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

FEATURES

- 50μA Max Supply Current per Amplifier
- 70μV Max Offset Voltage
- 250pA Max Offset Current
- 0.6μVp-p 0.1Hz to 10Hz Voltage Noise
- 3pAp-p 0.1Hz to 10Hz Current Noise
- 0.4μV/°C Offset Voltage Drift
- 200kHz Gain-Bandwidth-Product
- 0.07V/μs Slew Rate
- Single Supply Operation
  - Input Voltage Range Includes Ground
  - Output Swings to Ground while Sinking Current
  - No Pull Down Resistors are 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

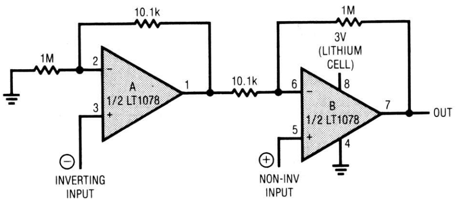
The LT1078 is a micropower dual op amp in the standard 8-pin configuration; the LT1079 is a micropower quad op amp offered in the standard 14-pin packages. Both devices are optimized for single supply operation at 5V. ±15V specifications are also provided.

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 LT1078/1079 was concentrated on reducing supply current without sacrificing other parameters. The offset voltage achieved is the lowest on any dual or quad non-chopper 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.

The 1/f corner of the voltage noise spectrum is at 0.7Hz, at least three times lower than on any monolithic op amp. This results in low frequency (0.1Hz to 10Hz) noise performance which can only be found on devices with an order of magnitude higher supply current.

Both the LT1078 and LT1079 can be operated from a single supply (as low as one lithium cell or two Ni-cad 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.

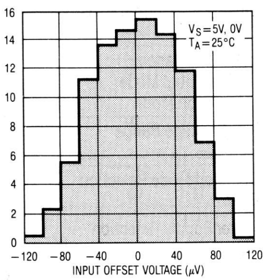
Single Battery, Micropower, Gain = 100, Instrumentation Amplifier



TYPICAL PERFORMANCE
INPUT OFFSET VOLTAGE = 40μV
INPUT OFFSET CURRENT = 0.2nA
TOTAL POWER DISSIPATION = 240μW
COMMON-MODE REJECTION = 110dB (AMPLIFIER LIMITED)
GAIN BANDWIDTH PRODUCT = 200kHz

OUTPUT NOISE = 85μVp-p 0.1Hz TO 10Hz
= 300μV_{RMS} OVER FULL BANDWIDTH
INPUT RANGE = 0.03V TO 1.8V
OUTPUT RANGE = 0.03V TO 2.3V (0.3mV ≤ $V_{IN+} - V_{IN-}$ ≤ 23mV)
OUTPUTS SINK CURRENT—NO PULL DOWN RESISTORS ARE NEEDED

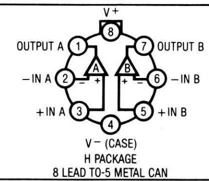
Distribution of Input Offset Voltage (LT1078 and LT1079 in All Packages)



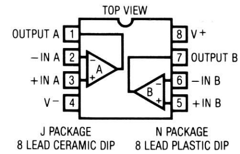
ABSOLUTE MAXIMUM RATINGS

Supply Voltage .... ± 22V
Differential Input Voltage .... ± 30V
Input Voltage .... Equal to Positive Supply Voltage
.... 5V Below Negative Supply Voltage
Output Short Circuit Duration .... Indefinite
Operating Temperature Range
LT1078AM/LT1078M/
LT1079AM/LT1079M .... – 55°C to 125°C
LT1078AC/LT1078C/
LT1079AC/LT1079C .... 0°C to 70°C
Storage Temperature Range
All Grades .... – 65°C to 150°C
Lead Temperature (Soldering, 10 sec.) .... 300°C

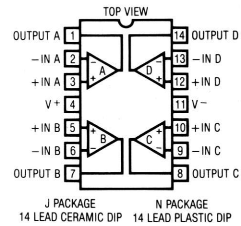
PACKAGE/ORDER INFORMATION



ORDER PART NUMBER: LT1078AMH, LT1078MH, LT1078ACH, LT1078CH



ORDER PART NUMBER: LT1078AMJ8, LT1078MJ8, LT1078ACJ8, LT1078CJ8, LT1078ACN8, LT1078CN8



ORDER PART NUMBER: LT1079AMJ, LT1079MJ, LT1079ACJ, LT1079CJ, LT1079ACN, LT1079CN

ELECTRICAL CHARACTERISTICS $V_S = 5V, 0V, V_{CM} = 0.1V, V_O = 1.4V, T_A = 25°C$, unless noted.

