

## Description

The TLV431Q is a three-terminal adjustable shunt regulator offering excellent temperature stability and output current handling capability up to 20mA. The output voltage may be set to any chosen voltage between 1.24 and 18 volts by selection of two external divider resistors.

The TLV431Q can be used as a replacement for Zener diodes in many applications requiring an improvement in Zener performance.

The TLV431Q is available in 3 tolerance bands with initial tolerances of 1%, 0.5%, and 0.2% for the A, B and T bands respectively.

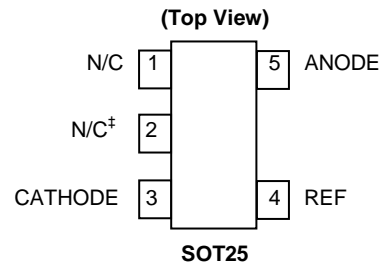
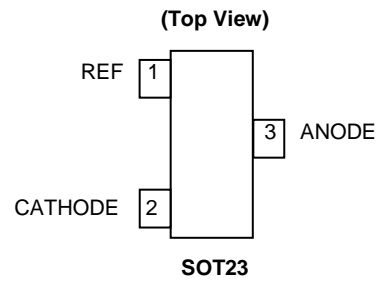
The TLV431Q is qualified to AEC-Q100 Grade 1 and is automotive-compliant supporting PPAP documentation.

## Features

- Low Voltage Operation,  $V_{REF} = 1.24V$
- Temperature Range -40 to +125°C
- Reference Voltage Tolerance at +25°C
  - 0.2% TLV431TQ
  - 0.5% TLV431BQ
  - 1% TLV431AQ
- Typical  $V_{REF}$  Deviation across Full Temperature Range (Note 1)
  - 4mV (0°C to +70°C)
  - 6mV (-40°C to +85°C)
  - 11mV (-40°C to +125°C)
- 80µA Minimum Cathode Current
- 0.25Ω Typical Output Impedance
- Adjustable Output Voltage  $V_{REF}$  to 18V
- **Totally Lead-Free & Fully RoHS Compliant (Notes 2 & 3)**
- **Halogen and Antimony Free. "Green" Device (Note 4)**
- **Qualified to AEC-Q100 Grade 1**
- **PPAP Capable (Note 5)**

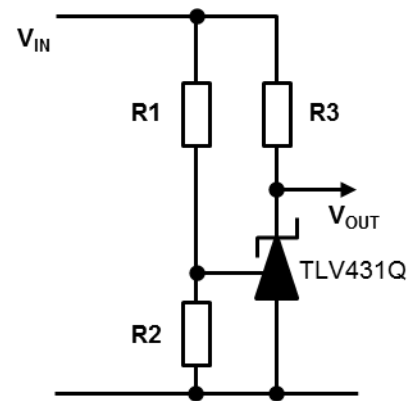
- Notes:
1. The  $V_{REF}$  deviation is defined as the differences between the maximum and minimum values obtained over the specified temperature range.
  2. No purposely added lead. Fully EU Directive 2002/95/EC (RoHS), 2011/65/EU (RoHS 2) & 2015/863/EU (RoHS 3) compliant.
  3. See <https://www.diodes.com/quality/lead-free/> for more information about Diodes Incorporated's definitions of Halogen- and Antimony-free, "Green" and Lead-free.
  4. Halogen- and Antimony-free "Green" products are defined as those which contain <900ppm bromine, <900ppm chlorine (<1500ppm total Br + Cl) and <1000ppm antimony compounds.
  5. Automotive products are AEC-Q100 qualified and are PPAP capable. Refer to <https://www.diodes.com/quality/>.

## Pin Assignments



‡ Pin should be left floating or connected to anode

## Typical Application Circuit



Adjustable High Accuracy Shunt Reference

### Absolute Maximum Ratings (Note 6)

Symbol	Parameter	Rating	Unit
$V_{KA}$	Cathode Voltage	20	V
$I_{KA}$	Continuous Cathode Current	-20 to +20	mA
$I_{REF}$	Reference Input Current Range	-0.05 to +3	mA
$V_{IN}$	Input Supply Voltage (Relative to Ground)	-0.03 to +18	V
$T_J$	Operating Junction Temperature	-40 to +150	°C
$T_S$	Storage Temperature	-65 to +150	°C
<b>ESD Susceptibility</b>			
HBM	Human Body Model	4	kV
MM	Machine Model	400	V
CDM	Charged Device Model	1	kV

Notes: 6. a) 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 conditions is not implied. Exposure to absolute-maximum-rated conditions for extended period may affect device reliability.

Semiconductor devices are ESD sensitive and may be damaged by exposure to ESD events. Suitable ESD precautions should be taken when handling and transporting these devices.

b) Ratings apply to ambient temperature at +25°C.

### Recommended Operating Conditions (@ $T_A = +25^\circ\text{C}$ , unless otherwise specified.)

Symbol	Parameter	Min	Max	Unit
$V_{KA}$	Cathode Voltage	$V_{REF}$	18	V
$I_{KA}$	Cathode Current	0.1	15	mA
$T_A$	Operating Ambient Temperature Range	-40	+125	°C

### Package Thermal Data

Package	$\theta_{JA}$	$P_{DIS}$ $T_A = +25^\circ\text{C}, T_J = +150^\circ\text{C}$
SOT23	380°C/W	330mW
SOT25	250°C/W	500mW

