XB431-TL SOT23-3

1 Features

- Low-Voltage Operation, V_{REF} = 1.24 V
- Adjustable Output Voltage, $V_O = V_{REF}$ to 6 V
- Reference Voltage Tolerances at 25°C
  - 0.5% for XB431-TL
  - 1% for XB431-TL
  - 1.5% for XB431-TL
- Typical Temperature Drift
  - 4 mV (0°C to 70°C)
  - 6 mV (–40°C to 85°C)
  - 11 mV (–40°C to 125°C)
- Low Operational Cathode Current, 80 µA Typ
- 0.25-Ω Typical Output Impedance
- Ultra-Small SC-70 Package Offers 40% Smaller Footprint Than SOT-23-3
- See XB431-TL for:
  - Wider V_{KA} (1.24 V to 18 V) and I_K (80 mA)
  - Additional SOT-89 Package
  - Multiple Pinouts for SOT-23-3 and SOT-89 Packages
- On Products Compliant to MIL-PRF-38535, All Parameters Are Tested Unless Otherwise Noted. On All Other Products, Production Processing Does Not Necessarily Include Testing of All Parameters.

2 Applications

- Adjustable Voltage and Current Referencing
- Secondary Side Regulation in Flyback SMPSs
- Zener Replacement
- Voltage Monitoring
- Comparator with Integrated Reference

3 Description

The XB431 device is a low-voltage 3-terminaladjustable voltage reference withspecified thermalstability over applicable industrialand commercialtemperature ranges. Output voltagecan be set to anyvalue between V_{REF} (1.24 V)and 6 V with twoexternal resistors (see Figure20). These devicesoperate from a lower voltage(1.24 V) than the widelyused XB431 shunt-regulator references.

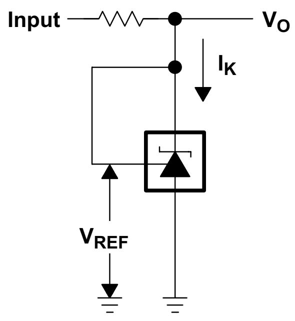
When used with an optocoupler, the XB431 device is an ideal voltage reference in isolated feedback circuits for 3-V to 3.3-V switching-mode power supplies. These devices have a typical output impedance of 0.25 Ω. Active output circuitry provides a very sharp turn-on characteristic, making them excellent replacements for low-voltage Zener diodes in many applications, including on-board regulation and adjustable power supplies.

4 Device Information(1)

PART NUMBER	PACKAGE (PIN)	BODY SIZE (NOM)
XB431x	SOT-23 (3)	2.90 mm x 1.30 mm
	SOT-23 (5)	2.90 mm x 1.60 mm
	SC70 (6)	2.00 mm x 1.25 mm
	TO-92 (3)	4.30 mm × 4.30 mm
	SOIC (8)	4.90 mm x 3.90 mm

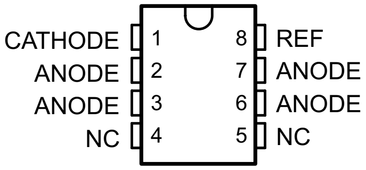
(1) For all available packages, see the orderable addendum at the end of the data sheet.

4 Simplified Schematic

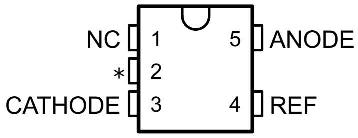


6 Pin Configuration and Functions

D (SOIC) PACKAGE
(TOP VIEW)



DBV (SOT-23-5) PACKAGE
(TOP VIEW)

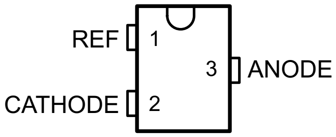


NC − No internal connection

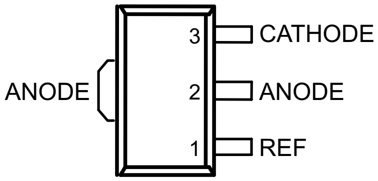
∗ For XB431: NC − No internal connection

∗ For XB431: Pin 2 is attached to Substrate and must be connected to ANODE or left open.

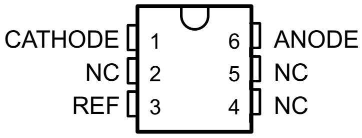
DBZ (SOT-23-3) PACKAGE
(TOP VIEW)



PK (SOT-89) PACKAGE
(TOP VIEW)

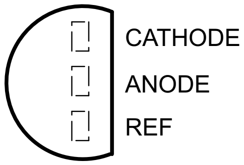


DCK (SC-70) PACKAGE
(TOP VIEW)



NC − No internal connection

LP (TO-92/TO-226) PACKAGE
(TOP VIEW)



Pin Functions

PIN							TYPE	DESCRIPTION
NAME	DBZ	DBV	PK	D	LP	DCK		
CATHODE	2	3	3	1	1	1	I/O	Shunt Current/Voltage input
REF	1	4	1	8	3	3	I	Threshold relative to common anode
ANODE	3	5	2	2, 3, 6, 7	2	6	O	Common pin, normally connected to ground
NC	—	1	—	4, 5	—	2, 4, 5	I	No Internal Connection
*	—	2	—	—	—	—	I	Substrate Connection

7 Specifications

7.1 Absolute Maximum Ratings

over operating free-air temperature range (unless otherwise noted)(1)

		MIN	MAX	UNIT
V_{KA}	Cathode voltage(2)		7	V
I_K	Continuous cathode current range	–20	20	mA
I_{ref}	Reference current range	–0.05	3	mA
	Operating virtual junction temperature		150	°C
T_{stg}	Storage temperature range	–65	150	°C

(1) 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.

(2) Voltage values are with respect to the anode terminal, unless otherwise noted.

7.2 ESD Ratings

PARAMETER		DEFINITION	VALUE	UNIT
$V_{(ESD)}$	Electrostatic discharge	Human body model (HBM), per ANSI/ESDA/JEDEC JS-001, all pins(1)	±2000	V
		Charged device model (CDM), per JEDEC specification JESD22-C101, all pins(2)	±1000	

(1) JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process.

(2) JEDEC document JEP157 states that 250-V CDM allows safe manufacturing with a standard ESD control process.

7.3 Thermal Information

THERMAL METRIC(1)		XB431x						UNIT
		DCK	D	PK	DBV	DBZ	LP	
		6 PINS	8 PINS	3 PINS	5 PINS	3 PINS	3 PINS	
$R_{\theta JA}$	Junction-to-ambient thermal resistance	87	97	52	206	206	140	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	259	39	9	131	76	55	

(1) For more information about traditional and new thermal metrics, see the *IC Package Thermal Metrics* application report (SPRA953).

7.4 Recommended Operating Conditions

over operating free-air temperature range (unless otherwise noted)

			MIN	MAX	UNIT
V_{KA}	Cathode voltage		V_{REF}	6	V
I_K	Cathode current		0.1	15	mA
T_A	Operating free-air temperature range	XB431	–40	125	°C

7.5 Electrical Characteristics for XB431

at 25°C free-air temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS			XB431			UNIT
					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	V
			T_A = full range(1) (see Figure 19)	XB431	1.21		1.27	
					1.202		1.278	
					1.194		1.286	
$V_{REF(dev)}$	V_{REF} deviation over full temperature range(2)	$V_{KA} = V_{REF}$, I_K = 10 mA(1) (see Figure 19)		XB431		4	12	mV
						6	20	
						11	31	
$\frac{\Delta V_{REF}}{\Delta V_{KA}}$	Ratio of V_{REF} change in cathode voltage change	$V_{KA} = V_{REF}$ to 6 V, I_K = 10 mA (see Figure 20)				–1.5	–2.7	mV/V
I_{ref}	Reference terminal current	I_K = 10 mA, R1 = 10 kΩ, R2 = open (see Figure 20)				0.15	0.5	µA
$I_{ref(dev)}$	I_{ref} deviation over full temperature range(2)	I_K = 10 mA, R1 = 10 kΩ, R2 = open(1) (see Figure 20)		XB431		0.05	0.3	µA
						0.1	0.4	
						0.15	0.5	
$I_{K(min)}$	Minimum cathode current for regulation	$V_{KA} = V_{REF}$ (see Figure 19)		XB431		55	80	µA
						55	100	
$I_{K(off)}$	Off-state cathode current	V_{REF} = 0, V_{KA} = 6 V (see Figure 21)				0.001	0.1	µA
$\|z_{KA}\|$	Dynamic impedance(3)	$V_{KA} = V_{REF}$, f ≤ 1 kHz, I_K = 0.1 mA to 15 mA (see Figure 19)				0.25	0.4	Ω

(1) Full temperature ranges are –40°C to 125°C for XB431 –40°C to 85°C for XB431 and 0°C to 70°C for XB431

(2) 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, αV_{REF}, is defined as:

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

where ΔT_A is the rated operating free-air temperature range of the device.
αV_{REF} can be positive or negative, depending on whether minimum V_{REF} or maximum V_{REF}, respectively, occurs at the lower temperature.

