

TL431C, TL431AC, TL431I, TL431AI, TL431M, TL431Y ADJUSTABLE PRECISION SHUNT REGULATORS

SLVS005I – JULY 1978 – REVISED AUGUST 1998

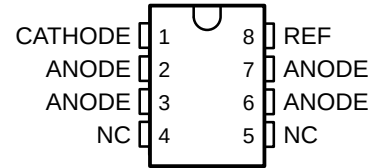
- Equivalent Full-Range Temperature Coefficient . . . 30 ppm/°C
- 0.2-Ω Typical Output Impedance
- Sink-Current Capability . . . 1 mA to 100 mA
- Low Output Noise
- Adjustable Output Voltage . . . V_{ref} to 36 V
- Available in a Wide Range of High-Density Packages

description

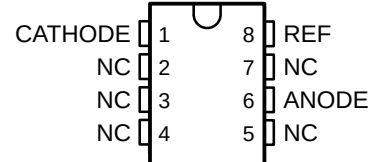
The TL431 and TL431A are 3-terminal adjustable shunt regulators with specified thermal stability over applicable automotive, commercial, and military temperature ranges. The output voltage can be set to any value between V_{ref} (approximately 2.5 V) and 36 V with two external resistors (see Figure 17). 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.

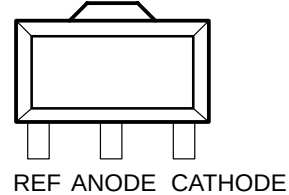
**D PACKAGE
(TOP VIEW)**



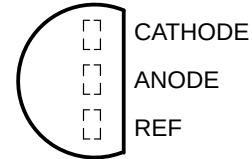
**JG, P, OR PW PACKAGE
(TOP VIEW)**



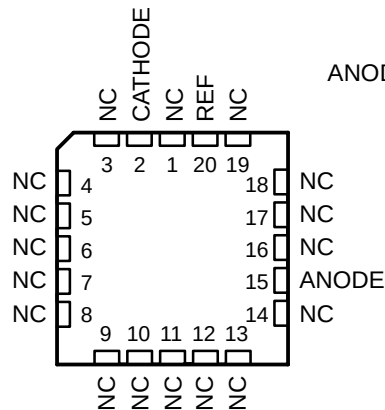
**PK PACKAGE
(TOP VIEW)**



**LP PACKAGE
(TOP VIEW)**

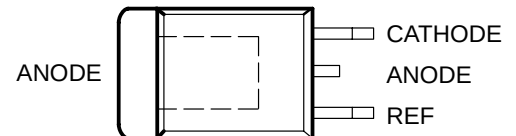


**FK PACKAGE
(TOP VIEW)**



NC – No internal connection

**KTP PACKAGE
(TOP VIEW)**



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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
INSTRUMENTS**

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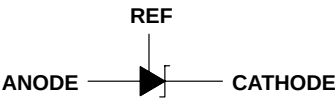
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ADJUSTABLE PRECISION SHUNT REGULATORS

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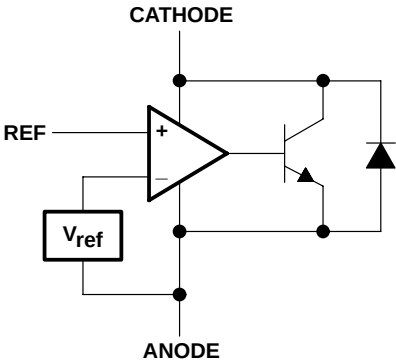
AVAILABLE OPTIONS									
T _A	PACKAGED DEVICES								CHIP FORM (Y)
	SMALL OUTLINE (D)	CHIP CARRIER (FK)	CERAMIC DIP (JG)	PLASTIC FLANGE MOUNT (KTP)	TO-226AA (LP)	PLASTIC DIP (P)	SOT-89 (PK)	SHRINK SMALL OUTLINE (PW)	
0°C to 70°C	TL431CD TL431ACD			TL431CKTPR	TL431CLP TL431ACL P	TL431CP TL431ACP	TL431CPK	TL431CPW	TL431Y
–40°C to 85°C	TL431ID TL431AID				TL431ILP TL431AILP	TL431IP TL431AIP	TL431IPK		
–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



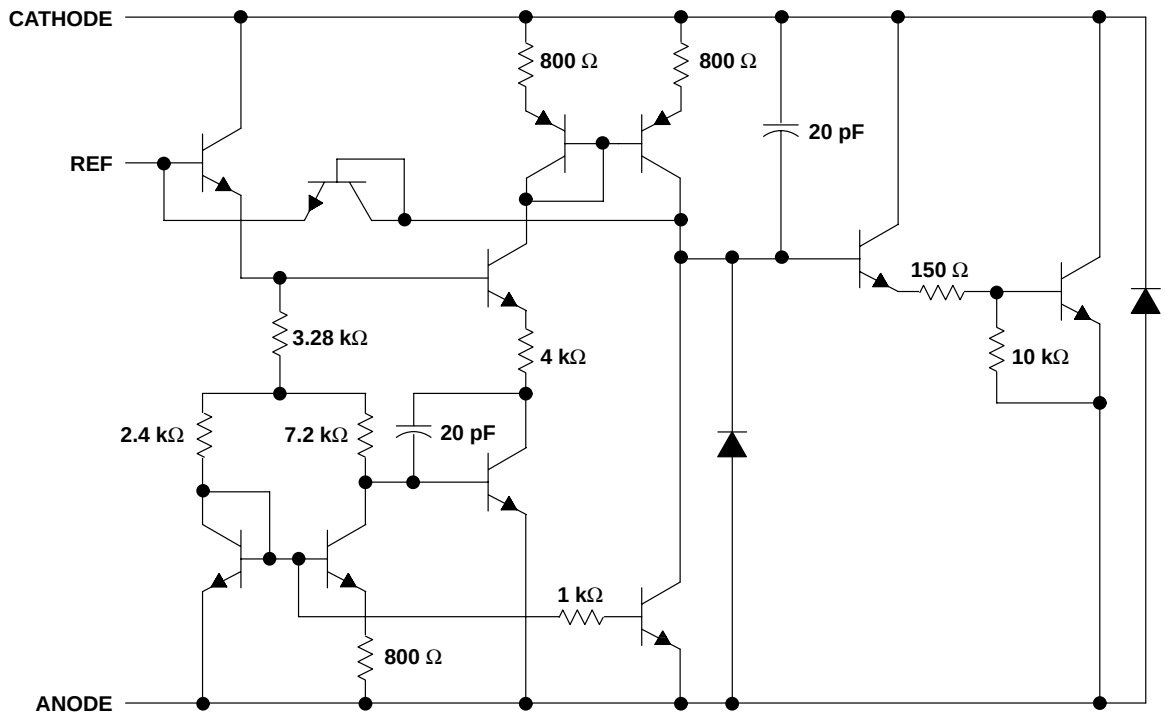
functional block diagram



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equivalent schematic[†]