**Electrical Characteristics** (@ $T_A = +25^\circ\text{C}$ ,  $I_K = 10\text{mA}$ , unless otherwise specified.)

Symbol	Parameter	Conditions	Min	Typ	Max	Unit	
$V_{REF}$	Reference Voltage	$V_{KA} = V_{REF}$ , $T_A = +25^\circ\text{C}$	TLV431AQ	1.228	1.24	1.252	V
			TLV431BQ	1.234	1.24	1.246	
			TLV431TQ	1.2375	1.24	1.2425	
		$V_{KA} = V_{REF}$ , $T_A = 0 \text{ to } +70^\circ\text{C}$	TLV431AQ	1.221	—	1.259	
			TLV431BQ	1.227	—	1.253	
			TLV431TQ	1.230	—	1.250	
		$V_{KA} = V_{REF}$ , $T_A = -40 \text{ to } +85^\circ\text{C}$	TLV431AQ	1.215	—	1.265	
			TLV431BQ	1.224	—	1.259	
			TLV431TQ	1.228	—	1.252	
		$V_{KA} = V_{REF}$ , $T_A = -40 \text{ to } +125^\circ\text{C}$	TLV431AQ	1.209	—	1.271	
			TLV431BQ	1.221	—	1.265	
			TLV431TQ	1.224	—	1.255	
$V_{REF(DEV)}$ (Note 7)	Deviation of Reference Voltage Over Full Temperature Range	$V_{KA} = V_{REF}$	$T_A = 0 \text{ to } +70^\circ\text{C}$	—	4	12	mV
			$T_A = -40 \text{ to } +85^\circ\text{C}$	—	6	20	
			$T_A = -40 \text{ to } +125^\circ\text{C}$	—	11	31	
$\frac{\Delta V_{REF}}{\Delta V_{KA}}$	Ratio of Change in Reference Voltage to the Change in Cathode Voltage	$V_{KA}$ for $V_{REF}$ to	6V	—	-1.5	-2.7	mV/V
			18V	—	-1.5	-2.7	
$I_{REF}$	Reference Input Current	$R_1 = 10\text{k}\Omega$ , $R_2 = \text{OC}$	—	0.15	0.5	$\mu\text{A}$	
$I_{REF(DEV)}$ (Note 7)	$I_{REF}$ Deviation Over Full Temperature Range	$R_1 = 10\text{k}\Omega$ , $R_2 = \text{OC}$	$T_A = 0 \text{ to } +70^\circ\text{C}$	—	0.05	0.3	$\mu\text{A}$
			$T_A = -40 \text{ to } +85^\circ\text{C}$	—	0.1	0.4	
			$T_A = -40 \text{ to } +125^\circ\text{C}$	—	0.15	0.5	
$I_{KMIN}$	Minimum Cathode Current for Regulation	$V_{KA} = V_{REF}$	$T_A = 0 \text{ to } +70^\circ\text{C}$	—	55	80	$\mu\text{A}$
			$T_A = -40 \text{ to } +85^\circ\text{C}$	—	55	80	
			$T_A = -40 \text{ to } +125^\circ\text{C}$	—	55	100	
$I_{K(OFF)}$	Off-State Current	$V_{KA} = 18\text{V}$ , $V_{REF} = 0\text{V}$	—	0.001	0.1	$\mu\text{A}$	
$Z_{KA}$ (Note 8)	Dynamic Output Impedance	$V_{KA} = V_{REF}$ , $f = <1\text{kHz}$ $I_K = 0.1 \text{ to } 15\text{mA}$	—	0.25	0.4	$\Omega$	

Notes: 7. The deviation parameters  $V_{REF(DEV)}$  and  $I_{REF(DEV)}$  are defined as the differences between the maximum and minimum values across the specified temperature range. The average full-range temperature coefficient of the reference input voltage,  $dV_{REF}/dT$ , is defined as:

$$\left| \frac{dV_{REF}}{dT} \right| \left( \frac{\text{ppm}}{^\circ\text{C}} \right) = \frac{\left( \frac{V_{REF(DEV)}}{V_{REF}(T_A=25^\circ\text{C})} \right) \times 10^6}{\Delta T_A}$$

where  $\Delta T_A$  is the rated operating free-air temperature range of the device.

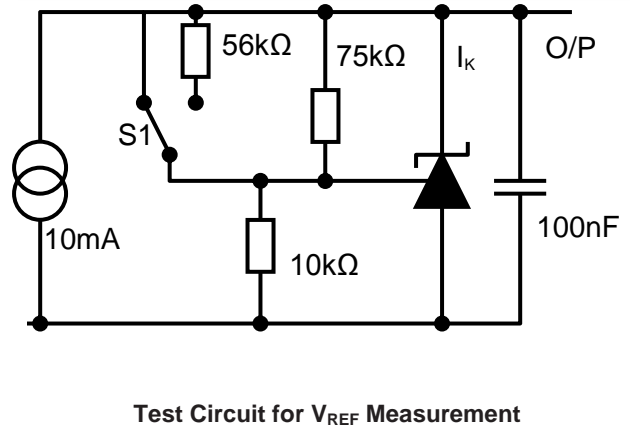
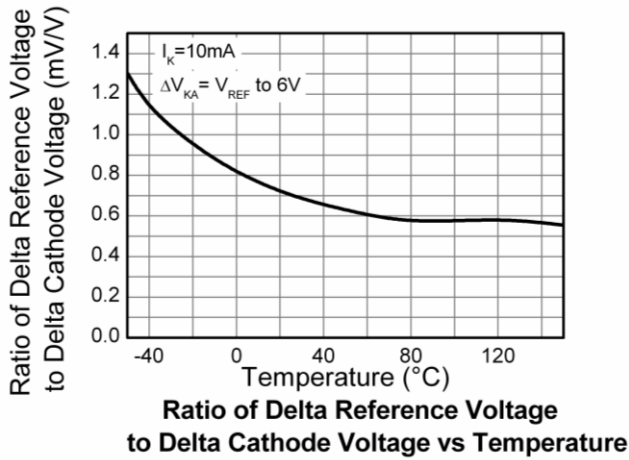
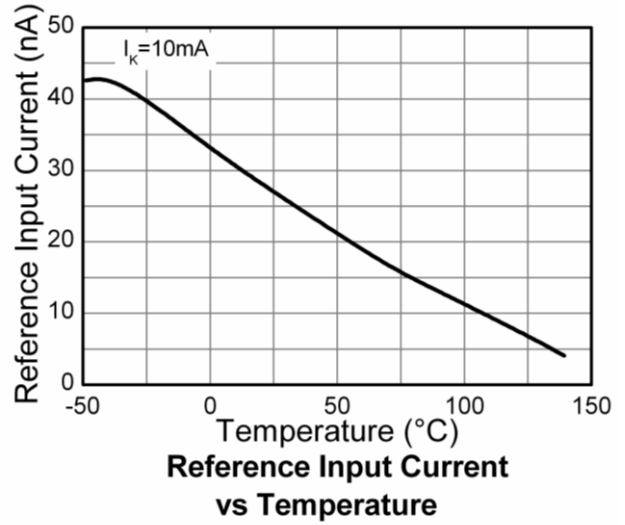
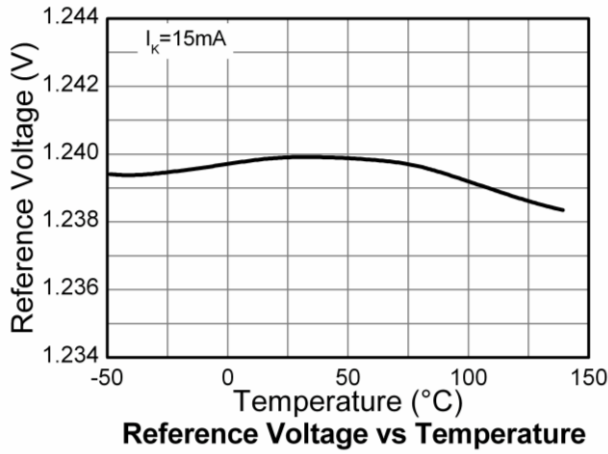
$dV_{REF}/dT$  can be positive or negative, depending on whether minimum  $V_{REF}$  or maximum  $V_{REF}$ , respectively, occurs at the lower temperature.

