

LT6220/LT6221/LT6222

ABSOLUTE MAXIMUM RATINGS (Note 1)

Total Supply Voltage (V_S^- to V_S^+)	12.6V	Maximum Junction Temperature	150°C
Input Voltage (Note 2).....	$\pm V_S$	(DD Package).....	125°C
Input Current (Note 2).....	$\pm 10\text{mA}$	Storage Temperature.....	-65°C to 150°C
Output Short Circuit Duration (Note 3)	Indefinite	(DD Package).....	-65°C to 125°C
Operating Temperature Range (Note 4)....	-40°C to 85°C	Lead Temperature (Soldering, 10 sec.).....	300°C
Specified Temperature Range (Note 5)	-40°C to 85°C		

PIN CONFIGURATION

TOP VIEW S5 PACKAGE 5-LEAD PLASTIC TSOT-23 $T_{JMAX} = 150^{\circ}\text{C}$, $\theta_{JA} = 250^{\circ}\text{C/W}$ (NOTE 10)	TOP VIEW S8 PACKAGE 8-LEAD PLASTIC SO $T_{JMAX} = 150^{\circ}\text{C}$, $\theta_{JA} = 190^{\circ}\text{C/W}$	
TOP VIEW DD PACKAGE 8-LEAD (3mm x 3mm) PLASTIC DFN $T_{JMAX} = 125^{\circ}\text{C}$, $\theta_{JA} = 160^{\circ}\text{C/W}$ (NOTE 10) EXPOSED PAD INTERNALLY CONNECTED TO V_S^- (PCB CONNECTION OPTIONAL)	TOP VIEW S8 PACKAGE 8-LEAD PLASTIC SO $T_{JMAX} = 150^{\circ}\text{C}$, $\theta_{JA} = 190^{\circ}\text{C/W}$	TOP VIEW GN PACKAGE 16-LEAD NARROW PLASTIC SSOP $T_{JMAX} = 150^{\circ}\text{C}$, $\theta_{JA} = 135^{\circ}\text{C/W}$

ORDER INFORMATION

LEAD FREE FINISH	TAPE AND REEL	PART MARKING	PACKAGE DESCRIPTION	SPECIFIED TEMPERATURE RANGE
LT6220CS5#PBF	LT6220CS5#TRPBF	LTAFP	5-Lead Plastic TSOT-23	0°C to 70°C
LT6220IS5#PBF	LT6220IS5#TRPBF	LTAFP	5-Lead Plastic TSOT-23	-40°C to 85°C
LT6220CS8#PBF	LT6220CS8#TRPBF	6220	8-Lead Plastic SO	0°C to 70°C
LT6220IS8#PBF	LT6220IS8#TRPBF	6220I	8-Lead Plastic SO	-40°C to 85°C
LT6221CDD#PBF	LT6221CDD#TRPBF	LADZ	8-Lead (3mm x 3mm) Plastic DFN	0°C to 70°C
LT6221IDD#PBF	LT6221IDD#TRPBF	LADZ	8-Lead (3mm x 3mm) Plastic DFN	-40°C to 85°C
LT6221CS8#PBF	LT6221CS8#TRPBF	6221	8-Lead Plastic SO	0°C to 70°C
LT6221IS8#PBF	LT6221IS8#TRPBF	6221I	8-Lead Plastic SO	-40°C to 85°C
LT6222CGN#PBF	LT6222CGN#TRPBF	6222	16-Lead Narrow Plastic SSOP	0°C to 70°C
LT6222IGN#PBF	LT6222IGN#TRPBF	6222I	16-Lead Narrow Plastic SSOP	-40°C to 85°C

Consult LTC Marketing for parts specified with wider operating temperature ranges.

Consult LTC Marketing for information on nonstandard lead based finish parts.

For more information on lead free part marking, go to: <http://www.linear.com/leadfree/>

For more information on tape and reel specifications, go to: <http://www.linear.com/tapeandree/>

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ELECTRICAL CHARACTERISTICS $T_A = 25^\circ\text{C}$, $V_S = 5\text{V}$, 0V ; $V_S = 3\text{V}$, 0V ; $V_{CM} = V_{OUT} = \text{half supply}$, unless otherwise noted.

SYMBOL	PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
V_{OS}	Input Offset Voltage	$V_{CM} = 0\text{V}$		70	350	μV
		$V_{CM} = 0\text{V}$ (DD Package)		150	700	μV
		$V_{CM} = 0\text{V}$ (S5 Package)		200	850	μV
		$V_{CM} = V_S$		0.5	2.5	mV
		$V_{CM} = V_S$ (S5 Package)		0.5	3	mV
ΔV_{OS}	Input Offset Voltage Shift	$V_S = 5\text{V}$, $V_{CM} = 0\text{V}$ to 3.5V		30	195	μV
		$V_S = 3\text{V}$, $V_{CM} = 0\text{V}$ to 1.5V		15	120	μV
	Input Offset Voltage Match (Channel-to-Channel) (Note 9)	$V_{CM} = 0\text{V}$		100	600	μV
		$V_{CM} = 0\text{V}$ (DD Package)		150	1100	μV
I_B	Input Bias Current	$V_{CM} = 1\text{V}$		15	150	nA
		$V_{CM} = V_S$		250	600	nA
	Input Bias Current Match (Channel-to-Channel) (Note 9)	$V_{CM} = 1\text{V}$		15	175	nA
		$V_{CM} = V_S$		20	250	nA
I_{OS}	Input Offset Current	$V_{CM} = 1\text{V}$		15	100	nA
		$V_{CM} = V_S$		15	100	nA
	Input Noise Voltage	0.1Hz to 10Hz		0.5		μV_{P-P}
e_n	Input Noise Voltage Density	$f = 10\text{kHz}$		10		$\text{nV}/\sqrt{\text{Hz}}$
i_n	Input Noise Current Density	$f = 10\text{kHz}$		0.8		$\text{pA}/\sqrt{\text{Hz}}$
C_{IN}	Input Capacitance			2		pF
A_{VOL}	Large Signal Voltage Gain	$V_S = 5\text{V}$, $V_{OUT} = 0.5\text{V}$ to 4.5V , $R_L = 1\text{k}$ at $V_S/2$	35	100		V/mV
		$V_S = 5\text{V}$, $V_{OUT} = 1\text{V}$ to 4V , $R_L = 100\Omega$ at $V_S/2$	3.5	10		V/mV
		$V_S = 3\text{V}$, $V_{OUT} = 0.5\text{V}$ to 2.5V , $R_L = 1\text{k}$ at $V_S/2$	30	90		V/mV
CMRR	Common Mode Rejection Ratio	$V_S = 5\text{V}$, $V_{CM} = 0\text{V}$ to 3.5V	85	102		dB
		$V_S = 3\text{V}$, $V_{CM} = 0\text{V}$ to 1.5V	82	102		dB
	CMRR Match (Channel-to-Channel) (Note 9)	$V_S = 5\text{V}$, $V_{CM} = 0\text{V}$ to 3.5V	79	100		dB
		$V_S = 3\text{V}$, $V_{CM} = 0\text{V}$ to 1.5V	76	100		dB
	Input Common Mode Range		0		V_S	V
PSRR	Power Supply Rejection Ratio	$V_S = 2.5\text{V}$ to 10V , $V_{CM} = 0\text{V}$	84	105		dB
			79	105		dB
	PSRR Match (Channel-to-Channel) (Note 9)					dB
	Minimum Supply Voltage (Note 6)			2.2	2.5	V
V_{OL}	Output Voltage Swing LOW (Note 7)	No Load		5	40	mV
		$I_{SINK} = 5\text{mA}$		100	200	mV
		$I_{SINK} = 20\text{mA}$		325	650	mV
V_{OH}	Output Voltage Swing HIGH (Note 7)	No Load		5	40	mV
		$I_{SOURCE} = 5\text{mA}$		130	250	mV
		$I_{SOURCE} = 20\text{mA}$		475	900	mV
I_{SC}	Short-Circuit Current	$V_S = 5\text{V}$	20	45		mA
		$V_S = 3\text{V}$	20	35		mA
I_S	Supply Current Per Amplifier			0.9	1	mA
GBW	Gain-Bandwidth Product	$V_S = 5\text{V}$, Frequency = 1MHz	35	60		MHz
SR	Slew Rate	$V_S = 5\text{V}$, $A_V = -1$, $R_L = 1\text{k}$, $V_{OUT} = 4\text{V}$	10	20		V/ μs
FPBW	Full Power Bandwidth	$V_S = 5\text{V}$, $A_V = 1$, $V_{OUT} = 4V_{P-P}$		1.6		MHz
HD	Harmonic Distortion	$V_S = 5\text{V}$, $A_V = 1$, $R_L = 1\text{k}$, $V_{OUT} = 2V_{P-P}$, $f_C = 500\text{kHz}$		-77.5		dBc
t_S	Settling Time	0.01%, $V_S = 5\text{V}$, $V_{STEP} = 2\text{V}$, $A_V = 1$, $R_L = 1\text{k}$		300		ns
ΔG	Differential Gain (NTSC)	$V_S = 5\text{V}$, $A_V = 2$, $R_L = 1\text{k}$		0.3		%
$\Delta\theta$	Differential Phase (NTSC)	$V_S = 5\text{V}$, $A_V = 2$, $R_L = 1\text{k}$		0.3		Deg

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ELECTRICAL CHARACTERISTICS The ● denotes the specifications which apply over the $0^{\circ}\text{C} \leq T_A \leq 70^{\circ}\text{C}$ temperature range. $V_S = 5\text{V}, 0\text{V}$; $V_S = 3\text{V}, 0\text{V}$; $V_{CM} = V_{OUT} = \text{half supply}$, unless otherwise noted.