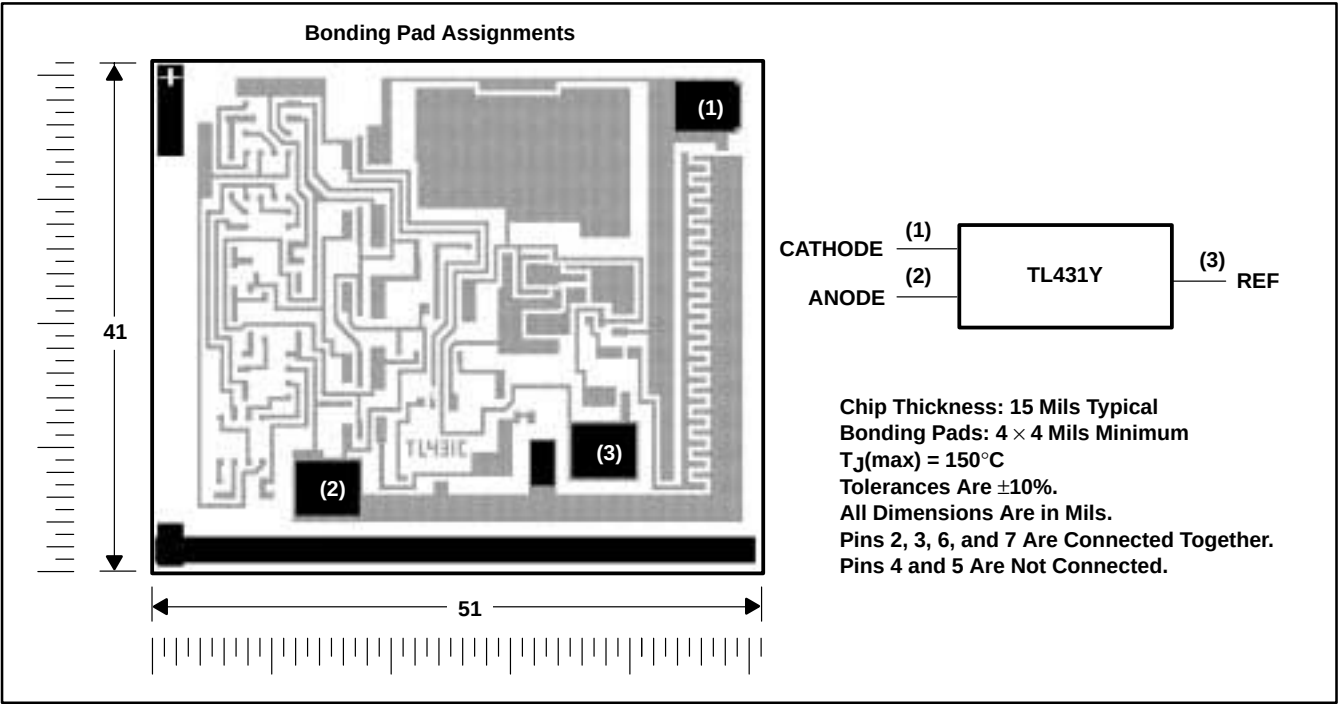
[†] All component values are nominal.

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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.



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.

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DISSIPATION RATING TABLE 1 – 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
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	$T_C = 25^\circ\text{C}$ POWER RATING	DERATING FACTOR ABOVE $T_C = 25^\circ\text{C}$	$T_C = 70^\circ\text{C}$ POWER RATING	$T_C = 85^\circ\text{C}$ 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
	I suffix	–40	85
	M suffix	–55	125



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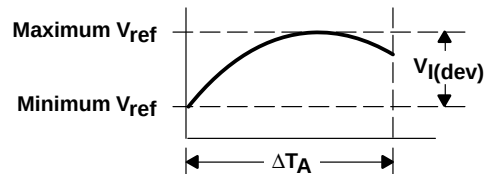
electrical characteristics over recommended operating conditions, $T_A = 25^\circ\text{C}$ (unless otherwise noted)

PARAMETER	TEST CIRCUIT	TEST CONDITIONS	TL431C			UNIT
			MIN	TYP	MAX	
V_{ref} Reference voltage	2	$V_{KA} = V_{\text{ref}}, I_{KA} = 10\text{ mA}$	2440	2495	2550	mV
$V_{I(\text{dev})}$ Deviation of reference voltage over full temperature range (see Figure 1)	2	$V_{KA} = V_{\text{ref}}, I_{KA} = 10\text{ mA}, T_A = \text{Full range}^\dagger$		4	25	mV
$\frac{\Delta V_{\text{ref}}}{\Delta V_{KA}}$ Ratio of change in reference voltage to the change in cathode voltage	3	$I_{KA} = 10\text{ mA}$	$\Delta V_{KA} = 10\text{ V} - V_{\text{ref}}$		-1.4	-2.7
			$\Delta V_{KA} = 36\text{ V} - 10\text{ V}$		-1	-2
I_{ref} Reference current	3	$I_{KA} = 10\text{ mA}, R1 = 10\text{ k}\Omega, R2 = \infty$		2	4	μA
$I_{I(\text{dev})}$ Deviation of reference current over full temperature range (see Figure 1)	3	$I_{KA} = 10\text{ mA}, R1 = 10\text{ k}\Omega, R2 = \infty, T_A = \text{Full range}^\dagger$		0.4	1.2	μA
I_{min} Minimum cathode current for regulation	2	$V_{KA} = V_{\text{ref}}$		0.4	1	mA
I_{off} Off-state cathode current	4	$V_{KA} = 36\text{ V}, V_{\text{ref}} = 0$		0.1	1	μA
$ z_{KA} $ Dynamic impedance (see Figure 1)	1	$I_{KA} = 1\text{ mA to } 100\text{ mA}, V_{KA} = V_{\text{ref}}, f \leq 1\text{ kHz}$		0.2	0.5	Ω

† Full temperature range is 0°C to 70°C for the TL431C.

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

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



where:

ΔT_A is the recommended operating free-air temperature range of the device.

$\alpha_{V_{\text{ref}}}$ can be positive or negative, depending on whether minimum V_{ref} or maximum V_{ref} , respectively, occurs at the lower temperature.

Example: maximum $V_{\text{ref}} = 2496\text{ mV}$ at 30°C , minimum $V_{\text{ref}} = 2492\text{ mV}$ at 0°C , $V_{\text{ref}} = 2495\text{ mV}$ at 25°C , $\Delta T_A = 70^\circ\text{C}$ for TL431C

$$|\alpha_{V_{\text{ref}}}| = \frac{\left(\frac{4\text{ mV}}{2495\text{ mV}} \right) \times 10^6}{70^\circ\text{C}} \approx 23\text{ ppm}/^\circ\text{C}$$

Because minimum V_{ref} occurs at the lower temperature, the coefficient is positive.

