

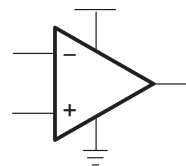
TLV2371-EP, TLV2372-EP, TLV2374-EP FAMILY OF 550- μ A/Ch 3-MHz RAIL-TO-RAIL INPUT/OUTPUT OPERATIONAL AMPLIFIERS

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- **Controlled Baseline**
 - One Assembly/Test Site, One Fabrication Site
- **Extended Temperature Performance of -55°C to 125°C**
- **Enhanced Diminishing Manufacturing Sources (DMS) Support**
- **Enhanced Product-Change Notification**
- **Qualification Pedigree†**
- **Rail-To-Rail Input/Output**
- **Wide Bandwidth . . . 3 MHz**
- **High Slew Rate . . . 2.4 V/ μ s**
- **Supply Voltage Range . . . 2.7 V to 16 V**
- **Supply Current . . . 550 μ A/Channel**
- **Input Noise Voltage . . . 39 nV/ $\sqrt{\text{Hz}}$**
- **Input Bias Current . . . 1 pA**
- **Specified Temperature Range -55°C to 125°C**
- **Ultrasmall Packaging**
 - 5-Pin SOT-23 (TLV2371)
 - 8-Pin MSOP (TLV2372)

† 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.

Operational Amplifier



description

The TLV237x single supply operational amplifiers provide rail-to-rail input and output capability. The TLV237x takes the minimum operating supply voltage down to 2.7 V over the extended automotive temperature range while adding the rail-to-rail output swing feature. The TLV237x also provides 3-MHz bandwidth from only 550 μ A. The maximum recommended supply voltage is 16 V, which allows the devices to be operated from (± 8 V supplies down to ± 1.35 V) a variety of rechargeable cells.

The CMOS inputs enable use in high-impedance sensor interfaces, with the lower voltage operation making an ideal alternative for the TLC227x in battery-powered applications. The rail-to-rail input stage further increases its versatility. The TLV237x is the seventh member of a rapidly growing number of RRIO products available from Texas Instruments and it is the first to allow operation up to 16-V rails with good ac performance.

The 2.7-V operation makes the TLV237x compatible with Li-Ion powered systems and the operating supply voltage range of many micro-power microcontrollers available today including Texas Instruments' MSP430.

SELECTION OF SIGNAL AMPLIFIER PRODUCTST

DEVICE	V _{DD} (V)	V _{IO} (μ V)	I _q /Ch (μ A)	I _{IB} (pA)	GBW (MHz)	SR (V/ μ s)	SHUTDOWN	RAIL-TO-RAIL	SINGLES/DUALS/QUADS
TLV237x	2.7–16	500	550	1	3	2.4	Yes	I/O	S/D/Q
TLC227x	4–16	300	1100	1	2.2	3.6	—	O	D/Q
TLV27x	2.7–16	500	550	1	3	2.4	—	O	S/D/Q
TLC27x	3–16	1100	675	1	1.7	3.6	—	—	S/D/Q
TLV246x	2.7–6	150	550	1300	6.4	1.6	Yes	I/O	S/D/Q
TLV247x	2.7–6	250	600	2	2.8	1.5	Yes	I/O	S/D/Q
TLV244x	2.7–10	300	725	1	1.8	1.4	—	O	D/Q

† Typical values measured at 5 V, 25°C



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.

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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FAMILY PACKAGE TABLE

DEVICE	NUMBER OF CHANNELS	PACKAGE TYPES				UNIVERSAL EVM BOARD
		SOIC	SOT-23	TSSOP	MSOP	
TLV2371	1	8	5	—	—	See the EVM Selection Guide (SLOU060)
TLV2372	2	8	—	—	8	
TLV2374	4	14	—	14	—	

TLV2371 AVAILABLE OPTIONS

T _A	V _{IO} MAX AT 25°C	PACKAGED DEVICES		
		SMALL OUTLINE (D)	SOT-23	
			(DBV)	SYMBOL
-55°C to 125°C	4.5 mV	TLV2371MDREP†	TLV2371MDBVREP	371E

TLV2372 AVAILABLE OPTIONS

T _A	V _{IO} MAX AT 25°C	PACKAGED DEVICES		
		SMALL OUTLINE (D)	MSOP	
			(DGK)	SYMBOL
-55°C to 125°C	4.5 mV	TLV2372MDREP†	TLV2372MDGKREP†	

† Product Preview

TLV2374 AVAILABLE OPTIONS

T _A	V _{IO} MAX AT 25°C	PACKAGED DEVICES	
		SMALL OUTLINE (D)	TSSOP (PW)
-55°C to 125°C	4.5 mV	TLV2374MDREP	TLV2374MPWREP†

† Product Preview

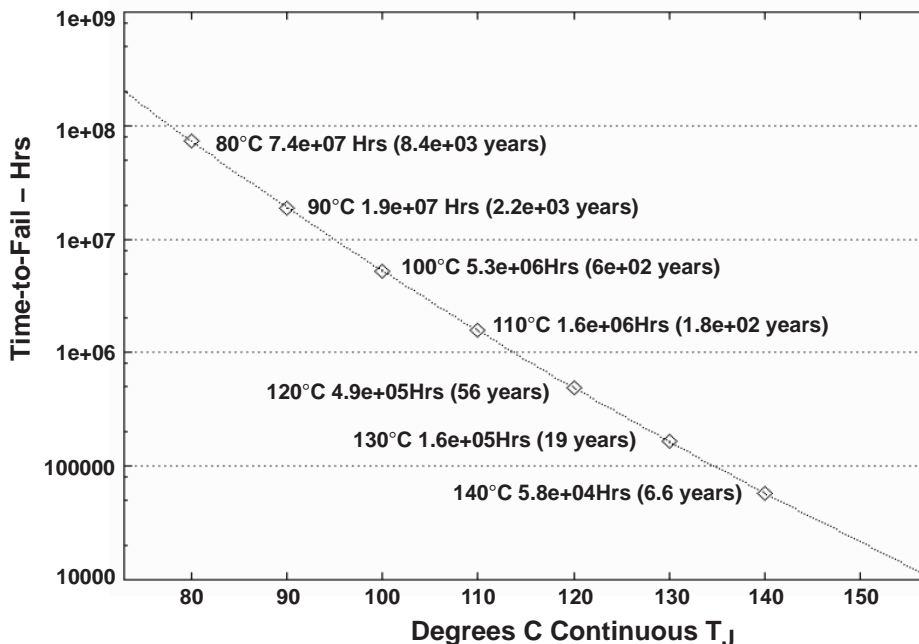


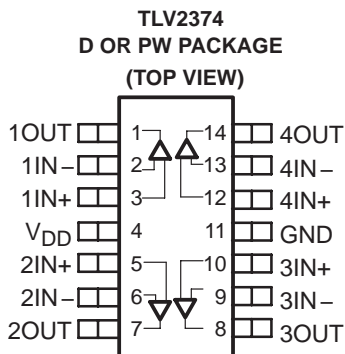
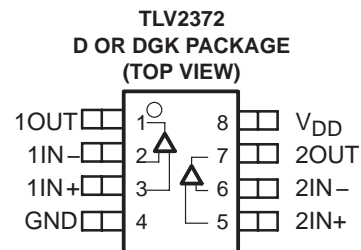
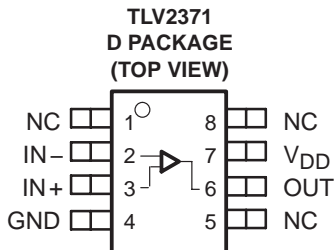
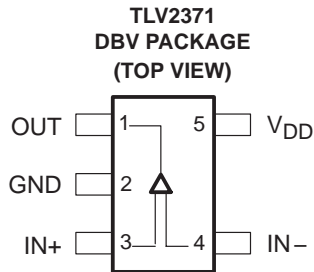
Figure 1. Wirebond Life Plot



