

# Micropower, Dual and Quad, Single Supply, Precision Op Amps

## FEATURES

- **SO Package with Standard Pinout**
- **Supply Current per Amplifier: 50 $\mu$ A Max**
- **Offset Voltage: 70 $\mu$ V Max**
- Offset Current: 250pA Max
- Voltage Noise: 0.6 $\mu$ V<sub>P-P</sub>, 0.1Hz to 10Hz
- Current Noise: 3pA<sub>P-P</sub>, 0.1Hz to 10Hz
- Offset Voltage Drift: 0.4 $\mu$ V/ $^{\circ}$ C
- Gain Bandwidth Product: 200kHz
- Slew Rate: 0.07V/ $\mu$ s
- Single Supply Operation
  - Input Voltage Range Includes Ground
  - Output Swings to Ground while Sinking Current
  - No Pull-Down Resistors Needed
- Output Sources and Sinks 5mA Load Current

## APPLICATIONS

- Battery or Solar-Powered Systems
  - Portable Instrumentation
  - Remote Sensor Amplifier
  - Satellite Circuitry
- Micropower Sample-and-Hold
- Thermocouple Amplifier
- Micropower Filters

## DESCRIPTION

The LT<sup>®</sup>2078 is a micropower dual op amp in 8-pin small outline, standard surface mount package, and LT2079 is a micropower quad op amp offered in the standard 14-pin surface mount package. Both devices are optimized for single supply operation at 5V.  $\pm$ 15V specifications are also provided.

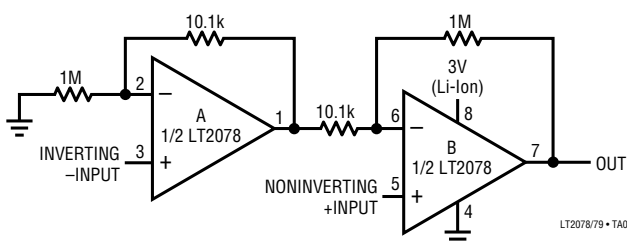
Micropower performance of competing devices is achieved at the expense of seriously degrading precision, noise, speed and output drive specifications. The design effort of the LT2078/LT2079 was concentrated on reducing supply current without sacrificing other parameters. The offset voltage achieved is the lowest on any dual or quad nonchopper stabilized op amp—micropower or otherwise. Offset current, voltage and current noise, slew rate and gain bandwidth product are all two to ten times better than on previous micropower op amps.

Both the LT2078/LT2079 can be operated from a single supply (as low as one lithium cell or two NiCd batteries). The input range goes below ground. The all NPN output stage swings to within a few millivolts of ground while sinking current—no power consuming pull-down resistors are needed. For applications requiring DIP packages refer to the LT1078/LT1079.

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## TYPICAL APPLICATION

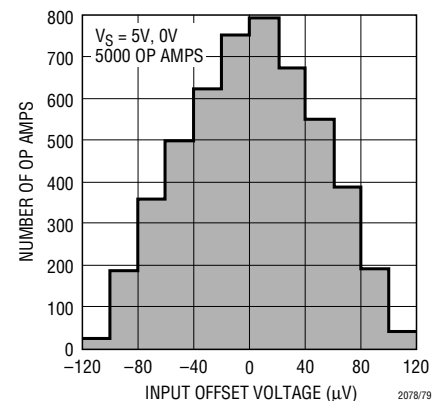
Single Battery, Micropower, Gain = 100, Instrumentation Amplifier



TYPICAL PERFORMANCE  
 INPUT OFFSET VOLTAGE = 40 $\mu$ V  
 INPUT OFFSET CURRENT = 0.2nA  
 TOTAL POWER DISSIPATION = 240 $\mu$ W  
 COMMON MODE REJECTION = 110dB (AMPLIFIER LIMITED)  
 GAIN BANDWIDTH PRODUCT = 200kHz

OUTPUT NOISE = 85  $\mu$ V<sub>P-P</sub> 0.1Hz TO 10Hz  
 = 300  $\mu$ V<sub>RMS</sub> OVER FULL BANDWIDTH  
 INPUT RANGE = 0.03V TO 1.8V  
 OUTPUT RANGE = 0.03V TO 2.3V  
 (0.3mV  $\leq$  V<sub>IN+</sub> - V<sub>IN-</sub>  $\leq$  23mV)  
 OUTPUTS SINK CURRENT—NO PULL-DOWN RESISTORS

Distribution of Input Offset Voltage

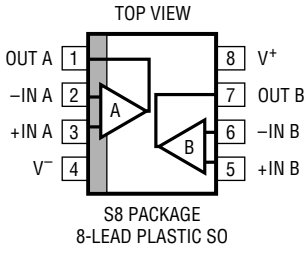
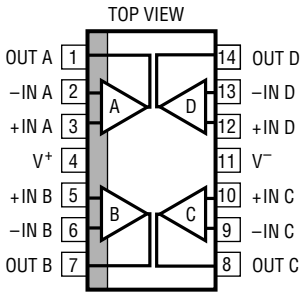


## ABSOLUTE MAXIMUM RATINGS

Supply Voltage .....  $\pm 22V$   
 Differential Input Voltage .....  $\pm 30V$   
 Input Voltage ..... Equal to Positive Supply Voltage  
 ..... 5V Below Negative Supply Voltage  
 Output Short-Circuit Duration ..... Indefinite

Specified Temperature Range  
 Commercial .....  $0^{\circ}C$  to  $70^{\circ}C$   
 Industrial .....  $-40^{\circ}C$  to  $85^{\circ}C$   
 Storage Temperature Range .....  $-65^{\circ}C$  to  $150^{\circ}C$   
 Lead Temperature (Soldering, 10 sec) .....  $300^{\circ}C$

## PACKAGE/ORDER INFORMATION

 <p>S8 PACKAGE 8-LEAD PLASTIC SO</p> <p><math>T_{JMAX} = 150^{\circ}C, \theta_{JA} = 190^{\circ}C/W</math></p>	ORDER PART NUMBER	 <p>S PACKAGE 14-LEAD PLASTIC SO</p> <p><math>T_{JMAX} = 150^{\circ}C, \theta_{JA} = 150^{\circ}C/W</math></p>	ORDER PART NUMBER
	LT2078ACS8 LT2078AIS8 LT2078CS8 LT2078IS8		LT2079AC LT2079AI LT2079C LT2079I
	PART MARKING		
	2078A    2078 2078AI   2078I		

Consult factory for Military grade parts.

## ELECTRICAL CHARACTERISTICS

$V_S = 5V, 0V, V_{CM} = 0.1V, V_O = 1.4V, T_A = 25^{\circ}C$ , unless otherwise noted.

SYMBOL	PARAMETER	CONDITIONS (NOTE 1)	LT2078AC/LT2078AI LT2079AC/LT2079AI			LT2078C/LT2078I LT2079C/LT2079I			UNITS
			MIN	TYP	MAX	MIN	TYP	MAX	
$V_{OS}$	Input Offset Voltage	LT2078 LT2079		30 35	70 110		40 40	120 150	$\mu V$ $\mu V$
$\frac{\Delta V_{OS}}{\Delta Time}$	Long Term Input Offset Voltage Stability			0.4			0.5		$\mu V/Mo$
$I_{OS}$	Input Offset Current			0.05	0.25		0.05	0.35	nA
$I_B$	Input Bias Current			6	8		6	10	nA
$e_n$	Input Noise Voltage	0.1Hz to 10Hz (Note 2)		0.6	1.2		0.6		$\mu V_{p-p}$
	Input Noise Voltage Density	$f_0 = 10Hz$ (Note 2) $f_0 = 1000Hz$ (Note 2)		29 28	45 37		29 28		$nV\sqrt{Hz}$ $nV\sqrt{Hz}$
$i_n$	Input Noise Current	0.1Hz to 10Hz (Note 2)		2.3	4.0		2.3		$pA_{p-p}$
	Input Noise Current Density	$f_0 = 10Hz$ (Note 2) $f_0 = 1000Hz$		0.06 0.02	0.10		0.06 0.02		$pA\sqrt{Hz}$ $pA\sqrt{Hz}$
	Input Resistance Differential Mode Common Mode	(Note 3)	400	800 6		300	800 6		$M\Omega$ $G\Omega$
	Input Voltage Range		3.5 0	3.8 -0.3		3.5 0	3.8 -0.3		V V
CMRR	Common Mode Rejection Ratio	$V_{CM} = 0V$ to $3.5V$	95	110		92	108		dB
PSRR	Power Supply Rejection Ratio	$V_S = 2.3V$ to $12V$	100	114		98	114		dB

