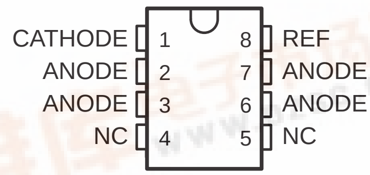
TLV431, TLV431A
LOW-VOLTAGE ADJUSTABLE PRECISION SHUNT REGULATORS

SLVS139D – JULY 1996 – REVISED AUGUST 2000

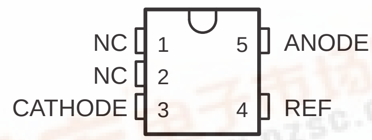
- **Low-Voltage Operation . . . Down to 1.24 V**
- **1% Reference-Voltage Tolerance (TLV431A)**
- **Adjustable Output Voltage, $V_O = V_{ref}$ to 6 V**
- **Low Operational Cathode Current . . . 80 μA Typ**
- **0.25-Ω Typical Output Impedance**
- **Package Options Include Plastic Small-Outline (D), Small-Outline Transistor (DBV), and Cylindrical (LP) Packages**

D PACKAGE
(TOP VIEW)



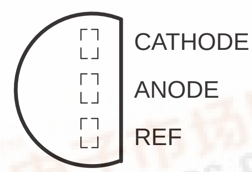
NC – No internal connection

DBV PACKAGE
(TOP VIEW)



NC – No internal connection

LP PACKAGE
(TOP VIEW)



description

The TLV431 and TLV431A are low-voltage three-terminal adjustable voltage references with specified thermal stability over applicable industrial and commercial temperature ranges. Output voltage can be set to any value between V_{ref} (1.24 V) and 6 V with two external resistors (see Figure 2). The TLV431 and TLV431A operate from a lower voltage (1.24 V) than the widely used TL431 and TL1431 shunt-regulator references.

When used with an optocoupler, the TLV431 and TLV431A are ideal voltage references in isolated feedback circuits for 3-V to 3.3-V switching-mode power supplies. These devices have a typical output impedance of 0.25 Ω. Active output circuitry provides a very sharp turn-on characteristic, making the TLV431 and TLV431A excellent replacements for low-voltage zener diodes in many applications, including onboard regulation and adjustable power supplies.

The TLV431C and TLV431AC devices are characterized for operation from 0°C to 70°C. The TLV431I and TLV431AI devices are characterized for operation from –40°C to 85°C.

AVAILABLE OPTIONS

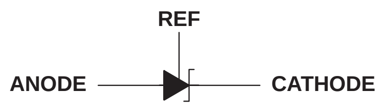
T_A	PACKAGED DEVICES		
	TO-92 (LP)	SOIC (D)	5-PIN SOT-23 (DBV)
0°C to 70°C	TLV431CLP TLV431ACLP	— —	TLV431CDBV TLV431ACDBV
–40°C to 85°C	TLV431ILP TLV431AILP	— TLV431AID	TLV431IDBV TLV431AIDBV

The D and LP packages are available taped and reeled. Add the suffix R to the device type (e.g., TLV431ACLPR). The DBV package is available only taped and reeled (e.g., TLV431AIDR).

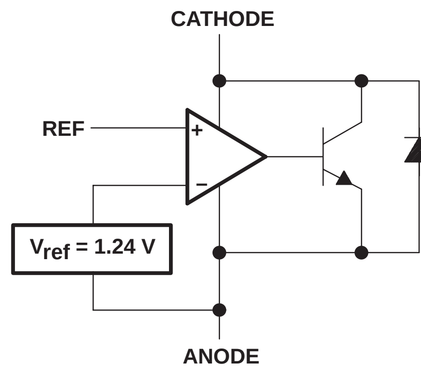
Please be aware that an important notice concerning availability, standard warranty, and use in critical applications of Texas Instruments semiconductor products and disclaimers thereto appears at the end of this data sheet.

