TLV2211, TLV2211Y
Advanced LinCMOS™ RAIL-TO-RAIL
MICROPOWER SINGLE OPERATIONAL AMPLIFIERS

SLOS156E − MAY 1996 − REVISED SEPTEMBER 2006

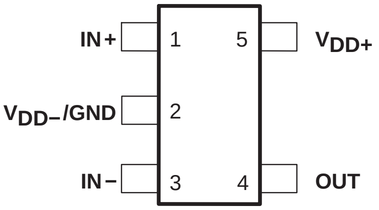
- **Output Swing Includes Both Supply Rails**
- **Low Noise . . . 21 nV/$\sqrt{\text{Hz}}$ Typ at f = 1 kHz**
- **Low Input Bias Current . . . 1 pA Typ**
- **Very Low Power . . . 11 µA Per Channel Typ**
- **Common-Mode Input Voltage Range Includes Negative Rail**
- **Wide Supply Voltage Range 2.7 V to 10 V**
- **Available in the SOT-23 Package**
- **Macromodel Included**

description

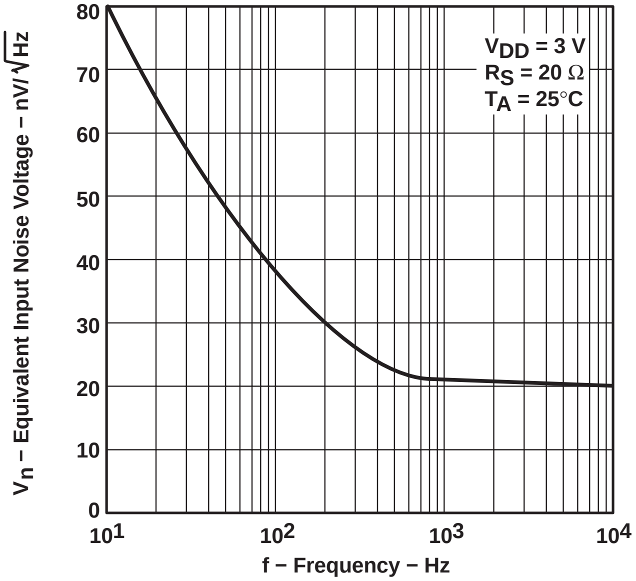
The TLV2211 is a single low-voltage operational amplifier available in the SOT-23 package. It consumes only 11 µA (typ) of supply current and is ideal for battery-power applications. Looking at Figure 1, the TLV2211 has a 3-V noise level of 22 nV/$\sqrt{\text{Hz}}$ at 1kHz; 5 times lower than competitive SOT-23 micropower solutions. The device exhibits rail-to-rail output performance for increased dynamic range in single- or split-supply applications. The TLV2211 is fully characterized at 3 V and 5 V and is optimized for low-voltage applications.

The TLV2211, exhibiting high input impedance and low noise, is excellent for small-signal conditioning for 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).

DBV PACKAGE
(TOP VIEW)



EQUIVALENT INPUT NOISE VOLTAGE† vs FREQUENCY



† All loads are referenced to 1.5 V.

Figure 1. Equivalent Input Noise Voltage Versus Frequency

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	TLV2211CDBV	VACC	TLV2211Y
−40°C to 85°C	3 mV	TLV2211IDBV	VACI	

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

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description (continued)

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 2). 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 to provide negative feedback. Finally, gain setting resistors and decoupling capacitor are easily placed around the package.

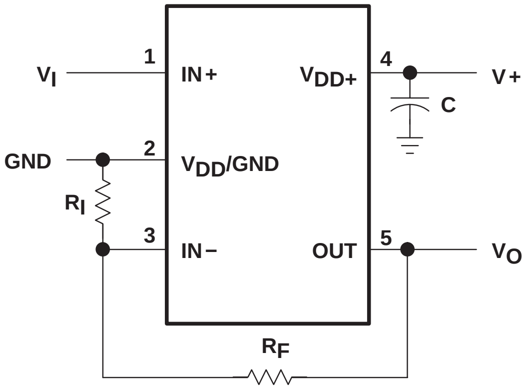
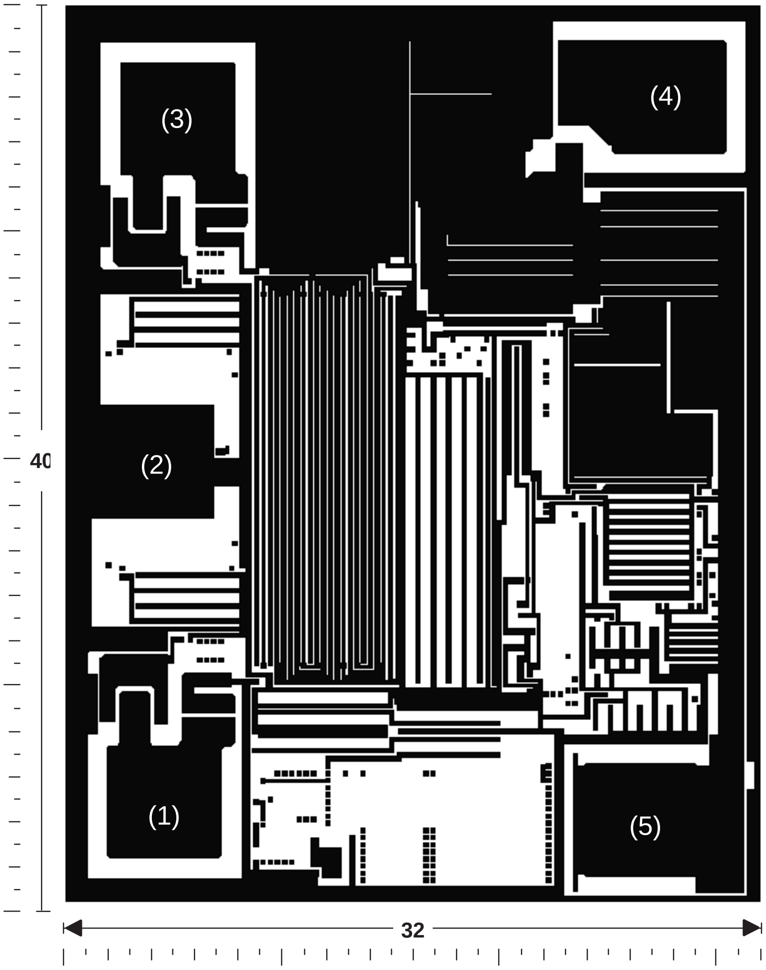


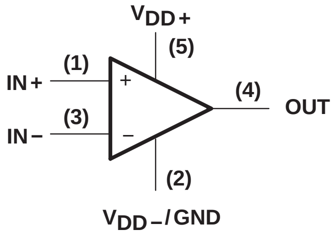
Figure 2. Typical Surface Mount Layout for a Fixed-Gain Noninverting Amplifier

TLV2211Y chip information

This chip, when properly assembled, displays characteristics similar to the TLV2211C. 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

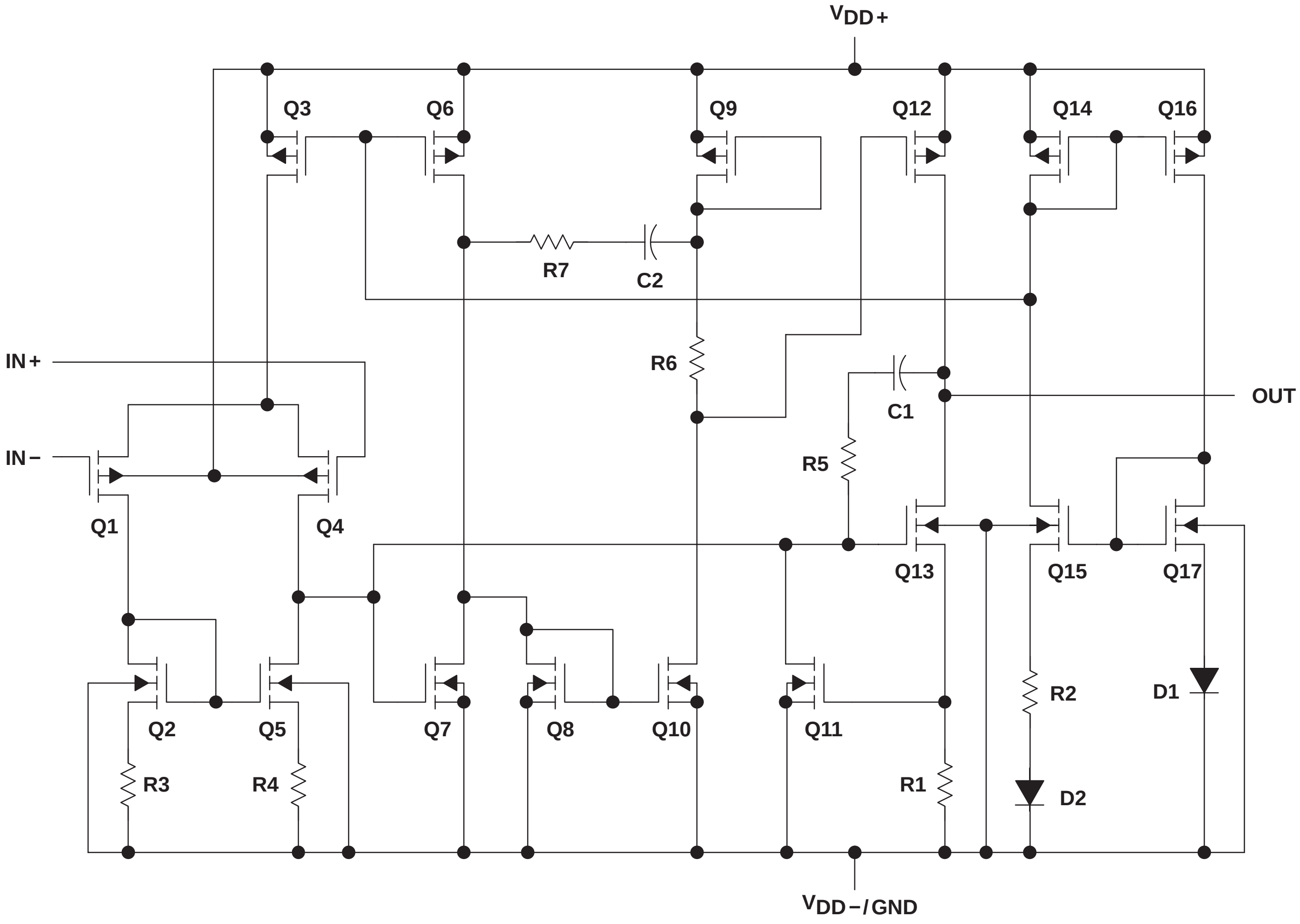
$T_J$max = 150°C

TOLERANCES ARE ±10%.

ALL DIMENSIONS ARE IN MILS.

PIN (2) IS INTERNALLY CONNECTED TO BACK SIDE OF CHIP.

equivalent schematic



COMPONENT COUNT†	
Transistors	23
Diodes	6
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)	±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: TLV2211C	0°C to 70°C
TLV2211I	−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	$T_A \leq 25°C$ 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

	TLV2211C		TLV2211I		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†	TLV2211C			TLV2211I			UNIT
					MIN	TYP	MAX	MIN	TYP	MAX	
V_{IO}	Input offset voltage	$V_{DD\pm}$ = ±1.5 V, V_O = 0,	V_{IC} = 0, R_S = 50 Ω	Full range		0.47	3		0.47	3	mV
α_{VIO}	Temperature coefficient of input offset voltage					1			1		µV/°C
	Input offset voltage long-term drift (see Note 4)			25°C		0.003			0.003		µV/mo
I_{IO}	Input offset current			Full range		0.5	60		0.5	60	pA
I_{IB}	Input bias current			Full range		1	60		1	60	pA
V_{ICR}	Common-mode input voltage range	$\lvert V_{IO}\rvert$ ≤5 mV,	R_S = 50 Ω	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} = −100 µA		25°C		2.94			2.94		V
		I_{OH} = −250 µA		25°C		2.85			2.85		
				Full range	2.5			2.5			
V_{OL}	Low-level output voltage	V_{IC} = 1.5 V,	I_{OL} = 50 µA	25°C		15			15		mV
		V_{IC} = 1.5 V,	I_{OL} = 500 µA	25°C		150			150		
				Full range			500			500	
A_{VD}	Large-signal differential voltage amplification	V_{IC} = 1.5 V, V_O = 1 V to 2 V	R_L = 10 kΩ‡	25°C	3	7		3	7		V/mV
				Full range	1			1			
			R_L = 1 MΩ‡	25°C		600			600		
$r_{i(d)}$	Differential input resistance			25°C		10^{12}			10^{12}		Ω
$r_{i(c)}$	Common-mode input resistance			25°C		10^{12}			10^{12}		Ω
$c_{i(c)}$	Common-mode input capacitance	f = 10 kHz,		25°C		5			5		pF
z_o	Closed-loop output impedance	f = 7 kHz,	A_V = 1	25°C		200			200		Ω
CMRR	Common-mode rejection ratio	V_{IC} = 0 to 1.7 V, R_S = 50 Ω	V_O = 1.5 V,	25°C	65	83		65	83		dB
				Full range	60			60			
k_{SVR}	Supply voltage rejection ratio (ΔV_{DD} /ΔV_{IO})	V_{DD} = 2.7 V to 8 V, No load	V_{IC} = V_{DD}/2 ,	25°C	80	95		80	95		dB
				Full range	80			80			
I_{DD}	Supply current	V_O = 1.5 V,	No load	25°C		11	25		11	25	µA
				Full range			30			30	

