LINEAR TECHNOLOGY

LT1413

Single Supply, Dual Precision Op Amp

FEATURES

Single Supply Operation:

- Input Goes Below Ground
- Output Swings to Ground Sinking Current
- No Pull-Down Resistors Needed
- Phase Reversal Protection

At 5V, 0V Low Cost Grade Specifications:

- 280µV Max Offset Voltage
- 380µV Max in S8 Package
- 0.8nA Max Offset Current
- 480µA Max Supply Current per Amplifier
- 0.5µV/°C Drift
- 1.4 Million Voltage Gain
- 950kHz Gain-Bandwidth Product
- 0.55µV$_{P-P}$, 0.1Hz to 10Hz Noise

APPLICATIONS

- Single Supply Systems
- Two and Three Op Amp Instrumentation Amplifiers
- Active Filters
- Battery-Powered Systems
- Strain Gauge and Bridge Amplifiers

DESCRIPTION

The LT1413 is a low cost, upgraded version of Linear Technology's industry standard LT1013 dual, single supply op amp. The LT1413 is optimized for single 5V applications, although ±15V specifications are also provided for completeness.

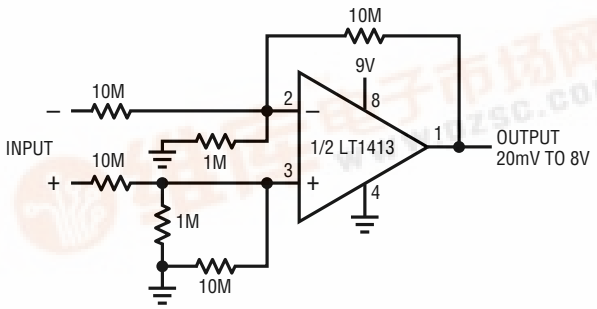
In the design of the LT1413, particular emphasis has been placed on low cost plastic and SO-8 package performance: 60µV offset voltage, 0.1nA offset current, in excess of 10mA output current at 330µA supply current and 140dB channel separation are some of the specifications achieved.

Other dual, single supply amplifiers are available to complement the LT1413 family: the micropower LT1078's supply current is 10 times lower with a 4.5 fold speed performance degradation compared to the LT1413. Conversely, the LT1211, LT1213 and LT1215 duals have 4 to 14 times higher supply current, but also 13 to 50 times higher speed.

Protected by U.S. Patent 4,775,884.

TYPICAL APPLICATION

+90V, –3V Common-Mode Range Difference Amplifier (A_V = 1)

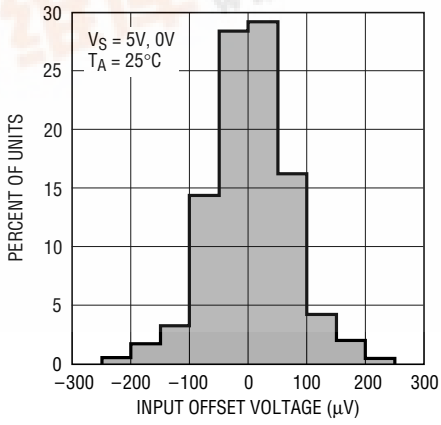


OUTPUT OFFSET = 1.5mV
(INPUT REFERRED = 125µV)
INPUT RESISTANCE = 11M
BANDWIDTH = 80kHz

(THE 0.1nA TYPICAL OFFSET CURRENT PERMITS THE USE OF 1MΩ RESISTORS)

LT1413 • TA03

Distribution of Input Offset Voltage (In Plastic DIP, N8 Package)



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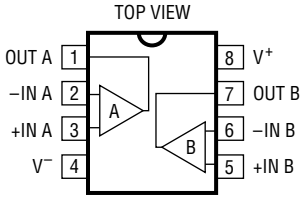
ABSOLUTE MAXIMUM RATINGS

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 ..... –40°C to 85°C
Storage Temperature Range ..... –65°C to 150°C
Lead Temperature (Soldering, 10 sec) ..... 300°C

Note: When the input voltage exceeds the maximum ratings, the input current should be limited to 10mA.

PACKAGE/ORDER INFORMATION

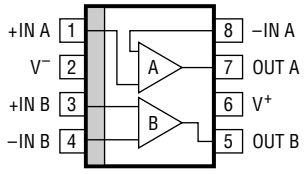


N8 PACKAGE
8-LEAD PLASTIC DIP

T_{JMAX} = 100°C, θ_{JA} = 130°C/W

ORDER PART NUMBER

LT1413ACN8
LT1413CN8



S8 PACKAGE
8-LEAD PLASTIC SOIC

NOTE: THIS PIN CONFIGURATION DIFFERS FROM THE 8-LEAD DIP PIN LOCATIONS. INSTEAD, IT FOLLOWS THE INDUSTRY STANDARD LT1013DS8 SO PACKAGE CONFIGURATION.