TEXAS INSTRUMENTS

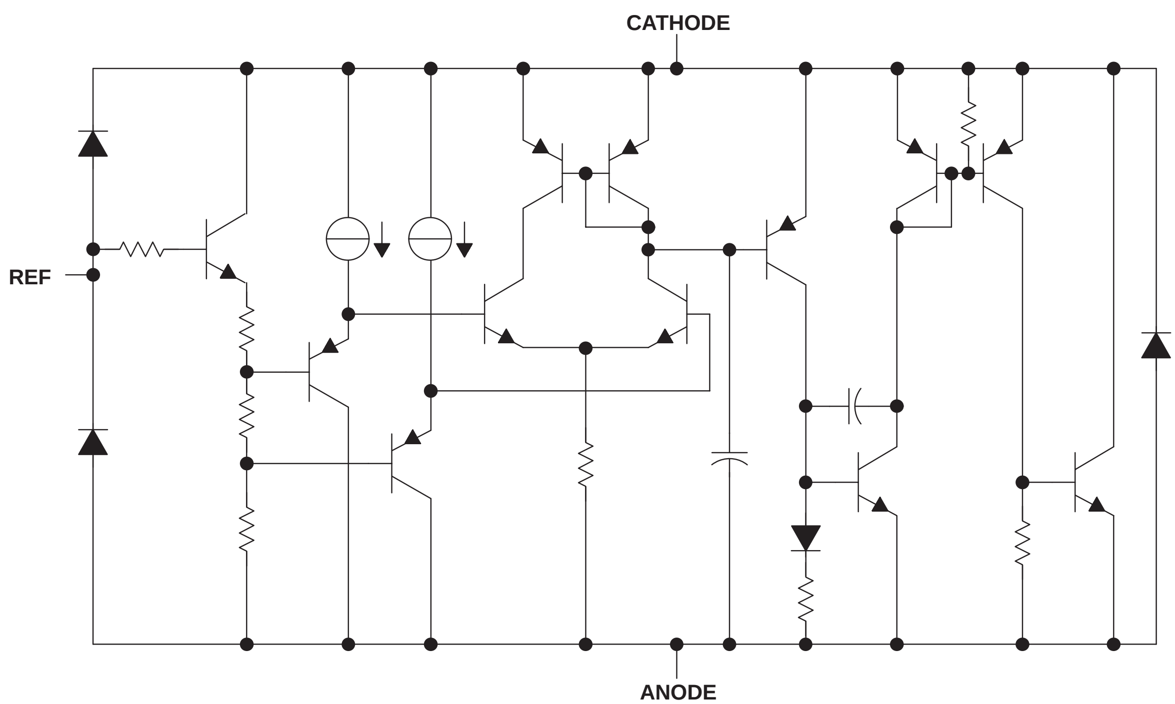
logic symbol



logic diagram (positive logic)



equivalent schematic



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

Cathode voltage, V_{KA} (see Note 1) . . . . 7 V
Continuous cathode current range, I_K . . . . –20 mA to 20 mA
Reference current range, I_{ref} . . . . –0.05 mA to 3 mA
Package thermal impedance, θ_{JA} (see Notes 2 and 3): D package . . . . 97°C/W
DBV package . . . . 206°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: 1. Voltage values are with respect to the anode terminal unless otherwise noted.
2. Maximum power dissipation is a function of T_J(max), θ_{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 affect reliability.
3. The package thermal impedance is calculated in accordance with JESD 51.

recommended operating conditions

		MIN	MAX	UNIT
Cathode voltage, V_{KA}		V_{ref}	6	V
Cathode current, I_K		0.1	15	mA
Operating free-air temperature range, T_A	TLV431C, TLV431AC	0	70	°C
	TLV431I, TLV431AI	–40	85	

electrical characteristics, T_A = 25°C (unless otherwise noted)

PARAMETER		TEST CONDITIONS		TLV431C			TLV431I			UNIT
				MIN	TYP	MAX	MIN	TYP	MAX	
V_{ref}	Reference voltage	$V_{KA} = V_{ref}$, I_K = 10 mA	T_A = 25°C	1.222	1.24	1.258	1.222	1.24	1.258	V
			T_A = full range (see Note 4 and Figure 1)	1.21		1.27	1.202		1.278	
$V_{ref(dev)}$	V_{ref} deviation over full temperature range (see Note 5)	$V_{KA} = V_{ref}$, I_K = 10 mA, (see Note 4 and Figure 1)			4	12		6	20	mV
$\frac{\Delta V_{ref}}{\Delta V_{KA}}$	Ratio of V_{ref} change in cathode voltage change	I_K = 10 mA, $V_{KA} = V_{ref}$ to 6 V, (see Figure 2)			–1.5	–2.7		–1.5	–2.7	mV/V
I_{ref}	Reference terminal current	I_K = 10 mA, R1 = 10 kΩ, R2 = open (see Figure 2)			0.15	0.5		0.15	0.5	µA
$I_{ref(dev)}$	I_{ref} deviation over full temperature range (see Note 5)	I_K = 10 mA, R1 = 10 kΩ, R2 = open (see Note 4 and Figure 2)			0.05	0.3		0.1	0.4	µA
$I_{K(min)}$	Minimum cathode current for regulation	$V_{KA} = V_{ref}$ (see Figure 1)			55	80		55	80	µA
$I_{K(off)}$	Off-state cathode current	V_{KA} = 6 V, V_{ref} = 0 (see Figure 3)			0.001	0.1		0.001	0.1	µA
$\|z_{KA}\|$	Dynamic impedance (see Note 6)	$V_{KA} = V_{ref}$, f ≤ 1 kHz, I_K = 0.1 mA to 15 mA (see Figure 1)			0.25	0.4		0.25	0.4	Ω

NOTES: 4. Full range is –40°C to 85°C for the TLV431I, and 0°C to 70°C for the TLV431C.

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

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

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

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

6. 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:

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

electrical characteristics, T_A = 25°C (unless otherwise noted)

PARAMETER		TEST CONDITIONS		TLV431AC			TLV431AI			UNIT
				MIN	TYP	MAX	MIN	TYP	MAX	
V_{ref}	Reference voltage	$V_{KA} = V_{ref}$, I_K = 10 mA,	T_A = 25°C	1.228	1.24	1.252	1.228	1.24	1.252	V
			T_A = full range, (see Note 4 and Figure 1)	1.221		1.259	1.215		1.265	
$V_{ref(dev)}$	V_{ref} deviation over full temperature range (see Note 5)	$V_{KA} = V_{ref}$, I_K = 10 mA (see Note 4 and Figure 1)			4	12		6	20	mV
$\frac{\Delta V_{ref}}{\Delta V_{KA}}$	Ratio of V_{ref} change in cathode voltage change	I_K = 10 mA, $V_{KA} = V_{ref}$ to 6 V (see Figure 2)			–1.5	–2.7		–1.5	–2.7	mV/V
I_{ref}	Reference terminal current	I_K = 10 mA, R1 = 10 kΩ (see Figure 2)			0.15	0.5		0.15	0.5	µA
$I_{ref(dev)}$	I_{ref} deviation over full temperature range (see Note 5)	I_K = 10 mA, R1 = 10 kΩ, R2 = open (see Note 4 and Figure 2)			0.05	0.3		0.1	0.4	µA
$I_{K(min)}$	Minimum cathode current for regulation	$V_{KA} = V_{ref}$ (see Figure 1)			55	80		55	80	µA
$I_{K(off)}$	Off-state cathode current	V_{KA} = 6 V, V_{ref} = 0, (see Figure 3)			0.001	0.1		0.001	0.1	µA
$\lvert z_{KA}\rvert$	Dynamic impedance (see Note 6)	$V_{KA} = V_{ref}$, f ≤ 1 kHz, I_K = 0.1 mA to 15 mA (see Figure 1)			0.25	0.4		0.25	0.4	Ω

