

TLC227x-Q1, TLC227xA-Q1 Advanced LinCMOS™ RAIL-TO-RAIL OPERATIONAL AMPLIFIERS

SGLS007B – FEBRUARY 2003 – REVISED OCTOBER 2003

- Qualification in Accordance With AEC-Q100†
- Qualified for Automotive Applications
- Customer-Specific Configuration Control Can Be Supported Along With Major-Change Approval
- ESD Protection Exceeds 2000 V Per MIL-STD-883, Method 3015; Exceeds 100 V Machine Model (C = 200 pF, R = 0); Exceeds 1500 V Charged Device Model
- 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_A = 25°C
- Macromodel Included
- Performance Upgrades for the TS272, TS274, TLC272, and TLC274

† Contact factory for details. Q100 qualification data available on request.

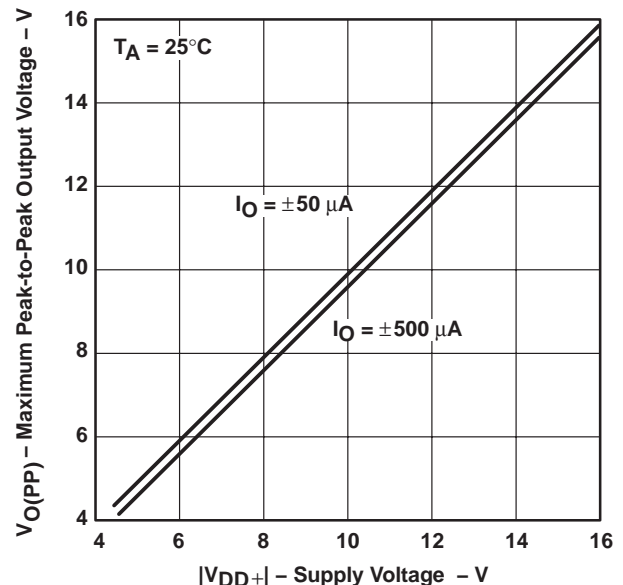
description

The TLC2272 and TLC2274 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 TLC227x 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 TLC227x has a noise voltage of 9 nV/√Hz, two times lower than competitive solutions.

The TLC227x, 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 is available with 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. For applications that require higher output drive and wider input voltage range, see the TLV2432 and TLV2442 devices.

MAXIMUM PEAK-TO-PEAK OUTPUT VOLTAGE
vs
SUPPLY VOLTAGE



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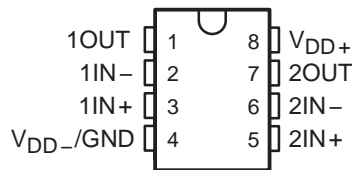
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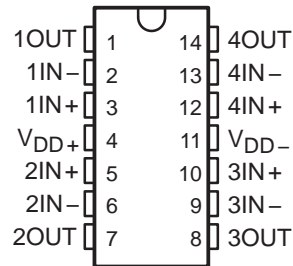
AVAILABLE OPTIONS

T _A	V _{IO} max At 25°C	PACKAGED DEVICES	
		SMALL OUTLINE (D)	TSSOP (PW)
-40°C to 125°C	950 μV 2.5 mV	TLC2272AQDRQ1 TLC2272QDRQ1	TLC2272AQPWRQ1 TLC2272QPWRQ1
-40°C to 125°C	950 μV 2.5 mV	TLC2274AQDRQ1 TLC2274QDRQ1	TLC2274AQPWRQ1 TLC2274QPWRQ1

TLC2272
D OR PW PACKAGE
(TOP VIEW)



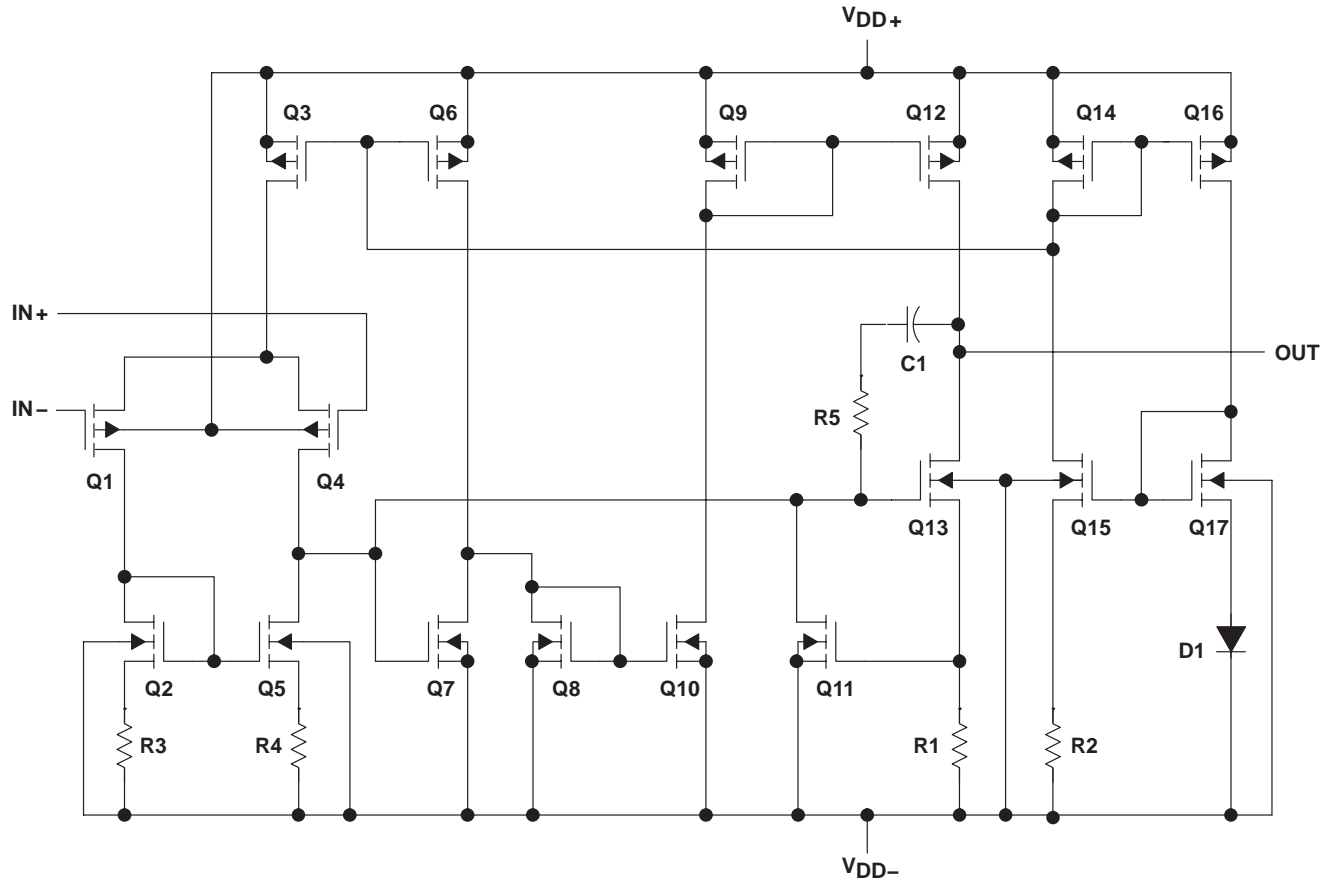
TLC2274
D OR PW PACKAGE
(TOP VIEW)



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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)	± 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)	± 5 mA
Output current, I_O	± 50 mA
Total current into V_{DD+}	± 50 mA
Total current out of V_{DD-}	± 50 mA
Duration of short-circuit current at (or below) 25°C (see Note 3)	unlimited
Continuous total dissipation	See Dissipation Rating Table
Operating free-air temperature range, T_A	-40°C to 125°C
Storage temperature range	-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.

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, $V_{DD\pm}$	± 2.2	± 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	-40	125	°C



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TLC2272Q electrical characteristics at specified free-air temperature, $V_{DD} = 5\text{ V}$ (unless otherwise noted)

PARAMETER	TEST CONDITIONS	T_A †	TLC2272Q			TLC2272AQ			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	μV	
		Full range			3000		1500		
α_{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 4)		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	$I_{OH} = -20\ \mu\text{A}$ $I_{OH} = -200\ \mu\text{A}$ $I_{OH} = -1\text{ mA}$	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	$V_{IC} = 2.5\text{ V},$ $I_{OL} = 50\ \mu\text{A}$ $V_{IC} = 2.5\text{ V},$ $I_{OL} = 500\ \mu\text{A}$ $V_{IC} = 2.5\text{ V},$ $I_{OL} = 5\text{ mA}$	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		
r_{id} Differential input resistance		25°C	10^{12}			10^{12}		Ω	
r_i Common-mode input resistance		25°C	10^{12}			10^{12}		Ω	
c_i Common-mode input capacitance	$f = 10\text{ kHz},$ P package	25°C	8			8		pF	
z_o Closed-loop output impedance	$f = 1\text{ MHz},$ $A_V = 10$	25°C	140			140		Ω	
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	2.2	3		2.2	3	mA	
		Full range			3		3		

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

‡ Referenced to 2.5 V

NOTE 4: 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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TLC2272Q operating characteristics at specified free-air temperature, $V_{DD} = 5\text{ V}$

PARAMETER	TEST CONDITIONS	T_A †	TLC2272Q			TLC2272AQ			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/ μs	
		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	μV	
		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		μs	
			To 0.01%	2.6		2.6			
ϕ_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 -40°C to 125°C for Q level part.

‡ Referenced to 2.5 V



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TLC2272Q electrical characteristics at specified free-air temperature, $V_{DD\pm} = \pm 5\text{ V}$ (unless otherwise noted)

PARAMETER	TEST CONDITIONS	T_A †	TLC2272Q			TLC2272AQ			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	μV	
		Full range			3000		1500		
α_{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 4)		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	-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	$I_O = -20\ \mu\text{A}$ $I_O = -200\ \mu\text{A}$ $I_O = -1\text{ mA}$	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	$V_{IC} = 0\text{ V},$ $I_O = 50\ \mu\text{A}$ $V_{IC} = 0\text{ V},$ $I_O = 500\ \mu\text{A}$ $V_{IC} = 0\text{ V},$ $I_O = 5\text{ mA}$	25°C		-4.99			-4.99	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	V/mV	
		Full range	20			20			
		25°C		300			300		
r_{id} Differential input resistance		25°C		10^{12}			10^{12}	Ω	
r_i Common-mode input resistance		25°C		10^{12}			10^{12}	Ω	
c_i Common-mode input capacitance	$f = 10\ \text{kHz},$ P package	25°C		8			8	pF	
z_o Closed-loop output impedance	$f = 1\ \text{MHz},$ $A_V = 10$	25°C		130			130	Ω	
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 ($\Delta V_{DD\pm}/\Delta V_{IO}$)	$V_{DD} = \pm 2.2\text{ V to } \pm 8\text{ V},$ $V_{IC} = 0\text{ V},$ 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	2.4	3		2.4	3	mA	
		Full range			3		3		

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

NOTE 4: 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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TLC2272Q operating characteristics at specified free-air temperature, $V_{DD\pm} = \pm 5\text{ V}$

PARAMETER	TEST CONDITIONS	T_A †	TLC2272Q			TLC2272AQ			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/ μ s	
		Full range	1.7			1.7			
V_n	Equivalent input noise voltage	25°C		50			50	nV/ $\sqrt{\text{Hz}}$	
		25°C		9			9		
V_{NPP}	Peak-to-peak equivalent input noise voltage	25°C		1			1	μ 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	25°C		2.25			2.25	MHz	
BOM	Maximum output-swing bandwidth $V_{O(PP)} = 4.6\text{ V}$, $R_L = 10\text{ k}\Omega$	25°C		0.54			0.54	MHz	
t_s	Settling time $A_V = -1$, Step = -2.3 V to 2.3 V , $R_L = 10\text{ k}\Omega$, $C_L = 100\text{ pF}$	25°C		To 0.1%	1.5		1.5	μ s	
				To 0.01%	3.2		3.2		
ϕ_m	Phase margin at unity gain $R_L = 10\text{ k}\Omega$, $C_L = 100\text{ pF}$	25°C		52°			52°		
		25°C		10			10	dB	

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



TLC2274Q electrical characteristics at specified free-air temperature, $V_{DD} = 5\text{ V}$ (unless otherwise noted)

PARAMETER	TEST CONDITIONS	T_A †	TLC2274Q			TLC2274AQ			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
V_{IO} Input offset voltage	$V_{DD} \pm \pm 2.5\text{ V}, V_{IC} = 0\text{ V}, V_O = 0\text{ V}, R_S = 50\ \Omega$	25°C	300	2500		300	950	μV	
		Full range			3000		1500		
α_{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 4)		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	$V_{IC} = 2.5\text{ V}, I_{OL} = 50\ \mu\text{A}$	25°C	0.01		0.01		V		
		25°C	0.09	0.15	0.09	0.15			
		Full range	0.15		0.15				
		25°C	0.9	1.5	0.9	1.5			
V_{OL} Low-level output voltage	$V_{IC} = 2.5\text{ V}, I_{OL} = 5\text{ mA}$	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			
r_{id} Differential input resistance		25°C	10^{12}			10^{12}	Ω		
r_i Common-mode input resistance		25°C	10^{12}			10^{12}	Ω		
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	140			140	Ω		
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	4.4	6	4.4	6	mA		
		Full range	6		6				

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

‡ Referenced to 2.5 V

NOTE 4: 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-Q1, TLC227xA-Q1
Advanced LinCMOS™ RAIL-TO-RAIL
OPERATIONAL AMPLIFIERS

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TLC2274Q operating characteristics at specified free-air temperature, $V_{DD} = 5\text{ V}$

PARAMETER	TEST CONDITIONS	T_A †	TLC2274Q			TLC2274AQ			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/ μs			
		Full range	1.7			1.7					
V_n	Equivalent input noise voltage	$f = 10\text{ Hz}$	25°C	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			μV	
		$f = 0.1\text{ Hz to }10\text{ Hz}$	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 = $0.5\text{ V to }2.5\text{ V}$, $R_L = 10\text{ k}\Omega$ ‡, $C_L = 100\text{ pF}$ ‡	To 0.1%	25°C	1.5			1.5			μs
			To 0.01%		2.6			2.6			
ϕ_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 -40°C to 125°C for Q level part.

