TL431-Q1/TL432-Q1 可调精密并联稳压器

1 特性

- 符合汽车类 应用要求
- 具有符合 AEC-Q100 测试指导的以下结果：
  - 器件温度等级 1：-40°C 至 125°C 的环境运行温度范围
- 25°C 下的基准电压容差：
  - 1%（A 级）
  - 0.5%（B 级）
- 温漂典型值：
  - 14mV（Q 级温度）
- 低输出噪声
- 0.2Ω 输出阻抗典型值
- 灌电流能力：1mA 至 100mA
- 可调节输出电压：V_{REF} 至 36V

2 应用

- 可调节电压和电流基准
- 反激式开关模式电源 (SMPS) 中的二次侧稳压
- 齐纳二极管替代产品
- 电压监控
- 具有集成基准电压的比较器

3 说明

TL431LI-Q1/TL432LI-Q1 是 TL431-Q1/TL432-Q1 的引脚对引脚替代品。TL43xLI-Q1 具有更好的稳定性、更低温漂 (VI(dev)) 以及更低基准电流 (Iref)，可提高系统精度。

TL431-Q1 是一款三引脚可调并联稳压器，在适用的汽车级温度范围内具有额定的热稳定性。通过两个外部电阻器即可将输出电压设置为 V_{REF}（大约 2.5V）至 36V 之间的任意值（参见图 28）。该器件具有 0.2Ω 的输出阻抗典型值。有源输出电路可提供非常急剧的导通特性，从而使该器件成为许多 应用中齐纳二极管的出色替代品，这些应用包括板载稳压、可调节电源和开关电源。

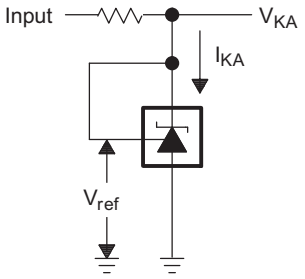
TL432-Q1 具有与 TL431-Q1 器件完全相同的功能和电气规格，但是具有不同的 DBZ 封装引脚排布。

器件信息(1)

器件型号	封装	封装尺寸（标称值）
TL431A-Q1	SOT-23 (5)	2.90mm × 1.60mm
TL43x-Q1	SOT-23 (3)	2.92mm × 1.30mm

(1) 如需了解所有可用封装，请参阅数据表末尾的可订购产品附录。

简化原理图



Copyright © 2016, Texas Instruments Incorporated

目录

1 特性 1
2 应用 1
3 说明 1
4 修订历史记录 2
5 **Pin Configuration and Functions** 3
6 **Specifications** 4
6.1 Absolute Maximum Ratings 4
6.2 ESD Ratings 4
6.3 Recommended Operating Conditions 4
6.4 Thermal Information 4
6.5 Electrical Characteristics: TL43x-Q1 4
6.6 Electrical Characteristics: TL43xA-Q1 5
6.7 Electrical Characteristics: TL43xB-Q1 5
6.8 Typical Characteristics 6
7 **Parameter Measurement Information** 9
8 **Detailed Description** 11
8.1 Overview 11
8.2 Functional Block Diagram 11
8.3 Feature Description 12
8.4 Device Functional Modes 12
9 **Application and Implementation** 13
9.1 Application Information 13
9.2 Typical Applications 13
10 **Power Supply Recommendations** 18
11 **Layout** 18
11.1 Layout Guidelines 18
11.2 Layout Example 18
12 器件和文档支持 19
12.1 文档支持 19
12.2 相关链接 19
12.3 接收文档更新通知 19
12.4 社区资源 19
12.5 商标 19
12.6 静电放电警告 19
12.7 Glossary 19
13 机械、封装和可订购信息 20

4 修订历史记录

注：之前版本的页码可能与当前版本有所不同。

Changes from Revision E (November 2016) to Revision F **Page**

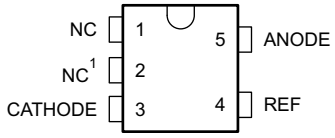
- TL431LI-Q1/TL432LI-Q1 是 TL431-Q1/TL432-Q1 的引脚对引脚替代品。TL43xLI-Q1 具有更好的稳定性、更低温漂 (VI(dev)) 以及更低基准电流 (Iref)，可提高系统精度。 1
- 合并了 TL431-Q1 与 TL432-Q1 数据表 1

Changes from Revision D (March 2013) to Revision E **Page**

- 已添加 *应用* 部分、*器件信息* 表、*引脚配置和功能* 部分、*规格* 部分、*ESD 额定值* 表、*详细 说明* 部分、*应用和实现* 部分、*电源建议* 部分、*布局* 部分、*器件和文档支持* 部分以及*机械、封装和可订购信息* 部分 1
- 已删除 *订购信息* 表；请参阅数据表末尾的*封装选项附录* 1
- Added *Thermal Information* table 4
- Changed $R_{\theta JA}$ values for 5-pin DBV (SOT-23) From: 206 To: 215 and for 3-pin DBZ (SOT-23) From: 206 To: 334.7 4

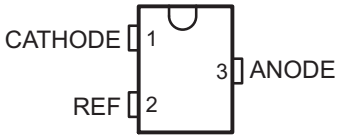
5 Pin Configuration and Functions

TL431A-Q1 DBV Package
5-Pin SOT-23
Top View

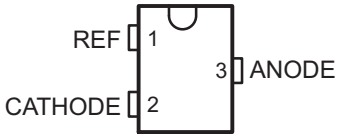


(1) Pin 2 is connected internally to ANODE (die substrate) and must be left floating or connected to ANODE.

TL431-Q1 DBZ Package
3-Pin SOT-23
Top View



TL432-Q1 DBZ Package
3-Pin SOT-23
Top View



Pin Functions

PIN				I/O	DESCRIPTION
NAME	TL431A-Q1	TL431-Q1	TL432-Q1		
	DBV	DBZ	DBZ		
ANODE	5	3	3	O	Common pin, normally connected to ground.
CATHODE	3	1	2	I/O	Shunt current or voltage input
NC	1, 2	—	—	—	No connection(1)
REF	4	2	1	I	Threshold relative to common anode

(1) Pin 2 of the 5-pin DBV (SOT-23) package is connected internally to ANODE (die substrate) and must be left floating or connected to ANODE.

6 Specifications

6.1 Absolute Maximum Ratings

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

		MIN	MAX	UNIT
Cathode voltage(2)			37	V
Continuous cathode current		–100	150	mA
Reference input current	Low	–50		µA
	High		10	mA
Operating junction temperature, T_J			150	°C
Storage temperature, T_{stg}		–65	150	°C

(1) Stresses beyond those listed under *Absolute Maximum Ratings* may cause permanent damage to the device. These are stress ratings only, which do not imply functional operation of the device at these or any other conditions beyond those indicated under *Recommended Operating Conditions*. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.
(2) Voltage values are with respect to the ANODE pin, unless otherwise noted.

6.2 ESD Ratings

			VALUE	UNIT
$V_{(ESD)}$	Electrostatic discharge	Human-body model (HBM), per AEC Q100-002(1)	±2500	V
		Charged-device model (CDM), per AEC Q100-011	±1000	
		Machine model (MM)	±200	

(1) AEC Q100-002 indicates that HBM stressing shall be in accordance with the ANSI/ESDA/JEDEC JS-001 specification.

6.3 Recommended Operating Conditions

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

		MIN	MAX	UNIT
V_{KA}	Cathode voltage	V_{REF}	36	V
I_{KA}	Cathode current	1	100	mA
T_A	Operating free-air temperature	–40	125	°C

6.4 Thermal Information

THERMAL METRIC(1)		TL43x-Q1		UNIT
		DBV (SOT-23)	DBZ (SOT-23)	
		5 PINS	3 PINS	
$R_{\theta JA}$	Junction-to-ambient thermal resistance	215	334.7	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	135.2	113.5	°C/W
$R_{\theta JB}$	Junction-to-board thermal resistance	43	67.6	°C/W
ψ_{JT}	Junction-to-top characterization parameter	19.6	6.7	°C/W
ψ_{JB}	Junction-to-board characterization parameter	42.1	65.9	°C/W

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

6.5 Electrical Characteristics: TL43x-Q1

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

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
V_{REF}	Reference voltage	$V_{KA} = V_{REF}$, I_{KA} = 10 mA, see Figure 20		2440	2495	2550	mV
$V_{I(DEV)}$	Deviation of reference voltage over full temperature(1)	$V_{KA} = V_{REF}$, I_{KA} = 10 mA, T_A = –40°C to 125°C, see Figure 20			14	34	mV
$\Delta V_{REF}/\Delta V_{KA}$	Ratio of change in reference voltage to the change in cathode voltage	I_{KA} = 10 mA, see Figure 21	ΔV_{KA} = 10 V – V_{REF}		–1.4	–2.7	mV/V
			ΔV_{KA} = 36 V – 10 V		–1	–2	

(1) The deviation parameters ($V_{I(DEV)}$ and $I_{I(DEV)}$) are defined as the differences between the maximum and minimum values obtained over the recommended temperature range.

Electrical Characteristics: TL43x-Q1 (continued)

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

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
I_{REF}	Reference current	I_{KA} = 10 mA, R1 = 10 kΩ, R2 = ∞, see Figure 21		2	4	µA
$I_{I(DEV)}$	Deviation of reference current over full temperature(1)	I_{KA} = 10 mA, R1 = 10 kΩ, R2 = ∞, T_A = –40°C to 125°C, see Figure 21		0.8	2.5	µA
I_{MIN}	Minimum cathode current for regulation	V_{KA} = V_{REF}, see Figure 20		0.4	1	mA
I_{OFF}	OFF-state cathode current	V_{KA} = 36 V, V_{REF} = 0, see Figure 22		0.1	1	µA
$\|Z_{KA}\|$	Dynamic impedance(1)	I_{KA} = 1 mA to 100 mA, V_{KA} = V_{REF}, f ≤ 1 kHz, see Figure 20		0.2	0.5	Ω

6.6 Electrical Characteristics: TL43xA-Q1

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

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
V_{REF}	Reference voltage	V_{KA} = V_{REF}, I_{KA} = 10 mA, see Figure 20		2470	2495	2520	mV
$V_{I(DEV)}$	Deviation of reference voltage over full temperature(1)	V_{KA} = V_{REF}, I_{KA} = 10 mA, T_A = –40°C to 125°C, see Figure 20			14	34	mV
$\Delta V_{REF}/\Delta V_{KA}$	Ratio of change in reference voltage to the change in cathode voltage	I_{KA} = 10 mA, see Figure 21	ΔV_{KA} = 10 V – V_{REF}		–1.4	–2.7	mV/V
			ΔV_{KA} = 36 V – 10 V		–1	–2	
I_{REF}	Reference current	I_{KA} = 10 mA, R1 = 10 kΩ, R2 = ∞, see Figure 21			2	4	µA
$I_{I(DEV)}$	Deviation of reference current over full temperature(1)	I_{KA} = 10 mA, R1 = 10 kΩ, R2 = ∞, T_A = –40°C to 125°C, see Figure 21			0.8	2.5	µA
I_{MIN}	Minimum cathode current for regulation	V_{KA} = V_{REF}, see Figure 20			0.4	0.7	mA
I_{OFF}	OFF-state cathode current	V_{KA} = 36 V, V_{REF} = 0, see Figure 22			0.1	0.5	µA
$\|Z_{KA}\|$	Dynamic impedance(1)	I_{KA} = 1 mA to 100 mA, V_{KA} = V_{REF}, f ≤ 1 kHz, see Figure 20			0.2	0.5	Ω

(1) The deviation parameters ($V_{I(DEV)}$ and $I_{I(DEV)}$) are defined as the differences between the maximum and minimum values obtained over the recommended temperature range.