† Full range for the TLV2211C is 0°C to 70°C. Full range for the TLV2211I 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 (unless otherwise noted)

PARAMETER		TEST CONDITIONS	T_A†	TLV2211C			TLV2211I			UNIT
				MIN	TYP	MAX	MIN	TYP	MAX	
SR	Slew rate at unity gain	V_O = 1.1 V to 1.9 V, R_L = 10 kΩ‡, C_L = 100 pF‡	25°C	0.01	0.025		0.01	0.025		V/µs
			Full range	0.005			0.005			
V_n	Equivalent input noise voltage	f = 10 Hz	25°C		80			80		nV/√Hz
		f = 1 kHz	25°C		22			22		
$V_{N(PP)}$	Peak-to-peak equivalent input noise voltage	f = 0.1 Hz to 1 Hz	25°C		660			660		nV
		f = 0.1 Hz to 10 Hz	25°C		880			880		
I_n	Equivalent input noise current		25°C		0.6			0.6		fA/√Hz
	Gain-bandwidth product	f = 10 kHz, R_L = 10 kΩ‡, C_L = 100 pF‡	25°C		56			56		kHz
B_{OM}	Maximum output-swing bandwidth	$V_{O(PP)}$ = 1 V, A_V = 1, R_L = 10 kΩ‡, C_L = 100 pF‡	25°C		7			7		kHz
ϕ_m	Phase margin at unity gain	R_L = 10 kΩ‡, C_L = 100 pF‡	25°C		56°			56°		
	Gain margin		25°C		20			20		dB

† Full range is −40°C to 85°C.
‡ Referenced to 1.5 V

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

PARAMETER		TEST CONDITIONS		T_A†	TLV2211C			TLV2211I			UNIT
					MIN	TYP	MAX	MIN	TYP	MAX	
V_{IO}	Input offset voltage	$V_{DD\pm}$ = ±2.5 V, V_O = 0,	V_{IC} = 0, R_S = 50 Ω	Full range		0.45	3		0.45	3	mV
α_{VIO}	Temperature coefficient of input offset voltage					0.5			0.5		µV/°C
	Input offset voltage long-term drift (see Note 5)			25°C		0.003			0.003		µV/mo
I_{IO}	Input offset current			25°C		0.5	60		0.5	60	pA
				Full range			150			150	
I_{IB}	Input bias current			25°C		1	60		1	60	pA
				Full range			150			150	
V_{ICR}	Common-mode input voltage range	$\|V_{IO}\|$ ≤5 mV	R_S = 50 Ω	25°C	0 to 4	−0.3 to 4.2		0 to 4	−0.3 to 4.2		V
				Full range	0 to 3.5			0 to 3.5			
V_{OH}	High-level output voltage	I_{OH} = −100 µA		25°C		4.95			4.95		V
		I_{OH} = −250 µA		25°C		4.875			4.875		
				Full range	4.5			4.5			
V_{OL}	Low-level output voltage	V_{IC} = 2.5 V,	I_{OL} = 50 µA	25°C		12			12		mV
		V_{IC} = 2.5 V,	I_{OL} = 500 µA	25°C		120			120		
				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 = 10 kΩ‡	25°C	6	12		6	12		V/mV
				Full range	3			3			
			R_L = 1 MΩ‡	25°C		800			800		
$r_{i(d)}$	Differential input resistance			25°C		10^{12}			10^{12}		Ω
$r_{i(c)}$	Common-mode input resistance			25°C		10^{12}			10^{12}		Ω
$c_{i(c)}$	Common-mode input capacitance	f = 10 kHz,		25°C		5			5		pF
z_o	Closed-loop output impedance	f = 7 kHz,	A_V = 1	25°C		200			200		Ω
CMRR	Common-mode rejection ratio	V_{IC} = 0 to 2.7 V, R_S = 50 Ω	V_O = 2.5 V,	25°C	70	83		70	83		dB
				Full range	70			70			
k_{SVR}	Supply voltage rejection ratio (ΔV_{DD} /ΔV_{IO})	V_{DD} = 4.4 V to 8 V, No load	V_{IC} = V_{DD}/2,	25°C	80	95		80	95		dB
				Full range	80			80			
I_{DD}	Supply current	V_O = 2.5 V,	No load	25°C		13	25		13	25	µA
				Full range			30			30	

† Full range for the TLV2211C is 0°C to 70°C. Full range for the TLV2211I is − 40°C to 85°C.

‡ Referenced to 1.5 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 (unless otherwise noted)

PARAMETER		TEST CONDITIONS	T_A†	TLV2211C			TLV2211I			UNIT
				MIN	TYP	MAX	MIN	TYP	MAX	
SR	Slew rate at unity gain	V_O = 1.5 V to 3.5 V, R_L = 10 kΩ‡, C_L = 100 pF‡	25°C	0.01	0.025		0.01	0.025		V/µs
			Full range	0.005			0.005			
V_n	Equivalent input noise voltage	f = 10 Hz	25°C		72			72		nV/√Hz
		f = 1 kHz	25°C		21			21		
$V_{N(PP)}$	Peak-to-peak equivalent input noise voltage	f = 0.1 Hz to 1 Hz	25°C		600			600		nV
		f = 0.1 Hz to 10 Hz	25°C		800			800		
I_n	Equivalent input noise current		25°C		0.6			0.6		fA/√Hz
	Gain-bandwidth product	f = 10 kHz, R_L = 10 kΩ‡, C_L = 100 pF‡	25°C		65			65		kHz
B_{OM}	Maximum output-swing bandwidth	$V_{O(PP)}$ = 2 V, A_V = 1, R_L = 10 kΩ‡, C_L = 100 pF‡	25°C		7			7		kHz
ϕ_m	Phase margin at unity gain	R_L = 10 kΩ‡, C_L = 100 pF‡	25°C		56°			56°		
	Gain margin		25°C		22			22		dB

† Full range is −40°C to 85°C.
‡ Referenced to 1.5 V

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

PARAMETER		TEST CONDITIONS	TLV2211Y			UNIT
			MIN	TYP	MAX	
V_{IO}	Input offset voltage	$V_{DD\pm}$ = ±1.5 V, V_O = 0, V_{IC} = 0, R_S = 50 Ω		0.47		mV
I_{IO}	Input offset current			0.5	60	pA
I_{IB}	Input bias current			1	60	pA
V_{ICR}	Common-mode input voltage range	$\lvert V_{IO} \rvert \le$ 5 mV, R_S = 50 Ω		−0.3 to 2.2		V
V_{OH}	High-level output voltage	I_{OH} = −100 µA		2.94		V
		I_{OH} = −200 µA		2.85		
V_{OL}	Low-level output voltage	V_{IC} = 0, I_{OL} = 50 µA		15		mV
		V_{IC} = 0, I_{OL} = 500 µA		150		
A_{VD}	Large-signal differential voltage amplification	V_{IC} = 1.5 V, V_O = 1 V to 2 V, R_L = 10 kΩ†		7		V/mV
		V_{IC} = 1.5 V, V_O = 1 V to 2 V, R_L = 1 MΩ†		600		
$r_{i(d)}$	Differential input resistance			10^{12}		Ω
$r_{i(c)}$	Common-mode input resistance			10^{12}		Ω
$c_{i(c)}$	Common-mode input capacitance	f = 10 kHz		5		pF
z_o	Closed-loop output impedance	f = 7 kHz, A_V = 1		200		Ω
CMRR	Common-mode rejection ratio	V_{IC} = 0 to 1.7 V, V_O = 1.5 V, R_S = 50 Ω		83		dB
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		95		dB
I_{DD}	Supply current	V_O = 1.5 V, No load		11		µA

† Referenced to 1.5 V

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

PARAMETER		TEST CONDITIONS	TLV2211Y			UNIT
			MIN	TYP	MAX	
V_{IO}	Input offset voltage	$V_{DD\pm} = \pm 2.5$ V, $V_{IC} = 0$, $V_O = 0$, $R_S = 50\ \Omega$		0.45		mV
I_{IO}	Input offset current			0.5	60	pA
I_{IB}	Input bias current			1	60	pA
V_{ICR}	Common-mode input voltage range	$\lvert V_{IO} \rvert \leq 5$ mV, $R_S = 50\ \Omega$		−0.3 to 4.2		V
V_{OH}	High-level output voltage	$I_{OH} = -100\ \mu A$		4.95		V
		$I_{OH} = -250\ \mu A$		4.875		
V_{OL}	Low-level output voltage	$V_{IC} = 2.5$ V, $I_{OL} = 50\ \mu A$		12		mV
		$V_{IC} = 2.5$ V, $I_{OL} = 500\ \mu A$		120		
A_{VD}	Large-signal differential voltage amplification	$V_{IC} = 2.5$ V, $V_O = 1$ V to 4 V, $R_L = 10\ k\Omega$†		12		V/mV
		$R_L = 1\ M\Omega$†		800		
$r_{i(d)}$	Differential input resistance			10^{12}		Ω
$r_{i(c)}$	Common-mode input resistance			10^{12}		Ω
$c_{i(c)}$	Common-mode input capacitance	f = 10 kHz		5		pF
z_o	Closed-loop output impedance	f = 7 kHz, $A_V = 1$		200		Ω
CMRR	Common-mode rejection ratio	$V_{IC} = 0$ to 2.7 V, $V_O = 2.5$ V, $R_S = 50\ \Omega$		83		dB
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		95		dB
I_{DD}	Supply current	$V_O = 2.5$ V, No load		13		µA

† Referenced to 1.5 V

TYPICAL CHARACTERISTICS

Table of Graphs

			FIGURE
V_{IO}	Input offset voltage	Distribution vs Common-mode input voltage	3, 4 5, 6
α_{VIO}	Input offset voltage temperature coefficient	Distribution	7, 8
I_{IB}/I_{IO}	Input bias and input offset currents	vs Free-air temperature	9
V_I	Input voltage	vs Supply voltage vs Free-air temperature	10 11
V_{OH}	High-level output voltage	vs High-level output current	12, 15
V_{OL}	Low-level output voltage	vs Low-level output current	13, 14, 16
$V_{O(PP)}$	Maximum peak-to-peak output voltage	vs Frequency	17
I_{OS}	Short-circuit output current	vs Supply voltage vs Free-air temperature	18 19
V_O	Output voltage	vs Differential input voltage	20, 21
A_{VD}	Differential voltage amplification	vs Load resistance vs Frequency vs Free-air temperature	22 23, 24 25, 26
z_o	Output impedance	vs Frequency	27, 28
CMRR	Common-mode rejection ratio	vs Frequency vs Free-air temperature	29 30
k_{SVR}	Supply-voltage rejection ratio	vs Frequency vs Free-air temperature	31, 32 33
I_{DD}	Supply current	vs Supply voltage	34
SR	Slew rate	vs Load capacitance vs Free-air temperature	35 36
V_O	Large-signal pulse response	vs Time	37, 38, 39, 40
V_O	Small-signal pulse response	vs Time	41, 42, 43, 44
V_n	Equivalent input noise voltage	vs Frequency	45, 46
	Noise voltage (referred to input)	Over a 10-second period	47
THD + N	Total harmonic distortion plus noise	vs Frequency	48
	Gain-bandwidth product	vs Free-air temperature vs Supply voltage	49 50
ϕ_m	Phase margin	vs Frequency vs Load capacitance	23, 24 51
	Gain margin	vs Load capacitance	52
B_1	Unity-gain bandwidth	vs Load capacitance	53