SYMBOL	PARAMETER	CONDITIONS (NOTE 1)	LT1078AM/AC LT1079AM/AC MIN	TYP	MAX	LT1078M/C LT1079M/C MIN	TYP	MAX	UNITS
V_{OS}	Input Offset Voltage	LT1078		30	70		40	120	µV
		LT1079		35	100		40	150	µV
$\frac{\Delta V_{OS}}{\Delta Time}$	Long Term Input Offset Voltage Stability			0.4			0.5		µV/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		µVp-p
	Input Noise Voltage Density	f_o = 10Hz (Note 2)		29	45		29		nV/√Hz
		f_o = 1000Hz (Note 2)		28	37		28		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 Resistance	(Note 3)							
	Differential Mode		400	800		300	800		MΩ
	Common-Mode			6			6		GΩ
	Input Voltage Range		3.5	3.8		3.5	3.8		V
			0	– 0.3		0	– 0.3		V
CMRR	Common-Mode Rejection Ratio	V_{CM} = 0V to 3.5V	97	110		94	108		dB
PSRR	Power Supply Rejection Ratio	V_S = 2.3V to 12V	102	114		100	114		dB
A_{VOL}	Large Signal Voltage Gain	V_O = 0.03V to 4V, No Load	200	1000		150	1000		V/mV
		V_O = 0.03V to 3.5V, R_L = 50k	150	600		120	600		V/mV

ELECTRICAL CHARACTERISTICS $V_S = 5V, 0V, V_{CM} = 0.1V, V_O = 1.4V, T_A = 25°C$, unless noted.

SYMBOL	PARAMETER	CONDITIONS (NOTE 1)	LT1078AM/AC LT1079AM/AC MIN	TYP	MAX	LT1078M/C LT1079M/C MIN	TYP	MAX	UNITS
	Maximum Output Voltage Swing	Output Low, No Load		3.5	6		3.5	6	mV
		Output Low, 2k to GND		0.55	1.0		0.55	1.0	mV
		Output Low, $I_{SINK} = 100\mu A$		95	130		95	130	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/μs
GBW	Gain Bandwidth Product	$f_o \le 20kHz$		200			200		kHz
I_S	Supply Current per Amplifier			38	50		39	55	μA
	Channel Separation	$\Delta V_{IN} = 3V, R_L = 10k$		130			130		dB
	Minimum Supply Voltage	(Note 4)		2.2	2.3		2.2	2.3	V

ELECTRICAL CHARACTERISTICS $V_S = 5V, 0V, V_{CM} = 0.1V, V_O = 1.4V, -55°C \le T_A \le 125°C$, unless noted.

SYMBOL	PARAMETER	CONDITIONS		LT1078AM/1079AM MIN	TYP	MAX	LT1078M/1079M MIN	TYP	MAX	UNITS
V_{OS}	Input Offset Voltage	LT1078	●		65	250		85	370	μV
		LT1079	●		80	280		100	400	μV
$\Delta V_{OS}/\Delta T$	Input Offset Voltage Drift	(Note 5)	●		0.4	1.8		0.5	2.5	μV/°C
I_{OS}	Input Offset Current		●		0.07	0.50		0.07	0.70	nA
I_B	Input Bias Current		●		7	10		7	12	nA
CMRR	Common-Mode Rejection Ratio	$V_{CM} = 0.05V$ to $3.2V$	●	92	106		88	104		dB
PSRR	Power Supply Rejection Ratio	$V_S = 3.1V$ to $12V$	●	98	110		94	110		dB
A_{VOL}	Large Signal Voltage Gain	$V_O = 0.05V$ to $4V$, No Load	●	110	600		80	600		V/mV
		$V_O = 0.05V$ to $3.5V, R_L = 50k$	●	80	400		60	400		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	μA

ELECTRICAL CHARACTERISTICS $V_S = 5V, 0V, V_{CM} = 0.1V, V_O = 1.4V, 0°C \le T_A \le 70°C$, unless noted.

SYMBOL	PARAMETER	CONDITIONS		LT1078AC/1079AC MIN	TYP	MAX	LT1078C/1079C MIN	TYP	MAX	UNITS
V_{OS}	Input Offset Voltage	LT1078	●		50	150		60	240	μV
		LT1079	●		60	180		70	270	μV
$\Delta V_{OS}/\Delta T$	Input Offset Voltage Drift	(Note 5)	●		0.4	1.8		0.5	2.5	μV/°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 $3.4V$	●	94	108		90	106		dB
PSRR	Power Supply Rejection Ratio	$V_S = 2.6V$ to $12V$	●	100	112		97	112		dB
A_{VOL}	Large Signal Voltage Gain	$V_O = 0.05V$ to $4V$, No Load	●	150	750		110	750		V/mV
		$V_O = 0.05V$ to $3.5V, R_L = 50K$	●	110	500		80	500		V/mV
	Maximum Output Voltage Swing	Output Low, No Load	●		4.0	7		4.0	7	mV
		Output Low, $I_{SINK} = 100\mu A$	●		105	150		105	150	mV
		Output High, No Load	●	4.1	4.3		4.1	4.3		V
		Output High, 2k to GND	●	3.3	3.8		3.3	3.8		V
I_S	Supply Current per Amplifier		●		40	55		42	63	μA

ELECTRICAL CHARACTERISTICS $V_S = \pm 15V, T_A = 25°C$, unless noted.

