

## FAMILY OF NANOWATT OPERATIONAL AMPLIFIERS AND PUSH-PULL COMPARATORS

### FEATURES

- **Micro-Power Operation . . . 1.4  $\mu$ A**
- **Input Common-Mode Range Exceeds the Rails . . .  $-0.1$  V to  $V_{CC} + 5$  V**
- **Supply Voltage Range . . . 2.5 V to 16 V**
- **Rail-to-Rail Input/Output (Amplifier)**
- **Reverse Battery Protection Up to 18 V**
- **Gain Bandwidth Product . . . 5.5 kHz (Amplifier)**
- **Push-Pull CMOS Output Stage (Comparator)**
- **Specified Temperature Range**
  - $T_A = -40^\circ\text{C}$  to  $125^\circ\text{C}$  . . . Industrial Grade
- **Ultrasmall Packaging**
  - 8-Pin MSOP (TLV2702)
- **Universal Op-Amp EVM (See the SLOU060 For More Information)**

The TLV270x's low supply current is coupled with extremely low input bias currents enabling them to be used with mega-ohm resistors making them ideal for portable, long active life, applications. DC accuracy is ensured with a low typical offset voltage as low as  $390\mu\text{V}$ , CMRR of 90 dB, and minimum open loop gain of 130 V/mV at 2.7 V.

The maximum recommended supply voltage is as high as 16 V and ensured operation down to 2.5 V, with electrical characteristics specified at 2.7 V, 5 V, and 15 V. The 2.5-V operation makes it compatible with Li-Ion battery-powered systems and many micro-power microcontrollers available today including TI's MSP430.

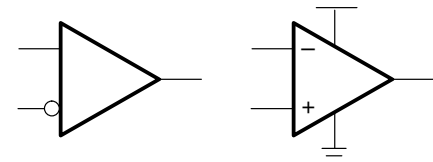
All members are available in PDIP and SOIC with the duals, one op-amp and one comparator, in the small MSOP package and quads, two operational amplifiers and two comparators, in the TSSOP package.

### APPLICATIONS

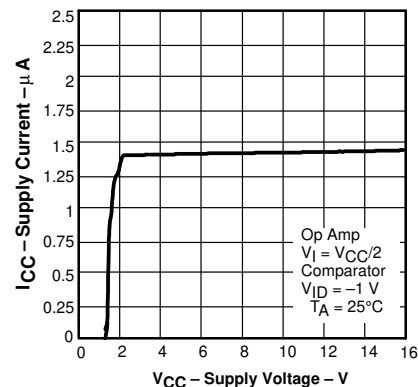
- **Portable Battery Monitoring**
- **Consumer Medical Electronics**
- **Security Detection Systems**

### DESCRIPTION

The TLV270x combines sub-micropower operational amplifier and comparator into a single package that produces excellent micropower signal conditioning with only  $1.4\mu\text{A}$  of supply current. This combination gives the designer more board space and reduces part counts in systems that require an operational amplifier and comparator. The low supply current makes it an ideal choice for battery powered portable applications where quiescent current is the primary concern. Reverse battery protection guards the amplifier from an over-current condition due to improper battery installation. For harsh environments, the inputs can be taken 5 V above the positive supply rail without damage to the device.



SUPPLY CURRENT  
vs  
SUPPLY VOLTAGE



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.

**A SELECTION OF OUTPUT COMPARATORST**

DEVICE	V <sub>CC</sub> (V)	V <sub>IO</sub> (μV)	I <sub>CC</sub> /Ch (μA)	GBW (kHz)	SR (V/μs)	t <sub>PLH</sub> (μs)	t <sub>PHL</sub> (μs)	t <sub>f</sub> (μs)	RAIL-TO-RAIL	OUTPUT STAGE
TLV270x	2.5 – 16	390	1.4‡	5.5	0.0025	56	83	8	I/O	PP
TLV230x	2.5 – 16	390	1.4‡	5.5	0.0025	55	30	5	I/O	OD
TLV240x	2.5 – 16	390	880	5.5	0.0025	—	—	—	I/O	—
TLV224x	2.5 – 12	600	1	5.5	0.002	—	—	—	I/O	—
TLV340x	2.5 – 16	250	0.47	—	—	55	30	5	I	OD
TLV370x	2.5 – 16	250	0.56	—	—	56	83	8	I	PP

† All specifications are typical values measured at 5 V.

‡ I<sub>CC</sub> is specified as one op-amp and one comparator.

**TLV2702 AVAILABLE OPTIONS**

T <sub>A</sub>	V <sub>IO</sub> max AT 25°C	PACKAGED DEVICES			
		SMALL OUTLINE† (D)	MSOP		PLASTIC DIP (P)
			MSOPT (DGK)	SYMBOLS	
-40°C to 125°C	4000 μV	TLV2702ID	TLV2702IDGK	xxTIAQF	TLV2702IP

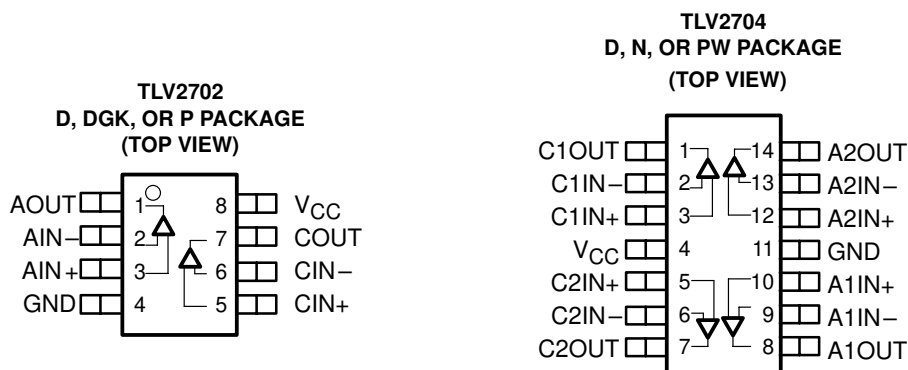
† This package is available taped and reeled. To order this packaging option, add an R suffix to the part number (e.g., TLV2702IDR).

**TLV2704 AVAILABLE OPTIONS**

T <sub>A</sub>	V <sub>IO</sub> max AT 25°C	PACKAGED DEVICES		
		SMALL OUTLINE† (D)	TSSOP (PW)	PLASTIC DIP (N)
-40°C to 125°C	4000 μV	TLV2704ID	TLV2704IPW	TLV2704IN

† This package is available taped and reeled. To order this packaging option, add an R suffix to the part number (e.g., TLV2704IDR).

**TLV270x PACKAGE PINOUTS**



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

Supply voltage, $V_{CC}$ (see Note 1)	17 V
Differential input voltage, $V_{ID}$	$V_{CC}$
Input voltage range, $V_I$ (see Notes 1 and 2)	0 to $V_{CC} + 5$ V
Input current range, $I_I$ (any input)	$\pm 10$ mA
Output current range, $I_O$	$\pm 10$ mA
Continuous total power dissipation	See Dissipation Rating Table
Operating free-air temperature range, $T_A$ : I suffix	$-40^\circ\text{C}$ to $125^\circ\text{C}$
Maximum junction temperature, $T_J$	$150^\circ\text{C}$
Storage temperature range, $T_{stg}$	$-65^\circ\text{C}$ to $150^\circ\text{C}$
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds	$260^\circ\text{C}$

† 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. Input voltage range is limited to 20 V max or  $V_{CC} + 5$  V, whichever is smaller.

**DISSIPATION RATING TABLE**

PACKAGE	$\theta_{JC}$ ( $^\circ\text{C}/\text{W}$ )	$\theta_{JA}$ ( $^\circ\text{C}/\text{W}$ )	$T_A \leq 25^\circ\text{C}$ POWER RATING	$T_A = 125^\circ\text{C}$ POWER RATING
D (8)	38.3	176	710 mW	142 mW
D (14)	26.9	122.3	1022 mW	204.4 mW
DGK (8)	54.2	259.9	481 mW	96.2 mW
N (14)	32	78	1600 mW	320.5 mW
P (8)	41	104	1200 mW	240.4 mW
PW (14)	29.3	173.6	720 mW	144 mW

**recommended operating conditions**

		MIN	MAX	UNIT
Supply voltage, $V_{CC}$	Single supply	2.5	16	V
	Split supply	$\pm 1.25$	$\pm 8$	
Common-mode input voltage range, $V_{ICR}$	Amplifier and comparator	-0.1	$V_{CC}+5$	V
Operating free-air temperature, $T_A$		-40	125	$^\circ\text{C}$

**electrical characteristics at recommended operating conditions,  $V_{CC} = 2.7, 5 \text{ V}$ , and  $15 \text{ V}$  (unless otherwise noted)**

**amplifier dc performance**

PARAMETER		TEST CONDITIONS	$T_A^\dagger$	MIN	TYP	MAX	UNIT
$V_{IO}$	Input offset voltage	$V_O = V_{CC}/2 \text{ V}$ , $V_{IC} = V_{CC}/2 \text{ V}$ , $R_S = 50 \Omega$	25°C	390	4000		$\mu\text{V}$
			Full range		6000		
$\alpha V_{IO}$	Offset voltage draft		25°C	3			$\mu\text{V}/^\circ\text{C}$
CMRR	Common-mode rejection ratio	$V_{IC} = 0 \text{ to } V_{CC}$ , $R_S = 50 \Omega$	$V_{CC} = 2.7 \text{ V}$	25°C	55	73	dB
				Full range	52		
			$V_{CC} = 5 \text{ V}$	25°C	60	80	
				Full range	55		
			$V_{CC} = 15 \text{ V}$	25°C	66	90	
				Full range	60		
AVD	Large-signal differential voltage amplification	$V_{CC} = 2.7 \text{ V}$ , $V_{O(pp)} = 1.5 \text{ V}$ , $R_L = 500 \text{ k}\Omega$	25°C	130	400	V/mV	
			Full range	30			
			$V_{CC} = 5 \text{ V}$ , $V_{O(pp)} = 3 \text{ V}$ , $R_L = 500 \text{ k}\Omega$	25°C	300		1000
				Full range	100		
			$V_{CC} = 15 \text{ V}$ , $V_{O(pp)} = 8 \text{ V}$ , $R_L = 500 \text{ k}\Omega$	25°C	400		1800
				Full range	120		
PSRR	Power supply rejection ratio ( $\Delta V_{CC}/\Delta V_{IO}$ )	$V_{IC} = V_{CC}/2 \text{ V}$ , No load	$V_{CC} = 2.7 \text{ to } 5 \text{ V}$	25°C	90	120	dB
				Full range	85		
			$V_{CC} = 5 \text{ to } 15 \text{ V}$	25°C	94	120	
				Full range	90		

$^\dagger$  Full range is  $-40^\circ\text{C}$  to  $125^\circ\text{C}$ .

