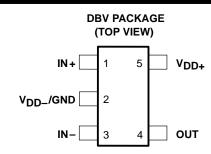
- Output Swing Includes Both Supply Rails
- Low Noise . . . 15 nV/ $\sqrt{\text{Hz}}$  Typ at f = 1 kHz
- Low Input Bias Current . . . 1 pA Typ
- Fully Specified for Single-Supply 3-V and 5-V Operation
- Common-Mode Input Voltage Range Includes Negative Rail
- High Gain Bandwidth . . . 2 MHz at
   V<sub>DD</sub> = 5 V With 600-Ω Load
- High Slew Rate . . . 1.6 V/μs at V<sub>DD</sub> = 5 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/ $\mu$ 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 the decoupling capacitor are easily placed around the package.

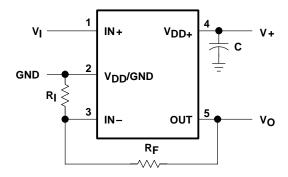


Figure 1. Typical Surface Mount Layout for a Fixed-Gain Noninverting Amplifier



Please be aware that an important notice concerning availability, standard warranty, and use in critical applications of Texas Instruments semiconductor products and disclaimers thereto appears at the end of this data sheet.

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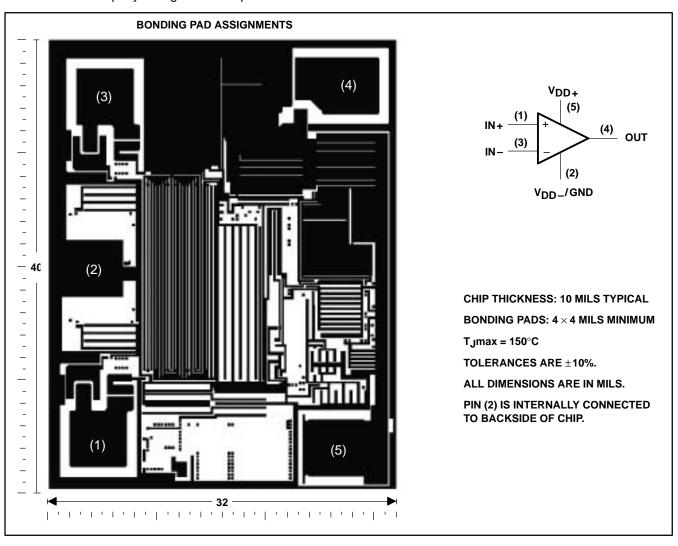
#### **AVAILABLE OPTIONS**

т.	Von may AT 25°C	PACKAGED DEVICES	SYMBOL	CHIP FORM‡	
T <sub>A</sub>	V <sub>IO</sub> max AT 25°C	SOT-23 (DBV) <sup>†</sup>	STWIBOL	(Y)	
0°C to 70°C	3 mV	TLV2231CDBV	VAEC	TLV2231Y	
-40°C to 85°C	3 mV	TLV2231IDBV	VAEI	11022311	

<sup>†</sup> The DBV package available in tape and reel only.

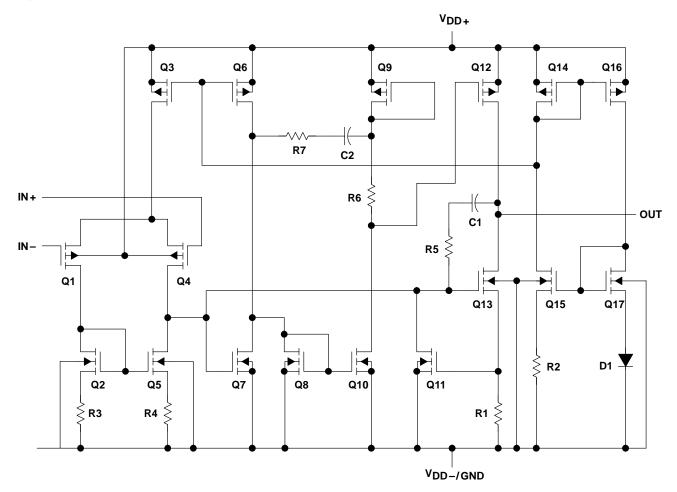
#### **TLV2231Y chip information**

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.



<sup>‡</sup> Chip forms are tested at  $T_A = 25$ °C only.

### equivalent schematic



COMPONENT COUNT <sup>†</sup>						
Transistors	23					
Diodes	5					
Resistors	11					
Capacitors	2					

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

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

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

Supply voltage, V <sub>DD</sub> (see Note 1)	12 V
Differential input voltage, V <sub>ID</sub> (see Note 2)	±V <sub>DD</sub>
Input voltage range, V <sub>I</sub> (any input, see Note 1)	0.3 V to V <sub>DD</sub>
Input current, I <sub>I</sub> (each input)	±5 mA
Output current, I <sub>O</sub>	±50 mA
Total current into V <sub>DD+</sub>	±50 mA
Total current out of V <sub>DD</sub>	±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 <sub>A</sub> : TLV2231C	0°C to 70°C
TLV2231I	40°C to 85°C
Storage temperature range, T <sub>stq</sub>	65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: DBV package	

<sup>†</sup> 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<sub>DD</sub> \_.
  - 2. Differential voltages are at the noninverting input with respect to the inverting input. Excessive current flows when input is brought below V<sub>DD</sub> = 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	$T_{\mbox{A}} \le 25^{\circ}\mbox{C}$ POWER RATING	DERATING FACTOR ABOVE T <sub>A</sub> = 25°C	T <sub>A</sub> = 70°C POWER RATING	T <sub>A</sub> = 85°C POWER RATING
DBV	150 mW	1.2 mW/°C	96 mW	78 mW

#### recommended operating conditions

	TLV2231C MIN MAX		TL	UNIT	
			MIN	MAX	UNII
Supply voltage, V <sub>DD</sub> (see Note 1)	2.7	10	2.7	10	V
Input voltage range, V <sub>I</sub>	$V_{DD-}$	V <sub>DD+</sub> -1.3	V <sub>DD</sub> -	V <sub>DD+</sub> -1.3	V
Common-mode input voltage, V <sub>IC</sub>	$V_{DD-}$	V <sub>DD+</sub> -1.3	V <sub>DD</sub> _	V <sub>DD+</sub> -1.3	V
Operating free-air temperature, T <sub>A</sub>	0	70	-40	85	°C

NOTE 1: All voltage values, except differential voltages, are with respect to V<sub>DD</sub> \_.



