

TLC225x, TLC225xA Advanced LinCMOS™ RAIL-TO-RAIL VERY LOW-POWER OPERATIONAL AMPLIFIERS

SLOS176D – FEBRUARY 1997 – REVISED MARCH 2001

- Output Swing Includes Both Supply Rails
- Low Noise . . . 19 nV/√Hz Typ at f = 1 kHz
- Low Input Bias Current . . . 1 pA Typ
- Fully Specified for Both Single-Supply and Split-Supply Operation
- Very Low Power . . . 35 μA Per Channel Typ
- Common-Mode Input Voltage Range Includes Negative Rail
- Low Input Offset Voltage
850 μV Max at T_A = 25°C (TLC225xA)
- Macromodel Included
- Performance Upgrades for the TS27L2/L4 and TLC27L2/L4
- Available in Q-Temp Automotive HighRel Automotive Applications Configuration Control / Print Support Qualification to Automotive Standards

description

The TLC2252 and TLC2254 are dual and quadruple operational amplifiers from Texas Instruments. Both devices exhibit rail-to-rail output performance for increased dynamic range in single- or split-supply applications. The TLC225x family consumes only 35 μA of supply current per channel. This micropower operation makes them good choices for battery-powered applications. The noise performance has been dramatically improved over previous generations of CMOS amplifiers. Looking at Figure 1, the TLC225x has a noise level of 19 nV/√Hz at 1kHz; four times lower than competitive micropower solutions.

The TLC225x amplifiers, exhibiting high input impedance and low noise, are excellent for small-signal conditioning for high-impedance sources, such as piezoelectric transducers. Because of the micropower dissipation levels, 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). For precision applications, the TLC225xA family is available and has a maximum input offset voltage of 850 μV. This family is fully characterized at 5 V and ±5 V.

The TLC2252/4 also makes great upgrades to the TLC27L2/L4 or TS27L2/L4 in standard designs. They offer increased output dynamic range, lower noise voltage, and lower input offset voltage. This enhanced feature set allows them to be used in a wider range of applications. For applications that require higher output drive and wider input voltage ranges, see the TLV2432 and TLV2442 devices. If the design requires single amplifiers, please see the TLV2211/21/31 family. These devices are single rail-to-rail operational amplifiers in the SOT-23 package. Their small size and low power consumption, make them ideal for high density, battery-powered equipment.

EQUIVALENT INPUT NOISE VOLTAGE
VS
FREQUENCY

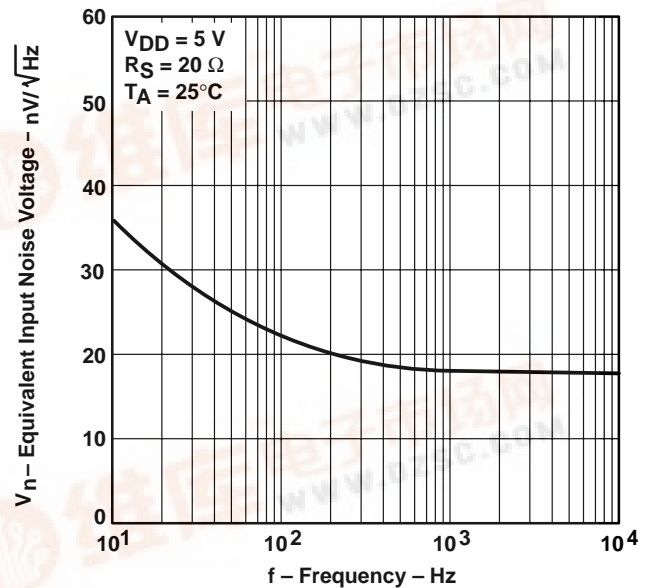


Figure 1

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.

Advanced LinCMOS is a trademark of Texas Instruments.

PRODUCTION DATA information is current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.



Copyright © 2001, Texas Instruments Incorporated
On products compliant to MIL-PRF-38535, all parameters are tested unless otherwise noted. On all other products, production processing does not necessarily include testing of all parameters.

TLC225x, TLC225xA
Advanced LinCMOS™ RAIL-TO-RAIL
VERY LOW-POWER OPERATIONAL AMPLIFIERS

SLOS176D – FEBRUARY 1997 – REVISED MARCH 2001

TLC2252 AVAILABLE OPTIONS

T _A	V _{IO} max AT 25°C	PACKAGED DEVICES					
		SMALL OUTLINE† (D)	CHIP CARRIER (FK)	CERAMIC DIP (JG)	PLASTIC DIP (P)	TSSOP‡ (PW)	CERAMIC FLATPACK (U)
0°C to 70°C	1500 μV	TLC2252CD	—	—	TLC2252CP	TLC2252CPW	—
-40°C to 125°C	850 μV	TLC2252AID	—	—	TLC2252AIP	TLC2252AIPW	—
	1500 μV	TLC2252ID	—	—	TLC2252IP	—	—
-40°C to 125°C	850 μV	TLC2252AQD	—	—	—	—	—
	1500 μV	TLC2252QD	—	—	—	—	—
-55°C to 125°C	850 μV	—	TLC2252AMFK	TLC2252AMJG	—	—	TLC2252AMU
	1500 μV	—	TLC2252MFK	TLC2252MJG	—	—	TLC2252MU

† The D packages are available taped and reeled. Add R suffix to device type (e.g., TLC2262CDR).

‡ The PW package is available only left-ended taped and reeled.

§ Chip forms are tested at 25°C only.

TLC2254 AVAILABLE OPTIONS

T _A	V _{IO} max AT 25°C	PACKAGED DEVICES					
		SMALL OUTLINE† (D)	CHIP CARRIER (FK)	CERAMIC DIP (J)	PLASTIC DIP (N)	TSSOP‡ (PW)	CERAMIC FLATPACK (W)
0°C to 70°C	1500 μV	TLC2254CD	—	—	TLC2254CN	TLC2254CPW	—
-40°C to 125°C	850 μV	TLC2254AID	—	—	TLC2254AIN	TLC2254AIPW	—
	1500 μV	TLC2254ID	—	—	TLC2254IN	—	—
-40°C to 125°C	850 μV	TLC2254AQD	—	—	—	—	—
	1500 μV	TLC2254QD	—	—	—	—	—
-55°C to 125°C	850 μV	—	TLC2254AMFK	TLC2254AMJ	—	—	TLC2254AMW
	1500 μV	—	TLC2254MFK	TLC2254MJ	—	—	TLC2254MW

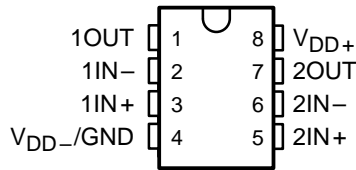
† The D packages are available taped and reeled. Add R suffix to the device type (e.g., TLC2254CDR).

‡ The PW package is available only left-end taped and reeled. Chips are tested at 25°C.

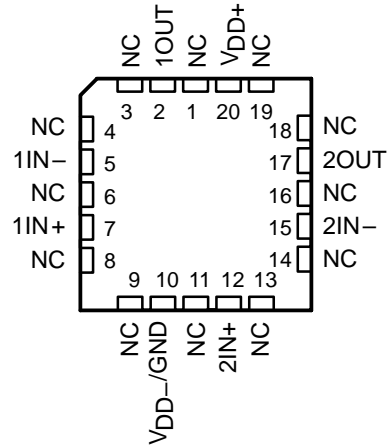
§ Chip forms are tested at 25°C only.

TLC225x, TLC225xA
Advanced LinCMOS™ RAIL-TO-RAIL
VERY LOW-POWER OPERATIONAL AMPLIFIERS
SLOS176D – FEBRUARY 1997 – REVISED MARCH 2001

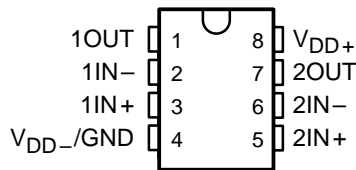
TLC2252C, TLC2252AC
TLC2252I, TLC2252AI
TLC2252Q, TLC2252AQ
D, P, OR PW PACKAGE
(TOP VIEW)



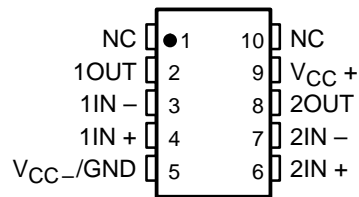
TLC2252M, TLC2252AM . . . FK PACKAGE
(TOP VIEW)



TLC2252M, TLC2252AM . . . JG PACKAGE
(TOP VIEW)

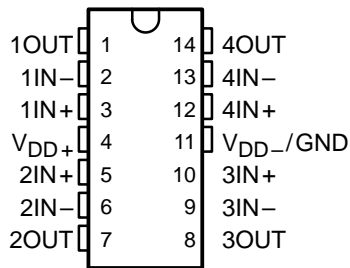


TLC2262M, TLC2252AM . . . U PACKAGE
(TOP VIEW)



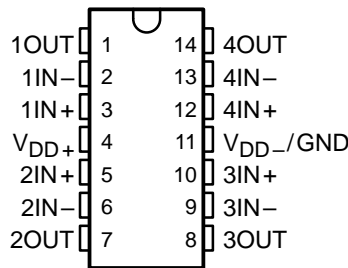
TLC2254C, TLC2254AC
TLC2254I, TLC2254AI
TLC2254Q, TLC2254AQ
D, N, OR PW PACKAGE

(TOP VIEW)

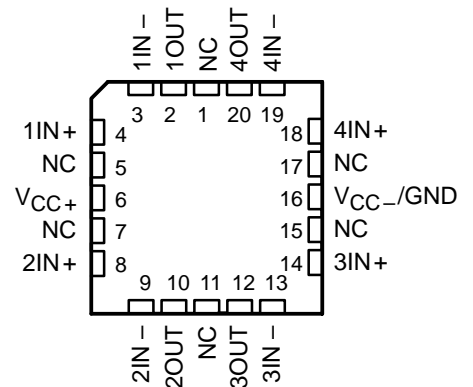


TLC2254M, TLC2254AM
J OR W PACKAGE

(TOP VIEW)



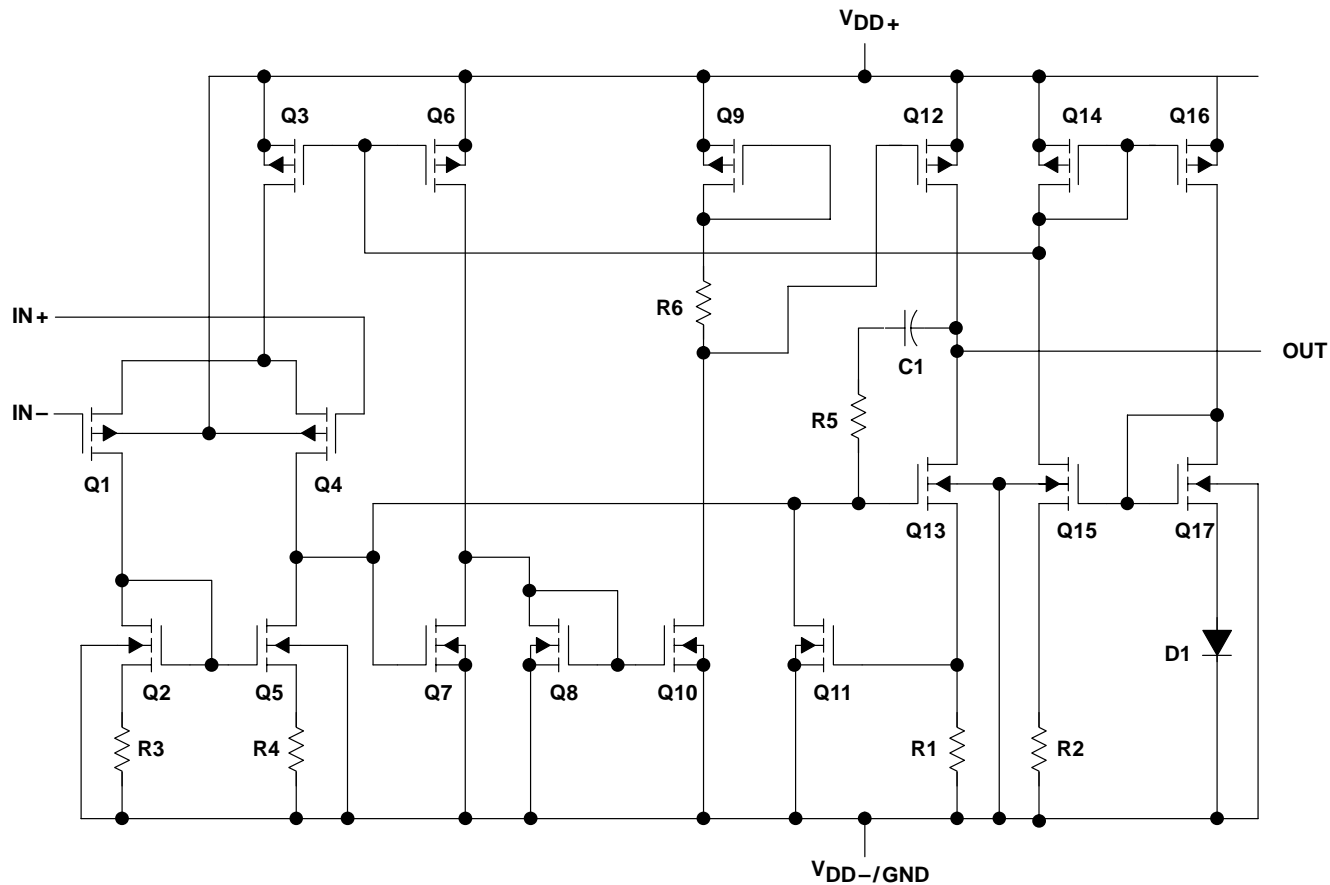
TLC2254M, TLC2254AM
FK PACKAGE
(TOP VIEW)



NC – No internal connection

TLC225x, TLC225xA
Advanced LinCMOS™ RAIL-TO-RAIL
VERY LOW-POWER OPERATIONAL AMPLIFIERS
 SLOS176D – FEBRUARY 1997 – REVISED MARCH 2001

equivalent schematic (each amplifier)



ACTUAL DEVICE COMPONENT COUNT†		
COMPONENT	TLC2252	TLC2254
Transistors	38	76
Resistors	30	56
Diodes	9	18
Capacitors	3	6

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

TLC225x, TLC225xA
Advanced LinCMOS™ RAIL-TO-RAIL
VERY LOW-POWER OPERATIONAL AMPLIFIERS
SLOS176D – FEBRUARY 1997 – REVISED MARCH 2001

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

Supply voltage, V_{DD+} (see Note 1)	8 V
Supply voltage, V_{DD-} (see Note 1)	–8 V
Differential input voltage, V_{ID} (see Note 2)	±16 V
Input voltage, V_I (any input, see Note 1)	±8 V
Input current, I_I (each input)	±5 mA
Output current, I_O	±50 mA
Total current into V_{DD+}	±50 mA
Total current out of V_{DD-}	±50 mA
Duration of short-circuit current at (or below) 25°C (see Note 3)	unlimited
Continuous total dissipation	See Dissipation Rating Table
Operating free-air temperature range, T_A : C suffix	0°C to 70°C
I suffix	–40°C to 125°C
Q suffix	–40°C to 125°C
M suffix	–55°C to 125°C
Storage temperature range, T_{stg}	–65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds	260°C

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

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

DISSIPATION RATING TABLE

PACKAGE	$T_A \leq 25^\circ\text{C}$ POWER RATING	DERATING FACTOR ABOVE $T_A = 25^\circ\text{C}$	$T_A = 70^\circ\text{C}$ POWER RATING	$T_A = 85^\circ\text{C}$ POWER RATING	$T_A = 125^\circ\text{C}$ POWER RATING
D–8	724 mW	5.8 mW/°C	464 mW	377 mW	144 mW
D–14	950 mW	7.6 mW/°C	608 mW	450 mW	190 mW
FK	1375 mW	11.0 mW/°C	880 mW	715 mW	275 mW
J	1375 mW	11.0 mW/°C	880 mW	715 mW	275 mW
JG	1050 mW	8.4 mW/°C	672 mW	546 mW	275 mW
N	1150 mW	9.2 mW/°C	736 mW	736 mW	—
P	1000 mW	8.0 mW/°C	640 mW	520 mW	—
PW–8	525 mW	4.2 mW/°C	336 mW	273 mW	—
PW–14	700 mW	5.6 mW/°C	448 mW	448 mW	—
U	700 mW	5.5 mW/°C	246 mW	330 mW	150 mW
W	700 mW	5.5 mW/°C	246 mW	330 mW	150 mW

recommended operating conditions

	C SUFFIX		I SUFFIX		Q SUFFIX		M SUFFIX		UNIT
	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	
Supply voltage, $V_{DD\pm}$	±2.2	±8	±2.2	±8	±2.2	±8	±2.2	±8	V
Input voltage range, V_I	V_{DD-}	$V_{DD+} - 1.5$	V_{DD-}	$V_{DD+} - 1.5$	V_{DD-}	$V_{DD+} - 1.5$	V_{DD-}	$V_{DD+} - 1.5$	V
Common-mode input voltage, V_{IC}	V_{DD-}	$V_{DD+} - 1.5$	V_{DD-}	$V_{DD+} - 1.5$	V_{DD-}	$V_{DD+} - 1.5$	V_{DD-}	$V_{DD+} - 1.5$	V
Operating free-air temperature, T_A	0	70	–40	125	–40	125	–55	125	°C

TLC225x, TLC225xA
Advanced LinCMOS™ RAIL-TO-RAIL
VERY LOW-POWER OPERATIONAL AMPLIFIERS

SLOS176D – FEBRUARY 1997 – REVISED MARCH 2001

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

PARAMETER	TEST CONDITIONS	T_A †	TLC2252C			UNIT
			MIN	TYP	MAX	
V_{IO} Input offset voltage	$V_{IC} = 0,$ $V_O = 0,$ $V_{DD} \pm = \pm 2.5\text{ V},$ $R_S = 50\ \Omega$	25°C	200 1500		μV	
		Full range	1750			
$\alpha_{V_{IO}}$ Temperature coefficient of input offset voltage		25°C to 70°C	0.5		$\mu\text{V}/^\circ\text{C}$	
Input offset voltage long-term drift (see Note 4)		25°C	0.003		$\mu\text{V}/\text{mo}$	
I_{IO} Input offset current		25°C	0.5	60	pA	
		Full range	100			
I_{IB} Input bias current	25°C	1	60	pA		
	Full range	100				
V_{ICR} Common-mode input voltage range	$R_S = 50\ \Omega,$ $ V_{IO} \leq 5\text{ mV}$	25°C	0 to 4	-0.3 to 4.2	V	
		Full range	0 to 3.5			
V_{OH} High-level output voltage	$I_{OH} = -20\ \mu\text{A}$	25°C	4.98		V	
	$I_{OH} = -75\ \mu\text{A}$	25°C	4.9	4.94		
	Full range	4.8				
V_{OL} Low-level output voltage	$I_{OH} = -150\ \mu\text{A}$	25°C	4.8	4.88	V	
	$V_{IC} = 2.5\text{ V},$ $I_{OL} = 50\ \mu\text{A}$	25°C	0.01			
		Full range	0.09	0.15		
	$V_{IC} = 2.5\text{ V},$ $I_{OL} = 500\ \mu\text{A}$	25°C	0.15			
		Full range	0.2	0.3		
	$V_{IC} = 2.5\text{ V},$ $I_{OL} = 1\text{ mA}$	25°C	0.3			
Full range		0.7	1			
$V_{IC} = 2.5\text{ V},$ $I_{OL} = 4\text{ mA}$	25°C	1.2				
	Full range	1.2				
	$V_{IC} = 2.5\text{ V},$ $V_O = 1\text{ V to }4\text{ V}$	25°C	100	350	V/mV	
		Full range	10			
A_{VD} Large-signal differential voltage amplification	$R_L = 100\text{ k}\Omega^\ddagger$ $R_L = 1\text{ M}\Omega^\ddagger$	25°C	1700			
		Full range	1700			
r_{id} Differential input resistance		25°C	10^{12}		Ω	
r_{ic} Common-mode input resistance		25°C	10^{12}		Ω	
c_{ic} Common-mode input capacitance	$f = 10\text{ kHz},$ P package	25°C	8		pF	
z_o Closed-loop output impedance	$f = 25\text{ kHz},$ $A_V = 10$	25°C	200		Ω	
CMRR Common-mode rejection ratio	$V_{IC} = 0\text{ to }2.7\text{ V},$ $V_O = 2.5\text{ V},$ $R_S = 50\ \Omega$	25°C	70	83	dB	
		Full range	70			
k_{SVR} Supply-voltage rejection ratio ($\Delta V_{DD}/\Delta V_{IO}$)	$V_{DD} = 4.4\text{ V to }16\text{ V},$ $V_{IC} = V_{DD}/2,$ No load	25°C	80	95	dB	
		Full range	80			
I_{DD} Supply current	$V_O = 2.5\text{ V},$ No load	25°C	70	125	μA	
		Full range	150			

† Full range is 0°C to 70°C.

‡ Referenced to 2.5 V

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

TLC225x, TLC225xA
Advanced LinCMOS™ RAIL-TO-RAIL
VERY LOW-POWER OPERATIONAL AMPLIFIERS
SLOS176D – FEBRUARY 1997 – REVISED MARCH 2001

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

PARAMETER		TEST CONDITIONS		T_A †	TLC2252C			UNIT
					MIN	TYP	MAX	
SR	Slew rate at unity gain	$V_O = 1.5\text{ V to }3.5\text{ V}, R_L = 100\text{ k}\Omega\ddagger, C_L = 100\text{ pF}\ddagger$		25°C	0.07	0.12	V/ μs	
				Full range	0.05			
V_n	Equivalent input noise voltage	f = 10 Hz		25°C	36		nV/ $\sqrt{\text{Hz}}$	
		f = 1 kHz		25°C	19			
$V_{N(PP)}$	Peak-to-peak equivalent input noise voltage	f = 0.1 Hz to 1 Hz		25°C	0.7		μV	
		f = 0.1 Hz to 10 Hz		25°C	1.1			
I_n	Equivalent input noise current			25°C	0.6		fA/ $\sqrt{\text{Hz}}$	
THD + N	Total harmonic distortion plus noise	$V_O = 0.5\text{ V to }2.5\text{ V}, f = 10\text{ kHz}, R_L = 50\text{ k}\Omega\ddagger$		25°C	$A_V = 1$			
					$A_V = 10$			
Gain-bandwidth product		f = 10 kHz, $C_L = 100\text{ pF}\ddagger$		25°C	0.2		MHz	
B_{OM}	Maximum output-swing bandwidth	$V_{O(PP)} = 2\text{ V}, R_L = 50\text{ k}\Omega\ddagger,$		25°C	$A_V = 1, C_L = 100\text{ pF}\ddagger$		kHz	
ϕ_m	Phase margin at unity gain	$R_L = 50\text{ k}\Omega\ddagger,$			$C_L = 100\text{ pF}\ddagger$			
Gain margin				25°C	15		dB	

† Full range is 0°C to 70°C.

‡ Referenced to 2.5 V

TLC225x, TLC225xA
Advanced LinCMOS™ RAIL-TO-RAIL
VERY LOW-POWER OPERATIONAL AMPLIFIERS

SLOS176D – FEBRUARY 1997 – REVISED MARCH 2001

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

PARAMETER	TEST CONDITIONS	T_A †	TLC2252C			UNIT
			MIN	TYP	MAX	
V_{IO} Input offset voltage	$V_{IC} = 0, V_O = 0, R_S = 50 \Omega$	25°C	200	1500		μV
		Full range		1750		
α_{VIO} Temperature coefficient of input offset voltage		25°C to 70°C	0.5			$\mu V/^\circ C$
Input offset voltage long-term drift (see Note 4)		25°C	0.003			$\mu V/mo$
I_{IO} Input offset current		25°C	0.5	60		pA
		Full range		100		
I_{IB} Input bias current	25°C	1	60		pA	
	Full range		100			
V_{ICR} Common-mode input voltage range	$ V_{IO} \leq 5$ mV, $R_S = 50 \Omega$	25°C	-5 to 4	-5.3 to 4.2		V
		Full range	-5 to 3.5			
V_{OM+} Maximum positive peak output voltage	$I_O = -20 \mu A$	25°C	4.98		V	
	$I_O = -100 \mu A$	25°C	4.9	4.93		
	Full range		4.7			
V_{OM-} Maximum negative peak output voltage	$I_O = -200 \mu A$	25°C	4.8	4.86	V	
	$V_{IC} = 0, I_O = 50 \mu A$	25°C	-4.99			
		Full range	-4.85	-4.91		
	$V_{IC} = 0, I_O = 500 \mu A$	25°C	-4.85			
		Full range	-4.7	-4.8		
	$V_{IC} = 0, I_O = 1$ mA	25°C	-4.7	-4.8		
Full range		-4.7				
$V_{IC} = 0, I_O = 4$ mA	25°C	-4	-4.3			
	Full range	-3.8				
A_{VD} Large-signal differential voltage amplification	$V_O = \pm 4$ V	$R_L = 100$ k Ω	25°C	45	650	V/mV
		$R_L = 1$ M Ω	Full range	10		
			25°C		3000	
r_{id} Differential input resistance		25°C	10^{12}		Ω	
r_{ic} Common-mode input resistance		25°C	10^{12}		Ω	
c_{ic} Common-mode input capacitance	$f = 10$ kHz, P package	25°C	8		pF	
z_o Closed-loop output impedance	$f = 25$ kHz, $A_V = 10$	25°C	190		Ω	
CMRR Common-mode rejection ratio	$V_{IC} = -5$ V to 2.7 V, $V_O = 0, R_S = 50 \Omega$	25°C	75	88	dB	
		Full range	75			
kSVR Supply-voltage rejection ratio ($\Delta V_{DD\pm} / \Delta V_{IO}$)	$V_{DD\pm} = 2.2$ V to ± 8 V, $V_{IC} = 0$, No load	25°C	80	95	dB	
		Full range	80			
I_{DD} Supply current	$V_O = 0$, No load	25°C	80	125	μA	
		Full range		150		

† Full range is 0°C to 70°C.