**amplifier and comparator input characteristics**

PARAMETER		TEST CONDITIONS	$T_A^\dagger$	MIN	TYP	MAX	UNIT
$I_{IO}$	Input offset current	$V_O = V_{CC}/2 \text{ V}$ , $V_{IC} = V_{CC}/2 \text{ V}$ $R_S = 50 \Omega$	25°C		25	250	pA
			0 to 70°C			300	
			Full range			700	
$I_{IB}$	Input bias current	$V_O = V_{CC}/2 \text{ V}$ , $V_{IC} = V_{CC}/2 \text{ V}$ $R_S = 50 \Omega$	25°C		100	500	pA
			0 to 70°C			550	
			Full range			1700	
$r_{i(d)}$	Differential input resistance		25°C		300		$\text{M}\Omega$
$C_{i(c)}$	Common-mode input capacitance	$f = 100 \text{ kHz}$	25°C		3		pF

$^\dagger$  Full range is  $-40^\circ\text{C}$  to  $125^\circ\text{C}$ .

electrical characteristics at recommended operating conditions,  $V_{CC} = 2.7, 5 \text{ V}$ , and  $15 \text{ V}$  (unless otherwise noted) (continued)

amplifier output characteristics

PARAMETER		TEST CONDITIONS	$T_A$ †	MIN	TYP	MAX	UNIT
$V_{OH}$	High-level output voltage	$V_{IC} = V_{CC}/2,$ $I_{OH} = -50 \mu\text{A}$	25°C	2.55		2.65	V
				Full range	2.5		
			25°C	4.85		4.95	
				Full range	4.8		
			25°C	14.8		14.95	
				Full range	14.8		
$V_{OL}$	Low-level output voltage	$V_{IC} = V_{CC}/2, I_{OL} = 50 \mu\text{A}$	25°C	180	260	mV	
			Full range	300			
$I_O$	Output current	$V_O = 0.5 \text{ V}$ from rail	25°C	±200		μA	
$Z_O$	Closed-loop output impedance	$f = 100 \text{ Hz}, A_V = 10$	25°C	1.2		kΩ	

† Full range is  $-40^\circ\text{C}$  to  $125^\circ\text{C}$ .

amplifier dynamic performance

PARAMETER		TEST CONDITIONS	$T_A$	MIN	TYP	MAX	UNIT
UGBW	Unity gain bandwidth	$R_L = 500 \text{ k}\Omega, C_L = 100 \text{ pF}$	25°C	5.5			kHz
SR	Slew rate at unity gain	$V_O(\text{pp}) = 0.8 \text{ V}, R_L = 500 \text{ k}\Omega, C_L = 100 \text{ pF}$	25°C	2.5			V/ms
$\phi_M$	Phase margin	$R_L = 500 \text{ k}\Omega, C_L = 100 \text{ pF}$	25°C	60°			
	Gain margin			15			dB
$t_s$	Settling time	$V_{CC} = 2.7 \text{ or } 5 \text{ V},$ $V(\text{STEP})_{PP} = 1 \text{ V},$ $A_V = -1,$ $C_L = 100 \text{ pF},$ $R_L = 100 \text{ k}\Omega$	25°C	0.1%		1.84	ms
				0.1%		6.1	
				0.01%		32	
$V_n$	Equivalent input noise voltage	$f = 0.1 \text{ to } 10 \text{ Hz}$	25°C	5.3			$\mu\text{V}_{pp}$
				$f = 100 \text{ Hz}$	500		
$I_n$	Equivalent input noise current	$f = 100 \text{ Hz}$	25°C	8			$\text{fA}/\sqrt{\text{Hz}}$

supply current

PARAMETER		TEST CONDITIONS	$T_A$ †	MIN	TYP	MAX	UNIT	
$I_{CC}$	Supply current (one op-amp and one comparator)	$V_O = V_{CC}/2$	25°C	$V_{CC} = 2.7 \text{ V or } 5 \text{ V}$		1.4	μA	
				25°C	$V_{CC} = 15 \text{ V}$			1.4
			Full range			3.7		
Reverse supply current		$V_{CC} = -18 \text{ V}, V_I = 0 \text{ V}, V_O = \text{open}$	25°C	50			nA	

† Full range is  $-40^\circ\text{C}$  to  $125^\circ\text{C}$ .

**electrical characteristics at recommended operating conditions,  $V_{CC} = 2.7, 5 \text{ V}$ , and  $15 \text{ V}$  (unless otherwise noted) (continued)**

**comparator dc performance**

PARAMETER		TEST CONDITIONS†		$T_A$ †	MIN	TYP	MAX	UNIT
$V_{IO}$	Input offset voltage	$V_{IC} = V_{CC}/2, R_S = 50 \Omega$		25°C	250	5000		$\mu\text{V}$
				Full range		7000		
$\alpha_{VIO}$	Offset voltage drift			25°C		3		$\mu\text{V}/^\circ\text{C}$
CMRR	Common-mode rejection ratio	$V_{IC} = 0 \text{ to } V_{CC}, R_S = 50 \Omega$	$V_{CC} = 2.7 \text{ V}$	25°C	55	72		dB
				Full range		50		
			$V_{CC} = 5 \text{ V}$	25°C	60	76		
				Full range		55		
			$V_{CC} = 15 \text{ V}$	25°C	65	88		
				Full range		60		
$A_{VD}$	Large-signal differential voltage amplification			25°C		1000		V/mV
PSRR	Power supply rejection ratio ( $\Delta V_{CC}/\Delta V_{IO}$ )	$V_{IC} = V_{CC}/2 \text{ V}$ , No load	$V_{CC} = 2.7 \text{ to } 5 \text{ V}$	25°C	75	100		dB
				Full range		70		
			$V_{CC} = 5 \text{ to } 15 \text{ V}$	25°C	85	105		
				Full range		80		

† Full range is  $-40^\circ\text{C}$  to  $125^\circ\text{C}$ .

**comparator output characteristics**

PARAMETER		TEST CONDITIONS†		$T_A$ †	MIN	TYP	MAX	UNIT
$r_{i(d)}$	Differential input resistance			25°C		300		$\text{M}\Omega$
$V_{OH}$	High-level output voltage	$V_{IC} = V_{CC}/2, V_{ID} = 1 \text{ V}$	$I_{OL} = -50 \mu\text{A}$	25°C	$V_{CC}-320$			mV
				Full range	$V_{CC}-450$			
$V_{OL}$	Low-level output voltage	$V_{IC} = V_{CC}/2, V_{ID} = -1 \text{ V}$	$I_{OL} = 50 \mu\text{A}$	25°C		80	200	mV
				Full range			300	

† Full range is  $-40^\circ\text{C}$  to  $125^\circ\text{C}$ .

**switching characteristics at recommended operating conditions,  $V_{CC} = 2.7 \text{ V}, 5 \text{ V}, 15 \text{ V}$  (unless otherwise noted)**

PARAMETER		TEST CONDITIONS		$T_A$	MIN	TYP	MAX	UNIT
$t_{(PLH)}$	Propagation response time, low-to-high-level output	$f = 10 \text{ kHz}, V_{STEP} = 100 \text{ mV}, C_L = 10 \text{ pF}, V_{CC} = 2.7 \text{ V}$	Overdrive = 2 mV	25°C	240		$\mu\text{s}$	
					Overdrive = 10 mV	64		
						Overdrive = 50 mV		36
Overdrive = 2 mV	167							
	Overdrive = 10 mV		67					
			Overdrive = 50 mV	37				
$t_{(PHL)}$		Propagation response time, high-to-low-level output				25°C		
$t_r$	Rise time	$C_L = 10 \text{ pF}, V_{CC} = 2.7 \text{ V}$		25°C		7		$\mu\text{s}$
$t_f$	Fall time	$C_L = 10 \text{ pF}, V_{CC} = 2.7 \text{ V}$	25°C		9		$\mu\text{s}$	

NOTE: The propagation response time specified is the interval between the input step function and the instant when the output crosses 1.4 V. Propagation responses are longer at higher supply voltages, refer to Figure 18 through Figure 36 for further details.

