

- **Qualified for Automotive Applications**
- **ESD Protection Exceeds 2000 V Per MIL-STD-883, Method 3015; Exceeds 150 V (TLC2252/52A) and 100 V (TLC2254/54A) Using Machine Model (C = 200 pF, R = 0)**
- **Output Swing Includes Both Supply Rails**
- **Low Noise . . . 19 nV/√Hz Typ at f = 1 kHz**
- **Low Input Bias Current . . . 1 pA Typ**
- **Fully Specified for Both Single-Supply and Split-Supply Operation**
- **Very Low Power . . . 35 μA Per Channel Typ**
- **Common-Mode Input Voltage Range Includes Negative Rail**
- **Low Input Offset Voltage**
850 μV Max at T_A = 25°C (TLC225xA)
- **Macromodel Included**
- **Performance Upgrades for the TS27L2/L4 and TLC27L2/L4**

description

The TLC2252 and TLC2254 are dual and quad operational amplifiers from Texas Instruments. Both devices exhibit rail-to-rail output performance for increased dynamic range in single- or split-supply applications. The TLC225x family consumes only 35 μA of supply current per channel. This micropower operation makes them good choices for battery-powered applications. The noise performance has been dramatically improved over previous generations of CMOS amplifiers. Looking at Figure 1, the TLC225x has a noise level of 19 nV/√Hz at 1 kHz; four times lower than competitive micropower solutions.

The TLC225x amplifiers, 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, 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 TLC225xA family is available and has a maximum input offset voltage of 850 μV. This family is fully characterized at 5 V and ±5 V.

The TLC2252/4 also makes great upgrades to the TLC27L2/L4 or TS27L2/L4 in standard designs. They offer increased output dynamic range, lower noise voltage, and lower input offset voltage. This enhanced feature set allows them to be used in a wider range of applications. For applications that require higher output drive and wider input voltage ranges, see the TLV2432 and TLV2442 devices. If the design requires single amplifiers, please see the TLV2211/21/31 family. These devices are single rail-to-rail operational amplifiers in the SOT-23 package. Their small size and low power consumption, make them ideal for high density, battery-powered equipment.

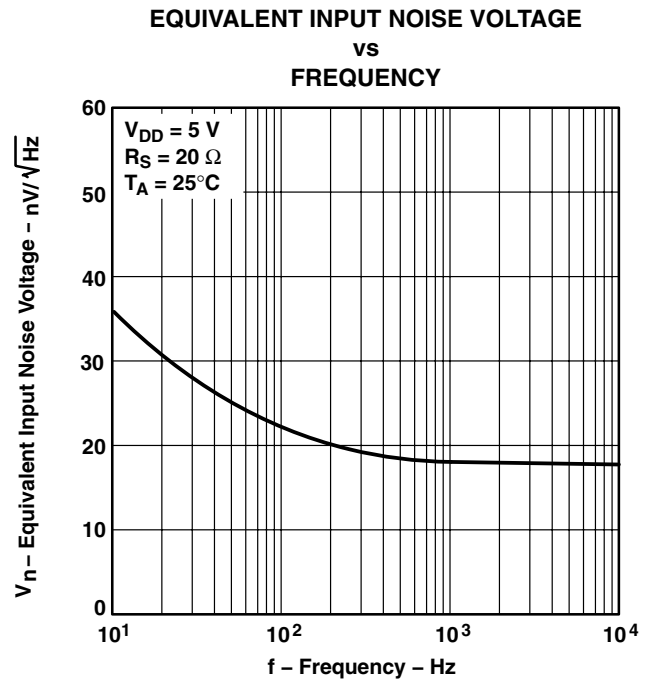


Figure 1



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

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TLC225x-Q1, TLC225xA-Q1

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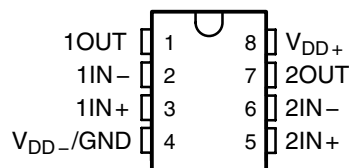
ORDERING INFORMATION†

T _A	V _{IO} max AT 25°C	PACKAGE‡		ORDERABLE PART NUMBER	TOP-SIDE MARKING
–40°C to 125°C	850 µV	SOIC (D)	Tape and reel	TLC2252AQDRQ1	2252AQ
		TSSOP (PW)	Tape and reel	TLC2252AQPWRQ1	2252AQ
	1550 µV	SOIC (D)	Tape and reel	TLC2252QDRQ1	2252Q1
		TSSOP (PW)	Tape and reel	TLC2252QPWRQ1	2252Q1
	850 µV	SOIC (D)	Tape and reel	TLC2254AQDRQ1	TLC2254AQ1
		TSSOP (PW)	Tape and reel	TLC2254AQPWRQ1	2254AQ
	1550 µV	SOIC (D)	Tape and reel	TLC2254QDRQ1	TLC2254Q1
		TSSOP (PW)	Tape and reel	TLC2254QPWRQ1	2254Q1

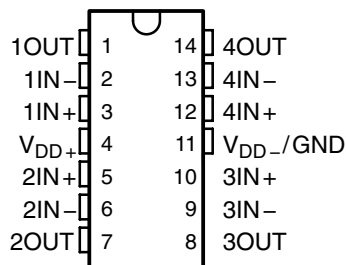
† For the most current package and ordering information, see the Package Option Addendum at the end of this document, or see the TI web site at <http://www.ti.com>.

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

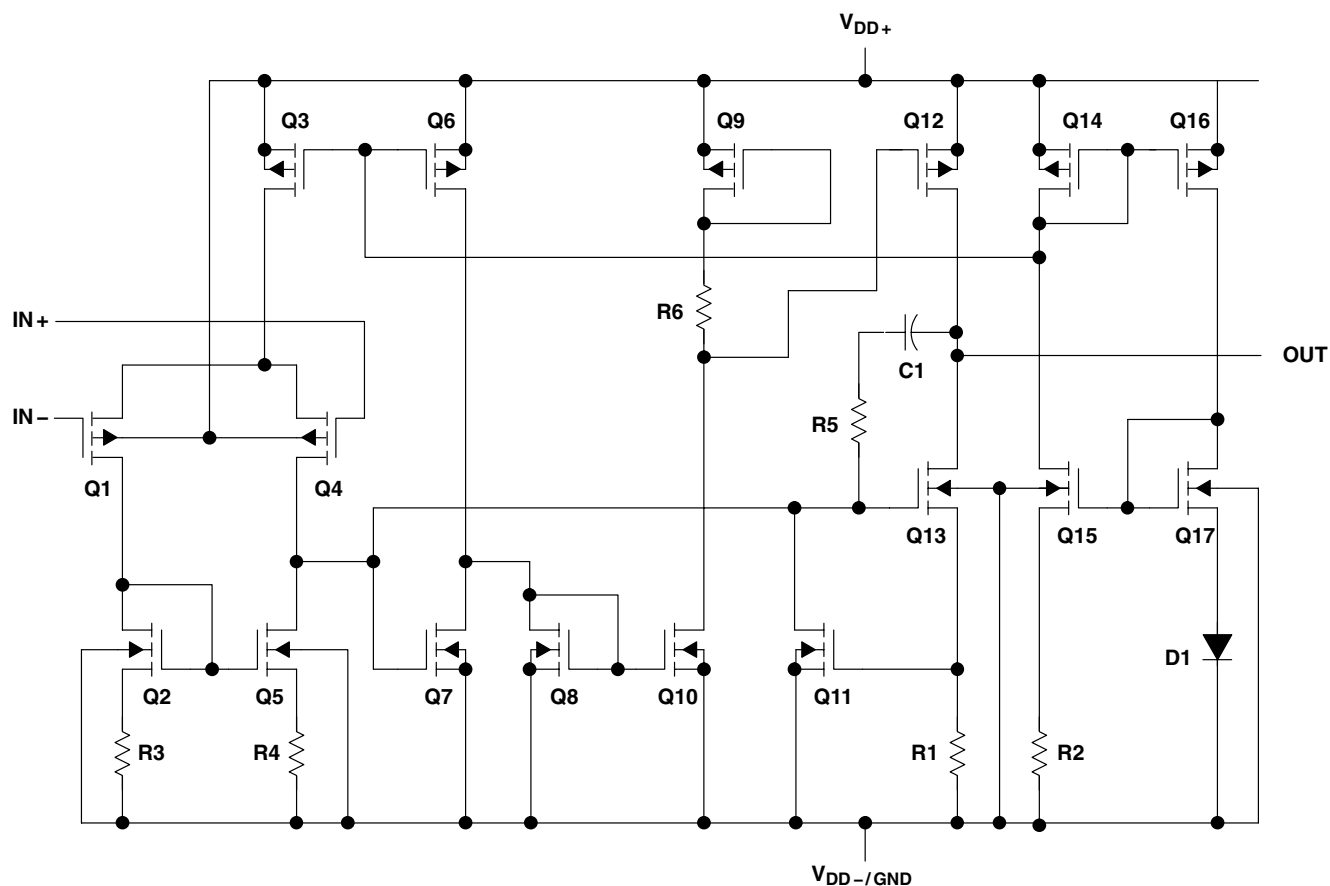
TLC2252, TLC2252A
D OR PW PACKAGE
(TOP VIEW)



TLC2254, TLC2254A
D OR PW PACKAGE
(TOP VIEW)



equivalent schematic (each amplifier)



ACTUAL DEVICE COMPONENT COUNT†		
COMPONENT	TLC2252	TLC2254
Transistors	38	76
Resistors	30	56
Diodes	9	18
Capacitors	3	6

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

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

Supply voltage, V_{DD+} (see Note 1)	8 V
Supply voltage, V_{DD-} (see Note 1)	–8 V
Differential input voltage, V_{ID} (see Note 2)	±16 V
Input voltage, V_I (any input, see Note 1)	±8 V
Input current, I_I (each input)	±5 mA
Output current, I_O	±50 mA
Total current into V_{DD+}	±50 mA
Total current out of V_{DD-}	±50 mA
Duration of short-circuit current at (or below) 25°C (see Note 3)	unlimited
Continuous total dissipation	See Dissipation Rating Table
Operating free-air temperature range, T_A : Q suffix	–40°C to 125°C
Storage temperature range, T_{stg}	–65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds	260°C

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

NOTES: 1. All voltage values, except differential voltages, are with respect to the midpoint between V_{DD+} and V_{DD-} .
2. Differential voltages are at $IN+$ with respect to $IN-$. Excessive current flows when input is brought below $V_{DD-} - 0.3$ V.
3. The output may be shorted to either supply. Temperature and/or supply voltages must be limited to ensure that the maximum dissipation rating is not exceeded.

DISSIPATION RATING TABLE

PACKAGE	$T_A \leq 25^\circ\text{C}$ POWER RATING	DERATING FACTOR ABOVE $T_A = 25^\circ\text{C}$	$T_A = 70^\circ\text{C}$ POWER RATING	$T_A = 85^\circ\text{C}$ POWER RATING	$T_A = 125^\circ\text{C}$ POWER RATING
D–8	724 mW	5.8 mW/°C	464 mW	377 mW	144 mW
D–14	950 mW	7.6 mW/°C	608 mW	450 mW	190 mW
PW–8	525 mW	4.2 mW/°C	336 mW	273 mW	105 mW
PW–14	700 mW	5.6 mW/°C	448 mW	364 mW	140 mW

recommended operating conditions

	MIN	MAX	UNIT
Supply voltage, $V_{DD\pm}$	±2.2	±8	V
Input voltage range, V_I	V_{DD-}	$V_{DD+} - 1.5$	V
Common-mode input voltage, V_{IC}	V_{DD-}	$V_{DD+} - 1.5$	V
Operating free-air temperature, T_A	–40	125	°C

[‡] Referenced to 2.5 V



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

PARAMETER		TEST CONDITIONS		T _A [†]	TLC2252-Q1			TLC2252A-Q1			UNIT
					MIN	TYP	MAX	MIN	TYP	MAX	
V _{IO}	Input offset voltage	V _{DD±} = ±2.5 V, V _{IC} = 0, V _O = 0, R _S = 50 Ω		25°C	200 1500			200 850			μV
	Full range			1750			1000				
α _{VIO}	Temperature coefficient of input offset voltage			25°C to 125°C	0.5			0.5			μV/°C
	Input offset voltage long-term drift (see Note 4)			25°C	0.003			0.003			μV/mo
I _{IO}	Input offset current			25°C	0.5 60			0.5 60			pA
				Full range	1000			1000			
I _{IB}	Input bias current			25°C	1 60			1 60			pA
				Full range	1000			1000			
V _{ICR}	Common-mode input voltage range	R _S = 50 Ω, V _{IO} ≤ 5 mV		25°C	0 −0.3 to to 4 4.2		0 −0.3 to to 4 4.2		V		
				Full range	0 to 3.5		0 to 3.5				
V _{OH}	High-level output voltage	I _{OH} = −20 μA		25°C	4.98		4.98		V		
		I _{OH} = −75 μA		25°C	4.9 4.94		4.9 4.94				
				Full range	4.8		4.8				
		I _{OH} = −150 μA		25°C	4.8 4.88		4.8 4.88				
V _{OL}	Low-level output voltage	V _{IC} = 2.5 V, I _{OL} = 50 μA		25°C	0.01		0.01		V		
		V _{IC} = 2.5 V, I _{OL} = 500 μA		25°C	0.09 0.15		0.09 0.15				
				Full range	0.15		0.15				
		V _{IC} = 2.5 V, I _{OL} = 4 mA		25°C	0.8 1		0.7 1				
				Full range	1.2		1.2				
A _{VD}	Large-signal differential voltage amplification	V _{IC} = 2.5 V, V _O = 1 V to 4 V	R _L = 100 kΩ [‡]	25°C	100 350		100 350		V/mV		
				Full range	10		10				
			R _L = 1 MΩ [‡]	25°C	1700		1700				
r _{id}	Differential input resistance			25°C	10 ¹²			10 ¹²		Ω	
r _{ic}	Common-mode input resistance			25°C	10 ¹²			10 ¹²		Ω	
c _{ic}	Common-mode input capacitance	f = 10 kHz,	f = 10 kHz,	25°C	8			8		pF	
z _o	Closed-loop output impedance	f = 25 kHz,	A _V = 10	25°C	200			200		Ω	
CMRR	Common-mode rejection ratio	V _{IC} = 0 to 2.7 V, V _O = 2.5 V, R _S = 50 Ω		25°C	70 83		70 83		dB		
				Full range	70		70				
k _{SVR}	Supply-voltage rejection ratio (ΔV _{DD} /ΔV _{IO})	V _{DD} = 4.4 V to 16 V, V _{IC} = V _{DD} /2, No load		25°C	80 95		80 95		dB		
				Full range	80		80				
I _{DD}	Supply current	V _O = 2.5 V, No load		25°C	70 125		70 125		μA		
				Full range	150		150				

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

‡ Referenced to 2.5 V

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

TLC225x-Q1, TLC225xA-Q1
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operating characteristics at specified free-air temperature, $V_{DD} = 5\text{ V}$

PARAMETER		TEST CONDITIONS		T _A [†]	TLC2252-Q1			TLC2252A-Q1			UNIT
					MIN	TYP	MAX	MIN	TYP	MAX	
SR	Slew rate at unity gain	V _O = 0.5 V to 3.5 V, R _L = 100 kΩ [‡] , C _L = 100 pF [‡]		25°C	0.07	0.12		0.07	0.12		V/μs
				Full range	0.05			0.05			
V _n	Equivalent input noise voltage	f = 10 Hz		25°C	36			36			nV/√Hz
		f = 1 kHz		25°C	19			19			
V _{N(PP)}	Peak-to-peak equivalent input noise voltage	f = 0.1 Hz to 1 Hz		25°C	0.7			0.7			μV
		f = 0.1 Hz to 10 Hz		25°C	1.1			1.1			
I _n	Equivalent input noise current			25°C	0.6			0.6			fA/√Hz
THD + N	Total harmonic distortion plus noise	V _O = 0.5 V to 2.5 V, f = 10 kHz, R _L = 50 kΩ [‡]	A _V = 1	25°C	0.2%			0.2%			
			A _V = 10		1%			1%			
	Gain-bandwidth product	f = 50 kHz, C _L = 100 pF [‡]	R _L = 50 kΩ [‡] ,	25°C	0.2			0.2			MHz
B _{OM}	Maximum output-swing bandwidth	V _{O(PP)} = 2 V, R _L = 50 kΩ [‡] ,	A _V = 1, C _L = 100 pF [‡]	25°C	30			30			kHz
ϕ _m	Phase margin at unity gain	R _L = 50 kΩ [‡] , C _L = 100 pF [‡]		25°C	63°			63°			
	Gain margin			25°C	15			15			dB