(3) The dynamic impedance is defined as $\left|z_{ka}\right| = \frac{\Delta V_{KA}}{\Delta I_K}$

When the device is operating with two external resistors (see Figure 20), the total dynamic impedance of the circuit is defined as:

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

7.6 Electrical Characteristics for XB431

at 25°C free-air temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS			XB431			UNIT
					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	V
			T_A = full range(1) (see Figure 19)	XB431	1.221		1.259	
					1.215		1.265	
					1.209		1.271	
$V_{REF(dev)}$	V_{REF} deviation over full temperature range(2)	$V_{KA} = V_{REF}$, I_K = 10 mA(1) (see Figure 19)		XB431		4	12	mV
						6	20	
						11	31	
$\frac{\Delta V_{REF}}{\Delta V_{KA}}$	Ratio of V_{REF} change in cathode voltage change	$V_{KA} = V_{REF}$ to 6 V, I_K = 10 mA (see Figure 20)				–1.5	–2.7	mV/V
I_{ref}	Reference terminal current	I_K = 10 mA, R1 = 10 kΩ, R2 = open (see Figure 20)				0.15	0.5	µA
$I_{ref(dev)}$	I_{ref} deviation over full temperature range(2)	I_K = 10 mA, R1 = 10 kΩ, R2 = open(1) (see Figure 20)		XB431		0.05	0.3	µA
						0.1	0.4	
						0.15	0.5	
$I_{K(min)}$	Minimum cathode current for regulation	$V_{KA} = V_{REF}$ (see Figure 19)		XB431		55	80	µA
						55	100	
$I_{K(off)}$	Off-state cathode current	V_{REF} = 0, V_{KA} = 6 V (see Figure 21)				0.001	0.1	µA
$\lvert z_{KA}\rvert$	Dynamic impedance(3)	$V_{KA} = V_{REF}$, f ≤ 1 kHz, I_K = 0.1 mA to 15 mA (see Figure 19)				0.25	0.4	Ω

(1) Full temperature ranges are –40°C to 125°C for XB431–40°C to 85°C for XB431 and 0°C to 70°C for XB431.

(2) 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, αV_{REF}, is defined as:

$$\left|\alpha V_{REF}\right|\left(\frac{ppm}{^\circ C}\right) = \frac{\left(\dfrac{V_{REF(dev)}}{V_{REF}\left(T_A = 25^\circ C\right)}\right)\times 10^6}{\Delta T_A}$$

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

αV_{REF} can be positive or negative, depending on whether minimum V_{REF} or maximum V_{REF}, respectively, occurs at the lower temperature.

(3) The dynamic impedance is defined as $\left|z_{ka}\right| = \frac{\Delta V_{KA}}{\Delta I_K}$

When the device is operating with two external resistors (see Figure 20), the total dynamic impedance of the circuit is defined as:

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

7.7 Electrical Characteristics for XB431

at 25°C free-air temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS			XB431			UNIT
					MIN	TYP	MAX	
V_{REF}	Reference voltage	$V_{KA} = V_{REF}$, I_K = 10 mA	T_A = 25°C		1.234	1.24	1.246	V
			T_A = full range[1] (see Figure 19)	XB431	1.227		1.253	
					1.224		1.259	
					1.221		1.265	
$V_{REF(dev)}$	V_{REF} deviation over full temperature range[2]	$V_{KA} = V_{REF}$, I_K = 10 mA[1] (see Figure 19)		XB431		4	12	mV
						6	20	
						11	31	
$\frac{\Delta V_{REF}}{\Delta V_{KA}}$	Ratio of V_{REF} change in cathode voltage change	$V_{KA} = V_{REF}$ to 6 V, I_K = 10 mA (see Figure 20)				–1.5	–2.7	mV/V
I_{ref}	Reference terminal current	I_K = 10 mA, R1 = 10 kΩ, R2 = open (see Figure 20)				0.1	0.5	µA
$I_{ref(dev)}$	I_{ref} deviation over full temperature range[2]	I_K = 10 mA, R1 = 10 kΩ, R2 = open[3] (see Figure 20)		XB431		0.05	0.3	µA
						0.1	0.4	
						0.15	0.5	
$I_{K(min)}$	Minimum cathode current for regulation	$V_{KA} = V_{REF}$ (see Figure 19)				55	100	µA
$I_{K(off)}$	Off-state cathode current	V_{REF} = 0, V_{KA} = 6 V (see Figure 21)				0.001	0.1	µA
$\lvert z_{KA}\rvert$	Dynamic impedance[4]	$V_{KA} = V_{REF}$, f ≤ 1 kHz, I_K = 0.1 mA to 15 mA (see Figure 19)				0.25	0.4	Ω

(1) Full temperature ranges are –40°C to 125°C for XB431, –40°C to 85°C for XB431, and 0°C to 70°C for XB431.

(2) 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, αV_{REF}, is defined as:

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

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

αV_{REF} can be positive or negative, depending on whether minimum V_{REF} or maximum V_{REF}, respectively, occurs at the lower temperature.

(3) Full temperature ranges are –40°C to 125°C for XB431, –40°C to 85°C for XB431, and 0°C to 70°C for XB431.

(4) The dynamic impedance is defined as $\left|z_{ka}\right| = \frac{\Delta V_{KA}}{\Delta I_K}$

When the device is operating with two external resistors (see Figure 20), the total dynamic impedance of the circuit is defined as:

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

7.8 Typical Characteristics

Operation of the device at these or any other conditions beyond those indicated in the *Recommended Operating Conditions* table are not implied.

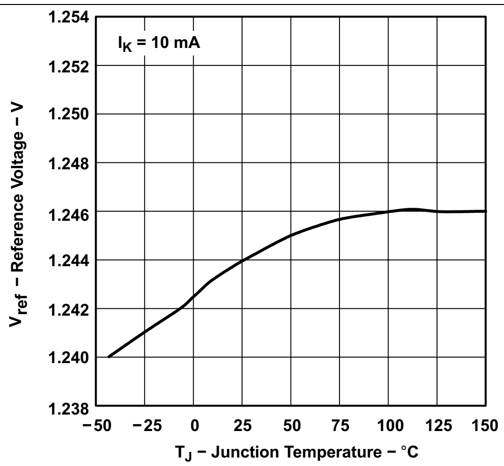


Figure 1. Reference Voltage vs Junction Temperature

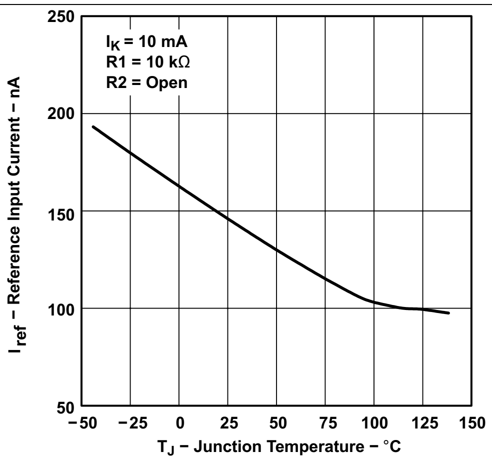


Figure 2. Reference Input Current vs Junction Temperature (for XB431)