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

	PARAMETER	TEST CON	IDITIONS	t	Т	LV22310	;	Т	LV22311	l		
	PARAMETER	TEST CON	ADITIONS	T <sub>A</sub> †	MIN	TYP	MAX	MIN	TYP	MAX	UNIT	
VIO	Input offset voltage					0.75	3		0.75	3	mV	
αΛΙΟ	Temperature coefficient of input offset voltage			Full range		0.5			0.5		μV/°C	
	Input offset voltage long-term drift (see Note 4)	$V_{DD\pm} = \pm 1.5 \text{ V},$ $V_{O} = 0,$	$V_{IC} = 0$ , R <sub>S</sub> = 50 $\Omega$	25°C		0.003			0.003		μV/mo	
IIO	Input offset current			25°C		0.5	60		0.5	60	pА	
	•			Full range		-	150	-	-	150		
Iв	Input bias current			25°C		1	60		1	60	pА	
				Full range			150			150	•	
V:	Common-mode input	. IRC = 50 0 IVI	11/1-1-/	25°C	0 to 2	-0.3 to 2.2		0 to 2	-0.3 to 2.2		V	
VICR	voltage range	$RS = 50 \Omega$	V <sub>IO</sub>   ≤5 mV	Full range	0 to 1.7			0 to 1.7			V	
		$I_{OH} = -1 \text{ mA}$		25°C		2.87			2.87			
Vон	High-level output	Jan. 2 mA		25°C		2.74			2.74		V	
	voltage	$I_{OH} = -2 \text{ mA}$		Full range	2			2				
	Law L	$V_{IC} = 1.5 V$ ,	$I_{OL} = 50 \mu A$	25°C		10			10			
$V_{OL}$	Low-level output voltage	$V_{10} = 1.5 \text{ V}$ $V_{10} = 500 \text{ µA}$	25°C		100			100		mV		
		V <sub>1</sub> C = 1.0 V,	-10L = 000 μ/τ	Full range			300			300		
	Large-signal	V <sub>IC</sub> = 1.5 V,	$R_{1} = 600 \Omega^{\ddagger}$	25°C	1	1.6		1	1.6			
AVD	differential voltage	$V_0 = 1.3 \text{ V},$ $V_0 = 1 \text{ V to 2 V}$		Full range	0.3			0.3			V/mV	
	amplification	Ŭ.	$R_L = 1 M\Omega^{\ddagger}$	25°C		250			250			
<sup>r</sup> id	Differential input resistance			25°C		1012			1012		Ω	
r <sub>ic</sub>	Common-mode input resistance			25°C		1012			1012		Ω	
c <sub>ic</sub>	Common-mode input capacitance	f = 10 kHz		25°C		6			6		pF	
z <sub>O</sub>	Closed-loop output impedance	f = 1 MHz,	A <sub>V</sub> = 1	25°C		156			156		Ω	
CMRR	Common-mode	V <sub>IC</sub> = 0 to 1.7 V,		25°C	60	70		60	70		40	
CIVIKK	rejection ratio	$V_0 = 1.5 \text{ V},$	$R_S = 50 \Omega$	Full range	55			55			dB	
ksvr	Supply voltage rejection ratio	V <sub>DD</sub> = 2.7 V to 8		25°C	70	96		70	96		dB	
-541	(ΔV <sub>DD</sub> /ΔV <sub>IO</sub> )	$V_{IC} = V_{DD}/2$ ,	- \/ /0 No lood	Full range	70			70				
Inc	Supply current	V <sub>O</sub> = 1.5 V,	25°0	25°C		750	1200		750	1200	^	
IDD	очрріу сипепі	VO = 1.5 V,	No load	Full range			1500			1500	μΑ	

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



<sup>‡</sup>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.

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

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

	NADAMETED.	TEST CONDITIONS		- +	Т	LV22310	;	Т	Γ <b>LV223</b> 11		UNIT									
'	PARAMETER	I IEST COND	IIIONS	T <sub>A</sub> †	MIN	TYP	MAX	MIN	TYP	MAX	UNII									
	Slew rate at unity		_	25°C	0.75	1.25		0.75	1.25											
SR	gain	$V_O = 1.1 \text{ V to } 1.9 \text{ V},$ $C_L = 100 \text{ pF}^{\ddagger}$	$R_L = 600 \Omega^{\ddagger}$ ,	Full range	0.5			0.5			V/μs									
v <sub>n</sub>	Equivalent input	f = 10 Hz		25°C		105			105		nV/√ <del>Hz</del>									
٧n	noise voltage	f = 1 kHz		25°C		16			16		IIV/VHZ									
\/\.\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\	Peak-to-peak equivalent input	f = 0.1 Hz to 1 Hz		25°C		1.4			1.4		μV									
V <sub>N(PP)</sub>	noise voltage	f = 0.1 Hz to 10 Hz		25°C	1.5			1.5		μν										
In	Equivalent input noise current			25°C	0.6		0.6		0.6		0.6		0.6		0.6		0.6			fA/√ <del>Hz</del>
		$V_O = 1 \text{ V to 2 V},$ f = 20 kHz,	A <sub>V</sub> = 1	25°C		0.285%			0.285%											
	Total harmonic	$R_{L} = 600 \Omega^{\ddagger}$	A <sub>V</sub> = 10	25 C		7.2%			7.2%											
THD+N	distortion plus noise	V <sub>O</sub> = 1 V to 2 V,	A <sub>V</sub> = 1			0.014%			0.014%											
	Tioise	f = 20 kHz,	A <sub>V</sub> = 10	25°C		0.098%		0.098%												
		R <sub>L</sub> = 600 Ω§	A <sub>V</sub> = 100			0.13%			0.13%											
	Gain-bandwidth product	f = 10  kHz, $C_L = 100 \text{ pF}^{\ddagger}$	$R_L = 600 \Omega^{\ddagger}$ ,	25°C		1.9			1.9		MHz									
ВОМ	Maximum output- swing bandwidth	$V_{O(PP)} = 1 \text{ V},$ $R_{L} = 600 \Omega^{\ddagger},$	$A_V = 1,$ $C_L = 100 \text{ pF}^{\ddagger}$	25°C		60			60		kHz									
<b>+</b> _	Settling time	$A_V = -1$ , Step = 1 V to 2 V,	To 0.1%	25°C		0.9			0.9		μs									
t <sub>S</sub>	octaing ame	$R_L = 600 \Omega^{\ddagger},$ $C_L = 100 pF^{\ddagger}$	To 0.01%	25 0		1.5			1.5		μδ									
φm	Phase margin at unity gain	$R_{L} = 600 \Omega^{\ddagger}$ ,	C <sub>L</sub> = 100 pF‡	25°C		50°			50°											
	Gain margin		·	25°C		8			8		dB									

<sup>†</sup> Full range is -40°C to 85°C.