‡ Referenced to 2.5 V



TLC2274Q electrical characteristics at specified free-air temperature, $V_{DD\pm} = \pm 5\text{ V}$ (unless otherwise noted)

PARAMETER	TEST CONDITIONS	T_A †	TLC2274Q			TLC2274AQ			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	μV		
		Full range			3000		1500			
αV_{IO} 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 4)		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	-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}			Ω	
r_i Common-mode input resistance		25°C	10^{12}			10^{12}			Ω	
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			Ω	
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 -40°C to 125°C for Q level part.

NOTE 4: 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-Q1, TLC227xA-Q1
Advanced LinCMOS™ RAIL-TO-RAIL
OPERATIONAL AMPLIFIERS

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TLC2274Q operating characteristics at specified free-air temperature, $V_{DD\pm} = \pm 5\text{ V}$

PARAMETER	TEST CONDITIONS	T_A †	TLC2274Q			TLC2274AQ			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/ μs		
		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			μV	
		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 $V_{O(PP)} = 4.6\text{ V}$, $R_L = 10\text{ k}\Omega$, $C_L = 100\text{ pF}$, $A_V = 1$	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			μs
			To 0.01%	3.2			3.2			
ϕ_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
	Gain margin	25°C	10			10			dB	

† Full range is -40°C to 125°C for Q 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**