SYMBOL	PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
V_{OS}	Input Offset Voltage	$V_{CM} = 0\text{V}$	●	90	500	μV
		$V_{CM} = 0\text{V}$ (DD Package)	●	180	850	μV
		$V_{CM} = 0\text{V}$ (S5 Package)	●	230	1250	μV
		$V_{CM} = V_S$	●	0.5	3	mV
		$V_{CM} = V_S$ (S5 Package)	●	0.5	3.5	mV
ΔV_{OS}	Input Offset Voltage Shift	$V_S = 5\text{V}, V_{CM} = 0\text{V}$ to 3.5V	●	30	280	μV
		$V_S = 3\text{V}, V_{CM} = 0\text{V}$ to 1.5V	●	15	190	μV
	Input Offset Voltage Match (Channel-to-Channel) (Note 9)	$V_{CM} = 0\text{V}$	●	110	850	μV
		$V_{CM} = 0\text{V}$ (DD Package)	●	180	1400	μV
$V_{OS\ TC}$	Input Offset Voltage Drift (Note 8)	(S5 Package)	●	1.5	5	$\mu\text{V}/^{\circ}\text{C}$
I_B	Input Bias Current	$V_{CM} = 1\text{V}$	●	20	175	nA
		$V_{CM} = V_S - 0.2\text{V}$	●	275	800	nA
	Input Bias Current Match (Channel-to-Channel) (Note 9)	$V_{CM} = 1\text{V}$	●	15	200	nA
		$V_{CM} = V_S - 0.2\text{V}$	●	20	300	nA
I_{OS}	Input Offset Current	$V_{CM} = 1\text{V}$	●	15	125	nA
		$V_{CM} = V_S - 0.2\text{V}$	●	15	125	nA
A_{VOL}	Large Signal Voltage Gain	$V_S = 5\text{V}, V_{OUT} = 0.5\text{V}$ to $4.5\text{V}, R_L = 1\text{k}\Omega$ at $V_S/2$	●	30	90	V/mV
		$V_S = 5\text{V}, V_{OUT} = 1\text{V}$ to $4\text{V}, R_L = 100\Omega$ at $V_S/2$	●	3	9	V/mV
		$V_S = 3\text{V}, V_{OUT} = 0.5\text{V}$ to $2.5\text{V}, R_L = 1\text{k}\Omega$ at $V_S/2$	●	25	80	V/mV
CMRR	Common Mode Rejection Ratio	$V_S = 5\text{V}, V_{CM} = 0\text{V}$ to 3.5V	●	82	100	dB
		$V_S = 3\text{V}, V_{CM} = 0\text{V}$ to 1.5V	●	78	100	dB
	CMRR Match (Channel-to-Channel) (Note 9)	$V_S = 5\text{V}, V_{CM} = 0\text{V}$ to 3.5V	●	77	100	dB
		$V_S = 3\text{V}, V_{CM} = 0\text{V}$ to 1.5V	●	73	100	dB
	Input Common Mode Range		●	0	V_S	V
PSRR	Power Supply Rejection Ratio	$V_S = 2.5\text{V}$ to $10\text{V}, V_{CM} = 0\text{V}$	●	81	104	dB
			●	76	104	dB
	PSRR Match (Channel-to-Channel) (Note 9)		●	76	104	dB
	Minimum Supply Voltage (Note 6)		●	2.2	2.5	V
V_{OL}	Output Voltage Swing LOW (Note 7)	No Load	●	8	50	mV
		$I_{SINK} = 5\text{mA}$	●	110	220	mV
		$I_{SINK} = 20\text{mA}$	●	375	750	mV
V_{OH}	Output Voltage Swing HIGH (Note 7)	No Load	●	8	50	mV
		$I_{SOURCE} = 5\text{mA}$	●	150	300	mV
		$I_{SOURCE} = 20\text{mA}$	●	600	1100	mV
I_{SC}	Short-Circuit Current	$V_S = 5\text{V}$	●	20	40	mA
		$V_S = 3\text{V}$	●	20	30	mA
I_S	Supply Current Per Amplifier		●	1	1.4	mA
GBW	Gain-Bandwidth Product	$V_S = 5\text{V}$, Frequency = 1MHz	●	30	60	MHz
SR	Slew Rate	$V_S = 5\text{V}, AV = -1, R_L = 1\text{k}\Omega, V_{OUT} = 4V_{P-P}$	●	9	18	V/ μs

ELECTRICAL CHARACTERISTICS

The ● denotes the specifications which apply over the $-40^{\circ}\text{C} \leq T_A \leq 85^{\circ}\text{C}$ temperature range. $V_S = 5\text{V}$, 0V ; $V_S = 3\text{V}$, 0V ; $V_{CM} = V_{OUT} = \text{half supply}$, unless otherwise noted. (Note 5)

SYMBOL	PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
V_{OS}	Input Offset Voltage	$V_{CM} = 0\text{V}$ ●		125	700	μV
		$V_{CM} = 0\text{V}$ (DD Package) ●		300	1300	μV
		$V_{CM} = 0\text{V}$ (S5 Package) ●		350	2000	μV
		$V_{CM} = V_S$ ●		0.75	3.5	mV
		$V_{CM} = V_S$ (S5 Package) ●		1	4.5	mV
ΔV_{OS}	Input Offset Voltage Shift	$V_S = 5\text{V}$, $V_{CM} = 0\text{V}$ to 3.5V ●		30	300	μV
		$V_S = 3\text{V}$, $V_{CM} = 0\text{V}$ to 1.5V ●		30	210	μV
	Input Offset Voltage Match (Channel-to-Channel) (Note 9)	$V_{CM} = 0\text{V}$ ●		175	1200	μV
		$V_{CM} = 0\text{V}$ (DD Package) ●		300	2200	μV
$V_{OS\ TC}$	Input Offset Voltage Drift (Note 8)	●		1.5	7.5	$\mu\text{V}/^{\circ}\text{C}$
		(S5 Package) ●		3.5	15	$\mu\text{V}/^{\circ}\text{C}$
I_B	Input Bias Current	$V_{CM} = 1\text{V}$ ●		25	200	nA
		$V_{CM} = V_S - 0.2\text{V}$ ●		300	900	nA
	Input Bias Current Match (Channel-to-Channel) (Note 9)	$V_{CM} = 1\text{V}$ ●		15	250	nA
		$V_{CM} = V_S - 0.2\text{V}$ ●		20	350	nA
I_{OS}	Input Offset Current	$V_{CM} = 1\text{V}$ ●		20	150	nA
		$V_{CM} = V_S - 0.2\text{V}$ ●		20	150	nA
A_{VOL}	Large Signal Voltage Gain	$V_S = 5\text{V}$, $V_{OUT} = 0.5\text{V}$ to 4.5V , $R_L = 1\text{k}$ at $V_S/2$ ●	25	70		V/mV
		$V_S = 5\text{V}$, $V_{OUT} = 1.5\text{V}$ to 3.5V , $R_L = 100\Omega$ at $V_S/2$ ●	2.5	8		V/mV
		$V_S = 3\text{V}$, $V_{OUT} = 0.5\text{V}$ to 2.5V , $R_L = 1\text{k}$ at $V_S/2$ ●	20	60		V/mV
CMRR	Common Mode Rejection Ratio	$V_S = 5\text{V}$, $V_{CM} = 0\text{V}$ to 3.5V ●	81	100		dB
		$V_S = 3\text{V}$, $V_{CM} = 0\text{V}$ to 1.5V ●	77	100		dB
	CMRR Match (Channel-to-Channel) (Note 9)	$V_S = 5\text{V}$, $V_{CM} = 0\text{V}$ to 3.5V ●	76	100		dB
		$V_S = 3\text{V}$, $V_{CM} = 0\text{V}$ to 1.5V ●	72	100		dB
	Input Common Mode Range	●	0		V_S	V
PSRR	Power Supply Rejection Ratio	$V_S = 2.5\text{V}$ to 10V , $V_{CM} = 0\text{V}$ ●	79	104		dB
	PSRR Match (Channel-to-Channel) (Note 9)	●	74	104		dB
	Minimum Supply Voltage (Note 6)	●		2.2	2.5	V
V_{OL}	Output Voltage Swing LOW (Note 7)	No Load ●		10	60	mV
		$I_{SINK} = 5\text{mA}$ ●		120	240	mV
		$I_{SINK} = 10\text{mA}$ ●		220	450	mV
V_{OH}	Output Voltage Swing HIGH (Note 7)	No Load ●		10	60	mV
		$I_{SOURCE} = 5\text{mA}$ ●		160	325	mV
		$I_{SOURCE} = 10\text{mA}$ ●		325	650	mV
I_{SC}	Short-Circuit Current	$V_S = 5\text{V}$ ●	12.5	30		mA
		$V_S = 3\text{V}$ ●	12.5	25		mA
I_S	Supply Current Per Amplifier	●		1.1	1.5	mA
GBW	Gain-Bandwidth Product	$V_S = 5\text{V}$, Frequency = 1MHz ●	25	50		MHz
SR	Slew Rate	$V_S = 5\text{V}$, $A_V = -1$, $R_L = 1\text{k}$, $V_{OUT} = 4\text{V}$ ●	8	15		V/ μs

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ELECTRICAL CHARACTERISTICS

$T_A = 25^\circ\text{C}$, $V_S = \pm 5\text{V}$, $V_{CM} = 0\text{V}$, $V_{OUT} = 0\text{V}$, unless otherwise noted.

SYMBOL	PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
V_{OS}	Input Offset Voltage	$V_{CM} = -5\text{V}$		80	500	μV
		$V_{CM} = -5\text{V}$ (DD Package)		150	750	μV
		$V_{CM} = -5\text{V}$ (S5 Package)		200	900	μV
		$V_{CM} = 5\text{V}$		0.7	2.5	mV
		$V_{CM} = 5\text{V}$ (S5 Package)		0.7	3	mV
ΔV_{OS}	Input Offset Voltage Shift	$V_{CM} = -5\text{V}$ to 3.5V		70	675	μV
	Input Offset Voltage Match (Channel-to-Channel) (Note 9)	$V_{CM} = -5\text{V}$		100	850	μV
		$V_{CM} = -5\text{V}$ (DD Package)		150	1300	μV
I_B	Input Bias Current	$V_{CM} = -4\text{V}$		20	150	nA
		$V_{CM} = 5\text{V}$		250	700	nA
	Input Bias Current Match (Channel-to-Channel)	$V_{CM} = -4\text{V}$		15	175	nA
		$V_{CM} = 5\text{V}$		20	250	nA
I_{OS}	Input Offset Current	$V_{CM} = -4\text{V}$		15	100	nA
		$V_{CM} = 5\text{V}$		15	100	nA
	Input Noise Voltage	0.1Hz to 10Hz		0.5		μV_{P-P}
e_n	Input Noise Voltage Density	$f = 10\text{kHz}$		10		$\text{nV}/\sqrt{\text{Hz}}$
i_n	Input Noise Current Density	$f = 10\text{kHz}$		0.8		$\text{pA}/\sqrt{\text{Hz}}$
C_{IN}	Input Capacitance	$f = 100\text{kHz}$		2		pF
A_{VOL}	Large Signal Voltage Gain	$V_{OUT} = -4\text{V}$ to 4V , $R_L = 1\text{k}$	35	95		V/mV
		$V_{OUT} = -2\text{V}$ to 2V , $R_L = 100\Omega$	3.5	10		V/mV
CMRR	Common Mode Rejection Ratio	$V_{CM} = -5\text{V}$ to 3.5V	82	102		dB
	CMRR Match (Channel-to-Channel)		77	100		dB
	Input Common Mode Range		V_S^-		V_S^+	V
PSRR	Power Supply Rejection Ratio	$V_S^+ = 2.5\text{V}$ to 10V , $V_S^- = 0\text{V}$, $V_{CM} = 0\text{V}$	84	105		dB
	PSRR Match (Channel-to-Channel)		79	105		dB
V_{OL}	Output Voltage Swing LOW (Note 7)	No Load		5	40	mV
		$I_{SINK} = 5\text{mA}$		100	200	mV
		$I_{SINK} = 20\text{mA}$		325	650	mV
V_{OH}	Output Voltage Swing HIGH (Note 7)	No Load		5	40	mV
		$I_{SOURCE} = 5\text{mA}$		130	250	mV
		$I_{SOURCE} = 20\text{mA}$		475	900	mV
I_{SC}	Short-Circuit Current		25	50		mA
I_S	Supply Current Per Amplifier			1	1.5	mA
GBW	Gain-Bandwidth Product	Frequency = 1MHz		60		MHz
SR	Slew Rate	$A_V = -1$, $R_L = 1\text{k}$, $V_{OUT} = \pm 4\text{V}$, Measure at $V_{OUT} = \pm 2\text{V}$		20		V/ μs
FPBW	Full Power Bandwidth	$V_{OUT} = 8\text{V}_{P-P}$		0.8		MHz
HD	Harmonic Distortion	$A_V = 1$, $R_L = 1\text{k}$, $V_{OUT} = 2\text{V}_{P-P}$, $f_C = 500\text{kHz}$		-77.5		dBc
t_S	Settling Time	0.01%, $V_{STEP} = 5\text{V}$, $A_V = 1$, $R_L = 1\text{k}$		375		ns
ΔG	Differential Gain (NTSC)	$A_V = 2$, $R_L = 1\text{k}$		0.15		%
$\Delta\theta$	Differential Phase (NTSC)	$A_V = 2$, $R_L = 1\text{k}$		0.6		Deg