**TYPICAL CHARACTERISTICS**

**Table of Graphs**

			<b>FIGURE</b>
$V_{IO}$	Input offset voltage	vs Common-mode input voltage	1, 2
$I_{IB}$	Input bias current	vs Free-air temperature	3, 5, 7
		vs Common-mode input voltage	4, 6
$I_{IO}$	Input offset current	vs Free-air temperature	3, 5, 7
		vs Common-mode input voltage	4, 6
$I_{CC}$	Supply current	vs Supply voltage	8
		vs Free-air temperature	9
<b>Amplifier</b>			
CMRR	Common-mode rejection ratio	vs Frequency	10
$V_{OH}$	High-level output voltage	vs High-level output current	11, 13
$V_{OL}$	Low-level output voltage	vs Low-level output current	12, 14
$V_{O(PP)}$	Output voltage, peak-to-peak	vs Frequency	15
PSRR	Power supply rejection ratio	vs Frequency	16
	Voltage noise over a 10 Second Period		17
$\phi_m$	Phase margin	vs Capacitive load	18
$A_{VD}$	Differential voltage gain	vs Frequency	19
	Phase	vs Frequency	19
	Gain-bandwidth product	vs Supply voltage	20
SR	Slew rate	vs Free-air temperature	21
	Large-signal follower pulse response		22
	Small-signal follower pulse response		23
	Large-signal inverting pulse response		24
	Small-signal inverting pulse response		25
<b>Comparator</b>			
$V_{OH}$	High-level output voltage	vs High-level output current	26, 28
$V_{OL}$	Low-level output voltage	vs Low-level output current	27, 29
	Output rise/fall time	vs Supply voltage	30
	Low-to-high level output response for various input overdrives		31, 33, 35
	High-to-low level output response for various input overdrives		32, 34, 36