SYMBOL	PARAMETER	CONDITIONS	LT1078AM/AC LT1079AM/AC MIN	TYP	MAX	LT1078M/C LT1079M/C MIN	TYP	MAX	UNITS
V_{OS}	Input Offset Voltage			45	250		50	350	μV
I_{OS}	Input Offset Current			0.05	0.25		0.05	0.35	nA
I_B	Input Bias Current			6	8		6	10	nA
	Input Voltage Range		13.5 −15.0	13.8 −15.3		13.5 −15.0	13.8 −15.3		V V
CMRR	Common-Mode Rejection Ratio	V_{CM} + 13.5V, −15V	100	114		97	114		dB
PSRR	Power Supply Rejection Ratio	V_S = 5V, 0V to ± 18V	102	114		100	114		dB
A_{VOL}	Large Signal Voltage Gain	V_O = ± 10V, R_L = 50k V_O = ± 10V, R_L = 2k	1000 400	5000 1100		1000 300	5000 1100		V/mV V/mV
V_{OUT}	Maximum Output Voltage Swing	R_L = 50k R_L = 2k	± 13.0 ± 11.0	± 14.0 ± 13.2		± 13.0 ± 11.0	± 14.0 ± 13.2		V V
SR	Slew Rate		0.06	0.10		0.06	0.10		V/μs
I_S	Supply Current per Amplifier			46	65		47	75	μA

ELECTRICAL CHARACTERISTICS $V_S = \pm 15V$, $-55°C \le T_A \le 125°C$, unless noted.

SYMBOL	PARAMETER	CONDITIONS		LT1078AM/1079AM MIN	TYP	MAX	LT1078M/1079M MIN	TYP	MAX	UNITS
V_{OS}	Input Offset Voltage		●		85	430		100	600	μV
$\Delta V_{OS}/\Delta T$	Input Offset Voltage Drift	(Note 5)	●		0.4	1.8		0.5	2.5	μV/°C
I_{OS}	Input Offset Current		●		0.07	0.50		0.07	0.70	nA
I_B	Input Bias Current		●		7	10		7	12	nA
A_{VOL}	Large Signal Voltage Gain	V_O = ± 10V, R_L = 5k	●	200	700		150	700		V/mV
CMRR	Common-Mode Rejection Ratio	V_{CM} = + 13V, − 14.9V	●	94	110		90	110		dB
PSRR	Power Supply Rejection Ratio	V_S = 5V, 0V to ± 18V	●	98	110		94	110		dB
	Maximum Output Voltage Swing	R_L = 5k	●	± 11.0	± 13.5		± 11.0	± 13.5		V
I_S	Supply Current per Amplifier		●		52	80		54	95	μA

ELECTRICAL CHARACTERISTICS $V_S = \pm 15V$, $0°C \le T_A \le 70°C$, unless noted.

SYMBOL	PARAMETER	CONDITIONS		LT1078AC/1079AC MIN	TYP	MAX	LT1078C/1079C MIN	TYP	MAX	UNITS
V_{OS}	Input Offset Voltage		●		60	330		75	460	μV
$\Delta V_{OS}/\Delta T$	Input Offset Voltage Drift	(Note 5)	●		0.4	1.8		0.5	2.5	μV/°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 = ± 10V, R_L = 5k	●	300	1200		250	1200		V/mV
CMRR	Common-Mode Rejection Ratio	V_{CM} = 13V, − 15V	●	97	112		94	112		dB
PSRR	Power Supply Rejection Ratio	V_S = 5V, 0V to ± 18V	●	100	112		97	112		dB
	Maximum Output Voltage Swing	R_L = 5k	●	± 11.0	± 13.6		± 11.0	± 13.6		V
I_S	Supply Current per Amplifier		●		49	73		50	85	μA

The ● denotes the 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 LT1079s (or 100 LT1078s) 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 $V_S = \pm 2.5V$, $V_O = 0V$.

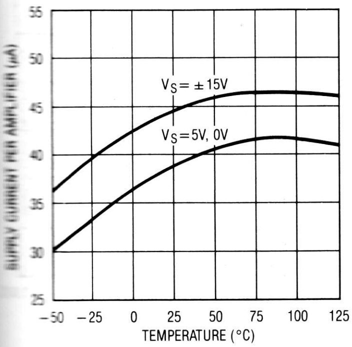
Note 3: This parameter is guaranteed by design and is not tested.

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 − 300μV.

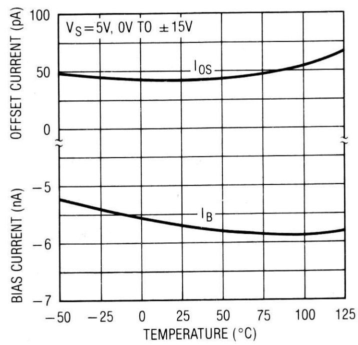
Note 5: This parameter is not 100% tested.

