Adjustable Precision Shunt Regulator

1. Description

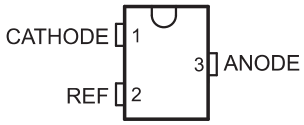
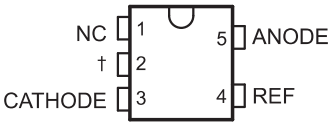
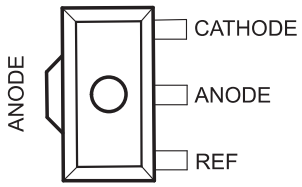
The TL431 and TL432 are three terminal adjustable shunt regulators offering excellent temperature stability and output current handling capability up to 100mA. The output voltage may be set to any chosen voltage between 2.5 and 36 volts by selection of two external divider resistors.

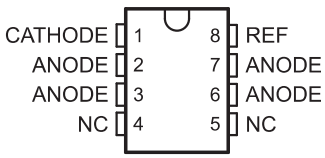
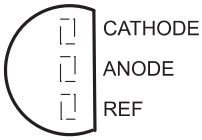
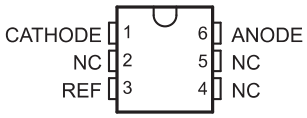
Both the TL431 and TL432 devices are offered in three grades, with initial tolerances (at 25°C) of 0.5%, 1%, and 2%, for the B, A, and standard grade, respectively. In addition, low output drift versus temperature ensures good stability over the entire temperature range.

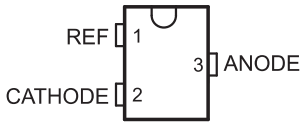
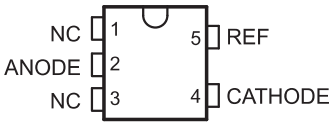
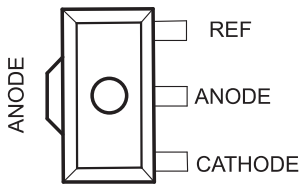
2. Features

- Temperature range -40 to +125ºC
- Low Output Noise
- 0.2Ω Typical Output Impedance
- Sink Current Capability: 1mA to 100mA
- Adjustable Output Voltage: V_{REF} to 36V
- Reference Voltage Tolerance at 25°C
  - TL431A: ± 1.0%
  - TL431B: ± 0.5%
  - TL431: ± 2%

3. Pin Configuration

TL431/SOT23-3	TL431/SOT23-5	TL431/SOT-89
		

TL431/SOIC-8	TL431/TO-92	TL431/SC70-6
		

TL432/SOT23-3	TL432/SOT23-5	TL432/SOT-89
		

4. Pin Configuration and Functions

Table 1. TL431 Pin Functions

PIN							TYPE	DESCRIPTION
NAME	SOT23-3	SOT23-5	SOT-89	SOP8	TO-92	SC70-6		
CATHODE	1	3	3	1	1	1	I/O	Shunt Current/Voltage input
REF	2	4	1	8	3	3	I	Threshold relative to common anode
ANODE	3	5	2	2, 3, 6, 7	2	6	O	Common pin, normally connected to ground

Table 2. TL432 Pin Functions

PIN				TYPE	DESCRIPTION
NAME	SOT23-3	SOT23-5	SOT-89		
CATHODE	2	4	1	I/O	Shunt Current/Voltage input
REF	1	5	3	I	Threshold relative to common anode
ANODE	3	2	2	O	Common pin, normally connected to ground

5. Ordering Information

DEVICE	Package Type	Packing	Packing Qty
TL431CM3	SOT23-3	Tape & Reel	3000pcs/reel
TL431ACM3	SOT23-3	Tape & Reel	3000pcs/reel
TL431BCM3	SOT23-3	Tape & Reel	3000pcs/reel
TL431CM5	SOT23-5	Tape & Reel	3000pcs/reel
TL431ACM5	SOT23-5	Tape & Reel	3000pcs/reel
TL431BCM5	SOT23-5	Tape & Reel	3000pcs/reel
TL431CZ	TO-92	BAG	1000pcs/box
TL431ACZ	TO-92	BAG	1000pcs/box
TL431BCZ	TO-92	BAG	1000pcs/box
TL431CMK	SOT89-3	Tape & Reel	1000pcs/reel
TL431ACMK	SOT89-3	Tape & Reel	1000pcs/reel
TL431BCMK	SOT89-3	Tape & Reel	1000pcs/reel
TL431CM	SOIC-8	Tape & Reel	2500pcs/reel
TL431ACM	SOIC-8	Tape & Reel	2500pcs/reel
TL431BCM	SOIC-8	Tape & Reel	2500pcs/reel
TL431ACM7	SC70-6	Tape & Reel	3000pcs/reel
TL431BCM7	SC70-6	Tape & Reel	3000pcs/reel
TL432CM3	SOT23-3	Tape & Reel	3000pcs/reel
TL432ACM3	SOT23-3	Tape & Reel	3000pcs/reel
TL432BCM3	SOT23-3	Tape & Reel	3000pcs/reel
TL432CMK	SOT89-3	Tape & Reel	1000pcs/reel
TL432BCMK	SOT89-3	Tape & Reel	1000pcs/reel
TL432CM5	SOT23-5	Tape & Reel	3000pcs/reel

