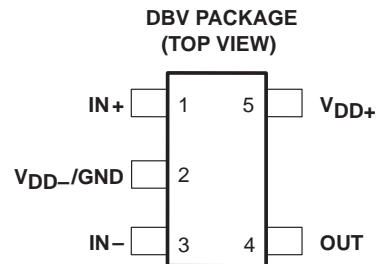


- Output Swing Includes Both Supply Rails
- Low Noise . . . 15 nV/ $\sqrt{\text{Hz}}$  Typ at  $f = 1 \text{ kHz}$
- Low Input Bias Current . . . 1 pA Typ
- Fully Specified for Single-Supply 3-V and 5-V Operation
- Common-Mode Input Voltage Range Includes Negative Rail
- High Gain Bandwidth . . . 2 MHz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

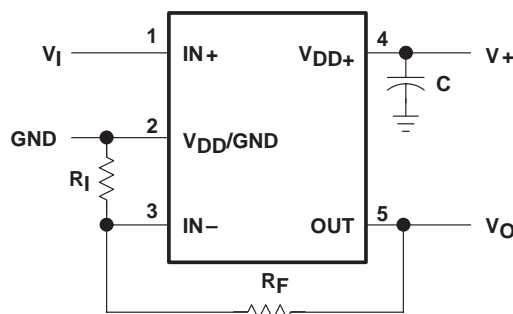


### description

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/ $\mu\text{s}$  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- $\Omega$  loads for telecom applications.

With a total area of 5.6mm<sup>2</sup>, 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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**TEXAS  
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**TLV2231, TLV2231Y**  
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**AVAILABLE OPTIONS**

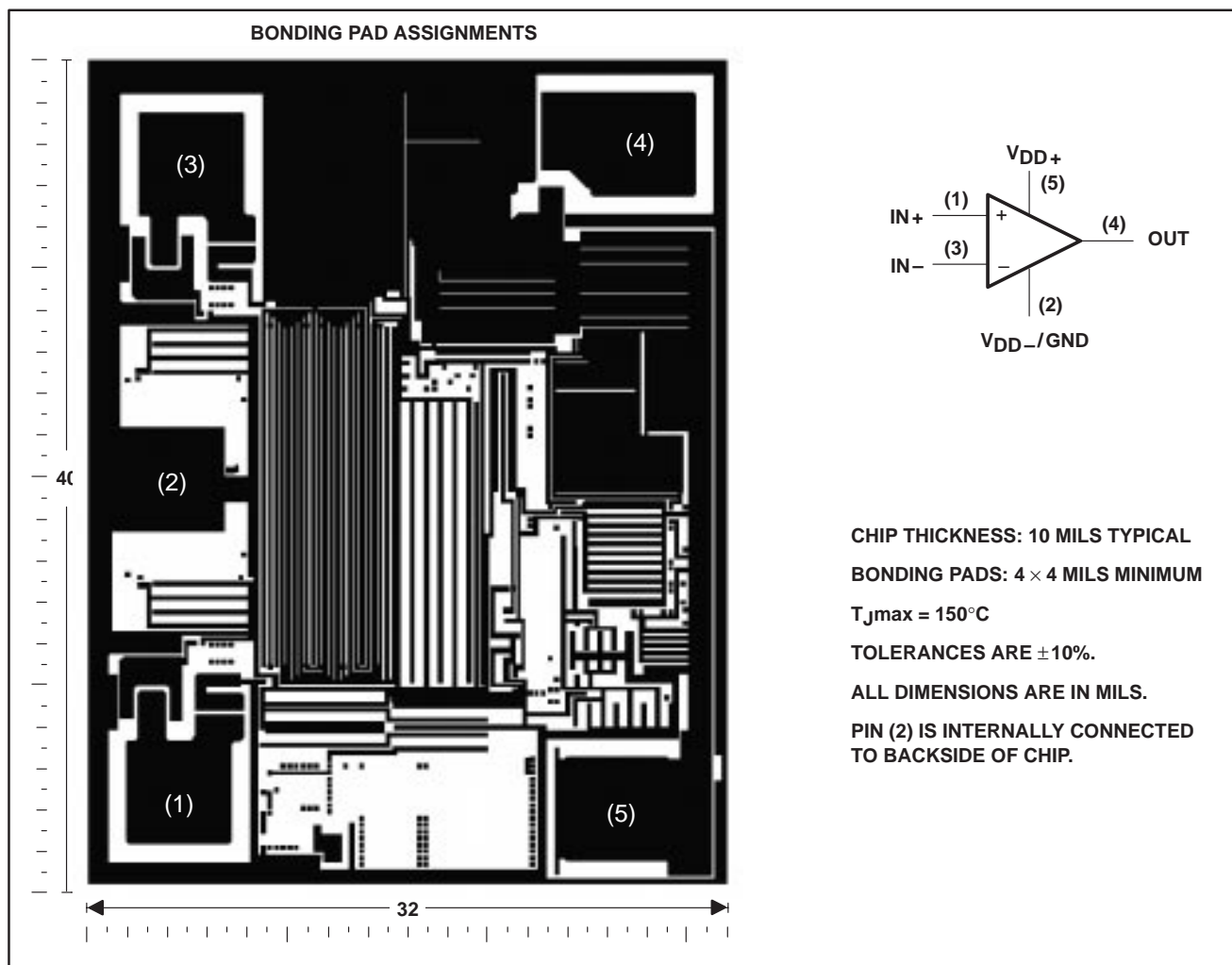
T <sub>A</sub>	V <sub>IO</sub> max AT 25°C	PACKAGED DEVICES	SYMBOL	CHIP FORM‡ (Y)
		SOT-23 (DBV)†		
0°C to 70°C	3 mV	TLV2231CDBV	VAEC	TLV2231Y
-40°C to 85°C	3 mV	TLV2231IDBV	VAEI	

† The DBV package available in tape and reel only.

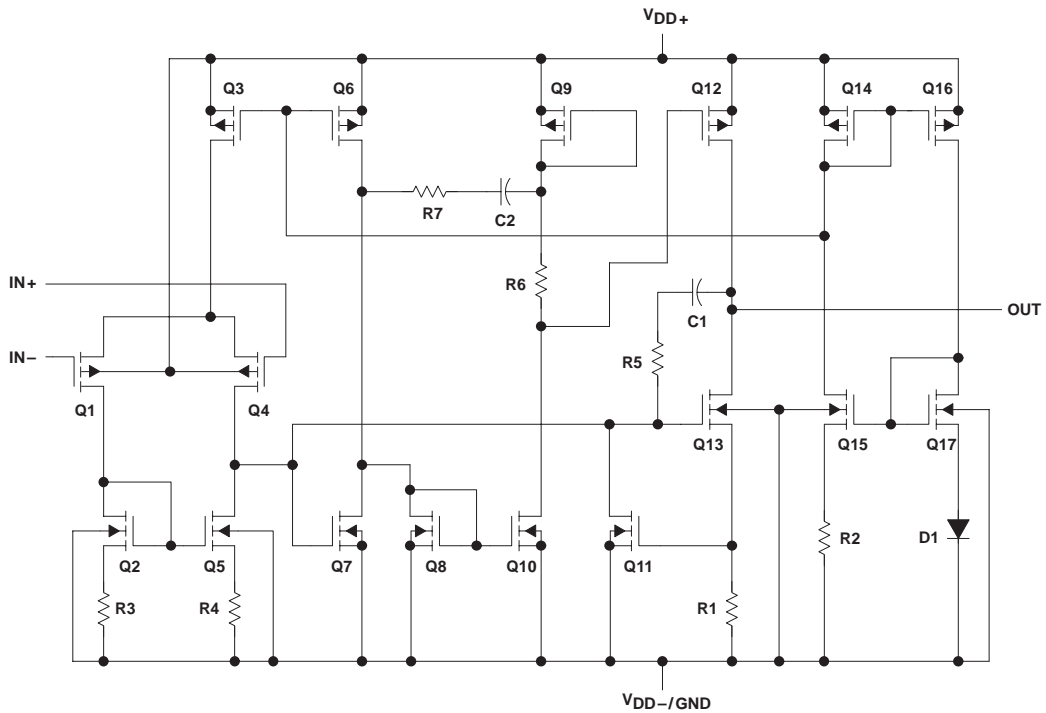
‡ Chip forms are tested at T<sub>A</sub> = 25°C only.

**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.



equivalent schematic



COMPONENT COUNT†	
Transistors	23
Diodes	5
Resistors	11
Capacitors	2

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

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**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)	$\pm 5$ mA
Output current, $I_O$	$\pm 50$ mA
Total current into $V_{DD+}$	$\pm 50$ mA
Total current out of $V_{DD-}$	$\pm 50$ 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	$T_A \leq 25^\circ\text{C}$ POWER RATING	DERATING FACTOR ABOVE $T_A = 25^\circ\text{C}$	$T_A = 70^\circ\text{C}$ POWER RATING	$T_A = 85^\circ\text{C}$ 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  $V_{DD-}$ .



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

PARAMETER	TEST CONDITIONS	$T_A$ †	TLV2231C			TLV2231I			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
$V_{IO}$ Input offset voltage	$V_{DD\pm} = \pm 1.5\text{ V}$ , $V_{IC} = 0$ , $V_O = 0$ , $R_S = 50\ \Omega$	Full range			0.75	3			mV
$\alpha_{VIO}$ Temperature coefficient of input offset voltage					0.5				$\mu\text{V}/^\circ\text{C}$
Input offset voltage long-term drift (see Note 4)		25°C	0.003		0.003		$\mu\text{V}/\text{mo}$		
$I_{IO}$ 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	$R_S = 50\ \Omega$ , $ V_{IO}  \leq 5\text{ 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	$I_{OH} = -1\text{ mA}$ $I_{OH} = -2\text{ mA}$	25°C	2.87		2.87		V		
		25°C	2.74		2.74				
		Full range	2		2				
$V_{OL}$ Low-level output voltage	$V_{IC} = 1.5\text{ V}$ , $I_{OL} = 50\ \mu\text{A}$ $V_{IC} = 1.5\text{ V}$ , $I_{OL} = 500\ \mu\text{A}$	25°C	10		10		mV		
		25°C	100		100				
		Full range	300		300				
$A_{VD}$ Large-signal differential voltage amplification	$V_{IC} = 1.5\text{ V}$ , $V_O = 1\text{ V to } 2\text{ V}$	25°C	$R_L = 600\ \Omega$ ‡		1	1.6	1	1.6	V/mV
			Full range		0.3		0.3		
		25°C	$R_L = 1\text{ M}\Omega$ ‡		250		250		
$r_{id}$ Differential input resistance		25°C	$10^{12}$		$10^{12}$		$\Omega$		
$r_{ic}$ Common-mode input resistance		25°C	$10^{12}$		$10^{12}$		$\Omega$		
$c_{ic}$ Common-mode input capacitance	$f = 10\text{ kHz}$	25°C	6		6		pF		
$z_o$ Closed-loop output impedance	$f = 1\text{ MHz}$ , $A_V = 1$	25°C	156		156		$\Omega$		
CMRR Common-mode rejection ratio	$V_{IC} = 0\text{ to } 1.7\text{ V}$ , $V_O = 1.5\text{ V}$ , $R_S = 50\ \Omega$	25°C	60	70	60	70	dB		
		Full range	55		55				
KSVR Supply voltage rejection ratio ( $\Delta V_{DD} / \Delta V_{IO}$ )	$V_{DD} = 2.7\text{ V to } 8\text{ V}$ , $V_{IC} = V_{DD}/2$ , No load	25°C	70	96	70	96	dB		
		Full range	70		70				
$I_{DD}$ Supply current	$V_O = 1.5\text{ V}$ , No load	25°C	750	1200	750	1200	$\mu\text{A}$		
		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  $T_A = 150^\circ\text{C}$  extrapolated to  $T_A = 25^\circ\text{C}$  using the Arrhenius equation and assuming an activation energy of 0.96 eV.



