

# TLV225x-EP, TLV225xA-EP Advanced LinCMOS™ RAIL-TO-RAIL VERY LOW-POWER OPERATIONAL AMPLIFIERS

SGLS217A – NOVEMBER 2003 – REVISED MARCH 2004

- **Controlled Baseline**
  - One Assembly/Test Site, One Fabrication Site
- **Extended Temperature Performance of –40°C to 125°C**
- **Enhanced Diminishing Manufacturing Sources (DMS) Support**
- **Enhanced Product-Change Notification**
- **Qualification Pedigree†**
- **ESD Protection Exceeds 2000 V Per MIL-STD-883, Method 3015; Exceeds 150 V (TLV2252/52A) and 100 V (TLV2254/54A) Using Machine Model (C = 200 pF, R = 0)**
- **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 . . . 34 μA Per Channel Typ**
- **Common-Mode Input Voltage Range Includes Negative Rail**
- **Low Input Offset Voltage**  
850 μV Max at T<sub>A</sub> = 25°C
- **Wide Supply Voltage Range**  
2.7 V to 16 V
- **Macromodel Included**

† Component qualification in accordance with JEDEC and industry standards to ensure reliable operation over an extended temperature range. This includes, but is not limited to, Highly Accelerated Stress Test (HAST) or biased 85/85, temperature cycle, autoclave or unbiased HAST, electromigration, bond intermetallic life, and mold compound life. Such qualification testing should not be viewed as justifying use of this component beyond specified performance and environmental limits.

## description/ordering information

The TLV2252 and TLV2254 are dual and quadruple low-voltage operational amplifiers from Texas Instruments. Both devices exhibit rail-to-rail output performance for increased dynamic range in single- or split-supply applications. The TLV225x family consumes only 34 μA of supply current per channel. This micropower operation makes them good choices for battery-powered applications. This family is fully characterized at 3 V and 5 V and is optimized for low-voltage applications. The noise performance has been dramatically improved over previous generations of CMOS amplifiers. The TLV225x has a noise level of 19 nV/√Hz at 1kHz, four times lower than competitive micropower solutions.

The TLV225x, 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 combined with 3-V operation, these devices work well in hand-held monitoring and remote-sensing applications. In addition, the rail-to-rail output feature with single or split supplies makes this family a great choice when interfacing with analog-to-digital converters (ADCs). For precision applications, the TLV225xA family is available and has a maximum input offset voltage of 850 μV.

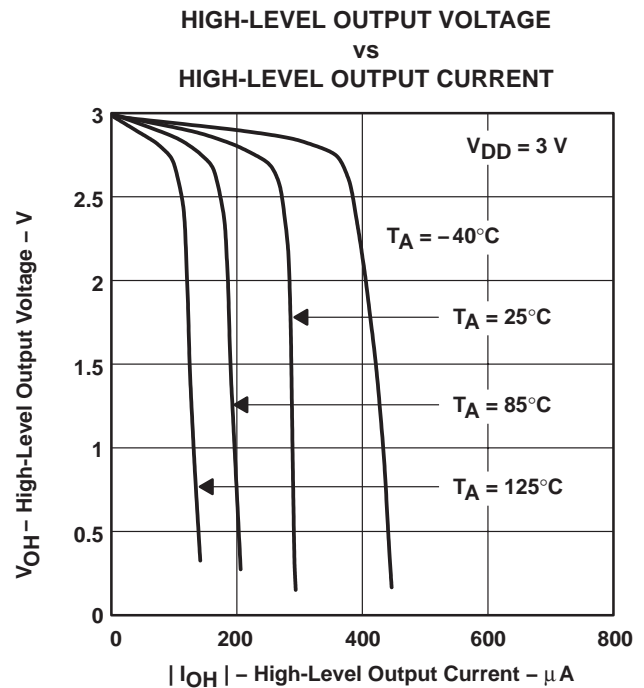


Figure 1



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.

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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.



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#### description/ordering information (continued)

The TLV2252/4 also make great upgrades to the TLV2322/4 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 range, see the TLV2432 and TLV2442 devices. If your 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.

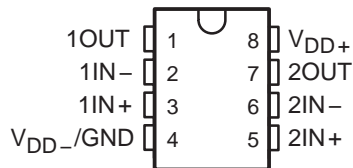
#### ORDERING INFORMATION

T <sub>A</sub>	V <sub>IOMax</sub> AT 25°C	PACKAGE†		ORDERABLE PART NUMBER	TOP-SIDE MARKING
-40°C to 125°C	850 μV	SOIC (D)	Tape and reel	TLV2252AQDREP	2252AE
		TSSOP (PW)	Tape and reel	TLV2252AQPWREP‡	
	1500 μV	SOIC (D)	Tape and reel	TLV2252QDREP	2252EP
		TSSOP (PW)	Tape and reel	TLV2252QPWREP‡	
-40°C to 125°C	850 μV	SOIC (D)	Tape and reel	TLV2254AQDREP	TLV2254AEP
		TSSOP (PW)	Tape and reel	TLV2254AQPWREP‡	
	1500 μV	SOIC (D)	Tape and reel	TLV2254QDREP	TLV2254EP
		TSSOP (PW)	Tape and reel	TLV2254QPWREP‡	

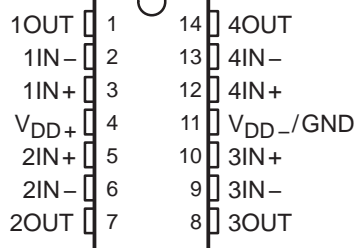
† Package drawings, standard packing quantities, thermal data, symbolization, and PCB design guidelines are available at [www.ti.com/sc/package](http://www.ti.com/sc/package).

‡ Product preview

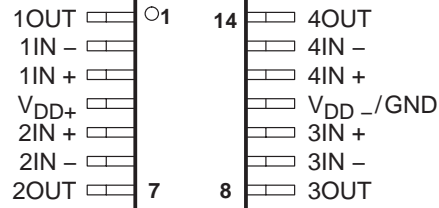
TLV2252, TLV2252A  
D OR PW PACKAGE  
(TOP VIEW)



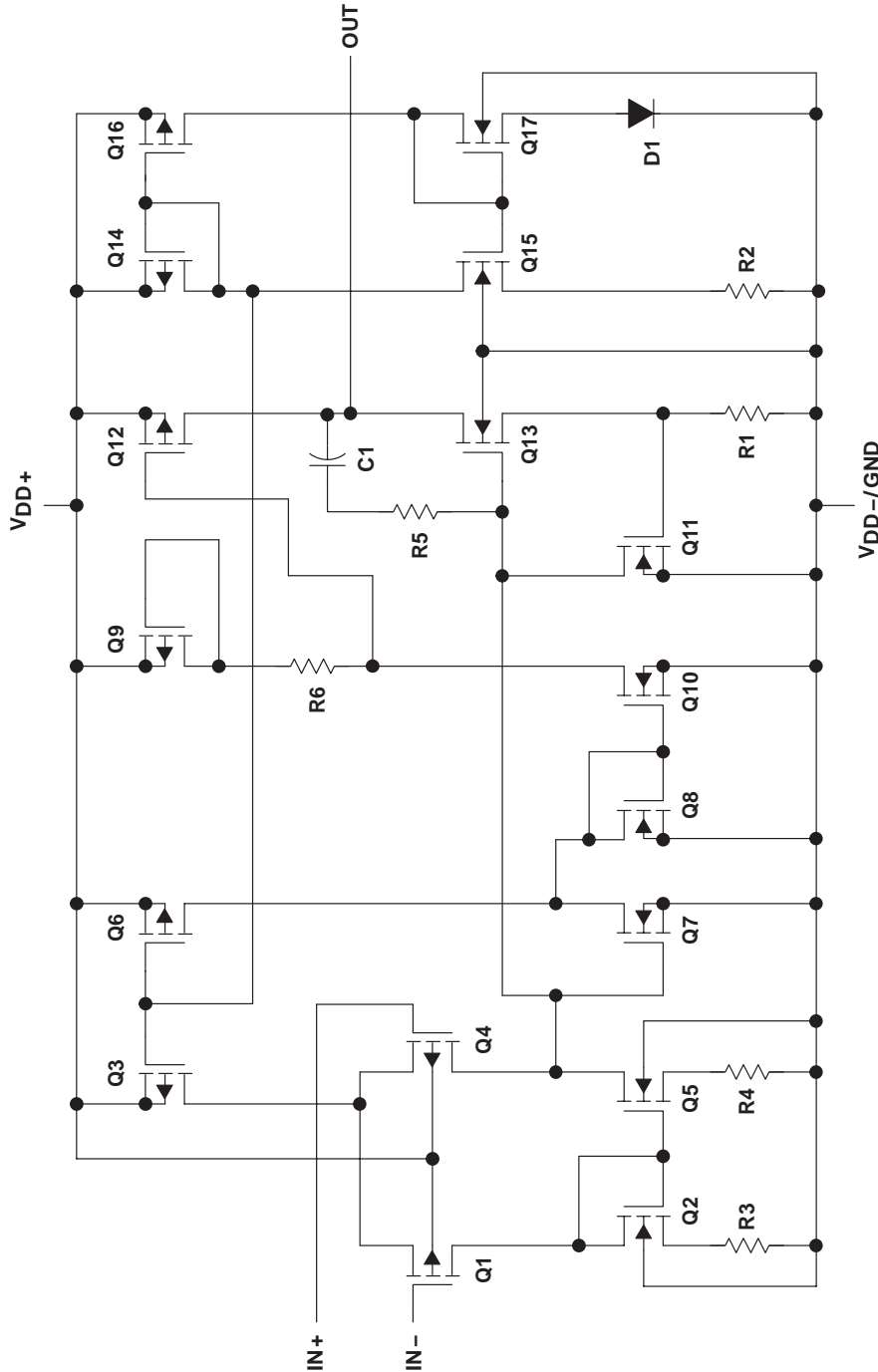
TLV2254, TLV2254A  
D PACKAGE  
(TOP VIEW)



TLV2254, TLV2254A  
PW PACKAGE  
(TOP VIEW)



equivalent schematic (each amplifier)



ACTUAL DEVICE COMPONENT COUNT†		
COMPONENT	TLV2252	TLV2254
Transistors	38	76
Resistors	30	56
Diodes	9	18
Capacitors	3	6

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

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

Supply voltage, $V_{DD}$ (see Note 1)	16 V
Differential input voltage, $V_{ID}$ (see Note 2)	$\pm V_{DD}$
Input voltage range, $V_I$ (any input, see Note 1)	$V_{DD-} - 0.3 \text{ V to } V_{DD+}$
Input current, $I_I$ (each input)	$\pm 5 \text{ mA}$
Output current, $I_O$	$\pm 50 \text{ mA}$
Total current into $V_{DD+}$	$\pm 50 \text{ mA}$
Total current out of $V_{DD-}$	$\pm 50 \text{ mA}$
Duration of short-circuit current (at or below) 25°C (see Note 3)	unlimited
Continuous total power dissipation	See Dissipation Rating Table
Operating free-air temperature range, $T_A$ : Q Suffix	-40°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: D and PW packages	260°C

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

- NOTES:
1. All voltage values, except differential voltages, are with respect to  $V_{DD-}$ .
  2. Differential voltages are at the noninverting input with respect to the inverting input. Excessive current flows when input is brought below  $V_{DD-} - 0.3 \text{ V}$ .
  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 $T_A = 25^\circ\text{C}$	$T_A = 85^\circ\text{C}$ POWER RATING	$T_A = 125^\circ\text{C}$ POWER RATING
D-8	725 mW	5.8 mW/°C	377 mW	145 mW
D-14	950 mW	7.6 mW/°C	494 mW	190 mW
PW-8	525 mW	4.2 mW/°C	273 mW	105 mW
PW-14	700 mW	5.6 mW/°C	364 mW	140 mW

**recommended operating conditions**

	MIN	MAX	UNIT
Supply voltage, $V_{DD}$ (see Note 1)	2.7	16	V
Input voltage range, $V_I$	$V_{DD-}$	$V_{DD+} - 1.3$	V
Common-mode input voltage, $V_{IC}$	$V_{DD-}$	$V_{DD+} - 1.3$	V
Operating free-air temperature, $T_A$	-40	125	°C

NOTE 1: All voltage values, except differential voltages, are with respect to  $V_{DD-}$ .

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**TLV2252-EP electrical characteristics at specified free-air temperature,  $V_{DD} = 3\text{ V}$  (unless otherwise noted)**

PARAMETER	TEST CONDITIONS	$T_A$ †	TLV2252-EP			TLV2252A-EP			UNIT	
			MIN	TYP	MAX	MIN	TYP	MAX		
$V_{IO}$ Input offset voltage		25°C	200	1500		200	850	$\mu\text{V}$		
		Full range			1750		1000			
$\alpha_{VIO}$ 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)	$V_{DD} \pm = \pm 1.5\text{ V}$ , $V_O = 0$ , $V_{IC} = 0$ , $R_S = 50\ \Omega$	25°C	0.003			0.003			$\mu\text{V}/\text{mo}$	
$I_{IO}$ Input offset current		25°C	0.5	60		0.5	60	$\text{pA}$		
		125°C	1000			1000				
$I_{IB}$ Input bias current		25°C	1	60		1	60	$\text{pA}$		
		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 2	-0.3 to 2.2		0 to 2	-0.3 to 2.2	$\text{V}$	
	Full range		0 to 1.7			0 to 1.7				
$V_{OH}$ High-level output voltage	$I_{OH} = -20\ \mu\text{A}$	25°C	2.98			2.98			$\text{V}$	
	$I_{OH} = -75\ \mu\text{A}$	25°C	2.9			2.9				
	$I_{OH} = -150\ \mu\text{A}$	Full range	2.8			2.8				
$V_{OL}$ Low-level output voltage	$V_{IC} = 1.5\text{ V}$ , $I_{OL} = 50\ \mu\text{A}$	25°C	10			10			$\text{mV}$	
	$V_{IC} = 1.5\text{ V}$ , $I_{OL} = 500\ \mu\text{A}$	25°C	100	150		100	150			
		Full range	165			165				
	$V_{IC} = 1.5\text{ V}$ , $I_{OL} = 1\text{ mA}$	25°C	200	300		200	300			
AVD Large-signal differential voltage amplification	$V_{IC} = 1.5\text{ V}$ , $V_O = 1\text{ V to }2\text{ V}$	$R_L = 100\ \text{k}\Omega^\ddagger$	25°C	100	250		100	250	$\text{V}/\text{mV}$	
		$R_L = 1\ \text{M}\Omega^\ddagger$	Full range	10			10			
			25°C	800			800			
$r_{i(d)}$ Differential input resistance		25°C	$10^{12}$			$10^{12}$			$\Omega$	
$r_{i(c)}$ Common-mode input resistance		25°C	$10^{12}$			$10^{12}$			$\Omega$	
$C_{i(c)}$ Common-mode input capacitance	$f = 10\ \text{kHz}$	25°C	8			8			$\text{pF}$	
$z_o$ Closed-loop output impedance	$f = 25\ \text{kHz}$ , $A_V = 10$	25°C	220			220			$\Omega$	
CMRR Common-mode rejection ratio	$V_{IC} = 0\text{ to }1.7\text{ V}$ , $V_O = 1.5\text{ V}$ , $R_S = 50\ \Omega$	25°C	65	75		65	77	$\text{dB}$		
		Full range	60			60				
$k_{SVR}$ Supply voltage rejection ratio ( $\Delta V_{DD} / \Delta V_{IO}$ )	$V_{DD} = 2.7\text{ V to }8\text{ V}$ , $V_{IC} = V_{DD}/2$ , No load	25°C	80	95		80	100	$\text{dB}$		
		Full range	80			80				
$I_{DD}$ Supply current	$V_O = 1.5\text{ V}$ , No load	25°C	68	125		68	125	$\mu\text{A}$		
		Full range	150			150				

† Full range is  $-40^\circ\text{C}$  to  $125^\circ\text{C}$  for Q level part.

