60MHz, Rail-to-Rail Output, 1.9nV/√Hz, 1.2mA Op Amp Family

FEATURES

- **Low Noise Voltage: 1.9nV/√Hz**
- **Low Supply Current: 1.2mA/Amp Max**
- **Low Offset Voltage: 350µV Max**
- Gain Bandwidth Product:
  LT6233: 60MHz; $A_V \geq 1$
  LT6233-10: 375MHz; $A_V \geq 10$
- Wide Supply Range: 3V to 12.6V
- Output Swings Rail-to-Rail
- Common Mode Rejection Ratio 115dB Typ
- Output Current: 30mA
- Operating Temperature Range −40°C to 85°C
- LT6233 Shutdown to 10µA Maximum
- LT6233/LT6233-10 in SOT-23 Package
- Dual LT6234 in 8-Pin SO and Tiny DFN Packages
- LT6235 in 16-Pin SSOP Package

APPLICATIONS

- Ultrasound Amplifiers
- Low Noise, Low Power Signal Processing
- Active Filters
- Driving A/D Converters
- Rail-to-Rail Buffer Amplifiers

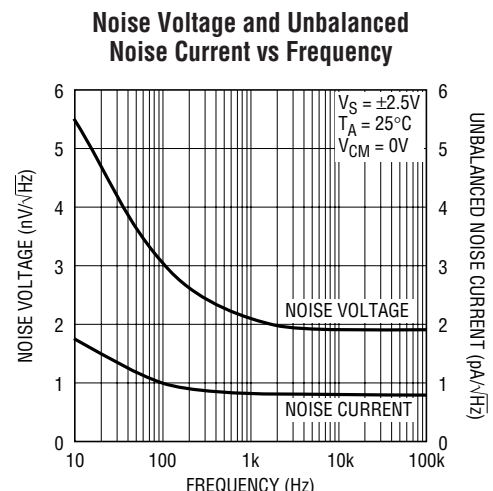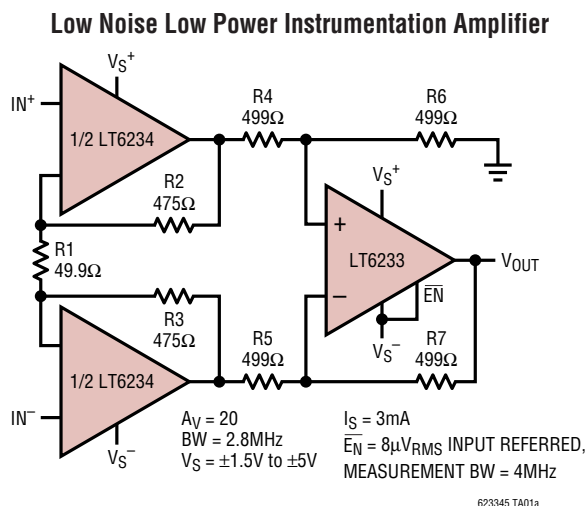*LT*, LTC and LT are registered trademarks of Linear Technology Corporation.

DESCRIPTION

The LT®6233/LT6234/LT6235 are single/dual/quad low noise, rail-to-rail output unity gain stable op amps that feature 1.9nV/√Hz noise voltage and draw only 1.2mA of supply current per amplifier. These amplifiers combine very low noise and supply current with a 60MHz gain bandwidth product, a 17V/µs slew rate and are optimized for low supply voltage signal conditioning systems. The LT6233-10 is a single amplifier optimized for higher gain applications resulting in higher gain bandwidth and slew rate. The LT6233 and LT6233-10 include an enable pin that can be used to reduce the supply current to less than 10µA.

The amplifier family has an output that swings within 50mV of either supply rail to maximize the signal dynamic range in low supply applications and is specified on 3.3V, 5V and ±5V supplies. The $e_n \bullet \sqrt{I_{SUPPLY}}$ product of 2.1 per amplifier is among the most noise efficient of any op amp.

The LT6233/LT6233-10 is available in the 6-lead SOT-23 package and the LT6234 dual is available in the 8-pin SO package with standard pinouts. For compact layouts, the dual is also available in a tiny dual fine pitch leadless package (DFN). The LT6235 is available in the 16-pin SSOP package.
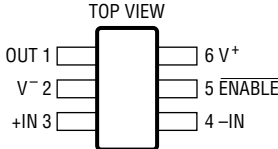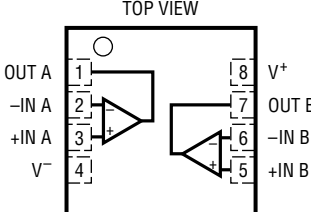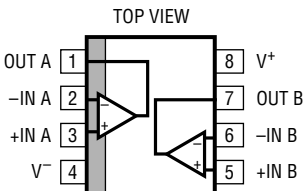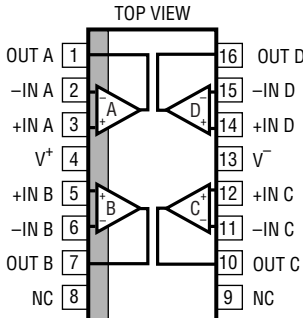
TYPICAL APPLICATION

Low Noise Low Power Instrumentation Amplifier

$A_V = 20$
BW = 2.8MHz
$V_S = \pm 1.5V$ to ±5V
$I_S = 3mA$
$\overline{E}_N = 8\mu V_{RMS}$ INPUT REFERRED,
MEASUREMENT BW = 4MHz

623345 TA01a

Noise Voltage and Unbalanced Noise Current vs Frequency

623345 TA01b

623345fa

ABSOLUTE MAXIMUM RATINGS (Note 1)

Total Supply Voltage (V⁺ to V⁻) 12.6V
Input Current (Note 2) .... ±40mA
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

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

PACKAGE/ORDER INFORMATION

	ORDER PART NUMBER
TOP VIEW OUT 1 — 6 V⁺ V⁻ 2 — 5 ENABLE +IN 3 — 4 −IN S6 PACKAGE 6-LEAD PLASTIC TSOT-23 T_JMAX = 150°C, θ_JA = 250°C/W	LT6233CS6 LT6233IS6 LT6233CS6-10 LT6233IS6-10
	S6 PART MARKING*
	LTAFL LTAFM

$T_{JMAX} = 150°C$, $θ_{JA} = 250°C/W$

	ORDER PART NUMBER
TOP VIEW OUT A 1 — 8 V⁺ −IN A 2 — 7 OUT B +IN A 3 — 6 −IN B V⁻ 4 — 5 +IN B 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)	LT6234CDD LT6234IDD
	DD PART MARKING*
	LAET

	ORDER PART NUMBER
TOP VIEW OUT A 1 — 8 V⁺ −IN A 2 — 7 OUT B +IN A 3 — 6 −IN B V⁻ 4 — 5 +IN B S8 PACKAGE 8-LEAD PLASTIC SO T_JMAX = 150°C, θ_JA = 190°C/W	LT6234CS8 LT6234IS8
	S8 PART MARKING
	6234 6234I

	ORDER PART NUMBER
TOP VIEW OUT A 1 — 16 OUT D −IN A 2 — 15 −IN D +IN A 3 — 14 +IN D V⁺ 4 — 13 V⁻ +IN B 5 — 12 +IN C −IN B 6 — 11 −IN C OUT B 7 — 10 OUT C NC 8 — 9 NC GN PACKAGE 16-LEAD NARROW PLASTIC SSOP T_JMAX = 150°C, θ_JA = 135°C/W	LT6235CGN LT6235IGN
	GN PART MARKING
	6235 6235I

*The temperature grade is identified by a label on the shipping container. Consult LTC Marketing for parts specified with wider operating temperature ranges.

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ELECTRICAL CHARACTERISTICS

$T_A = 25°C$, $V_S = 5V$, 0V; $V_S = 3.3V$, 0V; $V_{CM} = V_{OUT}$ = half supply,
$\overline{ENABLE}$ = 0V, unless otherwise noted.

SYMBOL	PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
V_{OS}	Input Offset Voltage	LT6233S6, LT6233S6-10		100	500	μV
		LT6234S8, LT6235GN		50	350	μV
		LT6234DD		75	450	μV
	Input Offset Voltage Match (Channel-to-Channel) (Note 6)			80	600	μV
I_B	Input Bias Current			1.5	3	μA
	I_B Match (Channel-to-Channel) (Note 6)			0.04	0.3	μA
I_{OS}	Input Offset Current			0.04	0.3	μA
	Input Noise Voltage	0.1Hz to 10Hz		220		nV_{P-P}
e_n	Input Noise Voltage Density	f = 10kHz, $V_S = 5V$		1.9	3	nV/√Hz
i_n	Input Noise Current Density, Balanced Source	f = 10kHz, $V_S = 5V$, $R_S = 10k$		0.43		pA/√Hz
	Unbalanced Source	f = 10kHz, $V_S = 5V$, $R_S = 10k$		0.78		pA/√Hz
	Input Resistance	Common Mode		22		MΩ
		Differential Mode		25		kΩ
C_{IN}	Input Capacitance	Common Mode		2.5		pF
		Differential Mode		4.2		pF
A_{VOL}	Large-Signal Gain	$V_S = 5V$, $V_O = 0.5V$ to 4.5V, $R_L = 10k$ to $V_S/2$	73	140		V/mV
		$R_L = 1k$ to $V_S/2$	18	35		V/mV
		$V_S = 3.3V$, $V_O = 0.65V$ to 2.65V, $R_L = 10k$ to $V_S/2$	53	100		V/mV
		$R_L = 1k$ to $V_S/2$	11	20		V/mV
V_{CM}	Input Voltage Range	Guaranteed by CMRR, $V_S = 5V$, 0V	1.5		4	V
		$V_S = 3.3V$, 0V	1.15		2.65	V
CMRR	Common Mode Rejection Ratio	$V_S = 5V$, $V_{CM} = 1.5V$ to 4V	90	115		dB
		$V_S = 3.3V$, $V_{CM} = 1.15V$ to 2.65V	85	110		dB
	CMRR Match (Channel-to-Channel) (Note 6)	$V_S = 5V$, $V_{CM} = 1.5V$ to 4V	84	115		dB
PSRR	Power Supply Rejection Ratio	$V_S = 3V$ to 10V	90	115		dB
	PSRR Match (Channel-to-Channel) (Note 6)	$V_S = 3V$ to 10V	84	115		dB
	Minimum Supply Voltage (Note 7)		3			V
V_{OL}	Output Voltage Swing LOW (Note 8)	No Load		4	40	mV
		$I_{SINK} = 5mA$		75	180	mV
		$V_S = 5V$, $I_{SINK} = 15mA$		165	320	mV
		$V_S = 3.3V$, $I_{SINK} = 10mA$		125	240	mV
V_{OH}	Output Voltage Swing HIGH (Note 8)	No Load		5	50	mV
		$I_{SOURCE} = 5mA$		85	195	mV
		$V_S = 5V$, $I_{SOURCE} = 15mA$		220	410	mV
		$V_S = 3.3V$, $I_{SOURCE} = 10mA$		165	310	mV
I_{SC}	Short-Circuit Current	$V_S = 5V$	±40	±55		mA
		$V_S = 3.3V$	±35	±50		mA
I_S	Supply Current per Amplifier			1.05	1.2	mA
	Disabled Supply Current per Amplifier	$\overline{ENABLE} = V^+ - 0.35V$		0.2	10	μA

ELECTRICAL CHARACTERISTICS

$T_A = 25°C$, $V_S = 5V$, 0V; $V_S = 3.3V$, 0V; $V_{CM} = V_{OUT}$ = half supply, $\overline{ENABLE}$ = 0V, unless otherwise noted.

