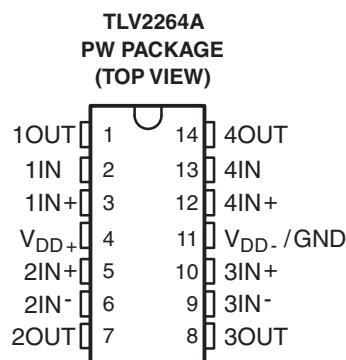
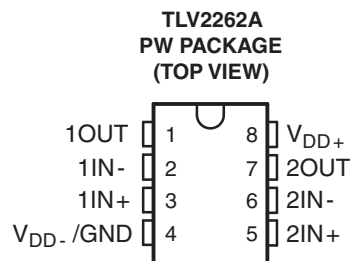


Advanced LinCMOS™ RAIL-TO-RAIL OPERATIONAL AMPLIFIERS

FEATURES

- Qualified for Automotive Applications
- 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
- Wide Supply Voltage Range . . . 2.7 V to 8 V
- Macromodel Included



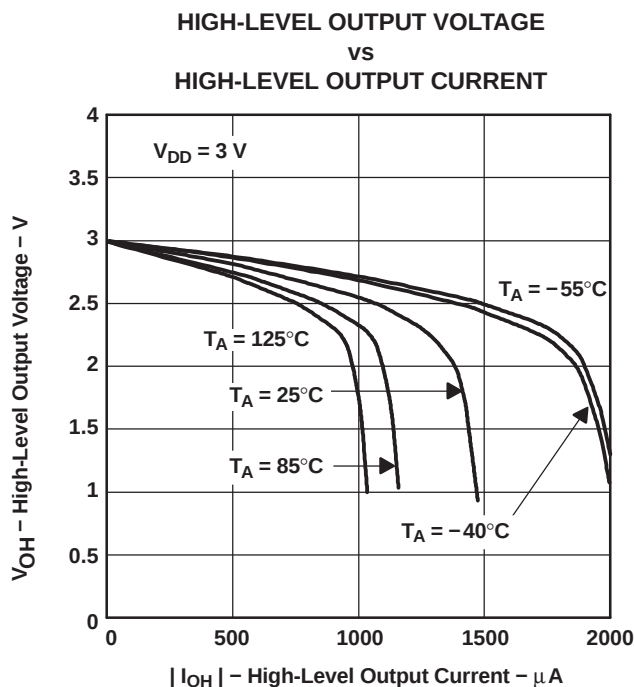
DESCRIPTION

The TLV2262 and TLV2264 are dual and quad low voltage operational amplifiers from Texas Instruments. Both devices exhibit rail-to-rail output performance for increased dynamic range in single or split supply applications. The TLV226x family offers a compromise between the micropower TLV225x 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. This family is fully characterized at 3 V and 5 V and is optimized for low-voltage applications. The noise performance has been dramatically improved over previous generations of CMOS amplifiers. Figure 1 depicts the low level of noise voltage for this CMOS amplifier, which has only 200 µA (typ) of supply current per amplifier.



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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Parts, PSpice are trademarks of MicroSim Corporation.



The TLV226x, exhibiting high input impedance and low noise, are excellent for small-signal conditioning for high-impedance sources, such as piezoelectric transducers. Because of the micropower dissipation levels combined with 3-V operation, these devices work well in hand-held monitoring and remote-sensing applications. In addition, the rail-to-rail output feature with single or split supplies makes this family a great choice when interfacing with analog-to-digital converters (ADCs). For precision applications, the TLV226xA family is available and has a maximum input offset voltage of 950 μ V.

The TLV2262/4 also makes great upgrades to the TLV2332/4 in standard designs. They offer increased output dynamic range, lower noise voltage and lower input offset voltage. This enhanced feature set allows them to be used in a wider range of applications. For applications that require higher output drive and wider input voltage range, see the TLV2432 and TLV2442 devices. If your design requires single amplifiers, please see the TLV2211/21/31 family. These devices are single rail-to-rail operational amplifiers in the SOT-23 package. Their small size and low power consumption make them ideal for high density, battery-powered equipment.

ORDERING INFORMATION⁽¹⁾

T_A	PACKAGE ⁽²⁾		ORDERABLE PART NUMBER	TOP-SIDE MARKING
-40°C to 125°C	TSSOP – PW (8 pin)	Reel of 2000	TLV2262AQPWRQ1	TQ262A
	TSSOP – PW (14 pin)	Reel of 2000	TLV2264AQPWRQ1	P2264AQ

(1) 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 www.ti.com.

(2) Package drawings, thermal data, and symbolization are available at www.ti.com/packaging.

EQUIVALENT SCHEMATIC (EACH AMPLIFIER)

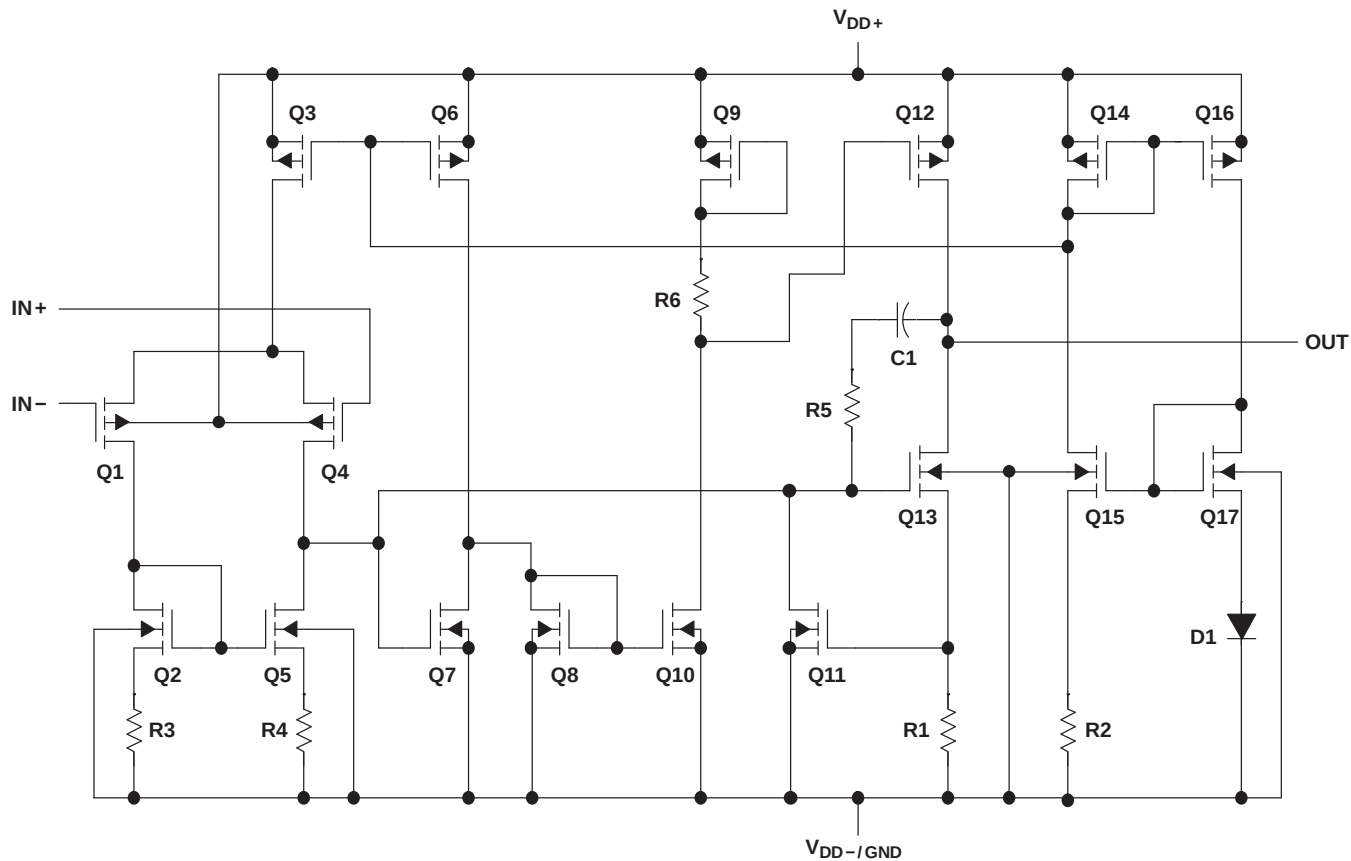


Table 1. Actual Device Component Count

COMPONENT	TLV2262	TLV2264
Transistors	38	76
Resistors	28	54
Diodes	9	18
Capacitors	3	6

ABSOLUTE MAXIMUM RATINGS⁽¹⁾

over operating free-air temperature range (unless otherwise noted)

V_{DD}	Supply voltage ⁽²⁾	–0.3 V to 16 V
V_{ID}	Differential input voltage ⁽³⁾	$\pm V_{DD}$
V_I	Input voltage range	$(V_{DD-} - 0.3 \text{ V})$ to V_{DD+}
I_I	Input current, any input	$\pm 5 \text{ mA}$
I_O	Output current	$\pm 50 \text{ mA}$
	Total current into V_{DD+}	$\pm 50 \text{ mA}$
	Total current out of V_{DD-}	$\pm 50 \text{ mA}$
	Duration of short-circuit current (at or below) 25°C ⁽⁴⁾	Unlimited
P_D	Continuous total power dissipation	See Dissipation Rating Table
T_A	Operating free-air temperature range	–40°C to 125°C
T_{stg}	Storage temperature range	–65°C to 150°C

- (1) 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.
- (2) All voltage values, except differential voltages, are with respect to V_{DD-} .
- (3) Differential voltages are at the noninverting input with respect to the inverting input. Excessive current flows when input is brought below $V_{DD-} - 0.3 \text{ V}$.
- (4) 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 RATINGS

PACKAGE	$T_A \leq 25^\circ\text{C}$ POWER RATING	DERATING FACTOR ABOVE $T_A = 25^\circ\text{C}$	$T_A = 85^\circ\text{C}$ POWER RATING	$T_A = 125^\circ\text{C}$ POWER RATING
PW-8	525 mW	4.2 mW/°C	273 mW	105 mW
PW-14	700 mW	5.6 mW/°C	364 mW	140 mW

RECOMMENDED OPERATING CONDITIONS

	MIN	MAX	UNIT
$V_{DD\pm}$ Supply voltage ⁽¹⁾	2.7	8	V
V_I Input voltage	V_{DD-}	$V_{DD+} - 1.3$	V
V_{IC} Common-mode input voltage	V_{DD-}	$V_{DD+} - 1.3$	V
T_A Operating free-air temperature	–40	125	°C

- (1) All voltage values, except differential voltages, are with respect to V_{DD-} .

TLV2262A ELECTRICAL CHARACTERISTICS

 $V_{DD} = 3\text{ V}$, over operating free-air temperature range (unless otherwise noted)

PARAMETER			TEST CONDITIONS		T _A	MIN	TYP	MAX	UNIT
V _{IO}	Input offset voltage	V _{DD±} = ±1.5 V, V _{IC} = 0, V _O = 0, R _S = 50 Ω		25°C		300	950	mV	
				Full range		1500			
α _{VIO}	Temperature coefficient of input offset voltage	V _{DD±} = ±1.5 V, V _{IC} = 0, V _O = 0, R _S = 50 Ω		25°C to 125°C		2		μV/°C	
	Input offset voltage long-term drift ⁽¹⁾	V _{DD±} = ±1.5 V, V _{IC} = 0, V _O = 0, R _S = 50 Ω		25°C		0.003		μV/mo	
I _{IO}	Input offset current	V _{DD±} = ±1.5 V, V _{IC} = 0, V _O = 0, R _S = 50 Ω		25°C		0.5	60	pA	
				125°C		800			
I _{IB}	Input bias current	V _{DD±} = ±1.5 V, V _{IC} = 0, V _O = 0, R _S = 50 Ω		25°C		1	60	pA	
				125°C		800			
V _{ICR}	Common-mode input voltage range	R _S = 50 Ω, V _{IO} ≤ 5 mV		25°C		0 to 2	−0.3 to 2.2	V	
				Full range		0 to 1.7			
V _{OH}	High-level output voltage	I _{OH} = −20 μA		25°C		2.99		V	
		I _{OH} = −100 μA		25°C		2.85			
				Full range		2.82			
		I _{OH} = −400 μA		25°C		2.7			
Full range				2.55					
V _{OL}	Low-level output voltage	V _{IC} = 1.5 V	I _{OL} = 50 μA	25°C		10		mV	
			I _{OL} = 500 μA	25°C		100	150		
				Full range		165			
			I _{OL} = 1 mA	25°C		200	300		
Full range		300							
A _{VD}	Large-signal differential voltage amplification	V _{IC} = 1.5 V, V _O = 1 V to 2 V	R _L = 50 kΩ ⁽²⁾	25°C		60	100	V/mV	
			R _L = 1 MΩ ⁽²⁾	Full range		25			
				25°C		100			
r _{i(d)}	Differential input resistance			25°C		10 ¹²		Ω	
r _{i(c)}	Common-mode input resistance			25°C		10 ¹²		Ω	
C _{i(c)}	Common-mode input capacitance	f = 10 kHz		25°C		8		pF	
Z _O	Closed-loop output impedance	f = 100 kHz, A _V = 10		25°C		270		Ω	
CMRR	Common-mode rejection ratio	V _{IC} = 0 to 1.7 V, V _O = 1.5 V, R _S = 50 Ω		25°C		65	77	dB	
				Full range		60			
k _{SVR}	Supply voltage rejection ratio (ΔV _{DD} /ΔV _{IO})	V _{DD} = 2.7 V to 8 V, V _{IC} = V _{DD} /2, No load		25°C		80	100	dB	
				Full range		80			
I _{DD}	Supply current	V _O = 1.5 V, No load		25°C		400	500	μA	
				Full range		500			

(1) 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.

