ABSOLUTE MAXIMUM RATINGS (Note 1)

Total Supply Voltage (V⁺ to V⁻) 18V
Input Current .... ±10mA
SHDN Pin Voltage (Note 7) .... V⁻ to V⁺
Output Short Current Duration (Note 2) .... Indefinite
Operating Temperature Range (Note 3) ... –40°C to 85°C
Specified Temperature Range (Note 4) .... –40°C to 85°C
Junction Temperature .... 150°C

Junction Temperature (DFN Packages) .... 125°C
Storage Temperature Range .... –65°C to 150°C
Storage Temperature Range
   DFN Packages .... –65°C to 125°C
Lead Temperature (Soldering, 10 sec)
   MSOP, SSOP Packages .... 300°C

PACKAGE/ORDER INFORMATION

TOP VIEW

DCB PACKAGE
6-LEAD (2mm × 3mm) PLASTIC DFN
T_{JMAX} = 125°C, θ_{JA} = 160°C/W (NOTE 2)
EXPOSED PAD (PIN 7) IS CONNECTED TO V⁻ (PIN 5)

TOP VIEW

MS8 PACKAGE
8-LEAD PLASTIC MSOP
T_{JMAX} = 150°C, θ_{JA} = 250°C/W

TOP VIEW

DD PACKAGE
10-LEAD (3mm × 3mm) PLASTIC DFN
T_{JMAX} = 125°C, θ_{JA} = 160°C/W (NOTE 2)
EXPOSED PAD (PIN 11) IS CONNECTED TO V⁻ (PIN 4)

ORDER PART NUMBER	DCB PART MARKING*	ORDER PART NUMBER	MS8 PART MARKING*	ORDER PART NUMBER	DD PART MARKING*
LT6000CDCB	LCDM	LT6001CMS8	LTBVD	LT6001CDD	LBVH
LT6000IDCB	LCDM	LT6001IMS8	LTBVD	LT6001IDD	LBVH

TOP VIEW

GN PACKAGE
16-LEAD NARROW PLASTIC SSOP
T_{JMAX} = 150°C, θ_{JA} = 135°C/W

TOP VIEW

DHC PACKAGE
16-LEAD (5mm × 3mm) DFN
T_{JMAX} = 125°C, θ_{JA} = 160°C/W (NOTE 2)
EXPOSED PAD (PIN 17) IS CONNECTED TO V⁻ (PIN 13)

ORDER PART NUMBER	GN PART MARKING	ORDER PART NUMBER	DHC PART MARKING*
LT6002CGN	6002	LT6002CDHC	6002
LT6002IGN	6002I	LT6002IDHC	6002

Order Options Tape and Reel: Add #TR
Lead Free: Add #PBF   Lead Free Tape and Reel: Add #TRPBF
Lead Free Part Marking: http://www.linear.com/leadfree/

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

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LINEAR TECHNOLOGY

ELECTRICAL CHARACTERISTICS

The ● denotes specifications which apply over the full specified temperature range, otherwise specifications are $T_A = 25°C$. $V_S = 1.8V$, $0V$, $V_{CM} = V_{OUT} = 0.5V$. For the LT6000 and the LT6001DD, $V_{\overline{SHDN}} = V^+$, unless otherwise noted.

SYMBOL	PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
V_{OS}	Input Offset Voltage	LT6001MS8			200	600	μV
		$0°C \le T_A \le 70°C$	●			800	μV
		$-40°C \le T_A \le 85°C$	●			950	μV
		LT6000DCB, LT6001DD, LT6002GN			250	750	μV
		$0°C \le T_A \le 70°C$	●			1000	μV
		$-40°C \le T_A \le 85°C$	●			1200	μV
		LT6002DHC			300	900	μV
		$0°C \le T_A \le 70°C$	●			1100	μV
		$-40°C \le T_A \le 85°C$	●			1300	μV
		$V_{CM} = V^+$ LT6001MS8			400	1000	μV
			●			1300	μV
		$V_{CM} = V^+$ LT6000DCB, LT6001DD, LT6002GN			500	1200	μV
			●			1550	μV
		$V_{CM} = V^+$ LT6002DHC			500	1300	μV
			●			1700	μV
$\Delta V_{OS}/\Delta T$	Input Offset Voltage Drift (Note 5)	$V_{CM} = 0.5V$	●		2	5	μV/°C
I_B	Input Bias Current	$V_{CM} = 0.5V$	●	−5	−2		nA
		$V_{CM} = V^-$	●	−5	−2		nA
		$V_{CM} = V^+$	●		4	10	nA
I_{OS}	Input Offset Current	$V_{CM} = 0.5V$	●		0.2	1	nA
		$V_{CM} = V^-$	●		0.2	1	nA
		$V_{CM} = V^+$	●		0.4	2	nA
	Input Noise Voltage	0.1Hz to 10Hz			1.2		$μV_{P-P}$
e_n	Input Voltage Noise Density	f = 1kHz			75		nV/√Hz
i_n	Input Current Noise Density	f = 1kHz			25		fA/√Hz
R_{IN}	Input Resistance	Common Mode ($V_{CM} = 0V$ to 0.6V)			3.5		GΩ
		Differential		10	25		MΩ
C_{IN}	Input Capacitance				5		pF
CMRR	Common Mode Rejection Ratio	$V_{CM} = 0V$ to 0.6V, $0°C \le T_A \le 70°C$	●	82	96		dB
		$V_{CM} = 0.1V$ to 0.6V, $-40°C \le T_A \le 85°C$	●	82	96		dB
		$V_{CM} = 0V$ to 1.8V	●	60	78		dB
	Input Voltage Range		●	0		1.8	V
PSRR	Power Supply Rejection Ratio	$V_S = 1.8V$ to 16V	●	86	100		dB
		$V_{CM} = V_O = 0.5V$					
	Minimum Supply	$V_{CM} = V_O = 0.5V$	●	1.8			V
A_{VOL}	Large-Signal Gain	$V_O = 0.25V$ to 1.25V					
		$R_L = 100k$ to GND		25	65		V/mV
		$R_L = 100k$ to GND	●	20			V/mV
		$R_L = 10k$ to GND		40	125		V/mV
		$R_L = 10k$ to GND	●	25			V/mV
V_{OL}	Output Swing Low (Note 6)	Input Overdrive = 30mV					
		No Load	●		30	60	mV
		$I_{SINK} = 100μA$	●		120	200	mV
V_{OH}	Output Swing High (Note 6)	Input Overdrive = 30mV					
		No Load	●		30	60	mV
		$I_{SOURCE} = 100μA$	●		140	225	mV
		$R_L = 10k$ to GND	●		160	250	mV

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ELECTRICAL CHARACTERISTICS
The ● denotes specifications which apply over the full specified temperature range, otherwise specifications are $T_A = 25°C$. $V_S = 1.8V$, $0V$, $V_{CM} = V_{OUT} = 0.5V$. For the LT6000 and the LT6001DD, $V_{\overline{SHDN}} = V^+$, unless otherwise noted.

SYMBOL	PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
I_{SC}	Short-Circuit Current	Short to GND		2	4		mA
		$0°C \leq T_A \leq 70°C$	●	1			mA
		$-40°C \leq T_A \leq 85°C$	●	0.4			mA
		Short to V^+		0.7	2		mA
		$0°C \leq T_A \leq 70°C$	●	0.4			mA
		$-40°C \leq T_A \leq 85°C$	●	0.15			mA
I_S	Supply Current per Amplifier				13	16	µA
		$0°C \leq T_A \leq 70°C$	●			22	µA
		$-40°C \leq T_A \leq 85°C$	●			24	µA
	Total Supply Current in Shutdown (Note 7)	$V_{\overline{SHDN}} = 0.3V$	●		0.8	1.5	µA
$I_{\overline{SHDN}}$	$\overline{SHDN}$ Pin Current (Note 7)	$V_{\overline{SHDN}} = 1.8V$	●		0	30	nA
		$V_{\overline{SHDN}} = 0V$	●	−300	−200		nA
	Shutdown Output Leakage Current (Note 7)	$V_{\overline{SHDN}} = 0.3V$ ($V^- \leq V_{OUT} \leq V^+$)	●		20		nA
V_L	$\overline{SHDN}$ Pin Input Low Voltage (Note 7)		●			0.3	V
V_H	$\overline{SHDN}$ Pin Input High Voltage (Note 7)		●	1.5V			V
t_{ON}	Turn On Time (Note 7)	$V_{\overline{SHDN}} = 0V$ to 1.8V, $R_L = 10k$			400		µs
t_{OFF}	Turn Off Time (Note 7)	$V_{\overline{SHDN}} = 1.8V$ to 0V, $R_L = 10k$			100		µs
GBW	Gain Bandwidth Product (Note 8)	Freq = 1kHz		32	50		kHz
		$0°C \leq T_A \leq 70°C$	●	28			kHz
		$-40°C \leq T_A \leq 85°C$	●	24			kHz
SR	Slew Rate	$A_V = -1$, $V_{OUT} = 0.25V$ to 1.5V		9	15		V/ms
		Measure 0.5V to 1.25V, $0°C \leq T_A \leq 70°C$	●	7			V/ms
		$-40°C \leq T_A \leq 85°C$	●	5			V/ms
FPBW	Full Power Bandwidth (Note 9)	$V_{OUT} = 1.25V_{P-P}$		2.3	3.8		kHz

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ELECTRICAL CHARACTERISTICS

The ● denotes specifications which apply over the full specified temperature range, otherwise specifications are $T_A = 25°C$. $V_S = 5V$, $0V$, $V_{CM} = V_{OUT} = 1/2$ Supply. For the LT6000 and the LT6001DD, $V_{\overline{SHDN}} = V^+$, unless otherwise noted.

