

TLV431, TLV431A

LOW-VOLTAGE ADJUSTABLE PRECISION SHUNT REGULATORS

SLVS139C – JULY 1996 – REVISED JULY 1999

- 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 μ A Typ
- 0.25- Ω Typical Output Impedance
- Package Options Include Plastic Small-Outline (D), SOT-23 (DBV), and Cylindrical (LP) Packages

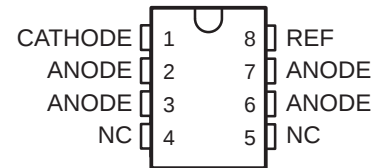
description

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.

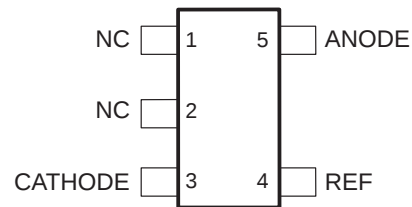
The TLV431C and TLV431AC devices are characterized for operation from 0°C to 70°C. The TLV431I and TLV431AI devices are characterized for operation from –40°C to 85°C.

**D PACKAGE
(TOP VIEW)**



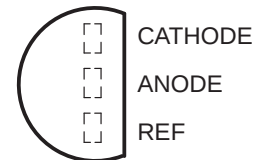
NC – No internal connection

**DBV PACKAGE
(TOP VIEW)**



NC – No internal connection

**LP PACKAGE
(TOP VIEW)**



AVAILABLE OPTIONS

T_A	PACKAGED DEVICES			CHIP FORM (Y)
	TO-92 (LP)	SOIC (D)	SOT-23 (DBV)	
0°C to 70°C	TLV431CLP TLV431ACL	— —	TLV431CDBV TLV431ACDBV	TLV431Y
–40°C to 85°C	TLV431ILP TLV431AIL	TLV431ID TLV431AID	TLV431IDBV TLV431AIDBV	

The LP package is available taped and reeled. Add the suffix R to the device type (e.g., TLV431ACLPR). The D and DBV are available only taped and reeled (e.g., TLV431IOR). Chip forms are tested at 25°C.



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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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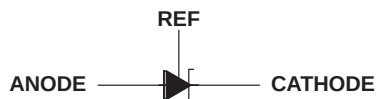
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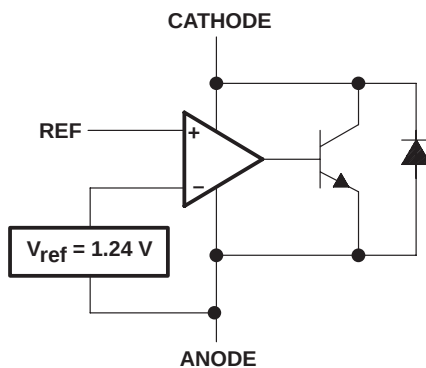
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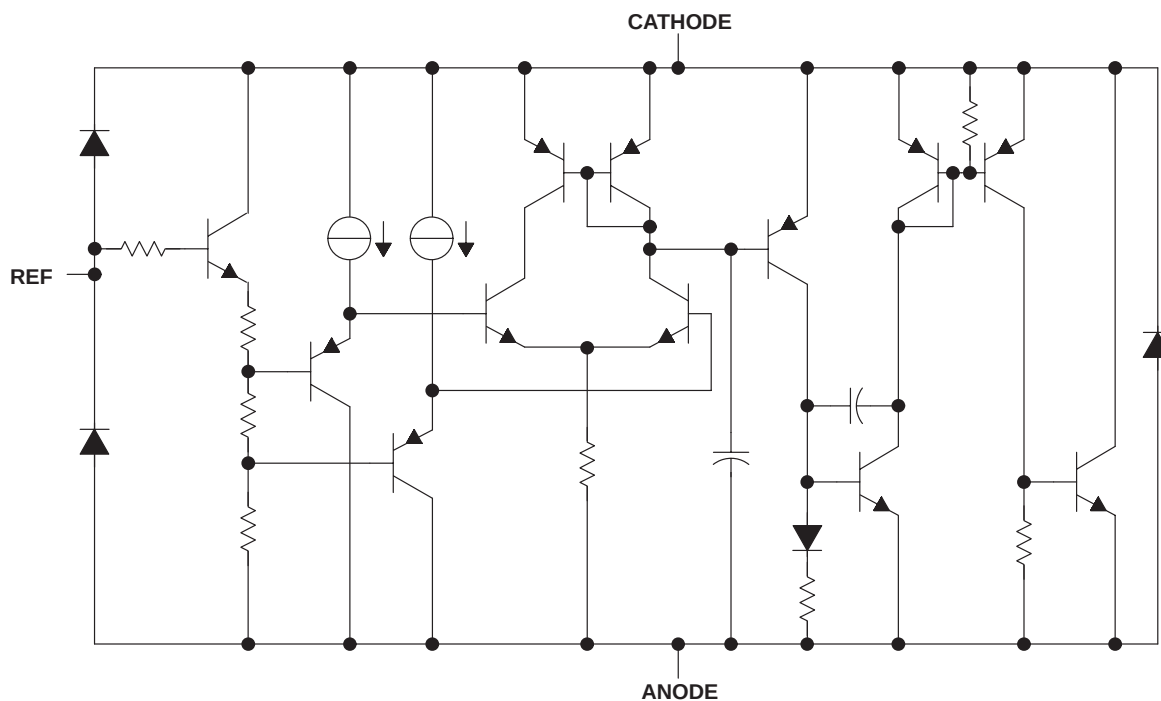
logic symbol



logic diagram (positive logic)



equivalent schematic



TLV431, TLV431A

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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	347°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 impact reliability.
 3. The package thermal impedance is calculated in accordance with JESD 51, except for through-hole packages, which use a trace length of zero.

