

# DATA SHEET

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**TL431C, TL431AC, TL431I,  
TL431AI, LM431AC**

Adjustable precision shunt regulators

Product specification

1997 Feb 25

## 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 2.5V) and 36V 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  $0^{\circ}\text{C}$  to  $+70^{\circ}\text{C}$ ; the TL431I and TL431AI are characterized for operation from  $-40^{\circ}\text{C}$  to  $+85^{\circ}\text{C}$ .

## FEATURES

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

## PIN CONFIGURATIONS

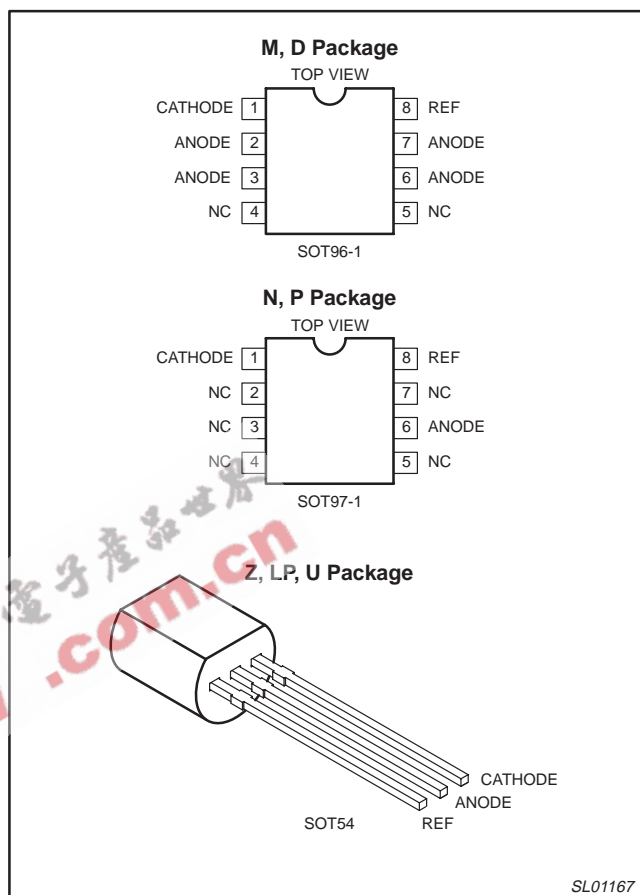


Figure 1. Pin Configuration

## ORDERING INFORMATION

DESCRIPTION	TEMPERATURE RANGE	INDUSTRY STANDARD PART NUMBER	ORDER CODE	DWG #
3-Pin Plastic TO92 <sup>2</sup>	$0^{\circ}\text{C}$ to $+70^{\circ}\text{C}$	TL431CLP	TL431CLPU	SOT54
3-Pin Plastic TO92 <sup>2</sup>	$0^{\circ}\text{C}$ to $+70^{\circ}\text{C}$	TL431ACLP	TL431ACLPU	SOT54
3-Pin Plastic TO92 <sup>2</sup>	$-40^{\circ}\text{C}$ to $+85^{\circ}\text{C}$	TL431ILP	TL431ILPU	SOT54
3-Pin Plastic TO92 <sup>2</sup>	$-40^{\circ}\text{C}$ to $+85^{\circ}\text{C}$	TL431AILP	TL431AILPU	SOT54
3-Pin Plastic TO92 <sup>2</sup>	$0^{\circ}\text{C}$ to $+70^{\circ}\text{C}$	LM431ACZ	LM431ACZU	SOT54
8-Pin Plastic Small Outline (SO) package	$0^{\circ}\text{C}$ to $+70^{\circ}\text{C}$	TL431CD	TL431CD	SOT96-1
8-Pin Plastic Small Outline (SO) package	$-40^{\circ}\text{C}$ to $+85^{\circ}\text{C}$	TL431ID	TL431ID	SOT96-1
8-Pin Plastic Small Outline (SO) package	$0^{\circ}\text{C}$ to $+70^{\circ}\text{C}$	TL431ACD	TL431ACD	SOT96-1
8-Pin Plastic Small Outline (SO) package	$-40^{\circ}\text{C}$ to $+85^{\circ}\text{C}$	TL431AID	TL431AID	SOT96-1
8-Pin Plastic Small Outline (SO) package	$0^{\circ}\text{C}$ to $+70^{\circ}\text{C}$	LM431ACM	LM431ACMD	SOT96-1
8-Pin Plastic Dual In-Line package (DIP)	$0^{\circ}\text{C}$ to $+70^{\circ}\text{C}$	TL431CP	TL431CPN	SOT97-1
8-Pin Plastic Dual In-Line package (DIP)	$-40^{\circ}\text{C}$ to $+85^{\circ}\text{C}$	TL431IP	TL431IPN	SOT97-1
8-Pin Plastic Dual In-Line package (DIP)	$0^{\circ}\text{C}$ to $+70^{\circ}\text{C}$	TL431ACP	TL431ACPN	SOT97-1
8-Pin Plastic Dual In-Line package (DIP)	$-40^{\circ}\text{C}$ to $+85^{\circ}\text{C}$	TL431AIP	TL431AIPN	SOT97-1

## NOTE:

1. SYMBOL INFORMATION: Parts will be marked with product name including temperature and electrical grade designators, but not the package identifier.
2. TO92 is normally shipped in bulk, i.e., in plastic bags (containing 1,000 parts), 5 bags per box. Tape and reel (or ammo box) is an option. See page 15 for information.

# Adjustable precision shunt regulators

# TL431C, TL431AC, TL431I, TL431AI, LM431AC

### 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 1.6mm (1/16 in.) from case for 10 sec: D or P pkgs	260	°C
	Lead temperature 1.6mm (1/16 in.) from case for 60 sec: LP pkg	300	°C

**NOTE:**

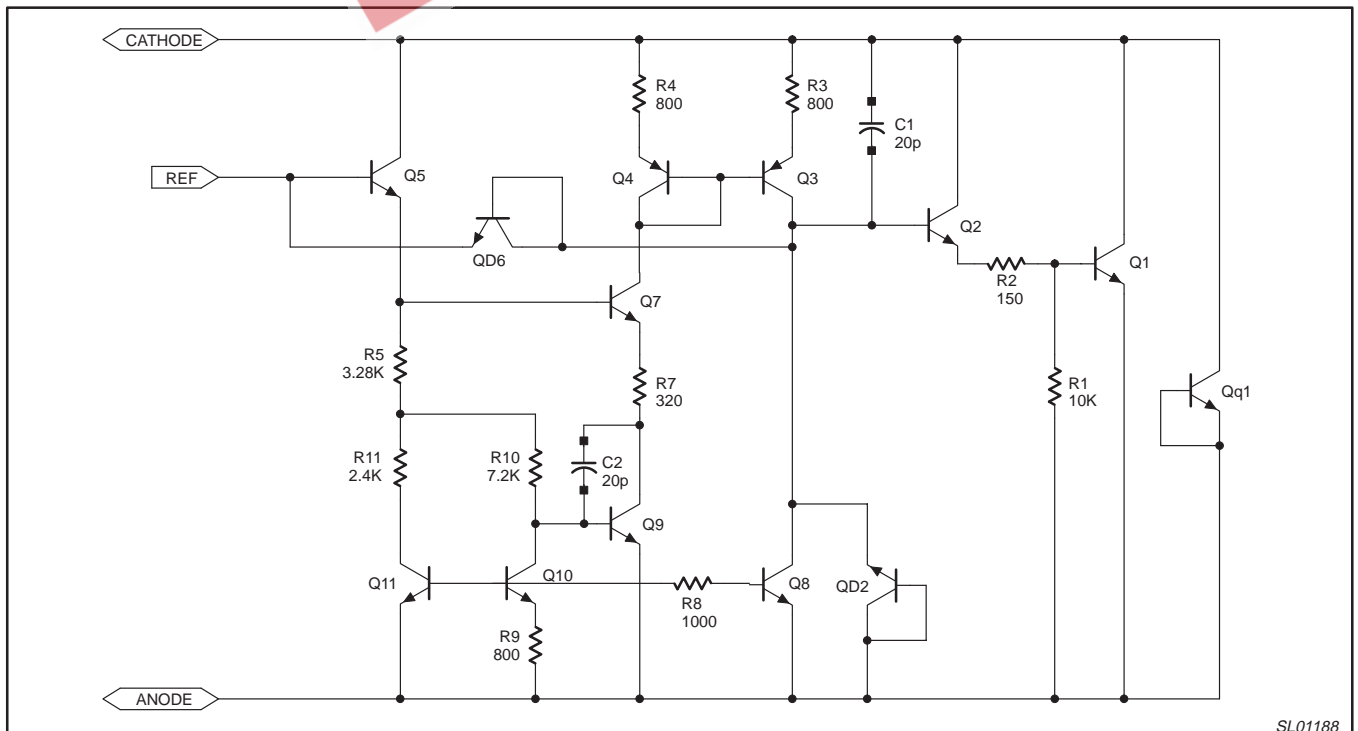
1. Voltage values are with respect to the anode terminal unless otherwise noted.

