National Semiconductor

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# LM4431
# Micropower Shunt Voltage Reference

## General Description

Ideal for space critical applications, the LM4431 voltage reference is available in the sub-miniature (3 mm x 1.3 mm) SOT-23 surface-mount package. The LM4431's advanced design eliminates the need for an external stabilizing capacitor while ensuring stability with any capacitive load, thus making the LM4431 easy to use. The operating current range is 100 µA to 15 mA.

The LM4431 utilizes fuse and zener-zap reverse breakdown voltage trim during wafer sort to ensure that the parts have an accuracy of better than ±2.0% at 25˚C. Bandgap reference temperature drift curvature correction and low dynamic impedance ensure stable reverse breakdown voltage accuracy over a wide range of operating temperatures and currents.

## Features

- Small package: SOT-23
- No output capacitor required
- Tolerates capacitive loads
- Fixed reverse breakdown voltage of 2.50V

## Key Specifications

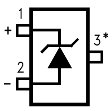
- Output voltage tolerance 25˚C: ±2.0% (max)
- Low output noise (10 Hz to 10 kHz): 35 $\mu V_{rms}$ (typ)
- Wide operating current range: 100 µA to 15 mA
- Commercial temperature range: 0˚C to +70˚C
- Low temperature coefficient: 30 ppm/˚C (typ)

## Applications

- Portable, Battery-Powered Equipment
- Data Acquisition Systems
- Instrumentation
- Process Control
- Energy Management
- Product Testing
- Power Supplies

## Connection Diagram

**SOT-23**

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* This pin must be left floating or connected to pin 2.

**Top View**
**Order Number LM4431M3-2.5**
**See NS Package Number M03B**
**(JEDEC Registration TO-236AB)**

## SOT-23 Package Marking Information

Only three fields of marking are possible on the SOT-23's small surface. The following table gives the meaning of the three fields.

| Part Marking | Field Definition |
|---|---|
| S2E | First Field:<br>S = Reference<br>Second Field:<br>2 = 2.500V Voltage Option<br>Third Field:<br>E = Initial Reverse Breakdown Voltage Tolerance of ±2.0% |

## Absolute Maximum Ratings (Note 1)

**If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/ Distributors for availability and specifications.**

| | |
|---|---|
| Reverse Current | 20 mA |
| Forward Current | 10 mA |
| Power Dissipation ($T_A$ = 25˚C) (Note 2) | |
| M3 Package | 306 mW |
| Storage Temperature | −65˚C to +150˚C |
| Lead Temperature | |
| M3 Package | |
| Vapor phase (60 seconds) | +215˚C |
| Infrared (15 seconds) | +220˚C |
| ESD Susceptibility | |
| Human Body Model (Note 3) | 2 kV |
| Machine Model (Note 3) | 200V |

See AN-450 "Surface Mounting Methods and Their Effect on Product Reliability" for other methods of soldering surface mount devices.

## Operating Ratings (Notes 1, 2)

| | |
|---|---|
| Temperature Range | |
| ($T_{min}$ ≤ $T_A$ ≤ $T_{max}$) | 0˚C ≤ $T_A$ ≤ +70˚C |
| Reverse Current | |
| LM4431-2.5 | 100 µA to 15 mA |

## LM4431-2.5 Electrical Characteristics

**Boldface limits apply for $T_A$ = $T_J$ = $T_{MIN}$ to $T_{MAX}$;** all other limits $T_A$ = $T_J$ = 25˚C.

| Symbol | Parameter | Conditions | Typical (Note 4) | LM4431M3 Limits (Note 5) | Units (Limit) |
|---|---|---|---|---|---|
| $V_R$ | Reverse Breakdown Voltage | $I_R$ = 100 µA | 2.500 | | V |
| | Reverse Breakdown VoltageTolerance | $I_R$ = 100 µA | | ±50 | mV (max) |
| $I_{RMIN}$ | Minimum Operating Current | | 45 | | µA |
| | | | | **100** | µA (max) |
| $\Delta V_R/\Delta T$ | Average Reverse Breakdown Voltage Temperature Coefficient | $I_R$ = 10 mA | ±30 | | ppm/˚C |
| | | $I_R$ = 1 mA | ±30 | | ppm/˚C |
| | | $I_R$ = 100 µA | ±30 | | ppm/˚C |
| $\Delta V_R/\Delta I_R$ | Reverse Breakdown Voltage Change with Operating Current Change | $I_{RMIN}$ ≤ $I_R$ ≤ 1 mA | 0.4 | | mV |
| | | | | 1.0 | mV (max) |
| | | | | **1.2** | mV (max) |
| | | 1 mA ≤ $I_R$ ≤ 15 mA | 2.5 | | mV |
| | | | | 8.0 | mV (max) |
| | | | | **25** | mV (max) |
| $Z_R$ | Reverse Dynamic Impedance | $I_R$ = 1 mA, f = 120 Hz<br>$I_{AC}$ = 0.1 $I_R$ | 1.0 | | Ω |
| $e_N$ | Wideband Noise | $I_R$ = 100 µA<br>10 Hz ≤ f ≤ 10 kHz | 35 | | $\mu V_{rms}$ |
| $\Delta V_R$ | Reverse Breakdown Voltage Long Term Stability | t = 1000 hrs<br>T = 25˚C ±0.1˚C<br>$I_R$ = 100 µA | 120 | | ppm |

