

DATA SHEET

Datasheet.Live

**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 0.2Ω. 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: 30ppm/°C
- 0.2Ω typical output impedance
- Sink current capability: 1mA to 100mA
- Low output noise
- Adjustable output voltage: V_{REF} to 36V

PIN CONFIGURATIONS

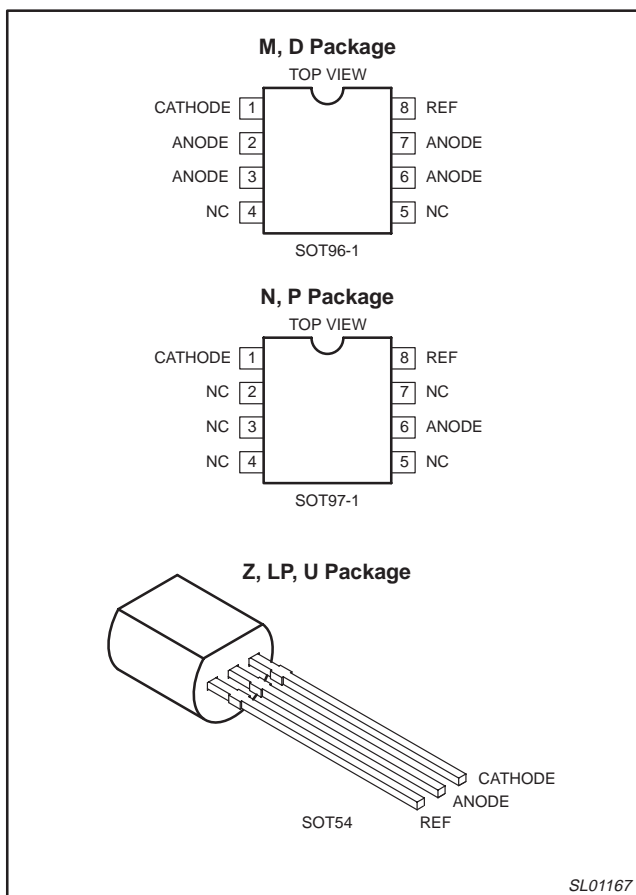


Figure 1. Pin Configuration

ORDERING INFORMATION

| DESCRIPTION | TEMPERATURE RANGE | INDUSTRY STANDARD PART NUMBER | ORDER CODE | DWG # |
|--|-------------------|-------------------------------|------------|---------|
| 3-Pin Plastic TO92 ² | 0°C to +70°C | TL431CLP | TL431CLPU | SOT54 |
| 3-Pin Plastic TO92 ² | 0°C to +70°C | TL431ACLP | TL431ACLPU | SOT54 |
| 3-Pin Plastic TO92 ² | -40°C to +85°C | TL431ILP | TL431ILPU | SOT54 |
| 3-Pin Plastic TO92 ² | -40°C to +85°C | TL431AILP | TL431AILPU | SOT54 |
| 3-Pin Plastic TO92 ² | 0°C to +70°C | LM431ACZ | LM431ACZU | SOT54 |
| 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 |

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 | 0 to +70 | °C |
| | C suffix | -40 to +85 | °C |
| | I suffix | | |
| 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 $T_{amb} = 25^{\circ}C$ | $T_{amb} = 25^{\circ}C$ Power Rating | $T_{amb} = 70^{\circ}C$ Power Rating | $T_{amb} = 85^{\circ}C$ Power Rating |
|---------|---|--------------------------------------|--------------------------------------|--------------------------------------|
| D | 5.8mW/°C | 725mW | 464mW | 429mW |
| LP | 6.2mW/°C | 775mW | 496mW | 403mW |
| P | 8.0mW/°C | 1000mW | 640mW | 520mW |

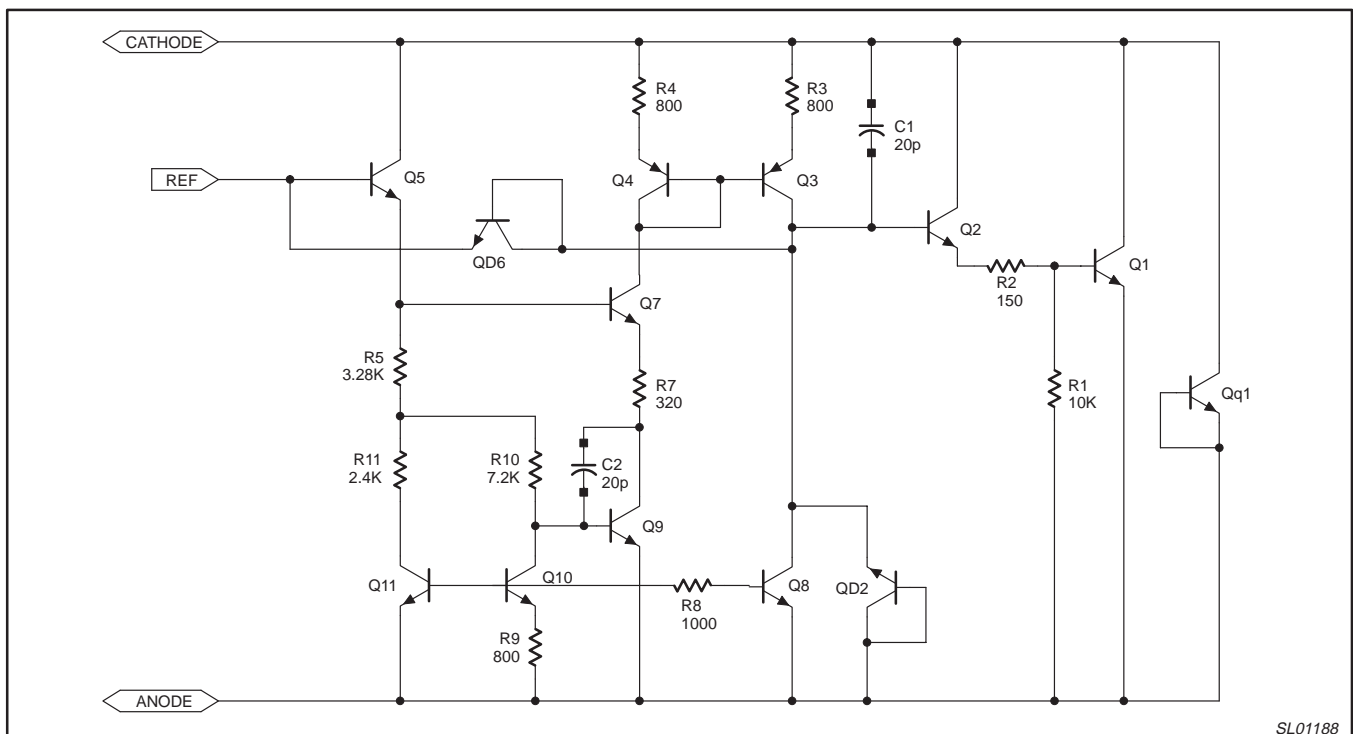


Figure 2. Equivalent Schematic

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 _{REF} | Reference input voltage | Fig. 3 | V _{KA} = V _{REF} , I _K = 10mA | 2470 | 2495 | 2520 | 2440 | 2495 | 2550 | mV |
| V _{REF(dev)} | Deviation of reference input voltage over full temperature range ³ | Fig. 3 | V _{KA} = V _{REF} , I _K = 10mA, T _{amb} = full range ² | | 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 = 10mA | ΔV _{KA} = 10V – V _{REF} | -1.4 | -2.7 | | -1.4 | -2.7 | mV/V |
| | | | | ΔV _{KA} = 36V – 10V | -1 | -2 | | -1 | -2 | |
| I _{REF} | Reference input current | Fig. 4 | I _K = 10mA, R ₁ = 10kΩ, R ₂ = ∞ | | 2 | 4 | | 2 | 4 | μA |
| I _{REF(dev)} | Deviation of reference input current over full temperature range ³ | Fig. 4 | I _K = 10mA, R ₁ = 10kΩ, R ₂ = ∞, T _{amb} = full range ² | | 0.8 | 1.2 | | 0.4 | 1.2 | μA |
| 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} = 36V, V _{REF} = 0 | | 0.1 | 0.5 | | 0.1 | 1 | μA |
| Z _{KA} | Dynamic impedance ⁴ | Fig. 3 | V _{KA} = V _{REF} , I _K = 1mA to 100mA, f ≤ 1kHz | | 0.2 | 0.5 | | 0.2 | 0.5 | Ω |

