

TLC226x-Q1, TLC226xA-Q1 Advanced LinCMOS™ RAIL-TO-RAIL OPERATIONAL AMPLIFIERS

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- Qualified for Automotive Applications
- ESD Protection Exceeds 2000 V Per MIL-STD-883, Method 3015; Exceeds 200 V Using Machine Model (C = 200 pF, R = 0)
- Output Swing includes Both Supply Rails
- Low Noise . . . 12 nV/√Hz Typ at f = 1 kHz
- Low Input Bias Current . . . 1 pA Typ
- Fully Specified for Both Single-Supply and Split-Supply Operation
- Low Power . . . 500 μA Max
- Common-Mode Input Voltage Range Includes Negative Rail
- Low Input Offset Voltage
950 μV Max at T_A = 25°C (TLC2262A)
- Macromodel Included
- Performance Upgrade for the TS27M2/M4 and TLC27M2/M4

description

The TLC2262 and TLC2264 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 TLC226x family offers a compromise between the micropower TLC225x and the ac performance of the TLC227x. It has low supply current for battery-powered applications, while still having adequate ac performance for applications that demand it. The noise performance has been dramatically improved over previous generations of CMOS amplifiers. Figure 1 depicts the low level of noise voltage for this CMOS amplifier, which has only 200 μA (typ) of supply current per amplifier.

The TLC226x, exhibiting high input impedance and low noise, are 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 TLC226xA family is available and has a maximum input offset voltage of 950 μV. This family is fully characterized at 5 V and ±5 V.

The TLC2262/4 also makes great upgrades to the TLC27M2/L4 or TS27M2/L4 in standard designs. They offer increased output dynamic range, lower noise voltage and lower input offset voltage. This enhanced feature set allows them to be used in a wider range of applications. For applications that require higher output drive and wider input voltage range, see the TLV2432 and TLV2442. If your design requires single amplifiers, please see the TLV2211/21/31 family. These devices are single rail-to-rail operational amplifiers in the SOT-23 package. Their small size and low power consumption, make them ideal for high density, battery-powered equipment.

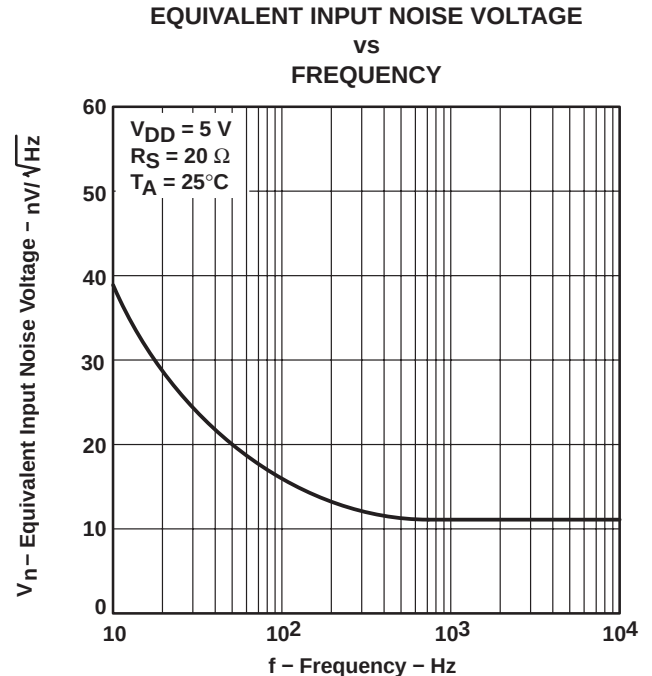


Figure 1



Please be aware that an important notice concerning availability, standard warranty, and use in critical applications of Texas Instruments semiconductor products and disclaimers thereto appears at the end of this data sheet.

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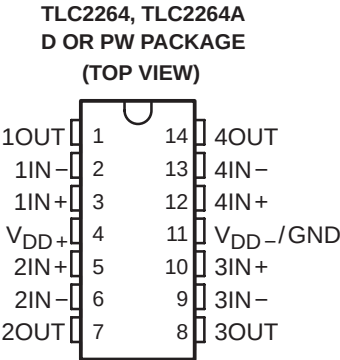
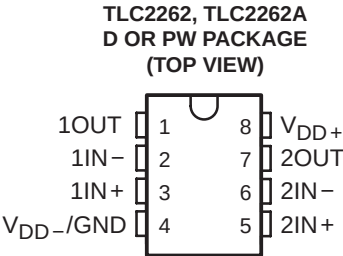
ORDERING INFORMATION†

T _A	V _{IO} max AT 25°C	PACKAGE‡		ORDERABLE PART NUMBER	TOP-SIDE MARKING
–40°C to 125°C	950 µV	SOIC (D)	Tape and reel	TLC2262AQDRQ1§	2262AQ1
	2.5 mV	SOIC (D)	Tape and reel	TLC2262QDRQ1§	2262Q1
	950 µV	TSSOP (PW)	Tape and reel	TLC2262AQPWRQ1§	2262AQ1
	2.5 mV	TSSOP (PW)	Tape and reel	TLC2262QPWRQ1§	2262Q1
	950 µV	SOIC (D)	Tape and reel	TLC2264AQDRQ1	2264AQ1
	2.5 mV	SOIC (D)	Tape and reel	TLC2264QDRQ1	2264Q1
	950 µV	TSSOP (PW)	Tape and reel	TLC2264AQPWRQ1	2264AQ1
	2.5 mV	TSSOP (PW)	Tape and reel	TLC2264QPWRQ1	2264Q1

† For the most current package and ordering information, see the Package Option Addendum at the end of this document, or see the TI web site at <http://www.ti.com>.

‡ Package drawings, thermal data, and symbolization are available at <http://www.ti.com/packaging>.

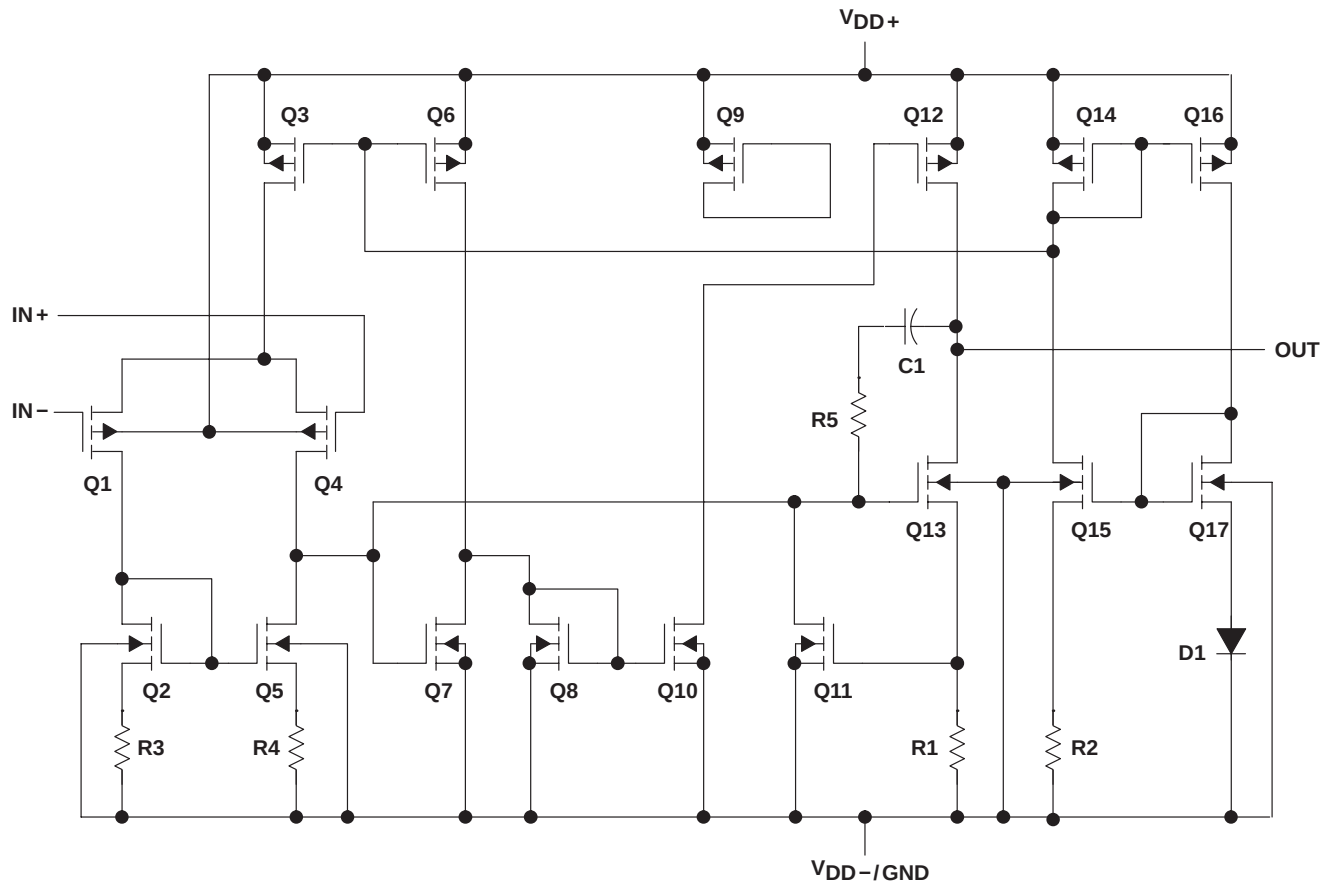
§ Product Preview.



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equivalent schematic (each amplifier)



ACTUAL DEVICE COMPONENT COUNT†		
COMPONENT	TLC2262	TLC2264
Transistors	38	76
Resistors	28	56
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, V_I (any input, see Note 1)	$V_{DD-} - 0.3 \text{ V}$ to V_{DD+}
Input current, I_I (each input)	±5 mA
Output current, I_O	±50 mA
Total current into V_{DD+}	±50 mA
Total current out of V_{DD-}	±50 mA
Duration of short-circuit current at (or below) 25°C (see Note 3)	unlimited
Continuous total dissipation	See Dissipation Rating Table
Operating free-air temperature range, T_A : Q suffix	–40°C to 125°C
Storage temperature range, T_{stg}	–65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: D 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 flows if input is brought below $V_{DD-} - 0.3 \text{ V}$.
3. The output may be shorted to either supply. Temperature and/or supply voltages must be limited to ensure that the maximum dissipation rating is not exceeded.

DISSIPATION RATING TABLE

PACKAGE	$T_A \leq 25^\circ\text{C}$ POWER RATING	DERATING FACTOR ABOVE $T_A = 25^\circ\text{C}$	$T_A = 70^\circ\text{C}$ 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	377 mW	145 mW
D–14	950 mW	7.6 mW/°C	608 mW	494 mW	190 mW
PW–14	750 mW	6.0 mW/°C	480 mW	389 mW	150 mW

recommended operating conditions

	MIN	MAX	UNIT
Supply voltage, $V_{DD\pm}$	±2.2	±8	V
Input voltage range, 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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TLC2262 electrical characteristics at specified free-air temperature, $V_{DD} = 5\text{ V}$ (unless otherwise noted)

PARAMETER		TEST CONDITIONS		T _A [†]	TLC2262-Q1			TLC2262A-Q1			UNIT	
					MIN	TYP	MAX	MIN	TYP	MAX		
V _{IO}	Input offset voltage	V _{DD} ± = ±2.5 V, V _{IC} = 0, V _O = 0, R _S = 50 Ω		25°C	300	2500		300	950	μV		
	Full range				3000		1500					
α _{VIO}	Temperature coefficient of input offset voltage			Full range	5			5		μV/°C		
	Input offset voltage long-term drift (see Note 4)			25°C	0.003			0.003		μV/mo		
I _{IO}	Input offset current			25°C	0.5			0.5		pA		
				125°C	800			800				
I _{IB}	Input bias current			25°C	1			1		pA		
				125°C	800			800				
V _{ICR}	Common-mode input voltage range			R _S = 50 Ω, V _{IO} ≤ 5 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 μA		25°C	4.99			4.99	V			
		I _{OH} = −100 μA		25°C	4.85	4.94		4.85		4.94		
				Full range	4.82			4.82				
		I _{OH} = −400 μA		25°C	4.7	4.85		4.7		4.85		
Full range	4.5					4.5						
V _{OL}	Low-level output voltage	V _{IC} = 2.5 V, I _{OL} = 50 μA		25°C	0.01			0.01	V			
		V _{IC} = 2.5 V, I _{OL} = 500 μA		25°C	0.09	0.15		0.09		0.15		
				Full range	0.15			0.15				
		V _{IC} = 2.5 V, I _{OL} = 4 mA		25°C	0.8	1		0.7		1		
				Full range	1.2			1.2				
A _{VD}	Large-signal differential voltage amplification	V _{IC} = 2.5 V, V _O = 1 V to 4 V	R _L = 50 kΩ‡	25°C	80	100		80	170	V/mV		
				Full range	50			50				
			R _L = 1 MΩ‡	25°C	550			550				
r _{i(d)}	Differential input resistance			25°C	10 ¹²			10 ¹²	Ω			
r _{i(c)}	Common-mode input resistance			25°C	10 ¹²			10 ¹²	Ω			
c _{i(c)}	Common-mode input capacitance	f = 10 kHz,	P package	25°C	8			8	pF			
z _o	Closed-loop output impedance	f = 100 kHz,	A _V = 10	25°C	240			240	Ω			
CMRR	Common-mode rejection ratio	V _{IC} = 0 to 2.7 V, V _O = 2.5 V, R _S = 50 Ω		25°C	70	83		70	83	dB		
				Full range	70			70				
k _{SVR}	Supply-voltage rejection ratio (ΔV _{DD} /ΔV _{IO})	V _{DD} = 4.4 V to 16 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 V, No load		25°C	400	500		400	500	μA		
				Full range	500			500				

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

‡ Referenced to 2.5 V

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

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TLC2262 operating characteristics at specified free-air temperature, $V_{DD} = 5\text{ V}$

PARAMETER		TEST CONDITIONS		T_A †	TLC2262-Q1			TLC2262A-Q1			UNIT
					MIN	TYP	MAX	MIN	TYP	MAX	
SR	Slew rate at unity gain	$V_O = 0.5\text{ V to }3.5\text{ V}, R_L = 50\text{ k}\Omega^\ddagger, C_L = 100\text{ pF}^\ddagger$		25°C	0.35	0.55		0.35	0.55		V/ μs
				Full range	0.25			0.25			
V_n	Equivalent input noise voltage	$f = 10\text{ Hz}$		25°C		40			40		nV/ $\sqrt{\text{Hz}}$
		$f = 1\text{ kHz}$		25°C		12			12		
$V_{N(PP)}$	Peak-to-peak equivalent input noise voltage	$f = 0.1\text{ Hz to }1\text{ Hz}$		25°C		0.7			0.7		μV
		$f = 0.1\text{ Hz to }10\text{ Hz}$		25°C		1.3			1.3		
I_n	Equivalent input noise current			25°C		0.6			0.6		fA/ $\sqrt{\text{Hz}}$
THD + N	Total harmonic distortion plus noise	$V_O = 0.5\text{ V to }2.5\text{ V}, f = 20\text{ kHz}, R_L = 50\text{ k}\Omega^\ddagger$		25°C		0.017%			0.017%		
						0.03%			0.03%		
	Gain-bandwidth product	$f = 50\text{ kHz}, C_L = 100\text{ pF}^\ddagger, R_L = 50\text{ k}\Omega^\ddagger$		25°C		0.82			0.82		MHz
B_{OM}	Maximum output-swing bandwidth	$V_{O(PP)} = 2\text{ V}, R_L = 50\text{ k}\Omega^\ddagger, A_V = 1, C_L = 100\text{ pF}^\ddagger$		25°C		185			185		kHz
t_s	Settling time	$A_V = -1, \text{ Step} = 0.5\text{ V to }2.5\text{ V}, R_L = 50\text{ k}\Omega^\ddagger, C_L = 100\text{ pF}^\ddagger$		25°C		6.4			6.4		μs
						14.1			14.1		
ϕ_m	Phase margin at unity gain	$R_L = 50\text{ k}\Omega^\ddagger, C_L = 100\text{ pF}^\ddagger$		25°C		56°			56°		
	Gain margin			25°C		11			11		dB

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

‡ Referenced to 2.5 V



TLC2262 electrical characteristics at specified free-air temperature, $V_{DD\pm} = \pm 5\text{ V}$ (unless otherwise noted)

PARAMETER	TEST CONDITIONS	$T_A^\dagger$	TLC2262-Q1			TLC2262A-Q1			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
V_{IO} Input offset voltage	$V_{IC} = 0, V_O = 0, R_S = 50\ \Omega$	25°C		300	2500		300	950	μV
		Full range			3000			1500	
α_{VIO} Temperature coefficient of input offset voltage		Full range		5			5		$\mu\text{V}/^\circ\text{C}$
Input offset voltage long-term drift (see Note 4)		25°C		0.003			0.003		$\mu\text{V}/\text{mo}$
I_{IO} Input offset current		25°C		0.5			0.5		pA
		125°C			800			800	
I_{IB} Input bias current		25°C		1			1		pA
		125°C			800			800	
V_{ICR} Common-mode input voltage range	$R_S = 50\ \Omega, V_{IO} \leq 5\text{ mV}$	25°C	-5 to 4	-5.3 to 4		-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
	$I_O = -100\ \mu\text{A}$	25°C		4.85	4.94		4.85	4.94	
		Full range		4.82			4.82		
	$I_O = -400\ \mu\text{A}$	25°C		4.7	4.85		4.7	4.85	
		Full range		4.5			4.5		
V_{OM-} Maximum negative peak output voltage	$V_{IC} = 0, I_O = 50\ \mu\text{A}$	25°C		-4.99			-4.99		V
	$V_{IC} = 0, I_O = 500\ \mu\text{A}$	25°C		-4.85	-4.91		-4.85	-4.91	
		Full range		-4.85			-4.85		
	$V_{IC} = 0, I_O = 4\text{ mA}$	25°C		-4	-4.3		-4	-4.3	
		Full range		-3.8			-3.8		
A_{VD} Large-signal differential voltage amplification	$V_O = \pm 4\text{ V}$	$R_L = 50\text{ k}\Omega$	25°C	80	200		80	200	V/mV
			Full range	50			50		
		$R_L = 1\text{ M}\Omega$	25°C		1000			1000	
$r_{i(d)}$ Differential input resistance		25°C			10^{12}			10^{12}	Ω
$r_{i(c)}$ Common-mode input resistance		25°C			10^{12}			10^{12}	Ω
$c_{i(c)}$ Common-mode input capacitance	$f = 10\text{ kHz}, \text{ P package}$	25°C			8			8	pF
z_o Closed-loop output impedance	$f = 100\text{ kHz}, A_V = 10$	25°C			220			220	Ω
CMRR Common-mode rejection ratio	$V_{IC} = -5\text{ V to } 2.7\text{ V}, V_O = 0, R_S = 50\ \Omega$	25°C		75	88		75	88	dB
		Full range		75			75		
k_{SVR} Supply-voltage rejection ratio ($\Delta V_{DD\pm} / \Delta V_{IO}$)	$V_{DD} = 4.4\text{ V to } 16\text{ V}, V_{IC} = V_{DD}/2, \text{ No load}$	25°C		80	95		80	95	dB
		Full range		80			80		
I_{DD} Supply current	$V_O = 0, \text{ No load}$	25°C		425	500		425	500	μA
		Full range			500			500	

[†] Full range is -40°C to 125°C for Q suffix.

