# Dual ±15V Zero-Drift Operational Amplifier

## FEATURES

- Maximum Offset Voltage Drift: 0.05µV/°C
- High Voltage Operation: ±18V
- No External Components Required
- Maximum Offset Voltage: 5µV
- Low Noise: 1.5µV$_{P-P}$ (0.1Hz to 10Hz)
- Minimum Voltage Gain: 125dB
- Minimum CMRR: 106dB
- Minimum PSRR: 110dB
- Low Supply Current: 0.9mA/Amplifier
- Single Supply Operation: 4.75V to 36V
- Input Common Mode Range Includes Ground
- Typical Overload Recovery Time: 20ms
- Available in 8-Lead N8 and 16-Lead SW Packages

## APPLICATIONS

- Strain Gauge Amplifiers
- Instrumentation Amplifiers
- Electronic Scales
- Medical Instrumentation
- Thermocouple Amplifiers
- High Resolution Data Acquisition

## DESCRIPTION

The LTC®1151 is a high voltage, high performance dual zero-drift operational amplifier. The two sample-and-hold capacitors per amplifier required externally by other chopper amplifiers are integrated on-chip. The LTC1151 also incorporates proprietary high voltage CMOS structures which allow operation at up to 36V total supply voltage.

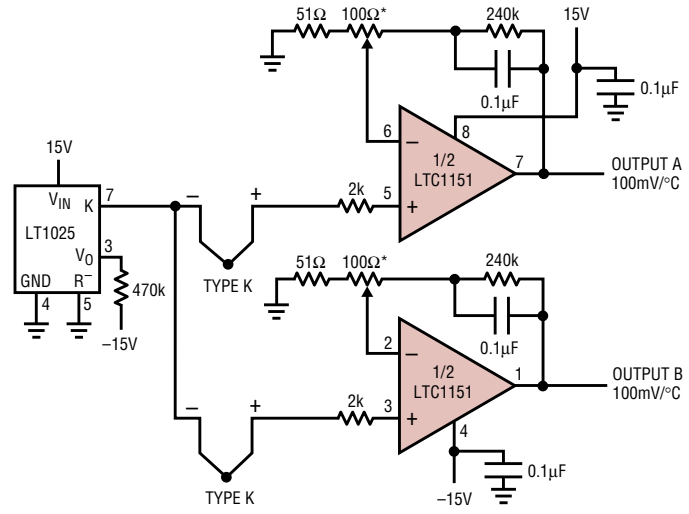
The LTC1151 has a typical offset voltage of 0.5µV, drift of 0.01µV/°C, 0.1Hz to 10Hz input noise voltage of 1.5µV$_{P-P}$, and a typical voltage gain of 140dB. It has a slew rate of 3V/µs and a gain-bandwidth product of 2.5MHz with a supply current of 0.9mA per amplifier. Overload recovery times from positive and negative saturation are 3ms and 20ms, respectively.

The LTC1151 is available in a standard 8-lead plastic DIP package as well as a 16-lead wide body SO. The LTC1151 is pin compatible with industry-standard dual op amps and runs from standard ±15V supplies, allowing it to plug in to most standard bipolar op amp sockets while offering significant improvement in DC performance.

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## TYPICAL APPLICATION

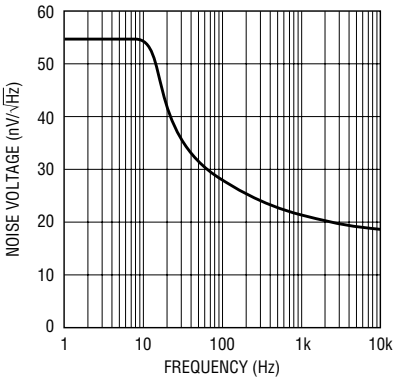
**±15V Dual Thermocouple Amplifier**




* FULL SCALE TRIM: TRIM FOR 10.0V OUTPUT WITH THERMOCOUPLE AT 100°C

1151 TA01

**Noise Spectrum**




1151 TA02

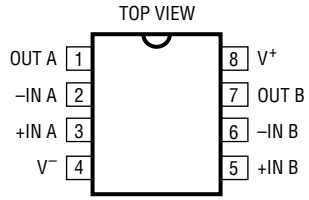
## ABSOLUTE MAXIMUM RATINGS

**(Note 1)**

Total Supply Voltage ($V^+$ to $V^-$) ..... 36V
Input Voltage (Note 2) ..... ($V^+$ + 0.3V) to ($V^-$ – 0.3V)
Output Short Circuit Duration ..... Indefinite
Burn-In Voltage ..... 36V

Operating Temperature Range
LTC1151C ..... 0°C to 70°C
Storage Temperature Range ..... –65°C to 150°C
Lead Temperature (Soldering, 10 sec)..... 300°C

## PACKAGE/ORDER INFORMATION

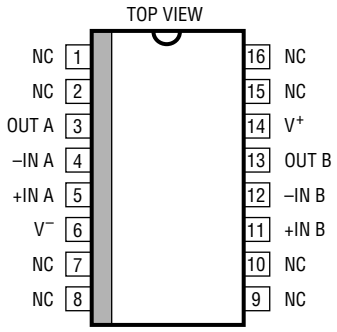



N8 PACKAGE
8-LEAD PLASTIC DIP

$T_{JMAX}$ = 110°C, $\theta_{JA}$ = 130°C/W

ORDER PART NUMBER

LTC1151CN8




SW PACKAGE
16-LEAD PLASTIC SO (WIDE)

$T_{JMAX}$ = 110°C, $\theta_{JA}$ = 200°C/W

ORDER PART NUMBER

LTC1151CSW

**Order Options** Tape and Reel: Add #TR Lead Free: Add #PBF Lead Free Tape and Reel: Add #TRPBF
Lead Free Part Marking: http://www.linear.com/leadfree/

Consult LTC Marketing for parts specified with wider operating temperature ranges.

