Single/Dual 145μA, 9.5nV/√Hz, A_V ≥5, Rail-to-Rail Output Precision Op Amps

FEATURES

- **35μV Maximum Offset Voltage (LT6013A)**
- **Low 1/f Noise: 200nV$_{P-P}$ (0.1Hz to 10Hz)**
  40nV$_{RMS}$ (0.1Hz to 10Hz)
- **Low White Noise: 9.5nV/√Hz (1kHz)**
- **Rail-to-Rail Output Swing**
- **145μA Supply Current per Amplifier**
- **250pA Maximum Input Bias Current (LT6013A)**
- **A_V ≥5 Stable; Up to 500pF C_{LOAD}**
- **0.2V/μs Slew Rate**
- **1.4MHz Gain Bandwidth Product**
- 120dB Minimum Voltage Gain, V_S = ±15V
- 0.8μV/°C Maximum V_{OS} Drift
- 2.7V to ±18V Supply Voltage Operation
- Operating Temperature Range: –40°C to 85°C
- Available in SO-8 and Space Saving 3mm × 3mm DFN Packages

APPLICATIONS

- Thermocouple Amplifiers
- Precision Photodiode Amplifiers
- Instrumentation Amplifiers
- Battery-Powered Precision Systems
- Low-Voltage Precision Systems
- Micro-Power Sensor Interface

DESCRIPTION

The LT®6013 and LT6014 op amps combine low noise and high precision input performance with low power consumption and rail-to-rail output swing. The amplifiers are stable in a gain of 5 or more and feature greatly improved CMRR and PSRR versus frequency compared to other precision op amps.

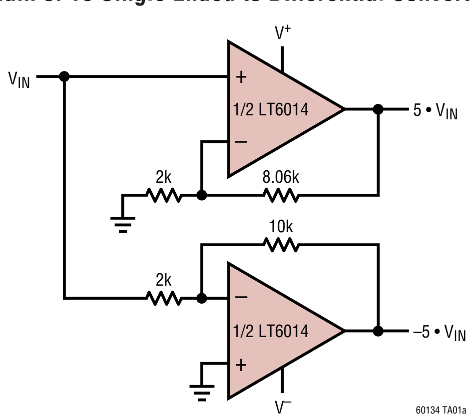
Input offset voltage is factory-trimmed to less than 35μV. The low drift and excellent long-term stability ensure a high accuracy over temperature and time. The 250pA maximum input bias current and 120dB minimum voltage gain further maintain this precision over operating conditions.

The LT6013 and LT6014 operate from any supply voltage from 2.7V to 36V and draw only 145μA of supply current per amplifier on a 5V supply. The output swings to within 40mV of either supply rail, making the amplifiers very useful for low voltage single supply operation.

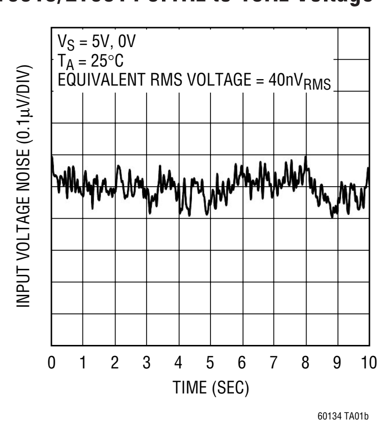
The amplifiers are fully specified at 5V and ±15V supplies and from –40°C to 85°C. The single LT6013 and dual LT6014 are both available in SO-8 and space saving 3mm × 3mm DFN packages. For unity gain stable versions, refer to the LT6010 and LT6011 data sheets.

TYPICAL APPLICATION

Gain of 10 Single Ended to Differential Converter



LT6013/LT6014 0.1Hz to 10Hz Voltage Noise

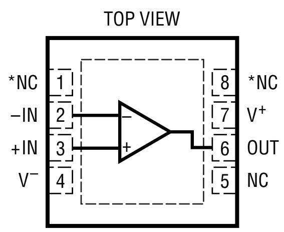
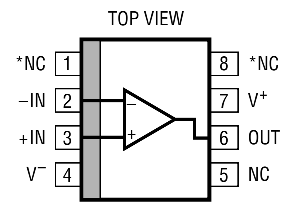
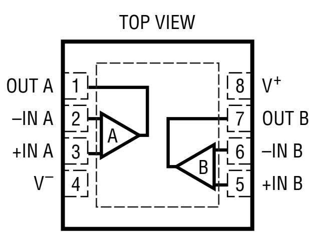
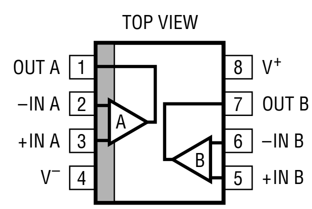


ABSOLUTE MAXIMUM RATINGS (Note 1)

Total Supply Voltage (V^+ to V^-) 40V
Differential Input Voltage (Note 2) 10V
Input Voltage .... V^+ to V^-
Input Current (Note 2) .... ±10mA
Output Short-Circuit Duration (Note 3)........... Indefinite
Operating Temperature Range (Note 4) .. –40°C to 85°C
Specified Temperature Range (Note 5) ... –40°C to 85°C

Maximum Junction Temperature
DD Package .... 125°C
S8 Package .... 150°C
Storage Temperature Range
DD Package .... –65°C to 125°C
S8 Package .... –65°C to 150°C
Lead Temperature (Soldering, 10 sec).................. 300°C

PACKAGE/ORDER INFORMATION

Package	ORDER PART NUMBER	Package	ORDER PART NUMBER
 DD PACKAGE 8-LEAD (3mm × 3mm) PLASTIC DFN T_{JMAX} = 125°C, θ_{JA} = 160°C/W UNDERSIDE METAL CONNECTED TO V^- (PCB CONNECTION OPTIONAL) *No Connection	LT6013CDD LT6013IDD LT6013ACDD LT6013AIDD **DD PART MARKING*** LBHC	 S8 PACKAGE 8-LEAD PLASTIC SO T_{JMAX} = 150°C, θ_{JA} = 190°C/W *No Connection	LT6013CS8 LT6013IS8 LT6013ACS8 LT6013AIS8 **S8 PART MARKING** 6013 6013I 6013A 6013AI
 DD PACKAGE 8-LEAD (3mm × 3mm) PLASTIC DFN T_{JMAX} = 125°C, θ_{JA} = 160°C/W UNDERSIDE METAL CONNECTED TO V^- (PCB CONNECTION OPTIONAL)	LT6014CDD LT6014IDD LT6014ACDD LT6014AIDD **DD PART MARKING*** LBCB	 S8 PACKAGE 8-LEAD PLASTIC SO T_{JMAX} = 150°C, θ_{JA} = 190°C/W	LT6014CS8 LT6014IS8 LT6014ACS8 LT6014AIS8 **S8 PART MARKING** 6014 6014I 6014A 6014AI

*Temperature and electrical grades are identified by a label on the shipping container.
Consult LTC Marketing for parts specified with wider operating temperature ranges.

ELECTRICAL CHARACTERISTICS

The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at T_A = 25°C. V_S = 5V, 0V; V_{CM} = 2.5V; R_L to 0V; unless otherwise specified. (Note 5)