‡ Referenced to 1.5 V

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



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**TLV2252-EP operating characteristics at specified free-air temperature,  $V_{DD} = 3\text{ V}$**

PARAMETER	TEST CONDITIONS	$T_A$ †	TLV2252-EP			TLV2252A-EP			UNIT	
			MIN	TYP	MAX	MIN	TYP	MAX		
SR	Slew rate at unity gain $V_O = 0.8\text{ V to }1.4\text{ V}, R_L = 100\text{ k}\Omega^\ddagger,$ $C_L = 100\text{ pF}^\ddagger$	25°C	0.07	0.1		0.07	0.1		V/ $\mu\text{s}$	
		Full range	0.05			0.05				
$V_n$	Equivalent input noise voltage	f = 10 Hz	25°C			35			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			0.6			$\mu\text{V}$	
		f = 0.1 Hz to 10 Hz	25°C			1.1				
$I_n$	Equivalent input noise current	25°C				0.6			fA/ $\sqrt{\text{Hz}}$	
	Gain-bandwidth product	f = 1 kHz, $C_L = 100\text{ pF}^\ddagger$	$R_L = 50\text{ k}\Omega^\ddagger,$	25°C			0.187			MHz
$B_{OM}$	Maximum output-swing bandwidth	$V_{O(PP)} = 1\text{ V},$ $R_L = 50\text{ k}\Omega^\ddagger,$	$A_V = 1,$ $C_L = 100\text{ pF}^\ddagger$	25°C			60			kHz
$\phi_m$	Phase margin at unity gain	$R_L = 50\text{ k}\Omega^\ddagger,$	$C_L = 100\text{ pF}^\ddagger$	25°C			63°			
	Gain margin			25°C			15			dB

† Full range is  $-40^\circ\text{C}$  to  $125^\circ\text{C}$  for Q level part.

‡ Referenced to 1.5 V

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**TLV2252-EP electrical characteristics at specified free-air temperature,  $V_{DD} = 5\text{ V}$  (unless otherwise noted)**

PARAMETER	TEST CONDITIONS	$T_A$ †	TLV2252-EP			TLV2252A-EP			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	$\mu\text{V}$	
		Full range			1750		1000		
$\alpha_{VIO}$ 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	
		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	$ V_{IO}  \leq 5\text{ mV}$ , $R_S = 50\ \Omega$	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	$I_{OH} = -20\ \mu\text{A}$ $I_{OH} = -75\ \mu\text{A}$ $I_{OH} = -150\ \mu\text{A}$	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	$V_{IC} = 2.5\text{ V}$ , $I_{OL} = 50\ \mu\text{A}$ $V_{IC} = 2.5\text{ V}$ , $I_{OL} = 500\ \mu\text{A}$ $V_{IC} = 2.5\text{ V}$ , $I_{OL} = 1\text{ mA}$	25°C	0.01			0.01			V
		25°C	0.09	0.15		0.09	0.15		
		Full range	0.15			0.15			
		25°C	0.2	0.3		0.2	0.3		
		Full range	0.3			0.3			
$A_{VD}$ 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	$10^{12}$			$10^{12}$			$\Omega$
$r_{i(c)}$ Common-mode input resistance		25°C	$10^{12}$			$10^{12}$			$\Omega$
$C_{i(c)}$ Common-mode input capacitance	$f = 10\text{ kHz}$	25°C	8			8			pF
$z_o$ Closed-loop output impedance	$f = 25\text{ kHz}$ , $A_V = 10$	25°C	200			200			$\Omega$
CMRR Common-mode rejection ratio	$V_{IC} = 0\text{ to }2.7\text{ V}$ , $V_O = 2.5\text{ V}$ , $R_S = 50\ \Omega$	25°C	70	83		70	83	dB	
		Full range	70			70			
$k_{SVR}$ Supply voltage rejection ratio ( $\Delta V_{DD}/\Delta V_{IO}$ )	$V_{DD} = 4.4\text{ V to }8\text{ V}$ , $V_{IC} = V_{DD}/2$ , No load	25°C	80	95		80	95	dB	
		Full range	80			80			

† Full range is  $-40^\circ\text{C}$  to  $125^\circ\text{C}$  for Q level part.

‡ 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.



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**TLV2252-EP electrical characteristics at specified free-air temperature,  $V_{DD} = 5\text{ V}$  (unless otherwise noted) (continued)**

PARAMETER	TEST CONDITIONS	$T_A$ †	TLV2252-EP			TLV2252A-EP			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
$I_{DD}$ Supply current	$V_O = 2.5\text{ V}$ , No load	25°C	70	125		70	125	$\mu\text{A}$	
		Full range		150			150		

† Full range is  $-40^\circ\text{C}$  to  $125^\circ\text{C}$  for Q level part.

**TLV2252-EP operating characteristics at specified free-air temperature,  $V_{DD} = 5\text{ V}$**

PARAMETER	TEST CONDITIONS	$T_A$ †	TLV2252-EP			TLV2252A-EP			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
SR Slew rate at unity gain	$V_O = 1.25\text{ V}$ to $2.75\text{ V}$ , $R_L = 100\text{ k}\Omega$ ‡, $C_L = 100\text{ pF}$ ‡	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	$f = 10\text{ Hz}$ $f = 1\text{ kHz}$	25°C		36			36	$\text{nV}/\sqrt{\text{Hz}}$	
		25°C		19			19		
$V_{N(PP)}$ Peak-to-peak equivalent input noise voltage	$f = 0.1\text{ Hz}$ to $1\text{ Hz}$ $f = 0.1\text{ Hz}$ to $10\text{ Hz}$	25°C		0.7			0.7	$\mu\text{V}$	
		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 $2.5\text{ V}$ , $f = 20\text{ kHz}$ , $R_L = 50\text{ k}\Omega$ ‡	25°C	$A_V = 1$		0.2%		0.2%		
			$A_V = 10$		1%		1%		
Gain-bandwidth product	$f = 50\text{ kHz}$ , $C_L = 100\text{ pF}$ ‡	25°C		0.2			0.2	MHz	
BOM Maximum output-swing bandwidth	$V_{O(PP)} = 2\text{ V}$ , $R_L = 50\text{ k}\Omega$ ‡	25°C		30			30	kHz	
$\phi_m$ Phase margin at unity gain Gain margin	$R_L = 50\text{ k}\Omega$ ‡, $C_L = 100\text{ pF}$ ‡	25°C		63°			63°	dB	
		25°C		15			15		

† Full range is  $-40^\circ\text{C}$  to  $125^\circ\text{C}$  for Q level part.

‡ Referenced to  $2.5\text{ V}$



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**TLV2254-EP electrical characteristics at specified free-air temperature,  $V_{DD} = 3\text{ V}$  (unless otherwise noted)**

PARAMETER	TEST CONDITIONS	$T_A$ †	TLV2254-EP			TLV2254A-EP			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
$V_{IO}$ Input offset voltage	$V_{DD\pm} = \pm 1.5\text{ V}$ , $V_O = 0$ , $V_{IC} = 0$ , $R_S = 50\ \Omega$	25°C	200	1500		200	850	$\mu\text{V}$	
		Full range			1750		1000		
$\alpha_{VIO}$ 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	
		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 2	-0.3 to 2.2		0 to 2	-0.3 to 2.2	V	
		Full range	0 to 1.7			0 to 1.7			
$V_{OH}$ High-level output voltage	$I_{OH} = -20\ \mu\text{A}$ $I_{OH} = -75\ \mu\text{A}$ $I_{OH} = -150\ \mu\text{A}$	25°C	2.98		2.98		V		
		25°C	2.9		2.9				
		Full range	2.8		2.8				
		25°C	2.8		2.8				
$V_{OL}$ Low-level output voltage	$V_{IC} = 1.5\text{ V}$ , $I_{OL} = 50\ \mu\text{A}$ $I_{OL} = 500\ \mu\text{A}$ $I_{OL} = 1\text{ mA}$	25°C	10		10		mV		
		25°C	100	150	100	150			
		Full range	165		165				
		25°C	200	300	200	300			
		Full range	300		300				
$A_{VD}$ Large-signal differential voltage amplification	$V_{IC} = 1.5\text{ V}$ , $V_O = 1\text{ V to }2\text{ V}$	$R_L = 100\ \text{k}\Omega$ ‡	25°C	100	225	100	225	V/mV	
			Full range	10		10			
		$R_L = 1\ \text{M}\Omega$ ‡	25°C	800		800			
$r_{i(d)}$ Differential input resistance		25°C	$10^{12}$		$10^{12}$		$\Omega$		
$r_{i(c)}$ Common-mode input resistance		25°C	$10^{12}$		$10^{12}$		$\Omega$		
$C_{i(c)}$ Common-mode input capacitance	$f = 10\ \text{kHz}$	25°C	8		8		pF		
$z_o$ Closed-loop output impedance	$f = 25\ \text{kHz}$ , $A_V = 10$	25°C	220		220		$\Omega$		
CMRR Common-mode rejection ratio	$V_{IC} = 0\text{ to }1.7\text{ V}$ , $V_O = 1.5\text{ V}$ , $R_S = 50\ \Omega$	25°C	65	75	65	77	dB		
		Full range	60		60				
$k_{SVR}$ Supply voltage rejection ratio ( $\Delta V_{DD}/\Delta V_{IO}$ )	$V_{DD} = 2.7\text{ V to }8\text{ V}$ , $V_{IC} = V_{DD}/2$ , No load	25°C	80	95	80	100	dB		
		Full range	80		80				

† Full range is -40°C to 125°C for Q level part.

‡ Referenced to 1.5 V

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



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**TLV2254-EP electrical characteristics at specified free-air temperature,  $V_{DD} = 3\text{ V}$  (unless otherwise noted) (continued)**

PARAMETER	TEST CONDITIONS	$T_A$ †	TLV2254-EP			TLV2254A-EP			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
$I_{DD}$	Supply current (four amplifiers)	$V_O = 1.5\text{ V}$ , No load	25°C		135	250	135 250		$\mu\text{A}$
			Full range		300		300		

† Full range is  $-40^\circ\text{C}$  to  $125^\circ\text{C}$  for Q level part.

**TLV2254-EP operating characteristics at specified free-air temperature,  $V_{DD} = 3\text{ V}$**

PARAMETER	TEST CONDITIONS	$T_A$ †	TLV2254-EP			TLV2254A-EP			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
SR	Slew rate at unity gain	$V_O = 0.5\text{ V}$ to $1.7\text{ V}$ , $R_L = 100\text{ k}\Omega$ ‡, $C_L = 100\text{ pF}$ ‡	25°C		0.07	0.1	0.07 0.1		$\text{V}/\mu\text{s}$
			Full range		0.05		0.05		
$V_n$	Equivalent input noise voltage	$f = 10\text{ Hz}$	25°C		35		35		$\text{nV}/\sqrt{\text{Hz}}$
			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		0.6		0.6		$\mu\text{V}$
			25°C		1.1		1.1		
$I_n$	Equivalent input noise current		25°C		0.6		0.6		$\text{fA}/\sqrt{\text{Hz}}$
	Gain-bandwidth product	$f = 1\text{ kHz}$ , $R_L = 50\text{ k}\Omega$ ‡, $C_L = 100\text{ pF}$ ‡	25°C		0.187		0.187		MHz
$B_{OM}$	Maximum output-swing bandwidth	$V_{O(PP)} = 1\text{ V}$ , $A_V = 1$ , $R_L = 50\text{ k}\Omega$ ‡, $C_L = 100\text{ pF}$ ‡	25°C		60		60		kHz
$\phi_m$	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  $-40^\circ\text{C}$  to  $125^\circ\text{C}$  for Q level part.

‡ Referenced to  $1.5\text{ V}$

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**TLV2254-EP electrical characteristics at specified free-air temperature,  $V_{DD} = 5\text{ V}$  (unless otherwise noted)**

PARAMETER	TEST CONDITIONS	$T_A$ †	TLV2254-EP			TLV2254A-EP			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	$\mu\text{V}$	
		Full range		1750		1000			
$\alpha_{VIO}$ 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	
		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	$ V_{IO}  \leq 5\text{ mV}$ , $R_S = 50\ \Omega$	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		
	$V_{IC} = 2.5\text{ V}$ , $I_{OL} = 500\ \mu\text{A}$	Full range	0.15			0.15			
		25°C	0.2	0.3		0.2	0.3		
	$V_{IC} = 2.5\text{ V}$ , $I_{OL} = 1\text{ mA}$	Full range	0.3			0.3			
		25°C	0.3			0.3			
$A_{VD}$ 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	$10^{12}$			$10^{12}$			$\Omega$
$r_{i(c)}$ Common-mode input resistance		25°C	$10^{12}$			$10^{12}$			$\Omega$
$C_{i(c)}$ Common-mode input capacitance	$f = 10\text{ kHz}$	25°C	8			8			pF
$z_o$ Closed-loop output impedance	$f = 25\text{ kHz}$ , $A_V = 10$	25°C	200			200			$\Omega$
CMRR Common-mode rejection ratio	$V_{IC} = 0\text{ to }2.7\text{ V}$ , $V_O = 2.5\text{ V}$ , $R_S = 50\ \Omega$	25°C	70	83		70	83	dB	
		Full range	70			70			
$k_{SVR}$ Supply voltage rejection ratio ( $\Delta V_{DD}/\Delta V_{IO}$ )	$V_{DD} = 4.4\text{ V to }8\text{ V}$ , $V_{IC} = V_{DD}/2$ , No load	25°C	80	95		80	95	dB	
		Full range	80			80			

† Full range is  $-40^\circ\text{C}$  to  $125^\circ\text{C}$  for Q level part.

‡ 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.



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**TLV2254-EP electrical characteristics at specified free-air temperature,  $V_{DD} = 5\text{ V}$  (unless otherwise noted) (continued)**

PARAMETER	TEST CONDITIONS	$T_A$ †	TLV2254-EP			TLV2254A-EP			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
$I_{DD}$ Supply current (four amplifiers)	$V_O = 2.5\text{ V}$ , No load	25°C		140	250		140	250	$\mu\text{A}$
		Full range			300			300	

† Full range is  $-40^\circ\text{C}$  to  $125^\circ\text{C}$  for Q level part.

**TLV2254-EP operating characteristics at specified free-air temperature,  $V_{DD} = 5\text{ V}$**

PARAMETER	TEST CONDITIONS	$T_A$ †	TLV2254-EP			TLV2254A-EP			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		$\text{V}/\mu\text{s}$
		Full range	0.05			0.05			
$V_n$ Equivalent input noise voltage	$f = 10\text{ Hz}$ $f = 1\text{ kHz}$	25°C		36			36		$\text{nV}/\sqrt{\text{Hz}}$
		25°C		19			19		
$V_{N(PP)}$ Peak-to-peak equivalent input noise voltage	$f = 0.1\text{ Hz}$ to $1\text{ Hz}$ $f = 0.1\text{ Hz}$ to $10\text{ Hz}$	25°C		0.7			0.7		$\mu\text{V}$
		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 $2.5\text{ V}$ , $f = 20\text{ kHz}$ , $R_L = 50\text{ k}\Omega$ ‡	25°C	$A_V = 1$		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	
$B_{OM}$ Maximum output-swing bandwidth	$V_{O(PP)} = 2\text{ V}$ , $R_L = 50\text{ k}\Omega$ ‡, $C_L = 100\text{ pF}$ ‡	25°C		30			30	kHz	
$\phi_m$ 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  $-40^\circ\text{C}$  to  $125^\circ\text{C}$  for Q level part.

