

# TLC227x-EP, TLC227xA-EP Advanced LinCMOS™ RAIL-TO-RAIL OPERATIONAL AMPLIFIERS

SGLS131B – JULY 2002 – REVISED DECEMBER 2003

- **Controlled Baseline**
  - One Assembly/Test Site, One Fabrication Site
- **Extended Temperature Performance of –55°C to 125°C**
- **Enhanced Diminishing Manufacturing Sources (DMS) Support**
- **Enhanced Product Change Notification**
- **Qualification Pedigree†**
- **Output Swing Includes Both Supply Rails**
- **Low Noise . . . 9 nV/√Hz Typ at f = 1 kHz**
- **Low Input Bias Current . . . 1 pA Typ**
- **Fully Specified for Both Single-Supply and Split-Supply Operation**
- **Common-Mode Input Voltage Range Includes Negative Rail**
- **High-Gain Bandwidth . . . 2.2 MHz Typ**
- **High Slew Rate . . . 3.6 V/μs Typ**
- **Low Input Offset Voltage**  
950 μV Max at T<sub>A</sub> = 25°C
- **Macromodel Included**
- **Performance Upgrades for the TS272, TS274, TLC272, and TLC274**

† 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.

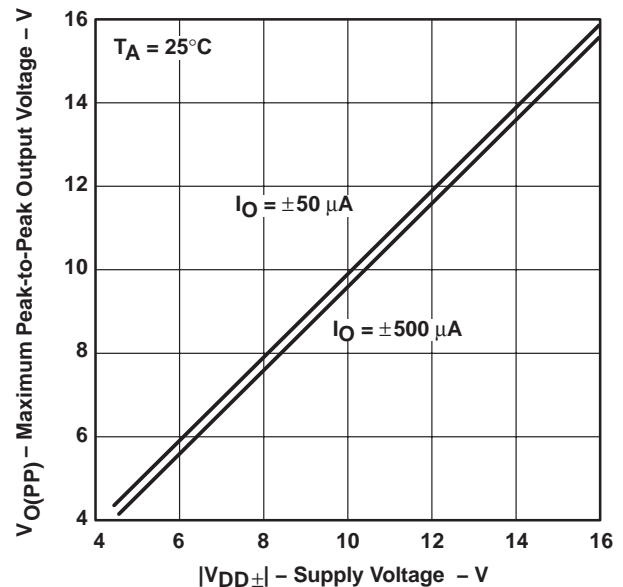
## description

The TLC2272A and TLC2274A 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 TLC227xA family offers 2 MHz of bandwidth and 3 V/μs of slew rate for higher speed applications. These devices offer comparable ac performance while having better noise, input offset voltage, and power dissipation than existing CMOS operational amplifiers. The TLC227xA has a noise voltage of 9 nV/√Hz, two times lower than competitive solutions.

The TLC227xA, exhibiting high input impedance and low noise, is excellent for small-signal conditioning for high-impedance sources, such as piezoelectric transducers. Because of the micro-power 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 TLC227xA family has a maximum input offset voltage of 950 μV. This family is fully characterized at 5 V and ±5 V.

The TLC2272/4 also makes great upgrades to the TLC272/4 or TS272/4 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.

MAXIMUM PEAK-TO-PEAK OUTPUT VOLTAGE  
vs  
SUPPLY VOLTAGE



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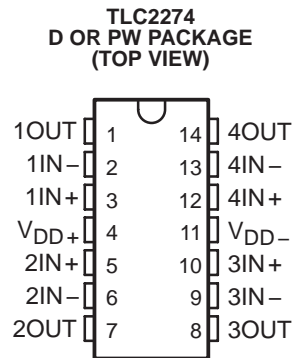
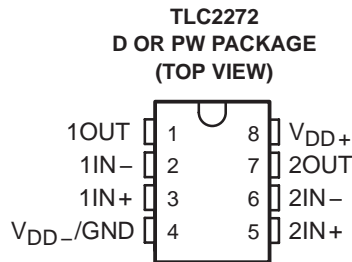
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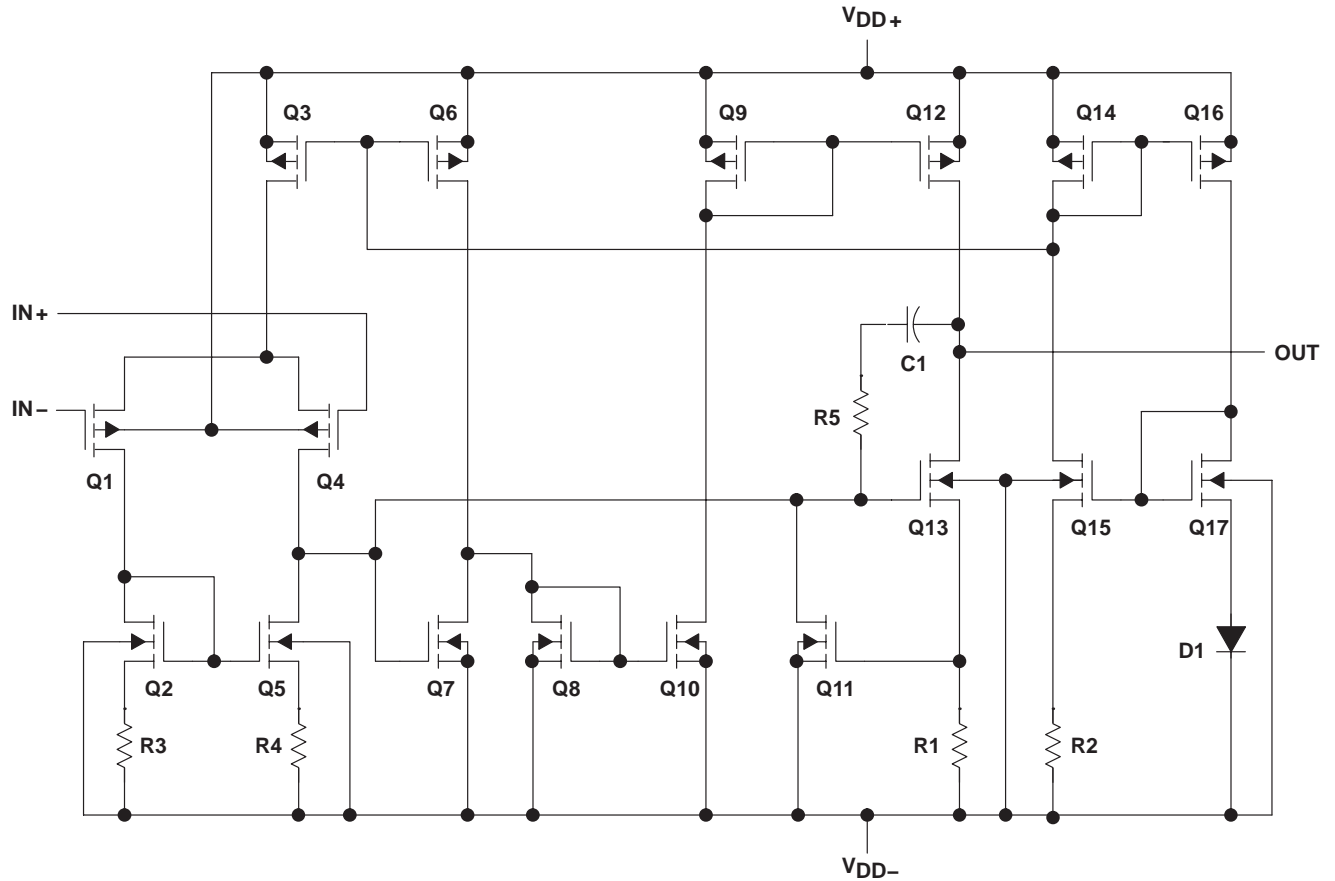
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**AVAILABLE OPTIONS**

T <sub>A</sub>	V <sub>IO</sub> max At 25°C	PACKAGED DEVICES	
		SMALL OUTLINE (D)	TSSOP (PW)
-55°C to 125°C	950 μV 2.5 mV	TLC2272AMDREP TLC2272MDREP	TLC2272AMPWREP TLC2272MPWREP
-55°C to 125°C	950 μV 2.5 mV	TLC2274AMDREP TLC2274MDREP	TLC2274AMPWREP TLC2274MPWREP



equivalent schematic (each amplifier)



ACTUAL DEVICE COMPONENT COUNT†		
COMPONENT	TLC2272	TLC2274
Transistors	38	76
Resistors	26	52
Diodes	9	18
Capacitors	3	6

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

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

Supply voltage, $V_{DD+}$ (see Note 1)	8 V
Supply voltage, $V_{DD-}$ (see Note 1)	-8 V
Differential input voltage, $V_{ID}$ (see Note 2)	$\pm 16$ V
Input voltage range, $V_I$ (any input, see Note 1)	$V_{DD-} - 0.3$ V to $V_{DD+}$
Input current, $I_I$ (any input)	$\pm 5$ mA
Output current, $I_O$	$\pm 50$ mA
Total current into $V_{DD+}$	$\pm 50$ mA
Total current out of $V_{DD-}$	$\pm 50$ mA
Duration of short-circuit current at (or below) 25°C (see Note 3)	unlimited
Continuous total dissipation	See Dissipation Rating Table
Operating free-air temperature range, $T_A$	-55°C to 125°C
Storage temperature range (see Note 4)	-65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: D or PW package	260°C

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

- NOTES:
1. All voltage values, except differential voltages, are with respect to the midpoint between  $V_{DD+}$  and  $V_{DD-}$ .
  2. Differential voltages are at  $IN+$  with respect to  $IN-$ . Excessive current will flow if 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.
  4. Long term high-temperature storage and/or extended use at maximum recommended operating conditions may result in a reduction of overall device life. See [http://www.ti.com/ep\\_quality](http://www.ti.com/ep_quality) for additional information on enhanced plastic packaging.

**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	725 mW	5.8 mW/°C	464 mW	337 mW	145 mW
D-14	950 mW	7.6 mW/°C	608 mW	494 mW	190 mW
PW-8	525 mW	4.2 mW/°C	336 mW	273 mW	105 mW
PW-14	700 mW	5.6 mW/°C	448 mW	364 mW	—

**recommended operating conditions**

	MIN	MAX	UNIT
Supply voltage, $V_{DD\pm}$	$\pm 2.2$	$\pm 8$	V
Input voltage, $V_I$	$V_{DD-}$	$V_{DD+} - 1.5$	V
Common-mode input voltage, $V_{IC}$	$V_{DD-}$	$V_{DD+} - 1.5$	V
Operating free-air temperature, $T_A$	-55	125	°C

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**TLC2272-EP electrical characteristics at specified free-air temperature,  $V_{DD} = 5\text{ V}$  (unless otherwise noted)**

PARAMETER	TEST CONDITIONS	$T_A$ †	TLC2272-EP			TLC2272A-EP			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
$V_{IO}$ Input offset voltage	$V_{IC} = 0\text{ V}, V_O = 0\text{ V}, V_{DD\pm} = \pm 2.5\text{ V}, R_S = 50\ \Omega$	25°C	300	2500		300	950	$\mu\text{V}$	
		Full range			3000		1500		
$\alpha_{VIO}$ Temperature coefficient of input offset voltage		25°C to 125°C	2			2		$\mu\text{V}/^\circ\text{C}$	
Input offset voltage long-term drift (see Note 5)		25°C	0.002			0.002		$\mu\text{V}/\text{mo}$	
$I_{IO}$ Input offset current		25°C	0.5	60		0.5	60	pA	
		Full range			800		800		
$I_{IB}$ Input bias current	25°C	1	60		1	60	pA		
	Full range			800		800			
$V_{ICR}$ Common-mode input voltage	$R_S = 50\ \Omega,  V_{IO}  \leq 5\text{ mV}$	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	4.99			4.99	V		
		25°C	4.85	4.93		4.85		4.93	
		Full range	4.85			4.85			
		25°C	4.25	4.65		4.25		4.65	
$V_{OL}$ Low-level output voltage	$I_{OL} = -1\text{ mA}$	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	0.9	1.5		0.9		1.5	
$A_{VD}$ Large-signal differential voltage amplification	$V_{IC} = 2.5\text{ V}, V_O = 1\text{ V to }4\text{ V}$	$R_L = 10\text{ k}\Omega$ ‡	25°C	10	35		10	35	V/mV
			Full range	10			10		
		$R_L = 1\text{ m}\Omega$ ‡	25°C	175			175		
			Full range						
$r_{id}$ Differential input resistance		25°C	$10^{12}$			$10^{12}$	$\Omega$		
$r_i$ Common-mode input resistance		25°C	$10^{12}$			$10^{12}$	$\Omega$		
$c_i$ Common-mode input capacitance	$f = 10\text{ kHz}, \text{ P package}$	25°C	8			8	pF		
$z_o$ Closed-loop output impedance	$f = 1\text{ MHz}, A_V = 10$	25°C	140			140	$\Omega$		
CMRR Common-mode rejection ratio	$V_{IC} = 0\text{ V to }2.7\text{ V}, V_O = 2.5\text{ V}, R_S = 50\ \Omega$	25°C	70	75		70	75	dB	
		Full range	70			70			
$k_{SVR}$ Supply-voltage rejection ratio ( $\Delta V_{DD}/\Delta V_{IO}$ )	$V_{DD} = 4.4\text{ V to }16\text{ V}, V_{IC} = V_{DD}/2, \text{ No load}$	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	2.2	3		2.2	3	mA	
		Full range			3		3		

† Full range is -55°C to 125°C for M level part.

‡ Referenced to 2.5 V

NOTE 5: Typical values are based on the input offset voltage shift observed through 168 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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**TLC2272-EP operating characteristics at specified free-air temperature,  $V_{DD} = 5\text{ V}$**

PARAMETER	TEST CONDITIONS	$T_A$ †	TLC2272-EP			TLC2272A-EP			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
SR	Slew rate at unity gain $V_O = 1.25\text{ V to }2.75\text{ V}$ , $R_L = 10\text{ k}\Omega$ ‡, $C_L = 100\text{ pF}$ ‡	25°C	2.3	3.6		2.3	3.6	V/ $\mu\text{s}$	
		Full range	1.7			1.7			
$V_n$	Equivalent input noise voltage $f = 10\text{ Hz}$ $f = 1\text{ kHz}$	25°C		50			50	nV/ $\sqrt{\text{Hz}}$	
		25°C		9			9		
$V_{NPP}$	Peak-to-peak equivalent input noise voltage $f = 0.1\text{ Hz to }1\text{ Hz}$ $f = 0.1\text{ Hz to }10\text{ Hz}$	25°C		1			1	$\mu\text{V}$	
		25°C		1.4			1.4		
$I_n$	Equivalent input noise current	25°C		0.6			0.6	fA/ $\sqrt{\text{Hz}}$	
THD + N	Total harmonic distortion plus noise $V_O = 0.5\text{ V to }2.5\text{ V}$ , $f = 20\text{ kHz}$ , $R_L = 10\text{ k}\Omega$ ‡	25°C		$A_V = 1$		0.0013%		0.0013%	
				$A_V = 10$		0.004%		0.004%	
				$A_V = 100$		0.03%		0.03%	
	Gain-bandwidth product $f = 10\text{ kHz}$ , $R_L = 10\text{ k}\Omega$ ‡, $C_L = 100\text{ pF}$ ‡	25°C		2.18			2.18	MHz	
BOM	Maximum output-swing bandwidth $V_{O(PP)} = 2\text{ V}$ , $R_L = 10\text{ k}\Omega$ ‡, $A_V = 1$ , $C_L = 100\text{ pF}$ ‡	25°C		1			1	MHz	
$t_s$	Settling time $A_V = -1$ , Step = 0.5 V to 2.5 V, $R_L = 10\text{ k}\Omega$ ‡, $C_L = 100\text{ pF}$ ‡	25°C		To 0.1%		1.5		1.5	$\mu\text{s}$
				To 0.01%		2.6		2.6	
$\phi_m$	Phase margin at unity gain $R_L = 10\text{ k}\Omega$ ‡, $C_L = 100\text{ pF}$ ‡	25°C		50°			50°		
	Gain margin	25°C		10			10	dB	

† Full range is  $-55^\circ\text{C}$  to  $125^\circ\text{C}$  for M level part.

‡ Referenced to 2.5 V

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**TLC2272-EP electrical characteristics at specified free-air temperature,  $V_{DD\pm} = \pm 5\text{ V}$  (unless otherwise noted)**

PARAMETER	TEST CONDITIONS	$T_A$ †	TLC2272-EP			TLC2272A-EP			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
$V_{IO}$ Input offset voltage	$V_{IC} = 0\text{ V},$ $R_S = 50\ \Omega$ $V_O = 0\text{ V},$	25°C	300	2500		300	950	$\mu\text{V}$	
		Full range			3000		1500		
$\alpha_{VIO}$ Temperature coefficient of input offset voltage		25°C to 125°C	2			2		$\mu\text{V}/^\circ\text{C}$	
Input offset voltage long-term drift (see Note 5)		25°C	0.002			0.002		$\mu\text{V}/\text{mo}$	
$I_{IO}$ Input offset current		25°C	0.5	60		0.5	60	$\text{pA}$	
		Full range			800		800		
$I_{IB}$ Input bias current		25°C	1	60		1	60	$\text{pA}$	
		Full range			800		800		
$V_{ICR}$ Common-mode input voltage	$R_S = 50\ \Omega,$ $ V_{IO}  \leq 5\text{ mV}$	25°C	-5 to 4	-5.3 to 4.2		-5 to 4	-5.3 to 4.2	$\text{V}$	
		Full range	-5 to 3.5			-5 to 3.5			
$V_{OM+}$ Maximum positive peak output voltage	$I_O = -20\ \mu\text{A}$ $I_O = -200\ \mu\text{A}$ $I_O = -1\text{ mA}$	25°C		4.99			4.99	$\text{V}$	
		25°C	4.85	4.93		4.85	4.93		
		Full range	4.85			4.85			
		25°C	4.25	4.65		4.25	4.65		
$V_{OM-}$ Maximum negative peak output voltage	$V_{IC} = 0\text{ V},$ $I_O = 50\ \mu\text{A}$ $V_{IC} = 0\text{ V},$ $I_O = 500\ \mu\text{A}$ $V_{IC} = 0\text{ V},$ $I_O = 5\text{ mA}$	25°C		-4.99			-4.99	$\text{V}$	
		25°C	-4.85	-4.91		-4.85	-4.91		
		Full range	-4.85			-4.85			
		25°C	-3.5	-4.1		-3.5	-4.1		
$A_{VD}$ Large-signal differential voltage amplification	$V_O = \pm 4\text{ V}$ $R_L = 10\ \text{k}\Omega$ $R_L = 1\ \text{m}\Omega$	25°C	20	50		20	50	$\text{V}/\text{mV}$	
		Full range	20			20			
		25°C		300			300		
$r_{id}$ Differential input resistance		25°C		$10^{12}$			$10^{12}$	$\Omega$	
$r_i$ Common-mode input resistance		25°C		$10^{12}$			$10^{12}$	$\Omega$	
$c_i$ Common-mode input capacitance	$f = 10\ \text{kHz},$ P package	25°C		8			8	$\text{pF}$	
$z_o$ Closed-loop output impedance	$f = 1\ \text{MHz},$ $A_V = 10$	25°C		130			130	$\Omega$	
CMRR Common-mode rejection ratio	$V_{IC} = -5\text{ V to } 2.7\text{ V},$ $V_O = 0\text{ V},$ $R_S = 50\ \Omega$	25°C	75	80		75	80	$\text{dB}$	
		Full range	75			75			
$k_{SVR}$ Supply-voltage rejection ratio ( $\Delta V_{DD\pm}/\Delta V_{IO}$ )	$V_{DD} = \pm 2.2\text{ V to } \pm 8\text{ V},$ $V_{IC} = 0\text{ V},$ No load	25°C	80	95		80	95	$\text{dB}$	
		Full range	80			80			
$I_{DD}$ Supply current	$V_O = 2.5\text{ V},$ No load	25°C		2.4	3		2.4	3	$\text{mA}$
		Full range			3		3		

† Full range is  $-55^\circ\text{C}$  to  $125^\circ\text{C}$  for M level part.

