

**TLV431**  
**1.24V COST EFFECTIVE SHUNT REGULATOR**

**Description**

The TLV431 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.

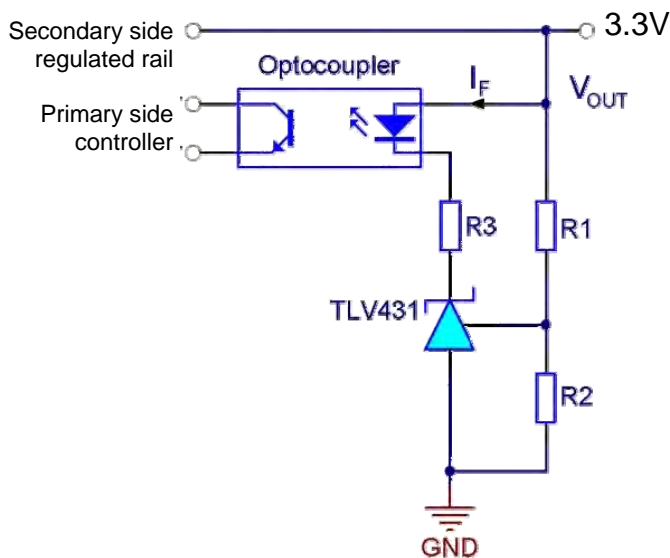
The TLV431 can be used as a replacement for zener diodes in many applications requiring an improvement in zener performance.

The TLV431 is available in 2 grades with initial tolerances of 1% and 0.5% for the A and B grades respectively.

**Features**

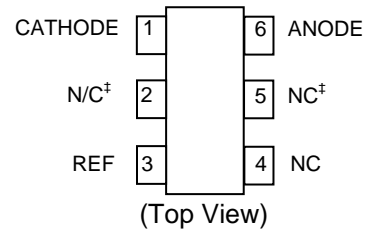
- Low Voltage Operation  $V_{REF} = 1.24V$
- Temperature range  $-40$  to  $125^{\circ}C$
- Reference Voltage Tolerance at  $25^{\circ}C$ 
  - o 0.5% TLV431B
  - o 1% TLV431A
- Typical temperature drift
  - o 4 mV ( $0^{\circ}C$  to  $70^{\circ}C$ )
  - o 6 mV ( $-40^{\circ}C$  to  $85^{\circ}C$ )
  - o 11mV ( $-40^{\circ}C$  to  $125^{\circ}C$ )
- 80 $\mu$ A Minimum cathode current
- 0.25 $\Omega$  Typical Output Impedance
- Adjustable Output Voltage  $V_{REF}$  to 18V
- Lead Free Finish. RoHS Compliant with "Green" Molding Compound (No Br, Sb)
- Qualified to AEC-Q100

**Typical Application Circuit**

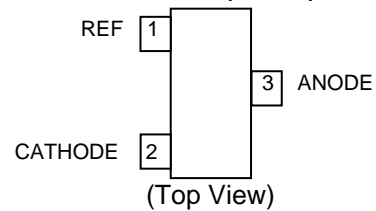


**Pin Assignments**

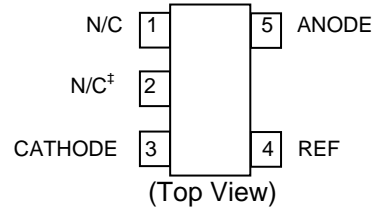
**TLV431\_H6 (SC70-6)**



**TLV431\_F (SOT23)**



**TLV431\_E5 (SOT25)**



† Pin should be left floating or connect to anode

### Absolute Maximum Ratings (Voltages to GND Unless Otherwise Stated)

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	-0.050 to 3	mA
$V_{IN}$	Input Supply Voltage (Relative to Ground)	-0.03 to 18	V
<b>ESD Susceptibility</b>			
HBM	Human Body Model	4	kV
MM	Machine Model	400	V
CDM	Charged Device Model	1	kV

(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.)

Parameter	Rating	Unit
Operating Junction Temperature	-40 to 150	°C
Storage Temperature	-65 to 150	°C

Operation above the absolute maximum rating may cause device failure.  
 Operation at the absolute maximum ratings, for extended periods, may reduce device reliability.  
 Unless otherwise stated voltages specified are relative to the ANODE pin.  
 These are stress ratings only. Operation outside the absolute maximum ratings may cause device failure.