<sup>‡</sup>Referenced to 1.5 V

<sup>§</sup> Referenced to 0 V

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

		î		1	, , , ,			1				
	PARAMETER	TEST CON	IDITIONS	T <sub>A</sub> †	Т	LV22310	3	Т	LV2231		UNIT	
		1=01 001		·A·	MIN	TYP	MAX	MIN	TYP	MAX	ON	
۷ <sub>IO</sub>	Input offset voltage	]				0.71	3		0.71	3	mV	
αVIO	Temperature coefficient of input offset voltage			Full range		0.5			0.5		μV/°C	
	Input offset voltage long-term drift (see Note 4)	$V_{DD\pm} = \pm 2.5 \text{ V},$ $V_{O} = 0,$	$V_{IC} = 0$ , RS = 50 $\Omega$	25°C		0.003			0.003		μV/mo	
	Input offset current			25°C		0.5	60		0.5	60	рA	
lio	input onset current			Full range			150			150	PΛ	
I <sub>IB</sub>	Input bias current			25°C		1	60		1	60	pА	
'ID	input blub burrent			Full range			150			150	ρ'n	
VICR	Common-mode input	$R_S = 50 \Omega$ ,	V O  ≤5 mV	25°C	0 to 4	-0.3 to 4.2		0 to 4	-0.3 to 4.2		V	
VICK	voltage range	115 = 30 22,	V  O   23 IIIV	Full range	0 to 3.7			0 to 3.7			V	
	I <sub>OH</sub> = -			25°C		4.9			4.9			
Vон	VOH High-level output voltage	I <sub>OH</sub> = -4 mA		25°C		4.6			4.6		V	
				Full range	4			4				
		$V_{IC} = 2.5 V$ ,	$I_{OL} = 500 \mu\text{A}$	25°C		80			80			
$V_{OL}$	Low-level output voltage	V <sub>IC</sub> = 2.5 V,	I <sub>OL</sub> = 1 mA	25°C		160			160		mV	
		V <sub>1</sub> C = 2.5 v,	IOL = TIIIA	Full range			500			500		
	Large-signal	\/ 2.5.\/	$R_{L} = 600 \Omega^{\ddagger}$	25°C	1	1.5		1	1.5		V/mV	
AVD	differential voltage	$V_{IC} = 2.5 \text{ V},$ $V_{O} = 1 \text{ V to 4 V}$	N_ = 000 32+	Full range	0.3			0.3				
	amplification	Ŭ	$R_L = 1 M\Omega^{\ddagger}$	25°C		400			400			
<sup>r</sup> id	Differential input resistance			25°C		1012			1012		Ω	
r <sub>ic</sub>	Common-mode input resistance			25°C		10 <sup>12</sup>			1012		Ω	
c <sub>ic</sub>	Common-mode input capacitance	f = 10 kHz		25°C		6			6		pF	
z <sub>o</sub>	Closed-loop output impedance	f = 1 MHz,	A <sub>V</sub> = 1	25°C		138			138		Ω	
CMDD	Common-mode	$V_{IC} = 0 \text{ to } 2.7 \text{ V},$		25°C	60	70		60	70		ďD	
CMRR	rejection ratio	$V_0 = 2.5 \text{ V},$	$R_S = 50 \Omega$	Full range	55			55			dB	
	Supply voltage	$V_{DD} = 4.4 \text{ V to } 8$	 3 V.	25°C	70	96		70	96			
ksvr	rejection ratio (ΔV <sub>DD</sub> /ΔV <sub>IO</sub> )	$V_{IC} = V_{DD}/2$	No load	Full range	70			70			dB	
I <sub>DD</sub>	Supply current	V <sub>O</sub> = 2.5 V,	No load	25°C		850	1300		850	1300	μΑ	
טט	- · FF:)0	] === -,		Full range			1600			1600	F '	

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



<sup>‡</sup>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  $T_A = 150^{\circ}C$  extrapolated to  $T_A = 25^{\circ}C$  using the Arrhenius equation and assuming an activation energy of 0.96 eV.

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

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

	DADAMETED	TEST COMPITIONS		_ +	Т	LV2231	3	7	ΓLV2231		UNIT	
,	PARAMETER	TEST CONDITIONS		T <sub>A</sub> †	MIN	TYP	MAX	MIN	TYP	MAX	וואט	
	Slew rate at unity	V <sub>O</sub> = 1.5 V to 3.5 V,	D. COO OT	25°C	1	1.6		1	1.6			
SR	gain	$C_L = 100 \text{ pF}^{\ddagger}$	$R_L = 600 \Omega^{\ddagger}$	Full range	0.7			0.7			V/μs	
٧n	Equivalent input	f = 10 Hz		25°C		100			100		nV/√Hz	
۷n	noise voltage	f = 1 kHz		25°C		15			15		IIV/√⊓Z	
V	Peak-to-peak	f = 0.1 Hz to 1 Hz		25°C 1.4			1.4		μV			
VN(PP)	equivalent input noise voltage	f = 0.1 Hz to 10 Hz		25°C	1.5				1.5		μν	
In	Equivalent input noise current			25°C		0.6			0.6		fA/√ <del>Hz</del>	
		$V_0 = 1.5 \text{ V to } 3.5 \text{ V},$	A <sub>V</sub> = 1	25°C		0.409%			0.409%			
	Total harmonic distortion plus noise	f = 20  kHz, $R_L = 600 \Omega^{\ddagger}$	A <sub>V</sub> = 10	25°C		3.68%			3.68%			
THD+N		V <sub>O</sub> = 1.5 V to 3.5 V,	A <sub>V</sub> = 1	25°C		0.018%			0.018%		1	
		f = 20 kHz,	A <sub>V</sub> = 10			0.045%			0.045%			
		R <sub>L</sub> = 600 Ω§	A <sub>V</sub> = 100		0.116%			0.116%				
	Gain-bandwidth product	f = 10 kHz, C <sub>L</sub> = 100 pF <sup>‡</sup>	$R_L = 600 \Omega^{\ddagger}$ ,	25°C		2			2		MHz	
ВОМ	Maximum output-swing bandwidth	$V_{O(PP)} = 1 \text{ V},$ $R_{L} = 600 \Omega^{\ddagger},$	A <sub>V</sub> = 1, C <sub>L</sub> = 100 pF‡	25°C		300			300		kHz	
	Settling time	$A_V = -1$ , Step = 1.5 V to 3.5 V,	To 0.1%	25°C		0.95			0.95			
t <sub>S</sub>	Setting time	$R_L = 600 \Omega^{\ddagger},$ $C_L = 100 pF^{\ddagger}$	To 0.01%	250		2.4			2.4		μs	
φm	Phase margin at unity gain	$R_{I} = 600 \Omega^{\ddagger}$	C <sub>I</sub> = 100 pF‡	25°C		48°			48°			
	Gain margin	1 -		25°C		8			8		dB	

<sup>†</sup> Full range is -40°C to 85°C.



<sup>‡</sup>Referenced to 2.5 V

<sup>§</sup> Referenced to 0 V

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

DADAMETED		TECT	TEST CONDITIONS			TLV2231Y			
	PARAMETER	l ESI	CONDITIONS		MIN	TYP	MAX	UNIT	
VIO	Input offset voltage					750		μV	
I <sub>IO</sub>	Input offset current	$V_{DD} \pm = \pm 1.5 \text{ V},$ $R_{S} = 50 \Omega$	$V_{IC} = 0$ ,	$V_O = 0$ ,		0.5		pA	
I <sub>IB</sub>	Input bias current	113 - 30 22				1		pA	
V <sub>ICR</sub>	Common-mode input voltage range	V <sub>1O</sub>   ≤5 mV,	R <sub>S</sub> = 50 Ω			-0.3 to 2.2		V	
Vон	High-level output voltage	I <sub>OH</sub> = -1 mA				2.87		V	
V	Law layed autout valtage	V <sub>IC</sub> = 1.5 V,	I <sub>OL</sub> = 50 μA			10		\ <i>(</i>	
VOL	Low-level output voltage	V <sub>IC</sub> = 1.5 V,	I <sub>OL</sub> = 500 μA			100		mV	
_	Large-signal differential voltage	V 4.V/- 0.V/	$R_L = 600 \Omega^{\dagger}$			1.6		) //> /	
AVD	amplification	$V_O = 1 \text{ V to 2 V}$	$R_L = 1 M\Omega^{\dagger}$		25			V/mV	
r <sub>id</sub>	Differential input resistance		•			1012		Ω	
r <sub>ic</sub>	Common-mode input resistance					1012		Ω	
c <sub>ic</sub>	Common-mode input capacitance	f = 10 kHz				6		pF	
z <sub>O</sub>	Closed-loop output impedance	f = 1 MHz,	A <sub>V</sub> = 1			156		Ω	
CMRR	Common-mode rejection ratio	$V_{IC} = 0 \text{ to } 1.7 \text{ V},$	V <sub>O</sub> = 0,	R <sub>S</sub> = 50 Ω	60	70		dB	
ksvr	Supply voltage rejection ratio (ΔV <sub>DD</sub> /ΔV <sub>IO</sub> )	V <sub>DD</sub> = 2.7 V to 8 V,	V <sub>IC</sub> = 0,	No load		96		dB	
lDD	Supply current	$V_{O} = 0$ ,	No load			750		μΑ	