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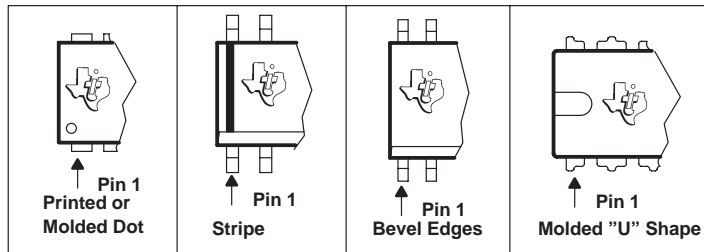
TLV237x PACKAGE PINOUTS(1)



NC – No internal connection

(1) SOT-23 may or may not be indicated

TYPICAL PIN 1 INDICATORS



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

Supply voltage, V_{DD} (see Note 1)	16.5 V
Differential input voltage, V_{ID}	$\pm V_{DD}$
Input voltage range, V_I (see Note 1)	-0.2 V to $V_{DD} + 0.2$ V
Input current range, I_I	± 10 mA
Output current range, I_O	± 100 mA
Package thermal impedance, θ_{JA} (see Notes 2 and 3):	
D (8-pin) package	176°C/W
D (14-pin) package	122.3°C/W
D (16-pin) package	114.7°C/W
DBV (5-pin) package	324.1°C/W
DGK (8-pin) package	259.96°C/W
PW (14-pin) package	173.6°C/W
Operating free-air temperature range, T_A	-55°C to 125°C
Maximum junction temperature, T_J	150°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 GND.
 2. Maximum power dissipation is a function of $T_{J(max)}$, θ_{JA} , and T_A . The maximum allowable power dissipation at any allowable ambient temperature is $P_D = (T_{J(max)} - T_A)/\theta_{JA}$. Selecting the maximum of 150°C can affect reliability.
 3. The package thermal impedance is calculated in accordance with JESD 51-7.

recommended operating conditions

		MIN	MAX	UNIT
Supply voltage, V_{DD}	Single supply	2.7	16	V
	Split supply	± 1.35	± 8	
Common-mode input voltage range, V_{ICR}		0	V_{DD}	V
Turnon voltage level, $V_{(ON)}$, relative to GND pin voltage			2	V
Turnoff voltage level, $V_{(OFF)}$, relative to GND pin voltage		0.8		V
Operating free-air temperature, T_A	M-suffix	-55	125	°C



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electrical characteristics at specified free-air temperature, $V_{DD} = 2.7\text{ V}$, 5 V , and 15 V (unless otherwise noted)

dc performance

PARAMETER		TEST CONDITIONS		T_A	MIN	TYP	MAX	UNIT
V_{IO}	Input offset voltage	$V_{IC} = V_{DD}/2,$ $R_S = 50\ \Omega$	$V_O = V_{DD}/2,$	25°C		2	4.5	mV
				Full range			6	
α_{VIO}	Offset voltage drift			25°C		2		$\mu\text{V}/^\circ\text{C}$
CMRR	Common-mode rejection ratio	$V_{IC} = 0\text{ to }V_{DD},$ $R_S = 50\ \Omega$	$V_{DD} = 2.7\text{ V}$	25°C	50	68	dB	
				Full range	47			
		$V_{IC} = 0\text{ to }V_{DD}-1.35\text{ V},$ $R_S = 50\ \Omega$	$V_{DD} = 2.7\text{ V}$	25°C	53	70		
				Full range	50			
		$V_{IC} = 0\text{ to }V_{DD},$ $R_S = 50\ \Omega,$	$V_{DD} = 5\text{ V}$	25°C	55	72		
				Full range	54			
		$V_{IC} = 0\text{ to }V_{DD}-1.35\text{ V},$ $R_S = 50\ \Omega,$	$V_{DD} = 5\text{ V}$	25°C	58	80		
				Full range	54			
		$V_{IC} = 0\text{ to }V_{DD},$ $R_S = 50\ \Omega,$	$V_{DD} = 15\text{ V}$	25°C	64	82		
				Full range	63			
		$V_{IC} = 0\text{ to }V_{DD}-1.35\text{ V},$ $R_S = 50\ \Omega,$	$V_{DD} = 15\text{ V}$	25°C	67	84		
				Full range	66			
A_{VD}	Large-signal differential voltage amplification	$V_{O(PP)} = V_{DD}/2,$ $R_L = 10\text{ k}\Omega$	$V_{DD} = 2.7\text{ V}$	25°C	95	106	dB	
				Full range	60			
			$V_{DD} = 5\text{ V}$	25°C	80	110		
				Full range	78			
			$V_{DD} = 15\text{ V}$	25°C	77	83		
				Full range	73			

input characteristics

PARAMETER		TEST CONDITIONS		T_A	MIN	TYP	MAX	UNIT
I_{IO}	Input offset current	$V_{DD} = 15\text{ V},$ $V_O = V_{DD}/2$	$V_{IC} = V_{DD}/2,$	25°C		1	60	pA
				125°C			1000	
I_{IB}	Input bias current	$V_{DD} = 15\text{ V},$ $V_O = V_{DD}/2$	$V_{IC} = V_{DD}/2,$	25°C		1	60	pA
				125°C			1000	
$r_{i(d)}$	Differential input resistance			25°C		1000		G Ω
C_{IC}	Common-mode input capacitance		$f = 21\text{ kHz}$	25°C		8		pF