AMPLIFIER AND COMPARATOR TYPICAL CHARACTERISTICS

INPUT OFFSET VOLTAGE  
vs  
COMMON-MODE INPUT VOLTAGE

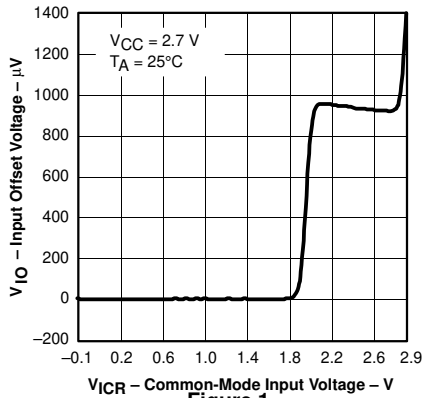


Figure 1

INPUT OFFSET VOLTAGE  
vs  
COMMON-MODE INPUT VOLTAGE

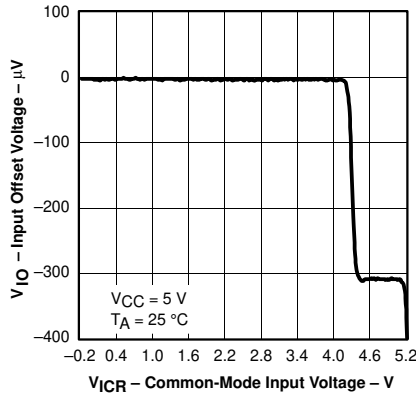


Figure 2

INPUT BIAS / OFFSET CURRENT  
vs  
FREE-AIR TEMPERATURE

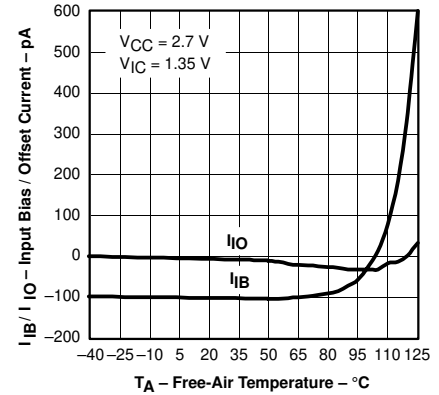


Figure 3

INPUT BIAS/OFFSET CURRENT  
vs  
COMMON MODE INPUT  
VOLTAGE

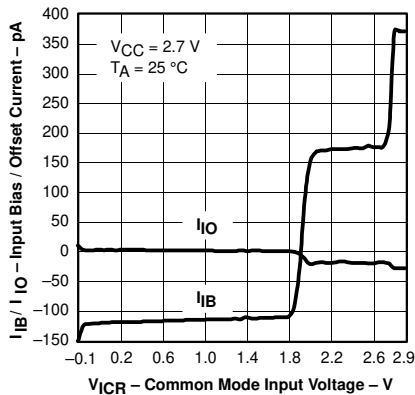


Figure 4

INPUT BIAS/OFFSET CURRENT  
vs  
FREE-AIR TEMPERATURE

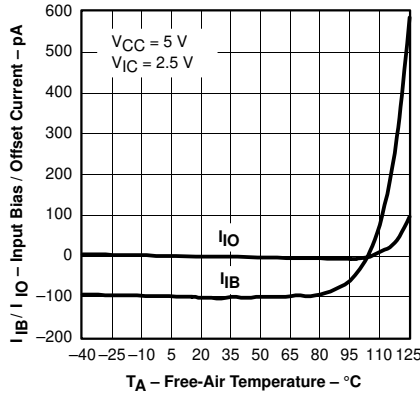


Figure 5

INPUT BIAS/OFFSET CURRENT  
vs  
COMMON-MODE INPUT  
VOLTAGE

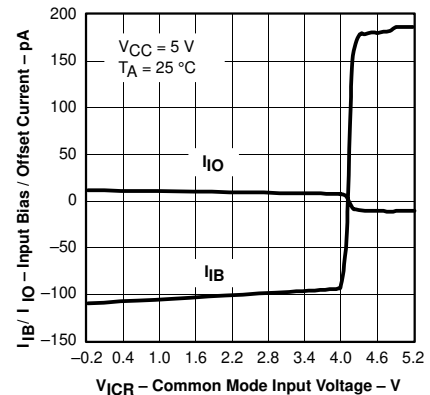


Figure 6

INPUT BIAS/OFFSET CURRENT  
vs  
FREE-AIR TEMPERATURE

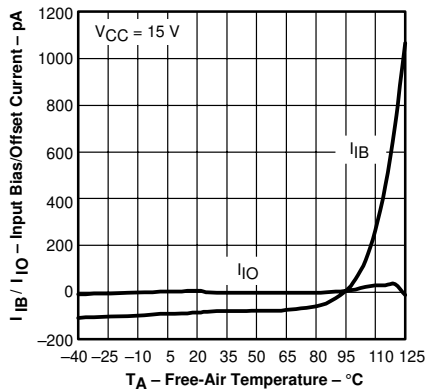


Figure 7

SUPPLY CURRENT  
vs  
SUPPLY VOLTAGE

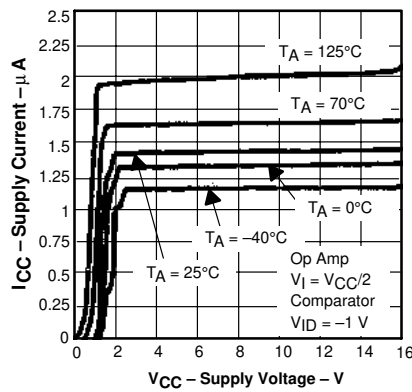


Figure 8

SUPPLY CURRENT  
vs  
FREE-AIR TEMPERATURE

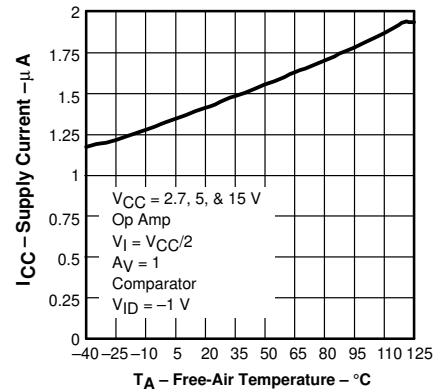


Figure 9



AMPLIFIER TYPICAL CHARACTERISTICS

COMMON-MODE REJECTION RATIO  
vs  
FREQUENCY

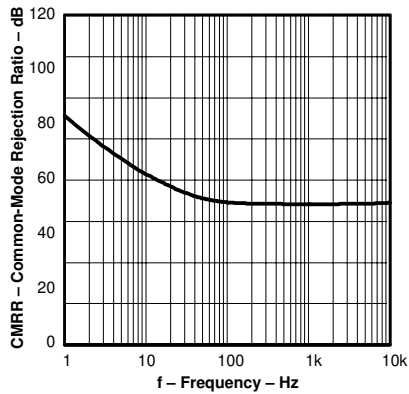


Figure 10

HIGH-LEVEL OUTPUT VOLTAGE  
vs  
HIGH-LEVEL OUTPUT CURRENT

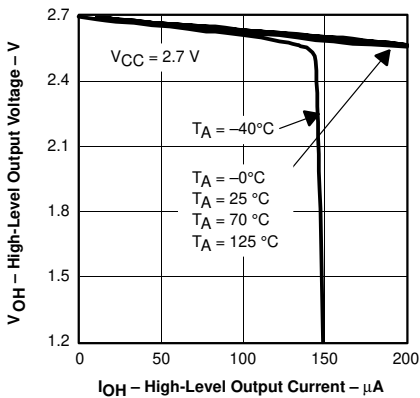


Figure 11

LOW-LEVEL OUTPUT VOLTAGE  
vs  
LOW-LEVEL OUTPUT CURRENT

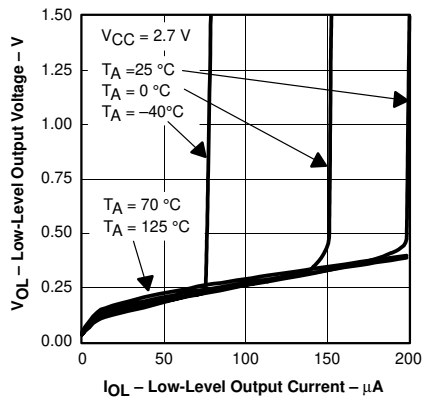


Figure 12

HIGH-LEVEL OUTPUT VOLTAGE  
vs  
HIGH-LEVEL OUTPUT CURRENT

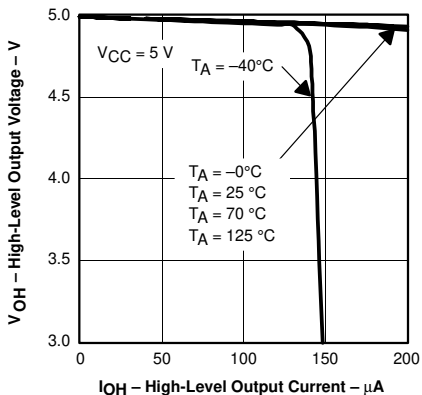


Figure 13

LOW-LEVEL OUTPUT VOLTAGE  
vs  
LOW-LEVEL OUTPUT CURRENT

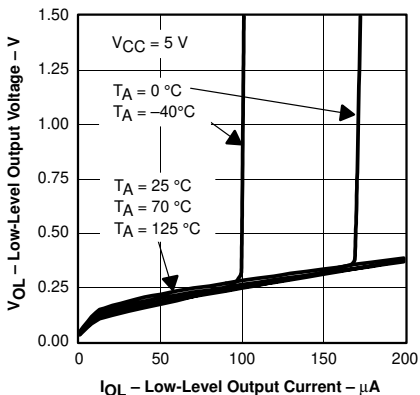


Figure 14

OUTPUT VOLTAGE  
PEAK-TO-PEAK  
vs  
FREQUENCY

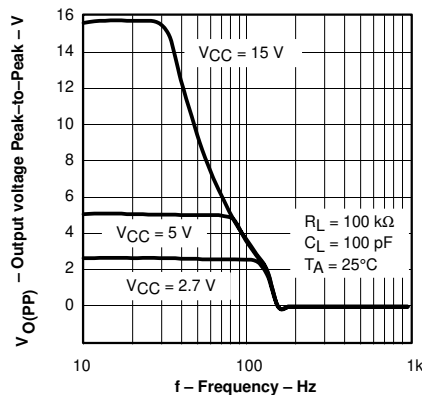


Figure 15

POWER SUPPLY REJECTION RATIO  
vs  
FREQUENCY

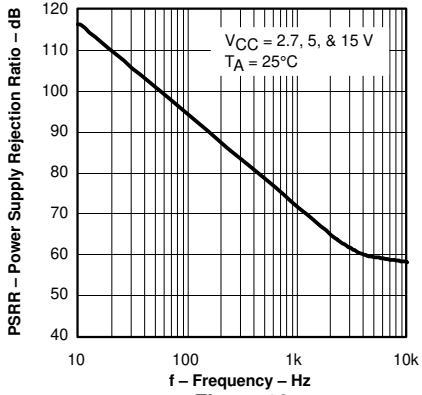


Figure 16

VOLTAGE NOISE  
OVER A 10 SECOND PERIOD

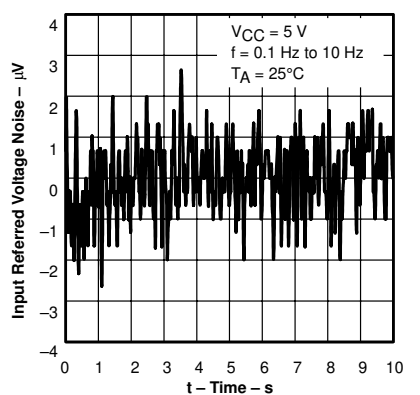


Figure 17

PHASE MARGIN  
vs  
CAPACITIVE LOAD

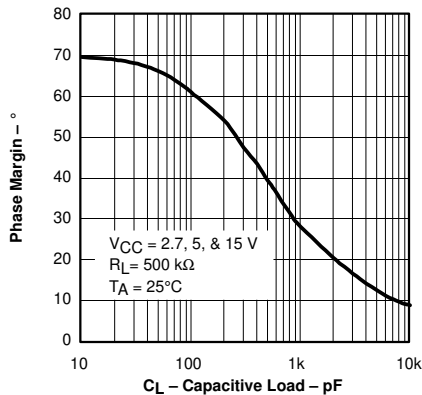


Figure 18

AMPLIFIER TYPICAL CHARACTERISTICS

DIFFERENTIAL VOLTAGE GAIN AND PHASE  
vs  
FREQUENCY

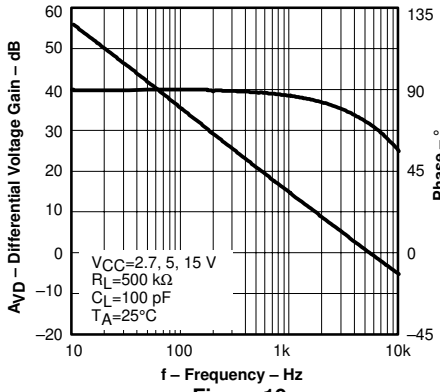


Figure 19

GAIN BANDWIDTH PRODUCT  
vs  
SUPPLY VOLTAGE

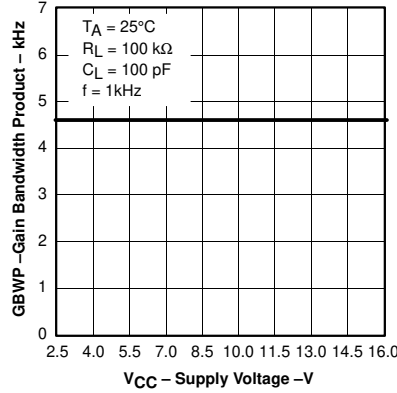


Figure 20

SLEW RATE  
vs  
FREE-AIR TEMPERATURE

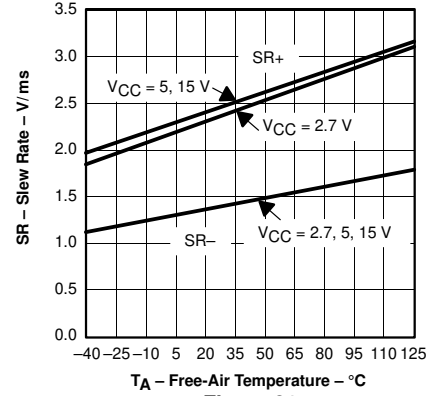


Figure 21

LARGE-SIGNAL FOLLOWER  
PULSE RESPONSE

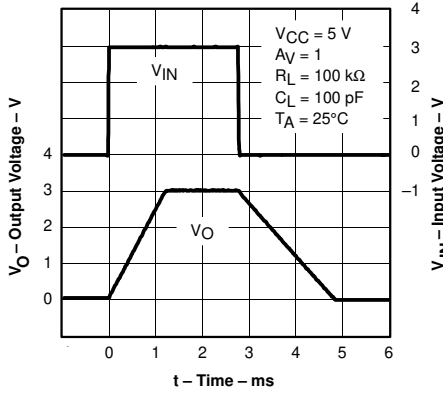


Figure 22

SMALL-SIGNAL FOLLOWER  
PULSE RESPONSE

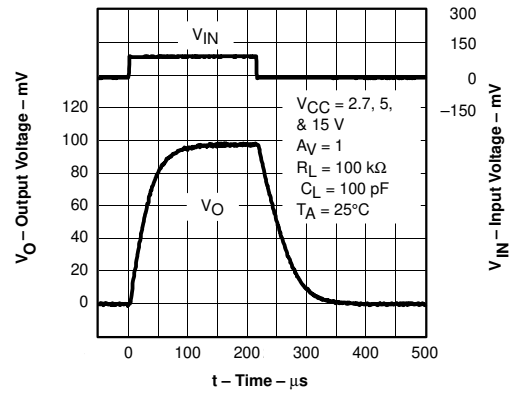


Figure 23

LARGE-SIGNAL INVERTING  
PULSE RESPONSE

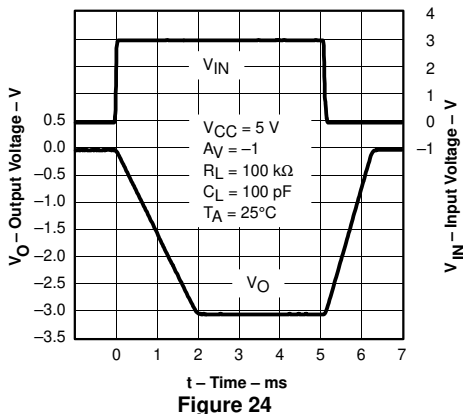


Figure 24

SMALL-SIGNAL INVERTING  
PULSE RESPONSE

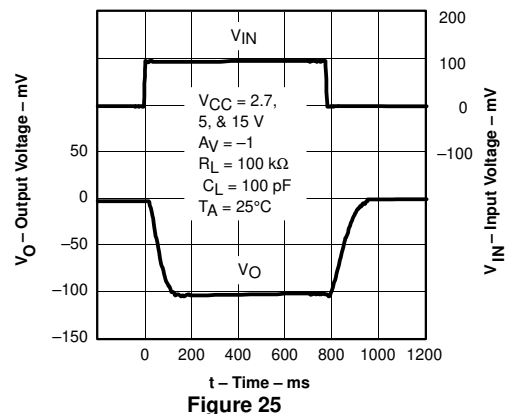
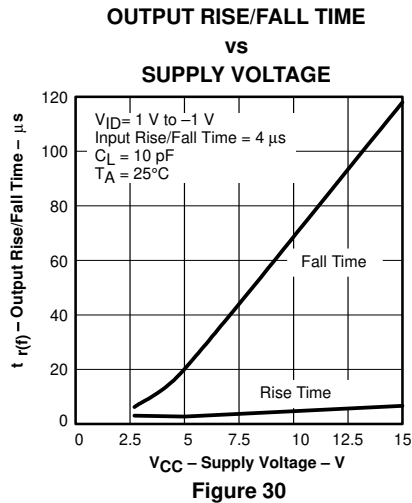
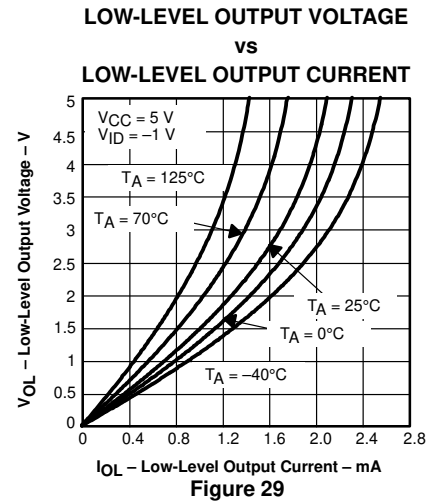
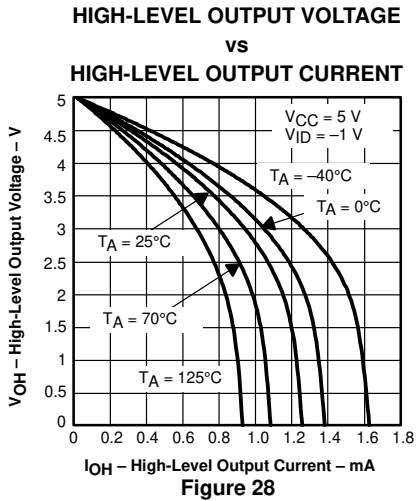
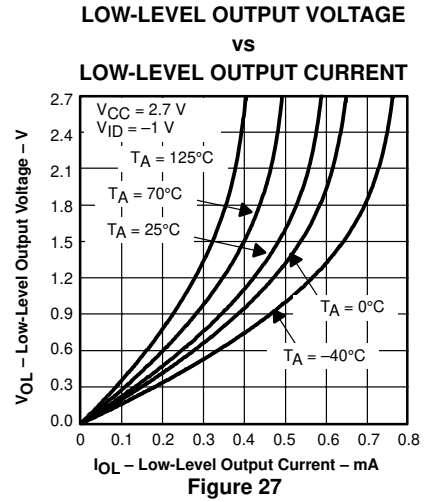
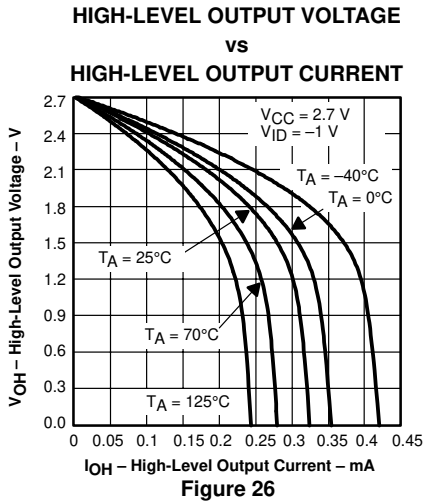