(2) Referenced to 1.5 V

TLV2262A OPERATING CHARACTERISTICS

$V_{DD} = 3\text{ V}$, over operating free-air temperature range (unless otherwise noted)

PARAMETER		TEST CONDITIONS	T_A	MIN	TYP	MAX	UNIT
SR	Slew rate at unity gain	$V_O = 0.5\text{ V to }1.7\text{ V}$, $R_L = 50\text{ k}\Omega^{(1)}$, $C_L = 100\text{ pF}^{(1)}$	25°C	0.35	0.55		V/ μs
			Full range	0.25			
V_n	Equivalent input noise voltage	$f = 10\text{ Hz}$	25°C		43		$\text{nV}/\sqrt{\text{Hz}}$
		$f = 1\text{ kHz}$	25°C		12		
$V_{N(PP)}$	Peak-to-peak equivalent input noise voltage	$f = 0.1\text{ Hz to }1\text{ Hz}$	25°C		0.6		μV
		$f = 0.1\text{ Hz to }10\text{ Hz}$	25°C		1		
I_n	Equivalent input noise current		25°C		0.6		$\text{fA}/\sqrt{\text{Hz}}$
THD+N	Total harmonic distortion plus noise	$V_O = 0.5\text{ V to }2.5\text{ V}$, $f = 20\text{ kHz}$, $R_L = 50\text{ k}\Omega^{(1)}$	$A_V = 1$	25°C	0.03		%
			$A_V = 10$	25°C	0.05		
	Gain-bandwidth product	$f = 1\text{ kHz}$, $R_L = 50\text{ k}\Omega^{(1)}$, $C_L = 100\text{ pF}^{(1)}$	25°C		0.67		MHz
B_{OM}	Maximum output-swing bandwidth	$V_{O(PP)} = 1\text{ V}$, $A_V = 1$, $R_L = 50\text{ k}\Omega^{(1)}$, $C_L = 100\text{ pF}^{(1)}$	25°C		395		kHz
t_s	Settling time	$A_V = -1$, Step = 1 V to 2 V, $R_L = 50\text{ k}\Omega^{(1)}$, $C_L = 100\text{ pF}^{(1)}$	To 0.1%	25°C	5.6		μs
			To 0.01%	25°C	12.5		
ϕ_m	Phase margin at unity gain	$R_L = 50\text{ k}\Omega^{(1)}$, $C_L = 100\text{ pF}^{(1)}$	25°C		55		°
G_m	Gain margin	$R_L = 50\text{ k}\Omega^{(1)}$, $C_L = 100\text{ pF}^{(1)}$	25°C		11		dB

(1) Referenced to 1.5 V

TLV2262A ELECTRICAL CHARACTERISTICS

 $V_{DD} = 5\text{ V}$, over operating free-air temperature range (unless otherwise noted)

PARAMETER		TEST CONDITIONS	T_A	MIN	TYP	MAX	UNIT
V_{IO}	Input offset voltage	$V_{DD\pm} = \pm 2.5\text{ V}$, $V_{IC} = 0$, $V_O = 0$, $R_S = 50\ \Omega$	25°C		300	950	mV
			Full range			1500	
α_{VIO}	Temperature coefficient of input offset voltage	$V_{DD\pm} = \pm 2.5\text{ V}$, $V_{IC} = 0$, $V_O = 0$, $R_S = 50\ \Omega$	25°C to 125°C		2		$\mu\text{V}/^\circ\text{C}$
	Input offset voltage long-term drift ⁽¹⁾	$V_{DD\pm} = \pm 2.5\text{ V}$, $V_{IC} = 0$, $V_O = 0$, $R_S = 50\ \Omega$	25°C		0.003		$\mu\text{V}/\text{mo}$
I_{IO}	Input offset current	$V_{DD\pm} = \pm 2.5\text{ V}$, $V_{IC} = 0$, $V_O = 0$, $R_S = 50\ \Omega$	25°C		0.5	60	pA
			125°C			800	
I_{IB}	Input bias current	$V_{DD\pm} = \pm 2.5\text{ V}$, $V_{IC} = 0$, $V_O = 0$, $R_S = 50\ \Omega$	25°C		1	60	pA
			125°C			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		V
			Full range	0 to 3.5			
V_{OH}	High-level output voltage	$I_{OH} = -20\ \mu\text{A}$ $I_{OH} = -100\ \mu\text{A}$ $I_{OH} = -400\ \mu\text{A}$	25°C		4.99		V
			25°C		4.85	4.94	
			Full range		4.82		
			25°C		4.7	4.85	
V_{OL}	Low-level output voltage	$V_{IC} = 2.5\text{ V}$ $I_{OL} = 50\ \mu\text{A}$ $I_{OL} = 500\ \mu\text{A}$ $I_{OL} = 1\text{ mA}$	25°C		0.01		V
			25°C		0.09	0.15	
			Full range			0.15	
			25°C		0.2	0.3	
A_{VD}	Large-signal differential voltage amplification	$V_{IC} = 2.5\text{ V}$, $V_O = 1\text{ V to }4\text{ V}$ $R_L = 50\text{ k}\Omega^{(2)}$ $R_L = 1\text{ M}\Omega^{(2)}$	25°C		80	170	V/mV
			Full range		50		
			25°C			550	
			Full range				
$r_{i(d)}$	Differential input resistance		25°C		10^{12}		Ω
$r_{i(c)}$	Common-mode input resistance		25°C		10^{12}		Ω
$C_{i(c)}$	Common-mode input capacitance	$f = 10\text{ kHz}$	25°C		8		pF
Z_o	Closed-loop output impedance	$f = 100\text{ kHz}$, $A_V = 10$	25°C		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	dB
			Full range		70		
k_{SVR}	Supply voltage rejection ratio ($\Delta V_{DD}/\Delta V_{IO}$)	$V_{DD} = 4.4\text{ V to }8\text{ V}$, $V_{IC} = V_{DD}/2$, No load	25°C		80	95	dB
			Full range		80		
I_{DD}	Supply current	$V_O = 2.5\text{ V}$, No load	25°C		400	500	μA
			Full range			500	

(1) 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.

(2) Referenced to 2.5 V

TLV2262A OPERATING CHARACTERISTICS

$V_{DD} = 5\text{ V}$, over operating free-air temperature range (unless otherwise noted)

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

(1) Referenced to 2.5 V

TLV2264A ELECTRICAL CHARACTERISTICS

 $V_{DD} = 3\text{ V}$, over operating free-air temperature range (unless otherwise noted)

PARAMETER		TEST CONDITIONS		T _A	MIN	TYP	MAX	UNIT
V _{IO}	Input offset voltage	V _{DD±} = ±1.5 V, V _{IC} = 0, V _O = 0, R _S = 50 Ω		25°C		300	950	mV
				Full range			1500	
α _{VIO}	Temperature coefficient of input offset voltage	V _{DD±} = ±1.5 V, V _{IC} = 0, V _O = 0, R _S = 50 Ω		25°C to 125°C		2		μV/°C
	Input offset voltage long-term drift ⁽¹⁾	V _{DD±} = ±1.5 V, V _{IC} = 0, V _O = 0, R _S = 50 Ω		25°C		0.003		μV/mo
I _{IO}	Input offset current	V _{DD±} = ±1.5 V, V _{IC} = 0, V _O = 0, R _S = 50 Ω		25°C		0.5	60	pA
				125°C			800	
I _{IB}	Input bias current	V _{DD±} = ±1.5 V, V _{IC} = 0, V _O = 0, R _S = 50 Ω		25°C		1	60	pA
				125°C			800	
V _{ICR}	Common-mode input voltage range	R _S = 50 Ω, V _{IO} ≤ 5 mV		25°C		0 to 2	−0.3 to 2.2	V
				Full range		0 to 1.7		
V _{OH}	High-level output voltage	I _{OH} = −20 μA		25°C		2.99		V
		I _{OH} = −100 μA		25°C		2.85		
				Full range		2.82		
		I _{OH} = −400 μA		25°C		2.7		
				Full range		2.6		
V _{OL}	Low-level output voltage	V _{IC} = 1.5 V	I _{OL} = 50 μA	25°C		10		mV
			I _{OL} = 500 μA	25°C		100	150	
				Full range		150		
			I _{OL} = 1 mA	25°C		200	300	
				Full range		300		
A _{VD}	Large-signal differential voltage amplification	V _{IC} = 1.5 V, V _O = 1 V to 2 V		R _L = 50 kΩ ⁽²⁾	25°C	60	100	V/mV
				Full range		25		
				R _L = 1 MΩ ⁽²⁾	25°C		100	
r _{i(d)}	Differential input resistance			25°C		10 ¹²		Ω
r _{i(c)}	Common-mode input resistance			25°C		10 ¹²		Ω
C _{i(c)}	Common-mode input capacitance	f = 10 kHz		25°C		8		pF
Z ₀	Closed-loop output impedance	f = 100 kHz, A _V = 10		25°C		270		Ω
CMRR	Common-mode rejection ratio	V _{IC} = 0 to 1.7 V, V _O = 1.5 V, R _S = 50 Ω		25°C		65	77	dB
				Full range		60		
k _{SVR}	Supply voltage rejection ratio (ΔV _{DD} /ΔV _{IO})	V _{DD} = 2.7 V to 8 V, V _{IC} = V _{DD} /2, No load		25°C		80	100	dB
				Full range		80		
I _{DD}	Supply current	V _O = 1.5 V, No load		25°C		0.8	1	mA
				Full range		1		

(1) 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.

(2) Referenced to 1.5 V

TLV2264A OPERATING CHARACTERISTICS
 $V_{DD} = 3\text{ V}$, over operating free-air temperature range (unless otherwise noted)

PARAMETER		TEST CONDITIONS	T_A	MIN	TYP	MAX	UNIT
SR	Slew rate at unity gain	$V_O = 0.5\text{ V to }1.7\text{ V}$, $R_L = 50\text{ k}\Omega^{(1)}$, $C_L = 100\text{ pF}^{(1)}$	25°C	0.35	0.55		V/ μs
			Full range	0.25			
V_n	Equivalent input noise voltage	$f = 10\text{ Hz}$	25°C		43		nV/ $\sqrt{\text{Hz}}$
		$f = 1\text{ kHz}$	25°C		12		
$V_{N(PP)}$	Peak-to-peak equivalent input noise voltage	$f = 0.1\text{ Hz to }1\text{ Hz}$	25°C		0.6		μV
		$f = 0.1\text{ Hz to }10\text{ Hz}$	25°C		1		
I_n	Equivalent input noise current		25°C		0.6		fA/ $\sqrt{\text{Hz}}$
THD+N	Total harmonic distortion plus noise	$V_O = 0.5\text{ V to }2.5\text{ V}$, $f = 20\text{ kHz}$, $R_L = 50\text{ k}\Omega^{(1)}$	$A_V = 1$ 25°C		0.03		%
			$A_V = 10$ 25°C		0.05		
	Gain-bandwidth product	$f = 1\text{ kHz}$, $R_L = 50\text{ k}\Omega^{(1)}$, $C_L = 100\text{ pF}^{(1)}$	25°C		0.67		MHz
B_{OM}	Maximum output-swing bandwidth	$V_{O(PP)} = 1\text{ V}$, $A_V = 1$, $R_L = 50\text{ k}\Omega^{(1)}$, $C_L = 100\text{ pF}^{(1)}$	25°C		395		kHz
t_s	Settling time	$A_V = -1$, Step = 1 V to 2 V, $R_L = 50\text{ k}\Omega^{(1)}$, $C_L = 100\text{ pF}^{(1)}$	To 0.1% 25°C		5.6		μs
			To 0.01% 25°C		12.5		
ϕ_m	Phase margin at unity gain	$R_L = 50\text{ k}\Omega^{(1)}$, $C_L = 100\text{ pF}^{(1)}$	25°C		55		°
G_m	Gain margin	$R_L = 50\text{ k}\Omega^{(1)}$, $C_L = 100\text{ pF}^{(1)}$	25°C		11		dB

(1) Referenced to 1.5 V

TLV2264A ELECTRICAL CHARACTERISTICS

 $V_{DD} = 5\text{ V}$, over operating free-air temperature range (unless otherwise noted)

PARAMETER	TEST CONDITIONS	T_A	MIN	TYP	MAX	UNIT
V_{IO} Input offset voltage	$V_{DD\pm} = \pm 2.5\text{ V}$, $V_{IC} = 0$, $V_O = 0$, $R_S = 50\ \Omega$	25°C		300	950	mV
		Full range			1500	
α_{VIO} Temperature coefficient of input offset voltage	$V_{DD\pm} = \pm 2.5\text{ V}$, $V_{IC} = 0$, $V_O = 0$, $R_S = 50\ \Omega$	25°C to 125°C		2		$\mu\text{V}/^\circ\text{C}$
Input offset voltage long-term drift ⁽¹⁾	$V_{DD\pm} = \pm 2.5\text{ V}$, $V_{IC} = 0$, $V_O = 0$, $R_S = 50\ \Omega$	25°C		0.003		$\mu\text{V}/\text{mo}$
I_{IO} Input offset current	$V_{DD\pm} = \pm 2.5\text{ V}$, $V_{IC} = 0$, $V_O = 0$, $R_S = 50\ \Omega$	25°C		0.5	60	pA
		125°C			800	
I_{IB} Input bias current	$V_{DD\pm} = \pm 2.5\text{ V}$, $V_{IC} = 0$, $V_O = 0$, $R_S = 50\ \Omega$	25°C		1	60	pA
		125°C			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		V
		Full range	0 to 3.5			
V_{OH} High-level output voltage	$I_{OH} = -20\ \mu\text{A}$ $I_{OH} = -100\ \mu\text{A}$ $I_{OH} = -400\ \mu\text{A}$	25°C		4.99		V
		25°C		4.85	4.94	
		Full range		4.82		
		25°C		4.7	4.85	
V_{OL} Low-level output voltage	$V_{IC} = 2.5\text{ V}$	25°C		0.01		V
		25°C		0.09	0.15	
		Full range			0.15	
		25°C		0.2	0.3	
A_{VD} Large-signal differential voltage amplification	$V_{IC} = 2.5\text{ V}$, $V_O = 1\text{ V to }4\text{ V}$	25°C		80	170	V/mV
		Full range		50		
		25°C			550	
		Full range			0.3	
$r_{i(d)}$ Differential input resistance		25°C		10^{12}		Ω
$r_{i(c)}$ Common-mode input resistance		25°C		10^{12}		Ω
$C_{i(c)}$ Common-mode input capacitance	$f = 10\text{ kHz}$	25°C		8		pF
Z_o Closed-loop output impedance	$f = 100\text{ kHz}$, $A_V = 10$	25°C		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	dB
		Full range		70		
k_{SVR} Supply voltage rejection ratio ($\Delta V_{DD}/\Delta V_{IO}$)	$V_{DD} = 4.4\text{ V to }8\text{ V}$, $V_{IC} = V_{DD}/2$, No load	25°C		80	95	dB
		Full range		80		
I_{DD} Supply current	$V_O = 2.5\text{ V}$, No load	25°C		0.8	1	mA
		Full range			1	

(1) 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.

(2) Referenced to 2.5 V

TLV2264A OPERATING CHARACTERISTICSV_{DD} = 5 V, over operating free-air temperature range (unless otherwise noted)

PARAMETER		TEST CONDITIONS		T _A	MIN	TYP	MAX	UNIT
SR	Slew rate at unity gain	V _O = 0.5 V to 3.5 V, R _L = 50 kΩ ⁽¹⁾ , C _L = 100 pF ⁽¹⁾		25°C	0.35	0.55		V/μs
				Full range	0.25			
V _n	Equivalent input noise voltage	f = 10 Hz		25°C		40		nV/√Hz
		f = 1 kHz		25°C		12		
V _{N(PP)}	Peak-to-peak equivalent input noise voltage	f = 0.1 Hz to 1 Hz		25°C		0.7		μV
		f = 0.1 Hz to 10 Hz		25°C		1.3		
I _n	Equivalent input noise current			25°C		0.6		fA/√Hz
THD+N	Total harmonic distortion plus noise	V _O = 0.5 V to 2.5 V, f = 20 kHz, R _L = 50 kΩ ⁽¹⁾	A _V = 1	25°C		0.017		%
			A _V = 10	25°C		0.03		
	Gain-bandwidth product	f = 50 kHz, R _L = 50 kΩ ⁽¹⁾ , C _L = 100 pF ⁽¹⁾		25°C		0.71		MHz
B _{OM}	Maximum output-swing bandwidth	V _{O(PP)} = 2 V, A _V = 1, R _L = 50 kΩ ⁽¹⁾ , C _L = 100 pF ⁽¹⁾		25°C		185		kHz
t _s	Settling time	A _V = –1, Step = 0.5 V to 2.5 V, R _L = 50 kΩ ⁽¹⁾ , C _L = 100 pF ⁽¹⁾	To 0.1%	25°C		6.4		μs
			To 0.01%	25°C		14.1		
φ _m	Phase margin at unity gain	R _L = 50 kΩ ⁽¹⁾ , C _L = 100 pF ⁽¹⁾		25°C		56		°
G _m	Gain margin	R _L = 50 kΩ ⁽¹⁾ , C _L = 100 pF ⁽¹⁾		25°C		11		dB

(1) Referenced to 2.5 V

TYPICAL CHARACTERISTICS

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

Table of Graphs

			FIGURE
V_{IO}	Input offset voltage	Distribution	2–5
		vs Common-mode voltage	6, 7
α_{VIO}	Input offset voltage temperature coefficient	Distribution	8–11
I_{IB}/I_{IO}	Input bias and input offset currents	vs Free-air temperature	12
		vs Supply voltage	13
V_I	Input voltage	vs Free-air temperature	14
		vs High-level output current	15, 18
V_{OH}	High-level output voltage	vs Low-level output current	16, 17, 19
V_{OL}	Low-level output voltage	vs Frequency	20
$V_{O(PP)}$	Maximum peak-to-peak output voltage	vs Supply voltage	21
I_{OS}	Short-circuit output current	vs Free-air temperature	22
		vs Output voltage	23, 24
V_{ID}	Differential input voltage	vs Load resistance	25
A_{VD}	Differential voltage amplification	vs Frequency	26, 27
A_{VD}	Large-signal differential voltage amplification	vs Free-air temperature	28, 29
		vs Frequency	30, 31
z_o	Output impedance	vs Frequency	32
		vs Free-air temperature	33
CMRR	Common-mode rejection ratio	vs Frequency	34, 35
		vs Free-air temperature	36, 37
k_{SVR}	Supply-voltage rejection ratio	vs Frequency	38, 39
		vs Free-air temperature	40
I_{DD}	Supply current	vs Load capacitance	41
		vs Free-air temperature	42, 43
SR	Slew rate		44, 45
V_O	Inverting large-signal pulse response		46, 47
V_O	Voltage-follower large-signal pulse response		48, 49
V_O	Inverting small-signal pulse response		50, 51
V_O	Voltage-follower small-signal pulse response		52
V_n	Equivalent input noise voltage	vs Frequency	53
	Input noise voltage	Over a 10-second period	54
	Integrated noise voltage	vs Frequency	55
		vs Supply voltage	56
THD+N	Total harmonic distortion plus noise	vs Free-air temperature	26, 27
		vs Load capacitance	57
ϕ_m	Phase margin	vs Load capacitance	58
G_m	Gain margin	vs Load capacitance	59
B_1	Unity-gain bandwidth	vs Load capacitance	60
	Overestimation of phase margin	vs Load capacitance	