<sup>†</sup> Referenced to 1.5 V

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

	PARAMETER	TEST	CONDITIONS		TI			
	PARAMETER	1531	CONDITIONS		MIN	TYP	MAX	UNIT
VIO	Input offset voltage					710		μV
IIO	Input offset current	$V_{DD} \pm = \pm 1.5 \text{ V},$ $R_S = 50 \Omega$	$V_{IC} = 0$ ,	$V_{O} = 0$ ,		0.5		pА
I <sub>IB</sub>	Input bias current	113 - 30 22				1		pА
VICR	Common-mode input voltage range	V <sub>IO</sub>   ≤5 mV,	R <sub>S</sub> = 50 Ω			-0.3 to 4.2		V
Vон	High-level output voltage	I <sub>OH</sub> = -1 mA				4.9		V
\/-·	l and land autorit raltage	V <sub>IC</sub> = 2.5 V,	I <sub>OL</sub> = 500 μA			80		\/
VOL	Low-level output voltage	V <sub>IC</sub> = 2.5 V,	I <sub>OL</sub> = 1 mA			160		mV
	Large-signal differential voltage	V 4.V/1- 0.V/	$R_L = 600 \Omega^{\dagger}$			15		\//\/
AVD	amplification	$V_O = 1 \text{ V to 2 V}$	$R_L = 1 M\Omega^{\dagger}$			400		V/mV
r <sub>id</sub>	Differential input resistance		•			1012		Ω
r <sub>ic</sub>	Common-mode input resistance					10 <sup>12</sup>		Ω
c <sub>ic</sub>	Common-mode input capacitance	f = 10 kHz				6		pF
z <sub>O</sub>	Closed-loop output impedance	f = 1 MHz,	A <sub>V</sub> = 1			138		Ω
CMRR	Common-mode rejection ratio	$V_{IC} = 0 \text{ to } 1.7 \text{ V},$	V <sub>O</sub> = 0,	$R_S = 50 \Omega$	60	70		dB
k <sub>SVR</sub>	Supply voltage rejection ratio $(\Delta V_{DD}/\Delta V_{IO})$	$V_{DD} = 2.7 \text{ V to 8 V},$	V <sub>IC</sub> = 0,	No load		96		dB
I <sub>DD</sub>	Supply current	V <sub>O</sub> = 0,	No load	·	·	850		μΑ

<sup>†</sup>Referenced to 2.5 V



### **Table of Graphs**

			FIGURE
VIO	Input offset voltage	Distribution vs Common-mode input voltage	2, 3 4, 5
αVIO	Input offset voltage temperature coefficient	Distribution	6, 7
I <sub>IB</sub> /I <sub>IO</sub>	Input bias and input offset currents	vs Free-air temperature	8
VI	Input voltage	vs Supply voltage vs Free-air temperature	9 10
Vон	High-level output voltage	vs High-level output current	11, 14
VOL	Low-level output voltage	vs Low-level output current	12, 13, 15
VO(PP)	Maximum peak-to-peak output voltage	vs Frequency	16
los	Short-circuit output current	vs Supply voltage vs Free-air temperature	17 18
Vo	Output voltage	vs Differential input voltage	19, 20
A <sub>VD</sub>	Differential voltage amplification	vs Load resistance	21
AVD	Large-signal differential voltage amplification	vs Frequency vs Free-air temperature	22, 23 24, 25
z <sub>O</sub>	Output impedance	vs Frequency	26, 27
CMRR	Common-mode rejection ratio	vs Frequency vs Free-air temperature	28 29
ksvr	Supply-voltage rejection ratio	vs Frequency vs Free-air temperature	30, 31 32
I <sub>DD</sub>	Supply current	vs Supply voltage	33
SR	Slew rate	vs Load capacitance vs Free-air temperature	34 35
Vo	Inverting large-signal pulse response	vs Time	36, 37
Vo	Voltage-follower large-signal pulse response	vs Time	38, 39
VO	Inverting small-signal pulse response	vs Time	40, 41
VO	Voltage-follower small-signal pulse response	vs Time	42, 43
V <sub>n</sub>	Equivalent input noise voltage	vs Frequency	44, 45
	Noise voltage (referred to input)	Over a 10-second period	46
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
φm	Phase margin	vs Frequency vs Load capacitance	22, 23 52, 53
B <sub>1</sub>	Unity-gain bandwidth	vs Load capacitance	54, 55



#### TYPICAL CHARACTERISTICS

Precentage of Amplifiers – %

# DISTRIBUTION OF TLV2231 INPUT OFFSET VOLTAGE

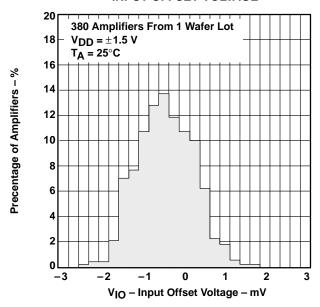


Figure 2

# DISTRIBUTION OF TLV2231 INPUT OFFSET VOLTAGE

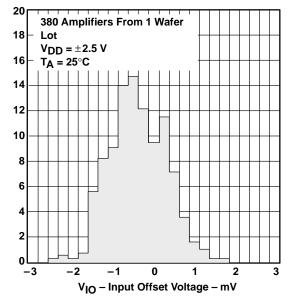
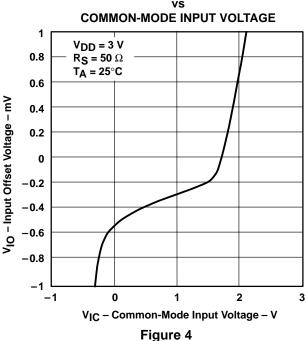
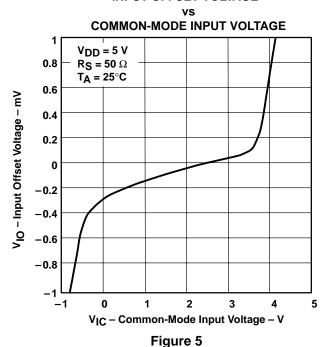


Figure 3

# INPUT OFFSET VOLTAGE† vs



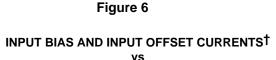
### INPUT OFFSET VOLTAGET

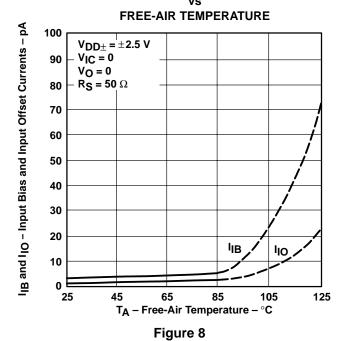


† For all curves where  $V_{DD} = 5 \text{ V}$ , all loads are referenced to 2.5 V. For all curves where  $V_{DD} = 3 \text{ V}$ , all loads are referenced to 1.5 V.



