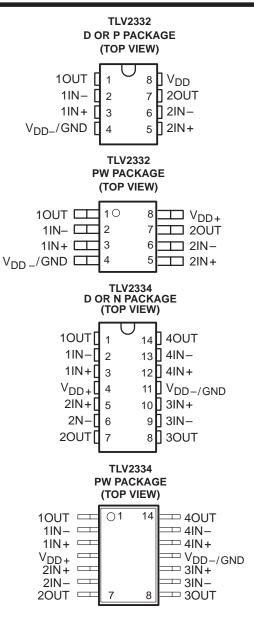
- Wide Range of Supply Voltages Over **Specified Temperature Range:**  $T_A = -40^{\circ}C \text{ to } 85^{\circ}C \dots 2 \text{ V to } 8 \text{ V}$ 
  - Fully Characterized at 3 V and 5 V
- Single-Supply Operation
- Common-Mode Input-Voltage Range Extends Below the Negative Rail and up to  $V_{DD} - 1 V \text{ at } T_A = 25^{\circ}C$
- **Output Voltage Range Includes Negative**
- High Input Impedance . . .  $10^{12} \Omega$  Typ
- **ESD-Protection Circuitry**
- **Designed-In Latch-Up Immunity**

### description

The TLV233x operational amplifiers are in a family of devices that has been specifically designed for use in low-voltage single-supply applications. Unlike the TLV2322 which is optimized for ultra-low power, the TLV233x is designed to provide a combination of low power and good ac performance. Each amplifier is fully functional down to a minimum supply voltage of 2 V, is fully characterized, tested, and specified at both 3-V and 5-V power supplies. The common-mode input-voltage range includes the negative rail and extends to within 1 V of the positive rail.

Having a maximum supply current of only 310 μA per amplifier over full temperature range, the TLV233x devices offer a combination of good ac performance and microampere supply currents. From a 3-V power supply, the amplifier's typical slew rate is 0.38 V/µs and its bandwidth is 300 kHz.



#### **AVAILABLE OPTIONS**

		Viemov		PACKAGED	DEVICES		CHIP FORMS
ТД		V <sub>IO</sub> max AT 25°C	SMALL OUTLINE <sup>†</sup> (D)	LINE <sup>†</sup> PLASTIC DIP PLASTIC DIP (N) (P)		TSSOP <sup>‡</sup> (PW)	(Y)
40°C 1	to 95°C	9 mV	TLV2332ID	_	TLV2332IP	TLV2332IPWLE	TLV2332Y
-40°C to 85°C		10 mV	TLV2334ID	TLV2334IN	_	TLV2334IPWLE	TLV2334Y

<sup>†</sup>The D package is available taped and reeled. Add R suffix to the device type (e.g., TLV2332IDR).

§ Chip forms are tested at 25°C only.



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.

LinCMOS is a trademark of Texas Instruments Incorporated.



<sup>&</sup>lt;sup>‡</sup> The PW package is only available left-end taped and reeled (e.g., TLV2332IPWLE).

# TLV2332, TLV2332Y, TLV2334, TLV2334Y LinCMOS™ LOW-VOLTAGE MEDIUM-POWER OPERATIONAL AMPLIFIERS

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### description (continued)

These amplifiers offer a level of ac performance greater than that of many other devices operating at comparable power levels. The TLV233x operational amplifiers are especially well suited for use in low-current or battery-powered applications.

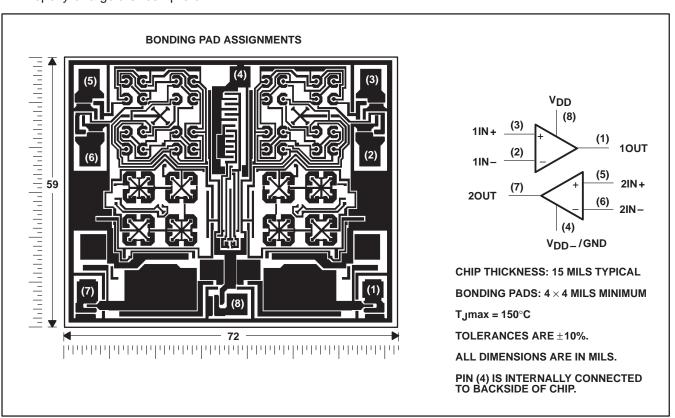
Low-voltage and low-power operation has been made possible by using the Texas Instruments silicon-gate LinCMOS™ technology. The LinCMOS process also features extremely high input impedance and ultra-low bias currents making these amplifiers ideal for interfacing to high-impedance sources such as sensor circuits or filter applications.

To facilitate the design of small portable equipment, the TLV233x is made available in a wide range of package options, including the small-outline and thin-shrink small-outline package (TSSOP). The TSSOP package has significantly reduced dimensions compared to a standard surface-mount package. Its maximum height of only 1.1 mm makes it particularly attractive when space is critical.

The device inputs and outputs are designed to withstand –100-mA currents without sustaining latch-up. The TLV233x incorporates internal ESD-protection circuits that prevents functional failures at voltages up to 2000 V as tested under MIL-STD 883C, Method 3015.2; however, care should be exercised in handling these devices as exposure to ESD may result in the degradation of the device parametric performance.

### TLV2332Y chip information

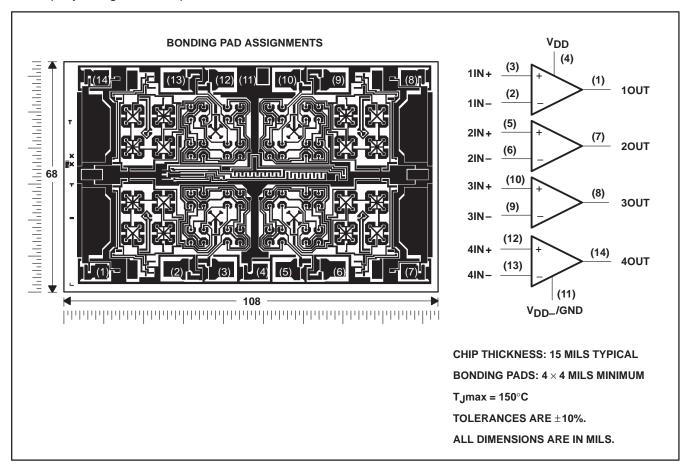
This chip, when properly assembled, display characteristics similar to the TLV2332. Thermal compression or ultrasonic bonding may be used on the doped-aluminum bonding pads. Chips may be mounted with conductive epoxy or a gold-silicon preform.



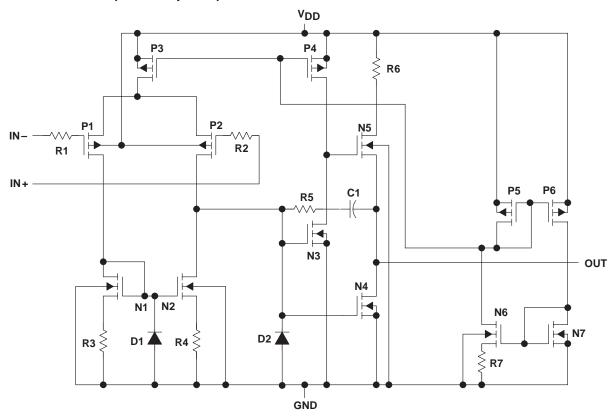


### **TLV2334Y chip information**

This chip, when properly assembled, displays characteristics similar to the TLV2334. Thermal compression or ultrasonic bonding may be used on the doped-aluminum bonding pads. Chips may be mounted with conductive epoxy or a gold-silicon preform.



### equivalent schematic (each amplifier)



ACTUAL DEVI	CE COMPONEN	T COUNT†		
COMPONENT	TLV2332	TLV2334		
Transistors	54	108		
Resistors	14	28		
Diodes	4	8		
Capacitors	2	4		

<sup>&</sup>lt;sup>†</sup> Includes both amplifiers and all ESD, bias, and trim circuitry.