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

‡ Referenced to 2.5 V



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

PARAMETER		TEST CONDITIONS		T _A [†]	TLC2252-Q1			TLC2252A-Q1			UNIT
					MIN	TYP	MAX	MIN	TYP	MAX	
V _{IO}	Input offset voltage	V _{IC} = 0, V _O = 0, R _S = 50 Ω		25°C	200	1500		200	850	μV	
	Full range			1750			1000				
α _{VIO}	Temperature coefficient of input offset voltage			25°C to 125°C	0.5			0.5			μV/°C
	Input offset voltage long-term drift (see Note 4)			25°C	0.003			0.003			μV/mo
I _{IO}	Input offset current			25°C	0.5	60		0.5	60	pA	
				Full range	1000			1000			
I _{IB}	Input bias current			25°C	1	60		1	60	pA	
				Full range	1000			1000			
V _{ICR}	Common-mode input voltage range	R _S = 50 Ω, V _{IO} ≤ 5 mV		25°C	-5 to 4	-5.3 to 4.2		-5 to 4	-5.3 to 4.2	V	
				Full range	-5 to 3.5		-5 to 3.5				
V _{OM+}	Maximum positive peak output voltage	I _O = -20 μA		25°C	4.98		4.98		V		
		I _O = -100 μA		25°C	4.9	4.93	4.9	4.93			
				Full range	4.7		4.7				
		I _O = -200 μA		25°C	4.8	4.86	4.8	4.86			
V _{OM-}	Maximum negative peak output voltage	V _{IC} = 0, I _O = 50 μA		25°C	-4.99		-4.99		V		
		V _{IC} = 0, I _O = 500 μA		25°C	-4.85	-4.91	-4.85	-4.91			
				Full range	-4.85		-4.85				
		V _{IC} = 0, I _O = 4 mA		25°C	-4	-4.3	-4	-4.3			
				Full range	-3.8		-3.8				
A _{VD}	Large-signal differential voltage amplification	V _O = ±4 V	R _L = 100 kΩ	25°C	40	150	40	150	V/mV		
				Full range	10		10				
			R _L = 1 MΩ	25°C	3000		3000				
r _{id}	Differential input resistance			25°C	10 ¹²		10 ¹²		Ω		
r _{ic}	Common-mode input resistance			25°C	10 ¹²		10 ¹²		Ω		
c _{ic}	Common-mode input capacitance	f = 10 kHz,	P package	25°C	8		8		pF		
z _o	Closed-loop output impedance	f = 25 kHz,	A _V = 10	25°C	190		190		Ω		
CMRR	Common-mode rejection ratio	V _{IC} = -5 V to 2.7 V, V _O = 0, R _S = 50 Ω		25°C	75	88	75	88	dB		
				Full range	75		75				
k _{SVR}	Supply-voltage rejection ratio (ΔV _{DD±} /ΔV _{IO})	V _{DD} = ±2.2 V to ±8 V, V _{IC} = 0, No load		25°C	80	95	80	95	dB		
				Full range	80		80				
I _{DD}	Supply current	V _O = 2.5 V, No load		25°C	80	125	80	125	μA		
				Full range	150		150				

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

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

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

PARAMETER	TEST CONDITIONS	$T_A^\dagger$	TLC2252-Q1			TLC2252A-Q1			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
SR	Slew rate at unity gain	$V_O = \pm 2\text{ V}$, $C_L = 100\text{ pF}$, $R_L = 100\text{ k}\Omega$	25°C	0.07	0.12	0.07	0.12		V/ μs
			Full range	0.05		0.05			
V_n	Equivalent input noise voltage	$f = 10\text{ Hz}$	25°C	38		38			nV/ $\sqrt{\text{Hz}}$
		$f = 1\text{ kHz}$	25°C	19		19			
$V_{N(PP)}$	Peak-to-peak equivalent input noise voltage	$f = 0.1\text{ Hz to }1\text{ Hz}$	25°C	0.8		0.8			μV
		$f = 0.1\text{ Hz to }10\text{ Hz}$	25°C	1.1		1.1			
I_n	Equivalent input noise current		25°C	0.6		0.6			fA/ $\sqrt{\text{Hz}}$
THD + N	Total harmonic distortion plus noise	$V_O = \pm 2.3\text{ V}$, $R_L = 50\text{ k}\Omega$, $f = 10\text{ kHz}$	25°C	$A_V = 1$	0.2%	$A_V = 1$	0.2%		
				$A_V = 10$	1%	$A_V = 10$	1%		
	Gain-bandwidth product	$f = 10\text{ kHz}$, $C_L = 100\text{ pF}$, $R_L = 50\text{ k}\Omega$	25°C		0.21		0.21		MHz
B_{OM}	Maximum output-swing bandwidth	$V_{O(PP)} = 4.6\text{ V}$, $R_L = 50\text{ k}\Omega$, $C_L = 100\text{ pF}$	25°C		14		14		kHz
ϕ_m	Phase margin at unity gain	$R_L = 50\text{ k}\Omega$, $C_L = 100\text{ pF}$	25°C		63°		63°		
	Gain margin		25°C		15		15		dB

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



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

PARAMETER		TEST CONDITIONS		T _A [†]	TLC2254-Q1			TLC2254A-Q1			UNIT
					MIN	TYP	MAX	MIN	TYP	MAX	
V _{IO}	Input offset voltage	V _{DD} ± ±2.5 V, V _{IC} = 0, V _O = 0, R _S = 50 Ω		25°C	200	1500		200	850	μV	
	Full range			1750			1000				
α _{VIO}	Temperature coefficient of input offset voltage			25°C to 125°C	0.5			0.5			μV/°C
	Input offset voltage long-term drift (see Note 4)			25°C	0.003			0.003			μV/mo
I _{IO}	Input offset current			25°C	0.5	60		0.5	60	pA	
				125°C	1000			1000			
I _{IB}	Input bias current			25°C	1	60		1	60	pA	
				125°C	1000			1000			
V _{ICR}	Common-mode input voltage range	R _S = 50 Ω, V _{IO} ≤ 5 mV		25°C	0 to 4	−0.3 to 4.2		0 to 4	−0.3 to 4.2	V	
				Full range	0 to 3.5			0 to 3.5			
V _{OH}	High-level output voltage	I _{OH} = −20 μA		25°C	4.98			4.98			V
		I _{OH} = −75 μA		25°C	4.9	4.94		4.9	4.94		
				Full range	4.8			4.8			
			I _{OH} = −150 μA	25°C	4.8	4.88		4.8	4.88		
V _{OL}	Low-level output voltage	V _{IC} = 2.5 V, I _{OL} = 50 μA		25°C	0.01			0.01			V
		V _{IC} = 2.5 V, I _{OL} = 500 μA		25°C	0.09	0.15		0.09	0.15		
				Full range	0.15			0.15			
		V _{IC} = 2.5 V, I _{OL} = 4 mA		25°C	0.8	1		0.7	1		
				Full range	1.2			1.2			
		A _{VD}	Large-signal differential voltage amplification	V _{IC} = 2.5 V, V _O = 1 V to 4 V	R _L = 100 kΩ‡	25°C	100	350		100	
	Full range				10			10			
R _L = 1 MΩ‡	25°C				1700			1700			
r _{i(d)}	Differential input resistance			25°C	10 ¹²			10 ¹²			Ω
r _{i(c)}	Common-mode input resistance			25°C	10 ¹²			10 ¹²			Ω
c _{i(c)}	Common-mode input capacitance	f = 10 kHz,	N package	25°C	8			8			pF
z _o	Closed-loop output impedance	f = 25 kHz,	A _V = 10	25°C	200			200			Ω
CMRR	Common-mode rejection ratio	V _{IC} = 0 to 2.7 V, V _O = 2.5 V, R _S = 50 Ω		25°C	70	83		70	83	dB	
				Full range	70			70			
k _{SVR}	Supply-voltage rejection ratio (ΔV _{DD} /ΔV _{IO})	V _{DD} = 4.4 V to 16 V, V _{IC} = V _{DD} /2, No load		25°C	80	95		80	95	dB	
				Full range	80			80			
I _{DD}	Supply current (four amplifiers)	V _O = 2.5 V, No load		25°C	140	250		140	250	μA	
				Full range	300			300			

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

‡ Referenced to 2.5 V

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



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

PARAMETER		TEST CONDITIONS		$T_A^\dagger$	TLC2254-Q1			TLC2254A-Q1			UNIT
					MIN	TYP	MAX	MIN	TYP	MAX	
SR	Slew rate at unity gain	$V_O = 0.5\text{ V to }3.5\text{ V}$, $R_L = 100\text{ k}\Omega^\ddagger$, $C_L = 100\text{ pF}^\ddagger$		25°C	0.07	0.12		0.07	0.12		V/ μs
				Full range	0.05			0.05			
V_n	Equivalent input noise voltage	$f = 10\text{ Hz}$		25°C		36			36		nV/ $\sqrt{\text{Hz}}$
		$f = 1\text{ kHz}$		25°C		19			19		
$V_{N(PP)}$	Peak-to-peak equivalent input noise voltage	$f = 0.1\text{ Hz to }1\text{ Hz}$		25°C		0.7			0.7		μV
		$f = 0.1\text{ Hz to }10\text{ Hz}$		25°C		1.1			1.1		
I_n	Equivalent input noise current			25°C		0.6			0.6		fA/ $\sqrt{\text{Hz}}$
THD + N	Total harmonic distortion plus noise	$V_O = 0.5\text{ V to }2.5\text{ V}$, $f = 20\text{ kHz}$, $R_L = 50\text{ k}\Omega^\ddagger$	$A_V = 1$	25°C		0.2%			0.2%		
			$A_V = 10$			1%			1%		
	Gain-bandwidth product	$f = 50\text{ kHz}$, $C_L = 100\text{ pF}^\ddagger$	$R_L = 50\text{ k}\Omega^\ddagger$	25°C		0.2			0.2		MHz
B_{OM}	Maximum output-swing bandwidth	$V_{O(PP)} = 2\text{ V}$, $R_L = 50\text{ k}\Omega^\ddagger$	$A_V = 1$, $C_L = 100\text{ pF}^\ddagger$	25°C		30			30		kHz
ϕ_m	Phase margin at unity gain	$R_L = 50\text{ k}\Omega^\ddagger$	$C_L = 100\text{ pF}^\ddagger$	25°C		63°			63°		
	Gain margin			25°C		15			15		dB

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

‡ Referenced to 2.5 V



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

PARAMETER		TEST CONDITIONS		T _A [†]	TLC2254-Q1			TLC2254A-Q1			UNIT
					MIN	TYP	MAX	MIN	TYP	MAX	
V _{IO}	Input offset voltage	V _{IC} = 0, V _O = 0, R _S = 50 Ω		25°C	200 1500			200 850			μV
Full range				1750			1000				
α _{VIO}	Temperature coefficient of input offset voltage			25°C to 125°C	0.5			0.5			μV/°C
Input offset voltage long-term drift (see Note 4)				25°C	0.003			0.003			μV/mo
I _{IO}	Input offset current			25°C	0.5 60			0.5 60			pA
				125°C			1000				
I _{IB}	Input bias current			25°C	1 60			1 60			pA
				125°C			1000				
V _{ICR}	Common-mode input voltage range	R _S = 50 Ω, V _{IO} ≤ 5 mV		25°C	–5 to 4	–5.3 to 4.2	–5 to 4	–5.3 to 4.2	V		
				Full range	–5 to 3.5		–5 to 3.5				
V _{OM+}	Maximum positive peak output voltage	I _O = –20 μA		25°C	4.98			4.98		V	
		I _O = –100 μA		25°C	4.9 4.93		4.9 4.93				
				Full range	4.7		4.7				
		I _O = –200 μA		25°C	4.8 4.86		4.8 4.86				
V _{OM–}	Maximum negative peak output voltage	V _{IC} = 0, I _O = 50 μA		25°C	–4.99			–4.99		V	
		V _{IC} = 0, I _O = 500 μA		25°C	–4.85 –4.91		–4.85 –4.91				
				Full range	–4.85		–4.85				
		V _{IC} = 0, I _O = 4 mA		25°C	–4 –4.3		–4 –4.3				
				Full range	–3.8		–3.8				
A _{VD}	Large-signal differential voltage amplification	V _O = ±4 V	R _L = 100 kΩ	25°C	40 150		40 150		V/mV		
			Full range			10					
			R _L = 1 MΩ	25°C	3000		3000				
r _{i(d)}	Differential input resistance			25°C	10 ¹²			10 ¹²		Ω	
r _{i(c)}	Common-mode input resistance			25°C	10 ¹²			10 ¹²		Ω	
c _{i(c)}	Common-mode input capacitance	f = 10 kHz, N package		25°C	8			8		pF	
z _o	Closed-loop output impedance	f = 25 kHz, A _V = 10		25°C	190			190		Ω	
CMRR	Common-mode rejection ratio	V _{IC} = –5 V to 2.7 V, V _O = 0, R _S = 50 Ω		25°C	75 88		75 88		dB		
				Full range			75				
k _{SVR}	Supply-voltage rejection ratio (ΔV _{DD±} /ΔV _{IO})	V _{DD±} = ±2.2 V to ±8 V, V _{IC} = V _{DD} /2, No load		25°C	80 95		80 95		dB		
				Full range			80				
I _{BD}	Supply current (four amplifiers)	V _O = 0, No load		25°C	160 250		160 250		μA		
				Full range			300				

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

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

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

PARAMETER		TEST CONDITIONS		T _A [†]	TLC2254-Q1			TLC2254A-Q1			UNIT
					MIN	TYP	MAX	MIN	TYP	MAX	
SR	Slew rate at unity gain	V _O = ±2 V, C _L = 100 pF	R _L = 100 kΩ,	25°C	0.07	0.12		0.07	0.12		V/μs
				Full range	0.05			0.05			
V _n	Equivalent input noise voltage	f = 10 Hz f = 1 kHz		25°C	38			38			nV/√Hz
				25°C	19			19			
V _{N(PP)}	Peak-to-peak equivalent input noise voltage	f = 0.1 Hz to 1 Hz		25°C	0.8			0.8			μV
		f = 0.1 Hz to 10 Hz		25°C	1.1			1.1			
I _n	Equivalent input noise current			25°C	0.6			0.6			fA/√Hz
THD + N	Total harmonic distortion plus noise	V _O = ±2.3 V, R _L = 50 kΩ, f = 20 kHz	A _V = 1	25°C	0.2%			0.2%			
			A _V = 10		1%			1%			
Gain-bandwidth product		f = 10 kHz, C _L = 100 pF	R _L = 50 kΩ,	25°C	0.21			0.21			MHz
B _{OM}	Maximum output-swing bandwidth	V _{O(PP)} = 4.6 V, R _L = 50 kΩ,	A _V = 1, C _L = 100 pF	25°C	14			14			kHz
φ _m	Phase margin at unity gain	R _L = 50 kΩ,	C _L = 100 pF	25°C	63°			63°			
Gain margin				25°C	15			15			dB

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



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Table of Graphs

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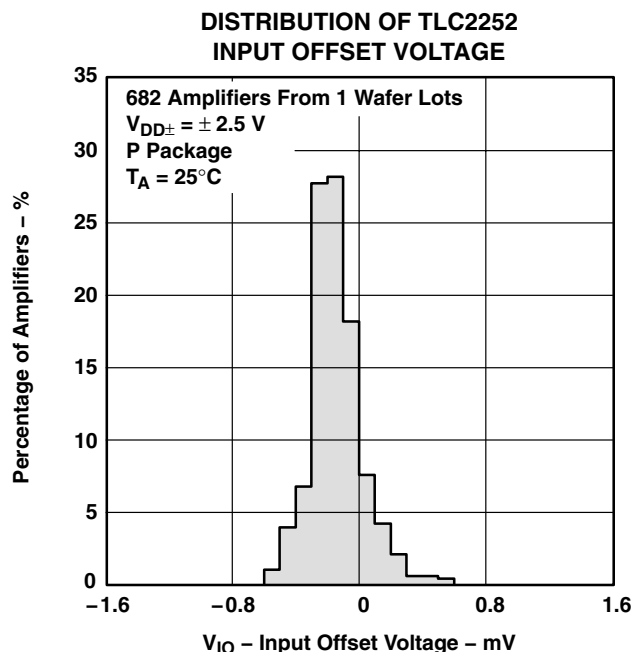


Figure 2

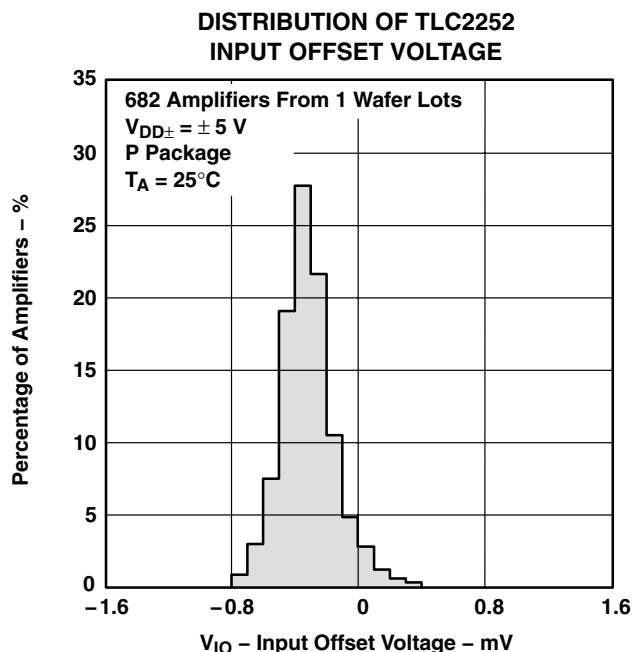


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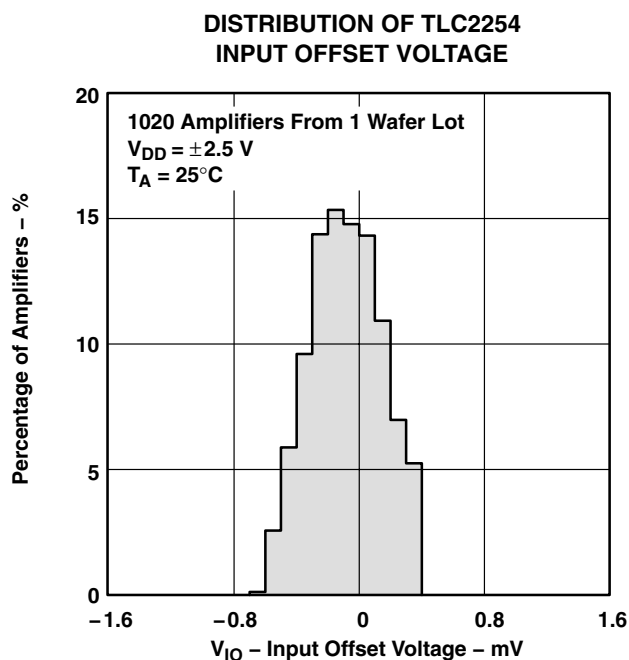


