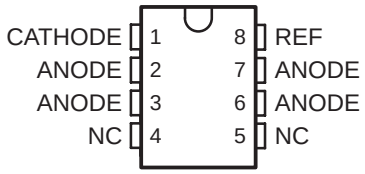
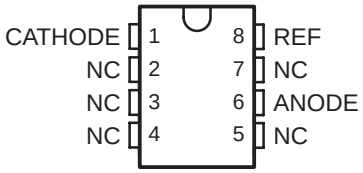
- **Operation From −40°C to 125°C**
- **Reference Voltage Tolerance at 25°C**
  - **0.5% . . . B Grade**
  - **1% . . . A Grade**
  - **2% . . . Standard Grade**
- **Typical Temperature Drift (TL431B)**
  - **6 mV (C Temp)**
  - **14 mV (I Temp, Q Temp)**
- **Low Output Noise**
- **0.2-Ω Typical Output Impedance**
- **Sink-Current Capability . . . 1 mA to 100 mA**
- **Adjustable Output Voltage . . . V_{ref} to 36 V**

TL431, TL431A, TL431B . . . D (SOIC) PACKAGE
(TOP VIEW)



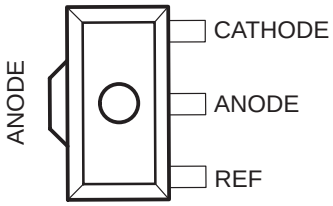
NC − No internal connection

TL431, TL431A, TL431B . . . P (PDIP), PS (SOP), OR PW (TSSOP) PACKAGE
(TOP VIEW)

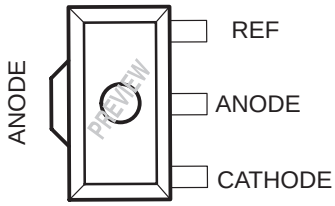


NC − No internal connection

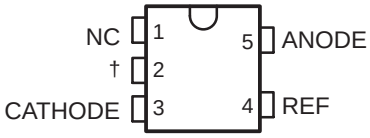
TL431, TL431A, TL431B . . . PK (SOT-89) PACKAGE
(TOP VIEW)



TL432, TL432A, TL432B . . . PK (SOT-89) PACKAGE
(TOP VIEW)

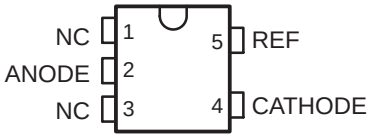


TL431, TL431A, TL431B . . . DBV (SOT-23-5) PACKAGE
(TOP VIEW)



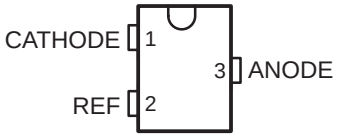
NC − No internal connection
† Pin 2 is attached to Substrate and must be connected to ANODE or left open.

TL432, TL432A, TL432B . . . DBV (SOT-23-5) PACKAGE
(TOP VIEW)

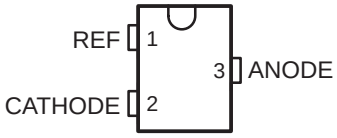


NC − No internal connection

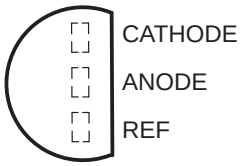
TL431, TL431A, TL431B . . . DBZ (SOT-23-3) PACKAGE
(TOP VIEW)



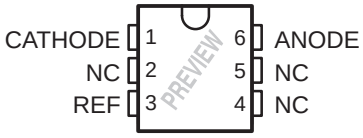
TL432, TL432A, TL432B . . . DBZ (SOT-23-3) PACKAGE
(TOP VIEW)



TL431, TL431A, TL431B . . . LP (TO-92/TO-226) PACKAGE
(TOP VIEW)

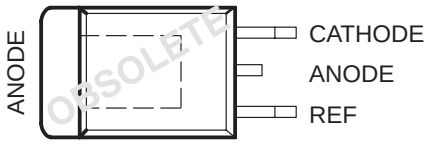


TL431A, TL431B . . . DCK (SC-70) PACKAGE
(TOP VIEW)



NC − No internal connection

TL431 . . . KTP (PowerFLEX™/TO-252) PACKAGE
(TOP VIEW)



description/ordering information

The TL431 and TL432 are three-terminal adjustable shunt regulators, with specified thermal stability over applicable automotive, commercial, and military temperature ranges. The output voltage can be set to any value between V_{ref} (approximately 2.5 V) and 36 V, with two external resistors (see Figure 17). These devices have a typical output impedance of 0.2 Ω. Active output circuitry provides a very sharp turn-on characteristic, making these devices excellent replacements for Zener diodes in many applications, such as onboard regulation, adjustable power supplies, and switching power supplies. The TL432 has exactly the same functionality and electrical specifications as the TL431, but has different pinouts for the DBV, DBZ, and PK packages.

Both the TL431 and TL432 devices are offered in three grades, with initial tolerances (at 25°C) of 0.5%, 1%, and 2%, for the B, A, and standard grade, respectively. In addition, low output drift vs temperature ensures good stability over the entire temperature range.

The TL43xxC devices are characterized for operation from 0°C to 70°C, the TL43xxI devices are characterized for operation from −40°C to 85°C, and the TL43xxQ devices are characterized for operation from −40°C to 125°C.

V_{ref} TOLERANCE (25°C) = 2%
TL431, TL432 ORDERING INFORMATION

T_A	PACKAGE†		ORDERABLE PART NUMBER	TOP-SIDE MARKING‡
0°C to 70°C	PDIP (P)	Tube of 50	TL431CP	TL431CP
	SOIC (D)	Tube of 75	TL431CD	TL431C
		Reel of 2500	TL431CDR	
	SOP (PS)	Reel of 2000	TL431CPSR	T431
	SOT-23-5 (DBV)	Reel of 3000	TL431CDBVR	T3C_
		Reel of 250	TL431CDBVT	
		Reel of 3000	TL432CDBVR	T4C_
		Reel of 250	TL432CDBVT	
	SOT-23-3 (DBZ)	Reel of 3000	TL431CDBZR	T3C_
		Reel of 250	TL431CDBZT	
		Reel of 3000	TL432CDBZR	T4C_
		Reel of 250	TL432CDBZT	
	SOT-89 (PK)	Reel of 1000	TL431CPK	43
			TL432CPK	2A
	TO-226/TO-92 (LP)	Bulk of 1000, straight lead	TL431CLP	TL431C
		Ammo of 2000, formed lead	TL431CLPM	
		Reel of 2000, formed lead	TL431CLPR	
	TSSOP (PW)	Tube of 150	TL431CPW	T431
		Reel of 2000	TL431CPWR	
−40°C to 85°C	PDIP (P)	Tube of 50	TL431IP	TL431IP
	SOIC (D)	Tube of 75	TL431ID	TL431I
		Reel of 2500	TL431IDR	
	SOT-23-5 (DBV)	Reel of 3000	TL431IDBVR	T3I_
		Reel of 250	TL431IDBVT	
		Reel of 3000	TL432IDBVR	T4I_
		Reel of 250	TL432IDBVT	
	SOT-23-3 (DBZ)	Reel of 3000	TL431IDBZR	T3I_
		Reel of 250	TL431IDBZT	
		Reel of 3000	TL432IDBZR	T4I_
		Reel of 250	TL432IDBZT	
	SOT-89 (PK)	Reel of 1000	TL431IPK	3I
			TL432IPK	2B
	TO-226/TO-92 (LP)	Bulk of 1000, straight lead	TL431ILP	TL431I
		Ammo of 2000, formed lead	TL431ILPM	
		Reel of 2000, formed lead	TL431ILPR	

† Package drawings, standard packing quantities, thermal data, symbolization, and PCB design guidelines are available at www.ti.com/sc/package.

‡ DBV/DBZ: The actual top-side marking has one additional character that designates the assembly/test site.

V_{ref} TOLERANCE (25°C) = 2%
TL431, TL432 ORDERING INFORMATION (CONTINUED)

T_A	PACKAGE†		ORDERABLE PART NUMBER	TOP-SIDE MARKING‡
−40°C to 125°C	SOT-23-5 (DBV)	Reel of 3000	TL431QDBVR	T3Q_
		Reel of 250	TL431QDBVT	
		Reel of 3000	TL432QDBVR	T4Q_
		Reel of 250	TL432QDBVT	
	SOT-23-3 (DBZ)	Reel of 3000	TL431QDBZR	T3Q_
		Reel of 250	TL431QDBZT	
		Reel of 3000	TL432QDBZR	T4Q_
		Reel of 250	TL432QDBZT	
	SOT-89 (PK)	Reel of 1000	TL431QPK	3Q
			TL432QPK	2C
	SC-70 (DCK)	Reel of 1000	TL431QDCKR	T6_
		Reel of 250	TL431QDCKT	

† Package drawings, standard packing quantities, thermal data, symbolization, and PCB design guidelines are available at www.ti.com/sc/package.

‡ DBV/DBZ/DCK: The actual top-side marking has one additional character that designates the assembly/test site.