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

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

† Full range is  $-40^\circ\text{C}$  to  $85^\circ\text{C}$ .

‡ Referenced to 1.5 V

§ Referenced to 0 V



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

PARAMETER	TEST CONDITIONS	$T_A$ †	TLV2231C			TLV2231I			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
$V_{IO}$ Input offset voltage	$V_{DD\pm} = \pm 2.5\text{ V}$ , $V_{IC} = 0$ , $V_O = 0$ , $R_S = 50\ \Omega$	Full range	0.71		3	0.71		3	mV
$\alpha_{VIO}$ Temperature coefficient of input offset voltage			0.5		0.5		$\mu\text{V}/^\circ\text{C}$		
Input offset voltage long-term drift (see Note 4)		25°C	0.003		0.003		$\mu\text{V}/\text{mo}$		
$I_{IO}$ 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	$R_S = 50\ \Omega$ , $ V_{IO}  \leq 5\text{ 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	0 to 3.7	0 to 3.7			
$V_{OH}$ High-level output voltage	$I_{OH} = -1\text{ mA}$ $I_{OH} = -4\text{ mA}$	25°C	4.9		4.9		V		
		25°C	4.6		4.6				
		Full range	4		4				
$V_{OL}$ Low-level output voltage	$V_{IC} = 2.5\text{ V}$ , $I_{OL} = 500\ \mu\text{A}$ $V_{IC} = 2.5\text{ V}$ , $I_{OL} = 1\text{ mA}$	25°C	80		80		mV		
		25°C	160		160				
		Full range	500		500				
$A_{VD}$ Large-signal differential voltage amplification	$V_{IC} = 2.5\text{ V}$ , $V_O = 1\text{ V to }4\text{ V}$	25°C	$R_L = 600\ \Omega$ ‡		1 1.5		V/mV		
			Full range		0.3				
		25°C	$R_L = 1\text{ M}\Omega$ ‡		400				
$r_{id}$ Differential input resistance		25°C	$10^{12}$		$10^{12}$		$\Omega$		
$r_{ic}$ Common-mode input resistance		25°C	$10^{12}$		$10^{12}$		$\Omega$		
$c_{ic}$ Common-mode input capacitance	$f = 10\text{ kHz}$	25°C	6		6		pF		
$z_o$ Closed-loop output impedance	$f = 1\text{ MHz}$ , $A_V = 1$	25°C	138		138		$\Omega$		
CMRR Common-mode rejection ratio	$V_{IC} = 0\text{ to }2.7\text{ V}$ , $V_O = 2.5\text{ V}$ , $R_S = 50\ \Omega$	25°C	60	70	60	70	dB		
		Full range	55		55				
KSVR Supply voltage rejection ratio ( $\Delta V_{DD} / \Delta V_{IO}$ )	$V_{DD} = 4.4\text{ V to }8\text{ V}$ , $V_{IC} = V_{DD}/2$ , No load	25°C	70	96	70	96	dB		
		Full range	70		70				
$I_{DD}$ Supply current	$V_O = 2.5\text{ V}$ , No load	25°C	850	1300	850	1300	$\mu\text{A}$		
		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  $T_A = 150^\circ\text{C}$  extrapolated to  $T_A = 25^\circ\text{C}$  using the Arrhenius equation and assuming an activation energy of 0.96 eV.



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

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

† Full range is  $-40^\circ\text{C}$  to  $85^\circ\text{C}$ .

‡ Referenced to 2.5 V

§ Referenced to 0 V





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electrical characteristics at  $V_{DD} = 3\text{ V}$ ,  $T_A = 25^\circ\text{C}$  (unless otherwise noted)

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

$^\dagger$  Referenced to 1.5 V

electrical characteristics at  $V_{DD} = 5\text{ V}$ ,  $T_A = 25^\circ\text{C}$  (unless otherwise noted)

PARAMETER	TEST CONDITIONS	TLV2231Y			UNIT
		MIN	TYP	MAX	
$V_{IO}$ Input offset voltage	$V_{DD} \pm \pm 1.5\text{ V}$ , $V_{IC} = 0$ , $V_O = 0$ , $R_S = 50\ \Omega$	710			$\mu\text{V}$
$I_{IO}$ Input offset current		0.5			$\text{pA}$
$I_{IB}$ Input bias current		1			$\text{pA}$
$V_{ICR}$ Common-mode input voltage range	$ V_{IO}  \leq 5\text{ mV}$ , $R_S = 50\ \Omega$	-0.3 to 4.2			$\text{V}$
$V_{OH}$ High-level output voltage	$I_{OH} = -1\text{ mA}$	4.9			$\text{V}$
$V_{OL}$ Low-level output voltage	$V_{IC} = 2.5\text{ V}$ , $I_{OL} = 500\ \mu\text{A}$	80			$\text{mV}$
	$V_{IC} = 2.5\text{ V}$ , $I_{OL} = 1\text{ mA}$	160			
$A_{VD}$ Large-signal differential voltage amplification	$V_O = 1\text{ V to } 2\text{ V}$	$R_L = 600\ \Omega^\dagger$	15		$\text{V/mV}$
		$R_L = 1\ \text{M}\Omega^\dagger$	400		
$r_{id}$ Differential input resistance		$10^{12}$			$\Omega$
$r_{ic}$ Common-mode input resistance		$10^{12}$			$\Omega$
$c_{ic}$ Common-mode input capacitance	$f = 10\text{ kHz}$	6			$\text{pF}$
$z_o$ Closed-loop output impedance	$f = 1\text{ MHz}$ , $A_V = 1$	138			$\Omega$
CMRR Common-mode rejection ratio	$V_{IC} = 0\text{ to } 1.7\text{ V}$ , $V_O = 0$ , $R_S = 50\ \Omega$	60	70		$\text{dB}$
$k_{SVR}$ Supply voltage rejection ratio ( $\Delta V_{DD}/\Delta V_{IO}$ )	$V_{DD} = 2.7\text{ V to } 8\text{ V}$ , $V_{IC} = 0$ , No load	96			$\text{dB}$
$I_{DD}$ Supply current	$V_O = 0$ , No load	850			$\mu\text{A}$