Figure 4

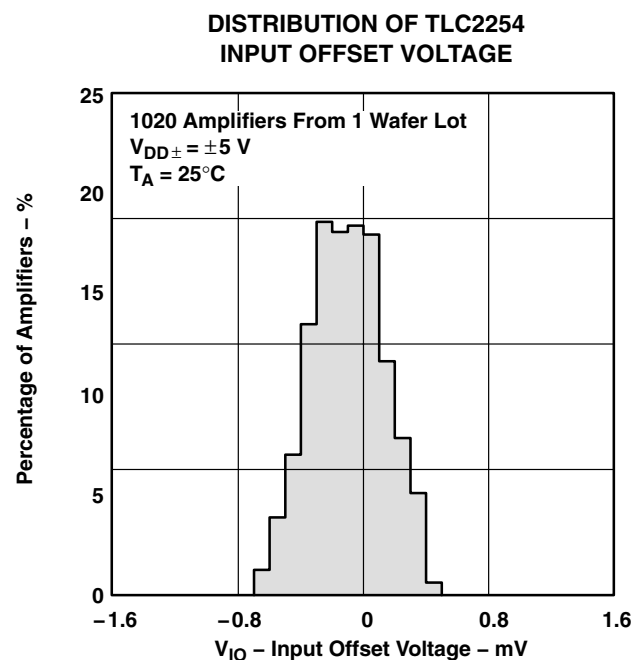


Figure 5



TYPICAL CHARACTERISTICS

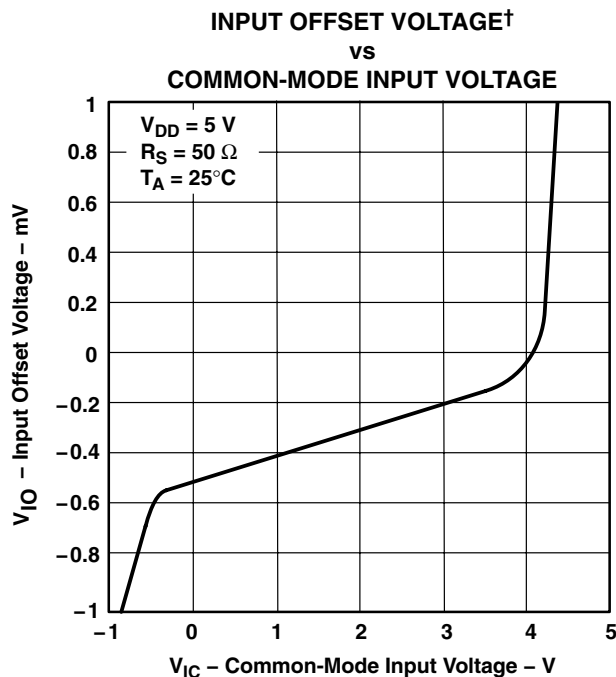


Figure 6

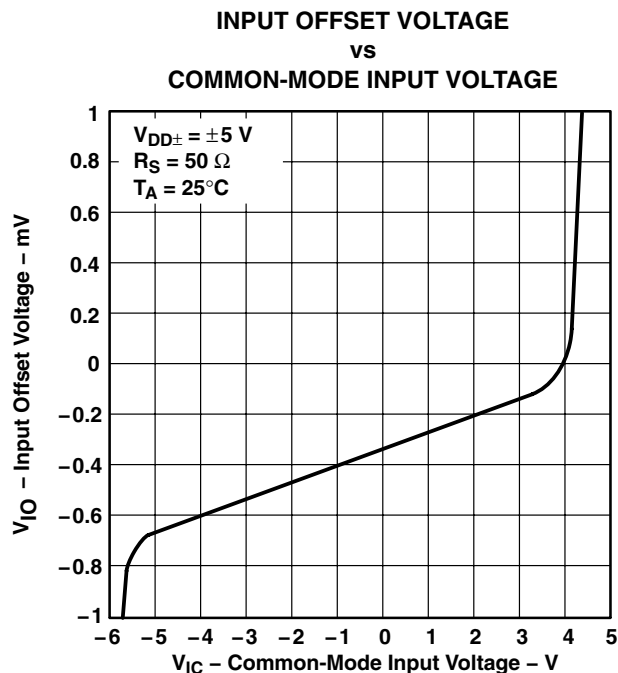


Figure 7

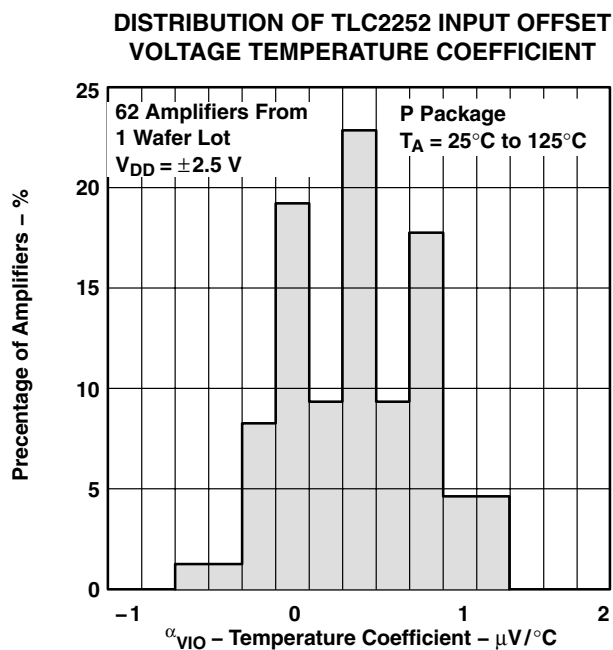


Figure 8

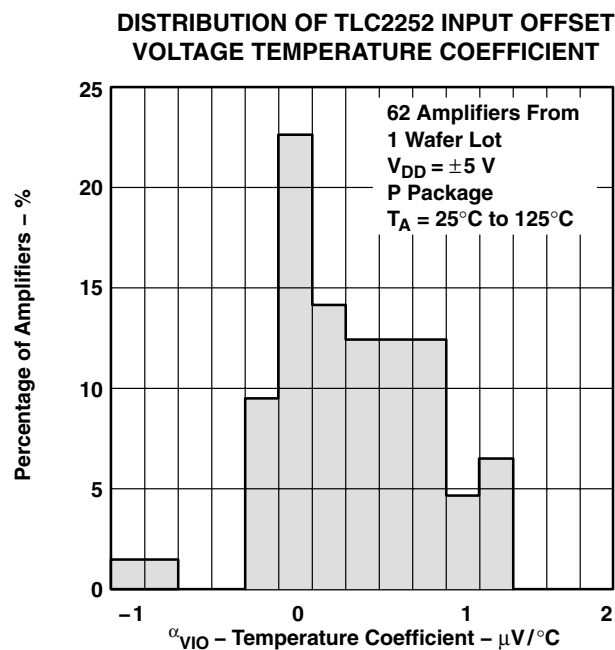


Figure 9

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

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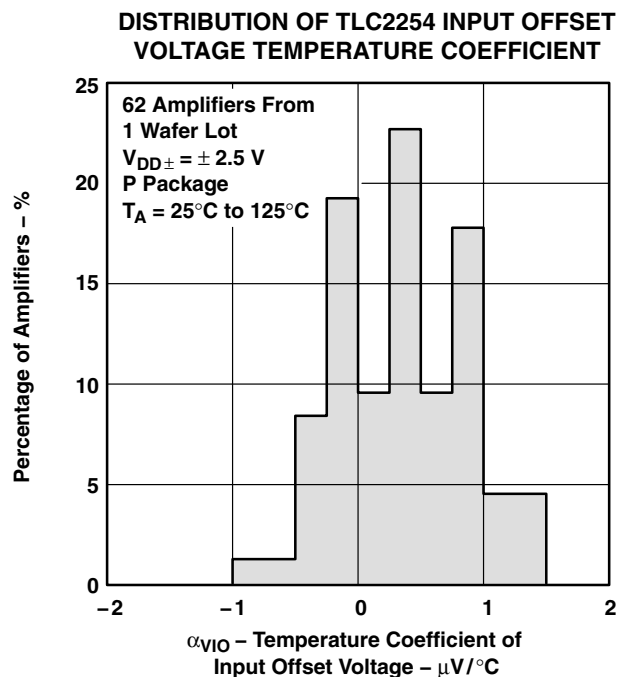


Figure 10

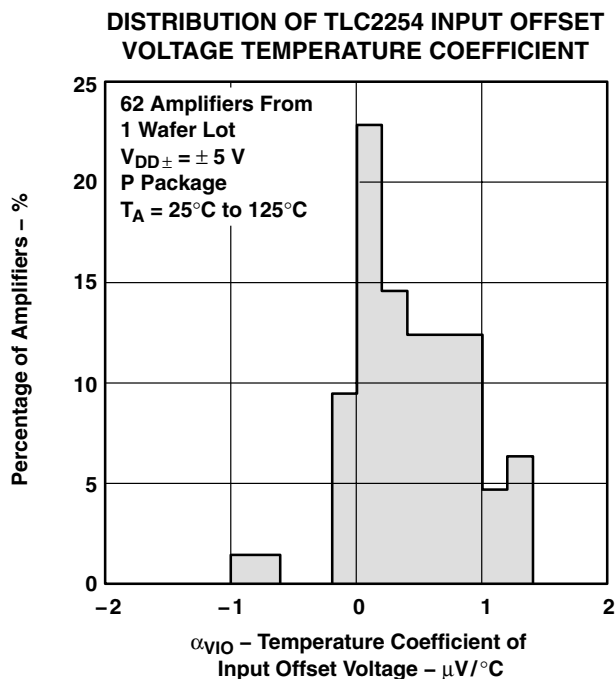


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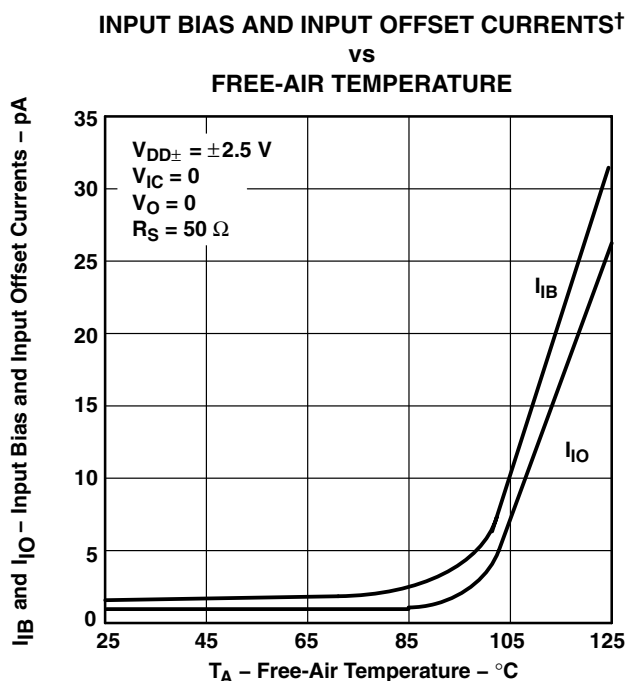


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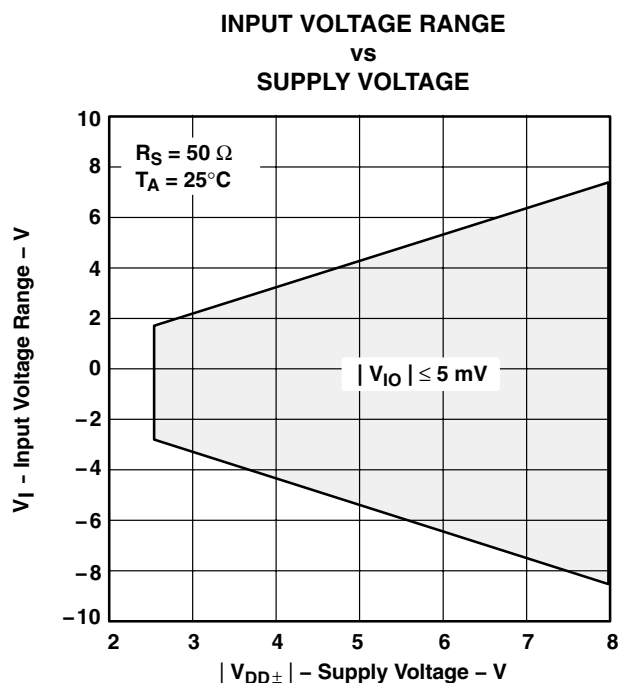


Figure 13

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

TYPICAL CHARACTERISTICS

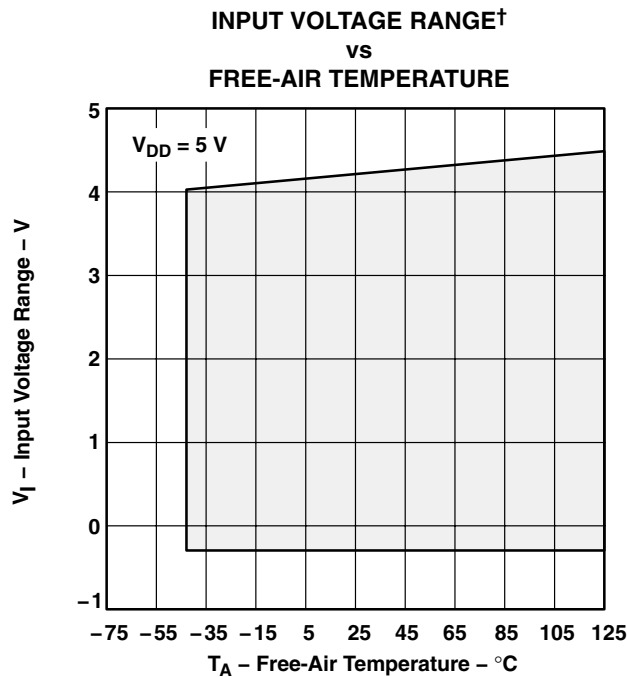


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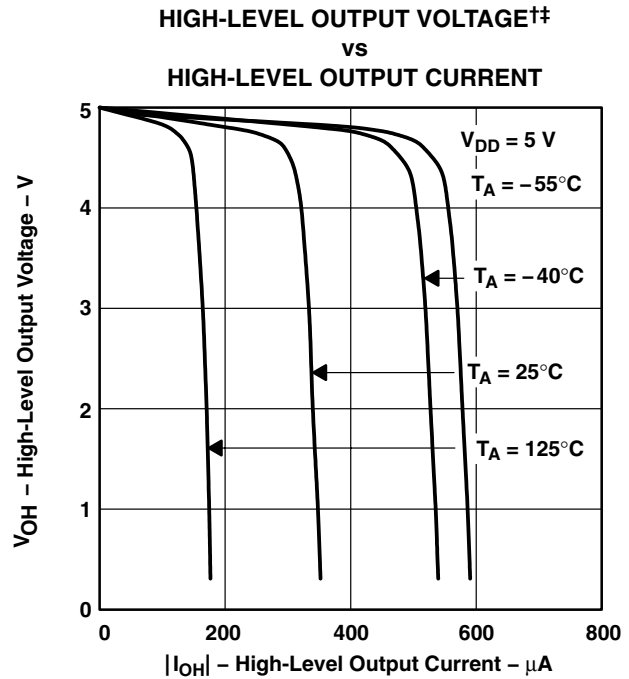


