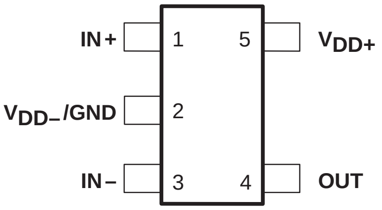
TLV2231, TLV2231Y
Advanced LinCMOS™ RAIL-TO-RAIL
LOW-POWER SINGLE OPERATIONAL AMPLIFIERS

SLOS158C – JUNE 1996 – REVISED SEPTEMBER 1997

- **Output Swing Includes Both Supply Rails**
- **Low Noise . . . 15 nV/$\sqrt{Hz}$ Typ at f = 1 kHz**
- **Low Input Bias Current . . . 1 pA Typ**
- **Fully Specified for Single-Supply 3-V and 5-V Operation**
- **Common-Mode Input Voltage Range Includes Negative Rail**
- **High Gain Bandwidth . . . 2 MHz at V_{DD} = 5 V with 600 Ω Load**
- **High Slew Rate . . . 1.6 V/μs at V_{DD} = 5 V**
- **Wide Supply Voltage Range 2.7 V to 10 V**
- **Macromodel Included**

DBV PACKAGE
(TOP VIEW)



description

The TLV2231 is a single low-voltage operational amplifier available in the SOT-23 package. It offers 2 MHz of bandwidth and 1.6 V/μs of slew rate for applications requiring good ac performance. The device exhibits rail-to-rail output performance for increased dynamic range in single or split supply applications. The TLV2231 is fully characterized at 3 V and 5 V and is optimized for low-voltage applications.

The TLV2231, exhibiting high input impedance and low noise, is excellent for small-signal conditioning of high-impedance sources, such as piezoelectric transducers. Because of the micropower dissipation levels combined with 3-V operation, these devices work well in hand-held monitoring and remote-sensing applications. In addition, the rail-to-rail output feature with single- or split-supplies makes this family a great choice when interfacing with analog-to-digital converters (ADCs). The device can also drive 600-Ω loads for telecom applications.

With a total area of 5.6mm^2, the SOT-23 package only requires one-third the board space of the standard 8-pin SOIC package. This ultra-small package allows designers to place single amplifiers very close to the signal source, minimizing noise pick-up from long PCB traces. TI has also taken special care to provide a pinout that is optimized for board layout (see Figure 1). Both inputs are separated by GND to prevent coupling or leakage paths. The OUT and IN– terminals are on the same end of the board for providing negative feedback. Finally, gain setting resistors and decoupling capacitor are easily placed around the package.

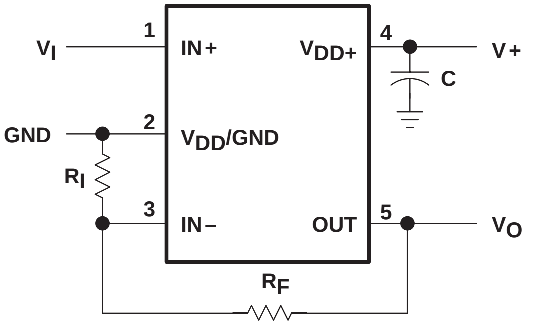


Figure 1. Typical Surface Mount Layout for a Fixed-Gain Noninverting Amplifier

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AVAILABLE OPTIONS

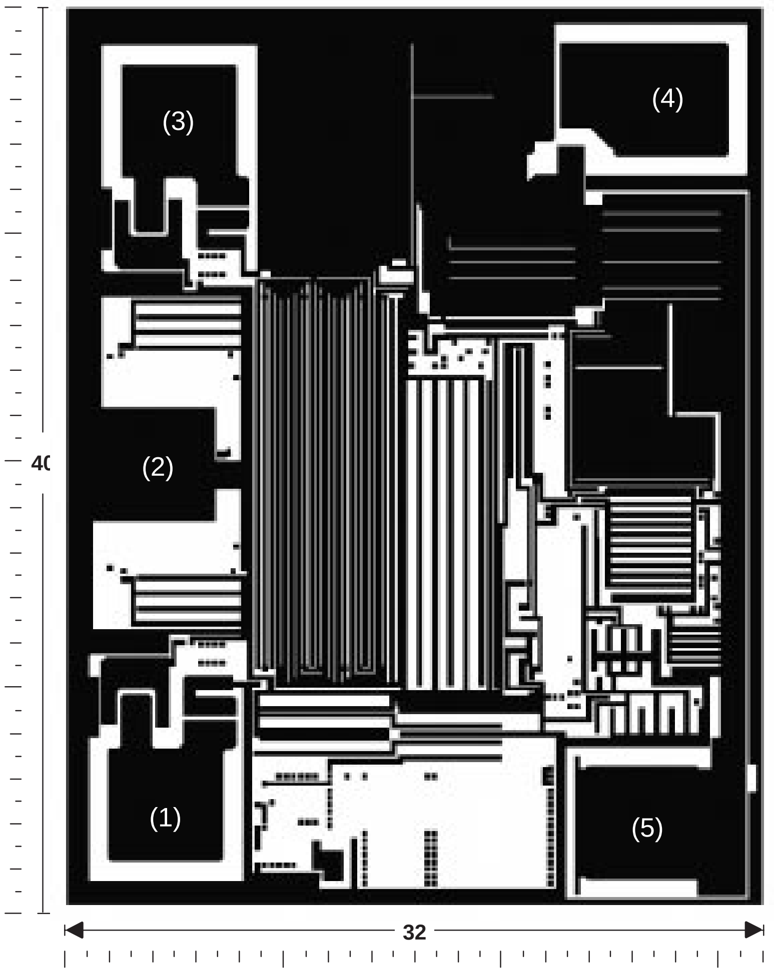
T_A	V_{IO}max AT 25°C	PACKAGED DEVICES	SYMBOL	CHIP FORM‡ (Y)
		SOT-23 (DBV)†		
0°C to 70°C	3 mV	TLV2231CDBV	VAEC	TLV2231Y
–40°C to 85°C	3 mV	TLV2231IDBV	VAEI	

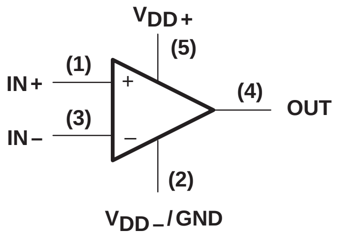
† The DBV package available in tape and reel only.
‡ Chip forms are tested at T_A = 25°C only.

TLV2231Y chip information

This chip, when properly assembled, displays characteristics similar to the TLV2231C. Thermal compression or ultrasonic bonding may be used on the doped-aluminum bonding pads. This chip may be mounted with conductive epoxy or a gold-silicon preform.

BONDING PAD ASSIGNMENTS





CHIP THICKNESS: 10 MILS TYPICAL

BONDING PADS: 4 × 4 MILS MINIMUM

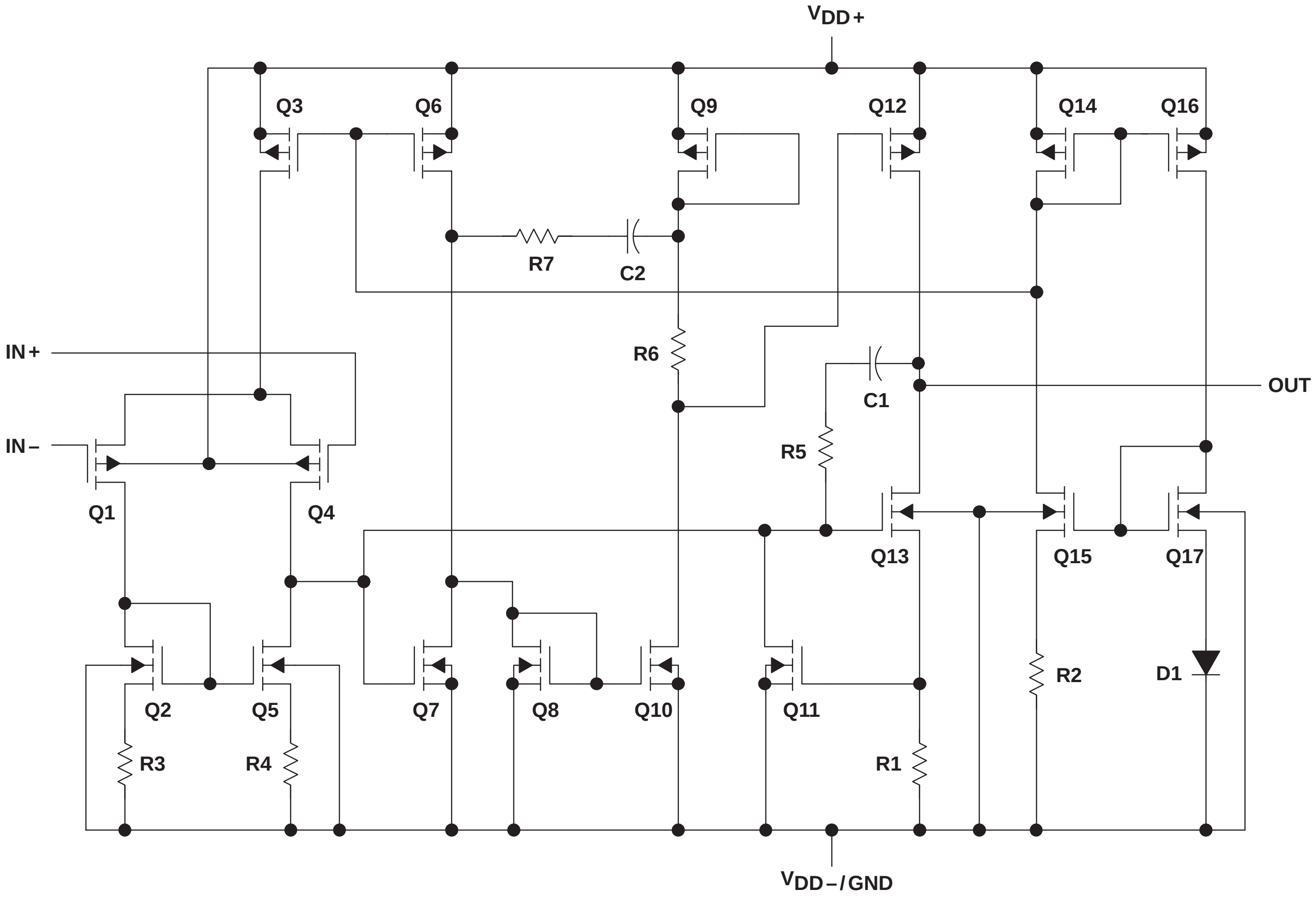
$T_J$max = 150°C

TOLERANCES ARE ±10%.

ALL DIMENSIONS ARE IN MILS.

PIN (2) IS INTERNALLY CONNECTED TO BACKSIDE OF CHIP.

equivalent schematic



COMPONENT COUNT†	
Transistors	23
Diodes	5
Resistors	11
Capacitors	2

† Includes both amplifiers and all ESD, bias, and trim circuitry

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)†

Supply voltage, V_{DD} (see Note 1)	12 V
Differential input voltage, V_{ID} (see Note 2)	$\pm V_{DD}$
Input voltage range, V_I (any input, see Note 1)	-0.3 V to V_{DD}
Input current, I_I (each input)	±5 mA
Output current, I_O	±50 mA
Total current into V_{DD+}	±50 mA
Total current out of V_{DD-}	±50 mA
Duration of short-circuit current (at or below) 25°C (see Note 3)	unlimited
Continuous total power dissipation	See Dissipation Rating Table
Operating free-air temperature range, T_A: TLV2231C	0°C to 70°C
TLV2231I	–40°C to 85°C
Storage temperature range, T_{stg}	–65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: DBV package	260°C

† Stresses beyond those listed under “absolute maximum ratings” may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under “recommended operating conditions” is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

NOTES: 1. All voltage values, except differential voltages, are with respect to V_{DD-}.
2. Differential voltages are at the noninverting input with respect to the inverting input. Excessive current flows when input is brought below $V_{DD-} - 0.3$ V.
3. The output may be shorted to either supply. Temperature and/or supply voltages must be limited to ensure that the maximum dissipation rating is not exceeded.