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	



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electrical characteristics at 25°C free-air temperature (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, α_{V_{ref}}, is defined as:

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

where:

ΔT_A is the rated operating temperature range of the device.

α_{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: $|z_{KA}| = \frac{\Delta V_{KA}}{\Delta I_{KA}}$

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

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

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electrical characteristics at 25°C free-air temperature (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 T _A = full range, (see Note 4 and Figure 1)	1.228	1.24	1.252	1.228	1.24	1.252	V
		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
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, α_{V_{ref}}, is defined as:

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

where:

ΔT_A is the rated operating temperature range of the device.

α_{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: $|z_{KA}| = \frac{\Delta V_{KA}}{\Delta I_{KA}}$

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

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

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electrical characteristics at 25°C free-air temperature

PARAMETER	TEST CONDITIONS	TLV431Y			UNIT
		MIN	TYP	MAX	
V_{ref}	Reference voltage	$V_{KA} = V_{ref}$, $I_K = 10$ mA (see Figure 1) $T_A = 25^\circ\text{C}$			V
$\frac{\Delta V_{ref}}{\Delta V_{KA}}$	Ratio of V_{ref} change in cathode voltage change	$I_K = 10$ mA, $\Delta V_{KA} = V_{ref}$ to 6 V (see Figure 2)			mV/V
I_{ref}	Reference terminal current	$I_K = 10$ mA, $R1 = 10$ k Ω , $R2 =$ open (see Figure 2)			μA
$I_{K(min)}$	Minimum cathode current for regulation	$V_{KA} = V_{ref}$ (see Figure 1)			μA
I_{off}	Off-state cathode current	$V_{KA} = 6$ V, $V_{ref} = 0$ (see Figure 3)			μA
$ z_{KA} $	Dynamic impedance (see Note 6)	$V_{KA} = V_{ref}$, $f \leq 1$ kHz, $I_K = 0.1$ mA to 15 mA (see Figure 1)			Ω

NOTE 6: 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 2), the total dynamic impedance of the circuit is given by:

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

PARAMETER MEASUREMENT INFORMATION

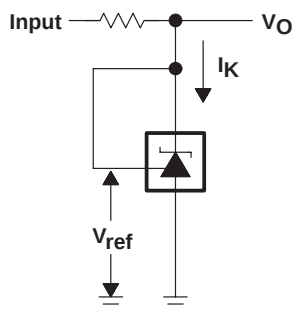


Figure 1. Test Circuit for $V_{KA} = V_{ref}$,
 $V_O = V_{KA} = V_{ref}$

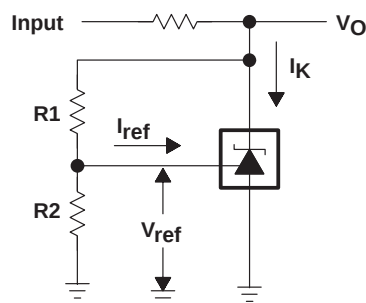


Figure 2. Test Circuit for $V_{KA} > V_{ref}$,
 $V_O = V_{KA} = V_{ref} \times (1 + R1/R2) + I_{ref} \times R1$

