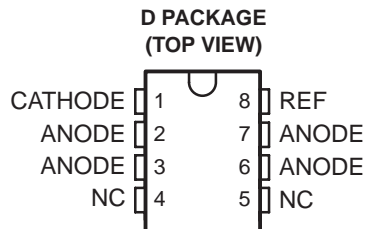


- Qualified for Automotive Applications
- 0.4% Initial Voltage Tolerance
- 0.2-Ω Typical Output Impedance
- Fast Turnon . . . 500 ns
- Sink Current Capability . . . 1 mA to 100 mA
- Low Reference Current (REF)
- Adjustable Output Voltage . . .  $V_{I(\text{ref})}$  to 36 V



NC – No internal connection  
ANODE terminals are connected internally.

## description/ordering information

The TL1431 is a precision programmable reference with specified thermal stability over the automotive temperature range. The output voltage can be set to any value between  $V_{I(\text{ref})}$  (approximately 2.5 V) and 36 V with two external resistors (see Figure 16). This device has a typical output impedance of 0.2 Ω. Active output circuitry provides a very sharp turnon characteristic, making the device an excellent replacement for Zener diodes and other types of references in applications such as onboard regulation, adjustable power supplies, and switching power supplies.

The TL1431Q is characterized for operation over the full automotive temperature range of –40°C to 125°C.

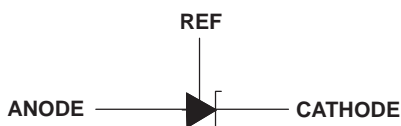
## ORDERING INFORMATION†

| T <sub>A</sub> | PACKAGE‡ |              | ORDERABLE PART NUMBER | TOP-SIDE MARKING |
|----------------|----------|--------------|-----------------------|------------------|
| –40°C to 125°C | SOIC (D) | Reel of 2500 | TL1431QDRQ1           | 1431Q1           |

† For the most current package and ordering information, see the Package Option Addendum at the end of this document, or see the TI web site at <http://www.ti.com>.

‡ Package drawings, thermal data, and symbolization are available at <http://www.ti.com/packaging>.

## symbol



Please be aware that an important notice concerning availability, standard warranty, and use in critical applications of Texas Instruments semiconductor products and disclaimers thereto appears at the end of this data sheet.

PRODUCTION DATA information is current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.

**TEXAS  
INSTRUMENTS**

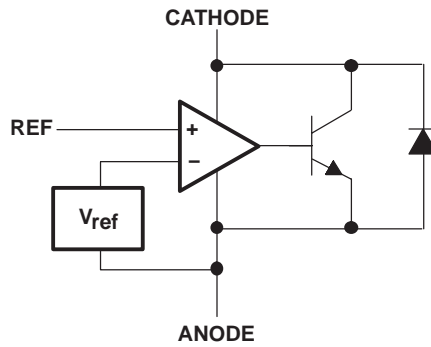
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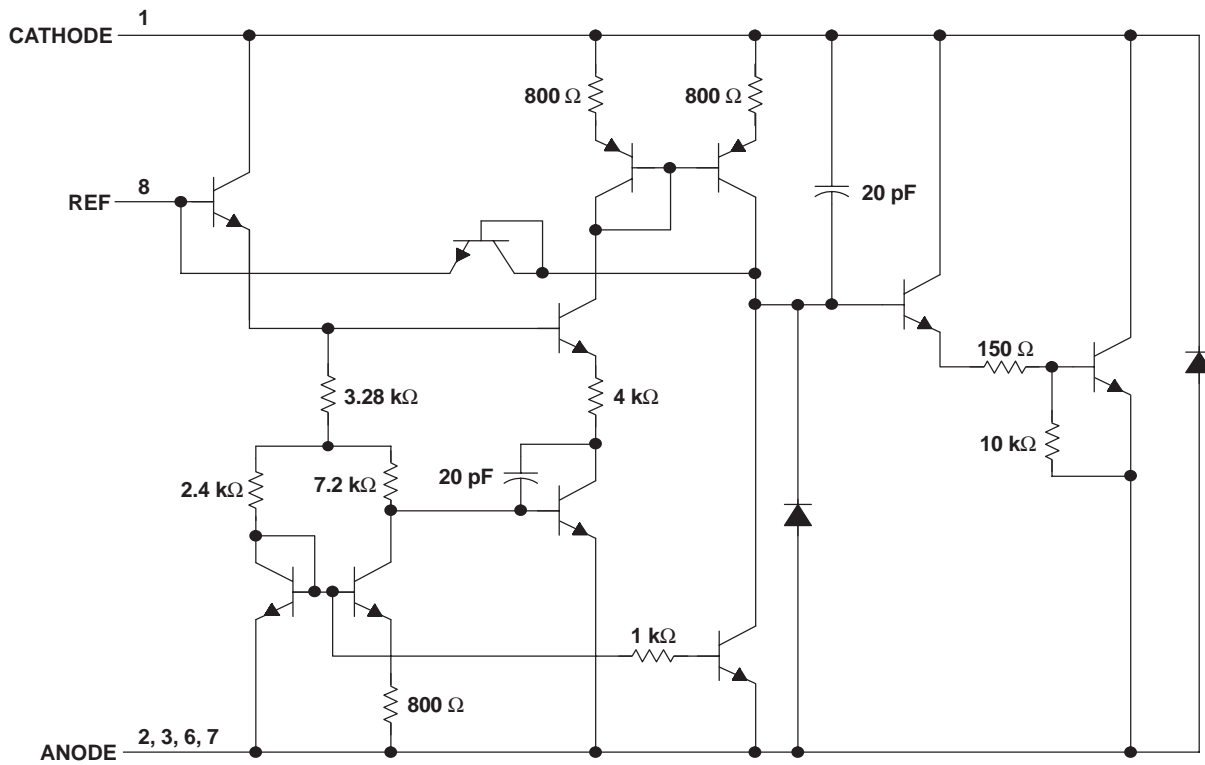
# TL1431-Q1 PRECISION PROGRAMMABLE REFERENCE

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## functional block diagram



## equivalent schematic†



† All component values are nominal.

**absolute maximum ratings over operating free-air temperature range (unless otherwise noted)†**

|  |                              |
|--|------------------------------|
| Cathode voltage, $V_{KA}$ (see Note 1) .....                       | 37 V                         |
| Continuous cathode current range, $I_{KA}$ .....                   | –100 mA to 150 mA            |
| Reference input current range, $I_{I(ref)}$ .....                  | –50 $\mu$ A to 10 mA         |
| Package thermal impedance, $\theta_{JA}$ (see Notes 2 and 3) ..... | 97°C/W                       |
| Operating virtual junction temperature, $T_J$ .....                | 150°C                        |
| Continuous total power dissipation .....                           | See Dissipation Rating Table |
| Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds ..... | 260°C                        |
| Storage temperature range, $T_{stg}$ .....                         | –65°C to 150°C               |

† Stresses beyond those listed under “absolute maximum ratings” may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under “recommended operating conditions” is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

- NOTES: 1. All voltage values are with respect to ANODE, unless otherwise noted.  
 2. Temperature and/or supply voltages must be limited to ensure that the maximum dissipation rating is not exceeded.  
 3. The package thermal impedance is calculated in accordance with JESD 51-7.