### 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 $T_{amb} = 25^\circ\text{C}$	$T_{amb} = 25^\circ\text{C}$ Power Rating	$T_{amb} = 70^\circ\text{C}$ Power Rating	$T_{amb} = 85^\circ\text{C}$ Power Rating
D	5.8mW/°C	725mW	464mW	429mW
LP	6.2mW/°C	775mW	496mW	403mW
P	8.0mW/°C	1000mW	640mW	520mW



**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 <sub>REF</sub>	Reference input voltage	Fig. 3	V <sub>KA</sub> = V <sub>REF</sub> , I <sub>K</sub> = 10mA	2470	2495	2520	2440	2495	2550	mV
V <sub>REF(dev)</sub>	Deviation of reference input voltage over full temperature range <sup>3</sup>	Fig. 3	V <sub>KA</sub> = V <sub>REF</sub> , I <sub>K</sub> = 10mA, T <sub>amb</sub> = full range <sup>2</sup>		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 <sub>K</sub> = 10mA	ΔV <sub>KA</sub> = 10V – V <sub>REF</sub>	-1.4	-2.7		-1.4	-2.7	mV/V
				ΔV <sub>KA</sub> = 36V – 10V	-1	-2		-1	-2	
I <sub>REF</sub>	Reference input current	Fig. 4	I <sub>K</sub> = 10mA, R <sub>1</sub> = 10kΩ, R <sub>2</sub> = ∞		2	4		2	4	μA
I <sub>REF(dev)</sub>	Deviation of reference input current over full temperature range <sup>3</sup>	Fig. 4	I <sub>K</sub> = 10mA, R <sub>1</sub> = 10kΩ, R <sub>2</sub> = ∞, T <sub>amb</sub> = full range <sup>2</sup>		0.8	1.2		0.4	1.2	μA
I <sub>MIN</sub>	Minimum cathode current for regulation	Fig. 3	V <sub>KA</sub> = V <sub>REF</sub>		0.4	0.6		0.4	1	mA
I <sub>OFF</sub>	Off-state cathode current	Fig. 5	V <sub>KA</sub> = 36V, V <sub>REF</sub> = 0		0.1	0.5		0.1	1	μA
Z <sub>KA</sub>	Dynamic impedance <sup>4</sup>	Fig. 3	V <sub>KA</sub> = V <sub>REF</sub> , I <sub>K</sub> = 1mA to 100mA, f ≤ 1kHz		0.2	0.5		0.2	0.5	Ω

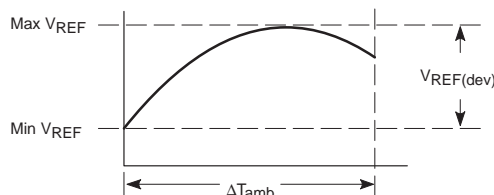
25°C free-air temperature, unless otherwise stated.

SYMBOL	PARAMETER	TEST CKT	TEST CONDITIONS	LIMITS						UNIT
				TL431AI			TL431I			
				MIN	TYP	MAX	MIN	TYP	MAX	
V <sub>REF</sub>	Reference input voltage	Fig. 3	V <sub>KA</sub> = V <sub>REF</sub> , I <sub>K</sub> = 10mA	2470	2495	2520	2440	2495	2550	mV
V <sub>REF(dev)</sub>	Deviation of reference input voltage over full temperature range <sup>3</sup>	Fig. 3	V <sub>KA</sub> = V <sub>REF</sub> , I <sub>K</sub> = 10mA, T <sub>amb</sub> = full range <sup>2</sup>		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 <sub>K</sub> = 10mA	ΔV <sub>KA</sub> = 10V – V <sub>REF</sub>	-1.4	-2.7		-1.4	-2.7	mV/V
				ΔV <sub>KA</sub> = 36V – 10V	-1	-2		-1	-2	
I <sub>REF</sub>	Reference input current	Fig. 4	I <sub>K</sub> = 10mA, R <sub>1</sub> = 10kΩ, R <sub>2</sub> = ∞		2	4		2	4	μA
I <sub>REF(dev)</sub>	Deviation of reference input current over full temperature range <sup>3</sup>	Fig. 4	I <sub>K</sub> = 10mA, R <sub>1</sub> = 10kΩ, R <sub>2</sub> = ∞, T <sub>amb</sub> = full range <sup>2</sup>		0.8	2.5		0.8	2.5	μA
I <sub>MIN</sub>	Minimum cathode current for regulation	Fig. 3	V <sub>KA</sub> = V <sub>REF</sub>		0.4	0.7		0.4	1	μA
I <sub>OFF</sub>	Off-state cathode current	Fig. 5	V <sub>KA</sub> = 36V, V <sub>REF</sub> = 0		0.1	0.5		0.1	1	μA
Z <sub>KA</sub>	Dynamic impedance <sup>4</sup>	Fig. 3	V <sub>KA</sub> = V <sub>REF</sub> , I <sub>K</sub> = 1mA to 100mA, f ≤ 1kHz		0.2	0.5		0.2	0.5	Ω

**NOTES:**

- 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.
- The deviation parameters V<sub>REF(dev)</sub> and I<sub>REF(dev)</sub> 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, αV<sub>REF</sub>, 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 ΔT<sub>amb</sub> 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  $V_{REF} = 2496\text{mV}$  at  $30^\circ\text{C}$ , Min  $V_{REF} = 2492\text{mV}$  at  $0^\circ\text{C}$ ,  $V_{REF} = 2495\text{mV}$  at  $25^\circ\text{C}$ ,  $DTA = 70^\circ\text{C}$  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.

4. 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 xx), 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