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

TLC225x, TLC225xA
Advanced LinCMOS™ RAIL-TO-RAIL
VERY LOW-POWER OPERATIONAL AMPLIFIERS
SLOS176D – FEBRUARY 1997 – REVISED MARCH 2001

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

PARAMETER		TEST CONDITIONS		T _A †	TLC2252C			UNIT
					MIN	TYP	MAX	
SR	Slew rate at unity gain	V _O = ±1.9 V, C _L = 100 pF	R _L = 100 kΩ,	25°C	0.07	0.12	V/μs	
				Full range	0.05			
V _n	Equivalent input noise voltage	f = 10 Hz		25°C	38		nV/√Hz	
		f = 1 kHz		25°C	19			
V _{N(PP)}	Peak-to-peak equivalent input noise voltage	f = 0.1 Hz to 1 Hz		25°C	0.8		μV	
		f = 0.1 Hz to 10 Hz		25°C	1.1			
I _n	Equivalent input noise current			25°C	0.6		fA/√Hz	
THD + N	Total harmonic distortion pulse duration	V _O = ±2.3 V, f = 10 kHz, R _L = 50 kΩ	A _V = 1	25°C	0.2%			
			A _V = 10		1%			
Gain-bandwidth product		f = 10 kHz, C _L = 100 pF	R _L = 50 kΩ,	25°C	0.21		MHz	
B _{OM}	Maximum output-swing bandwidth	V _{O(PP)} = 4.6 V, R _L = 50 kΩ,	A _V = 1, C _L = 100 pF	25°C	14		kHz	
φ _m	Phase margin at unity gain	R _L = 50 kΩ, C _L = 100 pF		25°C	63°			
	Gain margin			25°C	15		dB	

† Full range is 0°C to 70°C.

TLC225x, TLC225xA
Advanced LinCMOS™ RAIL-TO-RAIL
VERY LOW-POWER OPERATIONAL AMPLIFIERS

SLOS176D – FEBRUARY 1997 – REVISED MARCH 2001

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

PARAMETER	TEST CONDITIONS	T_A †	TLC2254C			UNIT
			MIN	TYP	MAX	
V_{IO} Input offset voltage	$V_{IC} = 0,$ $V_O = 0,$ $V_{DD\pm} = \pm 2.5\text{ V},$ $R_S = 50\ \Omega$	25°C	200 1500		μV	
		Full range	1750			
α_{VIO} Temperature coefficient of input offset voltage		25°C to 70°C	0.5		$\mu\text{V}/^\circ\text{C}$	
Input offset voltage long-term drift (see Note 4)		25°C	0.003		$\mu\text{V}/\text{mo}$	
I_{IO} Input offset current		25°C	0.5 60		pA	
		Full range	100			
I_{IB} Input bias current	25°C	1 60		pA		
	Full range	100				
V_{ICR} Common-mode input voltage range	$R_S = 50\ \Omega,$ $ V_{IO} \leq 5\text{ mV}$	25°C	0 to 4	-0.3 to 4.2	V	
		Full range	0 to 3.5			
V_{OH} High-level output voltage	$I_{OH} = -20\ \mu\text{A}$	25°C	4.98		V	
	$I_{OH} = -75\ \mu\text{A}$	25°C	4.9	4.94		
	Full range	4.8				
	$I_{OH} = -150\ \mu\text{A}$	25°C	4.8	4.88		
V_{OL} Low-level output voltage	$V_{IC} = 2.5\text{ V},$ $I_{OL} = 50\ \mu\text{A}$	25°C	0.01		V	
	$V_{IC} = 2.5\text{ V},$ $I_{OL} = 500\ \mu\text{A}$	25°C	0.09	0.15		
		Full range	0.15			
	$V_{IC} = 2.5\text{ V},$ $I_{OL} = 1\text{ mA}$	25°C	0.2	0.3		
		Full range	0.3			
	$V_{IC} = 2.5\text{ V},$ $I_{OL} = 4\text{ mA}$	25°C	0.7	1		
		Full range	1.2			
	A_{VD} Large-signal differential voltage amplification	$V_{IC} = 2.5\text{ V},$ $V_O = 1\text{ V to }4\text{ V}$	$R_L = 100\ \text{k}\Omega^\ddagger$	25°C		100 350
$R_L = 1\ \text{M}\Omega^\ddagger$			Full range	10		
			25°C	1700		
$r_{i(d)}$ Differential input resistance		25°C	10^{12}		Ω	
$r_{i(c)}$ Common-mode input resistance		25°C	10^{12}		Ω	
$c_{i(c)}$ Common-mode input capacitance	$f = 10\text{ kHz},$ N package	25°C	8		pF	
z_o Closed-loop output impedance	$f = 25\text{ kHz},$ $A_V = 10$	25°C	200		Ω	
CMRR Common-mode rejection ratio	$V_{IC} = 0\text{ to }2.7\text{ V},$ $V_O = 2.5\text{ V},$ $R_S = 50\ \Omega$	25°C	70	83	dB	
		Full range	70			
k_{SVR} Supply-voltage rejection ratio ($\Delta V_{DD}/\Delta V_{IO}$)	$V_{DD} = 4.4\text{ V to }16\text{ V},$ $V_{IC} = V_{DD}/2,$ No load	25°C	80	95	dB	
		Full range	80			
I_{DD} Supply current (four amplifiers)	$V_O = 2.5\text{ V},$ No load	25°C	140	250	μA	
		Full range	300			

† Full range is 0°C to 70°C.

‡ Referenced to 2.5 V

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

TLC225x, TLC225xA
Advanced LinCMOS™ RAIL-TO-RAIL
VERY LOW-POWER OPERATIONAL AMPLIFIERS
 SLOS176D – FEBRUARY 1997 – REVISED MARCH 2001

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

PARAMETER		TEST CONDITIONS		T_A †	TLC2254C			UNIT
					MIN	TYP	MAX	
SR	Slew rate at unity gain	$V_O = 1.4\text{ V to }2.6\text{ V}$ $R_L = 100\text{ k}\Omega$ ‡, $C_L = 100\text{ pF}$ ‡		25°C	0.07	0.12	$\text{V}/\mu\text{s}$	
				Full range	0.05			
V_n	Equivalent input noise voltage			25°C	36		$\text{nV}/\sqrt{\text{Hz}}$	
				25°C	19			
$V_{N(PP)}$	Peak-to-peak equivalent input noise voltage			25°C	0.7		μV	
				25°C	1.1			
I_n	Equivalent input noise current			25°C	0.6		$\text{fA}/\sqrt{\text{Hz}}$	
THD + N	Total harmonic distortion plus noise	$V_O = 0.5\text{ V to }2.5\text{ V}$, $f = 10\text{ kHz}$, $R_L = 50\text{ k}\Omega$ ‡		25°C	$A_V = 1$			
					$A_V = 10$			
	Gain-bandwidth product	$f = 10\text{ kHz}$, $C_L = 100\text{ pF}$ ‡	$R_L = 50\text{ k}\Omega$ ‡,	25°C	0.2		MHz	
B_{OM}	Maximum output-swing bandwidth	$V_{O(PP)} = 2\text{ V}$, $R_L = 50\text{ k}\Omega$ ‡,	$A_V = 1$, $C_L = 100\text{ pF}$ ‡	25°C	30		kHz	
ϕ_m	Phase margin at unity gain	$R_L = 50\text{ k}\Omega$ ‡,	$C_L = 100\text{ pF}$ ‡	25°C	63°			
	Gain margin			25°C	15		dB	

† Full range is 0°C to 70°C.

‡ Referenced to 2.5 V

TLC225x, TLC225xA
Advanced LinCMOS™ RAIL-TO-RAIL
VERY LOW-POWER OPERATIONAL AMPLIFIERS

SLOS176D – FEBRUARY 1997 – REVISED MARCH 2001

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

PARAMETER	TEST CONDITIONS	T_A †	TLC2254C			UNIT
			MIN	TYP	MAX	
V_{IO} Input offset voltage	$V_{IC} = 0, V_O = 0, R_S = 50\ \Omega$	25°C	200	1500		μV
		Full range		1750		
α_{VIO} Temperature coefficient of input offset voltage		25°C to 70°C	0.5			$\mu\text{V}/^\circ\text{C}$
Input offset voltage long-term drift (see Note 4)		25°C	0.003			$\mu\text{V}/\text{mo}$
I_{IO} Input offset current		25°C	0.5	60		pA
		Full range		100		
I_{IB} Input bias current		25°C	1	60		pA
		Full range		100		
V_{ICR} Common-mode input voltage range	$ V_{IO} \leq 5\text{ mV}, R_S = 50\ \Omega$	25°C	-5 to 4	-5.3 to 4.2		V
		Full range	-5 to 3.5			
V_{OM+} Maximum positive peak output voltage	$I_O = -20\ \mu\text{A}$	25°C	4.98		V	
	$I_O = -100\ \mu\text{A}$	25°C	4.9	4.93		
		Full range	4.7			
	$I_O = -200\ \mu\text{A}$	25°C	4.8	4.86		
V_{OM-} Maximum negative peak output voltage	$V_{IC} = 0, I_O = 50\ \mu\text{A}$	25°C	-4.99		V	
		25°C	-4.85	-4.91		
	$V_{IC} = 0, I_O = 500\ \mu\text{A}$	Full range	-4.85			
		25°C	-4.7	-4.8		
	$V_{IC} = 0, I_O = 1\ \text{mA}$	Full range	-4.7			
		25°C	-4	-4.3		
	$V_{IC} = 0, I_O = 4\ \text{mA}$	Full range	-3.8			
A_{VD} Large-signal differential voltage amplification	$V_O = \pm 4\ \text{V}$	$R_L = 100\ \text{k}\Omega$	25°C	40	150	V/mV
		$R_L = 1\ \text{M}\Omega$	Full range	10		
			25°C		3000	
$r_{i(d)}$ Differential input resistance		25°C		10^{12}	Ω	
$r_{i(c)}$ Common-mode input resistance		25°C		10^{12}	Ω	
$c_{i(c)}$ Common-mode input capacitance	$f = 10\ \text{kHz}, N$ package	25°C		8	pF	
z_o Closed-loop output impedance	$f = 25\ \text{kHz}, A_V = 10$	25°C		190	Ω	
CMRR Common-mode rejection ratio	$V_{IC} = -5\ \text{V to } 2.7\ \text{V}, V_O = 0, R_S = 50\ \Omega$	25°C	75	88	dB	
		Full range	75			
k_{SVR} Supply-voltage rejection ratio ($\Delta V_{DD\pm} / \Delta V_{IO}$)	$V_{DD\pm} = \pm 2.2\ \text{V to } \pm 8\ \text{V}, V_{IC} = 0, \text{No load}$	25°C	80	95	dB	
		Full range	80			
I_{DD} Supply current (four amplifiers)	$V_O = 0, \text{No load}$	25°C	160	250	μA	
		Full range		300		

† Full range is 0°C to 70°C.

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

TLC225x, TLC225xA
Advanced LinCMOS™ RAIL-TO-RAIL
VERY LOW-POWER OPERATIONAL AMPLIFIERS
SLOS176D – FEBRUARY 1997 – REVISED MARCH 2001

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

PARAMETER		TEST CONDITIONS		T _A †	TLC2254C			UNIT
					MIN	TYP	MAX	
SR	Slew rate at unity gain	V _O = ±1.9 V, C _L = 100 pF	R _L = 100 kΩ,	25°C	0.07	0.12	V/μs	
				Full range	0.05			
V _n	Equivalent input noise voltage	f = 10 Hz		25°C	38		nV/√Hz	
				25°C	19			
V _{N(PP)}	Peak-to-peak equivalent input noise voltage	f = 0.1 Hz to 1 Hz		25°C	0.8		μV	
				25°C	1.1			
I _n	Equivalent input noise current			25°C	0.6		fA/√Hz	
THD + N	Total harmonic distortion plus noise	V _O = ±2.3 V, f = 20 kHz, R _L = 50 kΩ	A _V = 1	25°C	0.2%			
					A _V = 10	1%		
Gain-bandwidth product		f = 10 kHz, C _L = 100 pF	R _L = 50 kΩ,	25°C	0.21		MHz	
BOM	Maximum output-swing bandwidth	V _{O(PP)} = 4.6 V, R _L = 50 kΩ,	A _V = 1, C _L = 100 pF	25°C	14		kHz	
φ _m	Phase margin at unity gain	R _L = 50 kΩ, C _L = 100 pF		25°C	63°			
	Gain margin			25°C	15		dB	

† Full range is 0°C to 70°C.

TLC225x, TLC225xA

Advanced LinCMOS™ RAIL-TO-RAIL

VERY LOW-POWER OPERATIONAL AMPLIFIERS

SLOS176D – FEBRUARY 1997 – REVISED MARCH 2001

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

PARAMETER	TEST CONDITIONS	T_A †	TLC2252I			TLC2252AI			UNIT	
			MIN	TYP	MAX	MIN	TYP	MAX		
V_{IO} Input offset voltage		25°C	200		1500	200		850	μV	
		Full range	1750			1000				
α_{VIO} Temperature coefficient of input offset voltage		25°C to 85°C	0.5			0.5			$\mu\text{V}/^\circ\text{C}$	
Input offset voltage long-term drift (see Note 4)	$V_{DD\pm} = \pm 2.5\text{ V}$, $V_{IC} = 0$, $V_O = 0$, $R_S = 50\ \Omega$	25°C	0.003			0.003			$\mu\text{V}/\text{mo}$	
I_{IO} Input offset current		25°C	0.5		60	0.5		60	pA	
		Full range	1000			1000				
I_{IB} Input bias current		25°C	1		60	1		60	pA	
	Full range	1000			1000					
V_{ICR} Common-mode input voltage range	$R_S = 50\ \Omega$, $ V_{IO} \leq 5\text{ mV}$	25°C	0 to 4	-0.3 to 4.2	0 to 4	-0.3 to 4.2			V	
		Full range	0 to 3.5		0 to 3.5					
V_{OH} High-level output voltage	$I_{OH} = -20\ \mu\text{A}$	25°C	4.98		4.98				V	
	$I_{OH} = -75\ \mu\text{A}$	25°C	4.9	4.94	4.9	4.94				
	Full range	4.8		4.8						
	$I_{OH} = -150\ \mu\text{A}$	25°C	4.8	4.88	4.8	4.88				
V_{OL} Low-level output voltage	$V_{IC} = 2.5\text{ V}$, $I_{OL} = 50\ \mu\text{A}$	25°C	0.01		0.01				V	
	$V_{IC} = 2.5\text{ V}$, $I_{OL} = 500\ \mu\text{A}$	25°C	0.09	0.15	0.09	0.15				
	Full range	0.15		0.15						
	$V_{IC} = 2.5\text{ V}$, $I_{OL} = 4\text{ mA}$	25°C	0.8	1	0.7	1				
Full range	1.2		1.2							
AVD Large-signal differential voltage amplification	$V_{IC} = 2.5\text{ V}$, $V_O = 1\text{ V to }4\text{ V}$	$R_L = 100\text{ k}\Omega$ ‡	25°C	100	350	100	350			V/mV
			Full range	10		10				
		$R_L = 1\text{ M}\Omega$ ‡	25°C	1700		1700				
r_{id} Differential input resistance		25°C	10^{12}		10^{12}				Ω	
r_{ic} Common-mode input resistance		25°C	10^{12}		10^{12}				Ω	
C_{ic} Common-mode input capacitance	$f = 10\text{ kHz}$, P package	25°C	8		8				pF	
z_o Closed-loop output impedance	$f = 25\text{ kHz}$, $A_V = 10$	25°C	200		200				Ω	
CMRR Common-mode rejection ratio	$V_{IC} = 0\text{ to }2.7\text{ V}$, $V_O = 2.5\text{ V}$, $R_S = 50\ \Omega$	25°C	70	83	70	83			dB	
		Full range	70		70					
k_{SVR} Supply-voltage rejection ratio ($\Delta V_{DD}/\Delta V_{IO}$)	$V_{DD} = 4.4\text{ V to }16\text{ V}$, $V_{IC} = V_{DD}/2$, No load	25°C	80	95	80	95			dB	
		Full range	80		80					
I_{DD} Supply current	$V_O = 2.5\text{ V}$, No load	25°C	70	125	70	125			μA	
		Full range	150		150					

† Full range is -40°C to 125°C .

‡ Referenced to 2.5 V

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

TLC225x, TLC225xA
Advanced LinCMOS™ RAIL-TO-RAIL
VERY LOW-POWER OPERATIONAL AMPLIFIERS
SLOS176D – FEBRUARY 1997 – REVISED MARCH 2001

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

PARAMETER	TEST CONDITIONS	T_A †	TLC2252I			TLC2252AI			UNIT	
			MIN	TYP	MAX	MIN	TYP	MAX		
SR	Slew rate at unity gain $V_O = 1.5\text{ V to }3.5\text{ V}$, $R_L = 100\text{ k}\Omega$ ‡, $C_L = 100\text{ pF}$ ‡	25°C	0.07	0.12		0.07	0.12		$\text{V}/\mu\text{s}$	
		Full range	0.05			0.05				
V_n	Equivalent input noise voltage	$f = 10\text{ Hz}$	25°C		36		36		$\text{nV}/\sqrt{\text{Hz}}$	
		$f = 1\text{ kHz}$	25°C		19		19			
$V_{N(PP)}$	Peak-to-peak equivalent input noise voltage	$f = 0.1\text{ Hz to }1\text{ Hz}$	25°C		0.7		0.7		μV	
		$f = 0.1\text{ Hz to }10\text{ Hz}$	25°C		1.1		1.1			
I_n	Equivalent input noise current		25°C		0.6		0.6	$\text{fA}/\sqrt{\text{Hz}}$		
THD + N	Total harmonic distortion plus noise $V_O = 0.5\text{ V to }2.5\text{ V}$, $f = 10\text{ kHz}$, $R_L = 50\text{ k}\Omega$ ‡	$A_V = 1$	25°C	0.2%			0.2%			
		$A_V = 10$		1%			1%			
	Gain-bandwidth product $f = 50\text{ kHz}$, $C_L = 100\text{ pF}$ ‡	$R_L = 50\text{ k}\Omega$ ‡	25°C		0.2		0.2	MHz		
BOM	Maximum output-swing bandwidth $V_{O(PP)} = 2\text{ V}$, $R_L = 50\text{ k}\Omega$ ‡	$A_V = 1$, $R_L = 50\text{ k}\Omega$ ‡	25°C		30		30	kHz		
ϕ_m	Phase margin at unity gain $R_L = 50\text{ k}\Omega$ ‡, $C_L = 100\text{ pF}$ ‡	25°C		63°		63°				
		25°C		15		15		dB		

† Full range is -40°C to 125°C .

‡ Referenced to 2.5 V

TLC225x, TLC225xA
Advanced LinCMOS™ RAIL-TO-RAIL
VERY LOW-POWER OPERATIONAL AMPLIFIERS

SLOS176D – FEBRUARY 1997 – REVISED MARCH 2001

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

PARAMETER	TEST CONDITIONS	T_A †	TLC2252I			TLC2252AI			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
V_{IO} Input offset voltage	$V_{IC} = 0, V_O = 0, R_S = 50\ \Omega$	25°C	200		1500	200		850	μV
		Full range	1750			1000			
α_{VIO} Temperature coefficient of input offset voltage		25°C to 85°C	0.5			0.5			$\mu\text{V}/^\circ\text{C}$
Input offset voltage long-term drift (see Note 4)		25°C	0.003			0.003			$\mu\text{V}/\text{mo}$
I_{IO} Input offset current		25°C	0.5	60		0.5	60		pA
		Full range	1000			1000			
I_{IB} Input bias current	25°C	1	60		1	60		pA	
	Full range	1000			1000				
V_{ICR} Common-mode input voltage range	$R_S = 50\ \Omega, V_{IO} \leq 5\ \text{mV}$	25°C	-5 to 4	-5.3 to 4.2		-5 to 4	-5.3 to 4.2	V	
		Full range	-5 to 3.5			-5 to 3.5			
V_{OM+} Maximum positive peak output voltage	$I_O = -20\ \mu\text{A}$	25°C	4.98		4.98		V		
	$I_O = -100\ \mu\text{A}$	25°C	4.9	4.93	4.9	4.93			
		Full range	4.7		4.7				
	$I_O = -200\ \mu\text{A}$	25°C	4.8	4.86	4.8	4.86			
V_{OM-} Maximum negative peak output voltage	$V_{IC} = 0, I_O = 50\ \mu\text{A}$	25°C	-4.99		-4.99		V		
	$V_{IC} = 0, I_O = 500\ \mu\text{A}$	25°C	-4.85	-4.91	-4.85	-4.91			
		Full range	-4.85		-4.85				
	$V_{IC} = 0, I_O = 4\ \text{mA}$	25°C	-4	-4.3	-4	-4.3			
		Full range	-3.8		-3.8				
	A_{VD} Large-signal differential voltage amplification	$V_O = \pm 4\ \text{V}$	$R_L = 50\ \text{k}\Omega$	25°C	40	150		40	150
Full range				10		10			
$R_L = 1\ \text{M}\Omega$			25°C	3000		3000			
r_{id} Differential input resistance		25°C	10 ¹²		10 ¹²		Ω		
r_{ic} Common-mode input resistance		25°C	10 ¹²		10 ¹²		Ω		
c_{ic} Common-mode input capacitance	f = 10 kHz, P package	25°C	8		8		pF		
z_o Closed-loop output impedance	f = 25 kHz, $A_V = 10$	25°C	190		190		Ω		
CMRR Common-mode rejection ratio	$V_{IC} = -5\ \text{V to } 2.7\ \text{V}, V_O = 0, R_S = 50\ \Omega$	25°C	75	88	75	88	dB		
		Full range	75		75				
k_{SVR} Supply-voltage rejection ratio ($\Delta V_{DD\pm} / \Delta V_{IO}$)	$V_{DD} = 4.4\ \text{V to } 16\ \text{V}, V_{IC} = V_{DD}/2, \text{ No load}$	25°C	80	95	80	95	dB		
		Full range	80		80				
I_{DD} Supply current	$V_O = 2.5\ \text{V}, \text{ No load}$	25°C	80	125	80	125	μA		
		Full range	150		150				

† Full range is -40°C to 125°C.

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

TLC225x, TLC225xA
Advanced LinCMOS™ RAIL-TO-RAIL
VERY LOW-POWER OPERATIONAL AMPLIFIERS
 SLOS176D – FEBRUARY 1997 – REVISED MARCH 2001

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

PARAMETER	TEST CONDITIONS	T_A †	TLC2252I			TLC2252AI			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
SR	Slew rate at unity gain $V_O = \pm 1.9\text{ V}$, $R_L = 100\text{ k}\Omega$, $C_L = 100\text{ pF}$	25°C	0.07	0.12		0.07	0.12		$\text{V}/\mu\text{s}$
		Full range	0.05			0.05			
V_n	Equivalent input noise voltage	$f = 10\text{ Hz}$	25°C		38		38		$\text{nV}/\sqrt{\text{Hz}}$
		$f = 1\text{ kHz}$	25°C		19		19		
$V_{N(PP)}$	Peak-to-peak equivalent input noise voltage	$f = 0.1\text{ Hz to }1\text{ Hz}$	25°C		0.8		0.8		μV
		$f = 0.1\text{ Hz to }10\text{ Hz}$	25°C		1.1		1.1		
I_n	Equivalent input noise current		25°C		0.6		0.6		$\text{fA}/\sqrt{\text{Hz}}$
THD + N	Total harmonic distortion plus noise	$V_O = \pm 2.3\text{ V}$, $R_L = 50\text{ k}\Omega$, $f = 10\text{ kHz}$	$A_V = 1$	25°C		0.2%		0.2%	
			$A_V = 10$			1%		1%	
	Gain-bandwidth product	$f = 10\text{ kHz}$, $R_L = 50\text{ k}\Omega$, $C_L = 100\text{ pF}$	25°C		0.21		0.21		MHz
B_{OM}	Maximum output-swing bandwidth	$V_{O(PP)} = 4.6\text{ V}$, $A_V = 1$, $R_L = 50\text{ k}\Omega$, $C_L = 100\text{ pF}$	25°C		14		14		kHz
ϕ_m	Phase margin at unity gain	$R_L = 50\text{ k}\Omega$, $C_L = 100\text{ pF}$	25°C		63°		63°		
			25°C		15		15		dB

† Full range is -40°C to 125°C .

TLC225x, TLC225xA
Advanced LinCMOS™ RAIL-TO-RAIL
VERY LOW-POWER OPERATIONAL AMPLIFIERS

SLOS176D – FEBRUARY 1997 – REVISED MARCH 2001

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

PARAMETER	TEST CONDITIONS	T_A †	TLC2254I			TLC2254AI			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
V_{IO} Input offset voltage	$V_{DD} \pm \pm 2.5\text{ V}$, $V_{IC} = 0$, $V_O = 0$, $R_S = 50\ \Omega$	25°C	200 1500		200 850		μV		
		Full range	1750			1000			
αV_{IO} Temperature coefficient of input offset voltage		25°C to 125°C	0.5		0.5		$\mu\text{V}/^\circ\text{C}$		
Input offset voltage long-term drift (see Note 4)		25°C	0.003		0.003		$\mu\text{V}/\text{mo}$		
I_{IO} Input offset current		25°C	0.5	60	0.5	60	pA		
		Full range	1000			1000			
I_{IB} Input bias current	25°C	1	60	1	60	pA			
	Full range	1000			1000				
V_{ICR} Common-mode input voltage range	$R_S = 50\ \Omega$, $ V_{IO} \leq 5\text{ mV}$	25°C	0 to 4	-0.3 to 4.2	0 to 4	-0.3 to 4.2	V		
		Full range	0 to 3.5		0 to 3.5				
V_{OH} High-level output voltage	$I_{OH} = -20\ \mu\text{A}$	25°C	4.98		4.98		V		
		25°C	4.9	4.94	4.9	4.94			
		Full range	4.8			4.8			
		$I_{OH} = -150\ \mu\text{A}$	25°C	4.8	4.88	4.8		4.88	
V_{OL} Low-level output voltage	$V_{IC} = 2.5\text{ V}$, $I_{OL} = 50\ \mu\text{A}$	25°C	0.01		0.01		V		
		25°C	0.09	0.15	0.09	0.15			
	Full range	0.15			0.15				
	$V_{IC} = 2.5\text{ V}$, $I_{OL} = 4\text{ mA}$	25°C	0.8	1	0.7	1			
		Full range	1.2			1.2			
A_{VD} Large-signal differential voltage amplification	$V_{IC} = 2.5\text{ V}$, $V_O = 1\text{ V to }4\text{ V}$	$R_L = 100\text{ k}\Omega$ ‡	25°C	100	350	100	350	V/mV	
			Full range	10			10		
		$R_L = 1\text{ M}\Omega$ ‡	25°C	1700			1700		
$r_{i(d)}$ Differential input resistance		25°C	1012		1012		Ω		
$r_{i(c)}$ Common-mode input resistance		25°C	1012		1012		Ω		
$C_{i(c)}$ Common-mode input capacitance	$f = 10\text{ kHz}$, N package	25°C	8		8		pF		
z_o Closed-loop output impedance	$f = 25\text{ kHz}$, $A_V = 10$	25°C	200		200		Ω		
CMRR Common-mode rejection ratio	$V_{IC} = 0\text{ to }2.7\text{ V}$, $V_O = 2.5\text{ V}$, $R_S = 50\ \Omega$	25°C	70	83	70	83	dB		
		Full range	70			70			
kSVR Supply-voltage rejection ratio ($\Delta V_{DD}/\Delta V_{IO}$)	$V_{DD} = 4.4\text{ V to }16\text{ V}$, $V_{IC} = V_{DD}/2$, No load	25°C	80	95	80	95	dB		
		Full range	80			80			
I_{DD} Supply current (four amplifiers)	$V_O = 2.5\text{ V}$, No load	25°C	140	250	140	250	μA		
		Full range	300			300			

† Full range is -40°C to 125°C .