### Recommended Operating Conditions

	Min	Max	Units
$V_{KA}$ 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

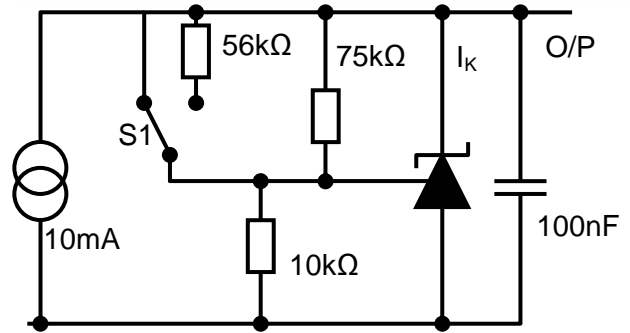
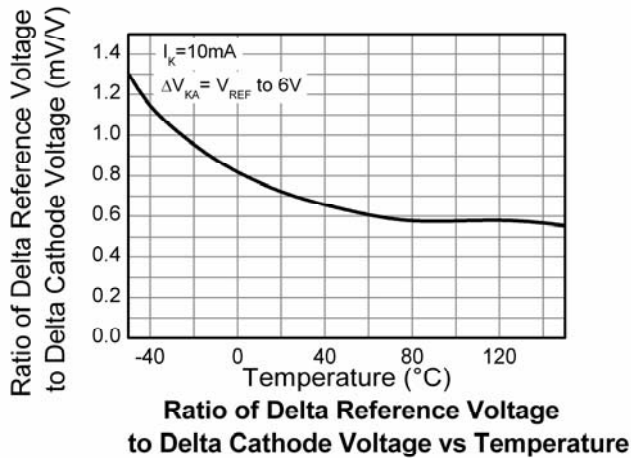
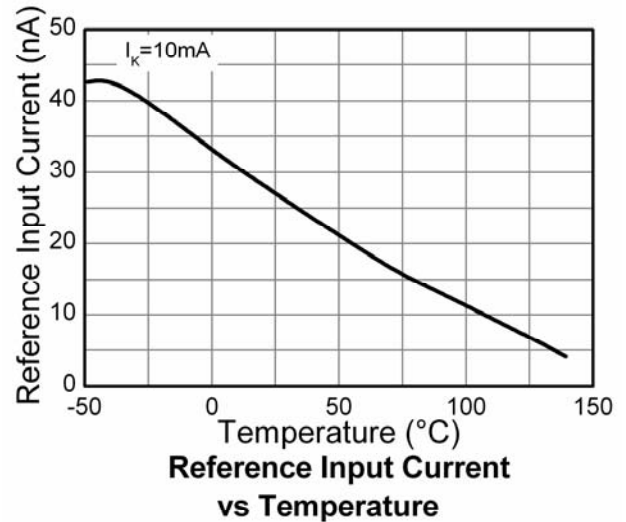
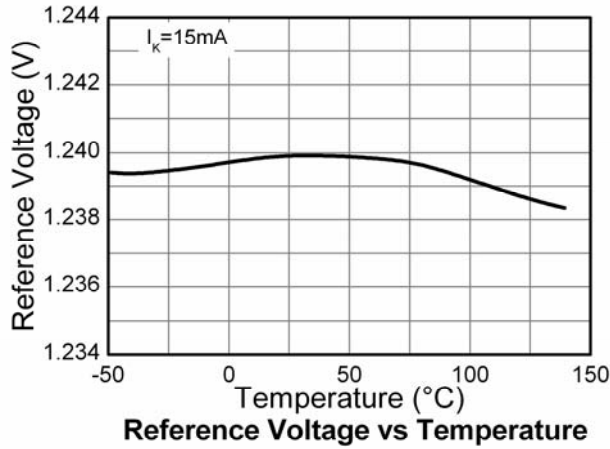
Package	$\theta_{JA}$	$P_{DIS}$ $T_A = 25^\circ\text{C}, T_J = 150^\circ\text{C}$
SOT23	380°C/W	330 mW
SOT25	250°C/W	500 mW
SC70-6	380°C/W	330 mW

## Electrical Characteristics

Electrical characteristics over recommended operating conditions,  $I_{KA} = 10\text{mA}$ ,  $T_A = 25^\circ\text{C}$ , unless otherwise stated

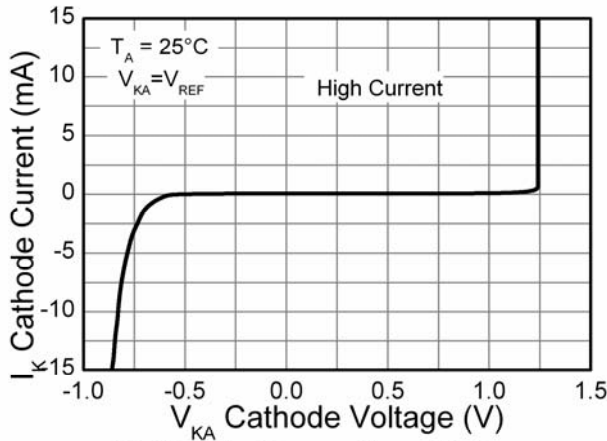
Symbol	Parameter	Conditions	Min.	Typ.	Max.	Units	
$V_{REF}$	Reference Voltage	$V_{KA} = V_{REF}$ , $T_A = 25^\circ\text{C}$	TLV431A	1.228	1.24	1.252	V
			TLV431B	1.234	1.24	1.246	
		$V_{KA} = V_{REF}$ , $T_A = 0 \text{ to } 70^\circ\text{C}$	TLV431A	1.221		1.259	
			TLV431B	1.227		1.253	
		$V_{KA} = V_{REF}$ , $T_A = -40 \text{ to } 85^\circ\text{C}$	TLV431A	1.215		1.265	
			TLV431B	1.224		1.259	
$V_{REF(\text{dev})}$	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	
$\frac{\Delta V_{REF}}{\Delta V_{KA}}$	Ration 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	$\mu\text{A}$	
$I_{REF(\text{dev})}$	$I_{REF}$ 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	
$I_{K(\text{OFF})}$	Off state current	$V_{KA} = 18\text{V}$ , $V_{REF} = 0\text{V}$		0.001	0.1	$\mu\text{A}$	
$Z_{KA}$	Dynamic output impedance	$V_{KA} = V_{REF}$ , $f = <1\text{kHz}$ $I_K = 0.1 \text{ to } 15\text{mA}$		0.25	0.4	$\Omega$	