**ELECTRICAL CHARACTERISTICS**  $V_S = 5V, 0V, V_{CM} = 0.1V, V_O = 1.4V, T_A = 25^\circ C$ , unless otherwise noted.

SYMBOL	PARAMETER	CONDITIONS (NOTE 1)	LT2078AC/LT2078AI LT2079AC/LT2079AI			LT2078C/LT2078I LT2079C/LT2079I			UNITS
			MIN	TYP	MAX	MIN	TYP	MAX	
$A_{VOL}$	Large-Signal Voltage Gain	$V_O = 0.03V$ to 4V, No Load $V_O = 0.03V$ to 3.5V, $R_L = 50k$	200 150	1000 600		150 120	1000 600		V/mV V/mV
	Maximum Output Voltage Swing	Output Low, No Load		3.5	6		3.5	6	mV
		Output Low, 2k to GND Output Low, $I_{SINK} = 100\mu A$		0.55 95	1.0 130		0.55 95	1.0 130	mV mV
		Output High, No Load	4.2	4.4		4.2	4.4		V
		Output High, 2k to GND	3.5	3.9		3.5	3.9		V
SR	Slew Rate	$A_V = 1, V_S = \pm 2.5V$	0.04	0.07		0.04	0.07		V/ $\mu s$
GBW	Gain Bandwidth Product	$f_0 \leq 20kHz$		200			200		kHz
$I_S$	Supply Current per Amplifier			38	50		39	55	$\mu A$
	Channel Separation	$\Delta V_{IN} = 3V, R_L = 10k, f \leq 10Hz$		110			110		dB
	Minimum Supply Voltage	(Note 4)		2.2	2.3		2.2	2.3	V

$V_S = 5V, 0V, V_{CM} = 0.1V, V_O = 1.4V, -40^\circ C \leq T_A \leq 85^\circ C$  for I grades, unless otherwise noted.

SYMBOL	PARAMETER	CONDITIONS		LT2078AI/LT2079AI			LT2078I/LT2079I			UNITS
				MIN	TYP	MAX	MIN	TYP	MAX	
$V_{OS}$	Input Offset Voltage	LT2078 LT2079	● ●		70 80	250 280		95 100	370 400	$\mu V$ $\mu V$
$\frac{\Delta V_{OS}}{\Delta T}$	Input Offset Voltage Drift (Note 5)	LT2078 LT2079	● ●		0.4 0.6	1.8 3.0		0.5 0.6	2.5 3.5	$\mu V/^\circ C$ $\mu V/^\circ C$
$I_{OS}$	Input Offset Current		●		0.07	0.70		0.1	1.0	nA
$I_B$	Input Bias Current		●		7	10		7	12	nA
CMRR	Common Mode Rejection Ratio	$V_{CM} = 0.05V$ to 3.2V	●		90	106		86	104	dB
PSRR	Power Supply Rejection Ratio	$V_S = 3.1V$ to 12V	●		96	110		92	110	dB
$A_{VOL}$	Large-Signal Voltage Gain	$V_O = 0.05V$ to 4V, No Load $V_O = 0.05V$ to 3.5V, $R_L = 50k$	● ●		110 80	600 400		80 60	600 400	V/mV V/mV
	Maximum Output Voltage Swing	Output Low, No Load	●		4.5	8		4.5	8	mV
		Output Low, $I_{SINK} = 100\mu A$	●		125	170		125	170	mV
		Output High, No Load	●	3.9	4.2		3.9	4.2		V
		Output High, 2k to GND	●	3.0	3.7		3.0	3.7		V
$I_S$	Supply Current per Amplifier		●		43	60		45	70	$\mu A$

$V_S = 5V, 0V, V_{CM} = 0.1V, V_O = 1.4V, 0^\circ C \leq T_A \leq 70^\circ C$ , unless otherwise noted (Note 6).

SYMBOL	PARAMETER	CONDITIONS		LT2078AC/LT2079AC			LT2078C/LT2079C			UNITS
				MIN	TYP	MAX	MIN	TYP	MAX	
$V_{OS}$	Input Offset Voltage	LT2078 LT2079	● ●		50 60	150 180		60 70	240 270	$\mu V$ $\mu V$
$\frac{\Delta V_{OS}}{\Delta T}$	Input Offset Voltage Drift (Note 5)	LT2078 LT2079	● ●		0.4 0.5	1.8 3.0		0.5 0.6	2.5 3.5	$\mu V/^\circ C$ $\mu V/^\circ C$
$I_{OS}$	Input Offset Current		●		0.06	0.35		0.06	0.50	nA
$I_B$	Input Bias Current		●		6	9		6	11	nA
CMRR	Common Mode Rejection Ratio	$V_{CM} = 0V$ to 3.4V	●		92	108		88	106	dB
PSRR	Power Supply Rejection Ratio	$V_S = 2.6V$ to 12V	●		98	112		95	112	dB

**ELECTRICAL CHARACTERISTICS**  $V_S = 5V, 0V, V_{CM} = 0.1V, V_O = 1.4V, 0^\circ C \leq T_A \leq 70^\circ C$ , unless otherwise noted.

SYMBOL	PARAMETER	CONDITIONS		LT2078AC/LT2079AC			LT2078C/LT2079C			UNITS
				MIN	TYP	MAX	MIN	TYP	MAX	
A <sub>VOL</sub>	Large-Signal Voltage Gain	V <sub>O</sub> = 0.05V to 4V, No Load V <sub>O</sub> = 0.05V to 3.5V, R <sub>L</sub> = 50k	●	150	750		110	750		V/mV
			●	110	500		80	500		V/mV
	Maximum Output Voltage Swing	Output Low, No Load Output Low, I <sub>SINK</sub> = 100μA	●		4.0	7		4.0	7	mV
			●		105	150		105	150	mV
		Output High, No Load Output High, 2k to GND	●	4.1	4.3		4.1	4.3		V
			●	3.3	3.8		3.3	3.8		V
I <sub>S</sub>	Supply Current per Amplifier		●		40	55		42	63	μA

$V_S = \pm 15V, T_A = 25^\circ C$ , unless otherwise noted.

SYMBOL	PARAMETER	CONDITIONS		LT2078AC/LT2078AI LT2079AC/LT2079AI			LT2078C/LT2078I LT2079C/LT2079I			UNITS
				MIN	TYP	MAX	MIN	TYP	MAX	
V <sub>OS</sub>	Input Offset Voltage	LT2078 LT2079			50	250		70	350	μV
					60	350		80	450	μV
I <sub>OS</sub>	Input Offset Current			0.05	0.25		0.05	0.35	nA	
I <sub>B</sub>	Input Bias Current			6	8		6	10	nA	
	Input Voltage Range			13.5	13.8		13.5	13.8		V
				-15.0	-15.3		-15.0	-15.3		V
CMRR	Common Mode Rejection Ratio	V <sub>CM</sub> = 13.5V, -15V		98	114		95	114		dB
PSRR	Power Supply Rejection Ratio	V <sub>S</sub> = 5V, 0V to ±18V		100	114		98	114		dB
A <sub>VOL</sub>	Large-Signal Voltage Gain	V <sub>O</sub> = ±10V, R <sub>L</sub> = 50k V <sub>O</sub> = ±10V, R <sub>L</sub> = 2k		1000	5000		1000	5000		V/mV
				400	1100		300	1100		V/mV
V <sub>OUT</sub>	Maximum Output Voltage Swing	R <sub>L</sub> = 50k R <sub>L</sub> = 2k		±13.0	±14.0		±13.0	±14.0		V
				±11.0	±13.2		±11.0	±13.2		V
SR	Slew Rate			0.06	0.10		0.06	0.10		V/μs
I <sub>S</sub>	Supply Current per Amplifier			46	65		47	75		μA

$V_S = \pm 15V, -40^\circ C \leq T_A \leq 85^\circ C$  for I grades, unless otherwise noted.