V_{ref} TOLERANCE (25°C) = 1%
TL431A, TL432A ORDERING INFORMATION

T_A	PACKAGE†		ORDERABLE PART NUMBER	TOP-SIDE MARKING‡
0°C to 70°C	PDIP (P)	Tube of 50	TL431ACP	TL431ACP
	SC-70 (DCK)	Reel of 3000	TL431ACDCKR	T4_
		Reel of 250	TL431ACDCKT	
	SOIC (D)	Tube of 75	TL431ACD	431AC
		Reel of 2500	TL431ACDR	
	SOP (PS)	Reel of 2000	TL431ACPSR	T431A
	SOT-23-5 (DBV)	Reel of 3000	TL431ACDBVR	TAC_
		Reel of 250	TL431ACDBVT	
		Reel of 3000	TL432ACDBVR	T4B_
		Reel of 250	TL432ACDBVT	
	SOT-23-3 (DBZ)	Reel of 3000	TL431ACDBZR	TAC_
		Reel of 250	TL431ACDBZT	
		Reel of 3000	TL432ACDBZR	T4B_
		Reel of 250	TL432ACDBZT	
	SOT-89 (PK)	Reel of 1000	TL431ACPK	4A
			TL432ACPK	2D
	TO-226/TO-92 (LP)	Bulk of 1000, straight lead	TL431ACLP	TL431AC
		Ammo of 2000, formed lead	TL431ACLPM	
		Reel of 2000, formed lead	TL431ACLPR	
		Reel of 2000, formed lead	TL431ACLPRE3	
	TSSOP (PW)	Tube of 150	TL431ACPW	T431A
		Reel of 2000	TL431ACPWR	

† Package drawings, standard packing quantities, thermal data, symbolization, and PCB design guidelines are available at www.ti.com/sc/package.

‡ DBV/DBZ/DCK: The actual top-side marking has one additional character that designates the assembly/test site.

V_{ref} TOLERANCE (25°C) = 1%
TL431A, TL432A ORDERING INFORMATION (CONTINUED)

T_A	PACKAGE†		ORDERABLE PART NUMBER	TOP-SIDE MARKING‡
−40°C to 85°C	PDIP (P)	Tube of 50	TL431AIP	TL431AIP
	SC-70 (DCK)	Reel of 3000	TL431AIDCKR	T5_
		Reel of 250	TL431AIDCKT	
	SOIC (D)	Tube of 75	TL431AID	431AI
		Reel of 2500	TL431AIDR	
	SOT-23-5 (DBV)	Reel of 3000	TL431AIDBVR	TAI_
		Reel of 250	TL431AIDBVT	
		Reel of 3000	TL432AIDBVR	T4A_
		Reel of 250	TL432AIDBVT	
	SOT-23-3 (DBZ)	Reel of 3000	TL431AIDBZR	TAI_
		Reel of 250	TL431AIDBZT	
		Reel of 3000	TL432AIDBZR	T4A_
		Reel of 250	TL432AIDBZT	
	SOT-89 (PK)	Reel of 1000	TL431AIPK	4B
			TL432AIPK	2E
	TO-226/TO-92 (LP)	Bulk of 1000, straight lead	TL431AILP	TL431AI
		Ammo of 2000, formed lead	TL431AILPM	
		Reel of 2000, formed lead	TL431AILPR	
−40°C to 125°C	SOT-23-5 (DBV)	Reel of 3000	TL431AQDBVR	TAQ_
		Reel of 250	TL431AQDBVT	
		Reel of 3000	TL432AQDBVR	T4D_
		Reel of 250	TL432AQDBVT	
	SOT-23-3 (DBZ)	Reel of 3000	TL431AQDBZR	TAQ_
		Reel of 250	TL431AQDBZT	
		Reel of 3000	TL432AQDBZR	T4D_
		Reel of 250	TL432AQDBZT	
	SOT-89 (PK)	Reel of 1000	TL431AQPK	4D
			TL432AQPK	2F
	SC-70 (PK)	Reel of 1000	TL431AQDCKR	T7_
		Reel of 250	TL431AQDCKT	

† Package drawings, standard packing quantities, thermal data, symbolization, and PCB design guidelines are available at www.ti.com/sc/package.

‡ DBV/DBZ/DCK: The actual top-side marking has one additional character that designates the assembly/test site.

V_{ref} TOLERANCE (25°C) = 0.5%
TL431B, TL432B ORDERING INFORMATION

T_A	PACKAGE†		ORDERABLE PART NUMBER	TOP-SIDE MARKING‡
0°C to 70°C	PDIP (P)	Tube of 50	TL431BCP	TL431BCP
	SC-70 (DCK)	Reel of 3000	TL431BCDCKR	T2_
		Reel of 250	TL431BCDCKT	
	SOIC (D)	Tube of 75	TL431BCD	T431B
		Reel of 2500	TL431BCDR	
	SOP (PS)	Reel of 2000	TL431BCPSR	TL431B
	SOT-23-5 (DBV)	Reel of 3000	TL431BCDBVR	T3G_
		Reel of 250	TL431BCDBVT	
		Reel of 3000	TL432BCDBVR	TBC_
		Reel of 250	TL432BCDBVT	
	SOT-23-3 (DBZ)	Reel of 3000	TL431BCDBZR	T3G_
		Reel of 250	TL431BCDBZT	
		Reel of 3000	TL432BCDBZR	TBC_
		Reel of 250	TL432BCDBZT	
	SOT-89 (PK)	Reel of 1000	TL431BCPK	4C
			TL432BCPK	2G
	TO-226/TO-92 (LP)	Bulk of 1000, straight lead	TL431BCLP	TL431B
		Ammo of 2000, formed lead	TL431BCLPM	
		Reel of 2000, formed lead	TL431BCLPR	
	TSSOP (PW)	Tube of 150	TL431BCPW	T431B
		Reel of 2000	TL431BCPWR	

† Package drawings, standard packing quantities, thermal data, symbolization, and PCB design guidelines are available at www.ti.com/sc/package.

‡ DBV/DBZ/DCK: The actual top-side marking has one additional character that designates the assembly/test site.

V_{ref} TOLERANCE (25°C) = 0.5%
TL431B, TL432B ORDERING INFORMATION (CONTINUED)

T_A	PACKAGE†		ORDERABLE PART NUMBER	TOP-SIDE MARKING‡
−40°C to 85°C	PDIP (P)	Tube of 50	TL431BIP	TL431BIP
	SC-70 (DCK)	Reel of 3000	TL431BIDCKR	T3_
		Reel of 250	TL431BIDCKT	
	SOIC (D)	Tube of 75	TL431BID	Z431B
		Reel of 2500	TL431BIDR	
	SOT-23-5 (DBV)	Reel of 3000	TL431BIDBVR	T3F_
		Reel of 250	TL431BIDBVT	
		Reel of 3000	TL432BIDBVR	T4F_
		Reel of 250	TL432BIDBVT	
	SOT-23-3 (DBZ)	Reel of 3000	TL431BIDBZR	T3F_
		Reel of 250	TL431BIDBZT	
		Reel of 3000	TL432BIDBZR	T4F_
		Reel of 250	TL432IBDBZT	
	SOT-89 (PK)	Reel of 1000	TL431BIPK	4I
			TL432BIPK	2H
	TO-226/TO-92 (LP)	Bulk of 1000, straight lead	TL431BILP	Z431B
		Ammo of 2000, formed lead	TL431BILPM	
		Reel of 2000, fomed lead	TL431BILPR	

† Package drawings, standard packing quantities, thermal data, symbolization, and PCB design guidelines are available at www.ti.com/sc/package.

‡ DBV/DBZ/DCK: The actual top-side marking has one additional character that designates the assembly/test site.

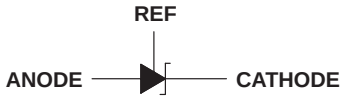
V_{ref} TOLERANCE (25°C) = 0.5%
TL431B, TL432B ORDERING INFORMATION (CONTINUED)

T_A	PACKAGE†		ORDERABLE PART NUMBER	TOP-SIDE MARKING‡
−40°C to 125°C	SOIC (D)	Tube of 75	TL431BQD	T431BQ
		Reel of 2500	TL431BQDR	
	SOT-23-5 (DBV)	Reel of 3000	TL431BQDBVR	T3H_
		Reel of 250	TL431BQDBVT	
		Reel of 3000	TL432BQDBVR	T4H_
		Reel of 250	TL432BQDBVT	
	SOT-23-3 (DBZ)	Reel of 3000	TL431BQDBZR	T3H_
		Reel of 250	TL431BQDBZT	
		Reel of 3000	TL432BQDBZR	T4H_
		Reel of 250	TL432BQDBZT	
	SOT-89 (PK)	Reel of 1000	TL431BQPK	3H
			TL432BQPK	2J
	TO-226/TO-92 (LP)	Bulk of 1000, straight lead	TL431BQLP	T431BQ
		Ammo of 2000, formed lead	TL431BQLPM	
		Reel of 2000, formed lead	TL431BQLPR	
	SC-70 (DCK)	Reel of 1000	TL431BQDCKR	T8_
		Reel of 250	TL431BQDCKT	

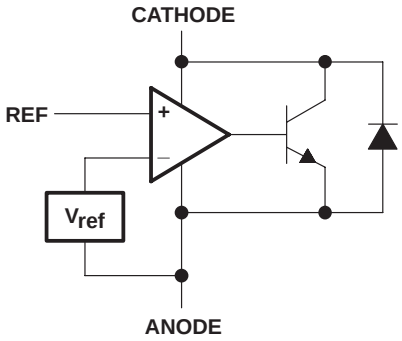
† Package drawings, standard packing quantities, thermal data, symbolization, and PCB design guidelines are available at www.ti.com/sc/package.

