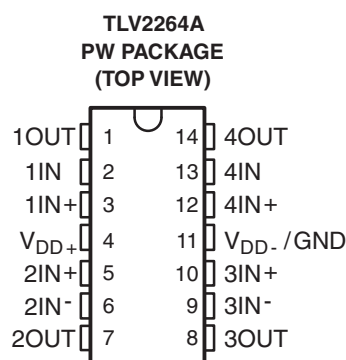
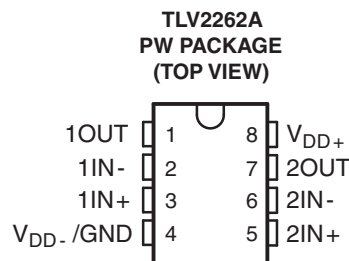


Advanced LinCMOS™ RAIL-TO-RAIL OPERATIONAL AMPLIFIERS

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



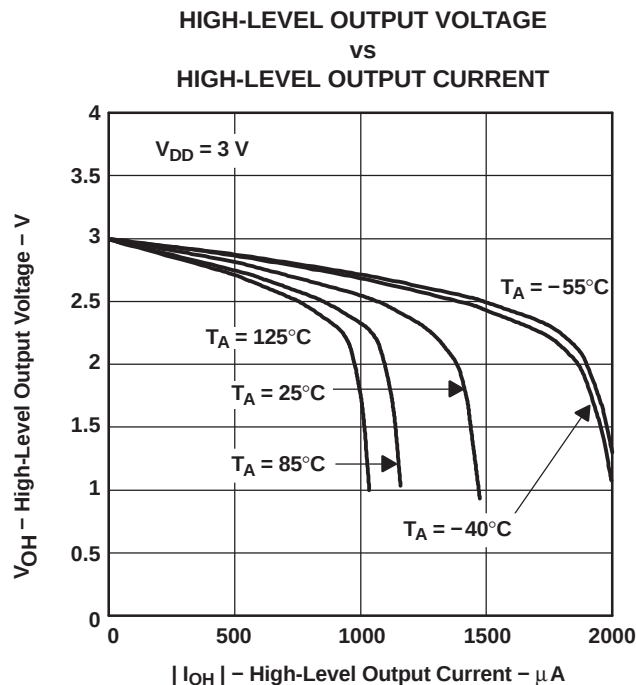
DESCRIPTION

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.

**Figure 1.**

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 μV .

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)

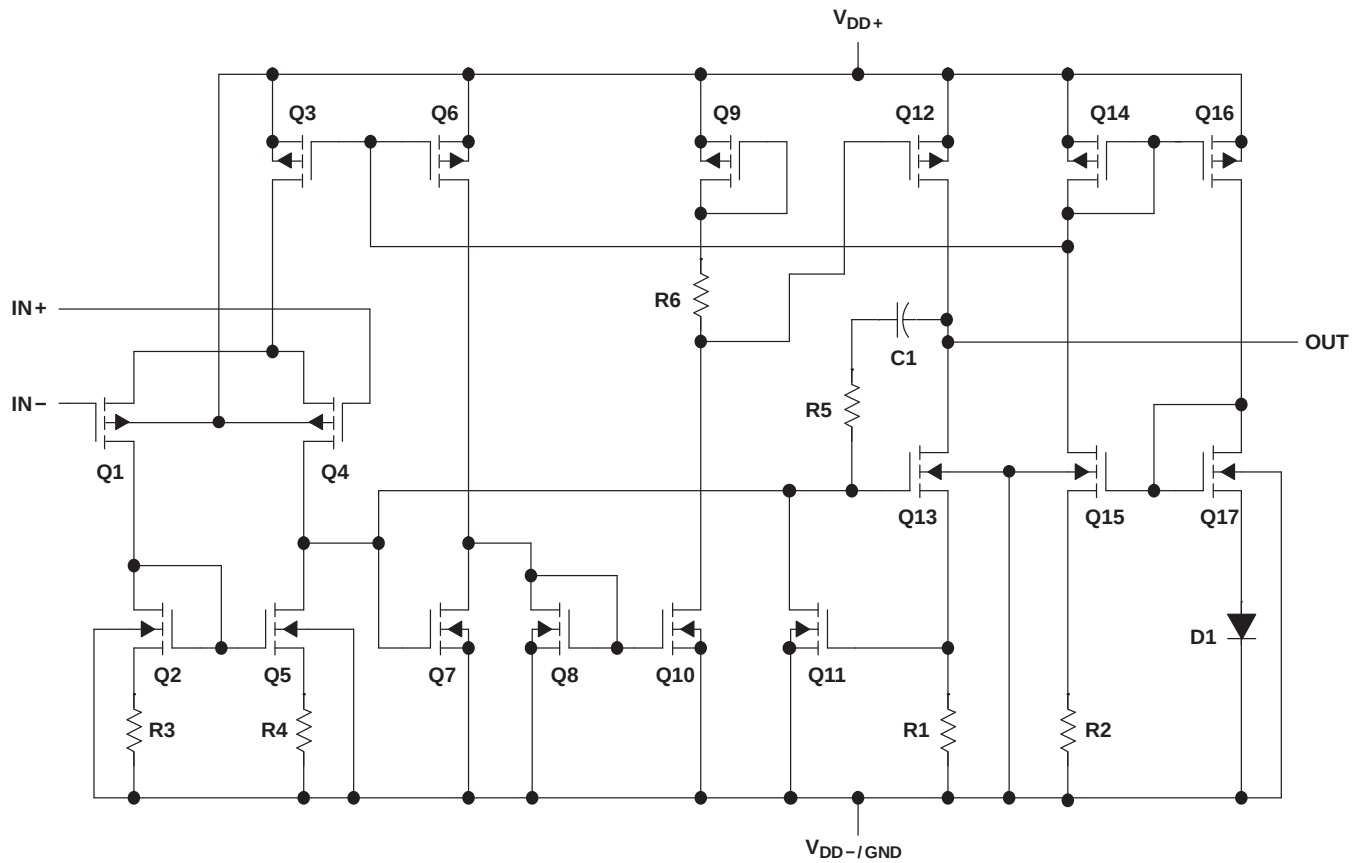


Table 1. Actual Device Component Count

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	$V_{DD\pm} = \pm 1.5\text{ V}$, $V_{IC} = 0$, $V_O = 0$, $R_S = 50\ \Omega$		25°C		300	950	mV
				Full range			1500	
α_{VIO}	Temperature coefficient of input offset voltage	$V_{DD\pm} = \pm 1.5\text{ V}$, $V_{IC} = 0$, $V_O = 0$, $R_S = 50\ \Omega$		25°C to 125°C		2		$\mu\text{V}/^\circ\text{C}$
	Input offset voltage long-term drift ⁽¹⁾	$V_{DD\pm} = \pm 1.5\text{ V}$, $V_{IC} = 0$, $V_O = 0$, $R_S = 50\ \Omega$		25°C		0.003		$\mu\text{V}/\text{mo}$
I_{IO}	Input offset current	$V_{DD\pm} = \pm 1.5\text{ V}$, $V_{IC} = 0$, $V_O = 0$, $R_S = 50\ \Omega$		25°C		0.5	60	pA
				125°C			800	
I_{IB}	Input bias current	$V_{DD\pm} = \pm 1.5\text{ V}$, $V_{IC} = 0$, $V_O = 0$, $R_S = 50\ \Omega$		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 2	–0.3 to 2.2		V
				Full range	0 to 1.7			
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		2.99		V
				25°C		2.85		
				Full range		2.82		
				25°C		2.7		
V_{OL}	Low-level output voltage	$V_{IC} = 1.5\text{ V}$		25°C		10		mV
				25°C		100	150	
				Full range			165	
				25°C		200	300	
A_{VD}	Large-signal differential voltage amplification	$V_{IC} = 1.5\text{ V}$, $V_O = 1\text{ V to }2\text{ V}$	$R_L = 50\text{ k}\Omega^{(2)}$ $R_L = 1\text{ M}\Omega^{(2)}$	25°C		60	100	V/mV
				Full range		25		
				25°C		100		
				Full range			300	
$r_{i(d)}$	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		270		Ω
CMRR	Common-mode rejection ratio	$V_{IC} = 0\text{ to }1.7\text{ V}$, $V_O = 1.5\text{ V}$, $R_S = 50\ \Omega$		25°C		65	77	dB
				Full range		60		
k_{SVR}	Supply voltage rejection ratio ($\Delta V_{DD}/\Delta V_{IO}$)	$V_{DD} = 2.7\text{ V to }8\text{ V}$, $V_{IC} = V_{DD}/2$, No load		25°C		80	100	dB
				Full range		80		
I_{DD}	Supply current	$V_O = 1.5\text{ V}$, 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 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/ μs
				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		μV
		$f = 0.1\text{ Hz to }10\text{ Hz}$		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		μs
			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±} = ±2.5 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±} = ±2.5 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±} = ±2.5 V, V _{IC} = 0, V _O = 0, R _S = 50 Ω		25°C		0.003		μV/mo
I _{IO}	Input offset current	V _{DD±} = ±2.5 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±} = ±2.5 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 4	–0.3 to 4.2	V
				Full range		0 to 3.5		
V _{OH}	High-level output voltage	I _{OH} = –20 μA		25°C		4.99		V
		I _{OH} = –100 μA		25°C		4.85	4.94	
				Full range		4.82		
		I _{OH} = –400 μA		25°C		4.7	4.85	
				Full range		4.5		
V _{OL}	Low-level output voltage	V _{IC} = 2.5 V	I _{OL} = 50 μA	25°C		0.01		V
			I _{OL} = 500 μA	25°C		0.09	0.15	
					Full range		0.15	
				I _{OL} = 1 mA	25°C		0.2	
				Full range		0.3		
A _{VD}	Large-signal differential voltage amplification	V _{IC} = 2.5 V, V _O = 1 V to 4 V		R _L = 50 kΩ ⁽²⁾	25°C	80	170	V/mV
					Full range	50		
				R _L = 1 MΩ ⁽²⁾	25°C		550	
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		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	dB
				Full range		70		
k _{SVR}	Supply voltage rejection ratio (ΔV _{DD} /ΔV _{IO})	V _{DD} = 4.4 V to 8 V, V _{IC} = V _{DD} /2, No load		25°C		80	95	dB
				Full range		80		
I _{DD}	Supply current	V _O = 2.5 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 2.5 V

TLV2264A 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/ μs
			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		μV
		$f = 0.1\text{ Hz to }10\text{ Hz}$	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		μs
			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

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
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V_{OH}	High-level output voltage	vs High-level output current	15, 18
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A_{VD}	Differential voltage amplification	vs Load resistance	25
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z_o	Output impedance	vs Frequency	30, 31
CMRR	Common-mode rejection ratio	vs Frequency	32
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k_{SVR}	Supply-voltage rejection ratio	vs Frequency	34, 35
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I_{DD}	Supply current	vs Free-air temperature	38, 39
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		vs Free-air temperature	41
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	Integrated noise voltage	vs Frequency	53
THD+N	Total harmonic distortion plus noise	vs Frequency	54
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		vs Load capacitance	57
G_m	Gain margin	vs Load capacitance	58
B_1	Unity-gain bandwidth	vs Load capacitance	59
	Overestimation of phase margin	vs Load capacitance	60

**DISTRIBUTION OF TLV2262
INPUT OFFSET VOLTAGE**

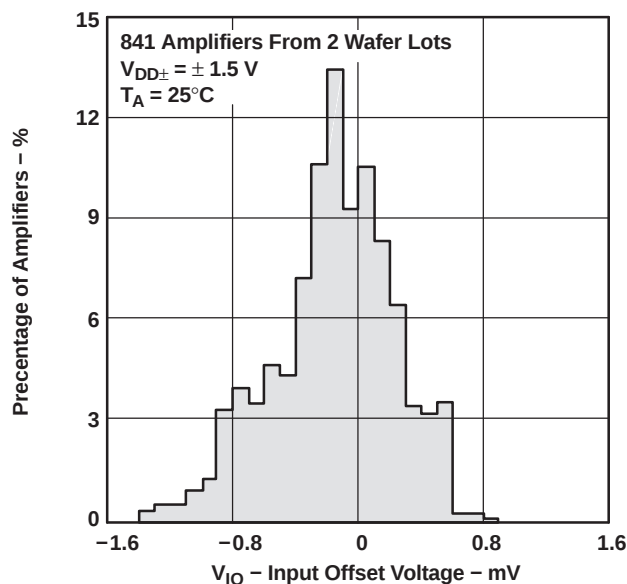


Figure 2.

**DISTRIBUTION OF TLV2262
INPUT OFFSET VOLTAGE**

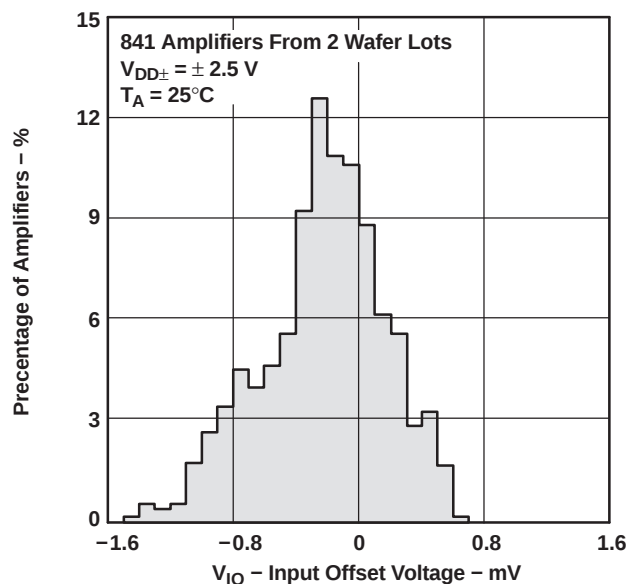


Figure 3.

**DISTRIBUTION OF TLV2264
INPUT OFFSET VOLTAGE**

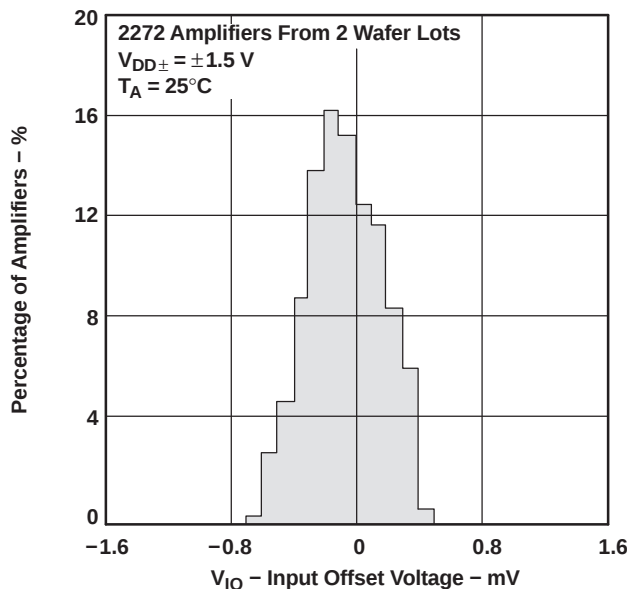


Figure 4.

