SEMICONDUCTORS

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.

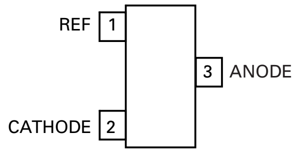
Features

- Low Voltage Operation .... V_{REF} = 1.24V
- Temperature range -40 to 125°C
- Reference Voltage Tolerance at 25°C
  - 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

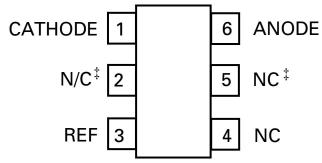
Applications

- Opto-coupler linearisation
- Linear regulators
- Improved Zener
- Variable reference

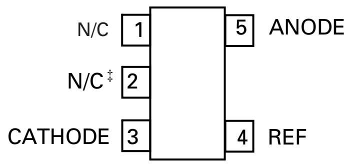
TLV431_F (SOT23)



TLV431_H6 (SC70-6)



TLV431_E5 (SOT23-5)



‡ Connected internally to substrate; should be left floating or connected to anode

Order Information

TOL	Order code	Pack	Part mark	Status	Reel Size (inches)	Tape width (mm)	Quantity per reel
1%	TLV431AE5TA	SOT23-5	V1A	Active	7	8	3000
	TLV431AFTA	SOT23	V1A	Active	7	8	3000
	TLV431AH6TA	SC70-6	V1A	Active	7	8	3000
0.5%	TLV431BE5TA	SOT23-5	V1B	Active	7	8	3000
	TLV431BFTA	SOT23	V1B	Active	7	8	3000
	TLV431BH6TA	SC70-6	V1B	Active	7	8	3000

Absolute Maximum Ratings

Cathode Voltage (V_{KA}) 20V

Continuous Cathode Current (I_{KA}) .... -20 to 20mA

Reference input current range (I_{REF})............................. -0.050 mA to 3mA

Operating Junction Temperature.. -40 to 150°C

Storage Temperature .... -55 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.

Package Thermal Data

Package	θ_{JA}	P_{DIS} T_A =25°C, T_J = 150°C
SOT23	380°C/W	330 mW
SOT23-5	250°C/W	500 mW
SC70-6	380°C/W	330mW

Recommended Operating Conditions

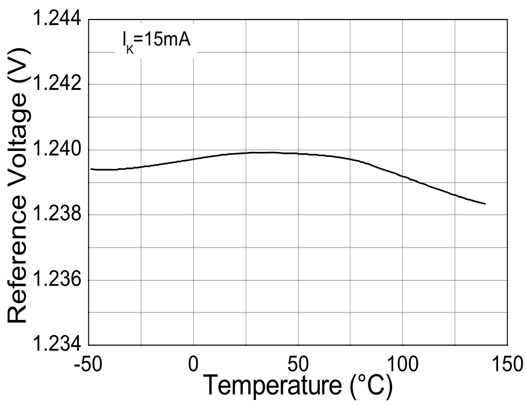
		Min	Max	Units
V_{KA}	Cathode Voltage	V_{REF}	18	V
I_{KA}	Cathode Current	0.1	15	mA
T_A	Operating Ambient temperature range	-40	125	°C

Electrical Characteristics

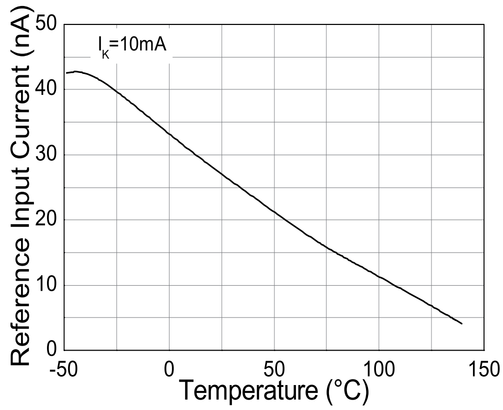
Electrical characteristics over recommended operating conditions, I_{KA} = 10mA, T_A = 25°C, unless otherwise stated.