DISSIPATION RATING TABLE

PACKAGE	$T_A \le 25°C$ POWER RATING	DERATING FACTOR ABOVE $T_A = 25°C$	$T_A = 70°C$ POWER RATING	$T_A = 85°C$ POWER RATING
DBV	150 mW	1.2 mW/°C	96 mW	78 mW

recommended operating conditions

	TLV2231C		TLV2231I		UNIT
	MIN	MAX	MIN	MAX	
Supply voltage, V_{DD} (see Note 1)	2.7	10	2.7	10	V
Input voltage range, V_I	V_{DD-}	$V_{DD+} - 1.3$	V_{DD-}	$V_{DD+} - 1.3$	V
Common-mode input voltage, V_{IC}	V_{DD-}	$V_{DD+} - 1.3$	V_{DD-}	$V_{DD+} - 1.3$	V
Operating free-air temperature, T_A	0	70	–40	85	°C

NOTE 1: All voltage values, except differential voltages, are with respect to V_{DD-}.

electrical characteristics at specified free-air temperature, V_{DD} = 3 V (unless otherwise noted)

PARAMETER		TEST CONDITIONS	T_A†	TLV2231C			TLV2231I			UNIT
				MIN	TYP	MAX	MIN	TYP	MAX	
V_{IO}	Input offset voltage	$V_{DD\pm} = \pm1.5$ V, V_{IC} = 0, V_O = 0, R_S = 50 Ω	Full range		0.75	3		0.75	3	mV
α_{VIO}	Temperature coefficient of input offset voltage				0.5			0.5		μV/°C
	Input offset voltage long-term drift (see Note 4)		25°C		0.003			0.003		μV/mo
I_{IO}	Input offset current		25°C		0.5			0.5		pA
			Full range			150			150	
I_{IB}	Input bias current		25°C		1			1		pA
			Full range			150			150	
V_{ICR}	Common-mode input voltage range	R_S = 50 Ω, $\lvert V_{IO}\rvert \le 5$ mV	25°C	0 to 2	−0.3 to 2.2		0 to 2	−0.3 to 2.2		V
			Full range	0 to 1.7			0 to 1.7			
V_{OH}	High-level output voltage	I_{OH} = −1 mA	25°C		2.87			2.87		V
		I_{OH} = −2 mA	25°C		2.74			2.74		
			Full range	2			2			
V_{OL}	Low-level output voltage	V_{IC} = 1.5 V, I_{OL} = 50 μA	25°C		10			10		mV
		V_{IC} = 1.5 V, I_{OL} = 500 μA	25°C		100			100		
			Full range			300			300	
A_{VD}	Large-signal differential voltage amplification	V_{IC} = 1.5 V, V_O = 1 V to 2 V, R_L = 600 Ω‡	25°C	1	1.6		1	1.6		V/mV
			Full range	0.3			0.3			
		R_L = 1 MΩ‡	25°C		250			250		
r_{id}	Differential input resistance		25°C		10^{12}			10^{12}		Ω
r_{ic}	Common-mode input resistance		25°C		10^{12}			10^{12}		Ω
c_{ic}	Common-mode input capacitance	f = 10 kHz	25°C		6			6		pF
z_o	Closed-loop output impedance	f = 1 MHz, A_V = 1	25°C		156			156		Ω
CMRR	Common-mode rejection ratio	V_{IC} = 0 to 1.7 V, V_O = 1.5 V, R_S = 50 Ω	25°C	60	70		60	70		dB
			Full range	55			55			
k_{SVR}	Supply voltage rejection ratio ($\Delta V_{DD}/\Delta V_{IO}$)	V_{DD} = 2.7 V to 8 V, $V_{IC} = V_{DD}/2$, No load	25°C	70	96		70	96		dB
			Full range	70			70			
I_{DD}	Supply current	V_O = 1.5 V, No load	25°C		750	1200		750	1200	μA
			Full range			1500			1500	

† Full range for the TLV2231C is 0°C to 70°C. Full range for the TLV2231I is – 40°C to 85°C.

‡ Referenced to 1.5 V

NOTE 4: Typical values are based on the input offset voltage shift observed through 500 hours of operating life test at T_A = 150°C extrapolated to T_A = 25°C using the Arrhenius equation and assuming an activation energy of 0.96 eV.

operating characteristics at specified free-air temperature, V_{DD} = 3 V

PARAMETER		TEST CONDITIONS		T_A†	TLV2231C			TLV2231I			UNIT
					MIN	TYP	MAX	MIN	TYP	MAX	
SR	Slew rate at unity gain	V_O = 1.1 V to 1.9 V, C_L = 100 pF‡	R_L = 600 Ω‡,	25°C	0.75	1.25		0.75	1.25		V/μs
				Full range	0.5			0.5			
V_n	Equivalent input noise voltage	f = 10 Hz		25°C		105			105		nV/√Hz
		f = 1 kHz		25°C		16			16		
$V_{N(PP)}$	Peak-to-peak equivalent input noise voltage	f = 0.1 Hz to 1 Hz		25°C		1.4			1.4		μV
		f = 0.1 Hz to 10 Hz		25°C		1.5			1.5		
I_n	Equivalent input noise current			25°C		0.6			0.6		fA /√Hz
THD+N	Total harmonic distortion plus noise	V_O = 1 V to 2 V, f = 20 kHz, R_L = 600 Ω‡	A_V = 1	25°C		0.285%			0.285%		
			A_V = 10			7.2%			7.2%		
		V_O = 1 V to 2 V, f = 20 kHz, R_L = 600 Ω§	A_V = 1	25°C		0.014%			0.014%		
			A_V = 10			0.098%			0.098%		
			A_V = 100			0.13%			0.13%		
	Gain-bandwidth product	f = 10 kHz, C_L = 100 pF‡	R_L = 600 Ω‡,	25°C		1.9			1.9		MHz
B_{OM}	Maximum output-swing bandwidth	$V_{O(PP)}$ = 1 V, R_L = 600 Ω‡,	A_V = 1, C_L = 100 pF‡	25°C		60			60		kHz
t_s	Settling time	A_V = –1, Step = 1 V to 2 V, R_L = 600 Ω‡, C_L = 100 pF‡	To 0.1%	25°C		0.9			0.9		μs
			To 0.01%			1.5			1.5		
ϕ_m	Phase margin at unity gain	R_L = 600 Ω‡,	C_L = 100 pF‡	25°C		50°			50°		
	Gain margin			25°C		8			8		dB

† Full range is –40°C to 85°C.
‡ Referenced to 1.5 V
§ Referenced to 0 V

electrical characteristics at specified free-air temperature, V_{DD} = 5 V (unless otherwise noted)

PARAMETER		TEST CONDITIONS		T_A†	TLV2231C			TLV2231I			UNIT
					MIN	TYP	MAX	MIN	TYP	MAX	
V_{IO}	Input offset voltage	$V_{DD\pm} = \pm2.5$ V, V_{IC} = 0, V_O = 0, R_S = 50 Ω		Full range		0.71	3		0.71	3	mV
α_{VIO}	Temperature coefficient of input offset voltage					0.5			0.5		µV/°C
	Input offset voltage long-term drift (see Note 4)			25°C		0.003			0.003		µV/mo
I_{IO}	Input offset current			25°C		0.5			0.5		pA
				Full range			150			150	
I_{IB}	Input bias current			25°C		1			1		pA
				Full range			150			150	
V_{ICR}	Common-mode input voltage range	R_S = 50 Ω, $\lvert V_{IO}\rvert \le 5$ mV		25°C	0 to 4	−0.3 to 4.2		0 to 4	−0.3 to 4.2		V
				Full range	0 to 3.7			0 to 3.7			
V_{OH}	High-level output voltage	I_{OH} = −1 mA		25°C		4.9			4.9		V
		I_{OH} = −4 mA		25°C		4.6			4.6		
				Full range	4			4			
V_{OL}	Low-level output voltage	V_{IC} = 2.5 V, I_{OL} = 500 µA		25°C		80			80		mV
		V_{IC} = 2.5 V, I_{OL} = 1 mA		25°C		160			160		
				Full range			500			500	
A_{VD}	Large-signal differential voltage amplification	V_{IC} = 2.5 V, V_O = 1 V to 4 V	R_L = 600 Ω‡	25°C	1	1.5		1	1.5		V/mV
				Full range	0.3			0.3			
			R_L = 1 MΩ‡	25°C		400			400		
r_{id}	Differential input resistance			25°C		10^{12}			10^{12}		Ω
r_{ic}	Common-mode input resistance			25°C		10^{12}			10^{12}		Ω
c_{ic}	Common-mode input capacitance	f = 10 kHz		25°C		6			6		pF
z_o	Closed-loop output impedance	f = 1 MHz, A_V = 1		25°C		138			138		Ω
CMRR	Common-mode rejection ratio	V_{IC} = 0 to 2.7 V, V_O = 2.5 V, R_S = 50 Ω		25°C	60	70		60	70		dB
				Full range	55			55			
k_{SVR}	Supply voltage rejection ratio ($\Delta V_{DD}/\Delta V_{IO}$)	V_{DD} = 4.4 V to 8 V, $V_{IC} = V_{DD}/2$, No load		25°C	70	96		70	96		dB
				Full range	70			70			
I_{DD}	Supply current	V_O = 2.5 V, No load		25°C		850	1300		850	1300	µA
				Full range			1600			1600	

† Full range for the TLV2231C is 0°C to 70°C. Full range for the TLV2231I is – 40°C to 85°C.
‡ Referenced to 2.5 V

NOTE 5: Typical values are based on the input offset voltage shift observed through 500 hours of operating life test at T_A = 150°C extrapolated to T_A = 25°C using the Arrhenius equation and assuming an activation energy of 0.96 eV.

operating characteristics at specified free-air temperature, V_{DD} = 5 V

PARAMETER		TEST CONDITIONS		T_A[†]	TLV2231C			TLV2231I			UNIT
					MIN	TYP	MAX	MIN	TYP	MAX	
SR	Slew rate at unity gain	V_O = 1.5 V to 3.5 V, C_L = 100 pF[‡]	R_L = 600 Ω[‡],	25°C	1	1.6		1	1.6		V/μs
				Full range	0.7			0.7			
V_n	Equivalent input noise voltage	f = 10 Hz		25°C		100			100		nV/√Hz
		f = 1 kHz		25°C		15			15		
$V_{N(PP)}$	Peak-to-peak equivalent input noise voltage	f = 0.1 Hz to 1 Hz		25°C		1.4			1.4		μV
		f = 0.1 Hz to 10 Hz		25°C		1.5			1.5		
I_n	Equivalent input noise current			25°C		0.6			0.6		fA /√Hz
THD+N	Total harmonic distortion plus noise	V_O = 1.5 V to 3.5 V, f = 20 kHz, R_L = 600 Ω[‡]	A_V = 1	25°C		0.409%			0.409%		
			A_V = 10			3.68%			3.68%		
		V_O = 1.5 V to 3.5 V, f = 20 kHz, R_L = 600 Ω[§]	A_V = 1	25°C		0.018%			0.018%		
			A_V = 10			0.045%			0.045%		
			A_V = 100			0.116%			0.116%		
	Gain-bandwidth product	f = 10 kHz, C_L = 100 pF[‡]	R_L = 600 Ω[‡],	25°C		2			2		MHz
B_{OM}	Maximum output-swing bandwidth	$V_{O(PP)}$ = 1 V, R_L = 600 Ω[‡],	A_V = 1, C_L = 100 pF[‡]	25°C		300			300		kHz
t_s	Settling time	A_V = –1, Step = 1.5 V to 3.5 V, R_L = 600 Ω[‡], C_L = 100 pF[‡]	To 0.1%	25°C		0.95			0.95		μs
			To 0.01%			2.4			2.4		
ϕ_m	Phase margin at unity gain	R_L = 600 Ω[‡],	C_L = 100 pF[‡]	25°C		48°			48°		
	Gain margin			25°C		8			8		dB

[†] Full range is –40°C to 85°C.
[‡] Referenced to 2.5 V
[§] Referenced to 0 V

electrical characteristics at V_{DD} = 3 V, T_A = 25°C (unless otherwise noted)

PARAMETER		TEST CONDITIONS	TLV2231Y			UNIT
			MIN	TYP	MAX	
V_{IO}	Input offset voltage	$V_{DD\pm} = \pm1.5$ V, $V_{IC} = 0$, $V_O = 0$, $R_S = 50\ \Omega$		750		µV
I_{IO}	Input offset current			0.5		pA
I_{IB}	Input bias current			1		pA
V_{ICR}	Common-mode input voltage range	$\lvert V_{IO}\rvert \le 5$ mV, $R_S = 50\ \Omega$		–0.3 to 2.2		V
V_{OH}	High-level output voltage	$I_{OH} = -1$ mA		2.87		V
V_{OL}	Low-level output voltage	$V_{IC} = 1.5$ V, $I_{OL} = 50\ \mu$A		10		mV
		$V_{IC} = 1.5$ V, $I_{OL} = 500\ \mu$A		100		
A_{VD}	Large-signal differential voltage amplification	$V_O = 1$ V to 2 V, $R_L = 600\ \Omega$[†]		1.6		V/mV
		$R_L = 1$ MΩ[†]		250		
r_{id}	Differential input resistance			10^{12}		Ω
r_{ic}	Common-mode input resistance			10^{12}		Ω
c_{ic}	Common-mode input capacitance	f = 10 kHz		6		pF
z_o	Closed-loop output impedance	f = 1 MHz, $A_V = 1$		156		Ω
CMRR	Common-mode rejection ratio	$V_{IC} = 0$ to 1.7 V, $V_O = 0$, $R_S = 50\ \Omega$	60	70		dB
k_{SVR}	Supply voltage rejection ratio ($\Delta V_{DD}/\Delta V_{IO}$)	$V_{DD} = 2.7$ V to 8 V, $V_{IC} = 0$, No load		96		dB
I_{DD}	Supply current	$V_O = 0$, No load		750		µA

[†] Referenced to 1.5 V

electrical characteristics at V_{DD} = 5 V, T_A = 25°C (unless otherwise noted)

PARAMETER		TEST CONDITIONS	TLV2231Y			UNIT
			MIN	TYP	MAX	
V_{IO}	Input offset voltage	$V_{DD\pm} = \pm1.5$ V, $V_{IC} = 0$, $V_O = 0$, $R_S = 50\ \Omega$		710		µV
I_{IO}	Input offset current			0.5		pA
I_{IB}	Input bias current			1		pA
V_{ICR}	Common-mode input voltage range	$\lvert V_{IO}\rvert \le 5$ mV, $R_S = 50\ \Omega$		–0.3 to 4.2		V
V_{OH}	High-level output voltage	$I_{OH} = -1$ mA		4.9		V
V_{OL}	Low-level output voltage	$V_{IC} = 2.5$ V, $I_{OL} = 500\ \mu$A		80		mV
		$V_{IC} = 2.5$ V, $I_{OL} = 1$ mA		160		
A_{VD}	Large-signal differential voltage amplification	$V_O = 1$ V to 2 V, $R_L = 600\ \Omega$[†]		15		V/mV
		$R_L = 1$ MΩ[†]		400		
r_{id}	Differential input resistance			10^{12}		Ω
r_{ic}	Common-mode input resistance			10^{12}		Ω
c_{ic}	Common-mode input capacitance	f = 10 kHz		6		pF
z_o	Closed-loop output impedance	f = 1 MHz, $A_V = 1$		138		Ω
CMRR	Common-mode rejection ratio	$V_{IC} = 0$ to 1.7 V, $V_O = 0$, $R_S = 50\ \Omega$	60	70		dB
k_{SVR}	Supply voltage rejection ratio ($\Delta V_{DD}/\Delta V_{IO}$)	$V_{DD} = 2.7$ V to 8 V, $V_{IC} = 0$, No load		96		dB
I_{DD}	Supply current	$V_O = 0$, No load		850		µA