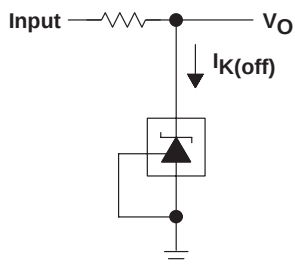
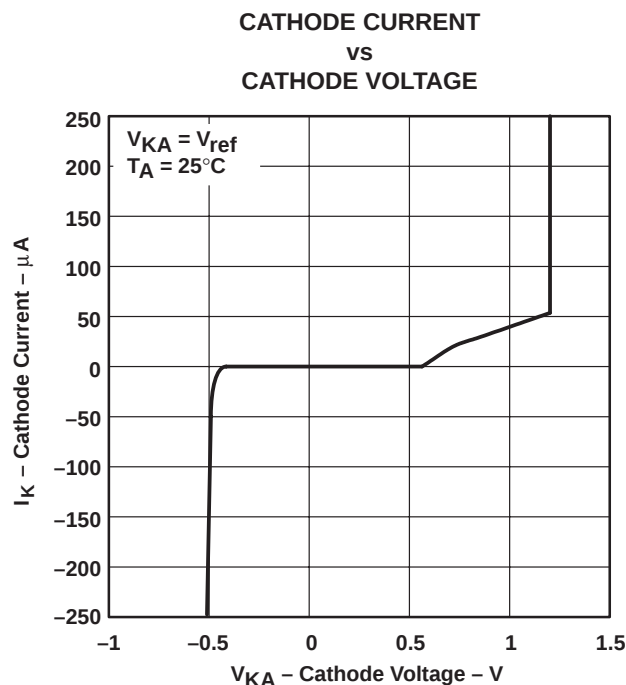
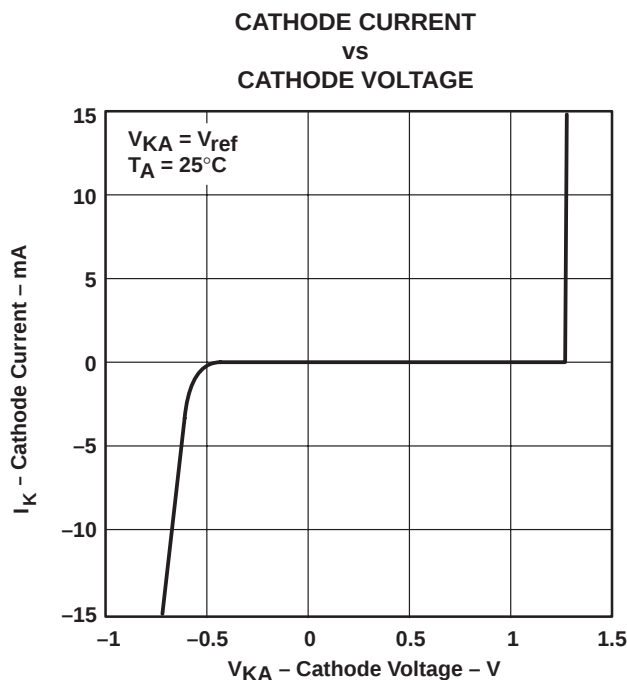
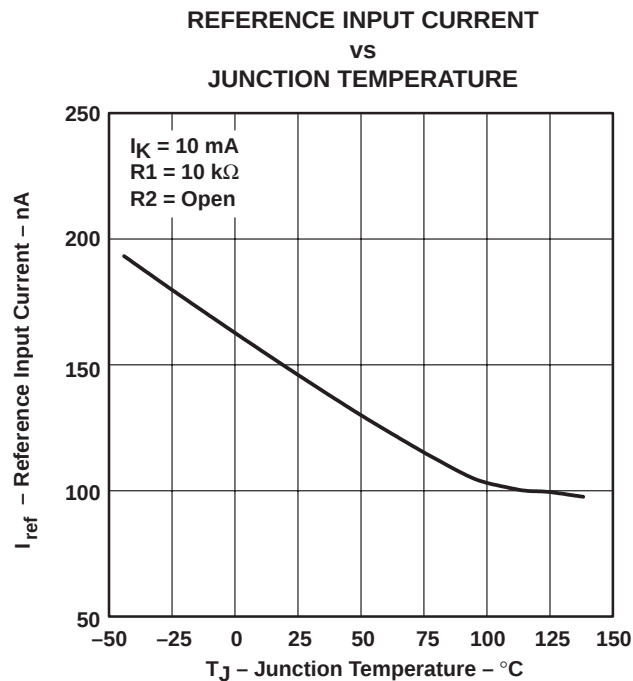
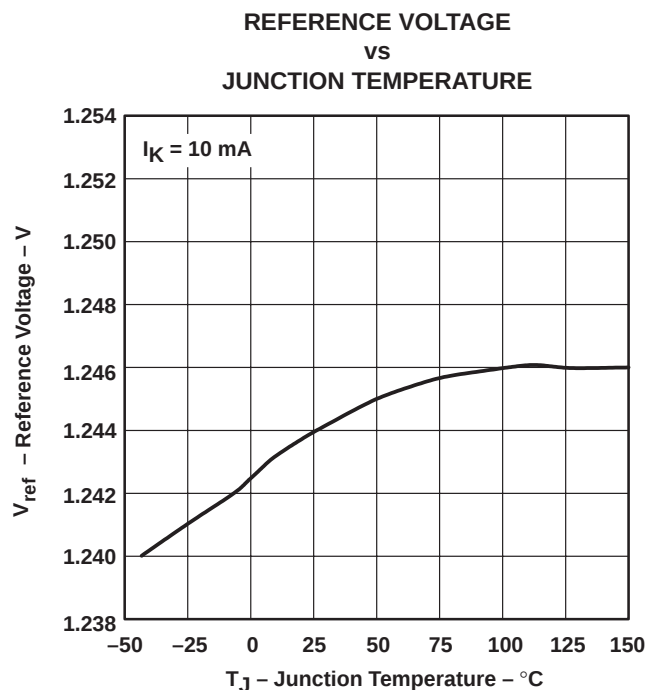


Figure 3. Test Circuit for $I_{K(off)}$

PARAMETER MEASUREMENT INFORMATION†



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

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PARAMETER MEASUREMENT INFORMATION†