SYMBOL	PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
V_{OS}	Input Offset Voltage (Note 8)	LT6013AS8			10	35	µV
		T_A = 0°C to 70°C	●			60	µV
		T_A = –40°C to 85°C	●			75	µV
		LT6013S8, LT6014AS8			20	60	µV
		T_A = 0°C to 70°C	●			85	µV
		T_A = –40°C to 85°C	●			110	µV
		LT6013ADD			20	60	µV
		T_A = 0°C to 70°C	●			110	µV
		T_A = –40°C to 85°C	●			150	µV
		LT6014S8			20	75	µV
		T_A = 0°C to 70°C	●			100	µV
		T_A = –40°C to 85°C	●			125	µV
		LT6013DD, LT6014ADD			30	85	µV
		T_A = 0°C to 70°C	●			135	µV
		T_A = –40°C to 85°C	●			170	µV
		LT6014DD			30	125	µV
		T_A = 0°C to 70°C	●			175	µV
		T_A = –40°C to 85°C	●			210	µV
$\Delta V_{OS}/\Delta T$	Input Offset Voltage Drift (Note 6)	S8 Packages	●		0.2	0.8	µV/°C
		DD Packages	●		0.2	1.4	µV/°C
I_{OS}	Input Offset Current (Note 8)	LT6013AS8, LT6013ADD			100	250	pA
		T_A = 0°C to 70°C	●			500	pA
		T_A = –40°C to 85°C	●			600	pA
		LT6014AS8, LT6014ADD			100	500	pA
		T_A = 0°C to 70°C	●			600	pA
		T_A = –40°C to 85°C	●			700	pA
		LT6013/LT6014 (Standard grades)			150	800	pA
		T_A = 0°C to 70°C	●			1000	pA
		T_A = –40°C to 85°C	●			1200	pA
I_B	Input Bias Current (Note 8)	LT6013AS8, LT6013ADD			100	±250	pA
		T_A = 0°C to 70°C	●			±500	pA
		T_A = –40°C to 85°C	●			±600	pA
		LT6013S8, LT6013DD, LT6014AS8, LT6014ADD			100	±400	pA
		T_A = 0°C to 70°C	●			±600	pA
		T_A = –40°C to 85°C	●			±800	pA
		LT6014S8, LT6014DD			150	±800	pA
		T_A = 0°C to 70°C	●			±1000	pA
		T_A = –40°C to 85°C	●			±1200	pA
e_n	Input Noise Voltage Density	f = 1kHz, LT6013/LT6014			9.5		$nV/\sqrt{Hz}$
		f = 1kHz, LT6013A/LT6014A			9.5	13	$nV/\sqrt{Hz}$
	Input Noise Voltage (Low Frequency)	Bandwidth = 0.01Hz to 1Hz			200		nV_{P-P}
					50		nV_{RMS}
		Bandwidth = 0.1Hz to 10Hz			200		nV_{P-P}
					40		nV_{RMS}

ELECTRICAL CHARACTERISTICS

The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at T_A = 25°C. V_S = 5V, 0V; V_{CM} = 2.5V; R_L to 0V; unless otherwise specified. (Note 5)

SYMBOL	PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
i_n	Input Noise Current Density	f = 1kHz			0.15		pA/√Hz
	Input Noise Current (Low Frequency)	Bandwidth = 0.01Hz to 1Hz			7 1.3		pA_{P-P} pA_{RMS}
		Bandwidth = 0.1Hz to 10Hz			5 0.4		pA_{P-P} pA_{RMS}
R_{IN}	Input Resistance	Common Mode, V_{CM} = 1V to 3.8V Differential			120 20		GΩ MΩ
C_{IN}	Input Capacitance				4		pF
V_{CM}	Input Voltage Range (Positive) Input Voltage Range (Negative)	Guaranteed by CMRR Guaranteed by CMRR	● ●	3.8	4 0.7	 1	V V
CMRR	Common Mode Rejection Ratio	V_{CM} = 1V to 3.8V	●	107	135		dB
	Minimum Supply Voltage	Guaranteed by PSRR	●		2.4	2.7	V
PSRR	Power Supply Rejection Ratio	V_S = 2.7V to 36V, V_{CM} = 1/2V_S	●	112	135		dB
A_{VOL}	Large-Signal Voltage Gain	R_L = 10k, V_{OUT} = 1V to 4V R_L = 2k, V_{OUT} = 1V to 4V	● ●	300 250	2000 2000		V/mV V/mV
	Channel Separation	V_{OUT} = 1V to 4V, LT6014	●	110	140		dB
V_{OUT}	Maximum Output Swing (Positive, Referred to V^+)	No Load, 50mV Overdrive	 ●		35	55 65	mV mV
		I_{SOURCE} = 1mA, 50mV Overdrive	 ●		120	170 220	mV mV
	Maximum Output Swing (Negative, Referred to 0V)	No Load, 50mV Overdrive	 ●		40	55 65	mV mV
		I_{SINK} = 1mA, 50mV Overdrive	 ●		150	225 275	mV mV
I_{SC}	Output Short-Circuit Current (Note 3)	V_{OUT} = 0V, 1V Overdrive, Source	 ●	8 4	14		mA mA
		V_{OUT} = 5V, –1V Overdrive, Sink	 ●	8 4	21		mA mA
SR	Slew Rate	A_V = –10, R_F = 50k, R_G = 5k T_A = 0°C to 70°C T_A = –40°C to 85°C	 ● ●	0.15 0.12 0.1	0.2		V/µs V/µs V/µs
GBW	Gain Bandwidth Product	f = 10kHz	 ●	1 0.9	1.4		MHz MHz
t_s	Settling Time	A_V = –4, 0.01%, V_{OUT} = 1.5V to 3.5V			20		µs
t_r, t_f	Rise Time, Fall Time	A_V = 5, 10% to 90%, 0.1V Step			1		µs

ELECTRICAL CHARACTERISTICS

The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at T_A = 25°C. V_S = 5V, 0V; V_{CM} = 2.5V; R_L to 0V; unless otherwise specified. (Note 5)

SYMBOL	PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
ΔV_{OS}	Offset Voltage Match (Note 7)	LT6014AS8			50	120	µV
		T_A = 0°C to 70°C	●			170	µV
		T_A = –40°C to 85°C	●			220	µV
		LT6014ADD			50	170	µV
		T_A = 0°C to 70°C	●			270	µV
		T_A = –40°C to 85°C	●			340	µV
		LT6014S8			50	150	µV
		T_A = 0°C to 70°C	●			200	µV
		T_A = –40°C to 85°C	●			250	µV
		LT6014DD			60	250	µV
		T_A = 0°C to 70°C	●			350	µV
		T_A = –40°C to 85°C	●			420	µV
ΔI_B	Input Bias Current Match (Note 7)	LT6014AS8, LT6014ADD			200	800	pA
		T_A = 0°C to 70°C	●			1200	pA
		T_A = –40°C to 85°C	●			1400	pA
		LT6014S8, LT6014DD			300	1600	pA
		T_A = 0°C to 70°C	●			2000	pA
		T_A = –40°C to 85°C	●			2400	pA
ΔCMRR	Common Mode Rejection Ratio Match (Note 7)	LT6014	●	101	135		dB
ΔPSRR	Power Supply Rejection Ratio Match (Note 7)	LT6014	●	106	135		dB
I_S	Supply Current	per Amplifier			145	165	µA
		T_A = 0°C to 70°C	●			210	µA
		T_A = –40°C to 85°C	●			230	µA

The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at T_A = 25°C. V_S = ±15V, V_{CM} = 0V, R_L to 0V, unless otherwise specified. (Note 5)

SYMBOL	PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
V_{OS}	Input Offset Voltage (Note 8)	LT6013AS8			20	60	µV
		T_A = 0°C to 70°C	●			80	µV
		T_A = –40°C to 85°C	●			110	µV
		LT6013S8			25	85	µV
		T_A = 0°C to 70°C	●			110	µV
		T_A = –40°C to 85°C	●			135	µV
		LT6013ADD			25	85	µV
		T_A = 0°C to 70°C	●			135	µV
		T_A = –40°C to 85°C	●			170	µV
		LT6013DD, LT6014AS8			30	135	µV
		T_A = 0°C to 70°C	●			160	µV
		T_A = –40°C to 85°C	●			185	µV
		LT6014S8			35	150	µV
		T_A = 0°C to 70°C	●			175	µV
		T_A = –40°C to 85°C	●			200	µV
		LT6014ADD			35	160	µV
		T_A = 0°C to 70°C	●			210	µV
		T_A = –40°C to 85°C	●			225	µV
		LT6014DD			40	200	µV
		T_A = 0°C to 70°C	●			250	µV
		T_A = –40°C to 85°C	●			275	µV

ELECTRICAL CHARACTERISTICS

The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at T_A = 25°C. V_S = ±15V, V_{CM} = 0V, R_L to 0V, unless otherwise specified. (Note 5)