## ELECTRICAL CHARACTERISTICS

**The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at $T_A$ = 25°C. $V_S$ = ±15V, unless otherwise specified.**

| PARAMETER | CONDITIONS | | LTC1151C MIN | LTC1151C TYP | LTC1151C MAX | UNITS |
|---|---|---|---|---|---|---|
| Input Offset Voltage | $T_A$ = 25°C (Note 3) | | | ±0.5 | ±5 | µV |
| Average Input Offset Drift | (Note 3) | ● | | ±0.01 | ±0.05 | µV/°C |
| Long Term Offset Voltage Drift | | | | 50 | | nV/√mo |
| Input Offset Current | $T_A$ = 25°C | <br>● | | ±20 | ±200<br>±0.5 | pA<br>nA |
| Input Bias Current | $T_A$ = 25°C | <br>● | | ±15 | ±100<br>±0.5 | pA<br>nA |
| Input Noise Voltage | $R_S$ = 100Ω, 0.1Hz to 10Hz<br>$R_S$ = 100Ω, 0.1Hz to 1Hz | | | 1.5<br>0.5 | | $\mu V_{P-P}$<br>$\mu V_{P-P}$ |
| Input Noise Current | f = 10Hz (Note 4) | | | 2.2 | | fA/√Hz |
| Input Voltage Range | Positive<br>Negative | ●<br>● | 12<br>–15 | 13.2<br>–15.3 | | V<br>V |
| Common Mode Rejection Ratio | $V_{CM}$ = $V^-$ to 12V | ● | 106 | 130 | | dB |
| Power Supply Rejection Ratio | $V_S$ = ±2.375V to ±16V | ● | 110 | 130 | | dB |
| Large-Signal Voltage Gain | $R_L$ = 10k, $V_{OUT}$ = ±10V | ● | 125 | 140 | | dB |

## ELECTRICAL CHARACTERISTICS

**The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at $T_A$ = 25°C. $V_S$ = ±15V, unless otherwise specified.**

| PARAMETER | CONDITIONS | | LTC1151C MIN | LTC1151C TYP | LTC1151C MAX | UNITS |
|---|---|---|---|---|---|---|
| Maximum Output Voltage Swing | $R_L$ = 10k, $T_A$ = 25°C<br>$R_L$ = 10k<br>$R_L$ = 100k | <br>●<br> | ±13.5<br>+10.5/–13.5<br> | ±14.50<br><br>±14.95 | <br><br> | V<br>V<br>V |
| Slew Rate | $R_L$ = 10k, $C_L$ = 50pF | | | 2.5 | | V/µs |
| Gain-Bandwidth Product | | | | 2 | | MHz |
| Supply Current per Amplifier | No Load, $T_A$ = 25°C<br>No Load | <br>● | | 0.9<br> | 1.5<br>2.0 | mA<br>mA |
| Internal Sampling Frequency | | | | 1000 | | Hz |

**The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at $T_A$ = 25°C. $V_S$ = 5V, unless otherwise specified.**

| | | | | | | |
|---|---|---|---|---|---|---|
| Input Offset Voltage | $T_A$ = 25°C (Note 3) | | | ±0.05 | ±5 | µV |
| Average Input Offset Drift | (Note 3) | ● | | ±0.01 | ±0.05 | µV/°C |
| Long Term Offset Voltage Drift | | | | 50 | | nV/$\sqrt{mo}$ |
| Input Offset Current | $T_A$ = 25°C | | | ±10 | 100 | pA |
| Input Bias Current | $T_A$ = 25°C | | | ±5 | 50 | pA |
| Input Noise Voltage | $R_S$ = 100Ω, 0.1Hz to 10Hz<br>$R_S$ = 100Ω, 0.1Hz to 1Hz | | | 2.0<br>0.7 | | $\mu V_{P-P}$<br>$\mu V_{P-P}$ |
| Input Noise Current | f = 10Hz (Note 4) | | | 1.3 | | fA/$\sqrt{Hz}$ |
| Input Voltage Range | Positive<br>Negative | | 2.7<br>0 | 3.2<br>–0.3 | | V<br>V |
| Common Mode Rejection Ratio | $V_{CM}$ = 0V to 2.7V | | 110 | | | dB |
| Power Supply Rejection Ratio | $V_S$ = ±2.375V to ±16V | ● | 110 | 130 | | dB |
| Large-Signal Voltage Gain | $R_L$ = 10k, $V_{OUT}$ = 0.3V to 4.5V | ● | 115 | 140 | | dB |
| Maximum Output Voltage Swing | $R_L$ = 10k to GND<br>$R_L$ = 100k to GND | | | 4.85<br>4.97 | | V<br>V |
| Slew Rate | $R_L$ = 10k, $C_L$ = 50pF | | | 1.5 | | V/µs |
| Gain Bandwidth Product | | | | 1.5 | | MHz |
| Supply Current per Amplifier | No Load, $T_A$ = 25°C | <br>● | | 0.5<br> | 1.0<br>1.5 | mA<br>mA |
| Internal Sampling Frequency | | | | 750 | | Hz |