TL432ACM5	SOT23-5	Tape & Reel	3000pcs/reel
TL432BCM5	SOT23-5	Tape & Reel	3000pcs/reel
TL431IM3	SOT23-3	Tape & Reel	3000pcs/reel
TL431AIM3	SOT23-3	Tape & Reel	3000pcs/reel
TL431BIM3	SOT23-3	Tape & Reel	3000pcs/reel
TL431IM5	SOT23-5	Tape & Reel	3000pcs/reel
TL431AIM5	SOT23-5	Tape & Reel	3000pcs/reel
TL431BIM5	SOT23-5	Tape & Reel	3000pcs/reel
TL431IZ	TO-92	BAG	1000pcs/box
TL431AIZ	TO-92	BAG	1000pcs/box
TL431BIZ	TO-92	BAG	1000pcs/box
TL431IMK	SOT89-3	Tape & Reel	1000pcs/reel
TL431AIMK	SOT89-3	Tape & Reel	1000pcs/reel
TL431BIMK	SOT89-3	Tape & Reel	1000pcs/reel
TL431IM	SOIC-8	Tape & Reel	2500pcs/reel
TL431AIM	SOIC-8	Tape & Reel	2500pcs/reel
TL431BIM	SOIC-8	Tape & Reel	2500pcs/reel
TL431AIM7	SC70-6	Tape & Reel	3000pcs/reel
TL431BIM7	SC70-6	Tape & Reel	3000pcs/reel
TL432IM3	SOT23-3	Tape & Reel	3000pcs/reel
TL432AIM3	SOT23-3	Tape & Reel	3000pcs/reel
TL432BIM3	SOT23-3	Tape & Reel	3000pcs/reel
TL432IMK	SOT89-3	Tape & Reel	1000pcs/reel
TL432AIMK	SOT89-3	Tape & Reel	1000pcs/reel
TL432BIMK	SOT89-3	Tape & Reel	1000pcs/reel
TL432IM5	SOT23-5	Tape & Reel	3000pcs/reel
TL432AIM5	SOT23-5	Tape & Reel	3000pcs/reel

Design Requirements

Table 3. Design Parameters

DESIGN PARAMETER	EXAMPLE VALUE
Input Voltage Range	0 V to 5 V
Input Resistance	10 kΩ
Supply Voltage	24 V
Cathode Current (Ik)	5 mA
Output Voltage Level	~2 V – V_{SUP}
Logic Input Thresholds VIH/VIL	V_L

6. Absolute Maximum Ratings

		MIN	MAX	UNIT
V_{KA}	Cathode voltage(2)	37		V
I_{KA}	Continuous cathode current range	–100	150	mA
$I_{I(ref)}$	Reference input current range	–0.05	10	mA
T_J	Operating virtual junction temperature	150		°C
T_{stg}	Storage temperature range	–65	150	°C

7. Thermal Information

THERMAL METRIC		TL43xx									UNIT
		8 PINS				6 PINS	5 PINS	3 PINS			
$R_{\theta JA}$	Junction-to-ambient thermal resistance	85	149	97	95	259	206	206	140	52	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	57	65	39	46	87	131	76	55	9	

8. Recommended Operating Conditions

			MIN	MAX	UNIT
V_{KA}	Cathode voltage		V_{ref}	36	V
I_{KA}	Cathode current		1	100	mA
T_A	Operating free-air temperature	TL43xxC	0	70	°C
		TL43xxI	–40	85	

Note: Maximum power dissipation is a function of $T_{J(max)}$, θ_{JA}, and T_A. The maximum allowable power dissipation at any allowable ambient temperature is $P_D = (T_{J(max)} – T_A)/\theta_{JA}$. Operating at the absolute maximum T_J of 150°C can affect reliability.

9. Electrical Characteristics

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

TL431C, TL432C

PARAMETER		TEST CONDITIONS		TL431C, TL432C			UNIT
				MIN	TYP	MAX	
V_{ref}	Reference voltage	V_{KA} = V_{ref}, I_{KA} = 10 mA		2440	2495	2550	mV
$V_{I(dev)}$	Deviation of reference input voltage over full temperature range(1)	V_{KA} = V_{ref}, I_{KA}=10mA,	SOT23-3 and TL432 devices		6	16	mV
			All other devices		4	25	
$\frac{\Delta V_{ref}}{\Delta V_{KA}}$	Ratio of change in reference voltage to the change in cathode voltage	I_{KA} = 10mA	ΔV_{KA} = 10V – V_{ref}		–1.4	–2.7	mV/V
			ΔV_{KA} = 36V – 10 V		–1	–2	
I_{ref}	Reference input current	I_{KA} = 10 mA, R1 = 10kΩ, R2 = ∞			2	4	μA
$I_{I(dev)}$	Deviation of reference input current over full temperature range(1)	I_{KA} = 10 mA, R1 = 10kΩ, R2 = ∞			0.4	1.2	μA
I_{min}	Minimum cathode current for regulation	V_{KA} = V_{ref}		0.4	1		mA
I_{off}	Off-state cathode current	V_{KA} = 36V, V_{ref} = 0		0.1	1		μA
|zKA|	Dynamic impedance(2)	V_{KA} = V_{ref}, f ≤ 1 kHz, I_{KA} = 1 mA to 100 mA			0.2	0.5	Ω

