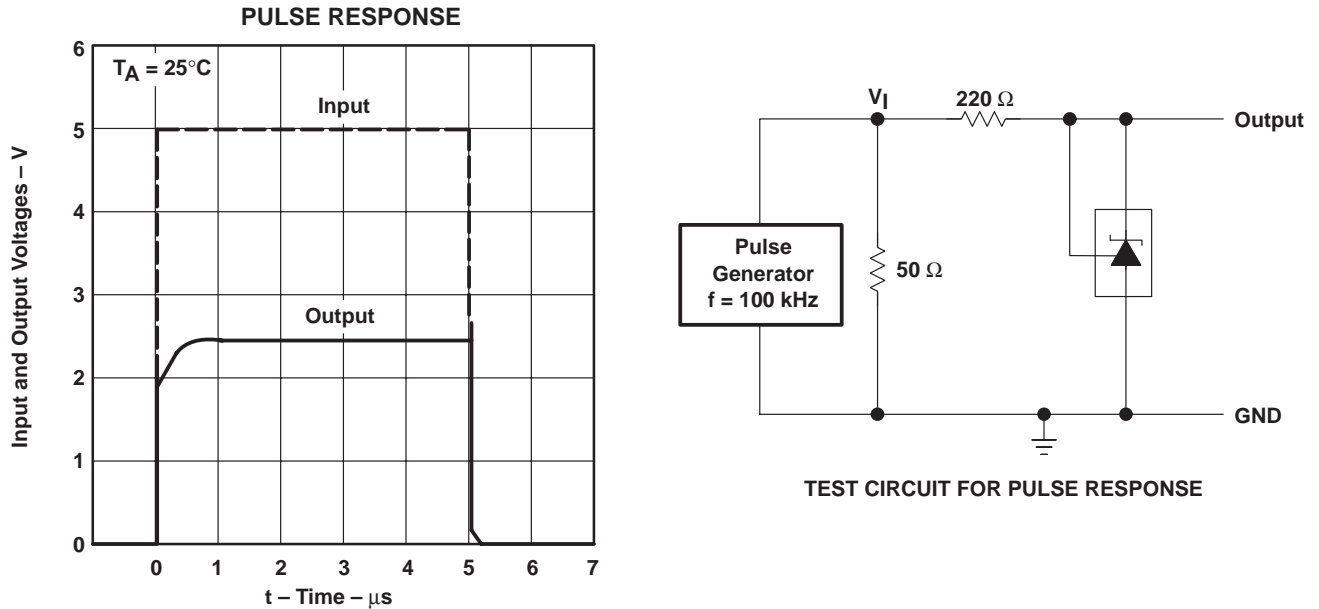
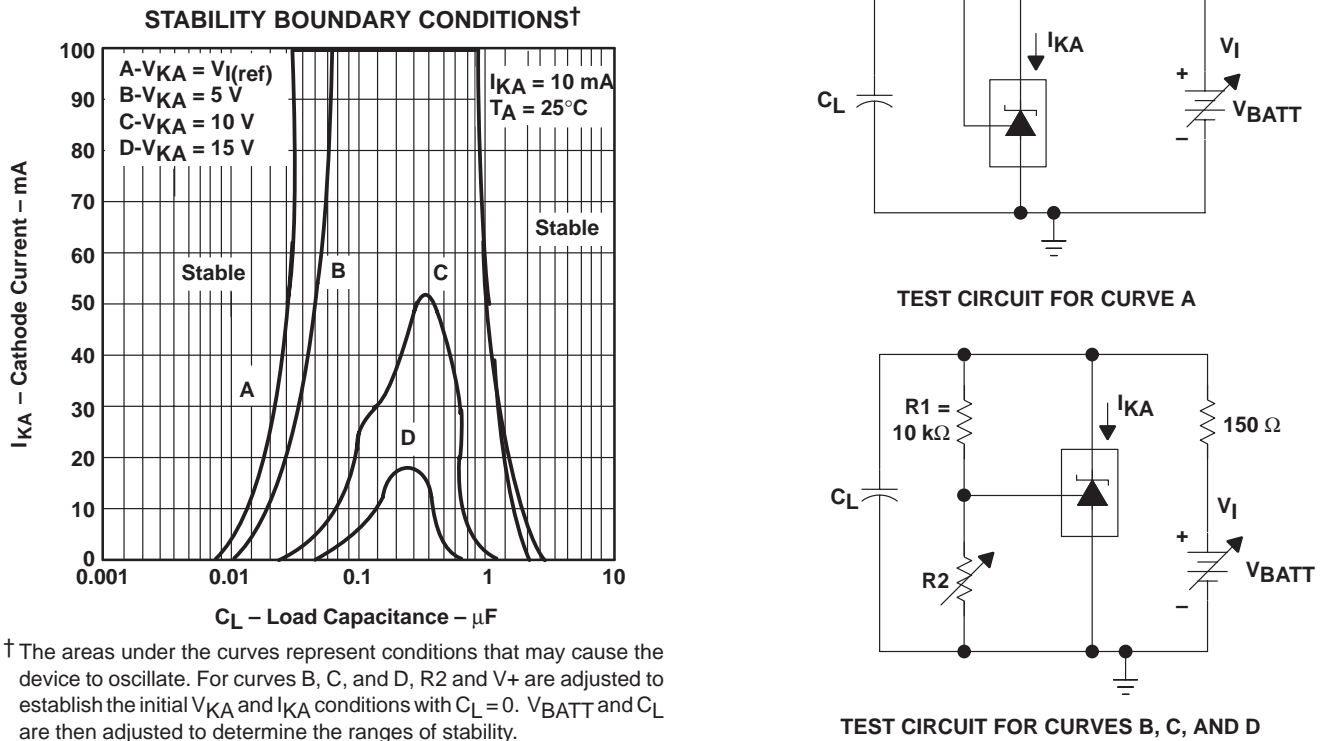