T_{JMAX} = 105°C, θ_{JA} = 200°C/W

ORDER PART NUMBER

LT1413S8

S8 PART MARKING

1413

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

SYMBOL	PARAMETER	CONDITIONS (Note 1)	LT1413ACN8 MIN	LT1413ACN8 TYP	LT1413ACN8 MAX	LT1413CN8/S8 MIN	LT1413CN8/S8 TYP	LT1413CN8/S8 MAX	UNITS
V_{OS}	Input Offset Voltage	LT1413N8 LT1413S8		50	150		60 80	280 380	µV µV
$\frac{\Delta V_{OS}}{\Delta Time}$	Long-Term Input Offset Voltage Stability			0.4			0.5		µV/Mo
I_{OS}	Input Offset Current			0.1	0.7		0.1	0.8	nA
I_B	Input Bias Current			9	15		9	18	nA
e_n	Input Noise Voltage	0.1Hz to 10Hz (Note 2)		0.55	1.1		0.55		μV_{P-P}
	Input Noise Voltage Density	f_O = 10Hz (Note 2) f_O = 1000Hz (Note 2)		24 23	38 30		24 23		nV/√Hz nV/√Hz
i_n	Input Noise Current	0.1Hz to 10Hz		2.8			2.8		pA_{P-P}
	Input Noise Current Density	f_O = 10Hz f_O = 1000Hz		0.07 0.02			0.07 0.02		pA/√Hz pA/√Hz
	Input Resistance Differential Mode Common Mode	(Note 3)	 300	 500 3		 250	 500 3		 MΩ GΩ
	Input Voltage Range		3.65 0	3.8 –0.3		3.65 0	3.8 –0.3		V V
CMRR	Common-Mode Rejection Ratio	V_{CM} = 0V to 3.65V	90	101		88	101		dB
PSRR	Power Supply Rejection Ratio	V_S = 3.2V to 12V	102	118		100	118		dB
A_{VOL}	Large-Signal Voltage Gain	V_O = 0.05V to 4V, No Load V_O = 0.05V to 3.5V, R_L = 2k	400 300	1400 1000		350 250	1400 1000		V/mV V/mV

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

SYMBOL	PARAMETER	CONDITIONS	LT1413ACN8 MIN	LT1413ACN8 TYP	LT1413ACN8 MAX	LT1413CN8/S8 MIN	LT1413CN8/S8 TYP	LT1413CN8/S8 MAX	UNITS
	Maximum Output Voltage Swing	Output Low, No Load		15	25		15	25	mV
		Output Low, 600Ω to GND		5	10		5	10	mV
		Output Low, I_{SINK} = 1mA		220	350		220	350	mV
		Output High, No Load	4.1	4.4		4.1	4.4		V
		Output High, 600Ω to GND	3.4	4.0		3.4	4.0		V
SR	Slew Rate	A_V = 1	0.2	0.3		0.2	0.3		V/µs
GBW	Gain-Bandwidth Product	f_O ≤ 100kHz (Note 4)	600	950		600	950		kHz
I_S	Supply Current per Amplifier			330	450		330	480	µA
	Channel Separation	ΔV_{IN} = 3V, R_L = 2k (Note 5)	125	140		123	140		dB
	Minimum Supply Voltage	(Note 6)		2.85	3.0		2.85	3.0	V

V_S = 5V, 0V, V_{CM} = 0.1V, V_O = 1.4V, 0°C ≤ T_A ≤ 70°C, unless otherwise noted.

SYMBOL	PARAMETER	CONDITIONS (Note 1)		LT1413ACN8 MIN	LT1413ACN8 TYP	LT1413ACN8 MAX	LT1413CN8/S8 MIN	LT1413CN8/S8 TYP	LT1413CN8/S8 MAX	UNITS
V_{OS}	Input Offset Voltage	LT1413N8	●		65	240		80	390	µV
		LT1413S8	●					100	490	µV
$\Delta V_{OS}/\Delta T$	Input Offset Voltage Drift	(Note 5)	●		0.3	2.0		0.4	2.5	µV/°C
I_{OS}	Input Offset Current		●		0.1	1.0		0.1	1.2	nA
I_B	Input Bias Current		●		10	20		10	23	nA
CMRR	Common-Mode Rejection Ratio	V_{CM} = 0V to 3.6V	●	88	100		85	100		dB
PSRR	Power Supply Rejection Ratio	V_S = 3.45V to 12V	●	100	117		97	117		dB
A_{VOL}	Large-Signal Voltage Gain	V_O = 0.07V to 3.9V, No Load	●	300	1100		300	1100		V/mV
		V_O = 0.07V to 3.2V, R_L = 2k	●	200	800		200	800		V/mV
	Maximum Output Voltage Swing	Output Low, No Load	●		18	32		18	32	mV
		Output Low, I_{SINK} = 1mA	●		270	430		270	430	mV
		Output High, No Load	●	4.0	4.3		4.0	4.3		V
		Output High, 600Ω to GND	●	3.3	3.9		3.2	3.9		V
I_S	Supply Current per Amplifier		●		350	500		350	530	µA