[†] Referenced to 2.5 V

TYPICAL CHARACTERISTICS

Table of Graphs

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V_{IO}	Input offset voltage	Distribution vs Common-mode input voltage	2, 3 4, 5
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V_I	Input voltage	vs Supply voltage vs Free-air temperature	9 10
V_{OH}	High-level output voltage	vs High-level output current	11, 14
V_{OL}	Low-level output voltage	vs Low-level output current	12, 13, 15
$V_{O(PP)}$	Maximum peak-to-peak output voltage	vs Frequency	16
I_{OS}	Short-circuit output current	vs Supply voltage vs Free-air temperature	17 18
V_O	Output voltage	vs Differential input voltage	19, 20
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A_{VD}	Large-signal differential voltage amplification	vs Frequency vs Free-air temperature	22, 23 24, 25
z_o	Output impedance	vs Frequency	26, 27
CMRR	Common-mode rejection ratio	vs Frequency vs Free-air temperature	28 29
k_{SVR}	Supply-voltage rejection ratio	vs Frequency vs Free-air temperature	30, 31 32
I_{DD}	Supply current	vs Supply voltage	33
SR	Slew rate	vs Load capacitance vs Free-air temperature	34 35
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V_n	Equivalent input noise voltage	vs Frequency	44, 45
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THD + N	Total harmonic distortion plus noise	vs Frequency	47
	Gain-bandwidth product	vs Free-air temperature vs Supply voltage	48 49
	Gain margin	vs Load capacitance	50, 51
ϕ_m	Phase margin	vs Frequency vs Load capacitance	22, 23 52, 53
B_1	Unity-gain bandwidth	vs Load capacitance	54, 55

TYPICAL CHARACTERISTICS

DISTRIBUTION OF TLV2231 INPUT OFFSET VOLTAGE

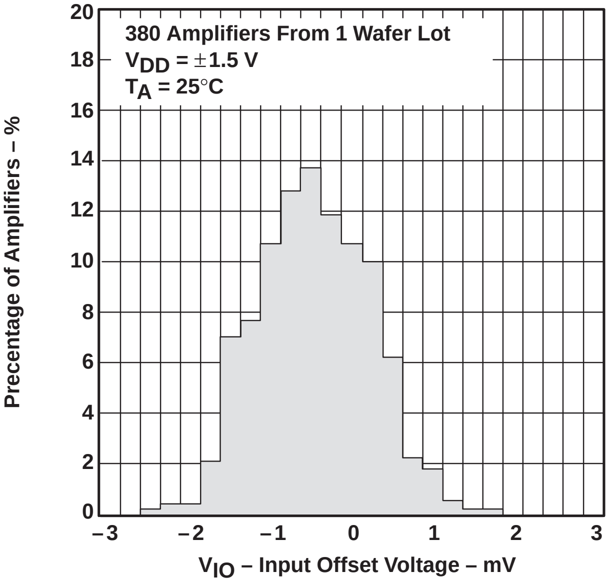

Figure 2

DISTRIBUTION OF TLV2231 INPUT OFFSET VOLTAGE

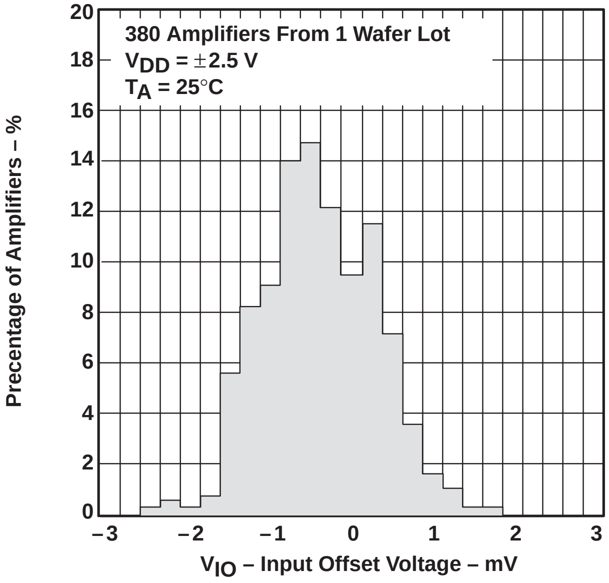

Figure 3

INPUT OFFSET VOLTAGE† vs COMMON-MODE INPUT VOLTAGE

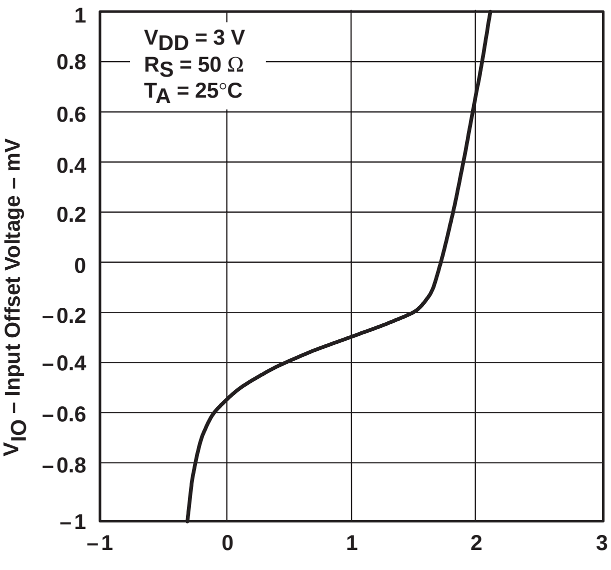

Figure 4

INPUT OFFSET VOLTAGE† vs COMMON-MODE INPUT VOLTAGE

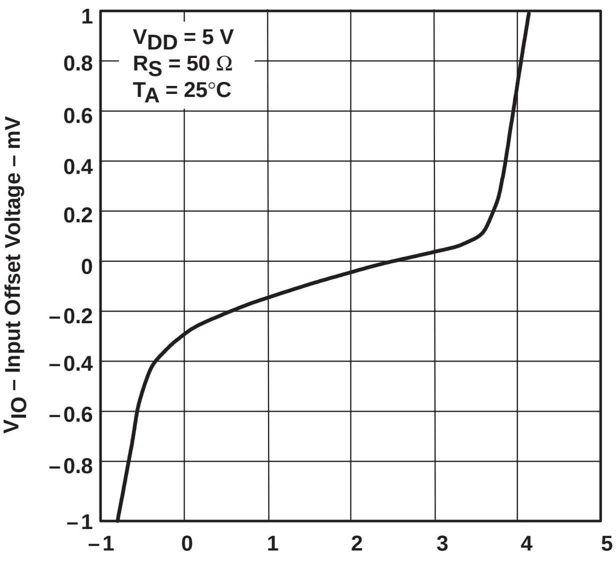

Figure 5

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† For all curves where V_{DD} = 5 V, all loads are referenced to 2.5 V. For all curves where V_{DD} = 3 V, all loads are referenced to 1.5 V.

TYPICAL CHARACTERISTICS

DISTRIBUTION OF TLV2231 INPUT OFFSET VOLTAGE TEMPERATURE COEFFICIENT†

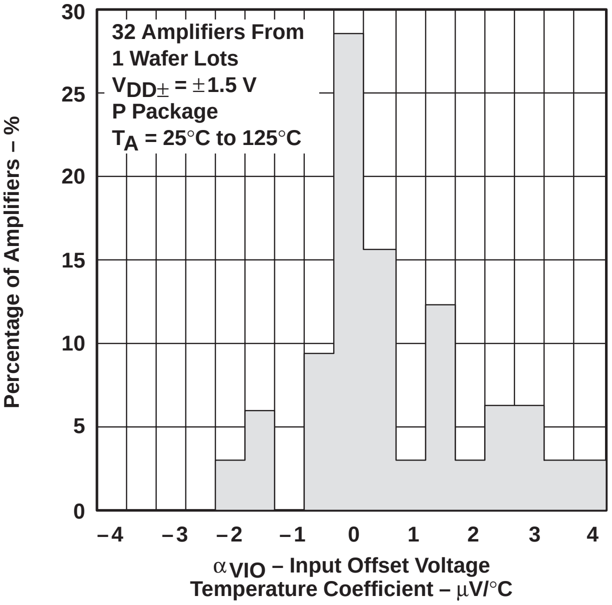

Figure 6

DISTRIBUTION OF TLV2231 INPUT OFFSET VOLTAGE TEMPERATURE COEFFICIENT†

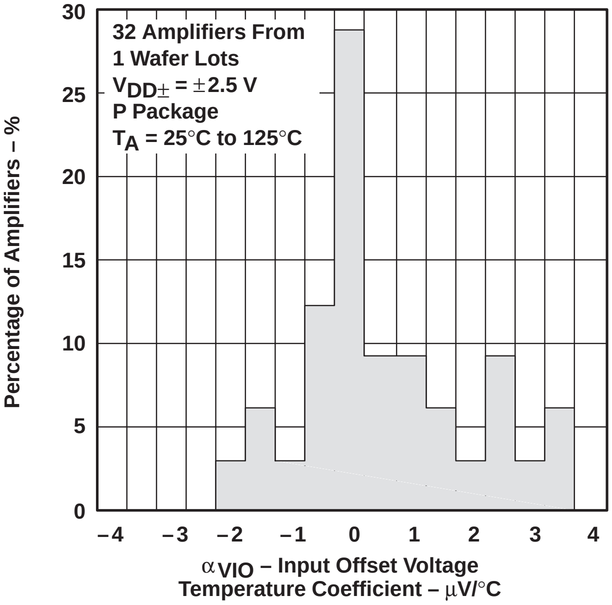

Figure 7

INPUT BIAS AND INPUT OFFSET CURRENTS† vs FREE-AIR TEMPERATURE

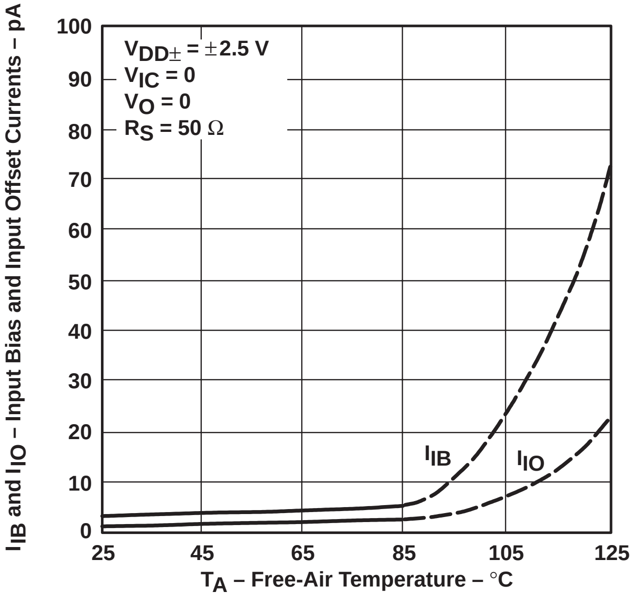

Figure 8

INPUT VOLTAGE vs SUPPLY VOLTAGE

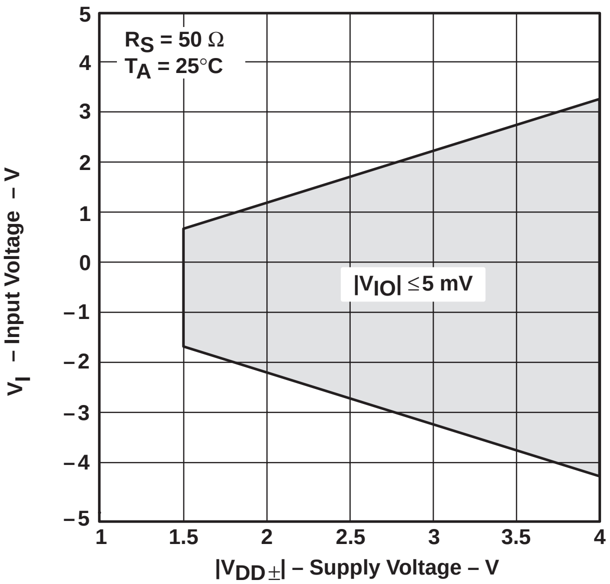

Figure 9

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† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

