

## FEATURES

- Rail-to-Rail Output Voltage Swing:  $\pm 2.4$  V at  $V_{CC} = \pm 2.5$  V
- Very Low Noise Level:  $4 \text{ nV}/\sqrt{\text{Hz}}$
- Ultra-Low Distortion: 0.003%
- High Dynamic Features: 12 MHz, 5 V/ $\mu\text{s}$
- Operating Range: 2.7 V to 12 V
- Latch-Up Performance Exceeds 100 mA Per JESD 78, Class II
- ESD Performance Tested Per JESD 22
  - 2000-V Human-Body Model (A114-B)
  - 200-V Machine Model (A115-A)
  - 1500-V Charged-Device Model (C101)

## APPLICATIONS

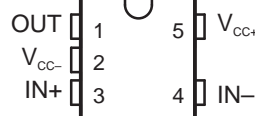
- Portable Equipment (CD Players, PDAs)
- Portable Communications (Cell Phones, Pagers)
- Instrumentation and Sensors
- Professional Audio Circuits

## DESCRIPTION/ORDERING INFORMATION

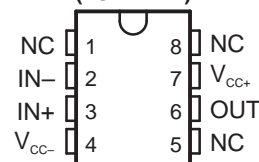
The TL97x family of operational amplifiers operates at voltages as low as  $\pm 1.35$  V and features output rail-to-rail signal swing. The TL97x boast characteristics that make them particularly well suited for portable and battery-supplied equipment. Very low noise and low distortion characteristics make them ideal for audio preamplification.

The TL971 is housed in the space-saving 5-pin SOT-23 package, which simplifies board design because of the ability to be placed anywhere (outside dimensions are 2.8 mm  $\times$  2.9 mm).

**TL971...DBV PACKAGE  
(TOP VIEW)**

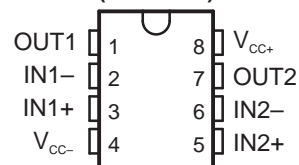


**TL971...D PACKAGE  
(TOP VIEW)**

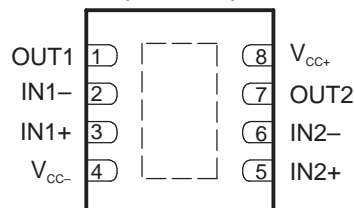


NC – No internal connection

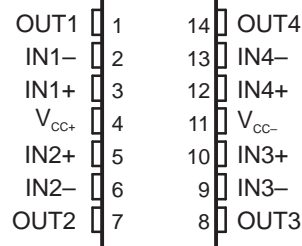
**TL972...D, P, OR PW PACKAGE  
(TOP VIEW)**



**TL972...DRG PACKAGE  
(TOP VIEW)**



**TL974...D, N, OR PW PACKAGE  
(TOP VIEW)**



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.

# TL971, TL972, TL974

## OUTPUT RAIL-TO-RAIL VERY-LOW-NOISE OPERATIONAL AMPLIFIERS

SLOS467E–OCTOBER 2006–REVISED OCTOBER 2007



### ORDERING INFORMATION<sup>(1)</sup>

T <sub>A</sub>	PACKAGE <sup>(2)</sup>			ORDERABLE PART NUMBER	TOP-SIDE MARKING <sup>(3)</sup>
–40°C to 125°C	Single	SOIC – D	Reel of 2500	TL971IDR	Z971
			Tube of 75	TL971ID	
		SOT-23 – DBV	Reel of 3000	TL971IDBVR	PREVIEW
			Reel of 250	TL971IDBVT	
	Dual	PDIP – P	Tube of 50	TL972IP	TL972IP
		QFN – DRG	Reel of 1000	TL972IDRGR	PREVIEW
		SOIC – D	Reel of 2500	TL972IDR	Z972
			Tube of 75	TL972ID	
		TSSOP – PW	Reel of 2000	TL972IPWR	Z972
			Tube of 150	TL972IPW	
	Quad	PDIP – N	Tube of 25	TL974IN	TL974IN
		SOIC – D	Reel of 2500	TL974IDR	TL974I
			Tube of 50	TL974ID	
		TSSOP – PW	Reel of 2000	TL974IPWR	Z974
Tube of 90			TL974IPW		

(1) For the most current package and ordering information, see the Package Option Addendum at the end of this document, or see the TI web site at [www.ti.com](http://www.ti.com).