**DISSIPATION RATING TABLE**

| PACKAGE | $T_A \leq 25^\circ\text{C}$<br>POWER RATING | DERATING FACTOR<br>ABOVE $T_A = 25^\circ\text{C}$ | $T_A = 70^\circ\text{C}$<br>POWER RATING | $T_A = 85^\circ\text{C}$<br>POWER RATING | $T_A = 125^\circ\text{C}$<br>POWER RATING |
|---------|---|---|--|--|---|
| D       | 1102 mW                                     | 10.3 mW/°C  | 638.5 mW                                 | 484 mW                                   | 72.1 mW                                   |

**recommended operating conditions**

|          |                                | MIN          | MAX | UNIT |
|----------|--------------------------------|--------------|-----|------|
| $V_{KA}$ | Cathode voltage                | $V_{I(ref)}$ | 36  | V    |
| $I_{KA}$ | Cathode current                | 1            | 100 | mA   |
| $T_A$    | Operating free-air temperature | –40          | 125 | °C   |

# TL1431-Q1 PRECISION PROGRAMMABLE REFERENCE

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## electrical characteristics at specified free-air temperature, $I_{KA} = 10 \text{ mA}$ (unless otherwise noted)

| PARAMETER  | TEST CONDITIONS   | $T_A$ †  | TEST CIRCUIT | MIN  | TYP  | MAX  | UNIT          |
|--|---|--|--------------|------|------|------|---------------|
| $V_{I(\text{ref})}$                              | Reference input voltage   | $V_{KA} = V_{I(\text{ref})}$   | Figure 1     | 2490 | 2500 | 2510 | mV            |
|  |   | Full range   |              | 2470 |      | 2530 |               |
| $V_{I(\text{dev})}$                              | Deviation of reference input voltage over full temperature range‡           | $V_{KA} = V_{I(\text{ref})}$   | Figure 1     |      | 17   | 55   | mV            |
| $\frac{\Delta V_{I(\text{ref})}}{\Delta V_{KA}}$ | Ratio of change in reference input voltage to the change in cathode voltage | $\Delta V_{KA} = 3 \text{ V to } 36 \text{ V}$   | Figure 2     |      | -1.1 | -2   | mV/V          |
| $I_{I(\text{ref})}$                              | Reference input current   | $R1 = 10 \text{ k}\Omega, R2 = \infty$   | Figure 2     |      | 1.5  | 2.5  | $\mu\text{A}$ |
|  |   | Full range   |              |      |      | 4    |               |
| $I_{I(\text{dev})}$                              | Deviation of reference input current over full temperature range‡           | $R1 = 10 \text{ k}\Omega, R2 = \infty$   | Figure 2     |      | 0.5  | 2    | $\mu\text{A}$ |
| $I_{\text{min}}$                                 | Minimum cathode current for regulation                                      | $V_{KA} = V_{I(\text{ref})}$   | Figure 1     |      | 0.45 | 1    | mA            |
| $I_{\text{off}}$                                 | Off-state cathode current   | $V_{KA} = 36 \text{ V}, V_{I(\text{ref})} = 0$   | Figure 3     |      | 0.18 | 0.5  | $\mu\text{A}$ |
|  |   | Full range   |              |      |      | 2    |               |
| $ z_{KA} $                                       | Output impedance§   | $V_{KA} = V_{I(\text{ref})}, f \leq 1 \text{ kHz}, I_{KA} = 1 \text{ mA to } 100 \text{ mA}$ | Figure 1     |      | 0.2  | 0.4  | $\Omega$      |

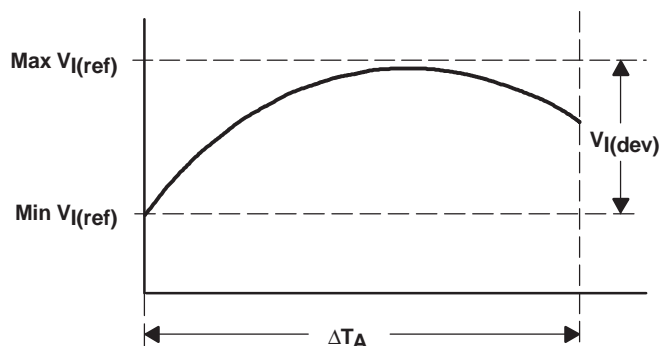
† Full range is  $-40^\circ\text{C}$  to  $125^\circ\text{C}$  for Q-suffix devices.

‡ The deviation parameters  $V_{I(\text{dev})}$  and  $I_{I(\text{dev})}$  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  $\alpha_{V_{I(\text{ref})}}$  is defined as:

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

where:

$\Delta T_A$  is the rated operating temperature range of the device.



$\alpha_{V_{I(\text{ref})}}$  is positive or negative, depending on whether minimum  $V_{I(\text{ref})}$  or maximum  $V_{I(\text{ref})}$ , respectively, occurs at the lower temperature.

§ The output impedance is defined as:  $|z_{KA}| = \frac{\Delta V_{KA}}{\Delta I_{KA}}$

When the device is operating with two external resistors (see Figure 2), the total dynamic impedance of the circuit is given by:  $|z'| = \frac{\Delta V}{\Delta I}$ ,

which is approximately equal to  $|z_{KA}| \left( 1 + \frac{R1}{R2} \right)$ .

