# Precision, Micropower, Single Supply Instrumentation Amplifier (Fixed Gain =10 or 100)

## FEATURES

- Gain Error — 0.04% Max
- Gain Non-Linearity — 0.0008% (8ppm) Max
- Gain Drift — 4ppm/°C Max
- Supply Current — 105μA Max
- Offset Voltage — 160μV Max
- Offset Voltage Drift — 0.4μV/°C Typ
- Offset Current — 600pA Max
- CMRR, G = 100 — 100dB Min
- 0.1Hz to 10Hz Noise — 0.9μVp-p Typ, 2.3pAp-p Typ
- Gain Bandwidth Product — 250kHz Min
- Single or Dual Supply Operation
- Surface Mount Package Available

## APPLICATIONS

- Differential Signal Amplification in Presence of Common-Mode Voltage
- Micropower Bridge Transducer Amplifier
  - Thermocouples
  - Strain Gauges
  - Thermistors
- Differential Voltage to Current Converter
- Transformer Coupled Amplifier
- 4mA-20mA Bridge Transmitter

## DESCRIPTION

The LT1101 establishes the following milestones:
(1) It is the first micropower instrumentation amplifier,
(2) It is the first single supply instrumentation amplifier,
(3) It is the first instrumentation amplifier to feature fixed gains of 10 and/or 100 in low cost, space-saving 8-lead packages.

The LT1101 is completely self-contained: no external gain setting resistor is required. The LT1101 combines its micropower operation (75μA supply current) with a gain error of 0.008%, gain linearity of 3ppm, gain drift of 1ppm/°C. The output is guaranteed to drive a 2k load to ±10V with excellent gain accuracy.

Other precision specifications are also outstanding: 50μV input offset voltage, 130pA input offset current, and low drift (0.4μV/°C and 0.7pA/°C). In addition, unlike other instrumentation amplifiers, there is no output offset voltage contribution to total error.

A full set of specifications are provided with ±15V dual supplies and for single 5V supply operation. The LT1101 can be operated from a single lithium cell or two Ni-Cad batteries. Battery voltage can drop as low as 1.8V, yet the LT1101 still maintains its gain accuracy. In single supply applications, both input and output voltages swing to within a few millivolts of ground. The output sinks current while swinging to ground — no external, power consuming pull down resistors are needed.

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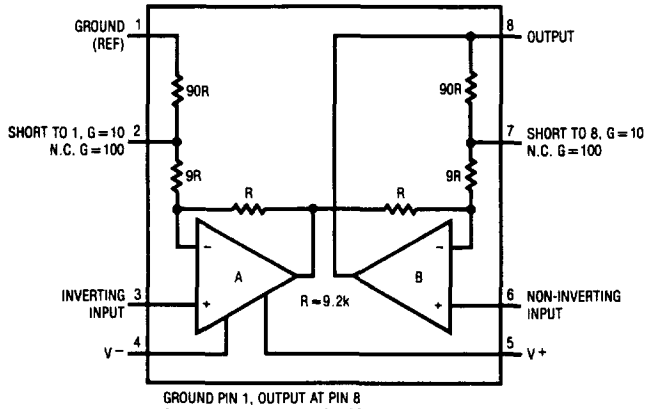
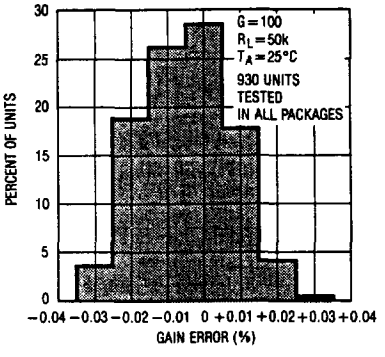
## BLOCK DIAGRAM




GROUND PIN 1, OUTPUT AT PIN 8
G=100: NO ADDITIONAL CONNECTIONS
G=10: SHORT PIN 2 TO PIN 1, SHORT PIN 7 TO PIN 8

**Gain Error Distribution**

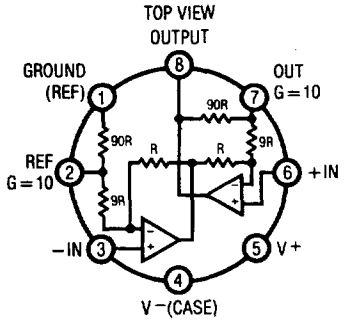


## ABSOLUTE MAXIMUM RATINGS

Supply Voltage ..... ±22V
Differential Input Voltage ..... ±36V
Input Voltage ..... Equal to Positive Supply Voltage
..... 10V Below Negative Supply Voltage
Output Short Circuit Duration ..... Indefinite
Lead Temperature (Soldering, 10 sec.)..... 300°C

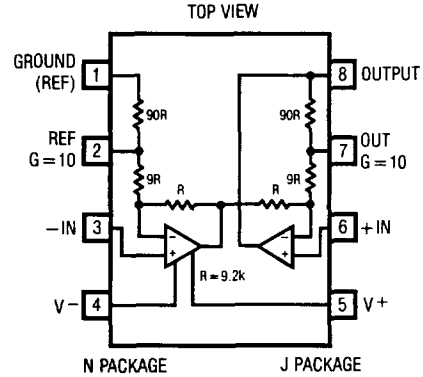
Operating Temperature Range
LT1101AM/LT1101M ..... –55°C to 125°C
LT1101AI/LT1101I ..... –40°C to 85°C
LT1101AC/LT1101C/LT1101S ..... 0°C to 70°C
Storage Temperature Range
All Grades ..... –65°C to 150°C

## PACKAGE/ORDER INFORMATION




H PACKAGE
8-LEAD TO-5 METAL CAN

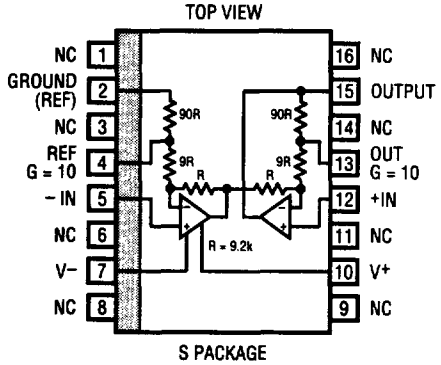
| ORDER PART NUMBER |
|---|
| LT1101AMH |
| LT1101MH |
| LT1101ACH |
| LT1101CH |




N PACKAGE
8-LEAD PLASTIC DIP

J PACKAGE
8-LEAD CERAMIC DIP

| ORDER PART NUMBER |
|---|
| LT1101AIN8 |
| LT1101IN8 |
| LT1101ACN8 |
| LT1101CN8 |
| LT1101AMJ8 |
| LT1101MJ8 |
| LT1101ACJ8 |
| LT1101CJ8 |




S PACKAGE
16-LEAD PLASTIC SOL

LT1101S

## ELECTRICAL CHARACTERISTICS

**$V_S$ = 5V, 0V, $V_{CM}$ = 0.1V, $V_{REF(PIN\ 1)}$ = 0.1V, G = 10 or 100, $T_A$ = 25°C, unless otherwise noted (Note 3).**

| SYMBOL | PARAMETER | CONDITIONS | LT1101AM/AI/AC MIN | LT1101AM/AI/AC TYP | LT1101AM/AI/AC MAX | LT1101M/I/C/S MIN | LT1101M/I/C/S TYP | LT1101M/I/C/S MAX | UNITS |
|---|---|---|---|---|---|---|---|---|---|
| $G_E$ | Gain Error | G = 100, $V_O$ = 0.1V to 3.5V, $R_L$ = 50k<br>G = 10, $V_O$ = 0.1V to 3.5V, $R_L$ = 50k | | 0.010<br>0.009 | 0.050<br>0.040 | | 0.011<br>0.010 | 0.075<br>0.060 | %<br>% |
| $G_{NL}$ | Gain Non-Linearity | G = 100, $R_L$ = 50k<br>G = 10, $R_L$ = 50k (Note 1) | | 20<br>3 | 60<br>7 | | 20<br>3 | 75<br>8 | ppm<br>ppm |
| $V_{OS}$ | Input Offset Voltage<br>LT1101S | | | 50 | 160 | | 60<br>250 | 220<br>600 | µV<br>µV |
| $I_{OS}$ | Input Offset Current | | | 0.13 | 0.60 | | 0.15 | 0.90 | nA |
| $I_B$ | Input Bias Current | | | 6 | 8 | | 6 | 10 | nA |
| $I_S$ | Supply Current | | | 75 | 105 | | 78 | 120 | µA |