**Note 1:** Absolute Maximum Ratings are those values beyond which the life of a device may be impaired.

**Note 2:** Connecting any terminal to voltages greater than $V^+$ or less than $V^-$ may cause destructive latch-up. It is recommended that no sources operating from external supplies be applied prior to power-up of the LTC1151.

**Note 3:** These parameters are guaranteed by design. Thermocouple effects preclude measurement of these voltage levels in high speed automatic test systems. $V_{OS}$ is measured to a limit determined by test equipment capability.

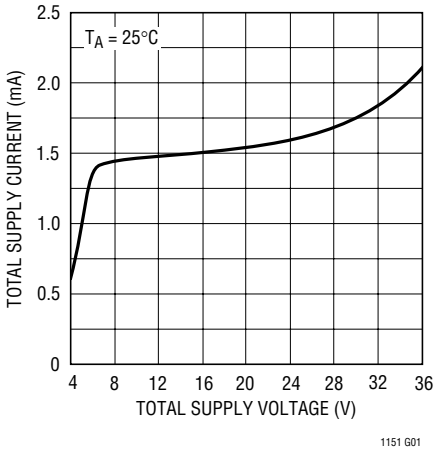
**Note 4:** Current Noise is calculated from the formula:

$$I_N = \sqrt{(2q \bullet I_b)}$$

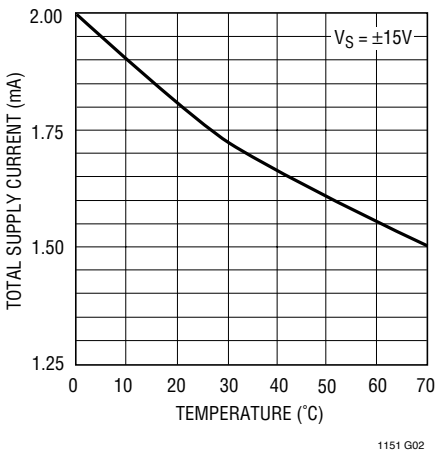
where $q = 1.6 \times 10^{-19}$ Coulomb.

