

TLV225x-EP, TLV225xA-EP Advanced LinCMOS™ RAIL-TO-RAIL VERY-LOW-POWER OPERATIONAL AMPLIFIERS

SGLS217B – NOVEMBER 2003 – REVISED JUNE 2006

- **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 (TLV2252/52A) and 100 V (TLV2254/54A) Using Machine Model (C = 200 pF, R = 0)**
- **Output Swing Includes Both Supply Rails**
- **Low Noise . . . 19 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 . . . 34 μA Per Channel (Typ)**
- **Common-Mode Input Voltage Range Includes Negative Rail**
- **Low Input Offset Voltage: 850 μV Max at $T_A = 25^{\circ}\text{C}$**
- **Wide Supply Voltage Range: 2.7 V to 16 V**
- **Macromodel Included**

† 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/ordering information

The TLV2252 and TLV2254 are dual and quadruple low-voltage operational amplifiers from Texas Instruments. Both devices exhibit rail-to-rail output performance for increased dynamic range in single- or split-supply applications. The TLV225x family consumes only 34 μA of supply current per channel. This micropower operation makes them good choices for battery-powered applications. This family is fully characterized at 3 V and 5 V and is optimized for low-voltage applications. The noise performance has been dramatically improved over previous generations of CMOS amplifiers. The TLV225x has a noise level of 19 nV/ $\sqrt{\text{Hz}}$ at 1kHz, four times lower than competitive micropower solutions.

The TLV225x, exhibiting high input impedance and low noise, are excellent for small-signal conditioning for high-impedance sources, such as piezoelectric transducers. Because of the micropower dissipation levels combined with 3-V operation, these devices work well in hand-held monitoring and remote-sensing applications. In addition, the rail-to-rail output feature with single or split supplies makes this family a great choice when interfacing with analog-to-digital converters (ADCs). For precision applications, the TLV225xA family is available and has a maximum input offset voltage of 850 μV .

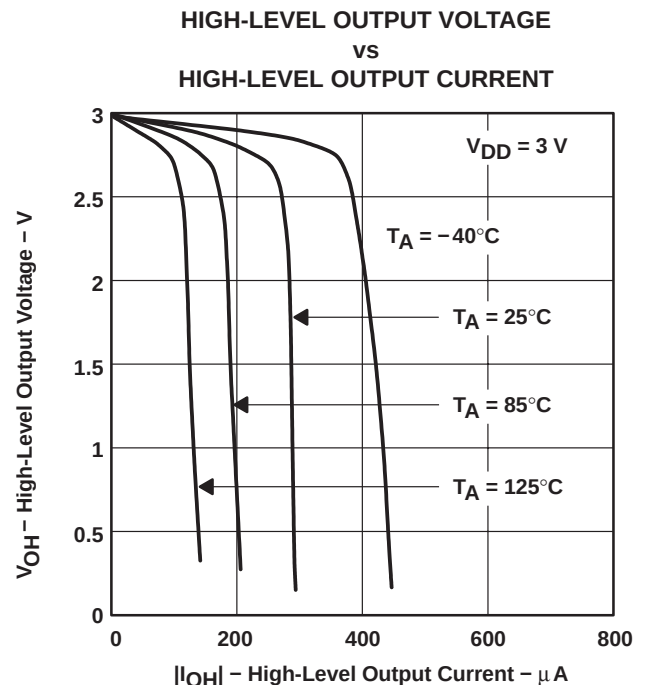


Figure 1



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.



POST OFFICE BOX 655303 • DALLAS, TEXAS 75265

Copyright © 2003 – 2006, Texas Instruments Incorporated

TLV225x-EP, TLV225xA-EP
Advanced LinCMOS™ RAIL-TO-RAIL
VERY-LOW-POWER OPERATIONAL AMPLIFIERS

SGLS217B – NOVEMBER 2003 – REVISED JUNE 2006

description/ordering information (continued)

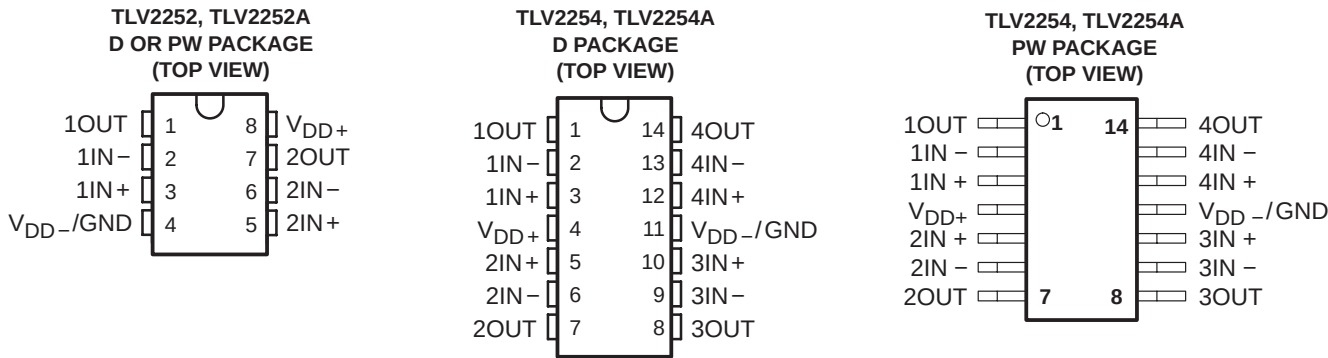
The TLV2252/2254 also make great upgrades to the TLV2322/2424 in standard designs. They offer increased output dynamic range, lower noise voltage, and lower input offset voltage. This enhanced feature set allows them to be used in a wider range of applications. For applications that require higher output drive and wider input voltage range, see the TLV2432 and TLV2442 devices. If your design requires single amplifiers, please see the TLV2211/21/31 family. These devices are single rail-to-rail operational amplifiers in the SOT-23 package. Small size and low power consumption make them ideal for high density, battery-powered equipment.

ORDERING INFORMATION

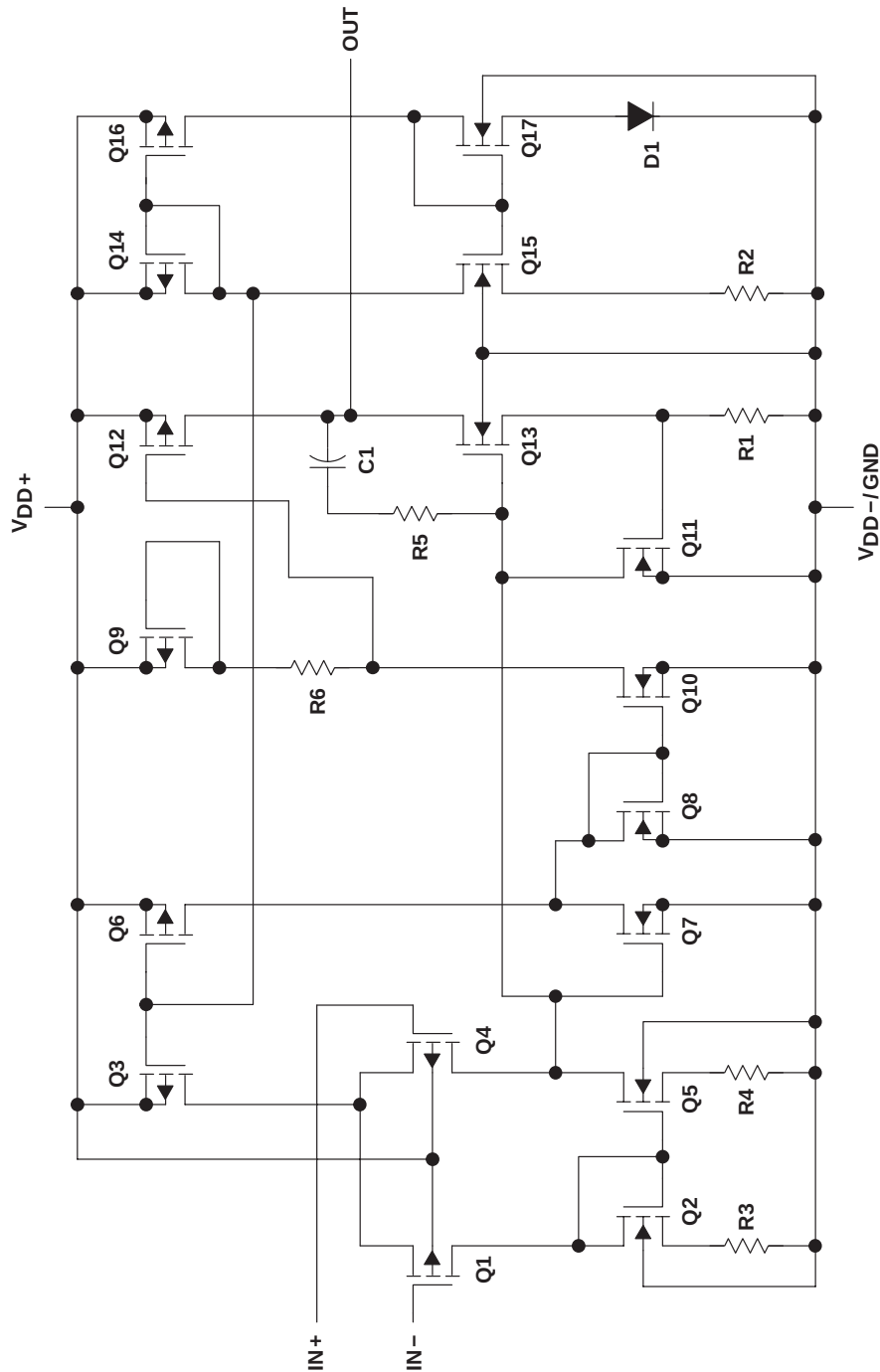
T _A	V _{IO} max AT 25°C	PACKAGE†		ORDERABLE PART NUMBER	TOP-SIDE MARKING
–40°C to 125°C	850 µV	SOIC (D)	Tape and reel	TLV2252AQDREP	2252AE
		TSSOP (PW)	Tape and reel	TLV2252AQPWREP‡	
	1500 µV	SOIC (D)	Tape and reel	TLV2252QDREP	2252EP
		TSSOP (PW)	Tape and reel	TLV2252QPWREP‡	
	850 µV	SOIC (D)	Tape and reel	TLV2254AQDREP	TLV2254AEP
		TSSOP (PW)	Tape and reel	TLV2254AQPWREP‡	
	1500 µV	SOIC (D)	Tape and reel	TLV2254QDREP	TLV2254EP
		TSSOP (PW)	Tape and reel	TLV2254QPWREP‡	

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

Product preview



equivalent schematic (each amplifier)



ACTUAL DEVICE COMPONENT COUNT†		
COMPONENT	TLV2252	TLV2254
Transistors	38	76
Resistors	30	56
Diodes	9	18
Capacitors	3	6

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

TLV225x-EP, TLV225xA-EP

Advanced LinCMOS™ RAIL-TO-RAIL

VERY LOW-POWER OPERATIONAL AMPLIFIERS

SGLS217B – NOVEMBER 2003 – REVISED JUNE 2006

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

Supply voltage, V_{DD} (see Note 1)	16 V
Differential input voltage, V_{ID} (see Note 2)	$\pm V_{DD}$
Input voltage range, V_I (any input, see Note 1)	$V_{DD-} - 0.3 \text{ V}$ to V_{DD+}
Input current, I_I (each input)	$\pm 5 \text{ mA}$
Output current, I_O	$\pm 50 \text{ mA}$
Total current into V_{DD+}	$\pm 50 \text{ mA}$
Total current out of V_{DD-}	$\pm 50 \text{ mA}$
Duration of short-circuit current (at or below 25°C) (see Note 3)	Unlimited
Continuous total power dissipation	See Dissipation Rating Table
Operating free-air temperature range, T_A	-40°C to 125°C
Storage temperature range, T_{stg}	-65°C to 150°C
Lead temperature 1,6 mm (1/16 in) from case for 10 s	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 V_{DD-} .
2. Differential voltages are at the noninverting input with respect to the inverting input. Excessive current flows when input is brought below $V_{DD-} - 0.3 \text{ V}$.
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 $T_A = 25^\circ\text{C}$	$T_A = 85^\circ\text{C}$ POWER RATING	$T_A = 125^\circ\text{C}$ POWER RATING
D-8	725 mW	5.8 mW/°C	377 mW	145 mW
D-14	950 mW	7.6 mW/°C	494 mW	190 mW
PW-8	525 mW	4.2 mW/°C	273 mW	105 mW
PW-14	700 mW	5.6 mW/°C	364 mW	140 mW

recommended operating conditions

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

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

TLV225x-EP, TLV225xA-EP
Advanced LinCMOS™ RAIL-TO-RAIL
VERY LOW-POWER OPERATIONAL AMPLIFIERS
 SGLS217B – NOVEMBER 2003 – REVISED JUNE 2006

TLV2252 electrical characteristics at specified free-air temperature, $V_{DD} = 3\text{ V}$ (unless otherwise noted)

PARAMETER	TEST CONDITIONS	$T_A^\dagger$	TLV2252			TLV2252A			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
V_{IO} Input offset voltage	$V_{DD} \pm \pm 1.5\text{ V}$, $V_{IC} = 0$, $V_O = 0$, $R_S = 50\ \Omega$	25°C		200	1500		200	850	μV
		Full range			1750			1000	
α_{VIO} Temperature coefficient of input offset voltage	$V_{DD} \pm \pm 1.5\text{ V}$, $V_{IC} = 0$, $V_O = 0$, $R_S = 50\ \Omega$	25°C to 85°C		0.5			0.5		$\mu\text{V}/^\circ\text{C}$
Input offset voltage long-term drift (see Note 4)	$V_{DD} \pm \pm 1.5\text{ V}$, $V_{IC} = 0$, $V_O = 0$, $R_S = 50\ \Omega$	25°C		0.003			0.003		$\mu\text{V}/\text{mo}$
I_{IO} Input offset current	$V_{DD} \pm \pm 1.5\text{ V}$, $V_{IC} = 0$, $V_O = 0$, $R_S = 50\ \Omega$	25°C		0.5	60		0.5	60	pA
		125°C			1000			1000	
I_{IB} Input bias current	$V_{DD} \pm \pm 1.5\text{ V}$, $V_{IC} = 0$, $V_O = 0$, $R_S = 50\ \Omega$	25°C		1	60		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 2	-0.3 to 2.2		0 to 2	-0.3 to 2.2		V
		Full range	0 to 1.7			0 to 1.7			
V_{OH} High-level output voltage	$I_{OH} = -20\ \mu\text{A}$	25°C		2.98			2.98		V
	$I_{OH} = -75\ \mu\text{A}$			2.9			2.9		
	$I_{OH} = -150\ \mu\text{A}$	Full range		2.8			2.8		
V_{OL} Low-level output voltage	$V_{IC} = 1.5\text{ V}$, $I_{OL} = 50\ \mu\text{A}$	25°C		10			10		mV
	$V_{IC} = 1.5\text{ V}$, $I_{OL} = 500\ \mu\text{A}$			100	150		100	150	
		Full range			165			165	
	$V_{IC} = 1.5\text{ V}$, $I_{OL} = 1\text{ mA}$	25°C		200	300		200	300	
		Full range			300			300	
A_{VD} Large-signal differential voltage amplification	$V_{IC} = 1.5\text{ V}$, $V_O = 1\text{ V to }2\text{ V}$	$R_L = 100\text{ k}\Omega^\ddagger$	25°C	100	250		100	250	V/mV
			Full range		10		10		
		$R_L = 1\text{ M}\Omega^\ddagger$	25°C		800		800		
$r_{i(d)}$ 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	$f = 10\text{ kHz}$	25°C		8			8		pF
z_o Closed-loop output impedance	$f = 25\text{ kHz}$, $A_V = 10$	25°C		220			220		Ω
CMRR Common-mode rejection ratio	$V_{IC} = 0\text{ to }1.7\text{ V}$, $V_O = 1.5\text{ V}$, $R_S = 50\ \Omega$	25°C	65	75		65	77		dB
		Full range		60			60		
k_{SVR} Supply-voltage rejection ratio ($\Delta V_{DD} / \Delta V_{IO}$)	$V_{DD} = 2.7\text{ V to }8\text{ V}$, $V_{IC} = V_{DD}/2$, No load	25°C	80	95		80	100		dB
		Full range		80			80		
I_{DD} Supply current	$V_O = 1.5\text{ V}$, No load	25°C		68	125		68	125	μA
		Full range			150			150	

† Full range is -40°C to 125°C .

‡ Referenced to 1.5 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.

TLV225x-EP, TLV225xA-EP
Advanced LinCMOS™ RAIL-TO-RAIL
VERY LOW-POWER OPERATIONAL AMPLIFIERS

SGLS217B – NOVEMBER 2003 – REVISED JUNE 2006

TLV2252 operating characteristics at specified free-air temperature, $V_{DD} = 3\text{ V}$

PARAMETER	TEST CONDITIONS	T_A †	TLV2252			TLV2252A			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
SR Slew rate at unity gain	$V_O = 0.8\text{ V to }1.4\text{ V}, R_L = 100\text{ k}\Omega^\ddagger, C_L = 100\text{ pF}^\ddagger$	25°C	0.07	0.1		0.07	0.1		V/ μs
		Full range	0.05			0.05			
V_n Equivalent input noise voltage	$f = 10\text{ Hz}$	25°C		35			35		nV/ $\sqrt{\text{Hz}}$
	$f = 1\text{ kHz}$			19			19		
$V_{N(PP)}$ Peak-to-peak equivalent input noise voltage	$f = 0.1\text{ Hz to }1\text{ Hz}$	25°C		0.6			0.6		μV
	$f = 0.1\text{ Hz to }10\text{ Hz}$			1.1			1.1		
I_n Equivalent input noise current		25°C		0.6			0.6		fA/ $\sqrt{\text{Hz}}$
Gain-bandwidth product	$f = 1\text{ kHz}, R_L = 50\text{ k}\Omega^\ddagger, C_L = 100\text{ pF}^\ddagger$	25°C		0.187			0.187		MHz
B_{OM} Maximum output-swing bandwidth	$V_{O(PP)} = 1\text{ V}, R_L = 50\text{ k}\Omega^\ddagger, A_V = 1, C_L = 100\text{ pF}^\ddagger$	25°C		60			60		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	$R_L = 50\text{ k}\Omega^\ddagger, C_L = 100\text{ pF}^\ddagger$	25°C		15			15		dB

† Full range is -40°C to 125°C.