## ELECTRICAL CHARACTERISTICS

**$V_S$ = 5V, 0V, $V_{CM}$ = 0.1V, $V_{REF(PIN\ 1)}$ = 0.1V, G = 10 or 100, $T_A$ = 25°C, unless otherwise noted (Note 3).**

| SYMBOL | PARAMETER | CONDITIONS | LT1101AM/AI/AC MIN | LT1101AM/AI/AC TYP | LT1101AM/AI/AC MAX | LT1101M/I/C/S MIN | LT1101M/I/C/S TYP | LT1101M/I/C/S MAX | UNITS |
|---|---|---|---|---|---|---|---|---|---|
| CMRR | Common-Mode Rejection Ratio | 1k Source Imbalance | | | | | | | |
| | | G = 100, $V_{CM}$ = 0.07V to 3.4V | 95 | 106 | | 92 | 105 | | dB |
| | | G = 10, $V_{CM}$ = 0.07V to 3.1V | 84 | 100 | | 82 | 99 | | dB |
| | Minimum Supply Voltage | (Note 4) | | 1.8 | 2.3 | | 1.8 | 2.3 | V |
| $V_O$ | Maximum Output Voltage Swing | Output High, 50k to GND | 4.1 | 4.3 | | 4.1 | 4.3 | | V |
| | | Output High, 2k to GND | 3.5 | 3.9 | | 3.5 | 3.9 | | V |
| | | Output Low, $V_{REF}$ = 0, No Load | | 3.3 | 6 | | 3.3 | 6 | mV |
| | | Output Low, $V_{REF}$ = 0, 2k to GND | | 0.5 | 1 | | 0.5 | 1 | mV |
| | | Output Low, $V_{REF}$ = 0, $I_{SINK}$ = 100μA | | 90 | 130 | | 90 | 130 | mV |
| BW | Bandwidth | G = 100 (Note 1) | 2.0 | 3.0 | | 2.0 | 3.0 | | kHz |
| | | G = 10 (Note 1) | 22 | 33 | | 22 | 33 | | kHz |
| SR | Slew Rate | (Note 1) | 0.04 | 0.07 | | 0.04 | 0.07 | | V/μs |

## ELECTRICAL CHARACTERISTICS

**$V_S$ = ±15V, $V_{CM}$ = 0V, $T_A$ = 25°C, Gain = 10 or 100, unless otherwise noted.**

| SYMBOL | PARAMETER | CONDITIONS | LT1101AM/AI/AC MIN | LT1101AM/AI/AC TYP | LT1101AM/AI/AC MAX | LT1101M/I/C/S MIN | LT1101M/I/C/S TYP | LT1101M/I/C/S MAX | UNITS |
|---|---|---|---|---|---|---|---|---|---|
| $G_E$ | Gain Error | G = 100, $V_O$ = ±10V, $R_L$ = 50k | | 0.008 | 0.040 | | 0.009 | 0.060 | % |
| | | G = 100, $V_O$ = ±10V, $R_L$ = 2k | | 0.011 | 0.055 | | 0.012 | 0.070 | % |
| | | G = 10, $V_O$ = ±10V, $R_L$ = 50k or 2k | | 0.008 | 0.040 | | 0.009 | 0.060 | % |
| $G_{NL}$ | Gain Non-Linearity | G = 100, $R_L$ = 50k | | 7 | 16 | | 8 | 20 | ppm |
| | | G = 100, $R_L$ = 2k | | 24 | 45 | | 25 | 60 | ppm |
| | | G = 10, $R_L$ = 50k or 2k | | 3 | 8 | | 3 | 9 | ppm |
| $V_{OS}$ | Input Offset Voltage | | | 50 | 160 | | 60 | 220 | μV |
| | | LT1101S | | | | | 250 | 600 | μV |
| $I_{OS}$ | Input Offset Current | | | 0.13 | 0.60 | | 0.15 | 0.90 | nA |
| $I_B$ | Input Bias Current | | | 6 | 8 | | 6 | 10 | nA |
| | Input Resistance | | | | | | | | |
| | Common-Mode | (Note 1) | 4 | 7 | | 3 | 7 | | GΩ |
| | Differential Mode | (Note 1) | 7 | 12 | | 5 | 12 | | GΩ |
| $e_n$ | Input Noise Voltage | 0.1Hz to 10Hz (Note 2) | | 0.9 | 1.8 | | 0.9 | | μVp-p |
| | Input Noise Voltage Density | $f_o$ = 10Hz (Note 2) | | 45 | 64 | | 45 | | nV/√Hz |
| | | $f_o$ = 1000Hz (Note 2) | | 43 | 54 | | 43 | | nV/√Hz |
| $i_n$ | Input Noise Current | 0.1Hz to 10Hz (Note 2) | | 2.3 | 4.0 | | 2.3 | | pAp-p |
| | Input Noise Current Density | $f_o$ = 10Hz (Note 2) | | 0.06 | 0.10 | | 0.06 | | pA/√Hz |
| | | $f_o$ = 1000Hz | | 0.02 | | | 0.02 | | pA/√Hz |
| | Input Voltage Range | G = 100 | +13.0 | +13.8 | | +13.0 | +13.8 | | V |
| | | | −14.4 | −14.7 | | −14.4 | −14.7 | | V |
| | | G = 10 | +11.5 | +12.5 | | +11.5 | +12.5 | | V |
| | | | −13.0 | −13.3 | | −13.0 | −13.3 | | V |
| CMRR | Common-Mode Rejection Ratio | 1k Source Imbalance | | | | | | | |
| | | G = 100, Over CM Range | 100 | 112 | | 98 | 112 | | dB |
| | | G = 10, Over CM Range | 84 | 100 | | 82 | 99 | | dB |
| PSRR | Power Supply Rejection Ratio | $V_S$ = +2.2V, −0.1V to ±18V | 102 | 114 | | 100 | 114 | | dB |
| $I_S$ | Supply Current | | | 92 | 130 | | 94 | 150 | μA |
| $V_O$ | Maximum Output Voltage Swing | $R_L$ = 50k | ±13.0 | ±14.2 | | ±13.0 | ±14.2 | | V |
| | | $R_L$ = 2k | ±11.0 | ±13.2 | | ±11.0 | ±13.2 | | V |
| BW | Bandwidth | G = 100 (Note 1) | 2.3 | 3.5 | | 2.3 | 3.5 | | kHz |
| | | G = 10 (Note 1) | 25 | 37 | | 25 | 37 | | kHz |
| SR | Slew Rate | | 0.06 | 0.10 | | 0.06 | 0.10 | | V/μs |

**Note 1:** This parameter is not tested. It is guaranteed by design and by inference from other tests.

**Note 2:** This parameter is tested on a sample basis only.

**Note 3:** These test conditions are equivalent to $V_S$ = 4.9V, −0.1V, $V_{CM}$ = 0V, $V_{REF(PIN\ 1)}$ = 0V.

**Note 4:** Minimum supply voltage is guaranteed by the power supply rejection test. The LT1101 actually works at 1.8V supply with minimal degradation in performance.

