

TLC225x-EP, TLC225xA-EP Advanced LinCMOS™ RAIL-TO-RAIL VERY LOW-POWER OPERATIONAL AMPLIFIERS

SGLS216 – NOVEMBER 2003

- **Controlled Baseline**
 - One Assembly/Test Site, One Fabrication Site
- **Extended Temperature Performance of -40°C to 125°C**
- **Enhanced Diminishing Manufacturing Sources (DMS) Support**
- **Enhanced Product-Change Notification**
- **Qualification Pedigree†**
- **ESD Protection Exceeds 2000 V Per MIL-STD-883, Method 3015; Exceeds 150 V (TLC2252/52A) and 100 V (TLC2254/54A) Using Machine Model ($C = 200\text{ pF}$, $R = 0$)**
- **Output Swing Includes Both Supply Rails**
- **Low Noise . . . $19\text{ nV}/\sqrt{\text{Hz}}$ Typ at $f = 1\text{ kHz}$**
- **Low Input Bias Current . . . 1 pA Typ**
- **Fully Specified for Both Single-Supply and Split-Supply Operation**
- **Very Low Power . . . $35\text{ }\mu\text{A}$ Per Channel Typ**
- **Common-Mode Input Voltage Range Includes Negative Rail**
- **Low Input Offset Voltage**
 $850\text{ }\mu\text{V}$ Max at $T_A = 25^{\circ}\text{C}$ (TLC225xA)
- **Macromodel Included**
- **Performance Upgrades for the TS27L2/L4 and TLC27L2/L4**

† Component qualification in accordance with JEDEC and industry standards to ensure reliable operation over an extended temperature range. This includes, but is not limited to, Highly Accelerated Stress Test (HAST) or biased 85/85, temperature cycle, autoclave or unbiased HAST, electromigration, bond intermetallic life, and mold compound life. Such qualification testing should not be viewed as justifying use of this component beyond specified performance and environmental limits.

description

The TLC2252 and TLC2254 are dual and quadruple operational amplifiers from Texas Instruments. Both devices exhibit rail-to-rail output performance for increased dynamic range in single- or split-supply applications. The TLC225x family consumes only $35\text{ }\mu\text{A}$ 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 $19\text{ nV}/\sqrt{\text{Hz}}$ 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 $850\text{ }\mu\text{V}$. This family is fully characterized at 5 V and $\pm 5\text{ V}$.

EQUIVALENT INPUT NOISE VOLTAGE
VS
FREQUENCY

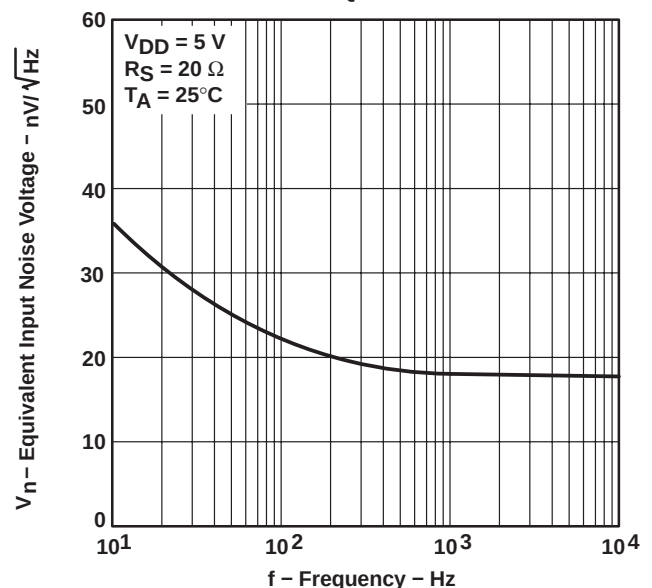


Figure 1



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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PRODUCTION DATA information is current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.



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description/ordering information (continued)

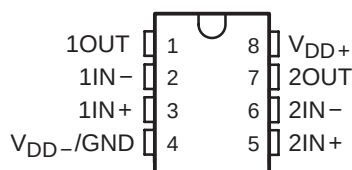
The TLC2252/4 also makes great upgrades to the TLC27L2/L4 or TS27L2/L4 in standard designs. They offer increased output dynamic range, lower noise voltage, and lower input offset voltage. This enhanced feature set allows them to be used in a wider range of applications. For applications that require 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.

ORDERING INFORMATION

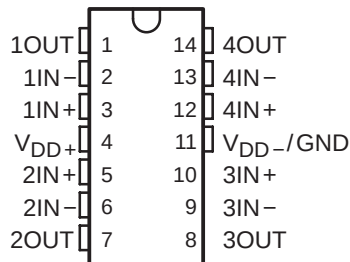
T _A	V _{IO} max AT 25°C	PACKAGE†		ORDERABLE PART NUMBER	TOP-SIDE MARKING
–40°C to 125°C	850 µV	SOIC (D)	Tape and reel	TLC2252AQDREP	2252AE
	1550 µV	SOIC (D)	Tape and reel	TLC2252QDREP	2252EP
	850 µV	SOIC (D)	Tape and reel	TLC2254AQDREP	TLC2254AEP
	1550 µV	SOIC (D)	Tape and reel	TLC2254QDREP	TLC2254EP

† Package drawings, standard packing quantities, thermal data, symbolization, and PCB design guidelines are available at www.ti.com/sc/package.

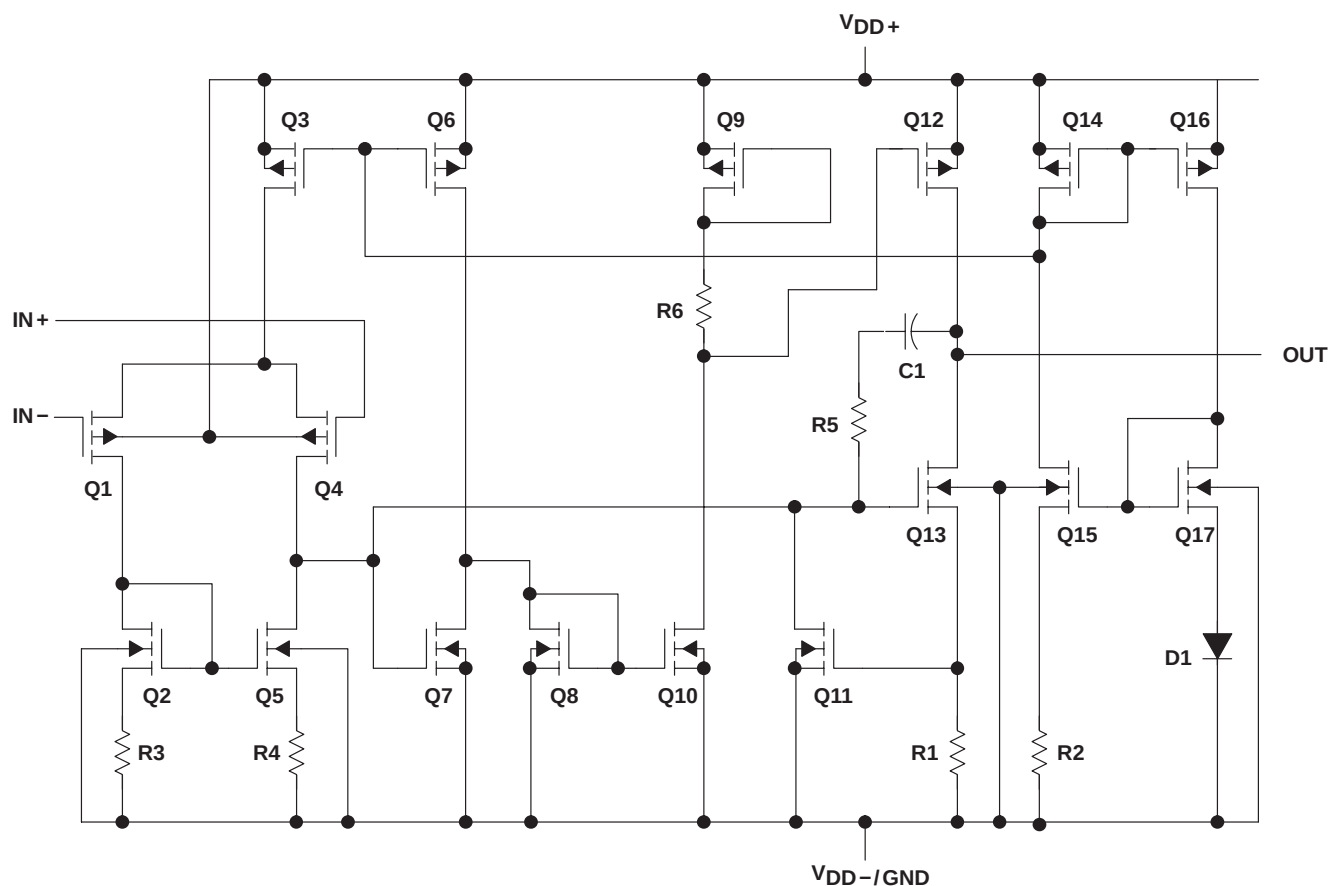
TLC2252, TLC2252A
D PACKAGE
(TOP VIEW)



TLC2254, TLC2254A
D 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

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



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

PARAMETER	TEST CONDITIONS	$T_A^\dagger$	TLC2252-EP			TLC2252A-EP			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
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	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			$\mu\text{V}/^\circ\text{C}$
Input offset voltage long-term drift (see Note 4)		25°C	0.003			0.003			$\mu\text{V}/\text{mo}$
I_{IO} Input offset current		25°C	0.5	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	$R_S = 50\ \Omega, V_{IO} \leq 5\text{ mV}$	25°C	0 to 4	-0.3 to 4.2		0 to 4	-0.3 to 4.2		V
		Full range	0 to 3.5			0 to 3.5			
V_{OH} High-level output voltage	$I_{OH} = -20\ \mu\text{A}$	25°C	4.98			4.98			V
	$I_{OH} = -75\ \mu\text{A}$	25°C	4.9	4.94		4.9	4.94		
		Full range	4.8			4.8			
	$I_{OH} = -150\ \mu\text{A}$	25°C	4.8	4.88		4.8	4.88		
V_{OL} Low-level output voltage	$V_{IC} = 2.5\text{ V}, I_{OL} = 50\ \mu\text{A}$	25°C	0.01			0.01			V
	$V_{IC} = 2.5\text{ V}, I_{OL} = 500\ \mu\text{A}$	25°C	0.09	0.15		0.09	0.15		
		Full range		0.15			0.15		
	$V_{IC} = 2.5\text{ V}, I_{OL} = 4\text{ mA}$	25°C	0.8	1		0.7	1		
		Full range		1.2			1.2		
A_{VD} Large-signal differential voltage amplification	$V_{IC} = 2.5\text{ V}, V_O = 1\text{ V to }4\text{ V}$	$R_L = 100\text{ k}\Omega^\ddagger$	25°C	100	350	100	350		V/mV
			Full range	10		10			
		$R_L = 1\text{ M}\Omega^\ddagger$	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	$f = 10\text{ kHz}, f = 10\text{ kHz},$	25°C	8			8			pF
z_o Closed-loop output impedance	$f = 25\text{ kHz}, A_V = 10$	25°C	200			200			Ω
CMRR Common-mode rejection ratio	$V_{IC} = 0\text{ to }2.7\text{ V}, V_O = 2.5\text{ V}, R_S = 50\ \Omega$	25°C	70	83		70	83		dB
		Full range	70			70			
k_{SVR} Supply-voltage rejection ratio ($\Delta V_{DD}/\Delta V_{IO}$)	$V_{DD} = 4.4\text{ V to }16\text{ V}, V_{IC} = V_{DD}/2, \text{ No load}$	25°C	80	95		80	95		dB
		Full range	80			80			
I_{DD} Supply current	$V_O = 2.5\text{ V}, \text{ No load}$	25°C	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.

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

PARAMETER		TEST CONDITIONS		$T_A^\dagger$	TLC2252-EP			TLC2252A-EP			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	$V_O = 0.5\text{ V to }2.5\text{ V}$, $f = 10\text{ kHz}$, $R_L = 50\text{ k}\Omega^\ddagger$	$A_V = 1$	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

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

PARAMETER	TEST CONDITIONS	$T_A^\dagger$	TLC2252-EP			TLC2252A-EP			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
V_{IO} Input offset voltage	$V_{IC} = 0, V_O = 0, R_S = 50 \Omega$	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			$\mu V/^\circ C$
Input offset voltage long-term drift (see Note 4)		25°C	0.003			0.003			$\mu V/mo$
I_{IO} Input offset current		25°C	0.5	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	$R_S = 50 \Omega, V_{IO} \leq 5$ mV	25°C	-5 to 4	-5.3 to 4.2		-5 to 4	-5.3 to 4.2		V
		Full range	-5 to 3.5			-5 to 3.5			
V_{OM+} Maximum positive peak output voltage	$I_O = -20 \mu A$	25°C		4.98			4.98		V
	$I_O = -100 \mu A$	25°C	4.9	4.93		4.9	4.93		
		Full range	4.7			4.7			
	$I_O = -200 \mu A$	25°C	4.8	4.86		4.8	4.86		
V_{OM-} Maximum negative peak output voltage	$V_{IC} = 0, I_O = 50 \mu A$	25°C		-4.99			-4.99		V
		25°C	-4.85	-4.91		-4.85	-4.91		
	$V_{IC} = 0, I_O = 500 \mu A$	Full range	-4.85			-4.85			
		25°C	-4	-4.3		-4	-4.3		
	$V_{IC} = 0, I_O = 4$ mA	Full range	-3.8			-3.8			
A_{VD} Large-signal differential voltage amplification	$V_O = \pm 4$ V	$R_L = 100$ k Ω	25°C	40	150	40	150		V/mV
			Full range	10		10			
		$R_L = 1$ M Ω	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, $V_O = 0, R_S = 50 \Omega$	25°C	75	88		75	88		dB
		Full range	75			75			
k_{SVR} Supply-voltage rejection ratio ($\Delta V_{DD\pm} / \Delta V_{IO}$)	$V_{DD} = \pm 2.2$ 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 $T_A = 150^\circ C$ extrapolated to $T_A = 25^\circ C$ using the Arrhenius equation and assuming an activation energy of 0.96 eV.



