

# 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
- Gain Bandwidth Product 2.3pAp-p Typ
- Single or Dual Supply Operation 250kHz Min
- 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:

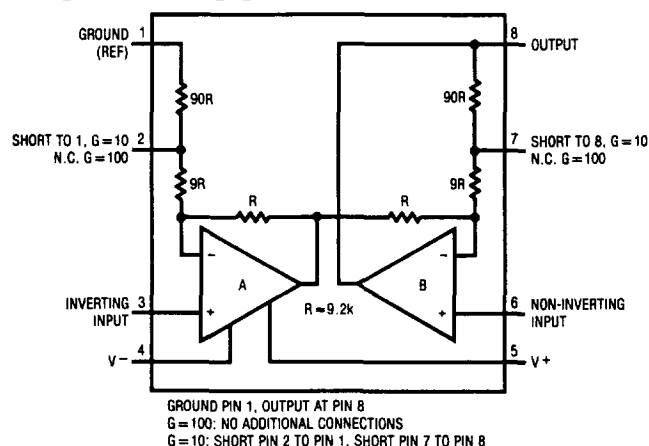
- (1) It is the first micropower instrumentation amplifier,
- (2) It is the first single supply instrumentation amplifier,
- (3) It is the first instrumentation amplifier to feature fixed gains of 10 and/or 100 in low cost, space-saving 8-lead packages.

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  $\pm 10V$  with excellent gain accuracy.

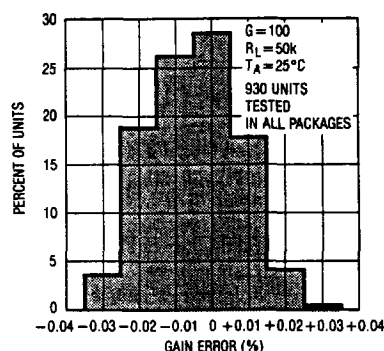
Other precision specifications are also outstanding: 50μV input offset voltage, 130pA input offset current, and low drift (0.4μV/°C and 0.7pA/°C). In addition, unlike other instrumentation amplifiers, there is no output offset voltage contribution to total error.

A full set of specifications are provided with  $\pm 15V$  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.

## BLOCK DIAGRAM



Gain Error Distribution



## ABSOLUTE MAXIMUM RATINGS

Supply Voltage .....  $\pm 22V$   
Differential Input Voltage .....  $\pm 36V$   
Input Voltage ..... Equal to Positive Supply Voltage  
..... 10V Below Negative Supply Voltage  
Output Short Circuit Duration ..... Indefinite  
Lead Temperature (Soldering, 10 sec.) .....  $300^{\circ}C$

### Operating Temperature Range

LT1101AM/LT1101M.....-55°C to 125°C

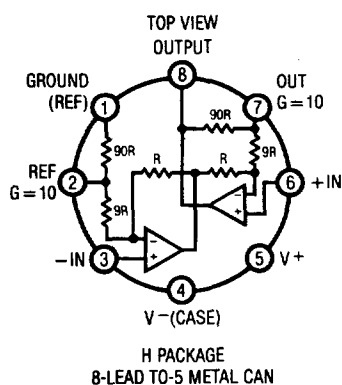
LT1101AI/LT1101I..... -40°C to 85°C

LT1101AC/LT1101C/LT1101S.....0°C to 70°C

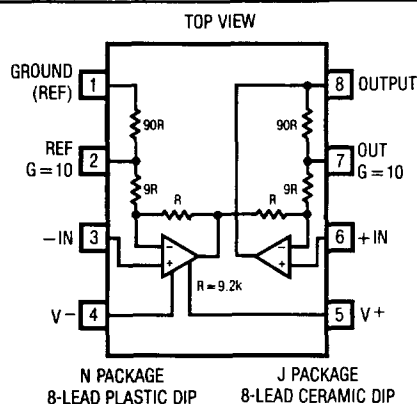
### Storage Temperature Range

**All Grades** ..... -65°C to 150°C

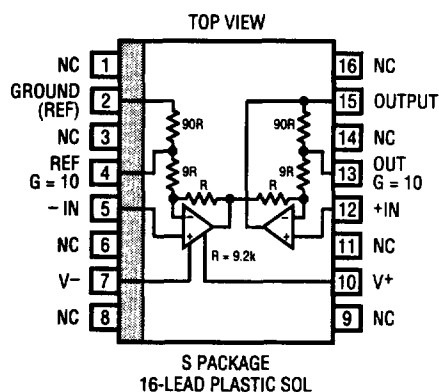
## PACKAGE/ORDER INFORMATION

ORDER PART  
NUMBER

LT1101AMH  
LT1101MH  
LT1101ACH  
LT1101CH

ORDER PART  
NUMBER

LT1101AIN8  
LT1101IN8  
LT1101ACN8  
LT1101CN8  
LT1101AMJ8  
LT1101MJ8  
LT1101ACJ8  
LT1101CJ8



LT1101S

## ELECTRICAL CHARACTERISTICS

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

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

## ELECTRICAL CHARACTERISTICS

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

SYMBOL	PARAMETER	CONDITIONS	LT1101AM/AI/AC			LT1101M/IC/CS			UNITS
			MIN	TYP	MAX	MIN	TYP	MAX	
CMRR	Common-Mode Rejection Ratio	1k Source Imbalance	95	106		92	105		dB
		$G = 100, V_{CM} = 0.07V \text{ to } 3.4V$ $G = 10, V_{CM} = 0.07V \text{ to } 3.1V$	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, $V_{REF} = 0, I_{SINK} = 100\mu A$		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/ $\mu s$

## ELECTRICAL CHARACTERISTICS

$V_S = \pm 15V, V_{CM} = 0V, T_A = 25^\circ C$ , Gain = 10 or 100, unless otherwise noted.