## ELECTRICAL CHARACTERISTICS

**$V_S = \pm 15V$, $V_{CM} = 0V$, Gain = 10 or 100, $-55°C \le T_A \le 125°C$ for AM/M grades, $-40°C \le T_A \le 85°C$ for AI/I grades, unless otherwise noted.**

| SYMBOL | PARAMETER | CONDITIONS | LT1101AM/AI MIN | LT1101AM/AI TYP | LT1101AM/AI MAX | LT1101M/I MIN | LT1101M/I TYP | LT1101M/I MAX | UNITS |
|---|---|---|---|---|---|---|---|---|---|
| $G_E$ | Gain Error | G = 100, $V_O = \pm 10V$, $R_L = 50k$ | | 0.024 | 0.070 | | 0.026 | 0.100 | % |
| | | G = 100, $V_O = \pm 10V$, $R_L = 5k$ | | 0.030 | 0.100 | | 0.035 | 0.130 | % |
| | | G = 10, $V_O = \pm 10V$, $R_L = 50k$ or 5k | | 0.015 | 0.070 | | 0.018 | 0.100 | % |
| $TCG_E$ | Gain Error Drift (Note 1) | G = 100, $R_L = 50k$ | | 2 | 4 | | 2 | 5 | ppm/°C |
| | | G = 100, $R_L = 5k$ | | 2 | 7 | | 2 | 8 | ppm/°C |
| | | G = 10, $R_L = 50k$ or 5k | | 1 | 4 | | 1 | 5 | ppm/°C |
| $G_{NL}$ | Gain Non-Linearity | G = 100, $R_L = 50k$ | | 24 | 70 | | 26 | 90 | ppm |
| | | G = 100, $R_L = 5k$ | | 70 | 300 | | 75 | 500 | ppm |
| | | G = 10, $R_L = 50k$ | | 4 | 13 | | 5 | 15 | ppm |
| | | G = 10, $R_L = 5k$ | | 10 | 40 | | 12 | 60 | ppm |
| $V_{OS}$ | Input Offset Voltage | | | 90 | 350 | | 110 | 500 | µV |
| $\Delta V_{OS}/\Delta T$ | Input Offset Voltage Drift | (Note 1) | | 0.4 | 2.0 | | 0.5 | 2.8 | µV/°C |
| $I_{OS}$ | Input Offset Current | | | 0.16 | 0.80 | | 0.19 | 1.30 | nA |
| $\Delta I_{OS}/\Delta T$ | Input Offset Current Drift | (Note 1) | | 0.5 | 4.0 | | 0.8 | 7.0 | pA/°C |
| $I_B$ | Input Bias Current | | | 7 | 10 | | 7 | 12 | nA |
| $\Delta I_B/\Delta T$ | Input Bias Current Drift | (Note 1) | | 10 | 25 | | 10 | 30 | pA/°C |
| CMRR | Common-Mode Rejection Ratio | G = 100, $V_{CM} = -14.4V$ to 13V | 96 | 111 | | 94 | 111 | | dB |
| | | G = 10, $V_{CM} = -13V$ to 11.5V | 80 | 99 | | 78 | 98 | | dB |
| PSRR | Power Supply Rejection Ratio | $V_S = +3.0$, $-0.1V$ to $\pm 18V$ | 98 | 110 | | 94 | 110 | | dB |
| $I_S$ | Supply Current | | | 105 | 165 | | 108 | 190 | µA |
| $V_O$ | Maximum Output Voltage Swing | $R_L = 50k$ | ±12.5 | ±14.0 | | ±12.5 | ±14.0 | | V |
| | | $R_L = 5k$ | ±11.0 | ±13.5 | | ±11.0 | ±13.5 | | V |

## ELECTRICAL CHARACTERISTICS

**$V_S = \pm 15V$, $V_{CM} = 0V$, Gain = 10 or 100, $0°C \le T_A \le 70°C$, unless otherwise noted.**

| SYMBOL | PARAMETER | CONDITIONS | LT1101AC MIN | LT1101AC TYP | LT1101AC MAX | LT1101C/S MIN | LT1101C/S TYP | LT1101C/S MAX | UNITS |
|---|---|---|---|---|---|---|---|---|---|
| $G_E$ | Gain Error | G = 100, $V_O = \pm 10V$, $R_L = 50k$ | | 0.012 | 0.055 | | 0.014 | 0.080 | % |
| | | G = 100, $V_O = \pm 10V$, $R_L = 2k$ | | 0.018 | 0.085 | | 0.020 | 0.100 | % |
| | | G = 10, $V_O = \pm 10V$, $R_L = 50k$ or 2k | | 0.009 | 0.055 | | 0.010 | 0.080 | % |
| $TCG_E$ | Gain Error Drift (Note 1) | G = 100, $R_L = 50k$ | | 1 | 4 | | 1 | 5 | ppm/°C |
| | | G = 100, $R_L = 2k$ | | 2 | 7 | | 2 | 9 | ppm/°C |
| | | G = 10, $R_L = 50k$ or 2k | | 1 | 4 | | 1 | 5 | ppm/°C |
| $G_{NL}$ | Gain Non-Linearity | G = 100, $R_L = 50k$ | | 9 | 25 | | 10 | 35 | ppm |
| | | G = 100, $R_L = 2k$ | | 33 | 75 | | 36 | 100 | ppm |
| | | G = 10, $R_L = 50k$ or 2k | | 4 | 10 | | 4 | 11 | ppm |
| $V_{OS}$ | Input Offset Voltage | | | 70 | 250 | | 85 | 350 | µV |
| | | LT1101S | | | | | 300 | 800 | µV |
| $\Delta V_{OS}/\Delta T$ | Input Offset Voltage Drift | (Note 1) | | 0.4 | 2.0 | | 0.5 | 2.8 | µV/°C |
| | | LT1101S | | | | | 1.2 | 4.5 | µV/°C |
| $I_{OS}$ | Input Offset Current | | | 0.14 | 0.70 | | 0.17 | 1.10 | nA |
| $\Delta I_{OS}/\Delta T$ | Input Offset Current Drift | (Note 1) | | 0.5 | 4.0 | | 0.8 | 7.0 | pA/°C |
| $I_B$ | Input Bias Current | | | 6 | 9 | | 6 | 11 | nA |
| $\Delta I_B/\Delta T$ | Input Bias Current Drift | (Note 1) | | 10 | 25 | | 10 | 30 | pA/°C |
| CMRR | Common-Mode Rejection Ratio | G = 100, $V_{CM} = -14.4V$ to 13V | 98 | 112 | | 96 | 112 | | dB |
| | | G = 10, $V_{CM} = -13V$ to 11.5V | 82 | 100 | | 80 | 99 | | dB |
| PSRR | Power Supply Rejection Ratio | $V_S = 2.5$, $-0.1V$ to $\pm 18V$ | 100 | 112 | | 97 | 112 | | dB |
| $I_S$ | Supply Current | | | 98 | 148 | | 100 | 170 | µA |
| $V_O$ | Maximum Output Voltage Swing | $R_L = 50k$ | ±12.5 | ±14.1 | | ±12.5 | ±14.1 | | V |
| | | $R_L = 2k$ | ±10.5 | ±13.0 | | ±10.5 | ±13.0 | | V |