Figure 15

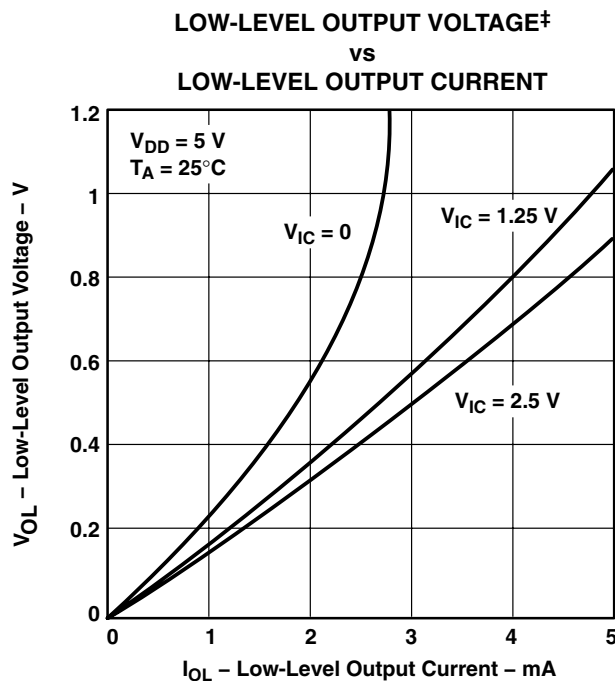


Figure 16

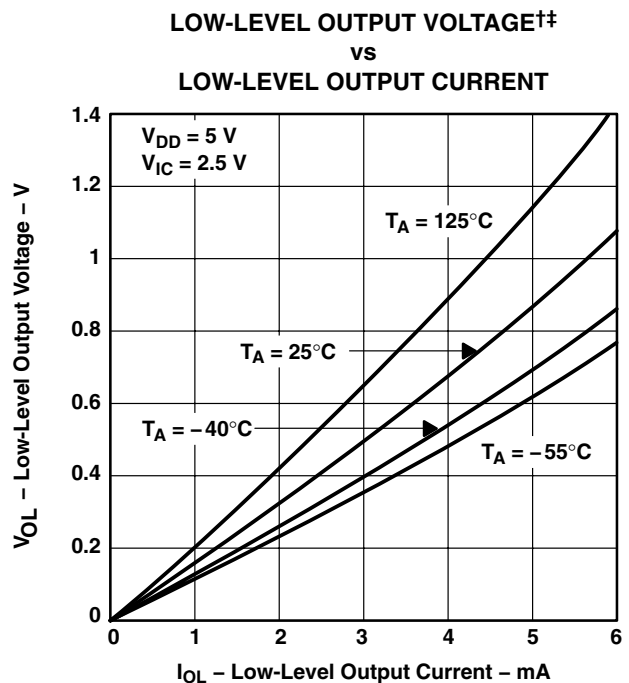


Figure 17

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

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

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TYPICAL CHARACTERISTICS

MAXIMUM POSITIVE PEAK OUTPUT VOLTAGE†
vs
OUTPUT CURRENT

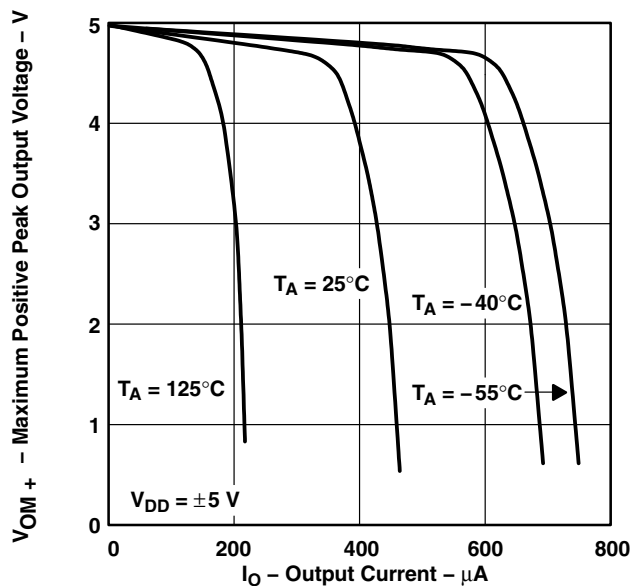


Figure 18

MAXIMUM NEGATIVE PEAK OUTPUT VOLTAGE†
vs
OUTPUT CURRENT

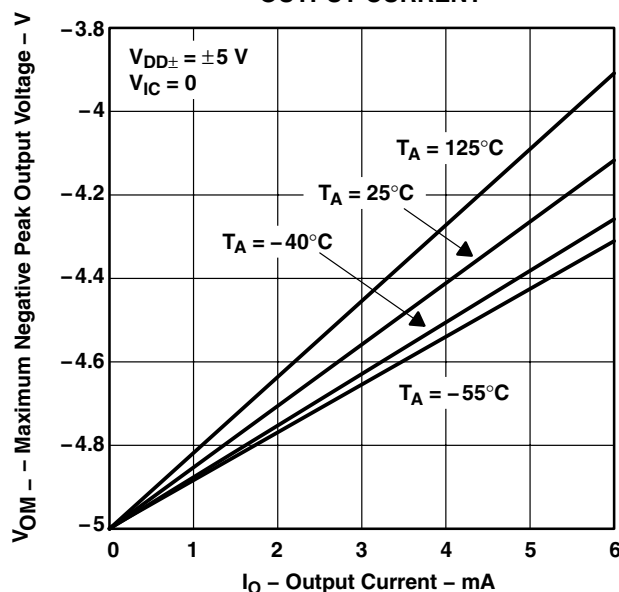


Figure 19

MAXIMUM PEAK-TO-PEAK OUTPUT VOLTAGE‡
vs
FREQUENCY

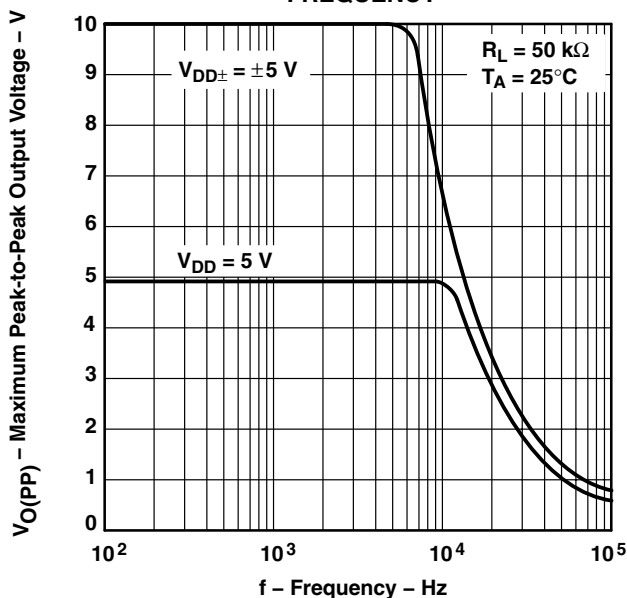


Figure 20

SHORT-CIRCUIT OUTPUT CURRENT
vs
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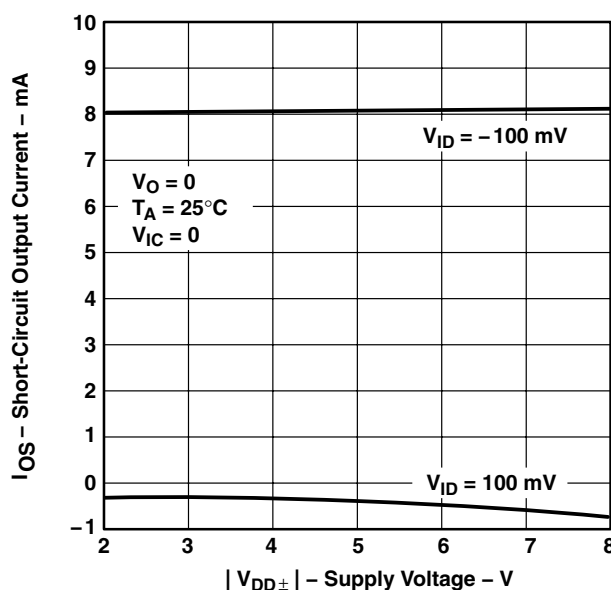


Figure 21

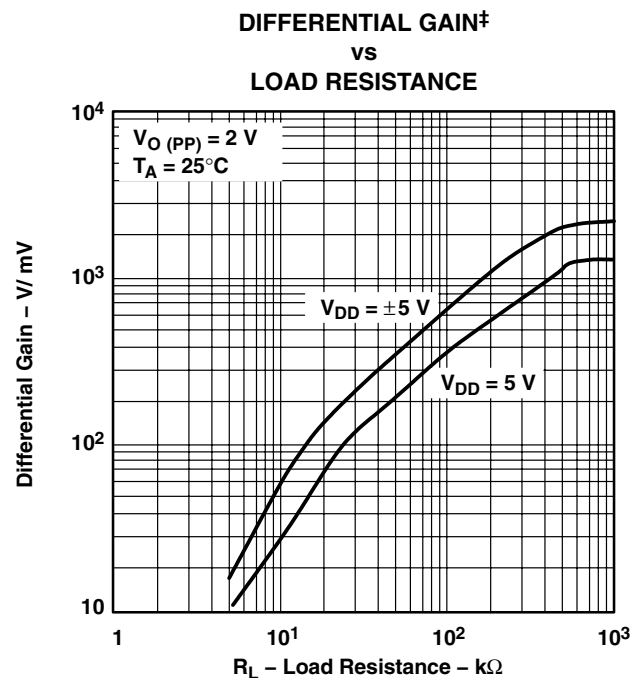
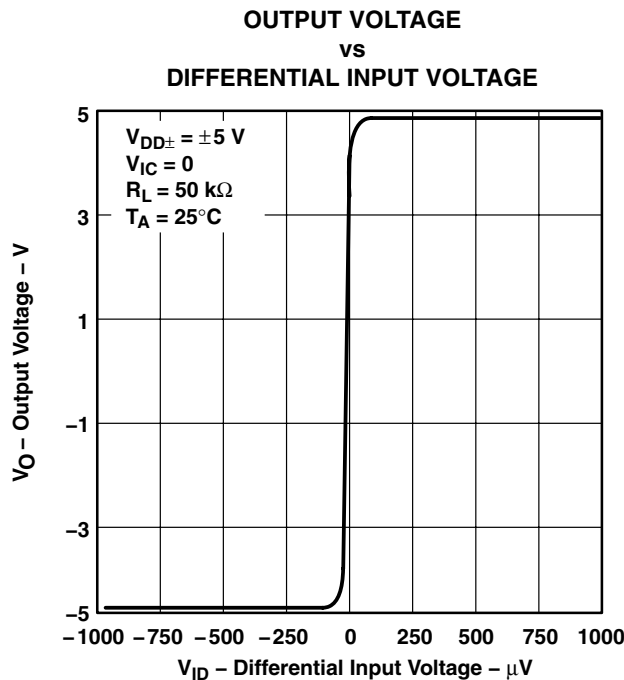
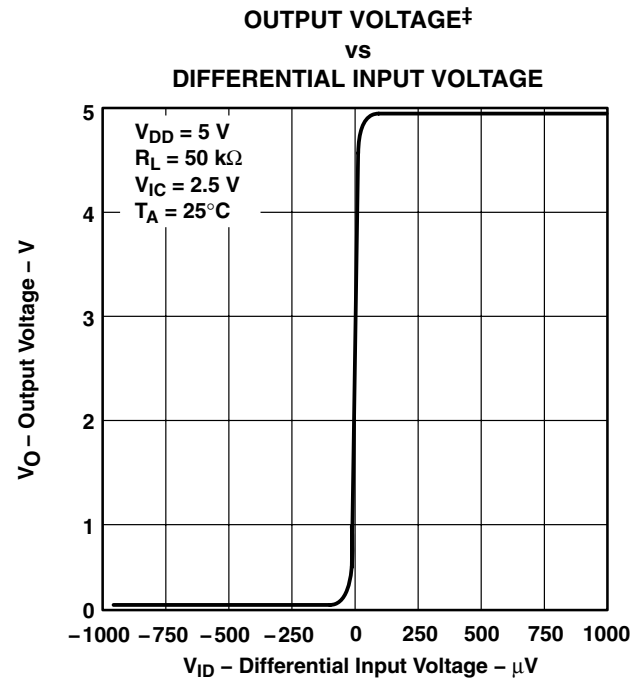
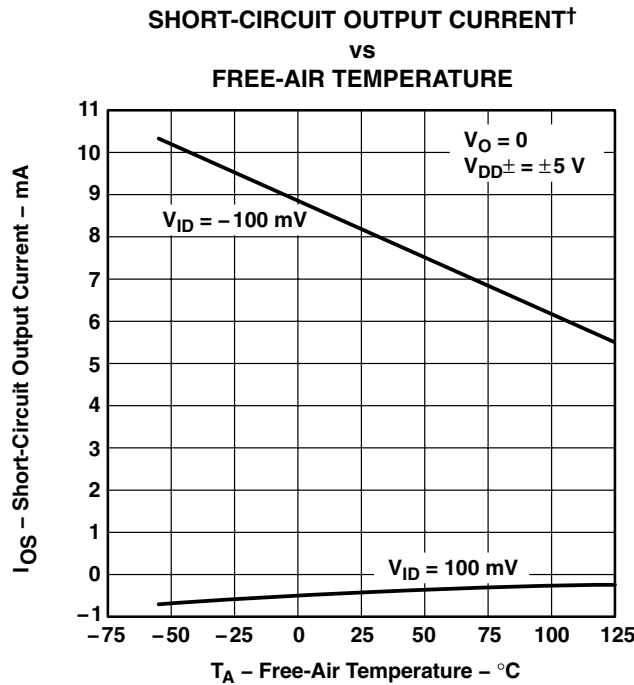
† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