‡ Referenced to 2.5 V

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

TLC225x, TLC225xA
Advanced LinCMOS™ RAIL-TO-RAIL
VERY LOW-POWER OPERATIONAL AMPLIFIERS
 SLOS176D – FEBRUARY 1997 – REVISED MARCH 2001

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

PARAMETER	TEST CONDITIONS	T_A †	TLC2254I			TLC2254AI			UNIT	
			MIN	TYP	MAX	MIN	TYP	MAX		
SR	Slew rate at unity gain $V_O = 1.4\text{ V to }2.6\text{ V}$, $R_L = 100\text{ k}\Omega$ ‡, $C_L = 100\text{ pF}$ ‡	25°C	0.07	0.12		0.07	0.12		$\text{V}/\mu\text{s}$	
		Full range	0.05			0.05				
V_n	Equivalent input noise voltage	$f = 10\text{ Hz}$	25°C		36		36		$\text{nV}/\sqrt{\text{Hz}}$	
		$f = 1\text{ kHz}$	25°C		19		19			
$V_{N(PP)}$	Peak-to-peak equivalent input noise voltage	$f = 0.1\text{ Hz to }1\text{ Hz}$	25°C		0.7		0.7		μV	
		$f = 0.1\text{ Hz to }10\text{ Hz}$	25°C		1.1		1.1			
I_n	Equivalent input noise current		25°C		0.6		0.6	$\text{fA}/\sqrt{\text{Hz}}$		
THD + N	Total harmonic distortion plus noise $V_O = 0.5\text{ V to }2.5\text{ V}$, $f = 20\text{ kHz}$, $R_L = 50\text{ k}\Omega$ ‡	$A_V = 1$	25°C	0.2%			0.2%			
		$A_V = 10$		1%			1%			
	Gain-bandwidth product $f = 50\text{ kHz}$, $C_L = 100\text{ pF}$ ‡	$R_L = 50\text{ k}\Omega$ ‡	25°C	0.2			0.2			MHz
BOM	Maximum output-swing bandwidth $V_{O(PP)} = 2\text{ V}$, $R_L = 50\text{ k}\Omega$ ‡	$A_V = 1$, $C_L = 100\text{ pF}$ ‡	25°C	30			30			kHz
ϕ_m	Phase margin at unity gain $R_L = 50\text{ k}\Omega$ ‡	$C_L = 100\text{ pF}$ ‡	25°C	63°			63°			
			25°C	15			15			dB

† Full range is -40°C to 125°C .

‡ Referenced to 2.5 V

TLC225x, TLC225xA
Advanced LinCMOS™ RAIL-TO-RAIL
VERY LOW-POWER OPERATIONAL AMPLIFIERS

SLOS176D – FEBRUARY 1997 – REVISED MARCH 2001

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

PARAMETER	TEST CONDITIONS	T _A †	TLC2254I			TLC2254AI			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
V _{IO} Input offset voltage		25°C	200	1500		200	850	μV	
		Full range		1750		1000			
αV _{IO} Temperature coefficient of input offset voltage		25°C to 125°C	0.5			0.5			μV/°C
Input offset voltage long-term drift (see Note 4)	V _{IC} = 0, V _O = 0, R _S = 50 Ω	25°C	0.003			0.003			μV/mo
I _{IO} Input offset current		25°C	0.5	60		0.5	60	pA	
		Full range		1000		1000			
I _{IB} Input bias current		25°C	1	60		1	60	pA	
		Full range		1000		1000			
V _{ICR} Common-mode input voltage range	R _S = 50 Ω, V _{IO} ≤ 5 mV	25°C	-5 to 4	-5.3 to 4.2		-5 to 4	-5.3 to 4.2	V	
		Full range	-5 to 3.5			-5 to 3.5			
V _{OM+} Maximum positive peak output voltage	I _O = -20 μA	25°C	4.98			4.98			V
	I _O = -100 μA	25°C	4.9	4.93		4.9	4.93		
		Full range	4.7			4.7			
	I _O = -200 μA	25°C	4.8	4.86		4.8	4.86		
V _{OM-} Maximum negative peak output voltage	V _{IC} = 0, I _O = 50 μA	25°C	-4.99			-4.99			V
	V _{IC} = 0, I _O = 500 μA	25°C	-4.85	-4.91		-4.85	-4.91		
		Full range	-4.85			-4.85			
	V _{IC} = 0, I _O = 4 mA	25°C	-4	-4.3		-4	-4.3		
		Full range	-3.8			-3.8			
	A _{VD} Large-signal differential voltage amplification	V _O = ±4 V	R _L = 100 kΩ	25°C	40	150		40	
Full range				10			10		
R _L = 1 MΩ			25°C	3000			3000		
r _{i(d)} Differential input resistance		25°C	10 ¹²			10 ¹²			Ω
r _{i(c)} Common-mode input resistance		25°C	10 ¹²			10 ¹²			Ω
c _{i(c)} Common-mode input capacitance	f = 10 kHz, N package	25°C	8			8			pF
z _o Closed-loop output impedance	f = 25 kHz, A _V = 10	25°C	190			190			Ω
CMRR Common-mode rejection ratio	V _{IC} = -5 V to 2.7 V, V _O = 0, R _S = 50 Ω	25°C	75	88		75	88	dB	
		Full range	75			75			
k _{SVR} Supply-voltage rejection ratio (ΔV _{DD±} /ΔV _{IO})	V _{DD±} = ±2.2 V to ±8 V, V _{IC} = V _{DD} /2, No load	25°C	80	95		80	95	dB	
		Full range	80			80			
I _{DD} Supply current (four amplifiers)	V _O = 0, No load	25°C	160	250		160	250	μA	
		Full range	300			300			

† Full range is -40°C to 125°C.

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.

TLC225x, TLC225xA
Advanced LinCMOS™ RAIL-TO-RAIL
VERY LOW-POWER OPERATIONAL AMPLIFIERS
 SLOS176D – FEBRUARY 1997 – REVISED MARCH 2001

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

PARAMETER	TEST CONDITIONS	T_A †	TLC2254I			TLC2254AI			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
SR	Slew rate at unity gain $V_O = \pm 1.9\text{ V}$, $C_L = 100\text{ pF}$, $R_L = 100\text{ k}\Omega$	25°C	0.07	0.12		0.07	0.12		$\text{V}/\mu\text{s}$
		Full range	0.05			0.05			
V_n	Equivalent input noise voltage	$f = 10\text{ Hz}$	25°C		38		38		$\text{nV}/\sqrt{\text{Hz}}$
		$f = 1\text{ kHz}$	25°C		19		19		
$V_{N(PP)}$	Peak-to-peak equivalent input noise voltage	$f = 0.1\text{ Hz to }1\text{ Hz}$	25°C		0.8		0.8		μV
		$f = 0.1\text{ Hz to }10\text{ Hz}$	25°C		1.1		1.1		
I_n	Equivalent input noise current		25°C		0.6		0.6	$\text{fA}/\sqrt{\text{Hz}}$	
THD + N	Total harmonic distortion plus noise	$V_O = \pm 2.3\text{ V}$, $R_L = 50\text{ k}\Omega$, $f = 20\text{ kHz}$	25°C	$A_V = 1$		0.2%		0.2%	
				$A_V = 10$		1%		1%	
	Gain-bandwidth product	$f = 10\text{ kHz}$, $C_L = 100\text{ pF}$	25°C		0.21		0.21	MHz	
BOM	Maximum output-swing bandwidth	$V_{O(PP)} = 4.6\text{ V}$, $R_L = 50\text{ k}\Omega$	25°C		14		14	kHz	
ϕ_m	Phase margin at unity gain	$R_L = 50\text{ k}\Omega$, $C_L = 100\text{ pF}$	25°C		63°		63°		
			25°C		15		15	dB	

† Full range is -40°C to 125°C .

TLC225x, TLC225xA
Advanced LinCMOS™ RAIL-TO-RAIL
VERY LOW-POWER OPERATIONAL AMPLIFIERS

SLOS176D – FEBRUARY 1997 – REVISED MARCH 2001

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

PARAMETER	TEST CONDITIONS	T_A †	TLC2252Q TLC2252M			TLC2252AQ TLC2252AM			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
V_{IO} Input offset voltage	$V_{DD\pm} = \pm 2.5\text{ V}$, $V_O = 0$, $V_{IC} = 0$, $R_S = 50\ \Omega$	25°C	200 1500		200 850		μV		
		Full range	1750		1000				
α_{VIO} Temperature coefficient of input offset voltage		25°C to 125°C	0.5		0.5		$\mu\text{V}/^\circ\text{C}$		
Input offset voltage long-term drift (see Note 4)		25°C	0.003		0.003		$\mu\text{V}/\text{mo}$		
I_{IO} Input offset current		25°C	0.5	60	0.5	60	pA		
		Full range	1000		1000				
I_{IB} Input bias current	25°C	1	60	1	60	pA			
	Full range	1000		1000					
V_{ICR} Common-mode input voltage range	$R_S = 50\ \Omega$, $ V_{IO} \leq 5\text{ mV}$	25°C	0 to 4	-0.3 to 4.2	0 to 4	-0.3 to 4.2	V		
		Full range	0 to 3.5		0 to 3.5				
V_{OH} High-level output voltage	$I_{OH} = -20\ \mu\text{A}$	25°C	4.98		4.98		V		
	$I_{OH} = -75\ \mu\text{A}$	25°C	4.9	4.94	4.9	4.94			
	Full range	4.8		4.8					
V_{OL} Low-level output voltage	$I_{OH} = -150\ \mu\text{A}$	25°C	4.8	4.88	4.8	4.88	V		
	$V_{IC} = 2.5\text{ V}$, $I_{OL} = 50\ \mu\text{A}$	25°C	0.01		0.01				
		Full range	0.09 0.15		0.09 0.15				
	$V_{IC} = 2.5\text{ V}$, $I_{OL} = 500\ \mu\text{A}$	25°C	0.01		0.01				
Full range		0.09 0.15		0.09 0.15					
AVD Large-signal differential voltage amplification	$V_{IC} = 2.5\text{ V}$, $V_O = 1\text{ V to }4\text{ V}$	$R_L = 100\ \text{k}\Omega$ ‡	25°C	100	350	100	350	V/mV	
			Full range	10		10			
		$R_L = 1\ \text{M}\Omega$ ‡	25°C	1700		1700			
			Full range	1.2		1.2			
r_{id} Differential input resistance		25°C	10^{12}		10^{12}		Ω		
r_{ic} Common-mode input resistance		25°C	10^{12}		10^{12}		Ω		
C_{ic} Common-mode input capacitance	$f = 10\ \text{kHz}$, $f = 10\ \text{kHz}$	25°C	8		8		pF		
Z_o Closed-loop output impedance	$f = 25\ \text{kHz}$, $A_V = 10$	25°C	200		200		Ω		
CMRR Common-mode rejection ratio	$V_{IC} = 0\text{ to }2.7\text{ V}$, $V_O = 2.5\text{ V}$, $R_S = 50\ \Omega$	25°C	70	83	70	83	dB		
		Full range	70		70				
k_{SVR} Supply-voltage rejection ratio ($\Delta V_{DD}/\Delta V_{IO}$)	$V_{DD} = 4.4\text{ V to }16\text{ V}$, $V_{IC} = V_{DD}/2$, No load	25°C	80	95	80	95	dB		
		Full range	80		80				
I_{DD} Supply current	$V_O = 2.5\text{ V}$, No load	25°C	70	125	70	125	μA		
		Full range	150		150				

† Full range is -40°C to 125°C for Q suffix, -55°C to 125°C for M suffix.

‡ Referenced to 2.5 V

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

TLC225x, TLC225xA
Advanced LinCMOS™ RAIL-TO-RAIL
VERY LOW-POWER OPERATIONAL AMPLIFIERS
 SLOS176D – FEBRUARY 1997 – REVISED MARCH 2001

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

PARAMETER	TEST CONDITIONS	T_A †	TLC2252Q TLC2252M			TLC2252AQ TLC2252AM			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
SR	Slew rate at unity gain $V_O = 0.5\text{ V to }3.5\text{ V}$, $R_L = 100\text{ k}\Omega$ ‡, $C_L = 100\text{ pF}$ ‡	25°C	0.07	0.12		0.07	0.12		V/ μs
		Full range	0.05			0.05			
V_n	Equivalent input noise voltage	f = 10 Hz		36			36		nV/ $\sqrt{\text{Hz}}$
		f = 1 kHz		19			19		
$V_{N(PP)}$	Peak-to-peak equivalent input noise voltage	f = 0.1 Hz to 1 Hz		0.7			0.7		μV
		f = 0.1 Hz to 10 Hz		1.1			1.1		
I_n	Equivalent input noise current	25°C		0.6			0.6	fA/ $\sqrt{\text{Hz}}$	
THD + N	Total harmonic distortion plus noise $V_O = 0.5\text{ V to }2.5\text{ V}$, f = 10 kHz, $R_L = 50\text{ k}\Omega$ ‡	$A_V = 1$		0.2%			0.2%		
		$A_V = 10$		1%			1%		
	Gain-bandwidth product	f = 50 kHz, $C_L = 100\text{ pF}$ ‡	$R_L = 50\text{ k}\Omega$ ‡,	25°C	0.2		0.2		MHz
BOM	Maximum output-swing bandwidth	$V_{O(PP)} = 2\text{ V}$, $R_L = 50\text{ k}\Omega$ ‡,	$A_V = 1$, $C_L = 100\text{ pF}$ ‡	25°C	30		30		kHz
ϕ_m	Phase margin at unity gain	$R_L = 50\text{ k}\Omega$ ‡,	$C_L = 100\text{ pF}$ ‡	25°C	63°		63°		
				25°C	15		15		dB
	Gain margin			25°C	15		15		dB

† Full range is – 40°C to 125°C for Q suffix, – 55°C to 125°C for M suffix.

‡ Referenced to 2.5 V

TLC225x, TLC225xA
Advanced LinCMOS™ RAIL-TO-RAIL
VERY LOW-POWER OPERATIONAL AMPLIFIERS

SLOS176D – FEBRUARY 1997 – REVISED MARCH 2001

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

PARAMETER	TEST CONDITIONS	T_A †	TLC2252Q TLC2252M			TLC2252AQ TLC2252AM			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
V_{IO} Input offset voltage	$V_{IC} = 0, V_O = 0,$ $R_S = 50 \Omega$	25°C	200 1500		200 850		μV		
		Full range	1750		1000				
α_{VIO} Temperature coefficient of input offset voltage		25°C to 125°C	0.5		0.5		$\mu V/^\circ C$		
Input offset voltage long-term drift (see Note 4)		25°C	0.003		0.003		$\mu V/mo$		
I_{IO} Input offset current		25°C	0.5	60	0.5	60	pA		
		Full range	1000		1000				
I_{IB} Input bias current	25°C	1	60	1	60	pA			
	Full range	1000		1000					
V_{ICR} Common-mode input voltage range	$R_S = 50 \Omega, V_{IO} \leq 5 mV$	25°C	-5 to 4	-5.3 to 4.2	-5 to 4	-5.3 to 4.2	V		
		Full range	-5 to 3.5		-5 to 3.5				
V_{OM+} Maximum positive peak output voltage	$I_O = -20 \mu A$	25°C	4.98		4.98		V		
	$I_O = -100 \mu A$	25°C	4.9	4.93	4.9	4.93			
		Full range	4.7		4.7				
	$I_O = -200 \mu A$	25°C	4.8	4.86	4.8	4.86			
V_{OM-} Maximum negative peak output voltage	$V_{IC} = 0, I_O = 50 \mu A$	25°C	-4.99		-4.99		V		
	$V_{IC} = 0, I_O = 500 \mu A$	25°C	-4.85	-4.91	-4.85	-4.91			
		Full range	-4.85		-4.85				
	$V_{IC} = 0, I_O = 4 mA$	25°C	-4	-4.3	-4	-4.3			
		Full range	-3.8		-3.8				
A_{VD} Large-signal differential voltage amplification	$V_O = \pm 4 V$	$R_L = 100 k\Omega$	25°C	40	150	40	150	V/mV	
			Full range	10		10			
		$R_L = 1 M\Omega$	25°C	3000		3000			
r_{id} Differential input resistance		25°C	1012		1012		Ω		
r_{ic} Common-mode input resistance		25°C	1012		1012		Ω		
c_{ic} Common-mode input capacitance	f = 10 kHz, P package	25°C	8		8		pF		
z_o Closed-loop output impedance	f = 25 kHz, $A_V = 10$	25°C	190		190		Ω		
CMRR Common-mode rejection ratio	$V_{IC} = -5 V$ to 2.7 V, $V_O = 0, R_S = 50 \Omega$	25°C	75	88	75	88	dB		
		Full range	75		75				
k_{SVR} Supply-voltage rejection ratio ($\Delta V_{DD\pm} / \Delta V_{IO}$)	$V_{DD} = \pm 2.2 V$ to $\pm 8 V,$ $V_{IC} = 0,$ No load	25°C	80	95	80	95	dB		
		Full range	80		80				
I_{DD} Supply current	$V_O = 2.5 V,$ No load	25°C	80	125	80	125	μA		
		Full range	150		150				

† Full range is -40°C to 125°C for Q suffix, -55°C to 125°C for M suffix.

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

TLC225x, TLC225xA
Advanced LinCMOS™ RAIL-TO-RAIL
VERY LOW-POWER OPERATIONAL AMPLIFIERS
 SLOS176D – FEBRUARY 1997 – REVISED MARCH 2001

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

PARAMETER	TEST CONDITIONS	T_A †	TLC2252Q TLC2252M			TLC2252AQ TLC2252AM			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
SR	Slew rate at unity gain $V_O = \pm 2\text{ V}$, $C_L = 100\text{ pF}$, $R_L = 100\text{ k}\Omega$	25°C	0.07	0.12		0.07	0.12		V/ μ s
		Full range	0.05			0.05			
V_n	Equivalent input noise voltage	f = 10 Hz		38			38		nV/ $\sqrt{\text{Hz}}$
		f = 1 kHz	25°C		19		19		
$V_{N(PP)}$	Peak-to-peak equivalent input noise voltage	f = 0.1 Hz to 1 Hz	25°C		0.8		0.8		μ V
		f = 0.1 Hz to 10 Hz	25°C		1.1		1.1		
I_n	Equivalent input noise current		25°C		0.6		0.6	fA/ $\sqrt{\text{Hz}}$	
THD + N	Total harmonic distortion plus noise $V_O = \pm 2.3\text{ V}$, $R_L = 50\text{ k}\Omega$, f = 10 kHz	$A_V = 1$	25°C		0.2%		0.2%		
		$A_V = 10$			1%		1%		
	Gain-bandwidth product	f = 10 kHz, $C_L = 100\text{ pF}$, $R_L = 50\text{ k}\Omega$	25°C		0.21		0.21	MHz	
BOM	Maximum output-swing bandwidth	$V_{O(PP)} = 4.6\text{ V}$, $R_L = 50\text{ k}\Omega$, $A_V = 1$, $C_L = 100\text{ pF}$	25°C		14		14	kHz	
ϕ_m	Phase margin at unity gain	$R_L = 50\text{ k}\Omega$, $C_L = 100\text{ pF}$	25°C		63°		63°		
	Gain margin		25°C		15		15	dB	

† Full range is – 40°C to 125°C for Q suffix, – 55°C to 125°C for M suffix.

TLC225x, TLC225xA
Advanced LinCMOS™ RAIL-TO-RAIL
VERY LOW-POWER OPERATIONAL AMPLIFIERS

SLOS176D – FEBRUARY 1997 – REVISED MARCH 2001

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

PARAMETER	TEST CONDITIONS	T_A †	TLC2254Q TLC2254M			TLC2254AQ TLC2254AM			UNIT	
			MIN	TYP	MAX	MIN	TYP	MAX		
V_{IO} Input offset voltage	$V_{DD\pm} = \pm 2.5\text{ V}$, $V_{IC} = 0$, $V_O = 0$, $R_S = 50\ \Omega$	25°C	200		1500	200		850	μV	
		Full range	1750			1000				
$\alpha_{V_{IO}}$ Temperature coefficient of input offset voltage		25°C to 125°C	0.5			0.5			$\mu\text{V}/^\circ\text{C}$	
Input offset voltage long-term drift (see Note 4)		25°C	0.003			0.003			$\mu\text{V}/\text{mo}$	
I_{IO} Input offset current		25°C	0.5	60		0.5	60		pA	
		125°C	1000			1000				
I_{IB} Input bias current	25°C	1	60		1	60		pA		
	125°C	1000			1000					
V_{ICR} Common-mode input voltage range	$R_S = 50\ \Omega$, $ V_{IO} \leq 5\text{ mV}$	25°C	0 to 4	-0.3 to 4.2		0 to 4	-0.3 to 4.2	V		
		Full range	0 to 3.5		0 to 3.5					
V_{OH} High-level output voltage	$I_{OH} = -20\ \mu\text{A}$	25°C	4.98		4.98		V			
		25°C	4.9	4.94		4.9		4.94		
		Full range	4.8			4.8				
		25°C	4.8	4.88		4.8		4.88		
V_{OL} Low-level output voltage	$V_{IC} = 2.5\text{ V}$, $I_{OL} = 50\ \mu\text{A}$	25°C	0.01		0.01		V			
		25°C	0.09	0.15		0.09		0.15		
		Full range	0.15			0.15				
		25°C	0.8	1		0.7		1		
		Full range	1.2			1.2				
A_{VD} Large-signal differential voltage amplification	$V_{IC} = 2.5\text{ V}$, $V_O = 1\text{ V to }4\text{ V}$	$R_L = 100\ \text{k}\Omega$ ‡	25°C	100	350		100	350		V/mV
			Full range	10			10			
		$R_L = 1\ \text{M}\Omega$ ‡	25°C	1700			1700			
$r_{i(d)}$ Differential input resistance		25°C	10 ¹²			10 ¹²			Ω	
$r_{i(c)}$ Common-mode input resistance		25°C	10 ¹²			10 ¹²			Ω	
$C_{i(c)}$ Common-mode input capacitance	$f = 10\ \text{kHz}$, N package	25°C	8			8			pF	
z_o Closed-loop output impedance	$f = 25\ \text{kHz}$, $A_V = 10$	25°C	200			200			Ω	
CMRR Common-mode rejection ratio	$V_{IC} = 0\text{ to }2.7\text{ V}$, $V_O = 2.5\text{ V}$, $R_S = 50\ \Omega$	25°C	70	83		70	83		dB	
		Full range	70			70				
k_{SVR} Supply-voltage rejection ratio ($\Delta V_{DD}/\Delta V_{IO}$)	$V_{DD} = 4.4\text{ V to }16\text{ V}$, $V_{IC} = V_{DD}/2$, No load	25°C	80	95		80	95		dB	
		Full range	80			80				
I_{DD} Supply current (four amplifiers)	$V_O = 2.5\text{ V}$, No load	25°C	140	250		140	250		μA	
		Full range	300			300				

† Full range is -40°C to 125°C for Q suffix, -55°C to 125°C for M suffix.

‡ Referenced to 2.5 V

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

TLC225x, TLC225xA
Advanced LinCMOS™ RAIL-TO-RAIL
VERY LOW-POWER OPERATIONAL AMPLIFIERS
 SLOS176D – FEBRUARY 1997 – REVISED MARCH 2001

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

PARAMETER	TEST CONDITIONS	T_A †	TLC2254Q TLC2254M			TLC2254AQ TLC2254AM			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
SR	Slew rate at unity gain $V_O = 0.5\text{ V to }3.5\text{ V}$, $R_L = 100\text{ k}\Omega^\ddagger$, $C_L = 100\text{ pF}^\ddagger$	25°C	0.07	0.12		0.07	0.12		V/ μs
		Full range	0.05			0.05			
V_n	Equivalent input noise voltage	$f = 10\text{ Hz}$		36			36		nV/ $\sqrt{\text{Hz}}$
		$f = 1\text{ kHz}$		19			19		
$V_{N(PP)}$	Peak-to-peak equivalent input noise voltage	$f = 0.1\text{ Hz to }1\text{ Hz}$		0.7			0.7		μV
		$f = 0.1\text{ Hz to }10\text{ Hz}$		1.1			1.1		
I_n	Equivalent input noise current	25°C		0.6			0.6	fA/ $\sqrt{\text{Hz}}$	
THD + N	Total harmonic distortion plus noise $V_O = 0.5\text{ V to }2.5\text{ V}$, $f = 20\text{ kHz}$, $R_L = 50\text{ k}\Omega^\ddagger$	$A_V = 1$		0.2%			0.2%		
		$A_V = 10$		1%			1%		
	Gain-bandwidth product $f = 50\text{ kHz}$, $C_L = 100\text{ pF}^\ddagger$	$R_L = 50\text{ k}\Omega^\ddagger$, 25°C		0.2			0.2		MHz
BOM	Maximum output-swing bandwidth $V_{O(PP)} = 2\text{ V}$, $R_L = 50\text{ k}\Omega^\ddagger$, $A_V = 1$, $C_L = 100\text{ pF}^\ddagger$	25°C		30			30		kHz
ϕ_m	Phase margin at unity gain $R_L = 50\text{ k}\Omega^\ddagger$, $C_L = 100\text{ pF}^\ddagger$	25°C		63°			63°		
		25°C		15			15		

† Full range is – 40°C to 125°C for Q suffix, – 55°C to 125°C for M suffix.