### **DISTRIBUTION OF TLV2231 INPUT OFFSET VOLTAGE TEMPERATURE COEFFICIENT**<sup>†</sup> 30 32 Amplifiers From 1 Wafer Lots $V_{DD\pm} = \pm 1.5 \text{ V}$ 25 P Package Percentage of Amplifiers – % $T_A = 25^{\circ}C$ to $125^{\circ}C$ 20 15 10 5 -4 -3 2 3 αVIO - Input Offset Voltage Temperature Coefficient − μV/°C





# DISTRIBUTION OF TLV2231 INPUT OFFSET VOLTAGE TEMPERATURE COEFFICIENT<sup>†</sup>

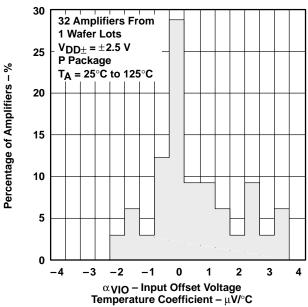
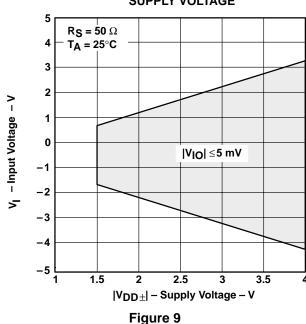


Figure 7

#### INPUT VOLTAGE vs SUPPLY VOLTAGE



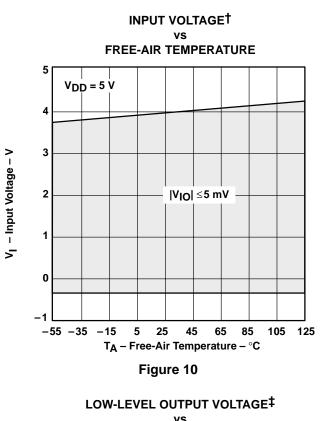
<sup>†</sup> Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

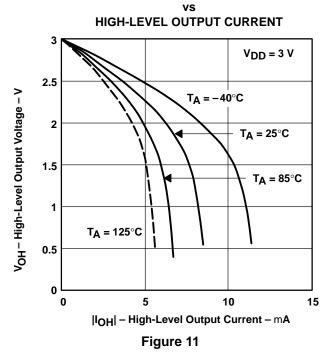


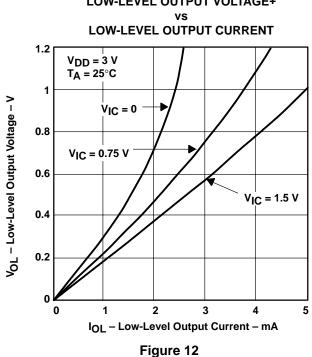
HIGH-LEVEL OUTPUT VOLTAGE†‡

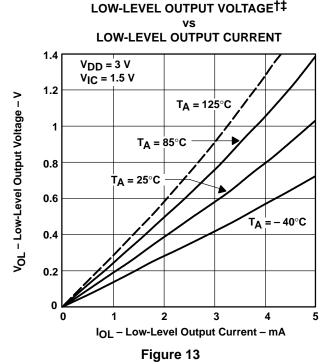
SLOS158D - JUNE 1996 - REVISED APRIL 2001

#### TYPICAL CHARACTERISTICS





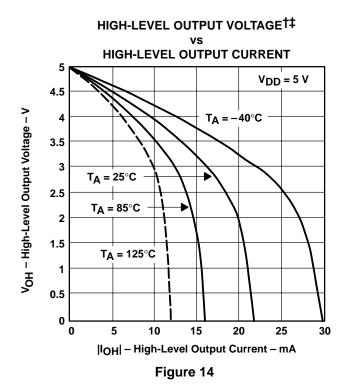


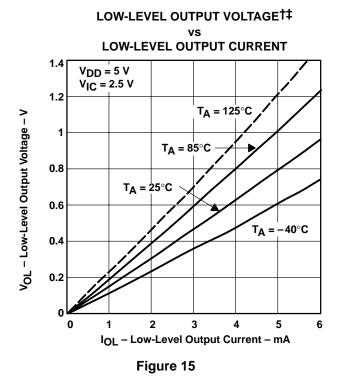


<sup>†</sup> Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

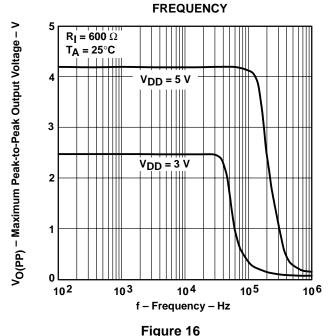
<sup>‡</sup> For all curves where  $V_{DD} = 5 \text{ V}$ , all loads are referenced to 2.5 V. For all curves where  $V_{DD} = 3 \text{ V}$ , all loads are referenced to 1.5 V.







# MAXIMUM PEAK-TO-PEAK OUTPUT VOLTAGE<sup>‡</sup> vs



# SHORT-CIRCUIT OUTPUT CURRENT vs SUPPLY VOLTAGE

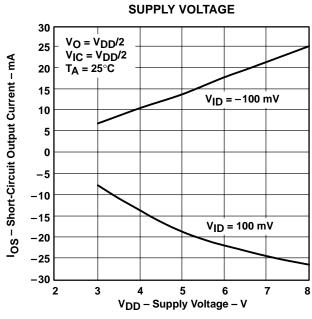


Figure 17

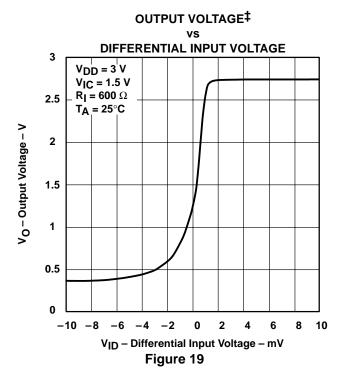
†Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

<sup>‡</sup> For all curves where V<sub>DD</sub> = 5 V, all loads are referenced to 2.5 V. For all curves where V<sub>DD</sub> = 3 V, all loads are referenced to 1.5 V.



