- **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 . . . $V_{I(ref)}$ to 36 V**
- **Available in a Wide Range of High-Density Packaging Options:**
  - **Small Outline (D)**
  - **TO-226AA (LP)**
  - **SOT-89 (PK)**

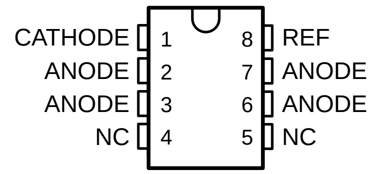
description

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 $V_{I(ref)}$ (approximately 2.5 V) and 36 V with two external resistors (see Figure 16). These devices have a typical output impedance of 0.2 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.

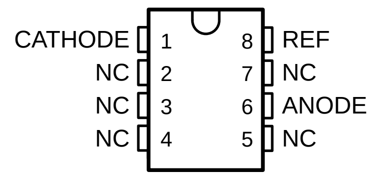
The TL431 is offered in a wide variety of high-density packaging options that includes an SOT-89-type package (suffix PK).

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.

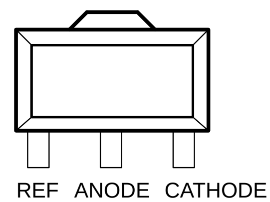
D OR PW PACKAGE
(TOP VIEW)



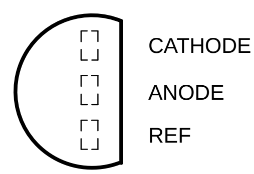
JG OR P PACKAGE
(TOP VIEW)



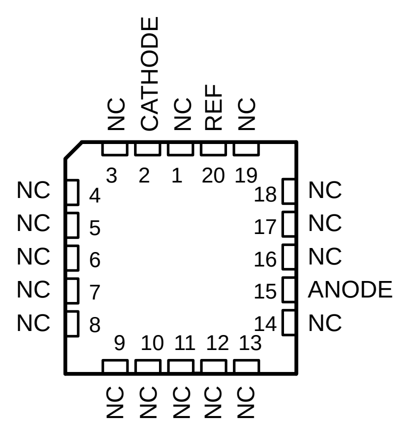
PK PACKAGE
(TOP VIEW)



LP PACKAGE
(TOP VIEW)



FK PACKAGE
(TOP VIEW)



NC – No internal connection

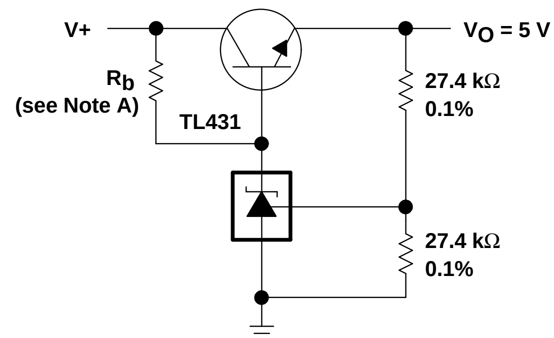
AVAILABLE OPTIONS

T_A	PACKAGED DEVICES							CHIP FORM (Y)
	SMALL OUTLINE (D)	CHIP CARRIER (FK)	CERAMIC DIP (JG)	TO-226AA (LP)	PLASTIC DIP (P)	SOT-89 (PK)	SHRINK SMALL OUTLINE (PW)	
0°C to 70°C	TL431CD TL431ACD			TL431CLP TL431ACLP	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 PK package is only available taped and reeled (no R suffix required). Chip forms are tested at T_A = 25°C.

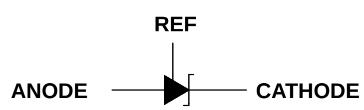
application schematic

5-V Precision Regulator

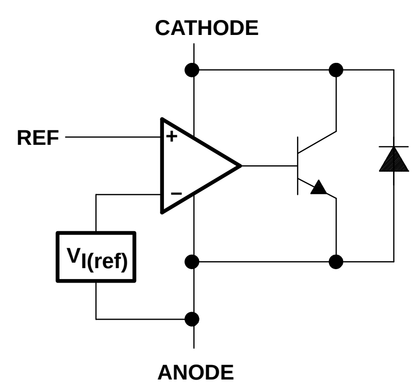


NOTE A: R_b should provide cathode current ≥ 1-mA to the TL431.