### TLV2332, TLV2332Y, TLV2334, TLV2334Y LinCMOS™ LOW-VOLTAGE MEDIUM-POWER OPERATIONAL AMPLIFIERS

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

Supply voltage, V <sub>DD</sub> (see Note 1)	8 V
Differential input voltage, V <sub>ID</sub> (see Note 2)	
Input voltage range, V <sub>I</sub> (any input)	
Input current, I <sub>I</sub>	±5 mA
Output current, IO	±30 mA
Duration of short-circuit current at (or below) $T_A = 25^{\circ}C$ (see Note 3)	unlimited
Continuous total dissipation	See Dissipation Rating Table
Operating free-air temperature range, T <sub>A</sub>	–40°C to 85°C
Storage temperature range	65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds	260°C

<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 network ground.
  - 2. Differential voltages are at the noninverting input with respect to the inverting input.
  - 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 (see application section).

#### **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> = 85°C POWER RATING
D-8	725 mW	5.8 mW/°C	377 mW
D-14	950 mW	7.6 mW/°C	494 mW
N	1575 mW	12.6 mW/°C	819 mW
Р	1000 mW	8.0 mW/°C	520 mW
PW-8	525 mW	4.2 mW/°C	273 mW
PW-14	700 mW	5.6 mW/°C	364 mW

### recommended operating conditions

			MAX	UNIT
Supply voltage, V <sub>DD</sub>	ipply voltage, V <sub>DD</sub>		8	V
O	V <sub>DD</sub> = 3 V	-0.2	1.8	\/
Common-mode input voltage, V <sub>IC</sub>	V <sub>DD</sub> = 5 V	-0.2	3.8	V
Operating free-air temperature, TA			85	°C



# TLV2332, TLV2332Y, TLV2334, TLV2334Y LinCMOS™ LOW-VOLTAGE MEDIUM-POWER OPERATIONAL AMPLIFIERS

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### TLV2332I electrical characteristics at specified free-air temperature

		TEOT				TLV2	332I			
	PARAMETER	TEST CONDITIONS	T <sub>A</sub> †	VI	DD = 3 \	/	۷ <sub>I</sub>	DD = 5 \	/	UNIT
				MIN	TYP	MAX	MIN	TYP	MAX	
VIO	Input offset voltage	V <sub>O</sub> = 1 V, V <sub>IC</sub> = 1 V,	25°C		0.6	9		1.1	9	m∨
V10	input onset voltage	$R_S = 50 \Omega$ , $R_L = 100 \text{ k}\Omega$	Full range			11			11	111 V
ανιο	Average temperature coefficient of input offset voltage		25°C to 85°C		1			1.7		μV/°C
IIO	Input offset current (see Note 4)	V <sub>O</sub> = 1 V,	25°C		0.1			0.1		pA
10	input onset current (see Note 4)	V <sub>IC</sub> = 1 V V <sub>O</sub> = 1 V, V <sub>IC</sub> = 1 V	85°C		22	1000		24	1000	PA
I <sub>IB</sub>	Input bias current (see Note 4)	$V_0 = 1 V$	25°C		0.6			0.6		pА
	,	V <sub>IC</sub> = 1 V	85°C		175	2000		200	2000	
Common-mode input			25°C	-0.2 to 2	-0.3 to 2.3		-0.2 to 4	-0.3 to 4.2		V
VICR	VICR voltage range (see Note 5)		Full range	-0.2 to 1.8			-0.2 to 3.8			V
.,		V <sub>IC</sub> = 1 V,	25°C	1.75	1.9		3.2	3.9		.,
VOH	High-level output voltage	$V_{ID} = 100 \text{ mV},$ $I_{OH} = -1 \text{ mA}$	Full range	1.7			3			V
VOL	Low-level output voltage	$V_{IC} = 1 \text{ V},$ $V_{ID} = -100 \text{ mV},$	25°C		115	150		95	150	mV
VOL	Low-level output voltage	$I_{OL} = 1 \text{ mA}$	Full range			190			190	111 V
Δ	Large-signal differential	V <sub>IC</sub> = 1 V,	25°C	25	83		25	170		V/mV
AVD	voltage amplification	$R_L$ = 100 kΩ, See Note 6	Full range	15			15			V/IIIV
CMDD	Common mode rejection ratio	V <sub>O</sub> = 1 V,	25°C	65	92		65	91		dB
CMRR	Common-mode rejection ratio	$V_{IC} = V_{ICR}min$ , $R_S = 50 \Omega$	Full range	60			60			uБ
le = =	Supply-voltage rejection ratio	V <sub>IC</sub> = 1 V,	25°C	70	94		70	94		٩D
ksvr	(ΔV <sub>DD</sub> /ΔV <sub>IO</sub> )	$V_O = 1 V$ , $R_S = 50 \Omega$	Full range	65			65			dB
	Supply ourrent	V <sub>O</sub> = 1 V,	25°C		160	500		210	560	
IDD	Supply current	V <sub>IC</sub> = 1 V, No load	Full range			620			800	μΑ

<sup>&</sup>lt;sup>†</sup> Full range is  $-40^{\circ}$ C to  $85^{\circ}$ C.

NOTES: 4. The typical values of input bias current and input offset current below 5 pA are determined mathematically.

- 5. This range also applies to each input individually.
  6. At V<sub>DD</sub> = 5 V, V<sub>O</sub> = 0.25 V to 2 V; at V<sub>DD</sub> = 3 V, V<sub>O</sub> = 0.5 V to 1.5 V.

# TLV2332, TLV2332Y, TLV2334, TLV2334Y LinCMOS™ LOW-VOLTAGE MEDIUM-POWER OPERATIONAL AMPLIFIERS

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## TLV2332I operating characteristics at specified free-air temperature, $V_{DD} = 3 \text{ V}$

	DADAMETED	TEST C	ONDITIONS	т.	TLV2332I		LINUT	
	PARAMETER	1551 C	ONDITIONS	TA	TV2332!         MIN       TYP       MAX         0.38          32          34          32          30          235          42°          39°	UNIT		
SR	Slew rate at unity gain	$V_{IC} = 1 \text{ V},$ $R_{I} = 100 \text{ k}\Omega,$	$V_{I(PP)} = 1 \text{ V},$ $C_{I} = 20 \text{ pF},$	25°C		0.38		V/µs
J SIX	Siew rate at unity gain	See Figure 34	ο <sub>L</sub> – 20 μ.,	85°C		0.29		ν/μδ
Vn	Equivalent input noise voltage	f =1 kHz, See Figure 35	$R_S = 20 \Omega$ ,	25°C		32		nV/√ <del>Hz</del>
Boss	Maximum output-swing bandwidth	Vo = VoH,	C <sub>L</sub> = 20 pF,	25°C		34		kHz
ВОМ	Maximum output-swing bandwidth	$R_L = 100 \text{ k}\Omega$ ,	See Figure 34	85°C		32		NI IZ
р.	Unity-gain bandwidth	V <sub>I</sub> = 10 mV,	C <sub>L</sub> = 20 pF,	25°C		300		kHz
B <sub>1</sub>	Offity-gain bandwidth	$R_L = 100 \text{ k}\Omega$ ,	See Figure 36	85°C		235		KIIZ
		V <sub>I</sub> = 10 mV,	f = B <sub>1</sub> ,	-40°C		42°		
φm	Phase margin	$C_L = 20 pF$ ,	$R_L = 100 \text{ k}\Omega$ ,	25°C		39°		
		See Figure 36		85°C		36°		