TYPICAL PERFORMANCE CHARACTERISTICS

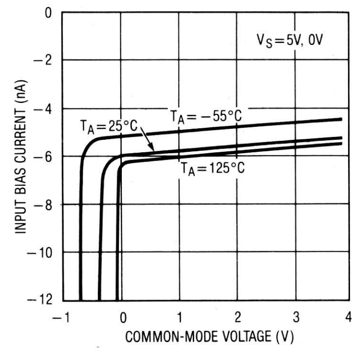
Supply Current vs Temperature



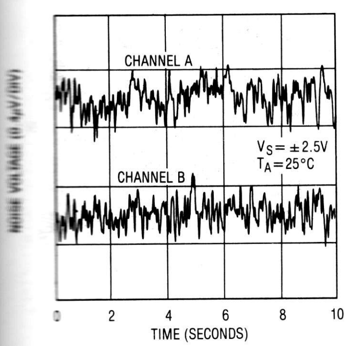
Input Bias and Offset Currents vs Temperature



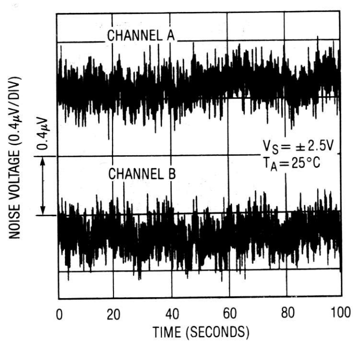
Input Bias Current vs Common-Mode Voltage



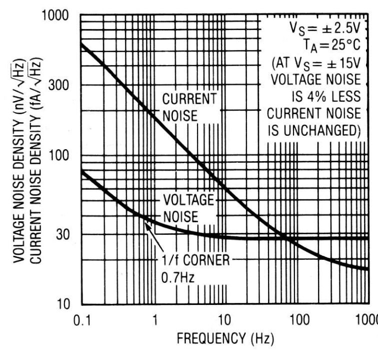
0.1Hz to 10Hz Noise



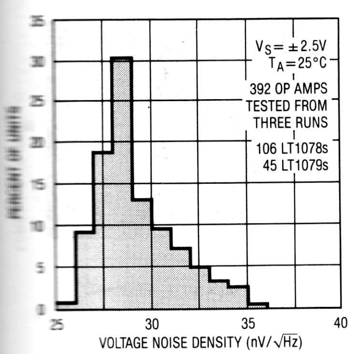
0.01Hz to 10Hz Noise



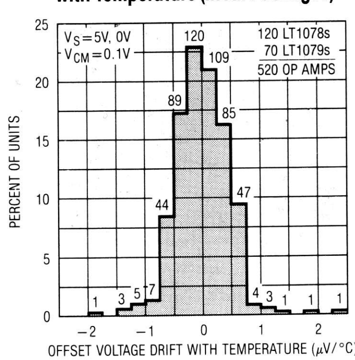
Noise Spectrum



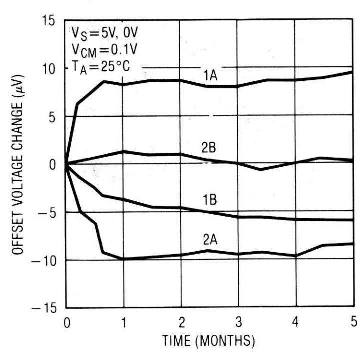
10Hz Voltage Noise Distribution



Distribution of Offset Voltage Drift with Temperature (In All Packages)

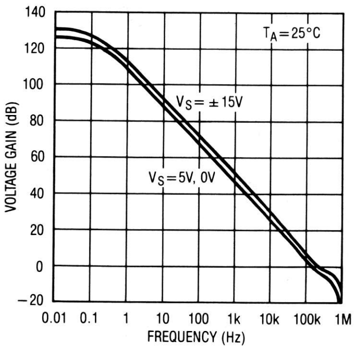


Long Term Stability of Two Representative Units (LT1078)