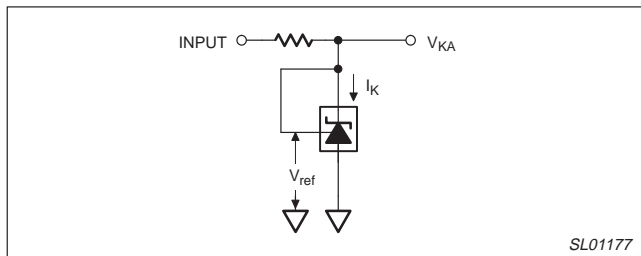


Figure 3. Test Circuit for  $V_{KA} = V_{ref}$

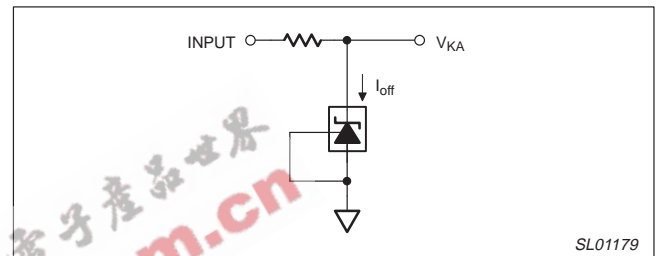


Figure 5. Test Circuit for  $I_{OFF}$

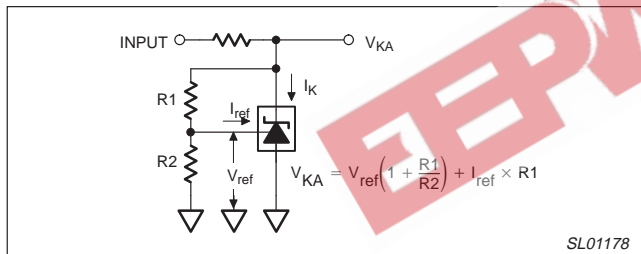


Figure 4. Test Circuit for  $V_{KA} > V_{ref}$

Adjustable precision shunt regulators

TL431C, TL431AC, TL431I,  
TL431AI, LM431AC

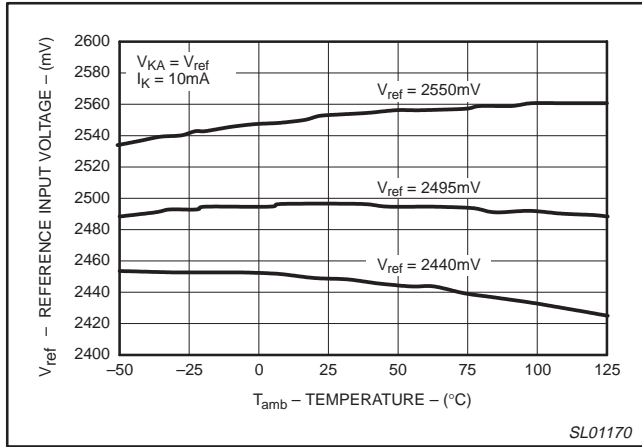


Figure 6. Reference Input Voltage vs. Temperature

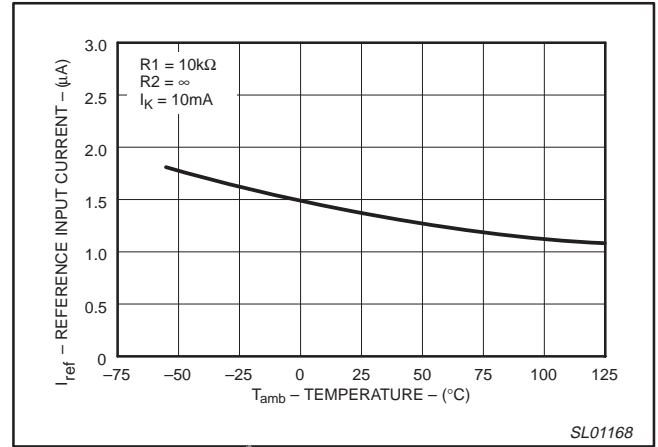


Figure 9. Reference Input Current vs. Temperature

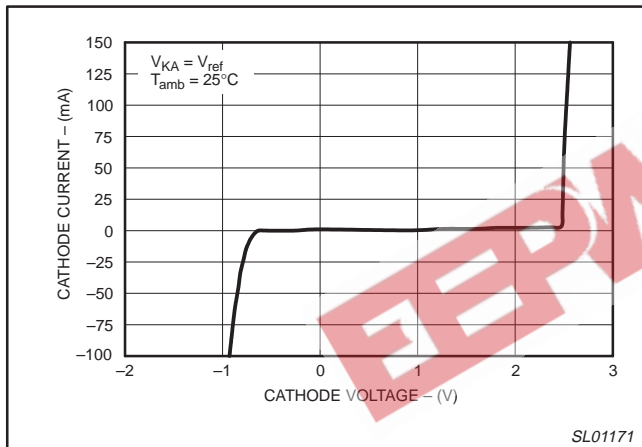


Figure 7. Cathode Current vs. Cathode Voltage

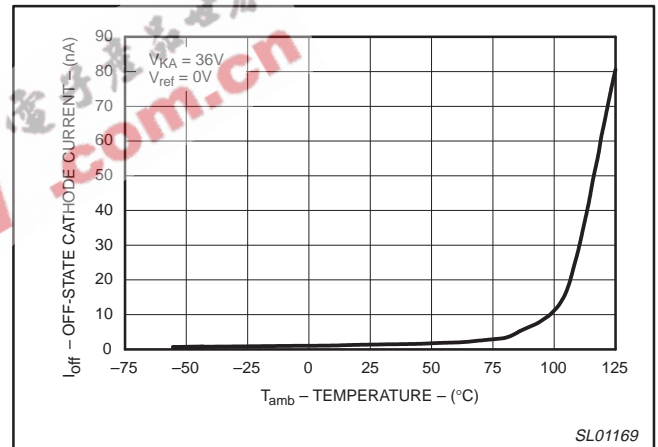


Figure 10. Off-State Cathode Current vs. Temperature

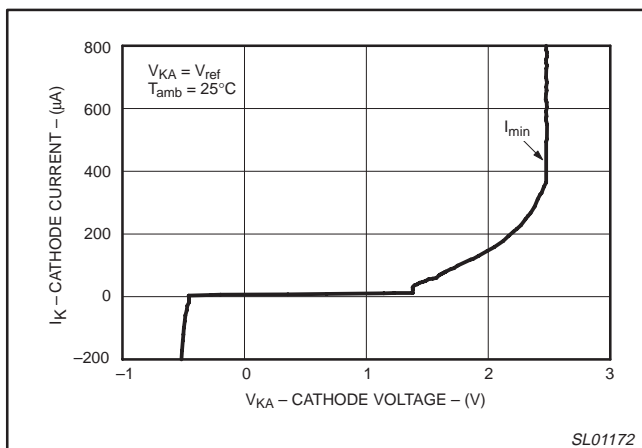


Figure 8. Cathode Current vs. Cathode Voltage

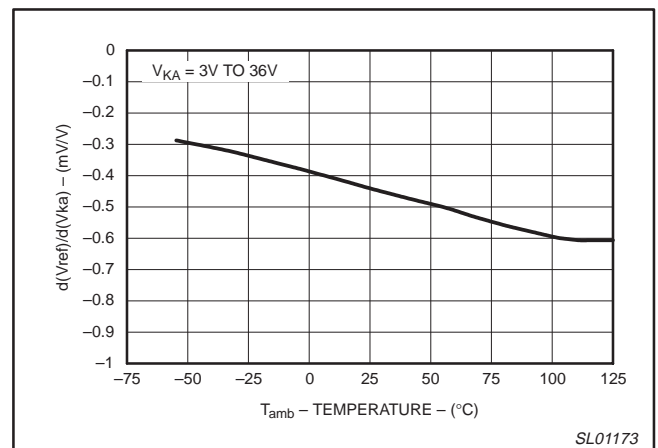


Figure 11. Ratio of Delta Reference Voltage to Delta Cathode Voltage over Temperature