ELECTRICAL CHARACTERISTICS

The ● denotes the specifications which apply over the $0^{\circ}\text{C} \leq T_A \leq 70^{\circ}\text{C}$ temperature range. $V_S = \pm 5\text{V}$, $V_{CM} = 0\text{V}$, $V_{OUT} = 0\text{V}$, unless otherwise noted.

SYMBOL	PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
V_{OS}	Input Offset Voltage	$V_{CM} = -5\text{V}$	●	100	650	μV
		$V_{CM} = -5\text{V}$ (DD Package)	●	180	900	μV
		$V_{CM} = -5\text{V}$ (S5 Package)	●	230	1300	μV
		$V_{CM} = 5\text{V}$	●	0.75	3	mV
		$V_{CM} = 5\text{V}$ (S5 Package)	●	0.75	3.5	mV
ΔV_{OS}	Input Offset Voltage Shift	$V_{CM} = -5\text{V}$ to 3.5V	●	90	850	μV
	Input Offset Voltage Match (Channel-to-Channel) (Note 9)	$V_{CM} = -5\text{V}$ $V_{CM} = -5\text{V}$ (DD Package)	● ●	90 180	1100 1500	μV μV
$V_{OS\ TC}$	Input Offset Voltage Drift (Note 8)	(S5 Package)	●	1.5	5	$\mu\text{V}/^{\circ}\text{C}$
			●	3.5	10	$\mu\text{V}/^{\circ}\text{C}$
I_B	Input Bias Current	$V_{CM} = -4\text{V}$	●	20	175	nA
		$V_{CM} = 4.8\text{V}$	●	275	800	nA
	Input Bias Current Match (Channel-to-Channel) (Note 9)	$V_{CM} = -4\text{V}$ $V_{CM} = 4.8\text{V}$	● ●	15 20	200 300	nA nA
I_{OS}	Input Offset Current	$V_{CM} = -4\text{V}$	●	15	125	nA
		$V_{CM} = 4.8\text{V}$	●	15	125	nA
A_{VOL}	Large Signal Voltage Gain	$V_{OUT} = -4\text{V}$ to 4V , $R_L = 1\text{k}$	●	30	90	V/mV
		$V_{OUT} = -2\text{V}$ to 2V , $R_L = 100\Omega$	●	3	9	V/mV
CMRR	Common Mode Rejection Ratio	$V_{CM} = -5\text{V}$ to 3.5V	●	80	100	dB
	CMRR Match (Channel-to-Channel) (Note 9)		●	75	100	dB
	Input Common Mode Range		●	V_S^-	V_S^+	V
PSRR	Power Supply Rejection Ratio	$V_S^+ = 2.5\text{V}$ to 10V , $V_S^- = 0\text{V}$, $V_{CM} = 0\text{V}$	●	81	104	dB
	PSRR Match (Channel-to-Channel) (Note 9)		●	76	104	dB
V_{OL}	Output Voltage Swing LOW (Note 7)	No Load	●	8	50	mV
		$I_{SINK} = 5\text{mA}$	●	110	220	mV
		$I_{SINK} = 20\text{mA}$	●	375	750	mV
V_{OH}	Output Voltage Swing HIGH (Note 7)	No Load	●	8	50	mV
		$I_{SOURCE} = 5\text{mA}$	●	150	300	mV
		$I_{SOURCE} = 20\text{mA}$	●	600	1100	mV
I_{SC}	Short-Circuit Current		●	20	40	mA
I_S	Supply Current Per Amplifier		●	1.2	2	mA
GBW	Gain-Bandwidth Product	Frequency = 1MHz	●	60		MHz
SR	Slew Rate	$A_V = -1$, $R_L = 1\text{k}$, $V_{OUT} = \pm 4\text{V}$, Measure at $V_{OUT} = \pm 2\text{V}$	●	18		V/ μs

LT6220/LT6221/LT6222

ELECTRICAL CHARACTERISTICS

The ● denotes the specifications which apply over the $-40^{\circ}\text{C} \leq T_A \leq 85^{\circ}\text{C}$ temperature range. $V_S = \pm 5\text{V}$, $V_{CM} = 0\text{V}$, $V_{OUT} = 0\text{V}$, unless otherwise noted. (Note 5)

SYMBOL	PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
V_{OS}	Input Offset Voltage	$V_{CM} = -5\text{V}$	●	150	800	μV
		$V_{CM} = -5\text{V}$ (DD Package)	●	300	1300	μV
		$V_{CM} = -5\text{V}$ (S5 Package)	●	350	2000	μV
		$V_{CM} = 5\text{V}$	●	0.75	3.5	mV
		$V_{CM} = 5\text{V}$ (S5 Package)	●	1	4.5	mV
ΔV_{OS}	Input Offset Voltage Shift	$V_{CM} = -5\text{V}$ to 3.5V	●	90	950	μV
	Input Offset Voltage Match (Channel-to-Channel) (Note 9)	$V_{CM} = -5\text{V}$	●	175	1350	μV
		$V_{CM} = -5\text{V}$ (DD Package)	●	300	2200	μV
$V_{OS\ TC}$	Input Offset Voltage Drift (Note 8)	(S5 Package)	●	1.5	7.5	$\mu\text{V}/^{\circ}\text{C}$
			●	3.5	15	$\mu\text{V}/^{\circ}\text{C}$
I_B	Input Bias Current	$V_{CM} = -4\text{V}$	●	25	200	nA
		$V_{CM} = 4.8\text{V}$	●	300	900	nA
	Input Bias Current Match (Channel-to-Channel) (Note 9)	$V_{CM} = -4\text{V}$	●	15	250	nA
		$V_{CM} = 4.8\text{V}$	●	20	350	nA
I_{OS}	Input Offset Current	$V_{CM} = -4\text{V}$	●	20	150	nA
		$V_{CM} = 4.8\text{V}$	●	20	150	nA
A_{VOL}	Large Signal Voltage Gain	$V_{OUT} = -4\text{V}$ to 4V , $R_L = 1\text{k}$	●	25	70	V/mV
		$V_{OUT} = -1\text{V}$ to 1V , $R_L = 100\Omega$	●	2.5	8	V/mV
CMRR	Common Mode Rejection Ratio	$V_{CM} = -5\text{V}$ to 3.5V	●	79	100	dB
	CMRR Match (Channel-to-Channel) (Note 9)		●	74	100	dB
	Input Common Mode Range		●	-5	5	V
PSRR	Power Supply Rejection Ratio	$V_S^+ = 2.5\text{V}$ to 10V , $V_S^- = 0\text{V}$, $V_{CM} = 0\text{V}$	●	79	104	dB
	PSRR Match (Channel-to-Channel) (Note 9)		●	74	104	dB
V_{OL}	Output Voltage Swing LOW (Note 7)	No Load	●	10	60	mV
		$I_{SINK} = 5\text{mA}$	●	120	240	mV
		$I_{SINK} = 10\text{mA}$	●	220	450	mV
V_{OH}	Output Voltage Swing HIGH (Note 7)	No Load	●	10	60	mV
		$I_{SOURCE} = 5\text{mA}$	●	160	325	mV
		$I_{SOURCE} = 10\text{mA}$	●	325	650	mV
I_{SC}	Short-Circuit Current		●	12.5	30	mA
I_S	Supply Current		●	1.4	2.25	mA
GBW	Gain-Bandwidth Product	Frequency = 1MHz	●	50		MHz
SR	Slew Rate	$A_V = -1$, $R_L = 1\text{k}$, $V_{OUT} = \pm 4\text{V}$, Measure at $V_{OUT} = \pm 2\text{V}$	●	15		V/ μs

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: The inputs are protected by back-to-back diodes. If the differential input voltage exceeds 1.4V , the input current should be limited to less than 10mA .

Note 3: A heat sink may be required to keep the junction temperature below the absolute maximum rating when the output is shorted indefinitely.

Note 4: The LT6220C/LT6221C/LT6222C and LT6220I/LT6221I/LT6222I are guaranteed functional over the temperature range of -40°C and 85°C .

Note 5: The LT6220C/LT6221C/LT6222C are guaranteed to meet specified performance from 0°C to 70°C . The LT6220C/LT6221C/LT6222C 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

LT6220I/LT6221I/LT6222I are guaranteed to meet specified performance from -40°C to 85°C .

Note 6: Minimum supply voltage is guaranteed by power supply rejection ratio test.

Note 7: Output voltage swings are measured between the output and power supply rails.

Note 8: This parameter is not 100% tested.

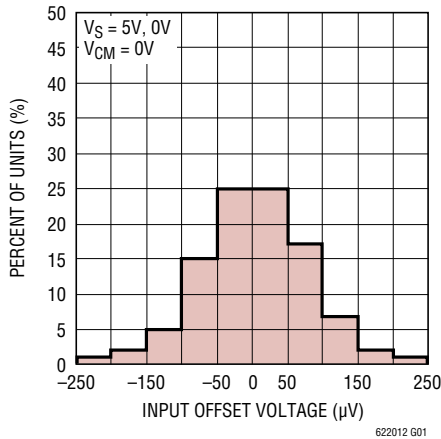
Note 9: Matching parameters are the difference between amplifiers A and D and between B and C on the LT6222; between the two amplifiers on the LT6221.