‡ Referenced to 2.5 V

TLC225x, TLC225xA
Advanced LinCMOS™ RAIL-TO-RAIL
VERY LOW-POWER OPERATIONAL AMPLIFIERS

SLOS176D – FEBRUARY 1997 – REVISED MARCH 2001

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

PARAMETER	TEST CONDITIONS	T_A †	TLC2254Q TLC2254M			TLC2254AQ TLC2254AM			UNIT	
			MIN	TYP	MAX	MIN	TYP	MAX		
V_{IO} Input offset voltage		25°C	200		1500	200		850	μ V	
		Full range	1750			1000				
α_{VIO} Temperature coefficient of input offset voltage		25°C to 125°C	0.5			0.5			μ V/°C	
Input offset voltage long-term drift (see Note 4)	$V_{IC} = 0, V_O = 0, R_S = 50 \Omega$	25°C	0.003			0.003			μ V/mo	
I_{IO} Input offset current		25°C	0.5	60		0.5	60		pA	
		125°C	1000			1000				
I_{IB} Input bias current		25°C	1		60	1		60	pA	
		125°C	1000			1000				
V_{ICR} Common-mode input voltage range	$R_S = 50 \Omega, V_{IO} \leq 5$ mV	25°C	-5 to 4	-5.3 to 4.2		-5 to 4	-5.3 to 4.2		V	
		Full range	-5 to 3.5			-5 to 3.5				
V_{OM+} Maximum positive peak output voltage	$I_O = -20 \mu$ A	25°C	4.98			4.98			V	
	$I_O = -100 \mu$ A	25°C	4.9	4.93		4.9	4.93			
		Full range	4.7			4.7				
	$I_O = -200 \mu$ A	25°C	4.8	4.86		4.8	4.86			
V_{OM-} Maximum negative peak output voltage	$V_{IC} = 0, I_O = 50 \mu$ A	25°C	-4.99			-4.99			V	
	$V_{IC} = 0, I_O = 500 \mu$ A	25°C	-4.85	-4.91		-4.85	-4.91			
		Full range	-4.85			-4.85				
	$V_{IC} = 0, I_O = 4$ mA	25°C	-4	-4.3		-4	-4.3			
A_{VD} Large-signal differential voltage amplification	$V_O = \pm 4$ V	$R_L = 100$ k Ω	25°C	40	150		40	150		V/mV
			Full range	10			10			
		$R_L = 1$ M Ω	25°C	3000			3000			
$r_{i(d)}$ Differential input resistance		25°C	10^{12}			10^{12}			Ω	
$r_{i(c)}$ Common-mode input resistance		25°C	10^{12}			10^{12}			Ω	
$c_{i(c)}$ Common-mode input capacitance	$f = 10$ kHz, N package	25°C	8			8			pF	
z_o Closed-loop output impedance	$f = 25$ kHz, $A_V = 10$	25°C	190			190			Ω	
CMRR Common-mode rejection ratio	$V_{IC} = -5$ V to 2.7 V, $V_O = 0, R_S = 50 \Omega$	25°C	75	88		75	88		dB	
		Full range	75			75				
k_{SVR} Supply-voltage rejection ratio ($\Delta V_{DD\pm}/\Delta V_{IO}$)	$V_{DD\pm} = \pm 2.2$ V to ± 8 V, $V_{IC} = V_{DD}/2$, No load	25°C	80	95		80	95		dB	
		Full range	80			80				
I_{DD} Supply current (four amplifiers)	$V_O = 0$, No load	25°C	160	250		160	250		μ A	
		Full range	300			300				

† Full range is -40°C to 125°C for Q suffix, -55°C to 125°C for M suffix.

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

TLC225x, TLC225xA
Advanced LinCMOS™ RAIL-TO-RAIL
VERY LOW-POWER OPERATIONAL AMPLIFIERS
 SLOS176D – FEBRUARY 1997 – REVISED MARCH 2001

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

PARAMETER	TEST CONDITIONS		T_A †	TLC2254Q TLC2254M			TLC2254AQ TLC2254AM			UNIT	
				MIN	TYP	MAX	MIN	TYP	MAX		
SR	Slew rate at unity gain	$V_O = \pm 2\text{ V}$, $C_L = 100\text{ pF}$	$R_L = 100\text{ k}\Omega$	25°C	0.07	0.12		0.07	0.12	V/ μs	
				Full range	0.05			0.05			
V_n	Equivalent input noise voltage			25°C	38			38			nV/ $\sqrt{\text{Hz}}$
				25°C	19			19			
$V_{N(PP)}$	Peak-to-peak equivalent input noise voltage			25°C	0.8			0.8			μV
				25°C	1.1			1.1			
I_n	Equivalent input noise current			25°C	0.6			0.6			fA/ $\sqrt{\text{Hz}}$
THD + N	Total harmonic distortion plus noise	$V_O = \pm 2.3\text{ V}$, $R_L = 50\text{ k}\Omega$, $f = 20\text{ kHz}$	$A_V = 1$	25°C	0.2%			0.2%			
			$A_V = 10$		1%			1%			
	Gain-bandwidth product	$f = 10\text{ kHz}$, $C_L = 100\text{ pF}$	$R_L = 50\text{ k}\Omega$	25°C	0.21			0.21			MHz
BOM	Maximum output-swing bandwidth	$V_{O(PP)} = 4.6\text{ V}$, $R_L = 50\text{ k}\Omega$	$A_V = 1$, $C_L = 100\text{ pF}$	25°C	14			14			kHz
ϕ_m	Phase margin at unity gain	$R_L = 50\text{ k}\Omega$	$C_L = 100\text{ pF}$	25°C	63°			63°			
	Gain margin			25°C	15			15			

† Full range is – 40°C to 125°C for Q suffix, – 55°C to 125°C for M suffix.

TLC225x, TLC225xA
Advanced LinCMOS™ RAIL-TO-RAIL
VERY LOW-POWER OPERATIONAL AMPLIFIERS
 SLOS176D – FEBRUARY 1997 – REVISED MARCH 2001

TYPICAL CHARACTERISTICS

Table of Graphs

			FIGURE
V_{IO}	Input offset voltage	Distribution vs Common-mode input voltage	2 – 5 6, 7
αV_{IO}	Input offset voltage temperature coefficient	Distribution	8 – 11
I_{IB}/I_{IO}	Input bias and input offset currents	vs Free-air temperature	12
V_I	Input voltage range	vs Supply voltage	13
		vs Free-air temperature	14
V_{OH}	High-level output voltage	vs High-level output current	15
V_{OL}	Low-level output voltage	vs Low-level output current	16, 17
V_{OM+}	Maximum positive peak output voltage	vs Output current	18
V_{OM-}	Maximum negative peak output voltage	vs Output current	19
$V_{O(PP)}$	Maximum peak-to-peak output voltage	vs Frequency	20
I_{OS}	Short-circuit output current	vs Supply voltage	21
		vs Free-air temperature	22
V_O	Output voltage	vs Differential input voltage	23, 24
		Differential gain	vs Load resistance
A_{VD}	Large-signal differential voltage amplification	vs Frequency	26, 27
		vs Free-air temperature	28, 29
z_o	Output impedance	vs Frequency	30, 31
CMRR	Common-mode rejection ratio	vs Frequency	32
		vs Free-air temperature	33
k _{SVR}	Supply-voltage rejection ratio	vs Frequency	34, 35
		vs Free-air temperature	36
I_{DD}	Supply current	vs Supply voltage	37
		vs Free-air temperature	38
SR	Slew rate	vs Load capacitance	39
		vs Free-air temperature	40
V_O	Inverting large-signal pulse response		41, 42
V_O	Voltage-follower large-signal pulse response		43, 44
V_O	Inverting small-signal pulse response		45, 46
V_O	Voltage-follower small-signal pulse response		47, 48
V_n	Equivalent input noise voltage	vs Frequency	49, 50
	Noise voltage (referred to input)	Over a 10-second period	51
	Integrated noise voltage	vs Frequency	52
THD + N	Total harmonic distortion plus noise	vs Frequency	53
		Gain-bandwidth product	vs Free-air temperature vs Supply voltage
ϕ_m	Phase margin	vs Frequency	26, 27
		vs Load capacitance	56
A_m	Gain margin	vs Load capacitance	57
B_1	Unity-gain bandwidth	vs Load capacitance	58
		Overestimation of phase margin	vs Load capacitance

TYPICAL CHARACTERISTICS

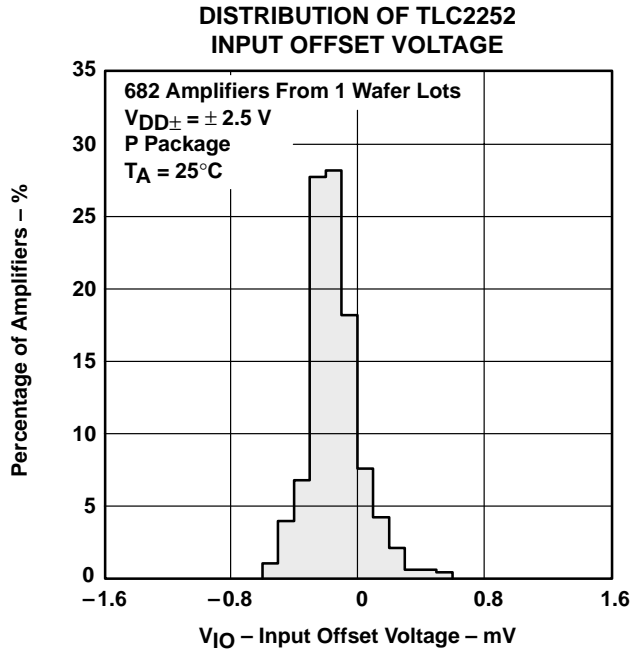


Figure 2

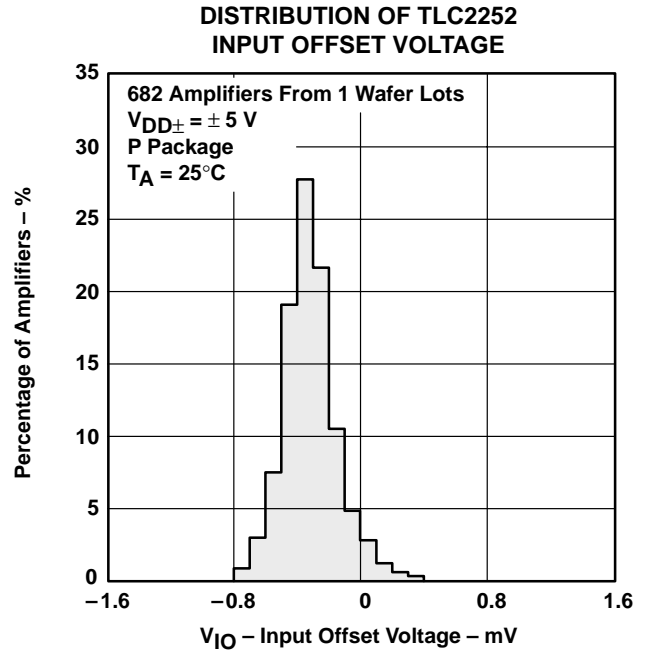


Figure 3

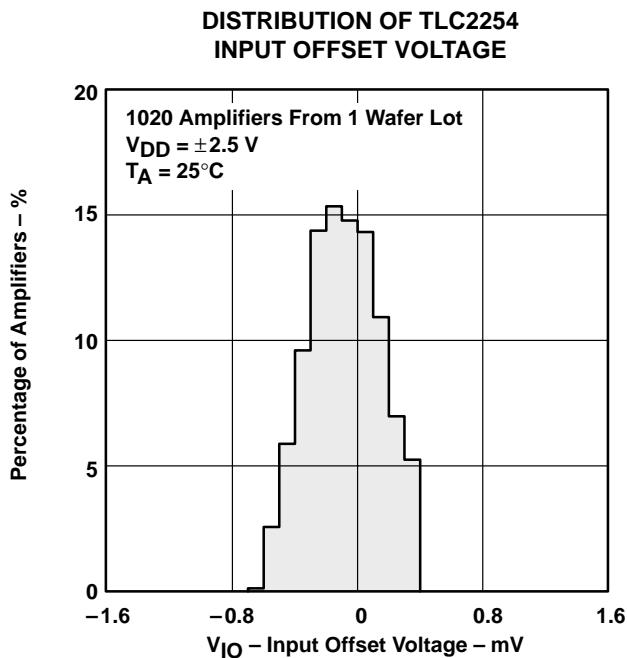


Figure 4

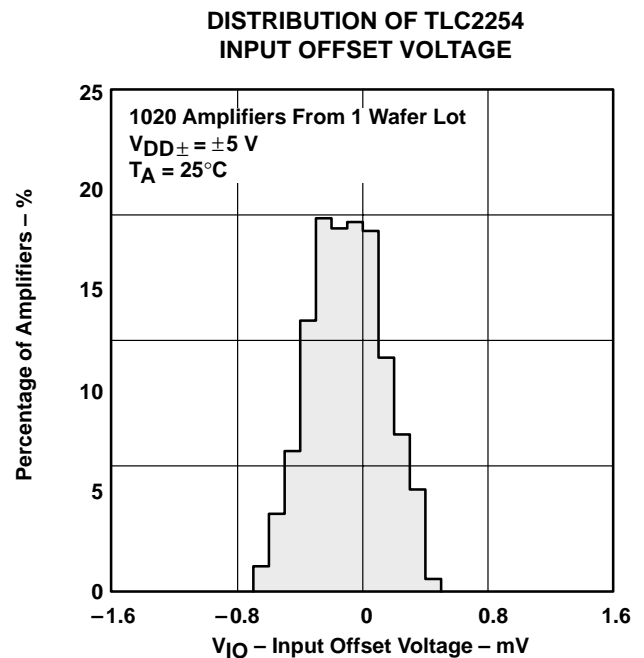


Figure 5

TLC225x, TLC225xA
Advanced LinCMOS™ RAIL-TO-RAIL
VERY LOW-POWER OPERATIONAL AMPLIFIERS
 SLOS176D – FEBRUARY 1997 – REVISED MARCH 2001

