

TLV2422, TLV2422A, TLV2422Y
Advanced LinCMOS™ RAIL-TO-RAIL OUTPUT
WIDE-INPUT-VOLTAGE MICROPOWER DUAL OPERATIONAL AMPLIFIERS

SLOS199C – SEPTEMBER 1997 – REVISED APRIL 2001

- Output Swing Includes Both Supply Rails
- Extended Common-Mode Input Voltage Range . . . 0 V to 4.5 V (Min) With 5-V Single Supply
- No Phase Inversion
- Low Noise . . . 18 nV/√Hz Typ at f = 1 kHz
- Low Input Offset Voltage
950 μV Max at T_A = 25°C (TLV2422A)
- Low Input Bias Current . . . 1 pA Typ
- Micropower Operation . . . 50 μA Per Channel
- 600-Ω Output Drive
- Available in Q-Temp Automotive
HighRel Automotive Applications
Configuration Control / Print Support
Qualification to Automotive Standards

description

The TLV2422 and TLV2422A are dual low-voltage operational amplifiers from Texas Instruments. The common-mode input voltage range for this device has been extended over the typical CMOS amplifiers making them suitable for a wide range of applications. In addition, the devices do not phase invert when the common-mode input is driven to the supply rails. This satisfies most design requirements without paying a premium for rail-to-rail input performance. They also exhibit rail-to-rail output performance for increased dynamic range in single- or split-supply applications. This family is fully characterized at 3-V and 5-V supplies and is optimized for low-voltage operation. The TLV2422 only requires 50 μA of supply current per channel, making it ideal for battery-powered applications. The TLV2422 also has increased output drive over previous rail-to-rail operational amplifiers and can drive 600-Ω loads for telecom applications.

Other members in the TLV2422 family are the high-power, TLV2442, and low-power, TLV2432, versions.

The TLV2422, exhibiting high input impedance and low noise, is excellent for small-signal conditioning for high-impedance sources, such as piezoelectric transducers. Because of the micropower dissipation levels and low-voltage 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 TLV2422A is available with a maximum input offset voltage of 950 μV.

If the design requires single operational amplifiers, see the TI TLV2211/21/31. This is a family of rail-to-rail output operational amplifiers in the SOT-23 package. Their small size and low power consumption, make them ideal for high density, battery-powered equipment.

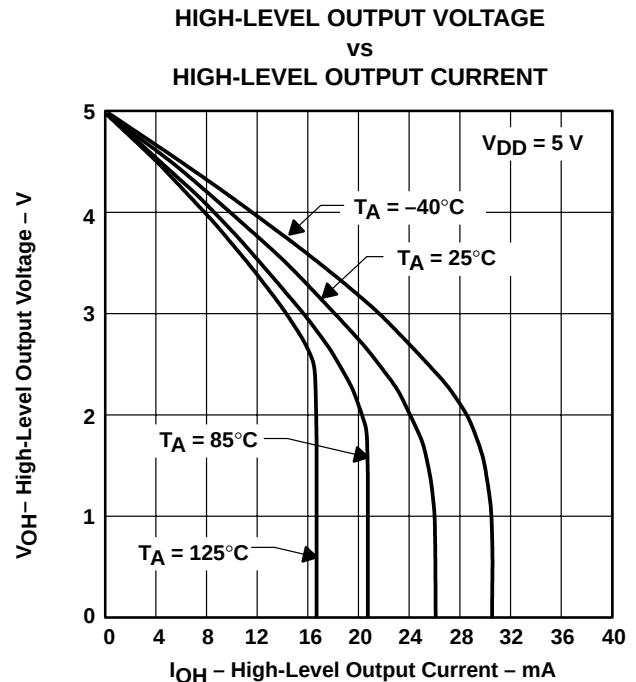


Figure 1



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

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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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On products compliant to MIL-PRF-38535, all parameters are tested unless otherwise noted. On all other products, production processing does not necessarily include testing of all parameters.

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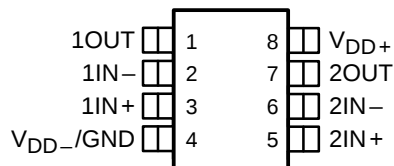
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AVAILABLE OPTIONS

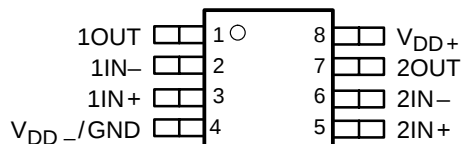
T _A	V _{IO} max AT 25°C	PACKAGED DEVICES					CHIP FORM (Y)
		SMALL OUTLINE (D)	CHIP CARRIER (FK)	CERAMIC DIP (JG)	TSSOP (PW)	CERAMIC FLAT PACK (U)	
0°C to 70°C	2.5 mV	TLV2422CD	—	—	TLV2422CPWLE	—	TLV2422Y
–40°C to 85°C	950 µV 2.5 mV	TLV2422AID TLV2422ID	— —	— —	TLV2422AIPWLE —	— —	
–40°C to 125°C	950 µV 2.5 mV	TLV2422AQD TLV2422QD	— —	— —	— —	— —	
–55°C to 125°C	950 µV 2 mV	— —	TLV2422AMFK TLV2422MFK	TLV2422AMJG TLV2422MJG	— —	TLV2422AMU TLV2422MU	

The D packages are available taped and reeled. Add R suffix to device type (e.g., TLV2422CDR). The PW package is available only left-end taped and reeled. Chips are tested at 25°C.

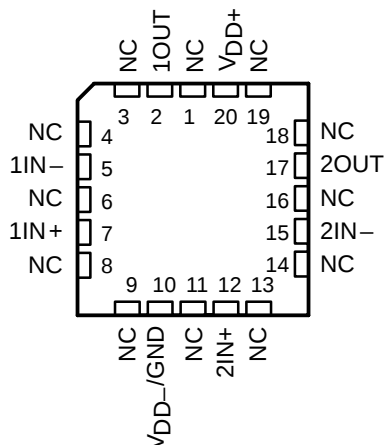
**D OR JG PACKAGE
(TOP VIEW)**



**PW PACKAGE
(TOP VIEW)**

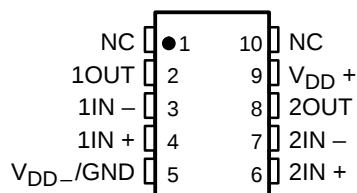


**FK PACKAGE
(TOP VIEW)**



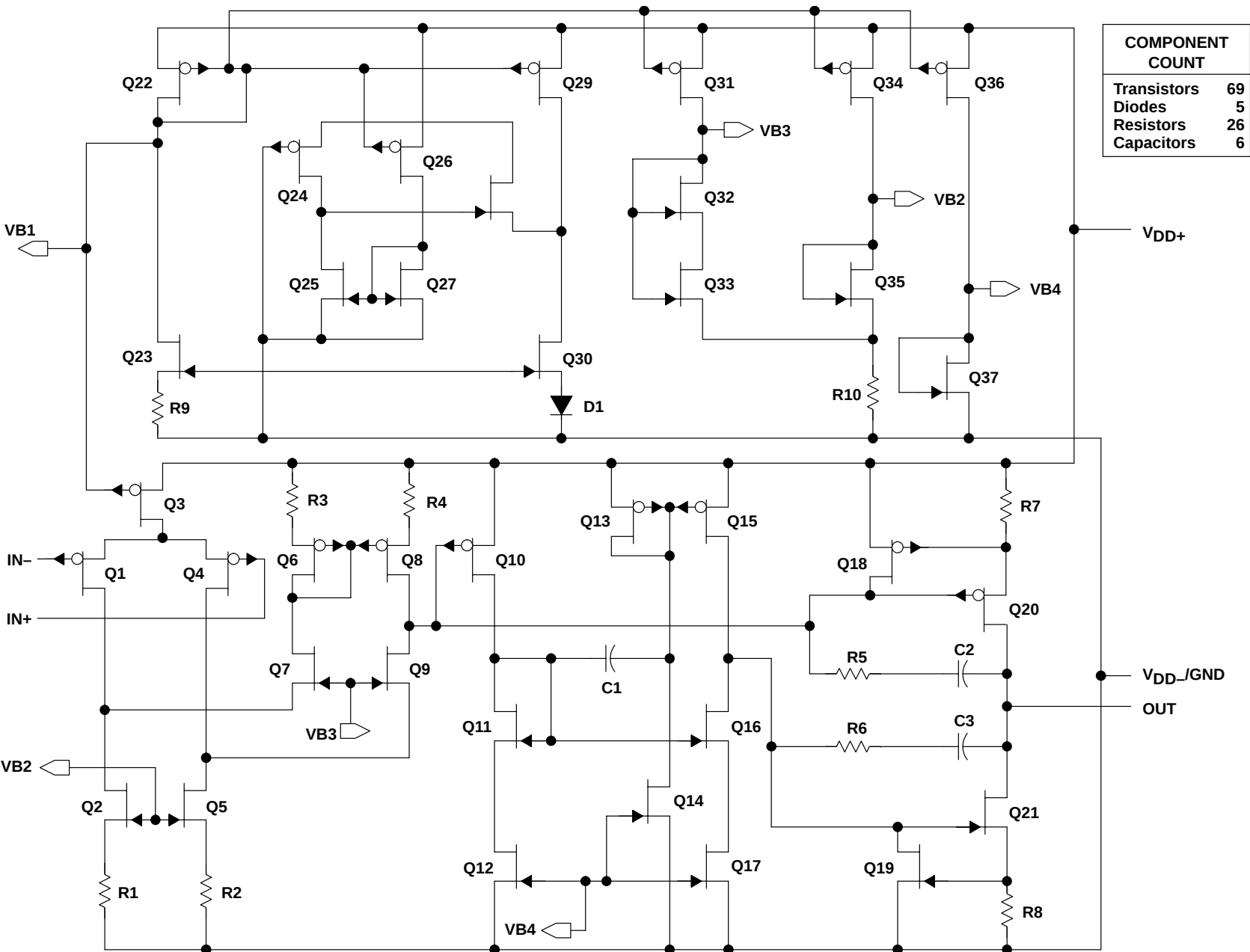
NC – No internal connection

**U PACKAGE
(TOP VIEW)**



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equivalent schematic (each amplifier)



COMPONENT COUNT	
Transistors	69
Diodes	5
Resistors	26
Capacitors	6

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

Supply voltage, V_{DD} (see Note 1)	12 V
Differential input voltage, V_{ID} (see Note 2)	$\pm V_{DD}$
Input voltage, V_I (any input, see Note 1): C and I suffix	-0.3 V to V_{DD}
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 power dissipation	See Dissipation Rating Table
Operating free-air temperature range, T_A : C suffix	0°C to 70°C
I suffix	-40°C to 85°C
Q suffix	-40°C to 125°C
M suffix	-55°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 if 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	725 mW	5.8 mW/°C	464 mW	377 mW	145 mW
FK	1375 mW	11.0 mW/°C	880 mW	715 mW	275 mW
JG	1050 mW	8.4 mW/°C	672 mW	546 mW	210 mW
PW	525 mW	4.2 mW/°C	336 mW	273 mW	105 mW
U	675 mW	5.4 mW/°C	432 mW	350 mW	135 mW

recommended operating conditions

	C SUFFIX		I SUFFIX		Q SUFFIX		M SUFFIX		UNIT
	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	
Supply voltage, $V_{DD\pm}$	2.7	10	2.7	10	2.7	10	2.7	10	V
Input voltage range, V_I	V_{DD-}	$V_{DD+} - 0.8$	V_{DD-}	$V_{DD+} - 0.8$	V_{DD-}	$V_{DD+} - 0.8$	V_{DD-}	$V_{DD+} - 0.8$	V
Common-mode input voltage, V_{IC}	V_{DD-}	$V_{DD+} - 0.8$	V_{DD-}	$V_{DD+} - 0.8$	V_{DD-}	$V_{DD+} - 0.8$	V_{DD-}	$V_{DD+} - 0.8$	V
Operating free-air temperature, T_A	0	70	-40	85	-40	125	-55	125	°C



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

PARAMETER		TEST CONDITIONS		T _A [†]	TLV2422C			UNIT
					MIN	TYP	MAX	
V _{IO}	Input offset voltage	V _{IC} = 0, V _O = 0, V _{DD} ± = ±2.5 V, R _S = 50 Ω		25°C	300		2000	μV
	Full range			2500				
αV _{IO}	Temperature coefficient of input offset voltage			25°C to 70°C	2		μV/°C	
	Input offset voltage long-term drift (see Note 4)			25°C	0.003		μV/mo	
I _{IO}	Input offset current			25°C	0.5		60	pA
				Full range	150			
I _{IB}	Input bias current			25°C	1		60	pA
				Full range	150			
V _{ICR}	Common-mode input voltage range	V _{IO} ≤ 5 mV, R _S = 50 Ω		25°C	0 to −0.25 to 2.5 to 2.75		V	
				Full range	0 to 2.2			
V _{OH}	High-level output voltage	I _{OH} = −100 μA		25°C	2.97		V	
		I _{OH} = −500 μA		25°C	2.75			
				Full range	2.5			
V _{OL}	Low-level output voltage	V _{IC} = 0, I _{OL} = 100 μA		25°C	0.05		V	
		V _{IC} = 0, I _{OL} = 250 μA		25°C	0.2			
				Full range	0.5			
A _{VD}	Large-signal differential voltage amplification	V _{IC} = 2.5 V, V _O = 1 V to 2 V	R _L = 10 kΩ [‡]	25°C	6		V/mV	
				Full range	3			
			R _L = 1 MΩ [‡]	25°C	700			
r _{i(d)}	Differential input resistance			25°C	10 ¹²		Ω	
r _{i(c)}	Common-mode input resistance			25°C	10 ¹²		Ω	
c _{i(c)}	Common-mode input capacitance	f = 10 kHz		25°C	8		pF	
z _o	Closed-loop output impedance	f = 100 kHz, A _V = 10		25°C	130		Ω	
CMRR	Common-mode rejection ratio	V _{IC} = 0 to 2.5 V, V _O = 1.5 V, R _S = 50 Ω		25°C	70		dB	
				Full range	70			
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		dB	
				Full range	80			
I _{DD}	Supply current	V _O = 1.5 V, No load		25°C	100		μA	
				Full range	175			

† Full range is 0°C to 70°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.