‡ Referenced to 1.5 V

TLV225x-EP, TLV225xA-EP
Advanced LinCMOS™ RAIL-TO-RAIL
VERY LOW-POWER OPERATIONAL AMPLIFIERS
 SGLS217B – NOVEMBER 2003 – REVISED JUNE 2006

TLV2252 electrical characteristics at specified free-air temperature, $V_{DD} = 5\text{ V}$ (unless otherwise noted)

PARAMETER	TEST CONDITIONS	$T_A^\dagger$	TLV2252			TLV2252A			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
V_{IO} Input offset voltage	$V_{DD} = \pm 2.5\text{ V}$, $V_O = 0$, $V_{IC} = 0$, $R_S = 50\ \Omega$	25°C		200	1500		200	850	μV
		Full range			1750			1000	
α_{VIO} Temperature coefficient of input offset voltage	$V_{DD} = \pm 2.5\text{ V}$, $V_O = 0$, $V_{IC} = 0$, $R_S = 50\ \Omega$	25°C to 85°C		0.5			0.5		$\mu\text{V}/^\circ\text{C}$
Input offset voltage long-term drift (see Note 4)	$V_{DD} = \pm 2.5\text{ V}$, $V_O = 0$, $V_{IC} = 0$, $R_S = 50\ \Omega$	25°C		0.003			0.003		$\mu\text{V}/\text{mo}$
I_{IO} Input offset current	$V_{DD} = \pm 2.5\text{ V}$, $V_O = 0$, $V_{IC} = 0$, $R_S = 50\ \Omega$	25°C		0.5	60		0.5	60	pA
		125°C			1000			1000	
I_{IB} Input bias current	$V_{DD} = \pm 2.5\text{ V}$, $V_O = 0$, $V_{IC} = 0$, $R_S = 50\ \Omega$	25°C		1	60		1	60	pA
		125°C			1000			1000	
V_{ICR} Common-mode input voltage range	$ V_{IO} \leq 5\text{ mV}$, $R_S = 50\ \Omega$	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
	$I_{OH} = -75\ \mu\text{A}$			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
	$V_{IC} = 2.5\text{ V}$, $I_{OL} = 500\ \mu\text{A}$			0.09	0.15		0.09	0.15	
		Full range			0.15			0.15	
	$V_{IC} = 2.5\text{ V}$, $I_{OL} = 1\text{ mA}$	25°C		0.2	0.3		0.2	0.3	
		Full range			0.3			0.3	
A_{VD} Large-signal differential voltage amplification	$V_{IC} = 2.5\text{ V}$, $V_O = 1\text{ V to }4\text{ V}$	$R_L = 100\text{ k}\Omega^\ddagger$	25°C	100	350		100	350	V/mV
			Full range	10			10		
		$R_L = 1\text{ M}\Omega^\ddagger$	25°C		1700			1700	
$r_{i(d)}$ 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	$f = 10\text{ kHz}$	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 ($\Delta V_{DD}/\Delta V_{IO}$)	$V_{DD} = 4.4\text{ V to }8\text{ V}$, $V_{IC} = V_{DD}/2$, No load	25°C		80	95		80	95	dB
		Full range		80			80		

† Full range is -40°C to 125°C .

‡ 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.

TLV225x-EP, TLV225xA-EP
Advanced LinCMOS™ RAIL-TO-RAIL
VERY LOW-POWER OPERATIONAL AMPLIFIERS

SGLS217B – NOVEMBER 2003 – REVISED JUNE 2006

TLV2252 electrical characteristics at specified free-air temperature, $V_{DD} = 5\text{ V}$ (unless otherwise noted) (continued)

PARAMETER	TEST CONDITIONS	$T_A^\dagger$	TLV2252			TLV2252A			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
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 level part.

TLV2252 operating characteristics at specified free-air temperature, $V_{DD} = 5\text{ V}$

PARAMETER		TEST CONDITIONS		T _A [†]	TLV2252			TLV2252A			UNIT
					MIN	TYP	MAX	MIN	TYP	MAX	
SR	Slew rate at unity gain	V _O = 1.25 V to 2.75 V, R _L = 100 kΩ [‡] , C _L = 100 pF [‡]		25°C	0.07	0.12		0.07	0.12		V/μs
				Full range	0.05			0.05			
V _n	Equivalent input noise voltage	f = 10 Hz		25°C	36			36			nV/√Hz
		f = 1 kHz		25°C	19			19			
V _{N(PP)}	Peak-to-peak equivalent input noise voltage	f = 0.1 Hz to 1 Hz		25°C	0.7			0.7			μV
		f = 0.1 Hz to 10 Hz		25°C	1.1			1.1			
I _n	Equivalent input noise current			25°C	0.6			0.6			fA/√Hz
THD+N	Total harmonic distortion plus noise	V _O = 0.5 V to 2.5 V, f = 20 kHz, R _L = 50 kΩ [‡]	A _V = 1	25°C	0.2%			0.2%			
			A _V = 10		1%			1%			
Gain-bandwidth product		f = 50 kHz, C _L = 100 pF [‡]	R _L = 50 kΩ [‡] ,	25°C	0.2			0.2			MHz
B _{OM}	Maximum output-swing bandwidth	V _{O(PP)} = 2 V, R _L = 50 kΩ [‡] ,	A _V = 1, C _L = 100 pF [‡]	25°C	30			30			kHz
φ _m	Phase margin at unity gain	R _L = 50 kΩ [‡] ,	C _L = 100 pF [‡]	25°C	63°			63°			
Gain margin		R _L = 50 kΩ [‡] ,	C _L = 100 pF [‡]	25°C	15			15			dB

† Full range is -40°C to 125°C .

‡ Referenced to 2.5 V



TLV225x-EP, TLV225xA-EP
Advanced LinCMOS™ RAIL-TO-RAIL
VERY LOW-POWER OPERATIONAL AMPLIFIERS

SGLS217B – NOVEMBER 2003 – REVISED JUNE 2006

TLV2254 electrical characteristics at specified free-air temperature, $V_{DD} = 3\text{ V}$ (unless otherwise noted)

PARAMETER		TEST CONDITIONS		T _A [†]	TLV2254		TLV2254A		UNIT
					MIN	TYP	MAX	MIN	
V _{IO}	Input offset voltage	V _{DD} ± = ±1.5 V, V _O = 0,	V _{IC} = 0, R _S = 50 Ω	25°C	200	1500	200	850	μV
				Full range		1750		1000	
αV _{IO}	Temperature coefficient of input offset voltage	V _{DD} ± = ±1.5 V, V _O = 0,	V _{IC} = 0, R _S = 50 Ω	25°C to 125°C	0.5		0.5		μV/°C
	Input offset voltage long-term drift (see Note 4)	V _{DD} ± = ±1.5 V, V _O = 0,	V _{IC} = 0, R _S = 50 Ω	25°C	0.003		0.003		μV/mo
I _{IO}	Input offset current	V _{DD} ± = ±1.5 V, V _O = 0,	V _{IC} = 0, R _S = 50 Ω	25°C	0.5	60	0.5	60	pA
				125°C	1000		1000		
I _{IB}	Input bias current	V _{DD} ± = ±1.5 V, V _O = 0,	V _{IC} = 0, R _S = 50 Ω	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 2	−0.3 to 2.2	0 to 2	−0.3 to 2.2	V
				Full range	0 to 1.7		0 to 1.7		
V _{OH}	High-level output voltage	I _{OH} = −20 μA		25°C	2.98		2.98		V
		I _{OH} = −75 μA			2.9		2.9		
				Full range	2.8		2.8		
		I _{OH} = −150 μA		25°C	2.8		2.8		
V _{OL}	Low-level output voltage	V _{IC} = 1.5 V, I _{OL} = 50 μA		25°C	10		10		mV
		V _{IC} = 1.5 V, I _{OL} = 500 μA			100	150	100	150	
				Full range	165		165		
		V _{IC} = 1.5 V, I _{OL} = 1 mA		25°C	200	300	200	300	
				Full range	300		300		
A _{VD}	Large-signal differential voltage amplification	V _{IC} = 1.5 V, V _O = 1 V to 2 V	R _L = 100 kΩ [‡] R _L = 1 MΩ [‡]	25°C	100	225	100	225	V/mV
				Full range	10		10		
				25°C	800		800		
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		25°C	8		8		pF
z _o	Closed-loop output impedance	f = 25 kHz,	A _V = 10	25°C	220		220		Ω
CMRR	Common-mode rejection ratio	V _{IC} = 0 to 1.7 V, V _O = 1.5 V, R _S = 50 Ω		25°C	65	75	65	77	dB
				Full range	60		60		
k _{SVR}	Supply-voltage rejection ratio (ΔV _{DD} /ΔV _{IO})	V _{DD} = 2.7 V to 8 V, V _{IC} = V _{DD} /2, No load		25°C	80	95	80	100	dB
				Full range	80		80		

† Full range is -40°C to 125°C .

‡ Referenced to 1.5 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.

TLV225x-EP, TLV225xA-EP
Advanced LinCMOS™ RAIL-TO-RAIL
VERY LOW-POWER OPERATIONAL AMPLIFIERS

SGLS217B – NOVEMBER 2003 – REVISED JUNE 2006

TLV2254 electrical characteristics at specified free-air temperature, $V_{DD} = 3\text{ V}$ (unless otherwise noted) (continued)

PARAMETER	TEST CONDITIONS	$T_A^\dagger$	TLV2254			TLV2254A			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
I_{DD} Supply current (four amplifiers)	$V_O = 1.5\text{ V}$, No load	25°C		135	250		135	250	μA
		Full range			300			300	

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

TLV2254 operating characteristics at specified free-air temperature, $V_{DD} = 3\text{ V}$

PARAMETER	TEST CONDITIONS	$T_A^\dagger$	TLV2254			TLV2254A			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
SR Slew rate at unity gain	$V_O = 0.5\text{ V}$ to 1.7 V , $R_L = 100\text{ k}\Omega^\ddagger$, $C_L = 100\text{ pF}^\ddagger$	25°C	0.07	0.1		0.07	0.1		$\text{V}/\mu\text{s}$
		Full range	0.05			0.05			
V_n Equivalent input noise voltage	$f = 10\text{ Hz}$	25°C		35			35		$\text{nV}/\sqrt{\text{Hz}}$
	$f = 1\text{ kHz}$			19			19		
$V_{N(PP)}$ Peak-to-peak equivalent input noise voltage	$f = 0.1\text{ Hz}$ to 1 Hz	25°C		0.6			0.6		μV
	$f = 0.1\text{ Hz}$ to 10 Hz			1.1			1.1		
I_n Equivalent input noise current		25°C		0.6			0.6		$\text{fA}/\sqrt{\text{Hz}}$
Gain-bandwidth product	$f = 1\text{ kHz}$, $R_L = 50\text{ k}\Omega^\ddagger$, $C_L = 100\text{ pF}^\ddagger$	25°C		0.187			0.187		MHz
B_{OM} Maximum output-swing bandwidth	$V_{O(PP)} = 1\text{ V}$, $A_V = 1$, $R_L = 50\text{ k}\Omega^\ddagger$, $C_L = 100\text{ pF}^\ddagger$	25°C		60			60		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	$R_L = 50\text{ k}\Omega^\ddagger$, $C_L = 100\text{ pF}^\ddagger$	25°C		15			15		dB

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

‡ Referenced to 1.5 V

TLV225x-EP, TLV225xA-EP
Advanced LinCMOS™ RAIL-TO-RAIL
VERY LOW-POWER OPERATIONAL AMPLIFIERS
 SGLS217B – NOVEMBER 2003 – REVISED JUNE 2006

TLV2254 electrical characteristics at specified free-air temperature, $V_{DD} = 5\text{ V}$ (unless otherwise noted)

PARAMETER	TEST CONDITIONS	$T_A^\dagger$	TLV2254			TLV2254A			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
V_{IO} Input offset voltage	$V_{DD} = \pm 2.5\text{ V}$, $V_{IC} = 0$, $V_O = 0$, $R_S = 50\ \Omega$	25°C		200	1500		200	850	μV
		Full range			1750			1000	
α_{VIO} Temperature coefficient of input offset voltage	$V_{DD} = \pm 2.5\text{ V}$, $V_{IC} = 0$, $V_O = 0$, $R_S = 50\ \Omega$	25°C to 125°C		0.5			0.5		$\mu\text{V}/^\circ\text{C}$
Input offset voltage long-term drift (see Note 4)	$V_{DD} = \pm 2.5\text{ V}$, $V_{IC} = 0$, $V_O = 0$, $R_S = 50\ \Omega$	25°C		0.003			0.003		$\mu\text{V}/\text{mo}$
I_{IO} Input offset current	$V_{DD} = \pm 2.5\text{ V}$, $V_{IC} = 0$, $V_O = 0$, $R_S = 50\ \Omega$	25°C		0.5	60		0.5	60	pA
		125°C			1000			1000	
I_{IB} Input bias current	$V_{DD} = \pm 2.5\text{ V}$, $V_{IC} = 0$, $V_O = 0$, $R_S = 50\ \Omega$	25°C		1	60		1	60	pA
		125°C			1000			1000	
V_{ICR} Common-mode input voltage range	$ V_{IO} \leq 5\text{ mV}$, $R_S = 50\ \Omega$	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
	$I_{OH} = -75\ \mu\text{A}$			4.9	4.94		4.9	4.94	
	$I_{OH} = -150\ \mu\text{A}$	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
	$V_{IC} = 2.5\text{ V}$, $I_{OL} = 500\ \mu\text{A}$			0.09	0.15		0.09	0.15	
		Full range			0.15			0.15	
	$V_{IC} = 2.5\text{ V}$, $I_{OL} = 1\text{ mA}$	25°C		0.2	0.3		0.2	0.3	
		Full range			0.3			0.3	
A_{VD} Large-signal differential voltage amplification	$V_{IC} = 2.5\text{ V}$, $V_O = 1\text{ V to }4\text{ V}$	$R_L = 100\text{ k}\Omega^\ddagger$	25°C	100	350		100	350	V/mV
			Full range	10			10		
		$R_L = 1\text{ M}\Omega^\ddagger$	25°C		1700			1700	
$r_{i(d)}$ 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	$f = 10\text{ kHz}$	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 ($\Delta V_{DD}/\Delta V_{IO}$)	$V_{DD} = 4.4\text{ V to }8\text{ V}$, $V_{IC} = V_{DD}/2$, No load	25°C		80	95		80	95	dB
		Full range		80			80		

† Full range is -40°C to 125°C .

‡ 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.

TLV225x-EP, TLV225xA-EP
Advanced LinCMOS™ RAIL-TO-RAIL
VERY LOW-POWER OPERATIONAL AMPLIFIERS

SGLS217B – NOVEMBER 2003 – REVISED JUNE 2006

TLV2254 electrical characteristics at specified free-air temperature, $V_{DD} = 5\text{ V}$ (unless otherwise noted) (continued)

PARAMETER	TEST CONDITIONS	$T_A^\dagger$	TLV2254			TLV2254A			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
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 .

TLV2254 operating characteristics at specified free-air temperature, $V_{DD} = 5\text{ V}$

PARAMETER	TEST CONDITIONS	$T_A^\dagger$	TLV2254			TLV2254A			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
SR Slew rate at unity gain	$V_O = 0.5\text{ V}$ to 3.5 V , $R_L = 100\text{ k}\Omega^\ddagger$, $C_L = 100\text{ pF}^\ddagger$	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	$f = 10\text{ Hz}$ $f = 1\text{ kHz}$	25°C		36			36		$\text{nV}/\sqrt{\text{Hz}}$
				19			19		
$V_{N(PP)}$ Peak-to-peak equivalent input noise voltage	$f = 0.1\text{ Hz}$ to 1 Hz $f = 0.1\text{ Hz}$ to 10 Hz	25°C		0.7			0.7		μV
				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	$V_O = 0.5\text{ V}$ to 2.5 V , $f = 20\text{ kHz}$, $R_L = 50\text{ k}\Omega^\ddagger$	25°C		0.2%			0.2%		
				1%			1%		
Gain-bandwidth product	$f = 50\text{ kHz}$, $R_L = 50\text{ k}\Omega^\ddagger$, $C_L = 100\text{ pF}^\ddagger$	25°C		0.2			0.2		MHz
B_{OM} Maximum output-swinging 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	$R_L = 50\text{ k}\Omega^\ddagger$, $C_L = 100\text{ pF}^\ddagger$	25°C		15			15		dB