Calculating Dynamic Impedance

The dynamic impedance is defined as: $|z_{KA}| = \frac{\Delta V_{KA}}{\Delta I_{KA}}$

When the device is operating with two external resistors (see Figure 3), the total dynamic impedance of the circuit is given by:

$$|z'| = \frac{\Delta V}{\Delta I} \approx |z_{KA}| \left(1 + \frac{R1}{R2} \right)$$

Figure 1. Calculating Deviation Parameters and Dynamic Impedance

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electrical characteristics over recommended operating conditions, $T_A = 25^\circ\text{C}$ (unless otherwise noted)

PARAMETER		TEST CIRCUIT	TEST CONDITIONS		TL431I			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†			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	$\frac{\text{mV}}{\text{V}}$	
				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
z _{KA}	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, $T_A = 25^\circ\text{C}$ (unless otherwise noted)

PARAMETER		TEST CIRCUIT	TEST CONDITIONS		TL431M			UNIT
					MIN	TYP	MAX	
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	$\frac{mV}{V}$	
				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	
z _{KA}	Dynamic impedance (see Figure 1)	1	I _{KA} = 1 mA to 100 mA, V _{KA} = V _{ref} , f ≤ 1 kHz		0.2	0.9*	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.



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electrical characteristics over recommended operating conditions, $T_A = 25^\circ\text{C}$ (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	$\frac{\text{mV}}{\text{V}}$	
				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
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 TL431AC.

electrical characteristics over recommended operating conditions, $T_A = 25^\circ\text{C}$ (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	$\frac{mV}{V}$	
				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‡			0.8	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
z _{KA}	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.



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electrical characteristics over recommended operating conditions, $T_A = 25^\circ\text{C}$ (unless otherwise noted)

PARAMETER	TEST CIRCUIT	TEST CONDITIONS	TL431Y			UNIT
			MIN	TYP	MAX	
V_{ref} Reference voltage	2	$V_{\text{KA}} = V_{\text{ref}}$, $I_{\text{KA}} = 10\text{ mA}$		2495		mV
$\frac{\Delta V_{\text{ref}}}{\Delta V_{\text{KA}}}$ Ratio of change in reference voltage to the change in cathode voltage	3	$I_{\text{KA}} = 10\text{ mA}$, $\Delta V_{\text{KA}} = 10\text{ V} - V_{\text{ref}}$		-1.4		$\frac{\text{mV}}{\text{V}}$
		$\Delta V_{\text{KA}} = 36\text{ V} - 10\text{ V}$		-1		
I_{ref} Reference input current	3	$I_{\text{KA}} = 10\text{ mA}$, $R_1 = 10\text{ k}\Omega$, $R_2 = \infty$		2		μA
I_{min} Minimum cathode current for regulation	2	$V_{\text{KA}} = V_{\text{ref}}$		0.4		mA
I_{off} Off-state cathode current	4	$V_{\text{KA}} = 36\text{ V}$, $V_{\text{ref}} = 0$		0.1		μA
$ z_{\text{KA}} $ Dynamic impedance [†]	2	$I_{\text{KA}} = 1\text{ mA to }100\text{ mA}$, $V_{\text{KA}} = V_{\text{ref}}$, $f \leq 1\text{ kHz}$		0.2		Ω

[†] Calculating dynamic impedance:

The dynamic impedance is defined as: $|z_{\text{KA}}| = \frac{\Delta V_{\text{KA}}}{\Delta I_{\text{KA}}}$

When the device is operating with two external resistors (see Figure 3), the total dynamic impedance of the circuit is given by:

$$|z'| = \frac{\Delta V}{\Delta I} \approx |z_{\text{KA}}| \left(1 + \frac{R_1}{R_2} \right)$$

PARAMETER MEASUREMENT INFORMATION

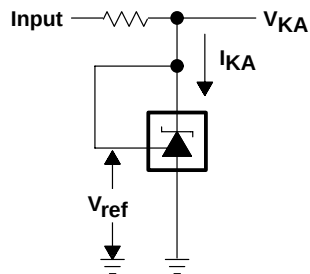


Figure 2. Test Circuit for $V_{\text{KA}} = V_{\text{ref}}$

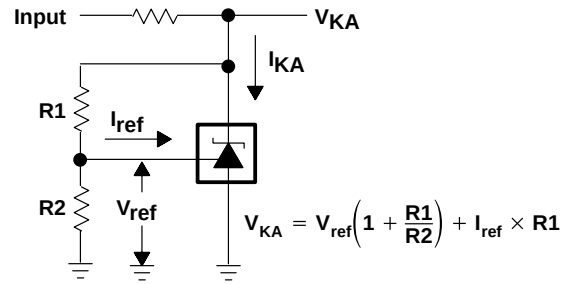


Figure 3. Test Circuit for $V_{\text{KA}} > V_{\text{ref}}$

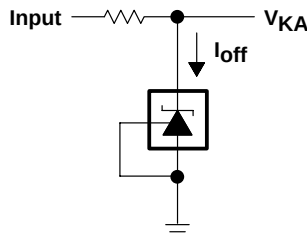


Figure 4. Test Circuit for I_{off}

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TYPICAL CHARACTERISTICS

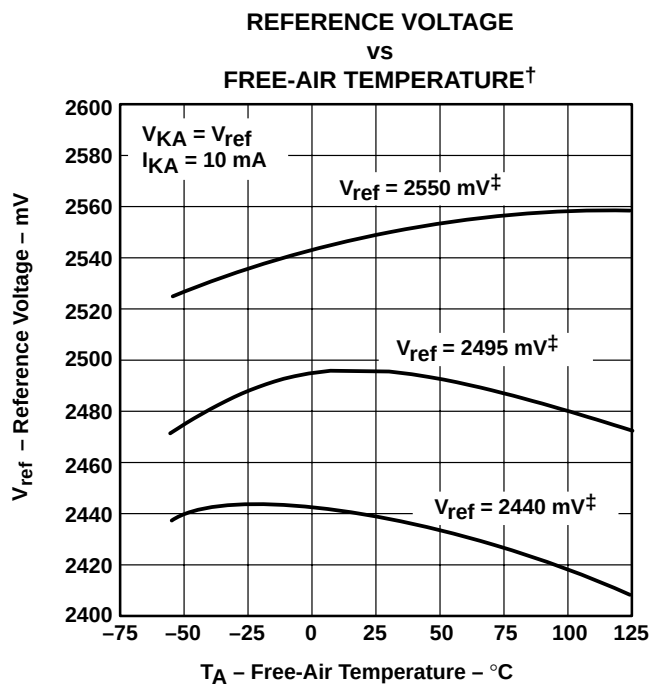
Table 1. Graphs

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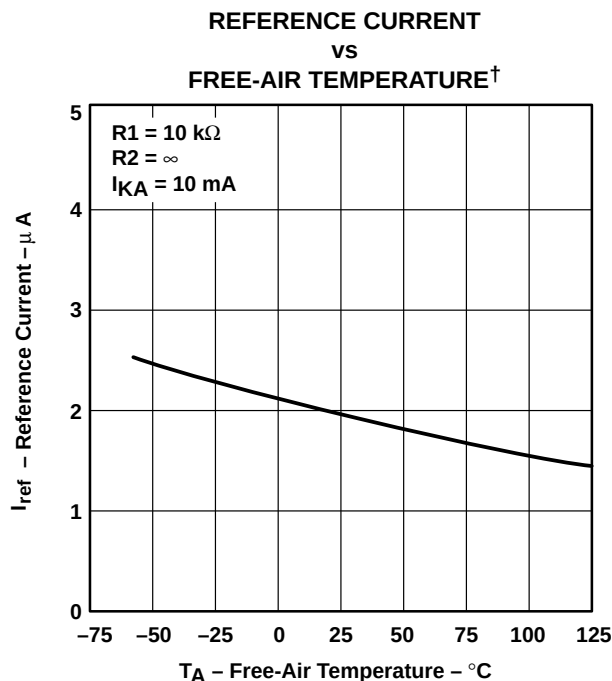
TYPICAL CHARACTERISTICS



† 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 $I_{KA} = 10 \text{ mA}$, $T_A = 25^\circ\text{C}$.