‡ DBV/DBZ/DCK: The actual top-side marking has one additional character that designates the assembly/test site.

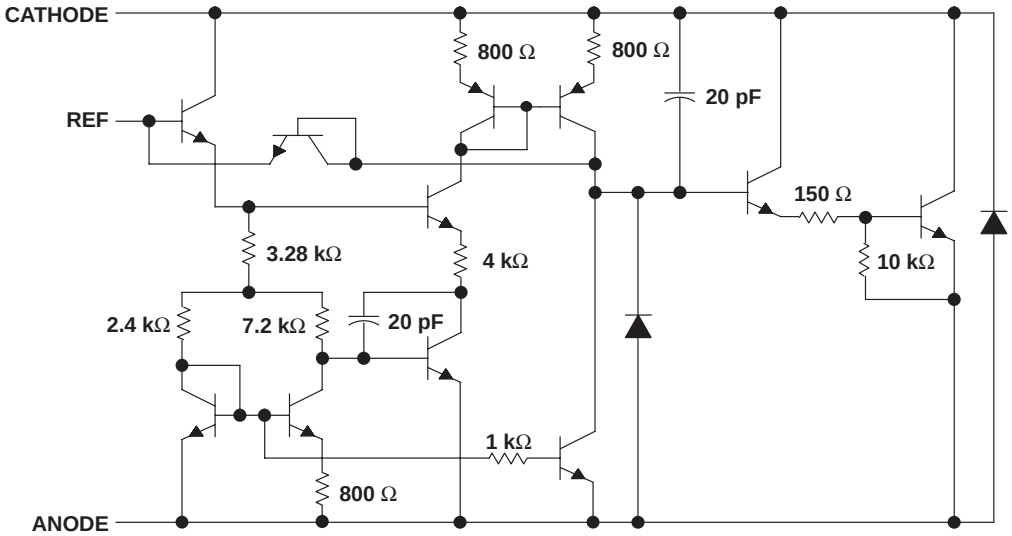
symbol



functional block diagram



equivalent schematic†



† All component values are nominal.

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
Operating virtual junction temperature, T_J . . . . . 150°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.

NOTE 1: Voltage values are with respect to the ANODE terminal, unless otherwise noted.

package thermal data (see Note 2)

PACKAGE	BOARD	θ_{JC}	θ_{JA}
PDIP (P)	High K, JESD 51-7	57°C/W	85°C/W
SC-70 (DCK)	High K, JESD 51-7	259°C/W	87°C/W
SOIC (D)	High K, JESD 51-7	39°C/W	97°C/W
SOP (PS)	High K, JESD 51-7	46°C/W	95°C/W
SOT-89 (PK)	High K, JESD 51-7	9°C/W	52°C/W
SOT-23-5 (DBV)	High K, JESD 51-7	131°C/W	206°C/W
SOT-23-3 (DBZ)	High K, JESD 51-7	76°C/W	206°C/W
TO-92 (LP)	High K, JESD 51-7	55°C/W	140°C/W
TSSOP (PW)	High K, JESD 51-7	65°C/W	149°C/W

NOTE 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.

recommended operating conditions

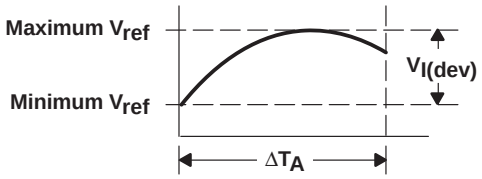
			MIN	MAX	UNIT
V_{KA}	Cathode voltage		V_{ref}	36	V
I_{KA}	Cathode current		1	100	mA
T_A	Operating free-air temperature range	TL43xxC	0	70	°C
		TL43xxI	−40	85	
		TL43xxQ	−40	125	

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

PARAMETER		TEST CIRCUIT	TEST CONDITIONS		TL431C TL432C			UNIT
					MIN	TYP	MAX	
V_{ref}	Reference voltage	2	V_{KA} = V_{ref}, I_{KA} = 10 mA		2440	2495	2550	mV
$V_{I(dev)}$	Deviation of reference voltage over full temperature range (see Figure 1)	2	V_{KA} = V_{ref}, I_{KA} = 10 mA, T_A = 0°C to 70°C	SOT23-3 and TL432 devices		6	16	mV
				All other devices		4	25	
$\frac{\Delta V_{ref}}{\Delta V_{KA}}$	Ratio of change in reference voltage to the change in cathode voltage	3	I_{KA} = 10 mA	ΔV_{KA} = 10 V − V_{ref}		−1.4	−2.7	$\frac{mV}{V}$
				ΔV_{KA} = 36 V − 10 V		−1	−2	
I_{ref}	Reference current	3	I_{KA} = 10 mA, R1 = 10 kΩ, R2 = ∞			2	4	µA
$I_{I(dev)}$	Deviation of reference current over full temperature range (see Figure 1)	3	I_{KA} = 10 mA, R1 = 10 kΩ, R2 = ∞, T_A = 0°C to 70°C			0.4	1.2	µA
I_{min}	Minimum cathode current for regulation	2	V_{KA} = V_{ref}			0.4	1	mA
I_{off}	Off-state cathode current	4	V_{KA} = 36 V, V_{ref} = 0			0.1	1	µA
$\|z_{KA}\|$	Dynamic impedance (see Figure 1)	1	I_{KA} = 1 mA to 100 mA, V_{KA} = V_{ref}, f ≤ 1 kHz			0.2	0.5	Ω

The deviation parameters $V_{ref(dev)}$ and $I_{ref(dev)}$ are defined as the differences between the maximum and minimum values obtained over the recommended temperature range. The average full-range temperature coefficient of the reference voltage, α_{Vref}, is defined as:

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



where:
ΔT_A is the recommended operating free-air 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.

Example: maximum V_{ref} = 2496 mV at 30°C, minimum V_{ref} = 2492 mV at 0°C, V_{ref} = 2495 mV at 25°C, ΔT_A = 70°C for TL431C

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

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

Calculating Dynamic Impedance

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

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

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

Figure 1. Calculating Deviation Parameters and Dynamic Impedance

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

PARAMETER		TEST CIRCUIT	TEST CONDITIONS		TL431I, TL432I			UNIT
					MIN	TYP	MAX	
V_{ref}	Reference voltage	2	V_{KA} = V_{ref},	I_{KA} = 10 mA	2440	2495	2550	mV
$V_{I(dev)}$	Deviation of reference voltage over full temperature range (see Figure 1)	2	V_{KA} = V_{ref}, I_{KA} = 10 mA, T_A = −40°C to 85°C	SOT23-3 and TL432 devices		14	34	mV
				All other devices		5	50	
$\frac{\Delta V_{ref}}{\Delta V_{KA}}$	Ratio of change in reference voltage to the change in cathode voltage	3	I_{KA} = 10 mA	ΔV_{KA} = 10 V − V_{ref}		−1.4	−2.7	$\frac{mV}{V}$
				ΔV_{KA} = 36 V − 10 V		−1	−2	
I_{ref}	Reference current	3	I_{KA} = 10 mA, R1 = 10 kΩ, R2 = ∞			2	4	µA
$I_{I(dev)}$	Deviation of reference current over full temperature range (see Figure 1)	3	I_{KA} = 10 mA, R1 = 10 kΩ, R2 = ∞, T_A = −40°C to 85°C			0.8	2.5	µA
I_{min}	Minimum cathode current for regulation	2	V_{KA} = V_{ref}			0.4	1	mA
I_{off}	Off-state cathode current	4	V_{KA} = 36 V,	V_{ref} = 0		0.1	1	µA
$\|z_{KA}\|$	Dynamic impedance (see Figure 1)	2	I_{KA} = 1 mA to 100 mA, V_{KA} = V_{ref}, f ≤ 1 kHz			0.2	0.5	Ω

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

PARAMETER		TEST CIRCUIT	TEST CONDITIONS		TL431Q, TL432Q			UNIT
					MIN	TYP	MAX	
V_{ref}	Reference voltage	2	V_{KA} = V_{ref},	I_{KA} = 10 mA	2440	2495	2550	mV
$V_{I(dev)}$	Deviation of reference voltage over full temperature range (see Figure 1)	2	V_{KA} = V_{ref}, I_{KA} = 10 mA, T_A = −40°C to 125°C			14	34	mV
$\frac{\Delta V_{ref}}{\Delta V_{KA}}$	Ratio of change in reference voltage to the change in cathode voltage	3	I_{KA} = 10 mA	ΔV_{KA} = 10 V − V_{ref}		−1.4	−2.7	$\frac{mV}{V}$
				ΔV_{KA} = 36 V − 10 V		−1	−2	
I_{ref}	Reference current	3	I_{KA} = 10 mA, R1 = 10 kΩ, R2 = ∞			2	4	µA
$I_{I(dev)}$	Deviation of reference current over full temperature range (see Figure 1)	3	I_{KA} = 10 mA, R1 = 10 kΩ, R2 = ∞, T_A = −40°C to 125°C			0.8	2.5	µA
I_{min}	Minimum cathode current for regulation	2	V_{KA} = V_{ref}			0.4	1	mA
I_{off}	Off-state cathode current	4	V_{KA} = 36 V,	V_{ref} = 0		0.1	1	µA
$\|z_{KA}\|$	Dynamic impedance (see Figure 1)	2	I_{KA} = 1 mA to 100 mA, V_{KA} = V_{ref}, f ≤ 1 kHz			0.2	0.5	Ω