SYMBOL	PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
I$_{\overline{ENABLE}}$	$\overline{ENABLE}$ Pin Current	$\overline{ENABLE}$ = 0.3V		−25	−75	μA
V$_L$	$\overline{ENABLE}$ Pin Input Voltage LOW				0.3	V
V$_H$	$\overline{ENABLE}$ Pin Input Voltage HIGH		V$^+$ − 0.35			V
	Output Leakage Current	$\overline{ENABLE}$ = V$^+$ − 0.35V, V$_O$ = 1.5V to 3.5V		0.2	10	μA
t$_{ON}$	Turn-On Time	$\overline{ENABLE}$ = 5V to 0V, R$_L$ = 1k, V$_S$ = 5V		500		ns
t$_{OFF}$	Turn-Off Time	$\overline{ENABLE}$ = 0V to 5V, R$_L$ = 1k, V$_S$ = 5V		76		μs
GBW	Gain Bandwidth Product	Frequency = 1MHz, V$_S$ = 5V LT6233-10		55 320		MHz MHz
SR	Slew Rate	V$_S$ = 5V, A$_V$ = −1, R$_L$ = 1k, V$_O$ = 0.5V to 4.5V	10	15		V/μs
		LT6233-10, V$_S$ = 5V, A$_V$ = −10, R$_L$ = 1k, V$_O$ = 0.5V to 4.5V		80		V/μs
FPBW	Full Power Bandwidth	V$_S$ = 5V, V$_{OUT}$ = 3V$_{P-P}$ (Note 9)	1.06	1.6		MHz
		LT6233-10, HD$_2$ = HD$_3$ ≤ 1%		2.2		MHz
t$_S$	Settling Time (LT6233, LT6234, LT6235)	0.1%, V$_S$ = 5V, V$_{STEP}$ = 2V, A$_V$ = −1, R$_L$ = 1k		175		ns

The ● denotes the specifications which apply over 0°C < T$_A$ < 70°C temperature range. V$_S$ = 5V, 0V; V$_S$ = 3.3V, 0V; V$_{CM}$ = V$_{OUT}$ = half supply, $\overline{ENABLE}$ = 0V, unless otherwise noted.

SYMBOL	PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
V$_{OS}$	Input Offset Voltage	LT6233S6, LT6233S6-10 LT6234S8, LT6235GN LT6234DD	● ● ●			600 450 550	μV μV μV
	Input Offset Voltage Match (Channel-to-Channel) (Note 6)		●			800	μV
V$_{OS}$ TC	Input Offset Voltage Drift (Note 10)	V$_{CM}$ = Half Supply	●		0.5	3.0	μV/°C
I$_B$	Input Bias Current		●			3.5	μA
	I$_B$ Match (Channel-to-Channel) (Note 6)		●			0.4	μA
I$_{OS}$	Input Offset Current		●			0.4	μA
A$_{VOL}$	Large-Signal Gain	V$_S$ = 5V, V$_O$ = 0.5V to 4.5V, R$_L$ = 10k to V$_S$/2 R$_L$ = 1k to V$_S$/2	● ●	47 12			V/mV V/mV
		V$_S$ = 3.3V, V$_O$ = 0.65V to 2.65V, R$_L$ = 10k to V$_S$/2 R$_L$ = 1k to V$_S$/2	● ●	40 7.5			V/mV V/mV
V$_{CM}$	Input Voltage Range	Guaranteed by CMRR, V$_S$ = 5V, 0V V$_S$ = 3.3V, 0V	● ●	1.5 1.15		4 2.65	V V
CMRR	Common Mode Rejection Ratio	V$_S$ = 5V, V$_{CM}$ = 1.5V to 4V V$_S$ = 3.3V, V$_{CM}$ = 1.15V to 2.65V	● ●	90 85			dB dB
	CMRR Match (Channel-to-Channel) (Note 6)	V$_S$ = 5V, V$_{CM}$ = 1.5V to 4V	●	84			dB
PSRR	Power Supply Rejection Ratio	V$_S$ = 3V to 10V	●	90			dB
	PSRR Match (Channel-to-Channel) (Note 6)	V$_S$ = 3V to 10V	●	84			dB
	Minimum Supply Voltage (Note 7)		●	3			V
V$_{OL}$	Output Voltage Swing LOW (Note 8)	No Load I$_{SINK}$ = 5mA V$_S$ = 5V, I$_{SINK}$ = 15mA V$_S$ = 3.3V, I$_{SINK}$ = 10mA	● ● ● ●			50 195 360 265	mV mV mV mV

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ELECTRICAL CHARACTERISTICS

The ● denotes the specifications which apply over 0°C < T$_A$ < 70°C temperature range. V$_S$ = 5V, 0V; V$_S$ = 3.3V, 0V; V$_{CM}$ = V$_{OUT}$ = half supply, $\overline{ENABLE}$ = 0V, unless otherwise noted.

SYMBOL	PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
V$_{OH}$	Output Voltage Swing HIGH (Note 8)	No Load	●			60	mV
		I$_{SOURCE}$ = 5mA	●			205	mV
		V$_S$ = 5V, I$_{SOURCE}$ = 15mA	●			435	mV
		V$_S$ = 3.3V, I$_{SOURCE}$ = 10mA	●			330	mV
I$_{SC}$	Short-Circuit Current	V$_S$ = 5V	●	±35			mA
		V$_S$ = 3.3V	●	±30			mA
I$_S$	Supply Current per Amplifier		●			1.45	mA
	Disabled Supply Current per Amplifier	$\overline{ENABLE}$ = V$^+$ – 0.25V	●		1		μA
I$_{\overline{ENABLE}}$	$\overline{ENABLE}$ Pin Current	$\overline{ENABLE}$ = 0.3V	●			−85	μA
V$_L$	$\overline{ENABLE}$ Pin Input Voltage LOW		●			0.3	V
V$_H$	$\overline{ENABLE}$ Pin Input Voltage HIGH		●	V$^+$ – 0.25			V
	Output Leakage Current	$\overline{ENABLE}$ = V$^+$ – 0.25V, V$_O$ = 1.5V to 3.5V	●		1		μA
t$_{ON}$	Turn-On Time	$\overline{ENABLE}$ = 5V to 0V, R$_L$ = 1k, V$_S$ = 5V	●		500		ns
t$_{OFF}$	Turn-Off Time	$\overline{ENABLE}$ = 0V to 5V, R$_L$ = 1k, V$_S$ = 5V	●		120		μs
SR	Slew Rate	V$_S$ = 5V, A$_V$ = −1, R$_L$ = 1k, V$_O$ = 0.5V to 4.5V	●	9			V/μs
		LT6233-10, A$_V$ = −10, R$_L$ = 1k, V$_O$ = 0.5V to 4.5V	●		75		V/μs
FPBW	Full Power Bandwidth (Note 9)	V$_S$ = 5V, V$_{OUT}$ = 3V$_{P-P}$ LT6233, LT6234, LT6235	●	955			kHz

The ● denotes the specifications which apply over −40°C < T$_A$ < 85°C temperature range. V$_S$ = 5V, 0V; V$_S$ = 3.3V, 0V; V$_{CM}$ = V$_{OUT}$ = half supply, $\overline{ENABLE}$ = 0V, unless otherwise noted. (Note 5)

SYMBOL	PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
V$_{OS}$	Input Offset Voltage	LT6233S6, LT6233S6-10	●			700	μV
		LT6234S8, LT6235GN	●			550	μV
		LT6234DD	●			650	μV
	Input Offset Voltage Match (Channel-to-Channel) (Note 6)		●			1000	μV
V$_{OS}$ TC	Input Offset Voltage Drift (Note 10)	V$_{CM}$ = Half Supply	●		0.5	3	μV/°C
I$_B$	Input Bias Current		●			4	μA
	I$_B$ Match (Channel-to-Channel) (Note 6)		●			0.4	μA
I$_{OS}$	Input Offset Current		●			0.5	μA
A$_{VOL}$	Large-Signal Gain	V$_S$ = 5V, V$_O$ = 0.5V to 4.5V, R$_L$ = 10k to V$_S$/2	●	45			V/mV
		R$_L$ = 1k to V$_S$/2	●	11			V/mV
		V$_S$ = 3.3V, V$_O$ = 0.65V to 2.65V, R$_L$ = 10k to V$_S$/2	●	38			V/mV
		R$_L$ = 1k to V$_S$/2	●	7			V/mV
V$_{CM}$	Input Voltage Range	Guaranteed by CMRR, V$_S$ = 5V, 0V	●	1.5		4	V
		V$_S$ = 3.3V, 0V	●	1.15		2.65	V
CMRR	Common Mode Rejection Ratio	V$_S$ = 5V, V$_{CM}$ = 1.5V to 4V	●	90			dB
		V$_S$ = 3.3V, V$_{CM}$ = 1.15V to 2.65V	●	85			dB
	CMRR Match (Channel-to-Channel) (Note 6)	V$_S$ = 5V, V$_{CM}$ = 1.5V to 4V	●	84			dB
PSRR	Power Supply Rejection Ratio	V$_S$ = 3V to 10V	●	90			dB

ELECTRICAL CHARACTERISTICS

The ● denotes the specifications which apply over −40°C < T_A < 85°C temperature range. V_S = 5V, 0V; V_S = 3.3V, 0V; V_{CM} = V_{OUT} = half supply, $\overline{ENABLE}$ = 0V, unless otherwise noted. (Note 5)

SYMBOL	PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
	PSRR Match (Channel-to-Channel) (Note 6)	V_S = 3V to 10V	●	84			dB
	Minimum Supply Voltage (Note 7)		●	3			V
V_{OL}	Output Voltage Swing LOW (Note 8)	No Load	●			50	mV
		I_{SINK} = 5mA	●			195	mV
		V_S = 5V, I_{SINK} = 15mA	●			370	mV
		V_S = 3.3V, I_{SINK} = 10mA	●			275	mV
V_{OH}	Output Voltage Swing HIGH (Note 6)	No Load	●			60	mV
		I_{SOURCE} = 5mA	●			210	mV
		V_S = 5V, I_{SOURCE} = 15mA	●			445	mV
		V_S = 3.3V, I_{SOURCE} = 10mA	●			335	mV
I_{SC}	Short-Circuit Current	V_S = 5V	●	±30			mA
		V_S = 3.3V	●	±20			mA
I_S	Supply Current per Amplifier		●			1.5	mA
	Disabled Supply Current per Amplifier	$\overline{ENABLE}$ = V$^+$ − 0.2V	●		1		μA
$I_{\overline{ENABLE}}$	$\overline{ENABLE}$ Pin Current	$\overline{ENABLE}$ = 0.3V	●			−100	μA
V_L	$\overline{ENABLE}$ Pin Input Voltage LOW		●			0.3	V
V_H	$\overline{ENABLE}$ Pin Input Voltage HIGH		●	V$^+$ − 0.2V			V
	Output Leakage Current	$\overline{ENABLE}$ = V$^+$ − 0.2V, V_O = 1.5V to 3.5V	●		1		μA
t_{ON}	Turn-On Time	$\overline{ENABLE}$ = 5V to 0V, R_L = 1k, V_S = 5V	●		500		ns
t_{OFF}	Turn-Off Time	$\overline{ENABLE}$ = 0V to 5V, R_L = 1k, V_S = 5V	●		135		μs
SR	Slew Rate	V_S = 5V, A_V = −1, R_L = 1k, V_O = 0.5V to 4.5V	●	8			V/μs
		LT6233-10, A_V = −10, R_L = 1k, V_O = 0.5V to 4.5V	●		70		V/μs
FPBW	Full Power Bandwidth (Note 9)	V_S = 5V, V_{OUT} = 3V$_{P-P}$ LT6233, LT6234, LT6235	●	848			kHz

T_A = 25°C, V_S = ±5V, V_{CM} = V_{OUT} = 0V, $\overline{ENABLE}$ = 0V, unless otherwise noted.

SYMBOL	PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
V_{OS}	Input Offset Voltage	LT6233S6, LT6233S6-10		100	500	μV
		LT6234S8, LT6235GN		50	350	μV
		LT6234DD		75	450	μV
	Input Offset Voltage Match (Channel-to-Channel) (Note 6)			100	600	μV
I_B	Input Bias Current			1.5	3	μA
	I_B Match (Channel-to-Channel) (Note 6)			0.04	0.3	μA
I_{OS}	Input Offset Current			0.04	0.3	μA
	Input Noise Voltage	0.1Hz to 10Hz		220		nV$_{P-P}$
e_n	Input Noise Voltage Density	f = 10kHz		1.9	3.0	nV/√Hz
i_n	Input Noise Current Density, Balanced Source	f = 10kHz, R_S = 10k		0.43		pA/√Hz
	Unbalanced Source	f = 10kHz, R_S = 10k		0.78		pA/√Hz

ELECTRICAL CHARACTERISTICS

$T_A = 25°C$, $V_S = ±5V$, $V_{CM} = V_{OUT} = 0V$, $\overline{ENABLE} = 0V$, unless otherwise noted.