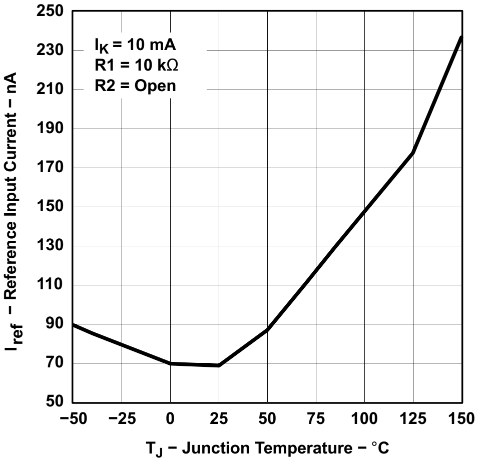


Figure 3. Reference Input Current vs Junction Temperature (for XB431)

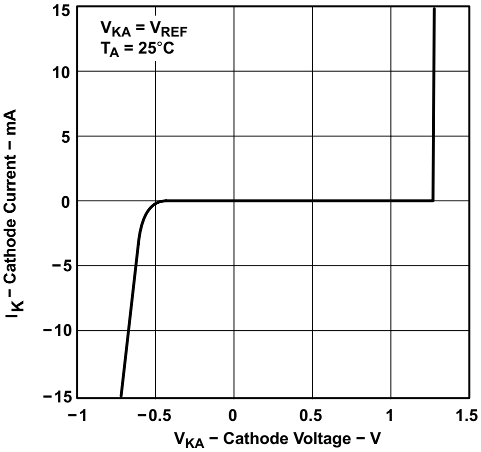


Figure 4. Cathode Current vs Cathode Voltage

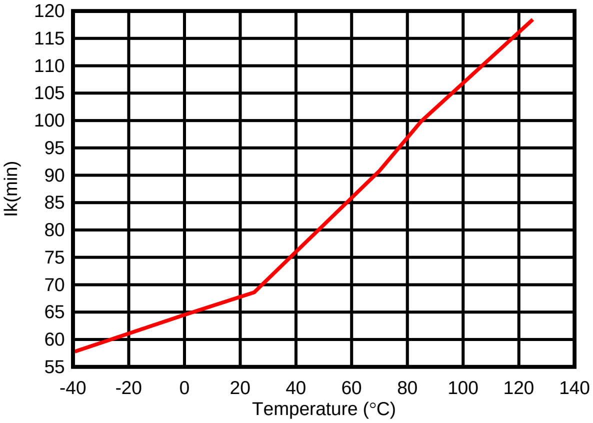


Figure 5. Minimum Cathode Current vs Temperature

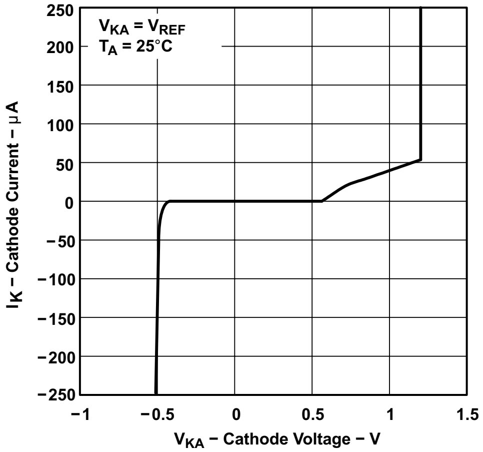


Figure 6. Cathode Current vs Cathode Voltage

Typical Characteristics (continued)

Operation of the device at these or any other conditions beyond those indicated in the *Recommended Operating Conditions* table are not implied.

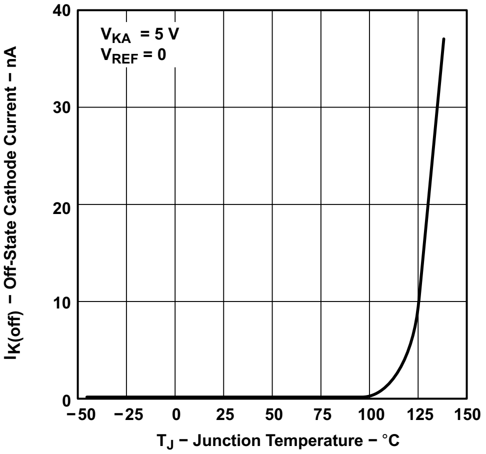


Figure 7. Off-State Cathode Current vs Junction Temperature (for XB431)

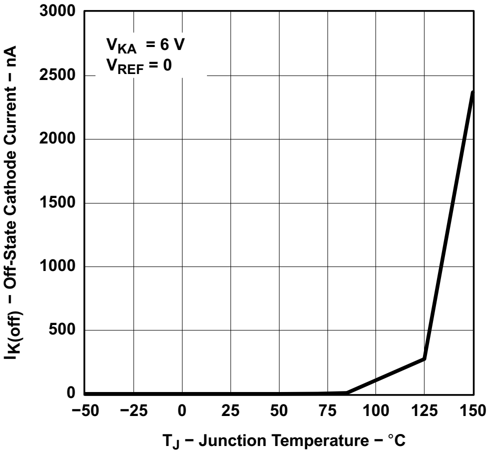


Figure 8. Off-State Cathode Current vs Junction Temperature (for XB431)

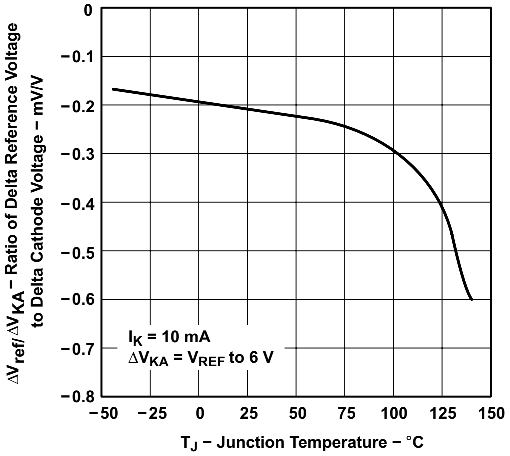


Figure 9. Ratio of Delta Reference Voltage to Delta Cathode Voltage vs Junction Temperature (for XB431)

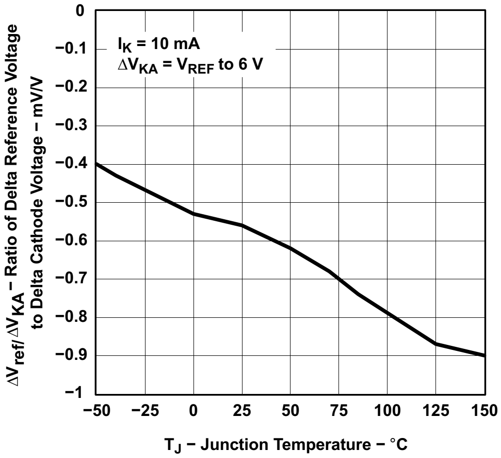
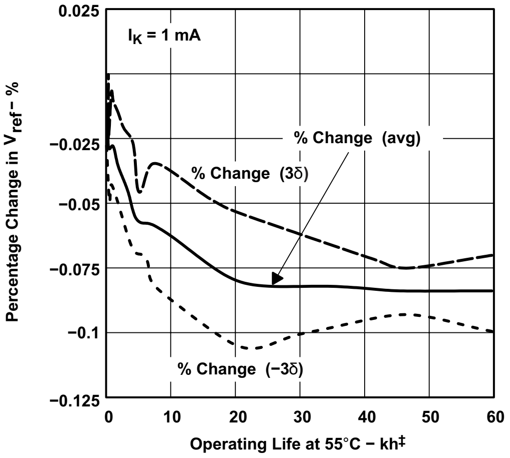


Figure 10. Ratio of Delta Reference Voltage to Delta Cathode Voltage vs Junction Temperature (for XB431)