## TLV2332I operating characteristics at specified free-air temperature, $V_{DD} = 5 \text{ V}$

	PARAMETER	TEST CO	ONDITIONS	т.	Т	LV2332I		UNIT	
	PARAMETER	IEST CC	SNOTTIONS	TA	MIN	TLV2332I  N TYP MAX  0.43  0.35  0.40  0.32  32  55  45  525  370  43°  40°  38°	MAX	UNIT	
		V <sub>IC</sub> = 1 V,	\\.\.\.\.\.\.\.\.\.\.\.\.\.\.\.\.\.\.\	25°C		0.43			
SR	Slew rate at unity gain	$R_L = 100 \text{ k}\Omega$	V <sub>I(PP)</sub> = 1 V	85°C		0.35		1///10	
J SK	Siew rate at unity gain	$C_L = 20 \text{ pF},$	\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\	25°C		0.40		V/μs	
		See Figure 34 VI(P)  f = 1 kHz, RS = See Figure 35  VO = VOH, CL =	V <sub>I(PP)</sub> = 2.5 V	85°C		0.32			
Vn	Equivalent input noise voltage	· ·	$R_S = 20 \Omega$ ,	25°C		32		nV/√ <del>Hz</del>	
D	Maximum autout autou handuidth	$V_O = V_{OH}$	C <sub>L</sub> = 20 pF,	25°C		55		lel I=	
ВОМ	Maximum output-swing bandwidth	$V_O = V_{OH}$	See Figure 34	85°C	45			kHz	
	Haite, and a bounderidab	V <sub>I</sub> = 10 mV,	C <sub>L</sub> = 20 pF,	25°C		525		1-11-	
B <sub>1</sub>	Unity-gain bandwidth	$R_L = 100 \text{ k}\Omega$	See Figure 36	85°C		370		kHz	
		V <sub>I</sub> = 10 mV,	f = B <sub>1</sub> ,	−40°C		43°			
φm	Phase margin	$C_L = 20 pF$ ,	$R_L = 100 \text{ k}\Omega$ ,	25°C		40°			
		See Figure 36		85°C		38°			

# TLV2332, TLV2332Y, TLV2334, TLV2334Y LinCMOS™ LOW-VOLTAGE MEDIUM-POWER OPERATIONAL AMPLIFIERS

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### TLV2334I electrical characteristics at specified free-air temperature

						TLV2	3341			
	PARAMETER	TEST CONDITIONS	T <sub>A</sub> †	V	DD = 3 \	/	V	DD = 5 \	/	UNIT
				MIN	TYP	MAX	MIN	TYP	MAX	
\/.a	Input offset voltage	$V_{O} = 1 \text{ V},  V_{IC} = 1 \text{ V},$	25°C		0.6	10		1.1	10	mV
VIO	input onset voltage	$R_S = 50 \Omega$ , $R_L = 100 kΩ$	Full range			12			12	IIIV
αγιο	Average temperature coefficient of input offset voltage		25°C to 85°C		1			1.7		μV/°C
lio	Input offset current (see Note 4)	V <sub>O</sub> = 1 V, V <sub>IC</sub> = 1 V	25°C		0.1			0.1		pА
IIO	input onset current (see Note 4)	VO = 1 V, VIC = 1 V	85°C		22	1000		24	1000	PΛ
Iв	Input bias current (see Note 4)	V <sub>O</sub> = 1 V, V <sub>IC</sub> = 1 V	25°C		0.6			0.6		pА
чв	input bias current (see Note 4)	VO = 1 V, VIC = 1 V	85°C		175	2000		200	2000	РΑ
V(	Common-mode input voltage		25°C	-0.2 to 2	-0.3 to 2.3		-0.2 to 4	-0.3 to 4.2		٧
	range (see Note 5)		Full range	-0.2 to 1.8			-0.2 to 3.8			V
\/	High lavel autout valtage	V <sub>IC</sub> = 1 V,	25°C	1.75	1.9		3.2	3.9		V
VOH	High-level output voltage	$V_{ID} = 100 \text{ mV},$ $I_{OH} = -1 \text{ mA}$	Full range	1.7			3			V
Vol	Low-level output voltage	$V_{IC} = 1 \text{ V},$ $V_{ID} = -100 \text{ mV},$	25°C		115	150		95	150	mV
VOL	Low-level output voltage	$I_{OL} = 1 \text{ mA}$	Full range			190			190	IIIV
Δ. σ.	Large-signal differential	$V_{IC} = 1 V$ , $R_{I} = 100 \text{ k}\Omega$ ,	25°C	25	83		25	170		V/mV
AVD	voltage amplification	See Note 6	Full range	15			15			V/IIIV
CMRR	Common mode rejection ratio	$V_O = 1 V$	25°C	65	92		65	91		dB
CIVICK	Common-mode rejection ratio	Common-mode rejection ratio $V_{IC} = V_{ICR}$ min, $R_S = 50 \Omega$	Full range	60			60			ub
kovp	Supply-voltage rejection ratio	$V_{DD} = 3 \text{ V to 5 V},$	25°C	70	94		70	94		dB
ksvr	$(\Delta V_{DD}/\Delta V_{IO})$	$V_{IC} = 1 \text{ V}, V_{O} = 1 \text{ V},$ $R_{S} = 50 \Omega$	Full range	65			65			<b>d</b> B
IDD	Supply current	$V_{O} = 1 \text{ V},  V_{IC} = 1 \text{ V},$	25°C		320	1000		420	1120	μА
טט.	очьый очнош	No load	Full range			1200			1600	μΑ

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

NOTES: 4. The typical values of input bias current and input offset current below 5 pA are determined mathematically.

- 5. This range also applies to each input individually.
  6. At V<sub>DD</sub> = 5 V, V<sub>O</sub> = 0.25 V to 2 V; at V<sub>DD</sub> = 3 V, V<sub>O</sub> = 0.5 V to 1.5 V.

## TLV2334I operating characteristics at specified free-air temperature, $V_{DD} = 3 \text{ V}$

	DADAMETED	TEST CO	NDITIONS	т.	T	LV2334I		UNIT
	PARAMETER	TEST CC	SNOTTIONS	TA	MIN	TYP	MAX	UNII
SR	Slew rate at unity gain	$V_{IC} = 1 \text{ V},$ $R_{I} = 100 \text{ k}\Omega,$	V <sub>I(PP)</sub> = 1 V, C <sub>L</sub> = 20 pF,	25°C		0.38		V/μs
J Six	Siew rate at unity gain	See Figure 34	OL = 20 pr,	85°C		0.29		ν/μδ
Vn	Equivalent input noise voltage	f = 1 kHz, See Figure 35	$R_S = 20 \Omega$ ,	25°C		32		nV/√ <del>Hz</del>
P	Maximum output-swing bandwidth	$V_O = V_{OH}$	C <sub>L</sub> = 20 pF,	25°C		34		kHz
ВОМ	Maximum output-swing bandwidth	$R_L = 100 \text{ k}\Omega$ ,	See Figure 34	85°C		32		KITZ
В.	Unity-gain bandwidth	$V_{I} = 10 \text{ mV},$	C <sub>L</sub> = 20 pF,	25°C		300		kHz
B <sub>1</sub>	Officy-gain bandwidth	$R_L = 100 \text{ k}\Omega$ ,	See Figure 36	85°C		235		KITZ
		V <sub>I</sub> = 10 mV,	4 D	−40°C		42°		
φm	Phase margin	$V_{I} = 10 \text{ mV},$ $C_{L} = 20 \text{ pF},$	$f = B_1$ , $R_1 = 100 \text{ k}\Omega$ ,	25°C		39°		
		See Figure 36		85°C		36°		

## TLV2334I operating characteristics at specified free-air temperature, $V_{DD} = 5 \text{ V}$

	PARAMETER	TEST CO	NDITIONS	т.	Т	LV2334I		UNIT
	PARAMETER	IESI CO	NDITIONS	TA	MIN	TYP	MAX	UNII
		V <sub>IC</sub> = 1 V,	\/\(\max_1 \)	25°C		0.43		
SR	Slow rate at unity gain	$R_L = 100 \text{ k}\Omega,$	V <sub>I(PP)</sub> = 1 V	85°C		0.35		V/μs
Jok	Slew rate at unity gain	$C_L = 20 \text{ pF},$	V//25> - 2.5 V	25°C		0.40		ν/μ5
		See Figure 34	$V_{I(PP)} = 2.5 V$	85°C		0.32		
Vn	Equivalent input noise voltage	f = 1 kHz, See Figure 35	$R_S = 20 \Omega$ ,	25°C		32		nV/√ <del>Hz</del>
Davi.	Maximum autout auting handwidth	VO = VOH,	C <sub>L</sub> = 20 pF,	25°C		55		kHz
ВОМ	Maximum output-swing bandwidth	$R_L = 100 \text{ k}\Omega$ ,	See Figure 34	85°C		45		KHZ
	Unity ania handridth	V <sub>I</sub> = 10 mV,	C <sub>L</sub> = 20 pF,	25°C		525		kHz
B <sub>1</sub>	Unity-gain bandwidth	$R_L = 100 \text{ k}\Omega$ ,	See Figure 36	85°C		370		KHZ
		V <sub>I</sub> = 10 mV,	f = B <sub>1</sub> ,	−40°C		43°		
φm	Phase margin	$C_L = 20 pF$ ,	$R_L = 100 \text{ k}\Omega$	25°C		40°		
		See Figure 36		85°C		38°		