**DISTRIBUTION OF TLV2264
INPUT OFFSET VOLTAGE**

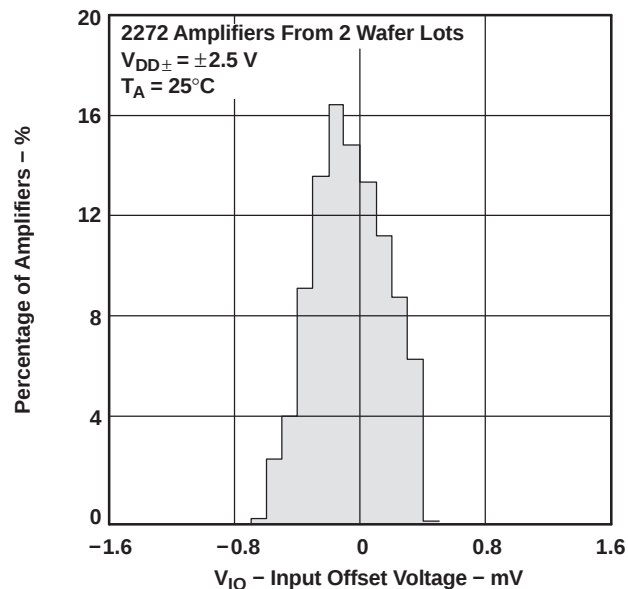


Figure 5.

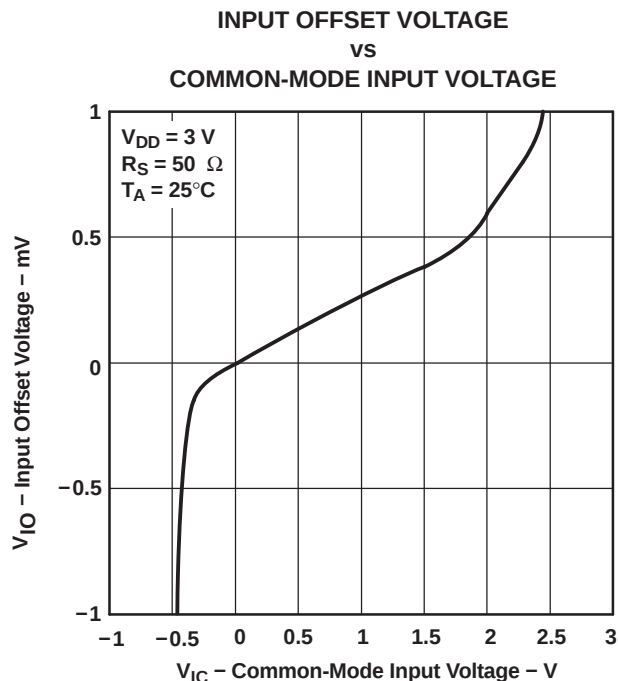


Figure 6.

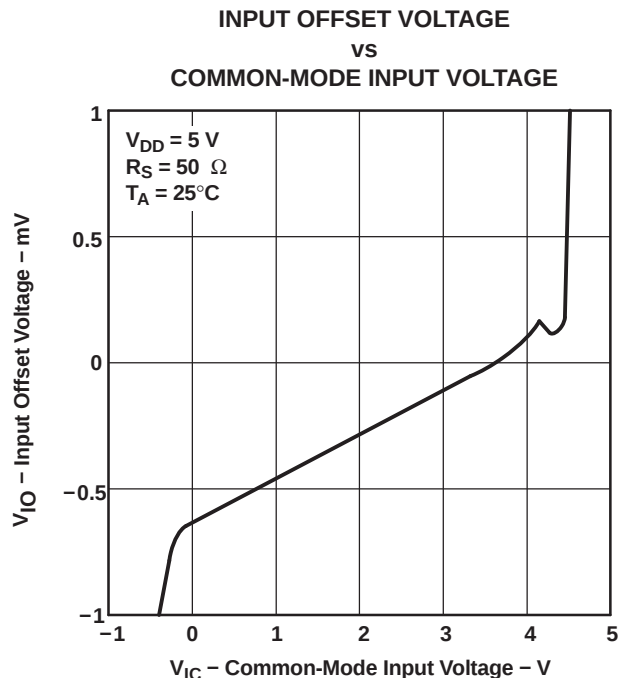


Figure 7.

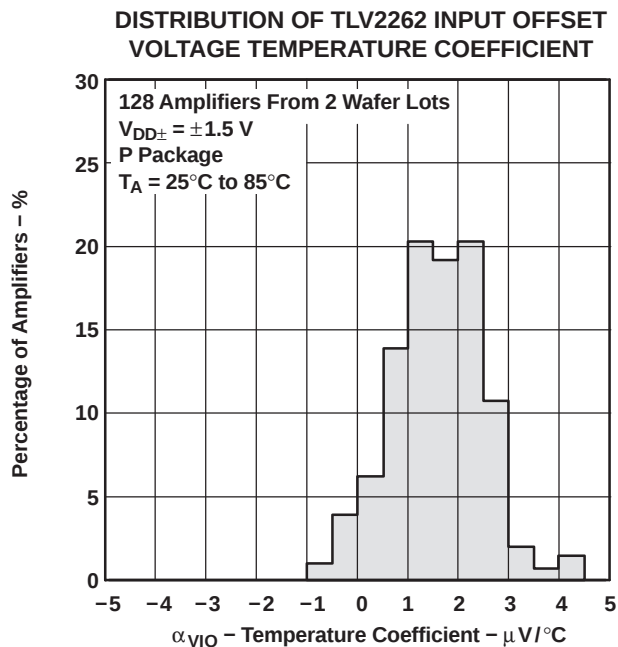


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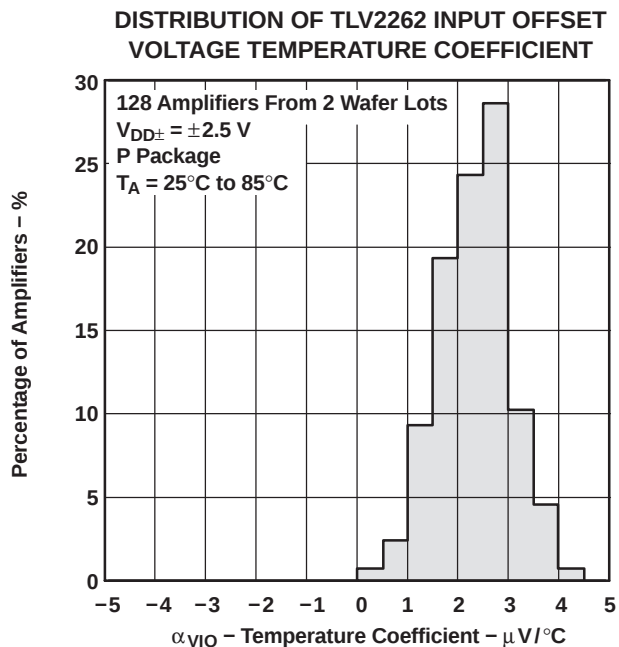


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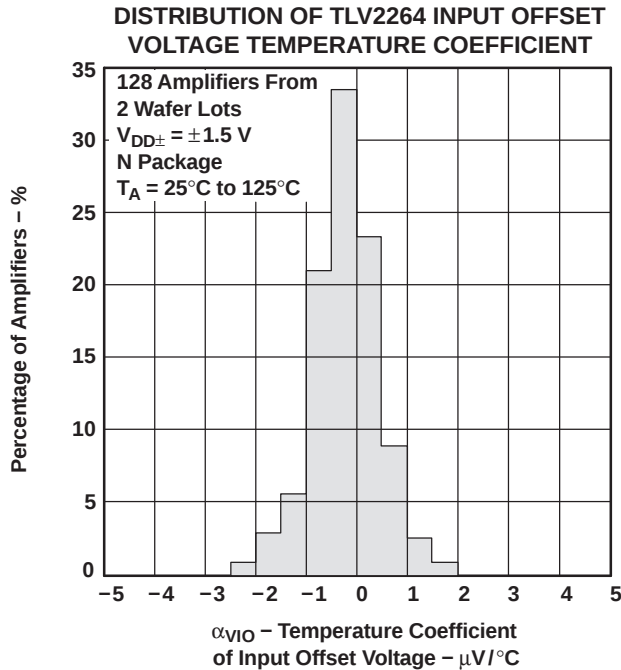


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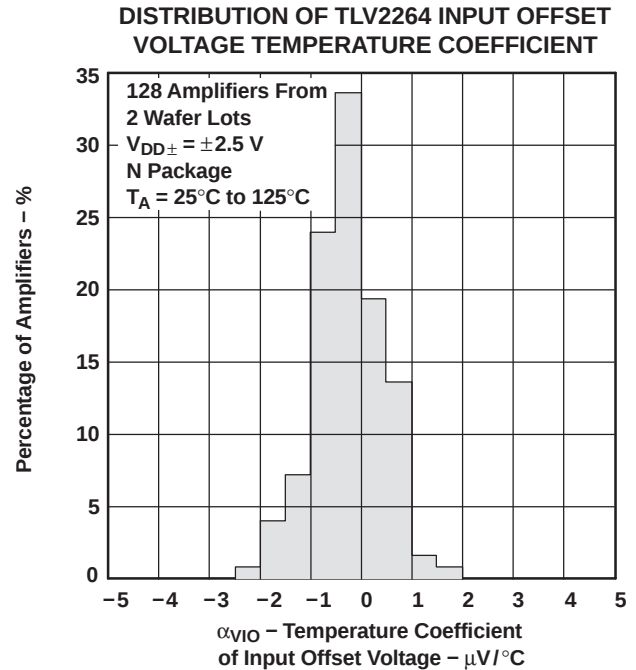


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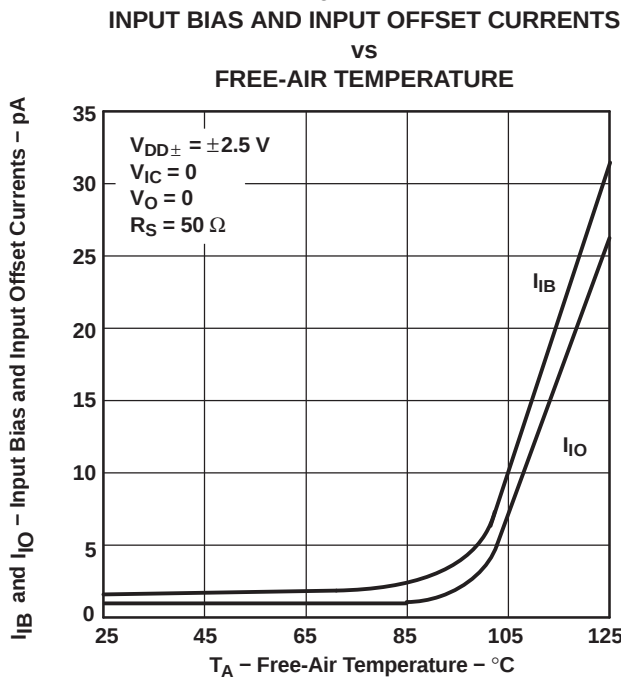


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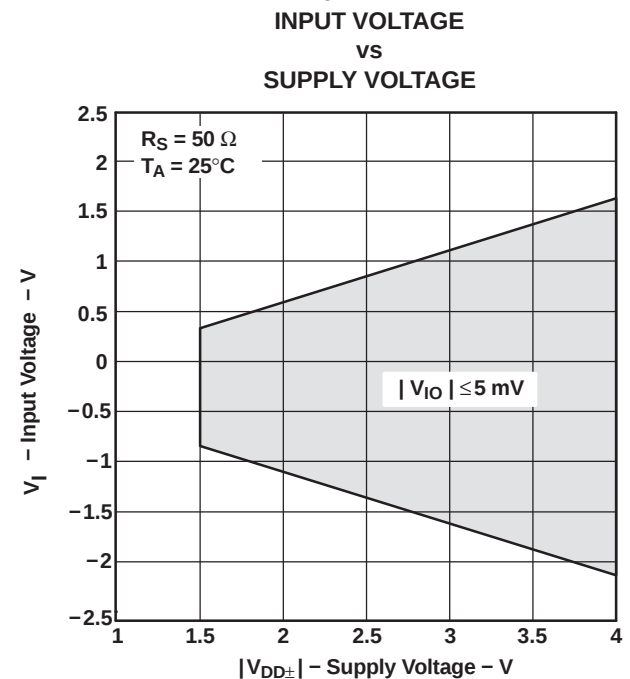


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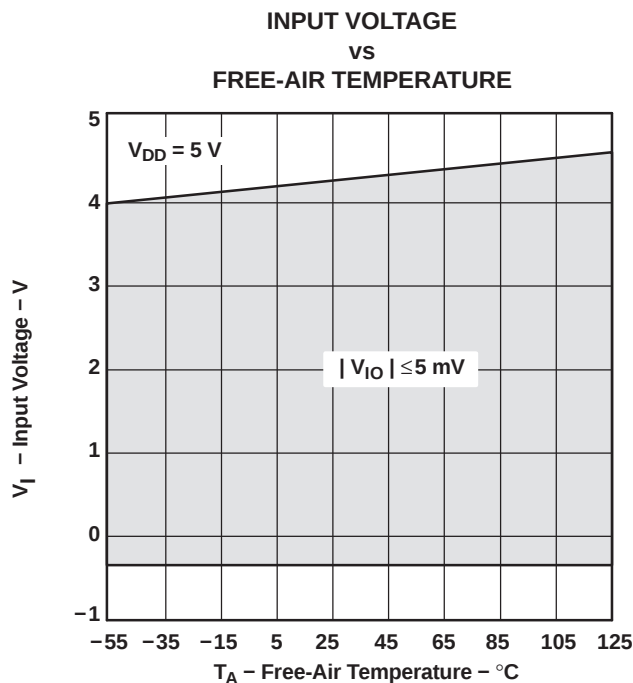