SYMBOL	PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
V_{OS}	Input Offset Voltage	LT6001MS8			200	600	µV
		$0°C \le T_A \le 70°C$	●			800	µV
		$-40°C \le T_A \le 85°C$	●			950	µV
		LT6000DCB, LT6001DD, LT6002GN			250	750	µV
		$0°C \le T_A \le 70°C$	●			1000	µV
		$-40°C \le T_A \le 85°C$	●			1200	µV
		LT6002DHC			300	900	µV
		$0°C \le T_A \le 70°C$	●			1100	µV
		$-40°C \le T_A \le 85°C$	●			1300	µV
		$V_{CM} = V^+$					
		LT6001MS8			400	1000	µV
			●			1300	µV
		$V_{CM} = V^+$					
		LT6000DCB, LT6001DD, LT6002GN			500	1200	µV
			●			1550	µV
		$V_{CM} = V^+$					
		LT6002DHC			500	1300	µV
			●			1700	µV
$\Delta V_{OS}/\Delta T$	Input Offset Voltage Drift (Note 5)	$V_{CM} = V_S/2$	●		2	5	µV/°C
I_B	Input Bias Current	$V_{CM} = V_S/2$	●	−6	−2		nA
		$V_{CM} = V^-$	●	−6	−2		nA
		$V_{CM} = V^+$	●		4	12	nA
I_{OS}	Input Offset Current	$V_{CM} = V_S/2$	●		0.2	1.2	nA
		$V_{CM} = V^-$	●		0.2	1.2	nA
		$V_{CM} = V^+$	●		0.4	2.4	nA
	Input Noise Voltage	0.1Hz to 10Hz			1.2		$µV_{P-P}$
e_n	Input Voltage Noise Density	$f = 1kHz$			75		$nV/\sqrt{Hz}$
i_n	Input Current Noise Density	$f = 1kHz$			25		$fA/\sqrt{Hz}$
R_{IN}	Input Resistance	Common Mode ($V_{CM} = 0V$ to 3.8V)			3.5		$G\Omega$
		Differential	●	8.5	25		$M\Omega$
C_{IN}	Input Capacitance				5		pF
CMRR	Common Mode Rejection Ratio	$V_{CM} = 0V$ to 3.8V, $0°C \le T_A \le 70°C$	●	90	105		dB
		$V_{CM} = 0.1V$ to 3.8V, $-40°C \le T_A \le 85°C$	●	90	105		dB
		$V_{CM} = 0V$ to 5V	●	68	86		dB
	Input Voltage Range		●	0		5	V
PSRR	Power Supply Rejection Ratio	$V_S = 1.8V$ to 16V	●	86	100		dB
		$V_{CM} = V_O = 0.5V$					
	Minimum Supply		●	1.8			V
A_{VOL}	Large-Signal Gain	$V_O = 0.5V$ to 4.5V					
		$R_L = 100k$ to $V_S/2$		30	60		V/mV
		$R_L = 100k$ to $V_S/2$	●	25			V/mV
		$R_L = 10k$ to $V_S/2$		16	25		V/mV
		$R_L = 10k$ to $V_S/2$	●	10			V/mV
		$R_L = 10k$ to GND		160	1000		V/mV
		$R_L = 10k$ to GND	●	80			V/mV
V_{OL}	Output Swing Low (Note 6)	Input Overdrive = 30mV					
		No Load	●		30	60	mV
		$I_{SINK} = 100µA$	●		120	200	mV
		$I_{SINK} = 500µA$	●		180	300	mV

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ELECTRICAL CHARACTERISTICS

The ● denotes specifications which apply over the full specified temperature range, otherwise specifications are T_A = 25°C. V_S = 5V, 0V, V_{CM} = V_{OUT} = 1/2 Supply. For the LT6000 and the LT6001DD, $V_{\overline{SHDN}}$ = V^+, unless otherwise noted.

SYMBOL	PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
V_{OH}	Output Swing High (Note 6)	Input Overdrive = 30mV					
		No Load	●		30	60	mV
		I_{SOURCE} = 100µA	●		140	225	mV
		R_L = 10k to GND	●		160	400	mV
I_{SC}	Short-Circuit Current	Short to GND		5	10		mA
		0°C ≤ T_A ≤ 70°C	●	4			mA
		−40°C ≤ T_A ≤ 85°C	●	3			mA
		Short to V^+		3.5	7.5		mA
		0°C ≤ T_A ≤ 70°C	●	2.5			mA
		−40°C ≤ T_A ≤ 85°C	●	1.5			mA
I_S	Supply Current per Amplifier				15	18	µA
		0°C ≤ T_A ≤ 70°C	●			24	µA
		−40°C ≤ T_A ≤ 85°C	●			27	µA
		V_S = ±8V			20	25	µA
			●			34	µA
	Total Supply Current in Shutdown (Note 7)	$V_{\overline{SHDN}}$ = 0.3V	●		3	5	µA
$I_{\overline{SHDN}}$	$\overline{SHDN}$ Pin Current (Note 7)	$V_{\overline{SHDN}}$ = 5V	●		0	30	nA
		$V_{\overline{SHDN}}$ = 0V	●	−1000	−650		nA
	Shutdown Output Leakage Current (Note 7)	$V_{\overline{SHDN}}$ = 0.3V ($V^- ≤ V_{OUT} ≤ V^+$)	●		20		nA
V_L	$\overline{SHDN}$ Pin Input Low Voltage (Note 7)		●			0.3	V
V_H	$\overline{SHDN}$ Pin Input High Voltage (Note 7)		●	4.7			V
t_{ON}	Turn On Time (Note 7)	$V_{\overline{SHDN}}$ = 0V to 5V, R_L = 10k			400		µs
t_{OFF}	Turn Off Time (Note 7)	$V_{\overline{SHDN}}$ = 5V to 0V, R_L = 10k			100		µs
GBW	Gain Bandwidth Product	Freq = 1kHz		40	60		kHz
		0°C ≤ T_A ≤ 70°C	●	35			kHz
		−40°C ≤ T_A ≤ 85°C	●	30			kHz
SR	Slew Rate	A_V = −1, V_{OUT} = 0.5V to 4.5V		11	18		V/ms
		Measure 1V to 4V, 0°C ≤ T_A ≤ 70°C	●	8			V/ms
		−40°C ≤ T_A ≤ 85°C	●	6			V/ms
FPBW	Full Power Bandwidth (Note 9)	V_{OUT} = $4V_{P-P}$		0.87	1.4		kHz

Note 1: Stresses beyond those listed under Absolute Maximum Ratings may cause permanent damage to the device. Exposure to any Absolute Maximum Rating condition for extended periods may affect device reliability and lifetime.

Note 2: A heat sink may be required to keep the junction temperature below the absolute maximum. This depends on the power supply voltage and how many amplifiers are shorted. The θ_{JA} specified for the DD and DHC packages is with minimal PCB heat spreading metal. Using expanded metal area on all layers of a board reduces this value.

Note 3: The LT6000C/LT6000I/LT6001C/LT6001I and LT6002C/LT6002I are guaranteed functional over the temperature range of −40°C to 85°C.

Note 4: The LT6000C/LT6001C/LT6002C is guaranteed to meet specified performance from 0°C to 70°C. The LT6000C/LT6001C/LT6002C are designed, characterized and expected to meet specified performance from

−40°C to 85°C but are not tested or QA sampled at these temperatures. The LT6000I/LT6001I/ LT6002I is guaranteed to meet specified performance from −40°C to 85°C.

Note 5: This parameter is not 100% tested.

Note 6: Output voltage swings are measured between the output and power supply rails.

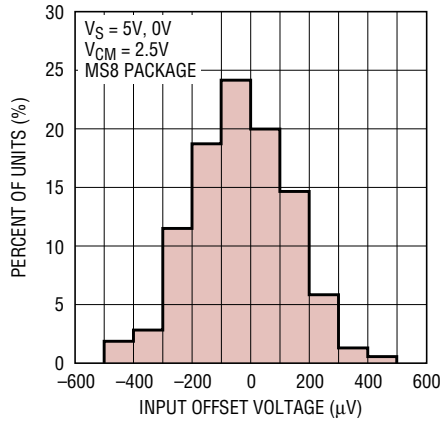**Note 7:** Specifications apply to the LT6000 or the LT6001DD with shutdown.

Note 8: Guaranteed by correlation to slew rate at V_S = 1.8V and GBW at V_S = 5V.