Note 10: Thermal resistance (θ_{JA}) varies with the amount of PC board metal connected to the package. The specified values are for short traces connected to the leads. If desired, the thermal resistance can be substantially reduced by connecting Pin 2 of the LT6220CS5/LT6220IS5 or the underside metal of DD packages to a larger metal area (V_S^- trace).

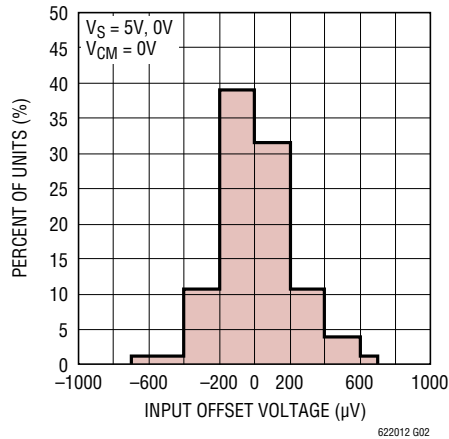
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TYPICAL PERFORMANCE CHARACTERISTICS

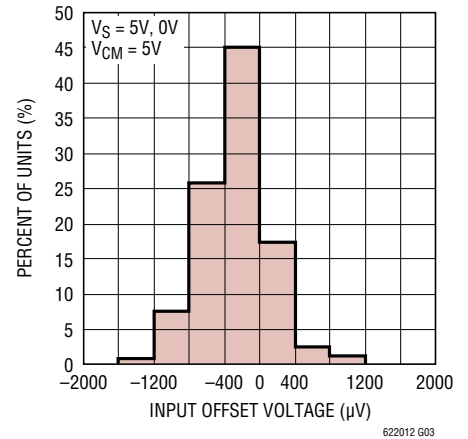
**V_{OS} Distribution, $V_{CM} = 0V$
(S8, PNP Stage)**



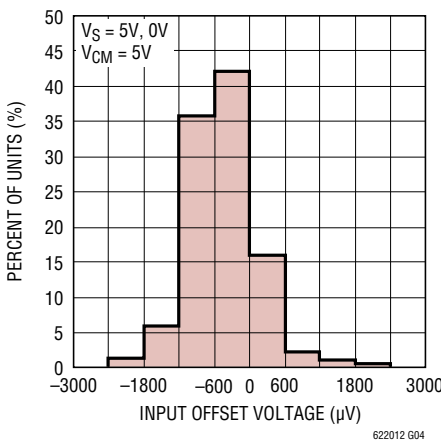
**V_{OS} Distribution, $V_{CM} = 0V$
(SOT5, PNP Stage)**



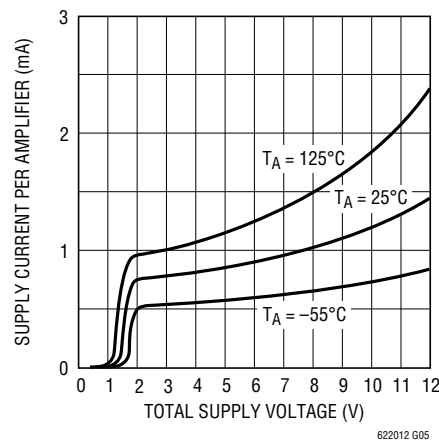
**V_{OS} Distribution, $V_{CM} = 5V$
(S8, NPN Stage)**



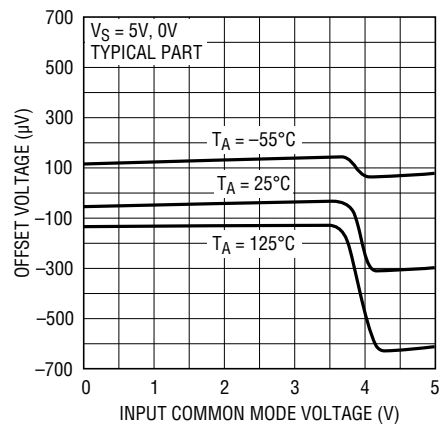
**V_{OS} Distribution, $V_{CM} = 5V$
(SOT5, NPN Stage)**



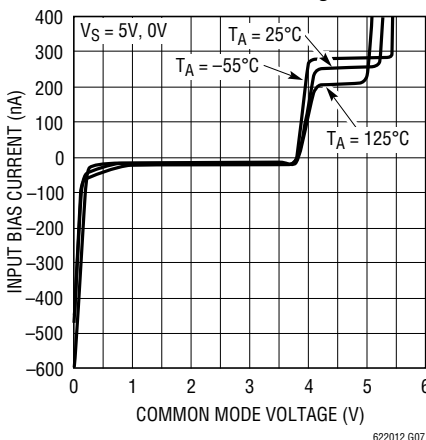
Supply Current vs Supply Voltage



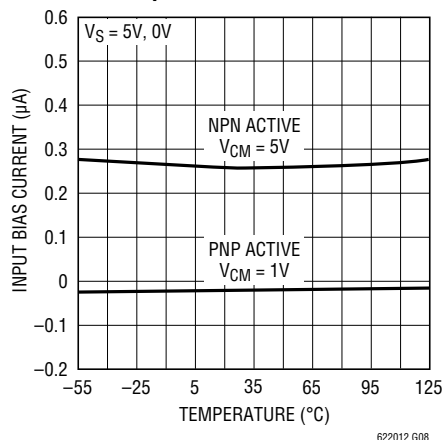
Offset Voltage vs Input Common Mode Voltage



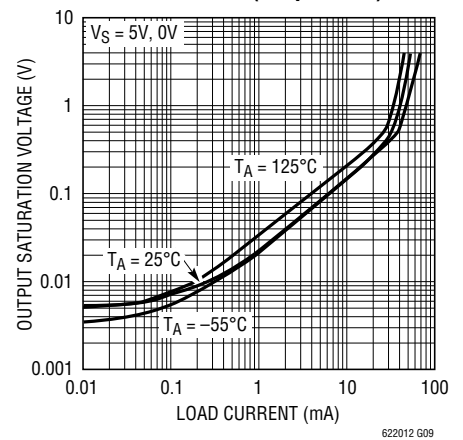
Input Bias Current vs Common Mode Voltage



Input Bias Current vs Temperature

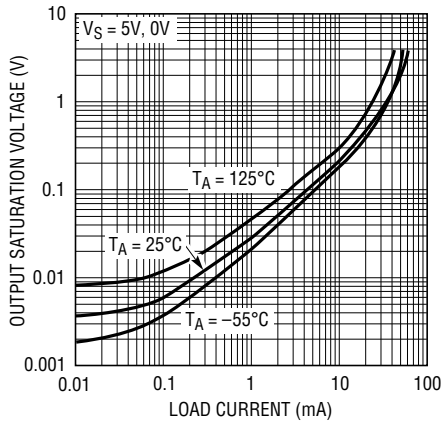


Output Saturation Voltage vs Load Current (Output Low)

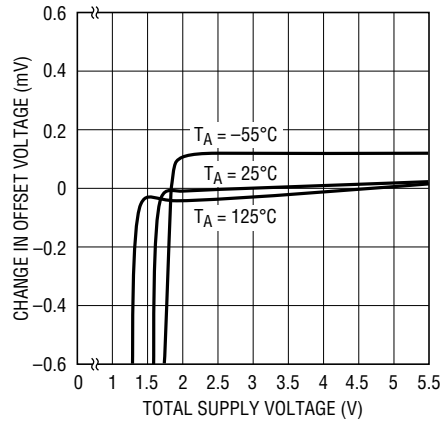


TYPICAL PERFORMANCE CHARACTERISTICS

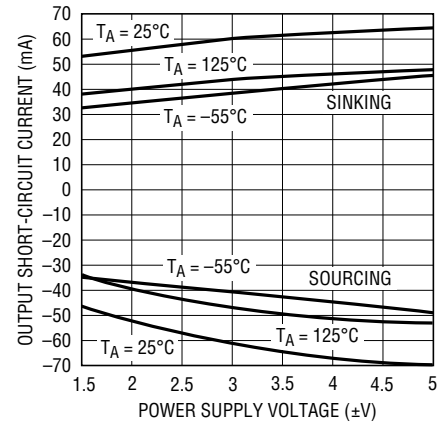
Output Saturation Voltage vs Load Current (Output High)



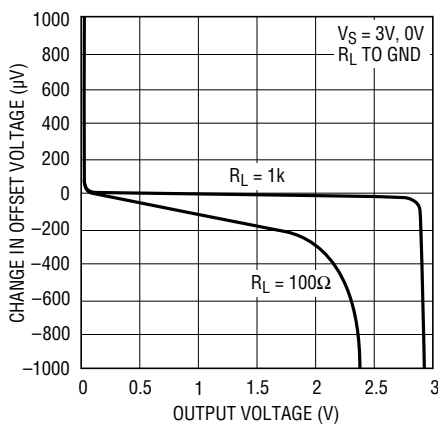
Minimum Supply Voltage



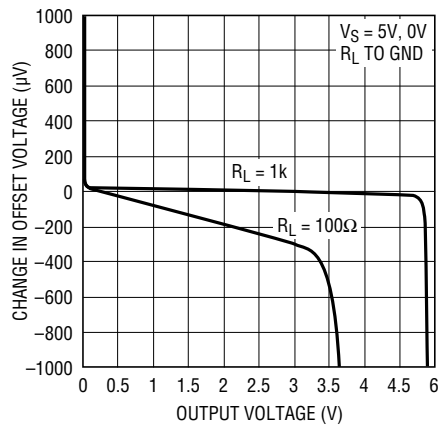
Output Short-Circuit Current vs Power Supply Voltage