‡ Referenced to 2.5 V



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TYPICAL CHARACTERISTICS

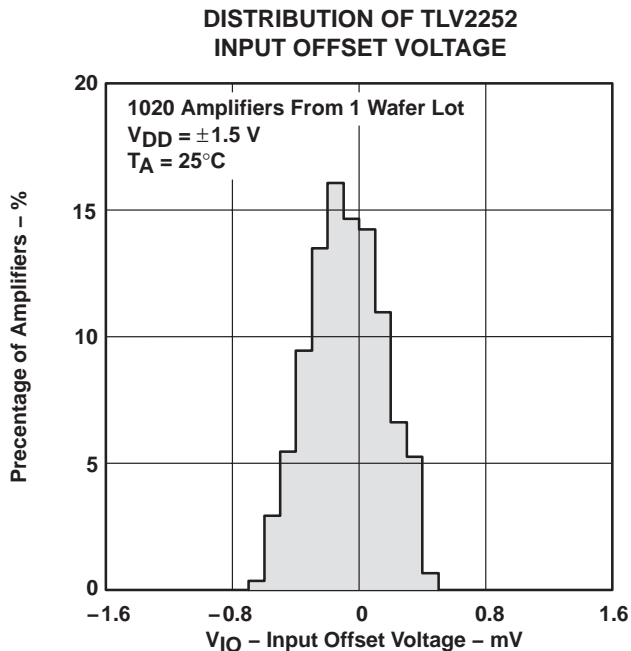


Figure 2

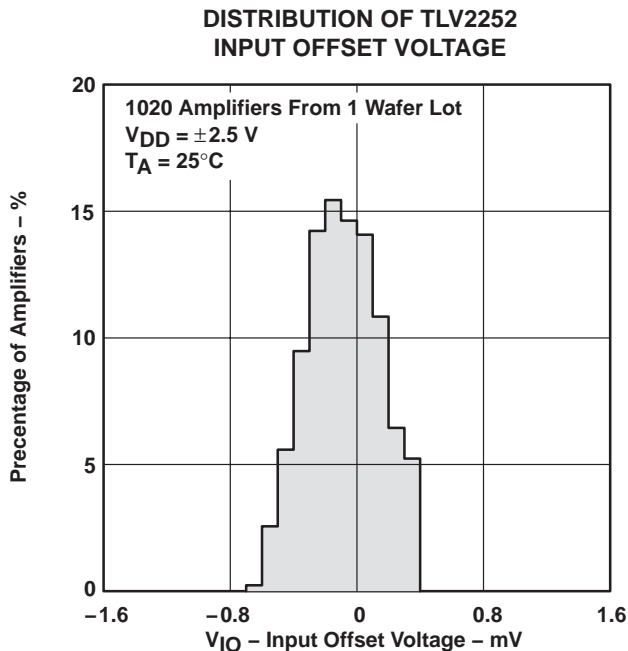


Figure 3

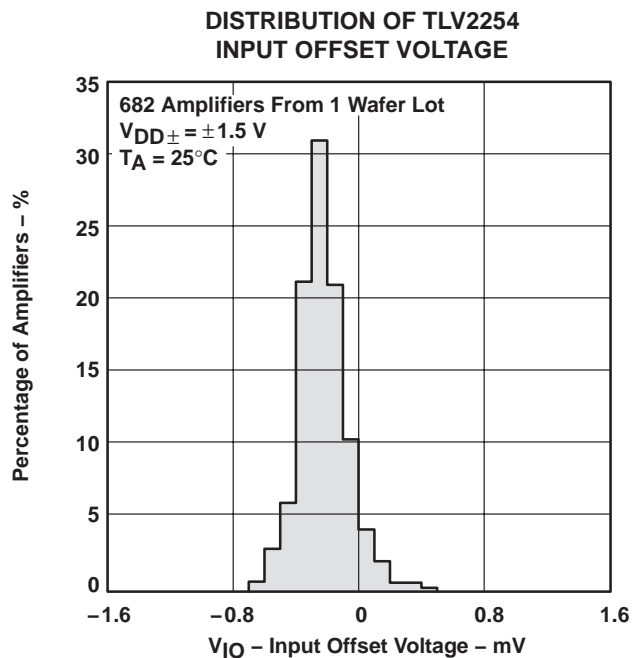


Figure 4

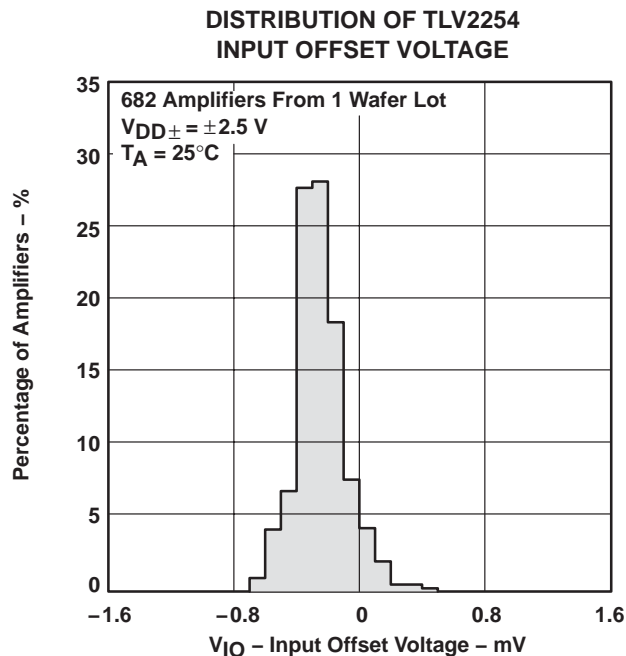
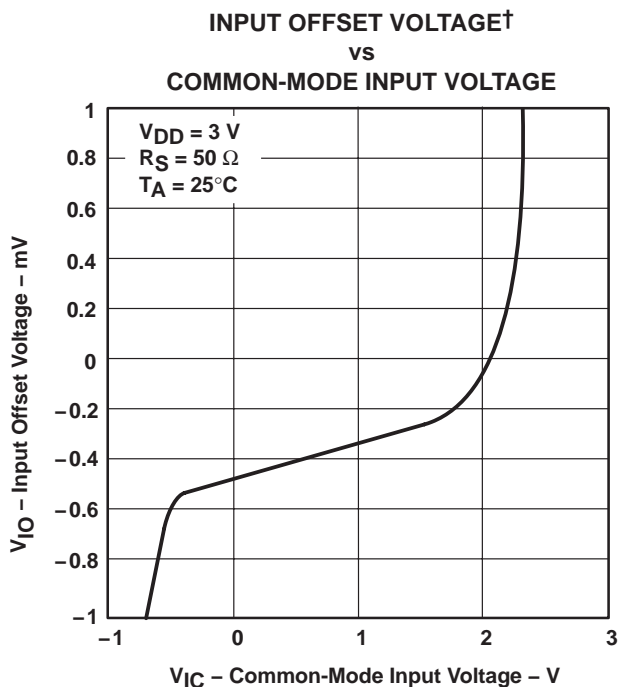


Figure 5

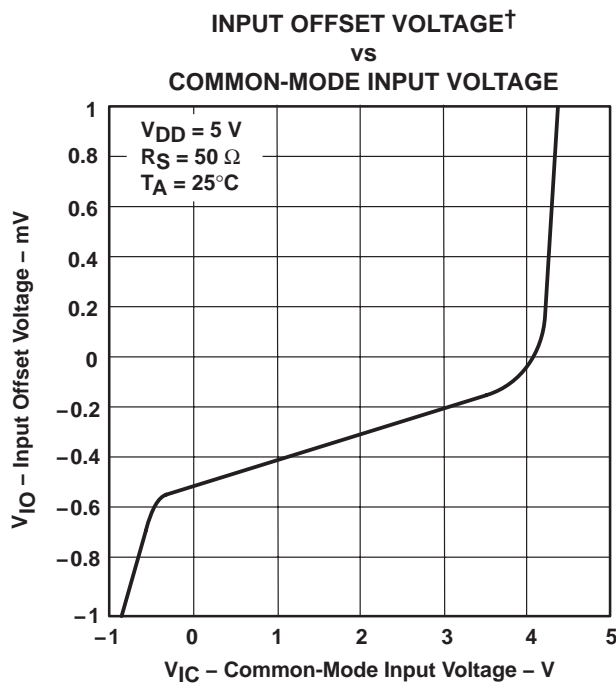
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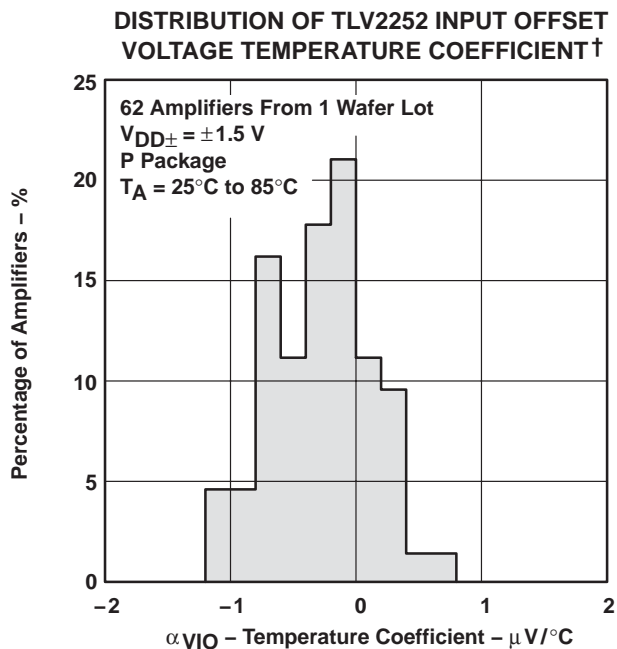
**TYPICAL CHARACTERISTICS**



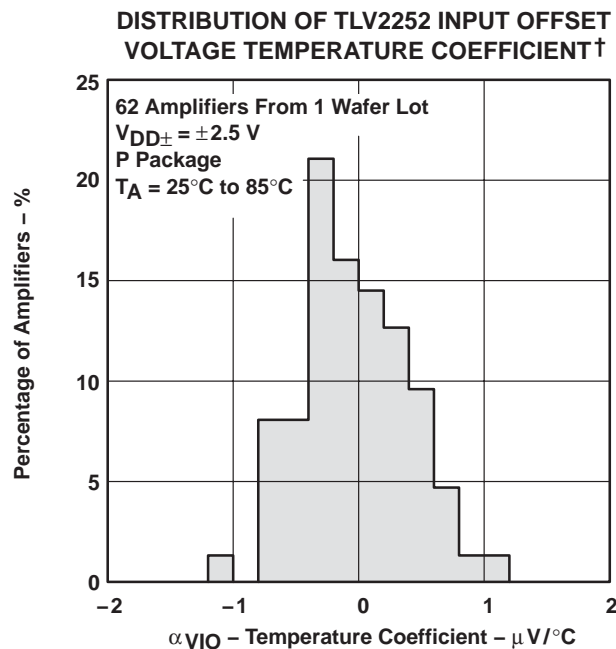
**Figure 6**



**Figure 7**



**Figure 8**

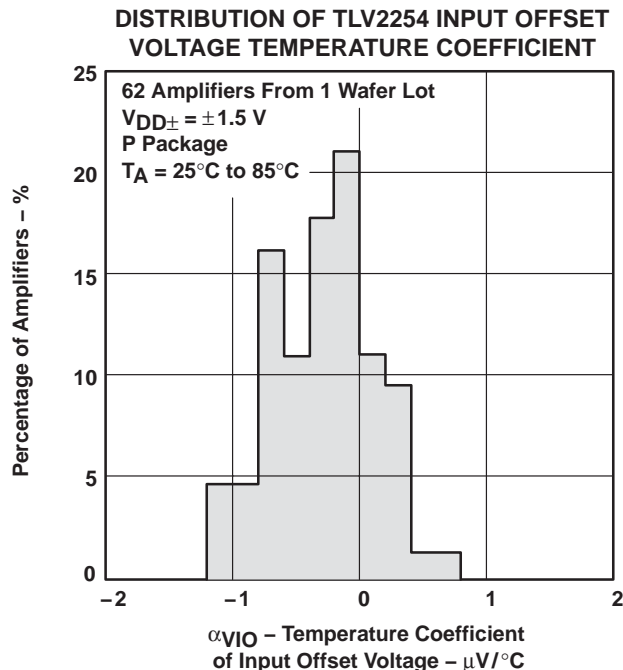


**Figure 9**

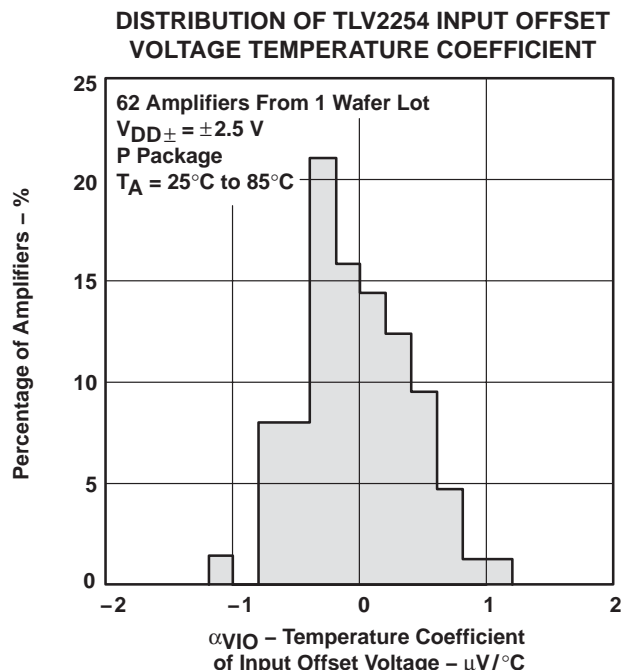
† For all curves where  $V_{DD} = 5\text{ V}$ , all loads are referenced to 2.5 V. For all curves where  $V_{DD} = 3\text{ V}$ , all loads are referenced to 1.5 V.