Note 9: Full-power bandwidth is calculated from the slew rate:
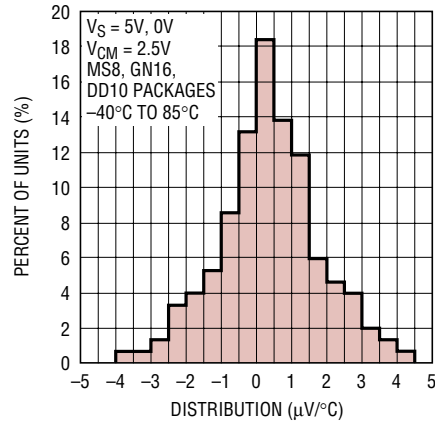
$$FPBW = SR/\pi V_{P-P}.$$

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TYPICAL PERFORMANCE CHARACTERISTICS
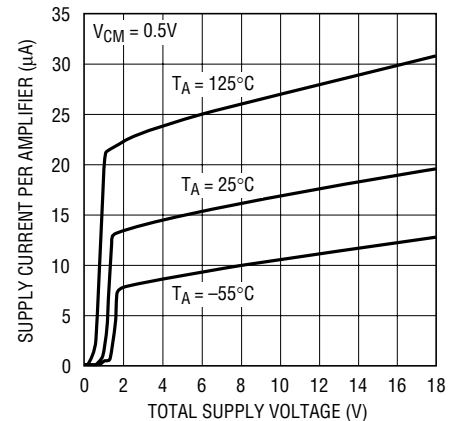
V_{OS} Distribution

$V_S = 5V, 0V$
$V_{CM} = 2.5V$
MS8 PACKAGE

60012 G01

TC V_{OS} Distribution

$V_S = 5V, 0V$
$V_{CM} = 2.5V$
MS8, GN16,
DD10 PACKAGES
−40°C TO 85°C

20012 G02

Supply Current vs Supply Voltage

$V_{CM} = 0.5V$

$T_A = 125°C$
$T_A = 25°C$
$T_A = −55°C$

600012 G03

Change in Input Offset Voltage vs Total Supply Voltage

$V_{CM} = 0.5V$

$T_A = 25°C$
$T_A = 125°C$
$T_A = −55°C$
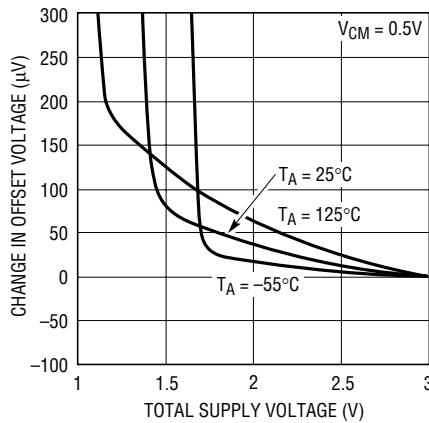
60012 G35

Input Offset Voltage vs Total Supply Voltage

$V_{CM} = 0.5V$
TYPICAL PART

$T_A = 125°C$
$T_A = 25°C$
$T_A = −55°C$
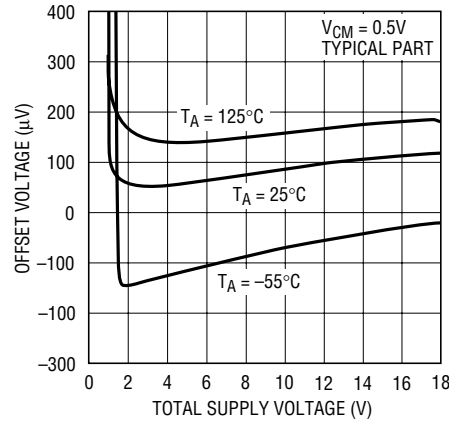
600012 G05

Input Offset Voltage vs Input Common Mode Voltage

$V_S = 5V, 0V$
TYPICAL PART

$T_A = 125°C$
$T_A = 25°C$
$T_A = −55°C$
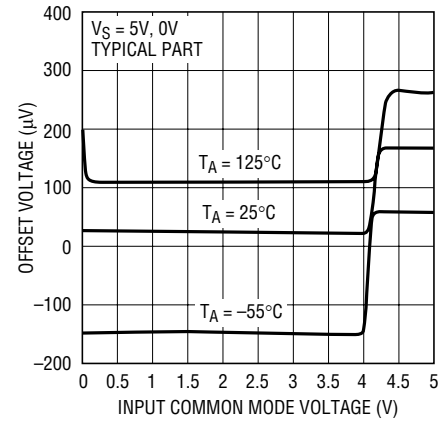
60012 G06

Input Bias Current vs Common Mode Voltage

$V_S = 5V, 0V$

$T_A = 125°C$
$T_A = 25°C$
$T_A = −55°C$
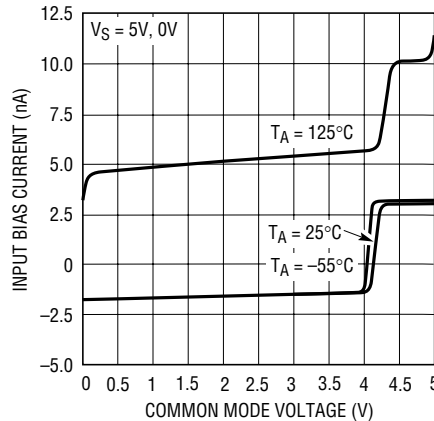
60012 G07

Output Saturation Voltage vs Load Current (Output High)

$V_S = 5V, 0V$
INPUT OVERDRIVE = 30mV

$T_A = 25°C$
$T_A = 125°C$
$T_A = −55°C$
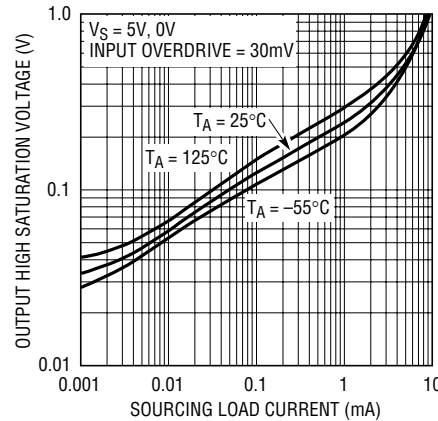
60012 G08

Output Saturation Voltage vs Load Current (Output Low)

$V_S = 5V, 0V$
INPUT OVERDRIVE = 30mV

$T_A = 25°C$
$T_A = 125°C$
$T_A = −55°C$
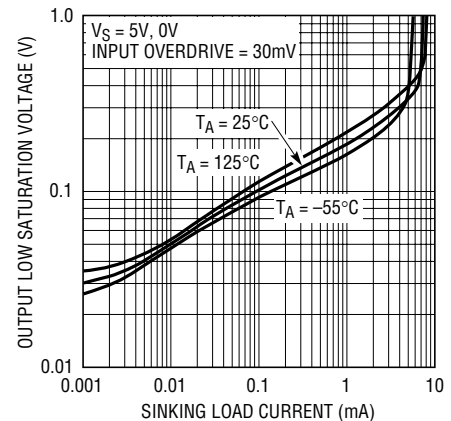
60012 G08

TYPICAL PERFORMANCE CHARACTERISTICS

Output Saturation Voltage vs Input Overdrive
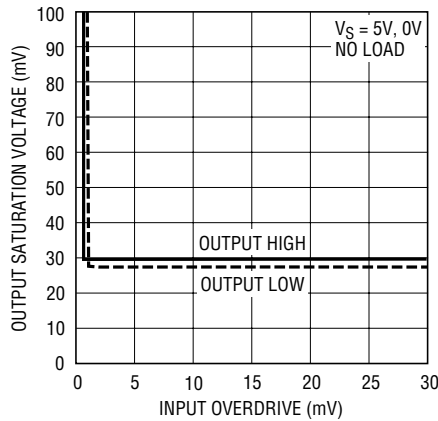
60012 G10

Output Short-Circuit Current vs Total Supply Voltage (Sourcing)
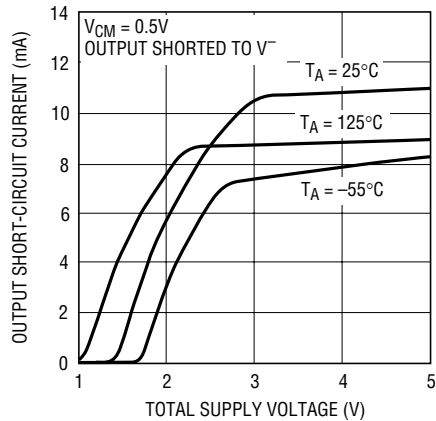
60012 G11

Output Short-Circuit Current vs Total Supply Voltage (Sinking)
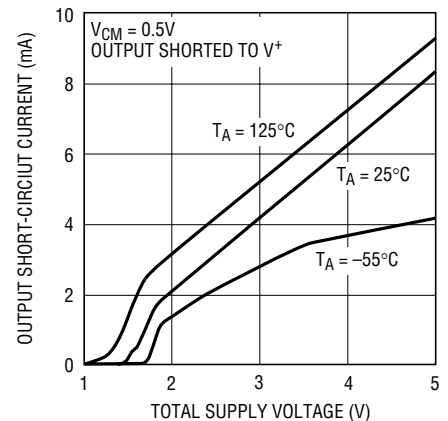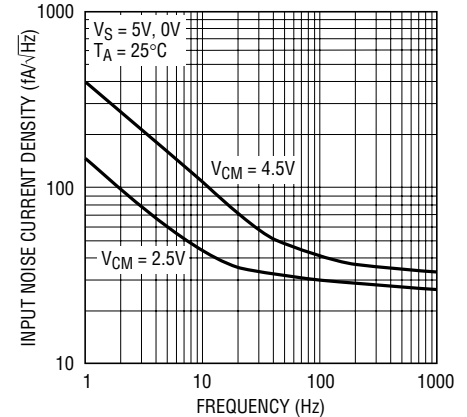

60012 G12

0.1Hz to 10Hz Output Voltage Noise
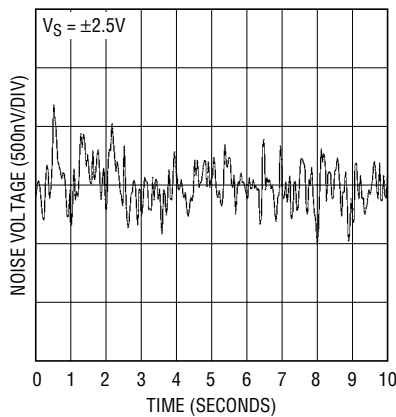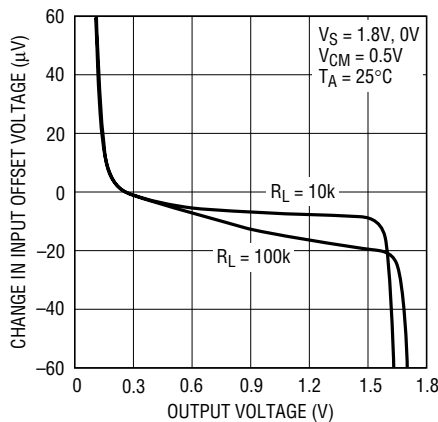