SYMBOL	PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
	Input Resistance	Common Mode Differential Mode		22 25		MΩ kΩ
C_{IN}	Input Capacitance	Common Mode Differential Mode		2.1 3.7		pF pF
A_{VOL}	Large-Signal Gain	$V_O = ±4.5V$, $R_L = 10k$ $R_L = 1k$	97 28	180 55		V/mV V/mV
V_{CM}	Input Voltage Range	Guaranteed by CMRR	−3		4	V
CMRR	Common Mode Rejection Ratio	$V_{CM} = −3V$ to $4V$	90	110		dB
	CMRR Match (Channel-to-Channel) (Note 6)	$V_{CM} = −3V$ to $4V$	84	120		dB
PSRR	Power Supply Rejection Ratio	$V_S = ±1.5V$ to $±5V$	90	115		dB
	PSRR Match (Channel-to-Channel) (Note 6)	$V_S = ±1.5V$ to $±5V$	84	115		dB
V_{OL}	Output Voltage Swing LOW (Note 8)	No Load $I_{SINK} = 5mA$ $I_{SINK} = 15mA$		4 75 165	40 180 320	mV mV mV
V_{OH}	Output Voltage Swing HIGH (Note 8)	No Load $I_{SOURCE} = 5mA$ $I_{SOURCE} = 15mA$		5 85 220	50 195 410	mV mV mV
I_{SC}	Short-Circuit Current		±40	±55		mA
I_S	Supply Current per Amplifier Disabled Supply Current per Amplifier	 $\overline{ENABLE} = 4.65V$		1.15 0.2	1.4 10	mA μA
$I_{\overline{ENABLE}}$	$\overline{ENABLE}$ Pin Current	$\overline{ENABLE} = 0.3V$		−35	−85	μA
V_L	$\overline{ENABLE}$ Pin Input Voltage LOW				0.3	V
V_H	$\overline{ENABLE}$ Pin Input Voltage HIGH		4.65			V
	Output Leakage Current	$\overline{ENABLE} = 4.65V$, $V_O = ±1V$		0.2	10	μA
t_{ON}	Turn-On Time	$\overline{ENABLE} = 5V$ to $0V$, $R_L = 1k$		900		ns
t_{OFF}	Turn-Off Time	$\overline{ENABLE} = 0V$ to $5V$, $R_L = 1k$		100		μs
GBW	Gain Bandwidth Product	Frequency = 1MHz LT6233-10	42 260	60 375		MHz MHz
SR	Slew Rate	$A_V = −1$, $R_L = 1k$, $V_O = −2V$ to $2V$	12	17		V/μs
		LT6233-10, $A_V = −10$, $R_L = 1k$, $V_O = −2V$ to $2V$		115		V/μs
FPBW	Full Power Bandwidth	$V_{OUT} = 3V_{P-P}$ (Note 9)	1.27	1.8		MHz
		LT6233-10, $HD_2 = HD_3 ≤ 1\%$		2.2		MHz
t_S	Settling Time (LT6233, LT6234, LT6235)	0.1%, $V_{STEP} = 2V$, $A_V = −1$, $R_L = 1k$		170		ns

ELECTRICAL CHARACTERISTICS

The ● denotes the specifications which apply over 0°C < T_A < 70°C temperature range. V_S = ±5V, V_{CM} = V_{OUT} = 0V, $\overline{ENABLE}$ = 0V, unless otherwise noted.

SYMBOL	PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
V_{OS}	Input Offset Voltage	LT6233S6, LT6233S6-10	●			600	μV
		LT6234S8, LT6235GN	●			450	μV
		LT6234DD	●			550	μV
	Input Offset Voltage Match (Channel-to-Channel) (Note 6)		●			800	μV
V_{OS} TC	Input Offset Voltage Drift (Note 10)		●		0.5	3	μV/°C
I_B	Input Bias Current		●			3.5	μA
	I_B Match (Channel-to-Channel) (Note 6)		●			0.4	μA
I_{OS}	Input Offset Current		●			0.4	μA
A_{VOL}	Large-Signal Gain	V_O = ±4.5V, R_L = 10k	●	75			V/mV
		R_L = 1k	●	22			V/mV
V_{CM}	Input Voltage Range	Guaranteed by CMRR	●	−3		4	V
CMRR	Common Mode Rejection Ratio	V_{CM} = −3V to 4V	●	90			dB
	CMRR Match (Channel-to-Channel) (Note 6)	V_{CM} = −3V to 4V	●	84			dB
PSRR	Power Supply Rejection Ratio	V_S = ±1.5V to ±5V	●	90			dB
	PSRR Match (Channel-to-Channel) (Note 6)	V_S = ±1.5V to ±5V	●	84			dB
V_{OL}	Output Voltage Swing LOW (Note 8)	No Load	●			50	mV
		I_{SINK} = 5mA	●			195	mV
		I_{SINK} = 15mA	●			360	mV
V_{OH}	Output Voltage Swing HIGH (Note 8)	No Load	●			60	mV
		I_{SOURCE} = 5mA	●			205	mV
		I_{SOURCE} = 15mA	●			435	mV
I_{SC}	Short-Circuit Current		●	±35			mA
I_S	Supply Current per Amplifier		●			1.7	mA
	Disabled Supply Current per Amplifier	$\overline{ENABLE}$ = 4.75V	●		1		μA
$I_{\overline{ENABLE}}$	$\overline{ENABLE}$ Pin Current	$\overline{ENABLE}$ = 0.3V	●			−95	μA
V_L	$\overline{ENABLE}$ Pin Input Voltage LOW		●			0.3	V
V_H	$\overline{ENABLE}$ Pin Input Voltage HIGH		●	4.75			V
	Output Leakage Current	$\overline{ENABLE}$ = 4.75V, V_O = ±1V	●		1		μA
t_{ON}	Turn-On Time	$\overline{ENABLE}$ = 5V to 0V, R_L = 1k	●		900		ns
t_{OFF}	Turn-Off Time	$\overline{ENABLE}$ = 0V to 5V, R_L = 1k	●		150		μs
SR	Slew Rate	A_V = −1, R_L = 1k, V_O = −2V to 2V	●	11			V/μs
		LT6233-10, A_V = −10, R_L = 1k, V_O = −2V to 2V	●		105		V/μs
FPBW	Full Power Bandwidth (Note 9)	V_{OUT} = 3V_{P-P} LT6233, LT6234, LT6235	●	1.16			MHz

ELECTRICAL CHARACTERISTICS
The ● denotes the specifications which apply over –40°C < T_A < 85°C temperature range. V_S = ±5V, V_{CM} = V_{OUT} = 0V, $\overline{ENABLE}$ = 0V, unless otherwise noted. (Note 5)

SYMBOL	PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
V_{OS}	Input Offset Voltage	LT6233S6, LT6233S6-10	●			700	μV
		LT6234S8, LT6235GN	●			550	μV
		LT6234DD	●			650	μV
	Input Offset Voltage Match (Channel-to-Channel) (Note 6)		●			1000	μV
V_{OS} TC	Input Offset Voltage Drift (Note 10)		●		0.5	3	μV/°C
I_B	Input Bias Current		●			4	μA
	I_B Match (Channel-to-Channel) (Note 6)		●			0.4	μA
I_{OS}	Input Offset Current		●			0.5	μA
A_{VOL}	Large-Signal Gain	V_O = ±4.5V, R_L = 10k	●	68			V/mV
		R_L = 1k	●	20			V/mV
V_{CM}	Input Voltage Range	Guaranteed by CMRR	●	–3		4	V
CMRR	Common Mode Rejection Ratio	V_{CM} = –3V to 4V	●	90			dB
	CMRR Match (Channel-to-Channel) (Note 6)	V_{CM} = –3V to 4V	●	84			dB
PSRR	Power Supply Rejection Ratio	V_S = ±1.5V to ±5V	●	90			dB
	PSRR Match (Channel-to-Channel) (Note 6)	V_S = ±1.5V to ±5V	●	84			dB
V_{OL}	Output Voltage Swing LOW (Note 8)	No Load	●			50	mV
		I_{SINK} = 5mA	●			195	mV
		I_{SINK} = 15mA	●			370	mV
V_{OH}	Output Voltage Swing HIGH (Note 8)	No Load	●			70	mV
		I_{SOURCE} = 5mA	●			210	mV
		I_{SOURCE} = 15mA	●			445	mV
I_{SC}	Short-Circuit Current		●	±30			mA
I_S	Supply Current per Amplifier		●			1.75	mA
	Disabled Supply Current per Amplifier	$\overline{ENABLE}$ = 4.8V	●		1		μA
$I_{\overline{ENABLE}}$	$\overline{ENABLE}$ Pin Current	$\overline{ENABLE}$ = 0.3V	●			–110	μA
V_L	$\overline{ENABLE}$ Pin Input Voltage LOW		●			0.3	V
V_H	$\overline{ENABLE}$ Pin Input Voltage HIGH		●	4.8			V
	Output Leakage Current	$\overline{ENABLE}$ = 4.8V, V_O = ±1V	●		1		μA
t_{ON}	Turn-On Time	$\overline{ENABLE}$ = 5V to 0V, R_L = 1k	●		900		ns
t_{OFF}	Turn-Off Time	$\overline{ENABLE}$ = 0V to 5V, R_L = 1k	●		160		μs
SR	Slew Rate	A_V = –1, R_L = 1k, V_O = –2V to 2V	●	10			V/μs
		LT6233-10, A_V = –10, R_L = 1k, V_O = –2V to 2V	●		95		V/μs
FPBW	Full Power Bandwidth (Note 9)	V_{OUT} = $3V_{P-P}$ LT6233, LT6234, LT6235	●	1.06			MHz

ELECTRICAL CHARACTERISTICS

Note 1: Absolute maximum ratings are those values beyond which the life of the device may be impaired.

Note 2: Inputs are protected by back-to-back diodes. If the differential input voltage exceeds 0.7V, the input current must be limited to less than 40mA.

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 LT6233C/LT6233I the LT6234C/LT6234I, and LT6235C/LT6235I are guaranteed functional over the temperature range of −40°C and 85°C.

Note 5: The LT6233C/LT6234C/LT6235C are guaranteed to meet specified performance from 0°C to 70°C. The LT6233C/LT6234C/LT6235C 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 LT6233I/LT6234I/LT6235I are guaranteed to meet specified performance from −40°C to 85°C.

Note 6: Matching parameters are the difference between the two amplifiers A and D and between B and C of the LT6235; between the two amplifiers of the LT6234. CMRR and PSRR match are defined as follows: CMRR and PSRR are measured in μV/V on the matched amplifiers. The difference is calculated between the matching sides in μV/V. The result is converted to dB.

Note 7: Minimum supply voltage is guaranteed by power supply rejection ratio test.

Note 8: Output voltage swings are measured between the output and power supply rails.

Note 9: Full-power bandwidth is calculated from the slew rate:
$$FPBW = SR/2\pi V_P$$

Note 10: This parameter is not 100% tested.

TYPICAL PERFORMANCE CHARACTERISTICS

(LT6233/LT6234/LT6235)

V_{OS} Distribution
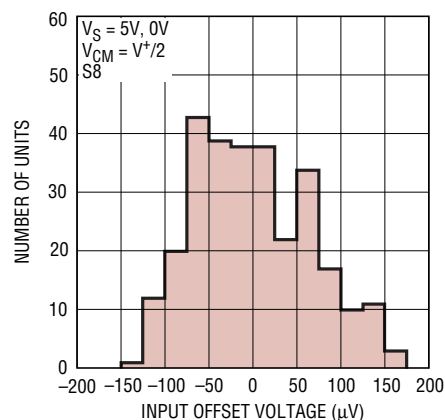
623345 G01

Supply Current vs Supply Voltage (Per Amplifier)
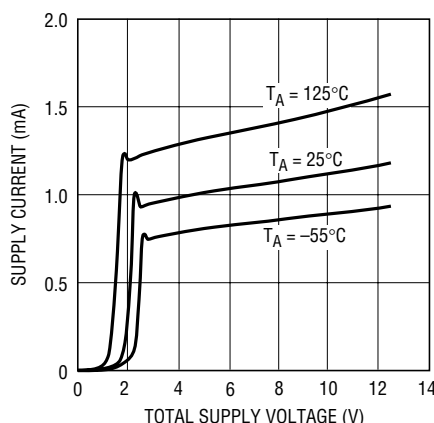
623345 G02

Offset Voltage vs Input Common Mode Voltage
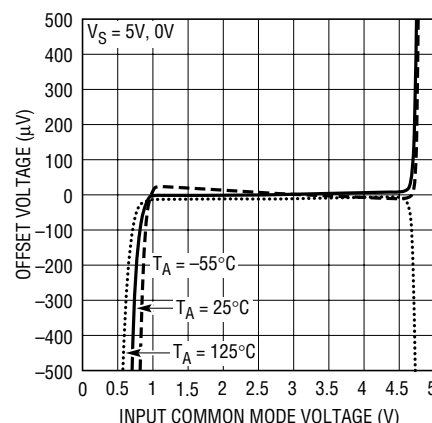
623345 G03