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	
		$V_{KA} = V_{REF}$ T_A = 0 to 70°C	TLV431A	1.221		1.259	
			TLV431B	1.227		1.253	
		$V_{KA} = V_{REF}$ T_A = -40 to 85°C	TLV431A	1.215		1.265	
			TLV431B	1.224		1.259	
		$V_{KA} = V_{REF}$ T_A = -40 to 125°C	TLV431A	1.209		1.271	
			TLV431B	1.221		1.265	
$V_{REF(dev)}$	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	
ΔV_{REF} ΔV_{KA}	Ratio of change in reference voltage to the change in cathode voltage	V_{KA} from 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

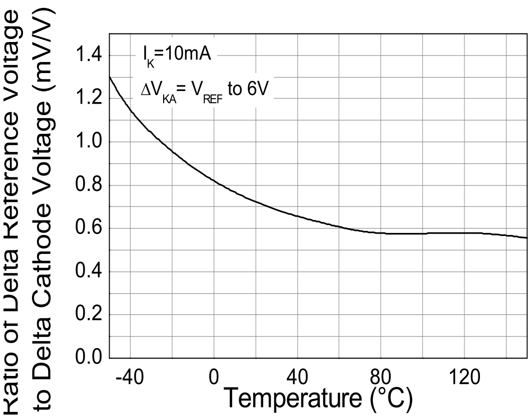
Typical Characteristics



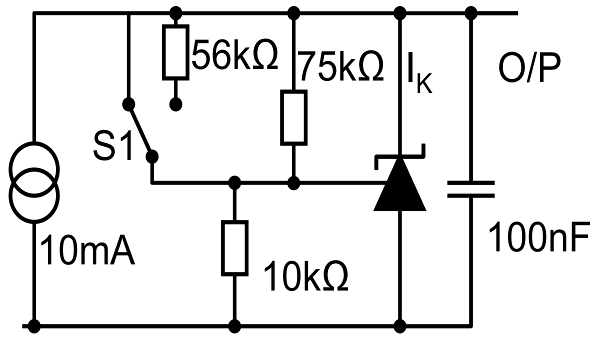
Reference Voltage vs Temperature



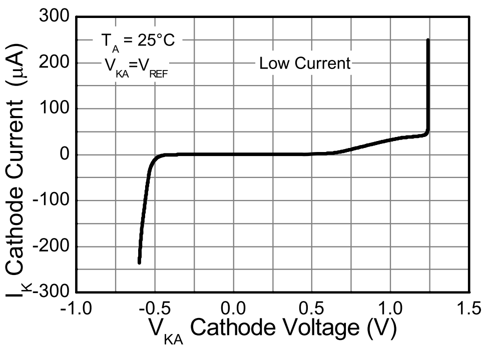
Reference Input Current vs Temperature



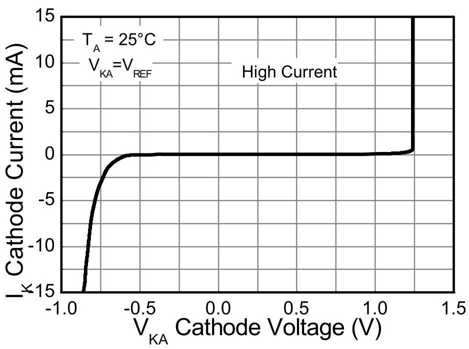
Ratio of Delta Reference Voltage to Delta Cathode Voltage vs Temperature