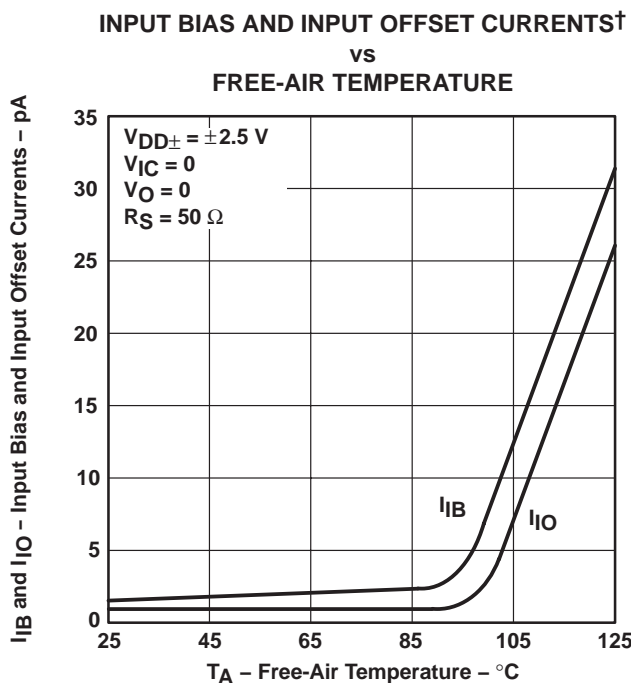
**TYPICAL CHARACTERISTICS**



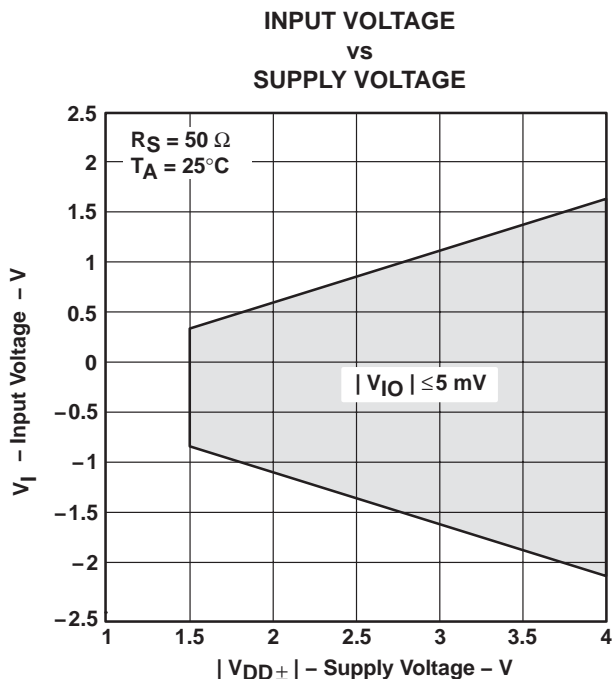
**Figure 10**



**Figure 11**



**Figure 12**

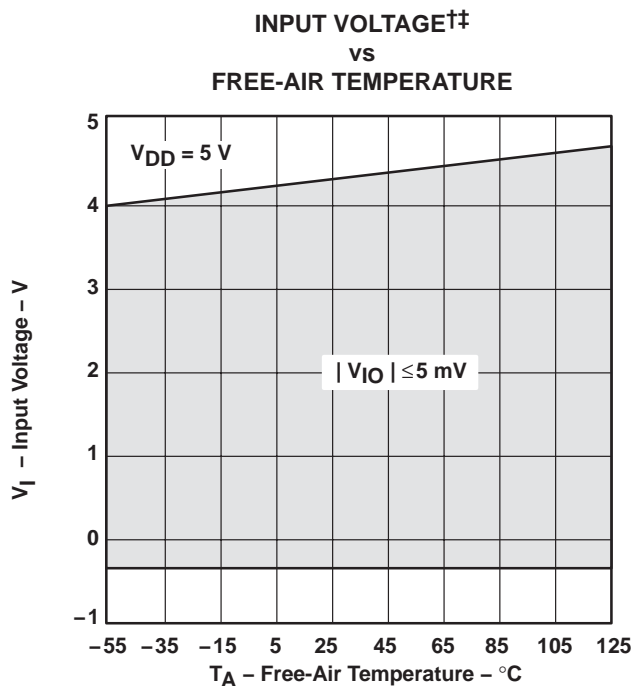


**Figure 13**

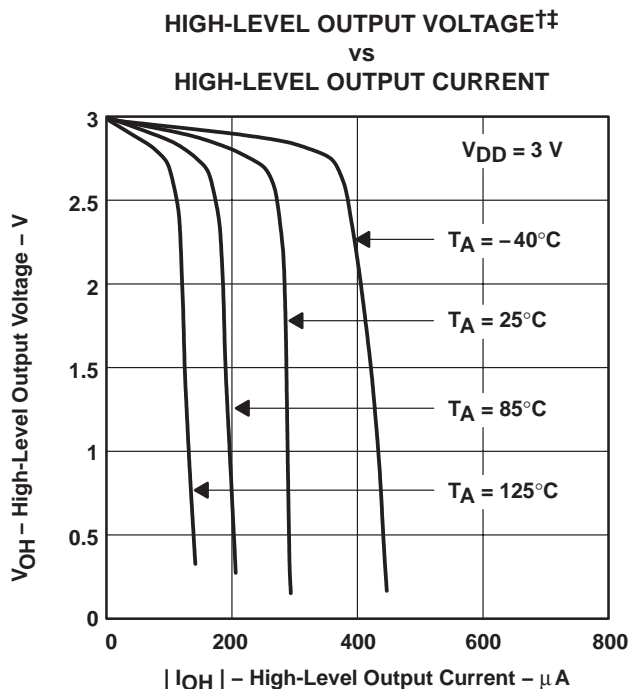
† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.



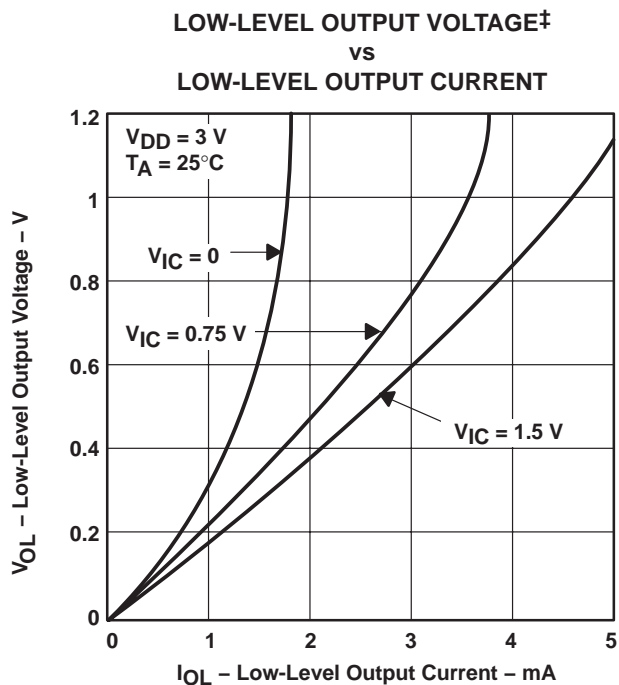
**TYPICAL CHARACTERISTICS**



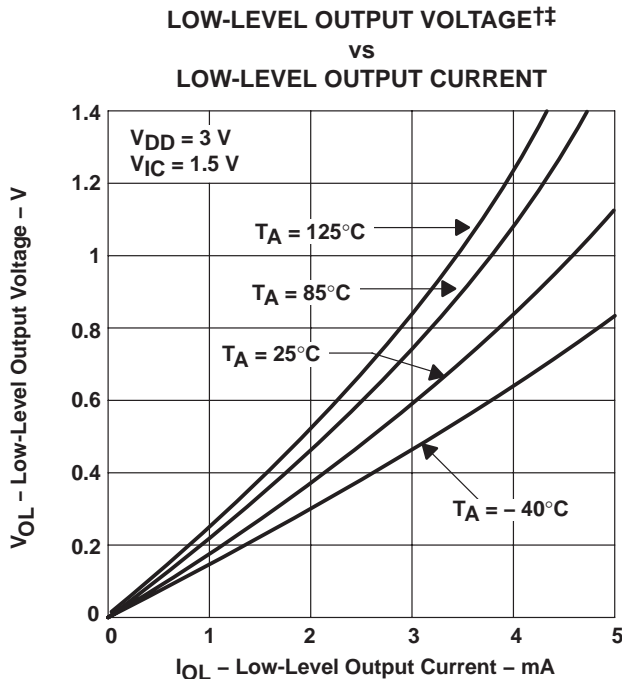
**Figure 14**



**Figure 15**



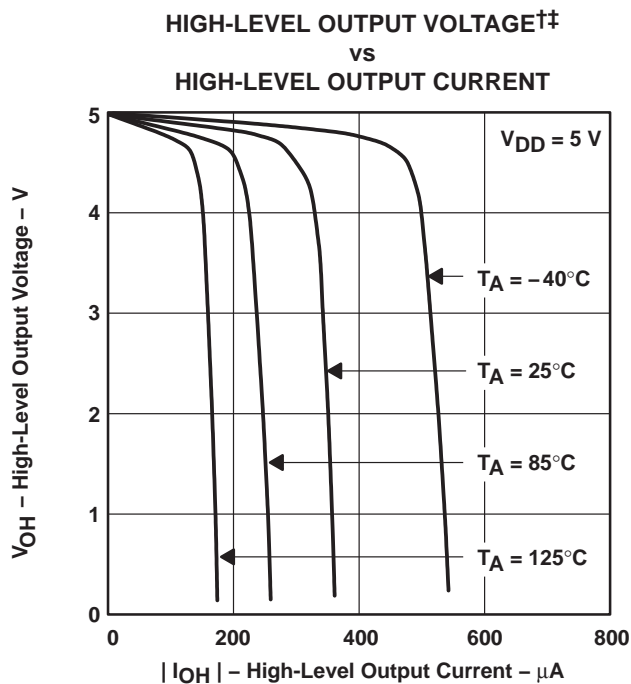
**Figure 16**



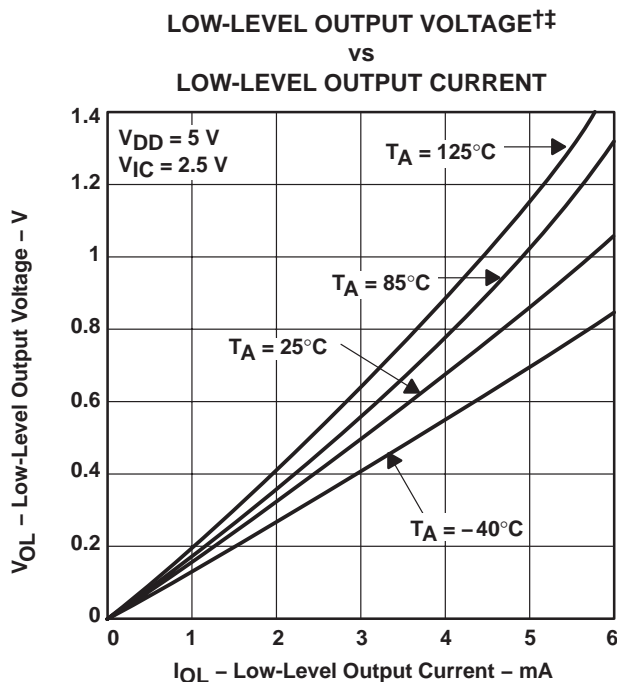
**Figure 17**

† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.  
 ‡ For all curves where  $V_{DD} = 5\text{ V}$ , all loads are referenced to 2.5 V. For all curves where  $V_{DD} = 3\text{ V}$ , all loads are referenced to 1.5 V.

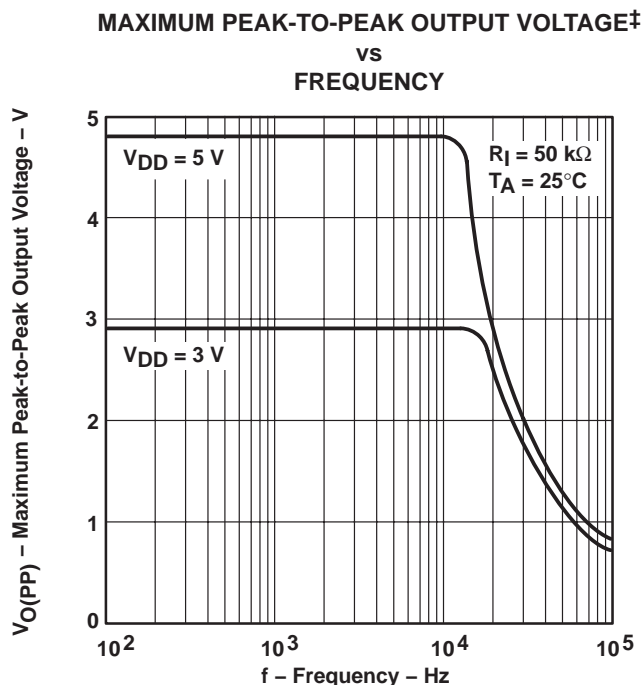
**TYPICAL CHARACTERISTICS**



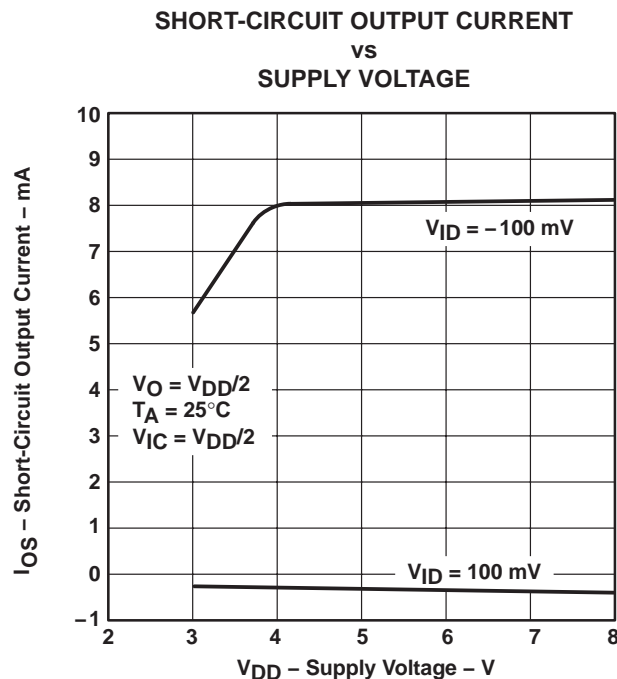
**Figure 18**



**Figure 19**



**Figure 20**

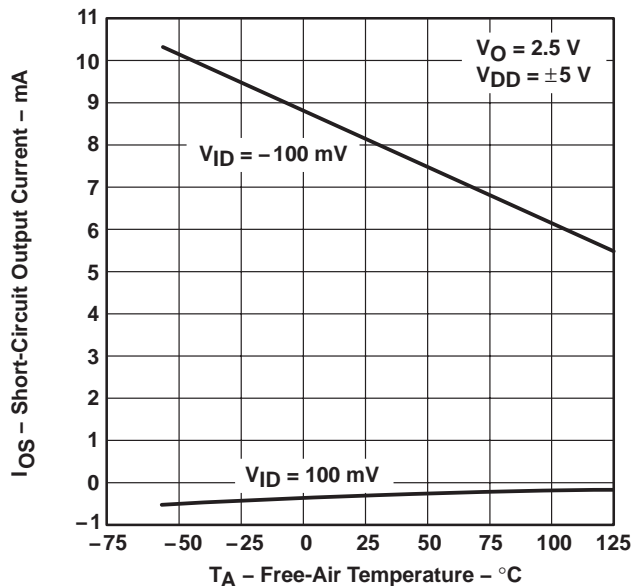


**Figure 21**

† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.  
 ‡ For all curves where  $V_{DD} = 5\text{ V}$ , all loads are referenced to 2.5 V. For all curves where  $V_{DD} = 3\text{ V}$ , all loads are referenced to 1.5 V.