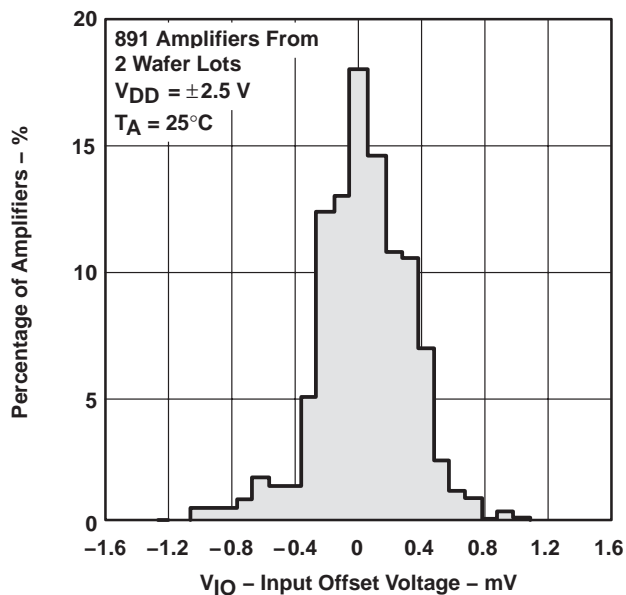


Figure 1

**DISTRIBUTION OF TLC2272
 INPUT OFFSET VOLTAGE**

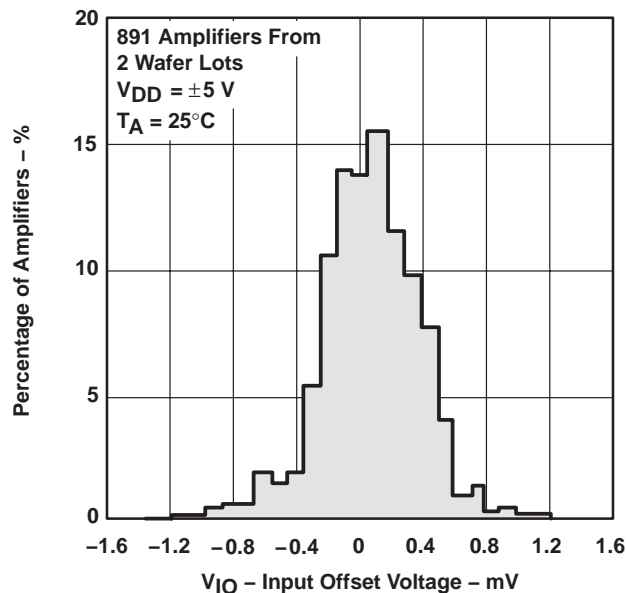


Figure 2

**DISTRIBUTION OF TLC2274
 INPUT OFFSET VOLTAGE**

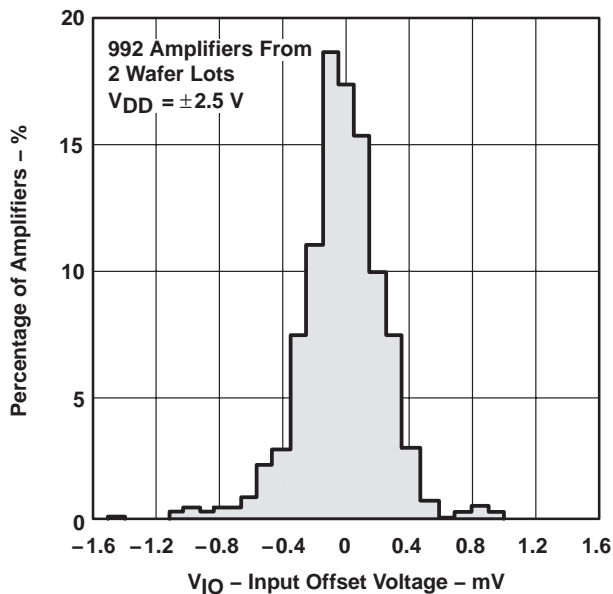


Figure 3

**DISTRIBUTION OF TLC2274
 INPUT OFFSET VOLTAGE**

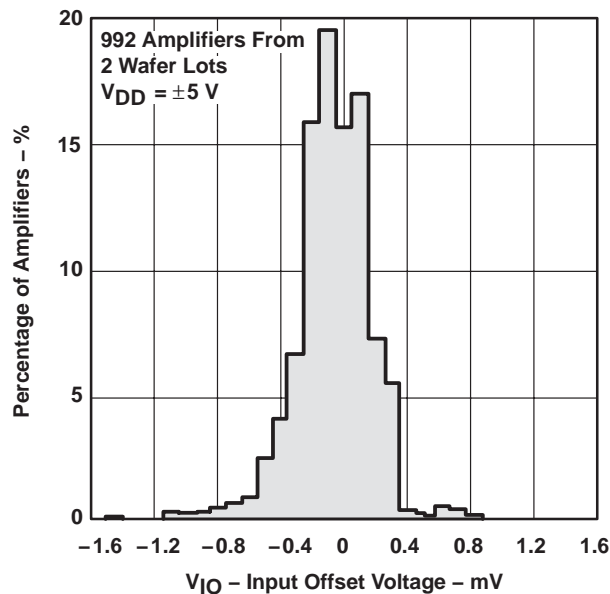


Figure 4

TYPICAL CHARACTERISTICS

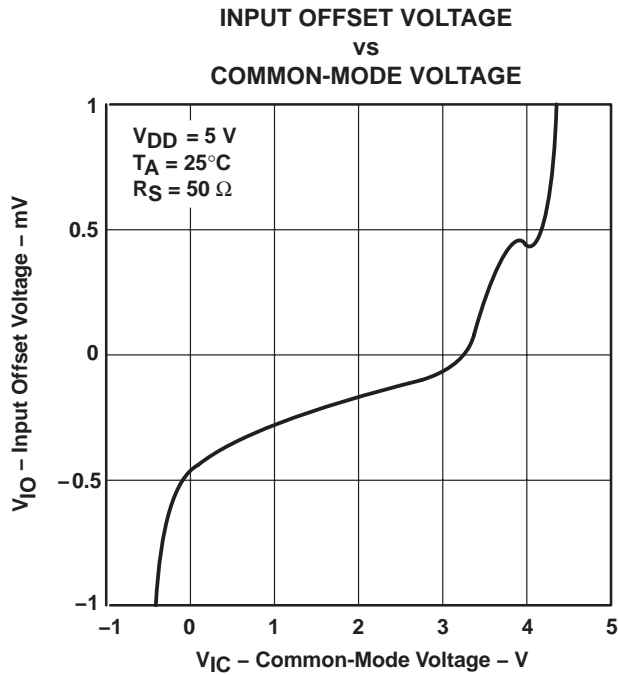


Figure 5

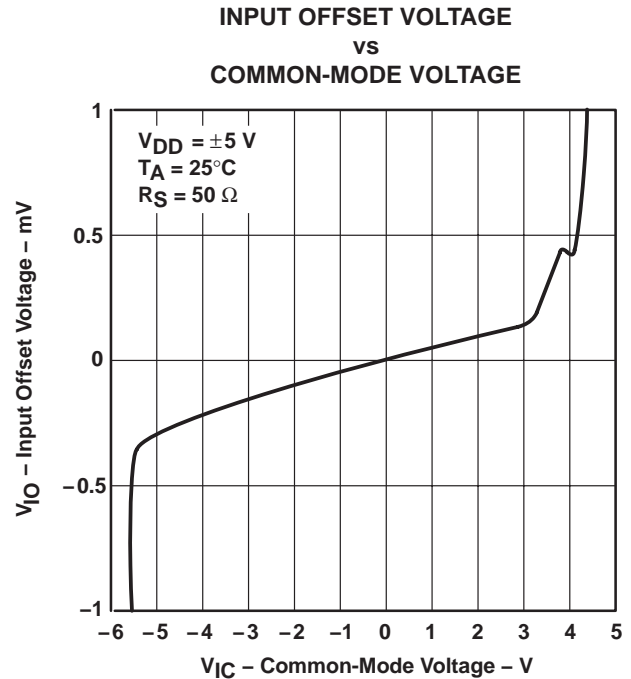


Figure 6

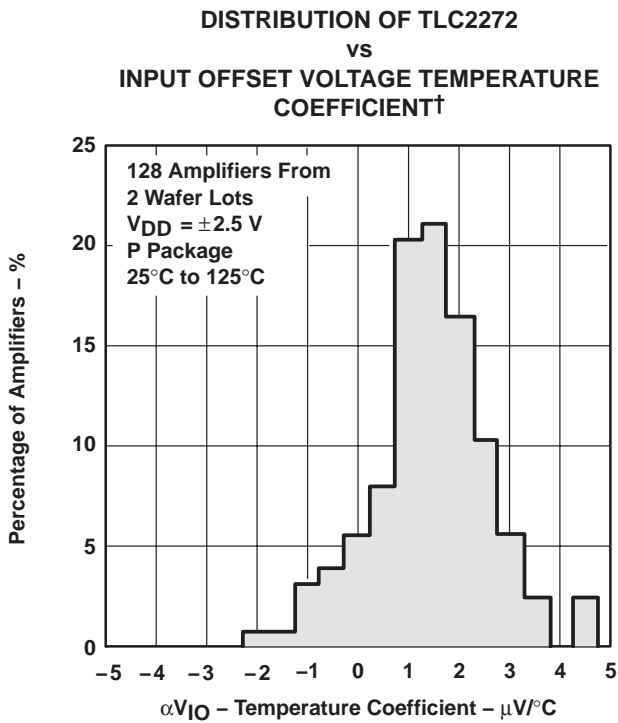


Figure 7

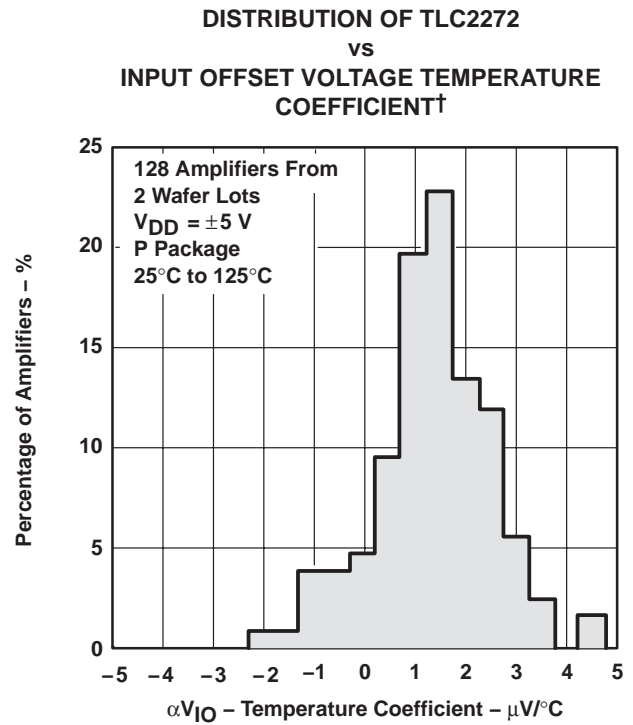


Figure 8

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

TYPICAL CHARACTERISTICS

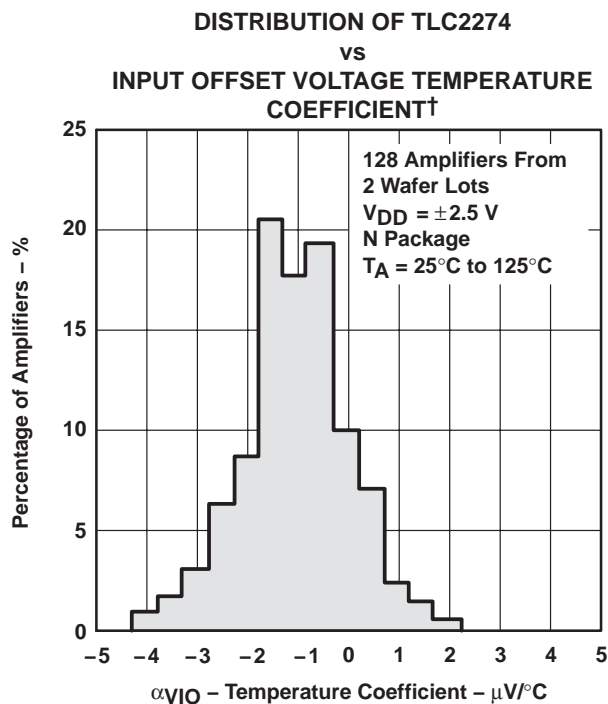


Figure 9

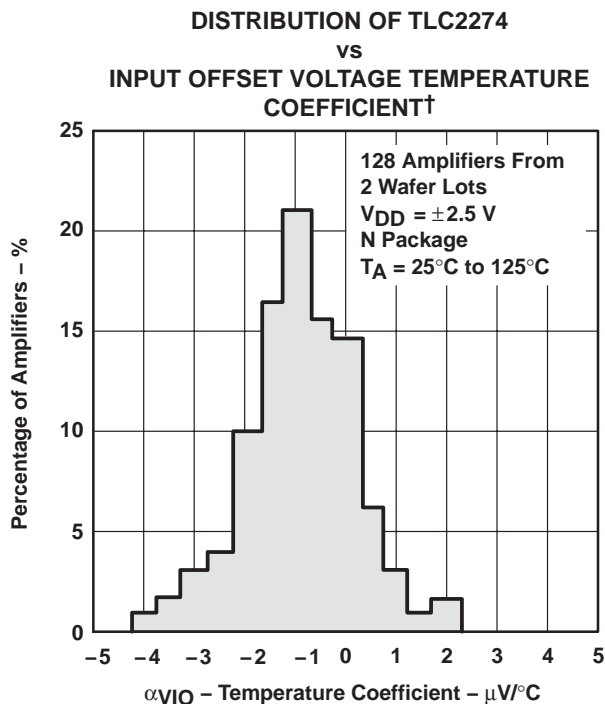


Figure 10

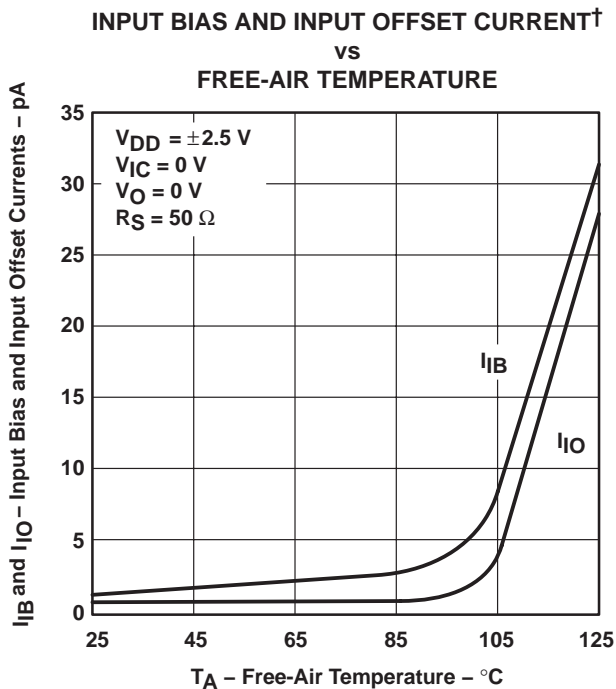


Figure 11

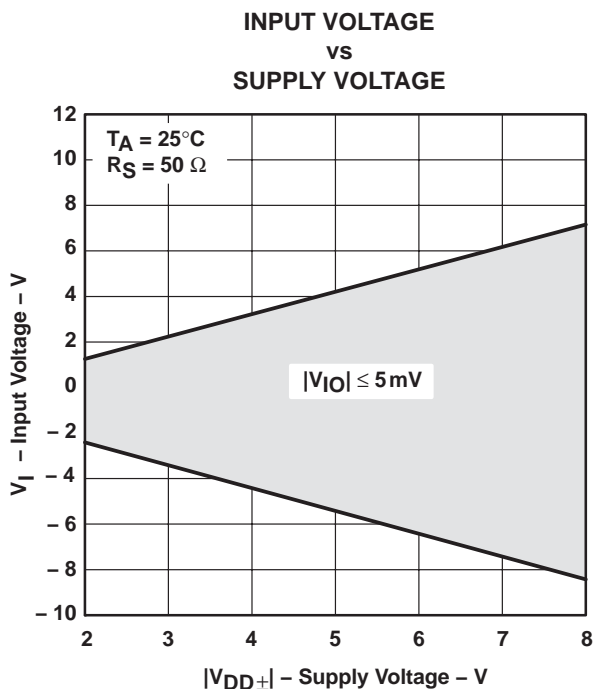


Figure 12

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

TYPICAL CHARACTERISTICS

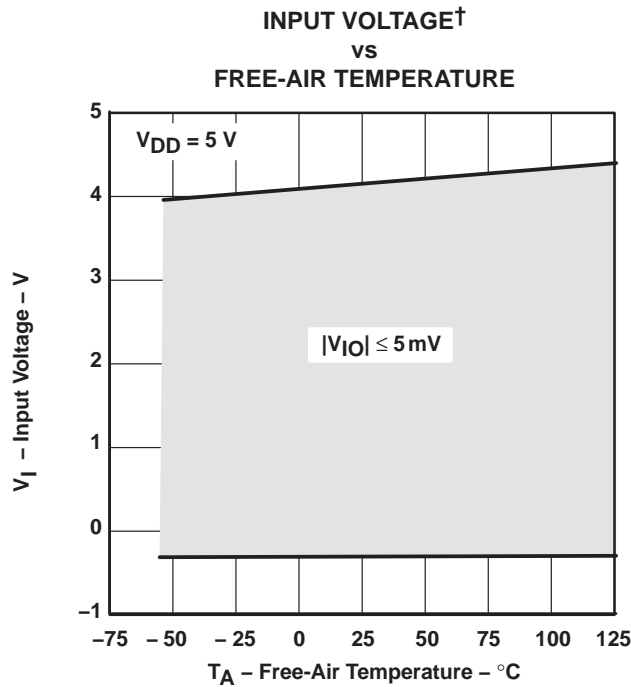


Figure 13

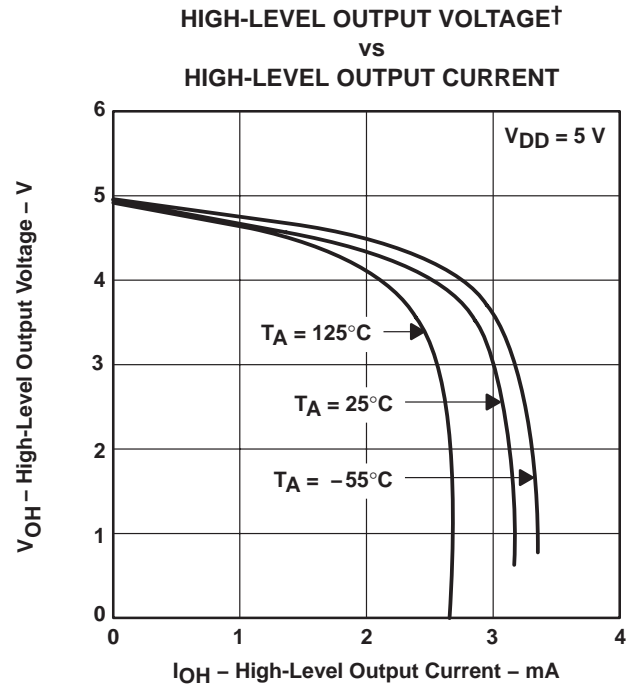