SYMBOL	PARAMETER	CONDITIONS		LT2078AI/LT2079AI			LT2078I/LT2079I			UNITS
				MIN	TYP	MAX	MIN	TYP	MAX	
V <sub>OS</sub>	Input Offset Voltage	LT2078 LT2079	●		90	430		120	600	μV
			●		100	500		130	700	μV
$\frac{\Delta V_{OS}}{\Delta T}$	Input Offset Voltage Drift (Note 5)	LT2078 LT2079	●		0.5	1.8		0.6	2.5	μV/°C
			●		0.6	3.0		0.7	3.8	μV/°C
I <sub>OS</sub>	Input Offset Current		●		0.07	0.70		0.1	1.0	nA
I <sub>B</sub>	Input Bias Current		●		7	10		7	12	nA
A <sub>VOL</sub>	Large-Signal Voltage Gain	V <sub>O</sub> = ±10V, R <sub>L</sub> = 5k	●	200	700		150	700		V/mV
CMRR	Common Mode Rejection Ratio	V <sub>CM</sub> = 13V, -14.9V	●	92	110		88	110		dB
PSRR	Power Supply Rejection Ratio	V <sub>S</sub> = 5V, 0V to ±18V	●	96	110		92	110		dB
			●	±11.0	±13.5		±11.0	±13.5		V
I <sub>S</sub>	Supply Current per Amplifier		●		52	80		54	95	μA

**ELECTRICAL CHARACTERISTICS**  $V_S = \pm 15V, 0^\circ C \leq T_A \leq 70^\circ C$ , unless otherwise noted (Note 6).

SYMBOL	PARAMETER	CONDITIONS	LT2078AC/LT2079AC			LT2078C/LT2079C			UNITS
			MIN	TYP	MAX	MIN	TYP	MAX	
$V_{OS}$	Input Offset Voltage	LT2078 LT2079	● ●	70 80	330 410	90 100	460 540	$\mu V$ $\mu V$	
$\frac{\Delta V_{OS}}{\Delta T}$	Input Offset Voltage Drift (Note 5)	LT2078 LT2079	● ●	0.5 0.6	1.8 3.0	0.6 0.7	2.5 3.8	$\mu V/^\circ C$ $\mu V/^\circ C$	
$I_{OS}$	Input Offset Current		●	0.06	0.35	0.06	0.50	nA	
$I_B$	Input Bias Current		●	6	9	6	11	nA	
$A_{VOL}$	Large-Signal Voltage Gain	$V_O = \pm 10V, R_L = 5k$	●	300	1200	250	1200	V/mV	
CMRR	Common Mode Rejection Ratio	$V_{CM} = 13V, -15V$	●	95	112	92	112	dB	
PSRR	Power Supply Rejection Ratio	$V_S = 5V, 0V$ to $\pm 18V$	●	98	112	95	112	dB	
	Maximum Output Voltage Swing	$R_L = 5k$	●	$\pm 11.0$	$\pm 13.6$	$\pm 11.0$	$\pm 13.6$	V	
$I_S$	Supply Current per Amplifier		●	49	73	50	85	$\mu A$	

The ● denotes specifications which apply over the full operating temperature range.

**Note 1:** Typical parameters are defined as the 60% yield of parameter distributions of individual amplifiers, i.e., out of 100 LT2079s (or 100 LT2078s) typically 240 op amps (or 120) will be better than the indicated specification.

**Note 2:** This parameter is tested on a sample basis only. All noise parameters are tested with  $V_S = \pm 2.5V, V_O = 0V$ .

**Note 3:** This parameter is guaranteed by design and is not tested.

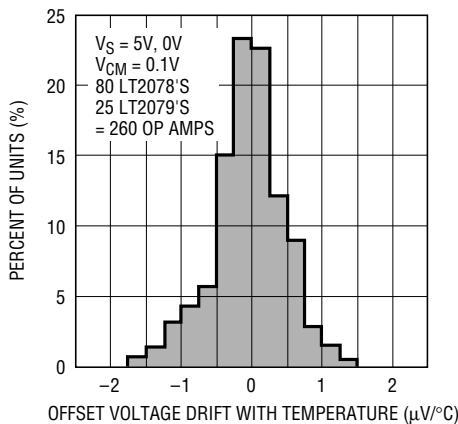
**Note 4:** Power supply rejection ratio is measured at the minimum supply voltage. The op amps actually work at 1.8V supply but with a typical offset skew of  $-300\mu V$ .

**Note 5:** This parameter is not 100% tested.

**Note 6:** The LT2078C/LT2079C are designed, characterized and expected to meet the industrial temperature limits, but are not tested at  $-40^\circ C$  and  $85^\circ C$ . I-grade parts are guaranteed.

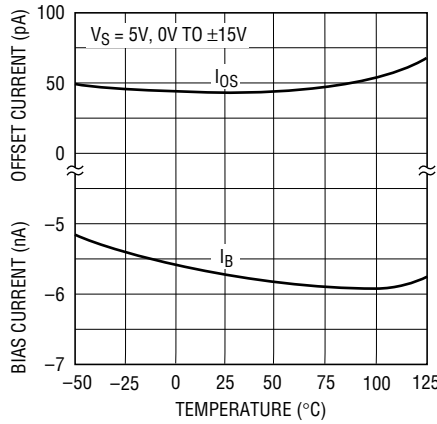
**TYPICAL PERFORMANCE CHARACTERISTICS**

**Distribution of Offset Voltage Drift with Temperature**



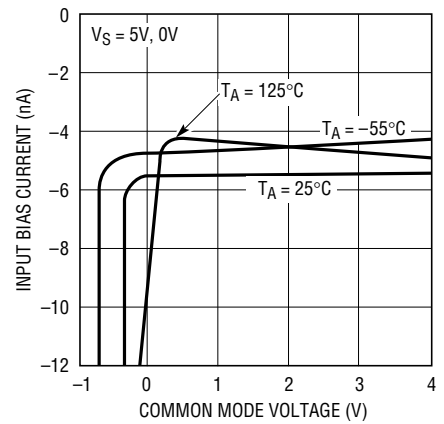
LT2078/79 • TPC01

**Input Bias and Offset Currents vs Temperature**



LT2078/79 • TPC02

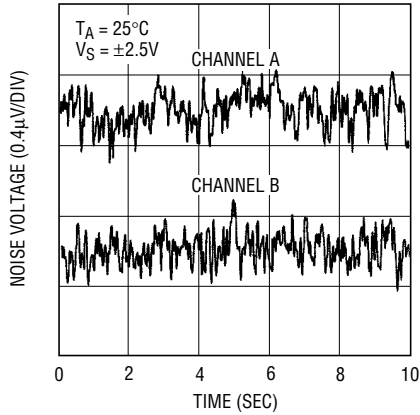
**Input Bias Current vs Common Mode Voltage**



LT2078/79 • TPC03

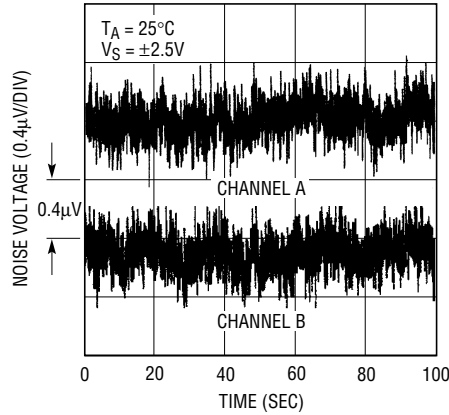
# TYPICAL PERFORMANCE CHARACTERISTICS

0.1Hz to 10Hz Noise



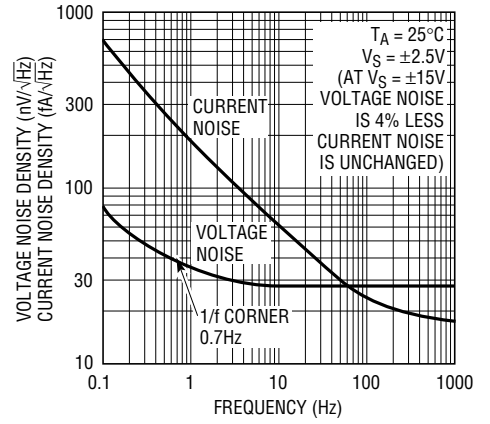
LT2078/79 • TPC04

0.01Hz to 10Hz Noise



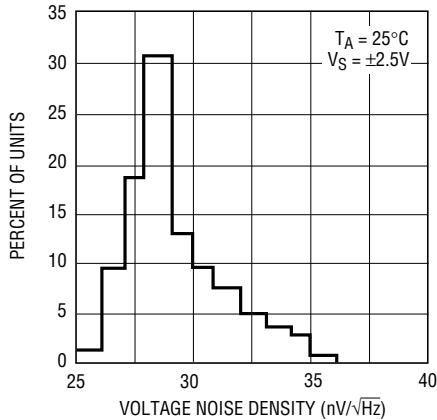
LT2078/79 • TPC05

Noise Spectrum



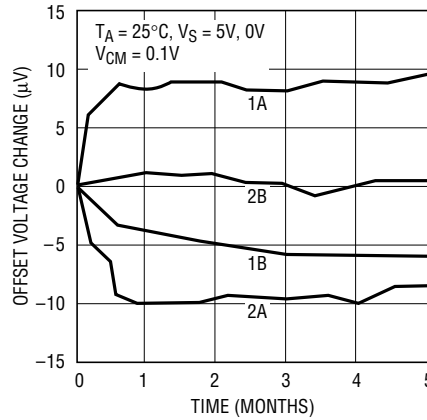
LT2078/79 • TPC06

10Hz Voltage Noise Distribution



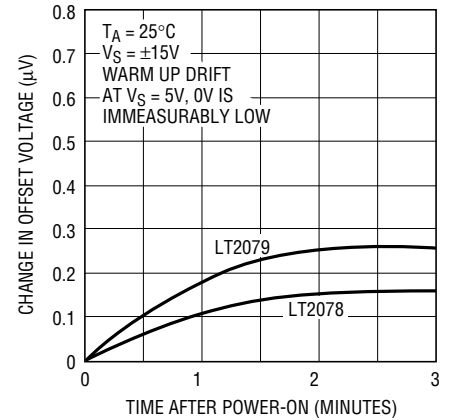
LT2078/79 • TPC07

Long Term Stability of Two Representative Units (LT2078)