## ELECTRICAL CHARACTERISTICS

**$V_S$ = 5V, 0V, $V_{CM}$ = 0.1V, $V_{REF(PIN\ 1)}$ = 0.1V, Gain = 10 or 100, −55°C ≤ $T_A$ ≤ 125°C for AM/M grades, −40°C ≤ $T_A$ ≤ 85°C for AI/I grades, unless otherwise noted.**

| SYMBOL | PARAMETER | CONDITIONS | LT1101AM/AI MIN | LT1101AM/AI TYP | LT1101AM/AI MAX | LT1101M/I MIN | LT1101M/I TYP | LT1101M/I MAX | UNITS |
|---|---|---|---|---|---|---|---|---|---|
| $G_E$ | Gain Error | G = 100, $V_O$ = 0.1V to 3.5V, $R_L$ = 50k | | 0.026 | 0.080 | | 0.028 | 0.120 | % |
| | | G = 10, $V_{CM}$ = 0.15, $R_L$ = 50k | | 0.011 | 0.070 | | 0.014 | 0.100 | % |
| $TCG_E$ | Gain Error Drift | $R_L$ = 50k (Note 1) | | 1 | 4 | | 1 | 5 | ppm/°C |
| $G_{NL}$ | Gain Non-Linearity | G = 100, $R_L$ = 50k | | 45 | 110 | | 48 | 140 | ppm |
| | | G = 10, $R_L$ = 50k (Note 1) | | 4 | 13 | | 5 | 15 | ppm |
| $V_{OS}$ | Input Offset Voltage | | | 90 | 350 | | 110 | 500 | µV |
| $\Delta V_{OS}/\Delta T$ | Input Offset Voltage Drift | (Note 1) | | 0.4 | 2.0 | | 0.5 | 2.8 | µV/°C |
| $I_{OS}$ | Input Offset Current | | | 0.16 | 0.80 | | 0.19 | 1.30 | nA |
| $\Delta I_{OS}/\Delta T$ | Input Offset Current Drift | (Note 1) | | 0.5 | 4.0 | | 0.8 | 7.0 | pA/°C |
| $I_B$ | Input Bias Current | | | 7 | 10 | | 7 | 12 | nA |
| $\Delta I_B/\Delta T$ | Input Bias Current Drift | (Note 1) | | 10 | 25 | | 10 | 30 | pA/°C |
| CMRR | Common-Mode Rejection Ratio | G = 100, $V_{CM}$ = 0.1V to 3.2V | 91 | 105 | | 88 | 104 | | dB |
| | | G = 10, $V_{CM}$ = 0.1V to 2.9V, $V_{REF}$ = 0.15V | 80 | 98 | | 77 | 97 | | dB |
| $I_S$ | Supply Current | | | 88 | 135 | | 92 | 160 | µA |
| $V_O$ | Maximum Output Voltage Swing | Output High, 50k to GND | 3.8 | 4.1 | | 3.8 | 4.1 | | V |
| | | Output High, 2k to GND | 3.0 | 3.7 | | 3.0 | 3.7 | | V |
| | | Output Low, $V_{REF}$ = 0, No Load | | 4.5 | 8 | | 4.5 | 8 | mV |
| | | Output Low, $V_{REF}$ = 0, 2k to GND | | 0.7 | 1.5 | | 0.7 | 1.5 | mV |
| | | Output Low, $V_{REF}$ = 0, $I_{SINK}$ = 100µA | | 125 | 170 | | 125 | 170 | mV |

## ELECTRICAL CHARACTERISTICS

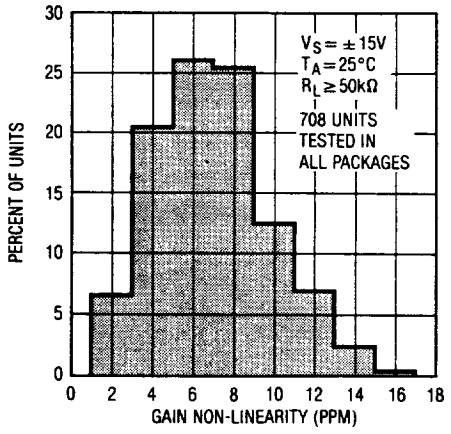
**$V_S$ = 5V, 0V, $V_{CM}$ = 0.1V, $V_{REF(PIN\ 1)}$ = 0.1V, Gain = 10 or 100, 0°C ≤ $T_A$ ≤ 70°C, unless otherwise noted.**

| SYMBOL | PARAMETER | CONDITIONS | LT1101AC MIN | LT1101AC TYP | LT1101AC MAX | LT1101C/S MIN | LT1101C/S TYP | LT1101C/S MAX | UNITS |
|---|---|---|---|---|---|---|---|---|---|
| $G_E$ | Gain Error | G = 100, $V_O$ = 0.1V to 3.5V, $R_L$ = 50k | | 0.017 | 0.065 | | 0.018 | 0.095 | % |
| | | G = 10, $V_{CM}$ = 0.15V, $R_L$ = 50k | | 0.010 | 0.060 | | 0.012 | 0.080 | % |
| $TCG_E$ | Gain Error Drift | $R_L$ = 50k (Note 1) | | 1 | 4 | | 1 | 5 | ppm/°C |
| $G_{NL}$ | Gain Non-Linearity | G = 100, $R_L$ = 50k | | 25 | 80 | | 25 | 100 | ppm |
| | | G = 10, $R_L$ = 50k (Note 1) | | 4 | 10 | | 4 | 11 | ppm |
| $V_{OS}$ | Input Offset Voltage | | | 70 | 250 | | 85 | 350 | µV |
| | | LT1101S | | | | | 300 | 800 | µV |
| $\Delta V_{OS}/\Delta T$ | Input Offset Voltage Drift | (Note 1) | | 0.4 | 2.0 | | 0.5 | 2.8 | µV/°C |
| | | LT1101S | | | | | 1.2 | 4.5 | µV/°C |
| $I_{OS}$ | Input Offset Current | | | 0.14 | 0.70 | | 0.17 | 1.10 | nA |
| $\Delta I_{OS}/\Delta T$ | Input Offset Current Drift | (Note 1) | | 0.5 | 4.0 | | 0.8 | 7.0 | pA/°C |
| $I_B$ | Input Bias Current | | | 6 | 9 | | 6 | 11 | nA |
| $\Delta I_B/\Delta T$ | Input Bias Current Drift | (Note 1) | | 10 | 25 | | 10 | 30 | pA/°C |
| CMRR | Common-Mode Rejection Ratio | G = 100, $V_{CM}$ = 0.07V to 3.3V | 93 | 105 | | 90 | 104 | | dB |
| | | G = 10, $V_{CM}$ = 0.07V to 3.0V, $V_{REF}$ = 0.15V | 82 | 99 | | 80 | 98 | | dB |
| $I_S$ | Supply Current | | | 80 | 120 | | 85 | 145 | µA |
| $V_O$ | Maximum Output Voltage Swing | Output High, 50k to GND | 4.0 | 4.2 | | 4.0 | 4.2 | | V |
| | | Output High, 2k to GND | 3.3 | 3.8 | | 3.3 | 3.8 | | V |
| | | Output Low, $V_{REF}$ = 0, No Load | | 4 | 7 | | 4 | 7 | mV |
| | | Output Low, $V_{REF}$ = 0, 2k to GND | | 0.6 | 1.2 | | 0.6 | 1.2 | mV |
| | | Output Low, $V_{REF}$ = 0, $I_{SINK}$ = 100µA | | 100 | 150 | | 100 | 150 | mV |

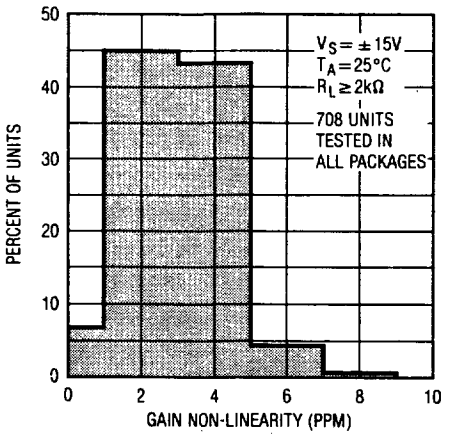
3

# TYPICAL PERFORMANCE CHARACTERISTICS

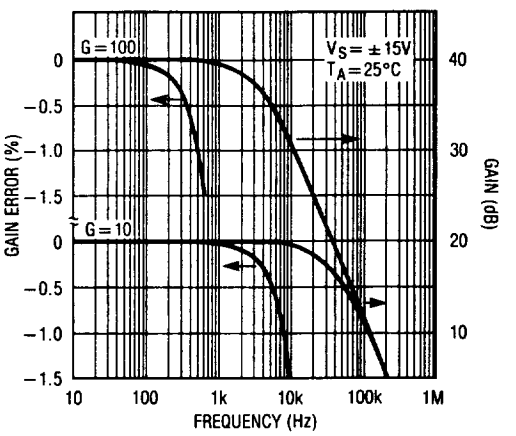
### Gain = 100 Non-Linearity Distribution