NOTES:
7. Full range is –40°C to 85°C for the TLV431I, and 0°C to 70°C for the TLV431C.
8. The deviation parameters $V_{ref(dev)}$ and $I_{ref(dev)}$ 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, $\alpha_{V_{ref}}$, is defined as:

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

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

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

9. 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:

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

PARAMETER MEASUREMENT INFORMATION

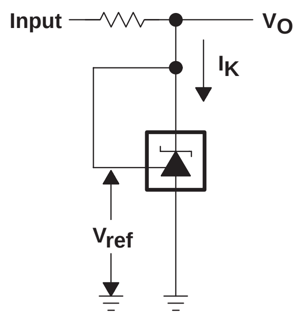


Figure 1. Test Circuit for $V_{KA} = V_{ref}$, $V_O = V_{KA} = V_{ref}$

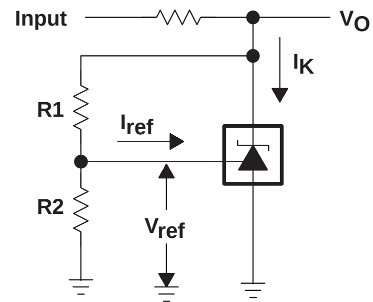


Figure 2. Test Circuit for $V_{KA} > V_{ref}$, $V_O = V_{KA} = V_{ref} \times (1 + R1/R2) + I_{ref} \times R1$

