

# DATA SHEET

**TL431C, TL431AC, TL431I,  
TL431AI, LM431AC**  
Adjustable precision shunt regulators

Product data  
Supersedes data of 1997 Feb 25

2002 Jan 22

# Adjustable precision shunt regulators

## TL431C, TL431AC, TL431I, TL431AI, LM431AC

### DESCRIPTION

The TL431 and TL431A are 3-terminal adjustable shunt regulators with specified thermal stability over applicable automotive and commercial temperature ranges. The output voltage may be set to any value between  $V_{REF}$  (approximately 2.5 V) and 36 V with two external resistors (see Figure 4). These devices have a typical output impedance of 0.2  $\Omega$ . Active output circuitry provides a very sharp turn-on characteristic, making these devices excellent replacements for zener diodes in many applications like on-board regulation, adjustable power supplies and switching power supplies.

The TL431C and TL431AC are characterized for operation from 0 °C to +70 °C; the TL431I and TL431AI are characterized for operation from -40 °C to +85 °C.

### FEATURES

- Equivalent full-range temperature coefficient: 30 ppm/°C
- 0.2  $\Omega$  typical output impedance
- Sink current capability: 1 mA to 100 mA
- Low output noise
- Adjustable output voltage:  $V_{REF}$  to 36 V

### PIN CONFIGURATIONS

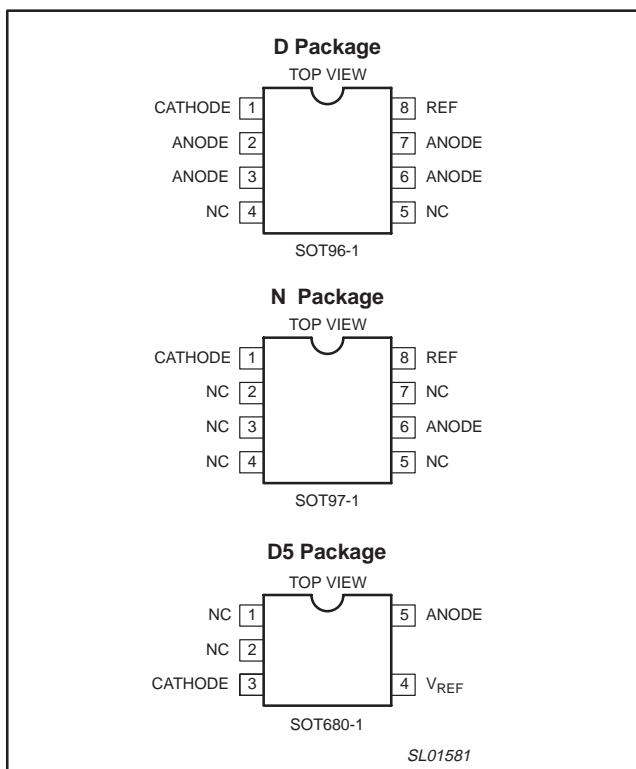


Figure 1. Pin configuration.

### ORDERING INFORMATION

DESCRIPTION	TEMPERATURE RANGE	INDUSTRY STANDARD PART NUMBER	ORDER CODE	DWG #
8-Pin Plastic Small Outline (SO) package	0 °C to +70 °C	TL431CD	TL431CD	SOT96-1
8-Pin Plastic Small Outline (SO) package	-40 °C to +85 °C	TL431ID	TL431ID	SOT96-1
8-Pin Plastic Small Outline (SO) package	0 °C to +70 °C	TL431ACD	TL431ACD	SOT96-1
8-Pin Plastic Small Outline (SO) package	-40 °C to +85 °C	TL431AID	TL431AID	SOT96-1
8-Pin Plastic Small Outline (SO) package	0 °C to +70 °C	LM431ACM	LM431ACMD	SOT96-1
8-Pin Plastic Dual In-Line package (DIP)	0 °C to +70 °C	TL431CP	TL431CPN	SOT97-1
8-Pin Plastic Dual In-Line package (DIP)	-40 °C to +85 °C	TL431IP	TL431IPN	SOT97-1
8-Pin Plastic Dual In-Line package (DIP)	0 °C to +70 °C	TL431ACP	TL431ACP	SOT97-1
8-Pin Plastic Dual In-Line package (DIP)	-40 °C to +85 °C	TL431AIP	TL431AIPN	SOT97-1
5-pin plastic small outline package (SO5)	0 °C to +70 °C		TL431ACD5	SOT680-1
5-pin plastic small outline package (SO5)	-40 °C to +85 °C		TL431AID5	SOT680-1
5-pin plastic small outline package (SO5)	0 °C to +70 °C		TL431CD5	SOT680-1
5-pin plastic small outline package (SO5)	-40 °C to +85 °C		TL431ID5	SOT680-1

### NOTE:

1. SYMBOL INFORMATION: Parts will be marked with product name including temperature and electrical grade designators, but not the package identifier.

# Adjustable precision shunt regulators

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## ABSOLUTE MAXIMUM RATINGS

SYMBOL	PARAMETER	RATING	UNITS
$V_{KA}$	Cathode voltage (see Note 1)	37	V
	Continuous cathode current range	-100 to +150	mA
	Reference input current range	0.05 to 10	mA
$T_{amb}$	Operating free-air temperature range C suffix I suffix	0 to +70	°C
		-40 to +85	°C
$T_{stg}$	Temperature storage range	-65 to 150	°C
	Lead temperature 1.6 mm (1/16 in.) from case for 10 sec: D5, D or P pkgs	260	°C

**NOTE:**

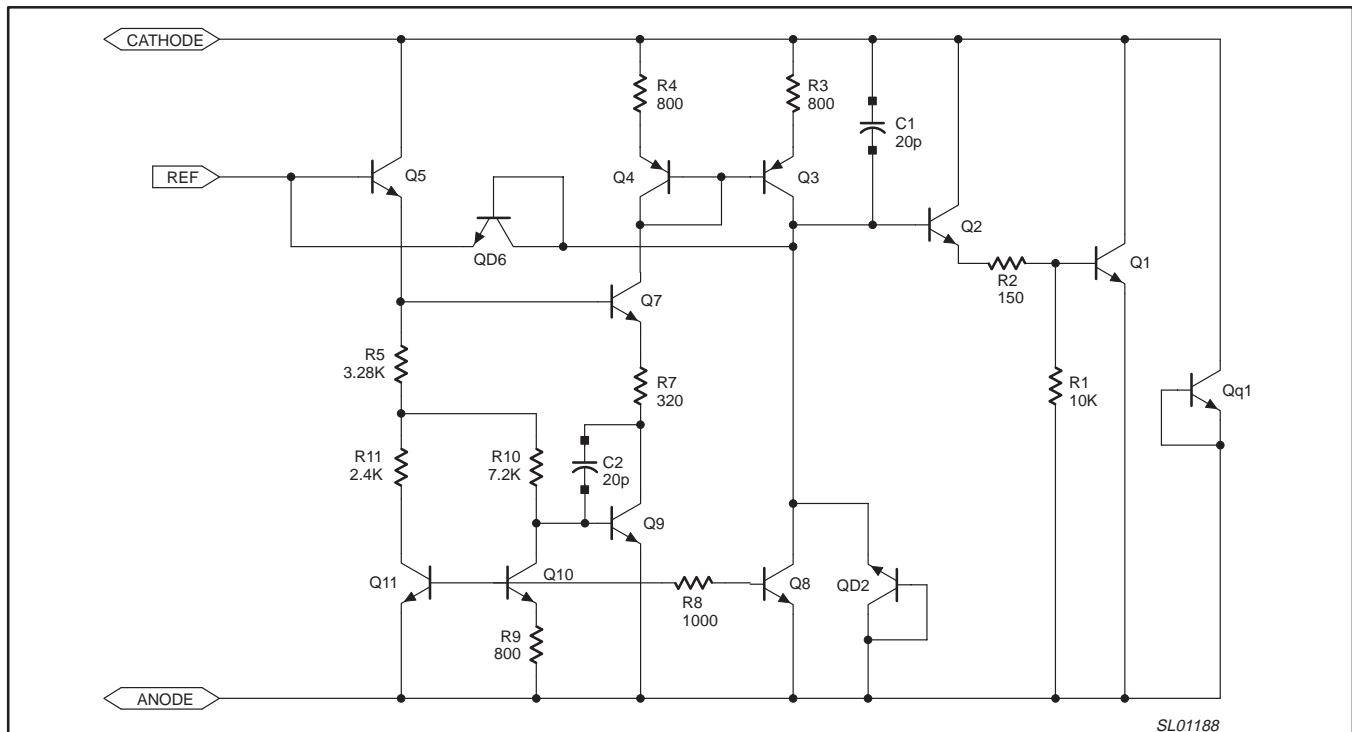
1. Voltage values are with respect to the ANODE terminal unless otherwise noted.