SYMBOL	PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
$\Delta V_{OS}/\Delta T$	Input Offset Voltage Drift (Note 6)	S8 Packages DD Packages	● ●		0.2 0.2	0.8 1.2	µV/°C µV/°C
I_{OS}	Input Offset Current (Note 8)	LT6013AS8, LT6013ADD T_A = 0°C to 70°C T_A = –40°C to 85°C	 ● ●		100	250 500 600	pA pA pA
		LT6014AS8, LT6014ADD T_A = 0°C to 70°C T_A = –40°C to 85°C	 ● ●		100	500 600 700	pA pA pA
		LT6013/LT6014 (Standard grades) T_A = 0°C to 70°C T_A = –40°C to 85°C	 ● ●		150	800 1000 1200	pA pA pA
I_B	Input Bias Current (Note 8)	LT6013AS8, LT6013ADD T_A = 0°C to 70°C T_A = –40°C to 85°C	 ● ●		100	±250 ±500 ±600	pA pA pA
		LT6013S8, LT6013DD, LT6014AS8, LT6014ADD T_A = 0°C to 70°C T_A = –40°C to 85°C	 ● ●		100	±400 ±600 ±800	pA pA pA
		LT6014S8, LT6014DD T_A = 0°C to 70°C T_A = –40°C to 85°C	 ● ●		150	±800 ±1000 ±1200	pA pA pA
e_n	Input Noise Voltage Density	f = 1kHz, LT6013/LT6014 f = 1kHz, LT6013A/LT6014A			9.5 9.5	 13	nV/√Hz nV/√Hz
	Input Noise Voltage (Low Frequency)	Bandwidth = 0.01Hz to 1Hz			200 50		nV_{P-P} nV_{RMS}
		Bandwidth = 0.1Hz to 10Hz			200 40		nV_{P-P} nV_{RMS}
i_n	Input Noise Current Density	f = 1kHz			0.15		pA/√Hz
	Input Noise Current (Low Frequency)	Bandwidth = 0.01Hz to 1Hz			7 1.3		pA_{P-P} pA_{RMS}
		Bandwidth = 0.1Hz to 10Hz			5 0.4		pA_{P-P} pA_{RMS}
R_{IN}	Input Resistance	Common Mode, V_{CM} = ±13.5V Differential			400 20		GΩ MΩ
C_{IN}	Input Capacitance				4		pF
V_{CM}	Input Voltage Range	Guaranteed by CMRR	●	±13.5	±14		V
CMRR	Common Mode Rejection Ratio	V_{CM} = –13.5V to 13.5V	 ●	115 112	135 135		dB dB
	Minimum Supply Voltage	Guaranteed by PSRR	●		±1.2	±1.35	V
PSRR	Power Supply Rejection Ratio	V_S = ±1.35V to ±18V	●	112	135		dB
A_{VOL}	Large-Signal Voltage Gain	R_L = 10k, V_{OUT} = –13.5V to 13.5V	 ●	1000 600	2000		V/mV V/mV
		R_L = 5k, V_{OUT} = –13.5V to 13.5V	 ●	500 300	1500		V/mV V/mV
	Channel Separation	V_{OUT} = –13.5V to 13.5V, LT6014	●	120	140		dB

ELECTRICAL CHARACTERISTICS

The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at T_A = 25°C. V_S = ±15V, V_{CM} = 0V, R_L to 0V, unless otherwise specified. (Note 5)

SYMBOL	PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
V_{OUT}	Maximum Output Swing (Positive, Referred to V^+)	No Load, 50mV Overdrive			45	80	mV
			●			100	mV
		I_{SOURCE} = 1mA, 50mV Overdrive			140	195	mV
			●			240	mV
	Maximum Output Swing (Negative, Referred to V^-)	No Load, 50mV Overdrive			45	80	mV
			●			100	mV
		I_{SINK} = 1mA, 50mV Overdrive			150	250	mV
			●			300	mV
I_{SC}	Output Short-Circuit Current (Note 3)	V_{OUT} = 0V, 1V Overdrive (Source)		8	15		mA
			●	5			mA
		V_{OUT} = 0V, –1V Overdrive (Sink)		8	20		mA
			●	5			mA
SR	Slew Rate	A_V = –10, R_F = 50k, R_G = 5k		0.15	0.2		V/µs
		T_A = 0°C to 70°C	●	0.12			V/µs
		T_A = –40°C to 85°C	●	0.1			V/µs
GBW	Gain Bandwidth Product	f = 10kHz		1.1	1.6		MHz
			●	1			MHz
t_s	Settling Time	A_V = –4, 0.01%, V_{OUT} = 0V to 10V			40		µs
t_r, t_f	Rise Time, Fall Time	A_V = 5, 10% to 90%, 0.1V Step			0.9		µs
ΔV_{OS}	Offset Voltage Match (Note 7)	LT6014AS8			50	270	µV
		T_A = 0°C to 70°C	●			320	µV
		T_A = –40°C to 85°C	●			370	µV
		LT6014ADD			50	320	µV
		T_A = 0°C to 70°C	●			420	µV
		T_A = –40°C to 85°C	●			450	µV
		LT6014S8			70	300	µV
		T_A = 0°C to 70°C	●			350	µV
		T_A = –40°C to 85°C	●			400	µV
		LT6014DD			80	400	µV
		T_A = 0°C to 70°C	●			500	µV
		T_A = –40°C to 85°C	●			550	µV
ΔI_B	Input Bias Current Match (Note 7)	LT6014AS8, LT6014ADD			200	800	pA
		T_A = 0°C to 70°C	●			1200	pA
		T_A = –40°C to 85°C	●			1400	pA
		LT6014S8, LT6014DD			300	1600	pA
		T_A = 0°C to 70°C	●			2000	pA
		T_A = –40°C to 85°C	●			2400	pA
ΔCMRR	Common Mode Rejection Ratio Match (Note 7)	LT6014	●	109	135		dB
ΔPSRR	Power Supply Rejection Ratio Match (Note 7)	LT6014	●	106	135		dB
I_S	Supply Current	per Amplifier			200	250	µA
		T_A = 0°C to 70°C	●			290	µA
		T_A = –40°C to 85°C	●			310	µA

ELECTRICAL CHARACTERISTICS

Note 1: Absolute Maximum Ratings are those beyond which the life of the device may be impaired.

Note 2: The inputs are protected by back-to-back diodes and internal series resistors. If the differential input voltage exceeds 10V, the input current must be limited to less than 10mA.

Note 3: A heat sink may be required to keep the junction temperature below absolute maximum ratings.

Note 4: The LT6013C/LT6014C and LT6013I/LT6014I are guaranteed functional over the operating temperature range of –40°C to 85°C.

Note 5: The LT6013C and LT6014C are guaranteed to meet the specified performance from 0°C to 70°C and are designed, characterized and expected to meet specified performance from –40°C to 85°C but is not tested or QA sampled at these temperatures. The LT6013I and LT6014I are guaranteed to meet specified performance from –40°C to 85°C.

Note 6: This parameter is not 100% tested.

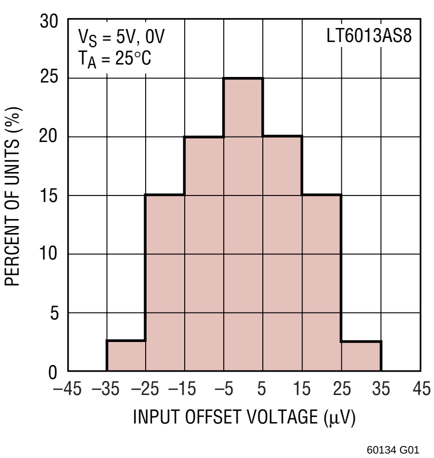
Note 7: Matching parameters are the difference between the two amplifiers. ΔCMRR and ΔPSRR are defined as follows: (1) CMRR and PSRR are measured in µV/V for the individual amplifiers. (2) The difference between matching amplifiers is calculated in µV/V. (3) The result is converted to dB.

Note 8: The specifications for V_{OS}, I_B, and I_{OS} depend on the grade and on the package. The following table clarifies the notations.