NOTE 4: Typical values are based on the input offset voltage shift observed through 500 hours of operating life test at $T_A = 150^\circ\text{C}$ 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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TLC2262 operating characteristics at specified free-air temperature, $V_{DD\pm} = \pm 5\text{ V}$

PARAMETER		TEST CONDITIONS		$T_A^\dagger$	TLC2262-Q1			TLC2262A-Q1			UNIT
					MIN	TYP	MAX	MIN	TYP	MAX	
SR	Slew rate at unity gain	$V_O = \pm 2\text{ V}$, $C_L = 100\text{ pF}$	$R_L = 50\text{ k}\Omega$	25°C	0.35	0.55		0.35	0.55		V/ μs
				Full range	0.25			0.25			
V_n	Equivalent input noise voltage	$f = 10\text{ Hz}$		25°C		43			43		nV/ $\sqrt{\text{Hz}}$
		$f = 1\text{ kHz}$		25°C		12			12		
$V_{N(PP)}$	Peak-to-peak equivalent input noise voltage	$f = 0.1\text{ Hz to }1\text{ Hz}$		25°C		0.8			0.8		μV
		$f = 0.1\text{ Hz to }10\text{ Hz}$		25°C		1.3			1.3		
I_n	Equivalent input noise current			25°C		0.6			0.6		fA/ $\sqrt{\text{Hz}}$
THD + N	Total harmonic distortion plus noise	$V_O = \pm 2.3\text{ V}$, $R_L = 50\text{ k}\Omega$, $f = 20\text{ kHz}$	$A_V = 1$	25°C		0.014%			0.014%		
			$A_V = 10$			0.024%			0.024%		
	Gain-bandwidth product	$f = 10\text{ kHz}$, $C_L = 100\text{ pF}$	$R_L = 50\text{ k}\Omega$	25°C		0.73			0.73		MHz
B_{OM}	Maximum output-swing bandwidth	$V_{O(PP)} = 4.6\text{ V}$, $R_L = 50\text{ k}\Omega$	$A_V = 1$, $C_L = 100\text{ pF}$	25°C		85			85		kHz
t_s	Settling time	$A_V = -1$, Step = $-2.3\text{ V to }2.3\text{ V}$, $R_L = 50\text{ k}\Omega$, $C_L = 100\text{ pF}$	To 0.1%	25°C		7.1			7.1		μs
			To 0.01%			16.5			16.5		
ϕ_m	Phase margin at unity gain	$R_L = 50\text{ k}\Omega$	$C_L = 100\text{ pF}$	25°C		57°			57°		
	Gain margin			25°C		11			11		dB

[†] Full range is -40°C to 125°C for Q suffix.

TLC2264 electrical characteristics at specified free-air temperature, $V_{DD} = 5\text{ V}$ (unless otherwise noted)

PARAMETER	TEST CONDITIONS	$T_A^\dagger$	TLC2264-Q1			TLC2264A-Q1			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
V_{IO} Input offset voltage	$V_{DD} = \pm 2.5\text{ V}, V_{IC} = 0, V_O = 0, R_S = 50\ \Omega$	25°C	300	2500		300	950		μV
		Full range		3000			1500		
α_{VIO} Temperature coefficient of input offset voltage		Full range		2			2		$\mu\text{V}/^\circ\text{C}$
Input offset voltage long-term drift (see Note 4)		25°C		0.003			0.003		$\mu\text{V}/\text{mo}$
I_{IO} Input offset current		25°C		0.5			0.5		pA
		125°C		800			800		
I_{IB} Input bias current		25°C		1			1		pA
		125°C		800			800		
V_{ICR} Common-mode input voltage range	$R_S = 50\ \Omega, V_{IO} \leq 5\text{ mV}$	25°C	0 to 4	-0.3 to 4.2		0 to 4	-0.3 to 4.2		V
		Full range	0 to 3.5			0 to 3.5			
V_{OH} High-level output voltage	$I_{OH} = -20\ \mu\text{A}$	25°C		4.99			4.99		V
	$I_{OH} = -100\ \mu\text{A}$	25°C	4.85	4.94		4.85	4.94		
		Full range	4.82			4.82			
	$I_{OH} = -400\ \mu\text{A}$	25°C	4.7	4.85		4.7	4.85		
		Full range	4.5			4.5			
V_{OL} Low-level output voltage	$V_{IC} = 2.5\text{ V}, I_{OL} = 50\ \mu\text{A}$	25°C		0.01			0.01		V
	$V_{IC} = 2.5\text{ V}, I_{OL} = 500\ \mu\text{A}$	25°C		0.09	0.15		0.09	0.15	
		Full range			0.15			0.15	
	$V_{IC} = 2.5\text{ V}, I_{OL} = 4\text{ mA}$	25°C		0.8	1		0.7	1	
		Full range			1.2			1.2	
A_{VD} Large-signal differential voltage amplification	$V_{IC} = 2.5\text{ V}, V_O = 1\text{ V to }4\text{ V}$	$R_L = 50\text{ k}\Omega^\ddagger$	25°C	80	100		80	170	V/mV
			Full range	50			50		
		$R_L = 1\text{ M}\Omega^\ddagger$	25°C		550			550	
$r_{i(d)}$ Differential input resistance		25°C		10^{12}			10^{12}		Ω
$r_{i(c)}$ Common-mode input resistance		25°C		10^{12}			10^{12}		Ω
$c_{i(c)}$ Common-mode input capacitance	$f = 10\text{ kHz}, \text{ N package}$	25°C		8			8		pF
z_o Closed-loop output impedance	$f = 100\text{ kHz}, A_V = 10$	25°C		240			240		Ω
CMRR Common-mode rejection ratio	$V_{IC} = 0\text{ to }2.7\text{ V}, V_O = 2.5\text{ V}, R_S = 50\ \Omega$	25°C	70	83		70	83		dB
		Full range	70			70			
k_{SVR} Supply-voltage rejection ratio ($\Delta V_{DD}/\Delta V_{IO}$)	$V_{DD} = 4.4\text{ V to }16\text{ V}$	25°C	80	95		80	95		dB
I_{DD} Supply current (four amplifiers)	$V_O = 2.5\text{ V}, \text{ No load}$	25°C		0.8	1		0.8	1	mA
		Full range			1			1	

[†] Full range is -40°C to 125°C for Q suffix.

[‡] Referenced to 2.5 V

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

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TLC2264 operating characteristics at specified free-air temperature, $V_{DD} = 5\text{ V}$

PARAMETER		TEST CONDITIONS		T_A †	TLC2264-Q1			TLC2264A-Q1			UNIT
					MIN	TYP	MAX	MIN	TYP	MAX	
SR	Slew rate at unity gain	$V_O = 0.5\text{ V to }3.5\text{ V}, R_L = 50\text{ k}\Omega^\ddagger, C_L = 100\text{ pF}^\ddagger$		25°C	0.35	0.55		0.35	0.55		V/ μs
				Full range	0.25			0.25			
V_n	Equivalent input noise voltage	$f = 10\text{ Hz}$		25°C		40			40		nV/ $\sqrt{\text{Hz}}$
		$f = 1\text{ kHz}$		25°C		12			12		
$V_{N(PP)}$	Peak-to-peak equivalent input noise voltage	$f = 0.1\text{ Hz to }1\text{ Hz}$		25°C		0.7			0.7		μV
		$f = 0.1\text{ Hz to }10\text{ Hz}$		25°C		1.3			1.3		
I_n	Equivalent input noise current			25°C		0.6			0.6		fA/ $\sqrt{\text{Hz}}$
THD + N	Total harmonic distortion plus noise	$V_O = 0.5\text{ V to }2.5\text{ V}, f = 20\text{ kHz}, R_L = 50\text{ k}\Omega^\ddagger$	$A_V = 1$	25°C		0.017%			0.017%		
			$A_V = 10$			0.03%			0.03%		
	Gain-bandwidth product	$f = 50\text{ kHz}, C_L = 100\text{ pF}^\ddagger$	$R_L = 50\text{ k}\Omega^\ddagger$	25°C		0.71			0.71		MHz
B_{OM}	Maximum output-swing bandwidth	$V_{O(PP)} = 2\text{ V}, R_L = 50\text{ k}\Omega^\ddagger$	$A_V = 1, C_L = 100\text{ pF}^\ddagger$	25°C		185			185		kHz
t_s	Settling time	$A_V = -1, \text{ Step} = 0.5\text{ V to }2.5\text{ V}, R_L = 50\text{ k}\Omega^\ddagger, C_L = 100\text{ pF}^\ddagger$	To 0.1%	25°C		6.4			6.4		μs
			To 0.01%			14.1			14.1		
ϕ_m	Phase margin at unity gain	$R_L = 50\text{ k}\Omega^\ddagger$	$C_L = 100\text{ pF}^\ddagger$	25°C		56°			56°		
	Gain margin			25°C		11			11		dB

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

‡ Referenced to 2.5 V



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TLC2264 electrical characteristics at specified free-air temperature, $V_{DD\pm} = \pm 5$ V (unless otherwise noted)

PARAMETER	TEST CONDITIONS	$T_A^\dagger$	TLC2264-Q1			TLC2264A-Q1			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
V_{IO} Input offset voltage	$V_{IC} = 0, V_O = 0, R_S = 50 \Omega$	25°C		300	2500		300	950	μV
		Full range			3000			1500	
α_{VIO} Temperature coefficient of input offset voltage		Full range		2			2		$\mu V/^\circ C$
Input offset voltage long-term drift (see Note 4)		25°C		0.003			0.003		$\mu V/mo$
I_{IO} Input offset current		25°C		0.5			0.5		pA
		125°C			800			800	
I_{IB} Input bias current		25°C		1			1		pA
		125°C			800			800	
V_{ICR} Common-mode input voltage range	$R_S = 50 \Omega, V_{IO} \leq 5$ mV	25°C	-5 to 4	-5.3 to 4.2		-5 to 4	-5.3 to 4.2		V
		Full range	-5 to 3.5			-5 to 3.5			
V_{OM+} Maximum positive peak output voltage	$I_O = -20 \mu A$	25°C		4.99			4.99		V
	$I_O = -100 \mu A$	25°C		4.85	4.94		4.85	4.94	
		Full range		4.82			4.82		
	$I_O = -400 \mu A$	25°C		4.7	4.85		4.7	4.85	
		Full range		4.5			4.5		
V_{OM-} Maximum negative peak output voltage	$V_{IC} = 0, I_O = 50 \mu A$	25°C		-4.99			-4.99		V
	$V_{IC} = 0, I_O = 500 \mu A$	25°C		-4.85	-4.91		-4.85	-4.91	
		Full range		-4.85			-4.85		
	$V_{IC} = 0, I_O = 4$ mA	25°C		-4	-4.3		-4	-4.3	
		Full range		-3.8			-3.8		
A_{VD} Large-signal differential voltage amplification	$V_O = \pm 4$ V	$R_L = 50$ k Ω	25°C	80	200		80	200	V/mV
			Full range	50			50		
		$R_L = 1$ M Ω	25°C		1000			1000	
$r_{i(d)}$ Differential input resistance		25°C		10^{12}			10^{12}		Ω
$r_{i(c)}$ Common-mode input resistance		25°C		10^{12}			10^{12}		Ω
$c_{i(c)}$ Common-mode input capacitance	$f = 10$ kHz, N package	25°C		8			8		pF
z_o Closed-loop output impedance	$f = 100$ kHz, $A_V = 10$	25°C		220			220		Ω
CMRR Common-mode rejection ratio	$V_{IC} = -5$ V to 2.7 V, $V_O = 0, R_S = 50 \Omega$	25°C		75	88		75	88	dB
		Full range		75			75		
k_{SVR} Supply-voltage rejection ratio ($\Delta V_{DD\pm}/\Delta V_{IO}$)	$V_{DD\pm} = \pm 2.2$ V to ± 8 V, $V_{IC} = V_{DD}/2$, No load	25°C		80	95		80	95	dB
		Full range		80			80		
I_{DD} Supply current (four amplifiers)	$V_O = 0$, No load	25°C		0.85	1		0.85	1	mA
		Full range			1			1	

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

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



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TLC2264 operating characteristics at specified free-air temperature, $V_{DD\pm} = \pm 5\text{ V}$

PARAMETER		TEST CONDITIONS		$T_A^\dagger$	TLC2264-Q1			TLC2264A-Q1			UNIT
					MIN	TYP	MAX	MIN	TYP	MAX	
SR	Slew rate at unity gain	$V_O = \pm 2\text{ V}$, $C_L = 100\text{ pF}$	$R_L = 50\text{ k}\Omega$,	25°C	0.35	0.55		0.35	0.55		V/ μs
				Full range	0.25			0.25			
V_n	Equivalent input noise voltage	$f = 10\text{ Hz}$		25°C		43			43		nV/ $\sqrt{\text{Hz}}$
		$f = 1\text{ kHz}$		25°C		12			12		
$V_{N(PP)}$	Peak-to-peak equivalent input noise voltage	$f = 0.1\text{ Hz to }1\text{ Hz}$		25°C		0.8			0.8		μV
		$f = 0.1\text{ Hz to }10\text{ Hz}$		25°C		1.3			1.3		
I_n	Equivalent input noise current			25°C		0.6			0.6		fA/ $\sqrt{\text{Hz}}$
THD + N	Total harmonic distortion plus noise	$V_O = \pm 2.3\text{ V}$, $R_L = 50\text{ k}\Omega$, $f = 20\text{ kHz}$	$A_V = 1$	25°C		0.014%			0.014%		
			$A_V = 10$			0.024%			0.024%		
	Gain-bandwidth product	$f = 10\text{ kHz}$, $C_L = 100\text{ pF}$	$R_L = 50\text{ k}\Omega$,	25°C		0.73			0.73		MHz
B_{OM}	Maximum output-swing bandwidth	$V_{O(PP)} = 4.6\text{ V}$, $R_L = 50\text{ k}\Omega$,	$A_V = 1$, $C_L = 100\text{ pF}$	25°C		70			70		kHz
t_s	Settling time	$A_V = -1$, Step = $-2.3\text{ V to }2.3\text{ V}$, $R_L = 50\text{ k}\Omega$, $C_L = 100\text{ pF}$	To 0.1%	25°C		7.1			7.1		μs
			To 0.01%			16.5			16.5		
ϕ_m	Phase margin at unity gain	$R_L = 50\text{ k}\Omega$,	$C_L = 100\text{ pF}$	25°C		57°			57°		
	Gain margin			25°C		11			11		dB

[†] Full range is -40°C to 125°C for Q suffix.