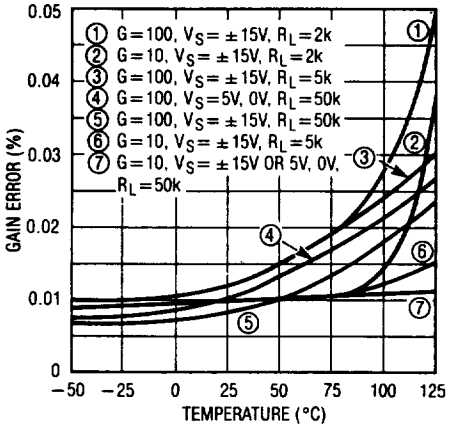

### Gain = 10 Non-Linearity Distribution



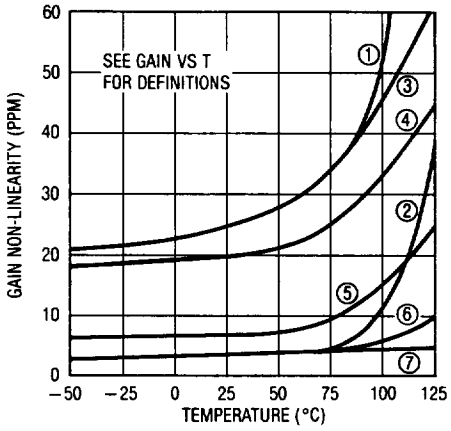

### Gain vs Frequency



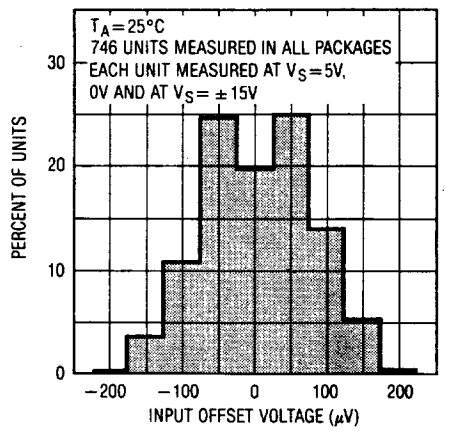

### Gain Error Over Temperature



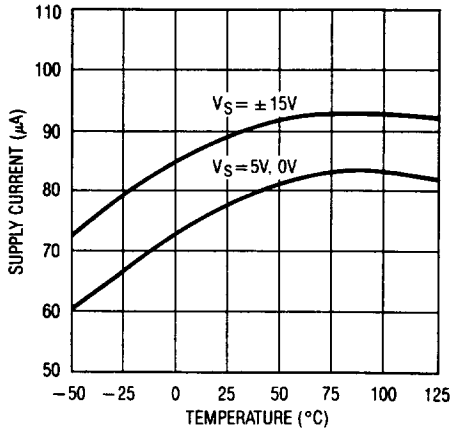

### Gain Non-Linearity Over Temperature



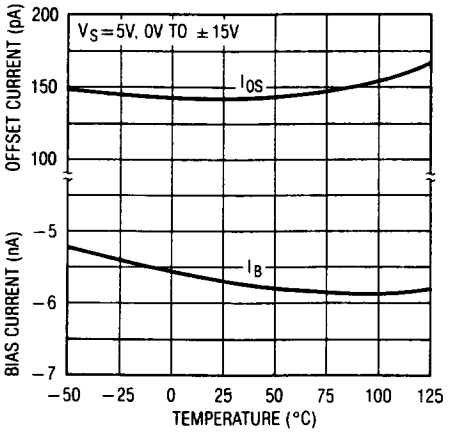

### Input Offset Voltage Distribution



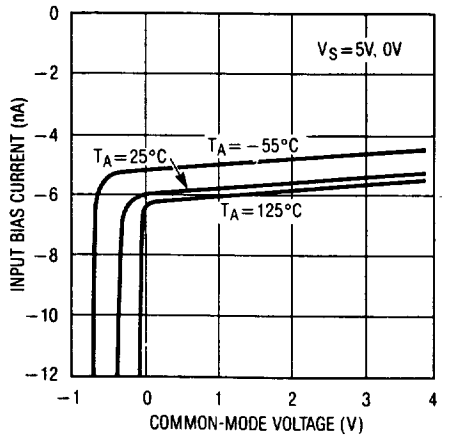

### Supply Current vs Temperature




### Input Bias and Offset Currents vs Temperature

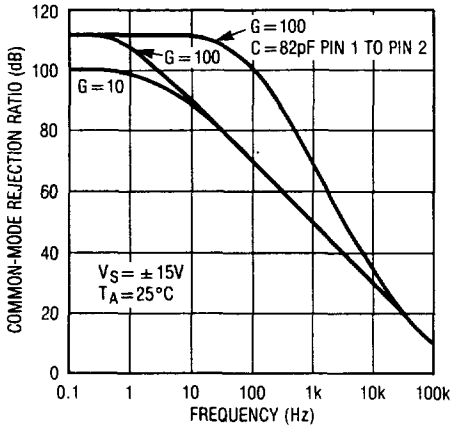



### Input Bias Current vs Common-Mode Voltage

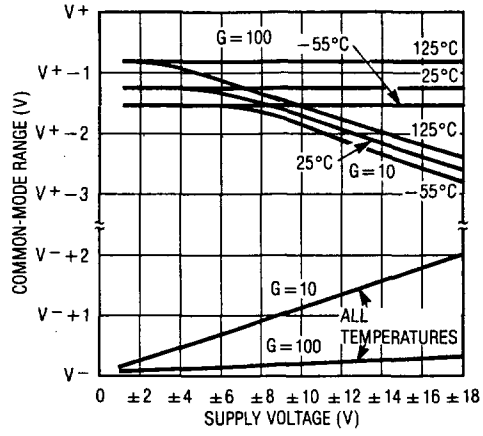


# TYPICAL PERFORMANCE CHARACTERISTICS

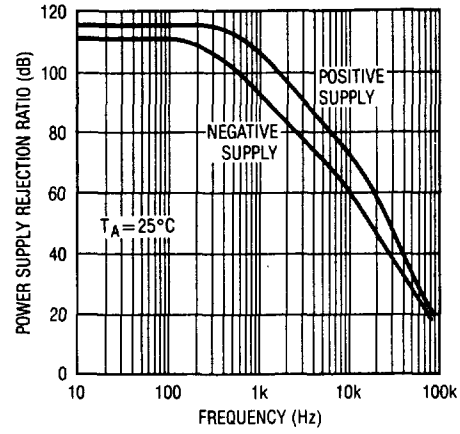
### Common-Mode Rejection Ratio vs Frequency



