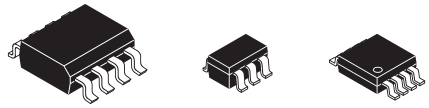


SLOS377A – SEPTEMBER 2001– REVISED JULY 2003

FAMILY OF MICROPOWER RAIL-TO-RAIL INPUT AND OUTPUT OPERATIONAL AMPLIFIERS

FEATURES

- **BiMOS Rail-to-Rail Input/Output**
- **Input Bias Current . . . 1 pA**
- **High Wide Bandwidth . . . 160 kHz**
- **High Slew Rate . . . 0.1 V/μs**
- **Supply Current . . . 7 μA (per channel)**
- **Input Noise Voltage . . . 90 nV/√Hz**
- **Supply Voltage Range . . . 2.7 V to 16 V**
- **Specified Temperature Range**
  - **–40°C to 125°C . . . Industrial Grade**
- **Ultra-Small Packaging**
  - **5 Pin SOT-23 (TLV2381)**

APPLICATIONS

- **Portable Medical**
- **Power Monitoring**
- **Low Power Security Detection Systems**
- **Smoke Detectors**

DESCRIPTION

The TLV238x single supply operational amplifiers provide rail-to-rail input and output capability. The TLV238x takes the minimum operating supply voltage down to 2.7 V over the extended industrial temperature range, while adding the rail-to-rail output swing feature. The TLV238x also provides 160-kHz bandwidth from only 7 μA. The maximum recommended supply voltage is 16 V, which allows the devices to be operated from (±8 V supplies down to ±1.35 V) two rechargeable cells.

The combination of rail-to-rail inputs and outputs make them good upgrades for the TLC27Lx family—offering more bandwidth at a lower quiescent current. The offset voltage is lower than the TLC27LxA variant.

To maintain cost effectiveness the TLV2381/2 are only available in the extended industrial temperature range. This means that one device can be used in a wide range of applications that include PDAs as well as automotive sensor interface.

All members are available in SOIC, with the singles in the small SOT-23 package, duals in the MSOP.

SELECTION GUIDE

DEVICE	V_S [V]	I_Q/ch [μA]	V_{ICR} [V]	V_{IO} [mV]	I_{IB} [pA]	GBW [MHz]	SLEW RATE [V/μs]	V_n, 1 kHz [nV/√Hz]
TLV238x	2.7 to 16	10	–0.2 to V_S + 0.2	4.5	60	0.16	0.06	100
TLV27Lx	2.7 to 16	11	–0.2 to V_S – 1.2	5	60	0.16	0.06	100
TLC27Lx	4 to 16	17	–0.2 to V_S – 1.5	10/5/2	60	0.085	0.03	68
OPAx349	1.8 to 5.5	2	–0.2 to V_S + 0.2	10	10	0.070	0.02	300
OPAx347	2.3 to 5.5	34	–0.2 to V_S + 0.2	6	10	0.35	0.01	60
TLC225x	2.7 to 16	62.5	0 to V_S – 1.5	1.5/0.85	60	0.200	0.02	19

NOTE: All dc specs are maximums while ac specs are typicals.

PACKAGE/ORDERING INFORMATION

PRODUCT	PACKAGE	PACKAGE CODE	SYMBOL	SPECIFIED TEMPERATURE RANGE	ORDER NUMBER	TRANSPORT MEDIA
TLV2381ID	SOIC-8	D	2381I	–40°C to 125°C	TLV2381ID	Tube
					TLV2381IDR	Tape and Reel
TLV2381IDBV	SOT-23	DBV	VBKI		TLV2381IDBVR	Tape and Reel
					TLV2381IDBVT	
TLV2382ID	SOIC-8	D	2382I		TLV2382ID	Tube
					TLV2382IDR	Tape and Reel

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

Supply voltage, V_S . . . . 16.5 V
Input voltage, V_I (see Notes 1 and 2) . . . . V_S + 0.2 V
Output current, I_O . . . . 100 mA
Differential input voltage, V_{ID} . . . . V_S
Continuous total power dissipation . . . . See Dissipation Rating Table
Maximum junction temperature, T_J . . . . 150°C
Operating free-air temperature range, T_A: I suffix . . . . –40°C to 125°C
Storage temperature range, T_{stg} . . . . –65°C to 125°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds . . . . 300°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. Relative to GND pin.
2. Maximum is 16.5 V or V_S+0.2 V whichever is the lesser value.

DISSIPATION RATING TABLE

PACKAGE	θ_{JC} (°C/W)	θ_{JA} (°C/W)	$T_A \leq 25°C$ POWER RATING	$T_A = 85°C$ POWER RATING
D (8)	38.3	176	710 mW	370 mW
DBV (5)	55	324.1	385 mW	201 mW
DBV (6)	55	294.3	425 mW	221 mW

recommended operating conditions

		MIN	MAX	UNIT
Supply voltage, (V_S)	Dual supply	±1.35	±8	V
	Single supply	2.7	16	
Input common-mode voltage range		–0.2	V_S+0.2	V
Operating free air temperature, T_A	I-suffix	–40	125	°C

electrical characteristics at recommended operating conditions, V_S = 2.7 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	$V_{IC} = V_S/2$, $V_O = V_S/2$, R_L = 100 kΩ, R_S = 50 Ω		25°C		0.5	4.5	mV
				Full range			6.5	
α_{VIO}	Offset voltage drift			25°C		1.1		µV/°C
CMRR	Common-mode rejection ratio	V_{IC} = 0 V to V_S, R_S = 50 Ω	V_S = 2.7 V	25°C	54	69		dB
				Full range	53			
		V_{IC} = 0 V to V_S–1.3 V, R_S = 50 Ω		25°C	71	86		
				Full range	70			
		V_{IC} = 0 V to V_S, R_S = 50 Ω	V_S = 5 V	25°C	58	74		dB
				Full range	57			
		V_{IC} = 0 V to V_S–1.3 V, R_S = 50 Ω		25°C	72	88		
				Full range	70			
		V_{IC} = 0 V to V_S, R_S = 50 Ω	V_S = 15 V	25°C	65	80		dB
				Full range	64			
		V_{IC} = 0 V to V_S–1.3 V, R_S = 50 Ω		25°C	72	90		
				Full range	70			
A_{VD}	Large-signal differential voltage amplification	$V_{O(PP)}=V_S/2$, R_L = 100 kΩ	V_S = 2.7 V	25°C	80	100		dB
				Full range	77			
			V_S = 5 V	25°C	80	100		
				Full range	77			
			V_S = 15 V	25°C	77	83		
				Full range	74			