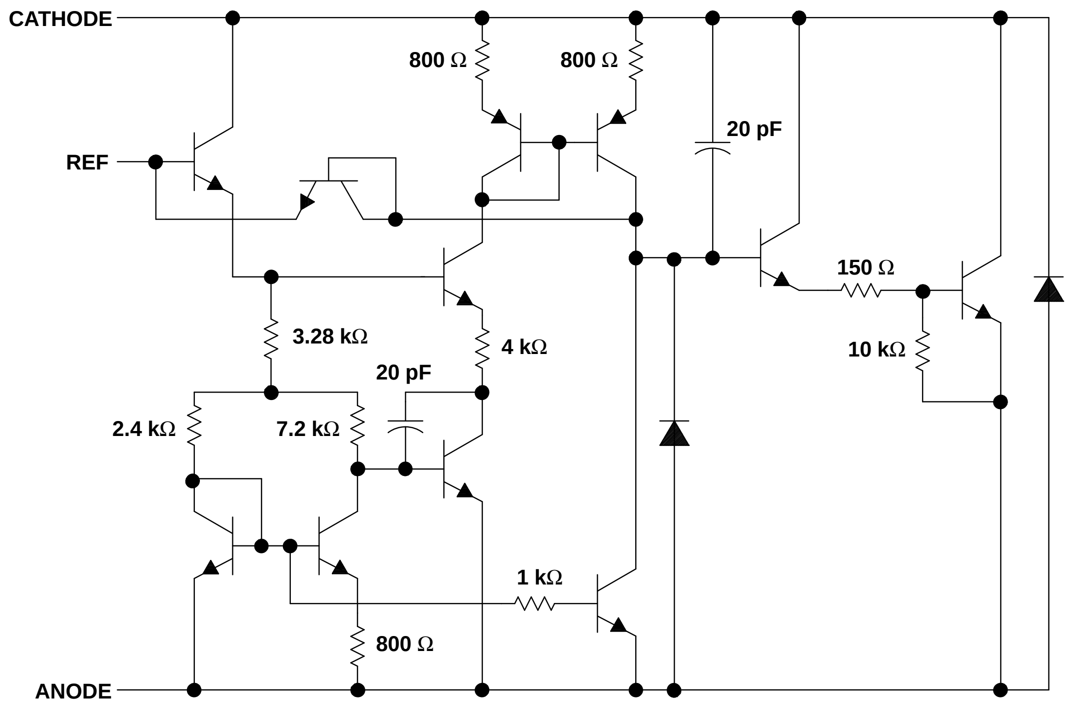
symbol



functional block diagram



equivalent schematic

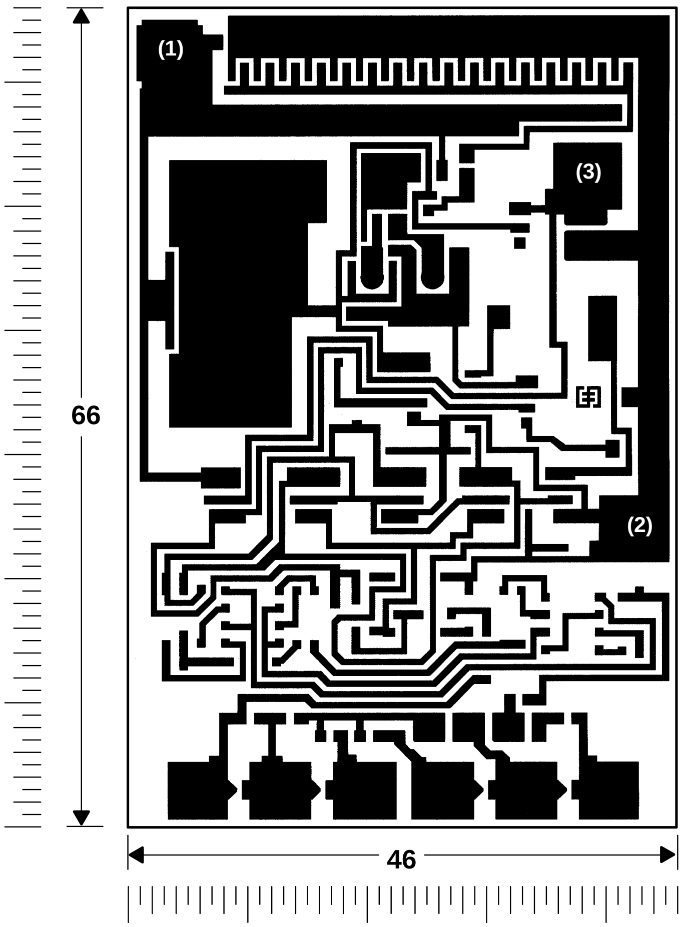


NOTE A: All component values are nominal.

TL431Y chip information

This chip, when properly assembled, displays characteristics similar to the TL431C. 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.

Pins 2,3,6, and 7 are connected together

Pins 4 and 5 are not connected

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
Operating free-air temperature range, T_A: C-suffix	0°C to 70°C
I-suffix	–40°C to 85°C
M-suffix	–55°C to 125°C
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.

DISSIPATION RATING TABLE 1 – 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
D	725 mW	5.8 mW/°C	464 mW	377 mW	—
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
LP	775 mW	6.2 mW/°C	496 mW	403 mW	—
P	1000 mW	8.0 mW/°C	640 mW	520 mW	—
PK	500 mW	4.0 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°C POWER RATING	DERATING FACTOR ABOVE T_C = 25°C	T_C = 70°C POWER RATING	T_C = 85°C POWER RATING
PK	3125 mW	25 mW/°C	2000 mW	1625 mW

recommended operating conditions

	MIN	MAX	UNIT
Cathode voltage, V_{KA}	$V_{I(ref)}$	36	V
Cathode current, I_{KA}	1	100	mA

electrical characteristics over recommended operating conditions, T_A = 25°C (unless otherwise noted)

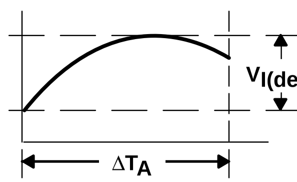
	PARAMETER	TEST CIRCUIT	TEST CONDITIONS	TL431C MIN	TL431C TYP	TL431C MAX	TL431I MIN	TL431I TYP	TL431I MAX	TL431M MIN	TL431M TYP	TL431M MAX	UNIT
$V_{I(ref)}$	Reference input voltage	1	$V_{KA} = V_{I(ref)}$, I_{KA} = 10 mA	2440	2495	2550	2440	2495	2550	2400	2495	2600	mV
$V_{I(dev)}$	Deviation of reference input voltage over full temperature range ‡	1	$V_{KA} = V_{I(ref)}$, I_{KA} = 10 mA, T_A = Full range †		4	17		5	30		22		mV
$\frac{\Delta V_{I(ref)}}{\Delta V_{KA}}$	Ratio of change in reference input voltage to the change in cathode voltage	2	I_{KA} = 10 mA, ΔV_{KA} = 10 V – $V_{I(ref)}$		–1.4	–2.7		–1.4	–2.7		–1.4	–3	$\frac{mV}{V}$
			I_{KA} = 10 mA, ΔV_{KA} = 36 V – 10 V		–1	–2		–1	–2		–1	–2.3	
$I_{I(ref)}$	Reference input current	2	I_{KA} = 10 mA, R1 = 10 kΩ, R2 = ∞		2	4		2	4		2	8*	μA
$I_{I(dev)}$	Deviation of reference input current over full temperature range ‡	2	I_{KA} = 10 mA, R1 = 10 kΩ, R2 = ∞, T_A = Full range †		0.4	1.2		0.8	2.5		1		μA
I_{min}	Minimum cathode current for regulation	1	$V_{KA} = V_{I(ref)}$		0.4	1		0.4	1		0.4	1.5	mA
I_{off}	Off-state cathode current	3	V_{KA} = 36 V, $V_{I(ref)}$ = 0		0.1	1		0.1	1		0.1	3	μA
$\lvert z_{KA} \rvert$	Dynamic impedance §	1	I_{KA} = 1 mA to 100 mA, $V_{KA} = V_{I(ref)}$, f ≤ 1 kHz		0.2	0.5		0.2	0.5		0.2	0.9*	Ω

* On products compliant to MIL-STD-883, Class B, this parameter is not production tested.

† Full temperature range is 0°C to 70°C for the TL431C, –40°C to 85°C for the TL431I, and –55°C to 125°C for the TL431M.

