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.

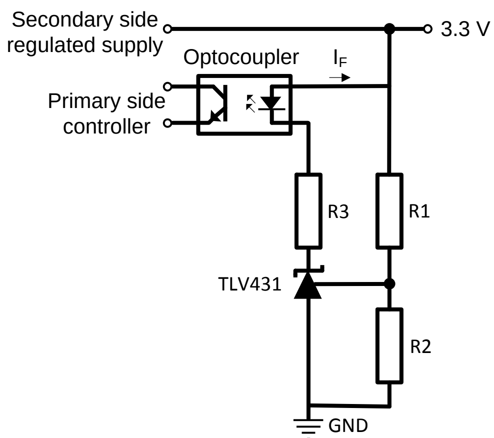
The TLV431 can be used as a replacement for zener diodes in many applications requiring an improvement in zener performance.

The TLV431 is available in 3 grades with initial tolerances of 1%, 0.5%, and 0.2% for the A, B and T grades respectively.

Features

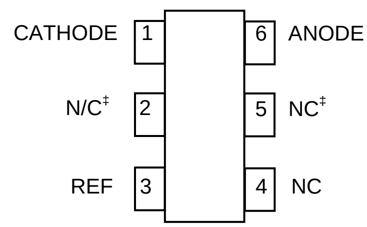
- Low Voltage Operation V_{REF} = 1.24V
- Temperature range -40 to +125°C
- Reference Voltage Tolerance at +25°C
  - 0.2% TLV431T
  - 0.5% TLV431B
  - 1% TLV431A
- Typical temperature drift
  - 4 mV (0°C to +70°C)
  - 6 mV (-40°C to +85°C)
  - 11mV (-40°C to +125°C)
- 80µA Minimum cathode current
- 0.25Ω Typical Output Impedance
- Adjustable Output Voltage V_{REF} to 18V
- **Lead-Free Finish; RoHS Compliant (Notes 1 & 2)**
- **Halogen and Antimony Free. "Green" Device (Note 3)**
- Qualified to AEC-Q100

Typical Application Circuit



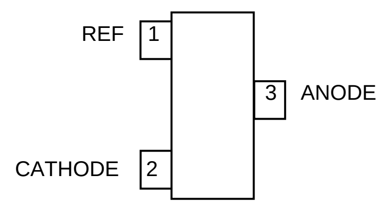
Pin Assignments

TLV431_H6 (SC70-6 [SOT363])



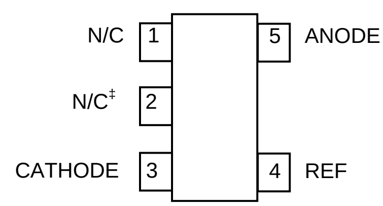
(Top View)

TLV431_F (SOT23)



(Top View)

TLV431_E5 (SOT25)



(Top View)

‡ Pin should be left floating or connect to anode

Notes:
1. EU Directive 2002/95/EC (RoHS) & 2011/65/EU (RoHS 2) compliant. All applicable RoHS exemptions applied.
2. See http://www.diodes.com for more information about Diodes Incorporated's definitions of Halogen- and Antimony-free, "Green" and Lead-free.
3. Halogen- and Antimony-free "Green" products are defined as those which contain <900ppm bromine, <900ppm chlorine (<1500ppm total Br + Cl) and <1000ppm antimony compounds.

Absolute Maximum Ratings (@T_A = +25°C, unless otherwise specified.)

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
ESD Susceptibility			
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 (@T_A = +25°C, unless otherwise specified.)

Symbol	Parameter	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

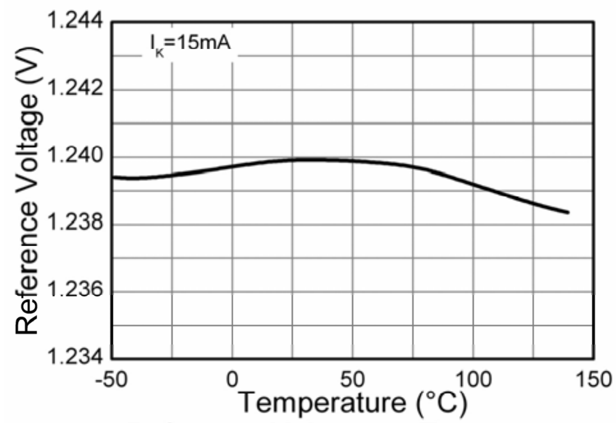
Package Thermal Data

Package	θ_{JA}	P_{DIS} T_A = +25°C, T_J = +150°C
SOT23	380°C/W	330mW
SOT25	250°C/W	500mW
SC70-6 (SOT363)	380°C/W	330mW