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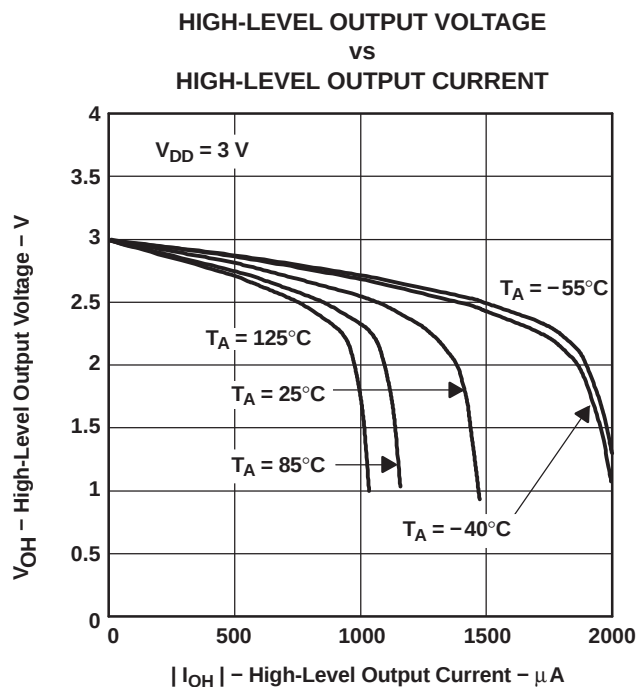


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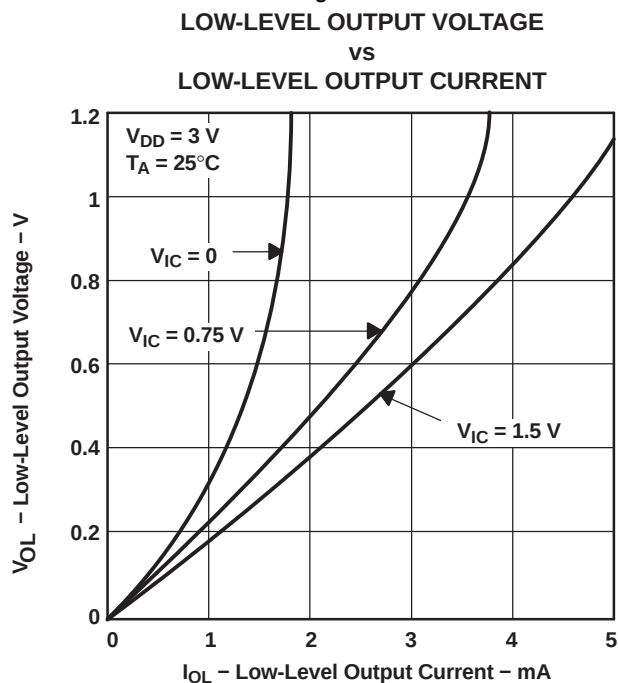


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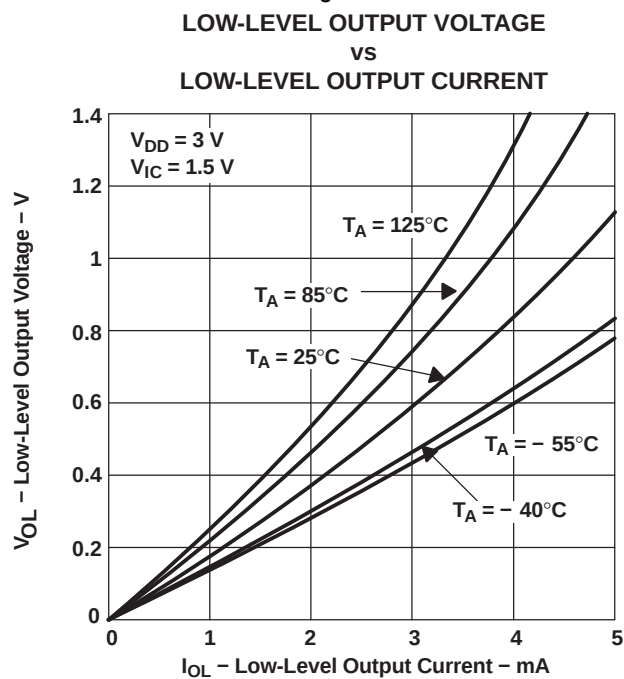


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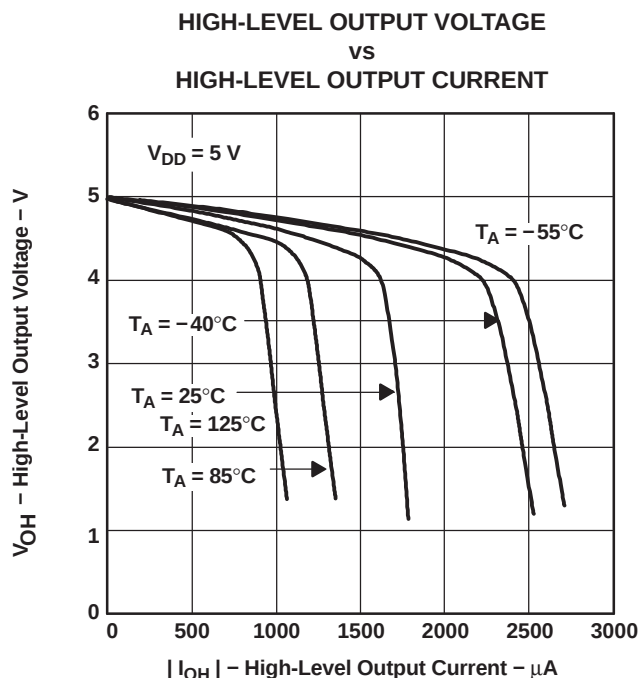


Figure 18.

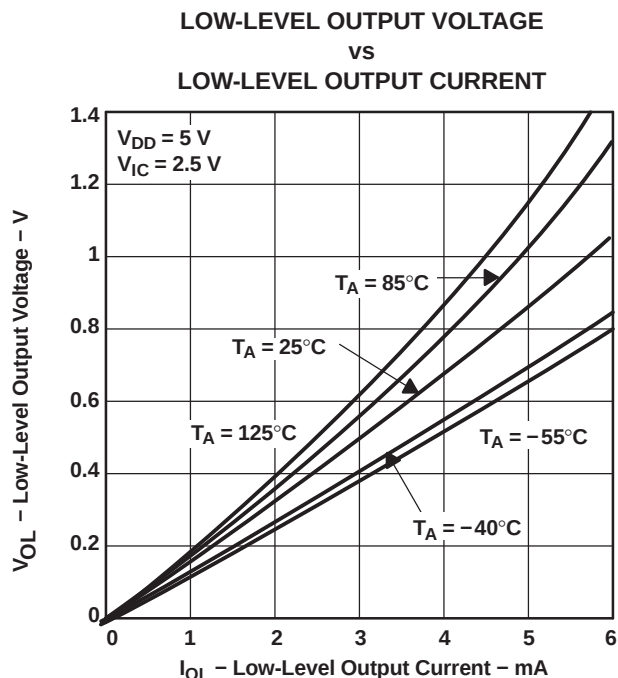


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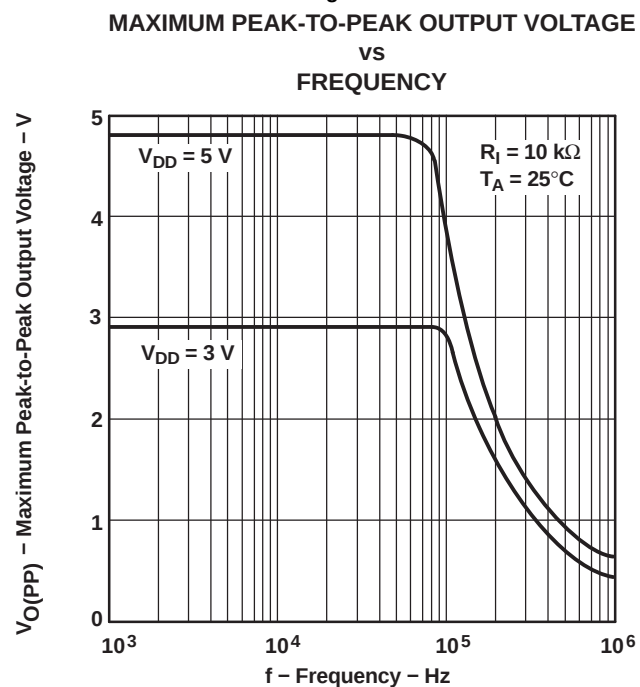


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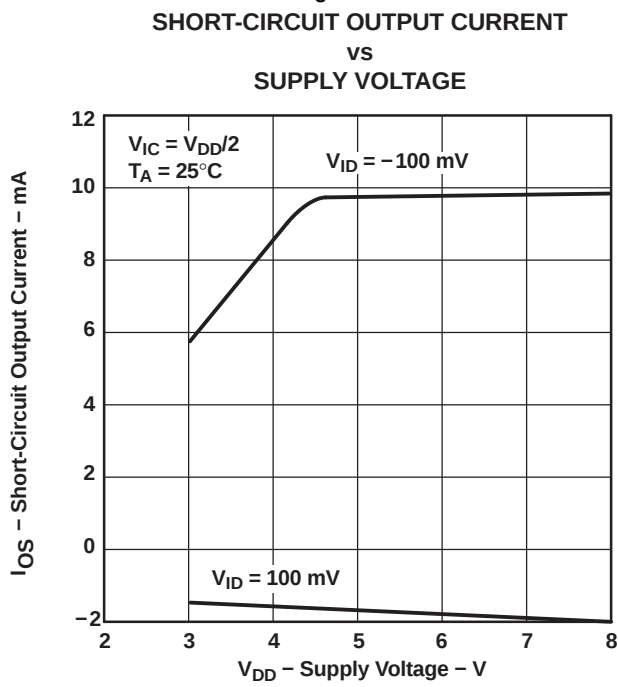
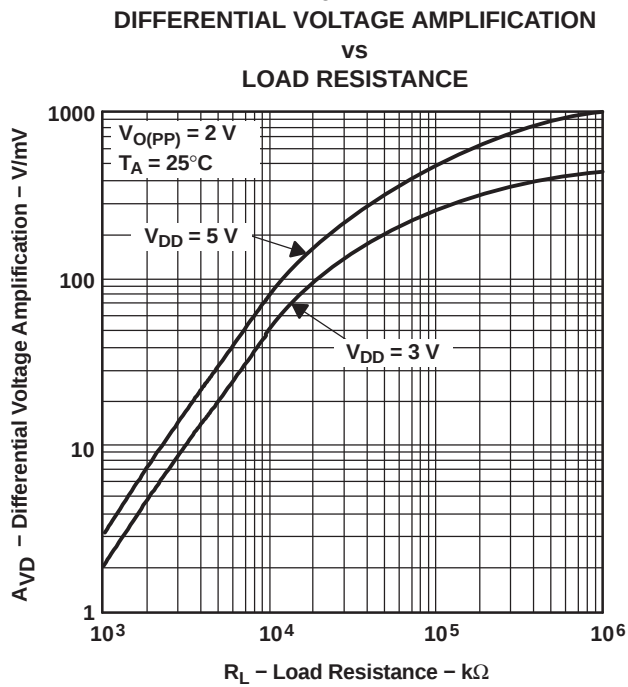
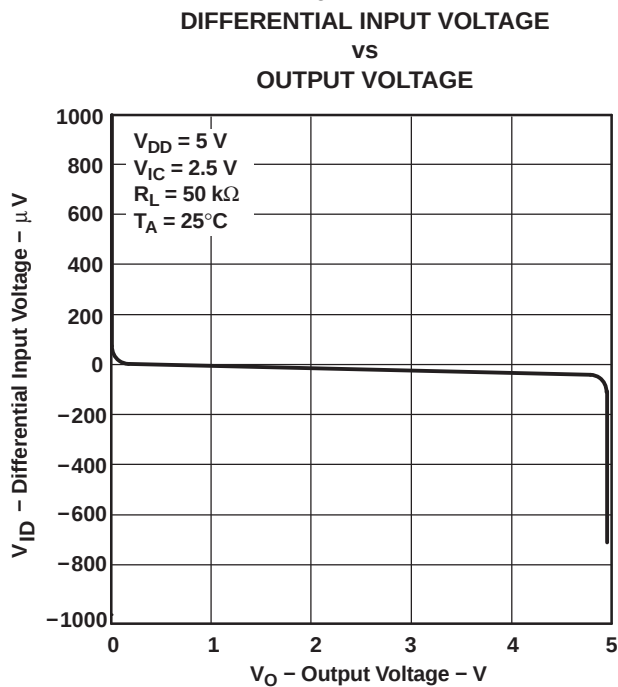
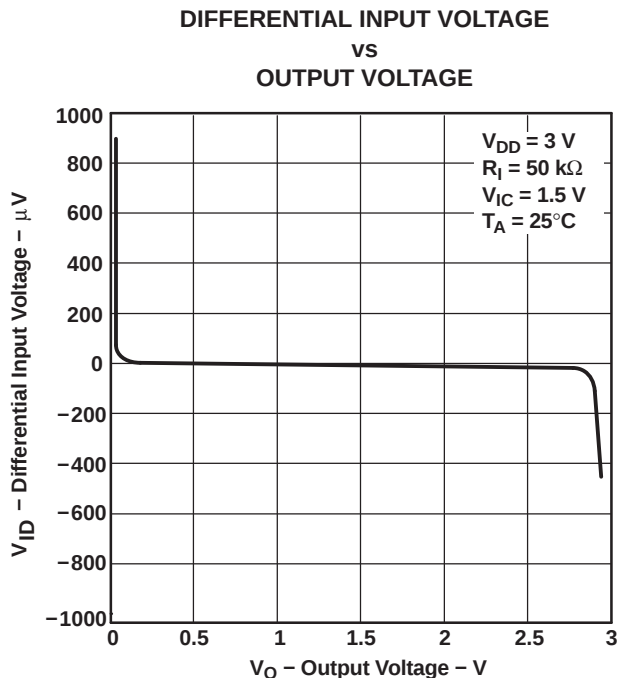
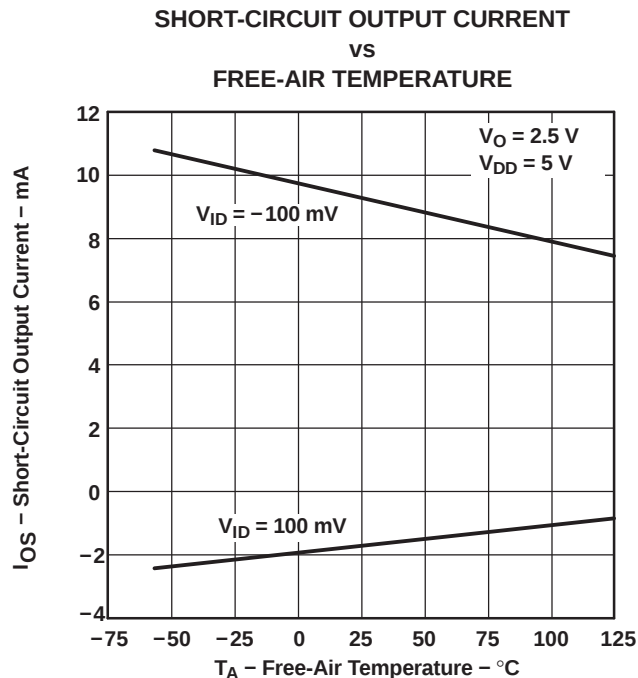


Figure 21.