(2) Package drawings, thermal data, and symbolization are available at [www.ti.com/packaging](http://www.ti.com/packaging).

(3) DBV: The actual top-side marking has one additional character that designates the wafer fab/assembly site.

## Absolute Maximum Ratings<sup>(1)</sup>

over operating free-air temperature range (unless otherwise noted)

			MIN	MAX	UNIT
V <sub>CC</sub>	Supply voltage range <sup>(2)</sup>		2.7	15	V
V <sub>ID</sub>	Differential input voltage <sup>(3)</sup>			±1	V
V <sub>IN</sub>	Input voltage range <sup>(4)</sup>		V <sub>CC-</sub> – 0.3	V <sub>CC+</sub> + 0.3	V
θ <sub>JA</sub>	Package thermal impedance, junction to free air	D package <sup>(5)</sup>	8 pin	97	°C/W
			14 pin	86	
		DBV package <sup>(5)</sup>		206	
		DRG package <sup>(6)</sup>		44	
		N package <sup>(5)</sup>		80	
		P package <sup>(5)</sup>		85	
		PW package <sup>(5)</sup>	8 pin	149	
			14 pin	113	
T <sub>J</sub>	Maximum junction temperature			150	°C
T <sub>lead</sub>	Maximum lead temperature	Soldering, 10 s		260	°C
T <sub>stg</sub>	Storage temperature range		–65	150	°C
ESD	Human-Body Model (HBM)			2	kV
	Machine Model (MM)			200	V
	Charged-Device Model (CDM)			1.5	kV

(1) 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.

(2) All voltage values, except differential voltages, are with respect to network ground terminal.

(3) Differential voltages for the noninverting input terminal are with respect to the inverting input terminal.

(4) The input and output voltages must never exceed V<sub>CC</sub> + 0.3 V.

(5) Package thermal impedance is calculated in accordance with JESD 51-7.

(6) Package thermal impedance is calculated in accordance with JESD 51-5.

## Recommended Operating Conditions

			MIN	MAX	UNIT
V <sub>CC</sub>	Supply voltage		2.7	12	V
V <sub>ICM</sub>	Common-mode input voltage		V <sub>CC-</sub> + 1.15	V <sub>CC+</sub> – 1.15	V
T <sub>A</sub>	Operating free-air temperature		–40	125	°C

# TL971, TL972, TL974

## OUTPUT RAIL-TO-RAIL VERY-LOW-NOISE OPERATIONAL AMPLIFIERS

SLOS467E–OCTOBER 2006–REVISED OCTOBER 2007

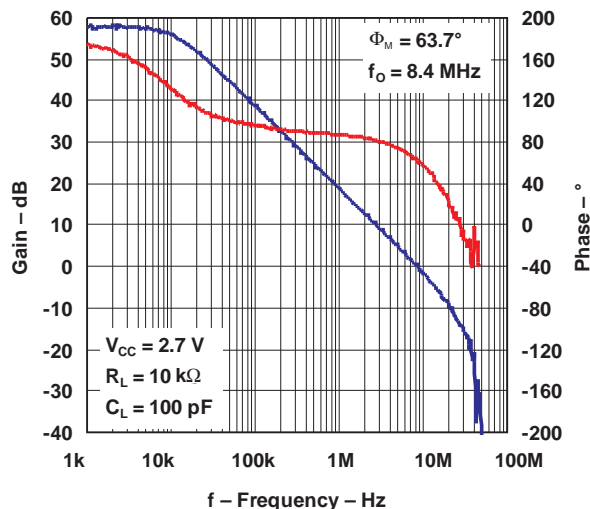
### Electrical Characteristics

$V_{CC+} = 2.5\text{ V}$ ,  $V_{CC-} = -2.5\text{ V}$ , full-range  $T_A = -40^{\circ}\text{C}$  to  $125^{\circ}\text{C}$  (unless otherwise noted)