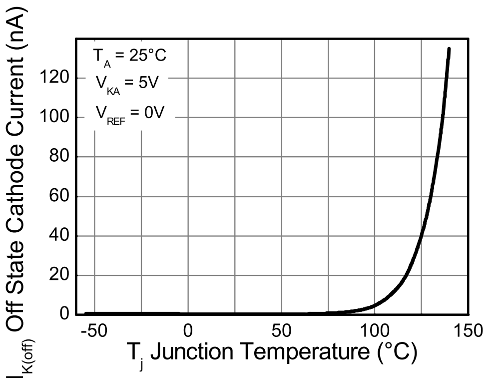
Typical Characteristics



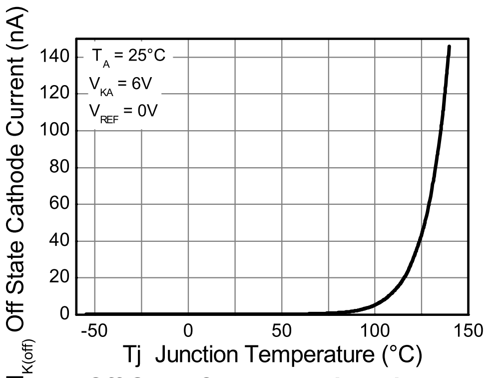
Cathode Current vs Voltage



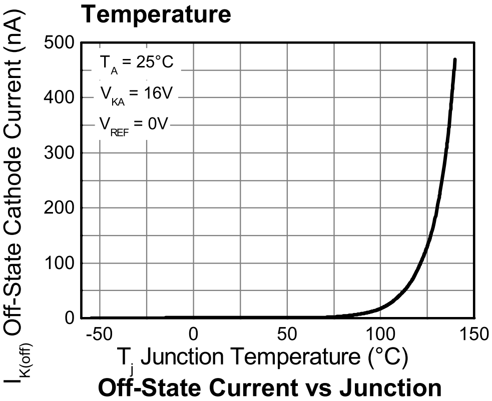
Cathode Current vs Voltage



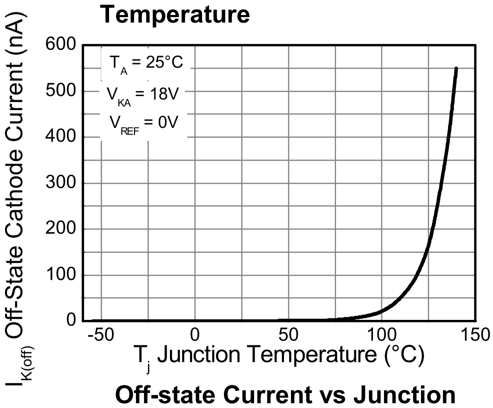
Off-State Current vs Junction Temperature