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**DISTRIBUTION OF TLC2262
INPUT OFFSET VOLTAGE**

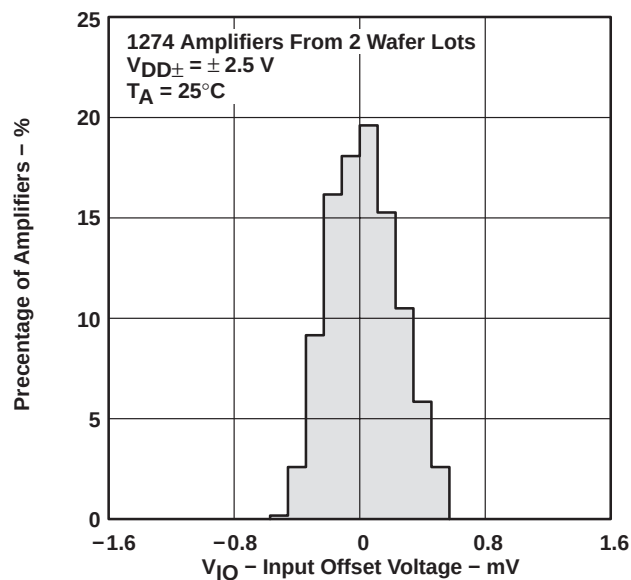


Figure 2

**DISTRIBUTION OF TLC2262
INPUT OFFSET VOLTAGE**

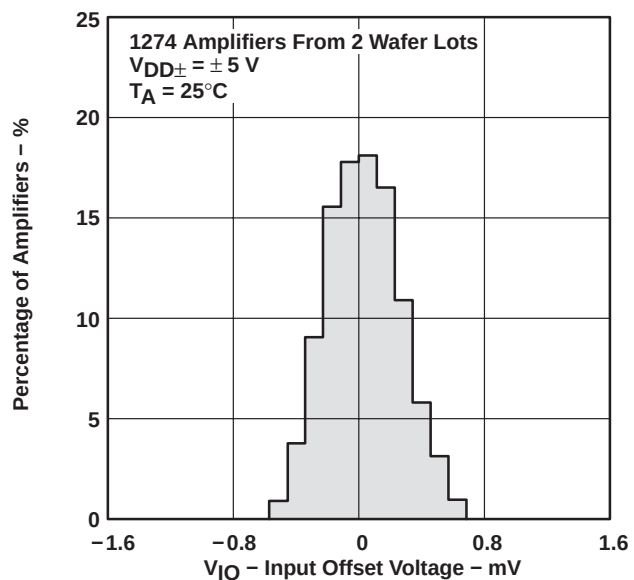


Figure 3

**DISTRIBUTION OF TLC2264
INPUT OFFSET VOLTAGE**

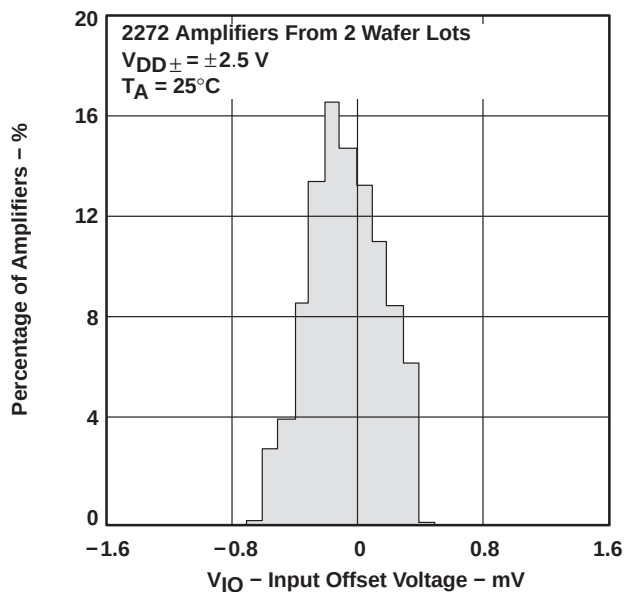


Figure 4

**DISTRIBUTION OF TLC2264
INPUT OFFSET VOLTAGE**

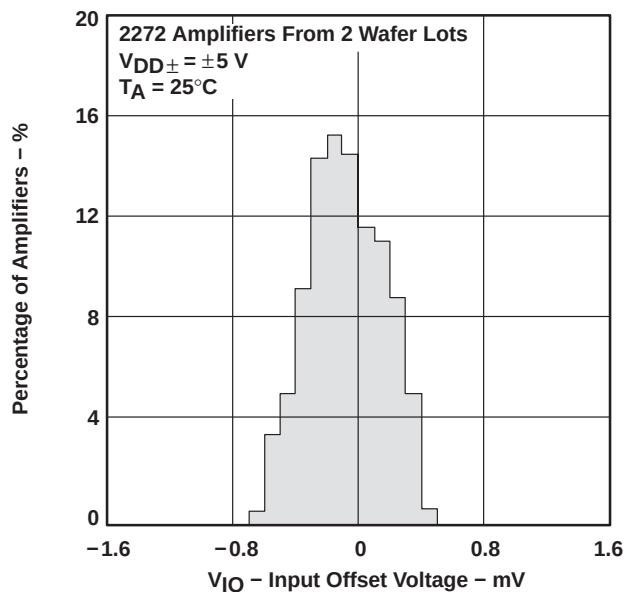
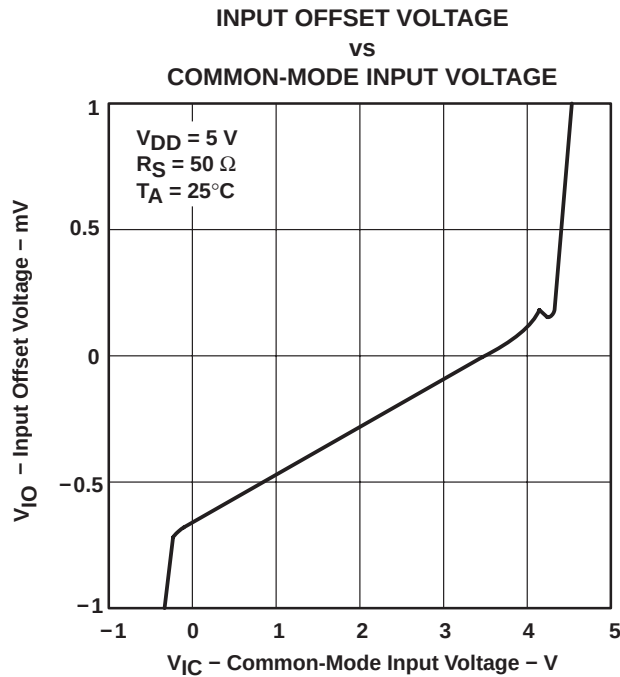


Figure 5

TYPICAL CHARACTERISTICS



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

Figure 6

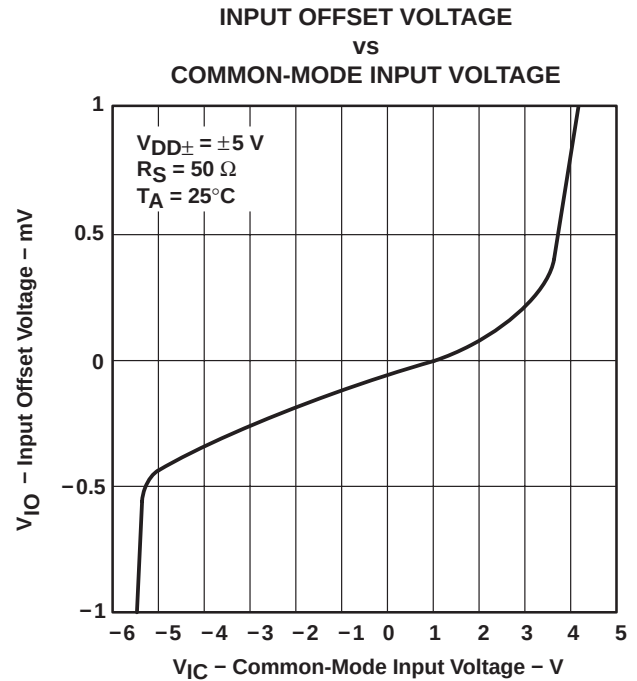


Figure 7

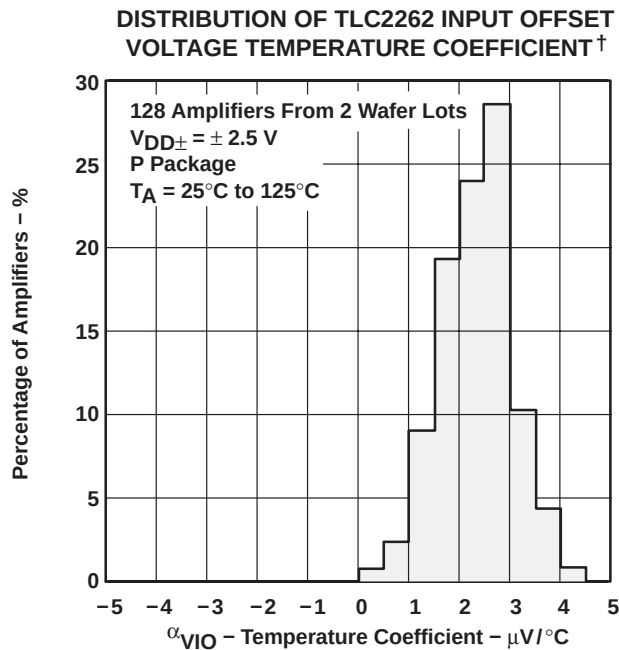


Figure 8

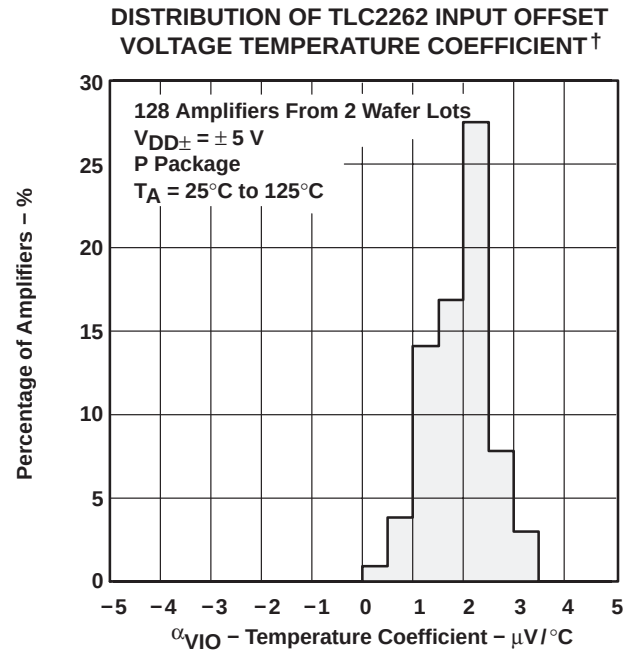


Figure 9

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

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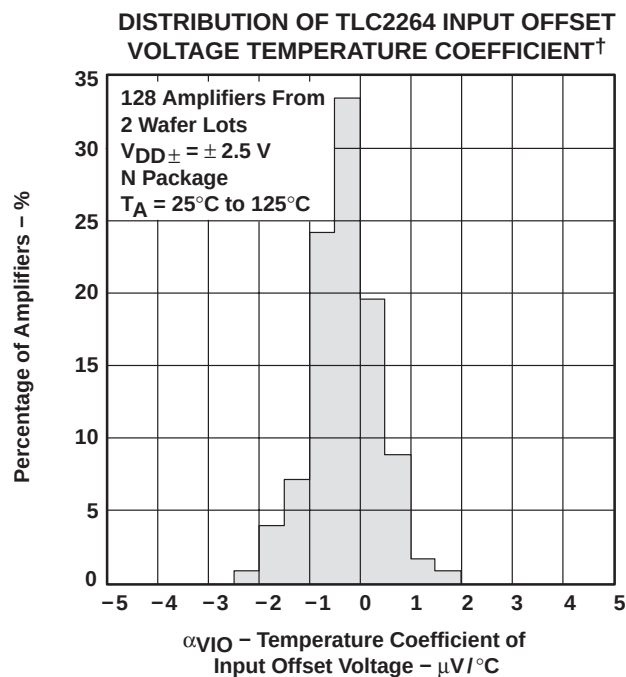