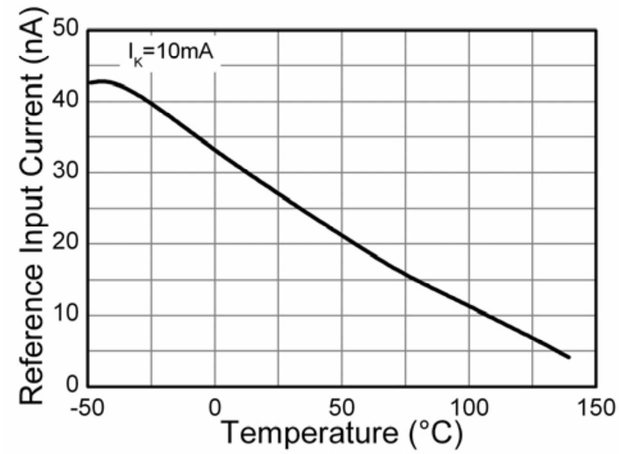
Electrical Characteristics (@T_A = +25°C, unless otherwise specified.)

Symbol	Parameter	Conditions		Min	Typ	Max	Units
V_{REF}	Reference Voltage	$V_{KA} = V_{REF}$, T_A = +25°C	TLV431A	1.228	1.24	1.252	V
			TLV431B	1.234	1.24	1.246	
			TLV431T	1.2375	1.24	1.2425	
		$V_{KA} = V_{REF}$, T_A = 0 to +70°C	TLV431A	1.221		1.259	
			TLV431B	1.227		1.253	
			TLV431T	1.230		1.250	
		$V_{KA} = V_{REF}$, T_A = -40 to +85°C	TLV431A	1.215		1.265	
			TLV431B	1.224		1.259	
			TLV431T	1.228		1.252	
		$V_{KA} = V_{REF}$, T_A = -40 to +125°C	TLV431A	1.209		1.271	
			TLV431B	1.221		1.265	
			TLV431T	1.224		1.255	
$V_{REF(dev)}$	Deviation of reference voltage over full temperature range	$V_{KA} = V_{REF}$	T_A = 0 to +70°C		4	12	mV
			T_A = -40 to +85°C		6	20	
			T_A = -40 to +125°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 = 10kΩ, R_2 = OC			0.15	0.5	µA
$I_{REF(dev)}$	I_{REF} deviation over full temperature range	R_1 = 10kΩ, R_2 = OC	T_A = 0 to +70°C		0.05	0.3	µA
			T_A = -40 to +85°C		0.1	0.4	
			T_A = -40 to +125°C		0.15	0.5	
I_{KMIN}	Minimum cathode current for regulation	$V_{KA} = V_{REF}$	T_A = 0 to +70°C		55	80	µA
			T_A = -40 to +85°C		55	80	
			T_A = -40 to +125°C		55	100	
$I_{K(OFF)}$	Off state current	V_{KA} = 18V, V_{REF} = 0V			0.001	0.1	µA
Z_{KA}	Dynamic output impedance	$V_{KA} = V_{REF}$, f = <1kHz I_K = 0.1 to 15mA			0.25	0.4	Ω