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

PARAMETER		TEST CONDITIONS		T _A [†]	TLV2422I			TLV2422AI			UNIT	
					MIN	TYP	MAX	MIN	TYP	MAX		
V _{IO}	Input offset voltage	V _{IC} = 0, V _O = 0, V _{DD} ± = ±2.5 V, R _S = 50 Ω		25°C	300	2000		300	950	μV		
	Full range			2500			1500					
αV _{IO}	Temperature coefficient of input offset voltage			25°C to 70°C	2			2			μV/°C	
	Input offset voltage long-term drift (see Note 4)			25°C	0.003			0.003			μV/mo	
I _{IO}	Input offset current			25°C	0.5	60		0.5	60	pA		
				Full range	150			150				
I _{IB}	Input bias current			25°C	1	60		1	60	pA		
				Full range	150			150				
V _{ICR}	Common-mode input voltage range			V _{IO} ≤ 5 mV, R _S = 50 Ω		25°C	0 to 2.5	−0.25 to 2.75		0 to 2.5	−0.25 to 2.75	V
						Full range	0 to 2.2			0 to 2.2		
V _{OH}	High-level output voltage	I _{OH} = −100 μA		25°C	2.97			2.97			V	
		I _{OH} = −500 μA		25°C	2.75			2.75				
				Full range	2.5			2.5				
V _{OL}	Low-level output voltage	V _{IC} = 0, I _{OL} = 100 μA		25°C	0.05			0.05			V	
		V _{IC} = 0, I _{OL} = 250 μA		25°C	0.2			0.2				
				Full range	0.5			0.5				
A _{VD}	Large-signal differential voltage amplification	V _{IC} = 2.5 V, V _O = 1 V to 2 V	R _L = 10 kΩ‡	25°C	6	10		6	10	V/mV		
				Full range	3			3				
			R _L = 1 MΩ‡	25°C	700			700				
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 = 100 kHz, A _V = 10		25°C	130			130			Ω	
CMRR	Common-mode rejection ratio	V _{IC} = 0 to 2.5 V, V _O = 1.5 V, R _S = 50 Ω		25°C	70	83		70	83	dB		
				Full range	70			70				
k _{SVR}	Supply-voltage rejection ratio (ΔV _{DD} /ΔV _{IO})	V _{DD} = 2.7 V to 8 V, V _{IC} = V _{DD} /2, No load		25°C	80	95		80	95	dB		
				Full range	80			80				
I _{DD}	Supply current	V _O = 1.5 V, No load		25°C	100	150		100	150	μA		
				Full range	175			175				

† Full range is -40°C to 85°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.



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

PARAMETER		TEST CONDITIONS		T _A [†]	TLV2422C, TLV2422I TLV2422AI			UNIT
					MIN	TYP	MAX	
SR	Slew rate at unity gain	V _O = 1.5 V to 3.5 V, R _L = 10 kΩ [‡] , C _L = 100 pF [‡]		25°C	0.01	0.02	V/μs	
				Full range	0.008			
V _n	Equivalent input noise voltage	f = 10 Hz		25°C	100		nV/√Hz	
		f = 1 kHz		25°C	23			
V _{N(PP)}	Peak-to-peak equivalent input noise voltage	f = 0.1 Hz to 1 Hz		25°C	2.7		μV	
		f = 0.1 Hz to 10 Hz		25°C	4			
I _n	Equivalent input noise current			25°C	0.6		fA√Hz	
THD + N	Total harmonic distortion plus noise	V _O = 0.5 V to 2.5 V, f = 1 kHz, R _L = 10 kΩ [‡]	A _V = 1	25°C	0.25%			
			A _V = 10		1.8%			
Gain-bandwidth product		f = 10 kHz, C _L = 100 pF [‡]	R _L = 10 kΩ [‡] ,	25°C	46		kHz	
B _{OM}	Maximum output-swing bandwidth	V _{O(PP)} = 1 V, R _L = 10 kΩ [‡] ,	A _V = 1, C _L = 100 pF [‡]	25°C	8.3		kHz	
t _s	Settling time	A _V = −1, Step = 0.5 V to 2.5 V, R _L = 10 kΩ [‡] , C _L = 100 pF [‡]	To 0.1%	25°C	8.6		μs	
			To 0.01%		16			
φ _m	Phase margin at unity gain	R _L = 10 kΩ [‡] , C _L = 100 pF [‡]		25°C	62°			
Gain margin				25°C	11		dB	

† Full range for the C version is 0°C to 70°C. Full range for the I version is –40°C to 85°C.

‡ Referenced to 2.5 V

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

PARAMETER	TEST CONDITIONS	$T_A^\dagger$	TLV2422Q, TLV2422M			TLV2422AQ, TLV2422AM			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
V_{IO} Input offset voltage	$V_{IC} = 0, V_O = 0, V_{DD} \pm = \pm 1.5\text{ V}, R_S = 50\ \Omega$	25°C		300	2000		300	950	μV
		Full range			2500			1800	
α_{VIO} Temperature coefficient of input offset voltage		Full range		2			2		$\mu\text{V}/^\circ\text{C}$
Input offset voltage long-term drift (see Note 4)		25°C		0.003			0.003		$\mu\text{V}/\text{mo}$
I_{IO} Input offset current		25°C		0.5	60		0.5	60	pA
		Full range			150			150	
I_{IB} Input bias current		25°C		1	60		1	60	pA
		Full range			300			300	
V_{ICR} Common-mode input voltage range		25°C	0 to 2.5	-0.25 to 2.75		0 to 2.5	-0.25 to 2.75		V
		Full range	0 to 2.2			0 to 2.2			
V_{OH} High-level output voltage	$I_{OH} = -100\ \mu\text{A}$	25°C		2.97			2.97		V
	$I_{OH} = -500\ \mu\text{A}$	25°C		2.75			2.75		
		Full range		2.5			2.5		
V_{OL} Low-level output voltage	$V_{IC} = 0, I_{OL} = 100\ \mu\text{A}$	25°C		0.05			0.05		V
	$V_{IC} = 0, I_{OL} = 250\ \mu\text{A}$	25°C		0.2			0.2		
		Full range			0.5			0.5	
A_{VD} Large-signal differential voltage amplification	$V_{IC} = 1.5\text{ V}, V_O = 1\text{ V to }2\text{ V}$	25°C	6	10		6	10		V/mV
		Full range	2			2			
		25°C		700			700		
$r_{i(d)}$ 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	$f = 100\text{ kHz}, A_V = 10$	25°C		130			130		Ω
$CMRR$ Common-mode rejection ratio	$V_{IC} = V_{ICR}\text{ min}, V_O = 1.5\text{ V}, R_S = 50\ \Omega$	25°C	70	83		70	83		dB
		Full range	70			70			
k_{SVR} Supply-voltage rejection ratio ($\Delta V_{DD}/\Delta V_{IO}$)	$V_{DD} = 2.7\text{ V to }8\text{ V}, V_{IC} = V_{DD}/2, \text{ No load}$	25°C	80	95		80	95		dB
		Full range	80			80			
I_{DD} Supply current	$V_O = 1.5\text{ V}, \text{ No load}$	25°C		100	150		100	150	μA
		Full range			175			175	

† Full range is -40°C to 125°C for Q level part, -55°C to 125°C for M level part.

‡ 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.



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

PARAMETER		TEST CONDITIONS		T _A [†]	TLV2422Q, TLV2422M, TLV2422AQ, TLV2422AM			UNIT
					MIN	TYP	MAX	
SR	Slew rate at unity gain	V _O = 1.1 V to 1.9 V, R _L = 10 kΩ [‡] , C _L = 100 pF [‡]		25°C	0.01	0.02	V/μs	
				Full range	0.008			
V _n	Equivalent input noise voltage	f = 10 Hz		25°C	100		nV/√Hz	
		f = 1 kHz		25°C	23			
V _{N(PP)}	Peak-to-peak equivalent input noise voltage	f = 0.1 Hz to 1 Hz		25°C	2.7		μV	
		f = 0.1 Hz to 10 Hz		25°C	4			
I _n	Equivalent input noise current			25°C	0.6		fA√Hz	
THD + N	Total harmonic distortion plus noise	V _O = 0.5 V to 2.5 V, f = 1 kHz, R _L = 10 kΩ [‡]	A _V = 1	25°C	0.25%			
			A _V = 10		1.8%			
Gain-bandwidth product		f = 10 kHz, C _L = 100 pF [‡]	R _L = 10 kΩ [‡] ,	25°C	46		kHz	
B _{OM}	Maximum output-swing bandwidth	V _{O(PP)} = 1 V, R _L = 10 kΩ [‡] ,	A _V = 1, C _L = 100 pF [‡]	25°C	8.3		kHz	
t _s	Settling time	A _V = −1, Step = 0.5 V to 2.5 V, R _L = 10 kΩ [‡] , C _L = 100 pF [‡]	To 0.1%	25°C	8.6		μs	
			To 0.01%		16			
φ _m	Phase margin at unity gain	R _L = 10 kΩ [‡] , C _L = 100 pF [‡]		25°C	62°			
	Gain margin			25°C	11		dB	

† Full range is –40°C to 125°C for Q level part, –55°C to 125°C for M level part.

‡ Referenced to 1.5 V

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

PARAMETER	TEST CONDITIONS	$T_A^\dagger$	TLV2422C			UNIT
			MIN	TYP	MAX	
V_{IO} Input offset voltage	$V_{IC} = 0, V_O = 0, V_{DD} \pm \pm 2.5\text{ V}, R_S = 50\ \Omega$	25°C		300	2000	μV
		Full range			2500	
α_{VIO} Temperature coefficient of input offset voltage		25°C to 70°C		2		$\mu\text{V}/^\circ\text{C}$
Input offset voltage long-term drift (see Note 4)		25°C		0.003		$\mu\text{V}/\text{mo}$
I_{IO} Input offset current		25°C		0.5	60	pA
		Full range			150	
I_{IB} Input bias current		25°C		1	60	pA
		Full range			150	
V_{ICR} Common-mode input voltage range	$ V_{IO} \leq 5\text{ mV}, R_S = 50\ \Omega$	25°C	0 to 4.5	-0.25 to 4.75		V
		Full range	0 to 4.2			
V_{OH} High-level output voltage	$I_{OH} = -100\ \mu\text{A}$	25°C		4.97		V
	$I_{OH} = -1\text{ mA}$	25°C		4.5	4.75	
		Full range		4.25		
V_{OL} Low-level output voltage	$V_{IC} = 2.5\text{ V}, I_{OL} = 100\ \mu\text{A}$	25°C		0.04		V
	$V_{IC} = 2.5\text{ V}, I_{OL} = 500\ \mu\text{A}$	25°C		0.15		
		Full range			0.5	
A_{VD} Large-signal differential voltage amplification	$V_{IC} = 2.5\text{ V}, V_O = 1\text{ V to }4\text{ V}$	25°C	8	12		V/mV
		Full range	5			
		25°C		1000		
$r_{i(d)}$ Differential input resistance		25°C		10^{12}		Ω
$r_{i(c)}$ Common-mode input resistance		25°C		10^{12}		Ω
$C_{i(c)}$ Common-mode input capacitance	$f = 10\text{ kHz}$	25°C		8		pF
z_O Closed-loop output impedance	$f = 100\text{ kHz}, A_V = 10$	25°C		130		Ω
CMRR Common-mode rejection ratio	$V_{IC} = 0\text{ to }4.5\text{ V}, V_O = 2.5\text{ V}, R_S = 50\ \Omega$	25°C	70	90		dB
		Full range	70			
k_{SVR} Supply-voltage rejection ratio ($\Delta V_{DD}/\Delta V_{IO}$)	$V_{DD} = 4.4\text{ V to }8\text{ V}, V_{IC} = V_{DD}/2, \text{ No load}$	25°C	80	95		dB
		Full range	80			
I_{DD} Supply current	$V_O = 2.5\text{ V}, \text{ No load}$	25°C		100	150	μA
		Full range			175	

† Full range is 0°C to 70°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.



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PARAMETER		TEST CONDITIONS		T _A [†]	TLV2422I			TLV2422AI			UNIT
					MIN	TYP	MAX	MIN	TYP	MAX	
V _{IO}	Input offset voltage	V _{IC} = 0, V _O = 0, V _{DD} ± = ±2.5 V, R _S = 50 Ω		25°C	300 2000		300 950		μV		
Full range				2500		1500					
α _{VIO}	Temperature coefficient of input offset voltage			25°C to 70°C	2		2		μV/°C		
Input offset voltage long-term drift (see Note 4)				25°C	0.003		0.003		μV/mo		
I _{IO}	Input offset current			25°C	0.5 60		0.5 60		pA		
				Full range 150			150				
I _{IB}	Input bias current			25°C	1 60		1 60		pA		
				Full range 150			150				
V _{ICR}	Common-mode input voltage range	V _{IO} ≤ 5 mV, R _S = 50 Ω		25°C	0 to 4.5 −0.25 to 4.75		0 to 4.5 −0.25 to 4.75		V		
				Full range	0 to 4.2		0 to 4.2				
V _{OH}	High-level output voltage	I _{OH} = −100 μA		25°C	4.97		4.97		V		
		I _{OH} = −1 mA		25°C	4.5 4.75		4.5 4.75				
				Full range	4.25		4.25				
V _{OL}	Low-level output voltage	V _{IC} = 2.5 V, I _{OL} = 100 μA		25°C	0.04		0.04		V		
		V _{IC} = 2.5 V, I _{OL} = 500 μA		25°C	0.15		0.15				
				Full range 0.5			0.5				
A _{VD}	Large-signal differential voltage amplification	V _{IC} = 2.5 V, V _O = 1 V to 4 V	R _L = 10 kΩ‡	25°C	8 12		8 12		V/mV		
			R _L = 1 MΩ‡	Full range	5		5				
				25°C	1000		1000				
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 = 100 kHz, A _V = 10		25°C	130		130		Ω		
CMRR	Common-mode rejection ratio	V _{IC} = 0 to 4.5 V, V _O = 2.5 V, R _S = 50 Ω		25°C	70 90		70 90		dB		
				Full range 70			70				
k _{SVR}	Supply-voltage rejection ratio (ΔV _{DD} /ΔV _{IO})	V _{DD} = 4.4 V to 8 V, V _{IC} = V _{DD} /2, No load		25°C	80 95		80 95		dB		
				Full range 80			80				
I _{DD}	Supply current	V _O = 2.5 V, No load		25°C	100 150		100 150		μA		
				Full range 175			175				

† Full range is -40°C to 85°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.