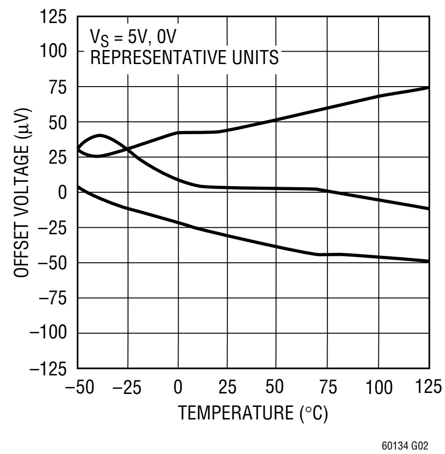
	STANDARD GRADE	A GRADE
S8 Package	LT6013S8, LT6014S8	LT6013AS8, LT6014AS8
DFN Package	LT6013DD, LT6014DD	LT6013ADD, LT6014ADD

TYPICAL PERFORMANCE CHARACTERISTICS

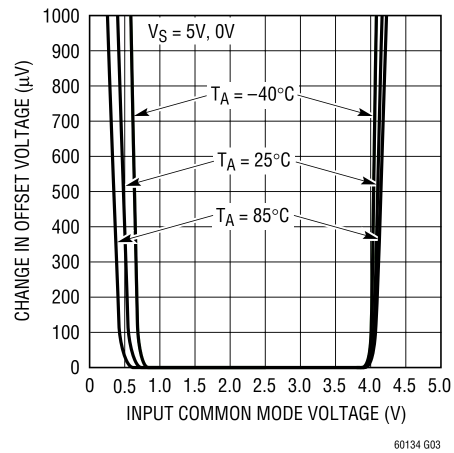
Distribution of Input Offset Voltage



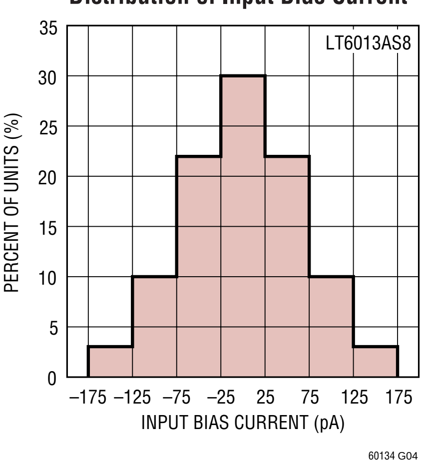
Input Offset Voltage vs Temperature



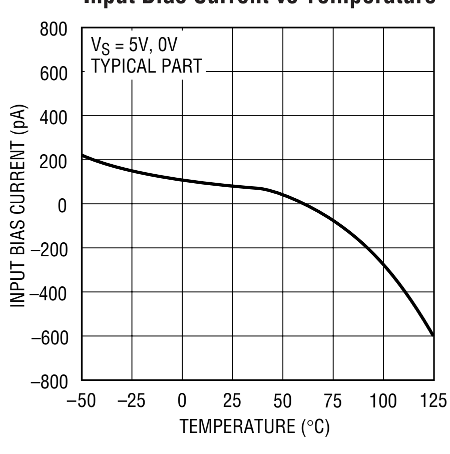
Offset Voltage vs Input Common Mode Voltage