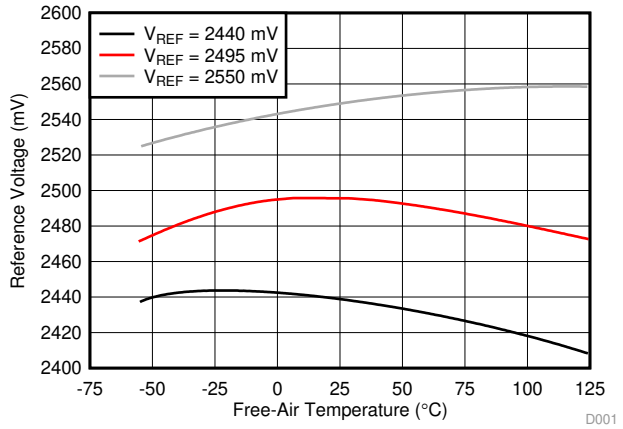
6.7 Electrical Characteristics: TL43xB-Q1

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

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
V_{REF}	Reference voltage	V_{KA} = V_{REF}, I_{KA} = 10 mA, see Figure 20		2483	2495	2507	mV
$V_{I(DEV)}$	Deviation of reference voltage over full temperature(1)	V_{KA} = V_{REF}, I_{KA} = 10 mA, T_A = –40°C to 125°C, see Figure 20			14	34	mV
$\Delta V_{REF}/\Delta V_{KA}$	Ratio of change in reference voltage to the change in cathode voltage	I_{KA} = 10 mA, see Figure 21	ΔV_{KA} = 10 V – V_{REF}		–1.4	–2.7	mV/V
			ΔV_{KA} = 36 V – 10 V		–1	–2	
I_{REF}	Reference current	I_{KA} = 10 mA, R1 = 10 kΩ, R2 = ∞, see Figure 21			2	4	µA
$I_{I(DEV)}$	Deviation of reference current over full temperature(1)	I_{KA} = 10 mA, R1 = 10 kΩ, R2 = ∞, T_A = –40°C to 125°C, see Figure 21			0.8	2.5	µA
I_{MIN}	Minimum cathode current for regulation	V_{KA} = V_{REF}, see Figure 20			0.4	0.7	mA
I_{OFF}	OFF-state cathode current	V_{KA} = 36 V, V_{REF} = 0, see Figure 22			0.1	0.5	µA
$\|Z_{KA}\|$	Dynamic impedance(1)	I_{KA} = 1 mA to 100 mA, V_{KA} = V_{REF}, f ≤ 1 kHz, see Figure 20			0.2	0.5	Ω

(1) The deviation parameters ($V_{I(DEV)}$ and $I_{I(DEV)}$) are defined as the differences between the maximum and minimum values obtained over the recommended temperature range.

6.8 Typical Characteristics



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

Figure 1. Reference Voltage vs Free-air Temperature

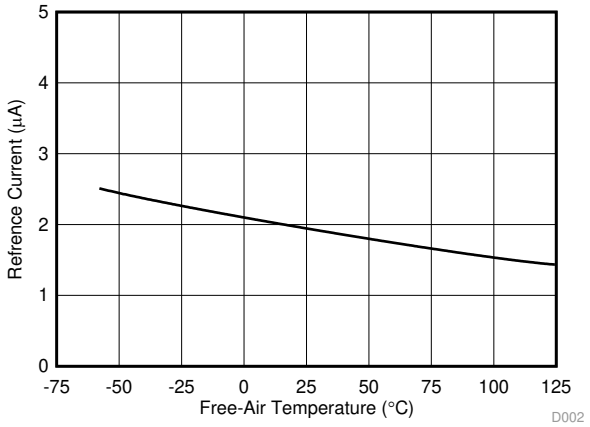


Figure 2. Reference Current vs Free-air Temperature

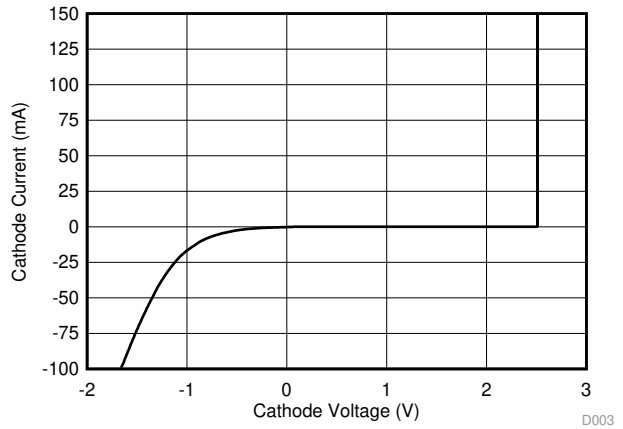


Figure 3. Cathode Current vs Cathode Voltage

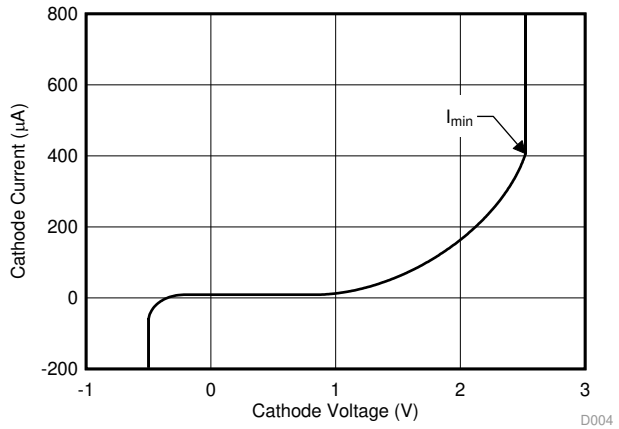


Figure 4. Cathode Current vs Cathode Voltage

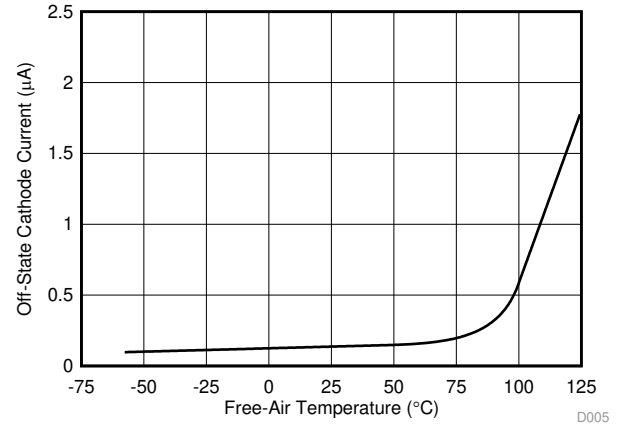


Figure 5. OFF-State Cathode Current vs Free-air Temperature

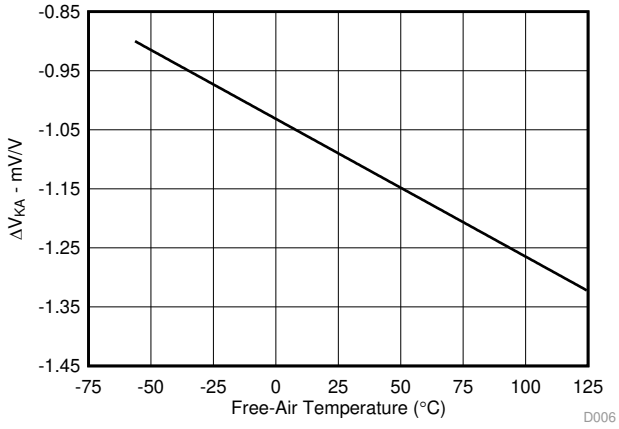


Figure 6. Ratio of Delta Reference Voltage to Delta Cathode Voltage vs Free-air Temperature

Typical Characteristics (continued)