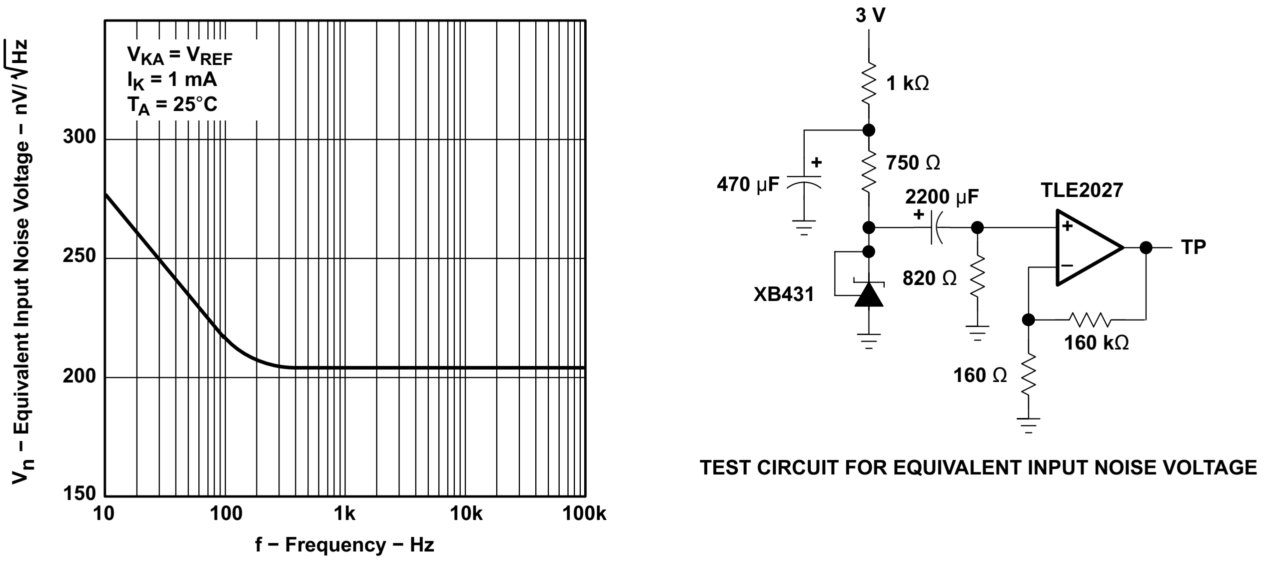
Typical Characteristics (continued)

Operation of the device at these or any other conditions beyond those indicated in the *Recommended Operating Conditions* table are not implied.



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

Figure 11. Percentage Change in V_{REF} vs Operating Life at 55°C

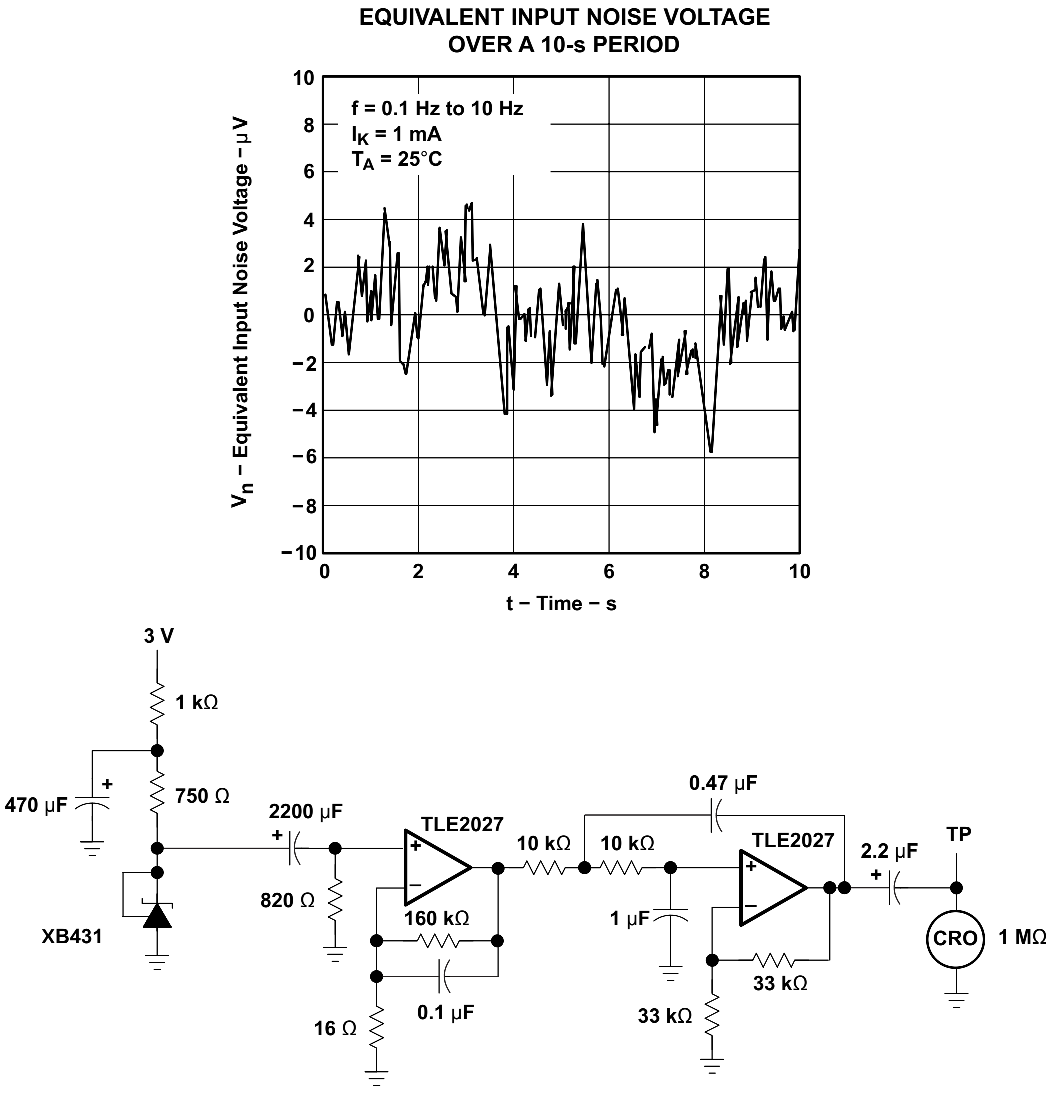


TEST CIRCUIT FOR EQUIVALENT INPUT NOISE VOLTAGE

Figure 12. Equivalent Input Noise Voltage

Typical Characteristics (continued)

Operation of the device at these or any other conditions beyond those indicated in the *Recommended Operating Conditions* table are not implied.

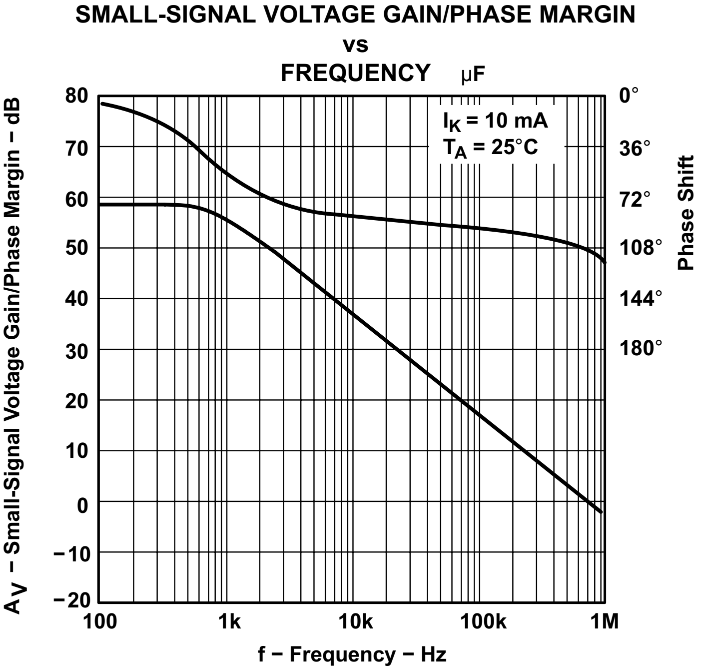


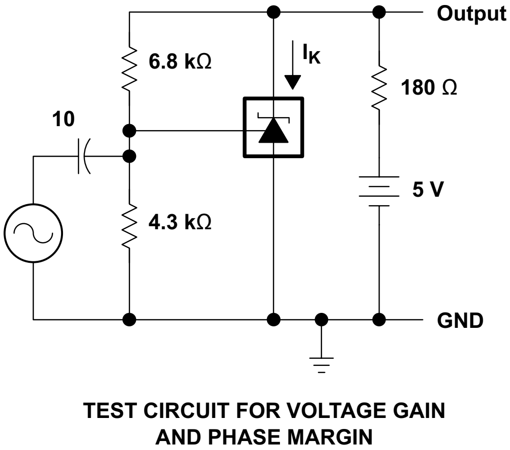
TEST CIRCUIT FOR 0.1-Hz TO 10-Hz EQUIVALENT NOISE VOLTAGE