## RECOMMENDED OPERATING CONDITIONS

SYMBOL	PARAMETER	MIN	MAX	UNITS
$V_{KA}$	Cathode voltage	$V_{REF}$	36	V
$I_K$	Cathode current	1	100	mA

**Table 1. Dissipation Rating Table – Free-Air Temperature**

Package	Derating Factor Above $T_{amb} = 25\text{ °C}$	$T_{amb} = 25\text{ °C}$ Power Rating	$T_{amb} = 70\text{ °C}$ Power Rating	$T_{amb} = 85\text{ °C}$ Power Rating
D5	5.1 mW/°C	637 mW	408 mW	332 mW
D	5.8 mW/°C	725 mW	464 mW	429 mW
P	8.0 mW/°C	1000 mW	640 mW	520 mW



**Figure 2. Equivalent schematic.**

# Adjustable precision shunt regulators

# TL431C, TL431AC, TL431I, TL431AI, LM431AC

## DC ELECTRICAL CHARACTERISTICS

25 °C free-air temperature, unless otherwise stated.

SYMBOL	PARAMETER	TEST CKT	TEST CONDITIONS	LIMITS						UNIT
				TL431AC			TL431C/LM431AC			
				MIN	TYP	MAX	MIN	TYP	MAX	
$V_{REF}$	Reference input voltage	Fig. 3	$V_{KA} = V_{REF}$ , $I_K = 10$ mA	2470	2495	2520	2440	2495	2550	mV
$V_{REF(dev)}$	Deviation of reference input voltage over full temperature range <sup>2</sup>	Fig. 3	$V_{KA} = V_{REF}$ , $I_K = 10$ mA; $T_{amb} = \text{full range}^1$		4	15		4	17	mV
$\frac{\Delta V_{REF}}{\Delta V_{KA}}$	Ratio of change in reference input voltage to the change in cathode voltage	Fig. 4	$I_K = 10$ mA	$\Delta V_{KA} = 10$ V – $V_{REF}$	-1.4	-2.7		-1.4	-2.7	mV/V
				$\Delta V_{KA} = 36$ V – 10 V	-1	-2		-1	-2	
$I_{REF}$	Reference input current	Fig. 4	$I_K = 10$ mA, $R_1 = 10$ k $\Omega$ , $R_2 = \infty$		2	4		2	4	$\mu$ A
$I_{REF(dev)}$	Deviation of reference input current over full temperature range <sup>2</sup>	Fig. 4	$I_K = 10$ mA, $R_1 = 10$ k $\Omega$ , $R_2 = \infty$ , $T_{amb} = \text{full range}^1$		0.8	1.2		0.4	1.2	$\mu$ A
$I_{MIN}$	Minimum cathode current for regulation	Fig. 3	$V_{KA} = V_{REF}$		0.4	0.6		0.4	1	mA
$I_{OFF}$	Off-state cathode current	Fig. 5	$V_{KA} = 36$ V, $V_{REF} = 0$		0.1	0.5		0.1	1	$\mu$ A
$ Z_{KA} $	Dynamic impedance <sup>3</sup>	Fig. 3	$V_{KA} = V_{REF}$ , $I_K = 1$ mA to 100 mA; $f \leq 1$ kHz		0.2	0.5		0.2	0.5	$\Omega$

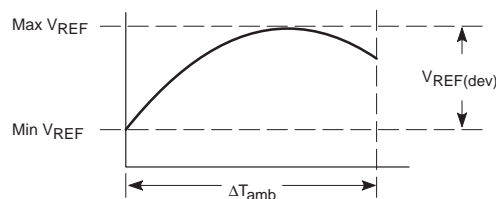
25 °C free-air temperature, unless otherwise stated.

SYMBOL	PARAMETER	TEST CKT	TEST CONDITIONS	LIMITS						UNIT
				TL431AI			TL431I			
				MIN	TYP	MAX	MIN	TYP	MAX	
$V_{REF}$	Reference input voltage	Fig. 3	$V_{KA} = V_{REF}$ , $I_K = 10$ mA	2470	2495	2520	2440	2495	2550	mV
$V_{REF(dev)}$	Deviation of reference input voltage over full temperature range <sup>2</sup>	Fig. 3	$V_{KA} = V_{REF}$ , $I_K = 10$ mA, $T_{amb} = \text{full range}^1$		5	25		5	30	mV
$\frac{\Delta V_{REF}}{\Delta V_{KA}}$	Ratio of change in reference input voltage to the change in cathode voltage	Fig. 4	$I_K = 10$ mA	$\Delta V_{KA} = 10$ V – $V_{REF}$	-1.4	-2.7		-1.4	-2.7	mV/V
				$\Delta V_{KA} = 36$ V – 10 V	-1	-2		-1	-2	
$I_{REF}$	Reference input current	Fig. 4	$I_K = 10$ mA, $R_1 = 10$ k $\Omega$ , $R_2 = \infty$		2	4		2	4	$\mu$ A
$I_{REF(dev)}$	Deviation of reference input current over full temperature range <sup>2</sup>	Fig. 4	$I_K = 10$ mA, $R_1 = 10$ k $\Omega$ , $R_2 = \infty$ , $T_{amb} = \text{full range}^1$		0.8	2.5		0.8	2.5	$\mu$ A
$I_{MIN}$	Minimum cathode current for regulation	Fig. 3	$V_{KA} = V_{REF}$		0.4	0.7		0.4	1	$\mu$ A
$I_{OFF}$	Off-state cathode current	Fig. 5	$V_{KA} = 36$ V, $V_{REF} = 0$		0.1	0.5		0.1	1	$\mu$ A
$ Z_{KA} $	Dynamic impedance <sup>3</sup>	Fig. 3	$V_{KA} = V_{REF}$ , $I_K = 1$ mA to 100 mA, $f \leq 1$ kHz		0.2	0.5		0.2	0.5	$\Omega$

**NOTES:**

1. Full temperature range is -40 °C to +85 °C for the TL431I and TL431AI, and 0 °C to +70 °C for the TL431C and TL431AC.
2. 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,  $\alpha V_{REF}$ , is defined as:

$$|\alpha V_{REF}| \left( \frac{\text{ppm}}{\text{deg C}} \right) = \frac{\left( \frac{V_{REF(dev)}}{V_{REF \text{ at } 25^\circ\text{C}}} \right) \cdot 10^6}{\Delta T_{amb}}$$



where  $\Delta T_{amb}$  is the rated operating free-air temperature range of the device.