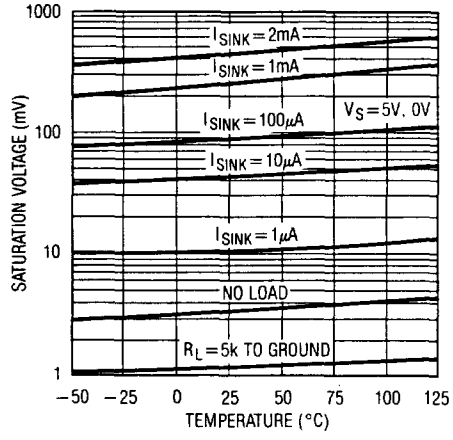

### Common-Mode Range vs Supply Voltage



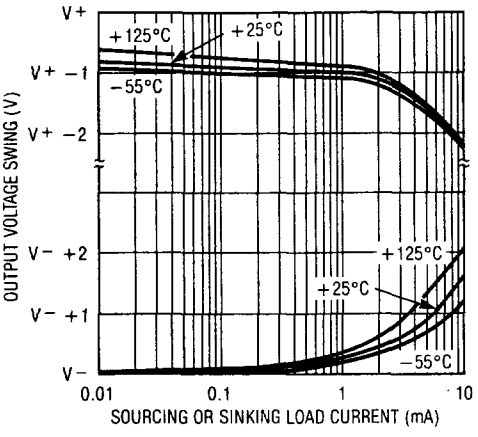

### Power Supply Rejection Ratio vs Frequency



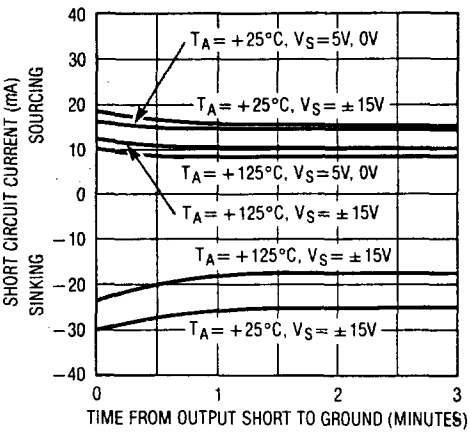

### Output Saturation vs Temperature vs Sink Current



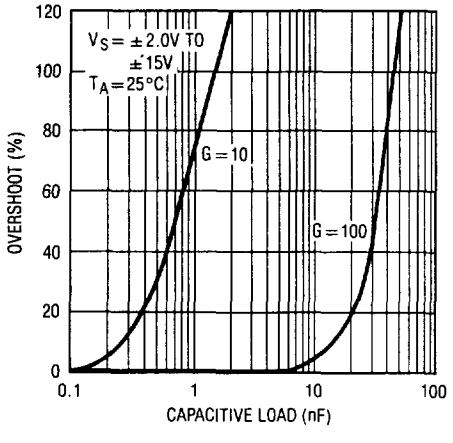

### Output Voltage Swing vs Load Current



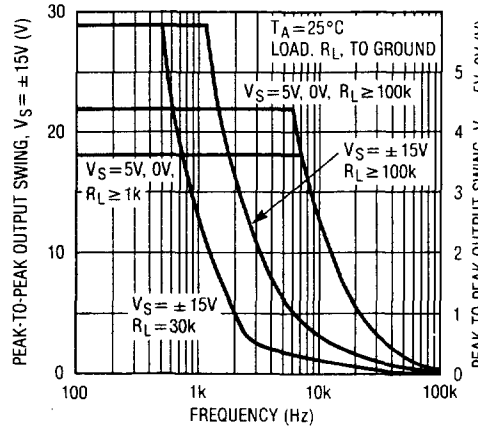

### Short Circuit Current vs Time



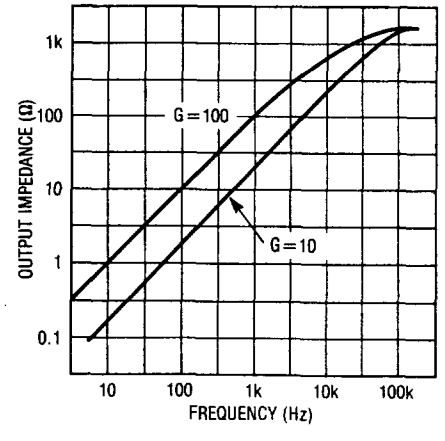

### Capacitive Load Handling




### Undistorted Output Swing vs Frequency

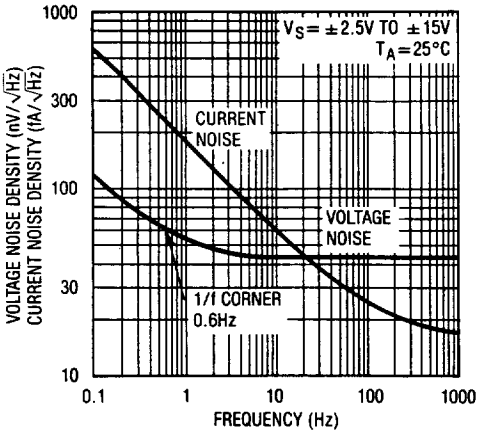



### Output Impedance vs Frequency

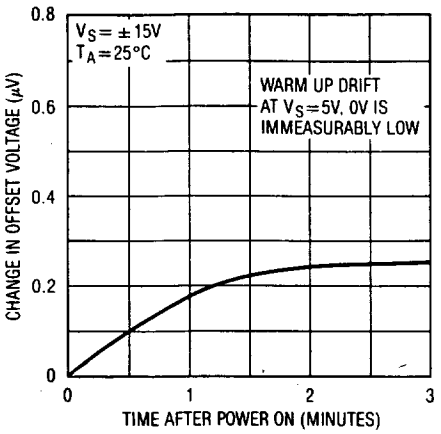


# TYPICAL PERFORMANCE CHARACTERISTICS

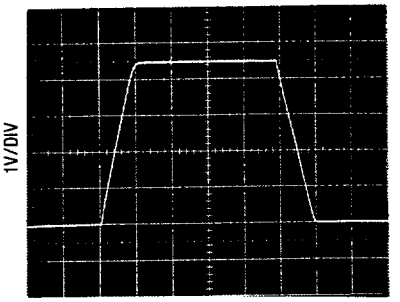
**Noise Spectrum**




**Warm-Up Drift**

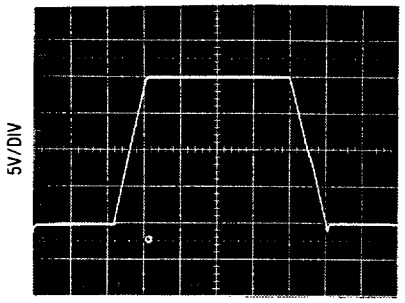



**Large Signal Transient Response**
**G = 10, $V_S$ = 5V, 0V**



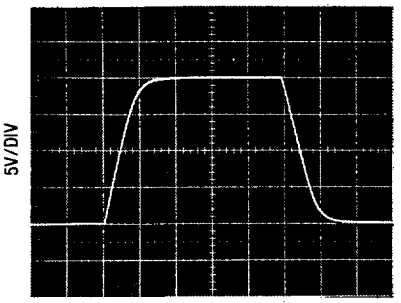

50μs/DIV
OUTPUT FROM 0V TO 4.5V, NO LOAD

**Large Signal Transient Response**
**G = 10, $V_S$ = ±15V**



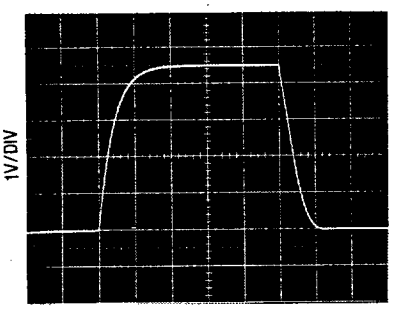

200μs/DIV
NO LOAD

**Large Signal Transient Response**
**G = 100, $V_S$ = ±15V**



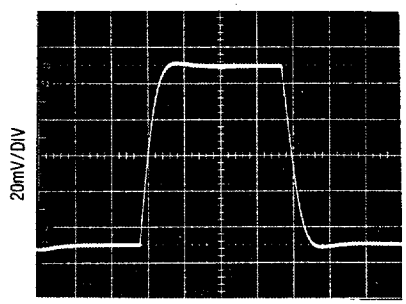

200μs/DIV
NO LOAD

**Large Signal Transient Response**
**G = 100, $V_S$ = 5V, 0V**



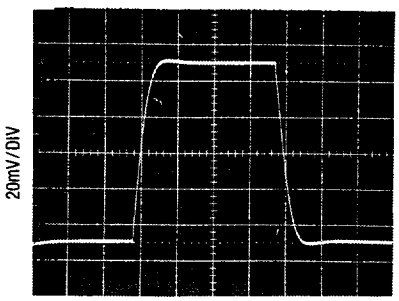

100μs/DIV
OUTPUT FROM 0V TO 4.5V, NO LOAD

**Small Signal Transient Response**
**G = 10, $V_S$ = 5V, 0V**



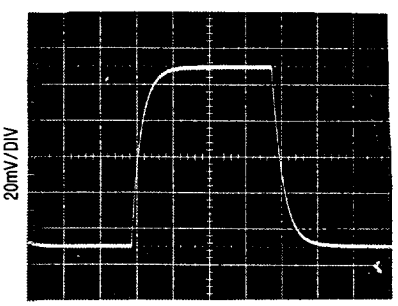

20μs/DIV
OUTPUT FROM 0.05V TO 0.15V, NO LOAD

**Small Signal Transient Response**
**G = 10, $V_S$ = ±15V**




20μs/DIV

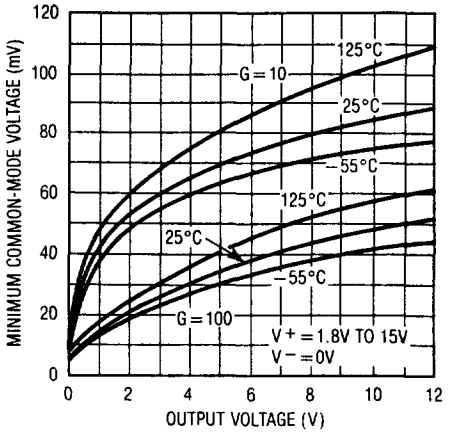
**Small Signal Transient Response**
**G = 100, $V_S$ = 5V, 0V**



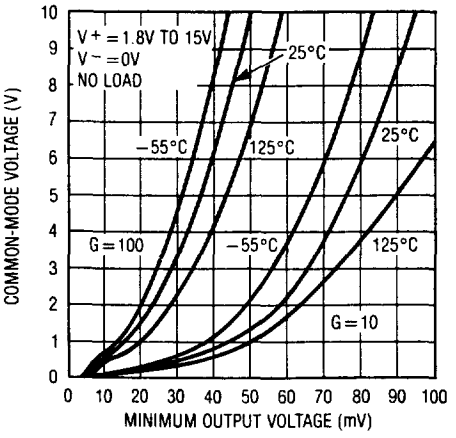

200μs/DIV
OUTPUT FROM 0.05V TO 0.15V, NO LOAD
(RESPONSE WITH $V_S$ = ±15V, G = 100 IS IDENTICAL)

# TYPICAL PERFORMANCE CHARACTERISTICS

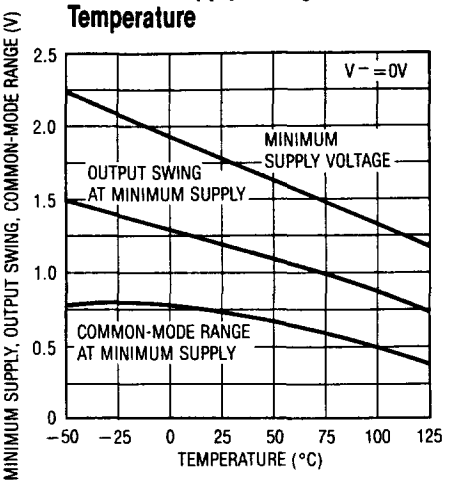
**Single Supply: Minimum Common-Mode Voltage vs Output Voltage**




**Single Supply: Minimum Output Voltage vs Common-Mode Voltage**




**Minimum Supply Voltage vs Temperature**




3

# APPLICATIONS INFORMATION

## Single Supply Applications

The LT1101 is the first instrumentation amplifier which is fully specified for single supply operation, i.e. when the negative supply is 0V. Both the input common-mode range and the output swing are within a few millivolts of ground.

Probably the most common application for instrumentation amplifiers is amplifying a differential signal from a transducer or sensor resistance bridge. All competitive instrumentation amplifiers have a minimum required common-mode voltage which is 3V to 5V above the negative supply. This means that the voltage across the bridge has to be 6V to 10V or dual supplies have to be used, i.e. micropower, single battery usage is not attainable on competitive devices.