† Full range is –40°C to 125°C.

input characteristics

PARAMETER		TEST CONDITIONS	T_A	MIN	TYP	MAX	UNIT
I_{IO}	Input offset current	$V_{IC} = V_S/2$, $V_O = V_S/2$, R_L = 100 kΩ , R_S = 50 Ω	≤25°C		1	60	pA
			≤70°C			100	
			≤125°C			1000	
I_{IB}	Input bias current		≤25°C		1	60	pA
			≤70°C			200	
			≤125°C			1000	
$r_{i(d)}$	Differential input resistance		25°C		1000		GΩ
C_{IC}	Common-mode input capacitance	f = 1 kHz	25°C		8		pF

electrical characteristics at recommended operating conditions, V_S = 2.7 V, 5 V, and 15 V (unless otherwise noted) (continued)

power supply

PARAMETER		TEST CONDITIONS	T_A†	MIN	TYP	MAX	UNIT
I_{DD}	Supply current (per channel)	$V_O = V_S/2$	25°C		7	10	µA
			Full range			15	
PSRR	Power supply rejection ratio ($\Delta V_S/\Delta V_{IO}$)	V_S = 2.7 V to 16V, No load, $V_{IC} = V_S/2$ V	25°C	74	82		dB
			Full range	70			

† Full range is –40°C to 125°C for I suffix.

output characteristics

PARAMETER		TEST CONDITIONS		T_A†	MIN	TYP	MAX	UNIT
V_O	Output voltage swing from rail	$V_{IC} = V_S/2$, I_O = 100 µA	V_S = 2.7 V	25°C	200	160		mV
				Full range	220			
			V_S = 5 V	25°C	120	85		
				Full range	200			
			V_S = 15 V	25°C	120	50		
				Full range	150			
		$V_{IC} = V_S/2$, I_O = 500 µA	V_S = 5 V	25°C	800	420		mV
				Full range	900			
			V_S = 15 V	25°C	400	200		
				Full range	500			
I_O	Output current	V_O = 0.5 V from rail	V_S = 2.7 V	25°C		400		µA

† Full range is –40°C to 125°C for I suffix.

dynamic performance

PARAMETER		TEST CONDITIONS		T_A	MIN	TYP	MAX	UNIT
GBP	Gain bandwidth product	R_L = 100 kΩ , C_L = 10 pF, f = 1 kHz		25°C		160		kHz
SR	Slew rate at unity gain	$V_{O(pp)}$ = 2 V, R_L = 100 kΩ, C_L = 10 pF		25°C		0.06		V/µs
				–40°C		0.05		
				125°C		0.08		
ϕ_M	Phase margin	R_L = 100 kΩ, C_L = 50 pF		25°C		62		°
	Gain margin			25°C		6.7		dB
t_s	Settling time (0.1%)	$V_{(STEP)pp}$ = 1 V, A_V = –1, C_L = 10 pF, R_L = 100 kΩ	Rise	25°C		31		µs
			Fall			61		

noise/distortion performance

PARAMETER		TEST CONDITIONS	T_A	MIN	TYP	MAX	UNIT
V_n	Equivalent input noise voltage	f = 1 kHz	25°C		90		nV/√Hz

TYPICAL CHARACTERISTICS

Table of Graphs

			FIGURE
V_{IO}	Input offset voltage	vs Common-mode input voltage	1, 2, 3
I_{IB}/I_{IO}	Input bias and offset current	vs Free-air temperature	4
V_{OH}	High-level output voltage	vs High-level output current	5, 7, 9
V_{OL}	Low-level output voltage	vs Low-level output current	6, 8, 10
I_Q	Quiescent current	vs Supply voltage	11
		vs Free-air temperature	12
	Supply voltage and supply current ramp up		13
A_{VD}	Differential voltage gain and phase shift	vs Frequency	14
GBP	Gain-bandwidth product	vs Free-air temperature	15
ϕ_m	Phase margin	vs Load capacitance	16
CMRR	Common-mode rejection ratio	vs Frequency	17
PSRR	Power supply rejection ratio	vs Frequency	18
	Input referred noise voltage	vs Frequency	19
SR	Slew rate	vs Free-air temperature	20
$V_{O(PP)}$	Peak-to-peak output voltage	vs Frequency	21
	Inverting small-signal response		22
	Inverting large-signal response		23
	Crosstalk	vs Frequency	24