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

‡ Referenced to 2.5 V

TYPICAL CHARACTERISTICS

Table of Graphs

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

TLV225x-EP, TLV225xA-EP
Advanced LinCMOS™ RAIL-TO-RAIL
VERY LOW-POWER OPERATIONAL AMPLIFIERS

SGLS217B – NOVEMBER 2003 – REVISED JUNE 2006

TYPICAL CHARACTERISTICS

**DISTRIBUTION OF TLV2252
INPUT OFFSET VOLTAGE**

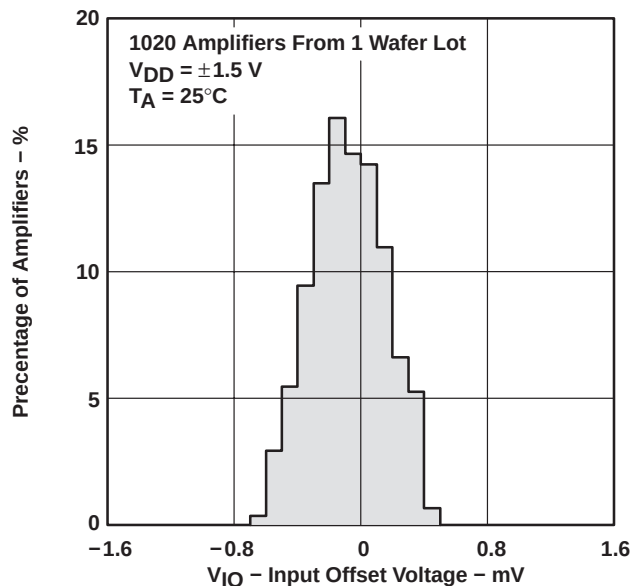


Figure 2

**DISTRIBUTION OF TLV2252
INPUT OFFSET VOLTAGE**

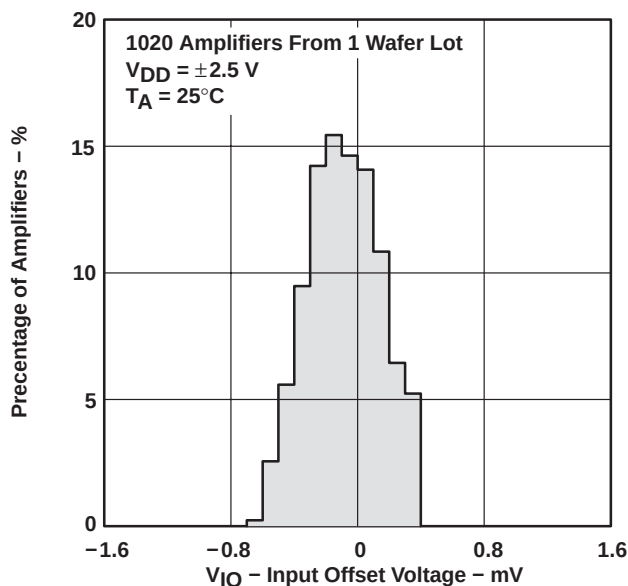


Figure 3

**DISTRIBUTION OF TLV2254
INPUT OFFSET VOLTAGE**

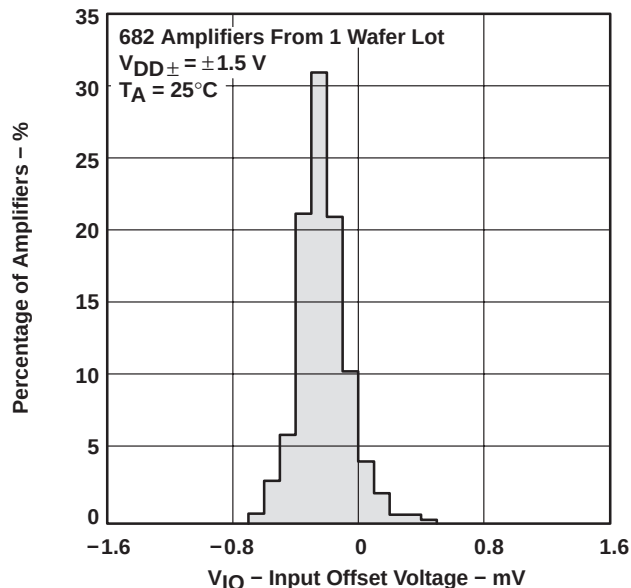


Figure 4

**DISTRIBUTION OF TLV2254
INPUT OFFSET VOLTAGE**

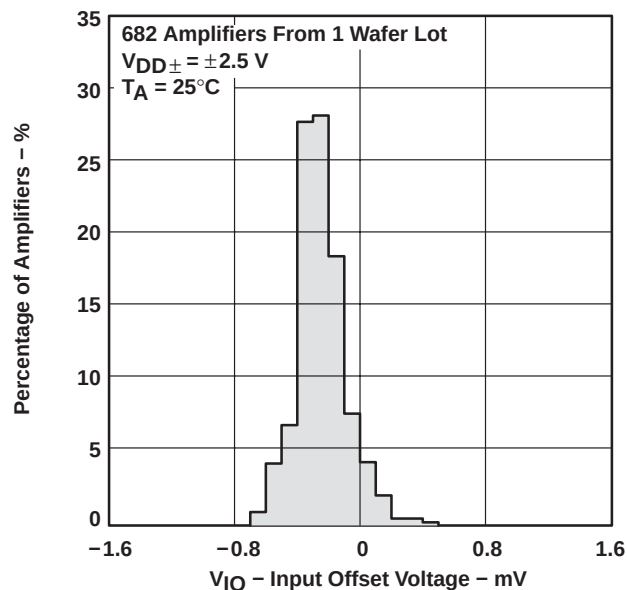


Figure 5

TYPICAL CHARACTERISTICS

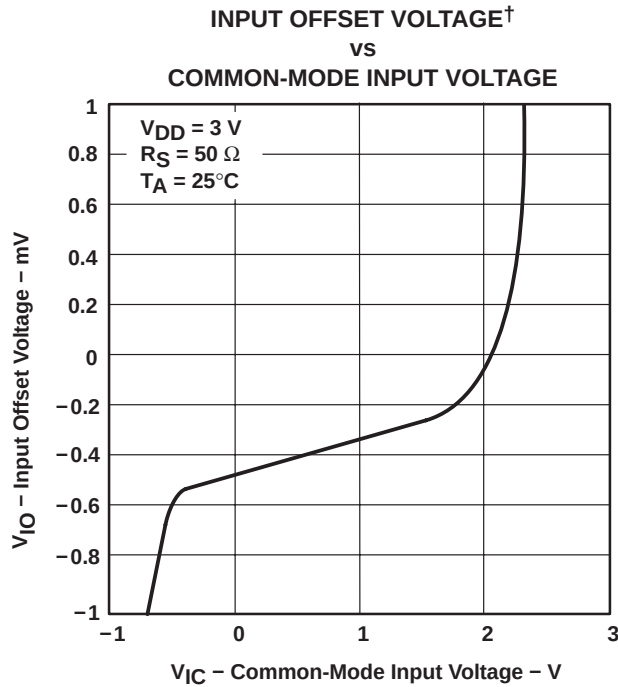


Figure 6

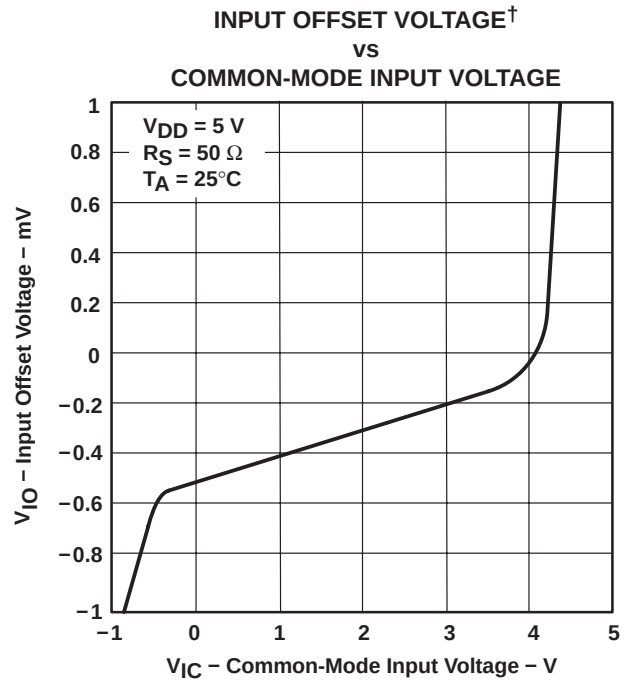


Figure 7

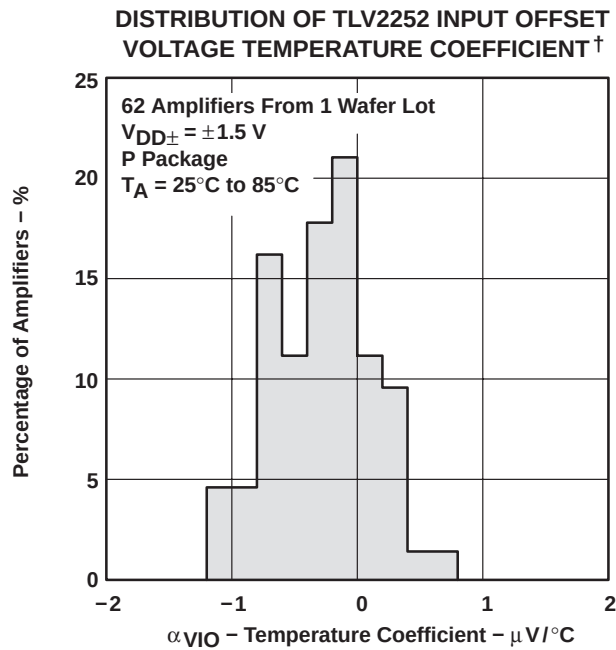


Figure 8

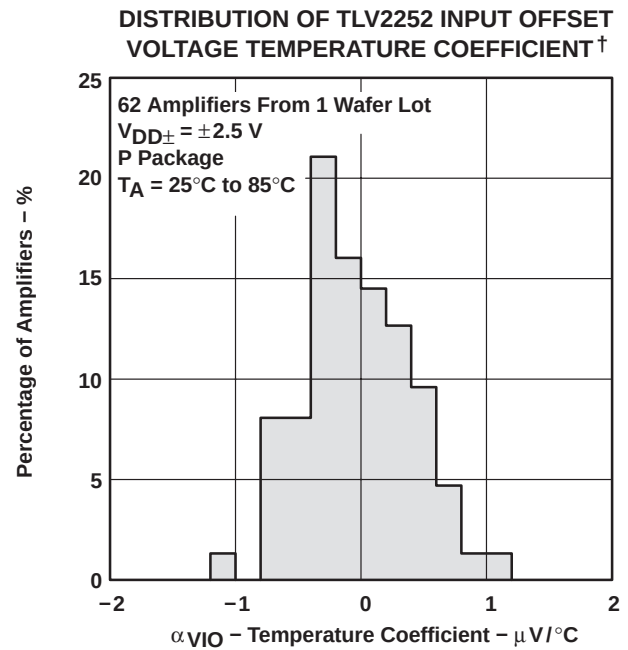


Figure 9

[†] For all curves where $V_{DD} = 5\text{ V}$, all loads are referenced to 2.5 V. For all curves where $V_{DD} = 3\text{ V}$, all loads are referenced to 1.5 V.

TLV225x-EP, TLV225xA-EP

Advanced LinCMOS™ RAIL-TO-RAIL

VERY LOW-POWER OPERATIONAL AMPLIFIERS

SGLS217B – NOVEMBER 2003 – REVISED JUNE 2006

TYPICAL CHARACTERISTICS

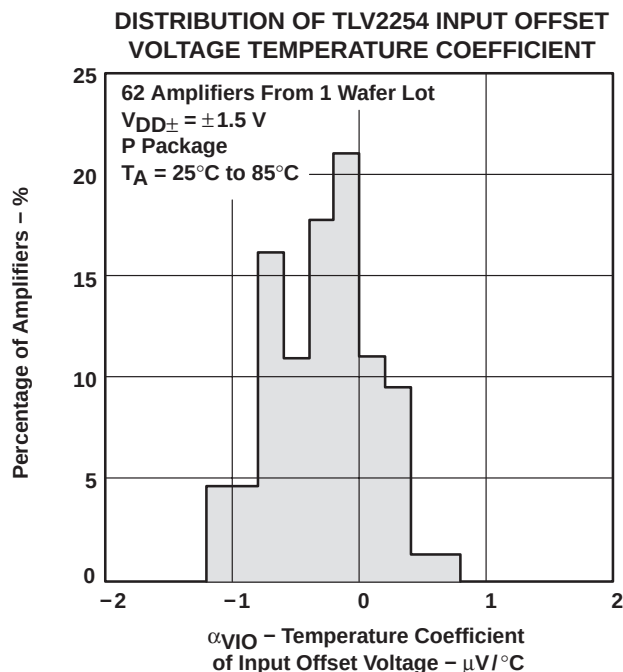


Figure 10

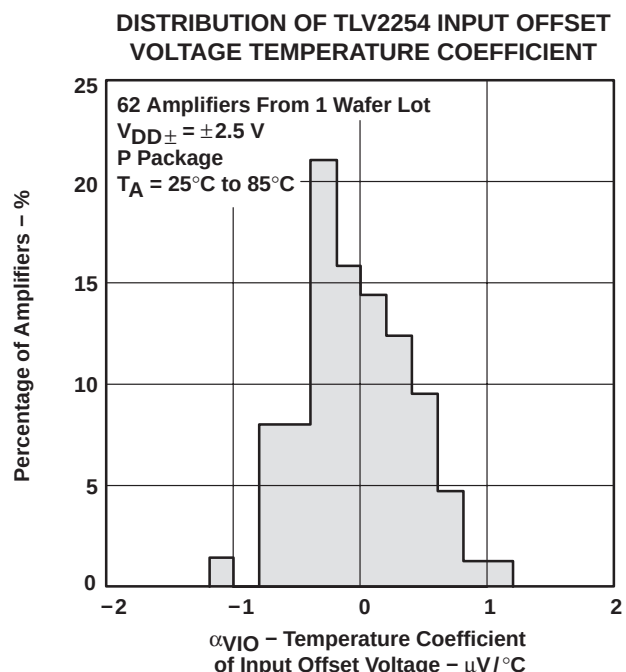


Figure 11

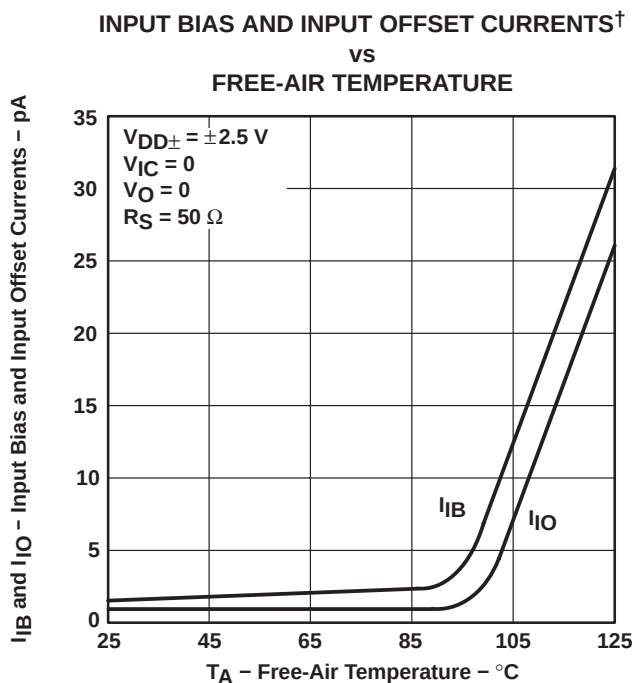


Figure 12

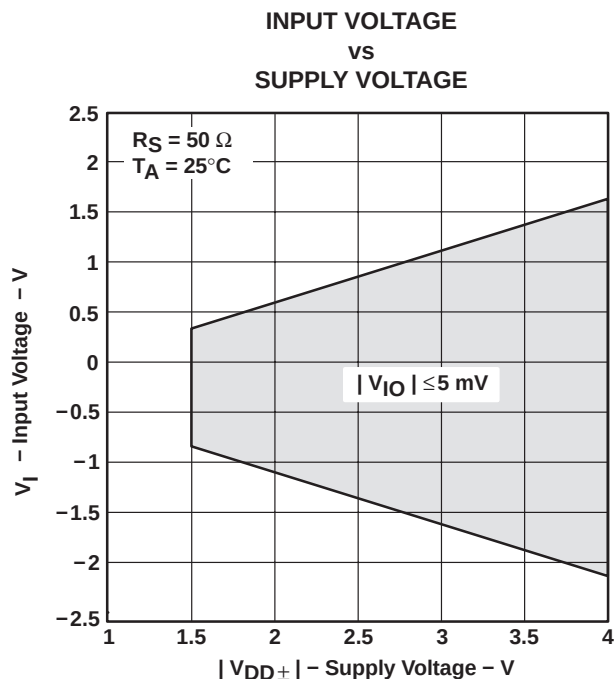
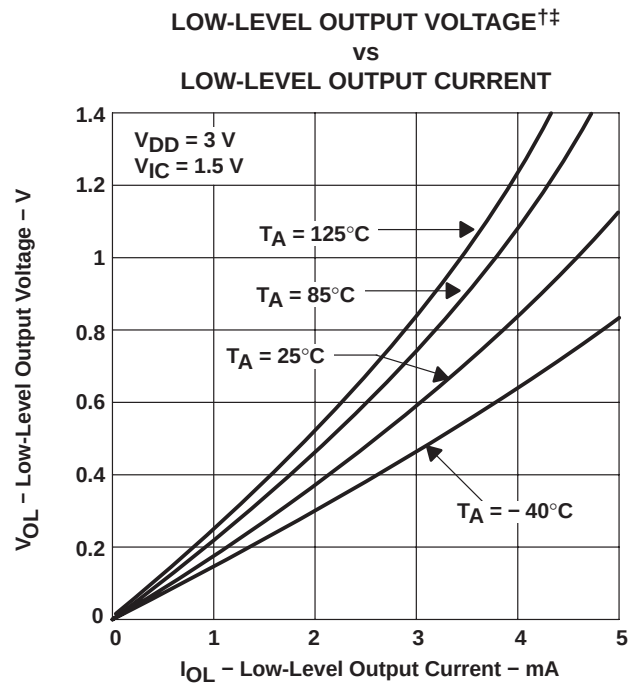
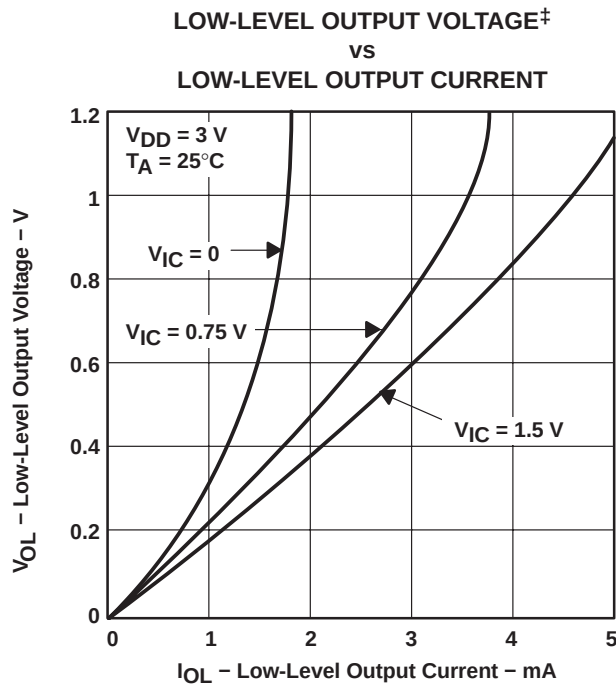
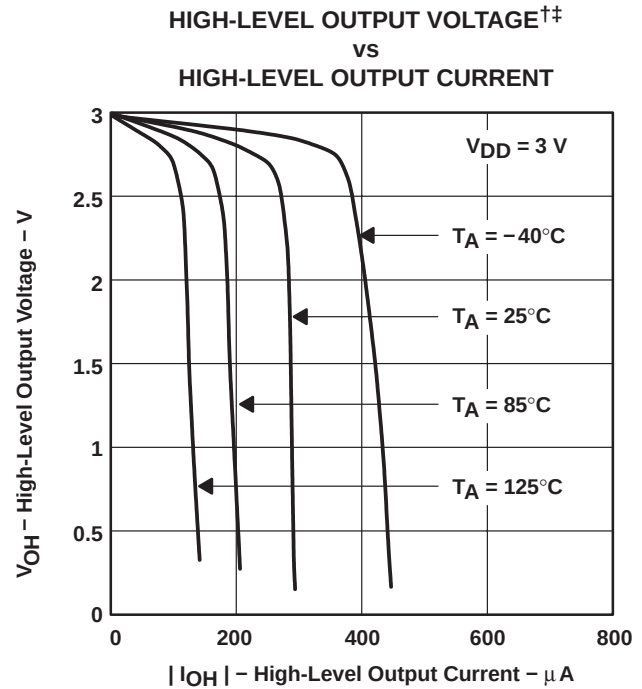
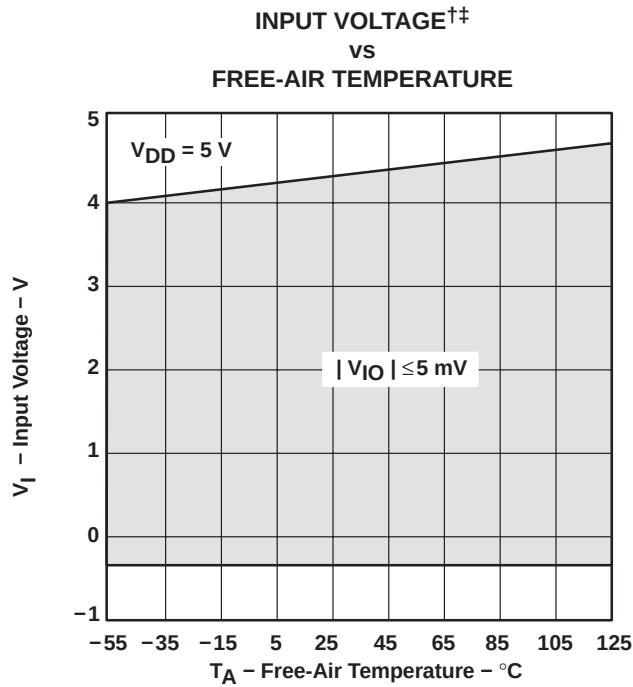