TL431I, TL432I

PARAMETER		TEST CONDITIONS		TL431I, TL432I			UNIT
				MIN	TYP	MAX	
V_{ref}	Reference voltage	V_{KA} = V_{ref}, I_{KA} = 10 mA		2440	2495	2550	mV
$V_{I(dev)}$	Deviation of reference input voltage over full temperature range(1)	V_{KA} = V_{ref}, I_{KA}=10mA,	SOT23-3 and TL432 devices		14	34	mV
			All other devices		5	50	
$\frac{\Delta V_{ref}}{\Delta V_{KA}}$	Ratio of change in reference voltage to the change in cathode voltage	I_{KA} = 10 mA	ΔV_{KA} = 10V – V_{ref}		–1.4	–2.7	mV/V
			ΔV_{KA} = 36V – 10V		–1	–2	
I_{ref}	Reference input current	I_{KA} = 10 mA, R1 = 10 kΩ, R2 = ∞			2	4	μA
$I_{I(dev)}$	Deviation of reference input current over full temperature range(1)	I_{KA} = 10 mA, R1 = 10 kΩ, R2 = ∞			0.8	2.5	μA
I_{min}	Minimum cathode current for regulation	V_{KA} = V_{ref}		0.4	1		mA
I_{off}	Off-state cathode current	V_{KA} = 36 V, V_{ref} = 0		0.1	1		μA
|zKA|	Dynamic impedance(2)	V_{KA} = V_{ref}, f ≤ 1kHz, I_{KA} = 1mA to 100mA			0.2	0.5	Ω

TL431AC, TL432AC

PARAMETER		TEST CONDITIONS		TL431AC, TL432AC			UNIT
				MIN	TYP	MAX	
V_{ref}	Reference voltage	V_{KA} = V_{ref}, I_{KA} = 10 mA		2470	2495	2520	mV
$V_{I(dev)}$	Deviation of reference input voltage over full temperature range(1)	V_{KA} = V_{ref}, I_{KA}=10mA,	SOT23-3 and TL432 devices		6	16	mV
			All other devices		4	25	
$\frac{\Delta V_{ref}}{\Delta V_{KA}}$	Ratio of change in reference voltage to the change in cathode voltage	I_{KA} = 10 mA	ΔV_{KA} = 10V –V_{ref}		–1.4	–2.7	mV/V
			ΔV_{KA} = 36V –10V		–1	–2	
I_{ref}	Reference input current	I_{KA} = 10 mA, R1 = 10 kΩ, R2 = ∞			2	4	μA
$I_{I(dev)}$	Deviation of reference input current over full temperature range(1)	I_{KA} = 10 mA, R1 = 10 kΩ, R2 = ∞			0.8	1.2	μA
I_{min}	Minimum cathode current for regulation	V_{KA} = V_{ref}			0.4	0.6	mA
I_{off}	Off-state cathode current	V_{KA} = 36 V, V_{ref} = 0			0.1	0.5	μA
|zKA|	Dynamic impedance(2)	V_{KA} = V_{ref}, f ≤ 1kHz, I_{KA} = 1mA to 100mA			0.2	0.5	Ω

TL431AI, TL432AI

PARAMETER		TEST CONDITIONS		TL431AI, TL432AI			UNIT
				MIN	TYP	MAX	
V_{ref}	Reference voltage	V_{KA} = V_{ref}, I_{KA} = 10 mA		2470	2495	2520	mV
$V_{I(dev)}$	Deviation of reference input voltage over full temperature range(1)	V_{KA} = V_{ref}, I_{KA}=10mA,	SOT23-3 and TL432 devices		14	34	mV
			All other devices		5	50	
$\frac{\Delta V_{ref}}{\Delta V_{KA}}$	Ratio of change in reference voltage to the change in cathode voltage	I_{KA} = 10mA	ΔV_{KA} = 10V–V_{ref}		–1.4	–2.7	mV/V
			ΔV_{KA} = 36V –10V		–1	–2	
I_{ref}	Reference input current	I_{KA} = 10mA, R1 = 10kΩ, R2 = ∞			2	4	μA
$I_{I(dev)}$	Deviation of reference input current over full temperature range(1)	I_{KA} = 10 mA, R1 = 10 kΩ, R2 = ∞			0.8	2.5	μA
I_{min}	Minimum cathode current for regulation	V_{KA} = V_{ref}			0.4	0.7	mA
I_{off}	Off-state cathode current	V_{KA} = 36V, V_{ref} =0			0.1	0.5	μA
|zKA|	Dynamic impedance(2)	V_{KA} = V_{ref}, f ≤ 1kHz, I_{KA} = 1mA to 100mA			0.2	0.5	Ω

TL431BC, TL432BC

PARAMETER		TEST CONDITIONS		TL431BC, TL432BC			UNIT
				MIN	TYP	MAX	
V_{ref}	Reference voltage	V_{KA} = V_{ref}, I_{KA} = 10mA		2483	2495	2507	mV
$V_{I(dev)}$	Deviation of reference input voltage over full temperature range(1)	V_{KA} = V_{ref}, I_{KA} = 10mA			6	16	mV
$\frac{\Delta V_{ref}}{\Delta V_{KA}}$	Ratio of change in reference voltage to the change in cathode voltage	I_{KA} = 10 mA	ΔV_{KA} = 10V – V_{ref}		–1.4	–2.7	mV/V
			ΔV_{KA} = 36V –10V		–	–2	
I_{ref}	Reference input current	I_{KA} = 10mA, R1 = 10kΩ, R2 = ∞			2	4	μA
$I_{I(dev)}$	Deviation of reference input current over full temperature range(1)	I_{KA} = 10 mA, R1 = 10 kΩ, R2 = ∞			0.8	1.2	μA
I_{min}	Minimum cathode current for regulation	V_{KA} = V_{ref}			0.4	0.6	mA
I_{off}	Off-state cathode current	V_{KA} = 36 V, V_{ref} = 0			0.1	0.5	μA
$\lvert z_{KA} \rvert$	Dynamic impedance(2)	V_{KA} = V_{ref}, f ≤ 1kHz, I_{KA} = 1mA to 100mA			0.2	0.5	Ω