# Adjustable precision shunt regulators

## TL431C, TL431AC, TL431I, TL431AI, LM431AC

$\alpha V_{REF}$  can be positive or negative depending on whether minimum  $V_{REF}$  or maximum  $V_{REF}$ , respectively, occurs at the lower temperature.  
 Example: Max  $V_{REF} = 2496$  mV at 30 °C, Min  $V_{REF} = 2492$  mV at 0 °C,  $V_{REF} = 2495$  mV at 25 °C,  $DTA = 70$  °C for TL431C.

$$|\alpha V_{REF}| = \frac{\left(\frac{4\text{mV}}{2495\text{mV}}\right) \cdot 10^6}{70^\circ\text{C}} = 23\text{ppm}/^\circ\text{C}$$

Because minimum  $V_{REF}$  occurs at the lower temperature, the coefficient is positive.

- The dynamic impedance is defined as:  $|Z_{KA}| = \frac{\Delta V_{KA}}{\Delta I_K}$

When the device is operating with two external resistors, (see Figure 4), the total dynamic impedance of the circuit is given by:

$$|Z'| = \frac{\Delta V}{\Delta I} \approx |Z_{KA}| \left(1 + \frac{R1}{R2}\right)$$

### PARAMETER MEASUREMENT INFORMATION

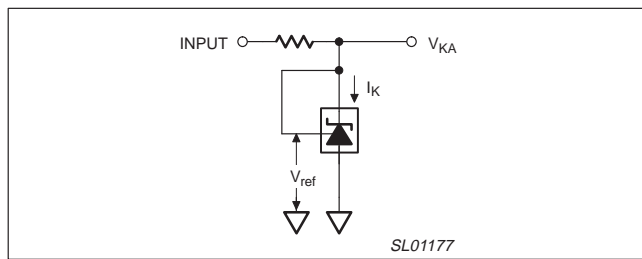