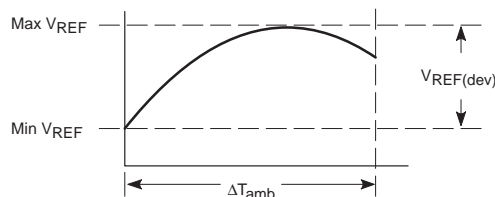
25°C free-air temperature, unless otherwise stated.

| SYMBOL | PARAMETER | TEST CKT | TEST CONDITIONS | LIMITS | | | | | | UNIT |
|--|---|----------|--|---|------|------|--------|------|------|------|
| | | | | TL431AI | | | TL431I | | | |
| | | | | MIN | TYP | MAX | MIN | TYP | MAX | |
| V _{REF} | Reference input voltage | Fig. 3 | V _{KA} = V _{REF} , I _K = 10mA | 2470 | 2495 | 2520 | 2440 | 2495 | 2550 | mV |
| V _{REF(dev)} | Deviation of reference input voltage over full temperature range ³ | Fig. 3 | V _{KA} = V _{REF} , I _K = 10mA, T _{amb} = full range ² | | 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 = 10mA | ΔV _{KA} = 10V – V _{REF} | -1.4 | -2.7 | | -1.4 | -2.7 | mV/V |
| | | | | ΔV _{KA} = 36V – 10V | -1 | -2 | | -1 | -2 | |
| I _{REF} | Reference input current | Fig. 4 | I _K = 10mA, R ₁ = 10kΩ, R ₂ = ∞ | | 2 | 4 | | 2 | 4 | μA |
| I _{REF(dev)} | Deviation of reference input current over full temperature range ³ | Fig. 4 | I _K = 10mA, R ₁ = 10kΩ, R ₂ = ∞, T _{amb} = full range ² | | 0.8 | 2.5 | | 0.8 | 2.5 | μA |
| I _{MIN} | Minimum cathode current for regulation | Fig. 3 | V _{KA} = V _{REF} | | 0.4 | 0.7 | | 0.4 | 1 | μA |
| I _{OFF} | Off-state cathode current | Fig. 5 | V _{KA} = 36V, V _{REF} = 0 | | 0.1 | 0.5 | | 0.1 | 1 | μA |
| Z _{KA} | Dynamic impedance ⁴ | Fig. 3 | V _{KA} = V _{REF} , I _K = 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_{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, αV_{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 ΔT_{amb} is the rated operating free-air temperature range of the device.

Adjustable precision shunt regulators

TL431C, TL431AC, TL431I, TL431AI, LM431AC

αV_{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°C , Min $V_{REF} = 2492\text{mV}$ at 0°C , $V_{REF} = 2495\text{mV}$ at 25°C , $\text{DTA} = 70^\circ\text{C}$ 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