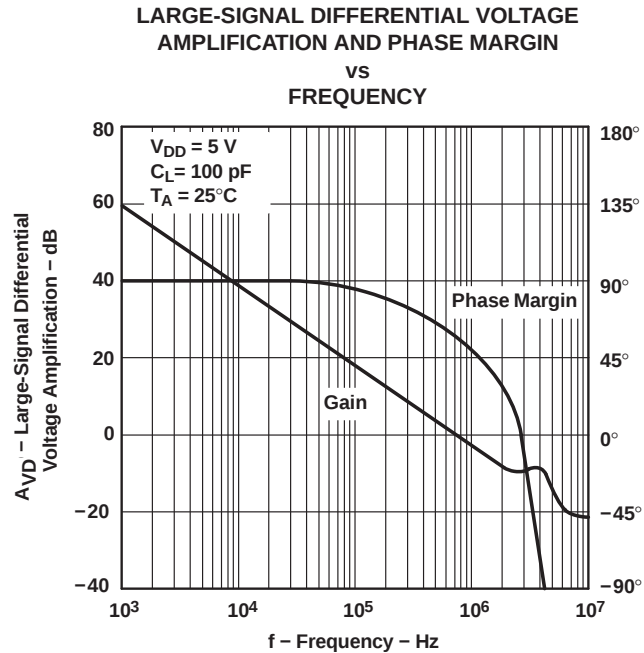


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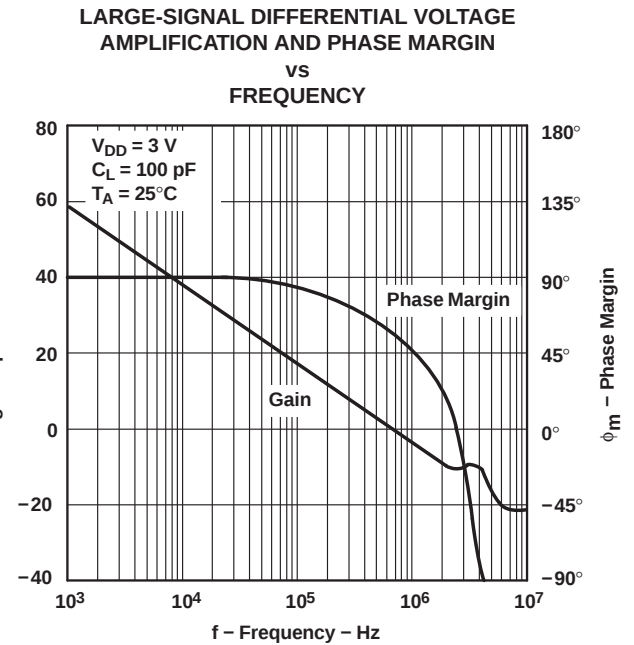


Figure 27.

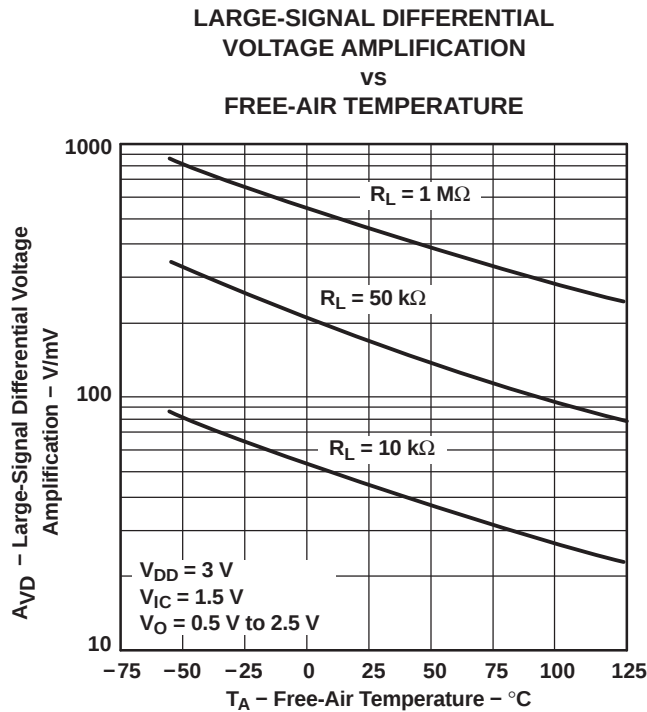


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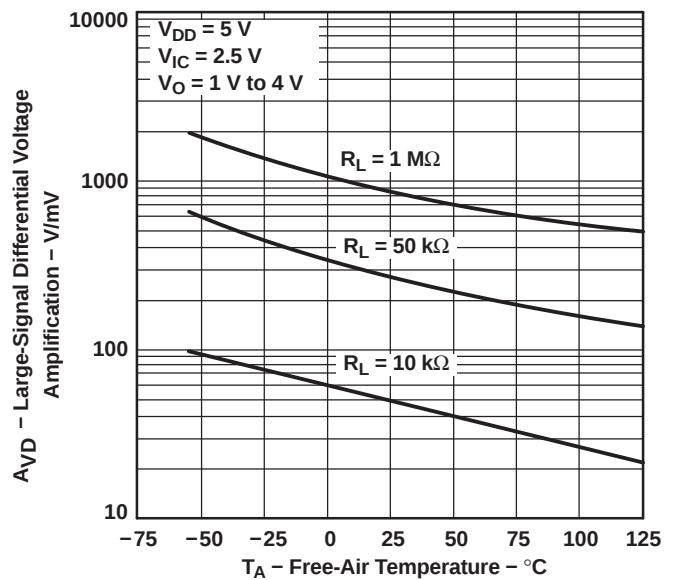


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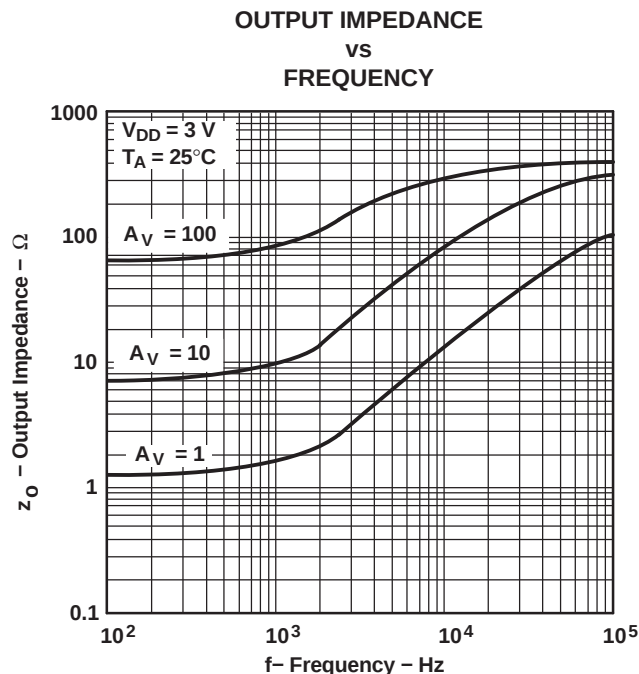


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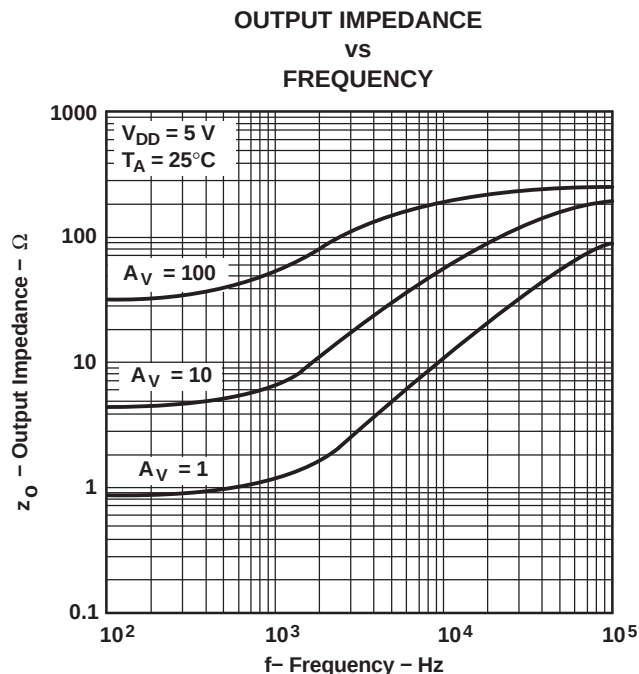


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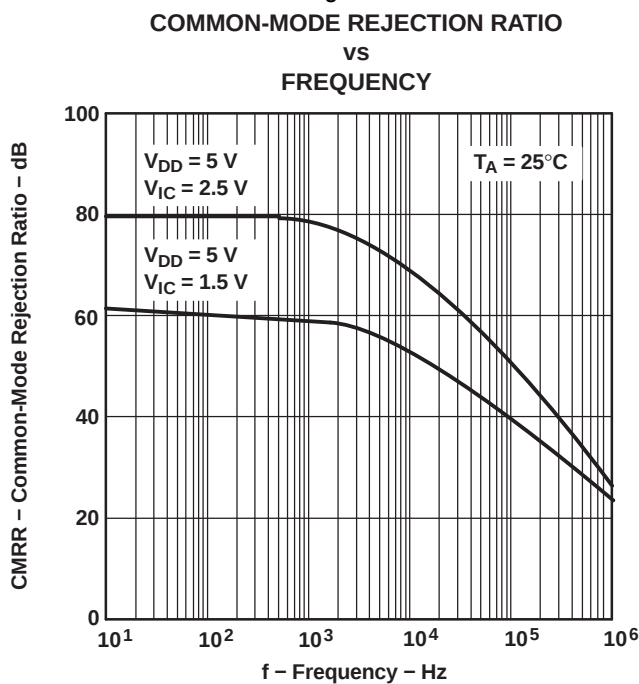


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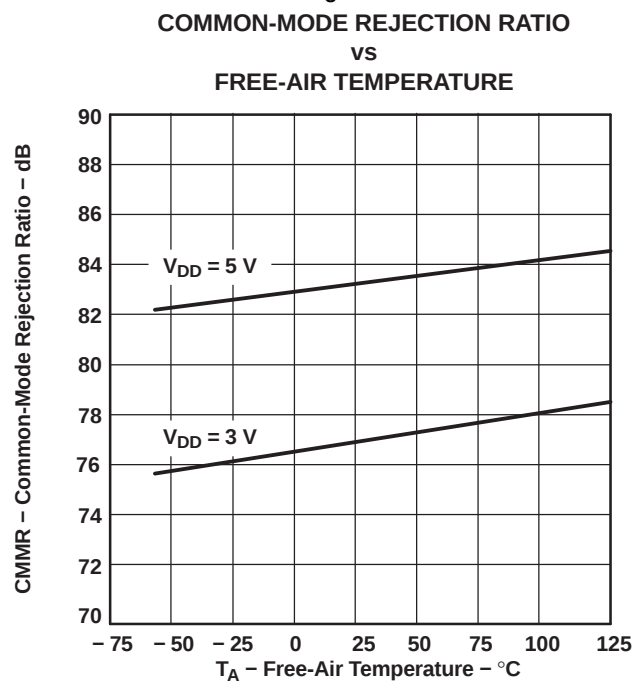
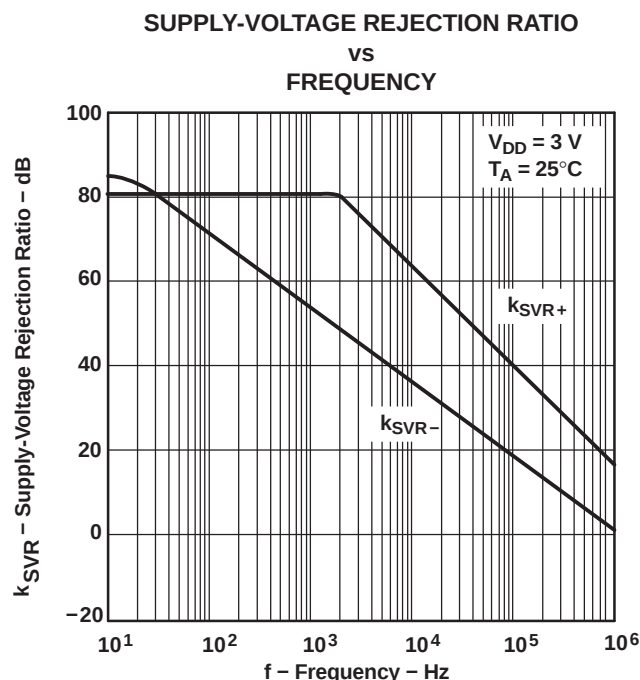
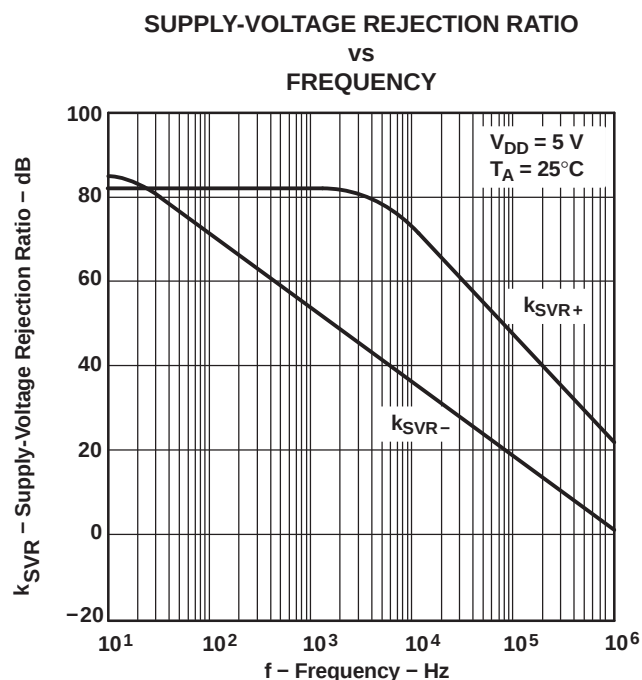
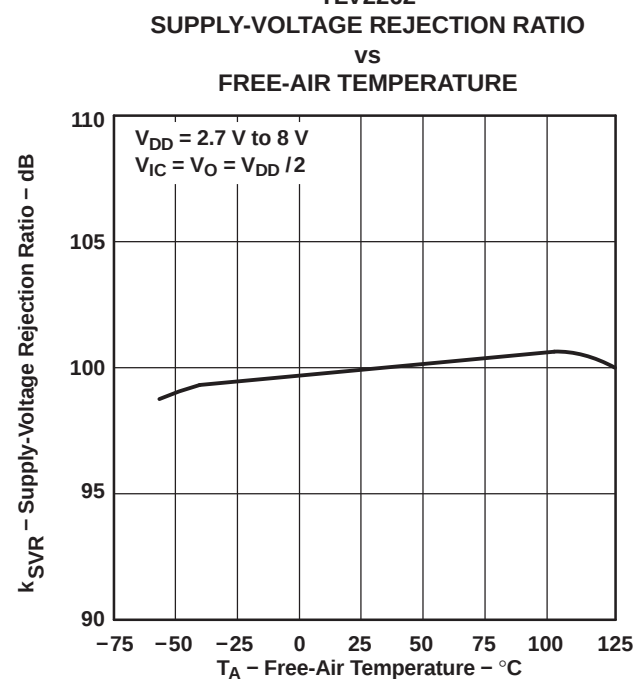