Figure 14



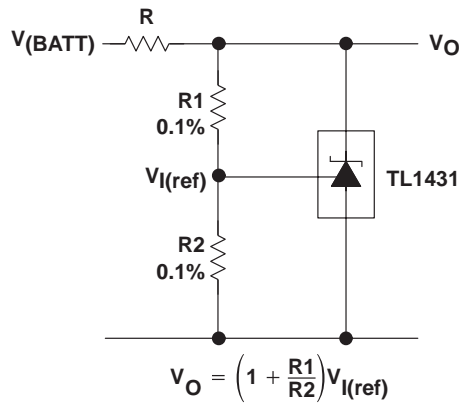
† The areas under the curves represent conditions that may cause the device to oscillate. For curves B, C, and D, R2 and V+ are adjusted to establish the initial V<sub>KA</sub> and I<sub>KA</sub> conditions with C<sub>L</sub> = 0. V<sub>BATT</sub> and C<sub>L</sub> are then adjusted to determine the ranges of stability.

Figure 15

APPLICATION INFORMATION

Table of Application Circuits

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

Figure 16. Shunt Regulator

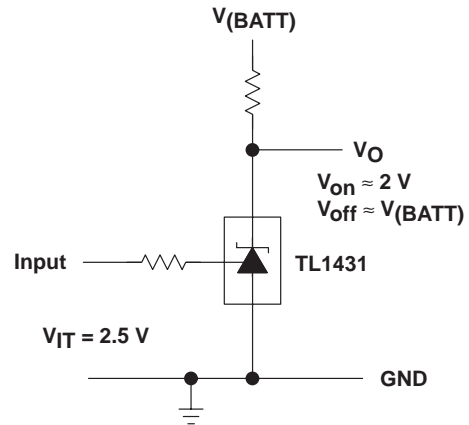
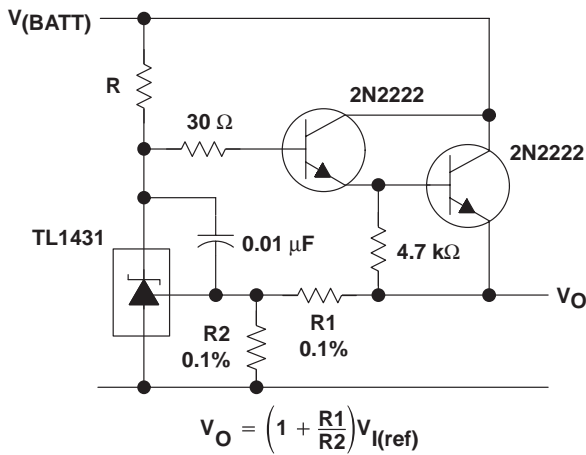