Figure 13. Equivalent Noise Voltage over a 10s Period

Typical Characteristics (continued)

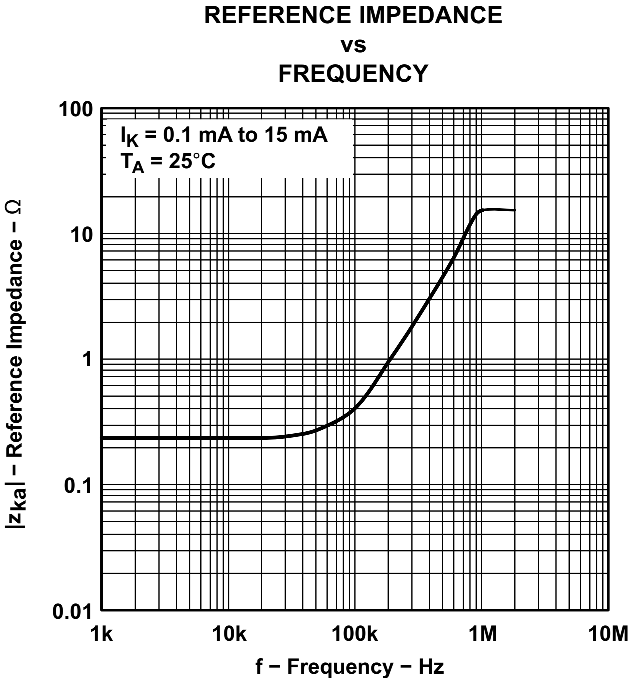
Operation of the device at these or any other conditions beyond those indicated in the *Recommended Operating Conditions* table are not implied.

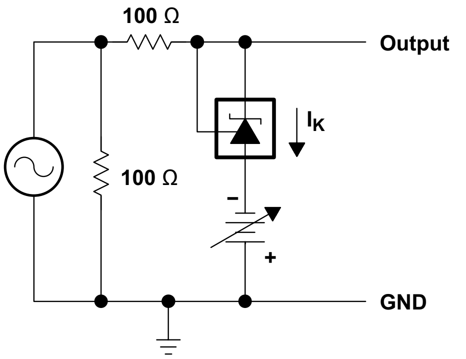




TEST CIRCUIT FOR VOLTAGE GAIN AND PHASE MARGIN

Figure 14. Voltage Gain and Phase Margin





TEST CIRCUIT FOR REFERENCE IMPEDANCE

Figure 15. Reference Impedance vs Frequency

Typical Characteristics (continued)

Operation of the device at these or any other conditions beyond those indicated in the *Recommended Operating Conditions* table are not implied.