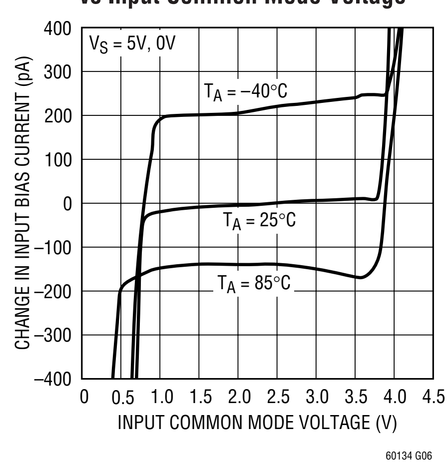
Distribution of Input Bias Current



Input Bias Current vs Temperature

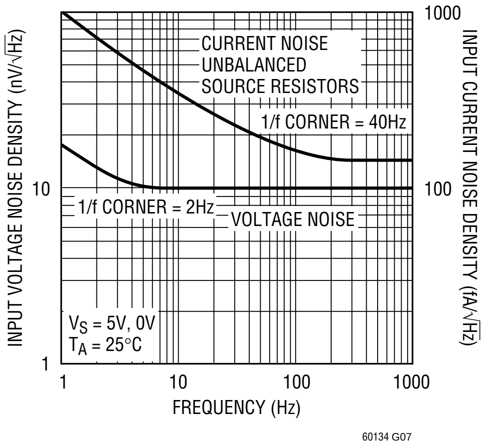


Input Bias Current vs Input Common Mode Voltage

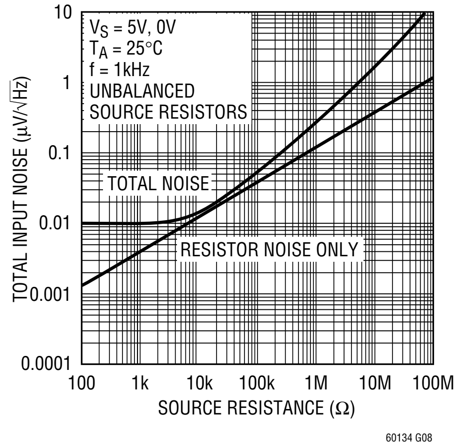


TYPICAL PERFORMANCE CHARACTERISTICS

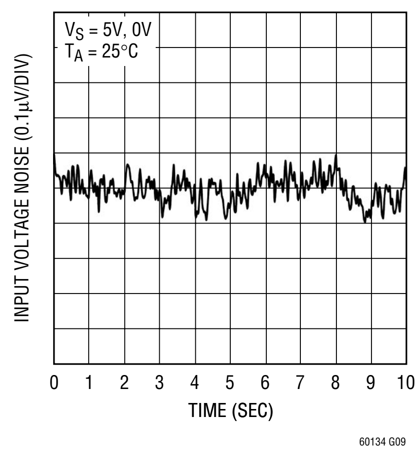
e_n, i_n vs Frequency



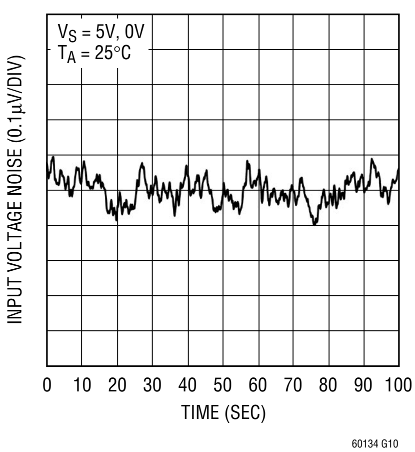
Total Input Noise vs Source Resistance



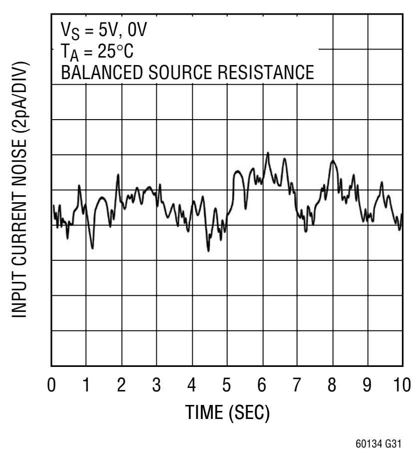
0.1Hz to 10Hz Voltage Noise



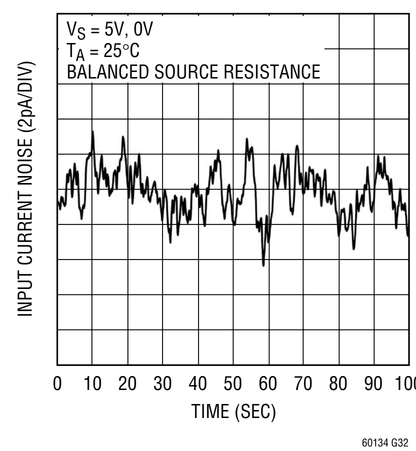
0.01Hz to 1Hz Voltage Noise



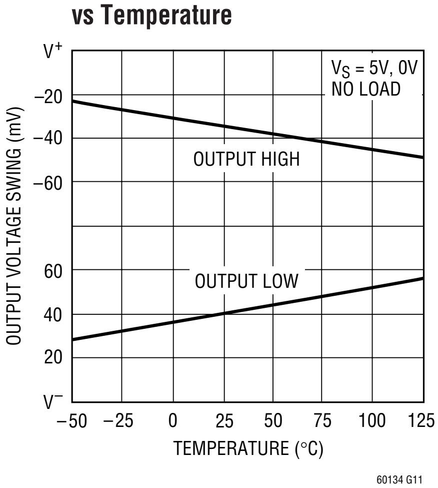
0.1Hz to 10Hz Current Noise



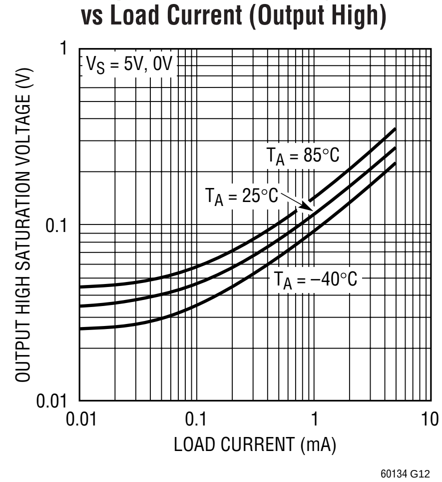
0.01Hz to 1Hz Current Noise



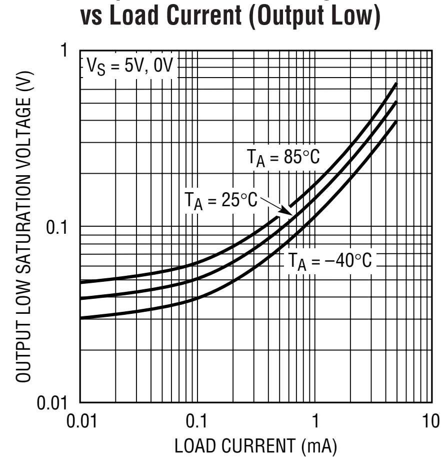
Output Voltage Swing vs Temperature



Output Saturation Voltage vs Load Current (Output High)

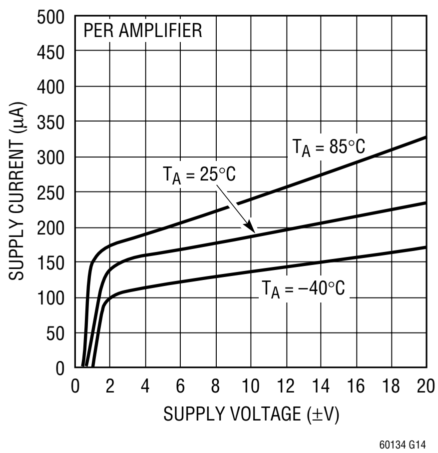


Output Saturation Voltage vs Load Current (Output Low)