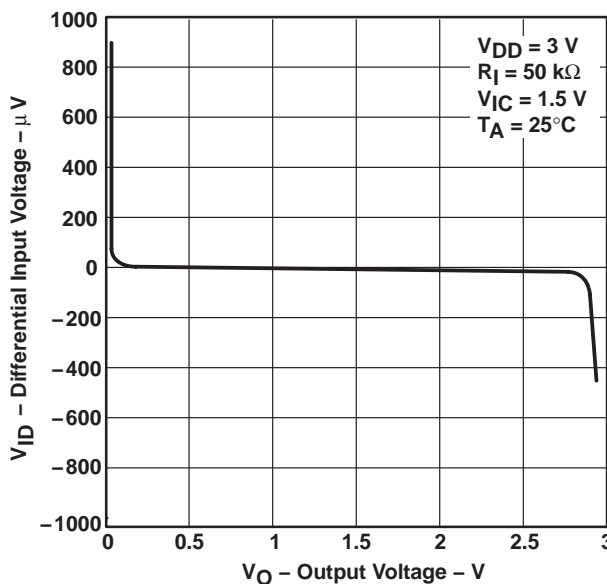
**TYPICAL CHARACTERISTICS**

**SHORT-CIRCUIT OUTPUT CURRENT†**  
**vs**  
**FREE-AIR TEMPERATURE**



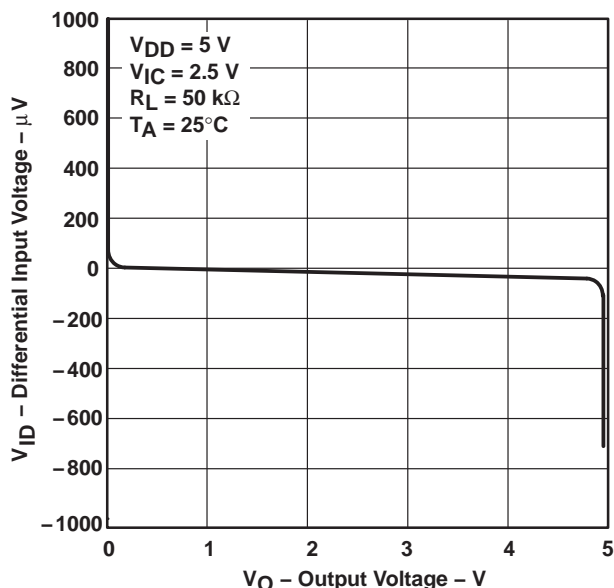
**Figure 22**

**DIFFERENTIAL INPUT VOLTAGE‡**  
**vs**  
**OUTPUT VOLTAGE**



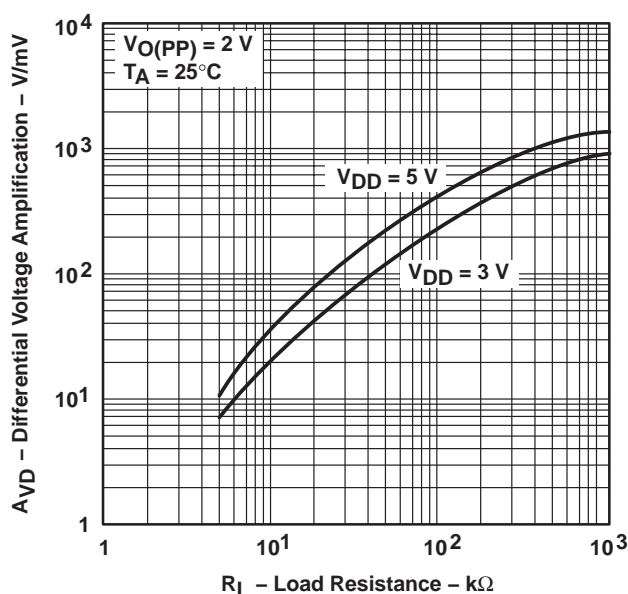
**Figure 23**

**DIFFERENTIAL INPUT VOLTAGE‡**  
**vs**  
**OUTPUT VOLTAGE**



**Figure 24**

**DIFFERENTIAL VOLTAGE AMPLIFICATION†‡**  
**vs**  
**LOAD RESISTANCE**



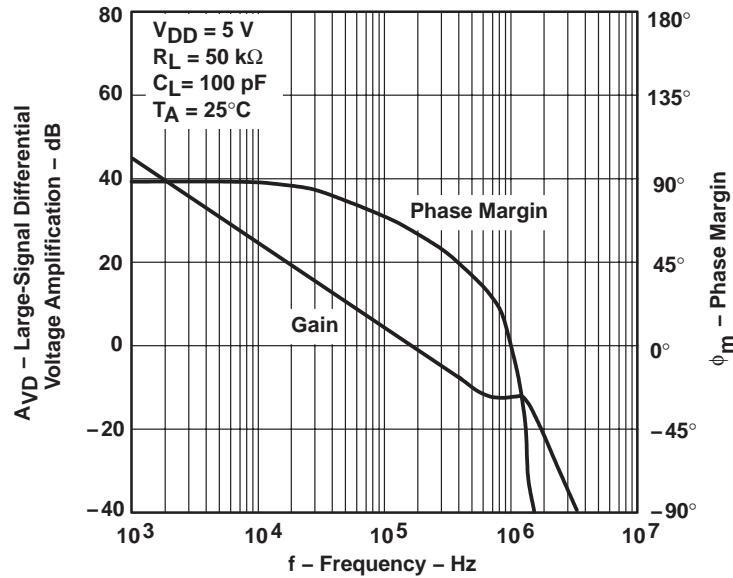
**Figure 25**

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

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

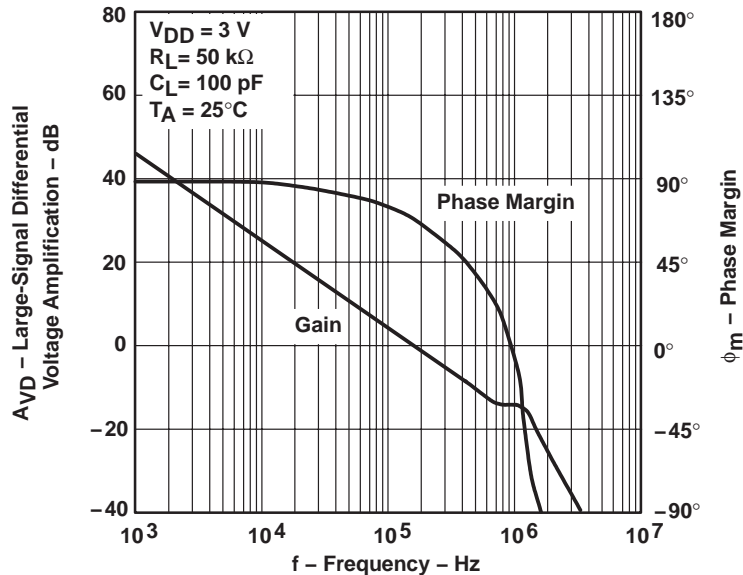
**TYPICAL CHARACTERISTICS**

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



**Figure 26**

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



**Figure 27**

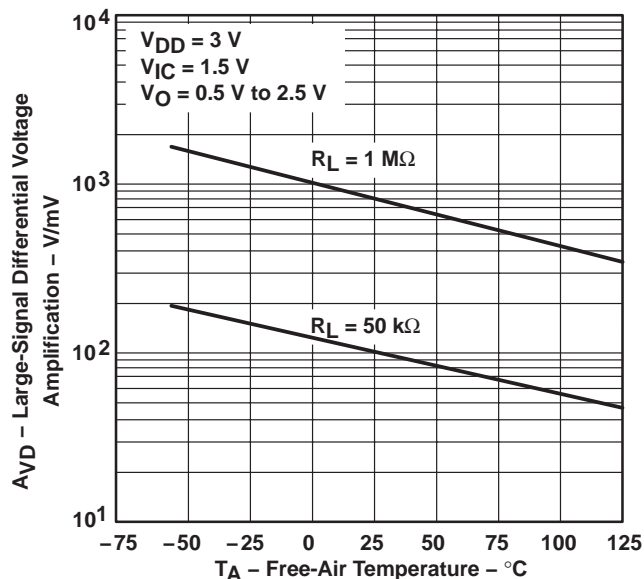
† For all curves where  $V_{DD} = 5\text{ V}$ , all loads are referenced to 2.5 V. For all curves where  $V_{DD} = 3\text{ V}$ , all loads are referenced to 1.5 V.

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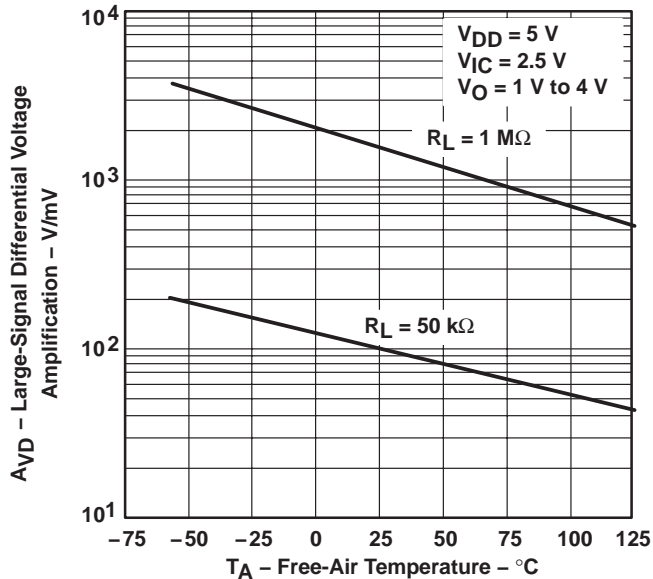
**TYPICAL CHARACTERISTICS**

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



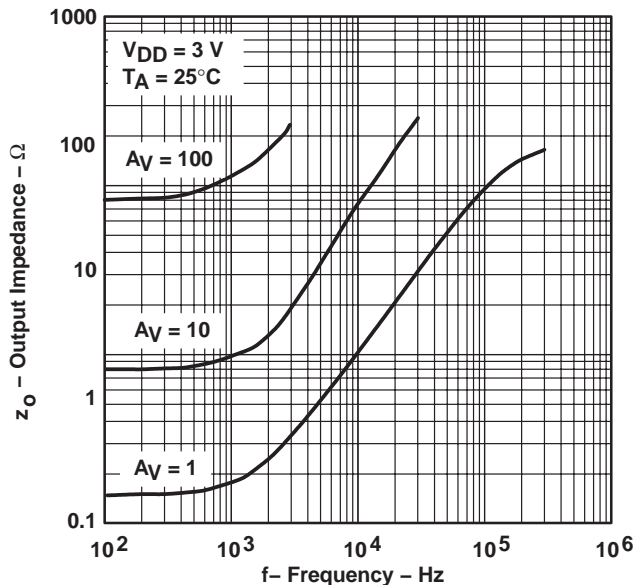
**Figure 28**

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



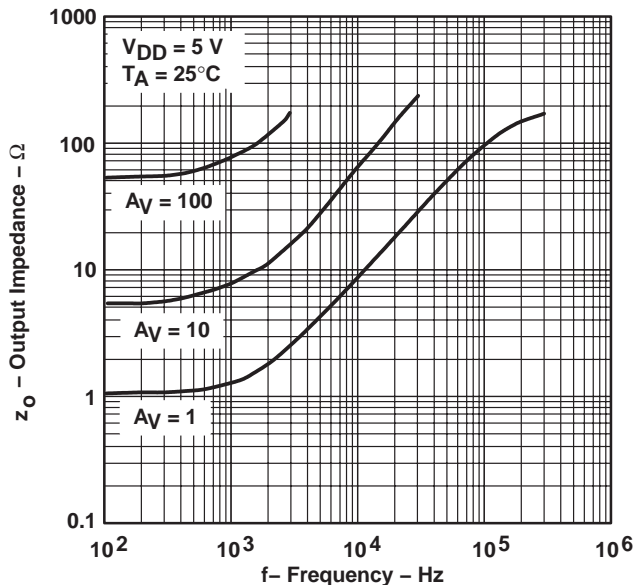
**Figure 29**

**OUTPUT IMPEDANCE†  
 vs  
 FREQUENCY**



**Figure 30**

**OUTPUT IMPEDANCE†  
 vs  
 FREQUENCY**



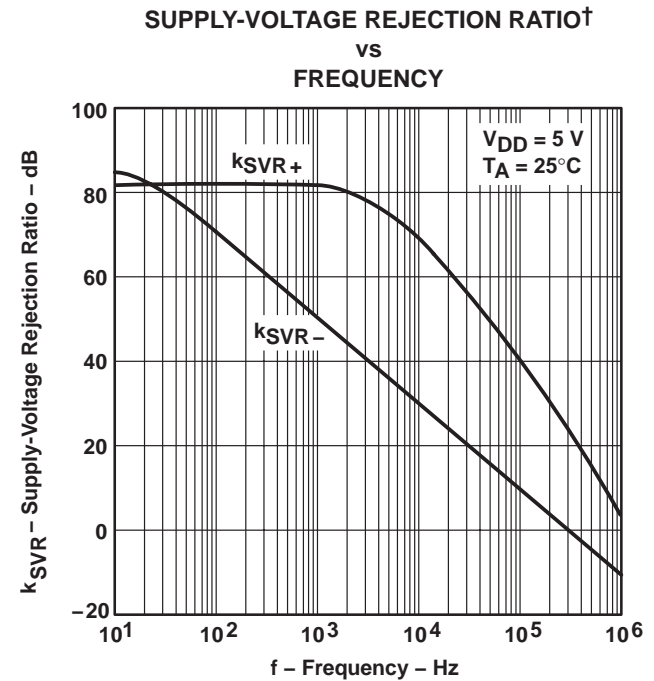
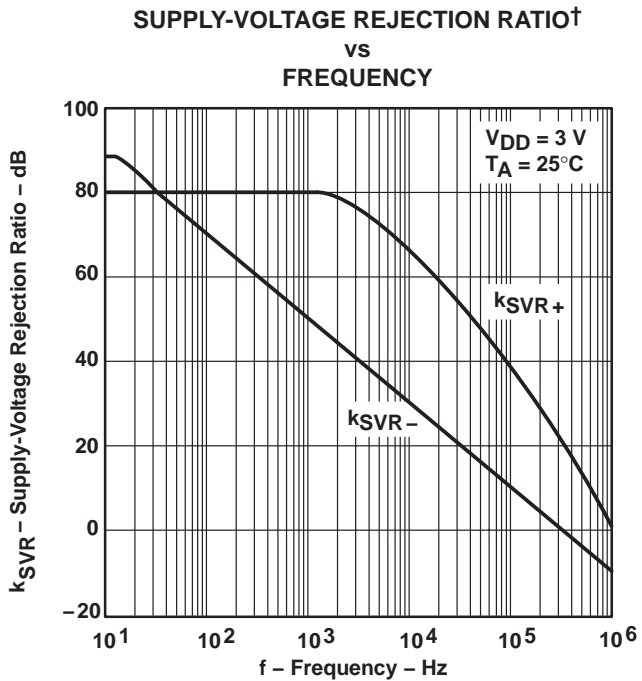
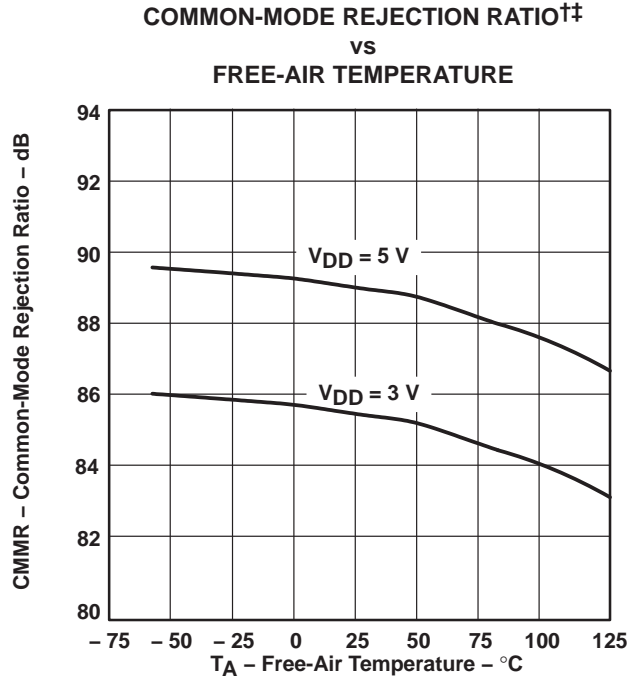
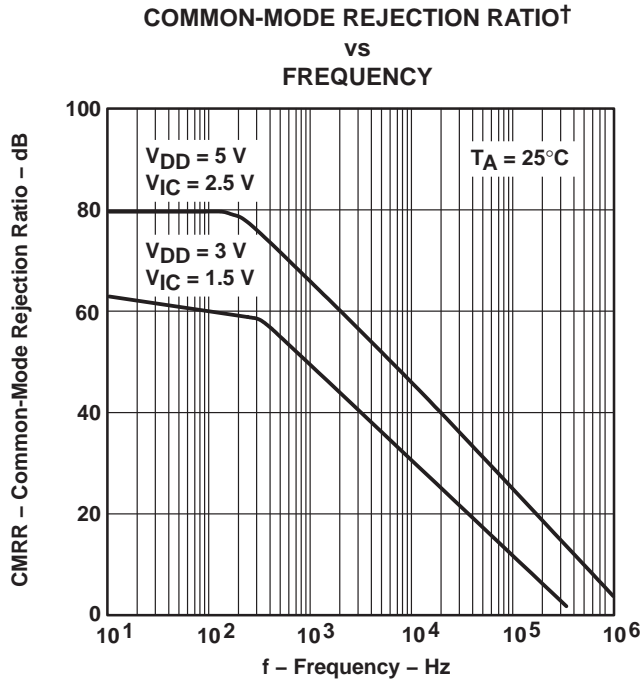
**Figure 31**

