

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 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**

† 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 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 1kHz; 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.

EQUIVALENT INPUT NOISE VOLTAGE
vs
FREQUENCY

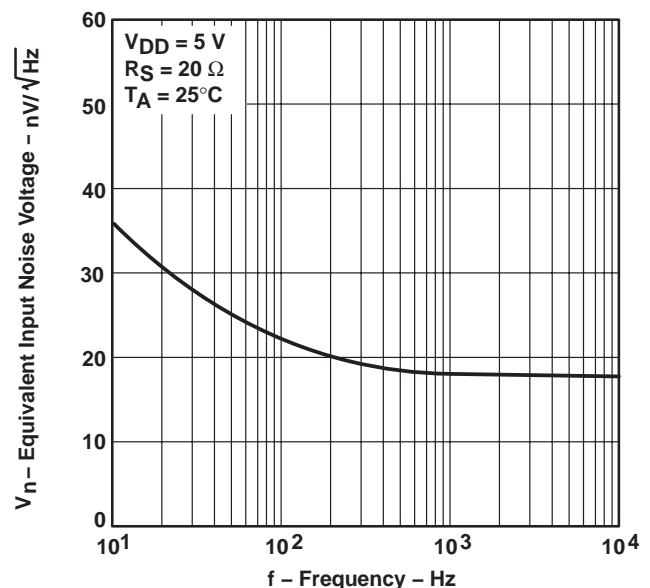


Figure 1



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.

Advanced LinCMOS is a trademark of Texas Instruments.

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.

 **TEXAS
INSTRUMENTS**

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TLC225x-EP, TLC225xA-EP

Advanced LinCMOS™ RAIL-TO-RAIL

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description/ordering information (continued)

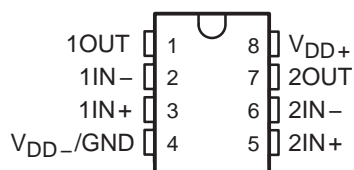
The TLC2252/4 also makes great upgrades to the TLC27L2/L4 or TS27L2/L4 in standard designs. They offer increased output dynamic range, lower noise voltage, and lower input offset voltage. This enhanced feature set allows them to be used in a wider range of applications. For applications that require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

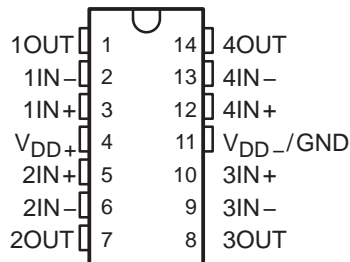
TA	V _{IO} max AT 25°C	PACKAGE†		ORDERABLE PART NUMBER	TOP-SIDE MARKING
-40°C to 125°C	850 μV	SOIC (D)	Tape and reel	TLC2252AQDREP	2252AE
	1550 μV	SOIC (D)	Tape and reel	TLC2252QDREP	2252EP
	850 μV	SOIC (D)	Tape and reel	TLC2254AQDREP	TLC2254AEP
	1550 μV	SOIC (D)	Tape and reel	TLC2254QDREP	TLC2254EP

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

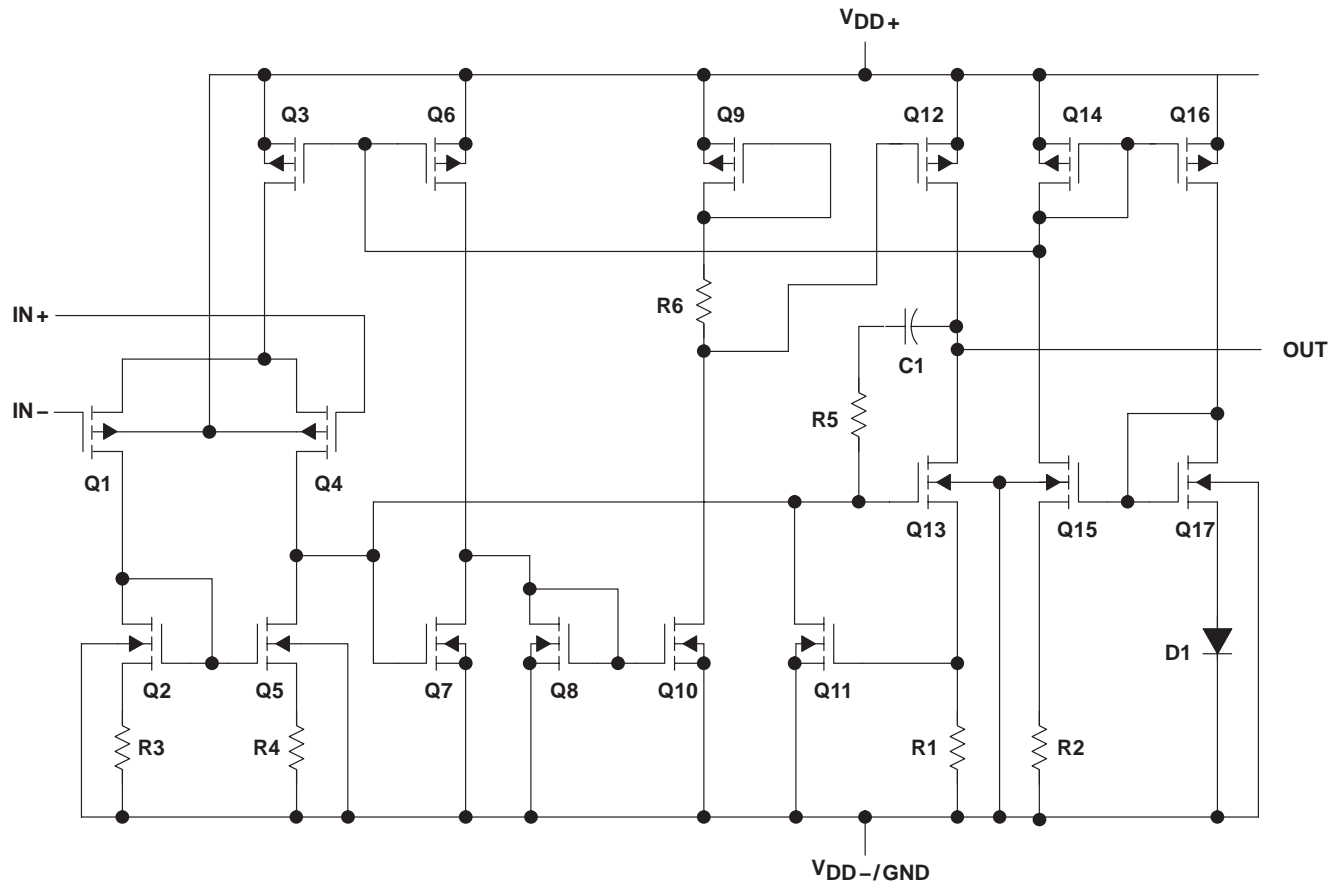
TLC2252, TLC2252A
D PACKAGE
(TOP VIEW)



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 †	TLC2252-EP			TLC2252A-EP			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
V_{IO} Input offset voltage		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)	$V_{DD\pm} = \pm 2.5\text{ V}$, $V_O = 0$, $V_{IC} = 0$, $R_S = 50\ \Omega$	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			
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
		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 ($\Delta V_{DD}/\Delta V_{IO}$)	$V_{DD} = 4.4\text{ V to }16\text{ V}$, $V_{IC} = V_{DD}/2$, No load	25°C	80	95		80	95	dB	
		Full range		80		80			
I_{DD} Supply current	$V_O = 2.5\text{ V}$, 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.



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

PARAMETER	TEST CONDITIONS	T_A †	TLC2252-EP			TLC2252A-EP			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
SR	Slew rate at unity gain $V_O = 0.5\text{ V to }3.5\text{ V}$, $R_L = 100\text{ k}\Omega$ ‡, $C_L = 100\text{ pF}$ ‡	25°C	0.07	0.12		0.07	0.12		V/ μ s
		Full range	0.05			0.05			
V_n	Equivalent input noise voltage $f = 10\text{ Hz}$ $f = 1\text{ kHz}$	25°C	36			36			nV/ $\sqrt{\text{Hz}}$
		25°C	19			19			
$V_{N(PP)}$	Peak-to-peak equivalent input noise voltage $f = 0.1\text{ Hz to }1\text{ Hz}$ $f = 0.1\text{ Hz to }10\text{ Hz}$	25°C	0.7			0.7			μ V
		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 $V_O = 0.5\text{ V to }2.5\text{ V}$, $f = 10\text{ kHz}$, $R_L = 50\text{ k}\Omega$ ‡	25°C	$A_V = 1$			0.2%			
			$A_V = 10$			1%			
	Gain-bandwidth product $f = 50\text{ kHz}$, $C_L = 100\text{ pF}$ ‡	25°C	$R_L = 50\text{ k}\Omega$ ‡			0.2			MHz
B_{OM}	Maximum output-swing bandwidth $V_{O(PP)} = 2\text{ V}$, $R_L = 50\text{ k}\Omega$ ‡	25°C	$A_V = 1$, $C_L = 100\text{ pF}$ ‡			30			kHz
ϕ_m	Phase margin at unity gain $R_L = 50\text{ k}\Omega$ ‡, $C_L = 100\text{ pF}$ ‡	25°C	63°			63°			
		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 †	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	
	$V_{IC} = 0, I_O = 500 \mu A$	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		
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 Hz	25°C			38			nV/ $\sqrt{\text{Hz}}$
		f = 1 kHz	25°C			19			
$V_{N(PP)}$	Peak-to-peak equivalent input noise voltage	f = 0.1 Hz to 1 Hz	25°C			0.8			μV
		f = 0.1 Hz to 10 Hz	25°C			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 kHz	$A_V = 1$	25°C			0.2%			
		$A_V = 10$	25°C			1%			
	Gain-bandwidth product f = 10 kHz, $C_L = 100\text{ pF}$, $R_L = 50\text{ k}\Omega$	25°C	0.21			0.21			MHz
BOM	Maximum output-swing bandwidth $V_{O(PP)} = 4.6\text{ V}$, $R_L = 50\text{ k}\Omega$, $C_L = 100\text{ pF}$	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°			
		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		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)	$V_{DD\pm} = \pm 2.5\text{ V}$, $V_{IC} = 0$, $V_O = 0$, $R_S = 50\ \Omega$	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	
		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\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					
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			
A_{VD} Large-signal differential voltage amplification	$V_{IC} = 2.5\text{ V}$, $V_O = 1\text{ V to }4\text{ V}$	$R_L = 100\text{ k}\Omega$ ‡	25°C	100	350		100	350		V/mV
			Full range	10			10			
		$R_L = 1\text{ M}\Omega$ ‡	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	$f = 10\text{ kHz}$, N package	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 ($\Delta V_{DD}/\Delta V_{IO}$)	$V_{DD} = 4.4\text{ V to }16\text{ V}$, $V_{IC} = V_{DD}/2$, No load	25°C	80	95		80	95		dB	
		Full range	80			80				
I_{DD} Supply current (four amplifiers)	$V_O = 2.5\text{ V}$, 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 †	TLC2254-EP			TLC2254A-EP			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
SR	Slew rate at unity gain $V_O = 0.5\text{ V to }3.5\text{ V}$, $R_L = 100\text{ k}\Omega$ ‡, $C_L = 100\text{ pF}$ ‡	25°C	0.07	0.12		0.07	0.12		V/ μ s
		Full range	0.05			0.05			
V_n	Equivalent input noise voltage $f = 10\text{ Hz}$ $f = 1\text{ kHz}$	25°C	36			36			nV/ $\sqrt{\text{Hz}}$
		25°C	19			19			
$V_{N(PP)}$	Peak-to-peak equivalent input noise voltage $f = 0.1\text{ Hz to }1\text{ Hz}$ $f = 0.1\text{ Hz to }10\text{ Hz}$	25°C	0.7			0.7			μ V
		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 $V_O = 0.5\text{ V to }2.5\text{ V}$, $f = 20\text{ kHz}$, $R_L = 50\text{ k}\Omega$ ‡	25°C	$A_V = 1$			0.2%			
			$A_V = 10$			1%			
	Gain-bandwidth product $f = 50\text{ kHz}$, $C_L = 100\text{ pF}$ ‡	$R_L = 50\text{ k}\Omega$ ‡, 25°C	0.2			0.2			MHz
B_{OM}	Maximum output-swing bandwidth $V_{O(PP)} = 2\text{ V}$, $R_L = 50\text{ k}\Omega$ ‡, $A_V = 1$, $C_L = 100\text{ pF}$ ‡	25°C	30			30			kHz
ϕ_m	Phase margin at unity gain $R_L = 50\text{ k}\Omega$ ‡, $C_L = 100\text{ pF}$ ‡	25°C	63°			63°			
		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, $V_{DD\pm} = \pm 5\text{ V}$ (unless otherwise noted)