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electrical characteristics at specified free-air temperature, $V_{DD} = 2.7\text{ V}$, 5 V , and 15 V (unless otherwise noted) (continued)

output characteristics

PARAMETER	TEST CONDITIONS	T_A	MIN	TYP	MAX	UNIT
V_{OH} High-level output voltage	$V_{IC} = V_{DD}/2, I_{OH} = -1\text{ mA}$	$V_{DD} = 2.7\text{ V}$	25°C	2.55	2.58	V
			Full range	2.48		
		$V_{DD} = 5\text{ V}$	25°C	4.9	4.93	
			Full range	4.85		
		$V_{DD} = 15\text{ V}$	25°C	14.92	14.96	
			Full range	14.9		
	$V_{IC} = V_{DD}/2, I_{OH} = -5\text{ mA}$	$V_{DD} = 2.7\text{ V}$	25°C	1.88	2	
			Full range	1.42		
		$V_{DD} = 5\text{ V}$	25°C	4.58	4.68	
			Full range	4.44		
		$V_{DD} = 15\text{ V}$	25°C	14.7	14.8	
			Full range	14.6		
V_{OL} Low-level output voltage	$V_{IC} = V_{DD}/2, I_{OL} = 1\text{ mA}$	$V_{DD} = 2.7\text{ V}$	25°C	0.1	0.15	V
			Full range		0.22	
		$V_{DD} = 5\text{ V}$	25°C	0.05	0.1	
			Full range		0.15	
		$V_{DD} = 15\text{ V}$	25°C	0.05	0.08	
			Full range		0.1	
	$V_{IC} = V_{DD}/2, I_{OL} = 5\text{ mA}$	$V_{DD} = 2.7\text{ V}$	25°C	0.52	0.7	
			Full range		1.15	
		$V_{DD} = 5\text{ V}$	25°C	0.28	0.4	
			Full range		0.54	
		$V_{DD} = 15\text{ V}$	25°C	0.19	0.3	
			Full range		0.35	

power supply

PARAMETER	TEST CONDITIONS	T_A	MIN	TYP	MAX	UNIT
I_{DD} Supply current (per channel)	$V_O = V_{DD}/2,$	$V_{DD} = 2.7\text{ V}$	25°C	470	560	μA
		$V_{DD} = 5\text{ V}$	25°C	550	660	
		$V_{DD} = 15\text{ V}$	25°C	750	900	
			Full range		1200	
PSRR Supply voltage rejection ratio ($\Delta V_{DD}/\Delta V_{IO}$)	$V_{DD} = 2.7\text{ V to }15\text{ V},$ No load	$V_{IC} = V_{DD}/2,$	25°C	70	80	dB
			Full range	65		



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electrical characteristics at specified free-air temperature, $V_{DD} = 2.7\text{ V}$, 5 V , and 15 V (unless otherwise noted) (continued)

dynamic performance

PARAMETER		TEST CONDITIONS		T_A	MIN	TYP	MAX	UNIT
UGBW	Unity gain bandwidth	$R_L = 2\text{ k}\Omega$, $C_L = 10\text{ pF}$	$V_{DD} = 2.7\text{ V}$	25°C	2.4		3	MHz
			$V_{DD} = 5\text{ V to }15\text{ V}$	25°C				
SR	Slew rate at unity gain	$V_{O(PP)} = V_{DD}/2$, $C_L = 50\text{ pF}$, $R_L = 10\text{ k}\Omega$	$V_{DD} = 2.7\text{ V}$	25°C	1.4	2	1	V/ μ s
				Full range				
			$V_{DD} = 5\text{ V}$	25°C	1.4	2.4	1.1	V/ μ s
				Full range				
			$V_{DD} = 15\text{ V}$	25°C	1.9	2.1	1.2	V/ μ s
				Full range				
ϕ_m	Phase margin	$R_L = 2\text{ k}\Omega$,	$C_L = 100\text{ pF}$	25°C	65°			
	Gain margin	$R_L = 2\text{ k}\Omega$,	$C_L = 10\text{ pF}$	25°C	18		dB	
t_s	Settling time	$V_{DD} = 2.7\text{ V}$, $V_{(STEP)PP} = 1\text{ V}$, $A_V = -1$, $C_L = 10\text{ pF}$, $R_L = 2\text{ k}\Omega$	0.1%	25°C	2.9		μ s	
			$V_{DD} = 5\text{ V}, 15\text{ V}$, $V_{(STEP)PP} = 1\text{ V}$, $A_V = -1$, $C_L = 47\text{ pF}$, $R_L = 2\text{ k}\Omega$		0.1%	2		

noise/distortion performance

PARAMETER		TEST CONDITIONS		T_A	MIN	TYP	MAX	UNIT
THD + N	Total harmonic distortion plus noise	$V_{DD} = 2.7\text{ V}$, $V_{O(PP)} = V_{DD}/2\text{ V}$, $R_L = 2\text{ k}\Omega$, $f = 10\text{ kHz}$	$A_V = 1$	25°C	0.02%			
			$A_V = 10$		0.05%			
			$A_V = 100$		0.18%			
			$V_{DD} = 5\text{ V}, 5\text{ V}$, $V_{O(PP)} = V_{DD}/2\text{ V}$, $R_L = 2\text{ k}\Omega$, $f = 10\text{ kHz}$	$A_V = 1$	25°C	0.02%		
				$A_V = 10$		0.09%		
				$A_V = 100$		0.5%		
V_n	Equivalent input noise voltage	$f = 1\text{ kHz}$	$f = 10\text{ kHz}$	25°C	39		nV/ $\sqrt{\text{Hz}}$	
					35			
I_n	Equivalent input noise current	$f = 1\text{ kHz}$		25°C	0.6		fA/ $\sqrt{\text{Hz}}$	