INPUT OFFSET VOLTAGE vs COMMON-MODE INPUT VOLTAGE

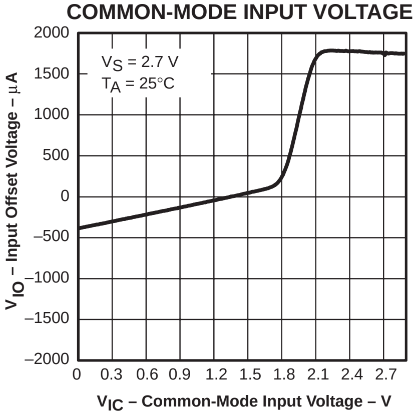


Figure 1

INPUT OFFSET VOLTAGE vs COMMON-MODE INPUT VOLTAGE

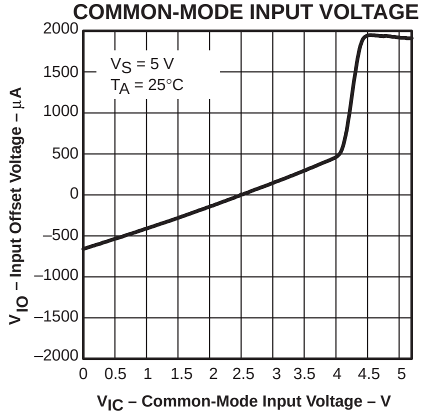


Figure 2

INPUT OFFSET VOLTAGE vs COMMON-MODE INPUT VOLTAGE

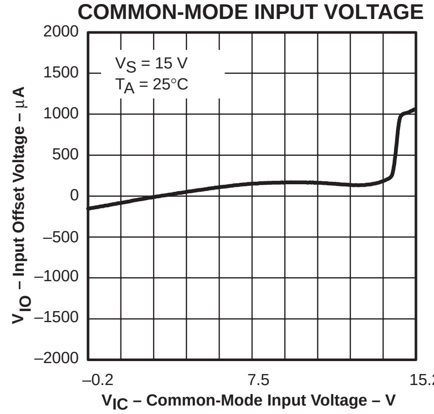


Figure 3

TYPICAL CHARACTERISTICS

INPUT BIAS AND INPUT OFFSET CURRENT vs FREE-AIR TEMPERATURE

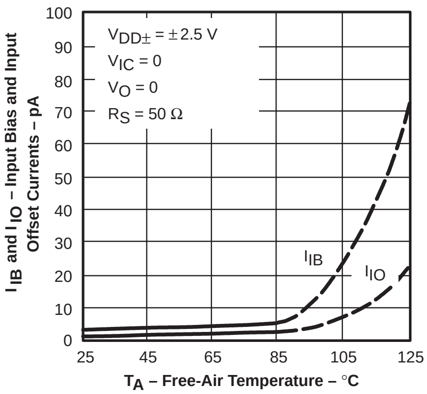


Figure 4

HIGH-LEVEL OUTPUT VOLTAGE vs HIGH-LEVEL OUTPUT CURRENT

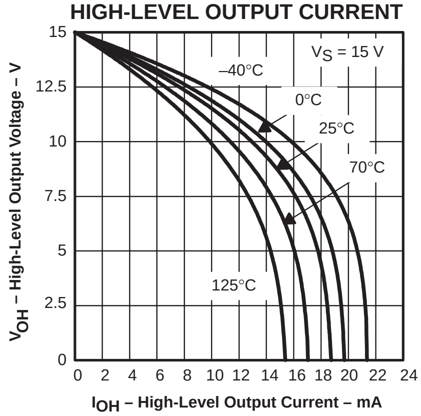


Figure 5

LOW-LEVEL OUTPUT VOLTAGE vs LOW-LEVEL OUTPUT CURRENT

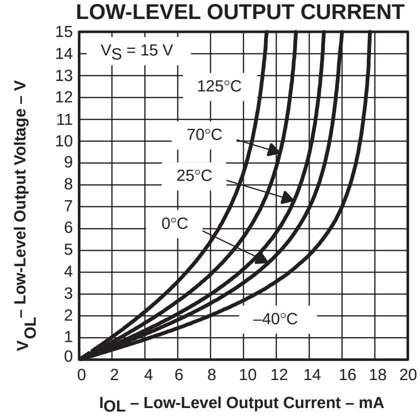


Figure 6

HIGH-LEVEL OUTPUT VOLTAGE vs HIGH-LEVEL OUTPUT CURRENT

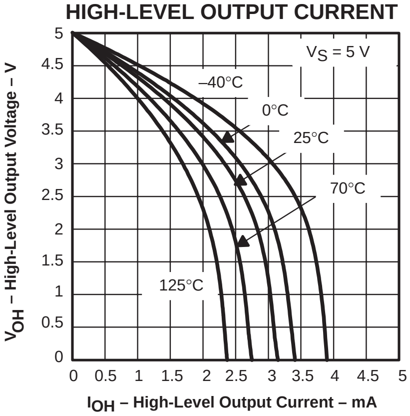


Figure 7

LOW-LEVEL OUTPUT VOLTAGE vs LOW-LEVEL OUTPUT CURRENT

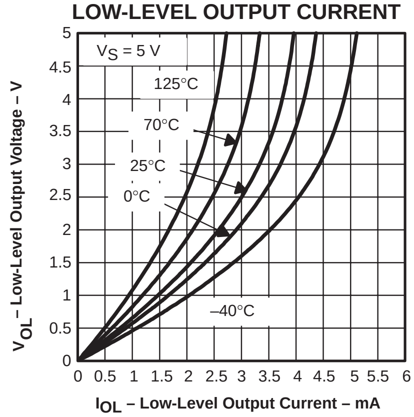


Figure 8

HIGH-LEVEL OUTPUT VOLTAGE vs HIGH-LEVEL OUTPUT CURRENT

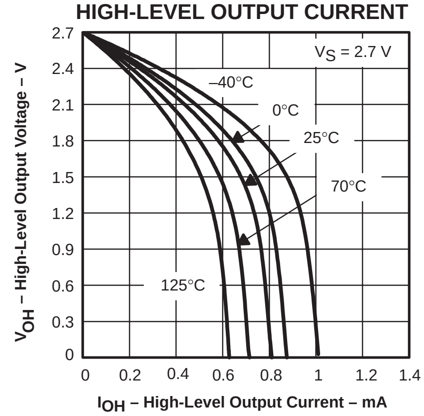