Input Bias Current vs Common Mode Voltage
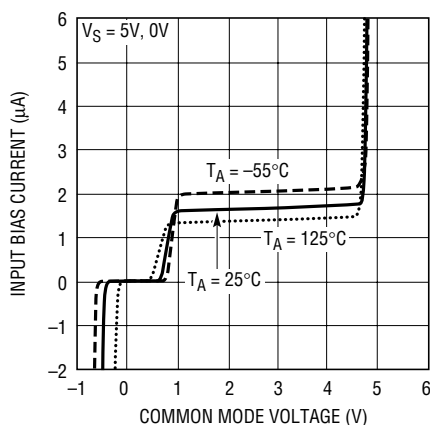
623345 G04

Input Bias Current vs Temperature
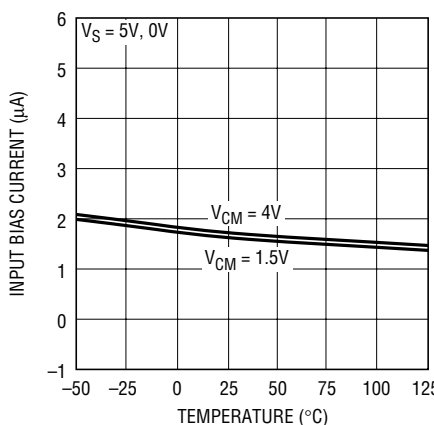
623345 G05

Output Saturation Voltage vs Load Current (Output Low)
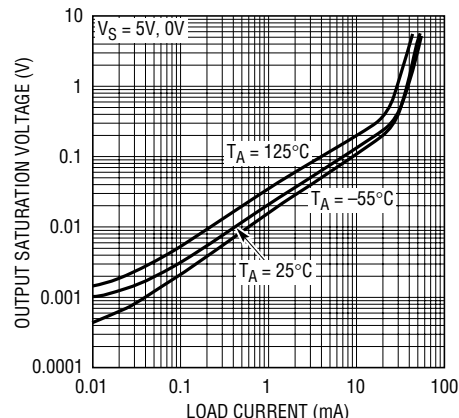
623345 G06

623345fa

TYPICAL PERFORMANCE CHARACTERISTICS

(LT6233/LT6234/LT6235)

**Output Saturation Voltage vs
Load Current (Output High)**
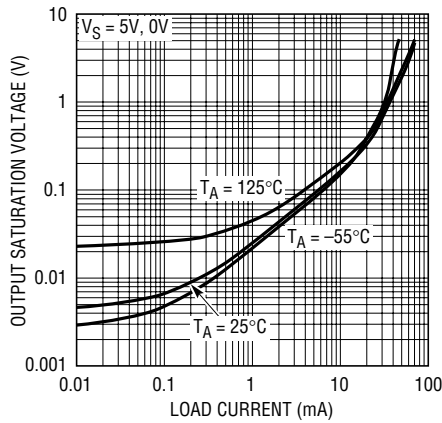
623345 G07

Minimum Supply Voltage
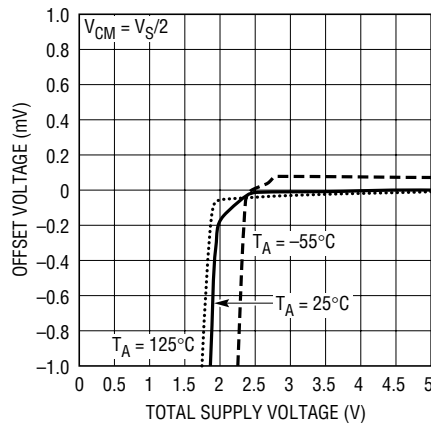
623345 G08

**Output Short Circuit Current vs
Power Supply Voltage**
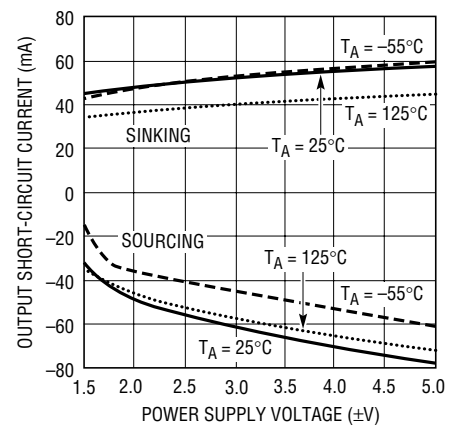
623345 G09

Open Loop Gain
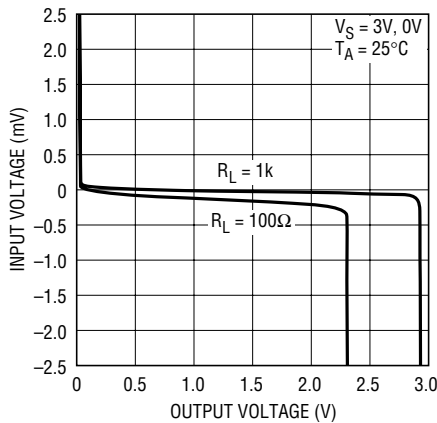
623345 G10

Open Loop Gain
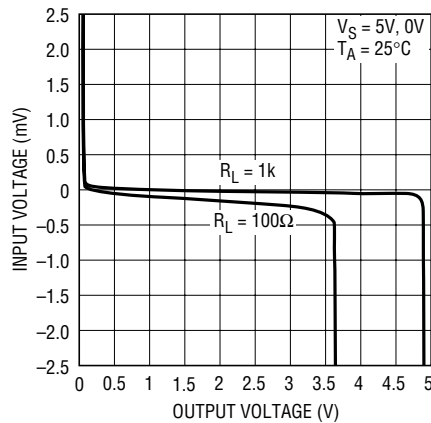
623345 G11

Open Loop Gain
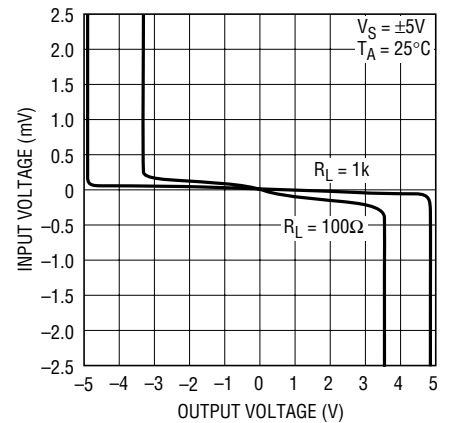
623345 G12

Offset Voltage vs Output Current
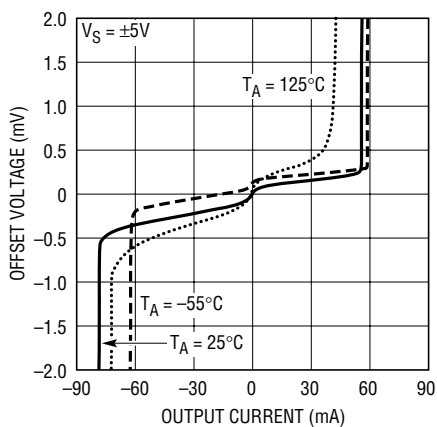
623345 G13

Warm-Up Drift vs Time
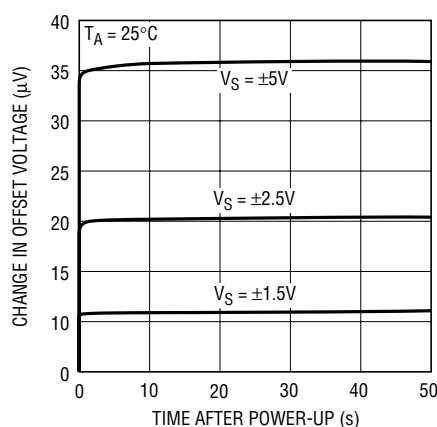
623345 G14

**Total Noise vs Total Source
Resistance**
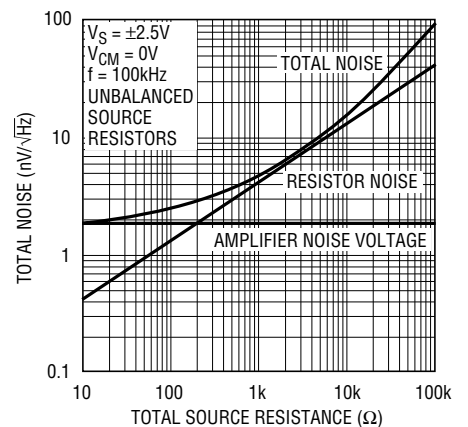
623345 G15

623345fa

TYPICAL PERFORMANCE CHARACTERISTICS

(LT6233/LT6234/LT6235)

Noise Voltage and Unbalanced Noise Current vs Frequency
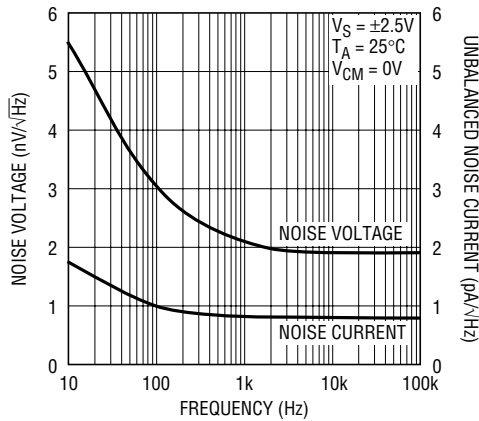
623345 G16

0.1Hz to 10Hz Output Voltage Noise
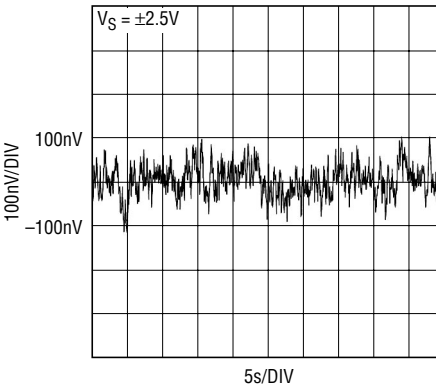
623345 G17

Gain Bandwidth and Phase Margin vs Temperature
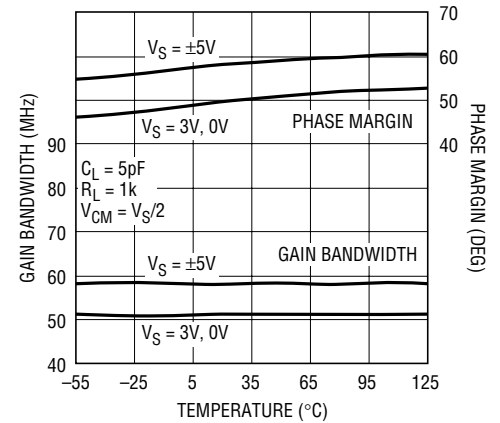
623345 G18

Open Loop Gain vs Frequency
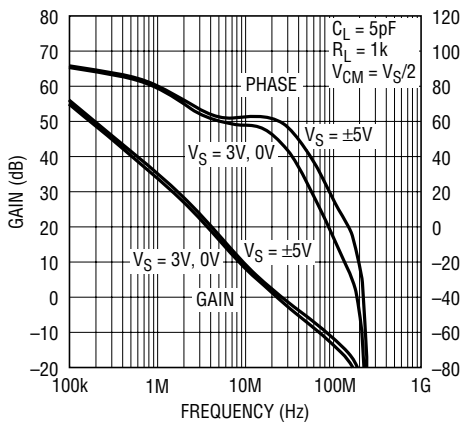
623345 G19

Gain Bandwidth and Phase Margin vs Supply Voltage
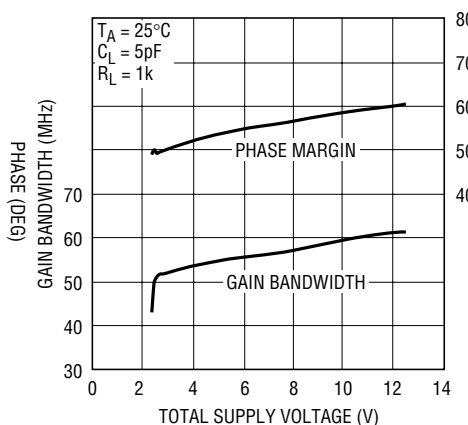
623345 G20