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TYPICAL CHARACTERISTICS

Table of Graphs

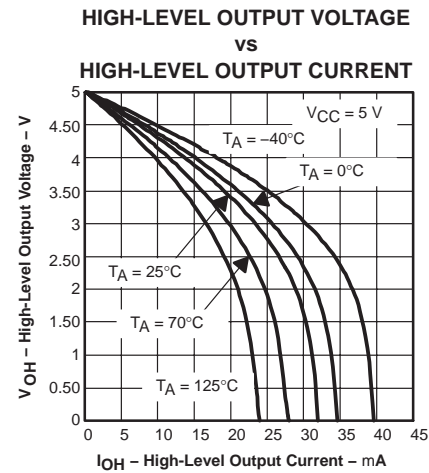
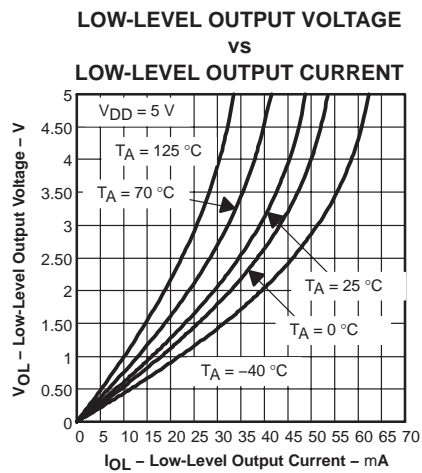
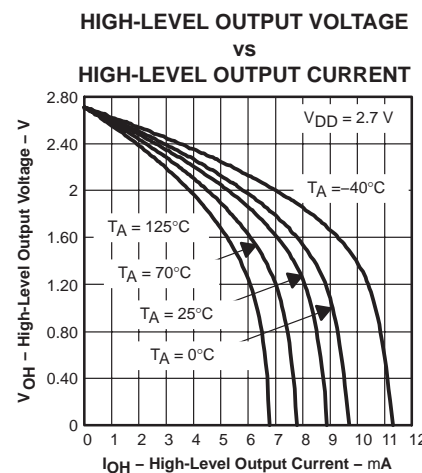
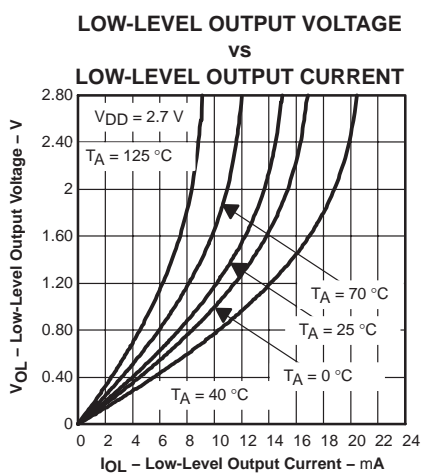
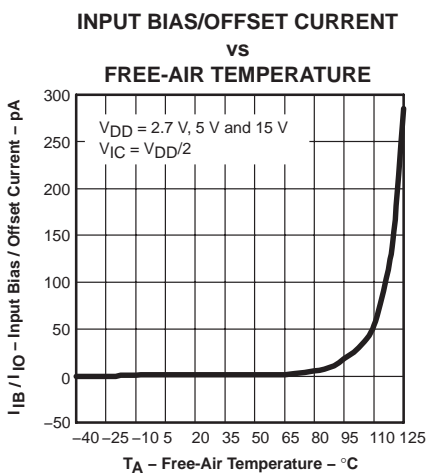
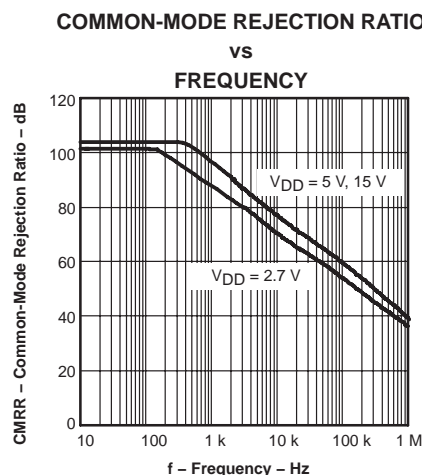
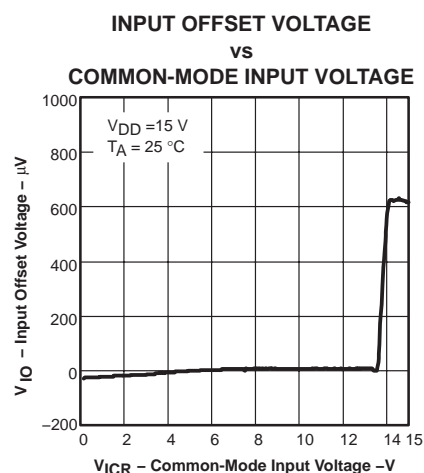
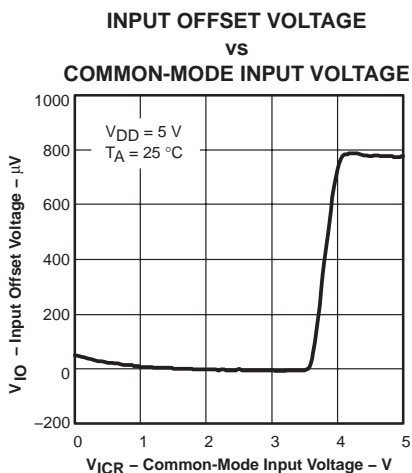
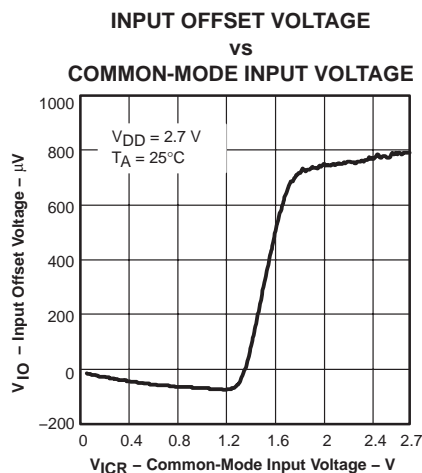
			FIGURE
V_{IO}	Input offset voltage	vs Common-mode input voltage	1, 2, 3
CMRR	Common-mode rejection ratio	vs Frequency	4
	Input bias and offset current	vs Free-air temperature	5
V_{OL}	Low-level output voltage	vs Low-level output current	6, 8, 10
V_{OH}	High-level output voltage	vs High-level output current	7, 9, 11
$V_{O(PP)}$	Peak-to-peak output voltage	vs Frequency	12
I_{DD}	Supply current	vs Supply voltage	13
PSRR	Power supply rejection ratio	vs Frequency	14
A_{VD}	Differential voltage gain & phase	vs Frequency	15
	Gain-bandwidth product	vs Free-air temperature	16
SR	Slew rate	vs Supply voltage	17
		vs Free-air temperature	18
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TYPICAL CHARACTERISTICS