Figure 13

† 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 all curves where $V_{DD} = 5$ V, all loads are referenced to 2.5 V. For all curves where $V_{DD} = 3$ V, all loads are referenced to 1.5 V.

TLV225x-EP, TLV225xA-EP

Advanced LinCMOS™ RAIL-TO-RAIL

VERY LOW-POWER OPERATIONAL AMPLIFIERS

SGLS217B – NOVEMBER 2003 – REVISED JUNE 2006

TYPICAL CHARACTERISTICS

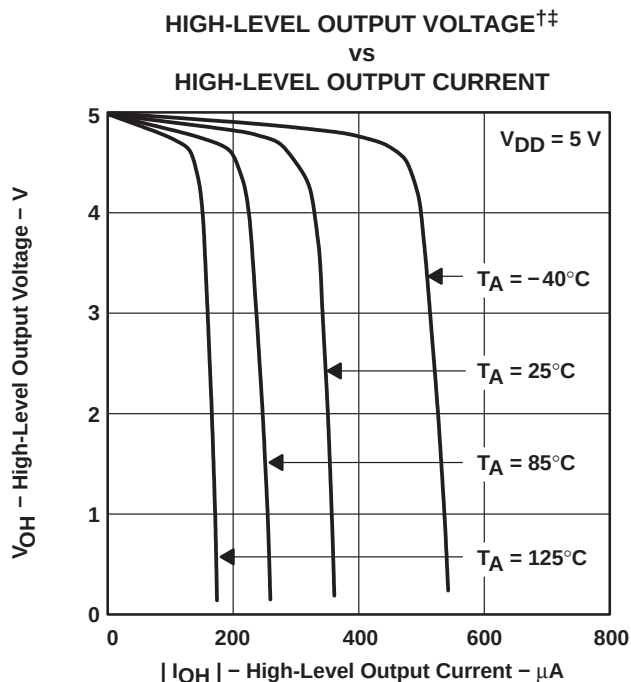


Figure 18

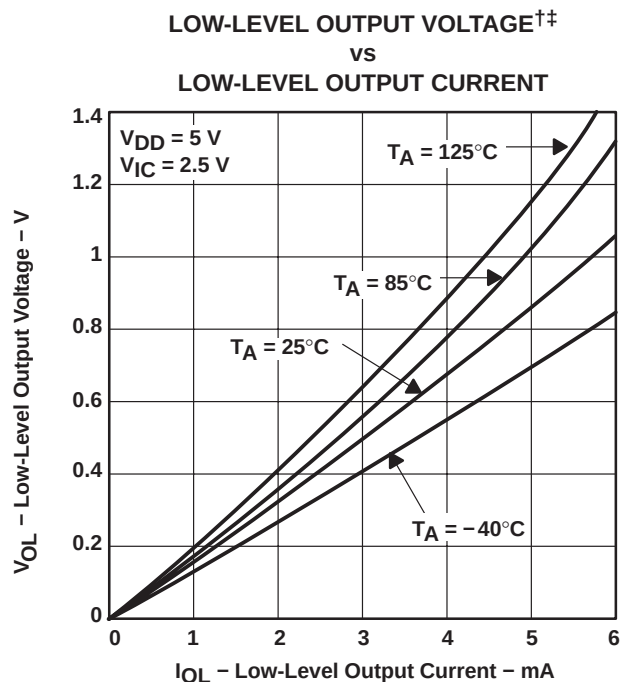


Figure 19

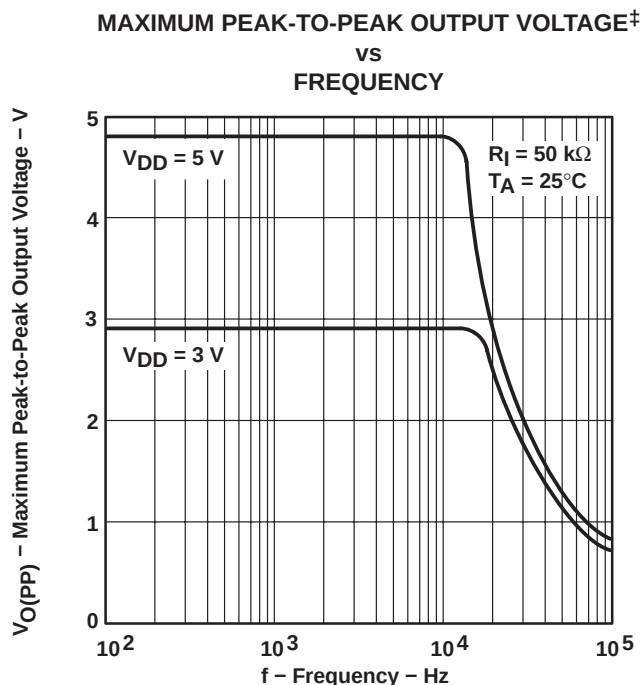


Figure 20

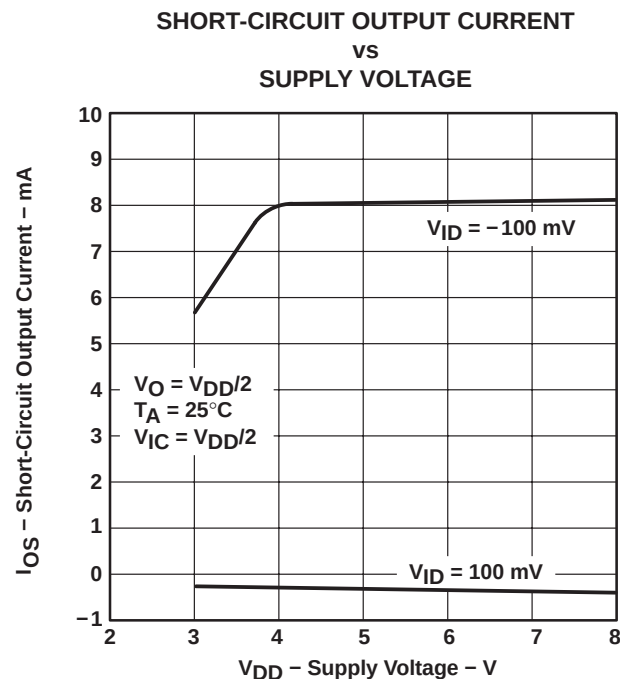
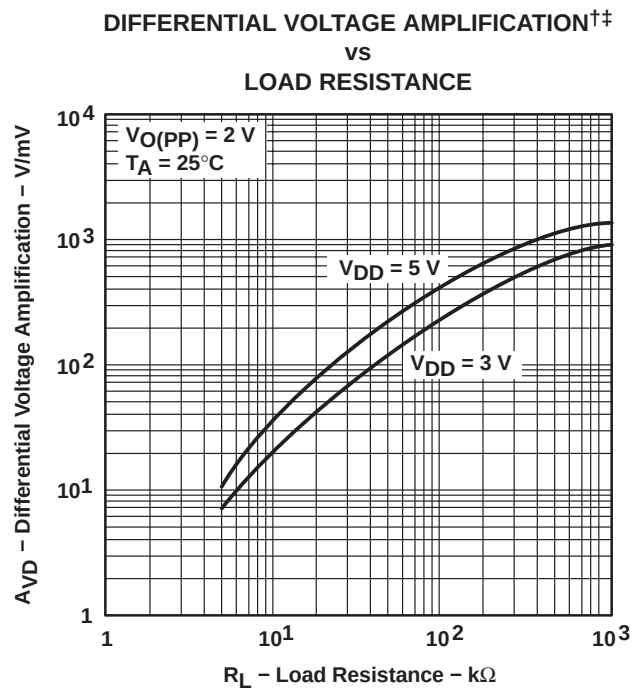
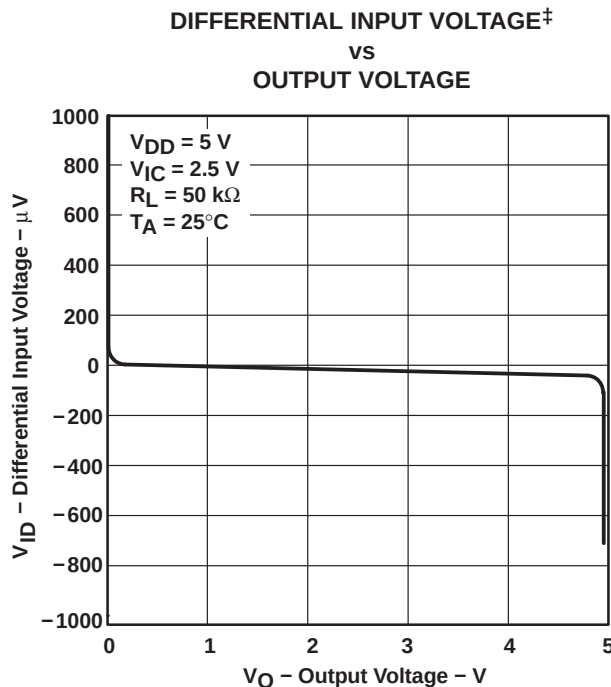
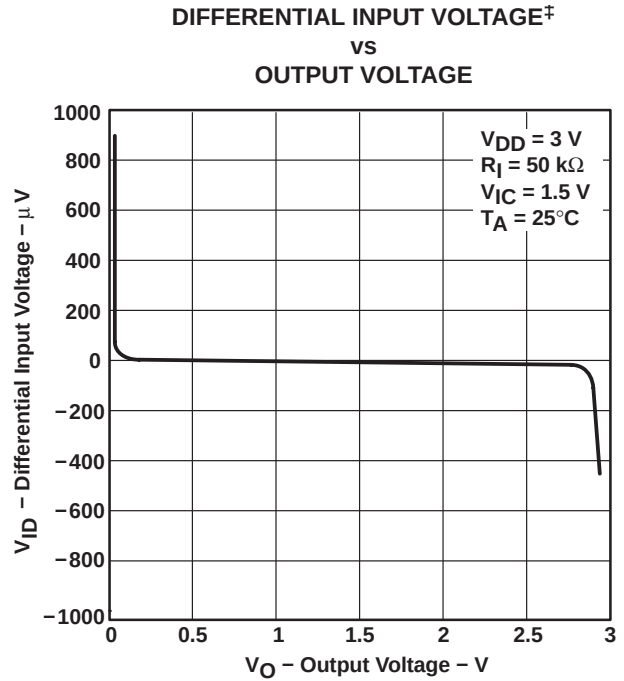
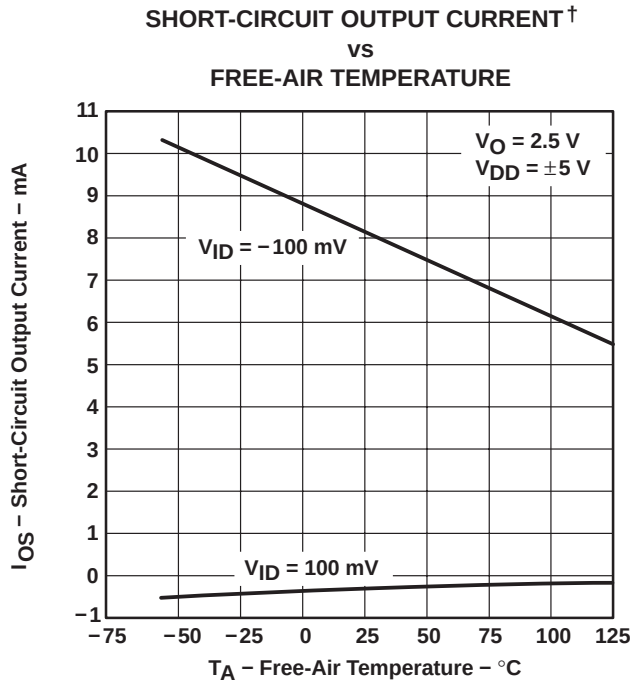


Figure 21

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

[‡] For all curves where $V_{DD} = 5\text{ V}$, all loads are referenced to 2.5 V. For all curves where $V_{DD} = 3\text{ V}$, all loads are referenced to 1.5 V.

TYPICAL CHARACTERISTICS



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

‡ For all curves where $V_{DD} = 5$ V, all loads are referenced to 2.5 V. For all curves where $V_{DD} = 3$ V, all loads are referenced to 1.5 V.

TLV225x-EP, TLV225xA-EP
Advanced LinCMOS™ RAIL-TO-RAIL
VERY LOW-POWER OPERATIONAL AMPLIFIERS

SGLS217B – NOVEMBER 2003 – REVISED JUNE 2006

TYPICAL CHARACTERISTICS

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

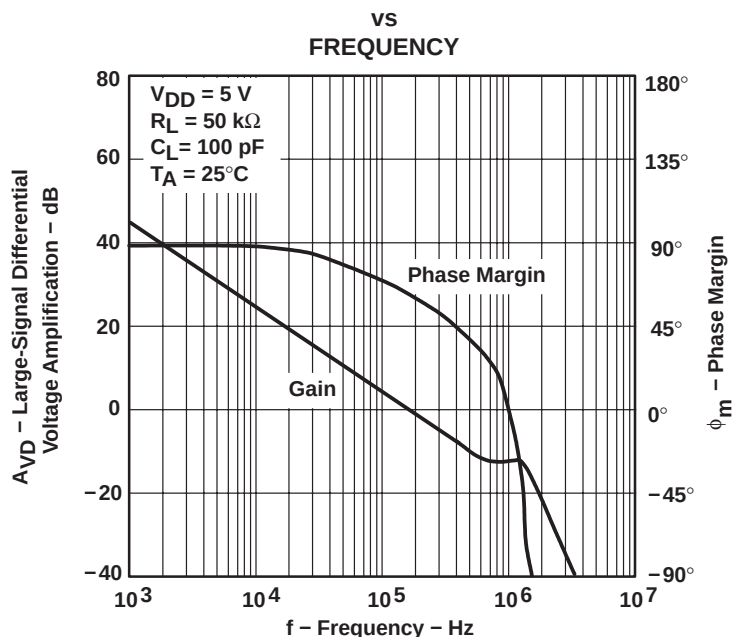


Figure 26

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

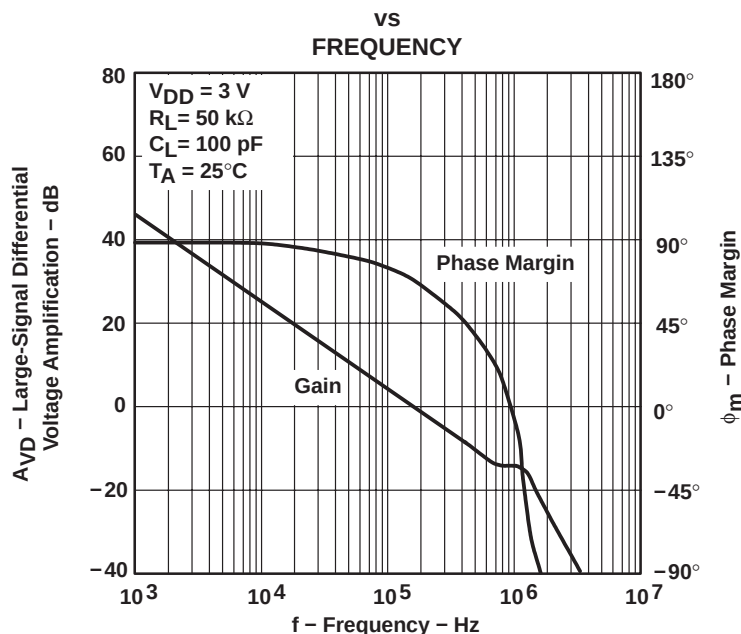


Figure 27

† For all curves where $V_{DD} = 5\text{ V}$, all loads are referenced to 2.5 V. For all curves where $V_{DD} = 3\text{ V}$, all loads are referenced to 1.5 V.