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

PARAMETER		TEST CONDITIONS	$T_A^\dagger$	TLC2252-EP			TLC2252A-EP			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		0.2%			0.2%		
		$A_V = 1$ $A_V = 10$			1%			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
BOM	Maximum output-swing bandwidth	$V_{O(PP)} = 4.6\text{ V}$, $R_L = 50\text{ k}\Omega$, $C_L = 100\text{ pF}$, $A_V = 1$	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-EP			TLC2254A-EP			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 [‡] R _L = 1 MΩ [‡]	25°C	100	350		100	350
Full range	10						10				
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-EP			TLC2254A-EP			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

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

PARAMETER	TEST CONDITIONS	$T_A^\dagger$	TLC2254-EP			TLC2254A-EP			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
V_{IO} Input offset voltage	$V_{IC} = 0, V_O = 0, R_S = 50 \Omega$	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			$\mu V/^\circ C$
Input offset voltage long-term drift (see Note 4)		25°C	0.003			0.003			$\mu V/mo$
I_{IO} Input offset current		25°C	0.5	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	$R_S = 50 \Omega, V_{IO} \leq 5$ mV	25°C	-5 to 4	-5.3 to 4.2		-5 to 4	-5.3 to 4.2		V
		Full range	-5 to 3.5			-5 to 3.5			
V_{OM+} Maximum positive peak output voltage	$I_O = -20 \mu A$	25°C		4.98			4.98		V
	$I_O = -100 \mu A$	25°C	4.9	4.93		4.9	4.93		
		Full range	4.7			4.7			
	$I_O = -200 \mu A$	25°C	4.8	4.86		4.8	4.86		
V_{OM-} Maximum negative peak output voltage	$V_{IC} = 0, I_O = 50 \mu A$	25°C		-4.99			-4.99		V
	$V_{IC} = 0, I_O = 500 \mu A$	25°C	-4.85	-4.91		-4.85	-4.91		
		Full range	-4.85			-4.85			
	$V_{IC} = 0, I_O = 4$ mA	25°C	-4	-4.3		-4	-4.3		
		Full range	-3.8			-3.8			
A_{VD} Large-signal differential voltage amplification	$V_O = \pm 4$ V	$R_L = 100$ k Ω	25°C	40	150	40	150		V/mV
			Full range	10		10			
		$R_L = 1$ M Ω	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, $V_O = 0, R_S = 50 \Omega$	25°C	75	88		75	88		dB
		Full range	75			75			
k_{SVR} Supply-voltage rejection ratio ($\Delta V_{DD\pm}/\Delta V_{IO}$)	$V_{DD\pm} = \pm 2.2$ V to ± 8 V, $V_{IC} = V_{DD}/2$, No load	25°C	80	95		80	95		dB
		Full range	80			80			
I_{DD} Supply current (four amplifiers)	$V_O = 0$, No load	25°C	160	250		160	250		μA
		Full range		300			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 $T_A = 150^\circ C$ extrapolated to $T_A = 25^\circ C$ using the Arrhenius equation and assuming an activation energy of 0.96 eV.

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

PARAMETER		TEST CONDITIONS		T _A [†]	TLC2254-EP			TLC2254A-EP			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		25°C	38			38			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	0.8			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.

TYPICAL CHARACTERISTICS

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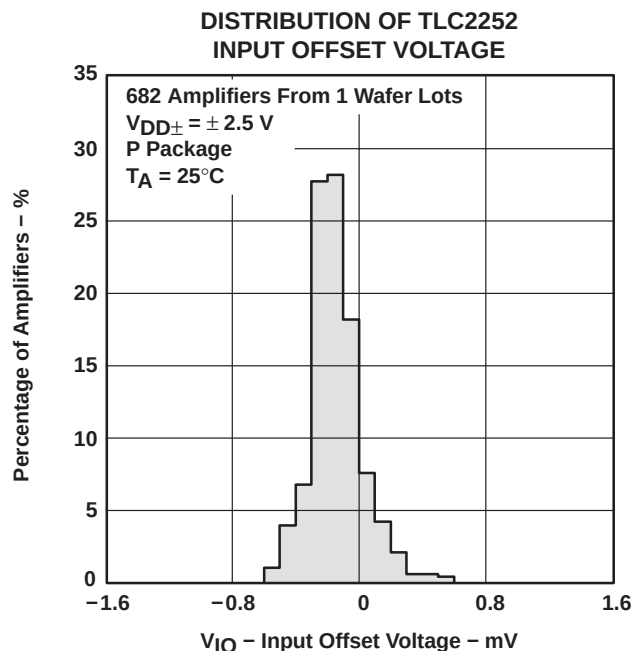


Figure 2

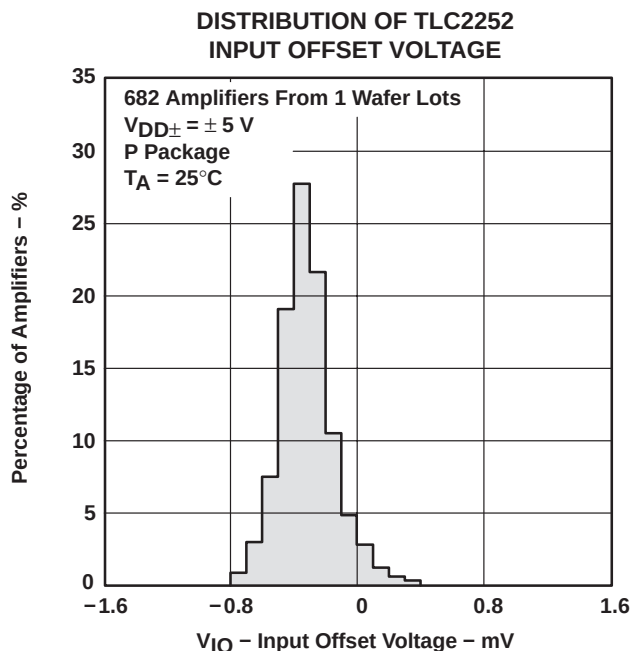


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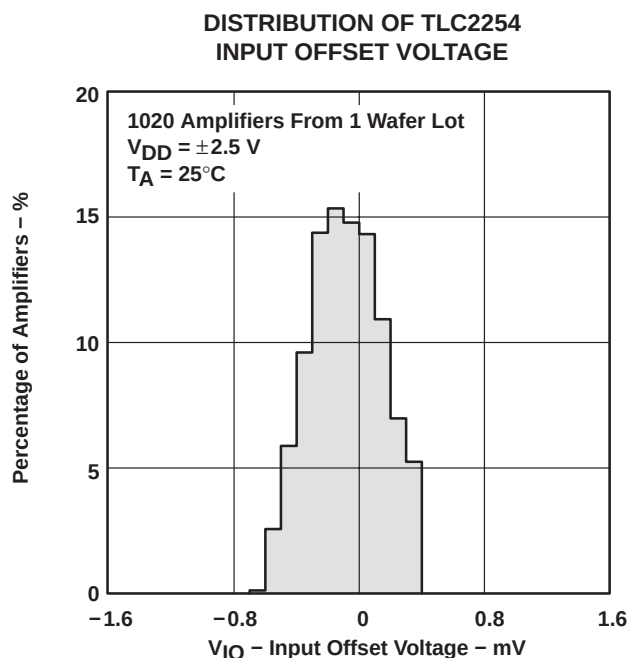


Figure 4

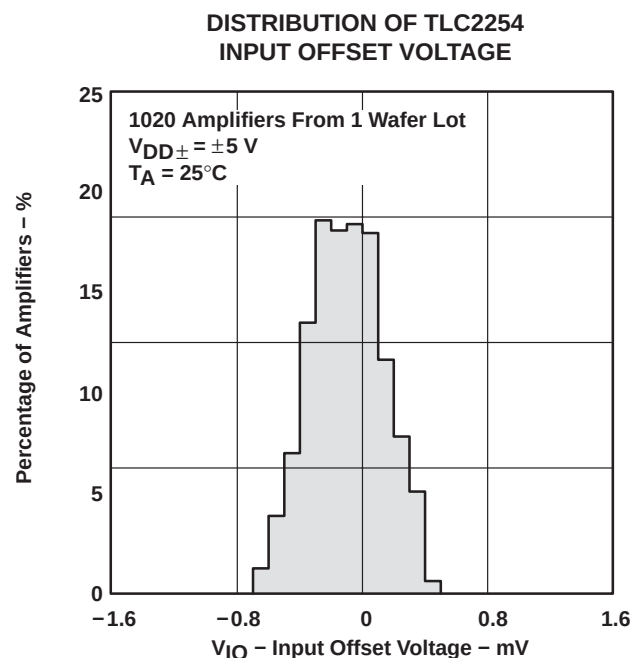


Figure 5

TYPICAL CHARACTERISTICS

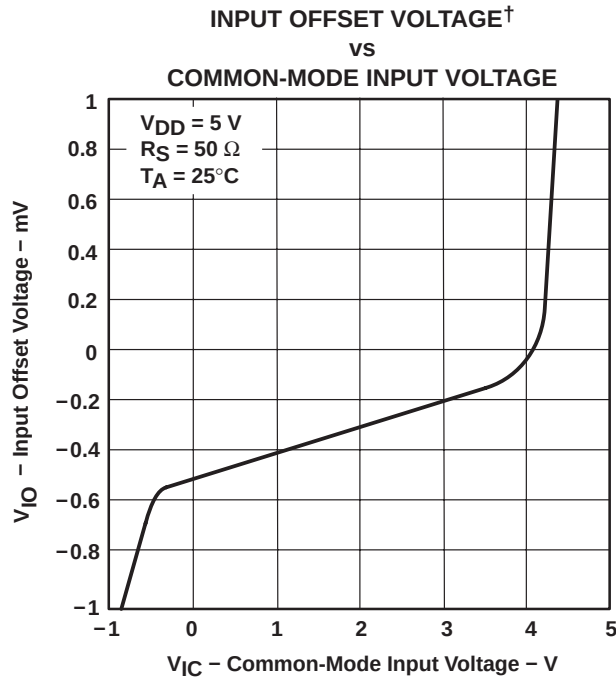


Figure 6

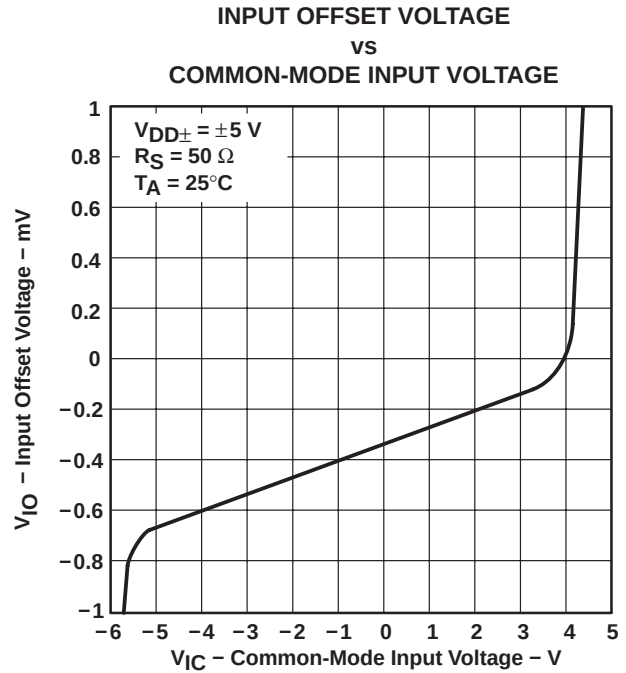


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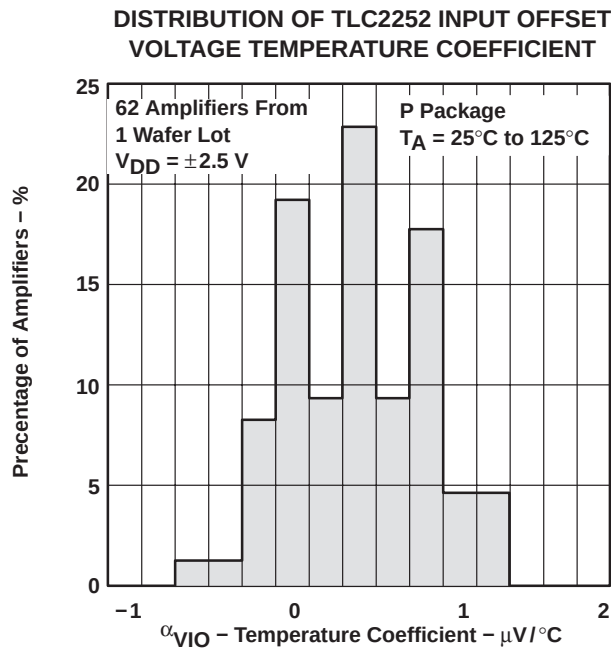


Figure 8

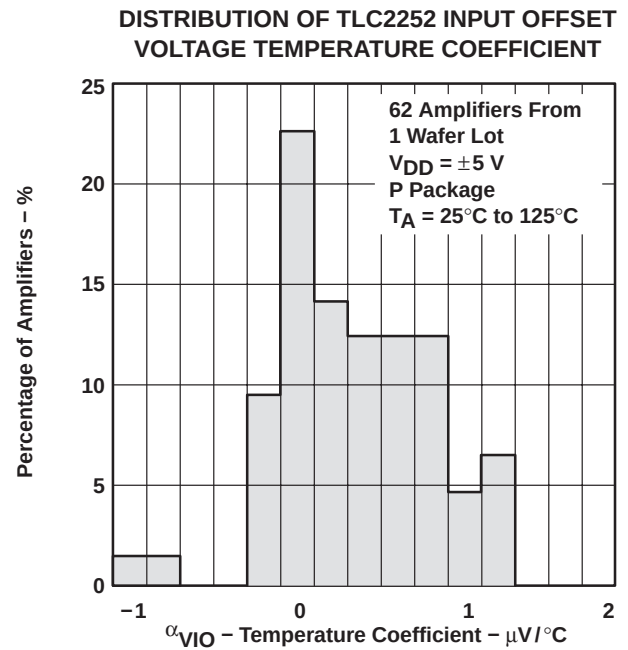


Figure 9

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

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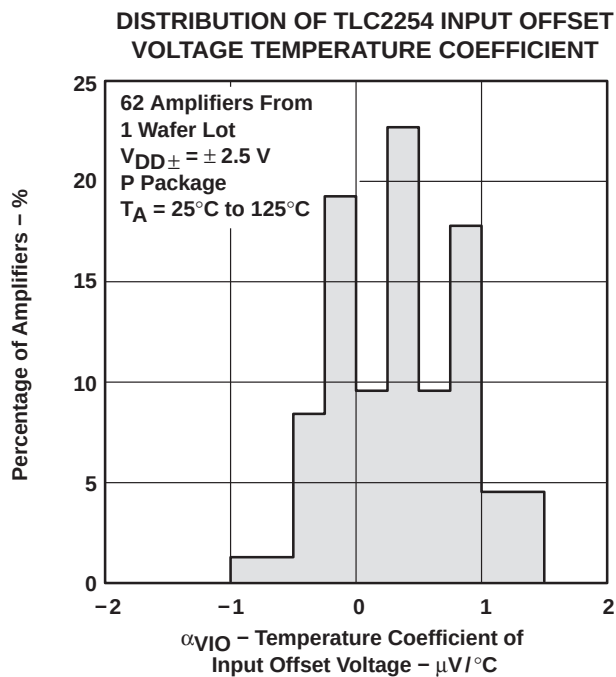