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

PARAMETER		TEST CIRCUIT	TEST CONDITIONS		TL431AC, TL432AC			UNIT
					MIN	TYP	MAX	
V_{ref}	Reference voltage	2	V_{KA} = V_{ref}, I_{KA} = 10 mA		2470	2495	2520	mV
$V_{I(dev)}$	Deviation of reference voltage over full temperature range (see Figure 1)	2	V_{KA} = V_{ref}, I_{KA} = 10 mA, T_A = 0°C to 70°C	SOT23-3, SC-70, and TL432 devices		6	16	mV
				All other devices		4	25	
$\frac{\Delta V_{ref}}{\Delta V_{KA}}$	Ratio of change in reference voltage to the change in cathode voltage	3	I_{KA} = 10 mA	ΔV_{KA} = 10 V − V_{ref}		−1.4	−2.7	$\frac{mV}{V}$
				ΔV_{KA} = 36 V − 10 V		−1	−2	
I_{ref}	Reference current	3	I_{KA} = 10 mA, R1 = 10 kΩ, R2 = ∞			2	4	µA
$I_{I(dev)}$	Deviation of reference current over full temperature range (see Figure 1)	3	I_{KA} = 10 mA, R1 = 10 kΩ, R2 = ∞, T_A = 0°C to 70°C			0.8	1.2	µA
I_{min}	Minimum cathode current for regulation	2	V_{KA} = V_{ref}			0.4	0.6	mA
I_{off}	Off-state cathode current	4	V_{KA} = 36 V, V_{ref} = 0			0.1	0.5	µA
$\|z_{KA}\|$	Dynamic impedance (see Figure 1)	1	I_{KA} = 1 mA to 100 mA, V_{KA} = V_{ref}, f ≤ 1 kHz			0.2	0.5	Ω

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

PARAMETER		TEST CIRCUIT	TEST CONDITIONS		TL431AI, TL432AI			UNIT
					MIN	TYP	MAX	
V_{ref}	Reference voltage	2	V_{KA} = V_{ref}, I_{KA} = 10 mA		2470	2495	2520	mV
$V_{I(dev)}$	Deviation of reference voltage over full temperature range (see Figure 1)	2	V_{KA} = V_{ref}, I_{KA} = 10 mA, T_A = −40°C to 85°C	SOT23-3, SC-70, and TL432 devices		14	34	mV
				All other packages		5	50	
$\frac{\Delta V_{ref}}{\Delta V_{KA}}$	Ratio of change in reference voltage to the change in cathode voltage	3	I_{KA} = 10 mA	ΔV_{KA} = 10 V − V_{ref}		−1.4	−2.7	$\frac{mV}{V}$
				ΔV_{KA} = 36 V − 10 V		−1	−2	
I_{ref}	Reference current	3	I_{KA} = 10 mA, R1 = 10 kΩ, R2 = ∞			2	4	µA
$I_{I(dev)}$	Deviation of reference current over full temperature range (see Figure 1)	3	I_{KA} = 10 mA, R1 = 10 kΩ, R2 = ∞, T_A = −40°C to 85°C			0.8	2.5	µA
I_{min}	Minimum cathode current for regulation	2	V_{KA} = V_{ref}			0.4	0.7	mA
I_{off}	Off-state cathode current	4	V_{KA} = 36 V, V_{ref} = 0			0.1	0.5	µA
$\|z_{KA}\|$	Dynamic impedance (see Figure 1)	2	I_{KA} = 1 mA to 100 mA, V_{KA} = V_{ref}, f ≤ 1 kHz			0.2	0.5	Ω

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

PARAMETER		TEST CIRCUIT	TEST CONDITIONS		TL431AQ TL432AQ			UNIT
					MIN	TYP	MAX	
V_{ref}	Reference voltage	2	V_{KA} = V_{ref}, I_{KA} = 10 mA		2470	2495	2520	mV
$V_{I(dev)}$	Deviation of reference voltage over full temperature range (see Figure 1)	2	V_{KA} = V_{ref}, I_{KA} = 10 mA, T_A = −40°C to 125°C			14	34	mV
$\frac{\Delta V_{ref}}{\Delta V_{KA}}$	Ratio of change in reference voltage to the change in cathode voltage	3	I_{KA} = 10 mA	ΔV_{KA} = 10 V − V_{ref}		−1.4	−2.7	$\frac{mV}{V}$
				ΔV_{KA} = 36 V − 10 V		−1	−2	
I_{ref}	Reference current	3	I_{KA} = 10 mA, R1 = 10 kΩ, R2 = ∞			2	4	µA
$I_{I(dev)}$	Deviation of reference current over full temperature range (see Figure 1)	3	I_{KA} = 10 mA, R1 = 10 kΩ, R2 = ∞, T_A = −40°C to 125°C			0.8	2.5	µA
I_{min}	Minimum cathode current for regulation	2	V_{KA} = V_{ref}			0.4	0.7	mA
I_{off}	Off-state cathode current	4	V_{KA} = 36 V, V_{ref} = 0			0.1	0.5	µA
$\|z_{KA}\|$	Dynamic impedance (see Figure 1)	2	I_{KA} = 1 mA to 100 mA, V_{KA} = V_{ref}, f ≤ 1 kHz			0.2	0.5	Ω

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

PARAMETER		TEST CIRCUIT	TEST CONDITIONS		TL431BC TL432BC			UNIT
					MIN	TYP	MAX	
V_{ref}	Reference voltage	2	V_{KA} = V_{ref}, I_{KA} = 10 mA		2483	2495	2507	mV
$V_{I(dev)}$	Deviation of reference voltage over full temperature range (see Figure 1)	2	V_{KA} = V_{ref}, I_{KA} = 10 mA, T_A = 0°C to 70°C			6	16	mV
$\frac{\Delta V_{ref}}{\Delta V_{KA}}$	Ratio of change in reference voltage to the change in cathode voltage	3	I_{KA} = 10 mA	ΔV_{KA} = 10 V − V_{ref}		−1.4	−2.7	$\frac{mV}{V}$
				ΔV_{KA} = 36 V − 10 V		−1	−2	
I_{ref}	Reference current	3	I_{KA} = 10 mA, R1 = 10 kΩ, R2 = ∞			2	4	µA
$I_{I(dev)}$	Deviation of reference current over full temperature range (see Figure 1)	3	I_{KA} = 10 mA, R1 = 10 kΩ, R2 = ∞, T_A = 0°C to 70°C			0.8	1.2	µA
I_{min}	Minimum cathode current for regulation	2	V_{KA} = V_{ref}			0.4	0.6	mA
I_{off}	Off-state cathode current	4	V_{KA} = 36 V, V_{ref} = 0			0.1	0.5	µA
$\|z_{KA}\|$	Dynamic impedance (see Figure 1)	1	I_{KA} = 1 mA to 100 mA, V_{KA} = V_{ref}, f ≤ 1 kHz			0.2	0.5	Ω

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

PARAMETER		TEST CIRCUIT	TEST CONDITIONS		TL431BI, TL432BI			UNIT
					MIN	TYP	MAX	
V_{ref}	Reference voltage	2	V_{KA} = V_{ref}, I_{KA} = 10 mA		2483	2495	2507	mV
$V_{I(dev)}$	Deviation of reference voltage over full temperature range (see Figure 1)	2	V_{KA} = V_{ref}, I_{KA} = 10 mA, T_A = −40°C to 85°C			14	34	mV
$\frac{\Delta V_{ref}}{\Delta V_{KA}}$	Ratio of change in reference voltage to the change in cathode voltage	3	I_{KA} = 10 mA	ΔV_{KA} = 10 V − V_{ref}		−1.4	−2.7	$\frac{mV}{V}$
				ΔV_{KA} = 36 V − 10 V		−1	−2	
I_{ref}	Reference current	3	I_{KA} = 10 mA, R1 = 10 kΩ, R2 = ∞			2	4	µA
$I_{I(dev)}$	Deviation of reference current over full temperature range (see Figure 1)	3	I_{KA} = 10 mA, R1 = 10 kΩ, R2 = ∞, T_A = −40°C to 85°C			0.8	2.5	µA
I_{min}	Minimum cathode current for regulation	2	V_{KA} = V_{ref}			0.4	0.7	mA
I_{off}	Off-state cathode current	4	V_{KA} = 36 V, V_{ref} = 0			0.1	0.5	µA
$\|z_{KA}\|$	Dynamic impedance (see Figure 1)	2	I_{KA} = 1 mA to 100 mA, V_{KA} = V_{ref}, f ≤ 1 kHz			0.2	0.5	Ω