TYPICAL CHARACTERISTICS

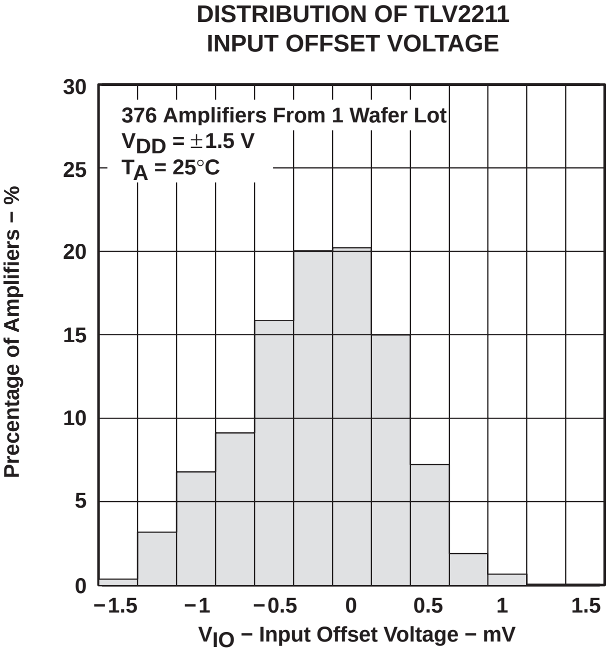


Figure 3

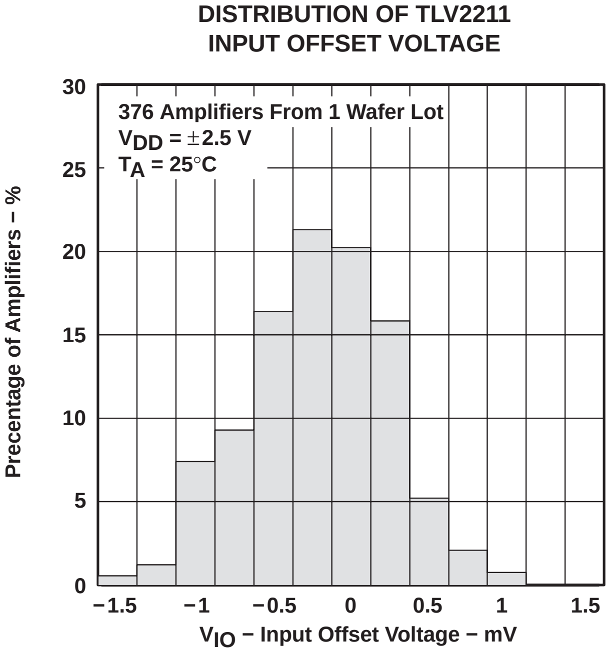


Figure 4

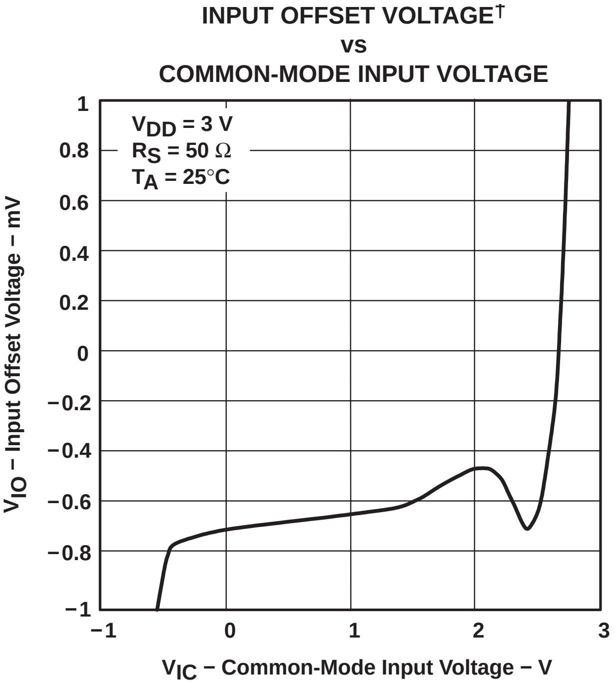


Figure 5

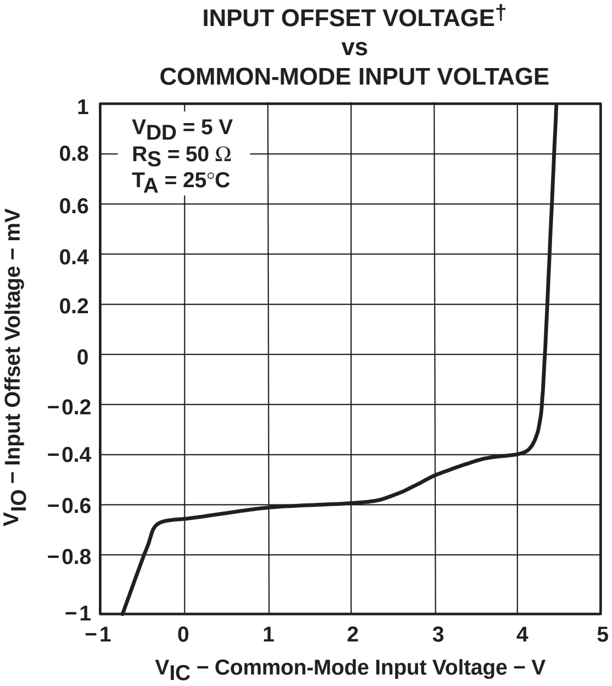


Figure 6

[†] 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 TLV2211 INPUT OFFSET VOLTAGE TEMPERATURE COEFFICIENT

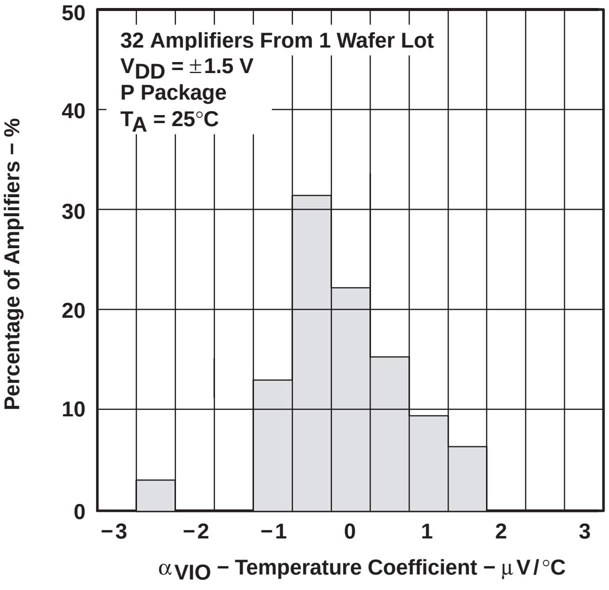


Figure 7

DISTRIBUTION OF TLV2211 INPUT OFFSET VOLTAGE TEMPERATURE COEFFICIENT

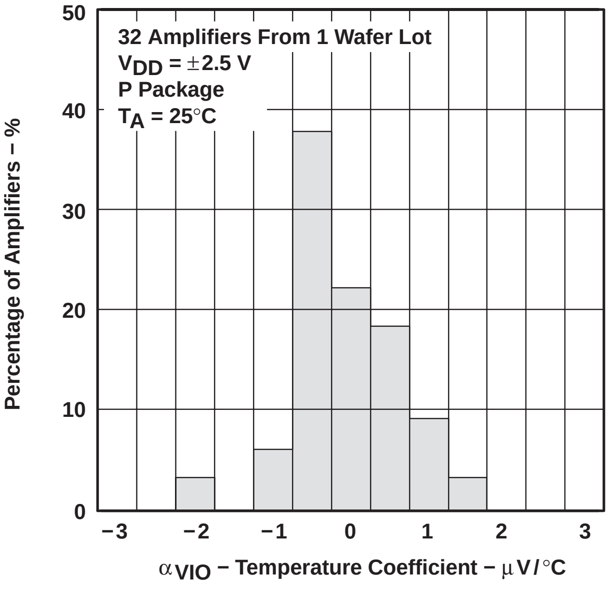


Figure 8

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

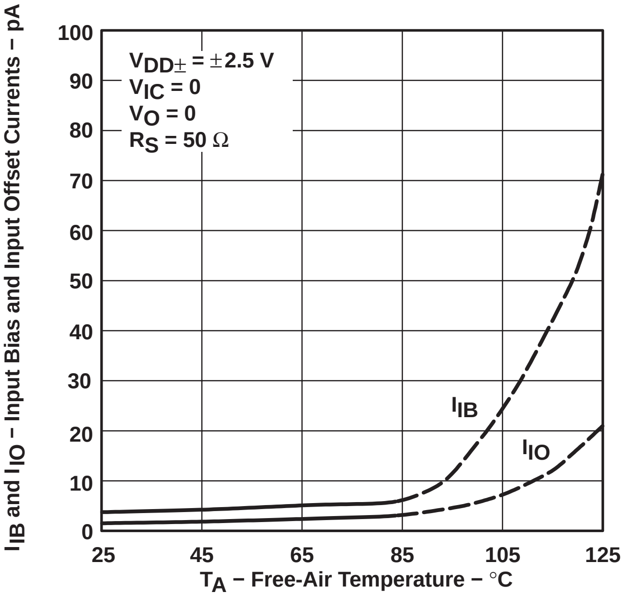


Figure 9

INPUT VOLTAGE vs SUPPLY VOLTAGE

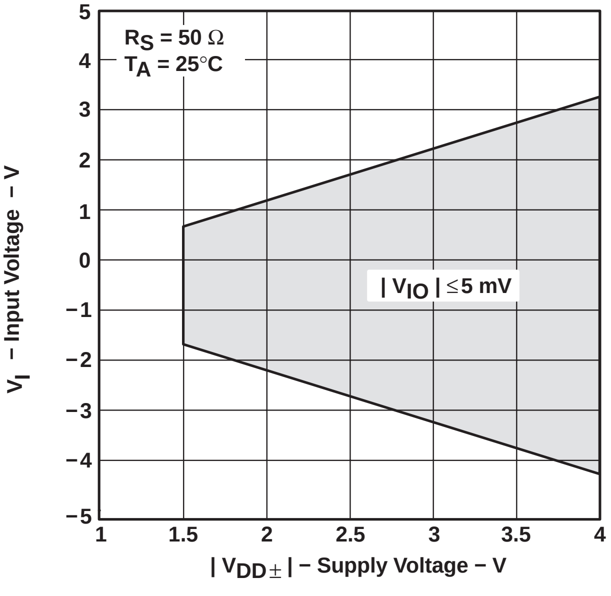


Figure 10

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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

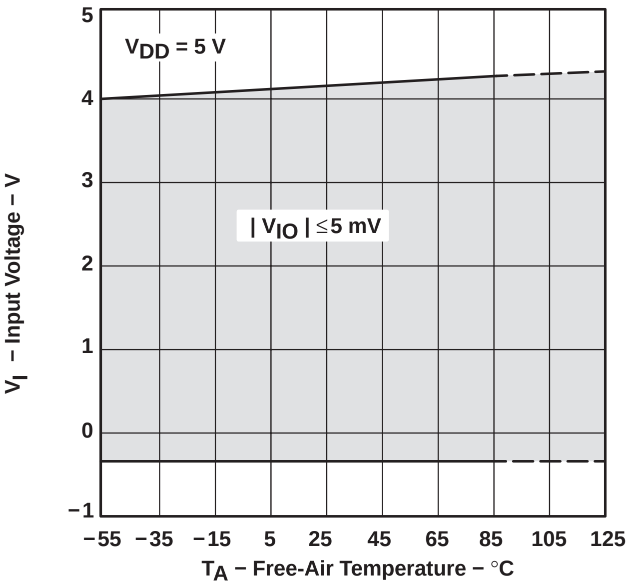

Figure 11

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

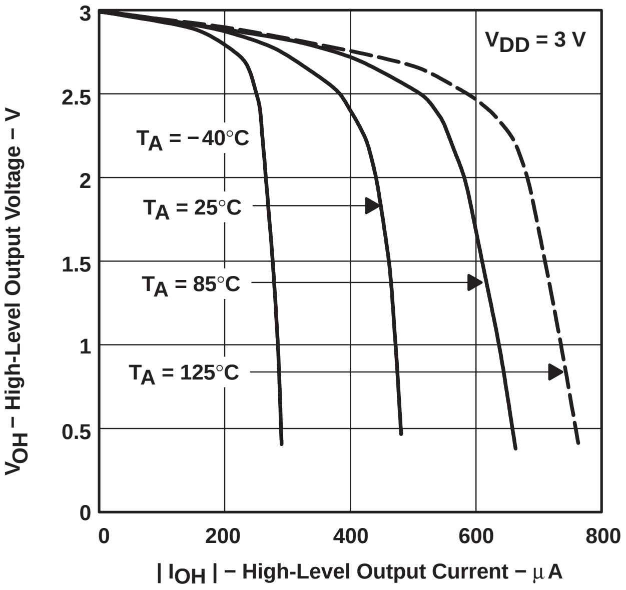

Figure 12

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

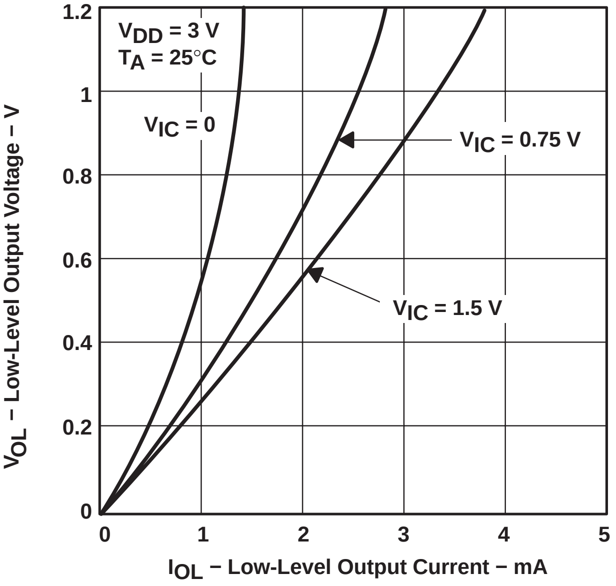

Figure 13

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

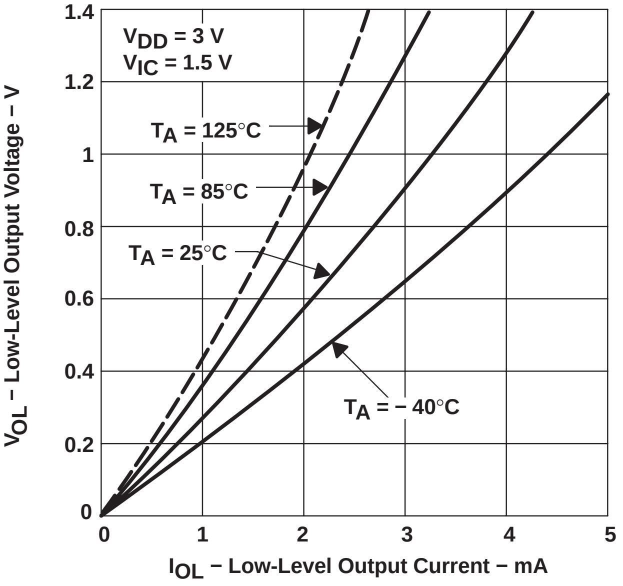

Figure 14

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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