## TYPICAL PERFORMANCE CHARACTERISTICS

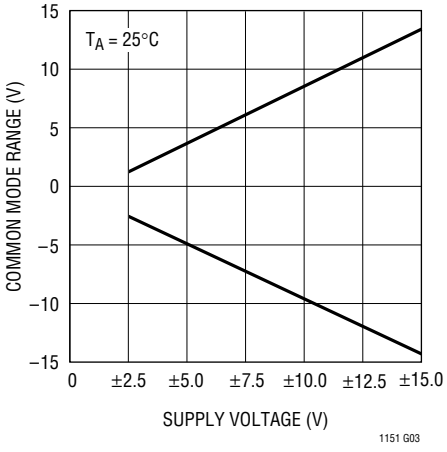
### Supply Current vs Supply Voltage



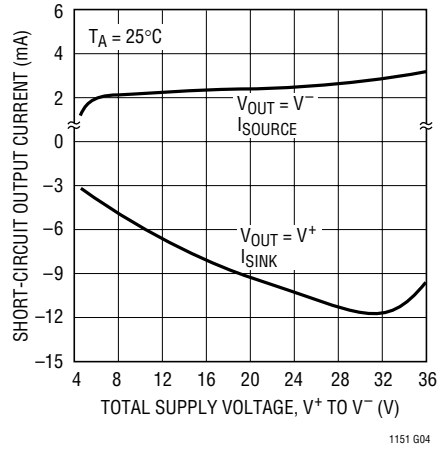

### Supply Current vs Temperature



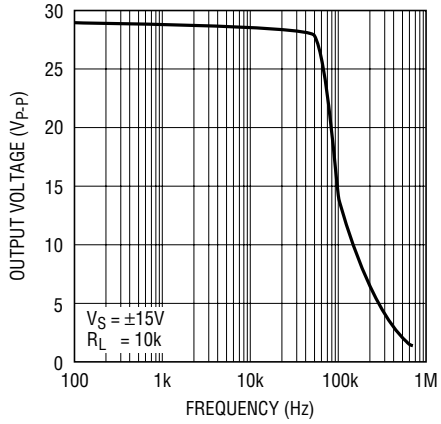

### Common Mode Input Voltage Range vs Supply Voltage



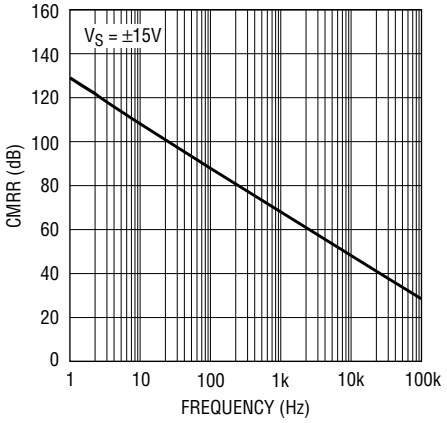

### Output Short-Circuit Current vs Supply Voltage



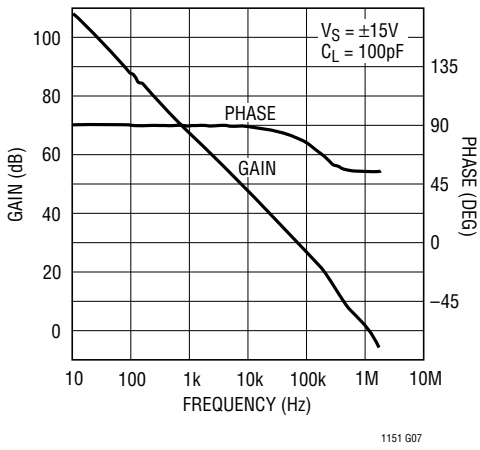

### Undistorted Output Swing vs Frequency



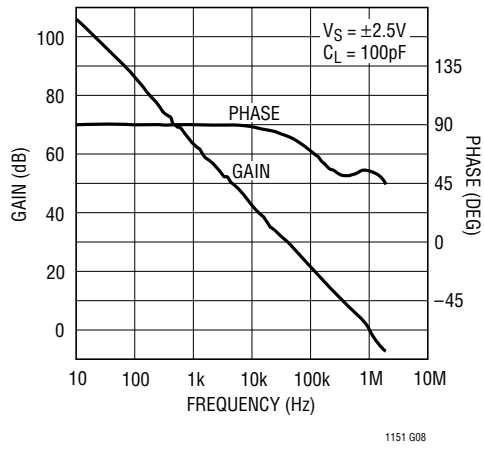

### CMRR vs Frequency



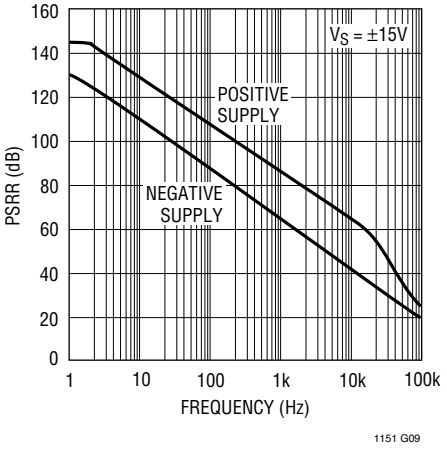

### Gain and Phase vs Frequency




### Gain and Phase vs Frequency

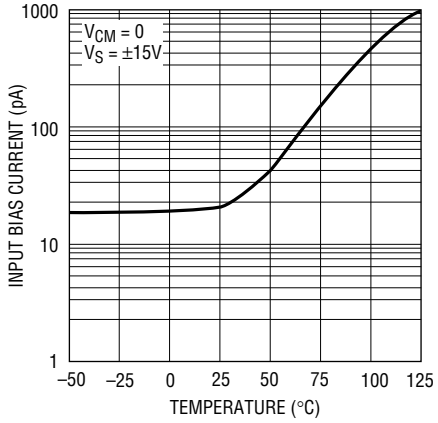



### PSRR vs Frequency

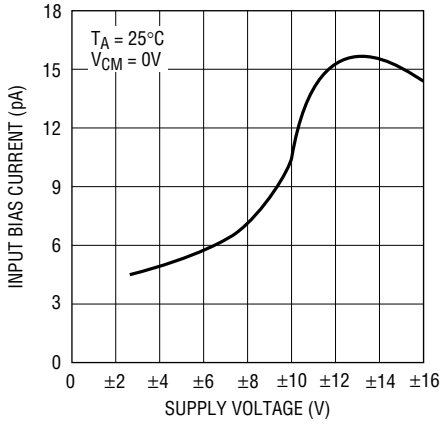


# TYPICAL PERFORMANCE CHARACTERISTICS

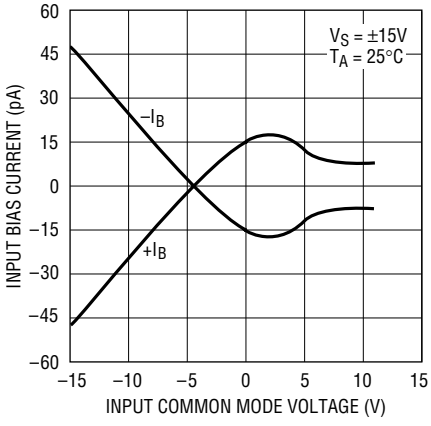
### Input Bias Current Magnitude vs Temperature