‡ The deviation parameters $V_{refI(dev)}$ and $I_{refI(dev)}$ 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:

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



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

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

Example: Max $V_{I(ref)}$ = 2496 mV at 30°C, Min $V_{I(ref)}$ = 2492 mV at 0°C, $V_{I(ref)}$ = 2495 mV at 25°C, ΔT_A = 70°C for TL431C

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

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

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

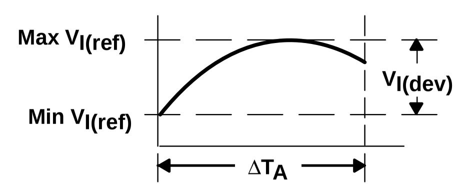
electrical characteristics over recommended operating conditions, T_A = 25°C (unless otherwise noted)

PARAMETER		TEST CIRCUIT	TEST CONDITIONS		TL431AC			TL431AI			UNIT
					MIN	TYP	MAX	MIN	TYP	MAX	
$V_{I(ref)}$	Reference input voltage	1	$V_{KA} = V_{I(ref)}$, I_{KA} = 10 mA		2470	2495	2520	2470	2495	2520	mV
$V_{I(dev)}$	Deviation of reference input voltage over full temperature range‡	1	$V_{KA} = V_{I(ref)}$, I_{KA} = 10 mA, T_A = Full range†			4	15		5	25	mV
$\frac{\Delta V_{I(ref)}}{\Delta V_{KA}}$	Ratio of change in reference input voltage to the change in cathode voltage	2	I_{KA} = 10 mA	ΔV_{KA} = 10 V – $V_{I(ref)}$		–1.4	–2.7		–1.4	–2.7	$\frac{mV}{V}$
				ΔV_{KA} = 36 V – 10 V		–1	–2		–1	–2	
$I_{I(ref)}$	Reference input current	2	I_{KA} = 10 mA, R1 = 10 kΩ, R2 = ∞			2	4		2	4	µA
$I_{I(dev)}$	Deviation of reference input current over full temperature range‡	2	I_{KA} = 10 mA, R1 = 10 kΩ, R2 = ∞, T_A = Full range†			0.8	1.2		0.8	2.5	µA
I_{min}	Minimum cathode current for regulation	1	$V_{KA} = V_{I(ref)}$			0.4	0.6		0.4	0.7	mA
I_{off}	Off-state cathode current	3	V_{KA} = 36 V, $V_{I(ref)}$ = 0			0.1	0.5		0.1	0.5	µA
$\lvert z_{ka}\rvert$	Dynamic impedance§	1	$V_{KA} = V_{I(ref)}$, I_{KA} = 1 mA to 100 mA, f ≤ 1 kHz			0.2	0.5		0.2	0.5	Ω

† Full temperature range is 0°C to 70°C for the TL431AC and –40°C to 85°C for the TL431AI.

‡ The deviation parameters $V_{refI(dev)}$ and $I_{refI(dev)}$ 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:

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



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

$\alpha_{VI(ref)}$ can be positive or negative depending on whether minimum $V_{I(ref)}$ or maximum $V_{I(ref)}$, respectively, occurs at the lower temperature.
Example: Max $V_{I(ref)}$ = 2496 mV at 30°C, Min $V_{I(ref)}$ = 2492 mV at 0°C, $V_{I(ref)}$ = 2495 mV at 25°C, ΔT_A = 70°C for TL431AC

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

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

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

electrical characteristics over recommended operating conditions, T_A = 25°C (unless otherwise noted)

PARAMETER		TEST CIRCUIT	TEST CONDITIONS		TL431Y MIN	TL431Y TYP	TL431Y MAX	UNIT
$V_{I(ref)}$	Reference input voltage	1	$V_{KA} = V_{I(ref)}$, I_{KA} = 10 mA			2495		mV
$\frac{\Delta V_{I(ref)}}{\Delta V_{KA}}$	Ratio of change in reference input voltage to the change in cathode voltage	2	I_{KA} = 10 mA	ΔV_{KA} = 10 V – $V_{I(ref)}$		–1.4		$\frac{mV}{V}$
				ΔV_{KA} = 36 V – 10 V		–1		
$I_{I(ref)}$	Reference input current	2	I_{KA} = 10 mA, R1 = 10 kΩ, R2 = ∞			2		μA
I_{min}	Minimum cathode current for regulation	1	$V_{KA} = V_{I(ref)}$			0.4		mA
I_{off}	Off-state cathode current	3	V_{KA} = 36 V, $V_{I(ref)}$ = 0			0.1		μA
$\lvert z_{KA} \rvert$	Dynamic impedance†	1	$V_{KA} = V_{I(ref)}$, I_{KA} = 1 mA to 100 mA, f ≤ 1 kHz			0.2		Ω

† The dynamic impedance is defined as: $\lvert z_{ka} \rvert = \frac{\Delta V_{KA}}{\Delta I_{KA}}$

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

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

PARAMETER MEASUREMENT INFORMATION

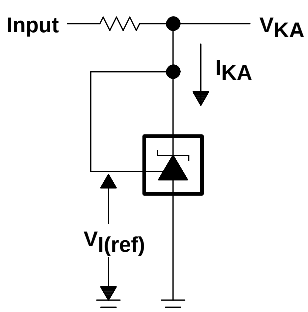


Figure 1. Test Circuit for $V_{KA} = V_{I(ref)}$

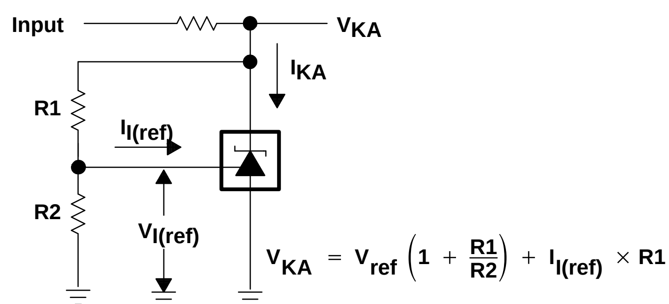


Figure 2. Test Circuit for $V_{KA} > V_{I(ref)}$

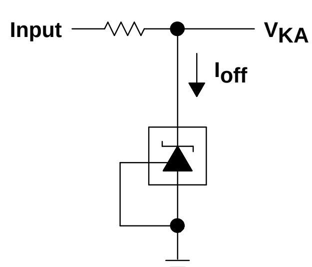


Figure 3. Test Circuit for I_{off}

TYPICAL CHARACTERISTICS

Table of Graphs

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

Table of Application Circuits

	FIGURE
Precision 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
High-current shunt regulator	20
Crowbar circuit	21
Precision 5-V, 1.5-A regulator	22
Efficient 5-V, precision regulator	23
PWM down converter with reference	24
Voltage monitor	25
Delay timer	26
Precision current limiter	27
Precision constant-current sink	28