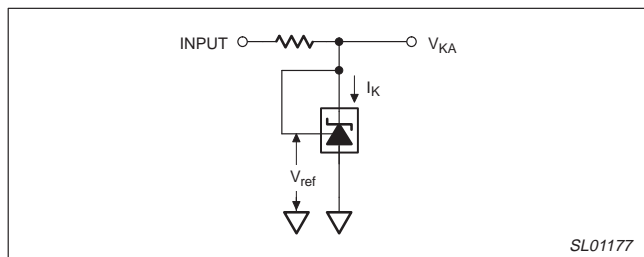


Figure 3. Test Circuit for $V_{KA} = V_{ref}$

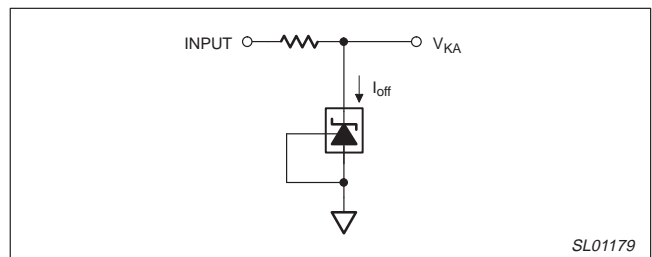


Figure 5. Test Circuit for I_{OFF}

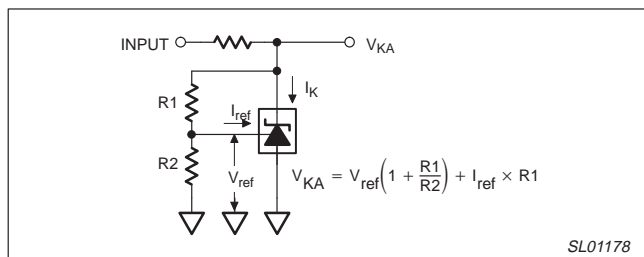


Figure 4. Test Circuit for $V_{KA} > V_{ref}$

Adjustable precision shunt regulators

TL431C, TL431AC, TL431I, TL431AI, LM431AC

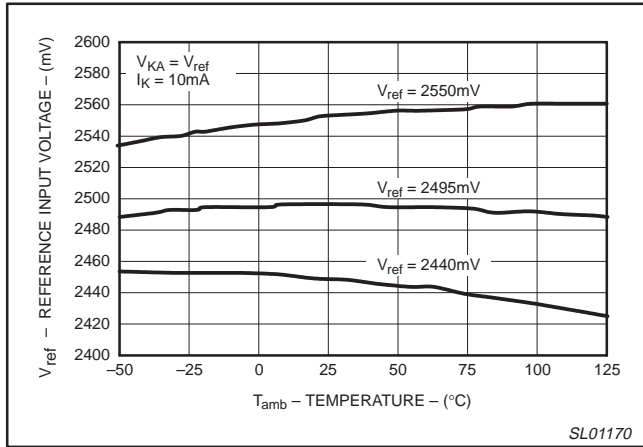


Figure 6. Reference Input Voltage vs. Temperature

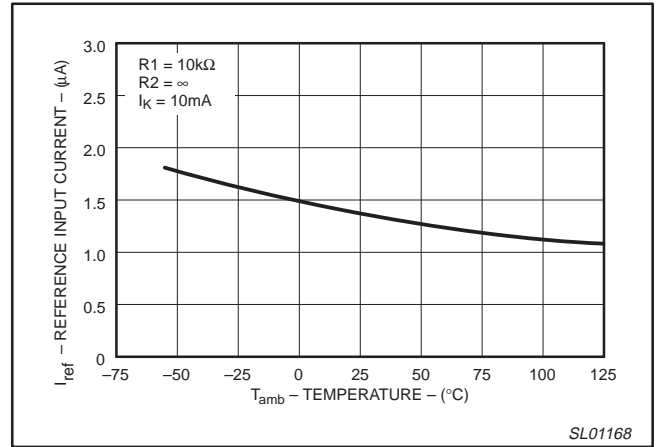


Figure 9. Reference Input Current vs. Temperature

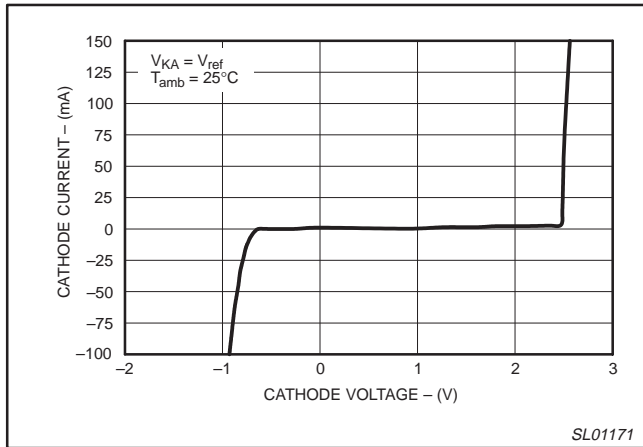


Figure 7. Cathode Current vs. Cathode Voltage

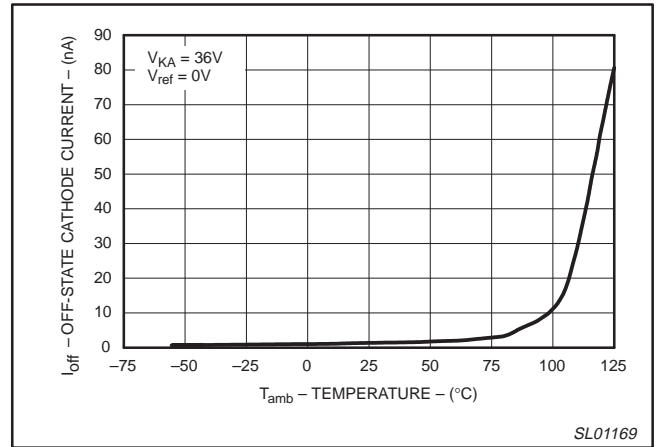


Figure 10. Off-State Cathode Current vs. Temperature

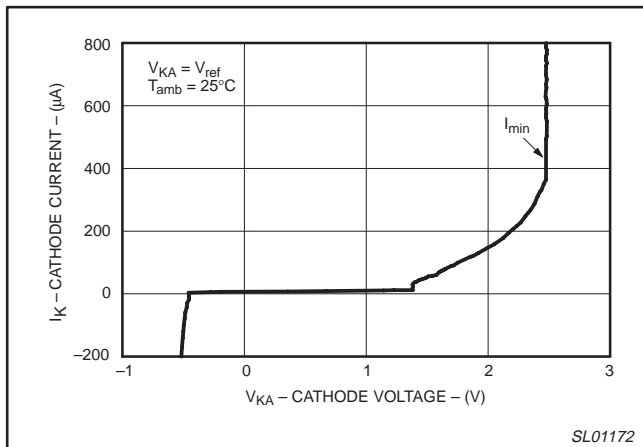


Figure 8. Cathode Current vs. Cathode Voltage

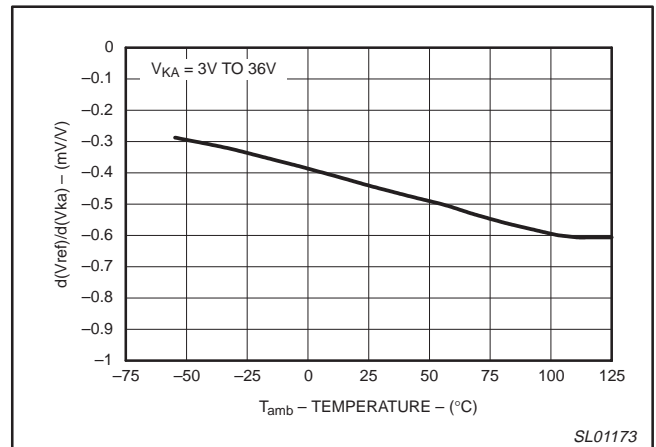


Figure 11. Ratio of Delta Reference Voltage to Delta Cathode Voltage over Temperature

Adjustable precision shunt regulators

TL431C, TL431AC, TL431I,
TL431AI, LM431AC

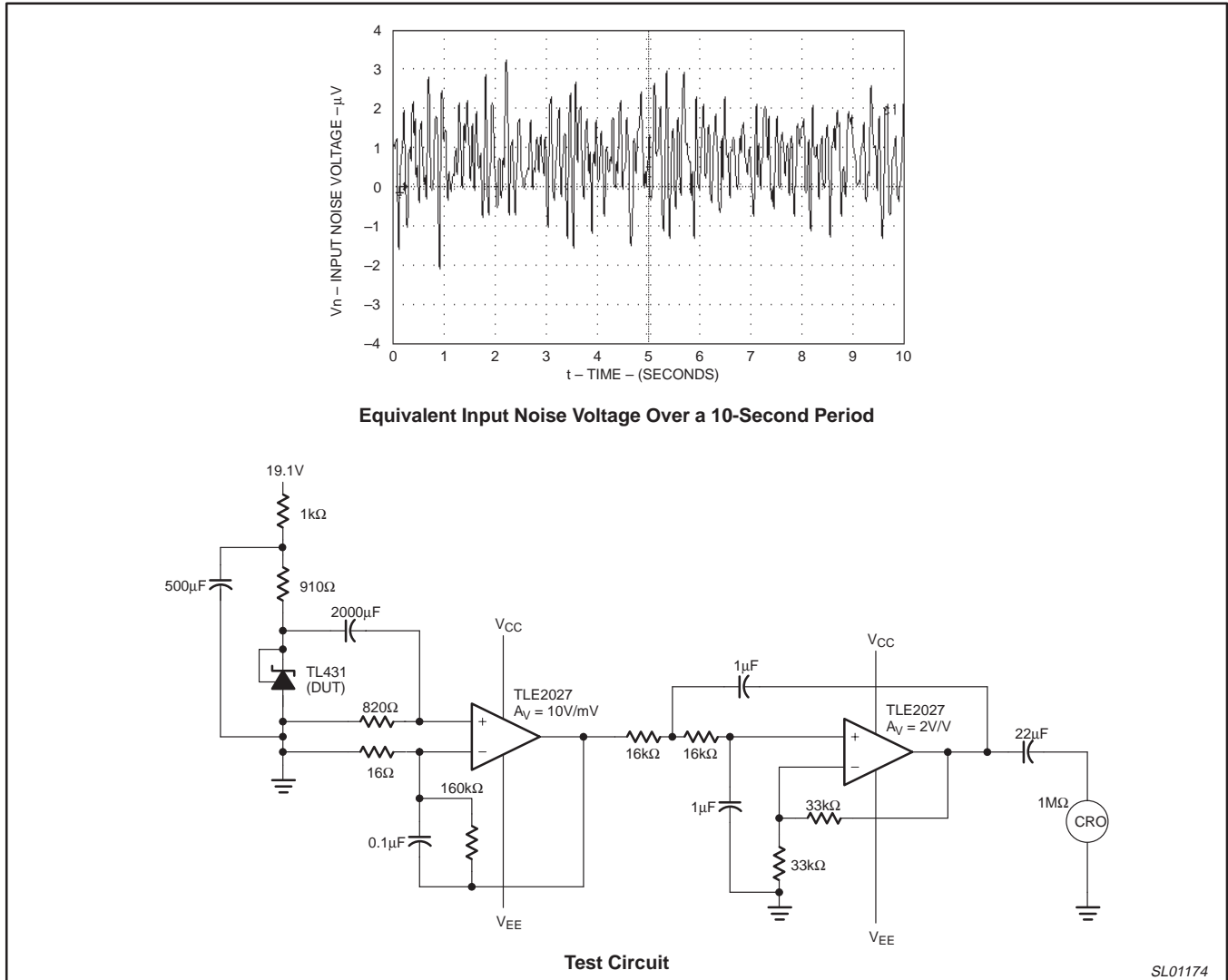


Figure 12.