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

PARAMETER		TEST CONDITIONS		T _A [†]	TLV2422C, TLV2422I TLV2422AI			UNIT
					MIN	TYP	MAX	
SR	Slew rate at unity gain	V _O = 1.5 V to 3.5 V, R _L = 10 kΩ [‡] , C _L = 100 pF [‡]		25°C	0.01	0.02	V/μs	
				Full range	0.008			
V _n	Equivalent input noise voltage	f = 10 Hz		25°C	100		nV/√Hz	
		f = 1 kHz		25°C	18			
V _{N(PP)}	Peak-to-peak equivalent input noise voltage	f = 0.1 Hz to 1 Hz		25°C	1.9		μV	
		f = 0.1 Hz to 10 Hz		25°C	2.8			
I _n	Equivalent input noise current			25°C	0.6		fA/√Hz	
THD + N	Total harmonic distortion plus noise	V _O = 1.5 V to 3.5 V, f = 1 kHz, R _L = 10 kΩ [‡]	A _V = 1	25°C	0.24%			
			A _V = 10		1.7%			
Gain-bandwidth product		f = 10 kHz, C _L = 100 pF [‡]	R _L =10 kΩ [‡] ,	25°C	52		kHz	
B _{OM}	Maximum output-swing bandwidth	V _{O(PP)} = 2 V, R _L = 10 kΩ [‡] ,	A _V = 1, C _L = 100 pF [‡]	25°C	5.3		kHz	
t _s	Settling time	A _V = −1, Step = 1.5 V to 3.5 V, R _L = 10 kΩ [‡] , C _L = 100 pF [‡]	To 0.1%	25°C	8.5		μs	
			To 0.01%		15.5			
φ _m	Phase margin at unity gain	R _L = 10 kΩ [‡] , C _L = 100 pF [‡]		25°C	66°			
Gain margin				25°C	11		dB	

† Full range for the C version is 0°C to 70°C. Full range for the I version is –40°C to 85°C.

‡ Referenced to 2.5 V



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

PARAMETER	TEST CONDITIONS	$T_A^\dagger$	TLV2422Q, TLV2422M			TLV2422AQ, TLV2422AM			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
V_{IO} Input offset voltage	$V_{IC} = 0, V_O = 0, V_{DD} \pm = \pm 2.5\text{ V}, R_S = 50\ \Omega$	25°C	300	2000		300	950		μV
		Full range		2500			1800		
α_{VIO} Temperature coefficient of input offset voltage		Full range	2			2			$\mu\text{V}/^\circ\text{C}$
Input offset voltage long-term drift (see Note 4)		25°C	0.003			0.003			$\mu\text{V}/\text{mo}$
I_{IO} Input offset current		25°C	0.5	60		0.5	60		pA
		Full range		150			150		
I_{IB} Input bias current		25°C	1	60		1	60		pA
		Full range		300			300		
V_{ICR} Common-mode input voltage range		25°C	0 to 4.5	-0.25 to 4.75		0 to 4.5	-0.25 to 4.75		V
		Full range	0 to 4.2			0 to 4.2			
V_{OH} High-level output voltage	$I_{OH} = -100\ \mu\text{A}$	25°C	4.97			4.97			V
	$I_{OH} = -1\text{ mA}$	25°C	4.75			4.75			
		Full range	4.5			4.5			
V_{OL} Low-level output voltage	$V_{IC} = 2.5\text{ V}, I_{OL} = 100\ \mu\text{A}$	25°C	0.04			0.04			V
	$V_{IC} = 2.5\text{ V}, I_{OL} = 500\ \mu\text{A}$	25°C	0.15			0.15			
		Full range		0.5			0.5		
A_{VD} Large-signal differential voltage amplification	$V_{IC} = 2.5\text{ V}, V_O = 1\text{ V to } 4\text{ V}$	$R_L = 10\text{ k}\Omega^\ddagger$	25°C	8	12	8	12		V/mV
			Full range	3		3			
		$R_L = 1\text{ M}\Omega^\ddagger$	25°C	1000		1000			
$r_{i(d)}$ 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	$f = 100\text{ kHz}, A_V = 10$	25°C	130			130			Ω
CMRR Common-mode rejection ratio	$V_{IC} = V_{ICR}\text{ min}, V_O = 2.5\text{ V}, R_S = 50\ \Omega$	25°C	70	90		70	90		dB
		Full range	70			70			
k_{SVR} Supply-voltage rejection ratio ($\Delta V_{DD}/\Delta V_{IO}$)	$V_{DD} = 4.4\text{ V to } 8\text{ V}, V_{IC} = V_{DD}/2, \text{ No load}$	25°C	80	95		80	95		dB
		Full range	80			80			
I_{DD} Supply current	$V_O = 2.5\text{ V}, \text{ No load}$	25°C	100	150		100	150		μA
		Full range		175			175		

† Full range is -40°C to 125°C for Q level part, -55°C to 125°C for M level part.

‡ 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 [†]	TLV2422Q, TLV2422M, TLV2422AQ, TLV2422AM			UNIT
					MIN	TYP	MAX	
SR	Slew rate at unity gain	V _O = 1.5 V to 3.5 V, R _L = 10 kΩ [‡] , C _L = 100 pF [‡]		25°C	0.01	0.02	V/μs	
				Full range	0.008			
V _n	Equivalent input noise voltage	f = 10 Hz		25°C	100		nV/√Hz	
		f = 1 kHz		25°C	18			
V _{N(PP)}	Peak-to-peak equivalent input noise voltage	f = 0.1 Hz to 1 Hz		25°C	1.9		μV	
		f = 0.1 Hz to 10 Hz		25°C	2.8			
I _n	Equivalent input noise current			25°C	0.6		fA/√Hz	
THD + N	Total harmonic distortion plus noise	V _O = 1.5 V to 3.5 V, f = 1 kHz, R _L = 10 kΩ [‡]	A _V = 1	25°C	0.24%			
			A _V = 10		1.7%			
Gain-bandwidth product		f = 10 kHz, R _L = 10 kΩ [‡] , C _L = 100 pF [‡]		25°C	52		kHz	
B _{OM}	Maximum output-swing bandwidth	V _{O(PP)} = 2 V, R _L = 10 kΩ [‡] ,	A _V = 1, C _L = 100 pF [‡]	25°C	5.3		kHz	
t _s	Settling time	A _V = −1, Step = 1.5 V to 3.5 V, R _L = 10 kΩ [‡] , C _L = 100 pF [‡]	To 0.1%	25°C	8.5		μs	
			To 0.01%		15.5			
φ _m	Phase margin at unity gain	R _L = 10 kΩ [‡] , C _L = 100 pF [‡]		25°C	66°			
Gain margin				25°C	11		dB	

† Full range is -40°C to 125°C for Q level part, -55°C to 125°C for M level part.

‡ Referenced to 2.5 V



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	Gain margin	vs Load capacitance	49
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DISTRIBUTION OF TLV2422
INPUT OFFSET VOLTAGE