PARAMETER MEASUREMENT INFORMATION

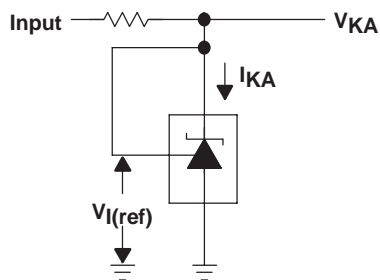


Figure 1. Test Circuit for  $V_{(KA)} = V_{ref}$

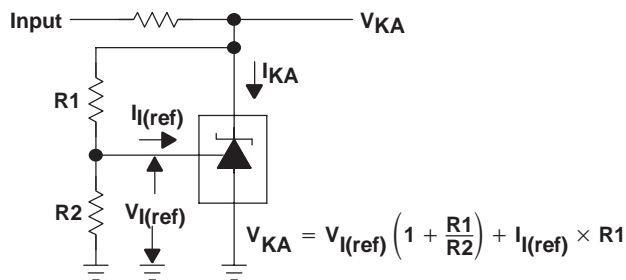


Figure 2. Test Circuit for  $V_{(KA)} > V_{ref}$

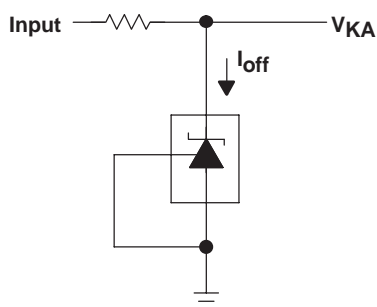


Figure 3. Test Circuit for  $I_{off}$

TYPICAL CHARACTERISTICS

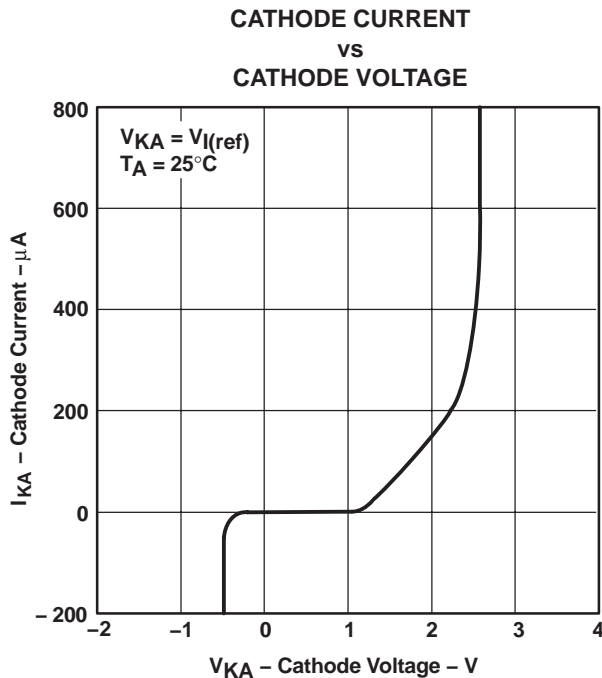
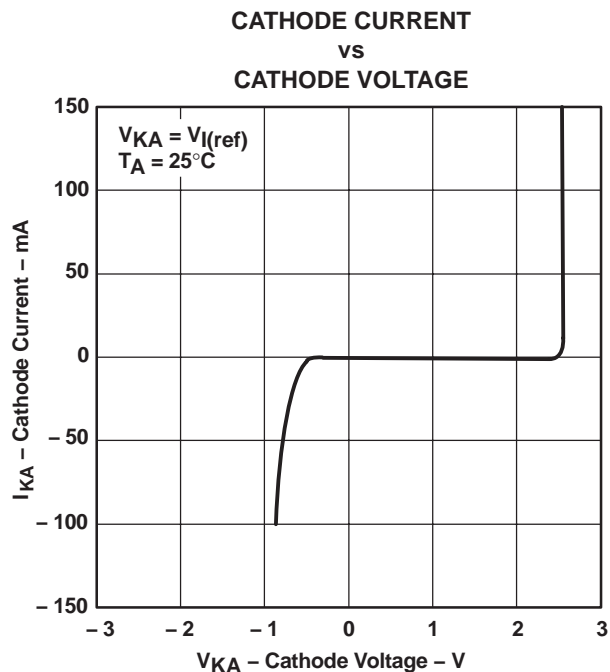
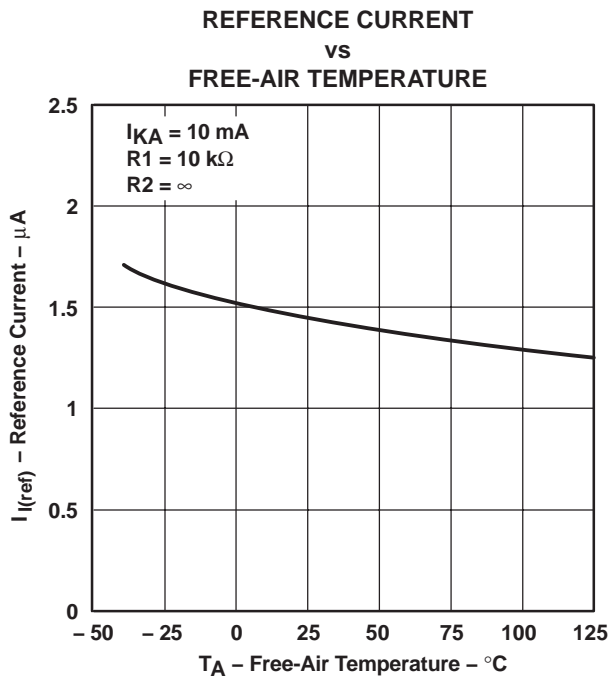
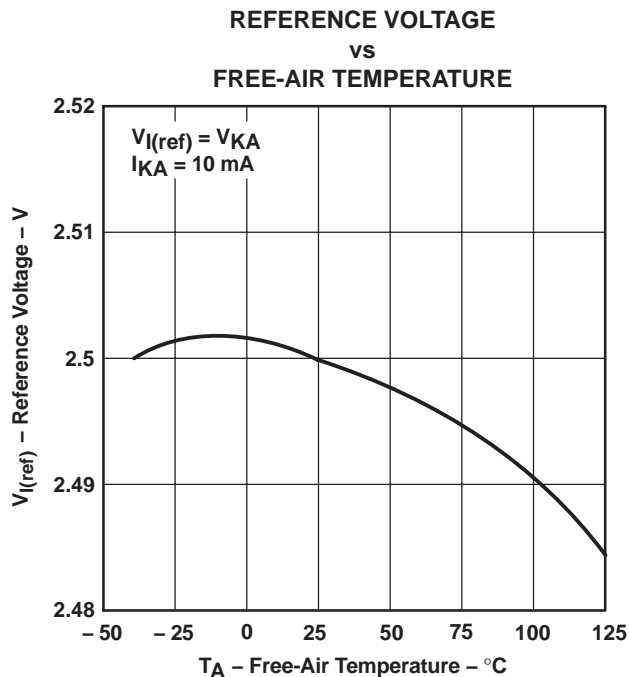
Table of Graphs

|   | FIGURE |
|---|--------|
| Reference voltage vs Free-air temperature   | 4      |
| Reference current vs Free-air temperature   | 5      |
| Cathode current vs Cathode voltage  | 6, 7   |
| Off-state cathode current vs Free-air temperature                                 | 8      |
| Ratio of delta reference voltage to delta cathode voltage vs Free-air temperature | 9      |
| Equivalent input-noise voltage vs Frequency                                       | 10     |
| Equivalent input-noise voltage over a 10-second period                            | 11     |
| Small-signal voltage amplification vs Frequency                                   | 12     |
| Reference impedance vs Frequency  | 13     |
| Pulse response  | 14     |
| Stability boundary conditions   | 15     |

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## TYPICAL CHARACTERISTICS†



† Data at high and low temperatures are applicable only within the recommended operating free-air temperature ranges of the various devices.