NOTE 5: Typical values are based on the input offset voltage shift observed through 168 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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**TLC2272-EP operating characteristics at specified free-air temperature,  $V_{DD\pm} = \pm 5\text{ V}$**

PARAMETER	TEST CONDITIONS	$T_A$ †	TLC2272-EP			TLC2272A-EP			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
SR	Slew rate at unity gain $V_O = \pm 1\text{ V}$ , $C_L = 100\text{ pF}$ $R_L = 10\text{ k}\Omega$	25°C	2.3	3.6		2.3	3.6	V/ $\mu\text{s}$	
		Full range	1.7			1.7			
$V_n$	Equivalent input noise voltage	$f = 10\text{ Hz}$		50			50	nV/ $\sqrt{\text{Hz}}$	
		$f = 1\text{ kHz}$	25°C		9		9		
$V_{NPP}$	Peak-to-peak equivalent input noise voltage	$f = 0.1\text{ Hz to }1\text{ Hz}$	25°C		1		1	$\mu\text{V}$	
		$f = 0.1\text{ Hz to }10\text{ Hz}$	25°C		1.4		1.4		
$I_n$	Equivalent input noise current		25°C		0.6		0.6	fA/ $\sqrt{\text{Hz}}$	
THD + N	Total harmonic distortion plus noise $V_O = \pm 2.3\text{ V}$ $R_L = 10\text{ k}\Omega$ , $f = 20\text{ kHz}$	$A_V = 1$	25°C		0.0011%		0.0011%		
		$A_V = 10$			0.004%		0.004%		
		$A_V = 100$			0.03%		0.03%		
	Gain-bandwidth product	$f = 10\text{ kHz}$ , $C_L = 100\text{ pF}$ $R_L = 10\text{ k}\Omega$	25°C		2.25		2.25	MHz	
BOM	Maximum output-swing bandwidth	$V_{O(PP)} = 4.6\text{ V}$ , $R_L = 10\text{ k}\Omega$ , $A_V = 1$ , $C_L = 100\text{ pF}$	25°C		0.54		0.54	MHz	
$t_s$	Settling time	$A_V = -1$ , Step = $-2.3\text{ V to }2.3\text{ V}$ , $R_L = 10\text{ k}\Omega$ , $C_L = 100\text{ pF}$	To 0.1%	25°C		1.5		1.5	$\mu\text{s}$
			To 0.01%			3.2		3.2	
$\phi_m$	Phase margin at unity gain	$R_L = 10\text{ k}\Omega$ , $C_L = 100\text{ pF}$	25°C		52°		52°		
	Gain margin		25°C		10		10	dB	

† Full range is  $-55^\circ\text{C}$  to  $125^\circ\text{C}$  for M level part.



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**TLC2274-EP electrical characteristics at specified free-air temperature,  $V_{DD} = 5\text{ V}$  (unless otherwise noted)**

PARAMETER	TEST CONDITIONS	$T_A$ †	TLC2274-EP			TLC2274A-EP			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
$V_{IO}$ Input offset voltage	$V_{DD} \pm \pm 2.5\text{ V}$ , $V_O = 0\text{ V}$ , $V_{IC} = 0\text{ V}$ , $R_S = 50\ \Omega$	25°C		300	2500		300	950	$\mu\text{V}$
		Full range			3000			1500	
$\alpha_{VIO}$ Temperature coefficient of input offset voltage		25°C to 125°C		2			2		$\mu\text{V}/^\circ\text{C}$
Input offset voltage long-term drift (see Note 5)		25°C		0.002			0.002		$\mu\text{V}/\text{mo}$
$I_{IO}$ Input offset current		25°C		0.5	60		0.5	60	$\text{pA}$
		Full range			800			800	
$I_{IB}$ Input bias current		25°C		1	60		1	60	$\text{pA}$
		Full range			800			800	
$V_{ICR}$ Common-mode input voltage		$R_S = 50\ \Omega$ , $ V_{IO}  \leq 5\text{ mV}$	25°C	0 to 4	-0.3 to 4.2		0 to 4	-0.3 to 4.2	$\text{V}$
			Full range	0 to 3.5			0 to 3.5		
$V_{OH}$ High-level output voltage	$I_{OH} = -20\ \mu\text{A}$	25°C		4.99			4.99	$\text{V}$	
		25°C		4.85	4.93		4.85		4.93
		Full range		4.85			4.85		
		25°C		4.25	4.65		4.25		4.65
$V_{OL}$ Low-level output voltage	$V_{IC} = 2.5\text{ V}$ , $I_{OL} = 50\ \mu\text{A}$	25°C		0.01			0.01	$\text{V}$	
		25°C		0.09	0.15		0.09		0.15
		Full range			0.15				0.15
		25°C		0.9	1.5		0.9		1.5
$V_{OL}$ Low-level output voltage	$V_{IC} = 2.5\text{ V}$ , $I_{OL} = 500\ \mu\text{A}$	25°C		0.01			0.01	$\text{V}$	
		25°C		0.09	0.15		0.09		0.15
		Full range			0.15				0.15
		25°C		0.9	1.5		0.9		1.5
$A_{VD}$ Large-signal differential voltage amplification	$V_{IC} = 2.5\text{ V}$ , $V_O = 1\text{ V to }4\text{ V}$	$R_L = 10\ \text{k}\Omega$ ‡	25°C	10	35		10	35	$\text{V/mV}$
			Full range		10			10	
		$R_L = 1\ \text{M}\Omega$ ‡	25°C		175			175	
$r_{id}$ Differential input resistance		25°C		$10^{12}$			$10^{12}$	$\Omega$	
$r_i$ Common-mode input resistance		25°C		$10^{12}$			$10^{12}$	$\Omega$	
$c_i$ Common-mode input capacitance	$f = 10\ \text{kHz}$ , N package	25°C		8			8	$\text{pF}$	
$z_o$ Closed-loop output impedance	$f = 1\ \text{MHz}$ , $A_V = 10$	25°C		140			140	$\Omega$	
CMRR Common-mode rejection ratio	$V_{IC} = 0\text{ V to }2.7\text{ V}$ , $V_O = 2.5\text{ V}$ , $R_S = 50\ \Omega$	25°C		70	75		70	75	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		4.4	6		4.4	6	mA
		Full range			6			6	

† Full range is  $-55^\circ\text{C}$  to  $125^\circ\text{C}$  for M level part.

‡ Referenced to 2.5 V

NOTE 5: Typical values are based on the input offset voltage shift observed through 168 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.

**TLC227x-EP, TLC227xA-EP**  
**Advanced LinCMOS™ RAIL-TO-RAIL**  
**OPERATIONAL AMPLIFIERS**

SGLS131A – JULY 2002 – REVISED NOVEMBER 2003

**TLC2274-EP operating characteristics at specified free-air temperature,  $V_{DD} = 5\text{ V}$**

PARAMETER	TEST CONDITIONS	$T_A$ †	TLC2274-EP			TLC2274A-EP			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
SR	Slew rate at unity gain $V_O = 0.5\text{ V to }2.5\text{ V},$ $R_L = 10\text{ k}\Omega$ ‡, $C_L = 100\text{ pF}$ ‡	25°C	2.3	3.6		2.3	3.6		V/ $\mu\text{s}$
		Full range	1.7			1.7			
$V_n$	Equivalent input noise voltage	$f = 10\text{ Hz}$		50			50		nV/ $\sqrt{\text{Hz}}$
		$f = 1\text{ kHz}$	25°C		9		9		
$V_{N(PP)}$	Peak-to-peak equivalent input noise voltage	$f = 0.1\text{ Hz to }1\text{ Hz}$	25°C		1		1		$\mu\text{V}$
		$f = 0.1\text{ Hz to }10\text{ Hz}$	25°C		1.4		1.4		
$I_n$	Equivalent input noise current		25°C		0.6		0.6	fA/ $\sqrt{\text{Hz}}$	
THD + N	Total harmonic distortion plus noise $V_O = 0.5\text{ V to }2.5\text{ V},$ $f = 20\text{ kHz},$ $R_L = 10\text{ k}\Omega$ ‡	$A_V = 1$	25°C		0.0013%		0.0013%		
		$A_V = 10$			0.004%		0.004%		
		$A_V = 100$			0.03%		0.03%		
	Gain-bandwidth product	$f = 10\text{ kHz},$ $C_L = 100\text{ pF}$ ‡	$R_L = 10\text{ k}\Omega$ ‡,	25°C		2.18		2.18	MHz
BOM	Maximum output-swing bandwidth	$V_{O(PP)} = 2\text{ V},$ $R_L = 10\text{ k}\Omega$ ‡,	$A_V = 1,$ $C_L = 100\text{ pF}$ ‡	25°C		1		1	MHz
$t_s$	Settling time	$A_V = -1,$ Step = 0.5 V to 2.5 V, $R_L = 10\text{ k}\Omega$ ‡, $C_L = 100\text{ pF}$ ‡	To 0.1%	25°C		1.5		1.5	$\mu\text{s}$
			To 0.01%			2.6		2.6	
$\phi_m$	Phase margin at unity gain	$R_L = 10\text{ k}\Omega$ ‡,	$C_L = 100\text{ pF}$ ‡	25°C		50°		50°	
	Gain margin			25°C		10		10	dB

† Full range is  $-55^\circ\text{C}$  to  $125^\circ\text{C}$  for M level part.

‡ Referenced to 2.5 V

**TLC227x-EP, TLC227xA-EP**  
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**TLC2274-EP electrical characteristics at specified free-air temperature,  $V_{DD\pm} = \pm 5\text{ V}$  (unless otherwise noted)**

PARAMETER	TEST CONDITIONS	$T_A$ †	TLC2274-EP			TLC2274A-EP			UNIT	
			MIN	TYP	MAX	MIN	TYP	MAX		
$V_{IO}$ Input offset voltage	$V_{IC} = 0\text{ V}, V_O = 0\text{ V}, R_S = 50\ \Omega$	25°C	300	2500		300	950	$\mu\text{V}$		
		Full range			3000		1500			
$\alpha_{VIO}$ Temperature coefficient of input offset voltage		25°C to 125°C	2			2			$\mu\text{V}/^\circ\text{C}$	
Input offset voltage long-term drift (see Note 5)		25°C	0.002			0.002			$\mu\text{V}/\text{mo}$	
$I_{IO}$ Input offset current		25°C	0.5	60		0.5	60	$\text{pA}$		
		Full range			800		800			
$I_{IB}$ Input bias current		25°C	1	60		1	60	$\text{pA}$		
		Full range			800		800			
$V_{ICR}$ Common-mode input voltage	$R_S = 50\ \Omega,  V_{IO}  \leq 5\text{ mV}$	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	4.99		4.99		V			
		25°C	4.85	4.93	4.85	4.93				
		Full range	4.85		4.85					
		25°C	4.25	4.65	4.25	4.65				
$V_{OM-}$ Maximum negative peak output voltage	$I_O = -1\text{ mA}$	25°C	-4.99		-4.99		V			
		25°C	-4.85	-4.91	-4.85	-4.91				
		Full range	-4.85		-4.85					
		25°C	-3.5	-4.1	-3.5	-4.1				
$V_{AVD}$ Large-signal differential voltage amplification	$V_O = \pm 4\text{ V}$	$R_L = 10\text{ k}\Omega$	25°C	20	50	20	50	V/mV		
			Full range	20		20				
		$R_L = 1\text{ M}\Omega$	25°C	300			300			
			Full range	300			300			
$r_{id}$ Differential input resistance		25°C	$10^{12}$			$10^{12}$			$\Omega$	
$r_i$ Common-mode input resistance		25°C	$10^{12}$			$10^{12}$			$\Omega$	
$c_i$ Common-mode input capacitance	$f = 10\text{ kHz}, \text{ N package}$	25°C	8			8			pF	
$z_o$ Closed-loop output impedance	$f = 1\text{ MHz}, A_V = 10$	25°C	130			130			$\Omega$	
CMRR Common-mode rejection ratio	$V_{IC} = -5\text{ V to } 2.7\text{ V}$ $V_O = 0\text{ V}, R_S = 50\ \Omega$	25°C	75	80		75	80	dB		
		Full range	75			75				
$k_{SVR}$ Supply-voltage rejection ratio ( $\Delta V_{DD\pm}/\Delta V_{IO}$ )	$V_{DD\pm} = \pm 2.2\text{ V to } \pm 8\text{ V}, V_{IC} = 0\text{ V}, \text{ No load}$	25°C	80	95		80	95	dB		
		Full range	80			80				
$I_{DD}$ Supply current	$V_O = 0\text{ V}, \text{ No load}$	25°C	4.8	6		4.8	6	mA		
		Full range	6			6				

† Full range is  $-55^\circ\text{C}$  to  $125^\circ\text{C}$  for M level part.

NOTE 5: Typical values are based on the input offset voltage shift observed through 168 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.

**TLC227x-EP, TLC227xA-EP**  
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SGLS131A – JULY 2002 – REVISED NOVEMBER 2003

**TLC2274-EP operating characteristics at specified free-air temperature,  $V_{DD\pm} = \pm 5\text{ V}$**

PARAMETER	TEST CONDITIONS	$T_A$ †	TLC2274-EP			TLC2274A-EP			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
SR	Slew rate at unity gain $V_O = \pm 2.3\text{ V}$ , $C_L = 100\text{ pF}$ , $R_L = 10\text{ k}\Omega$	25°C	2.3	3.6		2.3	3.6	V/ $\mu$ s	
		Full range	1.7			1.7			
$V_n$	Equivalent input noise voltage $f = 10\text{ Hz}$ $f = 1\text{ kHz}$	25°C		50			50	nV/ $\sqrt{\text{Hz}}$	
		25°C		9			9		
$V_{N(PP)}$	Peak-to-peak equivalent input noise voltage $f = 0.1\text{ Hz to }1\text{ Hz}$ $f = 0.1\text{ Hz to }10\text{ Hz}$	25°C		1			1	$\mu$ V	
		25°C		1.4			1.4		
$I_n$	Equivalent input noise current	25°C		0.6			0.6	fA/ $\sqrt{\text{Hz}}$	
THD + N	Total harmonic distortion plus noise $V_O = \pm 2.3\text{ V}$ , $R_L = 10\text{ k}\Omega$ , $f = 20\text{ kHz}$	25°C		$A_V = 1$		0.0011%		0.0011%	
				$A_V = 10$		0.004%		0.004%	
				$A_V = 100$		0.03%		0.03%	
	Gain-bandwidth product $f = 10\text{ kHz}$ , $C_L = 100\text{ pF}$ , $R_L = 10\text{ k}\Omega$	25°C		2.25			2.25	MHz	
BOM	Maximum output-swing bandwidth $V_{O(PP)} = 4.6\text{ V}$ , $R_L = 10\text{ k}\Omega$ , $A_V = 1$ , $C_L = 100\text{ pF}$	25°C		0.54			0.54	MHz	
$t_s$	Settling time $A_V = -1$ , Step = $-2.3\text{ V to }2.3\text{ V}$ , $R_L = 10\text{ k}\Omega$ , $C_L = 100\text{ pF}$	25°C		To 0.1%		1.5		1.5	$\mu$ s
				To 0.01%		3.2		3.2	
$\phi_m$	Phase margin at unit gain $R_L = 10\text{ k}\Omega$ , $C_L = 100\text{ pF}$	25°C		52°			52°		
		25°C		10			10	dB	

† Full range is  $-55^\circ\text{C}$  to  $125^\circ\text{C}$  for M level part.

## TYPICAL CHARACTERISTICS

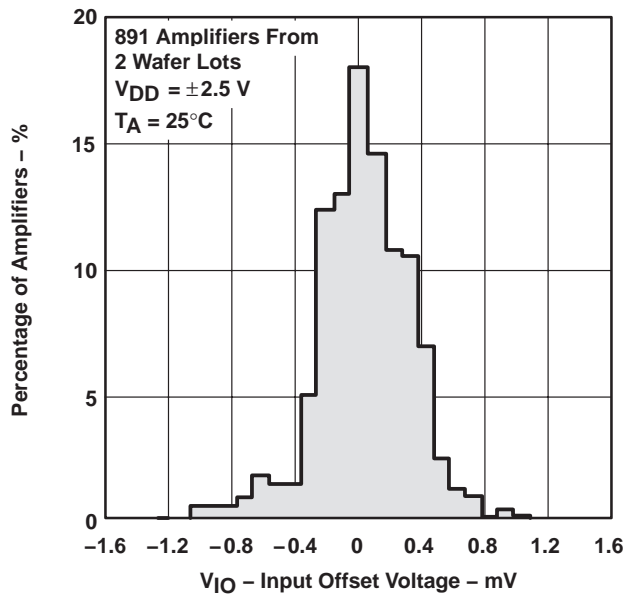
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NOTE: For all graphs where  $V_{DD} = 5\text{ V}$ , all loads are referenced to 2.5 V.