Figure 5



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

Figure 6

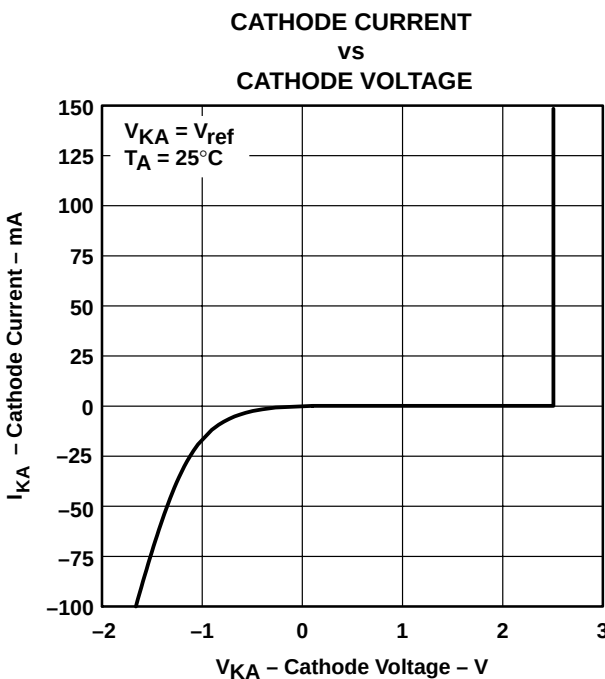


Figure 7

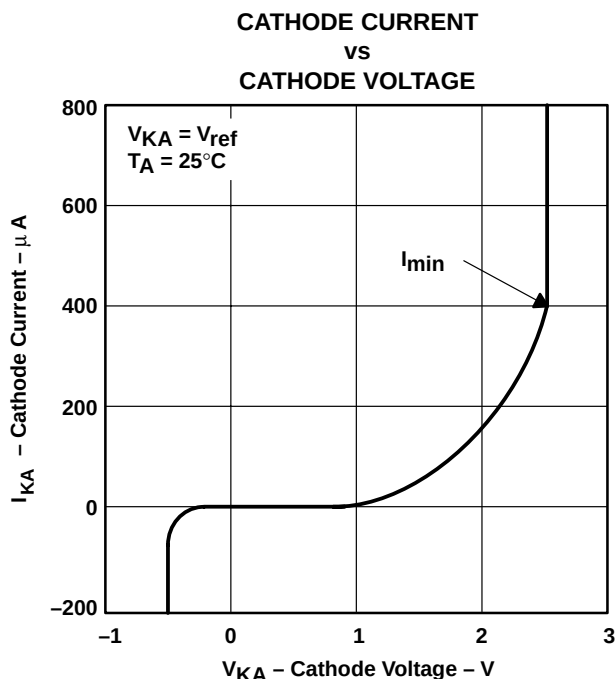
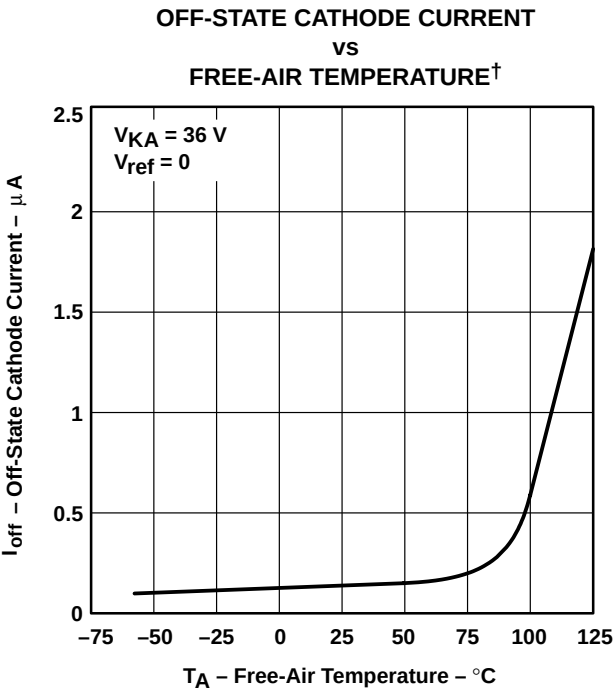


Figure 8

TL431C, TL431AC, TL431I, TL431AI, TL431M, TL431Y
ADJUSTABLE PRECISION SHUNT REGULATORS

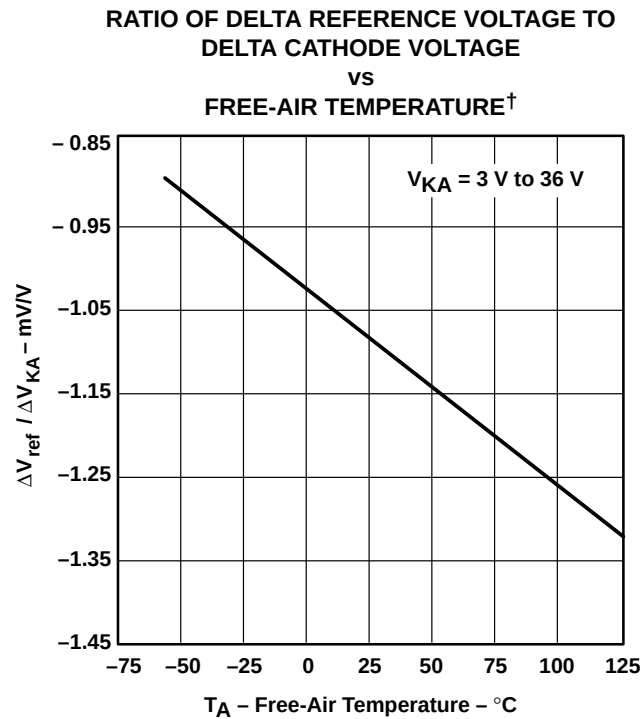
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TYPICAL CHARACTERISTICS