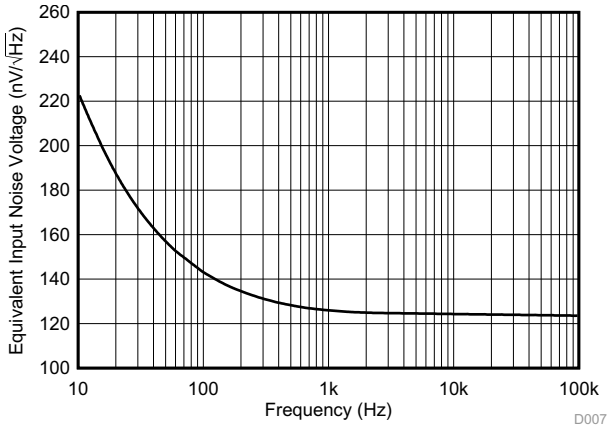


Figure 7. Equivalent Input Noise Voltage vs Frequency

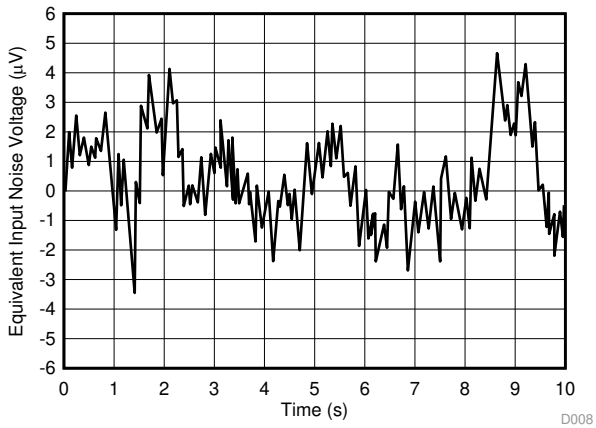


Figure 8. Equivalent Input Noise Voltage Over a 10-s Period

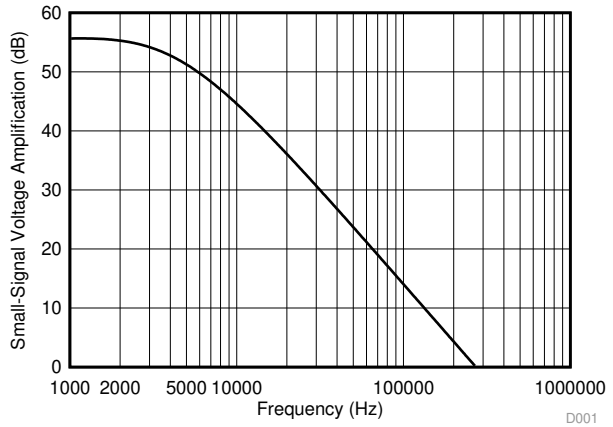


Figure 9. Small-Signal Voltage Amplification vs Frequency

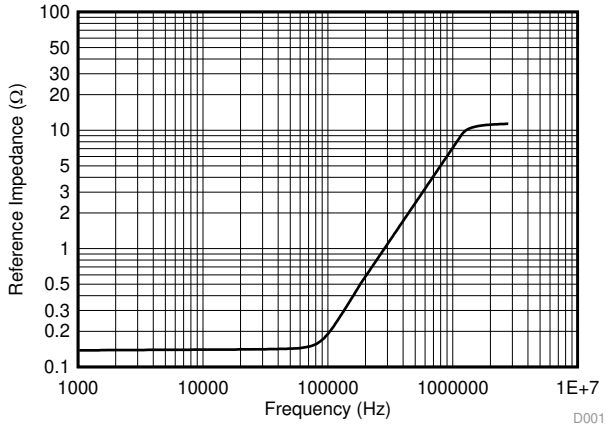


Figure 10. Reference Impedance vs Frequency

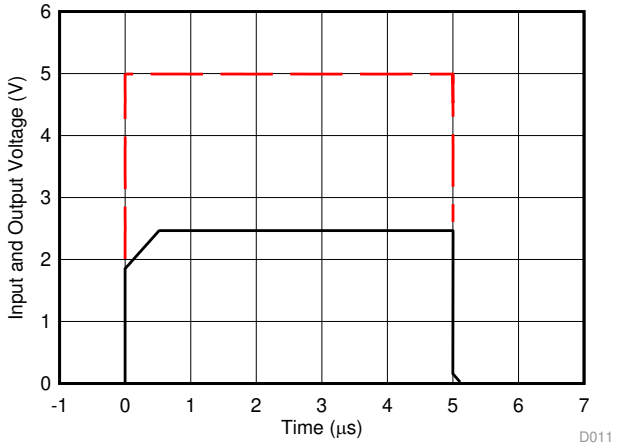
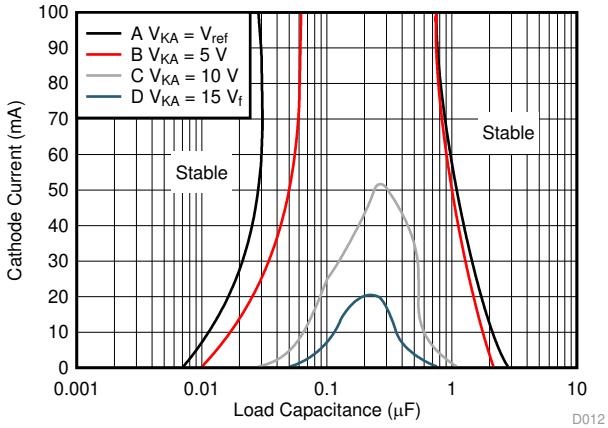


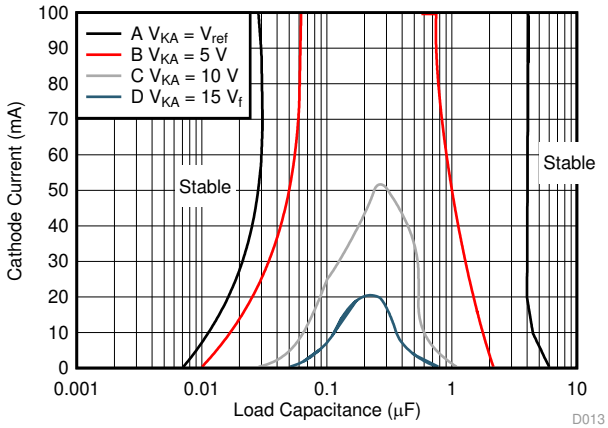
Figure 11. Pulse Response



The areas under the curves represent conditions that may cause the device to oscillate. For curves B, C, and D, R2 and V_{REF} 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 (see Figure 18 and Figure 19 for test circuits).

Figure 12. Stability Boundary Conditions for All TL43x Devices (Except for SOT23-3, SC-70, and Q-TEMP Devices)

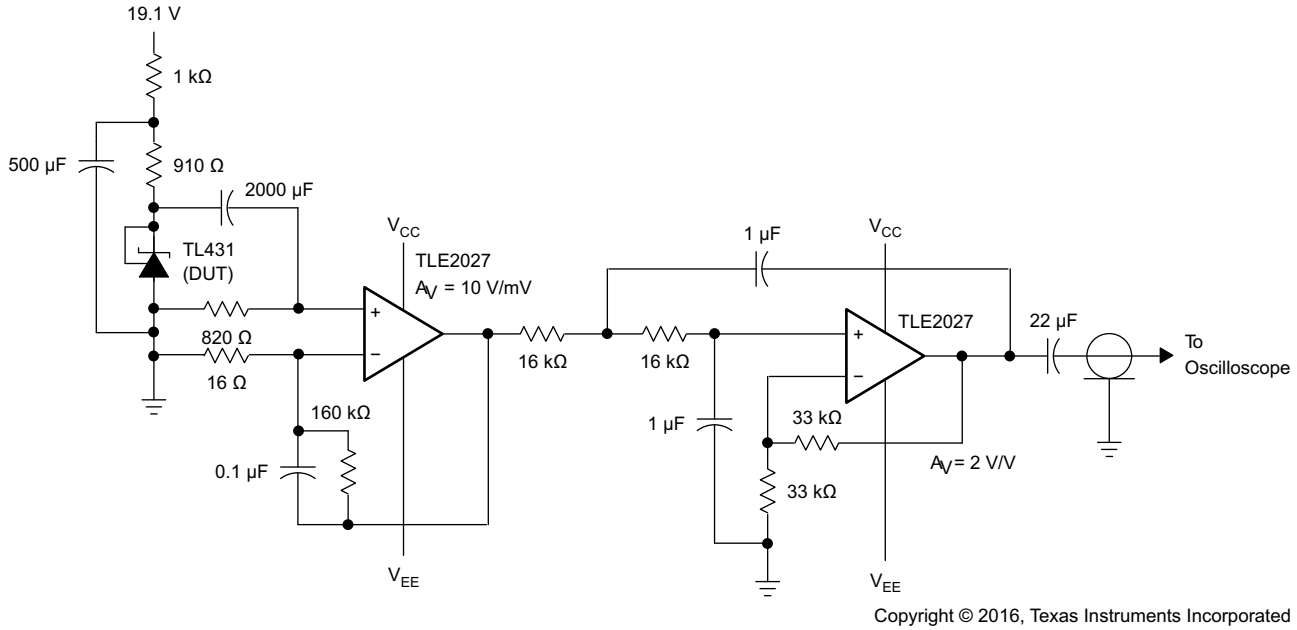
Typical Characteristics (continued)



The areas under the curves represent conditions that may cause the device to oscillate. For curves B, C, and D, R2 and V_{REF} 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 (see Figure 18 and Figure 19 for test circuits).

Figure 13. Stability Boundary Conditions for All TL43x, SOT-23, SC-70, and Q-TEMP Devices