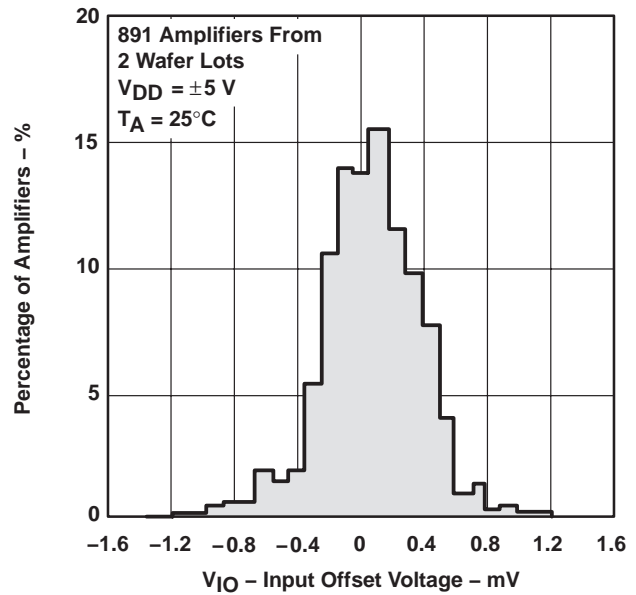
**TYPICAL CHARACTERISTICS**

**DISTRIBUTION OF TLC2272  
 INPUT OFFSET VOLTAGE**



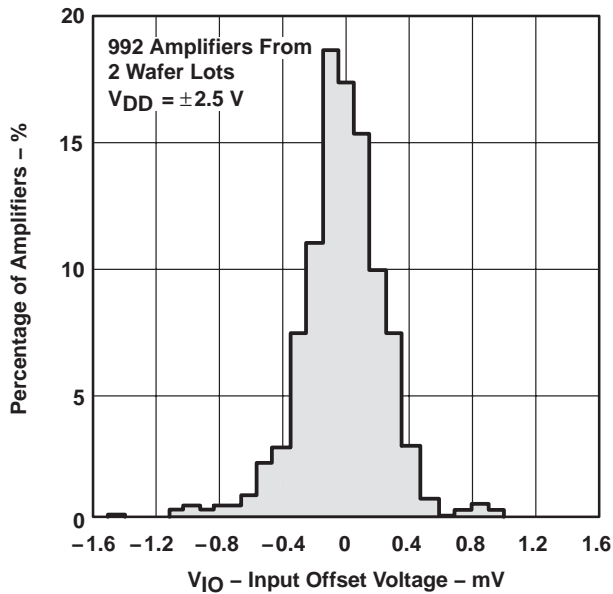
**Figure 1**

**DISTRIBUTION OF TLC2272  
 INPUT OFFSET VOLTAGE**



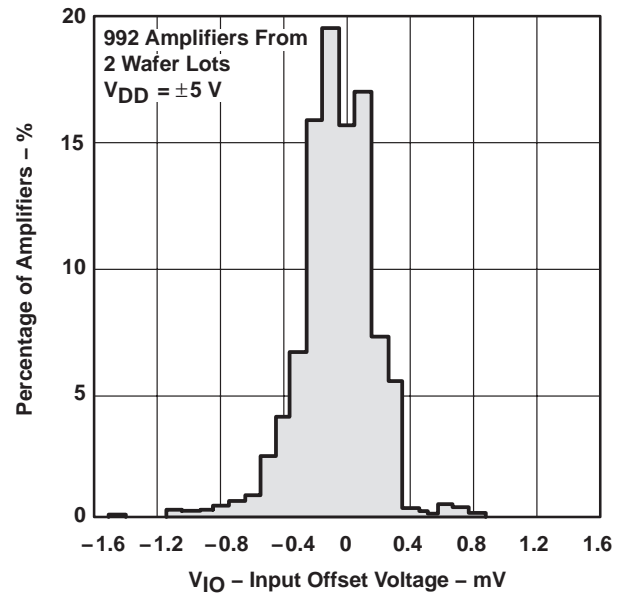
**Figure 2**

**DISTRIBUTION OF TLC2274  
 INPUT OFFSET VOLTAGE**



**Figure 3**

**DISTRIBUTION OF TLC2274  
 INPUT OFFSET VOLTAGE**



**Figure 4**



TYPICAL CHARACTERISTICS

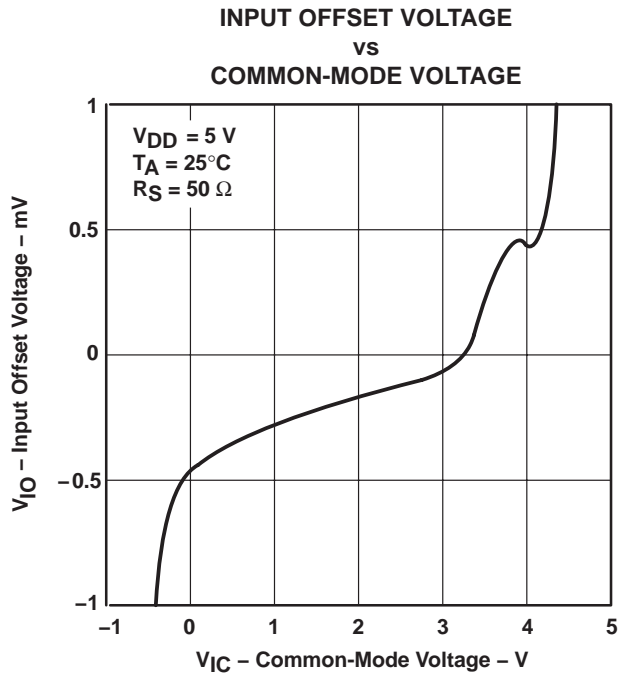


Figure 5

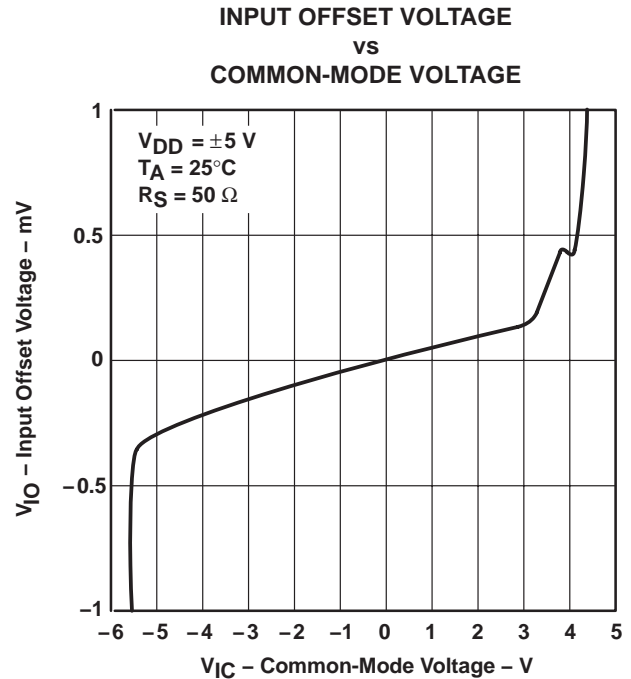


Figure 6

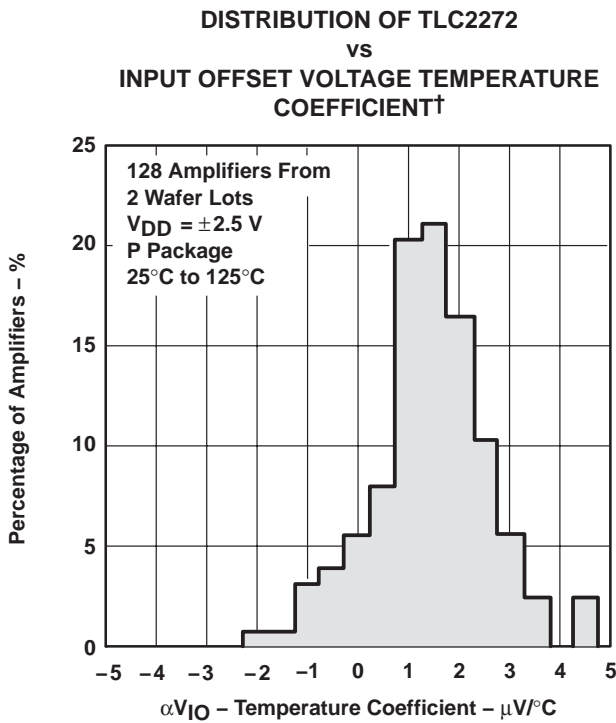


Figure 7

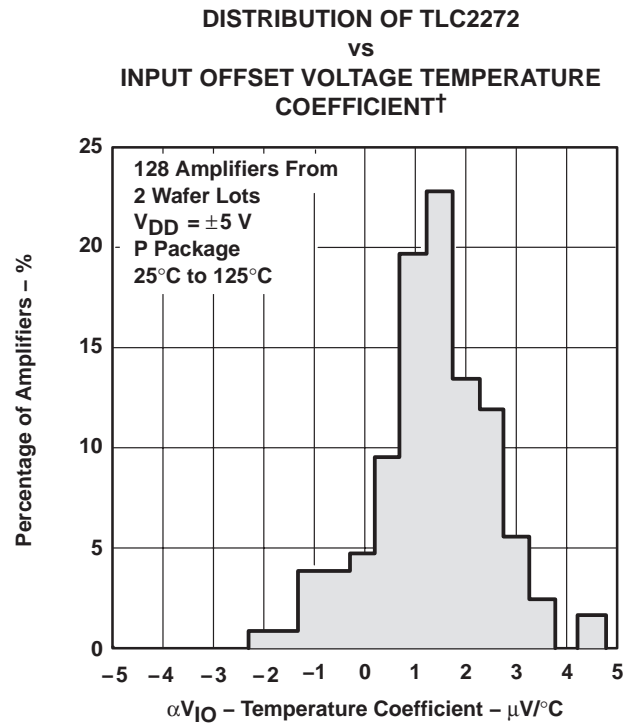
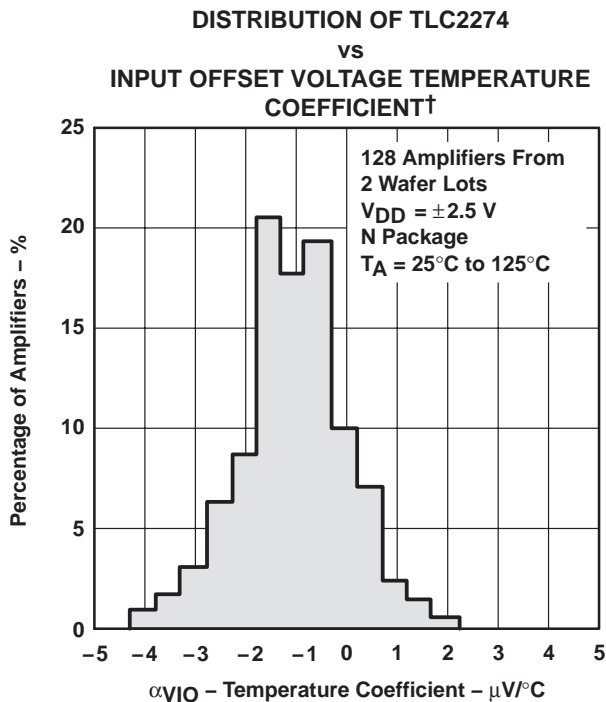