60012 G13

Noise Voltage Density vs Frequency
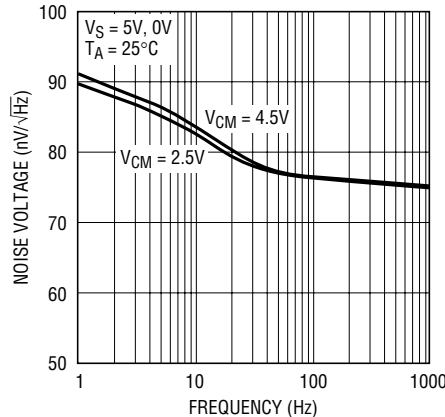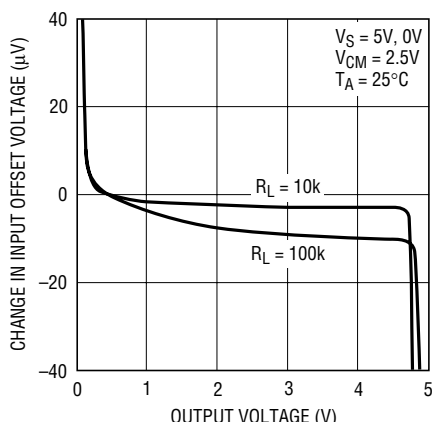

60012 G14

Input Noise Current vs Frequency

60012 G15

Open-Loop Gain

60012 G16

Open-Loop Gain

60012 G17

Open-Loop Gain

20012 G18

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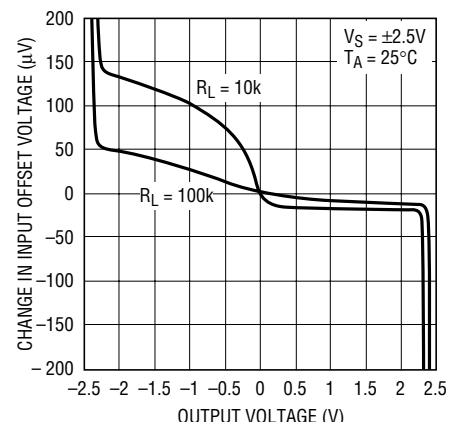
TYPICAL PERFORMANCE CHARACTERISTICS

Gain Bandwidth and Phase Margin vs Temperature

60012 G21
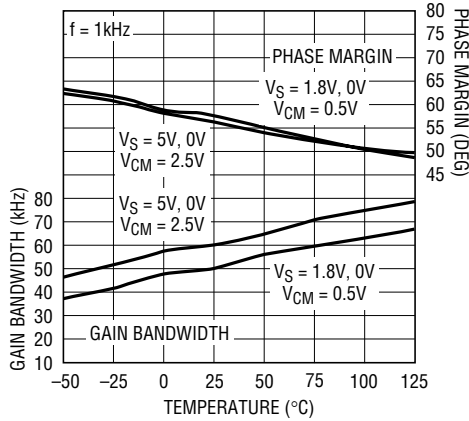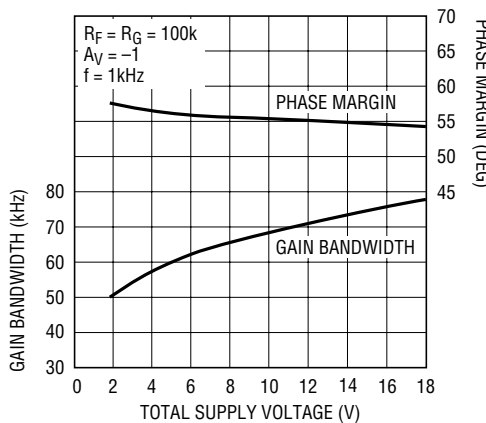
Slew Rate vs Temperature

60012 G22
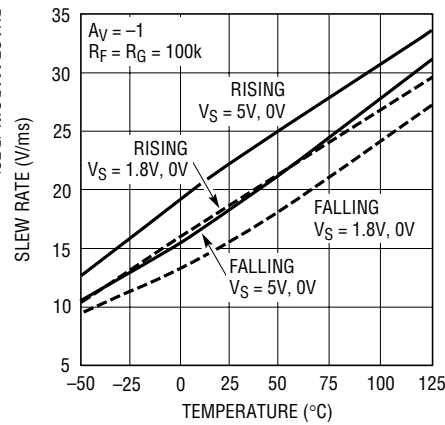
Gain and Phase vs Frequency

60012 G19
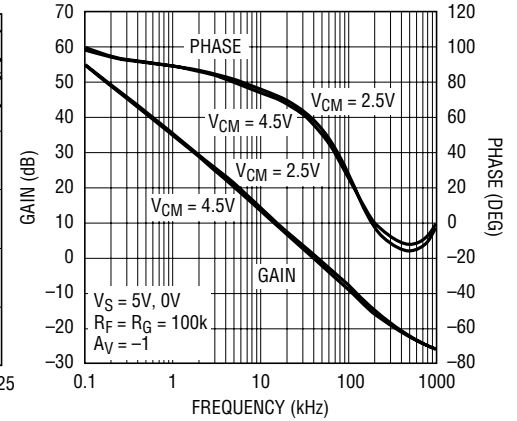
Gain Bandwidth and Phase Margin vs Supply Voltage

600012 G36

Capacitive Load Handling Overshoot vs Capacitive Load
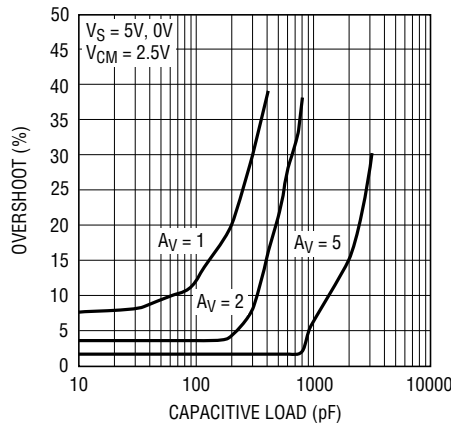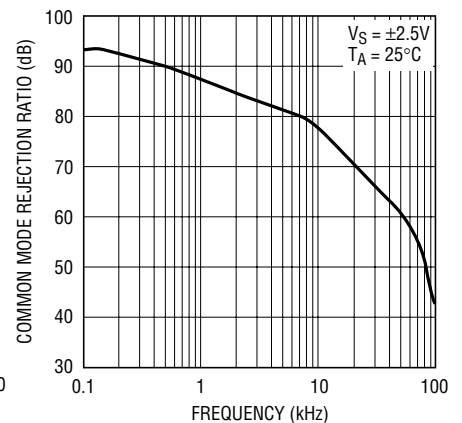
60012 G23

Common Mode Rejection Ratio vs Frequency

60012 G24

Power Supply Rejection Ratio vs Frequency

60012 G25

Output Impedance vs Frequency

60012 G26
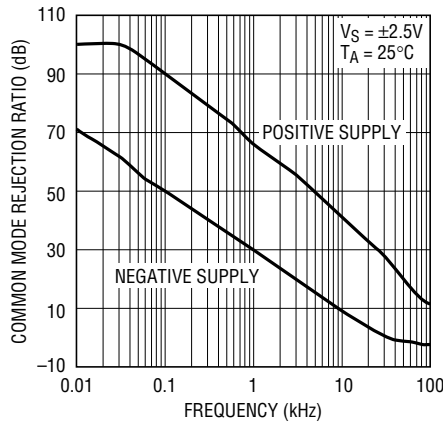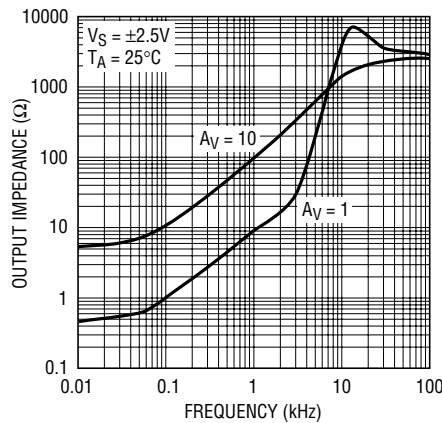
Disabled Output Impedance vs Frequency (LT6000/LT6001DD)