Figure 3. Test Circuit for  $V_{KA} = V_{ref}$

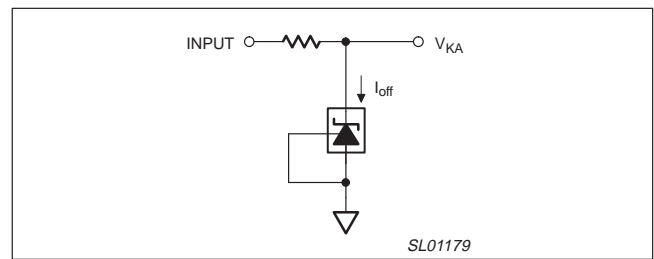


Figure 5. Test Circuit for  $I_{OFF}$

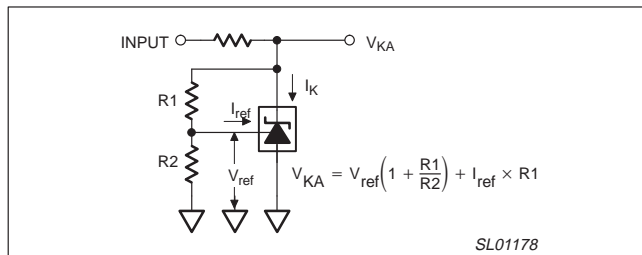


Figure 4. Test Circuit for  $V_{KA} > V_{ref}$

# Adjustable precision shunt regulators

## TL431C, TL431AC, TL431I, TL431AI, LM431AC

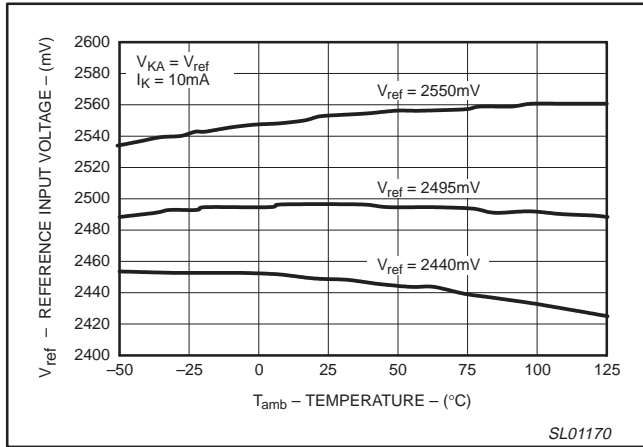


Figure 6. Reference Input Voltage vs. Temperature

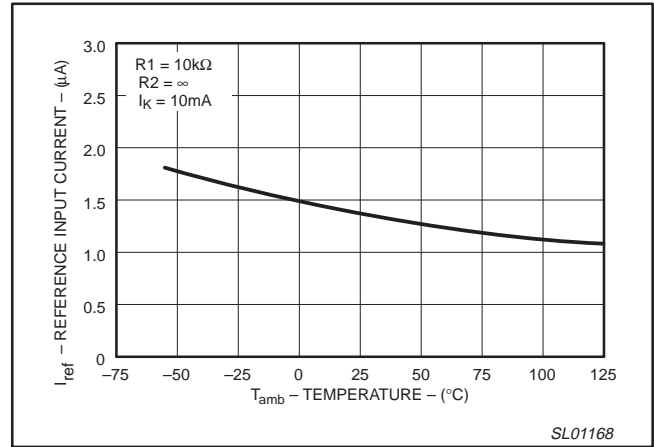


Figure 9. Reference Input Current vs. Temperature

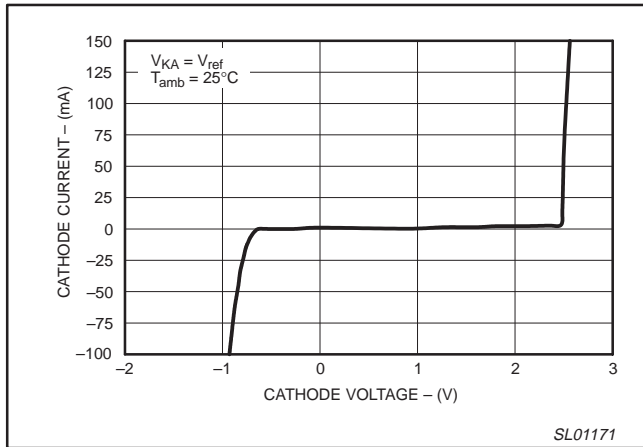


Figure 7. Cathode Current vs. Cathode Voltage

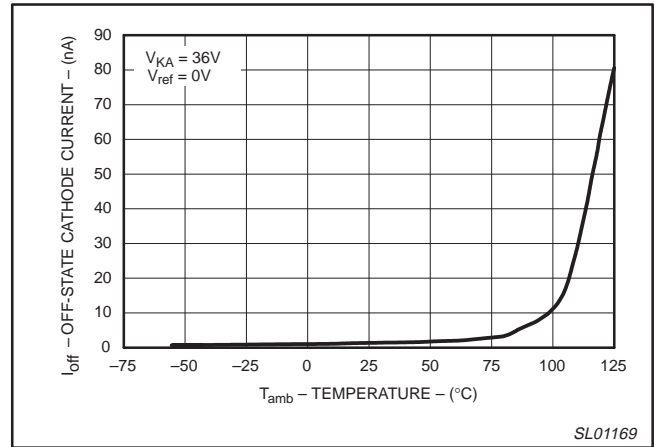


Figure 10. Off-State Cathode Current vs. Temperature

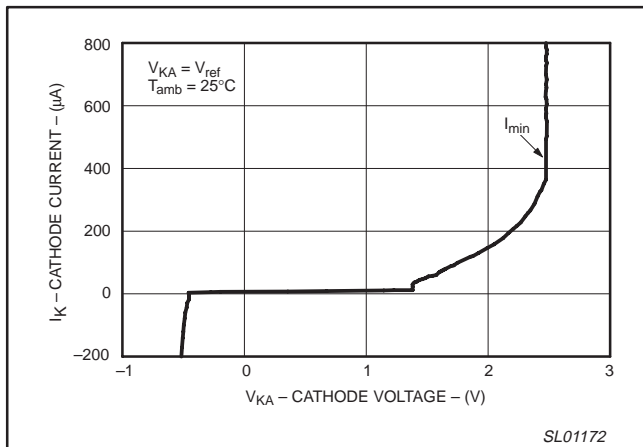


Figure 8. Cathode Current vs. Cathode Voltage

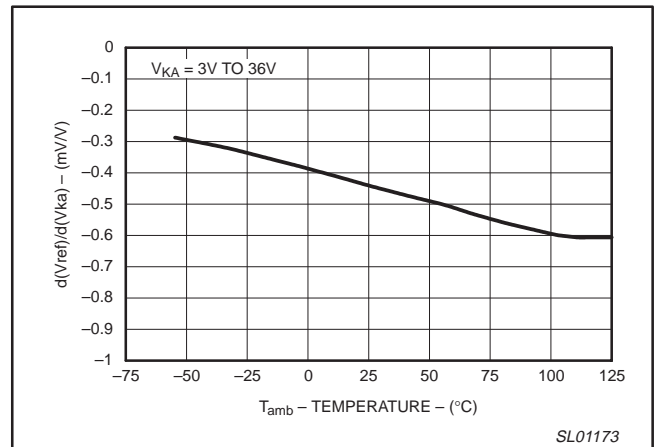


Figure 11. Ratio of Delta Reference Voltage to Delta Cathode Voltage over Temperature

Adjustable precision shunt regulators

TL431C, TL431AC, TL431I,  
TL431AI, LM431AC

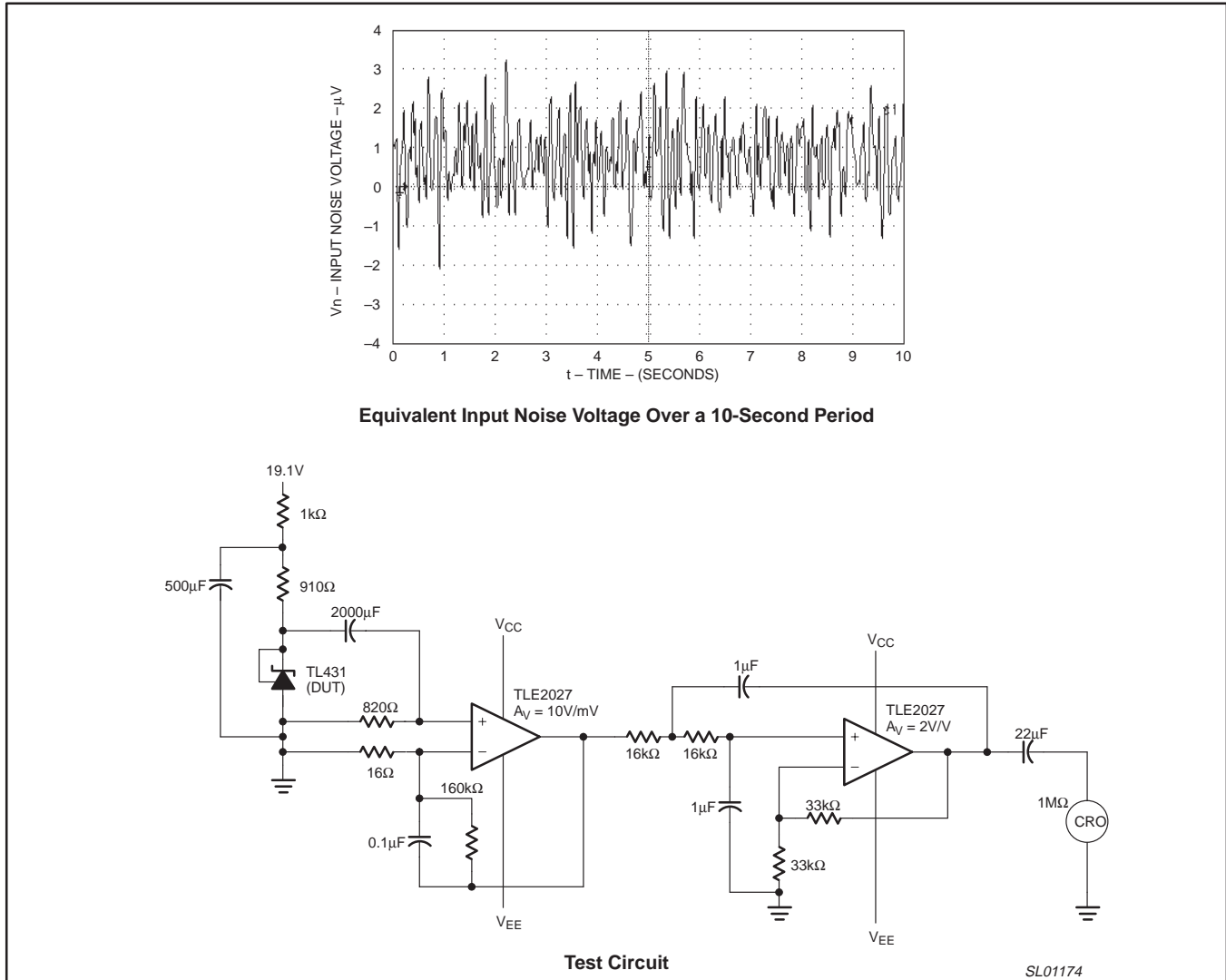


Figure 12.