$^\dagger$  Referenced to 2.5 V



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**TYPICAL CHARACTERISTICS**

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**TYPICAL CHARACTERISTICS**

**DISTRIBUTION OF TLV2231  
INPUT OFFSET VOLTAGE**

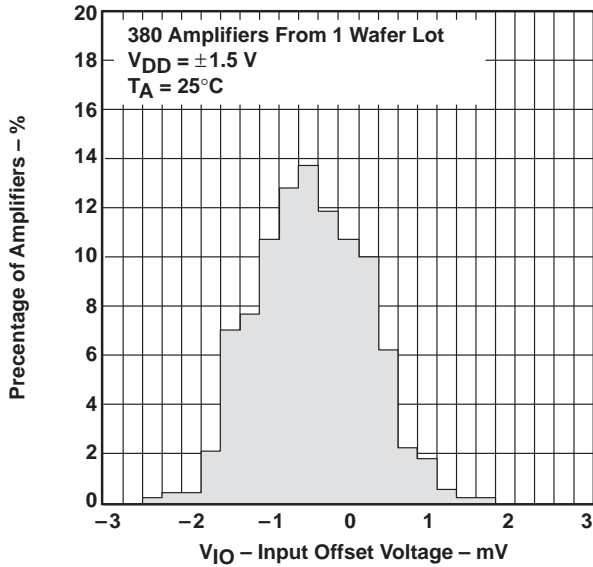


Figure 2

**DISTRIBUTION OF TLV2231  
INPUT OFFSET VOLTAGE**

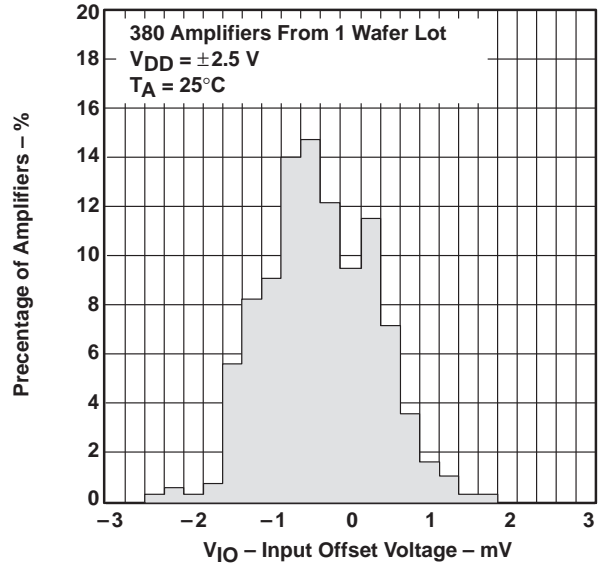


Figure 3

**INPUT OFFSET VOLTAGE†  
vs  
COMMON-MODE INPUT VOLTAGE**

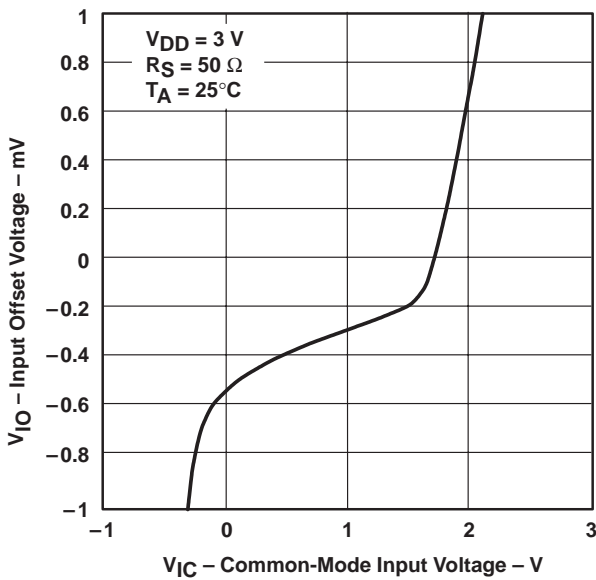


Figure 4

**INPUT OFFSET VOLTAGE†  
vs  
COMMON-MODE INPUT VOLTAGE**

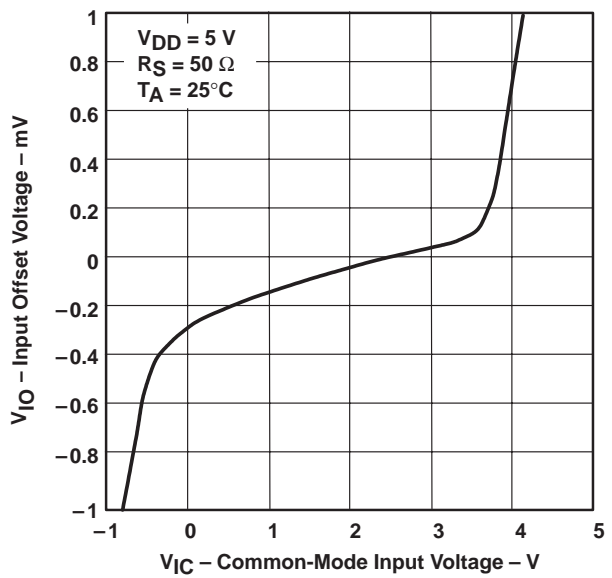


Figure 5

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

TYPICAL CHARACTERISTICS

DISTRIBUTION OF TLV2231 INPUT OFFSET VOLTAGE TEMPERATURE COEFFICIENT†

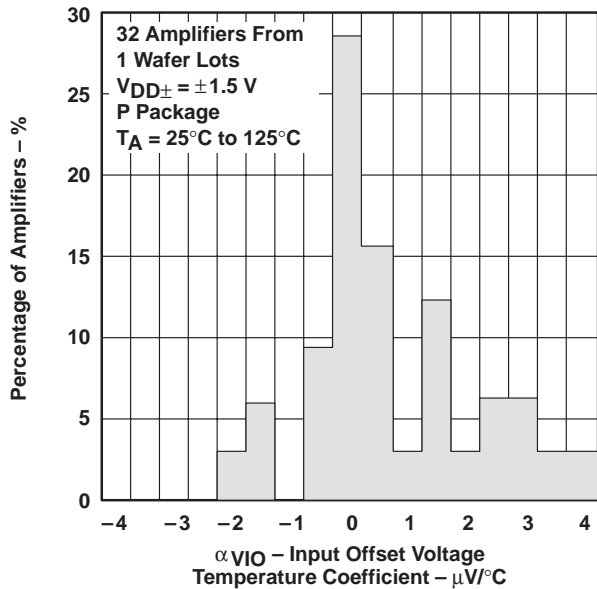


Figure 6

DISTRIBUTION OF TLV2231 INPUT OFFSET VOLTAGE TEMPERATURE COEFFICIENT†

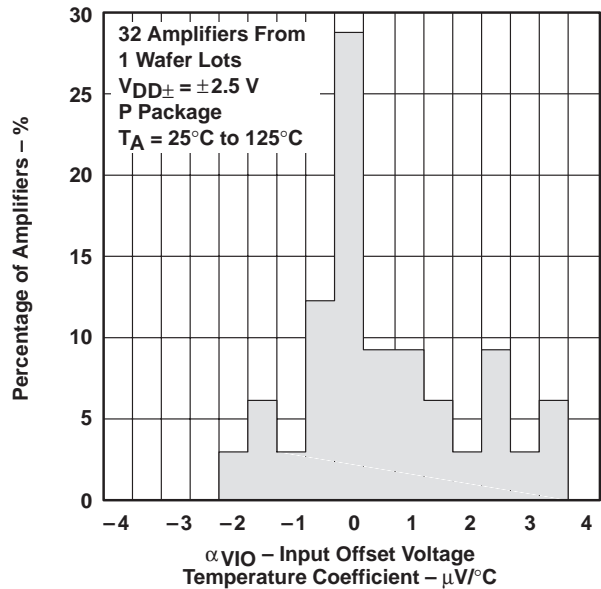


Figure 7

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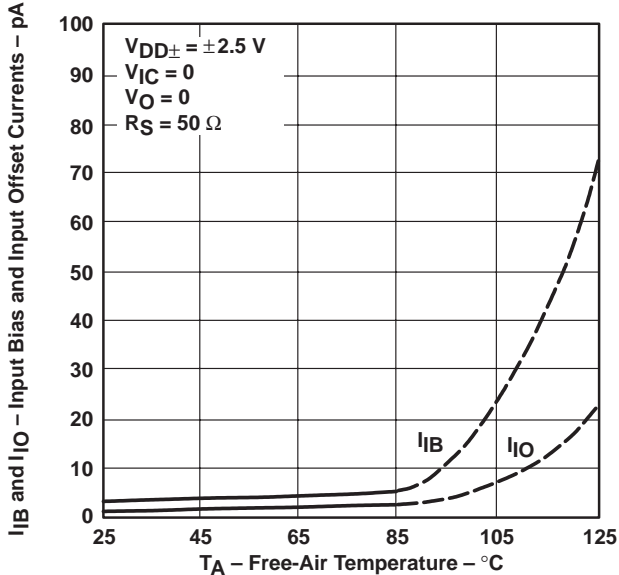


Figure 8

INPUT VOLTAGE  
 vs  
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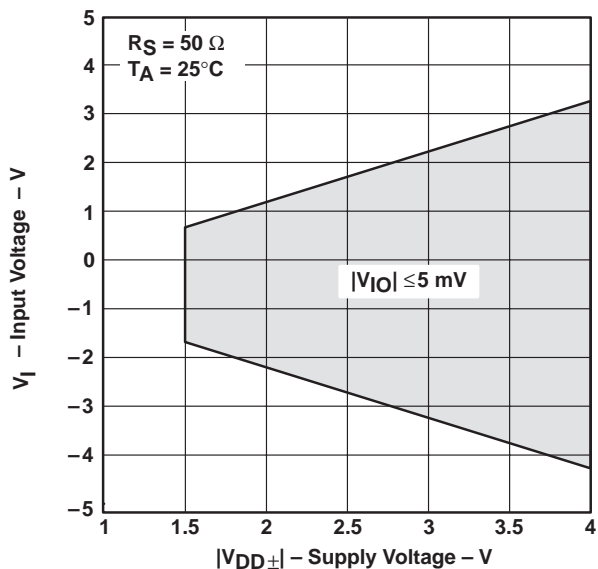
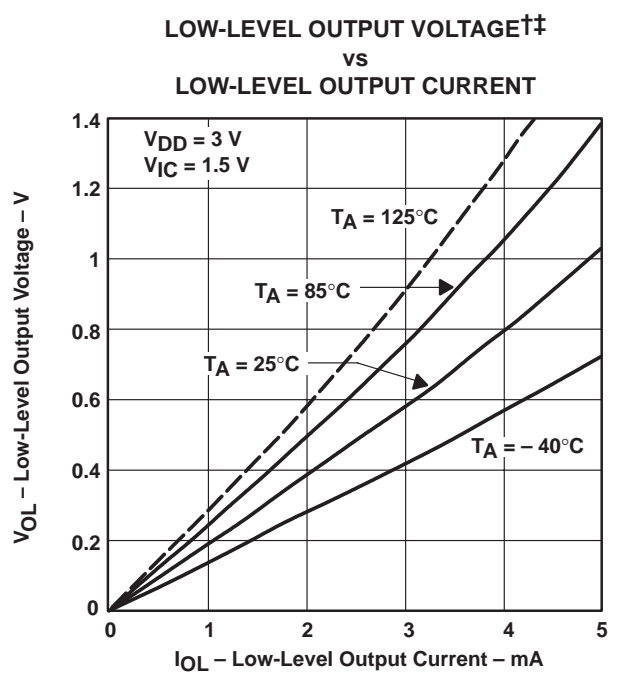
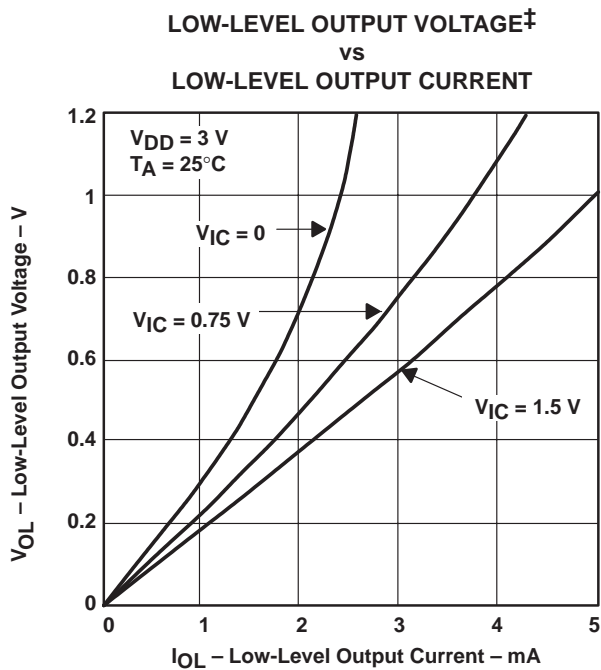
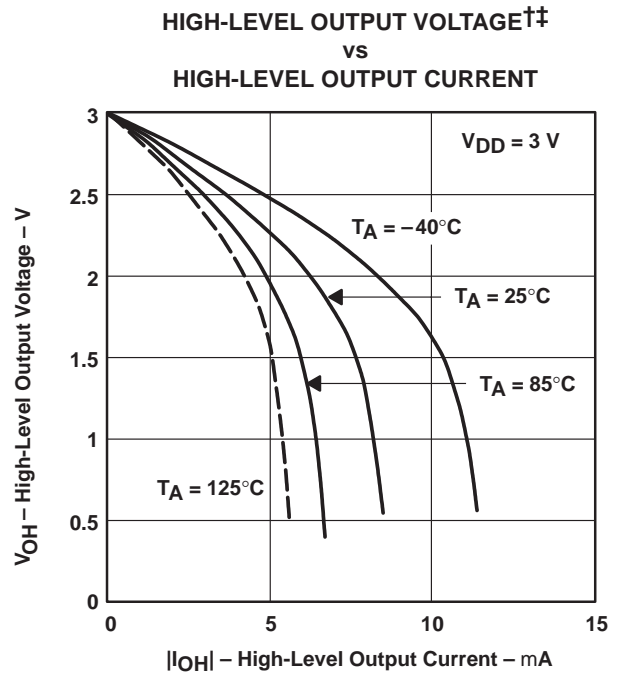
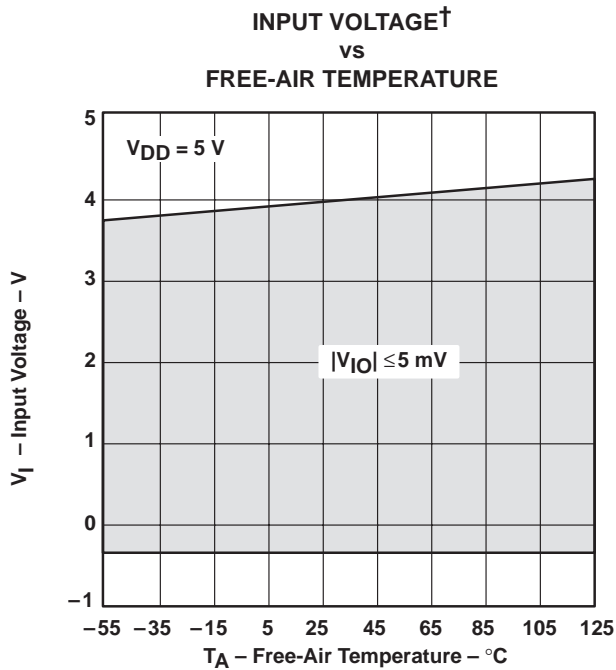