SYMBOL	PARAMETER	CONDITIONS	LT1101AM/AI/AC			LT1101M/IC/CS			UNITS
			MIN	TYP	MAX	MIN	TYP	MAX	
$G_E$	Gain Error	$G = 100, V_O = \pm 10V, R_L = 50k$		0.008	0.040		0.009	0.060	%
		$G = 100, V_O = \pm 10V, R_L = 2k$		0.011	0.055		0.012	0.070	%
		$G = 10, V_O = \pm 10V, R_L = 50k \text{ or } 2k$		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
		$G = 10, R_L = 50k \text{ or } 2k$		3	8		3	9	ppm
$V_{OS}$	Input Offset Voltage	LT1101S		50	160		60	220	$\mu V$
							250	600	$\mu V$
$I_{OS}$	Input Offset Current			0.13	0.60		0.15	0.90	nA
$I_B$	Input Bias Current			6	8		6	10	nA
$e_n$	Input Noise Voltage	(Note 1)	4	7		3	7		GΩ
		(Note 1)	7	12		5	12		GΩ
$e_n$	Input Noise Voltage Density	0.1Hz to 10Hz (Note 2)		0.9	1.8		0.9		$\mu V/p$
		$f_o = 10Hz$ (Note 2) $f_o = 1000Hz$ (Note 2)		45	64		45		nV/ $\sqrt{Hz}$ nV/ $\sqrt{Hz}$
$i_n$	Input Noise Current	0.1Hz to 10Hz (Note 2)		2.3	4.0		2.3		pA/p
		$f_o = 10Hz$ (Note 2) $f_o = 1000Hz$		0.06	0.10		0.06		pA/ $\sqrt{Hz}$ pA/ $\sqrt{Hz}$
	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	100	112		98	112		dB
		$G = 100$ , Over CM Range $G = 10$ , Over CM Range	84	100		82	99		dB
PSRR	Power Supply Rejection Ratio	$V_S = +2.2V, -0.1V \text{ to } \pm 18V$	102	114		100	114		dB
$I_S$	Supply Current			92	130		94	150	$\mu A$
$V_O$	Maximum Output Voltage Swing	$R_L = 50k$	$\pm 13.0$	$\pm 14.2$		$\pm 13.0$	$\pm 14.2$		V
		$R_L = 2k$	$\pm 11.0$	$\pm 13.2$		$\pm 11.0$	$\pm 13.2$		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/ $\mu s$

**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,  $-55^\circ C \leq T_A \leq 125^\circ C$  for AM/M grades,  $-40^\circ C \leq T_A \leq 85^\circ C$  for AI/I grades, unless otherwise noted.

SYMBOL	PARAMETER	CONDITIONS	LT1101AM/AI			LT1101M/I			UNITS
			MIN	TYP	MAX	MIN	TYP	MAX	
$G_E$	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/ $^\circ C$
		$G = 100$ , $R_L = 5k$		2	7		2	8	ppm/ $^\circ C$
		$G = 10$ , $R_L = 50k$ or $5k$		1	4		1	5	ppm/ $^\circ C$
$G_{NL}$	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	$\mu V$
$\Delta V_{OS}/\Delta T$	Input Offset Voltage Drift	(Note 1)		0.4	2.0		0.5	2.8	$\mu V/^\circ C$
$I_{OS}$	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/ $^\circ C$
$I_B$	Input Bias Current			7	10		7	12	nA
$\Delta I_B/\Delta T$	Input Bias Current Drift	(Note 1)		10	25		10	30	pA/ $^\circ C$
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	$\mu A$
$V_O$	Maximum Output Voltage Swing	$R_L = 50k$	$\pm 12.5$	$\pm 14.0$		$\pm 12.5$	$\pm 14.0$		V
		$R_L = 5k$	$\pm 11.0$	$\pm 13.5$		$\pm 11.0$	$\pm 13.5$		V

**ELECTRICAL CHARACTERISTICS**

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

SYMBOL	PARAMETER	CONDITIONS	LT1101AC			LT1101C/S			UNITS
			MIN	TYP	MAX	MIN	TYP	MAX	
$G_E$	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/ $^\circ C$
		$G = 100$ , $R_L = 2k$		2	7		2	9	ppm/ $^\circ C$
		$G = 10$ , $R_L = 50k$ or $2k$		1	4		1	5	ppm/ $^\circ C$
$G_{NL}$	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	LT1101S		70	250		85	350	$\mu V$
$\Delta V_{OS}/\Delta T$	Input Offset Voltage Drift	(Note 1) LT1101S		0.4	2.0		0.5	2.8	$\mu V/^\circ C$
$I_{OS}$	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/ $^\circ C$
$I_B$	Input Bias Current			6	9		6	11	nA
$\Delta I_B/\Delta T$	Input Bias Current Drift	(Note 1)		10	25		10	30	pA/ $^\circ C$
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	$\mu A$
$V_O$	Maximum Output Voltage Swing	$R_L = 50k$	$\pm 12.5$	$\pm 14.1$		$\pm 12.5$	$\pm 14.1$		V
		$R_L = 2k$	$\pm 10.5$	$\pm 13.0$		$\pm 10.5$	$\pm 13.0$		V