Figure 10

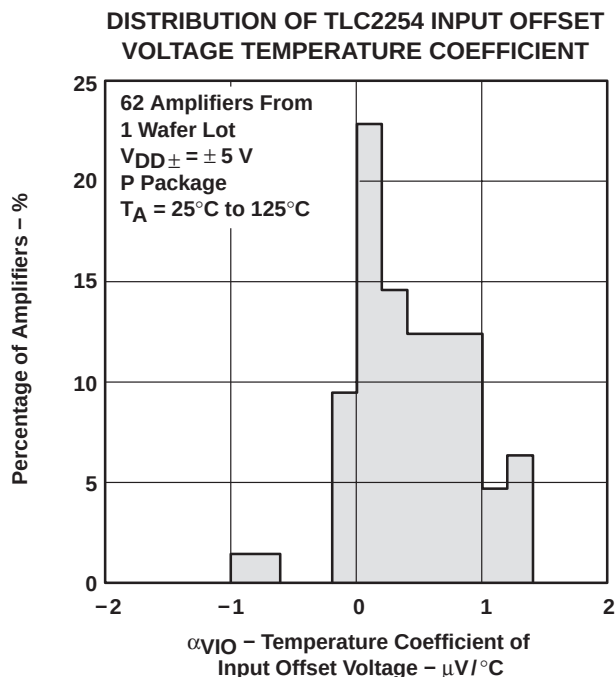


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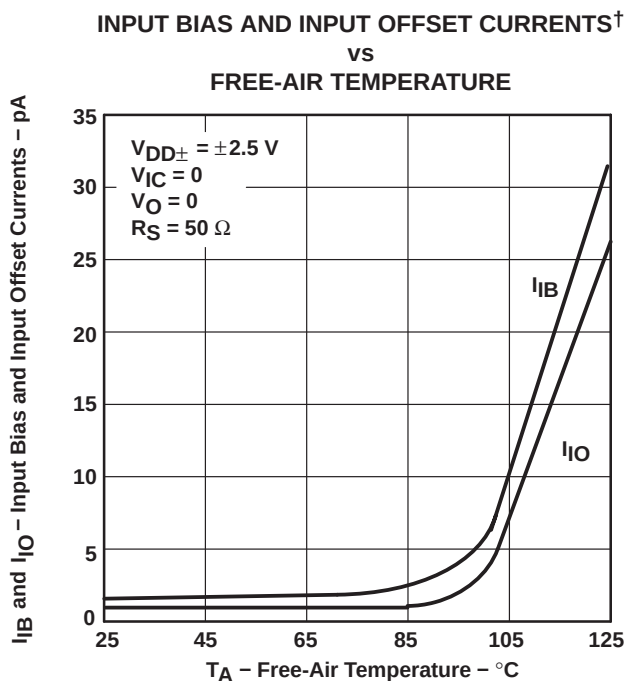


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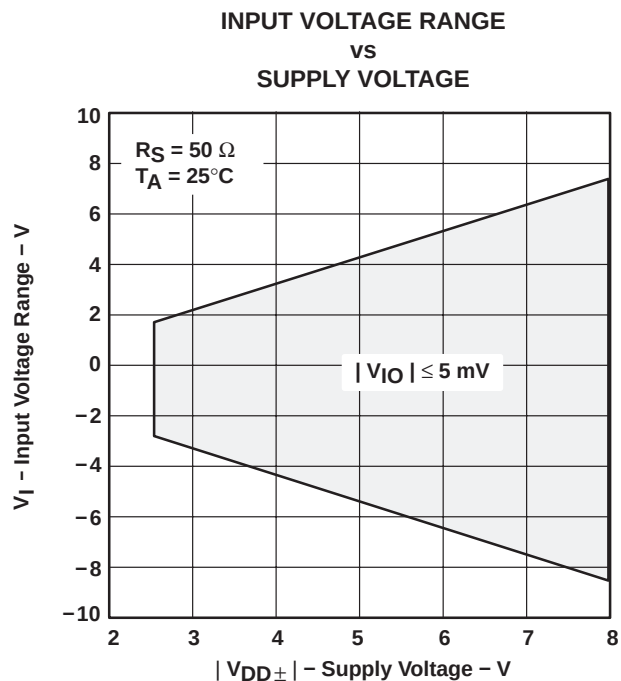
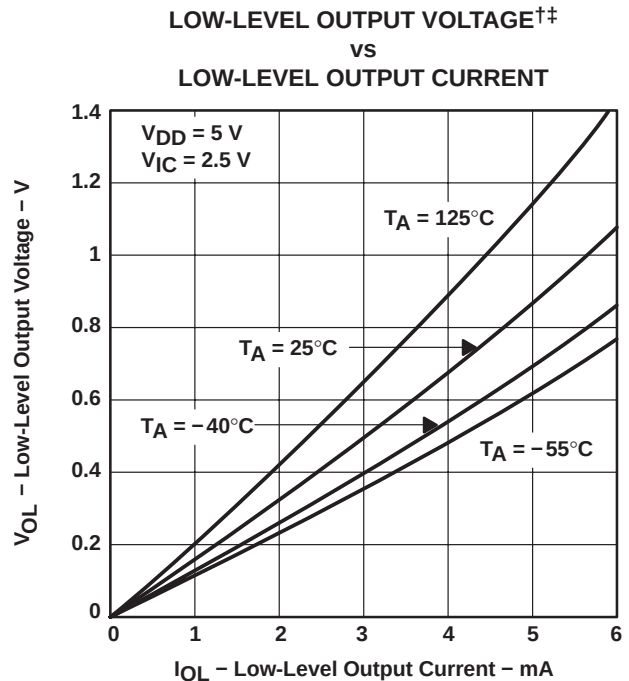
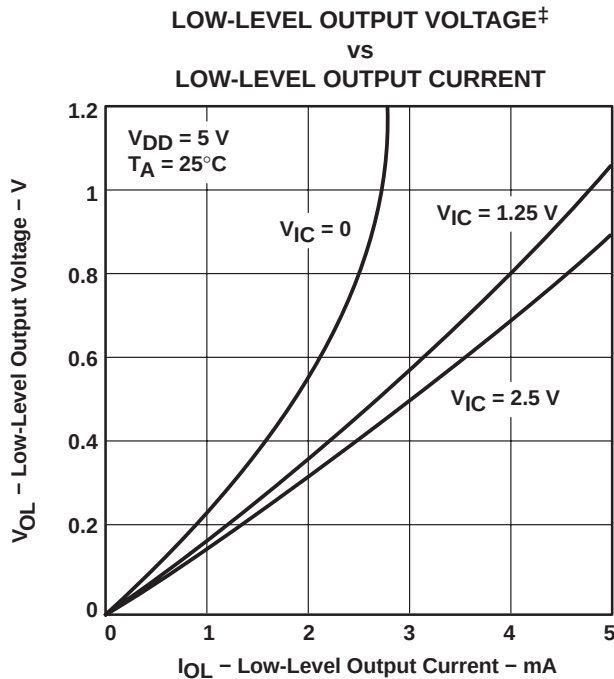
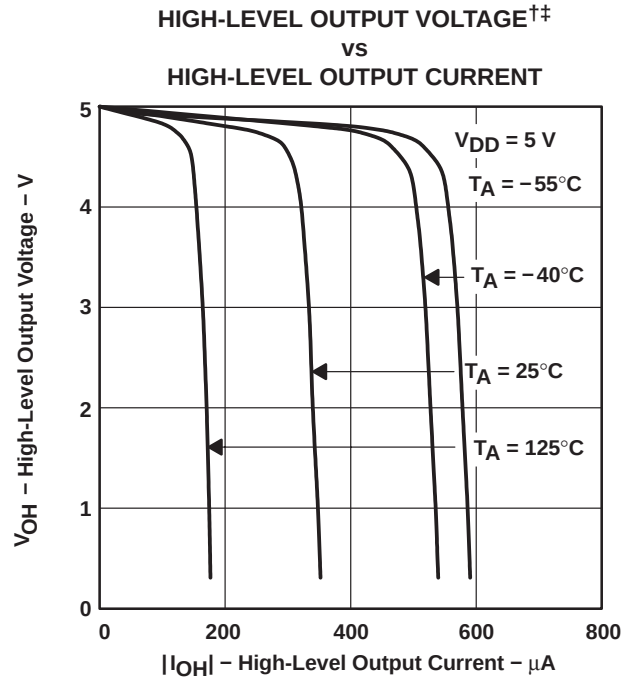
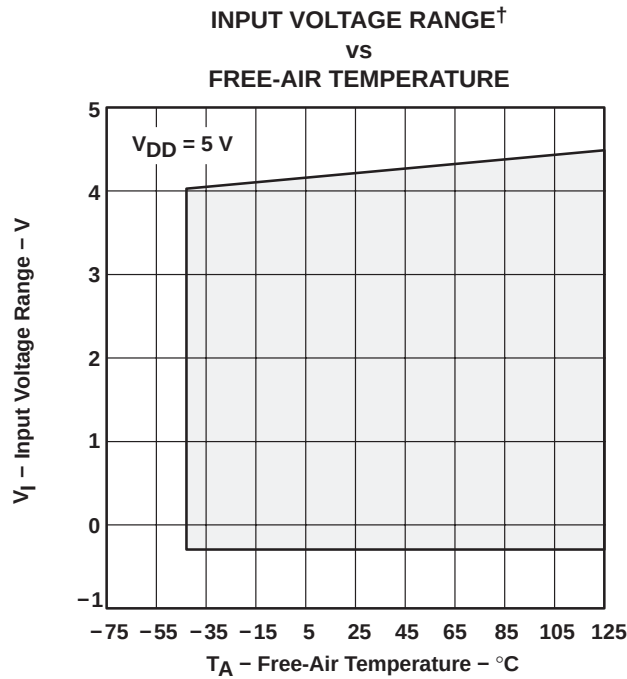