TL431BI, TL432BI

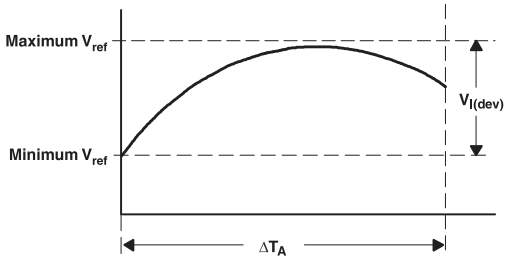
PARAMETER		TEST CONDITIONS		TL431BI, TL432BI			UNIT
				MIN	TYP	MAX	
V_{ref}	Reference voltage	V_{KA} = V_{ref}, I_{KA} = 10mA		2483	2495	2507	mV
$V_{I(dev)}$	Deviation of reference input voltage over full temperature range(1)	V_{KA} = V_{ref}, I_{KA} = 10mA			14	34	mV
$\frac{\Delta V_{ref}}{\Delta V_{KA}}$	Ratio of change in reference voltage to the change in cathode voltage	I_{KA} = 10 mA	ΔV_{KA} = 10V – V_{ref}		–1.4	–2.7	mV/V
			ΔV_{KA} = 36V – 10V		–1	–2	
I_{ref}	Reference input current	I_{KA} = 10mA, R1 = 10kΩ, R2 = ∞			2	4	μA
$I_{I(dev)}$	Deviation of reference input current over full temperature range(1)	I_{KA} = 10mA, R1 = 10kΩ, R2 = ∞			0.8	2.5	μA
I_{min}	Minimum cathode current for regulation	V_{KA} = V_{ref}			0.4	0.7	mA
I_{off}	Off-state cathode current	V_{KA} = 36V, V_{ref} = 0			0.1	0.5	μA
$\lvert z_{KA} \rvert$	Dynamic impedance(2)	V_{KA} = V_{ref}, f ≤ 1kHz, I_{KA} = 1mA to 100mA			0.2	0.5	Ω

(1) The deviation parameters $V_{ref(dev)}$ and $I_{ref(dev)}$ are defined as the differences between the maximum and minimum values obtained over the rated temperature range. The average full-range temperature coefficient of the reference input voltage α_{Vref} is defined as:

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

ΔT_A is the rated operating temperature range of the device.

where:



α_{Vref} is positive or negative, depending on whether minimum V_{ref} or maximum V_{ref}, respectively, occurs at the lower temperature.

(2) The dynamic impedance is defined as: $|Z_{KA}|=\frac{\Delta V_{KA}}{\Delta I_{KA}}$

When the device is operating with two external resistors, the total dynamic impedance of the circuit is given by: $|Z'|=\frac{\Delta V}{\Delta I}$, which is approximately equal to $|Z_{KA}|=\left(1+\frac{R1}{R2}\right)$.

10. Detailed Description

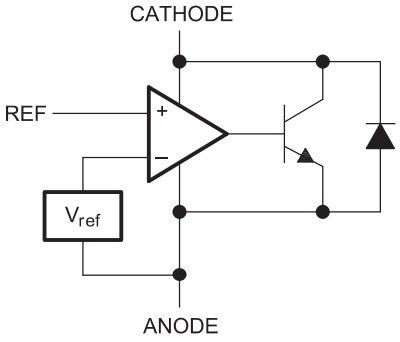
This standard device has proven ubiquity and versatility across a wide range of applications, ranging from power to signal path. This is due to it's key components containing an accurate voltage reference & opamp, which are very fundamental analog building blocks. TL43xx is used in conjunction with it's key components to behave as a single voltage reference, error amplifier, voltage clamp or comparator with integrated reference.

TL43xx can be operated and adjusted to cathode voltages from 2.5V to 36V, making this part optimum for a wide range of end equipments in industrial, auto, telecom & computing. In order for this device to behave as a shunt regulator or error amplifier, >1mA (I_{min}(max)) must be supplied in 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.

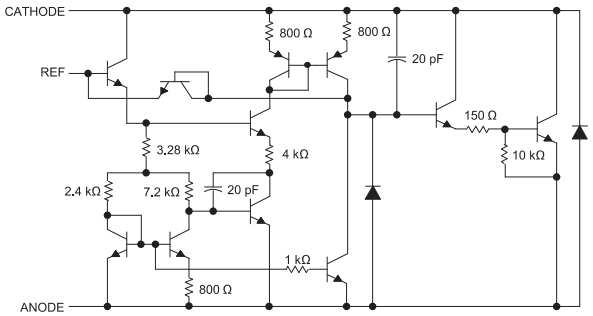
Various reference voltage options can be purchased with initial tolerances (at 25°C) of 0.5%, 1%, and 2%. These reference options are denoted by B (0.5%), A (1.0%) and blank (2.0%) after the TL431 or TL432. TL431 & TL432 are both functionaly, but have separate pinout options.

The TL43xxC devices are characterized for operation from 0°C to 70°C, the TL43xxI devices are characterized for operation from –40°C to 85°C, and the TL43xxQ devices are characterized for operation from –40°C to 125°C.