8. The dynamic impedance is defined as:

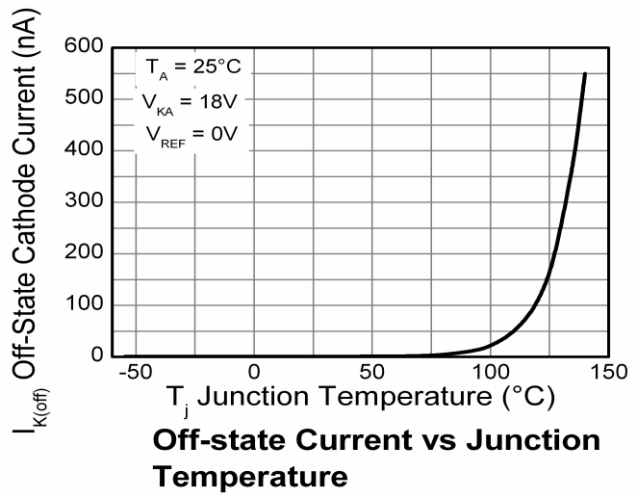
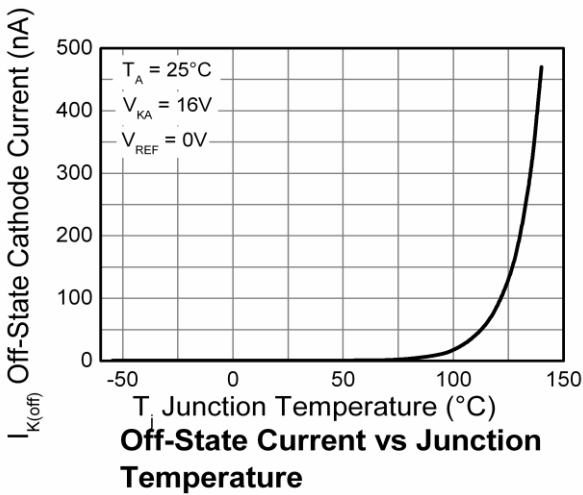
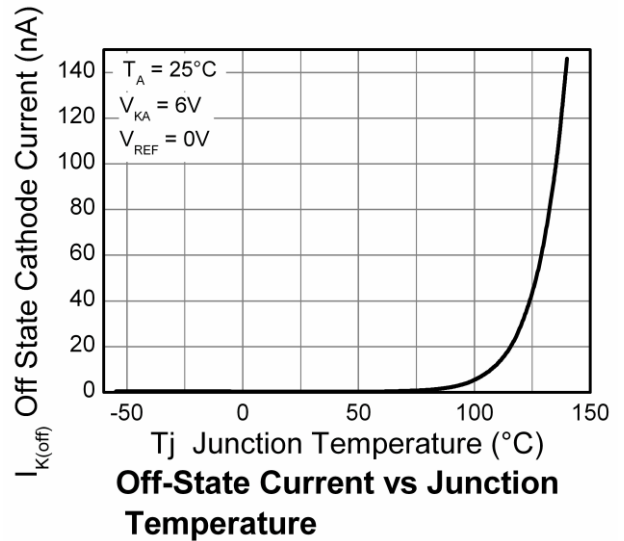
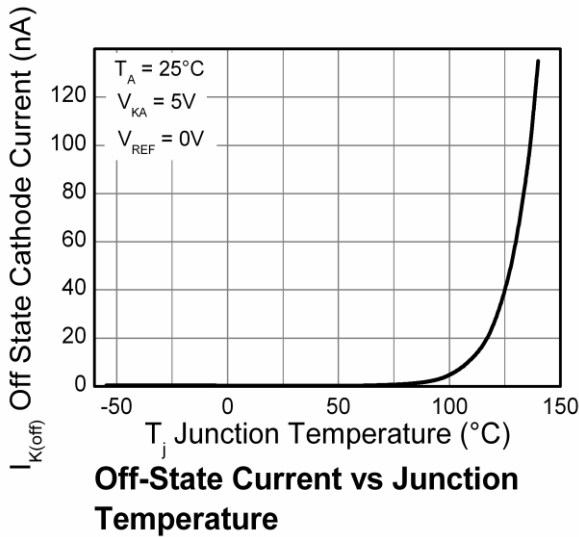
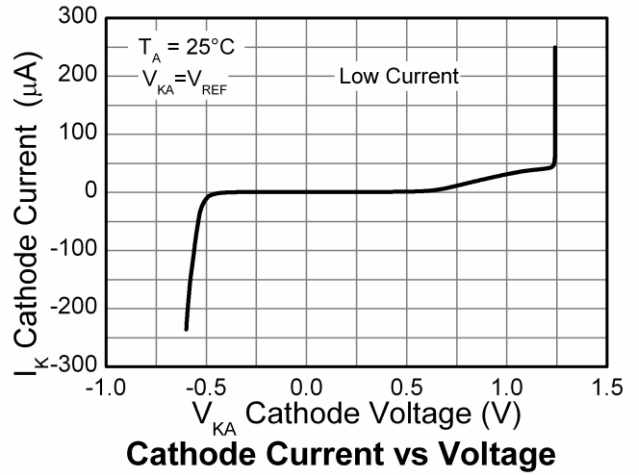
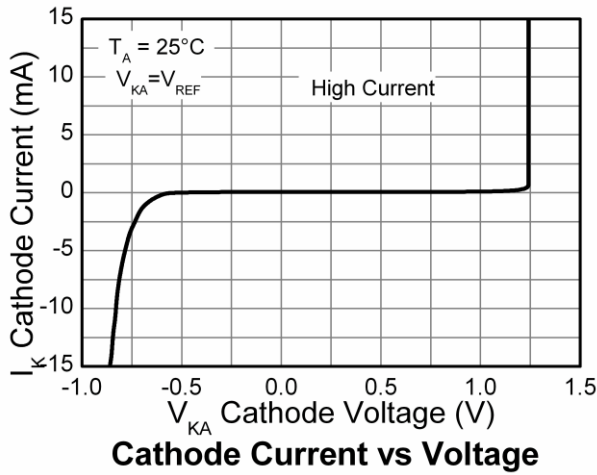
$$|Z_{KA}| = \frac{\Delta V_{KA}}{\Delta I_{KA}}$$