Figure 9

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

**TYPICAL CHARACTERISTICS**



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

TYPICAL CHARACTERISTICS

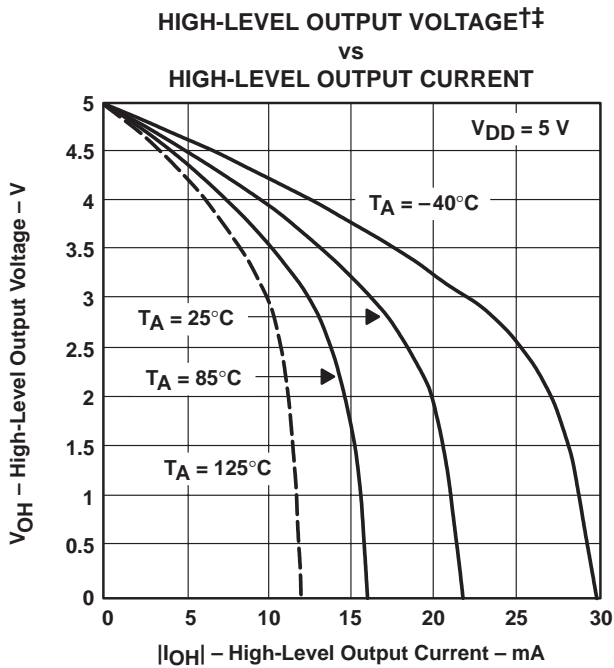


Figure 14

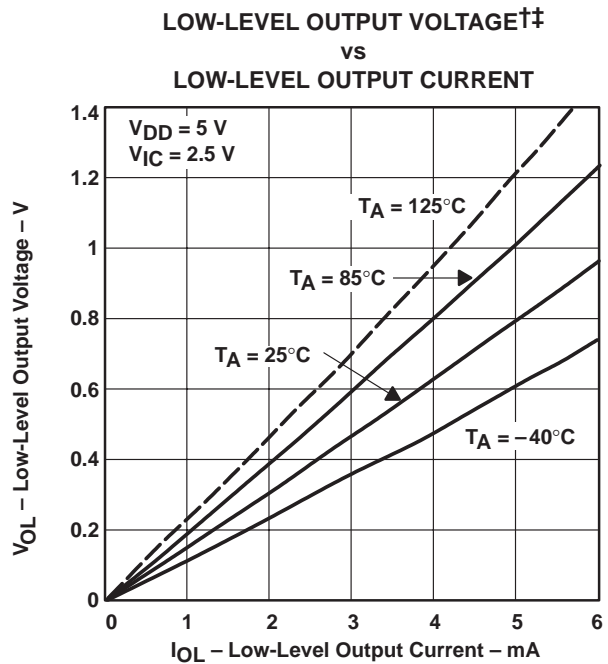


Figure 15

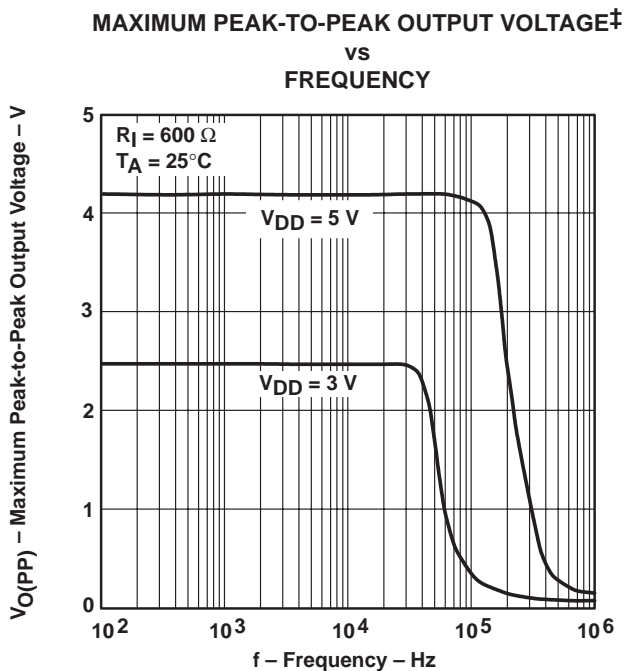


Figure 16

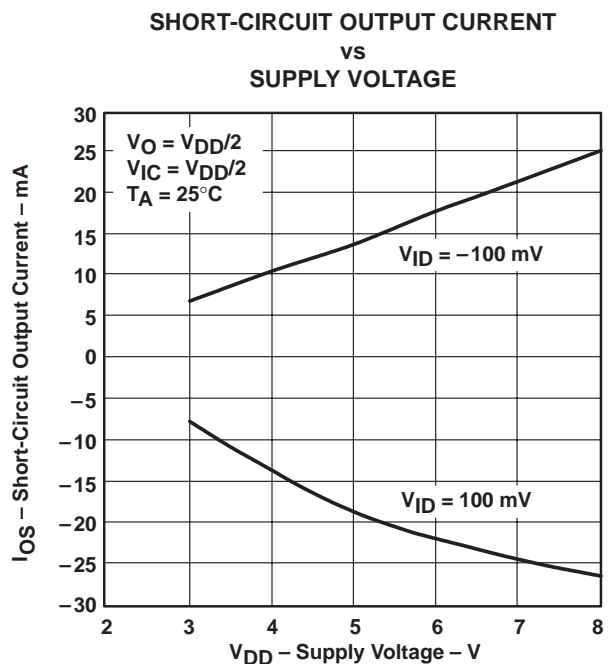
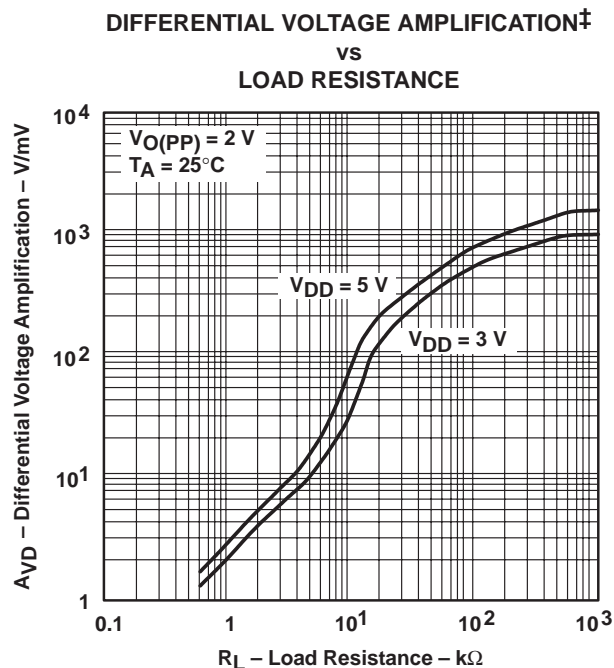
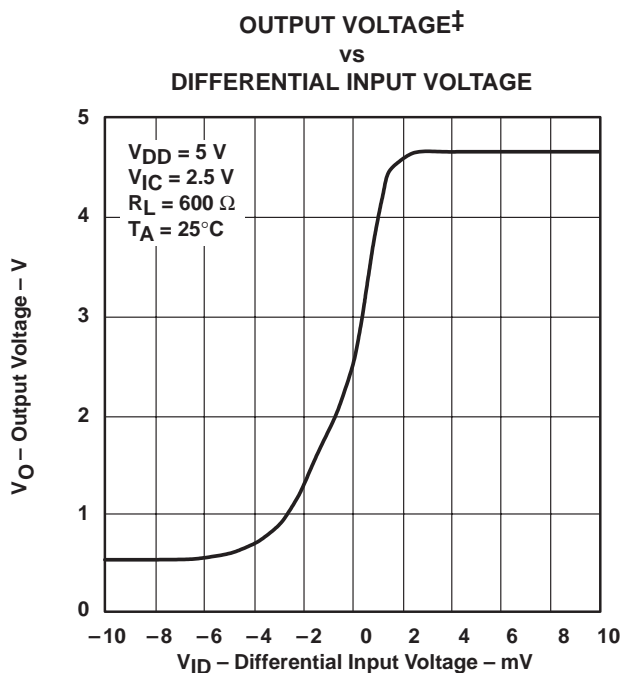
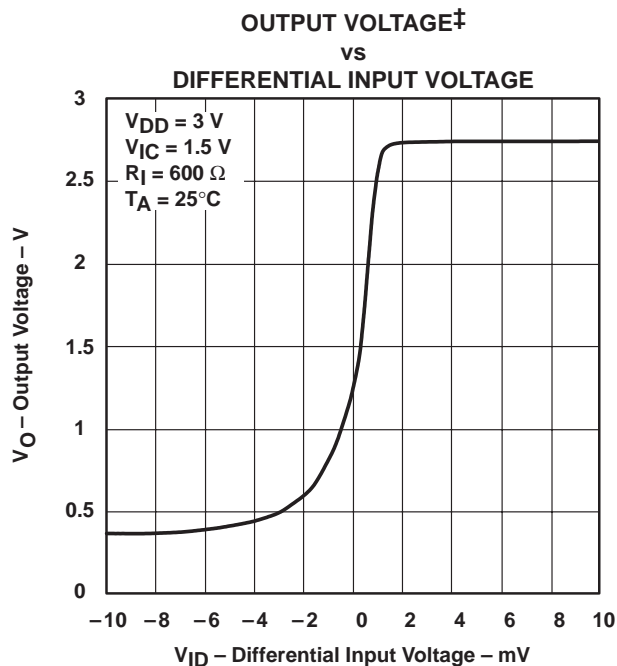
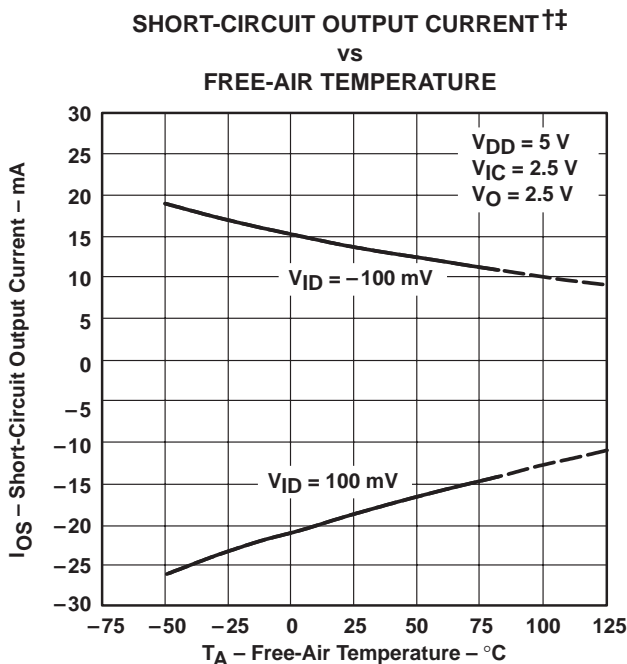