Figure 25

COMPARATOR TYPICAL CHARACTERISTICS



TYPICAL CHARACTERISTICS

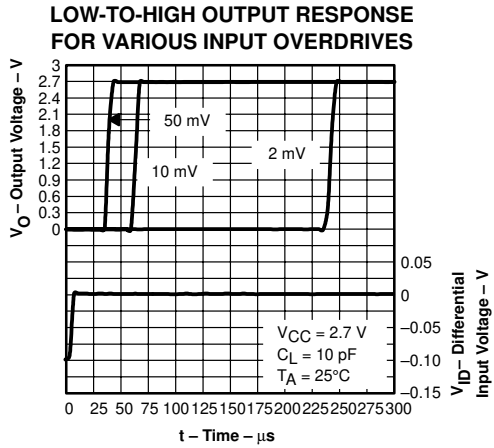


Figure 31

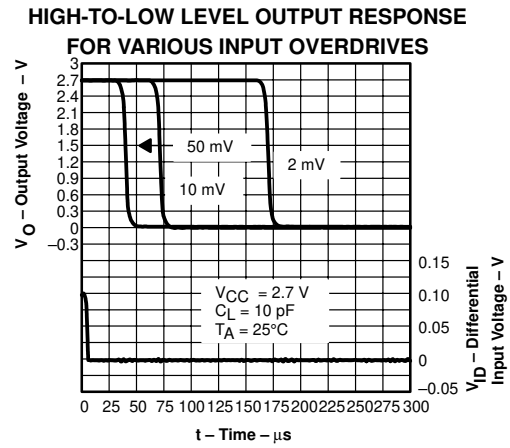


Figure 32

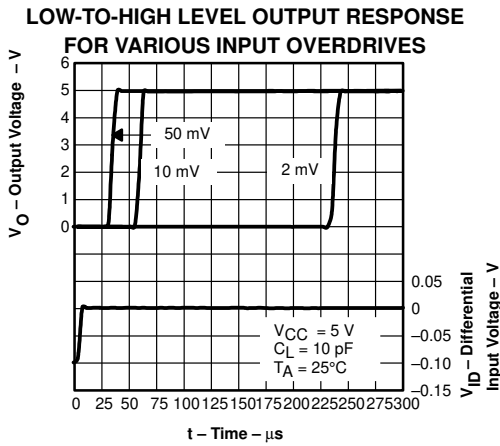


Figure 33

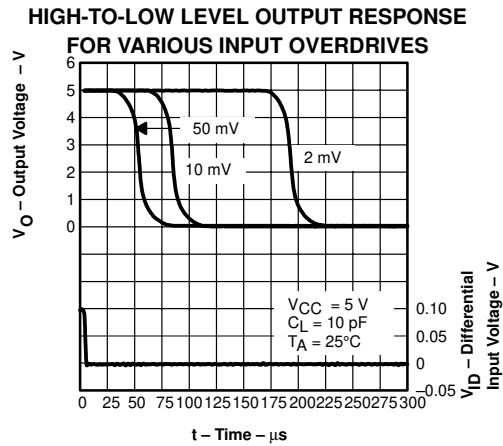


Figure 34

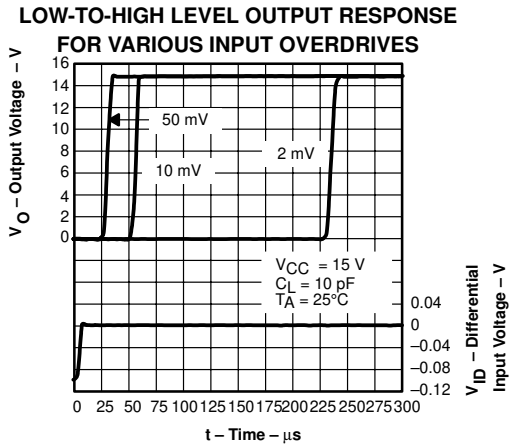


Figure 35

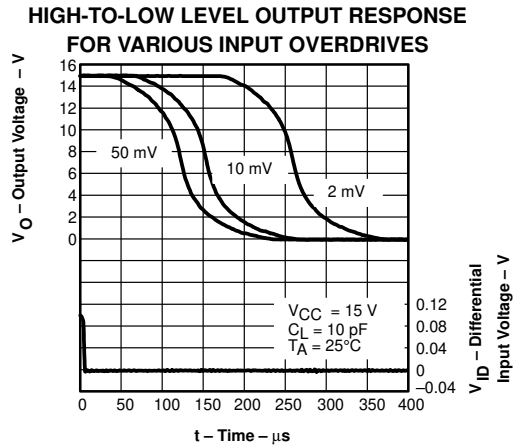


Figure 36

## APPLICATION INFORMATION

### reverse battery protection

The TLV2702/4 are protected against reverse battery voltage up to 18 V. When subjected to reverse battery condition the supply current is typically less than 100 nA at 25°C (inputs grounded and outputs open). This current is determined by the leakage of 6 Schottky diodes and will therefore increase as the ambient temperature increases.

When subjected to reverse battery conditions and negative voltages applied to the inputs or outputs, the input ESD structure will turn on—this current should be limited to less than 10 mA. If the inputs or outputs are referred to ground, rather than midrail, no extra precautions need be taken.

### common-mode input range

The TLV2702/4 has rail-rail input and outputs. For common-mode inputs from  $-0.1$  V to  $V_{CC} - 0.8$  V a PNP differential pair will provide the gain.

For inputs between  $V_{CC} - 0.8$  V and  $V_{CC}$ , two NPN emitter followers buffering a second PNP differential pair provide the gain. This special combination of NPN/PNP differential pair enables the inputs to be taken 5 V above the rails; because as the inputs go above  $V_{CC}$ , the NPNs switch from functioning as transistors to functioning as diodes. This will lead to an increase in input bias current. The second PNP differential pair continues to function normally as the inputs exceed  $V_{CC}$ .

The TLV2702/4 has a negative common-input range that exceeds ground by 100 mV. If the inputs are taken much below this, reduced open loop gain will be observed with the ultimate possibility of phase inversion.

### 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.

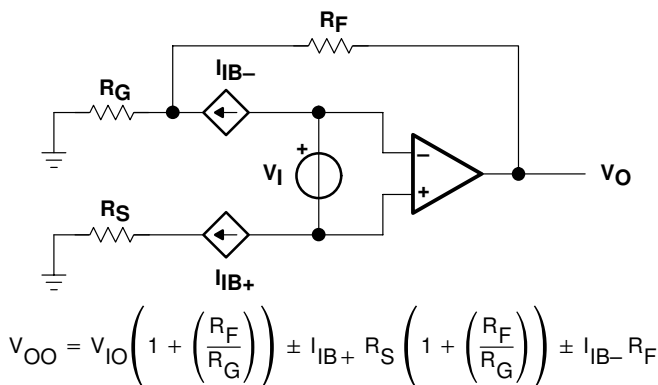


Figure 37. Output Offset Voltage Model

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 38).

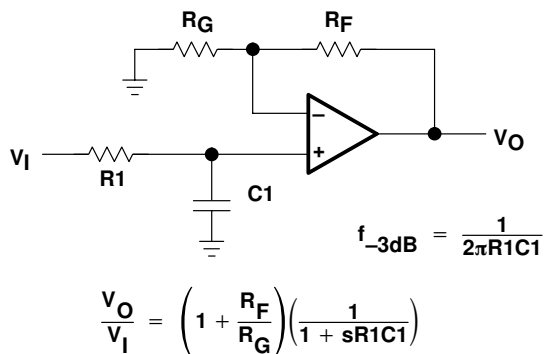


Figure 38. Single-Pole Low-Pass Filter

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.

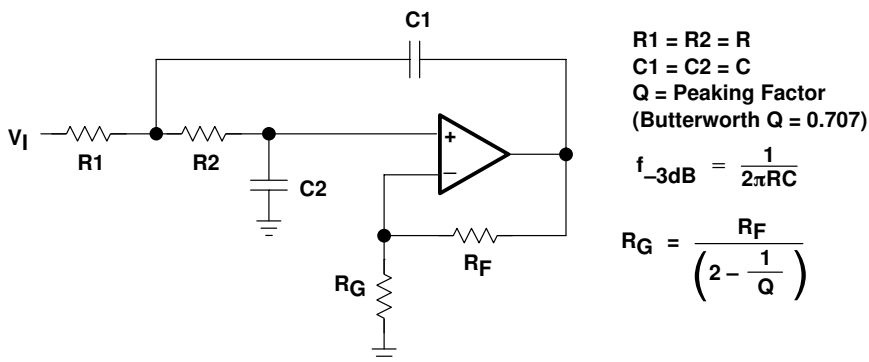


Figure 39. 2-Pole Low-Pass Sallen-Key Filter

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## APPLICATION INFORMATION

### circuit layout considerations

To achieve the levels of high performance of the TLV270x, 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- $\mu$ F tantalum capacitor in parallel with a 0.1- $\mu$ F 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- $\mu$ F ceramic capacitor should always be used on the supply terminal of every amplifier. In addition, the 0.1- $\mu$ 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 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.