TYPICAL CHARACTERISTICS†

REFERENCE INPUT VOLTAGE vs FREE-AIR TEMPERATURE†

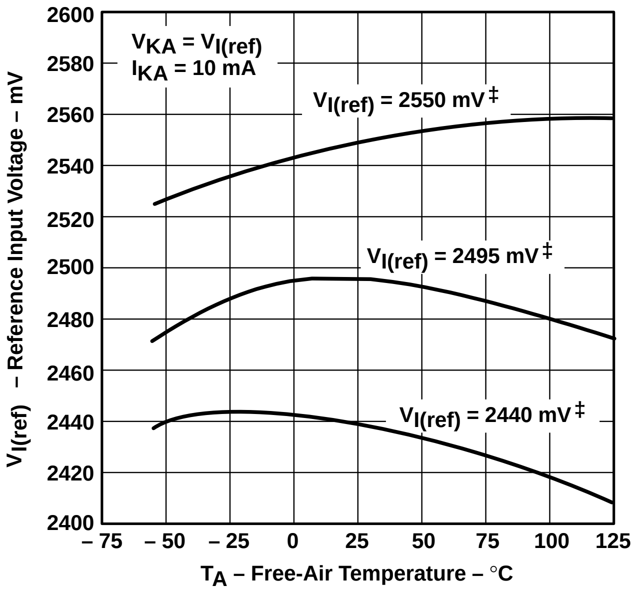


Figure 4

REFERENCE INPUT CURRENT vs FREE-AIR TEMPERATURE†

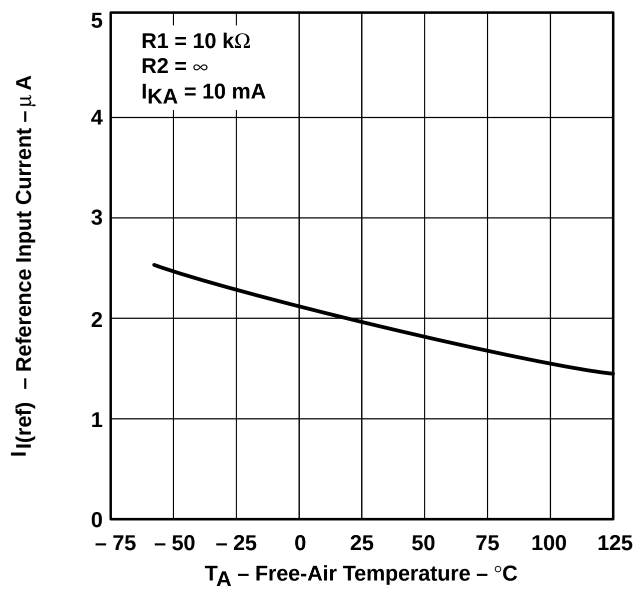


Figure 5

CATHODE CURRENT vs CATHODE VOLTAGE

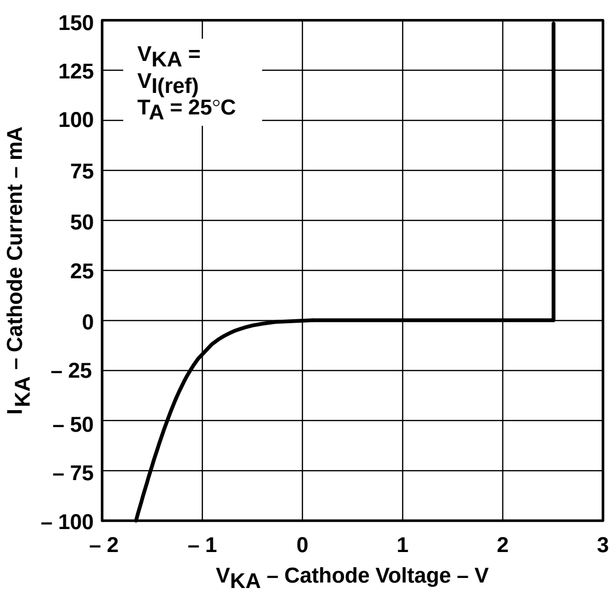


Figure 6

CATHODE CURRENT vs CATHODE VOLTAGE

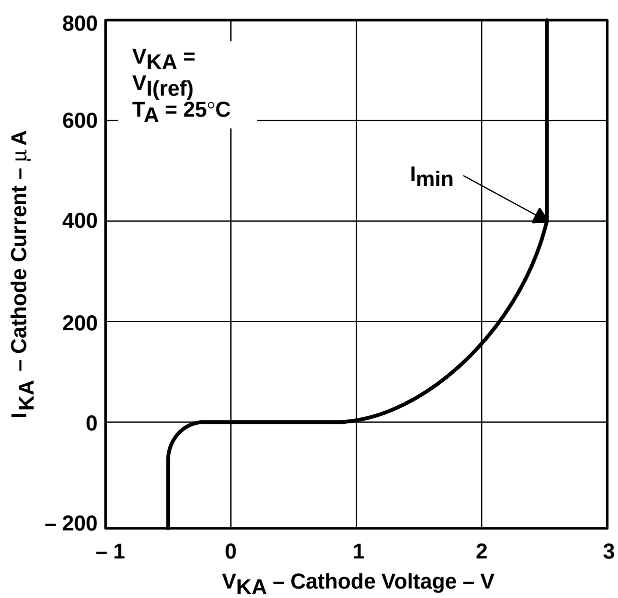


Figure 7

† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.
‡ Data is for devices having the indicated value of $V_{I(ref)}$ at I_{KA} = 10 mA, T_A = 25°C.