**DISTRIBUTION OF TLV2262
INPUT OFFSET VOLTAGE**

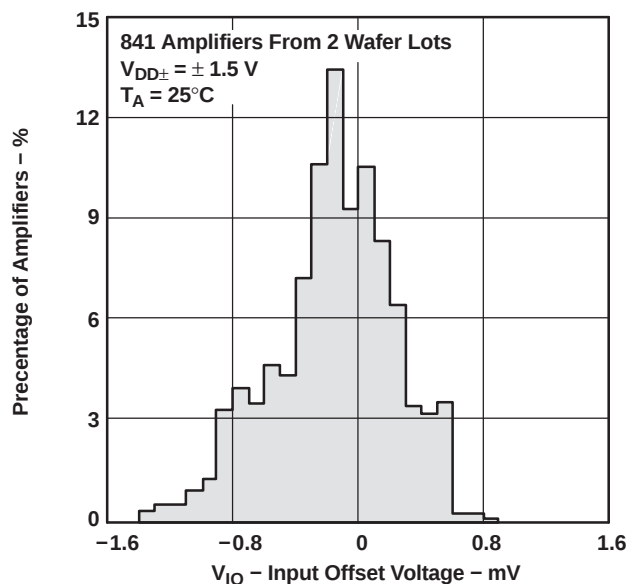


Figure 2.

**DISTRIBUTION OF TLV2262
INPUT OFFSET VOLTAGE**

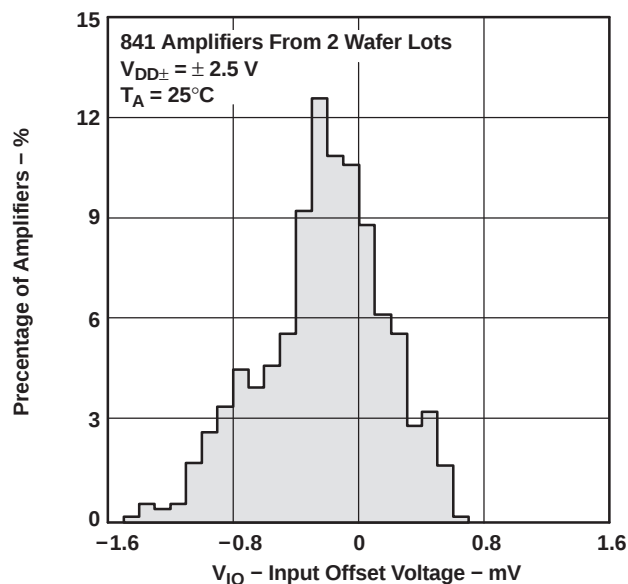


Figure 3.

**DISTRIBUTION OF TLV2264
INPUT OFFSET VOLTAGE**

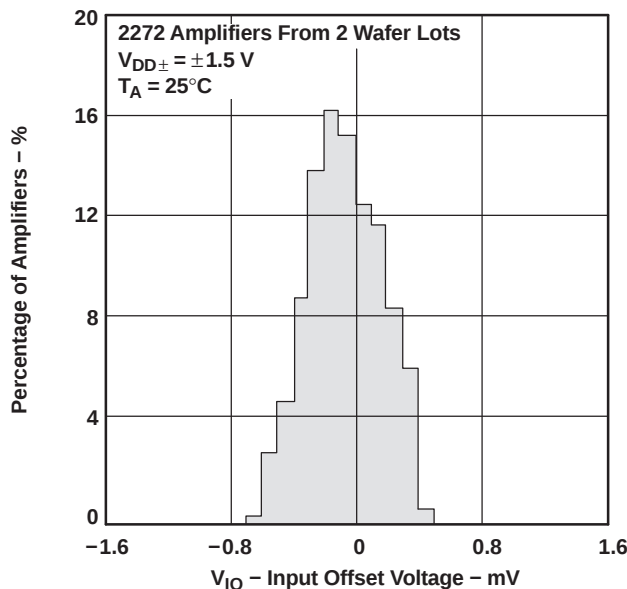


Figure 4.

**DISTRIBUTION OF TLV2264
INPUT OFFSET VOLTAGE**

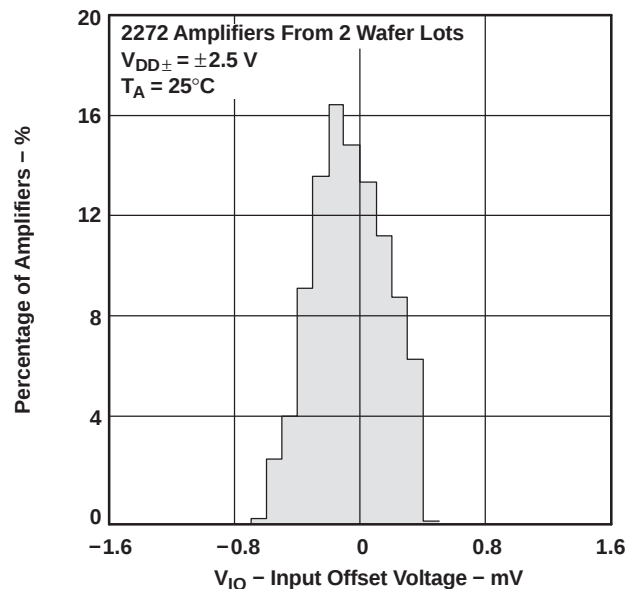


Figure 5.

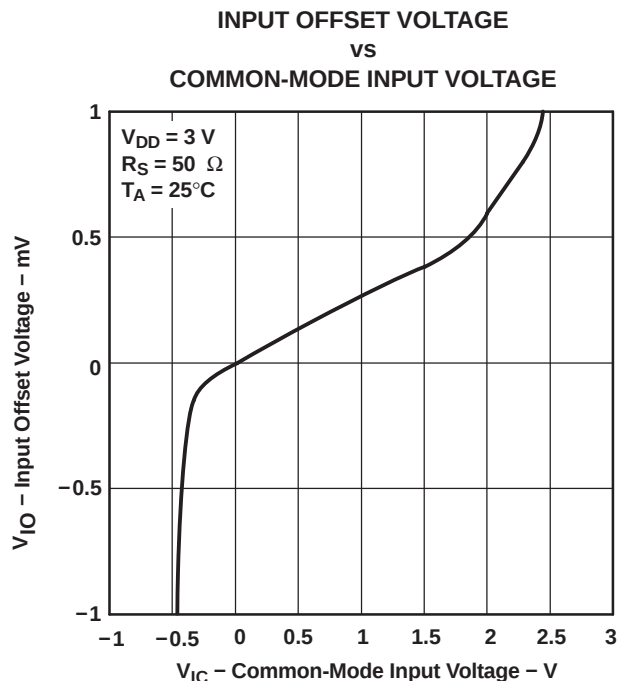


Figure 6.

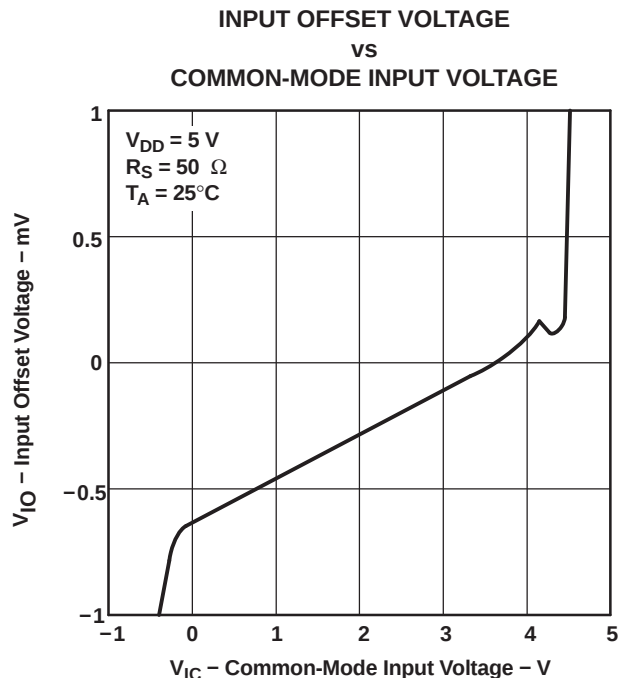


Figure 7.

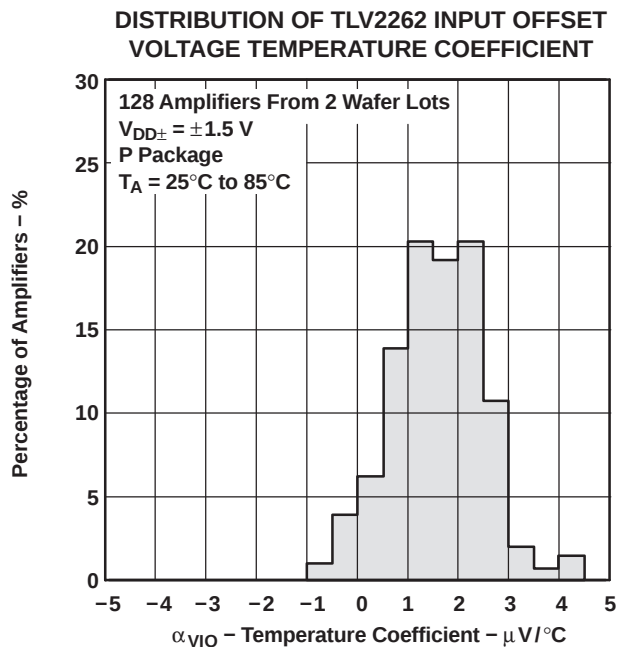


Figure 8.

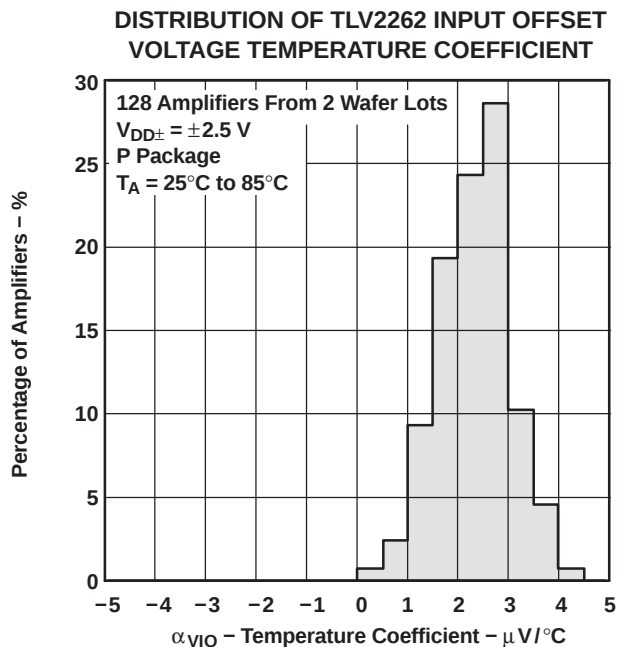


Figure 9.

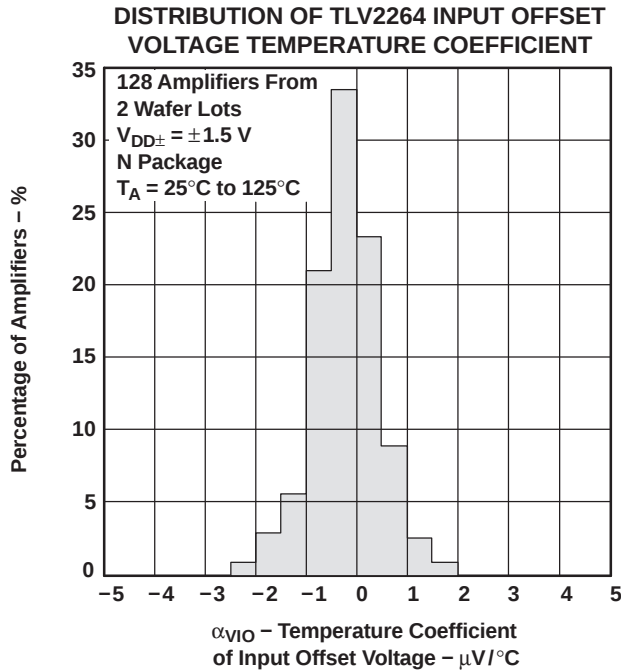


Figure 10.

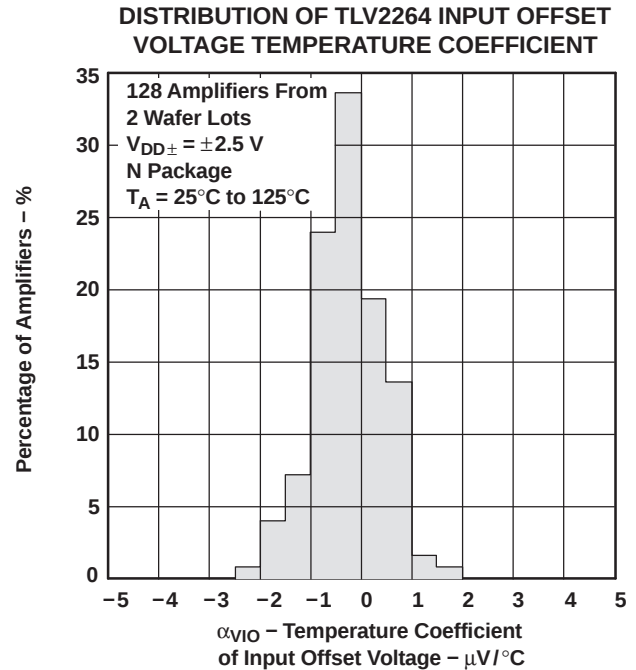


Figure 11.

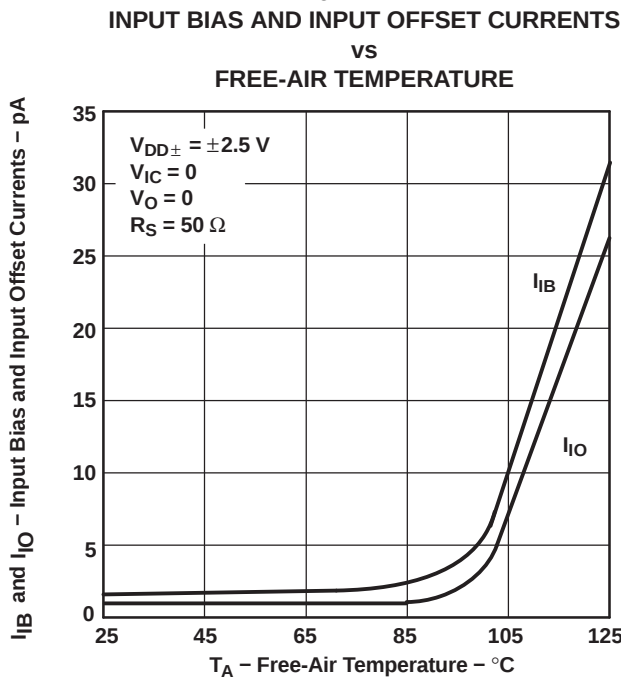


Figure 12.