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

PARAMETER		TEST CIRCUIT	TEST CONDITIONS		TL431BQ, TL432BQ			UNIT
					MIN	TYP	MAX	
V_{ref}	Reference voltage	2	V_{KA} = V_{ref}, I_{KA} = 10 mA		2483	2495	2507	mV
$V_{I(dev)}$	Deviation of reference voltage over full temperature range (see Figure 1)	2	V_{KA} = V_{ref}, I_{KA} = 10 mA, T_A = −40°C to 125°C			14	34	mV
$\frac{\Delta V_{ref}}{\Delta V_{KA}}$	Ratio of change in reference voltage to the change in cathode voltage	3	I_{KA} = 10 mA	ΔV_{KA} = 10 V − V_{ref}		−1.4	−2.7	$\frac{mV}{V}$
				ΔV_{KA} = 36 V − 10 V		−1	−2	
I_{ref}	Reference current	3	I_{KA} = 10 mA, R1 = 10 kΩ, R2 = ∞			2	4	µA
$I_{I(dev)}$	Deviation of reference current over full temperature range (see Figure 1)	3	I_{KA} = 10 mA, R1 = 10 kΩ, R2 = ∞, T_A = −40°C to 125°C			0.8	2.5	µA
I_{min}	Minimum cathode current for regulation	2	V_{KA} = V_{ref}			0.4	0.7	mA
I_{off}	Off-state cathode current	4	V_{KA} = 36 V, V_{ref} = 0			0.1	0.5	µA
$\|z_{KA}\|$	Dynamic impedance (see Figure 1)	1	I_{KA} = 1 mA to 100 mA, V_{KA} = V_{ref}, f ≤ 1 kHz			0.2	0.5	Ω

PARAMETER MEASUREMENT INFORMATION

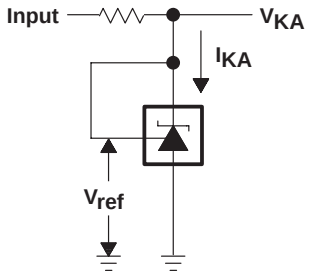


Figure 2. Test Circuit for $V_{KA} = V_{ref}$

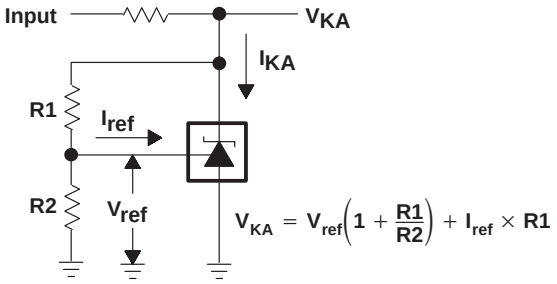


Figure 3. Test Circuit for $V_{KA} > V_{ref}$

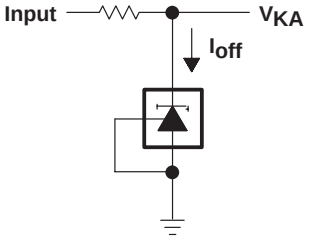


Figure 4. Test Circuit for I_{off}

TYPICAL CHARACTERISTICS

Table 1. Graphs

	FIGURE
Reference voltage vs Free-air temperature	5
Reference current vs Free-air temperature	6
Cathode current vs Cathode voltage	7, 8
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Table 2. Application Circuits

	FIGURE
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Precision high-current series regulator	19
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Delay timer	27
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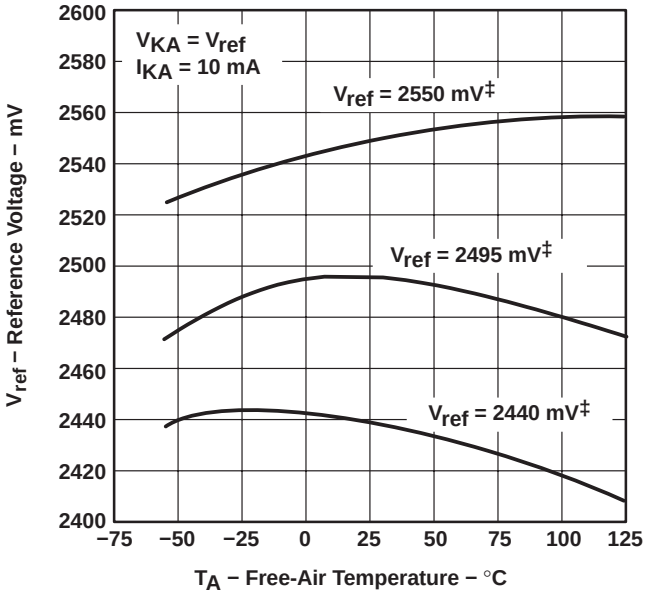
Precision constant-current sink	29

TYPICAL CHARACTERISTICS†

REFERENCE VOLTAGE vs FREE-AIR TEMPERATURE



‡ Data is for devices having the indicated value of V_{ref} at I_{KA} = 10 mA, T_A = 25°C.