TYPICAL CHARACTERISTICS†

OFF-STATE CATHODE CURRENT
vs
FREE-AIR TEMPERATURE

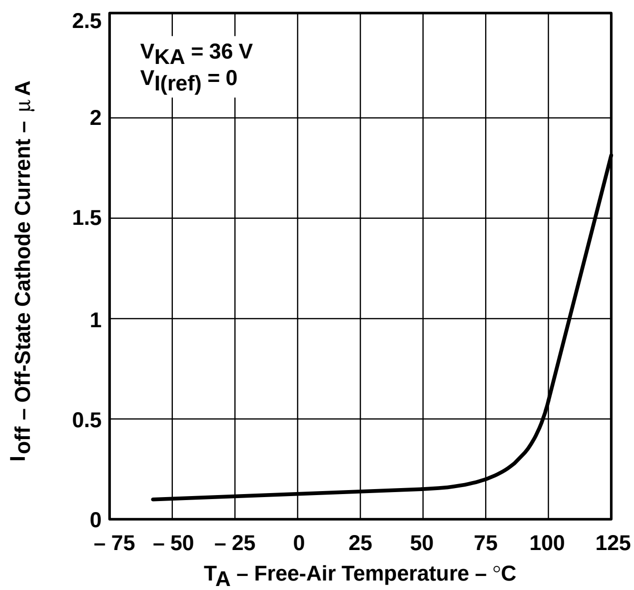


Figure 8

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

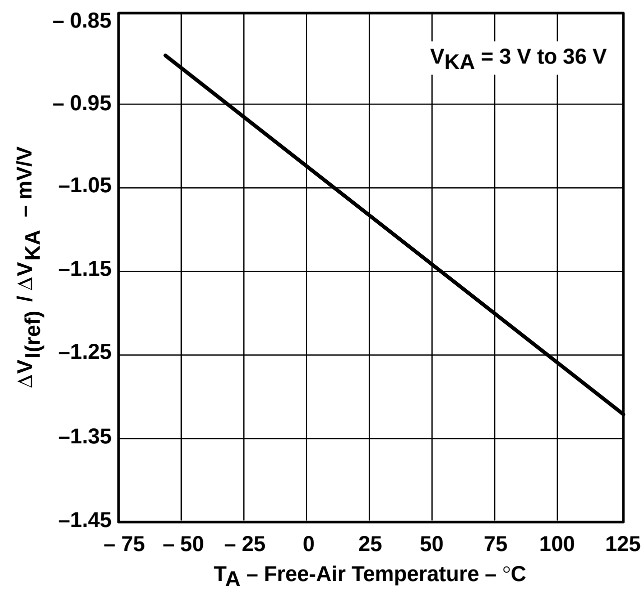


Figure 9

EQUIVALENT INPUT NOISE VOLTAGE
vs
FREQUENCY

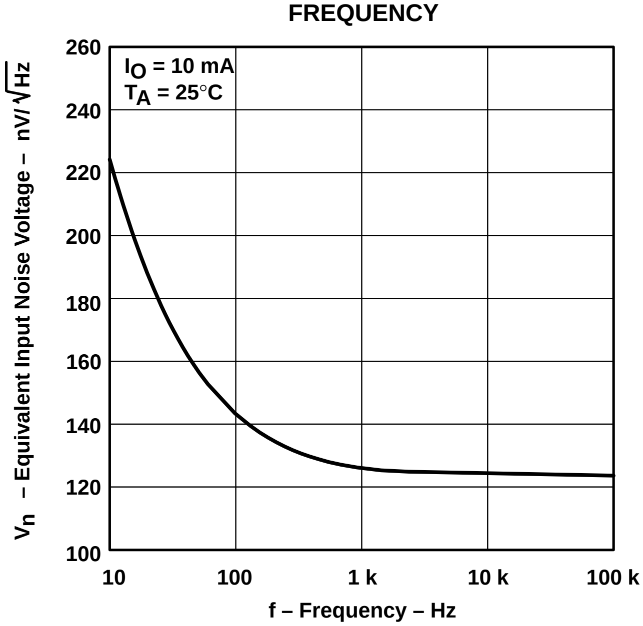
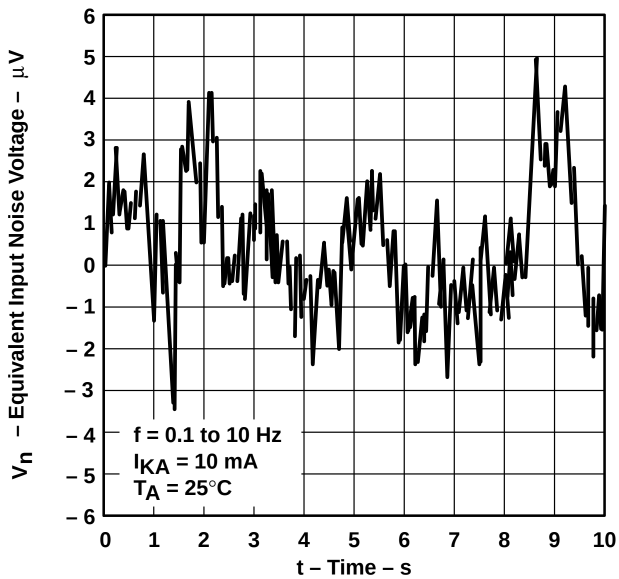