Figure 17

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

**TYPICAL CHARACTERISTICS**



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

TYPICAL CHARACTERISTICS

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

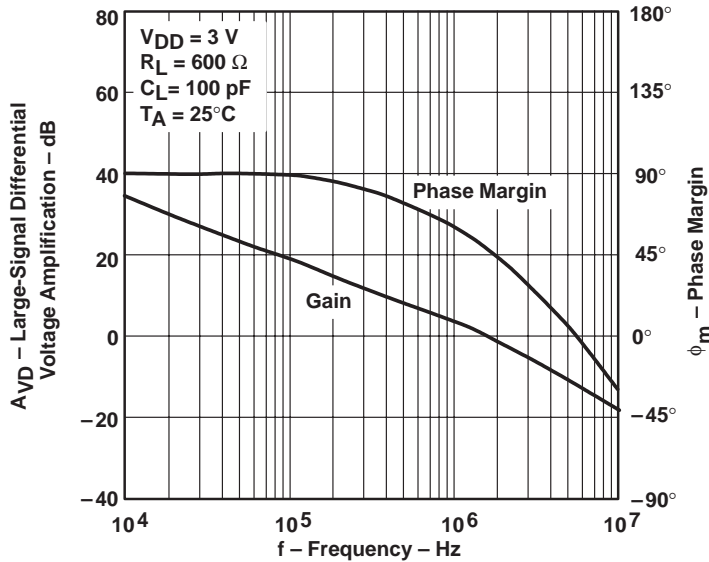


Figure 22

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

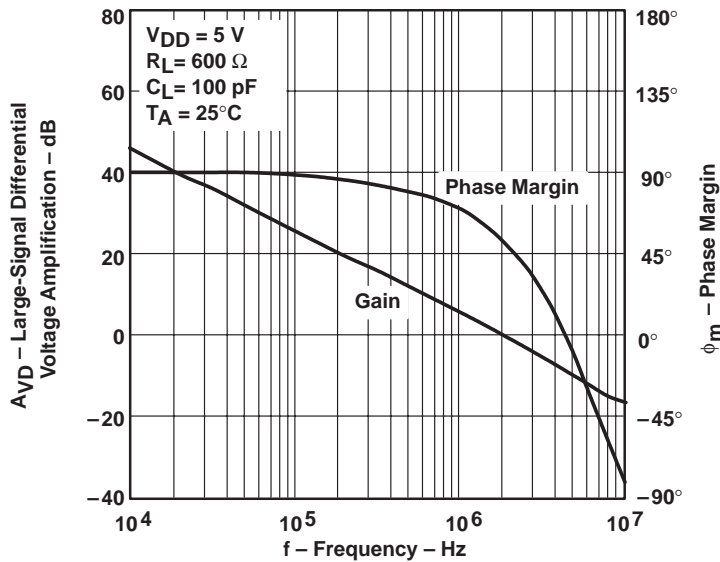


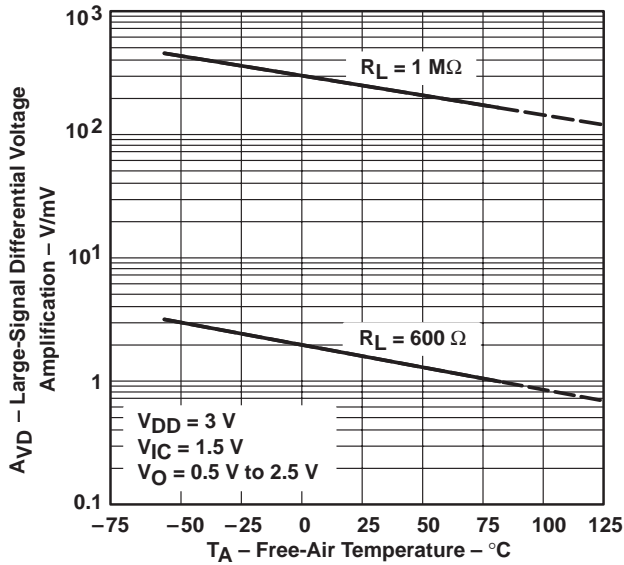
Figure 23

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



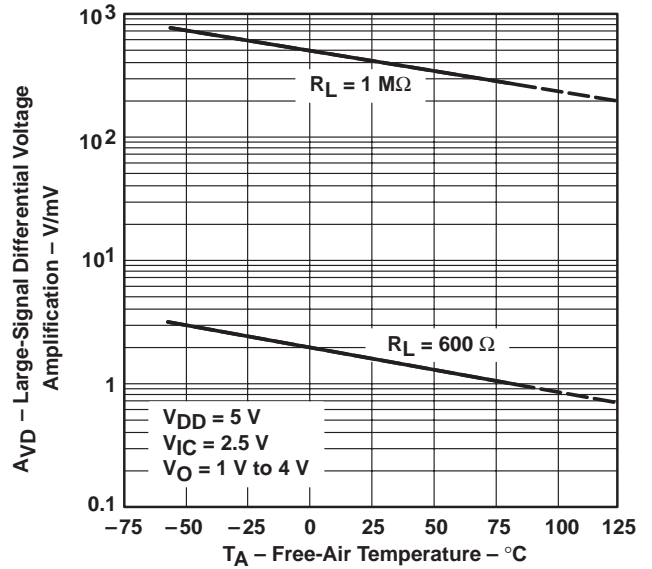
**TYPICAL CHARACTERISTICS**

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



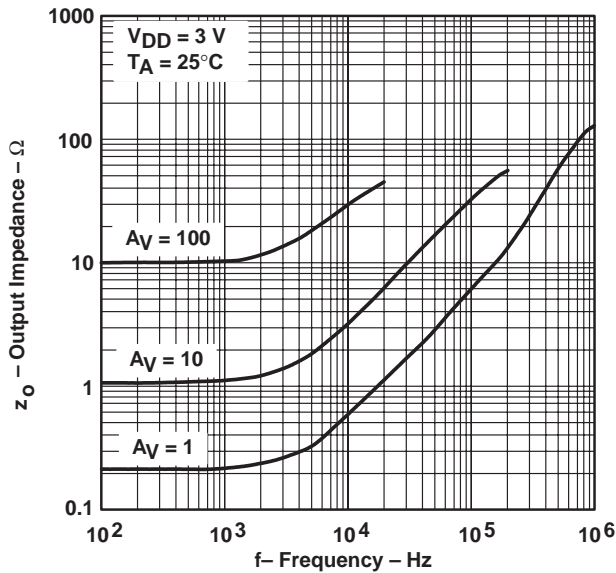
**Figure 24**

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



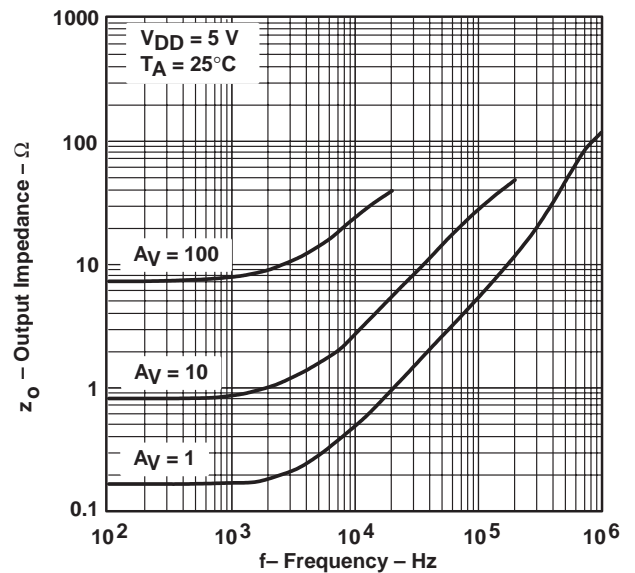
**Figure 25**

**OUTPUT IMPEDANCE†  
 vs  
 FREQUENCY**



**Figure 26**

**OUTPUT IMPEDANCE†  
 vs  
 FREQUENCY**



**Figure 27**

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