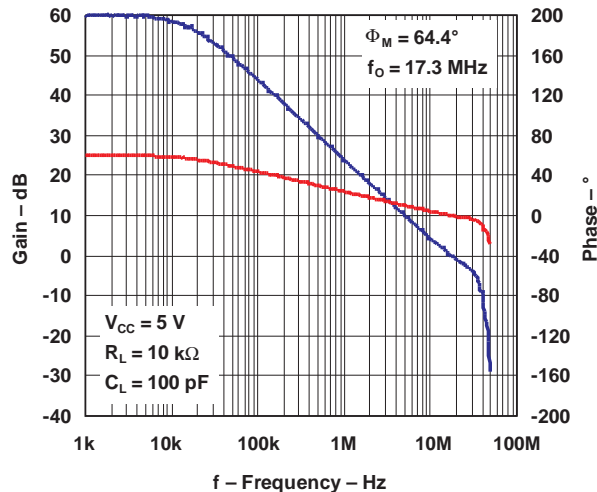
PARAMETER	TEST CONDITIONS	$T_A$	MIN	TYP	MAX	UNIT
$V_{IO}$ Input offset voltage		$25^{\circ}\text{C}$		1	4	mV
		Full range			6	
$\alpha V_{IO}$ Input offset voltage drift	$V_{ICM} = 0\text{ V}$ , $V_O = 0\text{ V}$	$25^{\circ}\text{C}$		5		$\mu\text{V}/^{\circ}\text{C}$
$I_{IO}$ Input offset current	$V_{ICM} = 0\text{ V}$ , $V_O = 0\text{ V}$	$25^{\circ}\text{C}$		10	150	nA
$I_{IB}$ Input bias current	$V_{ICM} = 0\text{ V}$ , $V_O = 0\text{ V}$	$25^{\circ}\text{C}$		200	750	nA
		Full range			1000	
$V_{ICM}$ Common-mode input voltage		$25^{\circ}\text{C}$	-1.35		1.35	V
CMRR Common-mode rejection ratio	$V_{ICM} = \pm 1.35\text{ V}$	$25^{\circ}\text{C}$	60	85		dB
SVR Supply-voltage rejection ratio	$V_{CC} = \pm 2\text{ V}$ to $\pm 3\text{ V}$	$25^{\circ}\text{C}$	60	70		dB
$A_{VD}$ Large-signal voltage gain	$R_L = 2\text{ k}\Omega$	$25^{\circ}\text{C}$	70	80		dB
$V_{OH}$ High-level output voltage	$R_L = 2\text{ k}\Omega$	$25^{\circ}\text{C}$	2	2.4		V
$V_{OL}$ Low-level output voltage	$R_L = 2\text{ k}\Omega$	$25^{\circ}\text{C}$		-2.4	-2	V
$I_{source}$ Output source current		$25^{\circ}\text{C}$	1.2	1.4		mA
	$V_{OUT} = \pm 2.5\text{ V}$	Full range	1			
$I_{sink}$ Output sink current		$25^{\circ}\text{C}$	50	80		mA
	$V_{OUT} = \pm 2.5\text{ V}$	Full range	25			
$I_{CC}$ Supply current (per amplifier)	Unity gain, No load	$25^{\circ}\text{C}$		2	2.8	mA
		Full range			3.2	
GBWP Gain bandwidth product	$f = 100\text{ kHz}$ , $R_L = 2\text{ k}\Omega$ , $C_L = 100\text{ pF}$	$25^{\circ}\text{C}$	8.5	12		MHz
SR Slew rate	$A_V = 1$ , $V_{IN} = \pm 1\text{ V}$	$25^{\circ}\text{C}$	3.5	5		V/ $\mu\text{s}$
		Full range	3			
$\Phi_m$ Phase margin at unity gain	$R_L = 2\text{ k}\Omega$ , $C_L = 100\text{ pF}$	$25^{\circ}\text{C}$		60		$^{\circ}$
Gm Gain margin	$R_L = 2\text{ k}\Omega$ , $C_L = 100\text{ pF}$	$25^{\circ}\text{C}$		10		dB
$V_n$ Equivalent input noise voltage	$f = 100\text{ kHz}$	$25^{\circ}\text{C}$		4		$\text{nV}/\sqrt{\text{Hz}}$
THD Total harmonic distortion	$f = 1\text{ kHz}$ , $A_V = -1$ , $R_L = 10\text{ k}\Omega$	$25^{\circ}\text{C}$		0.003		%