Slew Rate vs Temperature
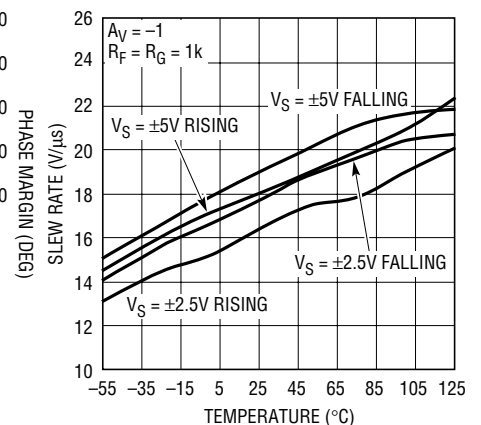
623345 G21

Output Impedance vs Frequency
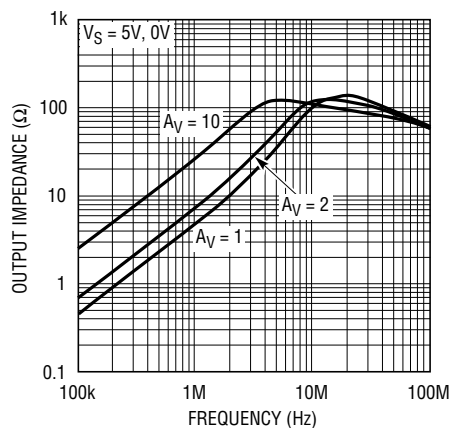
623345 G22

Common Mode Rejection Ratio vs Frequency
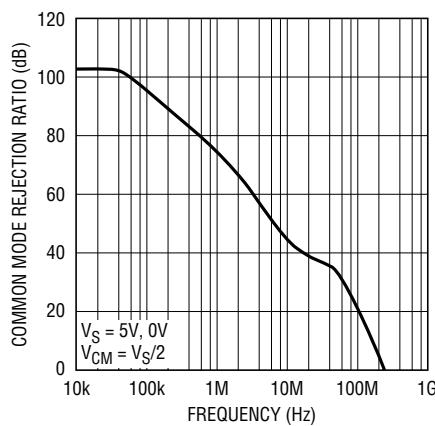
623345 G23

Channel Separation vs Frequency
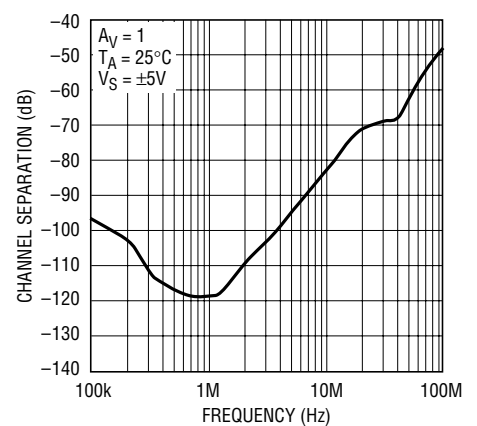
623345 G24

623345fa

TYPICAL PERFORMANCE CHARACTERISTICS

(LT6233/LT6234/LT6235)

Power Supply Rejection Ratio vs Frequency
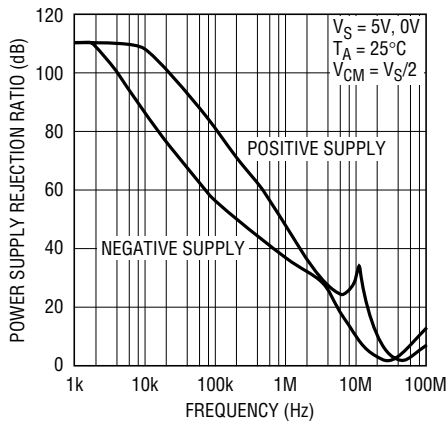
623345 G25

Series Output Resistance and Overshoot vs Capacitive Load
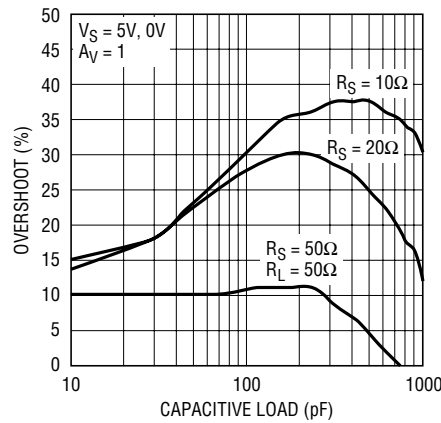
623345 G26

Series Output Resistance and Overshoot vs Capacitive Load
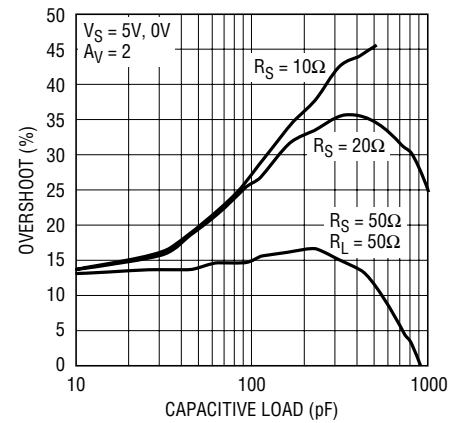
623345 G27

Settling Time vs Output Step (Non-Inverting)
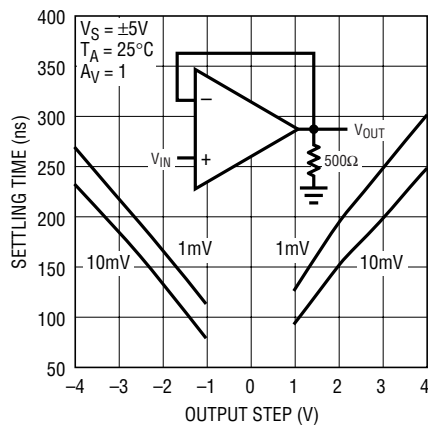
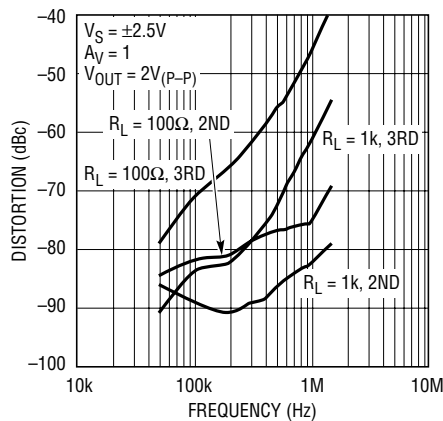623345 G28

Settling Time vs Output Step (Inverting)
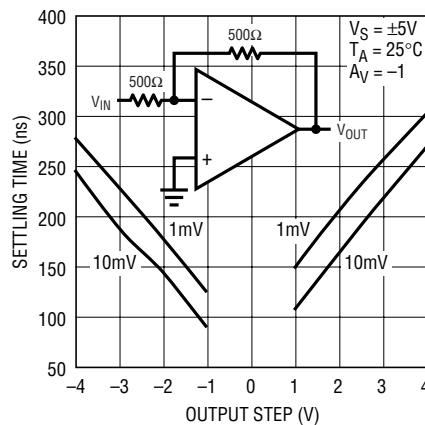
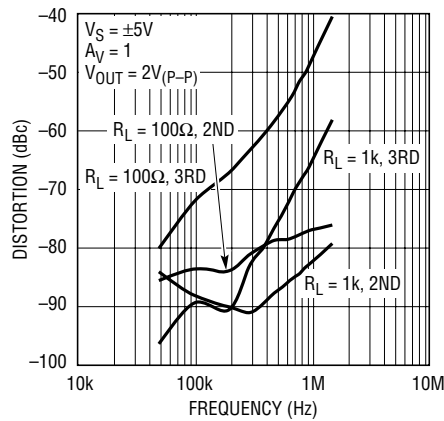623345 G29

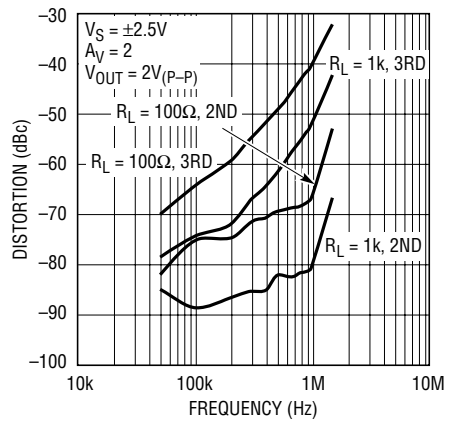### Maximum Undistorted Output Signal vs Frequency
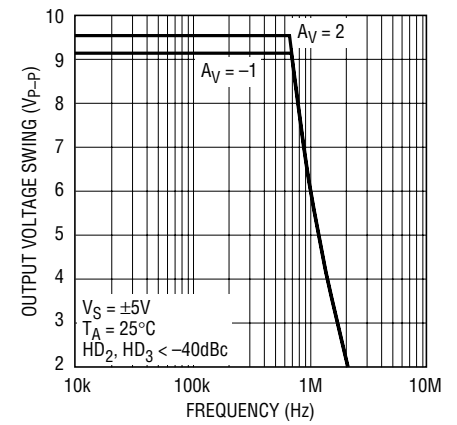
623345 G30

Distortion vs Frequency

623345 G31

Distortion vs Frequency
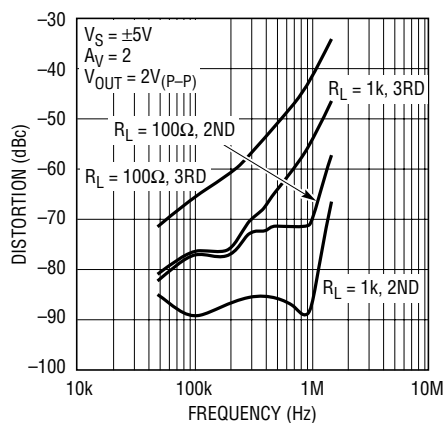

623345 G32

Distortion vs Frequency

623345 G33
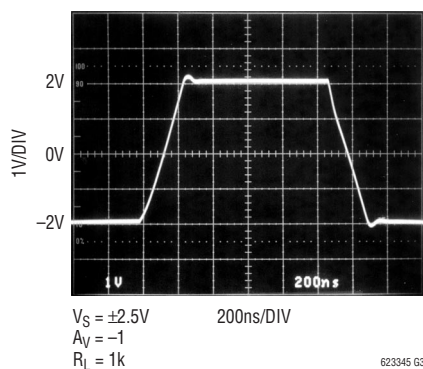
623345fa

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TYPICAL PERFORMANCE CHARACTERISTICS

(LT6233/LT6234/LT6235)

Distortion vs Frequency

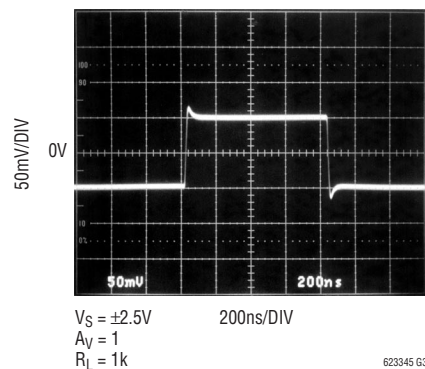$V_S = \pm5V$
$A_V = 2$
$V_{OUT} = 2V_{(P-P)}$

$R_L = 1k$, 3RD

$R_L = 100\Omega$, 2ND

$R_L = 100\Omega$, 3RD

$R_L = 1k$, 2ND

DISTORTION (dBc)

FREQUENCY (Hz)

623345 G34

Large Signal Response

1V/DIV

$V_S = \pm2.5V$
$A_V = -1$
$R_L = 1k$

200ns/DIV

623345 G35

Small Signal Response

50mV/DIV

$V_S = \pm2.5V$
$A_V = 1$
$R_L = 1k$

200ns/DIV

623345 G36

Large Signal Response

2V/DIV

$V_S = \pm5V$
$A_V = 1$
$R_L = 1k$

200ns/DIV
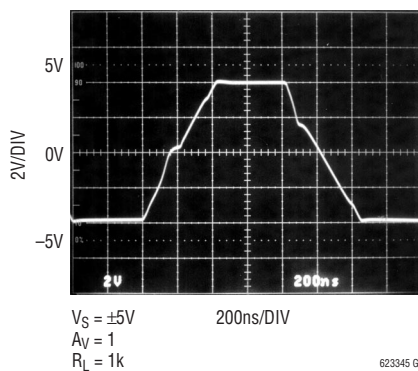
623345 G37

Output Overdrive Recovery

V_{IN} (1V/DIV)

V_{OUT} (2V/DIV)

$V_S = \pm2.5V$
$A_V = 3$

200ns/DIV
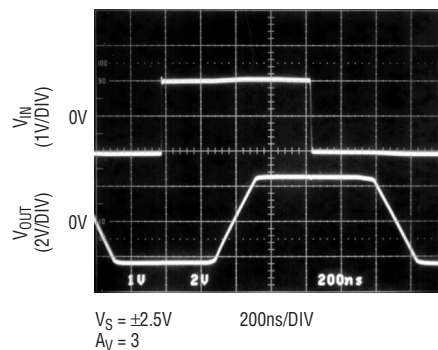
623345 G38

(LT6233) $\overline{ENABLE}$ Characteristics

Supply Current vs $\overline{ENABLE}$ Pin Voltage

SUPPLY CURRENT (mA)