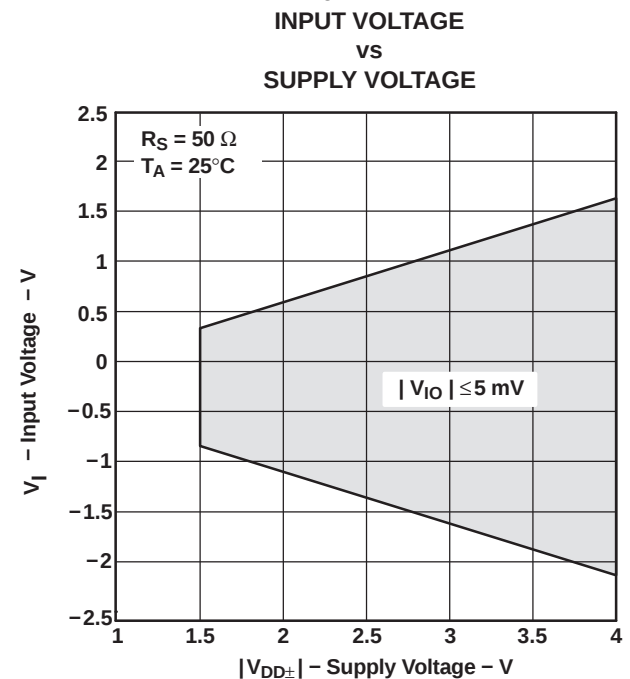


Figure 13.

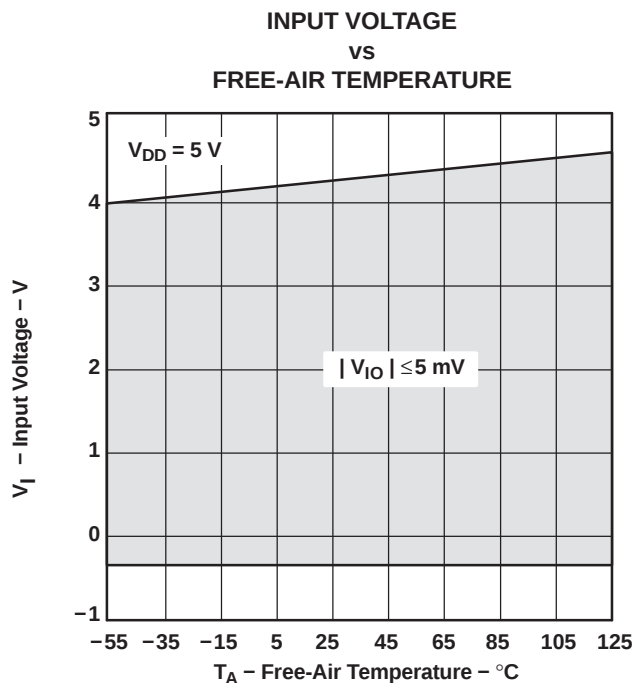


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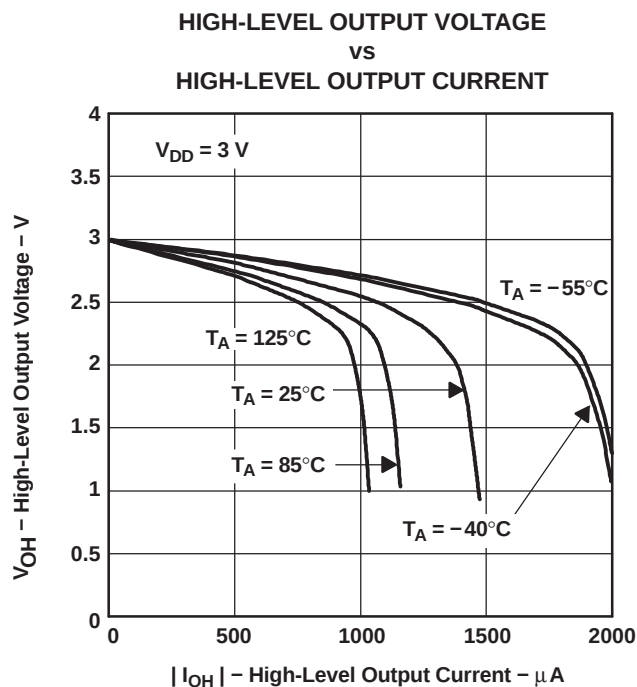


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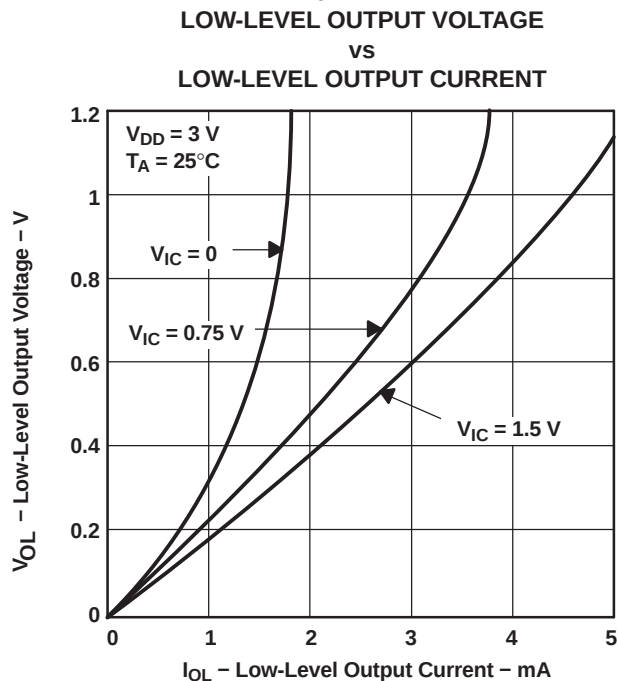


Figure 16.

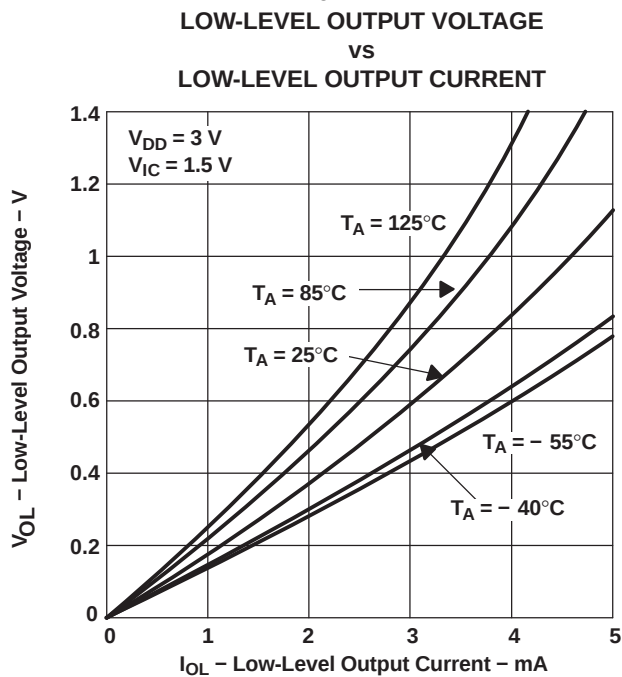


Figure 17.

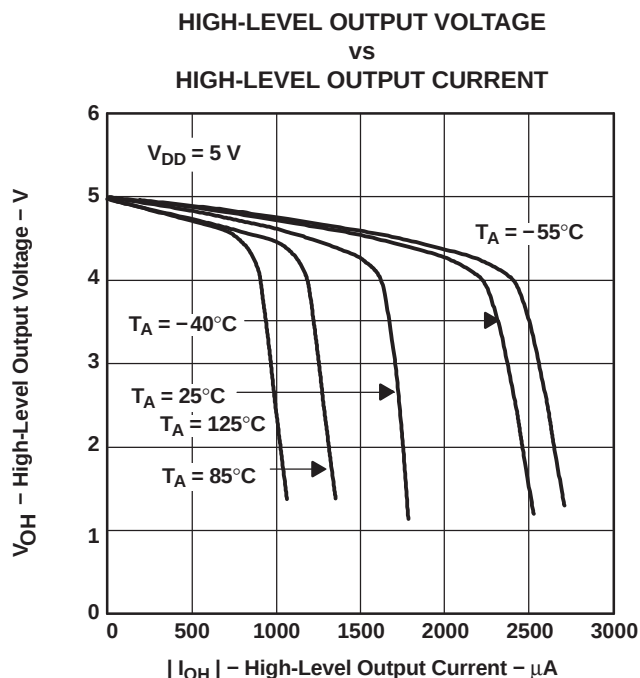


Figure 18.

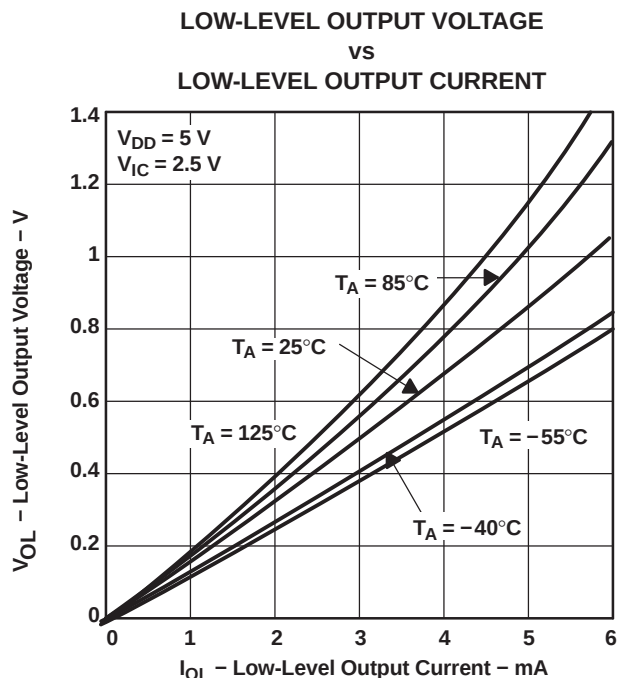


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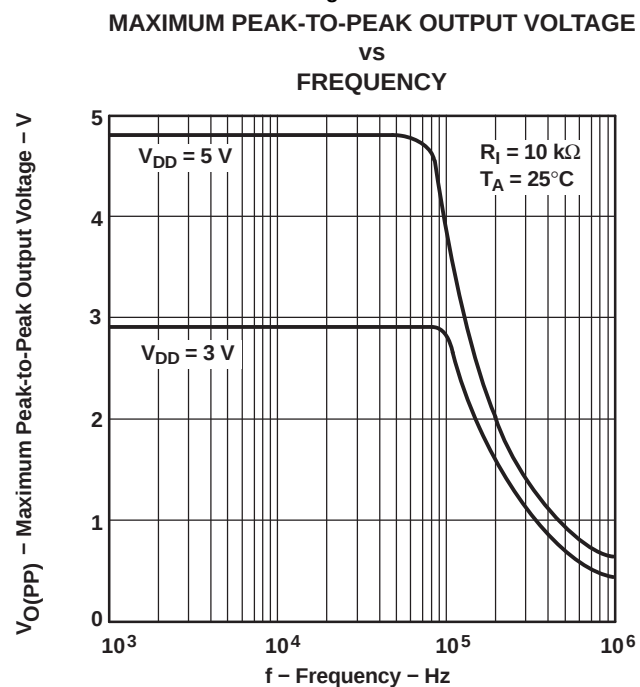


Figure 20.

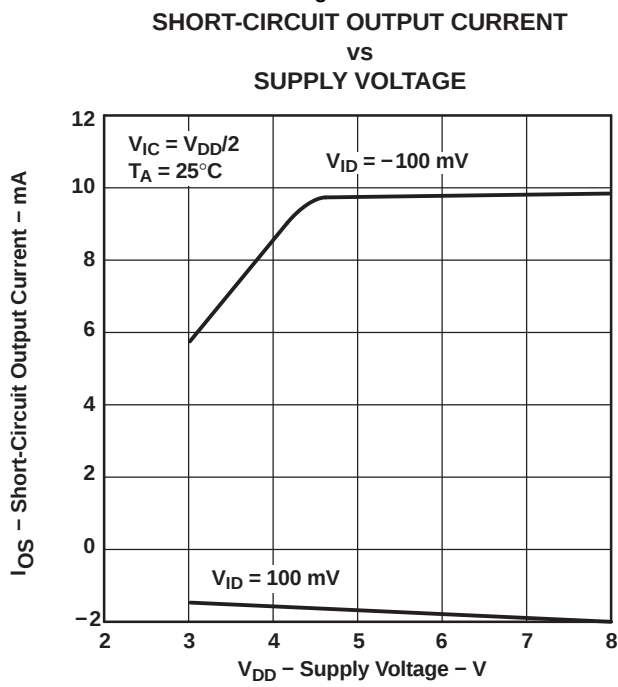
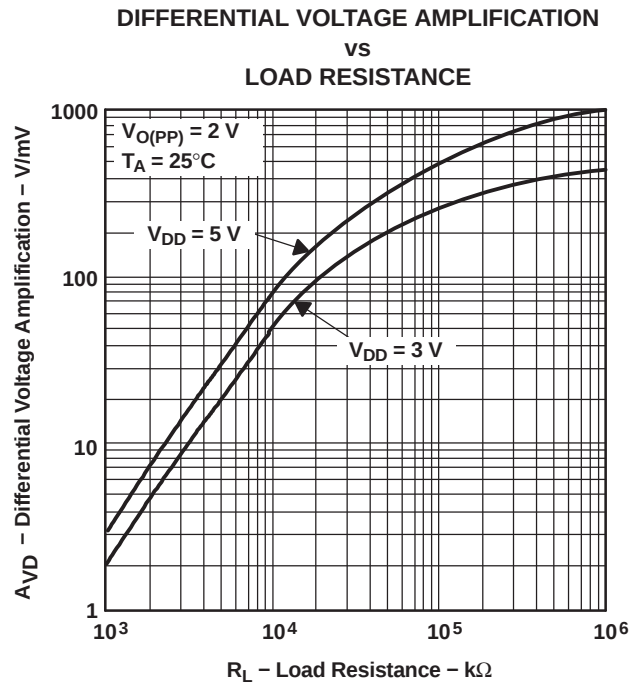
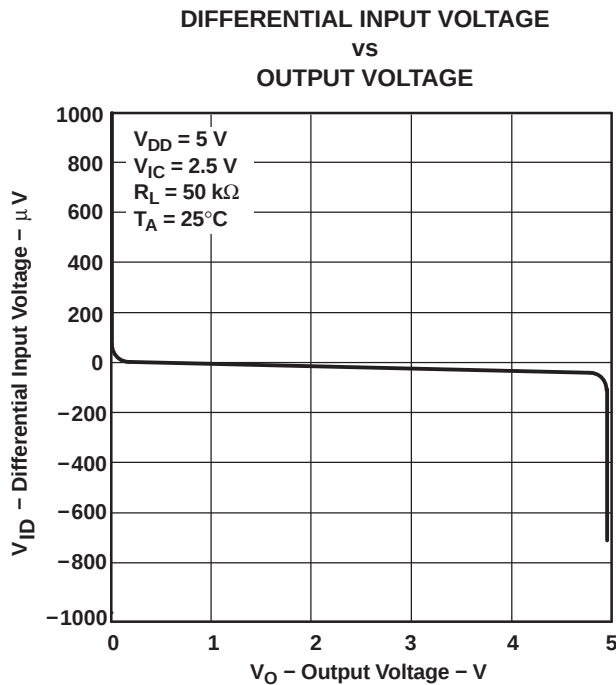
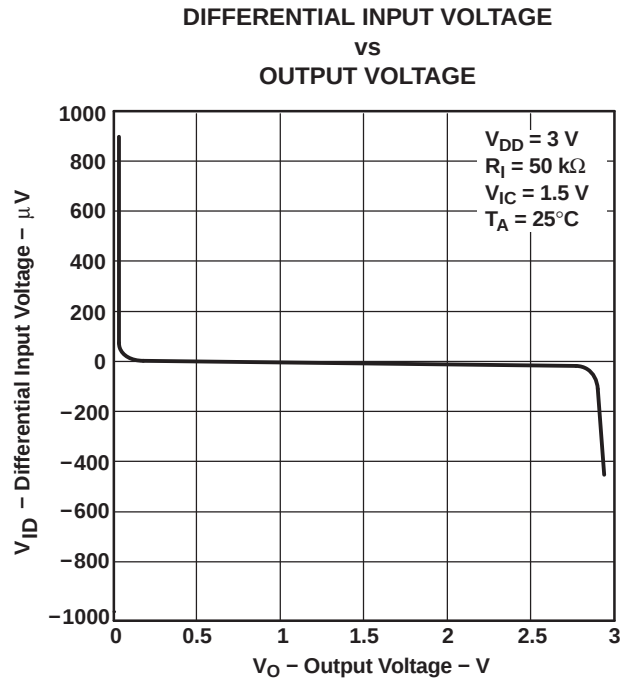
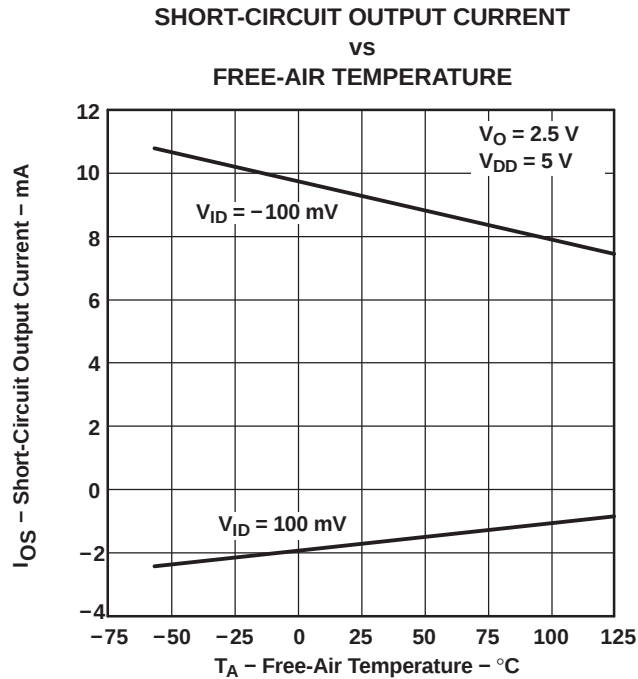


Figure 21.