**ELECTRICAL CHARACTERISTICS**

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

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

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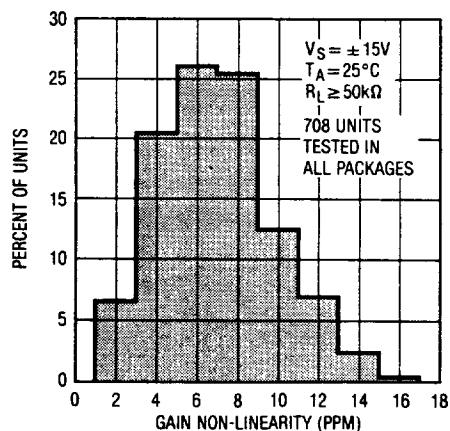
**ELECTRICAL CHARACTERISTICS**

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

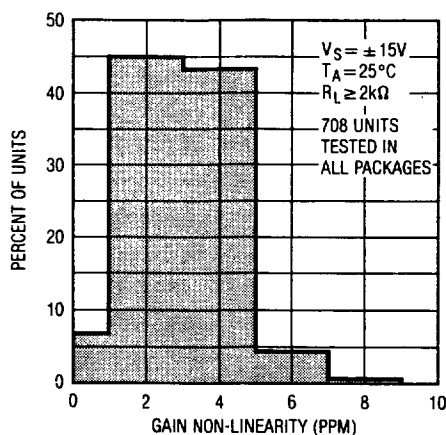
SYMBOL	PARAMETER	CONDITIONS	LT1101AC			LT1101C/S			UNITS
			MIN	TYP	MAX	MIN	TYP	MAX	
$G_E$	Gain Error	$G = 100, V_O = 0.1V$ to $3.5V, R_L = 50k$ $G = 10, V_{CM} = 0.15V, R_L = 50k$		0.017 0.010	0.065 0.060		0.018 0.012	0.095 0.080	% %
$TCG_E$	Gain Error Drift	$R_L = 50k$ (Note 1)		1	4		1	5	ppm/ $^\circ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

# TYPICAL PERFORMANCE CHARACTERISTICS

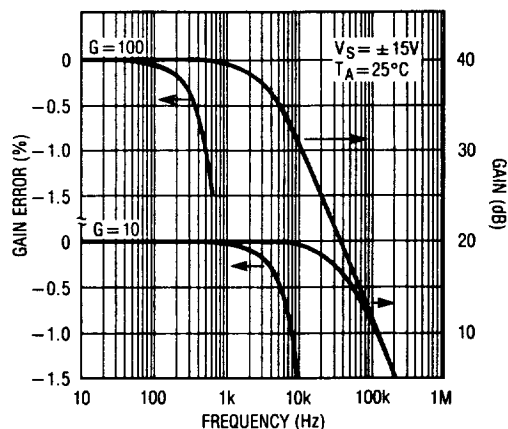
**Gain = 100 Non-Linearity Distribution**



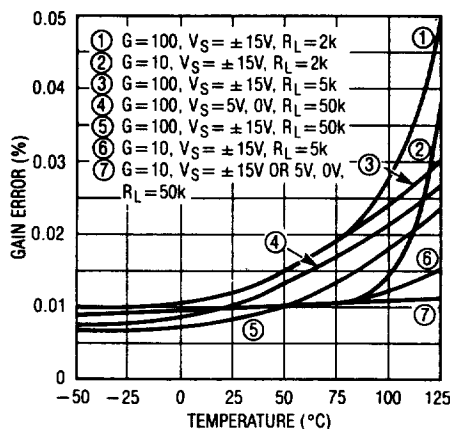
**Gain = 10 Non-Linearity Distribution**