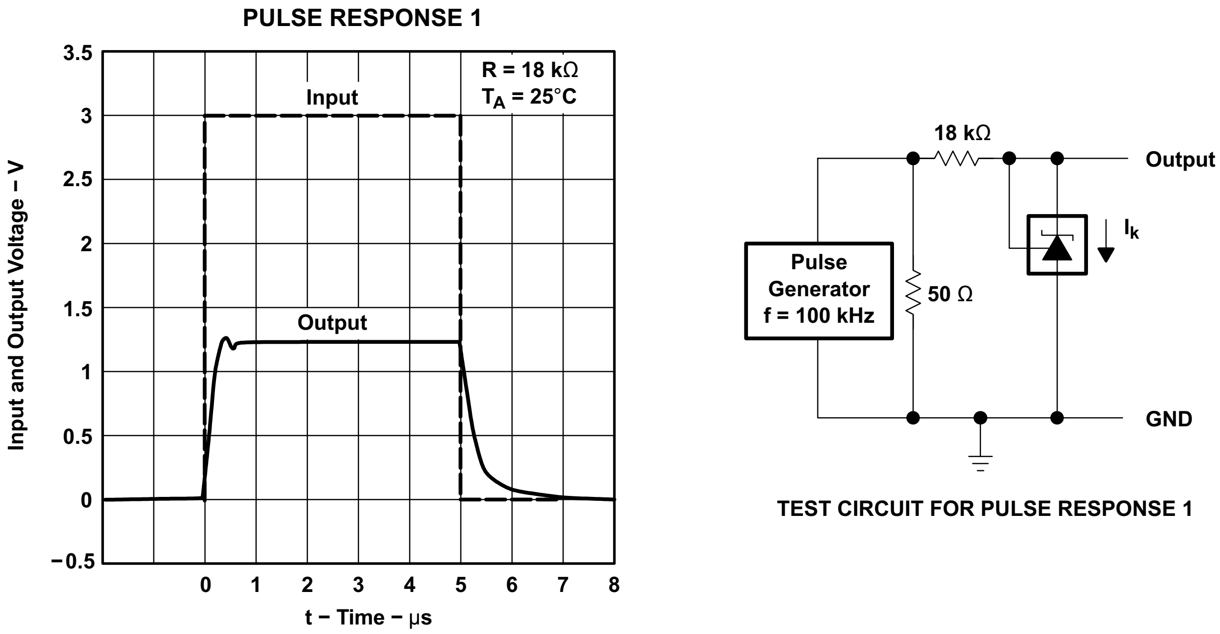


Figure 16. Pulse Response 1

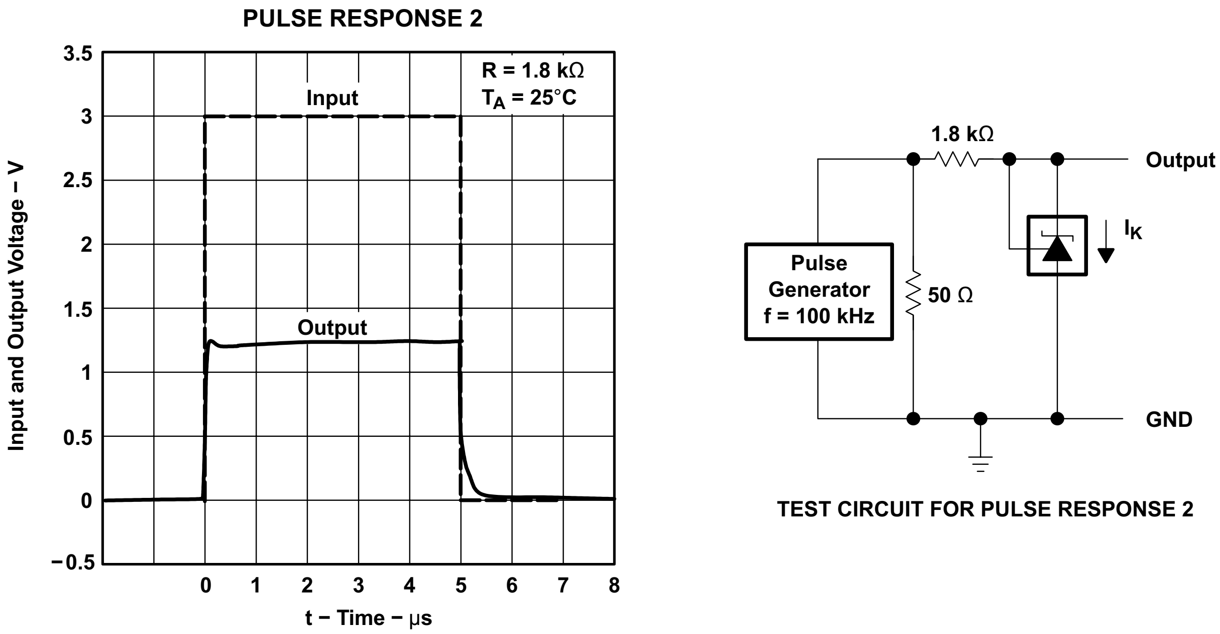
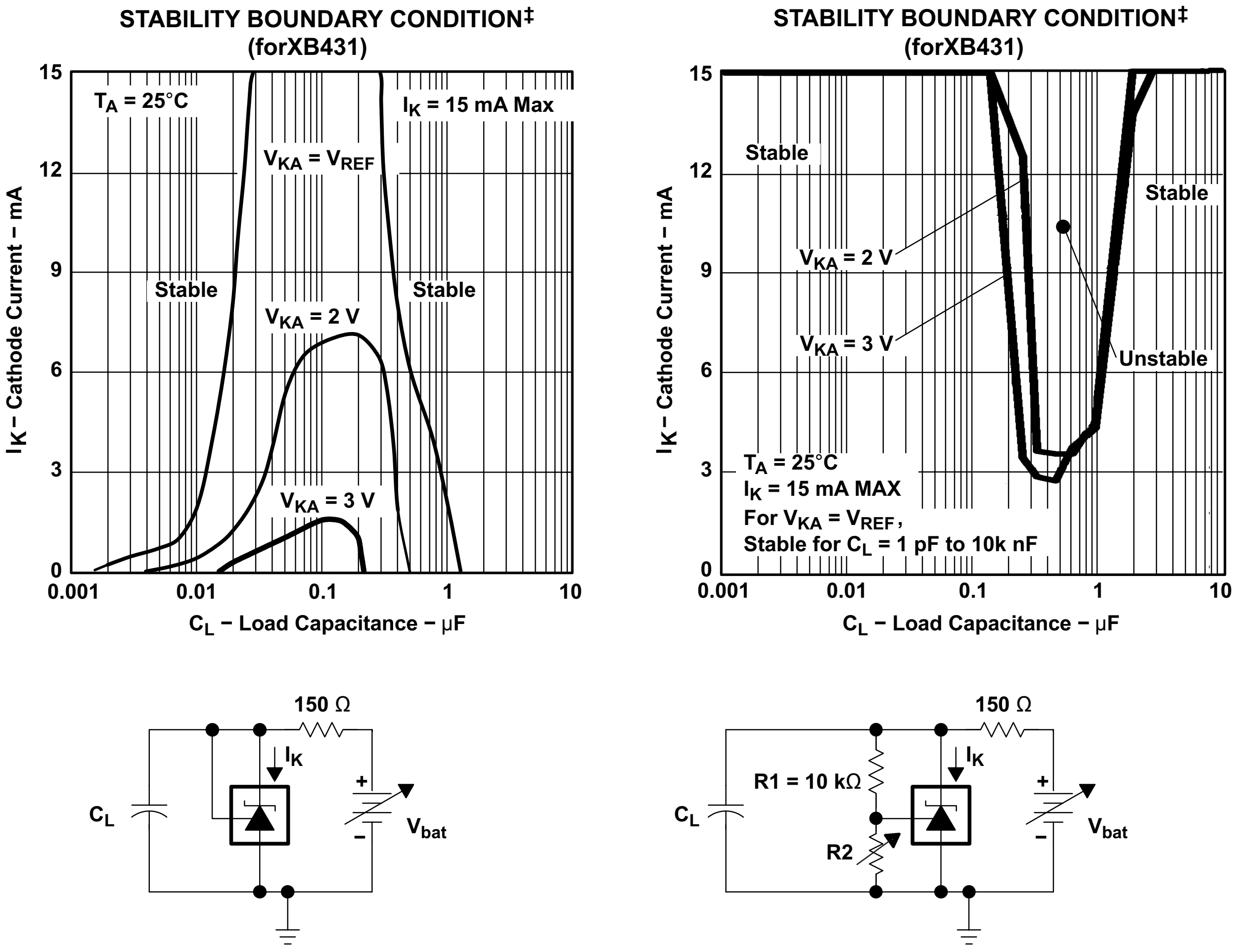


Figure 17. Pulse Response 2

Typical Characteristics (continued)

Operation of the device at these or any other conditions beyond those indicated in the *Recommended Operating Conditions* table are not implied.


STABILITY BOUNDARY CONDITION‡ (forXB431)

STABILITY BOUNDARY CONDITION‡ (forXB431)

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 18. Stability Boundary Conditions

8 Parameter Measurement Information

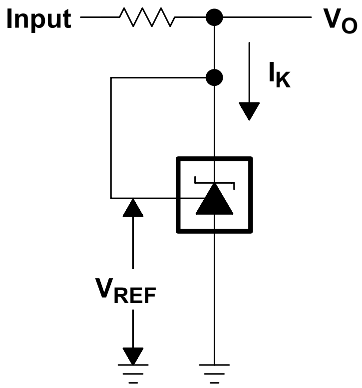


Figure 19. Test Circuit for $V_{KA} = V_{REF}$, $V_O = V_{KA} = V_{REF}$

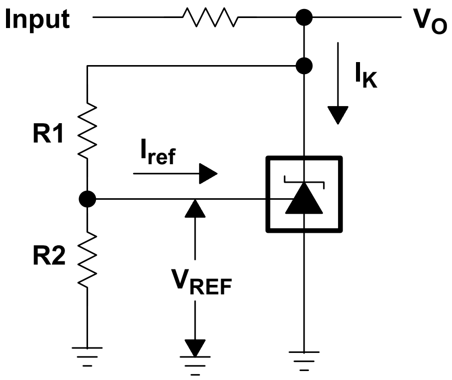


Figure 20. Test Circuit for $V_{KA} > V_{REF}$, $V_O = V_{KA} = V_{REF} \times (1 + R1/R2) + I_{ref} \times R1$

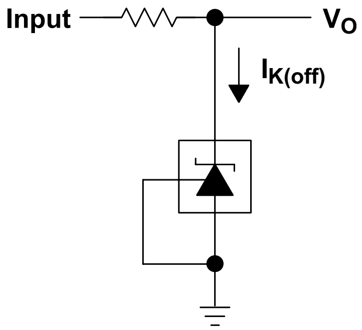


Figure 21. Test Circuit for $I_{K(off)}$

9 Detailed Description

9.1 Overview

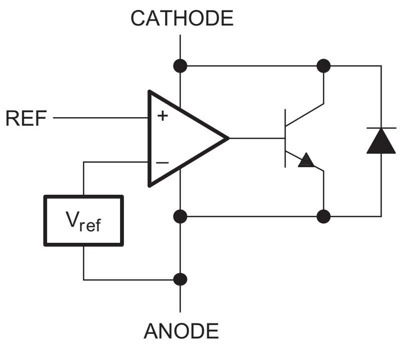
XB431 is a low power counterpart to XB431, having lower reference voltage (1.24 V vs 2.5 V) for lower voltage adjustability and lower minimum cathode current ($I_{k(min)}$=100 µA vs 1 mA). Like XB431, XB431 is used in conjunction with it's key components to behave as a single voltage reference, error amplifier, voltage clamp or comparator with integrated reference.

XB431 can be operated and adjusted to cathode voltages from 1.24V to 6V, making this part optimum for a wide range of end equipments in industrial, auto, telecom & computing. In order for this device to behave as a shunt regulator or error amplifier, > 100 µA (I_{min}(max)) must be supplied in to the cathode pin. Under this condition, feedback can be applied from the Cathode and Ref pins to create a replica of the internal reference voltage.

Various reference voltage options can be purchased with initial tolerances (at 25°C) of 0.5%, 1%, and 1.5%. These reference options are denoted by B (0.5%), A (1.0%) and blank (1.5%) after the XB431.

The XB431 devices are characterized for operation from 0°C to 70°C, the XB431 devices are characterized for operation from –40°C to 85°C, and the XB431 devices are characterized for operation from –40°C to 125°C.

9.2 Functional Block Diagram



9.3 Feature Description

XB431 consists of an internal reference and amplifier that outputs a sink current base on the difference between the reference pin and the virtual internal pin. The sink current is produced by an internal darlington pair.

When operated with enough voltage headroom (≥ 1.24 V) and cathode current (Ika), XB431 forces the reference pin to 1.24 V. However, the reference pin can not be left floating, as it needs $I_{ref} \geq 0.5$ µA (please see the Functional Block Diagram). This is because the reference pin is driven into an npn, which needs base current in order operate properly.