**Typical Characteristics**

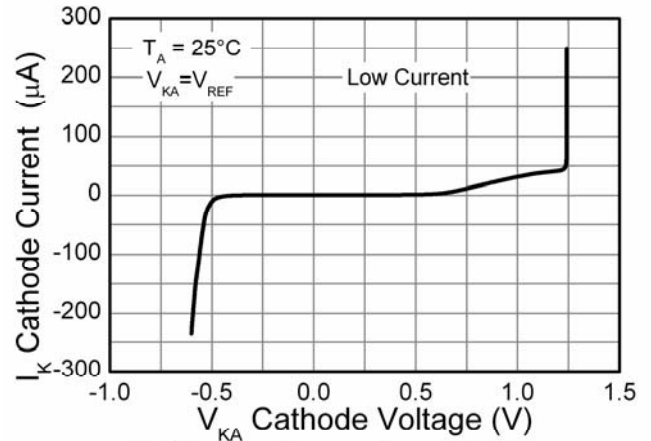


Test circuit for  $V_{REF}$  measurement

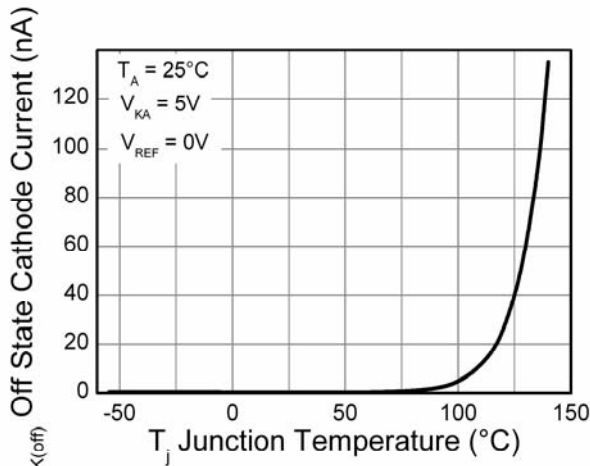
**Typical Characteristics (cont.)**



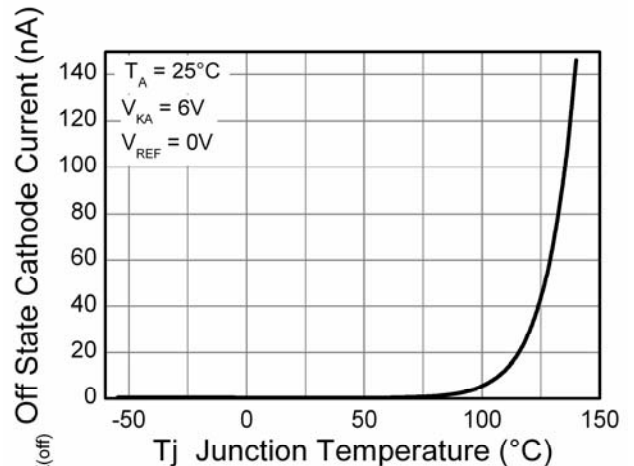
**Cathode Current vs Voltage**



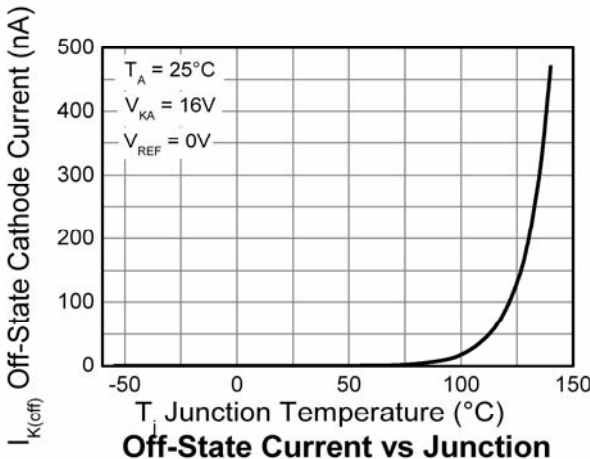
**Cathode Current vs Voltage**



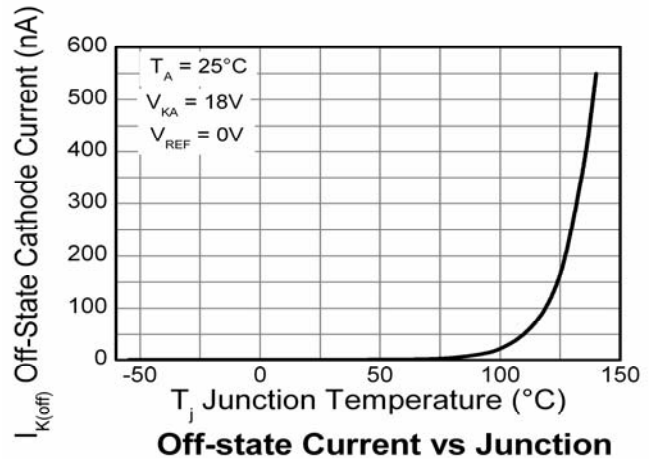
**Off-State Current vs Junction Temperature**