#### TYPICAL CHARACTERISTICS

#### SHORT-CIRCUIT OUTPUT CURRENT †‡ FREE-AIR TEMPERATURE 30 $V_{DD} = 5 V$ 25 $V_{IC} = 2.5 V$ IOS - Short-Circuit Output Current - mA V<sub>O</sub> = 2.5 V 20 15 $V_{ID} = -100 \text{ mV}$ 10 5 0 -5 -10 $V_{ID} = 100 \text{ mV}$ -15 -20 -25 -30-75 -5025 50 75 100 125 -250 TA - Free-Air Temperature - °C Figure 18



# 

-4 -2

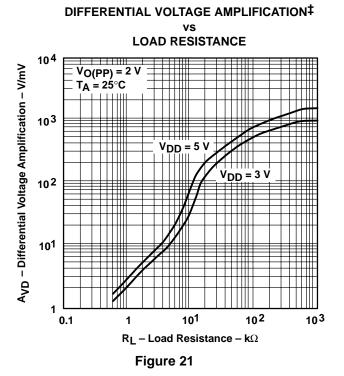
0 2

V<sub>ID</sub> - Differential Input Voltage - mV

Figure 20

-10 -8 -6

**OUTPUT VOLTAGE**‡



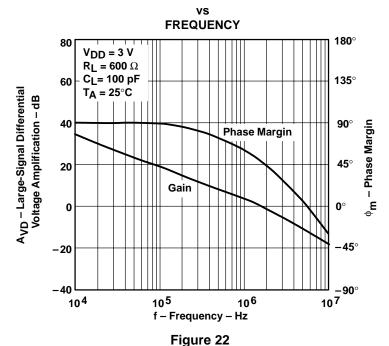
<sup>†</sup> Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

8 10

<sup>‡</sup> 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.

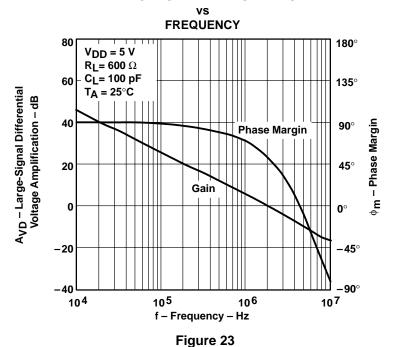


# LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION AND PHASE MARGINT



### . .94..0 ==

# LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION AND PHASE MARGIN<sup>†</sup>





† 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**†‡ FREE-AIR TEMPERATURE 103 $R_L = 1 M\Omega$ A<sub>VD</sub> - Large-Signal Differential Voltage 102 Amplification - V/mV 10<sup>1</sup> $R_L = 600 \Omega$ $V_{DD} = 3 V$ V<sub>IC</sub> = 1.5 V V<sub>O</sub> = 0.5 V to 2.5 V 0.1 -50 -25 25 50 75 100 125 $T_A$ – Free-Air Temperature – $^{\circ}$ C Figure 24

LARGE-SIGNAL DIFFERENTIAL
VOLTAGE AMPLIFICATION<sup>†‡</sup>
vs
FREE-AIR TEMPERATURE

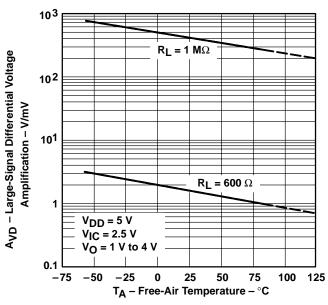
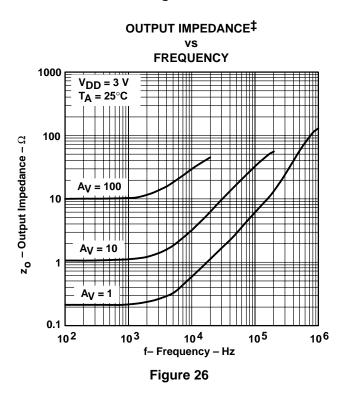
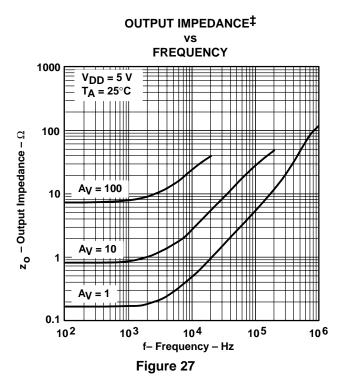


Figure 25



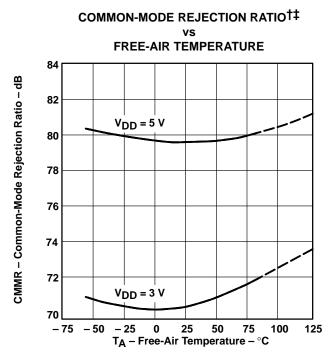


<sup>†</sup> Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

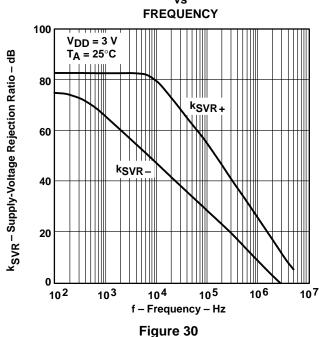
<sup>‡</sup> For all curves where V<sub>DD</sub> = 5 V, all loads are referenced to 2.5 V. For all curves where V<sub>DD</sub> = 3 V, all loads are referenced to 1.5 V.



### COMMON-MODE REJECTION RATIO<sup>†</sup> vs **FREQUENCY** 100 $T_A = 25^{\circ}C$ CMRR - Common-Mode Rejection Ratio - dB $V_{DD} = 5 V$ $V_{IC} = 2.5 V$ 80 $V_{DD} = 3 V$ 60 $V_{IC} = 1.5 V$ 40 20 105 106 102 104 103 107 f - Frequency - Hz Figure 28

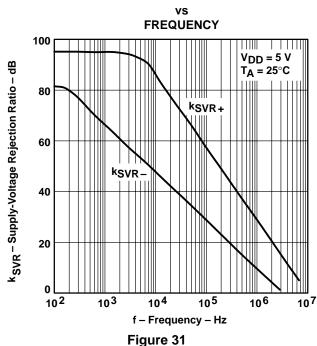


# SUPPLY-VOLTAGE REJECTION RATIOT vs



# SUPPLY-VOLTAGE REJECTION RATIO†

Figure 29



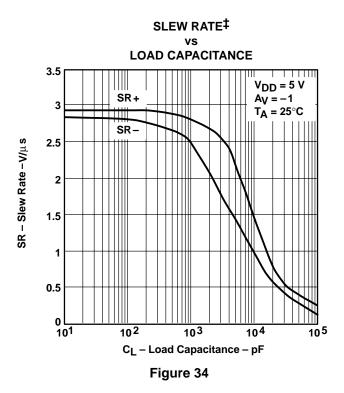
<sup>†</sup> For all curves where V<sub>DD</sub> = 5 V, all loads are referenced to 2.5 V. For all curves where V<sub>DD</sub> = 3 V, all loads are referenced to 1.5 V.

<sup>‡</sup> Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.



## SUPPLY-VOLTAGE REJECTION RATIO<sup>†</sup> FREE-AIR TEMPERATURE 100 V<sub>DD</sub> = 2.7 V to 8 V k<sub>SVR</sub> - Supply-Voltage Rejection Ratio - dB $V_{IC} = V_O = V_{DD}/2$ 98 96 94 92 100 \_75 -50 25 50 75 125 $T_A$ – Free-Air Temperature – $^{\circ}C$

Figure 32



SUPPLY CURRENT<sup>†</sup>
vs
SUPPLY VOLTAGE

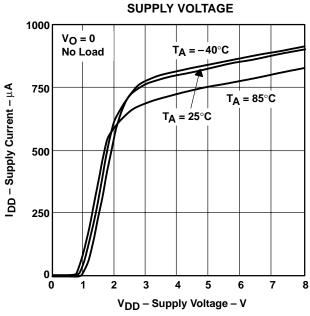


Figure 33

#### SLEW RATE<sup>†‡</sup> vs FREE-AIR TEMPERATURE

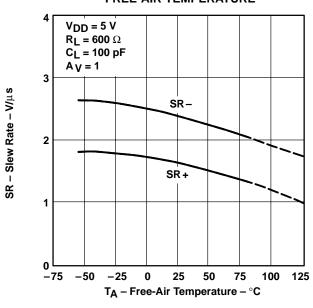


Figure 35

<sup>‡</sup> 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.