When feedback is applied from the Cathode and Reference pins, XB431 behaves as a Zener diode, regulating to a constant voltage dependent on current being supplied into the cathode. This is due to the internal amplifier and reference entering the proper operating regions. The same amount of current needed in the above feedback situation must be applied to this device in open loop, servo or error amplifying implementations in order for it to be in the proper linear region giving XB431 enough gain.

Unlike many linear regulators, XB431 is internally compensated to be stable without an output capacitor between the cathode and anode. However, if it is desired to use an output capacitor Figure 18 can be used as a guide to assist in choosing the correct capacitor to maintain stability.

9.4 Device Functional Modes

9.4.1 Open Loop (Comparator)

When the cathode/output voltage or current of XB431 is not being fed back to the reference/input pin in any form, this device is operating in open loop. With proper cathode current (Ika) applied to this device, XB431 will have the characteristics shown in Figure 6. With such high gain in this configuration, XB431 is typically used as a comparator. With the reference integrated makes XB431 the preferred choice when users are trying to monitor a certain level of a single signal.

9.4.2 Closed Loop

When the cathode/output voltage or current of XB431 is being fed back to the reference/input pin in any form, this device is operating in closed loop. The majority of applications involving XB431 use it in this manner to regulate a fixed voltage or current. The feedback enables this device to behave as an error amplifier, computing a portion of the output voltage and adjusting it to maintain the desired regulation. This is done by relating the output voltage back to the reference pin in a manner to make it equal to the internal reference voltage, which can be accomplished via resistive or direct feedback.

10 Applications and Implementation

10.1 Application Information

Figure 22 shows the XB431 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 in the topology shown in Figure 22.

The 431 family of devices are prevalent in these applications, being designers go to choice for secondary side regulation. Due to this prevalence, this section will further go on to explain operation and design in both states of XB431 that this application will see, open loop (Comparator + Vref) & closed loop (Shunt Regulator).

Further information about system stability and using a XB431 device for compensation can be found in the application note *Compensation Design With XB431 for UCC28600,* SLUA671.

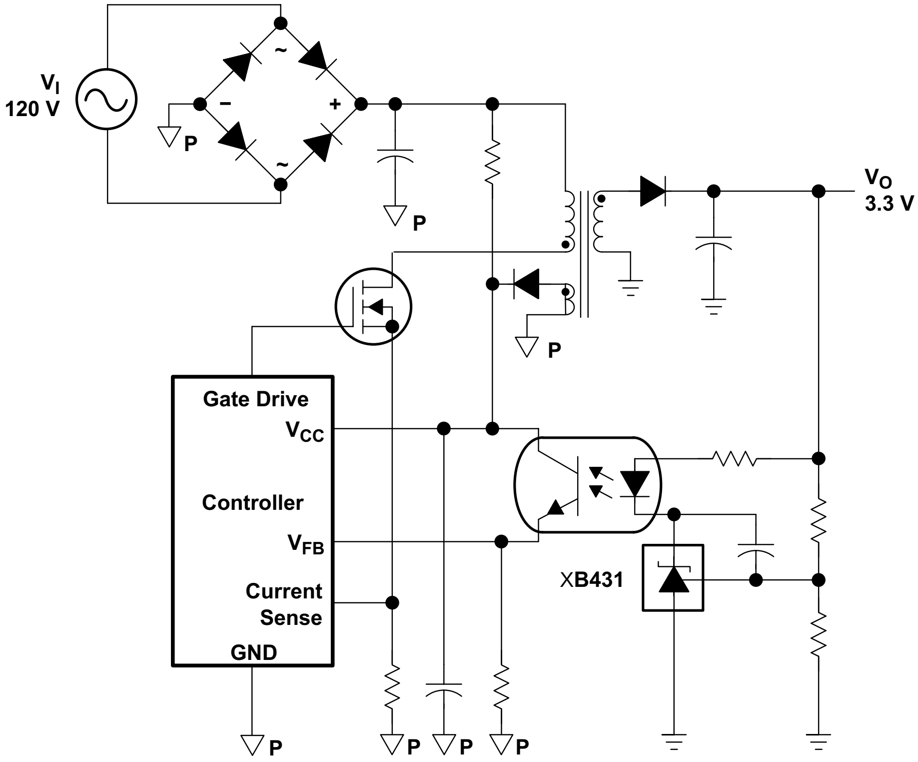


Figure 22. Flyback With Isolation Using XB431 as Voltage Reference and Error Amplifier

10.2 Typical Applications

10.2.1 Comparator with Integrated Reference (Open Loop)

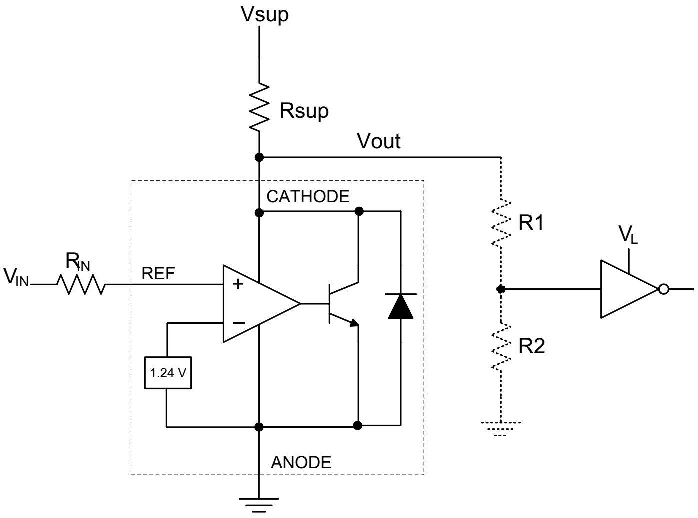


Figure 23. Comparator Application Schematic

10.2.1.1 Design Requirements

For this design example, use the parameters listed in Table 1 as the input parameters.

Table 1. Design Parameters

DESIGN PARAMETER	EXAMPLE VALUE
Input Voltage Range	0 V to 5 V
Input Resistance	10 kΩ
Supply Voltage	5 V
Cathode Current (Ik)	500 µA
Output Voltage Level	~1 V - Vsup
Logic Input Thresholds VIH/VIL	VL

10.2.1.2 Detailed Design Procedure

When using XB431 as a comparator with reference, determine the following:

- Input voltage range
- Reference voltage accuracy
- Output logic input high and low level thresholds
- Current source resistance

10.2.1.2.1 Basic Operation

In the configuration shown in Figure 23 XB431 will behave as a comparator, comparing the V_{ref} pin voltage to the internal virtual reference voltage. When provided a proper cathode current (I_k), XB431 will have enough open loop gain to provide a quick response. With the XB431 max Operating Current (Imin) being 100 uA and up to 150 uA over temperature, operation below that could result in low gain, leading to a slow response.

10.2.1.2.2 Overdrive

Slow or inaccurate responses can also occur when the reference pin is not provided enough overdrive voltage. This is the amount of voltage that is higher than the internal virtual reference. The internal virtual reference voltage will be within the range of 1.24V ±(0.5%, 1.0% or 1.5%) depending on which version is being used.

The more overdrive voltage provided, the faster the XB431 will respond. This can be seen in figures Figure 24 and Figure 25, where it displays the output responses to various input voltages.

For applications where XB431 is being used as a comparator, it is best to set the trip point to greater than the positive expected error (i.e. +1.0% for the A version). For fast response, setting the trip point to > 10% of the internal V_{ref} should suffice.

For minimal voltage drop or difference from Vin to the ref pin, it is recommended to use an input resistor < 10 kΩ to provide I_{ref}.

10.2.1.2.3 Output Voltage and Logic Input Level

In order for XB431 to properly be used as a comparator, the logic output must be readable by the recieving logic device. This is accomplished by knowing the input high and low level threshold voltage levels, typically denoted by V_{IH} & V_{IL}.

As seen in Figure 24, XB431 output low level voltage in open-loop/comparator mode is ~1 V, which is sufficient for some 3.3V supplied logic. However, would not work for 2.5 V and 1.8 V supplied logic. In order to accommodate this a resistive divider can be tied to the output to attenuate the output voltage to a voltage legible to the receiving low voltage logic device.