Adjustable precision shunt regulators

TL431C, TL431AC, TL431I,  
TL431AI, LM431AC

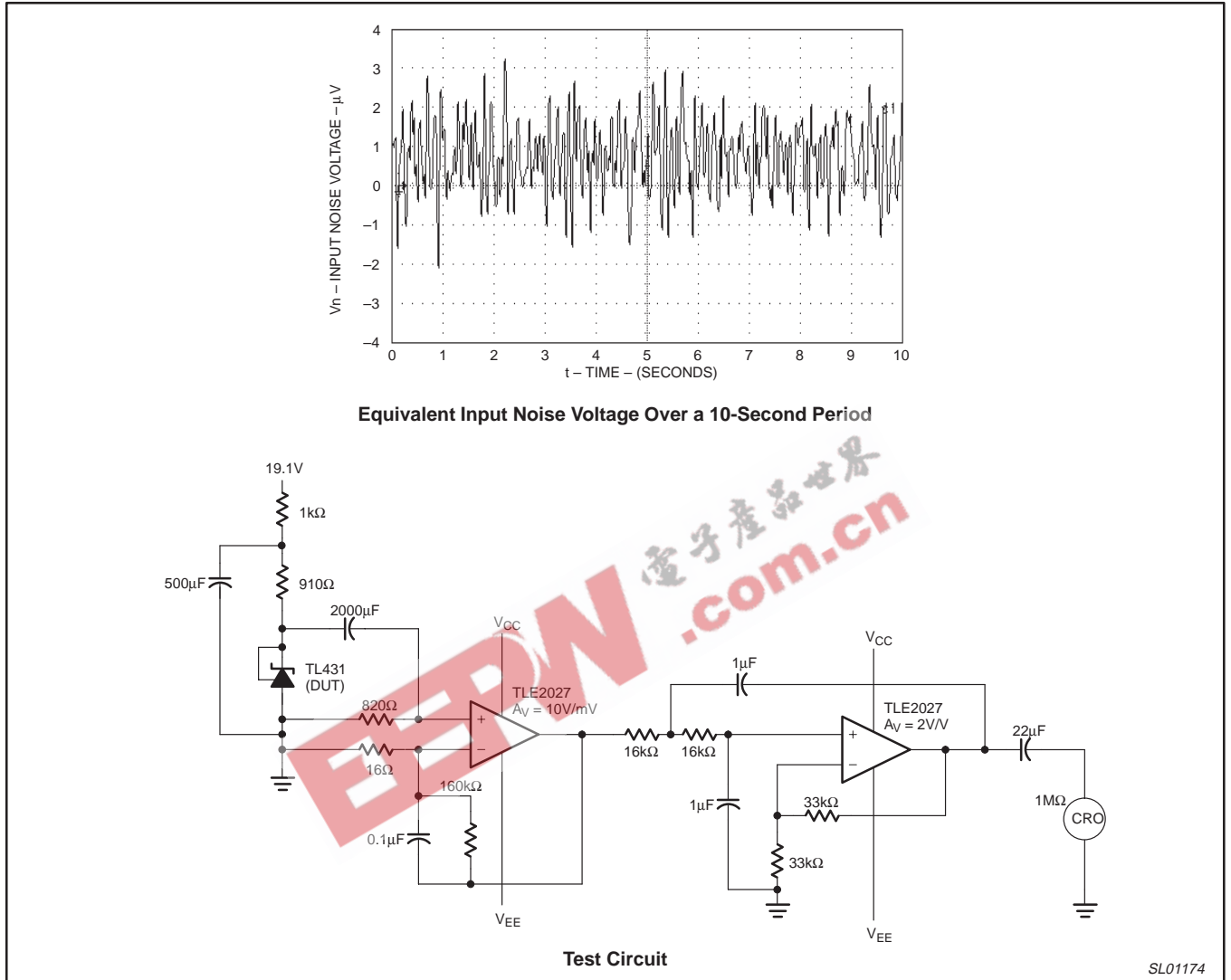


Figure 12.