TYPICAL CHARACTERISTICS

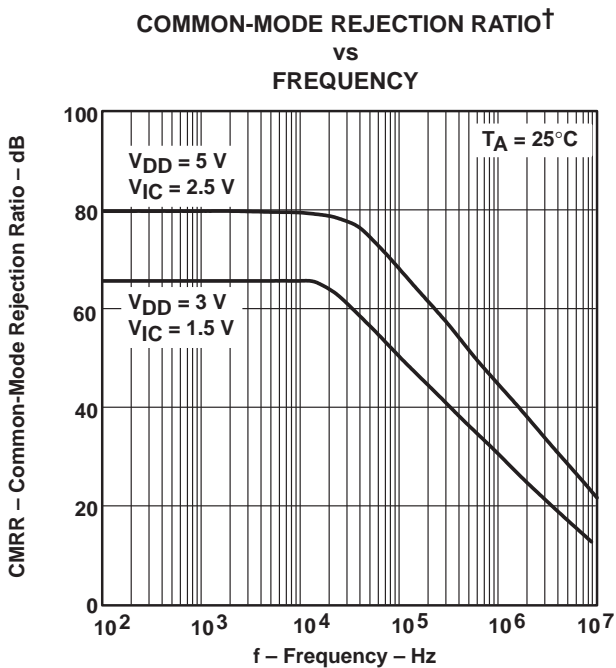


Figure 28

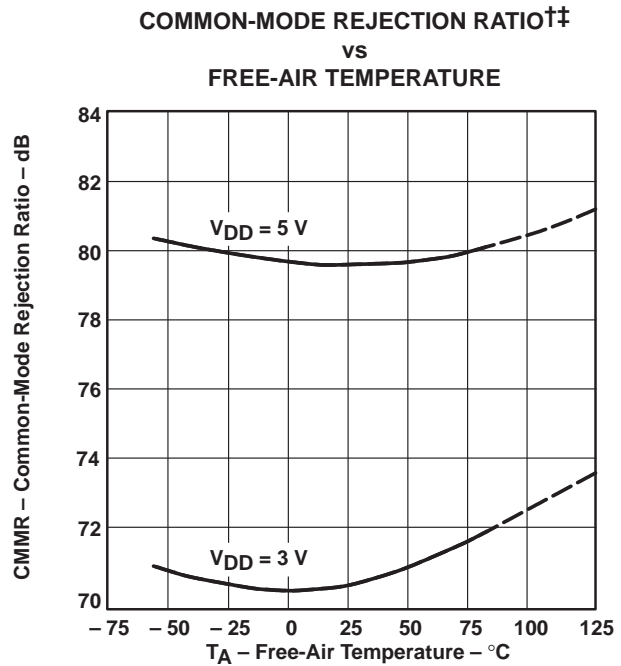


Figure 29

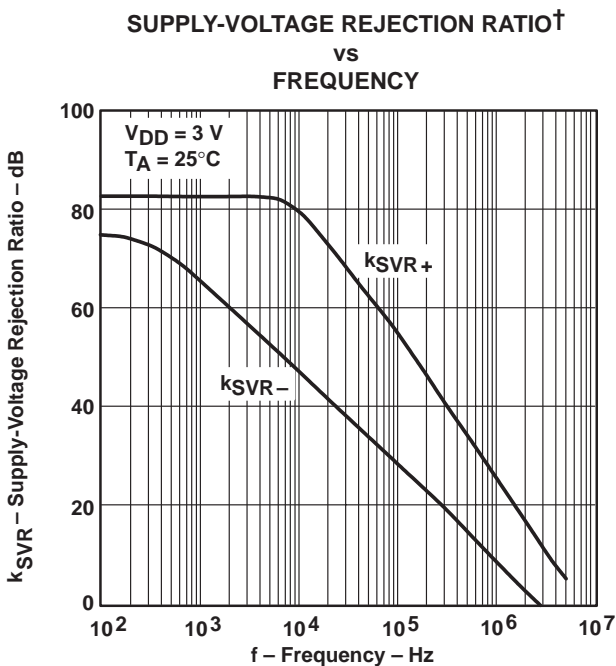


Figure 30

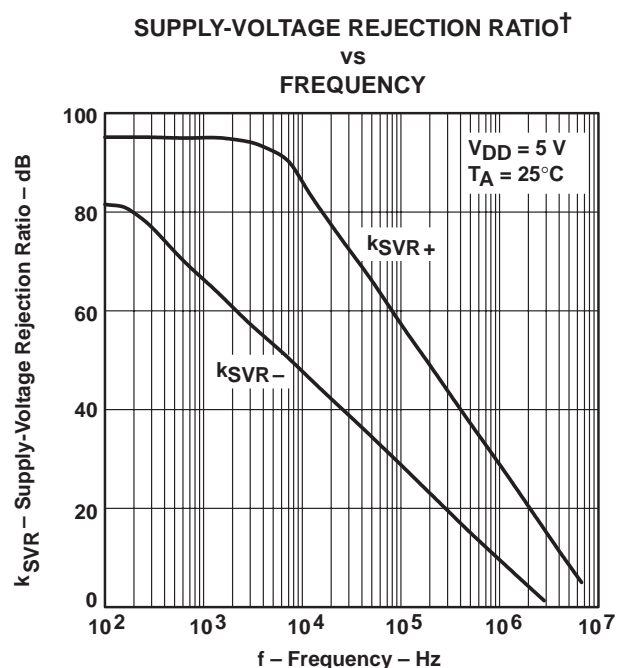
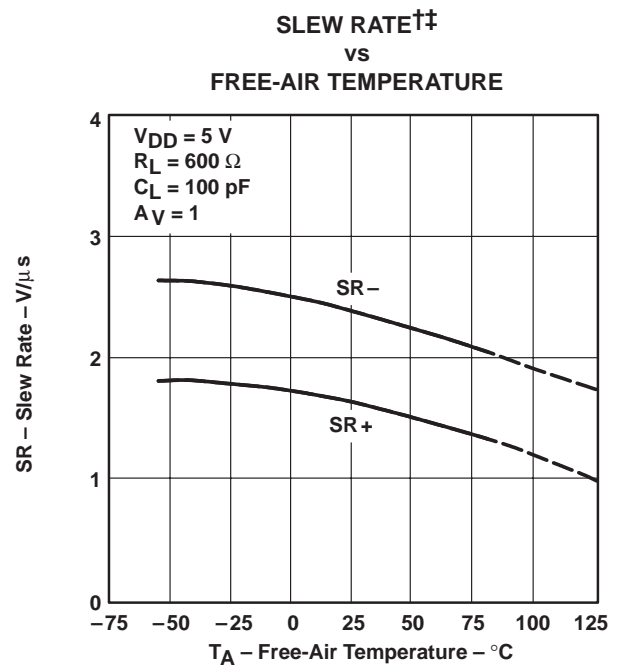
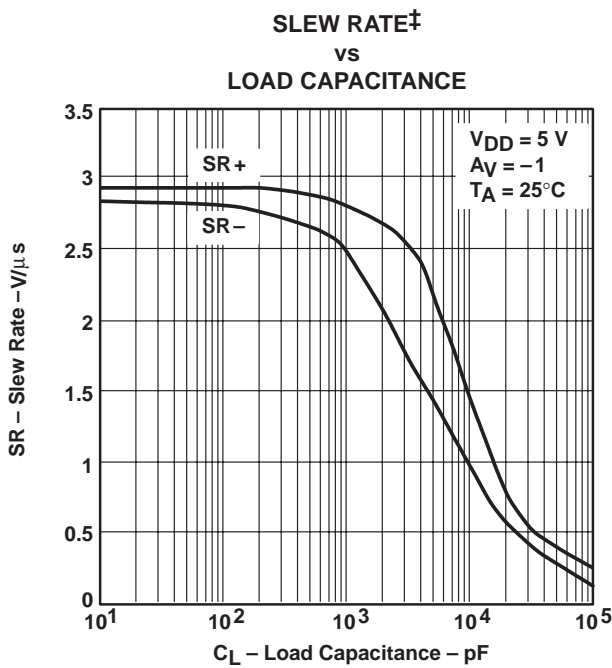
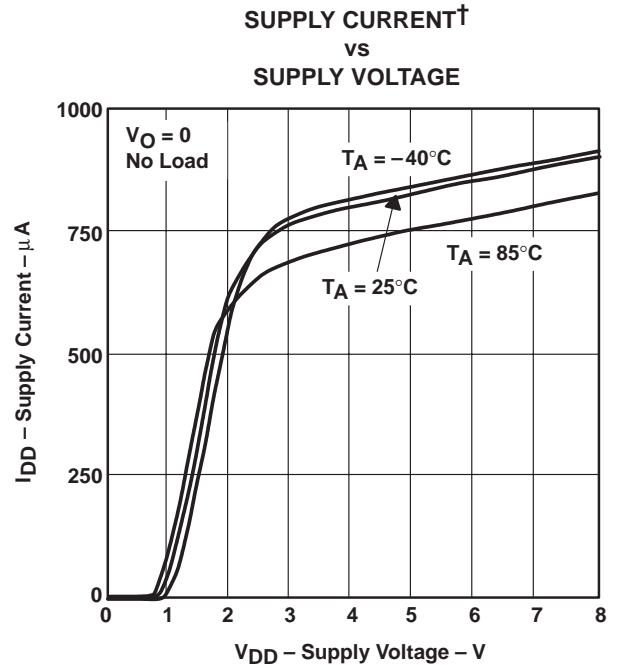
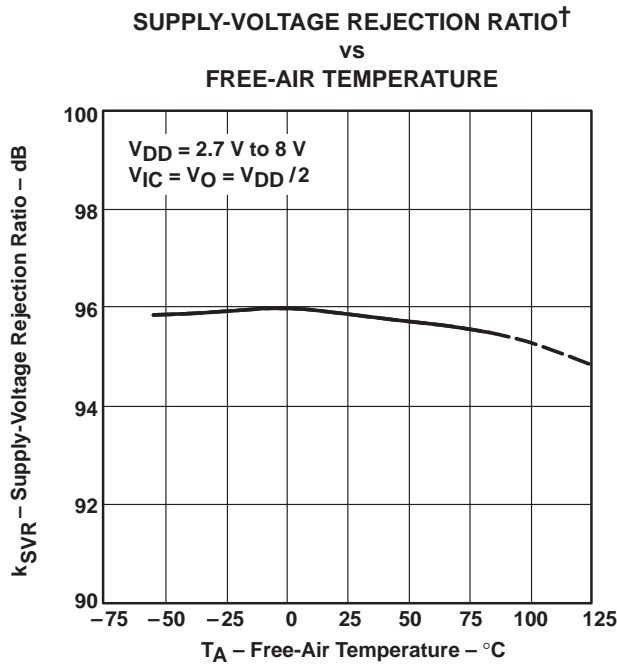


Figure 31

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



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

TYPICAL CHARACTERISTICS

INVERTING LARGE-SIGNAL PULSE RESPONSE†

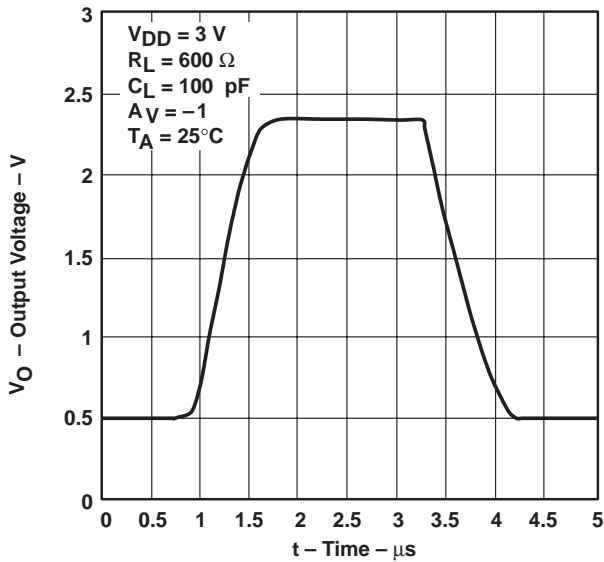


Figure 36

INVERTING LARGE-SIGNAL PULSE RESPONSE†

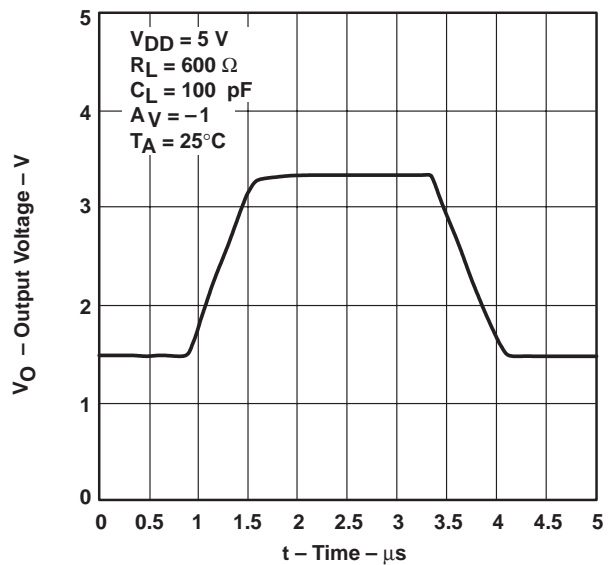


Figure 37

VOLTAGE-FOLLOWER LARGE-SIGNAL PULSE RESPONSE†

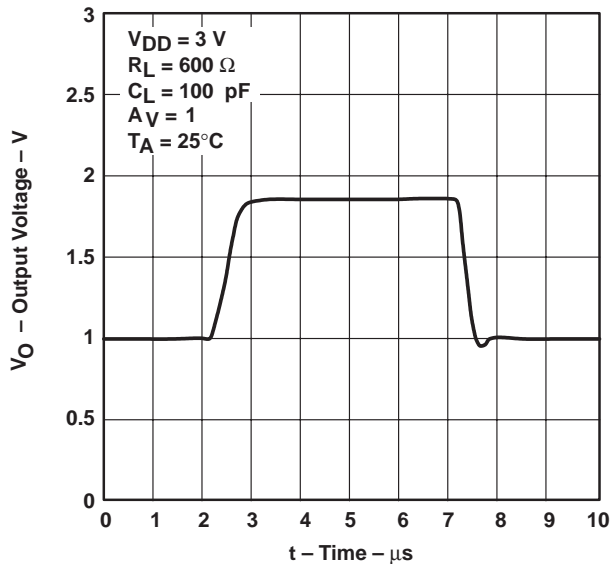


Figure 38

VOLTAGE-FOLLOWER LARGE-SIGNAL PULSE RESPONSE†

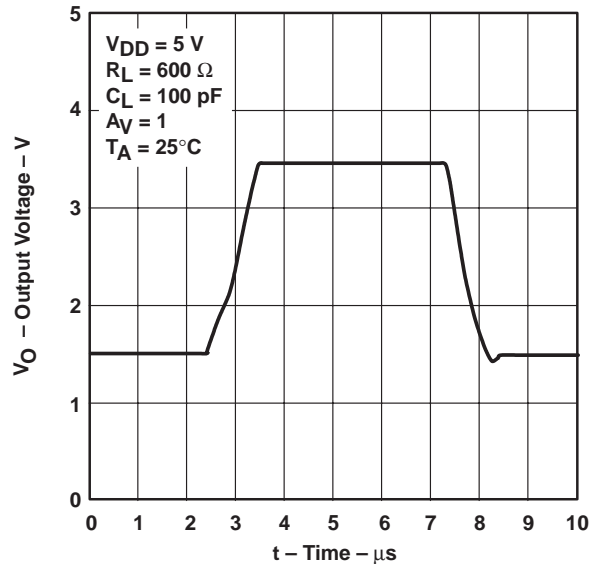
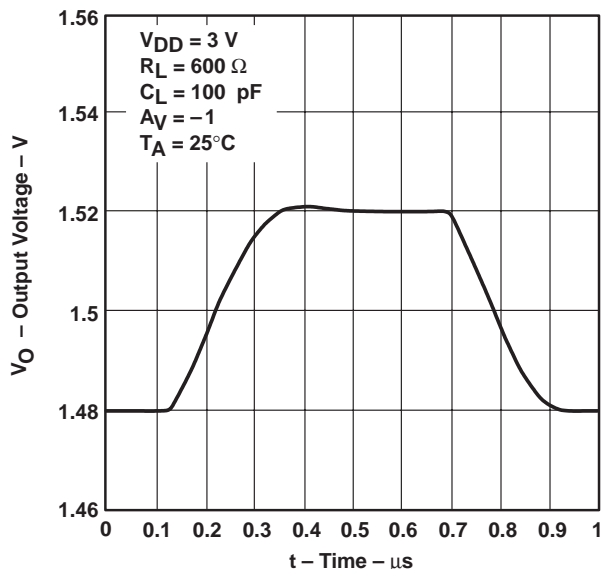