TYPICAL CHARACTERISTICS

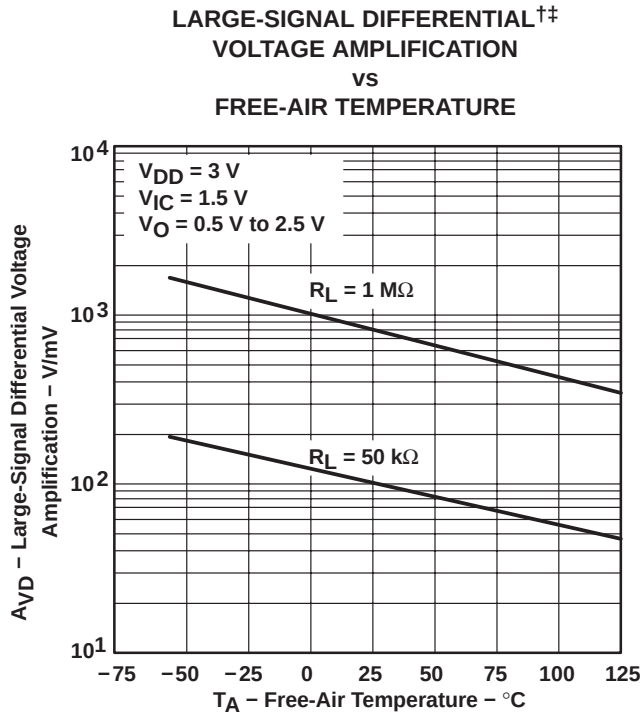


Figure 28

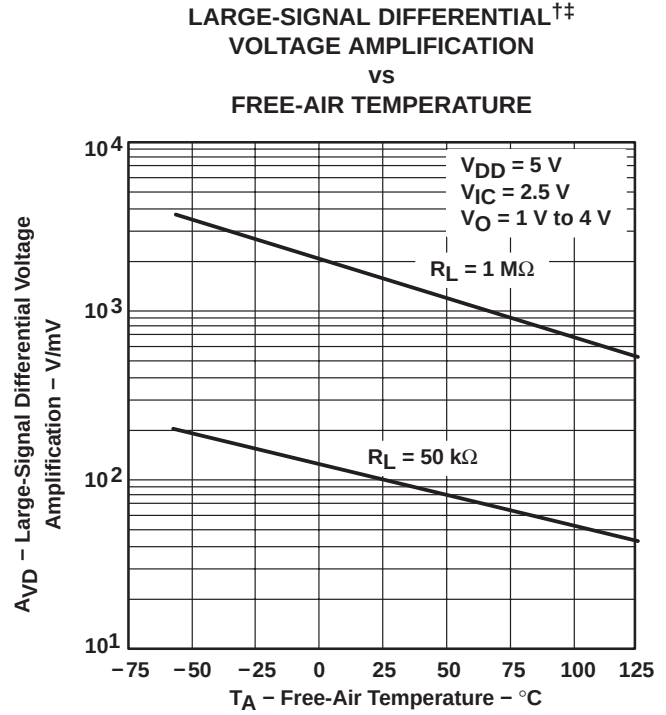


Figure 29

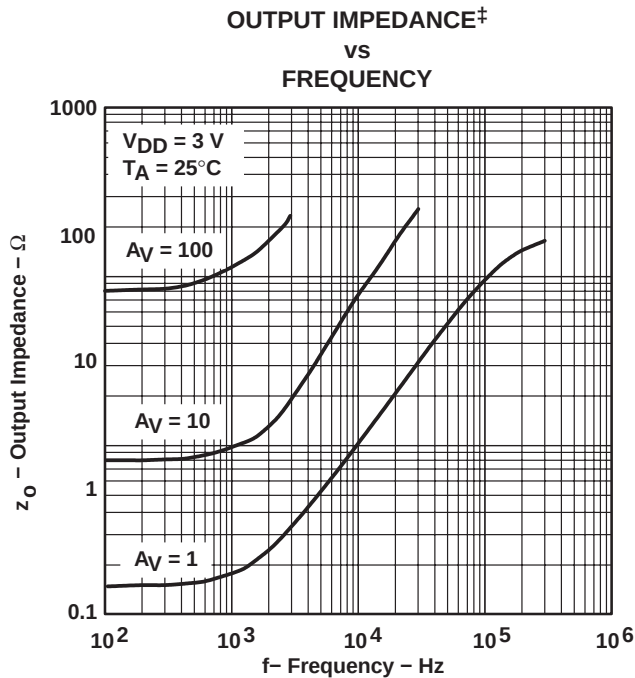


Figure 30

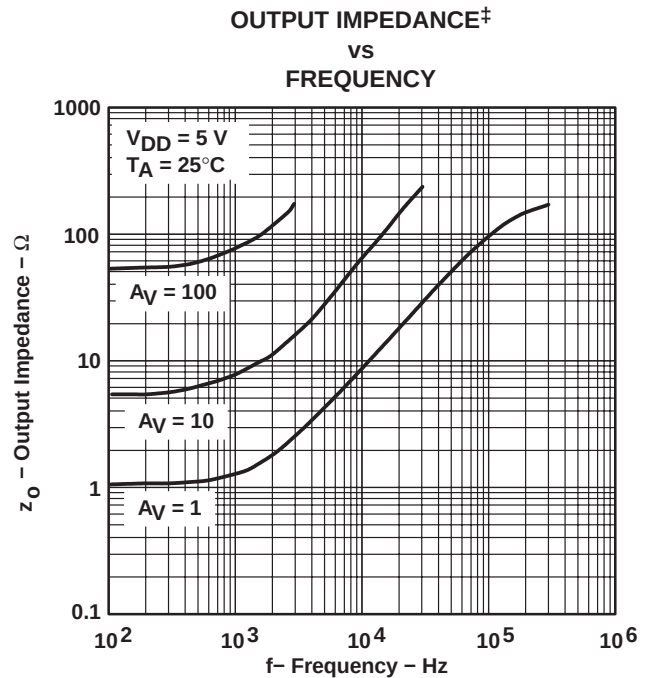


Figure 31

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

[‡] For all curves where $V_{DD} = 5\text{ V}$, all loads are referenced to 2.5 V. For all curves where $V_{DD} = 3\text{ V}$, all loads are referenced to 1.5 V.

TLV225x-EP, TLV225xA-EP

Advanced LinCMOS™ RAIL-TO-RAIL

VERY LOW-POWER OPERATIONAL AMPLIFIERS

SGLS217B – NOVEMBER 2003 – REVISED JUNE 2006

TYPICAL CHARACTERISTICS

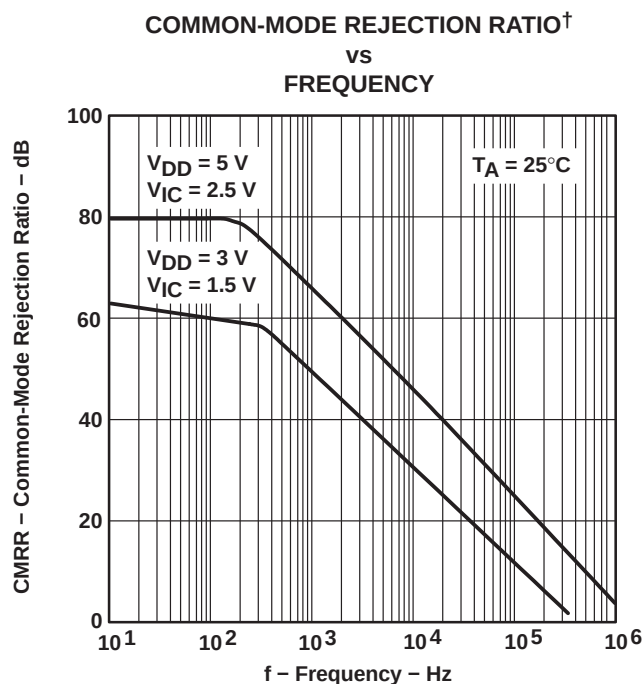


Figure 32

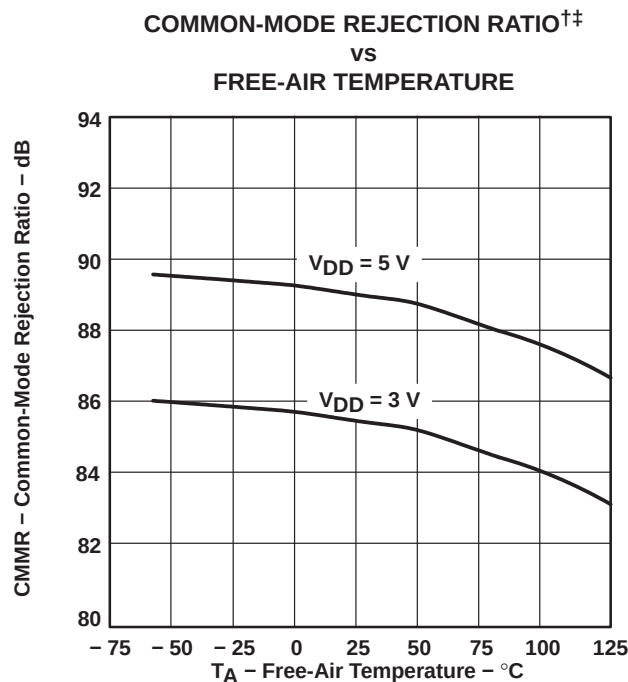


Figure 33

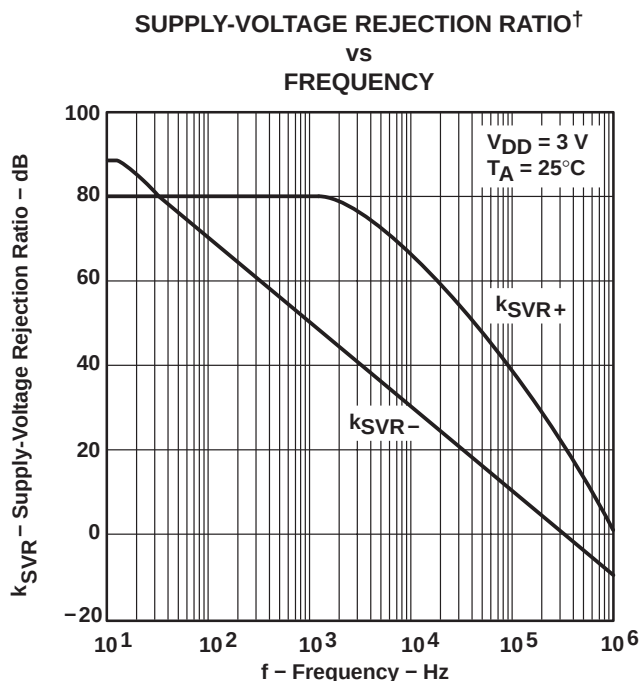


Figure 34

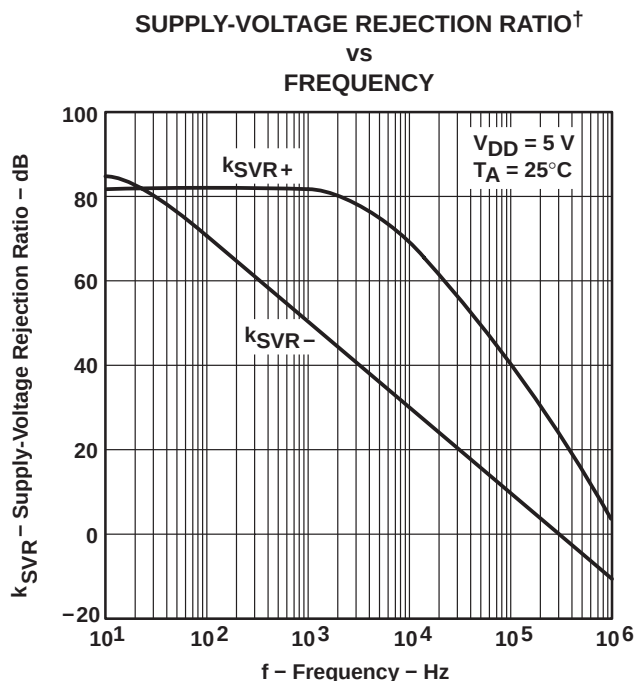


Figure 35

[†] For all curves where $V_{DD} = 5\text{ V}$, all loads are referenced to 2.5 V. For all curves where $V_{DD} = 3\text{ V}$, all loads are referenced to 1.5 V.

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

TYPICAL CHARACTERISTICS

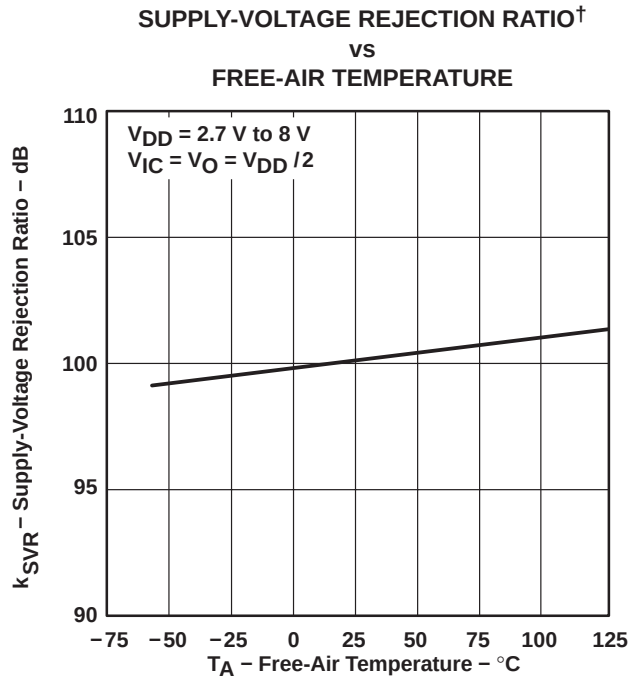


Figure 36

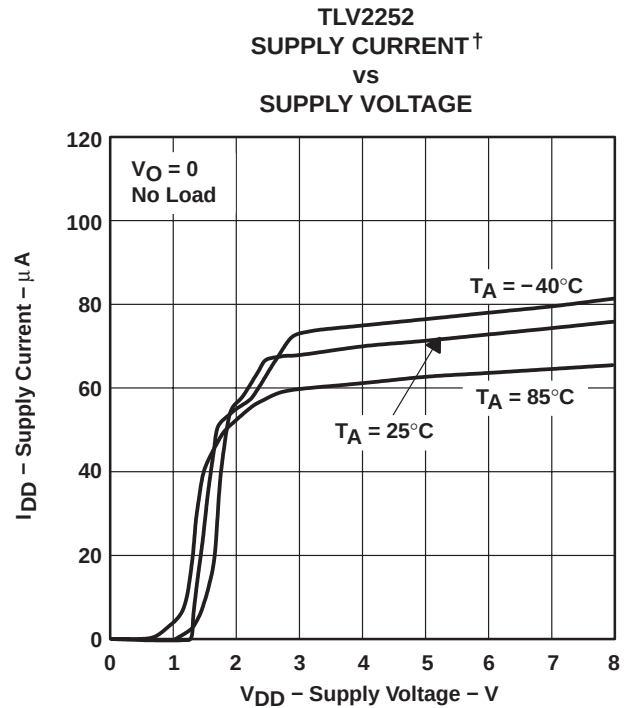


Figure 37

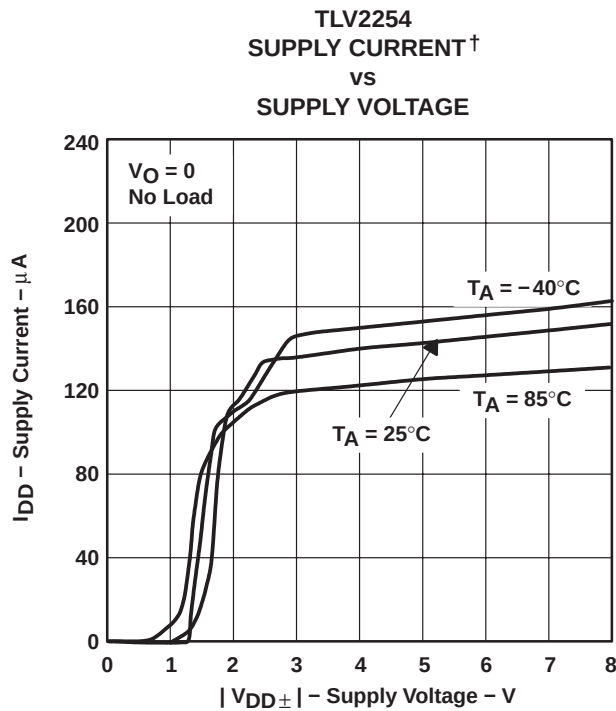


Figure 38

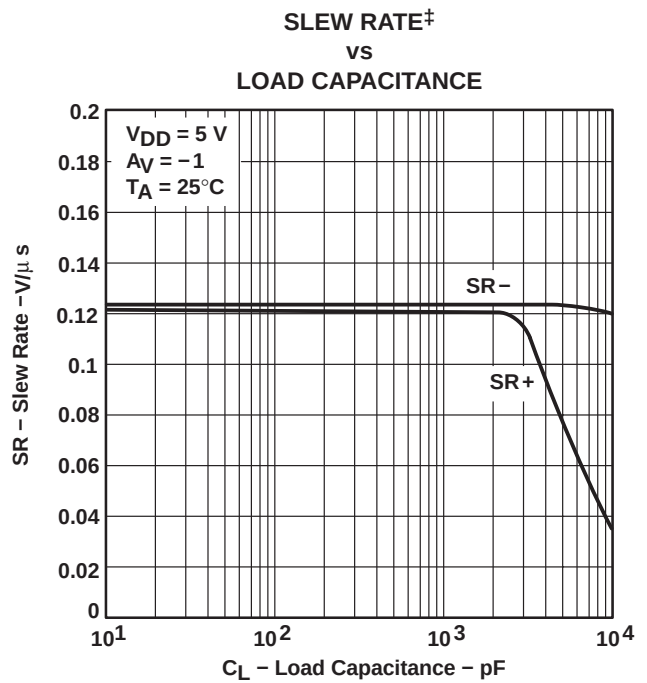


Figure 39

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

‡ For all curves where $V_{DD} = 5 \text{ V}$, all loads are referenced to 2.5 V. For all curves where $V_{DD} = 3 \text{ V}$, all loads are referenced to 1.5 V.