TYPICAL CHARACTERISTICS

INPUT VOLTAGE† vs FREE-AIR TEMPERATURE

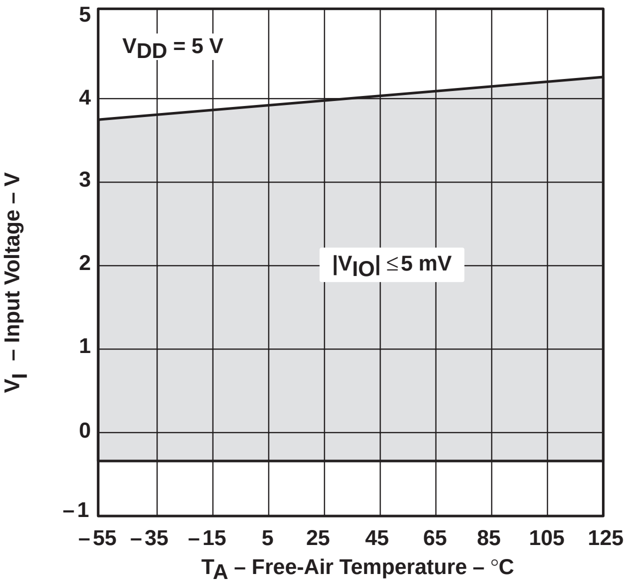

Figure 10

HIGH-LEVEL OUTPUT VOLTAGE†‡ vs HIGH-LEVEL OUTPUT CURRENT

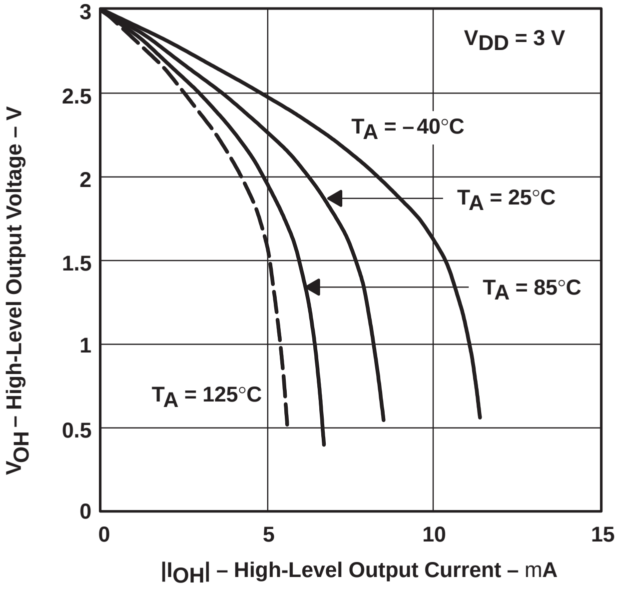

Figure 11

LOW-LEVEL OUTPUT VOLTAGE‡ vs LOW-LEVEL OUTPUT CURRENT

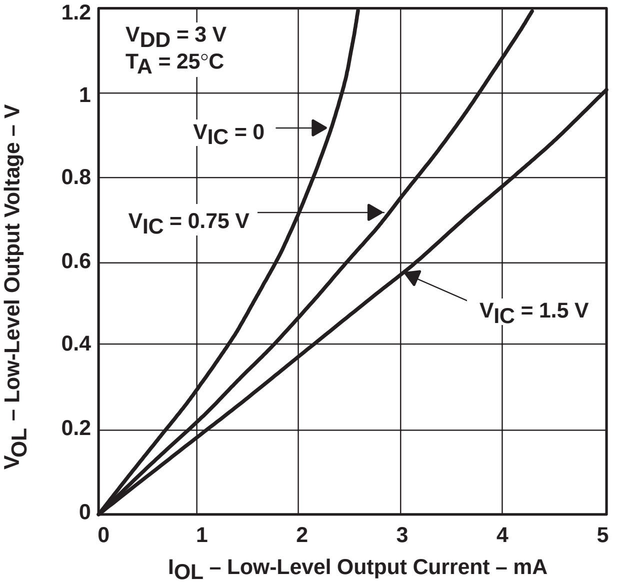

Figure 12

LOW-LEVEL OUTPUT VOLTAGE†‡ vs LOW-LEVEL OUTPUT CURRENT

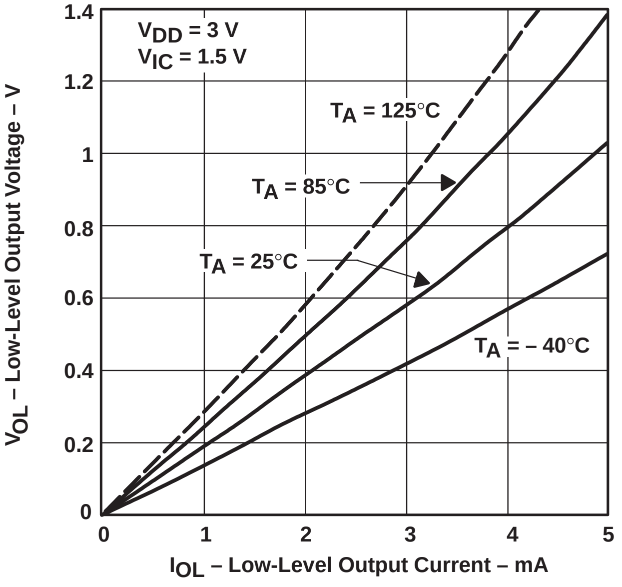

Figure 13

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† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.
‡ For all curves where V_{DD} = 5 V, all loads are referenced to 2.5 V. For all curves where V_{DD} = 3 V, all loads are referenced to 1.5 V.

TYPICAL CHARACTERISTICS

HIGH-LEVEL OUTPUT VOLTAGE†‡ vs HIGH-LEVEL OUTPUT CURRENT

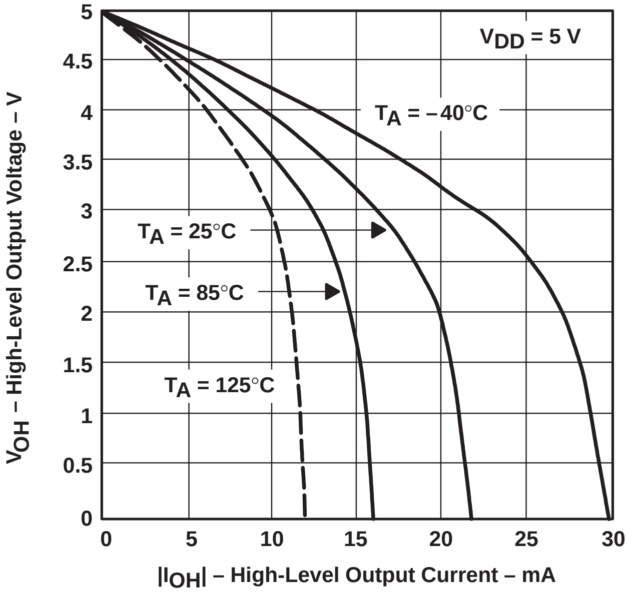

Figure 14

LOW-LEVEL OUTPUT VOLTAGE†‡ vs LOW-LEVEL OUTPUT CURRENT

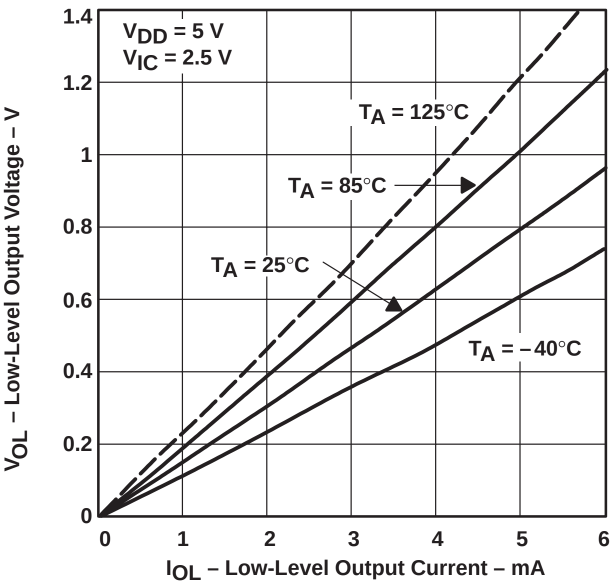

Figure 15

MAXIMUM PEAK-TO-PEAK OUTPUT VOLTAGE‡ vs FREQUENCY

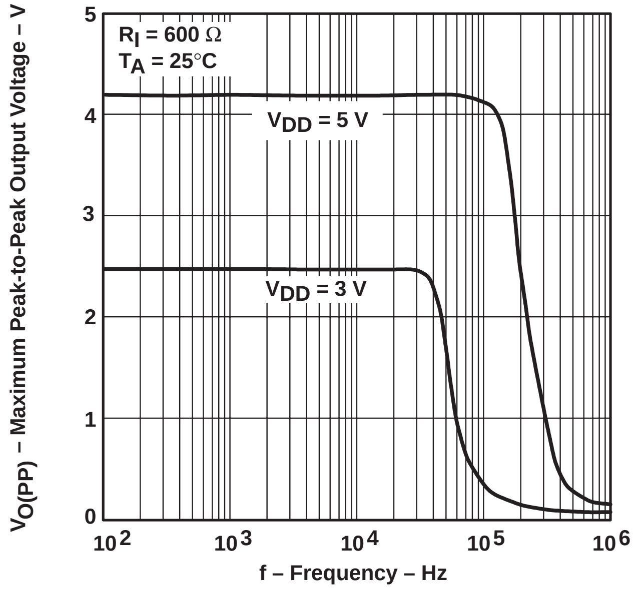

Figure 16

SHORT-CIRCUIT OUTPUT CURRENT vs SUPPLY VOLTAGE

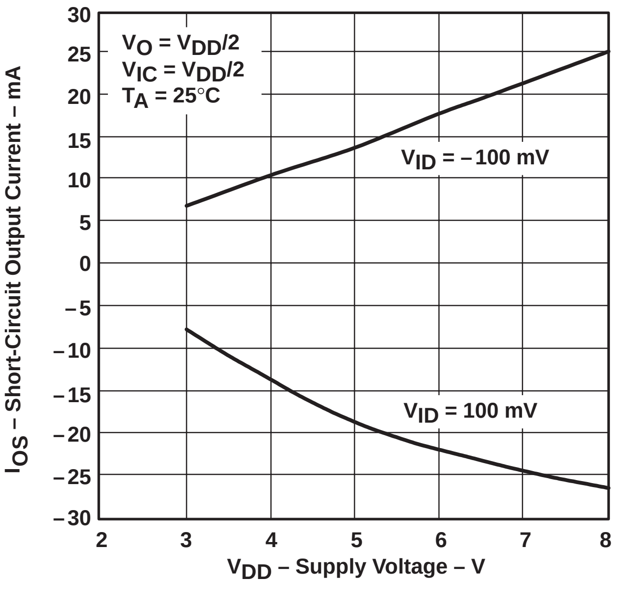

Figure 17

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† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.
‡ For all curves where V_{DD} = 5 V, all loads are referenced to 2.5 V. For all curves where V_{DD} = 3 V, all loads are referenced to 1.5 V.

TYPICAL CHARACTERISTICS

SHORT-CIRCUIT OUTPUT CURRENT†‡ vs FREE-AIR TEMPERATURE

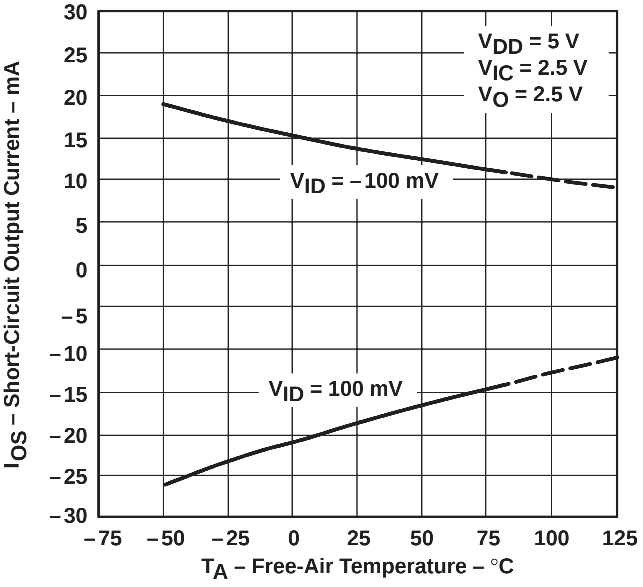

Figure 18

OUTPUT VOLTAGE‡ vs DIFFERENTIAL INPUT VOLTAGE

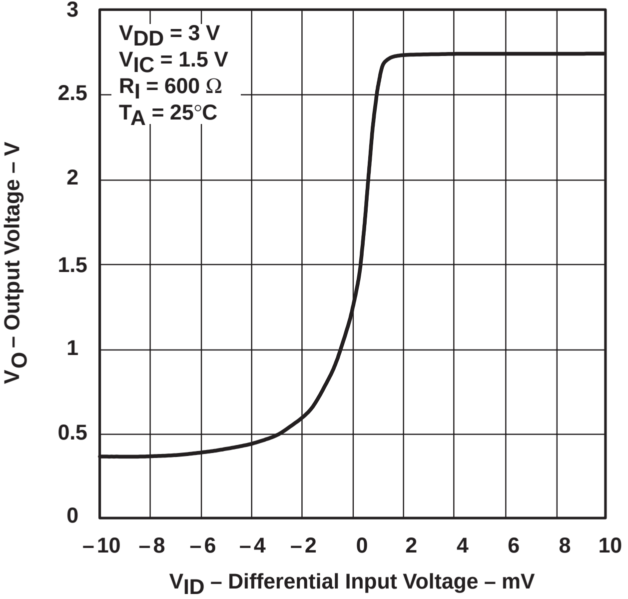

Figure 19

OUTPUT VOLTAGE‡ vs DIFFERENTIAL INPUT VOLTAGE

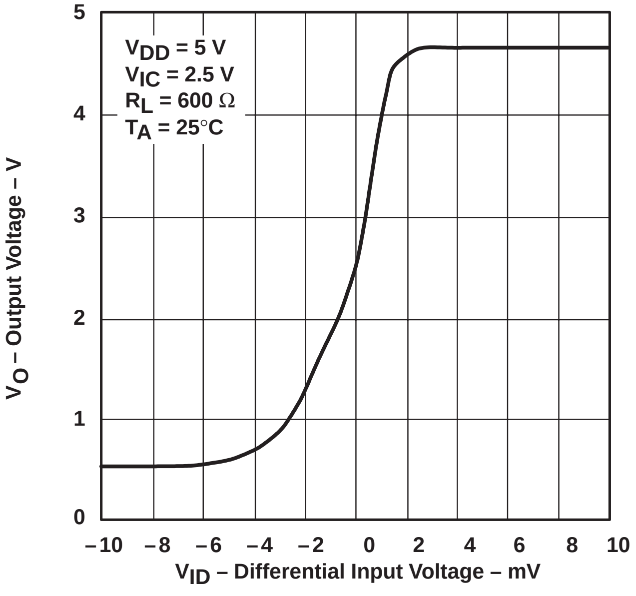

Figure 20

DIFFERENTIAL VOLTAGE AMPLIFICATION‡ vs LOAD RESISTANCE

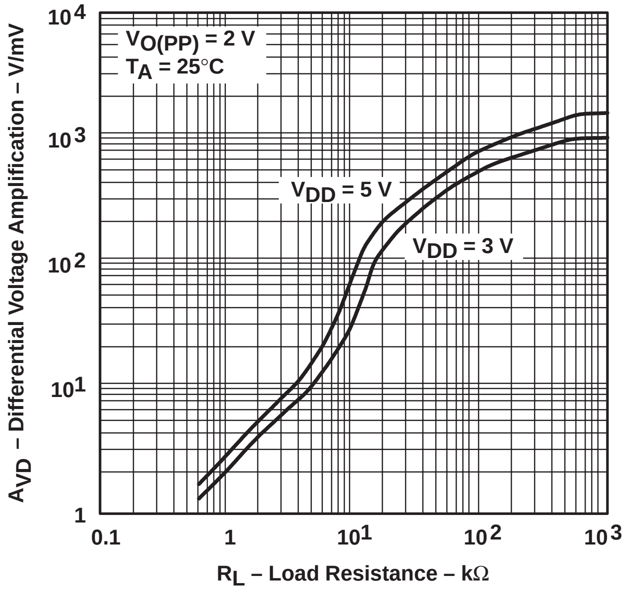

Figure 21

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† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.
‡ For all curves where V_{DD} = 5 V, all loads are referenced to 2.5 V. For all curves where V_{DD} = 3 V, all loads are referenced to 1.5 V.