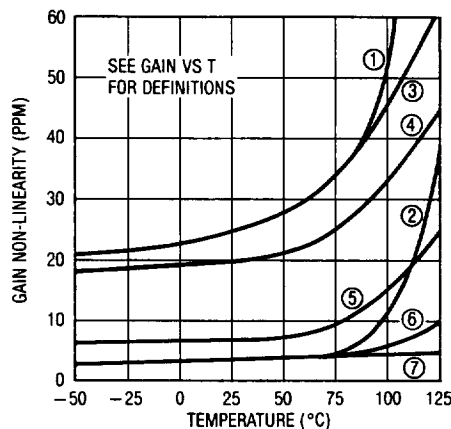
**Gain vs Frequency**



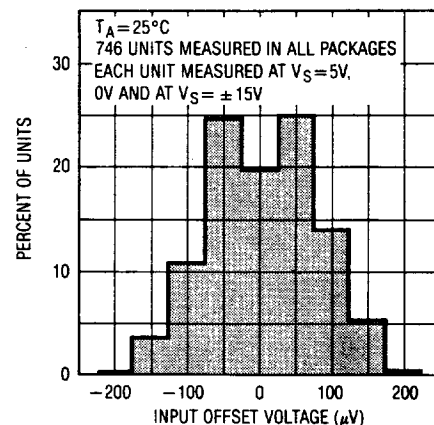
**Gain Error Over Temperature**



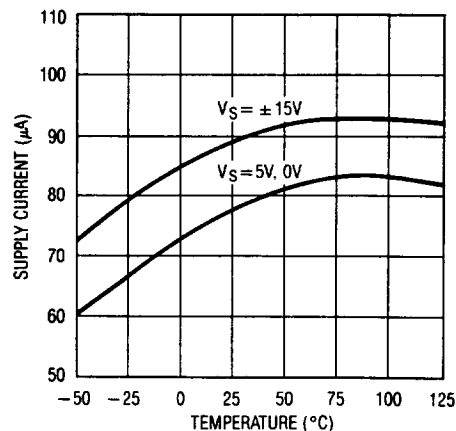
**Gain Non-Linearity Over Temperature**



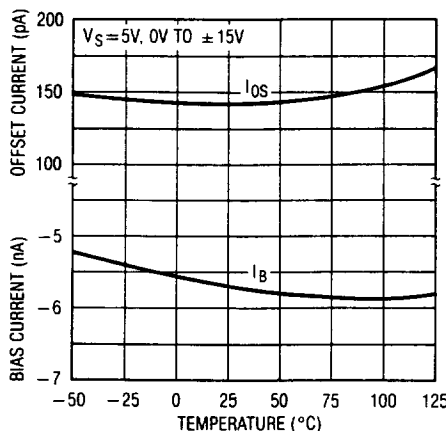
**Input Offset Voltage Distribution**



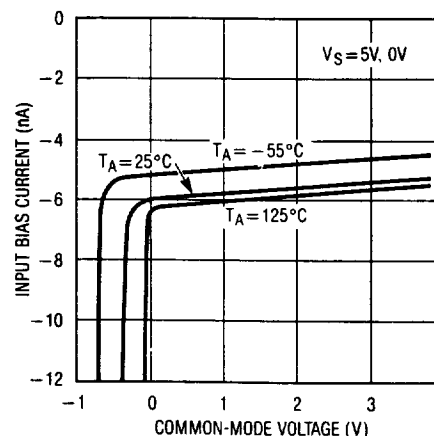
**Supply Current vs Temperature**



**Input Bias and Offset Currents vs Temperature**



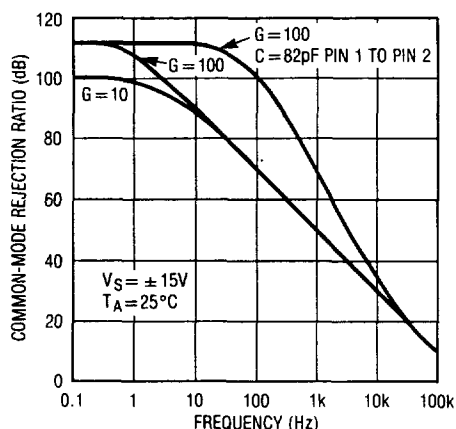
**Input Bias Current vs Common-Mode Voltage**



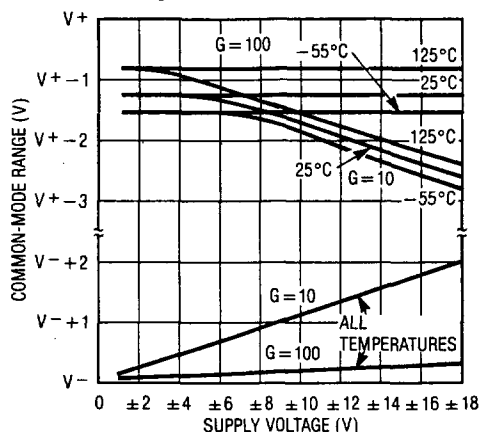
# TYPICAL PERFORMANCE CHARACTERISTICS

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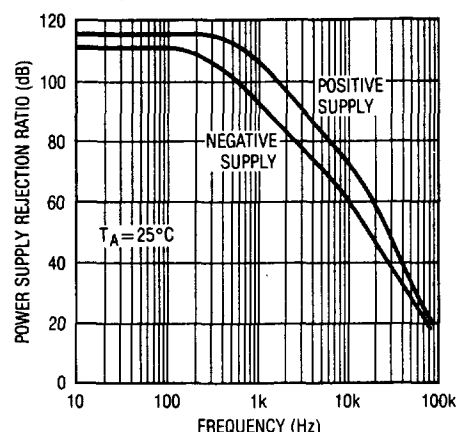
**Common-Mode Rejection Ratio vs Frequency**