$T_A = 125°C$

$T_A = 25°C$

$T_A = -55°C$

$V_S = \pm2.5V$
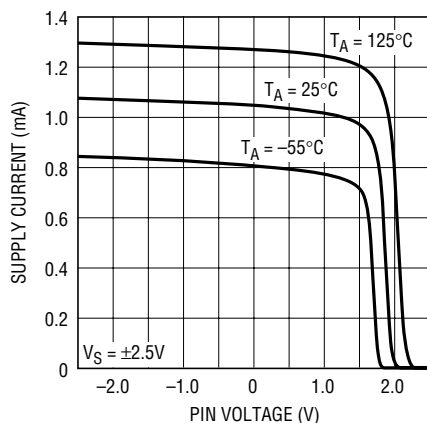
PIN VOLTAGE (V)

623345 G39

$\overline{ENABLE}$ Pin Current vs $\overline{ENABLE}$ Pin Voltage

$\overline{ENABLE}$ PIN CURRENT (μA)

$T_A = -55°C$

$T_A = 25°C$

$T_A = 125°C$

$V_S = \pm2.5V$
$A_V = 1$

PIN VOLTAGE (V)
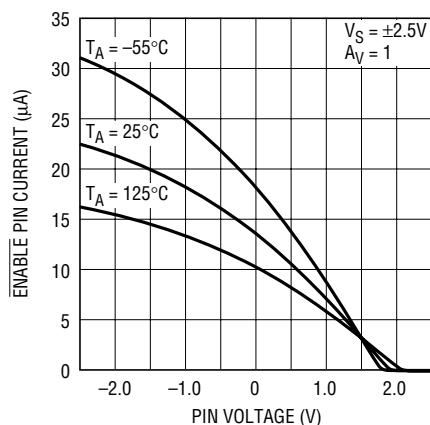
623345 G40

$\overline{ENABLE}$ Pin Response Time

76.0 μs

$\overline{ENABLE}$ PIN

V_{OUT}

$V_S = \pm2.5V$
$V_{IN} = 0.5V$
$A_V = 1$
$R_L = 1k$

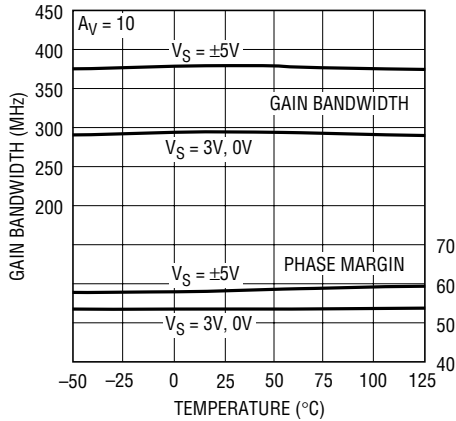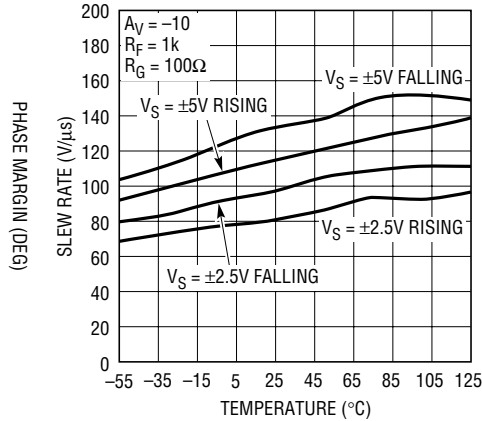200μs/DIV

623345 G41

623345fa

14
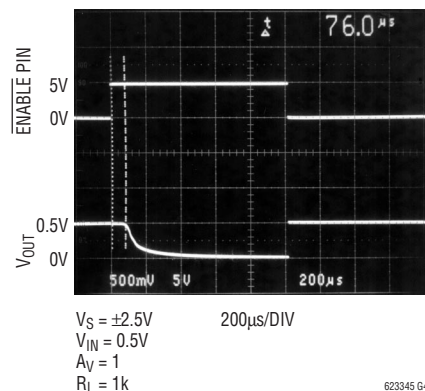
TYPICAL PERFORMANCE CHARACTERISTICS

(LT6233-10)

Gain Bandwidth and Phase Margin vs Temperature

623345 G42

Slew Rate vs Temperature

623345 G43

Series Output Resistance and Overshoot vs Capacitive Load

623345 G44

Open Loop Gain vs Frequency

623345 G45

Gain Bandwidth and Phase Margin vs Supply Voltage

623345 G46
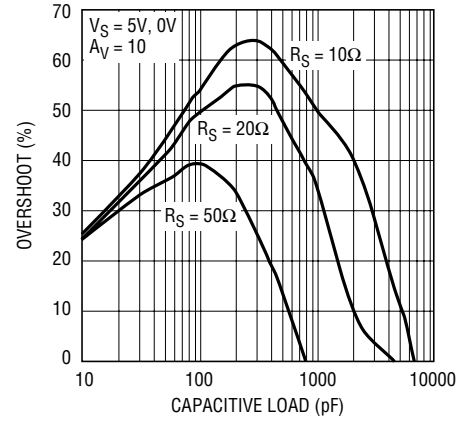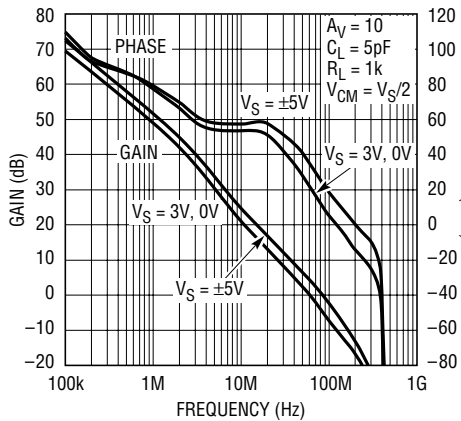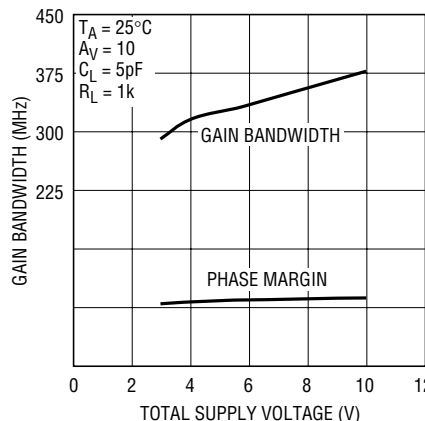
Gain Bandwidth vs Resistor Load

623345 G47

Common Mode Rejection Ratio vs Frequency

623345 G48
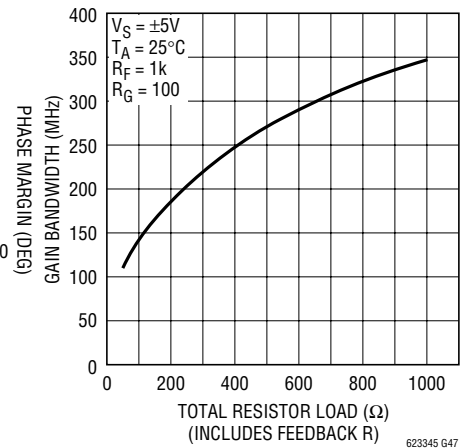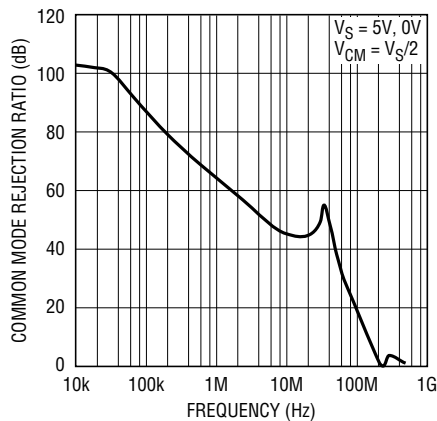
Maximum Undistorted Output vs Frequency
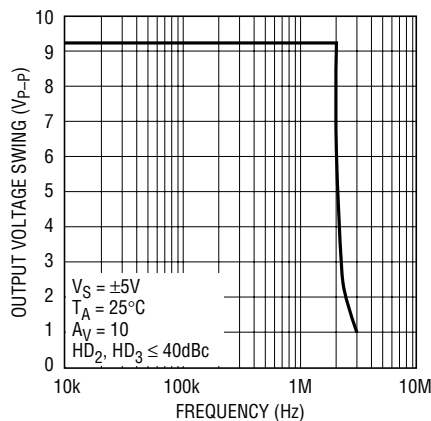
623345 G49

2nd and 3rd Harmonic Distortion vs Frequency

623345 G50
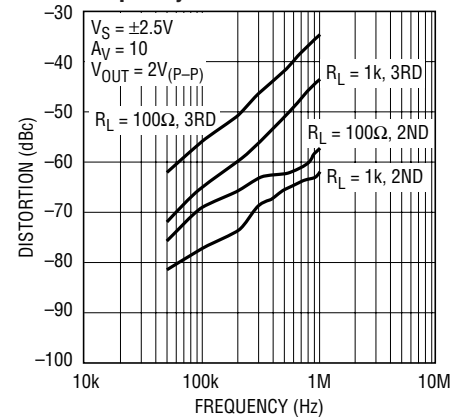
TYPICAL PERFORMANCE CHARACTERISTICS

(LT6233-10)

2nd and 3rd Harmonic Distortion vs Frequency

623345 G51

Large Signal Response

$V_S = \pm 5V$ 100ns/DIV
$A_V = 10$
$R_F = 900\Omega, R_G = 100\Omega$

623345 G52
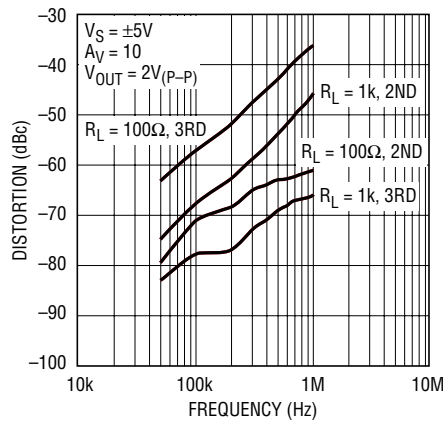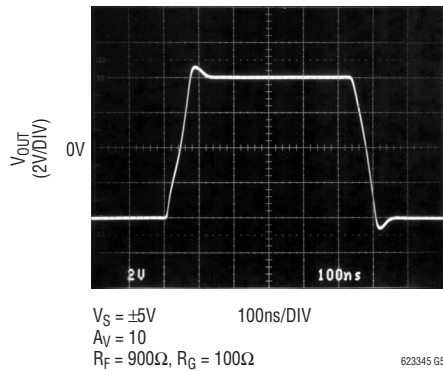
Output-Overload Recovery

$V_S = 5V, 0V$ 100ns/DIV
$A_V = 10$
$R_F = 900\Omega, R_G = 100\Omega$

623345 G53

Small Signal Response

$V_S = 5V, 0V$ 100ns/DIV
$A_V = 10$
$R_F = 900\Omega, R_G = 100\Omega$

623345 G54
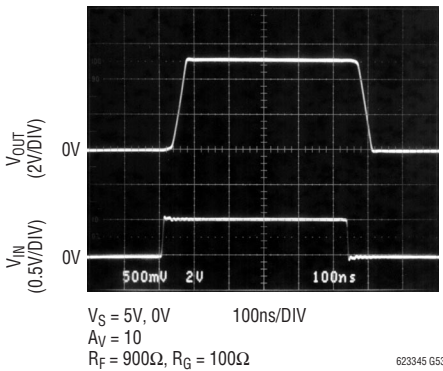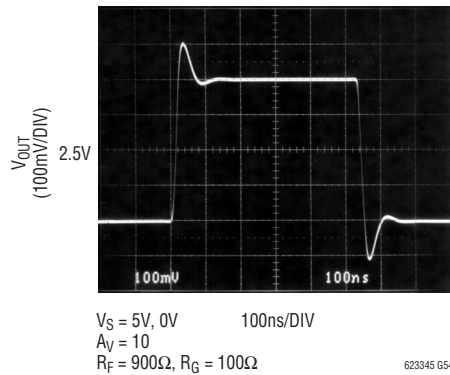
Input Referred High Frequency Noise Spectrum

623345 G55

16

623345fa
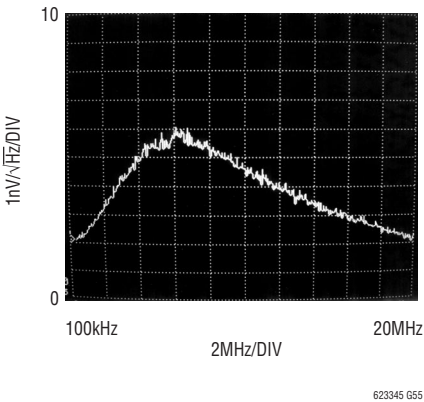
APPLICATIONS INFORMATION

Amplifier Characteristics

Figure 1 is a simplified schematic of the LT6233/LT6234/ LT6235, which has a pair of low noise input transistors Q1 and Q2. A simple current mirror Q3/Q4 converts the differential signal to a single-ended output, and these transistors are degenerated to reduce their contribution to the overall noise.