Figure 10

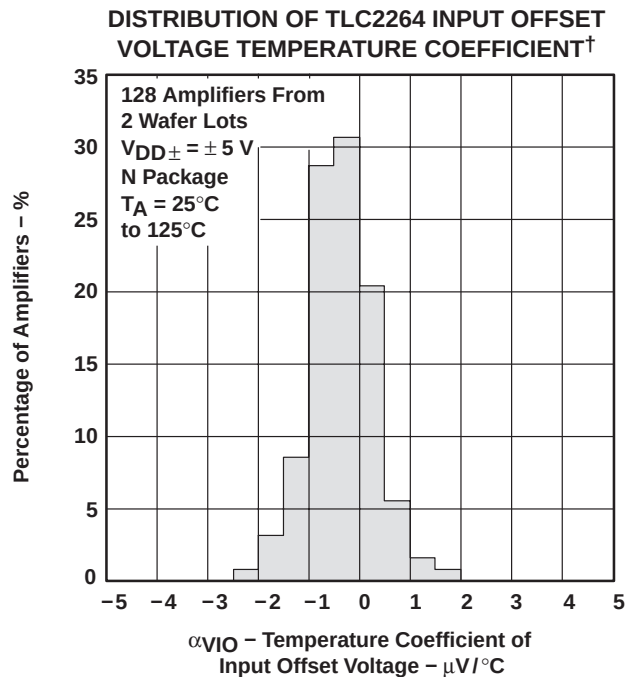


Figure 11

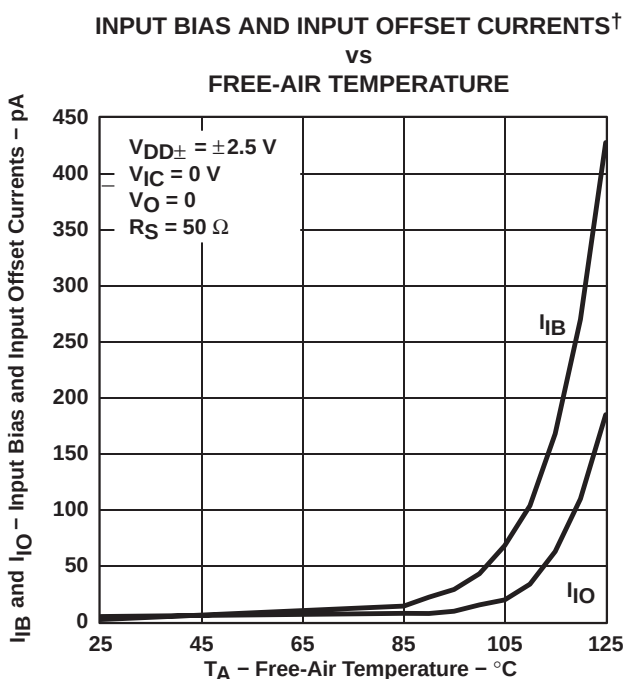


Figure 12

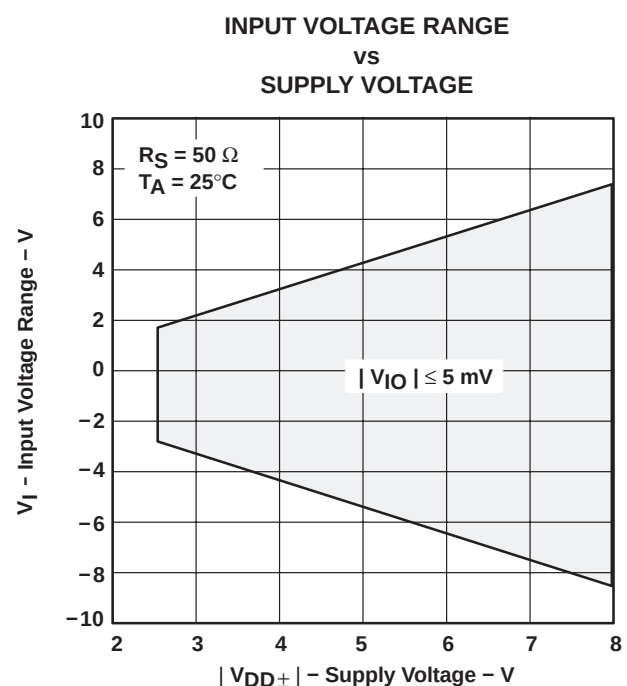


Figure 13

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

TYPICAL CHARACTERISTICS

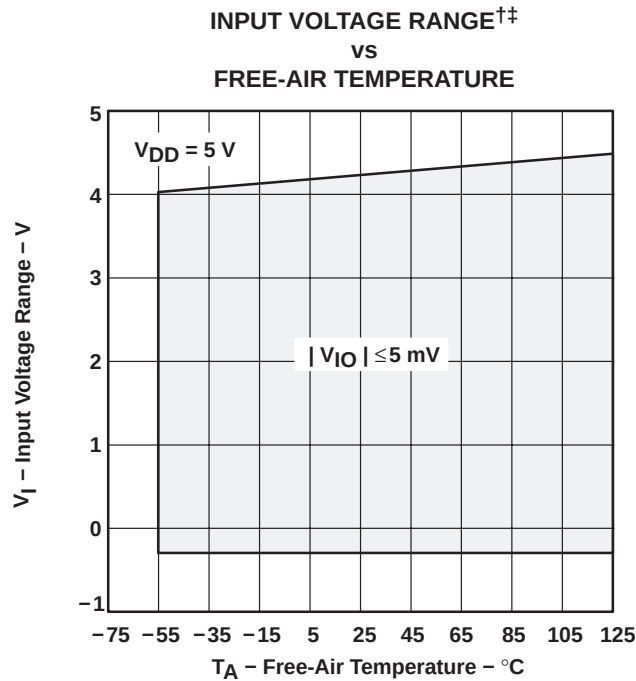


Figure 14

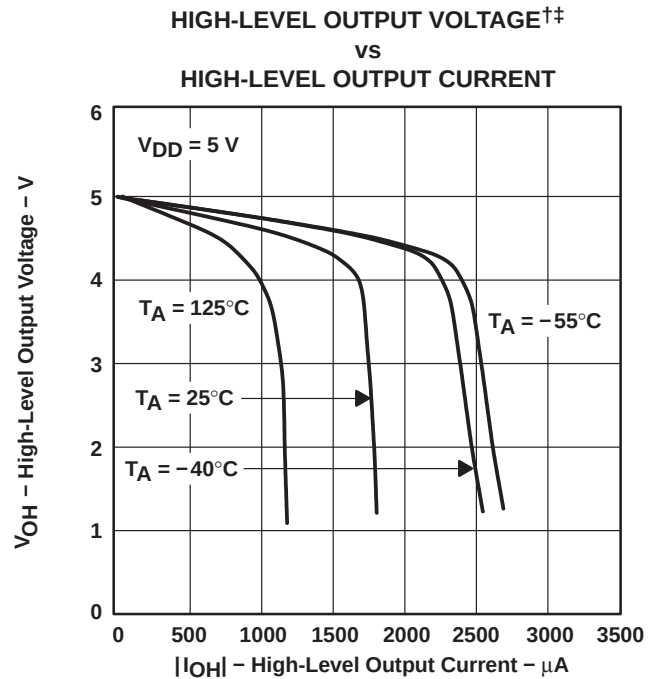


Figure 15

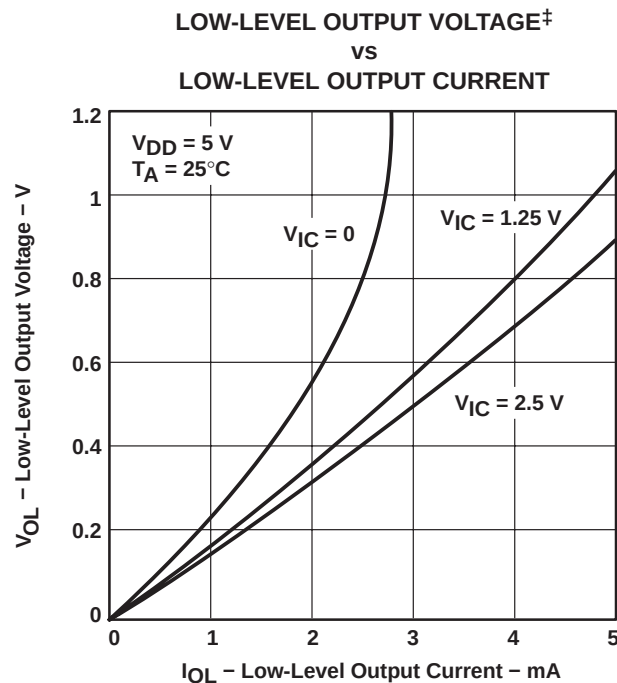


Figure 16

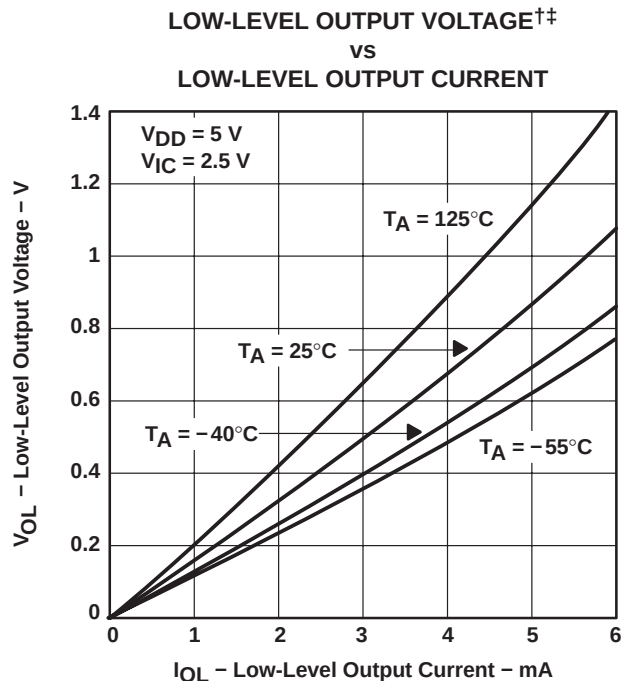


Figure 17

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

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

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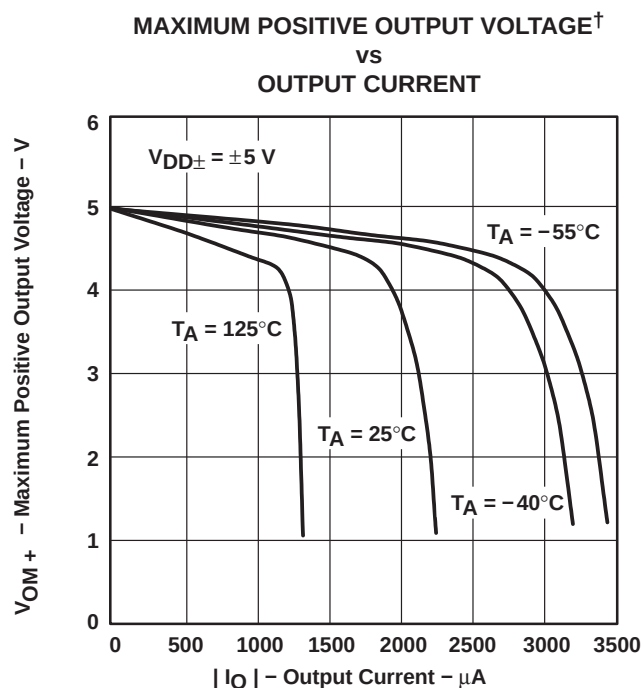


Figure 18

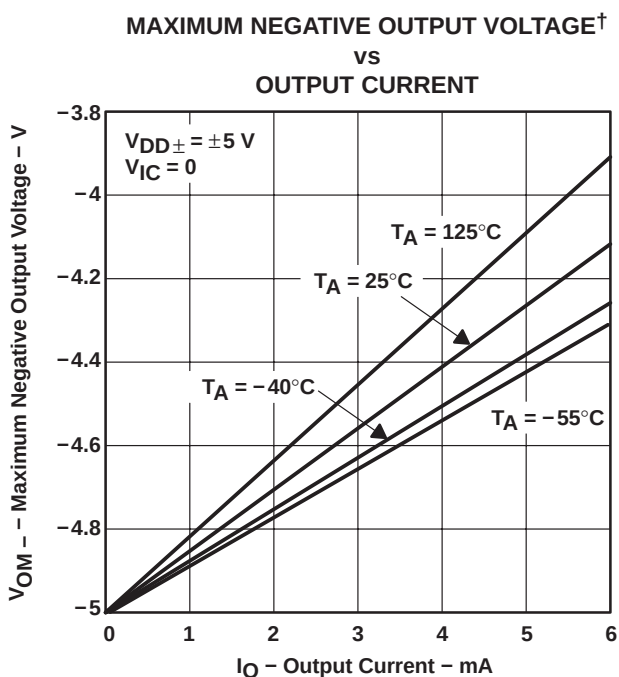


Figure 19

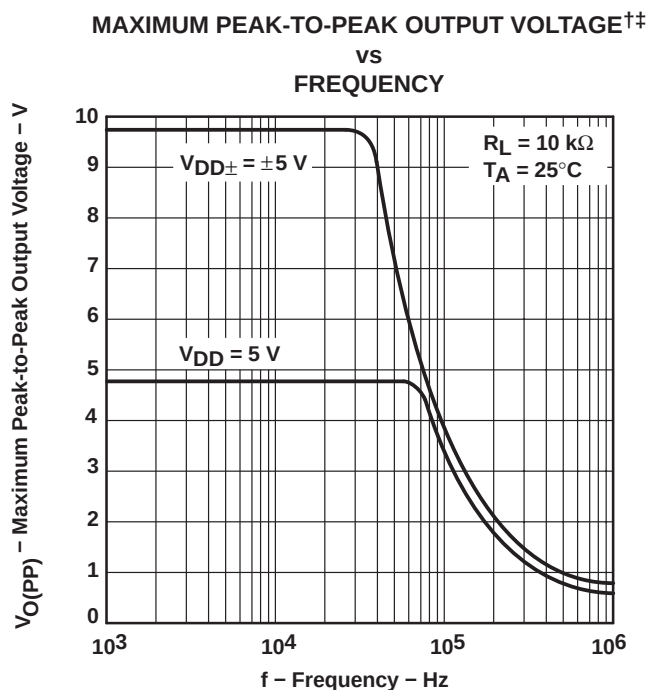


Figure 20

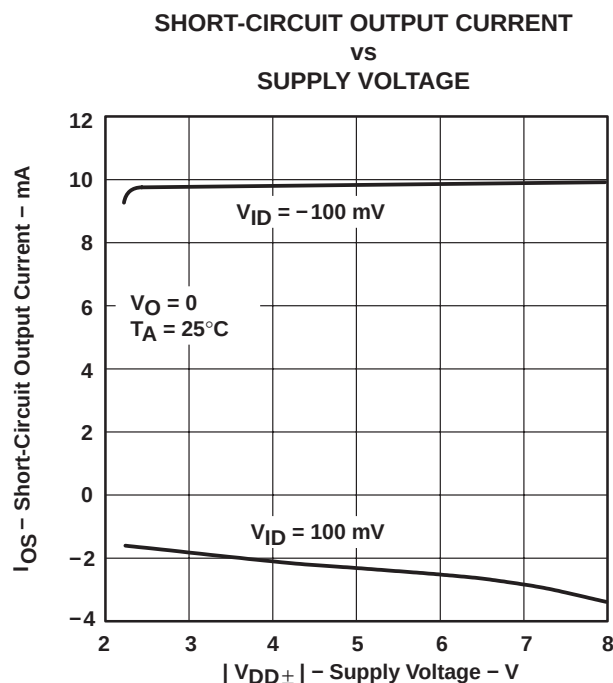


Figure 21

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

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

TYPICAL CHARACTERISTICS

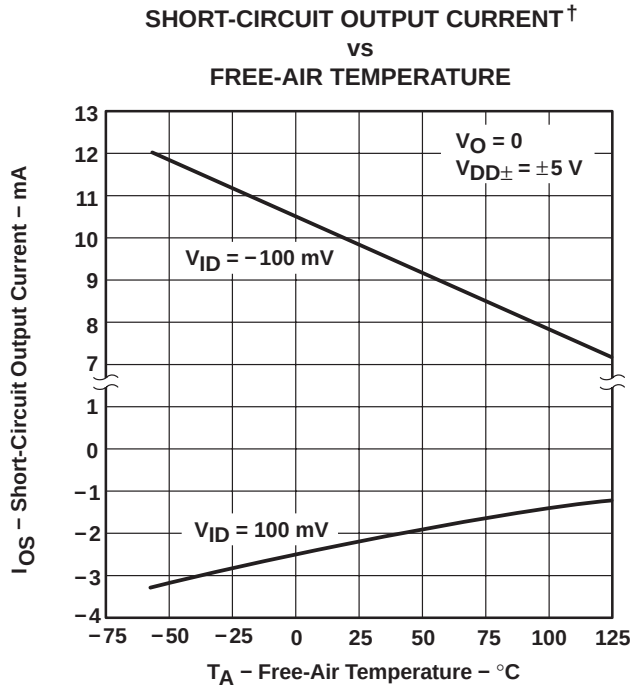


Figure 22

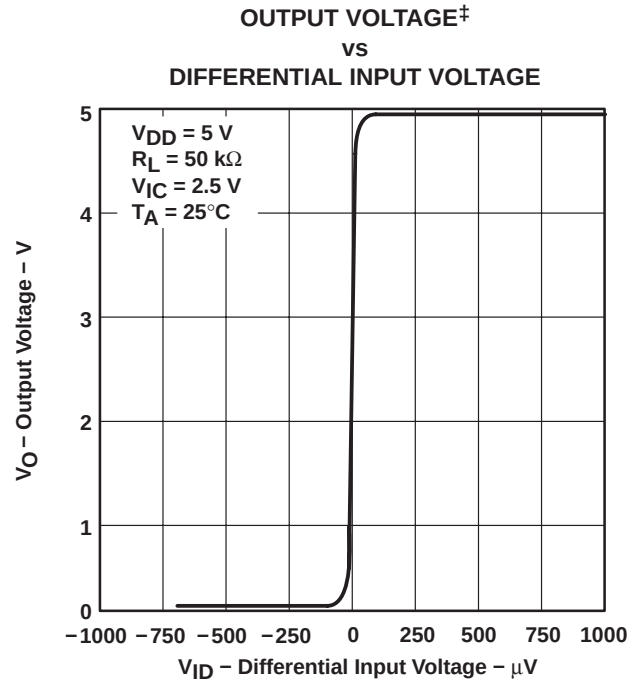


Figure 23

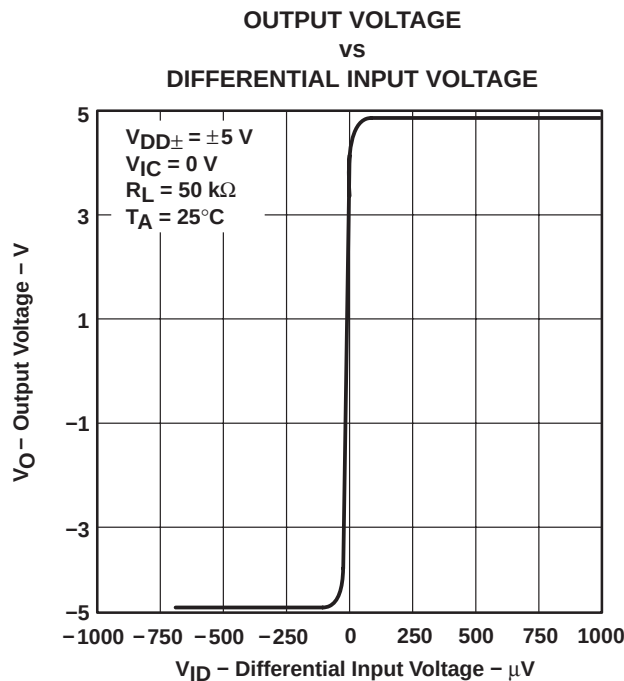


Figure 24

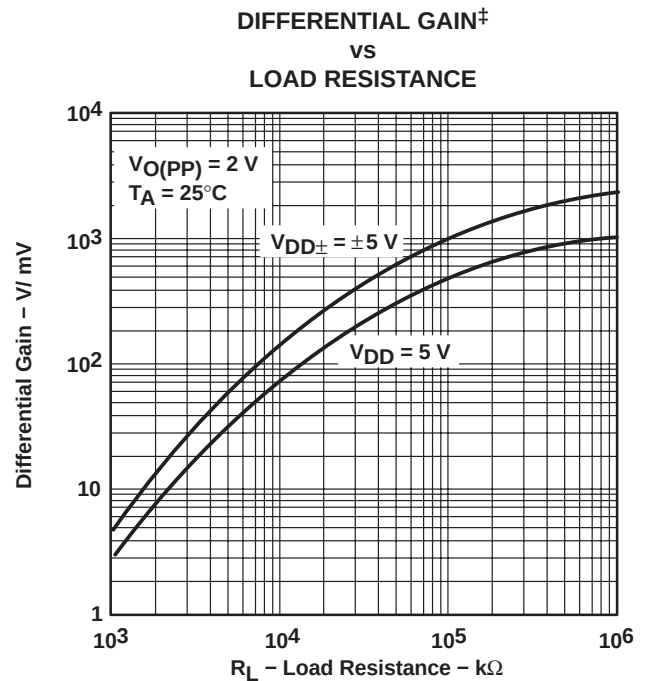


Figure 25

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

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

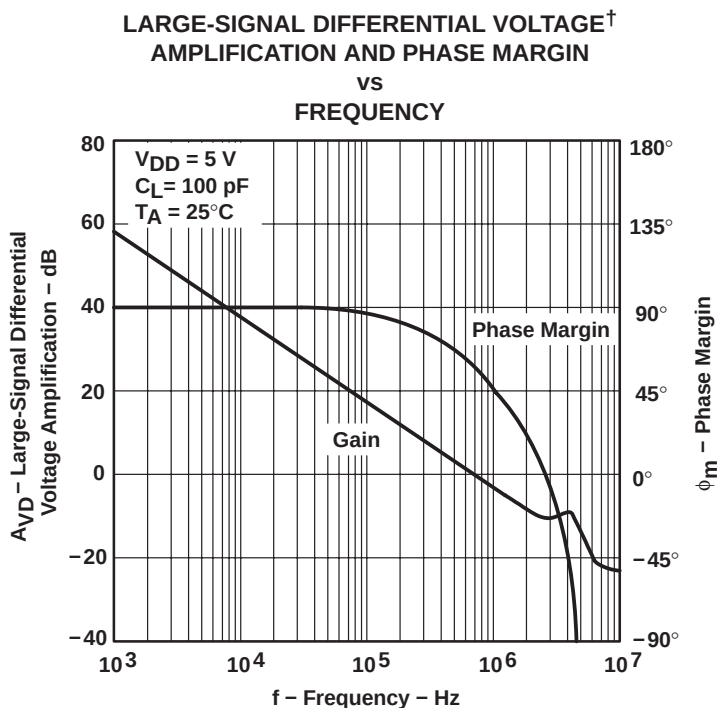
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[†] For curves where $V_{DD} = 5\text{ V}$, all loads are referenced to 2.5 V.