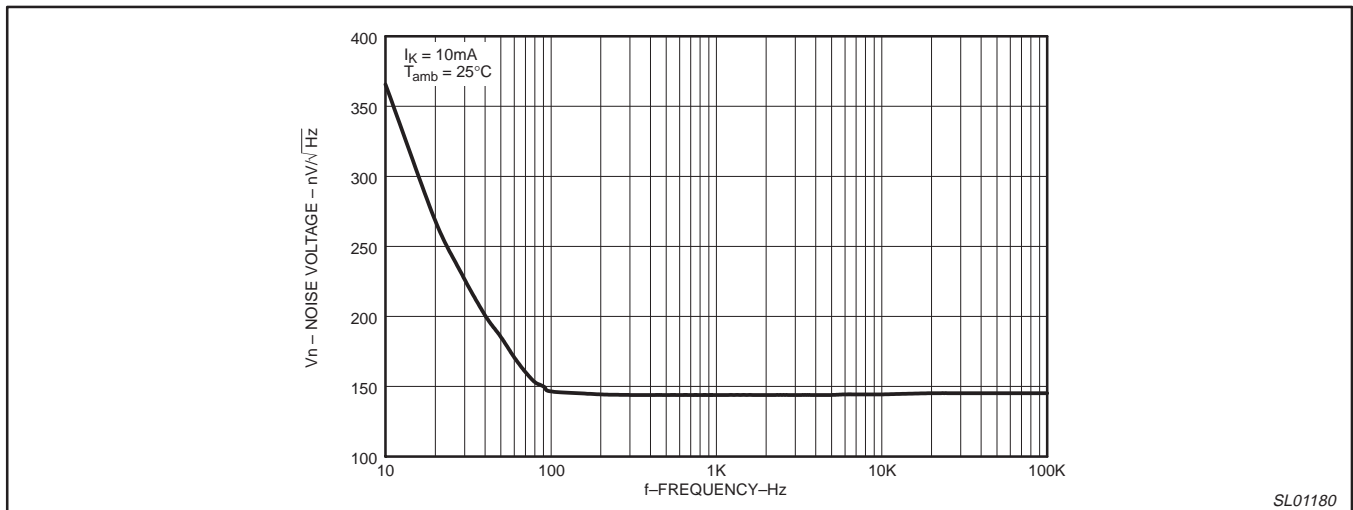


Figure 13. Equivalent Input Noise Voltage vs. Frequency

Adjustable precision shunt regulators

TL431C, TL431AC, TL431I,
TL431AI, LM431AC

TYPICAL CHARACTERISTICS