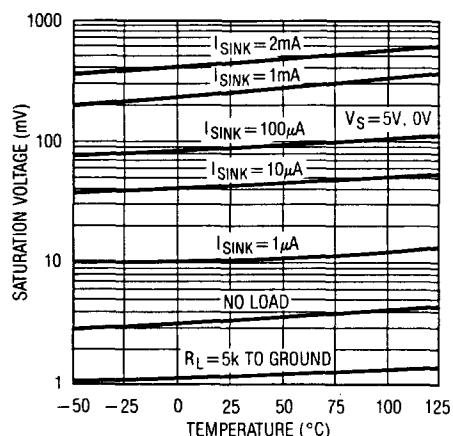
**Common-Mode Range vs Supply Voltage**



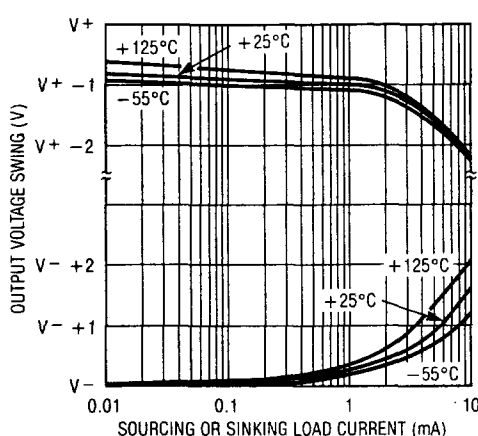
**Power Supply Rejection Ratio vs Frequency**



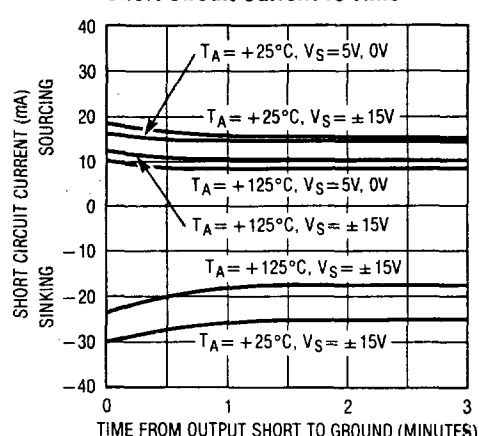
**Output Saturation vs Temperature vs Sink Current**



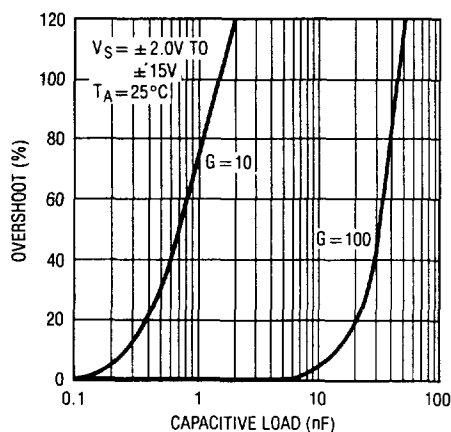
**Output Voltage Swing vs Load Current**



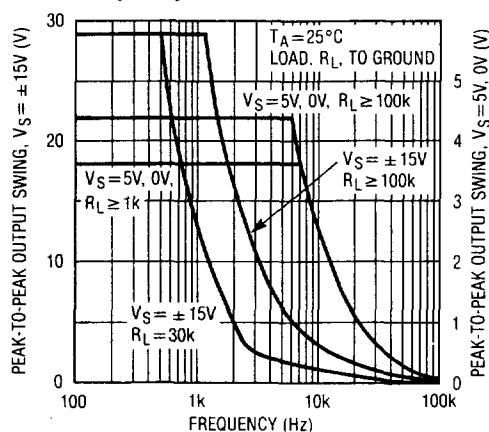
**Short Circuit Current vs Time**



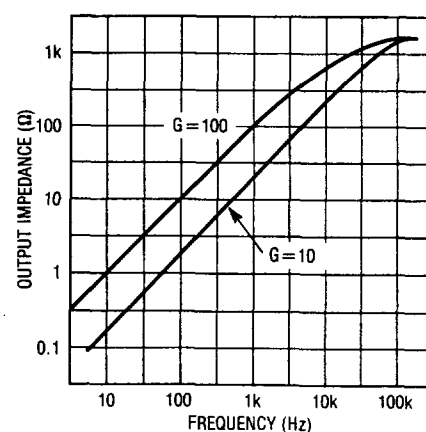
**Capacitive Load Handling**



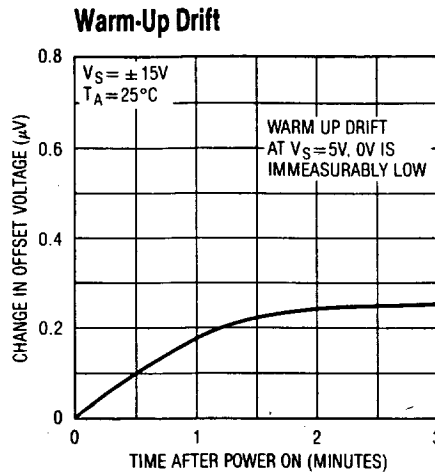
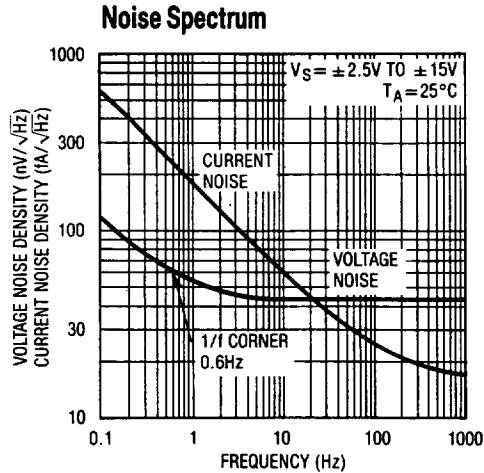
**Undistorted Output Swing vs Frequency**