TYPICAL CHARACTERISTICS

LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION AND PHASE MARGIN† vs FREQUENCY

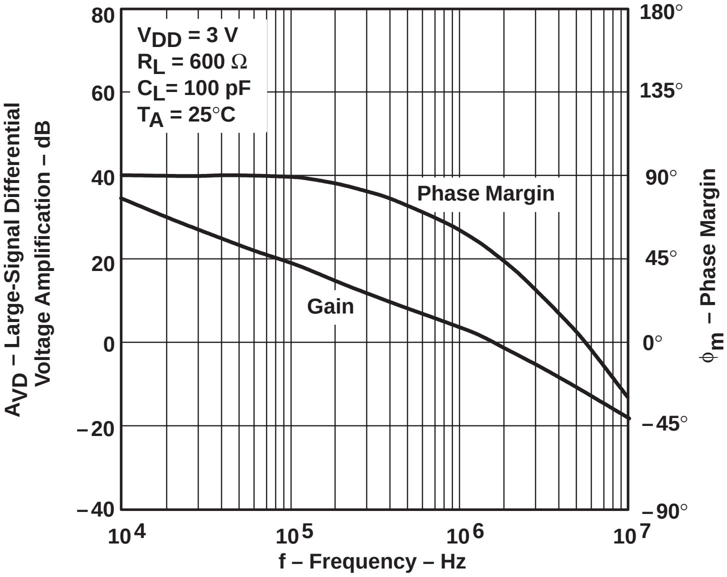

Figure 22

LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION AND PHASE MARGIN† vs FREQUENCY

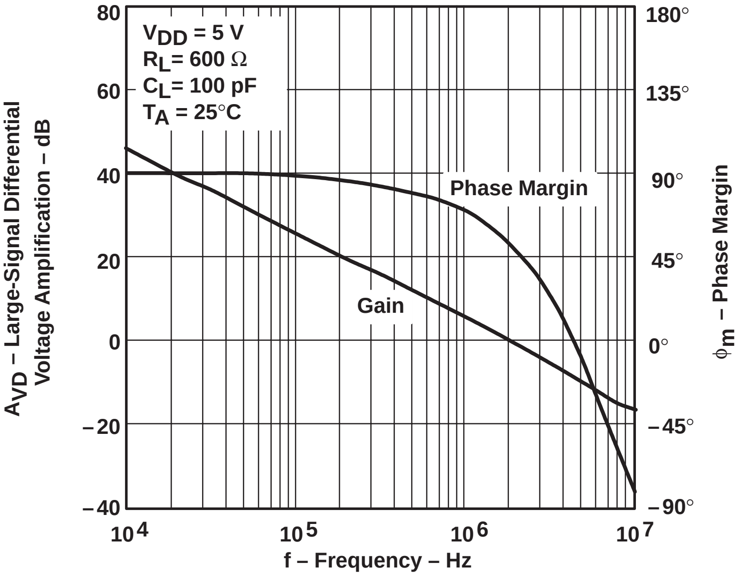

Figure 23

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† For all curves where V_{DD} = 5 V, all loads are referenced to 2.5 V. For all curves where V_{DD} = 3 V, all loads are referenced to 1.5 V.

TYPICAL CHARACTERISTICS

LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION†‡ vs FREE-AIR TEMPERATURE

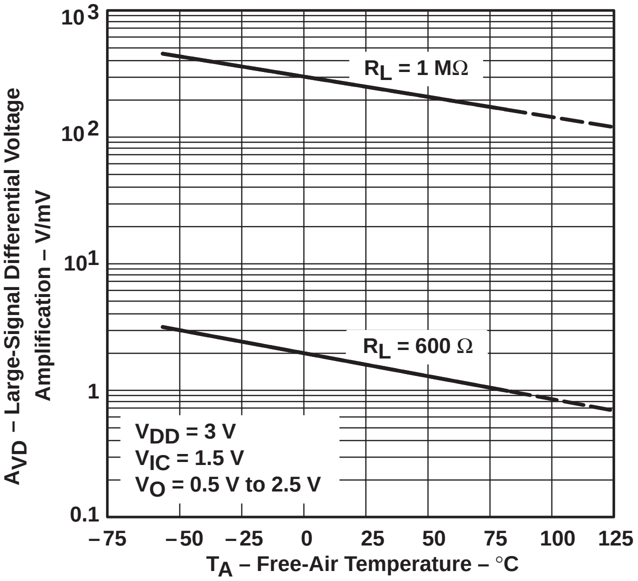

Figure 24

LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION†‡ vs FREE-AIR TEMPERATURE

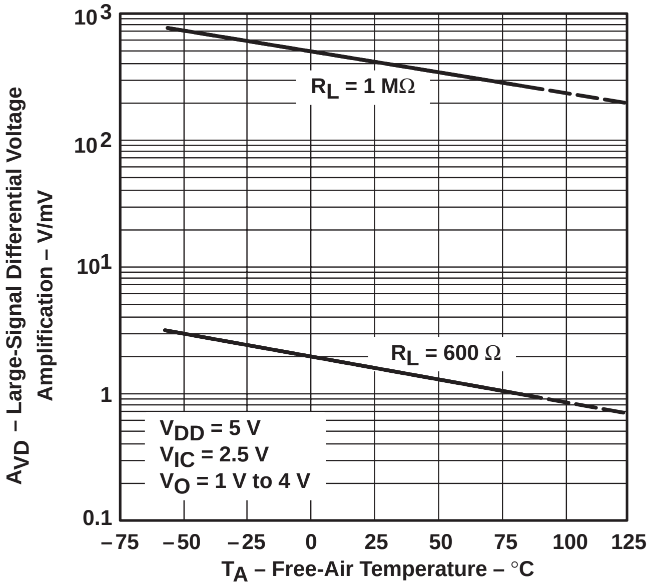

Figure 25

OUTPUT IMPEDANCE‡ vs FREQUENCY

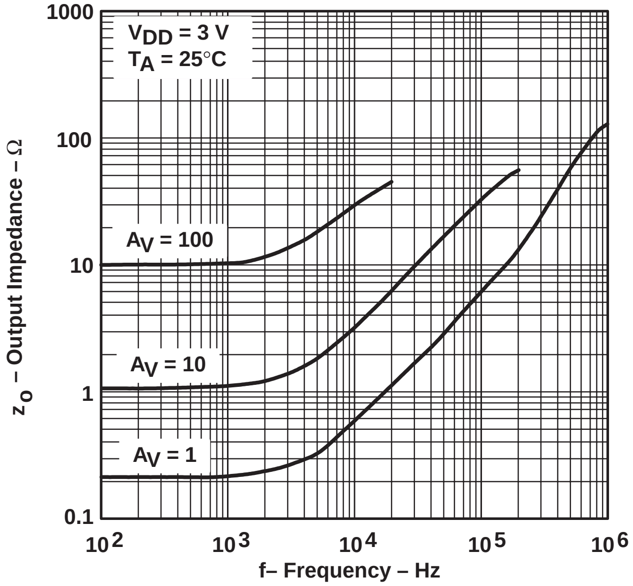

Figure 26

OUTPUT IMPEDANCE‡ vs FREQUENCY

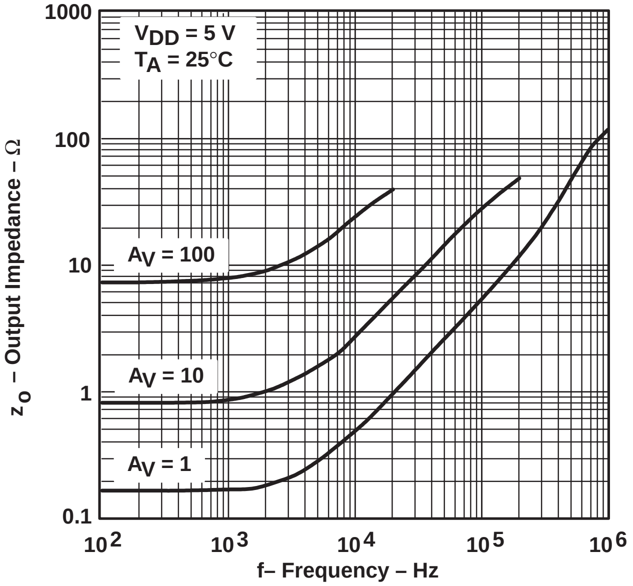

Figure 27

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† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.
‡ For all curves where V_{DD} = 5 V, all loads are referenced to 2.5 V. For all curves where V_{DD} = 3 V, all loads are referenced to 1.5 V.

TYPICAL CHARACTERISTICS

COMMON-MODE REJECTION RATIO† vs FREQUENCY

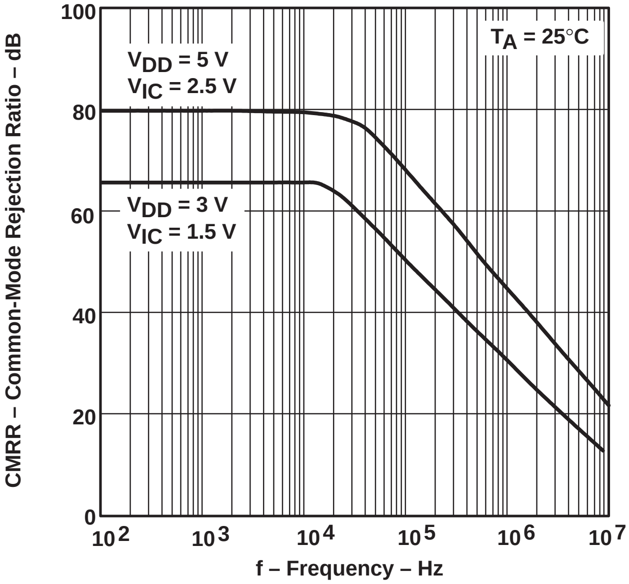

Figure 28

COMMON-MODE REJECTION RATIO†‡ vs FREQUENCY FREE-AIR TEMPERATURE

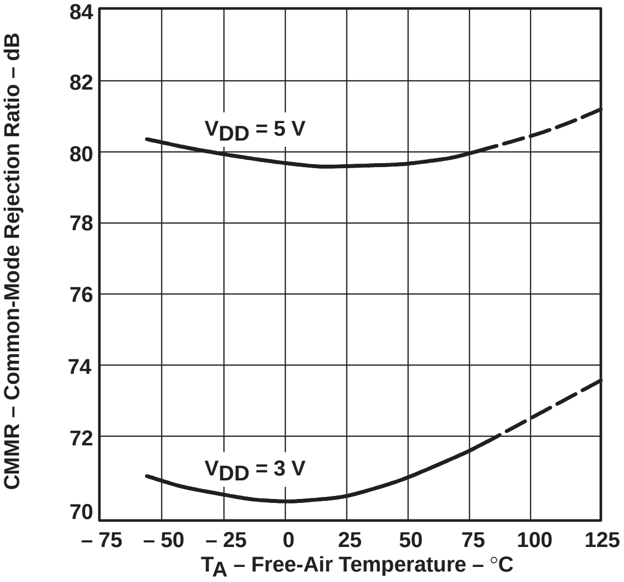

Figure 29

SUPPLY-VOLTAGE REJECTION RATIO† vs FREQUENCY

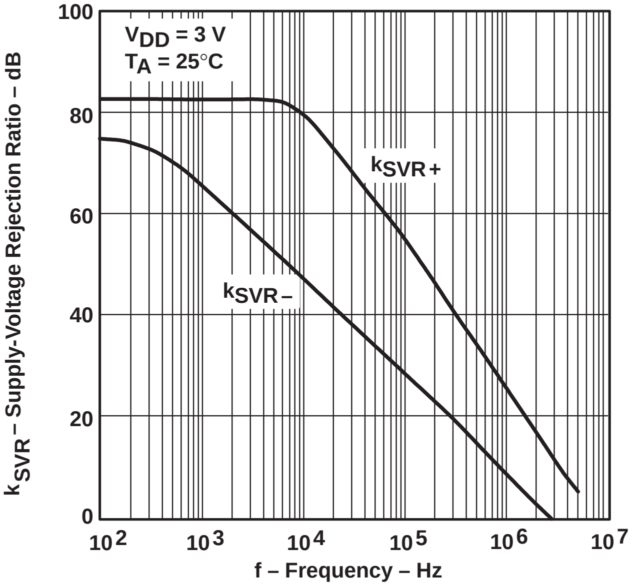

Figure 30

SUPPLY-VOLTAGE REJECTION RATIO† vs FREQUENCY

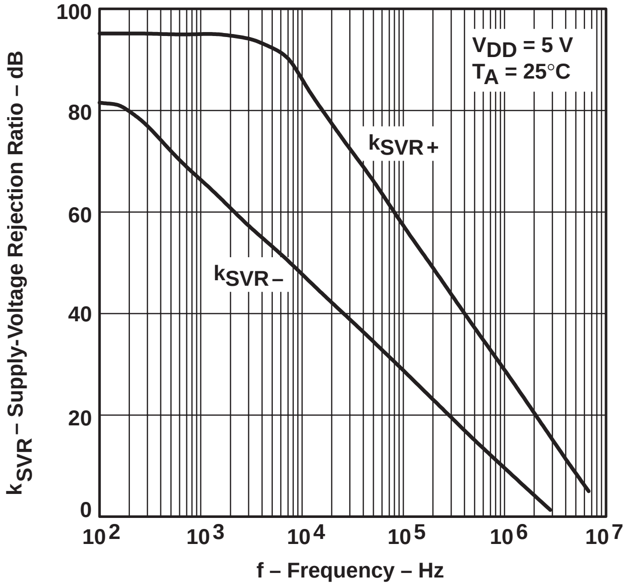

Figure 31

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† For all curves where $V_{DD} = 5$ V, all loads are referenced to 2.5 V. For all curves where $V_{DD} = 3$ V, all loads are referenced to 1.5 V.
‡ Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