TYPICAL CHARACTERISTICS†

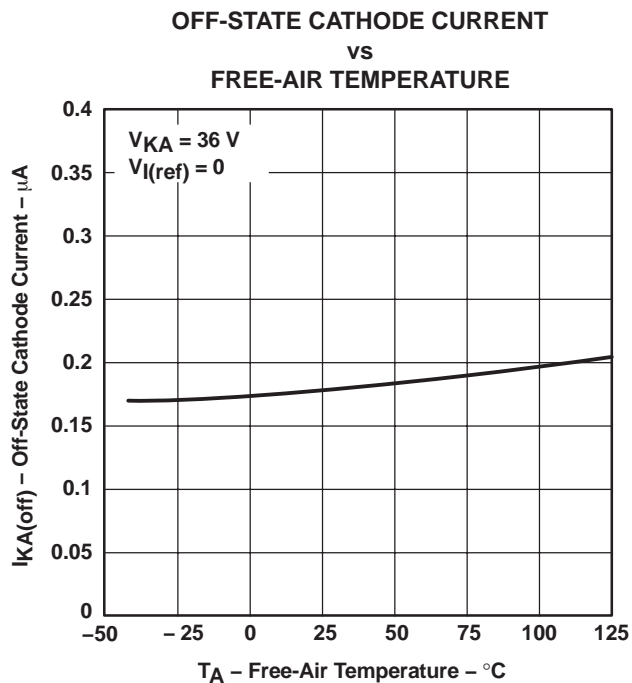


Figure 8

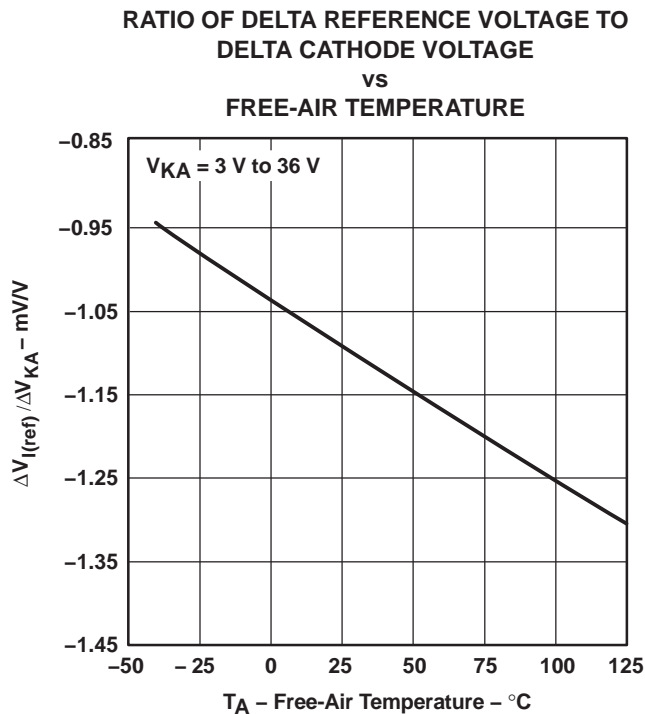


Figure 9

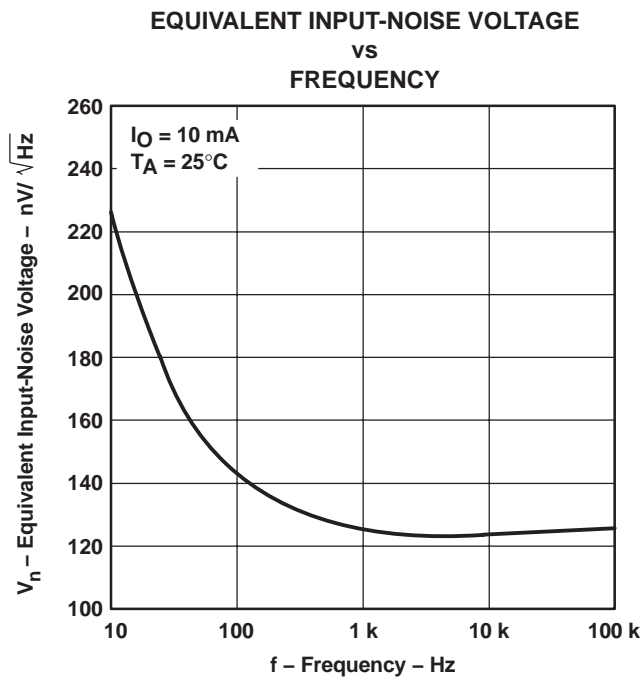


Figure 10

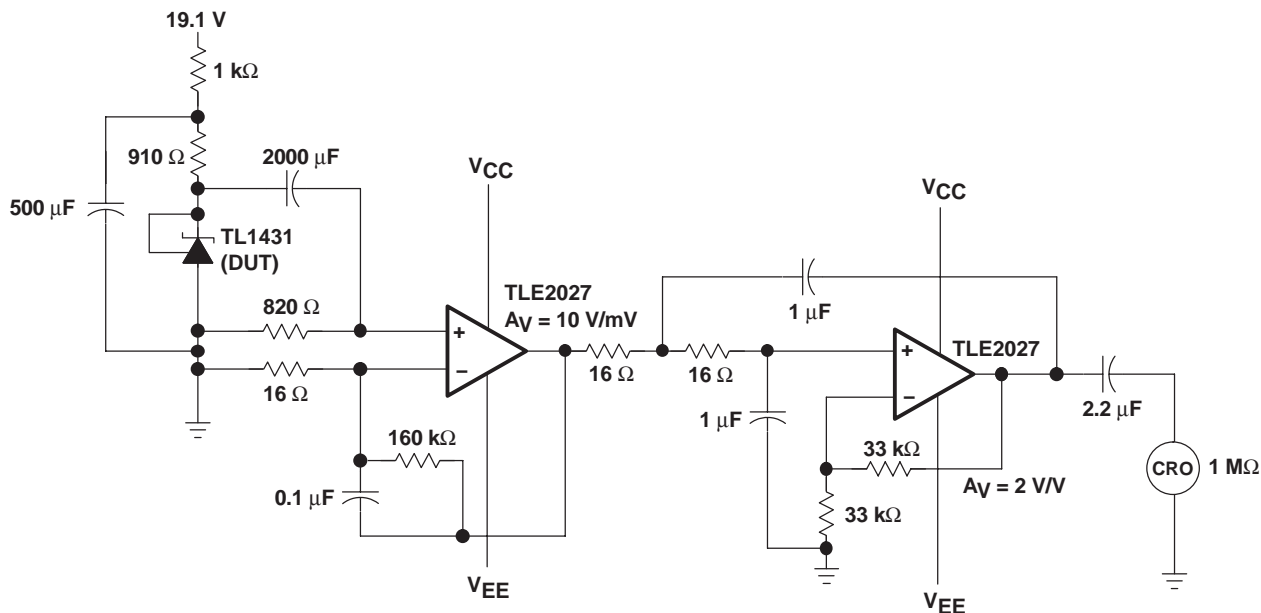
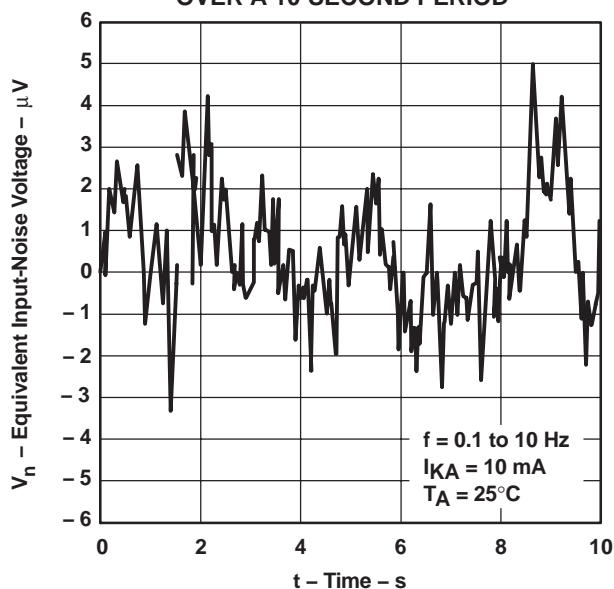
† Data at high and low temperatures are applicable only within the recommended operating free-air temperature ranges of the various devices.