TYPICAL CHARACTERISTICS

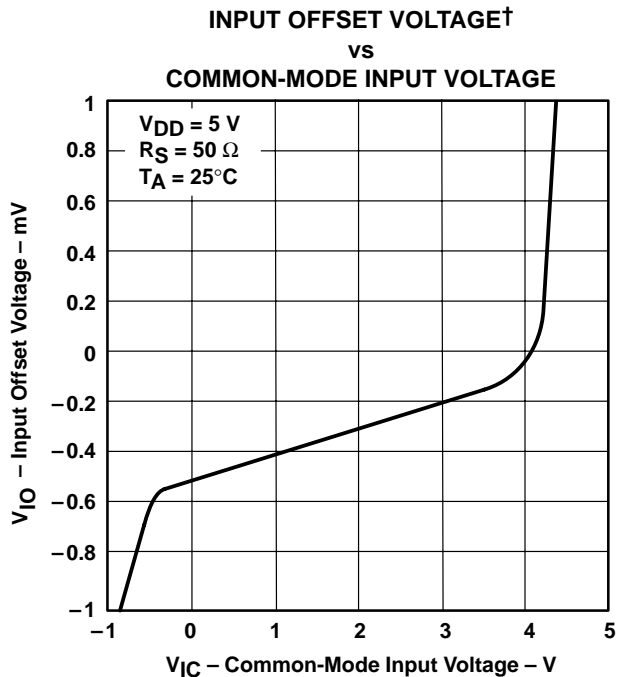


Figure 6

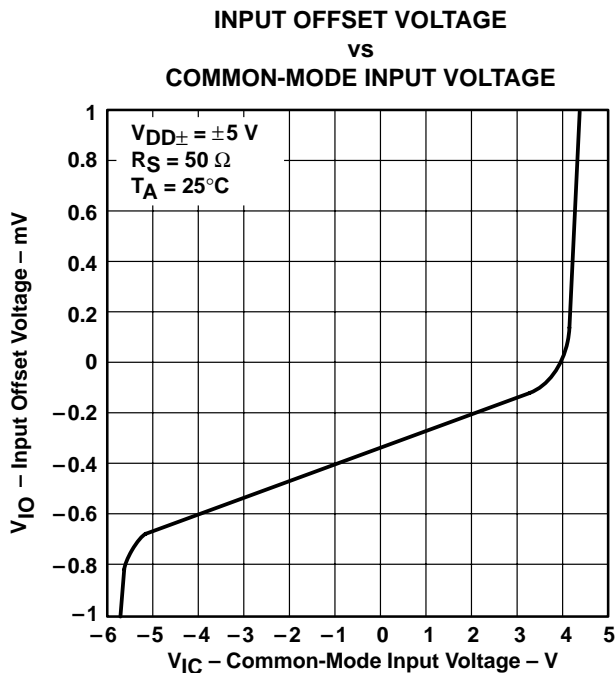


Figure 7

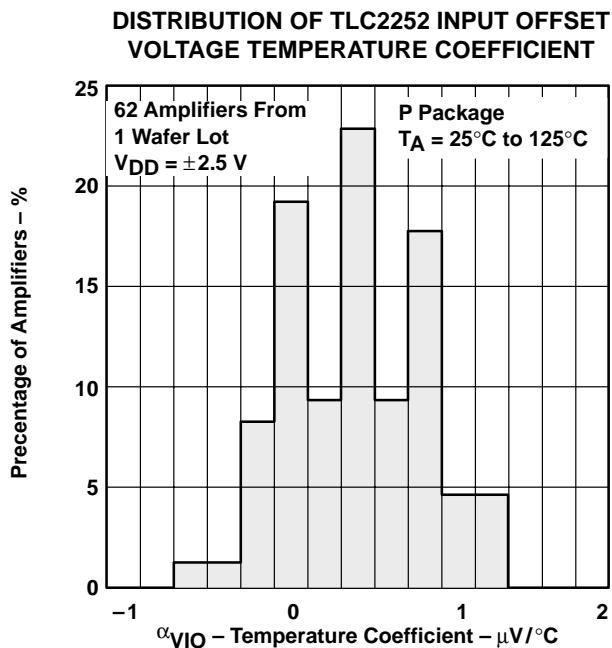


Figure 8

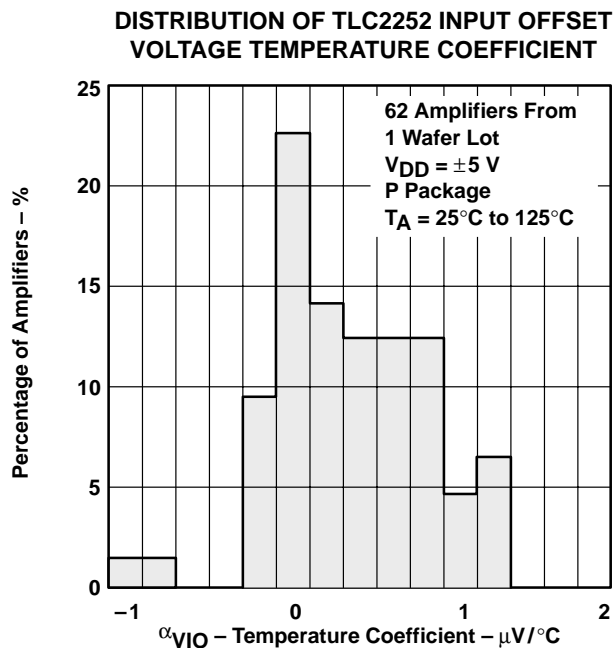


Figure 9

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

TYPICAL CHARACTERISTICS

DISTRIBUTION OF TLC2254 INPUT OFFSET VOLTAGE TEMPERATURE COEFFICIENT

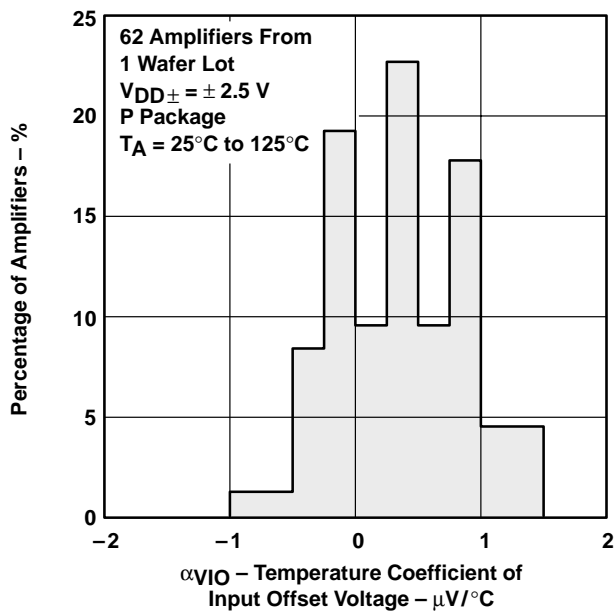


Figure 10

DISTRIBUTION OF TLC2254 INPUT OFFSET VOLTAGE TEMPERATURE COEFFICIENT

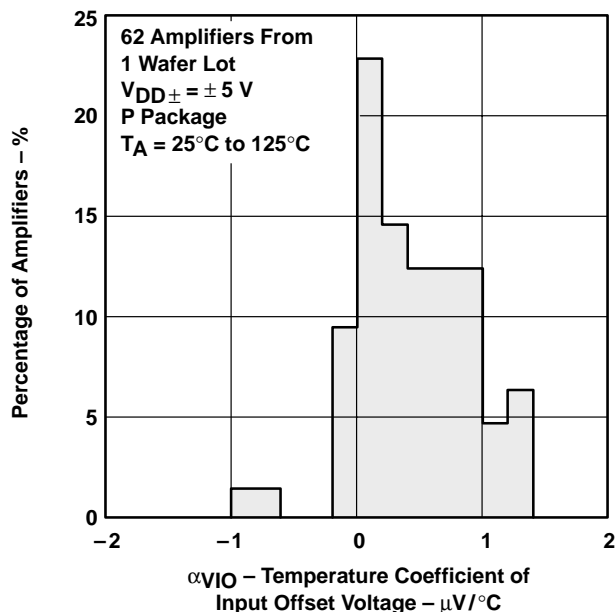


Figure 11

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

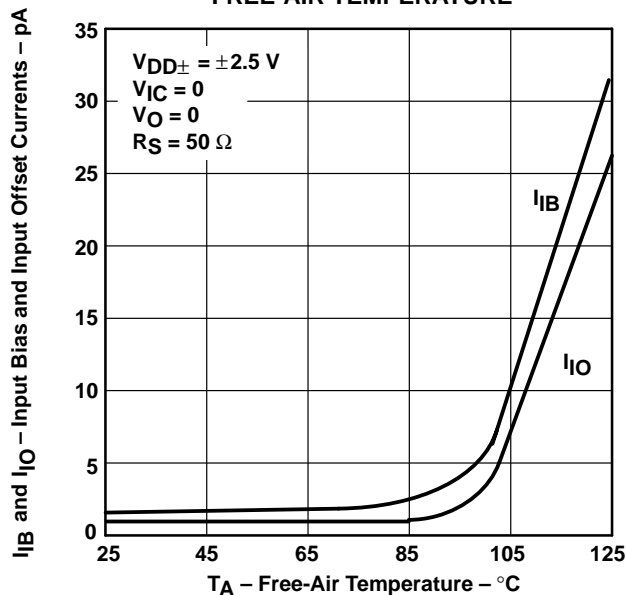


Figure 12

**INPUT VOLTAGE RANGE
vs
SUPPLY VOLTAGE**

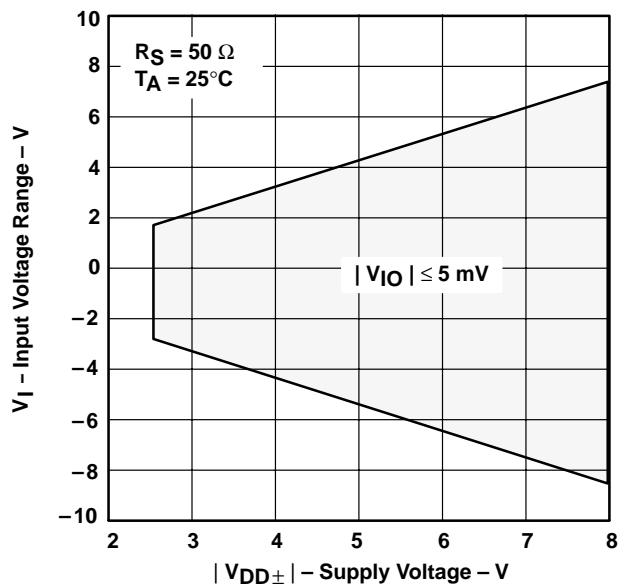


Figure 13

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

TYPICAL CHARACTERISTICS

INPUT VOLTAGE RANGE†
vs
FREE-AIR TEMPERATURE

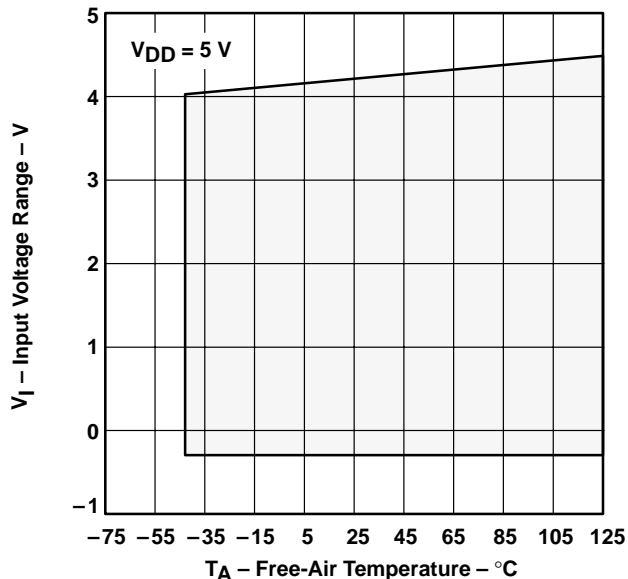


Figure 14

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

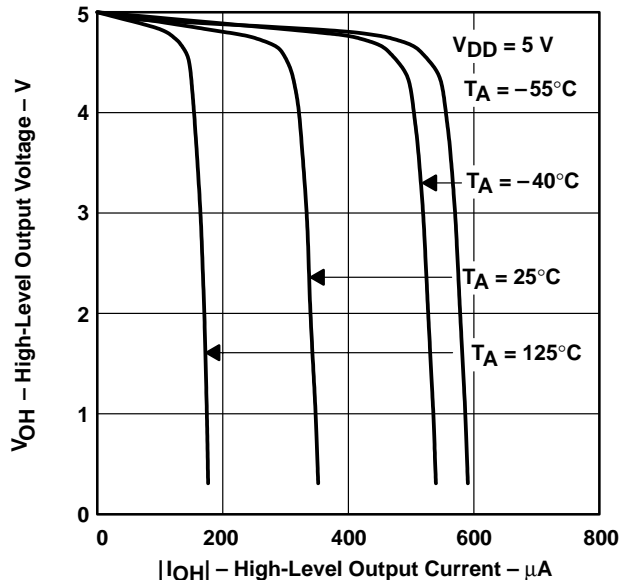


Figure 15

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

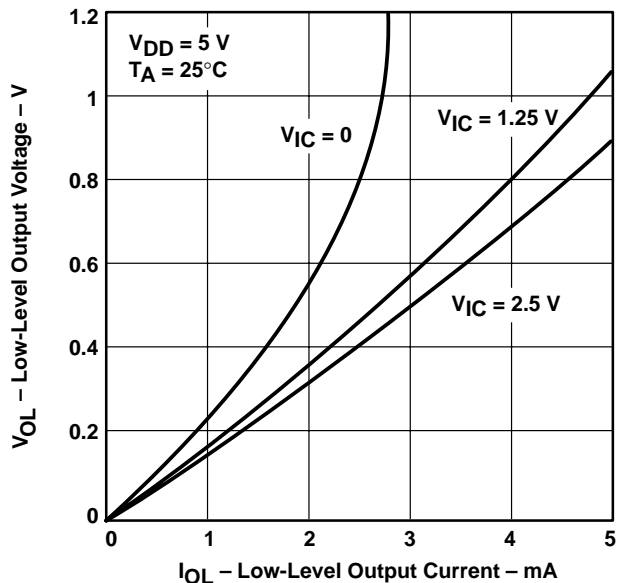


Figure 16

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

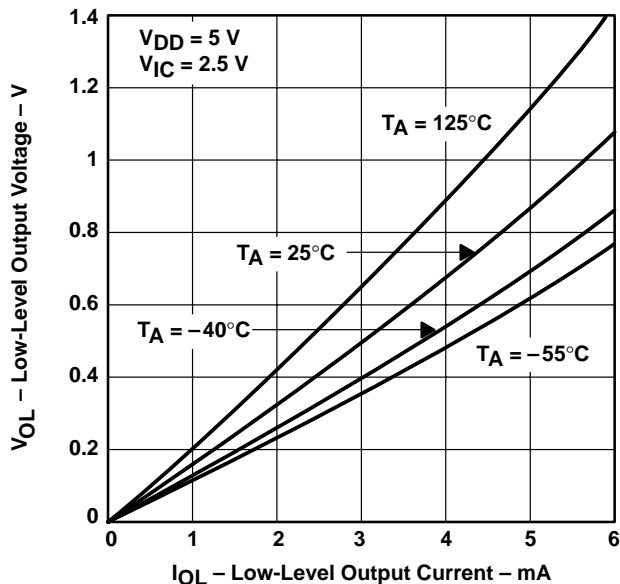


Figure 17

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

TYPICAL CHARACTERISTICS

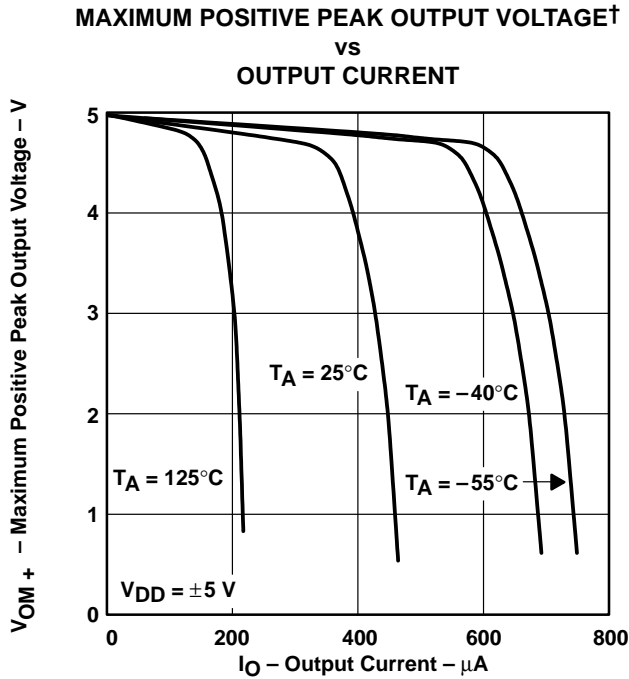


Figure 18

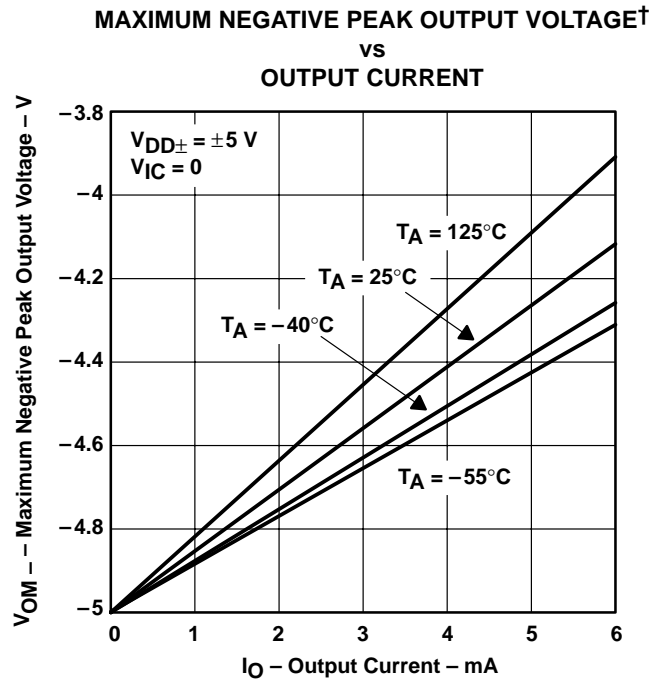


Figure 19

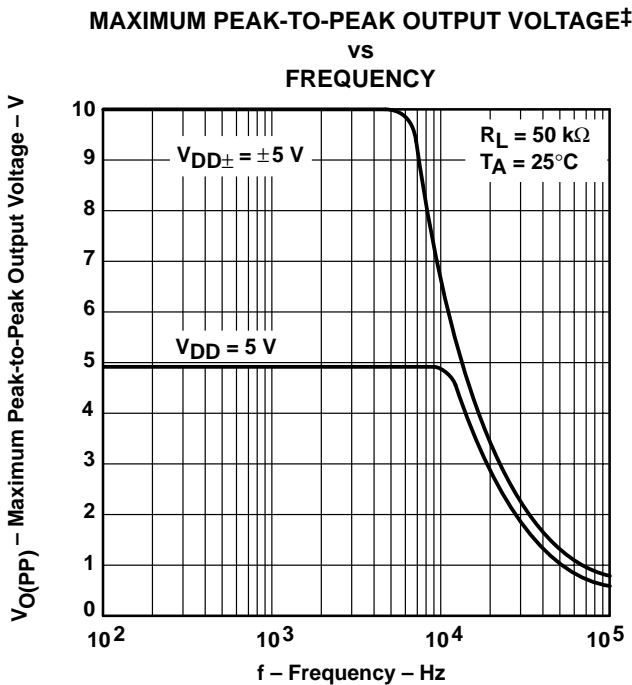


Figure 20

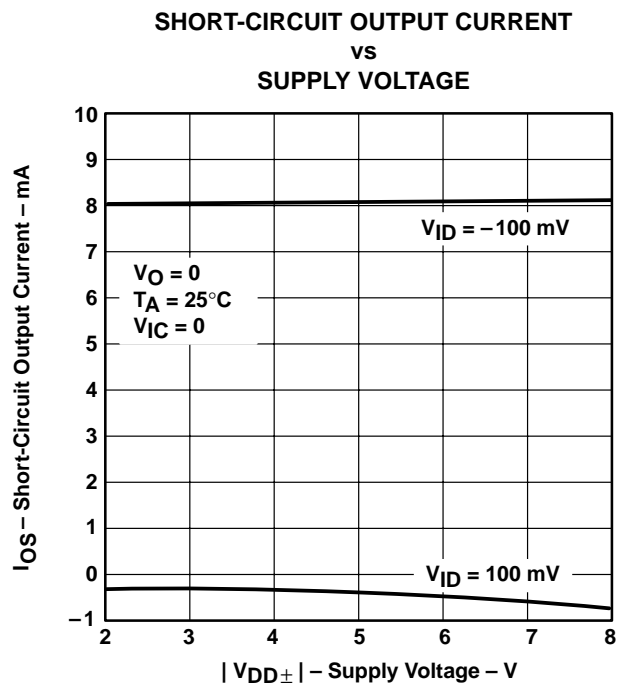


Figure 21

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

TLC225x, TLC225xA
Advanced LinCMOS™ RAIL-TO-RAIL
VERY LOW-POWER OPERATIONAL AMPLIFIERS
 SLOS176D – FEBRUARY 1997 – REVISED MARCH 2001

TYPICAL CHARACTERISTICS

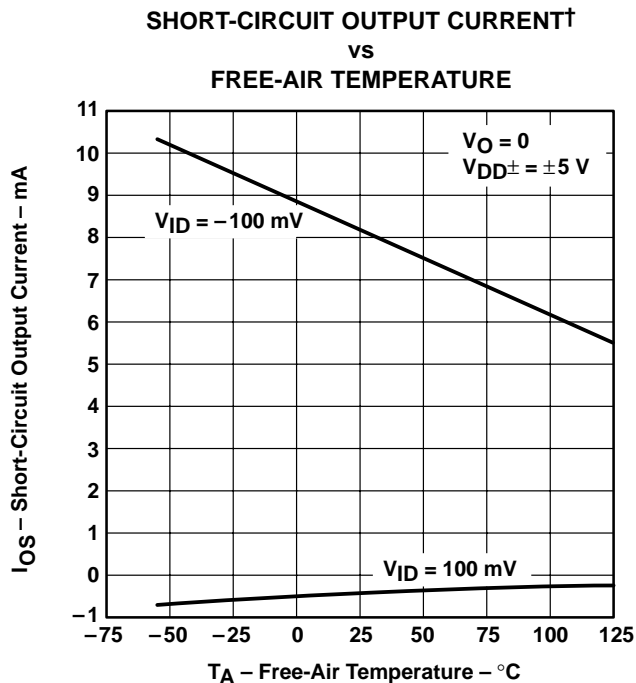


Figure 22

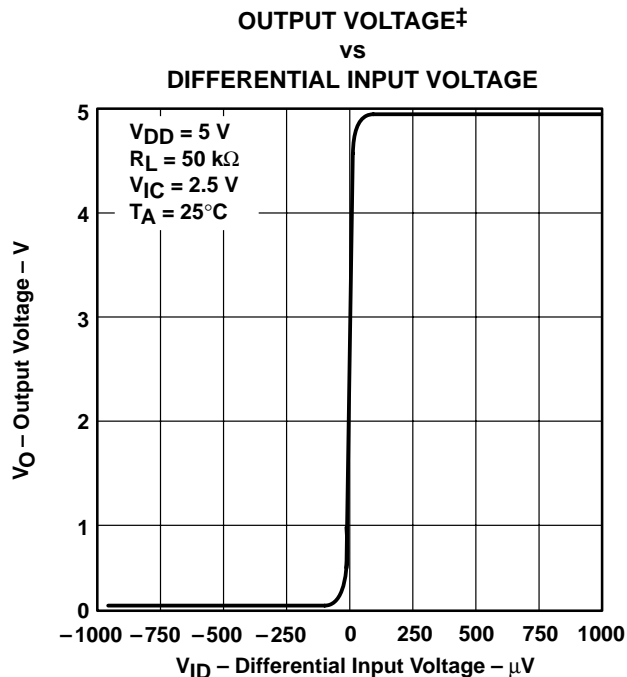


Figure 23

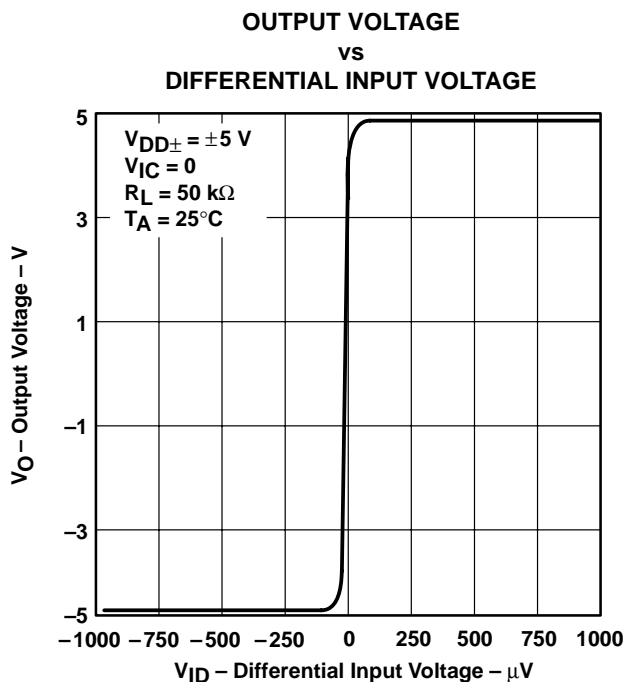


Figure 24

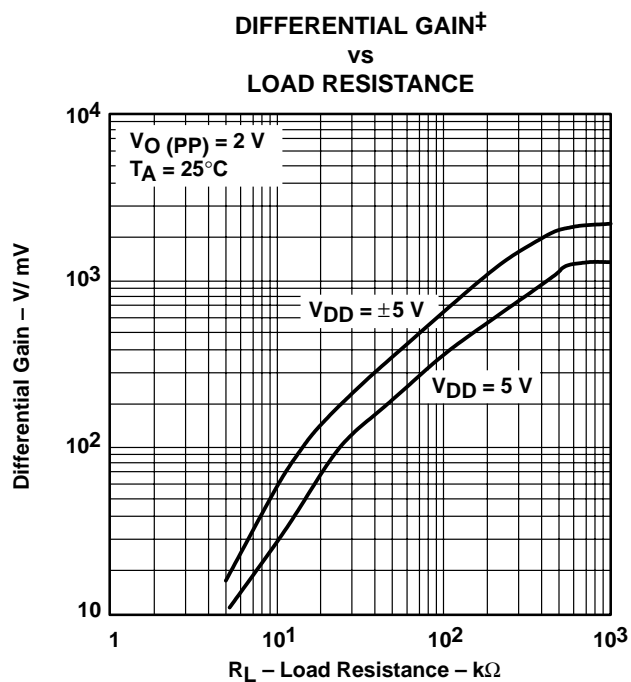


Figure 25

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

TYPICAL CHARACTERISTICS

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

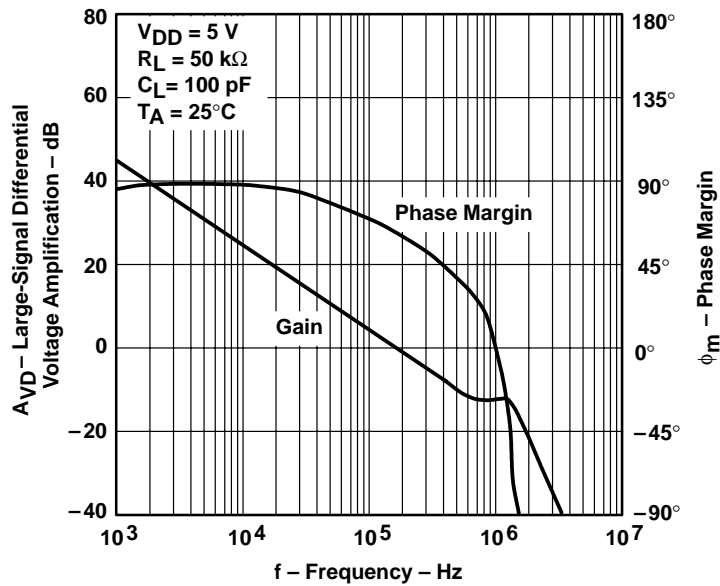


Figure 26

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

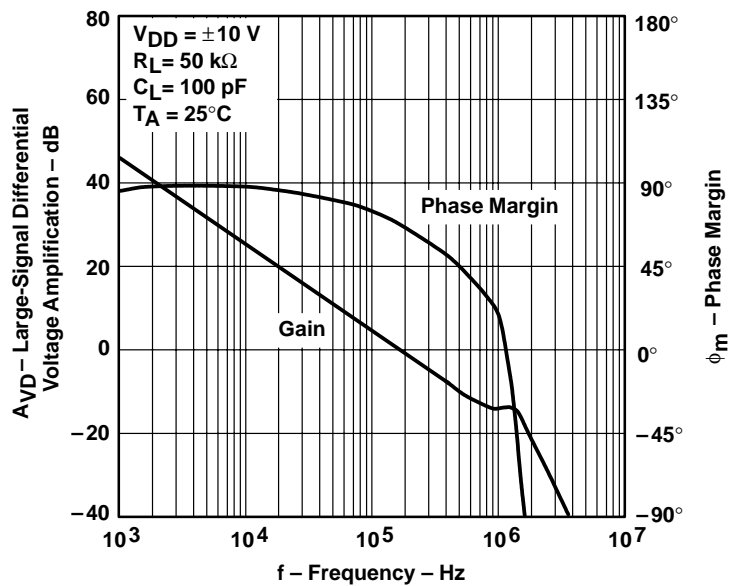
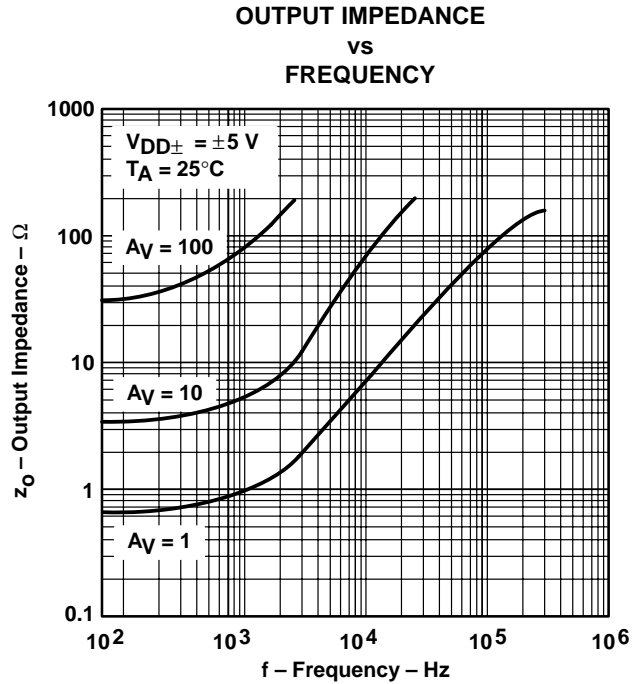
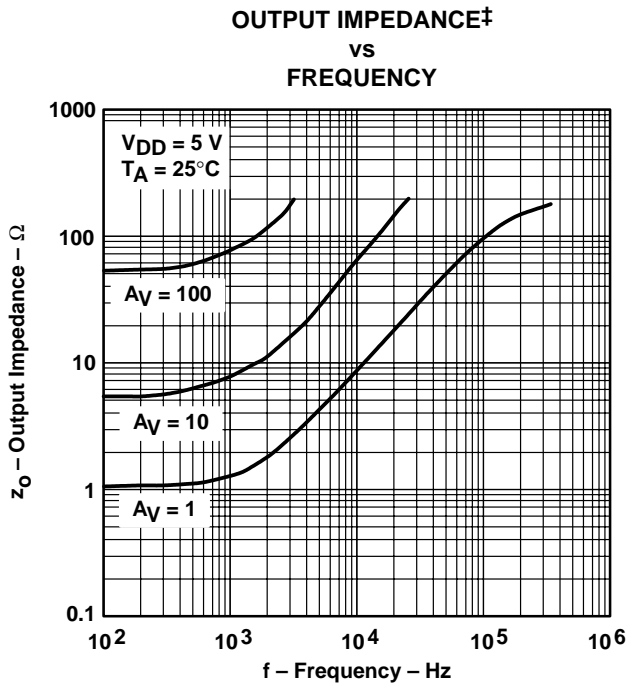
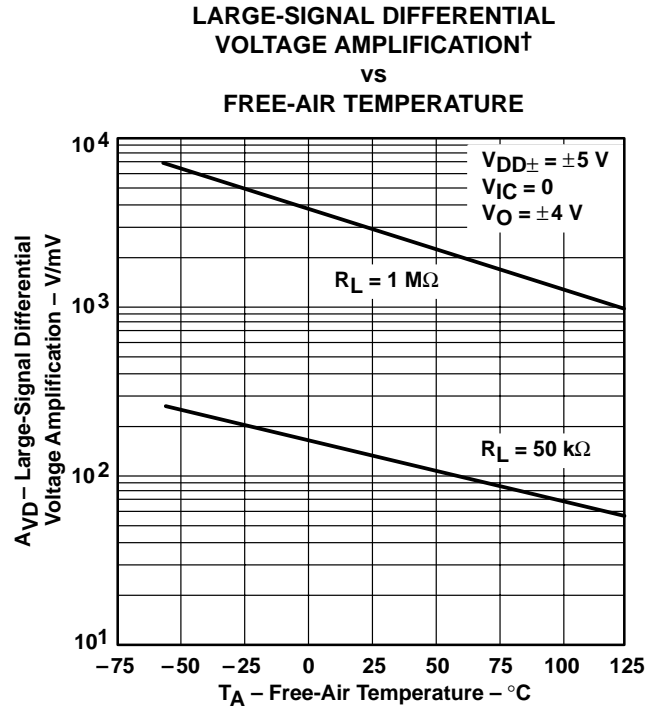
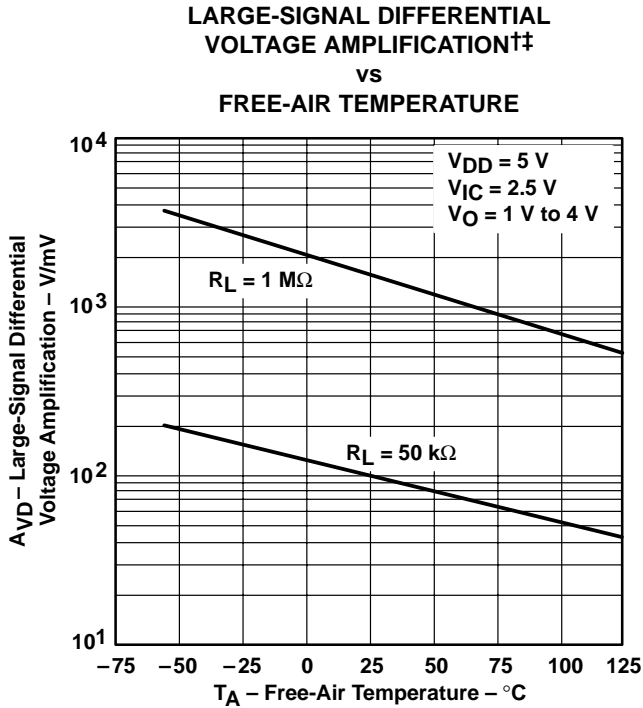


Figure 27

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

TLC225x, TLC225xA
Advanced LinCMOS™ RAIL-TO-RAIL
VERY LOW-POWER OPERATIONAL AMPLIFIERS
 SLOS176D – FEBRUARY 1997 – REVISED MARCH 2001

TYPICAL CHARACTERISTICS



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

TYPICAL CHARACTERISTICS

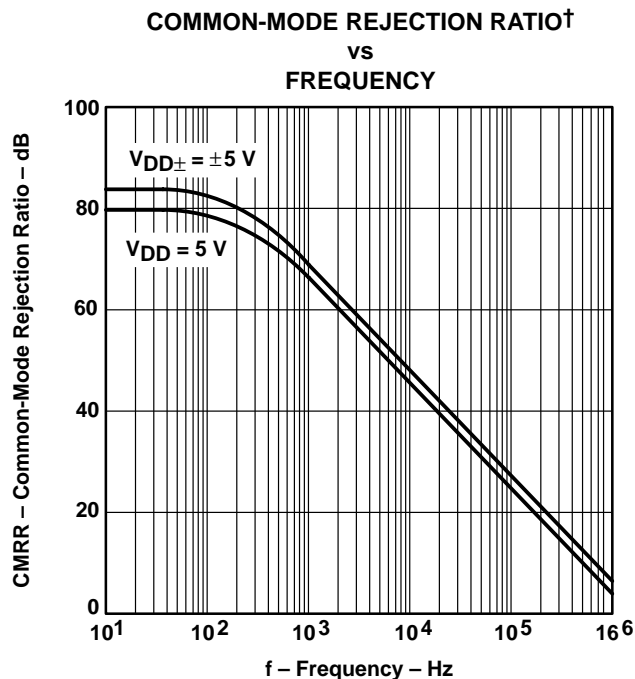


Figure 32

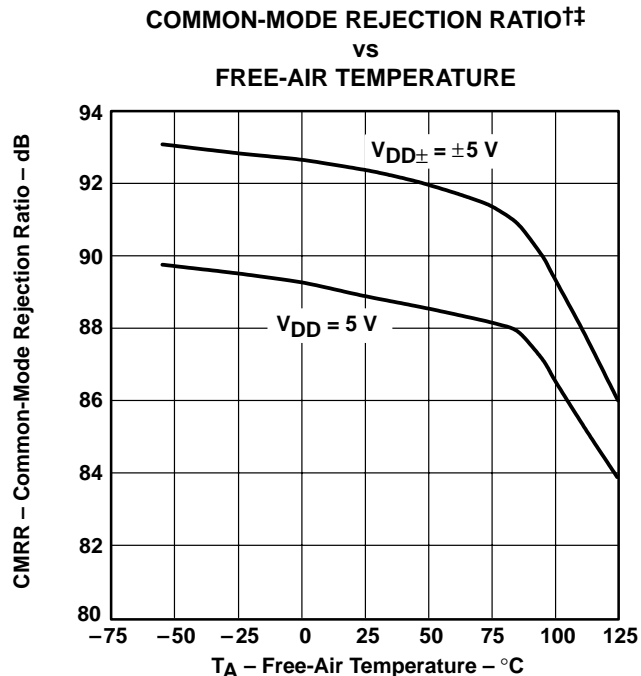


Figure 33

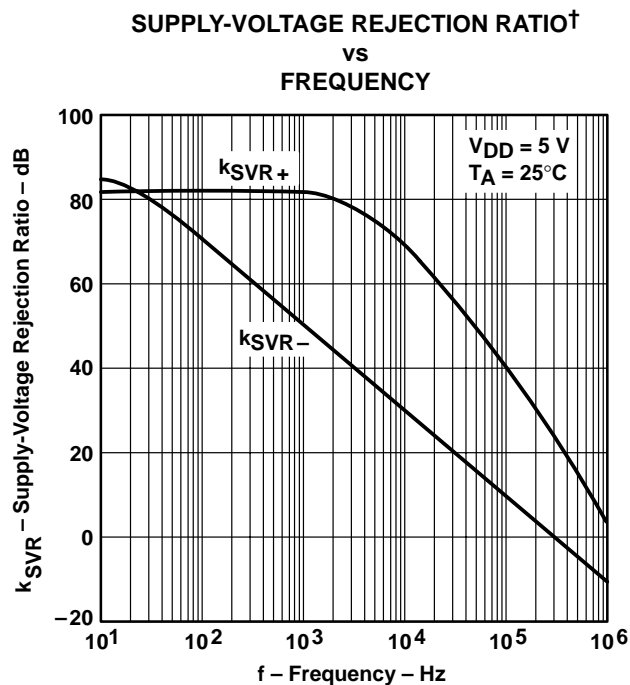


Figure 34

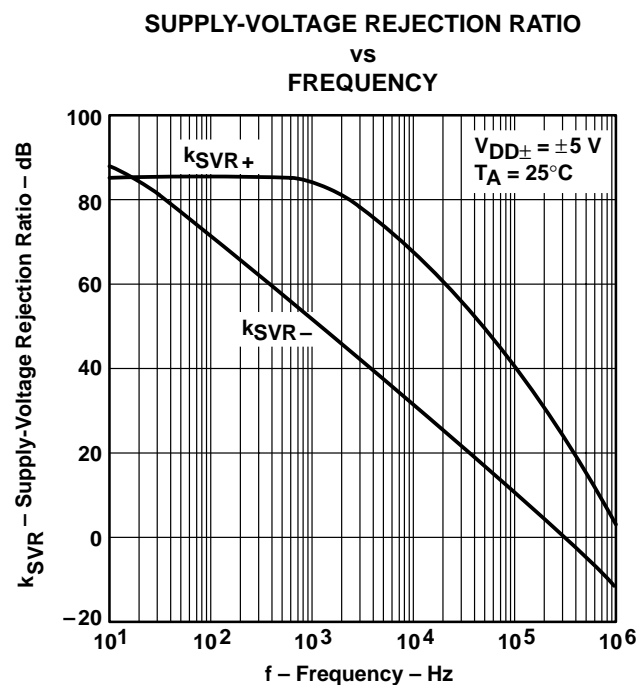


Figure 35

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

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

TLC225x, TLC225xA
Advanced LinCMOS™ RAIL-TO-RAIL
VERY LOW-POWER OPERATIONAL AMPLIFIERS
 SLOS176D – FEBRUARY 1997 – REVISED MARCH 2001