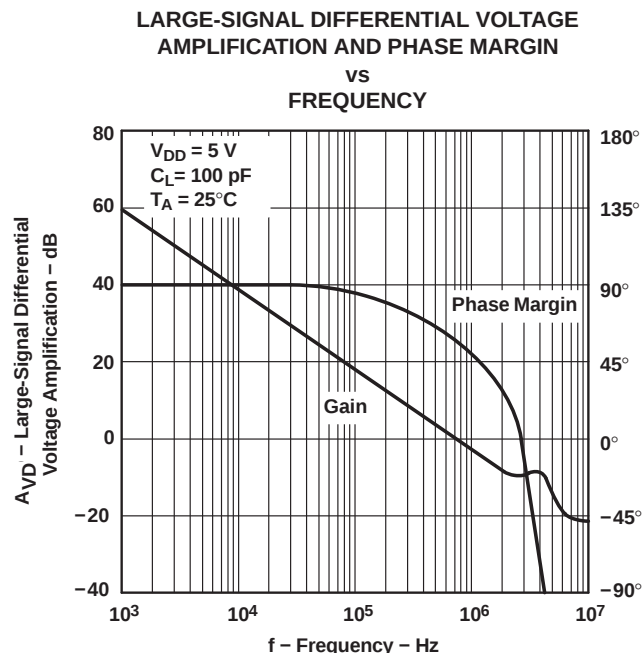


Figure 26.

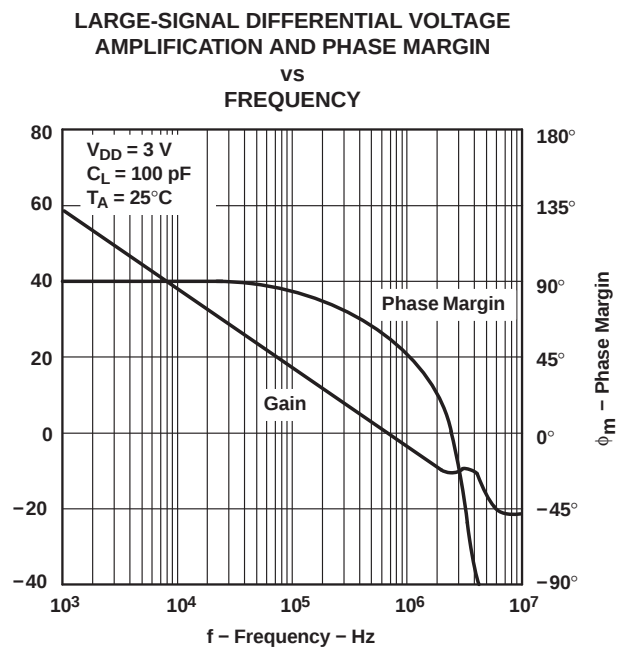


Figure 27.

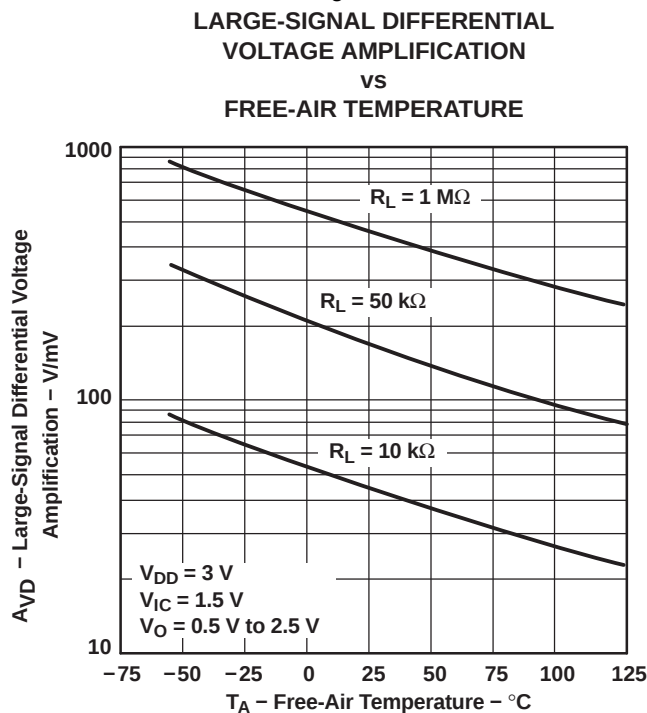


Figure 28.

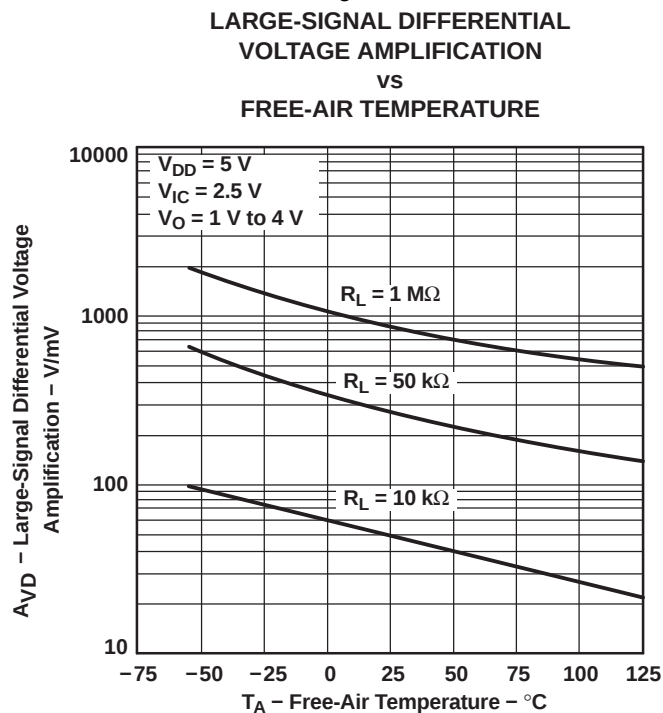


Figure 29.

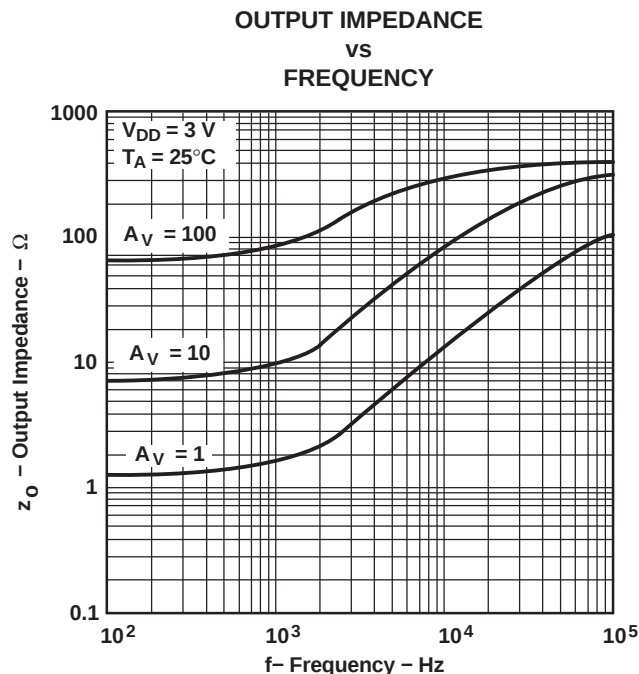


Figure 30.

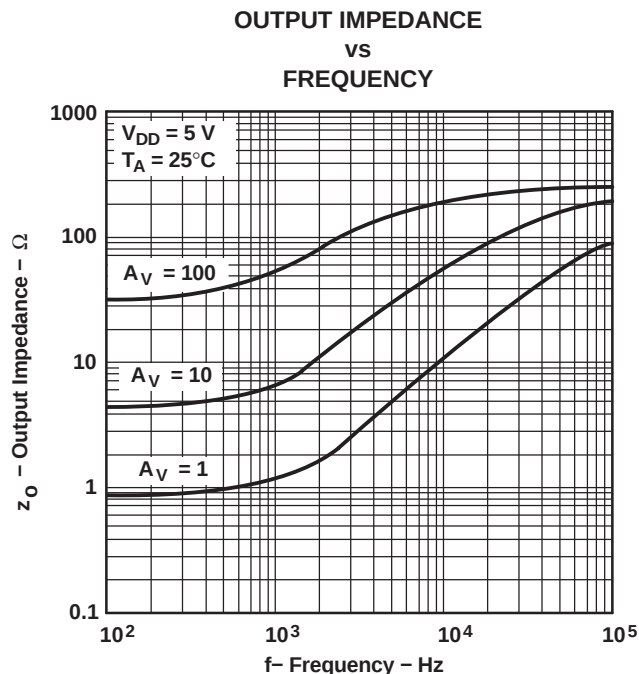


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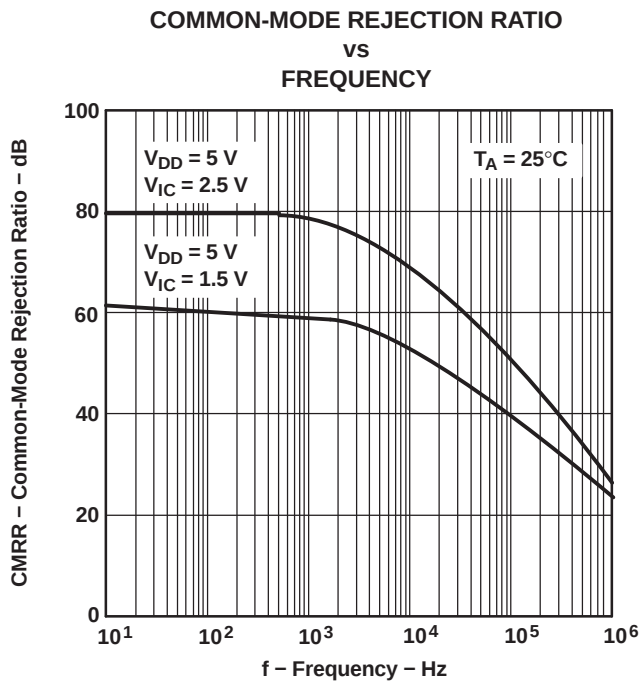


Figure 32.

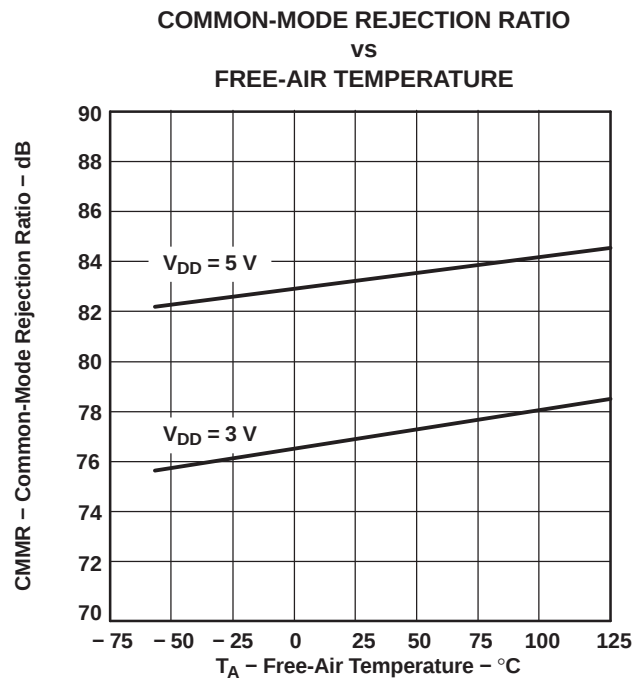


Figure 33.

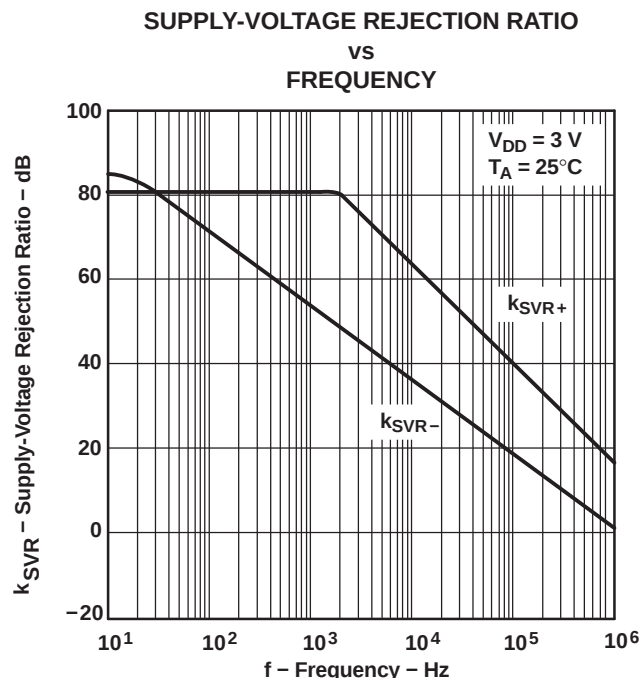


Figure 34.

TLV2262

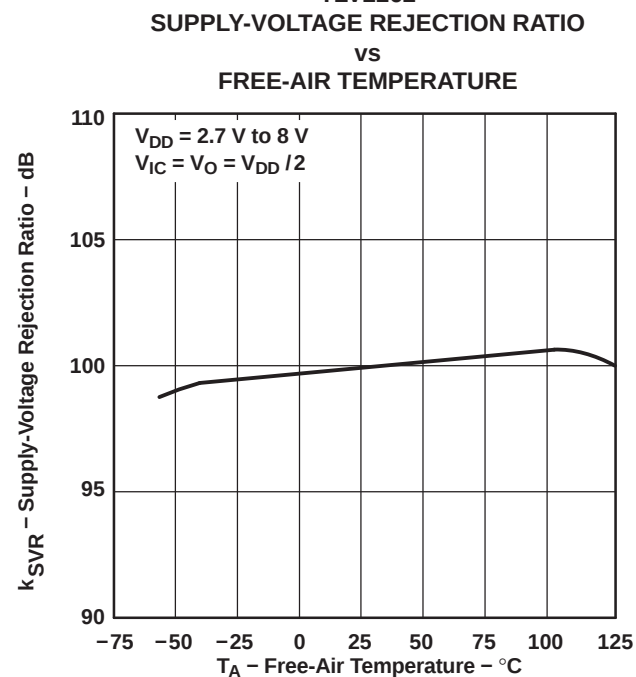


Figure 36.