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

Figure 9



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

Figure 10

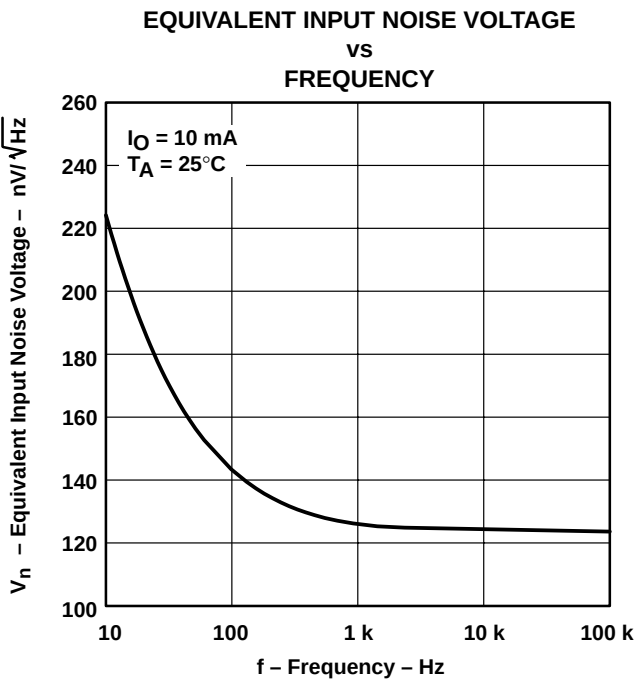


Figure 11



TYPICAL CHARACTERISTICS

EQUIVALENT INPUT NOISE VOLTAGE
OVER A 10-SECOND PERIOD

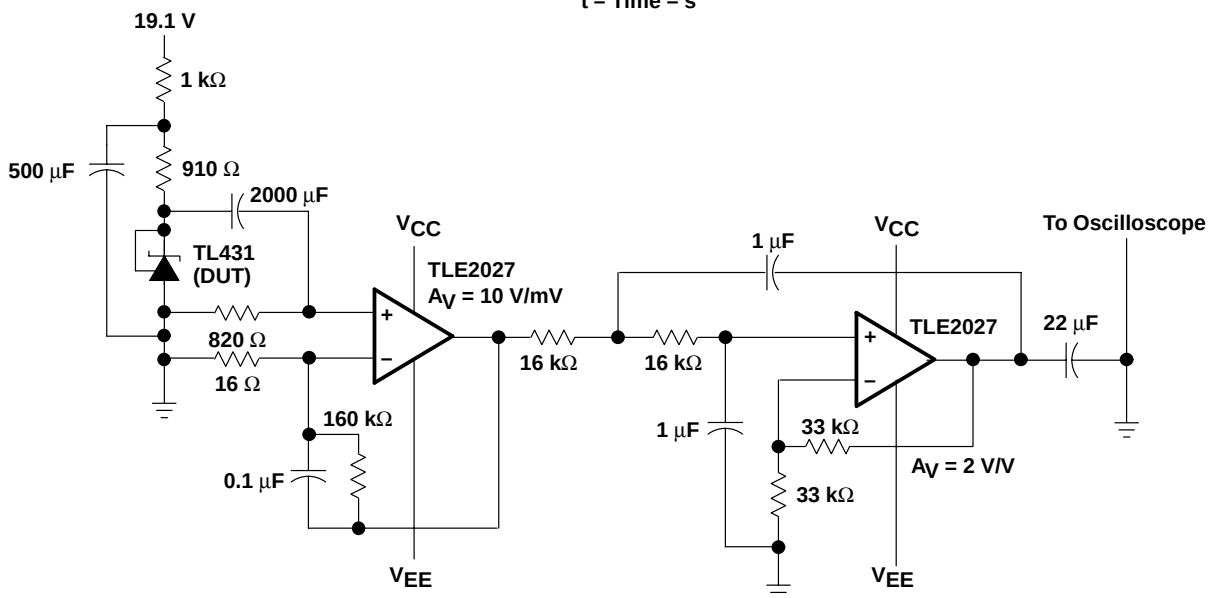
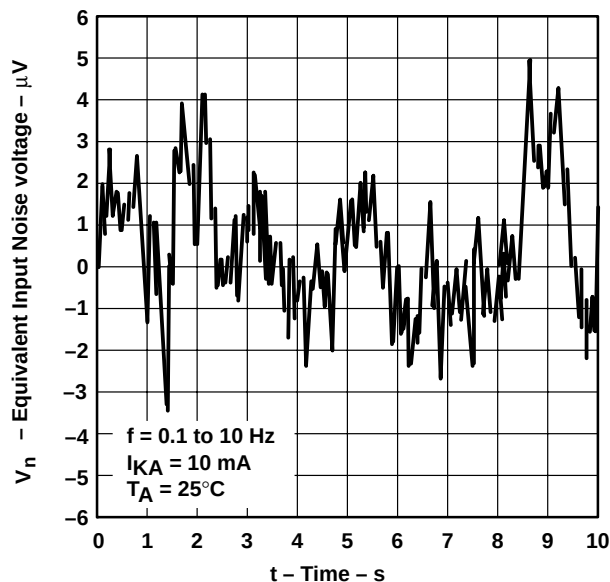