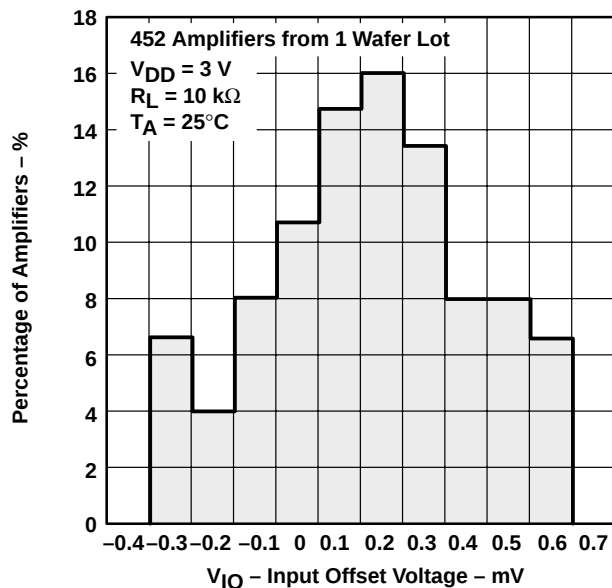


Figure 2

DISTRIBUTION OF TLV2422
INPUT OFFSET VOLTAGE

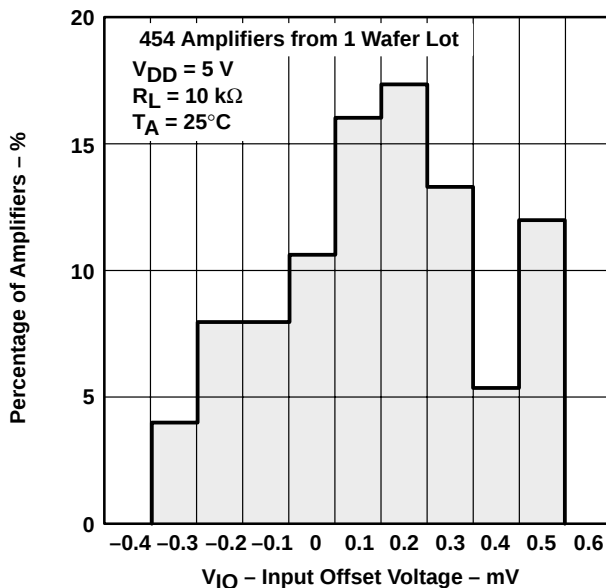


Figure 3

INPUT OFFSET VOLTAGE
VS
COMMON-MODE INPUT VOLTAGE

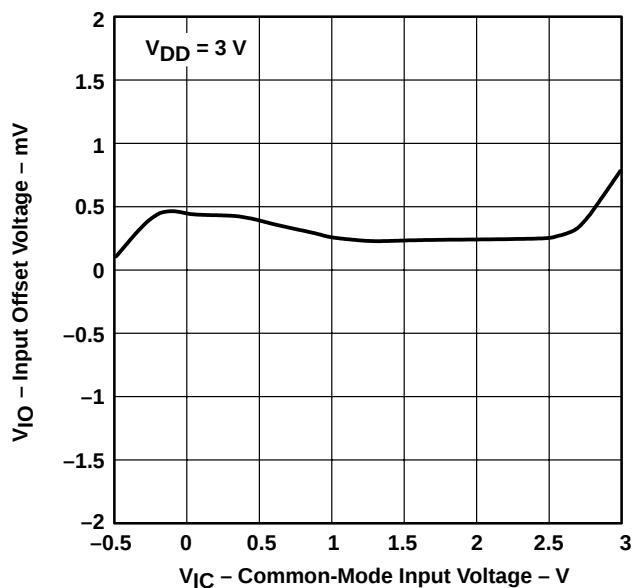


Figure 4

INPUT OFFSET VOLTAGE
VS
COMMON-MODE INPUT VOLTAGE

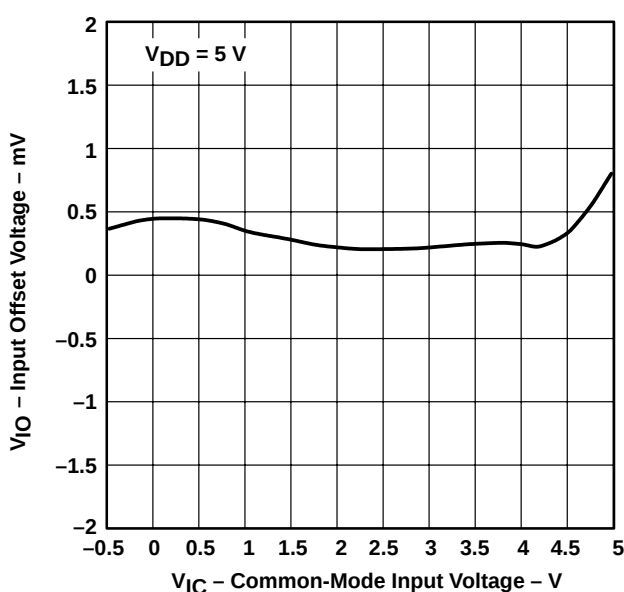


Figure 5

TYPICAL CHARACTERISTICS

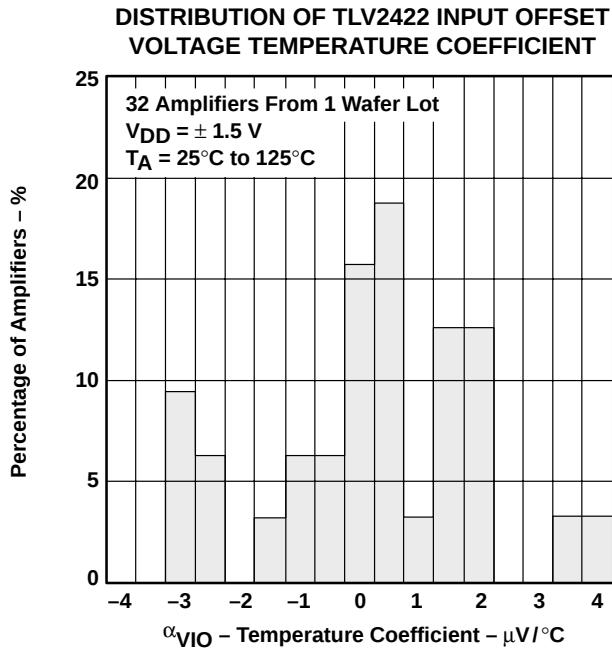


Figure 6

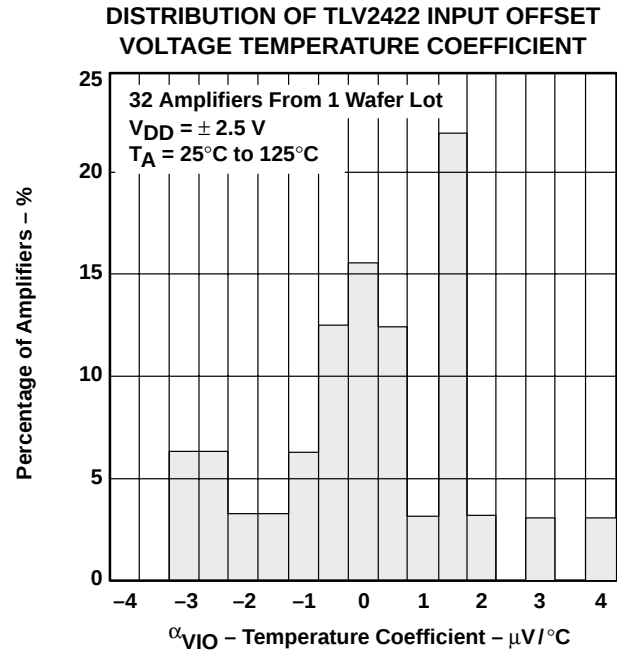


Figure 7

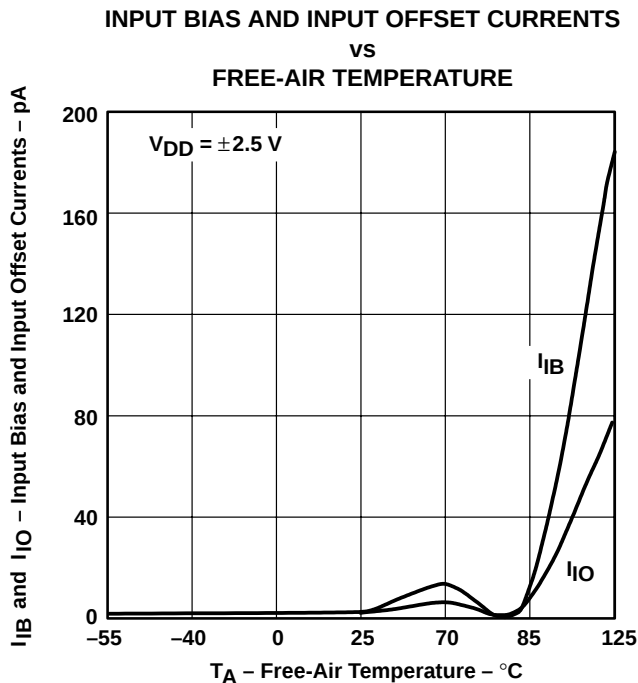


Figure 8

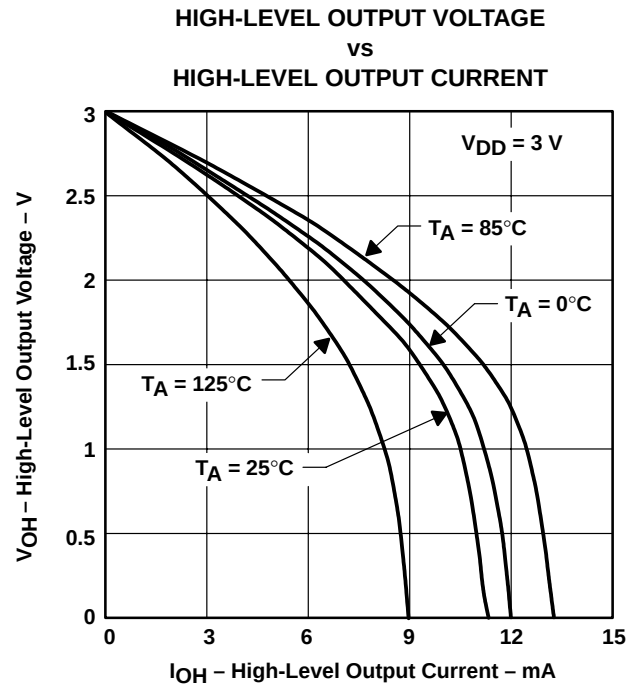


Figure 9

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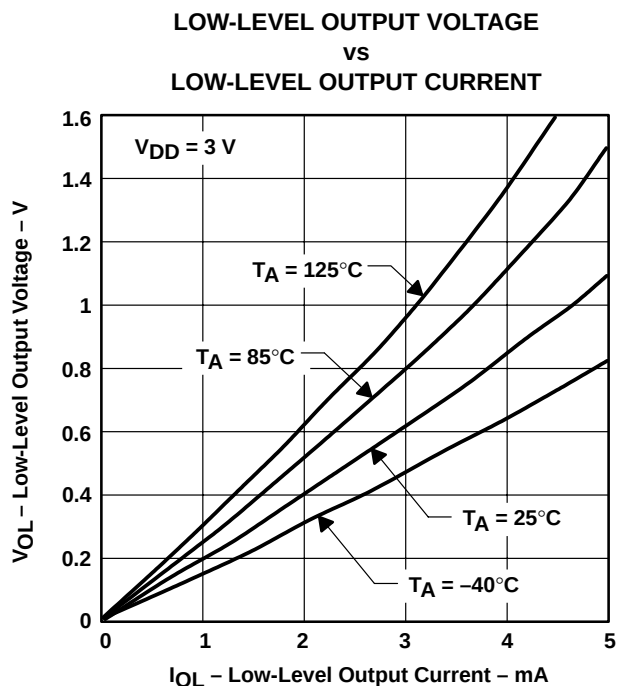


Figure 10

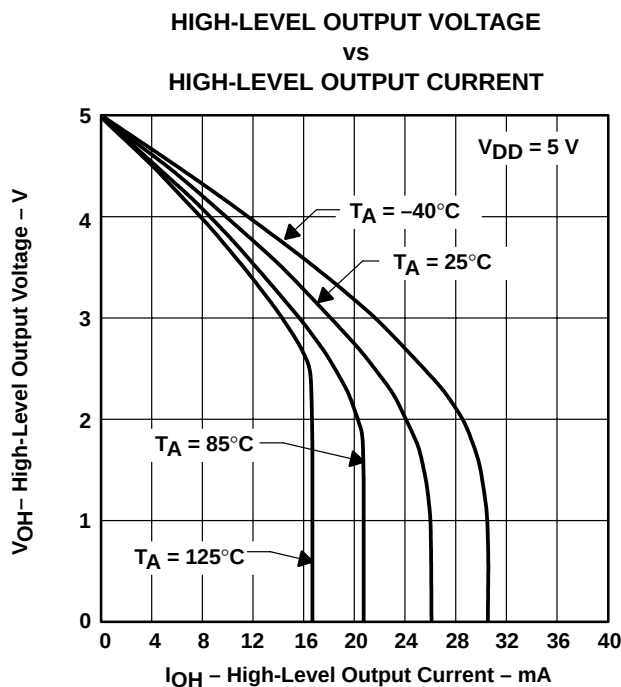


Figure 11

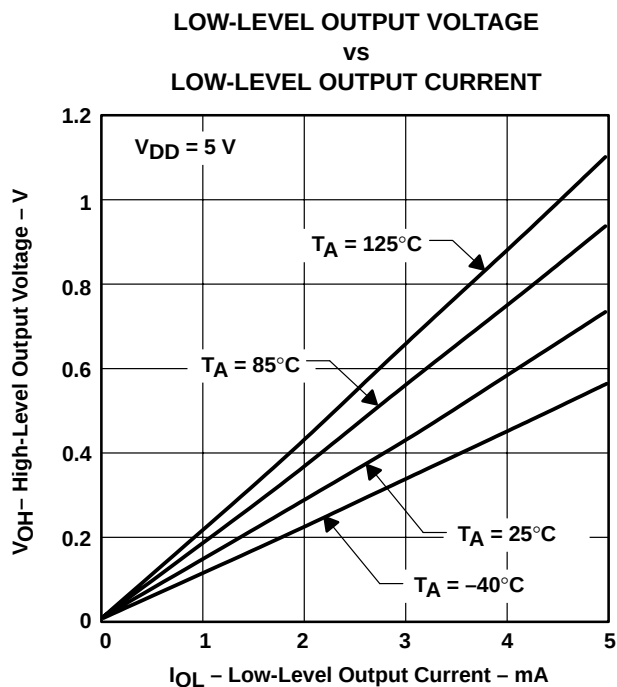


Figure 12

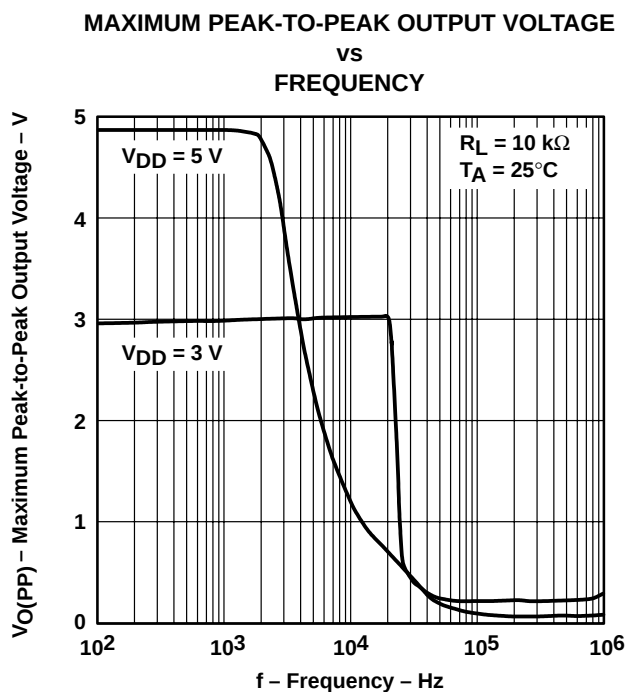
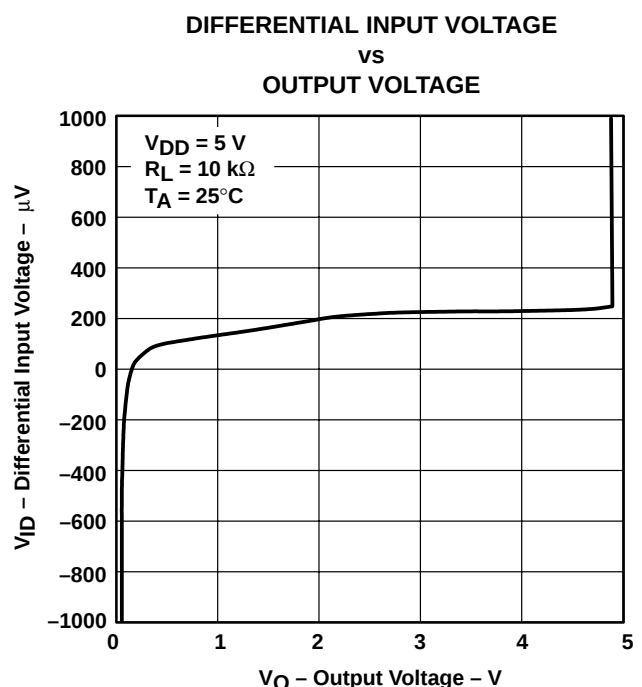
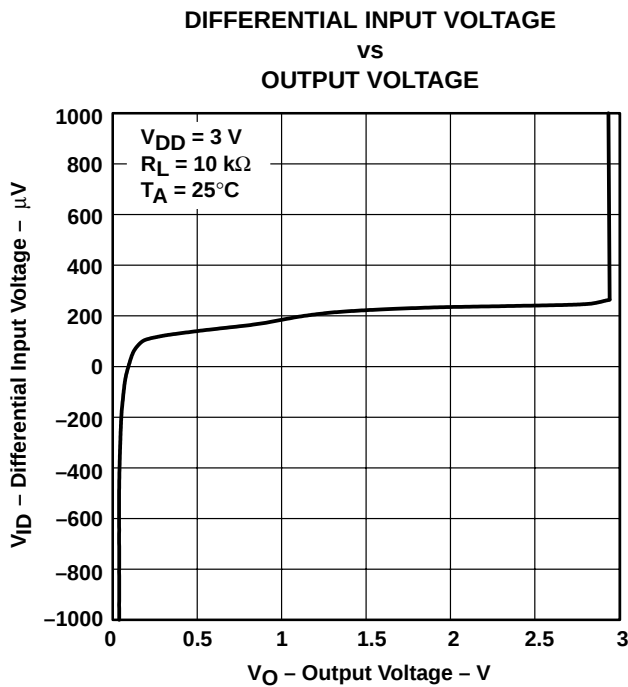
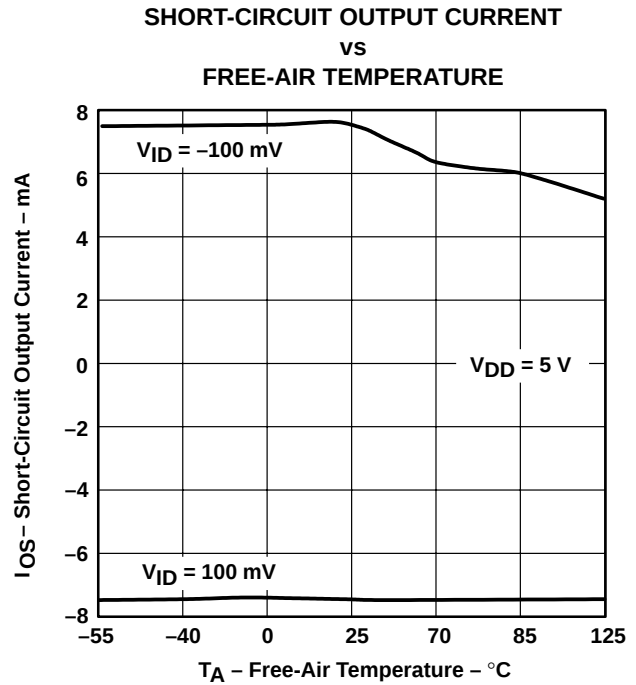
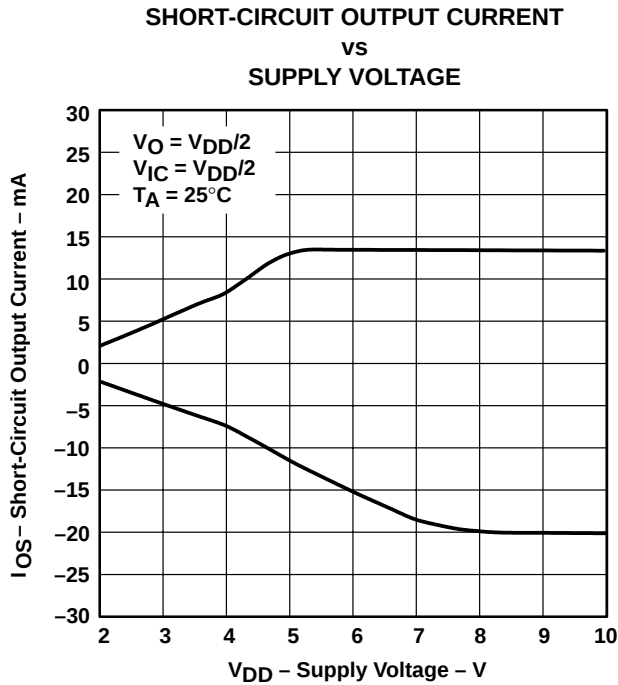