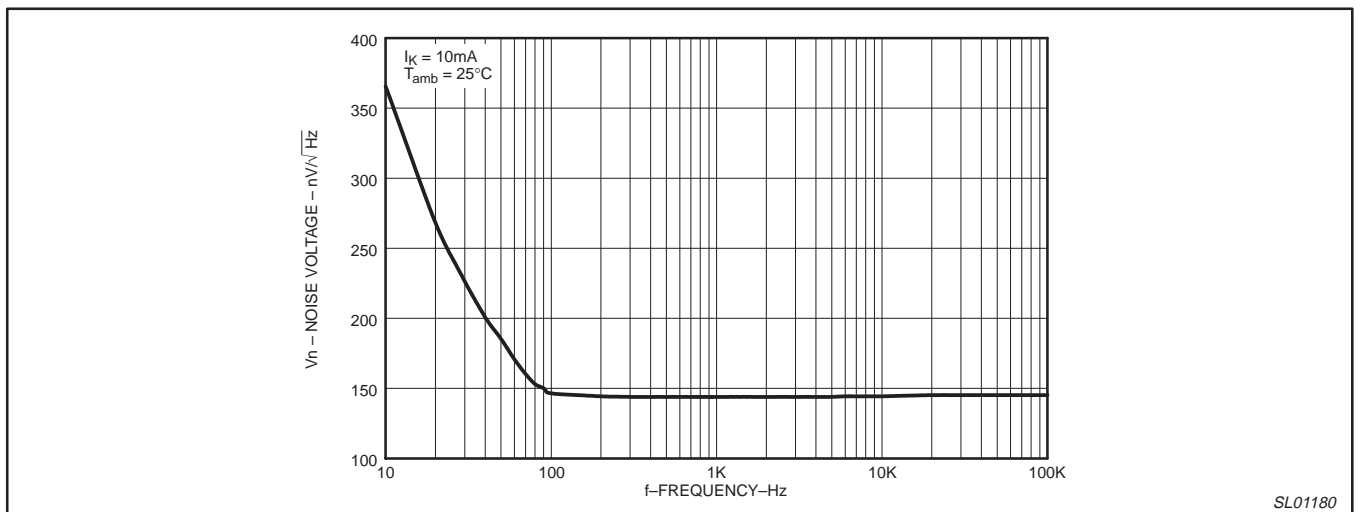


Figure 13. Equivalent Input Noise Voltage vs. Frequency

Adjustable precision shunt regulators

TL431C, TL431AC, TL431I,  
TL431AI, LM431AC

TYPICAL CHARACTERISTICS

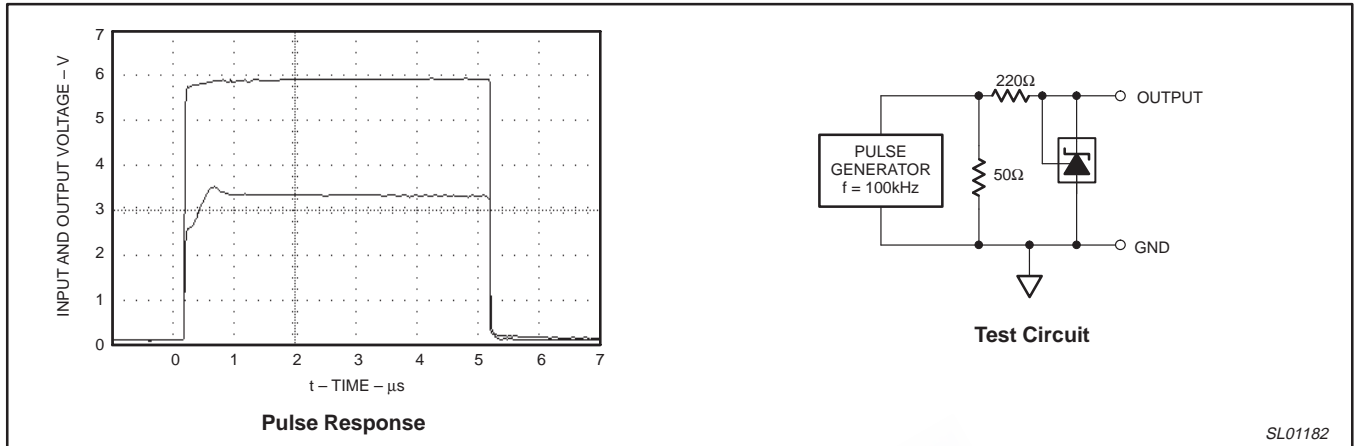


Figure 14. Pulse Response

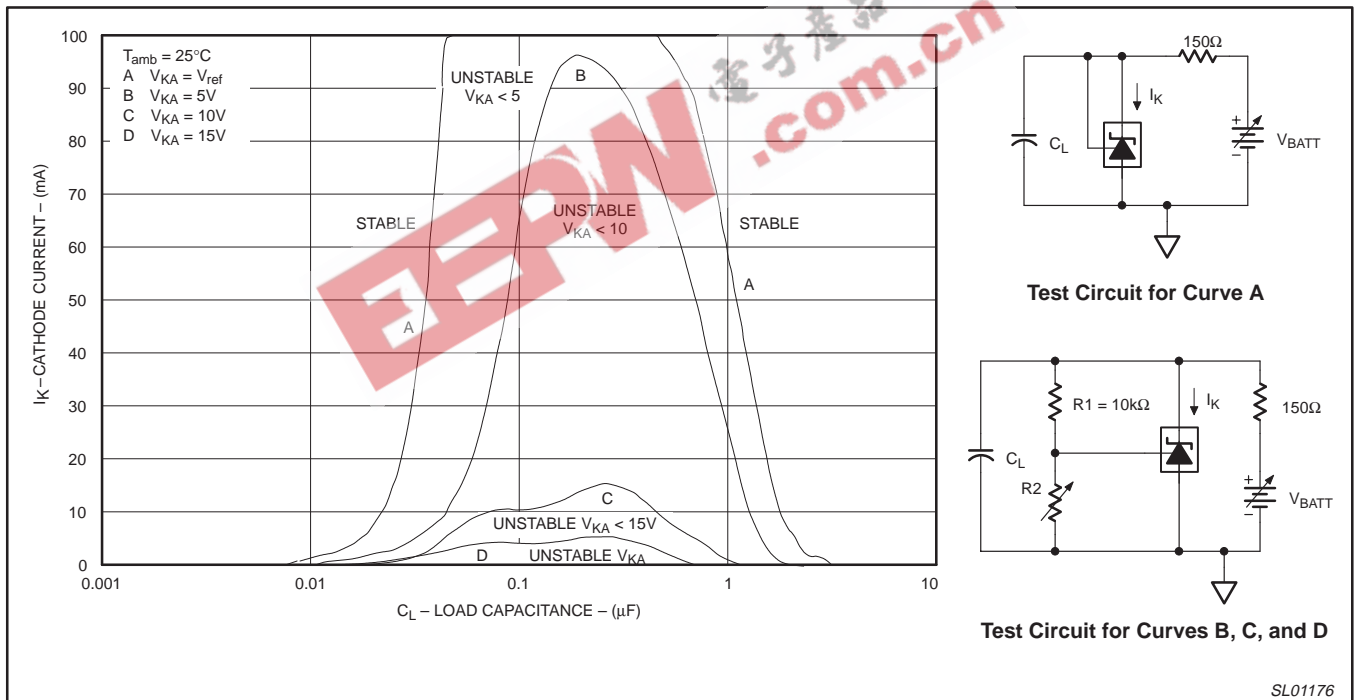


Figure 15. Stability Boundary Conditions



Adjustable precision shunt regulators

TL431C, TL431AC, TL431I,  
TL431AI, LM431AC

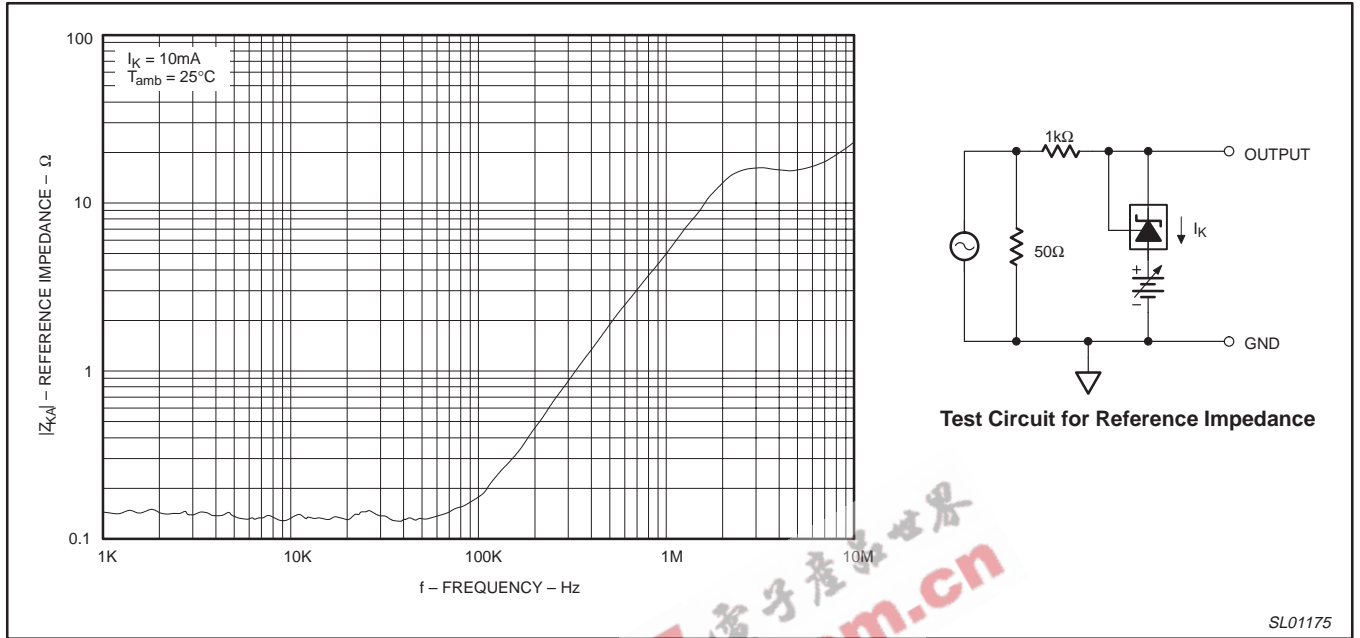


Figure 16. Reference Impedance vs. Frequency

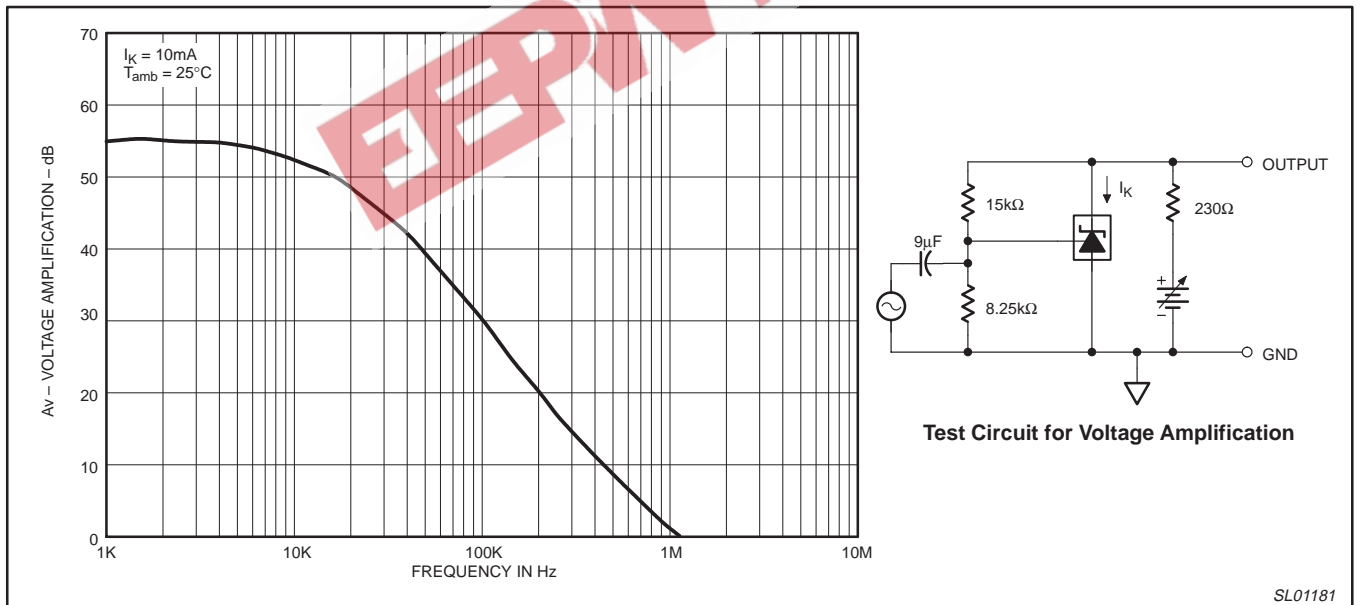


Figure 17. Small-Signal Voltage Amplification vs. Frequency

# Adjustable precision shunt regulators

# TL431C, TL431AC, TL431I, TL431AI, LM431AC

## TYPICAL APPLICATIONS

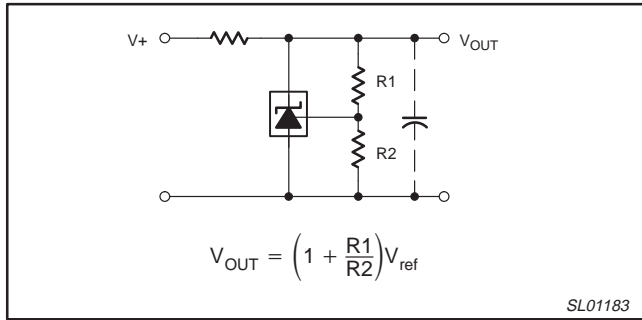


Figure 18. Shunt Regulator

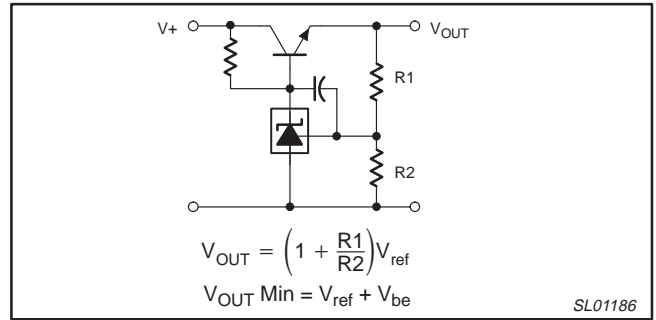


Figure 21. Series Pass Regulator

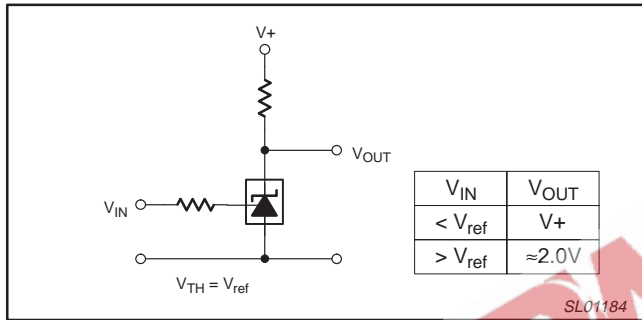