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TYPICAL CHARACTERISTICS

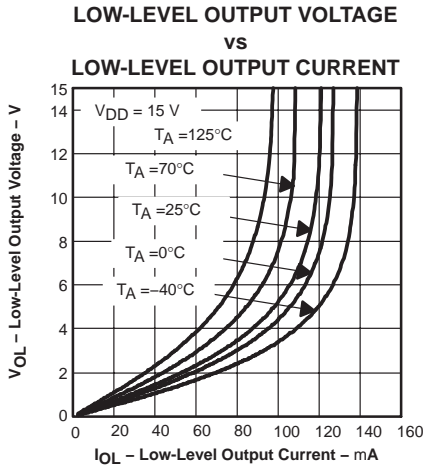


Figure 11

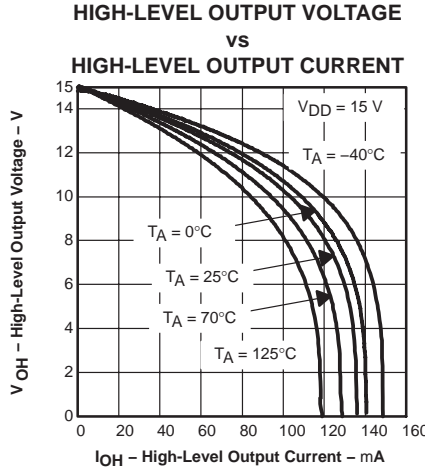


Figure 12

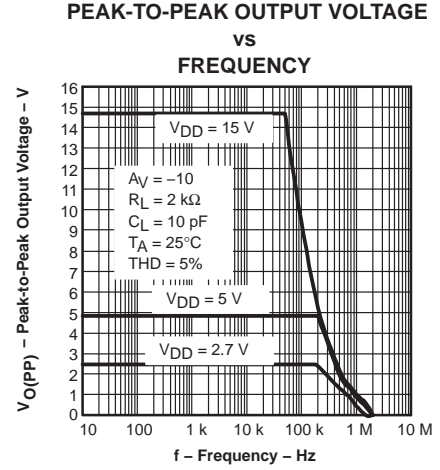


Figure 13

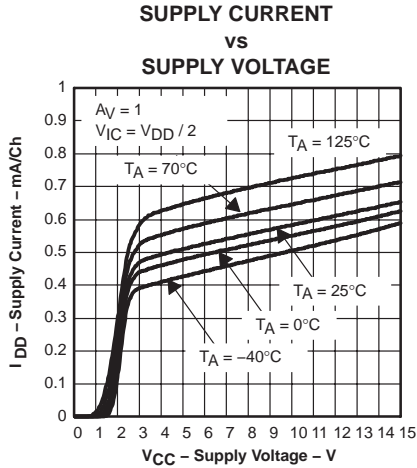


Figure 14

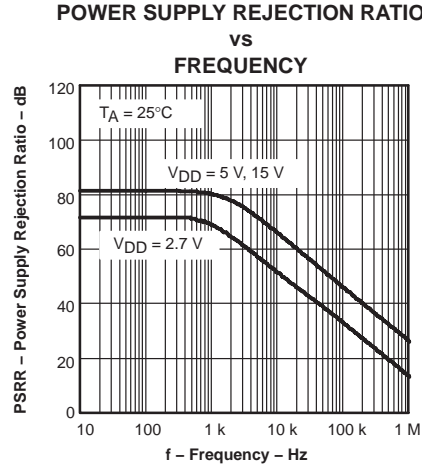


Figure 15

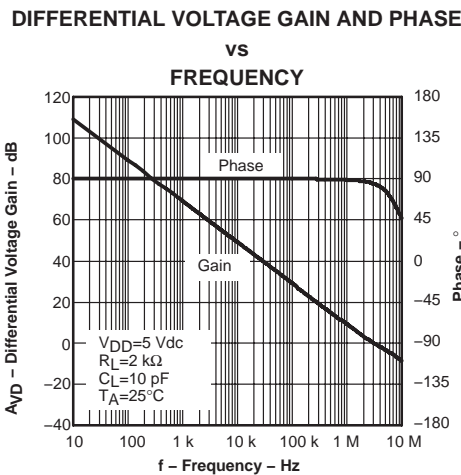


Figure 16

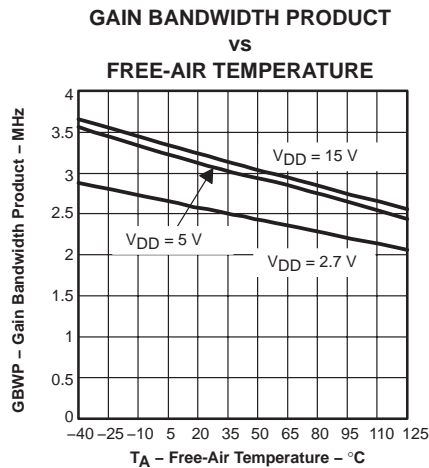


Figure 17



TLV2371-EP, TLV2372-EP, TLV2374-EP FAMILY OF 550- μ A/Ch 3-MHz RAIL-TO-RAIL INPUT/OUTPUT OPERATIONAL AMPLIFIERS

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TYPICAL CHARACTERISTICS

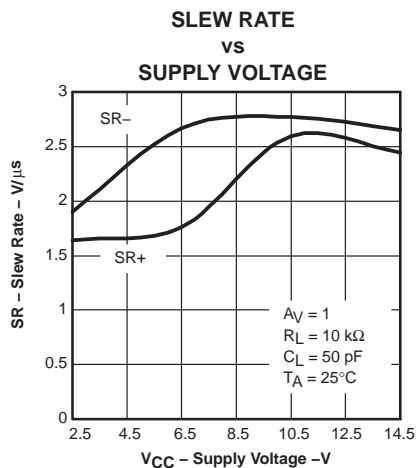


Figure 18

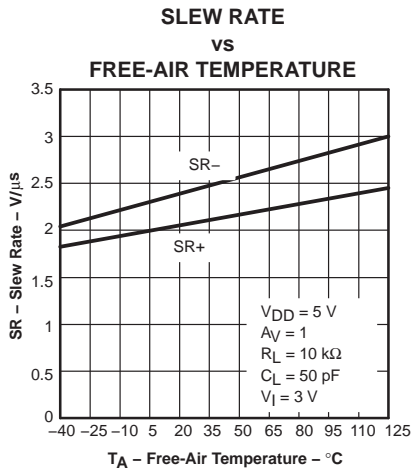


Figure 19

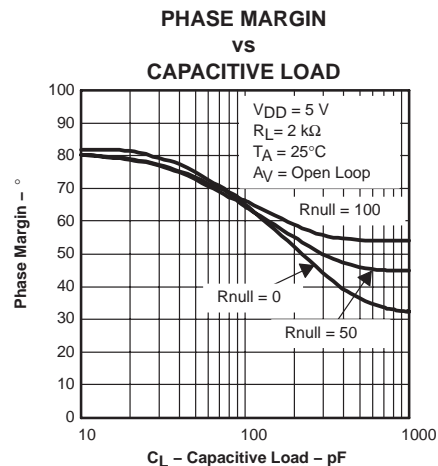


Figure 20

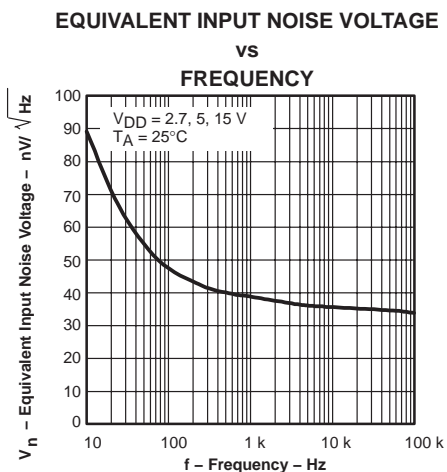


Figure 21

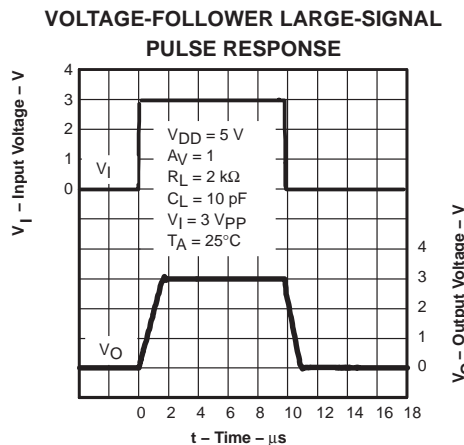


Figure 22

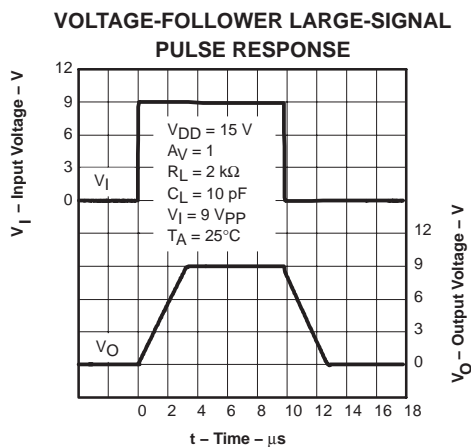


Figure 23

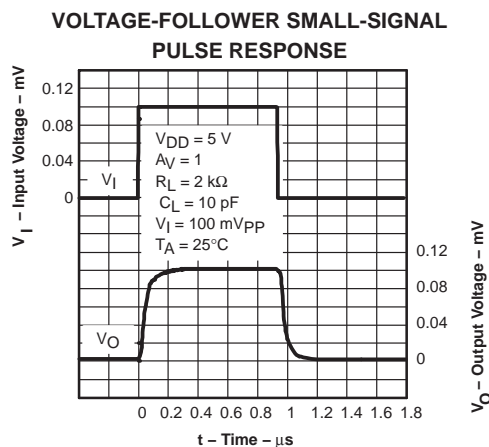


Figure 24



TLV2371-EP, TLV2372-EP, TLV2374-EP FAMILY OF 550- μ A/Ch 3-MHz RAIL-TO-RAIL INPUT/OUTPUT OPERATIONAL AMPLIFIERS

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TYPICAL CHARACTERISTICS

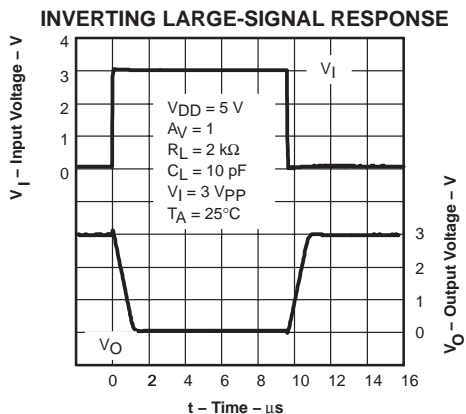


Figure 25

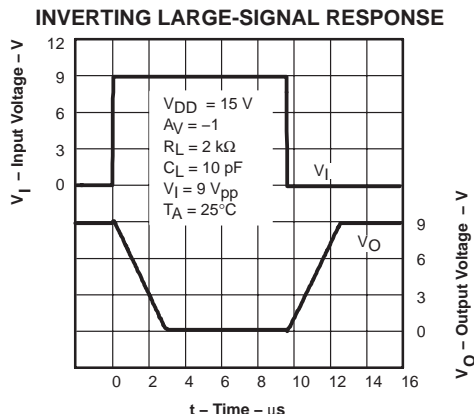


Figure 26

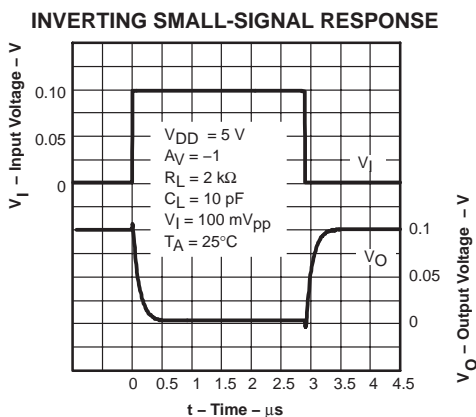


Figure 27

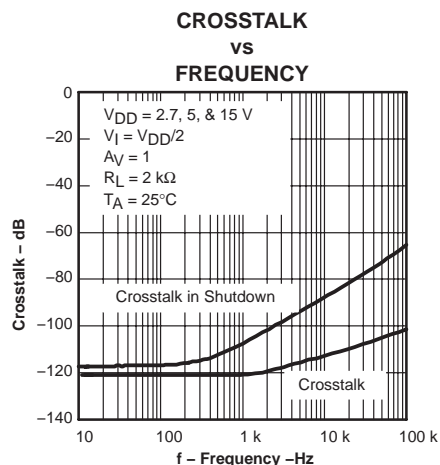


Figure 28

APPLICATION INFORMATION

rail-to-rail input operation

The TLV237x input stage consists of two differential transistor pairs, NMOS and PMOS, that operate together to achieve rail-to-rail input operation. The transition point between these two pairs can be seen in Figure 2 through Figure 4 for a 2.7-V, 5-V, and 15-V supply. As the common-mode input voltage approaches the positive supply rail, the input pair switches from the PMOS differential pair to the NMOS differential pair. This transition occurs approximately 1.35 V from the positive rail and results in a change in offset voltage due to different device characteristics between