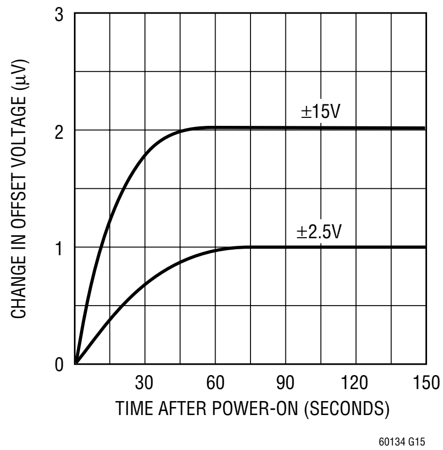


TYPICAL PERFORMANCE CHARACTERISTICS

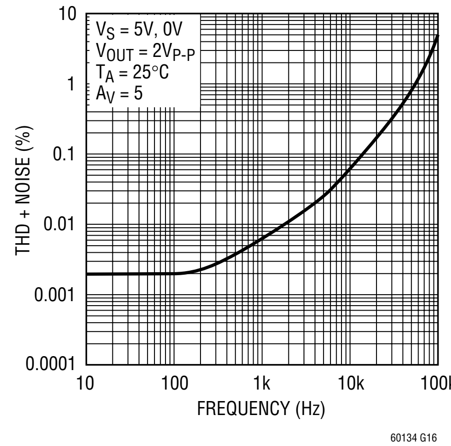
Supply Current vs Supply Voltage



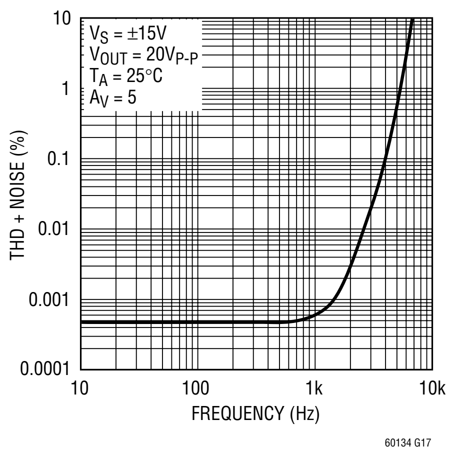
Warm-Up Drift



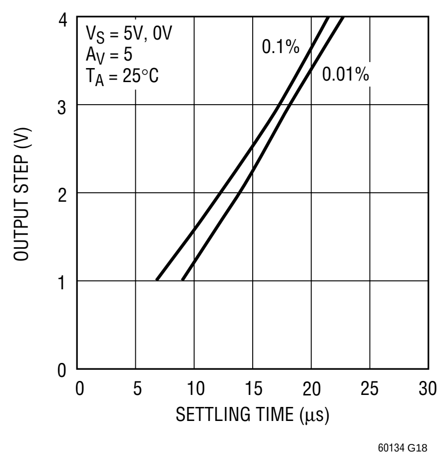
THD + Noise vs Frequency



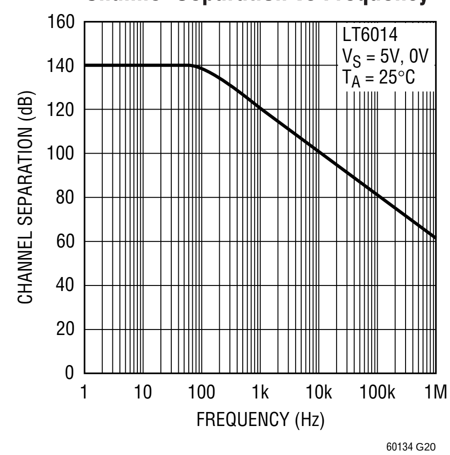
THD + Noise vs Frequency



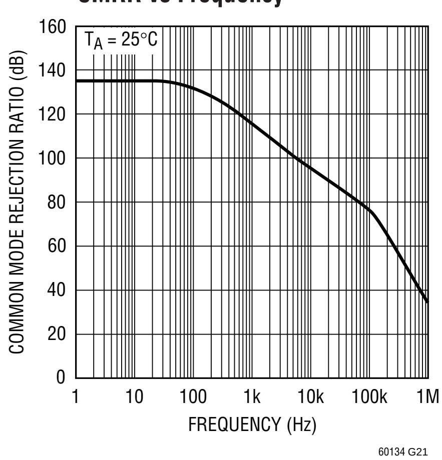
Settling Time vs Output Step



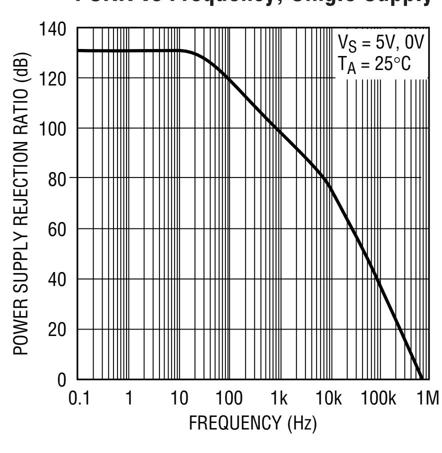
Channel Separation vs Frequency



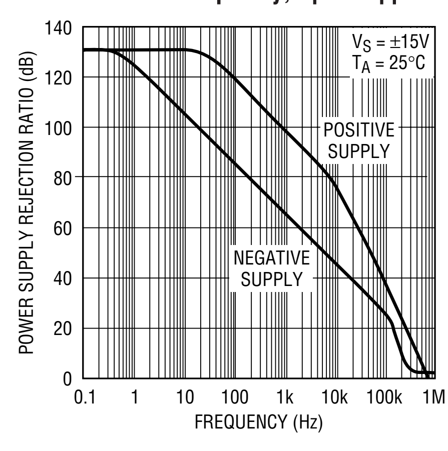
CMRR vs Frequency



PSRR vs Frequency, Single Supply

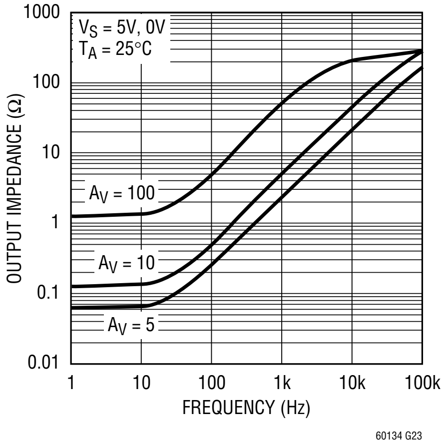


PSRR vs Frequency, Split Supplies

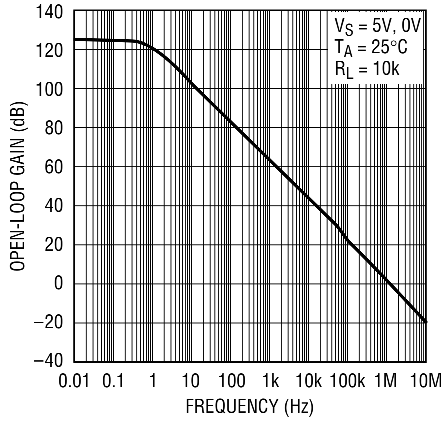


TYPICAL PERFORMANCE CHARACTERISTICS

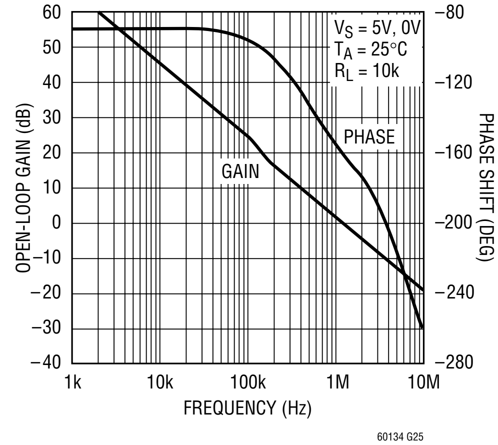
Output Impedance vs Frequency



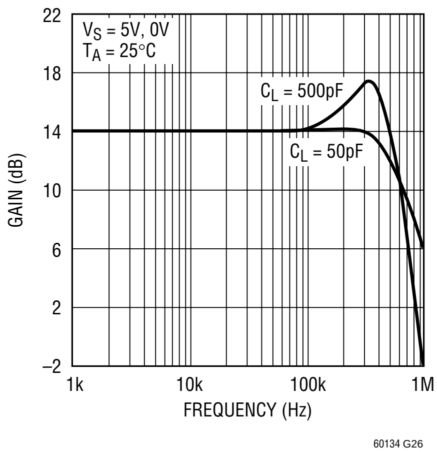
Open-Loop Gain vs Frequency



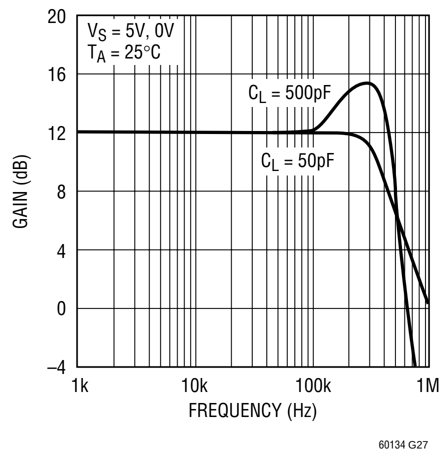
Gain and Phase vs Frequency



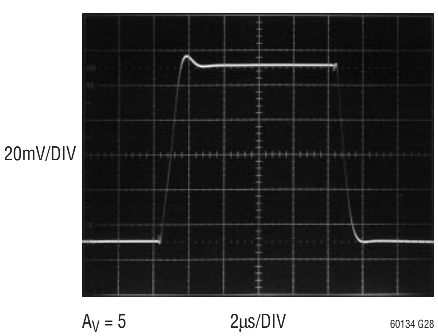
Gain vs Frequency, A_V = 5



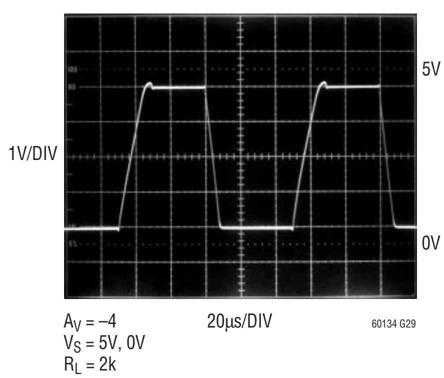
Gain vs Frequency, A_V = –4



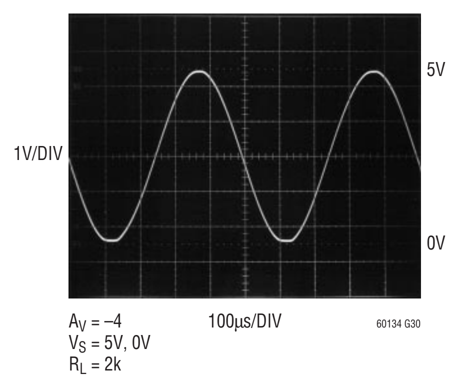
Small-Signal Transient Response



Large-Signal Transient Response



Rail-to-Rail Output Swing



APPLICATIONS INFORMATION

Not Unity-Gain Stable

The LT6013 and LT6014 amplifiers are optimized for the lowest possible noise and smallest package size, and are intentionally decompensated to be stable in a gain configuration of 5 or greater. Do not connect the amplifiers in a gain less than 5 (such as unity-gain). For a unity-gain stable amplifier with similar performance though slightly higher noise and lower bandwidth, see the LT6010 and LT6011/LT6012 datasheets.

Figure 1 shows simple inverting and non-inverting op amp configurations and indicates how to achieve a gain of 5 or greater. For more general feedback networks, determine the gain that the op amp "sees" as follows:

1. Suppose the op amp is removed from the circuit.
2. Apply a small-signal voltage at the output node of the op amp.
3. Find the differential voltage that would appear across the two inputs of the op amp.
4. The ratio of the output voltage to the input voltage is the gain that the op amp "sees". This ratio must be 5 or greater.

Do not place a capacitor bigger than 200pF between the output to the inverting input unless there is a 5 times larger capacitor from that input to AC ground. Otherwise, the op amp gain would drop to less than 5 at high frequencies, and the stability of the loop would be compromised.

The LT6013 and LT6014 can be used in lower gain configurations when an impedance is connected between the op amp inputs. Figure 2 shows inverting and non-inverting unity gain connections. The R_C network across the op amp inputs results in a large enough noise gain at high frequencies, thereby ensuring stability. At low frequencies, the capacitor is an open circuit so the DC precision (offset and noise) remains very good.