Figure 12. Test Circuit for Equivalent Input Noise Voltage

TL431C, TL431AC, TL431I, TL431AI, TL431M, TL431Y
ADJUSTABLE PRECISION SHUNT REGULATORS

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TYPICAL CHARACTERISTICS

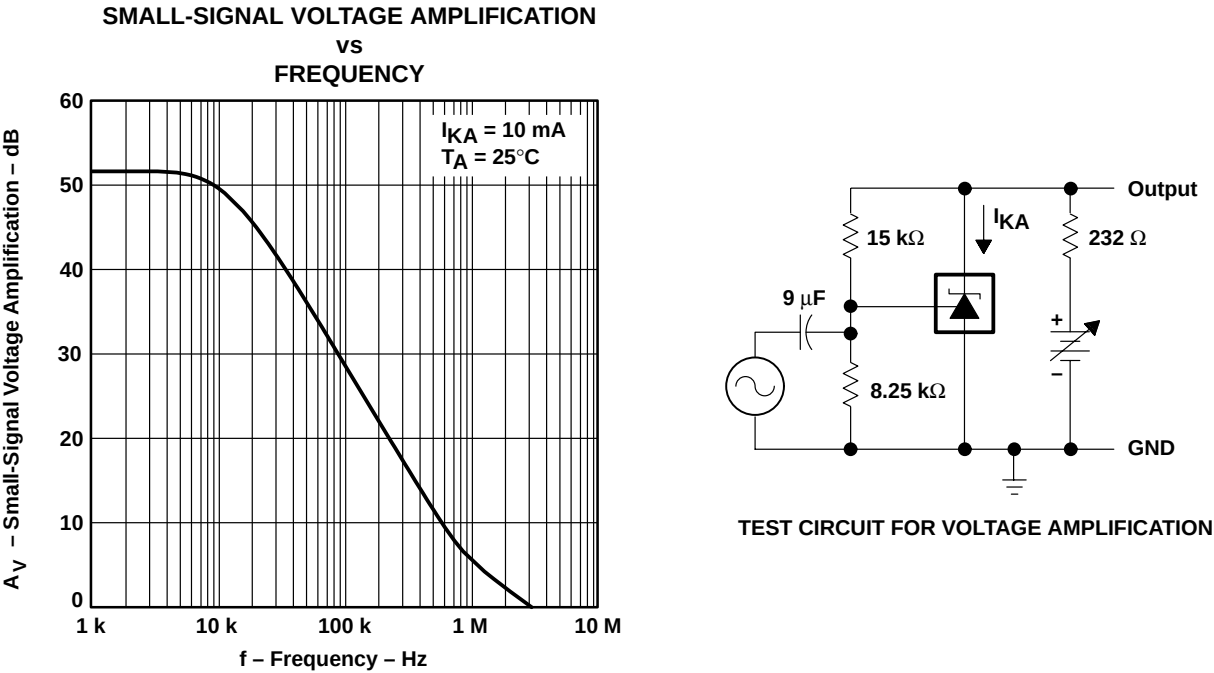


Figure 13

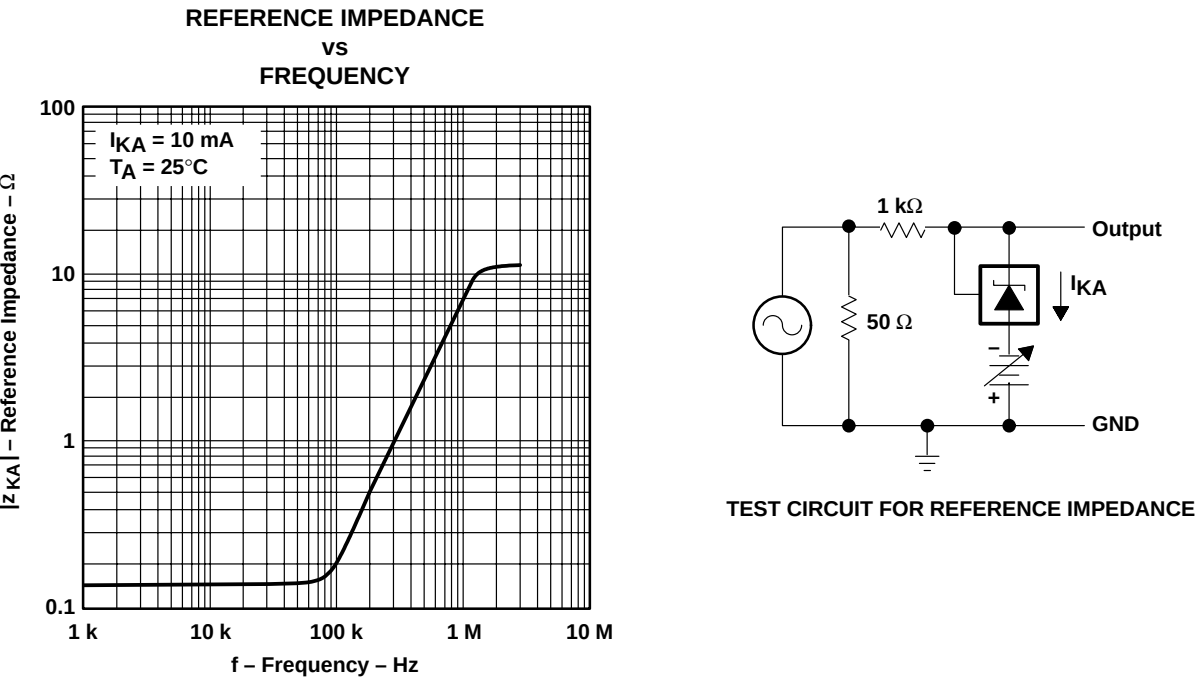


Figure 14

TYPICAL CHARACTERISTICS

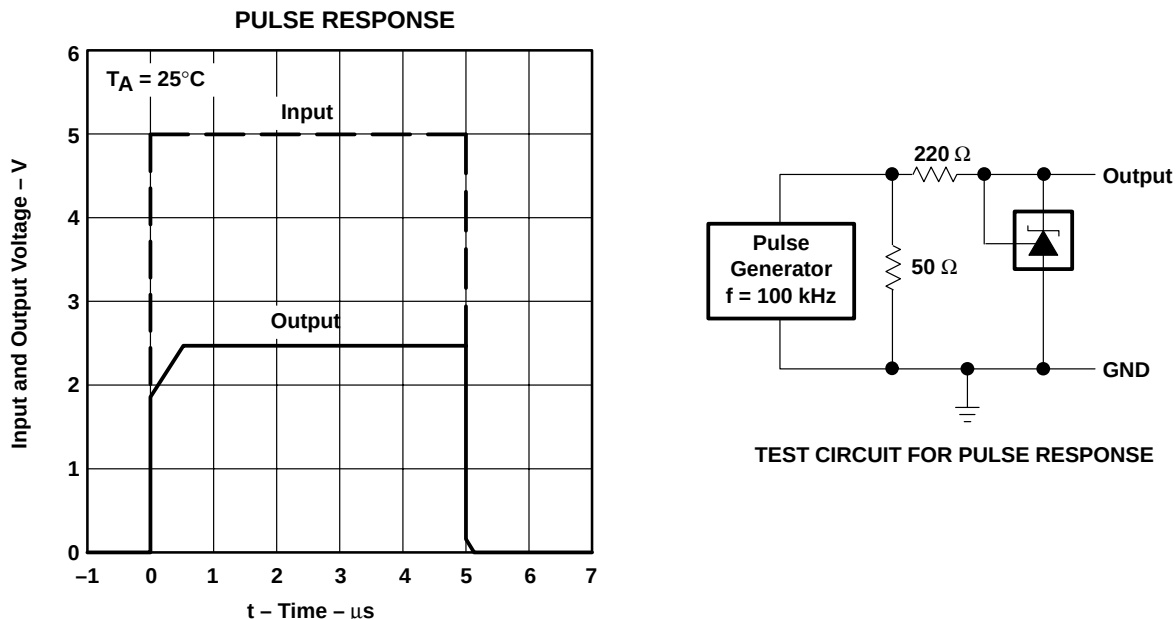


Figure 15

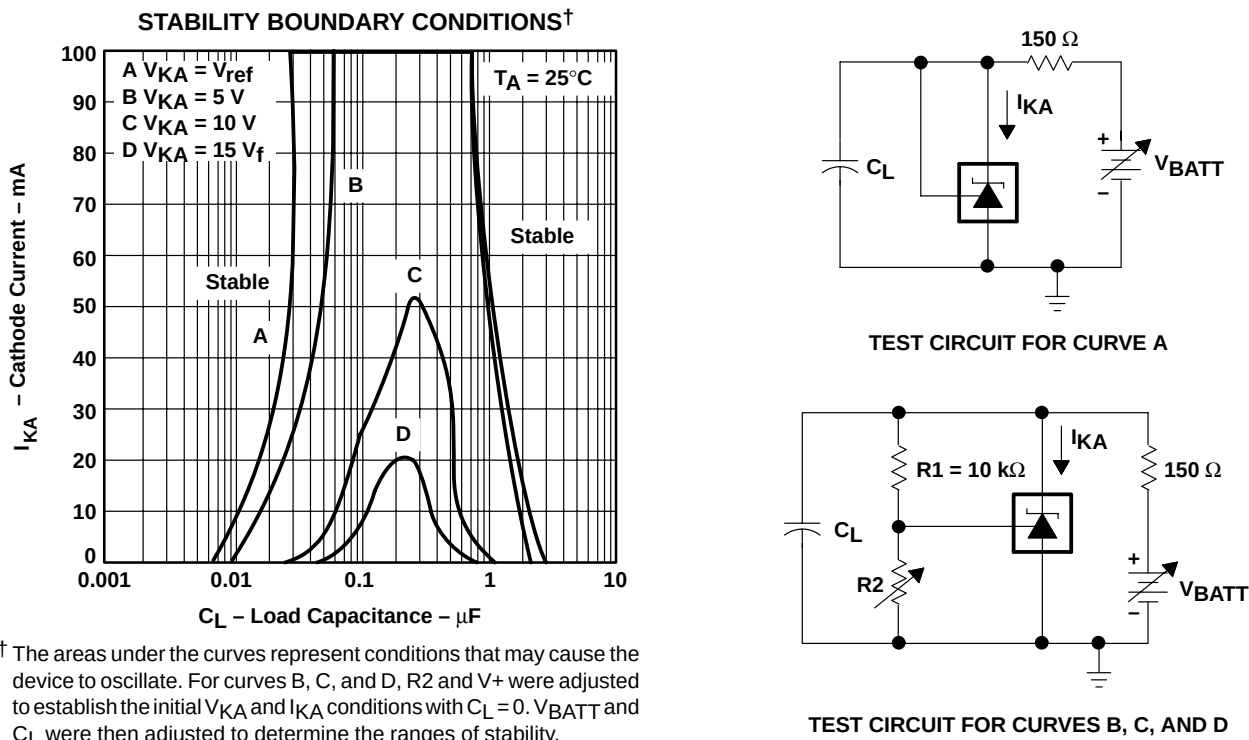
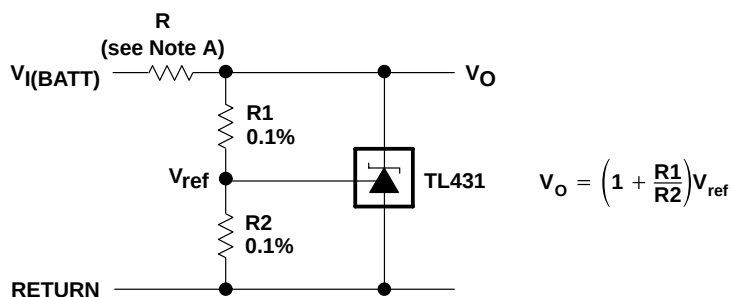


Figure 16

TL431C, TL431AC, TL431I, TL431AI, TL431M, TL431Y ADJUSTABLE PRECISION SHUNT REGULATORS

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APPLICATION INFORMATION