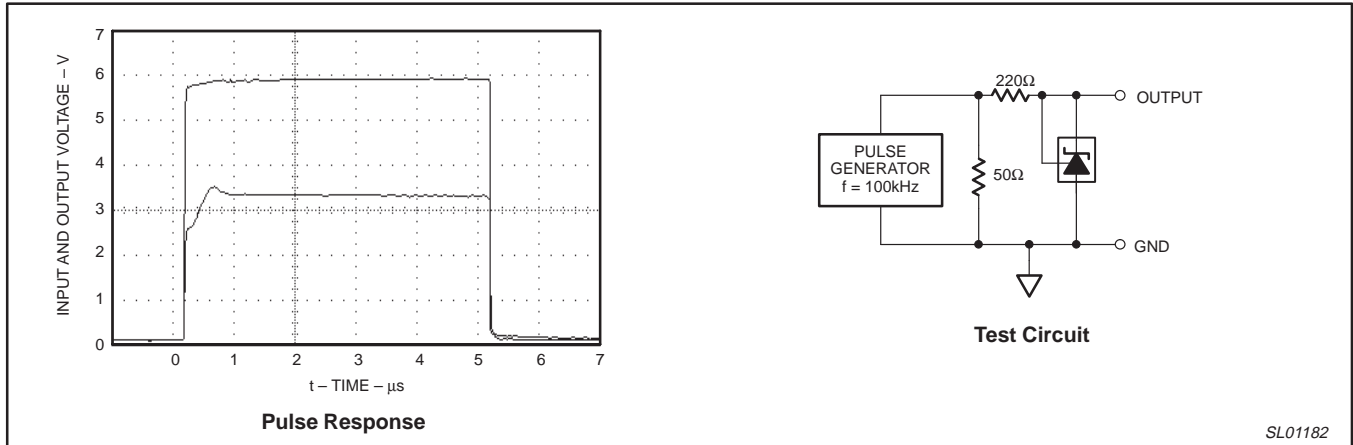


Figure 14. Pulse Response

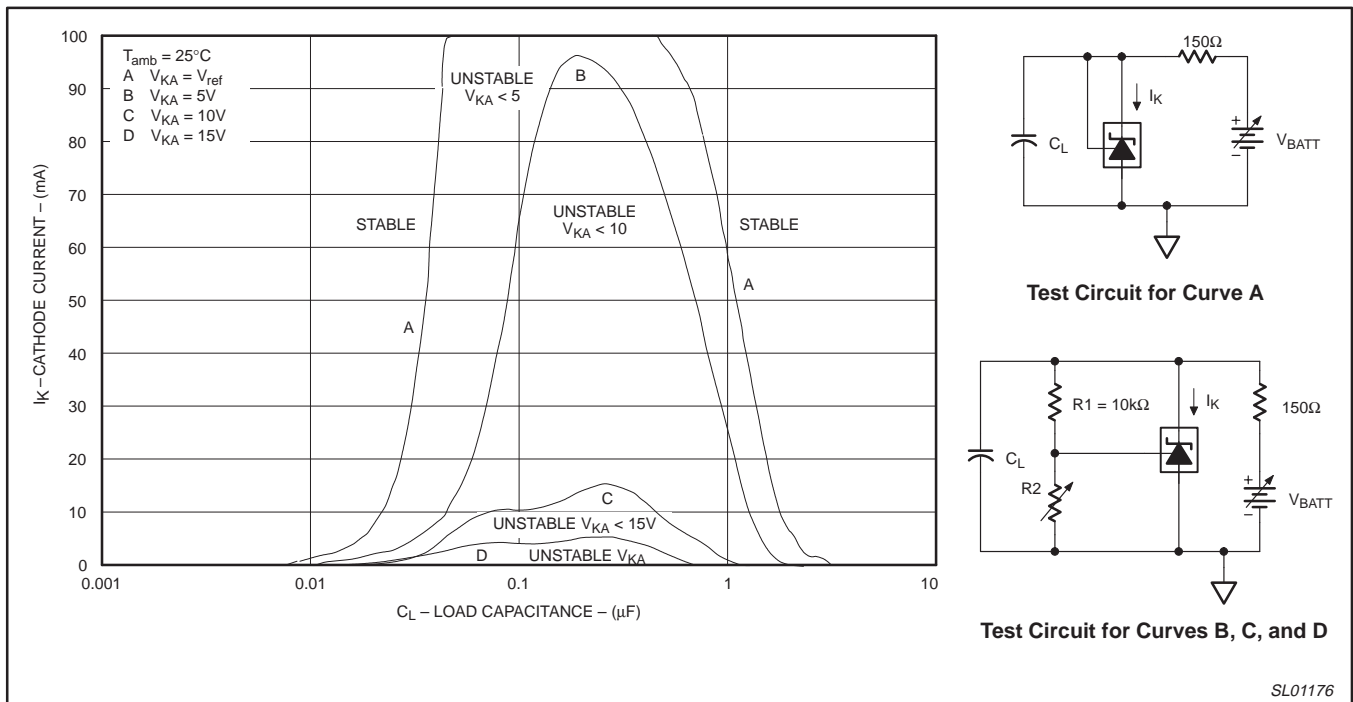
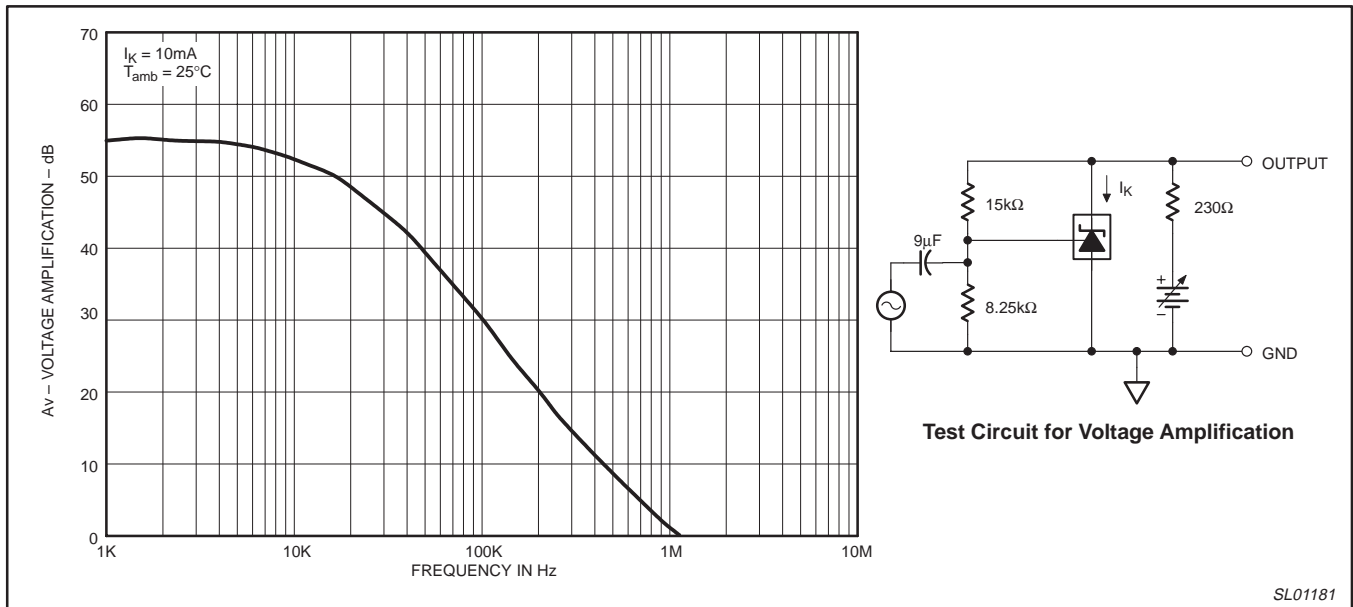
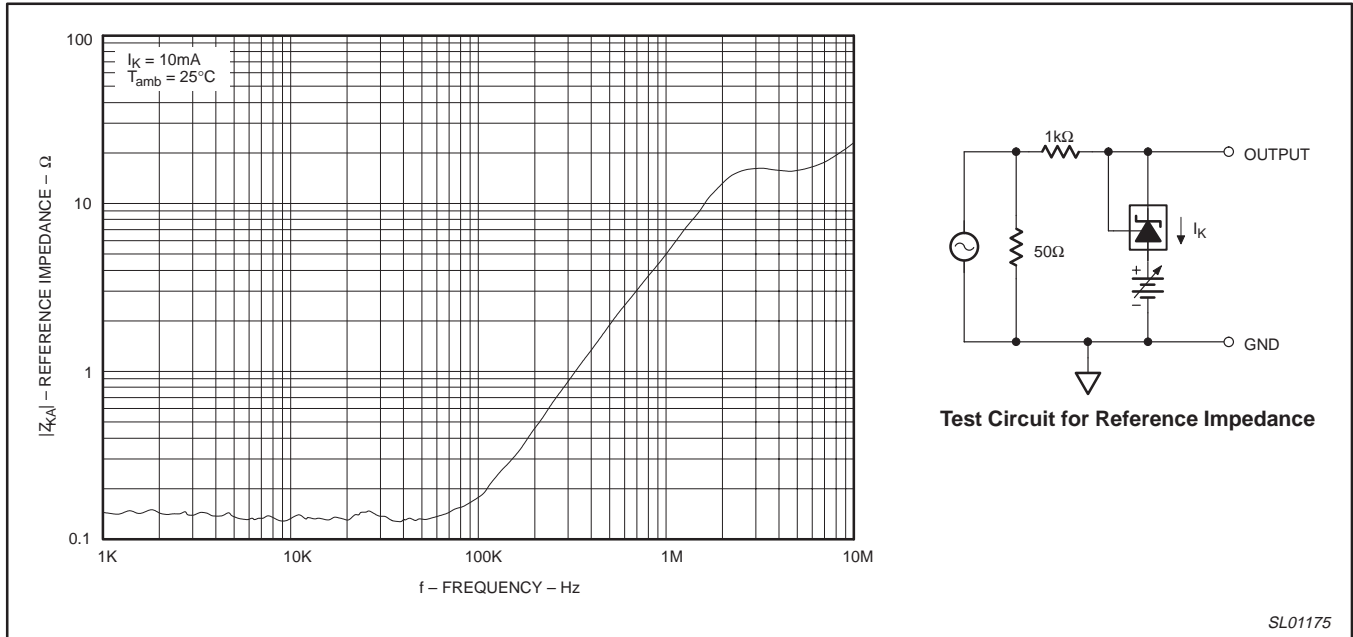