Figure 9

LOW-LEVEL OUTPUT VOLTAGE vs LOW-LEVEL OUTPUT CURRENT

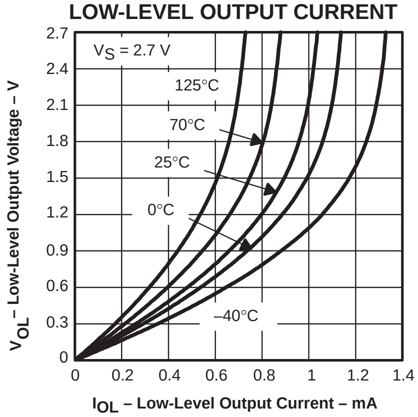


Figure 10

QUIESCENT CURRENT vs SUPPLY VOLTAGE

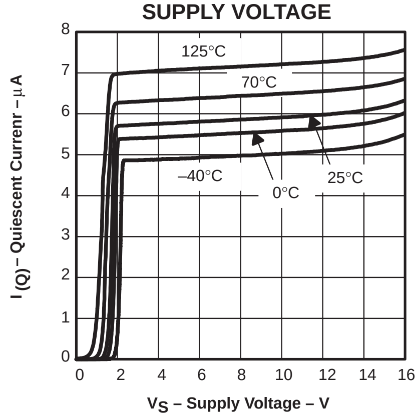


Figure 11

QUIESCENT CURRENT vs FREE-AIR TEMPERATURE

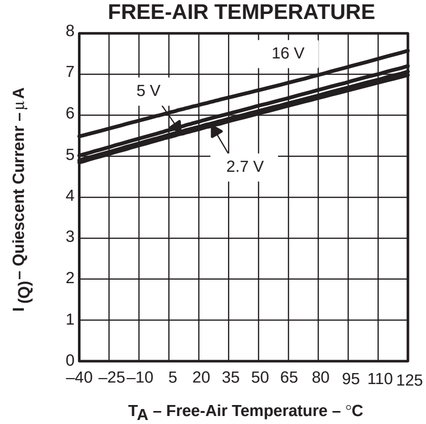


Figure 12

TYPICAL CHARACTERISTICS

SUPPLY VOLTAGE AND SUPPLY CURRENT RAMP UP

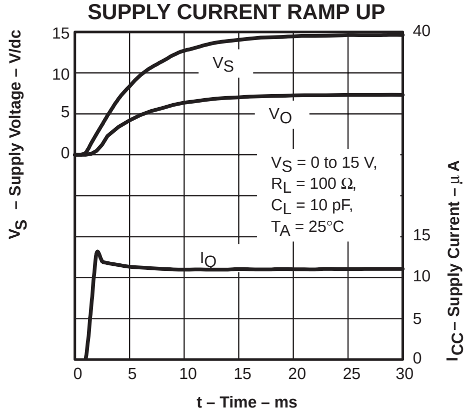


Figure 13

DIFFERENTIAL VOLTAGE GAIN AND PHASE SHIFT vs FREQUENCY

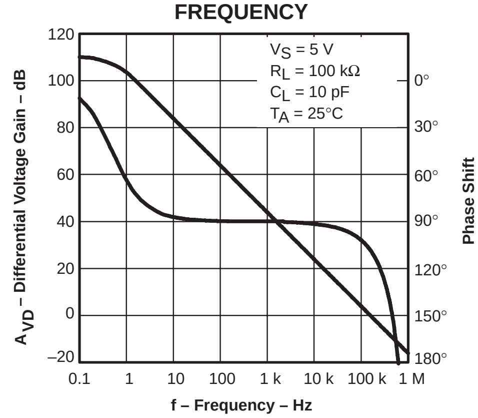


Figure 14

GAIN-BANDWIDTH PRODUCT vs FREE-AIR TEMPERATURE

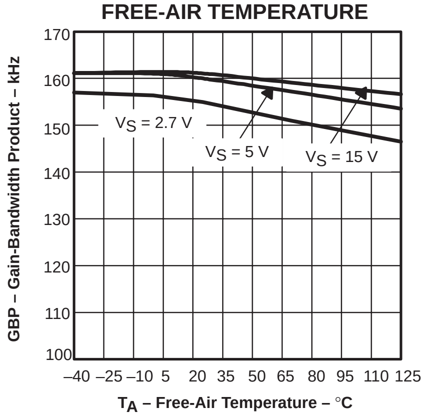


Figure 15

PHASE MARGIN vs LOAD CAPACITANCE

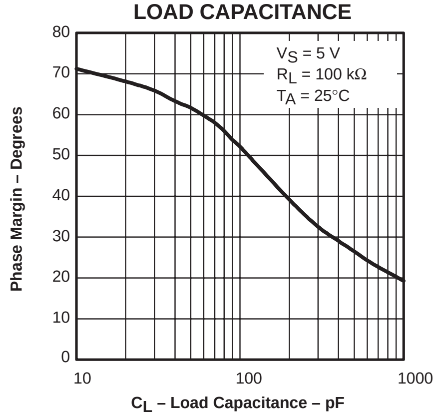


Figure 16

COMMON-MODE REJECTION RATIO vs FREQUENCY

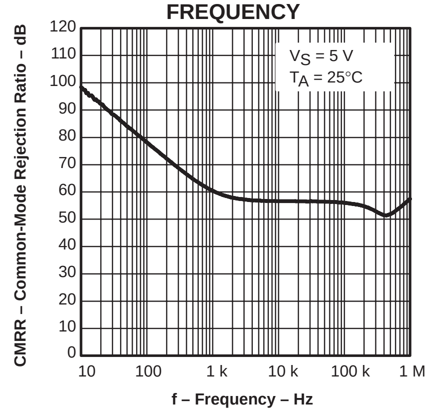


Figure 17

POWER SUPPLY REJECTION RATIO vs FREQUENCY

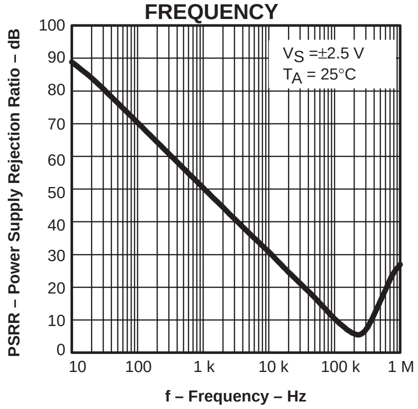


Figure 18

INPUT REFERRED NOISE VOLTAGE vs FREQUENCY

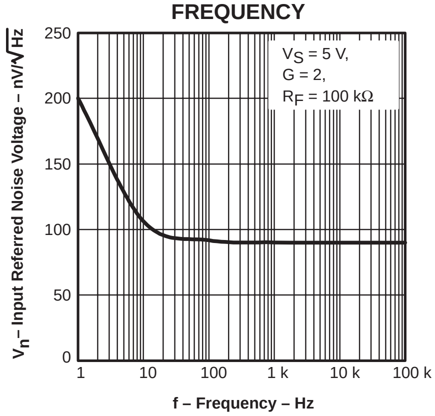