V_S = 5V, 0V, V_{CM} = 0.1V, V_O = 1.4V, –40°C ≤ T_A ≤ 85°C (Note 7)

SYMBOL	PARAMETER	CONDITIONS (Note 1)		LT1413ACN8 MIN	LT1413ACN8 TYP	LT1413ACN8 MAX	LT1413CN8/S8 MIN	LT1413CN8/S8 TYP	LT1413CN8/S8 MAX	UNITS
V_{OS}	Input Offset Voltage	LT1413N8	●		70	300		85	470	µV
		LT1413S8	●					110	570	µV
$\Delta V_{OS}/\Delta T$	Input Offset Voltage Drift		●		0.3	2.2		0.4	2.8	µV/°C
I_{OS}	Input Offset Current		●		0.2	1.4		0.2	1.7	nA
I_B	Input Bias Current		●		11	25		11	30	nA
CMRR	Common-Mode Rejection Ratio	V_{CM} = 0V to 3.4V	●	85	99		82	99		dB
PSRR	Power Supply Rejection Ratio	V_S = 3.9V to 12V	●	98	116		94	116		dB
A_{VOL}	Large-Signal Voltage Gain	V_O = 0.08V to 3.8V, No Load	●	220	1000		220	1000		V/mV
		V_O = 0.08V to 3.0V, R_L = 2k	●	150	700		150	700		V/mV
	Maximum Output Voltage Swing	Output Low, No Load	●		20	38		20	38	mV
		Output Low, I_{SINK} = 1mA	●		300	480		300	480	mV
		Output High, No Load	●	3.9	4.2		3.9	4.2		V
		Output High, 600Ω to GND	●	3.1	3.8		3.0	3.8		V
I_S	Supply Current per Amplifier		●		360	550		360	580	µA

ELECTRICAL CHARACTERISTICS $V_S = \pm15V$, $T_A = 25°C$, unless otherwise noted.

SYMBOL	PARAMETER	CONDITIONS (Note 1)	LT1413ACN8 MIN	LT1413ACN8 TYP	LT1413ACN8 MAX	LT1413CN8/S8 MIN	LT1413CN8/S8 TYP	LT1413CN8/S8 MAX	UNITS
V_{OS}	Input Offset Voltage	LT1413N8 LT1413S8		75	280		90 110	480 580	µV µV
I_{OS}	Input Offset Current			0.1	0.7		0.1	0.8	nA
I_B	Input Bias Current			8	15		8	18	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	117		97	114		dB
PSRR	Power Supply Rejection Ratio	$V_S = \pm2V$ to $\pm18V$	103	120		100	117		dB
A_{VOL}	Large-Signal Voltage Gain	$V_O = \pm10V$, R_L = 2k	1500	5000		1200	4000		V/mV
V_{OUT}	Maximum Output Voltage Swing	R_L = 2k	±13	±14		±12.5	±14		V
SR	Slew Rate		0.2	0.4		0.2	0.4		V/µs
I_S	Supply Current per Amplifier			350	500		350	550	µA

$V_S = \pm15V$, $0°C \le T_A \le 70°C$, unless otherwise noted.

SYMBOL	PARAMETER	CONDITIONS (Note 1)		LT1413ACN8 MIN	LT1413ACN8 TYP	LT1413ACN8 MAX	LT1413CN8/S8 MIN	LT1413CN8/S8 TYP	LT1413CN8/S8 MAX	UNITS
V_{OS}	Input Offset Voltage	LT1413N8 LT1413S8	● ●		95	390		110 130	620 720	µV µV
$\Delta V_{OS}/\Delta T$	Input Offset Voltage Drift	(Note 5)	●		0.4	2.5		0.5	3.0	µV/°C
I_{OS}	Input Offset Current		●		0.1	1.0		0.1	1.2	nA
I_B	Input Bias Current		●		9	20		9	23	nA
A_{VOL}	Large-Signal Voltage Gain	$V_O = \pm10V$, R_L = 2k	●	1000	4000		700	3000		V/mV
CMRR	Common-Mode Rejection Ratio	V_{CM} = 13V, −15V	●	98	116		94	113		dB
PSRR	Power Supply Rejection Ratio	$V_S = \pm2V$ to $\pm18V$	●	101	119		97	116		dB
	Maximum Output Voltage Swing	R_L = 2k	●	±12.5	±13.9		±12.0	±13.9		V
I_S	Supply Current per Amplifier		●		360	550		360	600	µA