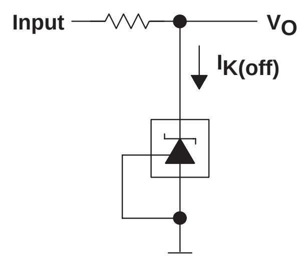


Figure 3. Test Circuit for $I_{K(off)}$

PARAMETER MEASUREMENT INFORMATION†

REFERENCE VOLTAGE vs JUNCTION TEMPERATURE

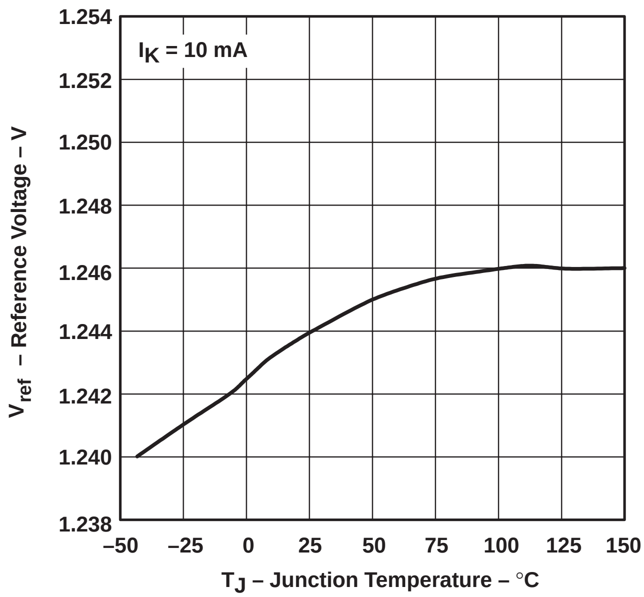


Figure 4

REFERENCE INPUT CURRENT vs JUNCTION TEMPERATURE

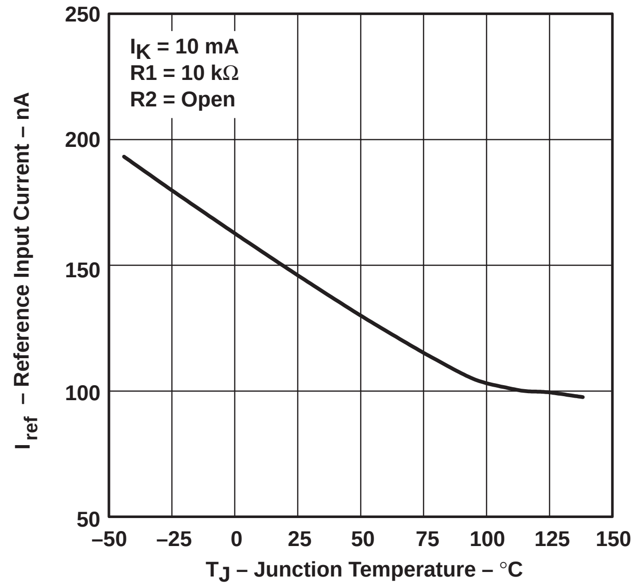


Figure 5

CATHODE CURRENT vs CATHODE VOLTAGE

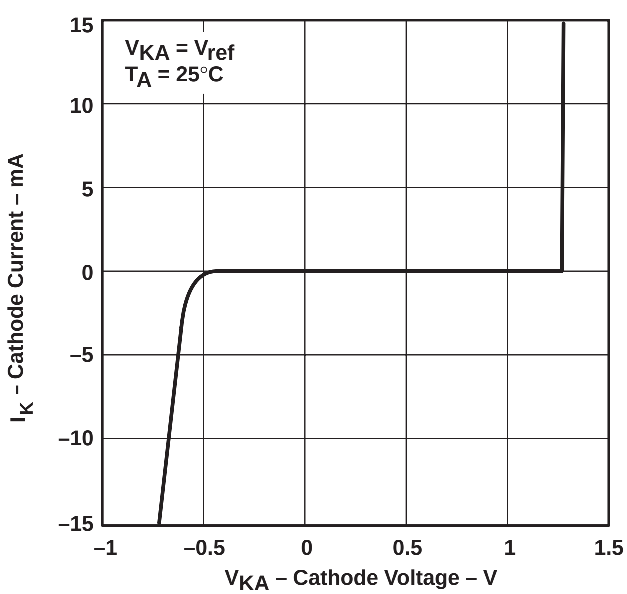


Figure 6

CATHODE CURRENT vs CATHODE VOLTAGE

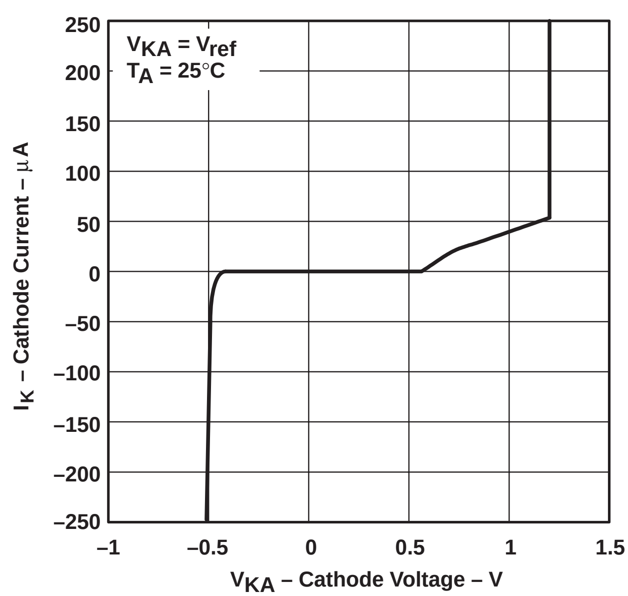


Figure 7

† Operation of the device at these or any other conditions beyond those indicated under “recommended operating conditions” is not implied.

PARAMETER MEASUREMENT INFORMATION†

OFF-STATE CATHODE CURRENT
vs
JUNCTION TEMPERATURE

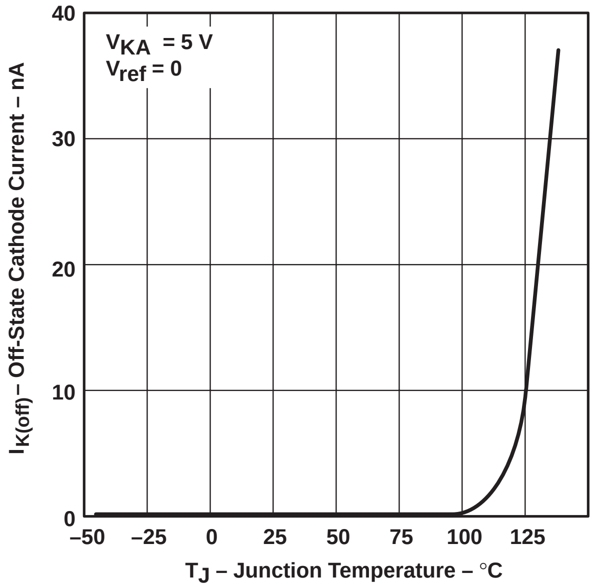


Figure 8

RATIO OF DELTA REFERENCE VOLTAGE
TO DELTA CATHODE VOLTAGE
vs
JUNCTION TEMPERATURE

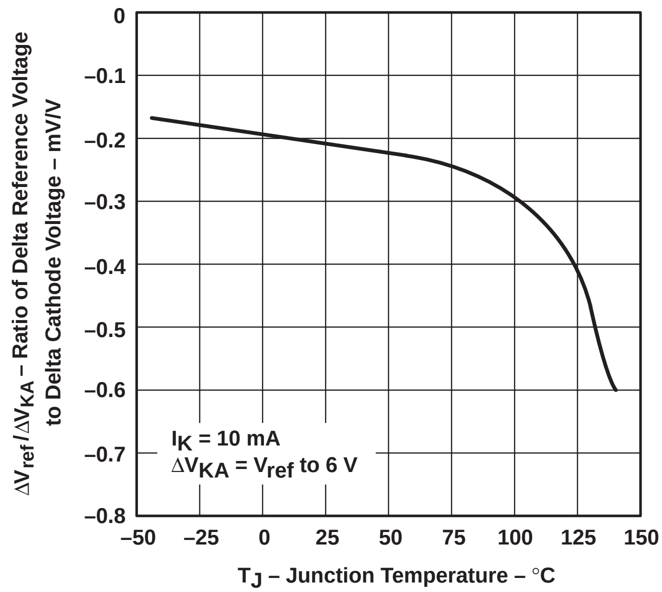
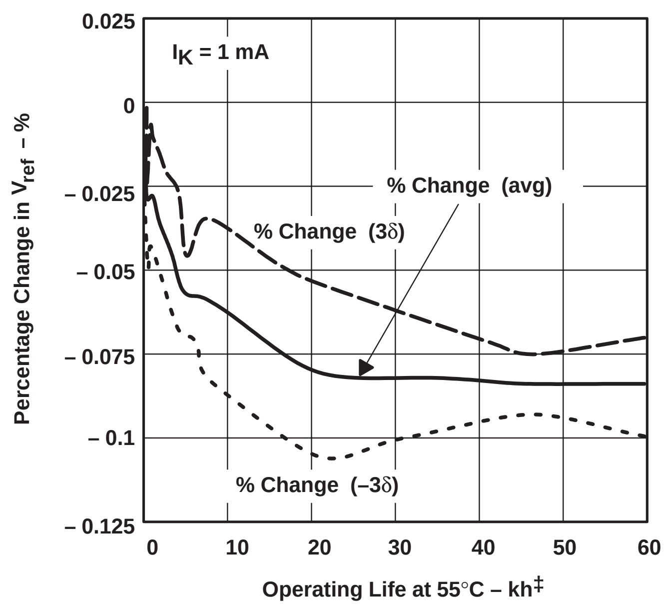