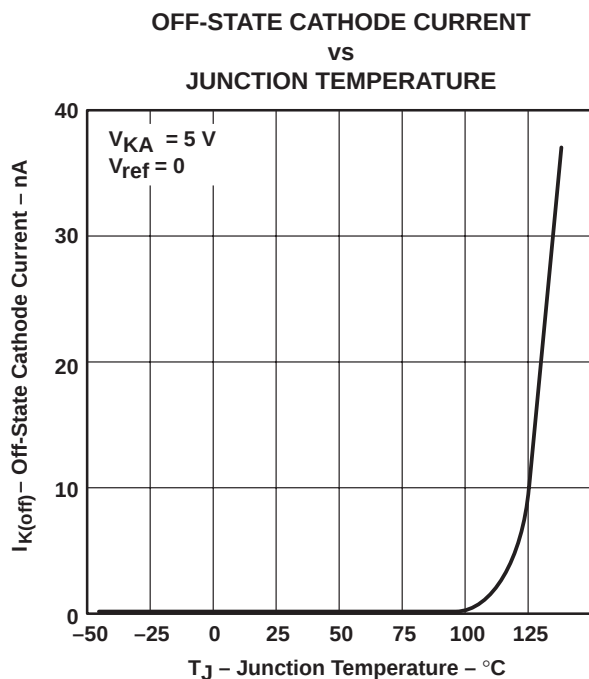


Figure 8

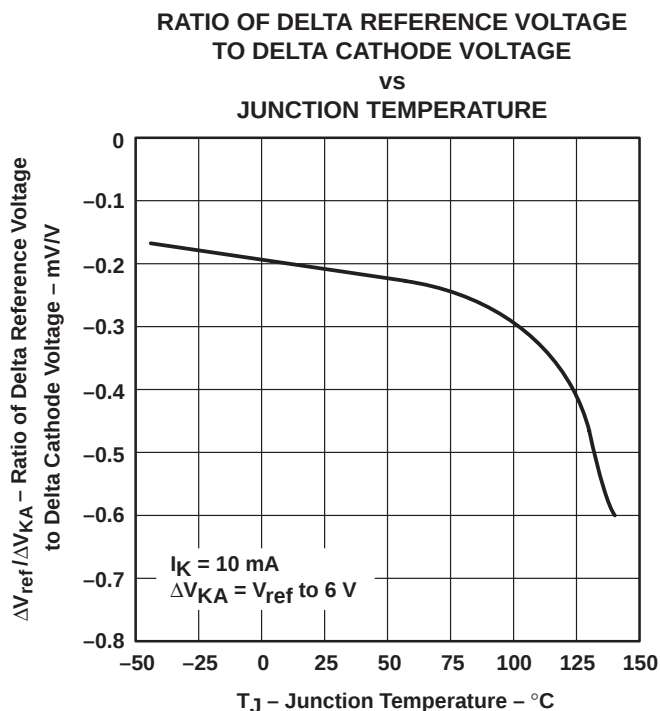


Figure 9

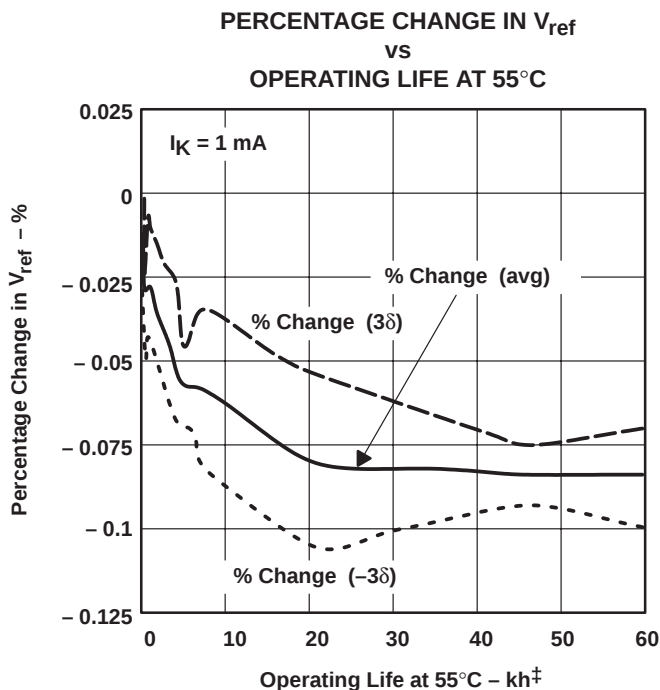


Figure 10

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

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



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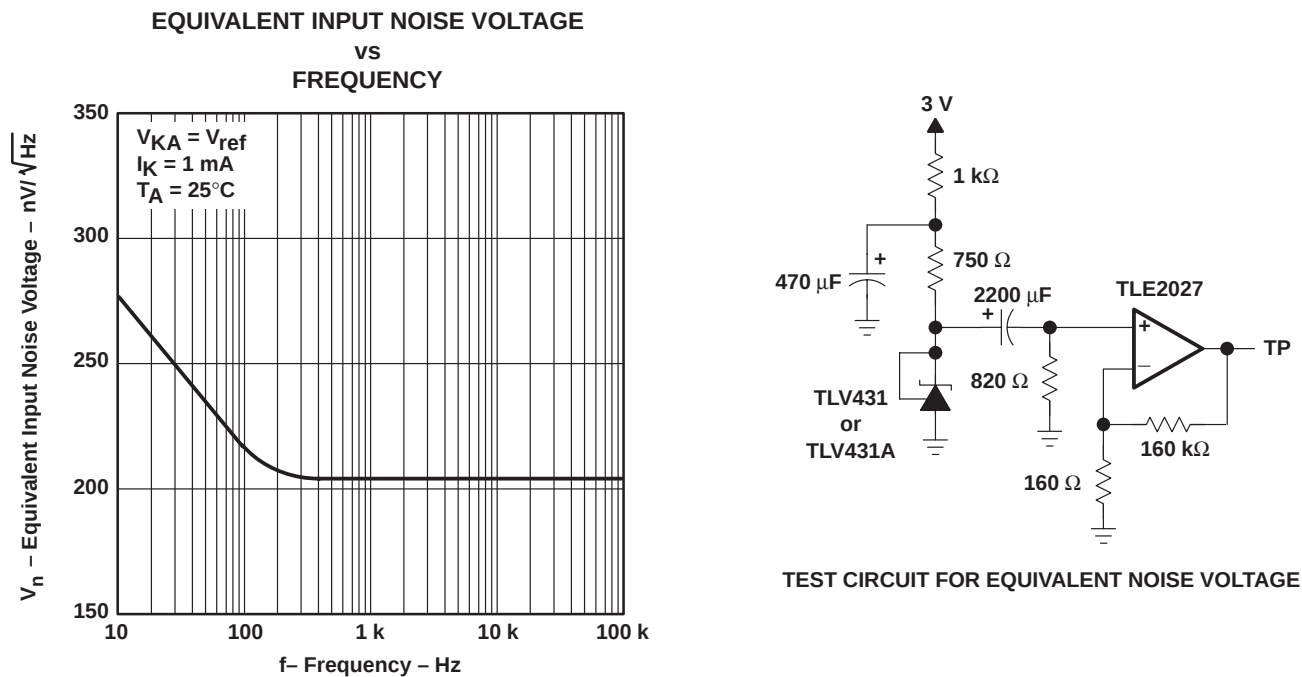