XB431 output high voltage is approximately V_{sup} due to TLV431 being open-collector. If V_{sup} is much higher than the receiving logic's maximum input voltage tolerance, the output must be attenuated to accommodate the outgoing logic's reliability.

When using a resistive divider on the output, be sure to make the sum of the resistive divider (R1 & R2 in Figure 23) is much greater than R_{sup} in order to not interfere with XB431 ability to pull close to V_{sup} when turning off.

10.2.1.2.3.1 Input Resistance

XB431 requires an input resistance in this application in order to source the reference current (I_{ref}) needed from this device to be in the proper operating regions while turning on. The actual voltage seen at the ref pin will be $V_{ref}=V_{in}-I_{ref}*R_{in}$. Since I_{ref} can be as high as 0.5 µA it is recommended to use a resistance small enough that will mitigate the error that I_{ref} creates from V_{in}.

10.2.1.3 Application Curves

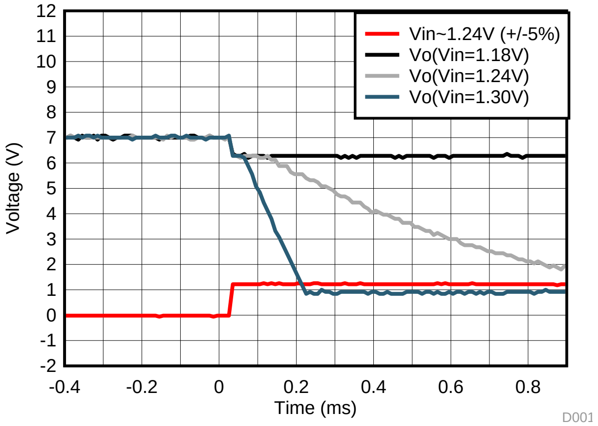


Figure 24. Output Response with Small Overdrive Voltages

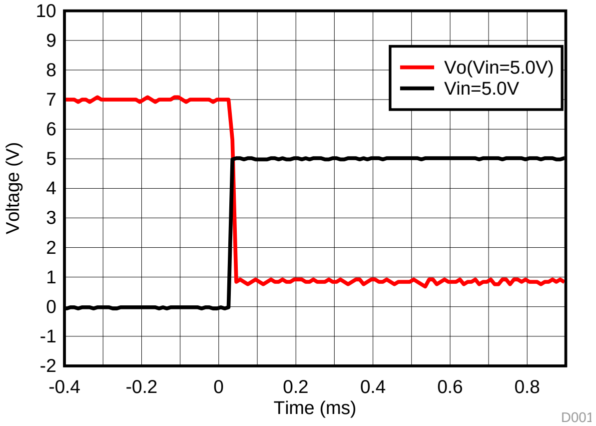


Figure 25. Output Response with Large Overdrive Voltage

10.2.2 Shunt Regulator/Reference

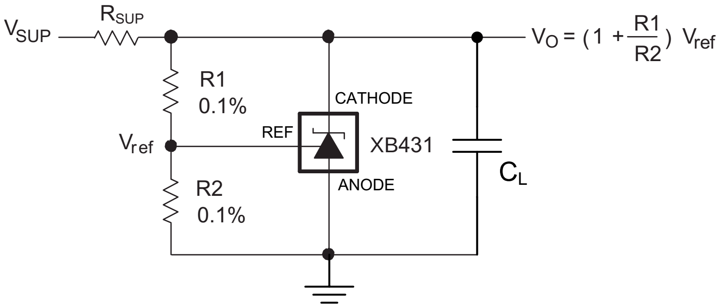


Figure 26. Shunt Regulator Schematic

10.2.2.1 Design Requirements

For this design example, use the parameters listed in Table 2 as the input parameters.

Table 2. Design Parameters

DESIGN PARAMETER	EXAMPLE VALUE
Reference Initial Accuracy	1.0%
Supply Voltage	6 V
Cathode Current (Ik)	1 mA
Output Voltage Level	1.24 V - 6 V
Load Capacitance	100 nF
Feedback Resistor Values and Accuracy (R1 & R2)	10 kΩ

10.2.2.2 Detailed Design Procedure

When using XB431 as a Shunt Regulator, determine the following:

- Input voltage range
- Temperature range
- Total accuracy
- Cathode current
- Reference initial accuracy
- Output capacitance

10.2.2.2.1 Programming Output/Cathode Voltage

In order to program the cathode voltage to a regulated voltage a resistive bridge must be shunted between the cathode and anode pins with the mid point tied to the reference pin. This can be seen in Figure 26, with R1 & R2 being the resistive bridge. The cathode/output voltage in the shunt regulator configuration can be approximated by the equation shown in Figure 26. The cathode voltage can be more accuratel determined by taking in to account the cathode current:

$V_O=(1+R1/R2)*V_{ref}–I_{ref}*R1$

In order for this equation to be valid, XB431 must be fully biased so that it has enough open loop gain to mitigate any gain error. This can be done by meeting the I_{min} spec denoted in *Recommended Operating Conditions* table.

10.2.2.2.2 Total Accuracy

When programming the output above unity gain (Vka=Vref), XB431 is susceptible to other errors that may effect the overall accuracy beyond V_{ref}. These errors include:

- R1 and R2 accuracies
- $V_{I(dev)}$ - Change in reference voltage over temperature
- $\Delta V_{ref} / \Delta V_{KA}$ - Change in reference voltage to the change in cathode voltage
- $|z_{KA}|$ - Dynamic impedance, causing a change in cathode voltage with cathode current

Worst case cathode voltage can be determined taking all of the variables in to account. Application note SLVA445 assists designers in setting the shunt voltage to achieve optimum accuracy for this device.

10.2.2.2.3 Stability

Though XB431 is stable with no capacitive load, the device that receives the shunt regulator's output voltage could present a capacitive load that is within the XB431 region of stability, shown in Figure 18. Also, designers may use capacitive loads to improve the transient response or for power supply decoupling.

10.2.2.3 Application Curves

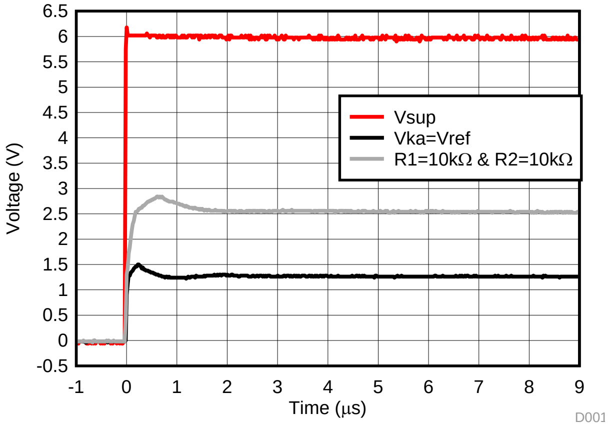


Figure 27. XB431 Start-up Response

11 Power Supply Recommendations

When using XB431 as a Linear Regulator to supply a load, designers will typically use a bypass capacitor on the output/cathode pin. When doing this, be sure that the capacitance is within the stability criteria shown in Figure 18.

In order to not exceed the maximum cathode current, be sure that the supply voltage is current limited. Also, be sure to limit the current being driven into the Ref pin, as not to exceed it's absolute maximum rating.

For applications shunting high currents, pay attention to the cathode and anode trace lengths, adjusting the width of the traces to have the proper current density.

12 Layout

12.1 Layout Guidelines

Place decoupling capacitors as close to the device as possible. Use appropriate widths for traces when shunting high currents to avoid excessive voltage drops.

12.2 Layout Example

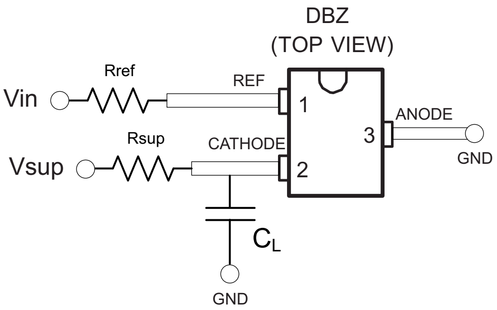


Figure 28. DBZ Layout Example

XB431-TL SOT23-3