the NMOS and PMOS pairs. If the input signal to the device is large enough to swing between both rails, this transition results in a reduction in common-mode rejection ratio (CMRR). If the input signal does not swing between both rails, it is best to bias the signal in the region where only one input pair is active. This is the region in Figure 2 through Figure 4 where the offset voltage varies slightly across the input range and optimal CMRR can be achieved. This has the greatest impact when operating from a 2.7-V supply voltage.

driving a capacitive load

When the amplifier is configured in this manner, capacitive loading directly on the output decreases the device's phase margin, leading to high frequency ringing or oscillations. Therefore, for capacitive loads of greater than 10 pF, it is recommended that a resistor be placed in series (R_{NULL}) with the output of the amplifier, as shown in Figure 29. A minimum value of 20 Ω should work well for most applications.

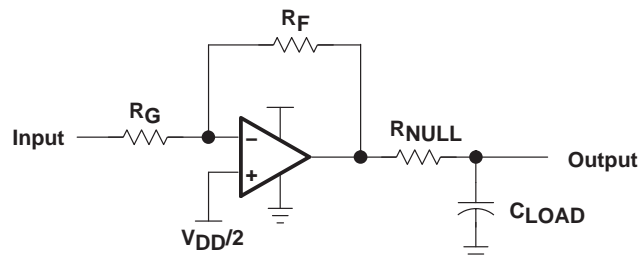


Figure 29. Driving a Capacitive Load

offset voltage

The output offset voltage, (V_{OO}) is the sum of the input offset voltage (V_{IO}) and both input bias currents (I_{IB}) times the corresponding gains. The schematic and formula in Figure 30 can be used to calculate the output offset voltage.

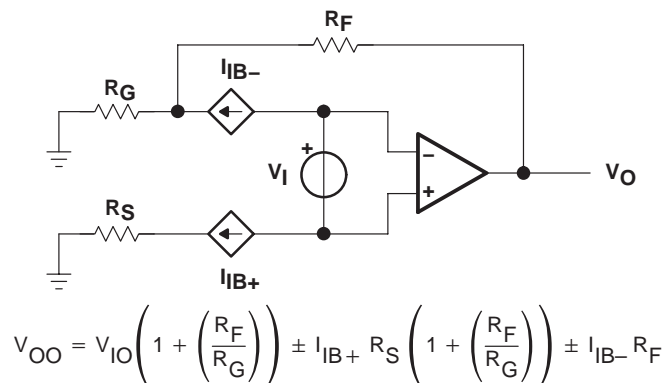


Figure 30. Output Offset Voltage Model

APPLICATION INFORMATION

general configurations

When receiving low-level signals, limiting the bandwidth of the incoming signals into the system is often required. The simplest way to accomplish this is to place an RC filter at the noninverting terminal of the amplifier (see Figure 31).

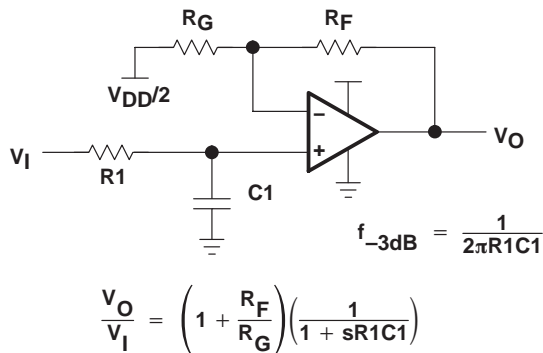


Figure 31. Single-Pole Low-Pass Filter

If even more attenuation is needed, a multiple pole filter is required. The Sallen-Key filter can be used for this task. For best results, the amplifier should have a bandwidth that is 8 to 10 times the filter frequency bandwidth. Failure to do this can result in phase shift of the amplifier.