Off-State Current vs Junction Temperature

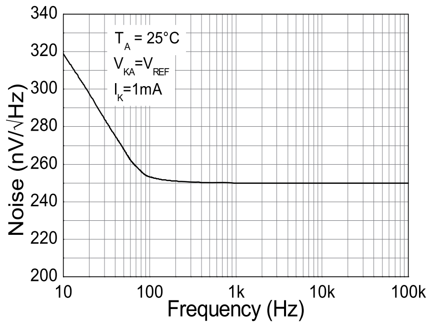


Off-State Current vs Junction Temperature

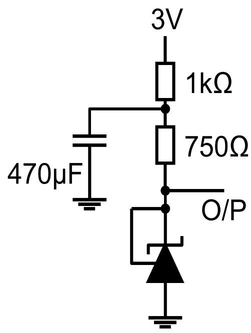


Off-state Current vs Junction Temperature

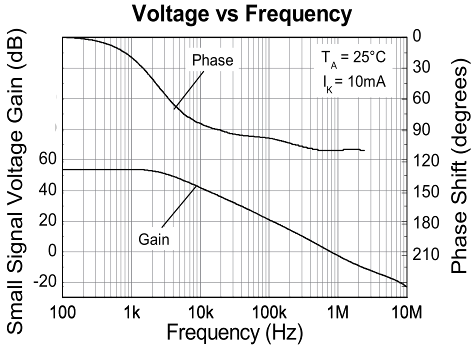
Typical Characteristics



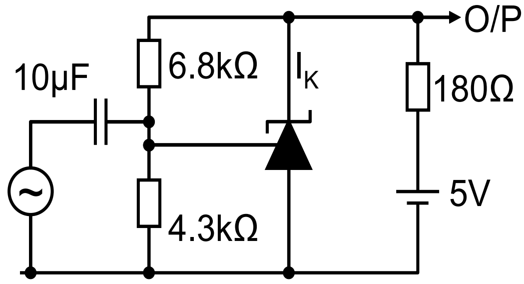
Equivalent Input Noise

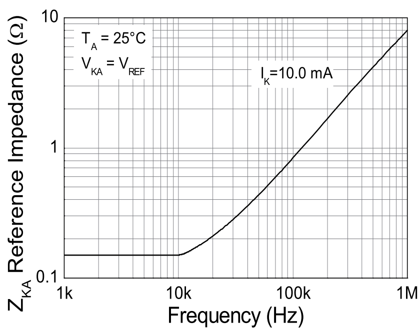


Voltage vs Frequency

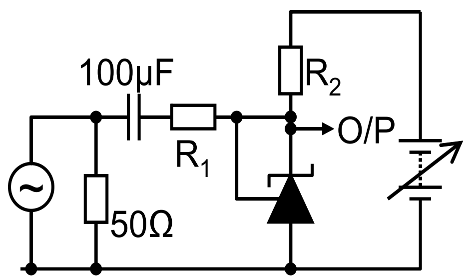


Phase Shift and Gain vs Frequency



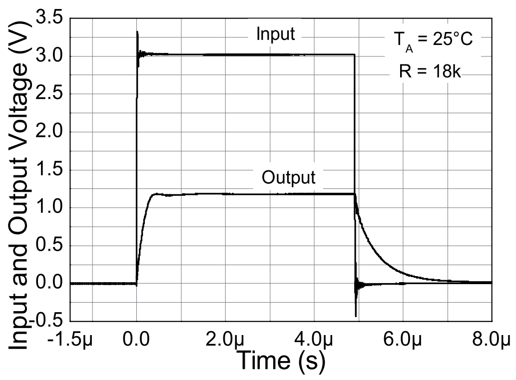


Reference Impedance vs Frequency

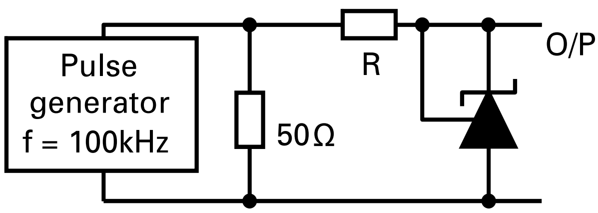


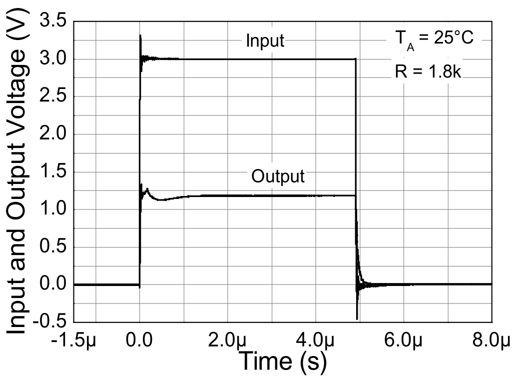
I_K	0.1mA	1-15mA
R1	1kΩ	100Ω
R2	1kΩ	100Ω

Typical Characteristics

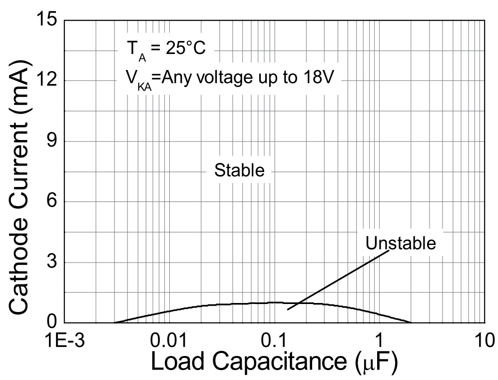


Pulse Response

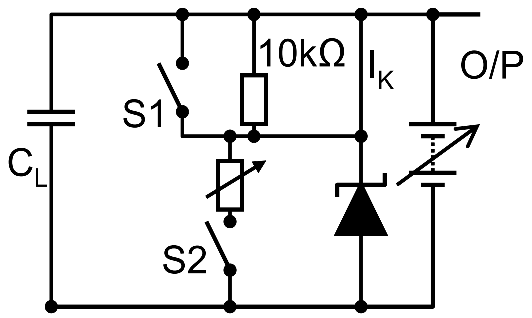




Pulse Response

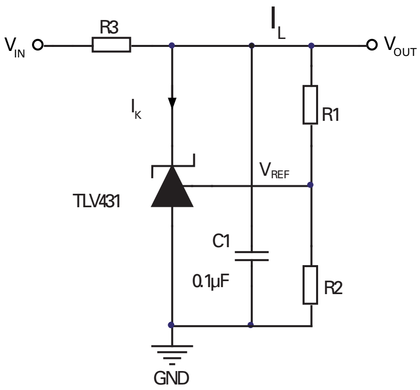


Stability Boundary Condition



Application information

In a conventional shunt regulator application (*Figure 1*), an external series resistor (R_S) is connected between the supply voltage 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}.



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

where

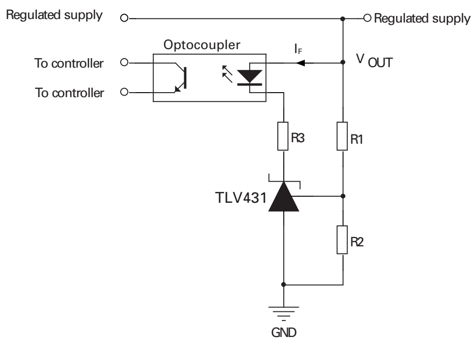
$$V_{KA} = V_{REF} \times \left(1 + \frac{R_1}{R_2}\right)$$

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

Figure 1. Basic shunt regulator

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.