Figure 13

TYPICAL CHARACTERISTICS



TYPICAL CHARACTERISTICS

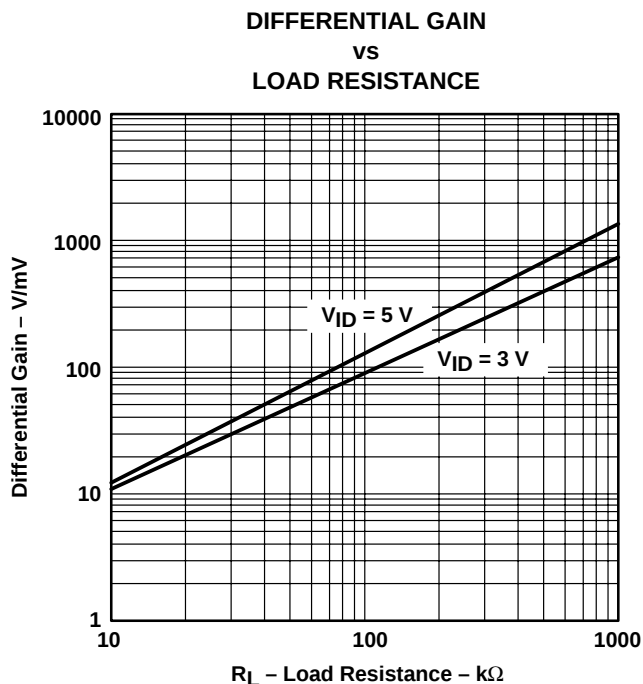


Figure 18

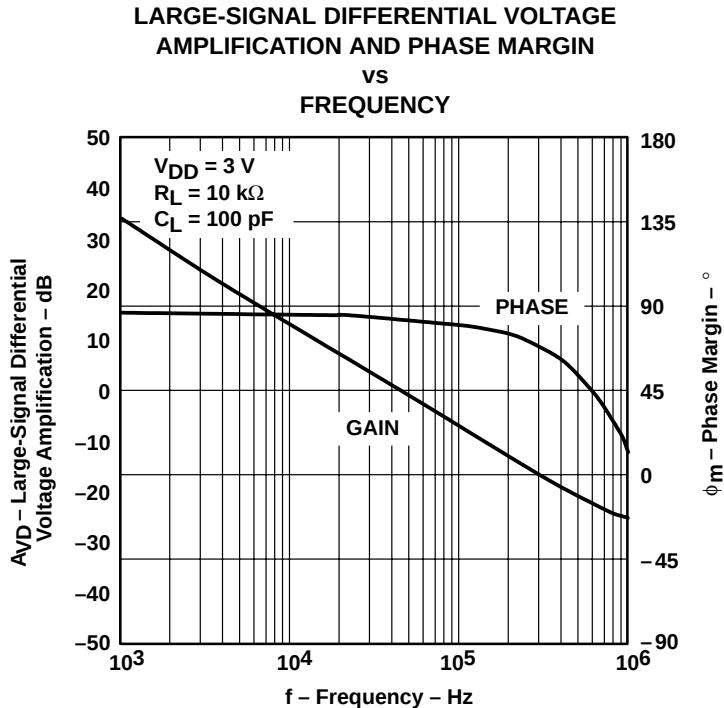


Figure 19

TYPICAL CHARACTERISTICS

LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION AND PHASE MARGIN

VS
FREQUENCY

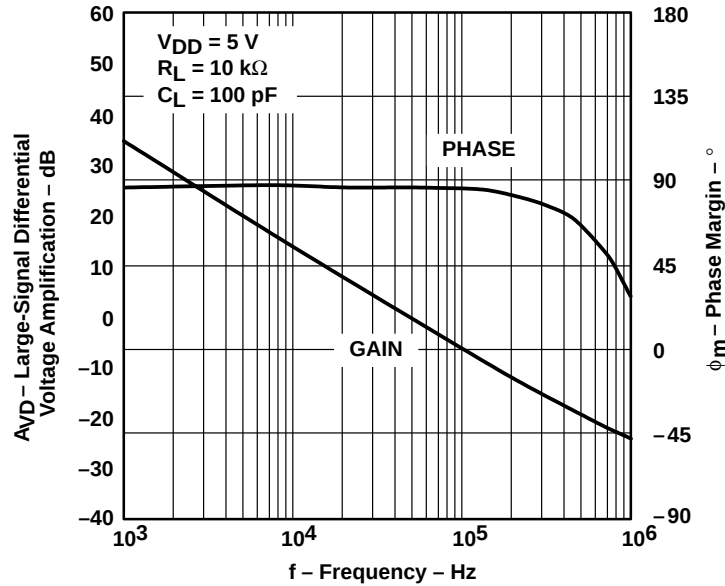


Figure 20

DIFFERENTIAL VOLTAGE AMPLIFICATION VS FREE-AIR TEMPERATURE

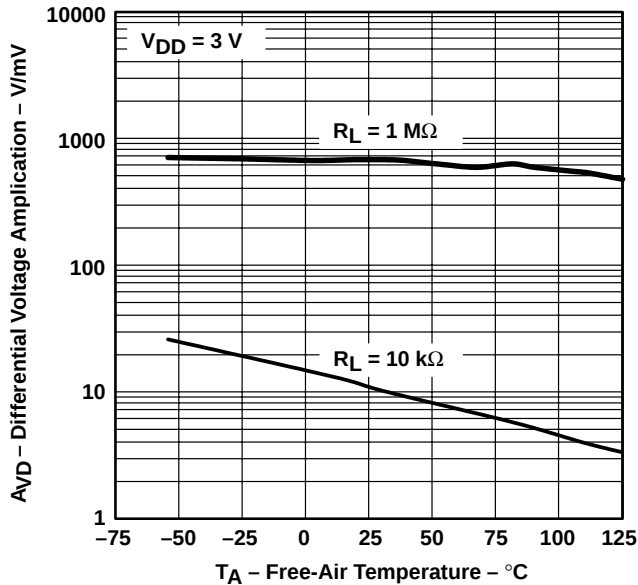


Figure 21

DIFFERENTIAL VOLTAGE AMPLIFICATION VS FREE-AIR TEMPERATURE

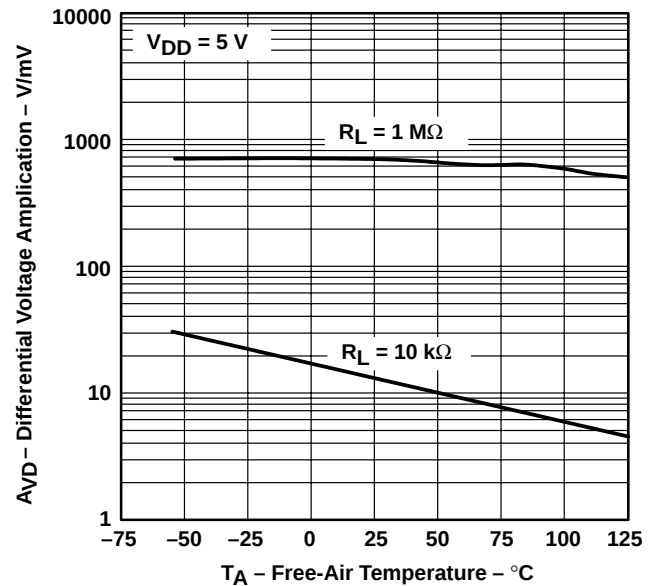


Figure 22

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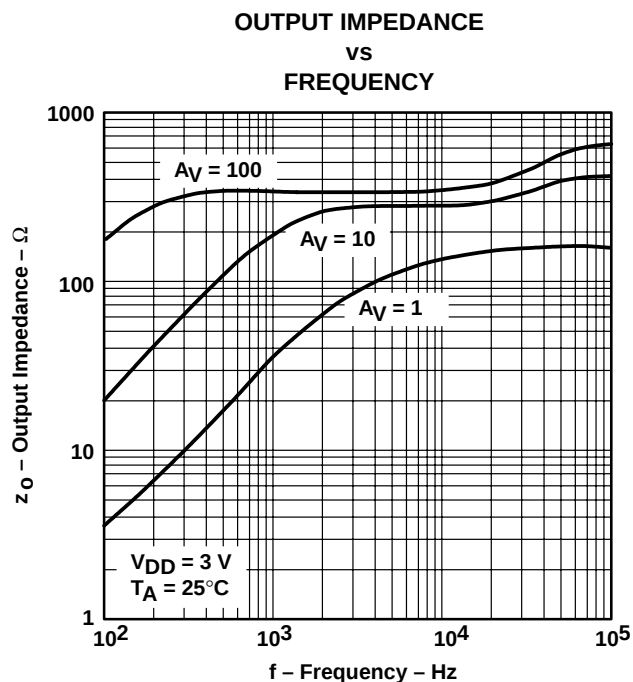