11. Functional Block Diagram



Equivalent Schematic



Detailed Schematic

12. Typical Characteristics

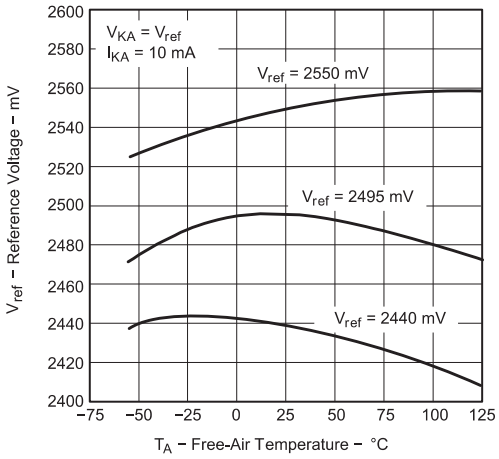


Figure 1. Reference Voltage vs Free-Air Temperature

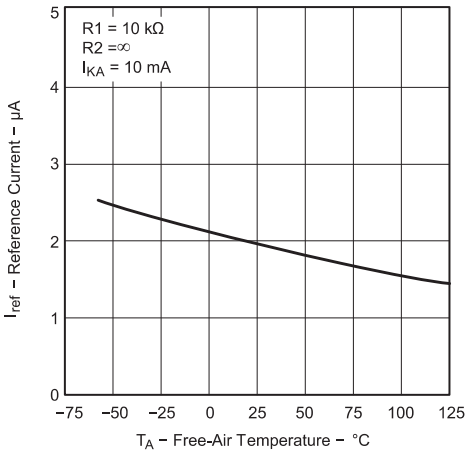


Figure 2. Reference Current vs Free-Air Temperature

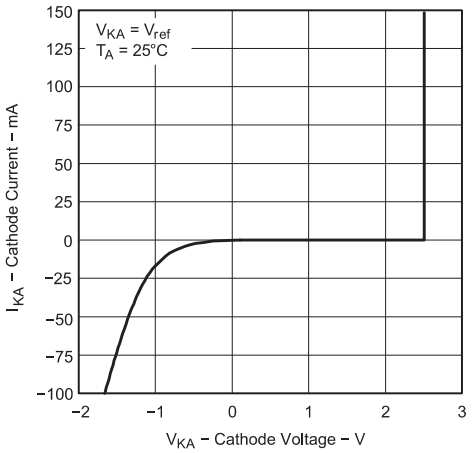


Figure 3. Cathode Current vs Cathode Voltage

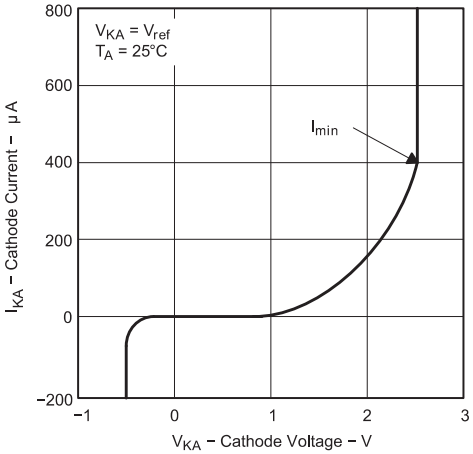


Figure 4. Cathode Current vs Cathode Voltage

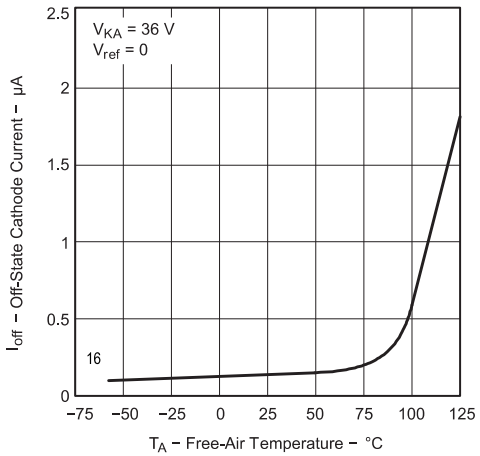


Figure 5. Off-State Cathode Current vs Free-Air Temperature

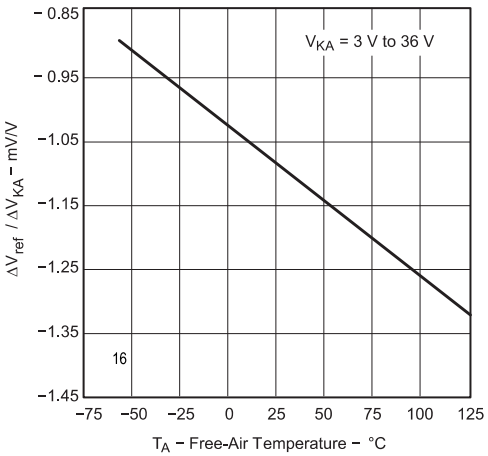


Figure 6. Ratio of Delta Reference Voltage to Delta Cathode Voltage vs Free-Air Temperature