# TLV2332, TLV2332Y, TLV2334, TLV2334Y LINCMOS™ LOW-VOLTAGE MEDIUM-POWER OPERATIONAL AMPLIFIERS

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## TLV2332Y electrical characteristics, $T_A = 25^{\circ}C$

						TLV2	332Y				
	PARAMETER	TEST CO	ONDITIONS	٧ı	DD = 3 \	/	VI	DD = 5 \	/	UNIT	
				MIN	TYP	MAX	MIN	TYP	MAX		
VIO	Input offset voltage	$V_O = 1 V$ , $R_S = 50 \Omega$ ,	$V_{IC} = 1 \text{ V},$ $R_L = 100 \text{ k}\Omega$		0.6			1.1		mV	
liO	Input offset current (see Note 4)	V <sub>O</sub> = 1 V,	V <sub>IC</sub> = 1 V		0.1			0.1		pА	
I <sub>IB</sub>	Input bias current (see Note 4)	$V_{O} = 1 V$ ,	V <sub>IC</sub> = 1 V		0.6			0.6		pА	
V <sub>ICR</sub>	Common-mode input voltage range (see Note 5)				-0.3 to 2.3			-0.3 to 4.2		V	
Vон	High-level output voltage	$V_{IC} = 1 V$ , $I_{OH} = -1 \text{ mA}$	V <sub>ID</sub> = 100 mV,		1.9			3.9		V	
VOL	Low-level output voltage	V <sub>IC</sub> = 1 V, I <sub>OL</sub> = 1 mA	V <sub>ID</sub> = 100 mV,		115			95		mV	
A <sub>VD</sub>	Large-signal differential voltage amplification	V <sub>IC</sub> = 1 V, See Note 6	$R_L = 100 \text{ k}\Omega$ ,		83			170		V/mV	
CMRR	Common-mode rejection ratio	$V_O = 1 V$ , $R_S = 50 \Omega$	V <sub>IC</sub> = V <sub>ICR</sub> min,		92			91		dB	
ksvr	Supply-voltage rejection ratio $(\Delta V_{DD}/\Delta V_{ID})$	$V_O = 1 V$ , $R_S = 50 \Omega$	V <sub>IC</sub> = 1 V,		94			94		dB	
I <sub>DD</sub>	Supply current	V <sub>O</sub> = 1 V, No load	V <sub>IC</sub> = 1 V,		160			210		μΑ	

NOTES: 4. The typical values of input bias current and input offset current below 5 pA are determined mathematically.

5. This range also applies to each input individually.

6. At  $V_{DD}$  = 5 V,  $V_{O}$  = 0.25 V to 2 V; at  $V_{DD}$  = 3 V,  $V_{O}$  = 0.5 V to 1.5 V.

# TLV2332, TLV2332Y, TLV2334, TLV2334Y LinCMOS™ LOW-VOLTAGE MEDIUM-POWER OPERATIONAL AMPLIFIERS

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## TLV2334Y electrical characteristics, $T_A = 25^{\circ}C$

	PARAMETER	TEST C	ONDITIONS	V <sub>DD</sub> = 3 V			VI	DD = 5 \	/	UNIT
				MIN	TYP	MAX	MIN	TYP	MAX	
VIO	Input offset voltage	$V_O = 1 V$ , $R_S = 50 \Omega$ ,	$V_{IC} = 1 V$ $R_L = 100 k\Omega$		0.6			1.1		mV
I <sub>IO</sub>	Input offset current (see Note 4)	$V_0 = 1 V$ ,	V <sub>IC</sub> = 1 V		0.1			0.1		pА
I <sub>IB</sub>	Input bias current (see Note 4)	$V_0 = 1 V$ ,	V <sub>IC</sub> = 1 V		0.6			0.6		pА
VICR	Common-mode input voltage range (see Note 5)				-0.3 to 2.3			-0.3 to 4.2		V
Vон	High-level output voltage	$V_{IC} = 1 V$ , $I_{OH} = -1 \text{ mA}$	$V_{ID} = 100 \text{ mV},$		1.9			3.9		V
VOL	Low-level output voltage	V <sub>IC</sub> = 1 V, I <sub>OL</sub> = 1 mA	$V_{ID} = -100 \text{ mV},$		115			95		mV
AVD	Large-signal differential voltage amplification	V <sub>IC</sub> = 1 V, See Note 6	$R_L = 100 \text{ k}\Omega$ ,		83			170		V/mV
CMRR	Common-mode rejection ratio	$V_O = 1 V$ , $R_S = 50 \Omega$	$V_{IC} = V_{ICR}min,$		92			91		dB
k <sub>SVR</sub>	Supply-voltage rejection ratio (ΔV <sub>DD</sub> /ΔV <sub>ID</sub> )	$V_{IC} = 1 V$ , R <sub>S</sub> = 50 $\Omega$	V <sub>O</sub> = 1 V,		94			94		dB
I <sub>DD</sub>	Supply current	V <sub>O</sub> = 1 V, No load	V <sub>IC</sub> = 1 V,		320			420		μΑ

NOTES: 4. The typical values of input bias current offset current below 5 pA are determined mathematically.

5. This range also applies to each input individually.

6. At  $V_{DD} = 5 \text{ V}$ ,  $V_{O} = 0.25 \text{ V}$  to 2 V; at  $V_{DD} = 3 \text{ V}$ ,  $V_{O} = 0.5 \text{ V}$  to 1.5 V.

# TLV2332, TLV2332Y, TLV2334, TLV2334Y LinCMOS™ LOW-VOLTAGE MEDIUM-POWER OPERATIONAL AMPLIFIERS

SLOS189 - FEBRUARY 1997

### **TYPICAL CHARACTERISTICS**

### **Table of Graphs**

			FIGURE
۷ıO	Input offset voltage	Distribution	1 – 4
αVIO	Input offset voltage temperature coefficient	Distribution	5 – 8
I <sub>IB</sub>	Input bias current	vs Free-air temperature	9
lιο	Input offset current	vs Free-air temperature	9
VIС	Common-mode input voltage	vs Supply voltage	10
VOH	High-level output voltage	vs High-level output current vs Supply voltage vs Free-air temperature	11 12 13
VOL	Low-level output voltage	vs Common-mode input voltage vs Free-air temperature vs Differential input voltage vs Low-level output current	14 15, 16 17 18
AVD	Large-signal differential voltage amplification	vs Supply voltage vs Free-air temperature vs Frequency	19 20 21, 22
I <sub>DD</sub>	Supply current	vs Supply voltage vs Free-air temperature	23 24
SR	Slew rate	vs Supply voltage vs Free-air temperature	25 26
V <sub>O(PP)</sub>	Maximum peak-to-peak output voltage	vs Frequency	27
B <sub>1</sub>	Unity-gain bandwidth	vs Supply voltage vs Free-air temperature	28 29
фm	Phase margin	vs Supply voltage vs Free-air temperature vs Load capacitance	30 31 32
	Phase shift	vs Frequency	21, 22
Vn	Equivalent input noise voltage	vs Frequency	33



### **TYPICAL CHARACTERISTICS**

## 

Figure 1

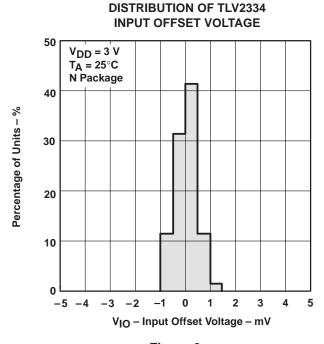


Figure 3

# DISTRIBUTION OF TLV2332 INPUT OFFSET VOLTAGE

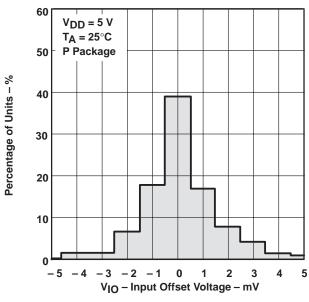


Figure 2

### DISTRIBUTION OF TLV2334 INPUT OFFSET VOLTAGE

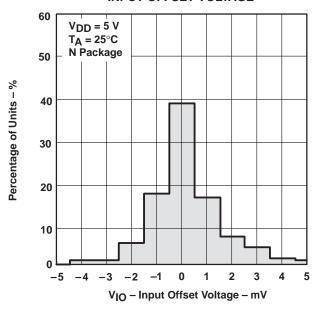
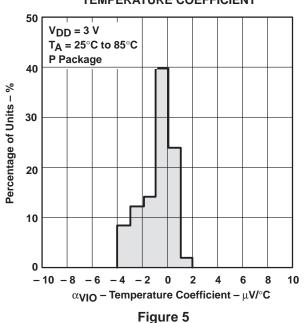