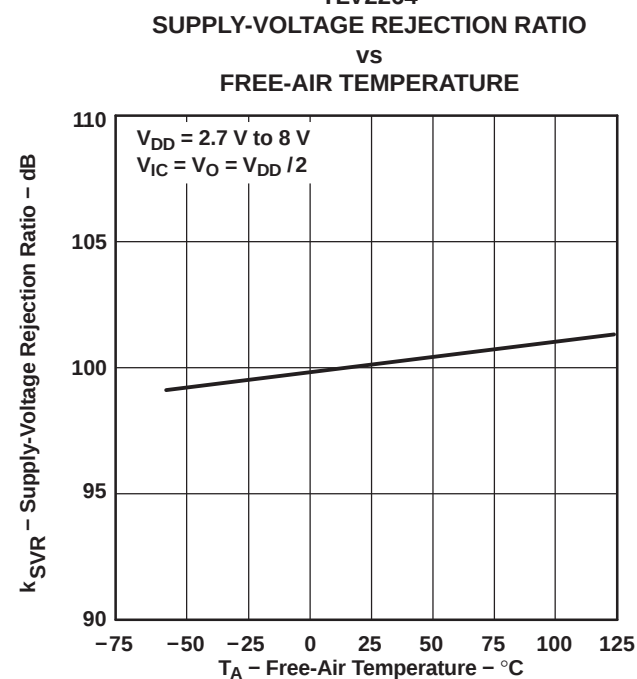
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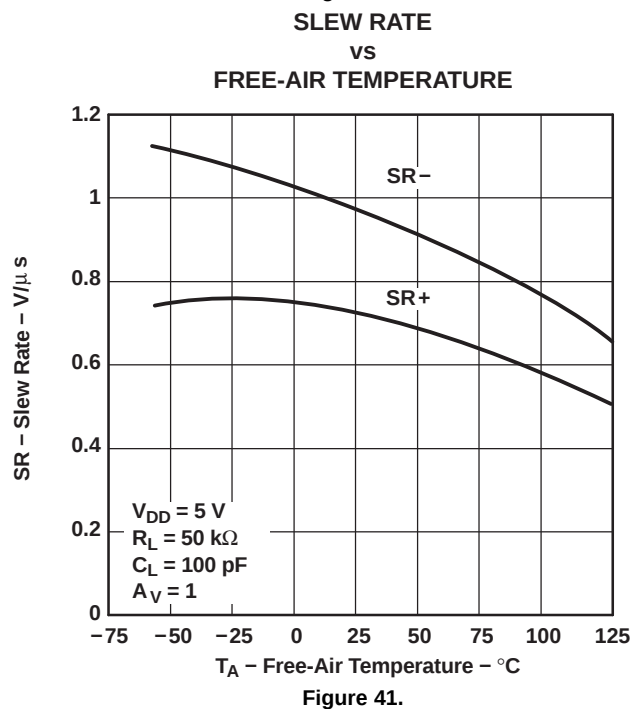
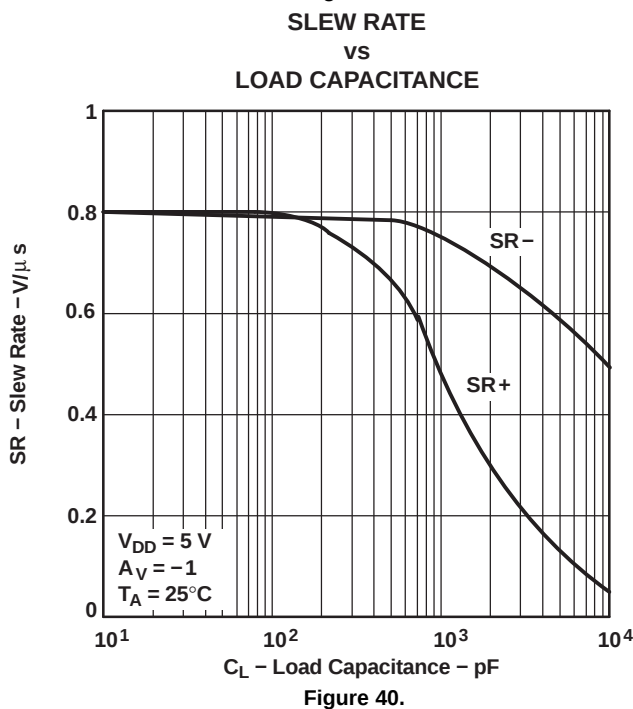
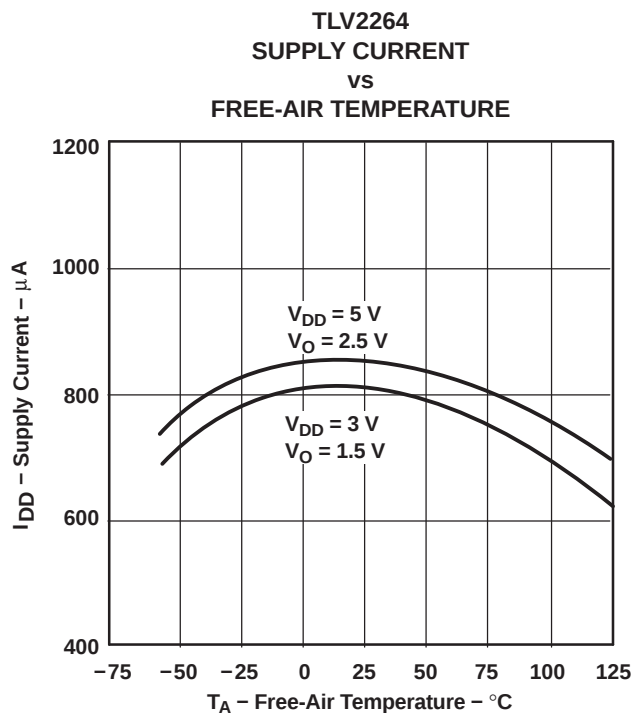
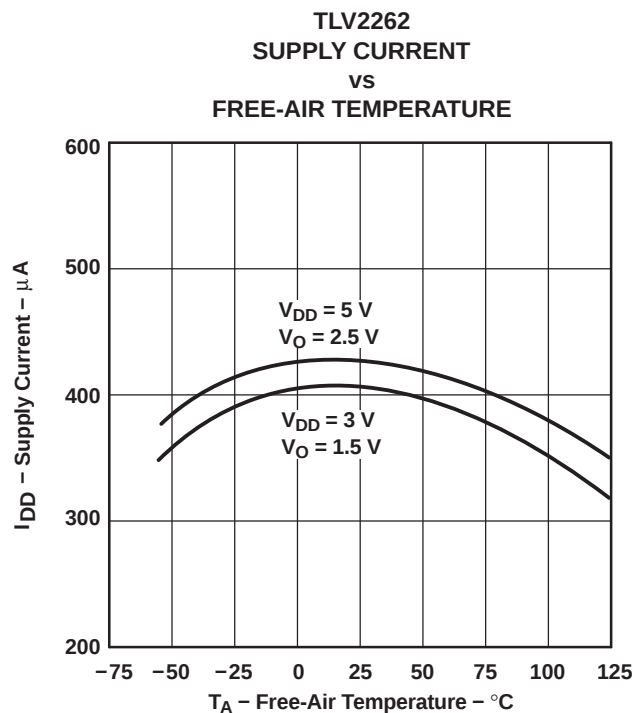


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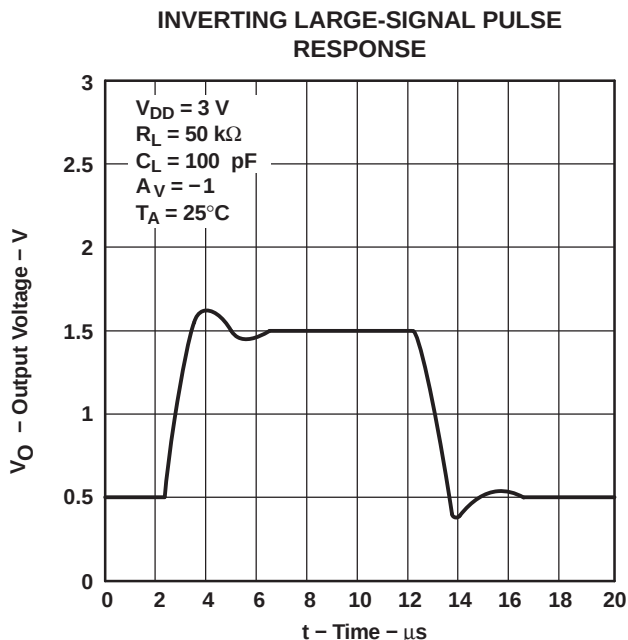


Figure 42.

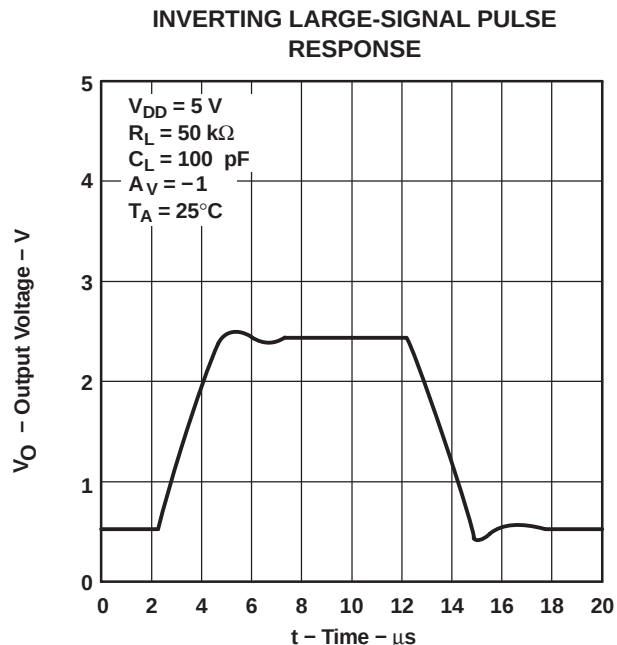


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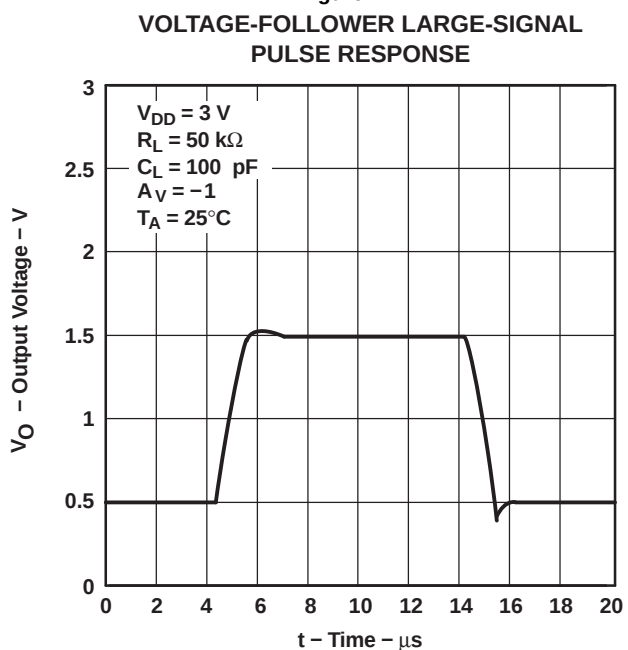


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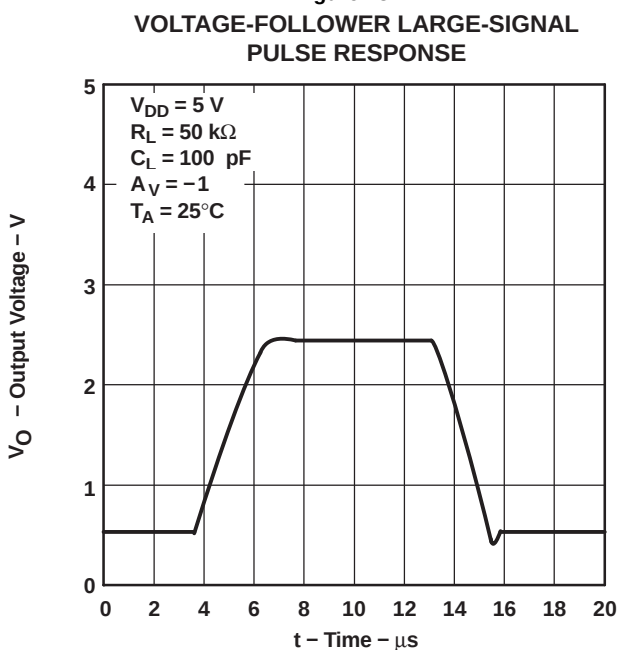


Figure 45.

**INVERTING SMALL-SIGNAL
PULSE RESPONSE**

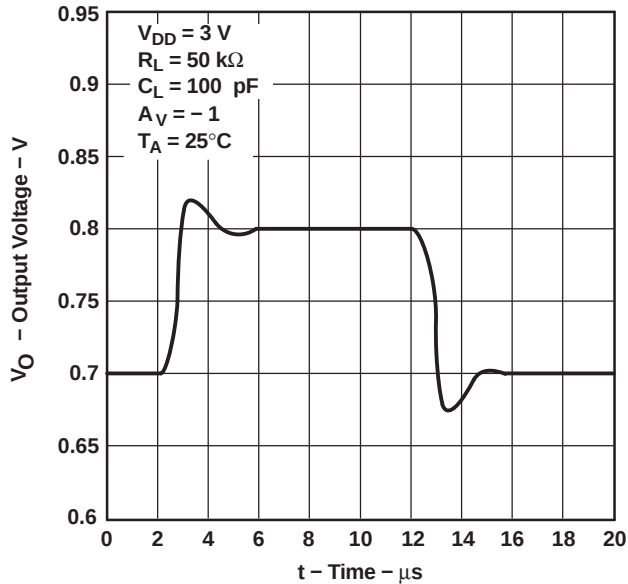


Figure 46.