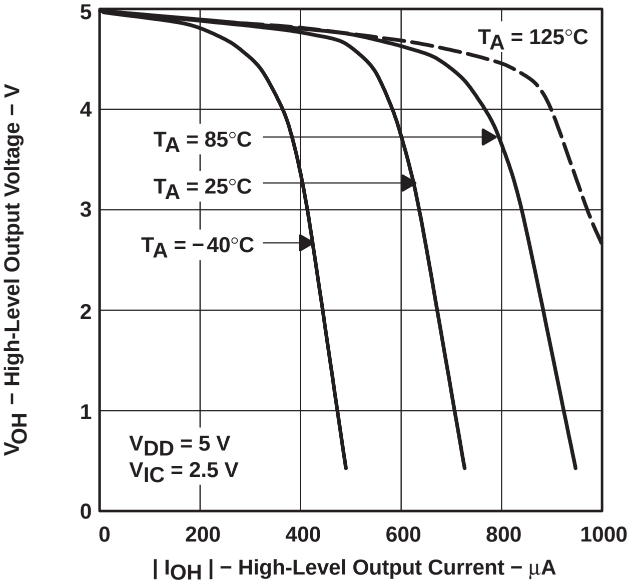

Figure 15

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

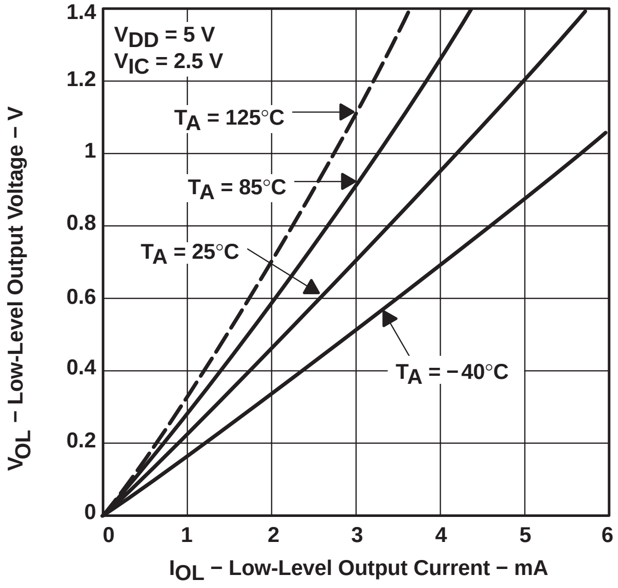

Figure 16

MAXIMUM PEAK-TO-PEAK OUTPUT VOLTAGE‡ vs FREQUENCY

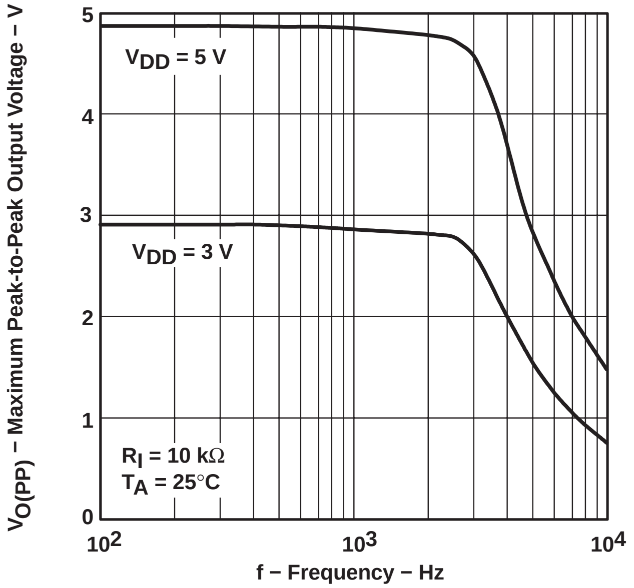

Figure 17

SHORT-CIRCUIT OUTPUT CURRENT vs SUPPLY VOLTAGE

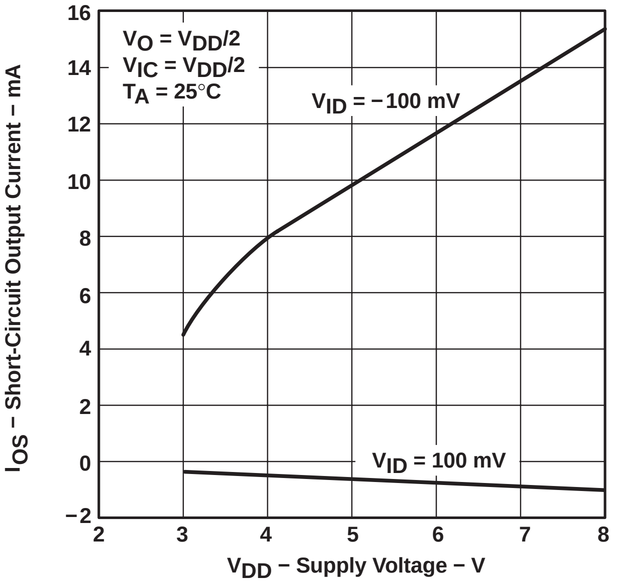

Figure 18

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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

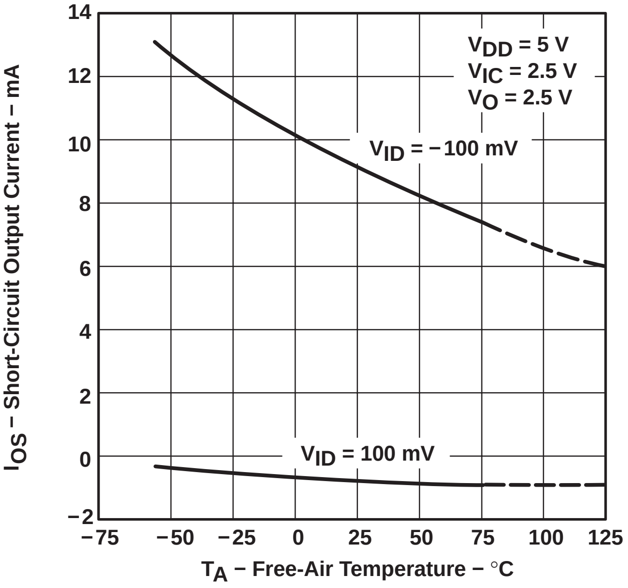

Figure 19

OUTPUT VOLTAGE‡ vs DIFFERENTIAL INPUT VOLTAGE

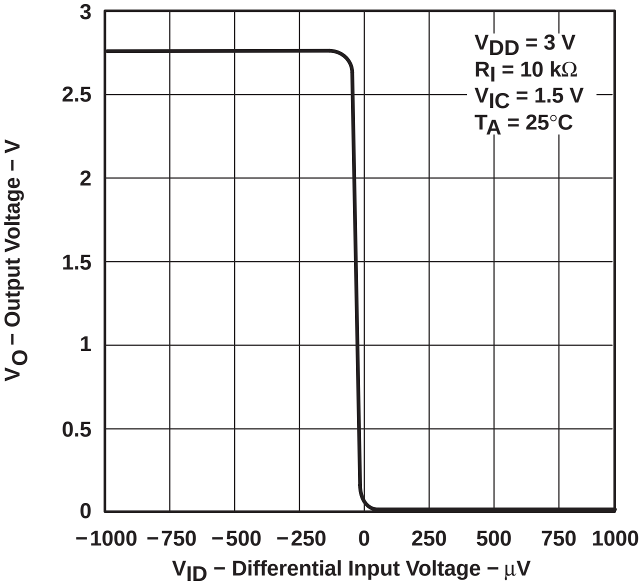

Figure 20

OUTPUT VOLTAGE‡ vs DIFFERENTIAL INPUT VOLTAGE

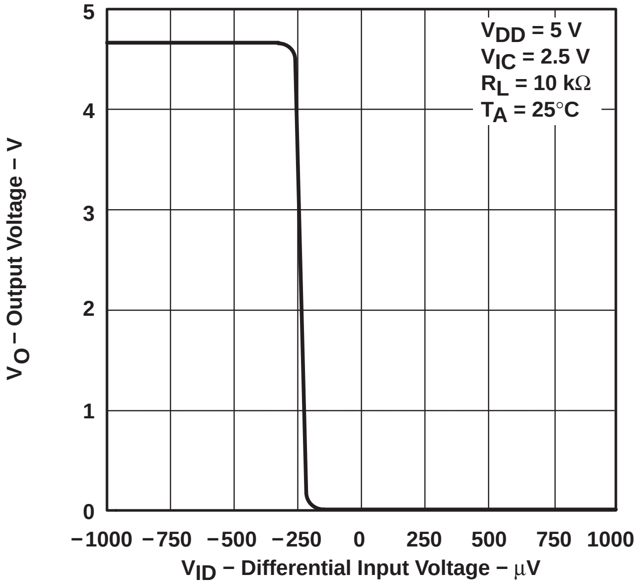

Figure 21

DIFFERENTIAL VOLTAGE AMPLIFICATION‡ vs LOAD RESISTANCE

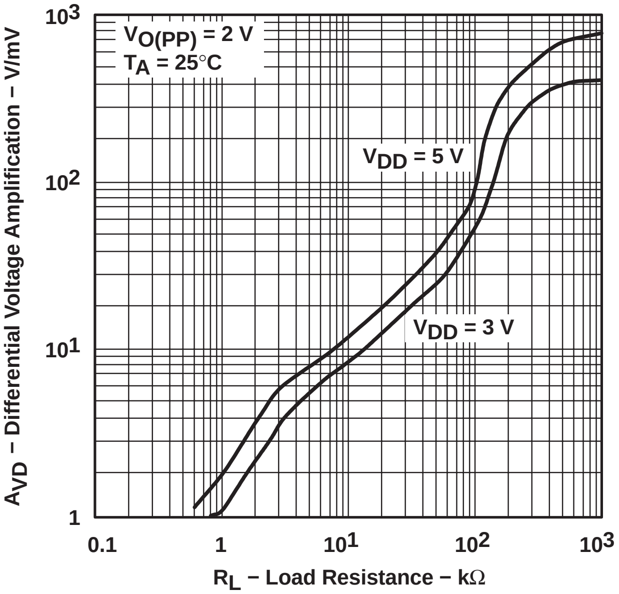

Figure 22

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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

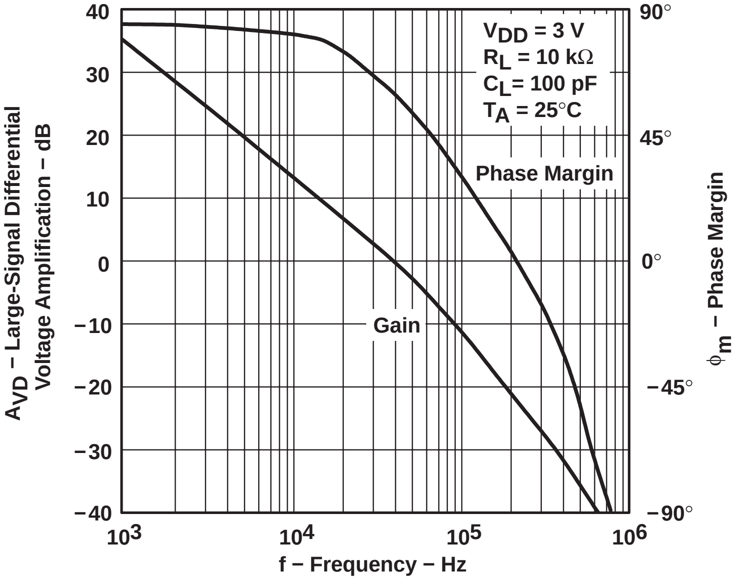

Figure 23

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

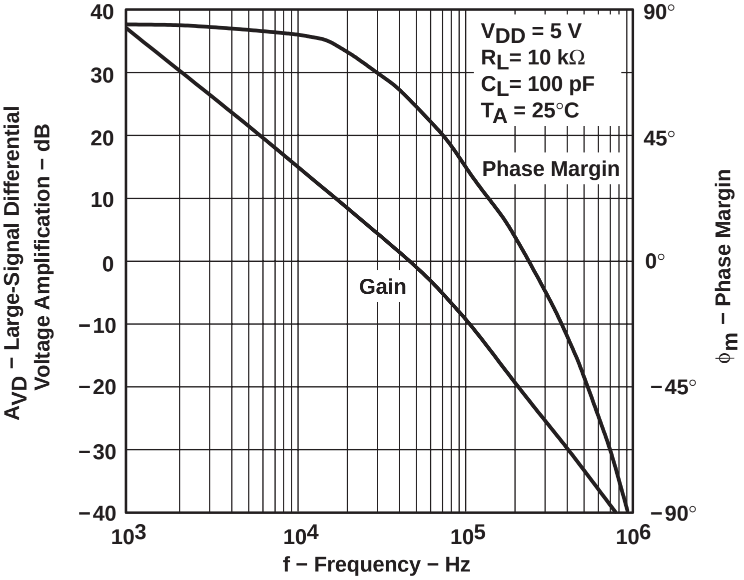

Figure 24

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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