Figure 14

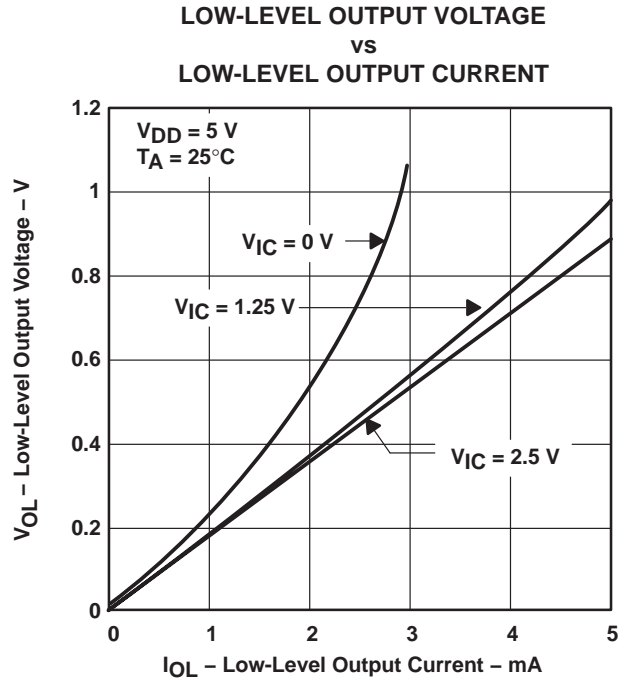


Figure 15

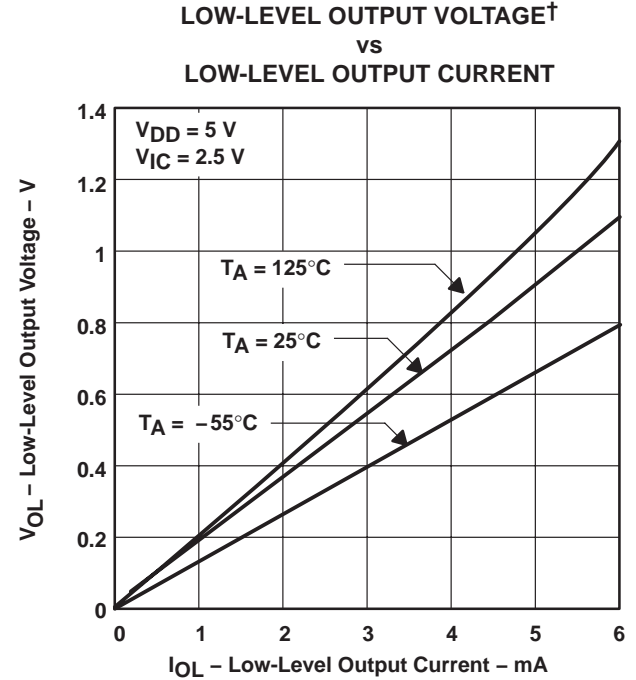


Figure 16

† 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**

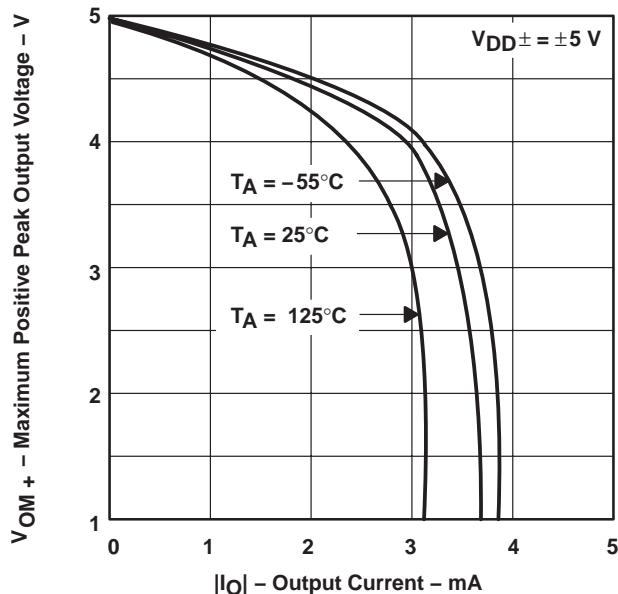


Figure 17

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

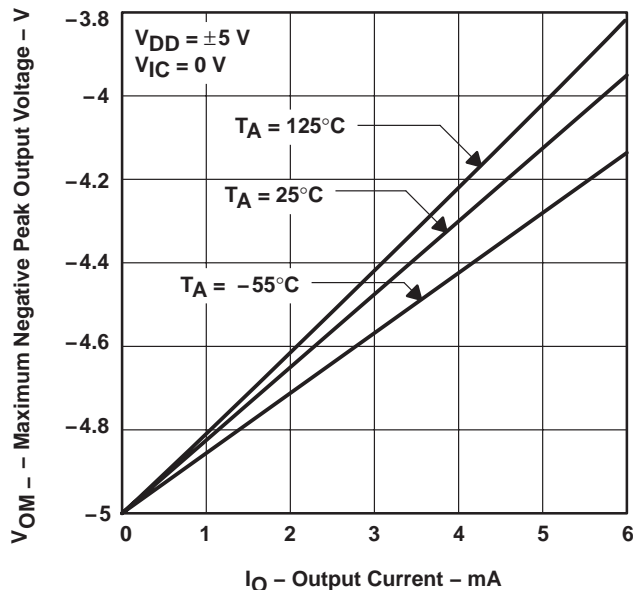


Figure 18

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

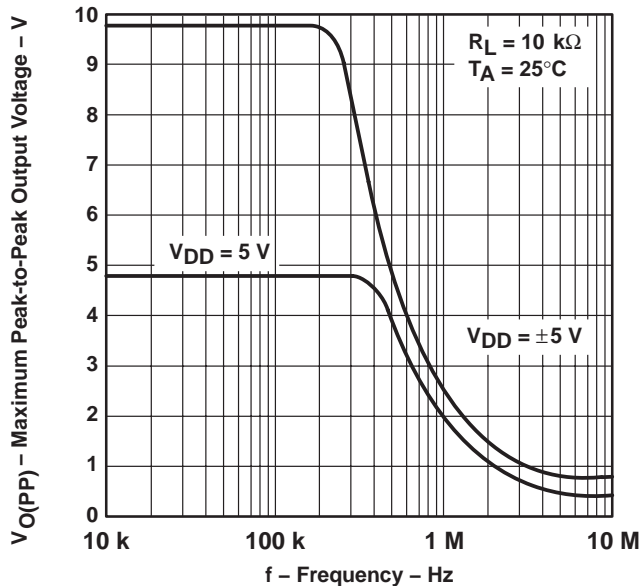


Figure 19

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

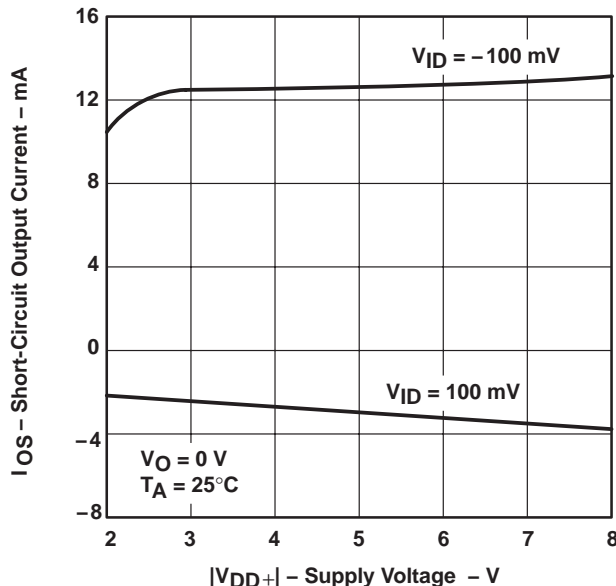


Figure 20

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

TYPICAL CHARACTERISTICS

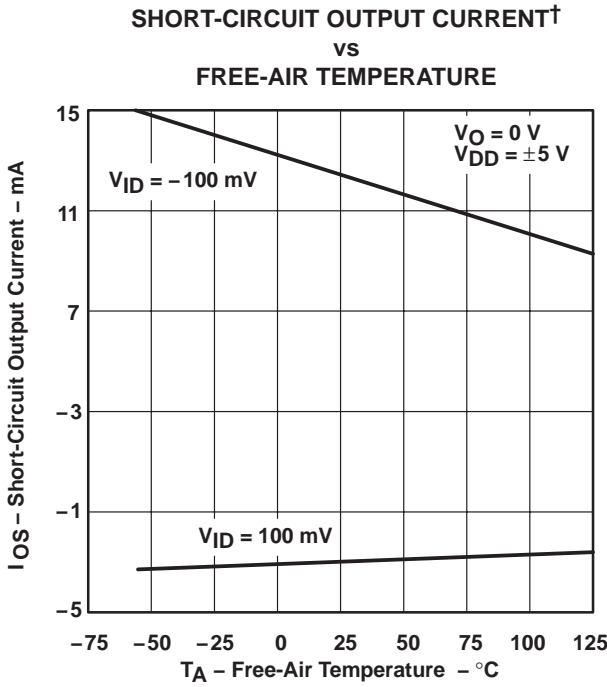


Figure 21

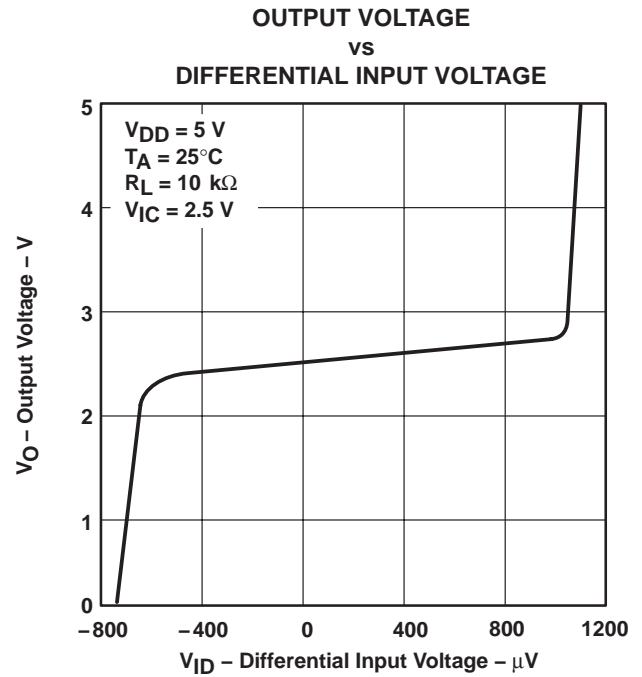


Figure 22

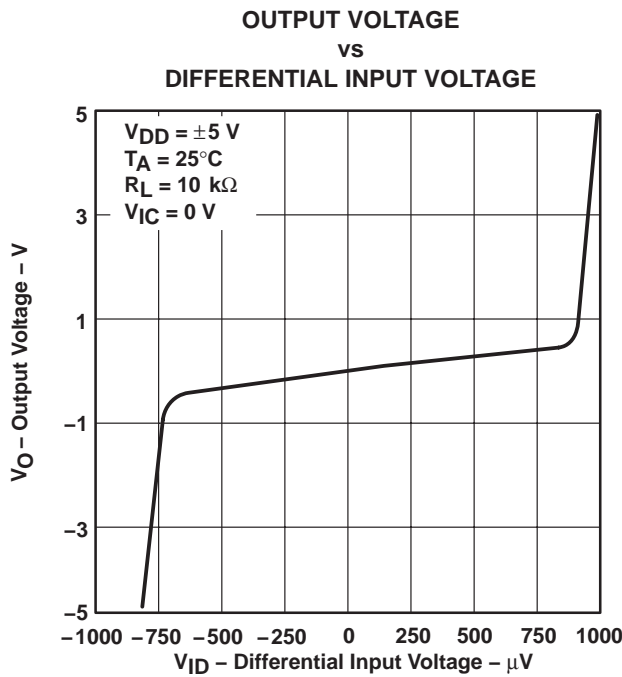


Figure 23

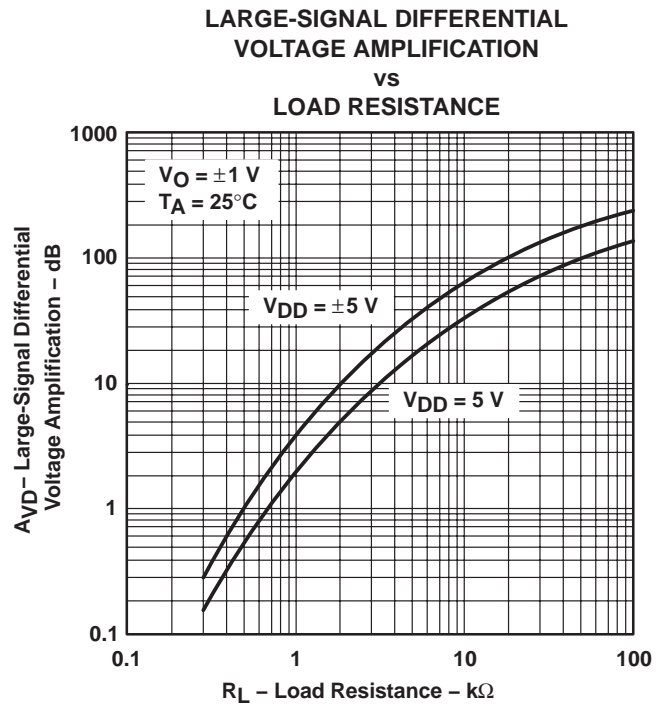


Figure 24

† 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

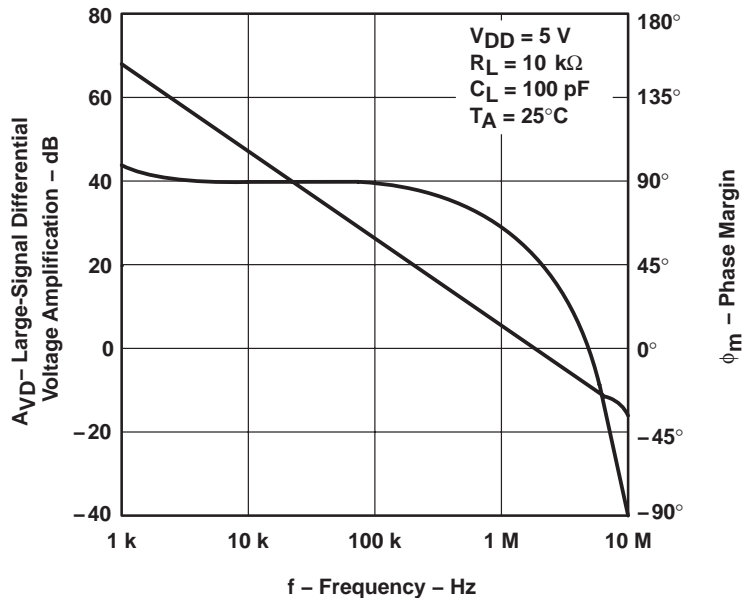


Figure 25

LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION AND PHASE MARGIN

vs