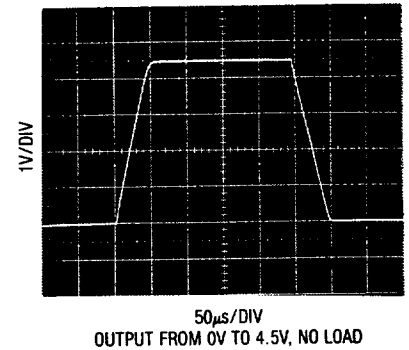
**Output Impedance vs Frequency**



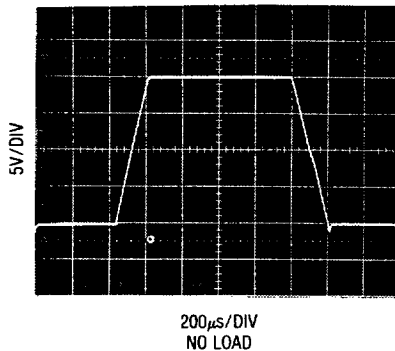
# TYPICAL PERFORMANCE CHARACTERISTICS



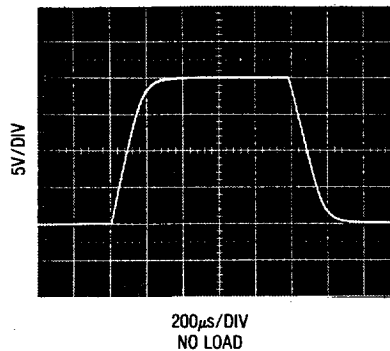
**Large Signal Transient Response**  
 $G = 10, V_S = 5V, 0V$



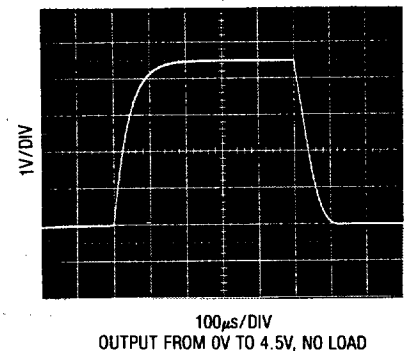
**Large Signal Transient Response**  
 $G = 10, V_S = \pm 15V$



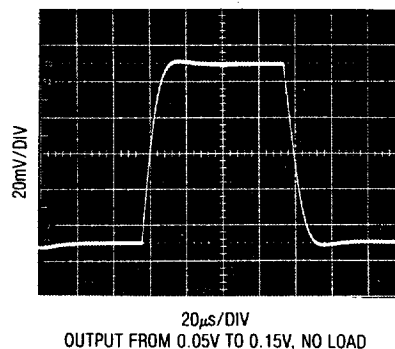
**Large Signal Transient Response**  
 $G = 100, V_S = \pm 15V$



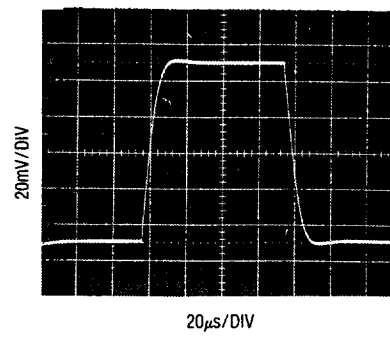
**Large Signal Transient Response**  
 $G = 100, V_S = 5V, 0V$



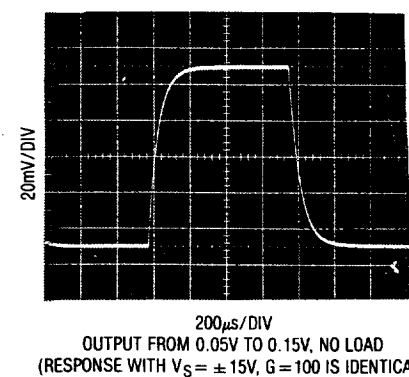
**Small Signal Transient Response**  
 $G = 10, V_S = 5V, 0V$



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



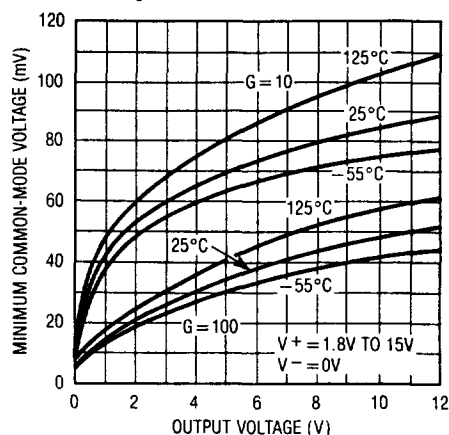
**Small Signal Transient Response**  
 $G = 100, V_S = 5V, 0V$