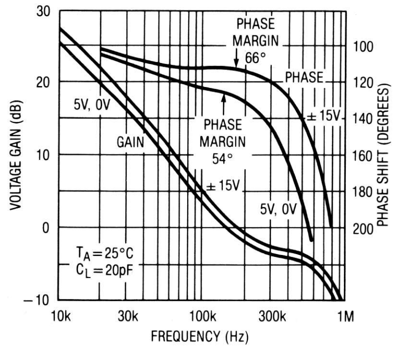


TYPICAL PERFORMANCE CHARACTERISTICS

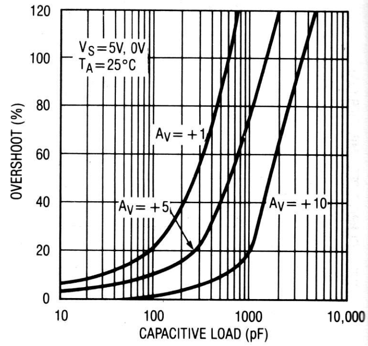
Voltage Gain vs Frequency



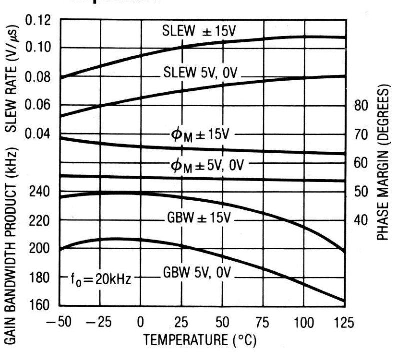
Gain, Phase vs Frequency



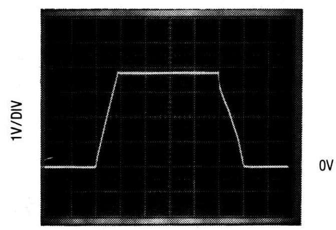
Capacitive Load Handling



Slew Rate, Gain Bandwidth Product and Phase Margin vs Temperature



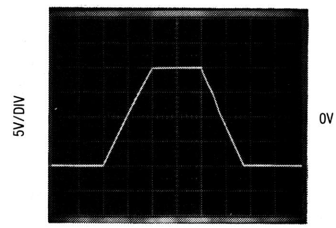
Large Signal Transient Response $V_S = 5V, 0V$



50µs/DIV

INPUT PULSE 0V TO 3.8V, $A_V = +1$, NO LOAD

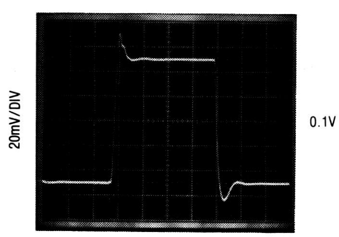
Large Signal Transient Response $V_S = ±15V$



100µs/DIV

$A_V = +1$, NO LOAD

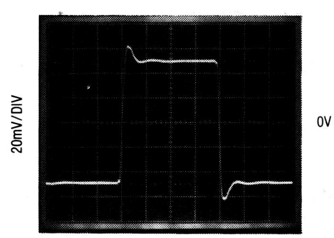
Small Signal Transient Response $V_S = 5V, 0V$



10µs/DIV

$A_V = +1$, $C_L = 15pF$, INPUT 50mV TO 150mV

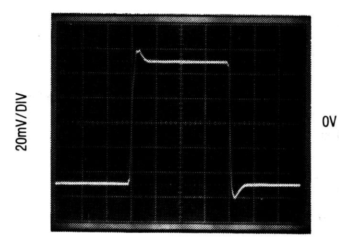
Small Signal Transient Response $V_S = ±2.5V$



10µs/DIV

$A_V = +1$, $C_L = 15pF$

Small Signal Transient Response $V_S = ±15V$

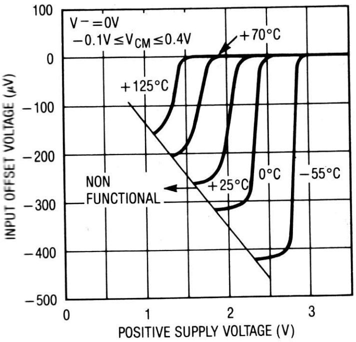


10µs/DIV

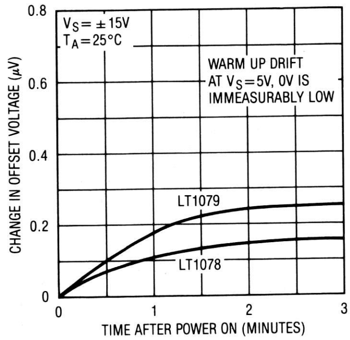
$A_V = +1$, $C_L = 15pF$

TYPICAL PERFORMANCE CHARACTERISTICS

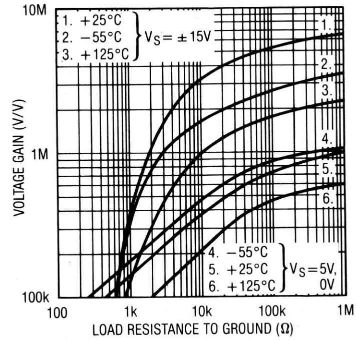
Minimum Supply Voltage



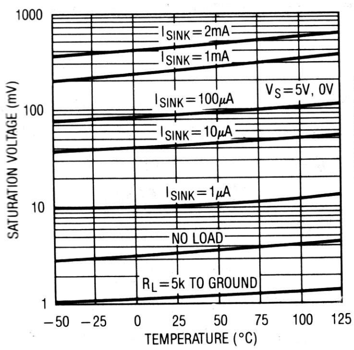
Warm-Up Drift



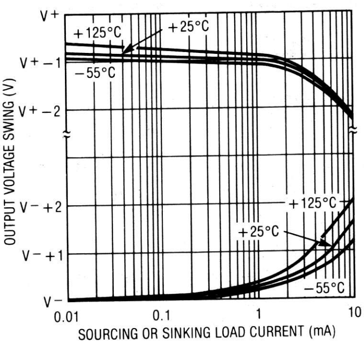
Voltage Gain vs Load Resistance



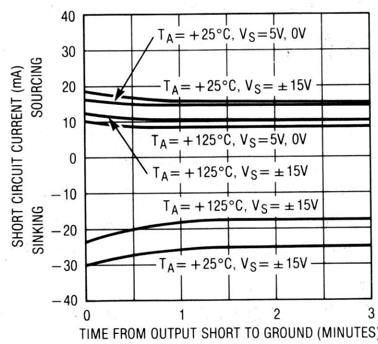
Output Saturation vs Temperature vs Sink Current