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## TYPICAL CHARACTERISTICS

### EQUIVALENT INPUT-NOISE VOLTAGE OVER A 10-SECOND PERIOD



TEST CIRCUIT FOR 0.1-Hz TO 10-Hz EQUIVALENT INPUT-NOISE VOLTAGE

Figure 11



TYPICAL CHARACTERISTICS

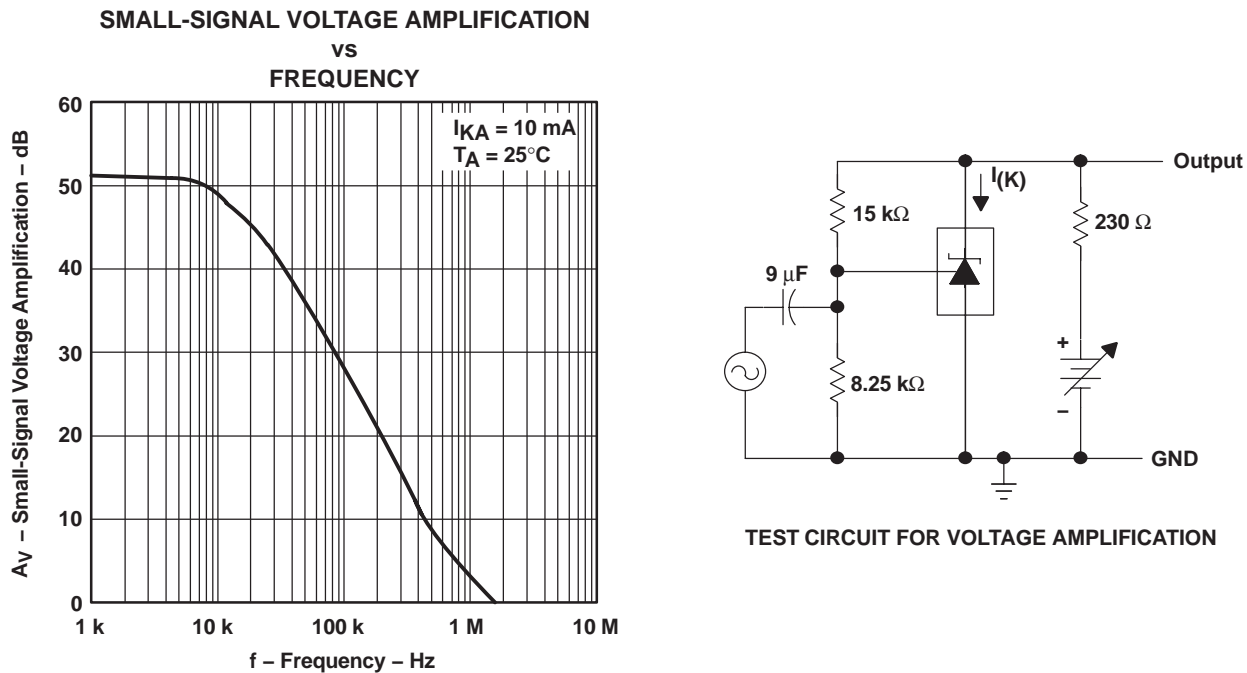


Figure 12

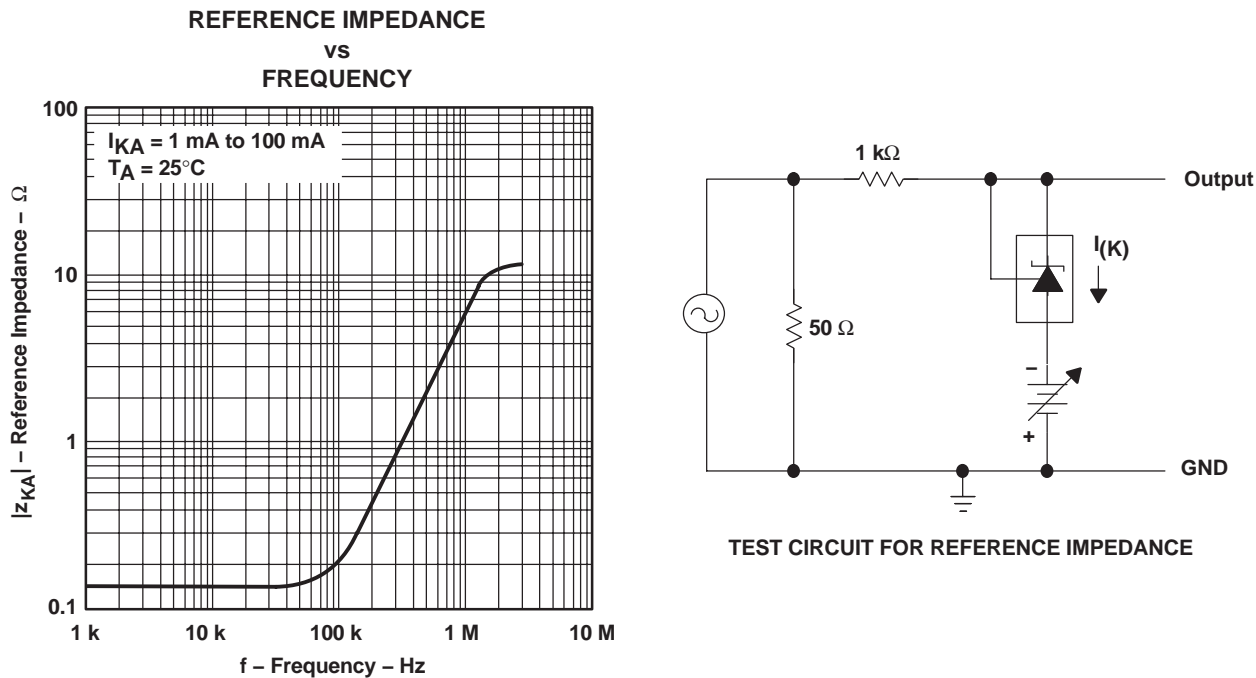


Figure 13

# TL1431-Q1 PRECISION PROGRAMMABLE REFERENCE

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## TYPICAL CHARACTERISTICS

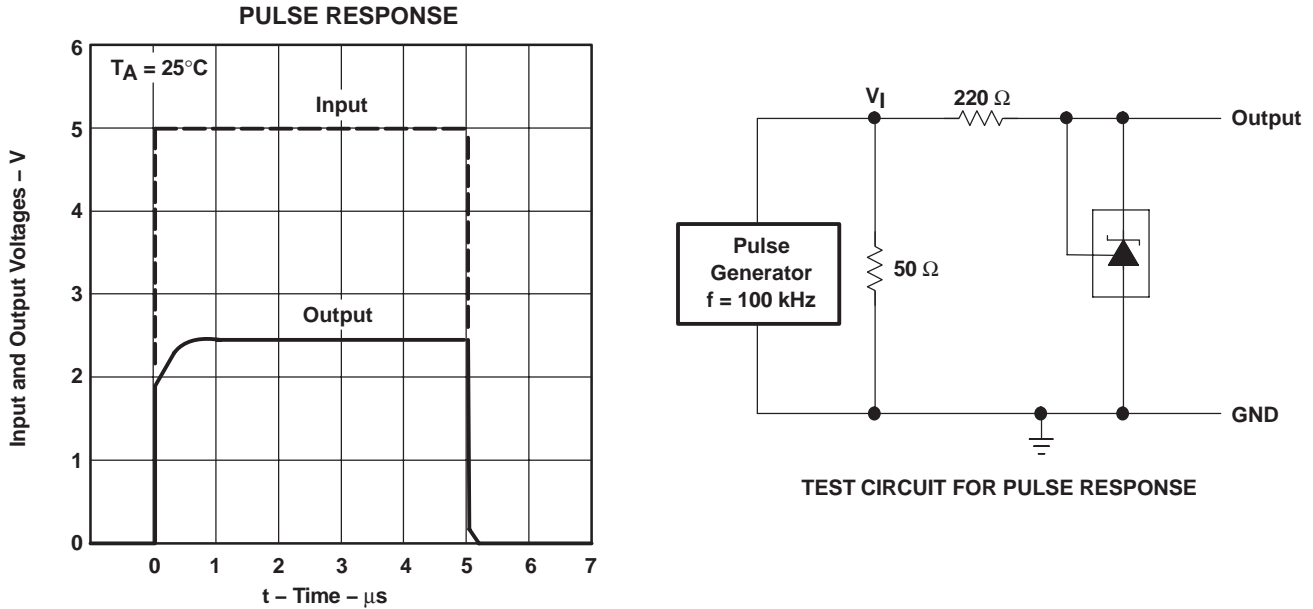
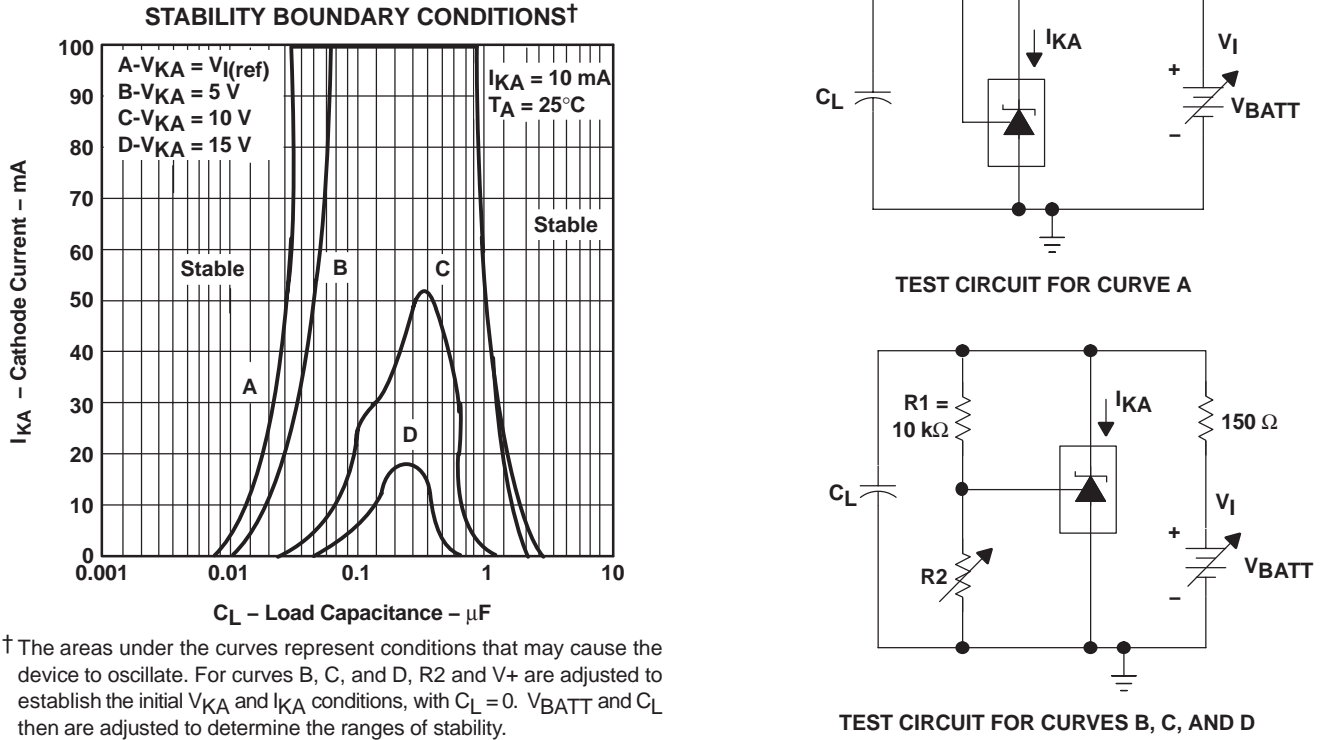


Figure 14



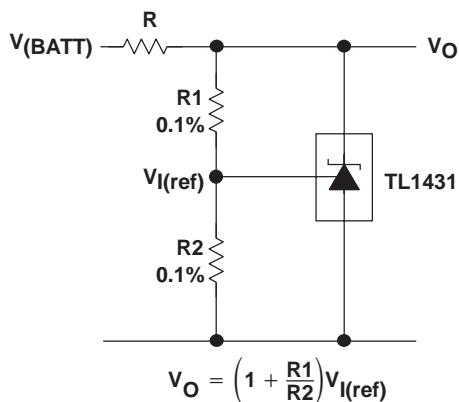
† The areas under the curves represent conditions that may cause the device to oscillate. For curves B, C, and D, R2 and V+ are adjusted to establish the initial  $V_{KA}$  and  $I_{KA}$  conditions, with  $C_L = 0$ .  $V_{BATT}$  and  $C_L$  then are adjusted to determine the ranges of stability.

Figure 15

APPLICATION INFORMATION

Table of Application Circuits

| APPLICATION   | FIGURE |
|---|--------|
| Shunt regulator   | 16     |
| Single-supply comparator with temperature-compensated threshold | 17     |
| Precision high-current series regulator                         | 18     |
| Output control of a three-terminal fixed regulator              | 19     |
| Higher-current shunt regulator                                  | 20     |
| Crowbar   | 21     |
| Precision 5-V, 1.5-A, 0.5% regulator                            | 22     |
| 5-V precision regulator   | 23     |
| PWM converter with 0.5% reference                               | 24     |
| Voltage monitor   | 25     |
| Delay timer   | 26     |
| Precision current limiter                                       | 27     |
| Precision constant-current sink                                 | 28     |



NOTE A: R should provide cathode current  $\geq 1$  mA to the TL1431 at minimum  $V_{(BATT)}$ .