PARAMETER	TEST CONDITIONS	T_A †	TLC2254-EP			TLC2254A-EP			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
V_{IO} Input offset voltage	$V_{IC} = 0, V_O = 0, R_S = 50\ \Omega$	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	
		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	$R_S = 50\ \Omega, V_{IO} \leq 5\ \text{mV}$	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	$I_O = -20\ \mu\text{A}$	25°C	4.98		4.98		V		
	$I_O = -100\ \mu\text{A}$	25°C	4.9	4.93	4.9	4.93			
		Full range	4.7		4.7				
	$I_O = -200\ \mu\text{A}$	25°C	4.8	4.86	4.8	4.86			
V_{OM-} Maximum negative peak output voltage	$V_{IC} = 0, I_O = 50\ \mu\text{A}$	25°C	-4.99		-4.99		V		
		25°C	-4.85	-4.91	-4.85	-4.91			
	Full range	-4.85		-4.85					
	$V_{IC} = 0, I_O = 4\ \text{mA}$	25°C	-4	-4.3	-4	-4.3			
		Full range	-3.8		-3.8				
	A_{VD} Large-signal differential voltage amplification	$V_O = \pm 4\ \text{V}$	$R_L = 100\ \text{k}\Omega$	25°C	40	150		40	150
Full range				10		10			
$R_L = 1\ \text{M}\Omega$			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	$f = 10\ \text{kHz}, \text{ N package}$	25°C	8			8		pF	
z_o Closed-loop output impedance	$f = 25\ \text{kHz}, A_V = 10$	25°C	190			190		Ω	
CMRR Common-mode rejection ratio	$V_{IC} = -5\ \text{V to } 2.7\ \text{V}, V_O = 0, R_S = 50\ \Omega$	25°C	75	88		75	88	dB	
		Full range	75			75			
k_{SVR} Supply-voltage rejection ratio ($\Delta V_{DD\pm}/\Delta V_{IO}$)	$V_{DD\pm} = \pm 2.2\ \text{V to } \pm 8\ \text{V}, V_{IC} = V_{DD}/2, \text{ No load}$	25°C	80	95		80	95	dB	
		Full range	80			80			
I_{DD} Supply current (four amplifiers)	$V_O = 0, \text{ No load}$	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 $T_A = 150^\circ\text{C}$ 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	TLC2254-EP			TLC2254A-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	$\text{V}/\mu\text{s}$	
				Full range	0.05			0.05			
V_n	Equivalent input noise voltage			25°C	38			38			$\text{nV}/\sqrt{\text{Hz}}$
				25°C	19			19			
$V_{N(PP)}$	Peak-to-peak equivalent input noise voltage			25°C	0.8			0.8			μV
				25°C	1.1			1.1			
I_n	Equivalent input noise current			25°C	0.6			0.6			$\text{fA}/\sqrt{\text{Hz}}$
THD + N	Total harmonic distortion plus noise	$V_O = \pm 2.3\text{ V}$, $R_L = 50\text{ k}\Omega$, $f = 20\text{ kHz}$	$A_V = 1$	25°C	0.2%			0.2%			
					$A_V = 10$	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
B_{OM}	Maximum output-swing bandwidth	$V_{O(PP)} = 4.6\text{ V}$, $R_L = 50\text{ k}\Omega$	$A_V = 1$, $C_L = 100\text{ pF}$	25°C	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			

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

TYPICAL CHARACTERISTICS

Table of Graphs

		FIGURE
V_{IO}	Input offset voltage	Distribution vs Common-mode input voltage
α_{VIO}	Input offset voltage temperature coefficient	Distribution
I_{IB}/I_{IO}	Input bias and input offset currents	vs Free-air temperature
V_I	Input voltage range	vs Supply voltage vs Free-air temperature
V_{OH}	High-level output voltage	vs High-level output current
V_{OL}	Low-level output voltage	vs Low-level output current
V_{OM+}	Maximum positive peak output voltage	vs Output current
V_{OM-}	Maximum negative peak output voltage	vs Output current
$V_{O(PP)}$	Maximum peak-to-peak output voltage	vs Frequency
I_{OS}	Short-circuit output current	vs Supply voltage vs Free-air temperature
V_O	Output voltage	vs Differential input voltage
	Differential gain	vs Load resistance
A_{VD}	Large-signal differential voltage amplification	vs Frequency vs Free-air temperature
z_o	Output impedance	vs Frequency
CMRR	Common-mode rejection ratio	vs Frequency vs Free-air temperature
k_{SVR}	Supply-voltage rejection ratio	vs Frequency vs Free-air temperature
I_{DD}	Supply current	vs Supply voltage vs Free-air temperature
SR	Slew rate	vs Load capacitance vs Free-air temperature
V_O	Inverting large-signal pulse response	
V_O	Voltage-follower large-signal pulse response	
V_O	Inverting small-signal pulse response	
V_O	Voltage-follower small-signal pulse response	
V_n	Equivalent input noise voltage	vs Frequency
	Noise voltage (referred to input)	Over a 10-second period
	Integrated noise voltage	vs Frequency
THD + N	Total harmonic distortion plus noise	vs Frequency
	Gain-bandwidth product	vs Free-air temperature vs Supply voltage
ϕ_m	Phase margin	vs Frequency vs Load capacitance
A_m	Gain margin	vs Load capacitance
B_1	Unity-gain bandwidth	vs Load capacitance
	Overestimation of phase margin	vs Load capacitance

TYPICAL CHARACTERISTICS

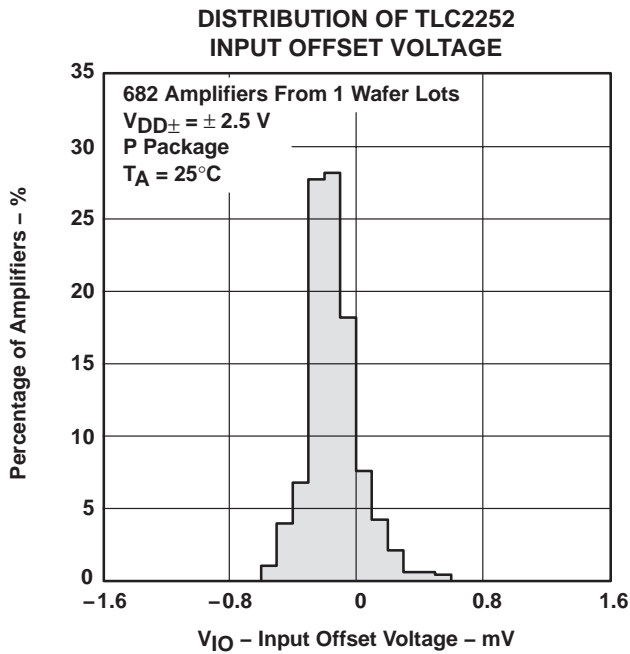


Figure 2

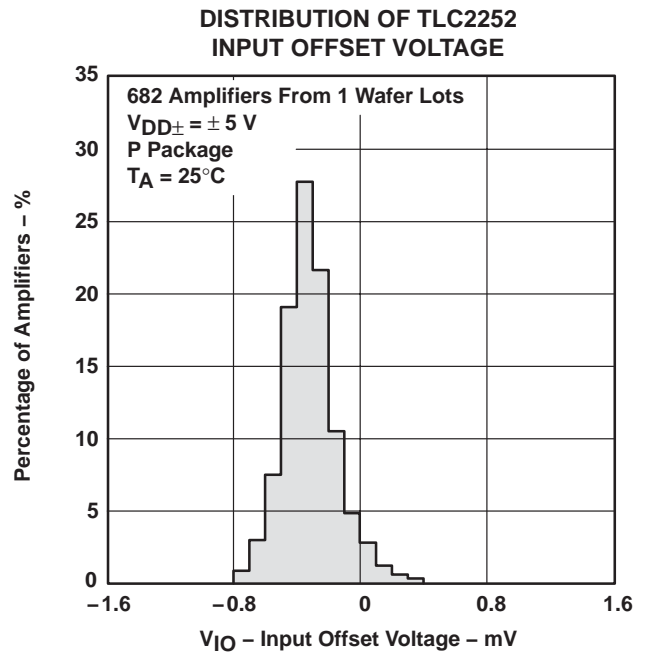


Figure 3

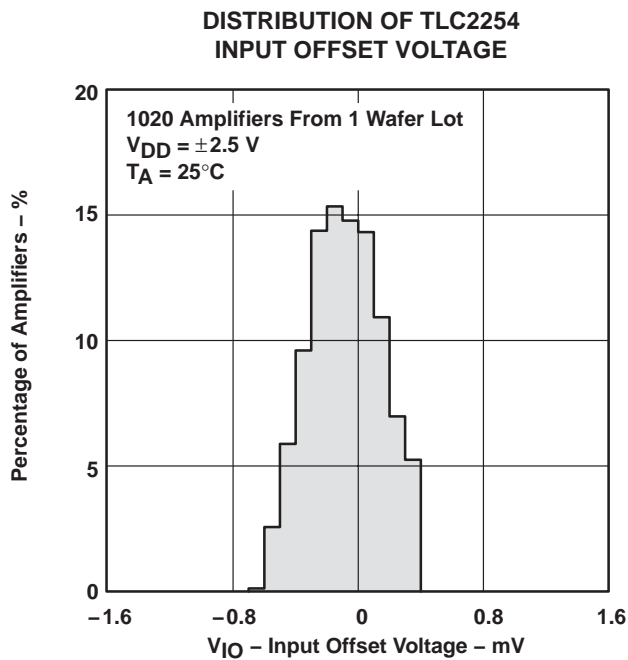


Figure 4

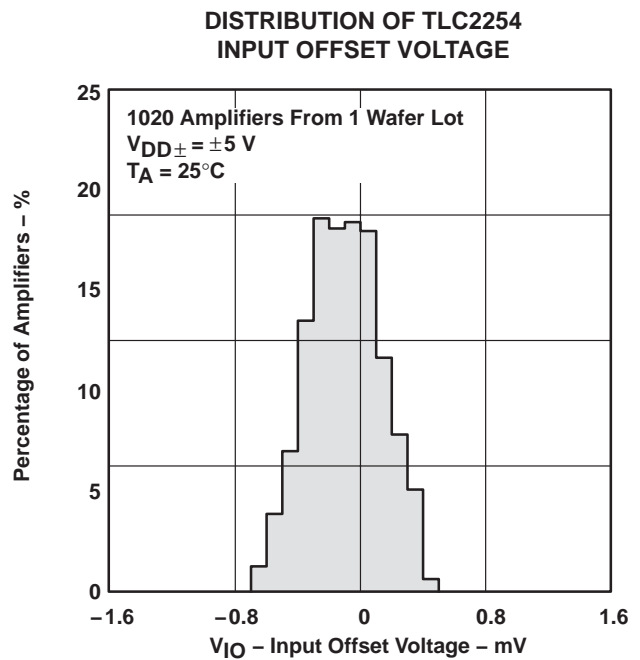
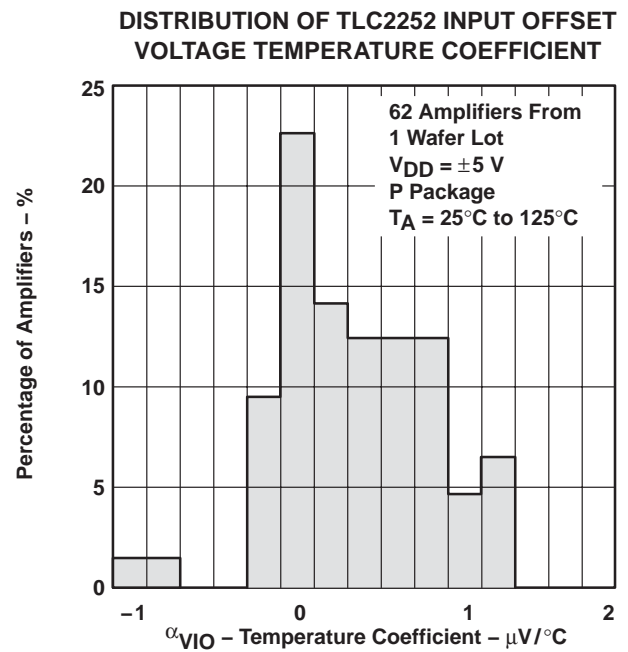
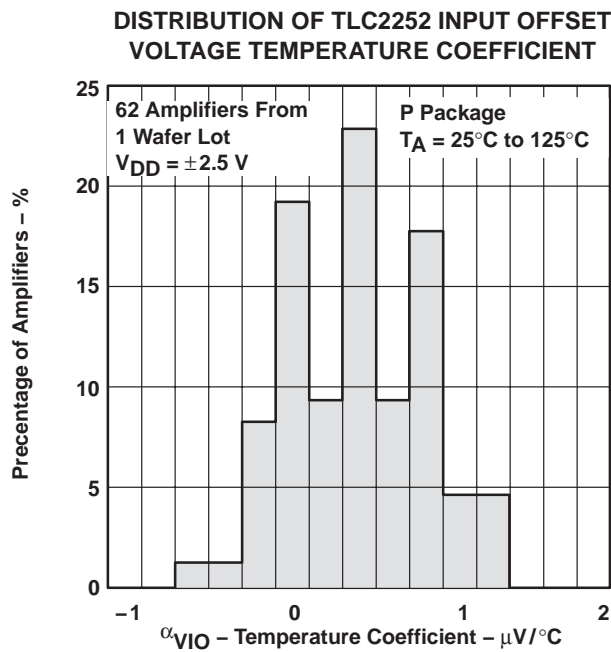
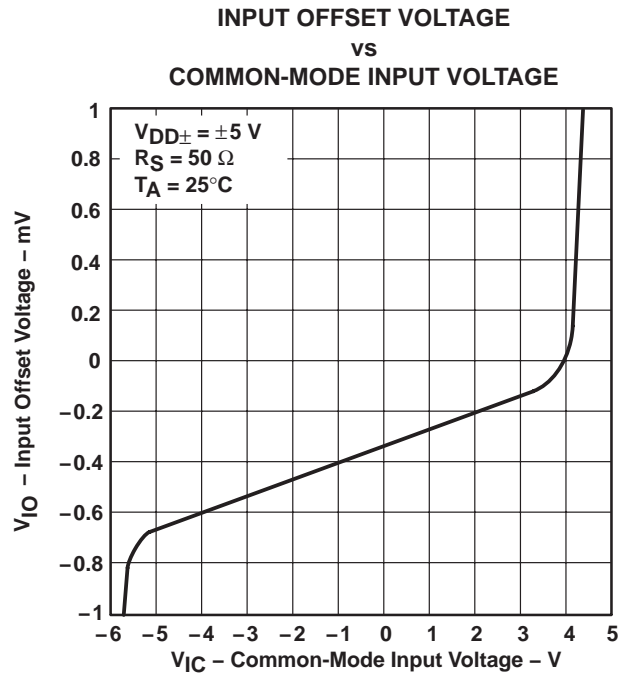
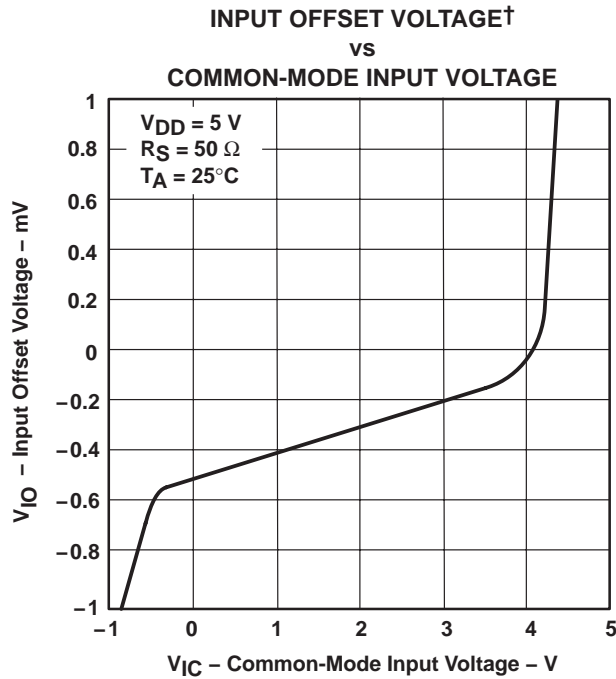