Figure 19. Single-Supply Comparator with Temperature-Compensated Threshold

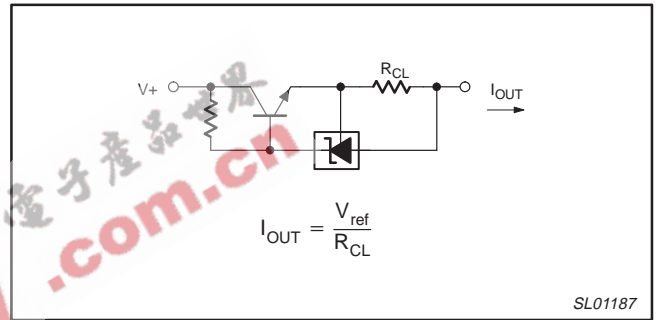


Figure 22. Constant Current Source

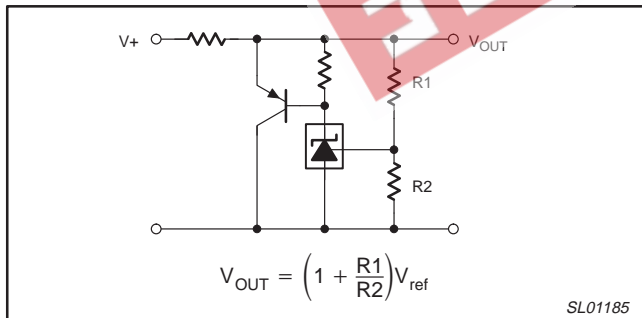


Figure 20. High Current Shunt Regulator

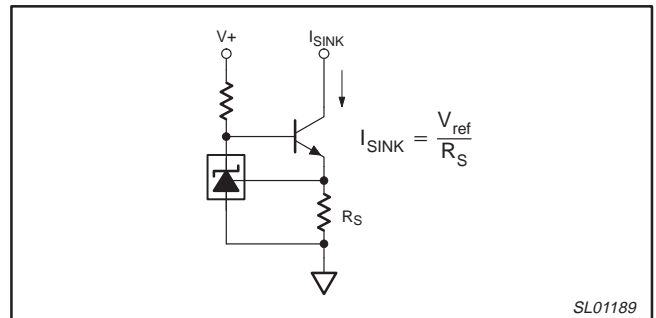


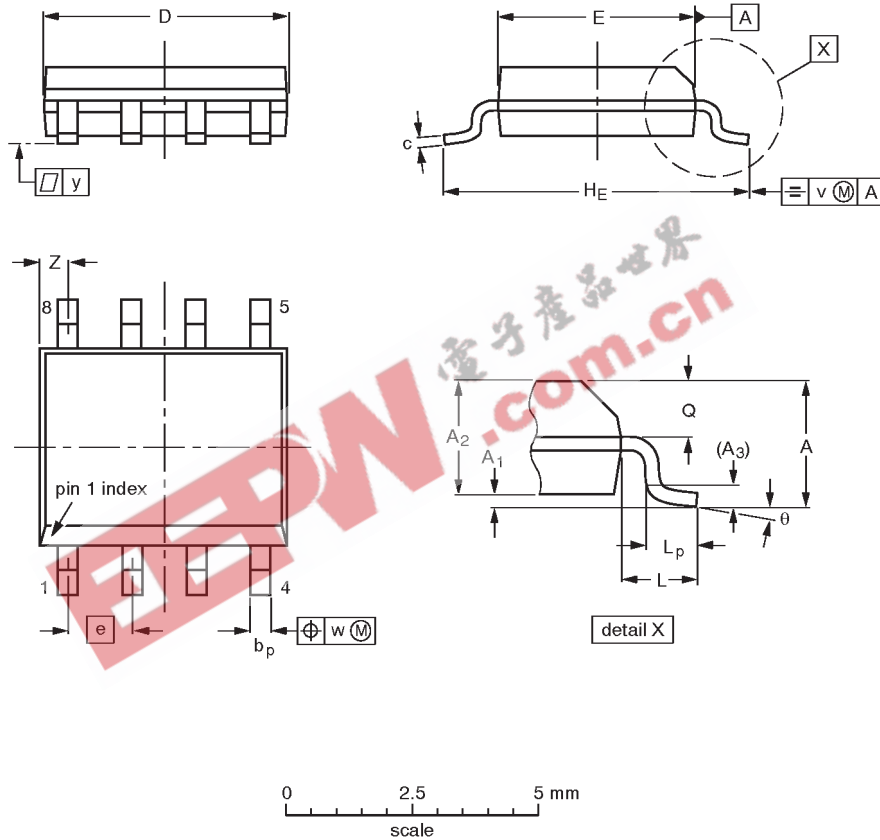
Figure 23. Constant Current Sink

Adjustable precision shunt regulators

TL431C, TL431AC, TL431I,  
TL431AI, LM431AC

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

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	H <sub>E</sub>	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	0.0098 0.0039	0.057 0.049	0.01	0.019 0.014	0.0098 0.0075	0.20 0.19	0.16 0.15	0.050	0.24 0.23	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.

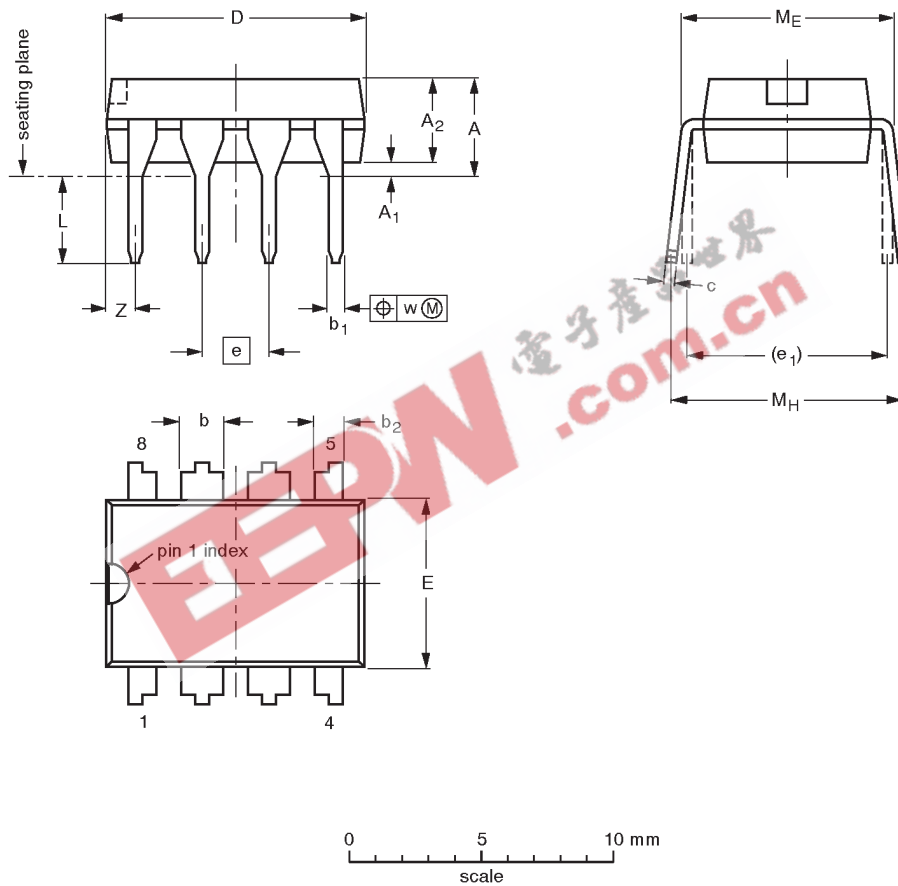
OUTLINE VERSION	REFERENCES				EUROPEAN PROJECTION	ISSUE DATE
	IEC	JEDEC	EIAJ			
SOT96-1	076E03S	MS-012AA				92-11-17 95-02-04