Figure 13

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

TYPICAL CHARACTERISTICS



[†] 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

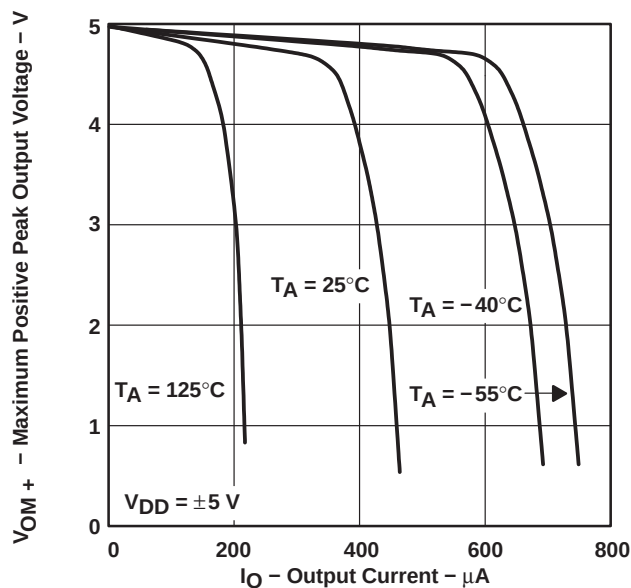


Figure 18

MAXIMUM NEGATIVE PEAK OUTPUT VOLTAGE[†]
VS
OUTPUT CURRENT

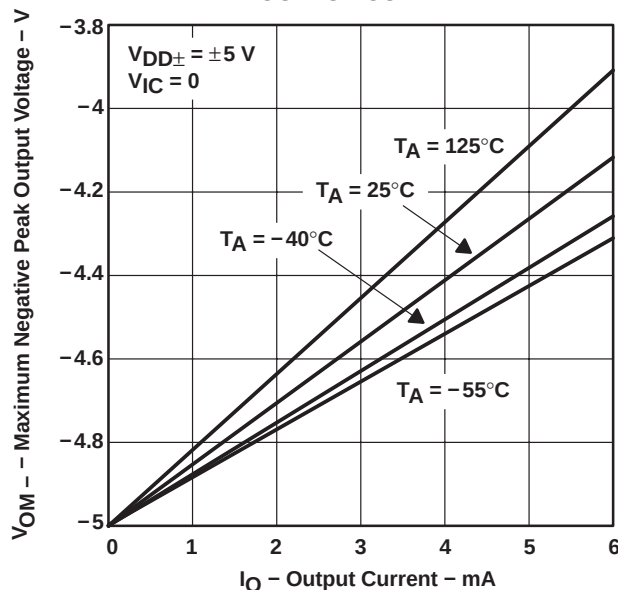


Figure 19

MAXIMUM PEAK-TO-PEAK OUTPUT VOLTAGE[‡]
VS
FREQUENCY

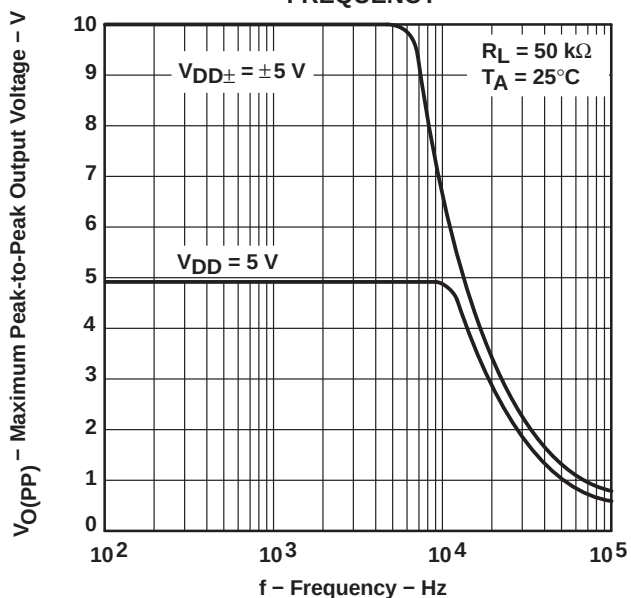


Figure 20

SHORT-CIRCUIT OUTPUT CURRENT
VS
SUPPLY VOLTAGE

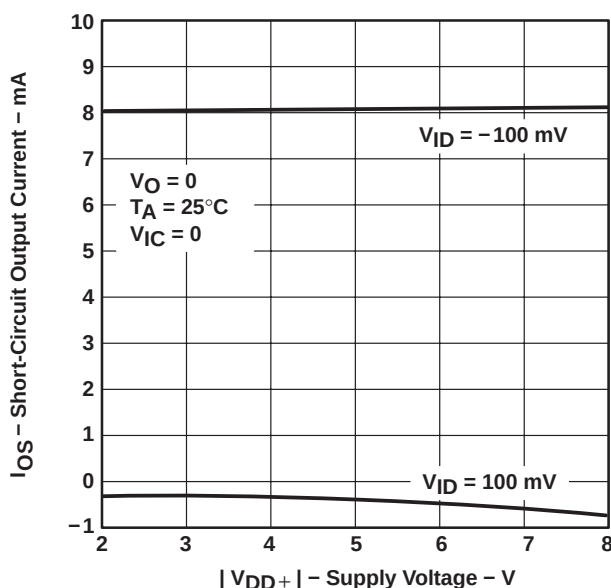
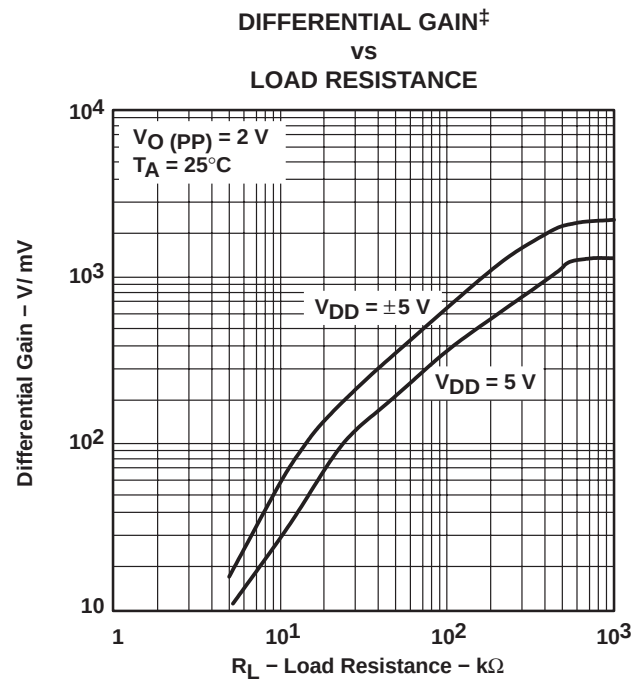
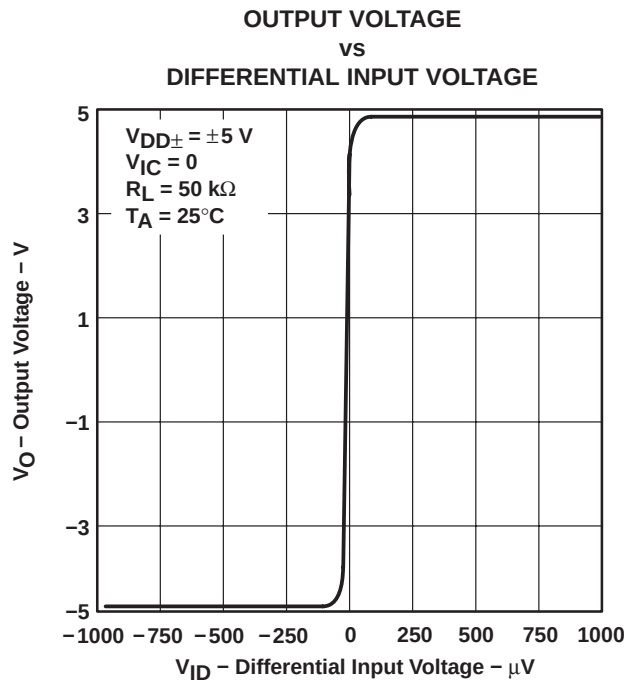
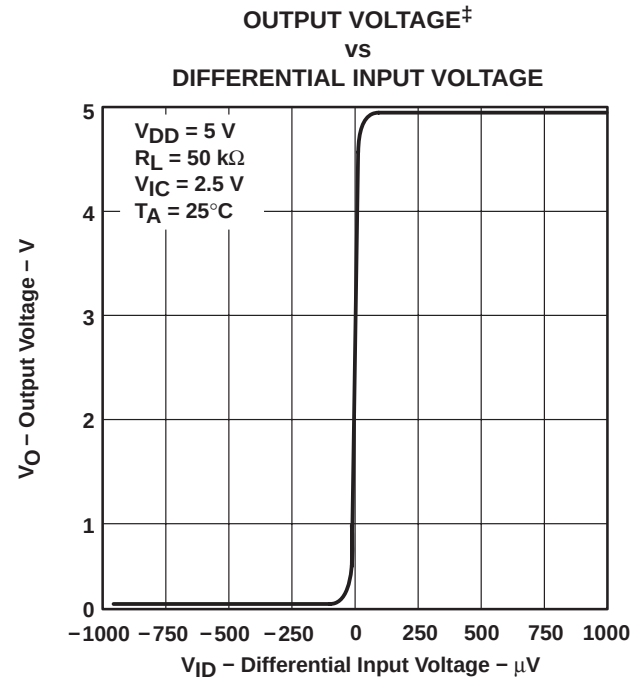
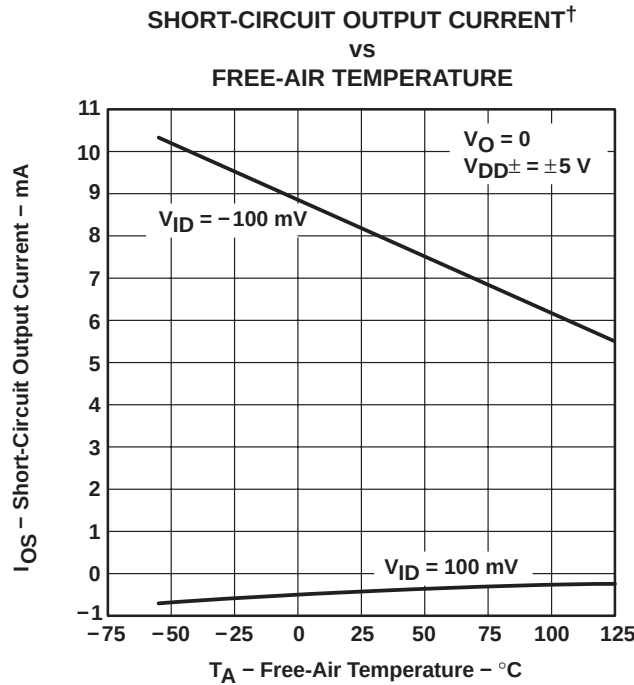


Figure 21

[†] 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.

TYPICAL CHARACTERISTICS



† 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

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

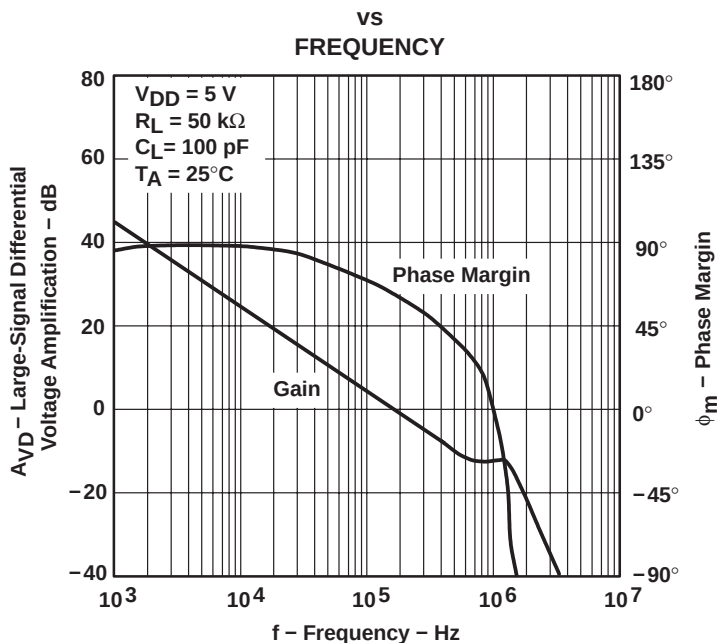


Figure 26

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

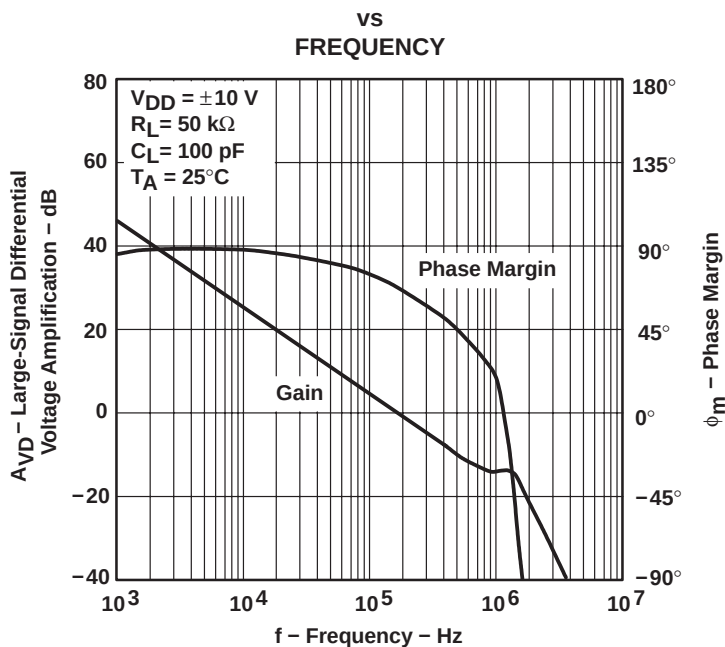
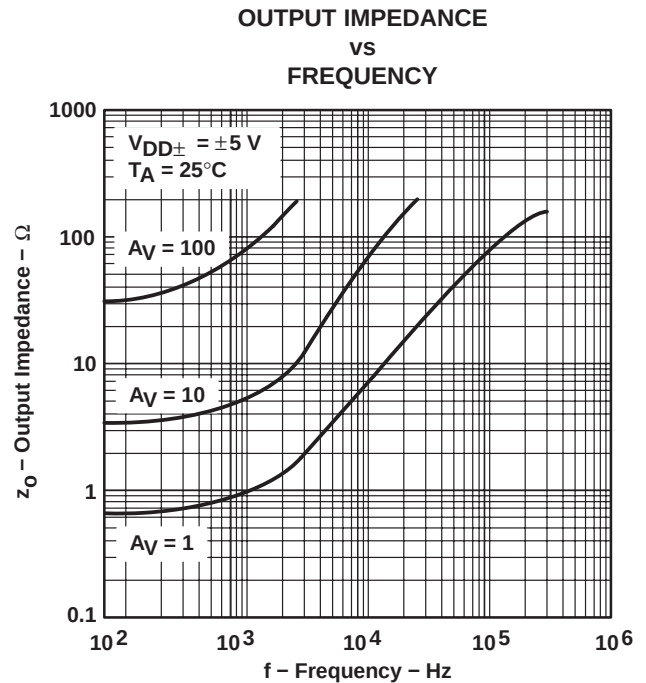
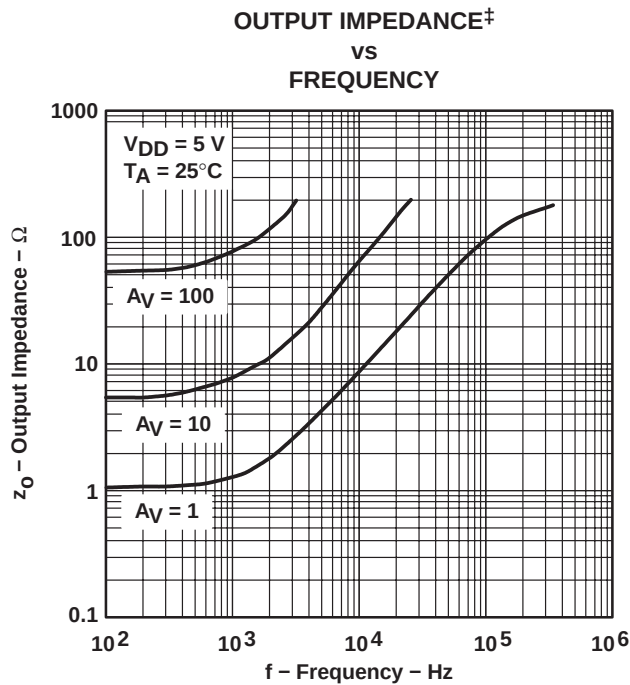
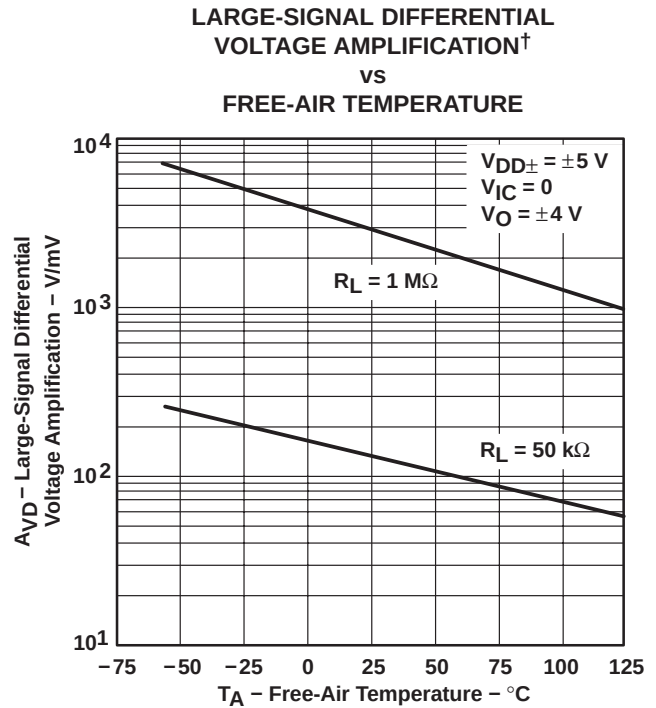
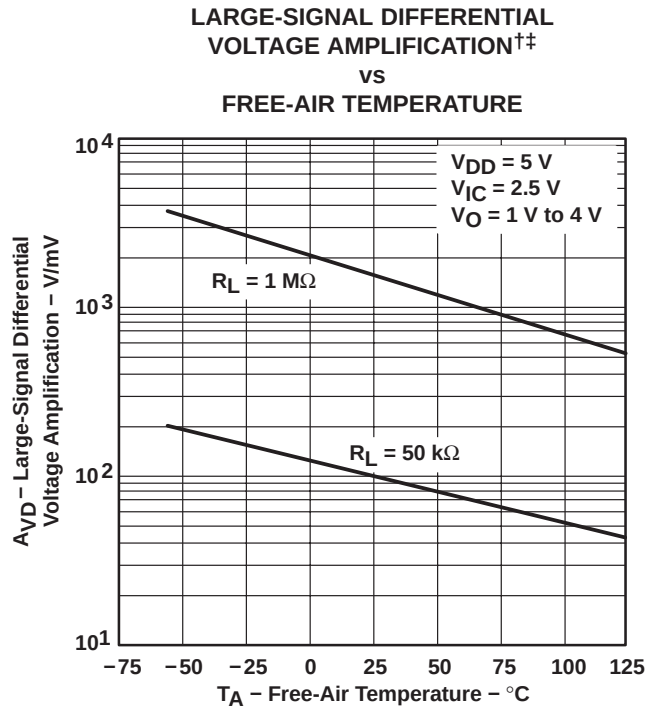


Figure 27

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

TYPICAL CHARACTERISTICS



† 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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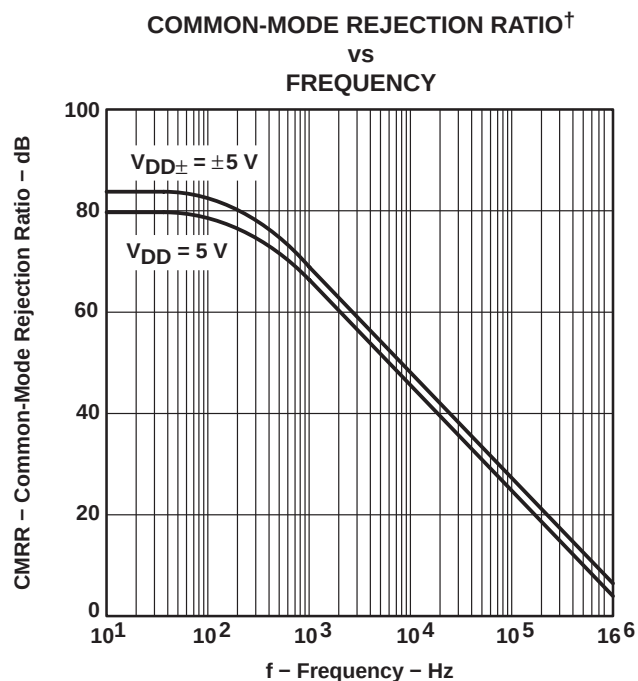