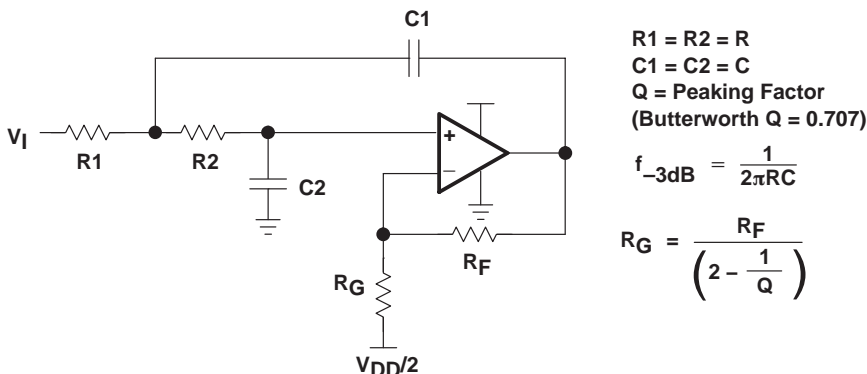


Figure 32. 2-Pole Low-Pass Sallen-Key Filter

APPLICATION INFORMATION

circuit layout considerations

To achieve the levels of high performance of the TLV237x, follow proper printed-circuit board design techniques. The following is a general set of guidelines.

- Ground planes—It is highly recommended that a ground plane be used on the board to provide all components with a low inductive ground connection. However, in the areas of the amplifier inputs and output, the ground plane can be removed to minimize the stray capacitance.
- Proper power supply decoupling—Use a 6.8- μ F tantalum capacitor in parallel with a 0.1- μ F ceramic capacitor on each supply terminal. It may be possible to share the tantalum capacitor among several amplifiers depending on the application, but a 0.1- μ F ceramic capacitor should always be used on the supply terminal of every amplifier. In addition, the 0.1- μ F capacitor should be placed as close as possible to the supply terminal. As this distance increases, the inductance in the connecting trace makes the capacitor less effective. The designer should strive for distances of less than 0.1 inches between the device power terminals and the ceramic capacitors.
- Sockets—Sockets can be used but are not recommended. The additional lead inductance in the socket pins often leads to stability problems. Surface-mount packages soldered directly to the printed-circuit board is the best implementation.
- Short trace runs/compact part placements—Optimum high performance is achieved when stray series inductance has been minimized. To realize this, the circuit layout should be made as compact as possible, thereby minimizing the length of all trace runs. Particular attention should be paid to the inverting input of the amplifier. Its length should be kept as short as possible. This helps to minimize stray capacitance at the input of the amplifier.
- Surface-mount passive components—Using surface-mount passive components is recommended for high performance amplifier circuits for several reasons. First, because of the extremely low lead inductance of surface-mount components, the problem with stray series inductance is greatly reduced. Second, the small size of surface-mount components naturally leads to a more compact layout thereby minimizing both stray inductance and capacitance. If leaded components are used, it is recommended that the lead lengths be kept as short as possible.

TLV2371-EP, TLV2372-EP, TLV2374-EP
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APPLICATION INFORMATION

general power dissipation considerations

For a given θ_{JA} , the maximum power dissipation is shown in Figure 33 and is calculated by the following formula:

$$P_D = \left(\frac{T_{MAX} - T_A}{\theta_{JA}} \right)$$

Where:

P_D = Maximum power dissipation of TLV237x IC (watts)

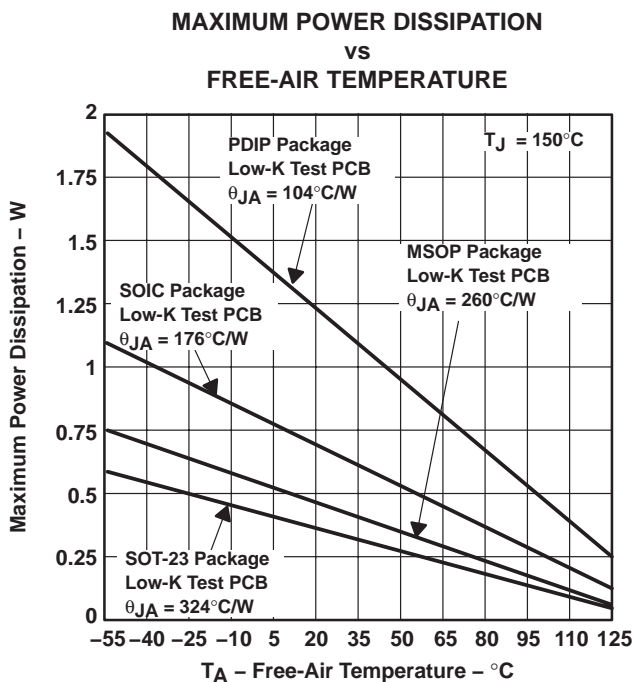
T_{MAX} = Absolute maximum junction temperature (150°C)

T_A = Free-ambient air temperature (°C)

θ_{JA} = $\theta_{JC} + \theta_{CA}$

θ_{JC} = Thermal coefficient from junction to case

θ_{CA} = Thermal coefficient from case to ambient air (°C/W)