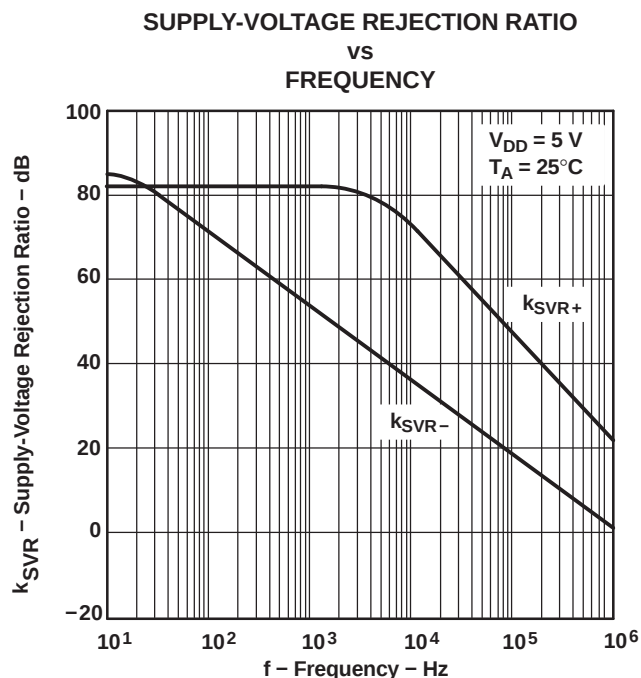


Figure 35.

TLV2264

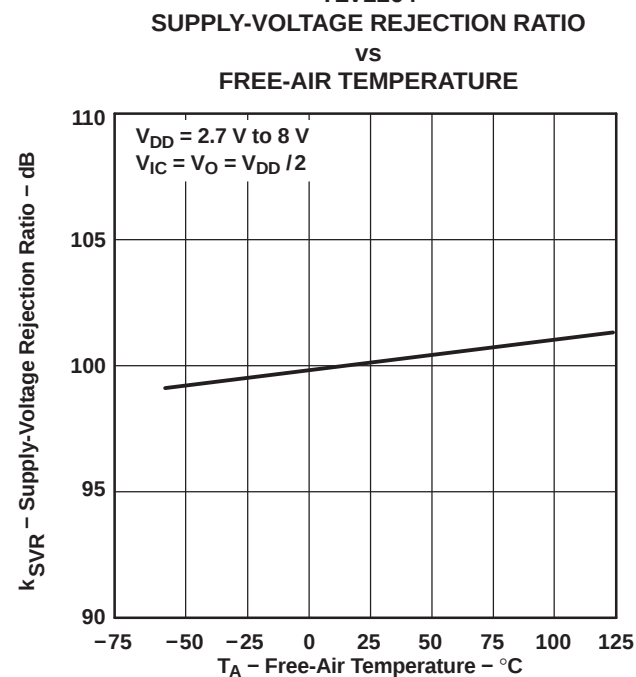
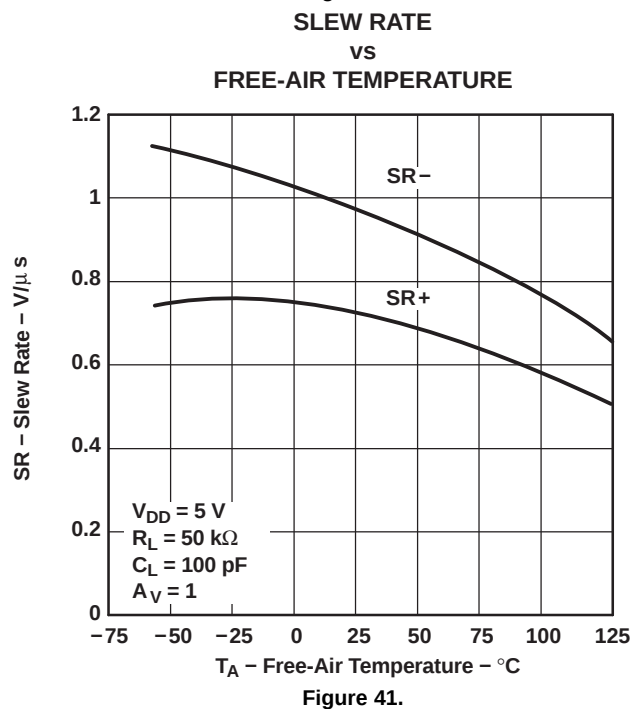
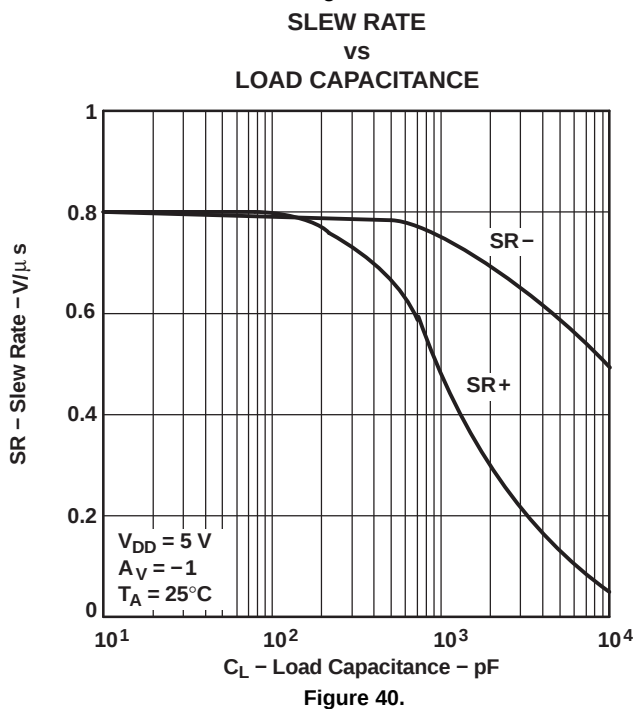
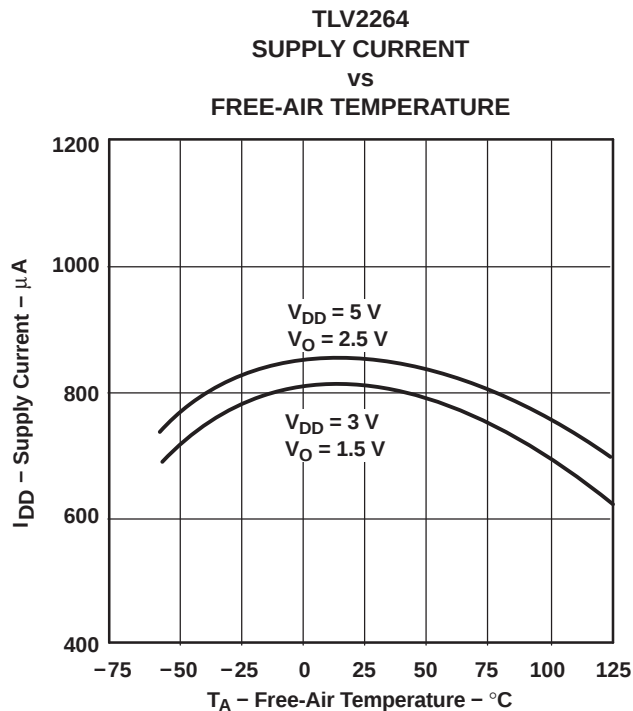
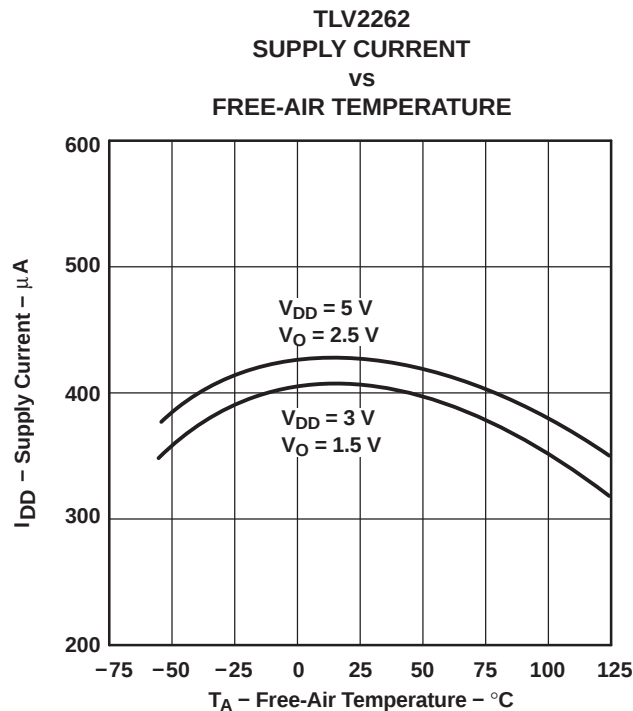


Figure 37.



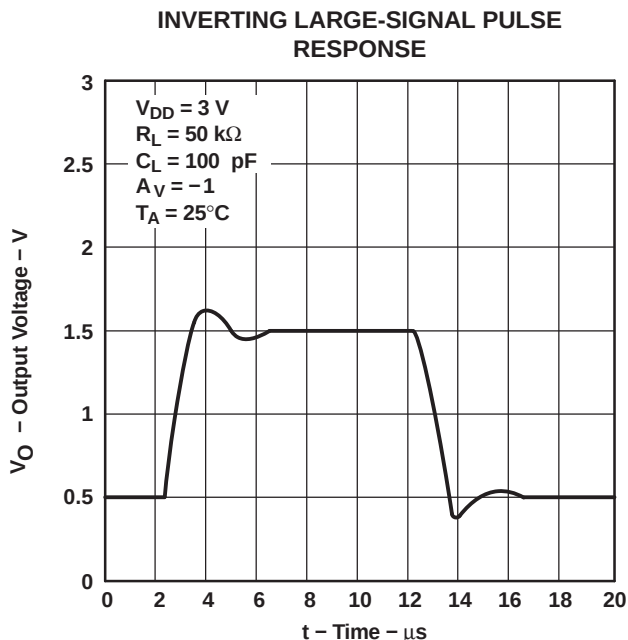


Figure 42.

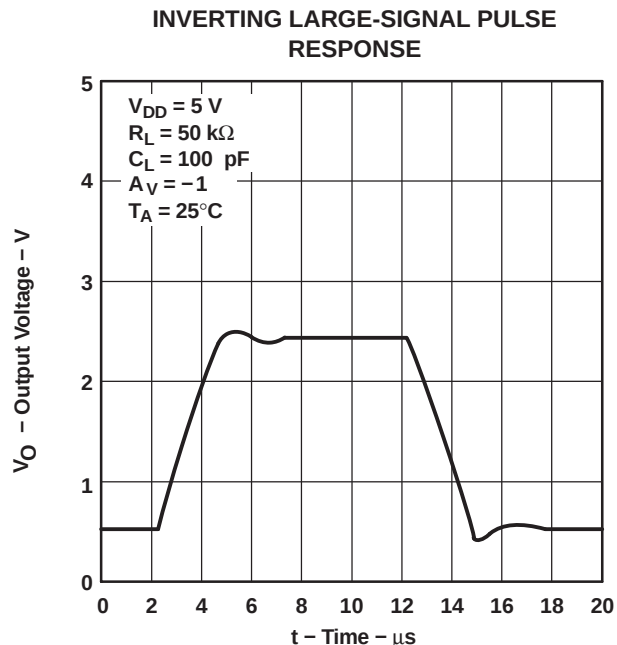


Figure 43.

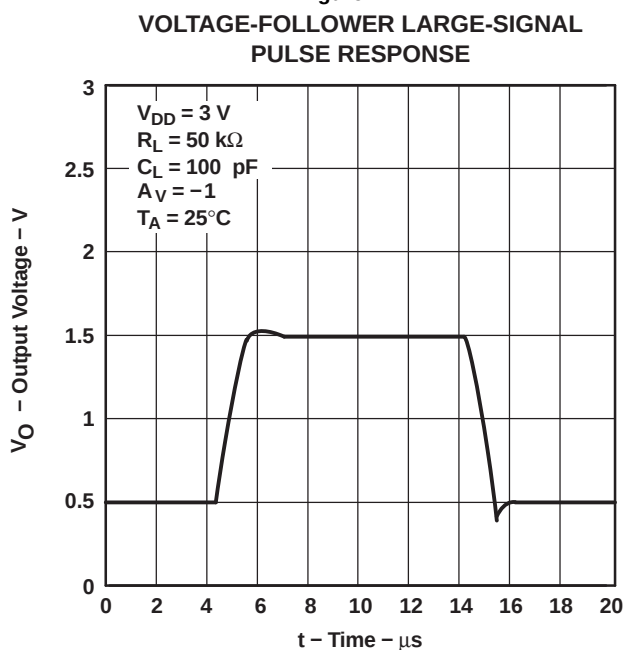


Figure 44.

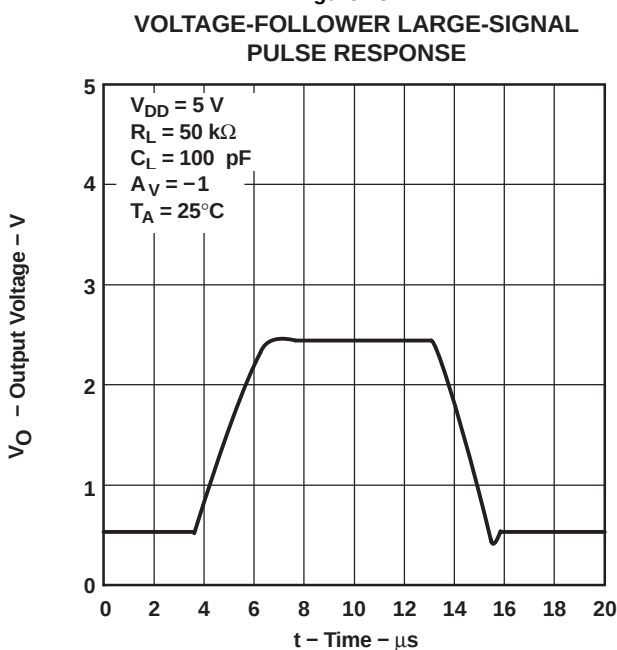


Figure 45.

**INVERTING SMALL-SIGNAL
PULSE RESPONSE**

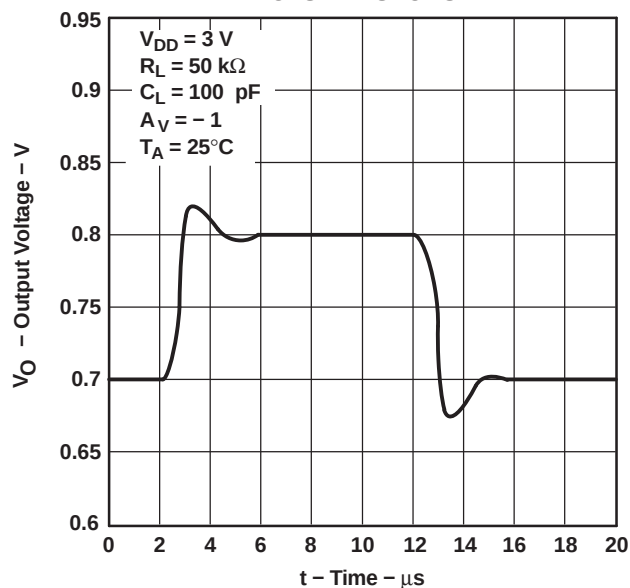


Figure 46.