Figure 16. Shunt Regulator

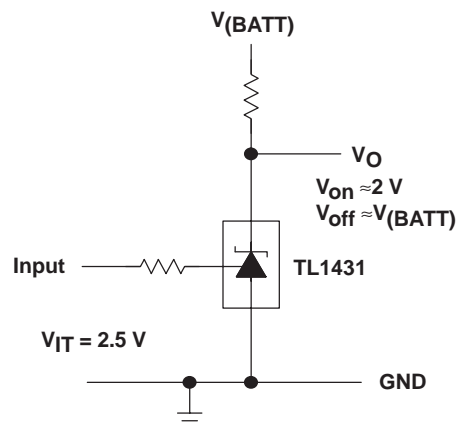
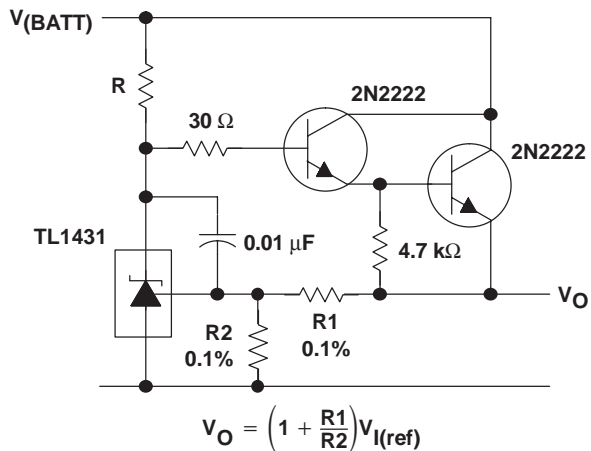


Figure 17. Single-Supply Comparator With Temperature-Compensated Threshold

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## APPLICATION INFORMATION



NOTE A: R should provide cathode current  $\geq 1$  mA to the TL1431 at minimum  $V_{(BATT)}$ .

Figure 18. Precision High-Current Series Regulator

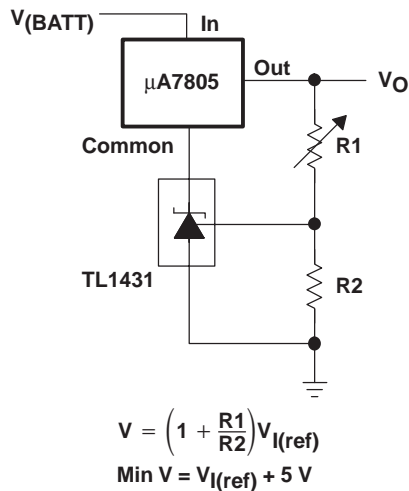


Figure 19. Output Control of a Three-Terminal Fixed Regulator

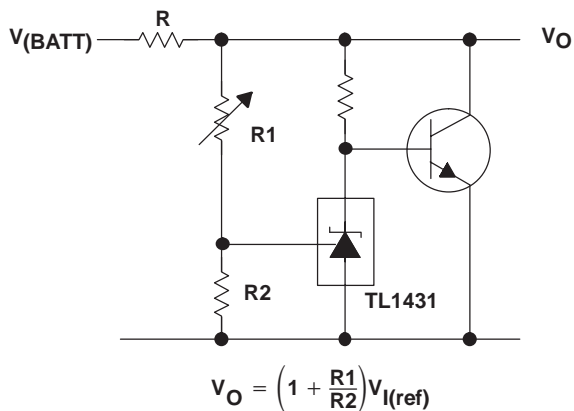
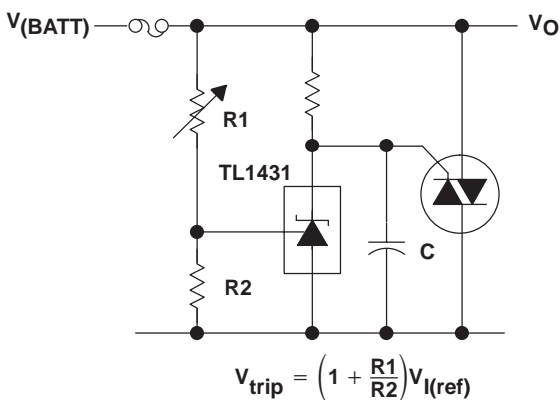


Figure 20. Higher-Current Shunt Regulator



NOTE A: Refer to the stability boundary conditions in Figure 15 to determine allowable values for C.

Figure 21. Crowbar

APPLICATION INFORMATION

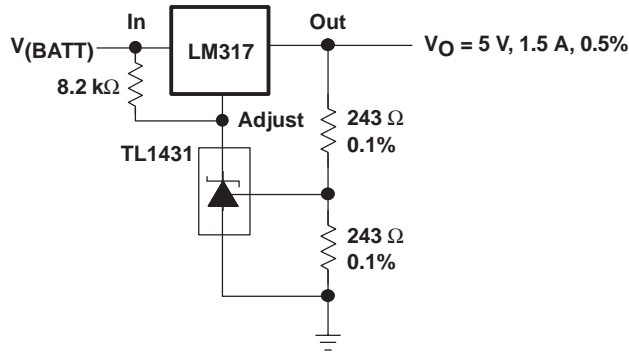
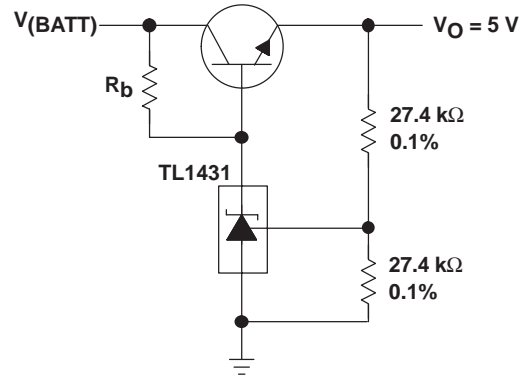


Figure 22. Precision 5-V, 1.5-A, 0.5% Regulator



NOTE A:  $R_b$  should provide cathode current  $\geq 1\text{ mA}$  to the TL1431.

Figure 23. 5-V Precision Regulator

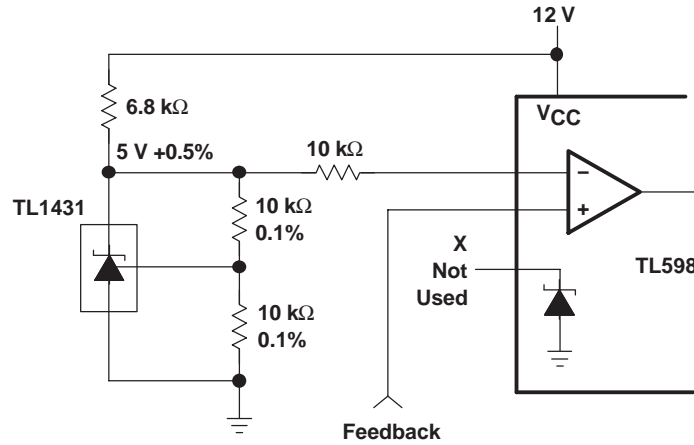
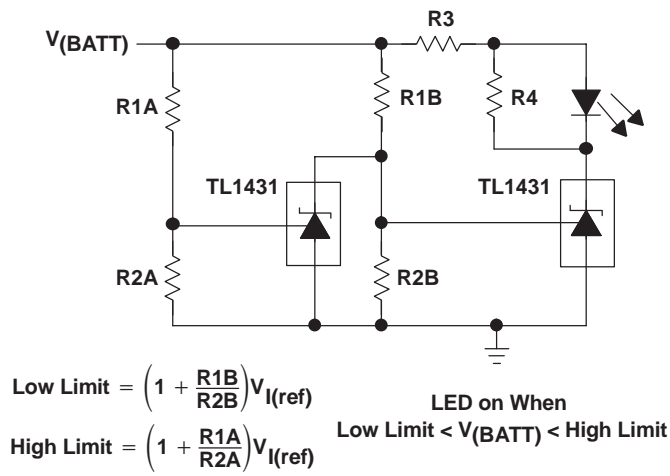


Figure 24. PWM Converter With 0.5% Reference

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## APPLICATION INFORMATION



NOTE A: Select R3 and R4 to provide the desired LED intensity and cathode current  $\geq 1$  mA to the TL1431.