Capacitor C1 reduces the unity cross frequency and improves the frequency stability without degrading the gain bandwidth of the amplifier. Capacitor C_M sets the overall amplifier gain bandwidth. The differential drive generator supplies current to transistors Q5 and Q6 that swing the output from rail-to-rail.

Figure 2. $V_S = \pm2.5V$, $A_V = 1$ with Large Overdrive

Figure 1. Simplified Schematic

Input Protection

There are back-to-back diodes, D1 and D2 across the + and – inputs of these amplifiers to limit the differential input voltage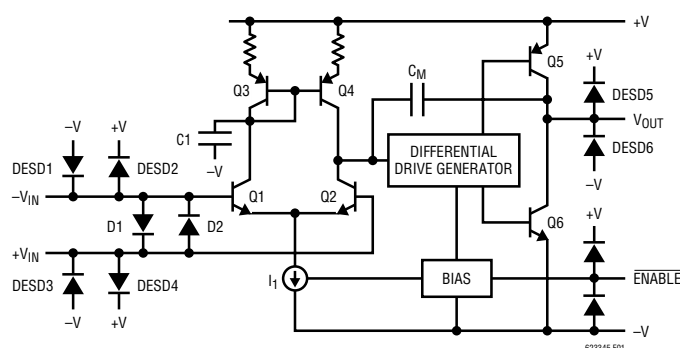 to ±0.7V. The inputs of the LT6233/LT6234/ LT6235 do not have internal resistors in series with the input transistors. This technique is often used to protect the input devices from over voltage that causes excessive current to flow. The addition of these resistors would significantly degrade the low noise voltage of these amplifiers. For instance, a 100Ω resistor in series with each input would generate 1.8nV/√Hz of noise, and the total amplifier noise voltage would rise from 1.9nV/√Hz to 2.6nV/√Hz. Once the input differential voltage exceeds ±0.7V, steady state current conducted through the protection diodes should be limited to ±40mA. This implies 25Ω of protection resistance is necessary per volt of overdrive beyond ±0.7V. These input diodes are rugged enough to
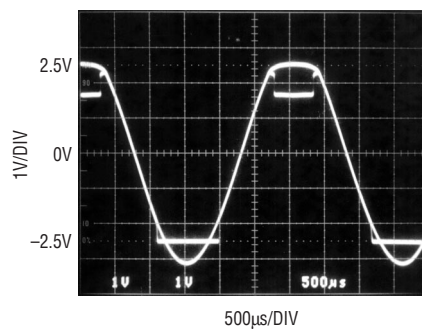
handle transient currents due to amplifier slew rate overdrive and clipping without protection resistors.

The photo of Figure 2 shows the output response to an input overdrive with the amplifier connected as a voltage follower. With the input signal low, current source I_1 saturates and the differential drive generator drives Q6 into saturation so the output voltage swings all the way to V⁻. The input can swing positive until transistor Q2 saturates into current mirror Q3/Q4. When saturation occurs, the output tries to phase invert, but diode D2 conducts current from the signal source to the output through the feedback connection. The output is clamped a diode drop below the input. In this photo, the input signal generator is limiting at about 20mA.

With the amplifier connected in a gain of $A_V \geq 2$, the output can invert with very heavy overdrive. To avoid this inversion, limit the input overdrive to 0.5V beyond the power supply rails.

ESD

The LT6233/LT6234/LT6235 have reverse-biased ESD protection diodes on all inputs and outputs as shown in Figure 1. If these pins are forced beyond either supply, unlimited current will flow through these diodes. If the current is transient and limited to one hundred milliamps or less, no damage to the device will occur.

Noise

The noise voltage of the LT6233/LT6234/LT6235 is equivalent to that of a 225Ω resistor, and for the lowest possible noise it is desirable to keep the source and feedback resistance at or below this value, i.e. $R_S + R_G || R_{FB} \leq 225\Omega$.

APPLICATIONS INFORMATION

With $R_S + R_G||R_{FB} = 225\Omega$ the total noise of the amplifier is:

$$e_N = \sqrt{(1.9nV)^2 + (1.9nV)^2} = 2.69nV/\sqrt{Hz}$$

Below this resistance value, the amplifier dominates the noise, but in the region between 225Ω and about 30k, the noise is dominated by the resistor thermal noise. As the total resistance is further increased beyond 30k, the amplifier noise current multiplied by the total resistance eventually dominates the noise.

The product of $e_N \cdot \sqrt{I_{SUPPLY}}$ is an interesting way to gauge low noise amplifiers. Most low noise amplifiers with low e_N have high I_{SUPPLY} current. In applications that require low noise voltage with the lowest possible supply current, this product can prove to be enlightening. The LT6233/LT6234/LT6235 have an $e_N \cdot \sqrt{I_{SUPPLY}}$ product of only 2.1 per amplifier, yet it is common to see amplifiers with similar noise specifications to have $e_N \cdot \sqrt{I_{SUPPLY}}$ as high as 13.5.

For a complete discussion of amplifier noise, see the LT1028 data sheet.

Enable Pin

The LT6233 and LT6233-10 include an $\overline{\text{ENABLE}}$ pin that shuts down the amplifier to 10μA maximum supply current. The $\overline{\text{ENABLE}}$ pin must be driven high to within 0.35V of V$^+$ to shut down the supply current. This can be accomplished with simple gate logic; however care must be taken if the logic and the LT6233 operate from different supplies. If this is the case, then open drain logic can be used with a pull-up resistor to ensure that the amplifier remains off. See Typical Characteristic Curves.

The output leakage current when disabled is very low; however, current can flow into the input protection diodes D1 and D2 if the output voltage exceeds the input voltage by a diode drop.

APPLICATIONS INFORMATION

Single Supply, Low Noise, Low Power, Bandpass Filter with Gain = 10
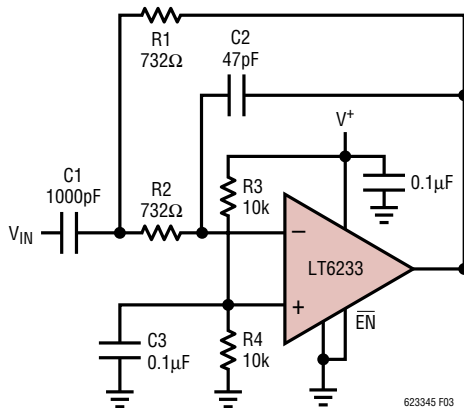
$$f_0 = \frac{1}{2\pi RC} = 1MHz$$

$C = \sqrt{C_1 C_2}$, $R = R1 = R2$

$$f_0 = \left(\frac{732\Omega}{R}\right) MHz, \text{ MAXIMUM } f_0 = 1MHz$$

$$f_{-3dB} = \frac{f_0}{2.5}$$

$A_V = 20dB$ at f_0

$\overline{E_N} = 6\mu V_{RMS}$ INPUT REFERRED

$I_S = 1.5mA$ FOR $V^+ = 5V$

623345 F03

**Frequency Response Plot of
Bandpass Filter**
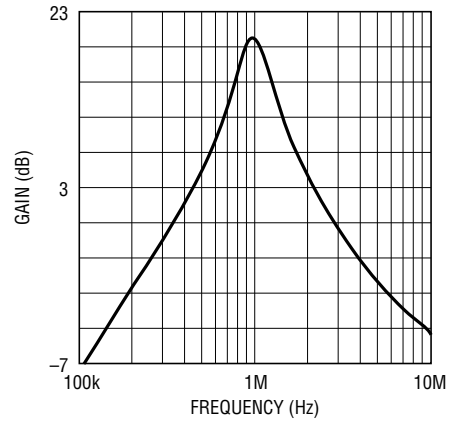
623345 F04

**Low Power, Low Noise, Single Supply, Instrumentation
Amplifier with Gain = 100**
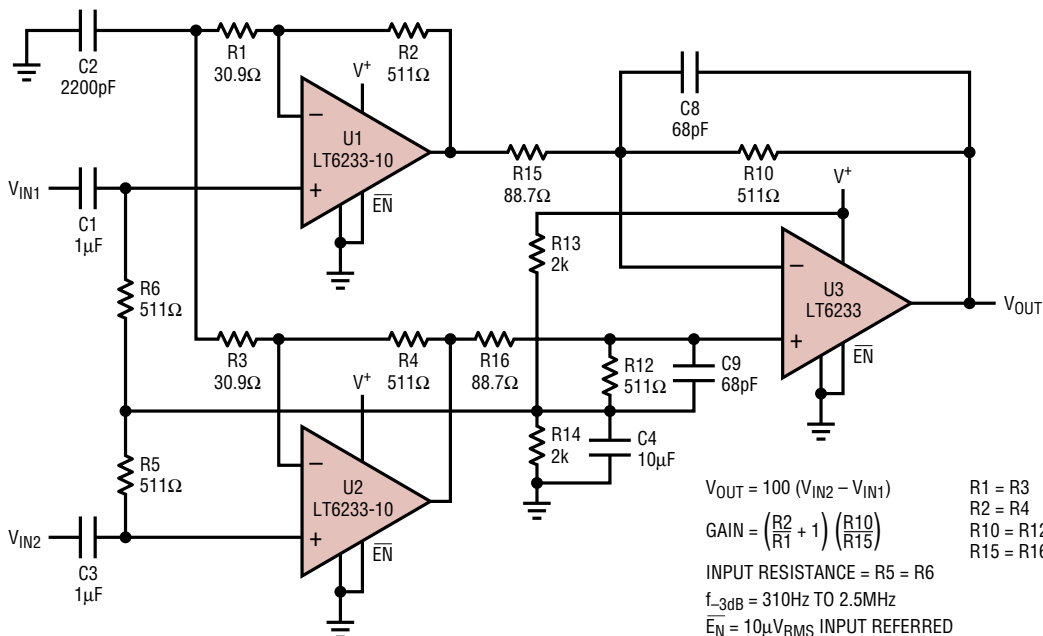
$V_{OUT} = 100(V_{IN2} - V_{IN1})$

$$GAIN = \left(\frac{R2}{R1} + 1\right)\left(\frac{R10}{R15}\right)$$

INPUT RESISTANCE = R5 = R6

$f_{-3dB} = 310Hz$ TO 2.5MHz

$\overline{E_N} = 10\mu V_{RMS}$ INPUT REFERRED

$I_S = 4.7mA$ FOR $V_S = 5V$, 0V

R1 = R3
R2 = R4
R10 = R12
R15 = R16

623345 F05

PACKAGE DESCRIPTION

S6 Package
6-Lead Plastic TSOT-23
(Reference LTC DWG # 05-08-1636)

0.62 MAX

0.95 REF

1.22 REF

3.85 MAX 2.62 REF

1.4 MIN
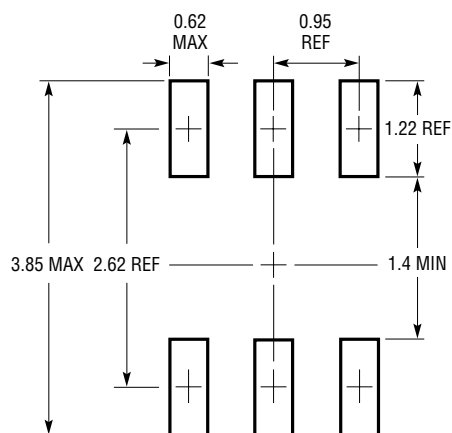
RECOMMENDED SOLDER PAD LAYOUT
PER IPC CALCULATOR

2.90 BSC (NOTE 4)

2.80 BSC

1.50 – 1.75 (NOTE 4)

PIN ONE ID

0.95 BSC

0.30 – 0.45
6 PLCS (NOTE 3)

0.20 BSC

DATUM 'A'

0.30 – 0.50 REF

0.09 – 0.20
(NOTE 3)