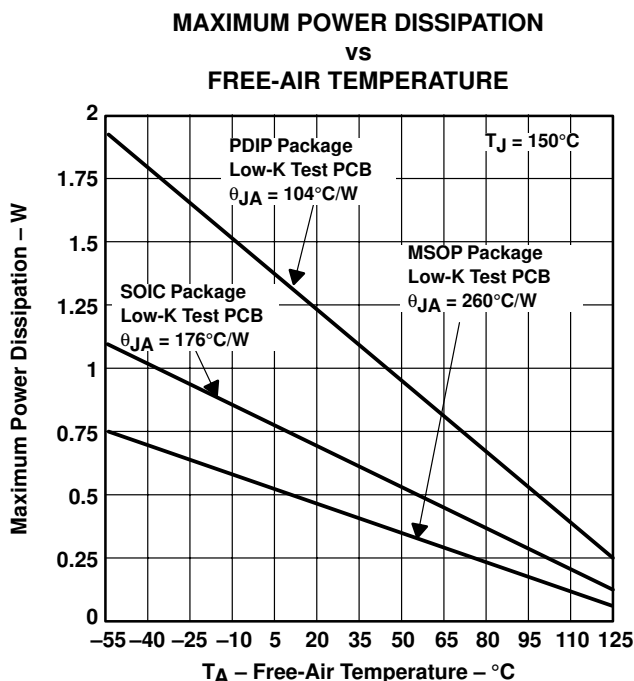
**general power dissipation considerations**

For a given  $\theta_{JA}$ , the maximum power dissipation is shown in Figure 40 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 TLV270x IC (watts)
- $T_{MAX}$  = Absolute maximum junction temperature (150°C)
- $T_A$  = Free-ambient air temperature (°C)
- $\theta_{JA}$  =  $\theta_{JC} + \theta_{CA}$
- $\theta_{JC}$  = Thermal coefficient from junction to case
- $\theta_{CA}$  = 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 40. Maximum Power Dissipation vs Free-Air Temperature**



APPLICATION INFORMATION

amplifier macromodel information

Macromodel information provided was derived using Microsim *Parts*™ Release 8, the model generation software used with Microsim *PSpice*™. The Boyle macromodel (see Note 2) and subcircuit in Figure 41 are generated using the TLV270x typical electrical and operating characteristics at  $T_A = 25^\circ\text{C}$ . Using this information, output simulations of the following key parameters can be generated to a tolerance of 20% (in most cases):

- Maximum positive output voltage swing
- Maximum negative output voltage swing
- Slew rate
- Quiescent power dissipation
- Input bias current
- Open-loop voltage amplification
- Unity-gain frequency
- Common-mode rejection ratio
- Phase margin
- DC output resistance
- AC output resistance
- Short-circuit output current limit

NOTE 3: G. R. Boyle, B. M. Cohn, D. O. Pederson, and J. E. Solomon, "Macromodeling of Integrated Circuit Operational Amplifiers", *IEEE Journal of Solid-State Circuits*, SC-9, 353 (1974).

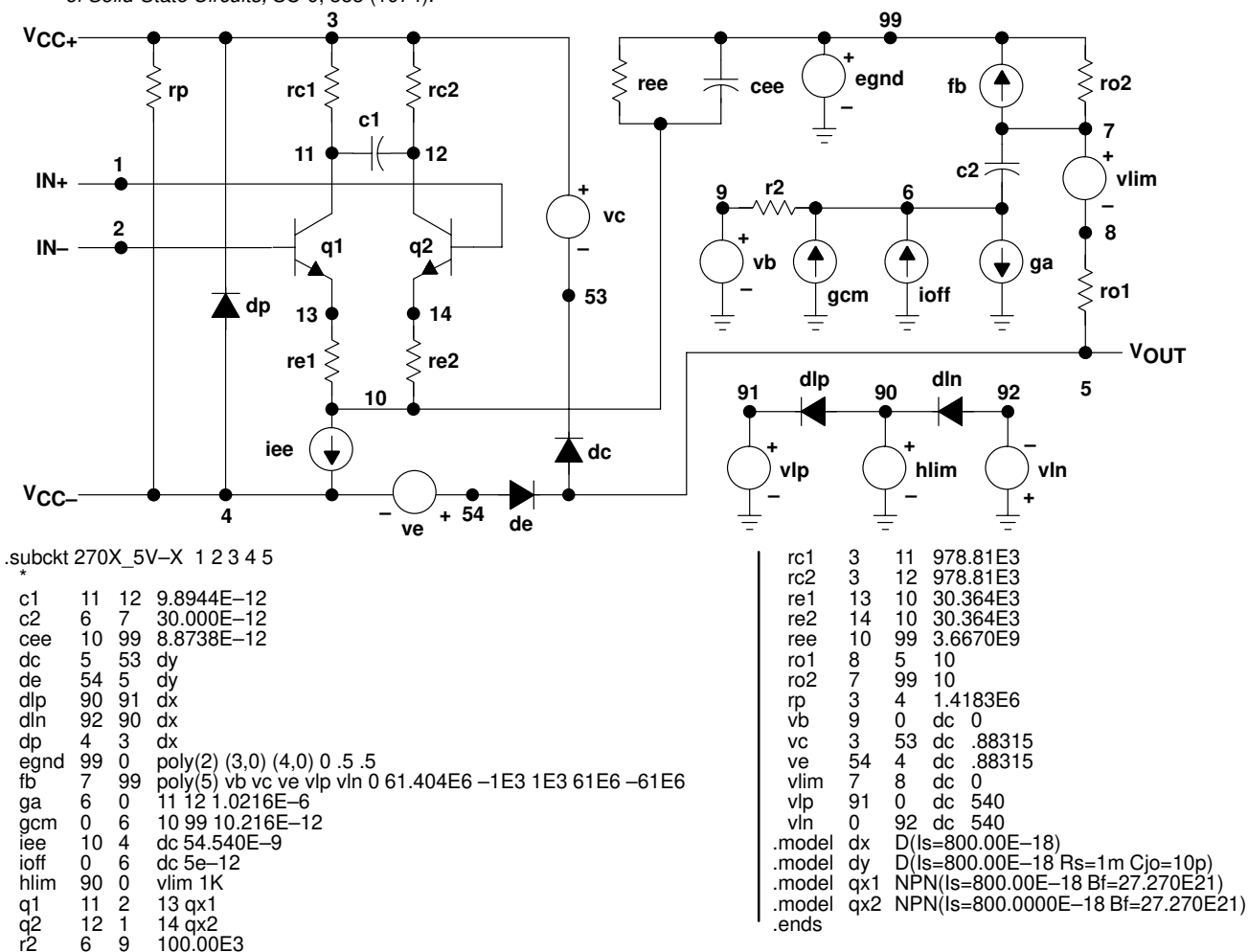


Figure 41. Boyle Macromodels and Subcircuit

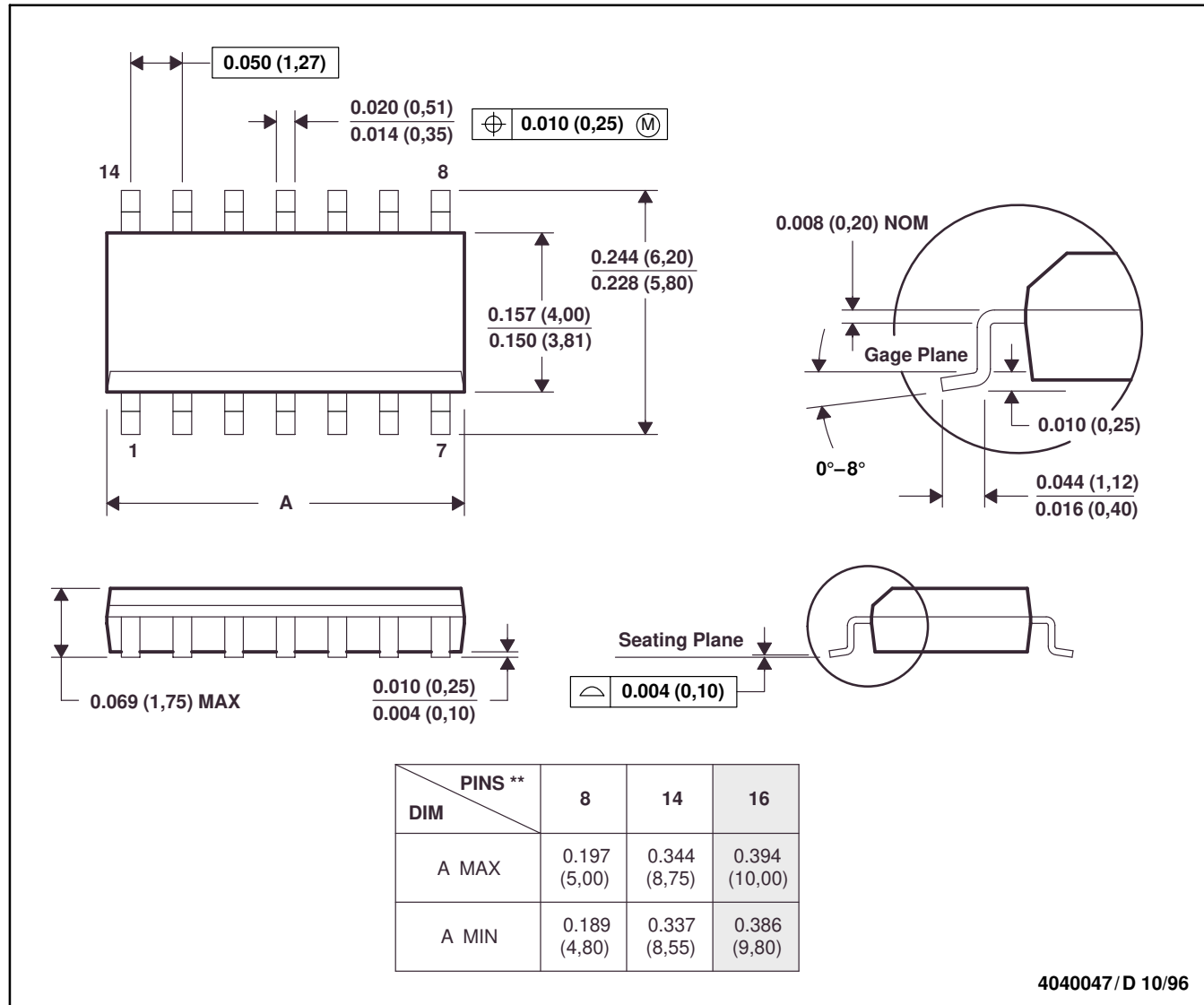
PSpice and Parts are trademarks of MicroSim Corporation.