FREQUENCY

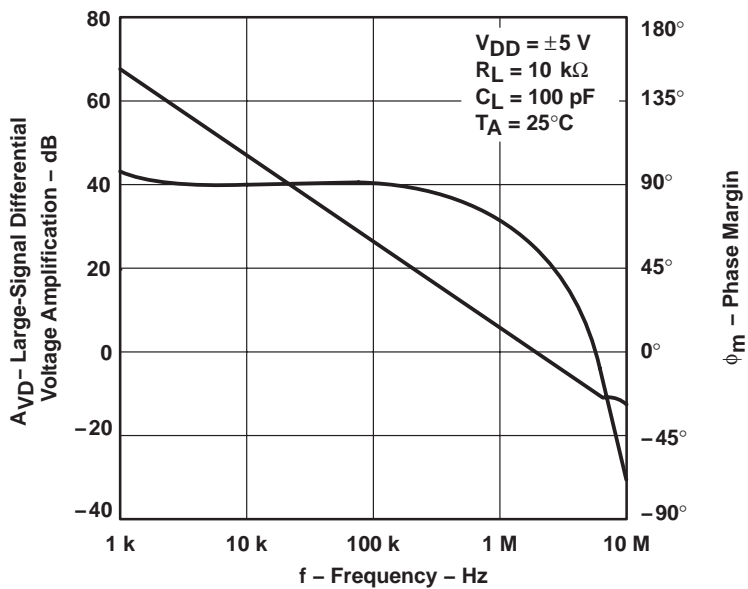


Figure 26

TYPICAL CHARACTERISTICS

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

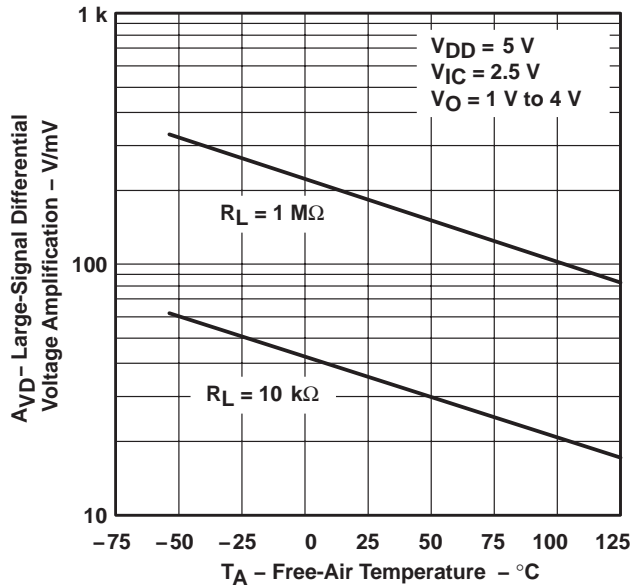


Figure 27

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

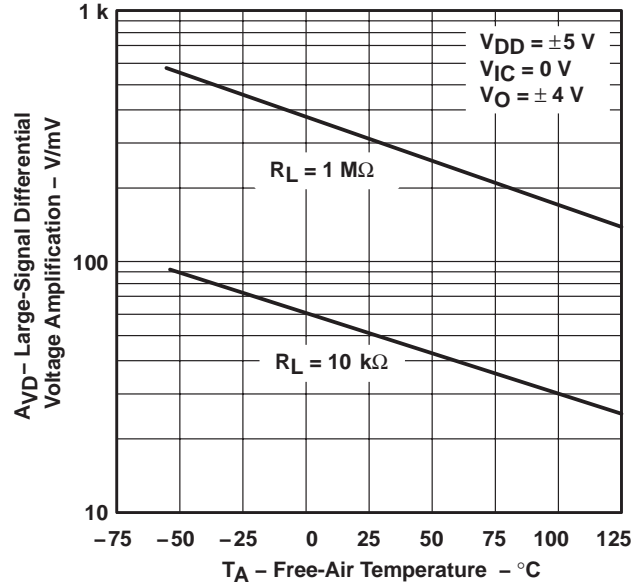


Figure 28

OUTPUT IMPEDANCE
 vs
 FREQUENCY

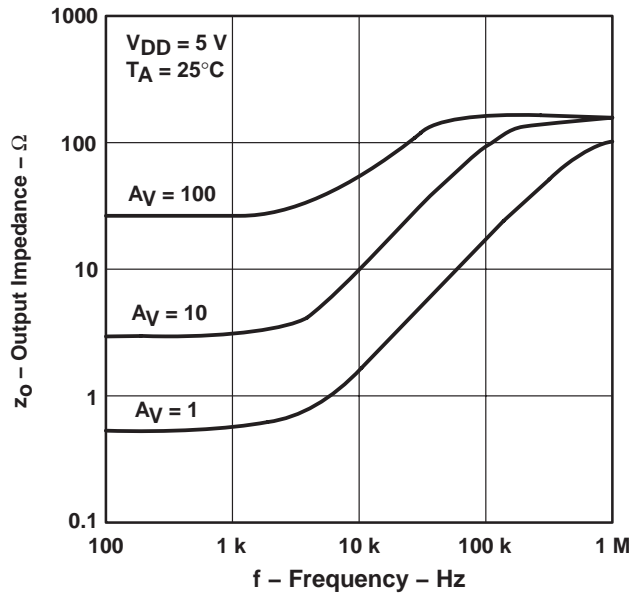


Figure 29

OUTPUT IMPEDANCE
 vs
 FREQUENCY

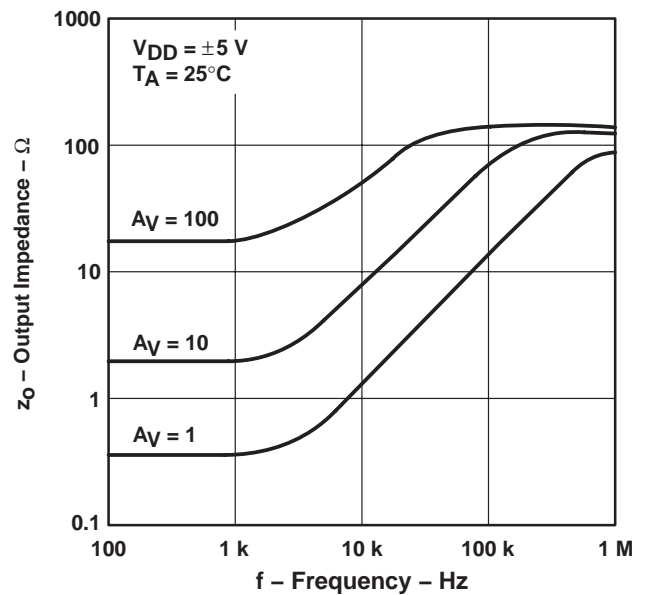


Figure 30

† 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**

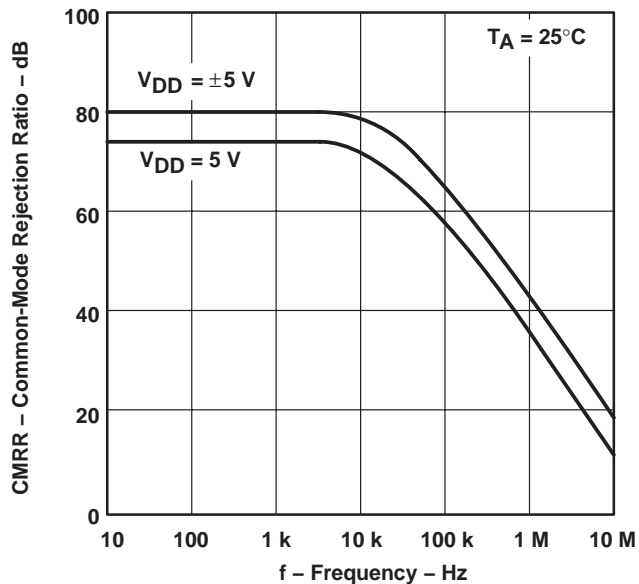


Figure 31

**COMMON-MODE REJECTION RATIO
vs
FREE-AIR TEMPERATURE**

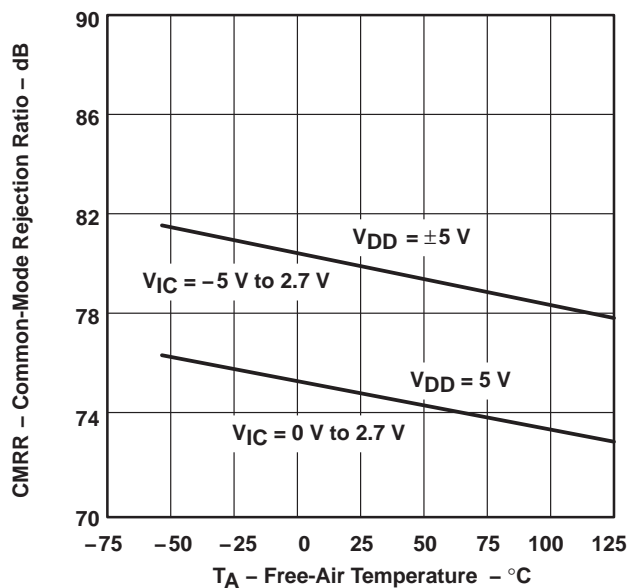


Figure 32

**SUPPLY-VOLTAGE REJECTION RATIO
vs
FREQUENCY**

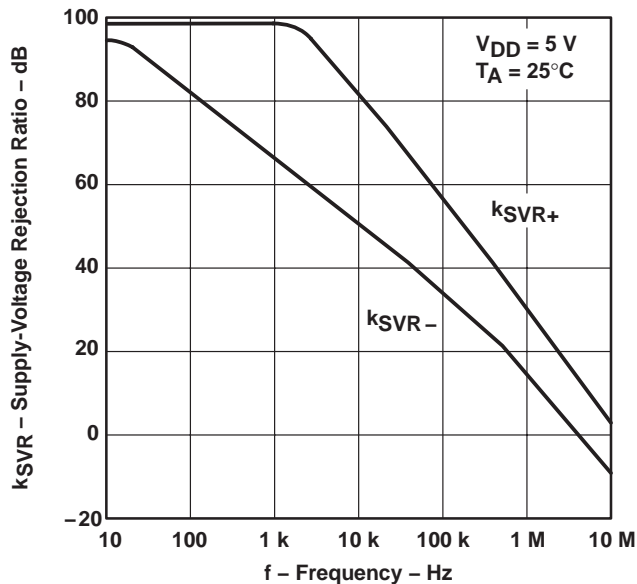


Figure 33

**SUPPLY-VOLTAGE REJECTION RATIO
vs
FREQUENCY**

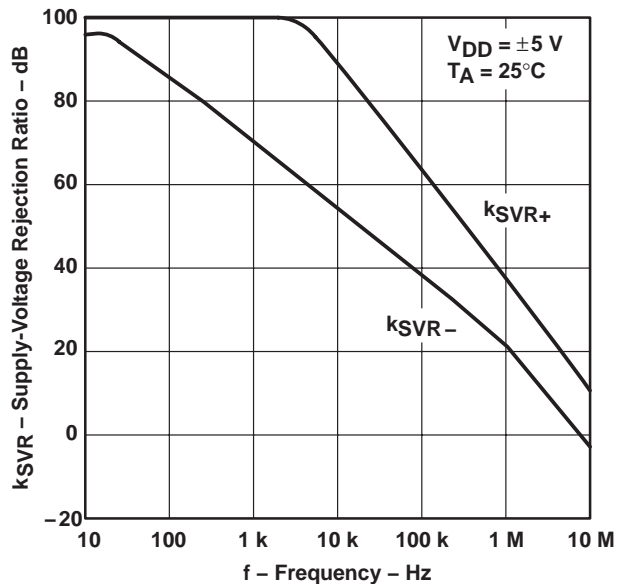
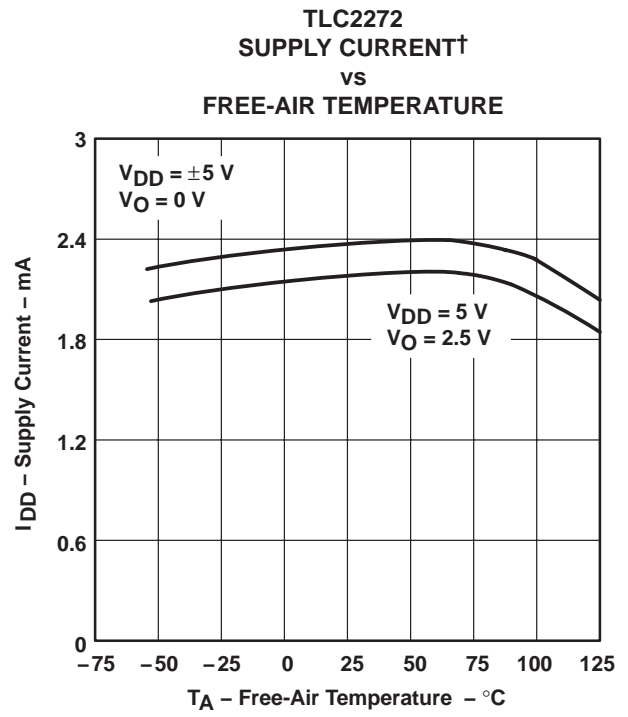
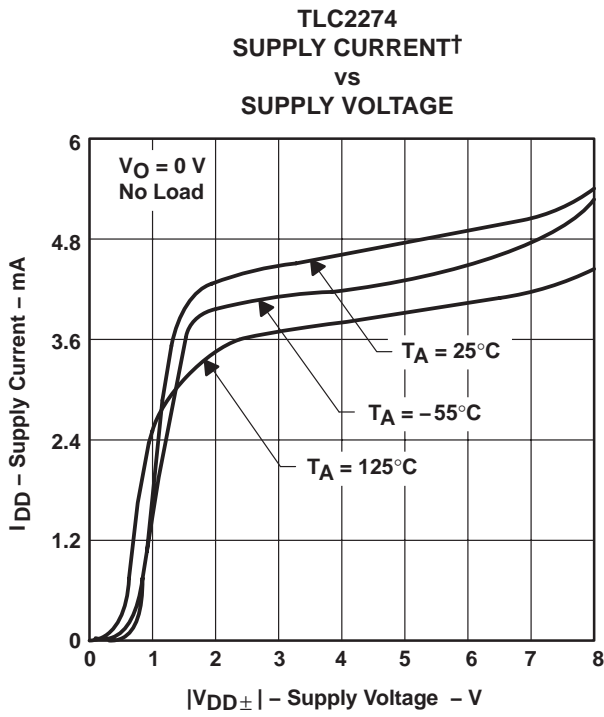
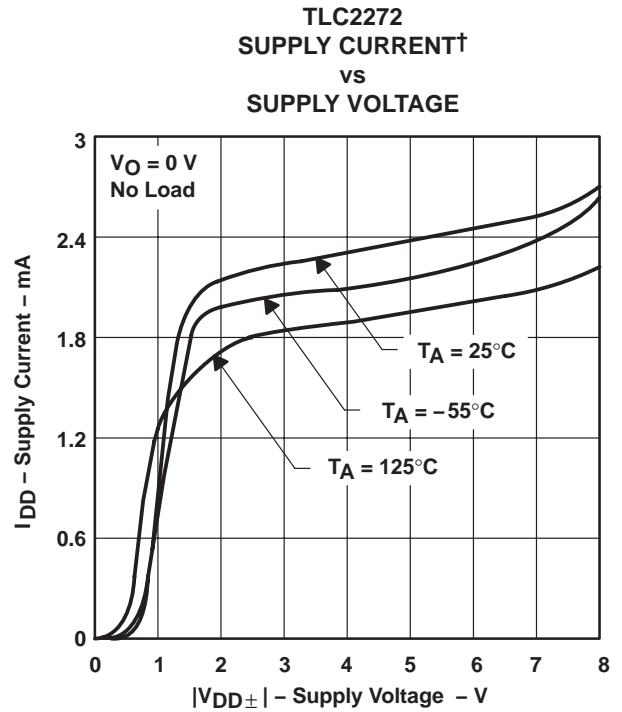
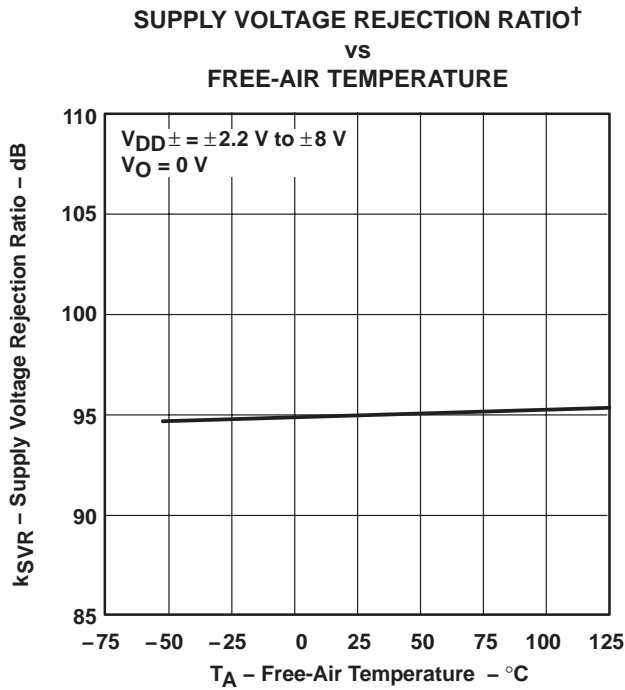