Figure 19

SLEW RATE vs FREE-AIR TEMPERATURE

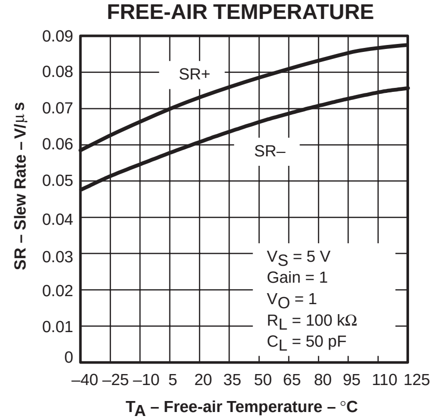


Figure 20

TYPICAL CHARACTERISTICS

PEAK-TO-PEAK OUTPUT VOLTAGE
vs
FREQUENCY

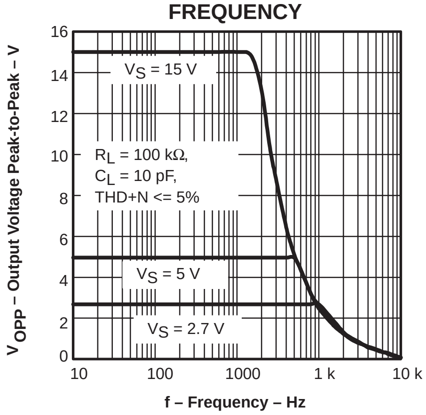


Figure 21

INVERTING SMALL-SIGNAL
RESPONSE

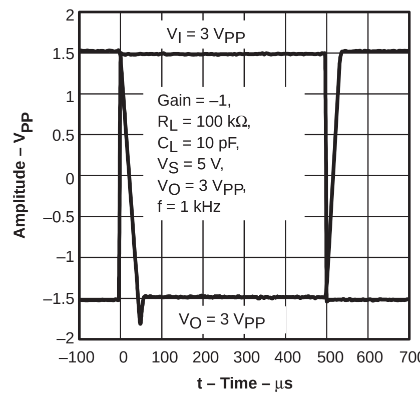


Figure 22

INVERTING LARGE-SIGNAL
RESPONSE

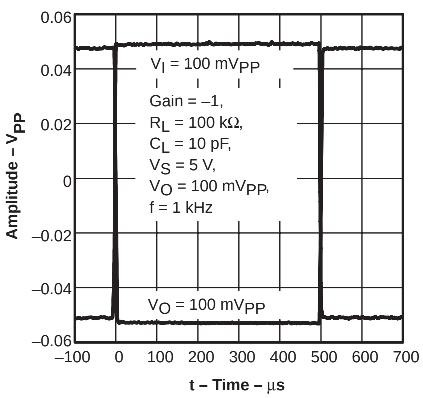


Figure 23

CROSSTALK
vs
FREQUENCY

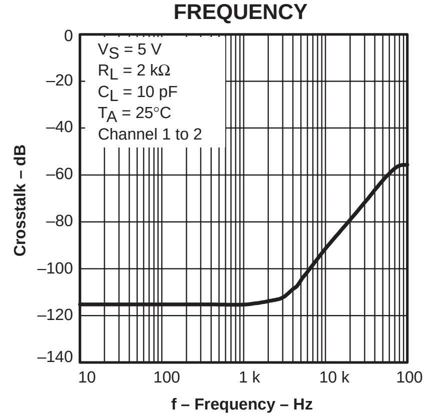
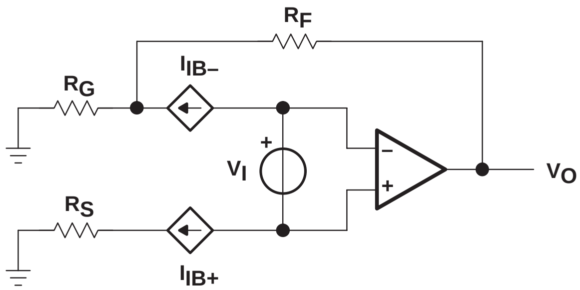


Figure 24

APPLICATION INFORMATION

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 following schematic and formula can be used to calculate the output offset voltage:

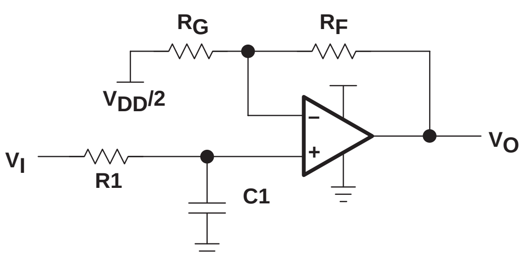


$$V_{OO} = V_{IO}\left(1 + \left(\frac{R_F}{R_G}\right)\right) \pm I_{IB+}\,R_S\left(1 + \left(\frac{R_F}{R_G}\right)\right) \pm I_{IB-}\,R_F$$

Figure 25. Output Offset Voltage Model

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 26).