Figure 17. Single-Supply Comparator With Temperature-Compensated Threshold

APPLICATION INFORMATION



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

Figure 18. Precision High-Current Series Regulator

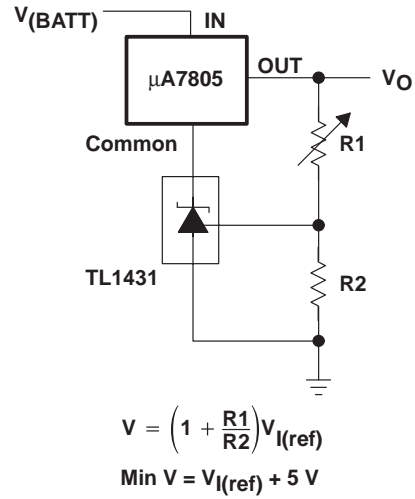


Figure 19. Output Control of a Three-Terminal Fixed Regulator

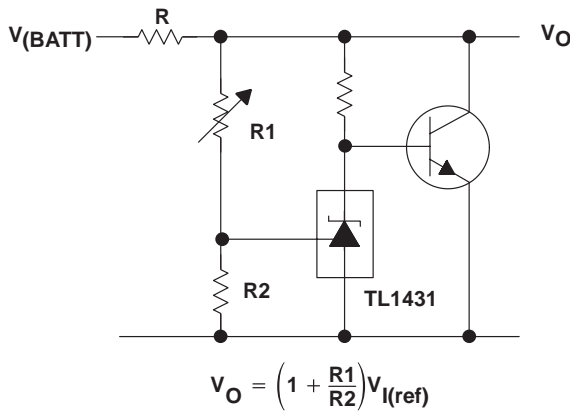
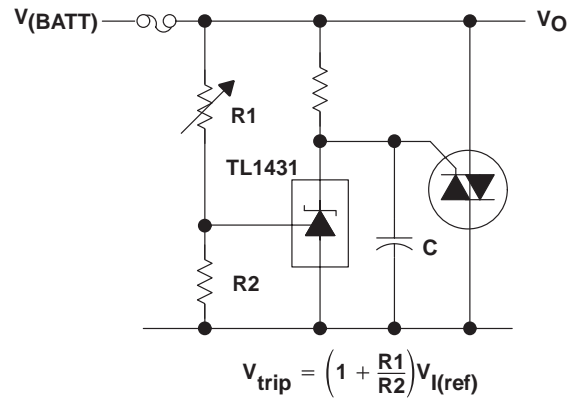


Figure 20. Higher-Current Shunt Regulator



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

Figure 21. Crowbar

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SLVS062F – DECEMBER 1991 – REVISED JANUARY 2000

## APPLICATION INFORMATION

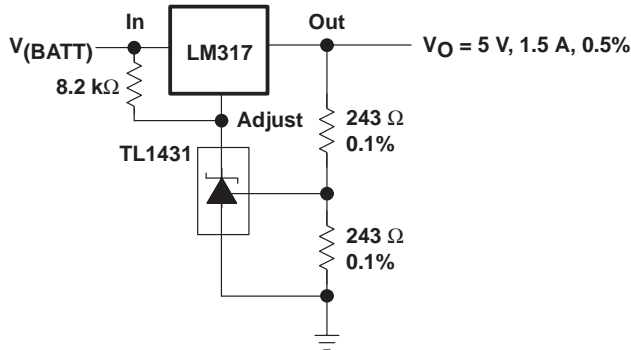
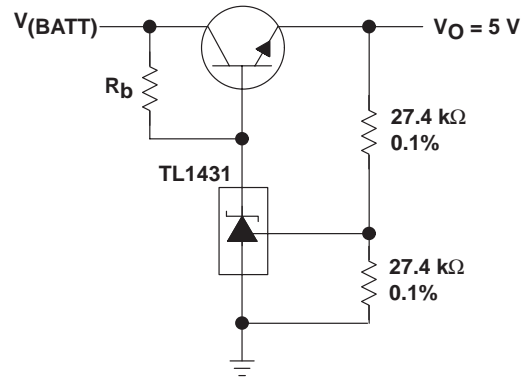


Figure 22. Precision 5-V, 1.5-A, 0.5% Regulator



NOTE A:  $R_b$  should provide cathode current  $\geq 1\text{ mA}$  to the TL1431.