TYPICAL CHARACTERISTICS

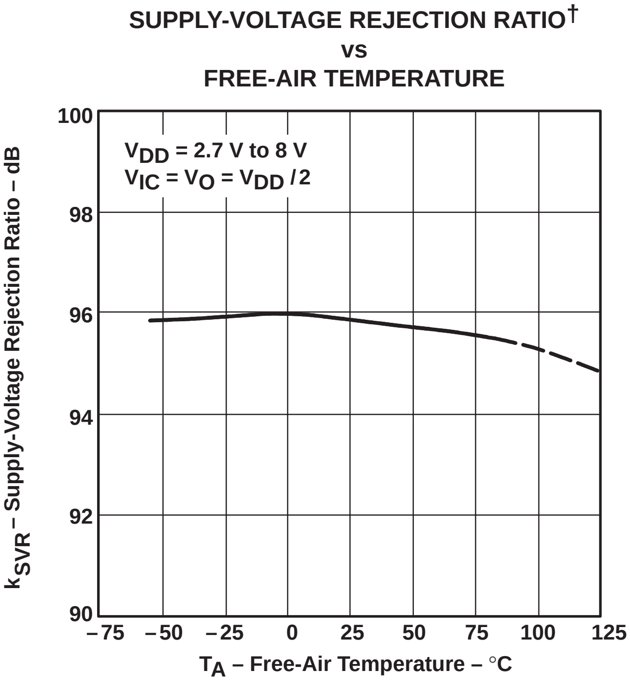

Figure 32

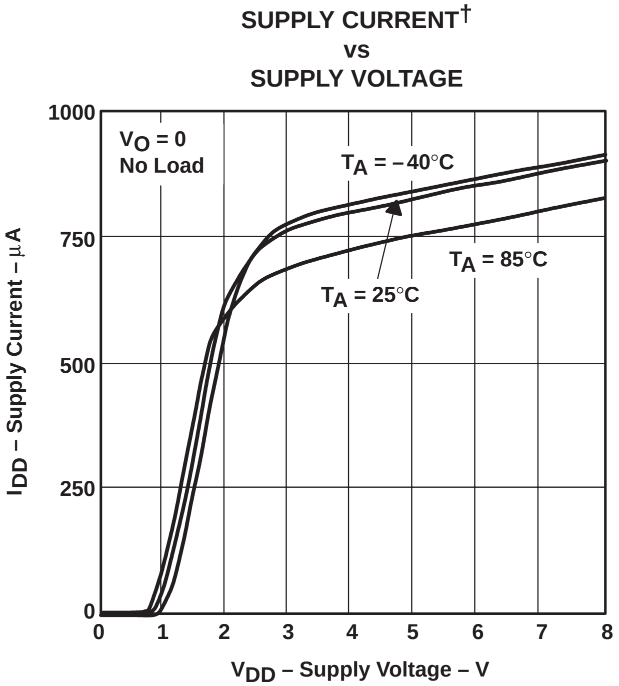

Figure 33

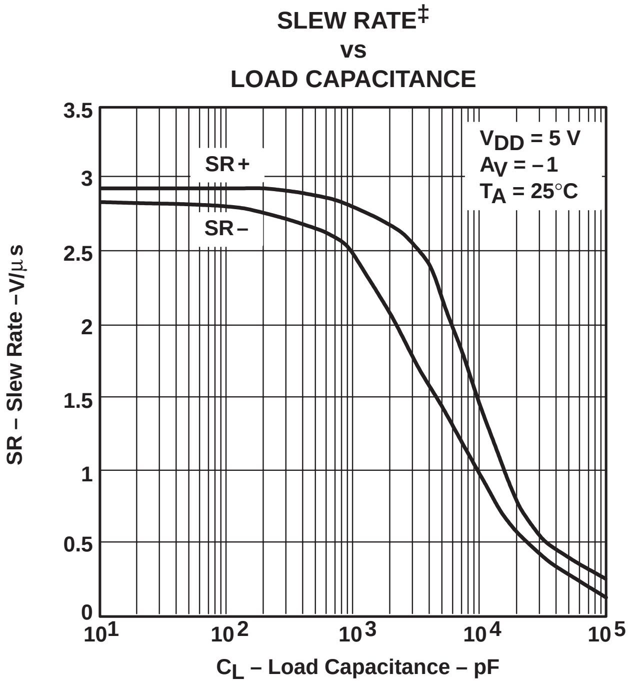

Figure 34

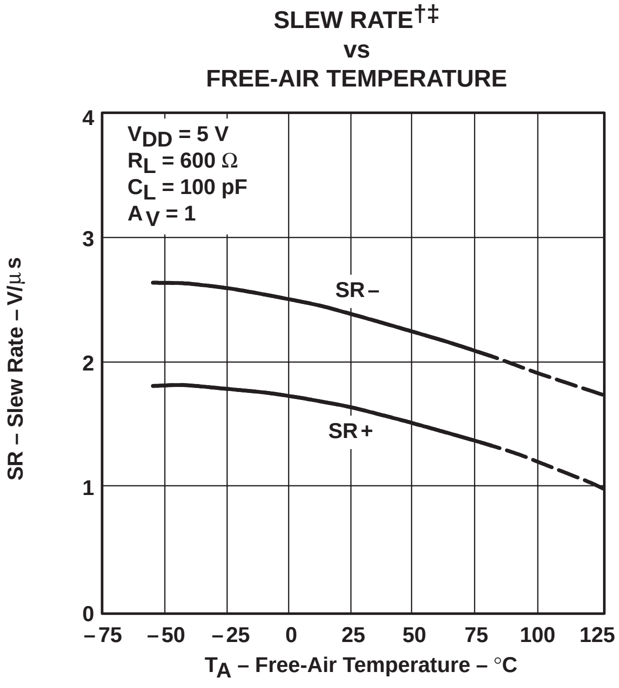

Figure 35

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† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.
‡ For all curves where V_{DD} = 5 V, all loads are referenced to 2.5 V. For all curves where V_{DD} = 3 V, all loads are referenced to 1.5 V.

TYPICAL CHARACTERISTICS

INVERTING LARGE-SIGNAL PULSE RESPONSE†

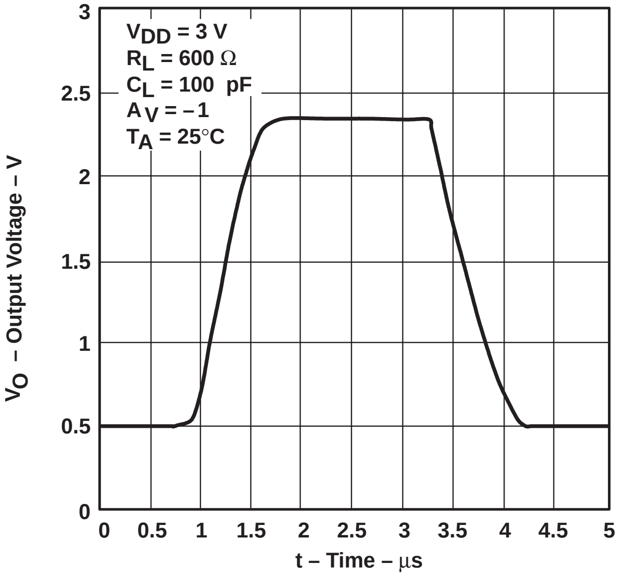

Figure 36

INVERTING LARGE-SIGNAL PULSE RESPONSE†

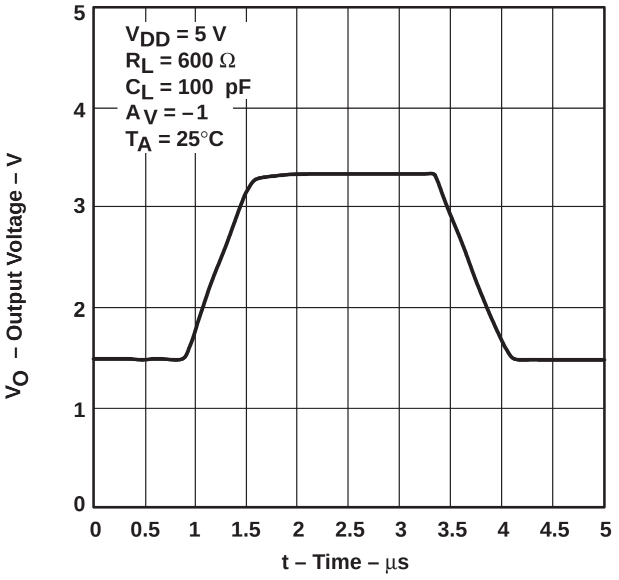

Figure 37

VOLTAGE-FOLLOWER LARGE-SIGNAL PULSE RESPONSE†

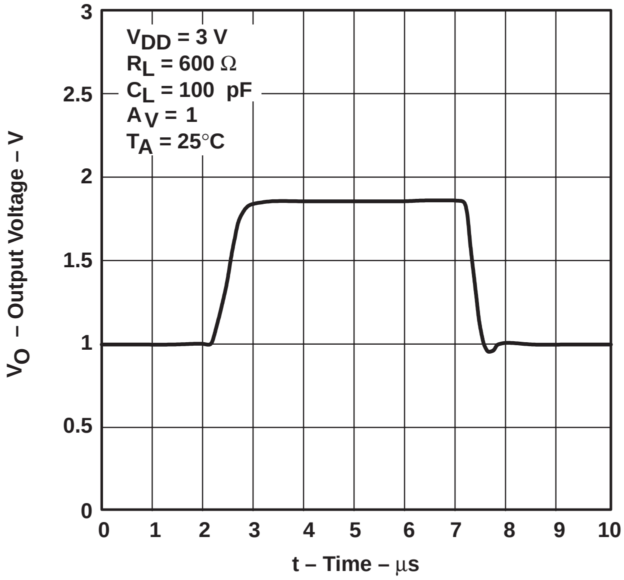

Figure 38

VOLTAGE-FOLLOWER LARGE-SIGNAL PULSE RESPONSE†

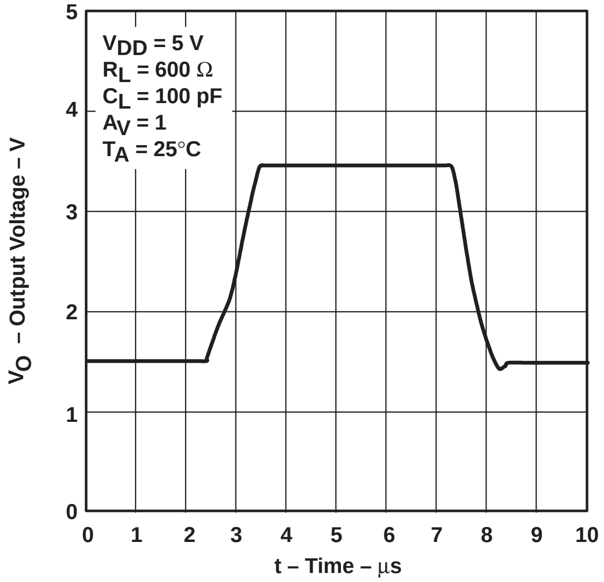

Figure 39

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† For all curves where V_{DD} = 5 V, all loads are referenced to 2.5 V. For all curves where V_{DD} = 3 V, all loads are referenced to 1.5 V.