Figure 23

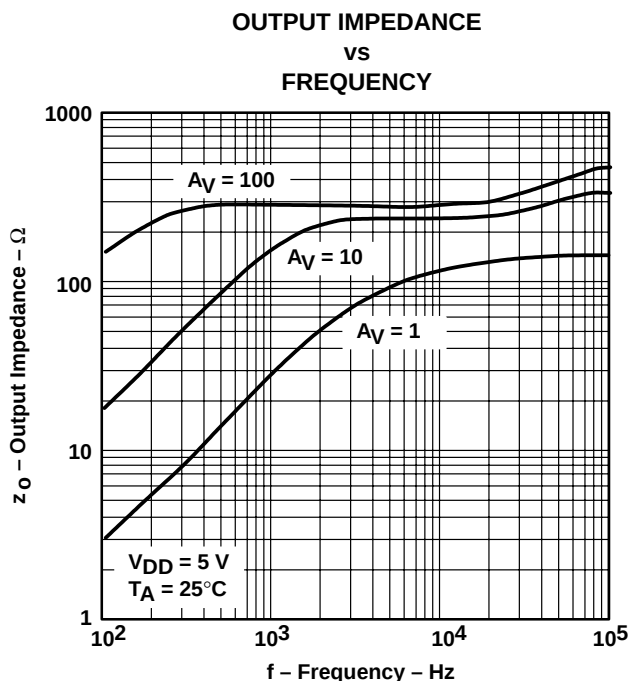


Figure 24

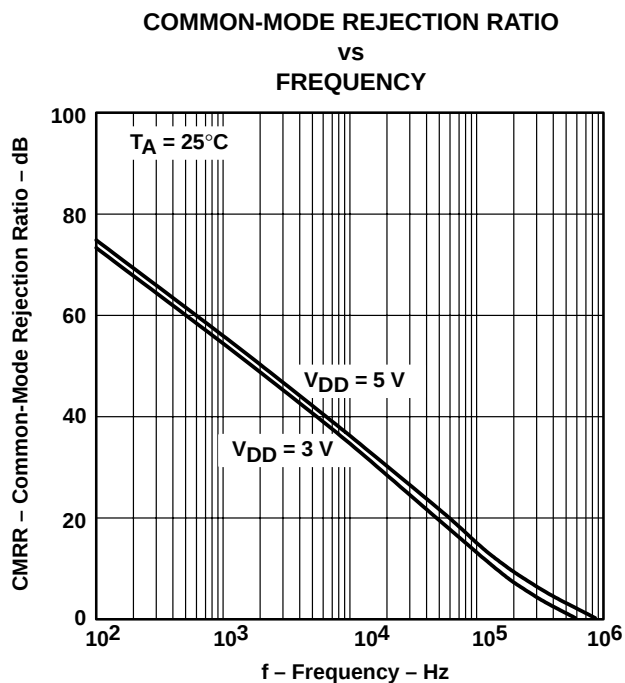


Figure 25

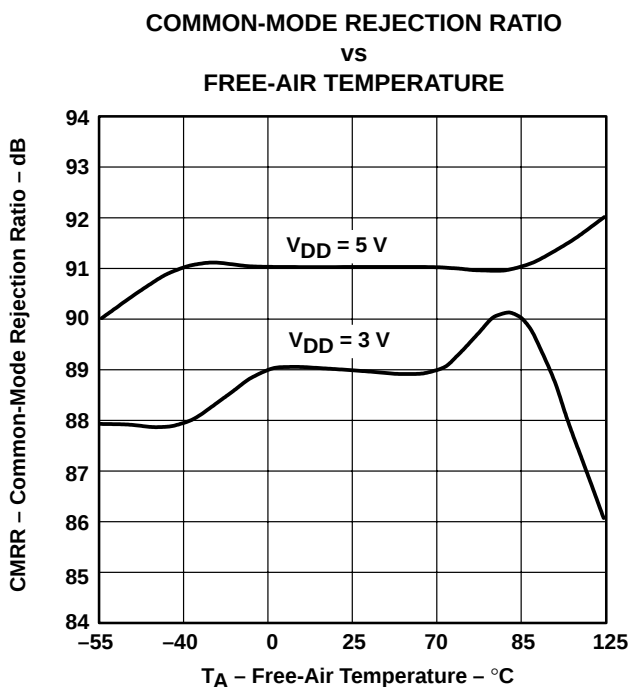


Figure 26

TYPICAL CHARACTERISTICS

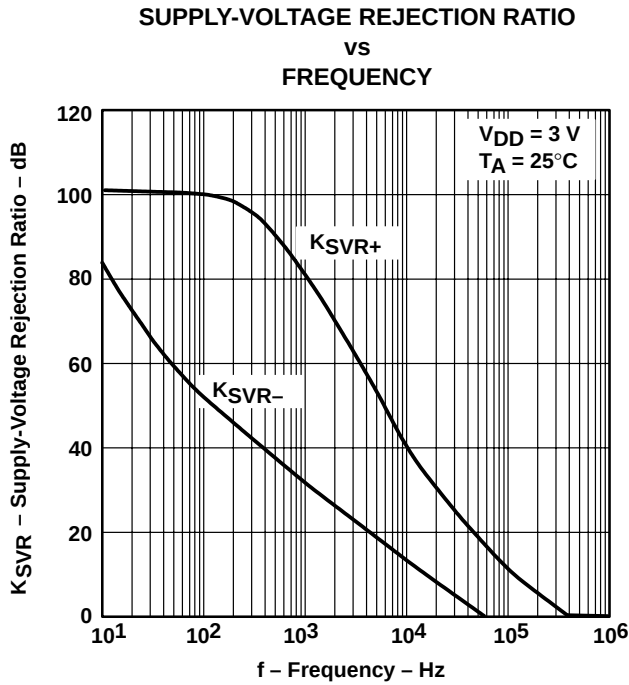


Figure 27

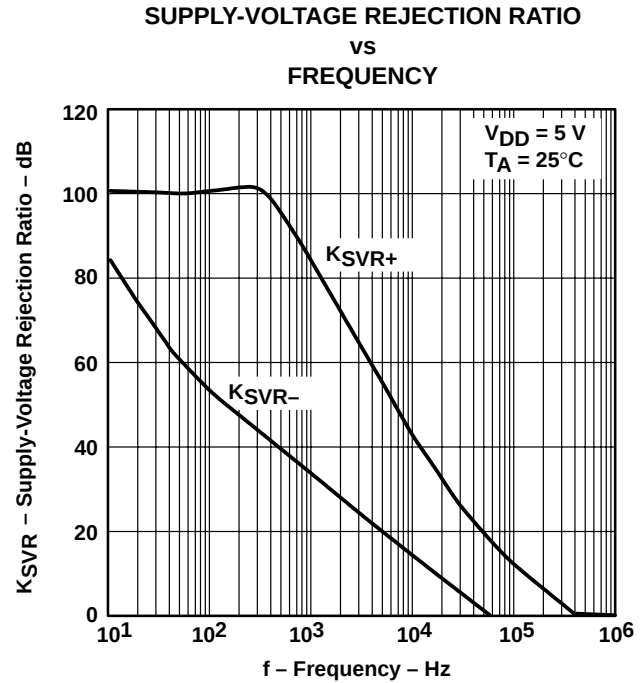


Figure 28

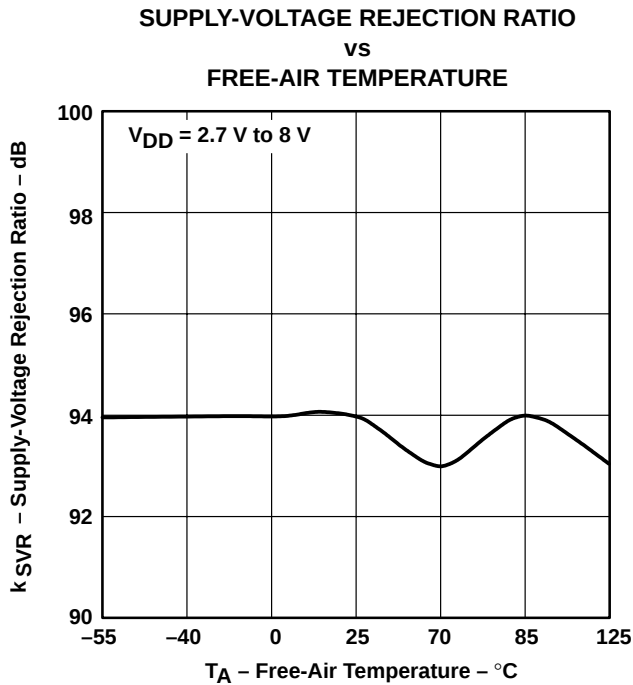


Figure 29

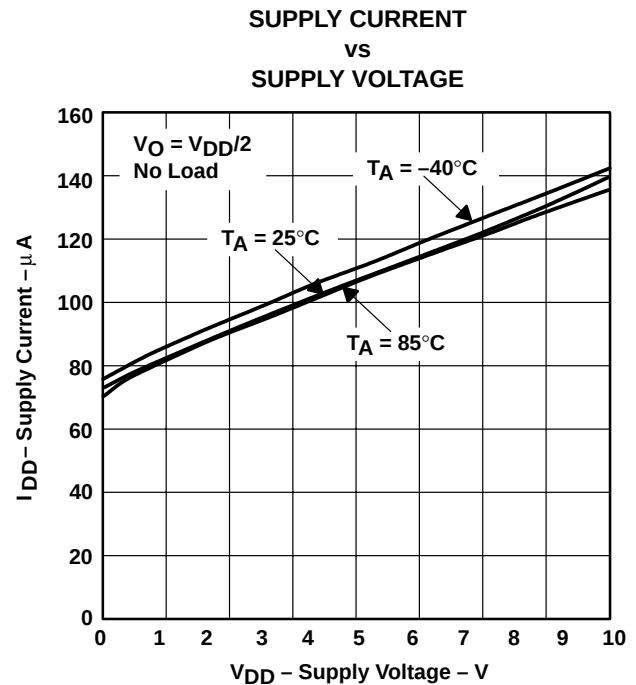


Figure 30

TLV2422, TLV2422A
Advanced LinCMOS™ RAIL-TO-RAIL OUTPUT
WIDE-INPUT-VOLTAGE MICROPOWER DUAL OPERATIONAL AMPLIFIERS

SLOS199C – SEPTEMBER 1997 – REVISED APRIL 2001

TYPICAL CHARACTERISTICS

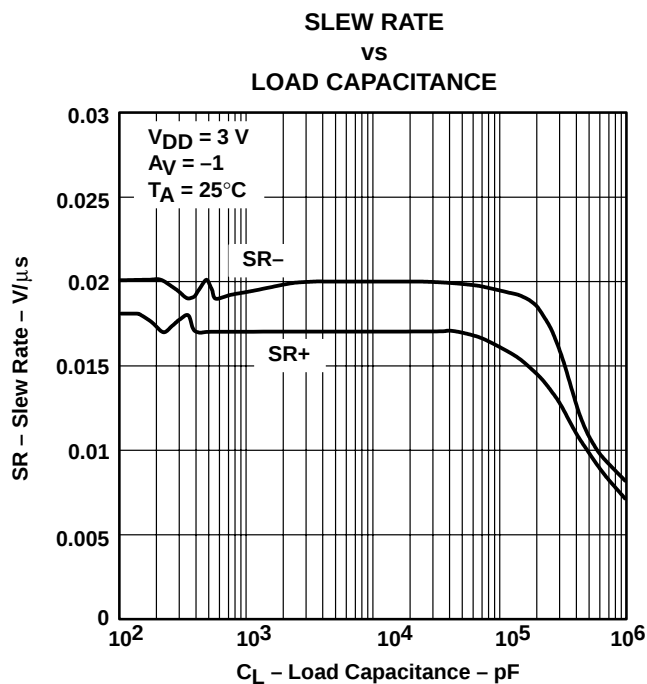


Figure 31

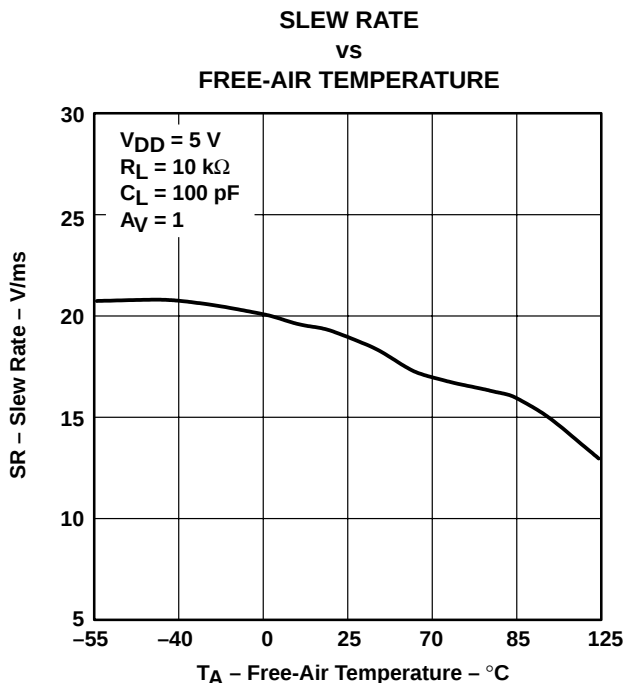


Figure 32

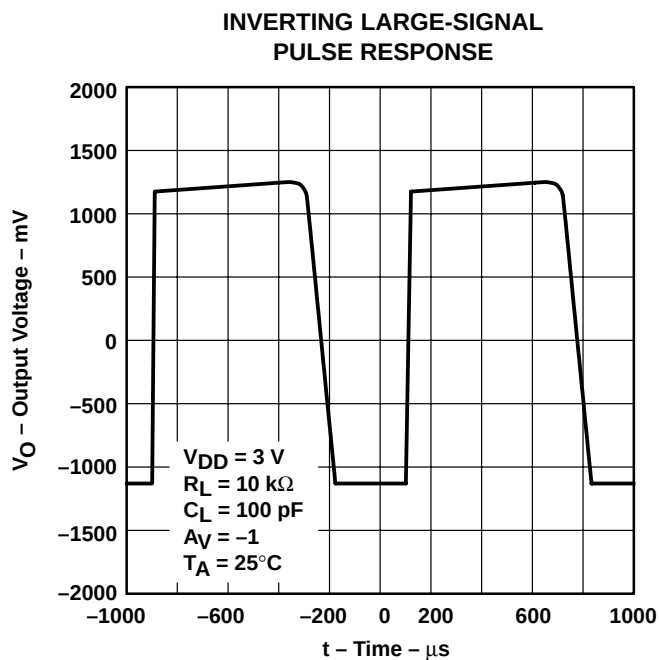


Figure 33

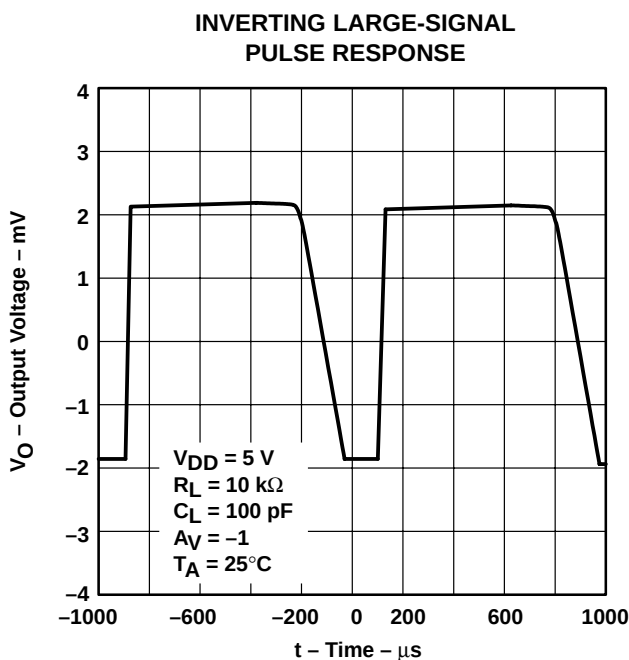


Figure 34

TYPICAL CHARACTERISTICS

**VOLTAGE-FOLLOWER LARGE-SIGNAL
PULSE RESPONSE**

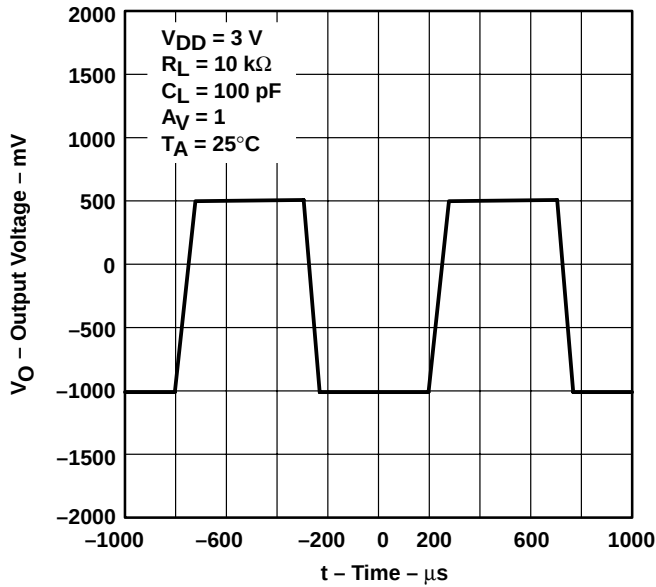


Figure 35

**VOLTAGE-FOLLOWER LARGE-SIGNAL
PULSE RESPONSE**

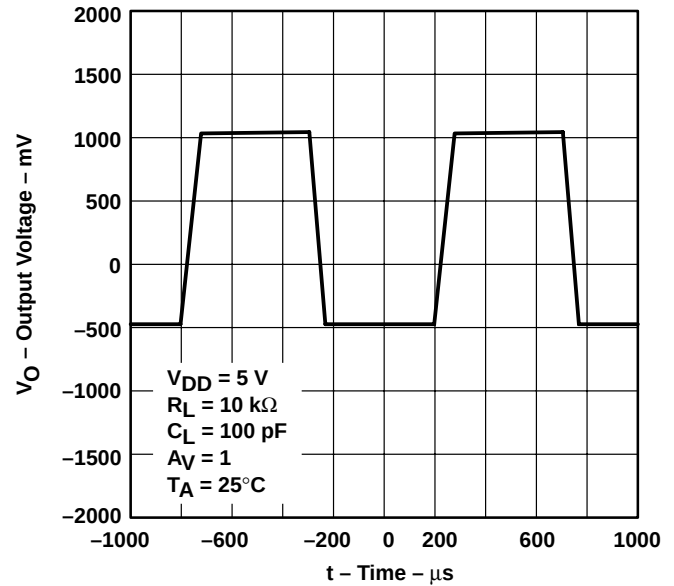


Figure 36

**INVERTING SMALL-SIGNAL
PULSE RESPONSE**

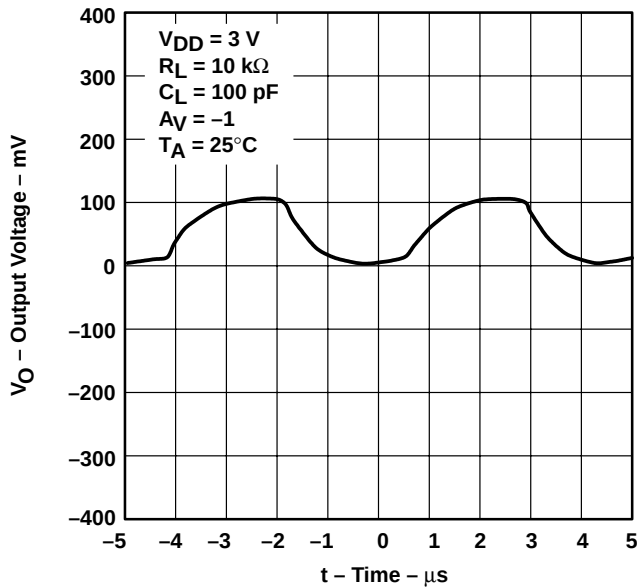


Figure 37

**INVERTING SMALL-SIGNAL
PULSE RESPONSE**

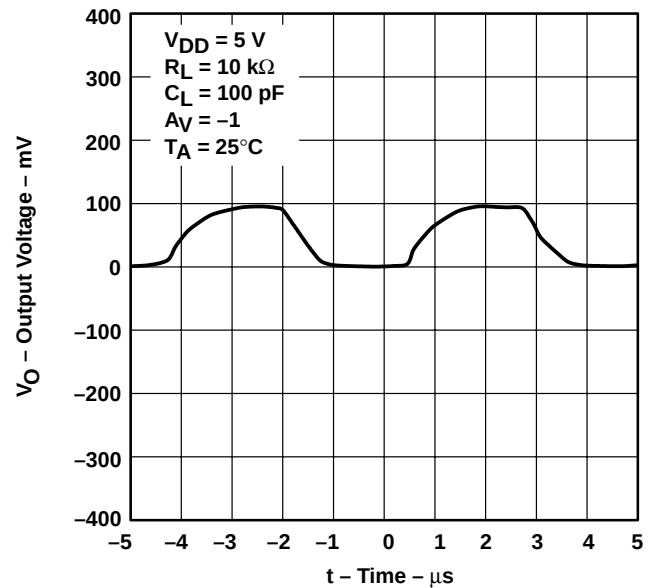


Figure 38

TLV2422, TLV2422A

Advanced LinCMOS™ RAIL-TO-RAIL OUTPUT

WIDE-INPUT-VOLTAGE MICROPOWER DUAL OPERATIONAL AMPLIFIERS

SLOS199C – SEPTEMBER 1997 – REVISED APRIL 2001

TYPICAL CHARACTERISTICS

VOLTAGE-FOLLOWER SMALL-SIGNAL
PULSE RESPONSE

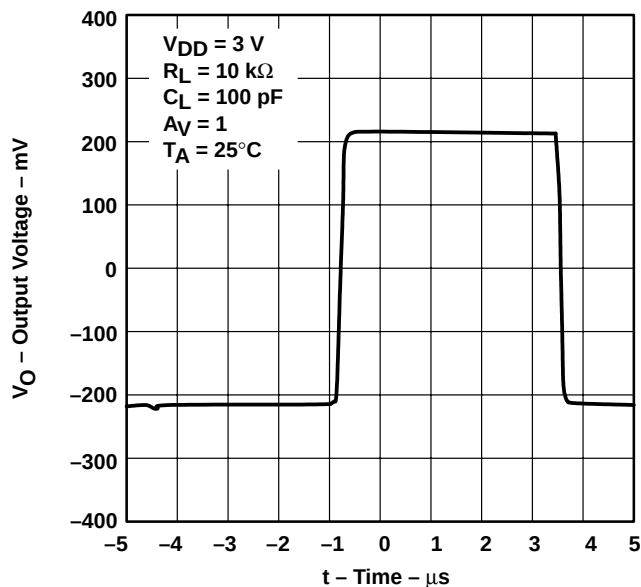


Figure 39

VOLTAGE-FOLLOWER SMALL-SIGNAL
PULSE RESPONSE

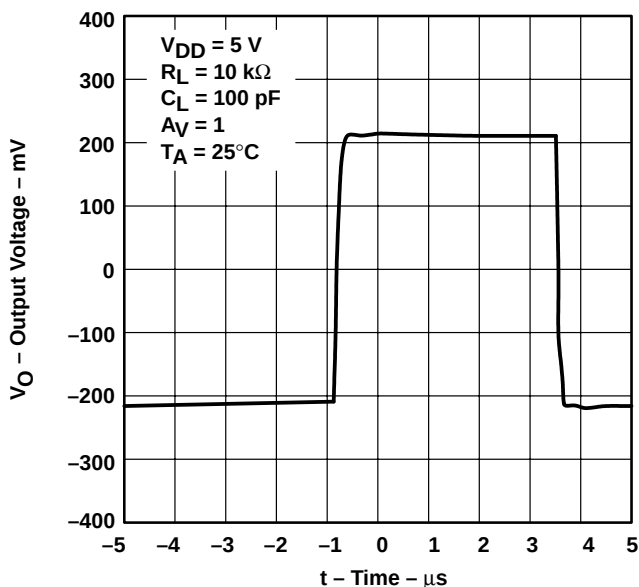


Figure 40

EQUIVALENT INPUT NOISE VOLTAGE
VS
FREQUENCY

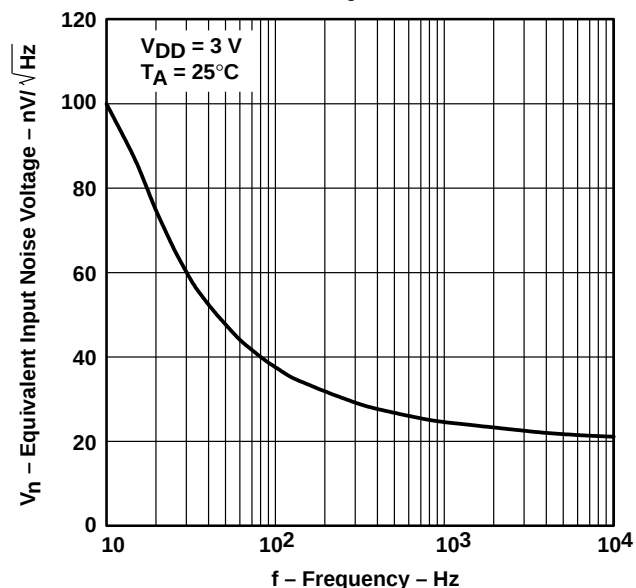


Figure 41

EQUIVALENT INPUT NOISE VOLTAGE
VS
FREQUENCY

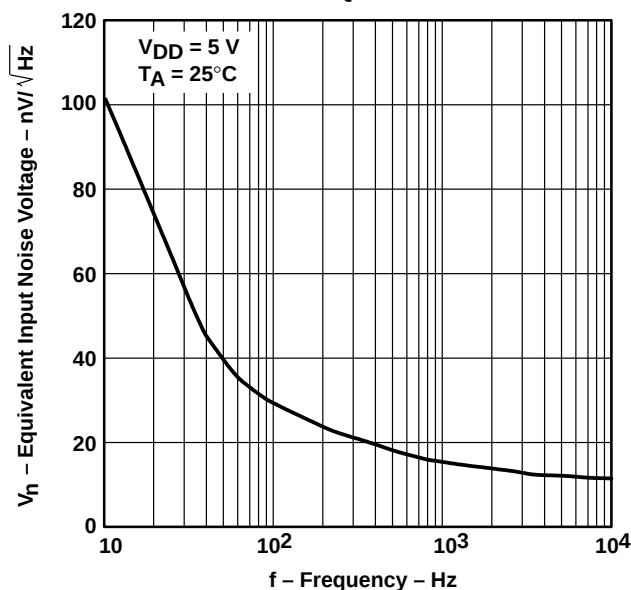


Figure 42

TYPICAL CHARACTERISTICS

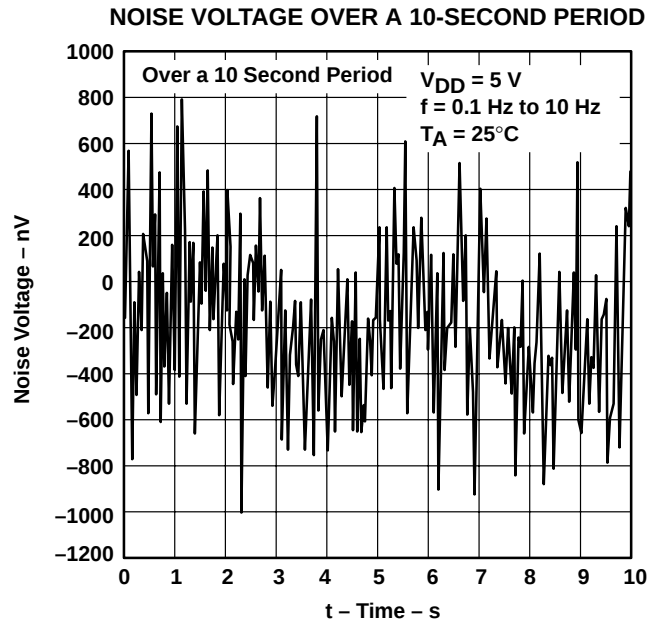


Figure 43

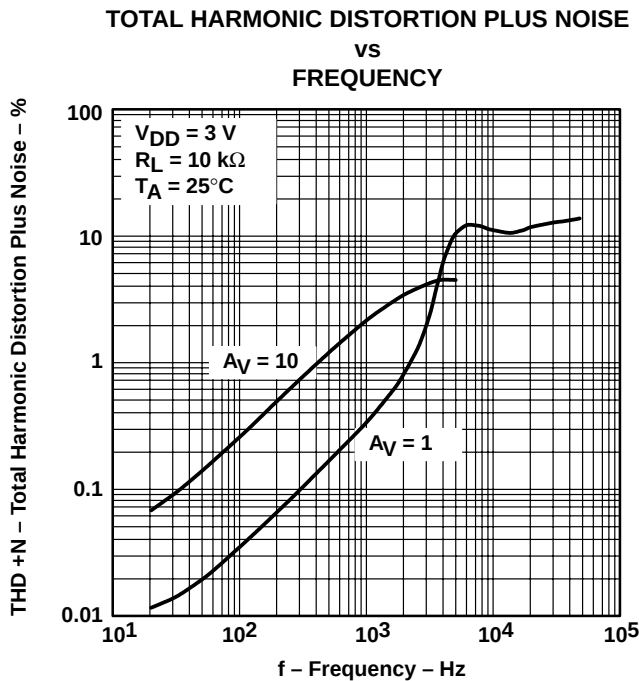


Figure 44

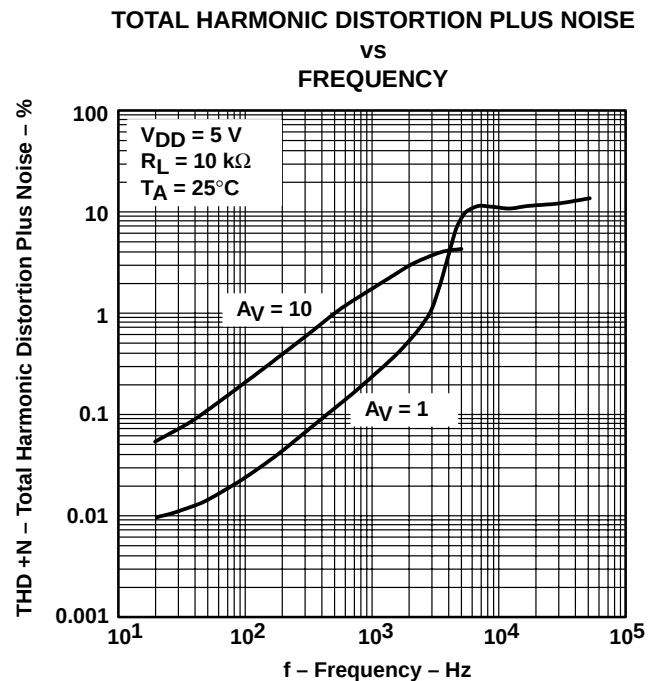


Figure 45

TLV2422, TLV2422A

Advanced LinCMOS™ RAIL-TO-RAIL OUTPUT

WIDE-INPUT-VOLTAGE MICROPOWER DUAL OPERATIONAL AMPLIFIERS

SLOS199C – SEPTEMBER 1997 – REVISED APRIL 2001

TYPICAL CHARACTERISTICS

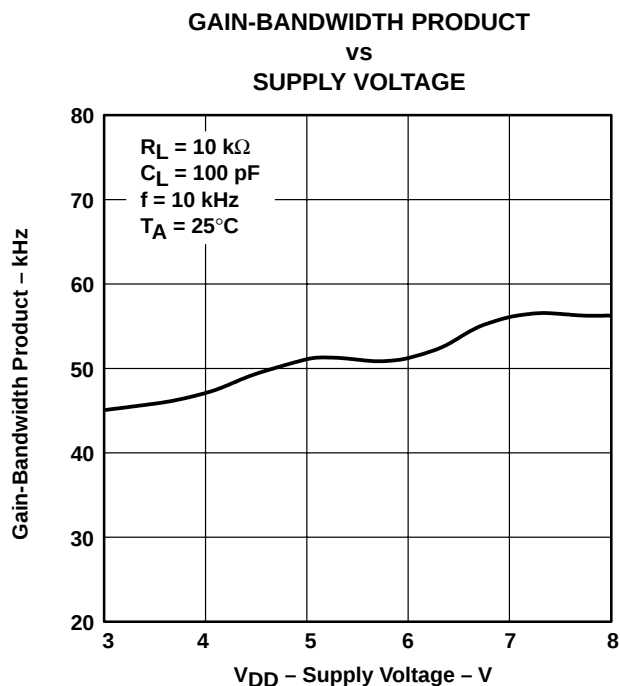


Figure 46

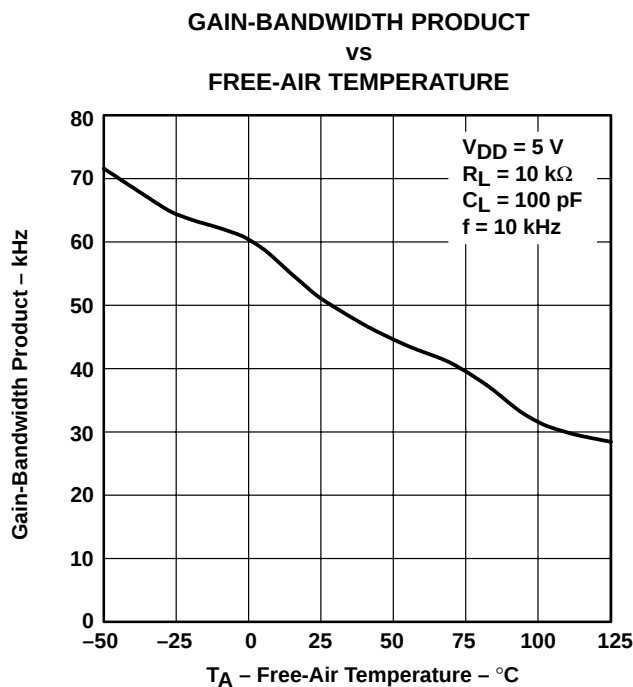


Figure 47

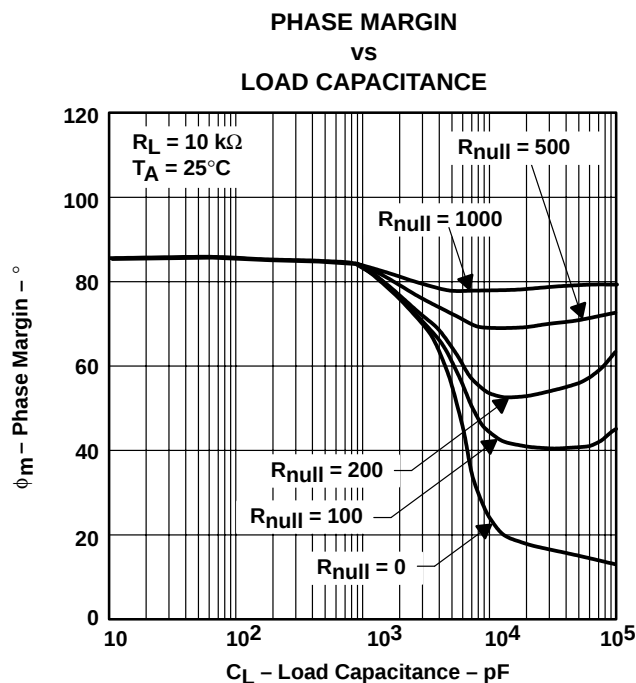


Figure 48

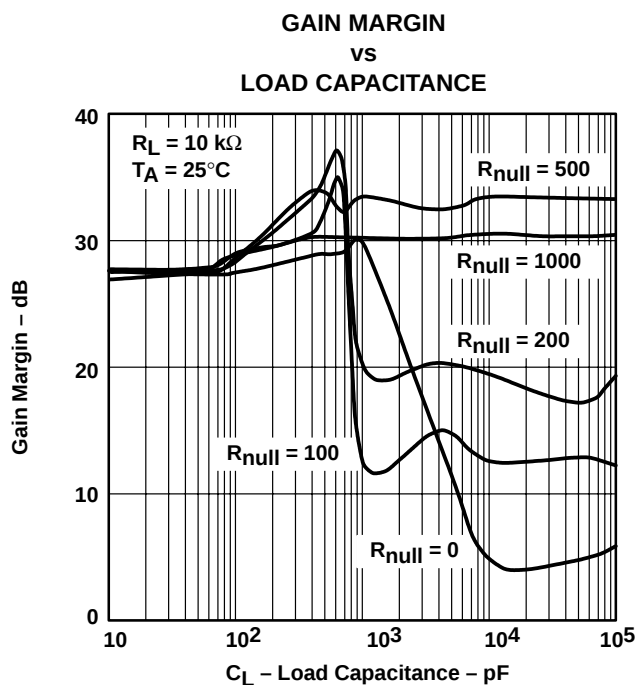