Figure 34

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

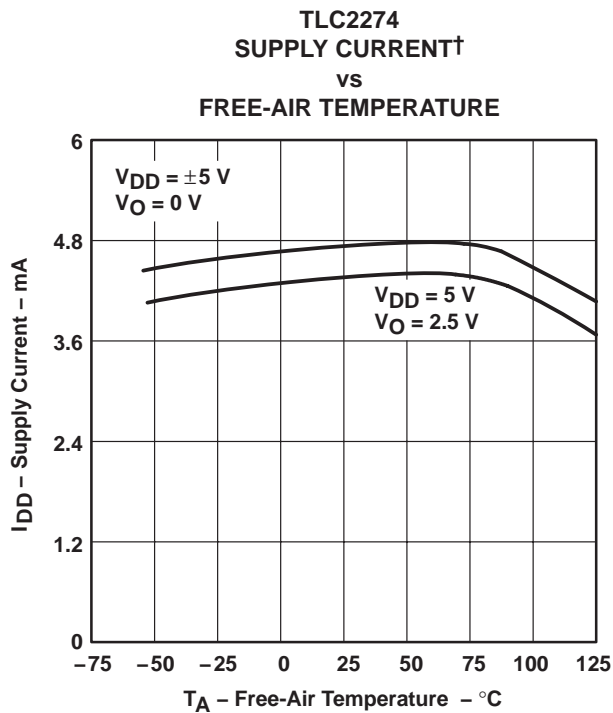


Figure 39

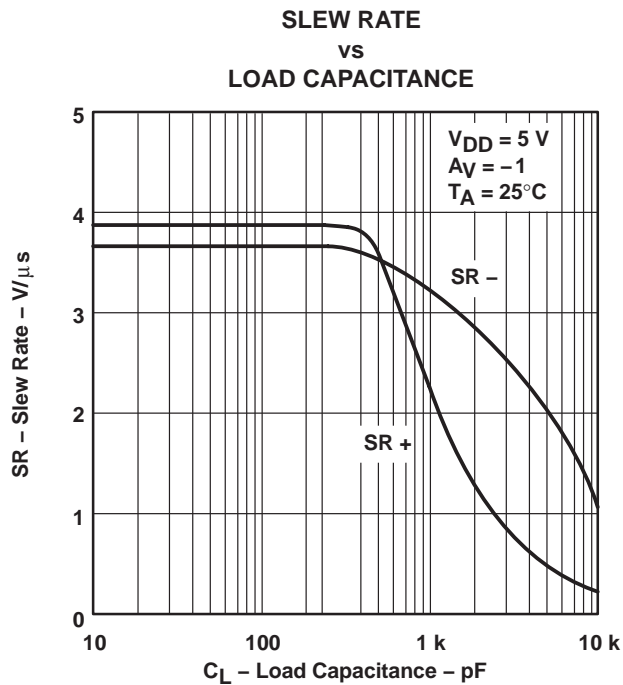


Figure 40

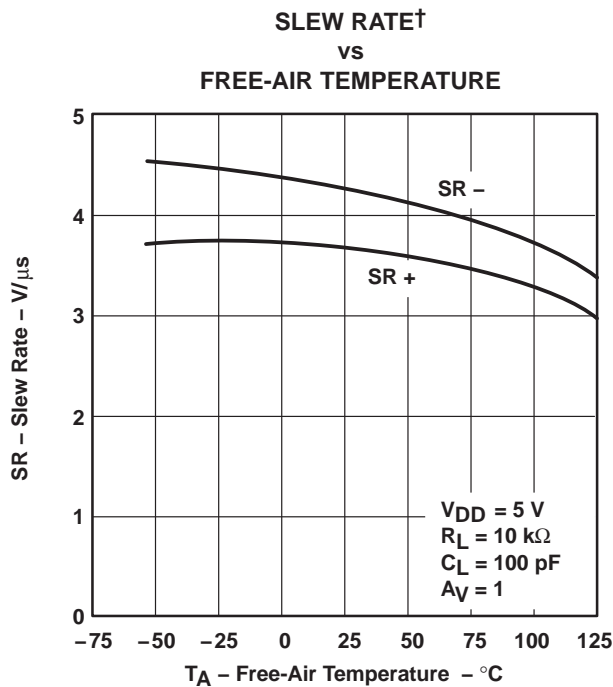


Figure 41

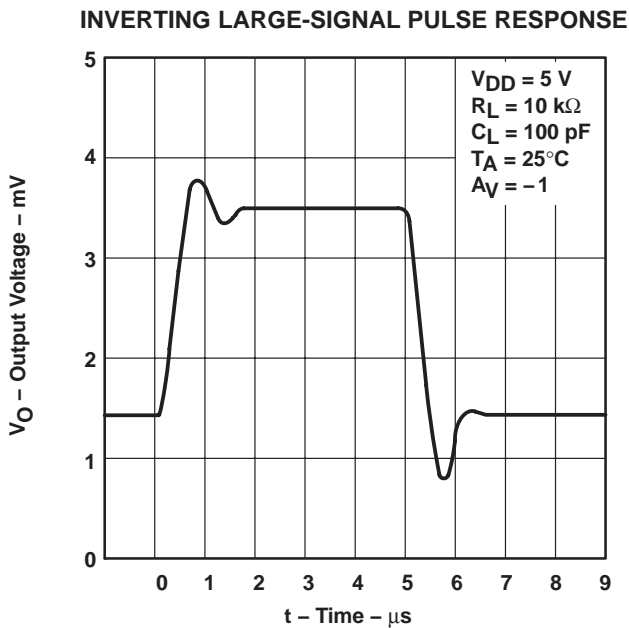


Figure 42

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

TYPICAL CHARACTERISTICS

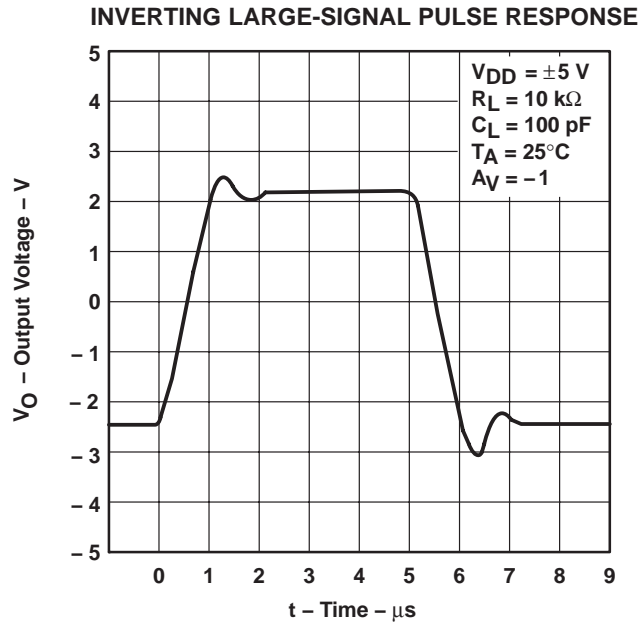


Figure 43

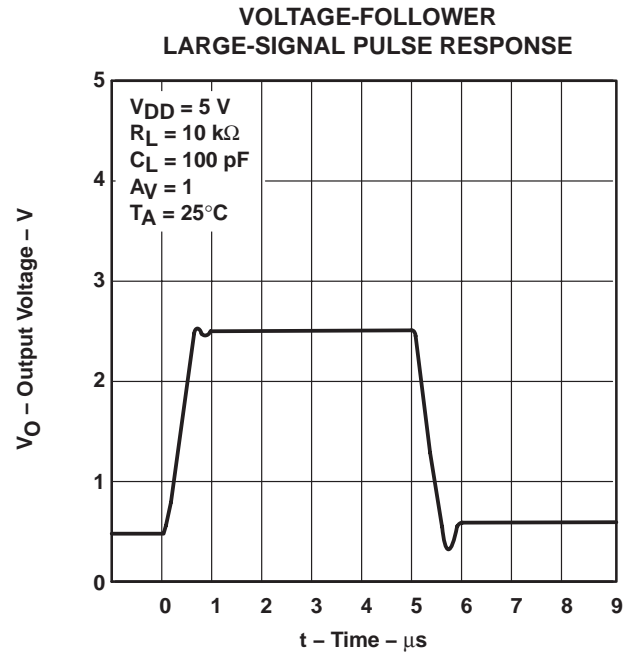


Figure 44

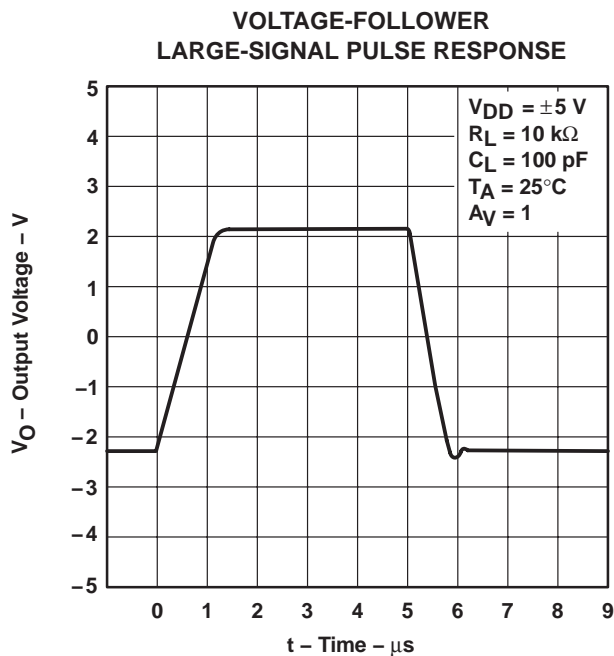


Figure 45

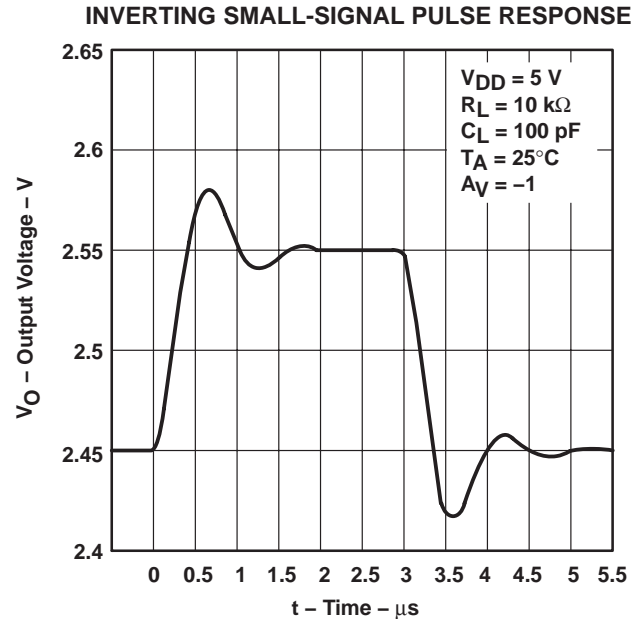


Figure 46

TYPICAL CHARACTERISTICS

INVERTING SMALL-SIGNAL PULSE RESPONSE

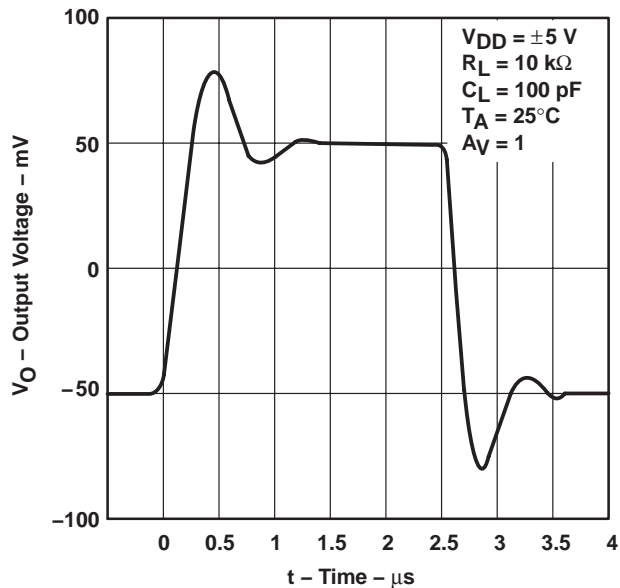


Figure 47

VOLTAGE-FOLLOWER SMALL-SIGNAL PULSE RESPONSE

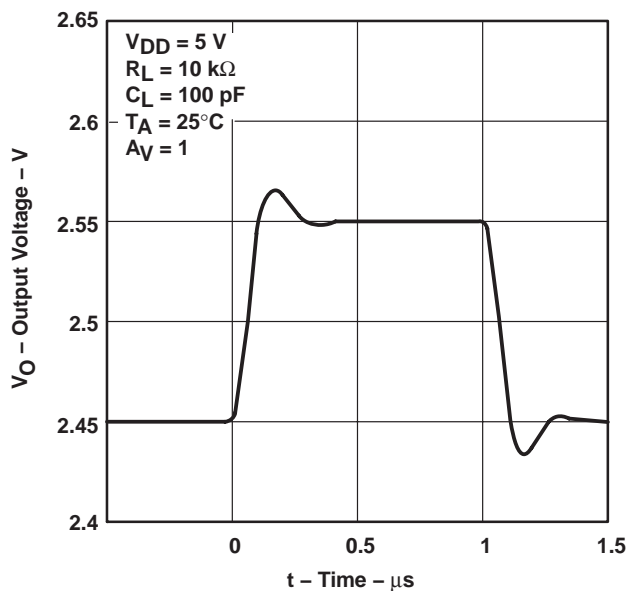


Figure 48

VOLTAGE-FOLLOWER SMALL-SIGNAL PULSE RESPONSE

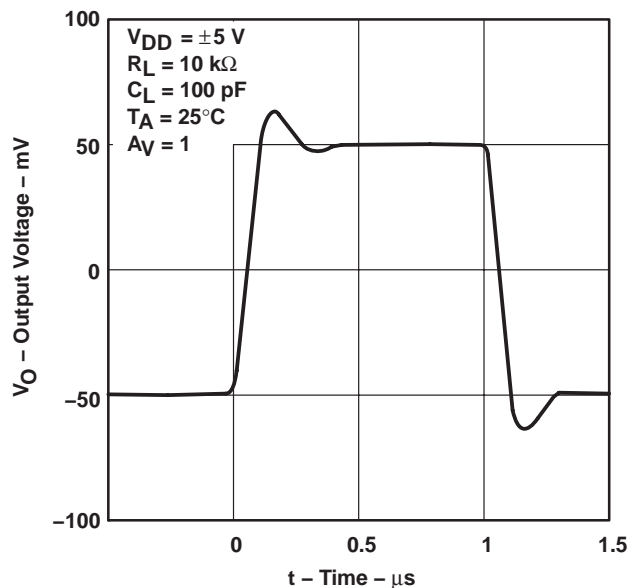


Figure 49

EQUIVALENT INPUT NOISE VOLTAGE vs FREQUENCY

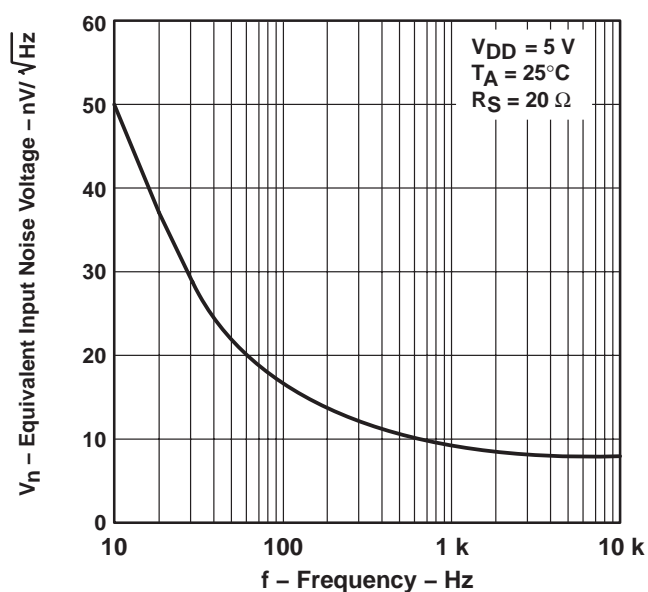
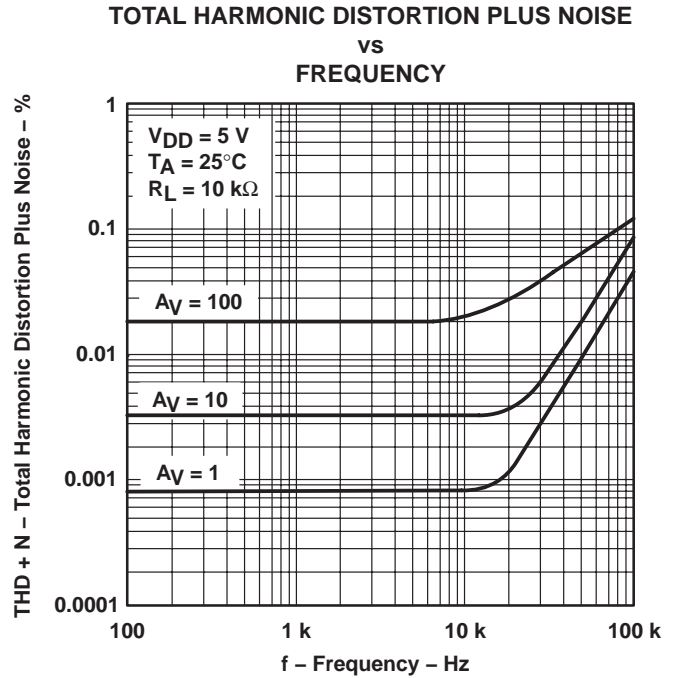
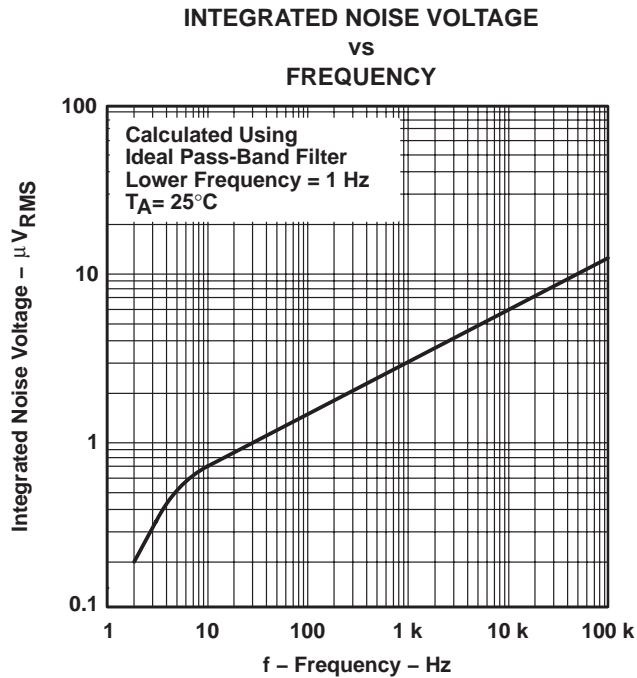