Figure 5

TYPICAL CHARACTERISTICS



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

TYPICAL CHARACTERISTICS

DISTRIBUTION OF TLC2254 INPUT OFFSET VOLTAGE TEMPERATURE COEFFICIENT

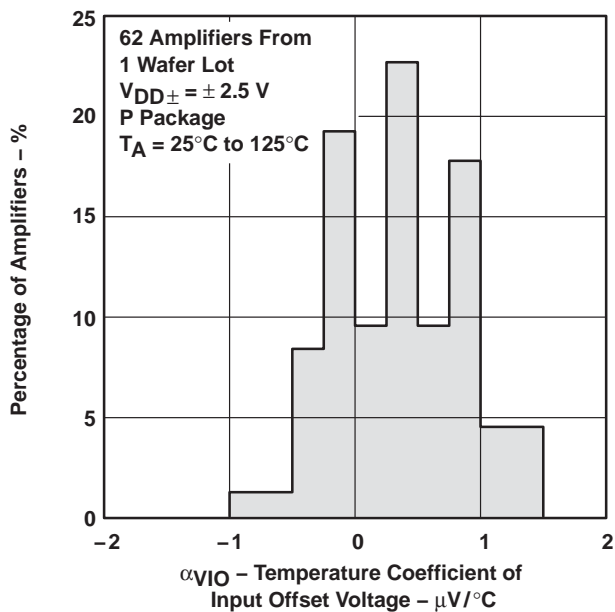


Figure 10

DISTRIBUTION OF TLC2254 INPUT OFFSET VOLTAGE TEMPERATURE COEFFICIENT

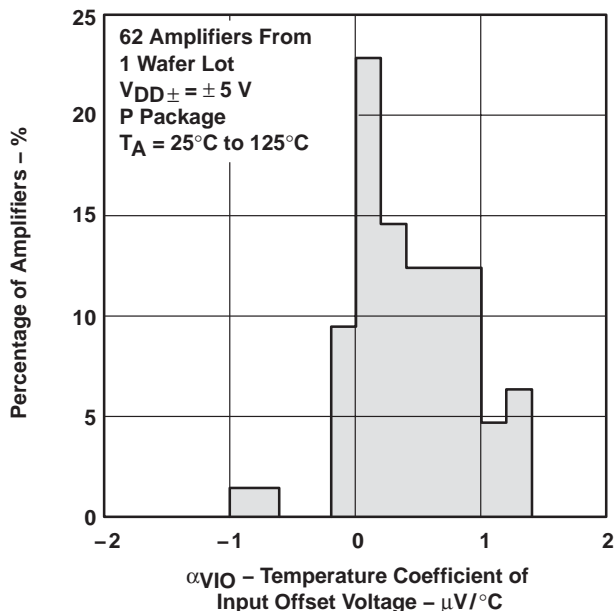


Figure 11

INPUT BIAS AND INPUT OFFSET CURRENTS† vs FREE-AIR TEMPERATURE

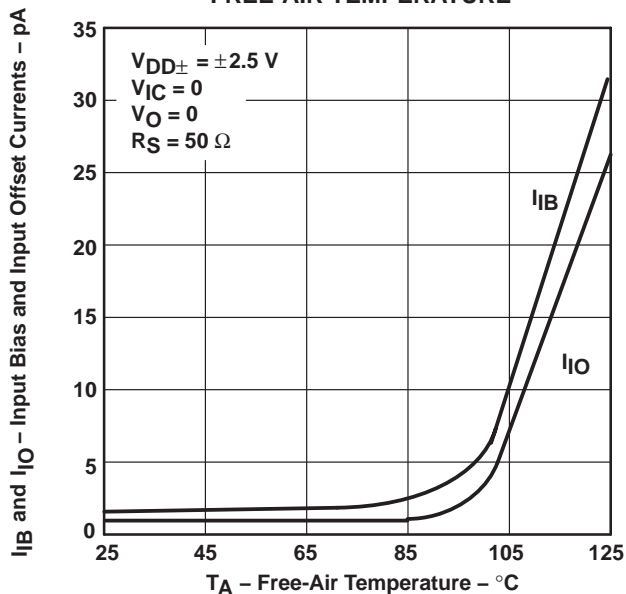


Figure 12

INPUT VOLTAGE RANGE vs SUPPLY VOLTAGE

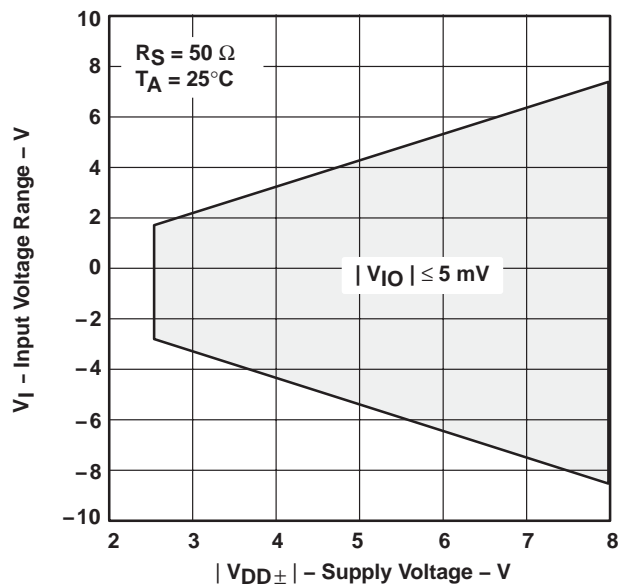


Figure 13

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

TYPICAL CHARACTERISTICS

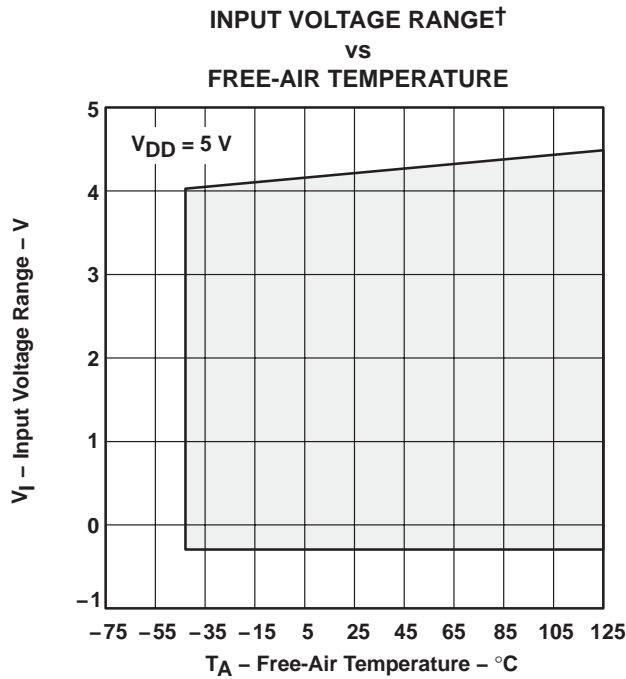


Figure 14

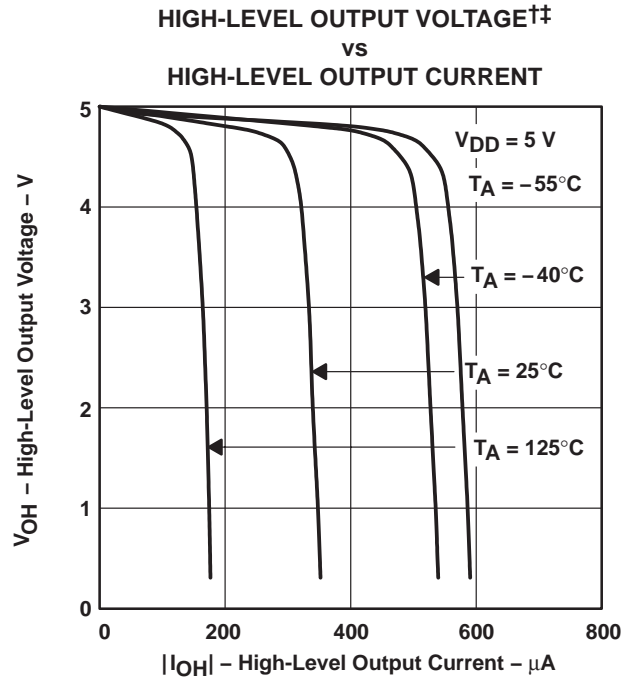


Figure 15

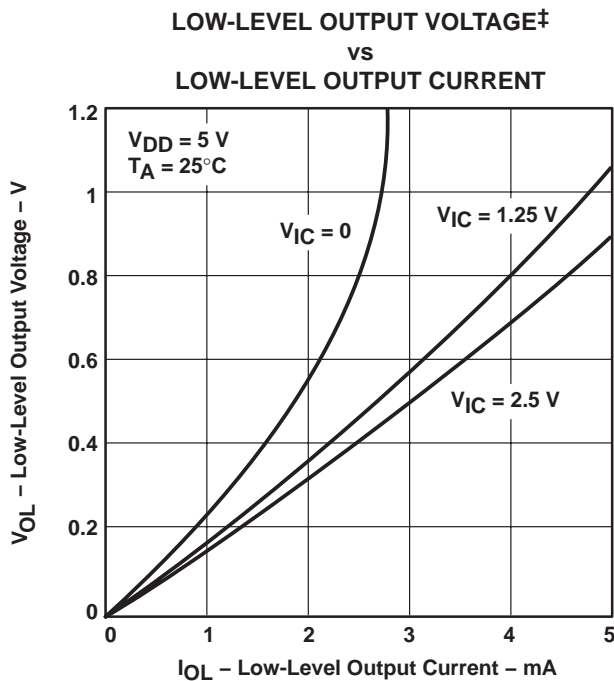


Figure 16

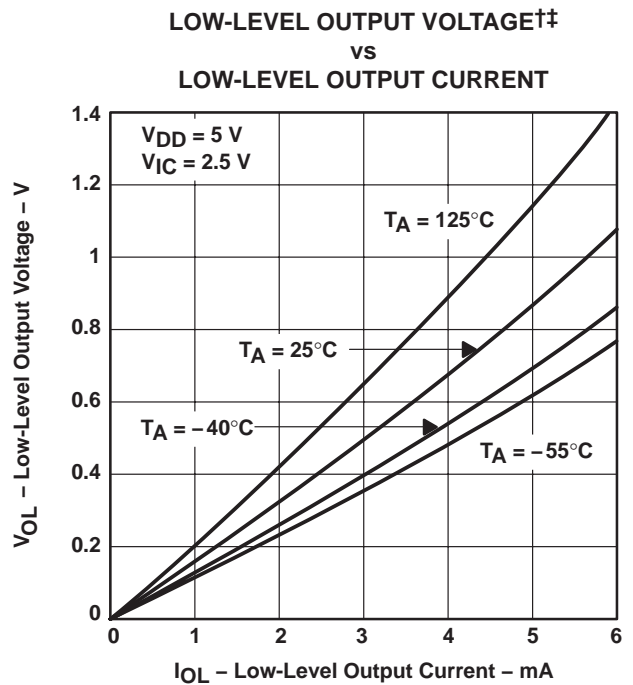


Figure 17

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

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

TYPICAL CHARACTERISTICS

MAXIMUM POSITIVE PEAK OUTPUT VOLTAGE†
vs
OUTPUT CURRENT

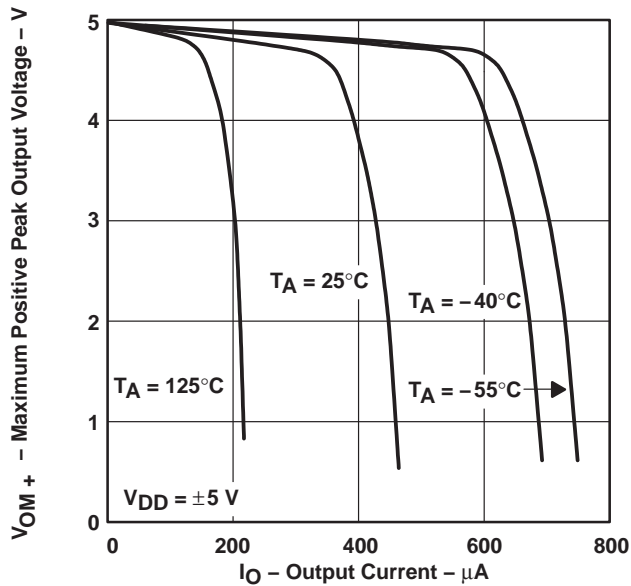


Figure 18

MAXIMUM NEGATIVE PEAK OUTPUT VOLTAGE†
vs
OUTPUT CURRENT