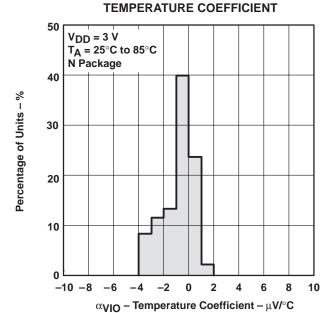
Figure 4

### **DISTRIBUTION OF TLV2332** INPUT OFFSET VOLTAGE **TEMPERATURE COEFFICIENT**



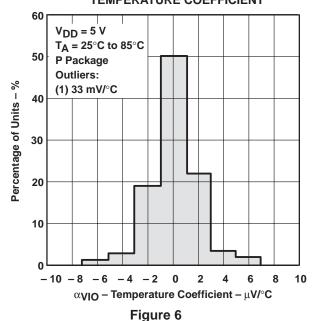
# **DISTRIBUTION OF TLV2334**

**INPUT OFFSET VOLTAGE** 



### Figure 7

### **DISTRIBUTION OF TLV2332 INPUT OFFSET VOLTAGE TEMPERATURE COEFFICIENT**



### **DISTRIBUTION OF TLV2334 INPUT OFFSET VOLTAGE TEMPERATURE COEFFICIENT**

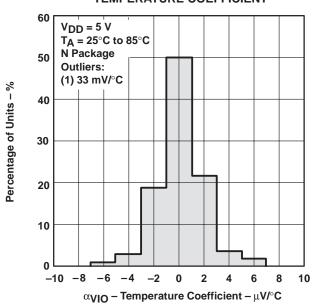
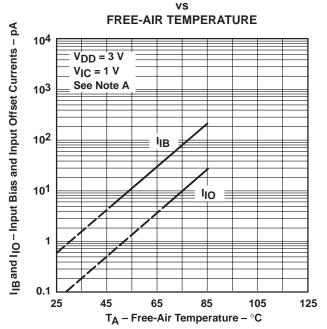


Figure 8



### TYPICAL CHARACTERISTICS

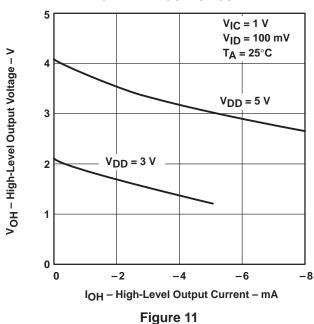
### INPUT BIAS CURRENT AND INPUT OFFSET CURRENT



NOTE: The typical values of input bias current and input offset current below 5 pA were determined mathematically.

### Figure 9

# HIGH-LEVEL OUTPUT VOLTAGE vs HIGH-LEVEL OUTPUT CURRENT



# COMMON-MODE INPUT VOLTAGE vs SUPPLY VOLTAGE

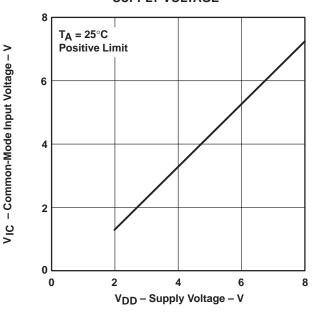
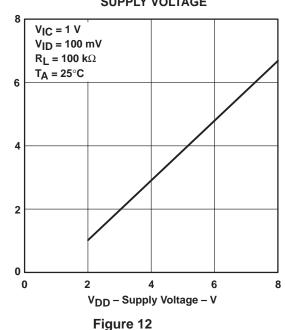


Figure 10

# HIGH-LEVEL OUTPUT VOLTAGE vs SUPPLY VOLTAGE

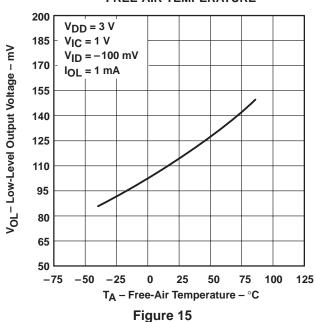


VOH - High-Level Output Voltage - V

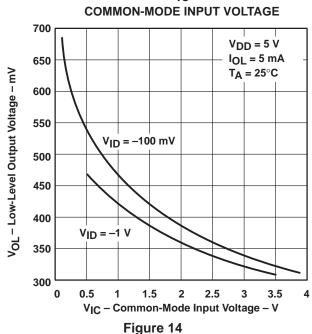
### **HIGH-LEVEL OUTPUT VOLTAGE** FREE-AIR TEMPERATURE $V_{DD} = 3 V$ **V**<sub>IC</sub> = 1 **V** V<sub>ID</sub> = 100 mV VOH - High-Level Output Voltage - V 2.4 1.8 1.2 $I_{OH} = -500 \mu A$ $I_{OH} = -1 \text{ mA}$ 0.6 $I_{OH} = -2 \text{ mA}$ IOH = -3 mA $I_{OH} = -4 \text{ mA}$ -75 -50 -25 25 50 75 100 125 TA - Free-Air Temperature - °C