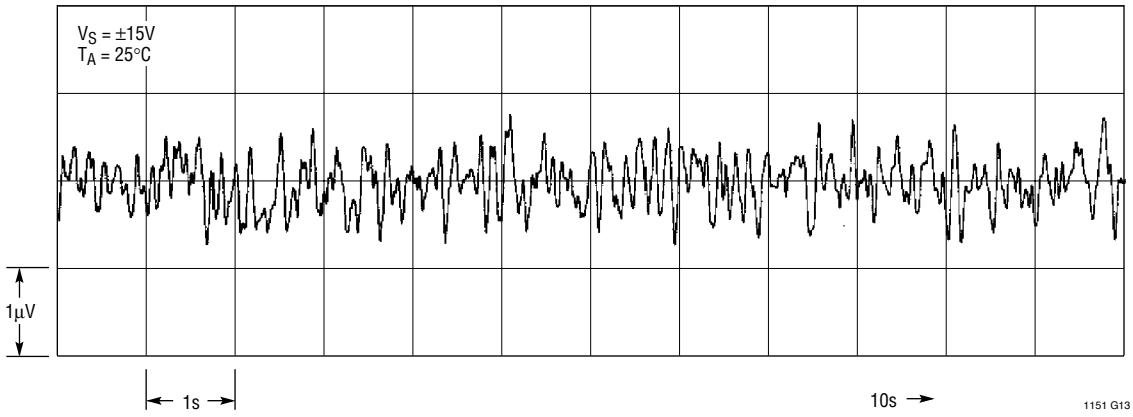

### Input Bias Current Magnitude vs Supply Voltage



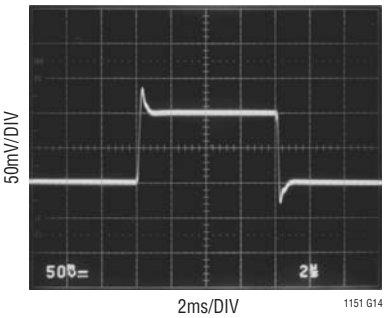

### Input Bias Current vs Input Common Mode Voltage




### 0.1Hz to 10Hz Noise

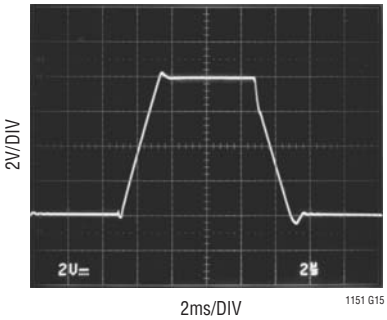



### Small-Signal Transient Response



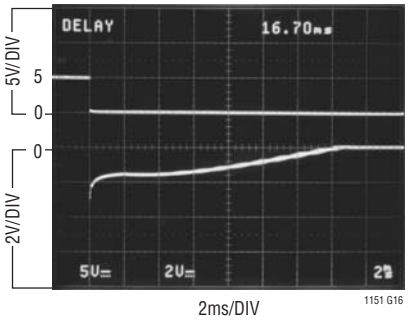

$V_S$ = ±15V, $A_V$ = 1
$C_L$ = 100pF, $R_L$ = 10k

### Large-Signal Transient Response




$V_S$ = ±15V, $A_V$ = 1
$C_L$ = 100pF, $R_L$ = 10k

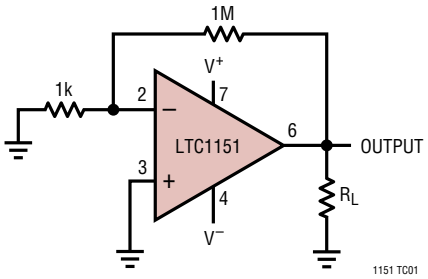
### Negative Overload Recovery



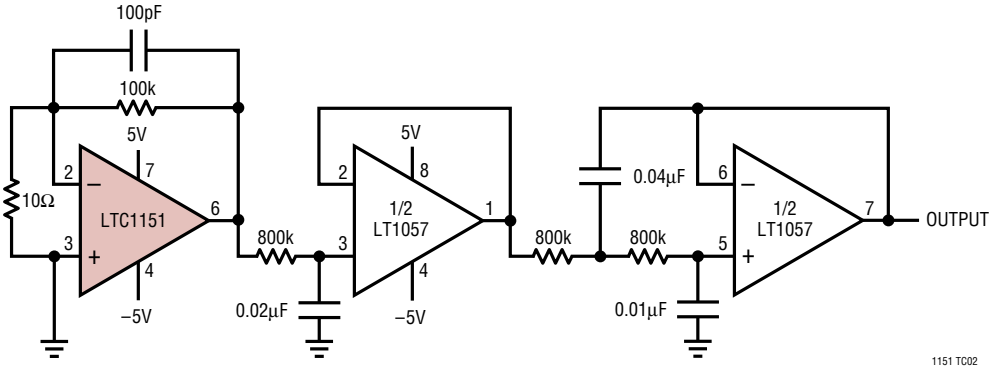

$V_S$ = ±15V, $A_V$ = –100
NOTE: POSITIVE OVERLOAD RECOVERY IS TYPICALLY 3ms.

## TEST CIRCUITS

**Offset Voltage Test Circuit**




**DC-10Hz Noise Test Circuit**



## APPLICATIONS INFORMATION

### ACHIEVING PICOAMPERE/MICROVOLT PERFORMANCE

#### Picoamperes

In order to realize the picoampere level of accuracy of the LTC1151 proper care must be exercised. Leakage currents in circuitry external to the amplifier can significantly degrade performance. High quality insulation should be used (e.g., Teflon); cleaning of all insulating surfaces to remove fluxes and other residues will probably be necessary, particularly for high temperature performance. Surface coating may be necessary to provide a moisture barrier in high humidity environments.