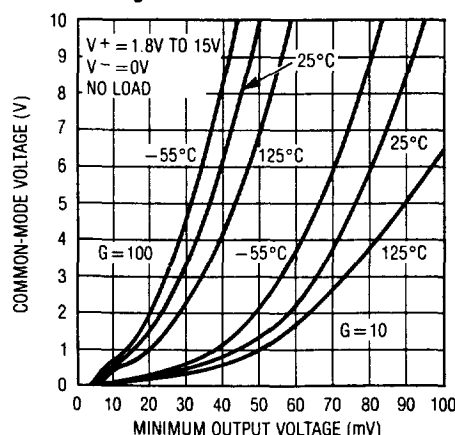


## TYPICAL PERFORMANCE CHARACTERISTICS

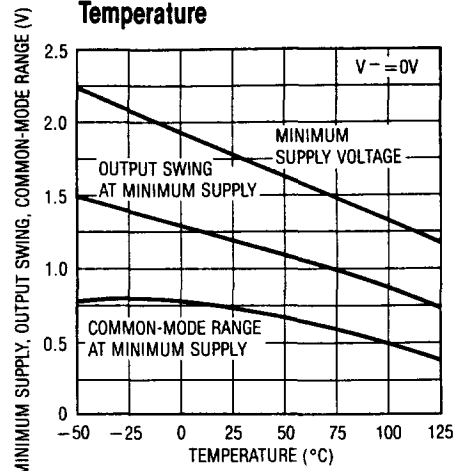
Single Supply: Minimum Common-Mode Voltage vs Output Voltage



Single Supply: Minimum Output Voltage vs Common-Mode Voltage



Minimum Supply Voltage vs Temperature



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## 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

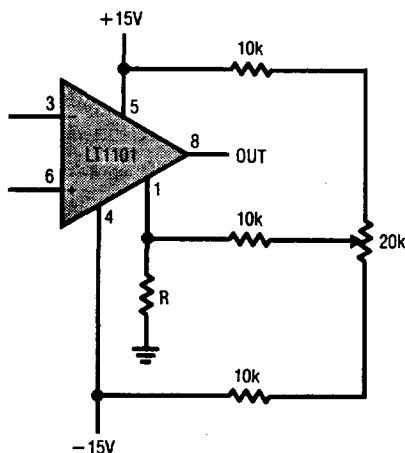
The common-mode rejection ratio (CMRR) of the LT1101 starts to roll off at a relatively low frequency. However, as shown on the CMRR vs Frequency plot, CMRR can be enhanced significantly by connecting an 82pF capacitor between pins 1 and 2. This improvement is only available in the gain 100 configuration,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

### Offset Nulling

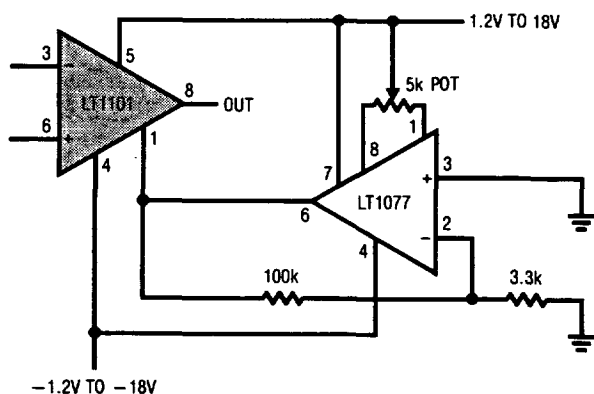
The LT1101 is not equipped with dedicated offset null terminals. In many bridge transducer or sensor applications, calibrating the bridge simultaneously eliminates the instrumentation amplifier's offset as a source of error. For example, in the Micropower Remote Temperature Sensor Application shown, 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  $R = 5\Omega$  for  $G = 10$ , and  $R = 50\Omega$  for  $G = 100$  then the effect of  $R$  on gain error is approximately 0.006%. Unfortunately, about  $450\mu A$  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  $45\mu A$ . The offset of the LT1077 is trimmed and amplified to match and cancel the offset voltage of the LT1101. Output offset null range is  $\pm 25mV$ .



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

### Input Protection

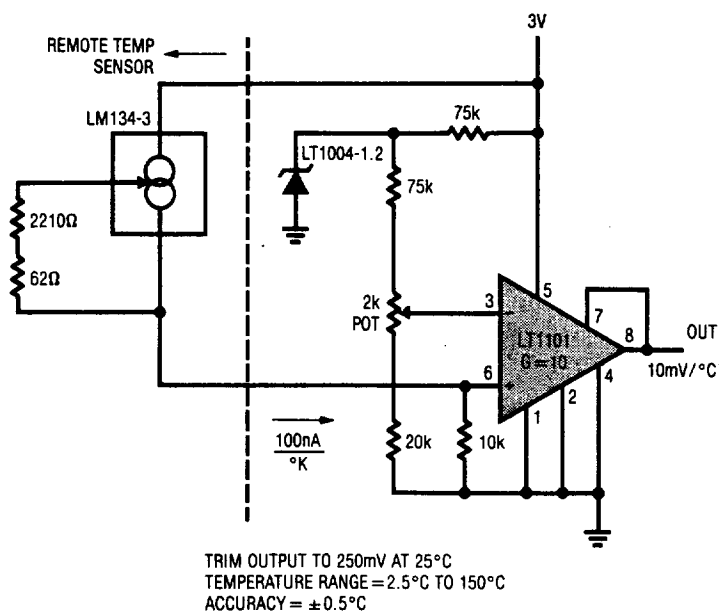
Instrumentation amplifiers are often used in harsh environments where overload conditions can occur. The LT1101 employs PNP input transistors, consequently the differential input voltage can be  $\pm 30V$  (with  $\pm 15V$  supplies,  $\pm 36V$  with  $\pm 18V$  supplies) without an increase in input bias current. Competitive instrumentation amplifiers have NPN inputs which are protected by back to back diodes. When the differential input voltage exceeds  $\pm 1.3V$  on these competitive devices, input current increases to the milliampere level; more than  $\pm 10V$  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 the input current is limited to 20mA.