TYPICAL CHARACTERISTICS

SUPPLY-VOLTAGE REJECTION RATIO†
 vs
FREE-AIR TEMPERATURE

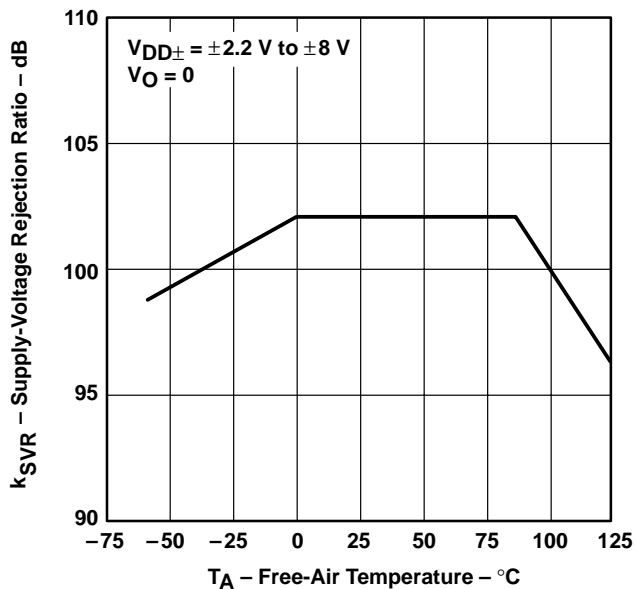


Figure 36

SUPPLY CURRENT†
 vs
SUPPLY VOLTAGE

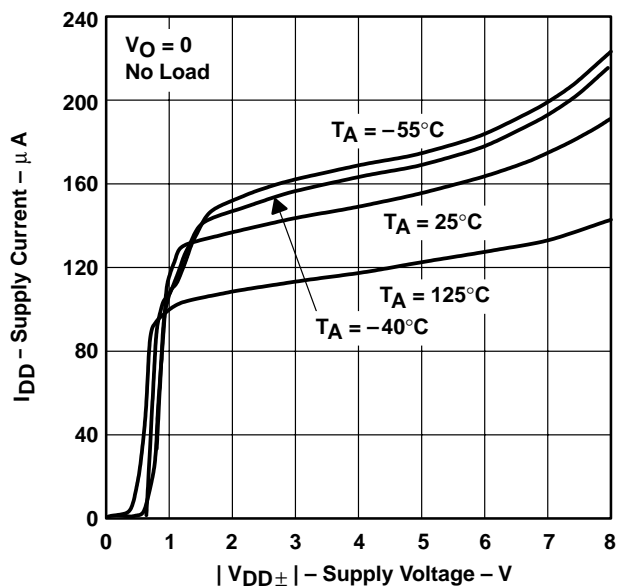


Figure 37

SUPPLY CURRENT†‡
 vs
FREE-AIR TEMPERATURE

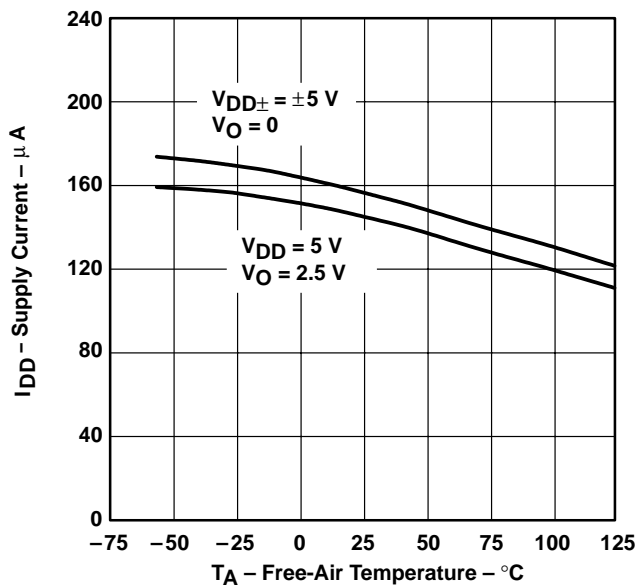


Figure 38

SLEW RATE‡
 vs
LOAD CAPACITANCE

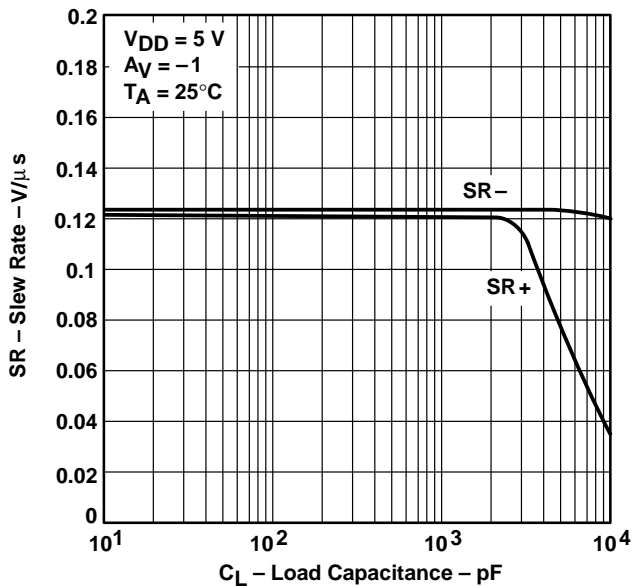
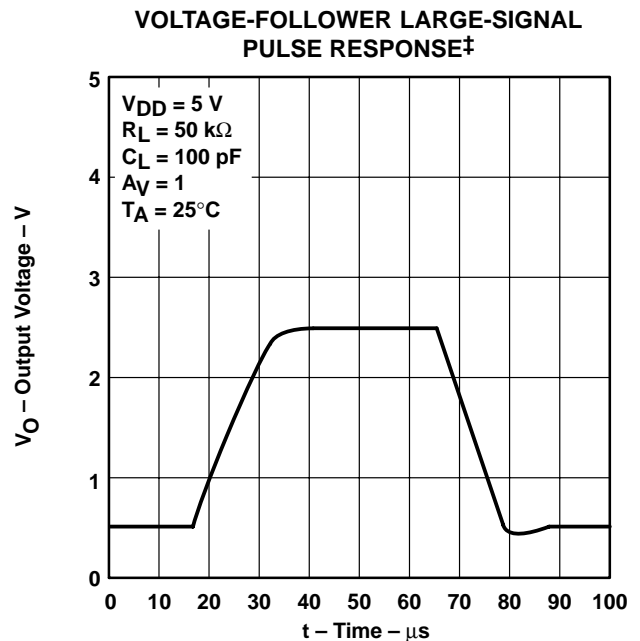
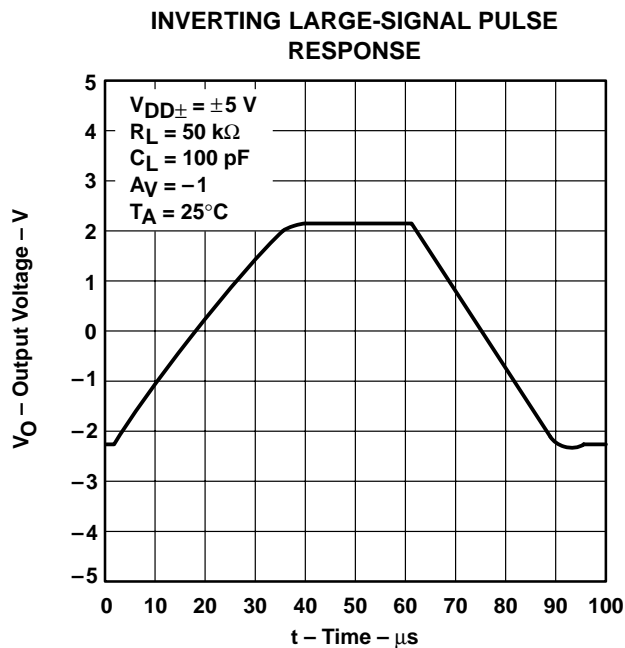
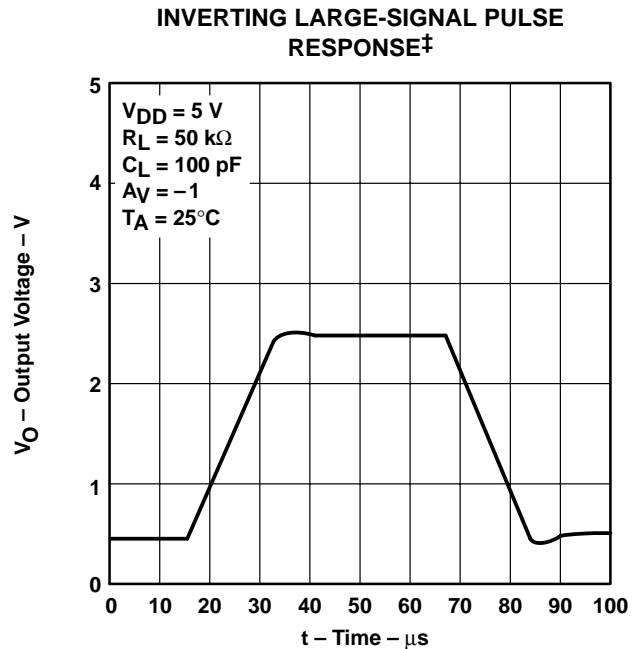
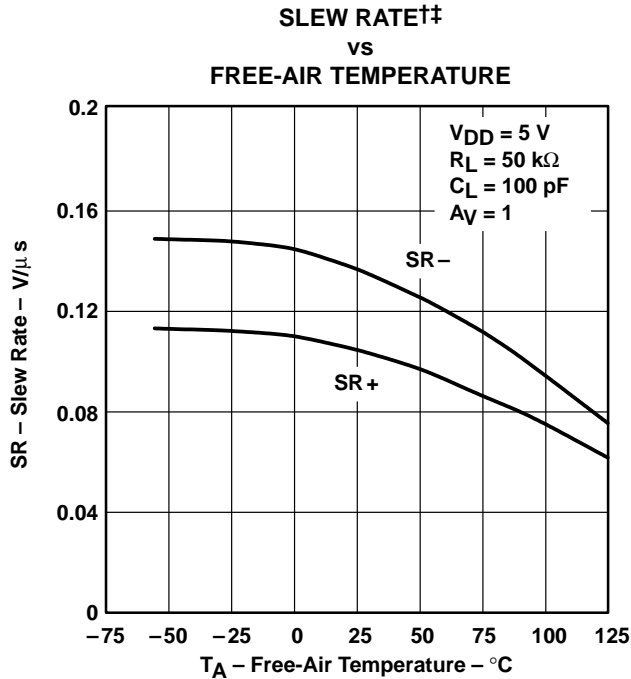


Figure 39

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

TYPICAL CHARACTERISTICS



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

TLC225x, TLC225xA
Advanced LinCMOS™ RAIL-TO-RAIL
VERY LOW-POWER OPERATIONAL AMPLIFIERS
 SLOS176D – FEBRUARY 1997 – REVISED MARCH 2001

TYPICAL CHARACTERISTICS

VOLTAGE-FOLLOWER LARGE-SIGNAL PULSE RESPONSE

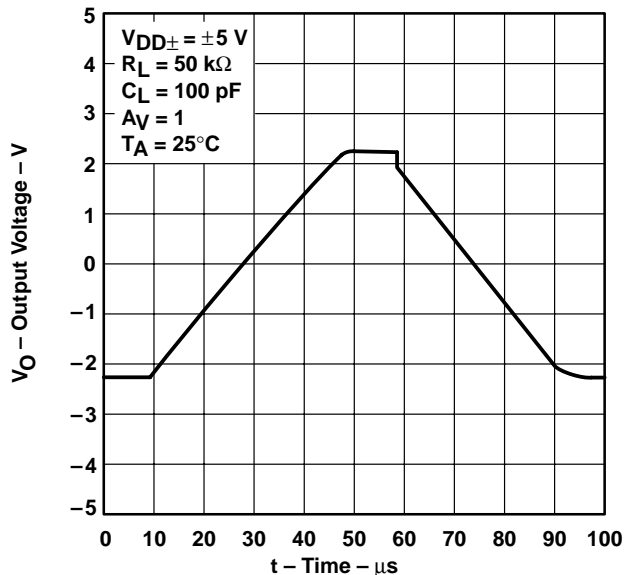


Figure 44

INVERTING SMALL-SIGNAL PULSE RESPONSE†

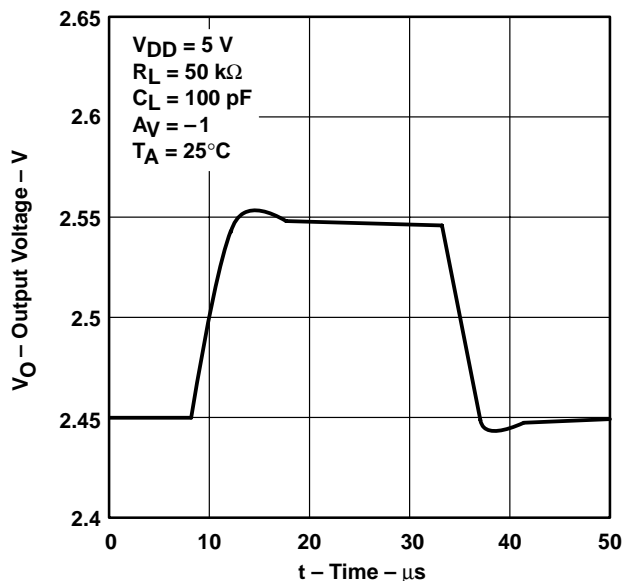


Figure 45

INVERTING SMALL-SIGNAL PULSE RESPONSE

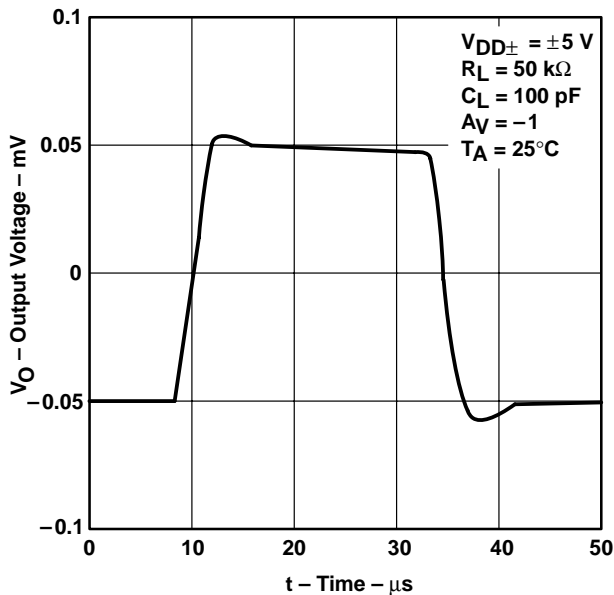


Figure 46

VOLTAGE-FOLLOWER SMALL-SIGNAL PULSE RESPONSE†

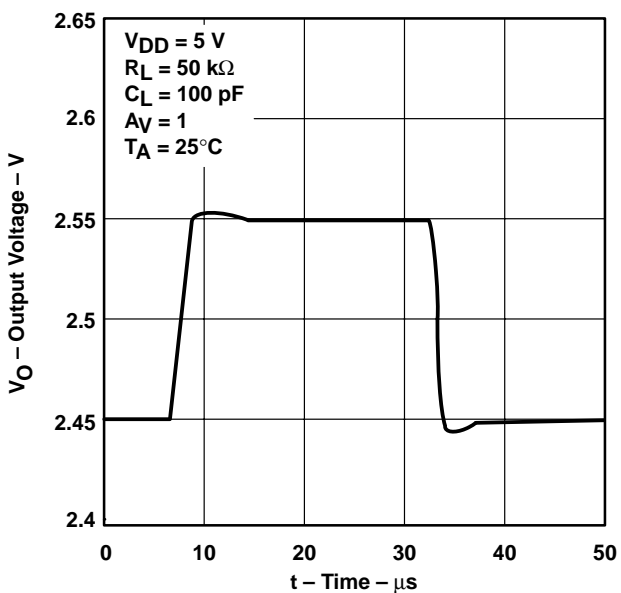


Figure 47

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

TYPICAL CHARACTERISTICS

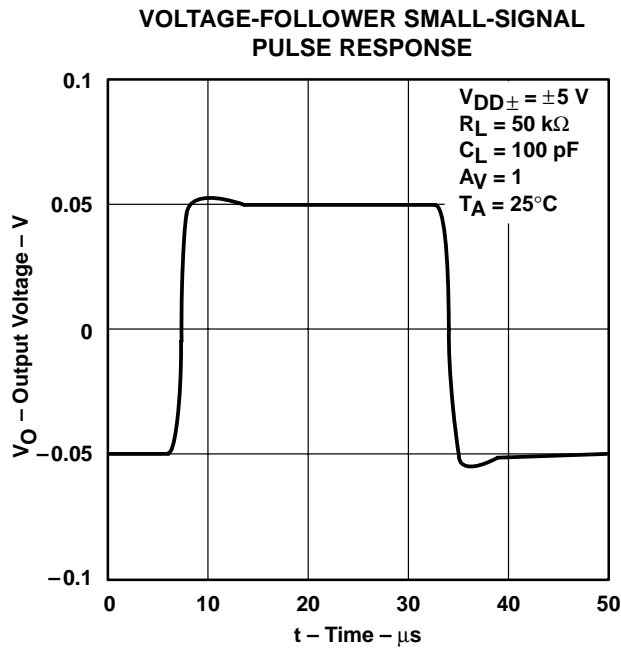


Figure 48

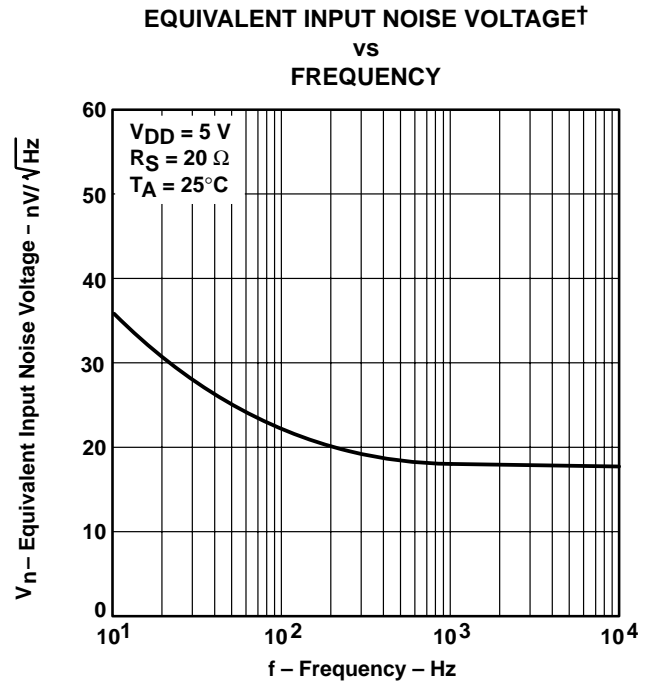


Figure 49

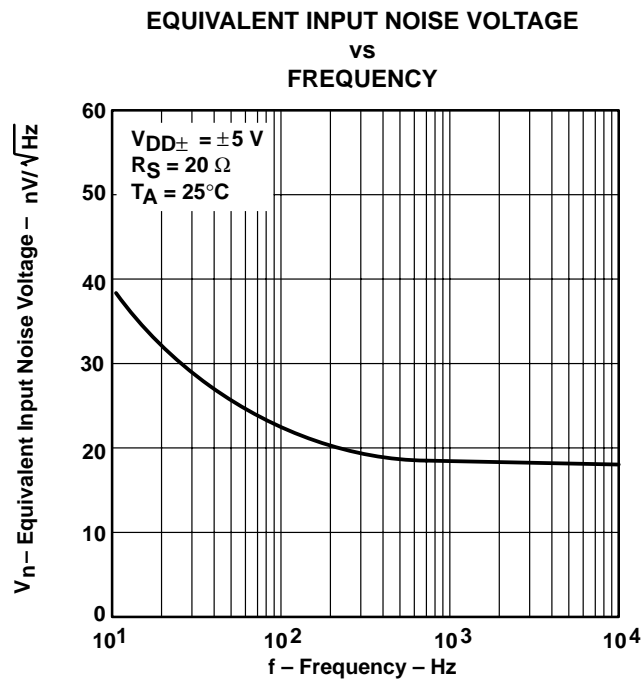


Figure 50

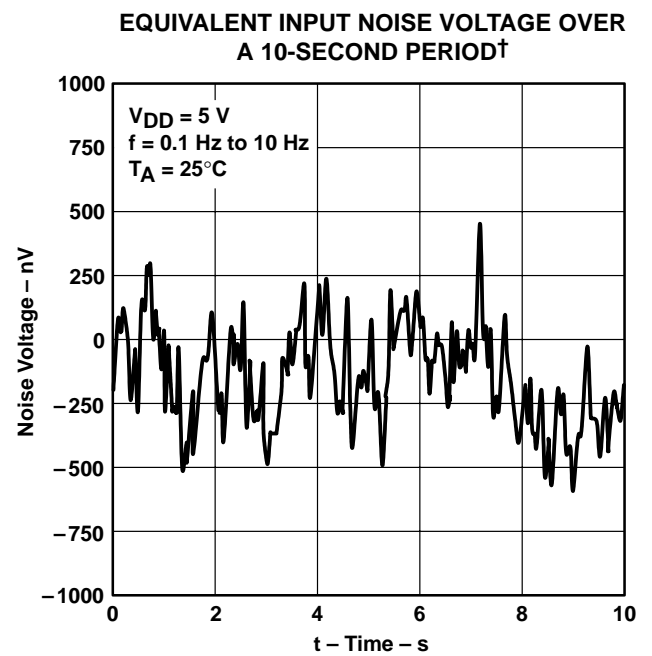


Figure 51

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

TLC225x, TLC225xA
Advanced LinCMOS™ RAIL-TO-RAIL
VERY LOW-POWER OPERATIONAL AMPLIFIERS
 SLOS176D – FEBRUARY 1997 – REVISED MARCH 2001