## TYPICAL CHARACTERISTICS

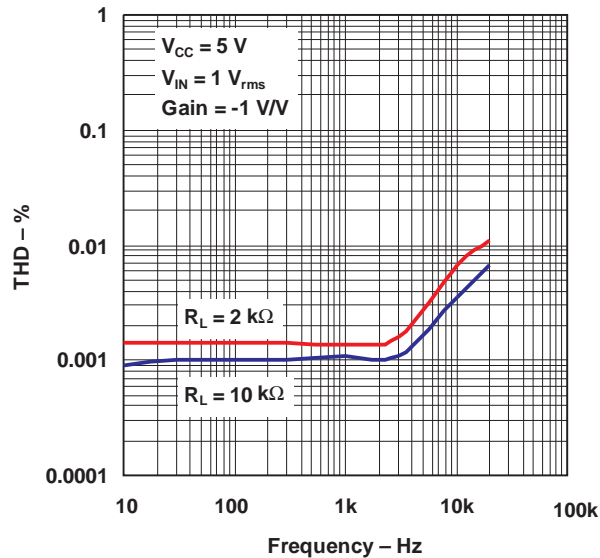
GAIN AND PHASE  
VS  
FREQUENCY



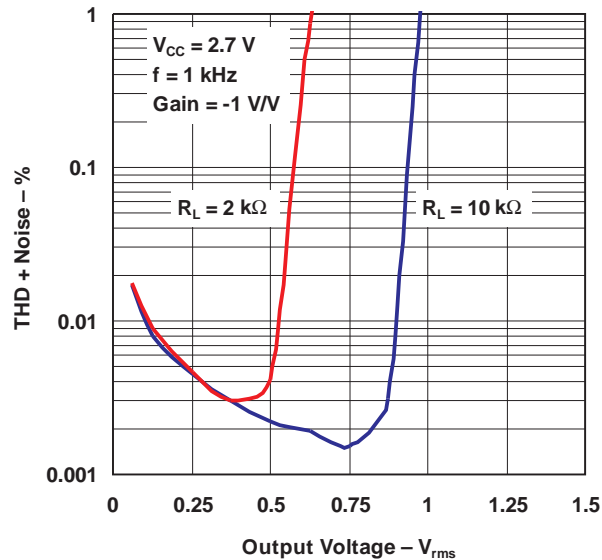
GAIN AND PHASE  
VS  
FREQUENCY



TOTAL HARMONIC DISTORTION  
VS  
FREQUENCY

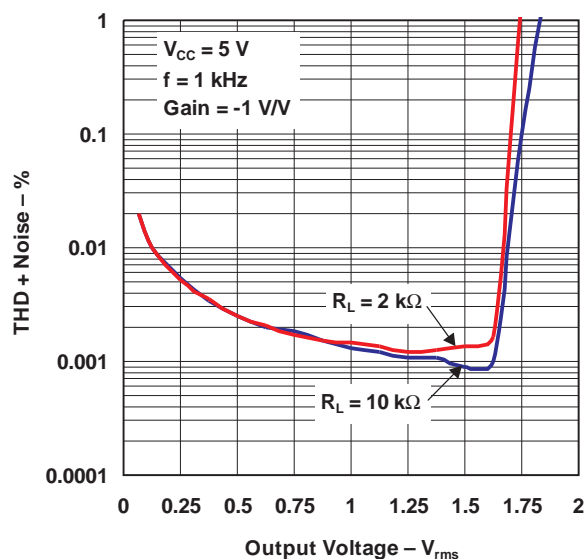