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

Figure 17. Shunt Regulator

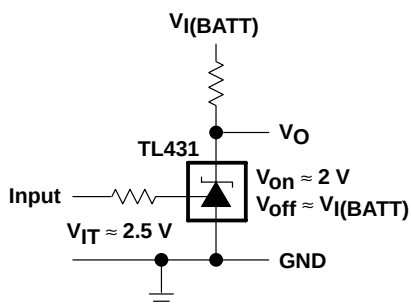
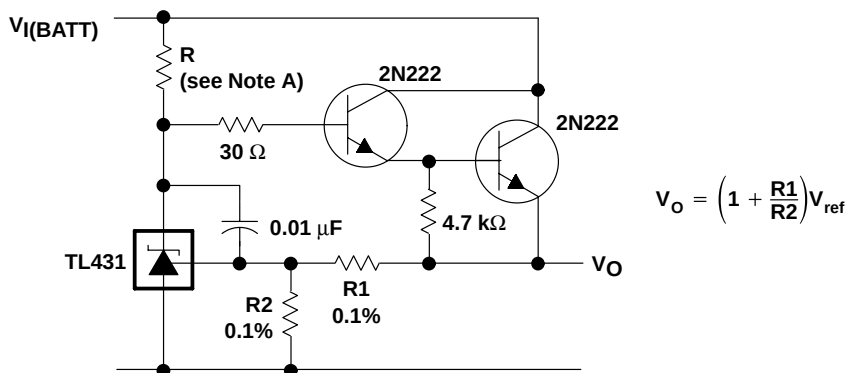


Figure 18. Single-Supply Comparator With Temperature-Compensated Threshold



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

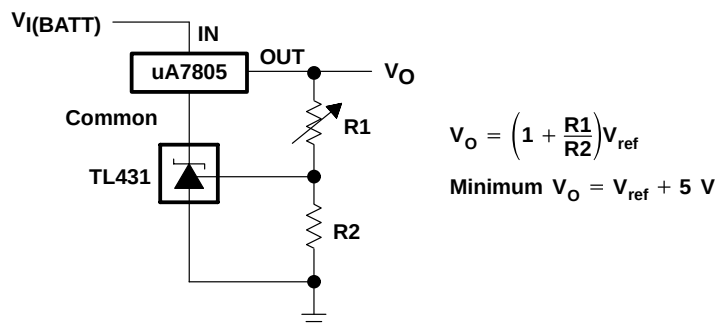


Figure 20. Output Control of a 3-Terminal Fixed Regulator

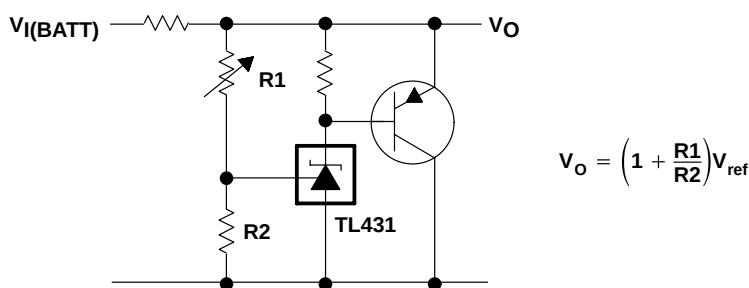
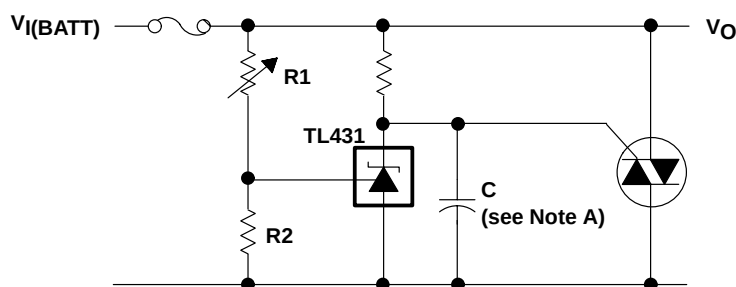


Figure 21. High-Current Shunt Regulator



NOTE A: Refer to the stability boundary conditions in Figure 16 to determine allowable values for C.