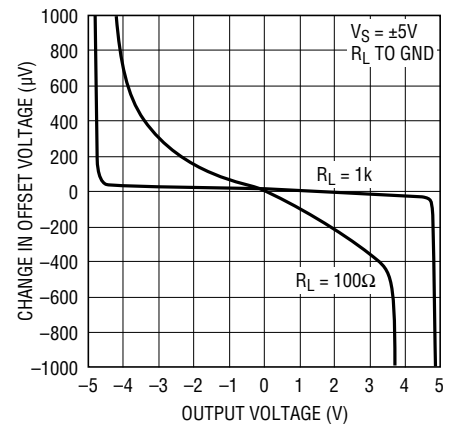
Open-Loop Gain



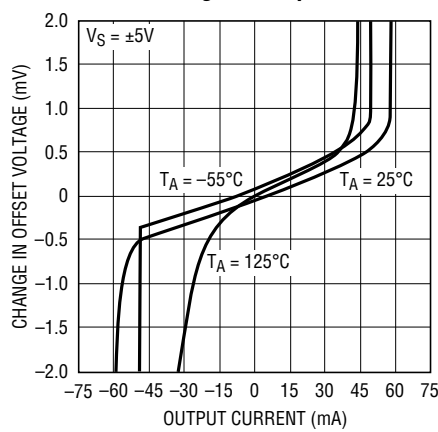
Open-Loop Gain



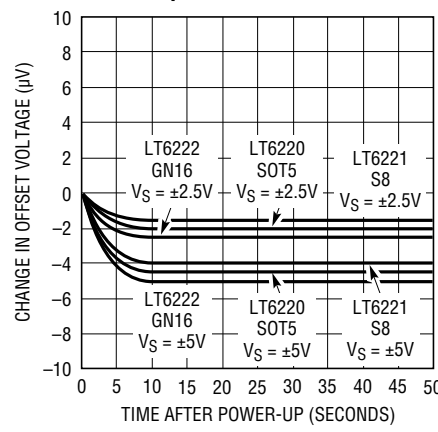
Open-Loop Gain



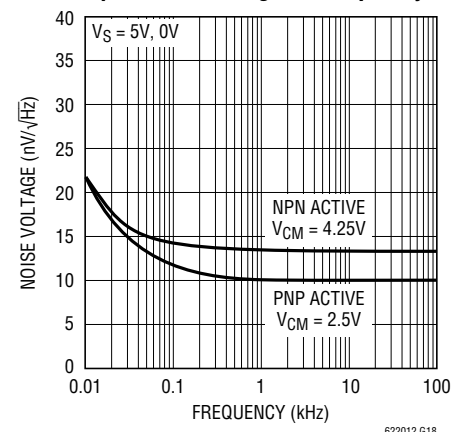
Offset Voltage vs Output Current



Warm-Up Drift vs Time

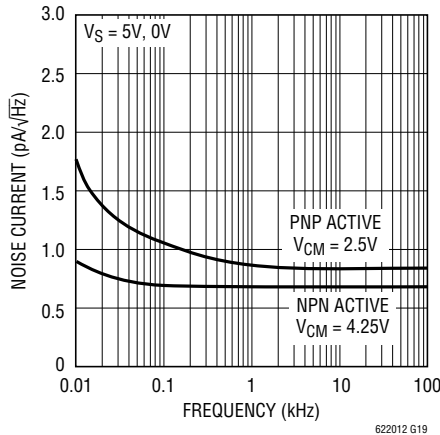


Input Noise Voltage vs Frequency

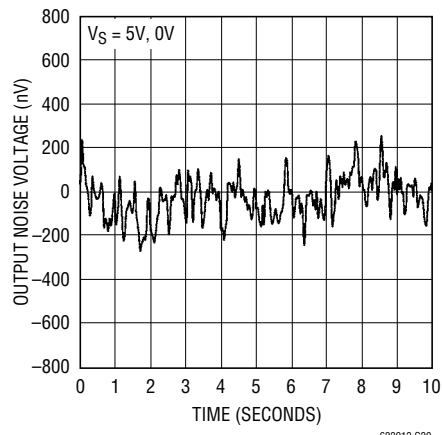


TYPICAL PERFORMANCE CHARACTERISTICS

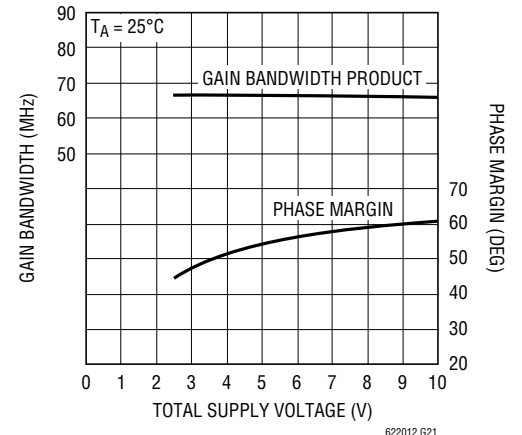
Input Current Noise vs Frequency



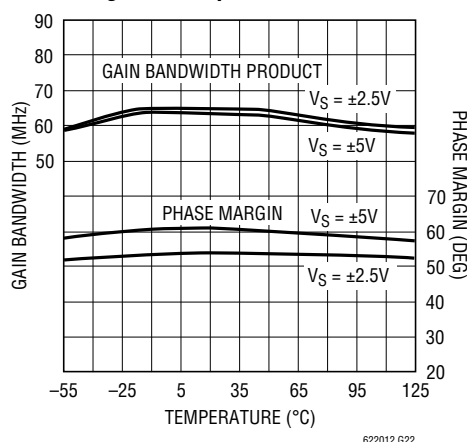
0.1Hz to 10Hz Output Voltage Noise



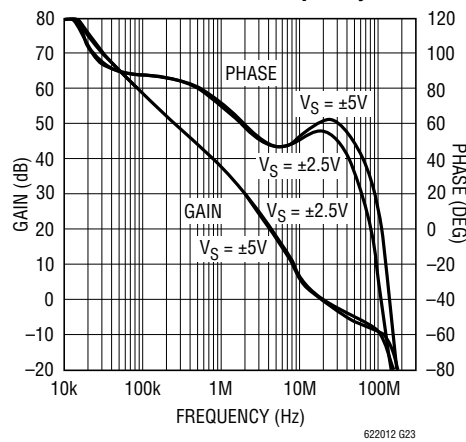
Gain Bandwidth and Phase Margin vs Supply Voltage



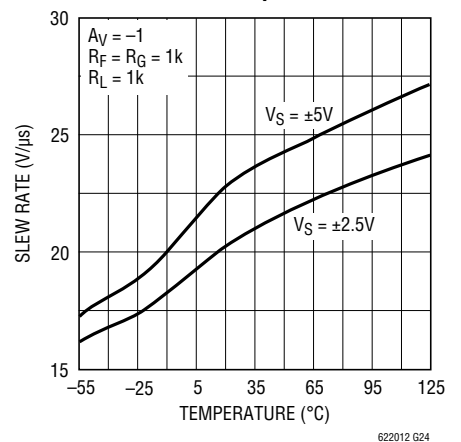
Gain Bandwidth and Phase Margin vs Temperature



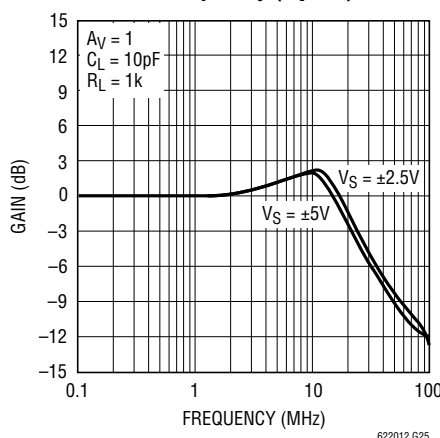
Gain and Phase vs Frequency



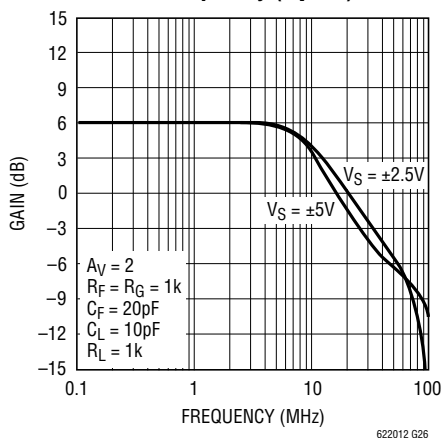
Slew Rate vs Temperature



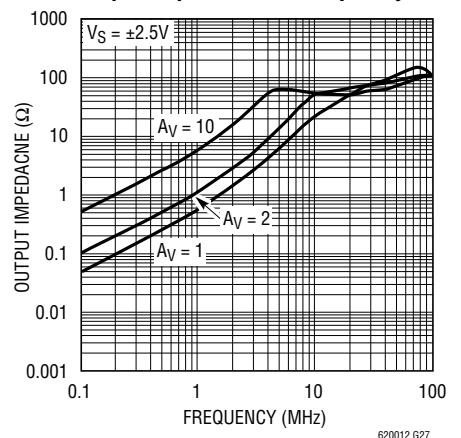
Gain vs Frequency ($A_V = 1$)



Gain vs Frequency ($A_V = 2$)

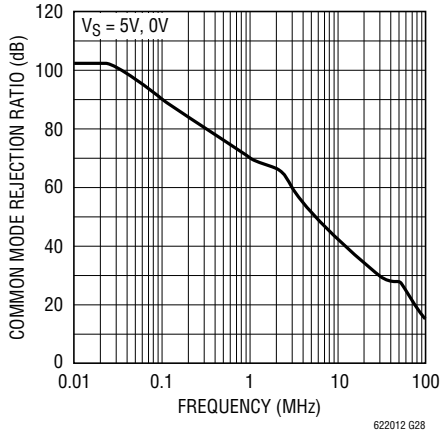


Output Impedance vs Frequency

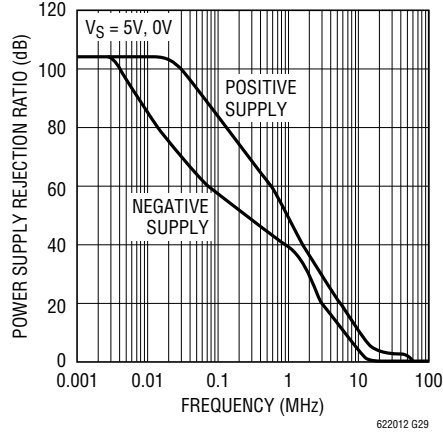


TYPICAL PERFORMANCE CHARACTERISTICS

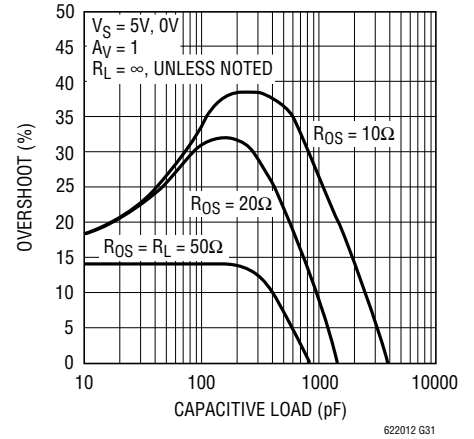
Common Mode Rejection Ratio vs Frequency