**Note 1:** Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Operating Ratings indicate conditions for which the device is functional, but do not guarantee specific performance limits. For guaranteed specifications and test conditions, see the Electrical Characteristics. The guaranteed specifications apply only for the test conditions listed. Some performance characteristics may degrade when the device is not operated under the listed test conditions.

**Note 2:** The maximum power dissipation must be derated at elevated temperatures and is dictated by $T_{Jmax}$ (maximum junction temperature), $\theta_{JA}$ (junction to ambient thermal resistance), and $T_A$ (ambient temperature). The maximum allowable power dissipation at any temperature is $PD_{max}$ = ($T_{Jmax}$ − $T_A$)/$\theta_{JA}$ or the number given in the Absolute Maximum Ratings, whichever is lower. For the LM4431, $T_{Jmax}$ = 125˚C, and the typical thermal resistance ($\theta_{JA}$), when board mounted, is 326˚C/W for the SOT-23 package.

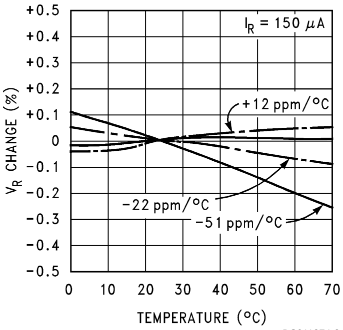
**Note 3:** The human body model is a 100 pF capacitor discharged through a 1.5 kΩ resistor into each pin. The machine model is a 200 pF capacitor discharged directly into each pin.

**Note 4:** Typicals are at $T_J$ = 25˚C and represent most likely parametric norm.

**Note 5:** Limits are 100% production tested at 25˚C. Limits over temperature are guaranteed through correlation using Statistical Quality Control (SQC) methods. The limits are used to calculate National's AOQL.

# Typical Performance Characteristics

**Temperature Drift for Different Average Temperature Coefficient**

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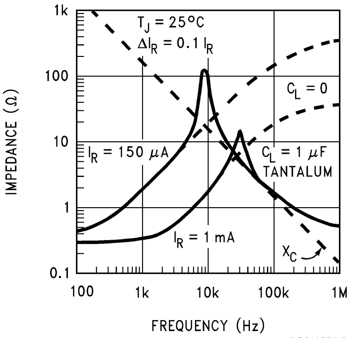
**Output Impedance vs Frequency**

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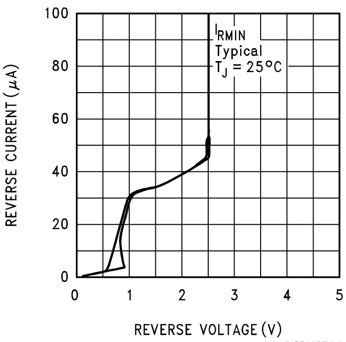
**Reverse Characteristics and Minimum Operating Current**

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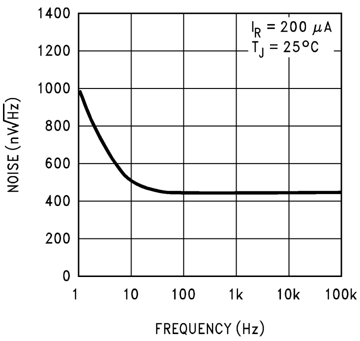
**Noise Voltage**

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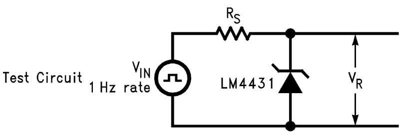
# Start-Up Characteristics

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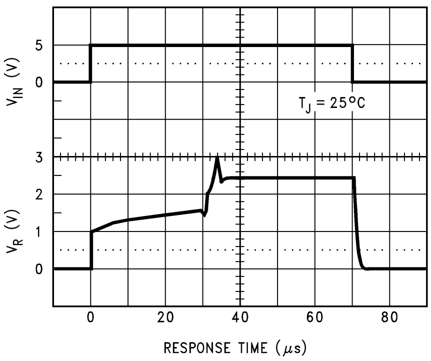
**LM4431-2.5 $R_S$ = 30k**