Figure 26

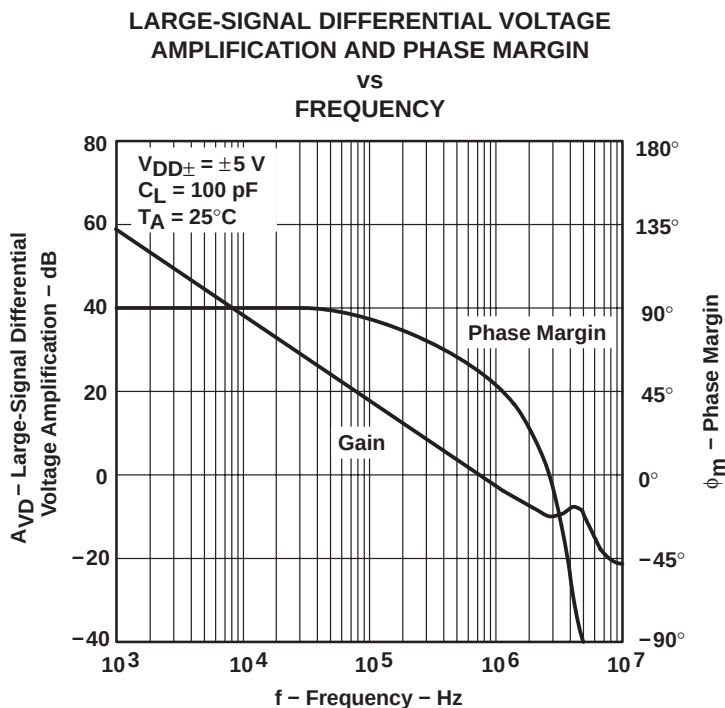


Figure 27

TYPICAL CHARACTERISTICS

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

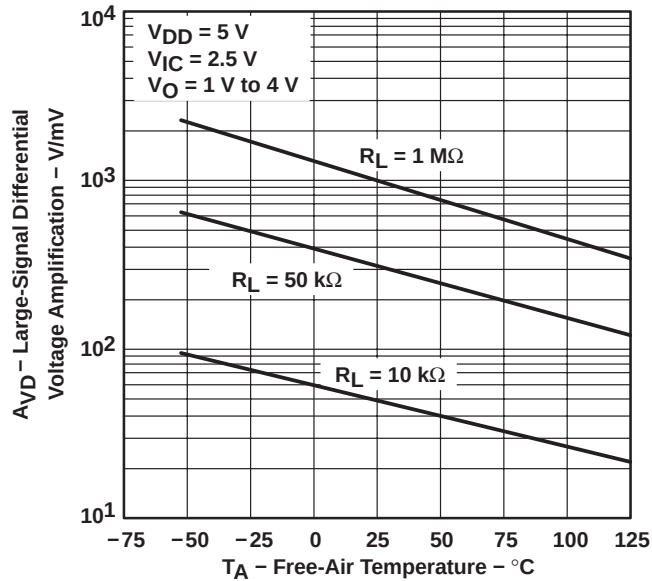


Figure 28

**LARGE-SIGNAL DIFFERENTIAL
VOLTAGE AMPLIFICATION†**
VS
FREE-AIR TEMPERATURE

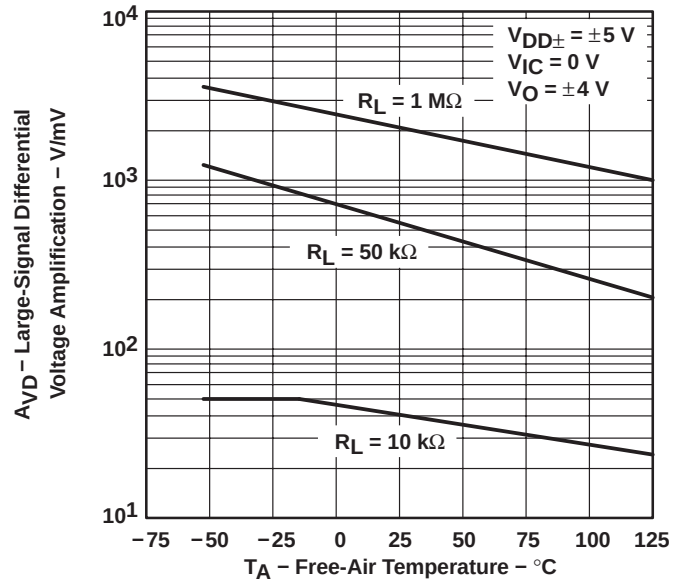


Figure 29

OUTPUT IMPEDANCE‡
VS
FREQUENCY

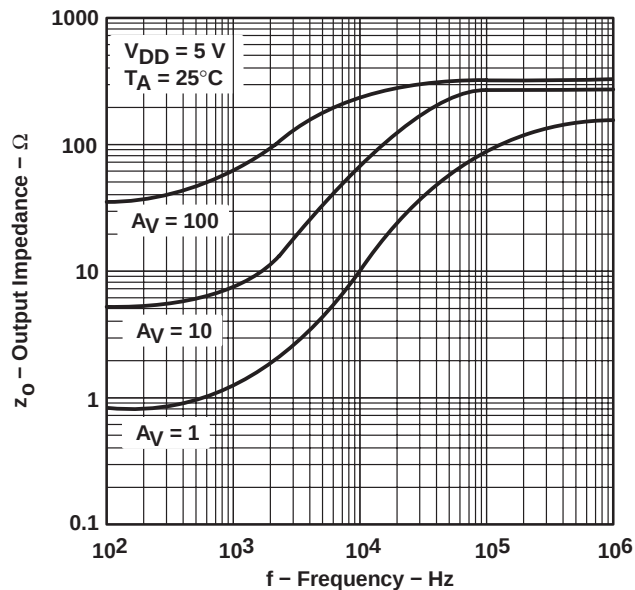


Figure 30

OUTPUT IMPEDANCE
VS
FREQUENCY

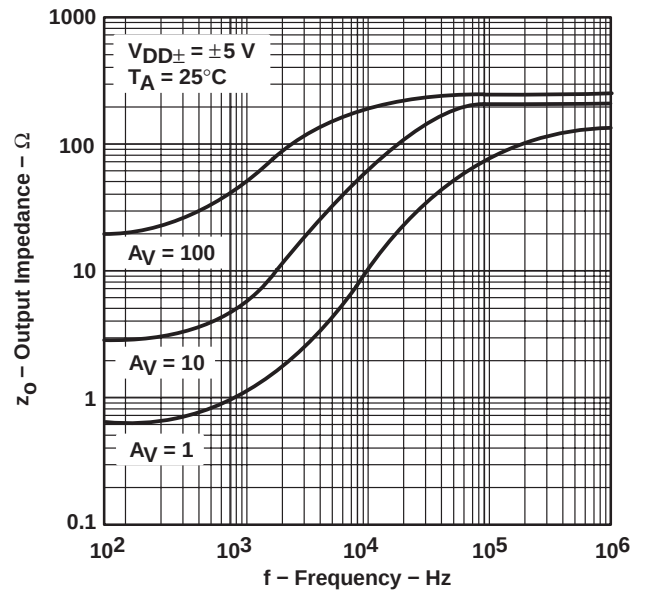


Figure 31

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

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

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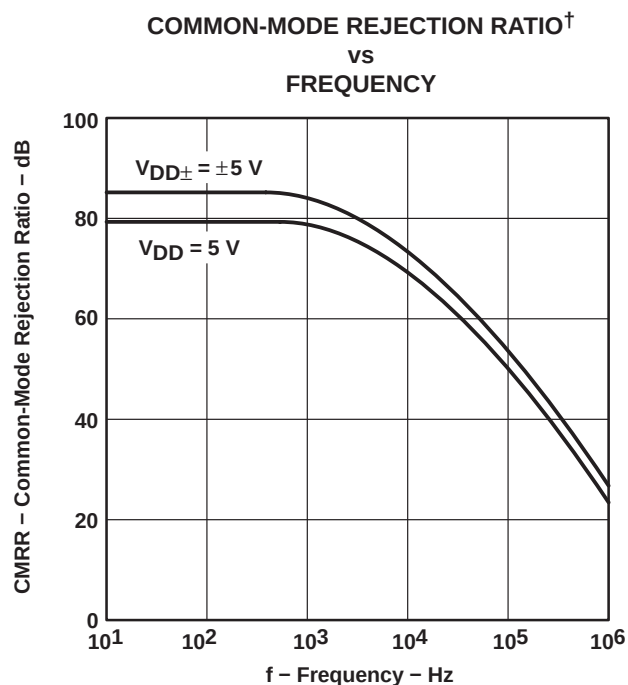