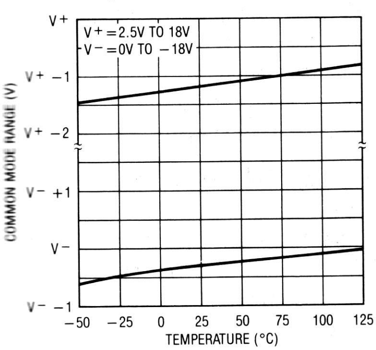
Output Voltage Swing vs Load Current



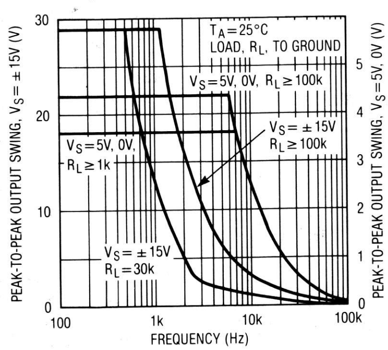
Short Circuit Current vs Time



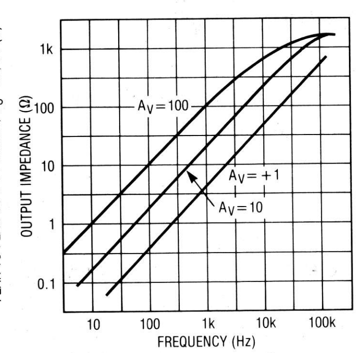
Common Mode Range vs Temperature



Undistorted Output Swing vs Frequency

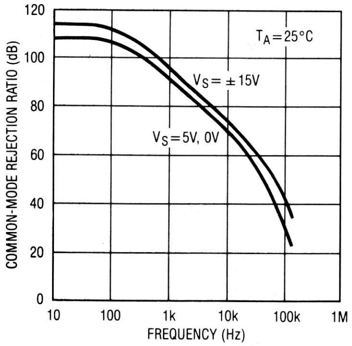


Closed Loop Output Impedance

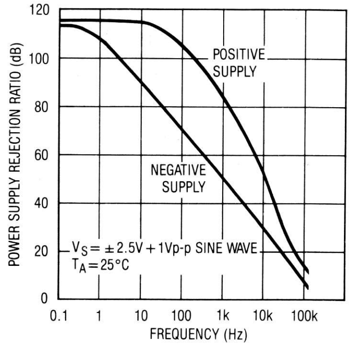


TYPICAL PERFORMANCE CHARACTERISTICS

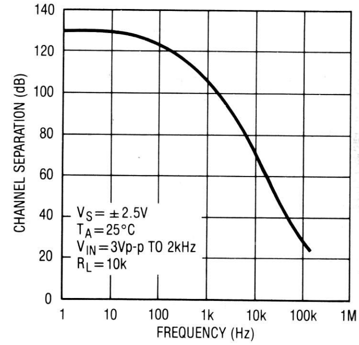
Common-Mode Rejection Ratio vs Frequency



Power Supply Rejection Ratio vs Frequency



Channel Separation vs Frequency



APPLICATIONS INFORMATION

The LT1078/LT1079 devices are fully specified with $V^+ = 5V$, $V^- = 0$, $V_{CM} = 0.1V$. 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 ±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 (= 2μV/V), at 9V the offset voltage change will be 8μV. Similarly, $V_S = \pm 2.5V$, $V_{CM} = 0$ is equivalent to a common-mode voltage change of 2.4V or a V_{OS} change of 7μV if CMRR = 110dB (3μV/V).

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

Single Supply Operation

The LT1078/LT1079 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.

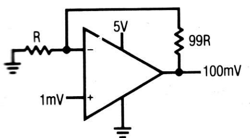
As an example, consider the instrumentation amplifier shown on the front page. When the common-mode signal is low and the output is high, amplifier A has to sink current. When the common-mode signal is high and the output low, amplifier B has to sink current. The competing devices require a 12k pull down resistor at the output of amplifier A and a 15k at the output of B to handle the specified signals. (The LT1078 does not need pull down resistors.) When the common-mode input is high and the output is high these pull down resistors draw 300μA (150μA each), which is excessive for micropower applications.

The instrumentation amplifier is by no means the only application requiring current sinking capability. In 7 of the 9 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.