**INVERTING SMALL-SIGNAL
PULSE RESPONSE**

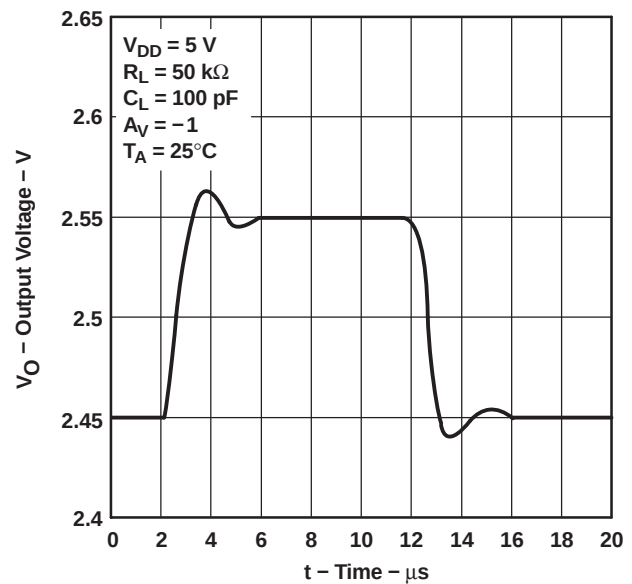


Figure 47.

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

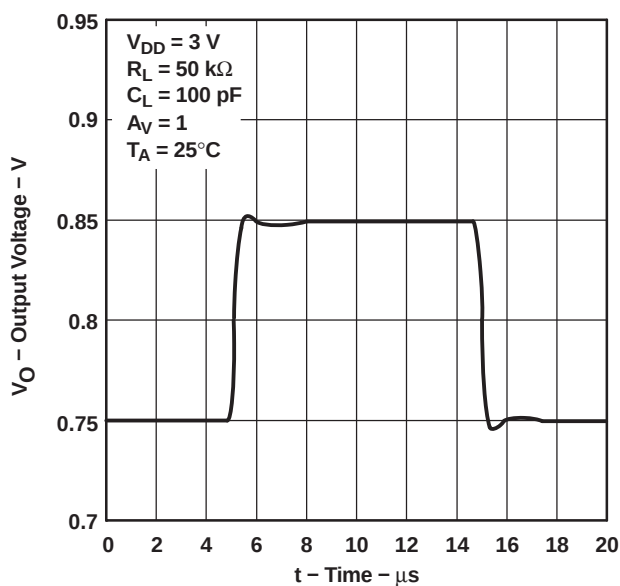


Figure 48.

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

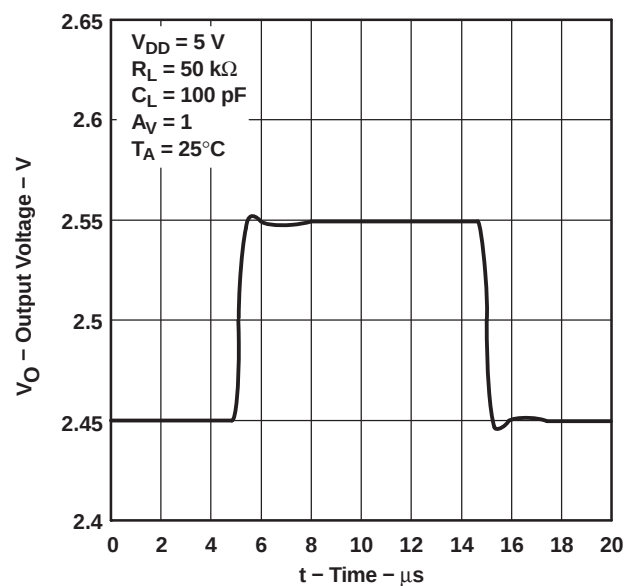


Figure 49.

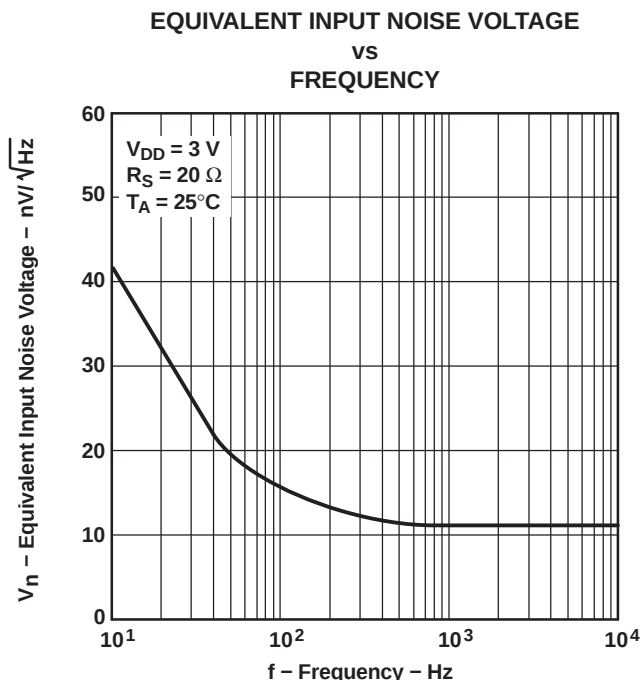


Figure 50.

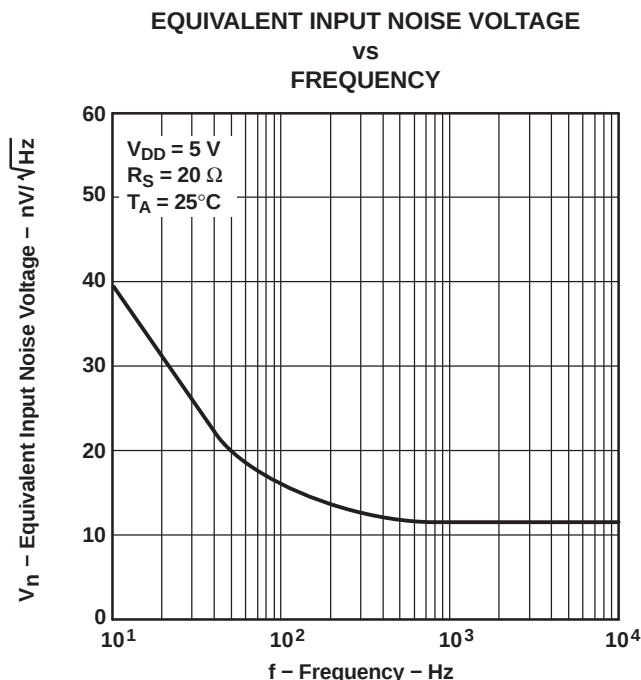


Figure 51.

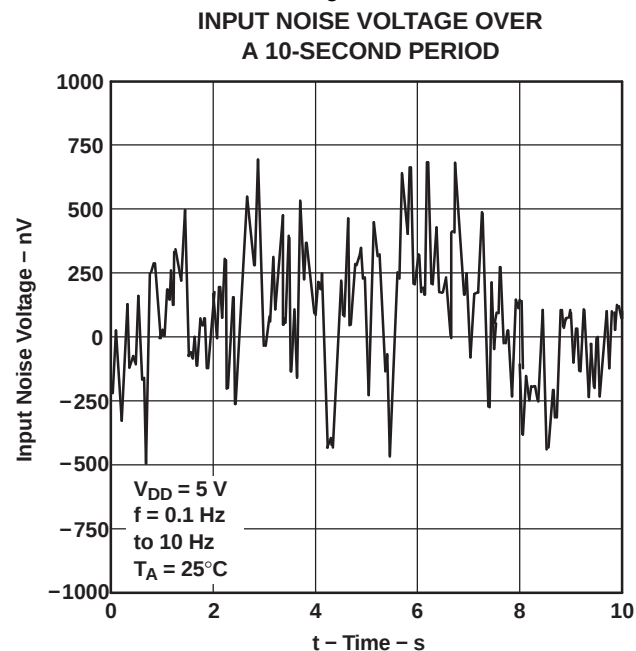


Figure 52.

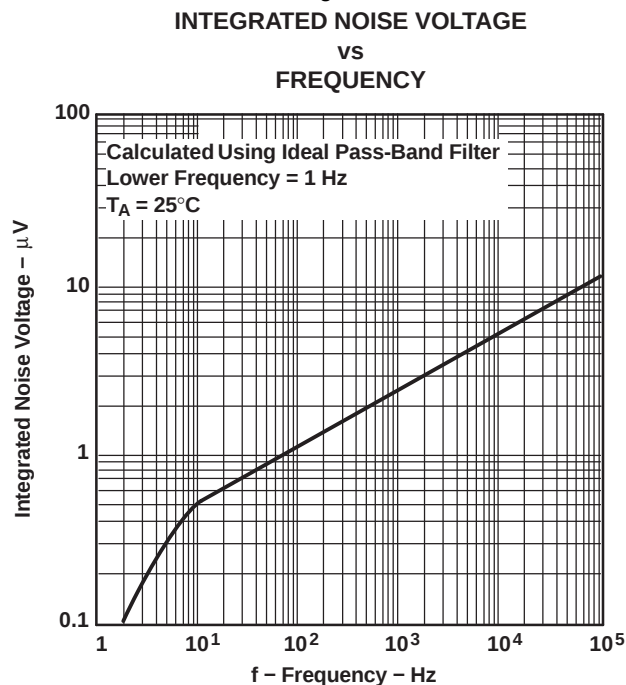


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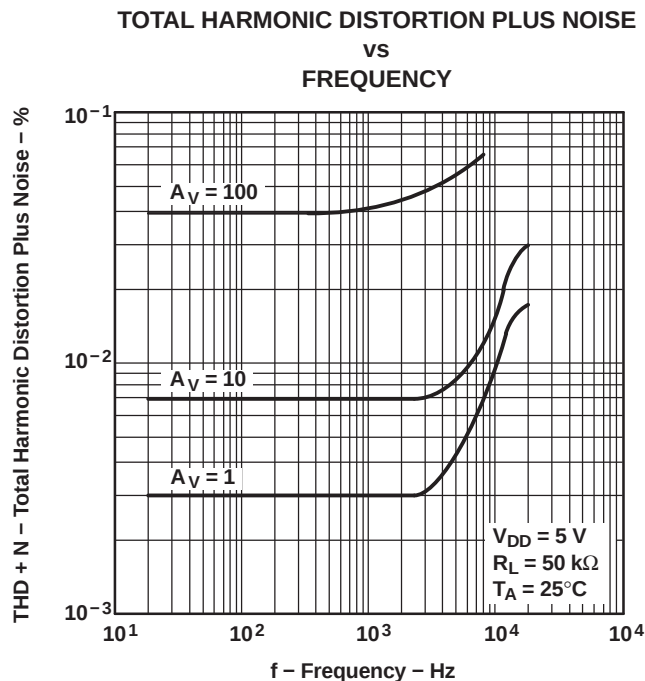


Figure 54.
**GAIN-BANDWIDTH PRODUCT
VS
FREE-AIR TEMPERATURE**

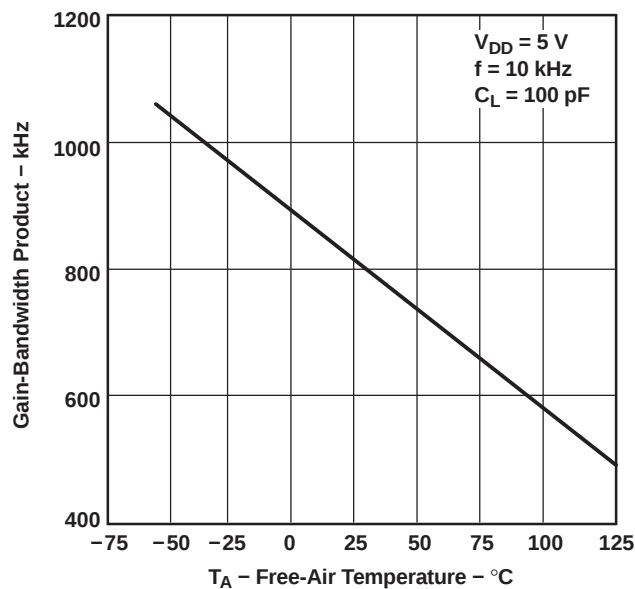


Figure 56.

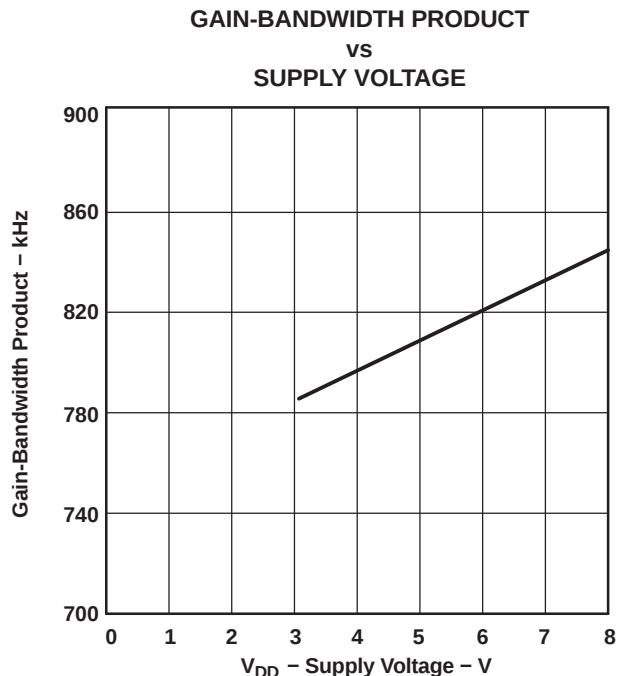


Figure 55.