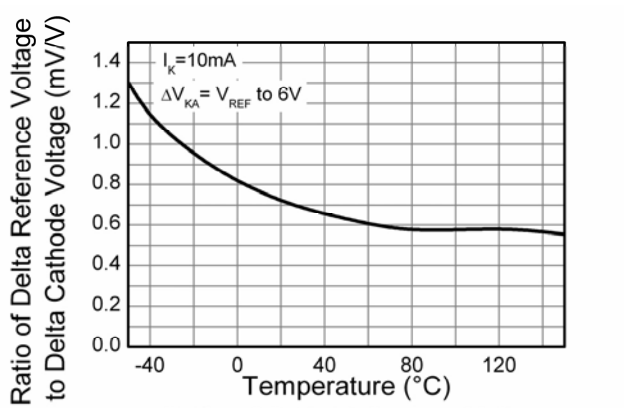
Typical Characteristics



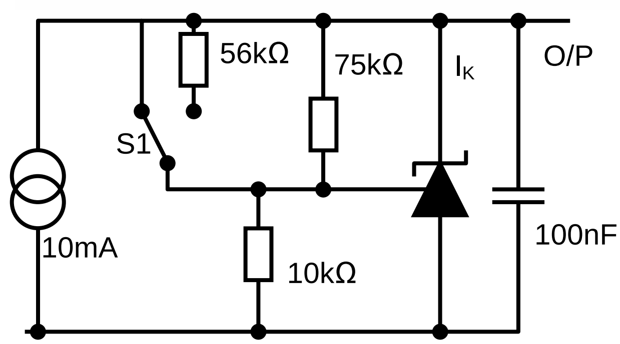
Reference Voltage vs Temperature



Reference Input Current vs Temperature

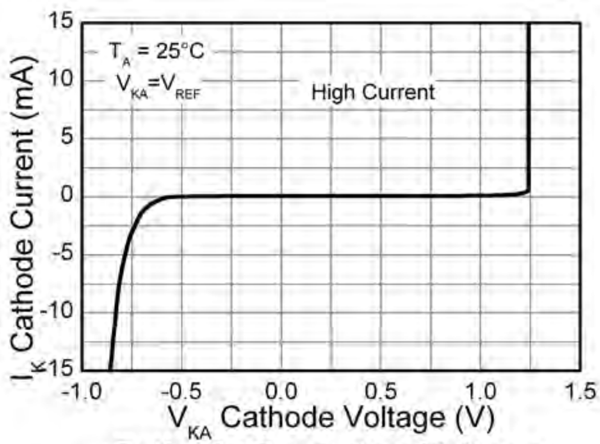


Ratio of Delta Reference Voltage to Delta Cathode Voltage vs Temperature

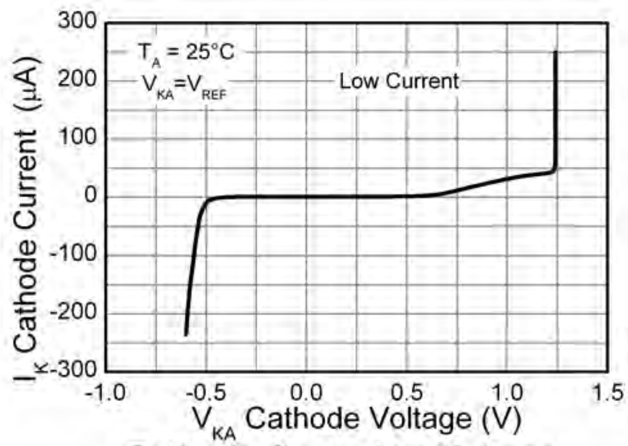


Test Circuit for V_{REF} Measurement

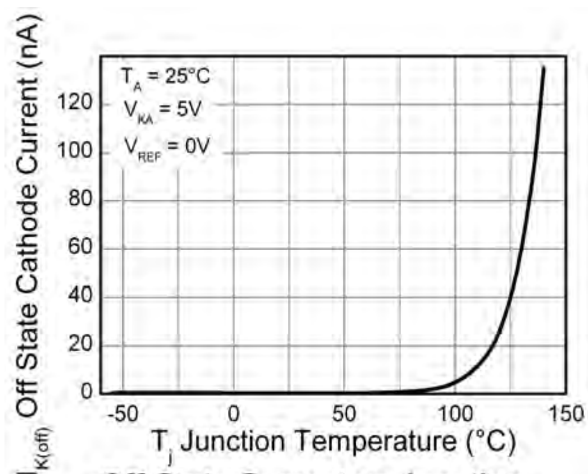
Typical Characteristics (cont.)