Figure 23. 5-V Precision Regulator

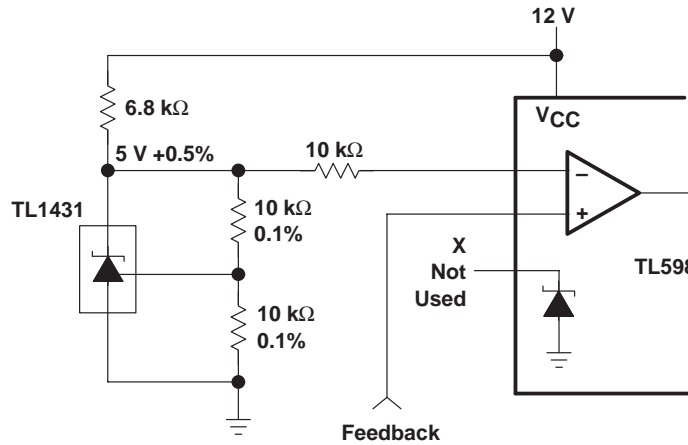
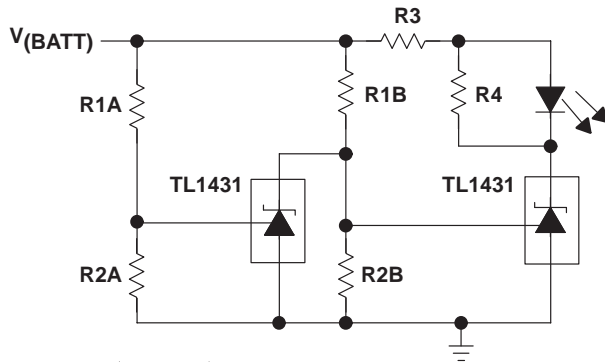


Figure 24. PWM Converter With 0.5% Reference



APPLICATION INFORMATION



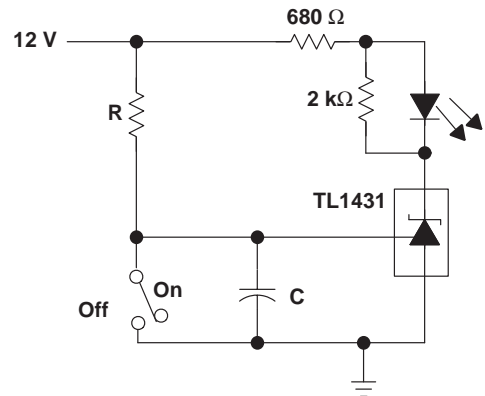
$$\text{Low Limit} = \left(1 + \frac{R1B}{R2B}\right) V_{I(\text{ref})}$$

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

LED on When  
Low Limit < V(BATT) < High Limit

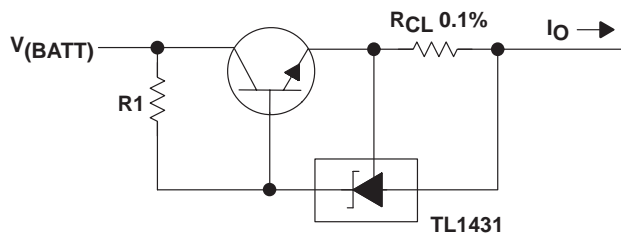
NOTE A: Select R3 and R4 to provide the desired LED intensity and cathode current  $\geq 1$  mA to the TL1431.

Figure 25. Voltage Monitor



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

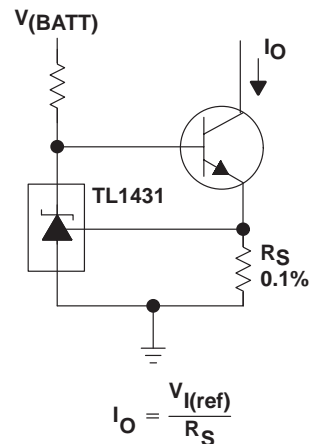
Figure 26. Delay Timer



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

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

Figure 27. Precision Current Limiter



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

Figure 28. Precision Constant-Current Sink

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