Figure 39

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

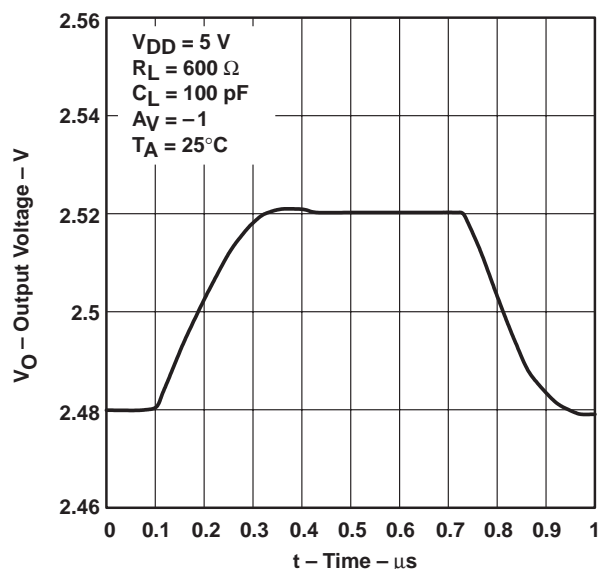
**TYPICAL CHARACTERISTICS**

**INVERTING SMALL-SIGNAL PULSE RESPONSE†**



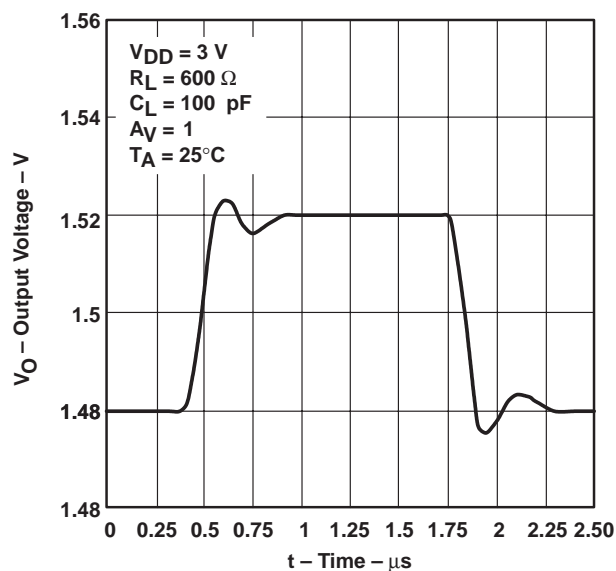
**Figure 40**

**INVERTING SMALL-SIGNAL PULSE RESPONSE†**



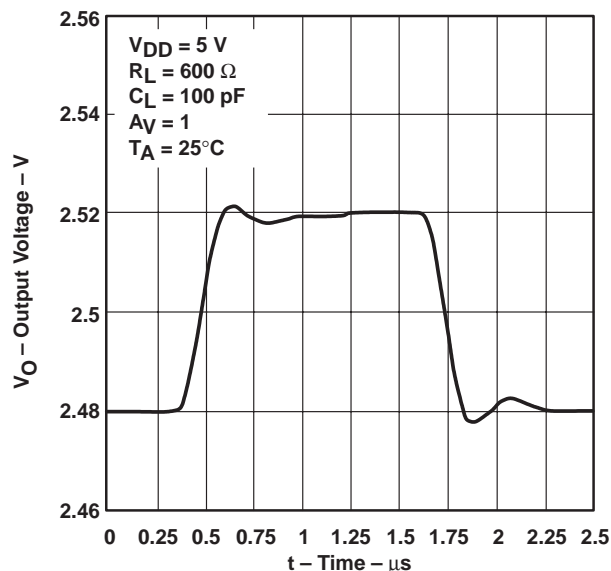
**Figure 41**

**VOLTAGE-FOLLOWER SMALL-SIGNAL PULSE RESPONSE†**



**Figure 42**

**VOLTAGE-FOLLOWER SMALL-SIGNAL PULSE RESPONSE†**



**Figure 43**

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

TYPICAL CHARACTERISTICS

EQUIVALENT INPUT NOISE VOLTAGE†  
 VS  
 FREQUENCY

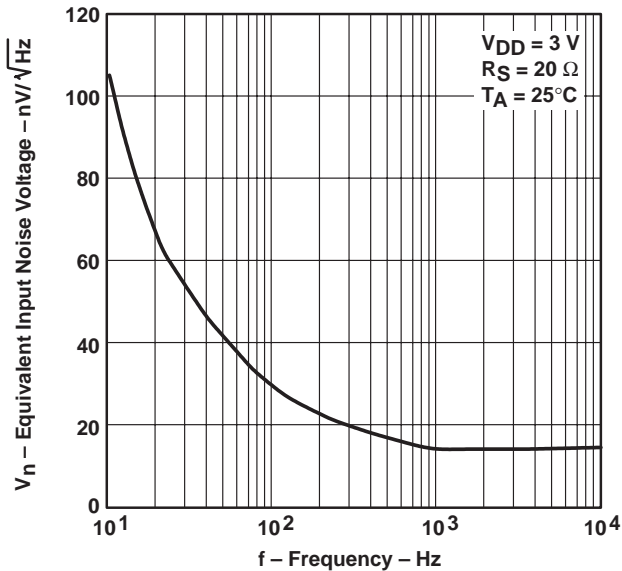


Figure 44

EQUIVALENT INPUT NOISE VOLTAGE†  
 VS  
 FREQUENCY

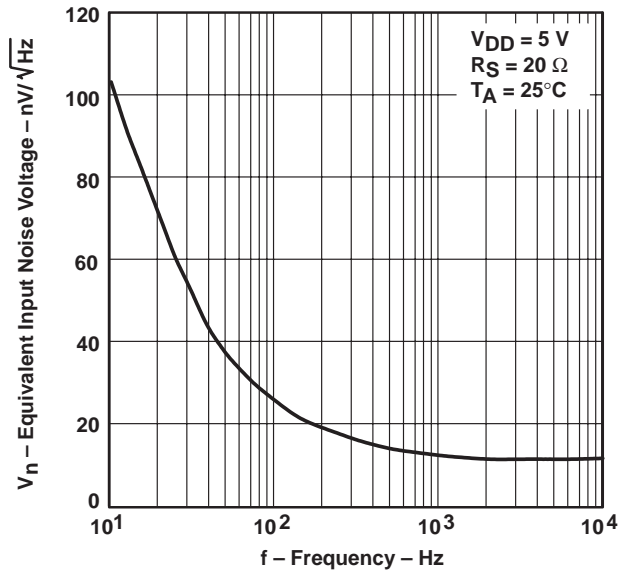


Figure 45

INPUT NOISE VOLTAGE OVER  
 A 10-SECOND PERIOD†

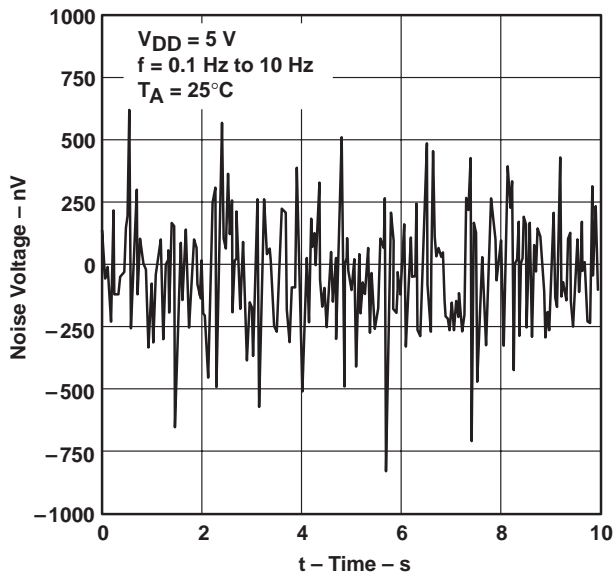


Figure 46

TOTAL HARMONIC DISTORTION PLUS NOISE†  
 VS  
 FREQUENCY

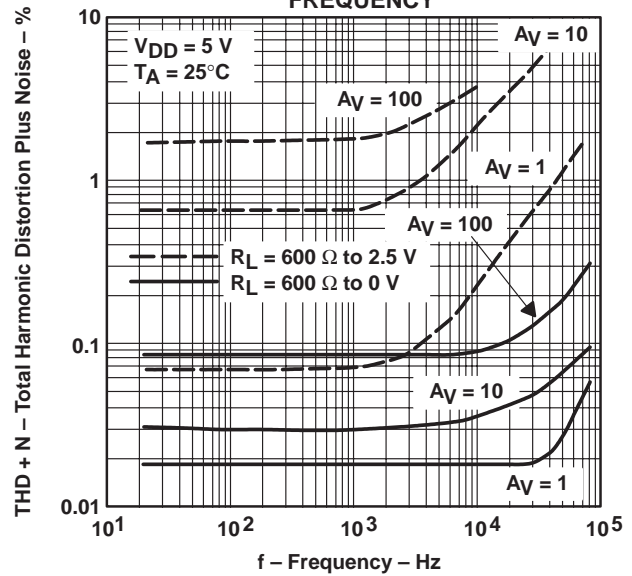
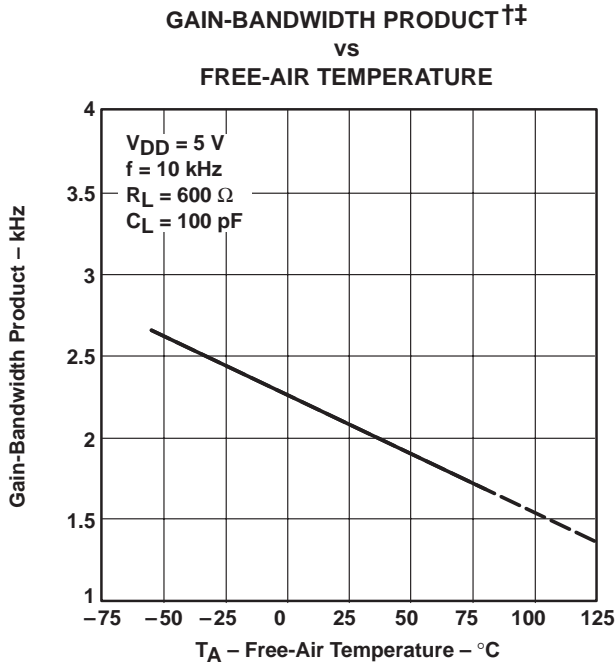