TOTAL HARMONIC DISTORTION + NOISE  
VS  
OUTPUT VOLTAGE

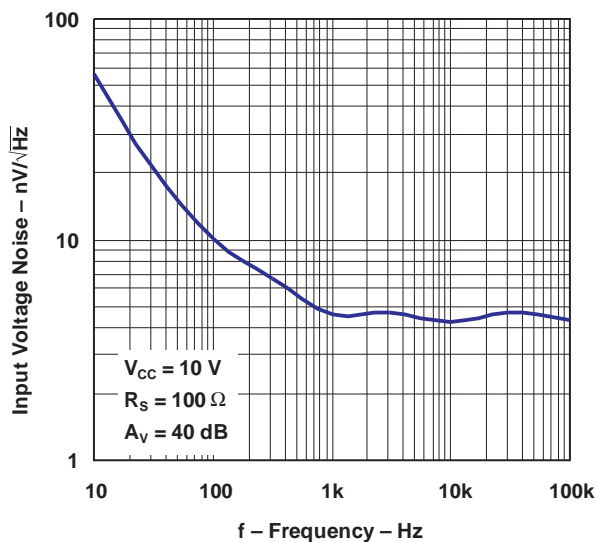


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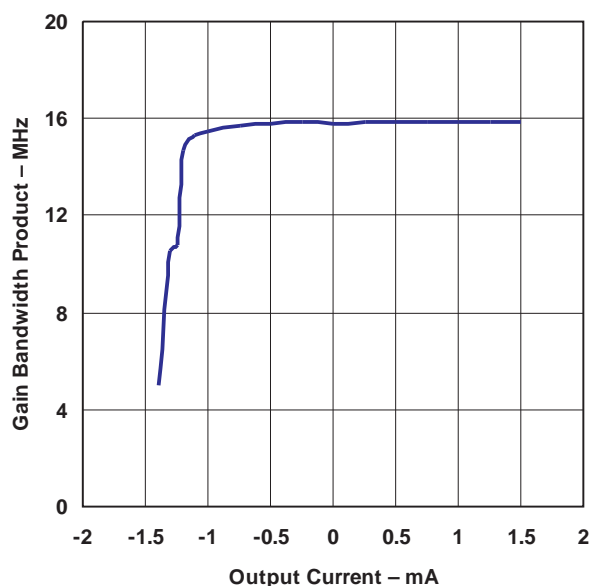
TOTAL HARMONIC DISTORTION + NOISE  
vs  
OUTPUT VOLTAGE