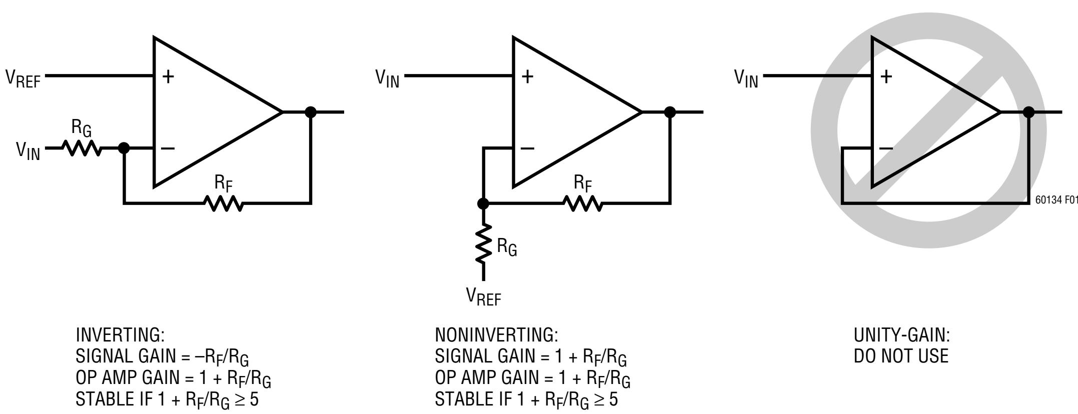


Figure 1. Use LT6013 and LT6014 in a Gain of 5 or Greater

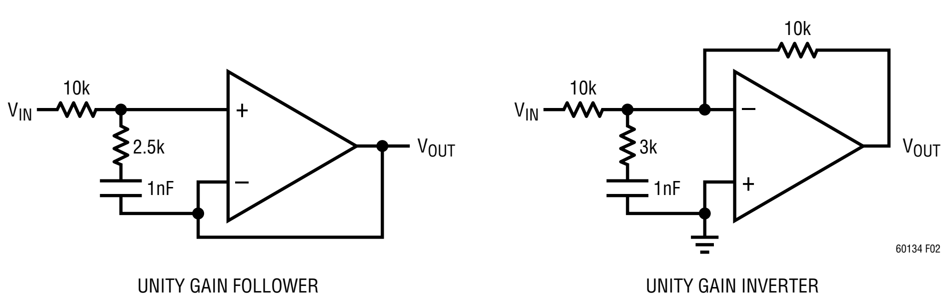


Figure 2. Stabilizing Op Amp for Unity Gain Operation

APPLICATIONS INFORMATION

Preserving Input Precision

Preserving the input accuracy of the LT6013 and LT6014 requires that the applications circuit and PC board layout do not introduce errors comparable to or greater than the 10μV typical offset of the amplifiers. Temperature differentials across the input connections can generate thermocouple voltages of 10's of microvolts so the connections to the input leads should be short, close together and away from heat dissipating components. Air currents across the board can also generate temperature differentials.

The extremely low input bias currents allow high accuracy to be maintained with high impedance sources and feedback resistors. The LT6013 and LT6014 low input bias currents are obtained by a cancellation circuit on-chip. This causes the resulting I_B^+ and I_B^- to be uncorrelated, as implied by the I_{OS} specification being comparable to I_B. Do not try to balance the input resistances in each input lead; instead keep the resistance at either input as low as possible for maximum accuracy.

Leakage currents on the PC board can be higher than the input bias current. For example, 10GΩ of leakage between a 15V supply lead and an input lead will generate 1.5nA! Surround the input leads with a guard ring driven to the same potential as the input common mode to avoid excessive leakage in high impedance applications.

Input Protection

The LT6013/LT6014 features on-chip back-to-back diodes between the input devices, along with 500Ω resistors in series with either input. This internal protection limits the input current to approximately 10mA (the maximum allowed) for a 10V differential input voltage. Use additional external series resistors to limit the input current to 10mA in applications where differential inputs of more than 10V are expected. For example, a 1k resistor in series with each input provides protection against 30V differential voltage.

Input Common Mode Range

The LT6013/LT6014 output is able to swing close to each power supply rail (rail-to-rail out), but the input stage is limited to operating between $V^- + 1V$ and $V^+ – 1.2V$. Exceeding this common mode range will cause the gain to drop to zero; however, no phase reversal will occur.

Total Input Noise

The LT6013 and LT6014 amplifiers contribute negligible noise to the system when driven by sensors (sources) with impedance between 10kΩ and 1MΩ. Throughout this range, total input noise is dominated by the $4kTR_S$ noise of the source. If the source impedance is less than 10kΩ, the input voltage noise of the amplifier starts to contribute with a minimum noise of $9.5nV/\sqrt{Hz}$ for very low source impedance. If the source impedance is more than 1MΩ, the input current noise of the amplifier, multiplied by this high impedance, starts to contribute and eventually dominate. Total input noise spectral density can be calculated as:

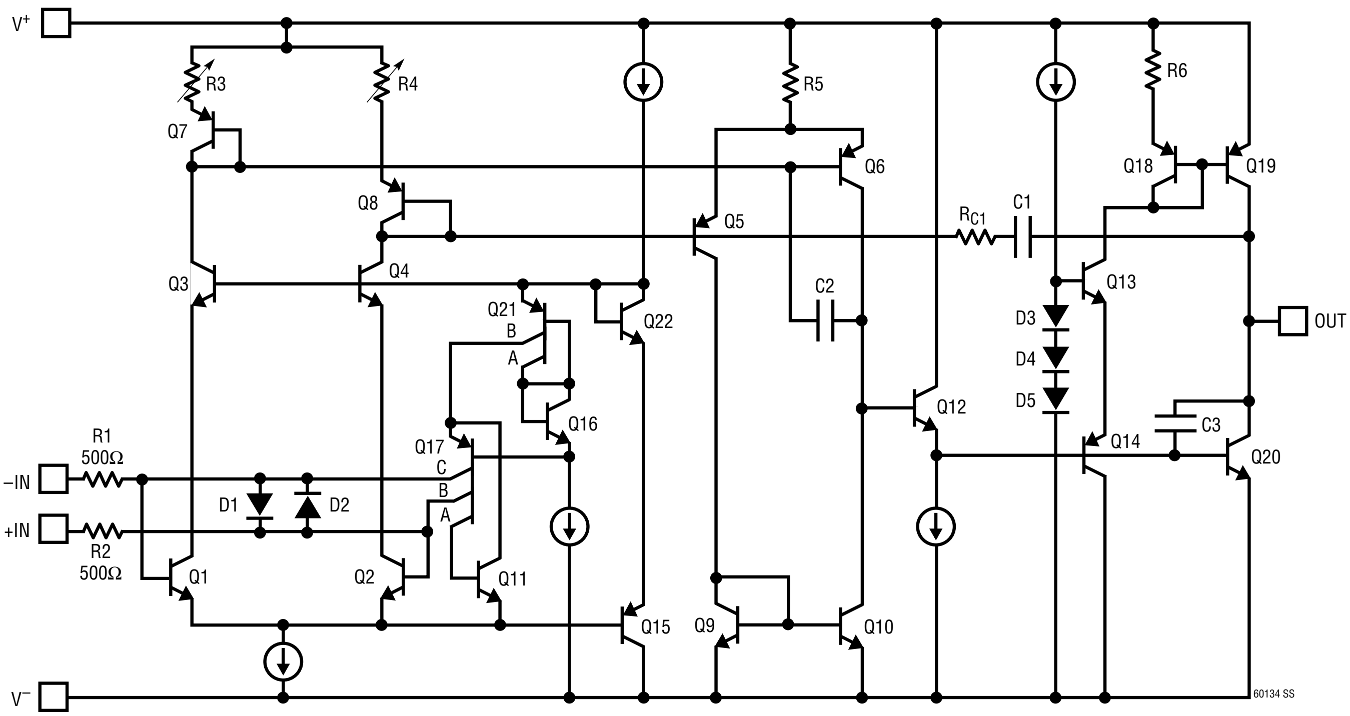
$$v_{n(TOTAL)} = \sqrt{e_n^2 + 4kTR_S + (i_n R_S)^2}$$

where $e_n = 9.5nV/\sqrt{Hz}$, $i_n = 0.15pA/\sqrt{Hz}$ and R_S is the total impedance at the input, including the source impedance.

Capacitive Loads

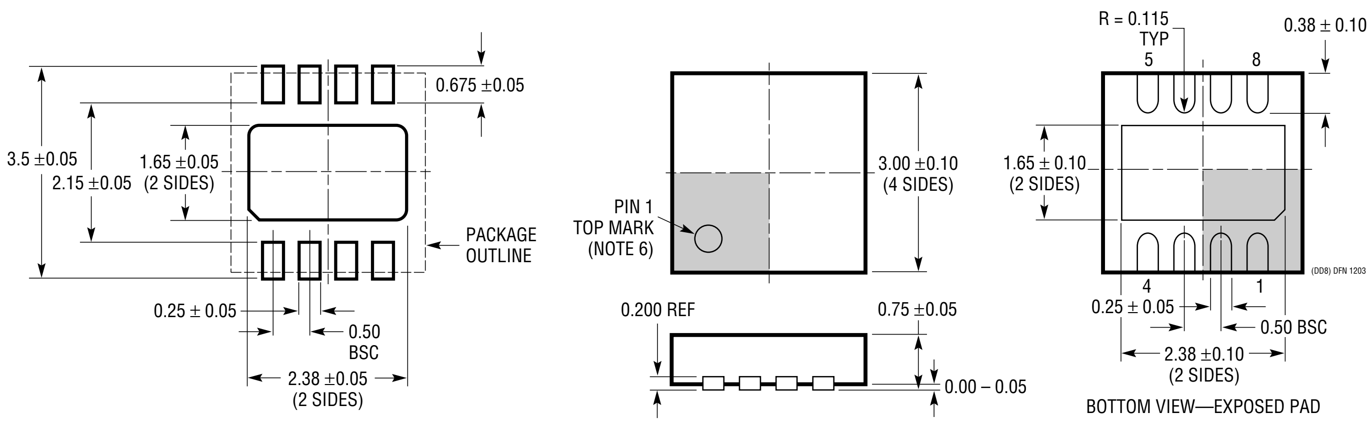
The LT6013 and LT6014 can drive capacitive loads up to 500pF at a gain of 5. The capacitive load driving capability increases as the amplifier is used in higher gain configurations. A small series resistance between the output and the load further increases the amount of capacitance that the amplifier can drive.