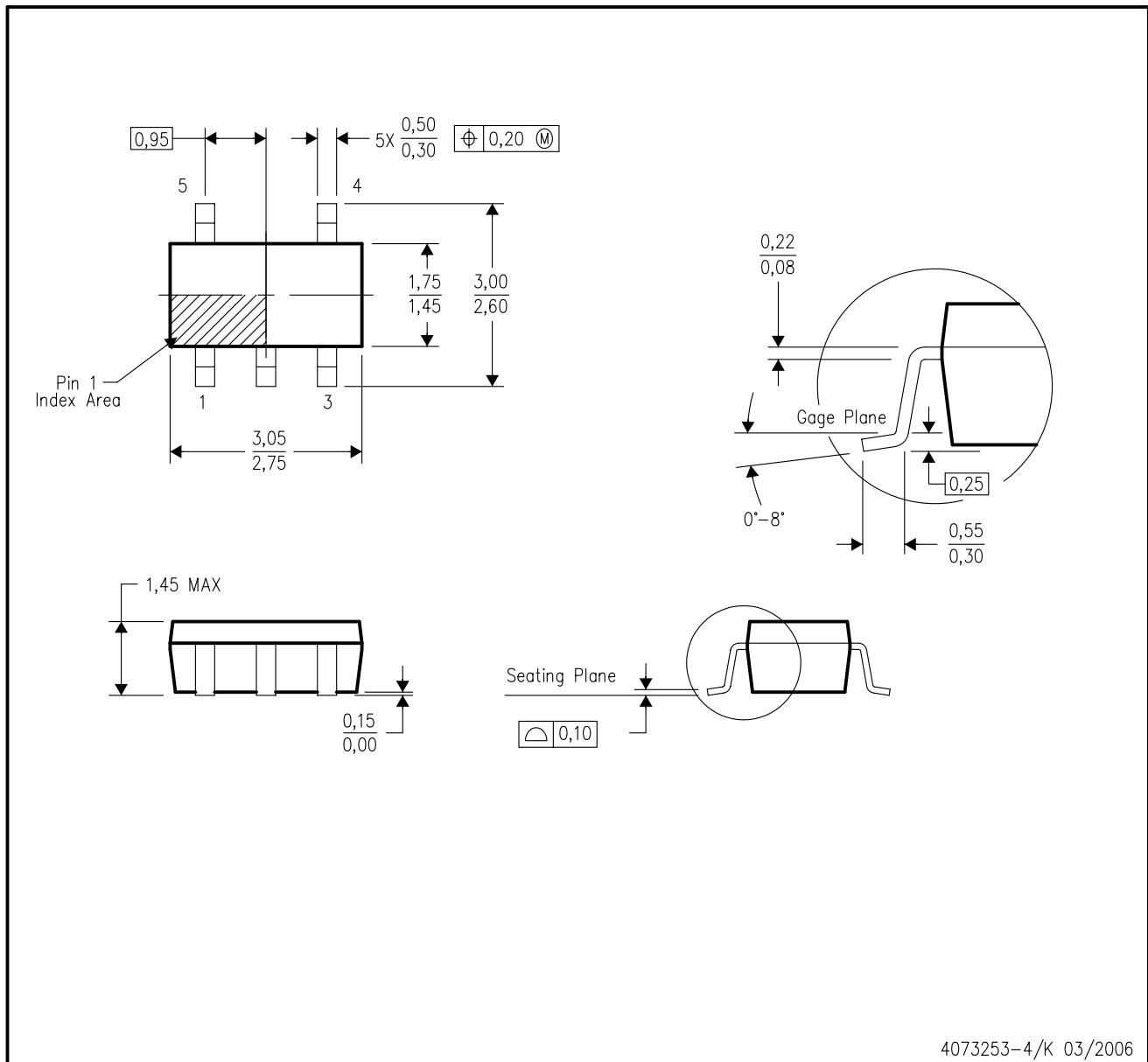
NOTE A: Results are with no air flow and using JEDEC Standard Low-K test PCB.

Figure 33.



DBV (R-PDSO-G5)

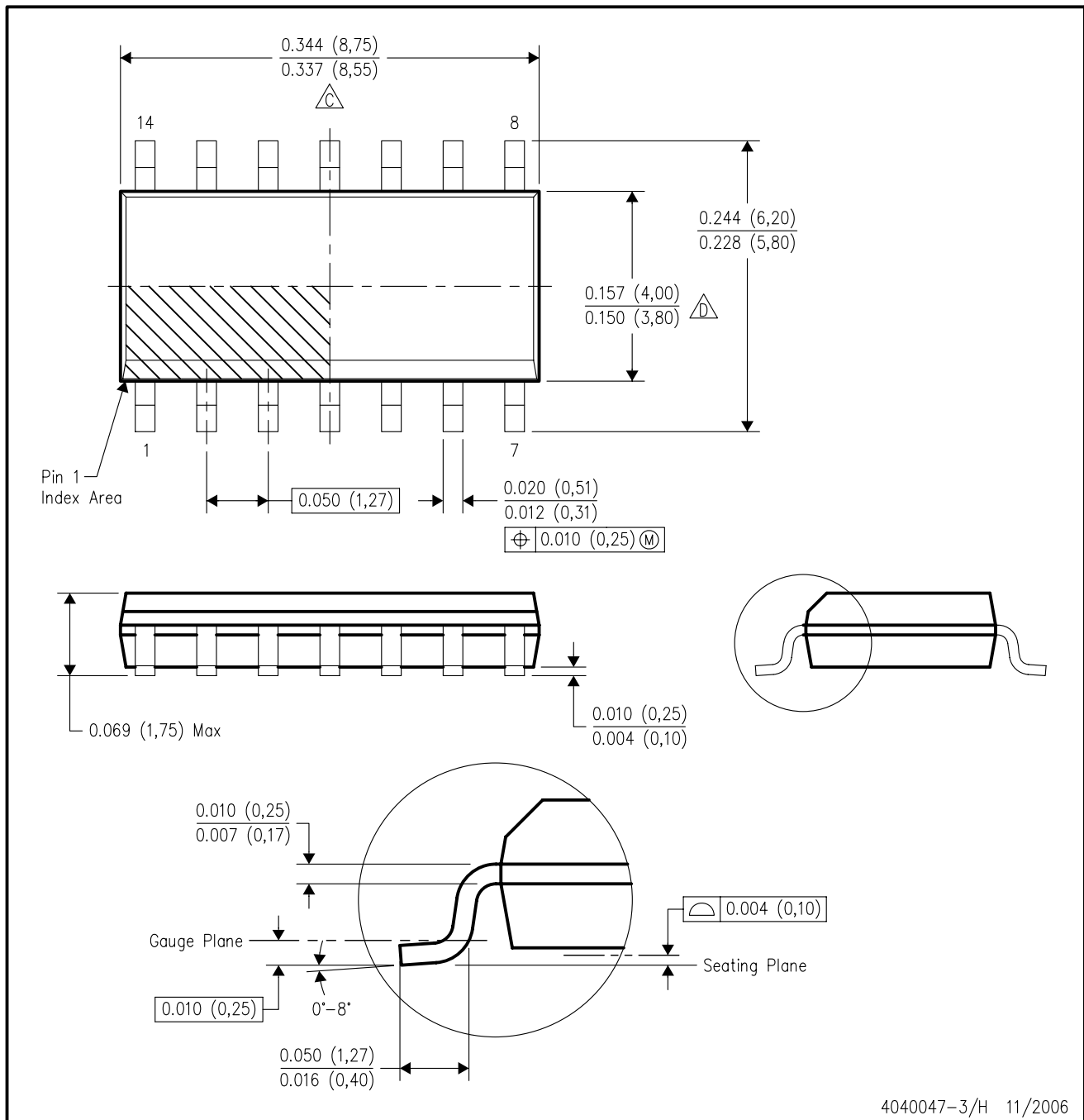
PLASTIC SMALL-OUTLINE PACKAGE



- NOTES:
- A. All linear dimensions are in millimeters.
 - B. This drawing is subject to change without notice.
 - C. Body dimensions do not include mold flash or protrusion. Mold flash and protrusion shall not exceed 0.15 per side.
 - D. Falls within JEDEC MO-178 Variation AA.

D (R-PDSO-G14)

PLASTIC SMALL-OUTLINE PACKAGE



- NOTES:
- A. All linear dimensions are in inches (millimeters).
 - B. This drawing is subject to change without notice.
 - C. Body length does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed .006 (0,15) per end.
 - D. Body width does not include interlead flash. Interlead flash shall not exceed .017 (0,43) per side.
 - E. Reference JEDEC MS-012 variation AB.

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