TYPICAL CHARACTERISTICS

**INTEGRATED NOISE VOLTAGE
 vs
 FREQUENCY**

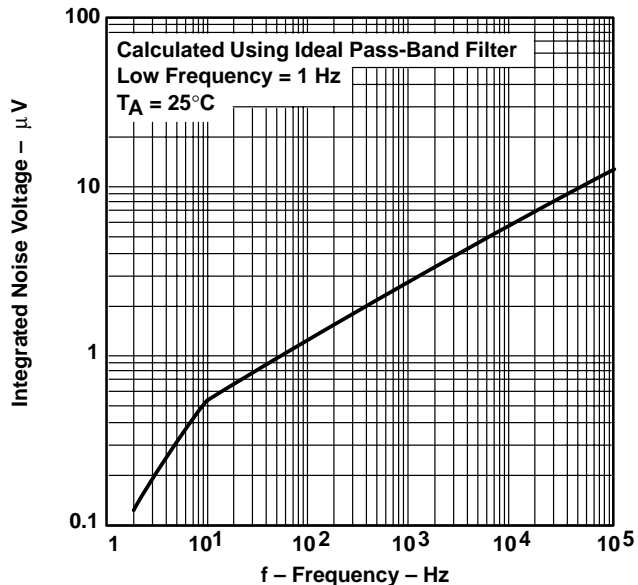


Figure 52

**TOTAL HARMONIC DISTORTION PLUS NOISE†
 vs
 FREQUENCY**

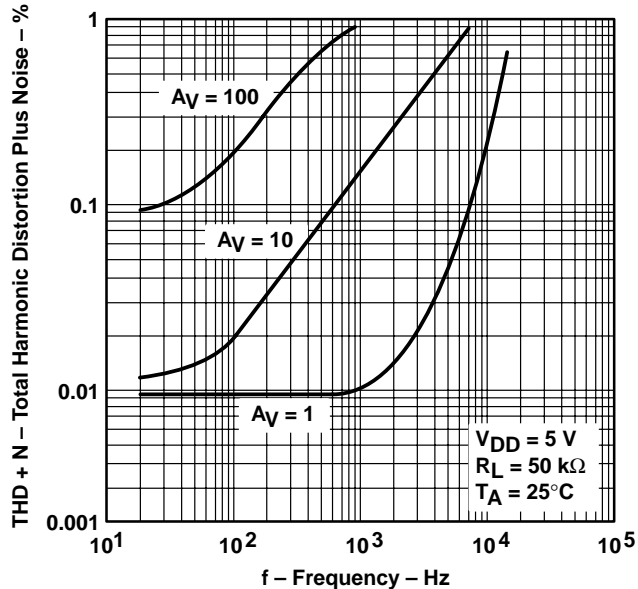


Figure 53

**GAIN-BANDWIDTH PRODUCT†‡
 vs
 FREE-AIR TEMPERATURE**

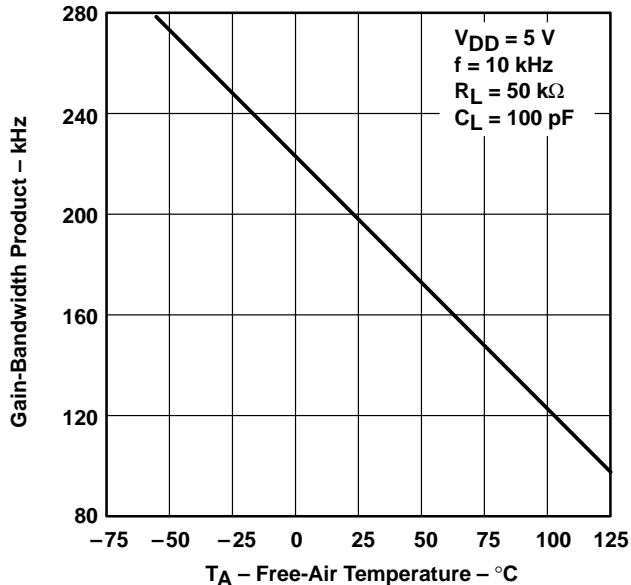


Figure 54

**GAIN-BANDWIDTH PRODUCT
 vs
 SUPPLY VOLTAGE**

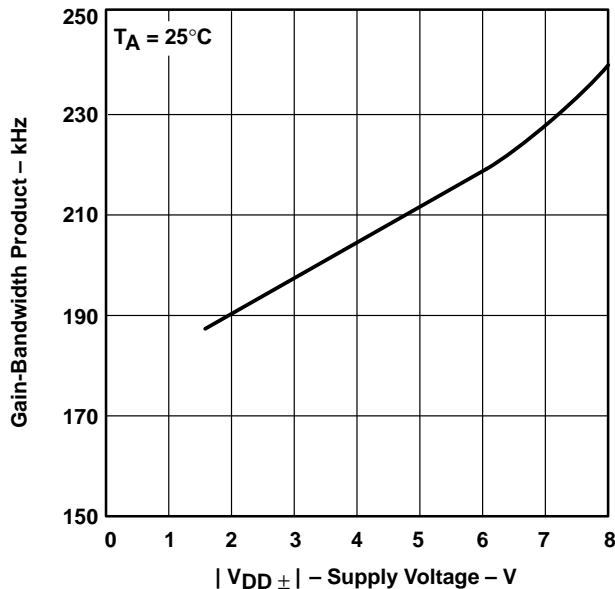


Figure 55

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

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

TYPICAL CHARACTERISTICS

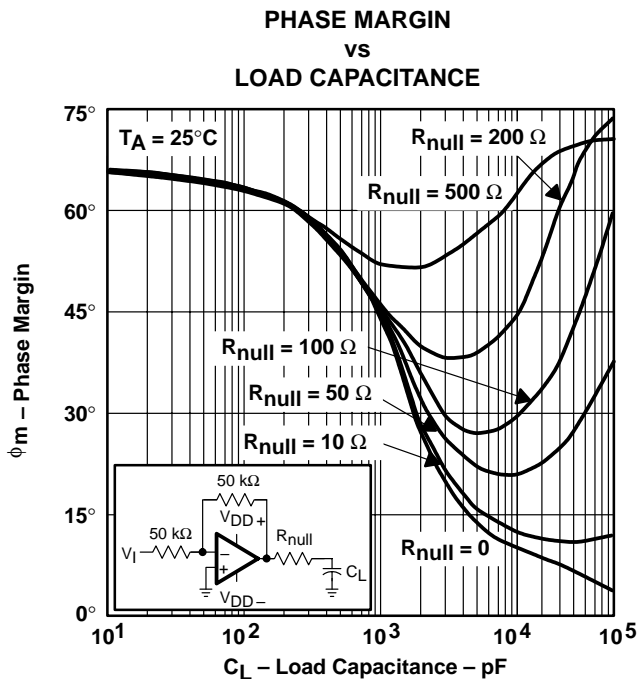


Figure 56

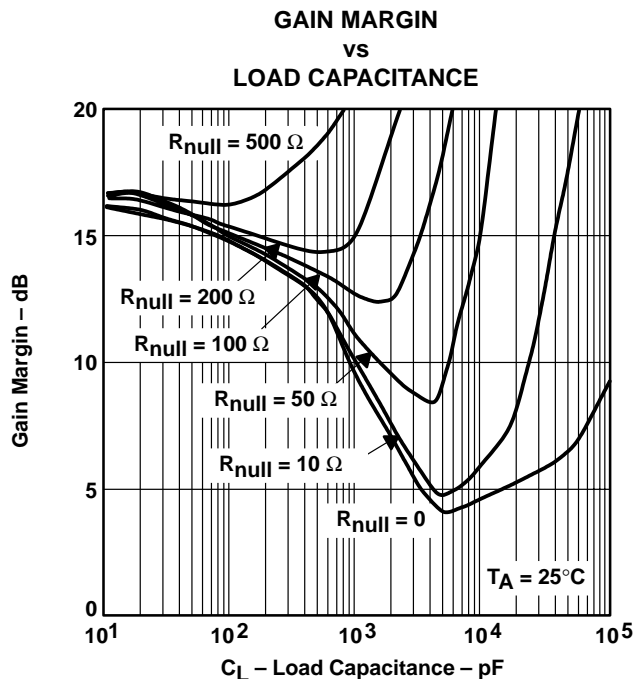


Figure 57

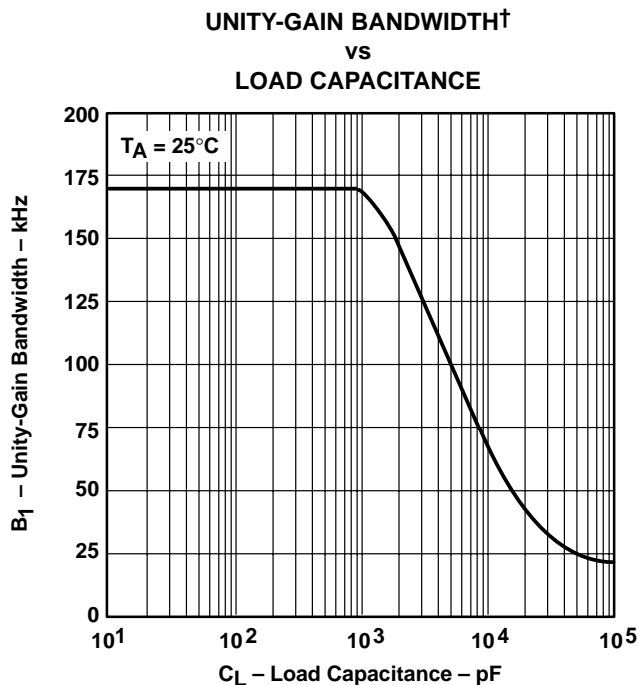


Figure 58

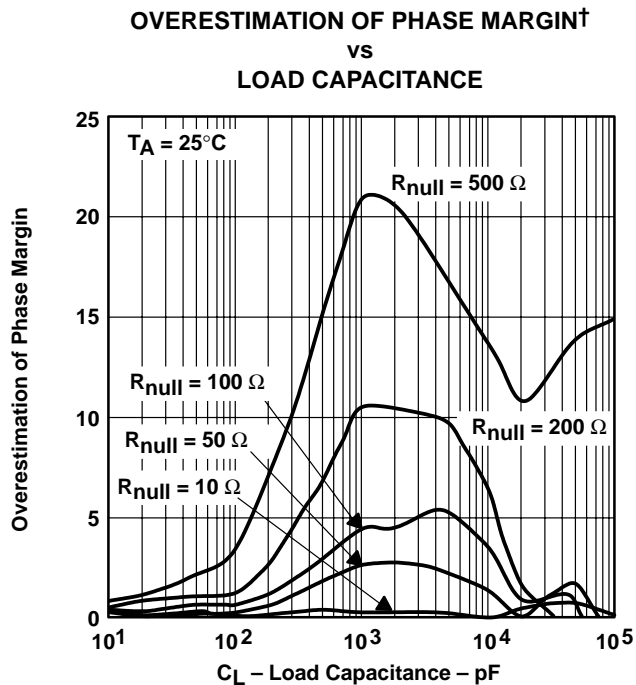


Figure 59

† See application information

APPLICATION INFORMATION

driving large capacitive loads

The TLC225x is designed to drive larger capacitive loads than most CMOS operational amplifiers. Figure 56 and Figure 57 illustrate its ability to drive loads up to 1000 pF while maintaining good gain and phase margins ($R_{null} = 0$).

A smaller series resistor (R_{null}) at the output of the device (see Figure 60) improves the gain and phase margins when driving large capacitive loads. Figure 56 and Figure 57 show the effects of adding series resistances of 10 Ω , 50 Ω , 100 Ω , 200 Ω , and 500 Ω . The addition of this series resistor has two effects: the first is that it adds a zero to the transfer function and the second is that it reduces the frequency of the pole associated with the output load in the transfer function.

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

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

Where :

- $\Delta\phi_{m1}$ = Improvement in phase margin
- UGBW = Unity-gain bandwidth frequency
- R_{null} = Output series resistance
- C_L = Load capacitance

The unity-gain bandwidth (UGBW) frequency decreases as the capacitive load increases (see Figure 58). To use equation 1, UGBW must be approximated from Figure 58.

Using equation 1 alone overestimates the improvement in phase margin, as illustrated in Figure 59. The overestimation is caused by the decrease in the frequency of the pole associated with the load, thus providing additional phase shift and reducing the overall improvement in phase margin.

Using Figure 60, with equation 1 enables the designer to choose the appropriate output series resistance to optimize the design of circuits driving large capacitance loads.

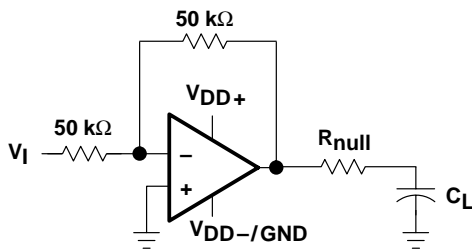


Figure 60. Series-Resistance Circuit

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 5) and subcircuit in Figure 61 are generated using the TLC225x typical electrical and operating characteristics at $T_A = 25^\circ\text{C}$. Using this information, output simulations of the following key parameters can be generated to a tolerance of 20% (in most cases):

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

NOTE 5: 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).

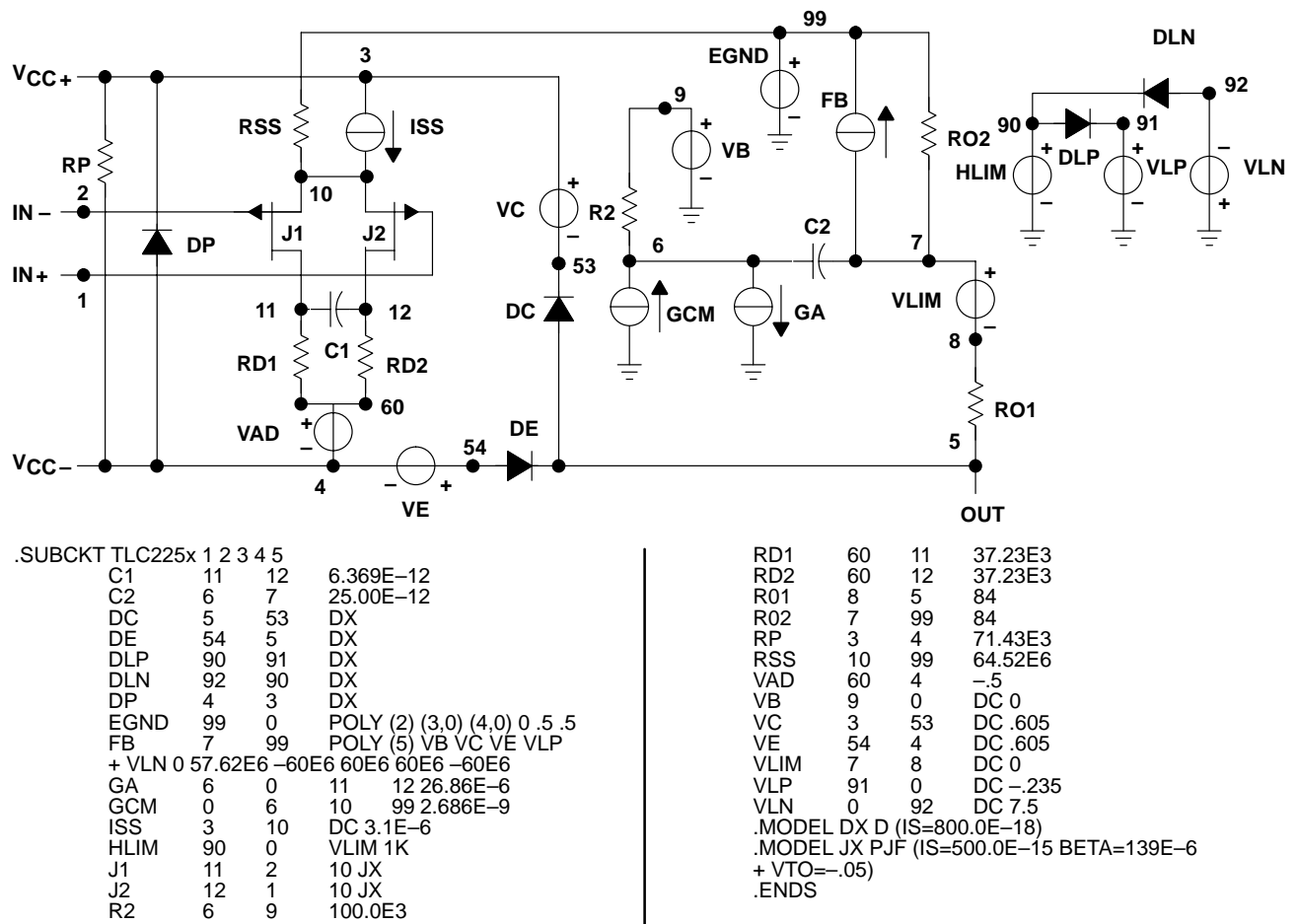


Figure 61. Boyle Macromodel and Subcircuit

TLC225x, TLC225xA
Advanced LinCMOS™ RAIL-TO-RAIL
VERY LOW-POWER OPERATIONAL AMPLIFIERS

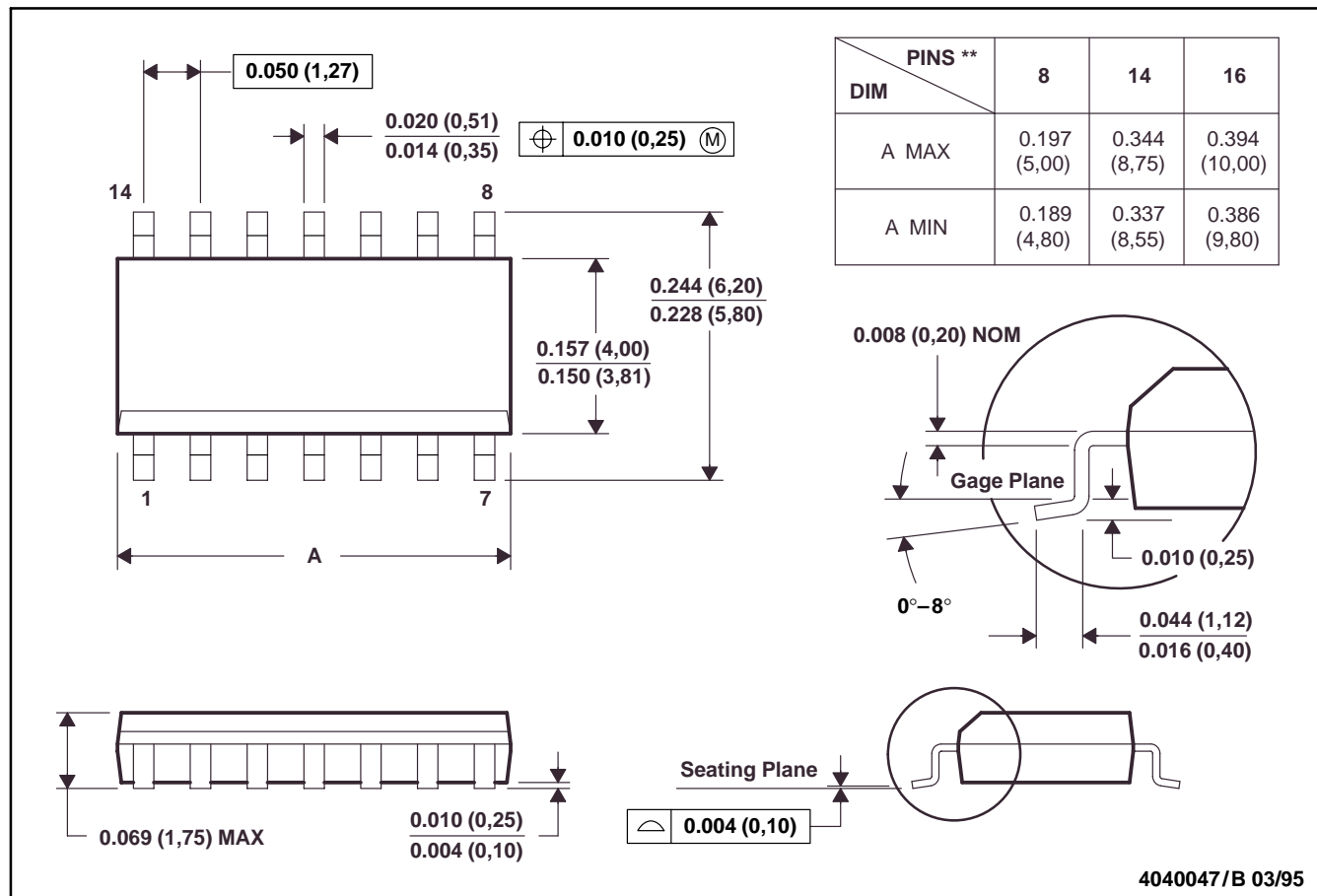
SLOS176D – FEBRUARY 1997 – REVISED MARCH 2001

MECHANICAL INFORMATION

D (R-PDSO-G)**

PLASTIC SMALL-OUTLINE PACKAGE

14 PIN SHOWN



4040047/B 03/95

- NOTES: A. All linear dimensions are in inches (millimeters).
 B. This drawing is subject to change without notice.
 C. Body dimensions do not include mold flash or protrusion, not to exceed 0.006 (0,15).
 D. Four center pins are connected to die mount pad.
 E. Falls within JEDEC MS-012

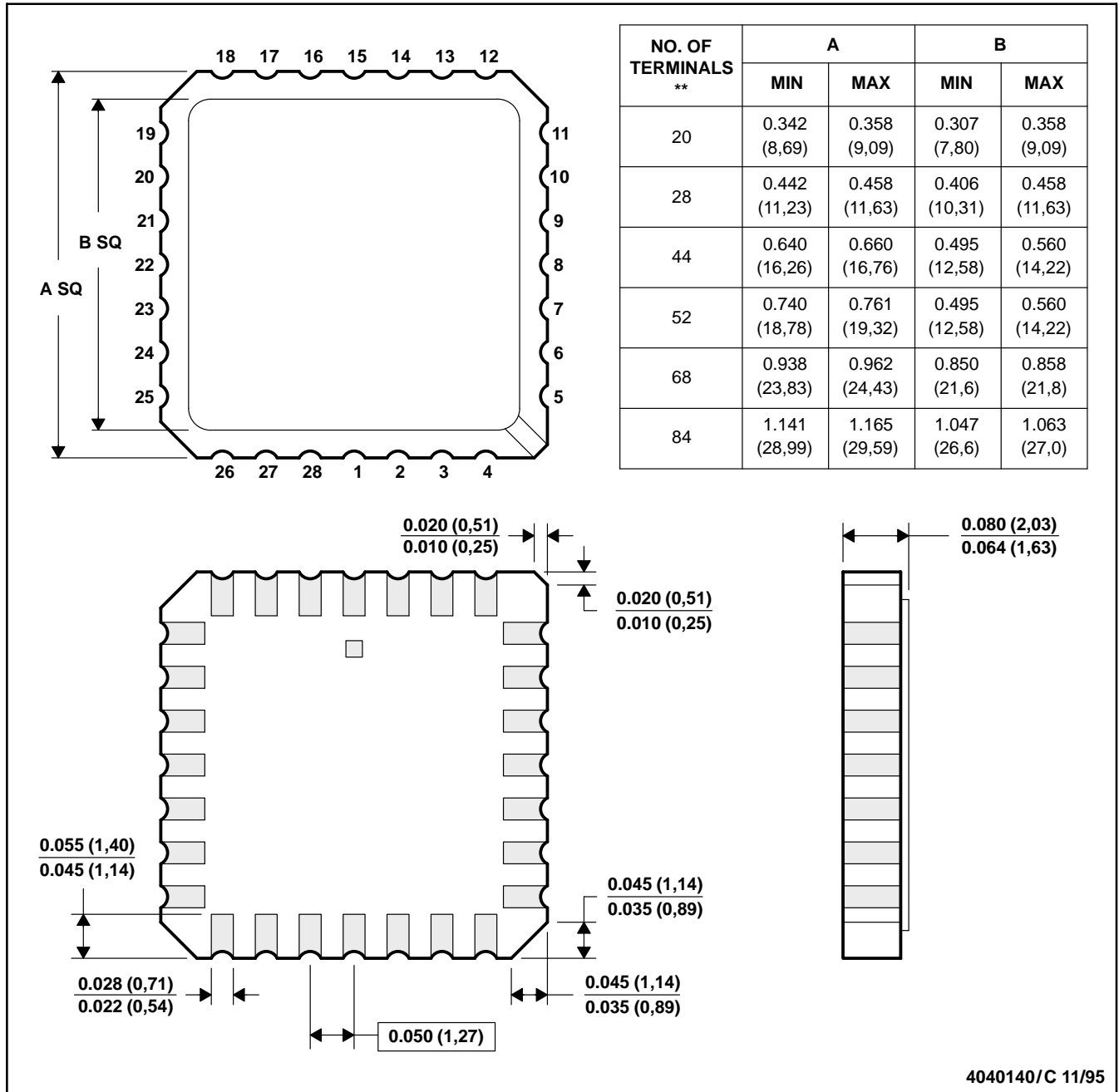
TLC225x, TLC225xA
Advanced LinCMOS™ RAIL-TO-RAIL
VERY LOW-POWER OPERATIONAL AMPLIFIERS
SLOS176D – FEBRUARY 1997 – REVISED MARCH 2001

MECHANICAL INFORMATION

FK (S-CQCC-N)**

LEADLESS CERAMIC CHIP CARRIER

28 TERMINAL SHOWN



- NOTES: A. All linear dimensions are in inches (millimeters).
 B. This drawing is subject to change without notice.
 C. This package can be hermetically sealed with a metal lid.
 D. The terminals are gold plated.
 E. Falls within JEDEC MS-004

TLC225x, TLC225xA
Advanced LinCMOS™ RAIL-TO-RAIL
VERY LOW-POWER OPERATIONAL AMPLIFIERS

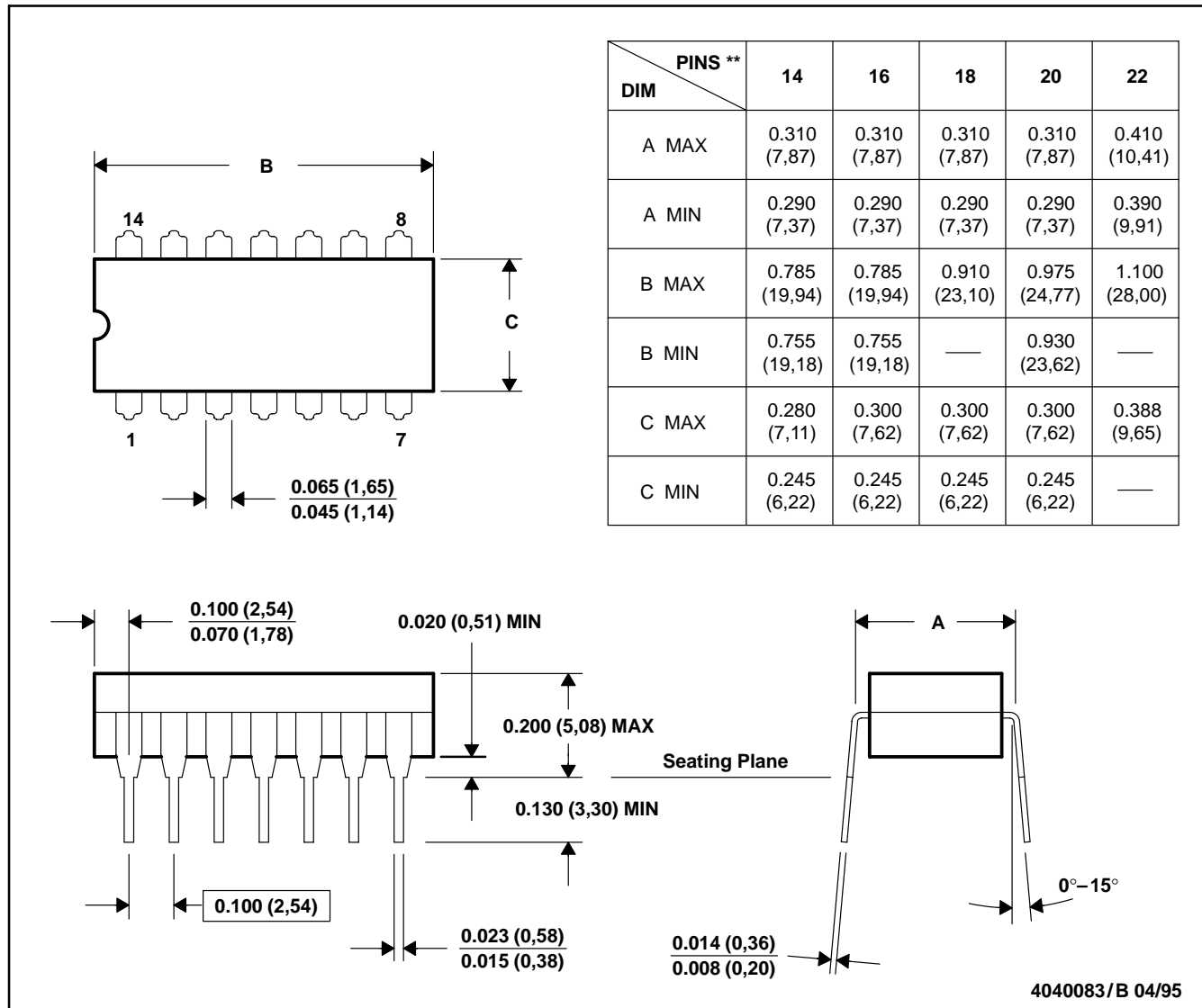
SLOS176D – FEBRUARY 1997 – REVISED MARCH 2001