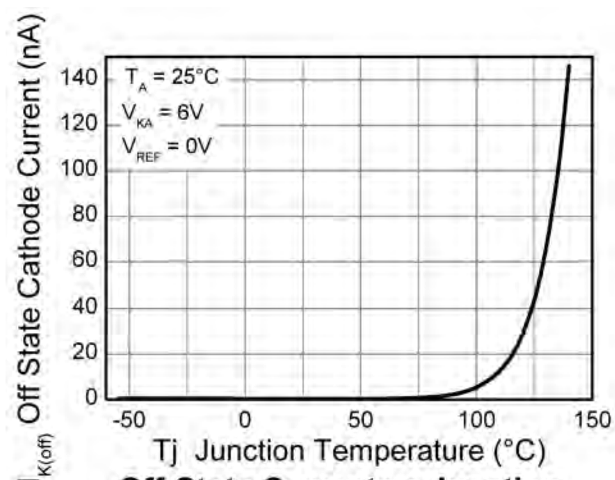
Cathode Current vs Voltage



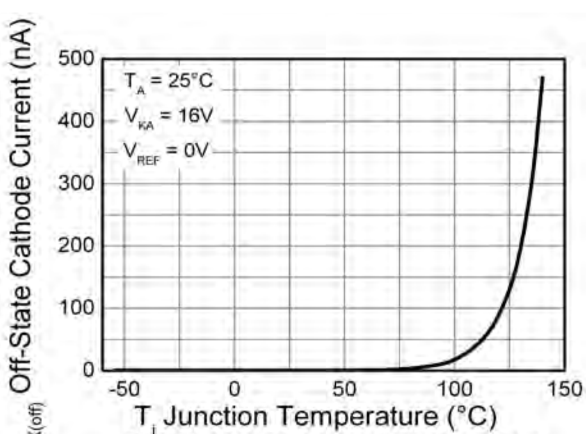
Cathode Current vs Voltage



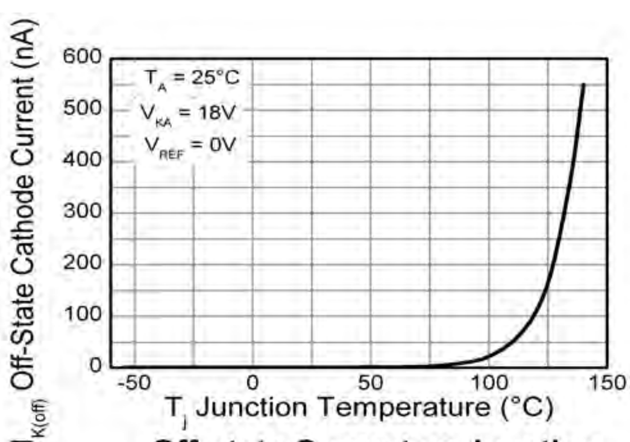
Off-State Current vs Junction Temperature



Off-State Current vs Junction Temperature

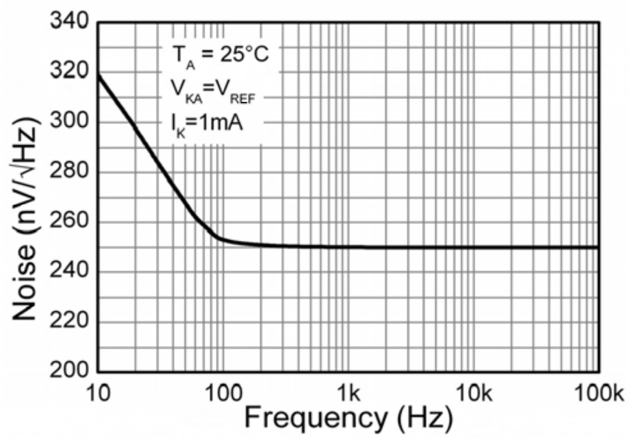


Off-State Current vs Junction Temperature

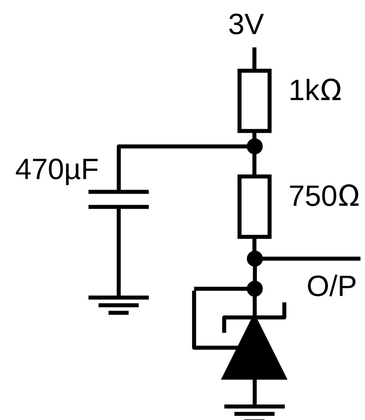


Off-state Current vs Junction Temperature

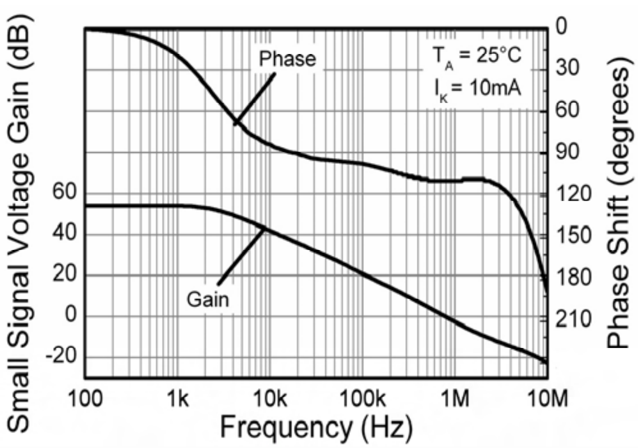
Typical Characteristics (cont.)