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



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

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TYPICAL CHARACTERISTICS

**LARGE-SIGNAL DIFFERENTIAL VOLTAGE
AMPLIFICATION AND PHASE MARGIN†**

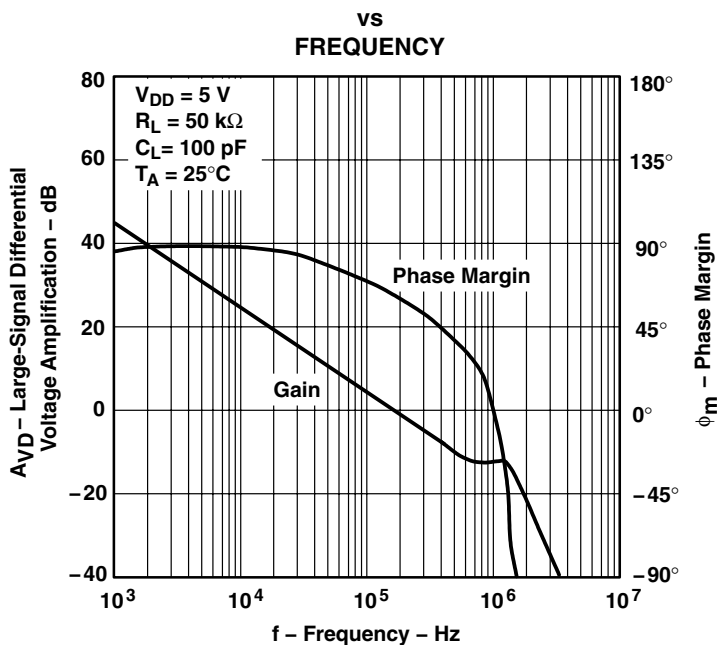


Figure 26

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

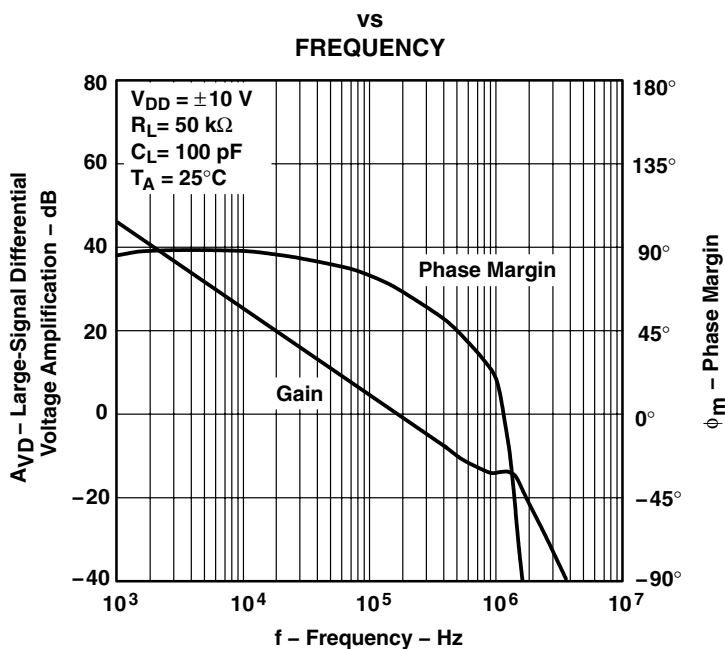


Figure 27

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



TYPICAL CHARACTERISTICS

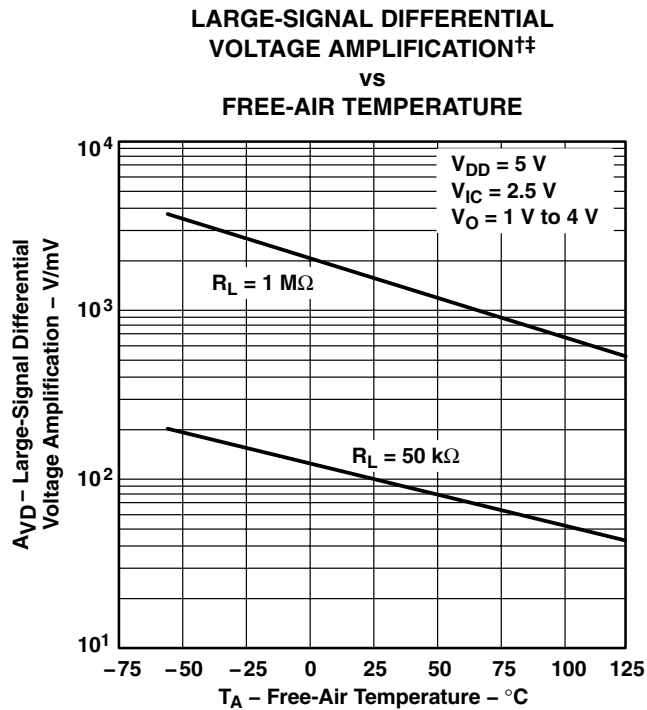


Figure 28

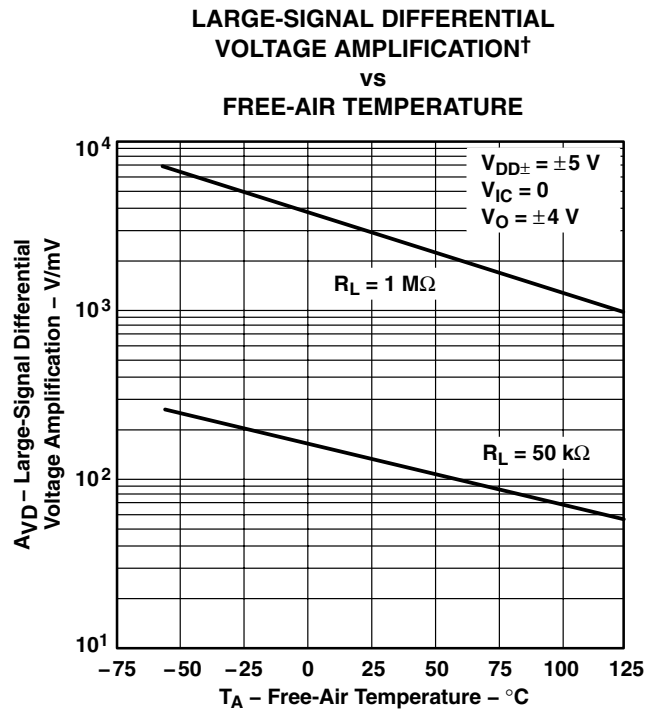


Figure 29

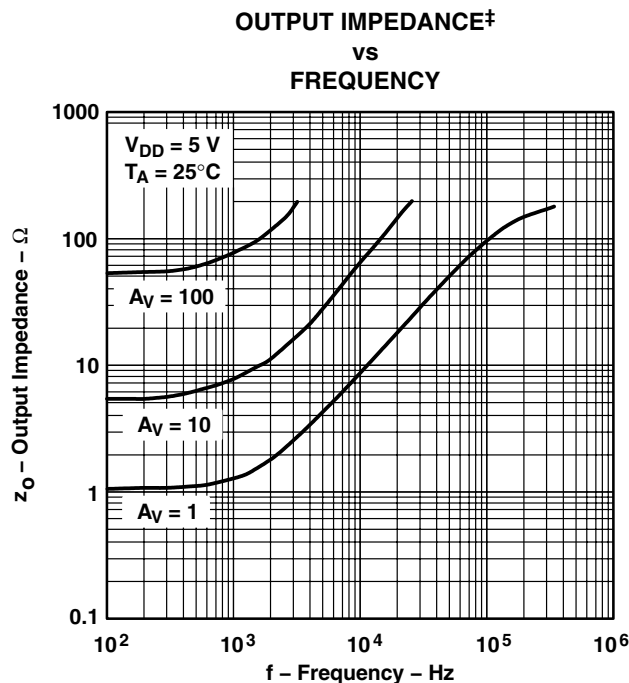


Figure 30

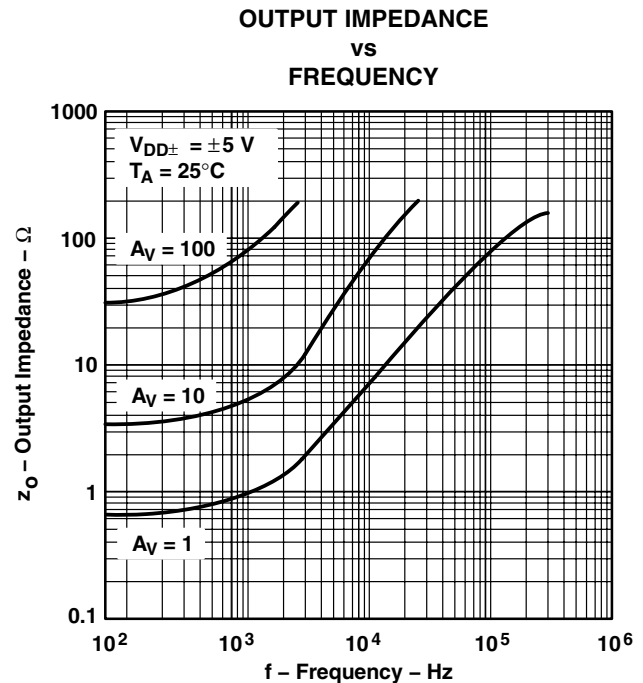


Figure 31

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

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

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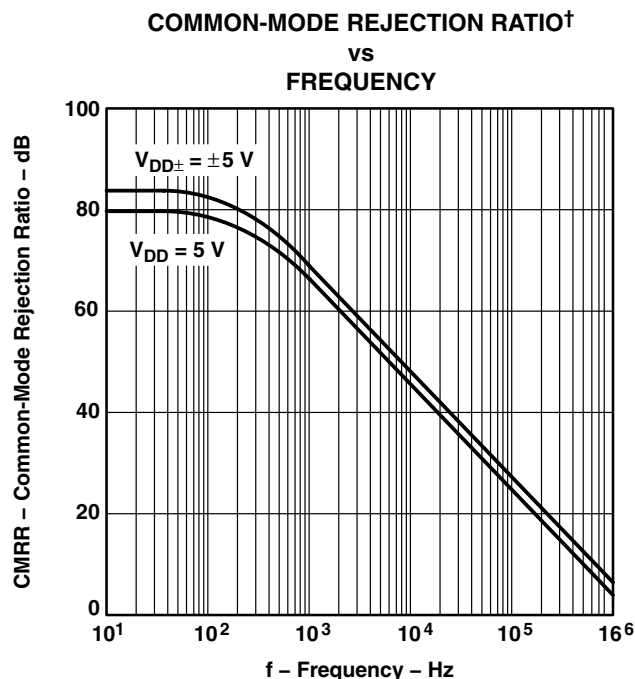


Figure 32

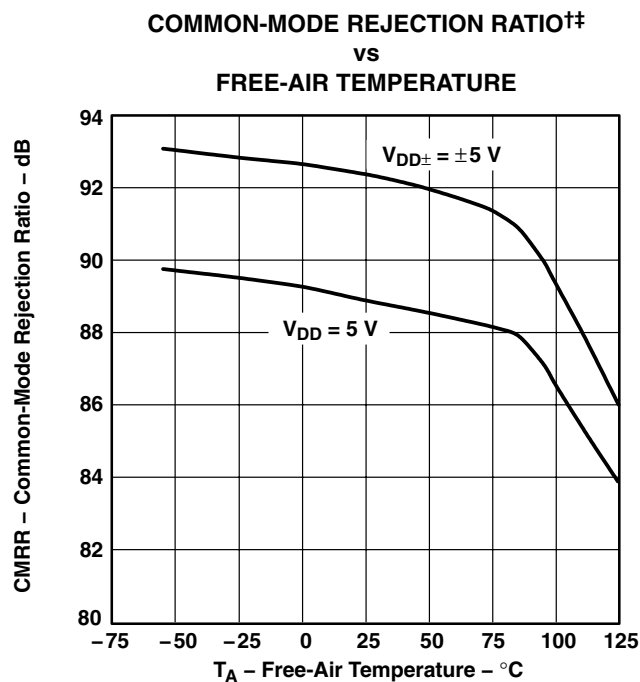


Figure 33

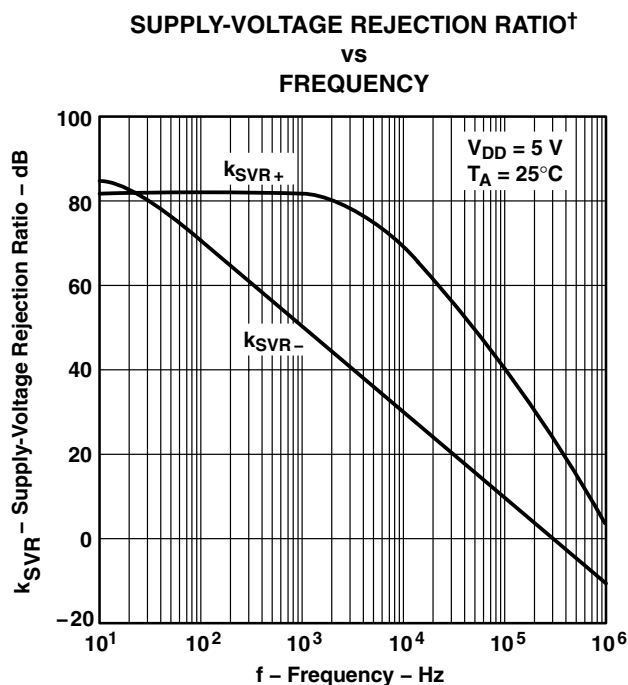


Figure 34

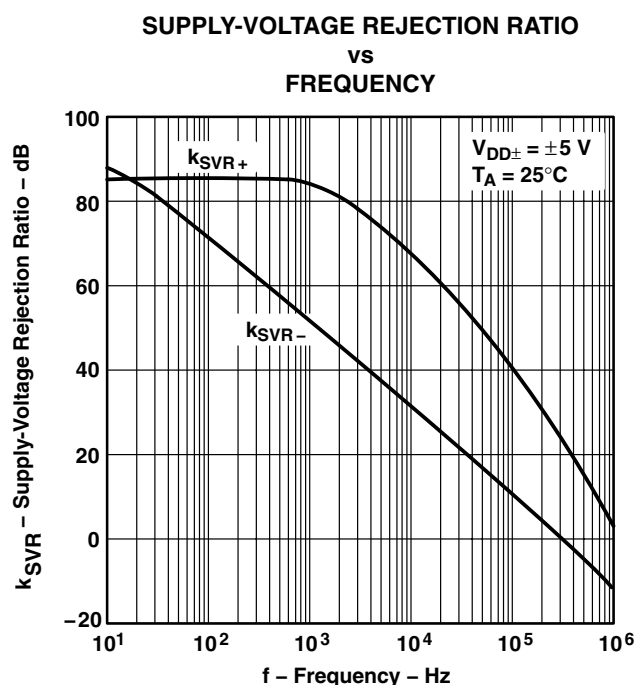


Figure 35

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

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



TYPICAL CHARACTERISTICS

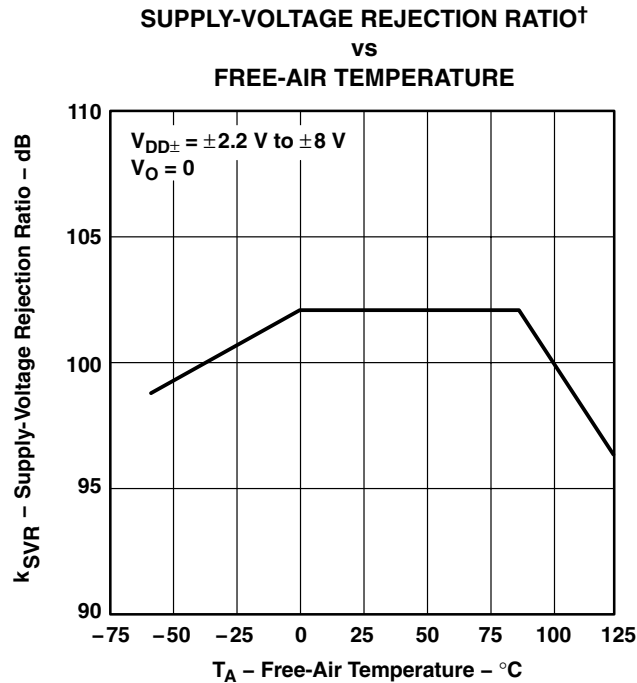


Figure 36

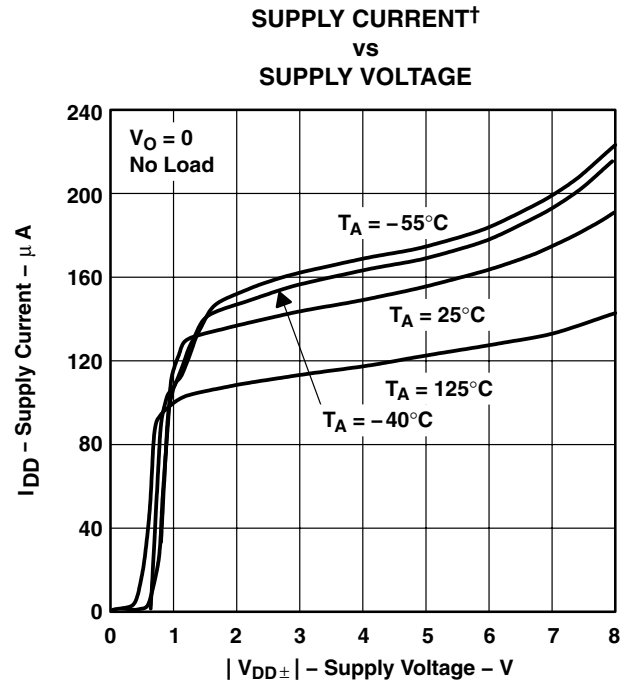


Figure 37

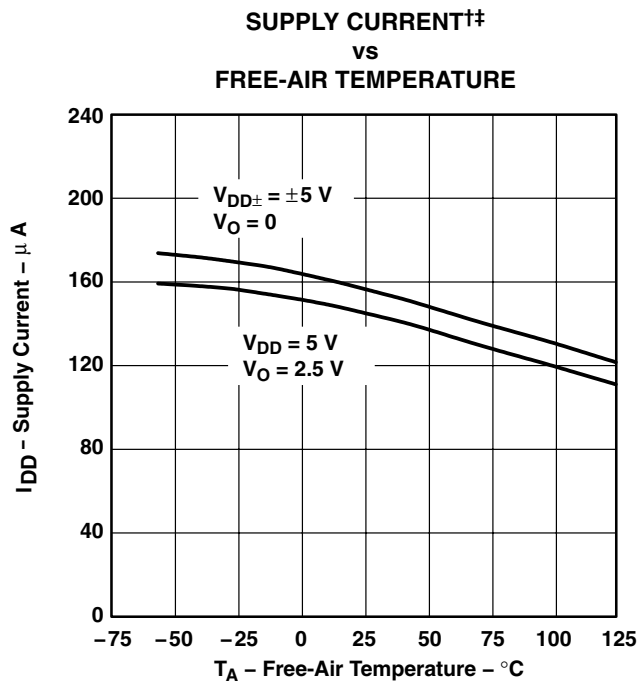


Figure 38

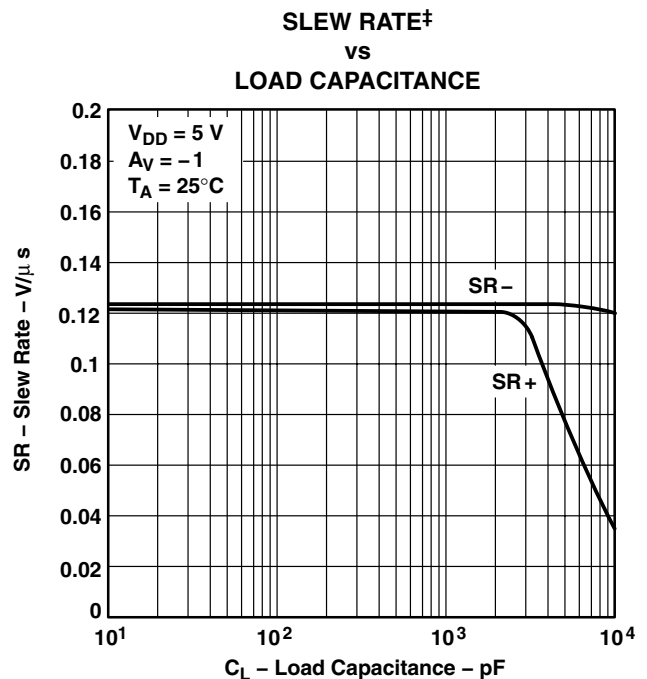


Figure 39

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

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

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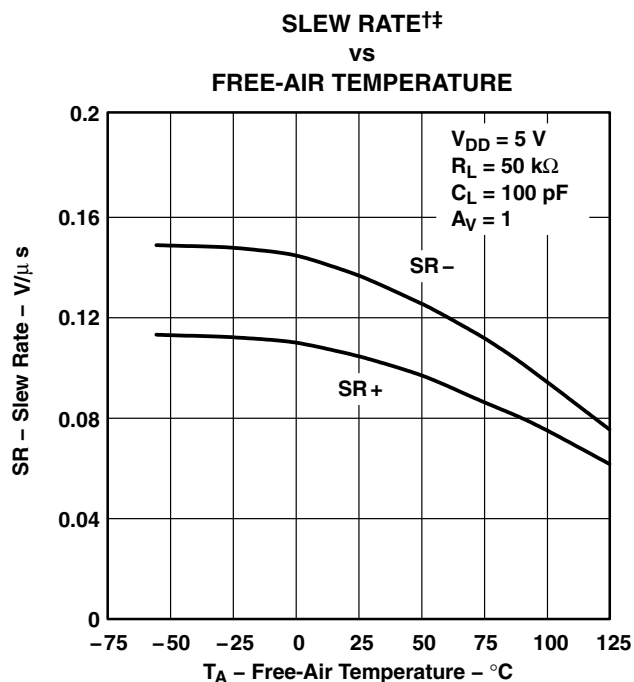