Figure 11

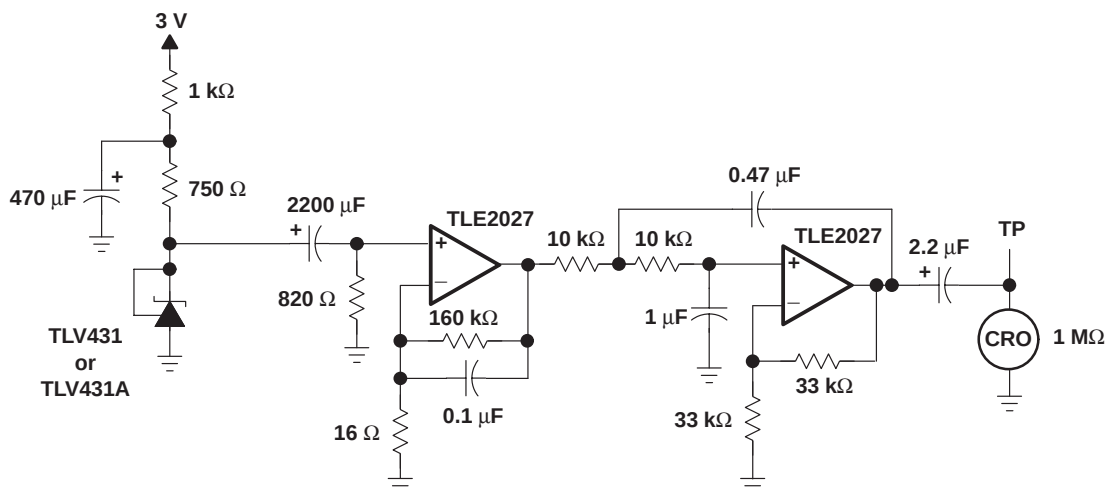
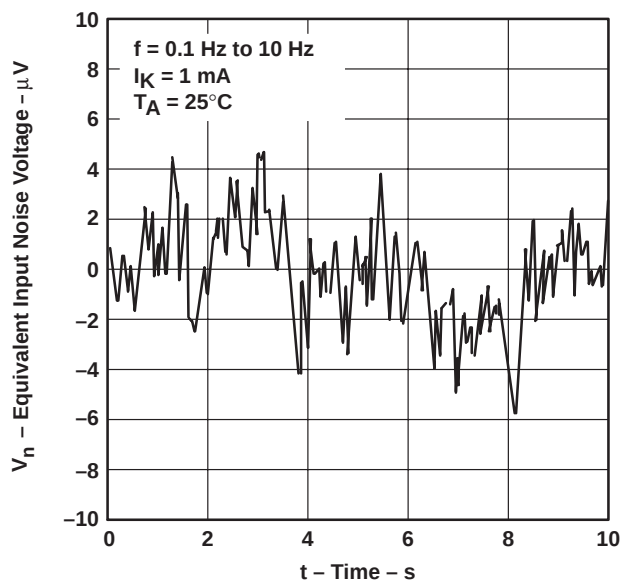
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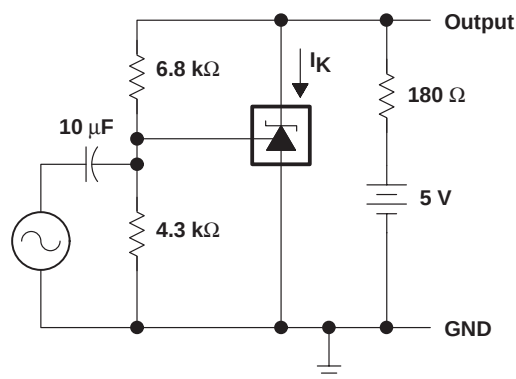
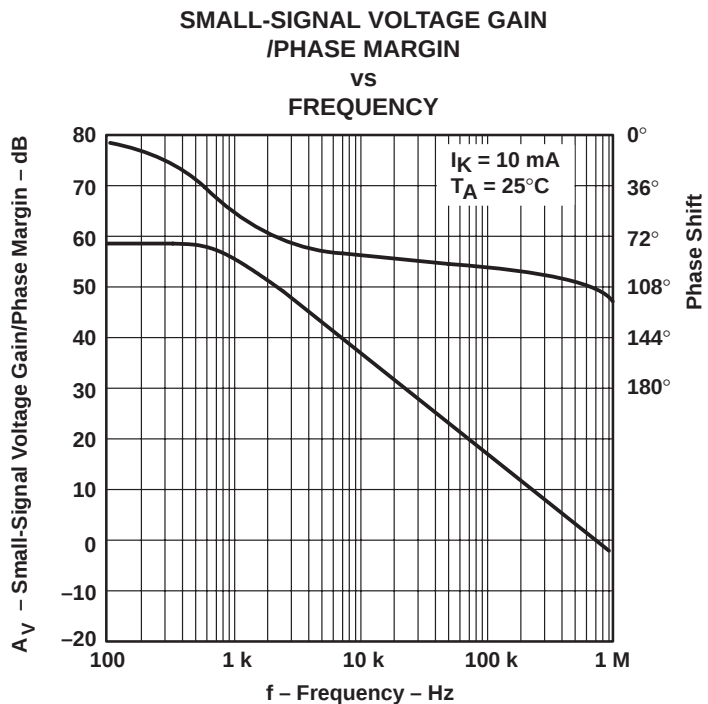
EQUIVALENT INPUT NOISE VOLTAGE
OVER A 10-SECOND PERIOD