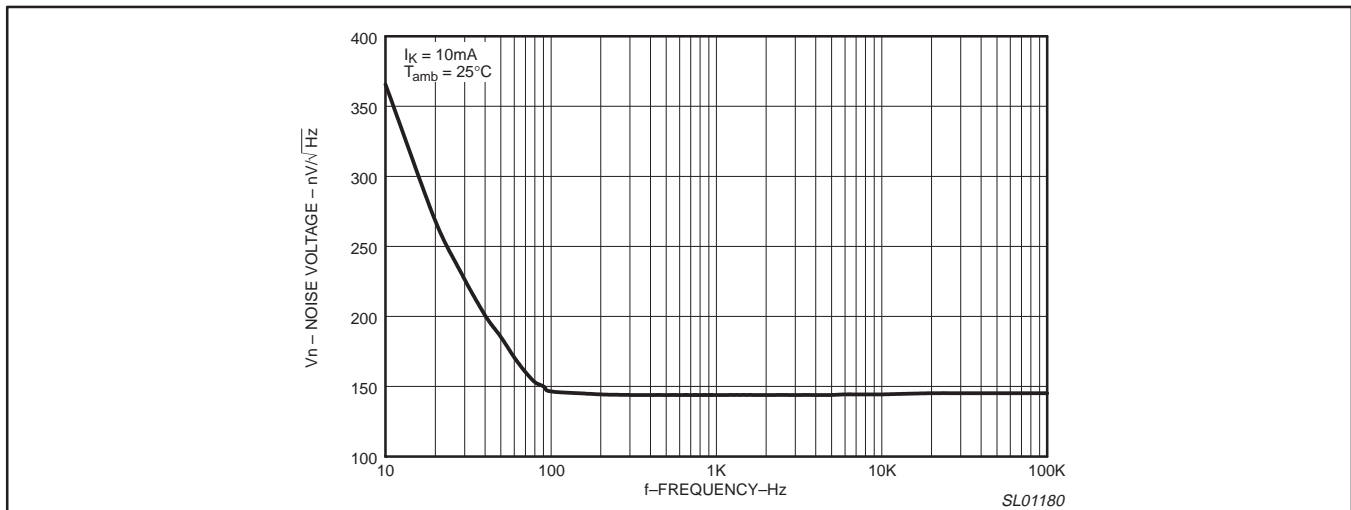


Figure 13. Equivalent Input Noise Voltage vs. Frequency

# Adjustable precision shunt regulators

TL431C, TL431AC, TL431I,  
TL431AI, LM431AC

## TYPICAL CHARACTERISTICS

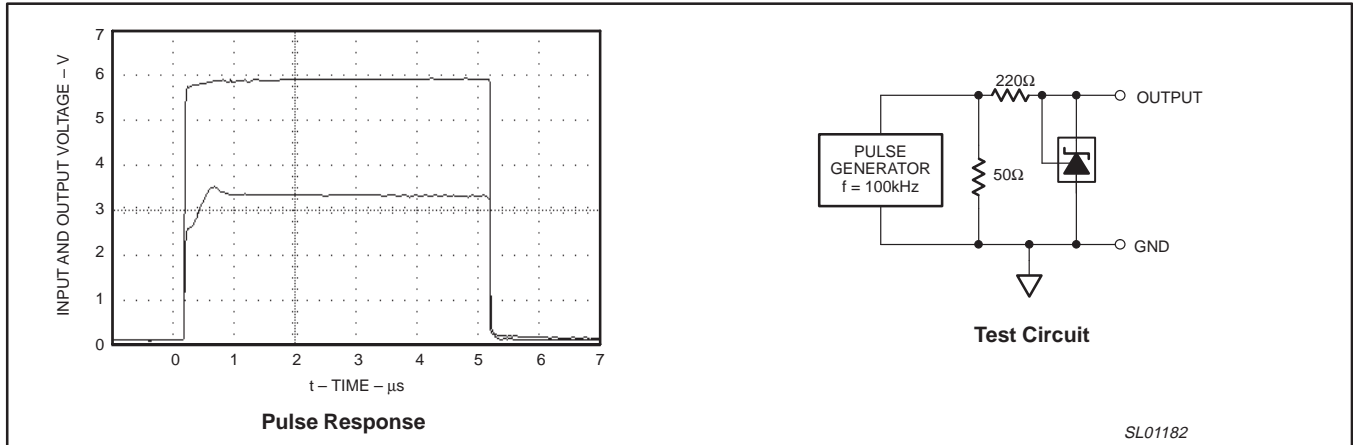


Figure 14. Pulse Response

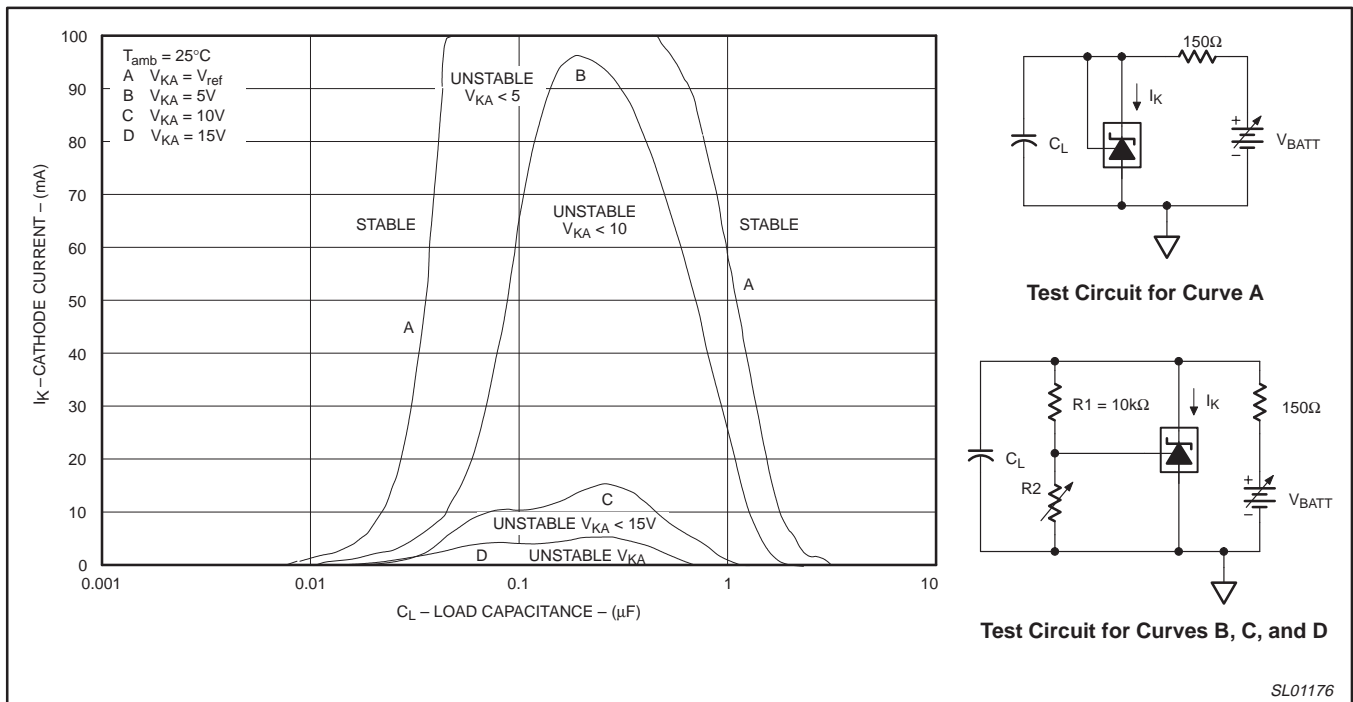


Figure 15. Stability Boundary Conditions



# Adjustable precision shunt regulators

## TL431C, TL431AC, TL431I, TL431AI, LM431AC

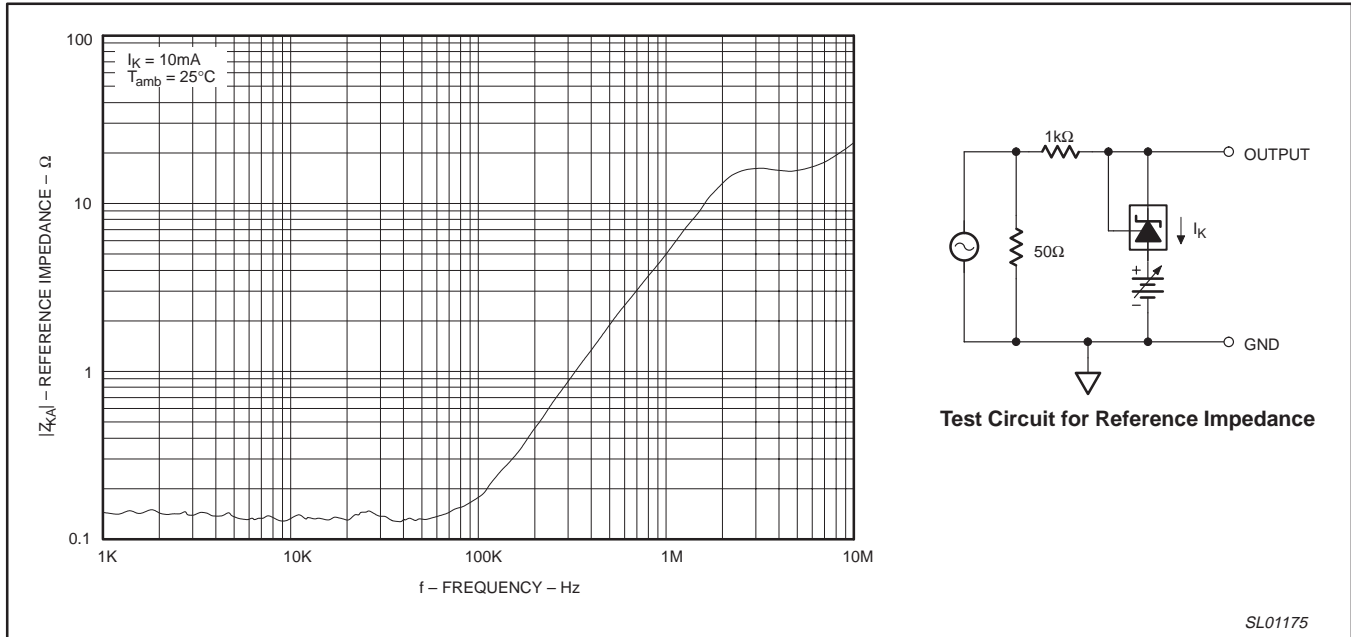


Figure 16. Reference Impedance vs. Frequency

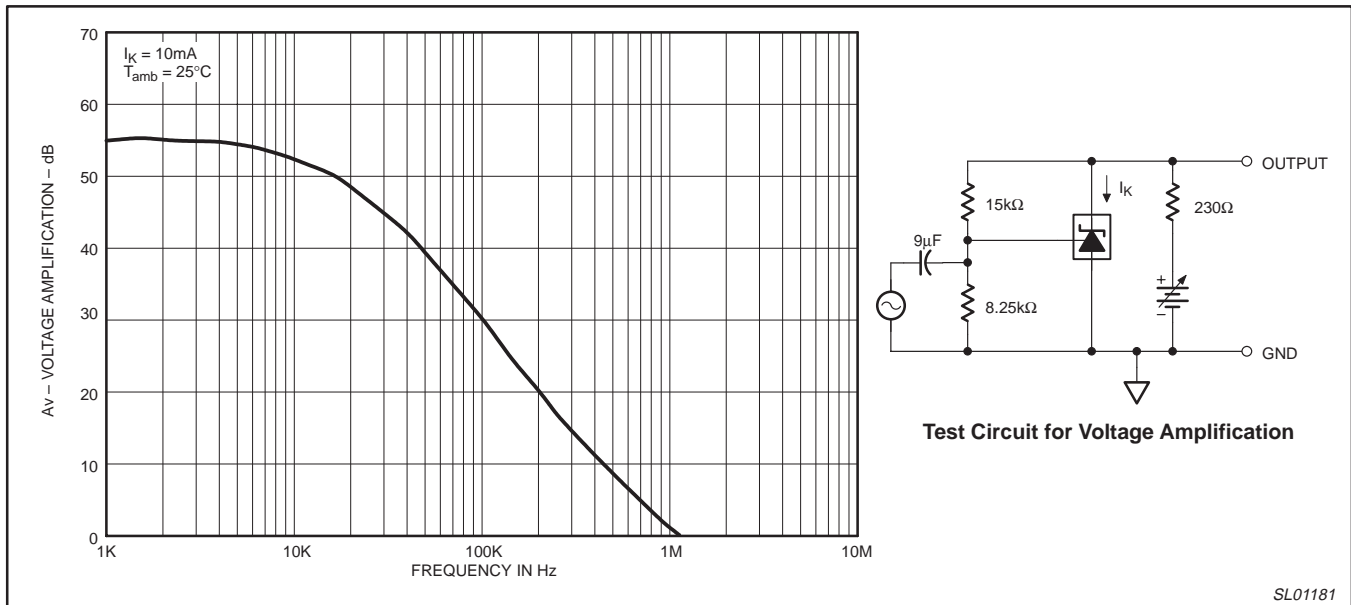


Figure 17. Small-Signal Voltage Amplification vs. Frequency

# Adjustable precision shunt regulators

TL431C, TL431AC, TL431I,  
TL431AI, LM431AC

## TYPICAL APPLICATIONS

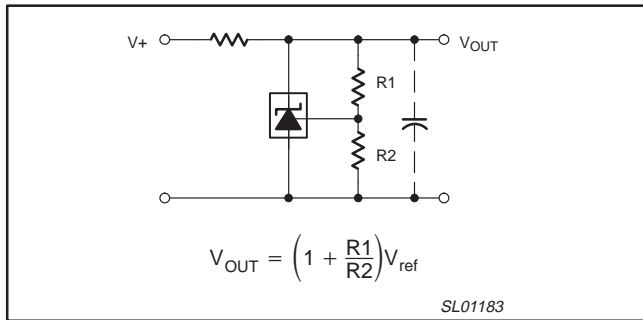