**Off-State Current vs Junction Temperature**

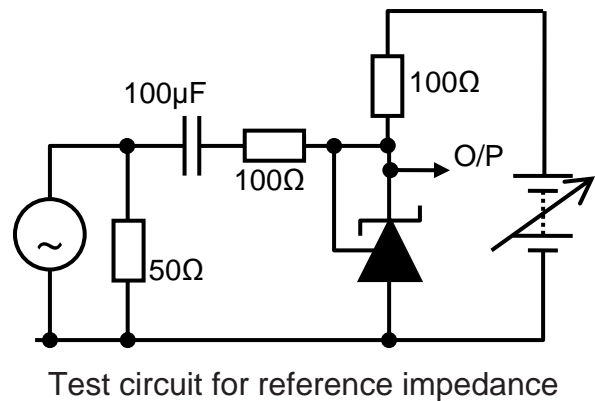
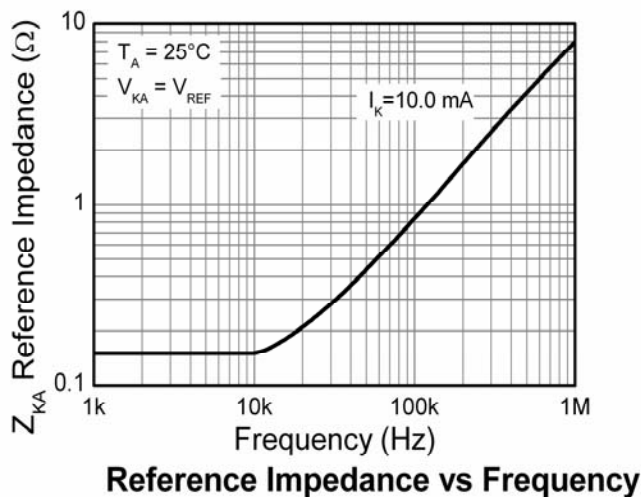
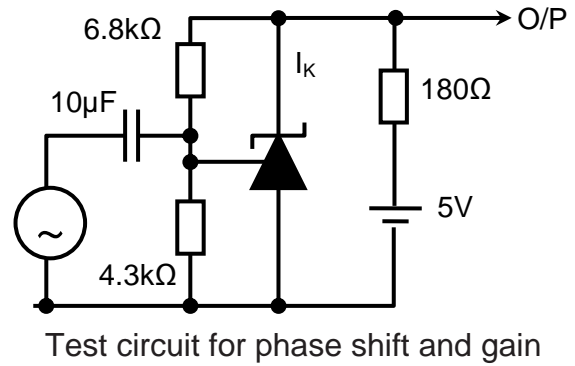
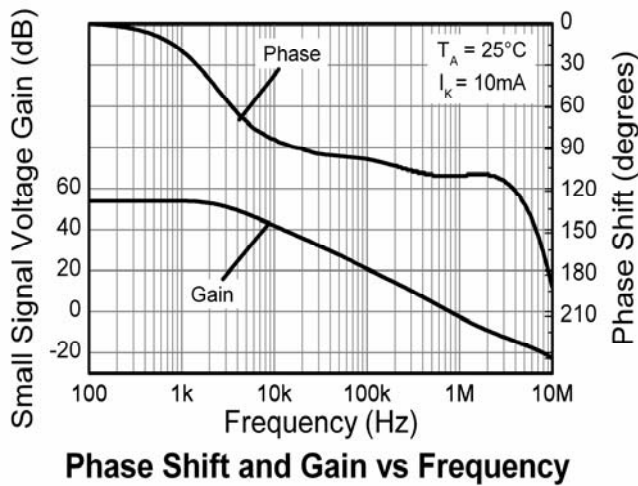
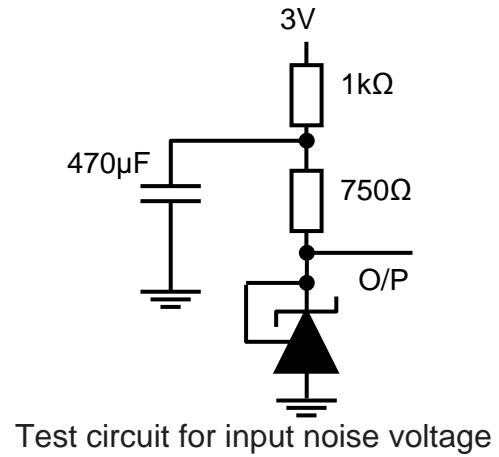
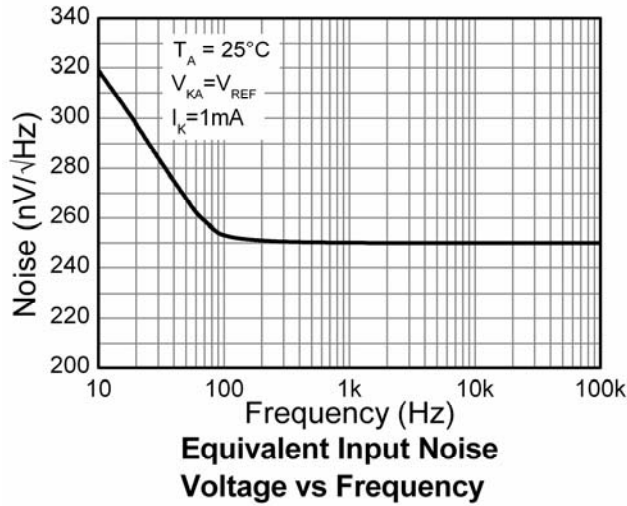