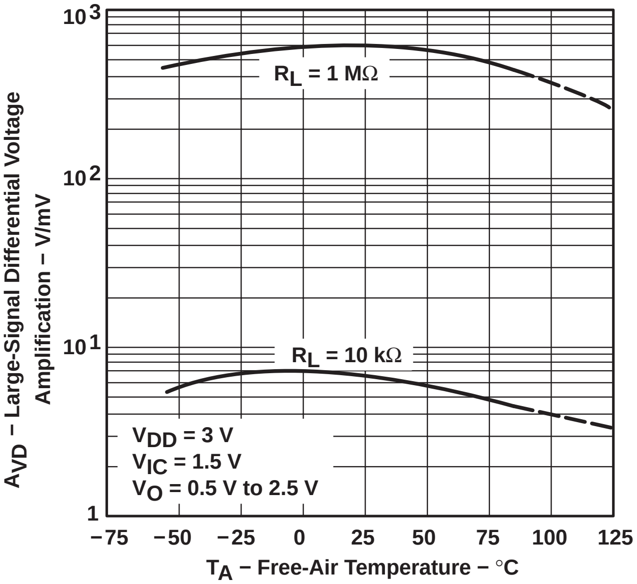

Figure 25

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

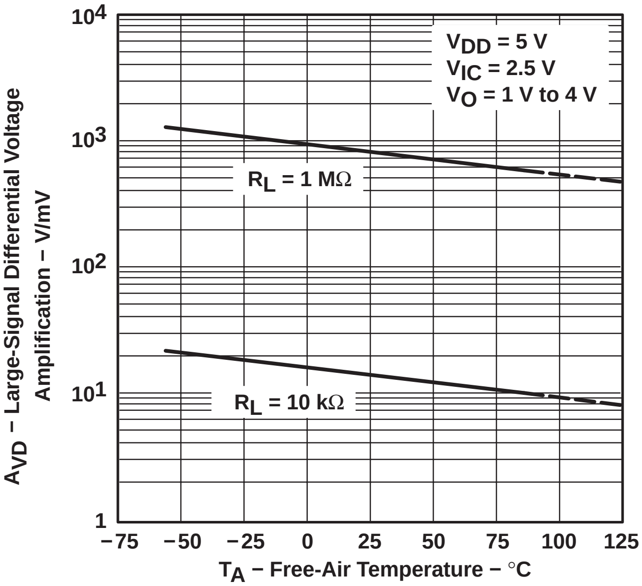

Figure 26

OUTPUT IMPEDANCE‡ vs FREQUENCY

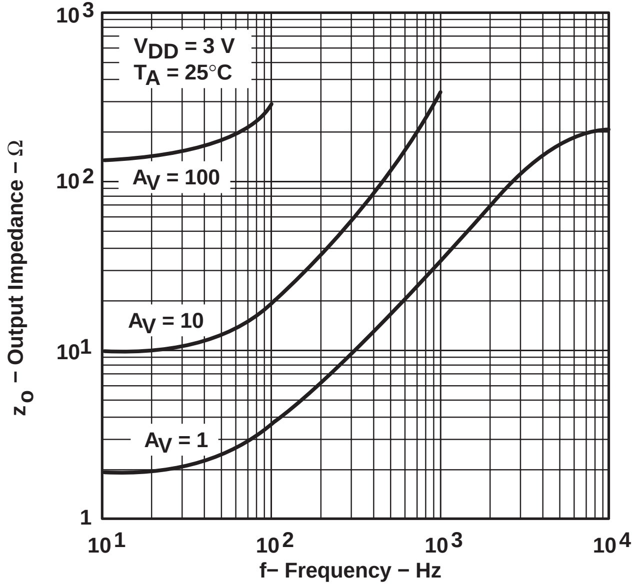

Figure 27

OUTPUT IMPEDANCE‡ vs FREQUENCY

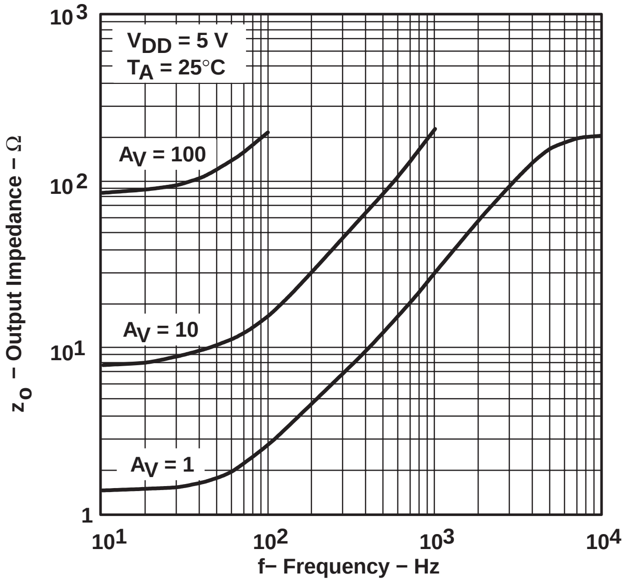

Figure 28

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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

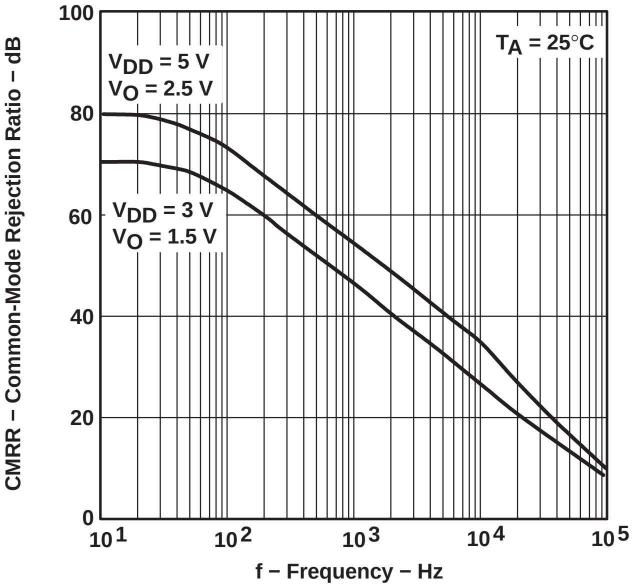

Figure 29

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

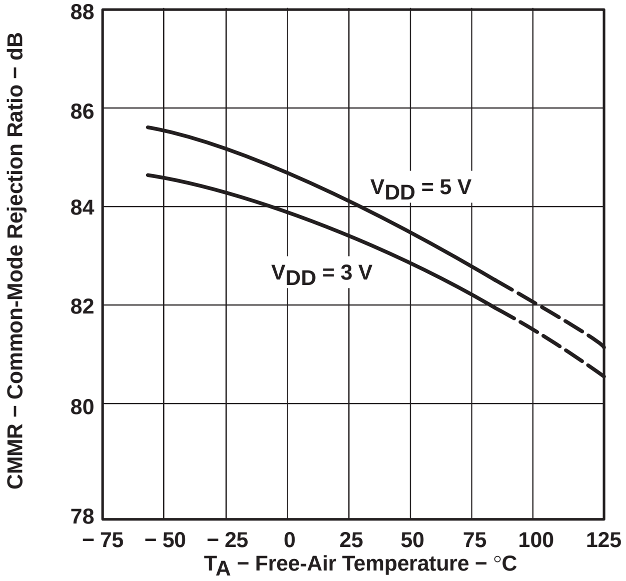

Figure 30

SUPPLY-VOLTAGE REJECTION RATIO†
vs
FREQUENCY

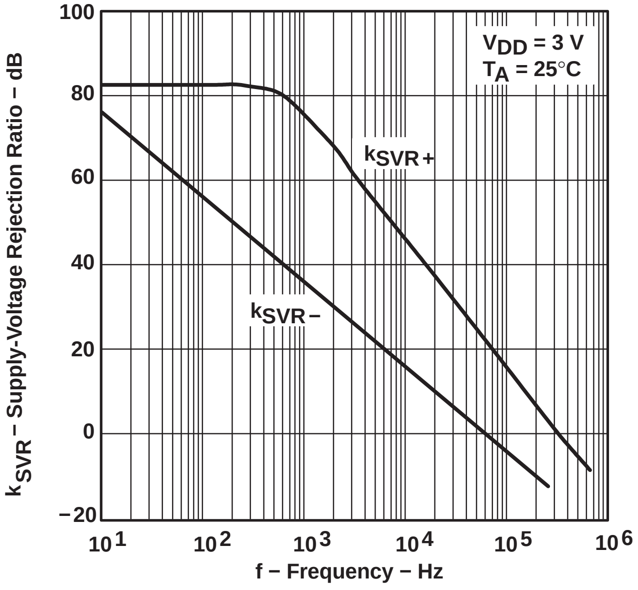

Figure 31

SUPPLY-VOLTAGE REJECTION RATIO†
vs
FREQUENCY

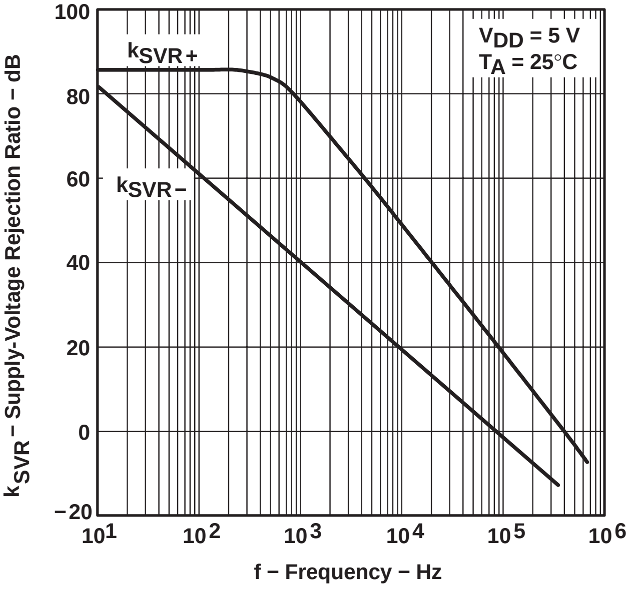

Figure 32

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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