Figure 18. Shunt Regulator

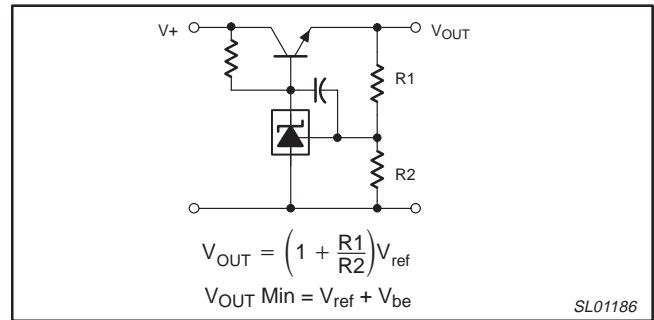


Figure 21. Series Pass Regulator

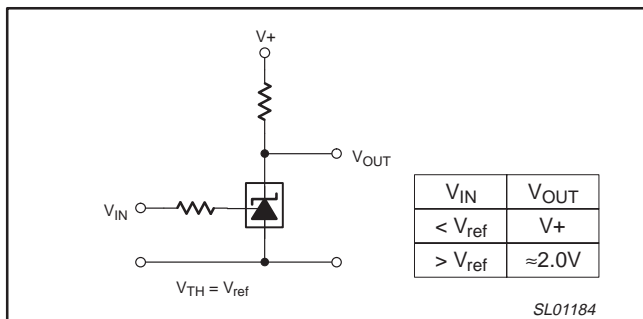


Figure 19. Single-Supply Comparator with Temperature-Compensated Threshold

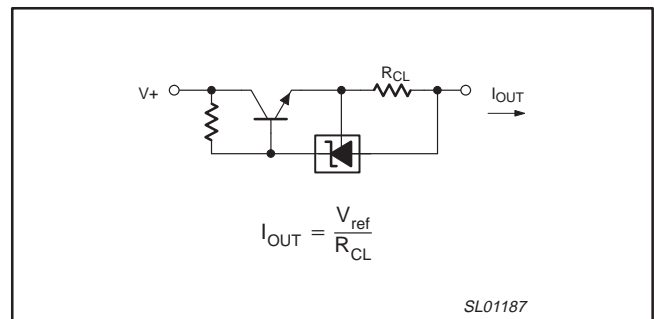


Figure 22. Constant Current Source

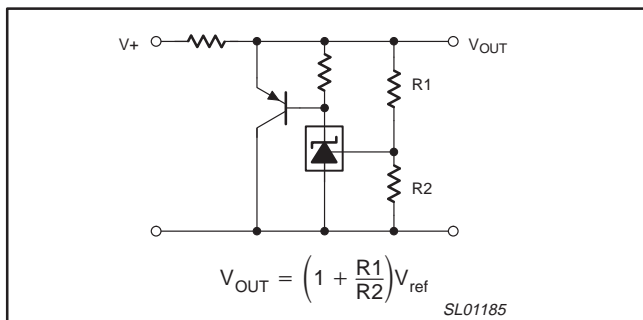


Figure 20. High Current Shunt Regulator

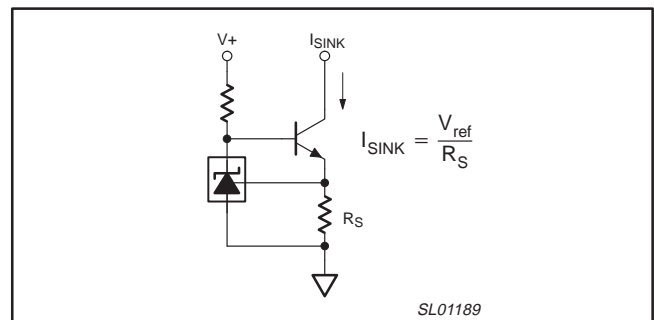


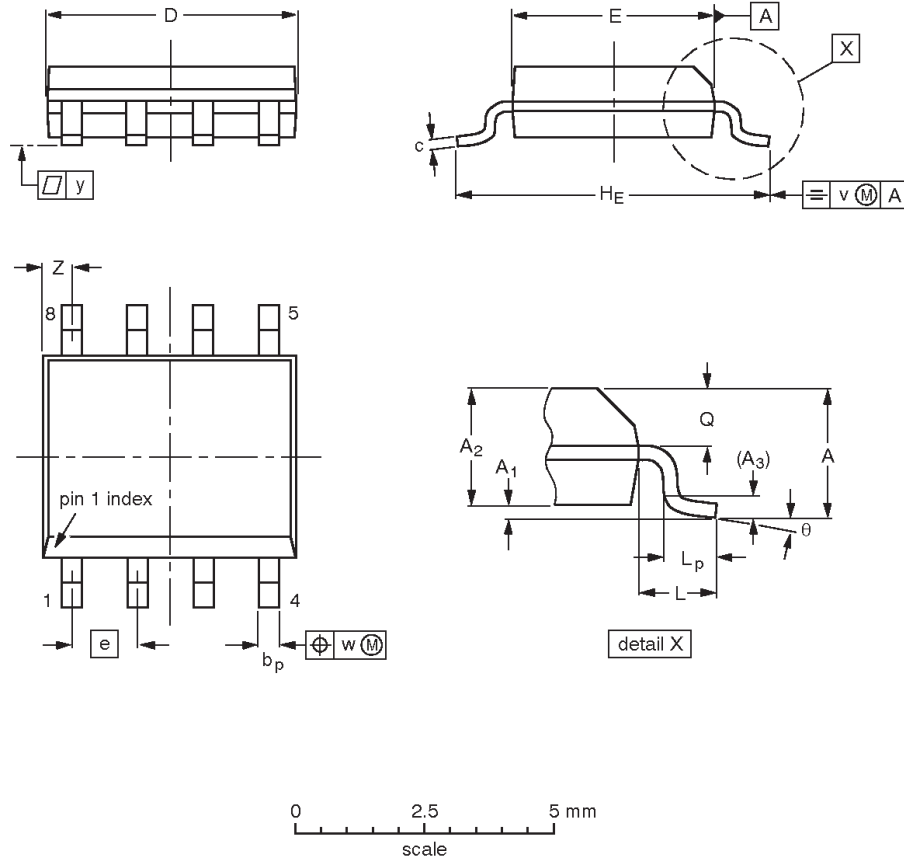
Figure 23. Constant Current Sink

# Adjustable precision shunt regulators

TL431C, TL431AC, TL431I,  
TL431AI, LM431AC

**S08:** plastic small outline package; 8 leads; body width 3.9 mm

**SOT96-1**



**DIMENSIONS (inch dimensions are derived from the original mm dimensions)**

UNIT	A max.	