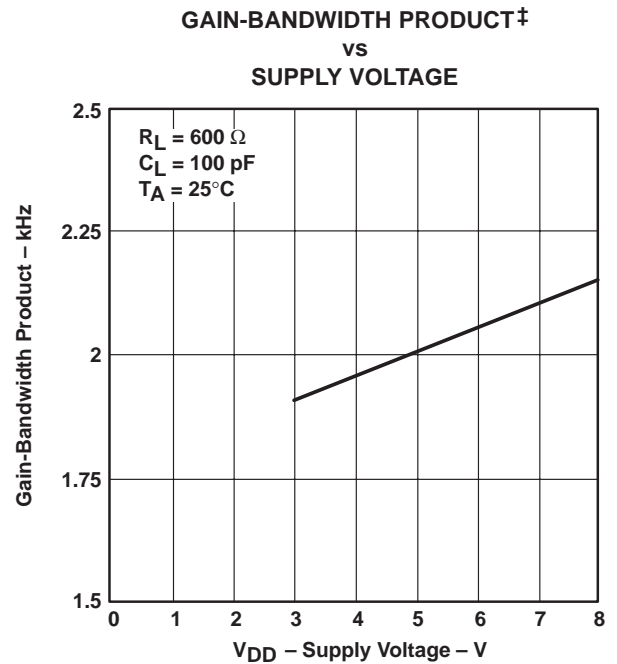
Figure 47

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

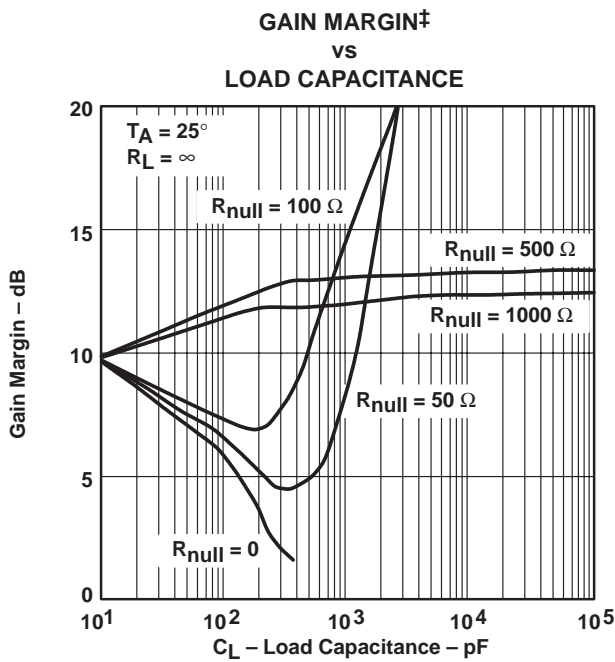
**TYPICAL CHARACTERISTICS**



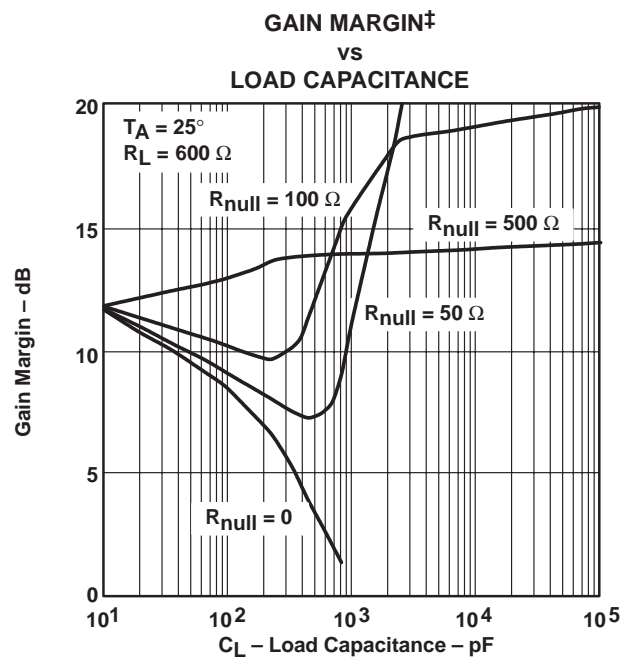
**Figure 48**



**Figure 49**



**Figure 50**



**Figure 51**

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

TYPICAL CHARACTERISTICS

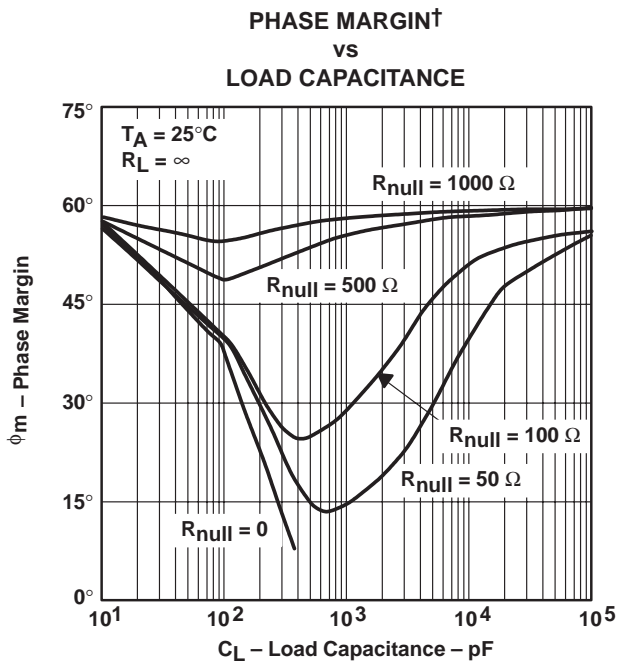


Figure 52

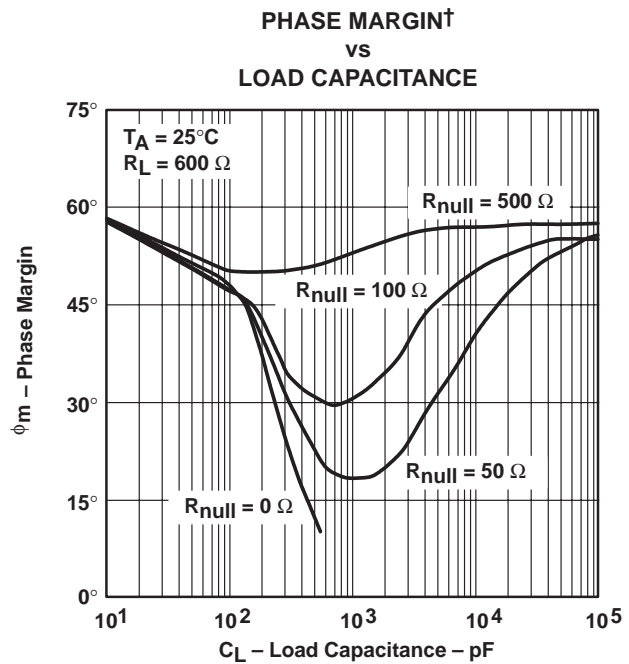


Figure 53

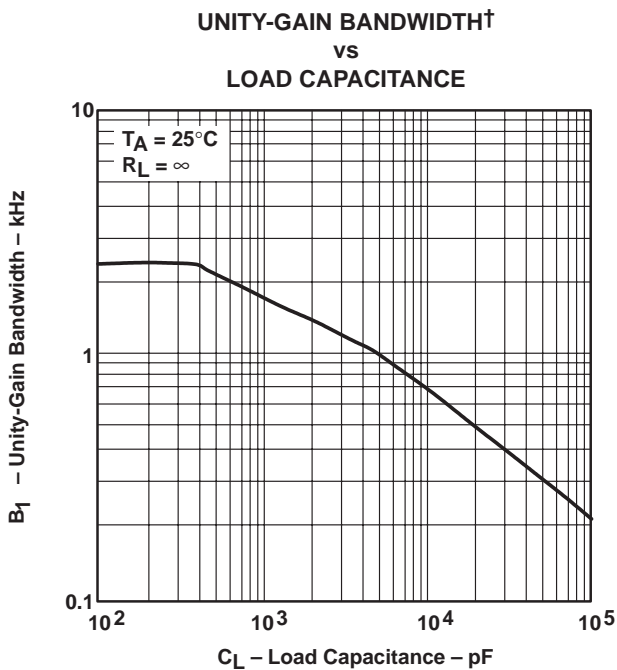


Figure 54

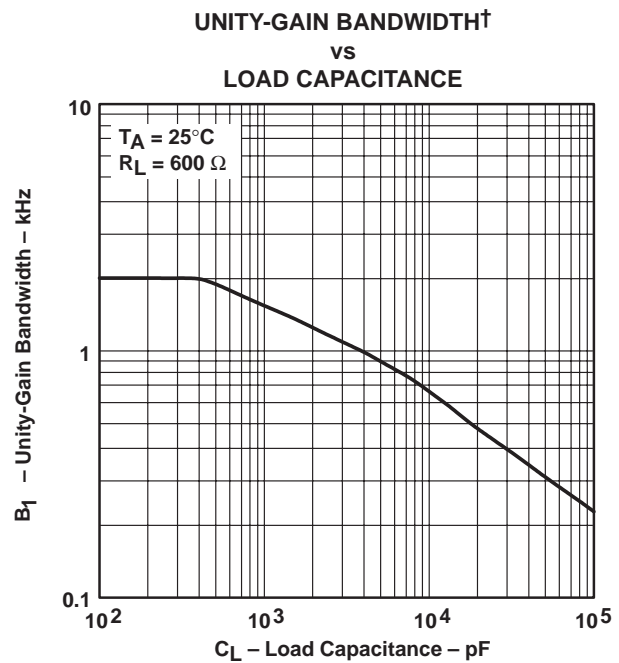


Figure 55

† For all curves where  $V_{DD} = 5\text{ V}$ , all loads are referenced to 2.5 V. For all curves where  $V_{DD} = 3\text{ V}$ , 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  $\Omega$ , 100  $\Omega$ , 500  $\Omega$ , and 1000  $\Omega$ . 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.

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

where :

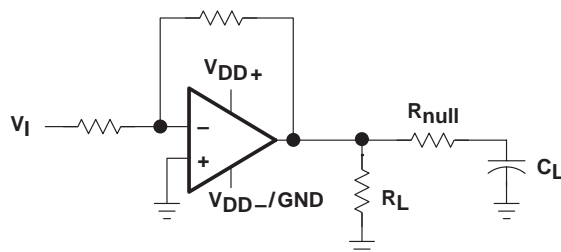
$\Delta\phi_{m1}$  = improvement in phase margin

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**

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**LOW-POWER SINGLE OPERATIONAL AMPLIFIERS**  
 SLOS158C – JUNE 1996 – REVISED SEPTEMBER 1997

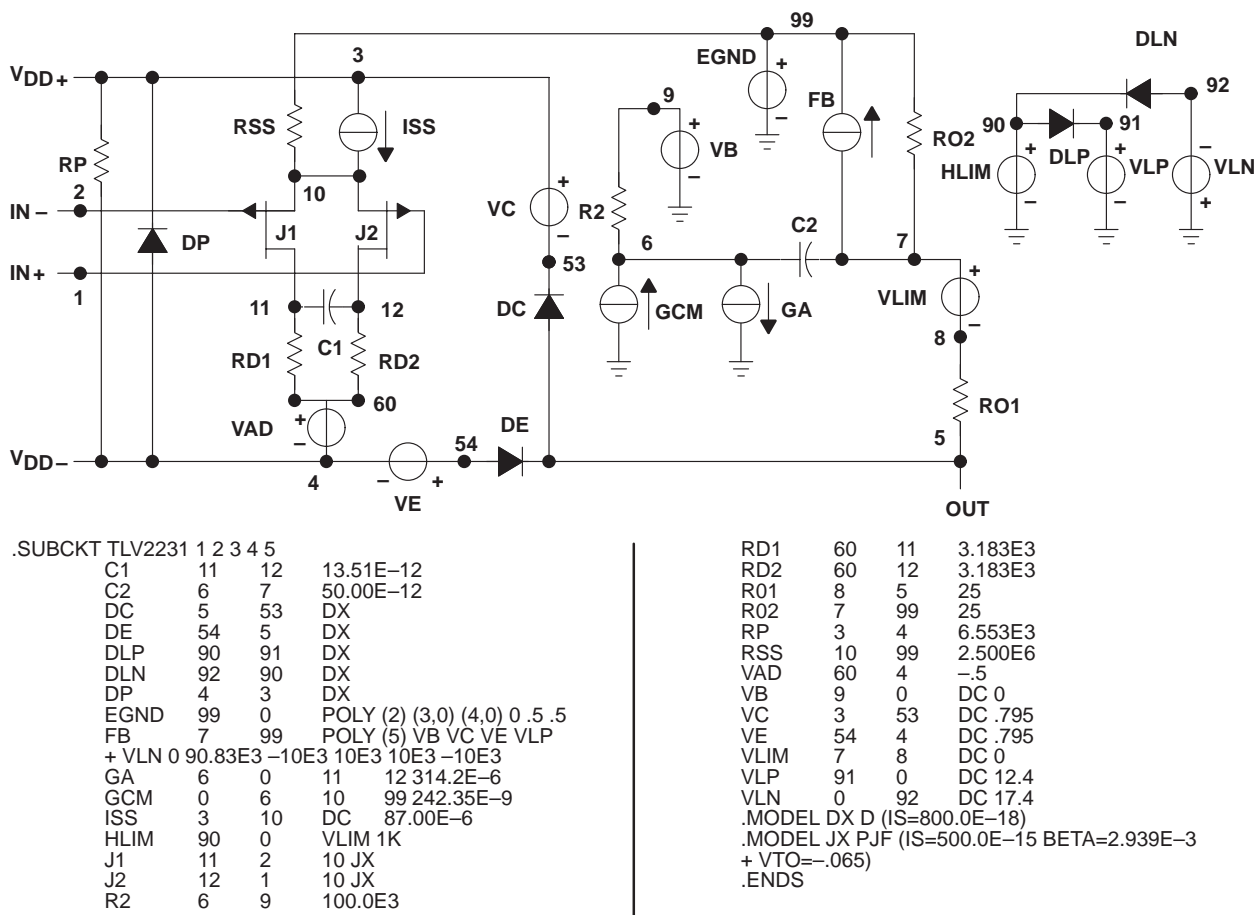
**APPLICATION INFORMATION**

**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  $T_A = 25^\circ\text{C}$ . 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).



**Figure 57. Boyle Macromodel and Subcircuit**

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