Figure 5

REFERENCE CURRENT vs FREE-AIR TEMPERATURE

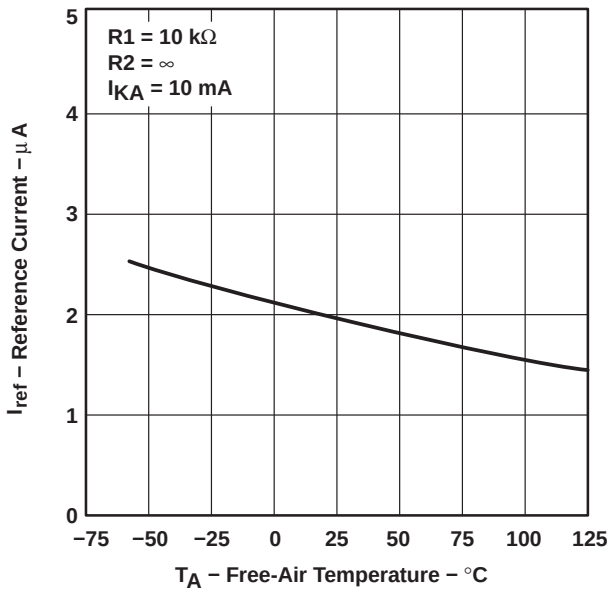


Figure 6

CATHODE CURRENT vs CATHODE VOLTAGE

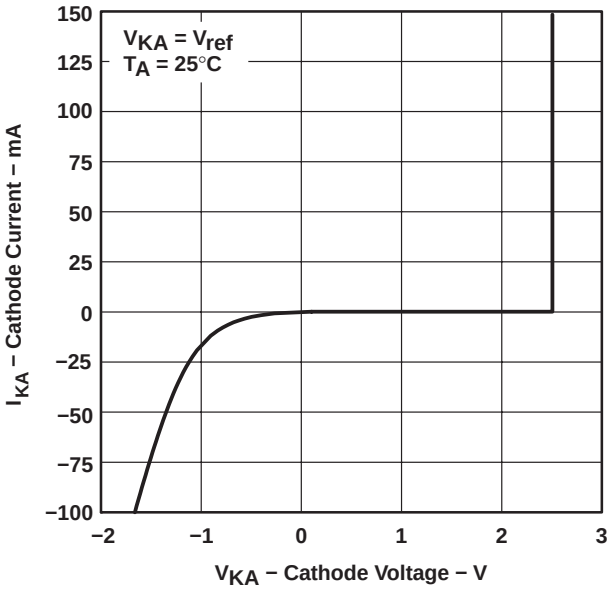


Figure 7

CATHODE CURRENT vs CATHODE VOLTAGE

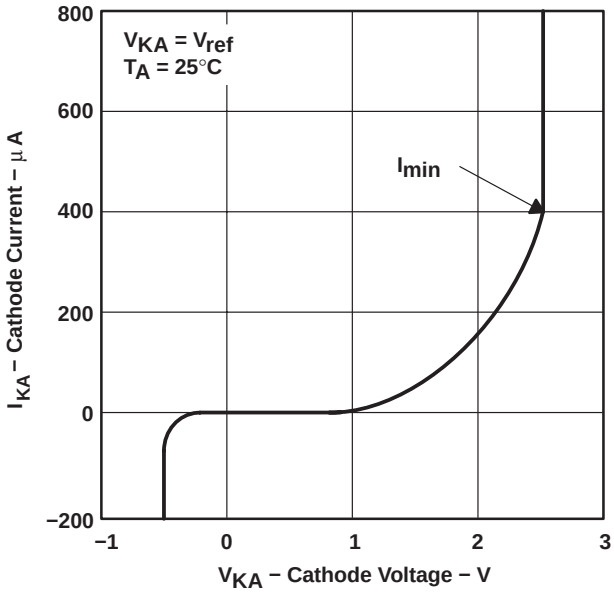


Figure 8

TYPICAL CHARACTERISTICS†

OFF-STATE CATHODE CURRENT
vs
FREE-AIR TEMPERATURE

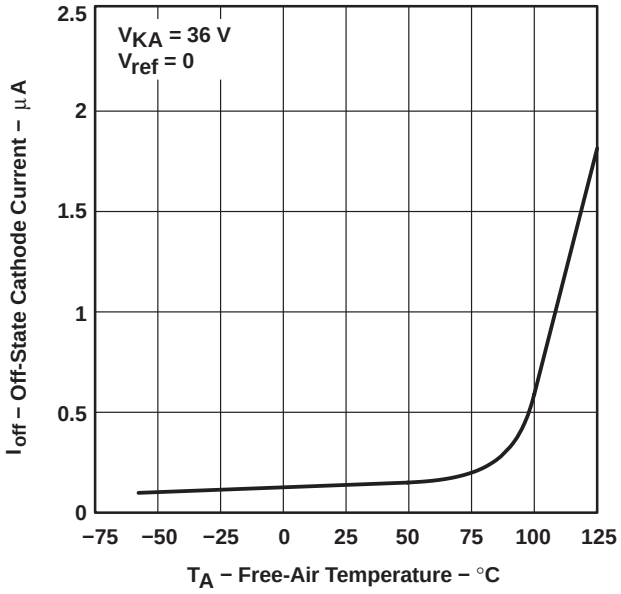


Figure 9

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

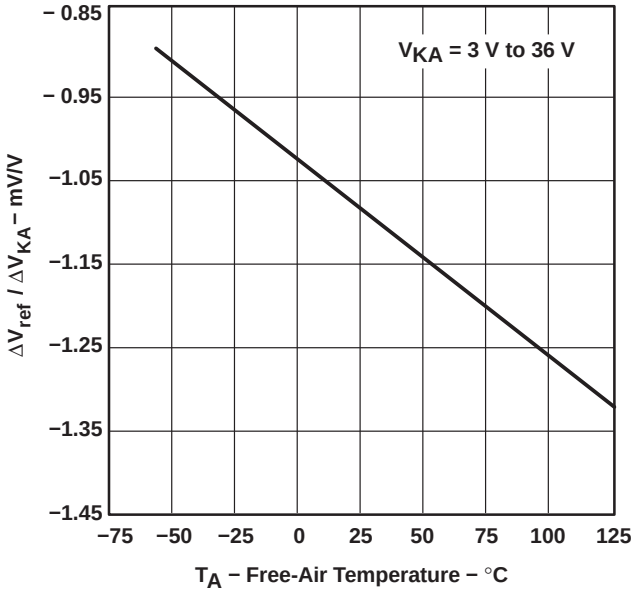


Figure 10

EQUIVALENT INPUT NOISE VOLTAGE
vs
FREQUENCY

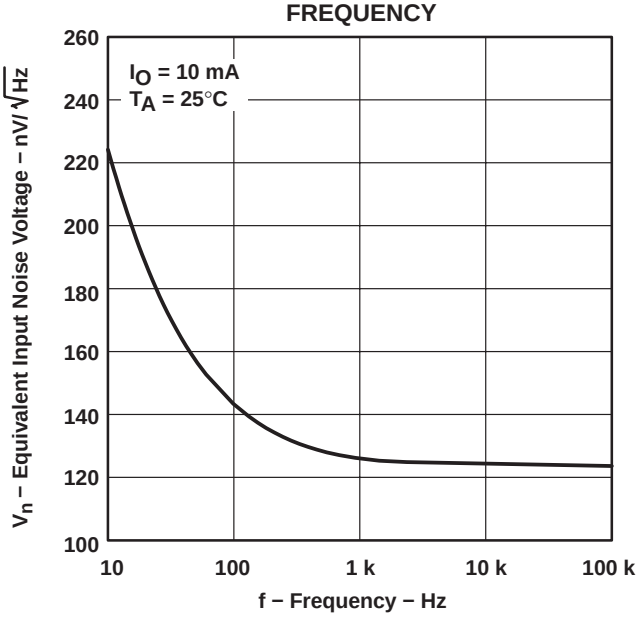


Figure 11

TYPICAL CHARACTERISTICS

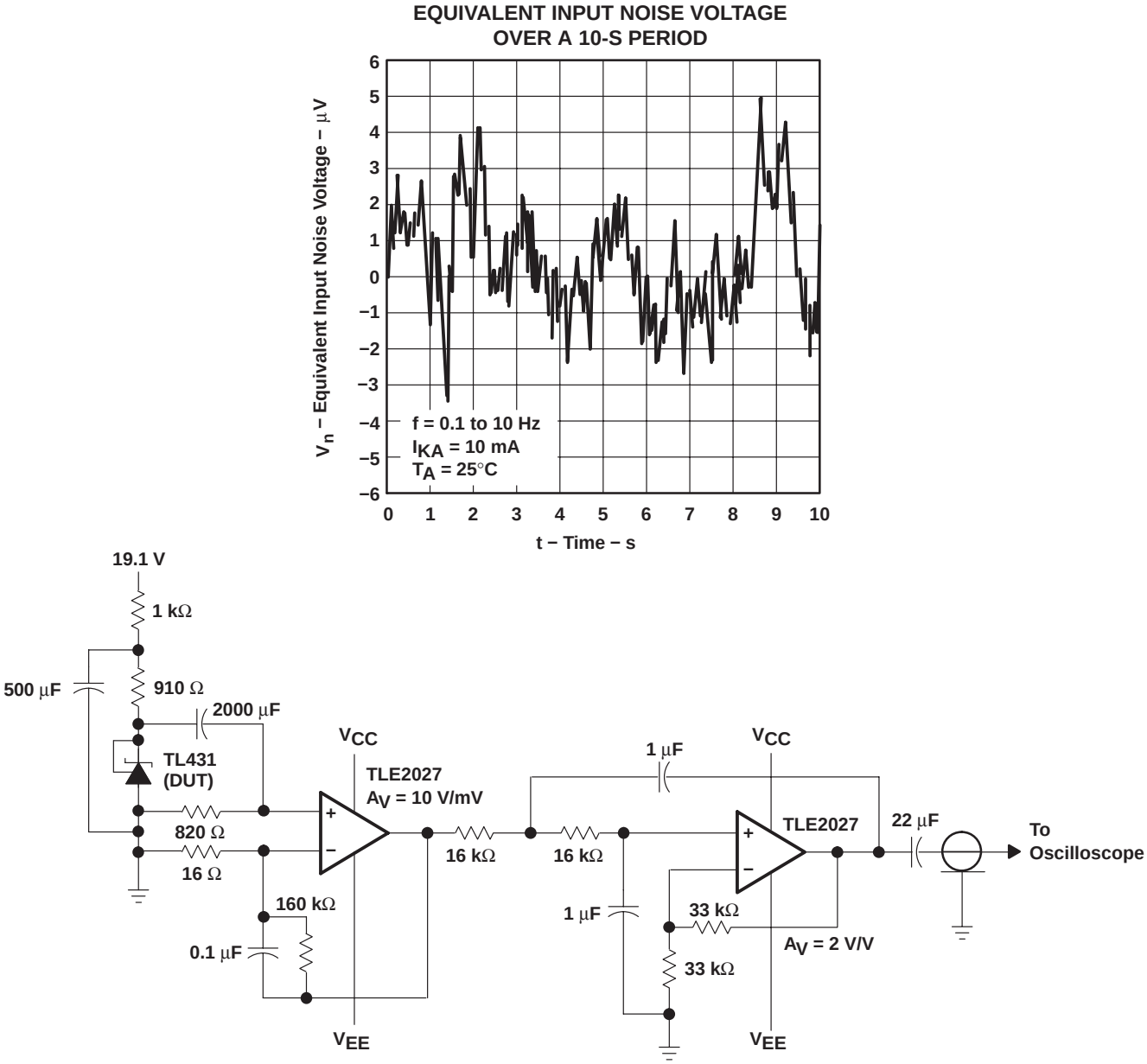
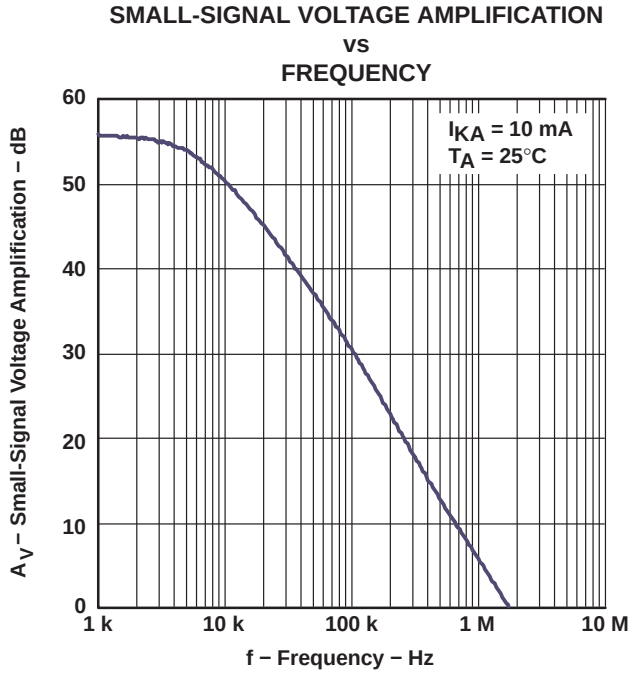
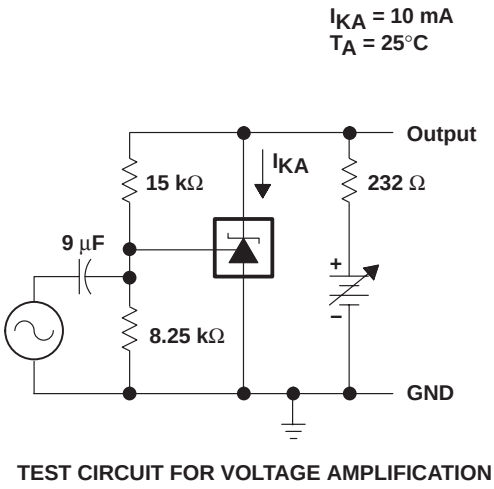