**Off-State Current vs Junction Temperature**

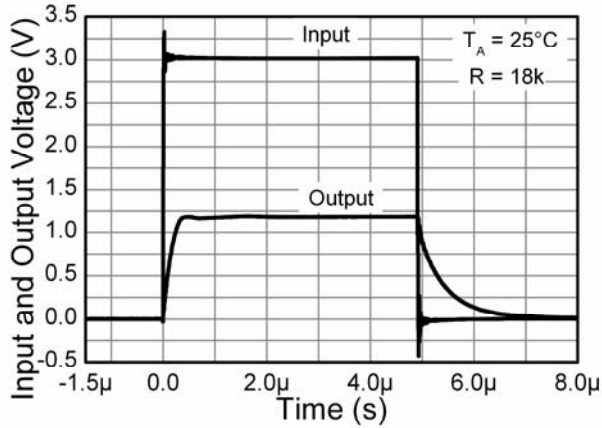


**Off-state Current vs Junction Temperature**

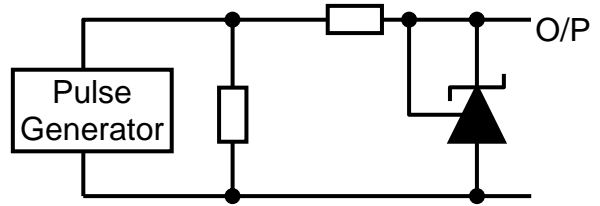
**Typical Characteristics (cont.)**



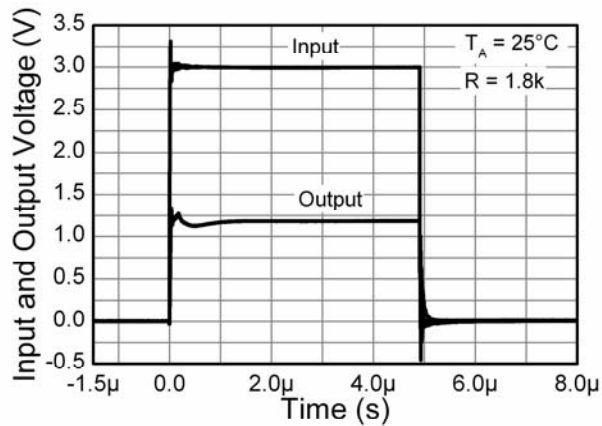
**Typical Characteristics (cont.)**



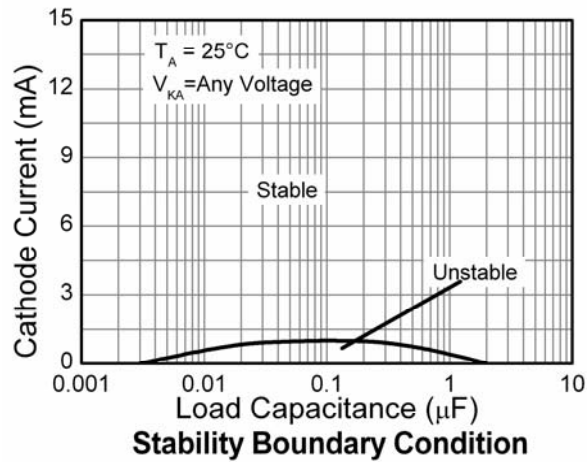
**Pulse Response**



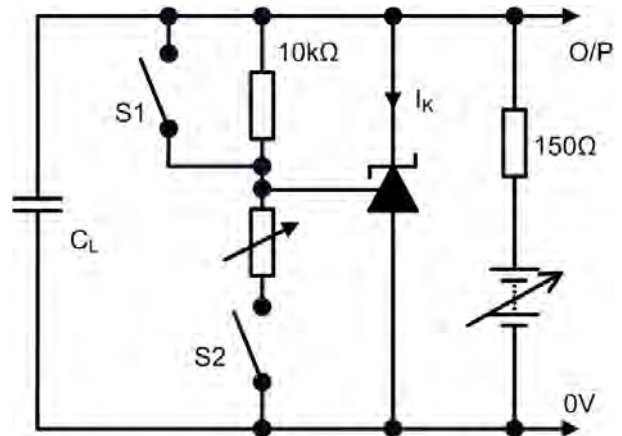
Test circuit for pulse response



**Pulse Response**



**Stability Boundary Condition**





**Application Information**

In a conventional shunt regulator application (Figure 1), an external series resistor ( $R_3$ ) is connected between the supply voltage,  $V_{IN}$ , and the TLV431.

$R_3$  determines the current that flows through the load ( $I_L$ ) and the TLV431 ( $I_K$ ). The TLV431 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,  $R_3$  should be small enough to supply at least the minimum acceptable  $I_{KMIN}$  to the TLV431 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,  $R_3$  should be large enough so that the current flowing through the TLV431 is less than 15 mA.

$R_3$  is determined by the supply voltage, ( $V_{IN}$ ), the load and operating current, ( $I_L$  and  $I_K$ ), and the TLV431’s reverse breakdown voltage,  $V_{KA}$ .