A <sub>1</sub>	A <sub>2</sub>	A <sub>3</sub>	b <sub>p</sub>	c	D <sup>(1)</sup>	E <sup>(2)</sup>	e	HE	L	L <sub>p</sub>	Q	v	w	y	Z <sup>(1)</sup>	θ
mm	1.75	0.25 0.10	1.45 1.25	0.25	0.49 0.36	0.25 0.19	5.0 4.8	4.0 3.8	1.27	6.2 5.8	1.05	1.0 0.4	0.7 0.6	0.25	0.25	0.1	0.7 0.3	8° 0°
inches	0.069	0.010 0.004	0.057 0.049	0.01	0.019 0.014	0.0100 0.0075	0.20 0.19	0.16 0.15	0.050	0.244 0.228	0.041	0.039 0.016	0.028 0.024	0.01	0.01	0.004	0.028 0.012	

**Notes**

1. Plastic or metal protrusions of 0.15 mm maximum per side are not included.
2. Plastic or metal protrusions of 0.25 mm maximum per side are not included.

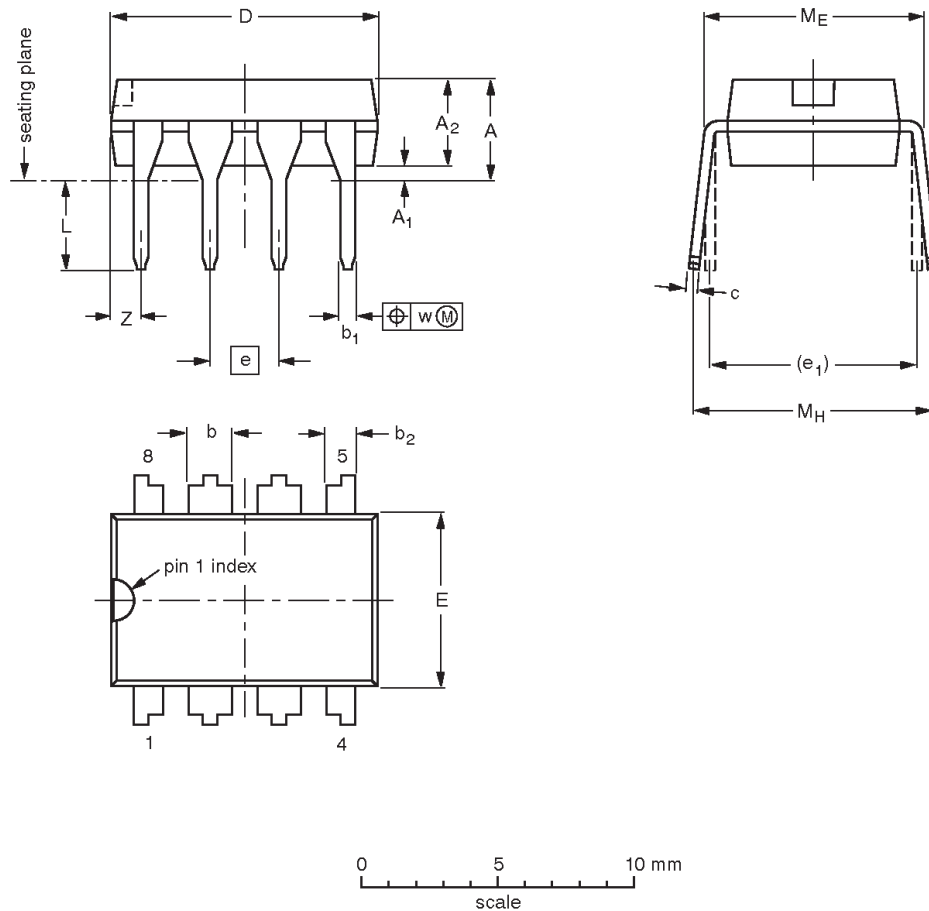
OUTLINE VERSION	REFERENCES				EUROPEAN PROJECTION	ISSUE DATE
	IEC	JEDEC	EIAJ			
SOT96-1	076E03	MS-012				97-05-22 99-12-27