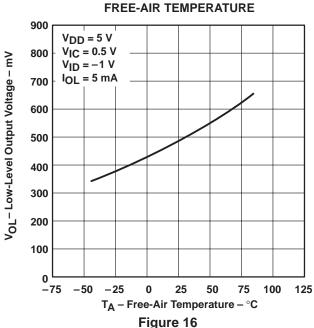
Figure 13

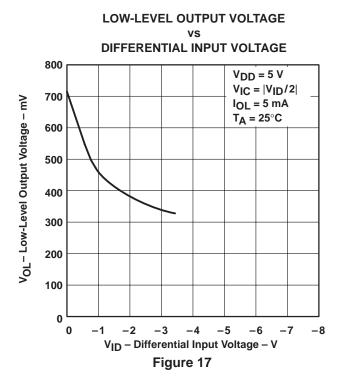


# LOW-LEVEL OUTPUT VOLTAGE VS COMMON MODE INDUST VOLTAGE

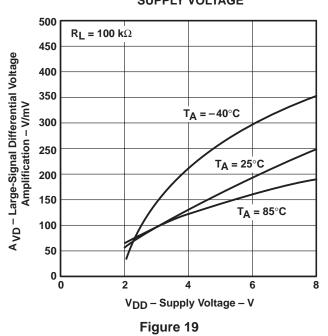


# LOW-LEVEL OUTPUT VOLTAGE vs

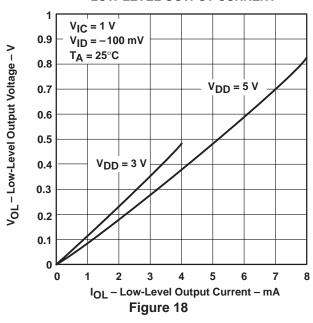




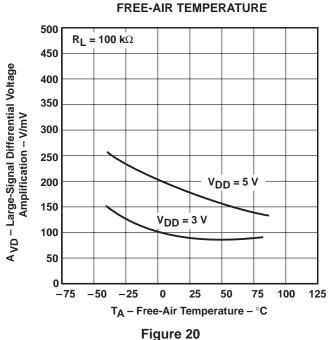
LARGE-SIGNAL
DIFFERENTIAL VOLTAGE AMPLIFICATION
vs
SUPPLY VOLTAGE



LOW-LEVEL OUTPUT VOLTAGE
vs
LOW-LEVEL OUTPUT CURRENT



LARGE-SIGNAL
DIFFERENTIAL VOLTAGE AMPLIFICATION
vs





# LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION AND PHASE SHIFT

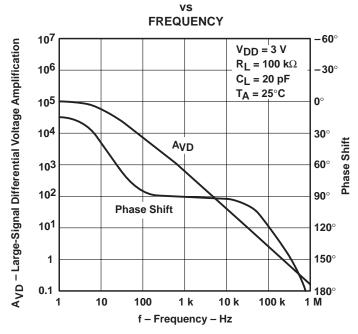


Figure 21

# LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION AND PHASE SHIFT

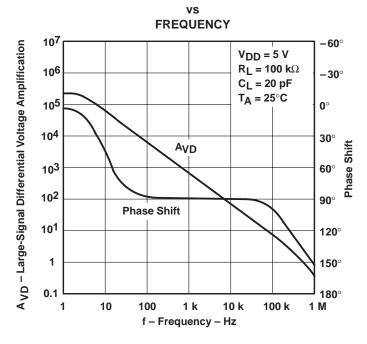
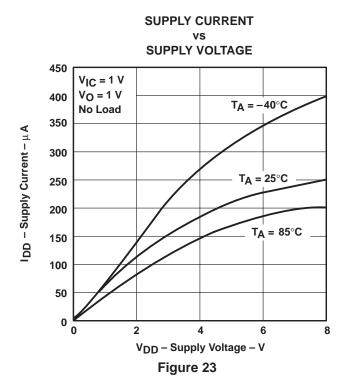
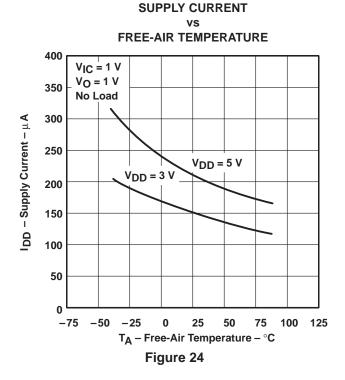
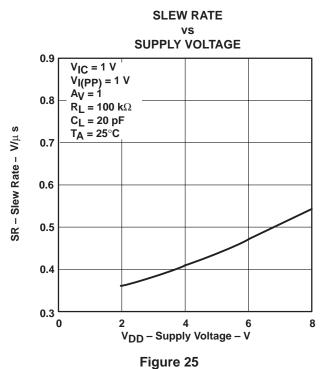


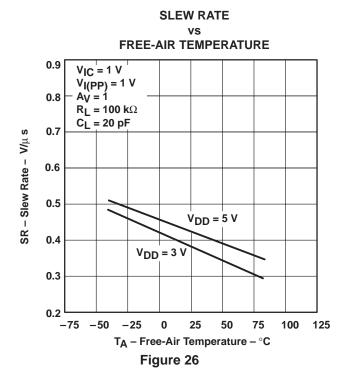
Figure 22



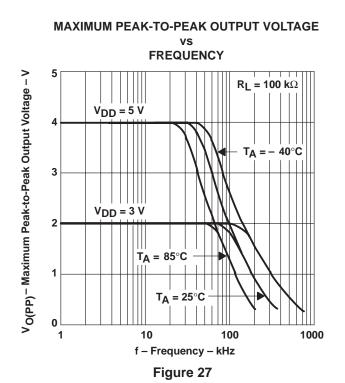


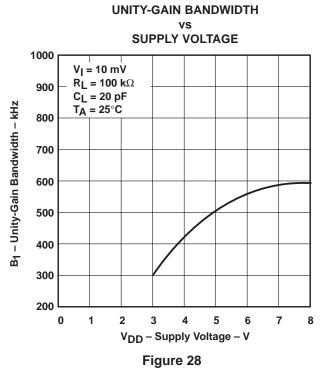






### TYPICAL CHARACTERISTICS





# UNITY-GAIN BANDWIDTH vs

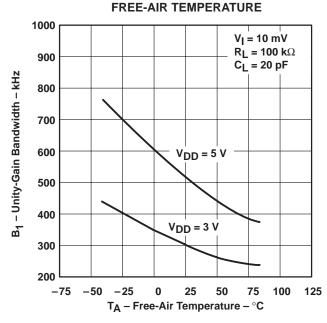


Figure 29

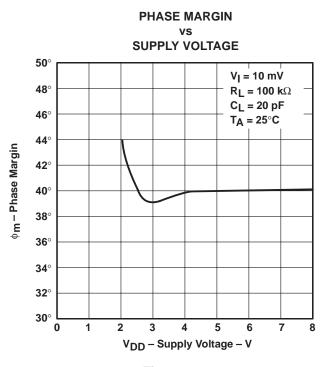
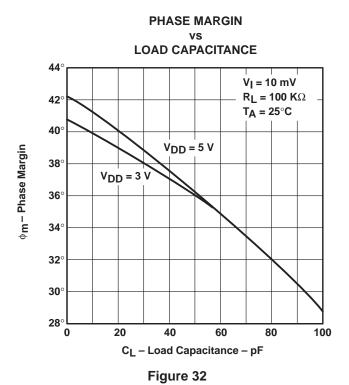


Figure 30



FREE-AIR TEMPERATURE

**PHASE MARGIN** 

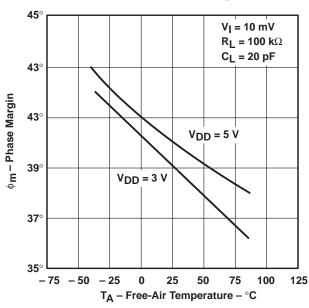


Figure 31

### **EQUIVALENT INPUT NOISE VOLTAGE**

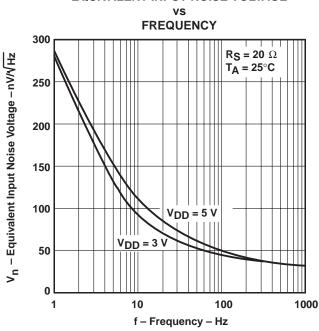


Figure 33

### PARAMETER MEASUREMENT INFORMATION

### single-supply versus split-supply test circuits

Because the TLV233x is optimized for single-supply operation, circuit configurations used for the various tests often present some inconvenience since the input signal, in many cases, must be offset from ground. This inconvenience can be avoided by testing the device with split supplies and the output load tied to the negative rail. A comparison of single-supply versus split-supply test circuits is shown below. The use of either circuit gives the same result.

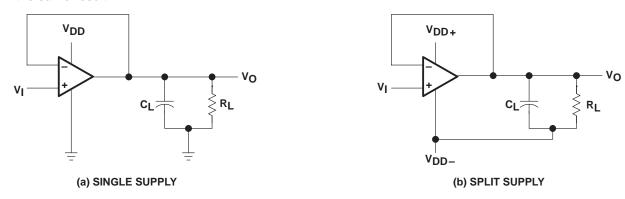


Figure 34. Unity-Gain Amplifier

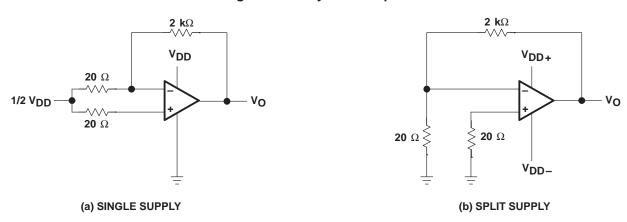


Figure 35. Noise-Test Circuit

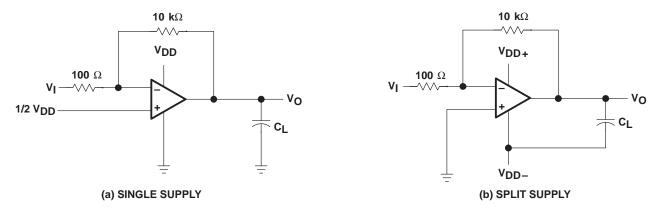


Figure 36. Gain-of-100 Inverting Amplifier



### PARAMETER MEASUREMENT INFORMATION

### input bias current

Because of the high input impedance of the TLV233x operational amplifier, attempts to measure the input bias current can result in erroneous readings. The bias current at normal ambient temperature is typically less than 1 pA, a value that is easily exceeded by leakages on the test socket. Two suggestions are offered to avoid erroneous measurements:

- Isolate the device from other potential leakage sources. Use a grounded shield around and between the device inputs (see Figure 37). Leakages that would otherwise flow to the inputs are shunted away.
- Compensate for the leakage of the test socket by actually performing an input bias current test (using a
  picoammeter) with no device in the test socket. The actual input bias current can then be calculated by
  subtracting the open-socket leakage readings from the readings obtained with a device in the test
  socket.