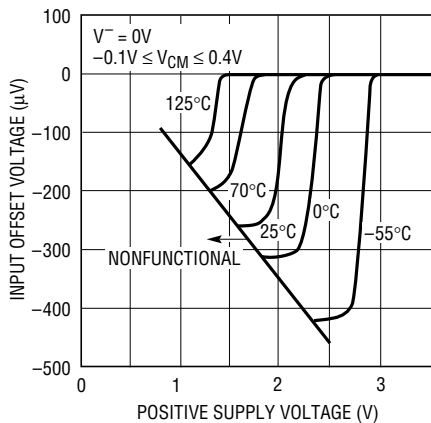
LT2078/79 • TPC08

Warm-Up Drift



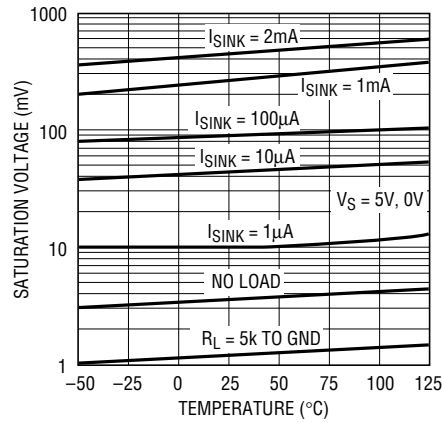
LT2078/79 • TPC09

Minimum Supply Voltage



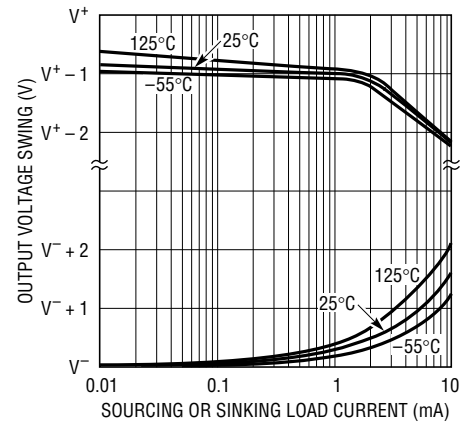
LT2078/79 • TPC10

Output Saturation vs Temperature vs Sink Current



LT2078/79 • TPC11

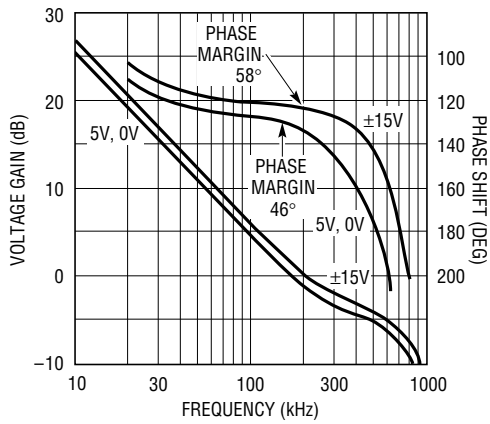
Output Voltage Swing vs Load Current



LT2078/79 • TPC11.5

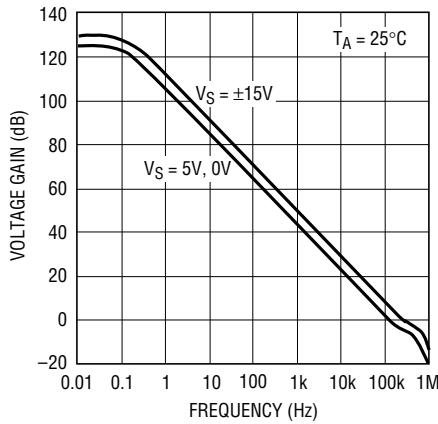
# TYPICAL PERFORMANCE CHARACTERISTICS

**Gain, Phase vs Frequency**



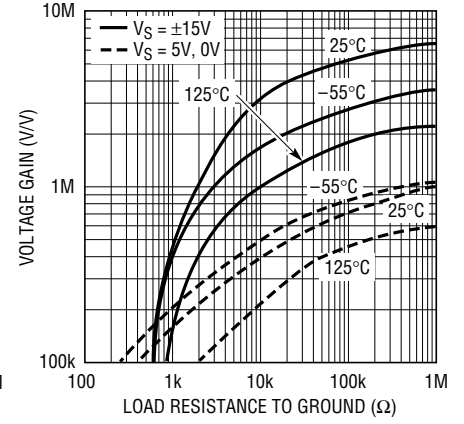
LT2078/79 • TPC12

**Voltage Gain vs Frequency**



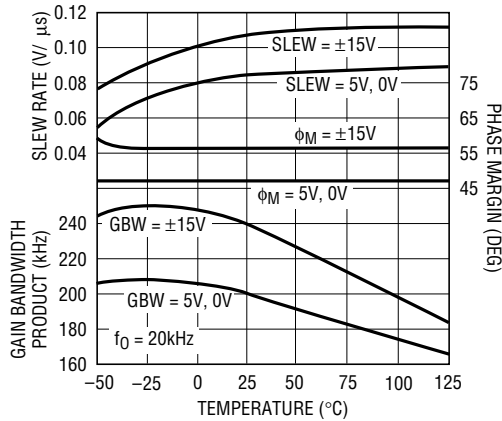
LT2078/79 • TPC13

**Voltage Gain vs Load Resistance**



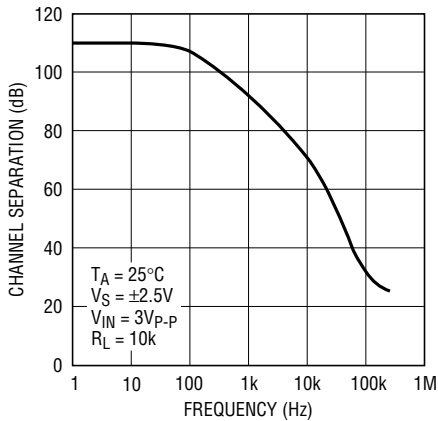
LT2078/79 • TPC14

**Slew Rate, Gain Bandwidth Product and Phase Margin vs Temperature**



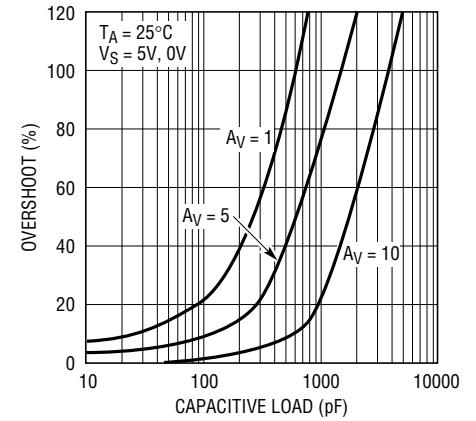
LT2078/79 • TPC15

**Channel Separation vs Frequency**



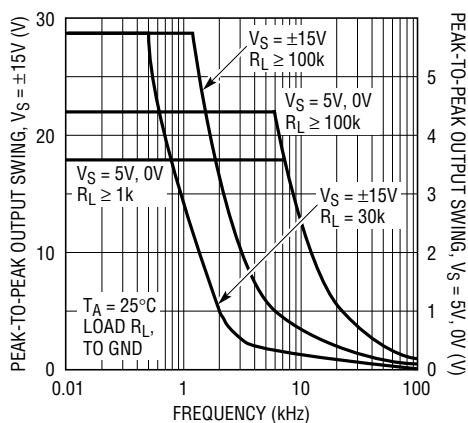
LT2078/79 • TPC16

**Capacitive Load Handling**



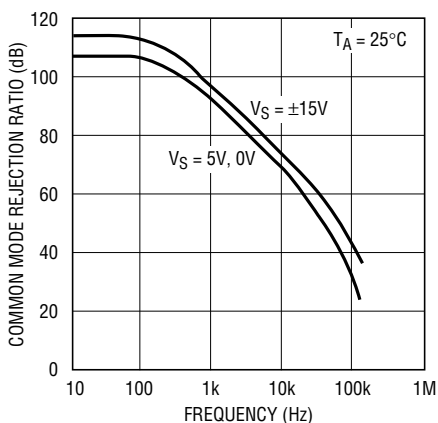
LT2078/79 • TPC17