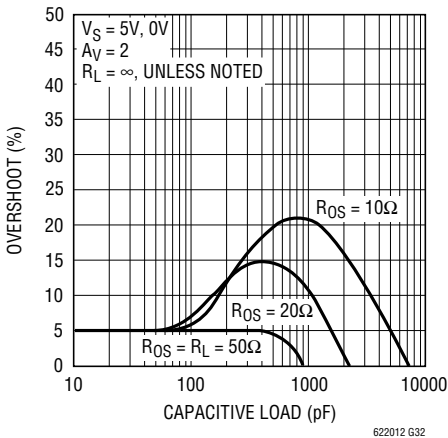
Power Supply Rejection Ratio vs Frequency



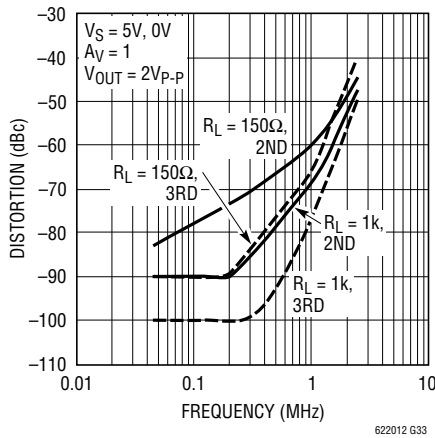
Series Output Resistor vs Capacitive Load



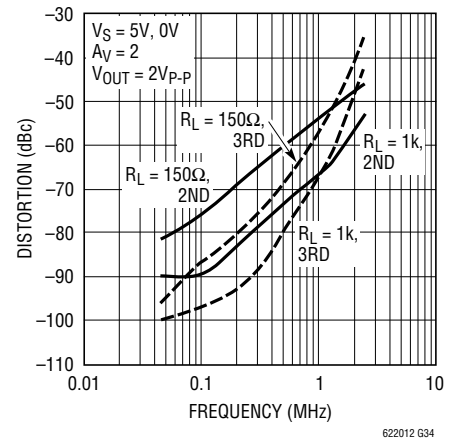
Series Output Resistor vs Capacitive Load



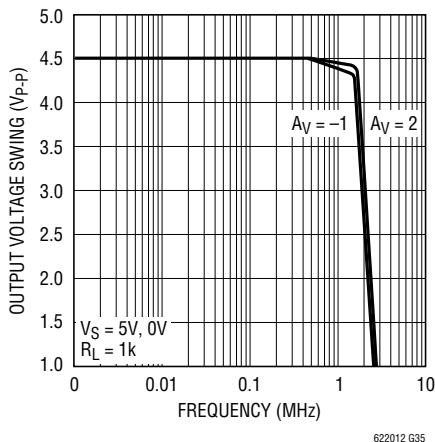
Distortion vs Frequency



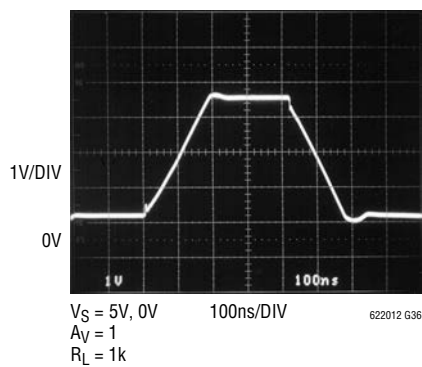
Distortion vs Frequency



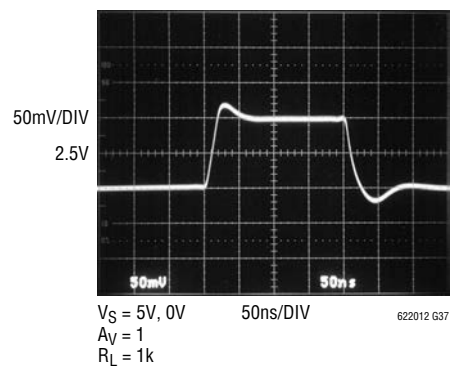
Maximum Undistorted Output Signal vs Frequency



5V Large-Signal Response

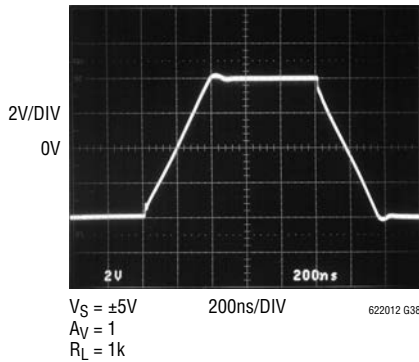


5V Small-Signal Response

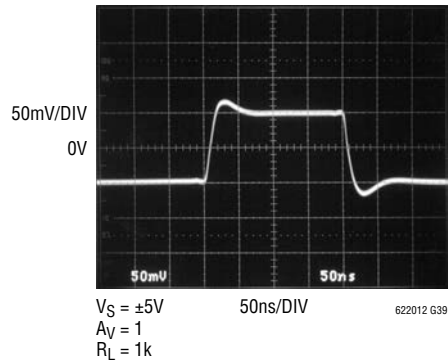


TYPICAL PERFORMANCE CHARACTERISTICS

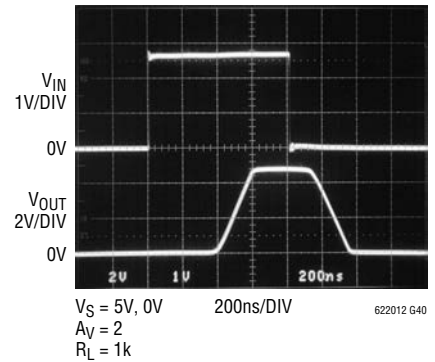
±5V Large-Signal Response



±5V Small-Signal Response



Output Overdriven Recovery



APPLICATIONS INFORMATION

Circuit Description

The LT6220/LT6221/LT6222 have an input and output signal range that covers from the negative power supply to the positive power supply. Figure 1 depicts a simplified schematic of the amplifier. The input stage comprises two differential amplifiers, a PNP stage, Q1/Q2, and an NPN stage, Q3/Q4, that are active over different ranges of common mode input voltage. The PNP stage is active between the negative supply to approximately 1.2V below the positive supply. As the input voltage moves closer toward the positive supply, the transistor Q5 will steer the

tail current, I_1 , to the current mirror, Q6/Q7, activating the NPN differential pair and the PNP pair becomes inactive for the rest of the input common mode range up to the positive supply. Also, at the input stage, devices Q17 to Q19 act to cancel the bias current of the PNP input pair. When Q1/Q2 are active, the current in Q16 is controlled to be the same as the current Q1/Q2. Thus, the base current of Q16 is nominally equal to the base current of the input devices. The base current of Q16 is then mirrored by devices Q17-Q19 to cancel the base current of the input devices Q1/Q2.

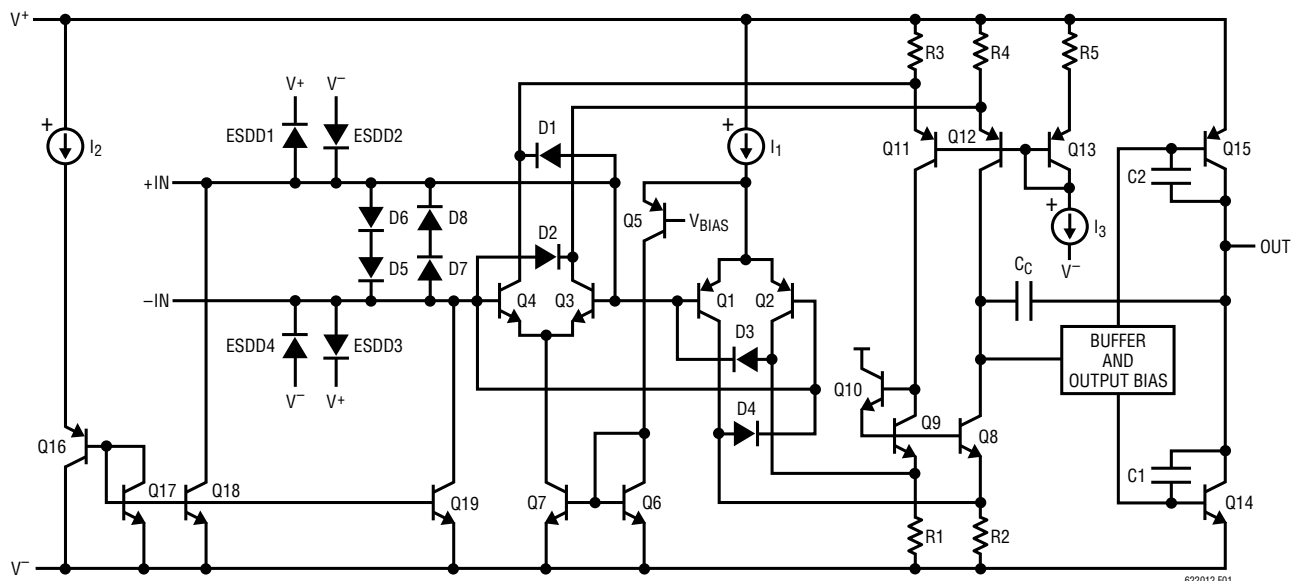


Figure 1. LT6220/LT6221/LT6222 Simplified Schematic Diagram

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APPLICATIONS INFORMATION

A pair of complementary common emitter stages Q14/Q15 that enable the output to swing from rail-to-rail construct the output stage. The capacitors C2 and C3 form the local feedback loops that lower the output impedance at high frequency. These devices are fabricated by Linear Technology's proprietary high speed complementary bipolar process.

Power Dissipation

The LT6222, with four amplifiers, is housed in a small 16-lead SSOP package and typically has a thermal resistance (θ_{JA}) of 135°C/W. It is necessary to ensure that the die's junction temperature does not exceed 150°C. The junction temperature, T_J , is calculated from the ambient temperature, T_A , power dissipation, P_D , and thermal resistance, θ_{JA} :

$$T_J = T_A + (P_D \cdot \theta_{JA})$$

The power dissipation in the IC is the function of the supply voltage, output voltage and the load resistance. For a given supply voltage, the worst-case power dissipation $P_{D(MAX)}$ occurs when the maximum supply current and the output voltage is at half of either supply voltage for a given load resistance. $P_{D(MAX)}$ is given by:

$$P_{D(MAX)} = (V_S \cdot I_{S(MAX)}) + \left(\frac{V_S}{2} \right)^2 / R_L$$

Example: For an LT6222 in a 16-lead SSOP package operating on $\pm 5V$ supplies and driving a 100 Ω load, the worst-case power dissipation is given by:

$$\begin{aligned} P_{D(MAX)}/\text{Amp} &= (10 \cdot 1.8\text{mA}) + (2.5)^2 / 100 \\ &= 0.018 + 0.0625 = 80.5\text{mW} \end{aligned}$$

If all four amplifiers are loaded simultaneously, then the total power dissipation is 322mW.