SUPPLY-VOLTAGE REJECTION RATIO†
vs
FREE-AIR TEMPERATURE

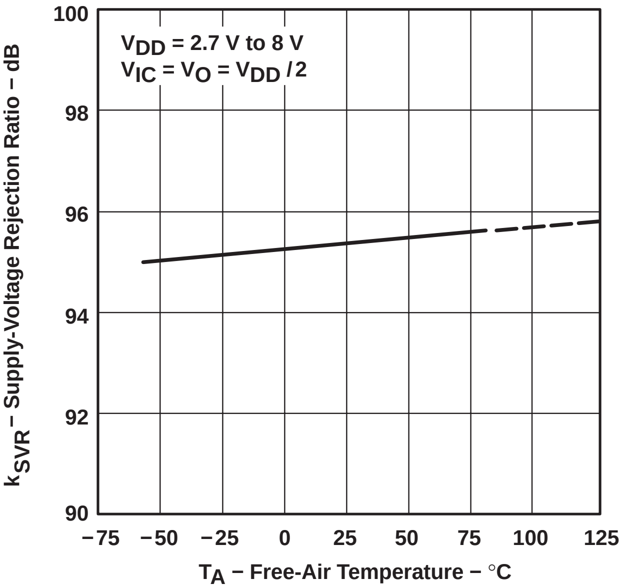

Figure 33

SUPPLY CURRENT†
vs
SUPPLY VOLTAGE

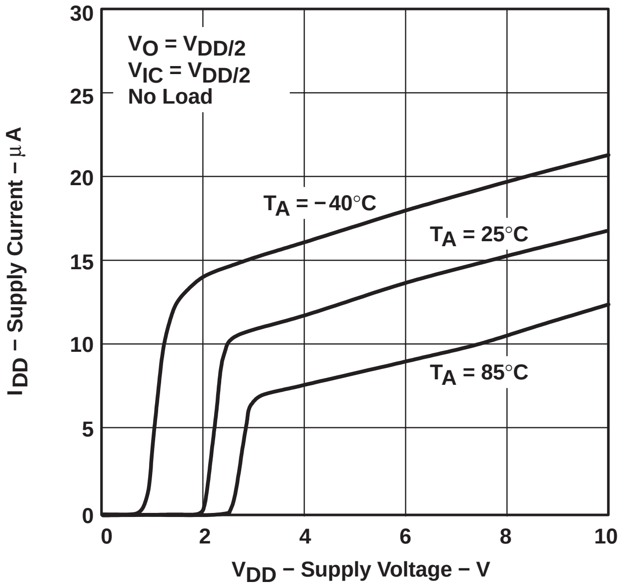

Figure 34

SLEW RATE‡
vs
LOAD CAPACITANCE

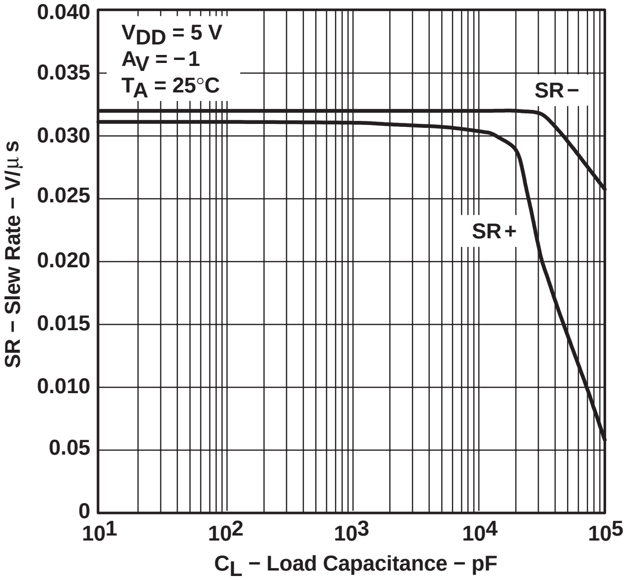

Figure 35

SLEW RATE†‡
vs
FREE-AIR TEMPERATURE

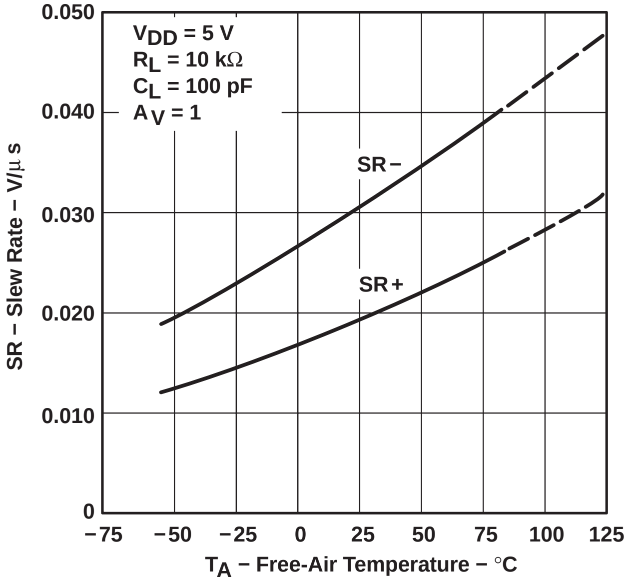

Figure 36

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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†

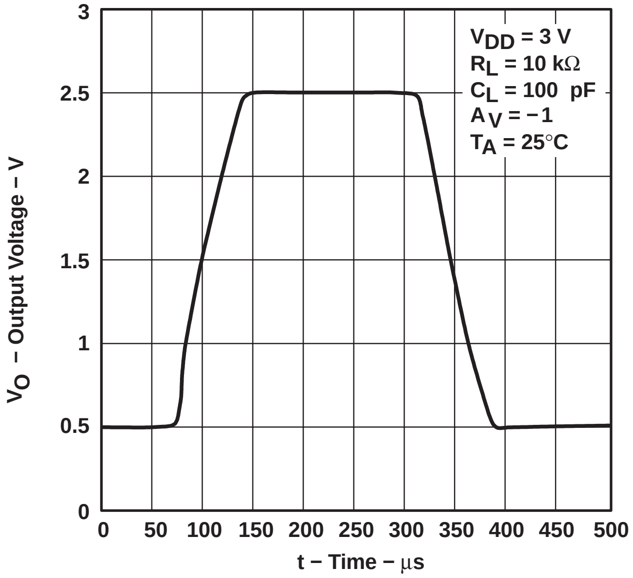

Figure 37

INVERTING LARGE-SIGNAL PULSE RESPONSE†

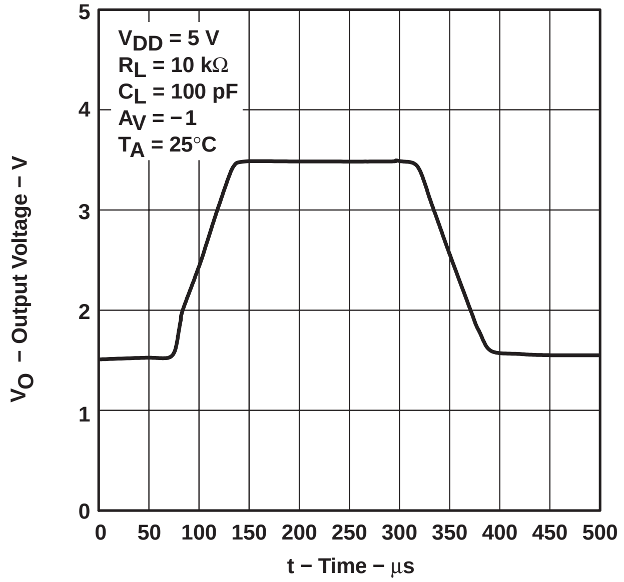

Figure 38

VOLTAGE-FOLLOWER LARGE-SIGNAL PULSE RESPONSE†

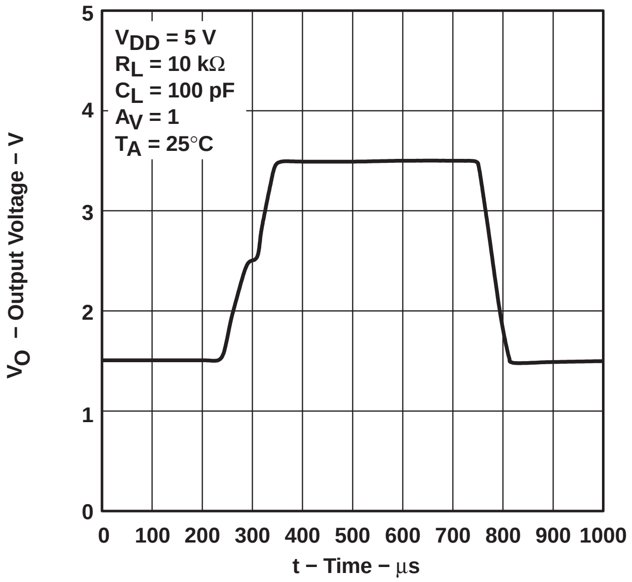

Figure 39

VOLTAGE-FOLLOWER LARGE-SIGNAL PULSE RESPONSE†

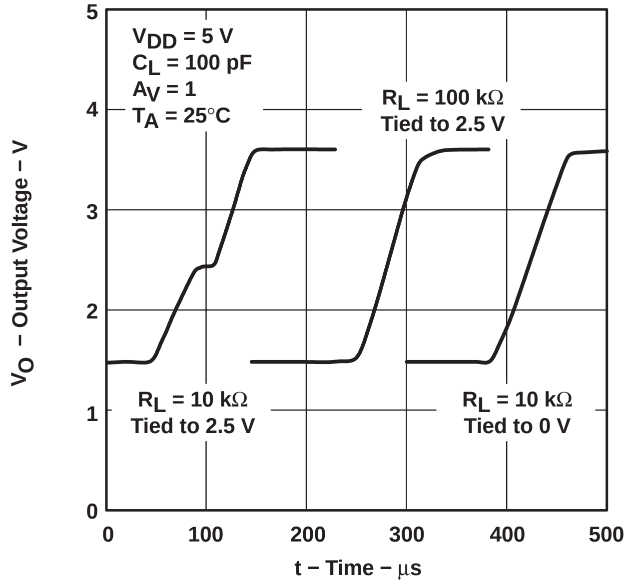

Figure 40

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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†

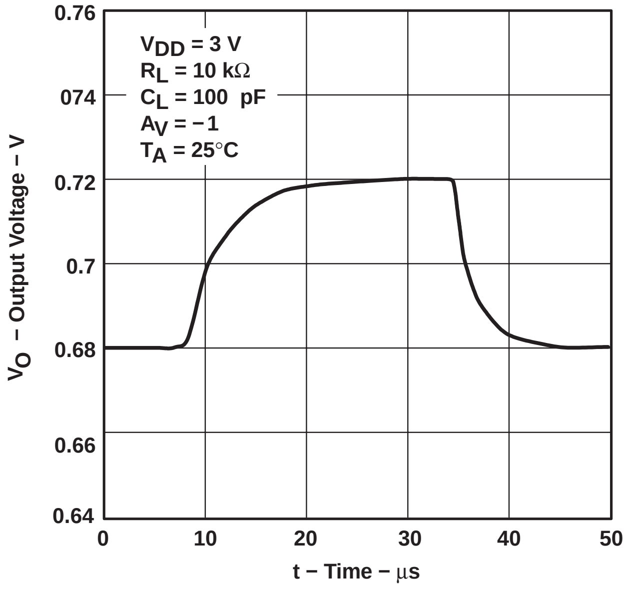

Figure 41

INVERTING SMALL-SIGNAL PULSE RESPONSE†

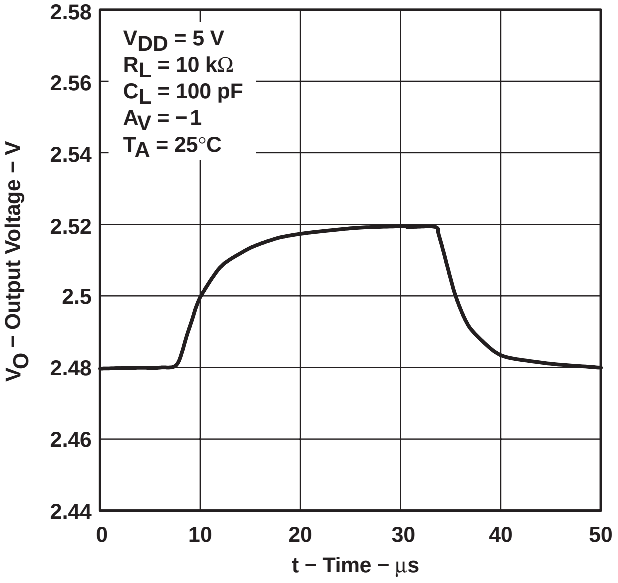

Figure 42

VOLTAGE-FOLLOWER SMALL-SIGNAL PULSE RESPONSE†

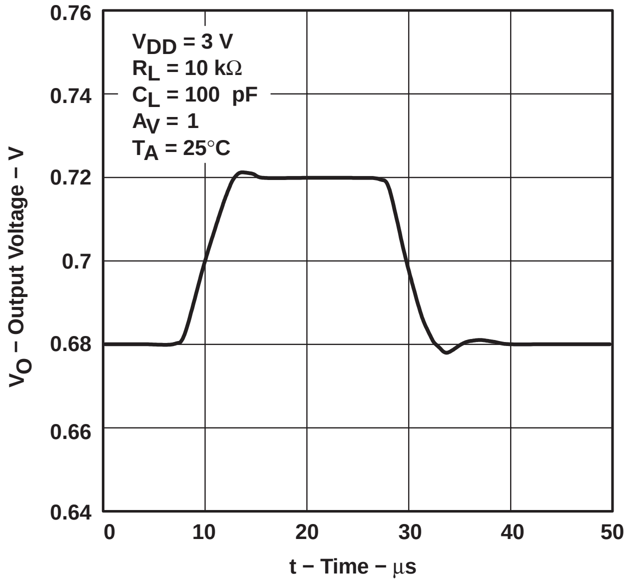

Figure 43

VOLTAGE-FOLLOWER SMALL-SIGNAL PULSE RESPONSE†

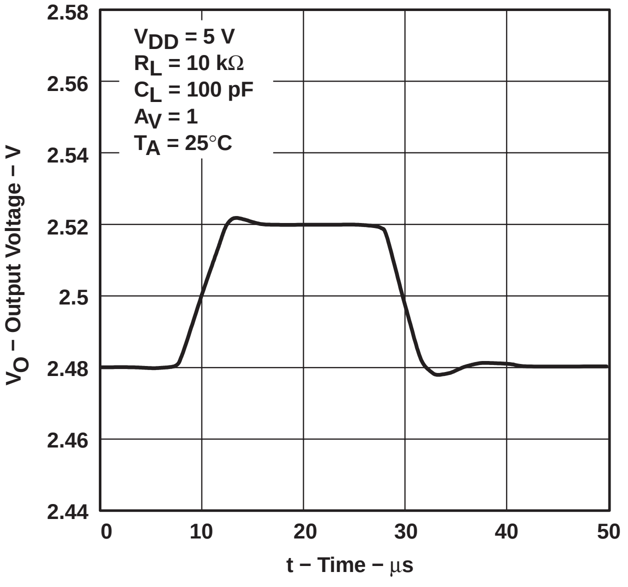

Figure 44

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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