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

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



**TYPICAL CHARACTERISTICS**



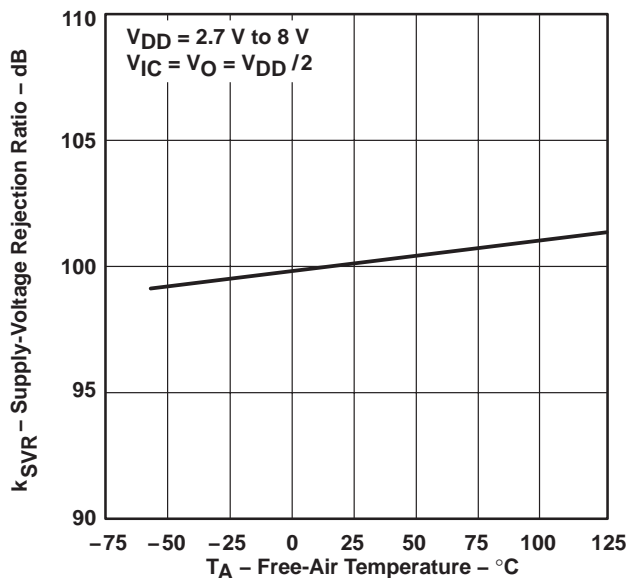
† For all curves where  $V_{DD} = 5\text{ V}$ , all loads are referenced to 2.5 V. For all curves where  $V_{DD} = 3\text{ V}$ , all loads are referenced to 1.5 V.  
 †† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

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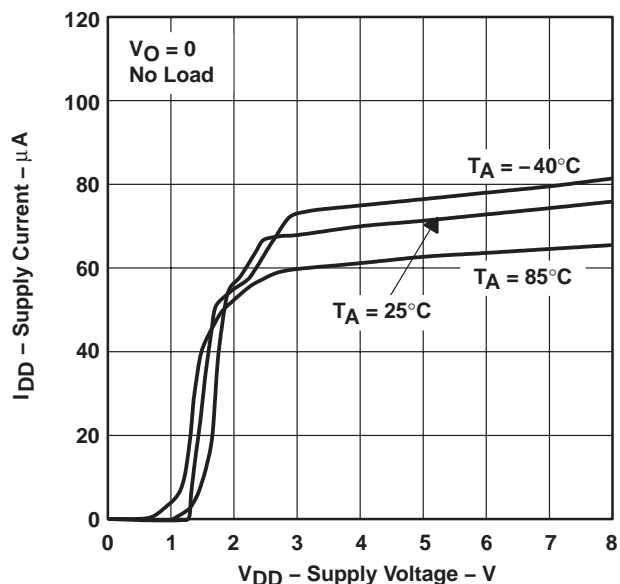
**TYPICAL CHARACTERISTICS**

**SUPPLY-VOLTAGE REJECTION RATIO†**  
**vs**  
**FREE-AIR TEMPERATURE**



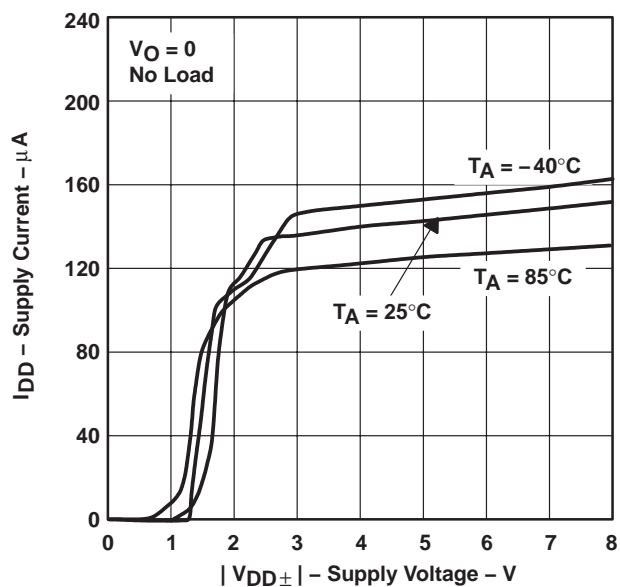
**Figure 36**

**TLV2252**  
**SUPPLY CURRENT†**  
**vs**  
**SUPPLY VOLTAGE**



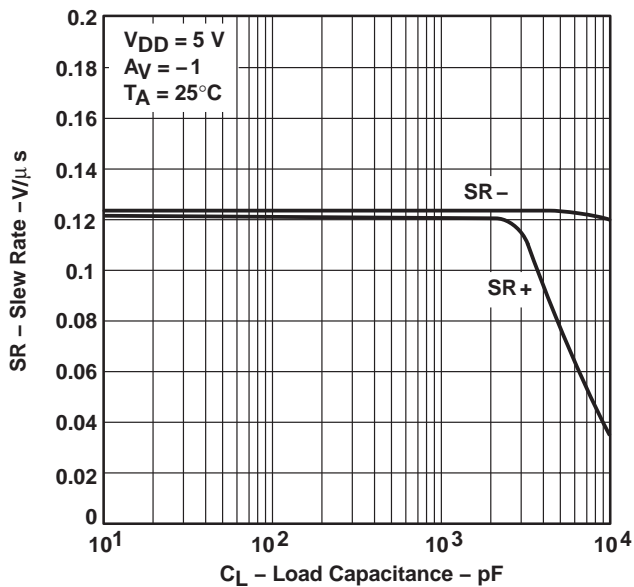
**Figure 37**

**TLV2254**  
**SUPPLY CURRENT†**  
**vs**  
**SUPPLY VOLTAGE**



**Figure 38**

**SLEW RATE‡**  
**vs**  
**LOAD CAPACITANCE**



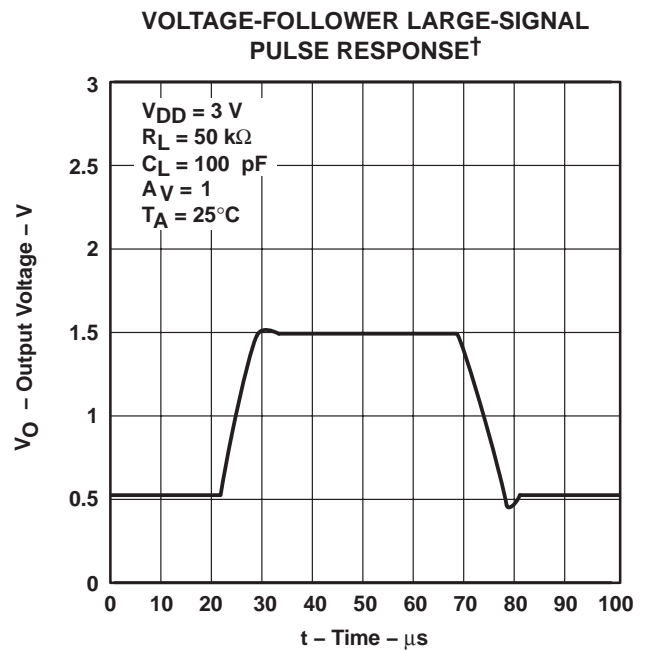
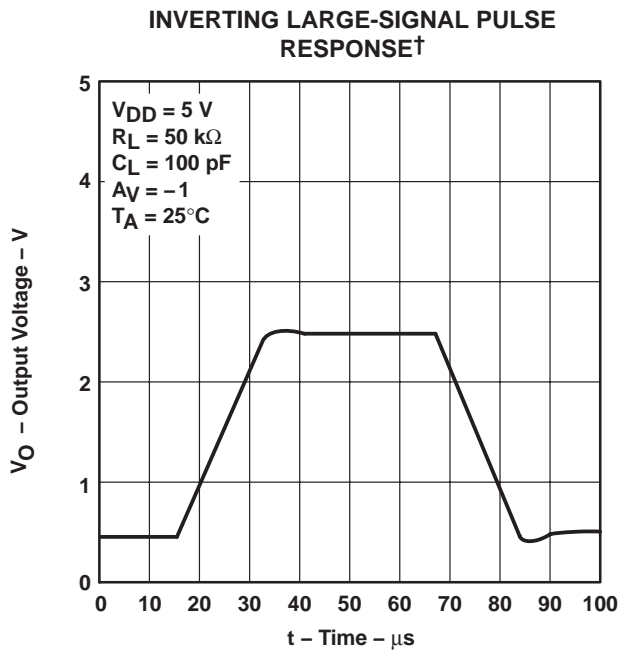
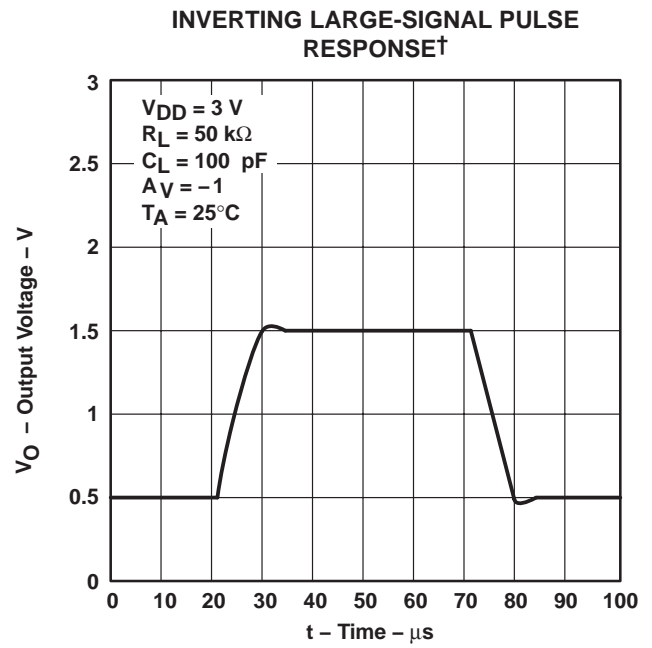
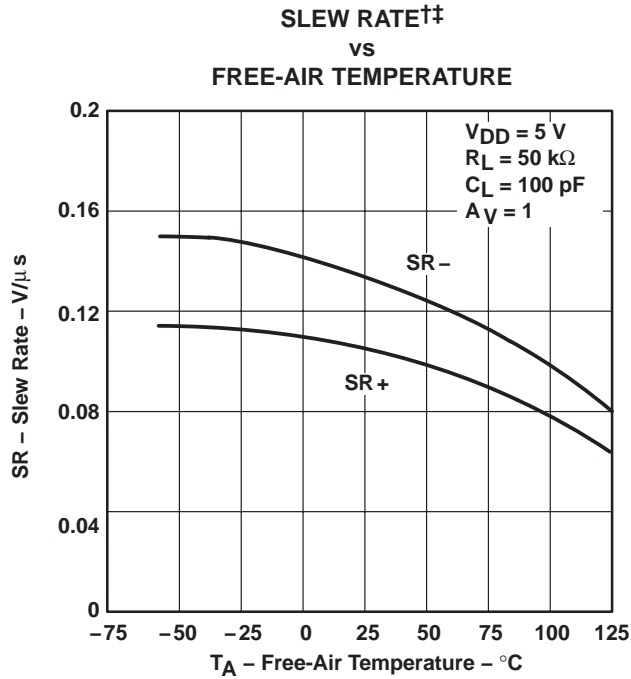
**Figure 39**

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

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



**TYPICAL CHARACTERISTICS**

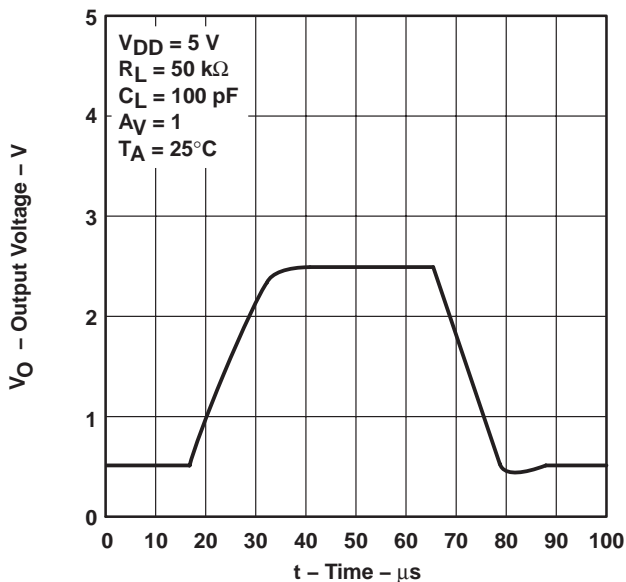


† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.  
 ‡ For all curves where  $V_{DD} = 5\text{ V}$ , all loads are referenced to 2.5 V. For all curves where  $V_{DD} = 3\text{ V}$ , all loads are referenced to 1.5 V.