TYPICAL CHARACTERISTICS

INVERTING SMALL-SIGNAL PULSE RESPONSE†

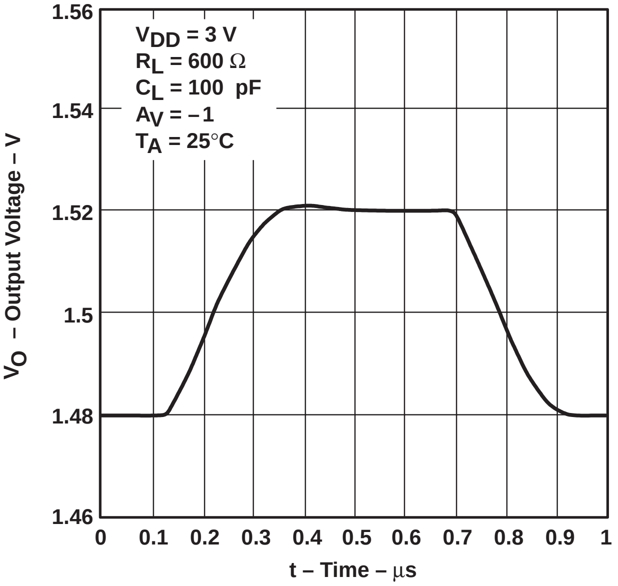

Figure 40

INVERTING SMALL-SIGNAL PULSE RESPONSE†

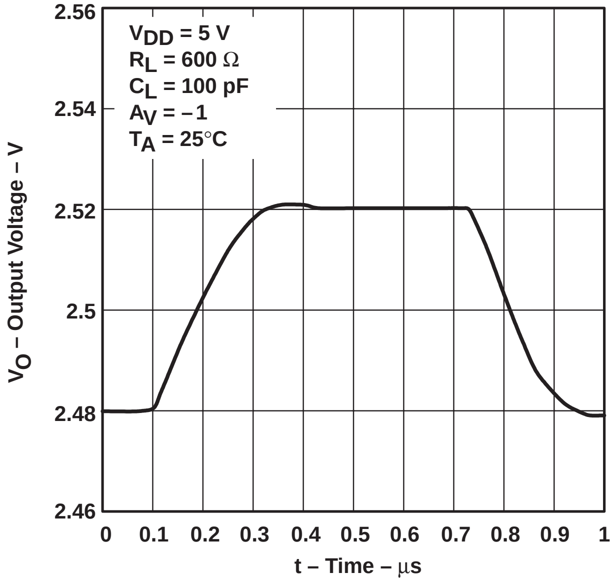

Figure 41

VOLTAGE-FOLLOWER SMALL-SIGNAL PULSE RESPONSE†

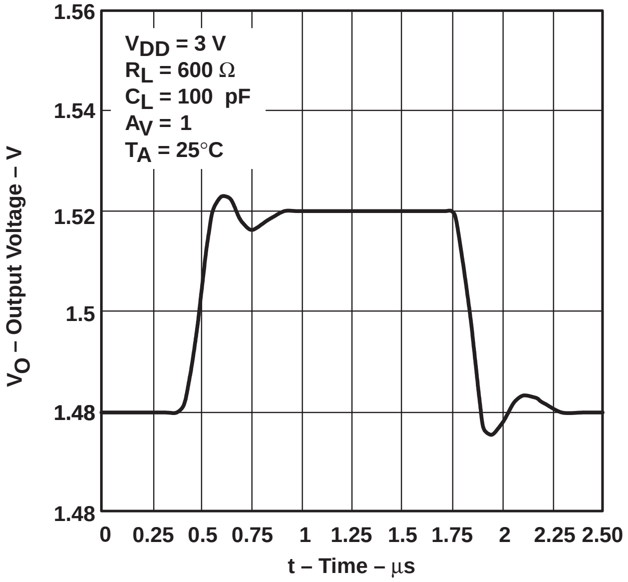

Figure 42

VOLTAGE-FOLLOWER SMALL-SIGNAL PULSE RESPONSE†

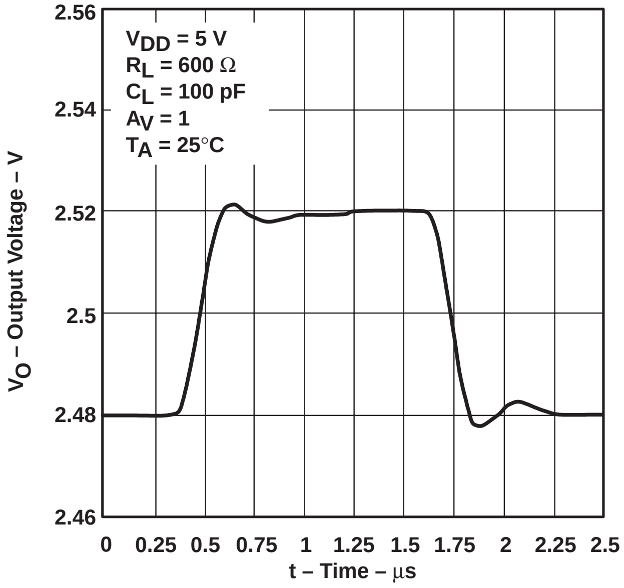

Figure 43

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† For all curves where V_{DD} = 5 V, all loads are referenced to 2.5 V. For all curves where V_{DD} = 3 V, all loads are referenced to 1.5 V.

TYPICAL CHARACTERISTICS

EQUIVALENT INPUT NOISE VOLTAGE[†]
vs
FREQUENCY

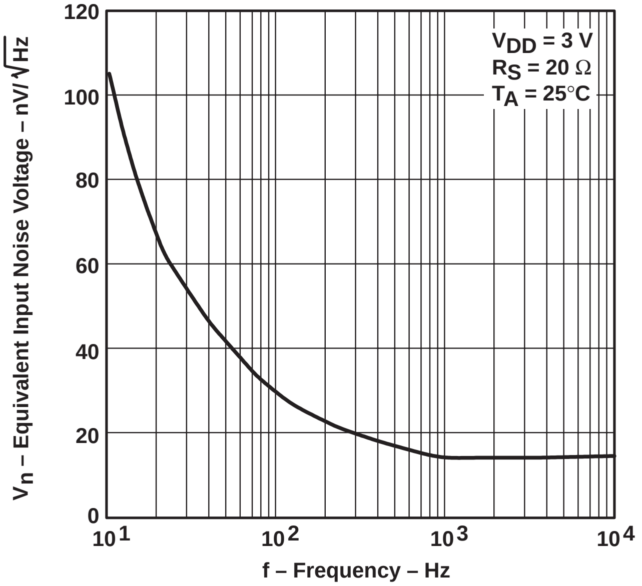

Figure 44

EQUIVALENT INPUT NOISE VOLTAGE[†]
vs
FREQUENCY

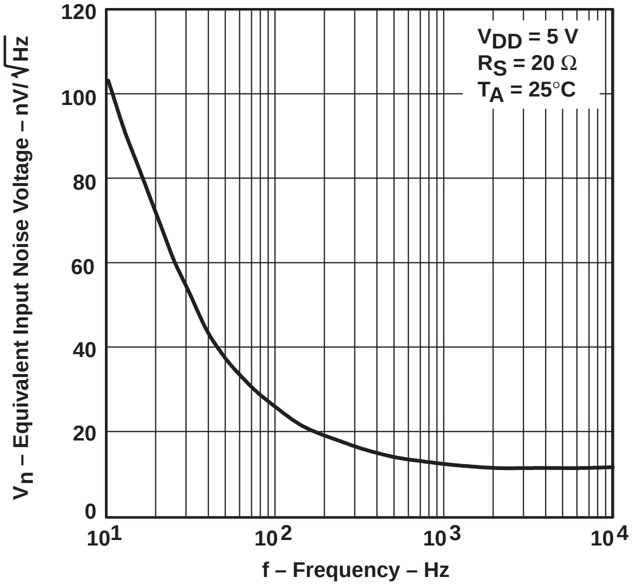

Figure 45

INPUT NOISE VOLTAGE OVER
A 10-SECOND PERIOD[†]

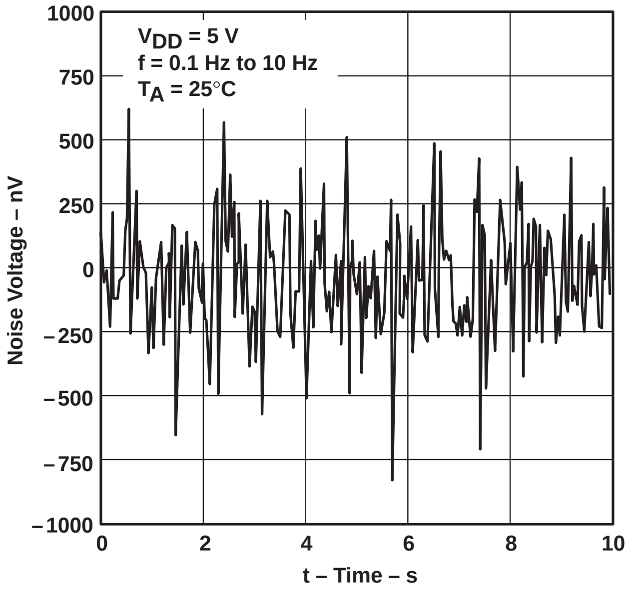

Figure 46

TOTAL HARMONIC DISTORTION PLUS NOISE[†]
vs
FREQUENCY

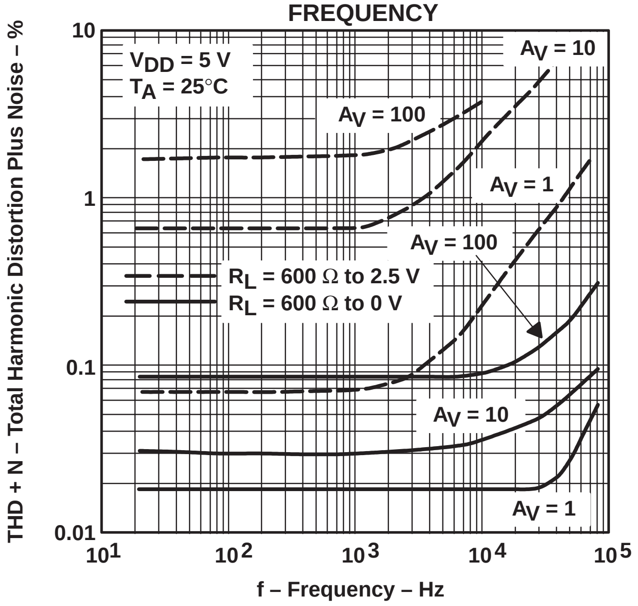

Figure 47

[†] For all curves where V_{DD} = 5 V, all loads are referenced to 2.5 V. For all curves where V_{DD} = 3 V, all loads are referenced to 1.5 V.

TYPICAL CHARACTERISTICS

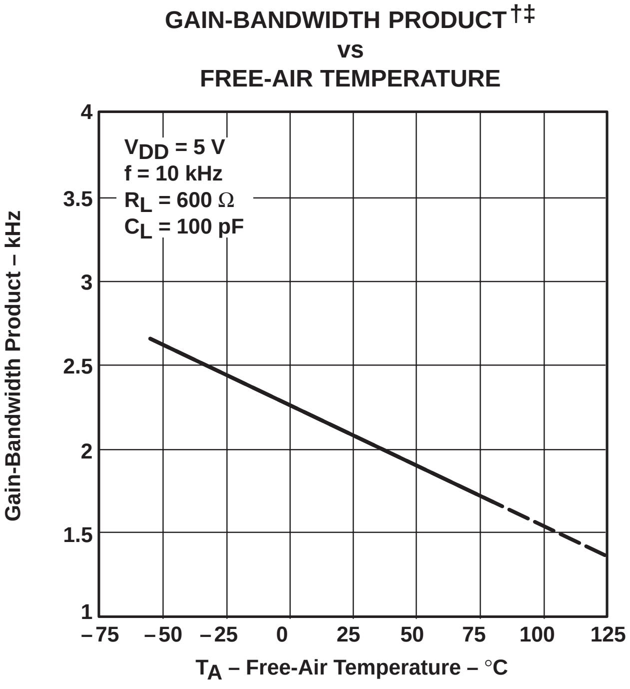

Figure 48

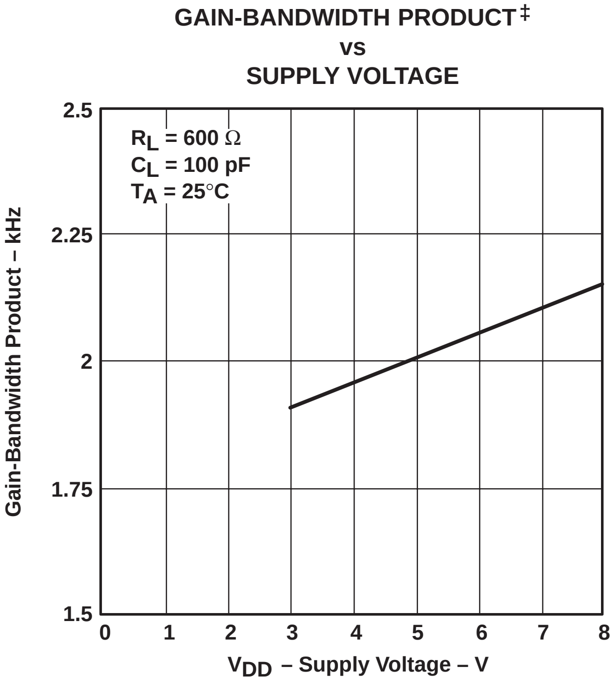

Figure 49

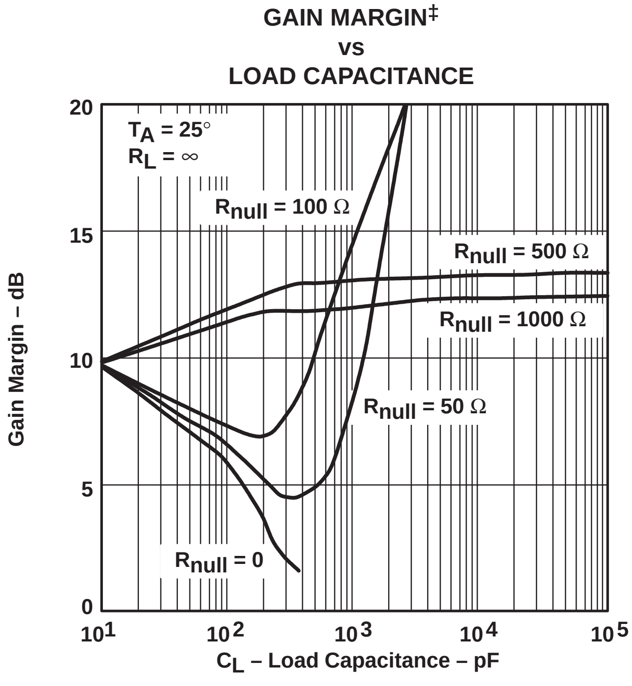

Figure 50

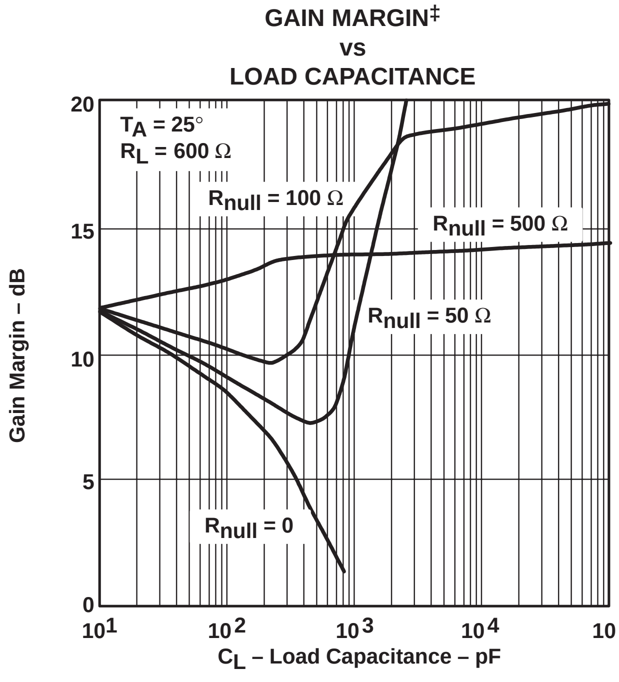

Figure 51

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† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.
‡ For all curves where V_{DD} = 5 V, all loads are referenced to 2.5 V. For all curves where V_{DD} = 3 V, all loads are referenced to 1.5 V.