Figure 9

PERCENTAGE CHANGE IN V_{ref}
vs
OPERATING LIFE AT 55°C

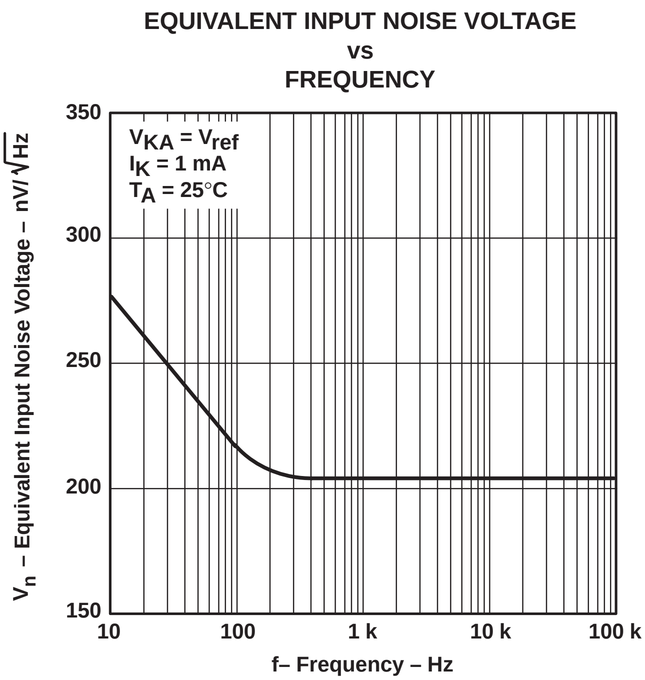


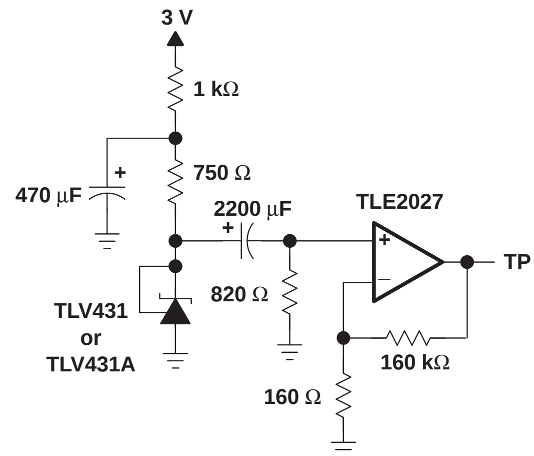
‡ Extrapolated from life-test data taken at 125°C; the activation energy assumed is 0.7 eV.

Figure 10

† Operation of the device at these or any other conditions beyond those indicated under “recommended operating conditions” is not implied.

PARAMETER MEASUREMENT INFORMATION



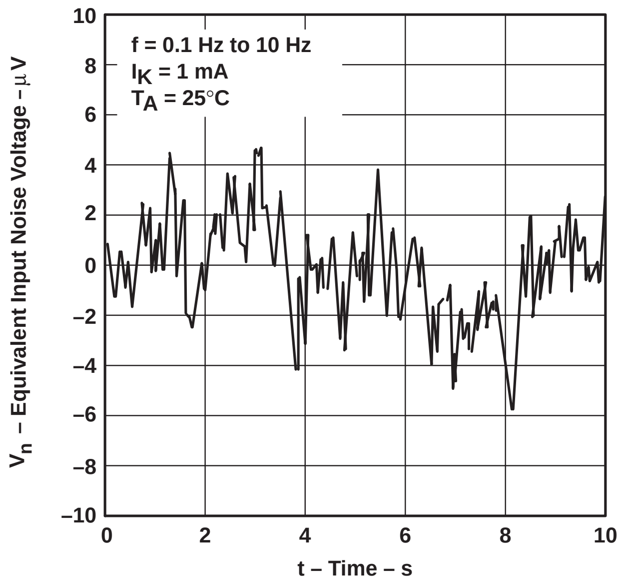


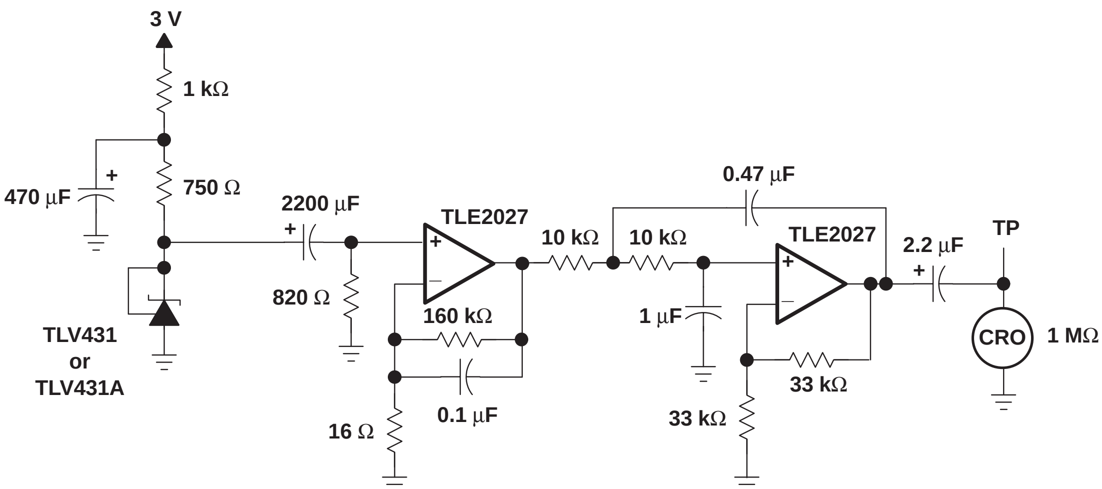
TEST CIRCUIT FOR EQUIVALENT NOISE VOLTAGE