7 Parameter Measurement Information



Copyright © 2016, Texas Instruments Incorporated

Figure 14. Test Circuit for Equivalent Input Noise Voltage

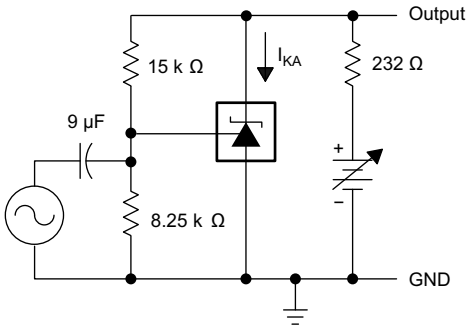


Figure 15. Test Circuit for Voltage Amplification

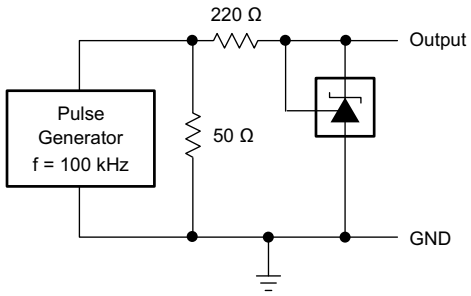


Figure 17. Test Circuit for Pulse Response

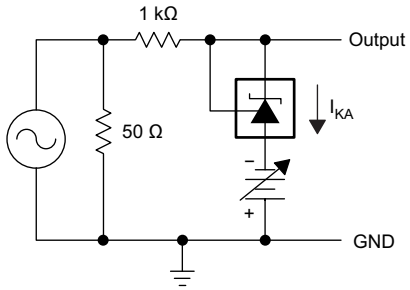


Figure 16. Test Circuit for Reference Impedance

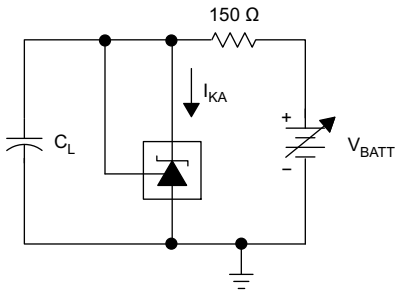


Figure 18. Test Circuit for Curve A

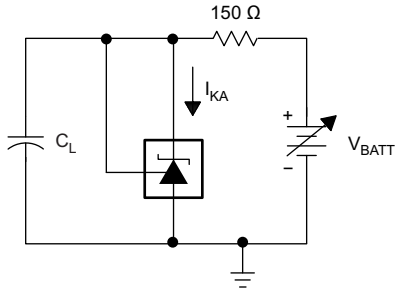


Figure 19. Test Circuit for Curves B, C, and D

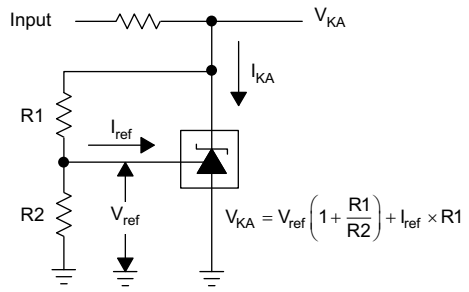


Figure 21. Test Circuit for $V_{KA} > V_{REF}$

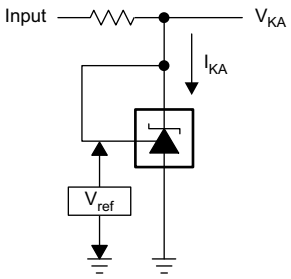


Figure 20. Test Circuit for $V_{KA} = V_{REF}$

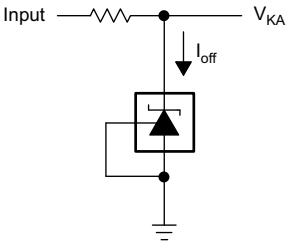


Figure 22. Test Circuit for I_{OFF}

8 Detailed Description

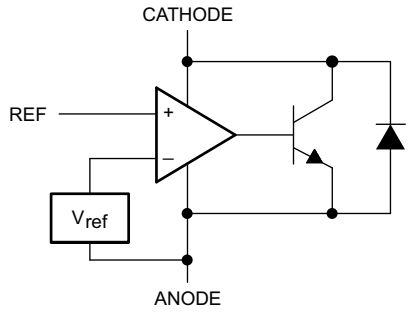
8.1 Overview

This device has proven ubiquity and versatility across a wide range of applications, ranging from power to signal path. This is due to its key components containing an accurate voltage reference and op amp, which are fundamental analog building blocks. The TL43x-Q1 can be used as a single voltage reference, error amplifier, voltage clamp, or comparator with integrated reference.

The TL43x-Q1 can be operated and adjusted to cathode voltages from 2.5 V to 36 V, making this part optimum for a wide range of end equipments in industrial, auto, telecommunications, and computing. For this device to behave as a shunt regulator or error amplifier, at least 1 mA ($I_{MIN(MAX)}$) must be supplied 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.

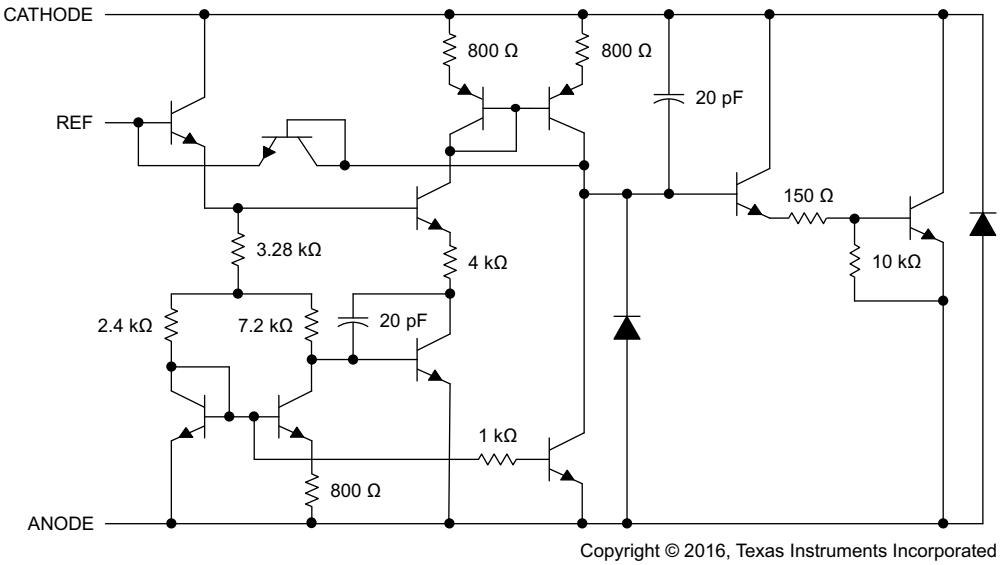
Various reference voltage options can be purchased with initial tolerances (at 25°C) of 0.5% and 1%. These reference options are denoted by B (0.5%) or A (1%) in the part number (TL431x-Q1).

8.2 Functional Block Diagram



Copyright © 2016, Texas Instruments Incorporated

Figure 23. Equivalent Schematic



Copyright © 2016, Texas Instruments Incorporated

All component values are nominal.

Figure 24. Detailed Schematic

8.3 Feature Description

The TL43x-Q1 consists of an internal reference and amplifier that outputs a sink current based on the difference between the reference pin and the virtual internal pin. The sink current is produced by the internal Darlington pair, shown in Figure 24. A Darlington pair is used to allow this device to sink a maximum current of 100 mA.

When operated with enough voltage headroom (at least 2.5 V) and cathode current (I_{KA}), the TL43x-Q1 forces the reference pin to 2.5 V. However, the reference pin can not be left floating, as I_{REF} must be at least 4 µA (see *Specifications*). This is because the reference pin is driven into an NPN, which requires base current to operate properly.

When feedback is applied from the CATHODE and REF pins, the TL43x-Q1 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 required in the above feedback situation must be applied to this device in open loop, servo, or error amplifying implementations for it to be in the proper linear region giving the device enough gain.

Unlike many linear regulators, the TL43x-Q1 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 24 can be used as a guide to assist in choosing the correct capacitor to maintain stability.

8.4 Device Functional Modes

8.4.1 Open Loop (Comparator)

When the cathode or output voltage or current of the TL43x-Q1 is not being fed back to the reference or input pin in any form, the device operates in open loop. With proper cathode current (I_{KA}) applied to this device, the TL43x-Q1 has the characteristics shown in Figure 24. With such high gain in this configuration, the device is typically used as a comparator. The integrated reference makes TL43x the prefered choice when trying to monitor a certain level of a single signal.

8.4.2 Closed Loop

When the cathode or output voltage or current of the TL43x-Q1 is being fed back to the reference or input pin in any form, the device operates in closed loop. The majority of applications involving the TL43x-Q1 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 through resistive or direct feedback.

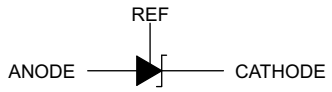


Figure 25. Logic Symbol

9 Application and Implementation

NOTE

Information in the following applications sections is not part of the TI component specification, and TI does not warrant its accuracy or completeness. TI's customers are responsible for determining suitability of components for their purposes. Customers should validate and test their design implementation to confirm system functionality.

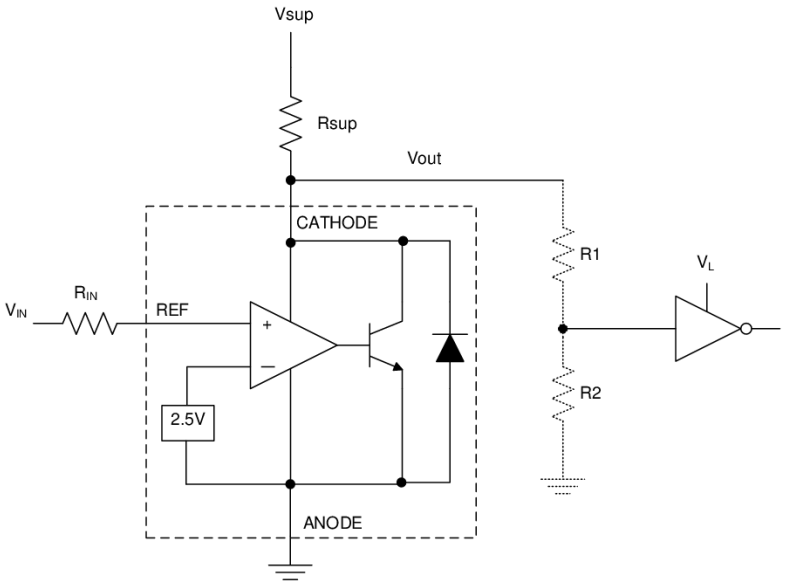
9.1 Application Information

As this device has many applications and setups, there are many situations that this data sheet can not characterize in detail. The linked application notes help the make the best choices when using this part.

Understanding Stability Boundary Conditions Charts in TL431, TL432 Data Sheet provides a deeper understanding of this devices stability characteristics and aid the user in making the right choices when choosing a load capacitor. *Setting the Shunt Voltage on an Adjustable Shunt Regulator* assists designers in setting the shunt voltage to achieve optimum accuracy for this device.

9.2 Typical Applications

9.2.1 Comparator Application



Copyright © 2016, Texas Instruments Incorporated

Figure 26. Comparator Application Schematic

Typical Applications (continued)

9.2.1.1 Design Requirements

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

Table 1. Design Parameters

PARAMETER	VALUE
Input voltage	0 V to 5 V
Input resistance	10 kΩ
Supply voltage	24 V
Cathode current, I_K	5 mA
Output voltage level	Approximately 2 V to V_{SUP}
Logic input thresholds, V_{IH} / V_{IL}	V_L

9.2.1.2 Detailed Design Procedure

When using the TL43x-Q1 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

9.2.1.2.1 Basic Operation

In the configuration shown in Figure 26 the TL43x-Q1 behaves as a comparator, comparing the REF pin voltage to the internal virtual reference voltage. When provided a proper cathode current (I_{KA}), the TL43x-Q1 has enough open loop gain to provide a quick response. This is shown in Figure 27, where the R_{SUP} = 10 kΩ (I_{KA} = 500 µA) situation responds much slower than R_{SUP} = 1 kΩ (I_{KA} = 5 mA). With the TL43x-Q1's maximum operating current (I_{MIN}) being 1 mA, operation below that could result in low gain, leading to a slow response.

9.2.1.2.2 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 is within the range of 2.5 V ± (0.5%, 1%, or 1.5%) depending on which version is being used. The more overdrive voltage provided, the faster the TL43x-Q1 responds.