MECHANICAL INFORMATION

J (R-GDIP-T)**

CERAMIC DUAL-IN-LINE PACKAGE

14 PIN SHOWN

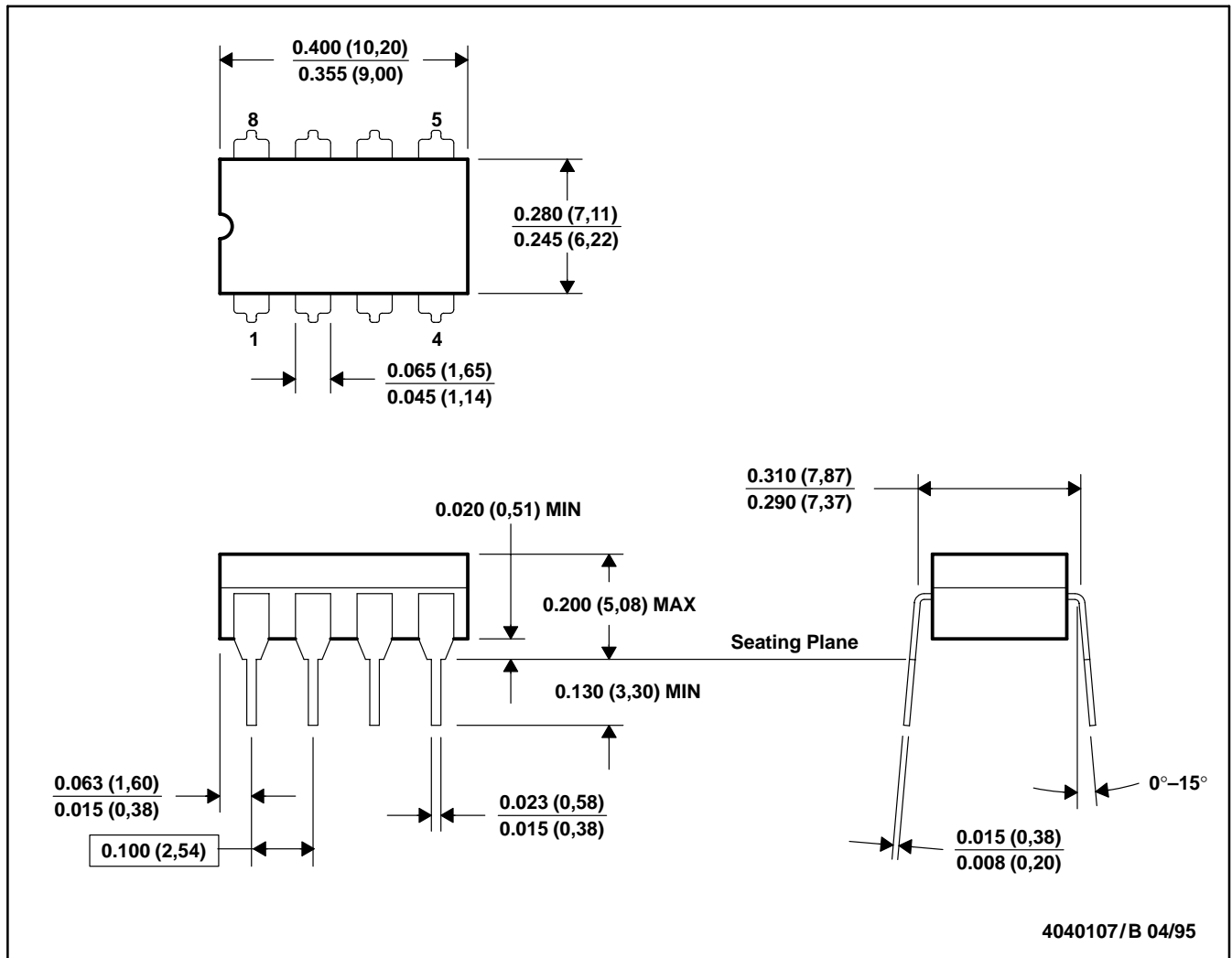


- NOTES: A. All linear dimensions are in inches (millimeters).
 B. This drawing is subject to change without notice.
 C. This package can be hermetically sealed with a ceramic lid using glass frit.
 D. Index point is provided on cap for terminal identification only.
 E. Falls within MIL-STD-1835 GDIP1-T14, GDIP1-T16, GDIP1-T18, GDIP1-T20, and GDIP1-T22

MECHANICAL INFORMATION

JG (R-GDIP-T8)

CERAMIC DUAL-IN-LINE PACKAGE



- NOTES: A. All linear dimensions are in inches (millimeters).
 B. This drawing is subject to change without notice.
 C. This package can be hermetically sealed with a ceramic lid using glass frit.
 D. Index point is provided on cap for terminal identification and/or on pressed ceramic glass frit seal.
 E. Falls within MIL-STD-1835 GDIP1-T8

TLC225x, TLC225xA
Advanced LinCMOS™ RAIL-TO-RAIL
VERY LOW-POWER OPERATIONAL AMPLIFIERS

SLOS176D – FEBRUARY 1997 – REVISED MARCH 2001

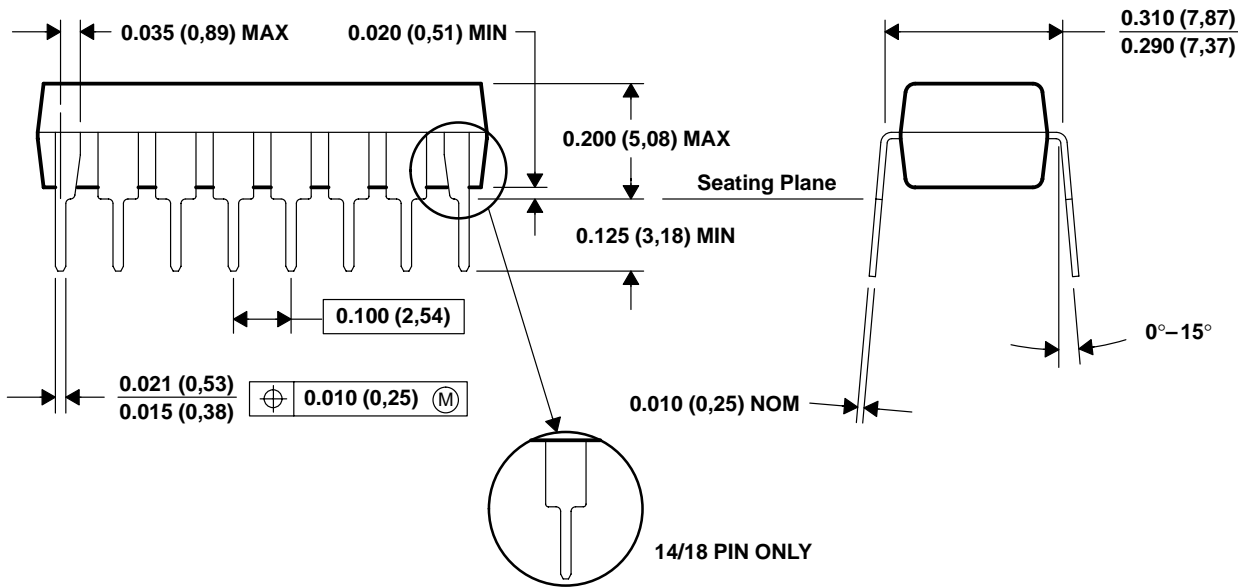
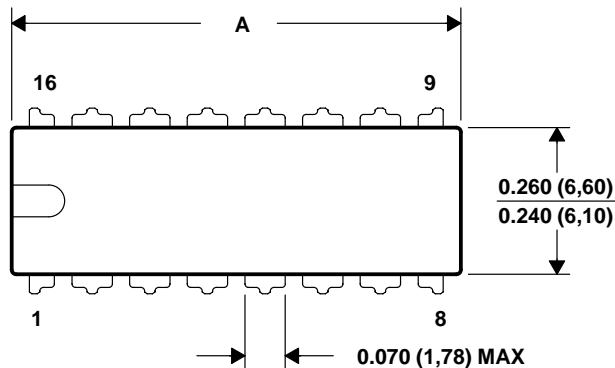
MECHANICAL INFORMATION

N (R-PDIP-T)**

PLASTIC DUAL-IN-LINE PACKAGE

16 PIN SHOWN

DIM \ PINS **	14	16	18	20
A MAX	0.775 (19,69)	0.775 (19,69)	0.920 (23,37)	0.975 (24,77)
A MIN	0.745 (18,92)	0.745 (18,92)	0.850 (21,59)	0.940 (23,88)



4040049/C 08/95

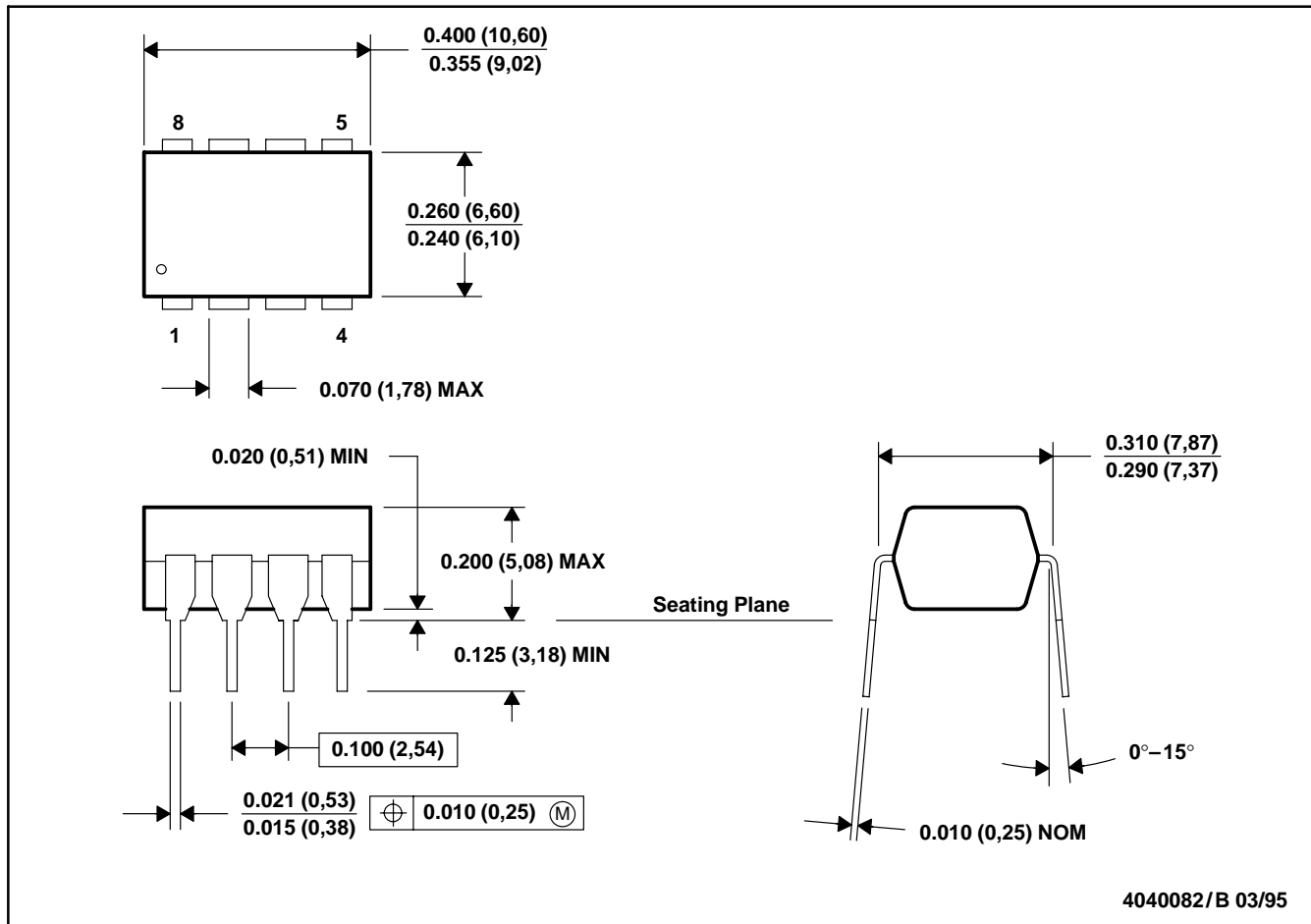
- NOTES: A. All linear dimensions are in inches (millimeters).
 B. This drawing is subject to change without notice.
 C. Falls within JEDEC MS-001 (20 pin package is shorter than MS-001.)

TLC225x, TLC225xA
Advanced LinCMOS™ RAIL-TO-RAIL
VERY LOW-POWER OPERATIONAL AMPLIFIERS
SLOS176D – FEBRUARY 1997 – REVISED MARCH 2001

MECHANICAL INFORMATION

P (R-PDIP-T8)

PLASTIC DUAL-IN-LINE PACKAGE



- NOTES: A. All linear dimensions are in inches (millimeters).
 B. This drawing is subject to change without notice.
 C. Falls within JEDEC MS-001

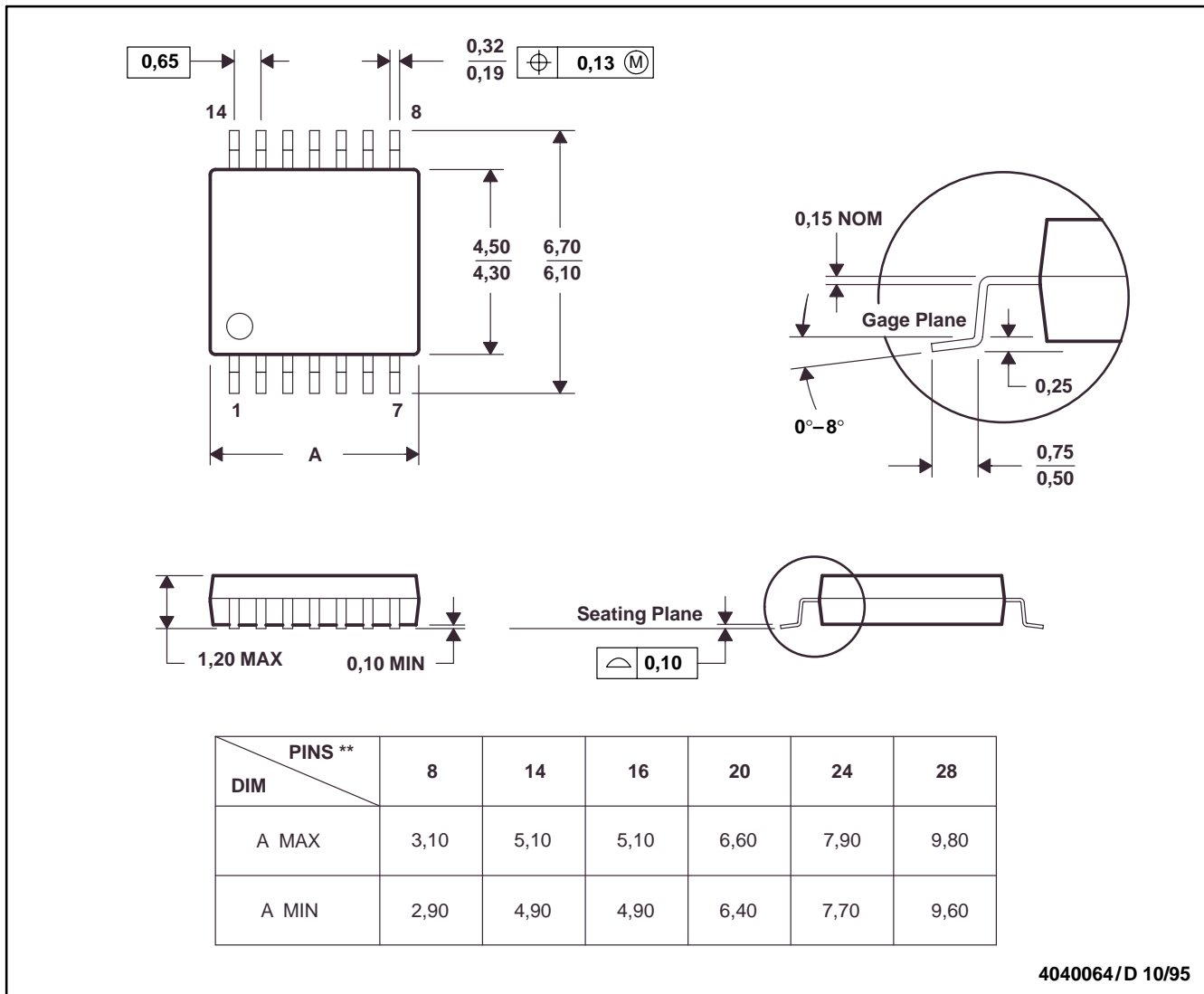
TLC225x, TLC225xA
Advanced LinCMOS™ RAIL-TO-RAIL
VERY LOW-POWER OPERATIONAL AMPLIFIERS
 SLOS176D – FEBRUARY 1997 – REVISED MARCH 2001

MECHANICAL INFORMATION

PW (R-PDSO-G)**

PLASTIC SMALL-OUTLINE PACKAGE

14 PIN SHOWN



4040064/D 10/95

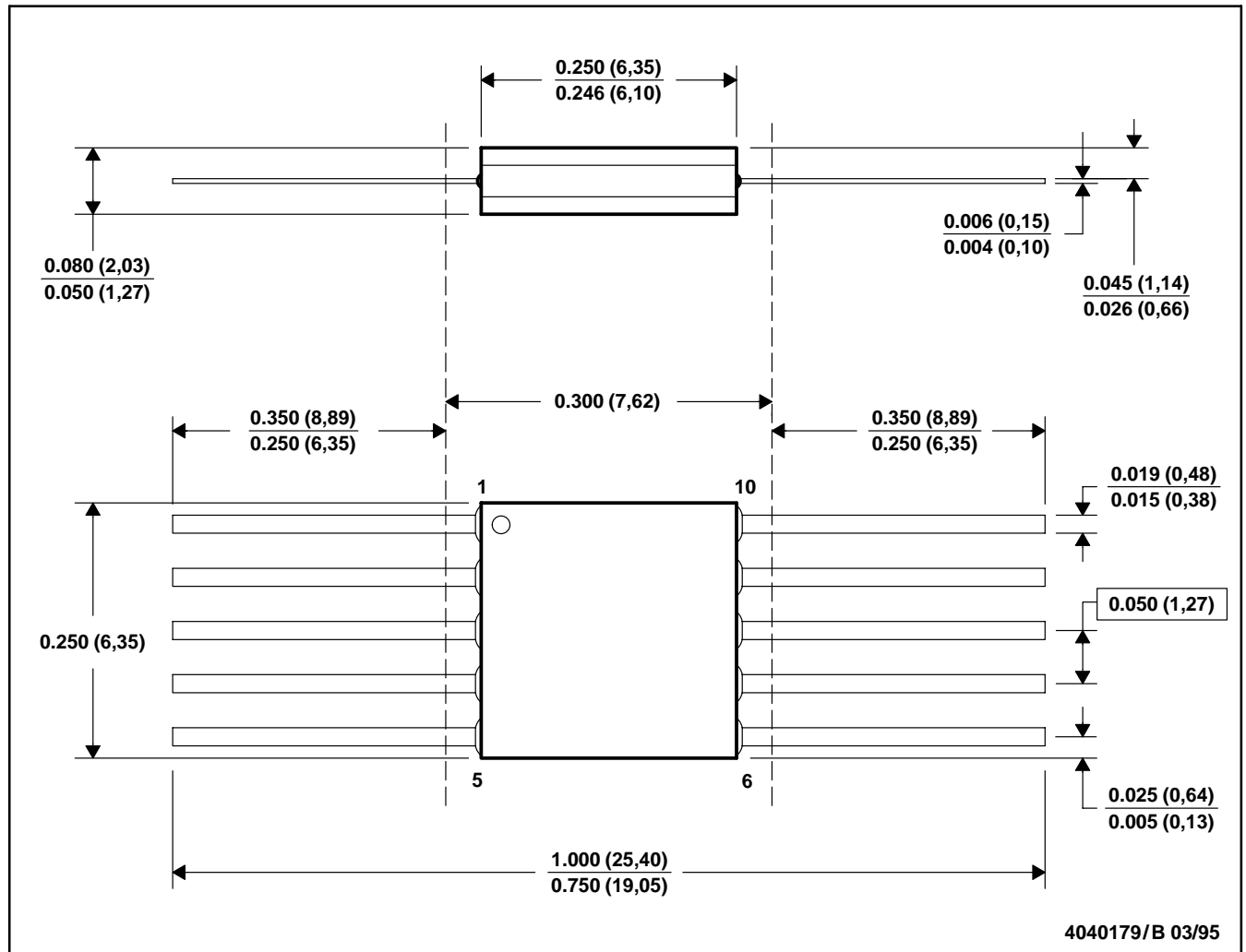
- NOTES: A. All linear dimensions are in millimeters.
 B. This drawing is subject to change without notice.
 C. Body dimensions do not include mold flash or protrusion not to exceed 0,15.
 D. Falls within JEDEC MO-153

TLC225x, TLC225xA
Advanced LinCMOS™ RAIL-TO-RAIL
VERY LOW-POWER OPERATIONAL AMPLIFIERS
SLOS176D – FEBRUARY 1997 – REVISED MARCH 2001

MECHANICAL INFORMATION

U (S-GDFP-F10)

CERAMIC DUAL FLATPACK



- NOTES: A. All linear dimensions are in inches (millimeters).
B. This drawing is subject to change without notice.
C. This package can be hermetically sealed with a ceramic lid using glass frit.
D. Index point is provided on cap for terminal identification only.
E. Falls within MIL STD 1835 GDFP1-F10 and JEDEC MO-092AA

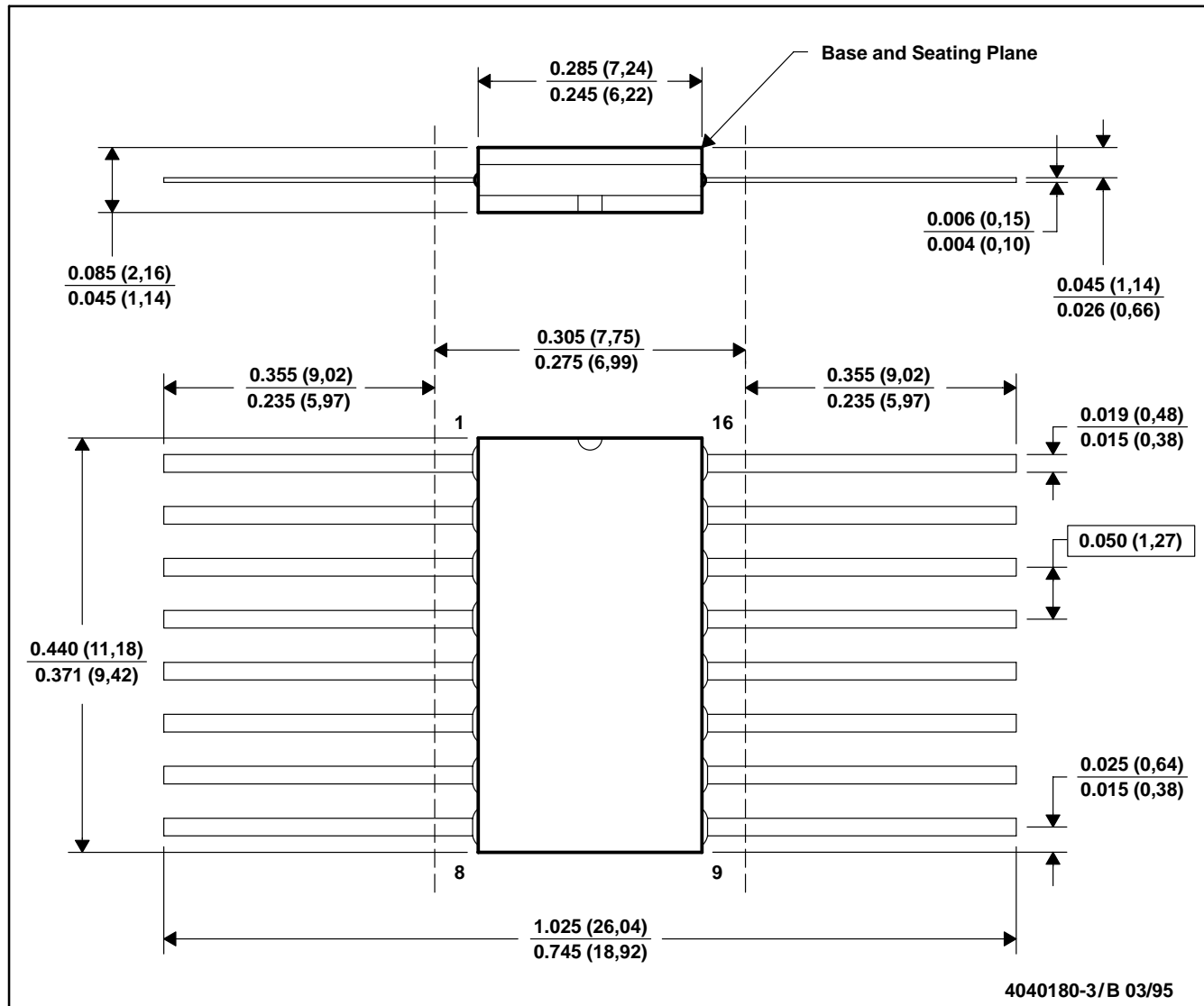
TLC225x, TLC225xA
Advanced LinCMOS™ RAIL-TO-RAIL
VERY LOW-POWER OPERATIONAL AMPLIFIERS

SLOS176D – FEBRUARY 1997 – REVISED MARCH 2001

MECHANICAL INFORMATION

W (R-GDFP-F16)

CERAMIC DUAL FLATPACK



- NOTES: A. All linear dimensions are in inches (millimeters).
 B. This drawing is subject to change without notice.
 C. This package can be hermetically sealed with a ceramic lid using glass frit.
 D. Index point is provided on cap for terminal identification only.
 E. Falls within MIL-STD-1835 GDFP1-F16 and JEDEC MO-092AC

IMPORTANT NOTICE

Texas Instruments and its subsidiaries (TI) reserve the right to make changes to their products or to discontinue any product or service without notice, and advise customers to obtain the latest version of relevant information to verify, before placing orders, that information being relied on is current and complete. All products are sold subject to the terms and conditions of sale supplied at the time of order acknowledgment, including those pertaining to warranty, patent infringement, and limitation of liability.

TI warrants performance of its products to the specifications applicable at the time of sale in accordance with TI's standard warranty. Testing and other quality control techniques are utilized to the extent TI deems necessary to support this warranty. Specific testing of all parameters of each device is not necessarily performed, except those mandated by government requirements.

Customers are responsible for their applications using TI components.

In order to minimize risks associated with the customer's applications, adequate design and operating safeguards must be provided by the customer to minimize inherent or procedural hazards.

TI assumes no liability for applications assistance or customer product design. TI does not warrant or represent that any license, either express or implied, is granted under any patent right, copyright, mask work right, or other intellectual property right of TI covering or relating to any combination, machine, or process in which such products or services might be or are used. TI's publication of information regarding any third party's products or services does not constitute TI's approval, license, warranty or endorsement thereof.

Reproduction of information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations and notices. Representation or reproduction of this information with alteration voids all warranties provided for an associated TI product or service, is an unfair and deceptive business practice, and TI is not responsible nor liable for any such use.

Resale of TI's products or services with statements different from or beyond the parameters stated by TI for that product or service voids all express and any implied warranties for the associated TI product or service, is an unfair and deceptive business practice, and TI is not responsible nor liable for any such use.

Also see: [Standard Terms and Conditions of Sale for Semiconductor Products](http://www.ti.com/sc/docs/stdterms.htm), www.ti.com/sc/docs/stdterms.htm

Mailing Address:

Texas Instruments
Post Office Box 655303
Dallas, Texas 75265