Figure 49

TYPICAL CHARACTERISTICS

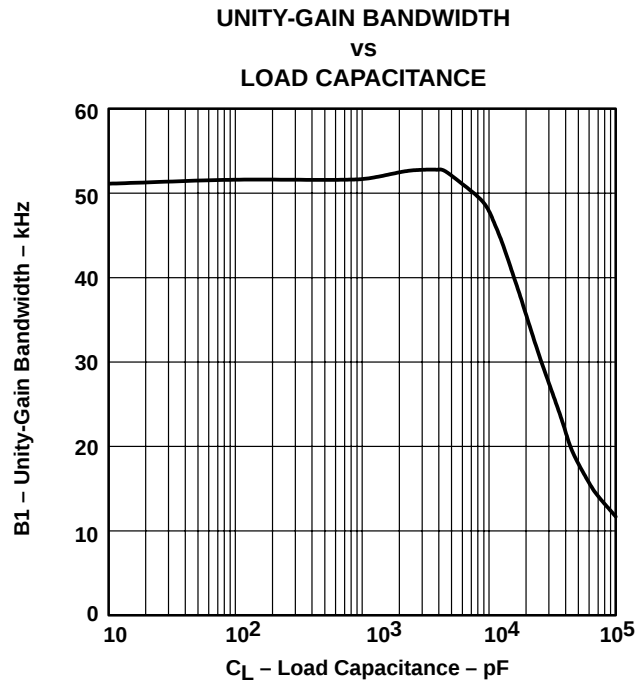


Figure 50

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)
5962-9751401QHA	Active	Production	CFP (U) 10	25 TUBE	No	SNPB	N/A for Pkg Type	-55 to 125	9751401QHA TLV2422M
TLV2422AID	Active	Production	SOIC (D) 8	75 TUBE	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 85	2422AI
TLV2422AID.A	Active	Production	SOIC (D) 8	75 TUBE	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 85	2422AI
TLV2422AIPWR	Active	Production	TSSOP (PW) 8	2000 LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 85	2422AI
TLV2422AIPWR.A	Active	Production	TSSOP (PW) 8	2000 LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 85	2422AI
TLV2422CD	Active	Production	SOIC (D) 8	75 TUBE	Yes	NIPDAU	Level-1-260C-UNLIM	0 to 70	2422C
TLV2422CD.A	Active	Production	SOIC (D) 8	75 TUBE	Yes	NIPDAU	Level-1-260C-UNLIM	0 to 70	2422C
TLV2422ID	Active	Production	SOIC (D) 8	75 TUBE	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 85	2422I
TLV2422ID.A	Active	Production	SOIC (D) 8	75 TUBE	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 85	2422I
TLV2422IDR	Active	Production	SOIC (D) 8	2500 LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 85	2422I
TLV2422IDR.A	Active	Production	SOIC (D) 8	2500 LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 85	2422I
TLV2422MUB	Active	Production	CFP (U) 10	25 TUBE	No	SNPB	N/A for Pkg Type	-55 to 125	9751401QHA TLV2422M
TLV2422MUB.A	Active	Production	CFP (U) 10	25 TUBE	No	SNPB	N/A for Pkg Type	-55 to 125	9751401QHA TLV2422M

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

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

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

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

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

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

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

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OTHER QUALIFIED VERSIONS OF TLV2422, TLV2422M :

- Catalog : [TLV2422](#)
- Automotive : [TLV2422-Q1](#), [TLV2422-Q1](#)
- Military : [TLV2422M](#)

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
TLV2422AIPWR	TSSOP	PW	8	2000	330.0	12.4	7.0	3.6	1.6	8.0	12.0	Q1
TLV2422IDR	SOIC	D	8	2500	330.0	12.4	6.4	5.2	2.1	8.0	12.0	Q1

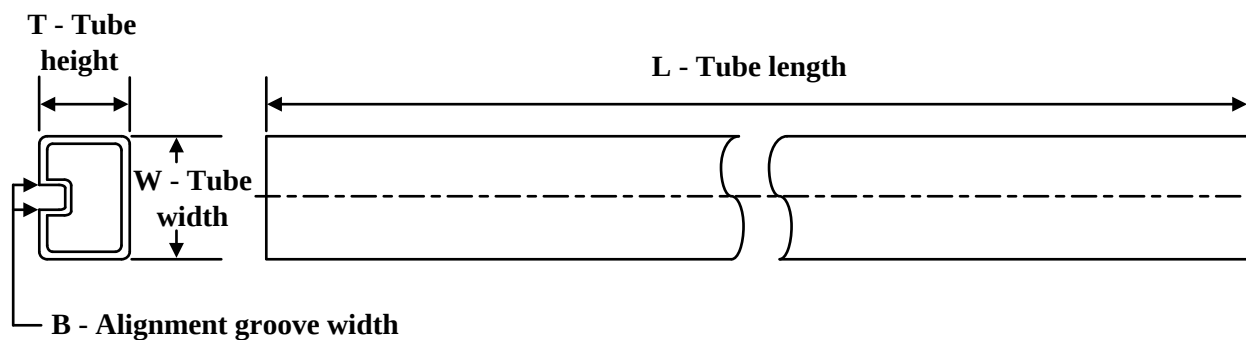
TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