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

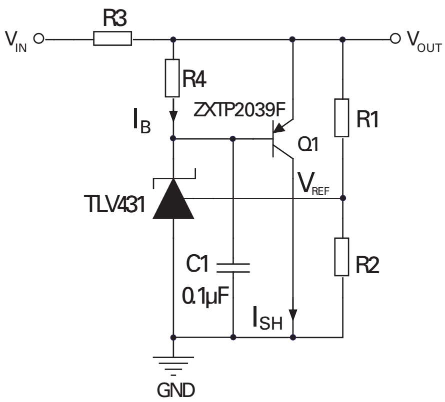
$$\frac{V_{OUT} - 2.7}{I_{F(min)}} > R3 \geq \frac{V_{OUT(max)} - 2.7}{15mA}$$

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

Printed circuit board layout considerations

The TLV431 in the SOT23-5 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 SOT23-5 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 TLV431



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

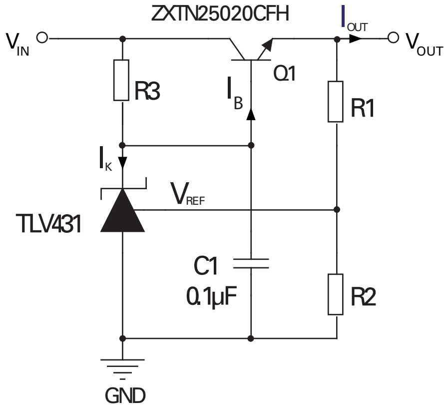
$$R3 = \frac{V_{IN} - (V_{OUT} + V_{BE})}{I_B}$$

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

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



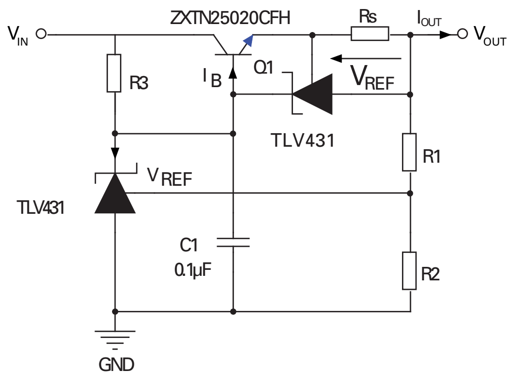
$$V_{OUT} = V_{REF}\left(1 + \frac{R1}{R2}\right)$$

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

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

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 2 above.



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

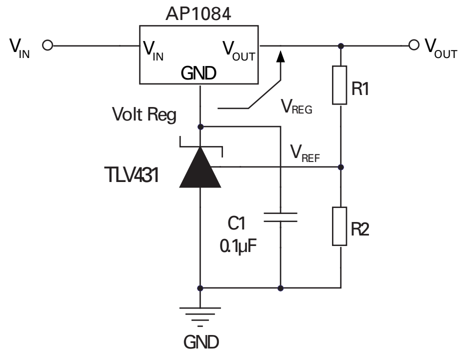
$$R3 = \frac{V_{IN} - (V_{OUT} + V_{BE})}{I_B + I_K}$$

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

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

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.



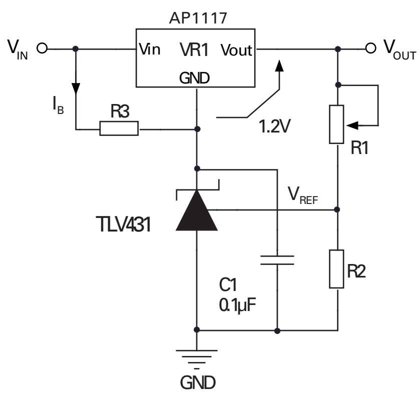
$$V_{OUT} = V_{REF}\left(1 + \frac{R1}{R2}\right)$$

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

(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.