60012 G27

600012fa

9
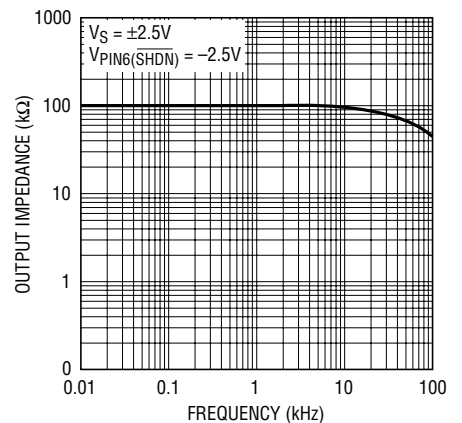
TYPICAL PERFORMANCE CHARACTERISTICS

Large-Signal Response
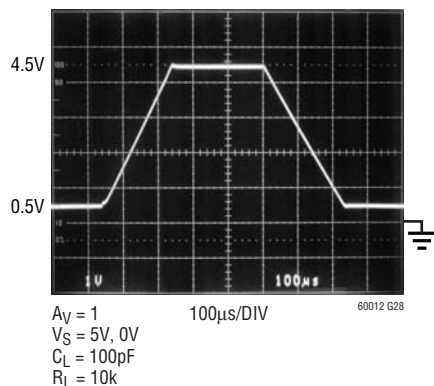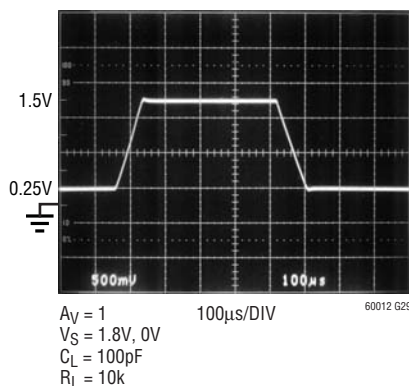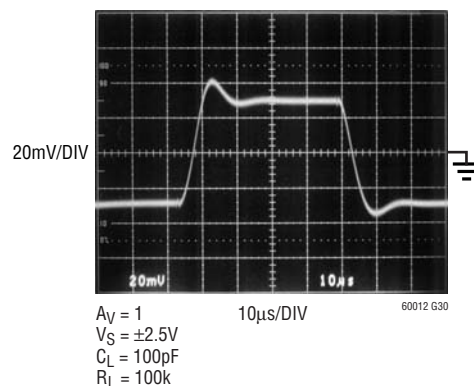
4.5V

0.5V

$A_V = 1$
$V_S = 5V, 0V$
$C_L = 100pF$
$R_L = 10k$
100µs/DIV
1V   100µs   60012 G28

Large-Signal Response

1.5V

0.25V

$A_V = 1$
$V_S = 1.8V, 0V$
$C_L = 100pF$
$R_L = 10k$
100µs/DIV
500mV   100µs   60012 G29

Small-Signal Response

20mV/DIV

$A_V = 1$
$V_S = ±2.5V$
$C_L = 100pF$
$R_L = 100k$
10µs/DIV
20mV   10µs   60012 G30

**Total Supply Current
vs $\overline{SHDN}$ Pin Voltage (LT6001DD)**

60012 G31

**Total Supply Current
vs $\overline{SHDN}$ Pin Voltage (LT6001DD)**

60012 G32
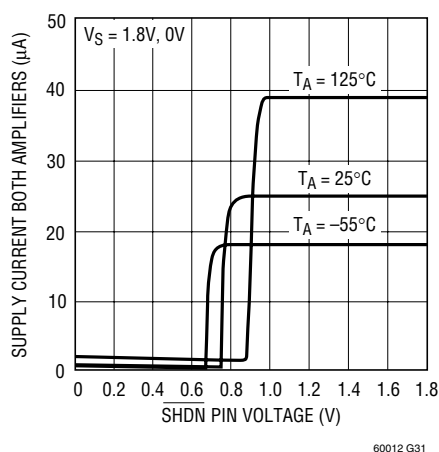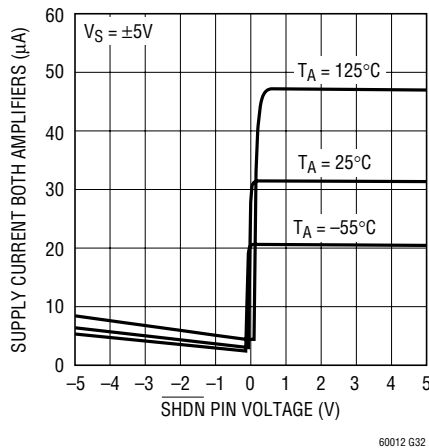
**Shutdown Response
(LT6000/LT6001DD)**
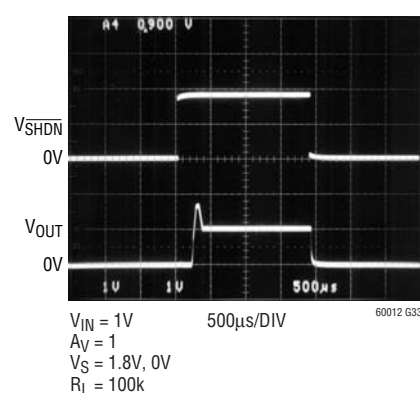
$V_{IN} = 1V$
$A_V = 1$
$V_S = 1.8V, 0V$
$R_L = 100k$
500µs/DIV
1V   1V   500µs   60012 G33

**Supply Current
vs $\overline{SHDN}$ Pin Voltage (LT6000)**

60012 G37

**Supply Current
vs $\overline{SHDN}$ Pin Voltage (LT6000)**

60012 G34

600012fa
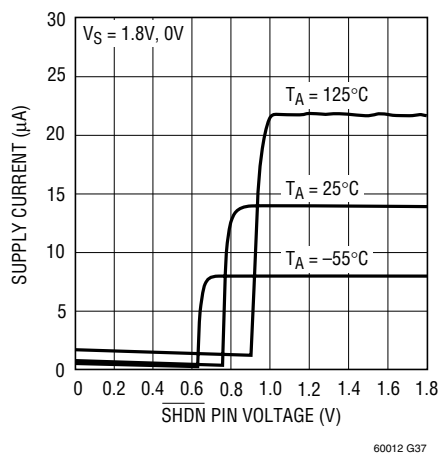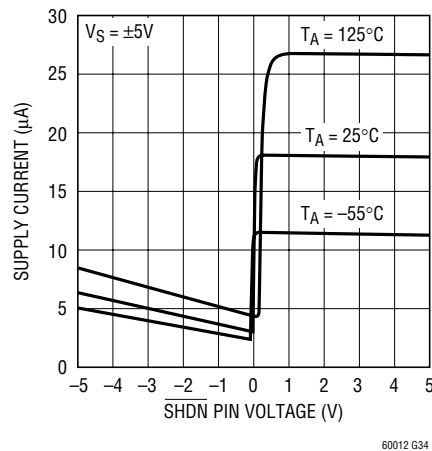
SIMPLIFIED SCHEMATIC
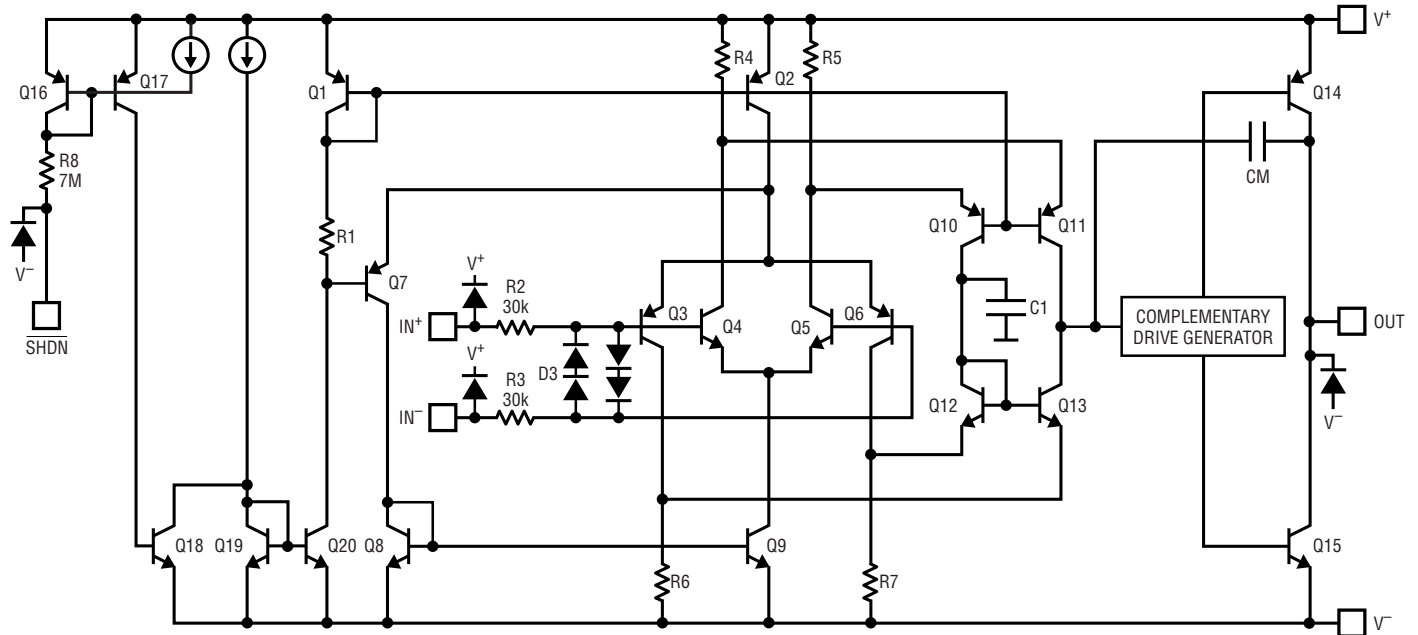
Figure 1

APPLICATIONS INFORMATION

Supply Voltage

The positive supply of the LT6000/LT6001/LT6002 should be bypassed with a small capacitor (about 0.01µF) within an inch of the pin. When driving heavy loads, an additional 4.7µF electrolytic capacitor should be used. When using split supplies, the same is true for the negative supply pin.