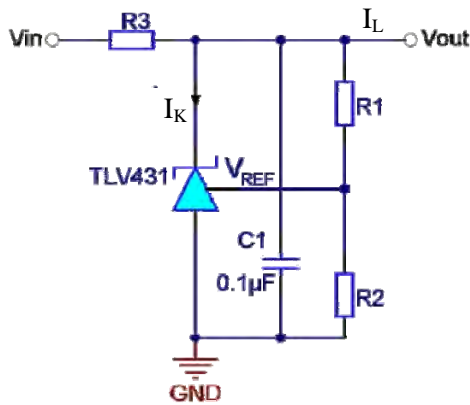


Figure 1

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

where

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

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

The values of  $R_1$  and  $R_2$  should be large enough so that the current flowing through them is much smaller than the current through  $R_3$  yet not too large that the voltage drop across them caused  $I_{REF}$  affects the reference accuracy.

The most frequent application of the TLV431 is in isolated low output voltage power supplies where the regulated output is galvanically isolated from the controller. As shown in figure 2 the TLV431 drives current,  $I_F$ , through the opto-coupler’s LED which in turn drives the isolated transistor which is connected to the controller on the primary side of the power supply.

This completes the feedback path through the isolation barrier and ensures that a stable isolated supply is maintained.

Assuming a forward drop of 1.4V across the opto-coupler diode allows output voltages as low as 2.7V to be regulated.

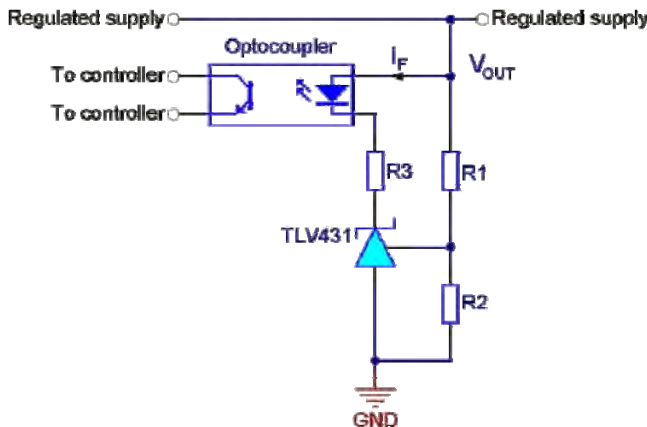


Figure 2. Using the TLV431 as the regulating element in an isolated PSU

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

$$\frac{V_{OUT} - 2.7}{I_{F(min)}} > R_3 \geq \frac{V_{OUT(max)} - 2.7}{15mA}$$



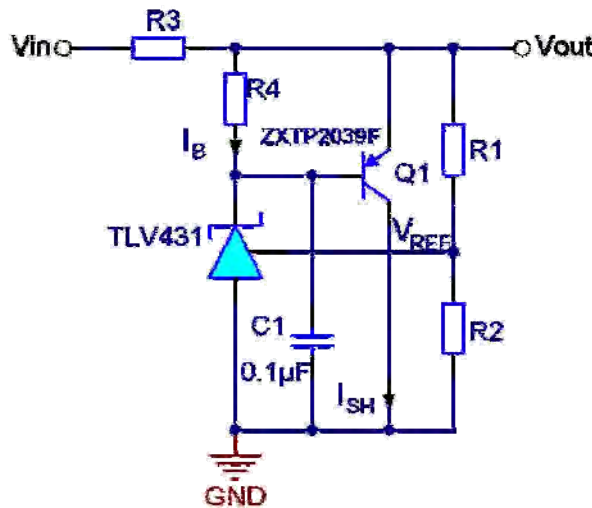
**Application Information (cont.)**

**Printed circuit board layout considerations**

The TLV431 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.

TLV431 in the SC70-6 package has the die attached to pin 2 and 5, which results in an electrical contact between pins 2, 5 and pin 6. Therefore, pins 2 and 5 must be left floating or connected to pin 6.

**Other applications of the TLV431**



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

$$R3 = \frac{V_{IN} - V_{OUT}}{I_{SH} + I_B}$$

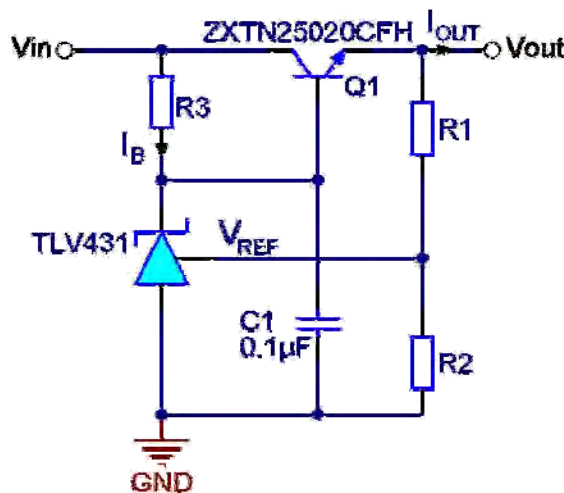
$$R4 = \frac{V_{BE}}{I_B}$$

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

**Figure 3. High current shunt regulator**

It may at times be required to shunt-regulate more current than the 15mA that the TLV431 is capable of.

Figure 3 shows how this can be done using transistor Q1 to amplify the TLV431's current. Care needs to be taken that the power dissipation and/or SOA requirements of the transistor is not exceeded.