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

#### **TYPICAL CHARACTERISTICS**

# INVERTING LARGE-SIGNAL PULSE RESPONSE<sup>†</sup>

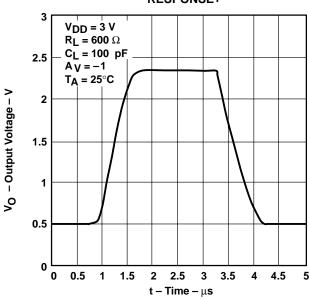


Figure 36

# INVERTING LARGE-SIGNAL PULSE RESPONSE†

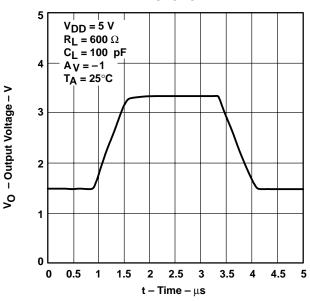


Figure 37

# VOLTAGE-FOLLOWER LARGE-SIGNAL PULSE RESPONSE<sup>†</sup>

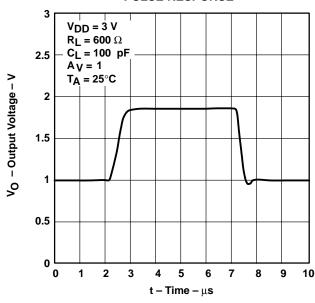


Figure 38

# VOLTAGE-FOLLOWER LARGE-SIGNAL PULSE RESPONSET

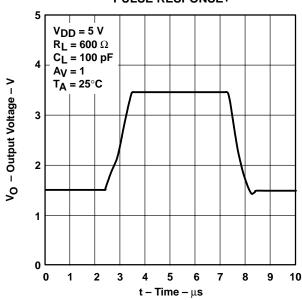


Figure 39

 $\dagger$  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.



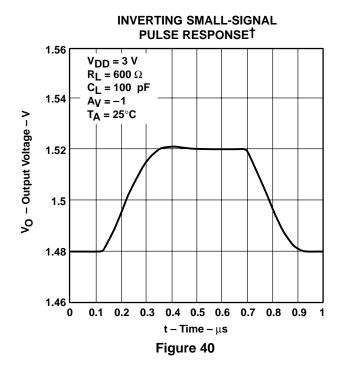
**INVERTING SMALL-SIGNAL** 

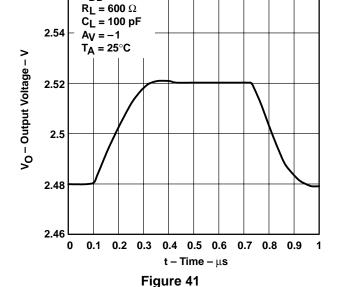
**PULSE RESPONSE**†

#### TYPICAL CHARACTERISTICS

2.56

 $V_{DD} = 5 V$ 







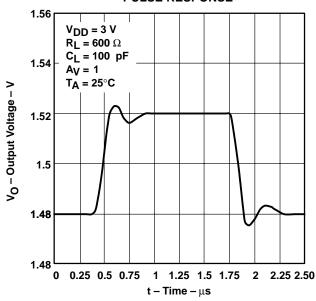


Figure 42

VOLTAGE-FOLLOWER SMALL-SIGNAL PULSE RESPONSE<sup>†</sup>

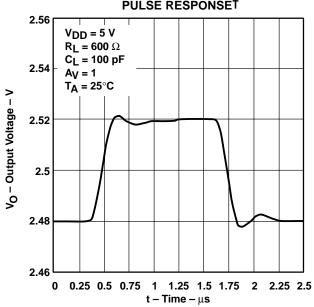


Figure 43

 $\dagger$  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.



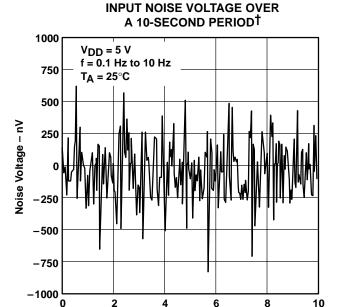
#### TYPICAL CHARACTERISTICS

# **EQUIVALENT INPUT NOISE VOLTAGE**<sup>†</sup> **FREQUENCY** 120 $V_{DD} = 3 V$ $V_{n}$ – Equivalent Input Noise Voltage – nV/ $\sqrt{\text{Hz}}$ $R_S = 20 \Omega$ T<sub>A</sub> = 25°C 100 80 60 40 20 101 10<sup>2</sup> 103 104

f - Frequency - Hz

Figure 44

# **EQUIVALENT INPUT NOISE VOLTAGE**<sup>†</sup> **FREQUENCY** 120 $V_{DD} = 5 V$ V<sub>n</sub> − Equivalent Input Noise Voltage − nV/VHz $R_S = 20 \Omega$ $T_A = 25^{\circ}C$ 100 80 60 40 20 0 101 102 103 104 f - Frequency - Hz



t - Time - s

Figure 46

### TOTAL HARMONIC DISTORTION PLUS NOISET

Figure 45

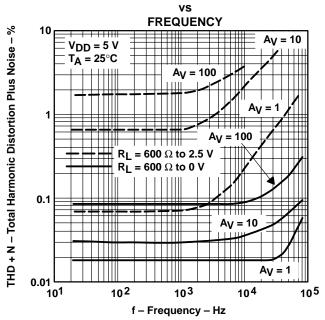


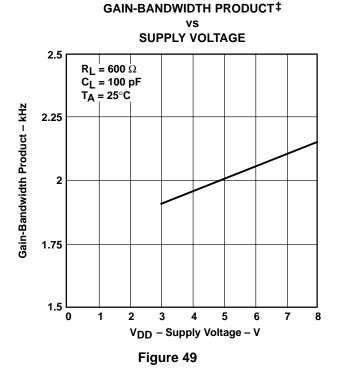
Figure 47

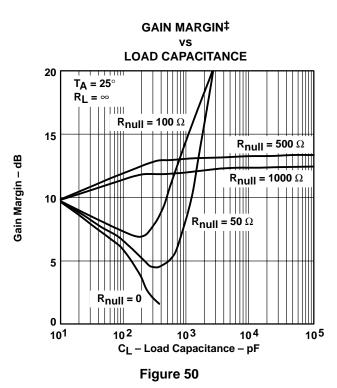
† For all curves where  $V_{DD} = 5 \text{ V}$ , all loads are referenced to 2.5 V. For all curves where  $V_{DD} = 3 \text{ V}$ , all loads are referenced to 1.5 V.