Figure 15. Stability Boundary Conditions

Adjustable precision shunt regulators

TL431C, TL431AC, TL431I,
TL431AI, LM431AC



Adjustable precision shunt regulators

TL431C, TL431AC, TL431I,
TL431AI, LM431AC

TYPICAL APPLICATIONS

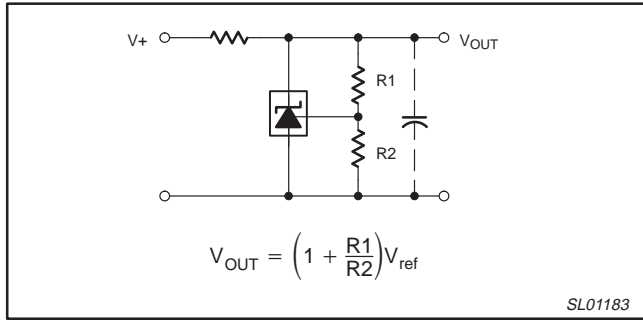


Figure 18. Shunt Regulator

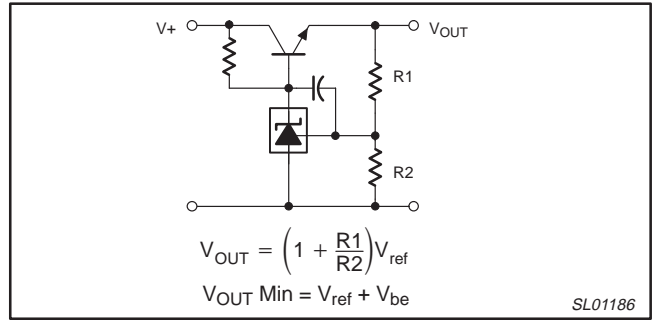


Figure 21. Series Pass Regulator

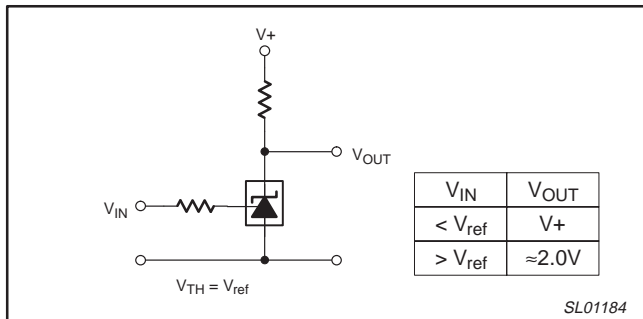


Figure 19. Single-Supply Comparator with Temperature-Compensated Threshold

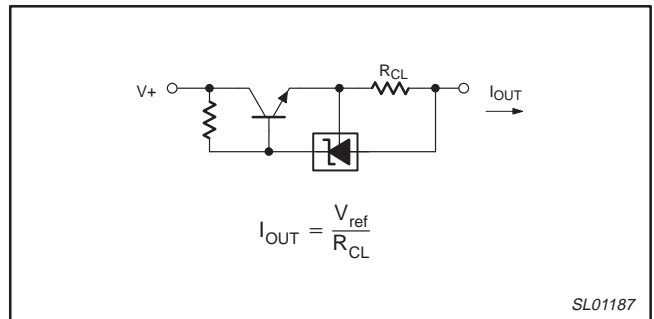


Figure 22. Constant Current Source

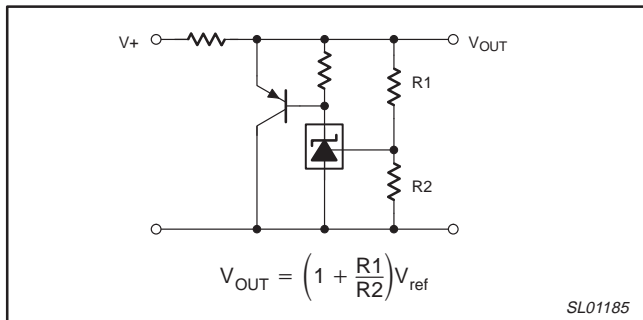


Figure 20. High Current Shunt Regulator

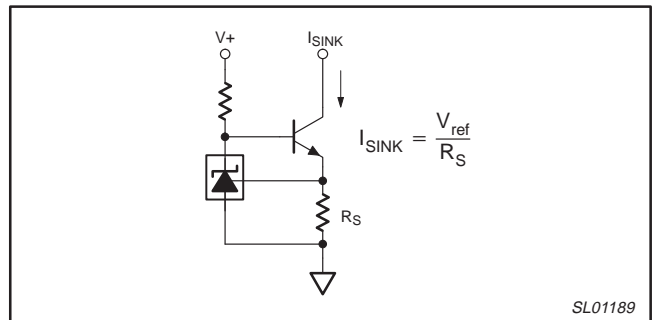


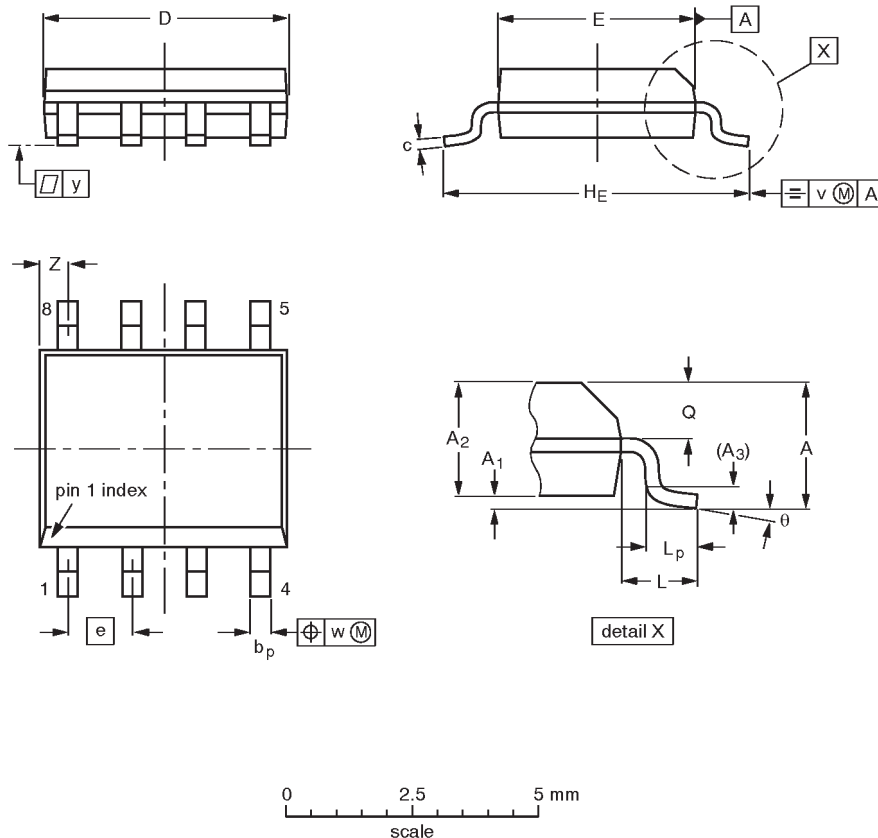
Figure 23. Constant Current Sink

Adjustable precision shunt regulators

TL431C, TL431AC, TL431I,
TL431AI, LM431AC

SO8: 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 ₁ | A ₂ | A ₃ | b _p | c | D ⁽¹⁾ | E ⁽²⁾ | e | H _E | L | L _p | Q | v | w | y | Z ⁽¹⁾ | 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.