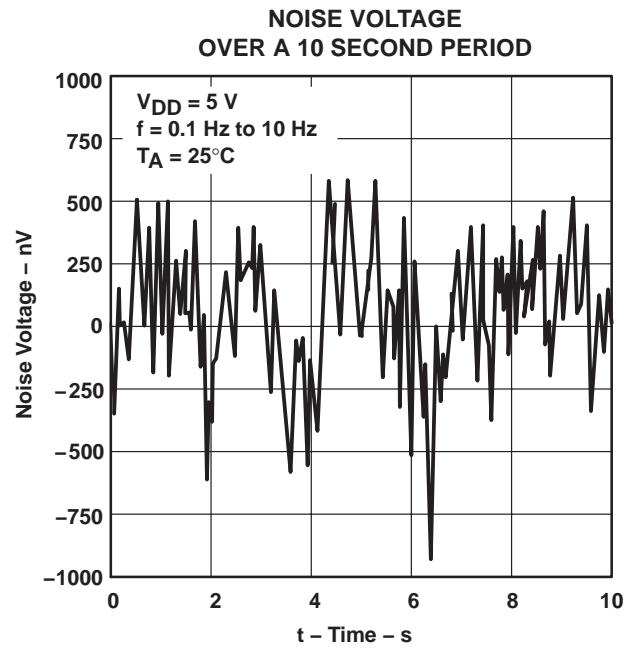
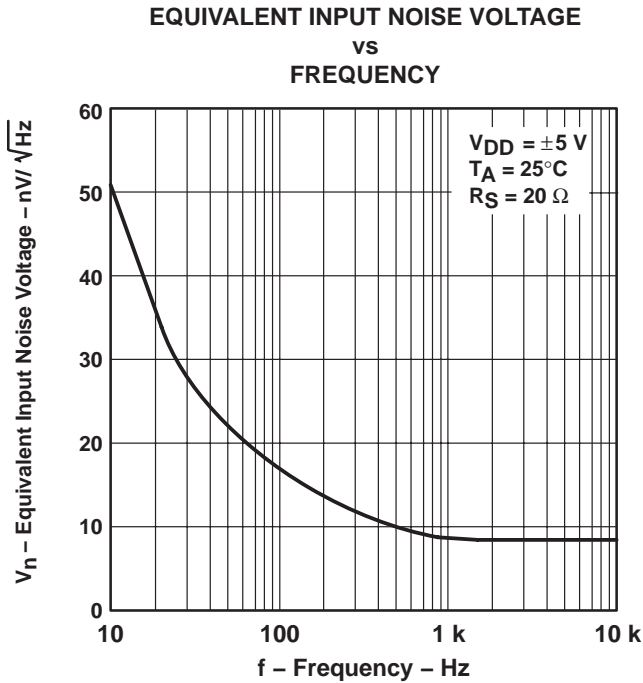


Figure 50

TYPICAL CHARACTERISTICS



TYPICAL CHARACTERISTICS

GAIN-BANDWIDTH PRODUCT
vs
SUPPLY VOLTAGE

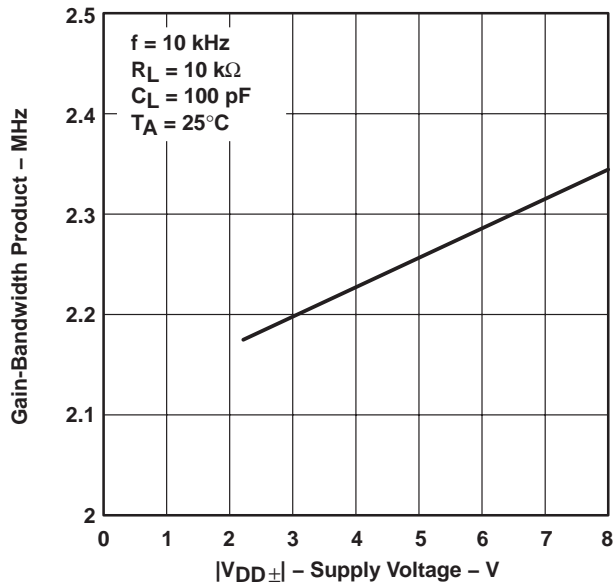


Figure 55

GAIN-BANDWIDTH PRODUCT†
vs
FREE-AIR TEMPERATURE

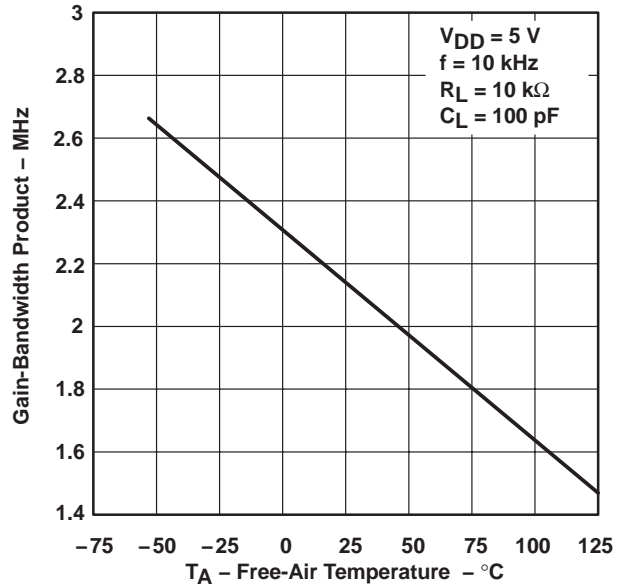


Figure 56

PHASE MARGIN
vs
LOAD CAPACITANCE

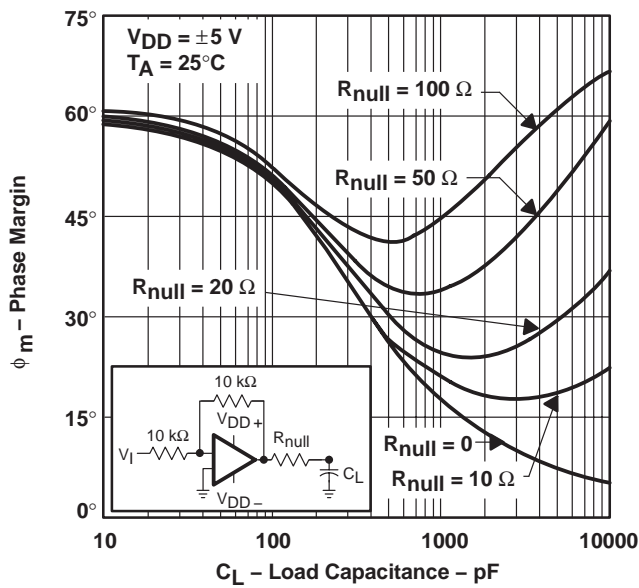


Figure 57

GAIN MARGIN
vs
LOAD CAPACITANCE

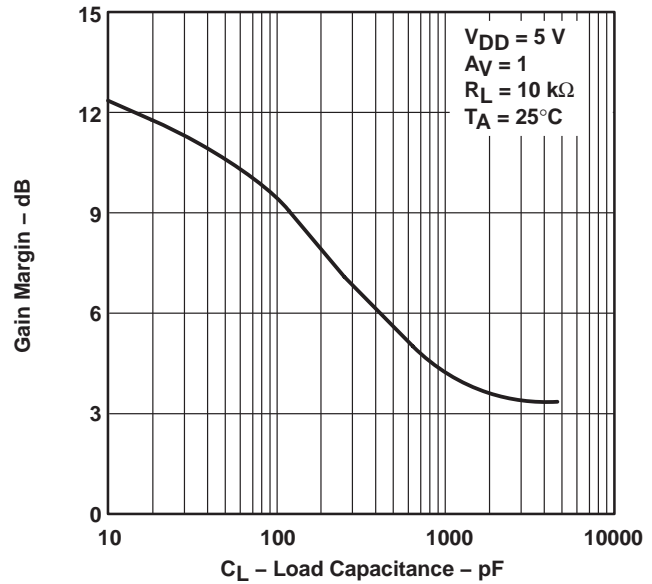


Figure 58

† 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 5) and subcircuit in Figure 59 were generated using the TLC227x typical electrical and operating characteristics at T_A = 25°C. Using this information, output simulations of the following key parameters can be generated to a tolerance of 20% (in most cases):

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

NOTE 5: G. R. Boyle, B. M. Cohn, D. O. Pederson, and J. E. Solomon, "Macromodeling of Integrated Circuit Operational Amplifiers", *IEEE Journal of Solid-State Circuits*, SC-9, 353 (1974).