**Undistorted Output Swing vs Frequency**



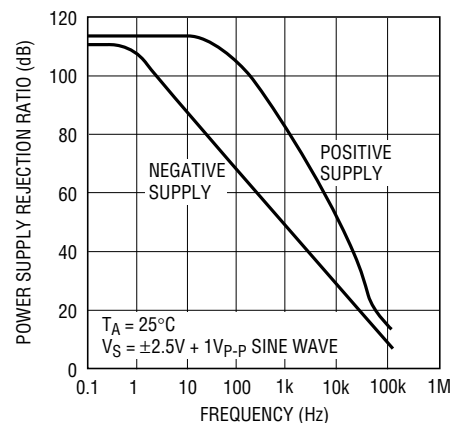
LT2078/79 • TPC18

**Common Mode Rejection Ratio vs Frequency**



LT2078/79 • TPC19

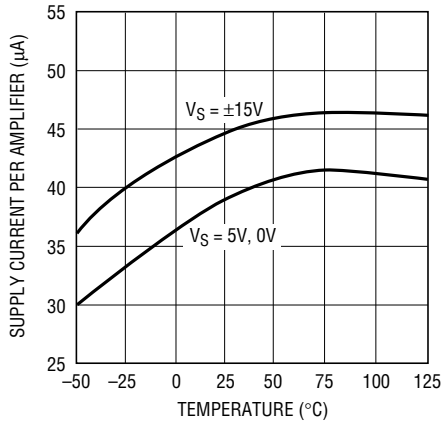
**Power Supply Rejection Ratio vs Frequency**



LT2078/79 • TPC20

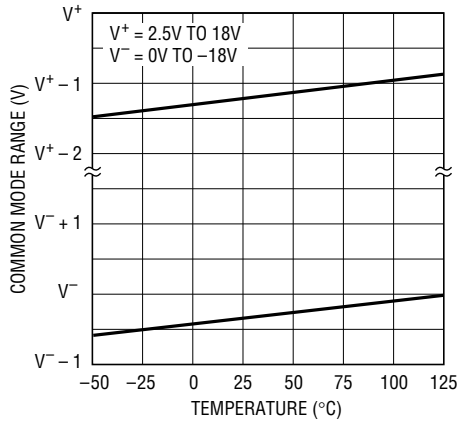
# TYPICAL PERFORMANCE CHARACTERISTICS

**Supply Current vs Temperature**



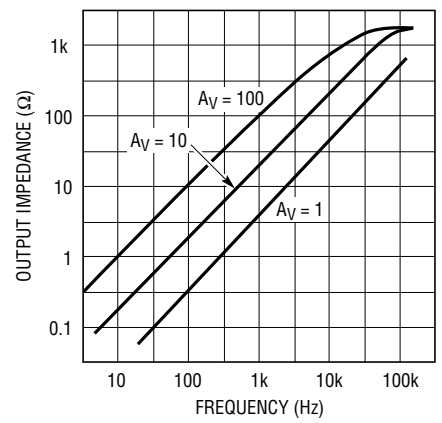
LT2078/79 • TPC21

**Common Mode Range vs Temperature**



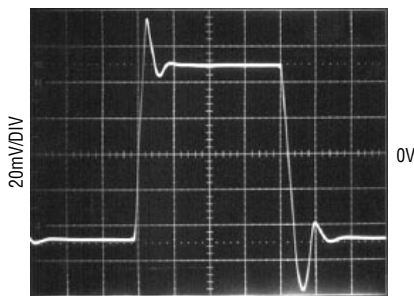
LT2078/79 • TPC22

**Closed-Loop Output Impedance**



LT2078/79 • TPC23

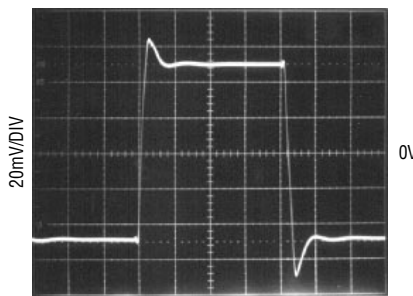
**Small-Signal Transient Response  
VS = 5V, 0V**



AV = 1  
CL = 15pF  
INPUT 50mV TO 150mV

LT2078/79 • TPC24

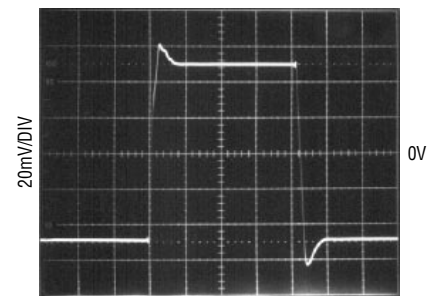
**Small-Signal Transient Response  
VS = ± 2.5V**



AV = 1  
CL = 15pF

LT2078/79 • TPC25

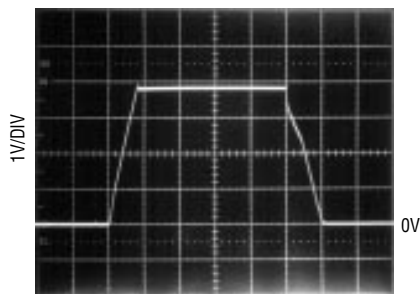
**Small-Signal Transient Response  
VS = ± 15V**



AV = 1  
CL = 15pF

LT2078/79 • TPC26

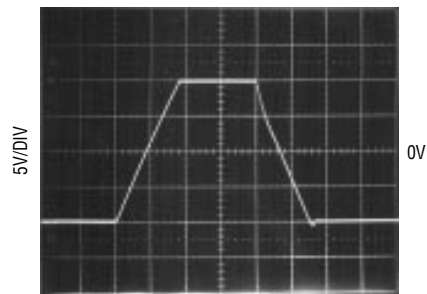
**Large-Signal Transient Response  
VS = 5V, 0V**