Figure 32

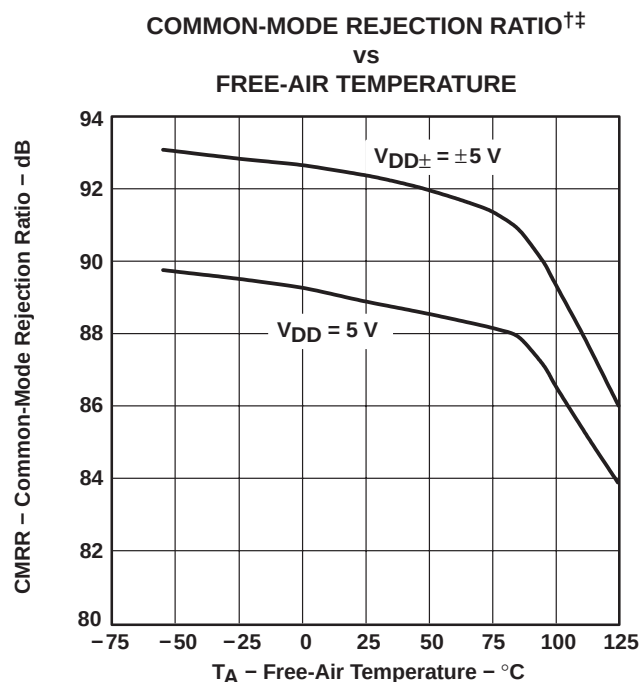


Figure 33

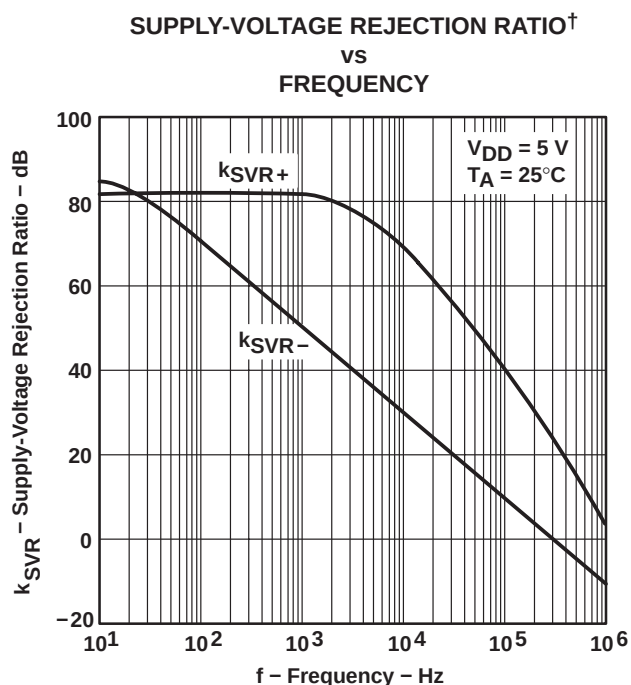


Figure 34

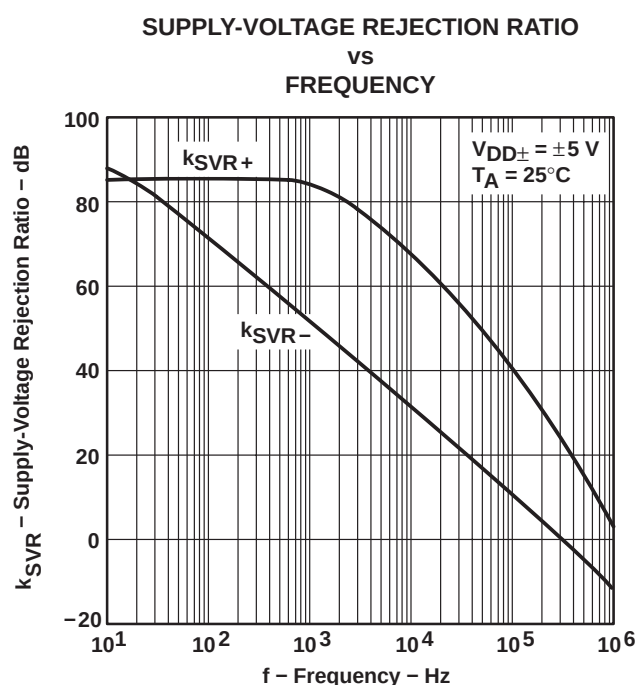


Figure 35

† 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

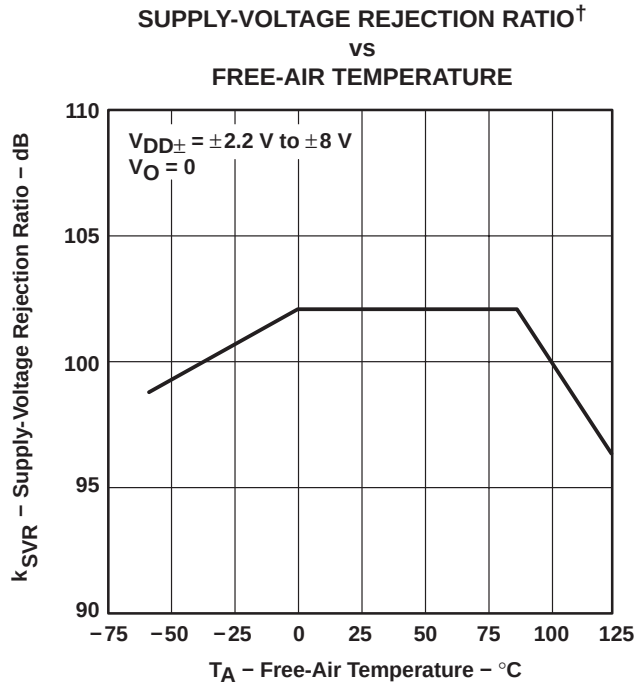


Figure 36

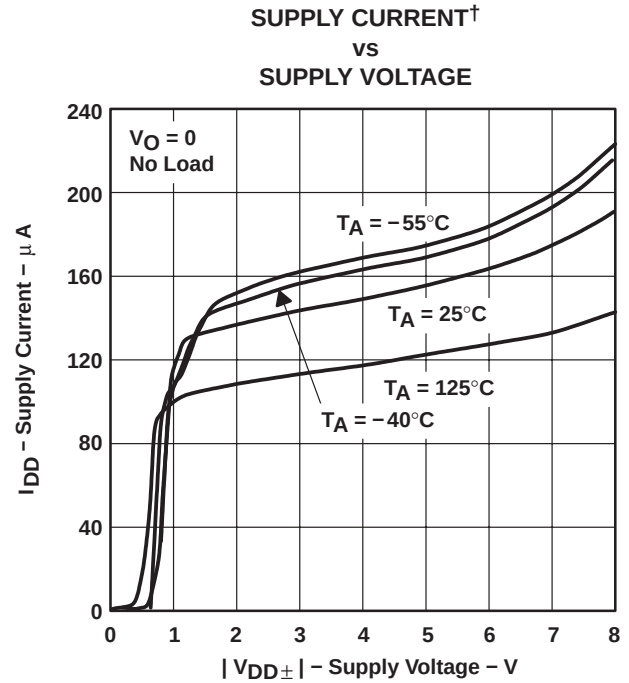


Figure 37

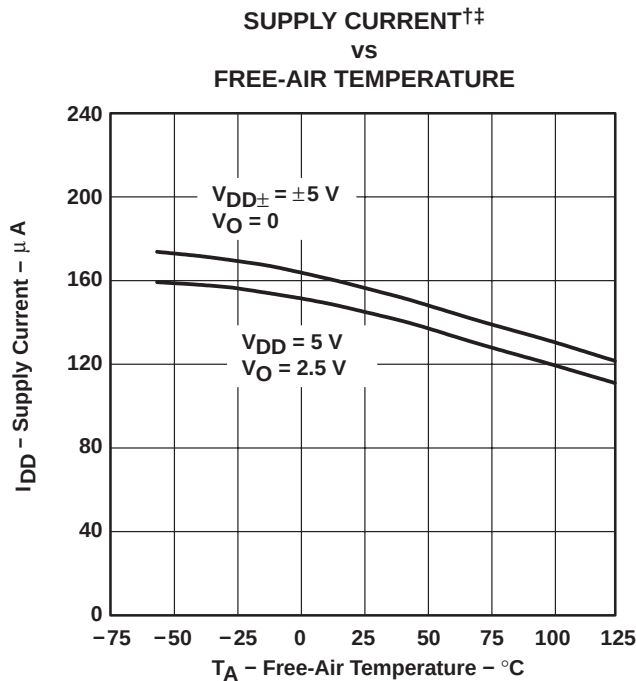


Figure 38

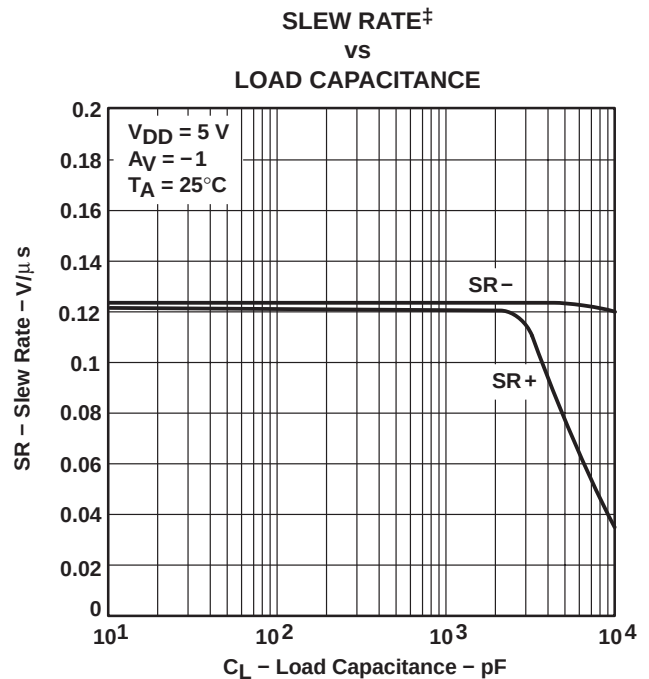


Figure 39

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

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

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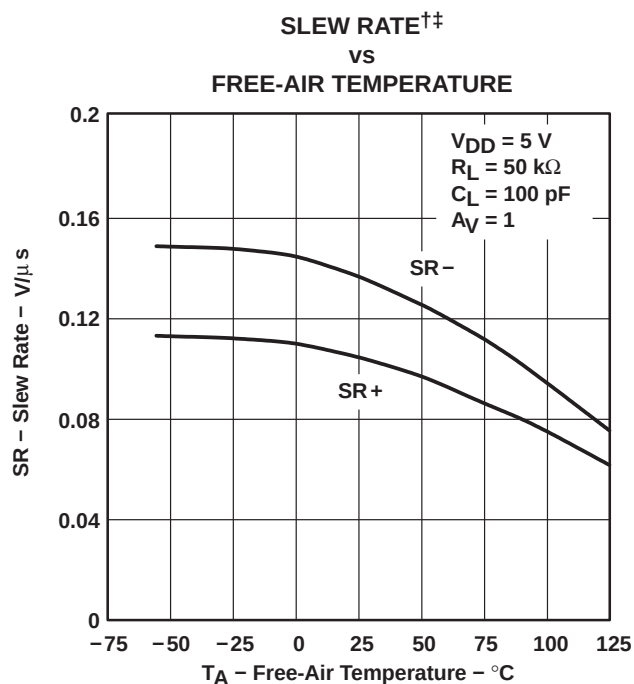


Figure 40

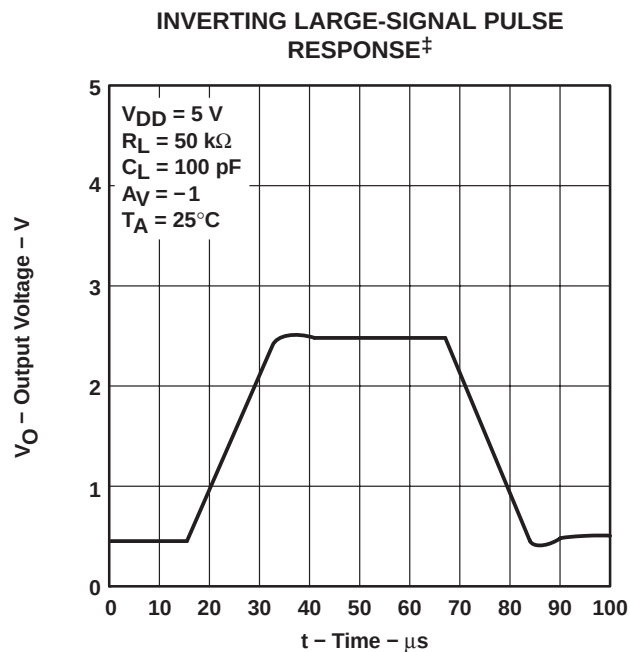


Figure 41

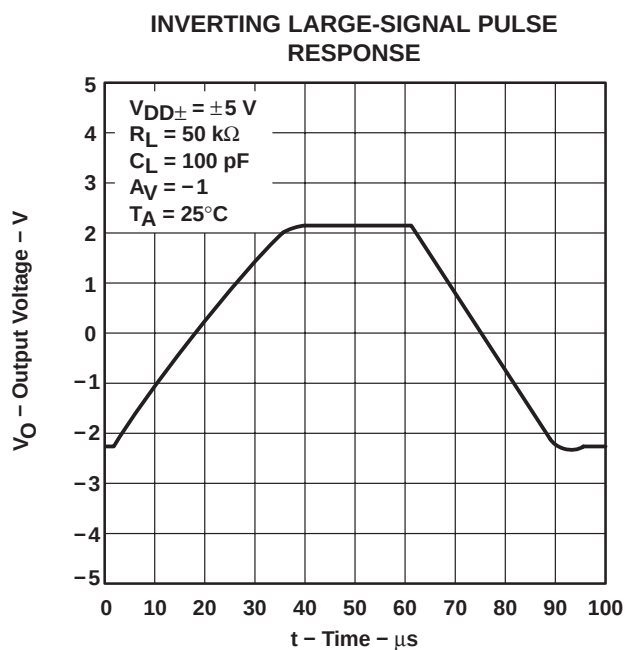


Figure 42

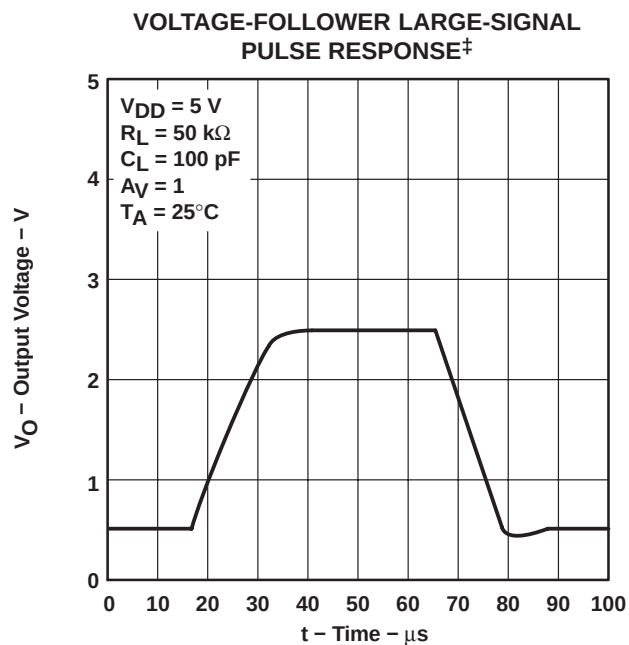


Figure 43

[†] 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.