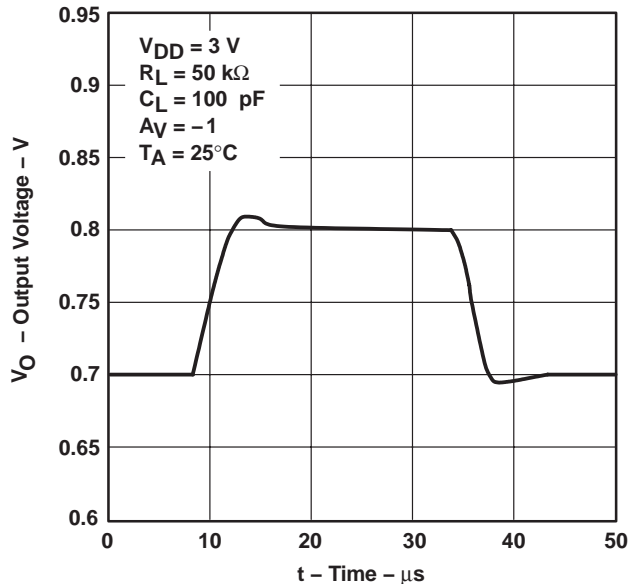
**TYPICAL CHARACTERISTICS**

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



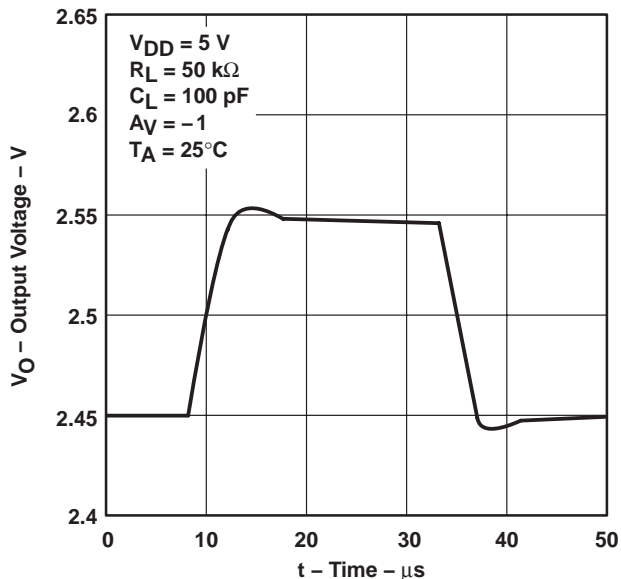
**Figure 44**

**INVERTING SMALL-SIGNAL PULSE RESPONSE†**



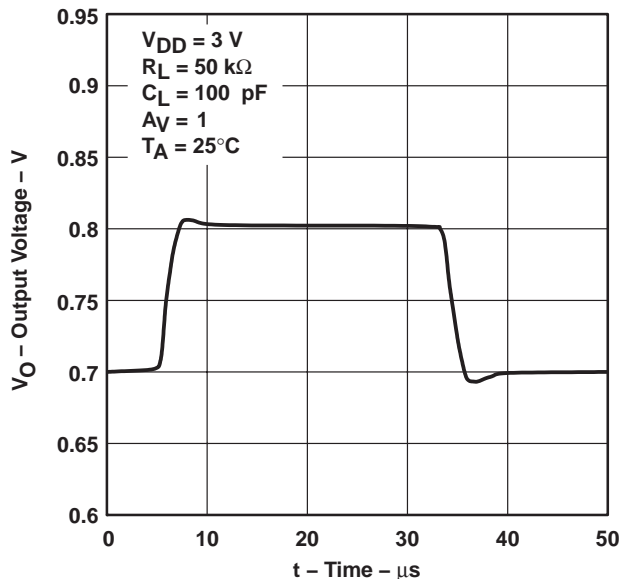
**Figure 45**

**INVERTING SMALL-SIGNAL PULSE RESPONSE†**



**Figure 46**

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



**Figure 47**

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

TYPICAL CHARACTERISTICS

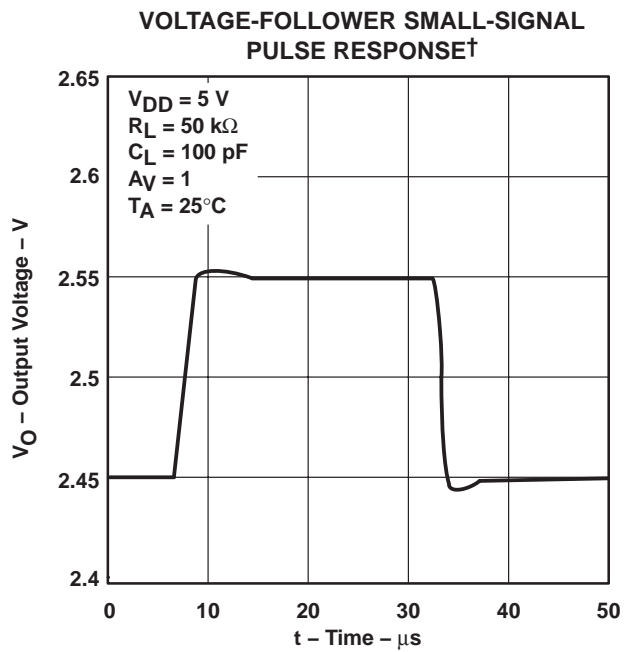


Figure 48

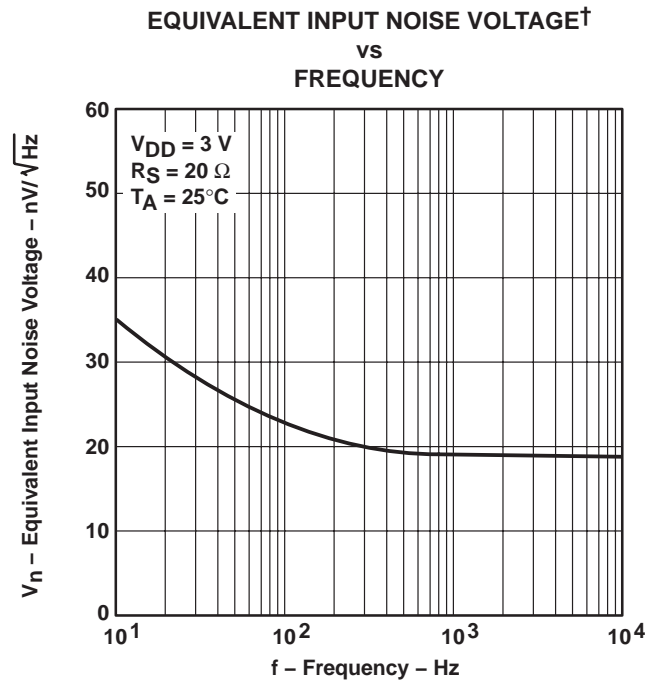


Figure 49

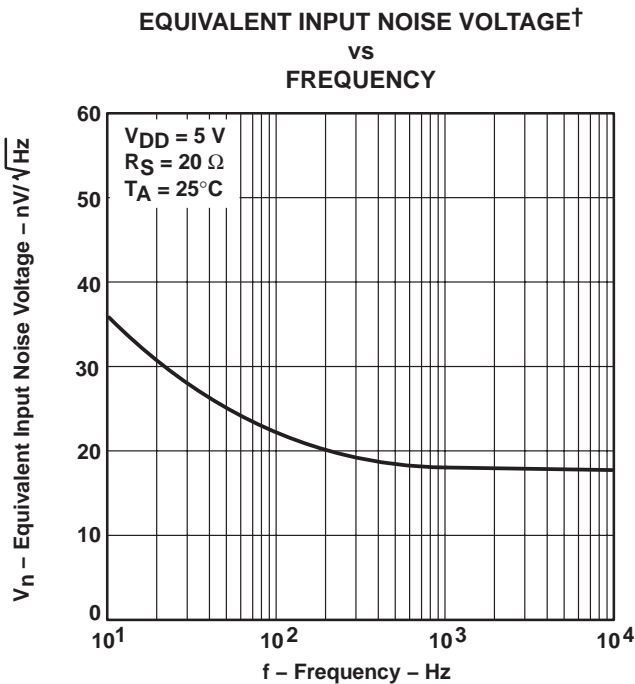


Figure 50

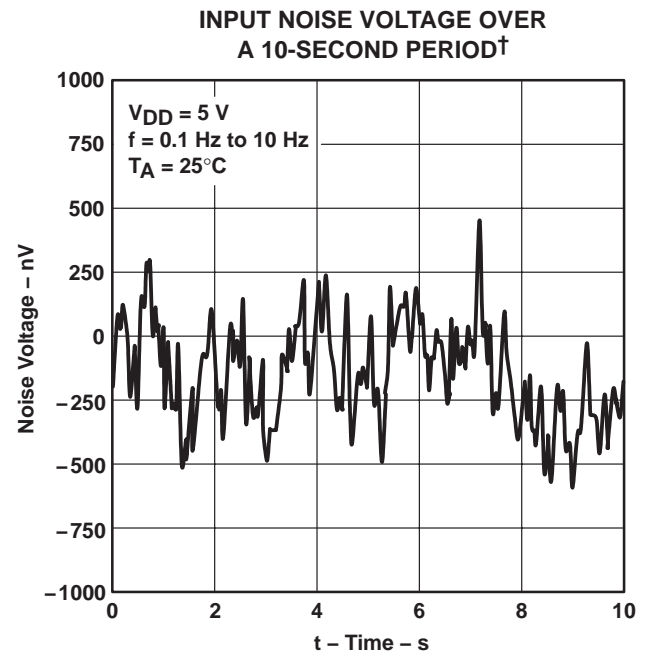


Figure 51

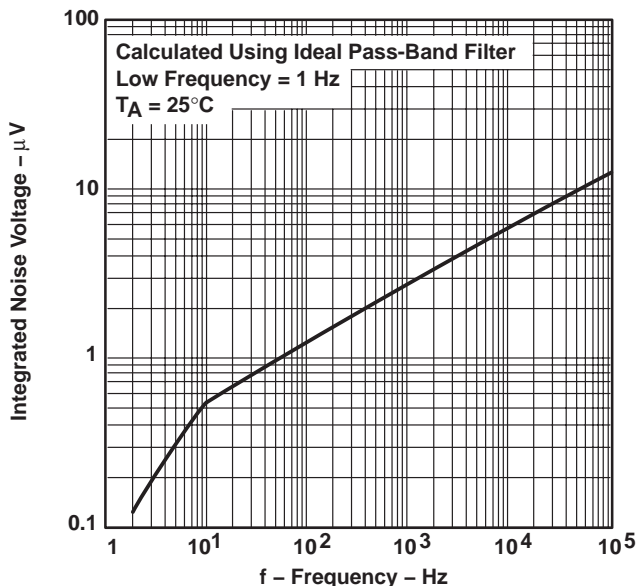
† For all curves where  $V_{DD} = 5\text{ V}$ , all loads are referenced to 2.5 V. For all curves where  $V_{DD} = 3\text{ V}$ , all loads are referenced to 1.5 V.

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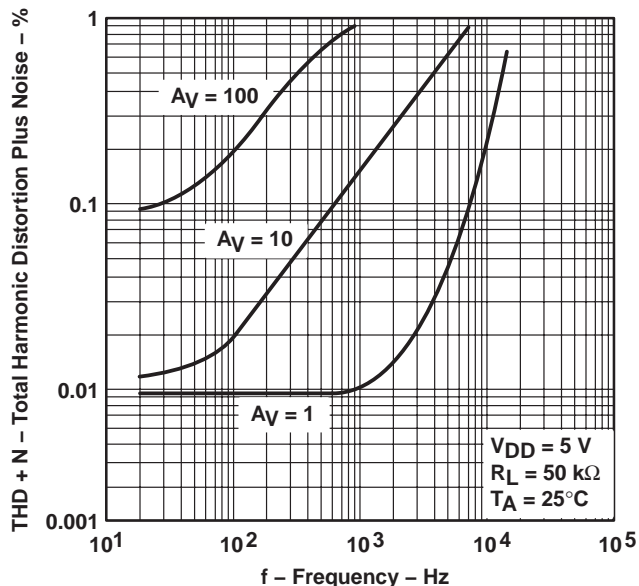
**TYPICAL CHARACTERISTICS**

**INTEGRATED NOISE VOLTAGE†**  
**vs**  
**FREQUENCY**



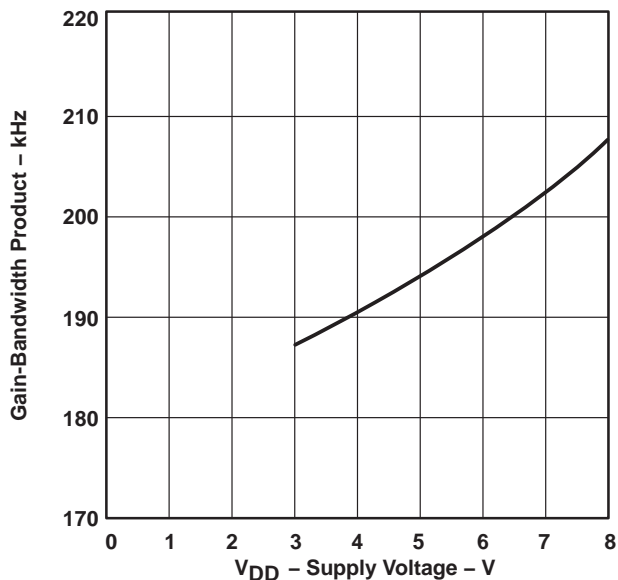
**Figure 52**

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



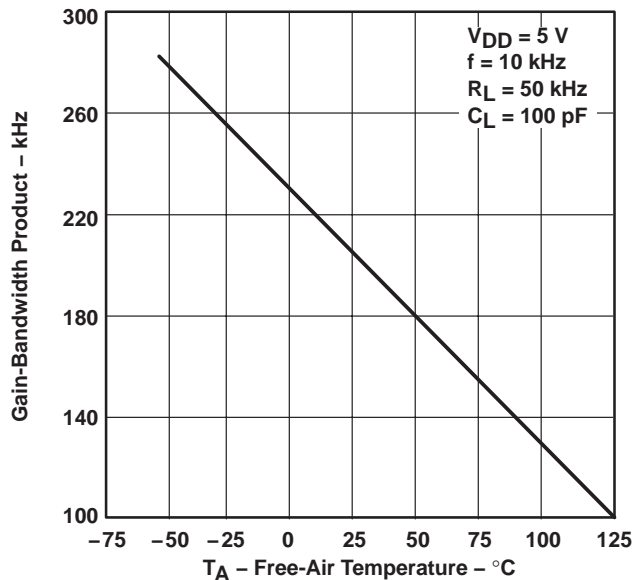
**Figure 53**

**GAIN-BANDWIDTH PRODUCT**  
**vs**  
**SUPPLY VOLTAGE**



**Figure 54**

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

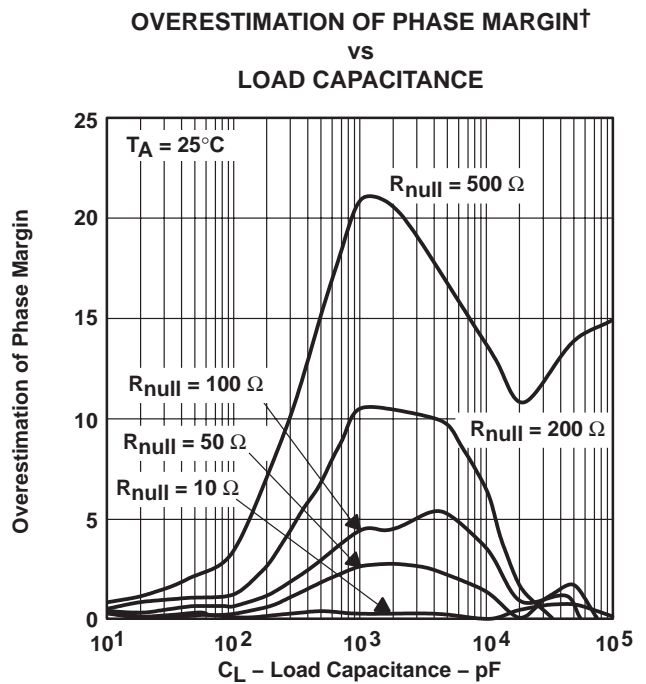
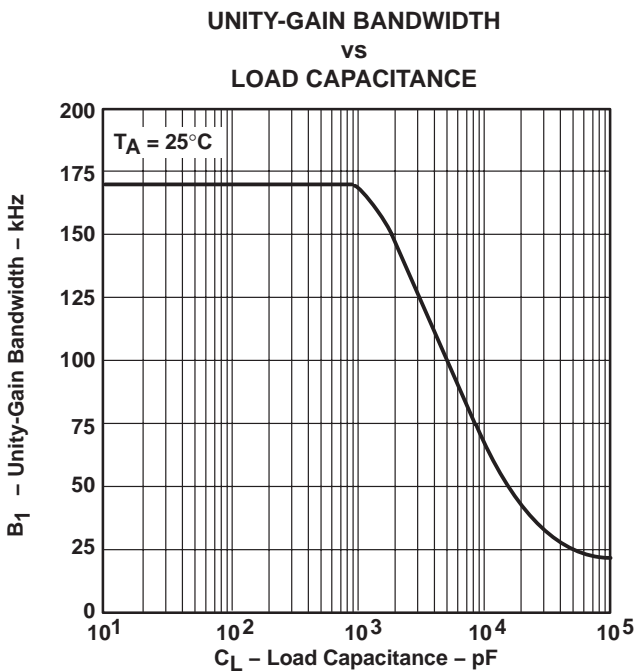
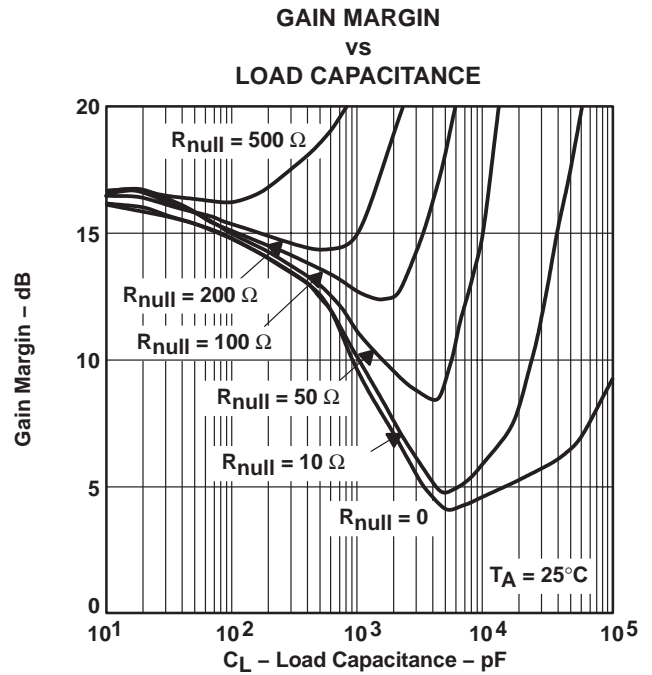
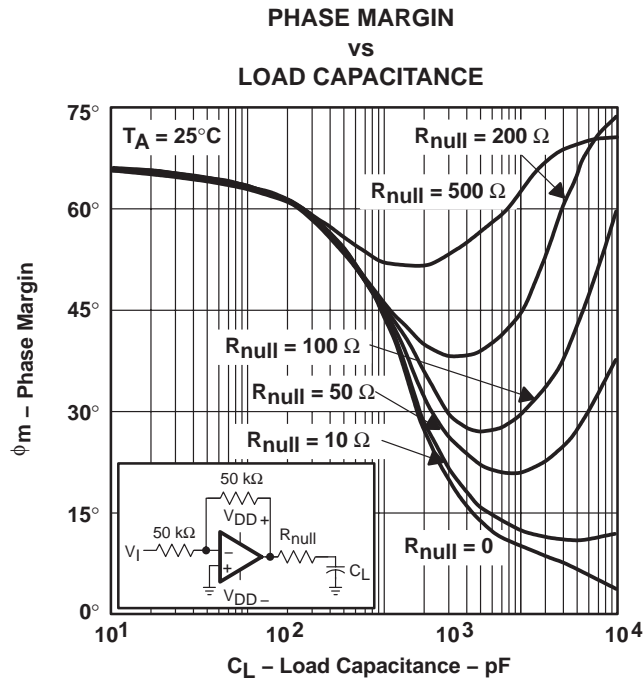


**Figure 55**

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



TYPICAL CHARACTERISTICS



† See application information

† For all curves where  $V_{DD} = 5\text{ V}$ , all loads are referenced to 2.5 V. For all curves where  $V_{DD} = 3\text{ V}$ , all loads are referenced to 1.5 V.  
 ‡ Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

**APPLICATION INFORMATION**

**driving large capacitive loads**

The TLV2252 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 55 and Figure 56 show the effects of adding series resistances of 10  $\Omega$ , 50  $\Omega$ , 100  $\Omega$ , 200  $\Omega$ , and 500  $\Omega$ . The addition of this series resistor has two effects: the first adds a zero to the transfer function and the second reduces the frequency of the pole associated with the output load in the transfer function.