TLV225x-EP, TLV225xA-EP

Advanced LinCMOS™ RAIL-TO-RAIL

VERY LOW-POWER OPERATIONAL AMPLIFIERS

SGLS217B – NOVEMBER 2003 – REVISED JUNE 2006

TYPICAL CHARACTERISTICS

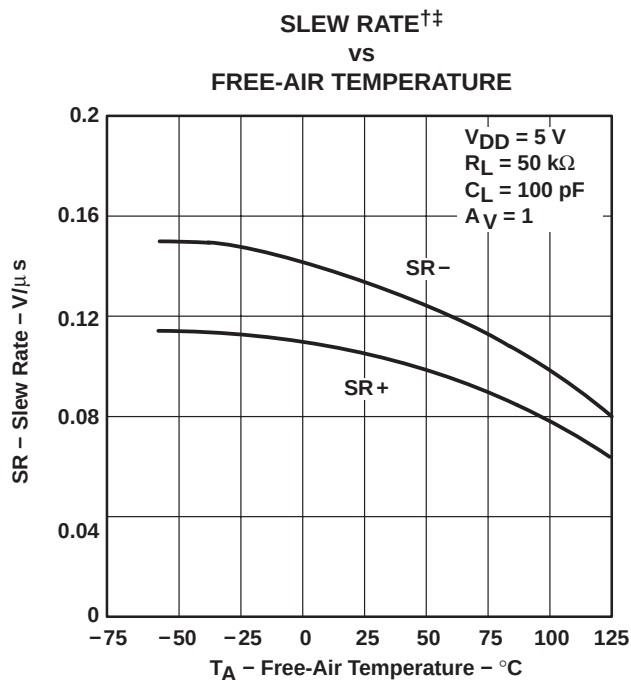


Figure 40

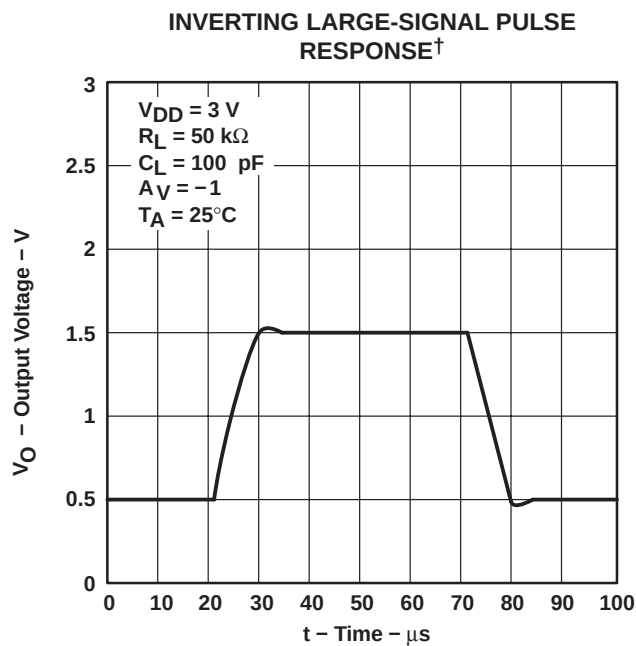


Figure 41

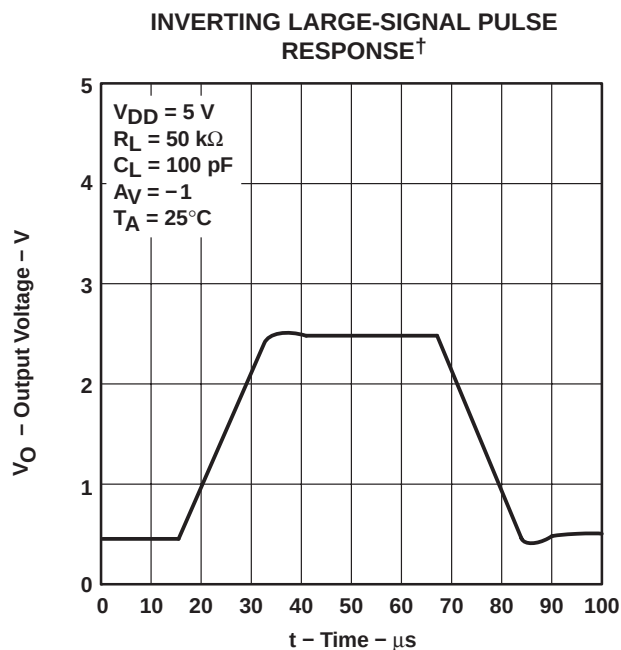


Figure 42

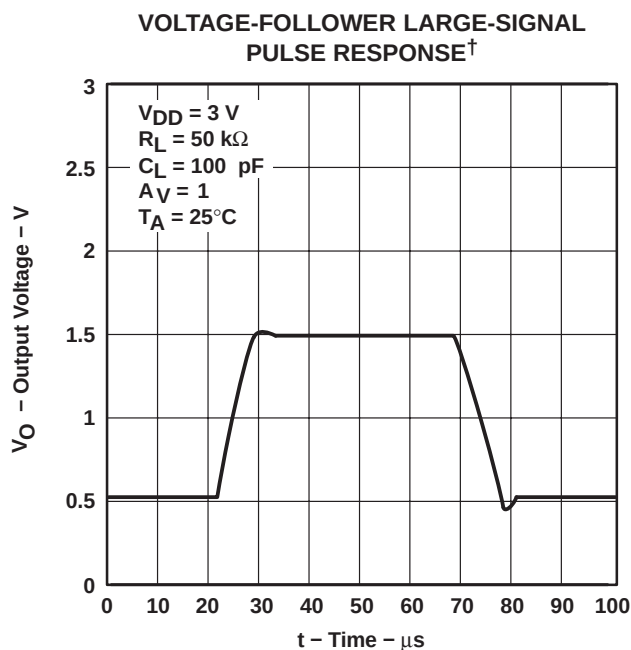


Figure 43

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

[‡] For all curves where $V_{DD} = 5\text{ V}$, all loads are referenced to 2.5 V. For all curves where $V_{DD} = 3\text{ V}$, all loads are referenced to 1.5 V.

TYPICAL CHARACTERISTICS

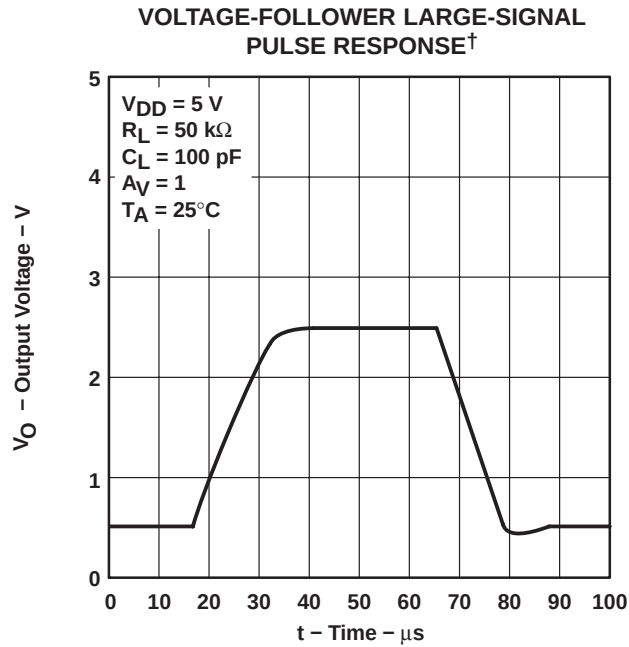


Figure 44

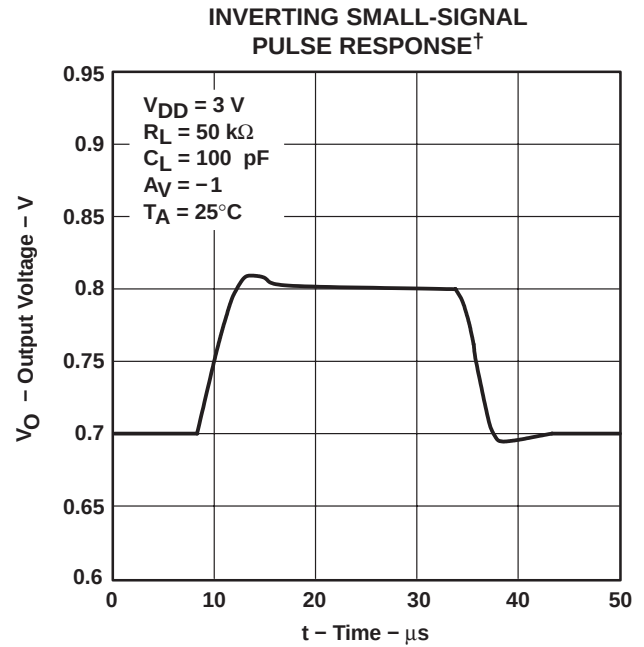


Figure 45

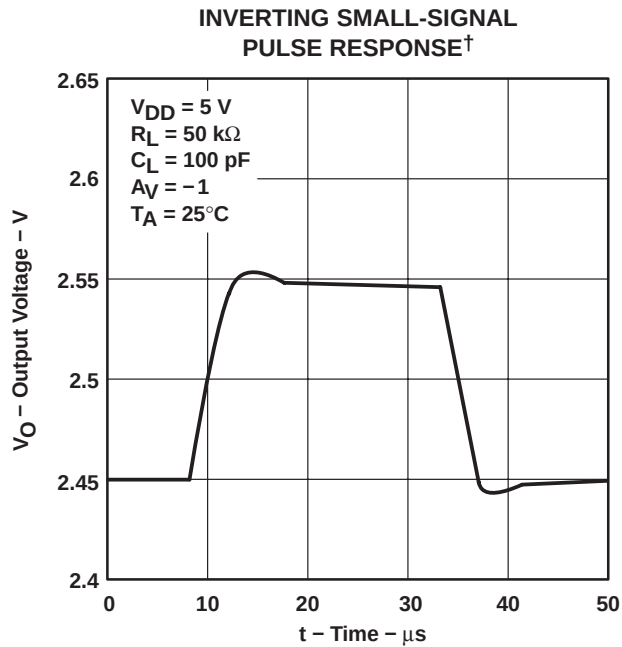


Figure 46

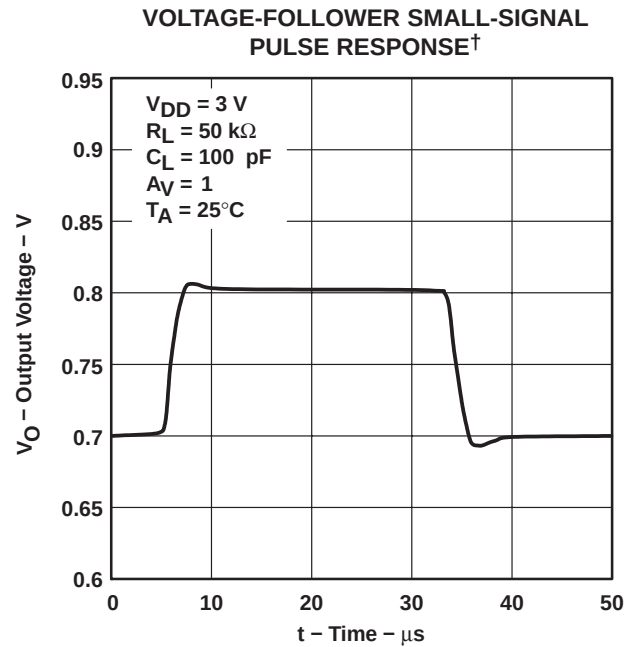


Figure 47

† For all curves where $V_{DD} = 5\text{ V}$, all loads are referenced to 2.5 V. For all curves where $V_{DD} = 3\text{ V}$, all loads are referenced to 1.5 V.

TLV225x-EP, TLV225xA-EP

Advanced LinCMOS™ RAIL-TO-RAIL

VERY LOW-POWER OPERATIONAL AMPLIFIERS

SGLS217B – NOVEMBER 2003 – REVISED JUNE 2006

TYPICAL CHARACTERISTICS

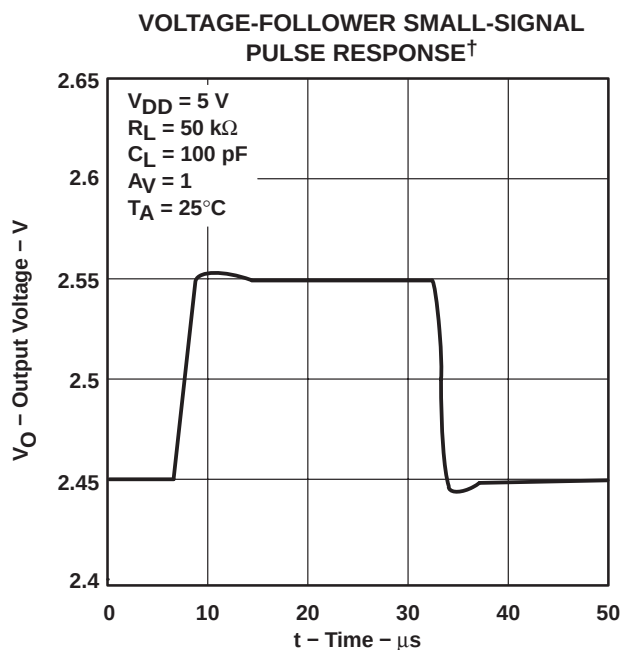


Figure 48

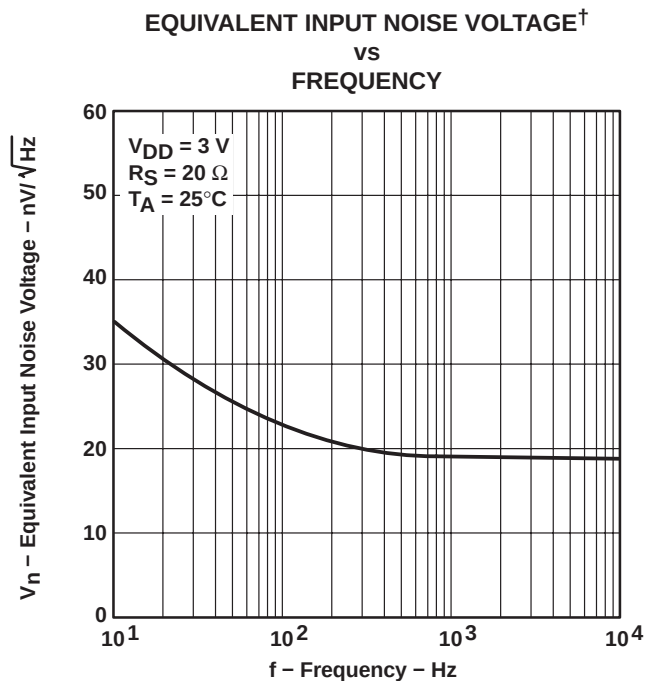


Figure 49

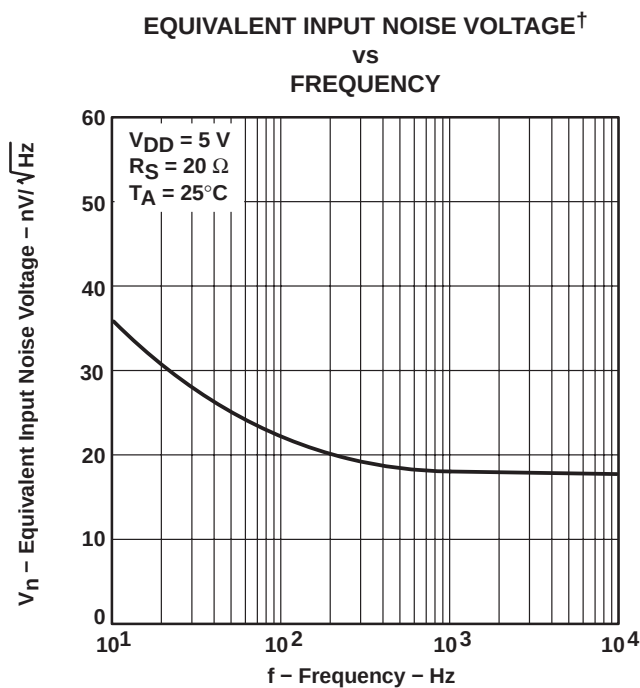


Figure 50

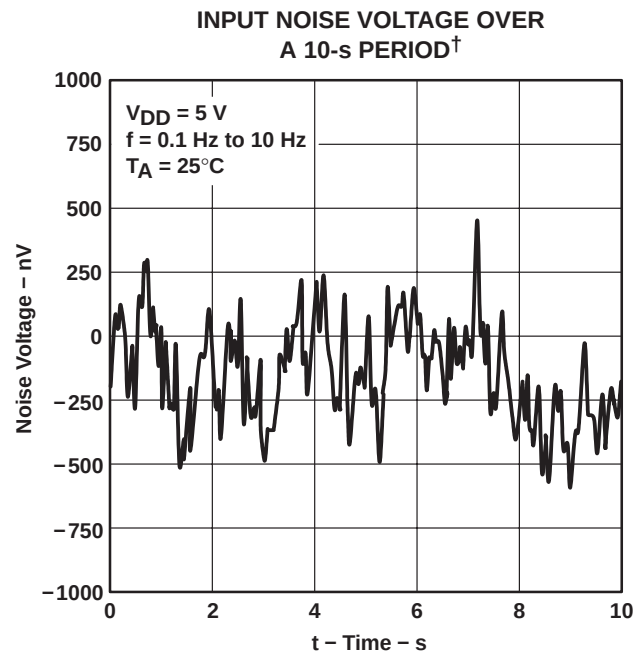


Figure 51

† For all curves where $V_{DD} = 5\text{ V}$, all loads are referenced to 2.5 V. For all curves where $V_{DD} = 3\text{ V}$, all loads are referenced to 1.5 V.