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

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

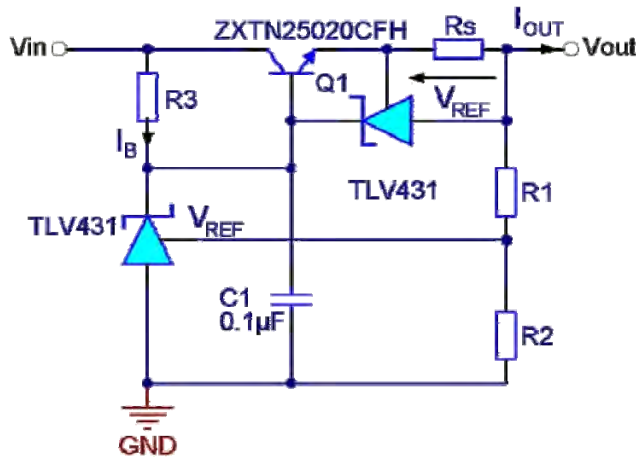
$$\left( \frac{I_{OUT(max)}}{h_{FE(min)}} \right) < I_B \leq 15mA$$

**Figure 4. Basic series regulator**

A very effective and simple series regulator can be implemented as shown in Figure 4 above. This may be preferable if the load requires more current than can be provided by the TLV431 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.

**Application Information (cont.)**

**Printed circuit board layout considerations (continued)**



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

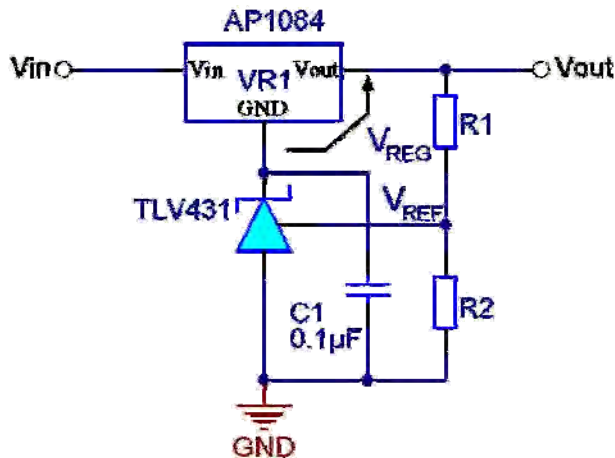
$$R3 = \frac{V_{IN} - (V_{OUT} + V_{BE})}{I_B}$$

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

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

**Figure 5. Series regulator with current limit**

Figure 5 adds current limit to the series regulator in Figure 4 using a second TLV431. 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 TLV431, 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.



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

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

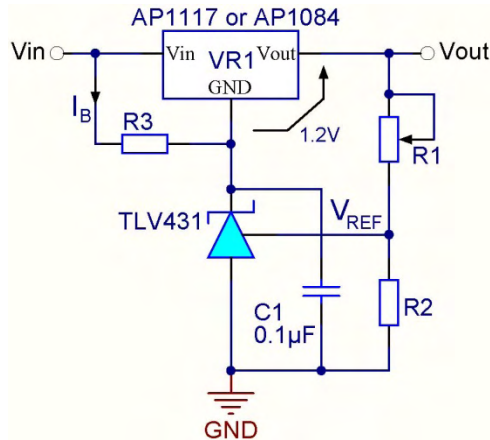
(All features of the regulator such as short circuit protection, thermal shutdown, etc, are maintained.)

**Figure 6. Increasing output voltage of a fixed linear regulator**

One of the useful applications of the TLV431 is in using it to improve the accuracy and/or extend the range and flexibility of fixed voltage regulators. In the circuit in Figure 6 above both the output voltage and its accuracy are entirely determined by the TLV431, R1 and R2. However the rest of the features of the regulator (up to 5A output current, output current limiting and thermal shutdown) are all still available.

**Application Information (cont.)**

**Printed circuit board layout considerations (cont.)**



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

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

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

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

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

**Figure 7. Adjustable linear voltage regulator**

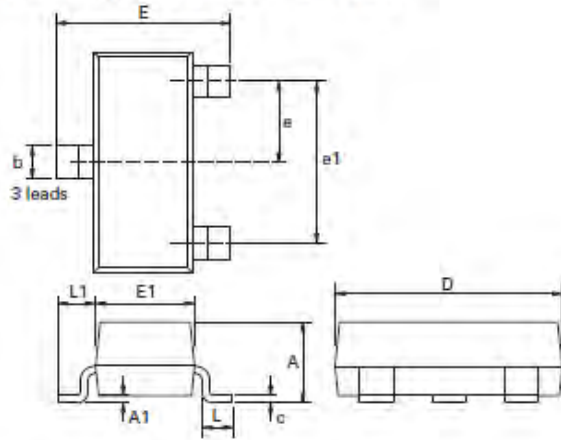
Figure 7 is similar to Figure 6 with adjustability added. Note the addition of R3. This is only required for the AP1117 due to the fact that its ground or adjustment pin can only supply a few micro-Amps of current at best. R3 is therefore needed to provide sufficient bias current for the TLV431.