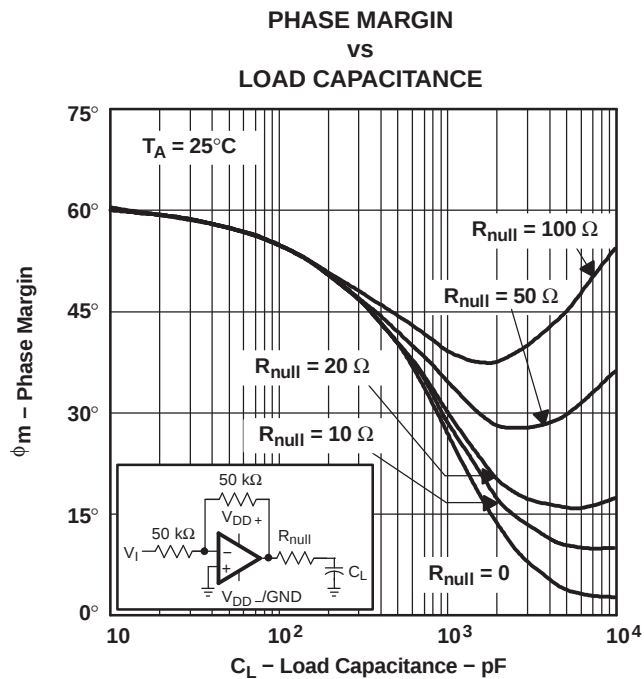


Figure 57.

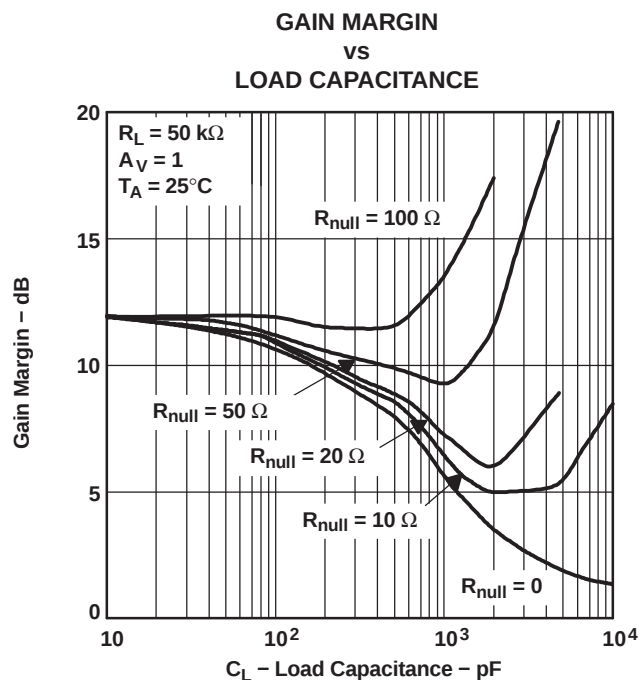


Figure 58.

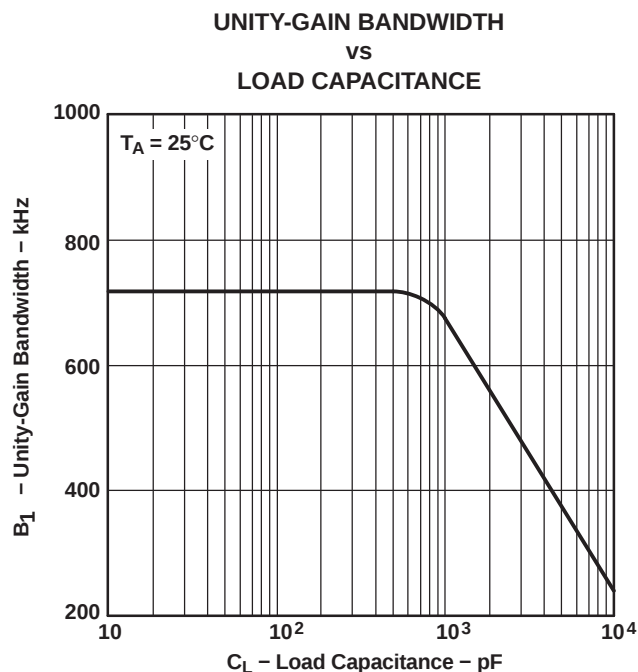
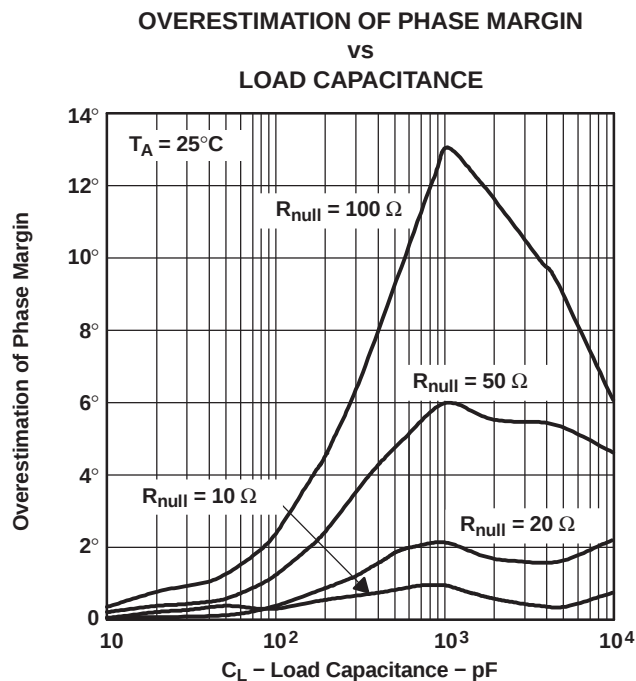


Figure 59.



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.

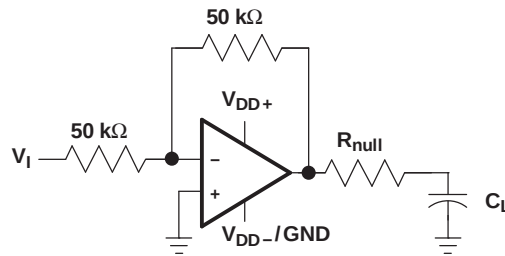


Figure 61. Series-Resistance Circuit

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).

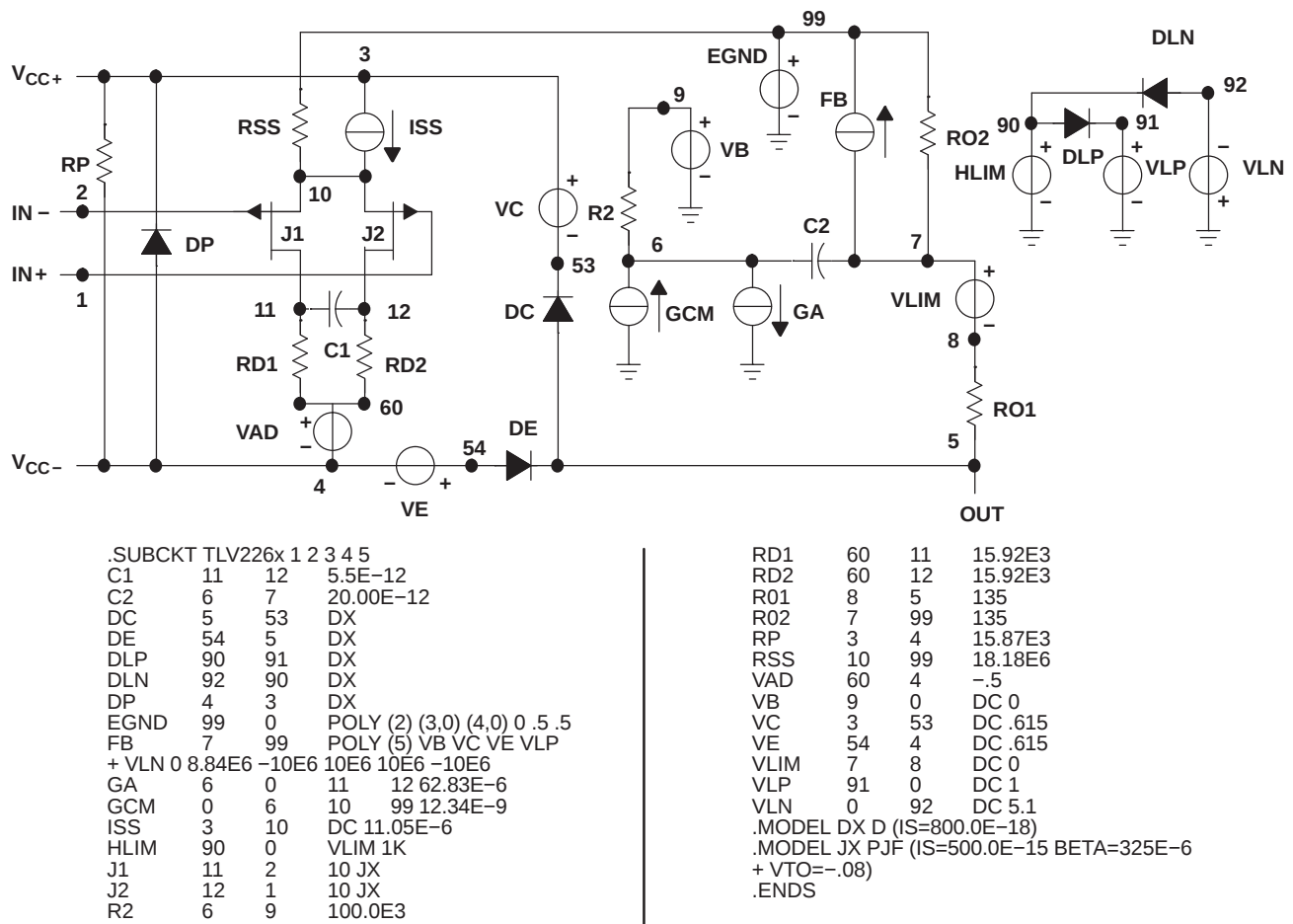


Figure 62. Boyle Macromodel and Subcircuit

PACKAGING INFORMATION

Orderable Device	Status ⁽¹⁾	Package Type	Package Drawing	Pins	Package Qty	Eco Plan ⁽²⁾	Lead/Ball Finish	MSL Peak Temp ⁽³⁾
TLV2262AQDRQ1	OBSOLETE	SOIC	D	8		TBD	Call TI	Call TI
TLV2262AQPWRQ1	ACTIVE	TSSOP	PW	8	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLV2262QDRQ1	OBSOLETE	SOIC	D	8		TBD	Call TI	Call TI
TLV2264AQDRQ1	OBSOLETE	SOIC	D	14		TBD	Call TI	Call TI
TLV2264AQPWRQ1	ACTIVE	TSSOP	PW	14	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLV2264QDRQ1	OBSOLETE	SOIC	D	14		TBD	Call TI	Call TI

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

ACTIVE: Product device recommended for new designs.

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

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

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

OBSOLETE: TI has discontinued the production of the device.

⁽²⁾ Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check <http://www.ti.com/productcontent> for the latest availability information and additional product content details.

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

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

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

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

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

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OTHER QUALIFIED VERSIONS OF TLV2262-Q1, TLV2262A-Q1, TLV2264-Q1, TLV2264A-Q1 :

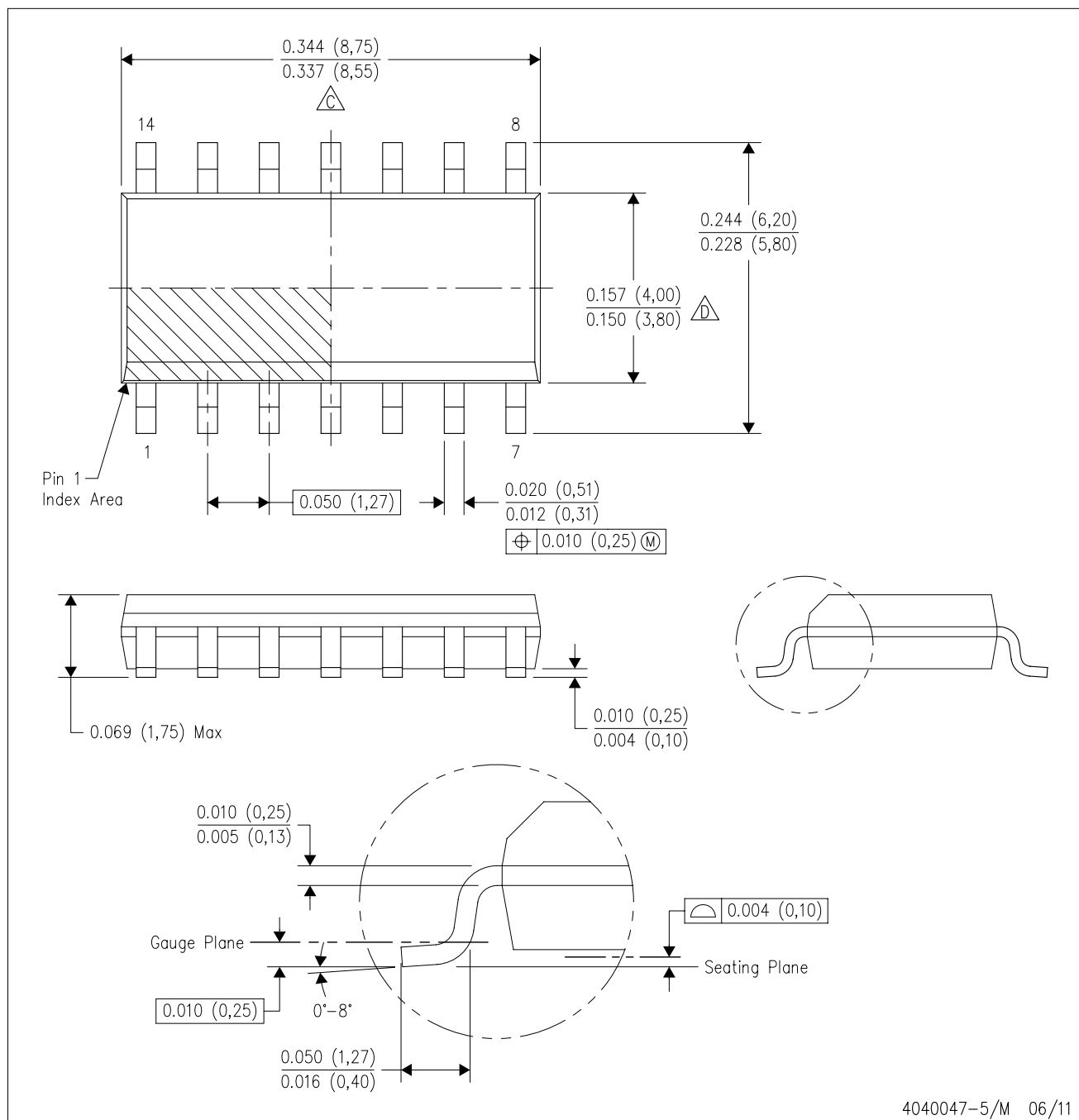
- Catalog: [TLV2262](#), [TLV2262A](#), [TLV2264](#), [TLV2264A](#)
- Military: [TLV2262M](#), [TLV2262AM](#), [TLV2264M](#), [TLV2264AM](#)

NOTE: Qualified Version Definitions:

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

D (R-PDSO-G14)

PLASTIC SMALL OUTLINE



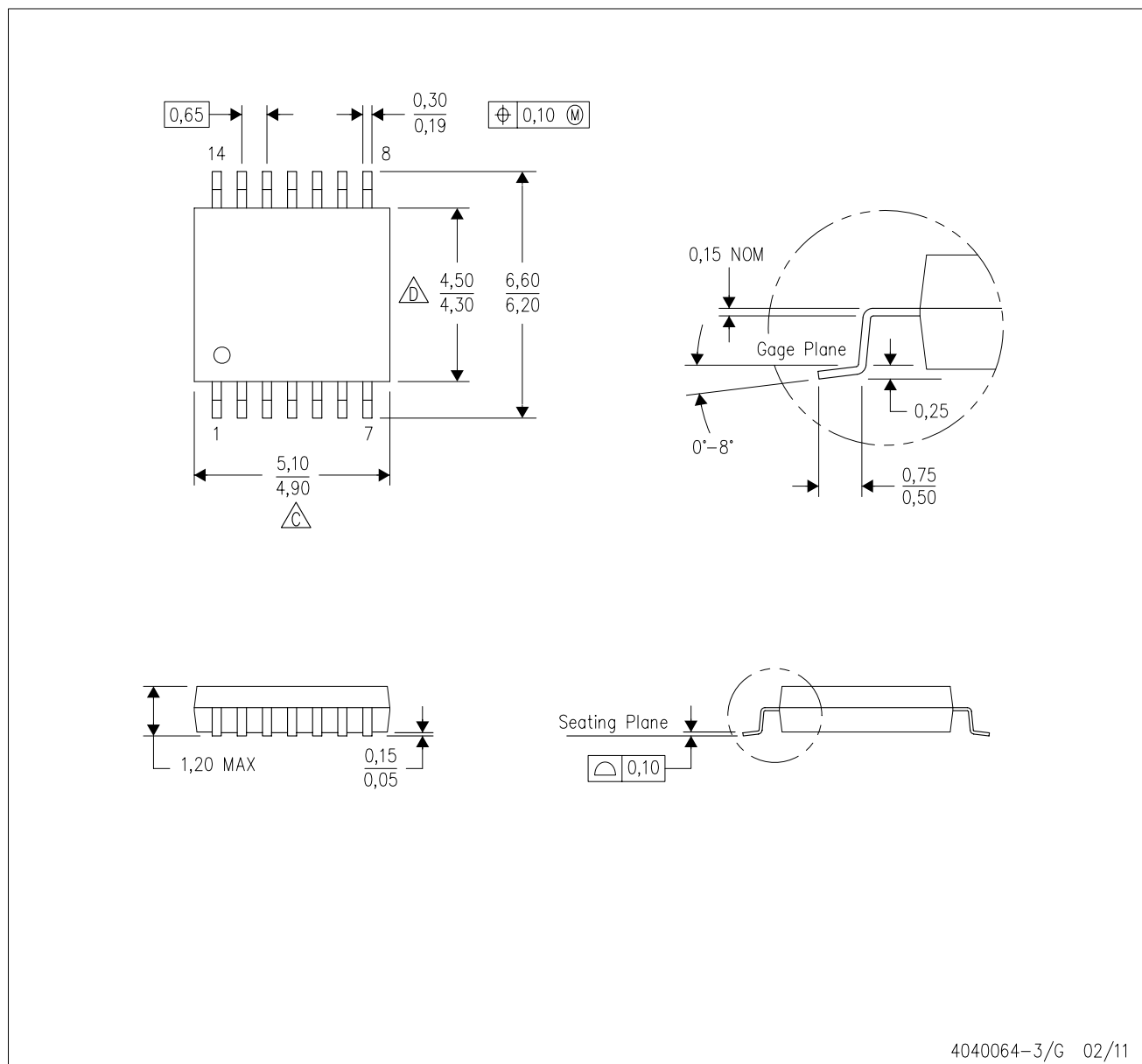
4040047-5/M 06/11

NOTES:

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

PW (R-PDSO-G14)

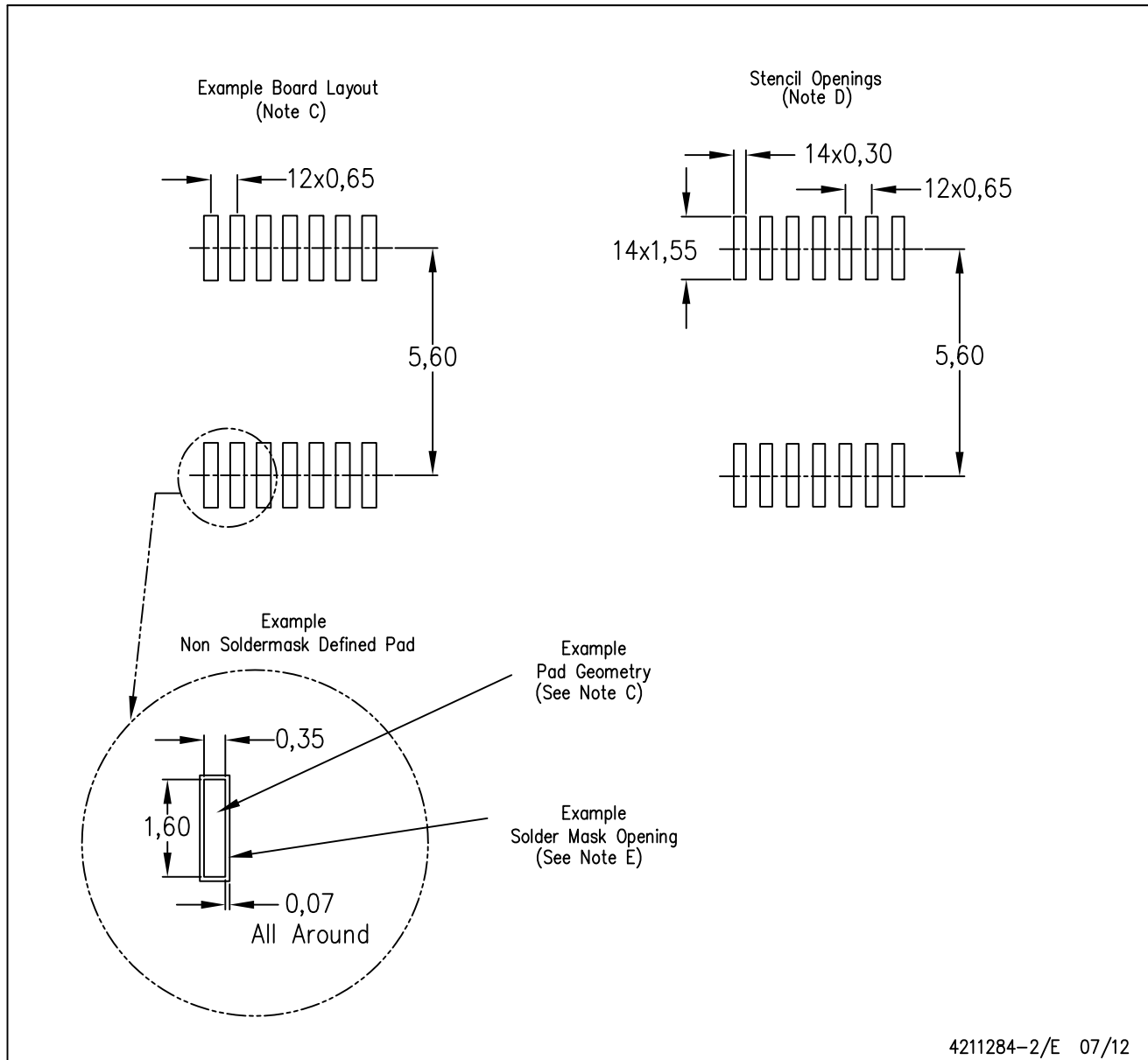
PLASTIC SMALL OUTLINE



- NOTES:
- A. All linear dimensions are in millimeters. Dimensioning and tolerancing per ASME Y14.5M-1994.
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 - E. Falls within JEDEC MO-153

PW (R-PDSO-G14)

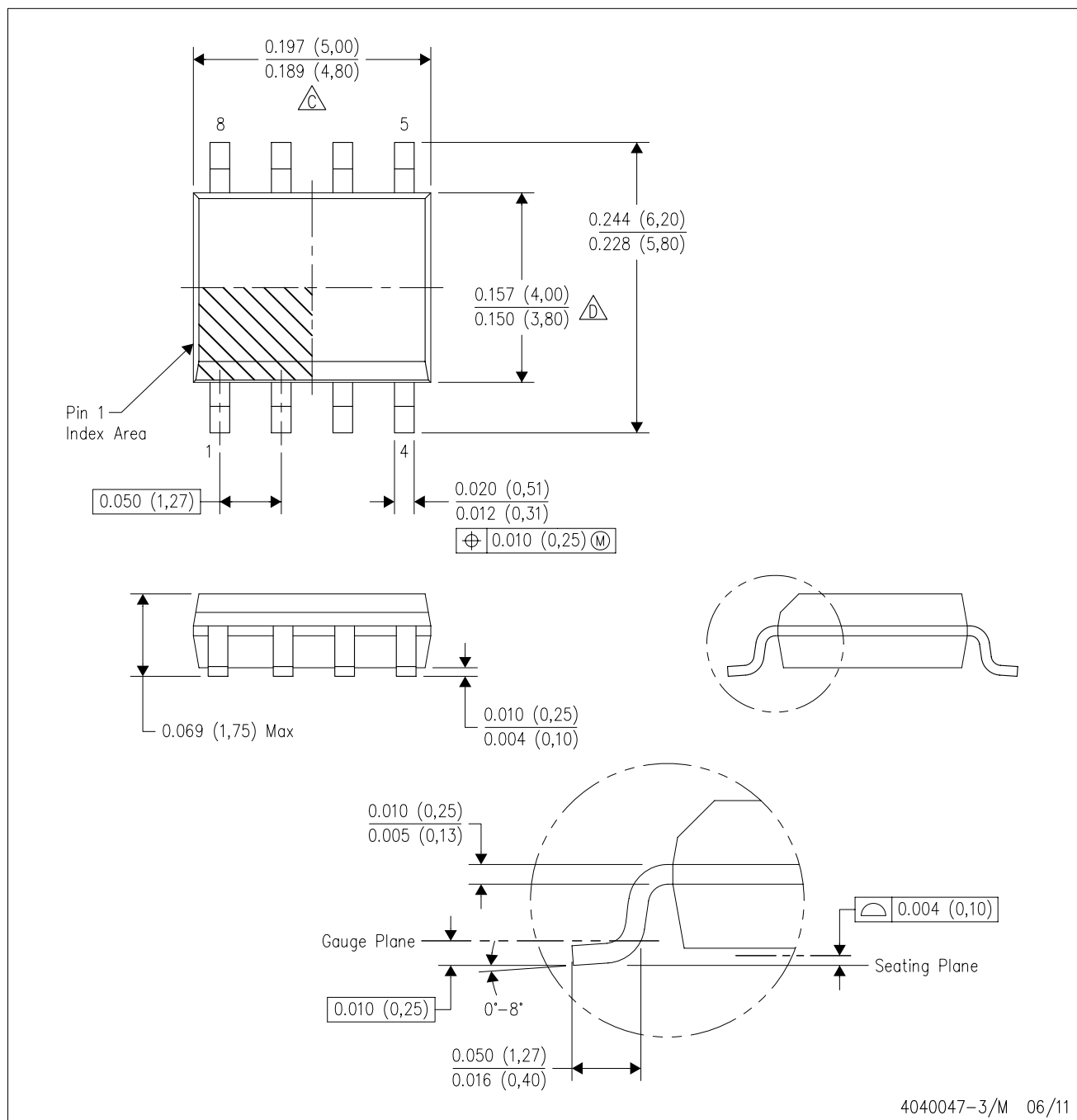
PLASTIC SMALL OUTLINE



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

D (R-PDSO-G8)

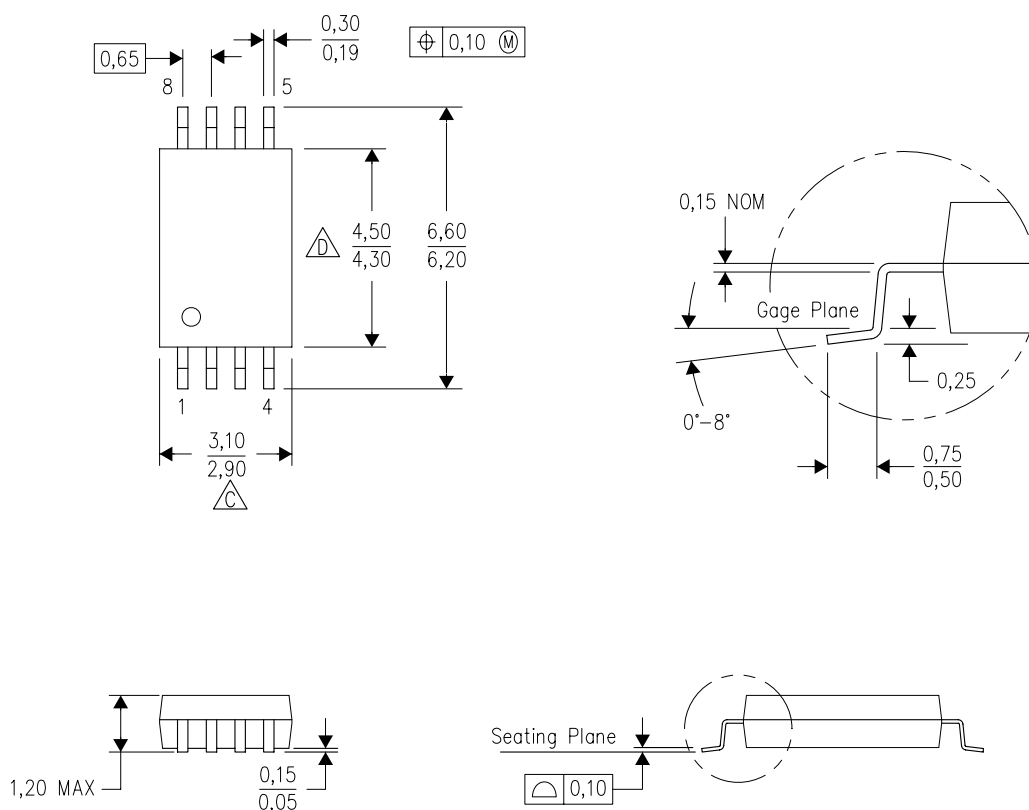
PLASTIC SMALL OUTLINE



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

PW (R-PDSO-G8)

PLASTIC SMALL OUTLINE



4040064-2/G 02/11

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

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