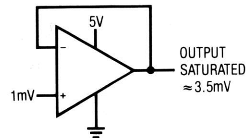
APPLICATIONS INFORMATION

Since the output of the LT1078/LT1079 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 1 mV input signal will cause the amplifier to set up in its linear region in the gain 100 configuration shown below, but is not enough to make the amplifier function properly in the voltage follower mode.

Gain 100 Amplifier



Voltage Follower



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 (a and b), OP-90/290/490 (b only):

a) 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 LT1078/LT1079, resistors in series with the input protect the devices even when the input is 5V below ground.

b) 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 lock-up in servo systems. Due to a unique phase reversal protection circuitry, the LT1078/LT1079's output does not reverse, as illustrated below, even when the inputs are at −1.0V.

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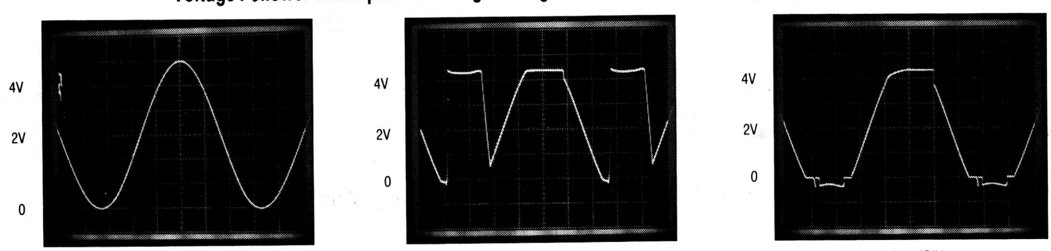
Voltage Follower with Input Exceeding the Negative Common-Mode Range (V_S = 5V, 0V)



1ms/DIV — 6Vp-p INPUT, −1.0 TO +5.0V

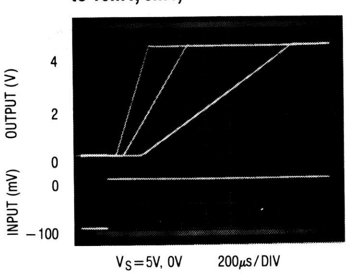
1ms/DIV — OP-90 EXHIBITS OUTPUT PHASE REVERSAL

1ms/DIV — LT1078/LT1079 NO PHASE REVERSAL

Comparator Applications

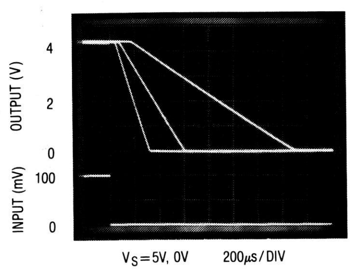
The single supply operation of the LT1078/1079 and its ability to swing close to ground while sinking current lends itself to use as a precision comparator with TTL compatible output.

Comparator Rise Response Time to 10mV, 5mV, 2mV Overdrives



V_S=5V, 0V 200μs/DIV

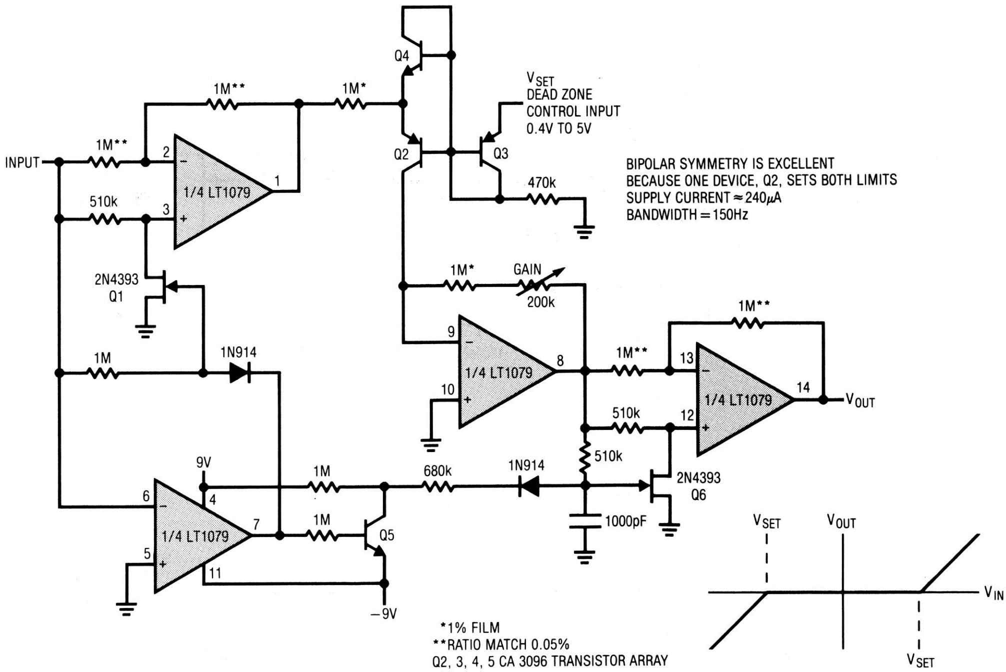
Comparator Fall Response Time to 10mV, 5mV, 2mV Overdrives