**INVERTING SMALL-SIGNAL
PULSE RESPONSE**

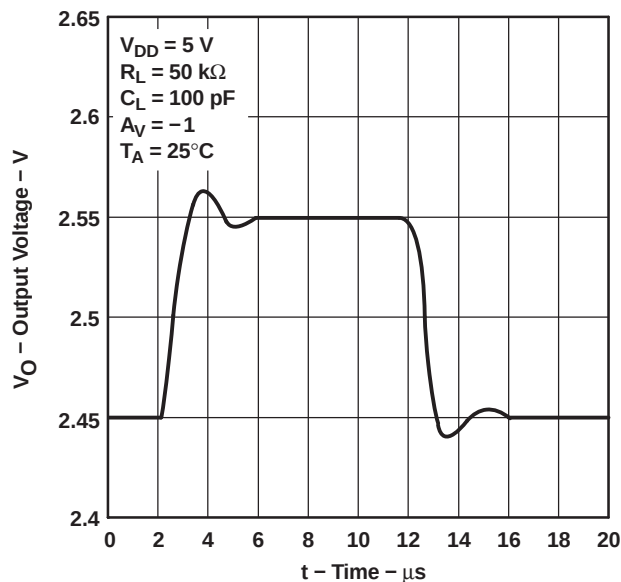


Figure 47.

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

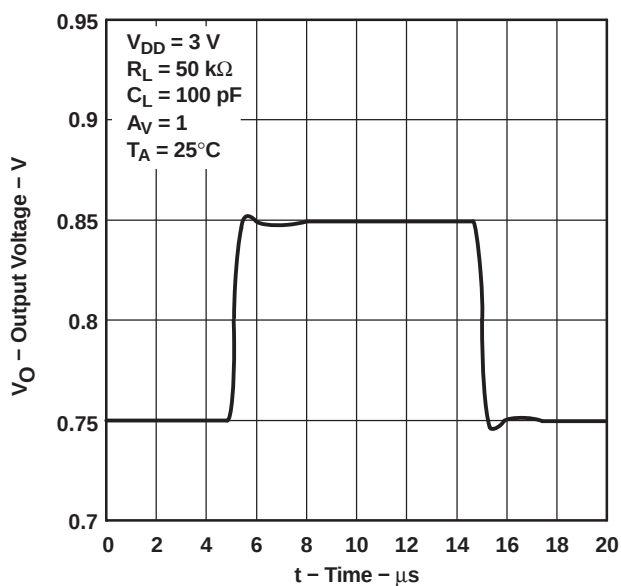


Figure 48.

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

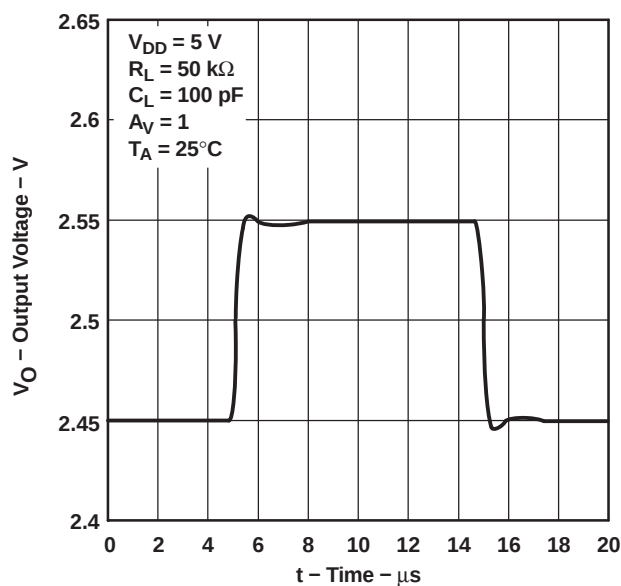


Figure 49.

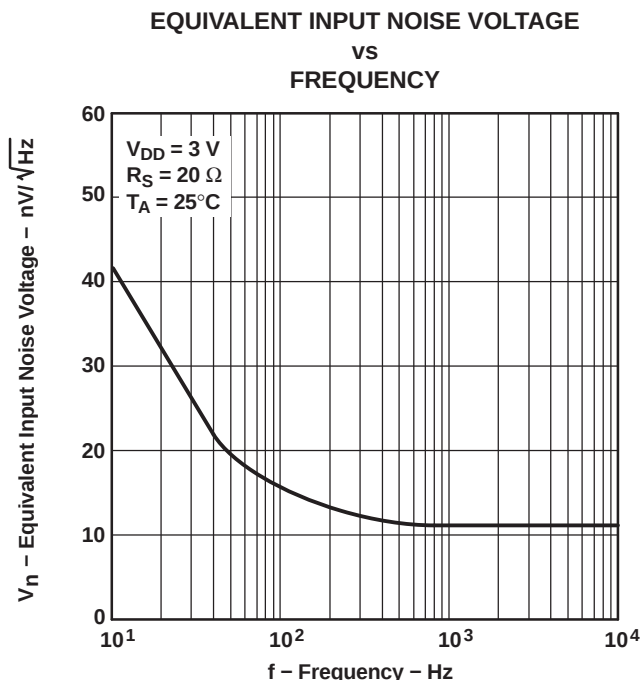


Figure 50.

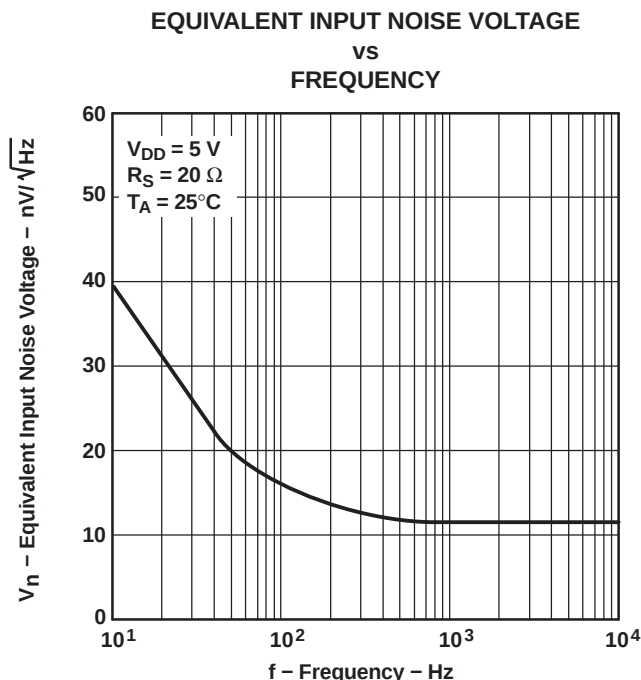


Figure 51.

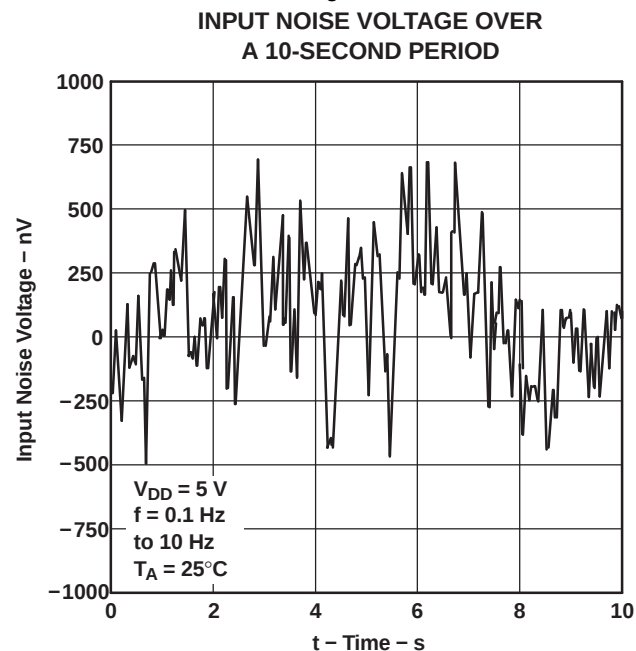


Figure 52.

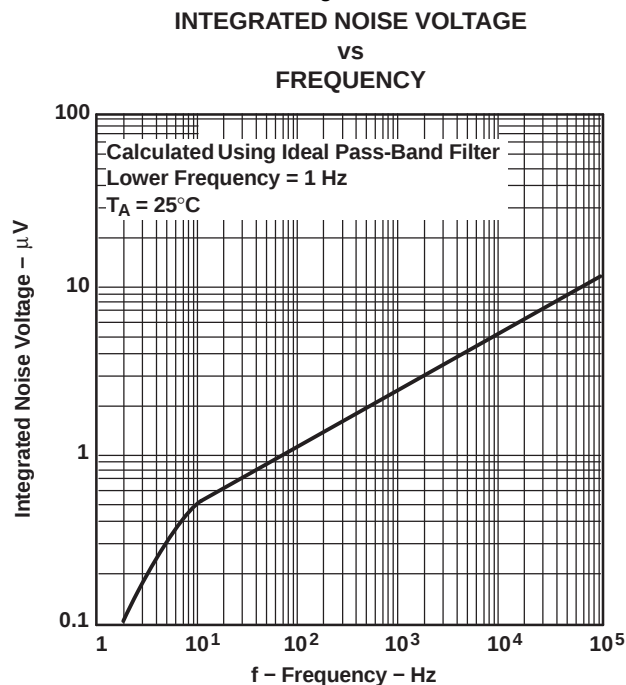


Figure 53.

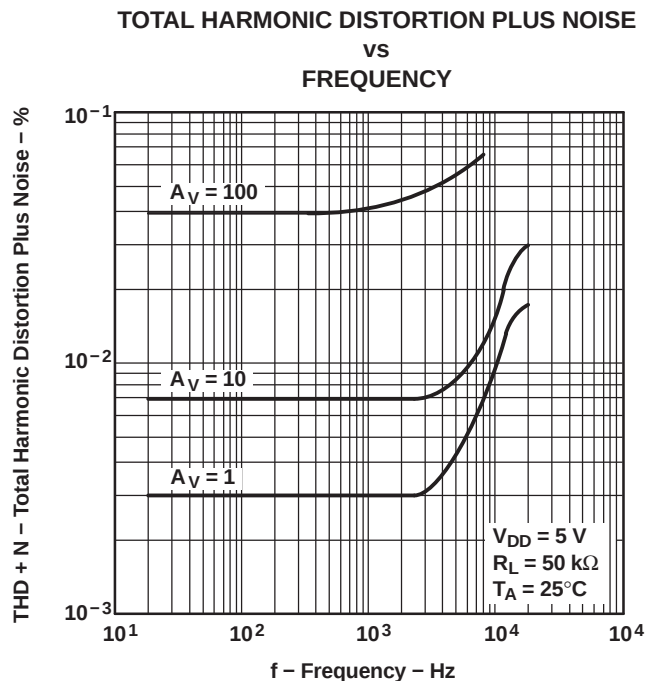


Figure 54.
**GAIN-BANDWIDTH PRODUCT
VS
FREE-AIR TEMPERATURE**

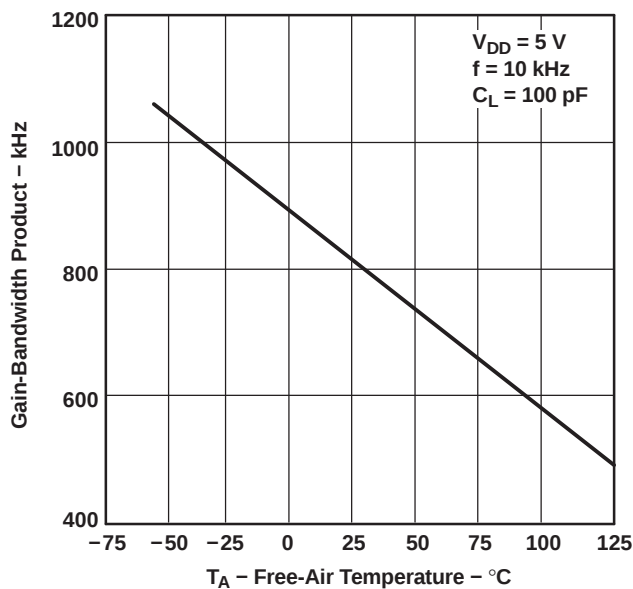


Figure 56.

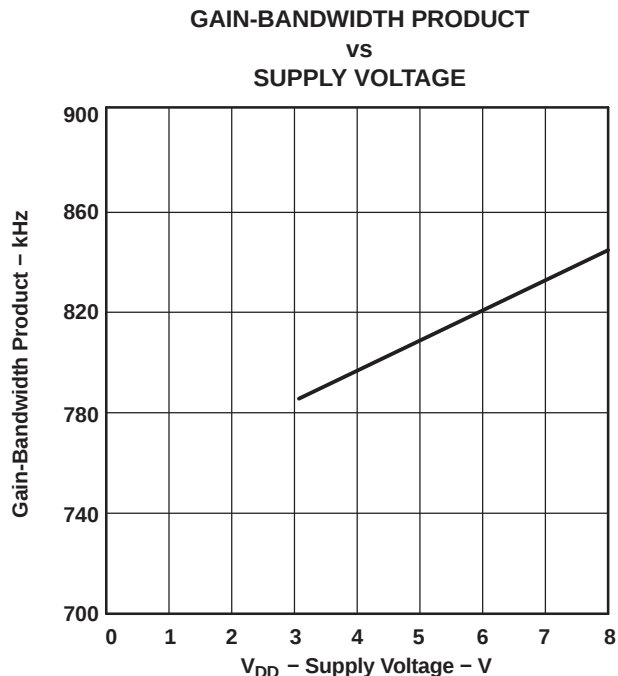


Figure 55.

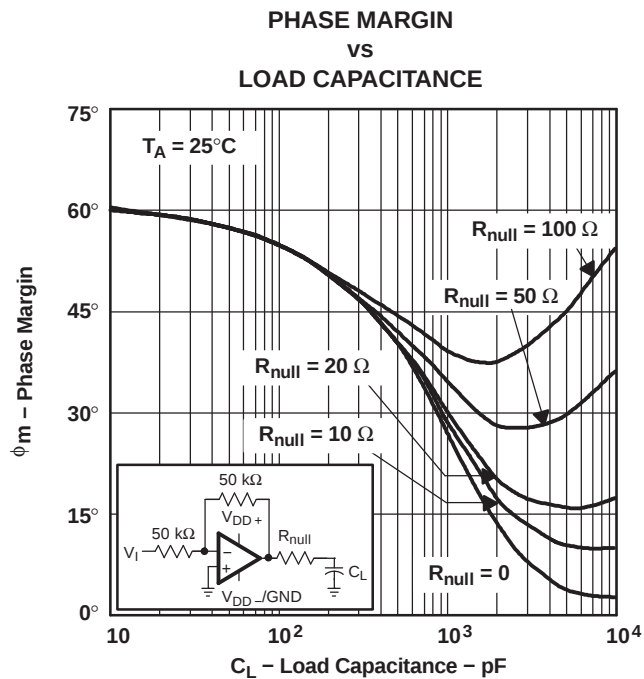


Figure 57.

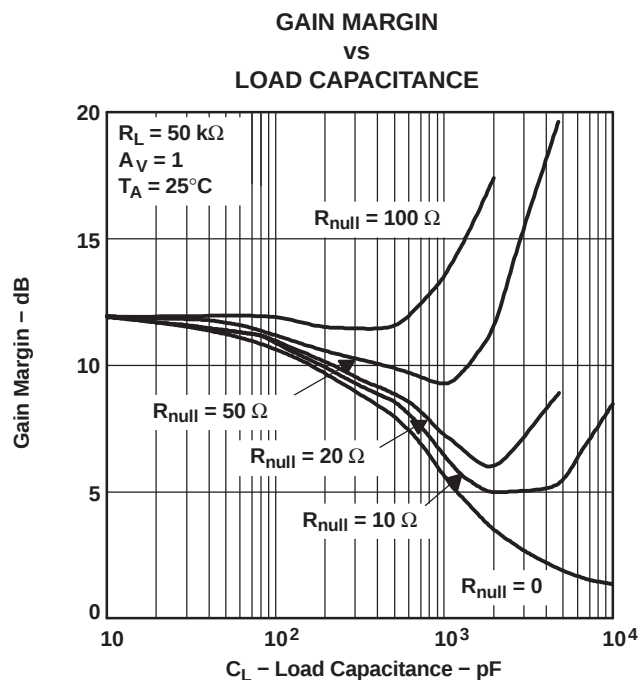


Figure 58.