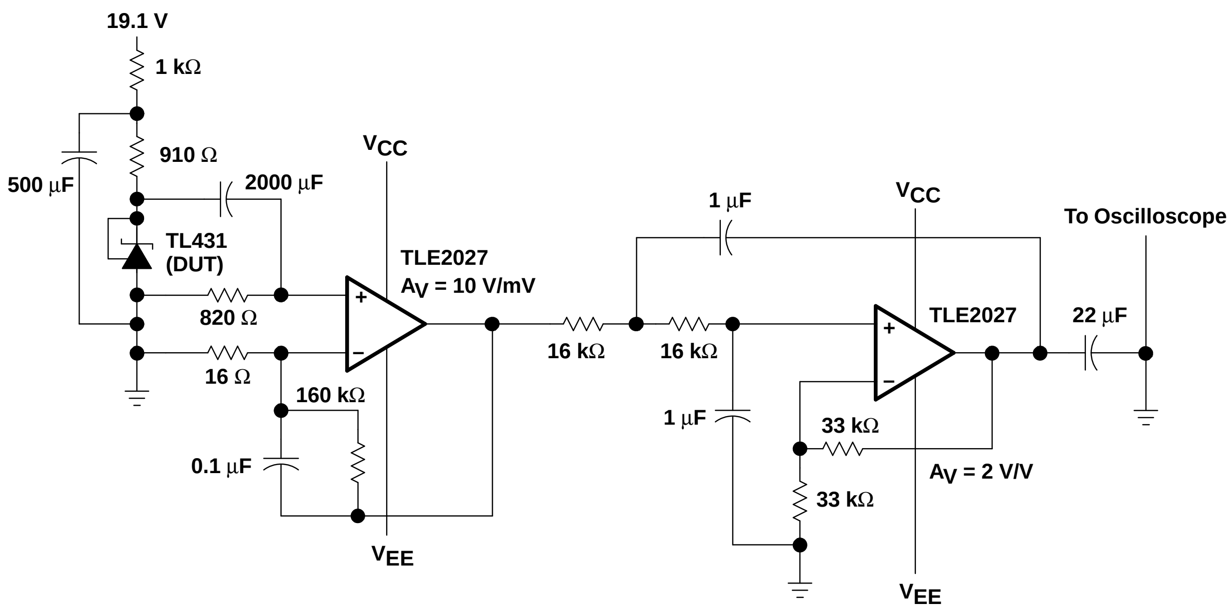
Figure 10

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

TYPICAL CHARACTERISTICS

EQUIVALENT INPUT NOISE VOLTAGE OVER A 10-SECOND PERIOD

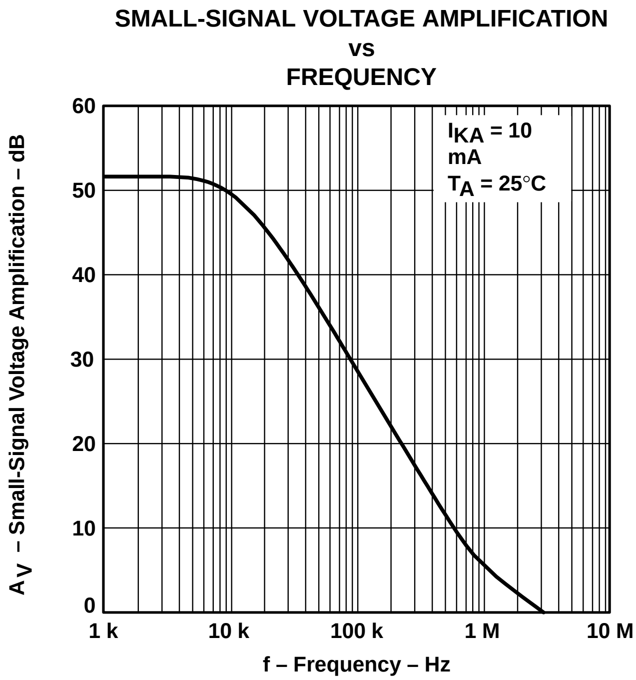


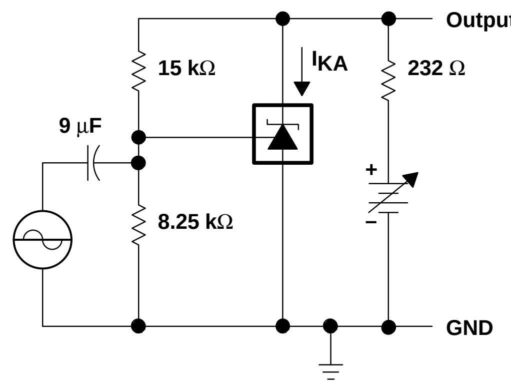


TEST CIRCUIT FOR EQUIVALENT INPUT NOISE VOLTAGE

Figure 11

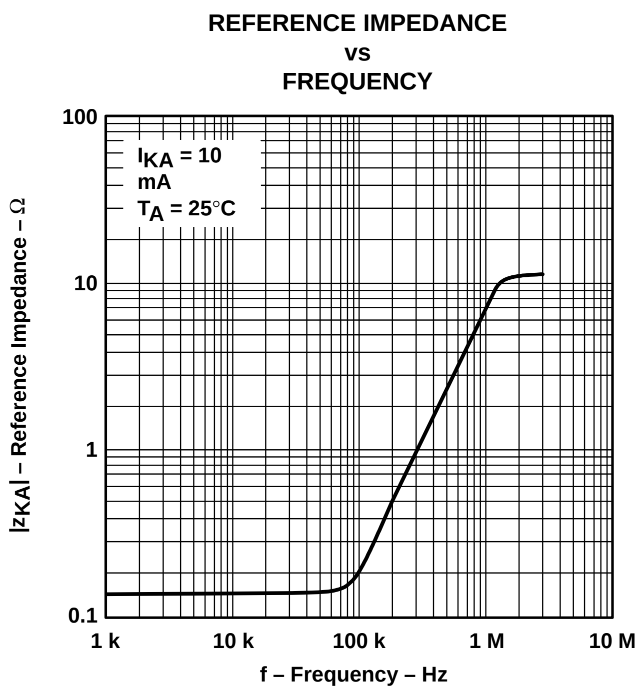
TYPICAL CHARACTERISTICS

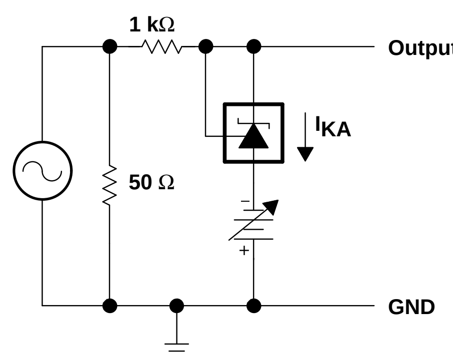




TEST CIRCUIT FOR VOLTAGE AMPLIFICATION

Figure 12

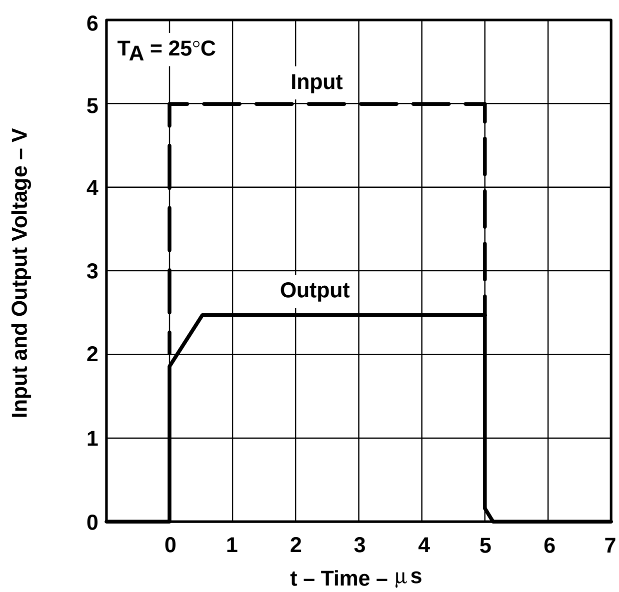


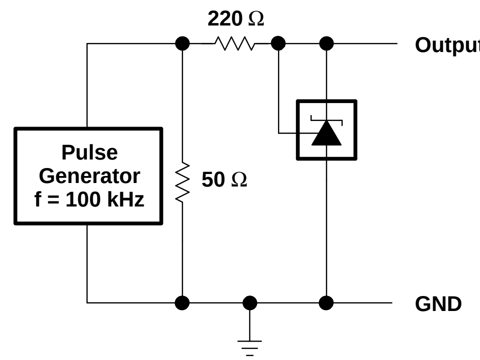


TEST CIRCUIT FOR REFERENCE IMPEDANCE

Figure 13

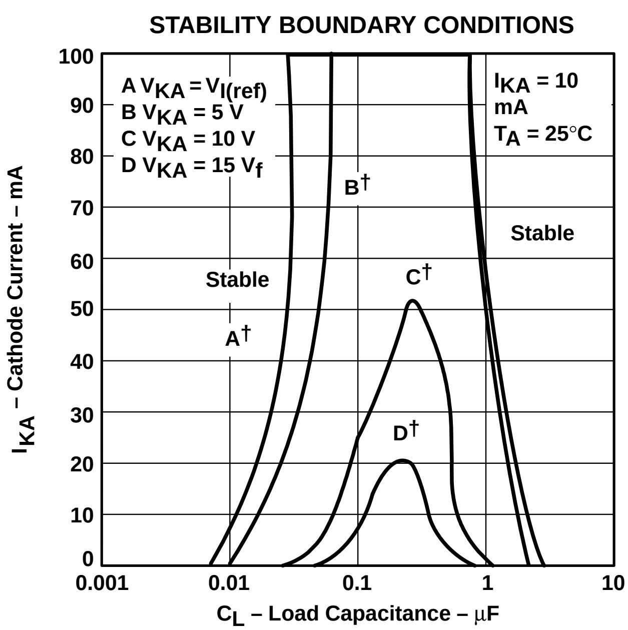
TYPICAL CHARACTERISTICS

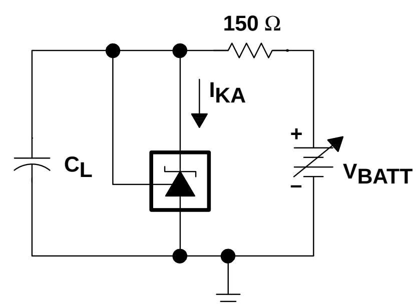




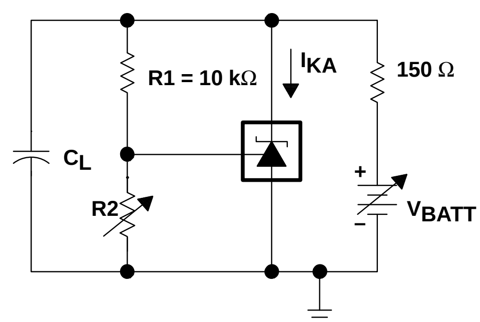
TEST CIRCUIT FOR PULSE RESPONSE

Figure 14





TEST CIRCUIT FOR CURVE A