For applications where the TL43x-Q1 is being used as a comparator, it is best to set the trip point to greater than the positive expected error (for example: +1% for the A version). For fast response, setting the trip point to at least 10% of the internal V_{REF} should suffice.

For minimal drop or difference from V_{INREF} to the REF pin, TI recommends using an input resistor <10 kΩ to provide I_{REF}

9.2.1.2.3 Output Voltage and Logic Input Level

For the TL43x-Q1 to properly be used as a comparator, the logic output must be readable by the receiving logic device. This is accomplished by knowing the input high and low level threshold voltage levels, typically denoted by V_{IH} and V_{IL}.

As seen in Figure 26, the TL43x-Q1's output low level voltage in open-loop or comparator mode is approximately 2 V, which is typically sufficient for 5-V supplied logic. However, would not work for 3.3-V and 1.8-V supplied logic. 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.

The TL43x-Q1's output high voltage is equal to V_{SUP} due to the TL43x-Q1 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, ensure the sum of the resistive divider (R1 and R2 in Figure 24) is much greater than R_{SUP} to not interfere with the TL43x-Q1's ability to pull close to V_{SUP} when turning off.

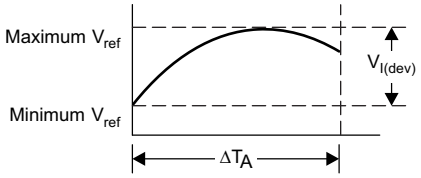
9.2.1.2.4 Input Resistance

In this application, the TL43x-Q1 requires an input resistance in addition to the reference current (I_{REF}) to ensure the device is in the proper operating regions while turning on. The actual voltage seen at the REF pin is $V_{REF} = V_{IN} – I_{REF} \times R_{IN}$. Because I_{REF} can be as high as 4 µA, TI recommends using a resistance small enough to mitigate the error that I_{REF} creates from V_{IN}.

9.2.1.2.5 Deviation Parameters and Calculating Dynamic Impedance

The deviation parameters, $V_{I(DEV)}$ and $I_{I(DEV)}$, 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 in Equation 1.

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



where

- ΔT_A is the recommended operating free-air temperature range of the device (1)

α_{Vref} 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 TL43x.

$$\left|\alpha_{V_{ref}}\right| = \frac{\left(\frac{4\text{ mV}}{2495\text{ mV}}\right) \times 10^6}{70^{\circ}C} \approx \frac{23\text{ ppm}}{^{\circ}C} \quad (2)$$

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

The dynamic impedance is defined as $|Z_{KA}| = \Delta V_{KA} / \Delta I_{KA}$.

When the device is operating with two external resistors, see Figure 21, the total dynamic impedance of the circuit is given by Equation 3.

$$|z'| = \frac{\Delta V}{\Delta I} \approx |Z_{KA}|\left(1 + \frac{R1}{R2}\right) \quad (3)$$

9.2.1.3 Application Curve

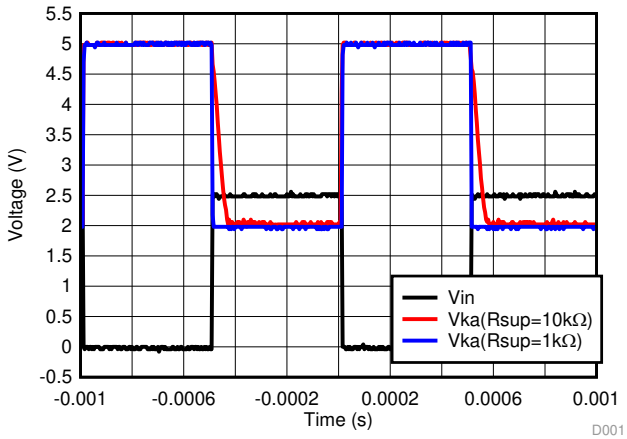
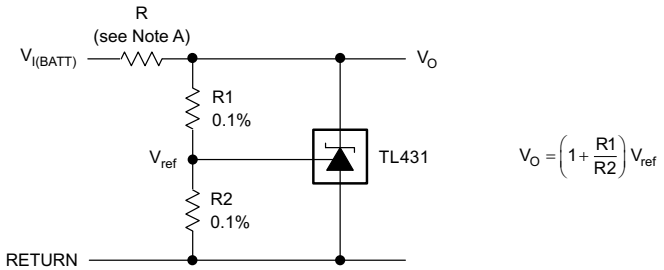


Figure 27. Output Response With Various Cathode Currents

9.2.2 Other Application Circuits

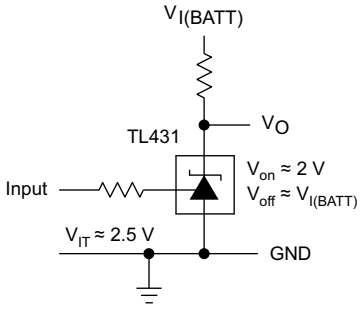
Figure 28 to Figure 40 show application circuit examples using the TL431-Q1 device. Customers must fully validate and test any circuit before implementing a design based on an example in this section. Unless otherwise noted, the design procedures in *Comparator Application* are applicable.



Copyright © 2016, Texas Instruments Incorporated

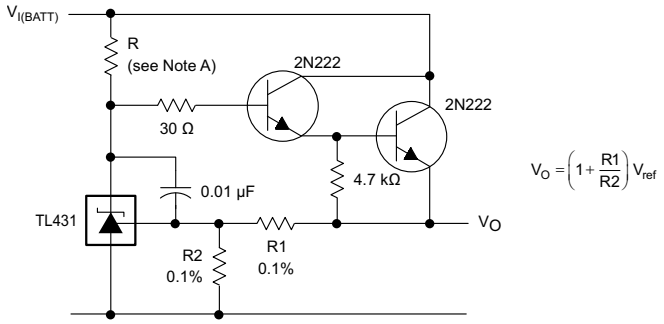
A. R must provide cathode current ≥1 mA to the TL431-Q1 at minimum $V_{I(BATT)}$.

Figure 28. Shunt Regulator



Copyright © 2016, Texas Instruments Incorporated

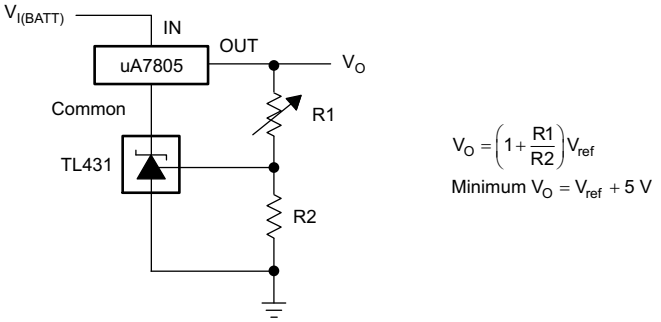
Figure 29. Single-Supply Comparator with Temperature-Compensated Threshold



Copyright © 2016, Texas Instruments Incorporated

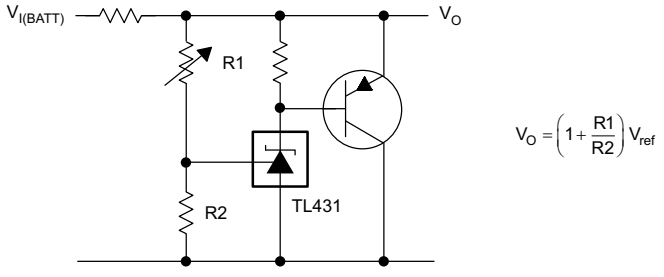
A. R must provide cathode current ≥1 mA to the TL431-Q1 at minimum $V_{I(BATT)}$.

Figure 30. Precision High-Current Series Regulator



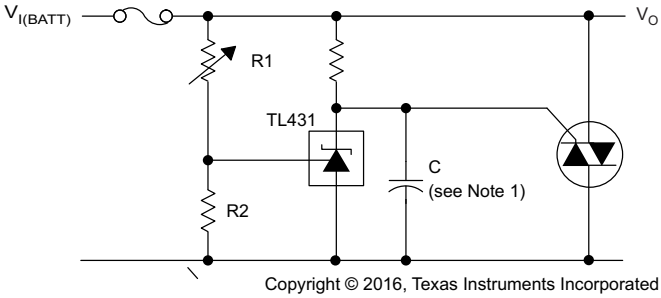
Copyright © 2016, Texas Instruments Incorporated

Figure 31. Output Control of a Three-Terminal Fixed Regulator



Copyright © 2016, Texas Instruments Incorporated

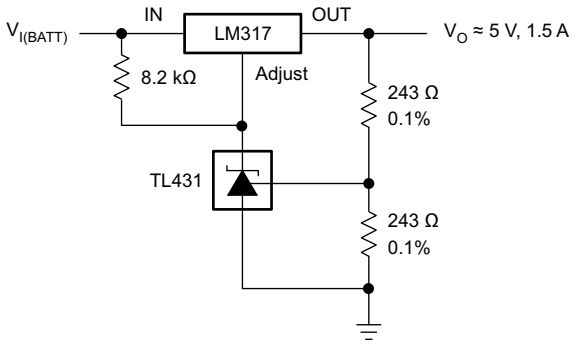
Figure 32. High-Current Shunt Regulator



Copyright © 2016, Texas Instruments Incorporated

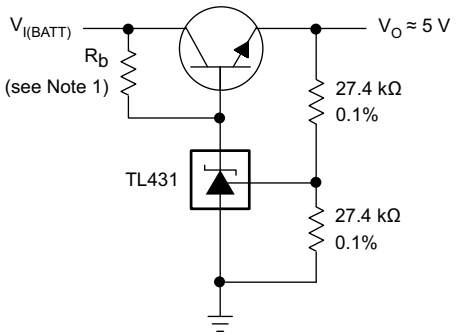
(1) See Figure 12 and Figure 13 to determine allowable values for C.