When the device is operating with two external resistors (see Typical Application Circuit Figure 1), the total dynamic impedance of the circuit is increased by a factor of  $(1 + R_1/R_2)$ .

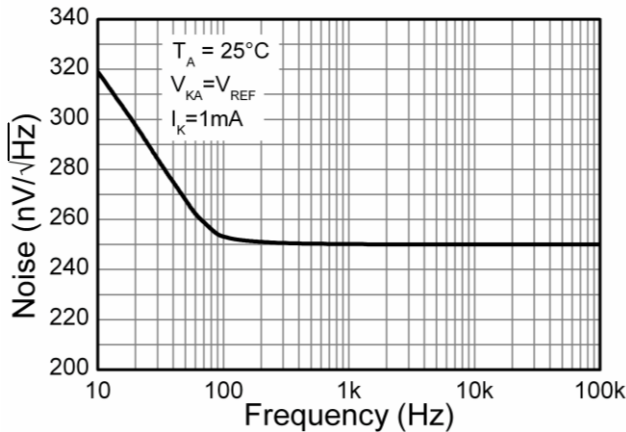
**Typical Characteristics**



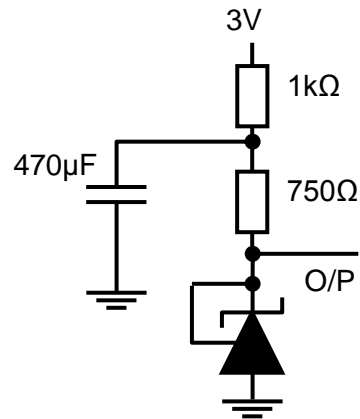
**Typical Characteristics (Cont.)**



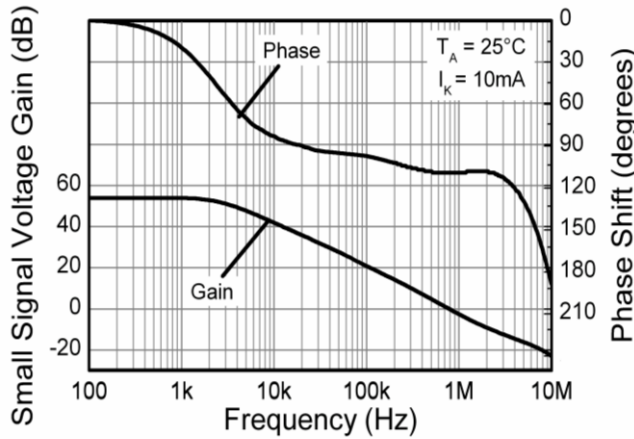
**Typical Characteristics (Cont.)**



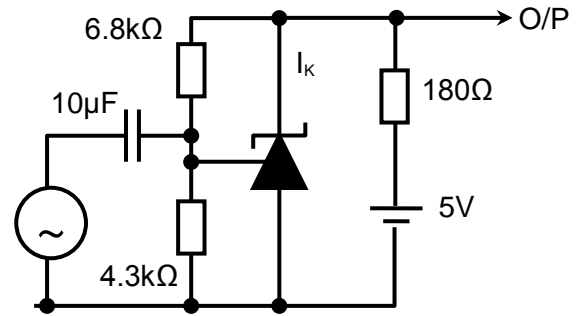
**Equivalent Input Noise Voltage vs Frequency**