Board leakage can be minimized by encircling the input connections with a guard ring operated at a potential close to that of the inputs: in inverting configurations the guard ring should be tied to ground; in noninverting connections to the inverting input. Guarding both sides of the printed circuit board is required. Bulk leakage reduction depends on the guard ring width.

#### Microvolts

Thermocouple effects must be considered if the LTC1151's ultra low drift is to be fully utilized. Any connection of dissimilar metals forms a thermoelectric junction producing an electric potential which varies with temperature (Seebeck effect). As temperature sensors, thermocouples exploit this phenomenon to produce useful information. In low drift amplifier circuits the effect is a primary source of error.

Connectors, switches, relay contacts, sockets, resistors, solder, and even copper wire are all candidates for thermal EMF generation. Junctions of copper wire from different manufacturers can generate thermal EMFs of 200nV/°C; four times the maximum drift specification of the LTC1151.

Minimizing thermal EMF-induced errors is possible if judicious attention is given to circuit board layout and component selection. It is good practice to minimize the number of junctions in the amplifier's input signal path. Avoid connectors, sockets, switches and relays where possible. In instances where this is not possible, attempt to balance the number and type of junctions so that differential cancellation occurs. Doing this may involve deliberately introducing junctions to offset unavoidable junctions.

Figure 1 is an example of the introduction of an unnecessary resistor to promote differential thermal balance. Maintaining compensating junctions in close physical proximity will keep them at the same temperature and reduce thermal EMF errors.

When connectors, switches, relays and/or sockets are necessary they should be selected for low thermal EMF activity. The same techniques of thermally balancing and coupling the matching junctions are effective in reducing the thermal EMF errors of these components.

## APPLICATIONS INFORMATION

Resistors are another source of thermal EMF errors. Table 1 shows the thermal EMF generated for different resistors. The temperature gradient across the resistor is important, not the ambient temperature. There are two junctions formed at each end of the resistor and if these junctions are at the same temperature, their thermal EMFs will cancel each other. The thermal EMF numbers are approximate and vary with resistor value. High values give higher thermal EMF.

**Table 1. Resistor Thermal EMF**

| RESISTOR TYPE | THERMAL EMF/°C GRADIENT |
|---|---|
| Tin Oxide | >1mV/°C |
| Carbon Composition | ~450µV/°C |
| Metal Film | ~20µV/°C |
| Wire Wound<br>Evenohm, Manganin | ~2µV/°C |

### PACKAGE-INDUCED OFFSET VOLTAGE

Package-induced thermal EMF effects are another important source of errors. They arise at the junctions formed when wire or printed circuit traces contact a package lead. Like all the previously mentioned thermal EMF effects, they are outside the LTC1151's offset nulling loop and cannot be cancelled. The input offset voltage specification of the LTC1151 is actually set by the package-induced warm-up drift rather than by the circuit itself. The thermal time constant ranges from 0.5 to 3 minutes, depending on package type.

### ALIASING

Like all sampled data systems, the LTC1151 exhibits aliasing behavior at input frequencies near the sampling frequency. The LTC1151 includes a high frequency correction loop which minimizes this effect. As a result, aliasing is not a problem for many applications.

For a complete discussion of the correction circuitry and aliasing behavior, please refer to the LTC1051/LTC1053 data sheet.

### LOW SUPPLY OPERATION

The minimum supply for proper operation of the LTC1151 is typically 4.0V (±2.0V). In single supply applications, PSRR is guaranteed down to 4.7V (±2.35V) to ensure proper operation at minimum TTL supply voltage of 4.75V.

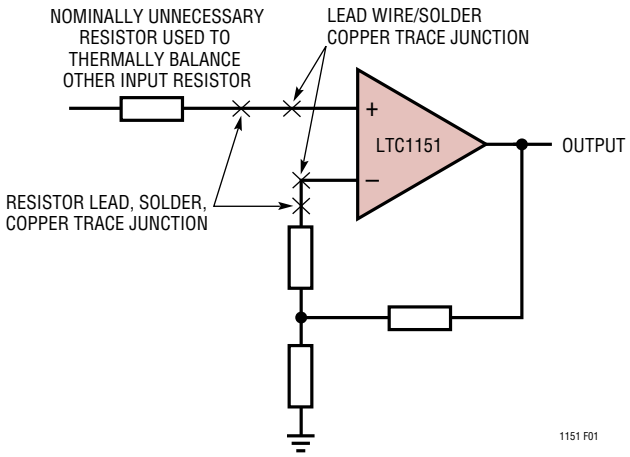
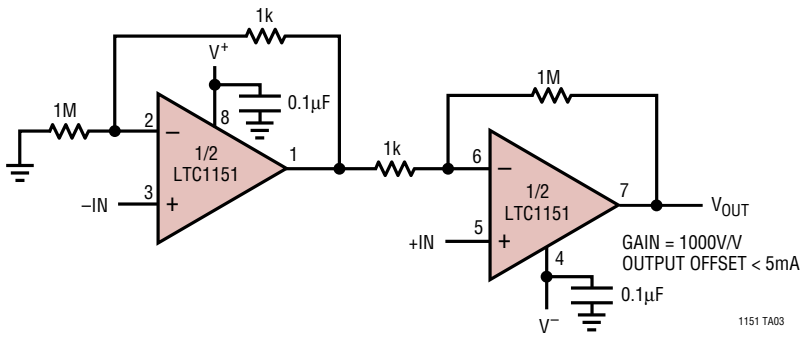