$V_S = \pm15V$, $-40°C \le T_A \le 85°C$ (Note 7)

SYMBOL	PARAMETER	CONDITIONS (Note 1)		LT1413ACN8 MIN	LT1413ACN8 TYP	LT1413ACN8 MAX	LT1413CN8/S8 MIN	LT1413CN8/S8 TYP	LT1413CN8/S8 MAX	UNITS
V_{OS}	Input Offset Voltage	LT1413N8 LT1413S8	● ●		100	460		120 140	700 800	µV µV
$\Delta V_{OS}/\Delta T$	Input Offset Voltage Drift		●		0.4	2.8		0.5	3.3	µV/°C
I_{OS}	Input Offset Current		●		0.2	1.4		0.2	1.7	nA
I_B	Input Bias Current		●		10	25		10	30	nA
A_{VOL}	Large-Signal Voltage Gain	$V_O = \pm10V$, R_L = 2k	●	800	3000		500	2400		V/mV
CMRR	Common-Mode Rejection Ratio	V_{CM} = 13V, −15V	●	97	115		92	112		dB
PSRR	Power Supply Rejection Ratio	V_S ±2V to ±18V	●	100	118		95	115		dB
	Maximum Output Voltage Swing	R_L = 2k	●	±12.2	±13.8		±11.8	±13.8		V
I_S	Supply Current per Amplifier		●		370	580		370	630	µA

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 LT1413s typically 120 op amps will be better than the indicated specification.

Note 2: This parameter is tested on a sample basis only. All noise parameters are tested with $V_S = \pm2.5V$, V_O = 0V.

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

Note 4: Gain-Bandwidth Product is not tested. It is inferred from the slew rate measurement.

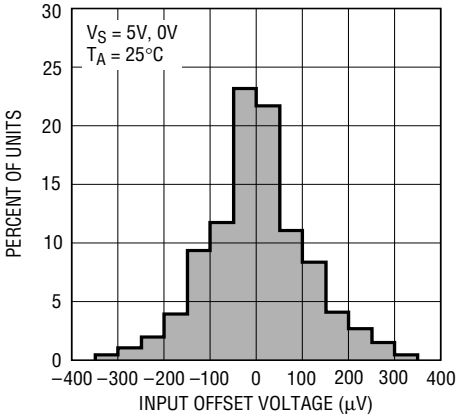
Note 5: This parameter is not 100% tested.

Note 6: At the minimum supply voltage, the offset voltage changes less than 200µV compared to its value at 5V, 0V.

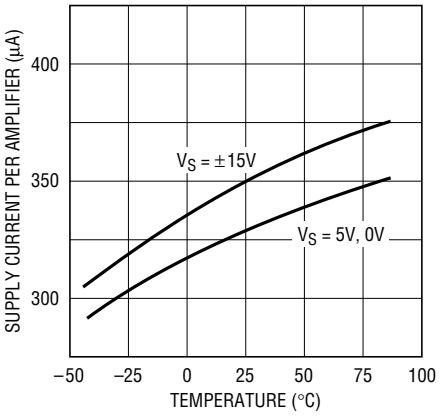
Note 7: The LT1413 is not tested and is not quality-assurance sampled at −40°C and at 85°C. These specifications are guaranteed by design, correlation and/or inference from 0°C, 25°C and/or 70°C tests.

TYPICAL PERFORMANCE CHARACTERISTICS

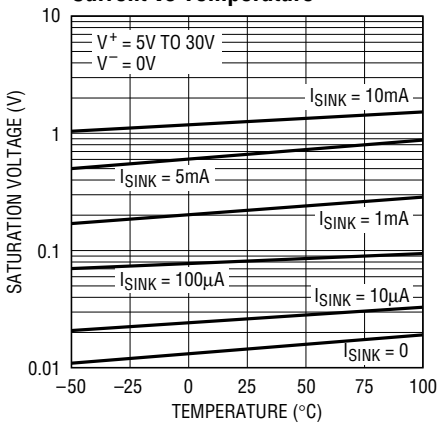
Distribution of Input Offset Voltage (In S8 Package)



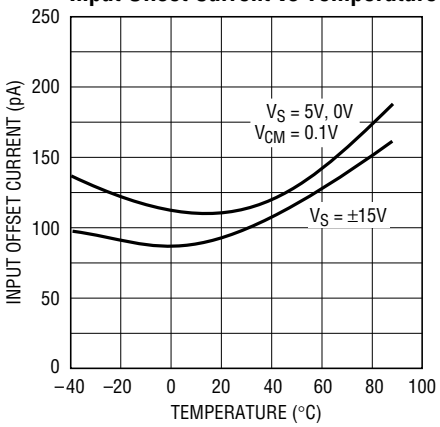
Supply Current vs Temperature



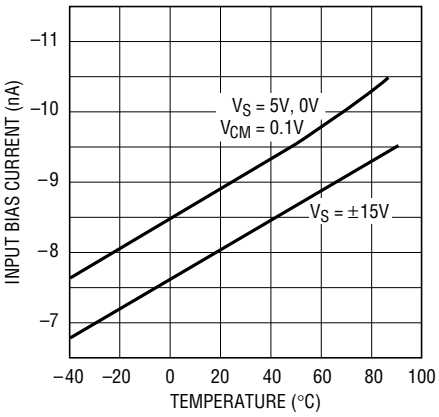
Output Saturation vs Sink Current vs Temperature