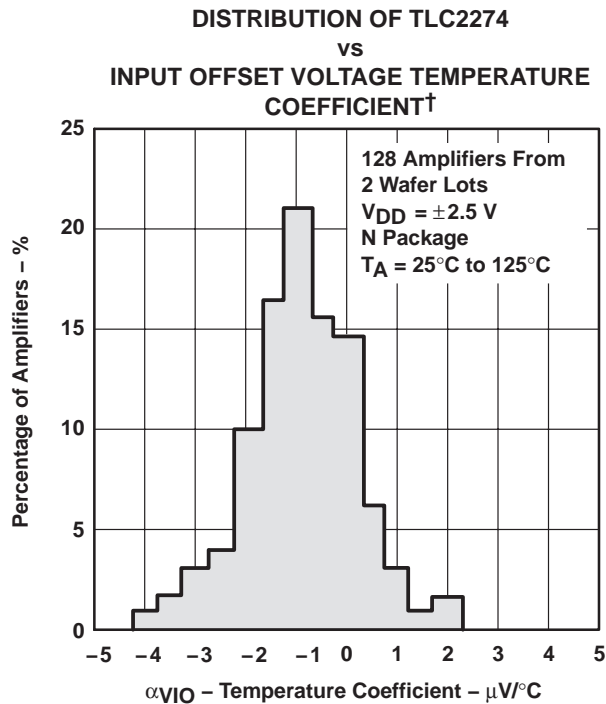
Figure 8

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

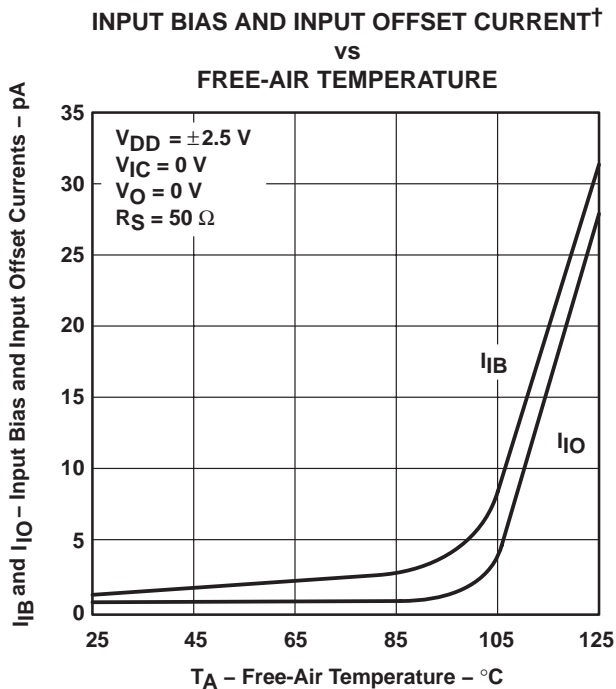
**TYPICAL CHARACTERISTICS**



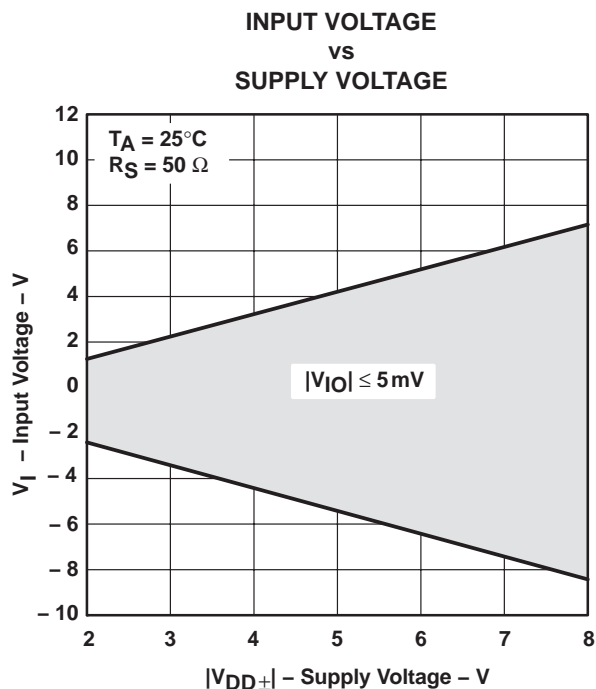
**Figure 9**



**Figure 10**



**Figure 11**



**Figure 12**

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



TYPICAL CHARACTERISTICS

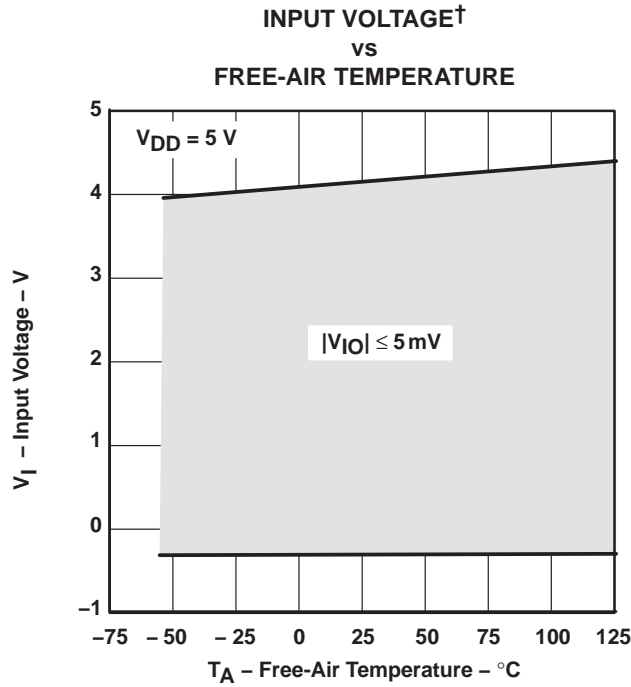


Figure 13

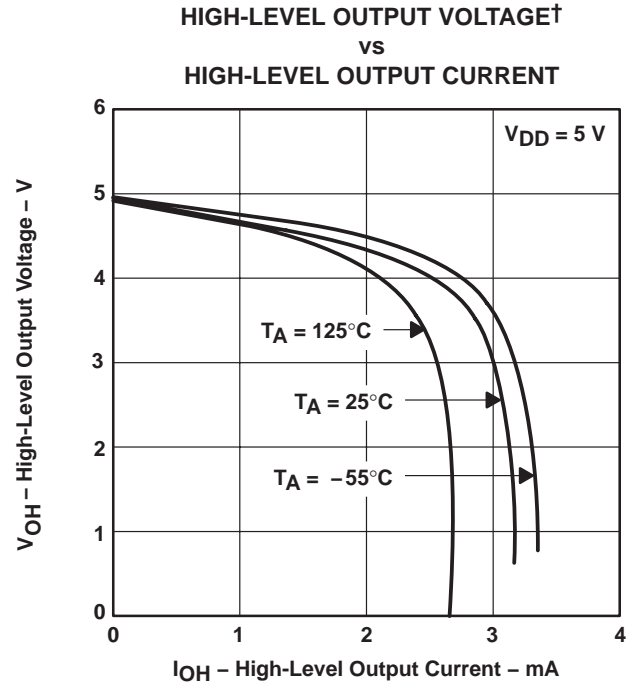


Figure 14

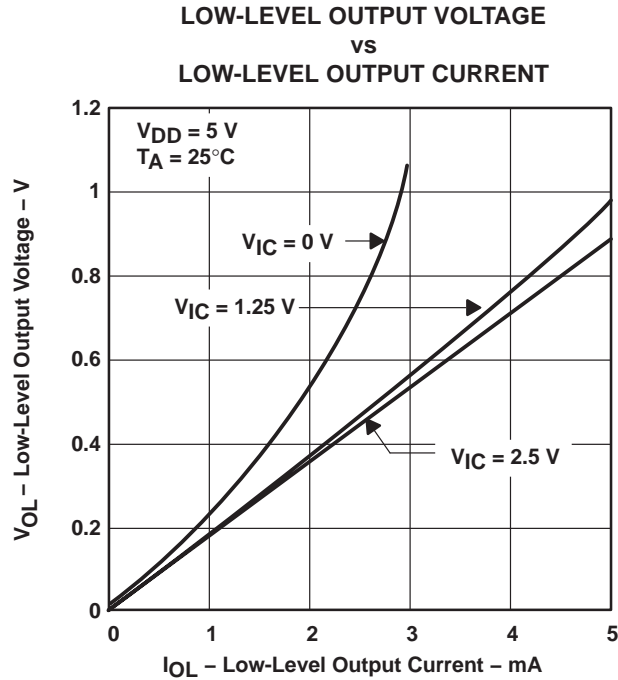


Figure 15

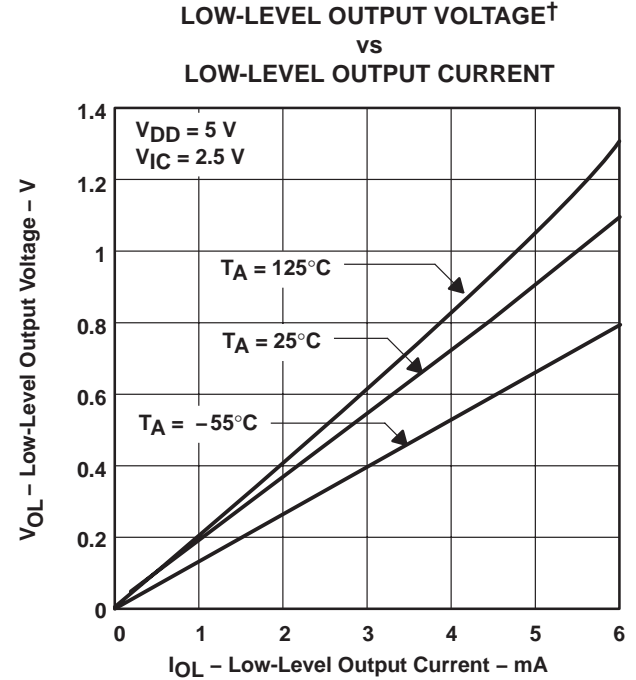
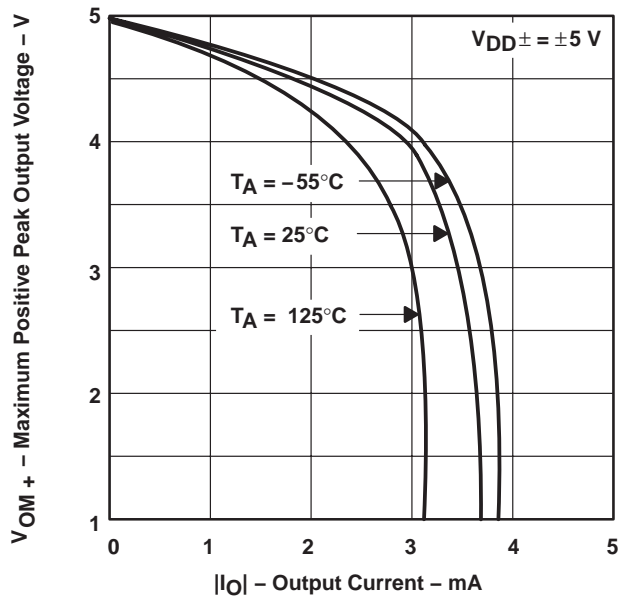


Figure 16

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

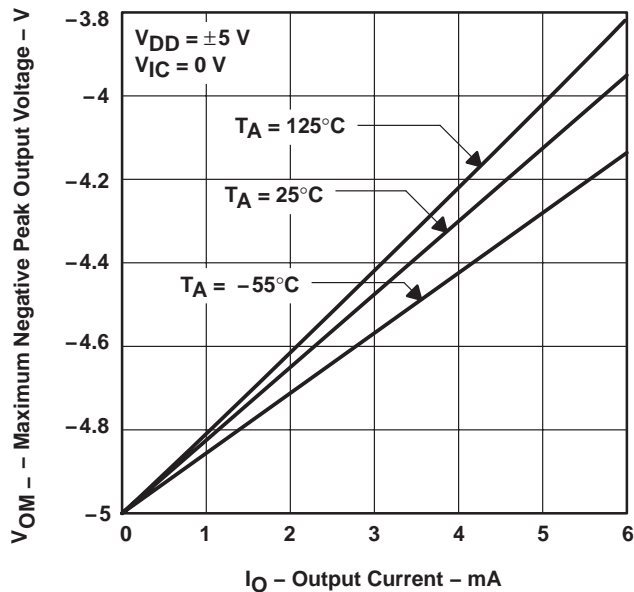
**TYPICAL CHARACTERISTICS**

**MAXIMUM POSITIVE PEAK OUTPUT VOLTAGE†**  
**vs**  
**OUTPUT CURRENT**



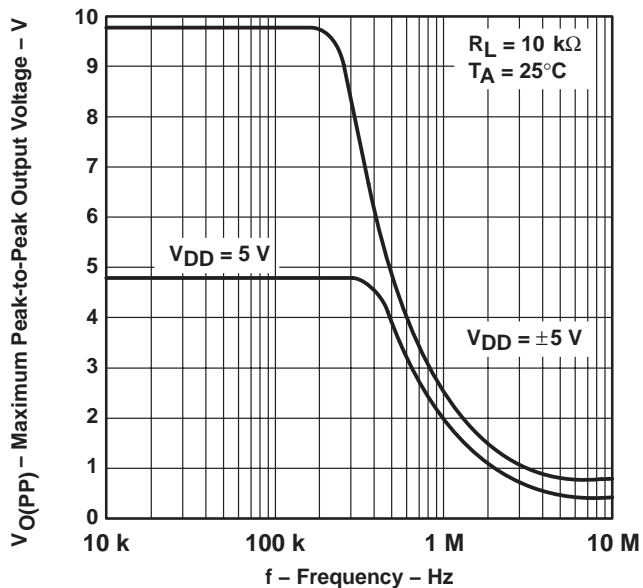
**Figure 17**

**MAXIMUM NEGATIVE PEAK OUTPUT VOLTAGE†**  
**vs**  
**OUTPUT CURRENT**



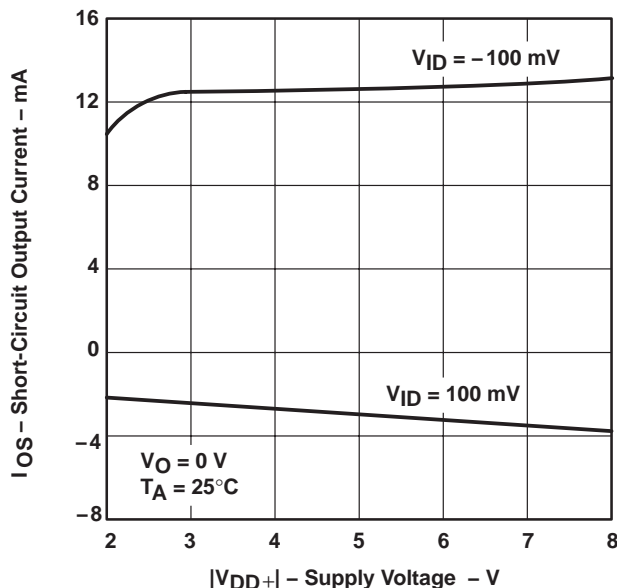
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**MAXIMUM PEAK-TO-PEAK OUTPUT VOLTAGE**  
**vs**  
**FREQUENCY**



**Figure 19**

**SHORT-CIRCUIT OUTPUT CURRENT**  
**vs**  
**SUPPLY VOLTAGE**



**Figure 20**

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

TYPICAL CHARACTERISTICS

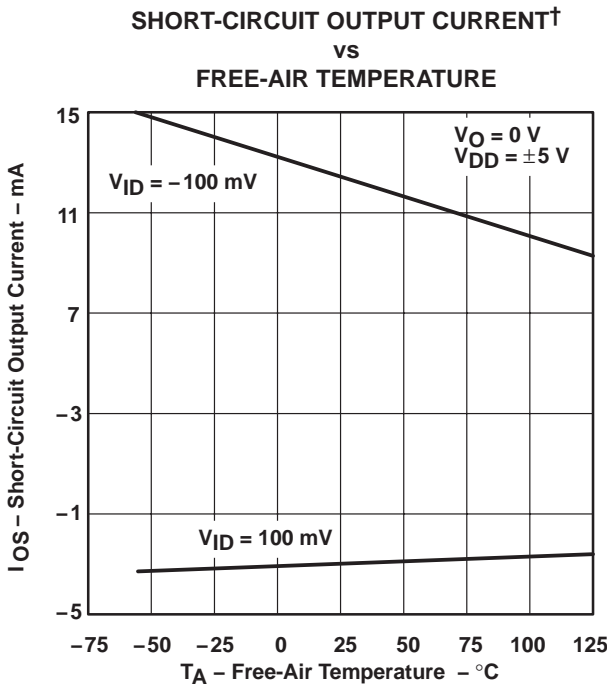


Figure 21

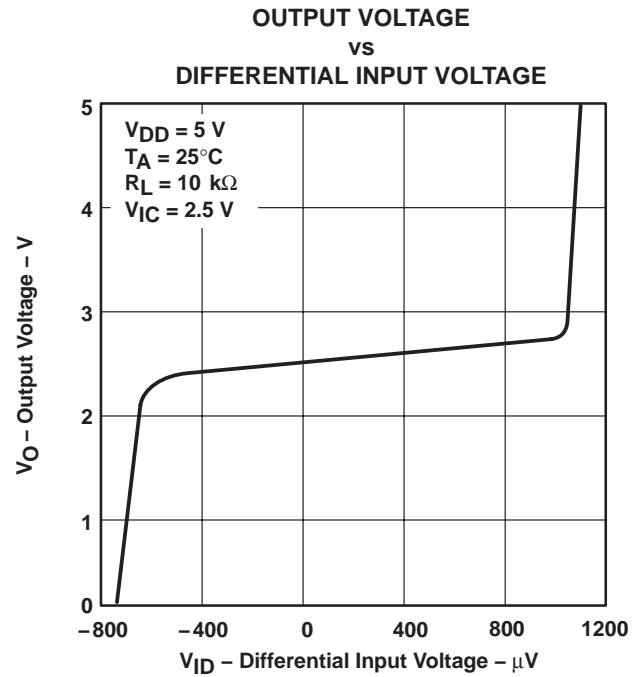


Figure 22

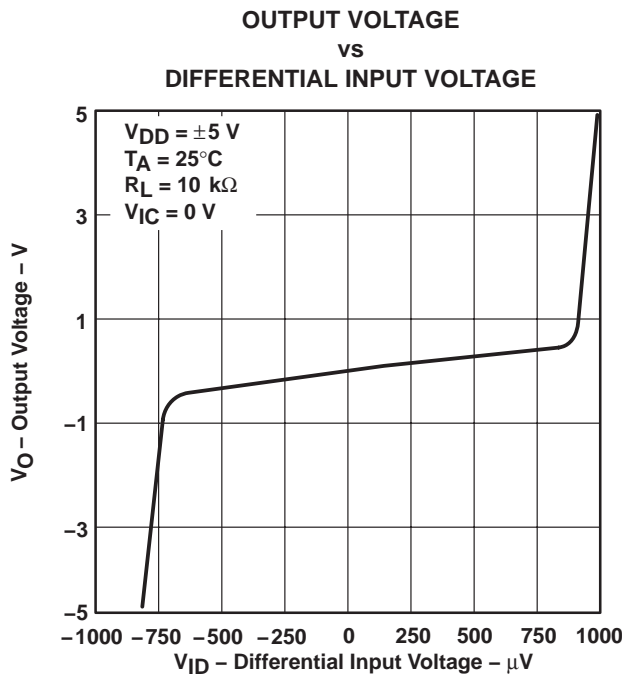


Figure 23

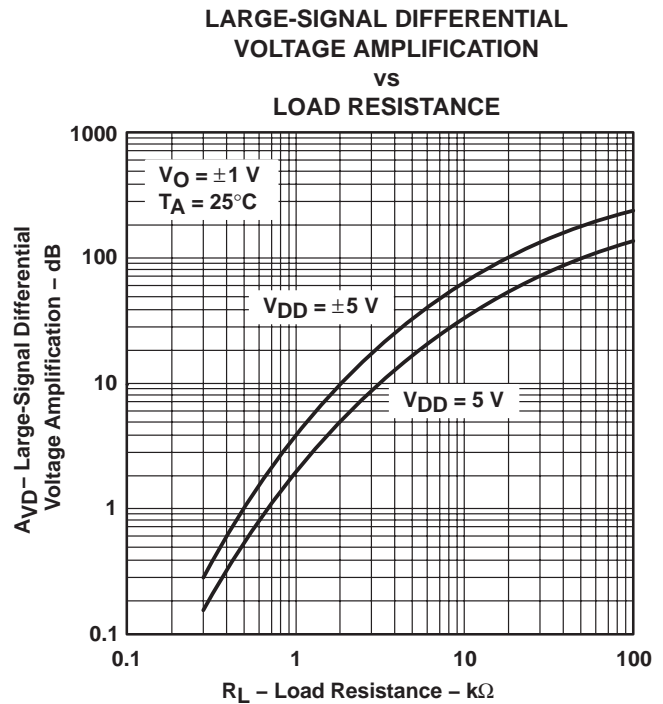
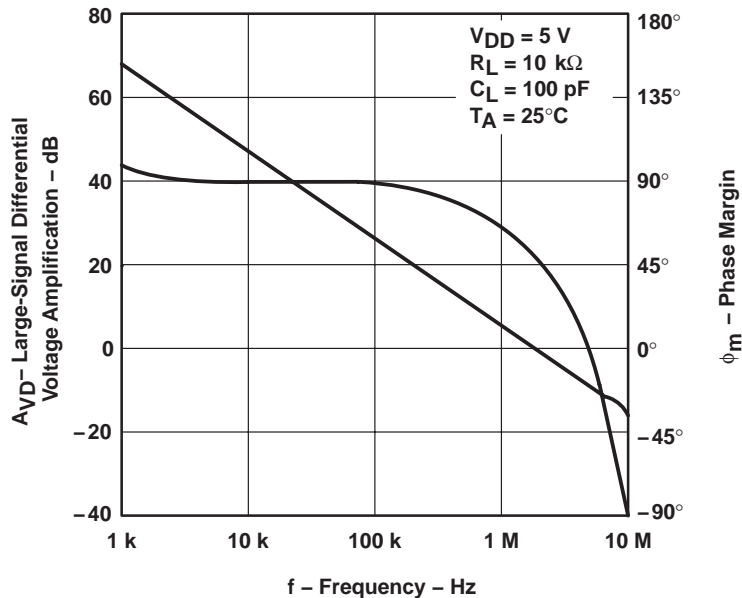