Figure 33. Crowbar Circuit



Copyright © 2016, Texas Instruments Incorporated

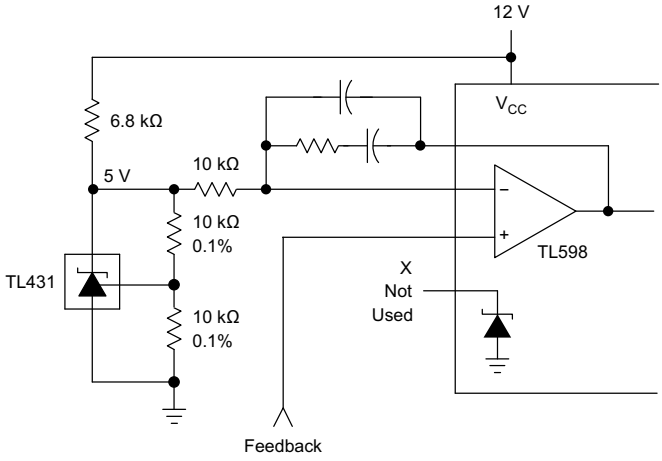
Figure 34. Precision 5-V, 1.5-A Regulator



Copyright © 2016, Texas Instruments Incorporated

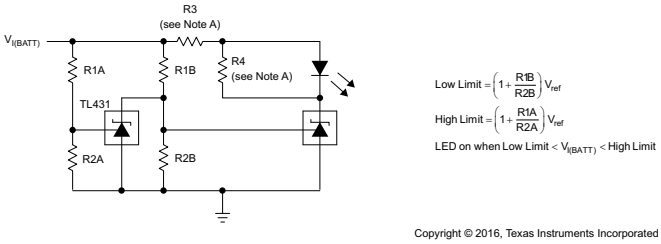
(1) R_b must provide cathode current ≥1 mA to the TL431-Q1.

Figure 35. Efficient 5-V Precision Regulator



Copyright © 2016, Texas Instruments Incorporated

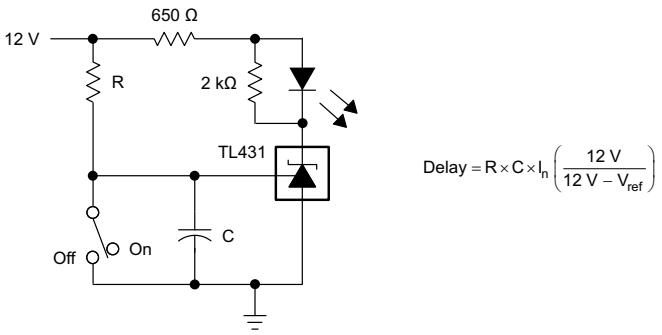
Figure 36. PWM Converter with Reference



Copyright © 2016, Texas Instruments Incorporated

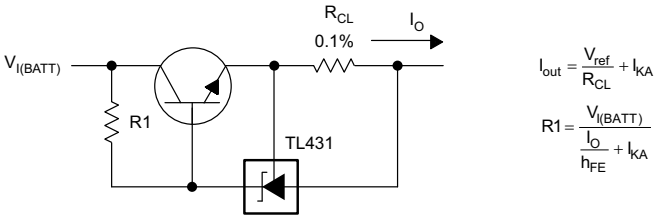
A. R3 and R4 are selected to provide the desired LED intensity and cathode current ≥1 mA to the TL431-Q1 at the available $V_{I(BATT)}$.

Figure 37. Voltage Monitor



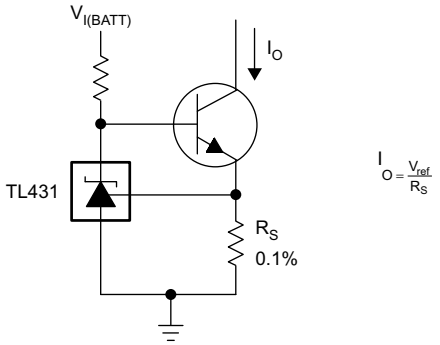
Copyright © 2016, Texas Instruments Incorporated

Figure 38. Delay Timer



Copyright © 2016, Texas Instruments Incorporated

Figure 39. Precision Current Limiter



Copyright © 2016, Texas Instruments Incorporated

Figure 40. Precision Constant-Current Sink

10 Power Supply Recommendations

When using the TL43x-Q1 as a linear regulator to supply a load, designers typically use a bypass capacitor on the output or cathode pin. When doing this, be sure that the capacitance is within the stability criteria shown in Figure 12 and Figure 13.

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 its 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.

11 Layout

11.1 Layout Guidelines

Bypass capacitors must be placed as close to the device as possible. Current-carrying traces must have widths appropriate for the amount of current they are carrying; in the case of the TL43x-Q1, these currents are low.

11.2 Layout Example

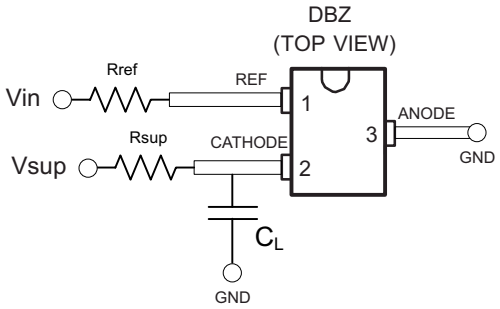


Figure 41. DBZ Layout Example

12 器件和文档支持

12.1 文档支持

12.1.1 相关文档

请参阅如下相关文档：

- *《具有可调节并联基准的汽车 LED 照明》*
- *《了解 TL431/TL432 数据表中的稳定性边界条件图》*
- *《在可调节并联稳压器上设置并联电压》*

12.2 相关链接

下表列出了快速访问链接。类别包括技术文档、支持与社区资源、工具和软件，以及申请样片或购买产品的快速链接。

表 **2.** 相关链接

器件	产品文件夹	样片与购买	技术文档	工具与软件	支持和社区
TL431-Q1	单击此处	单击此处	单击此处	单击此处	单击此处
TL432-Q1	单击此处	单击此处	单击此处	单击此处	单击此处
TL431LI-Q1	单击此处	单击此处	单击此处	单击此处	单击此处
TL432LI-Q1	单击此处	单击此处	单击此处	单击此处	单击此处

12.3 接收文档更新通知

要接收文档更新通知，请导航至 ti.com. 上的器件产品文件夹。单击右上角的*通知我*进行注册，即可每周接收产品信息更改摘要。有关更改的详细信息，请查看任何已修订文档中包含的修订历史记录。

12.4 社区资源

The following links connect to TI community resources. Linked contents are provided "AS IS" by the respective contributors. They do not constitute TI specifications and do not necessarily reflect TI's views; see TI's Terms of Use.

TI E2E™ Online Community ***TI's Engineer-to-Engineer (E2E) Community.*** Created to foster collaboration among engineers. At e2e.ti.com, you can ask questions, share knowledge, explore ideas and help solve problems with fellow engineers.

Design Support ***TI's Design Support*** Quickly find helpful E2E forums along with design support tools and contact information for technical support.

12.5 商标

E2E is a trademark of Texas Instruments.
All other trademarks are the property of their respective owners.

12.6 静电放电警告

ESD 可能会损坏该集成电路。德州仪器 (TI) 建议通过适当的预防措施处理所有集成电路。如果不遵守正确的处理措施和安装程序，可能会损坏集成电路。

ESD 的损坏小至导致微小的性能降级，大至整个器件故障。 精密的集成电路可能更容易受到损坏，这是因为非常细微的参数更改都可能会导致器件与其发布的规格不相符。

12.7 Glossary

SLYZ022 — *TI Glossary*.

This glossary lists and explains terms, acronyms, and definitions.

13 机械、封装和可订购信息

以下页面包含机械、封装和可订购信息。这些信息是指定器件的最新可用数据。数据如有变更，恕不另行通知，且不会对此文档进行修订。如需获取此数据表的浏览器版本，请查阅左侧的导航栏。

PACKAGE OPTION ADDENDUM

10-Dec-2020

PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead finish/ Ball material (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
TL431AQDBVRQ1	ACTIVE	SOT-23	DBV	5	3000	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	-40 to 125	TACQ	Samples
TL431AQDBZRQ1	ACTIVE	SOT-23	DBZ	3	3000	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	-40 to 125	TAQU	Samples
TL431BQDBZRQ1	ACTIVE	SOT-23	DBZ	3	3000	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	-40 to 125	T3FU	Samples
TL432AQDBZRQ1	ACTIVE	SOT-23	DBZ	3	3000	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	-40 to 125	TOIQ	Samples
TL432BQDBZRQ1	ACTIVE	SOT-23	DBZ	3	3000	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	-40 to 125	TOHQ	Samples

(1) The marketing status values are defined as follows:
ACTIVE: Product device recommended for new designs.
LIFEBUY: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.
NRND: Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.
PREVIEW: Device has been announced but is not in production. Samples may or may not be available.
OBSOLETE: TI has discontinued the production of the device.

(2) **RoHS:** TI defines "RoHS" to mean semiconductor products that are compliant with the current EU RoHS requirements for all 10 RoHS substances, including the requirement that RoHS substance do not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, "RoHS" products are suitable for use in specified lead-free processes. TI may reference these types of products as "Pb-Free".
RoHS Exempt: TI defines "RoHS Exempt" to mean products that contain lead but are compliant with EU RoHS pursuant to a specific EU RoHS exemption.
Green: TI defines "Green" to mean the content of Chlorine (Cl) and Bromine (Br) based flame retardants meet JS709B low halogen requirements of <=1000ppm threshold. Antimony trioxide based flame retardants must also meet the <=1000ppm threshold requirement.

(3) MSL, Peak Temp. - The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

(5) Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

(6) Lead finish/Ball material - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material values may wrap to two lines if the finish value exceeds the maximum column width.

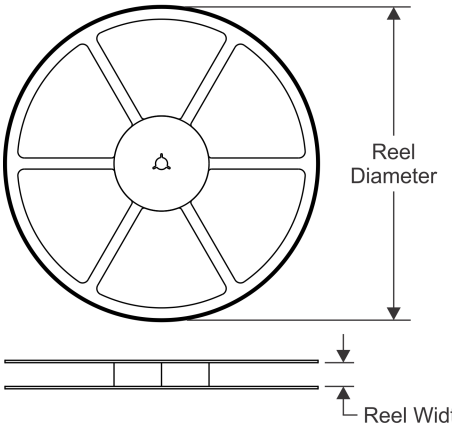
10-Dec-2020

Important Information and Disclaimer: The information provided on this page represents TI's knowledge and belief as of the date that it is provided. TI bases its knowledge and belief on information provided by third parties, and makes no representation or warranty as to the accuracy of such information. Efforts are underway to better integrate information from third parties. TI has taken and continues to take reasonable steps to provide representative and accurate information but may not have conducted destructive testing or chemical analysis on incoming materials and chemicals. TI and TI suppliers consider certain information to be proprietary, and thus CAS numbers and other limited information may not be available for release.