# Adjustable precision shunt regulators

TL431C, TL431AC, TL431I,  
TL431AI, LM431AC

DIP8: plastic dual in-line package; 8 leads (300 mil)

SOT97-1



**DIMENSIONS (inch dimensions are derived from the original mm dimensions)**

UNIT	A max.	A <sub>1</sub> min.	A <sub>2</sub> max.	b	b <sub>1</sub>	b <sub>2</sub>	c	D <sup>(1)</sup>	E <sup>(1)</sup>	e	e <sub>1</sub>	L	M <sub>E</sub>	M <sub>H</sub>	w	Z <sup>(1)</sup> max.
mm	4.2	0.51	3.2	1.73 1.14	0.53 0.38	1.07 0.89	0.36 0.23	9.8 9.2	6.48 6.20	2.54	7.62	3.60 3.05	8.25 7.80	10.0 8.3	0.254	1.15
inches	0.17	0.020	0.13	0.068 0.045	0.021 0.015	0.042 0.035	0.014 0.009	0.39 0.36	0.26 0.24	0.10	0.30	0.14 0.12	0.32 0.31	0.39 0.33	0.01	0.045

**Note**

1. Plastic or metal protrusions of 0.25 mm maximum per side are not included.

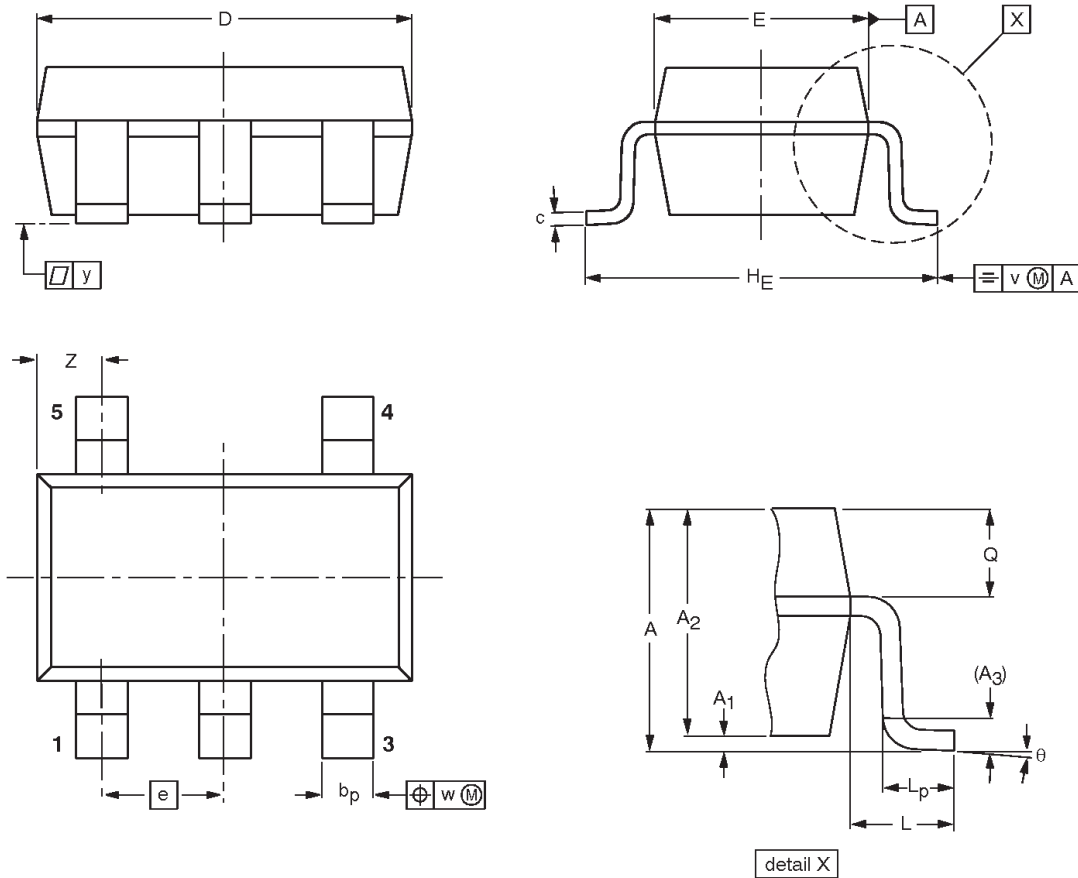
OUTLINE VERSION	REFERENCES				EUROPEAN PROJECTION	ISSUE DATE
	IEC	JEDEC	EIAJ			
SOT97-1	050G01	MO-001	SC-504-8			95-02-04 99-12-27

Adjustable precision shunt regulators

TL431C, TL431AC, TL431I,  
TL431AI, LM431AC

S05: plastic small outline package; 5 leads; body width 1.6 mm

SOT680-1



**DIMENSIONS (mm are the original dimensions)**

UNIT	A max.	A <sub>1</sub>	A <sub>2</sub>	A <sub>3</sub>	b <sub>p</sub>	c	D <sup>(1)</sup>	E <sup>(1)</sup>	e	H <sub>E</sub>	L	L <sub>p</sub>	Q	v	w	y	z <sup>(1)</sup>	θ
mm	1.45	0.15 0.05	1.3 0.9	0.2	0.5 0.3	0.22 0.08	3.05 2.75	1.75 1.45	0.95	3.0 2.6	0.6	0.6 0.3	0.45 0.35	0.2	0.2	0.1	0.75 0.25	8° 0°

**Note**

1. Plastic or metal protrusions of 0.25 mm maximum per side are not included.

OUTLINE VERSION	REFERENCES				EUROPEAN PROJECTION	ISSUE DATE
	IEC	JEDEC	JEITA			
SOT680-1		MO-178				<del>01-03-22</del> 01-11-15

## Adjustable precision shunt regulators

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TL431AI, LM431AC

## Data sheet status

Data sheet status <sup>[1]</sup>	Product status <sup>[2]</sup>	Definitions
Objective data	Development	This data sheet contains data from the objective specification for product development. Philips Semiconductors reserves the right to change the specification in any manner without notice.
Preliminary data	Qualification	This data sheet contains data from the preliminary specification. Supplementary data will be published at a later date. Philips Semiconductors reserves the right to change the specification without notice, in order to improve the design and supply the best possible product.
Product data	Production	This data sheet contains data from the product specification. Philips Semiconductors reserves the right to make changes at any time in order to improve the design, manufacturing and supply. Changes will be communicated according to the Customer Product/Process Change Notification (CPCN) procedure SNW-SQ-650A.

[1] Please consult the most recently issued data sheet before initiating or completing a design.

[2] The product status of the device(s) described in this data sheet may have changed since this data sheet was published. The latest information is available on the Internet at URL <http://www.semiconductors.philips.com>.

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**Short-form specification** — The data in a short-form specification is extracted from a full data sheet with the same type number and title. For detailed information see the relevant data sheet or data handbook.

**Limiting values definition** — Limiting values given are in accordance with the Absolute Maximum Rating System (IEC 60134). Stress above one or more of the limiting values may cause permanent damage to the device. These are stress ratings only and operation of the device at these or at any other conditions above those given in the Characteristics sections of the specification is not implied. Exposure to limiting values for extended periods may affect device reliability.

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