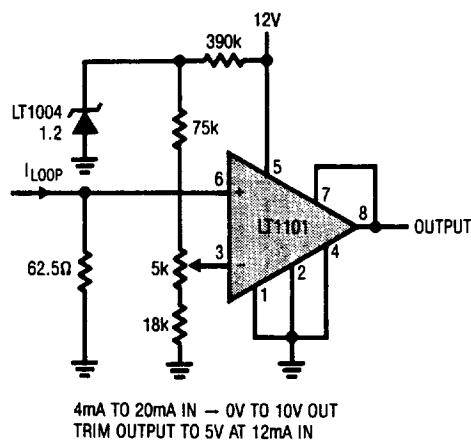
$500\Omega$  resistors in series with the inputs protect the LT1101 when the inputs are pulled as much as 10V below the negative supply.

# APPLICATIONS INFORMATION

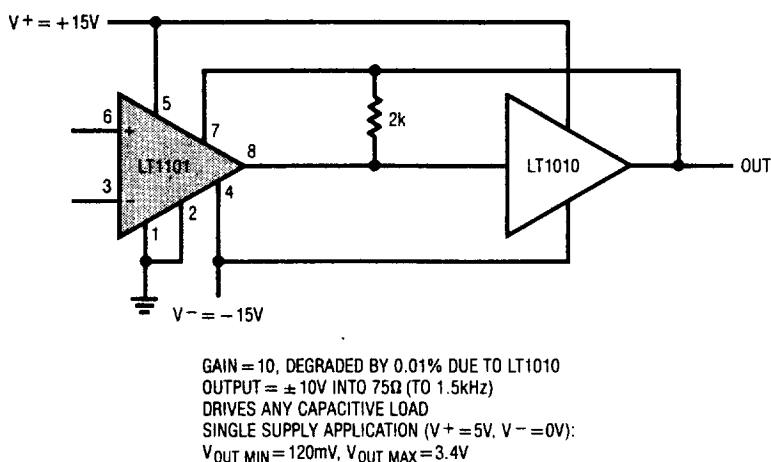
## Micropower, Battery Operated, Remote Temperature Sensor



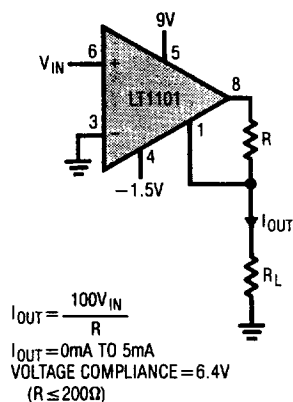
## 4mA to 20mA Loop Receiver



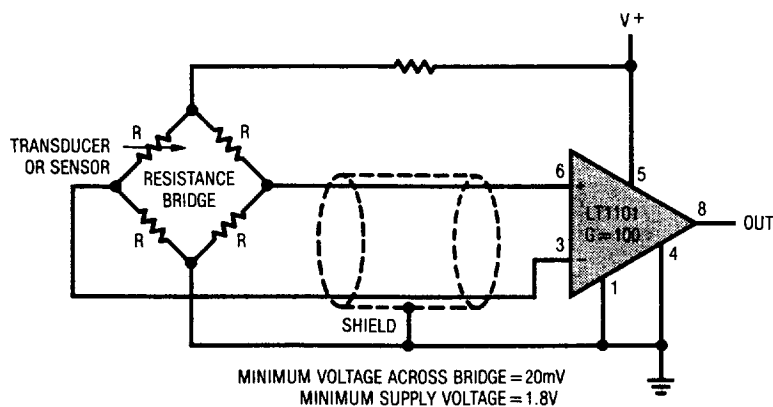
## Instrumentation Amplifier with ±150mA Output Current



## Voltage Controlled Current Source



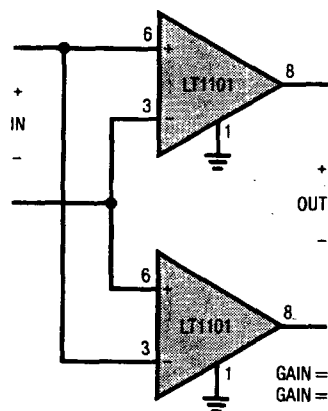
## Differential Voltage Amplification from a Resistance Bridge



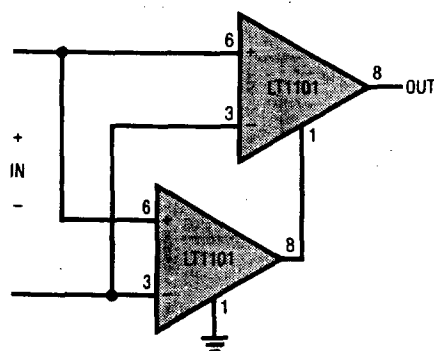
# APPLICATIONS INFORMATION

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)