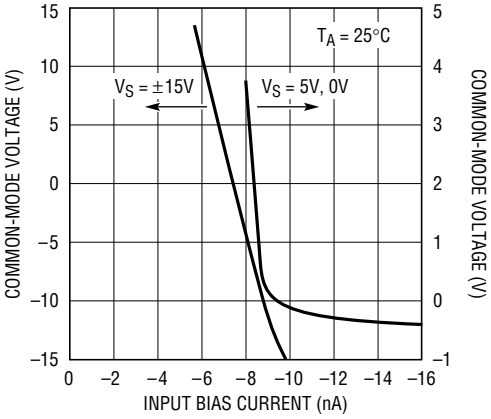
Input Offset Current vs Temperature



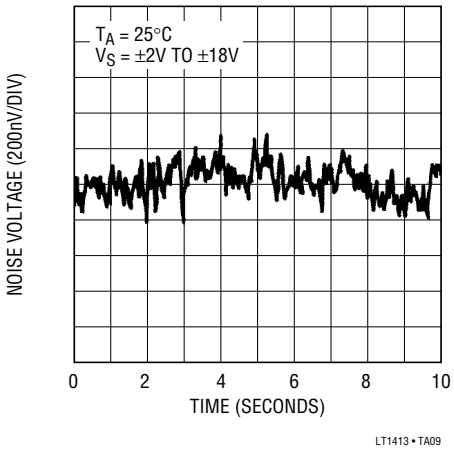
Input Bias Current vs Temperature



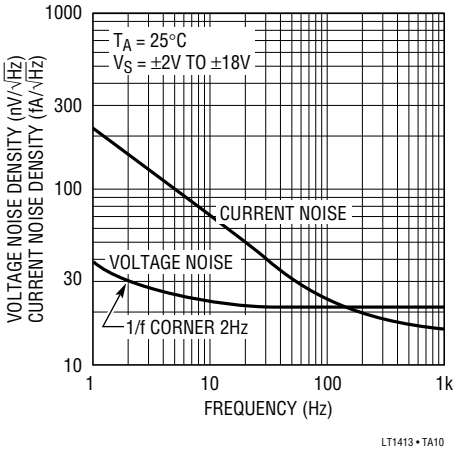
Input Bias Current vs Common-Mode Voltage