Figure 24

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

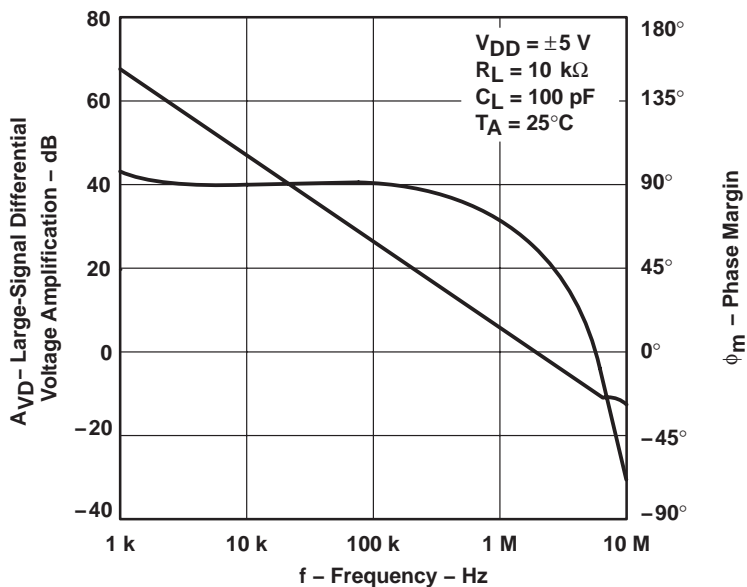
**TYPICAL CHARACTERISTICS**

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



**Figure 25**

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



**Figure 26**



TYPICAL CHARACTERISTICS

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

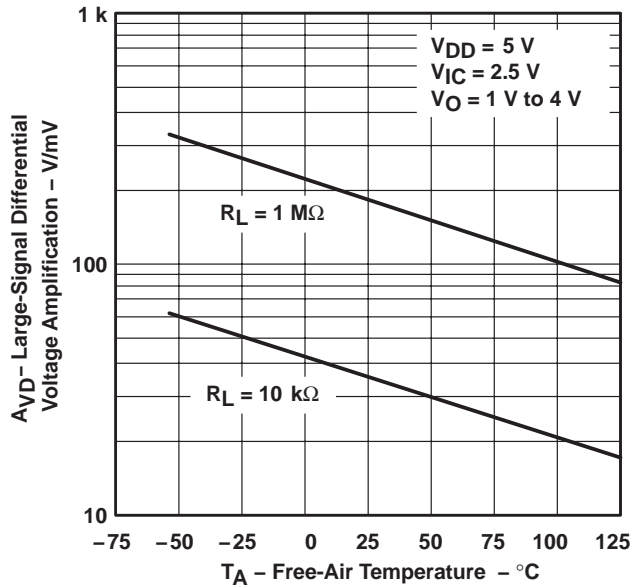


Figure 27

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

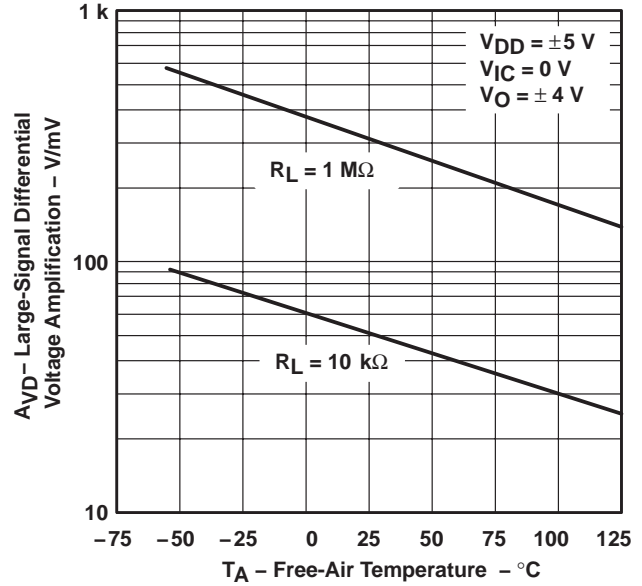


Figure 28

OUTPUT IMPEDANCE  
vs  
FREQUENCY

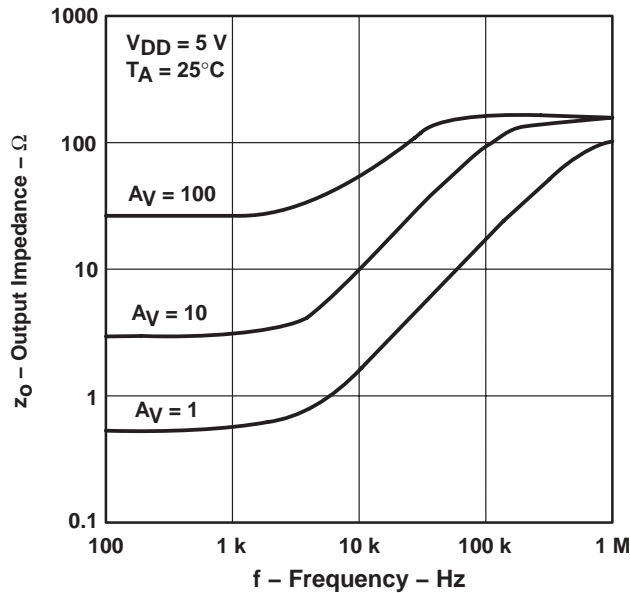


Figure 29

OUTPUT IMPEDANCE  
vs  
FREQUENCY

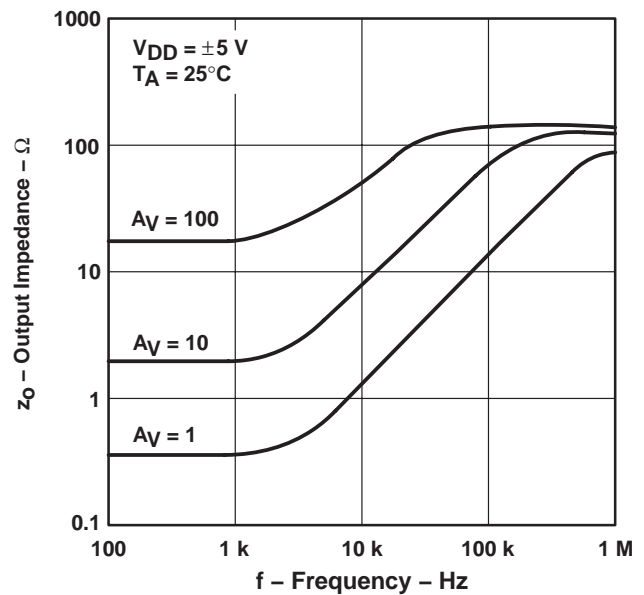


Figure 30

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

TYPICAL CHARACTERISTICS

COMMON-MODE REJECTION RATIO  
 vs  
 FREQUENCY

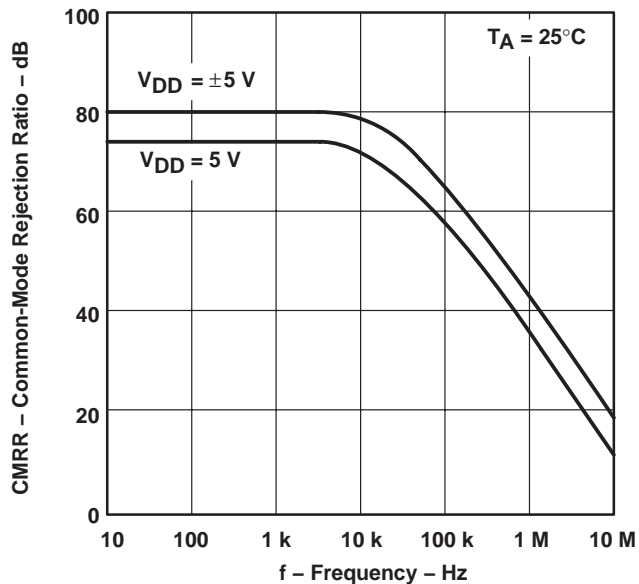


Figure 31

COMMON-MODE REJECTION RATIO  
 vs  
 FREE-AIR TEMPERATURE

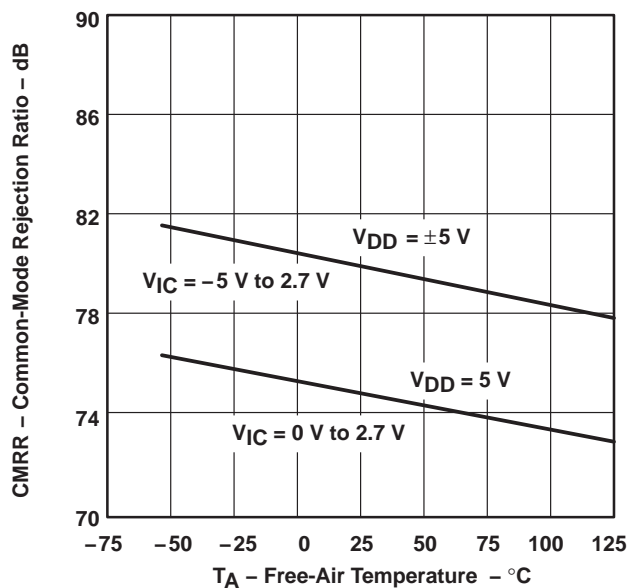


Figure 32

SUPPLY-VOLTAGE REJECTION RATIO  
 vs  
 FREQUENCY

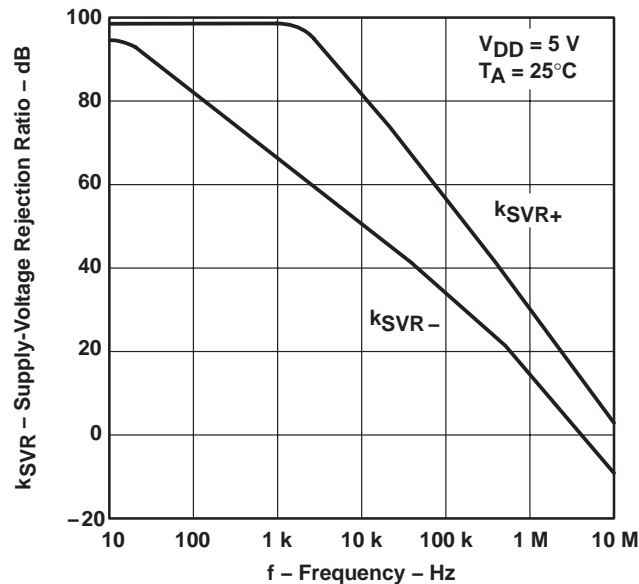


Figure 33

SUPPLY-VOLTAGE REJECTION RATIO  
 vs  
 FREQUENCY

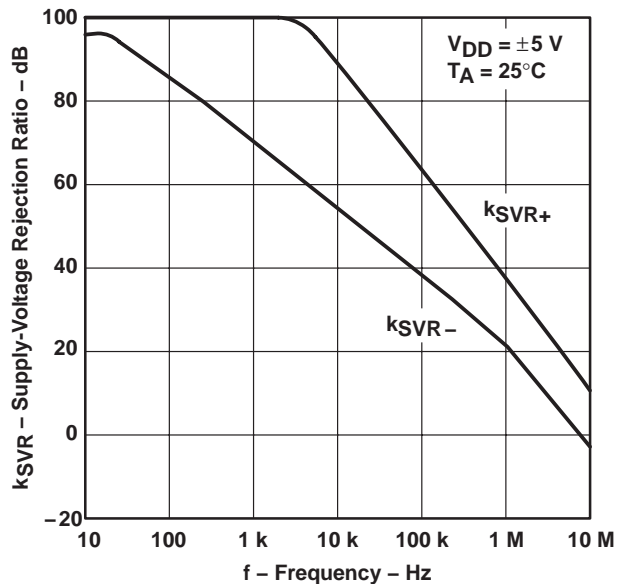
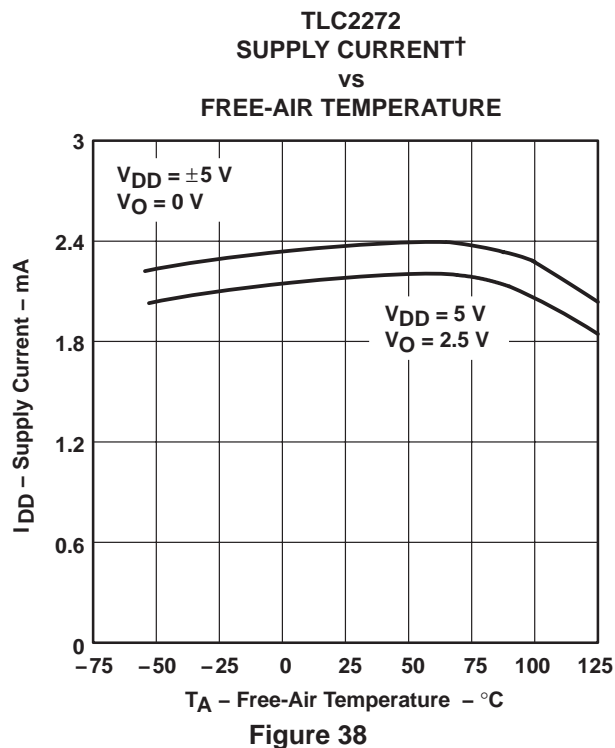
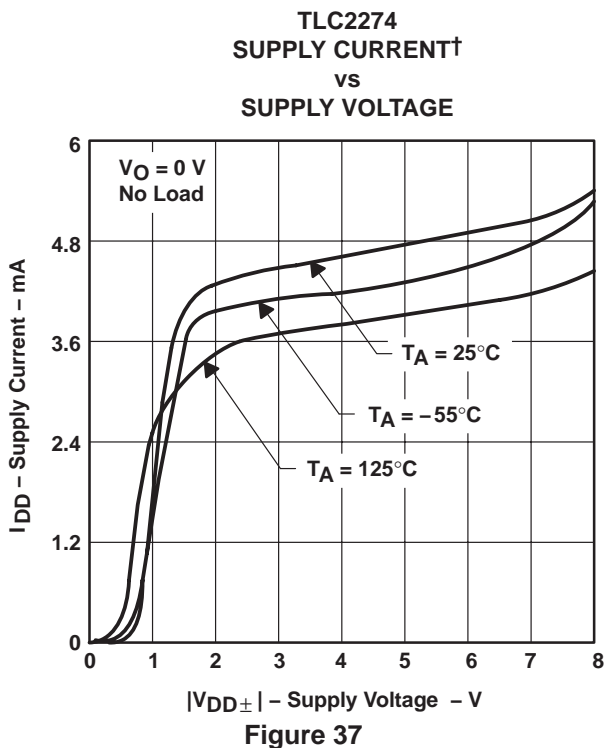
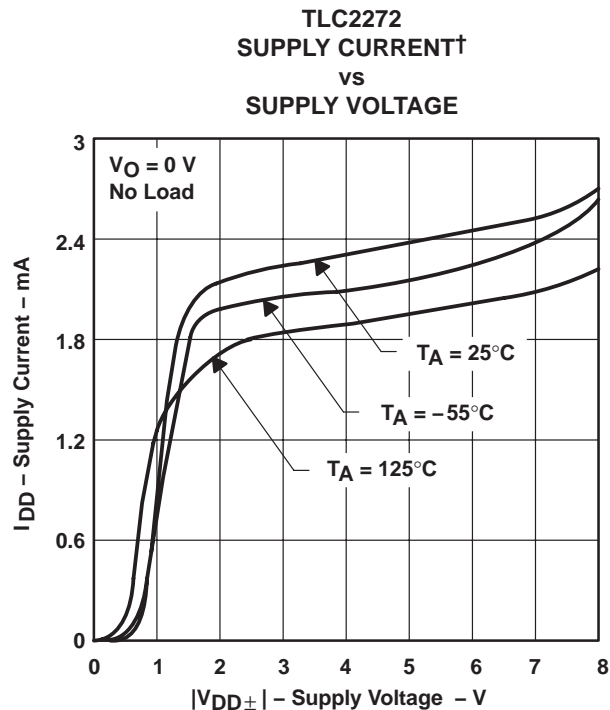
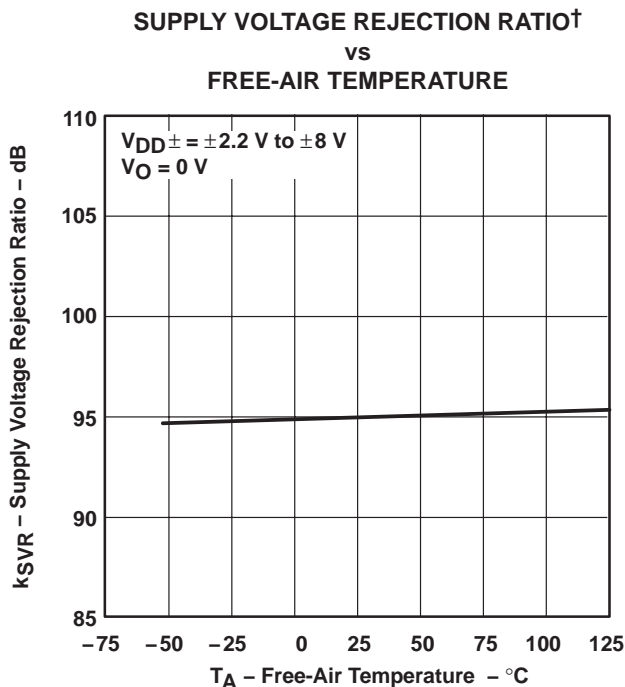