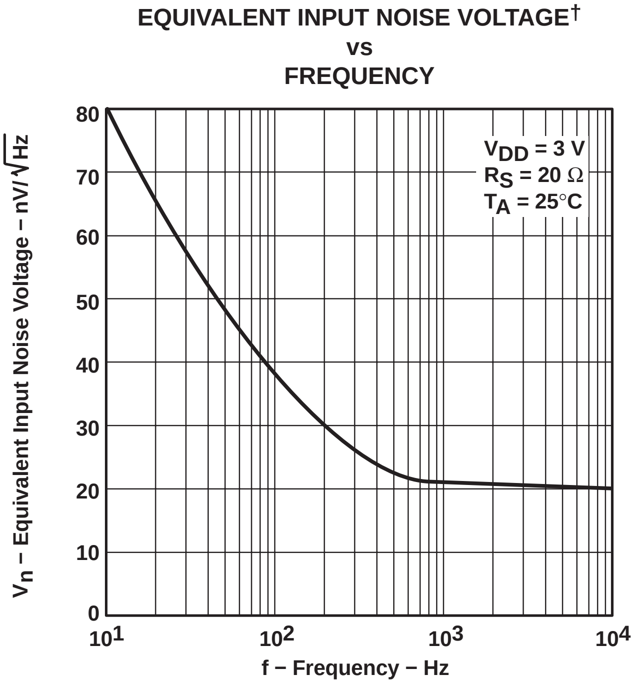

Figure 45

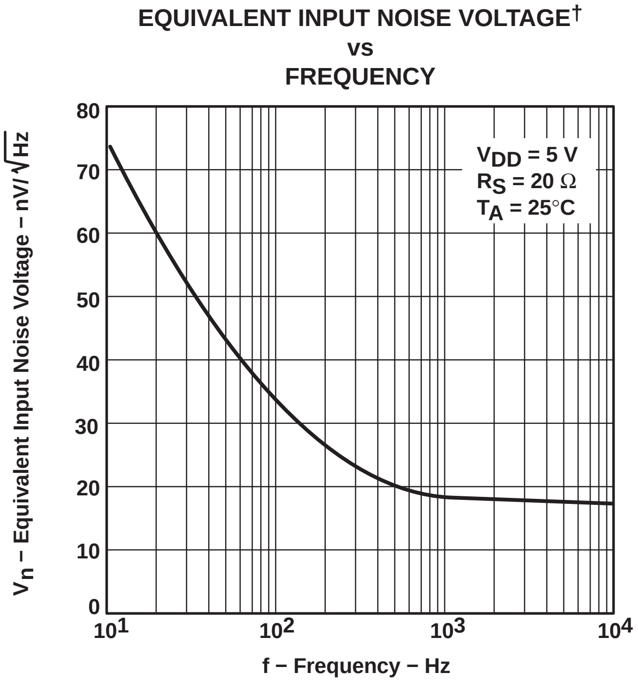

Figure 46

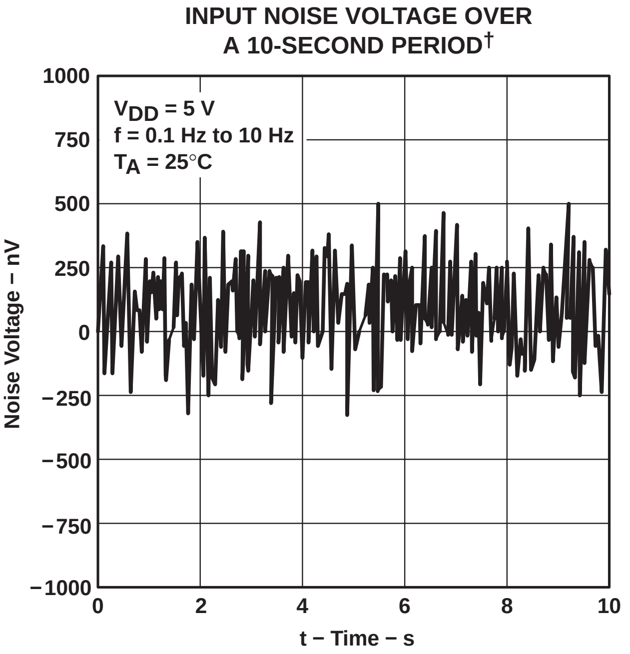

Figure 47

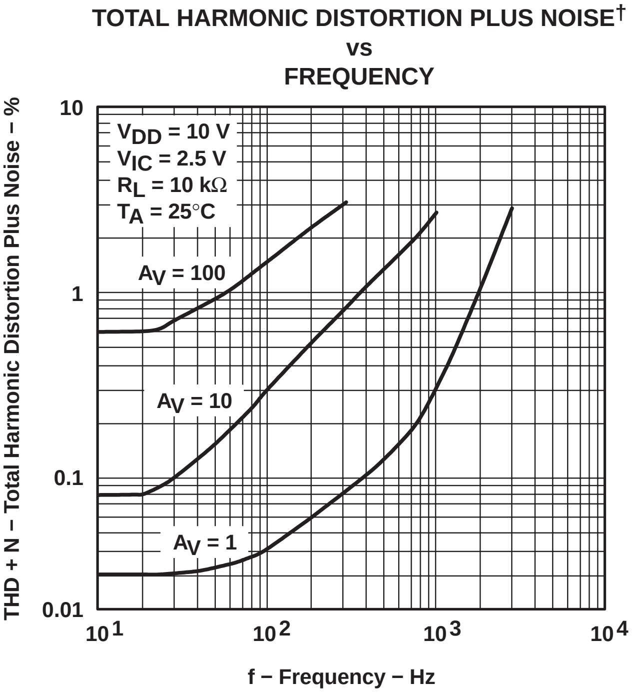

Figure 48

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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

GAIN-BANDWIDTH PRODUCT[†][‡]
vs
FREE-AIR TEMPERATURE

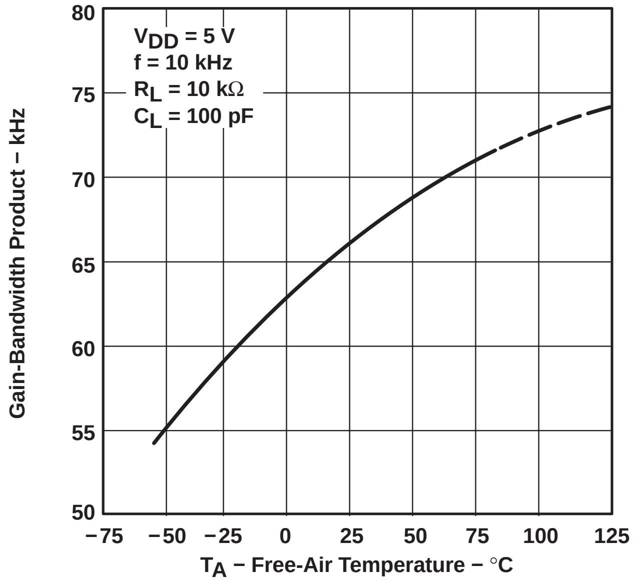


Figure 49

GAIN-BANDWIDTH PRODUCT
vs
SUPPLY VOLTAGE

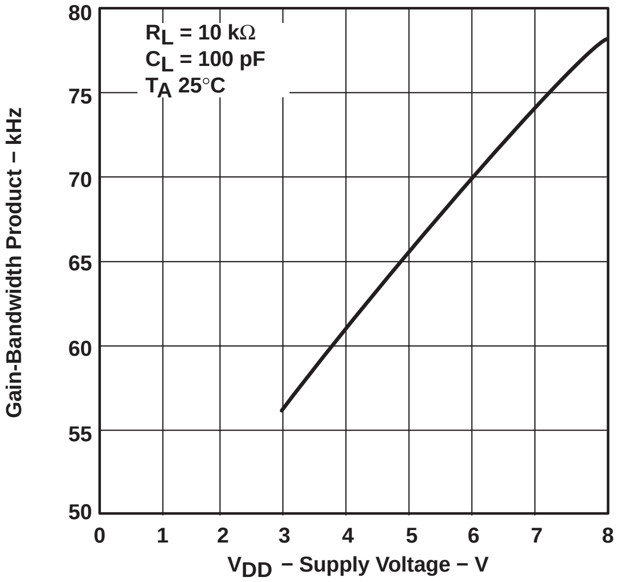


Figure 50

PHASE MARGIN
vs
LOAD CAPACITANCE

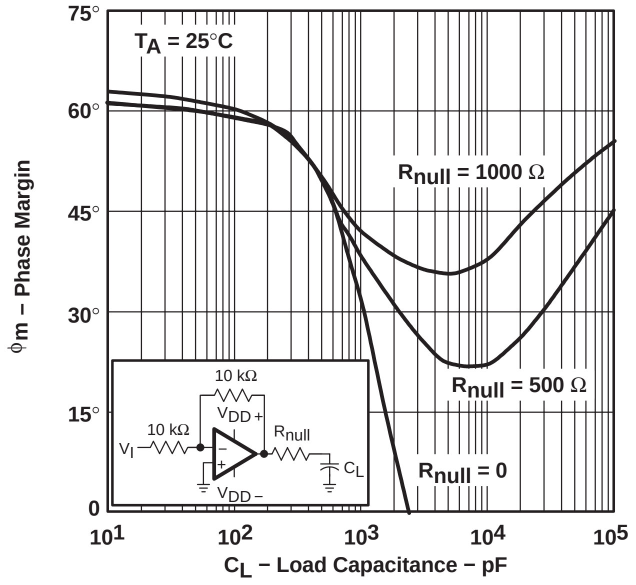


Figure 51

GAIN MARGIN
vs
LOAD CAPACITANCE

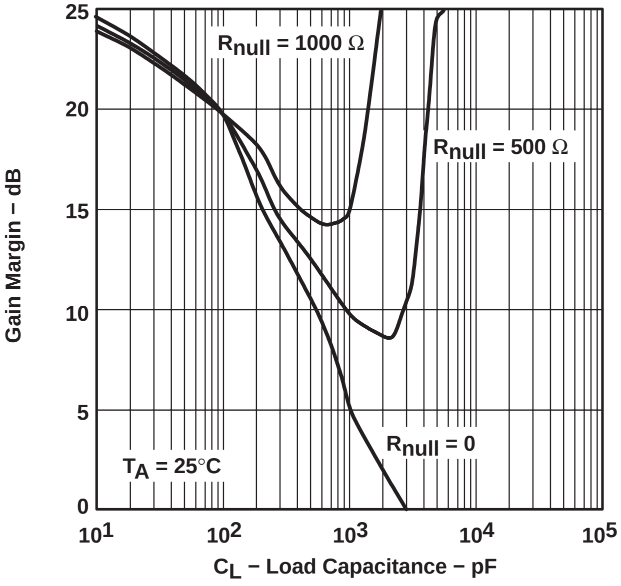


Figure 52

[†] 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

UNITY-GAIN BANDWIDTH vs LOAD CAPACITANCE

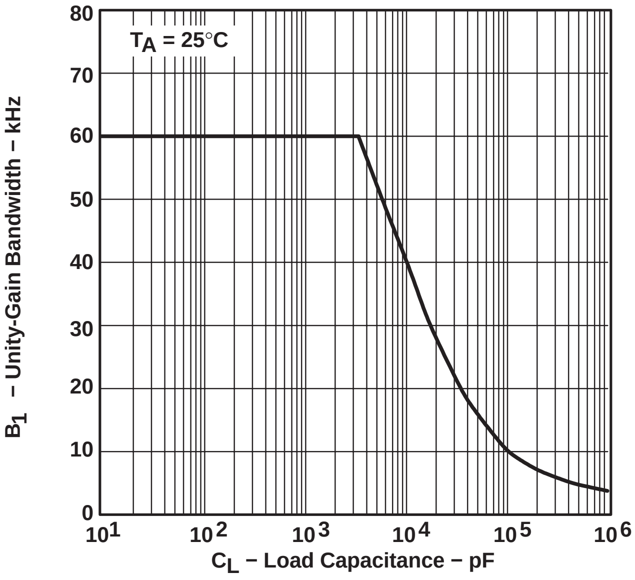


Figure 53

APPLICATION INFORMATION

driving large capacitive loads

The TLV2211 is designed to drive larger capacitive loads than most CMOS operational amplifiers. Figures 51 and 52 illustrate its ability to drive loads up to 600 pF while maintaining good gain and phase margins (R_{null} = 0).

A smaller series resistor (R_{null}) at the output of the device (see Figure 54) improves the gain and phase margins when driving large capacitive loads. Figures 51 and 52 show the effects of adding series resistances of 500 Ω and 1000 Ω. The addition of this series resistor has two effects: the first is that it adds a zero to the transfer function and the second 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 improvement in phase margin, equation 1 can be used.