Figure 32

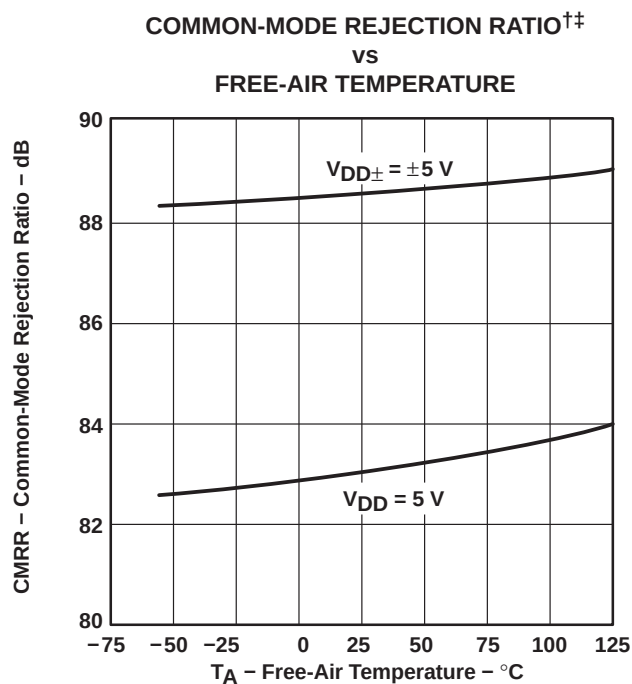


Figure 33

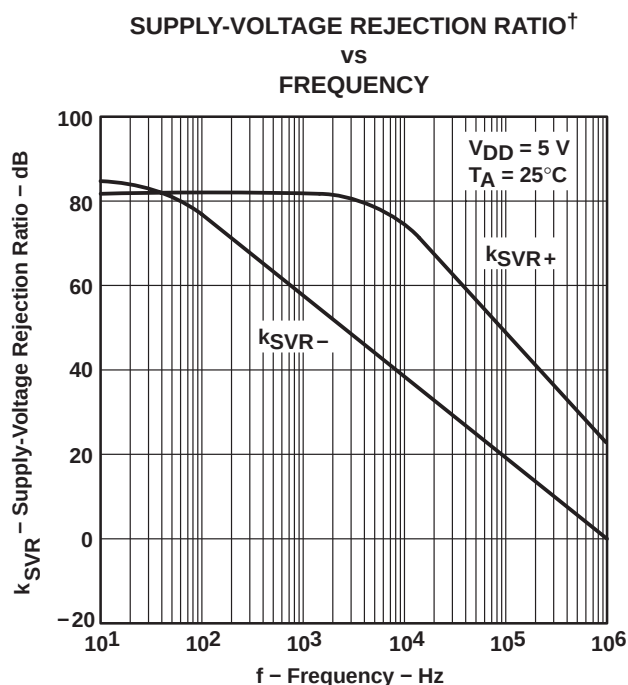


Figure 34

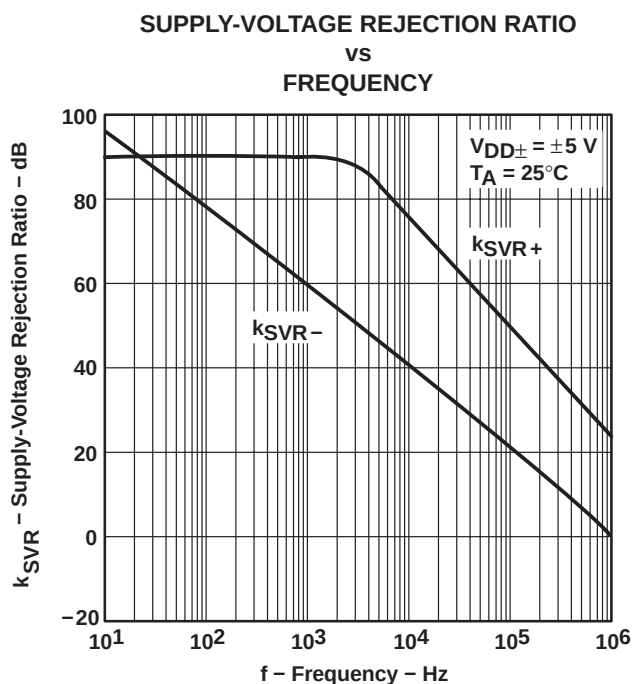


Figure 35

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

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

TYPICAL CHARACTERISTICS

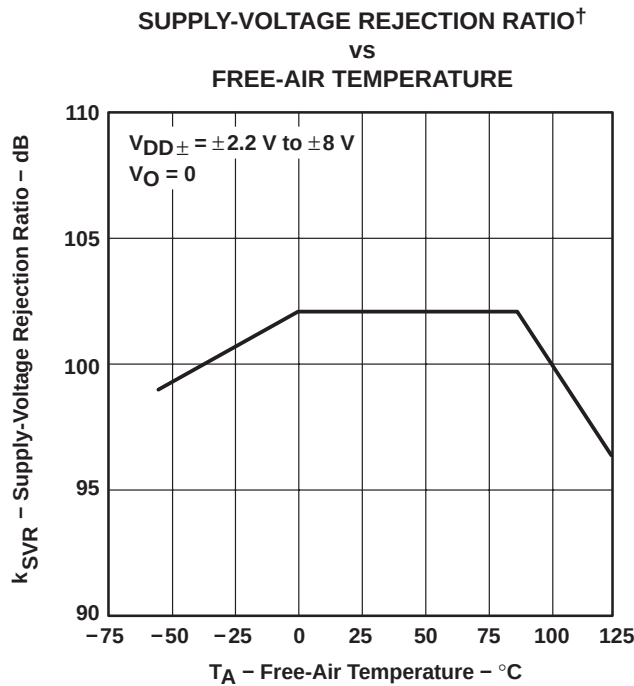


Figure 36

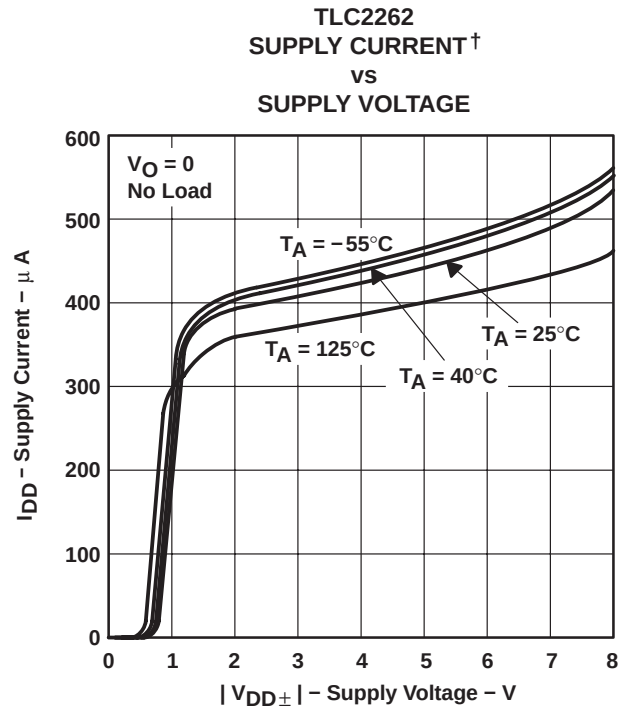


Figure 37

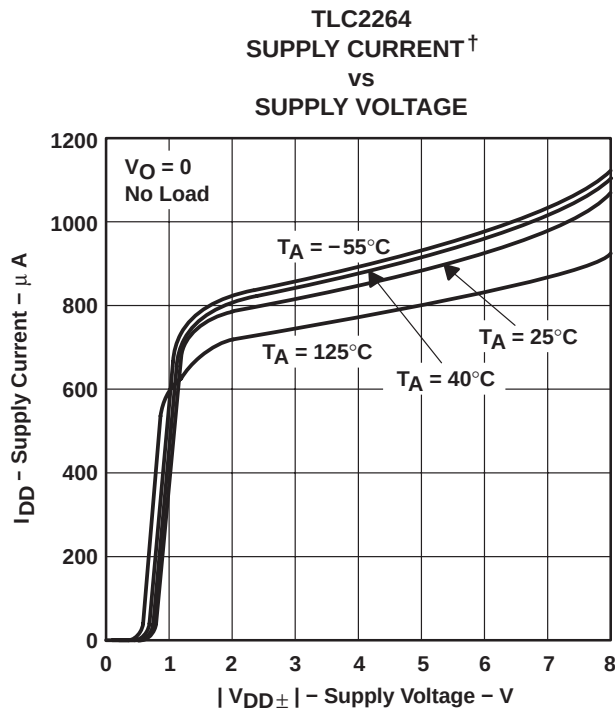


Figure 38

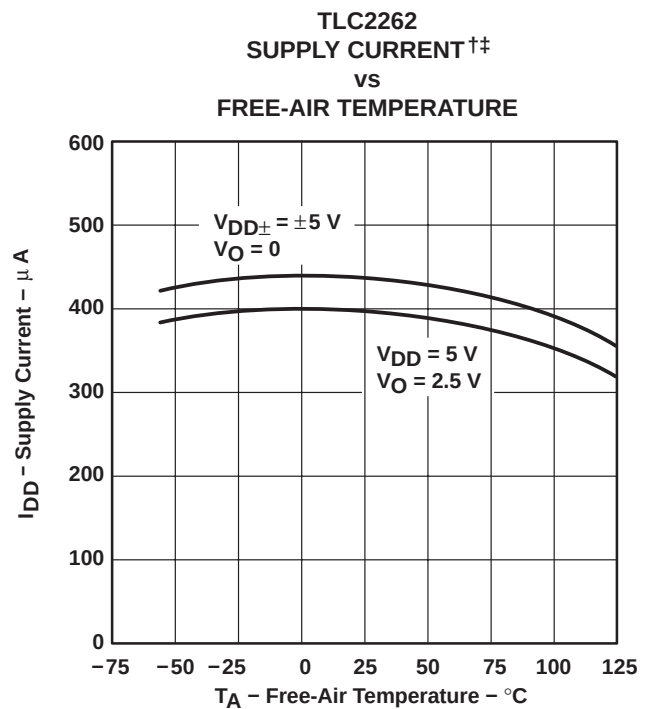


Figure 39

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

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

TLC226x-Q1, TLC226xA-Q1

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TYPICAL CHARACTERISTICS

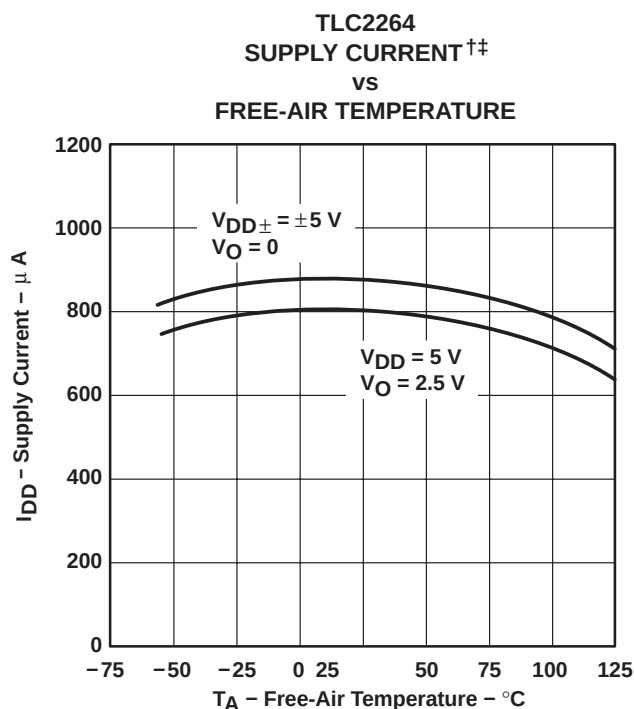


Figure 40

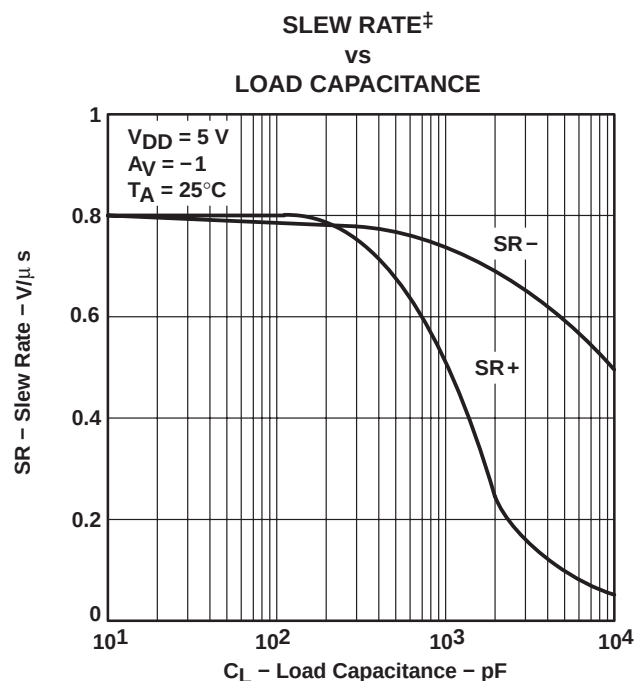


Figure 41

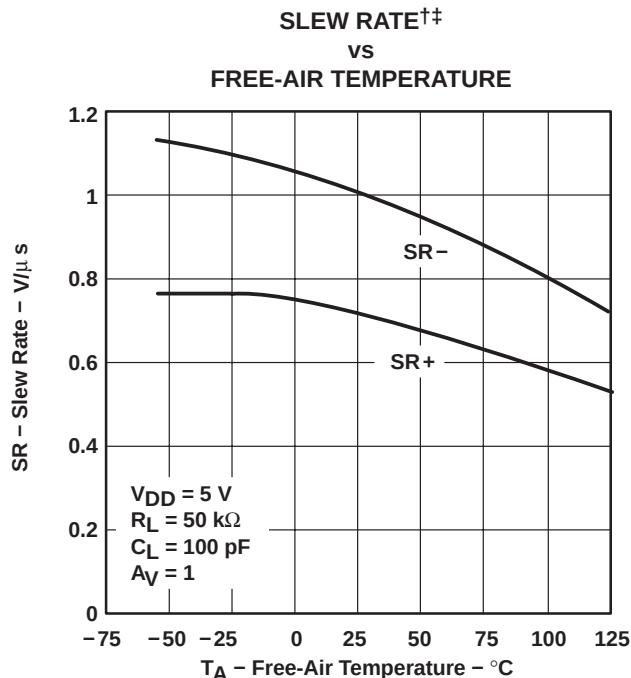


Figure 42

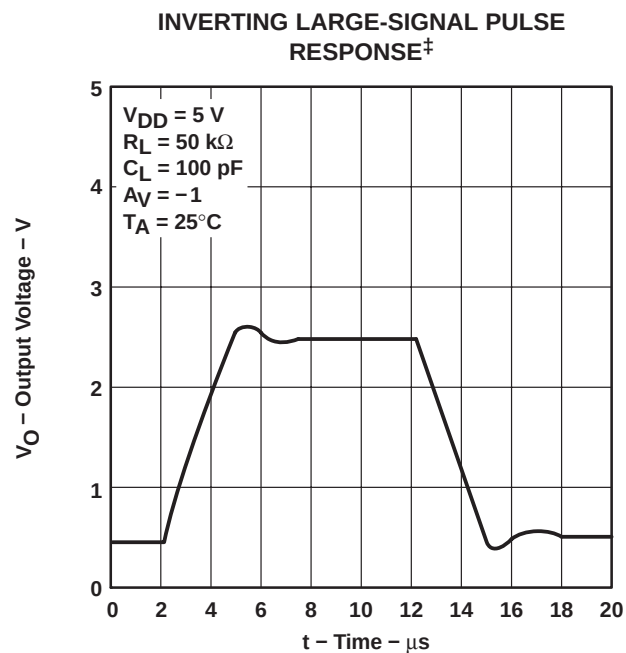


Figure 43

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

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

TYPICAL CHARACTERISTICS

INVERTING LARGE-SIGNAL PULSE RESPONSE

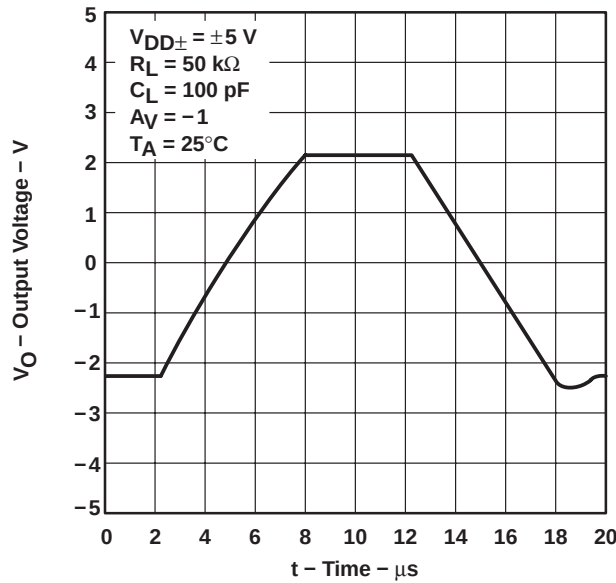


Figure 44

VOLTAGE-FOLLOWER LARGE-SIGNAL PULSE RESPONSE†

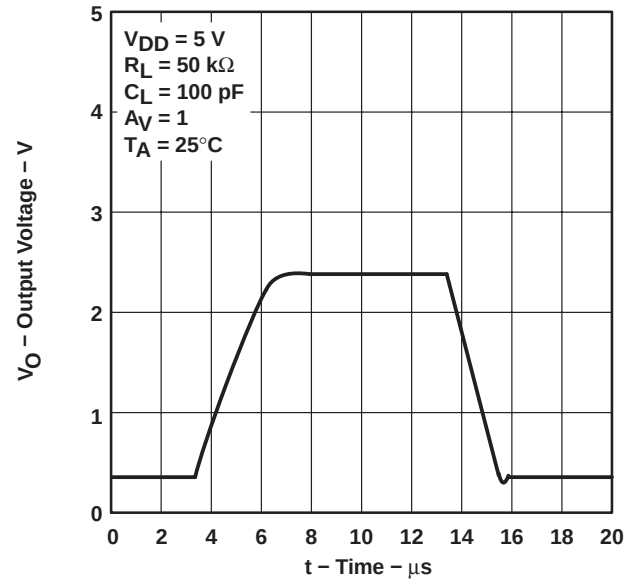


Figure 45

VOLTAGE-FOLLOWER LARGE-SIGNAL PULSE RESPONSE

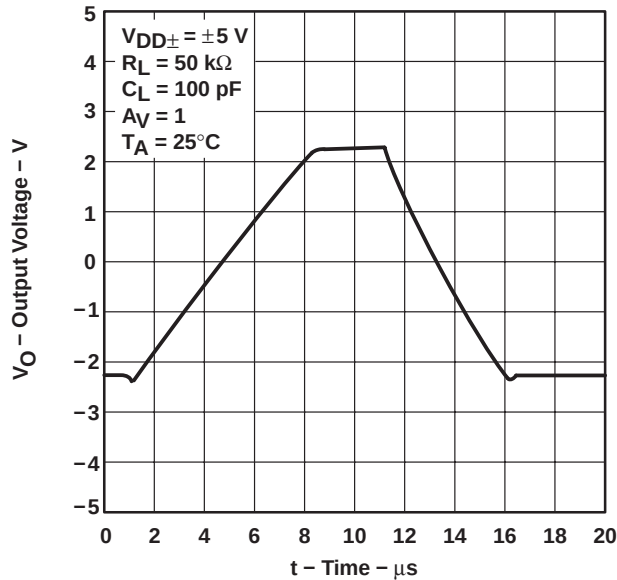


Figure 46

INVERTING SMALL-SIGNAL PULSE RESPONSE†

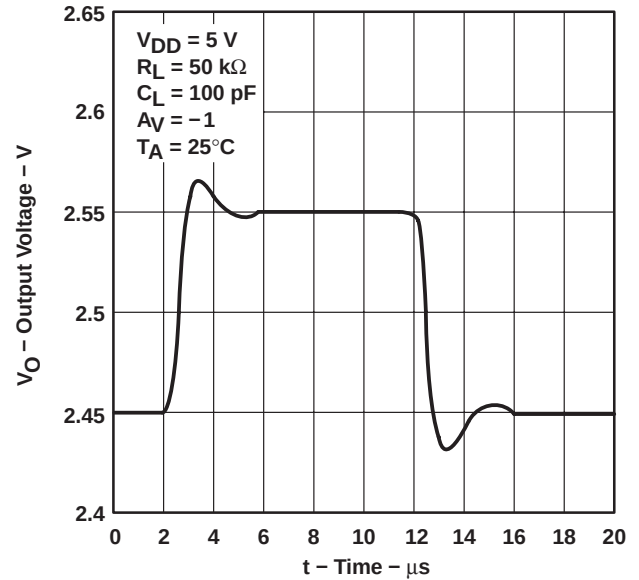


Figure 47

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

TLC226x-Q1, TLC226xA-Q1

Advanced LinCMOS™ RAIL-TO-RAIL

OPERATIONAL AMPLIFIERS

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TYPICAL CHARACTERISTICS

INVERTING SMALL-SIGNAL
PULSE RESPONSE

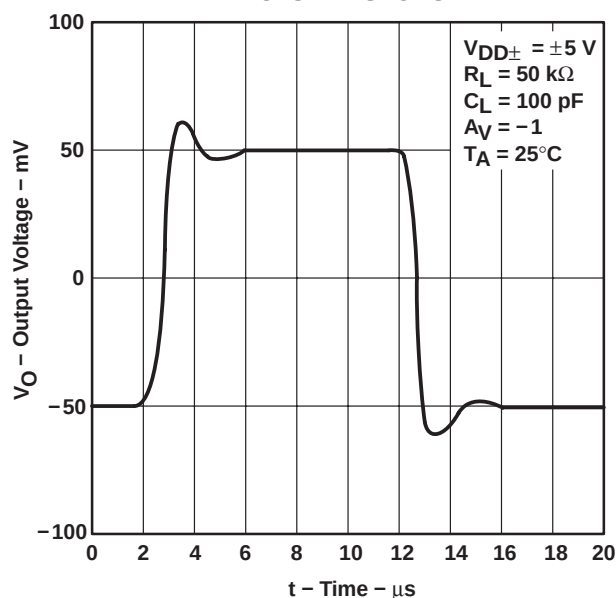


Figure 48

VOLTAGE-FOLLOWER SMALL-SIGNAL
PULSE RESPONSE†

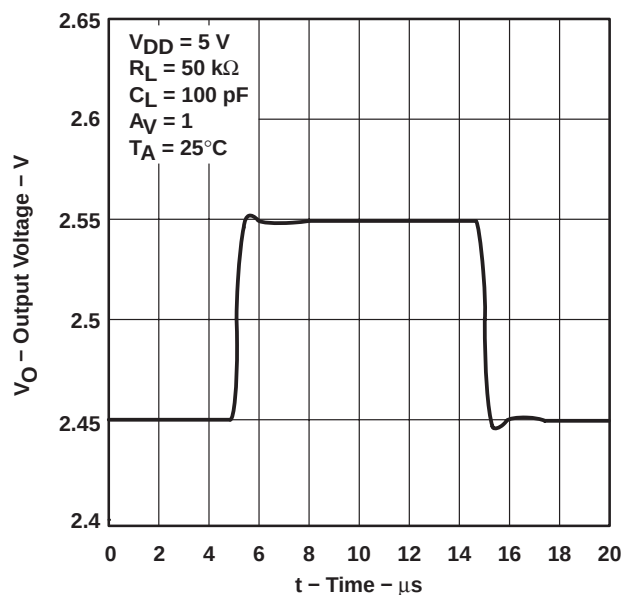


Figure 49

VOLTAGE-FOLLOWER SMALL-SIGNAL
PULSE RESPONSE

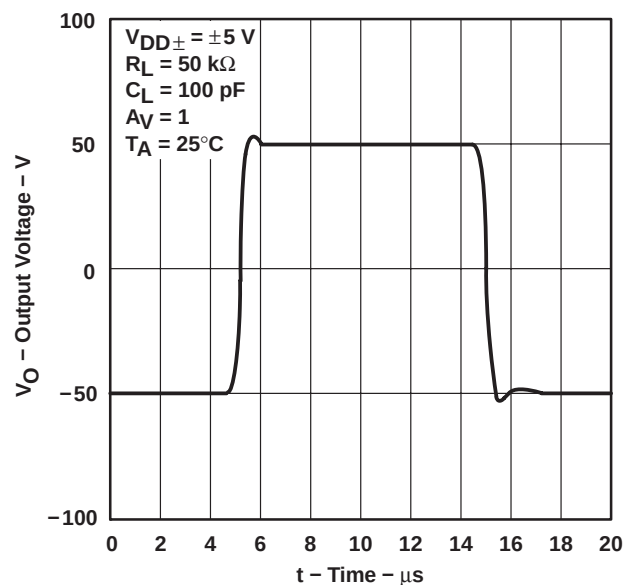


Figure 50

EQUIVALENT INPUT NOISE VOLTAGE†
vs
FREQUENCY

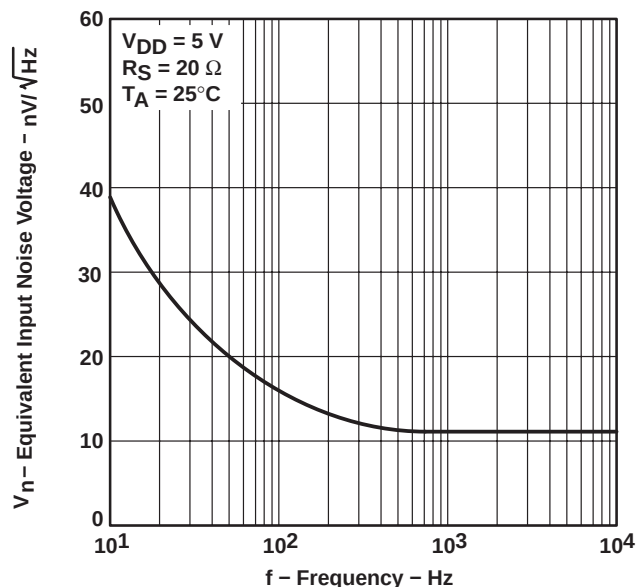


Figure 51

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

TYPICAL CHARACTERISTICS

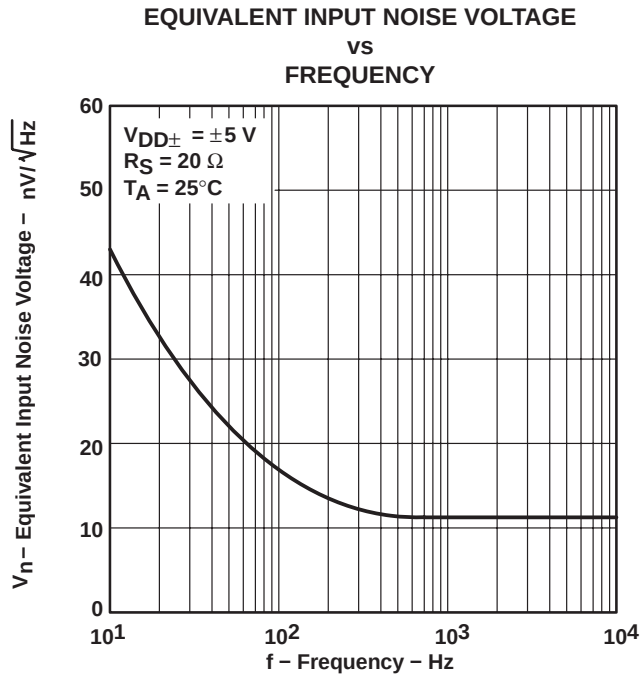


Figure 52

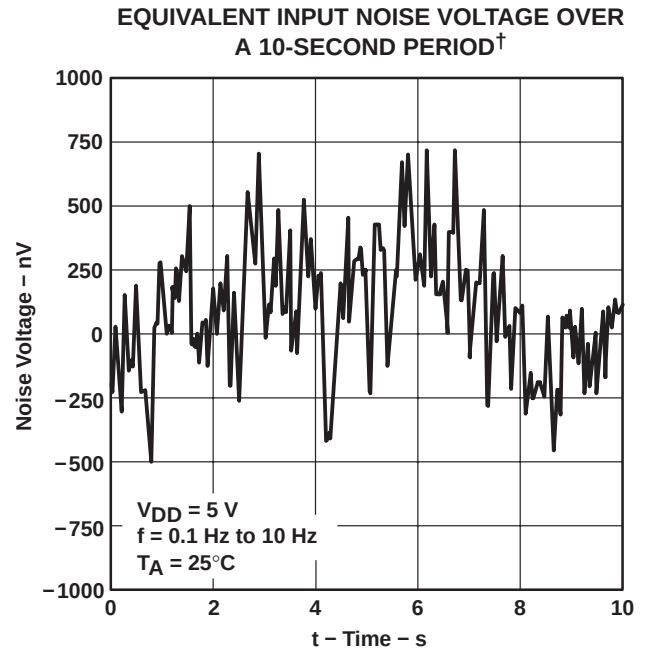


Figure 53

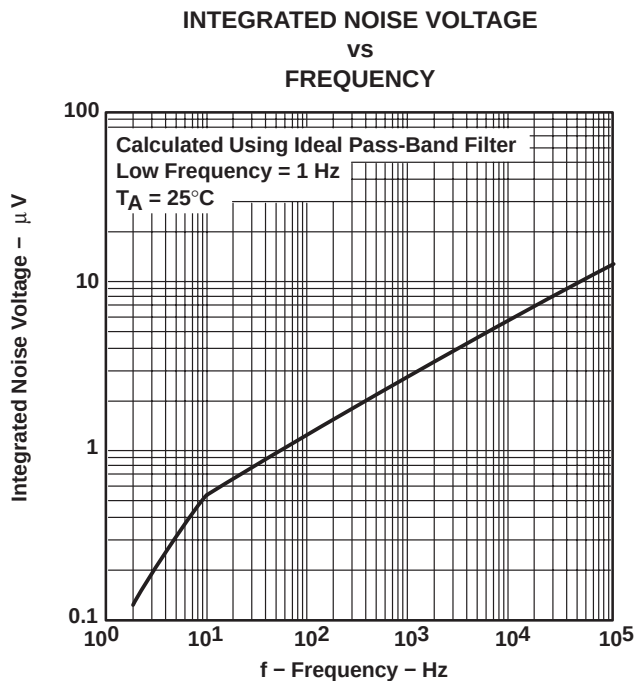


Figure 54

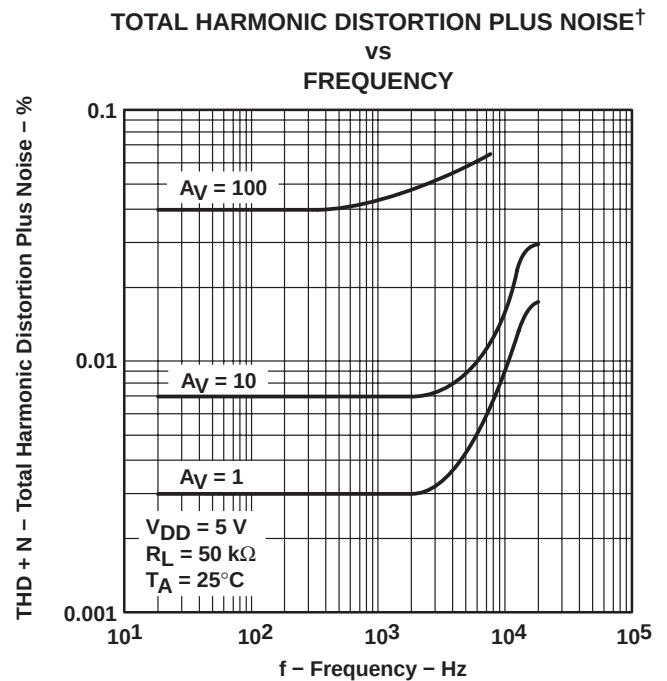


Figure 55

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

TLC226x-Q1, TLC226xA-Q1

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TYPICAL CHARACTERISTICS

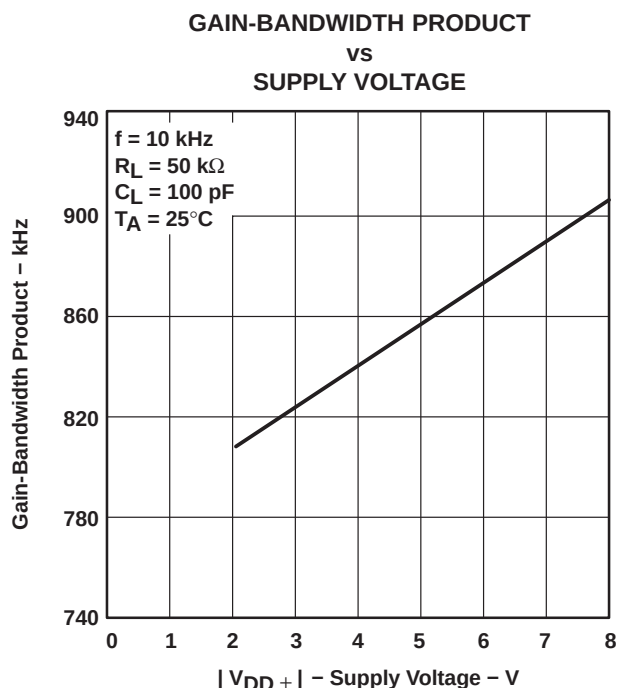


Figure 56

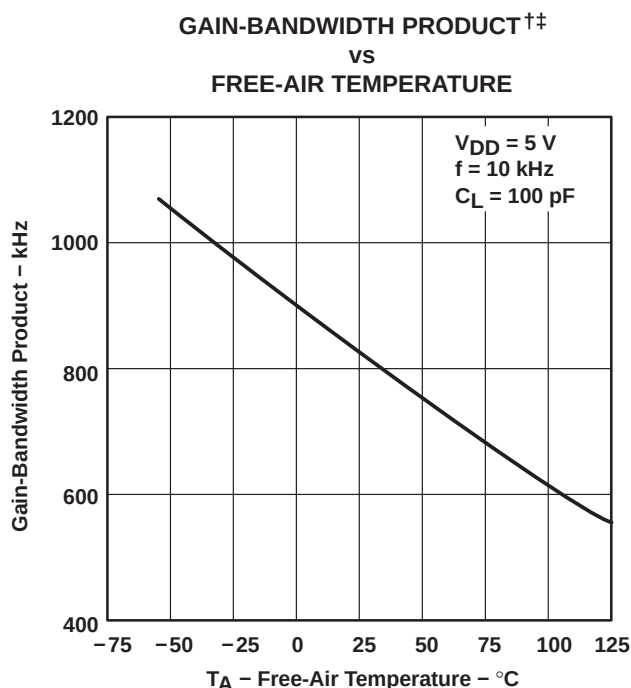


Figure 57

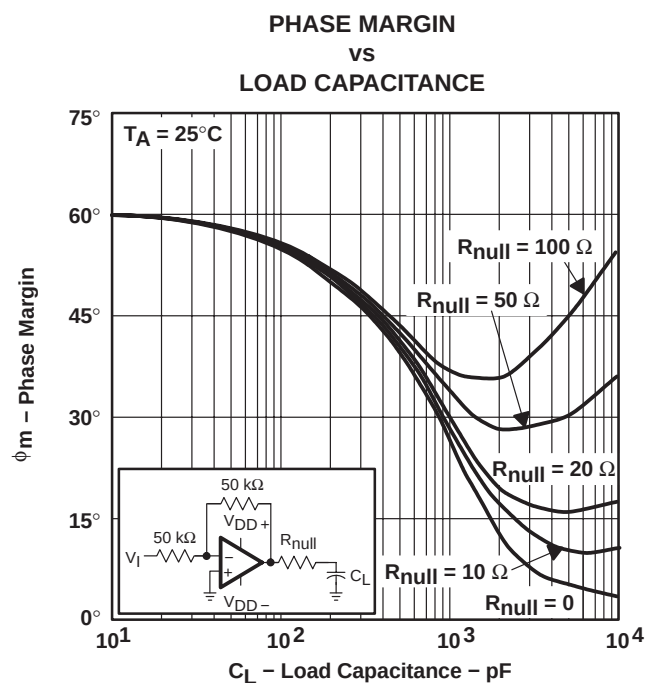


Figure 58

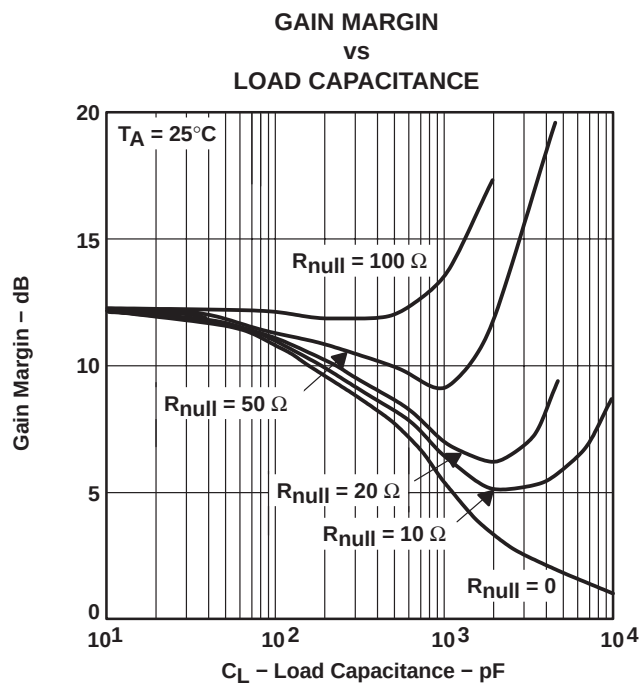


Figure 59

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

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

TYPICAL CHARACTERISTICS

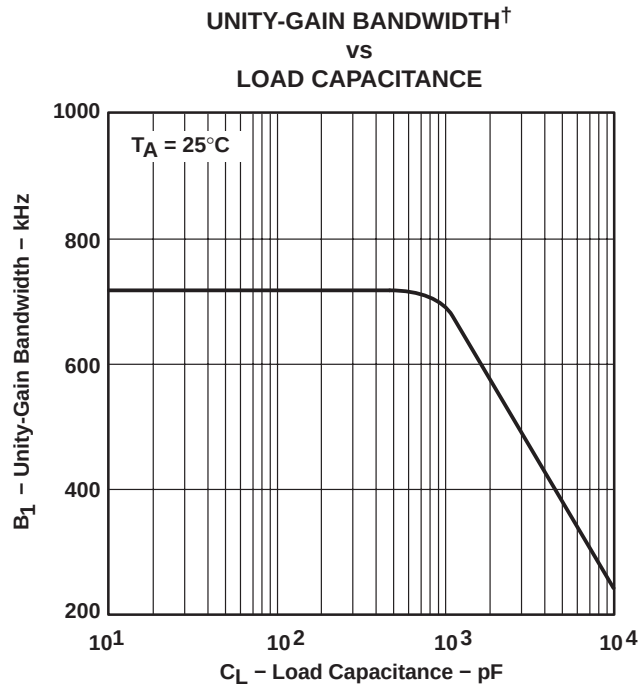


Figure 60

[†] See application information

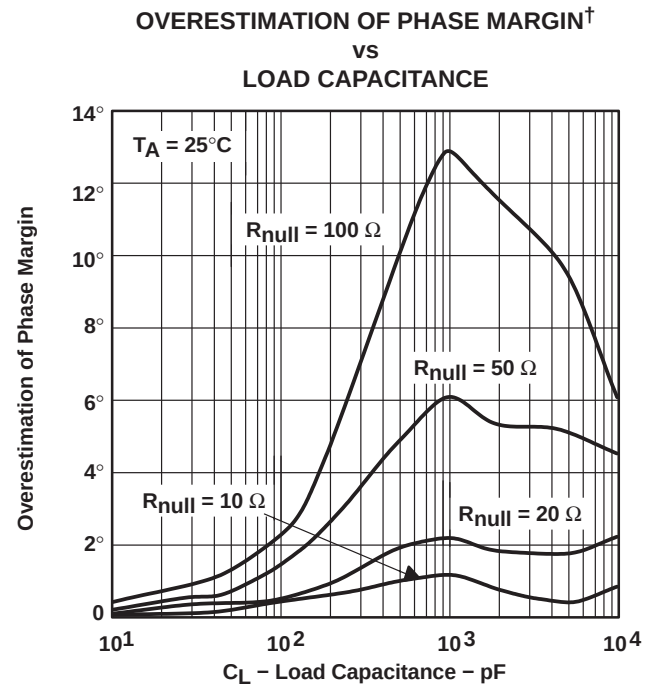


Figure 61

APPLICATION INFORMATION

driving large capacitive loads

The TLC226x is designed to drive larger capacitive loads than most CMOS operational amplifiers. Figure 58 and Figure 59 illustrate its ability to drive loads greater than 400 pF while maintaining good gain and phase margins ($R_{null} = 0$).