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

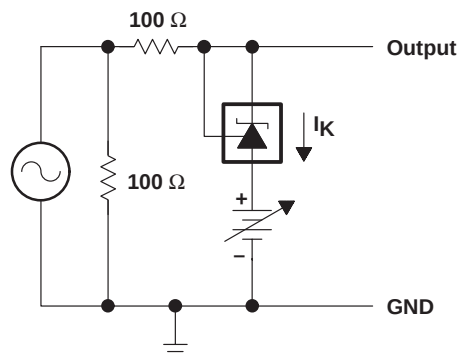
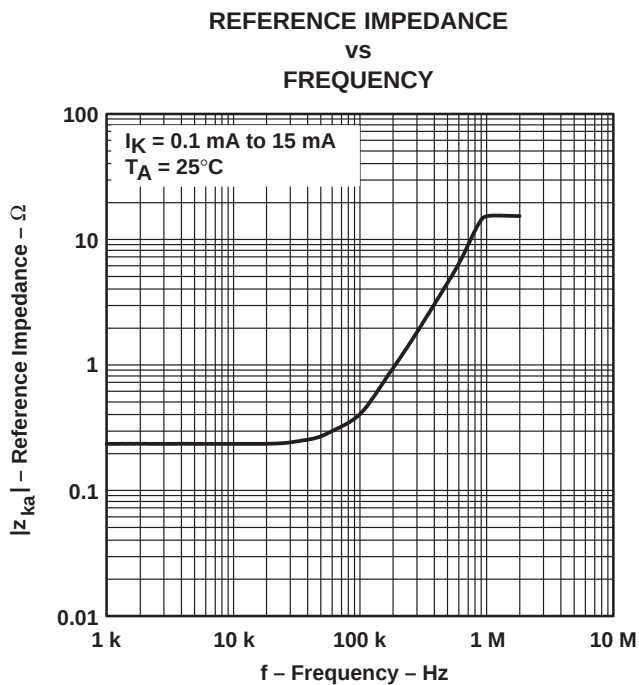
Figure 12

PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT FOR VOLTAGE GAIN AND PHASE MARGIN