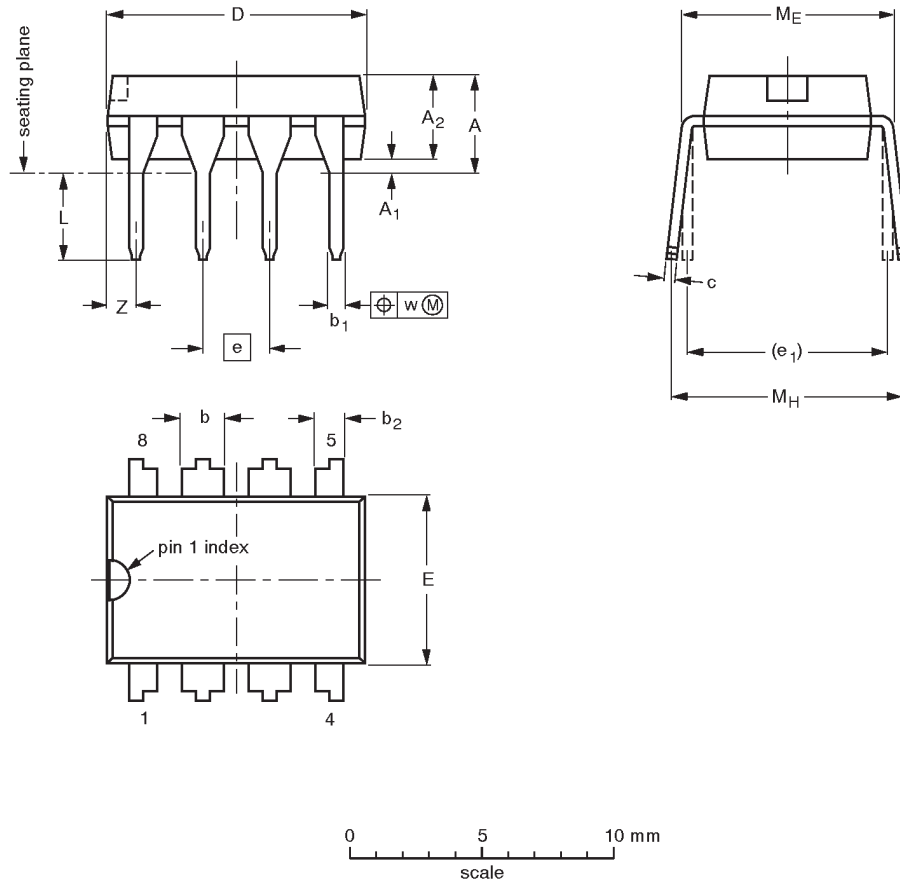
| OUTLINE VERSION | REFERENCES | | | | EUROPEAN PROJECTION | ISSUE DATE |
|-----------------|------------|----------|------|--|---------------------|----------------------|
| | IEC | JEDEC | EIAJ | | | |
| SOT96-1 | 076E03S | MS-012AA | | | | 92-11-17 95-02-04 |

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 ₁ min. | A ₂ max. | b | b ₁ | b ₂ | c | D ⁽¹⁾ | E ⁽¹⁾ | e | e ₁ | L | M _E | M _H | w | Z ⁽¹⁾ 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

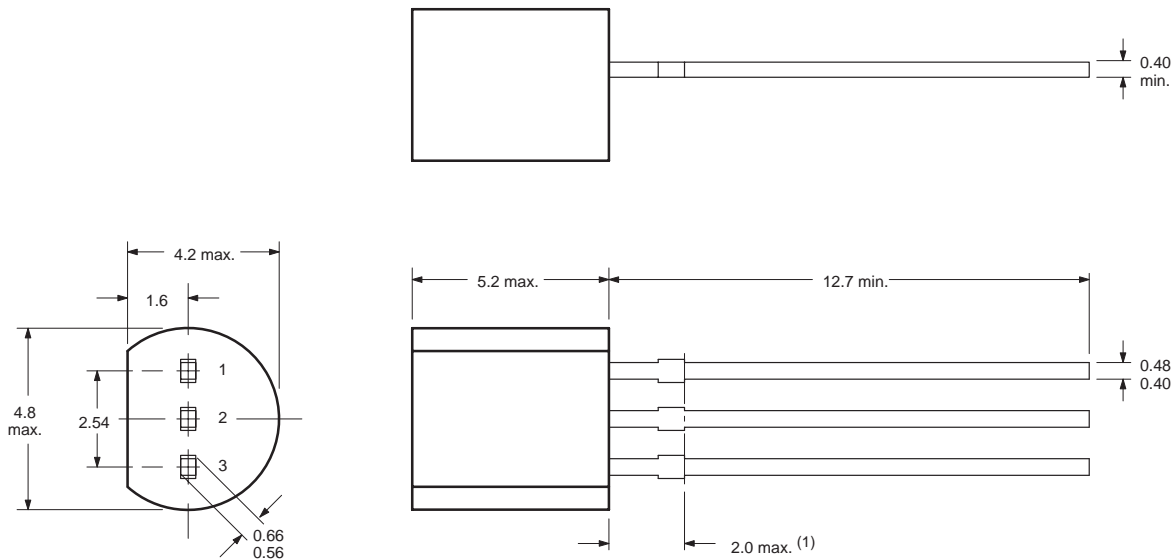
1. Plastic or metal protrusions of 0.25 mm maximum per side are not included.

| 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



Dimensions in mm.

(1) Terminal dimensions within this zone are uncontrolled to allow for flow of plastic and terminal irregularities.

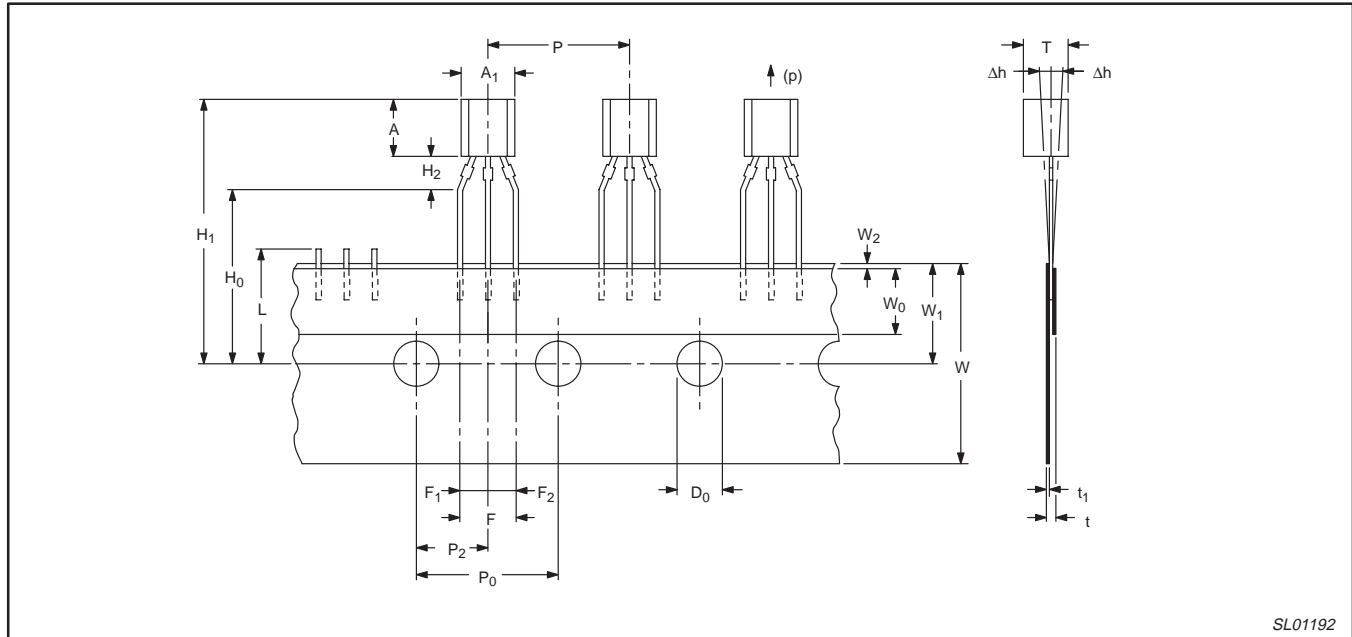
SL01191

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 ₁ | 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 ₀ | Feed hole pitch | – | 12.7 | – | ±0.3 | mm | |
| | Cumulative pitch error | – | – | – | ±0.1 | mm | Note 1 |
| P ₂ | 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 ₀ | Hold-down tape width | – | 6 | – | ±0.2 | mm | |
| W ₁ | Hole position | – | 9 | – | +0.7/–0.5 | mm | |
| W ₂ | Hold-down tape position | – | 0.5 | – | ±0.2 | mm | |
| H ₀ | Lead wire clinch height | – | 16.5 | – | ±0.5 | mm | |
| H ₁ | Component height | – | – | 23.25 | – | mm | |
| L | Length of snapped leads | – | – | 11 | – | mm | |
| D ₀ | Feed hole diameter | – | 4 | – | ±0.2 | mm | |
| t | Total tape thickness | – | – | 1.2 | – | mm | |
| F ₁ , F ₂ | Lead-to-lead distance | – | – | – | +0.4/–0.2 | mm | |
| H ₂ | 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.