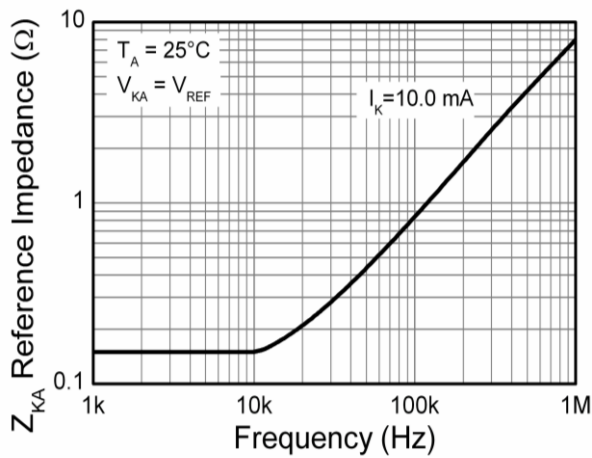
**Test Circuit for Input Noise Voltage**



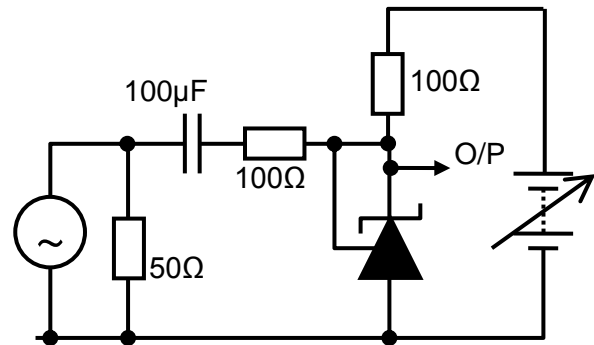
**Phase Shift and Gain vs Frequency**



**Test Circuit for Phase Shift and Gain**

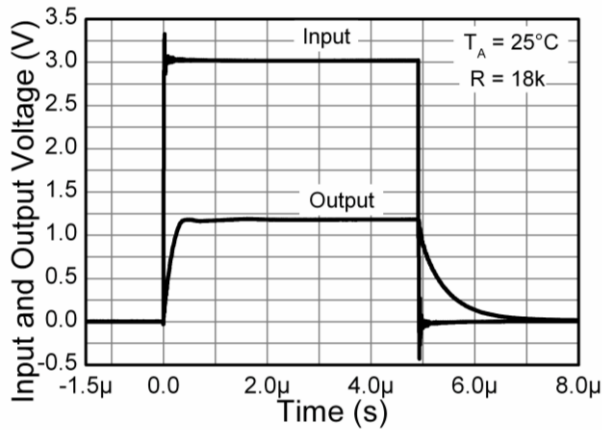


**Reference Impedance vs Frequency**

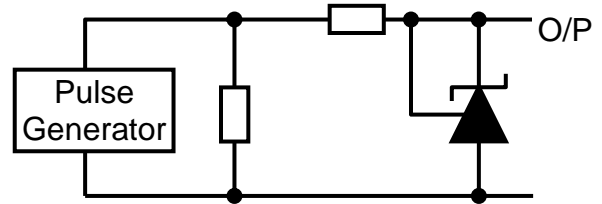


**Test Circuit for Reference Impedance**

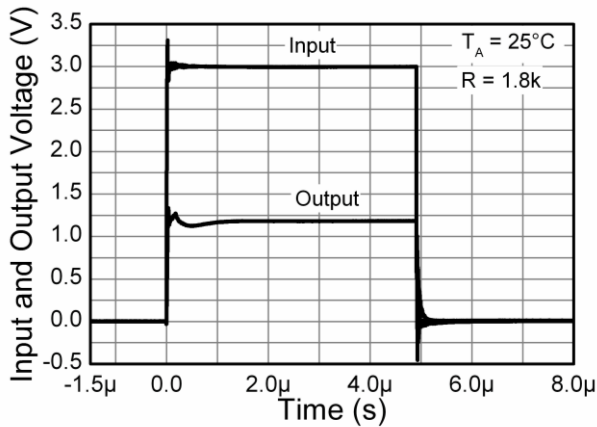
**Typical Characteristics (Cont.)**



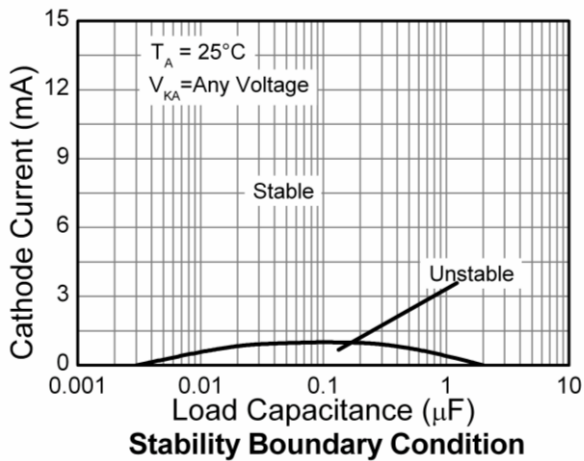
**Pulse Response**



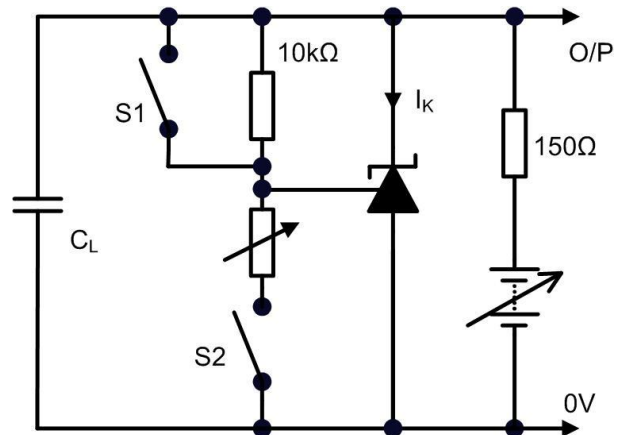
**Test Circuit for Pulse Response**



**Pulse Response**



**Stability Boundary Condition**

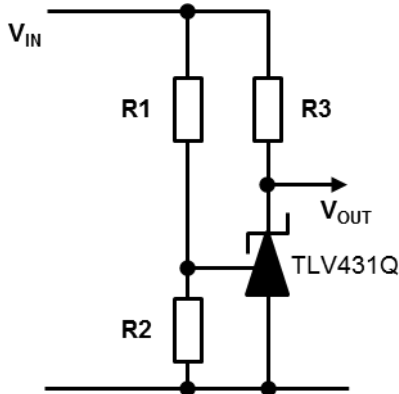


**Application Notes**

In a conventional shunt regulator application (Figure 1), an external series resistor (R3) is connected between the supply voltage,  $V_{IN}$ , and the TLV431Q. The 0.5% and 0.2% tolerance versions allow the creation of a high accuracy adjustable shunt reference.