TYPICAL CHARACTERISTICS

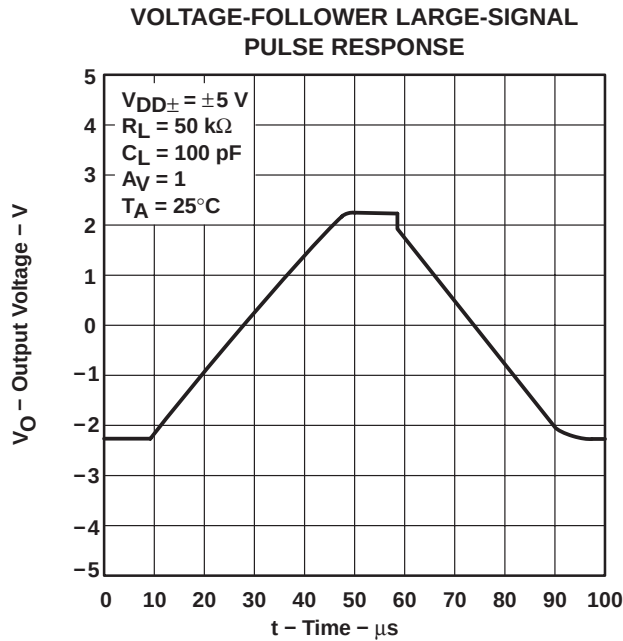


Figure 44

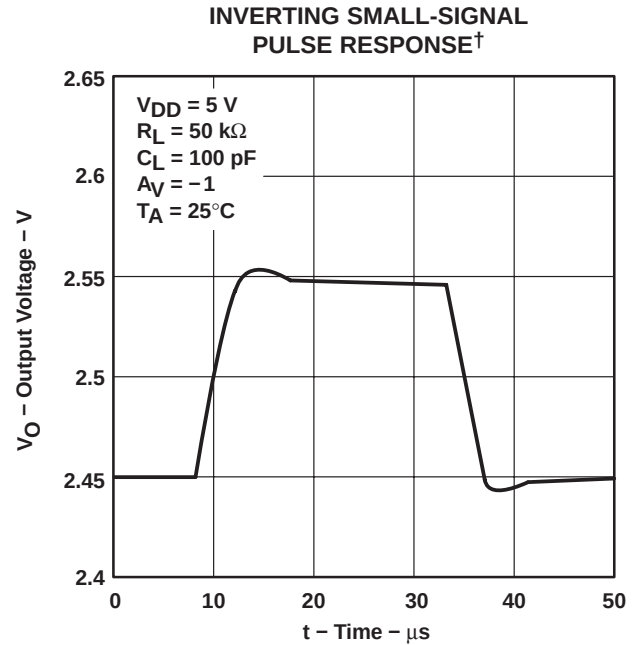


Figure 45

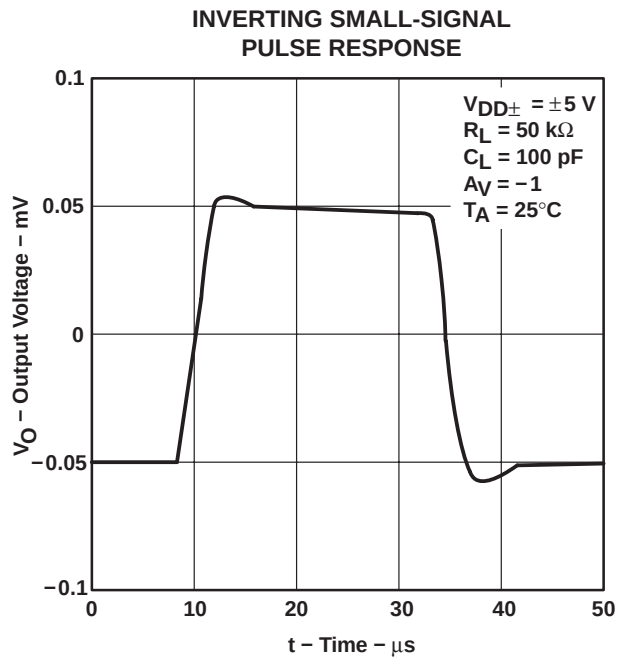


Figure 46

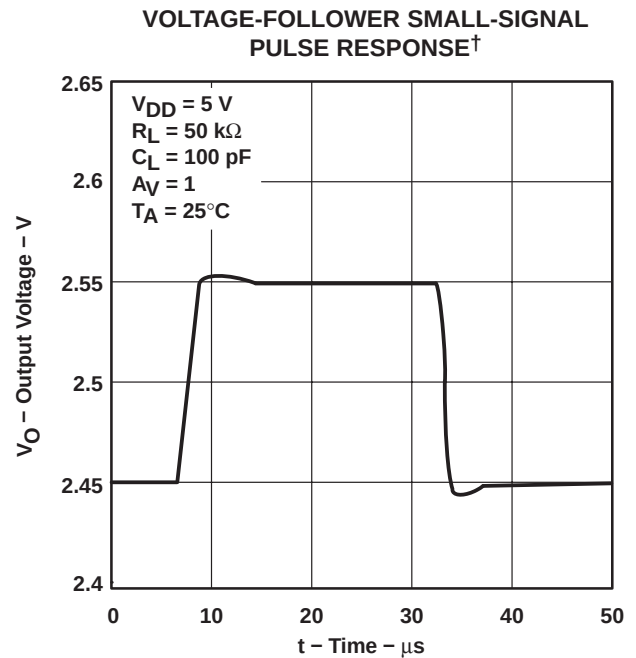


Figure 47

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

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TYPICAL CHARACTERISTICS

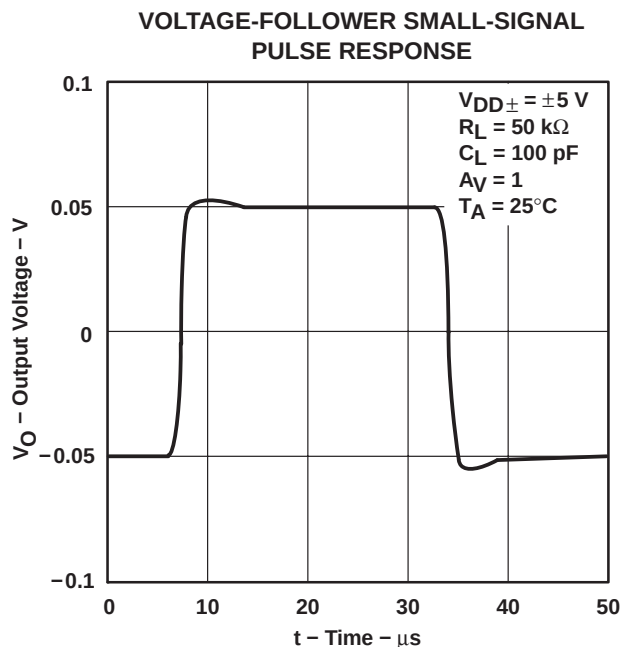


Figure 48

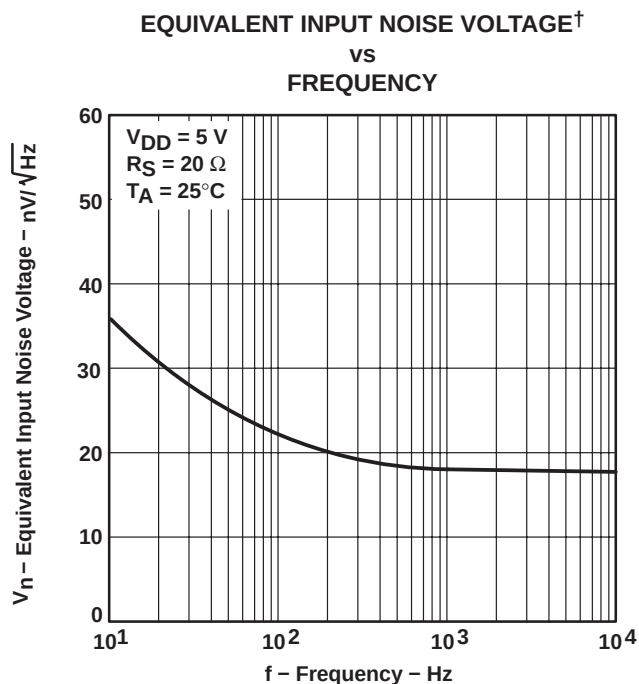


Figure 49

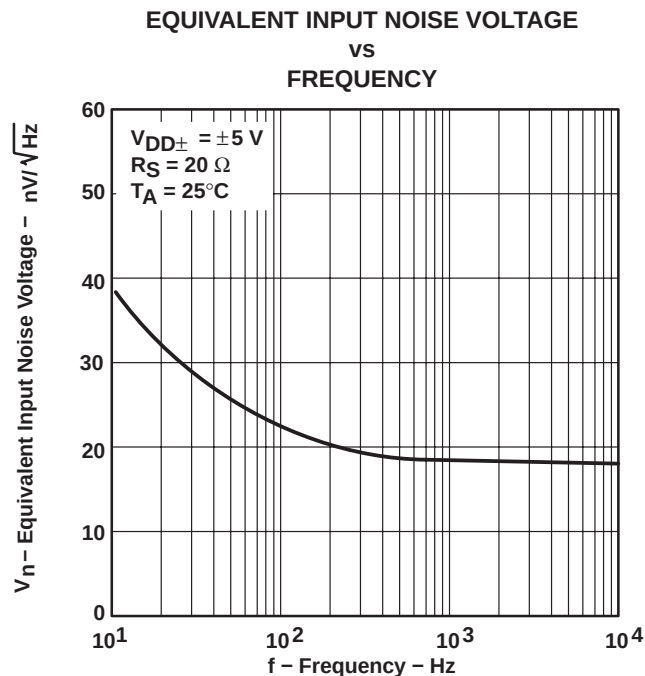


Figure 50

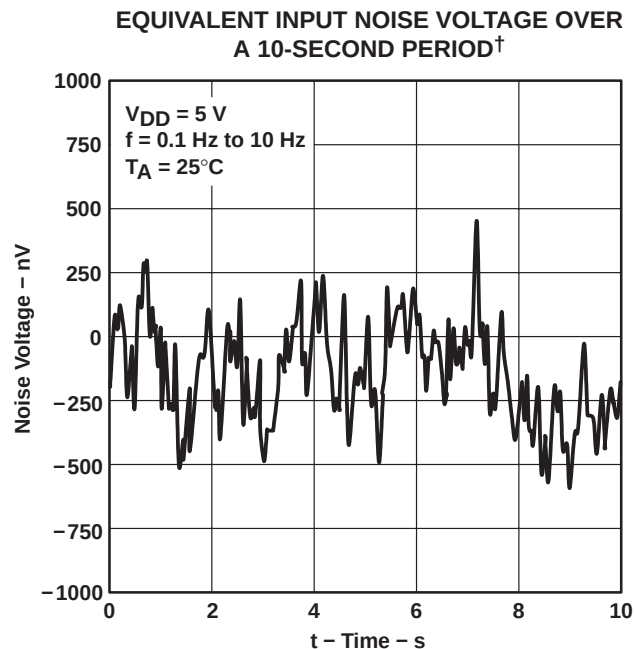


Figure 51

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

TYPICAL CHARACTERISTICS

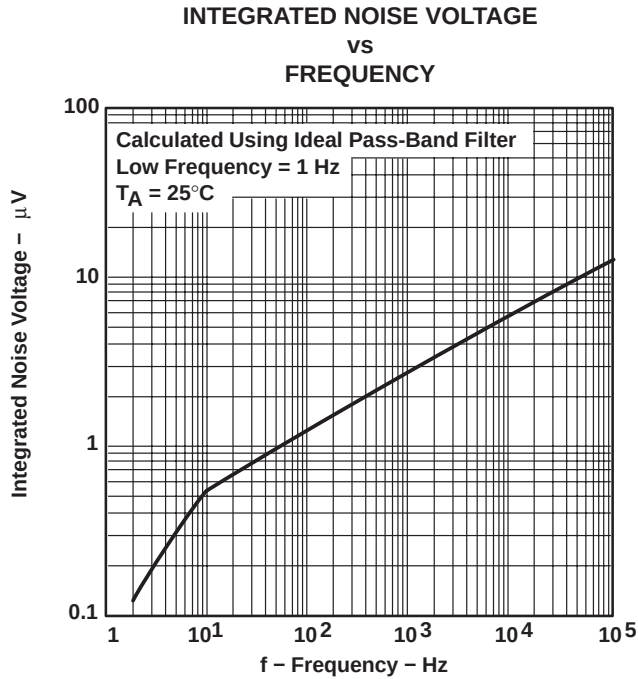


Figure 52

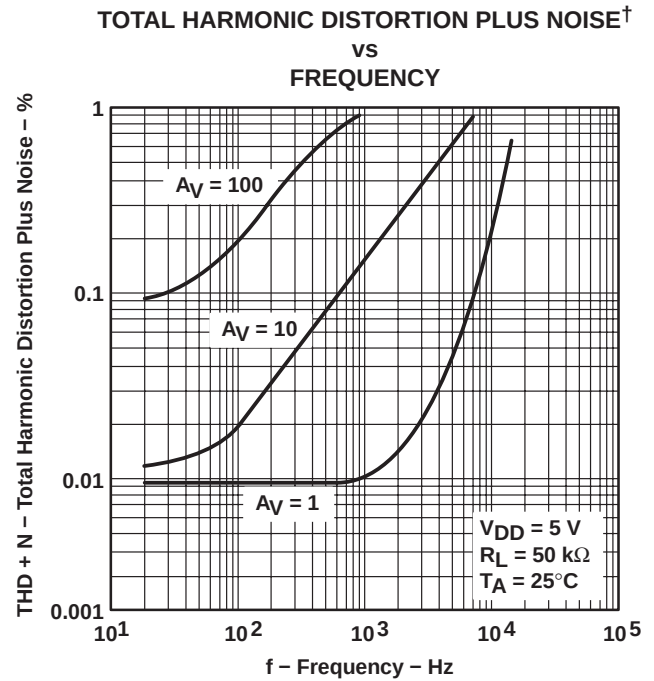


Figure 53

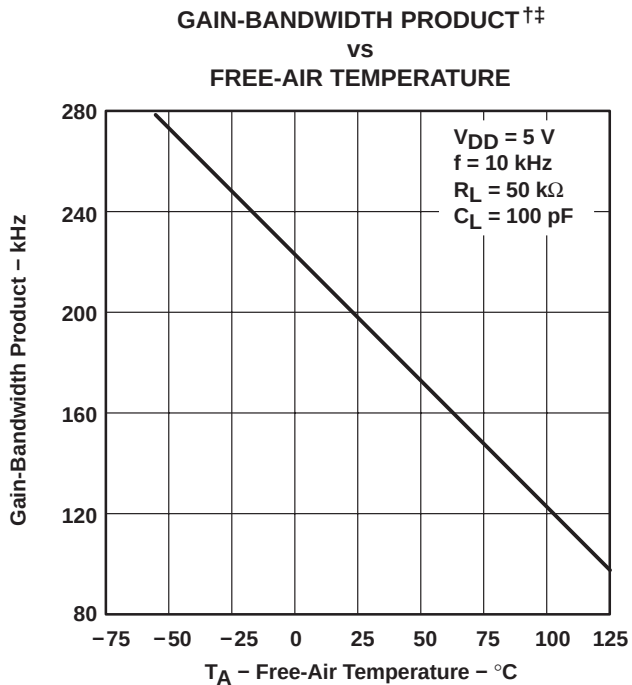


Figure 54