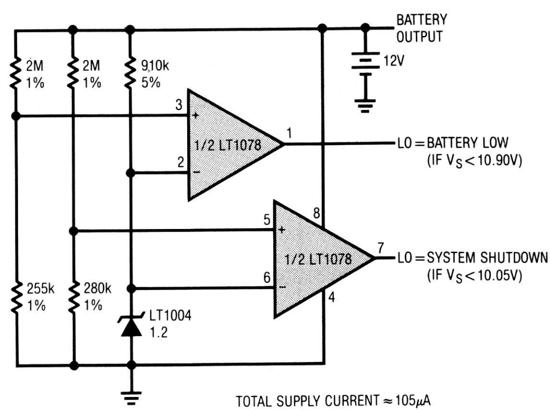
V_S=5V, 0V 200μs/DIV

TYPICAL APPLICATIONS

Micropower Dead Zone Generator



Lead Acid Low Battery Detector with System Shutdown



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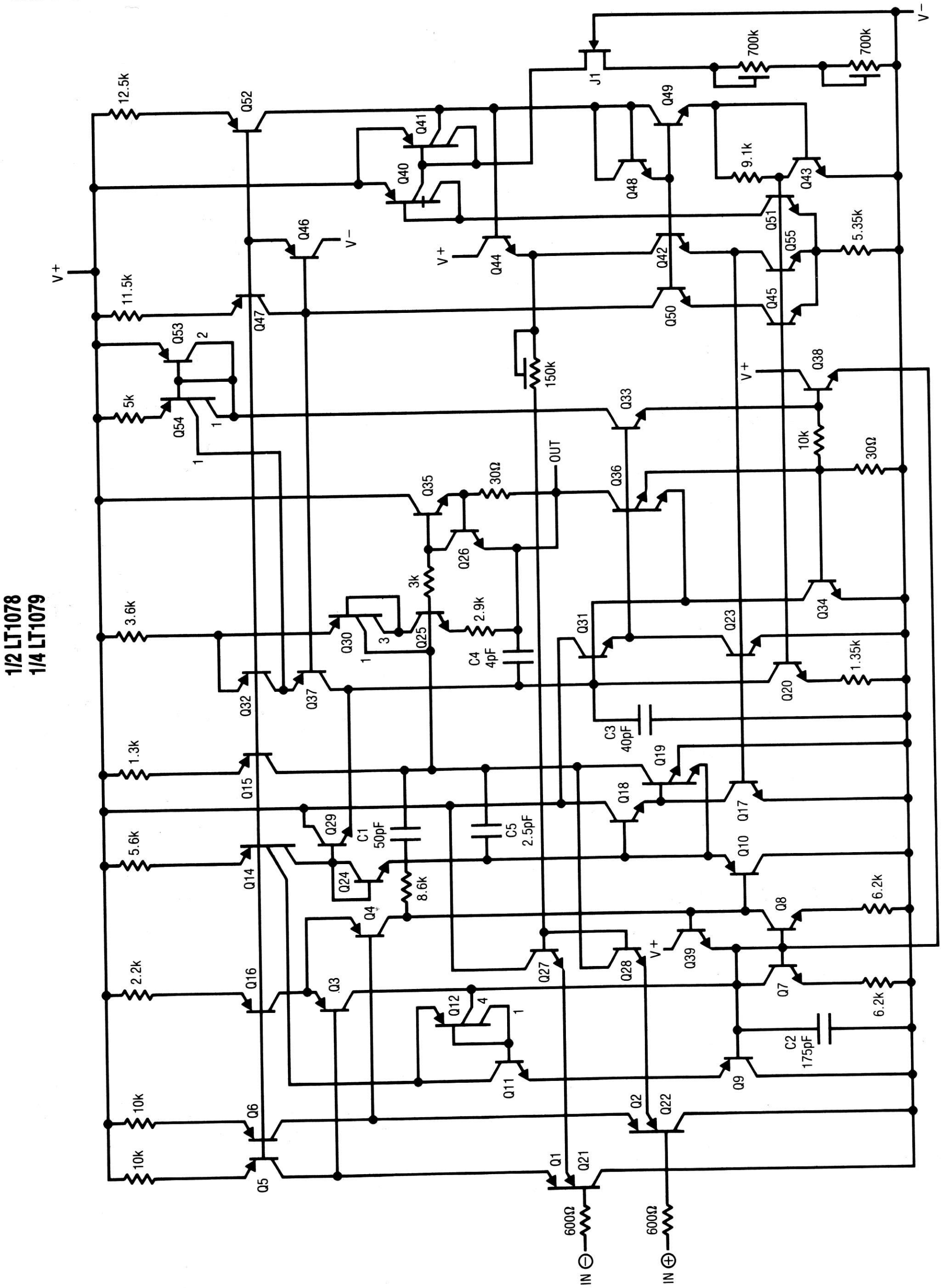
Ausgang = Zeichenfehler?

SIMPLIFIED SCHEMATIC



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