MECHANICAL DATA

D (R-PDSO-G\*\*)

PLASTIC SMALL-OUTLINE PACKAGE

14 PIN SHOWN

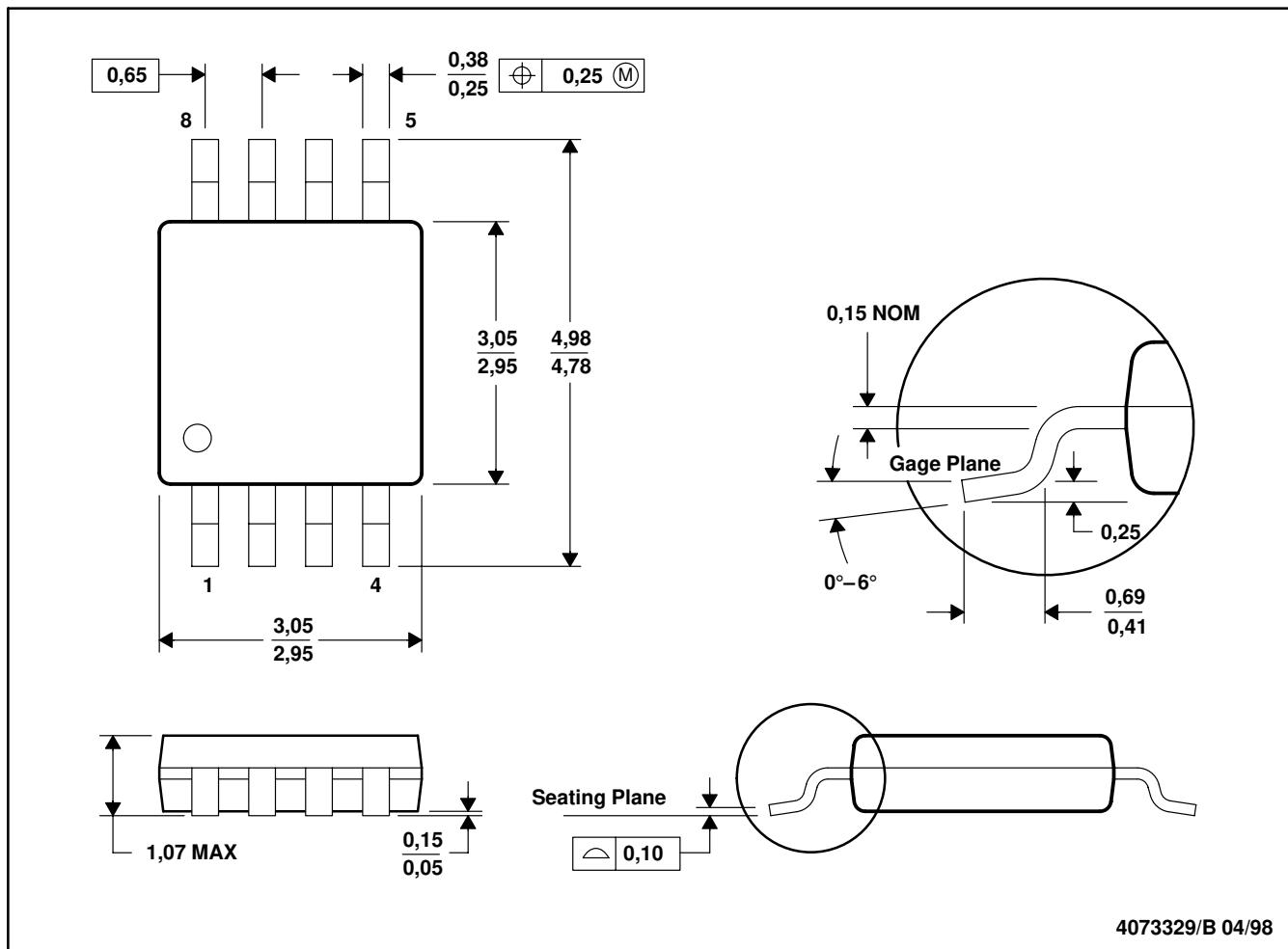


- NOTES: A. All linear dimensions are in inches (millimeters).  
 B. This drawing is subject to change without notice.  
 C. Body dimensions do not include mold flash or protrusion, not to exceed 0.006 (0,15).

MECHANICAL INFORMATION

DGK (R-PDSO-G8)

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.  
 D. Falls within JEDEC MO-187

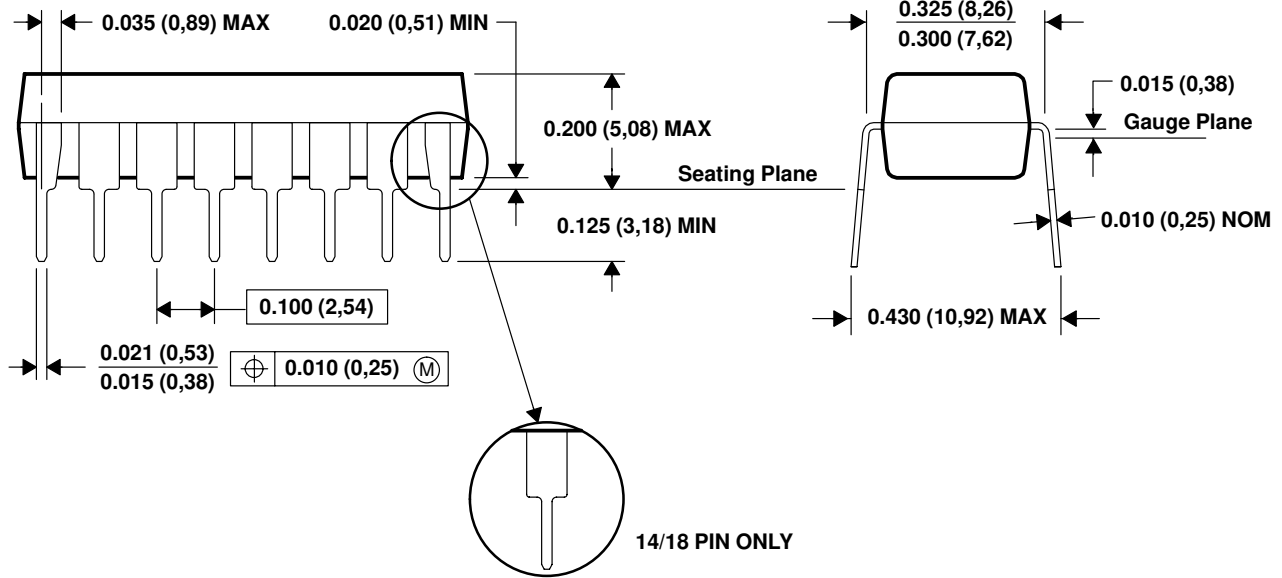
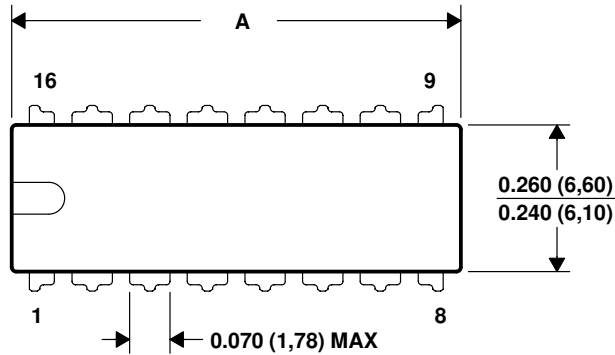
**MECHANICAL INFORMATION**

**N (R-PDIP-T\*\*)**

**PLASTIC DUAL-IN-LINE PACKAGE**

16 PINS SHOWN

DIM \ PINS **	14	16	18	20
A MAX	0.775 (19,69)	0.775 (19,69)	0.920 (23,37)	0.975 (24,77)
A MIN	0.745 (18,92)	0.745 (18,92)	0.850 (21,59)	0.940 (23,88)