R3 determines the current that flows through the load ( $I_L$ ) and the TLV431Q ( $I_K$ ). The TLV431Q will adjust how much current it sinks or “shunts” to maintain a voltage equal to  $V_{REF}$  across its feedback pin. Since load current and supply voltage may vary, R3 should be small enough to supply at least the minimum acceptable  $I_{KMIN}$  to the TLV431Q even when the supply voltage is at its minimum and the load current is at its maximum value. When the supply voltage is at its maximum and  $I_L$  is at its minimum, R3 should be large enough so that the current flowing through the TLV431Q is less than 15mA.

R3 is determined by the supply voltage, ( $V_{IN}$ ), the load and operating current, ( $I_L$  and  $I_K$ ), and the TLV431Q’s reverse breakdown voltage,  $V_{KA}$ .



$$R_3 = \frac{V_{IN} - V_{KA}}{I_L + I_K}$$

where

$$V_{KA} = V_{REF} \times \left(1 + \frac{R_1}{R_2}\right)$$

and  $V_{KA} = V_{OUT}$

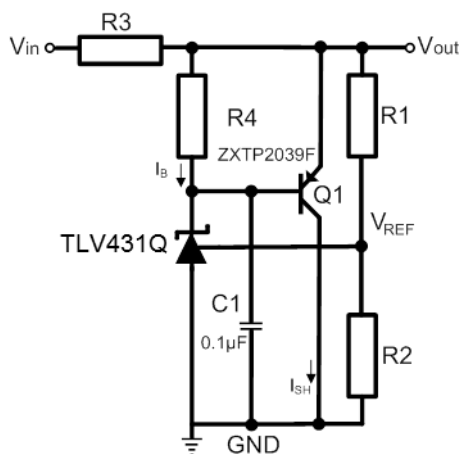
Figure 1. Adjustable Low Voltage Reference

The values of R1 and R2 should be large enough so that the current flowing through them is much smaller than the current through R3 yet not too large so that the voltage drop across them caused by  $I_{REF}$  affects the reference accuracy.

**Printed Circuit Board Layout Considerations**

The TLV431Q in the SOT25 package has the die attached to pin 2, which results in an electrical contact between pin 2 and pin 5. Therefore, pin 2 of the SOT25 package must be left floating or connected to pin 5.

**Other Applications of the TLV431Q**



$$V_{OUT} = V_{REF} \left(1 + \frac{R_1}{R_2}\right)$$

$$R_3 = \frac{V_{IN} - V_{OUT}}{I_{SH} + I_B}$$

$$R_4 = \frac{V_{BE}}{I_B}$$

$$\left(\frac{I_{SH}}{h_{FE(min)}}\right) < I_B \leq 15mA$$

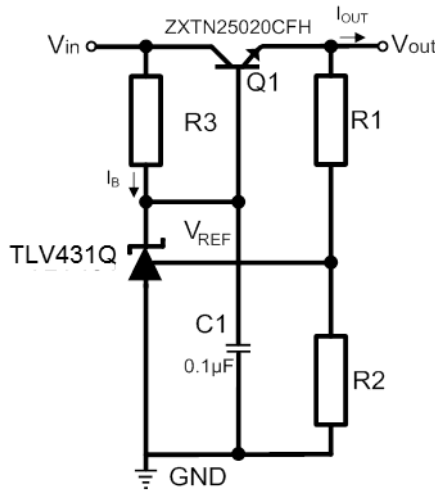
Figure 2. High Current Shunt Regulator

It may at times be required to shunt-regulate more current than the 15mA that the TLV431Q is capable of.

Figure 2 shows how this can be done using transistor Q1 to amplify the TLV431Q’s current. Care needs to be taken that the power dissipation and/or SOA requirements of the transistor is not exceeded.



**Application Notes** (Cont.)



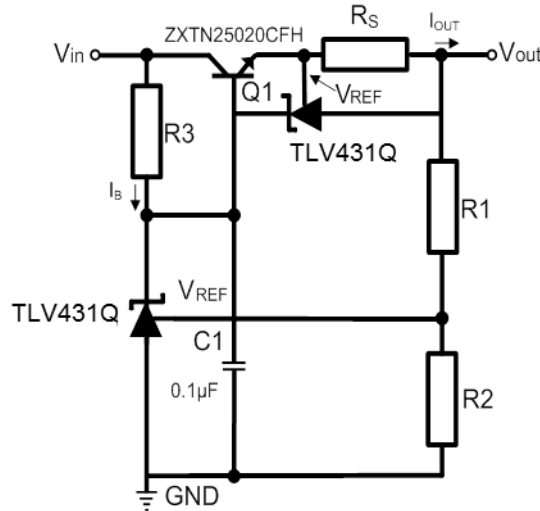
$$V_{OUT} = V_{REF} \left( 1 + \frac{R1}{R2} \right)$$

$$R3 = \frac{V_{IN} - (V_{OUT} + V_{BE})}{I_B}$$

$$\left( \frac{I_{OUT(max)}}{h_{FE(min)}} \right) < I_B \leq 15mA$$

Figure 3. Basic Series Regulator

A very effective and simple series regulator can be implemented as shown in Figure 3 above. This may be preferable if the load requires more current than can be provided by the TLV431Q alone and there is a need to conserve power when the load is not being powered. This circuit also uses one component less than the shunt circuit shown in Figure 3 above.