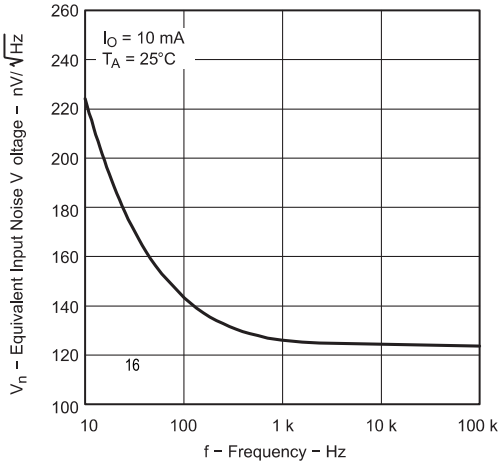


Figure 7. Equivalent Input Noise Voltage vs Frequency

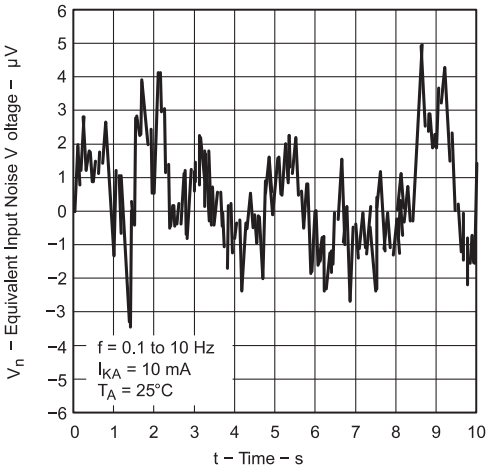


Figure 8. Equivalent Input Noise Voltage Over a 10-S Period

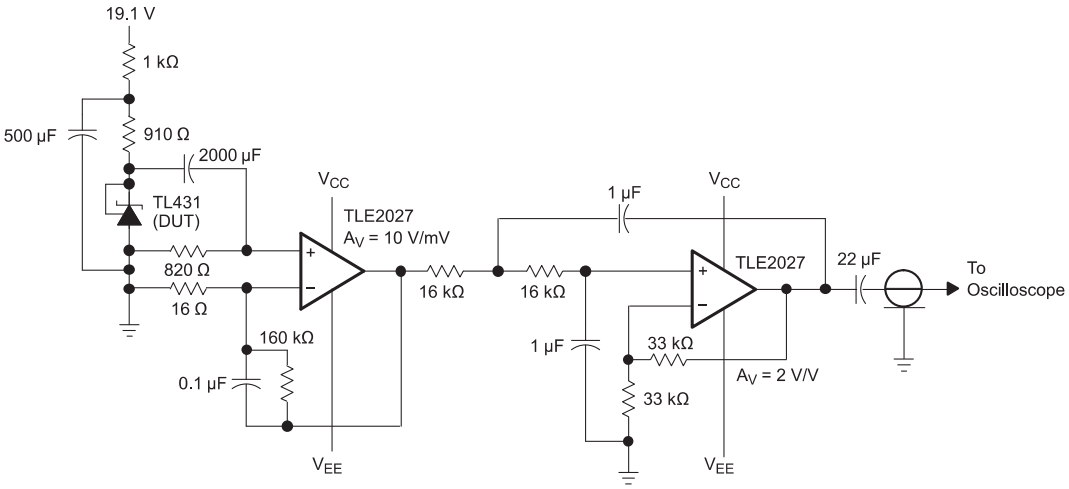


Figure 9. Test Circuit for Equivalent Input Noise Voltage Over a 10-S Period

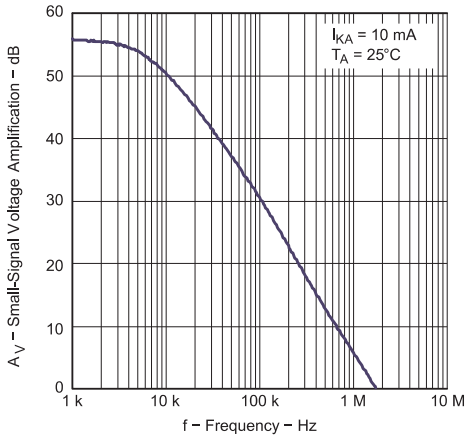


Figure 10. Small-Signal Voltage Amplification vs Frequency

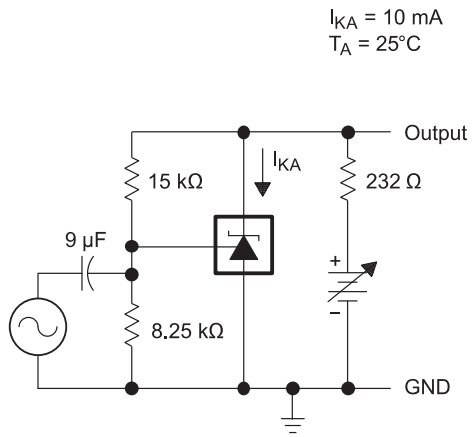
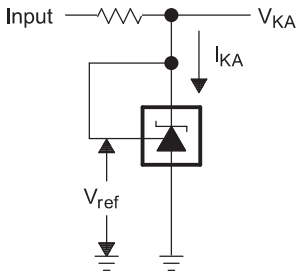


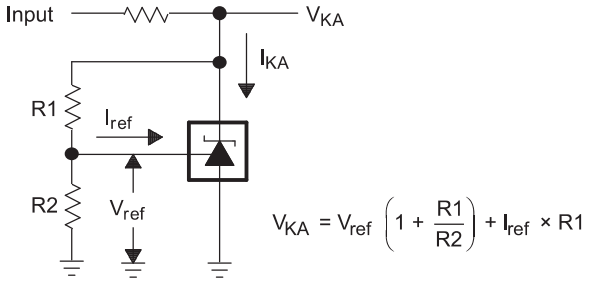
Figure 11. Test Circuit for Voltage Amplification