TYPICAL CHARACTERISTICS

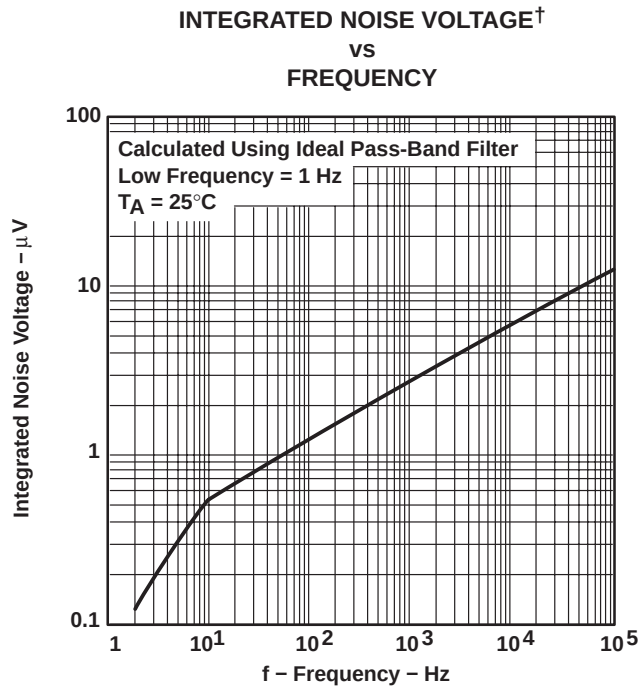


Figure 52

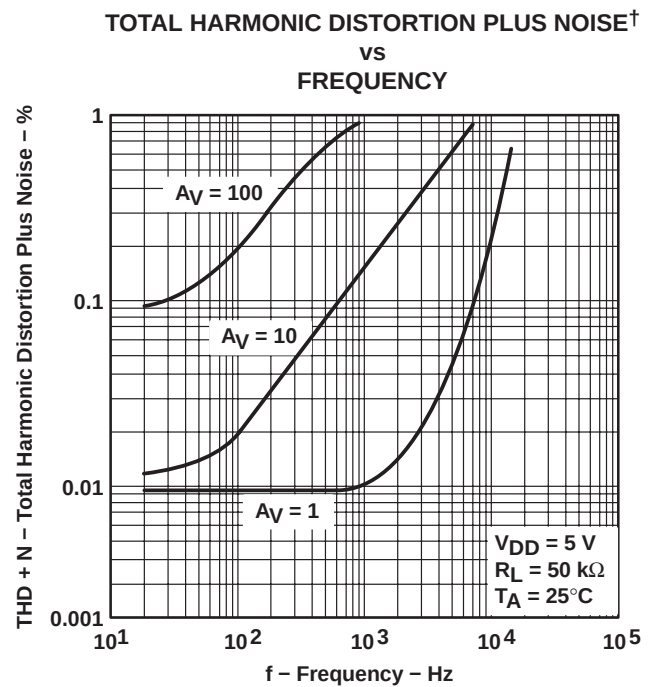


Figure 53

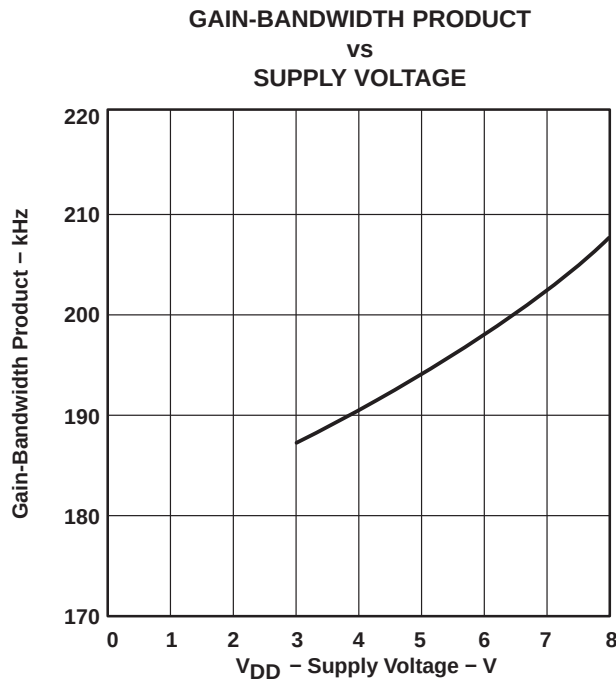


Figure 54

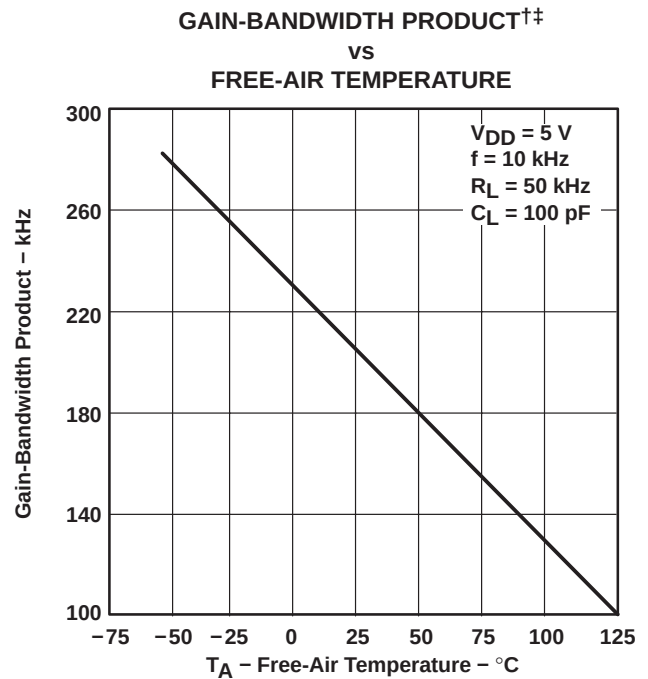


Figure 55

[†] For all curves where $V_{DD} = 5\text{ V}$, all loads are referenced to 2.5 V. For all curves where $V_{DD} = 3\text{ V}$, all loads are referenced to 1.5 V.

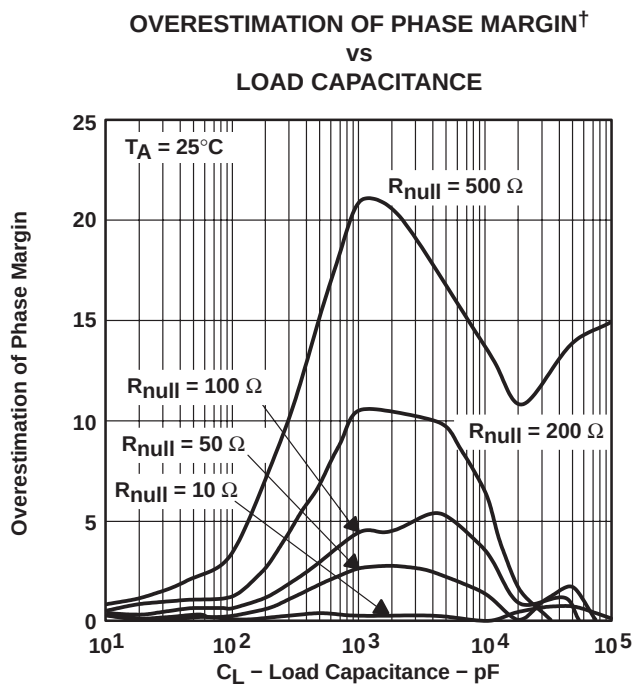
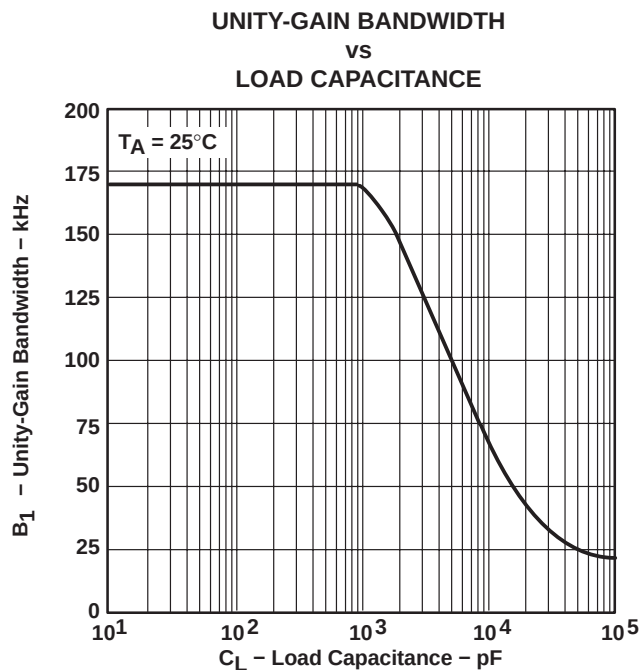
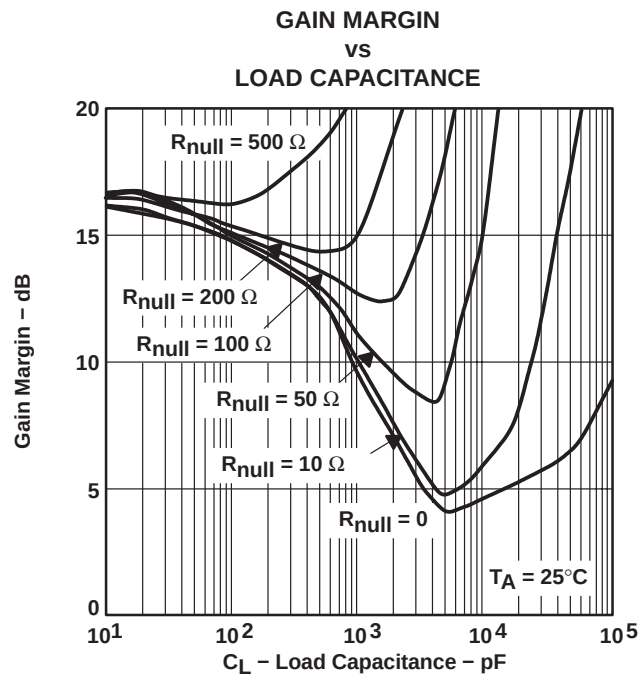
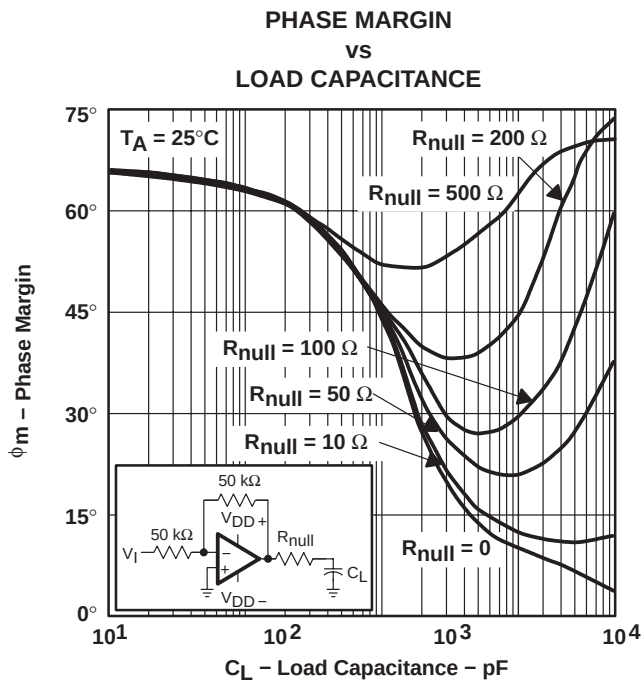
TLV225x-EP, TLV225xA-EP

Advanced LinCMOS™ RAIL-TO-RAIL

VERY LOW-POWER OPERATIONAL AMPLIFIERS

SGLS217B – NOVEMBER 2003 – REVISED JUNE 2006

TYPICAL CHARACTERISTICS



† For all curves where $V_{DD} = 5$ V, all loads are referenced to 2.5 V. For all curves where $V_{DD} = 3$ V, all loads are referenced to 1.5 V.

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

APPLICATION INFORMATION

driving large capacitive loads

The TLV2252 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 55 and Figure 56 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 adds a zero to the transfer function and the second 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, 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.

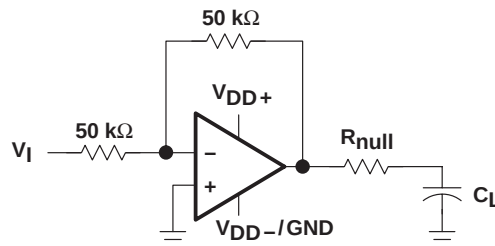


Figure 60. Series-Resistance Circuit

TLV225x-EP, TLV225xA-EP

Advanced LinCMOS™ RAIL-TO-RAIL

VERY LOW-POWER OPERATIONAL AMPLIFIERS

SGLS217B – NOVEMBER 2003 – REVISED JUNE 2006

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 TLV2252 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).

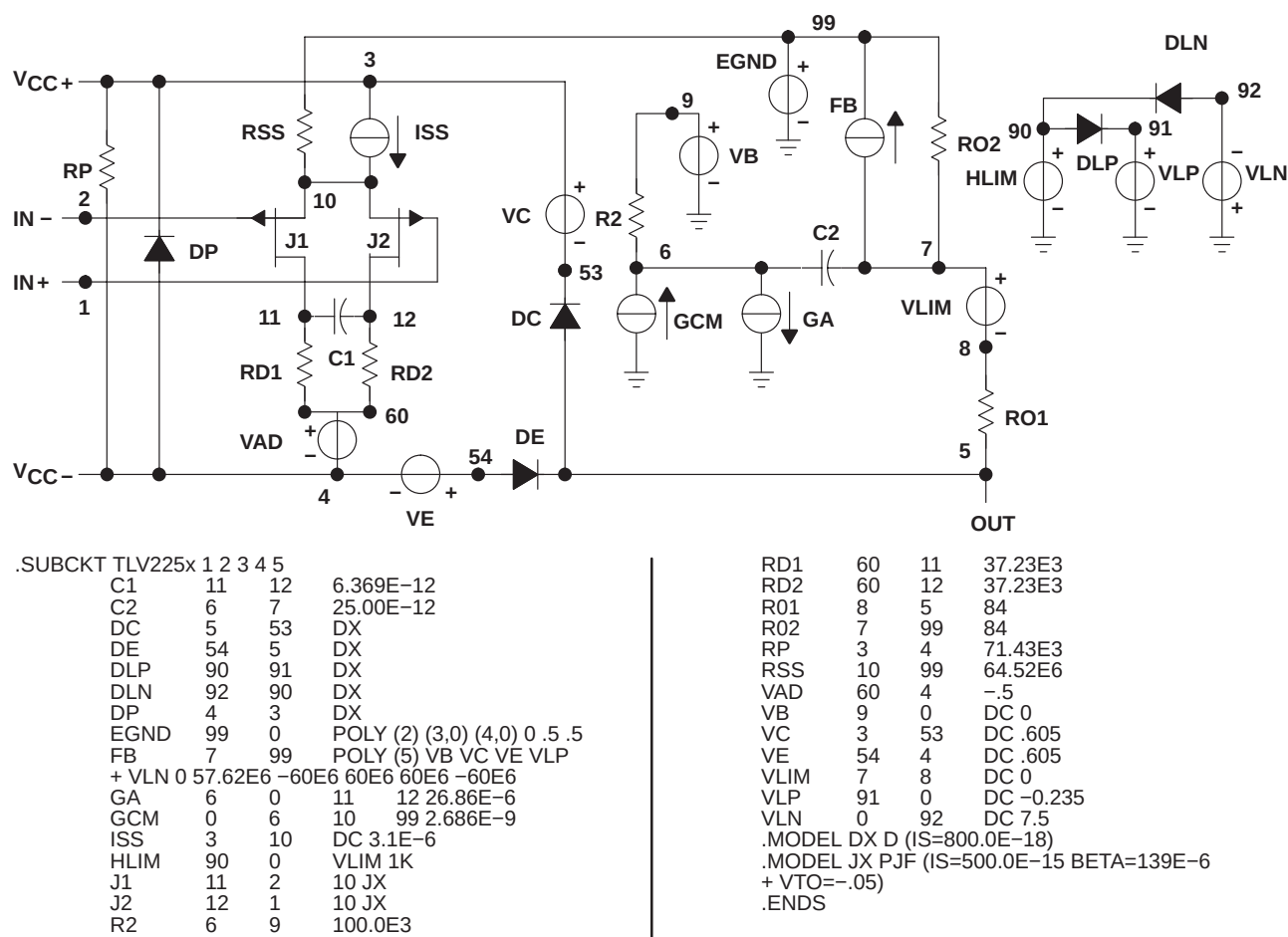


Figure 61. Boyle Macromodel and Subcircuit

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)
TLV2252AQDREP	Active	Production	SOIC (D) 8	2500 LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	2252AE
TLV2252AQDREP.A	Active	Production	SOIC (D) 8	2500 LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	2252AE
TLV2254AQDREP	Active	Production	SOIC (D) 14	2500 LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	TLV2254AEP
TLV2254AQDREP.A	Active	Production	SOIC (D) 14	2500 LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	TLV2254AEP
V62/04651-02UE	Active	Production	SOIC (D) 8	2500 LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	2252AE
V62/04651-04XE	Active	Production	SOIC (D) 14	2500 LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	TLV2254AEP

⁽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.

Important Information and Disclaimer: The information provided on this page represents TI's knowledge and belief as of the date that it is provided. TI bases its knowledge and belief on information provided by third parties, and makes no representation or warranty as to the accuracy of such information. Efforts are underway to better integrate information from third parties. TI has taken and continues to take reasonable steps to provide representative and accurate information but may not have conducted destructive testing or chemical analysis on incoming materials and chemicals. TI and TI suppliers consider certain information to be proprietary, and thus CAS numbers and other limited information may not be available for release.