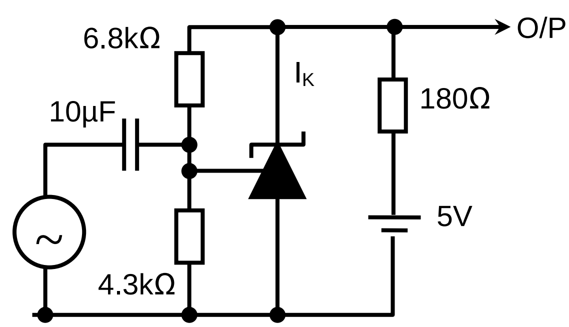
Equivalent Input Noise Voltage vs Frequency



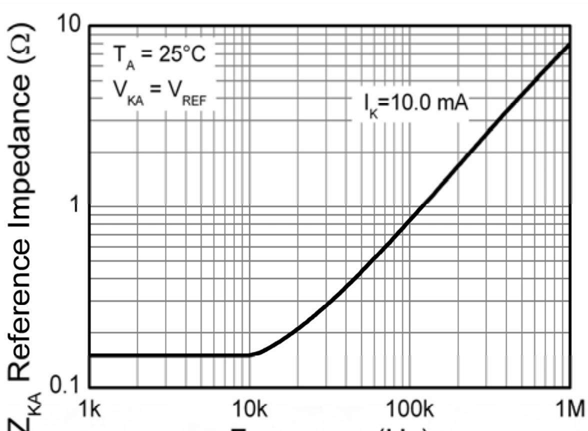
Test Circuit for Input Noise Voltage



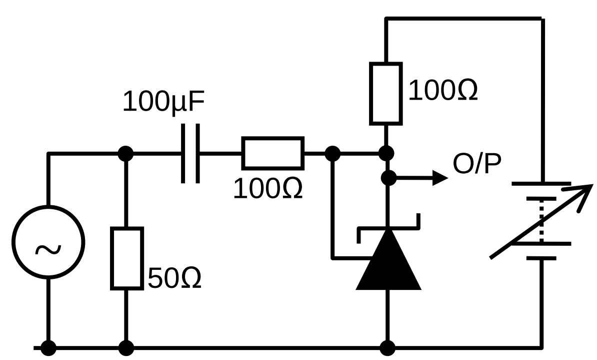
Phase Shift and Gain vs Frequency



Test Circuit for Phase Shift and Gain

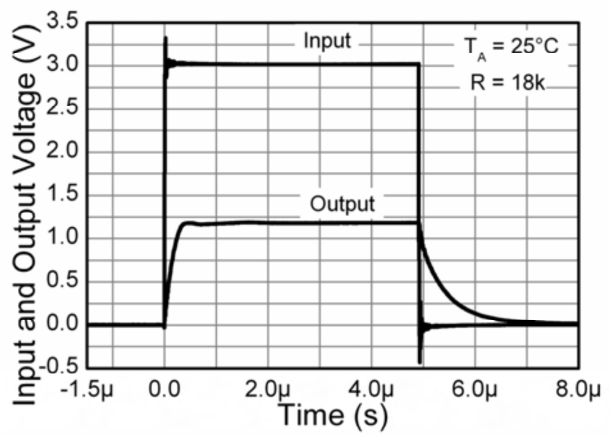


Reference Impedance vs Frequency

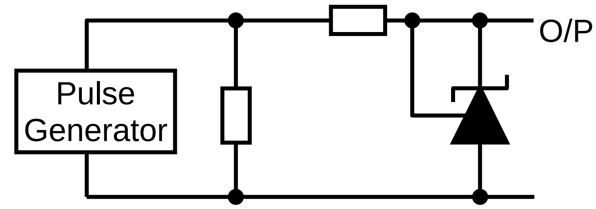


Test Circuit for Reference Impedance

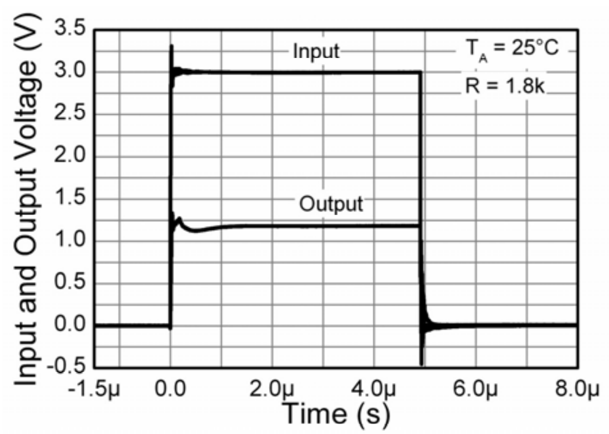
Typical Characteristics (cont.)