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

Where :

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

APPLICATION INFORMATION

driving large capacitive loads (continued)

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

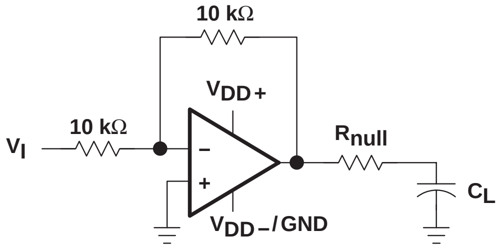


Figure 54. Series-Resistance Circuit

driving heavy dc loads

The TLV2211 is designed to provide better sinking and sourcing output currents than earlier CMOS rail-to-rail output devices. This device is specified to sink 500 µA and source 250 µA at V_{DD} = 3 V and V_{DD} = 5 V at a maximum quiescent I_{DD} of 25 µA. This provides a greater than 90% power efficiency.

When driving heavy dc loads, such as 10 kΩ, the positive edge can experience some distortion under slewing conditions. This condition can be seen in Figure 39. This condition is affected by three factors:

- Where the load is referenced. When the load is referenced to either rail, this condition does not occur. The distortion occurs only when the output signal swings through the point where the load is referenced. Figure 40 illustrates two 10-kΩ load conditions. The first load condition shows the distortion seen for a 10-kΩ load tied to 2.5 V. The third load condition shows no distortion for a 10-kΩ load tied to 0 V.
- Load resistance. As the load resistance increases, the distortion seen on the output decreases. Figure 40 illustrates the difference seen on the output for a 10-kΩ load and a 100-kΩ load with both tied to 2.5 V.
- Input signal edge rate. Faster input edge rates for a step input result in more distortion than with slower input edge rates.

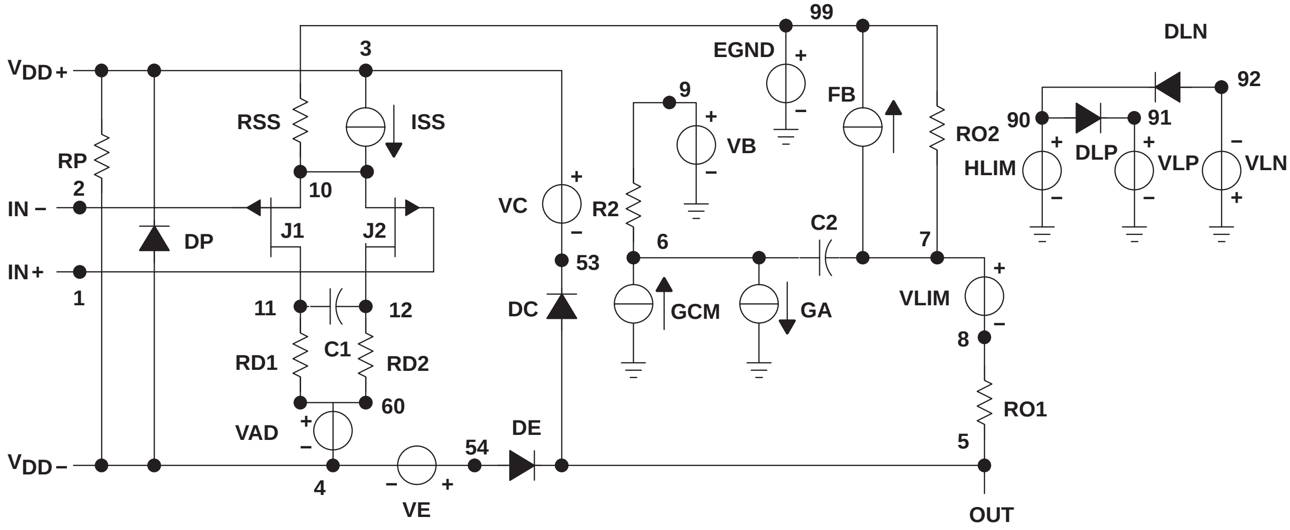
APPLICATION INFORMATION

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 54 are generated using the TLV2211 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 TLV2211 1 2 3 4 5
          C1       11     12     8.86E−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 4.29E6 −6E6 6E6 6E6 −6E6
          GA       6      0      11     12 9.425E−6
          GCM      0      6      10     99 1320.2E−12
          ISS      3      10     DC 1.250E−6
          HLIM     90     0      VLIM 1K
          J1       11     2      10 JX
          J2       12     1      10 JX
          R2       6      9      100.0E3
```

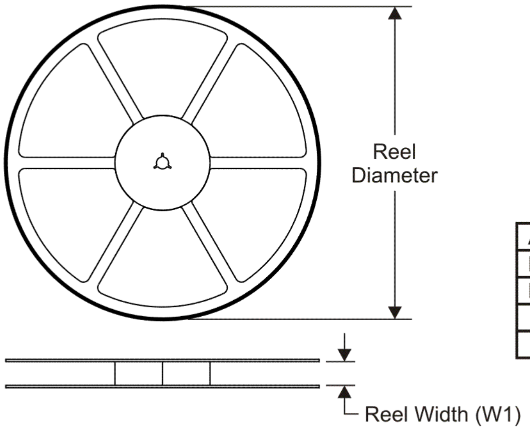
```
RD1      60     11     106.1E3
RD2      60     12     106.1E3
R01      8      5      50
R02      7      99     150
RP       3      4      419.2E3
RSS      10     99     160.0E6
VAD      60     4      −.5
VB       9      0      DC 0
VC       3      53     DC .55
VE       54     4      DC .55
VLIM     7      8      DC 0
VLP      91     0      DC 0.1
VLN      0      92     DC 2.6
.MODEL DX D (IS=800.0E−18)
.MODEL JX PJF (IS=500.0E−15 BETA=166E−6
+ VTO=−.004)
.ENDS
```

Figure 55. Boyle Macromodel and Subcircuit

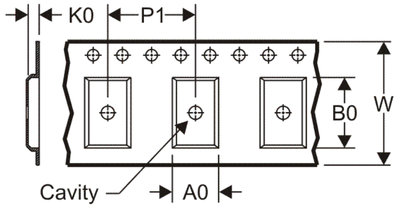
PSpice and *Parts* are trademark of MicroSim Corporation.

TAPE AND REEL INFORMATION

REEL DIMENSIONS

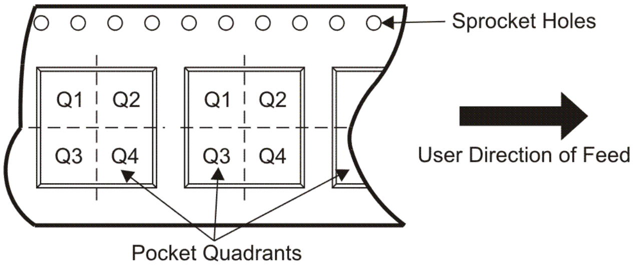


TAPE DIMENSIONS



A0	Dimension designed to accommodate the component width
B0	Dimension designed to accommodate the component length
K0	Dimension designed to accommodate the component thickness
W	Overall width of the carrier tape
P1	Pitch between successive cavity centers

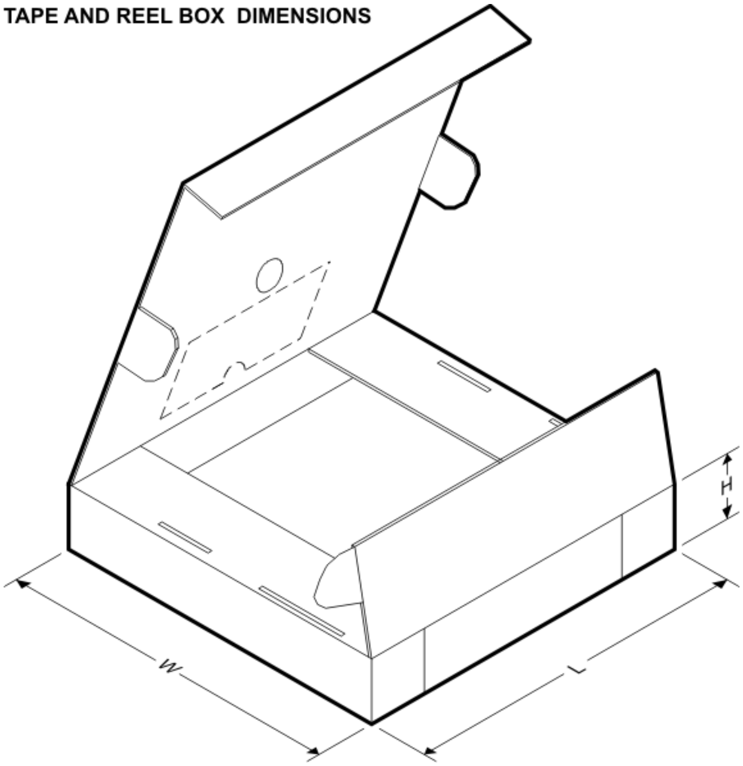
QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
TLV2211CDBVR	SOT-23	DBV	5	3000	180.0	9.0	3.15	3.2	1.4	4.0	8.0	Q3
TLV2211CDBVT	SOT-23	DBV	5	250	180.0	9.0	3.15	3.2	1.4	4.0	8.0	Q3
TLV2211IDBVR	SOT-23	DBV	5	3000	180.0	9.0	3.15	3.2	1.4	4.0	8.0	Q3
TLV2211IDBVT	SOT-23	DBV	5	250	180.0	9.0	3.15	3.2	1.4	4.0	8.0	Q3

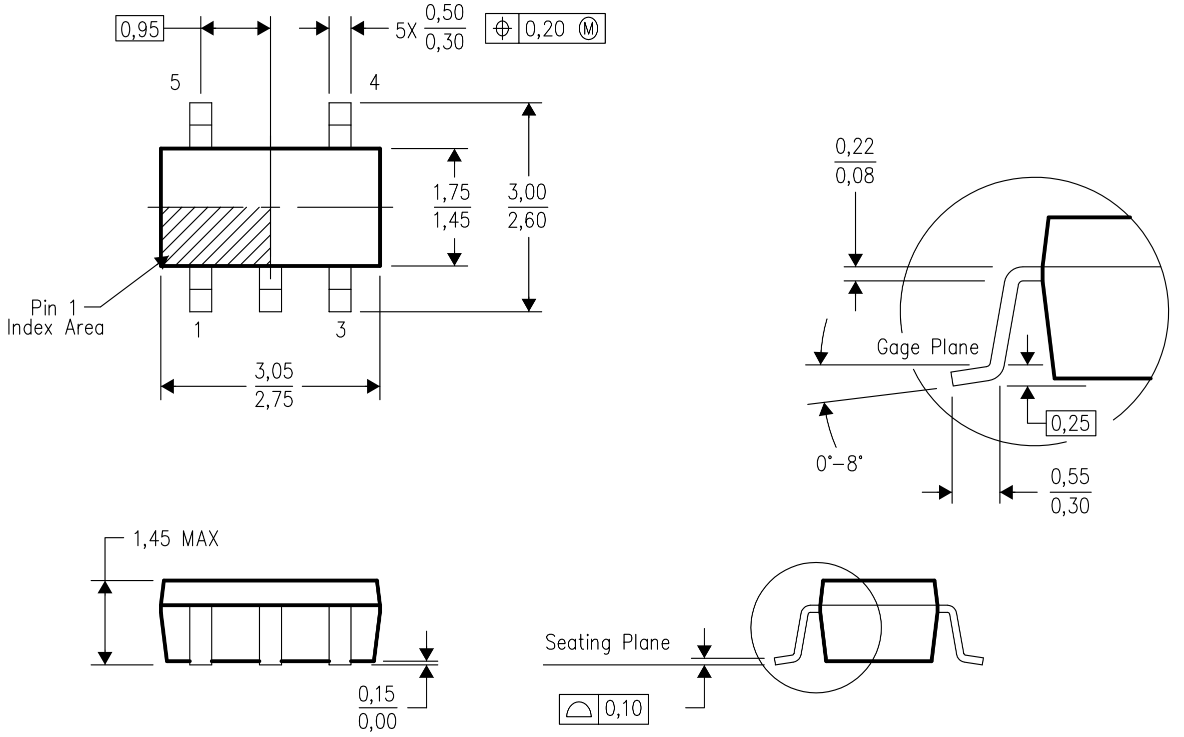
TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
TLV2211CDBVR	SOT-23	DBV	5	3000	182.0	182.0	20.0
TLV2211CDBVT	SOT-23	DBV	5	250	182.0	182.0	20.0
TLV2211IDBVR	SOT-23	DBV	5	3000	182.0	182.0	20.0
TLV2211IDBVT	SOT-23	DBV	5	250	182.0	182.0	20.0

DBV (R-PDSO-G5) PLASTIC SMALL-OUTLINE PACKAGE



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NOTES:
- A. All linear dimensions are in millimeters.
- B. This drawing is subject to change without notice.
- C. Body dimensions do not include mold flash or protrusion. Mold flash and protrusion shall not exceed 0.15 per side.
- D. Falls within JEDEC MO-178 Variation AA.

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