Rail-to-Rail Characteristics

The LT6000/LT6001/LT6002 are fully functional for an input signal range from the negative supply to the positive supply. Figure 1 shows a simplified schematic of the amplifier. The input stage consists of two differential amplifiers, a PNP stage Q3/Q6 and an NPN stage Q4/Q5 that are active over different ranges of the input common mode voltage. The PNP stage is active for common mode voltages, V_{CM}, between the negative supply to approximately 1V below the positive supply. As V_{CM} moves closer towards the positive supply, the transistor Q7 will steer Q2's tail current to the current mirror Q8/Q9, activating the NPN differential pair. The PNP pair becomes inactive for

the rest of the input common mode range up to the positive supply.

The second stage is a folded cascode and current mirror that converts the input stage differential signals into a single ended output. Capacitor C1 reduces the unity cross frequency and improves the frequency stability without degrading the gain bandwidth of the amplifier. The complementary drive generator supplies current to the output transistors that swing from rail to rail.

Input

The input bias current depends on which stage is active. The input bias current polarity depends on the input common mode voltage. When the PNP stage is active, the input bias currents flow out of the input pins. They flow in the opposite direction when the NPN stage is active. The offset error due to the input bias currents can be minimized by equalizing the noninverting and inverting source impedance.

APPLICATIONS INFORMATION

The input offset voltage changes depending on which input stage is active; input offset voltage is trimmed on both input stages, and is guaranteed to be 600μV max in the PNP stage. By trimming the input offset voltage of both input stages, the input offset voltage over the entire common mode range (CMRR) is typically 400μV, maintaining the precision characteristics of the amplifier.

The input stage of the LT6000/LT6001/LT6002 incorporates phase reversal protection to prevent wrong polarity outputs from occurring when the inputs are driven up to 2V below the negative rail. 30k protective resistors are included in the input leads so that current does not become excessive when the inputs are forced below V⁻ or when a large differential signal is applied. Input current should be limited to 10mA when the inputs are driven above the positive rail.

Output

The output of the LT6000/LT6001/LT6002 can swing to within 30mV of the positive rail with no load and within 30mV of the negative rail with no load. When monitoring input voltages within 30mV of the positive rail or within 30mV of the negative rail, gain should be taken to keep the output from clipping. The LT6000/LT6001/LT6002 can typically source 10mA on a single 5V supply, sourcing current is reduced to 4mA on a single 1.8V supply as noted in the electrical characteristics.

The normally reverse-biased substrate diode from the output to V⁻ will cause unlimited currents to flow when the output is forced below V⁻. If the current is transient and limited to 100mA, no damage will occur.

Start-Up and Output Saturation Characteristics

Micropower op amps are often not micropower during start-up characteristics or during output saturation. This can wreak havoc on limited current supplies, in the worst case there may not be enough supply current available to take the system up to nominal voltages. Also, when the output saturates, the part may draw excessive current and pull down the supplies, compromising rail-to-rail performance. Figure 1 shows the start-up characteristics of the LT6000/LT6001/LT6002 for three limiting cases. The circuits are shown in Figure 2. One circuit creates a positive offset forcing the output to come up saturated high. Another circuit creates a negative offset forcing the output to come up saturated low, while the last circuit brings the output up at 1/2 supply. In all cases, the supply current is well controlled and is not excessive when the output is on either rail.
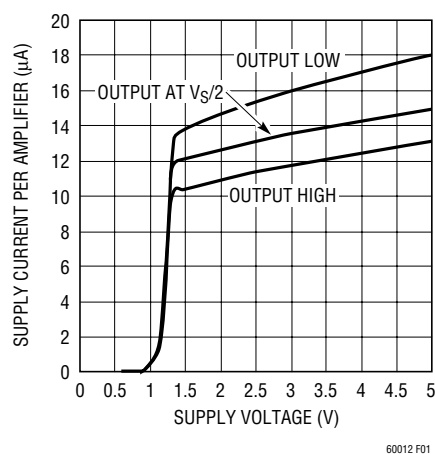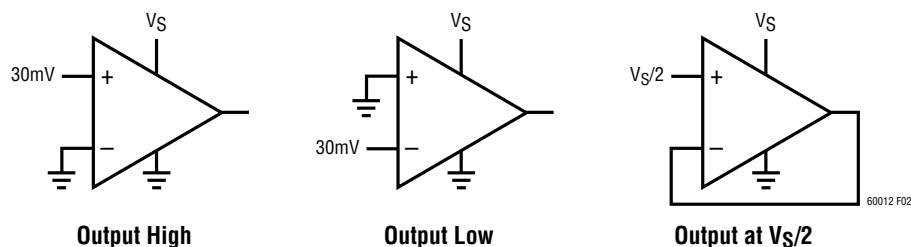

Figure 1. Start-Up Characteristics

Figure 2. Circuits for Start-Up Characteristics

APPLICATIONS INFORMATION

The LT6000/LT6001/LT6002 outputs can swing to within a respectable 30mV of each rail and draw virtually no excessive supply current. Figure 3 compares the dual LT6001 to a competitive part. Both op amps are in unity gain and their outputs are driven into each rail. The supply current is shown when the op amps are in linear operation and when they are driven into each rail. As can be seen from Figure 3, the supply current of the competitive part increases 3-fold or 5-fold depending on which rail the output goes to whereas the LT6001 draws virtually no excessive current.
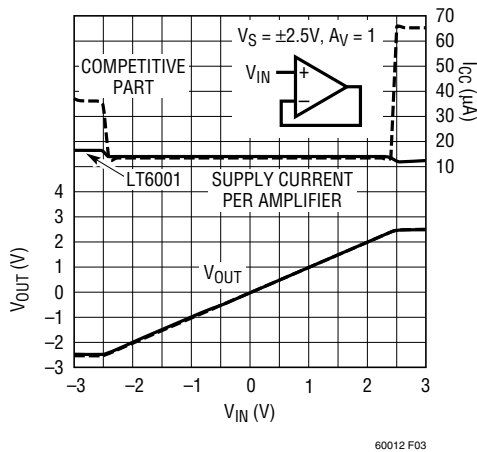

Figure 3. V_{OUT} and I_{CC} vs Input Voltage

Gain

The open-loop gain is almost independent of load when the output is sourcing current. This optimizes performance in single supply applications where the load is returned to ground. The typical performance curve of Open-Loop Gain for various loads shows the details.

Shutdown

The single LT6000 and the 10-lead dual LT6001 include a shutdown feature that disables the part reducing quiescent current and makes the output high impedance. The devices can be shut down by bringing the $\overline{SHDN}$ pin within 0.3V of V⁻. The amplifiers are guaranteed to shut down if the $\overline{SHDN}$ pin is brought within 0.3V of V⁻. The exact switchover point will be a function of the supply voltage. See the Typical Performance Characteristics curves Supply Current vs Shutdown Pin Voltage. When shut down the total supply current is about 0.8µA and the output leakage current is 20nA (V⁻ ≤ V_{OUT} ≤ V⁺). For normal operation the $\overline{SHDN}$ pin should be tied to V⁺. It can be left floating, however, parasitic leakage currents over 1µA at the $\overline{SHDN}$ pin may inadvertently place the part into shutdown.

TYPICAL APPLICATION

Gain of 100 Amplifier
(400kHz GBW on 30μA Supply)

Gain vs Frequency

14
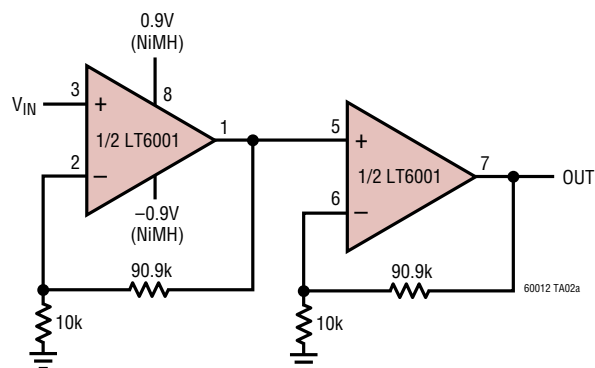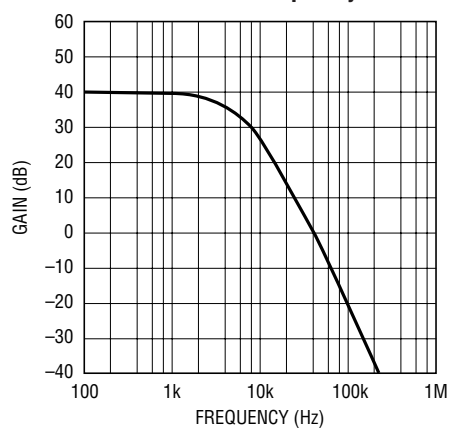
PACKAGE DESCRIPTION

DCB Package
6-Lead Plastic DFN (2mm × 3mm)
(Reference LTC DWG # 05-08-1715)

0.70 ±0.05

3.55 ±0.05

1.65 ±0.05
(2 SIDES)

2.15 ±0.05

PACKAGE
OUTLINE

0.25 ± 0.05

0.50 BSC

1.35 ±0.05
(2 SIDES)

RECOMMENDED SOLDER PAD PITCH AND DIMENSIONS

2.00 ±0.10
(2 SIDES)

3.00 ±0.10
(2 SIDES)

PIN 1 BAR
TOP MARK
(SEE NOTE 6)

R = 0.115
TYP

R = 0.05
TYP

0.40 ± 0.10

1.65 ± 0.10
(2 SIDES)

PIN 1 NOTCH
R0.20 OR 0.25
× 45° CHAMFER

(DCB6) DFN 0405

0.25 ± 0.05

0.50 BSC

1.35 ±0.10
(2 SIDES)