AV = 1, NO LOAD  
INPUT PULSE 0V TO 3.8V

LT2078/79 • TPC27

**Large-Signal Transient Response  
VS = ± 15V**



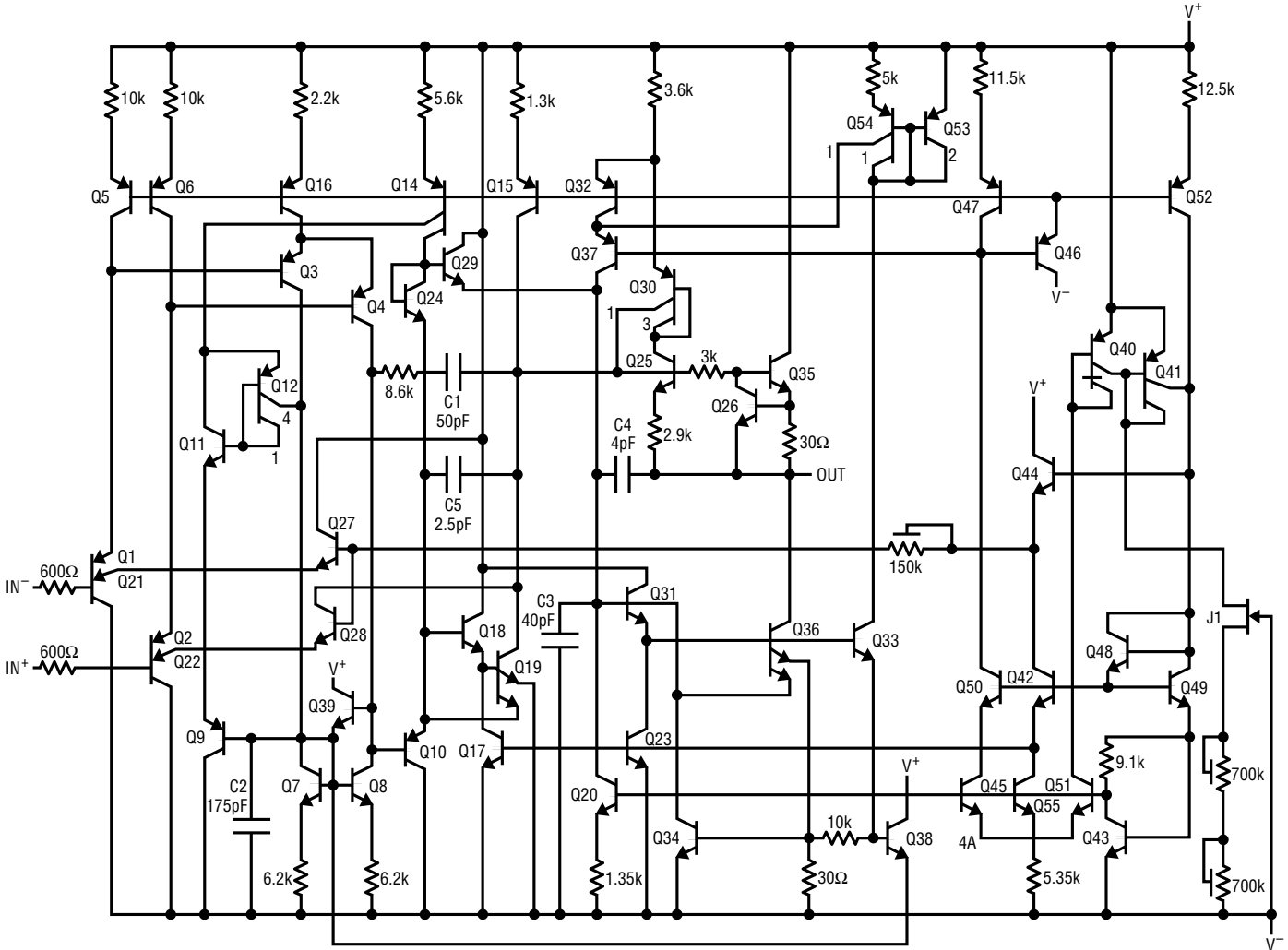
AV = 1  
NO LOAD

LT2078/79 • TPC28



SIMPLIFIED SCHEMATIC

1/2 LT2078, 1/4 LT2079



LT2078/79 • SIMPLIFIED SCHEM

## APPLICATIONS INFORMATION

The LT2078/LT2079 devices are fully specified with  $V^+ = 5V$ ,  $V^- = 0V$ ,  $V_{CM} = 0.1V$ . This set of operating conditions appears to be the most representative for battery powered micropower circuits. Offset voltage is internally trimmed to a minimum value at these supply voltages. When 9V or 3V batteries or  $\pm 2.5V$  dual supplies are used, bias and offset current changes will be minimal. Offset voltage changes will be just a few microvolts as given by the PSRR and CMRR specifications. For example, if  $PSRR = 114dB (=2\mu V/V)$ , at 9V the offset voltage change will be  $8\mu V$ . Similarly,  $V_S = \pm 2.5V$ ,  $V_{CM} = 0V$  is equivalent to a common mode voltage change of 2.4V or a  $V_{OS}$  change of  $7\mu V$  if  $CMRR = 110dB (3\mu V/V)$ .

A full set of specifications is also provided at  $\pm 15V$  supply voltages for comparison with other devices and for completeness.

### Single Supply Operation

The LT2078/LT2079 is quite tolerant of power supply bypassing. In some applications requiring faster settling time the positive supply pin of the LT2078/LT2079 should be bypassed with a small capacitor (about 0.1 $\mu F$ ). The same is true for the negative supply pin when using split supplies.

The LT2078/LT2079 are fully specified for single supply operation, i.e., when the negative supply is 0V. Input common mode range goes below ground and the output swings within a few millivolts of ground while sinking current. All competing micropower op amps either cannot swing to within 600mV of ground (OP-20, OP-220, OP-420) or need a pull-down resistor connected to the output to swing to ground (OP-90, OP-290, OP-490, HA5141/42/44). This difference is critical because in many applications these competing devices cannot be operated as micropower op amps and swing to ground simultaneously.

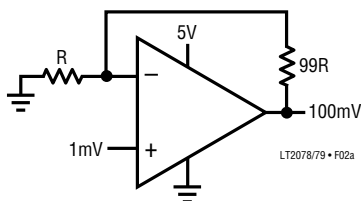


Figure 1a. Gain 100 Amplifier

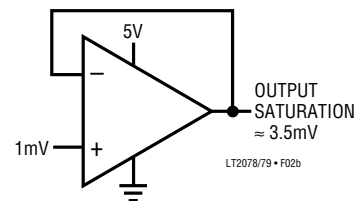


Figure 1b. Voltage Follower

As an example, consider the instrumentation amplifier shown on the front page. When the common mode signal is low and the output is high, amplifier A has to sink current. When the common mode signal is high and the output low, amplifier B has to sink current. The competing devices require a 12k pull-down resistor at the output of amplifier A and a 15k at the output of B to handle the specified signals. (The LT2078 does not need pull-down resistors.) When the common mode input is high and the output is high these pull-down resistors draw 300 $\mu A$  (150 $\mu A$  each), which is excessive for micropower applications.

The instrumentation amplifier is by no means the only application requiring current sinking capability. In seven of the nine single supply applications shown in this data sheet the op amps have to be able to sink current. In two of the applications the first amplifier has to sink only the 6nA input bias current of the second op amp. The competing devices, however, cannot even sink 6nA without a pull-down resistor

Since the output of the LT2078/LT2079 cannot go exactly to ground, but can only approach ground to within a few millivolts, care should be exercised to ensure that the output is not saturated. For example, a 1mV input signal will cause the amplifier to set up in its linear region in the gain 100 configuration shown in Figure 1, but is not enough to make the amplifier function properly in the voltage follower mode.

Single supply operation can also create difficulties at the input. The driving signal can fall below 0V — inadvertently or on a transient basis. If the input is more than a few hundred millivolts below ground, two distinct problems can occur on previous single supply designs, such as the LM124, LM158, OP-20, OP-21, OP-220, OP-221, OP-420 (1 and 2), OP-90/290/490 (2 only):

## APPLICATIONS INFORMATION

1. When the input is more than a diode drop below ground, unlimited current will flow from the substrate ( $V^-$  terminal) to the input. This can destroy the unit. On the LT2078/LT2079, resistors in series with the input protect the devices even when the input is 5V below ground.
2. When the input is more than 400mV below ground (at 25°C), the input stage saturates and phase reversal occurs at the output. This can cause lockup in servo systems. Due to a unique phase reversal protection circuitry, the LT2078/LT2079 output does not reverse, as illustrated in Figure 2, even when the inputs are at  $-1V$ .

### Distortion

There are two main contributors of distortion in op amps: distortion caused by nonlinear common mode rejection and output crossover distortion as the output transitions from sourcing to sinking current. The common mode

rejection of the LT2078/LT2079 is very good, typically 108dB. Therefore, as long as the input operates in the normal common mode range, there will be very little common mode induced distortion. If the op amp is operating inverting there is no common mode induced distortion. Crossover distortion will increase as the output load resistance decreases. For the lowest distortion the LT2078/LT2079 should be operated with the output always sourcing current, this is usually accomplished by putting a resistor from the output to  $V^-$ . In an inverting configuration with no load, the output will source and sink current through the feedback resistor. High value feedback resistors will reduce crossover distortion and maintain micropower operation.

### Matching Specifications

In many applications the performance of a system depends on the matching between two op amps, rather than

Table 1

PARAMETER	LT2078AC/LT2079AC/LT2078AI/LT2079AI		LT2078C/LT2079C/LT2078I/LT2079I		UNITS	
	50% YIELD	98% YIELD	50% YIELD	98% YIELD		
$V_{OS}$ Match, $\Delta V_{OS}$	LT2078	30	110	50	190	$\mu V$
	LT2079	40	150	50	250	$\mu V$
Temperature Coefficient $\Delta V_{OS}$		0.5	1.2	0.6	1.8	$\mu V/^\circ C$
Average Noninverting $I_B$		6	8	6	10	nA
Match of Noninverting $I_B$		0.12	0.4	0.15	0.5	nA
CMRR Match		120	100	117	97	dB
PSRR Match		117	105	117	102	dB

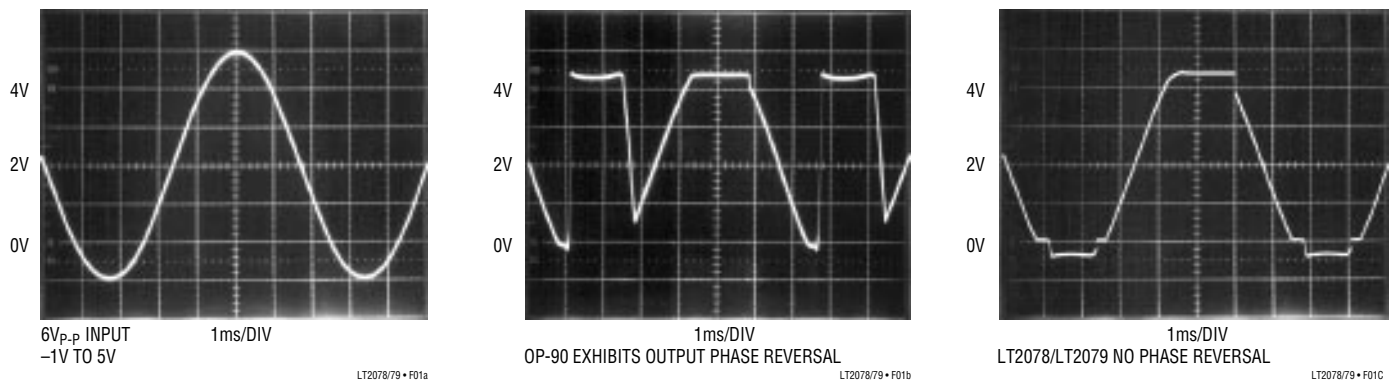


Figure 2. Voltage Follower with Input Exceeding the Negative Common Mode Range ( $V_S = 5V, 0V$ )

## APPLICATIONS INFORMATION

the individual characteristics of the two devices, the two and three op amp instrumentation amplifier configurations shown in this data sheet are examples. Matching characteristics are not 100% tested on the LT2078/LT2079.