0.80 – 0.90

1.00 MAX

0.01 – 0.10

1.90 BSC
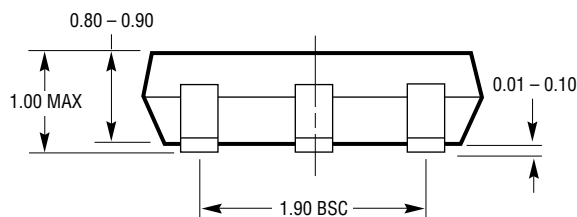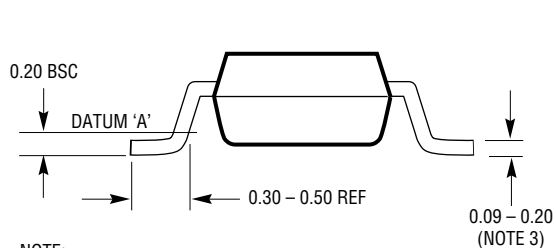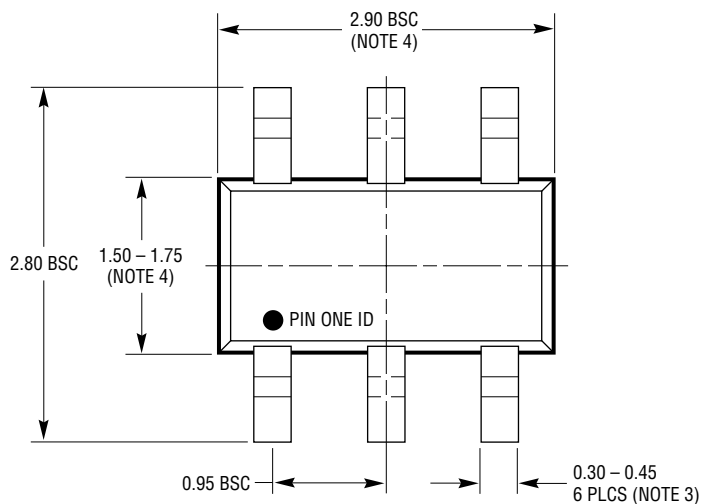
S6 TSOT-23 0302

NOTE:
1. DIMENSIONS ARE IN MILLIMETERS
2. DRAWING NOT TO SCALE
3. DIMENSIONS ARE INCLUSIVE OF PLATING
4. DIMENSIONS ARE EXCLUSIVE OF MOLD FLASH AND METAL BURR
5. MOLD FLASH SHALL NOT EXCEED 0.254mm
6. JEDEC PACKAGE REFERENCE IS MO-193

623345fa

PACKAGE DESCRIPTION

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

RECOMMENDED SOLDER PAD PITCH AND DIMENSIONS

0.675 ±0.05

3.5 ±0.05

1.65 ±0.05
(2 SIDES)

2.15 ±0.05

PACKAGE OUTLINE

0.25 ± 0.05

0.50 BSC

2.38 ±0.05
(2 SIDES)

3.00 ±0.10
(4 SIDES)

PIN 1
TOP MARK
(NOTE 6)

0.200 REF

0.75 ±0.05

0.00 – 0.05

R = 0.115
TYP

0.38 ± 0.10

5   8

1.65 ± 0.10
(2 SIDES)

4   1

(DD8) DFN 1203

0.25 ± 0.05

0.50 BSC

2.38 ±0.10
(2 SIDES)

BOTTOM VIEW—EXPOSED PAD

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

PACKAGE DESCRIPTION

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

.050 BSC

.045 ±.005

.245
MIN

.160 ±.005

.030 ±.005
TYP

RECOMMENDED SOLDER PAD LAYOUT

.189 – .197
(4.801 – 5.004)
NOTE 3

8 7 6 5

.228 – .244
(5.791 – 6.197)

.150 – .157
(3.810 – 3.988)
NOTE 3

1 2 3 4

$\dfrac{.010 - .020}{(0.254 - 0.508)} \times 45°$

.008 – .010
(0.203 – 0.254)

0°– 8° TYP

.016 – .050
(0.406 – 1.270)

.053 – .069
(1.346 – 1.752)

.004 – .010
(0.101 – 0.254)

.014 – .019
(0.355 – 0.483)
TYP

.050
(1.270)
BSC
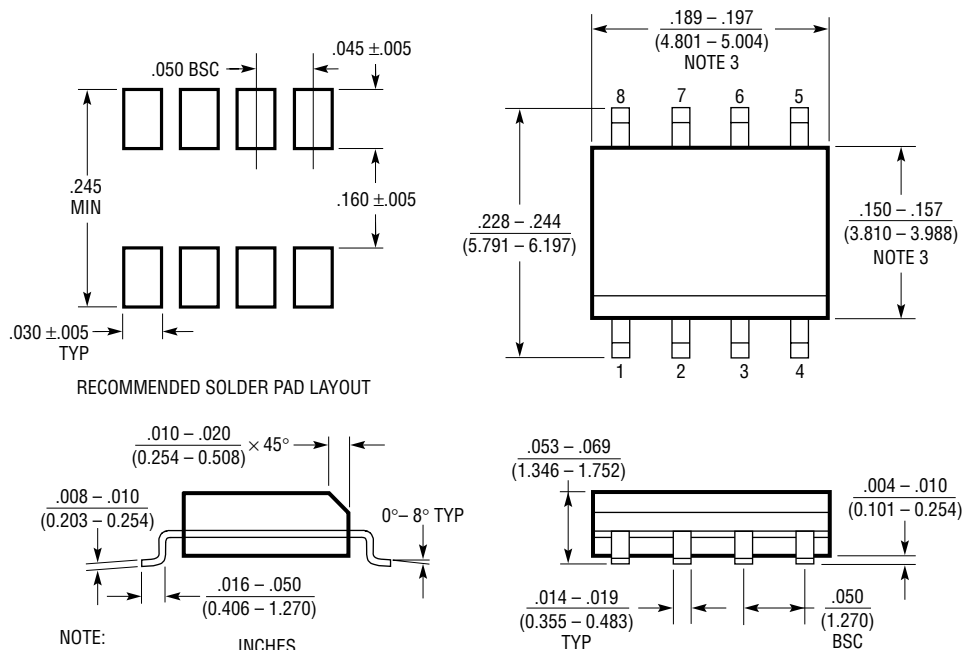
NOTE:
1. DIMENSIONS IN $\dfrac{\text{INCHES}}{\text{(MILLIMETERS)}}$
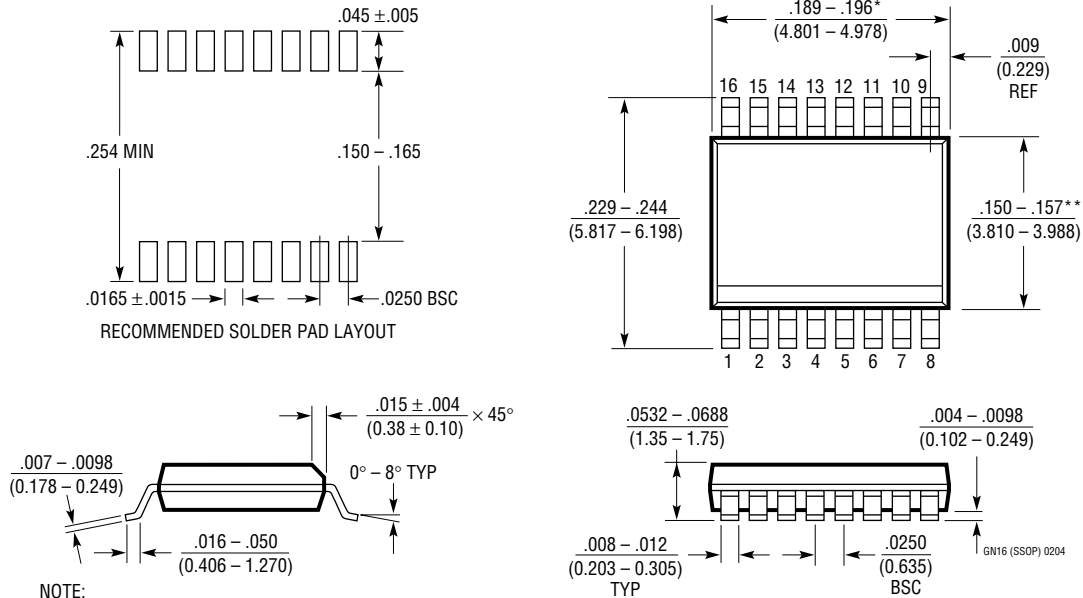
2. DRAWING NOT TO SCALE

3. THESE DIMENSIONS DO NOT INCLUDE MOLD FLASH OR PROTRUSIONS.
   MOLD FLASH OR PROTRUSIONS SHALL NOT EXCEED .006" (0.15mm)

SO8 0303

623345fa

PACKAGE DESCRIPTION

GN Package
16-Lead Plastic SSOP (Narrow .150 Inch)
(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

.007 – .0098
(0.178 – 0.249)

.015 ± .004
(0.38 ± 0.10) × 45°

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 $\dfrac{\text{INCHES}}{\text{(MILLIMETERS)}}$

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

TYPICAL APPLICATIONS

The LT6233 is applied as a transimpedance amplifier with an I-to-V conversion gain of 10kΩ set by R1. The LT6233 is ideally suited to this application because of its low input offset voltage and current, and its low noise. This is because the 10k resistor has an inherent thermal noise of $13nV/\sqrt{Hz}$ or $1.3pA/\sqrt{Hz}$ at room temperature, while the LT6233 contributes only 2nV and $0.8pA /\sqrt{Hz}$. So, with respect to both voltage and current noises, the LT6233 is actually quieter than the gain resistor.

The circuit uses an avalanche photodiode with the cathode biased to approximately 200V. When light is incident on the photodiode, it induces a current I_{PD} which flows into the amplifier circuit. The amplifier output falls negative to maintain balance at its inputs. The transfer function is therefore $V_{OUT} = -I_{PD} \bullet 10k$. C1 ensures stability and good settling characteristics. Output offset was measured at better than 500µV, so low in part because R2 serves to cancel the DC effects of bias current. Output noise was measured at below $1mV_{P-P}$ on a 20MHz measurement bandwidth, with C2 shunting R2's thermal noise. As shown in the scope photo, the rise time is 45ns, indicating a signal bandwidth of 7.8MHz.

Low Power Avalanche Photodiode Transimpedance Amplifier
I_S = 1.2mA
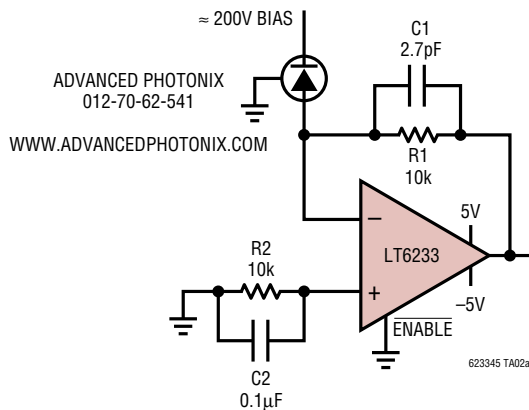
OUTPUT OFFSET = 500µV TYPICAL
BANDWIDTH = 7.8MHz
OUTPUT NOISE = $1mV_{P-P}$ (20MHz MEASUREMENT BW)

Photodiode Amplifier Time Domain Response

100ns/DIV
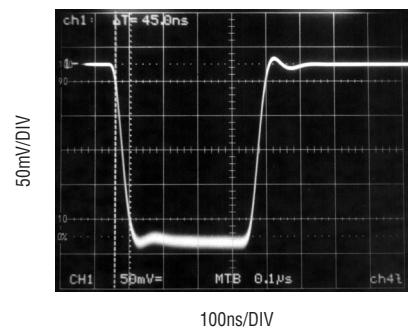
623345 TA02b

RELATED PARTS

PART NUMBER	DESCRIPTION	COMMENTS
LT1028	Single, Ultra Low Noise 50MHz Op Amp	$0.85nV/\sqrt{Hz}$
LT1677	Single, Low Noise Rail-to-Rail Amplifier	3V Operation, 2.5mA, $4.5nV/\sqrt{Hz}$, 60µV Max V_{OS}
LT1806/LT1807	Single/Dual, Low Noise 325MHz Rail-to-Rail Amplifier	2.5V Operation, 550µV Max V_{OS}, $3.5nV/\sqrt{Hz}$
LT6200/LT6201	Single/Dual, Low Noise 165MHz	$0.95nV/\sqrt{Hz}$, Rail-to-Rail Input and Output
LT6202/LT6203/LT6204	Single/Dual/Quad, Low Noise, Rail-to-Rail Amplifier	$1.9nV/\sqrt{Hz}$, 3mA Max, 100MHz Gain Bandwidth