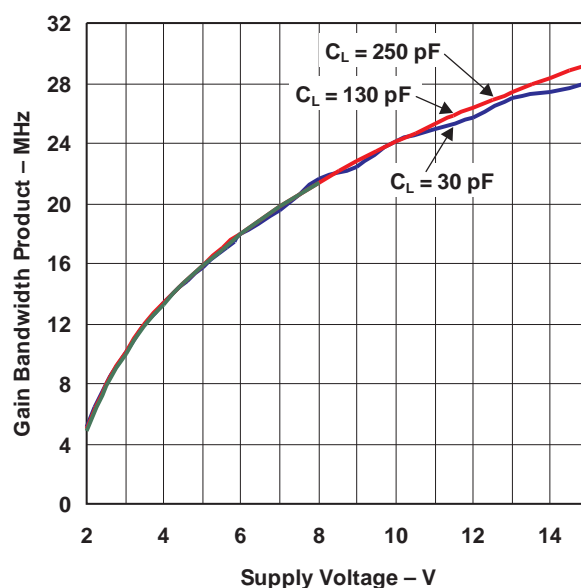
INPUT VOLTAGE NOISE  
vs  
FREQUENCY



GAIN BANDWIDTH PRODUCT  
vs  
OUTPUT CURRENT

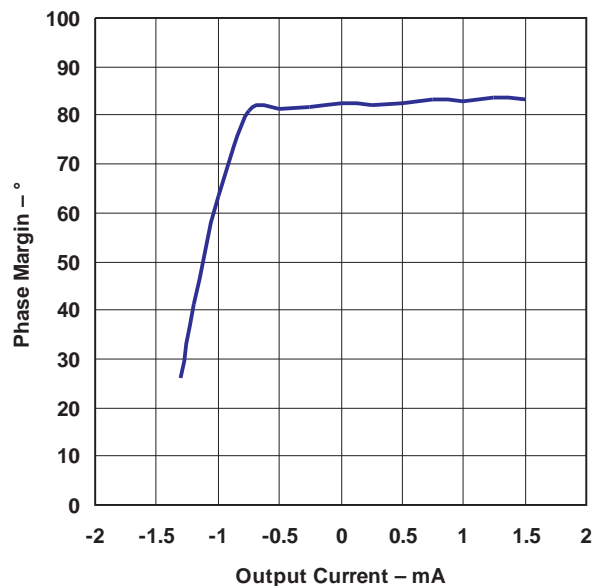


GAIN BANDWIDTH PRODUCT  
vs  
SUPPLY VOLTAGE

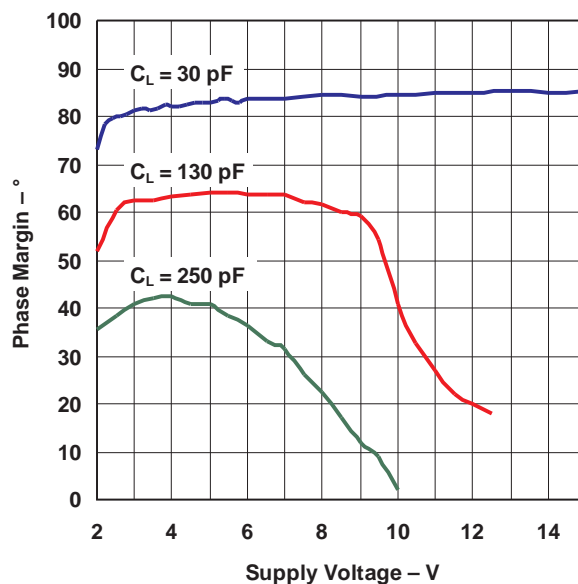


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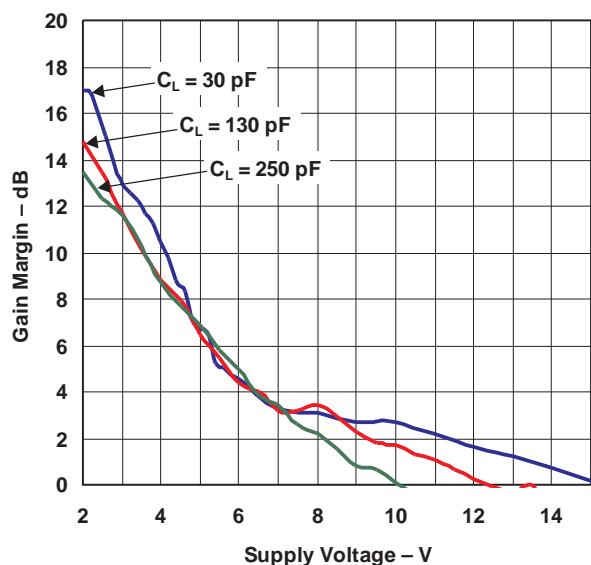
PHASE MARGIN  
vs  
OUTPUT CURRENT