Figure 34

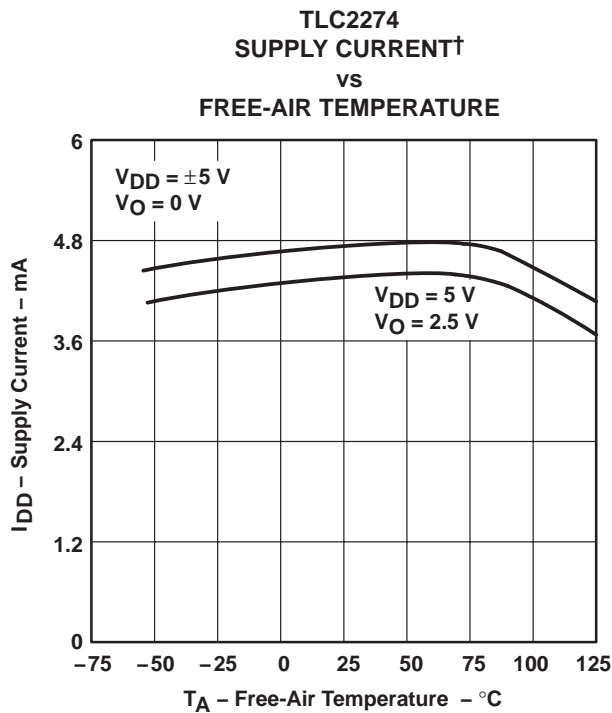


TYPICAL CHARACTERISTICS

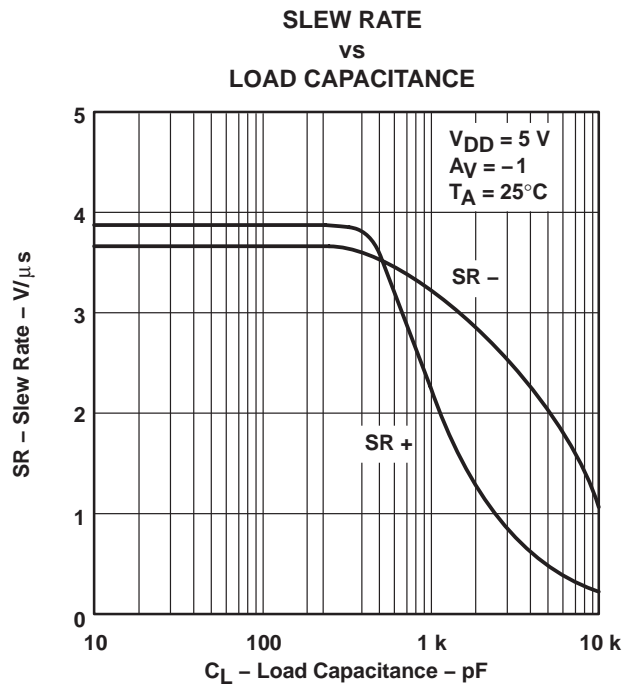


† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

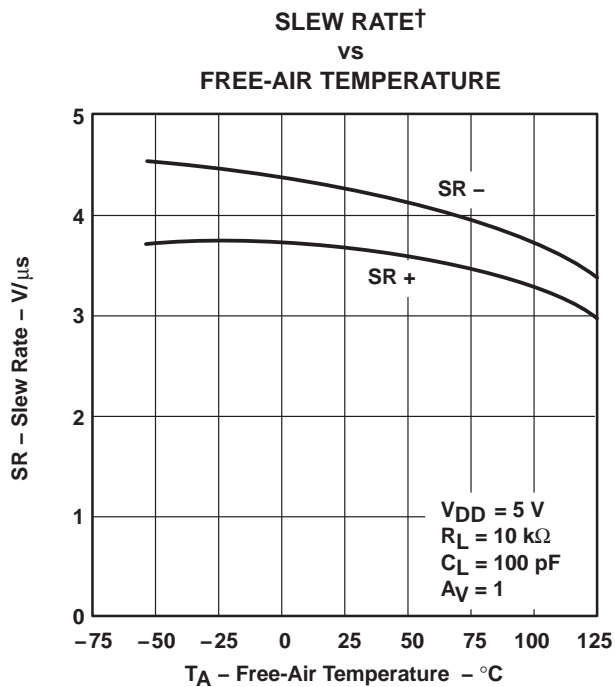
**TYPICAL CHARACTERISTICS**



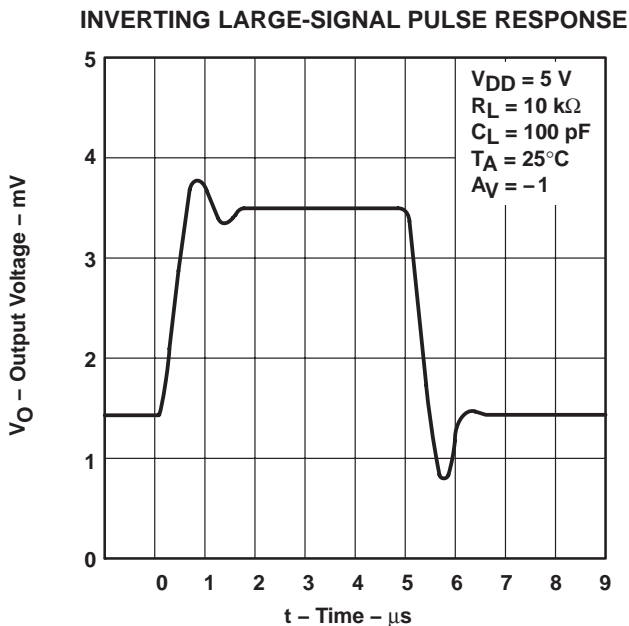
**Figure 39**



**Figure 40**



**Figure 41**



**Figure 42**

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



TYPICAL CHARACTERISTICS

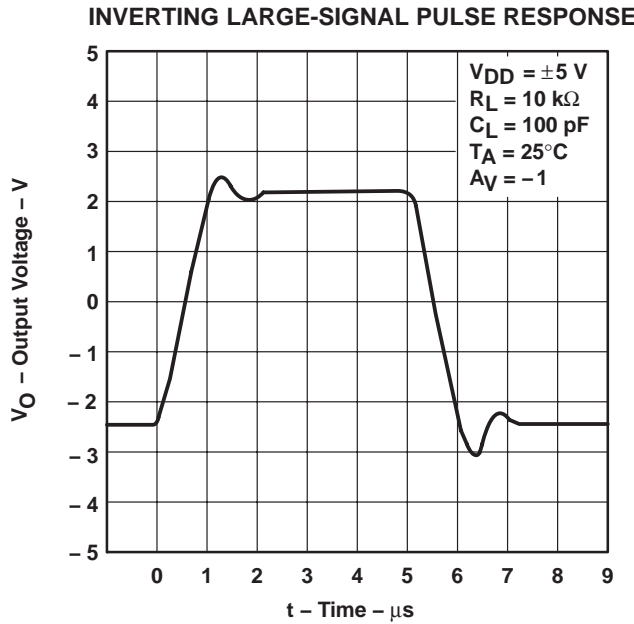


Figure 43

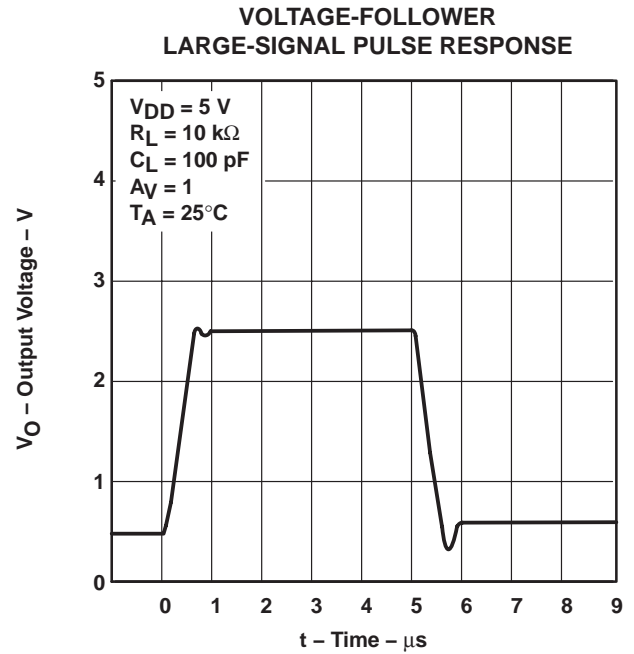


Figure 44

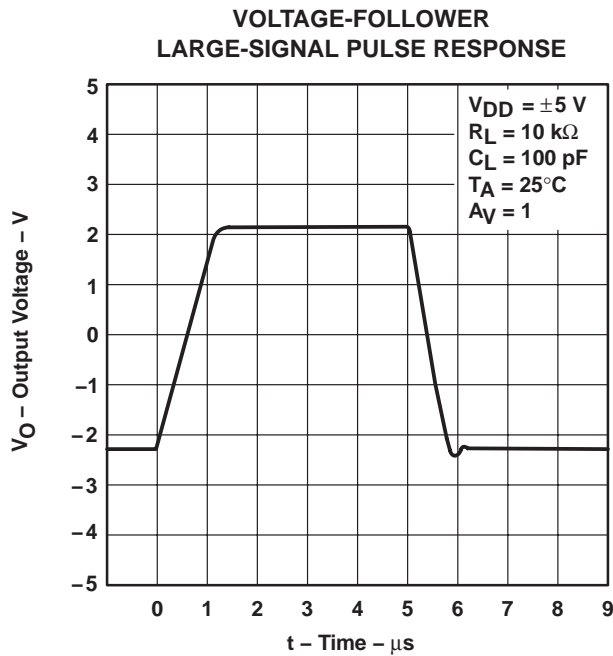


Figure 45

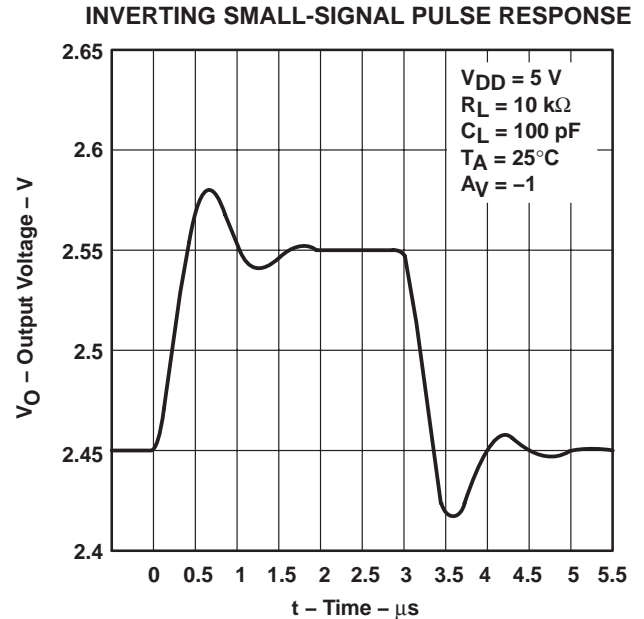
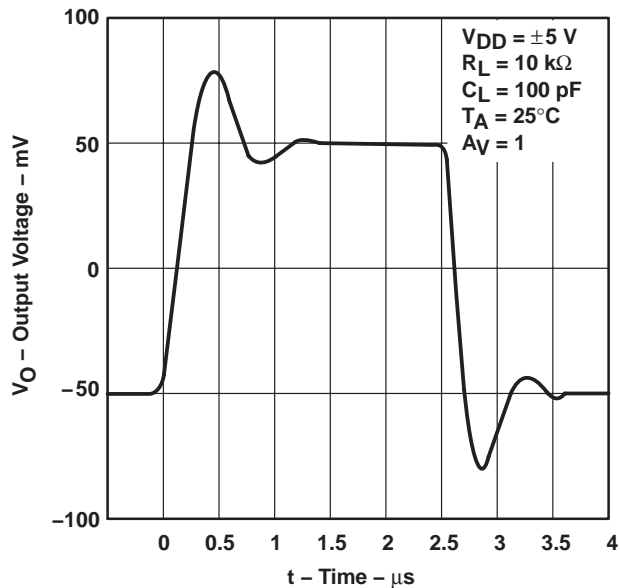


Figure 46

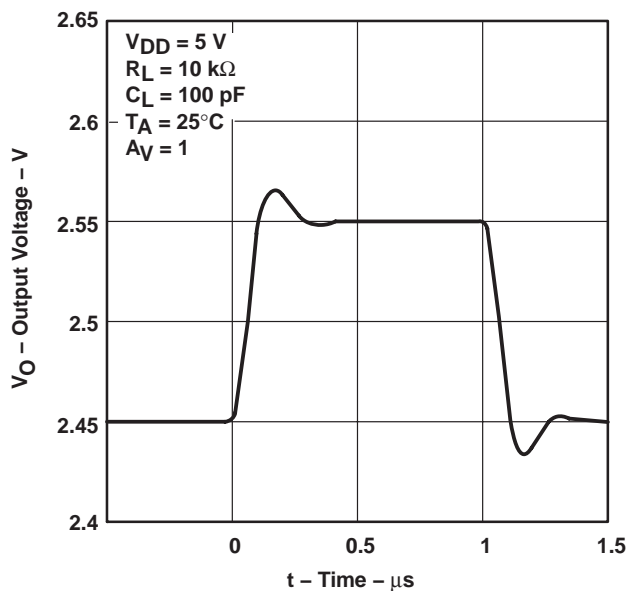
**TYPICAL CHARACTERISTICS**

**INVERTING SMALL-SIGNAL PULSE RESPONSE**



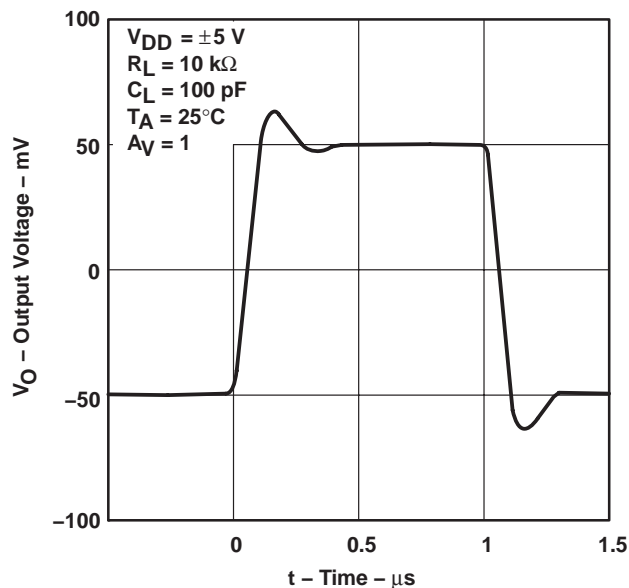
**Figure 47**

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



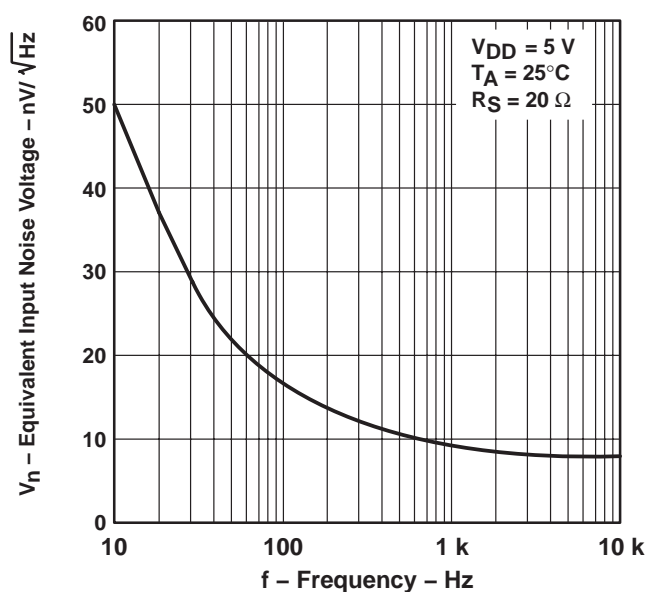
**Figure 48**

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



**Figure 49**

**EQUIVALENT INPUT NOISE VOLTAGE vs FREQUENCY**



**Figure 50**

TYPICAL CHARACTERISTICS

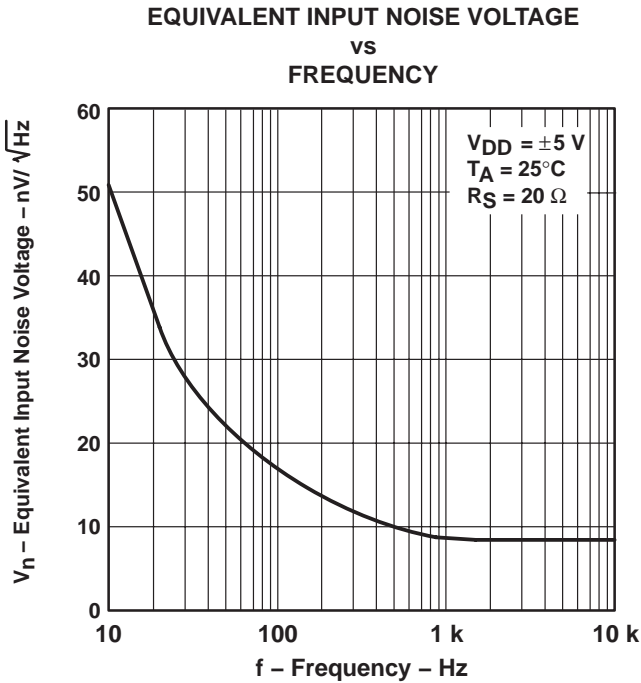


Figure 51

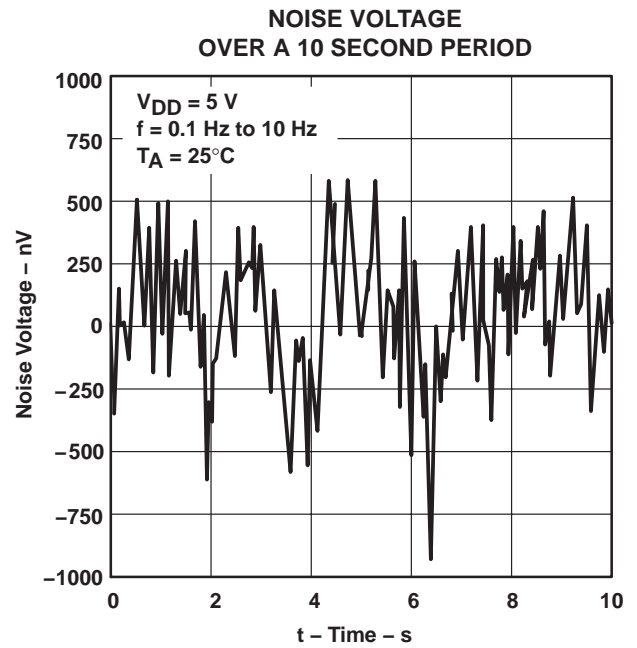


Figure 52

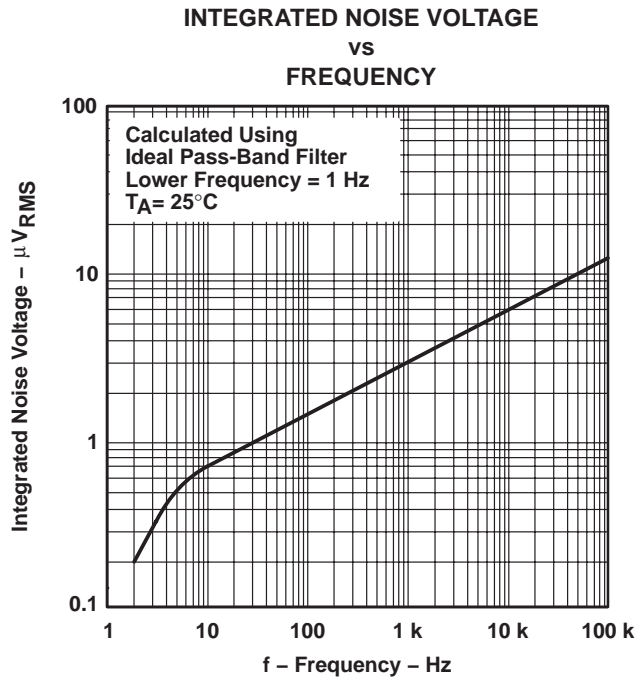


Figure 53

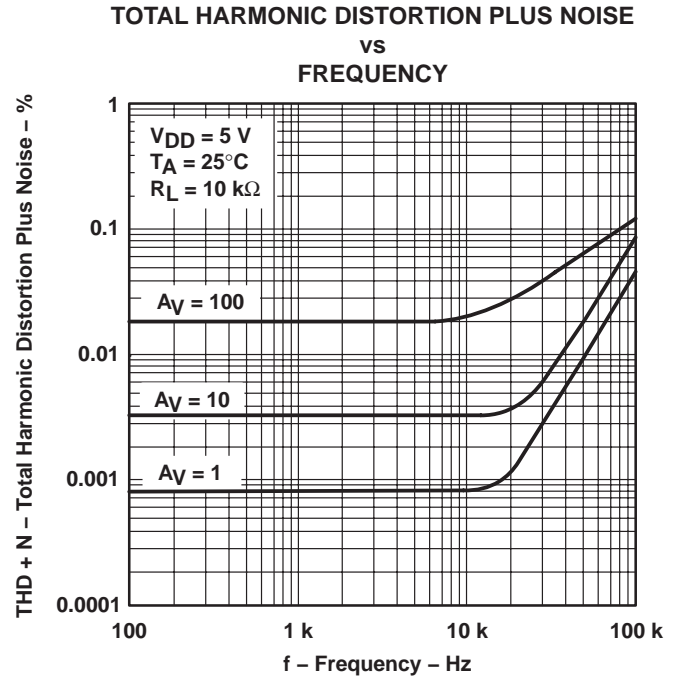
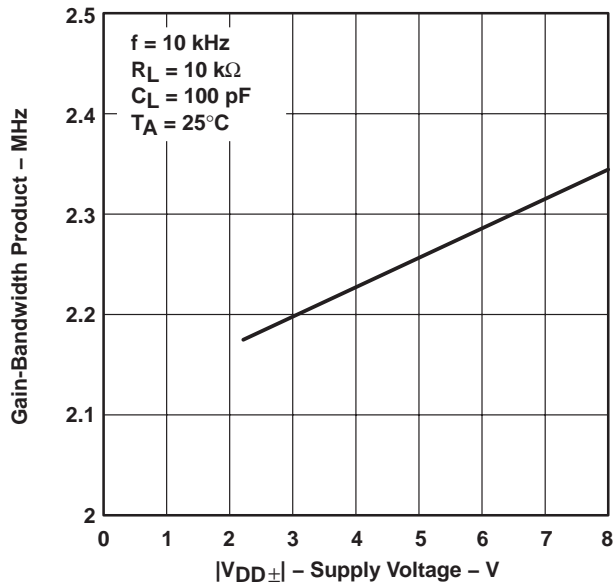