0.200 REF

0.75 ±0.05

0.00 – 0.05

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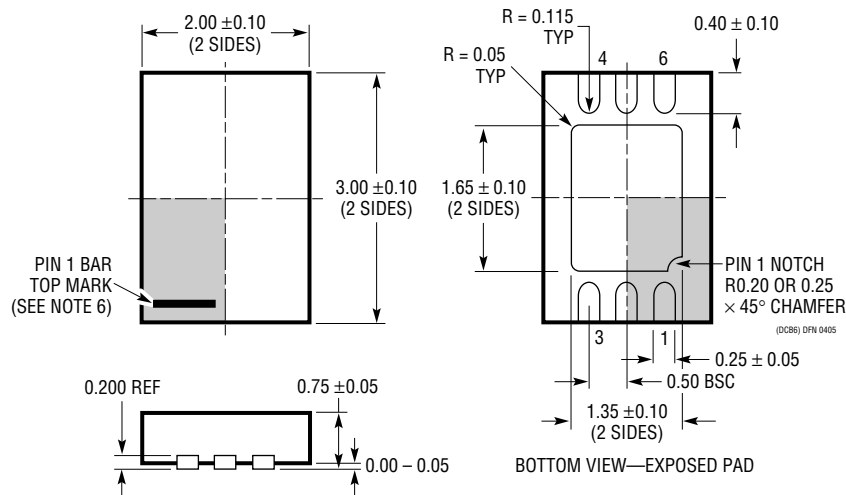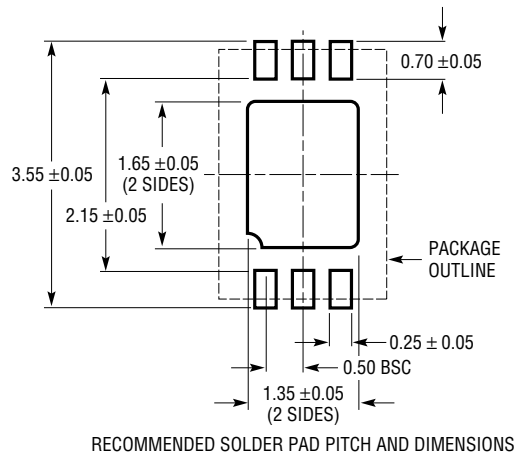
NOTE:
1. DRAWING TO BE MADE A JEDEC PACKAGE OUTLINE M0-229 VARIATION OF (TBD)
2. DRAWING NOT TO SCALE
3. ALL DIMENSIONS ARE IN MILLIMETERS
4. DIMENSIONS OF EXPOSED PAD ON BOTTOM OF PACKAGE DO NOT INCLUDE
   MOLD FLASH. MOLD FLASH, IF PRESENT, SHALL NOT EXCEED 0.15mm ON ANY SIDE
5. EXPOSED PAD SHALL BE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

PACKAGE DESCRIPTION

MS8 Package
8-Lead Plastic MSOP
(Reference LTC DWG # 05-08-1660)

RECOMMENDED SOLDER PAD LAYOUT

DETAIL "A"

GAUGE PLANE

DETAIL "A"

SEATING PLANE

MSOP (MS8) 0204
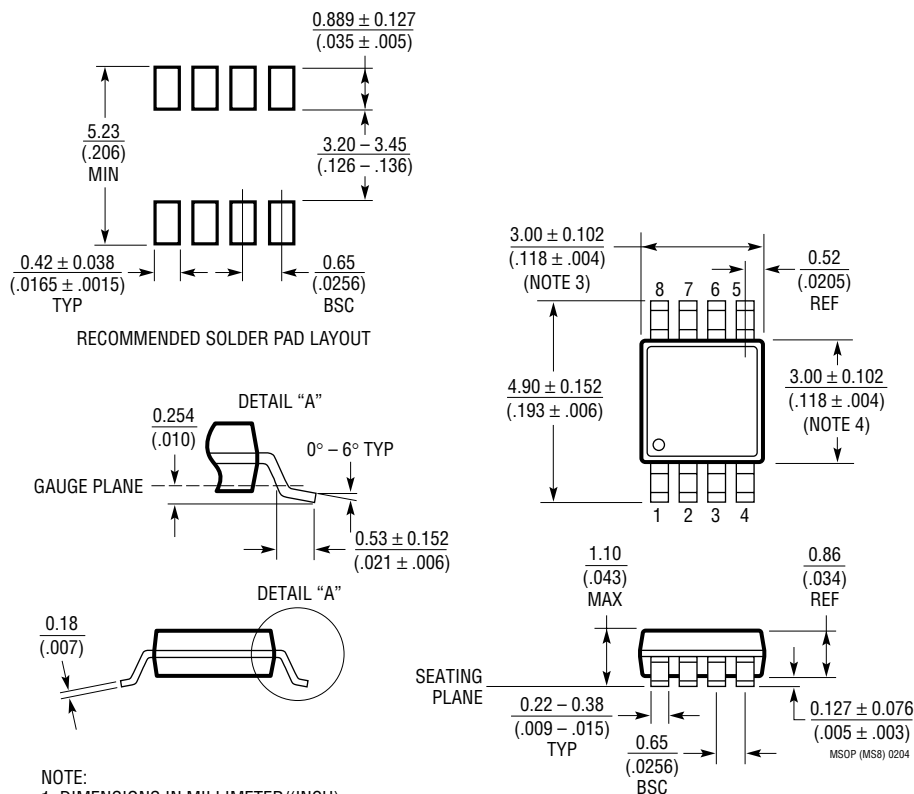
NOTE:
1. DIMENSIONS IN MILLIMETER/(INCH)
2. DRAWING NOT TO SCALE
3. DIMENSION DOES NOT INCLUDE MOLD FLASH, PROTRUSIONS OR GATE BURRS.
   MOLD FLASH, PROTRUSIONS OR GATE BURRS SHALL NOT EXCEED 0.152mm (.006") PER SIDE
4. DIMENSION DOES NOT INCLUDE INTERLEAD FLASH OR PROTRUSIONS.
   INTERLEAD FLASH OR PROTRUSIONS SHALL NOT EXCEED 0.152mm (.006") PER SIDE
5. LEAD COPLANARITY (BOTTOM OF LEADS AFTER FORMING) SHALL BE 0.102mm (.004") MAX

600012fa

PACKAGE DESCRIPTION

DD Package
10-Lead (3mm × 3mm) Plastic DFN
(Reference LTC DWG # 05-08-1699)

3.50 ±0.05

2.15 ±0.05

1.65 ±0.05
(2 SIDES)

0.675 ±0.05

PACKAGE
OUTLINE

0.25 ± 0.05

0.50
BSC

2.38 ±0.05
(2 SIDES)

RECOMMENDED SOLDER PAD PITCH AND DIMENSIONS

3.00 ±0.10
(4 SIDES)

PIN 1
TOP MARK
(SEE NOTE 6)

0.200 REF

0.75 ±0.05

0.00 – 0.05

R = 0.115
TYP

0.38 ± 0.10

6   10

1.65 ± 0.10
(2 SIDES)

5   1

0.25 ± 0.05

0.50 BSC

2.38 ±0.10
(2 SIDES)

(DD10) DFN 1103

BOTTOM VIEW—EXPOSED PAD

NOTE:
1. DRAWING TO BE MADE A JEDEC PACKAGE OUTLINE M0-229 VARIATION OF (WEED-2).
   CHECK THE LTC WEBSITE DATA SHEET FOR CURRENT STATUS OF VARIATION ASSIGNMENT
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 THE
   TOP AND BOTTOM OF PACKAGE

PACKAGE DESCRIPTION

GN Package
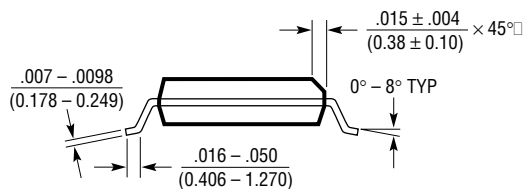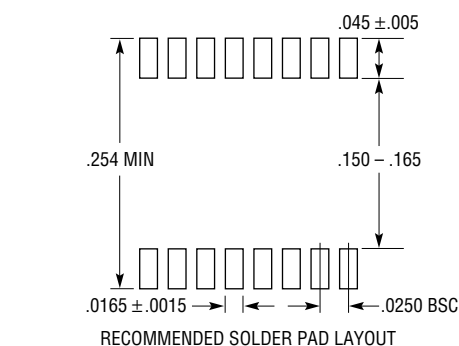**16-Lead Narrow Plastic SSOP**
(Reference LTC DWG # 05-08-1641)

.045 ±.005

.254 MIN

.150 – .165

.0165 ±.0015

.0250 BSC

RECOMMENDED SOLDER PAD LAYOUT

.189 – .196*
(4.801 – 4.978)

.009
(0.229)
REF

16 15 14 13 12 11 10 9

.229 – .244
(5.817 – 6.198)

.150 – .157**
(3.810 – 3.988)

1 2 3 4 5 6 7 8

.015 ± .004
(0.38 ± 0.10) × 45°

.007 – .0098
(0.178 – 0.249)

0° – 8° TYP

.016 – .050
(0.406 – 1.270)

.0532 – .0688
(1.35 – 1.75)