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

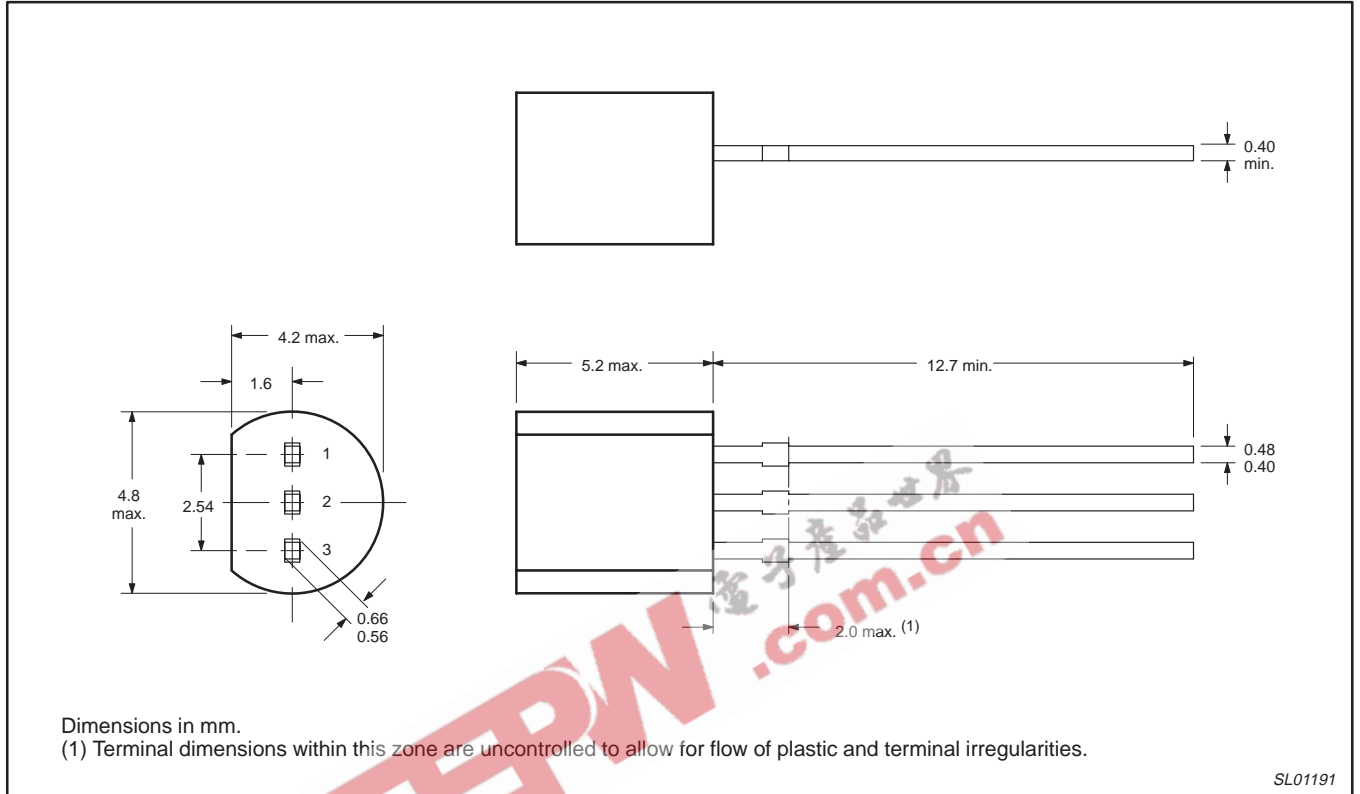
1. Plastic or metal protrusions of 0.25 mm maximum per side are not included.

OUTLINE VERSION	REFERENCES				EUROPEAN PROJECTION	ISSUE DATE
	IEC	JEDEC	EIAJ			
SOT97-1	050G01	MO-001AN				92-11-17 95-02-04

Adjustable precision shunt regulators

TL431C, TL431AC, TL431I,  
TL431AI, LM431AC

SOT54



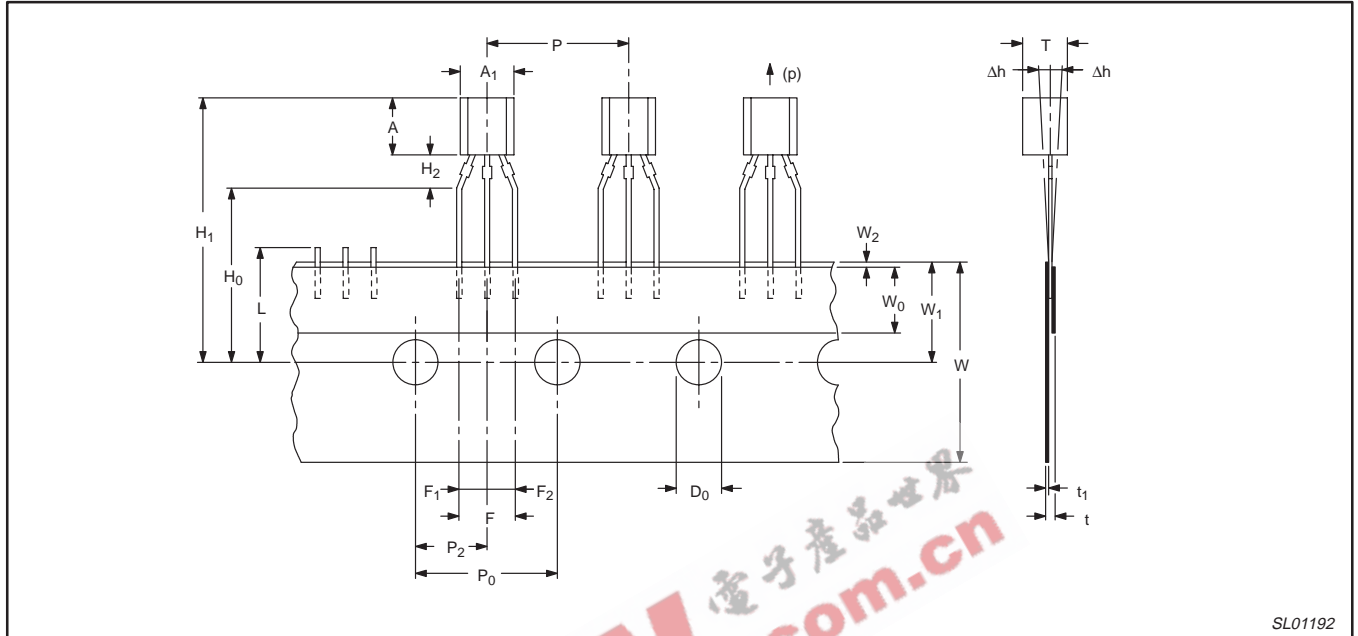
SL01191

Adjustable precision shunt regulators

TL431C, TL431AC, TL431I,  
TL431AI, LM431AC

TO-92 transistors on tape

TO-92



SL01192

Table 2. Tape specification (TO-92 leaded types)