Some specifications are guaranteed by definition. For example, 70 $\mu$ V maximum offset voltage implies that mismatch cannot be more than 140 $\mu$ V. 95dB (= 17.5 $\mu$ V/V) CMRR means that worst-case CMRR match is 89dB (= 35 $\mu$ V/V). However, Table 1 can be used to estimate the

expected matching performance at  $V_S = 5V, 0V$  between the two sides of the LT2078, and between amplifiers A and D, and between amplifiers B and C of the LT2079.

### Comparator Applications

The single supply operation of the LT2078/LT2079 and its ability to swing close to ground while sinking current lends itself to use as a precision comparator with TTL compatible output.

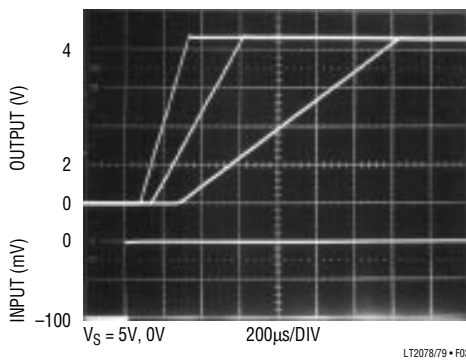


Figure 3. Comparator Rise Response Time to 10mV, 5mV, 2mV Overdrives

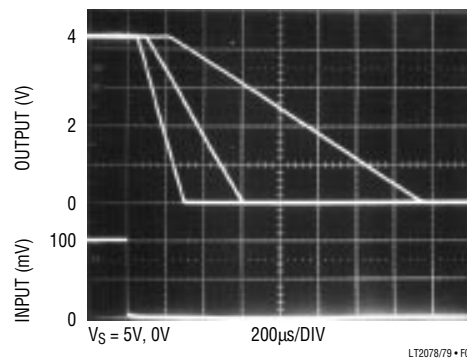
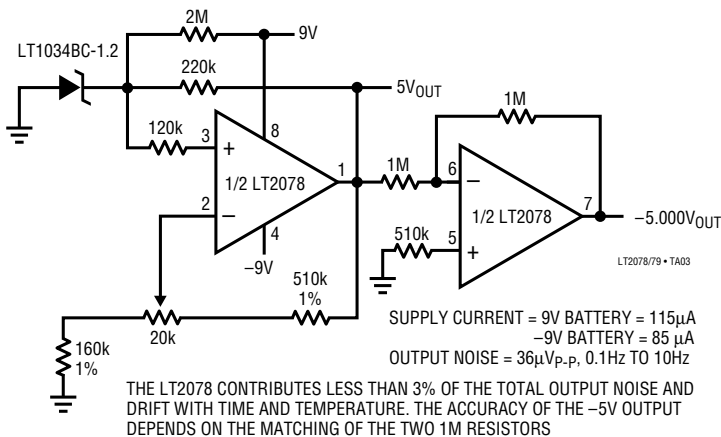


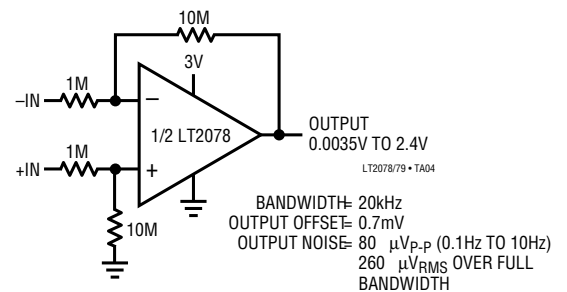
Figure 4. Comparator Fall Response Time to 10mV, 5mV, 2mV Overdrives

## TYPICAL APPLICATIONS

### Micropower, 10ppm/°C, $\pm 5V$ Reference



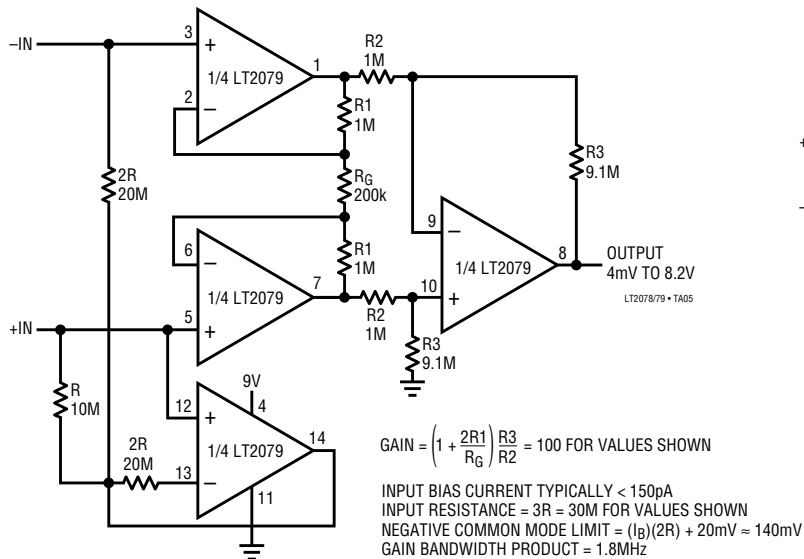
### Gain of 10 Difference Amplifier



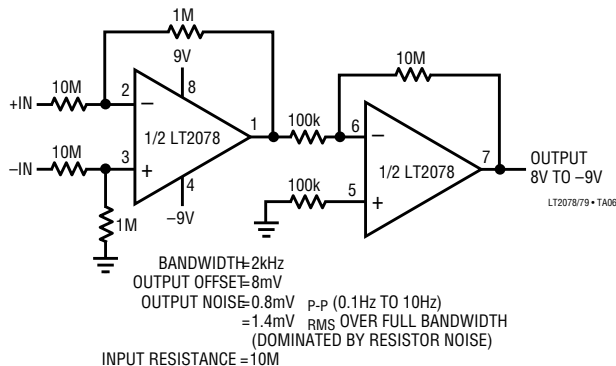
THE USEFULNESS OF DIFFERENCE AMPLIFIERS IS LIMITED BY THE FACT THAT THE INPUT RESISTANCE IS EQUAL TO THE SOURCE RESISTANCE. THE PICOAMPERE OFFSET CURRENT AND LOW CURRENT NOISE OF THE LT2078 ALLOWS THE USE OF 1M SOURCE RESISTORS WITHOUT DEGRADATION IN PERFORMANCE. IN ADDITION, WITH MEGOHM RESISTORS MICROPOWER OPERATION CAN BE MAINTAINED

# TYPICAL APPLICATIONS

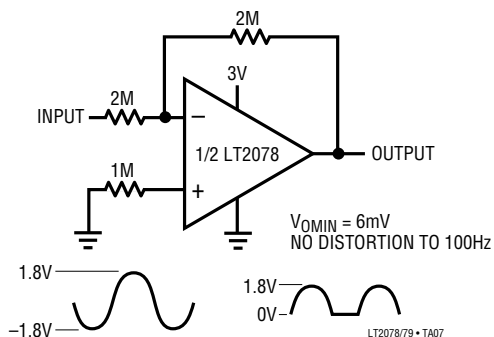
**Picoampere Input Current, Triple Op Amp Instrumentation Amplifier with Bias Current Cancellation**



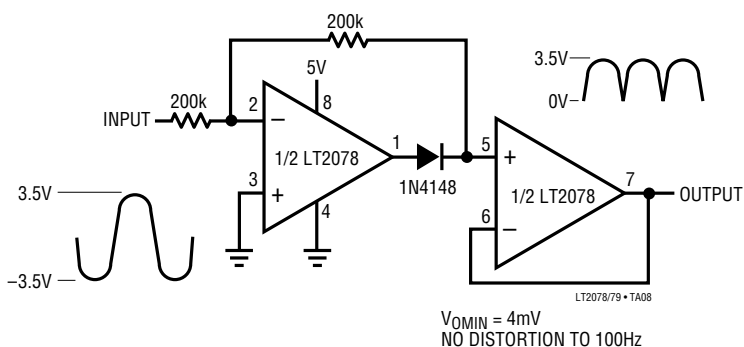
**85V, -100V Common Mode Range Instrumentation Amplifier ( $A_V = 10$ )**