**Figure 1. Extra Resistors Cancel Thermal EMF**

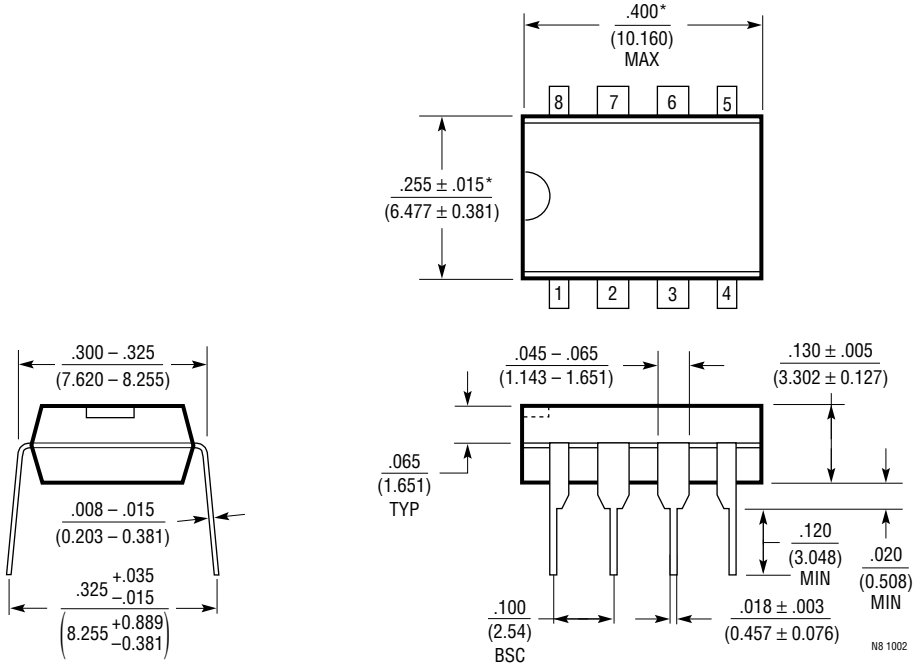
## TYPICAL APPLICATIONS

**High Voltage Instrumentation Amplifier**



# PACKAGE DESCRIPTION

**N8 Package**
**8-Lead PDIP (Narrow .300 Inch)**
(Reference LTC DWG # 05-08-1510)

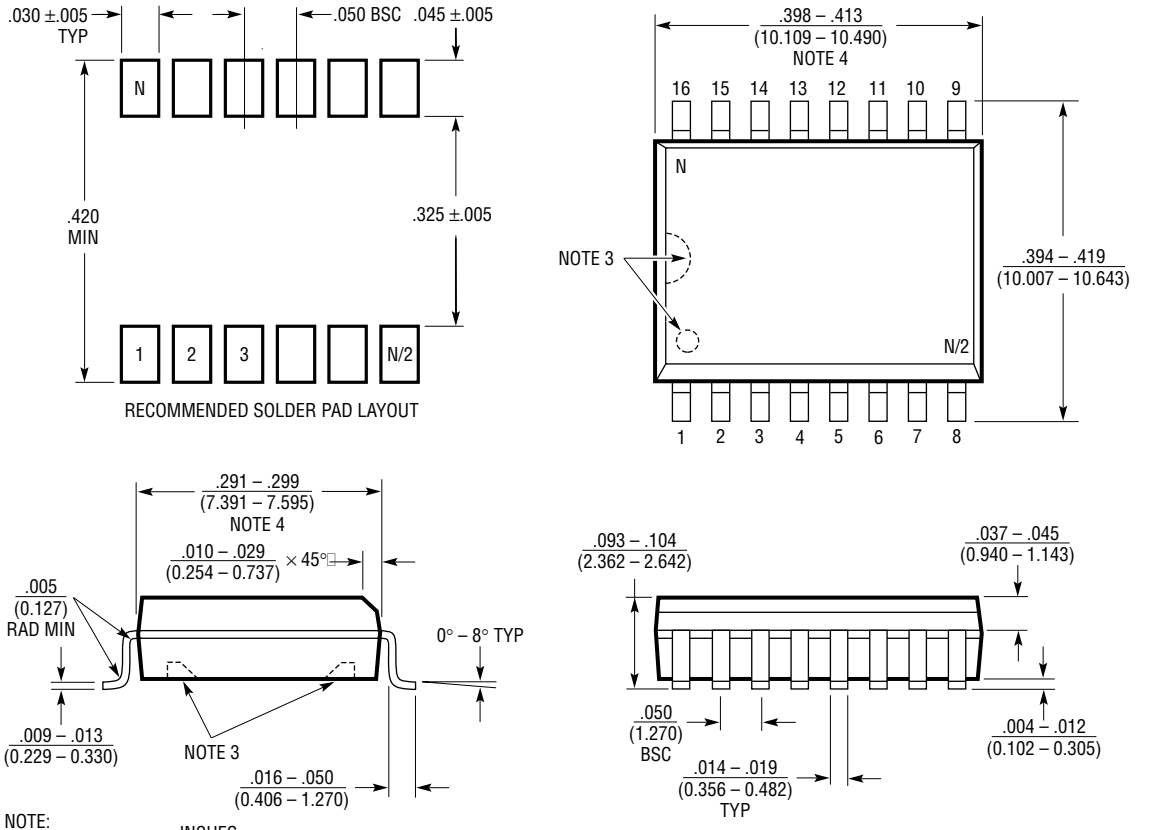



NOTE:
1. DIMENSIONS ARE INCHES / MILLIMETERS

*THESE DIMENSIONS DO NOT INCLUDE MOLD FLASH OR PROTRUSIONS.
MOLD FLASH OR PROTRUSIONS SHALL NOT EXCEED .010 INCH (0.254mm)

# PACKAGE DESCRIPTION

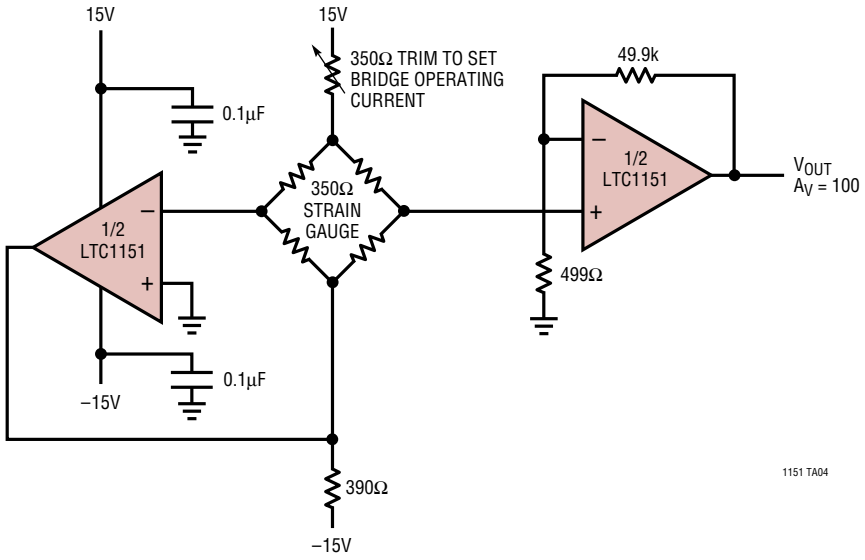
**SW Package**
**16-Lead Plastic Small Outline (Wide .300 Inch)**
(Reference LTC DWG # 05-08-1620)




NOTE:
1. DIMENSIONS IN $\frac{\text{INCHES}}{(\text{MILLIMETERS})}$
2. DRAWING NOT TO SCALE
3. PIN 1 IDENT, NOTCH ON TOP AND CAVITIES ON THE BOTTOM OF PACKAGES ARE THE MANUFACTURING OPTIONS. THE PART MAY BE SUPPLIED WITH OR WITHOUT ANY OF THE OPTIONS
4. THESE DIMENSIONS DO NOT INCLUDE MOLD FLASH OR PROTRUSIONS. MOLD FLASH OR PROTRUSIONS SHALL NOT EXCEED .006" (0.15mm)

## TYPICAL APPLICATIONS

**Bridge Amplifier with Active Common-Mode Suppression**




## RELATED PARTS

| PART NUMBER | DESCRIPTION | COMMENTS |