Figure 54

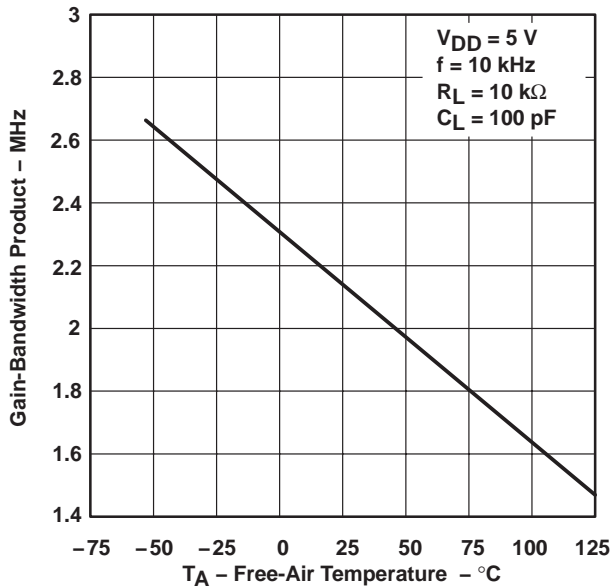
**TYPICAL CHARACTERISTICS**

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



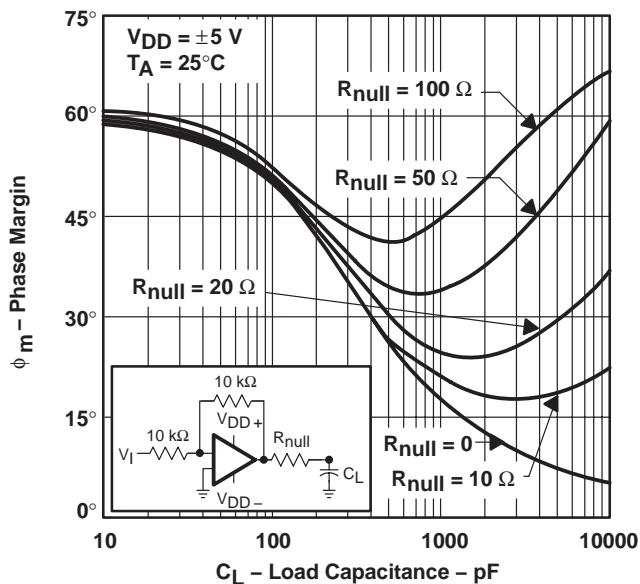
**Figure 55**

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



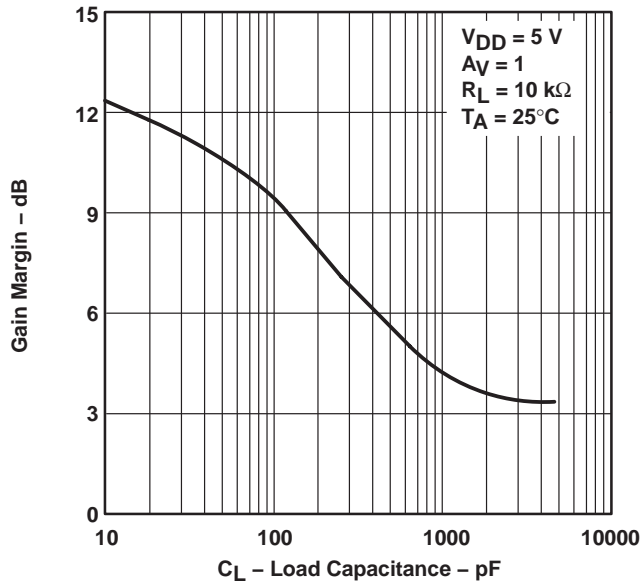
**Figure 56**

**PHASE MARGIN**  
**vs**  
**LOAD CAPACITANCE**



**Figure 57**

**GAIN MARGIN**  
**vs**  
**LOAD CAPACITANCE**



**Figure 58**

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

## APPLICATION INFORMATION

### macromodel information

Macromodel information provided was derived using Microsim *Parts*™, the model generation software used with Microsim *PSpice*™. The Boyle macromodel (see Note 6) and subcircuit in Figure 59 were generated using the TLC227x typical electrical and operating characteristics at  $T_A = 25^\circ\text{C}$ . Using this information, output simulations of the following key parameters can be generated to a tolerance of 20% (in most cases):

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

NOTE 6: G. R. Boyle, B. M. Cohn, D. O. Pederson, and J. E. Solomon, "Macromodeling of Integrated Circuit Operational Amplifiers", *IEEE Journal of Solid-State Circuits*, SC-9, 353 (1974).

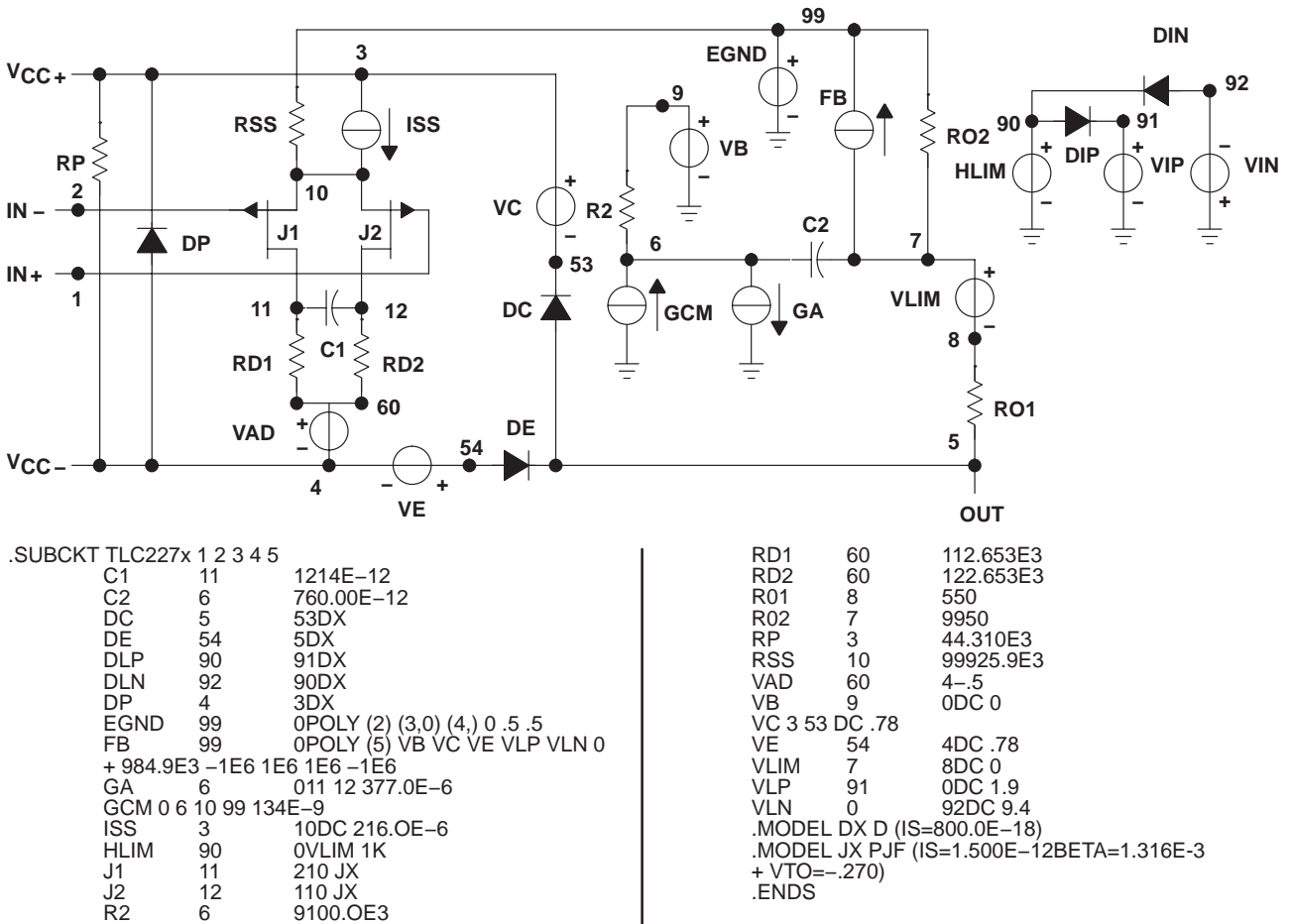


Figure 59. Boyle Macromodel and Subcircuit

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Macromodels, simulation models, or other models provided by TI, directly or indirectly, are not warranted by TI as fully representing all of the specification and operating characteristics of the semiconductor product to which the model relates.

**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>
TLC2272AMDREP	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLC2272AMDREPG4	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLC2274AMDREP	ACTIVE	SOIC	D	14	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLC2274AMPWREP	ACTIVE	TSSOP	PW	14	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLC2274MDREP	ACTIVE	SOIC	D	14	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLC2274MPWREP	ACTIVE	TSSOP	PW	14	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
V62/03618-01XE	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
V62/03618-02UE	ACTIVE	TSSOP	PW	14	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
V62/03618-02YE	ACTIVE	SOIC	D	14	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
V62/03618-04UE	ACTIVE	TSSOP	PW	14	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
V62/03618-04YE	ACTIVE	SOIC	D	14	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-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 - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check <http://www.ti.com/productcontent> for the latest availability information and additional product content details.

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

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

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

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

<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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**OTHER QUALIFIED VERSIONS OF TLC2272A-EP, TLC2274-EP, TLC2274A-EP :**

- Catalog: [TLC2272A](#), [TLC2274](#), [TLC2274A](#)
- Automotive: [TLC2272A-Q1](#), [TLC2274-Q1](#), [TLC2274A-Q1](#)
- Military: [TLC2272AM](#), [TLC2274M](#), [TLC2274AM](#)

**NOTE: Qualified Version Definitions:**

- Catalog - TI's standard catalog product
- Automotive - Q100 devices qualified for high-reliability automotive applications targeting zero defects
- Military - QML certified for Military and Defense Applications

**TAPE AND REEL INFORMATION**

**QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE**


\*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
TLC2272AMDREP	SOIC	D	8	2500	330.0	12.4	6.4	5.2	2.1	8.0	12.0	Q1
TLC2274AMDREP	SOIC	D	14	2500	330.0	16.4	6.5	9.0	2.1	8.0	16.0	Q1
TLC2274AMPWREP	TSSOP	PW	14	2000	330.0	12.4	6.9	5.6	1.6	8.0	12.0	Q1
TLC2274MDREP	SOIC	D	14	2500	330.0	16.4	6.5	9.0	2.1	8.0	16.0	Q1
TLC2274MPWREP	TSSOP	PW	14	2000	330.0	12.4	6.9	5.6	1.6	8.0	12.0	Q1



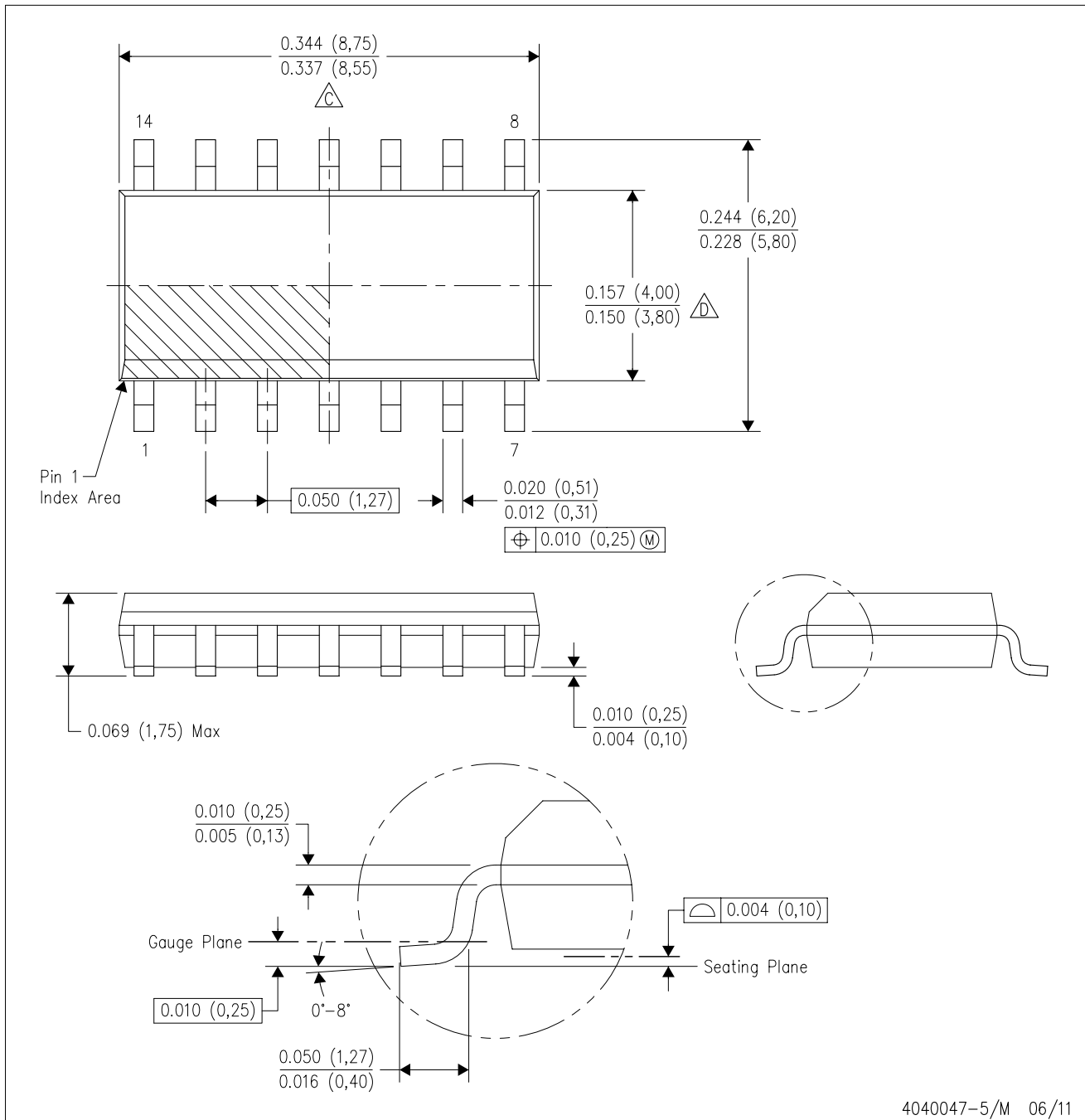
**TAPE AND REEL BOX DIMENSIONS**




\*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
TLC2272AMDREP	SOIC	D	8	2500	346.0	346.0	29.0
TLC2274AMDREP	SOIC	D	14	2500	333.2	345.9	28.6
TLC2274AMPWREP	TSSOP	PW	14	2000	346.0	346.0	29.0
TLC2274MDREP	SOIC	D	14	2500	333.2	345.9	28.6
TLC2274MPWREP	TSSOP	PW	14	2000	346.0	346.0	29.0

D (R-PDSO-G14)

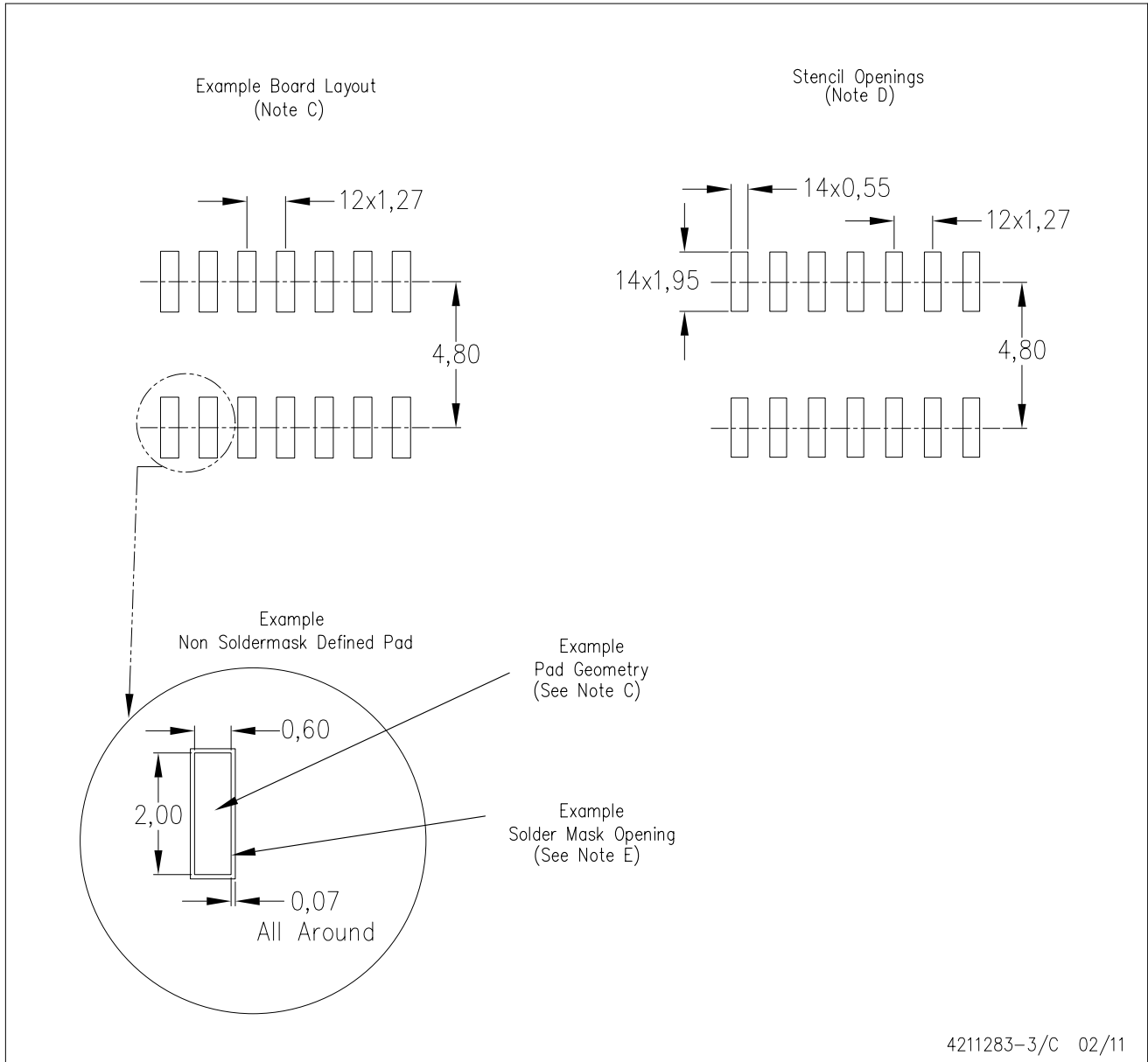
PLASTIC SMALL OUTLINE



- NOTES:
- A. All linear dimensions are in inches (millimeters).
  - B. This drawing is subject to change without notice.
  -  Body length does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.006 (0,15) each side.
  -  Body width does not include interlead flash. Interlead flash shall not exceed 0.017 (0,43) each side.
  - E. Reference JEDEC MS-012 variation AB.