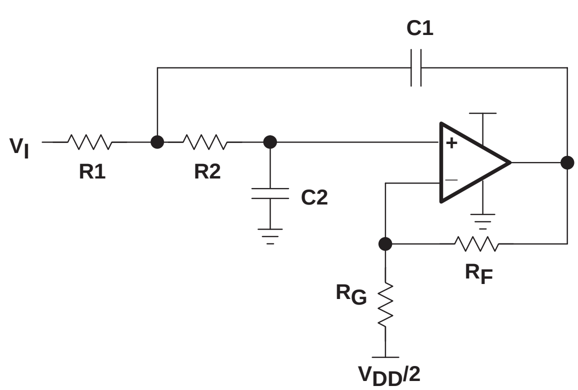


$$\frac{V_O}{V_I} = \left(1 + \frac{R_F}{R_G}\right)\left(\frac{1}{1 + sR1C1}\right)$$

$$f_{-3dB} = \frac{1}{2\pi R1C1}$$

Figure 26. 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.



R1 = R2 = R
C1 = C2 = C
Q = Peaking Factor
(Butterworth Q = 0.707)

$$f_{-3dB} = \frac{1}{2\pi RC}$$

$$R_G = \frac{R_F}{\left(2 - \frac{1}{Q}\right)}$$

Figure 27. 2-Pole Low-Pass Sallen-Key Filter

APPLICATION INFORMATION

circuit layout considerations

To achieve the levels of high performance of the TLV238x, follow proper printed-circuit board design techniques. A general set of guidelines is given in the following.

- 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-µF tantalum capacitor in parallel with a 0.1-µF ceramic capacitor on each supply terminal. It may be possible to share the tantalum among several amplifiers depending on the application, but a 0.1-µF ceramic capacitor should always be used on the supply terminal of every amplifier. In addition, the 0.1-µF 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 will often lead 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 will help 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.

APPLICATION INFORMATION

general power dissipation considerations

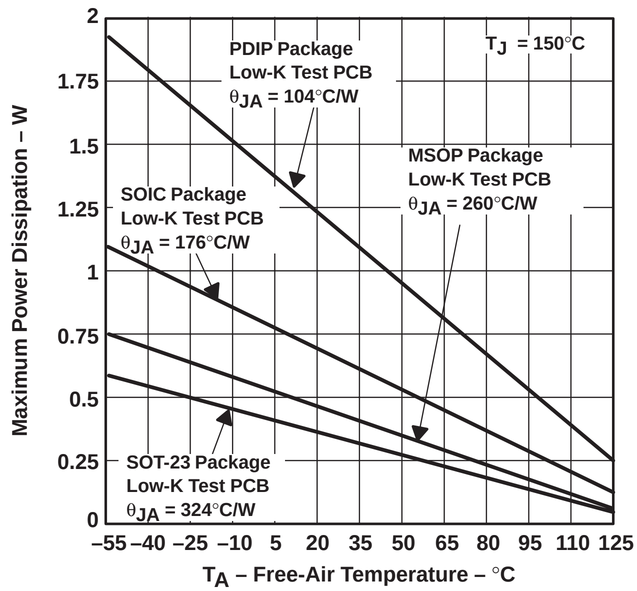
For a given θ_{JA}, the maximum power dissipation is shown in Figure 28 and is calculated by the following formula:

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

Where:

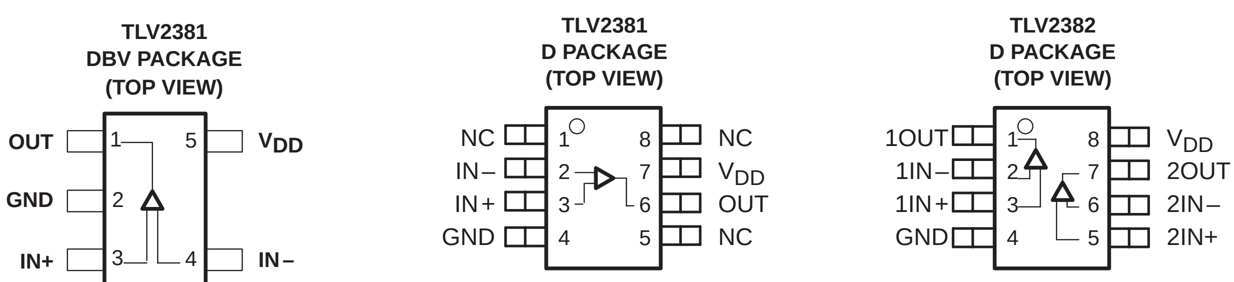
P_D = Maximum power dissipation of TLV238x IC (watts)
T_{MAX} = Absolute maximum junction temperature (150°C)
T_A = Free-ambient air temperature (°C)
θ_{JA} = $\theta_{JC} + \theta_{CA}$
θ_{JC} = Thermal coefficient from junction to case
θ_{CA} = Thermal coefficient from case to ambient air (°C/W)

MAXIMUM POWER DISSIPATION
vs
FREE-AIR TEMPERATURE



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

Figure 28. Maximum Power Dissipation vs Free-Air Temperature



NC – No internal connection

PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish	MSL Peak Temp (3)
TLV2381ID	ACTIVE	SOIC	D	8	75	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLV2381IDBVR	ACTIVE	SOT-23	DBV	5	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLV2381IDBVRG4	ACTIVE	SOT-23	DBV	5	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLV2381IDBVT	ACTIVE	SOT-23	DBV	5	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLV2381IDBVTG4	ACTIVE	SOT-23	DBV	5	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLV2381IDG4	ACTIVE	SOIC	D	8	75	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLV2381IDR	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLV2381IDRG4	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLV2381IP	PREVIEW	PDIP	P	8		TBD	Call TI	Call TI
TLV2382ID	ACTIVE	SOIC	D	8	75	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLV2382IDG4	ACTIVE	SOIC	D	8	75	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLV2382IDR	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLV2382IDRG4	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLV2382IP	OBSOLETE	PDIP	P	8		TBD	Call TI	Call TI

(1) The marketing status values are defined as follows:
ACTIVE: Product device recommended for new designs.
LIFEBUY: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.
NRND: Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.
PREVIEW: Device has been announced but is not in production. Samples may or may not be available.
OBSOLETE: TI has discontinued the production of the device.