.004 – .0098
(0.102 – 0.249)
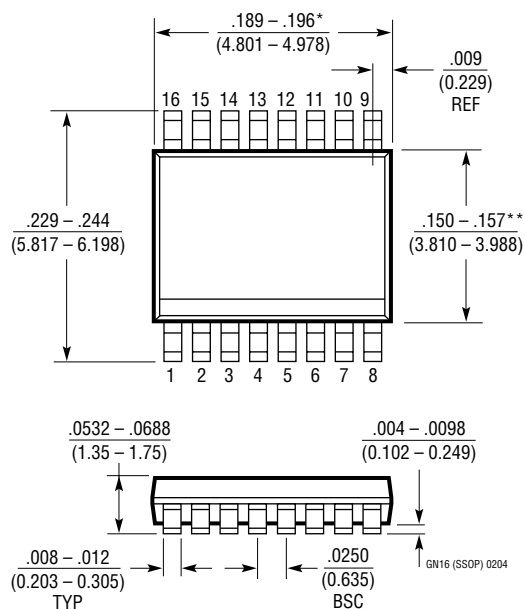
.008 – .012
(0.203 – 0.305)
TYP

.0250
(0.635)
BSC

GN16 (SSOP) 0204

NOTE:
1. CONTROLLING DIMENSION: INCHES
2. DIMENSIONS ARE IN $\frac{INCHES}{(MILLIMETERS)}$
3. DRAWING NOT TO SCALE
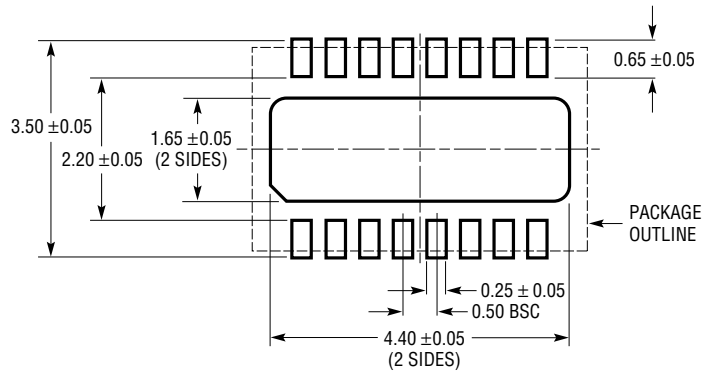   *DIMENSION DOES NOT INCLUDE MOLD FLASH. MOLD FLASH
   SHALL NOT EXCEED 0.006" (0.152mm) PER SIDE
   **DIMENSION DOES NOT INCLUDE INTERLEAD FLASH. INTERLEAD
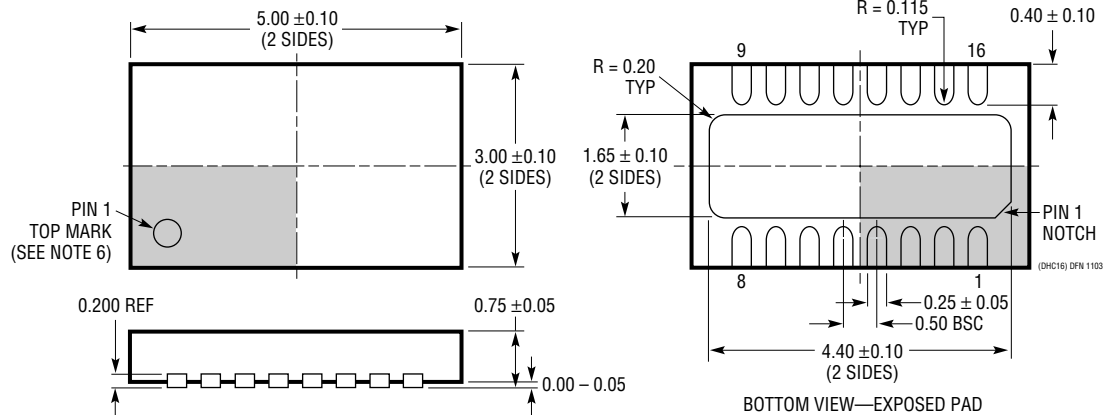   FLASH SHALL NOT EXCEED 0.010" (0.254mm) PER SIDE

600012fa

PACKAGE DESCRIPTION

DHC Package
16-Lead (5mm × 5mm) Plastic DFN
(Reference LTC DWG # 05-08-1706)

3.50 ±0.05

2.20 ±0.05

1.65 ±0.05
(2 SIDES)

0.65 ±0.05

PACKAGE
OUTLINE

0.25 ± 0.05

0.50 BSC

4.40 ±0.05
(2 SIDES)

RECOMMENDED SOLDER PAD PITCH AND DIMENSIONS

5.00 ±0.10
(2 SIDES)

3.00 ±0.10
(2 SIDES)

PIN 1
TOP MARK
(SEE NOTE 6)

0.200 REF

0.75 ±0.05

0.00 – 0.05

R = 0.115
TYP

0.40 ± 0.10

R = 0.20
TYP

9

16

1.65 ± 0.10
(2 SIDES)

PIN 1
NOTCH

8

1

(DHC16) DFN 1103

0.25 ± 0.05

0.50 BSC

4.40 ±0.10
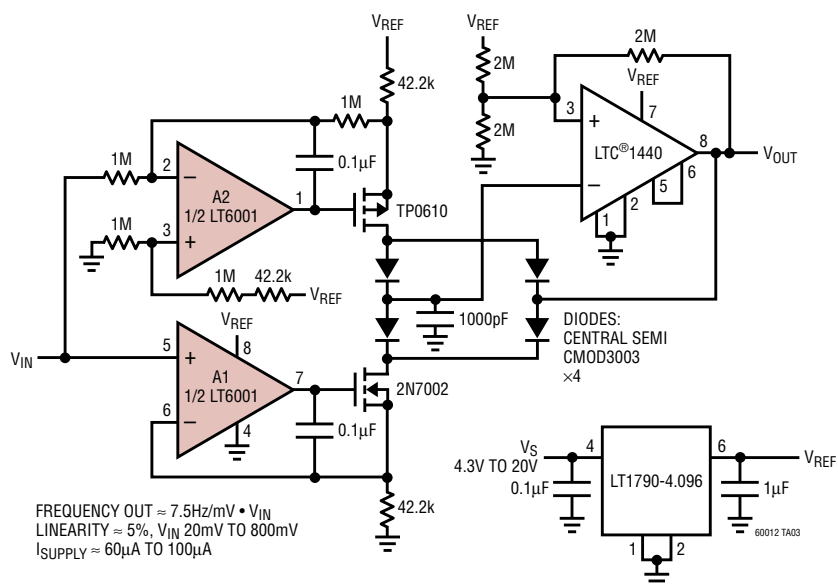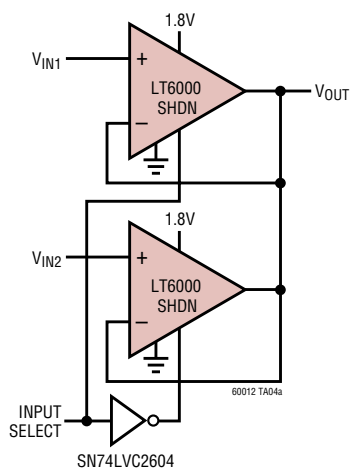(2 SIDES)

BOTTOM VIEW—EXPOSED PAD

NOTE:
1. DRAWING PROPOSED TO BE MADE VARIATION OF VERSION (WJED-1) IN JEDEC
   PACKAGE OUTLINE MO-229
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 THE
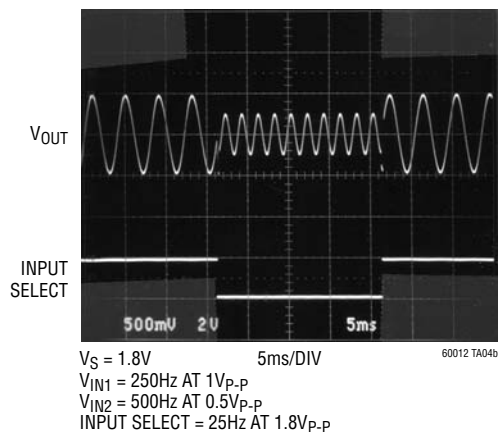   TOP AND BOTTOM OF PACKAGE

TYPICAL APPLICATION

Low Power V-to-F Converter

FREQUENCY OUT ≈ 7.5Hz/mV • V_{IN}
LINEARITY ≈ 5%, V_{IN} 20mV TO 800mV
I_{SUPPLY} ≈ 60µA TO 100µA

MUX Amplifier

MUX Amplifier Waveforms

V_S = 1.8V   5ms/DIV
V_{IN1} = 250Hz AT 1V_{P-P}
V_{IN2} = 500Hz AT 0.5V_{P-P}
INPUT SELECT = 25Hz AT 1.8V_{P-P}

RELATED PARTS

PART NUMBER	DESCRIPTION	COMMENTS
LT2178/LT2179	17µA Dual/Quad Single Supply Op Amps	120µV $V_{OS(MAX)}$, Gain Bandwidth = 60kHz
LT1490A/LT1491A	50µA Dual/Quad Over-The-Top® Rail-to-Rail Input and Output Op Amps	950µV $V_{OS(MAX)}$, Gain Bandwidth = 200kHz
LT1494/LT1495/LT1496	1.5µA Max Single/Dual/Quad Over-The-Top Precision Rail-to-Rail Input and Output Op Amps	375µV $V_{OS(MAX)}$, Gain Bandwidth = 2.7kHz
LT1672/LT1673/LT1674	2µA Max, AV ≥ 5, Single/Dual/Quad Over-The-Top Precision Rail-to-Rail Input and Output Op Amps	Gain of 5 Stable, Gain Bandwidth = 12kHz
LT1782	Micropower, Over-The-Top SOT-23 Rail-to-Rail Input and Output Op Amps	SOT-23, 800µV $V_{OS(MAX)}$, I_S = 55µA (Max), Gain Bandwidth = 200kHz, Shutdown Pin

Over-The-Top is a registered trademark of Linear Technology Corporation.

600012fa

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