A smaller series resistor (R_{null}) at the output of the device (see Figure 62) improves the gain and phase margins when driving large capacitive loads. Figure 58 and Figure 59 show the effects of adding series resistances of 10 Ω , 20 Ω , 50 Ω , and 100 Ω . The addition of this series resistor has two effects: the first is that it adds a zero to the transfer function and the second is that it reduces the frequency of the pole associated with the output load in the transfer function.

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

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

Where :

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

The unity-gain bandwidth (UGBW) frequency decreases as the capacitive load increases (see Figure 60). To use equation 1, UGBW must be approximated from Figure 60.

Using equation 1 alone overestimates the improvement in phase margin, as illustrated in Figure 61. The overestimation is caused by the decrease in the frequency of the pole associated with the load, thus providing additional phase shift and reducing the overall improvement in phase margin. The pole associated with the load is reduced by the factor calculated in equation 2.

$$F = \frac{1}{1 + g_m \times R_{null}} \quad (2)$$

Where :

- F = factor reducing frequency of pole
- g_m = small-signal output transconductance (typically 4.83×10^{-3} mhos)
- R_{null} = output series resistance

For the TLC226x, the pole associated with the load is typically 7 MHz with 100-pF load capacitance. This value varies inversely with C_L : at $C_L = 10$ pF, use 70 MHz, at $C_L = 1000$ pF, use 700 kHz, and so on.

Reducing the pole associated with the load introduces phase shift, thereby reducing phase margin. This results in an error in the increase in phase margin expected by considering the zero alone (equation 1). Equation 3 approximates the reduction in phase margin due to the movement of the pole associated with the load. The result of this equation can be subtracted from the result of the equation in equation 1 to better approximate the improvement in phase margin.

APPLICATION INFORMATION

driving large capacitive loads (continued)

$$\Delta\theta_{m2} = \tan^{-1} \left[\frac{UGBW}{(F \times P_2)} \right] - \tan^{-1} \left(\frac{UGBW}{P_2} \right) \quad (3)$$

Where :

$\Delta\theta_{m2}$ = reduction in phase margin

UGBW = unity-gain bandwidth frequency

F = factor from equation 2

P_2 = unadjusted pole (70 MHz @10 pF, 7 MHz @100 pF, etc.)

Using these equations with Figure 60 and Figure 61 enables the designer to choose the appropriate output series resistance to optimize the design of circuits driving large capacitive loads.

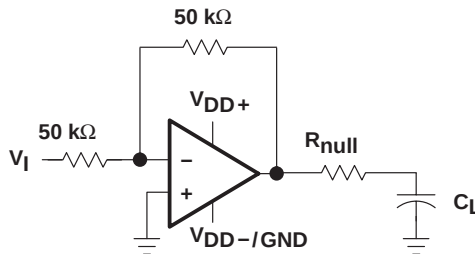


Figure 62. Series-Resistance Circuit

TLC226x-Q1, TLC226xA-Q1

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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 63 are generated using the TLC226x typical electrical and operating characteristics at $T_A = 25^\circ\text{C}$. Using this information, output simulations of the following key parameters can be generated to a tolerance of 20% (in most cases):

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

NOTE 4: G. R. Boyle, B. M. Cohn, D. O. Pederson, and J. E. Solomon, "Macromodeling of Integrated Circuit Operational Amplifiers," *IEEE Journal of Solid-State Circuits*, SC-9, 353 (1974).