The maximum ambient temperature at which the part is allowed to operate is:

$$\begin{aligned} T_A &= T_J - (P_{D(MAX)} \cdot 135^\circ\text{C/W}) \\ &= 150^\circ\text{C} - (0.322\text{W} \cdot 135^\circ\text{C/W}) = 106.5^\circ\text{C} \end{aligned}$$

Input Offset Voltage

The offset voltage will change depending upon which input stage is active. The PNP input stage is active from the negative supply rail to 1.2V below the positive supply rail, then the NPN input stage is activated for the remaining input range up to the positive supply rail during which the PNP stage remains inactive. The offset voltage is typically less than 70 μ V in the range that the PNP input stage is active.

Input Bias Current

The LT6220/LT6221/LT6222 employ a patent pending technique to trim the input bias current to less than 150nA for the input common mode voltage of 0.2V above the negative supply rail to 1.2V below the positive rail. The low input offset voltage and low input bias current of the LT6220/LT6221/LT6222 provide precision performance especially for high source impedance applications.

Output

The LT6220/LT6221/LT6222 can deliver a large output current, so the short-circuit current limit is set around 50mA to prevent damage to the device. Attention must be paid to keep the junction temperature of the IC below the absolute maximum rating of 150°C (refer to the Power Dissipation section) when the output is in continuous short circuit. The output of the amplifier has reverse-biased diodes connected to each supply. If the output is forced beyond either supply, unlimited current will flow through these diodes. If the current is transient and limited to several hundred milliamperes, no damage will occur to the device.

Overdrive Protection

When the input voltage exceeds the power supplies, two pair of crossing diodes, D1 to D4, will prevent the output from reversing polarity. If the input voltage exceeds either power supply by 700mV, diode D1/D2 or D3/D4 will turn on to keep the output at the proper polarity. For the phase reversal protection to perform properly, the input current must be limited to less than 5mA. If the amplifier

TYPICAL APPLICATIONS

As the signal level increases though, the output of the op amp goes more negative. At 12.5μA of photodiode current, the 100kΩ gain dictates that the LT6220 output will be about 1.25V below ground. However, at that point the emitter of Q2 will be at ground, and the base of Q1 will be 1V below ground. Thus, Q1 turns on and photodiode current starts to flow through R2. The transimpedance gain is therefore now reduced to R1||R2, or about 3.1kΩ. The circuit response is shown in Figure 3. Note the smooth transition between the two operating gains, as well as the linearity.

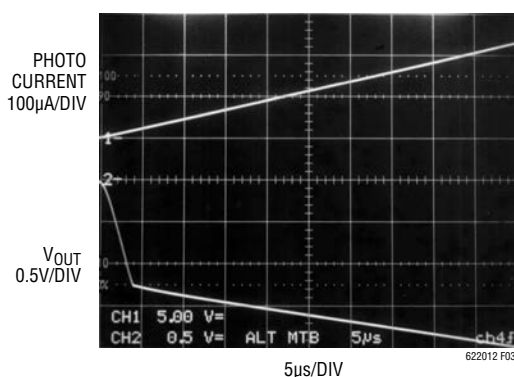


Figure 3. Stepped-Gain Photodiode Amplifier Response

Single 3V Supply, 1MHz, 4th Order Butterworth Filter

The circuit shown in Figure 4 makes use of the low voltage operation and the wide bandwidth of the LT6221 to create a DC accurate 1MHz 4th order lowpass filter powered from a 3V supply. The amplifiers are configured in the inverting mode for the lowest distortion and the output can swing rail-to-rail for maximum dynamic range. Figure 5 displays the frequency response of the filter. Stopband attenuation is greater than 100dB at 50MHz.

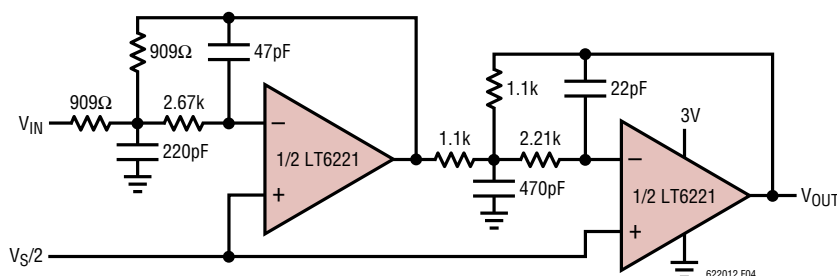


Figure 4. 3V, 1MHz, 4th Order Butterworth Filter

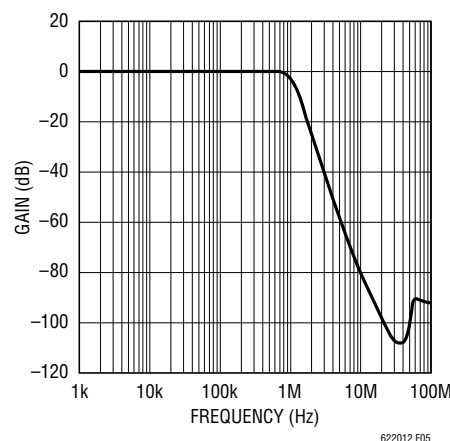


Figure 5. Frequency Response of Filter

Differential-In/Differential-Out Amplifier

The circuit of Figure 6 shows the LT6222 applied as a buffered differential-in differential-out amplifier with a gain of 2. Op amps A and B are configured as simple unity-gain buffers, offering high input impedance to upstream circuitry. Resistors R1 and R2 perform an averaging function on the common mode input voltage and R3 attenuates it by a factor of 2/3 and references it to the voltage source V_{OCM} . The resultant voltage, $V_{MID} = 2/3 \cdot V_{ICM}$, is placed at the noninverting inputs of op amps C and D. The other four resistors set gains of +3 from the noninverting input and -2 through the inverting path. Thus the output voltage of the upper path is:

$$\begin{aligned} -OUT &= 3 \cdot (2/3 \cdot V_{ICM} + 1/3 \cdot V_{OCM}) - 2 \\ &\quad \cdot (V_{ICM} + V_{DIFF}/2) \\ &= 2V_{ICM} + V_{OCM} - 2V_{ICM} - V_{DIFF} \\ &= V_{OCM} - V_{DIFF} \end{aligned}$$

TYPICAL APPLICATIONS

and the output of the lower path is:

$$\begin{aligned} +OUT &= 3 \cdot (2/3 \cdot V_{ICM} + 1/3 \cdot V_{OCM}) - 2 \\ &\quad \cdot (V_{ICM} - V_{DIFF}/2) \\ &= 2V_{ICM} + V_{OCM} - 2V_{ICM} + V_{DIFF} \\ &= V_{OCM} + V_{DIFF} \end{aligned}$$

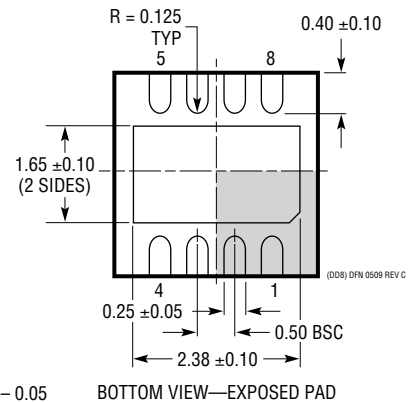
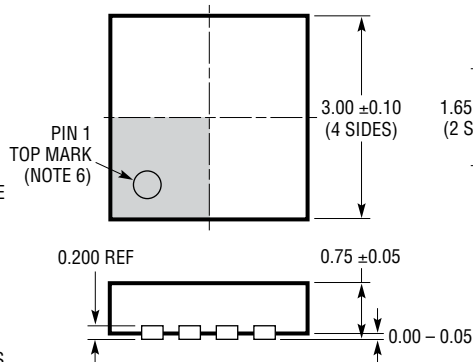
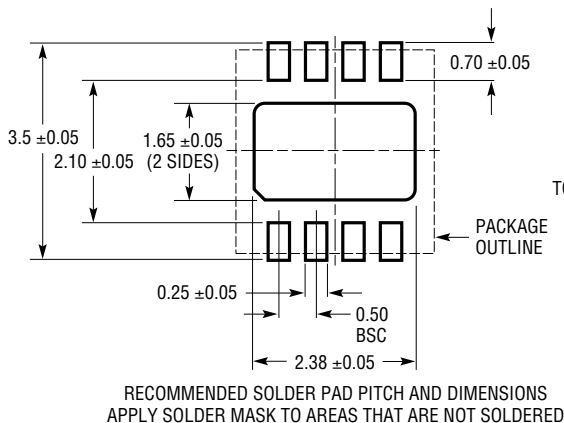
Note that the input common mode voltage does not appear in the output as either a common mode or a difference mode term. However the voltage V_{OCM} does appear in the output terms, and with the same polarity, so it sets up the output DC level. Also, the differential input voltage V_{DIFF} appears fully at both outputs with opposite polarity,

giving rise to the effective differential gain of 2. Calculations show that using 1% resistors gives worst-case input common mode feedthrough better than -31dB , whether looking at the output common mode or difference mode. Considering the 6dB of gain, worst-case common mode rejection ratio is 37dB . (Remember this is assuming 1% resistors. Of course, this can be improved with more precise resistors.) Results achieved on the bench with typical 1% resistors showed 67dB of CMRR at low frequency and 40dB CMRR at 1MHz . Gains other than 2 can be achieved by setting $R3 = \alpha \cdot (R1 || R2)$, $R5 = \alpha \cdot R4$ and $R7 = \alpha \cdot R6$ where gain = α .

PACKAGE DESCRIPTION

Please refer to <http://www.linear.com/designtools/packaging/> for the most recent package drawings.