Figure 13



TEST CIRCUIT FOR REFERENCE IMPEDANCE

Figure 14

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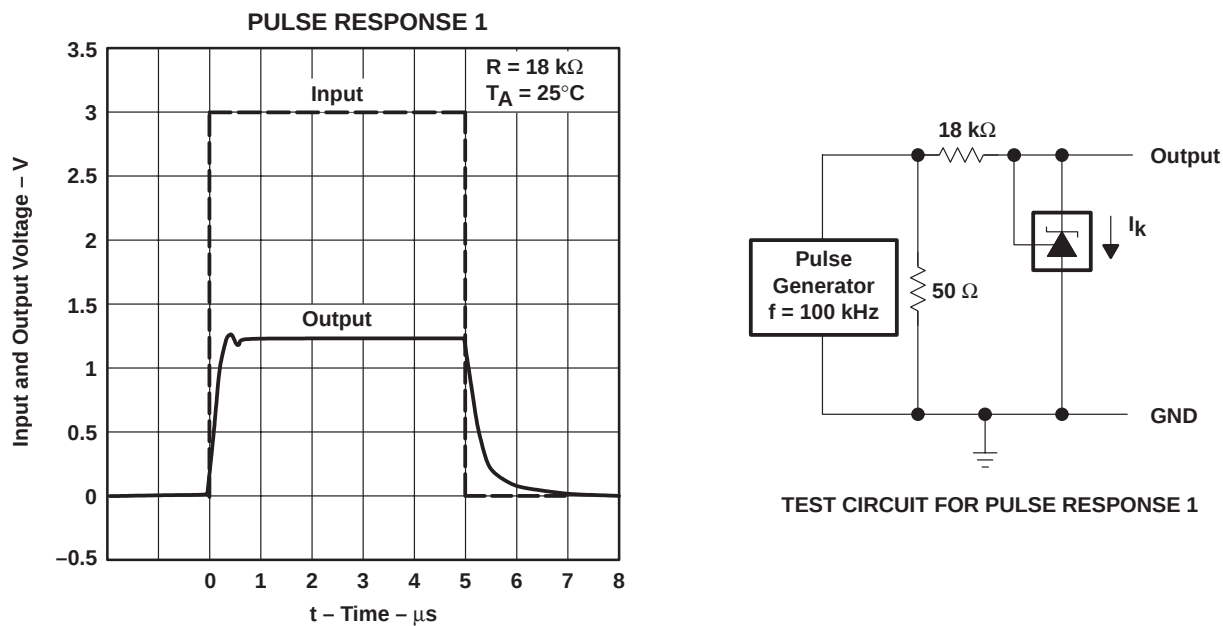


Figure 15

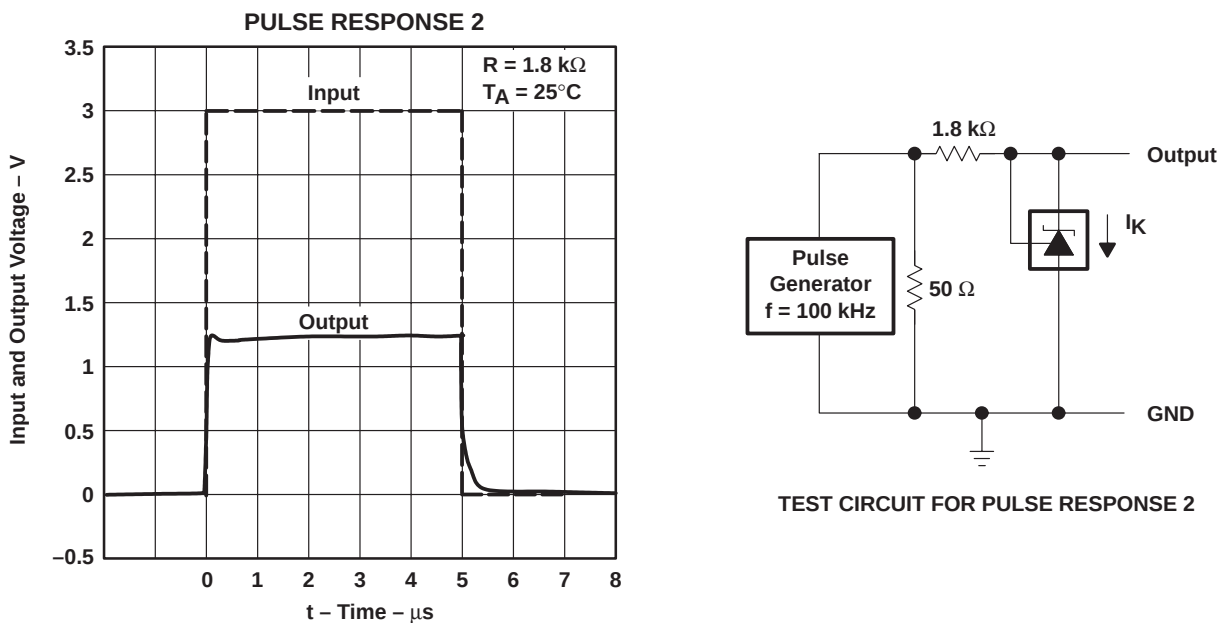
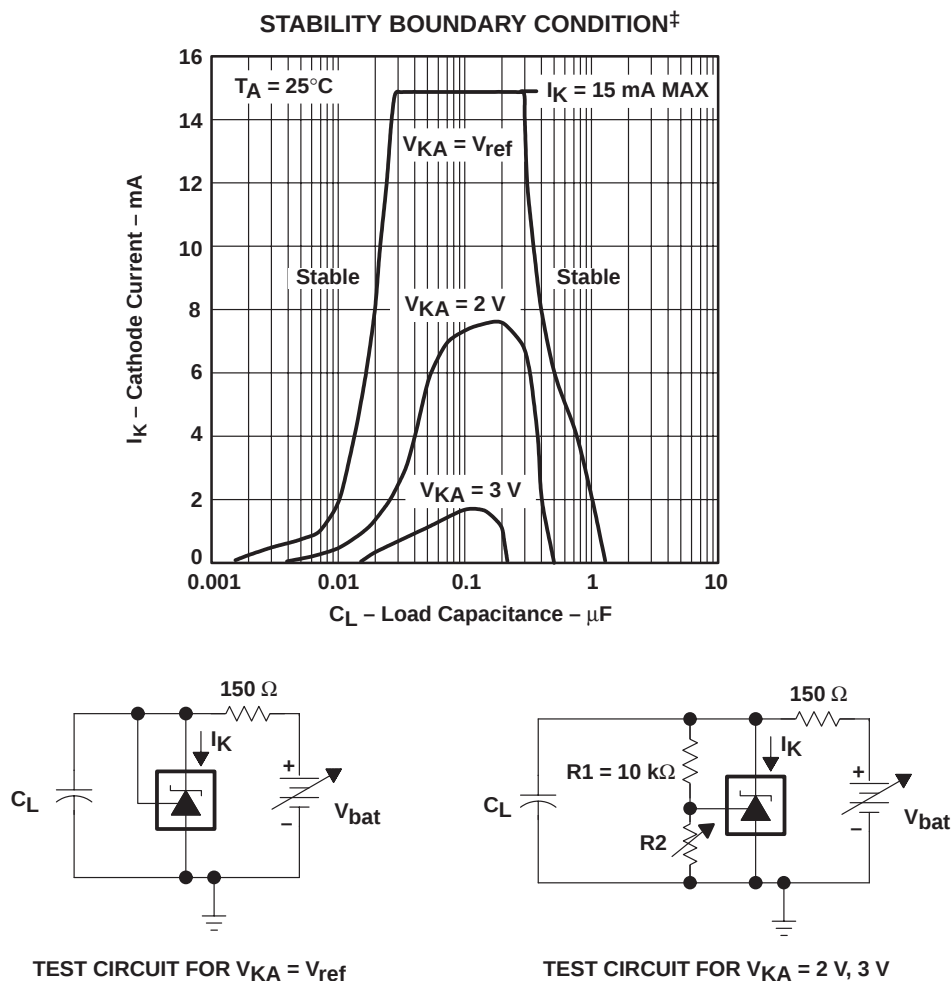