Figure 11

PARAMETER MEASUREMENT INFORMATION

EQUIVALENT INPUT NOISE VOLTAGE
OVER A 10-SECOND PERIOD



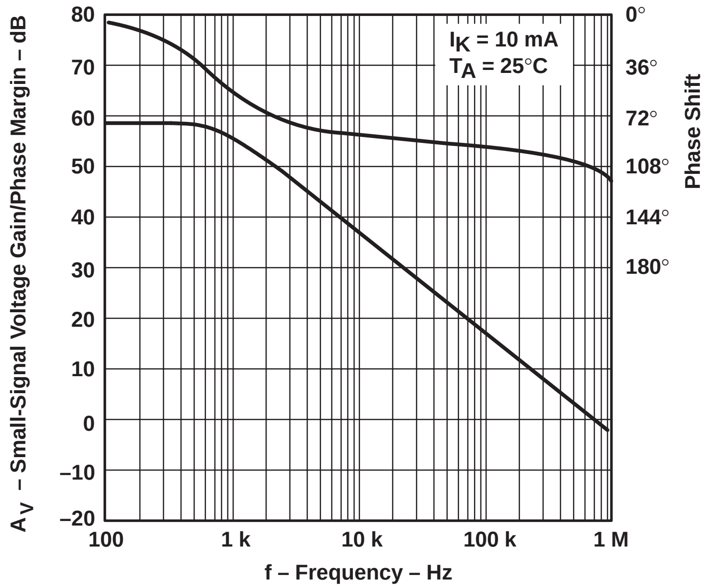


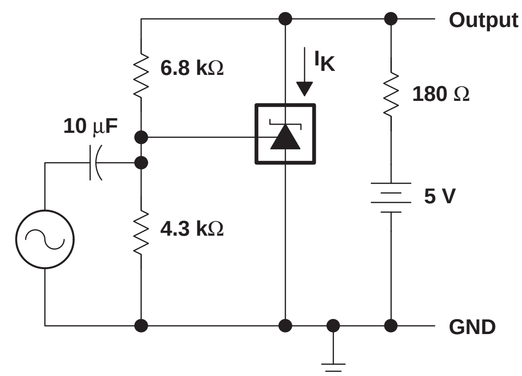
TEST CIRCUIT FOR 0.1-Hz TO 10-Hz EQUIVALENT NOISE VOLTAGE