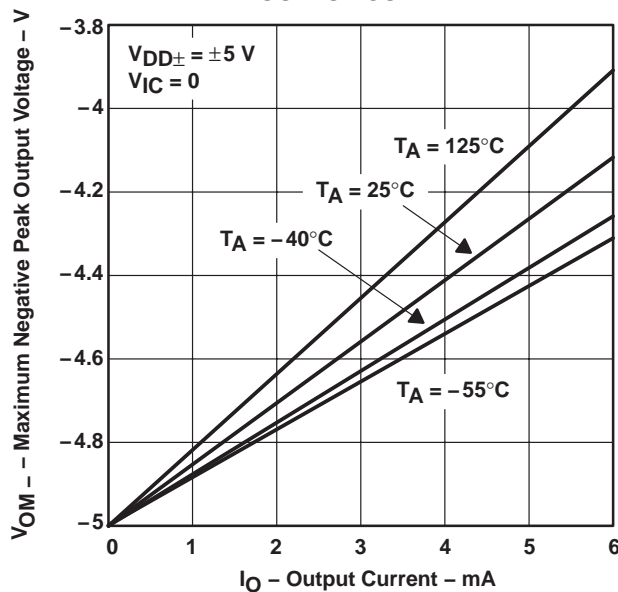


Figure 19

MAXIMUM PEAK-TO-PEAK OUTPUT VOLTAGE‡
vs
FREQUENCY

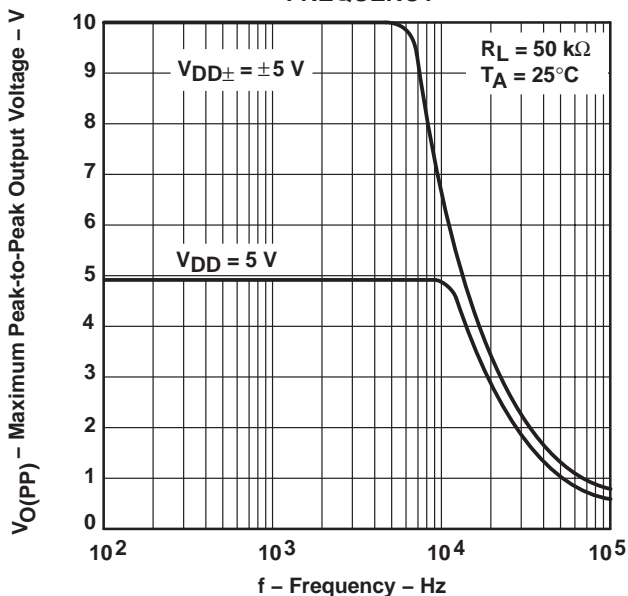


Figure 20

SHORT-CIRCUIT OUTPUT CURRENT
vs
SUPPLY VOLTAGE

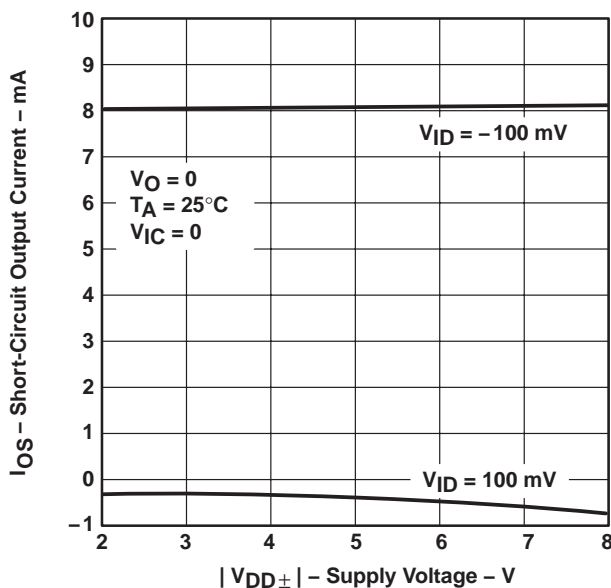


Figure 21

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

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

TYPICAL CHARACTERISTICS

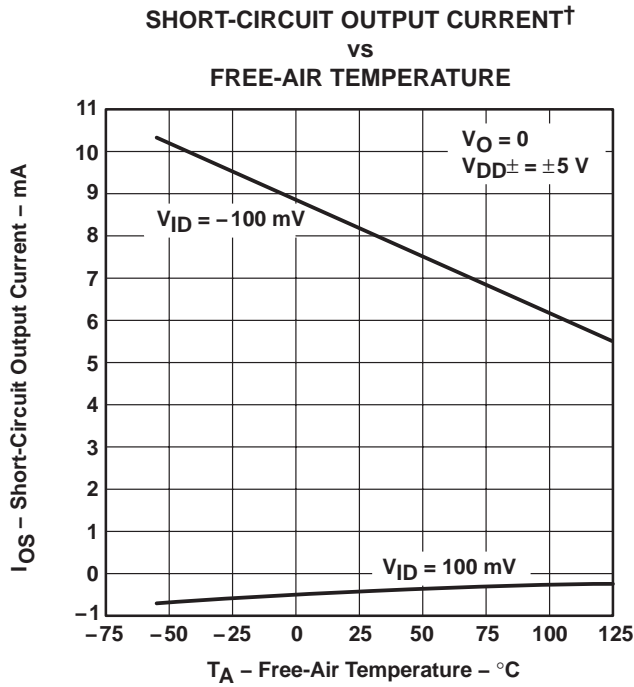


Figure 22

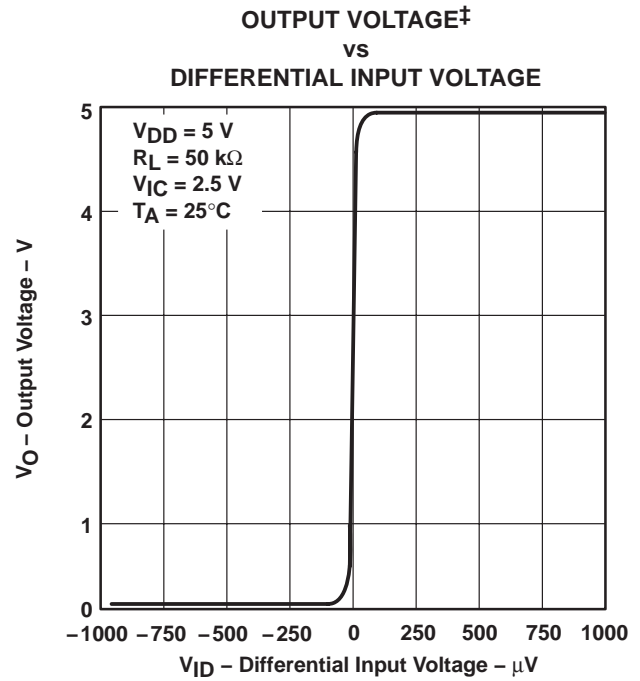


Figure 23

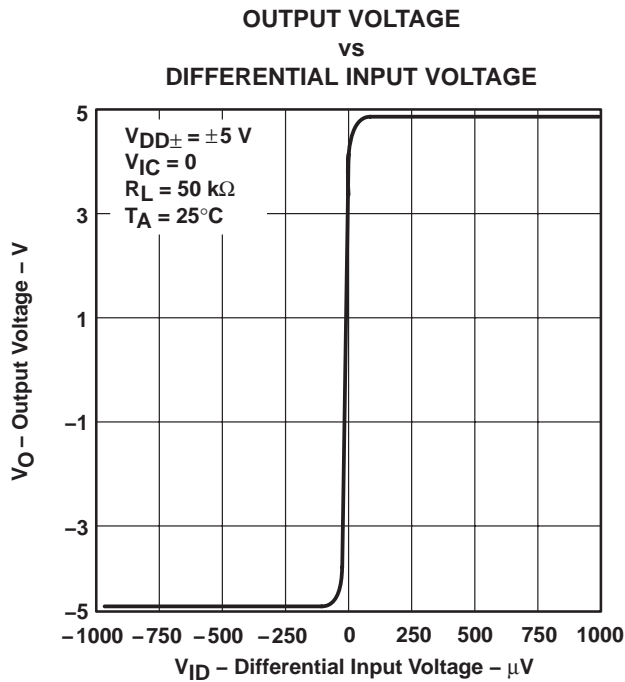


Figure 24

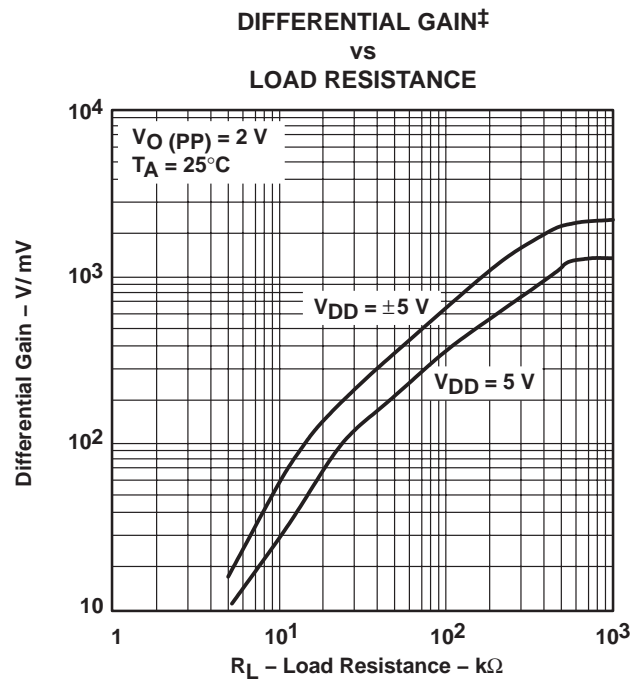


Figure 25

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

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

TYPICAL CHARACTERISTICS

LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION AND PHASE MARGIN†

vs
FREQUENCY

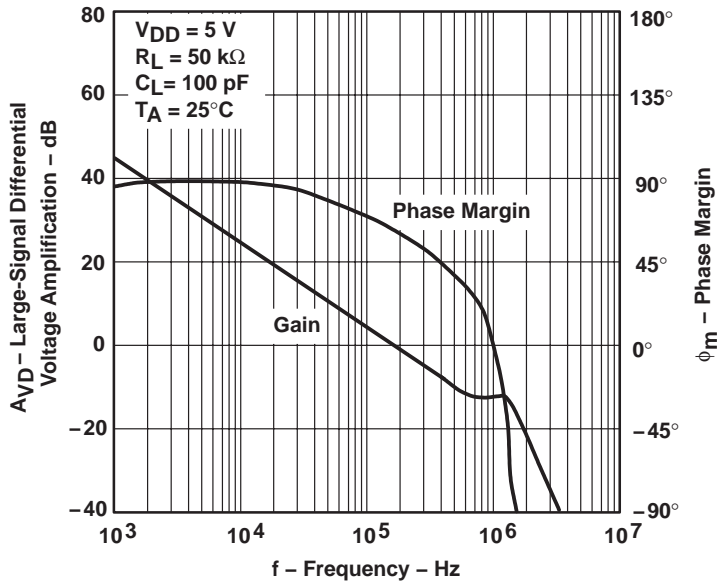


Figure 26

LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION AND PHASE MARGIN

vs
FREQUENCY

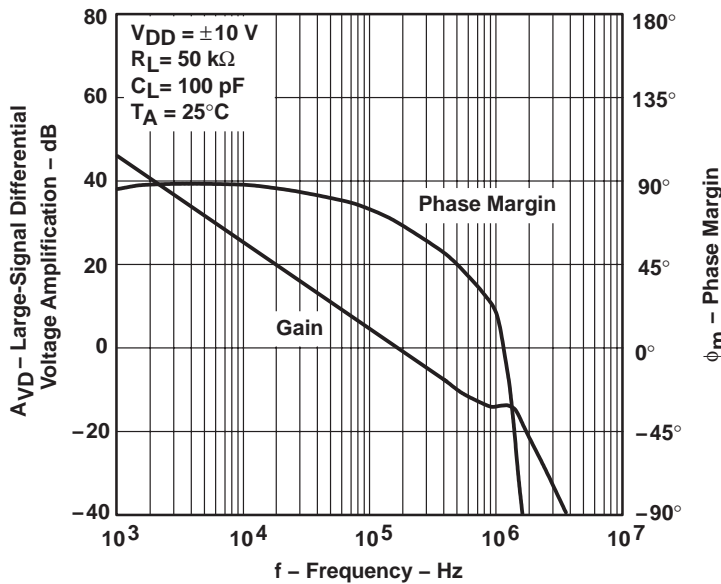
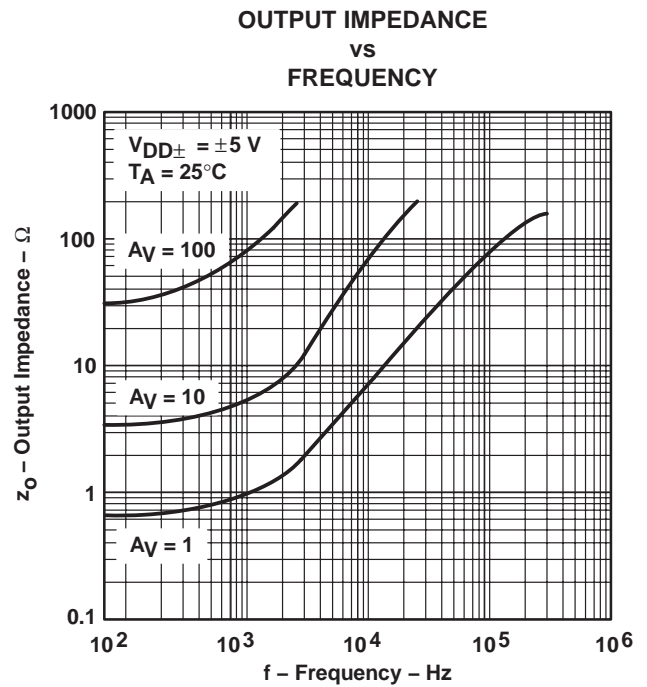
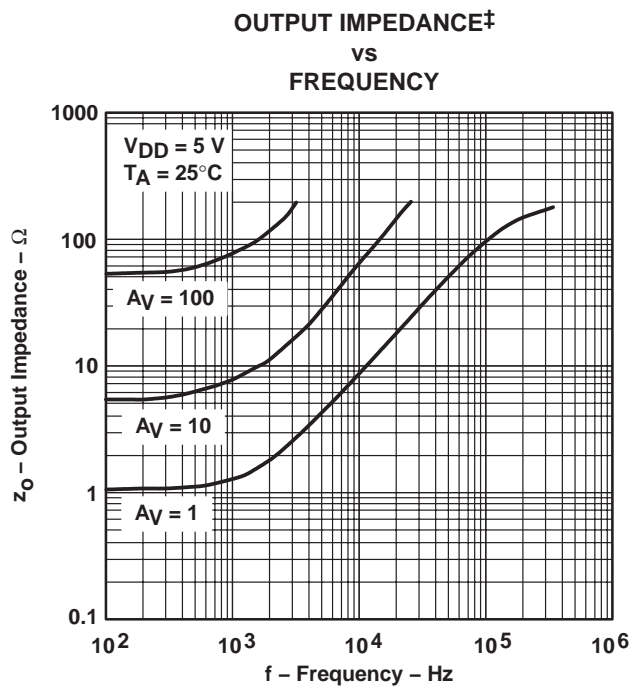
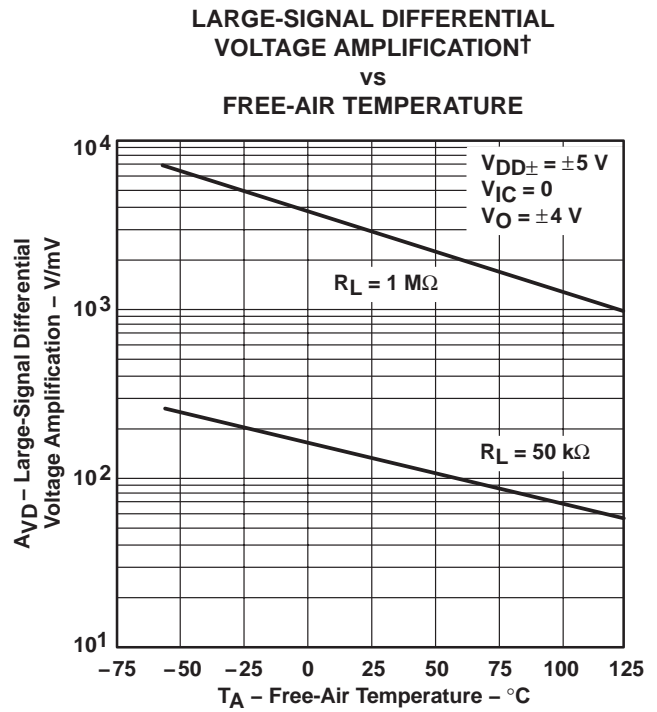
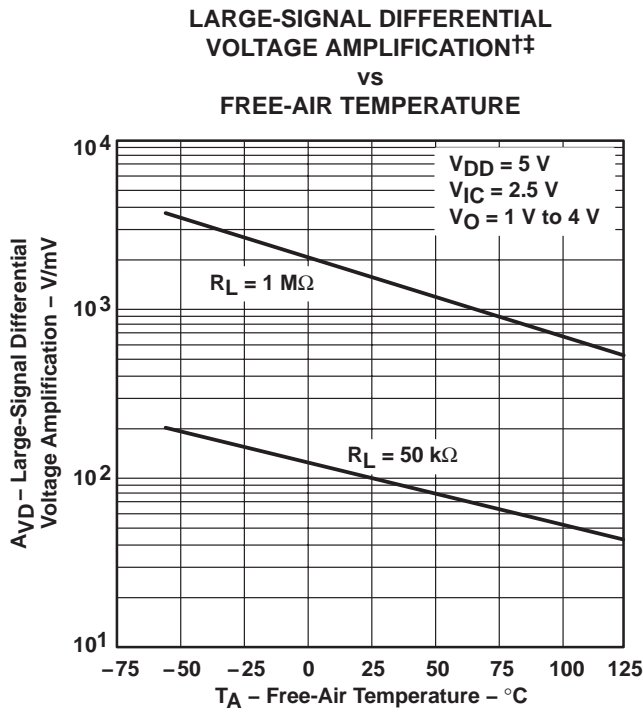