SYMBOL	DIMENSION	SPECIFICATIONS					REMARKS
		MIN.	NOM.	MAX.	TOL.	UNIT	
A <sub>1</sub>	Body width	4	–	4.8	–	mm	
A	Body height	4.8		5.2	–	mm	
T	Body thickness	3.5		3.9	–	mm	
P	Pitch of component	–	12.7	–	±1	mm	
P <sub>0</sub>	Feed hole pitch	–	12.7	–	±0.3	mm	
	Cumulative pitch error	–	–	–	±0.1	mm	Note 1
P <sub>2</sub>	Feed hole center to component center	–	6.35	–	±0.4	mm	to be measured at bottom of clinch
F	Distance between outer leads	–	5.08	–	+0.6/–0.2	mm	
Δh	Component alignment	–	0	1	–	mm	
W	Tape width	–	18	–	±0.5	mm	
W <sub>0</sub>	Hold-down tape width	–	6	–	±0.2	mm	
W <sub>1</sub>	Hole position	–	9	–	+0.7/–0.5	mm	
W <sub>2</sub>	Hold-down tape position	–	0.5	–	±0.2	mm	
H <sub>0</sub>	Lead wire clinch height	–	16.5	–	±0.5	mm	
H <sub>1</sub>	Component height	–	–	23.25	–	mm	
L	Length of snipped leads	–	–	11	–	mm	
D <sub>0</sub>	Feed hole diameter	–	4	–	±0.2	mm	
t	Total tape thickness	–	–	1.2	–	mm	
F <sub>1</sub> , F <sub>2</sub>	Lead-to-lead distance	–	–	–	+0.4/–0.2	mm	
H <sub>2</sub>	Clinch height	–	–	–	–	mm	
(p)	Pull-out force	6	–	–	–	N	

NOTE:

1. Measured over 20 devices.

# Adjustable precision shunt regulators

# TL431C, TL431AC, TL431I, TL431AI, LM431AC

### Tape splicing

Splice the carrier tape on the back and/or front so that the feed hole pitch ( $P_0$ ) is maintained.

### Bulk packing

In addition to TO-92 on tape, TO-92 can also be delivered in bulk. Products are packed in boxes in foil and plastic bags with 1,000 pieces to a bag and 5 bags to a box.

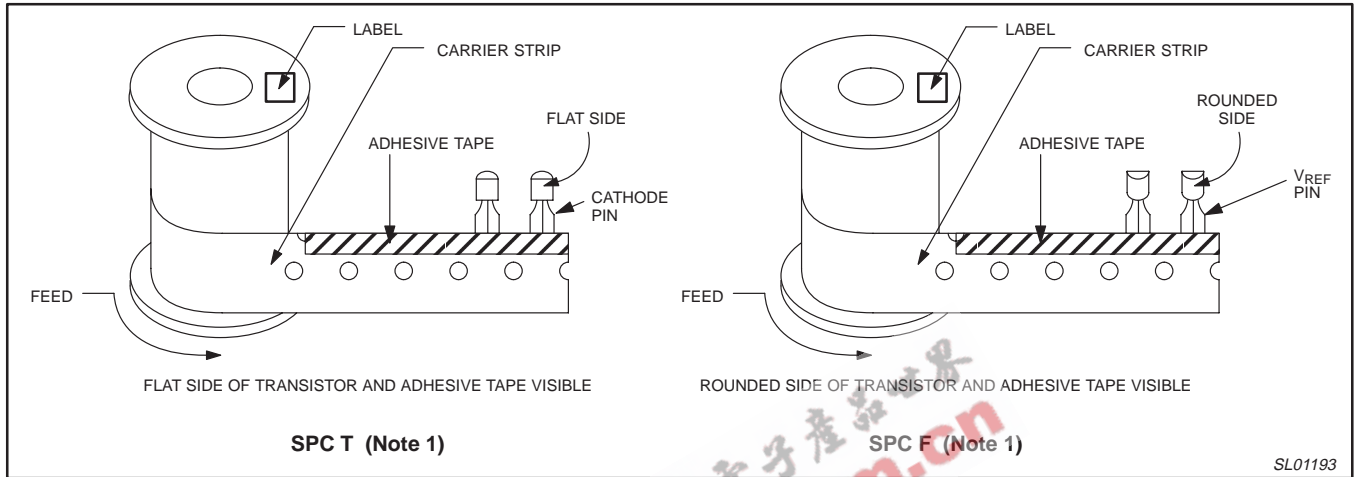
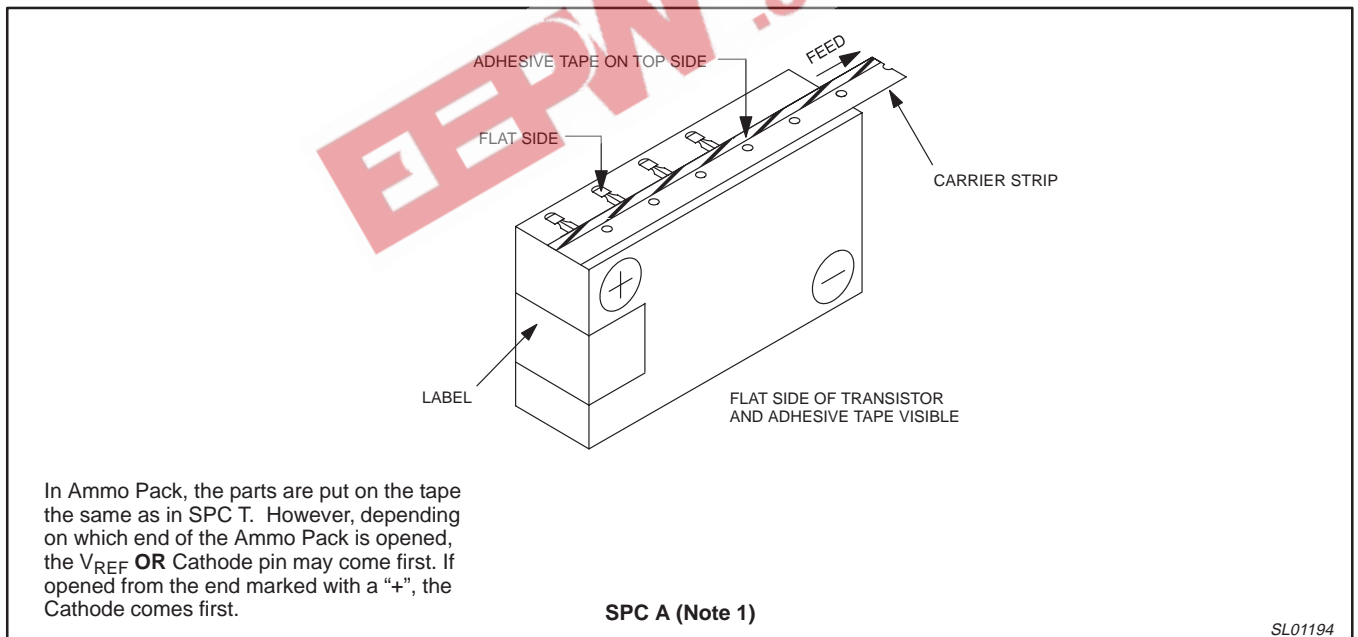


Figure 24. TO-92 Reel Styles

SL01193



SPC A (Note 1)

SL01194

Figure 25. TO-92 Ammo Pack Styles

**NOTE:**

1. Order SPC F, T or A depending on what is required.

## Adjustable precision shunt regulators

TL431C, TL431AC, TL431I,  
TL431AI, LM431AC

## DEFINITIONS

Data Sheet Identification	Product Status	Definition
<i>Objective Specification</i>	<b>Formative or in Design</b>	This data sheet contains the design target or goal specifications for product development. Specifications may change in any manner without notice.
<i>Preliminary Specification</i>	<b>Preproduction Product</b>	This data sheet contains preliminary data, and supplementary data will be published at a later date. Philips Semiconductors reserves the right to make changes at any time without notice in order to improve design and supply the best possible product.
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