Figure 40

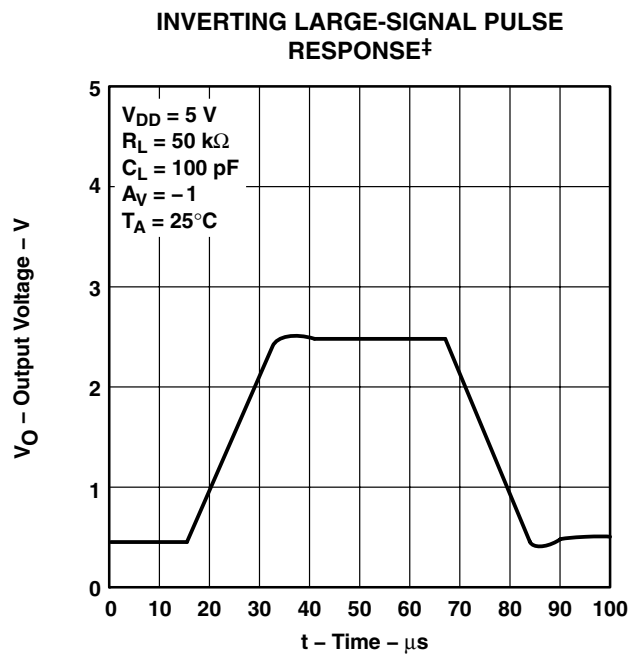


Figure 41

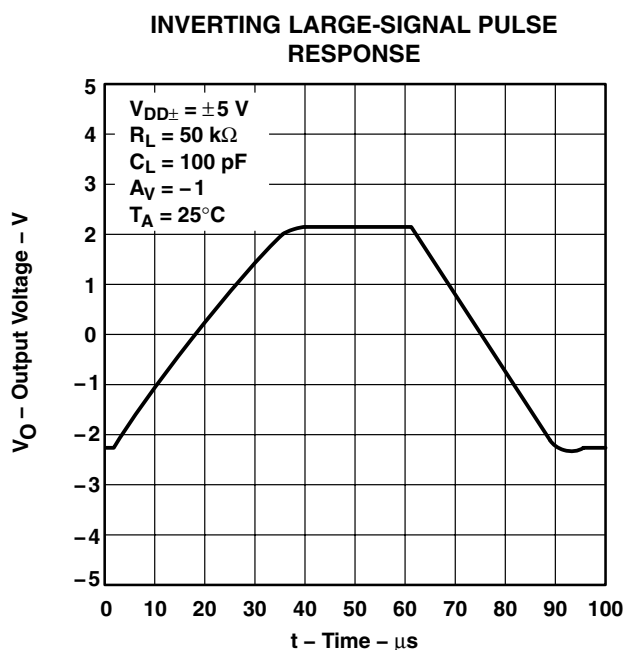


Figure 42

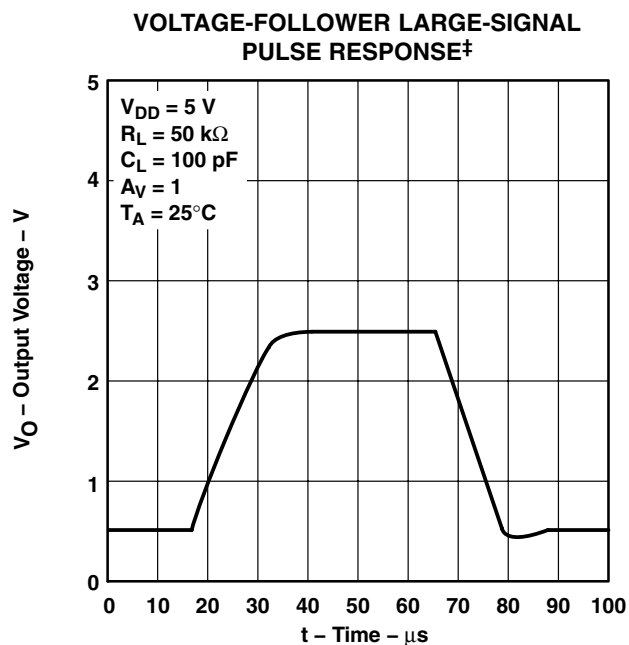


Figure 43

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

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



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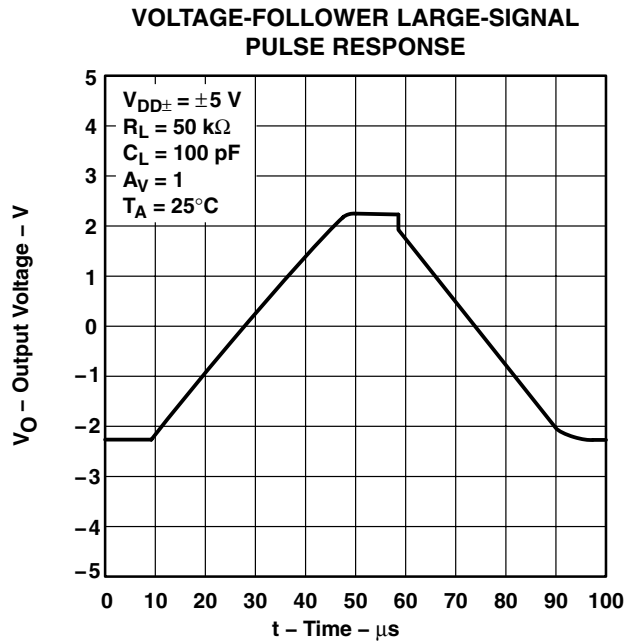


Figure 44

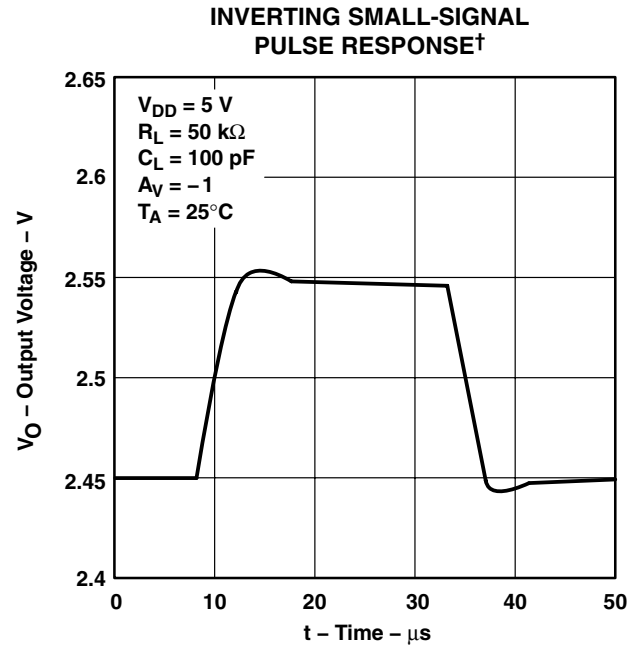


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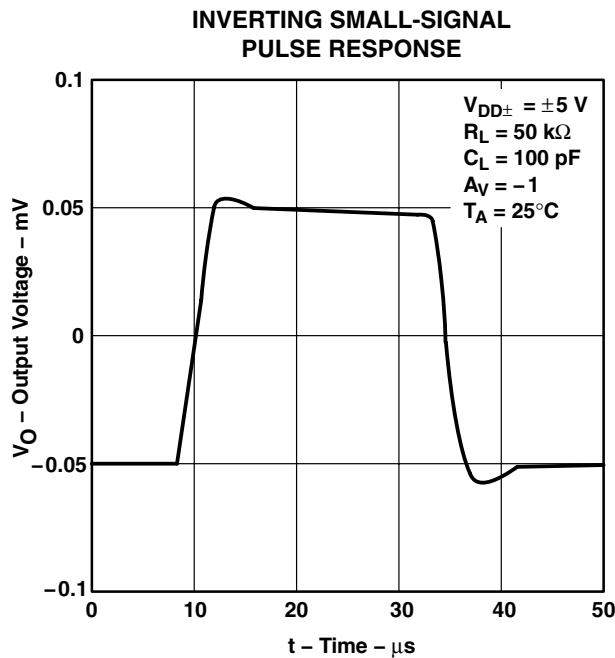


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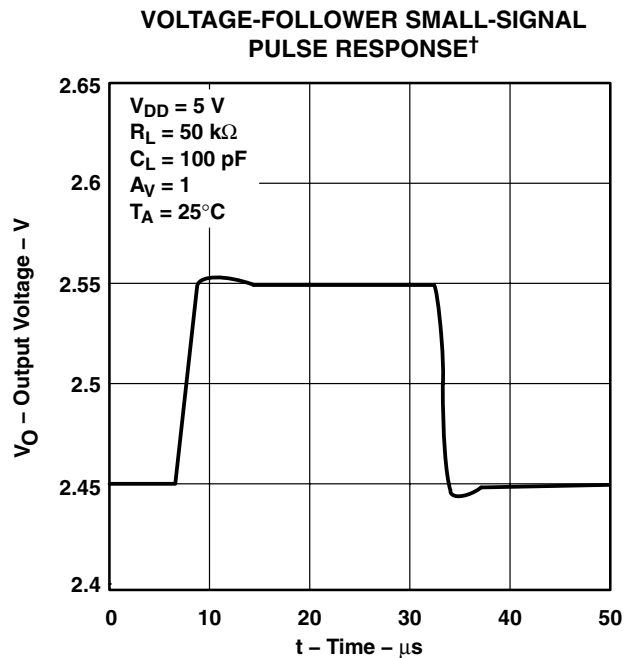


Figure 47

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

TLC225x-Q1, TLC225xA-Q1

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VERY LOW-POWER OPERATIONAL AMPLIFIERS