SIMPLIFIED SCHEMATIC (One Amplifier)



PACKAGE DESCRIPTION

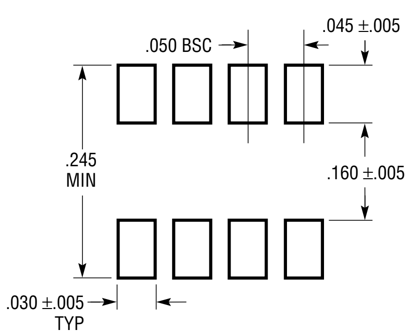
DD Package
8-Lead Plastic DFN (3mm × 3mm)
(Reference LTC DWG # 05-08-1698)



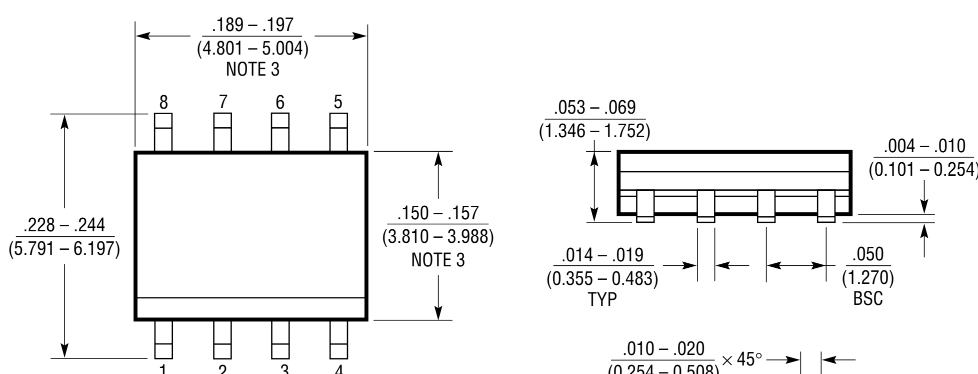
RECOMMENDED SOLDER PAD PITCH AND DIMENSIONS

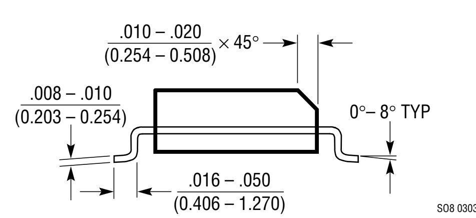
NOTE:
1. DRAWING TO BE MADE A JEDEC PACKAGE OUTLINE M0-229 VARIATION OF (WEED-1)
2. DRAWING NOT TO SCALE
3. ALL DIMENSIONS ARE IN MILLIMETERS
4. DIMENSIONS OF EXPOSED PAD ON BOTTOM OF PACKAGE DO NOT INCLUDE MOLD FLASH. MOLD FLASH, IF PRESENT, SHALL NOT EXCEED 0.15mm ON ANY SIDE
5. EXPOSED PAD SHALL BE SOLDER PLATED
6. SHADED AREA IS ONLY A REFERENCE FOR PIN 1 LOCATION ON TOP AND BOTTOM OF PACKAGE

S8 Package
8-Lead Plastic Small Outline (Narrow .150 Inch)
(Reference LTC DWG # 05-08-1610)



RECOMMENDED SOLDER PAD LAYOUT

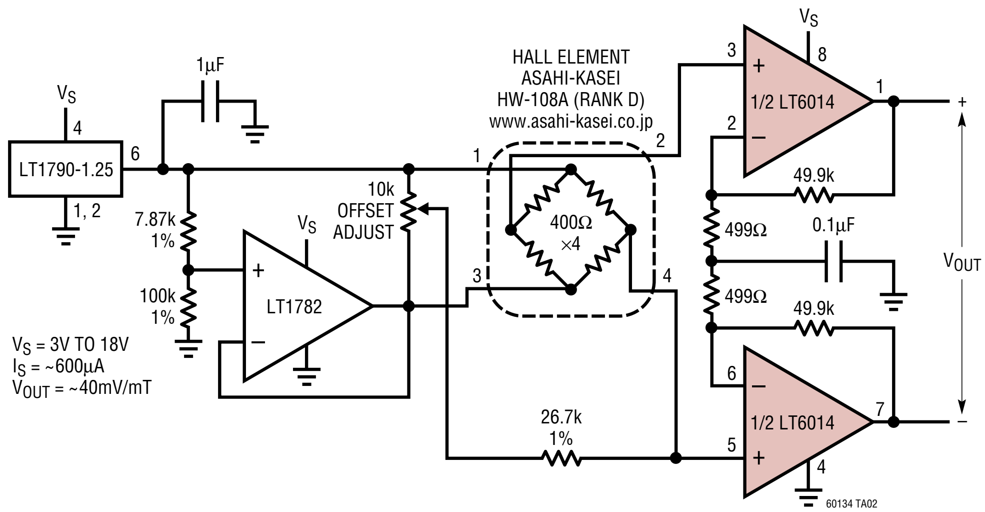




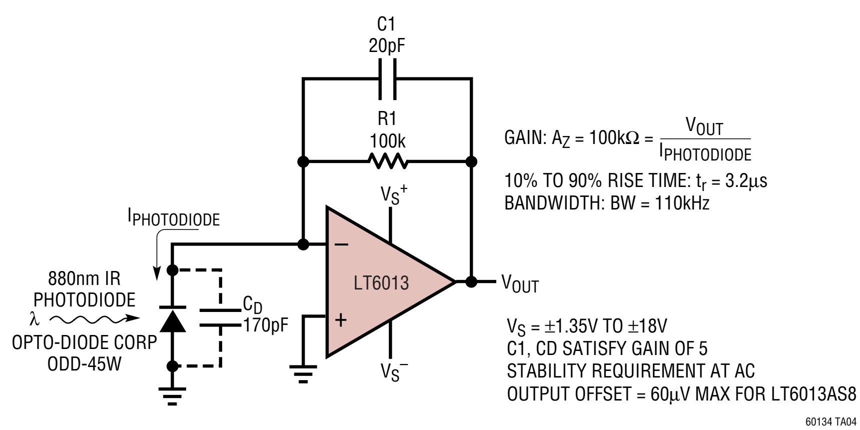
NOTE:
1. DIMENSIONS IN $\frac{\text{INCHES}}{\text{(MILLIMETERS)}}$
2. DRAWING NOT TO SCALE
3. THESE DIMENSIONS DO NOT INCLUDE MOLD FLASH OR PROTRUSIONS. MOLD FLASH OR PROTRUSIONS SHALL NOT EXCEED .006" (0.15mm)

TYPICAL APPLICATION

Low Power Hall Sensor Amplifier



Precision Micropower Photodiode Amplifier



RELATED PARTS

PART NUMBER	DESCRIPTION	COMMENTS
LT1112/LT1114	Dual/Quad Low Power, Picoamp Input Precision Op Amps	250pA Input Bias Current
LT1880	Rail-to-Rail Output, Picoamp Input Precision Op Amp	SOT-23
LT1881/LT1882	Dual/Quad Rail-to-Rail Output, Picoamp Input Precision Op Amps	C_{LOAD} Up to 1000pF
LT1884/LT1885	Dual/Quad Rail-to-Rail Output, Picoamp Input Precision Op Amps	9.5nV/$\sqrt{Hz}$ Input Noise
LT6011/LT6012	Dual/Quad Low Power Rail-to-Rail Output, Precision Op Amps	14nV/$\sqrt{Hz}$, Unity-Gain Stable Version of LT6014
LT6010	Single Low Power Rail-to-Rail Output, Precision Op Amp	200pA Input Bias Current, Shutdown Feature

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