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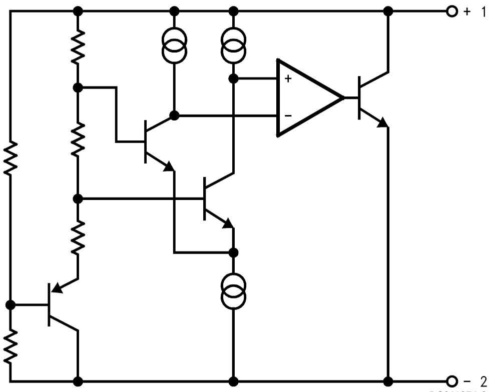
## Functional Block Diagram

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## Applications Information

The LM4431 is a micro-power curvature-corrected 2.5V bandgap shunt voltage reference. For space critical applications, the LM4431 is available in the sub-miniature SOT-23 surface-mount package. The LM4431 has been designed for stable operation without the need of an external capacitor connected between the "+" pin and the "−" pin. If, however, a bypass capacitor is used, the LM4431 remains stable. The operating current range is 100 µA to 15 mA.

The LM4431's SOT-23 package has a parasitic Schottky diode between pin 2 (−) and pin 3 (Die attach interface contact). Therefore, pin 3 of the SOT-23 package must be left floating or connected to pin 2.

In a conventional shunt regulator application (*Figure 1*) , an external series resistor ($R_S$) is connected between the supply voltage and the LM4431. $R_S$ determines the current that flows through the load ($I_L$) and the LM4431 ($I_Q$). Since load current and supply voltage may vary, $R_S$ should be small enough to supply at least the minimum acceptable $I_Q$ to the LM4431 even when the supply voltage is at its minimum and the load current is at its maximum value. When the supply voltage is at its maximum and $I_L$ is at its minimum, $R_S$ should be large enough so that the current flowing through the LM4431 is less than 15 mA.

$R_S$ is determined by the supply voltage, ($V_S$), the load and operating current, ($I_L$ and $I_Q$), and the LM4431's reverse breakdown voltage, $V_R$.

$$R_S = \frac{V_S - V_R}{I_L + I_Q}$$

## Typical Applications

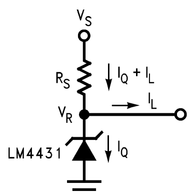


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**FIGURE 1. Shunt Regulator**

## Typical Applications (Continued)

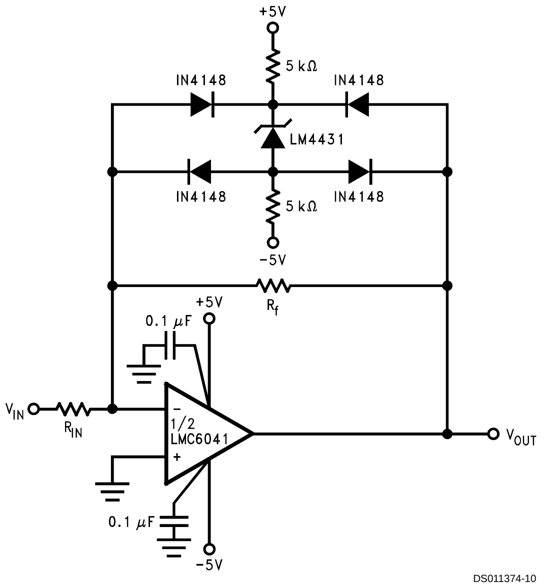



**FIGURE 2. Bounded amplifier reduces saturation-induced delays and can prevent succeeding stage damage. Nominal clamping voltage is ±3.9V (LM4431's reverse breakdown voltage +2 diode $V_F$).**