Figure 25. Voltage Monitor

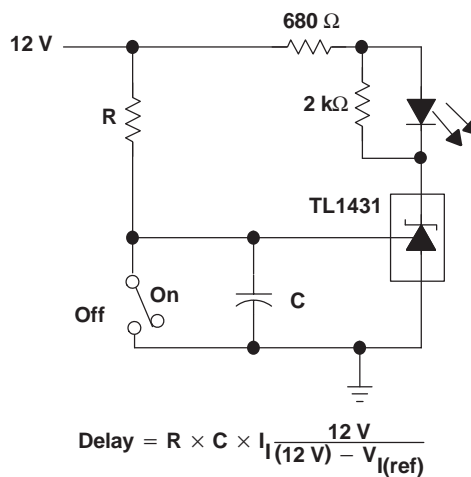


Figure 26. Delay Timer

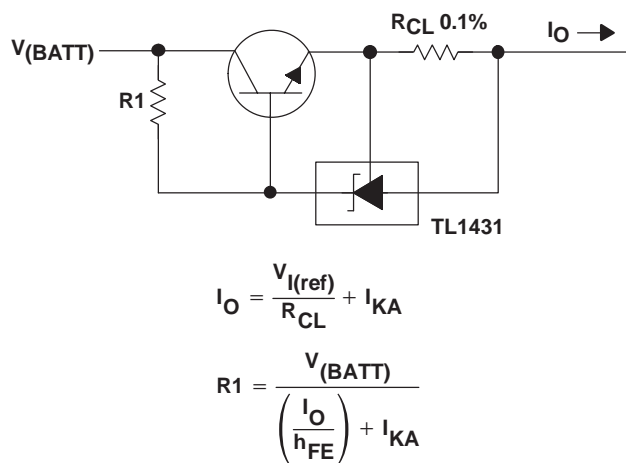


Figure 27. Precision Current Limiter

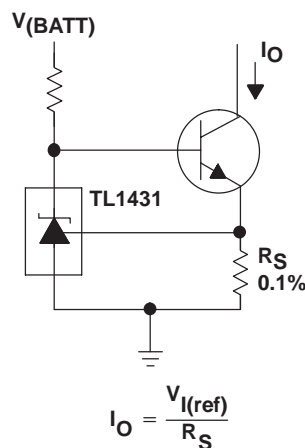


Figure 28. Precision Constant-Current Sink

**PACKAGING INFORMATION**

| Orderable Device | Status <sup>(1)</sup> | Package Type | Package Drawing | Pins | Package Qty | Eco Plan <sup>(2)</sup>    | Lead/<br>Ball Finish | MSL Peak Temp <sup>(3)</sup> | Samples<br>(Requires Login)          |
|------------------|-----------------------|--------------|-----------------|------|-------------|----------------------------|----------------------|------------------------------|--------------------------------------|
| TL1431QDRG4Q1    | ACTIVE                | SOIC         | D               | 8    | 2500        | Green (RoHS<br>& no Sb/Br) | CU NIPDAU            | Level-1-260C-UNLIM           | <a href="#">Purchase Samples</a>     |
| TL1431QDRQ1      | ACTIVE                | SOIC         | D               | 8    | 2500        | Green (RoHS<br>& no Sb/Br) | CU NIPDAU            | Level-1-260C-UNLIM           | <a href="#">Request Free Samples</a> |

<sup>(1)</sup> The marketing status values are defined as follows:

**ACTIVE:** Product device recommended for new designs.

**LIFEBUY:** TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.

**NRND:** Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.

**PREVIEW:** Device has been announced but is not in production. Samples may or may not be available.

**OBsolete:** TI has discontinued the production of the device.

<sup>(2)</sup> Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check <http://www.ti.com/productcontent> for the latest availability information and additional product content details.

**TBD:** The Pb-Free/Green conversion plan has not been defined.

**Pb-Free (RoHS):** TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.

**Pb-Free (RoHS Exempt):** This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.

**Green (RoHS & no Sb/Br):** TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

<sup>(3)</sup> MSL, Peak Temp. -- The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

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**OTHER QUALIFIED VERSIONS OF TL1431-Q1 :**

● Catalog: [TL1431](#)

● Enhanced Product: [TL1431-EP](#)

● Military: [TL1431M](#)

● Space: [TL1431-SP](#)

NOTE: Qualified Version Definitions:

- Catalog - TI's standard catalog product
- Enhanced Product - Supports Defense, Aerospace and Medical Applications
- Military - QML certified for Military and Defense Applications
- Space - Radiation tolerant, ceramic packaging and qualified for use in Space-based application



D (R-PDSO-G8)

PLASTIC SMALL OUTLINE



- NOTES:
- A. All linear dimensions are in inches (millimeters).
  - B. This drawing is subject to change without notice.
  - C. Body length does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.006 (0,15) each side.
  - D. Body width does not include interlead flash. Interlead flash shall not exceed 0.017 (0,43) each side.
  - E. Reference JEDEC MS-012 variation AA.

D (R-PDSO-G8)

PLASTIC SMALL OUTLINE



- NOTES:
- A. All linear dimensions are in millimeters.
  - B. This drawing is subject to change without notice.
  - C. Publication IPC-7351 is recommended for alternate designs.
  - D. Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Refer to IPC-7525 for other stencil recommendations.
  - E. Customers should contact their board fabrication site for solder mask tolerances between and around signal pads.

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| DLP® Products          | <a href="http://www.dlp.com">www.dlp.com</a>   |
| DSP                    | <a href="http://dsp.ti.com">dsp.ti.com</a>   |
| Clocks and Timers      | <a href="http://www.ti.com/clocks">www.ti.com/clocks</a>                             |
| Interface              | <a href="http://interface.ti.com">interface.ti.com</a>                               |
| Logic                  | <a href="http://logic.ti.com">logic.ti.com</a>                                       |
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| Microcontrollers       | <a href="http://microcontroller.ti.com">microcontroller.ti.com</a>                   |
| RFID                   | <a href="http://www.ti-rfid.com">www.ti-rfid.com</a>                                 |
| OMAP Mobile Processors | <a href="http://www.ti.com/omap">www.ti.com/omap</a>                                 |
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| Consumer Electronics          | <a href="http://www.ti.com/consumer-apps">www.ti.com/consumer-apps</a>                   |
| Energy and Lighting           | <a href="http://www.ti.com/energy">www.ti.com/energy</a>                                 |
| Industrial                    | <a href="http://www.ti.com/industrial">www.ti.com/industrial</a>                         |
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