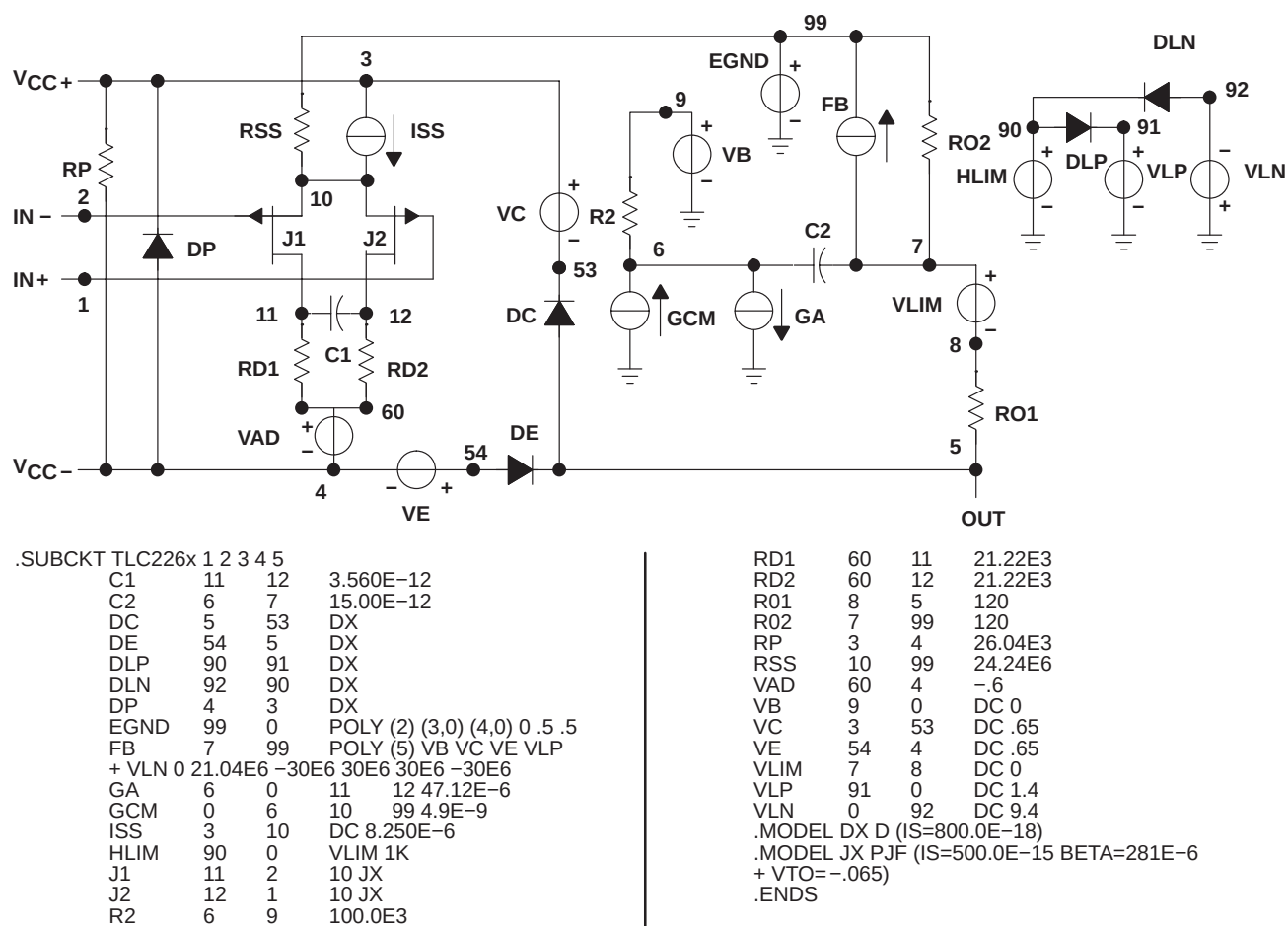


Figure 63. Boyle Macromodel and Subcircuit

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POST OFFICE BOX 655303 • DALLAS, TEXAS 75265

PACKAGING INFORMATION

Orderable part number	Status (1)	Material type (2)	Package Pins	Package qty Carrier	RoHS (3)	Lead finish/ Ball material (4)	MSL rating/ Peak reflow (5)	Op temp (°C)	Part marking (6)
TLC2264AQPWRG4Q1	Active	Production	TSSOP (PW) 14	2000 LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	2264AQ
TLC2264AQPWRG4Q1.A	Active	Production	TSSOP (PW) 14	2000 LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	2264AQ
TLC2264AQPWRG4Q1.B	Active	Production	TSSOP (PW) 14	2000 LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	2264AQ
TLC2264AQPWRQ1	Active	Production	TSSOP (PW) 14	2000 LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	2264AQ
TLC2264AQPWRQ1.A	Active	Production	TSSOP (PW) 14	2000 LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	2264AQ
TLC2264AQPWRQ1.B	Active	Production	TSSOP (PW) 14	2000 LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	2264AQ

⁽¹⁾ **Status:** For more details on status, see our [product life cycle](#).

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

⁽³⁾ **RoHS values:** Yes, No, RoHS Exempt. See the [TI RoHS Statement](#) for additional information and value definition.

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

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

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

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

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

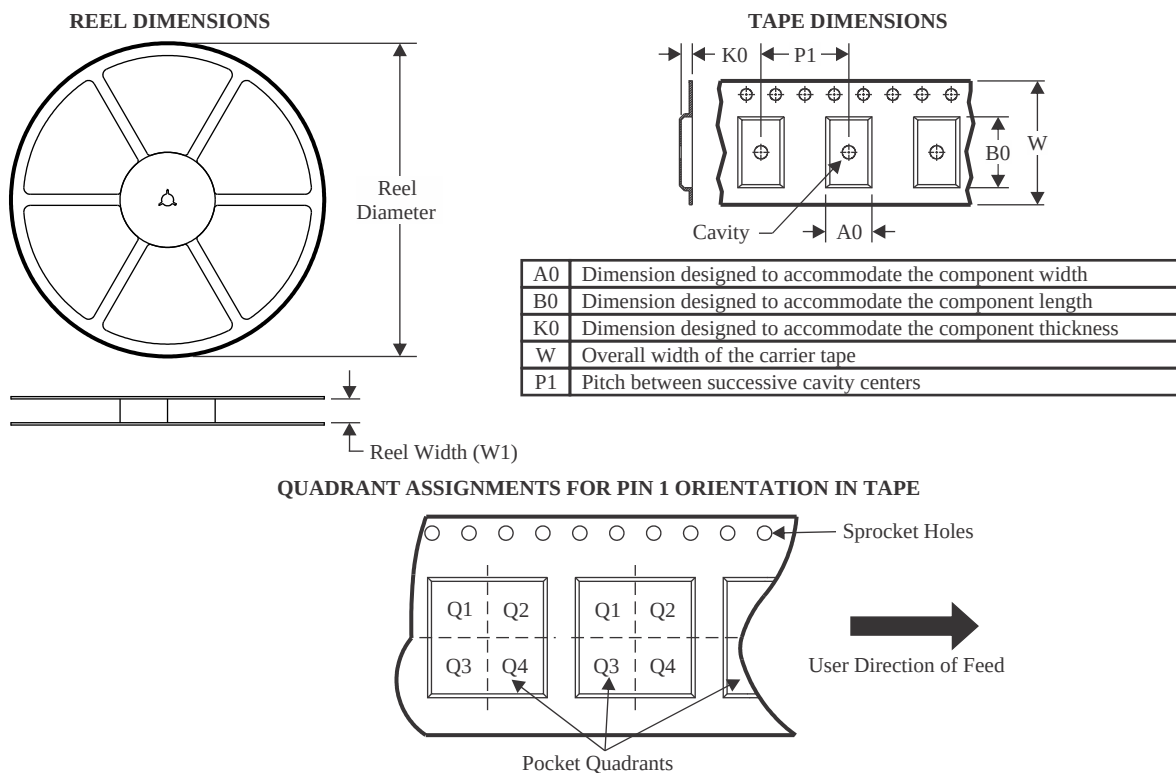
OTHER QUALIFIED VERSIONS OF TLC2264A-Q1 :

- Catalog : [TLC2264A](#)
- Military : [TLC2264AM](#)

NOTE: Qualified Version Definitions:

- Catalog - TI's standard catalog product
- Military - QML certified for Military and Defense Applications

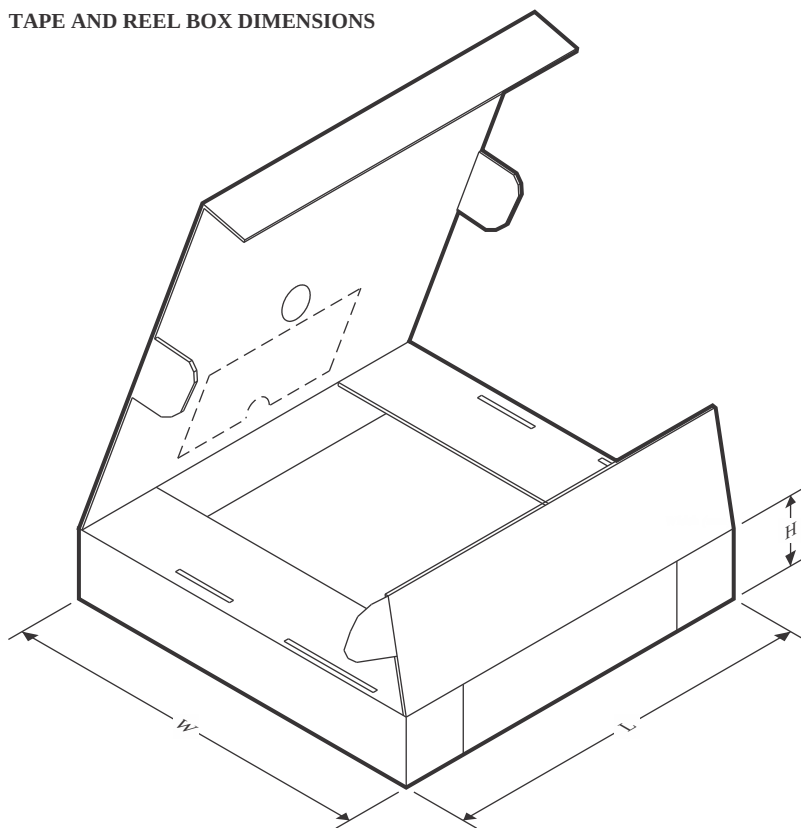
TAPE AND REEL INFORMATION



*All dimensions are nominal

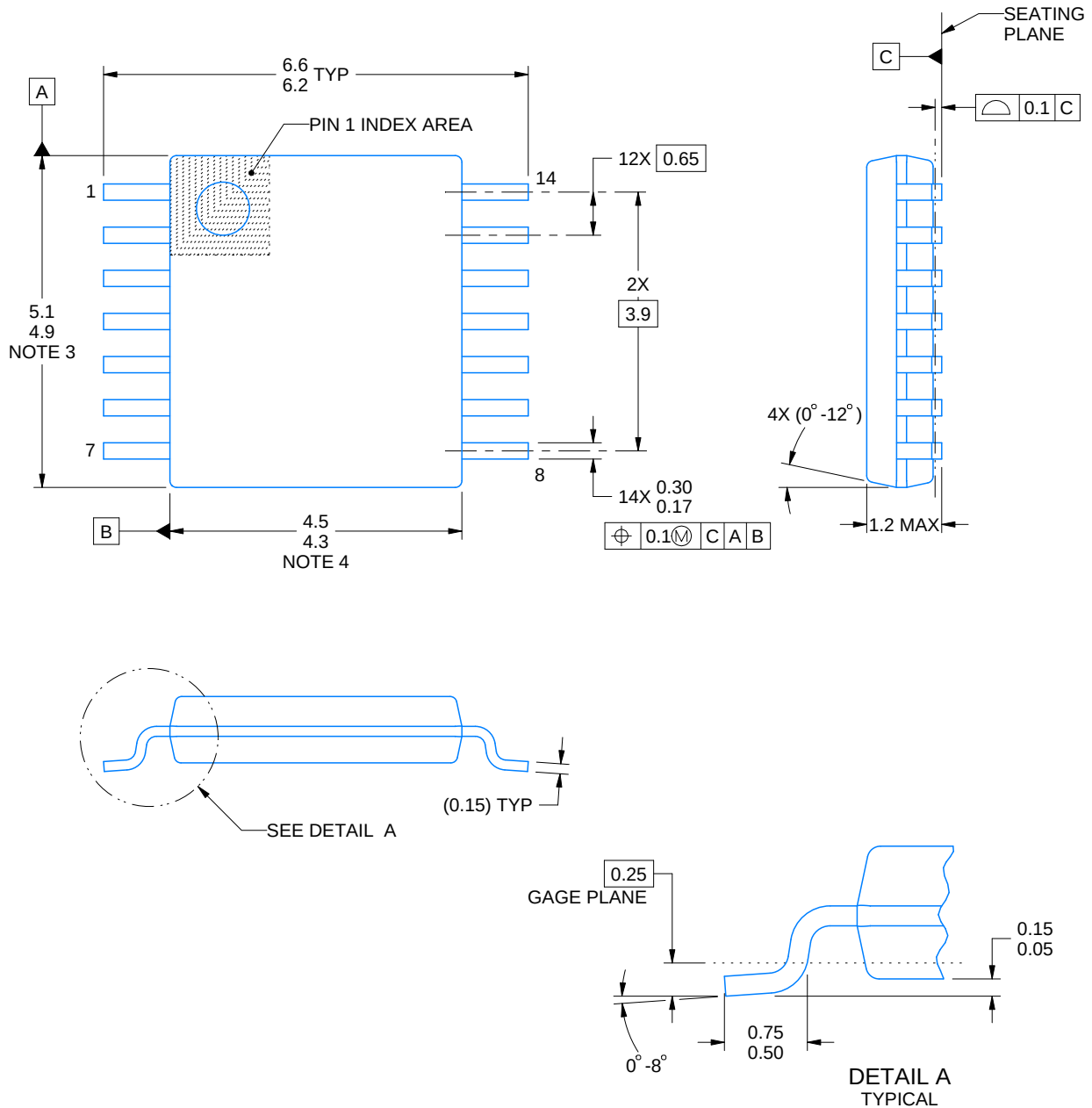
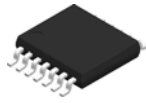
Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
TLC2264AQPWRG4Q1	TSSOP	PW	14	2000	330.0	12.4	6.9	5.6	1.6	8.0	12.0	Q1
TLC2264AQPWRQ1	TSSOP	PW	14	2000	330.0	12.4	6.9	5.6	1.6	8.0	12.0	Q1

TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
TLC2264AQPWRG4Q1	TSSOP	PW	14	2000	356.0	356.0	35.0
TLC2264AQPWRQ1	TSSOP	PW	14	2000	356.0	356.0	35.0



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NOTES:

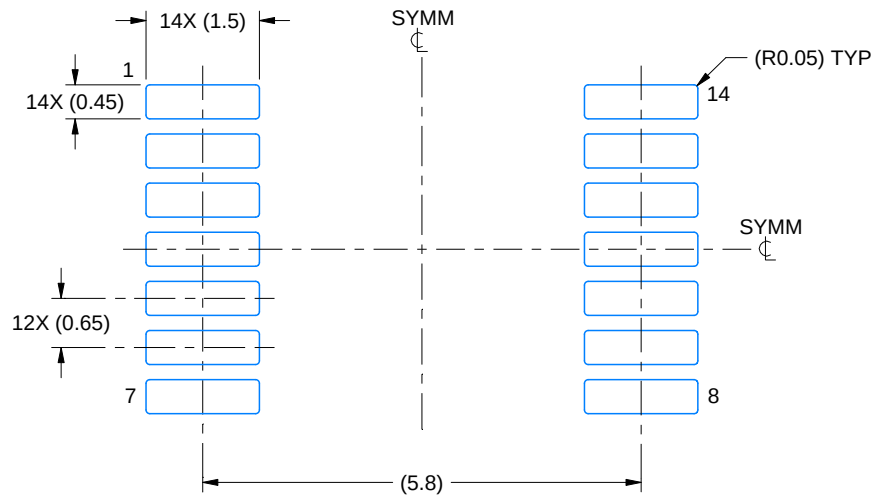
1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.15 mm per side.
4. This dimension does not include interlead flash. Interlead flash shall not exceed 0.25 mm per side.
5. Reference JEDEC registration MO-153.

EXAMPLE BOARD LAYOUT

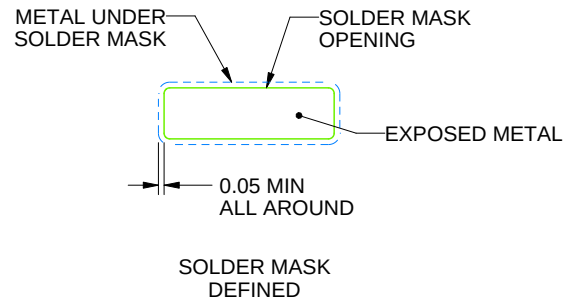
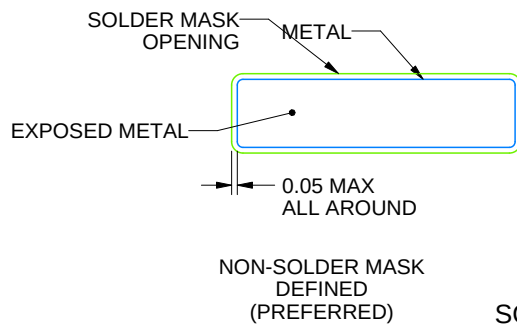
PW0014A

TSSOP - 1.2 mm max height

SMALL OUTLINE PACKAGE



LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE: 10X



SOLDER MASK DETAILS

4220202/B 12/2023

NOTES: (continued)

6. Publication IPC-7351 may have alternate designs.

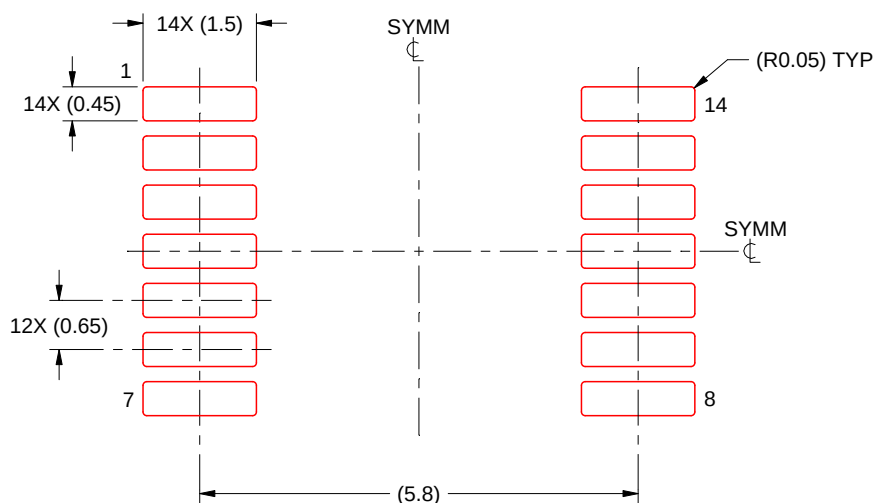
7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.

EXAMPLE STENCIL DESIGN

PW0014A

TSSOP - 1.2 mm max height

SMALL OUTLINE PACKAGE



SOLDER PASTE EXAMPLE
BASED ON 0.125 mm THICK STENCIL
SCALE: 10X

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NOTES: (continued)

8. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
9. Board assembly site may have different recommendations for stencil design.

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