The minimum output voltage obtainable on the LT1101 is a function of the input common-mode voltage. When the common-mode voltage is high and the output is low, current will flow from the output of amplifier A into the output of amplifier B. See the Minimum Output Voltage vs Common-Mode Voltage plot.

Similarly, the Minimum Common-Mode Voltage vs Output Voltage plot specifies the expected common-mode range. When the output is high and input common-mode is low, the output of amplifier A has to sink current coming from the output of amplifier B. Since amplifier A is effectively in unity gain, its input is limited by its output.

## Common-Mode Rejection vs Frequency

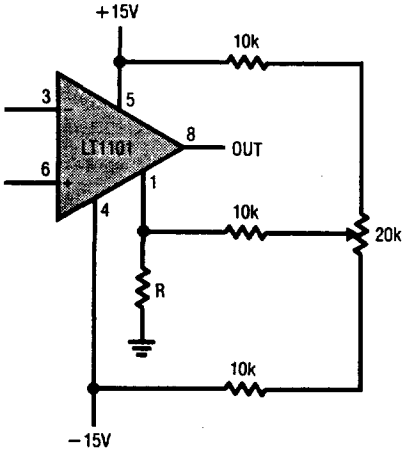
The common-mode rejection ratio (CMRR) of the LT1101 starts to roll off at a relatively low frequency. However, as shown on the CMRR vs Frequency plot, CMRR can be enhanced significantly by connecting an 82pF capacitor between pins 1 and 2. This improvement is only available in the gain 100 configuration, and it is in excess of 30dB at 60Hz.

## Offset Nulling

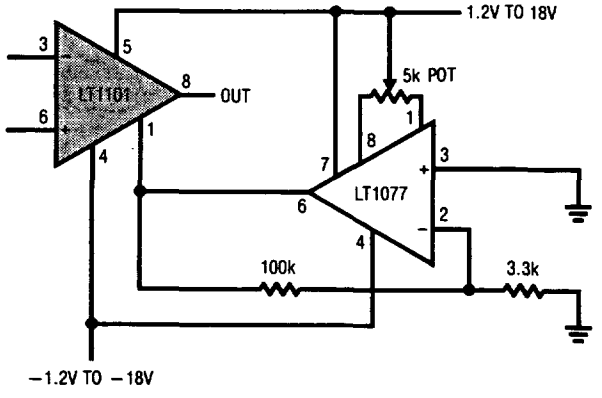
The LT1101 is not equipped with dedicated offset null terminals. In many bridge transducer or sensor applications, calibrating the bridge simultaneously eliminates the instrumentation amplifier's offset as a source of error. For example, in the Micropower Remote Temperature Sensor Application shown, one adjustment removes the offset errors due to the temperature sensor, voltage reference and the LT1101.

## APPLICATIONS INFORMATION

A simple resistive offset adjust procedure is shown below. If R = 5Ω for G = 10, and R = 50Ω for G = 100 then the effect of R on gain error is approximately 0.006%. Unfortunately, about 450μA has to flow through R to bias the reference terminal (pin 1) and to null out the worst-case offset voltage. The total current through the resistor network can exceed 1mA, and the micropower advantage of the LT1101 is lost.




Another offset adjust scheme uses the LT1077 micropower op amp to drive the reference pin 1. Gain error and common-mode rejection are unaffected, the total current increase is 45μA. The offset of the LT1077 is trimmed and amplified to match and cancel the offset voltage of the LT1101. Output offset null range is ±25mV.




### Gains Between 10 and 100

Gains between 10 and 100 can be achieved by connecting two equal resistors (= $R_X$) between pins 1 and 2 and pins 7 and 8.

$$\text{Gain} = 10 + \frac{R_X}{R + R_X/90}$$

The nominal value of R is 9.2kΩ. The usefulness of this method is limited by the fact that R is not controlled to better than ±10% absolute accuracy in production. However, on any specific unit 90R can be measured between pins 1 and 2.