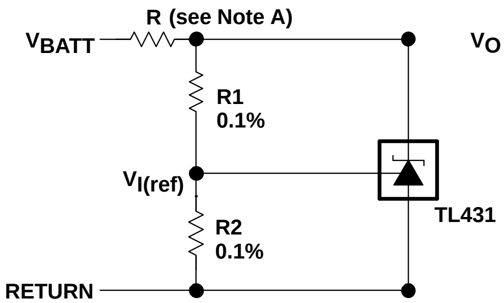


TEST CIRCUIT FOR CURVES B, C, AND D

Figure 15

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

APPLICATION INFORMATION



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

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

Figure 16. Shunt Regulator

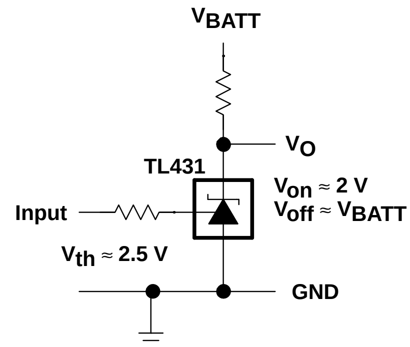
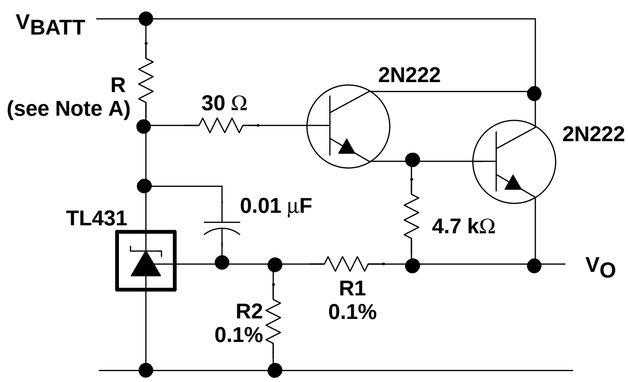


Figure 17. Single-Supply Comparator With Temperature-Compensated Threshold

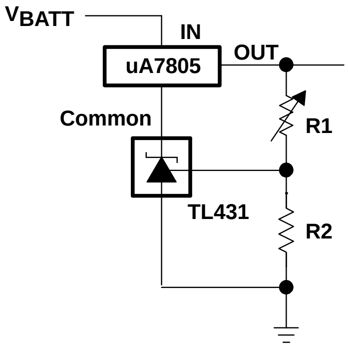


$$V_O = \left(1 + \frac{R1}{R2}\right) V_{ref}$$

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

Figure 18. Precision High-Current Series Regulator

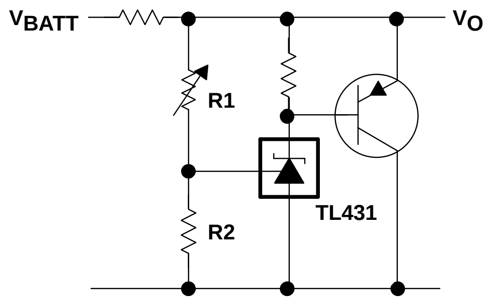
APPLICATION INFORMATION



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

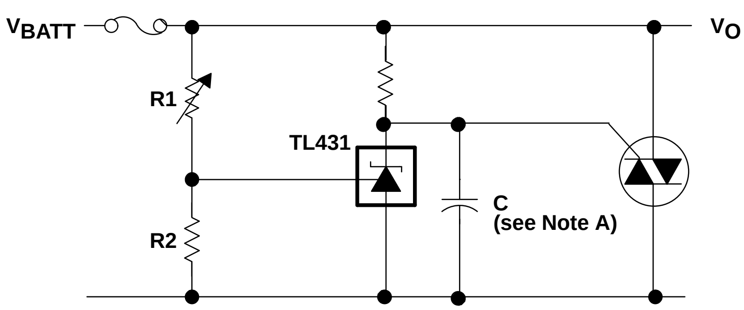
$$\text{Min } V_O = V_{I(ref)} + 5\text{ V}$$