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



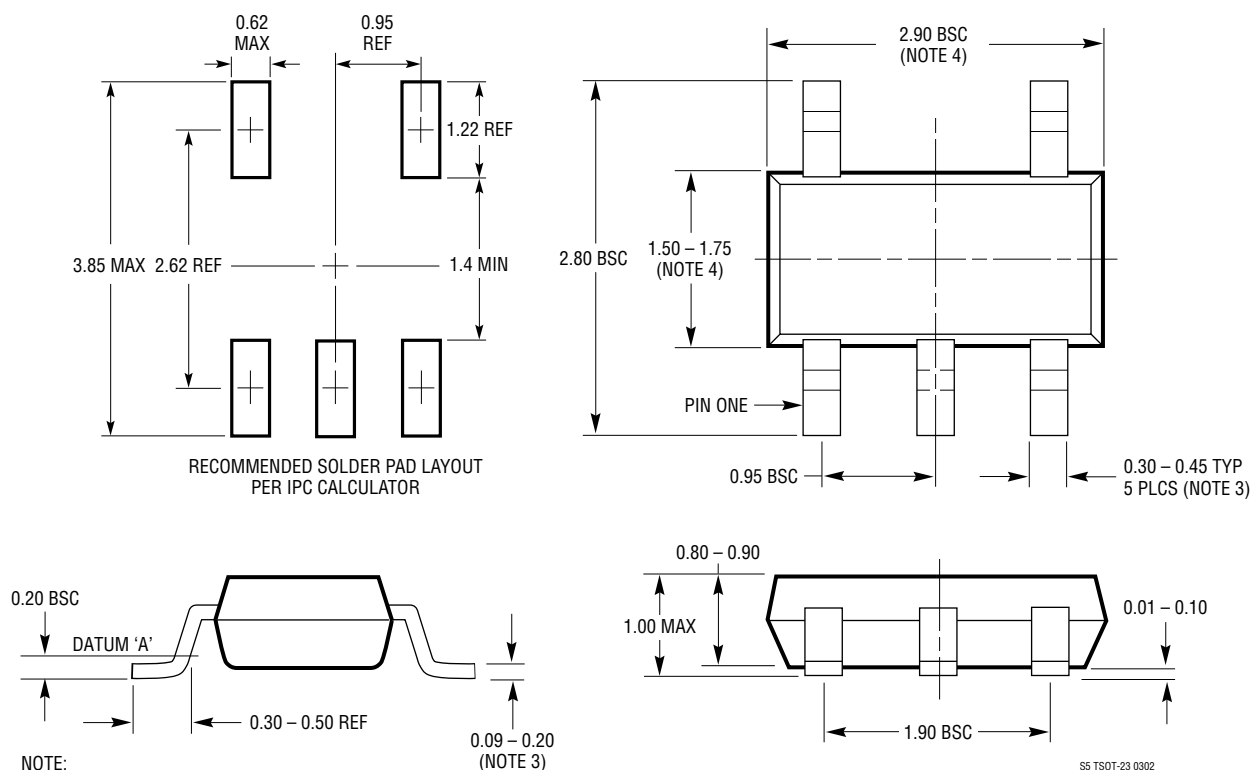
NOTE:

1. DRAWING TO BE MADE A JEDEC PACKAGE OUTLINE MO-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

PACKAGE DESCRIPTION

Please refer to <http://www.linear.com/designtools/packaging/> for the most recent package drawings.

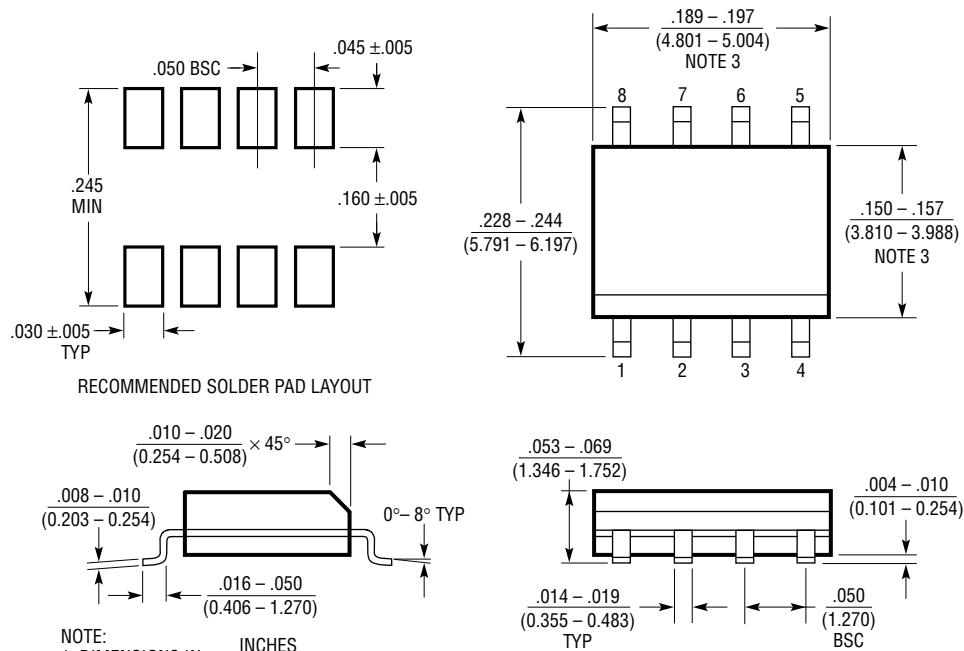
S5 Package 5-Lead Plastic TSOT-23 (Reference LTC DWG # 05-08-1635)



PACKAGE DESCRIPTION

Please refer to <http://www.linear.com/designtools/packaging/> for the most recent package drawings.

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



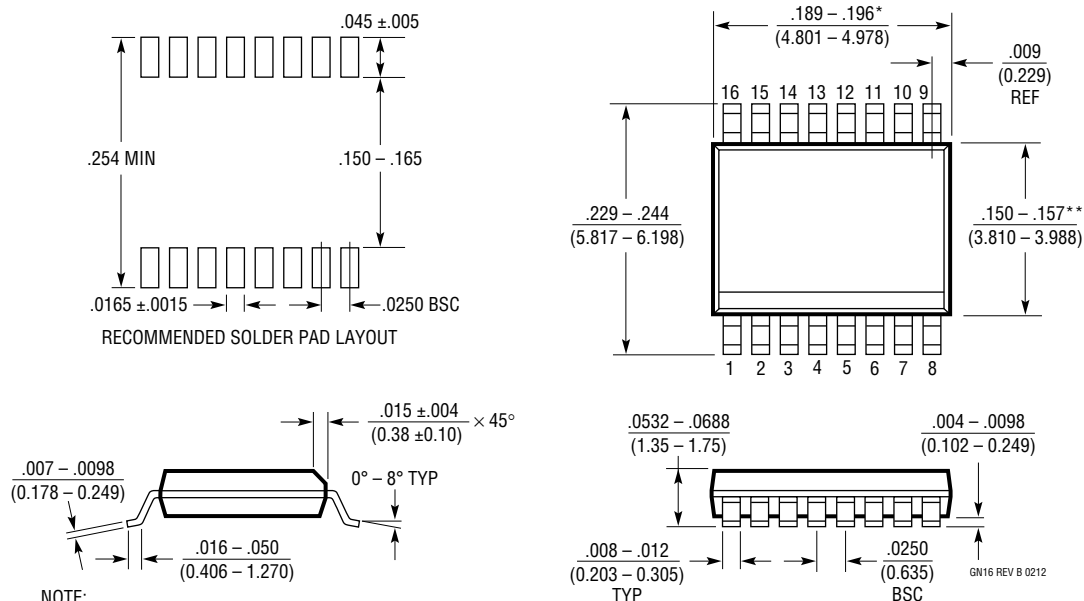
- NOTE:
1. DIMENSIONS IN INCHES (MILLIMETERS)
 2. DRAWING NOT TO SCALE
 3. THESE DIMENSIONS DO NOT INCLUDE MOLD FLASH OR PROTRUSIONS.
MOLD FLASH OR PROTRUSIONS SHALL NOT EXCEED .006" (0.15mm)
 4. PIN 1 CAN BE BEVEL EDGE OR A DIMPLE

S08 REV G 0212

PACKAGE DESCRIPTION

Please refer to <http://www.linear.com/designtools/packaging/> for the most recent package drawings.

GN Package 16-Lead Plastic SSOP (Narrow .150 Inch) (Reference LTC DWG # 05-08-1641 Rev B)



REVISION HISTORY (Revision history begins at Rev B)

REV	DATE	DESCRIPTION	PAGE NUMBER
B	05/14	Added V_{OUT} information to Typical Application.	1
		Updated the Order Information table.	2
C	05/15	Updated Order Information table to reflect Specified Temperature Range	2

TYPICAL APPLICATION

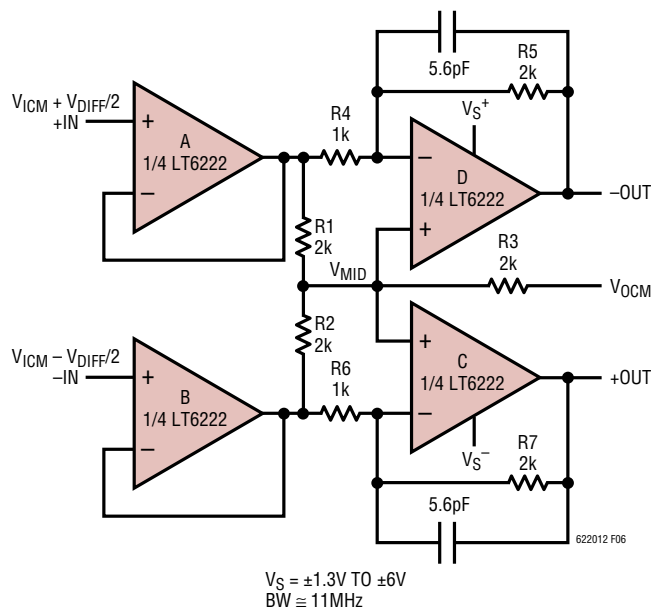


Figure 6. Buffered Gain of 2 Differential-In/Differential-Out Amplifier

RELATED PARTS

PART NUMBER	DESCRIPTION	COMMENTS
LT1498/LT1499	Dual/Quad 10MHz, 6V/μs Rail-to-Rail Input/Output C_{LOAD} Op Amps	High DC Accuracy, 475μV $V_{OS(MAX)}$ Max Supply Current 2.2mA/Amp, Wide Supply Range, 2.2V to 30V
LT1800/LT1801/LT1802	Single/Dual/Quad 80MHz, 25V/μs, Low Power Rail-to-Rail Input/Output Precision Op Amps	350μV $V_{OS(MAX)}$, 250nA $I_{BIAS(MAX)}$, Max Supply Current 2mA/Amp
LT1803/LT1804/LT1805	Single/Dual/Quad 85MHz, 100V/μs Rail-to-Rail Input/Output Op Amps	2mV $V_{OS(MAX)}$, Max Supply Current 3mA/Amp
LT1806/LT1807	Single/Dual 325MHz, 140V/μs Rail-to-Rail Input/Output Op Amps	High DC Accuracy, 550μV $V_{OS(MAX)}$ Max Low Noise 3.5nV/√Hz Low Distortion -80dBc at 5MHz, Power Down (LT1806)
LT1809/LT1810	Single/Dual 180MHz, Rail-to-Rail Input/Output Op Amps	350V/μs Slew Rate, Low Distortion -90dBc at 5MHz, Power Down (LT1809)