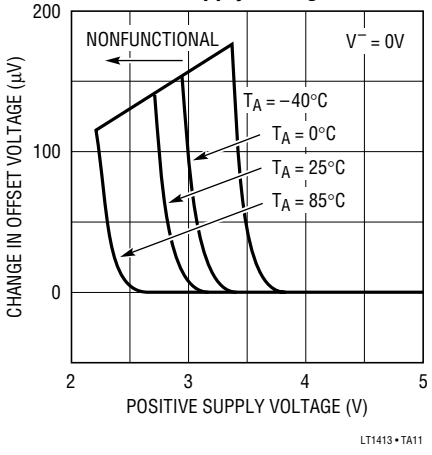
0.1Hz to 10Hz Noise



Noise Spectrum

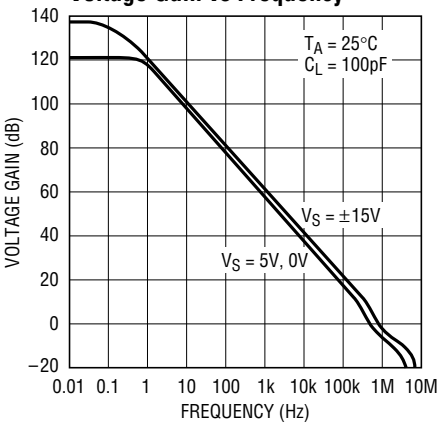


Minimum Supply Voltage



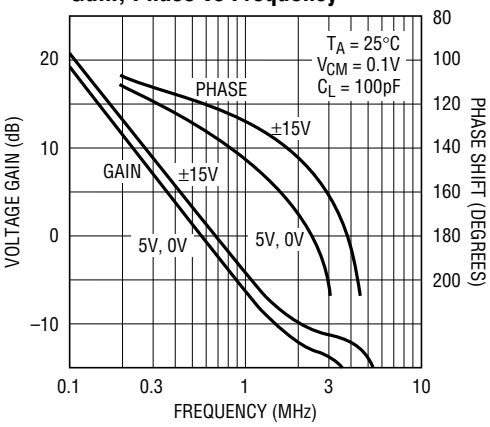
TYPICAL PERFORMANCE CHARACTERISTICS

Voltage Gain vs Frequency



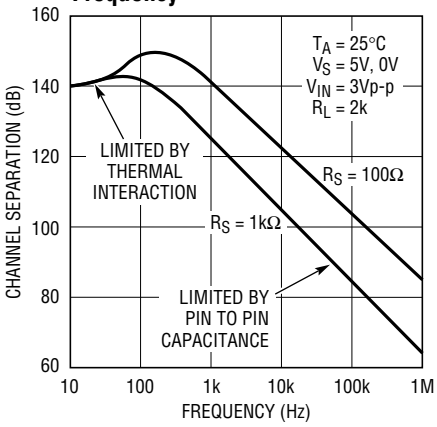
LT1413 • TA12

Gain, Phase vs Frequency



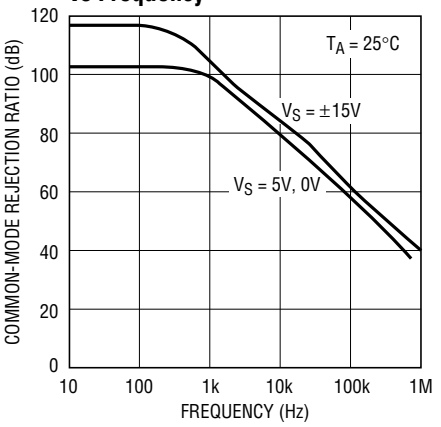
LT1413 • TA13

Channel Separation vs Frequency



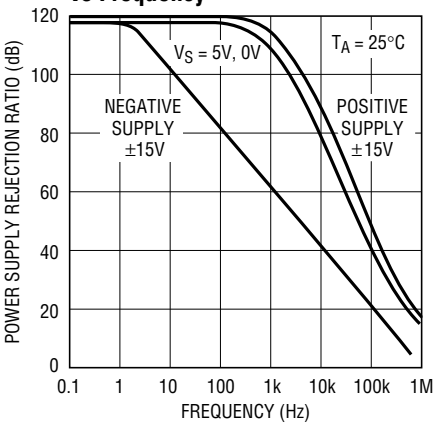
LT1413 • TA14

Common-Mode Rejection Ratio vs Frequency



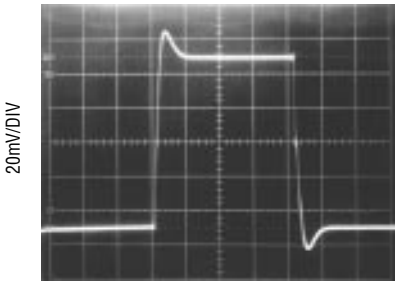
LT1413 • TA15

Power Supply Rejection Ratio vs Frequency



LT1413 • TA16

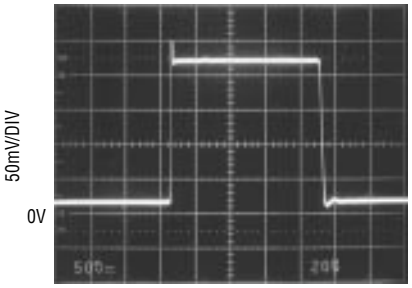
Small Signal Transient Response, V_S = ±15V



A_V = +1 2µs/DIV

LT1413 • TA17

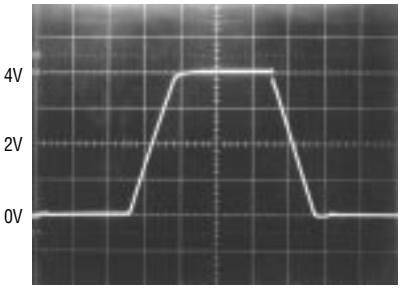
Small Signal Transient Response, V_S = 5V, 0V



A_V = +1 20µs/DIV
INPUT = 20mV TO 220mV PULSE

LT1413 • TA18

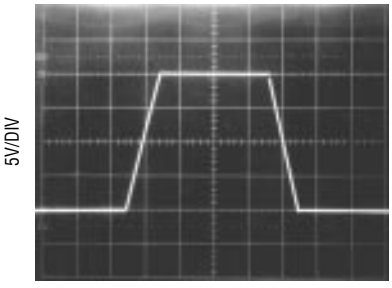
Large Signal Transient Response, V_S = 5V, 0V



A_V = +1 10µs/DIV
NO LOAD
INPUT = 0V TO 4V PULSE

LT1413 • TA19

Large Signal Transient Response, V_S = ±15V



A_V = +1 50µs/DIV

LT1413 • TA20

APPLICATIONS INFORMATION

Single Supply Operation

The LT1413 is fully specified for single supply operation, i.e., when the negative supply is 0V. Input common-mode range includes ground; the output swings within a few millivolts of ground.