(2) Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check http://www.ti.com/productcontent for the latest availability information and additional product content details.
TBD: The Pb-Free/Green conversion plan has not been defined.
Pb-Free (RoHS): TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.
Pb-Free (RoHS Exempt): This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.
Green (RoHS & no Sb/Br): TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

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

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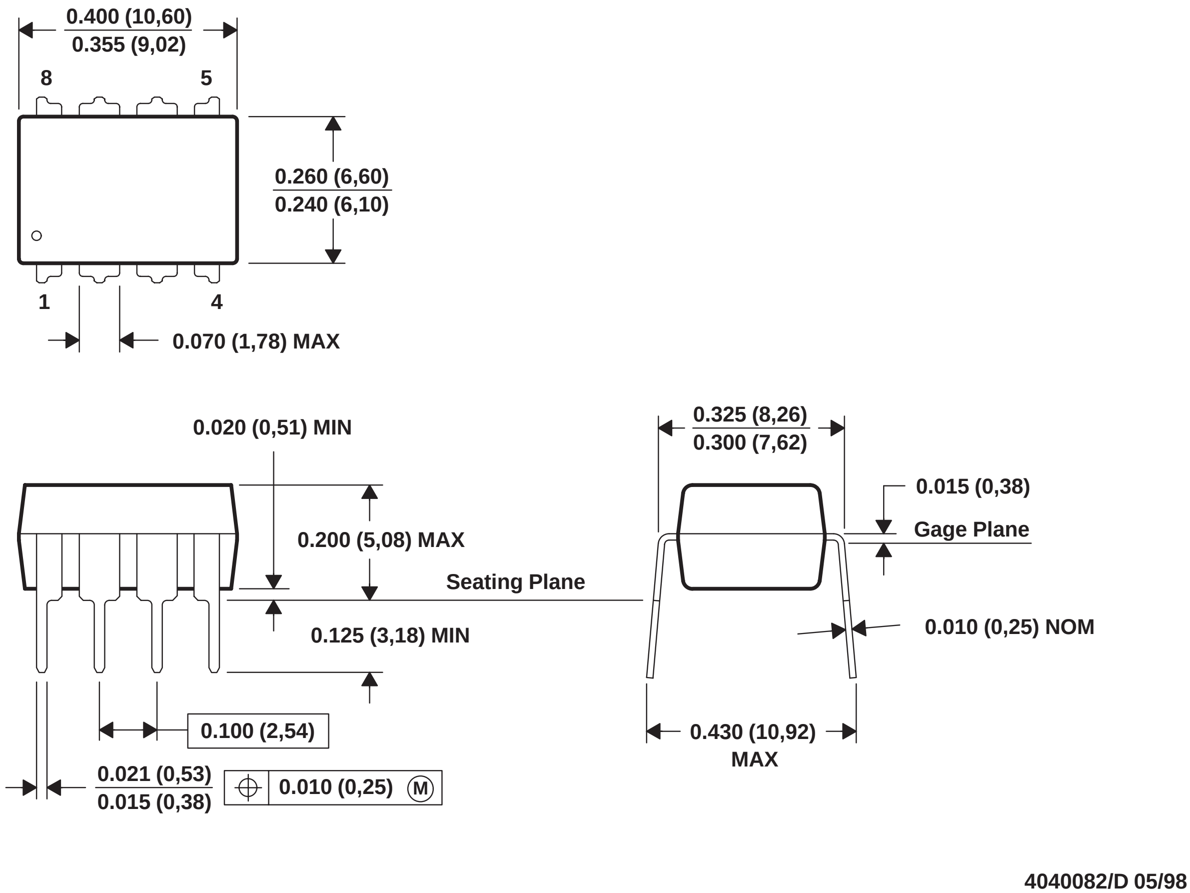
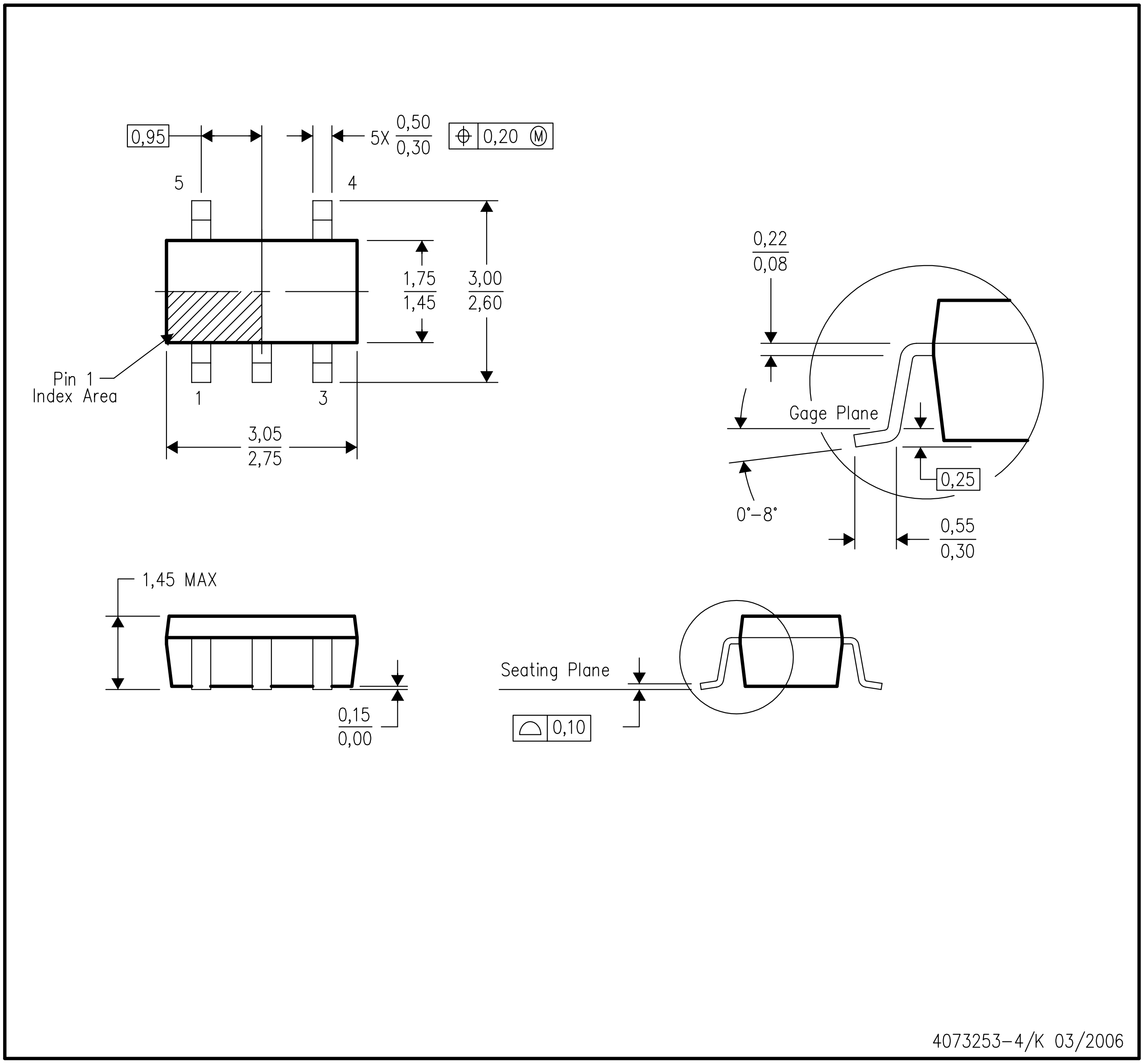
P (R-PDIP-T8) **PLASTIC DUAL-IN-LINE**