Figure 27

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

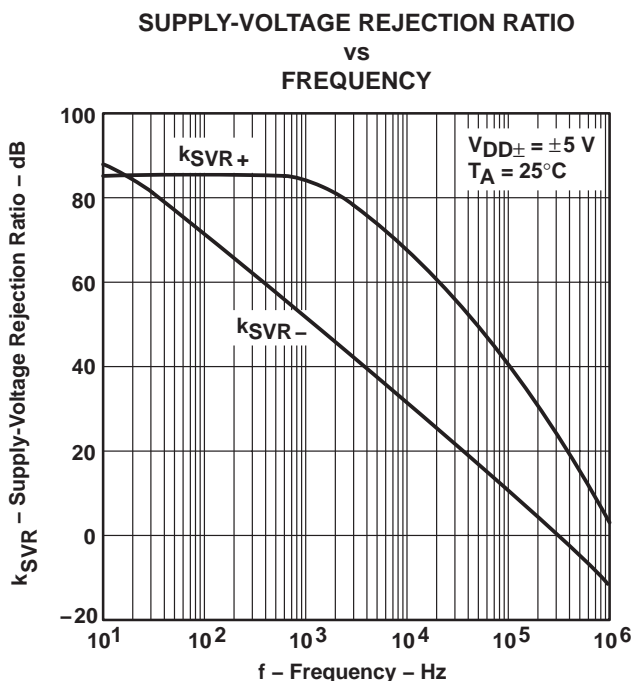
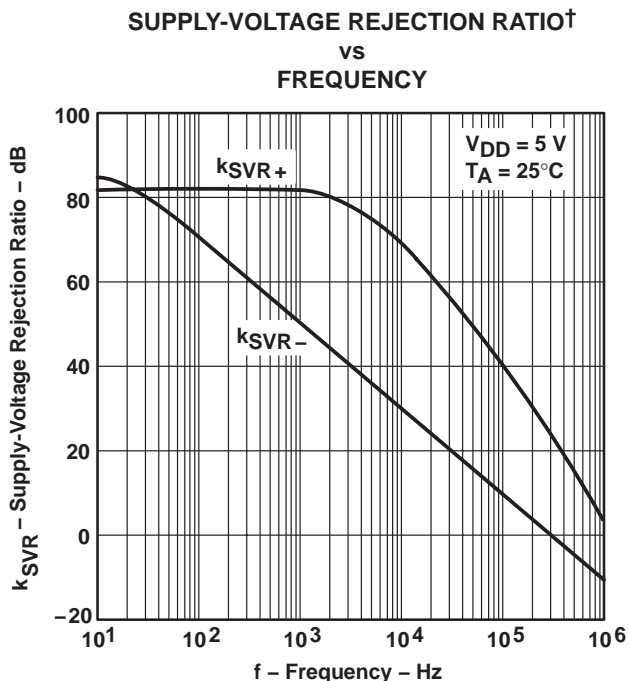
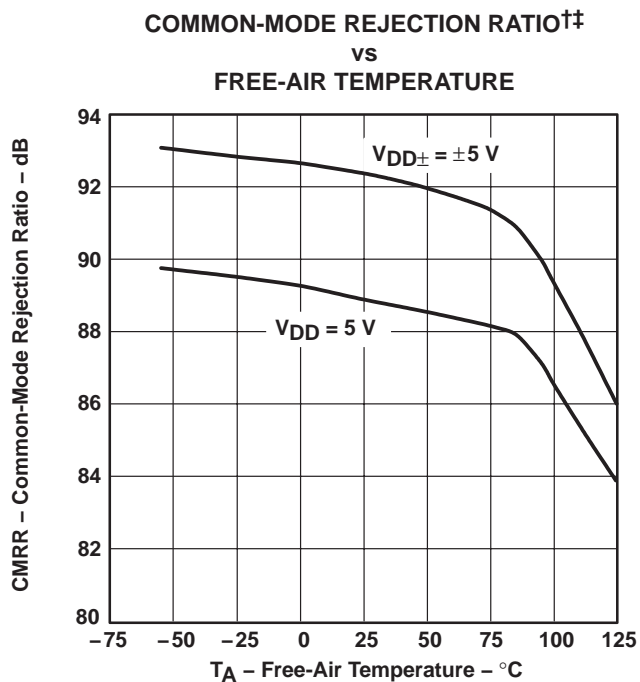
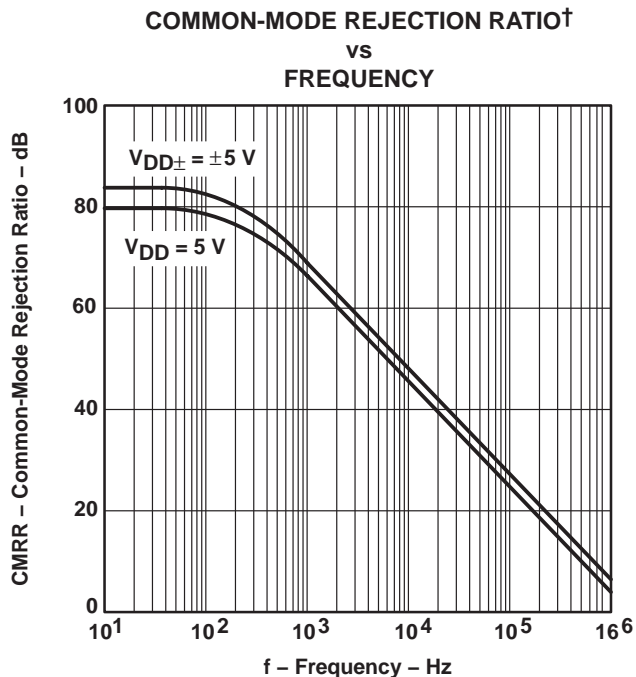
TYPICAL CHARACTERISTICS



† 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.

TYPICAL CHARACTERISTICS



† 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

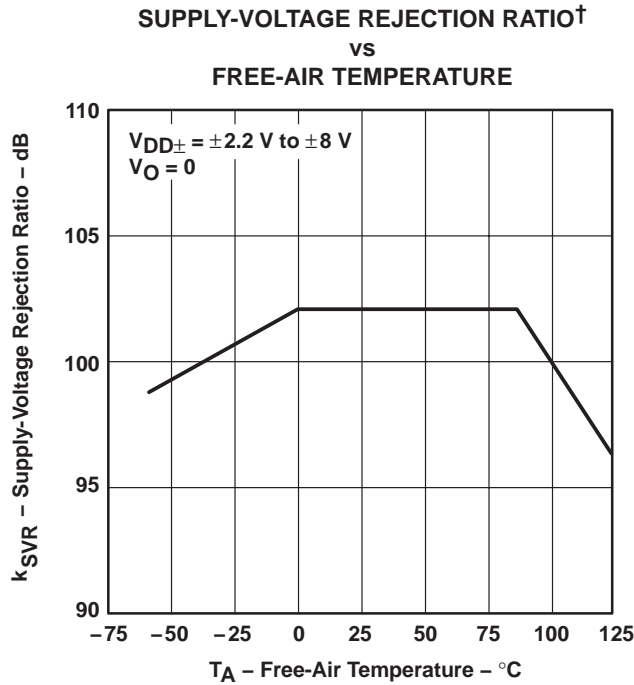


Figure 36

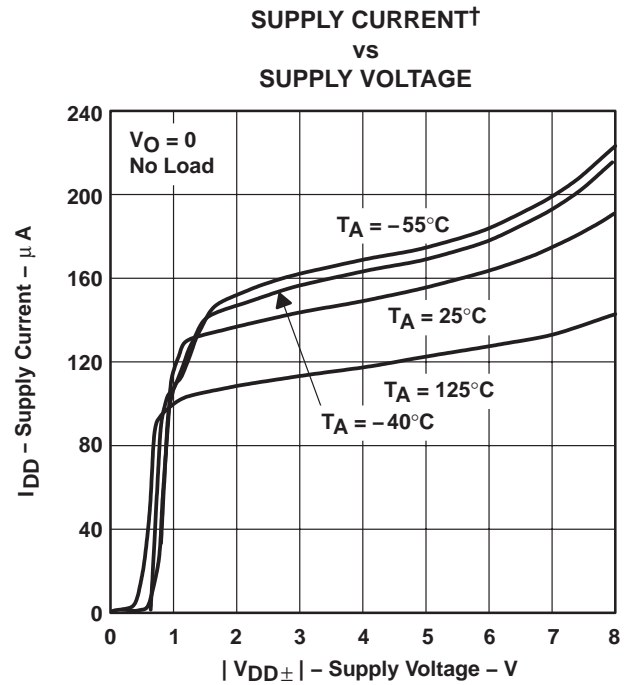


Figure 37

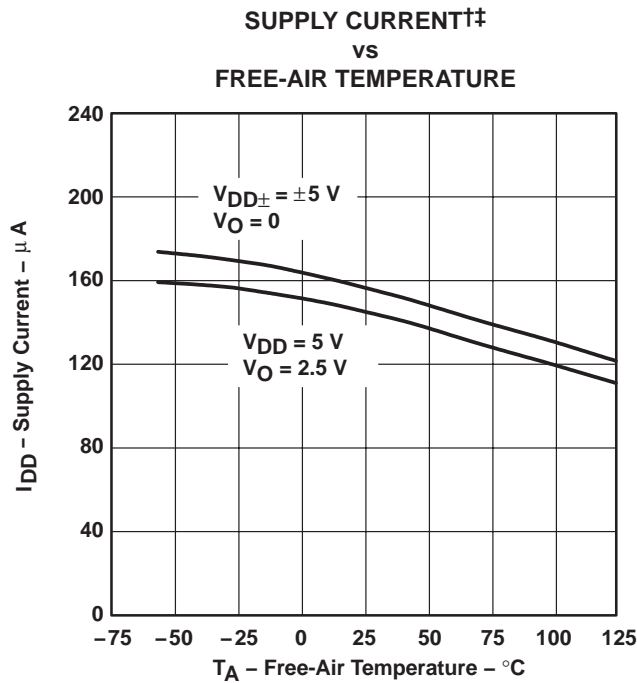


Figure 38

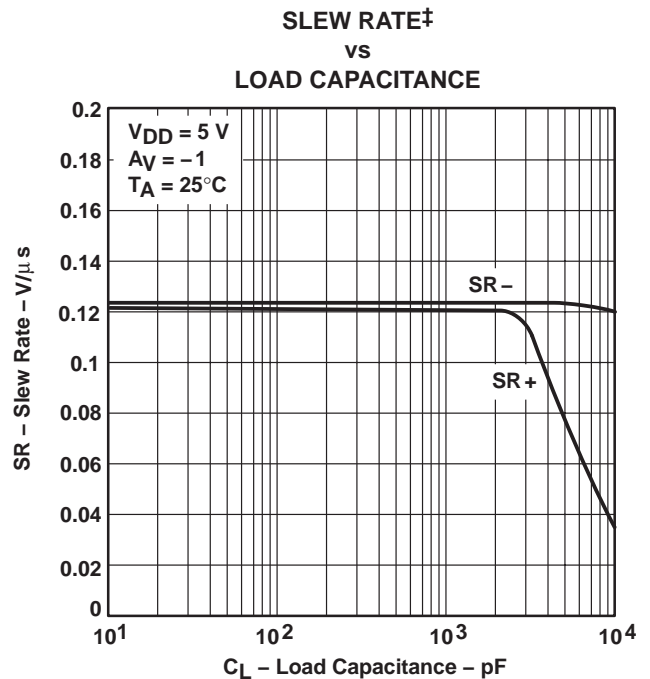


Figure 39

† 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.