### Input Protection

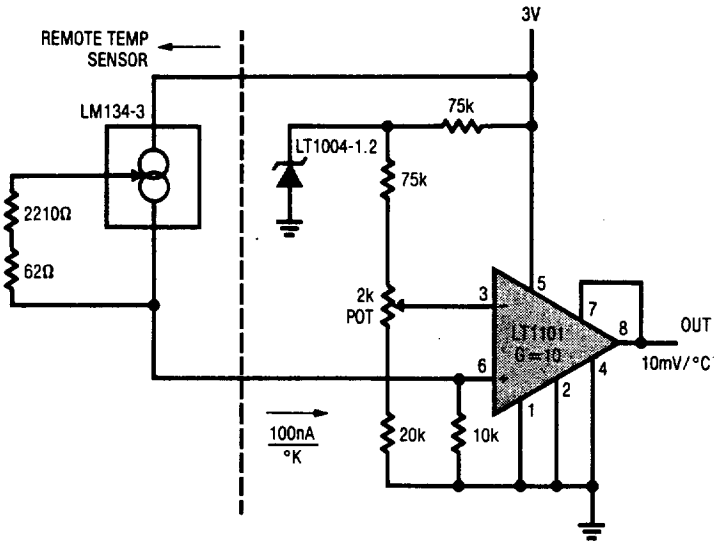
Instrumentation amplifiers are often used in harsh environments where overload conditions can occur. The LT1101 employs PNP input transistors, consequently the differential input voltage can be ±30V (with ±15V supplies, ±36V with ±18V supplies) without an increase in input bias current. Competitive instrumentation amplifiers have NPN inputs which are protected by back to back diodes. When the differential input voltage exceeds ±1.3V on these competitive devices, input current increases to the milliampere level; more than ±10V differential voltage can cause permanent damage.

When the LT1101's inputs are pulled above the positive supply, the inputs will clamp a diode voltage above the positive supply. No damage will occur if tne input current is limited to 20mA.

500Ω resistors in series with the inputs protect the LT1101 when the inputs are pulled as much as 10V below the negative supply.

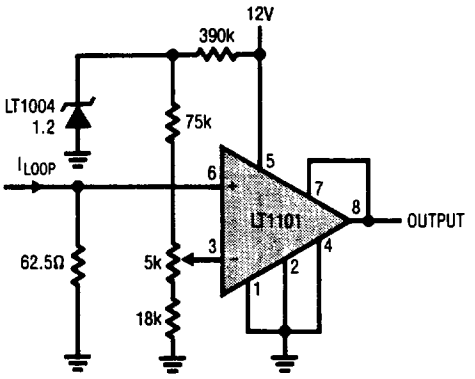
# APPLICATIONS INFORMATION

### Micropower, Battery Operated, Remote Temperature Sensor



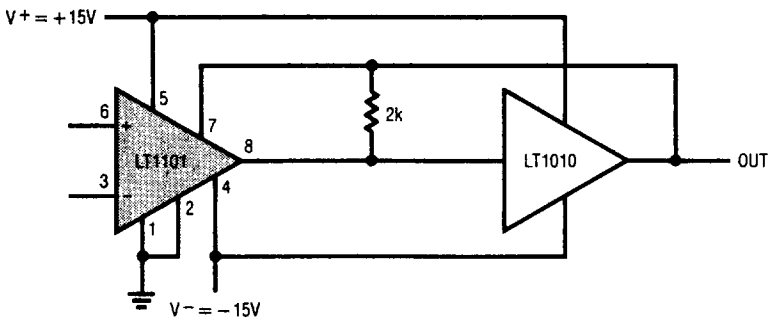

TRIM OUTPUT TO 250mV AT 25°C
TEMPERATURE RANGE = 2.5°C TO 150°C
ACCURACY = ±0.5°C

### 4mA to 20mA Loop Receiver



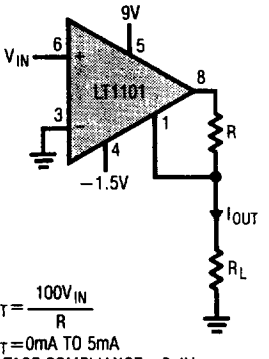

4mA TO 20mA IN — 0V TO 10V OUT
TRIM OUTPUT TO 5V AT 12mA IN

### Instrumentation Amplifier with ±150mA Output Current




GAIN = 10, DEGRADED BY 0.01% DUE TO LT1010
OUTPUT = ±10V INTO 75Ω (TO 1.5kHz)
DRIVES ANY CAPACITIVE LOAD
SINGLE SUPPLY APPLICATION (V+ = 5V, V− = 0V):
$V_{OUT\ MIN}$ = 120mV, $V_{OUT\ MAX}$ = 3.4V

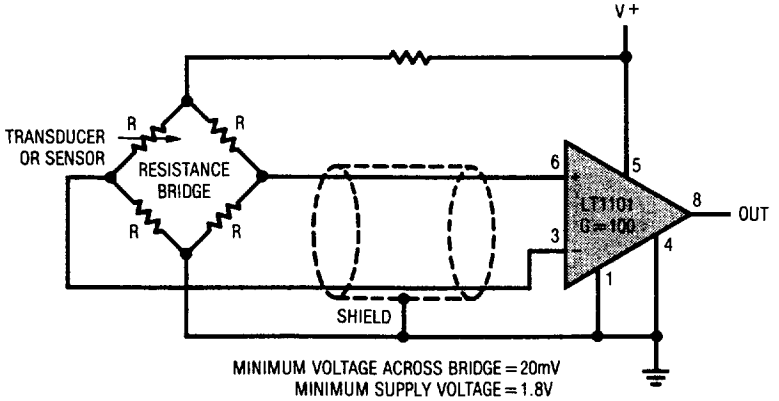
### Voltage Controlled Current Source




$$I_{OUT} = \frac{100V_{IN}}{R}$$

$I_{OUT}$ = 0mA TO 5mA
VOLTAGE COMPLIANCE = 6.4V
($R \leq 200\Omega$)

### Differential Voltage Amplification from a Resistance Bridge

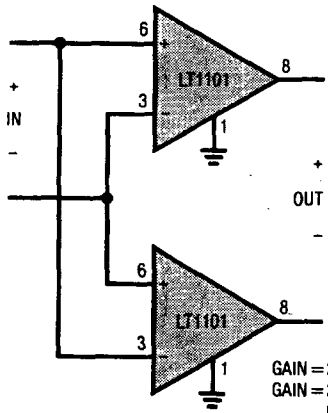



MINIMUM VOLTAGE ACROSS BRIDGE = 20mV
MINIMUM SUPPLY VOLTAGE = 1.8V

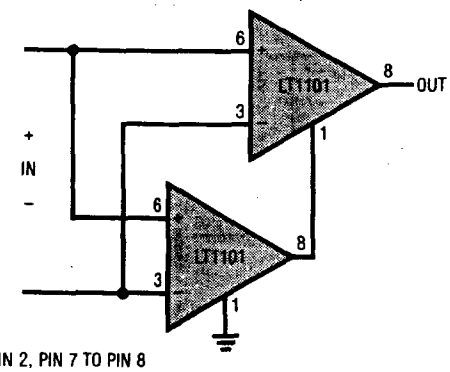
# APPLICATIONS INFORMATION

## Gain = 20, 110 or 200 Instrumentation Amplifiers

**Differential Output**




**Single Ended Output**




GAIN = 200, AS SHOWN
GAIN = 20, SHORT PIN 1 TO PIN 2, PIN 7 TO PIN 8 ON BOTH DEVICES
GAIN = 110, SHORT PIN 1 TO PIN 2, PIN 7 TO PIN 8 ON ONE DEVICE, NOT ON THE OTHER
INPUT REFERRED NOISE IS REDUCED BY $\sqrt{2}$ (G = 200 OR 20)