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

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

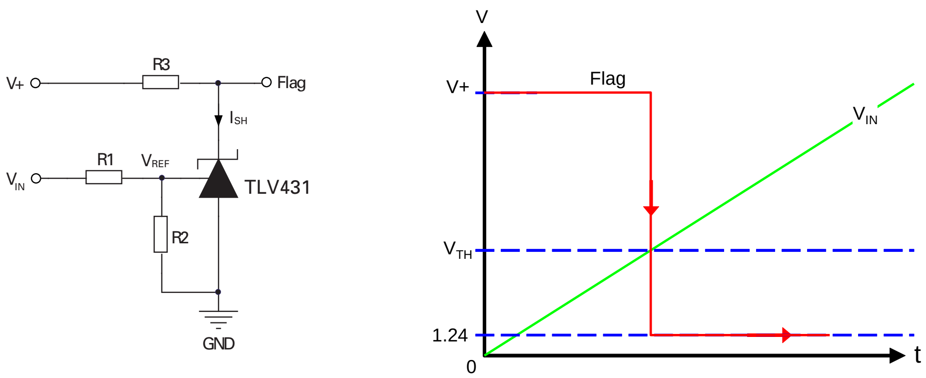
$$R3 = \frac{V_{IN} - (V_{OUT} - V_{REG})}{I_B}$$

$$0.1mA \leq I_B \leq 15mA$$

(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.



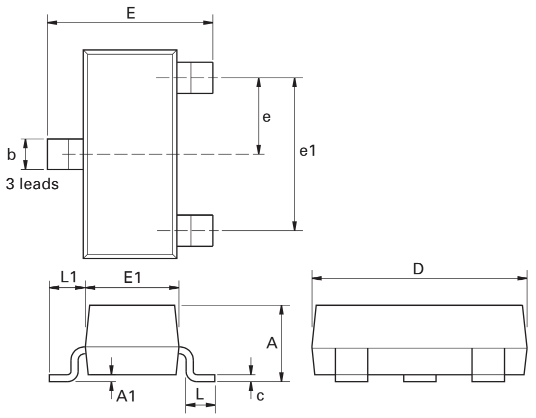
$$V_{TH} = V_{REF}\left(1 + \frac{R1}{R2}\right) \qquad R3 = \frac{V^{+} - 1.24}{I_{SH}} \qquad 0.1mA \le I_{SH} \le 18mA$$

Figure 8. Using the TLV431 as a level detector

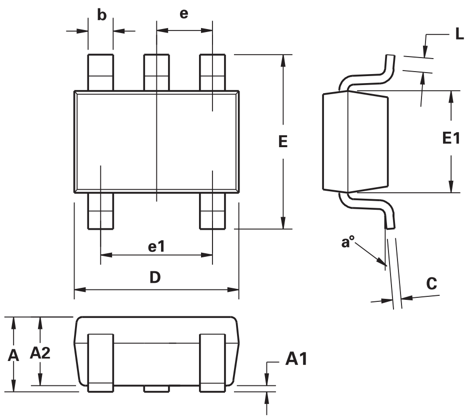
In its open loop state, the TLV431 is analogous to a line-powered comparator with its non-inverting input internally connected to a 1.24V reference voltage. This means the remaining inverting input can be used for comparator functions.

Figure 8 above shows the TLV431 being used as a level comparator. Its output (Flag) is normally high and goes low when the input reaches or exceeds the threshold (V_{TH}) determined by R1 and R2.

Package Outline - SOT23



SOT23-5



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		-	-	-	-	-

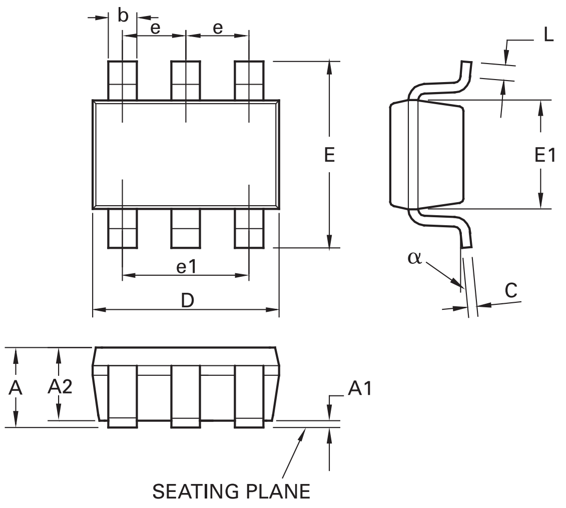
Note: Controlling dimensions are in millimeters. Approximate dimensions are provided in inches

Dimension table - SOT23-5

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 - 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		a°	0	8	0	8

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

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Definitions

Product change

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"Last time buy (LTB)"	Device will be discontinued and last time buy period and delivery is in effect
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"Obsolete"	Production has been discontinued

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