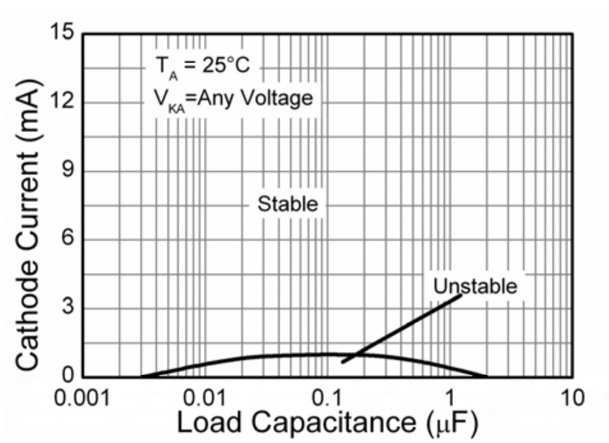
Pulse Response



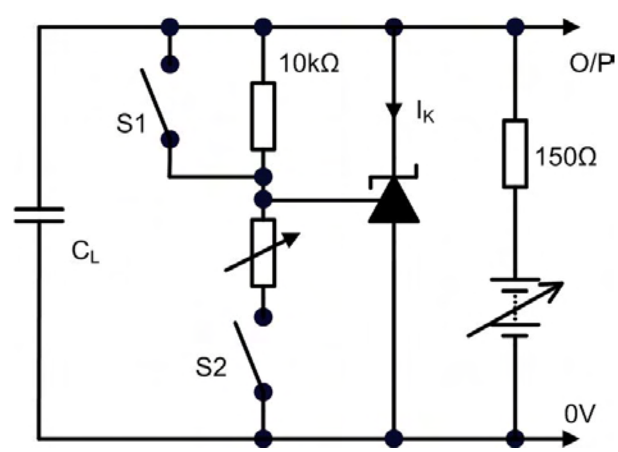
Test Circuit for Pulse Response



Pulse Response



Stability Boundary Condition



Application Notes

In a conventional shunt regulator application (Figure 1), an external series resistor (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 15mA.

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}.

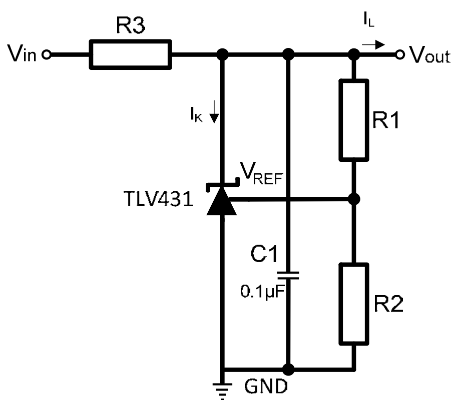


Figure 1

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

where

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

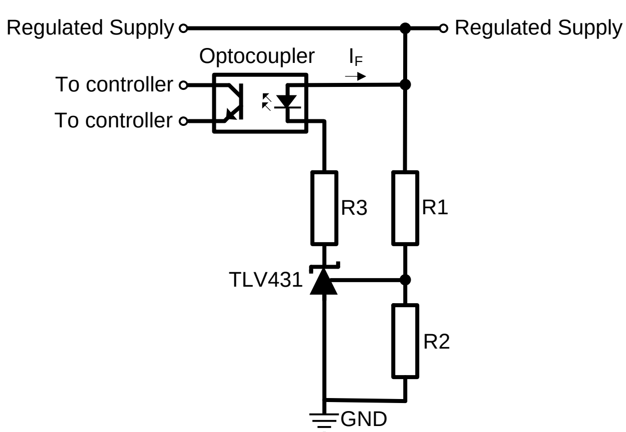
and $V_{KA} = V_{OUT}$

The values of 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 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.



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

$$\frac{V_{OUT} - 2.7}{I_{F(min)}} > R3 \geq \frac{V_{OUT(max)} - 2.7}{15mA}$$

Figure 2. Using the TLV431 as the Regulating Element in an Isolated PSU

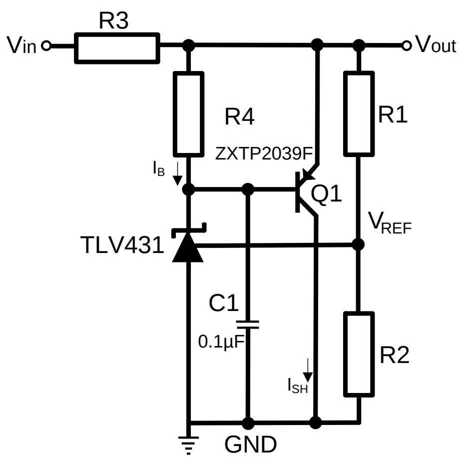
Application Notes (cont.)