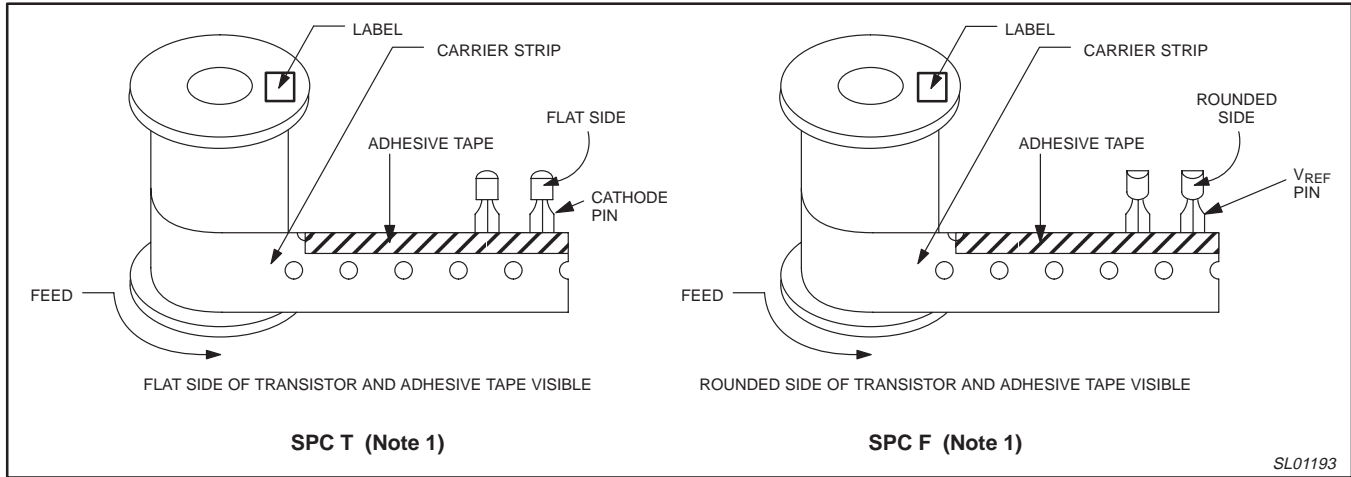


Figure 24. TO-92 Reel Styles

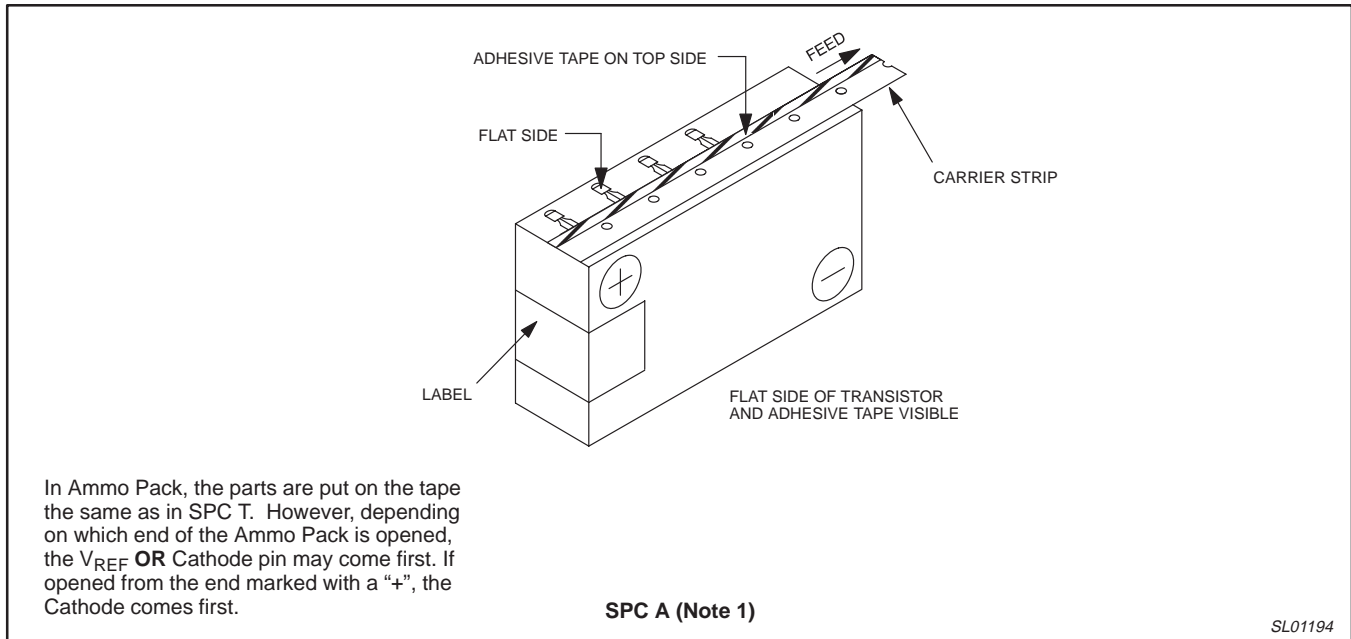


Figure 25. TO-92 Ammo Pack Styles

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> | Formative or in Design | 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> | Preproduction Product | 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. |
| <i>Product Specification</i> | Full Production | This data sheet contains Final Specifications. Philips Semiconductors reserves the right to make changes at any time without notice, in order to improve design and supply the best possible product. |

Philips Semiconductors and Philips Electronics North America Corporation reserve the right to make changes, without notice, in the products, including circuits, standard cells, and/or software, described or contained herein in order to improve design and/or performance. Philips Semiconductors assumes no responsibility or liability for the use of any of these products, conveys no license or title under any patent, copyright, or mask work right to these products, and makes no representations or warranties that these products are free from patent, copyright, or mask work right infringement, unless otherwise specified. Applications that are described herein for any of these products are for illustrative purposes only. Philips Semiconductors makes no representation or warranty that such applications will be suitable for the specified use without further testing or modification.

LIFE SUPPORT APPLICATIONS

Philips Semiconductors and Philips Electronics North America Corporation Products are not designed for use in life support appliances, devices, or systems where malfunction of a Philips Semiconductors and Philips Electronics North America Corporation Product can reasonably be expected to result in a personal injury. Philips Semiconductors and Philips Electronics North America Corporation customers using or selling Philips Semiconductors and Philips Electronics North America Corporation Products for use in such applications do so at their own risk and agree to fully indemnify Philips Semiconductors and Philips Electronics North America Corporation for any damages resulting from such improper use or sale.

Philips Semiconductors
811 East Arques Avenue
P.O. Box 3409
Sunnyvale, California 94088-3409
Telephone 800-234-7381

© Copyright Philips Electronics North America Corporation 1997
All rights reserved. Printed in U.S.A.

Let's make things better.