13. Parameter Measurement Information

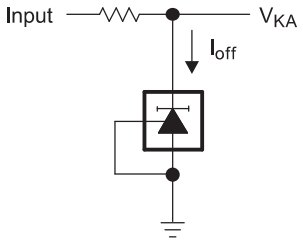
Test Circuit for $V_{KA} = V_{ref}$



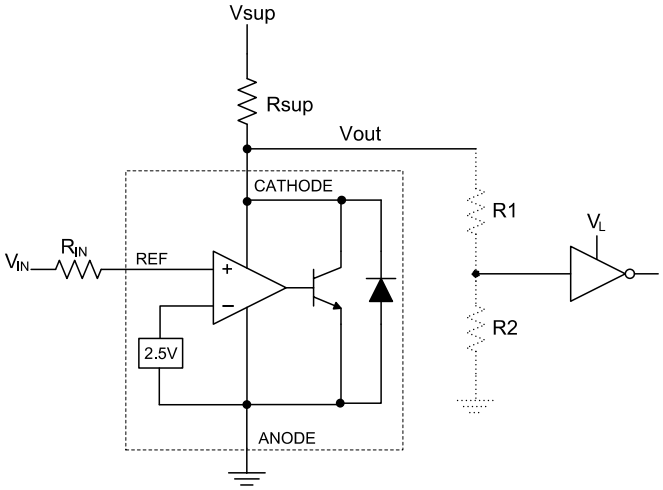
Test Circuit for $V_{KA} > V_{ref}$



Test Circuit for I_{off}



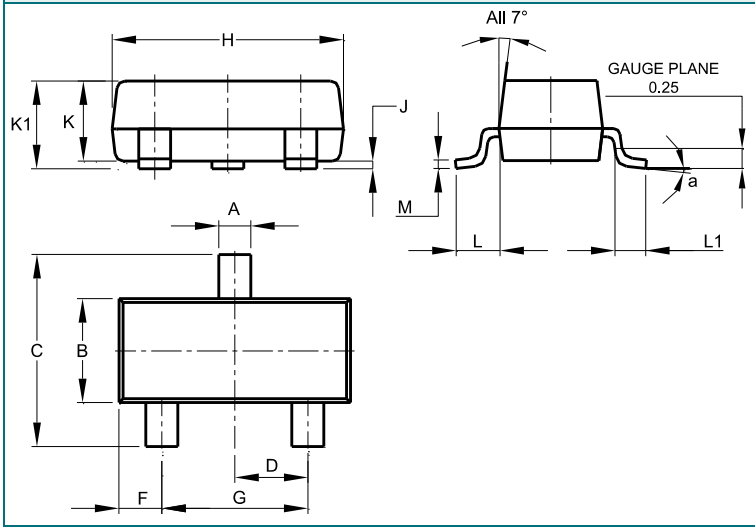
14. Typical Applications



Comparator Application Schematic

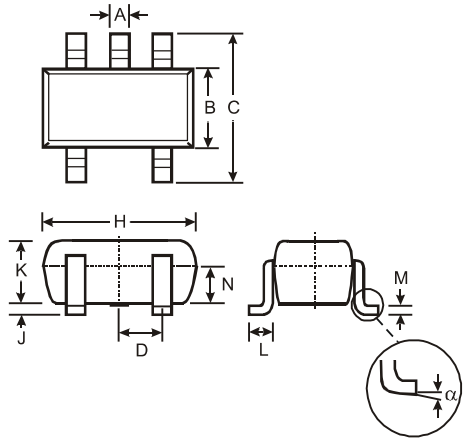
15. Package Outlines

SOT-23-3



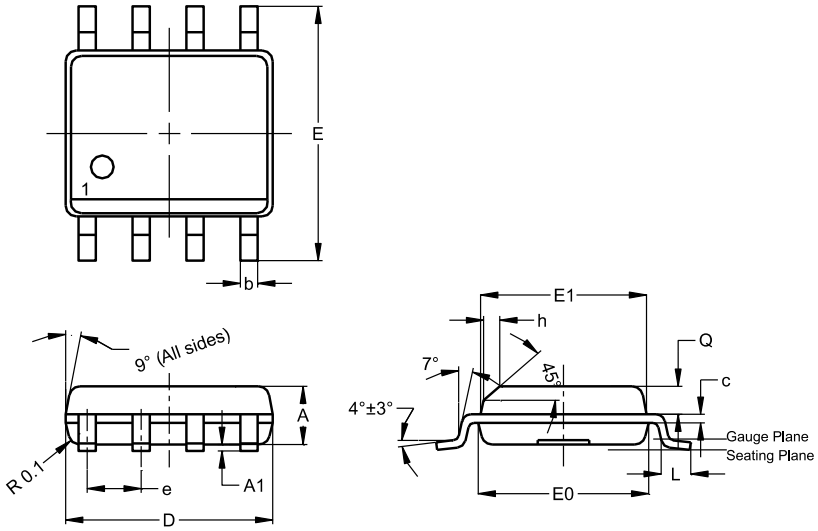
SOT23			
Dim	Min	Max	Typ
A	0.37	0.51	0.40
B	1.20	1.40	1.30
C	2.30	2.50	2.40
D	0.89	1.03	0.915
F	0.45	0.60	0.535
G	1.78	2.05	1.83
H	2.80	3.00	2.90
J	0.013	0.10	0.05
K	0.890	1.00	0.975
K1	0.903	1.10	1.025
L	0.45	0.61	0.55
L1	0.25	0.55	0.40
M	0.085	0.150	0.110
a	0°	8°	--
All Dimensions in mm			

SOT-23-5



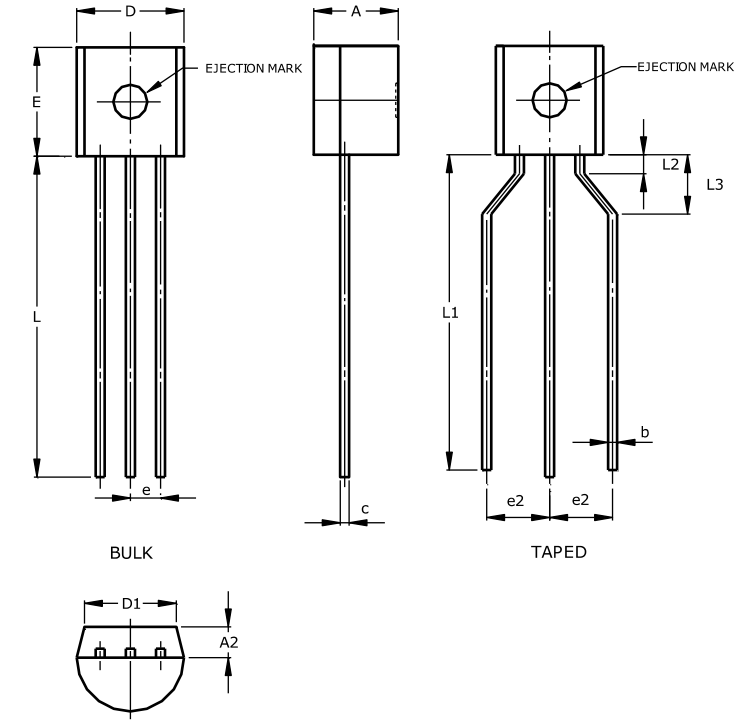
SOT-23-5			
Dim	Min	Max	Typ
A	0.35	0.50	0.38
B	1.50	1.70	1.60
C	2.70	3.00	2.80
D	-	-	0.95
H	2.90	3.10	3.00
J	0.013	0.10	0.05
K	1.00	1.30	1.10
L	0.35	0.55	0.40
M	0.10	0.20	0.15
N	0.70	0.80	0.75
α	0°	8°	-
All Dimensions in mm			