Many automatic testers as well as some bench-top operational amplifier testers use the servo-loop technique with a resistor in series with the device input to measure the input bias current (the voltage drop across the series resistor is measured and the bias current is calculated). This method requires that a device be inserted into a test socket to obtain a correct reading; therefore, an open-socket reading is not feasible using this method.

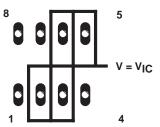


Figure 37. Isolation Metal Around Device Inputs (P package)

### low-level output voltage

To obtain low-level supply-voltage operation, some compromise is necessary in the input stage. This compromise results in the device low-level output voltage being dependent on both the common-mode input voltage level as well as the differential input voltage level. When attempting to correlate low-level output readings with those quoted in the electrical specifications, these two conditions should be observed. If conditions other than these are to be used, please refer to the Typical Characteristics section of this data sheet.

### input offset voltage temperature coefficient

Erroneous readings often result from attempts to measure temperature coefficient of input offset voltage. This parameter is actually a calculation using input offset voltage measurements obtained at two different temperatures. When one (or both) of the temperatures is below freezing, moisture can collect on both the device and the test socket. This moisture results in leakage and contact resistance which can cause erroneous input offset voltage readings. The isolation techniques previously mentioned have no effect on the leakage since the moisture also covers the isolation metal itself, thereby rendering it useless. These measurements should be performed at temperatures above freezing to minimize error.

### full-power response

Full-power response, the frequency above which the operational amplifier slew rate limits the output voltage swing, is often specified two ways: full-linear response and full-peak response. The full-linear response is



### PARAMETER MEASUREMENT INFORMATION

generally measured by monitoring the distortion level of the output while increasing the frequency of a sinusoidal input signal until the maximum frequency is found above which the output contains significant distortion. The full-peak response is defined as the maximum output frequency, without regard to distortion, above which full peak-to-peak output swing cannot be maintained.

Because there is no industry-wide accepted value for significant distortion, the full-peak response is specified in this data sheet and is measured using the circuit of Figure 34. The initial setup involves the use of a sinusoidal input to determine the maximum peak-to-peak output of the device (the amplitude of the sinusoidal wave is increased until clipping occurs). The sinusoidal wave is then replaced with a square wave of the same amplitude. The frequency is then increased until the maximum peak-to-peak output can no longer be maintained (Figure 38). A square wave is used to allow a more accurate determination of the point at which the maximum peak-to-peak output is reached.

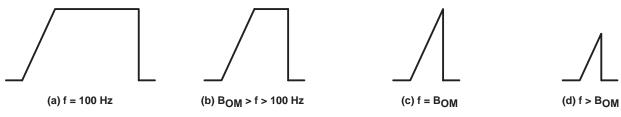


Figure 38. Full-Power-Response Output Signal

### test time

Inadequate test time is a frequent problem, especially when testing CMOS devices in a high-volume, short-test-time environment. Internal capacitances are inherently higher in CMOS than in bipolar and BiFET devices and require longer test times than their bipolar and BiFET counterparts. The problem becomes more pronounced with reduced supply levels and lower temperatures.

### APPLICATION INFORMATION

### single-supply operation

While the TLV233x performs well using dual-power supplies (also called balanced or split supplies), the design is optimized for single-supply operation. This includes an input common-mode voltage range that encompasses ground as well as an output voltage range that pulls down to ground. The supply voltage range extends down to 2 V, thus allowing operation with supply levels commonly available for TTL and HCMOS.

Many single-supply applications require that a voltage be applied to one input to establish a reference level that is above ground. This virtual ground can be generated using two large resistors, but a preferred technique is to use a virtual-ground generator such as the TLE2426 (see Figure 39).

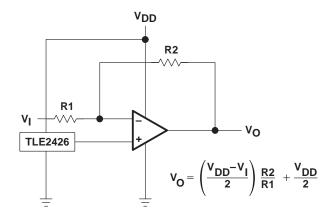


Figure 39. Inverting Amplifier With Voltage Reference



### **APPLICATION INFORMATION**

### single-supply operation (continued)

The TLE2426 supplies an accurate voltage equal to  $V_{DD}/2$ , while consuming very little power and is suitable for supply voltages of greater than 4 V. The TLV233x works well in conjunction with digital logic; however, when powering both linear devices and digital logic from the same power supply, the following precautions are recommended:

- Power the linear devices from separate bypassed supply lines (see Figure 40); otherwise, the linear device supply rails can fluctuate due to voltage drops caused by high switching currents in the digital logic.
- Use proper bypass techniques to reduce the probability of noise-induced errors. Single capacitive decoupling is often adequate; however, RC decoupling may be necessary in high-frequency applications.

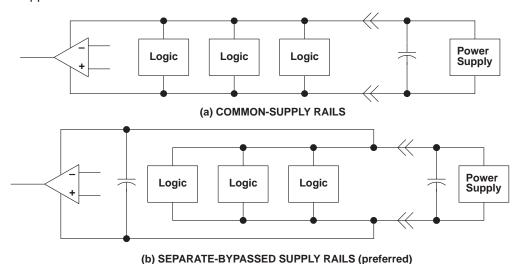


Figure 40. Common Versus Separate Supply Rails

### input characteristics

The TLV233x is specified with a minimum and a maximum input voltage that, if exceeded at either input, could cause the device to malfunction. Exceeding this specified range is a common problem, especially in single-supply operation. The lower the range limit includes the negative rail, while the upper range limit is specified at  $V_{DD}-1\ V$  at  $T_A=25\ C$  and at  $V_{DD}-1.2\ V$  at all other temperatures.

The use of the polysilicon-gate process and the careful input circuit design gives the TLV233x very good input offset voltage drift characteristics relative to conventional metal-gate processes. Offset voltage drift in CMOS devices is highly influenced by threshold voltage shifts caused by polarization of the phosphorus dopant implanted in the oxide. Placing the phosphorus dopant in a conductor (such as a polysilicon gate) alleviates the polarization problem, thus reducing threshold voltage shifts by more than an order of magnitude. The offset voltage drift with time has been calculated to be typically  $0.1~\mu\text{V/month}$ , including the first month of operation.

Because of the extremely high input impedance and resulting low bias-current requirements, the TLV233x is well suited for low-level signal processing; however, leakage currents on printed-circuit boards and sockets can easily exceed bias-current requirements and cause a degradation in device performance.

### APPLICATION INFORMATION

### input characteristics (continued)

It is good practice to include guard rings around inputs (similar to those of Figure 37 in the Parameter Measurement Information section). These guards should be driven from a low-impedance source at the same voltage level as the common-mode input (see Figure 41).

The inputs of any unused amplifiers should be tied to ground to avoid possible oscillation.

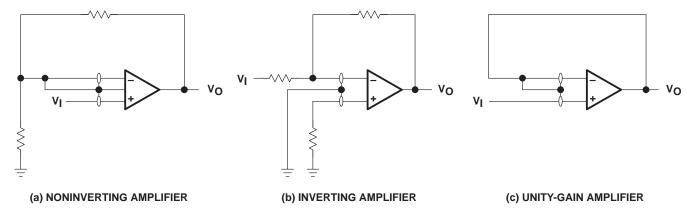


Figure 41. Guard-Ring Schemes

### noise performance

The noise specifications in operational amplifiers circuits are greatly dependent on the current in the first-stage differential amplifier. The low input bias-current requirements of the TLV233x results in a very low noise current, which is insignificant in most applications. This feature makes the device especially favorable over bipolar devices when using values of circuit impedance greater than 50 k $\Omega$ , since bipolar devices exhibit greater noise currents.

### feedback

Operational amplifiers circuits nearly always employ feedback, and since feedback is the first prerequisite for oscillation, caution is appropriate. Most oscillation problems result from driving capacitive loads and ignoring stray input capacitance. A small-value capacitor connected in parallel with the feedback resistor is an effective remedy (see Figure 42). The value of this capacitor is optimized empirically.