TYPICAL CHARACTERISTICS

PHASE MARGIN† vs LOAD CAPACITANCE

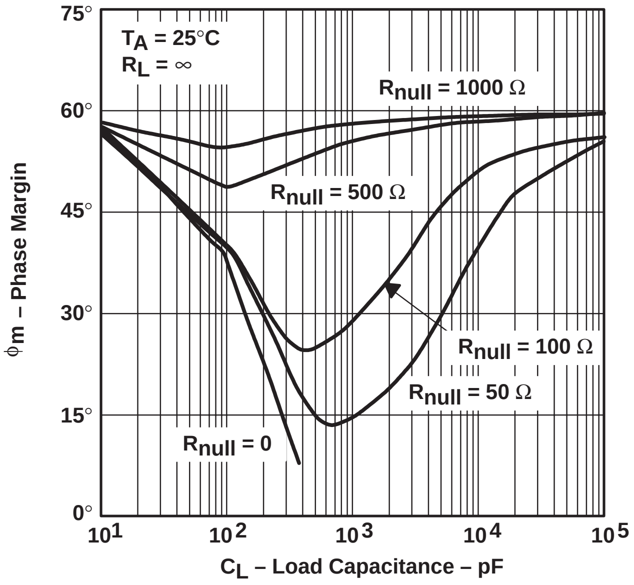

Figure 52

PHASE MARGIN† vs LOAD CAPACITANCE

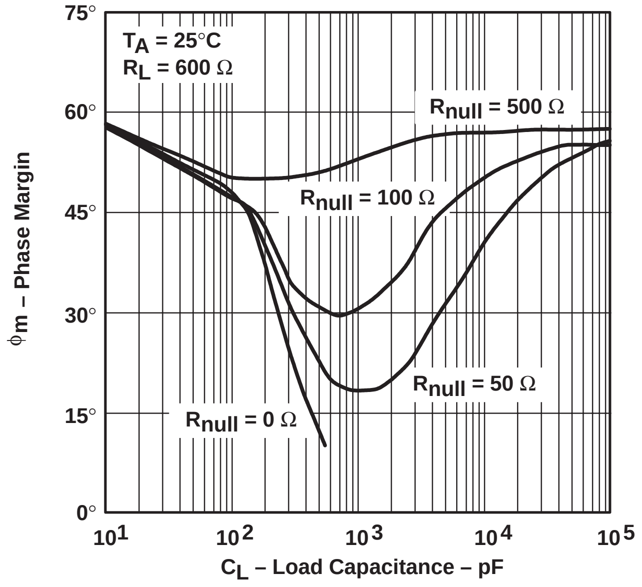

Figure 53

UNITY-GAIN BANDWIDTH† vs LOAD CAPACITANCE

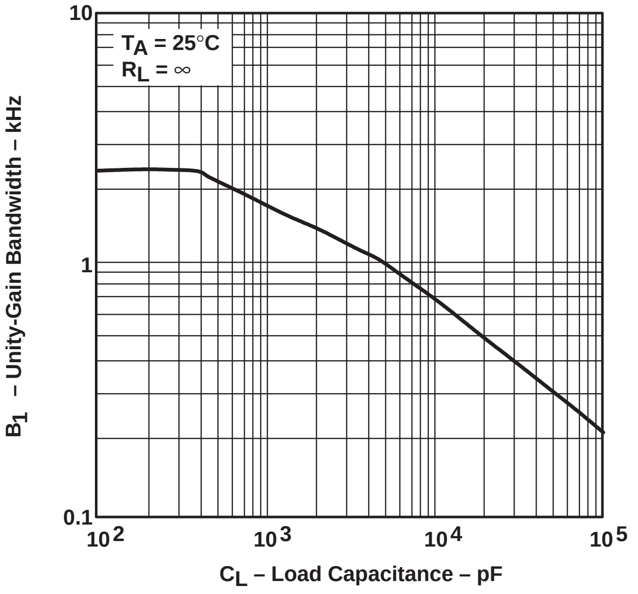

Figure 54

UNITY-GAIN BANDWIDTH† vs LOAD CAPACITANCE

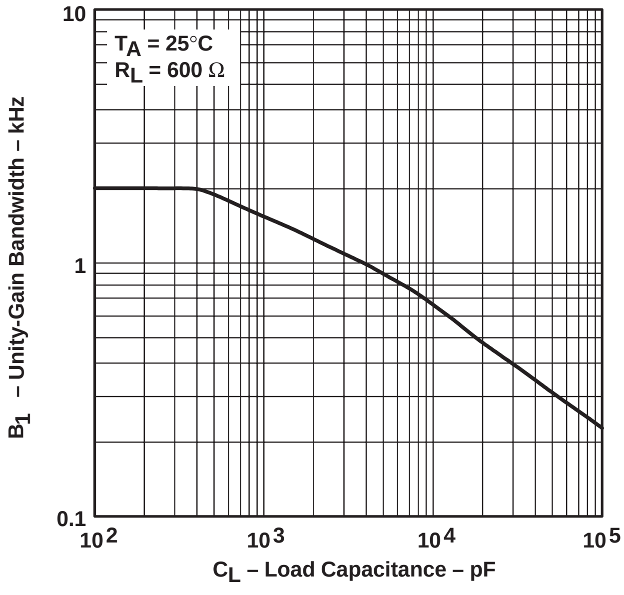

Figure 55

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† For all curves where V_{DD} = 5 V, all loads are referenced to 2.5 V. For all curves where V_{DD} = 3 V, all loads are referenced to 1.5 V.

APPLICATION INFORMATION

driving large capacitive loads

The TLV2231 is designed to drive larger capacitive loads than most CMOS operational amplifiers. Figure 50 through Figure 55 illustrate its ability to drive loads greater than 100 pF while maintaining good gain and phase margins (R_{null} = 0).

A small series resistor (R_{null}) at the output of the device (see Figure 56) improves the gain and phase margins when driving large capacitive loads. Figure 50 through Figure 53 show the effects of adding series resistances of 50 Ω, 100 Ω, 500 Ω, and 1000 Ω. The addition of this series resistor has two effects: the first effect is that it adds a zero to the transfer function and the second effect is that it reduces the frequency of the pole associated with the output load in the transfer function.

The zero introduced to the transfer function is equal to the series resistance times the load capacitance. To calculate the approximate improvement in phase margin, equation 1 can be used.

$$\Delta\phi_{m1} = \tan^{-1}\left(2 \times \pi \times \text{UGBW} \times R_{null} \times C_L\right) \qquad (1)$$

where :

$\Delta\phi_{m1}$ = improvement in phase margin
UGBW = unity-gain bandwidth frequency
R_{null} = output series resistance
C_L = load capacitance

The unity-gain bandwidth (UGBW) frequency decreases as the capacitive load increases (see Figure 54 and Figure 55). To use equation 1, UGBW must be approximated from Figure 54 and Figure 55.

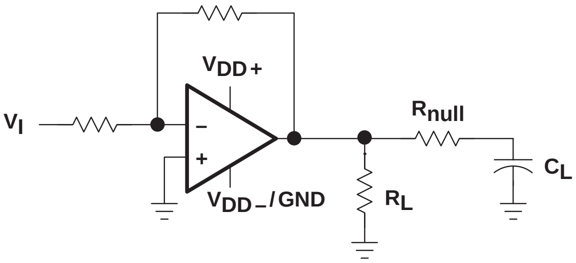


Figure 56. Series-Resistance Circuit

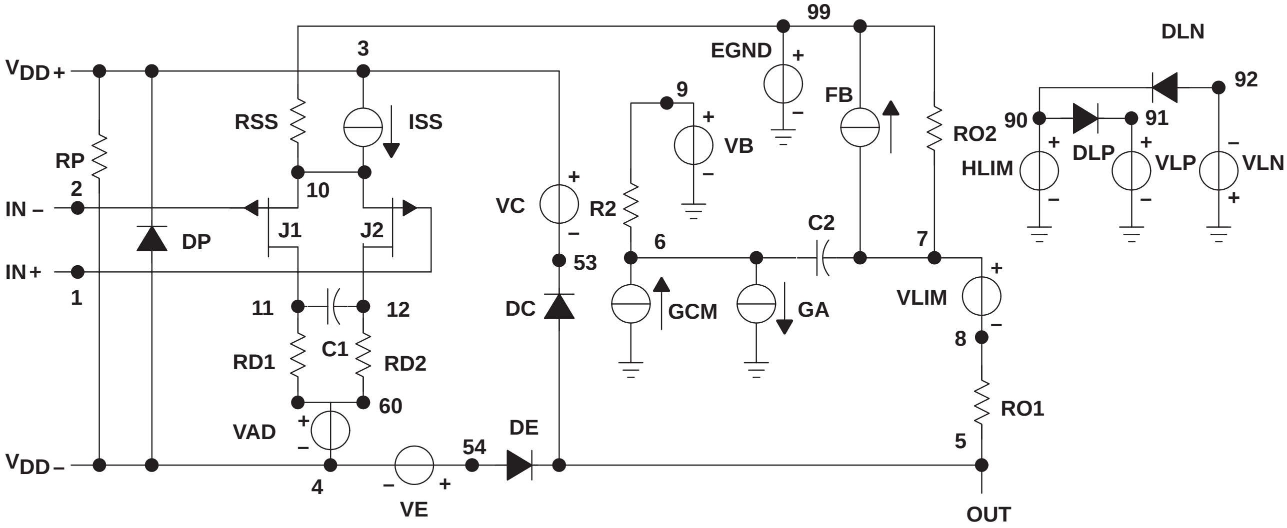
APPLICATION INFORMATION

macromodel information

Macromodel information provided was derived using Microsim *Parts*™, the model generation software used with Microsim *PSpice*™. The Boyle macromodel (see Note 6) and subcircuit in Figure 57 are generated using the TLV2231 typical electrical and operating characteristics at T_A = 25°C. Using this information, output simulations of the following key parameters can be generated to a tolerance of 20% (in most cases):

- Maximum positive output voltage swing
- Maximum negative output voltage swing
- Slew rate
- Quiescent power dissipation
- Input bias current
- Open-loop voltage amplification
- Unity-gain frequency
- Common-mode rejection ratio
- Phase margin
- DC output resistance
- AC output resistance
- Short-circuit output current limit

NOTE 6: G. R. Boyle, B. M. Cohn, D. O. Pederson, and J. E. Solomon, "Macromodeling of Integrated Circuit Operational Amplifiers," *IEEE Journal of Solid-State Circuits,* SC-9, 353 (1974).



```
.SUBCKT TLV2231 1 2 3 4 5
        C1      11    12    13.51E–12
        C2      6     7     50.00E–12
        DC      5     53    DX
        DE      54    5     DX
        DLP     90    91    DX
        DLN     92    90    DX
        DP      4     3     DX
        EGND    99    0     POLY (2) (3,0) (4,0) 0 .5 .5
        FB      7     99    POLY (5) VB VC VE VLP
        + VLN 0 90.83E3 –10E3 10E3 10E3 –10E3
        GA      6     0     11    12 314.2E–6
        GCM     0     6     10    99 242.35E–9
        ISS     3     10    DC    87.00E–6
        HLIM    90    0     VLIM 1K
        J1      11    2     10 JX
        J2      12    1     10 JX
        R2      6     9     100.0E3
RD1     60     11     3.183E3
RD2     60     12     3.183E3
R01     8      5      25
R02     7      99     25
RP      3      4      6.553E3
RSS     10     99     2.500E6
VAD     60     4      –.5
VB      9      0      DC 0
VC      3      53     DC .795
VE      54     4      DC .795
VLIM    7      8      DC 0
VLP     91     0      DC 12.4
VLN     0      92     DC 17.4
.MODEL DX D (IS=800.0E–18)
.MODEL JX PJF (IS=500.0E–15 BETA=2.939E–3
+ VTO=–.065)
.ENDS
```

Figure 57. Boyle Macromodel and Subcircuit

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