$$V_{OUT} = V_{REF} \left( 1 + \frac{R1}{R2} \right)$$

$$R3 = \frac{V_{IN} - (V_{OUT} + V_{BE})}{I_B}$$

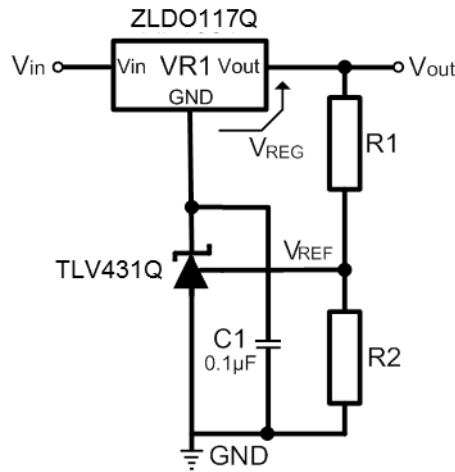
$$\left( \frac{I_{OUT(max)}}{h_{FE(min)}} \right) < I_B \leq 18mA$$

$$R_S = \frac{V_{REF}}{I_{OUT(max)}}$$

Figure 4. Series Regulator with Current Limit

Figure 4 adds current limit to the series regulator in Figure 3 using a second TLV431Q. For currents below the limit, the circuit works normally supplying the required load current at the design voltage. However, should attempts be made to exceed the design current set by the second TLV431Q, the device begins to shunt current away from the base of Q1. This begins to reduce the output voltage and thus ensuring that the output current is clamped at the design value. Subject only to Q1's ability to withstand the resulting power dissipation, the circuit can withstand either a brief or indefinite short circuit.

**Application Notes** (Cont.)



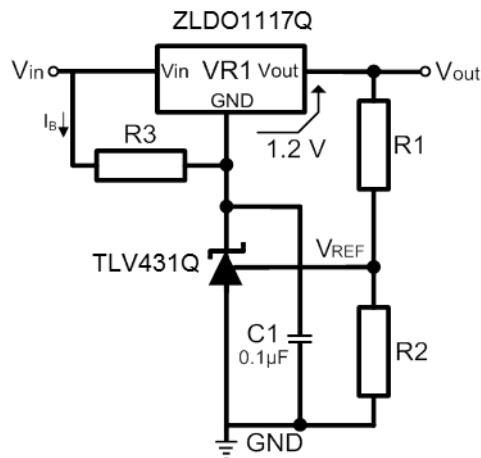
$$V_{OUT} = V_{REF} \left( 1 + \frac{R1}{R2} \right)$$

$$V_{OUT} \geq (V_{REG} + V_{REF})$$

(All features of the regulator such as short circuit protection, thermal shutdown, etc, are maintained.)

Figure 5. Increasing Output Voltage of a Fixed Linear Regulator

One of the useful applications of the TLV431Q is in using it to improve the accuracy and/or extend the range and flexibility of fixed voltage regulators. In the circuit in Figure 5 above both the output voltage and its accuracy are entirely determined by the TLV431Q, R1 and R2. However, the rest of the features of the regulator (up to 1A output current, output current limiting and thermal shutdown) are all still available.



$$V_{OUT} = V_{REF} \left( 1 + \frac{R1}{R2} \right)$$

$$V_{OUT} \geq (V_{REG} + V_{REF})$$

$$R3 = \frac{V_{IN} - (V_{OUT} - V_{REG})}{I_B}$$

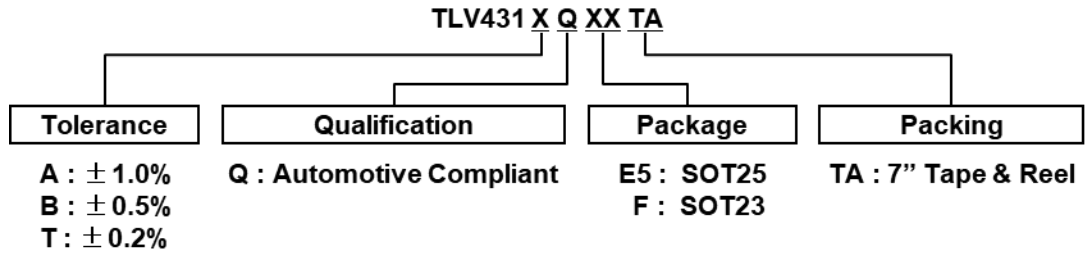
$$0.1mA \leq I_B \leq 18mA$$

(All features of the regulator such as short circuit protection, thermal shutdown, etc, are maintained.)

Figure 6. Adjustable Linear Voltage Regulator

Figure 6 is similar to Figure 5 with adjustability added. Note the addition of R3, This is added to provide sufficient bias current for the TLV431Q.

**Ordering Information**

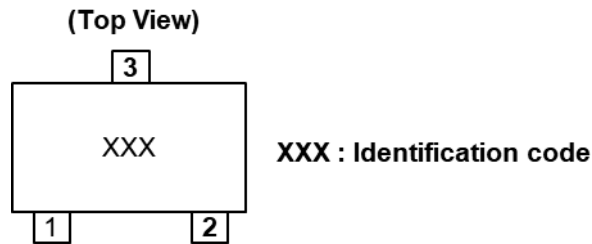


Tol.	Part Number	Package (Note 9)	Identification Code	Reel Size	Tape Width	Quantity per Reel	Compliance/Qualification (Note 10)
1%	TLV431AQE5TA	SOT25	V1A	7", 180mm	8mm	3,000	Automotive
	TLV431AQFTA	SOT23	V1A	7", 180mm	8mm	3,000	Automotive
0.5%	TLV431BQE5TA	SOT25	V1B	7", 180mm	8mm	3,000	Automotive
	TLV431BQFTA	SOT23	V1B	7", 180mm	8mm	3,000	Automotive
0.2%	TLV431TQFTA	SOT23	V1T	7", 180mm	8mm	3,000	Automotive