Figure 12. Test Circuit for Equivalent Input Noise Voltage

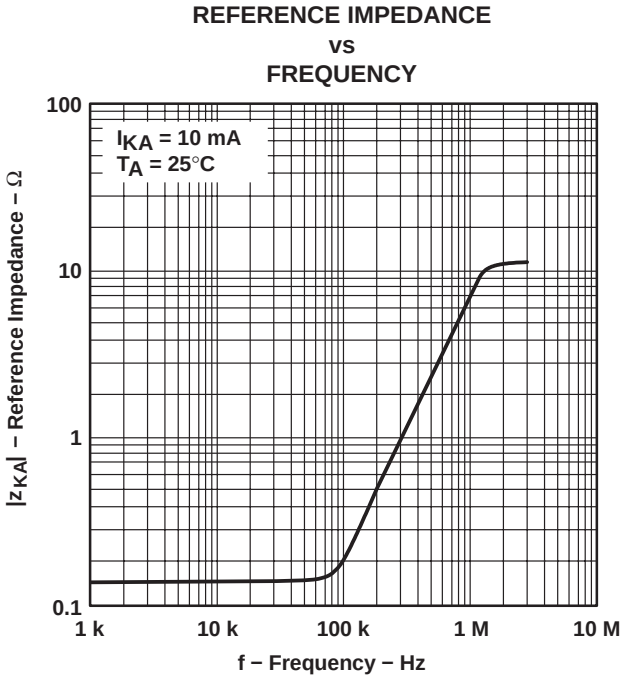
TYPICAL CHARACTERISTICS

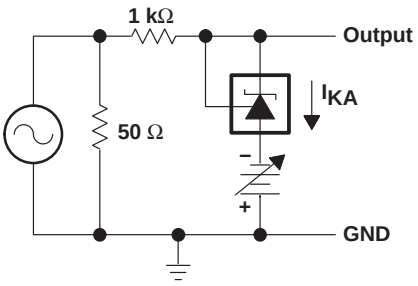




TEST CIRCUIT FOR VOLTAGE AMPLIFICATION

Figure 13





TEST CIRCUIT FOR REFERENCE IMPEDANCE

Figure 14

TYPICAL CHARACTERISTICS

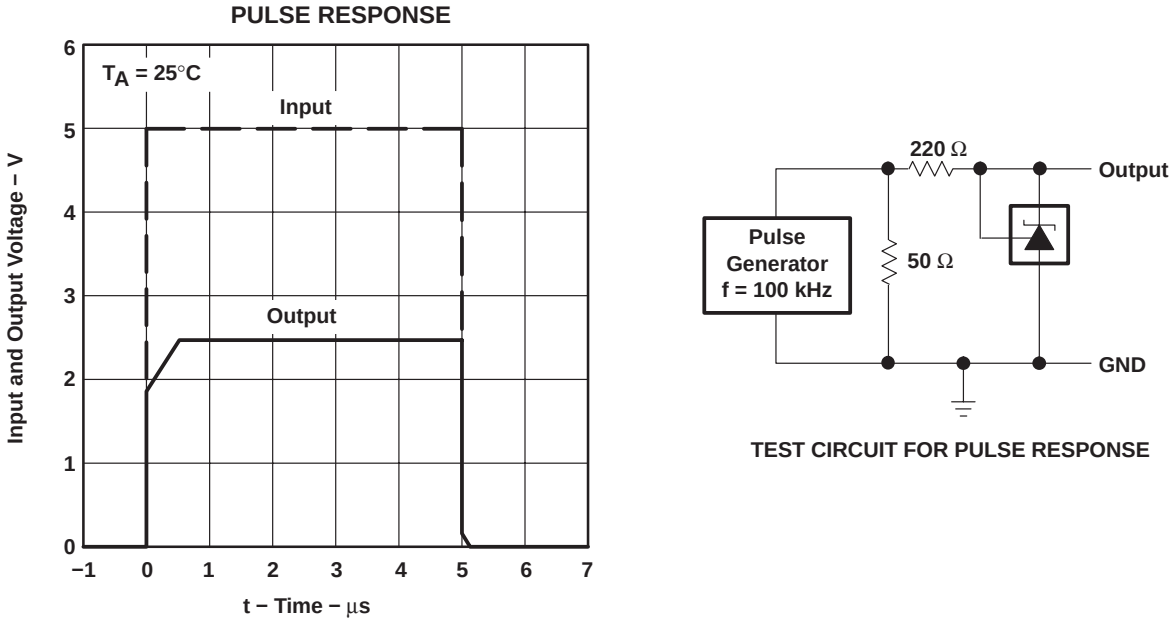
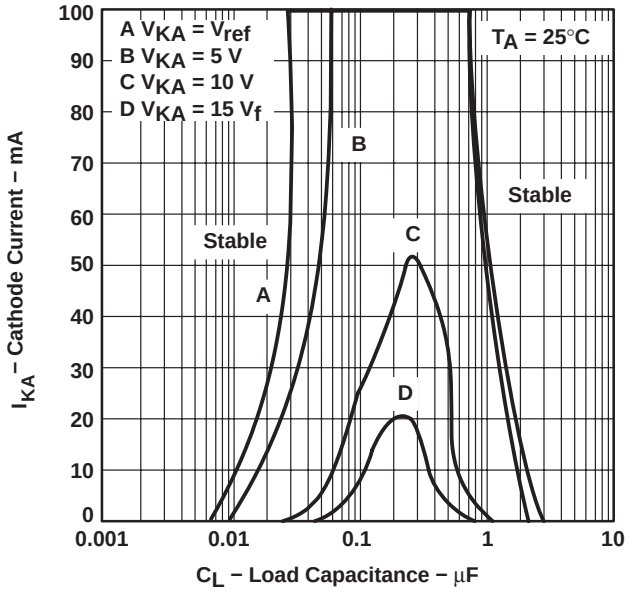
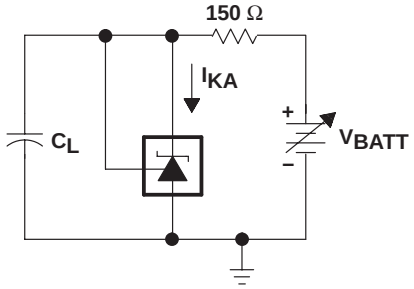


Figure 15

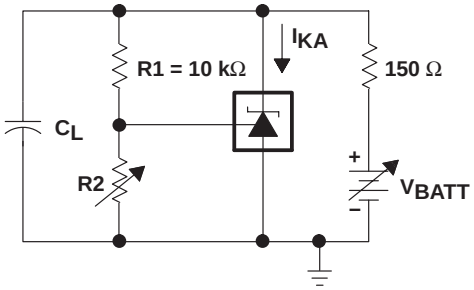
TYPICAL CHARACTERISTICS

STABILITY BOUNDARY CONDITIONS†
FOR ALL TL431 AND TL431A DEVICES
(EXCEPT FOR SOT23-3, SC-70, AND Q-TEMP DEVICES)



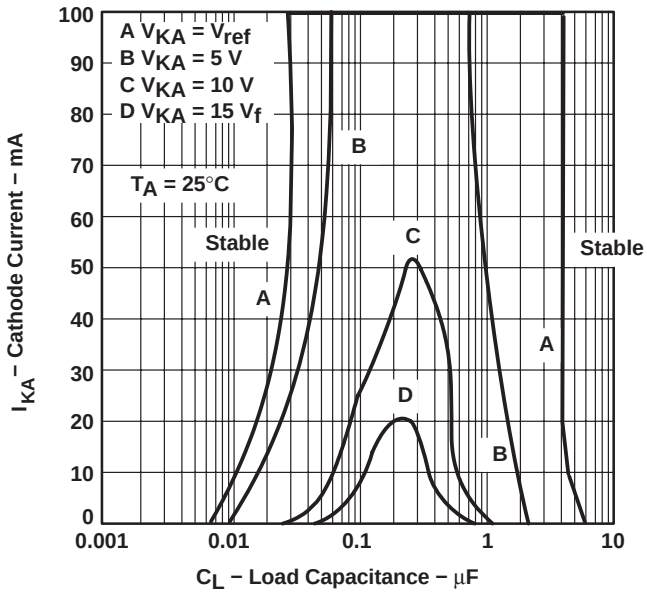


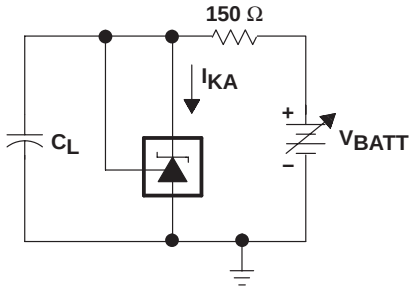
TEST CIRCUIT FOR CURVE A



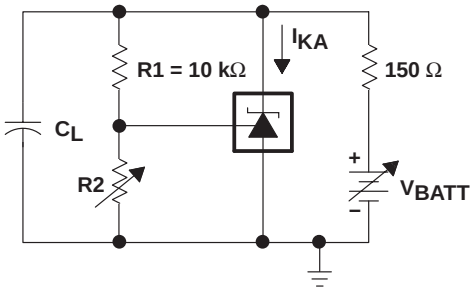
TEST CIRCUIT FOR CURVES B, C, AND D

STABILITY BOUNDARY CONDITIONS†
FOR ALL TL431B, TL432, SOT-23, SC-70, AND Q-TEMP DEVICES





TEST CIRCUIT FOR CURVE A

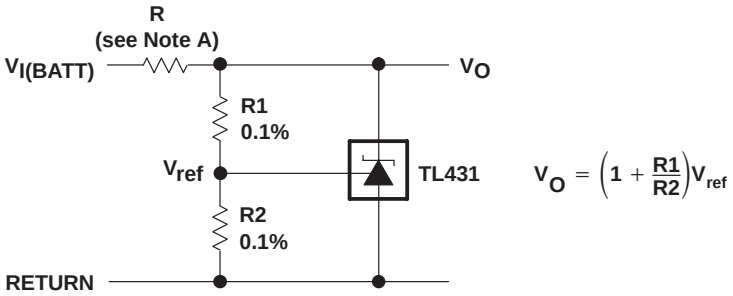


TEST CIRCUIT FOR CURVES B, C, AND D

† 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 then were adjusted to determine the ranges of stability.