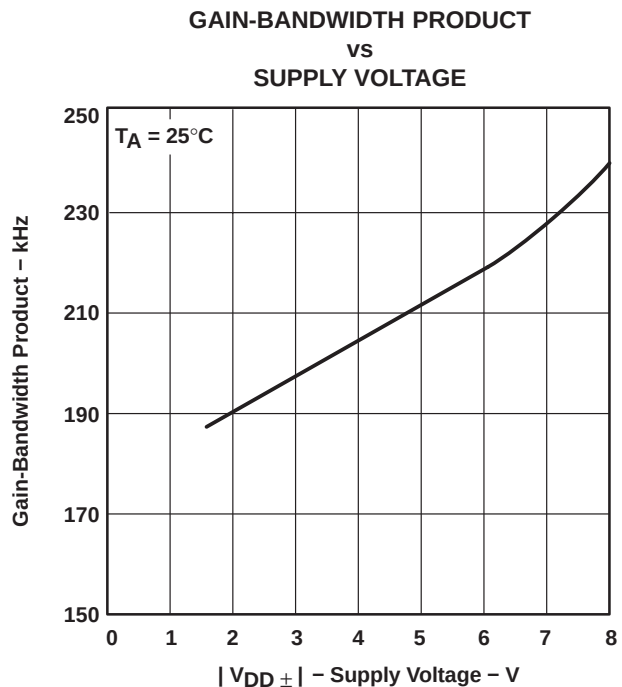


Figure 55

† 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.

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TYPICAL CHARACTERISTICS

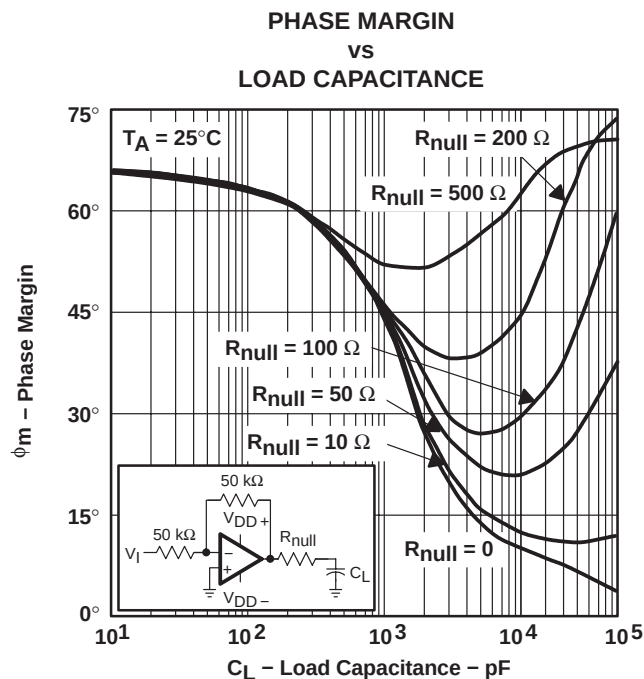


Figure 56

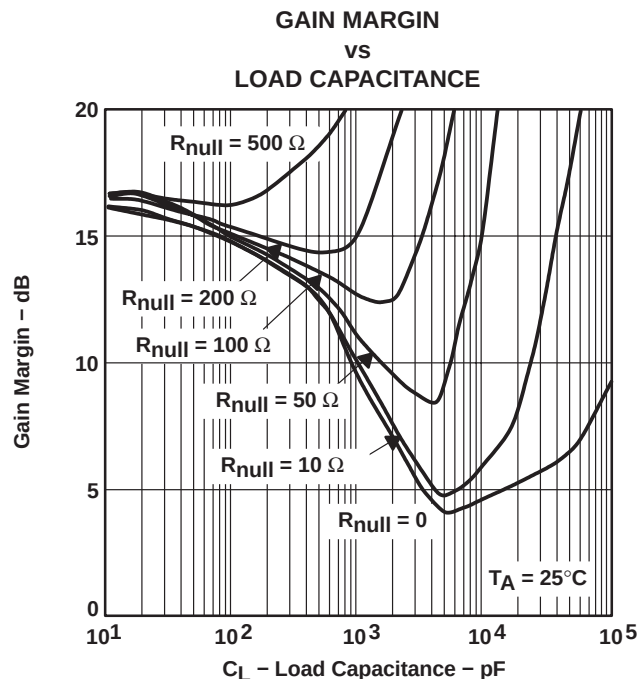


Figure 57

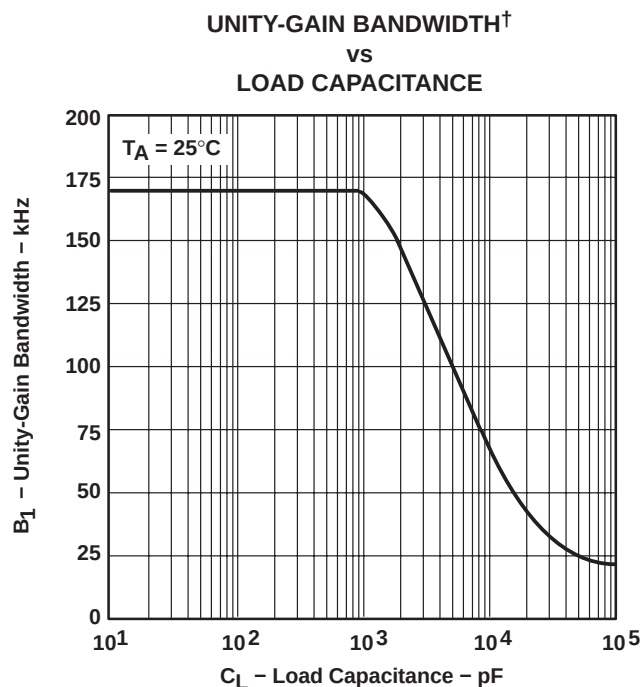


Figure 58

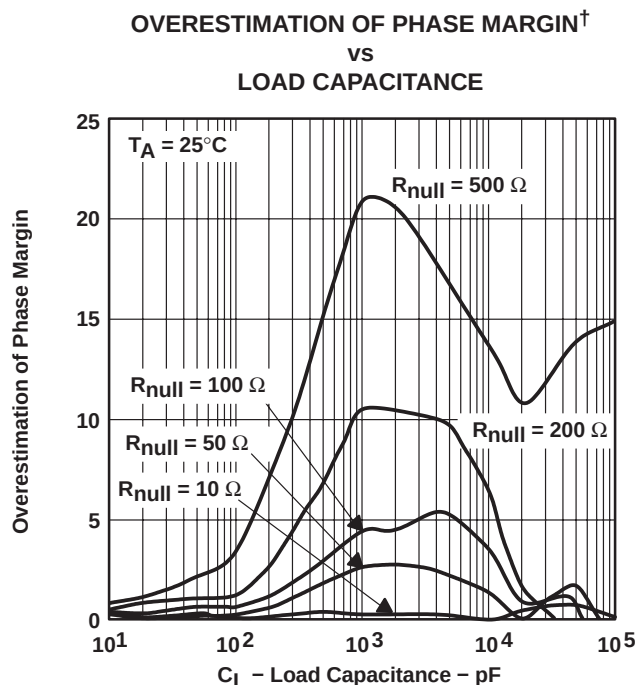


Figure 59

† 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.

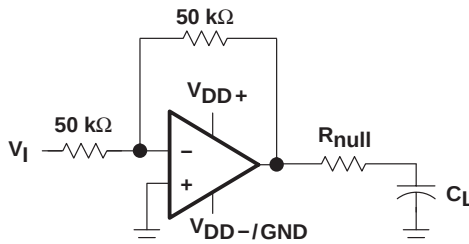


Figure 60. Series-Resistance Circuit

TLC225x-EP, TLC225xA-EP

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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).

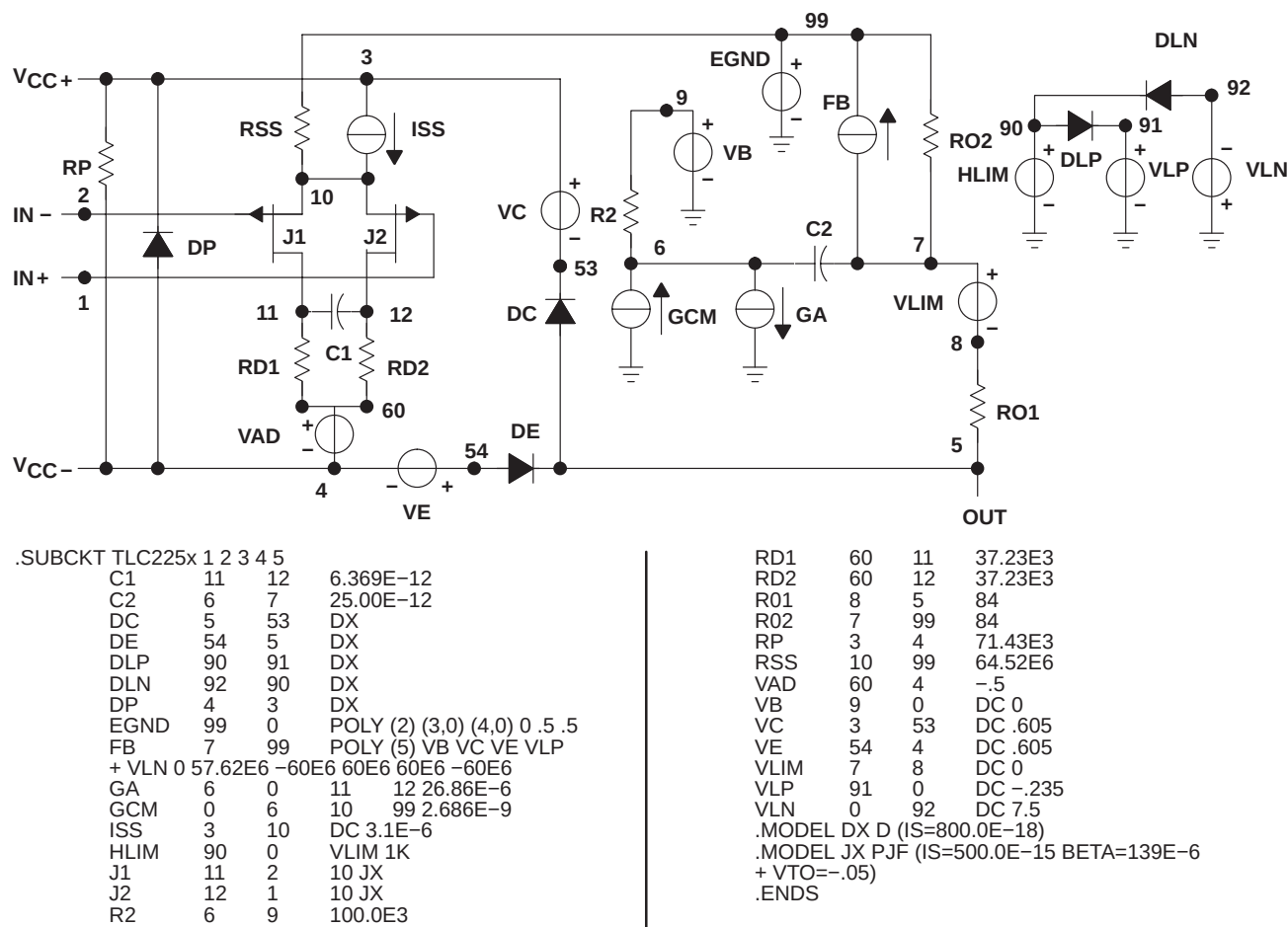


Figure 61. Boyle Macromodel and Subcircuit

PSPice and Parts are trademarks of MicroSim Corporation.