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 (SOT363) 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



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

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

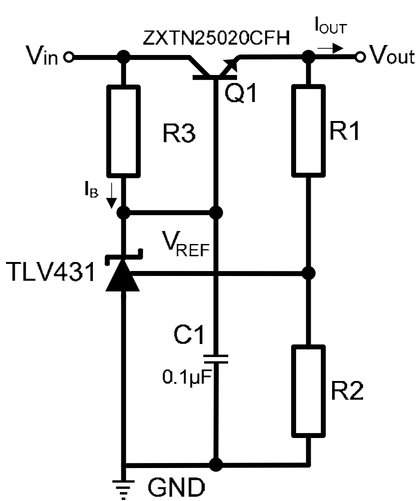
$$R4 = \frac{V_{BE}}{I_B}$$

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

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.



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

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

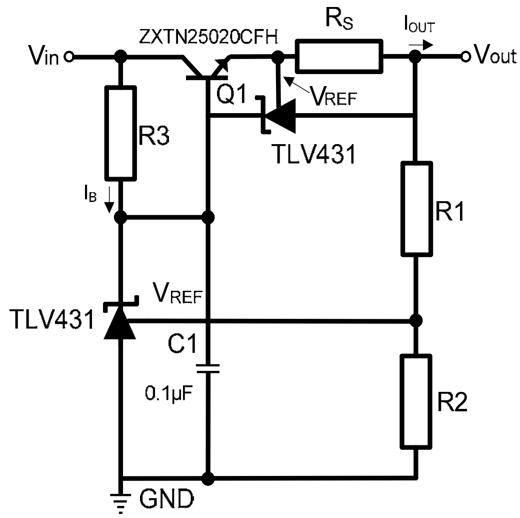
$$\left(\frac{I_{OUT(max)}}{h_{FE(min)}}\right) < I_B \leq 15mA$$

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 Notes (cont.)

Printed Circuit Board Layout Considerations (cont.)



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

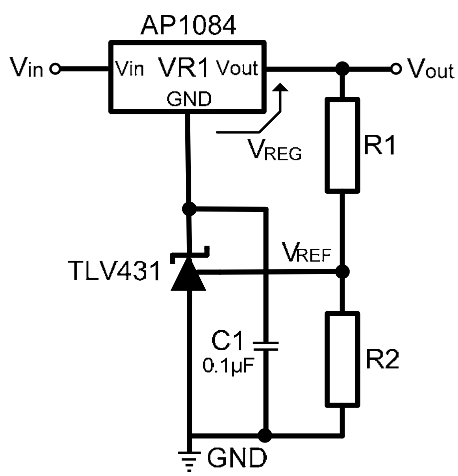
$$R3 = \frac{V_{IN} - (V_{OUT} + V_{BE})}{I_B}$$

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

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

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.



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

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

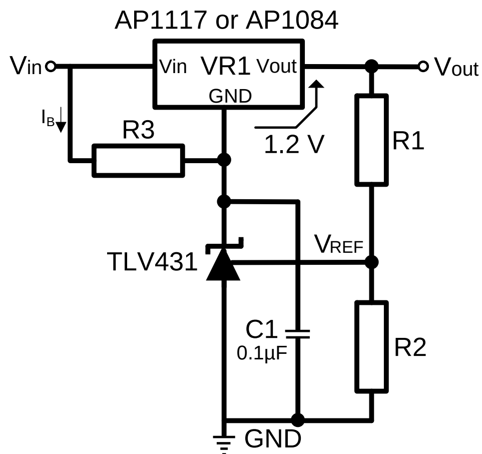
(All features of the regulator such as short circuit protection, thermal shutdown, etc, are maintained.)

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 Notes (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.

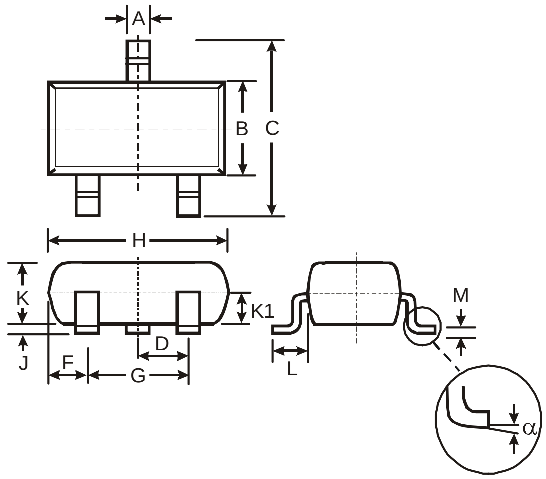
Ordering Information

Tol.	Part Number	Package	Part Mark	Status	Reel Size	Tape Width	Quanity per Reel
1%	TLV431AE5TA	SOT25	V1A	Active	7", 180mm	8mm	3000
	TLV431AFTA	SOT23	V1A	Active	7", 180mm	8mm	3000
	TLV431AH6TA	SC70-6 (SOT363)	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 (SOT363)	V1B	Active	7", 180mm	12mm	1000
0.2%	TLV431TFTA	SOT23	V1T	Active	7", 180mm	8mm	3000

Package Outline Dimensions (All dimensions in mm.)