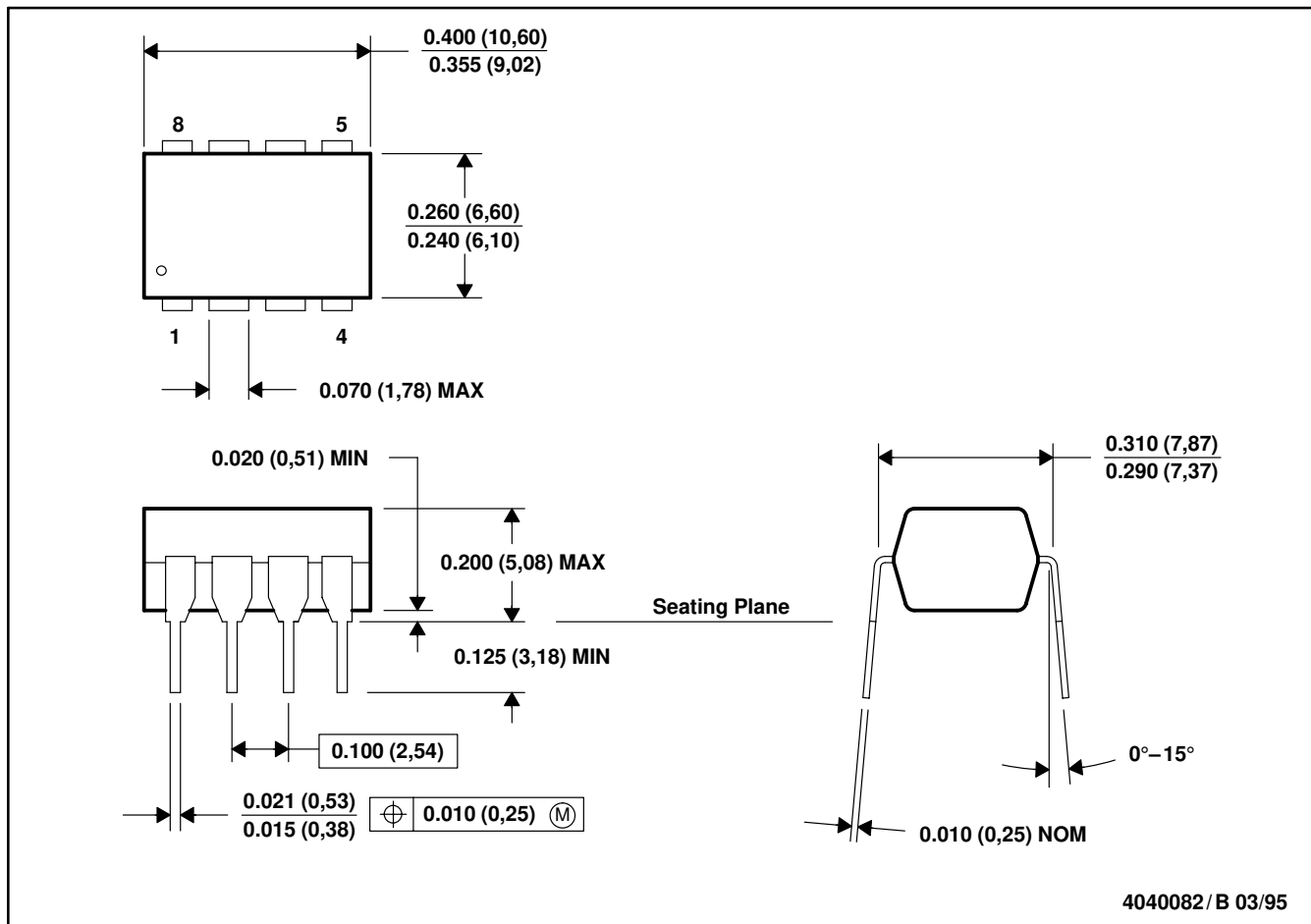
4040049/D 02/00

- NOTES: A. All linear dimensions are in inches (millimeters).  
 B. This drawing is subject to change without notice.  
 C. Falls within JEDEC MS-001 (20-pin package is shorter than MS-001).

MECHANICAL INFORMATION

P (R-PDIP-T8)

PLASTIC DUAL-IN-LINE PACKAGE



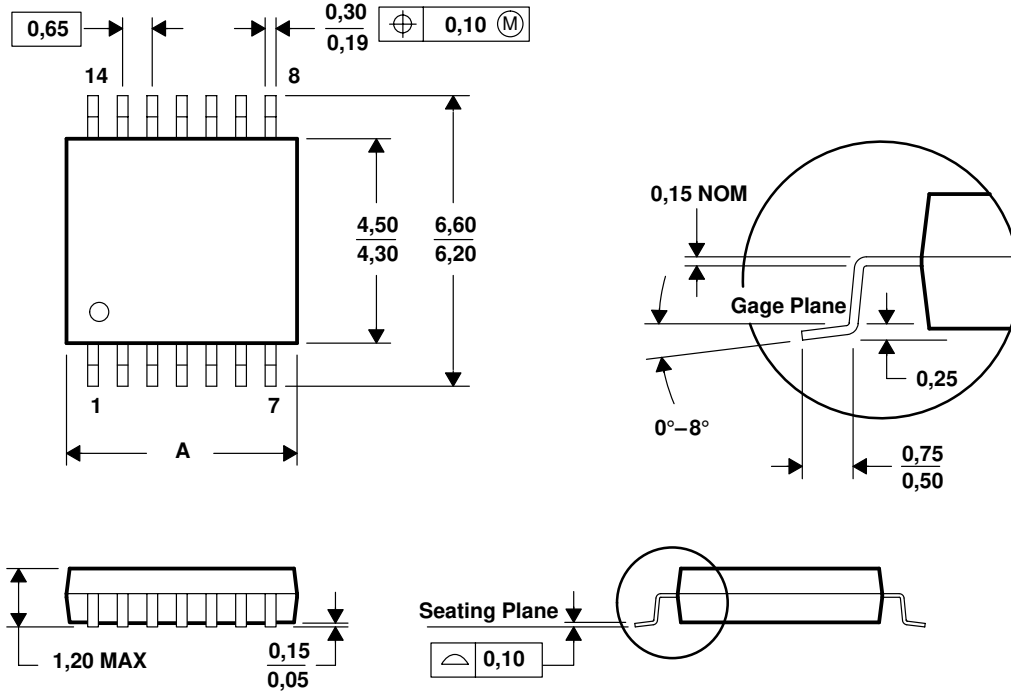
- NOTES: A. All linear dimensions are in inches (millimeters).  
 B. This drawing is subject to change without notice.  
 C. Falls within JEDEC MS-001

**MECHANICAL INFORMATION**

**PW (R-PDSO-G\*\*)**

**PLASTIC SMALL-OUTLINE PACKAGE**

14 PINS SHOWN



DIM \ PINS **	8	14	16	20	24	28
	A MAX	3,10	5,10	5,10	6,60	7,90
A MIN	2,90	4,90	4,90	6,40	7,70	9,60

4040064/F 01/97

- 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 not to exceed 0,15.  
 D. Falls within JEDEC MO-153

**PACKAGING INFORMATION**

Orderable Device	Status <sup>(1)</sup>	Package Type	Package Drawing	Pins	Package Qty	Eco Plan <sup>(2)</sup>	Lead/Ball Finish	MSL Peak Temp <sup>(3)</sup>
TLV2702ID	ACTIVE	SOIC	D	8	75	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLV2702IDG4	ACTIVE	SOIC	D	8	75	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLV2702IDGK	ACTIVE	MSOP	DGK	8	80	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLV2702IDGKG4	ACTIVE	MSOP	DGK	8	80	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLV2702IDGKR	ACTIVE	MSOP	DGK	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLV2702IDGKRG4	ACTIVE	MSOP	DGK	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLV2702IP	ACTIVE	PDIP	P	8	50	Pb-Free (RoHS)	CU NIPDAU	N / A for Pkg Type
TLV2702IPE4	ACTIVE	PDIP	P	8	50	Pb-Free (RoHS)	CU NIPDAU	N / A for Pkg Type
TLV2704ID	ACTIVE	SOIC	D	14	50	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLV2704IDG4	ACTIVE	SOIC	D	14	50	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM

<sup>(1)</sup> 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.

<sup>(2)</sup> 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.

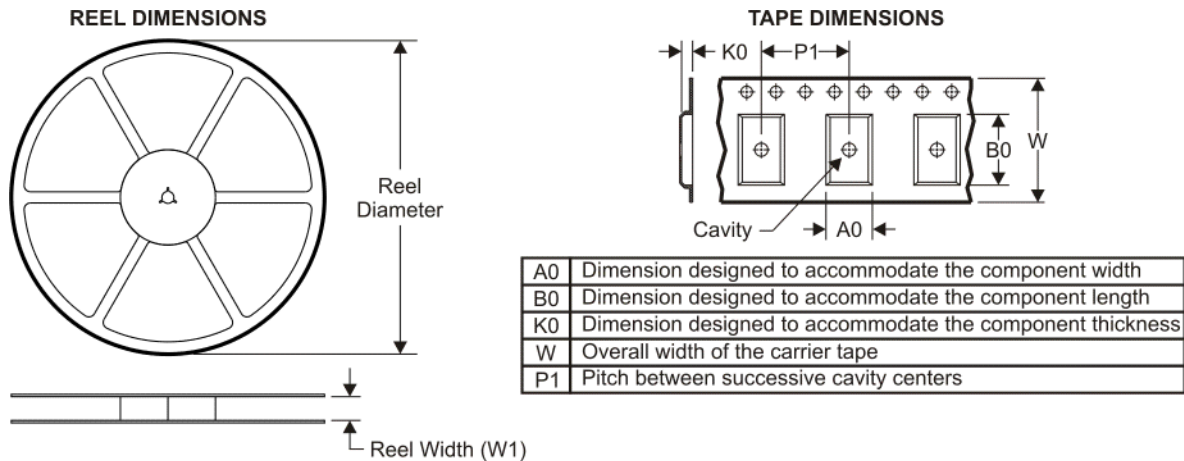
**Green (RoHS & no Sb/Br):** TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

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

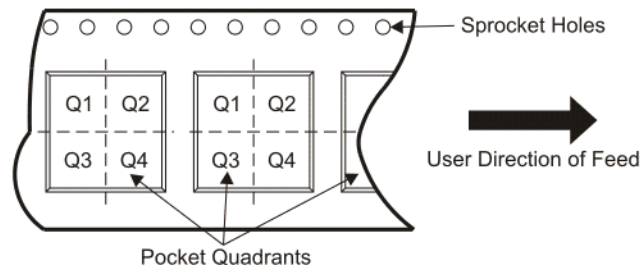
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## TAPE AND REEL INFORMATION



### QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



\*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
TLV2702IDGKR	MSOP	DGK	8	2500	330.0	12.4	5.3	3.4	1.4	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)
TLV2702IDGKR	MSOP	DGK	8	2500	358.0	335.0	35.0

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Medical	<a href="http://www.ti.com/medical">www.ti.com/medical</a>
Military	<a href="http://www.ti.com/military">www.ti.com/military</a>
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Security	<a href="http://www.ti.com/security">www.ti.com/security</a>
Telephony	<a href="http://www.ti.com/telephony">www.ti.com/telephony</a>
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