D (R-PDSO-G14)

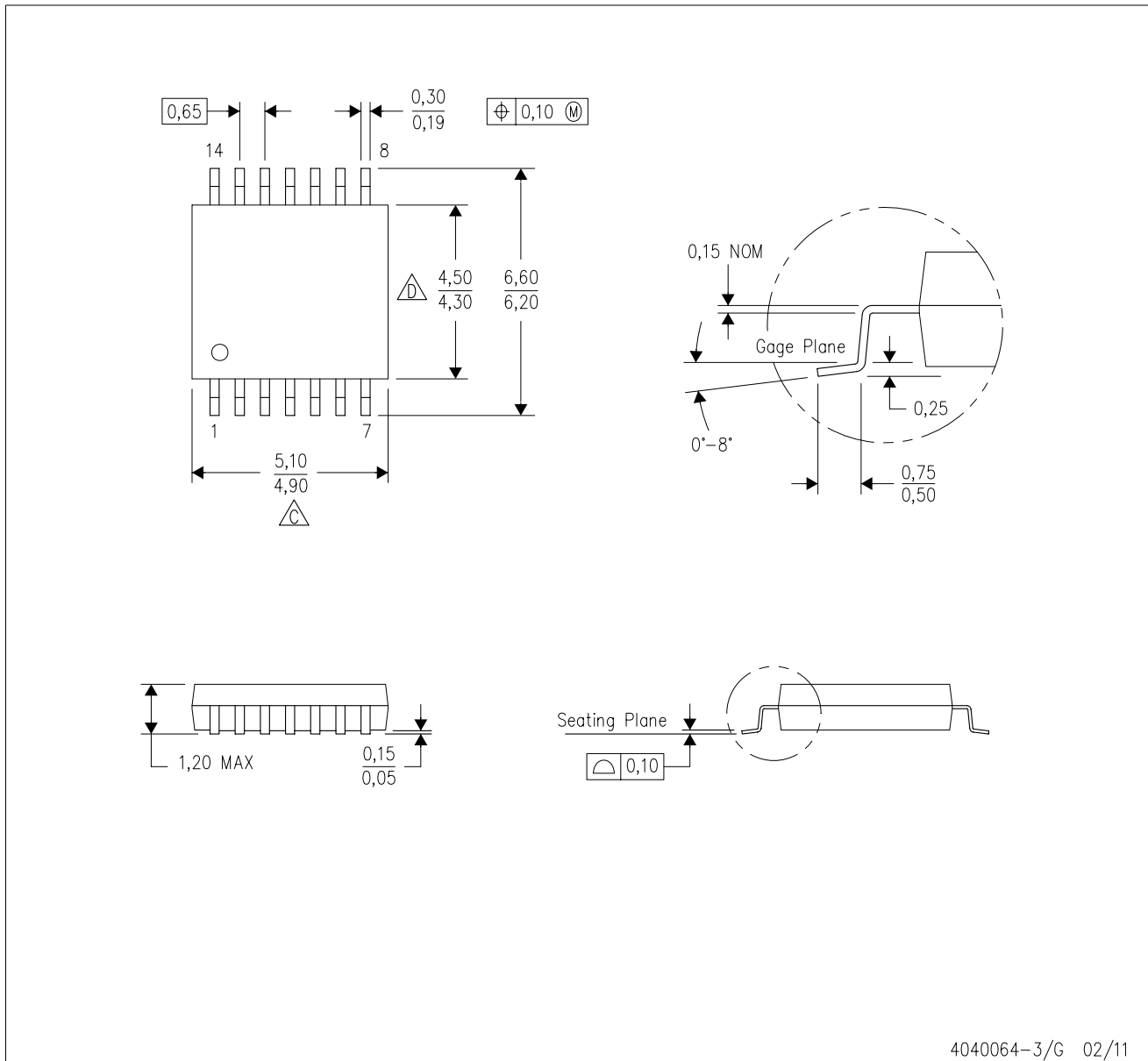
PLASTIC SMALL OUTLINE





- NOTES:
- All linear dimensions are in millimeters.
  - This drawing is subject to change without notice.
  - Publication IPC-7351 is recommended for alternate designs.
  - Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Refer to IPC-7525 for other stencil recommendations.
  - Customers should contact their board fabrication site for solder mask tolerances between and around signal pads.

PW (R-PDSO-G14)

PLASTIC SMALL OUTLINE

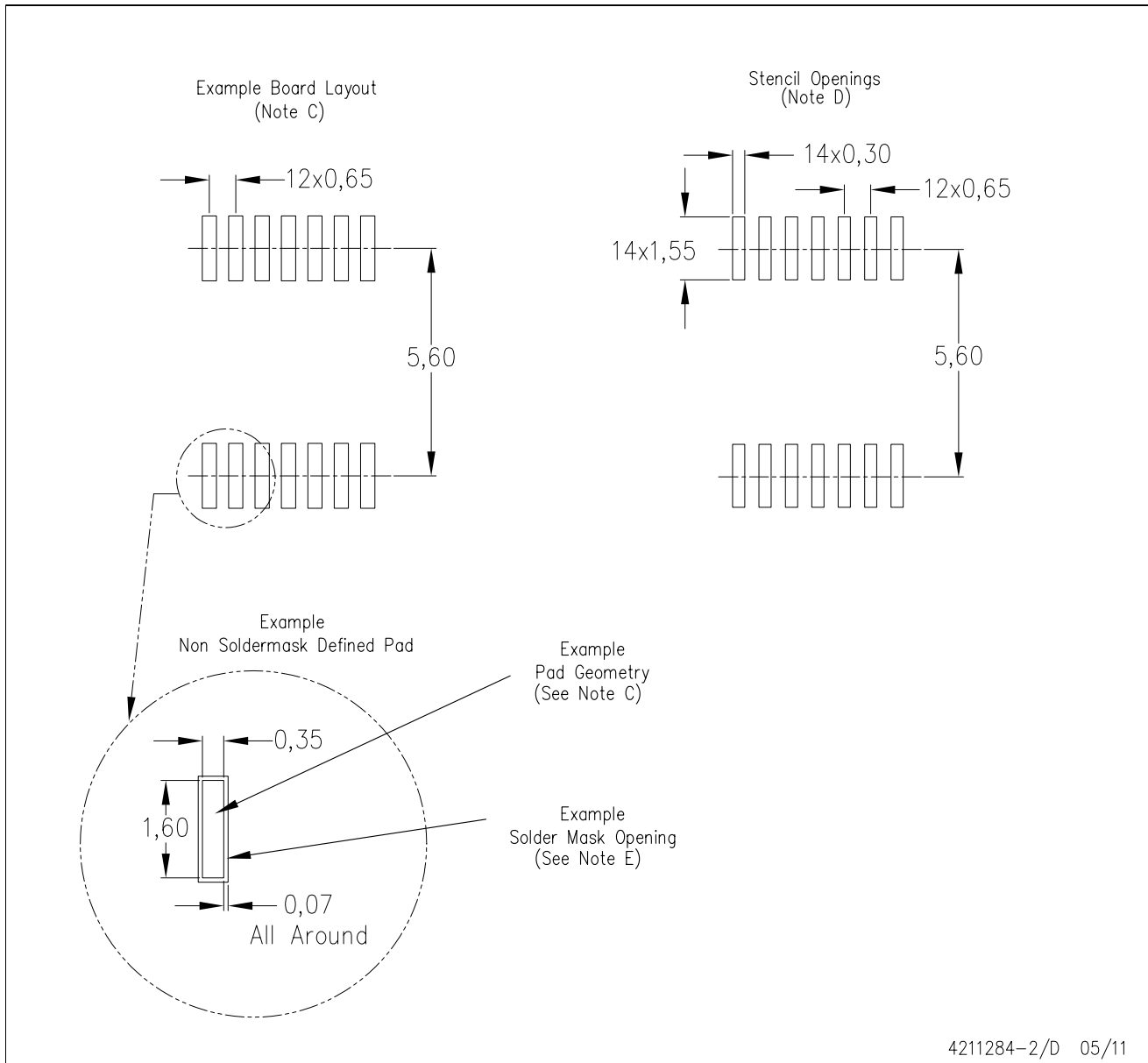


4040064-3/G 02/11

- NOTES:
- A. All linear dimensions are in millimeters. Dimensioning and tolerancing per ASME Y14.5M-1994.
  - B. This drawing is subject to change without notice.
  -  Body length does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0,15 each side.
  -  Body width does not include interlead flash. Interlead flash shall not exceed 0,25 each side.
  - E. Falls within JEDEC MO-153

PW (R-PDSO-G14)

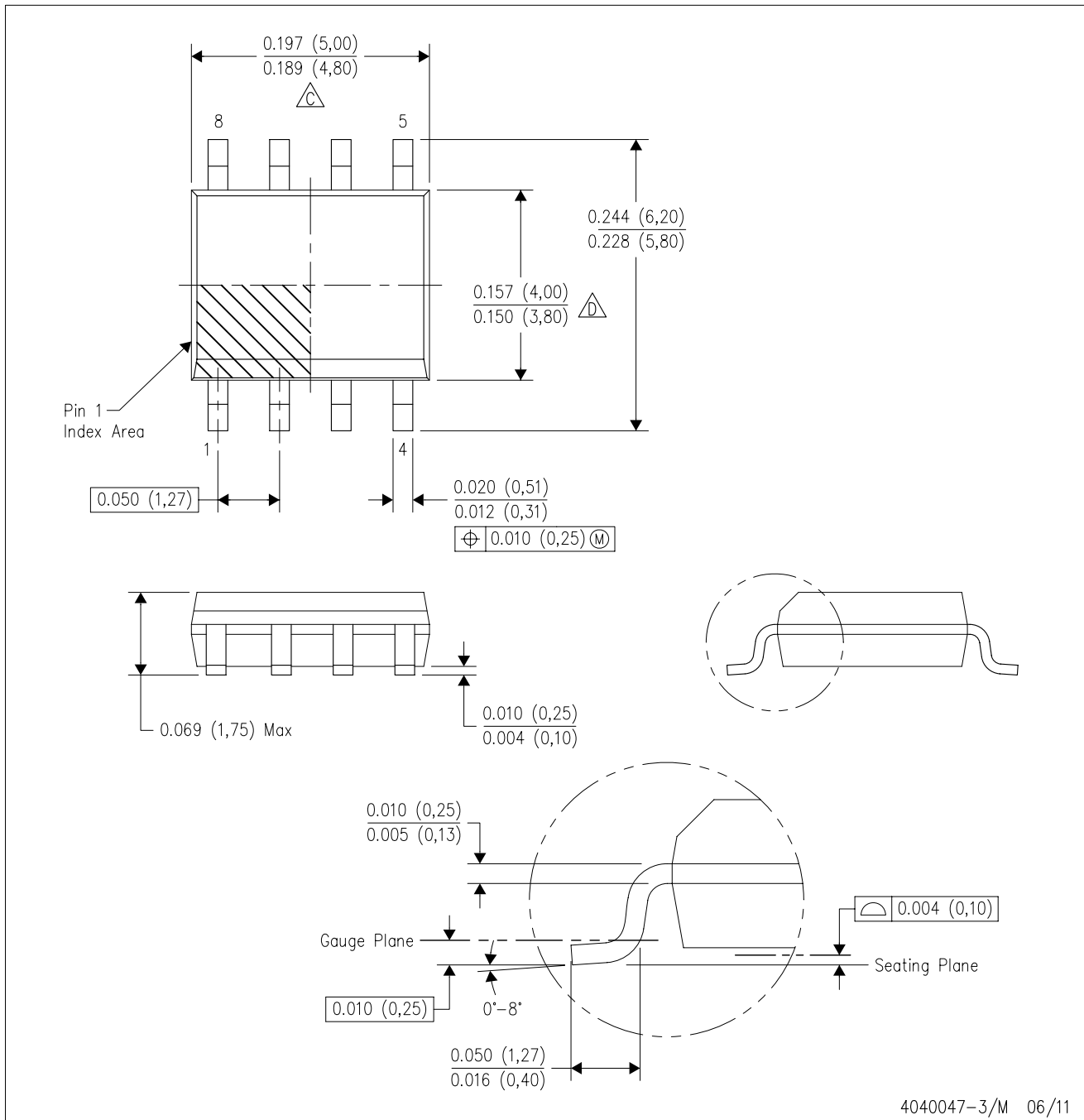
PLASTIC SMALL OUTLINE



- NOTES:
- All linear dimensions are in millimeters.
  - This drawing is subject to change without notice.
  - Publication IPC-7351 is recommended for alternate designs.
  - Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Refer to IPC-7525 for other stencil recommendations.
  - Customers should contact their board fabrication site for solder mask tolerances between and around signal pads.

D (R-PDSO-G8)

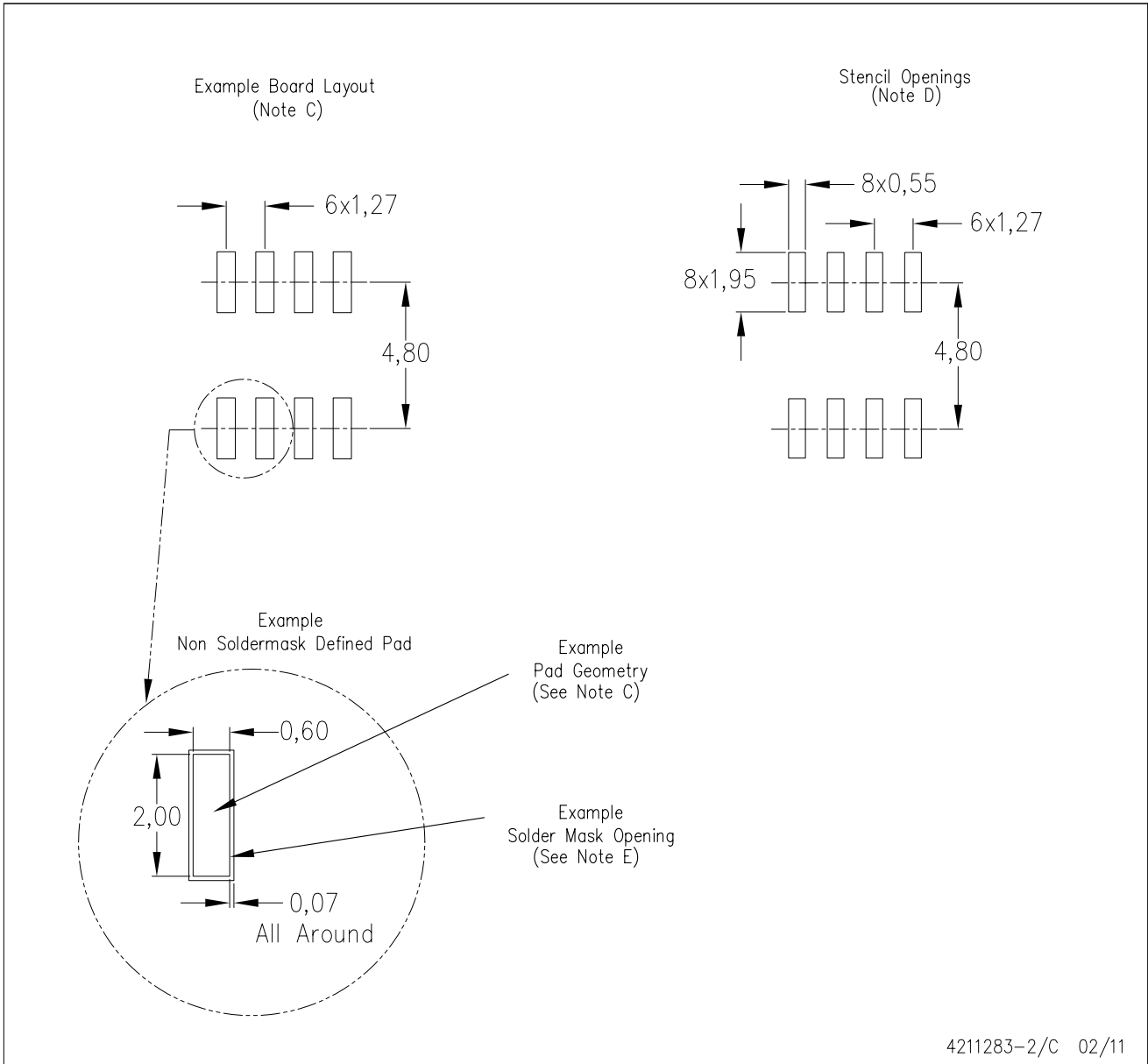
PLASTIC SMALL OUTLINE



- NOTES:
- A. All linear dimensions are in inches (millimeters).
  - B. This drawing is subject to change without notice.
  - $\triangle C$  Body length does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.006 (0,15) each side.
  - $\triangle D$  Body width does not include interlead flash. Interlead flash shall not exceed 0.017 (0,43) each side.
  - E. Reference JEDEC MS-012 variation AA.

D (R-PDSO-G8)

PLASTIC SMALL OUTLINE



- NOTES:
- A. All linear dimensions are in millimeters.
  - B. This drawing is subject to change without notice.
  - C. Publication IPC-7351 is recommended for alternate designs.
  - D. Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Refer to IPC-7525 for other stencil recommendations.
  - E. Customers should contact their board fabrication site for solder mask tolerances between and around signal pads.

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DSP	<a href="http://dsp.ti.com">dsp.ti.com</a>
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Consumer Electronics	<a href="http://www.ti.com/consumer-apps">www.ti.com/consumer-apps</a>
Energy and Lighting	<a href="http://www.ti.com/energy">www.ti.com/energy</a>
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