Figure 22. Crowbar Circuit

TL431C, TL431AC, TL431I, TL431AI, TL431M, TL431Y ADJUSTABLE PRECISION SHUNT REGULATORS

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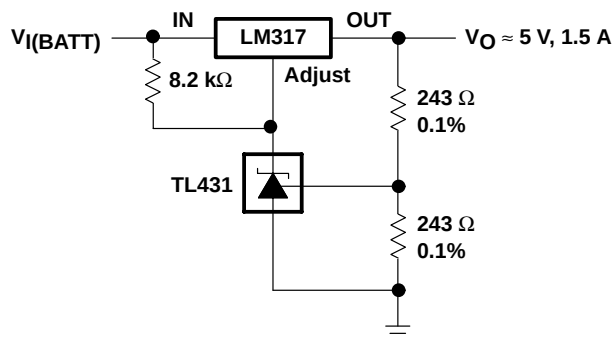
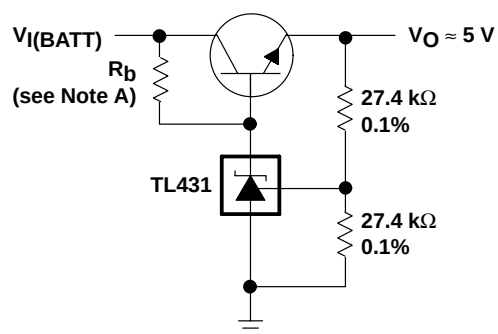


Figure 23. Precision 5-V 1.5-A Regulator



NOTE A: R_b should provide cathode current $\geq 1\text{-mA}$ to the TL431.

Figure 24. Efficient 5-V Precision Regulator

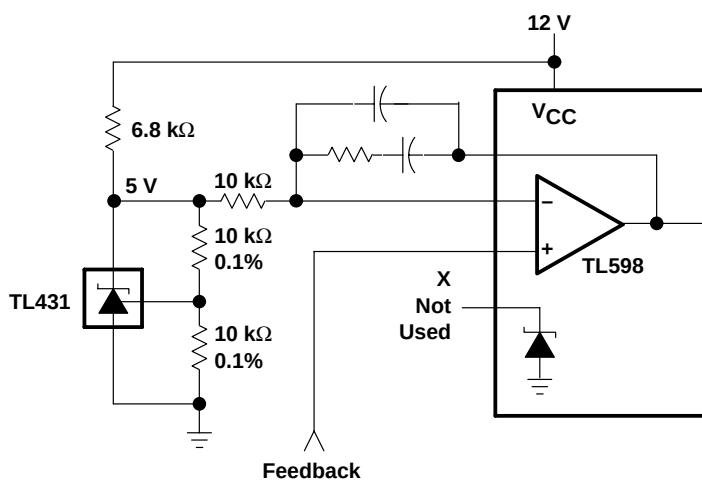
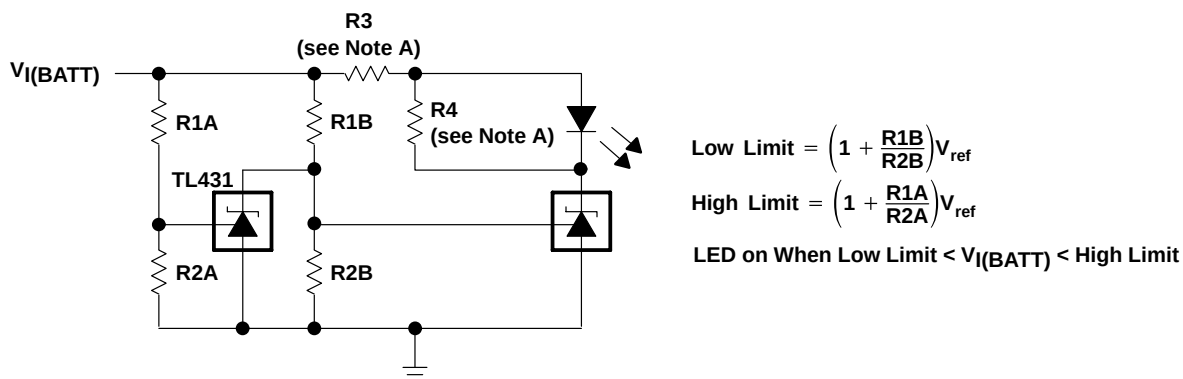


Figure 25. PWM Converter With Reference

APPLICATION INFORMATION



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

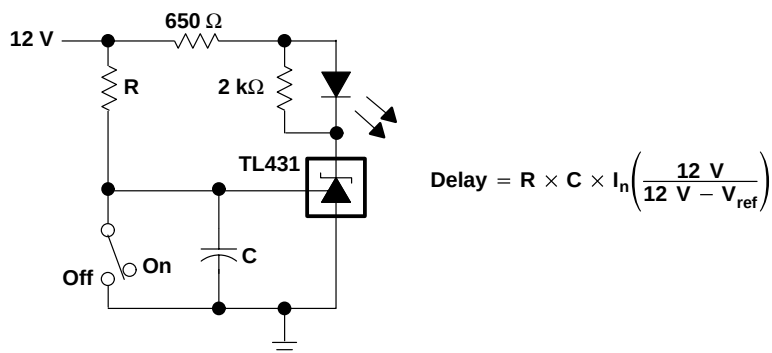


Figure 27. Delay Timer

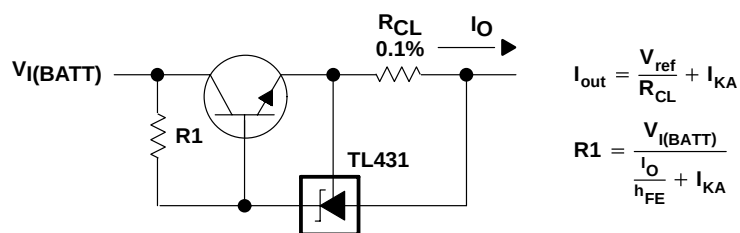


Figure 28. Precision Current Limiter

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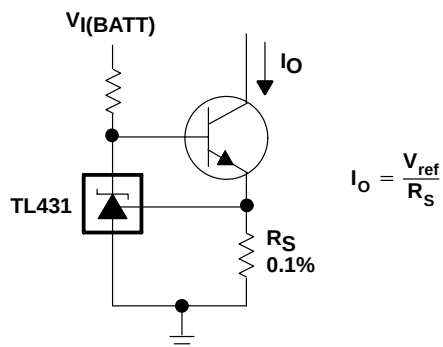


Figure 29. Precision Constant-Current Sink

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