TYPICAL CHARACTERISTICS

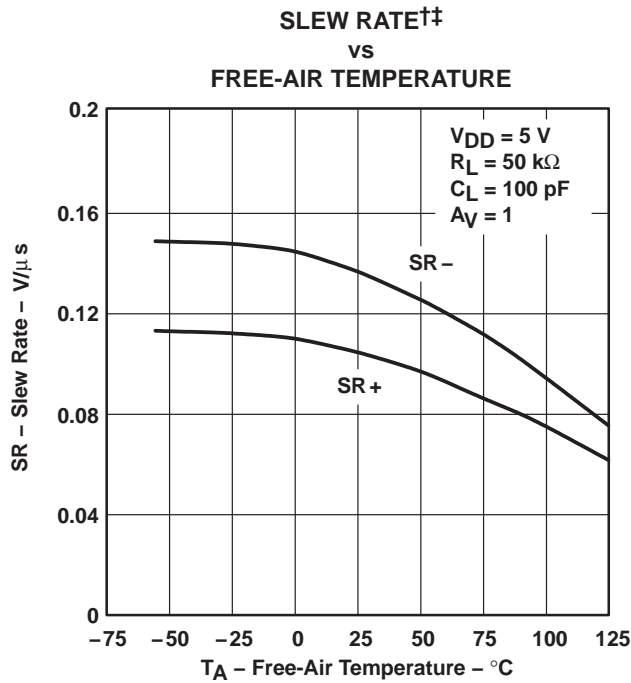


Figure 40

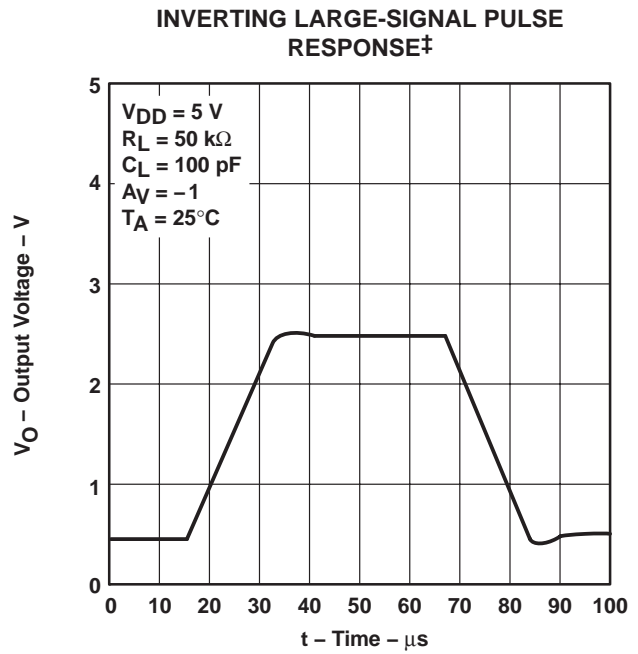


Figure 41

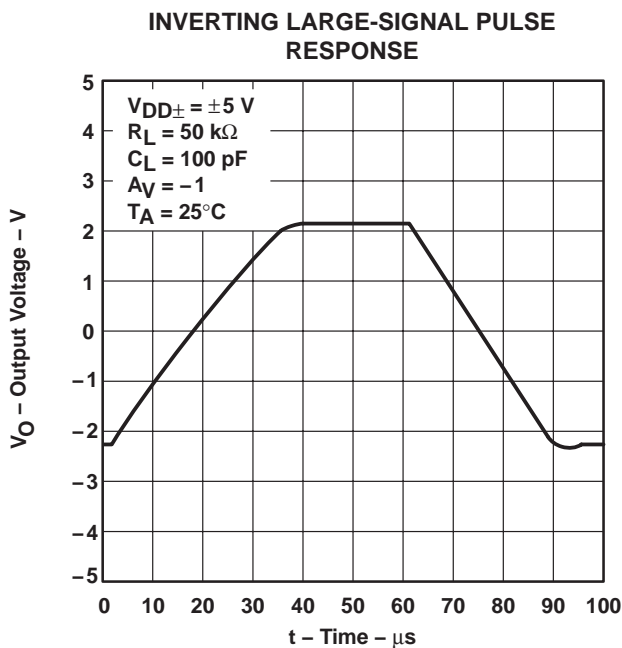


Figure 42

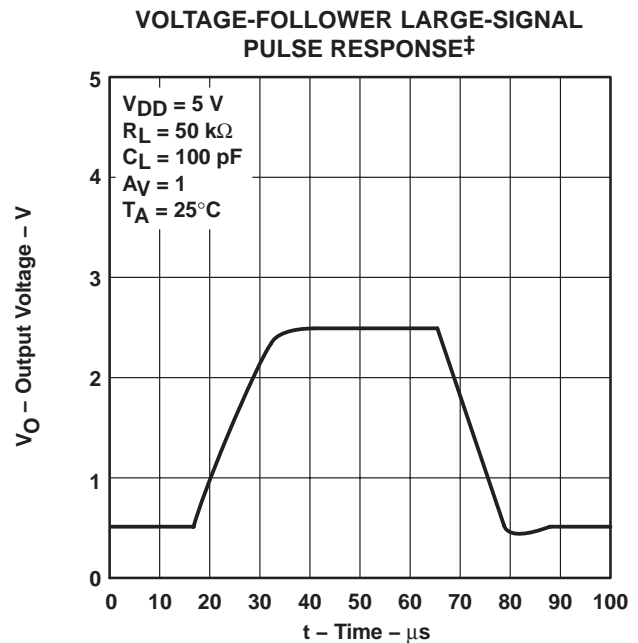


Figure 43

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

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

TYPICAL CHARACTERISTICS

VOLTAGE-FOLLOWER LARGE-SIGNAL PULSE RESPONSE

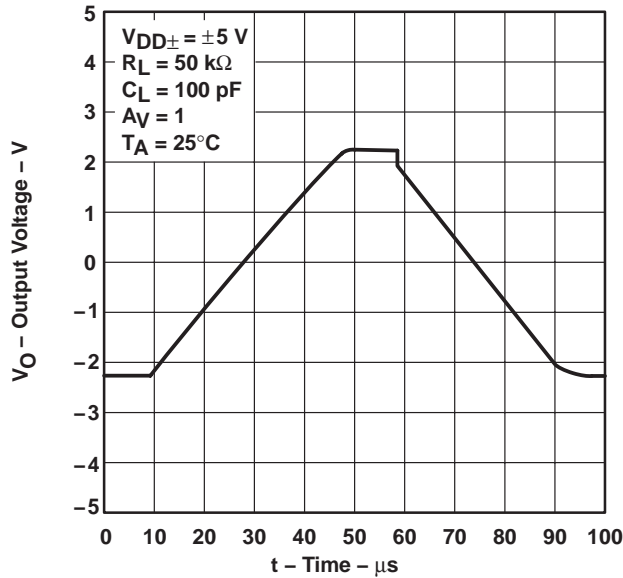


Figure 44

INVERTING SMALL-SIGNAL PULSE RESPONSE†

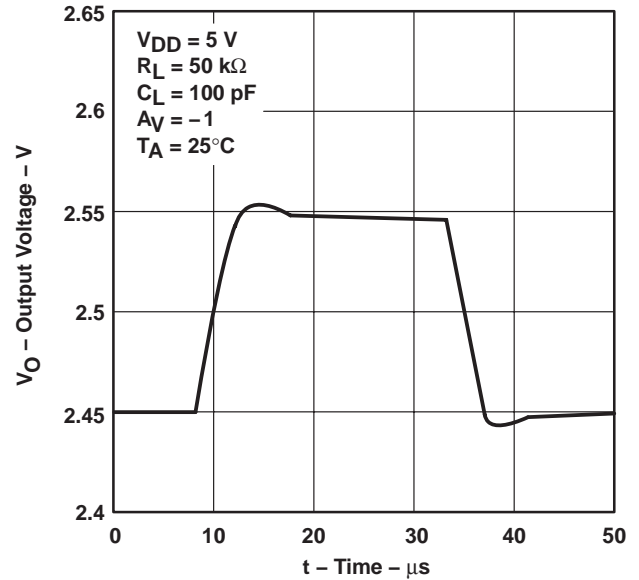


Figure 45

INVERTING SMALL-SIGNAL PULSE RESPONSE

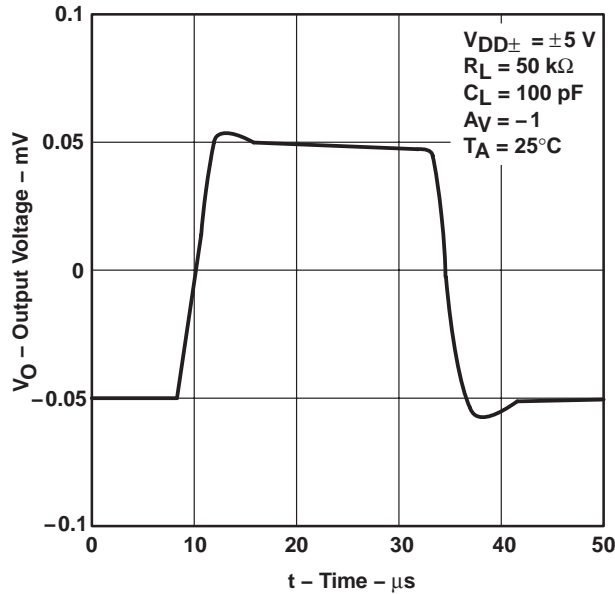


Figure 46

VOLTAGE-FOLLOWER SMALL-SIGNAL PULSE RESPONSE†

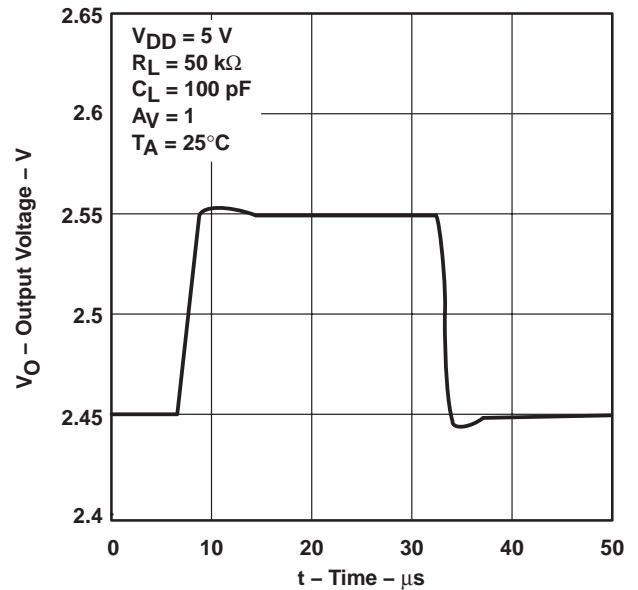


Figure 47

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

TYPICAL CHARACTERISTICS

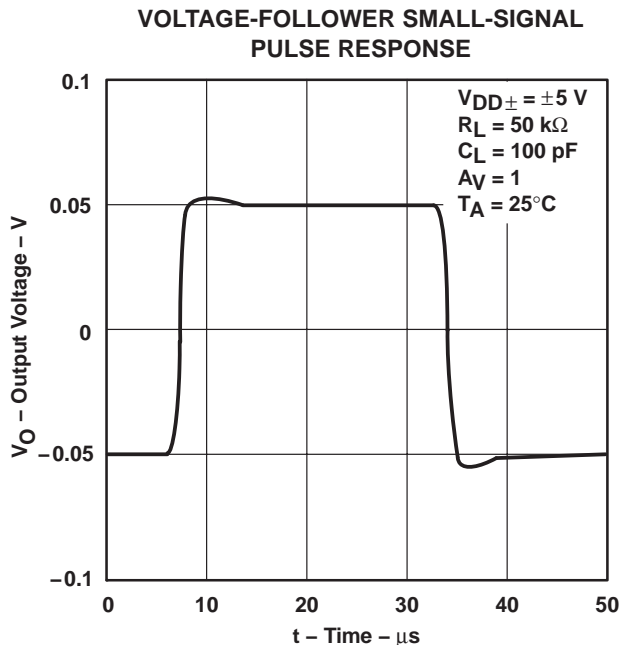


Figure 48

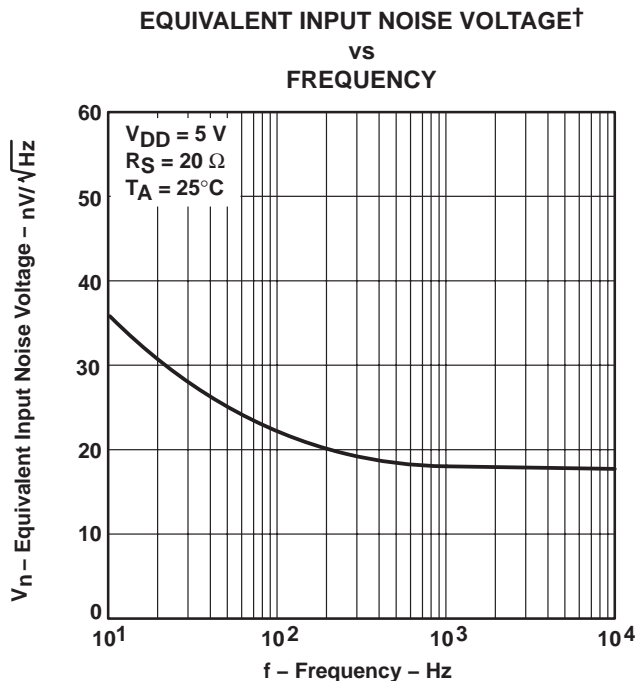


Figure 49

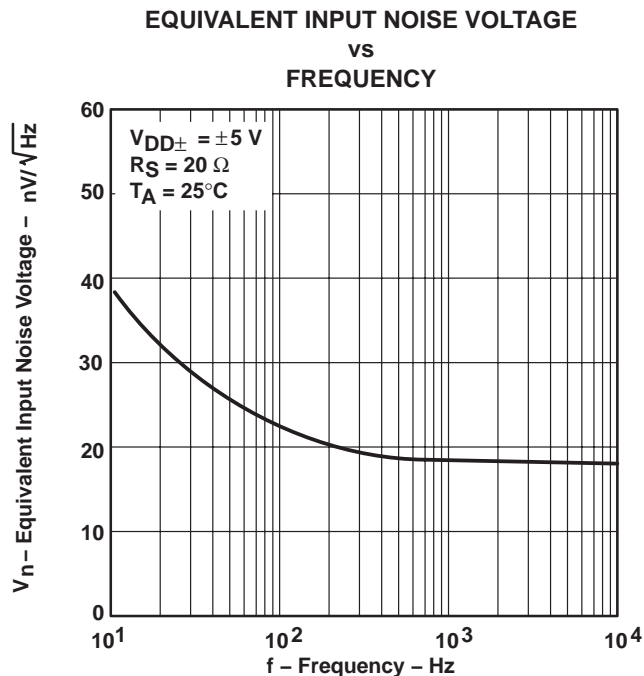