|---|---|---|
| LTC1049 | Low Power Zero-Drift Op Amp | Low Supply Current 200µA |
| LTC1050 | Precision Zero-Drift Op Amp | Single Supply Operation 4.75V to 16V, Noise Tested and Guaranteed |
| LTC1051/LTC1053 | Precision Zero-Drift Op Amp | Dual/Quad |
| LTC1150 | ±15V Zero-Drift Op Amp | High Voltage Operation ±18V |
| LTC1152 | Rail-to-Rail Input and Output Zero-Drift Op Amp | Single Zero-Drift Op Amp with Rail-to-Rail Input and Output and Shutdown |
| LT1677 | Low Noise Rail-toRail Input and Output | $V_{OS}$ = 90µV, $V_S$ = 2.7V to 44V Precision Op Amp |
| LT1884/LT1885 | Rail-to-Rail Output Precision Op Amp | $V_{OS}$ = 50µV, $I_B$ = 400pA, $V_S$ = 2.7V to 40V |
| LTC2050/LTC2051/LTC2052 | Single/Dual/Quad Zero-Drift Op Amp | Single Supply, 2.7V to ±5V, SOT-23/MS8/GN 16 Package |
| LTC2053 | Zero-Drift Instrumentation Amp | Rail-to-Rail, MS8, 116dB, Two Resistors Set Gain |
| LTC2054/LTC2055 | Single/Dual Zero-Drift Op Amp | 150µA per Amplifier (Max), SOT-23/MS8 Package |


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