POST OFFICE BOX 655303 • DALLAS, TEXAS 75265

PACKAGING INFORMATION

Orderable part number	Status (1)	Material type (2)	Package Pins	Package qty Carrier	RoHS (3)	Lead finish/ Ball material (4)	MSL rating/ Peak reflow (5)	Op temp (°C)	Part marking (6)
TLC2252AQDREP	Active	Production	SOIC (D) 8	2500 LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	2252AE
TLC2254AQDREP	Active	Production	SOIC (D) 14	2500 LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	TLC2254AEP

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

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

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

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

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

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

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

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

OTHER QUALIFIED VERSIONS OF TLC2252A-EP, TLC2254A-EP :

- Catalog : [TLC2252A](#), [TLC2254A](#)

- Automotive : [TLC2252A-Q1](#), [TLC2254A-Q1](#)
- Military : [TLC2252AM](#), [TLC2254AM](#)

NOTE: Qualified Version Definitions:

- Catalog - TI's standard catalog product
- Automotive - Q100 devices qualified for high-reliability automotive applications targeting zero defects
- Military - QML certified for Military and Defense Applications

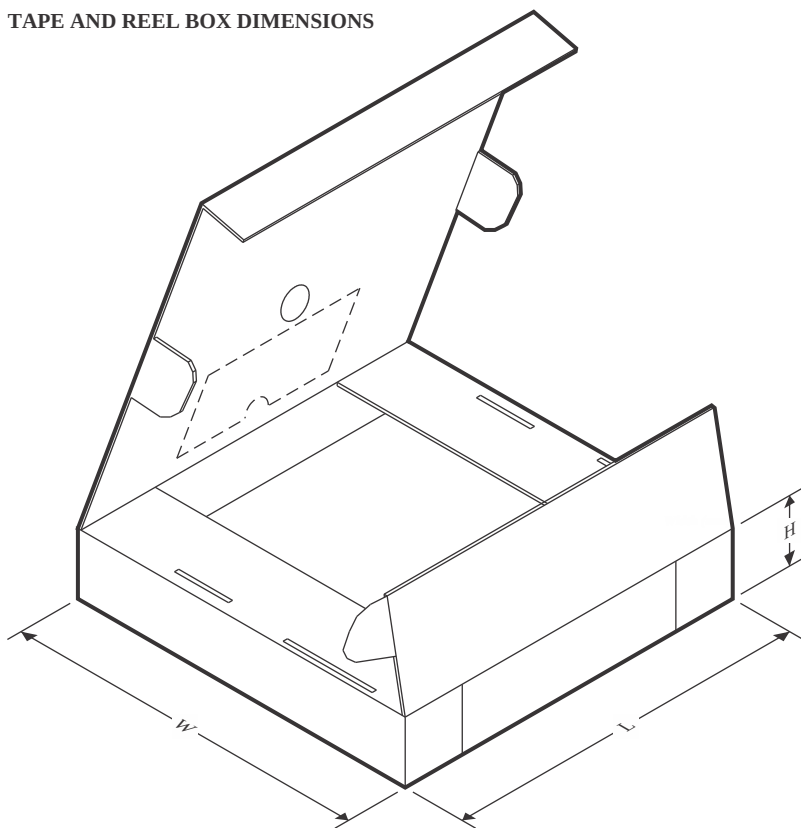
TAPE AND REEL INFORMATION



*All dimensions are nominal

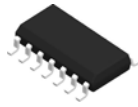
Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
TLC2252AQDREP	SOIC	D	8	2500	330.0	12.4	6.4	5.2	2.1	8.0	12.0	Q1
TLC2254AQDREP	SOIC	D	14	2500	330.0	16.4	6.5	9.0	2.1	8.0	16.0	Q1

TAPE AND REEL BOX DIMENSIONS

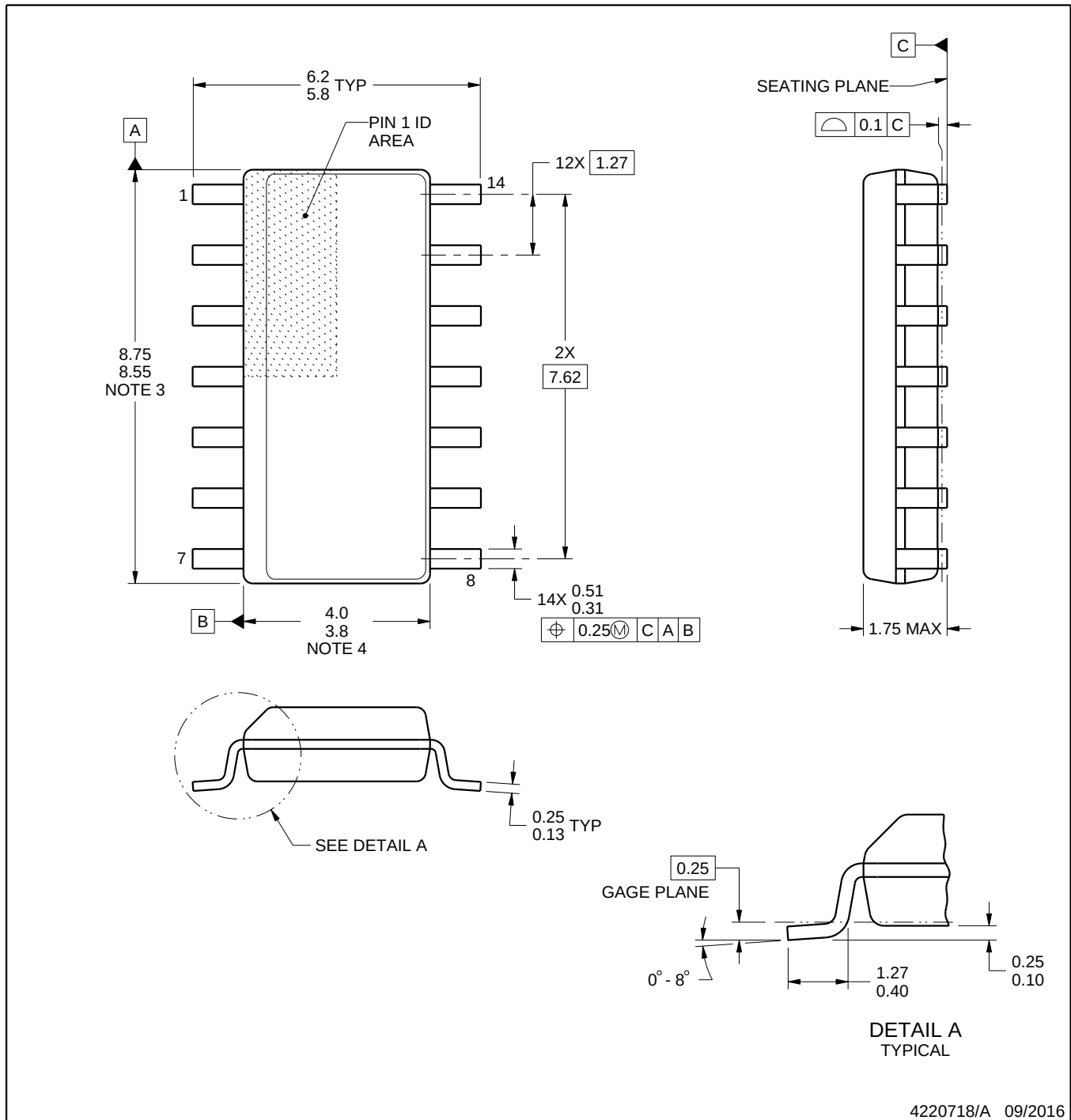


*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
TLC2252AQDREP	SOIC	D	8	2500	340.5	338.1	20.6
TLC2254AQDREP	SOIC	D	14	2500	340.5	336.1	32.0

D0014A**PACKAGE OUTLINE****SOIC - 1.75 mm max height**

SMALL OUTLINE INTEGRATED CIRCUIT

**NOTES:**

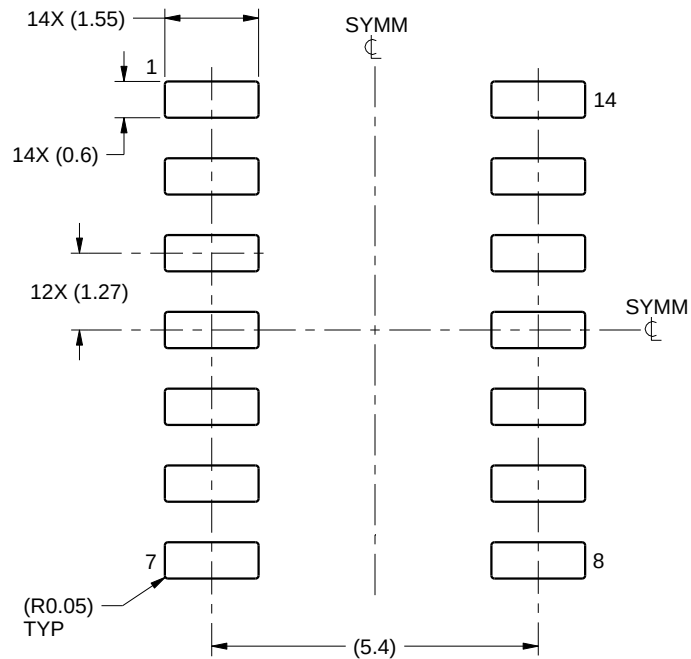
1. All linear dimensions are in millimeters. Dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.15 mm, per side.
4. This dimension does not include interlead flash. Interlead flash shall not exceed 0.43 mm, per side.
5. Reference JEDEC registration MS-012, variation AB.

EXAMPLE BOARD LAYOUT

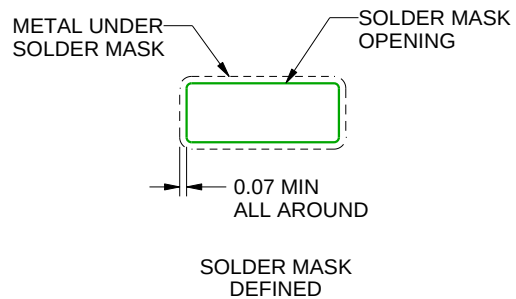
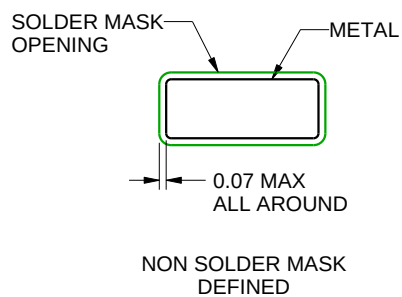
D0014A

SOIC - 1.75 mm max height

SMALL OUTLINE INTEGRATED CIRCUIT



LAND PATTERN EXAMPLE
SCALE:8X



SOLDER MASK DETAILS

4220718/A 09/2016

NOTES: (continued)

6. Publication IPC-7351 may have alternate designs.

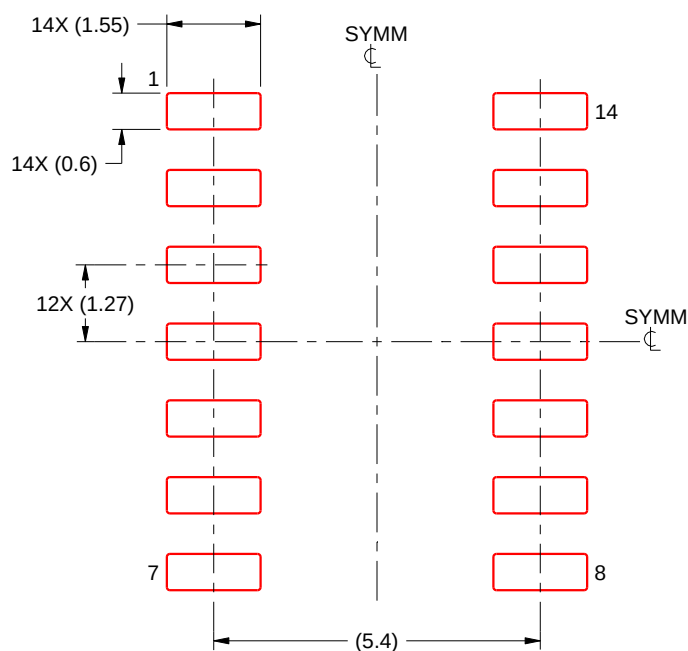
7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.

EXAMPLE STENCIL DESIGN

D0014A

SOIC - 1.75 mm max height

SMALL OUTLINE INTEGRATED CIRCUIT



SOLDER PASTE EXAMPLE
BASED ON 0.125 mm THICK STENCIL
SCALE:8X

4220718/A 09/2016

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.



PACKAGE OUTLINE

SOIC - 1.75 mm max height

SMALL OUTLINE INTEGRATED CIRCUIT



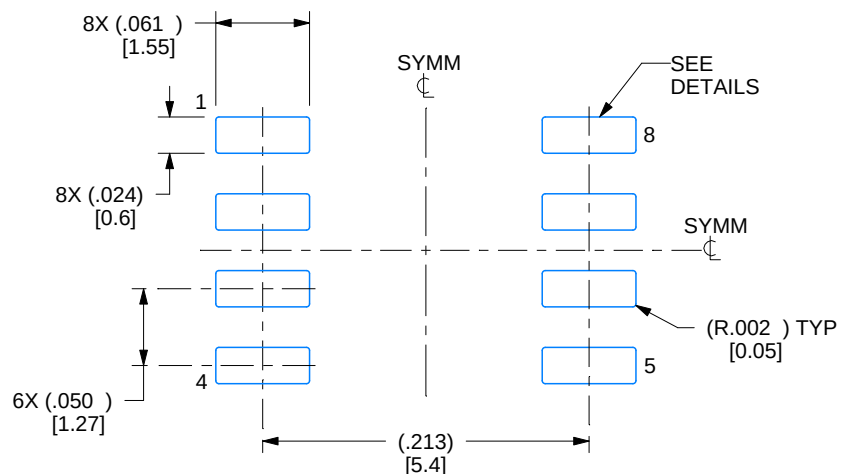
1. Linear dimensions are in inches [millimeters]. Dimensions in parenthesis are for reference only. Controlling dimensions are in inches. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This dimension does not include mold flash, protrusions, or gate 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

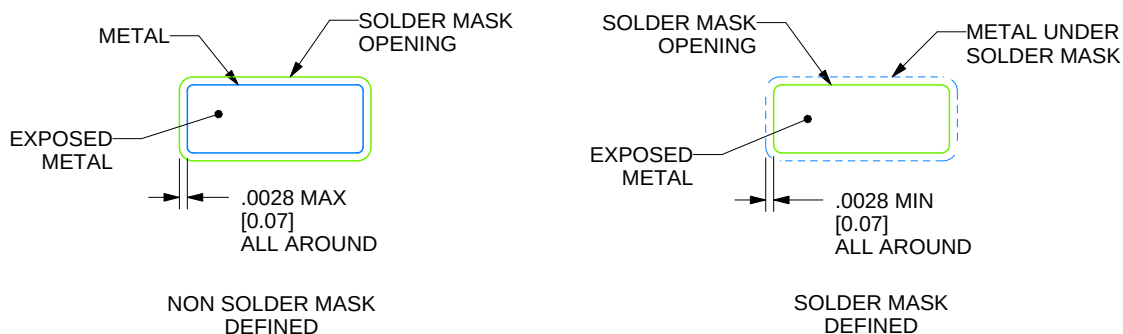
D0008A

SOIC - 1.75 mm max height

SMALL OUTLINE INTEGRATED CIRCUIT



LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE:8X



SOLDER MASK DETAILS

4214825/C 02/2019

NOTES: (continued)

6. Publication IPC-7351 may have alternate designs.

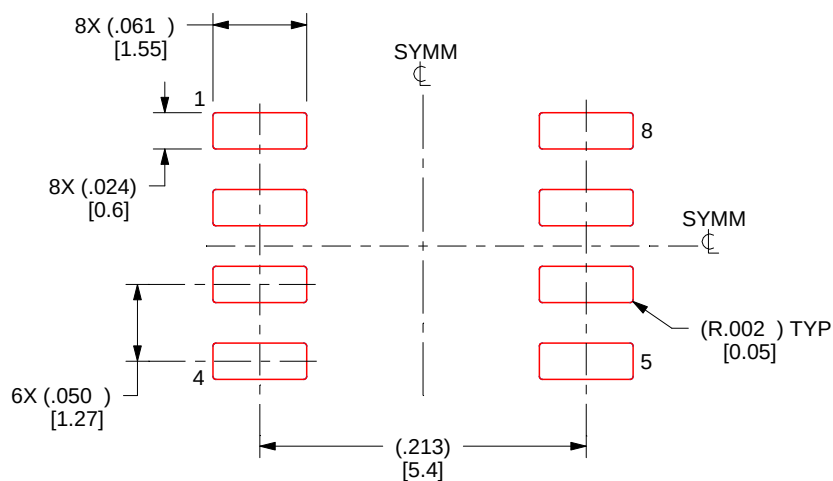
7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.

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.

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