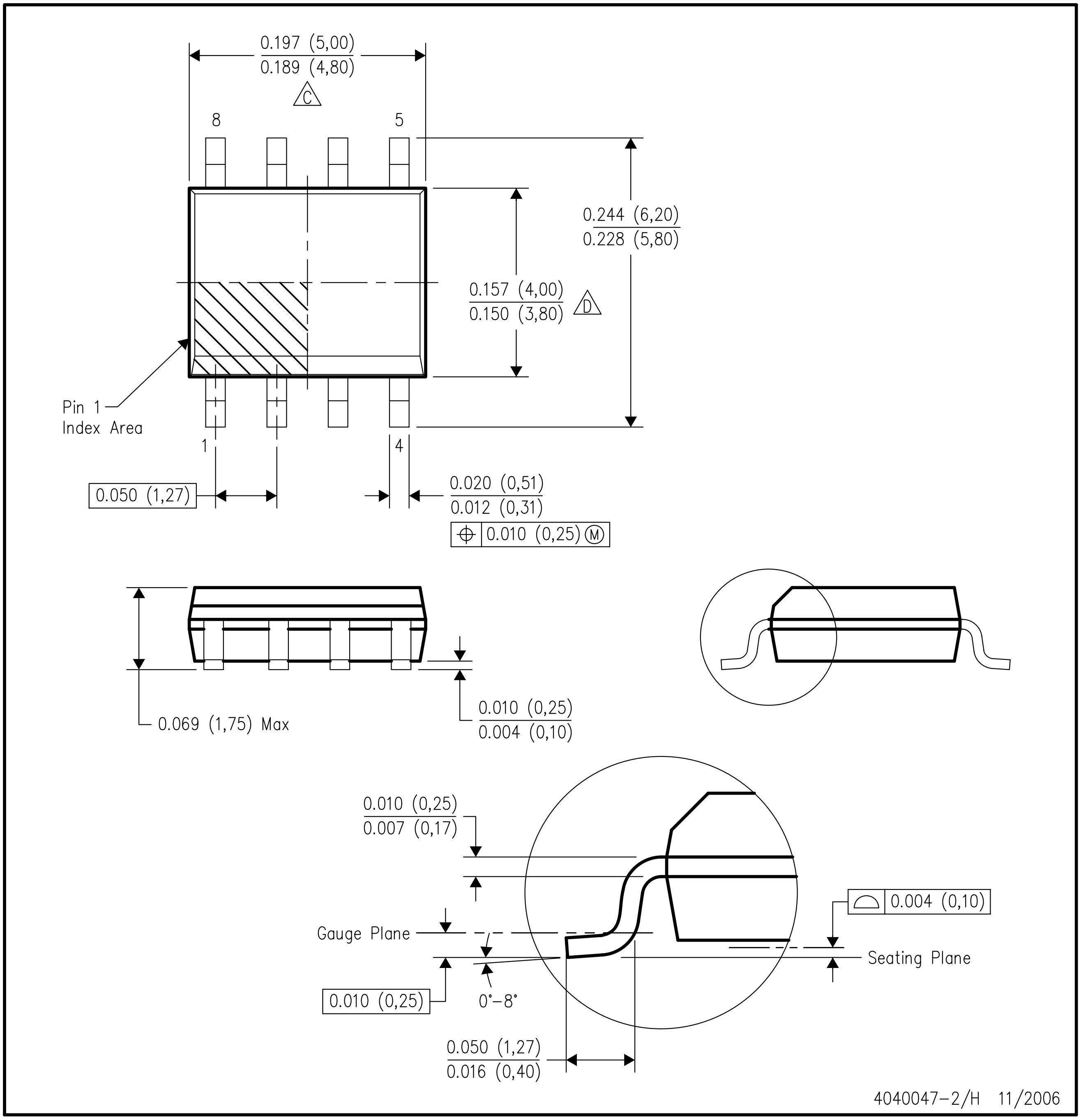
NOTES: A. All linear dimensions are in inches (millimeters).
B. This drawing is subject to change without notice.
C. Falls within JEDEC MS-001

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-G8) 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 AA.