**Ordering Information**

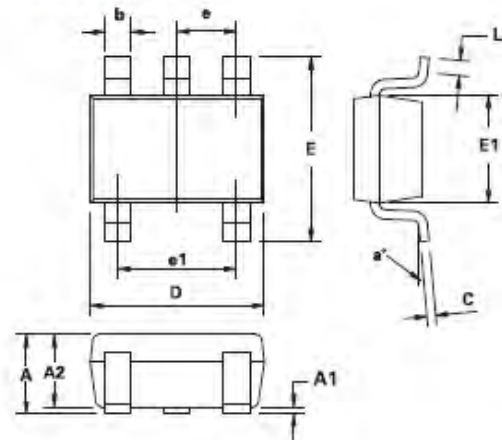
Tol.	Orde Code	Pack	Part Mark	Status	Reel Size	Tape Width	Quantity per Reel
1%	TLV431AE5TA	SOT25	V1A	Active	7", 180mm	8mm	3000
	TLV431AFTA	SOT23	V1A	Active	7", 180mm	8mm	3000
	TLV431AH6TA	SC70-6	V1A	Active	7", 180mm	12mm	1000
0.5%	TLV431BE5TA	SOT25	V1B	Active	7", 180mm	8mm	3000
	TLV431BFTA	SOT23	V1B	Active	7", 180mm	8mm	3000
	TLV431BH6TA	SC70-6	V1B	Active	7", 180mm	12mm	1000

**Package Outline Dimensions**

**SOT23**



**SOT25**



**Dimension Table SOT23**

Dim.	Millimeters		Inches		Dim.	Millimeters		Inches	
	Min.	Max.	Min.	Max.		Min.	Max.	Min.	Max.
A	-	1.12	-	0.044	e1	1.90 NOM		0.075 NOM	
A1	0.01	0.10	0.0004	0.004	E	2.10	2.64	0.083	0.104
b	0.30	0.50	0.012	0.020	E1	1.20	1.40	0.047	0.055
c	0.085	0.20	0.003	0.008	L	0.25	0.60	0.0098	0.0236
D	2.80	3.04	0.110	0.120	L1	0.45	0.62	0.018	0.024
e	0.95 NOM		0.037 NOM		-	-	-	-	-

**Note:** Controlling dimensions are in millimeters. Approximate dimensions are provided in inches

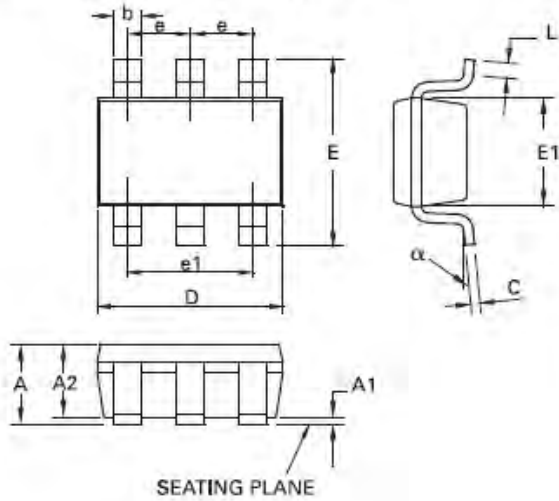
**Dimension Table SOT25**

Dim.	Millimeters		Inches		Dim.	Millimeters		Inches	
	Min.	Max.	Min.	Max.		Min.	Max.	Min.	Max.
A	0.9	1.45	0.0354	0.0570	E	2.20	3.20	0.0866	0.1181
A1	0.00	0.15	0.00	0.0059	E1	1.30	1.80	0.0511	0.0708
A2	0.90	1.3	0.0354	0.0511	e	0.95 REF		0.0374	
b	0.20	0.50	0.0078	0.0196	e1	1.90 REF		0.0748	
C	0.09	0.26	0.0035	0.0102	L	0.10	0.60	0.0039	0.0236
D	2.70	3.10	0.1062	0.1220	a°	0	30	0	30

**Note:** Controlling dimensions are in millimeters. Approximate dimensions are provided in inches

**Package Outline Dimensions (cont.)**

SC70-6



Dim.	Millimeters		Inches		Dim.	Millimeters		Inches	
	Min.	Max.	Min.	Max.		Min.	Max.	Min.	Max.
A	0.80	1.10	0.0315	0.0433	E	2.10 BSC		0.0826 BSC	
A1	0	0.10	0	0.0039	E1	1.25 BSC		0.0492 BSC	
A2	0.80	1.00	0.0315	0.0394	e	0.65 BSC		0.0255 BSC	
b	0.15	0.30	0.006	0.0118	e1	1.30 BSC		0.0511 BSC	
C	0.08	0.25	0.0031	0.0098	L	0.26	0.46	0.0102	0.0181
D	2.00 BSC		0.0787 BSC		alpha	0	8	0	8

**Note:** Controlling dimensions are in millimeters. Approximate dimensions are provided in inches

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**LIFE SUPPORT**

Diodes Incorporated products are specifically not authorized for use as critical components in life support devices or systems without the express written approval of the Chief Executive Officer of Diodes Incorporated. As used herein:

A. Life support devices or systems are devices or systems which:

1. are intended to implant into the body, or
2. support or sustain life and whose failure to perform when properly used in accordance with instructions for use provided in the labeling can be reasonably expected to result in significant injury to the user.

B. A critical component is any component in a life support device or system whose failure to perform can be reasonably expected to cause the failure of the life support device or to affect its safety or effectiveness.

Customers represent that they have all necessary expertise in the safety and regulatory ramifications of their life support devices or systems, and acknowledge and agree that they are solely responsible for all legal, regulatory and safety-related requirements concerning their products and any use of Diodes Incorporated products in such safety-critical, life support devices or systems, notwithstanding any devices- or systems-related information or support that may be provided by Diodes Incorporated. Further, Customers must fully indemnify Diodes Incorporated and its representatives against any damages arising out of the use of Diodes Incorporated products in such safety-critical, life support devices or systems.

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