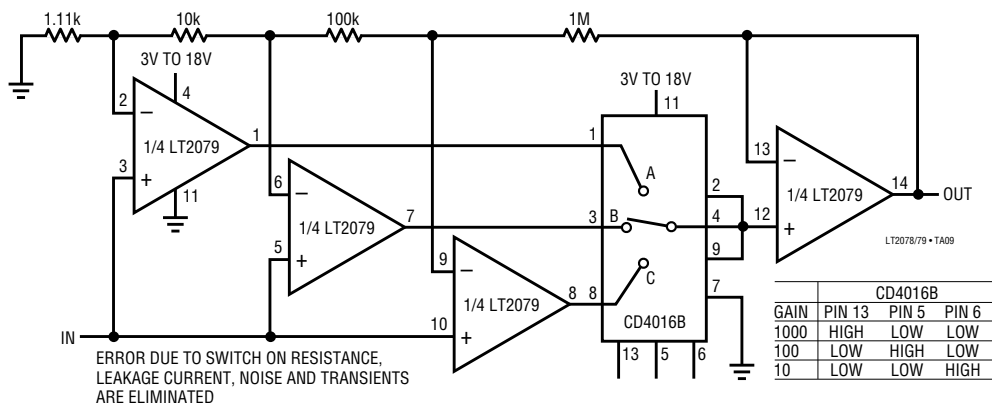
**Half-Wave Rectifier**



**Absolute Value Circuit (Full-Wave Rectifier)**



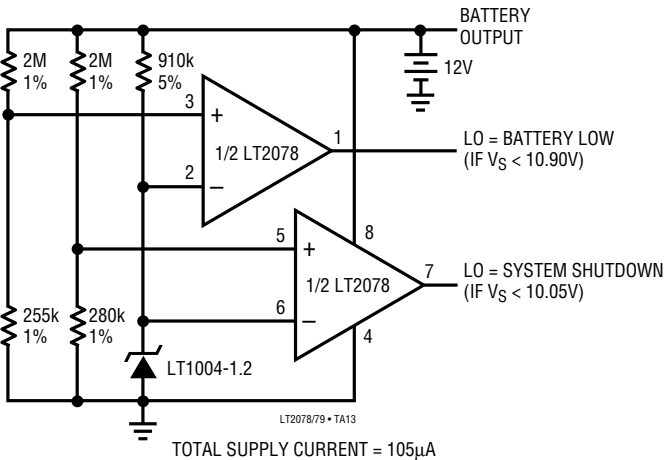
**Programmable Gain Amplifier (Single Supply)**





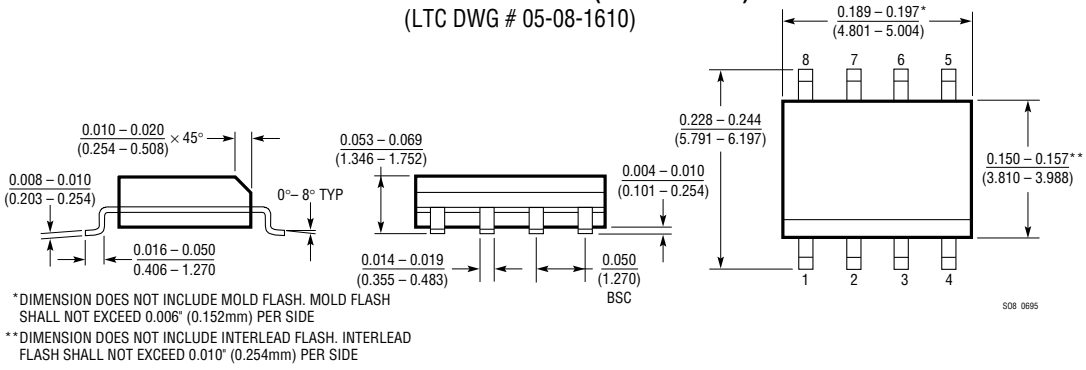
**TYPICAL APPLICATIONS**

**Lead-Acid Low-Battery Detector with System Shutdown**

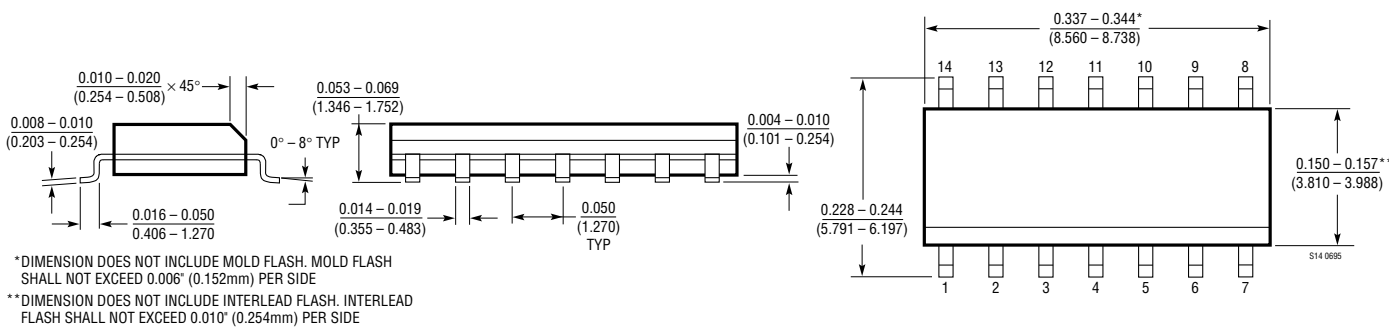


**PACKAGE DESCRIPTION** Dimensions in inches (millimeters) unless otherwise noted.

**S8 Package**  
**8-Lead Plastic Small Outline (Narrow 0.150)**  
 (LTC DWG # 05-08-1610)

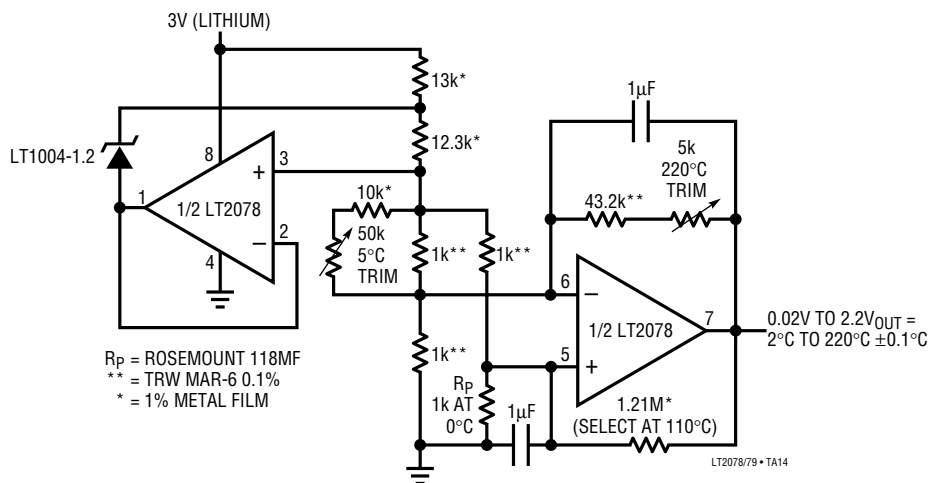


**S Package**  
**14-Lead Plastic Small Outline (Narrow 0.150)**  
 (LTC DWG # 05-08-1610)



## TYPICAL APPLICATION

Platinum RTD Signal Conditioner with Curvature Correction



## RELATED PARTS

PART NUMBER	DESCRIPTION	COMMENTS
LT1178/LT1179	Dual/Quad 17 $\mu$ A Max, Single Supply Precision Op Amps	70 $\mu$ V $V_{OS}$ Max and 2.5 $\mu$ V/ $^{\circ}$ C Drift Max, 85kHz GBW, 0.04V/ $\mu$ s Slew Rate, Input/Output Common Mode Includes Ground
LT1211/LT1212	14MHz, 7V/ $\mu$ s Single Supply Dual and Quad Precision Op Amps	275 $\mu$ V $V_{OS}$ Max, 6 $\mu$ V/ $^{\circ}$ C Drift Max Input Voltage Range Includes Ground
LT1490/LT1491	Dual/ Quad Micropower Rail-to-Rail Input and Output Op Amps	Single Supply Input Range: -0.4V to 44V, Micropower 50 $\mu$ A Amplifier, Rail-to-Rail Input and Output, 200kHz GBW
LT2178/LT2179	Dual/Quad 17 $\mu$ A Max, Single Supply Precision Op Amps	SO-8 and 14-Lead Standard Pinout, 70 $\mu$ V $V_{OS}$ Max, 85kHz GBW