### electrostatic-discharge protection

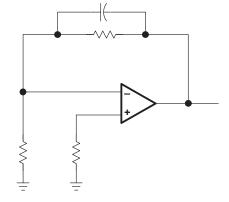


Figure 42. Compensation for Input Capacitance

The TLV233x incorporates an internal electrostatic-discharge (ESD)-protection circuit that prevents functional failures at voltages up to 2000 V as tested under MIL-PRF-38535. Method 3015.2. Care should be exercised, however, when handling these devices as exposure to ESD may result in the degradation of the device parametric performance. The protection circuit also causes the input bias currents to be temperature dependent and have the characteristics of a reverse-biased diode.



### **APPLICATION INFORMATION**

### latch-up

Because CMOS devices are susceptible to latch-up due to their inherent parasitic thyristors, the TLV233x inputs and outputs are designed to withstand -100-mA surge currents without sustaining latch-up; however, techniques should be used to reduce the chance of latch-up whenever possible. Internal-protection diodes should not by design be forward biased. Applied input and output voltage should not exceed the supply voltage by more than 300 mV. Care should be exercised when using capacitive coupling on pulse generators. Supply transients should be shunted by the use of decoupling capacitors (0.1  $\mu$ F typical) located across the supply rails as close to the device as possible.

The current path established if latch-up occurs is usually between the positive supply rail and ground and can be triggered by surges on the supply lines and/or voltages on either the output or inputs that exceed the supply voltage. Once latch-up occurs, the current flow is limited only by the impedance of the power supply and the forward resistance of the parasitic thyristor and usually results in the destruction of the device. The chance of latch-up occurring increases with increasing temperature and supply voltages.

### output characteristics

The output stage of the TLV233x is designed to sink and source relatively high amounts of current (see Typical Characteristics). If the output is subjected to a short-circuit condition, this high-current capability can cause device damage under certain conditions. Output current capability increases with supply voltage.

Although the TLV233x possesses excellent high-level output voltage and current capability, methods are available for boosting this capability if needed. The simplest method involves the use of a pullup resistor (Rp) connected from the output to the positive supply rail (see Figure 43). There are two disadvantages to the use of this circuit. First, the NMOS pulldown transistor N4 (see equivalent schematic) must sink a comparatively large amount of current. In this circuit, N4 behaves like a linear resistor with an on resistance between approximately 60  $\Omega$  and 180  $\Omega$ , depending on how hard the operational amplifier input is driven. With very low values of Rp, a voltage offset from 0 V at the output occurs. Secondly, pullup resistor R<sub>P</sub> acts as a drain load to N4 and the gain of the operational amplifier is reduced at output voltage levels where N5 is not supplying the output current.

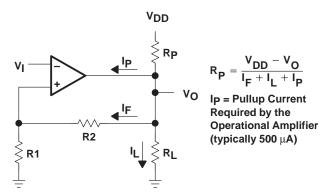


Figure 43. Resistive Pullup to Increase VOH

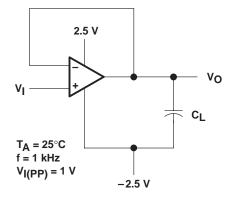


Figure 44. Test Circuit for Output Characteristics

All operating characteristics of the TLV233x are measured using a 20-pF load. The device drives higher capacitive loads; however, as output load capacitance increases, the resulting response pole occurs at lower frequencies thereby causing ringing, peaking, or even oscillation (see Figure 44 and Figure 45). In many cases, adding some compensation in the form of a series resistor in the feedback loop alleviates the problem.

### **APPLICATION INFORMATION**

### output characteristics (continued)

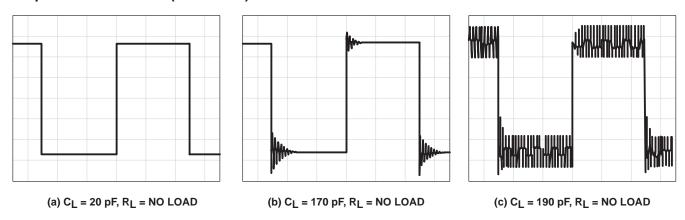


Figure 45. Effect of Capacitive Loads

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### PACKAGING INFORMATION

Orderable part number	Status	Material type	Package   Pins	Package qty   Carrier	RoHS	Lead finish/	MSL rating/	Op temp (°C)	Part marking
	(1)	(2)			(3)	Ball material	Peak reflow		(6)
						(4)	(5)		
TLV2332ID	Active	Production	SOIC (D)   8	75   TUBE	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 85	23321
TLV2332ID.A	Active	Production	SOIC (D)   8	75   TUBE	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 85	23321
TLV2332IDR	Active	Production	SOIC (D)   8	2500   LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 85	23321
TLV2332IDR.A	Active	Production	SOIC (D)   8	2500   LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 85	23321
TLV2332IP	Active	Production	PDIP (P)   8	50   TUBE	Yes	NIPDAU	N/A for Pkg Type	-40 to 85	TLV2332IP
TLV2332IP.A	Active	Production	PDIP (P)   8	50   TUBE	Yes	NIPDAU	N/A for Pkg Type	-40 to 85	TLV2332IP
TLV2332IPWR	Active	Production	TSSOP (PW)   8	2000   LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 85	TY2332
TLV2332IPWR.A	Active	Production	TSSOP (PW)   8	2000   LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 85	TY2332

<sup>(1)</sup> Status: For more details on status, see our product life cycle.

Multiple part markings will be inside parentheses. Only one part marking contained in parentheses and separated by a "~" will appear on a part. If a line is indented then it is a continuation of the previous line and the two combined represent the entire part marking for that device.

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<sup>(2)</sup> Material type: When designated, preproduction parts are prototypes/experimental devices, and are not yet approved or released for full production. Testing and final process, including without limitation quality assurance, reliability performance testing, and/or process qualification, may not yet be complete, and this item is subject to further changes or possible discontinuation. If available for ordering, purchases will be subject to an additional waiver at checkout, and are intended for early internal evaluation purposes only. These items are sold without warranties of any kind.

<sup>(3)</sup> RoHS values: Yes, No. RoHS Exempt. See the TI RoHS Statement for additional information and value definition.

<sup>(4)</sup> Lead finish/Ball material: Parts may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material values may wrap to two lines if the finish value exceeds the maximum column width.

<sup>(5)</sup> MSL rating/Peak reflow: The moisture sensitivity level ratings and peak solder (reflow) temperatures. In the event that a part has multiple moisture sensitivity ratings, only the lowest level per JEDEC standards is shown. Refer to the shipping label for the actual reflow temperature that will be used to mount the part to the printed circuit board.

<sup>(6)</sup> Part marking: There may be an additional marking, which relates to the logo, the lot trace code information, or the environmental category of the part.

### **PACKAGE OPTION ADDENDUM**

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In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.

## **PACKAGE MATERIALS INFORMATION**

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### TAPE AND REEL INFORMATION





A0	Dimension designed to accommodate the component width
В0	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 Drawing		SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
TLV2332IDR	SOIC	D	8	2500	330.0	12.4	6.4	5.2	2.1	8.0	12.0	Q1
TLV2332IPWR	TSSOP	PW	8	2000	330.0	12.4	7.0	3.6	1.6	8.0	12.0	Q1

## **PACKAGE MATERIALS INFORMATION**

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### \*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
TLV2332IDR	SOIC	D	8	2500	340.5	338.1	20.6
TLV2332IPWR	TSSOP	PW	8	2000	353.0	353.0	32.0

## **PACKAGE MATERIALS INFORMATION**

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### **TUBE**



### \*All dimensions are nominal

Device	Package Name	Package Type	Pins	SPQ	L (mm)	W (mm)	T (µm)	B (mm)
TLV2332ID	D	SOIC	8	75	507	8	3940	4.32
TLV2332ID.A	D	SOIC	8	75	507	8	3940	4.32
TLV2332IP	Р	PDIP	8	50	506	13.97	11230	4.32
TLV2332IP.A	Р	PDIP	8	50	506	13.97	11230	4.32

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Last updated 10/2025