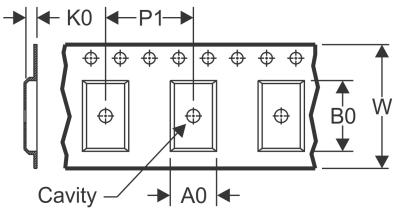
In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.

TAPE AND REEL INFORMATION

REEL DIMENSIONS

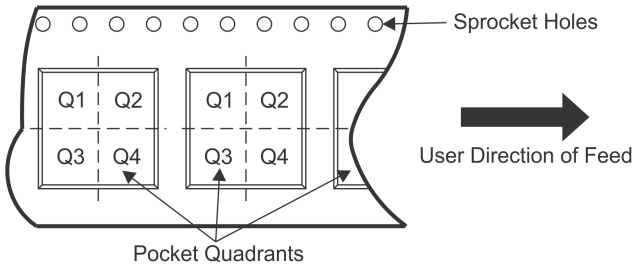


TAPE DIMENSIONS



A0	Dimension designed to accommodate the component width
B0	Dimension designed to accommodate the component length
K0	Dimension designed to accommodate the component thickness
W	Overall width of the carrier tape
P1	Pitch between successive cavity centers

QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



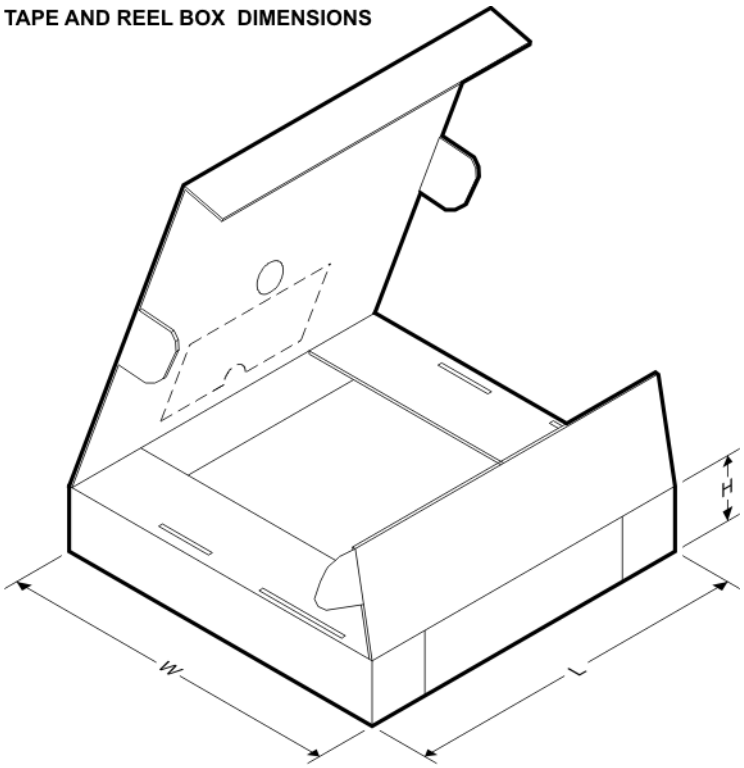
*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
TL431AQDBVRQ1	SOT-23	DBV	5	3000	180.0	8.4	3.2	3.2	1.4	4.0	8.0	Q3
TL431AQDBZRQ1	SOT-23	DBZ	3	3000	179.0	8.4	3.15	2.95	1.22	4.0	8.0	Q3
TL431BQDBZRQ1	SOT-23	DBZ	3	3000	179.0	8.4	3.15	2.95	1.22	4.0	8.0	Q3
TL432AQDBZRQ1	SOT-23	DBZ	3	3000	180.0	8.4	3.15	2.95	1.22	4.0	8.0	Q3
TL432BQDBZRQ1	SOT-23	DBZ	3	3000	179.0	8.4	3.15	2.95	1.22	4.0	8.0	Q3

PACKAGE MATERIALS INFORMATION

5-Jan-2021

TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

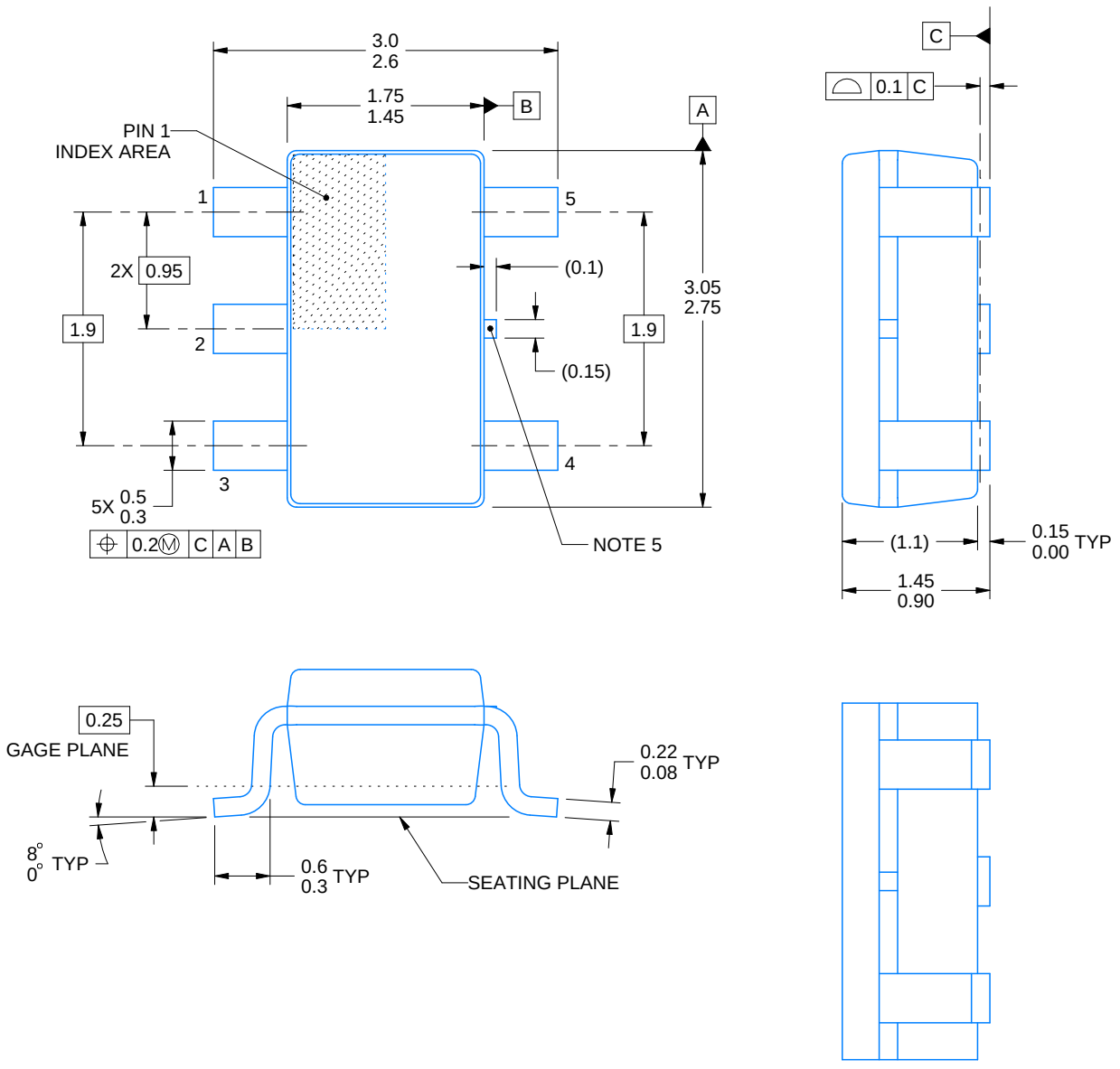
Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
TL431AQDBVRQ1	SOT-23	DBV	5	3000	200.0	183.0	25.0
TL431AQDBZRQ1	SOT-23	DBZ	3	3000	200.0	183.0	25.0
TL431BQDBZRQ1	SOT-23	DBZ	3	3000	200.0	183.0	25.0
TL432AQDBZRQ1	SOT-23	DBZ	3	3000	200.0	183.0	25.0
TL432BQDBZRQ1	SOT-23	DBZ	3	3000	200.0	183.0	25.0

PACKAGE OUTLINE

DBV0005A

SOT-23 - 1.45 mm max height

SMALL OUTLINE TRANSISTOR



ALTERNATIVE PACKAGE SINGULATION VIEW

4214839/J 02/2024

NOTES:

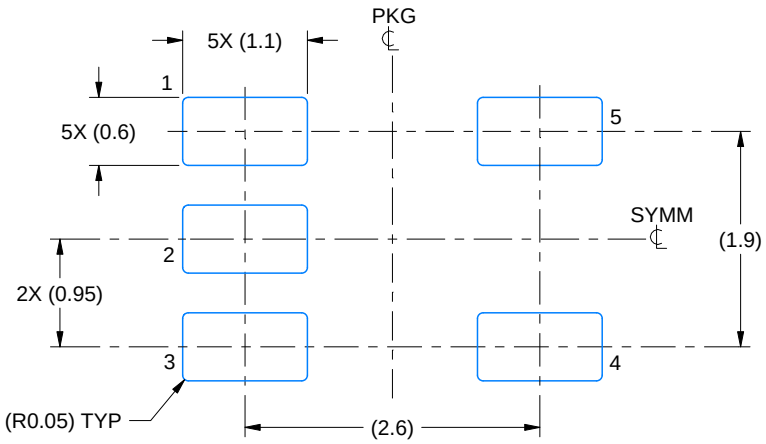
1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. Refernce JEDEC MO-178.
4. Body dimensions do not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.25 mm per side.
5. Support pin may differ or may not be present.