SOIC-8



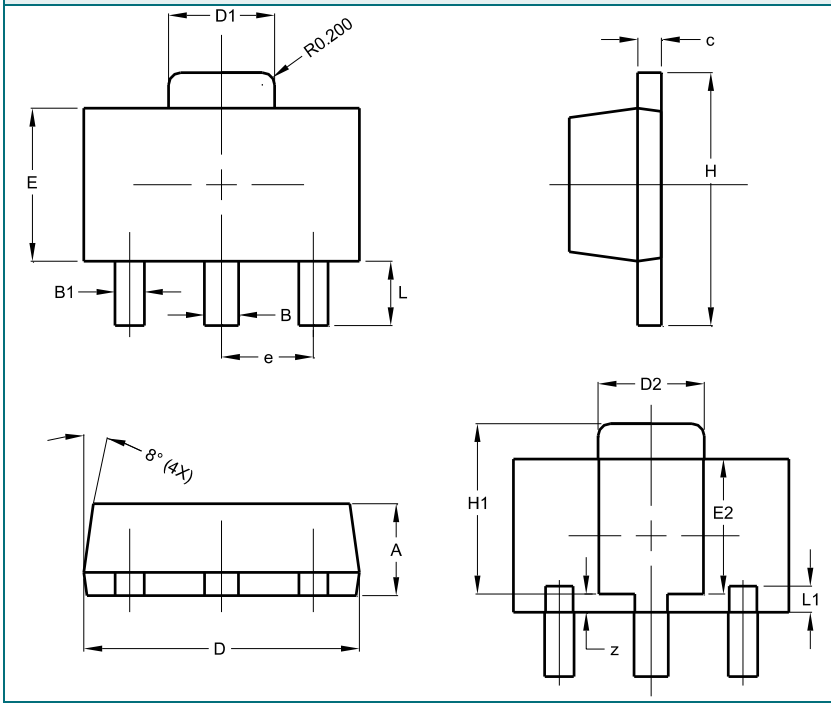
SOIC-8			
Dim	Min	Max	Typ
A	1.40	1.50	1.45
A1	0.10	0.20	0.15
b	0.30	0.50	0.40
c	0.15	0.25	0.20
D	4.85	4.95	4.90
E	5.90	6.10	6.00
E1	3.80	3.90	3.85
E0	3.85	3.95	3.90
e	--	--	1.27
h	-	--	0.35
L	0.62	0.82	0.72
Q	0.60	0.70	0.65
All Dimensions in mm			

TO-92



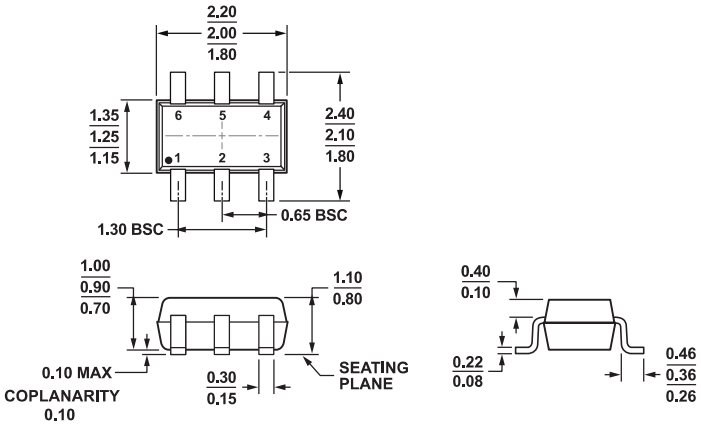
TO92			
Dim	Min	Max	Typ
A	3.45	3.66	-
A2	1.22	1.37	-
b	-	-	0.38
c	-	-	0.38
D	4.27	4.78	-
D1	-	-	3.87
E	4.32	4.83	-
e	-	-	1.27
e2	2.40	2.90	-
L	12.98	15.00	-
L1	12.80	15.00	-
L2	0.80	-	-
L3	2.00	3.00	-
All Dimensions in mm			

SOT-89



SOT89			
Dim	Min	Max	Typ
A	1.40	1.60	1.50
B	0.50	0.62	0.56
B1	0.42	0.54	0.48
c	0.35	0.43	0.38
D	4.40	4.60	4.50
D1	1.62	1.83	1.733
D2	1.61	1.81	1.71
E	2.40	2.60	2.50
E2	2.05	2.35	2.20
e	-	-	1.50
H	3.95	4.25	4.10
H1	2.63	2.93	2.78
L	0.90	1.20	1.05
L1	0.327	0.527	0.427
z	0.20	0.40	0.30
All Dimensions in mm			

SC-70



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