Figure 50

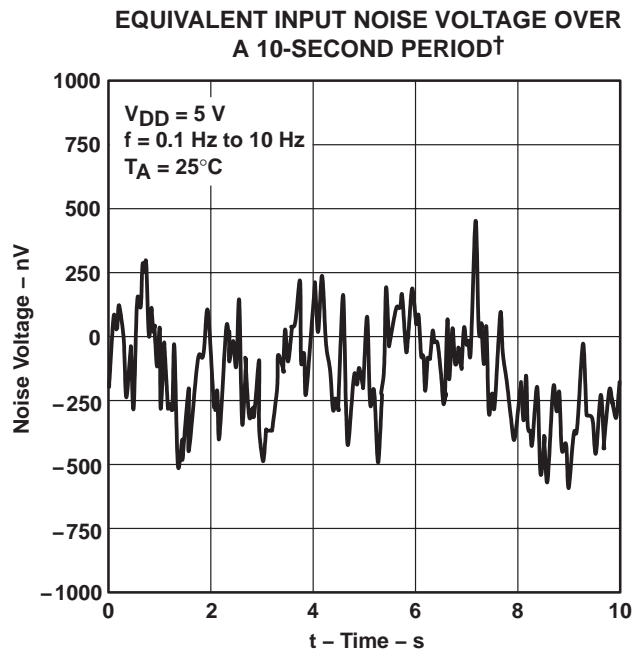


Figure 51

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

TYPICAL CHARACTERISTICS

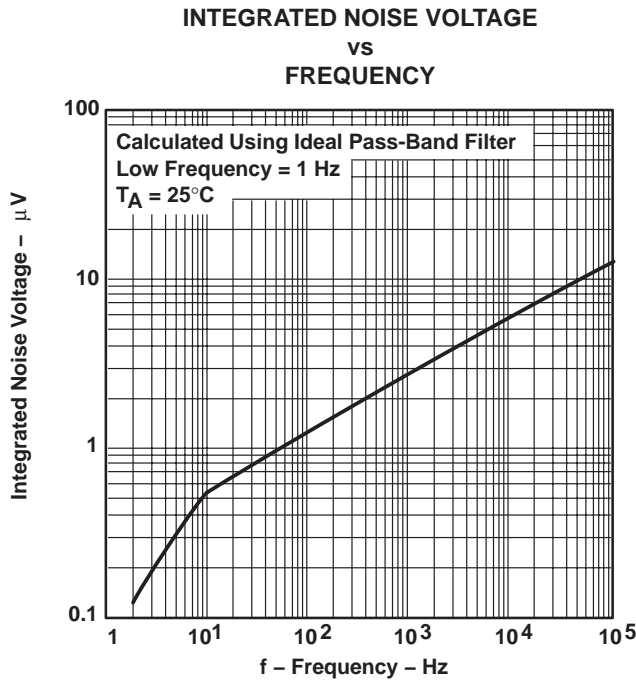


Figure 52

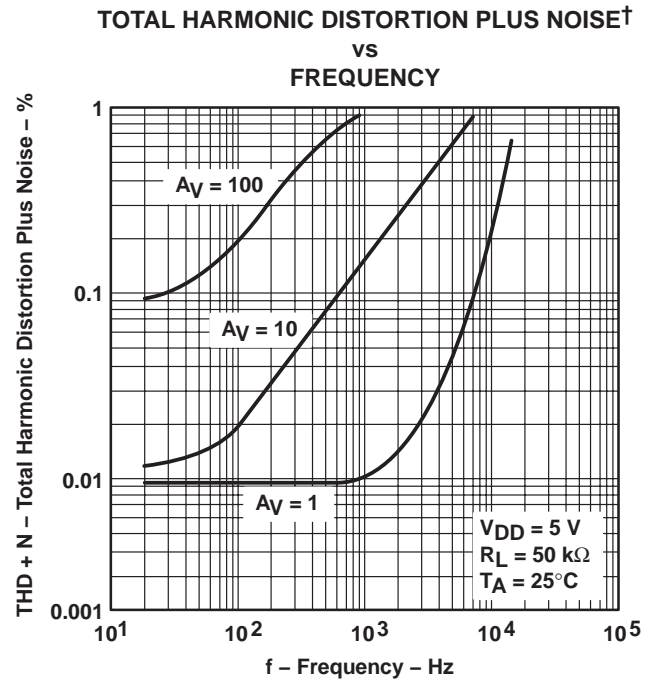


Figure 53

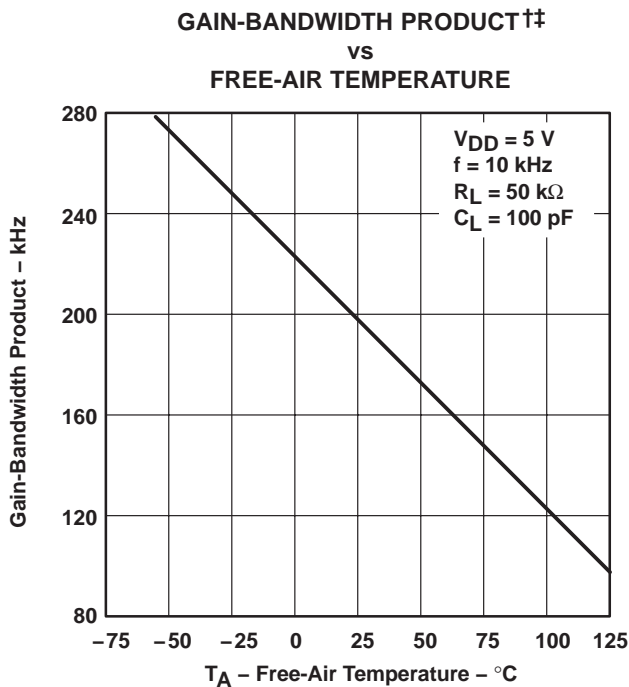


Figure 54

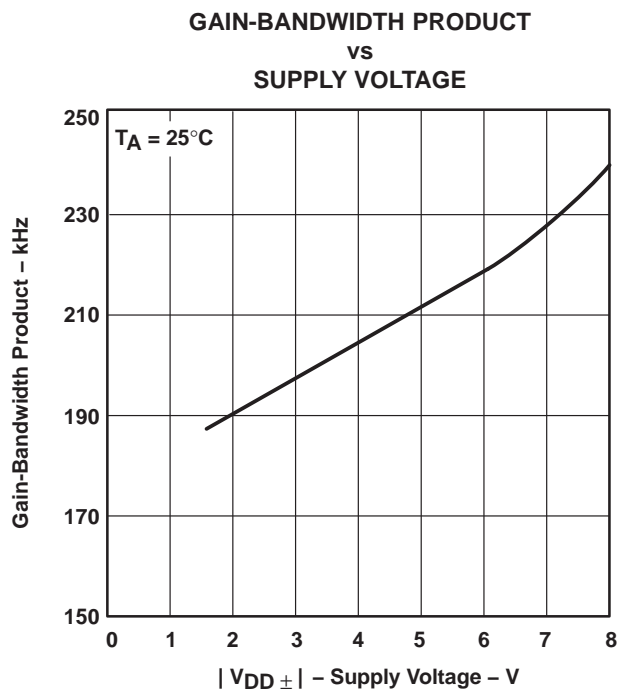


Figure 55

† 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.

TYPICAL CHARACTERISTICS

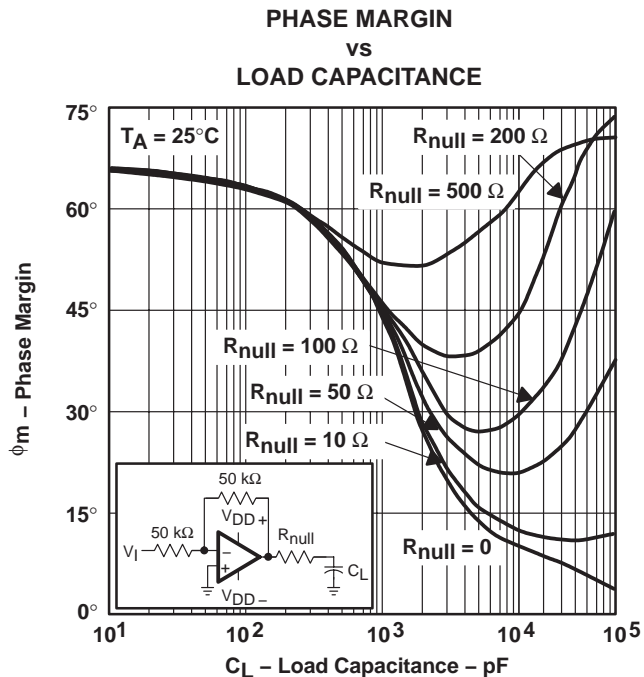


Figure 56

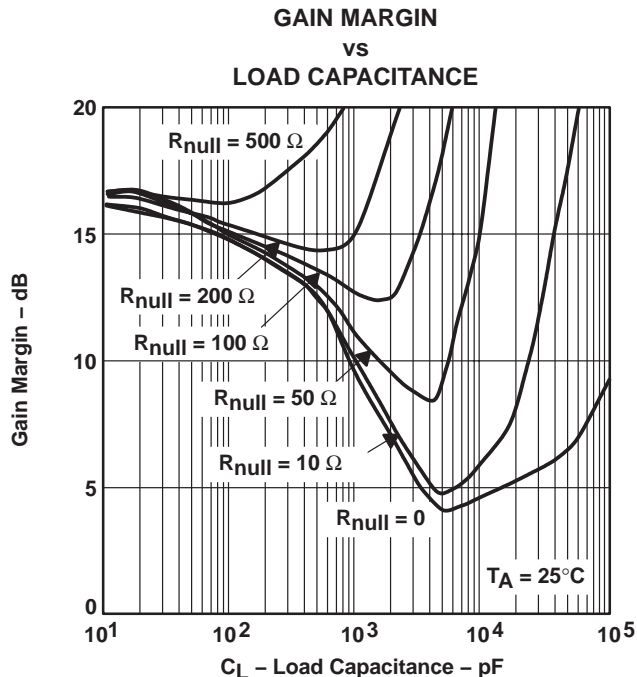


Figure 57

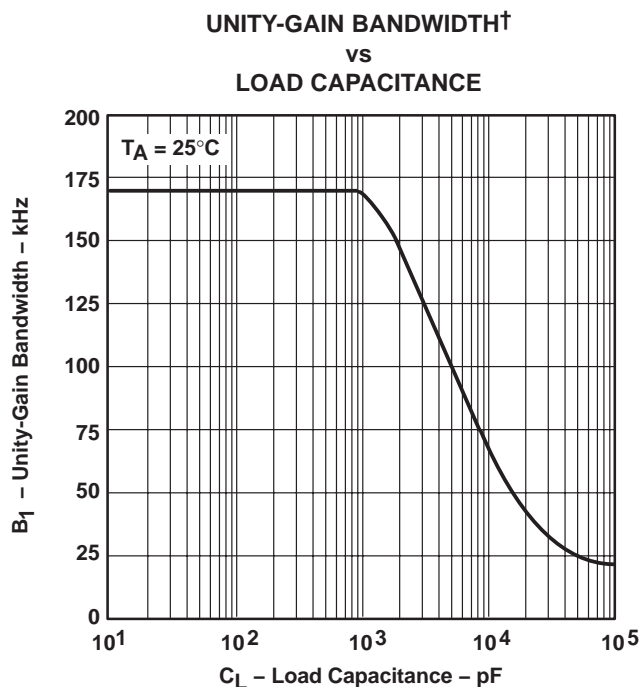


Figure 58

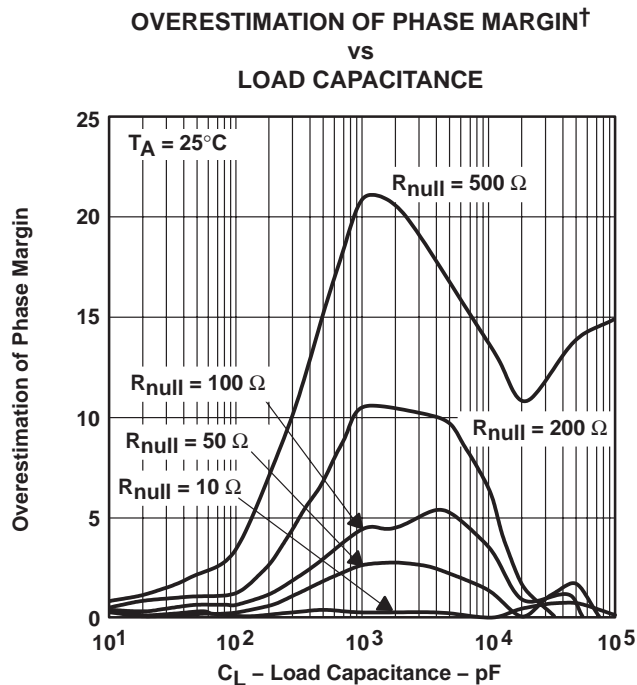


Figure 59

† 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.

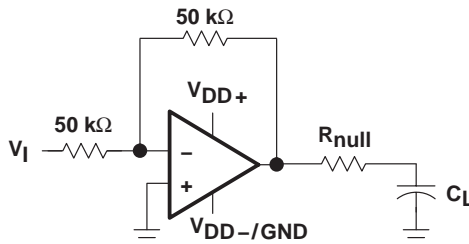


Figure 60. Series-Resistance Circuit

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

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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).