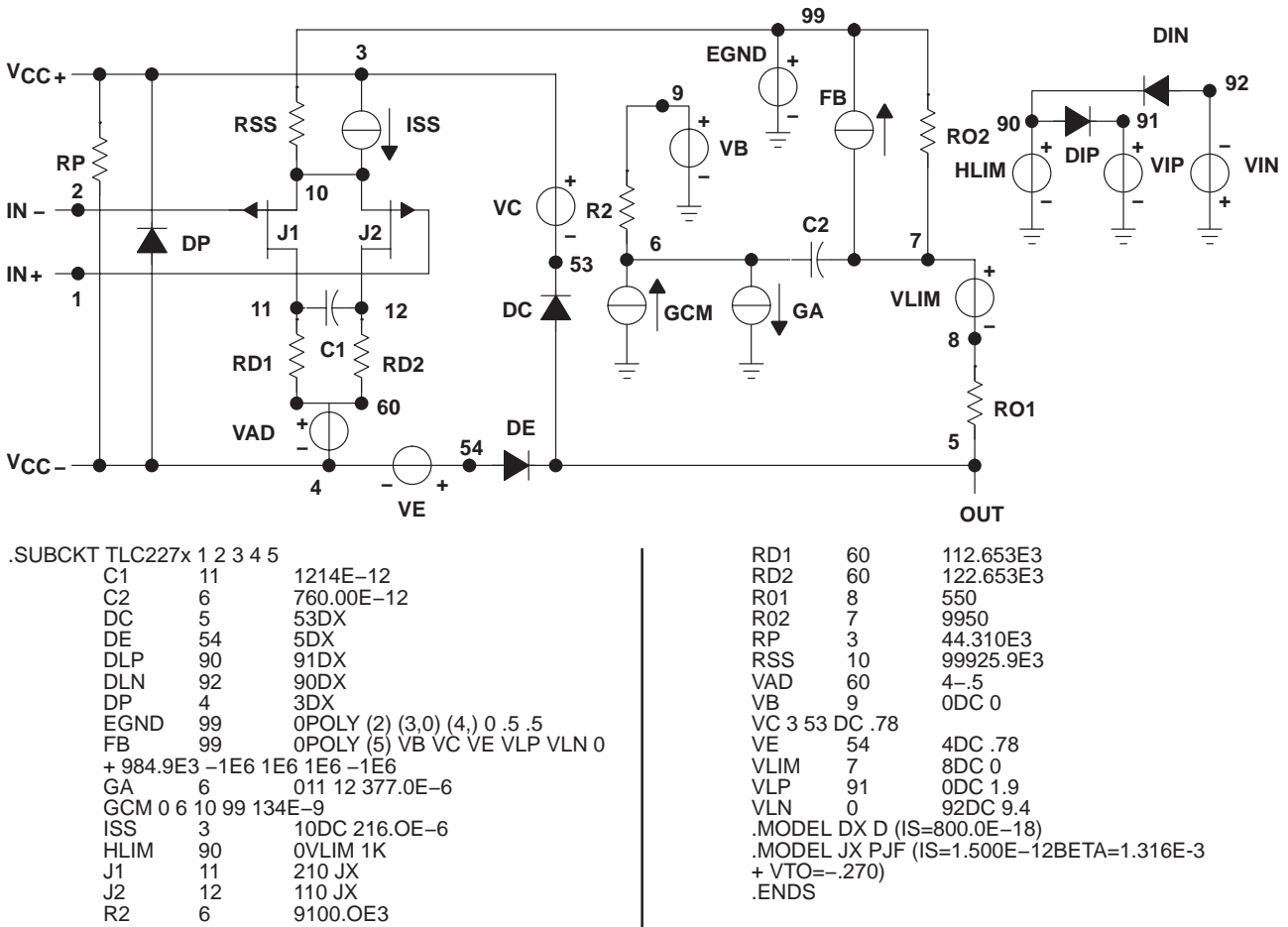


Figure 59. Boyle Macromodel and Subcircuit

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PACKAGING INFORMATION

Orderable Device	Status ⁽¹⁾	Package Type	Package Drawing	Pins	Package Qty	Eco Plan ⁽²⁾	Lead/Ball Finish	MSL Peak Temp ⁽³⁾
TLC2272AQDRQ1	ACTIVE	SOIC	D	8	2500	Pb-Free (RoHS)	CU NIPDAU	Level-2-250C-1 YEAR/ Level-1-235C-UNLIM
TLC2272AQPWRQ1	ACTIVE	TSSOP	PW	8	2000	None	CU NIPDAU	Level-1-250C-UNLIM
TLC2272QDRQ1	ACTIVE	SOIC	D	8	2500	None	CU NIPDAU	Level-1-220C-UNLIM
TLC2272QPWRQ1	ACTIVE	TSSOP	PW	8	2000	None	CU NIPDAU	Level-1-250C-UNLIM
TLC2274AQDRQ1	ACTIVE	SOIC	D	14	2500	Pb-Free (RoHS)	CU NIPDAU	Level-2-250C-1 YEAR/ Level-1-235C-UNLIM
TLC2274AQPWRQ1	ACTIVE	TSSOP	PW	14	2000	None	CU NIPDAU	Level-1-250C-UNLIM
TLC2274QDRQ1	ACTIVE	SOIC	D	14	2500	Pb-Free (RoHS)	CU NIPDAU	Level-2-250C-1 YEAR/ Level-1-235C-UNLIM
TLC2274QPWRQ1	ACTIVE	TSSOP	PW	14	2000	None	CU NIPDAU	Level-1-250C-UNLIM

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

ACTIVE: Product device recommended for new designs.

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

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

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

OBSOLETE: TI has discontinued the production of the device.

⁽²⁾ Eco Plan - 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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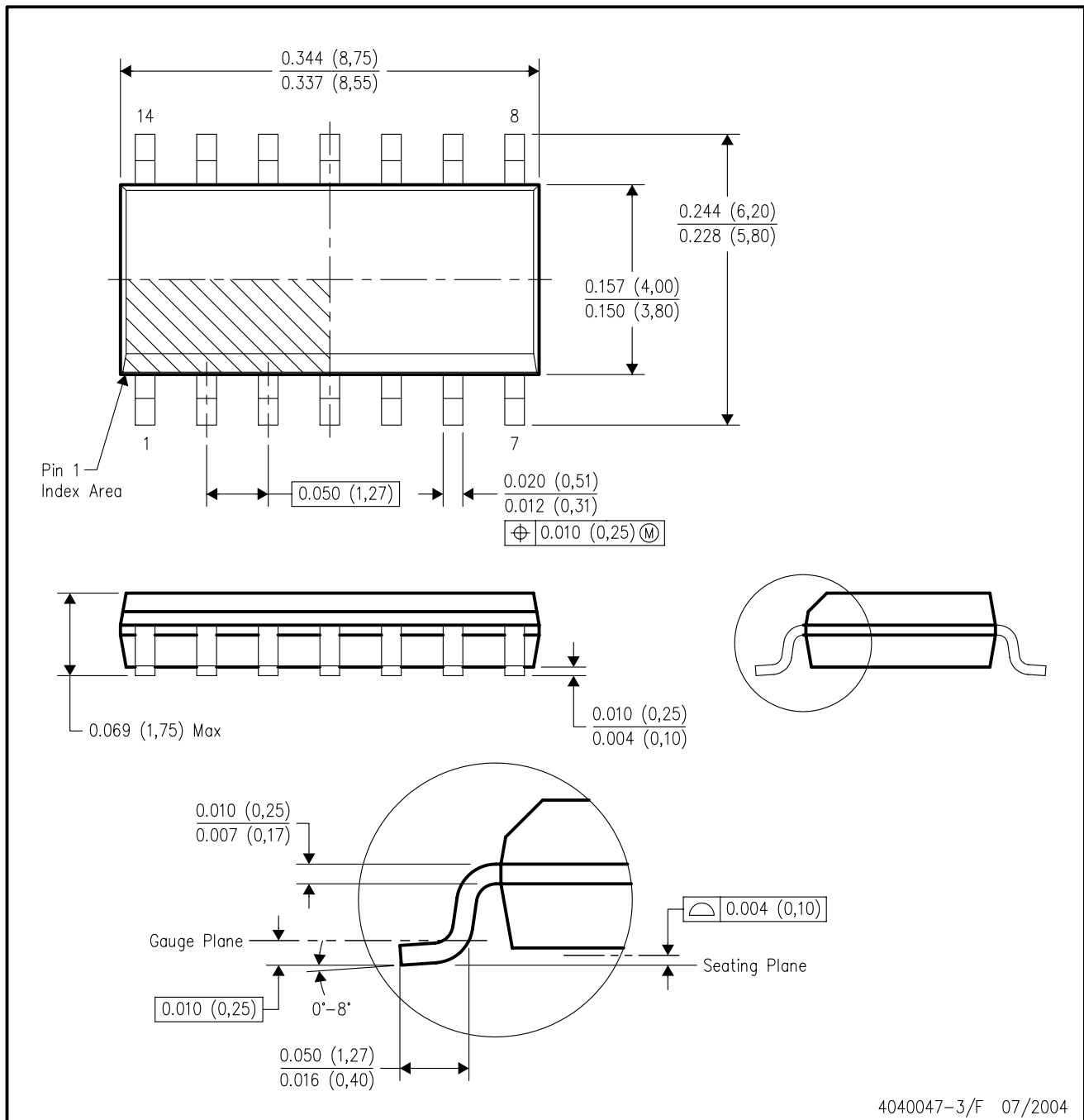
⁽³⁾ MSL, Peak Temp. -- The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

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D (R-PDSO-G14)

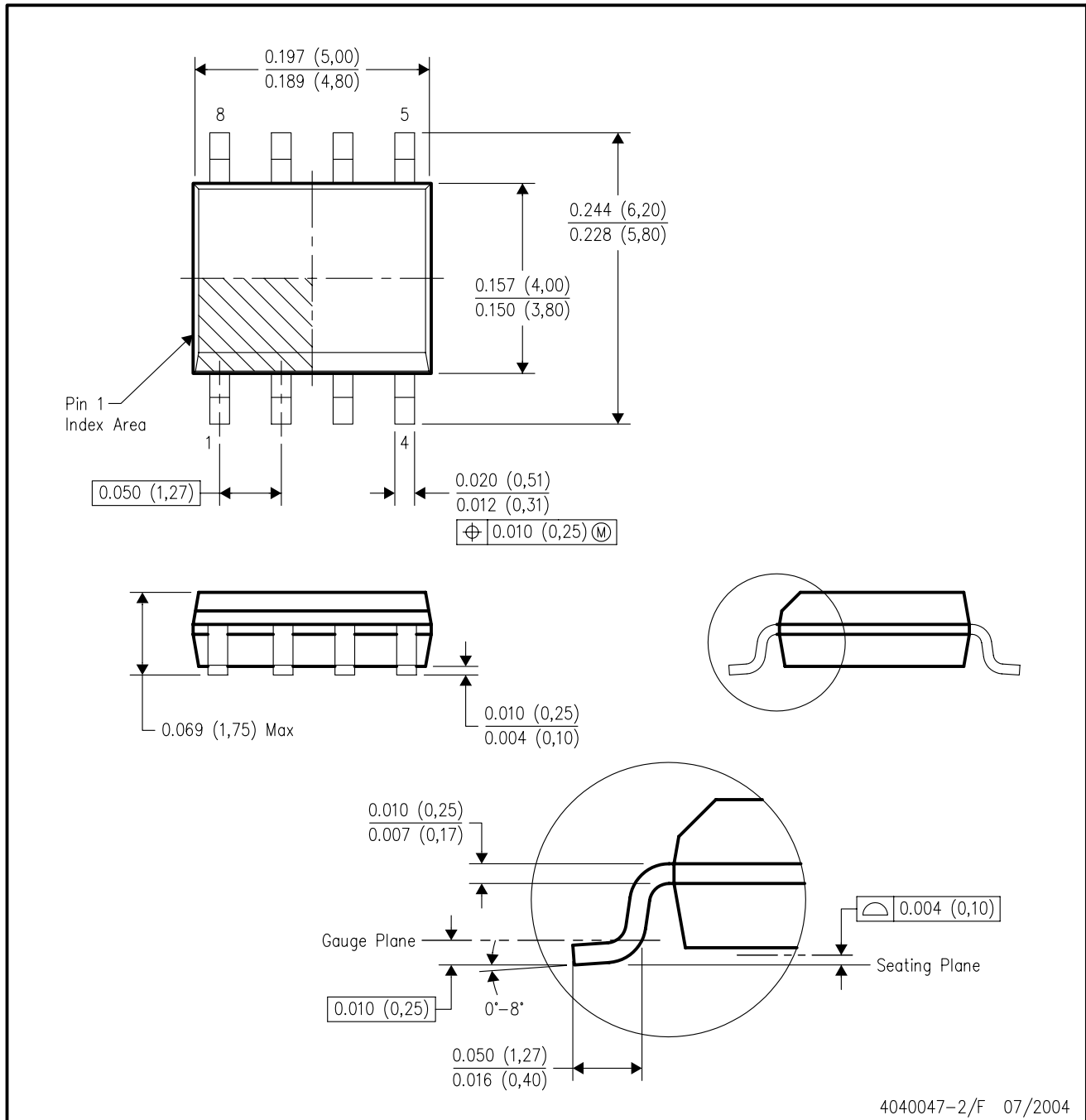
PLASTIC SMALL-OUTLINE PACKAGE



- 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).
 - D. Falls within JEDEC MS-012 variation AA.

PW (R-PDSO-G**)

PLASTIC SMALL-OUTLINE PACKAGE

14 PINS SHOWN



4040064/F 01/97

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

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