TLV2422AIPWR	TSSOP	PW	8	2000	353.0	353.0	32.0
TLV2422IDR	SOIC	D	8	2500	353.0	353.0	32.0

TUBE



*All dimensions are nominal

Device	Package Name	Package Type	Pins	SPQ	L (mm)	W (mm)	T (μm)	B (mm)
5962-9751401QHA	U	CFP	10	25	506.98	26.16	6220	NA
TLV2422AID	D	SOIC	8	75	507	8	3940	4.32
TLV2422AID	D	SOIC	8	75	505.46	6.76	3810	4
TLV2422AID.A	D	SOIC	8	75	505.46	6.76	3810	4
TLV2422AID.A	D	SOIC	8	75	507	8	3940	4.32
TLV2422CD	D	SOIC	8	75	505.46	6.76	3810	4
TLV2422CD	D	SOIC	8	75	507	8	3940	4.32
TLV2422CD.A	D	SOIC	8	75	505.46	6.76	3810	4
TLV2422CD.A	D	SOIC	8	75	507	8	3940	4.32
TLV2422ID	D	SOIC	8	75	507	8	3940	4.32
TLV2422ID	D	SOIC	8	75	505.46	6.76	3810	4
TLV2422ID.A	D	SOIC	8	75	505.46	6.76	3810	4
TLV2422ID.A	D	SOIC	8	75	507	8	3940	4.32
TLV2422MUB	U	CFP	10	25	506.98	26.16	6220	NA
TLV2422MUB.A	U	CFP	10	25	506.98	26.16	6220	NA

EXAMPLE BOARD LAYOUT

D0008A

SOIC - 1.75 mm max height

SMALL OUTLINE INTEGRATED CIRCUIT



4214825/C 02/2019

NOTES: (continued)

6. Publication IPC-7351 may have alternate designs.

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

EXAMPLE STENCIL DESIGN

D0008A

SOIC - 1.75 mm max height

SMALL OUTLINE INTEGRATED CIRCUIT



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

4214825/C 02/2019

NOTES: (continued)

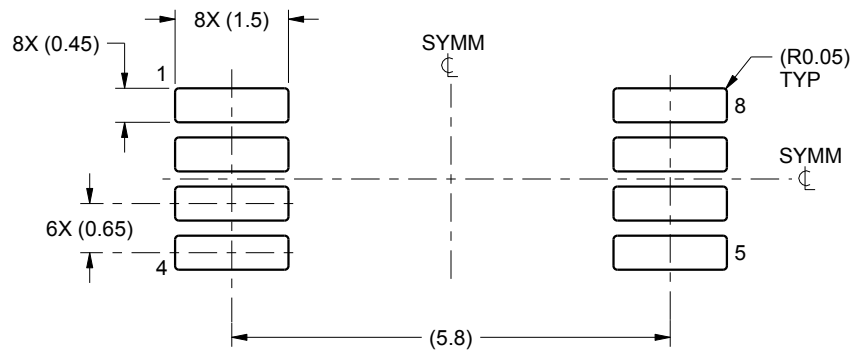
8. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
9. Board assembly site may have different recommendations for stencil design.

EXAMPLE BOARD LAYOUT

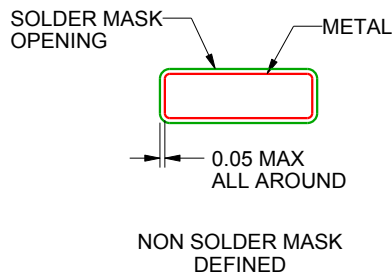
PW0008A

TSSOP - 1.2 mm max height

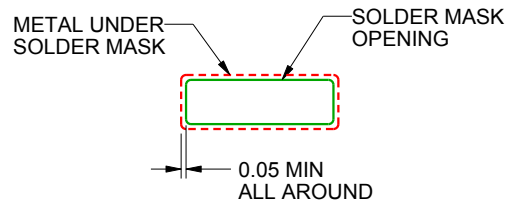
SMALL OUTLINE PACKAGE



LAND PATTERN EXAMPLE
SCALE:10X



NON SOLDER MASK
DEFINED



SOLDER MASK
DEFINED

SOLDER MASK DETAILS
NOT TO SCALE

4221848/A 02/2015

NOTES: (continued)

6. Publication IPC-7351 may have alternate designs.

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

EXAMPLE STENCIL DESIGN

PW0008A

TSSOP - 1.2 mm max height

SMALL OUTLINE PACKAGE



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

4221848/A 02/2015

NOTES: (continued)

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

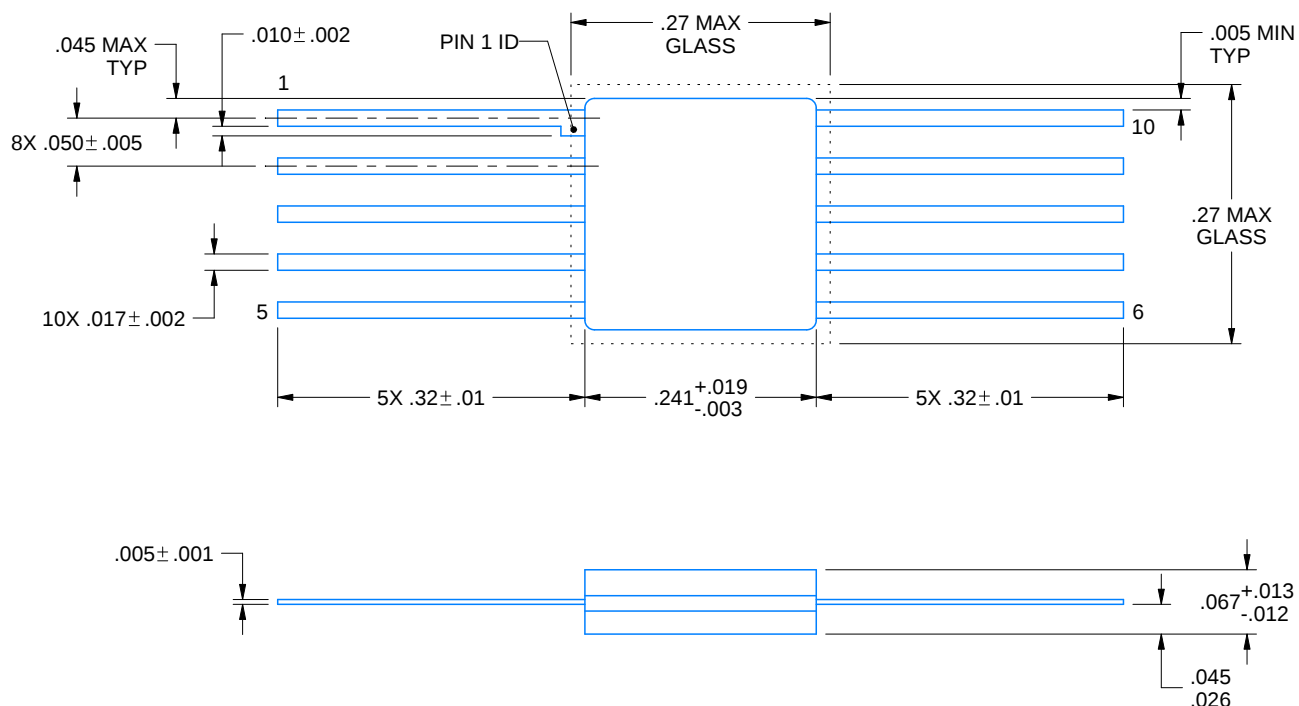
U0010A



PACKAGE OUTLINE

CFP - 2.03 mm max height

CERAMIC FLATPACK



4225582/A 01/2020

NOTES:

1. All linear dimensions are in inches. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.

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