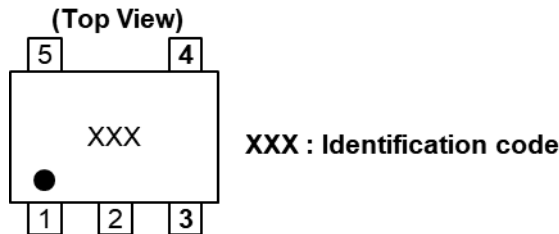
Notes: 9. For packaging details, go to our website at <https://www.diodes.com/design/support/packaging/diodes-packaging/>.  
 10. TLV431Q has been qualified to AEC-Q100 grade 1 and is classified as "Automotive-Compliant" which supports PPAP documentation. See TLV431 for commercial variants.

**Marking Information**

(1) SOT23



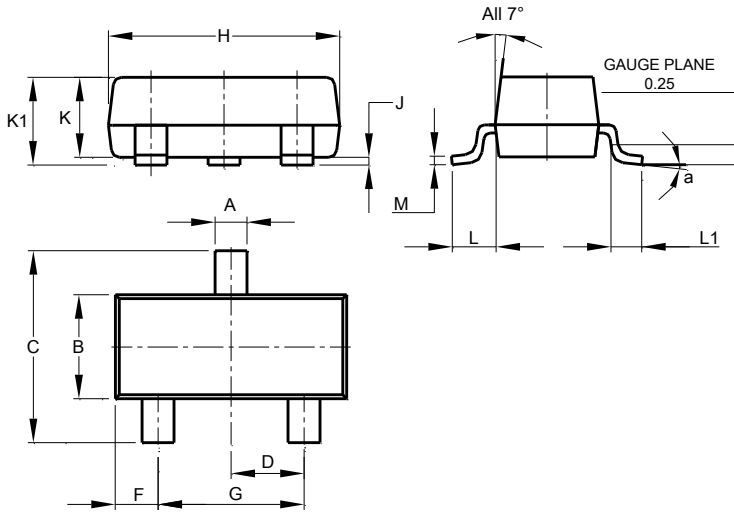
(2) SOT25



**Package Outline Dimensions**

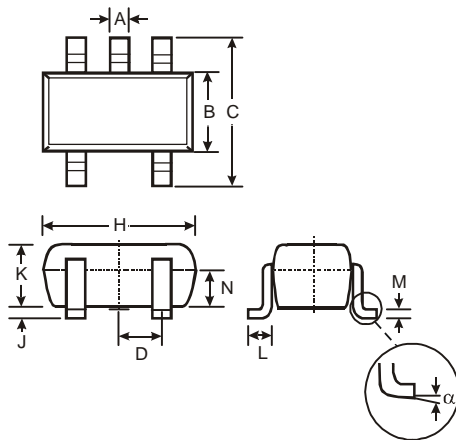
Please see <http://www.diodes.com/package-outlines.html> for the latest version.

(1) Package Type: SOT23



SOT23			
Dim	Min	Max	Typ
A	0.37	0.51	0.40
B	1.20	1.40	1.30
C	2.30	2.50	2.40
D	0.89	1.03	0.915
F	0.45	0.60	0.535
G	1.78	2.05	1.83
H	2.80	3.00	2.90
J	0.013	0.10	0.05
K	0.890	1.00	0.975
K1	0.903	1.10	1.025
L	0.45	0.61	0.55
L1	0.25	0.55	0.40
M	0.085	0.150	0.110
a	0°	8°	--
All Dimensions in mm			

(2) Package Type: SOT25

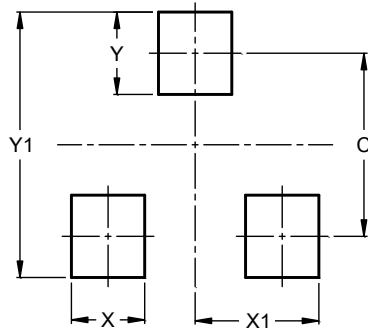


SOT25			
Dim	Min	Max	Typ
A	0.35	0.50	0.38
B	1.50	1.70	1.60
C	2.70	3.00	2.80
D	-	-	0.95
H	2.90	3.10	3.00
J	0.013	0.10	0.05
K	1.00	1.30	1.10
L	0.35	0.55	0.40
M	0.10	0.20	0.15
N	0.70	0.80	0.75
α	0°	8°	-
All Dimensions in mm			

## Suggested Pad Layout

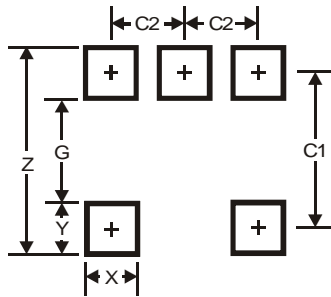
Please see <http://www.diodes.com/package-outlines.html> for the latest version.

### (1) Package Type: SOT23



Dimensions	Value (in mm)
C	2.0
X	0.8
X1	1.35
Y	0.9
Y1	2.9

### (2) Package Type: SOT25



Dimensions	Value
Z	3.20
G	1.60
X	0.55
Y	0.80
C1	2.40
C2	0.95

- Note: The suggested land pattern dimensions have been provided for reference only, as actual pad layouts may vary depending on application. These dimensions may be modified based on user equipment capability or fabrication criteria. A more robust pattern may be desired for wave soldering and is calculated by adding 0.2 mm to the 'Z' dimension. For further information, please reference document IPC-7351A, Naming Convention for Standard SMT Land Patterns, and for International grid details, please see document IEC, Publication 97.
- Note: For high voltage applications, the appropriate industry sector guidelines should be considered with regards to creepage and clearance distances between device Terminals and PCB tracking.

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