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-21 and OP-221.

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 LT1413, the 400Ω resistors, in series with the input (see Schematic Diagram), 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 (transistors Q3 and Q4) and phase reversal occurs at the output. This can cause lock-up in servo systems. Due to a unique phase reversal protection circuitry (Q21, Q22, Q27, Q28), the LT1413 outputs do not reverse, as illustrated below, even when the inputs are at –1.5V. Keep the output of the other amplifier out of negative saturation for the phase reversal protection to function properly.

Since the output of the LT1413 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 below, but is not enough to make the amplifier function properly in the voltage-follower mode.

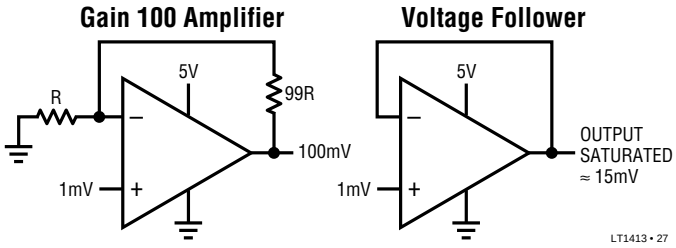
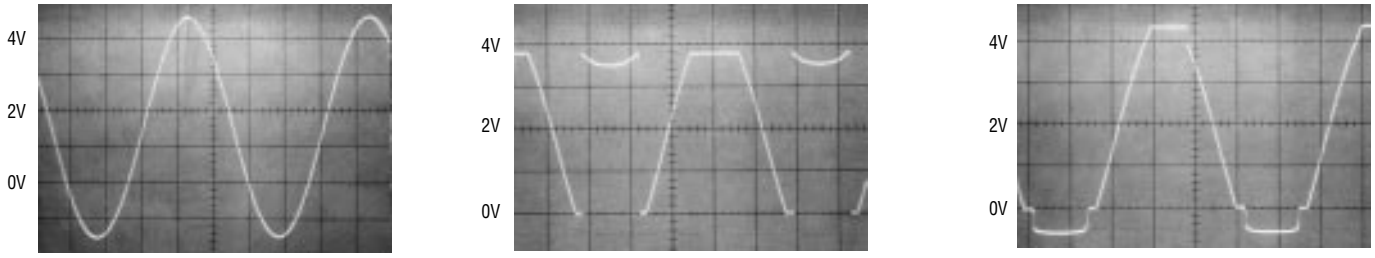


Figure 1.

Comparator Applications

The single supply operation of the LT1413 lends itself to its use as a precision comparator with TTL compatible output; the response time is shown below.