SGLS188B – OCTOBER 2003 – REVISED APRIL 2008

TYPICAL CHARACTERISTICS

VOLTAGE-FOLLOWER SMALL-SIGNAL
PULSE RESPONSE

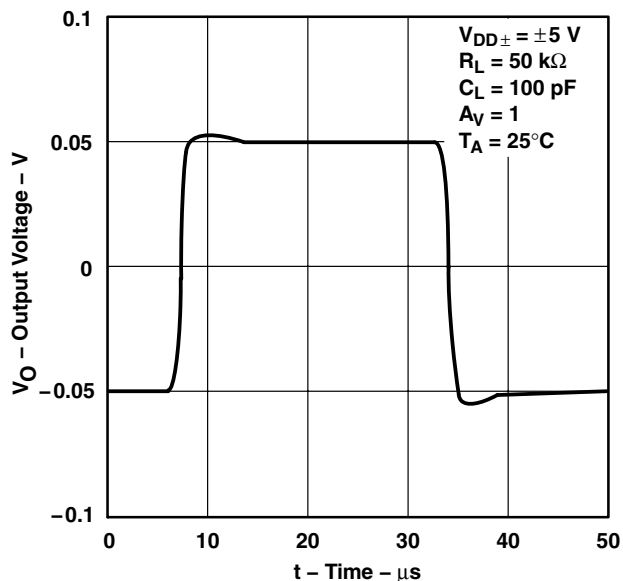


Figure 48

EQUIVALENT INPUT NOISE VOLTAGE†
vs
FREQUENCY

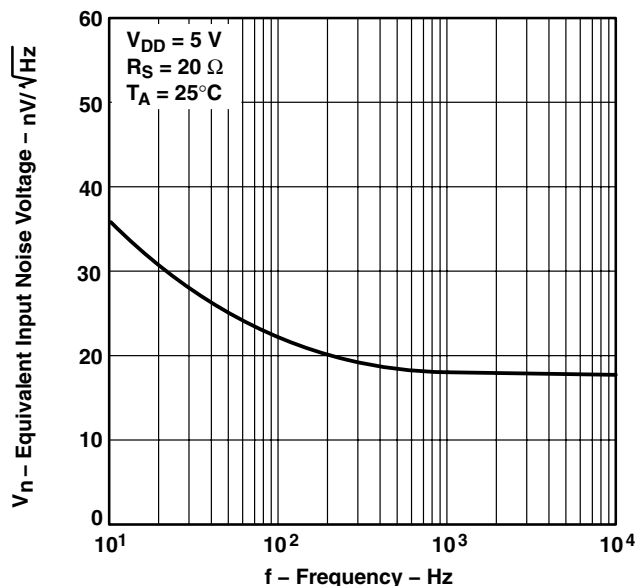


Figure 49

EQUIVALENT INPUT NOISE VOLTAGE
vs
FREQUENCY

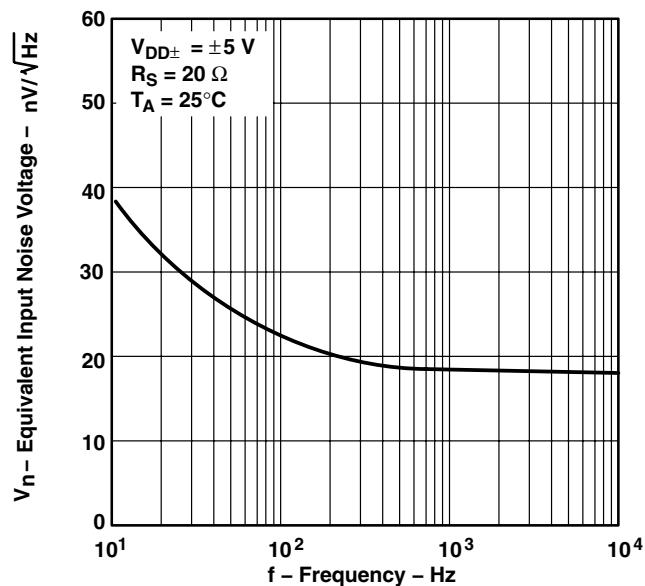


Figure 50

EQUIVALENT INPUT NOISE VOLTAGE OVER
A 10-SECOND PERIOD†

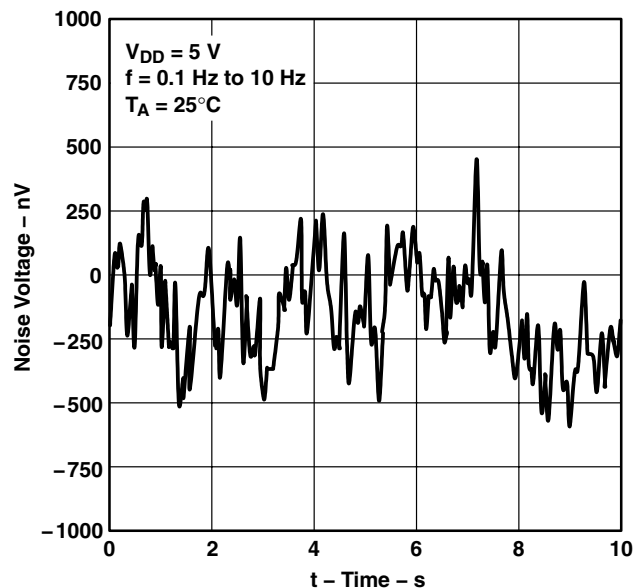


Figure 51

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

TYPICAL CHARACTERISTICS

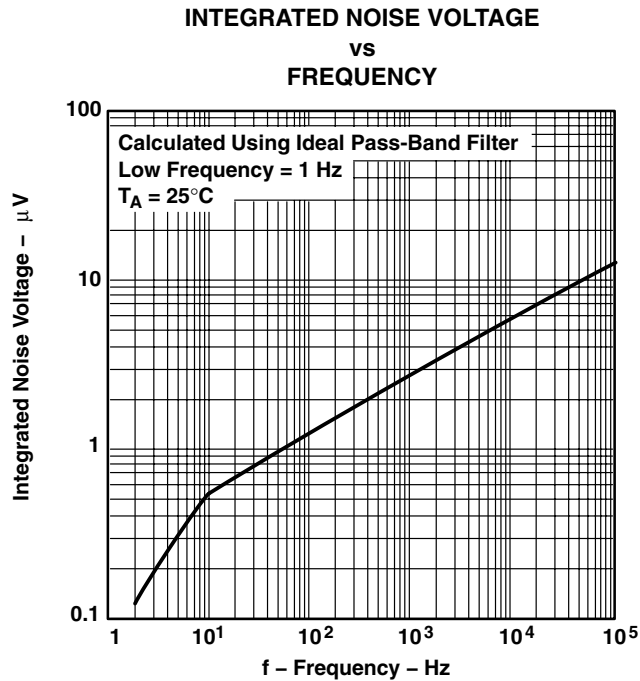


Figure 52

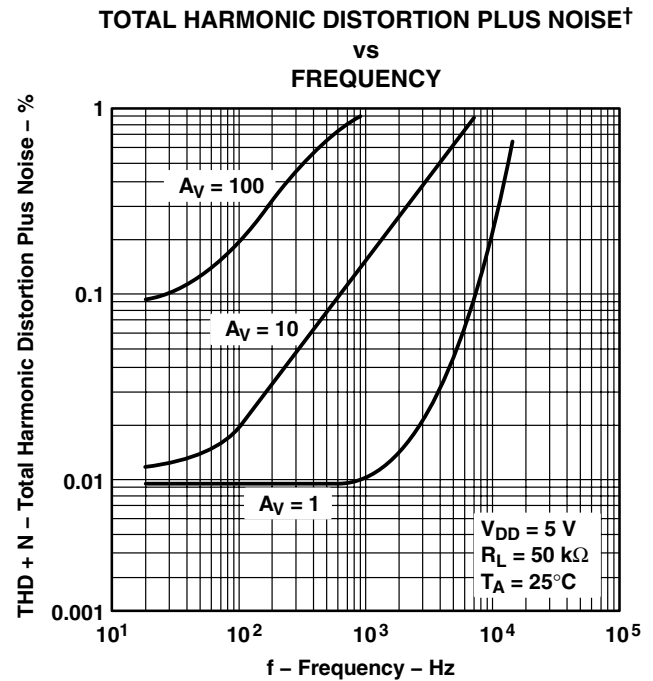


Figure 53

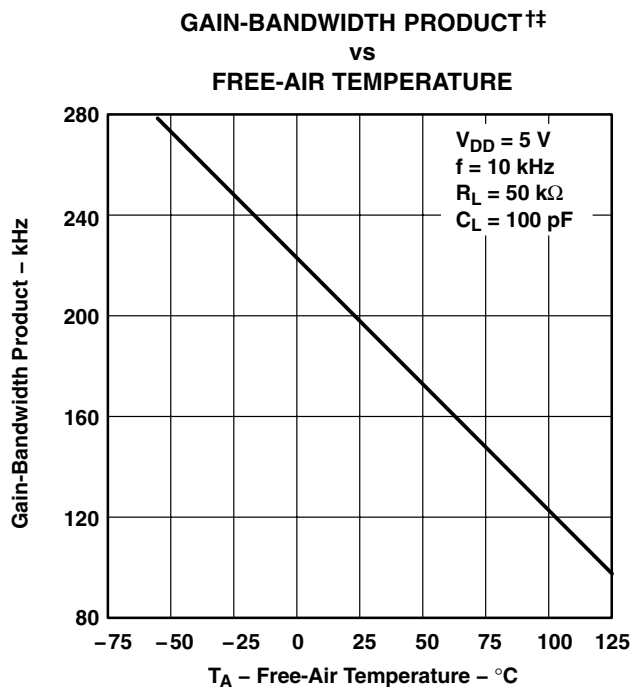


Figure 54

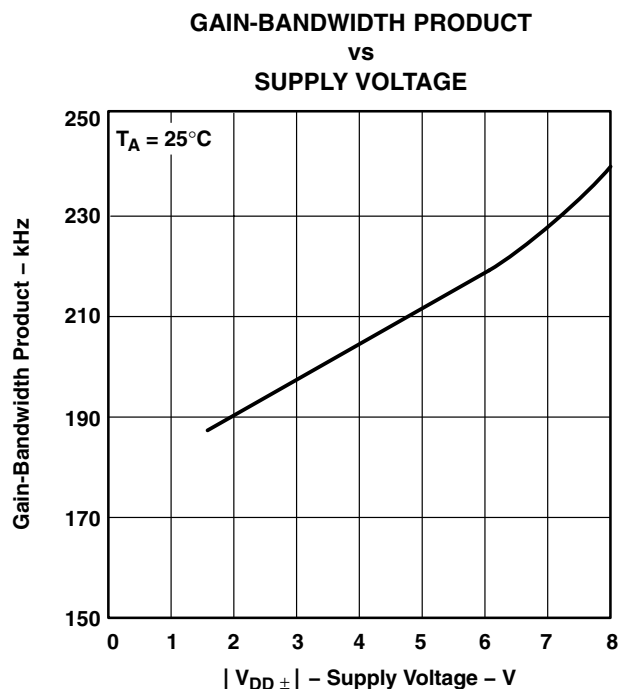


Figure 55

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

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

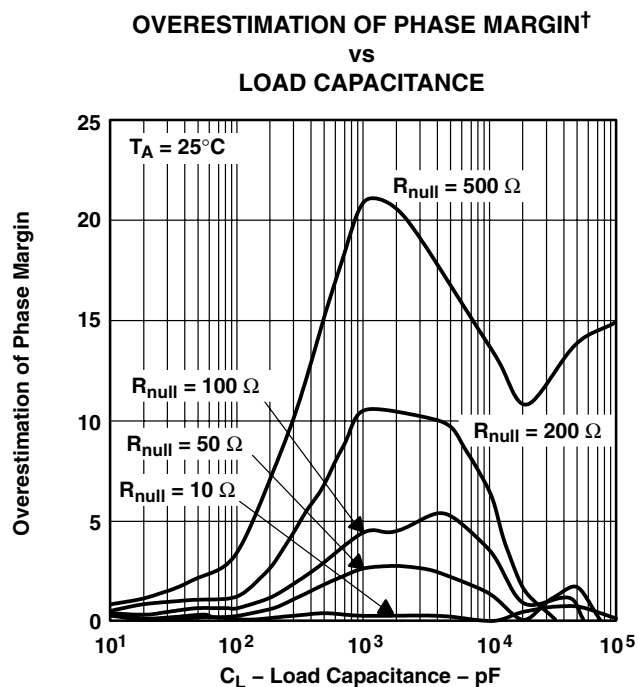
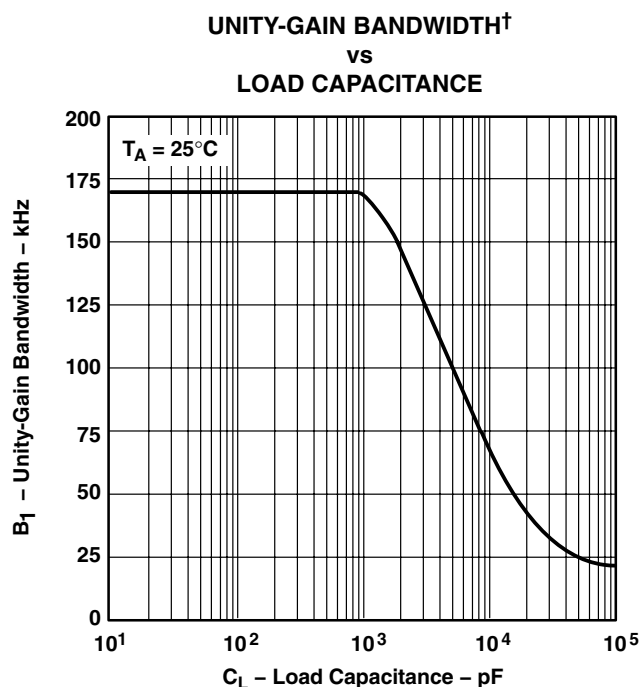
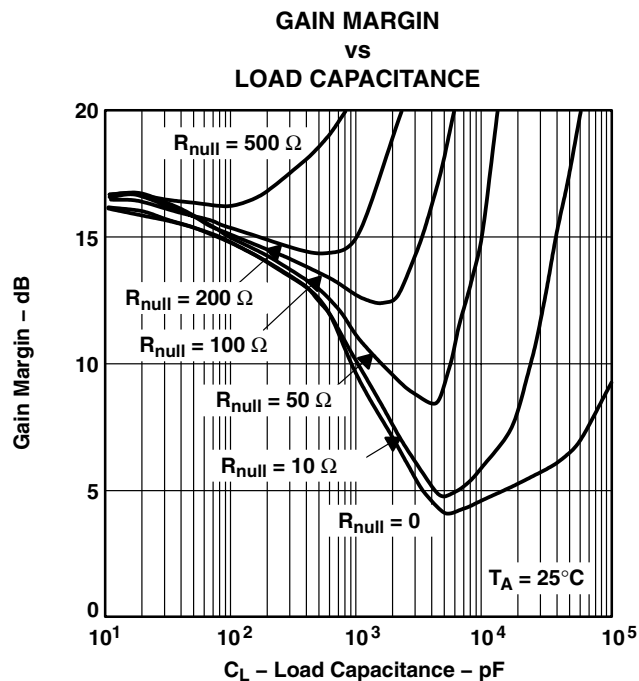
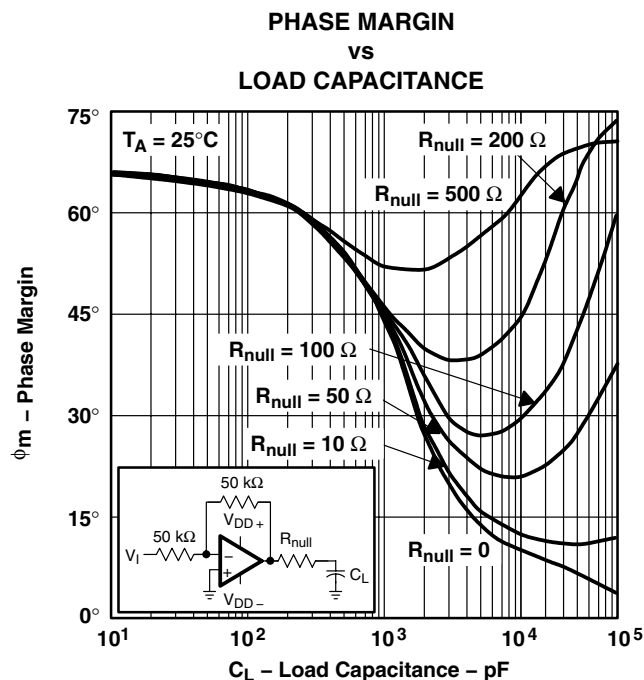
TLC225x-Q1, TLC225xA-Q1

Advanced LinCMOS™ RAIL-TO-RAIL

VERY LOW-POWER OPERATIONAL AMPLIFIERS

SGLS188B – OCTOBER 2003 – REVISED APRIL 2008

TYPICAL CHARACTERISTICS



† See application information

APPLICATION INFORMATION

driving large capacitive loads

The TLC225x is designed to drive larger capacitive loads than most CMOS operational amplifiers. Figure 56 and Figure 57 illustrate its ability to drive loads up to 1000 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 60) improves the gain and phase margins when driving large capacitive loads. Figure 56 and Figure 57 show the effects of adding series resistances of 10 Ω , 50 Ω , 100 Ω , 200 Ω , and 500 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.

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

Where :

$\Delta\phi_{m1}$ = Improvement in phase margin

UGBW = Unity-gain bandwidth frequency

R_{null} = Output series resistance

C_L = Load capacitance

The unity-gain bandwidth (UGBW) frequency decreases as the capacitive load increases (see Figure 58). To use equation 1, UGBW must be approximated from Figure 58.

Using equation 1 alone overestimates the improvement in phase margin, as illustrated in Figure 59. The overestimation is caused by the decrease in the frequency of the pole associated with the load, thus providing additional phase shift and reducing the overall improvement in phase margin.

Using Figure 60, with equation 1 enables the designer to choose the appropriate output series resistance to optimize the design of circuits driving large capacitance loads.

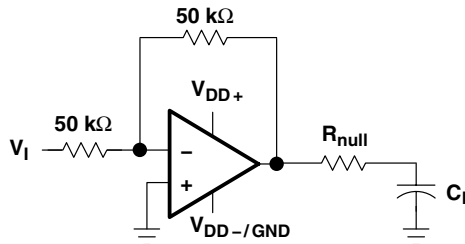


Figure 60. Series-Resistance Circuit

TLC225x-Q1, TLC225xA-Q1

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APPLICATION INFORMATION

macromodel information

Macromodel information provided was derived using MicroSim *Parts*™, the model generation software used with MicroSim *PSpice*™. The Boyle macromodel (see Note 5) and subcircuit in Figure 61 are generated using the TLC225x typical electrical and operating characteristics at $T_A = 25^\circ\text{C}$. Using this information, output simulations of the following key parameters can be generated to a tolerance of 20% (in most cases):

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

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

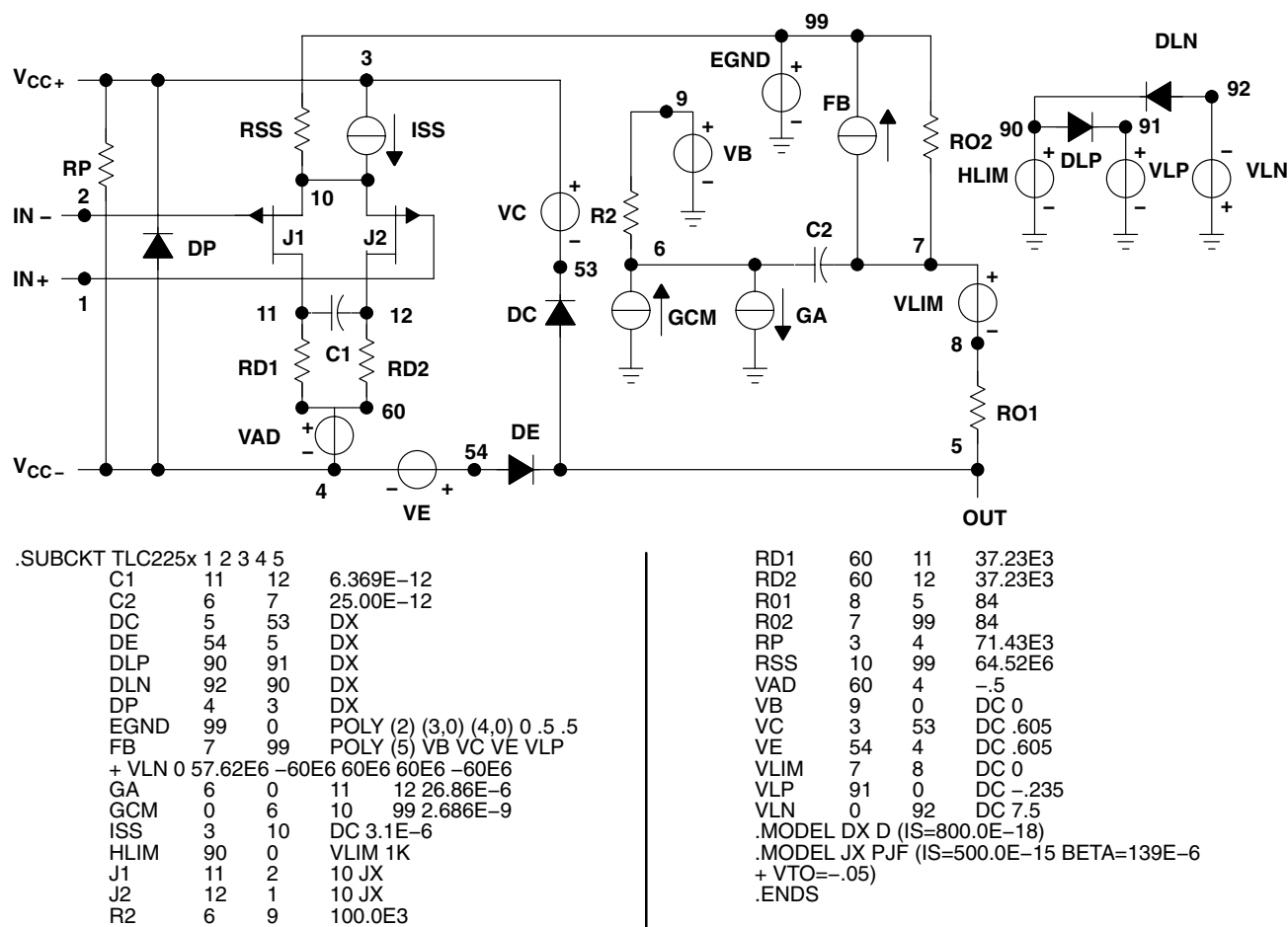


Figure 61. Boyle Macromodel and Subcircuit

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POST OFFICE BOX 1443 • HOUSTON, TEXAS 77251-1443

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)
TLC2252AQDRG4Q1	Active	Production	SOIC (D) 8	2500 LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	2252AQ
TLC2252AQDRG4Q1.A	Active	Production	SOIC (D) 8	2500 LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	2252AQ
TLC2252AQDRQ1	Active	Production	SOIC (D) 8	2500 LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	2252AQ
TLC2252AQDRQ1.A	Active	Production	SOIC (D) 8	2500 LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	2252AQ
TLC2252AQPWRG4Q1	Active	Production	TSSOP (PW) 8	2000 LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	2252AQ
TLC2252AQPWRG4Q1.A	Active	Production	TSSOP (PW) 8	2000 LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	2252AQ
TLC2254AQPWRQ1	Active	Production	TSSOP (PW) 14	2000 LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	2254AQ
TLC2254AQPWRQ1.A	Active	Production	TSSOP (PW) 14	2000 LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	2254AQ

⁽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 TLC2252A-Q1, TLC2254A-Q1 :

- Catalog : [TLC2252A](#), [TLC2254A](#)
- Enhanced Product : [TLC2252A-EP](#), [TLC2254A-EP](#)
- Military : [TLC2252AM](#), [TLC2254AM](#)

NOTE: Qualified Version Definitions:

- Catalog - TI's standard catalog product
- Enhanced Product - Supports Defense, Aerospace and Medical Applications
- Military - QML certified for Military and Defense Applications

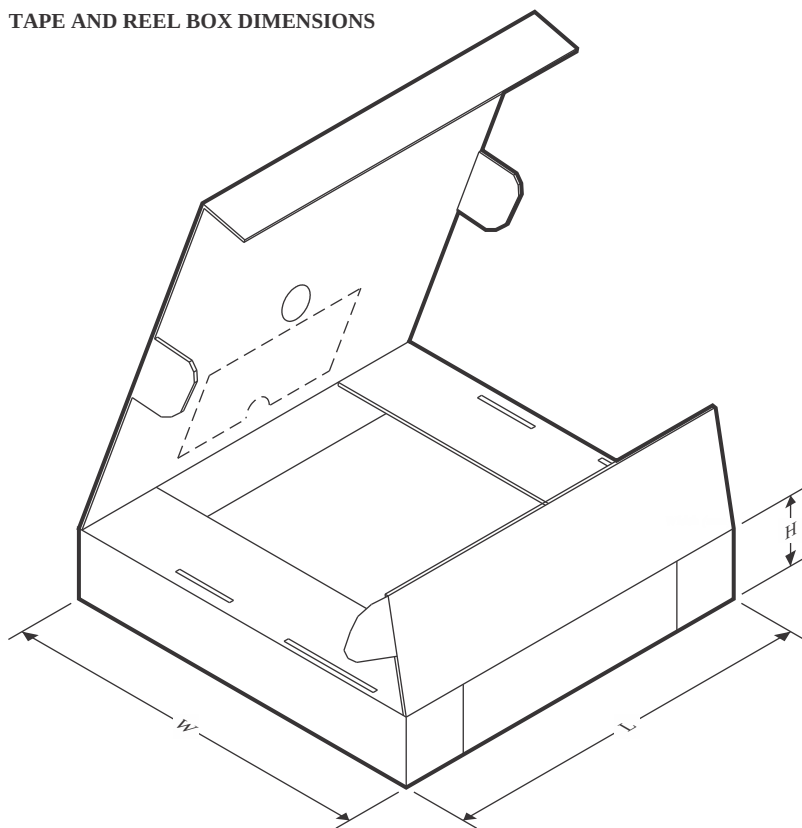
TAPE AND REEL INFORMATION



*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
TLC2252AQPWRG4Q1	TSSOP	PW	8	2000	330.0	12.4	7.0	3.6	1.6	8.0	12.0	Q1
TLC2254AQPWRQ1	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)
TLC2252AQPWRG4Q1	TSSOP	PW	8	2000	353.0	353.0	32.0
TLC2254AQPWRQ1	TSSOP	PW	14	2000	353.0	353.0	32.0