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

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

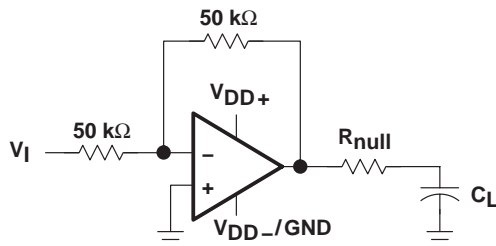
Where :

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

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, 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**

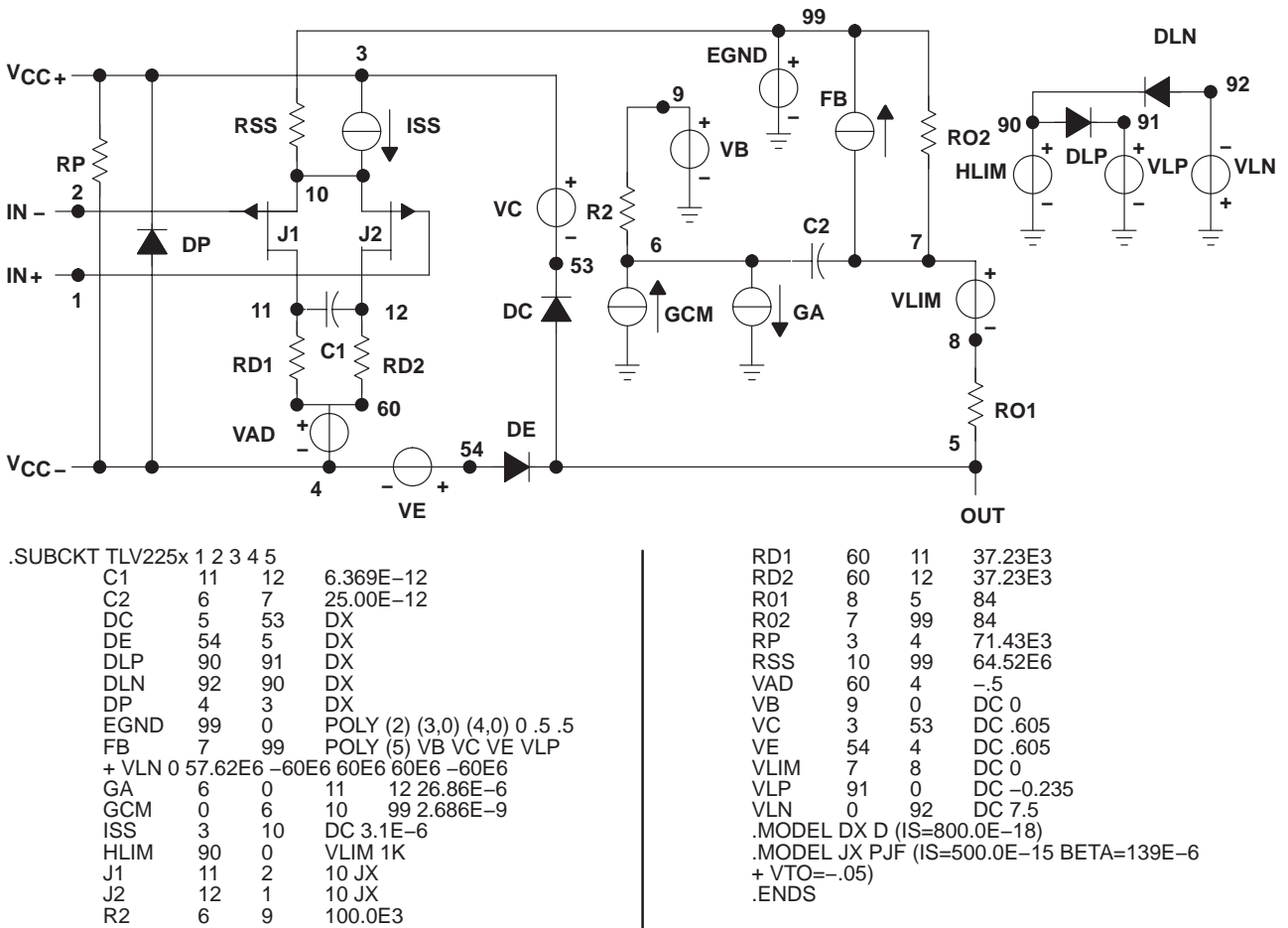
## APPLICATION INFORMATION

### 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 TLV2252 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 4: 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**

*PSpice* and *Parts* are trademarks of MicroSim Corporation.

**PACKAGING INFORMATION**

Orderable Device	Status <sup>(1)</sup>	Package Type	Package Drawing	Pins	Package Qty	Eco Plan <sup>(2)</sup>	Lead/Ball Finish	MSL Peak Temp <sup>(3)</sup>
TLV2252AQDREP	ACTIVE	SOIC	D	8	2500	Pb-Free (RoHS)	CU NIPDAU	Level-2-250C-1 YEAR/ Level-1-235C-UNLIM
TLV2252QDREP	ACTIVE	SOIC	D	8	2500	Pb-Free (RoHS)	CU NIPDAU	Level-2-250C-1 YEAR/ Level-1-235C-UNLIM
TLV2254QDREP	ACTIVE	SOIC	D	14	2500	Pb-Free (RoHS)	CU NIPDAU	Level-2-250C-1 YEAR/ Level-1-235C-UNLIM
V62/04651-01UE	ACTIVE	SOIC	D	8	2500	Pb-Free (RoHS)	CU NIPDAU	Level-2-250C-1 YEAR/ Level-1-235C-UNLIM
V62/04651-02UE	ACTIVE	SOIC	D	8	2500	Pb-Free (RoHS)	CU NIPDAU	Level-2-250C-1 YEAR/ Level-1-235C-UNLIM
V62/04651-03XE	ACTIVE	SOIC	D	14	2500	Pb-Free (RoHS)	CU NIPDAU	Level-2-250C-1 YEAR/ Level-1-235C-UNLIM

<sup>(1)</sup> The marketing status values are defined as follows:

**ACTIVE:** Product device recommended for new designs.

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

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

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

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

<sup>(2)</sup> Eco Plan - May not be currently available - please check <http://www.ti.com/productcontent> for the latest availability information and additional product content details.

**None:** Not yet available Lead (Pb-Free).

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

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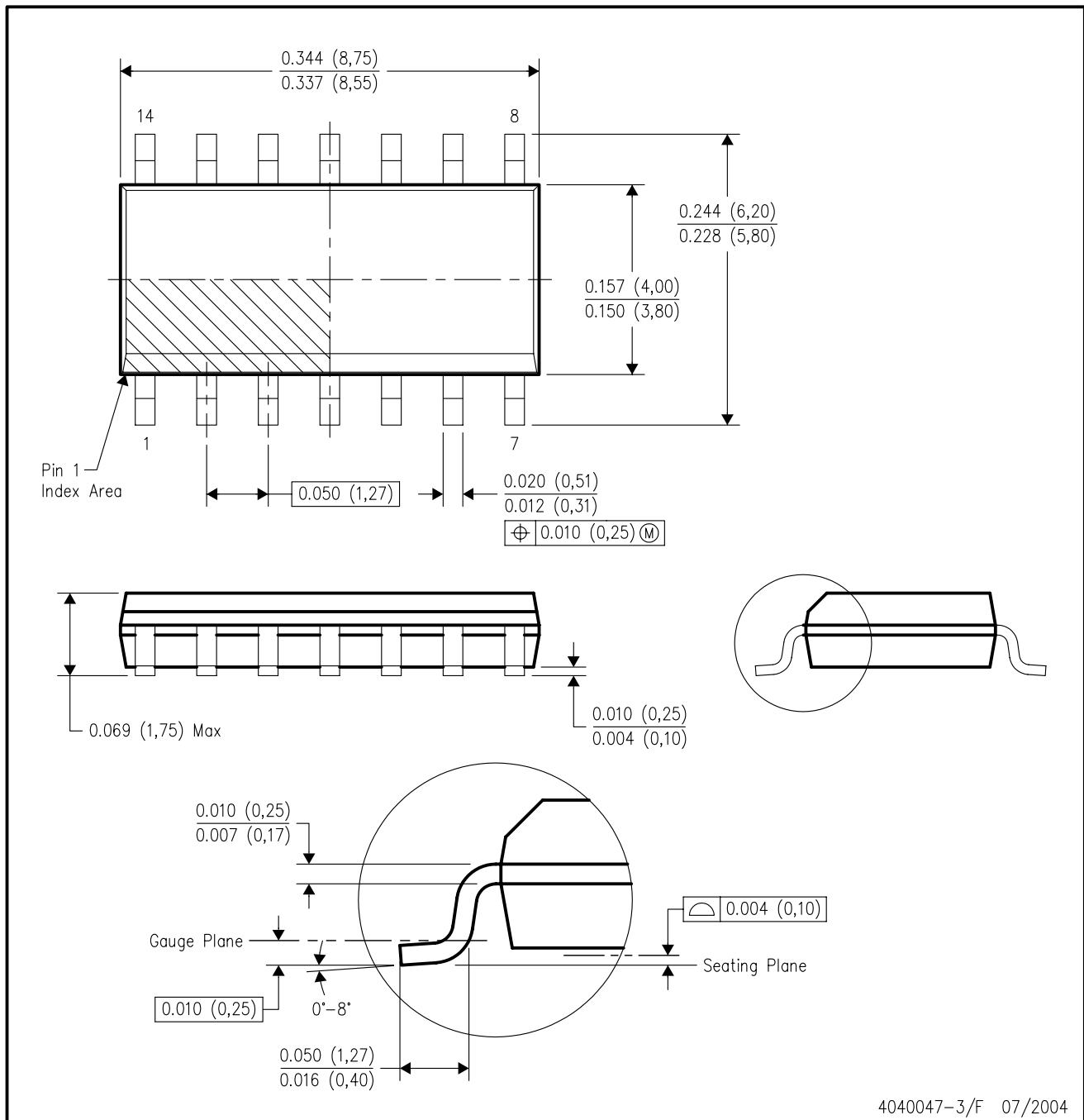
<sup>(3)</sup> MSL, Peak Temp. -- The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

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D (R-PDSO-G14)

PLASTIC SMALL-OUTLINE PACKAGE

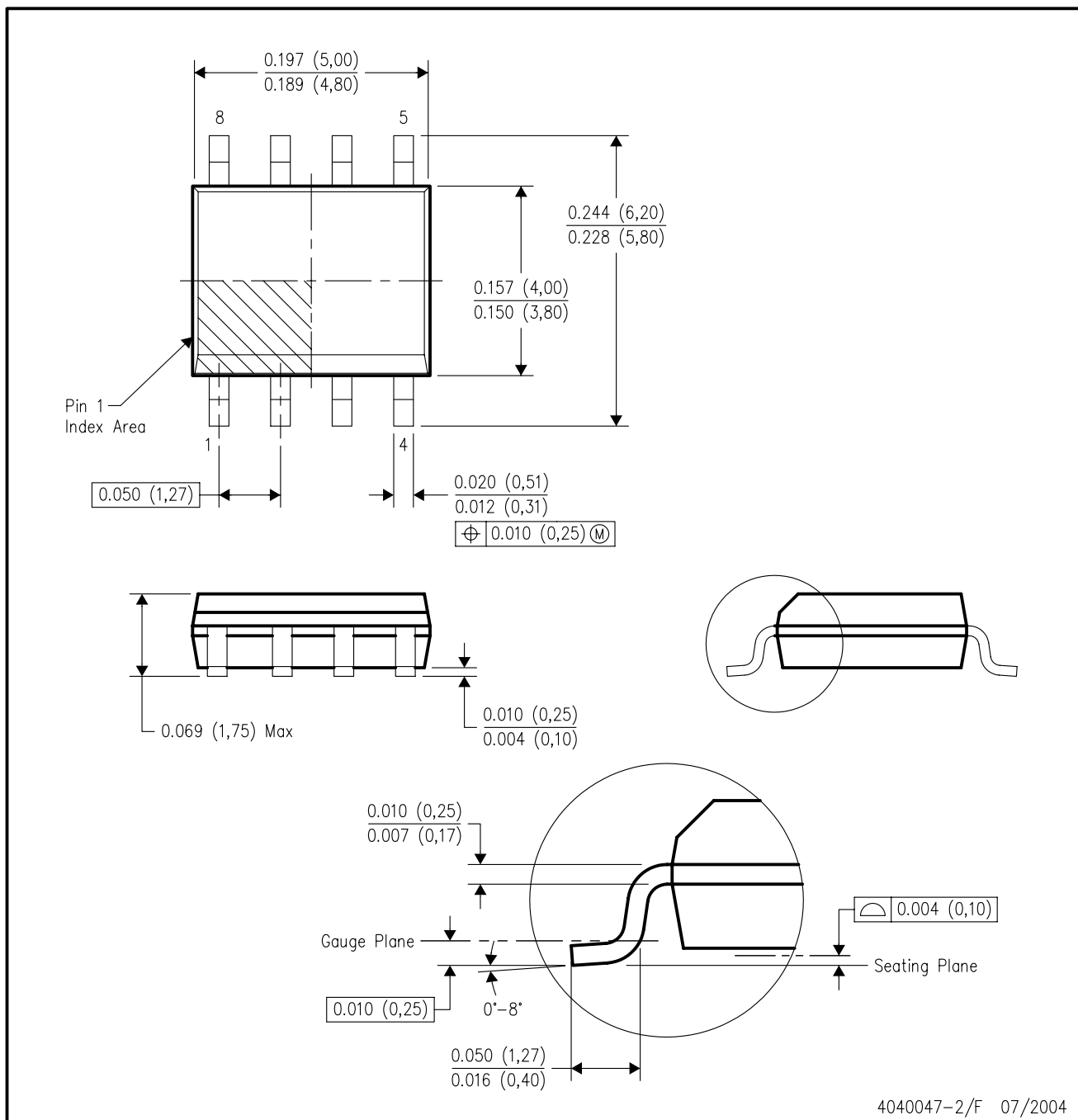


- NOTES:
- A. All linear dimensions are in inches (millimeters).
  - B. This drawing is subject to change without notice.
  - C. Body dimensions do not include mold flash or protrusion not to exceed 0.006 (0,15).
  - D. Falls within JEDEC MS-012 variation AB.



D (R-PDSO-G8)

PLASTIC SMALL-OUTLINE PACKAGE



- 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).
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		Telephony	<a href="http://www.ti.com/telephony">www.ti.com/telephony</a>
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