Figure 12

PARAMETER MEASUREMENT INFORMATION

SMALL-SIGNAL VOLTAGE GAIN /PHASE MARGIN vs FREQUENCY

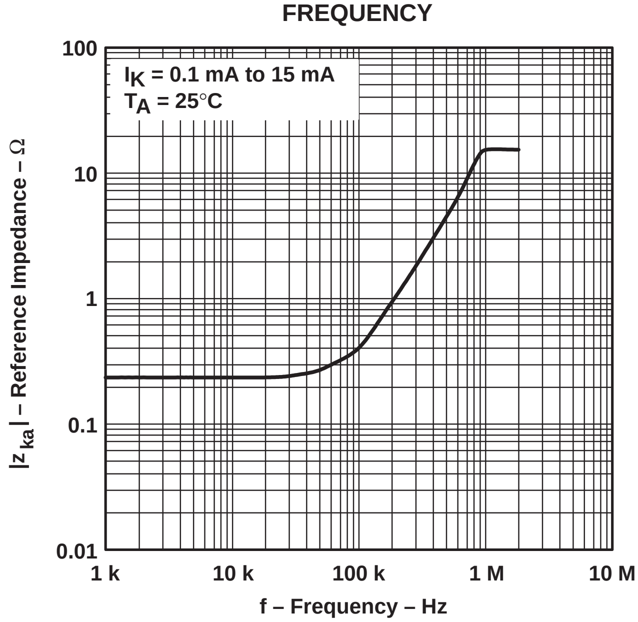


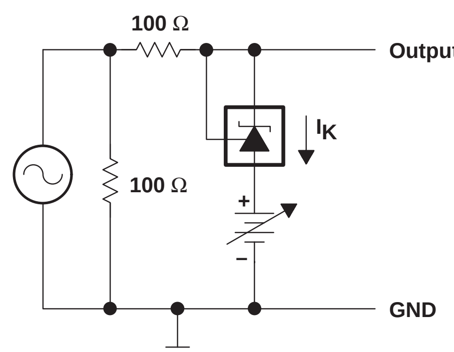


TEST CIRCUIT FOR VOLTAGE GAIN AND PHASE MARGIN

Figure 13

REFERENCE IMPEDANCE vs FREQUENCY

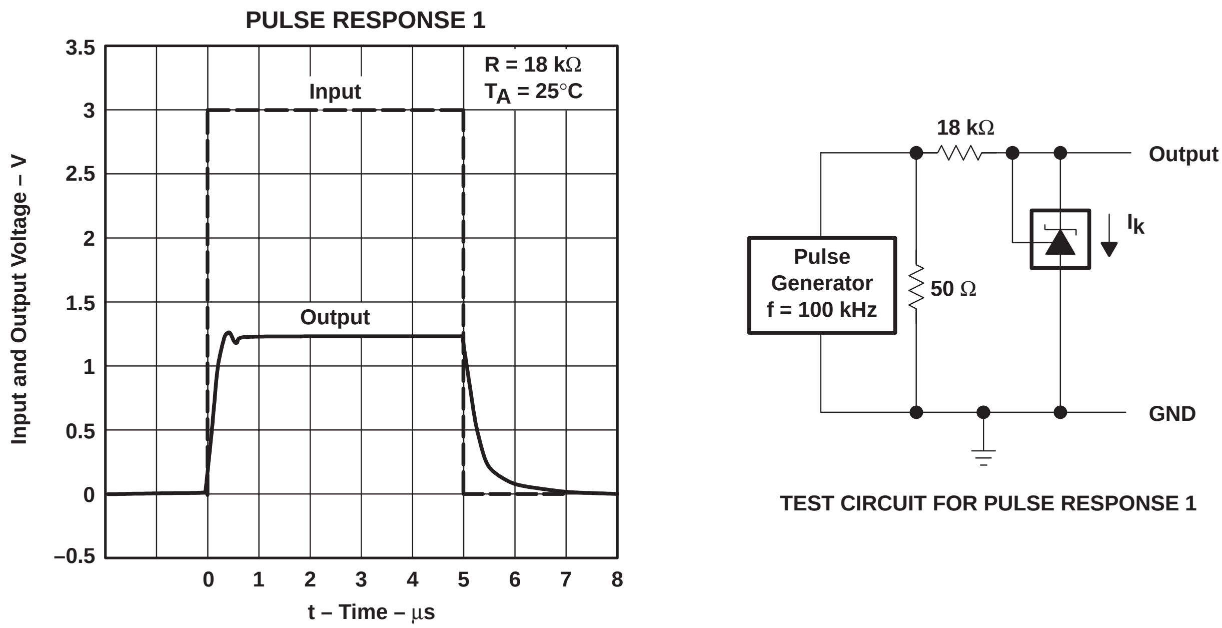




TEST CIRCUIT FOR REFERENCE IMPEDANCE

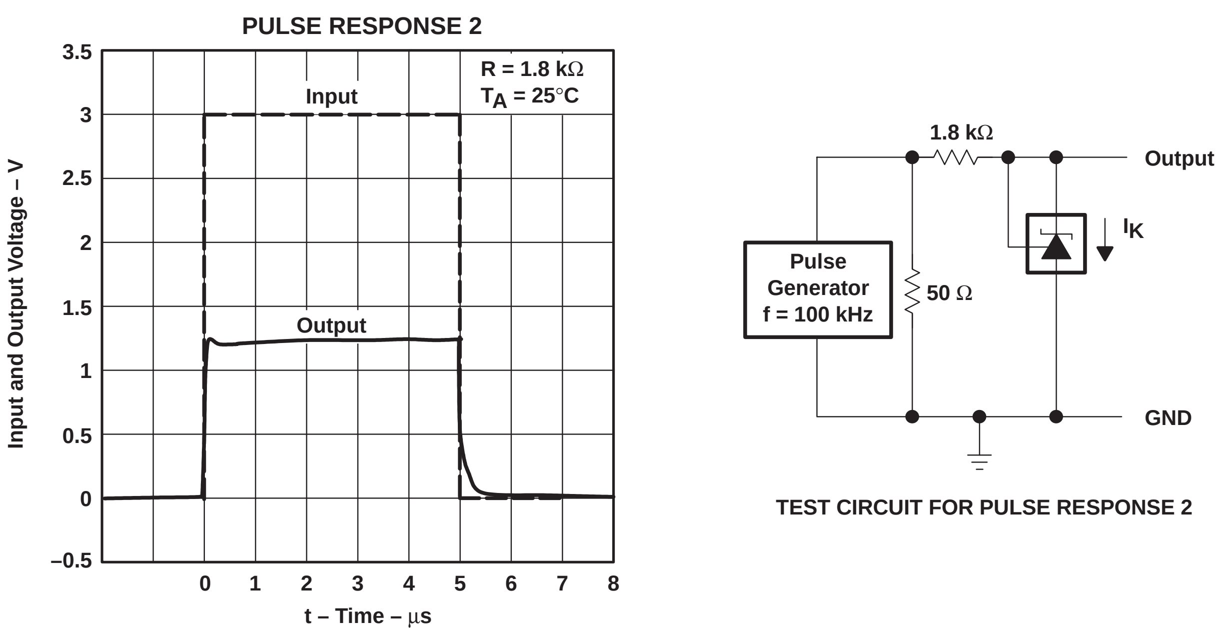
Figure 14

PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT FOR PULSE RESPONSE 1

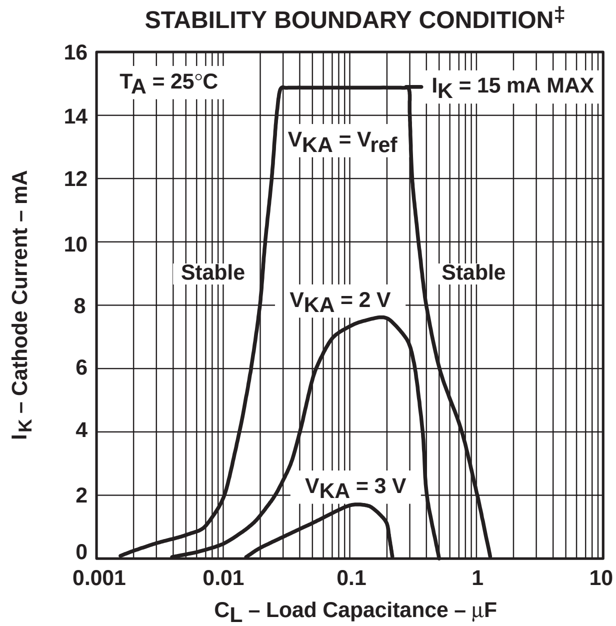
Figure 15

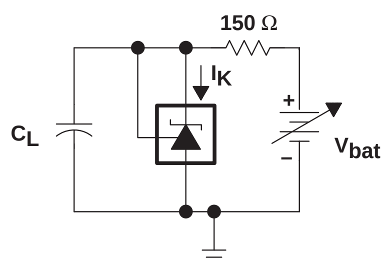


TEST CIRCUIT FOR PULSE RESPONSE 2

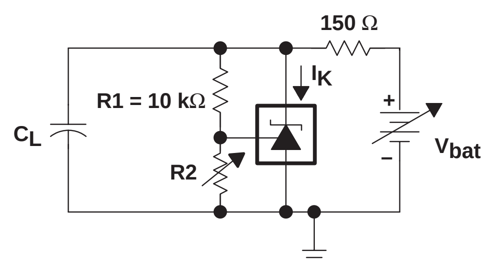
Figure 16

PARAMETER MEASUREMENT INFORMATION†





TEST CIRCUIT FOR $V_{KA} = V_{ref}$



TEST CIRCUIT FOR V_{KA} = 2 V, 3 V

‡ The areas under the curves represent conditions that may cause the device to oscillate. For V_{KA} = 2-V and 3-V curves, R2 and V_{bat} were adjusted to establish the initial V_{KA} and I_K conditions with C_L = 0. V_{bat} and C_L then were adjusted to determine the ranges of stability.

Figure 17

† Operation of the device at these or any other conditions beyond those indicated under "recommended operating conditions" is not implied.

APPLICATION INFORMATION

Figure 18 shows the TLV431 or TLV431A used in a 3.3-V isolated flyback supply. Output voltage V_O can be as low as reference voltage V_{ref} (1.24 V ± 1%). The output of the regulator, plus the forward voltage drop of the optocoupler LED (1.24 + 1.4 = 2.64 V), determine the minimum voltage that can be regulated in an isolated supply configuration. Regulated voltage as low as 2.7 Vdc is possible using the circuit in Figure 18.

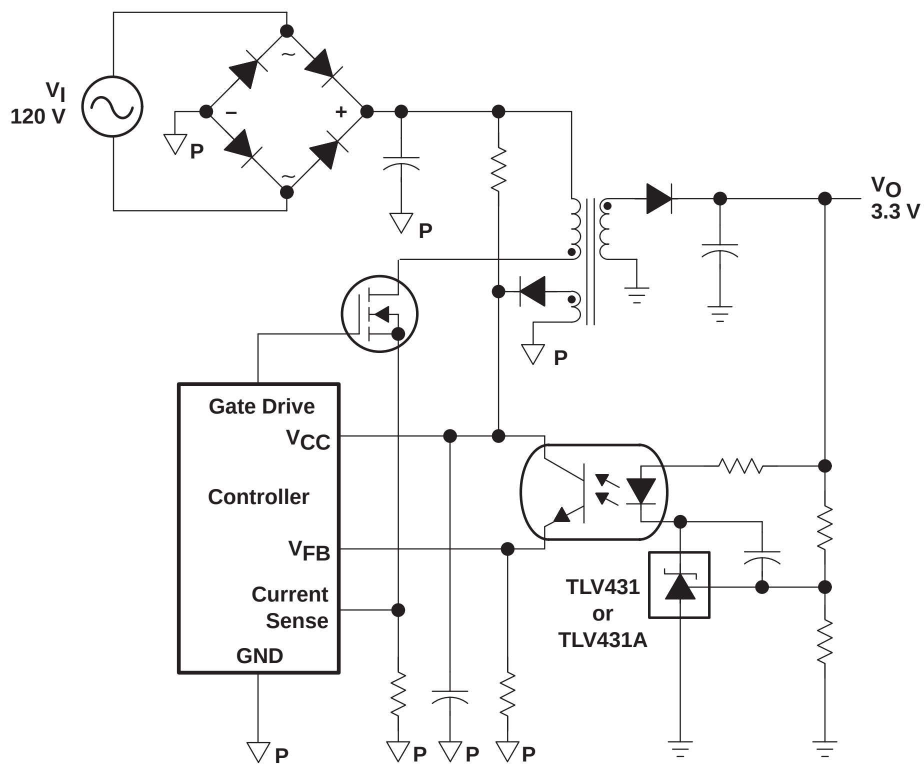


Figure 18. Flyback With Isolation Using TLV431 or TLV431A as Voltage Reference and Error Amplifier

IMPORTANT NOTICE

Texas Instruments and its subsidiaries (TI) reserve the right to make changes to their products or to discontinue any product or service without notice, and advise customers to obtain the latest version of relevant information to verify, before placing orders, that information being relied on is current and complete. All products are sold subject to the terms and conditions of sale supplied at the time of order acknowledgment, including those pertaining to warranty, patent infringement, and limitation of liability.

TI warrants performance of its semiconductor products to the specifications applicable at the time of sale in accordance with TI's standard warranty. Testing and other quality control techniques are utilized to the extent TI deems necessary to support this warranty. Specific testing of all parameters of each device is not necessarily performed, except those mandated by government requirements.

Customers are responsible for their applications using TI components.

In order to minimize risks associated with the customer's applications, adequate design and operating safeguards must be provided by the customer to minimize inherent or procedural hazards.

TI assumes no liability for applications assistance or customer product design. TI does not warrant or represent that any license, either express or implied, is granted under any patent right, copyright, mask work right, or other intellectual property right of TI covering or relating to any combination, machine, or process in which such semiconductor products or services might be or are used. TI's publication of information regarding any third party's products or services does not constitute TI's approval, warranty or endorsement thereof.