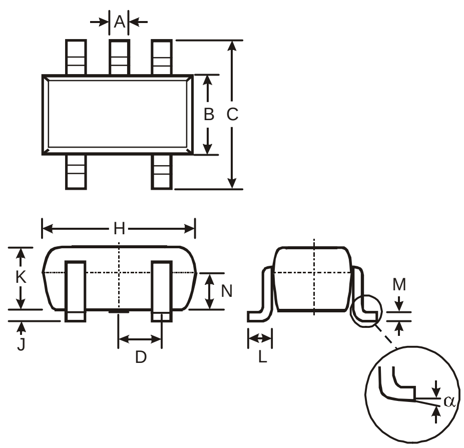
Please see AP02002 at http://www.diodes.com/datasheets/ap02002.pdf for latest version.

SOT23



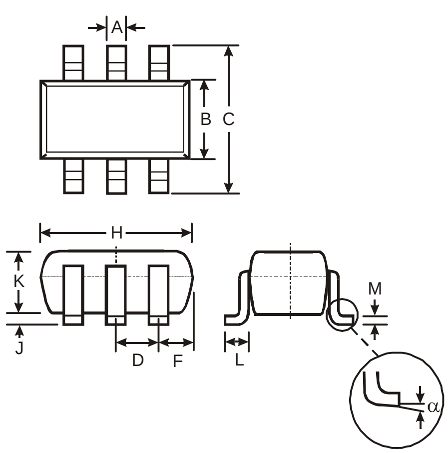
SOT23			
Dim	**Min**	**Max**	**Typ**
A	0.37	0.51	0.40
B	1.20	1.40	1.30
C	2.30	2.50	2.40
D	0.89	1.03	0.915
F	0.45	0.60	0.535
G	1.78	2.05	1.83
H	2.80	3.00	2.90
J	0.013	0.10	0.05
K	0.903	1.10	1.00
K1	—	—	0.400
L	0.45	0.61	0.55
M	0.085	0.18	0.11
α	0°	8°	—
All Dimensions in mm			

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			

SC70-6 (SOT363)

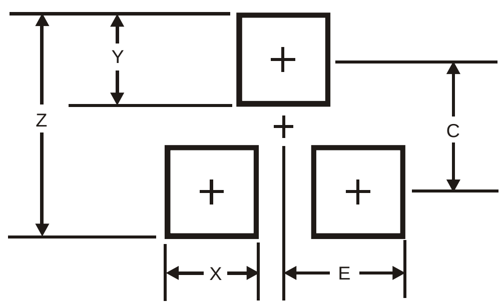


SC70-6 (SOT363)			
Dim	**Min**	**Max**	**Typ**
A	0.10	0.30	0.25
B	1.15	1.35	1.30
C	2.00	2.20	2.10
D	0.65 Typ		
F	0.40	0.45	0.425
H	1.80	2.20	2.15
J	0	0.10	0.05
K	0.90	1.00	1.00
L	0.25	0.40	0.30
M	0.10	0.22	0.11
α	0°	8°	-
All Dimensions in mm			

Suggested Pad Layout

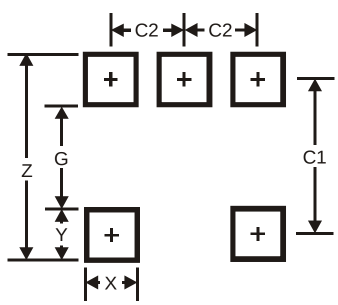
Please see AP02001 at http://www.diodes.com/datasheets/ap02001.pdf for the latest version.

SOT23



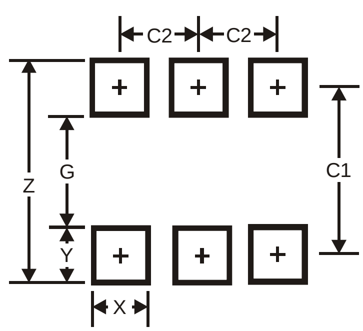
Dimensions	Value (in mm)
Z	2.9
X	0.8
Y	0.9
C	2.0
E	1.35

SOT25



Dimensions	Value (in mm)
Z	3.20
G	1.60
X	0.55
Y	0.80
C1	2.40
C2	0.95

SC70-6 (SOT363)



Dimensions	Value (in mm)
Z	2.5
G	1.3
X	0.42
Y	0.6
C1	1.9
C2	0.65

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