Figure 16

APPLICATION INFORMATION



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

Figure 17. Shunt Regulator

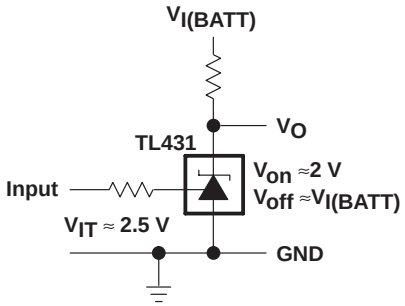
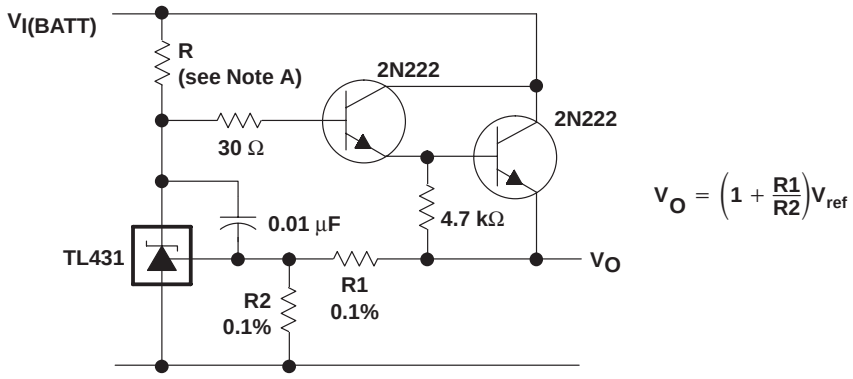


Figure 18. Single-Supply Comparator With Temperature-Compensated Threshold



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

Figure 19. Precision High-Current Series Regulator

APPLICATION INFORMATION

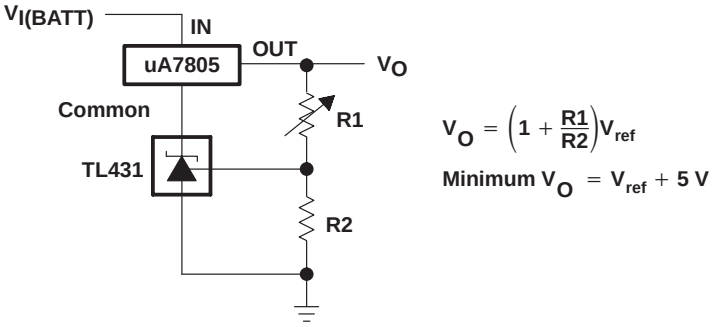


Figure 20. Output Control of a Three-Terminal Fixed Regulator

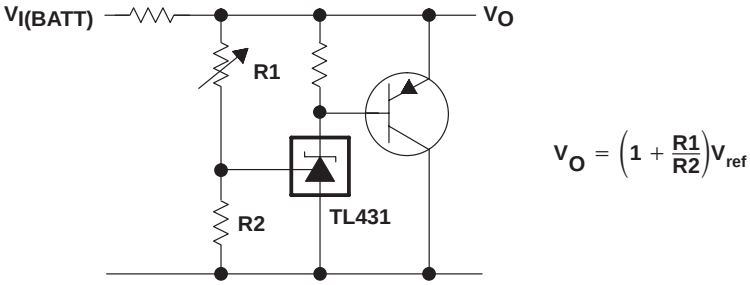
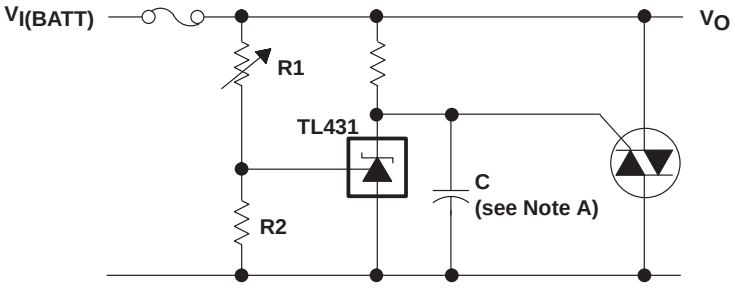


Figure 21. High-Current Shunt Regulator



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

Figure 22. Crowbar Circuit

APPLICATION INFORMATION

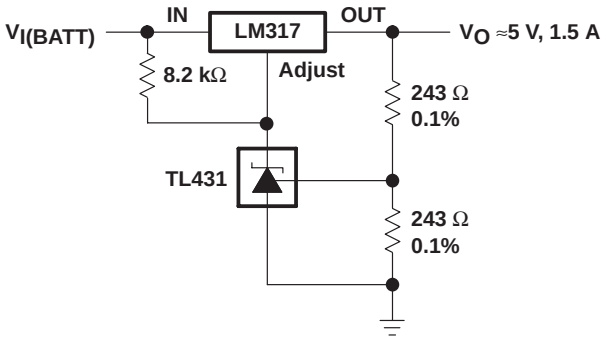
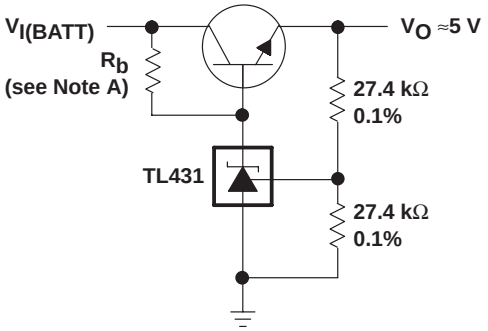


Figure 23. Precision 5-V 1.5-A Regulator



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

Figure 24. Efficient 5-V Precision Regulator

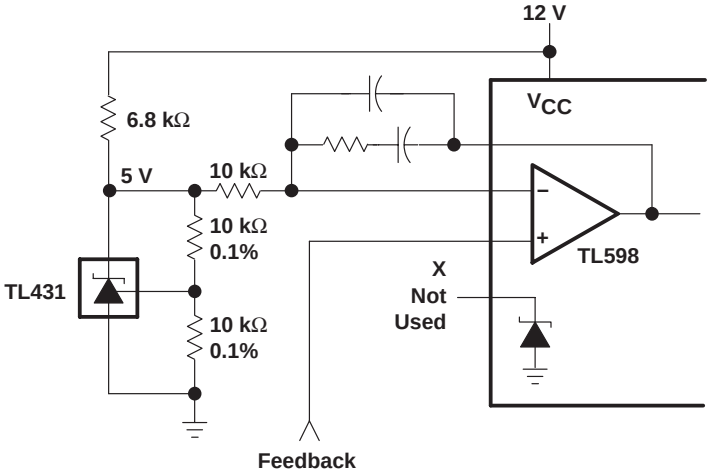
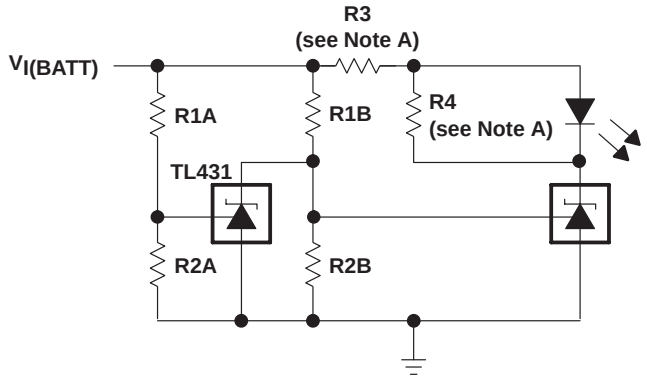


Figure 25. PWM Converter With Reference

APPLICATION INFORMATION



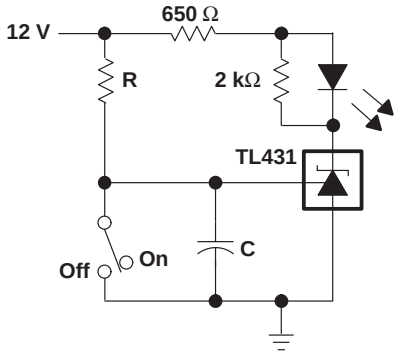
$$\text{Low Limit} = \left(1 + \frac{R1B}{R2B}\right)V_{ref}$$

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

LED on When Low Limit < $V_{I(BATT)}$ < High Limit

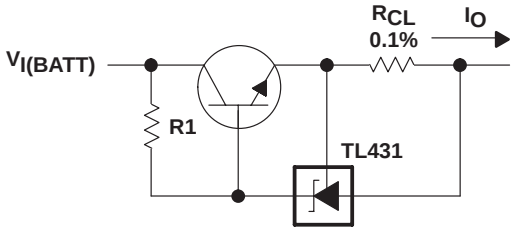
NOTE A: R3 and R4 are selected to provide the desired LED intensity and cathode current ≥1 mA to the TL431 at the available $V_{I(BATT)}$.

Figure 26. Voltage Monitor



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

Figure 27. Delay Timer



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

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

Figure 28. Precision Current Limiter