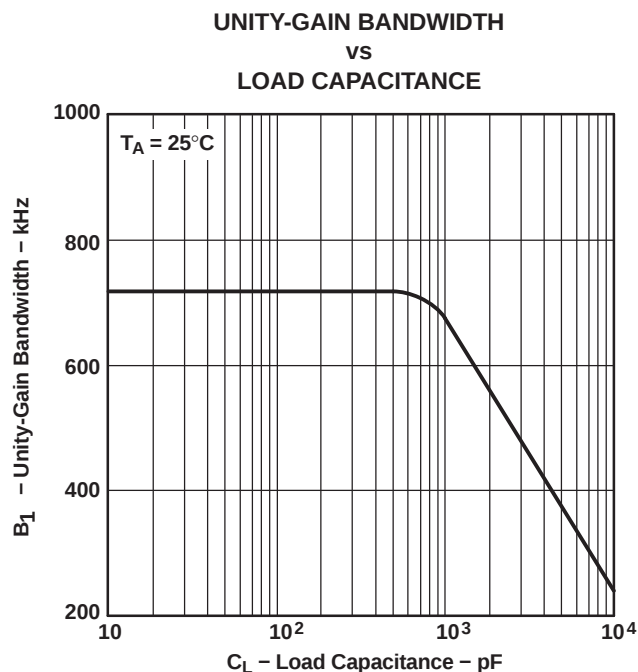
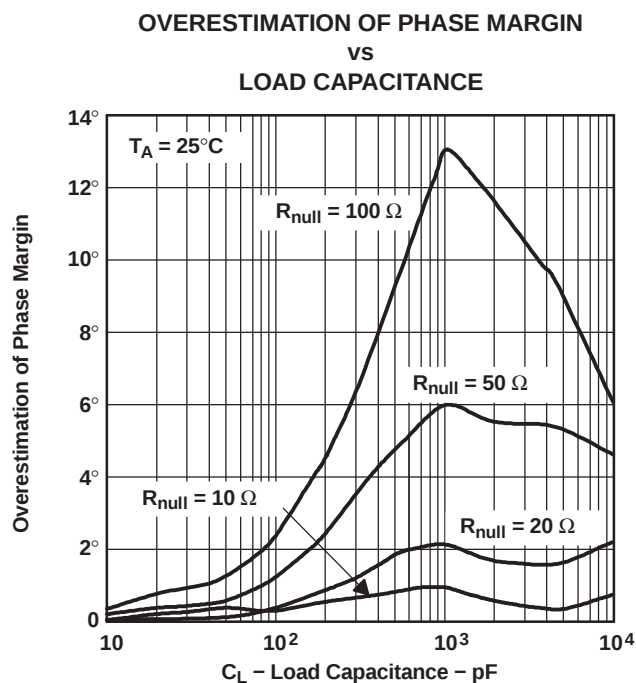


Figure 59.



NOTE: See application information.

Figure 60.

APPLICATION INFORMATION

Driving Large Capacitive Loads

The TLV226x is designed to drive larger capacitive loads than most CMOS operational amplifiers. Figure 51 and Figure 52 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 61) improves the gain and phase margins when driving large capacitive loads. Figure 51 and Figure 52 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.

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

Where :

$\Delta\theta_{m1}$ = improvement in phase margin

UGBW = unity-gain bandwidth frequency

R_{null} = output series resistance

C_L = load capacitance

(1)

The unity-gain bandwidth (UGBW) frequency decreases as the capacitive load increases (see Figure 53). To use Equation 1, UGBW must be approximated from Figure 53.

Using Equation 1 alone overestimates the improvement in phase margin as illustrated in Figure 60. The overestimation is caused by the decrease in the frequency of the pole associated with the load, providing additional phase shift and reducing the overall improvement in phase margin. The pole associated with the load is reduced by the factor calculated in Equation 2.

$$F = \frac{1}{1 + g_m \times R_{null}}$$

Where :

F = factor reducing frequency of pole

g_m = small-signal output transconductance (typically 4.83×10^{-3} mhos)

R_{null} = output series resistance

(2)

For the TLV226x, 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 (see 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 1 to better approximate the improvement in phase margin.

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

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.)

(3)

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.

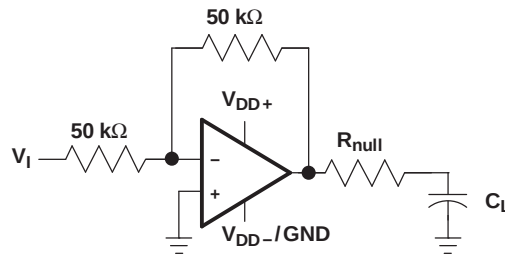


Figure 61. Series-Resistance Circuit

Macromodel Information

Macromodel information provided was derived using Microsim Parts™, the model generation software used with Microsim PSpice™. The Boyle macromodel⁽¹⁾ and subcircuit in [Figure 62](#) are generated using the TLV226x 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

(1) 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).

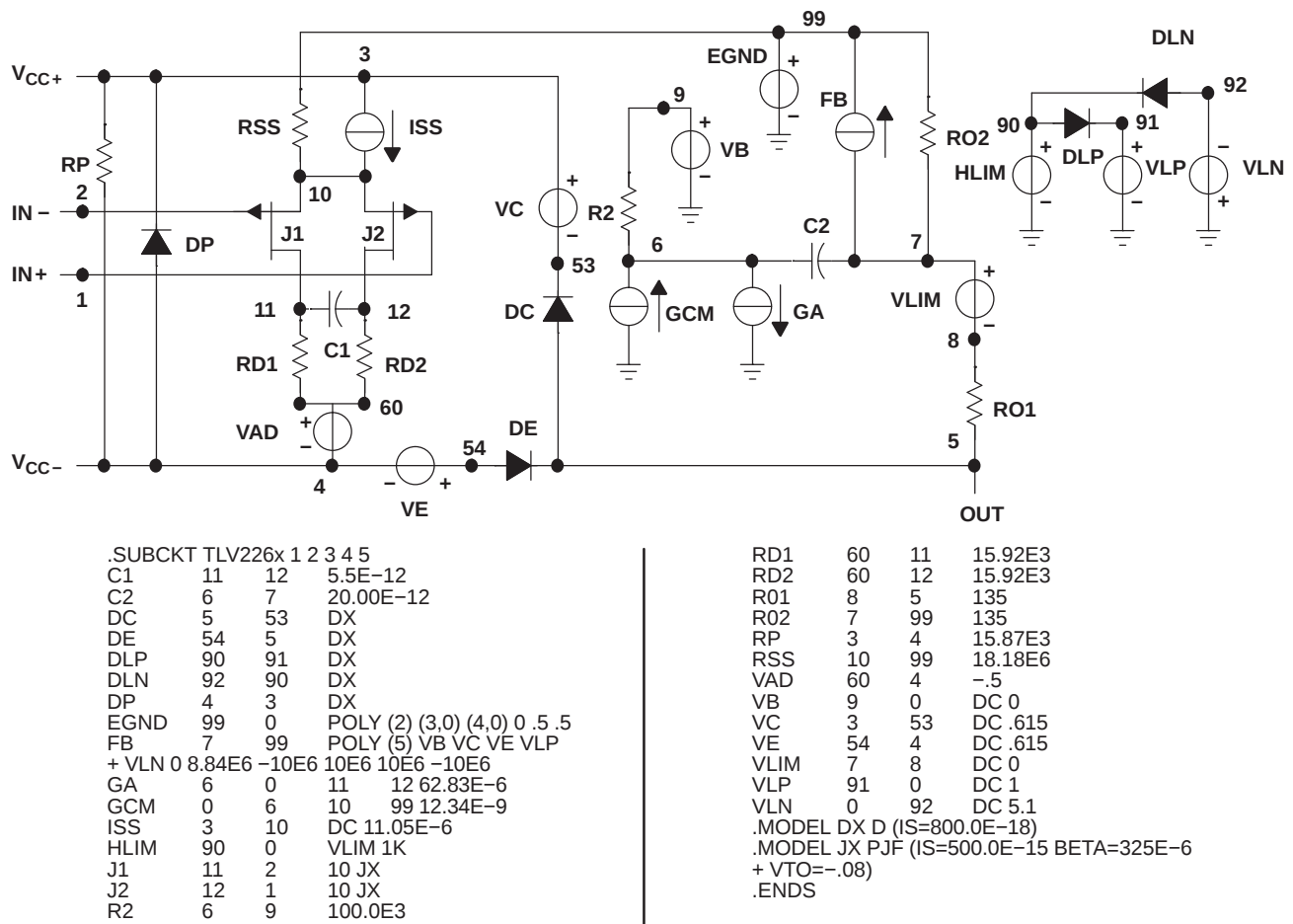


Figure 62. Boyle Macromodel and Subcircuit

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)
TLV2262AQPWRQ1	Active	Production	TSSOP (PW) 8	2000 LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	TQ262A
TLV2262AQPWRQ1.A	Active	Production	TSSOP (PW) 8	2000 LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	TQ262A
TLV2264AQPWRQ1	Active	Production	TSSOP (PW) 14	2000 LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	P2264AQ
TLV2264AQPWRQ1.A	Active	Production	TSSOP (PW) 14	2000 LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	P2264AQ
TLV2264AQPWRQ1.B	Active	Production	TSSOP (PW) 14	2000 LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	P2264AQ

⁽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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OTHER QUALIFIED VERSIONS OF TLV2262A-Q1, TLV2264A-Q1 :

- Catalog : [TLV2262A](#), [TLV2264A](#)
- Military : [TLV2262AM](#), [TLV2264AM](#)

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
TLV2262AQPWRQ1	TSSOP	PW	8	2000	330.0	12.4	7.0	3.6	1.6	8.0	12.0	Q1
TLV2264AQPWRQ1	TSSOP	PW	14	2000	330.0	12.4	6.9	5.6	1.6	8.0	12.0	Q1

TAPE AND REEL BOX DIMENSIONS



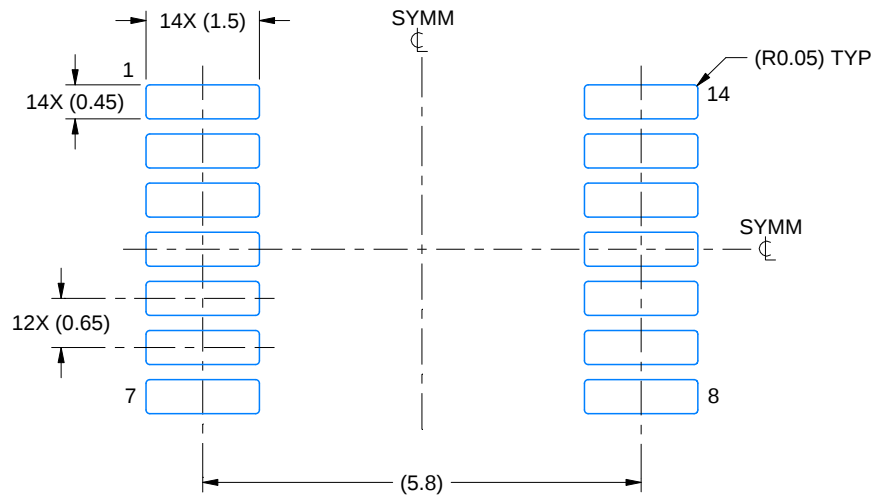
*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
TLV2262AQPWRQ1	TSSOP	PW	8	2000	353.0	353.0	32.0
TLV2264AQPWRQ1	TSSOP	PW	14	2000	353.0	353.0	32.0

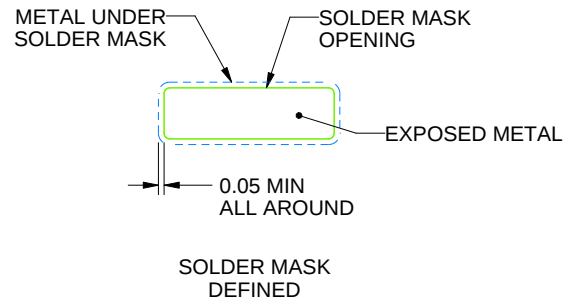
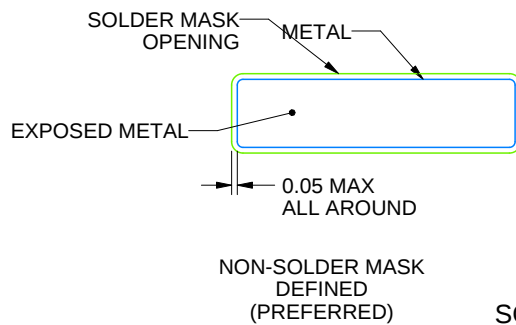
PW0014A

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

4220202/B 12/2023

NOTES: (continued)

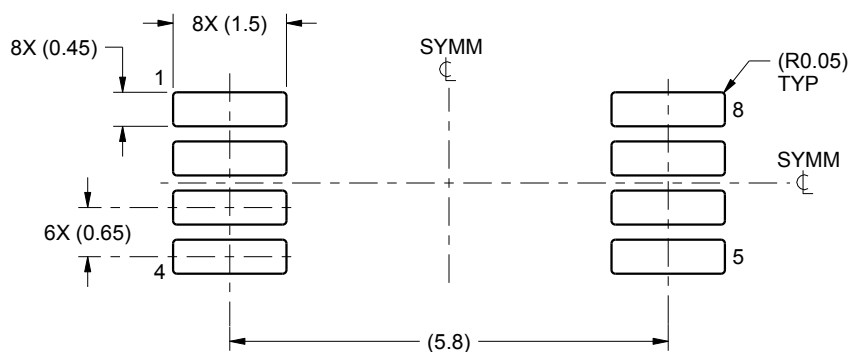
8. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
9. Board assembly site may have different recommendations for stencil design.

EXAMPLE BOARD LAYOUT

PW0008A

TSSOP - 1.2 mm max height

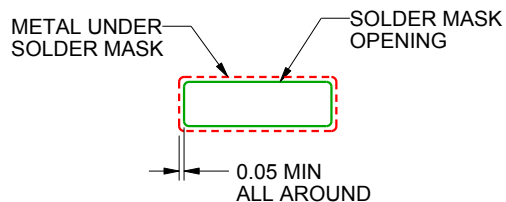
SMALL OUTLINE PACKAGE



LAND PATTERN EXAMPLE
SCALE:10X



NON SOLDER MASK
DEFINED



SOLDER MASK
DEFINED

SOLDER MASK DETAILS
NOT TO SCALE

4221848/A 02/2015

NOTES: (continued)

6. Publication IPC-7351 may have alternate designs.

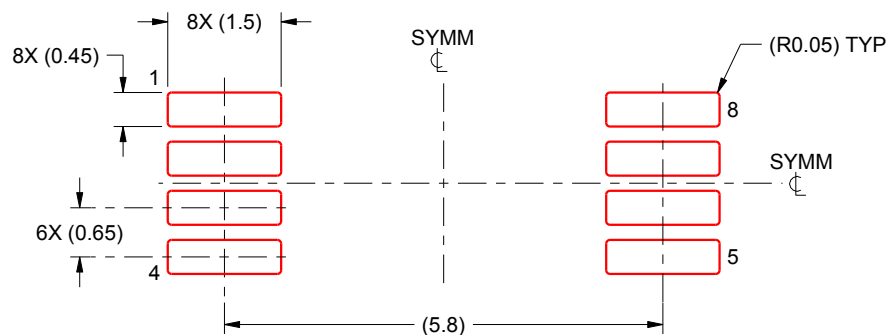
7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.

EXAMPLE STENCIL DESIGN

PW0008A

TSSOP - 1.2 mm max height

SMALL OUTLINE PACKAGE



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

4221848/A 02/2015

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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