EXAMPLE BOARD LAYOUT

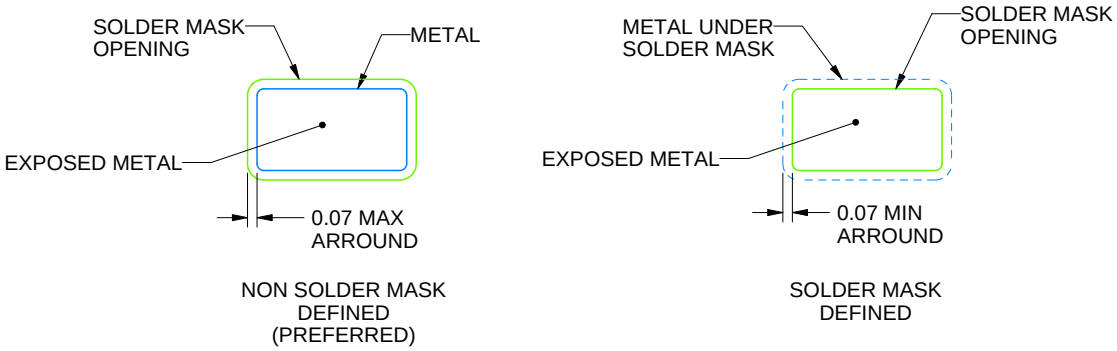
DBV0005A

SOT-23 - 1.45 mm max height

SMALL OUTLINE TRANSISTOR



LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE:15X



SOLDER MASK DETAILS

4214839/J 02/2024

NOTES: (continued)

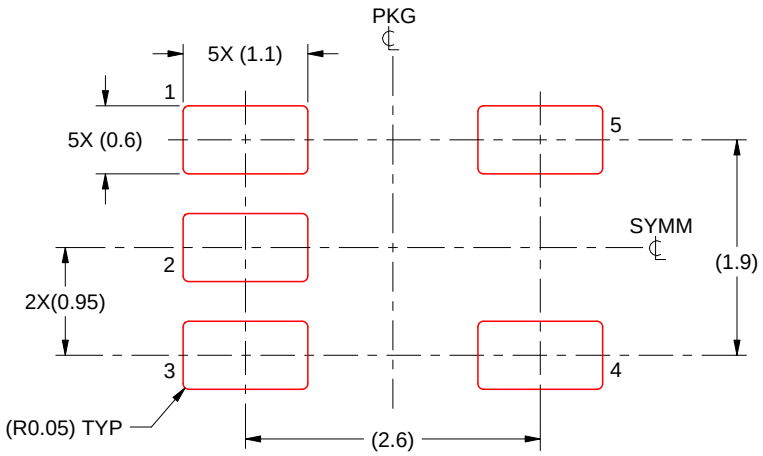
6. Publication IPC-7351 may have alternate designs.
7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.

EXAMPLE STENCIL DESIGN

DBV0005A

SOT-23 - 1.45 mm max height

SMALL OUTLINE TRANSISTOR



SOLDER PASTE EXAMPLE
BASED ON 0.125 mm THICK STENCIL
SCALE:15X

4214839/J 02/2024

NOTES: (continued)

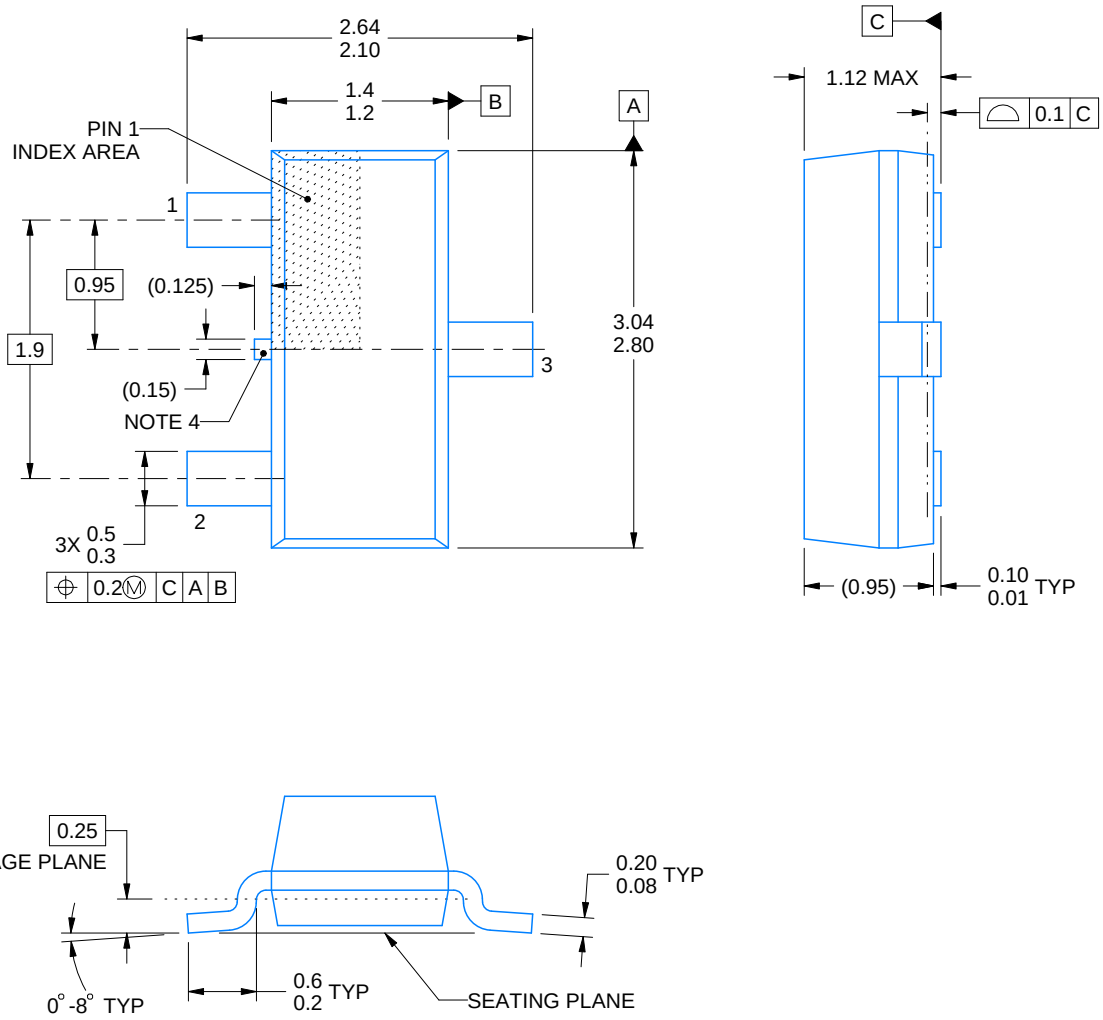
8. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
9. Board assembly site may have different recommendations for stencil design.

PACKAGE OUTLINE

DBZ0003A

SOT-23 - 1.12 mm max height

SMALL OUTLINE TRANSISTOR



4214838/D 03/2023

NOTES:

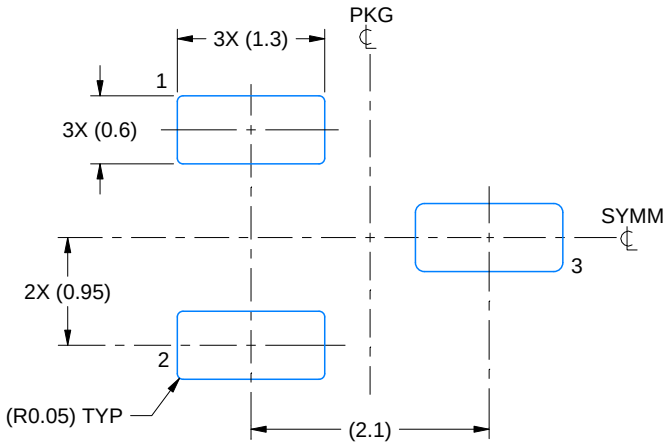
1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. Reference JEDEC registration TO-236, except minimum foot length.
4. Support pin may differ or may not be present.

EXAMPLE BOARD LAYOUT

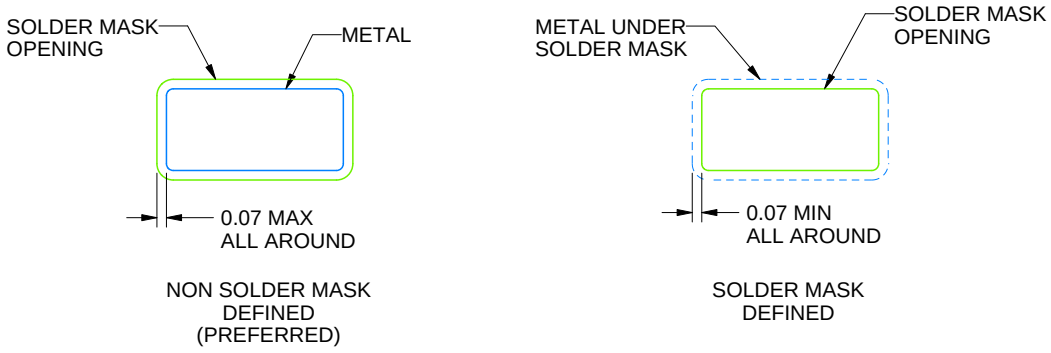
DBZ0003A

SOT-23 - 1.12 mm max height

SMALL OUTLINE TRANSISTOR



LAND PATTERN EXAMPLE
SCALE:15X



SOLDER MASK DETAILS

4214838/D 03/2023

NOTES: (continued)

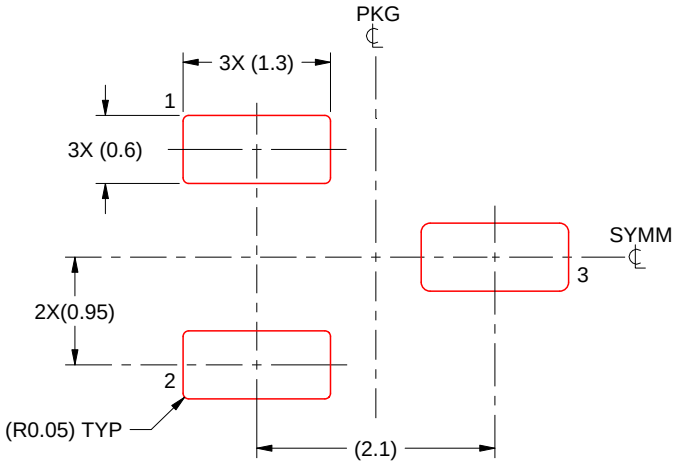
4. Publication IPC-7351 may have alternate designs.
5. Solder mask tolerances between and around signal pads can vary based on board fabrication site.

EXAMPLE STENCIL DESIGN

DBZ0003A

SOT-23 - 1.12 mm max height

SMALL OUTLINE TRANSISTOR



SOLDER PASTE EXAMPLE
BASED ON 0.125 THICK STENCIL
SCALE:15X

4214838/D 03/2023

NOTES: (continued)

6. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
7. Board assembly site may have different recommendations for stencil design.