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 TLV2252A-EP, TLV2254A-EP :

- Catalog : [TLV2252A](#), [TLV2254A](#)
- Automotive : [TLV2252A-Q1](#)
- Military : [TLV2252AM](#)

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

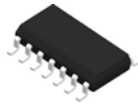
Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
TLV2252AQDREP	SOIC	D	8	2500	330.0	12.4	6.4	5.2	2.1	8.0	12.0	Q1
TLV2254AQDREP	SOIC	D	14	2500	330.0	16.4	6.5	9.0	2.1	8.0	16.0	Q1

TAPE AND REEL BOX DIMENSIONS

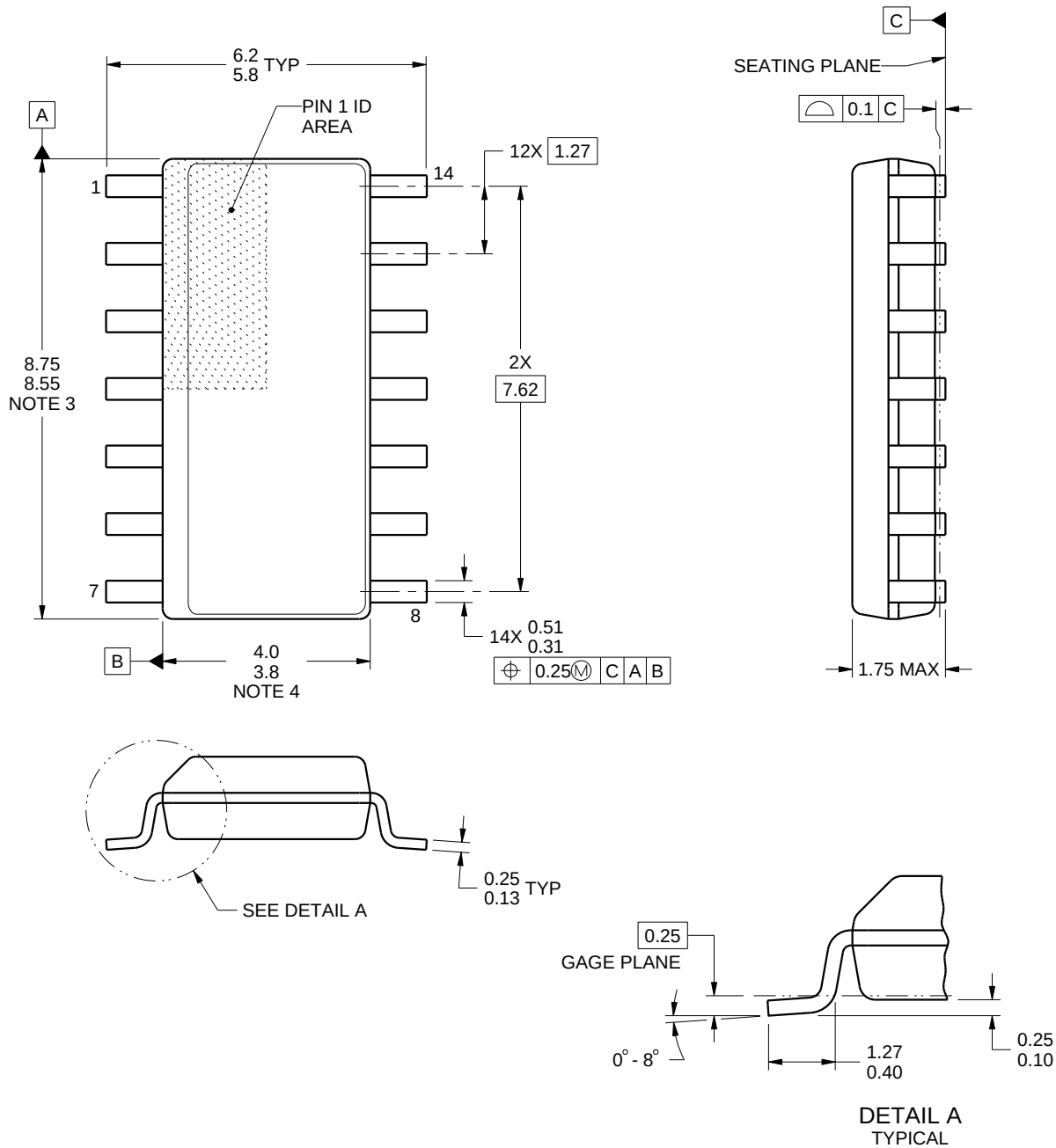


*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
TLV2252AQDREP	SOIC	D	8	2500	353.0	353.0	32.0
TLV2254AQDREP	SOIC	D	14	2500	340.5	336.1	32.0

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

SMALL OUTLINE INTEGRATED CIRCUIT



4220718/A 09/2016

NOTES:

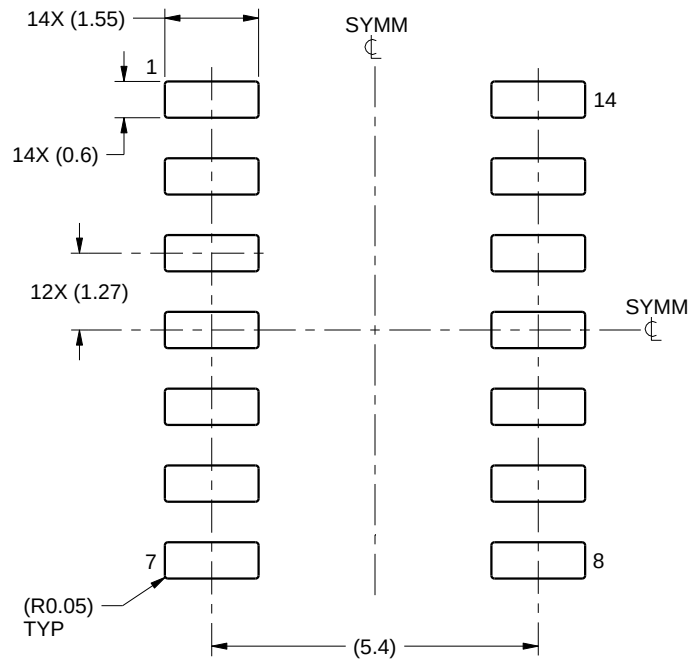
1. All linear dimensions are in millimeters. Dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate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

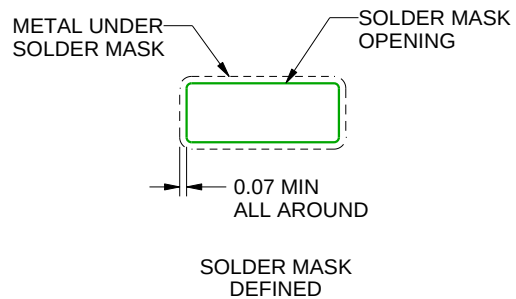
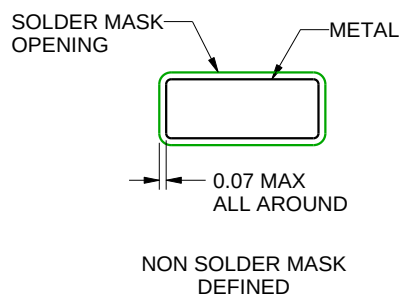
D0014A

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.

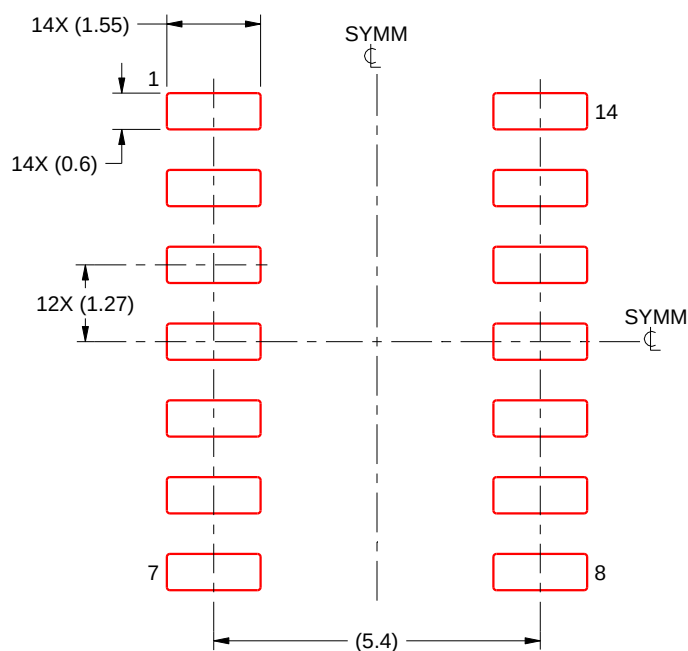
7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.

EXAMPLE STENCIL DESIGN

D0014A

SOIC - 1.75 mm max height

SMALL OUTLINE INTEGRATED CIRCUIT

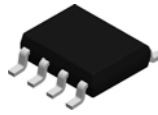


SOLDER PASTE EXAMPLE
BASED ON 0.125 mm THICK STENCIL
SCALE:8X

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.

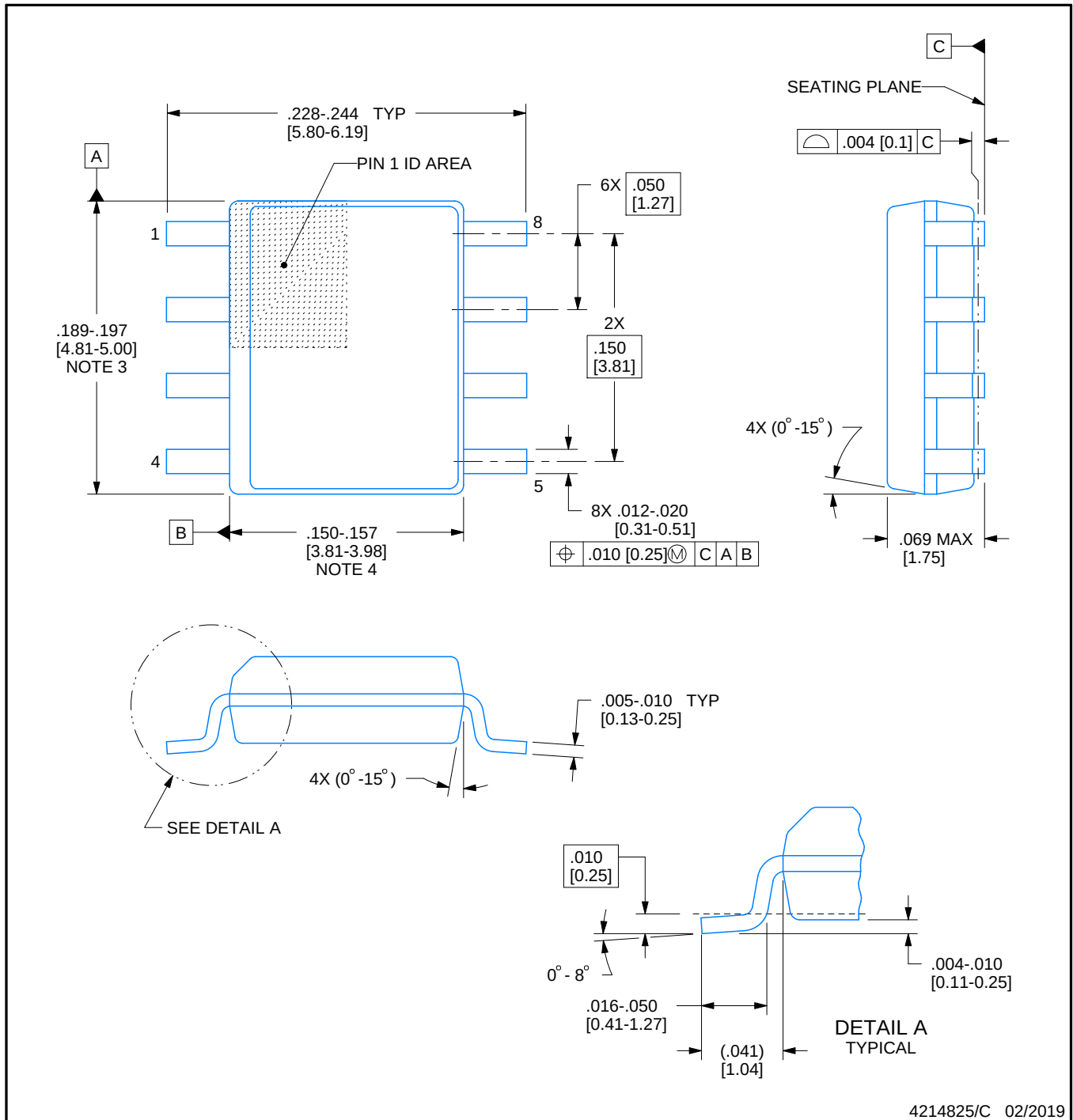


D0008A

PACKAGE OUTLINE

SOIC - 1.75 mm max height

SMALL OUTLINE INTEGRATED CIRCUIT



4214825/C 02/2019

NOTES:

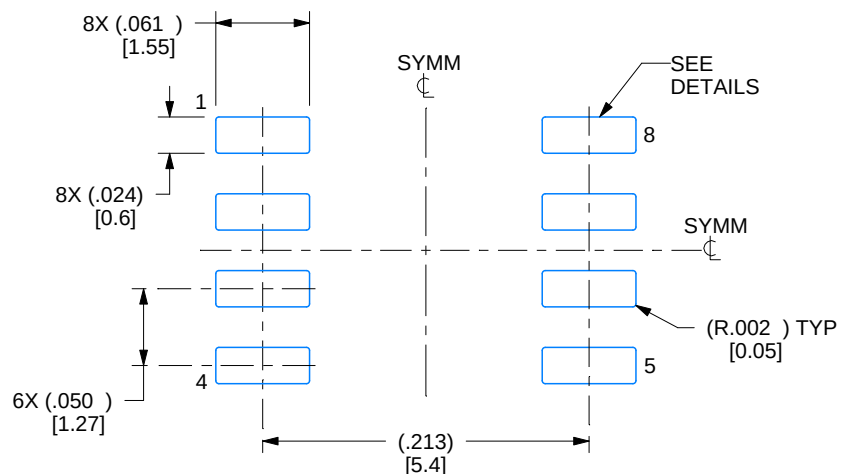
1. Linear dimensions are in inches [millimeters]. Dimensions in parenthesis are for reference only. Controlling dimensions are in inches. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This dimension does not include mold flash, protrusions, or gate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

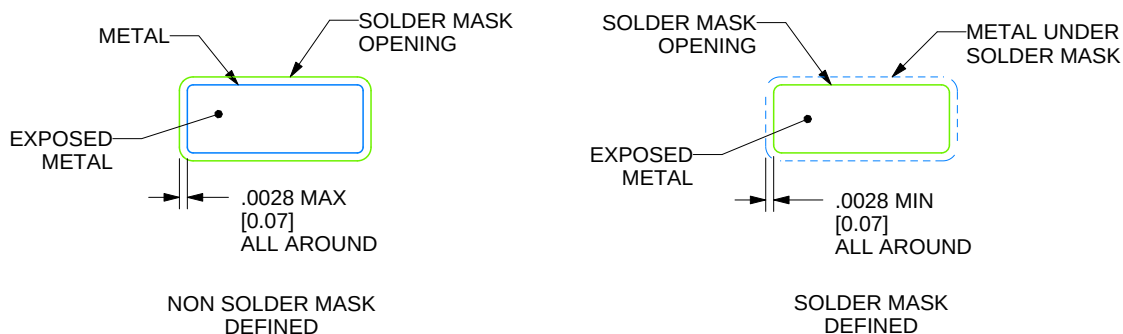
D0008A

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.

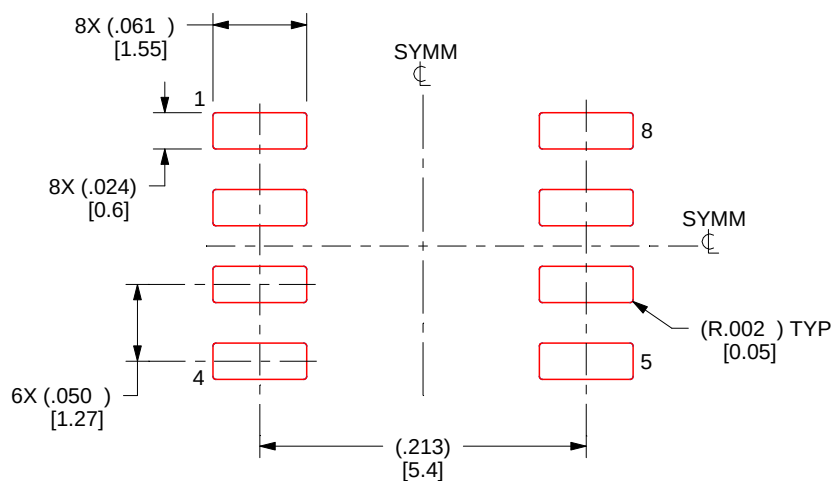
7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.

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.

IMPORTANT NOTICE AND DISCLAIMER

TI PROVIDES TECHNICAL AND RELIABILITY DATA (INCLUDING DATA SHEETS), DESIGN RESOURCES (INCLUDING REFERENCE DESIGNS), APPLICATION OR OTHER DESIGN ADVICE, WEB TOOLS, SAFETY INFORMATION, AND OTHER RESOURCES "AS IS" AND WITH ALL FAULTS, AND DISCLAIMS ALL WARRANTIES, EXPRESS AND IMPLIED, INCLUDING WITHOUT LIMITATION ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

These resources are intended for skilled developers designing with TI products. You are solely responsible for (1) selecting the appropriate TI products for your application, (2) designing, validating and testing your application, and (3) ensuring your application meets applicable standards, and any other safety, security, regulatory or other requirements.

These resources are subject to change without notice. TI grants you permission to use these resources only for development of an application that uses the TI products described in the resource. Other reproduction and display of these resources is prohibited. No license is granted to any other TI intellectual property right or to any third party intellectual property right. TI disclaims responsibility for, and you will fully indemnify TI and its representatives against, any claims, damages, costs, losses, and liabilities arising out of your use of these resources.

TI's products are provided subject to [TI's Terms of Sale](#) or other applicable terms available either on [ti.com](https://www.ti.com) or provided in conjunction with such TI products. TI's provision of these resources does not expand or otherwise alter TI's applicable warranties or warranty disclaimers for TI products.

TI objects to and rejects any additional or different terms you may have proposed.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265
Copyright © 2025, Texas Instruments Incorporated