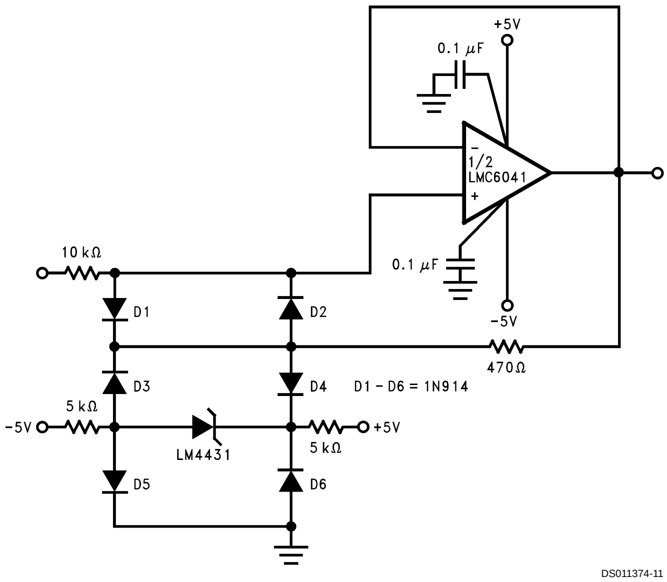
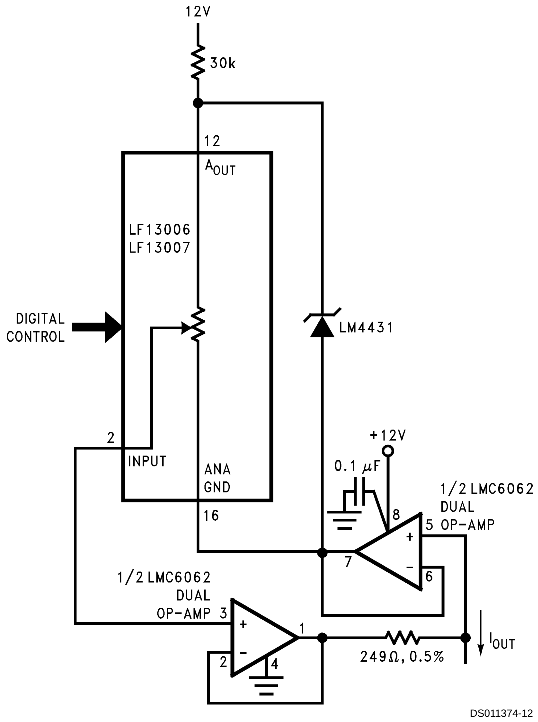


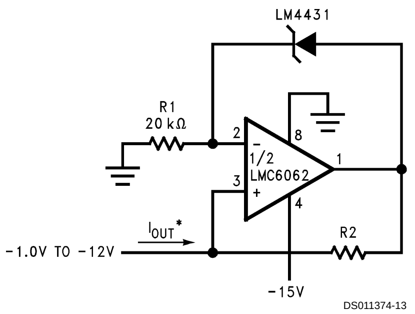

**FIGURE 3. Protecting Op Amp input. The bounding voltage is ±4V with the LM4431 (LM4431's reverse breakdown voltage + 3 diode $V_F$).**

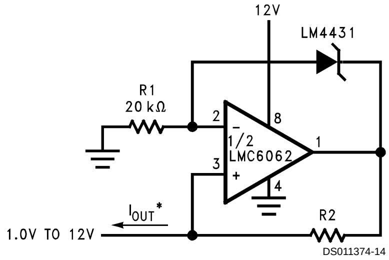
## Typical Applications (Continued)




$$I_{OUT} = \frac{2.5V}{249\Omega}\left[\frac{1}{\text{gain set \#}}\right]$$

**FIGURE 4. Programmable Current Source**

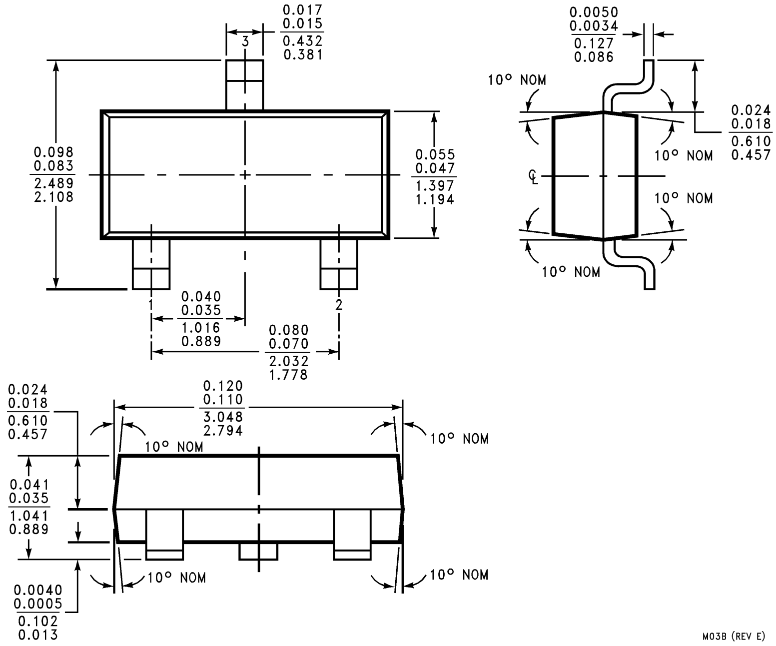



$$^{*}I_{OUT} = \frac{2.5V}{R2}$$

**FIGURE 5. Precision 1 µA to 1 mA Current Sources**

## Physical Dimensions inches (millimeters) unless otherwise noted




**Plastic Surface Mount Package (M3)**
**NS Package Number M03B**
**(JEDEC Registration TO-236AB)**

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