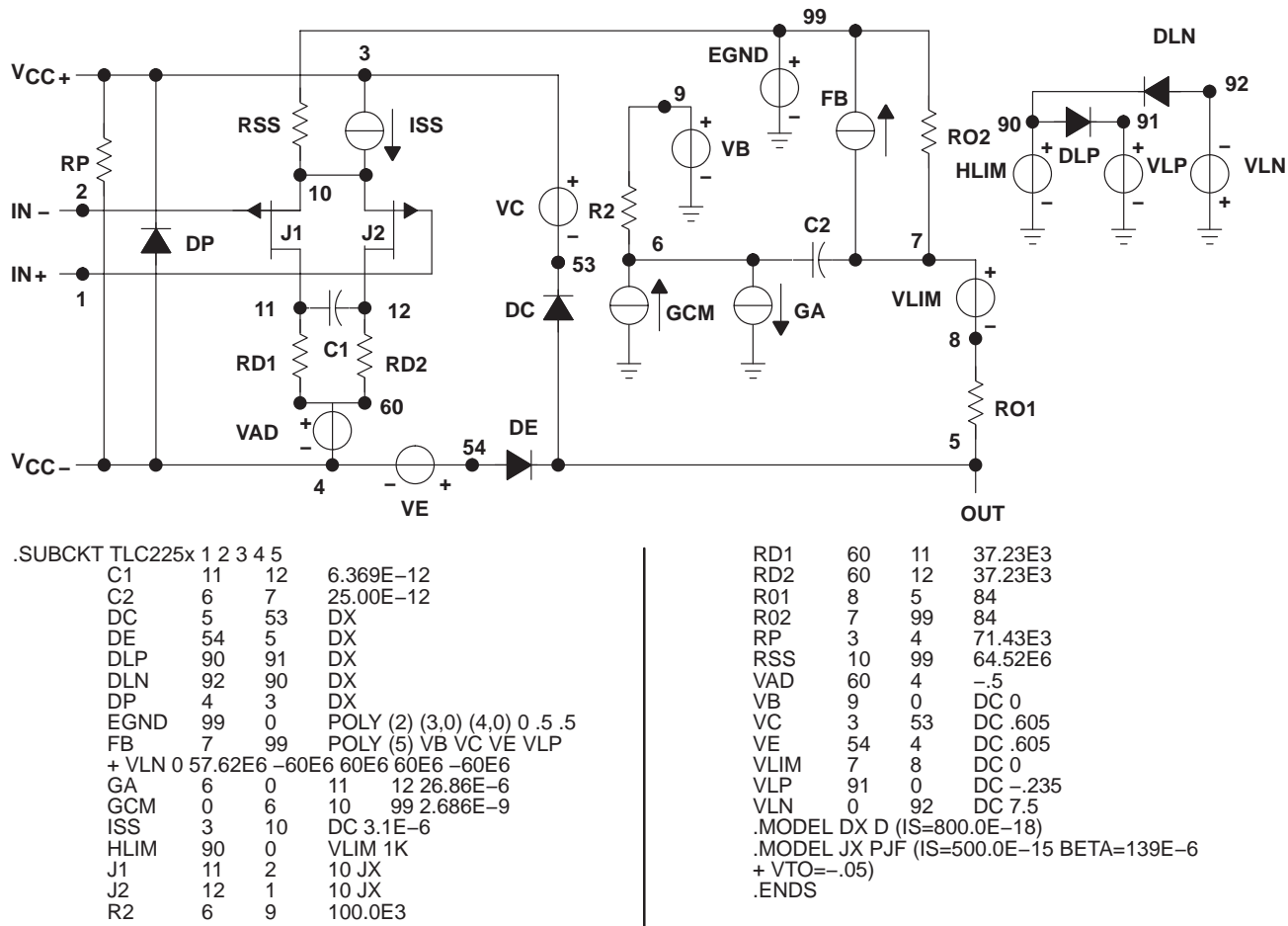


Figure 61. Boyle Macromodel and Subcircuit

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PACKAGING INFORMATION

Orderable Device	Status ⁽¹⁾	Package Type	Package Drawing	Pins	Package Qty	Eco Plan ⁽²⁾	Lead/Ball Finish	MSL Peak Temp ⁽³⁾
TLC2252AQDREP	ACTIVE	SOIC	D	8	2500	Pb-Free (RoHS)	CU NIPDAU	Level-2-250C-1 YEAR/ Level-1-235C-UNLIM
TLC2252QDREP	ACTIVE	SOIC	D	8	2500	Pb-Free (RoHS)	CU NIPDAU	Level-2-250C-1 YEAR/ Level-1-235C-UNLIM
TLC2254AQDREP	ACTIVE	SOIC	D	14	2500	Pb-Free (RoHS)	CU NIPDAU	Level-2-250C-1 YEAR/ Level-1-235C-UNLIM
TLC2254QDREP	ACTIVE	SOIC	D	14	2500	Pb-Free (RoHS)	CU NIPDAU	Level-2-250C-1 YEAR/ Level-1-235C-UNLIM
V62/04682-01XE	ACTIVE	SOIC	D	8	2500	Pb-Free (RoHS)	CU NIPDAU	Level-2-250C-1 YEAR/ Level-1-235C-UNLIM
V62/04682-02XE	ACTIVE	SOIC	D	8	2500	Pb-Free (RoHS)	CU NIPDAU	Level-2-250C-1 YEAR/ Level-1-235C-UNLIM
V62/04682-03YE	ACTIVE	SOIC	D	14	2500	Pb-Free (RoHS)	CU NIPDAU	Level-2-250C-1 YEAR/ Level-1-235C-UNLIM
V62/04682-04YE	ACTIVE	SOIC	D	14	2500	Pb-Free (RoHS)	CU NIPDAU	Level-2-250C-1 YEAR/ Level-1-235C-UNLIM

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

ACTIVE: Product device recommended for new designs.

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

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

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

OBSOLETE: TI has discontinued the production of the device.

⁽²⁾ Eco Plan - May not be currently available - please check <http://www.ti.com/productcontent> for the latest availability information and additional product content details.

None: Not yet available Lead (Pb-Free).

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

Green (RoHS & no Sb/Br): TI defines "Green" to mean "Pb-Free" and in addition, uses package materials that do not contain halogens, including bromine (Br) or antimony (Sb) above 0.1% of total product weight.

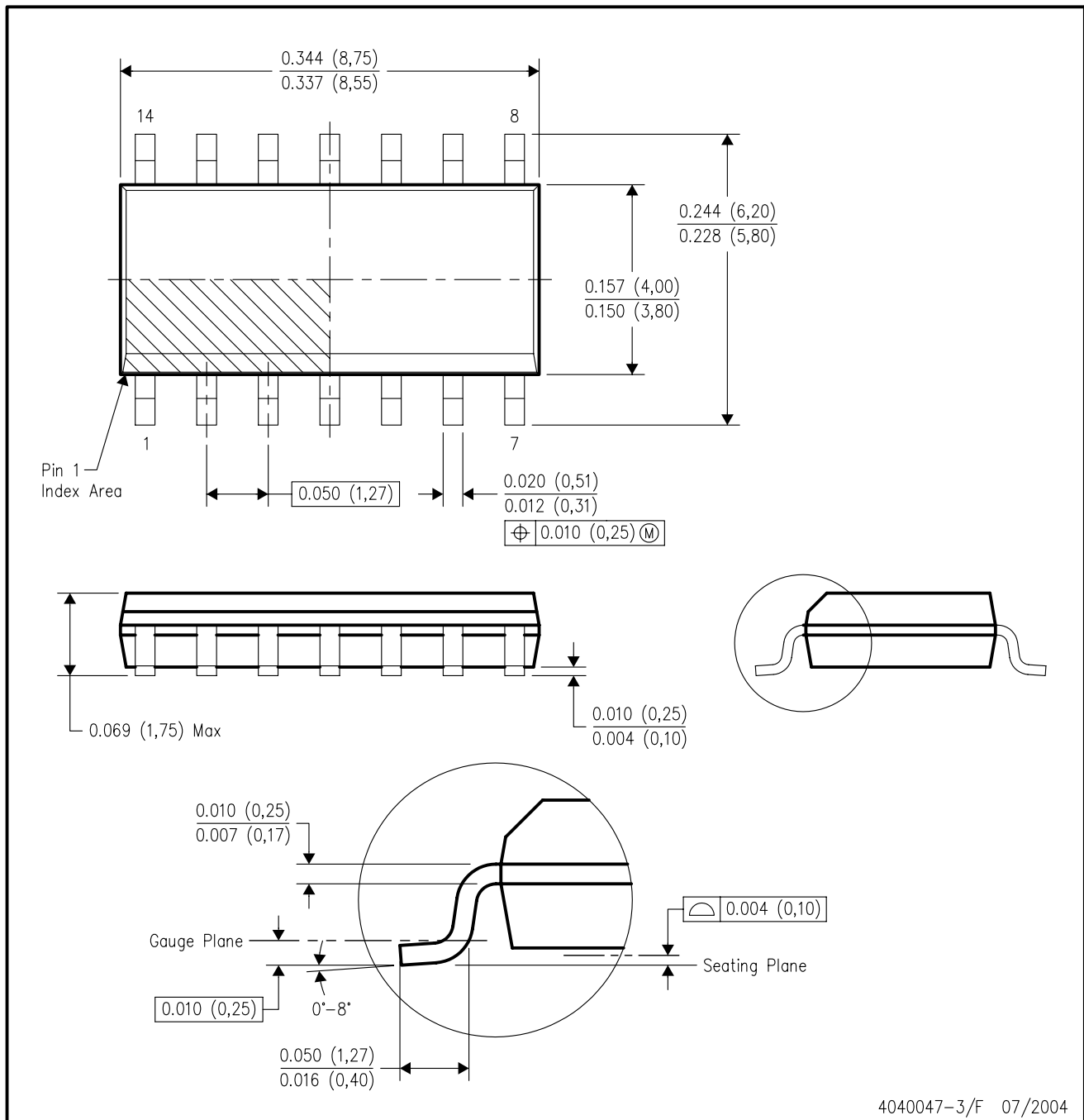
⁽³⁾ MSL, Peak Temp. -- The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

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D (R-PDSO-G14)

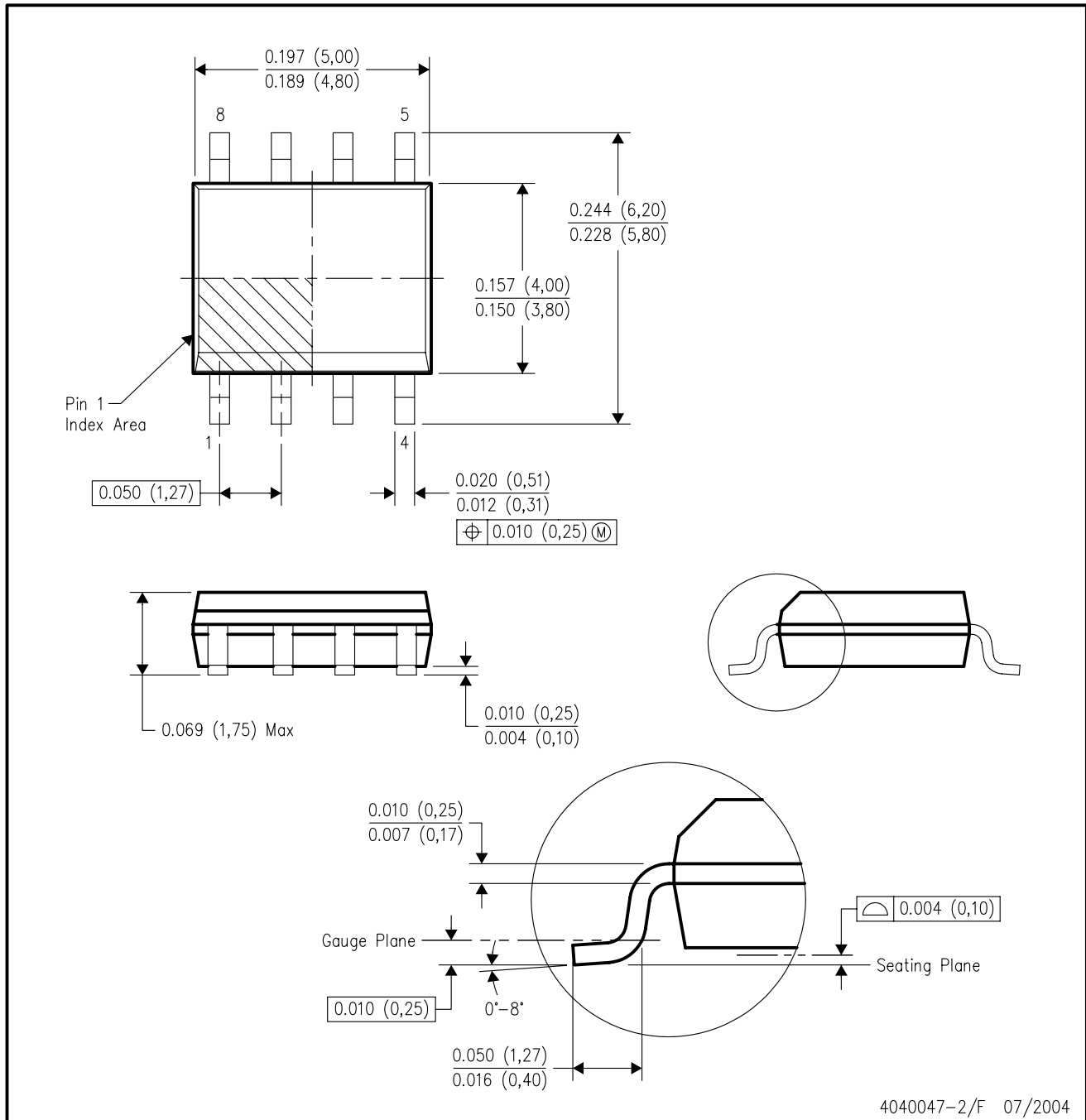
PLASTIC SMALL-OUTLINE PACKAGE



- NOTES:
- A. All linear dimensions are in inches (millimeters).
 - B. This drawing is subject to change without notice.
 - C. Body dimensions do not include mold flash or protrusion not to exceed 0.006 (0,15).
 - D. Falls within JEDEC MS-012 variation AB.

D (R-PDSO-G8)

PLASTIC SMALL-OUTLINE PACKAGE



- NOTES:
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