Voltage Follower with Input Exceeding the Negative Common-Mode Range

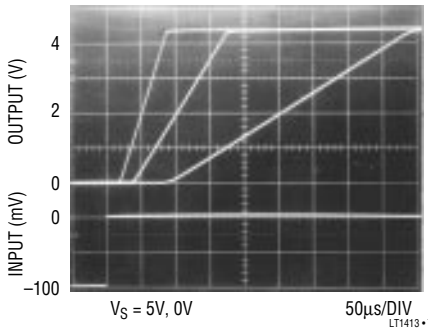


$6V_{P-P}$ INPUT, –1.5V TO 4.5V
LT1413 • TA21

LM324, LM358, OP-221
EXHIBIT OUTPUT PHASE REVERSAL
LT1413 • TA22

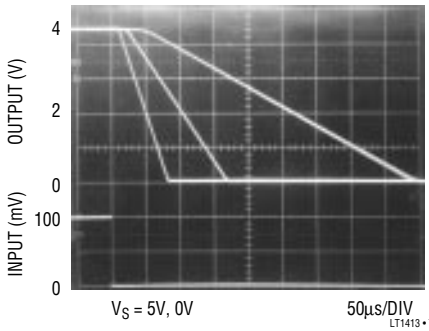
LT1413
NO PHASE REVERSAL
LT1413 • TA23

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



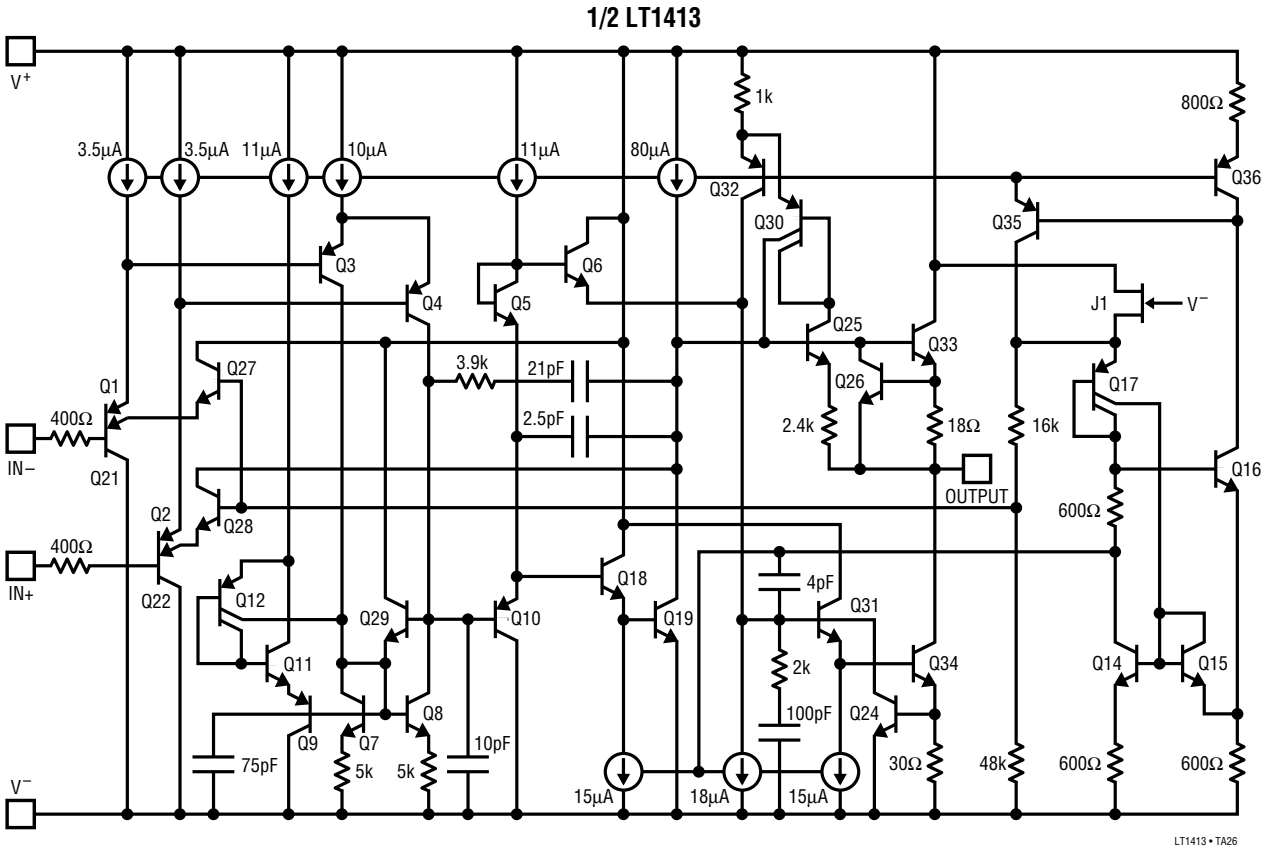
LT1413 • TA24

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



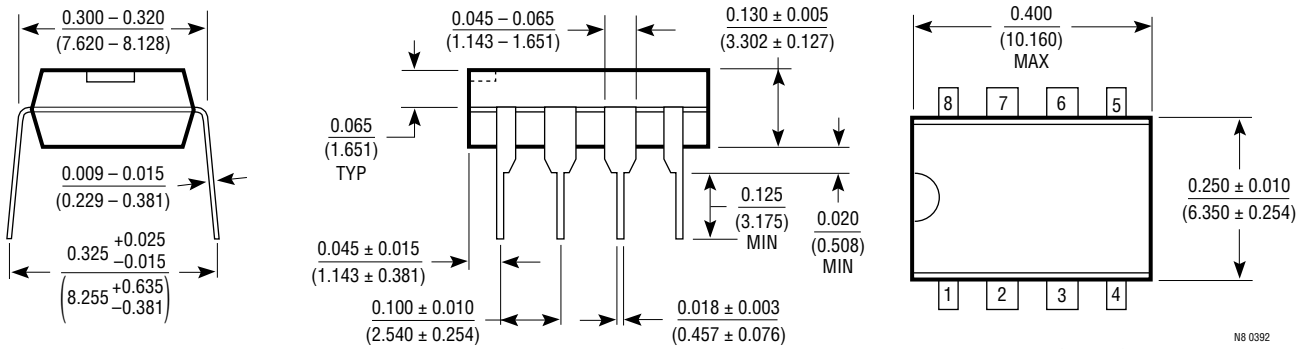
LT1413 • TA25

SIMPLIFIED SCHEMATIC



PACKAGE DESCRIPTION

N8 Package, 8-Lead Plastic DIP



S8 Package, 8-Lead Plastic SOIC