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



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

Figure 20. High-Current Shunt Regulator



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

Figure 21. Crowbar Circuit

APPLICATION INFORMATION

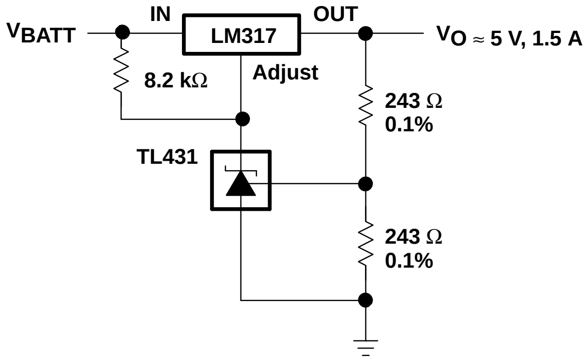
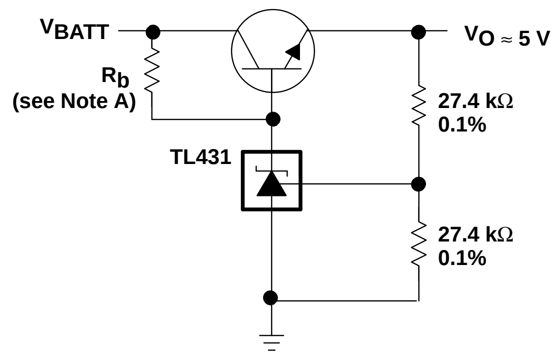


Figure 22. Precision 5-V, 1.5-A Regulator



NOTE A. R_b should provide cathode current ≥ 1-mA to the TL431.

Figure 23. Efficient 5-V Precision Regulator

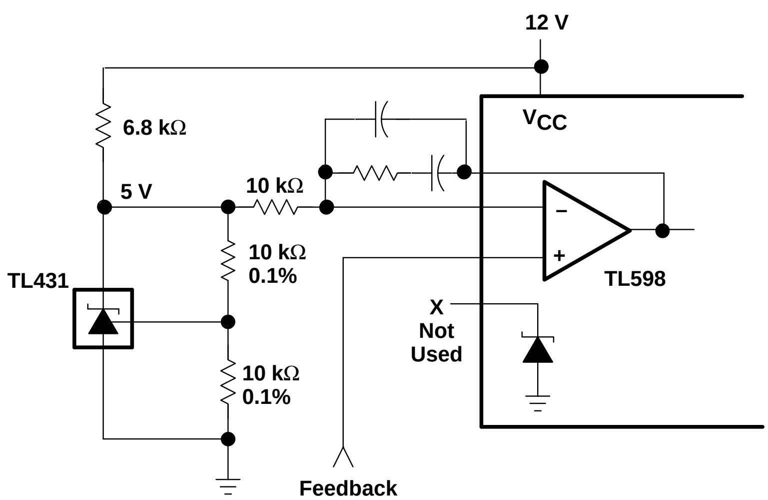
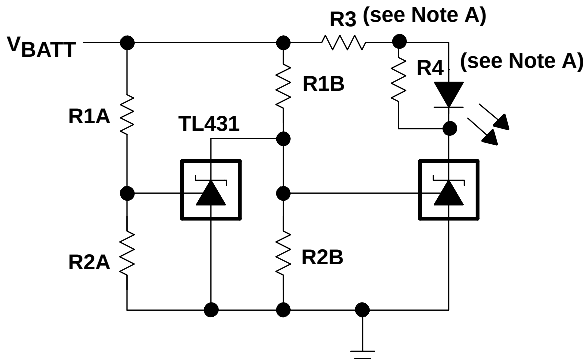


Figure 24. PWM Converter With Reference

APPLICATION INFORMATION



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

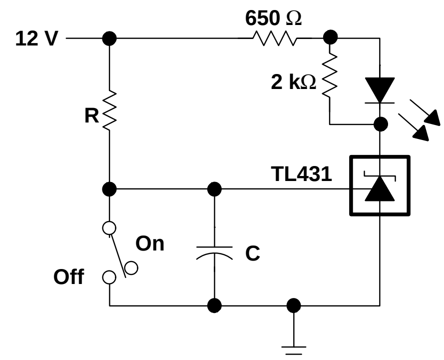
$$\text{High Limit} = \left(1 + \frac{R1A}{R2A}\right) V_{I(ref)}$$

LED on when

Low Limit $< V_{BATT} <$ High Limit

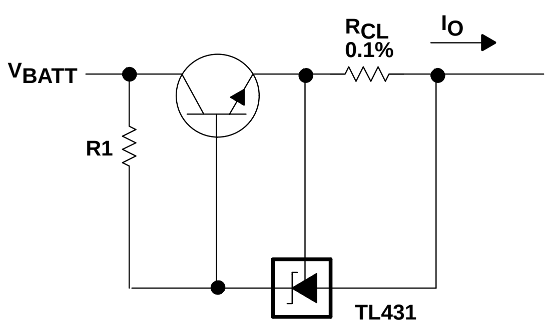
NOTE A: R3 and R4 are selected to provide the desired LED intensity and cathode current ≥ 1 mA to the TL431 at the available V_{BATT}.

Figure 25. Voltage Monitor



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

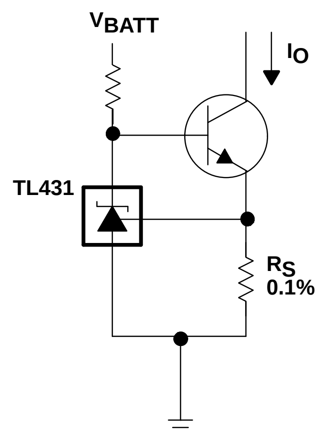
Figure 26. Delay Timer



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

$$R1 = \frac{V_{BATT}}{\frac{I_O}{h_{FE}} + I_{KA}}$$

Figure 27. Precision Current Limiter



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

Figure 28. Precision Constant-Current Sink

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