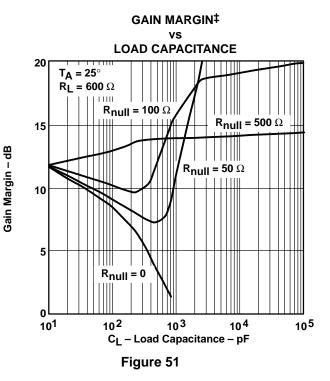


#### **TYPICAL CHARACTERISTICS**

### **GAIN-BANDWIDTH PRODUCT †**‡ FREE-AIR TEMPERATURE $V_{DD} = 5 V$ f = 10 kHz $R_L = 600 \Omega$ 3.5 Gain-Bandwidth Product - kHz $C_L = 100 pF$ 3 2.5 2 1.5 25 50 75 100 125 -75 -50 -250 T<sub>A</sub> - Free-Air Temperature - °C Figure 48



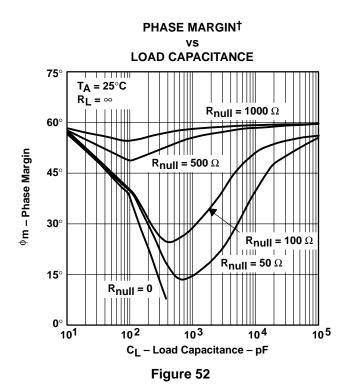


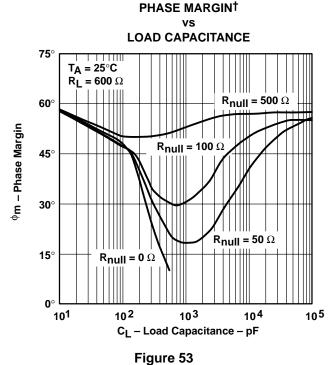


<sup>†</sup>Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

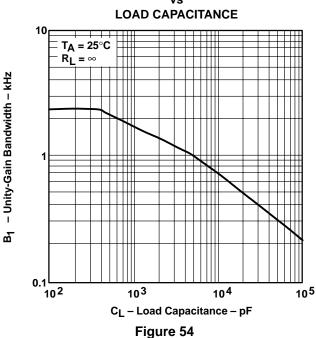
<sup>‡</sup> For all curves where  $V_{DD} = 5 \text{ V}$ , all loads are referenced to 2.5 V. For all curves where  $V_{DD} = 3 \text{ V}$ , all loads are referenced to 1.5 V.



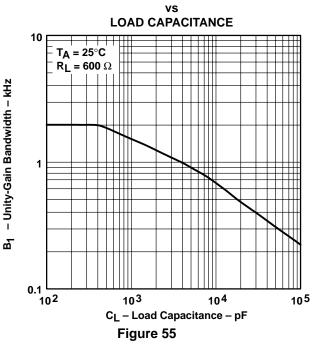








## UNITY-GAIN BANDWIDTH†



† 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<sub>null</sub> = 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.

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

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

UGBW = Unity - gain bandwidth frequency

R<sub>null</sub> = Output series resistance

 $C_1$  = 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.

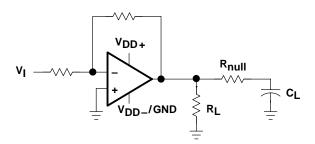


Figure 56. Series-Resistance Circuit

#### 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 TA = 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).

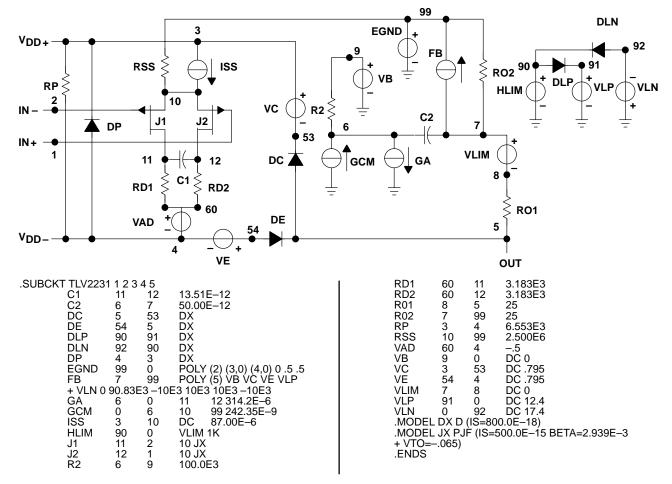


Figure 57. Boyle Macromodel and Subcircuit

PSpice and Parts are trademark of MicroSim Corporation.







com 4-Mar-2008

#### PACKAGING INFORMATION

Orderable Device	Status <sup>(1)</sup>	Package Type	Package Drawing	Pins	Package Qty	e Eco Plan <sup>(2)</sup>	Lead/Ball Finish	MSL Peak Temp <sup>(3)</sup>
TLV2231CDBVR	ACTIVE	SOT-23	DBV	5	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLV2231CDBVRG4	ACTIVE	SOT-23	DBV	5	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLV2231CDBVT	ACTIVE	SOT-23	DBV	5	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLV2231CDBVTG4	ACTIVE	SOT-23	DBV	5	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLV2231IDBVR	ACTIVE	SOT-23	DBV	5	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLV2231IDBVRG4	ACTIVE	SOT-23	DBV	5	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLV2231IDBVT	ACTIVE	SOT-23	DBV	5	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLV2231IDBVTG4	ACTIVE	SOT-23	DBV	5	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM

(1) The marketing status values are defined as follows:

ACTIVE: Product device recommended for new designs.

LIFEBUY: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.

**NRND:** Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.

PREVIEW: Device has been announced but is not in production. Samples may or may not be available.

**OBSOLETE:** TI has discontinued the production of the device.

(2) Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check http://www.ti.com/productcontent for the latest availability information and additional product content details.

TBD: The Pb-Free/Green conversion plan has not been defined.

**Pb-Free** (RoHS): TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.

**Pb-Free (RoHS Exempt):** This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.

Green (RoHS & no Sb/Br): TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

(3) MSL, Peak Temp. -- The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

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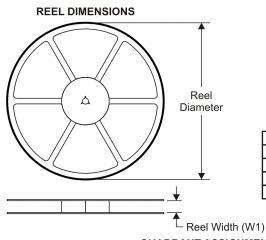
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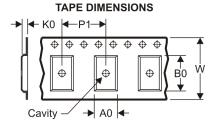




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#### TAPE AND REEL INFORMATION





	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		SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
TLV2231CDBVR	SOT-23	DBV	5	3000	180.0	9.0	3.15	3.2	1.4	4.0	8.0	Q3
TLV2231CDBVT	SOT-23	DBV	5	250	180.0	9.0	3.15	3.2	1.4	4.0	8.0	Q3
TLV2231IDBVR	SOT-23	DBV	5	3000	180.0	9.0	3.15	3.2	1.4	4.0	8.0	Q3
TLV2231IDBVT	SOT-23	DBV	5	250	180.0	9.0	3.15	3.2	1.4	4.0	8.0	Q3

# PACKAGE MATERIALS INFORMATION

11-Mar-2008



\*All dimensions are nominal

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Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
TLV2231CDBVR	SOT-23	DBV	5	3000	182.0	182.0	20.0
TLV2231CDBVT	SOT-23	DBV	5	250	182.0	182.0	20.0
TLV2231IDBVR	SOT-23	DBV	5	3000	182.0	182.0	20.0
TLV2231IDBVT	SOT-23	DBV	5	250	182.0	182.0	20.0

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