Figure 16

PARAMETER MEASUREMENT INFORMATION[†]



[‡] The areas under the curves represent conditions that may cause the device to oscillate. For $V_{KA} = 2\text{-V}$ 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.

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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} ($1.24\text{ V} \pm 1\%$). The output of the regulator, plus the forward voltage drop of the optocoupler LED ($1.24 + 1.4 = 2.64\text{ V}$), 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.

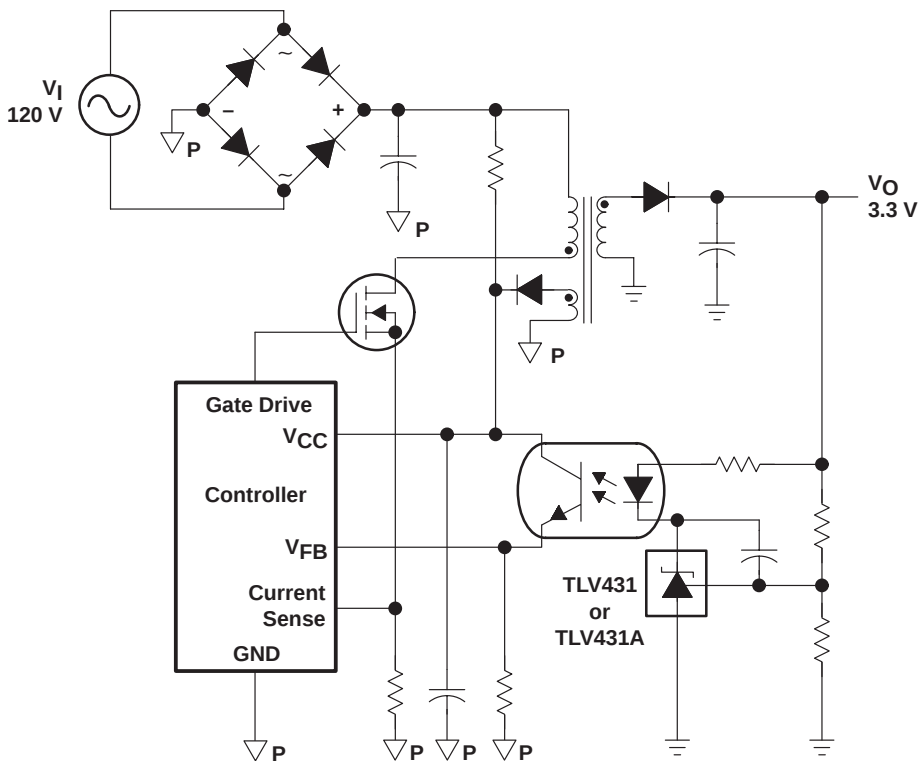


Figure 18. Flyback With Isolation Using TLV431 or TLV431A as Voltage Reference and Error Amplifier

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