PACKAGE OUTLINE

SOIC - 1.75 mm max height

SMALL OUTLINE INTEGRATED CIRCUIT



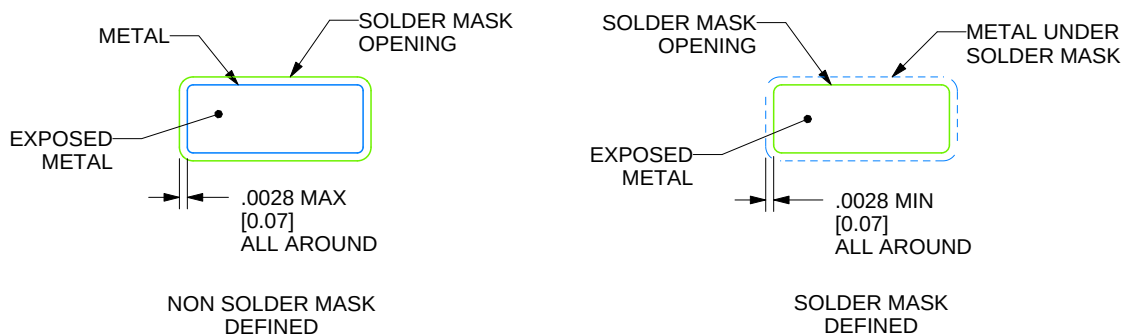
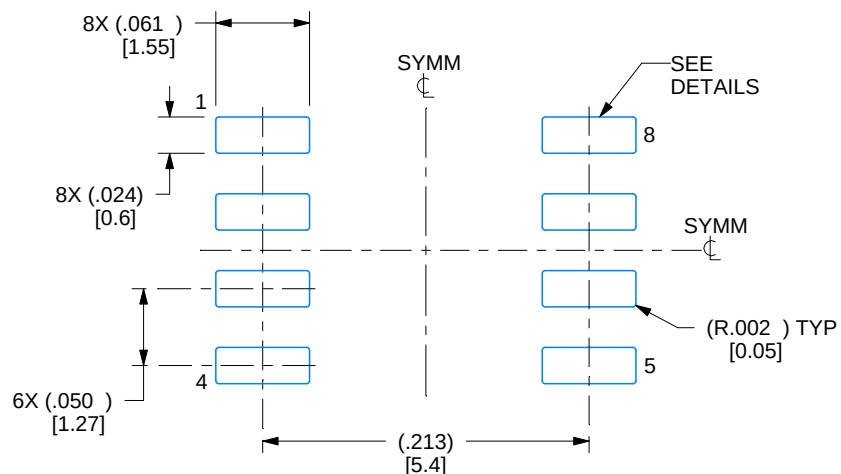
1. Linear dimensions are in inches [millimeters]. Dimensions in parenthesis are for reference only. Controlling dimensions are in inches. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed .006 [0.15] per side.
4. This dimension does not include interlead flash.
5. Reference JEDEC registration MS-012, variation AA.

EXAMPLE BOARD LAYOUT

D0008A

SOIC - 1.75 mm max height

SMALL OUTLINE INTEGRATED CIRCUIT



4214825/C 02/2019

NOTES: (continued)

6. Publication IPC-7351 may have alternate designs.

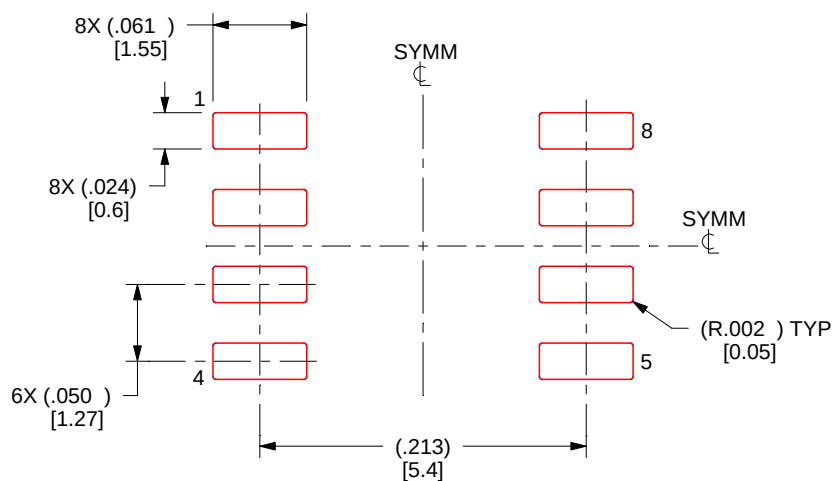
7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.

EXAMPLE STENCIL DESIGN

D0008A

SOIC - 1.75 mm max height

SMALL OUTLINE INTEGRATED CIRCUIT



SOLDER PASTE EXAMPLE
BASED ON .005 INCH [0.125 MM] THICK STENCIL
SCALE:8X

4214825/C 02/2019

NOTES: (continued)

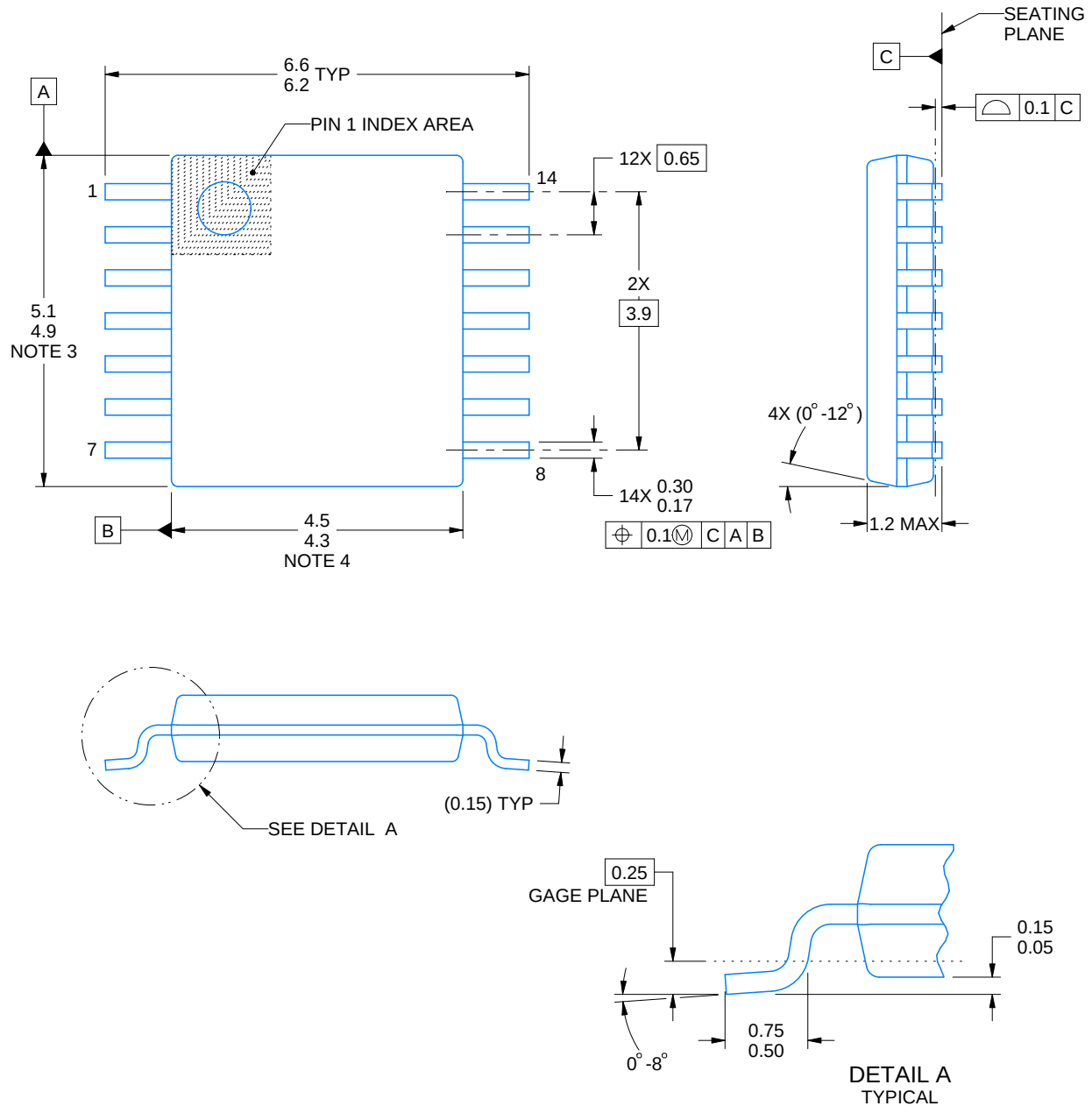
8. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
9. Board assembly site may have different recommendations for stencil design.

PW0014A

PACKAGE OUTLINE

TSSOP - 1.2 mm max height

SMALL OUTLINE PACKAGE



4220202/B 12/2023

NOTES:

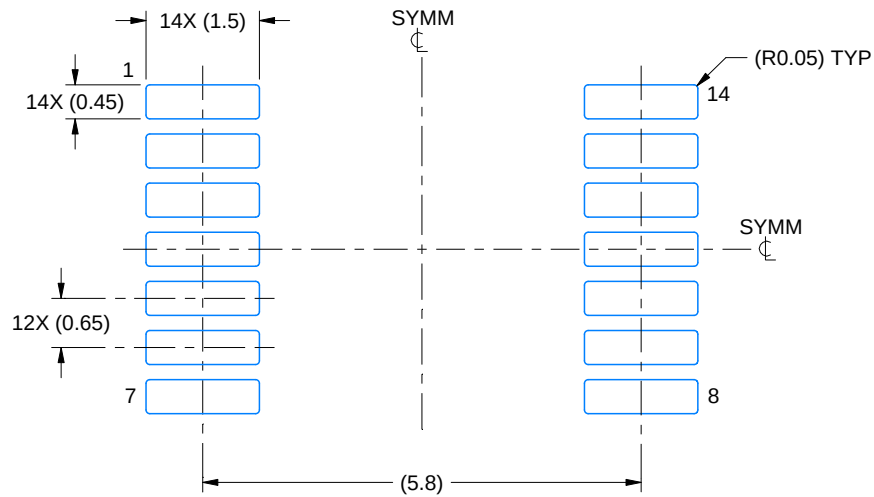
1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or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

EXAMPLE BOARD LAYOUT

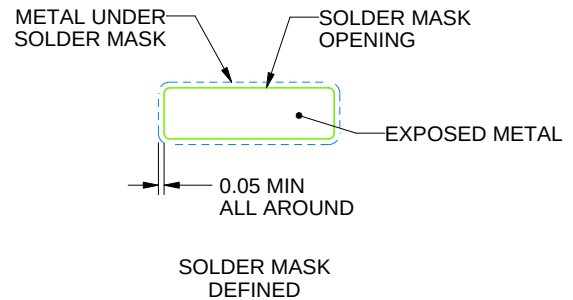
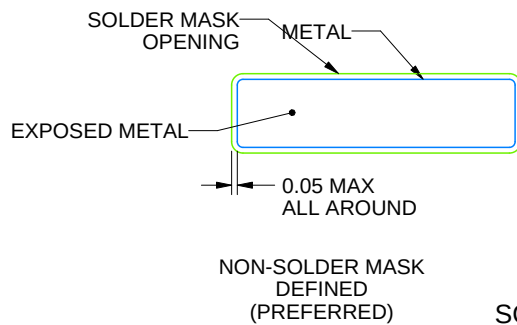
PW0014A

TSSOP - 1.2 mm max height

SMALL OUTLINE PACKAGE



LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE: 10X



SOLDER MASK DETAILS

4220202/B 12/2023

NOTES: (continued)

6. Publication IPC-7351 may have alternate designs.

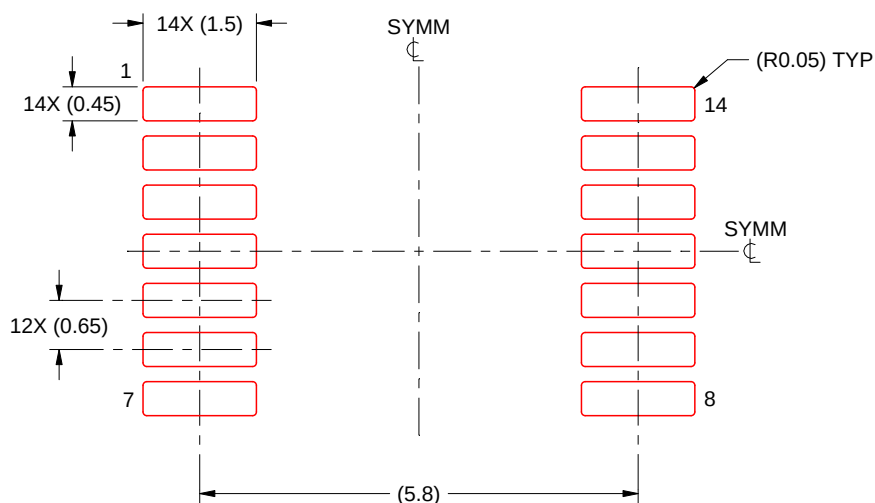
7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.

EXAMPLE STENCIL DESIGN

PW0014A

TSSOP - 1.2 mm max height

SMALL OUTLINE PACKAGE



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

4220202/B 12/2023

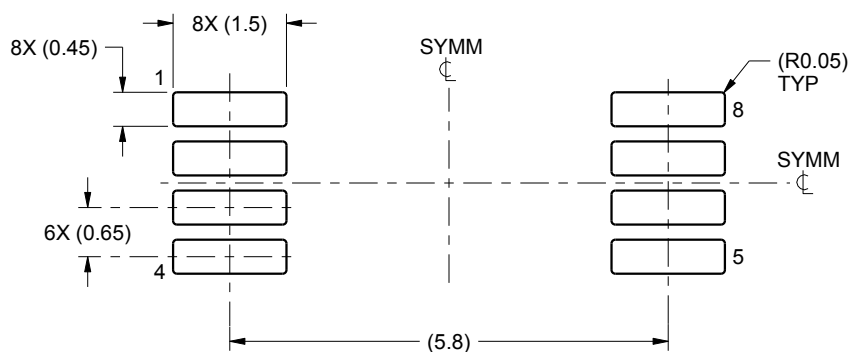
NOTES: (continued)

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.

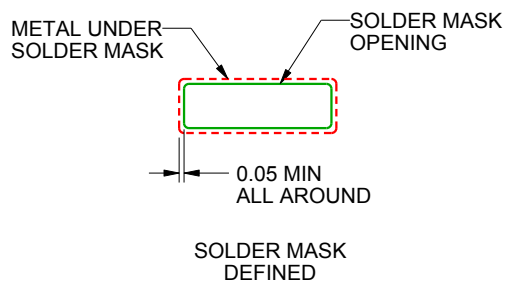
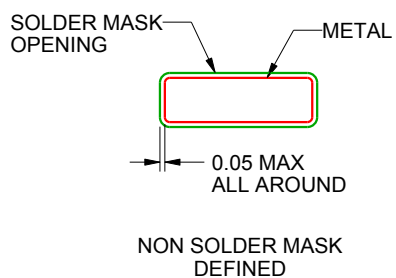
PW0008A

TSSOP - 1.2 mm max height

SMALL OUTLINE PACKAGE



LAND PATTERN EXAMPLE
SCALE:10X



SOLDER MASK DETAILS
NOT TO SCALE

4221848/A 02/2015

NOTES: (continued)

6. Publication IPC-7351 may have alternate designs.

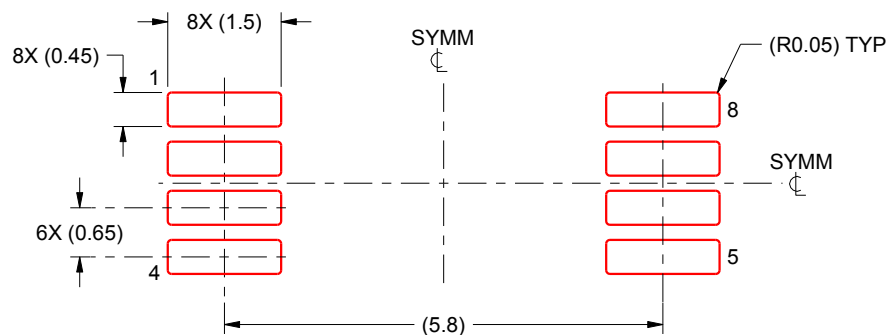
7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.

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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