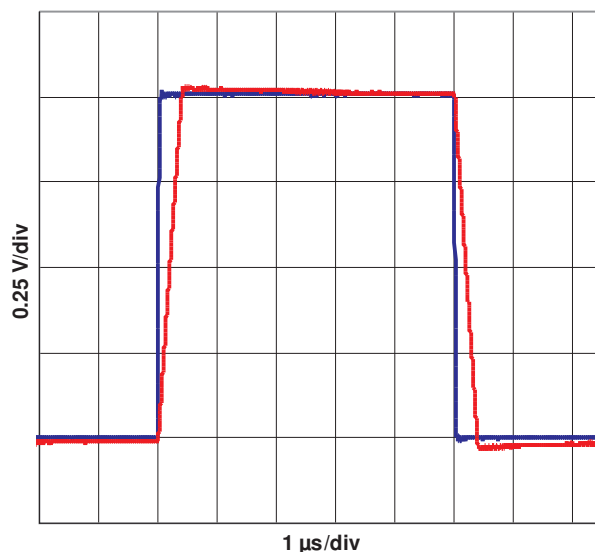
PHASE MARGIN  
vs  
SUPPLY VOLTAGE



GAIN MARGIN  
vs  
SUPPLY VOLTAGE

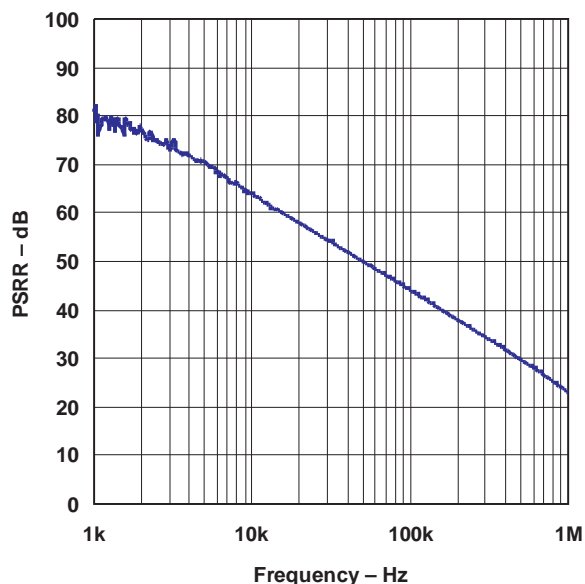


INPUT RESPONSE

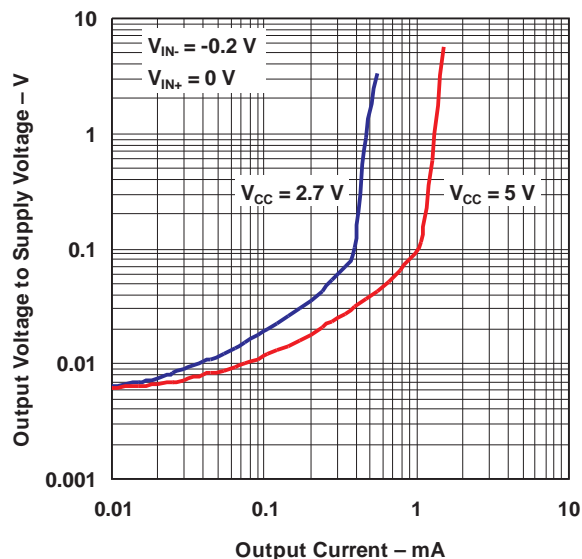


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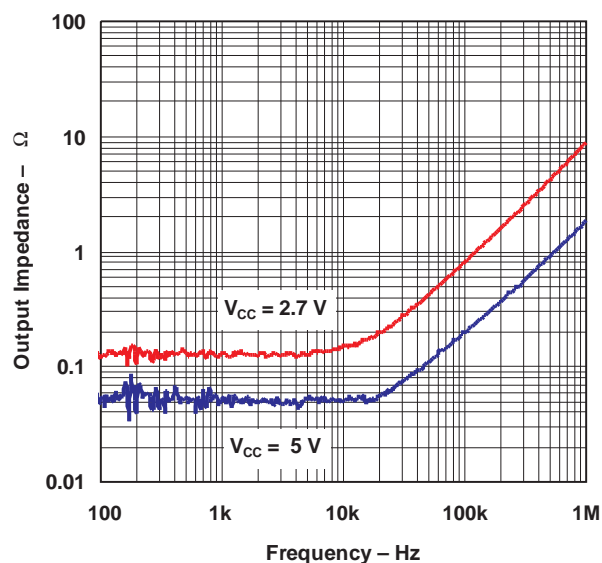
POWER-SUPPLY RIPPLE REJECTION  
vs  
FREQUENCY



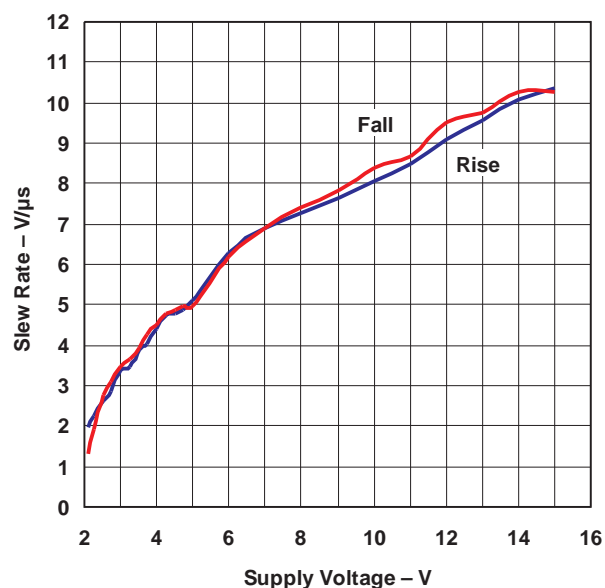
OUTPUT VOLTAGE  
vs  
OUTPUT CURRENT



OUTPUT IMPEDANCE  
vs  
FREQUENCY



SLEW RATE  
vs  
SUPPLY VOLTAGE





**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>
TL971ID	ACTIVE	SOIC	D	8	75	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TL971IDG4	ACTIVE	SOIC	D	8	75	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TL971IDR	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TL971IDRG4	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TL972ID	ACTIVE	SOIC	D	8	75	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TL972IDG4	ACTIVE	SOIC	D	8	75	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TL972IDR	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TL972IDRG4	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TL972IP	ACTIVE	PDIP	P	8	50	Pb-Free (RoHS)	CU NIPDAU	N / A for Pkg Type
TL972IPE4	ACTIVE	PDIP	P	8	50	Pb-Free (RoHS)	CU NIPDAU	N / A for Pkg Type
TL972IPW	ACTIVE	TSSOP	PW	8	150	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TL972IPWG4	ACTIVE	TSSOP	PW	8	150	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TL972IPWR	ACTIVE	TSSOP	PW	8	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TL972IPWRG4	ACTIVE	TSSOP	PW	8	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TL974ID	ACTIVE	SOIC	D	14	50	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TL974IDG4	ACTIVE	SOIC	D	14	50	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TL974IDR	ACTIVE	SOIC	D	14	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TL974IDRG4	ACTIVE	SOIC	D	14	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TL974IN	ACTIVE	PDIP	N	14	25	Pb-Free (RoHS)	CU NIPDAU	N / A for Pkg Type
TL974INE4	ACTIVE	PDIP	N	14	25	Pb-Free (RoHS)	CU NIPDAU	N / A for Pkg Type
TL974IPW	ACTIVE	TSSOP	PW	14	90	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TL974IPWG4	ACTIVE	TSSOP	PW	14	90	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TL974IPWR	ACTIVE	TSSOP	PW	14	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TL974IPWRG4	ACTIVE	TSSOP	PW	14	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM

<sup>(1)</sup> The marketing status values are defined as follows:

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**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.

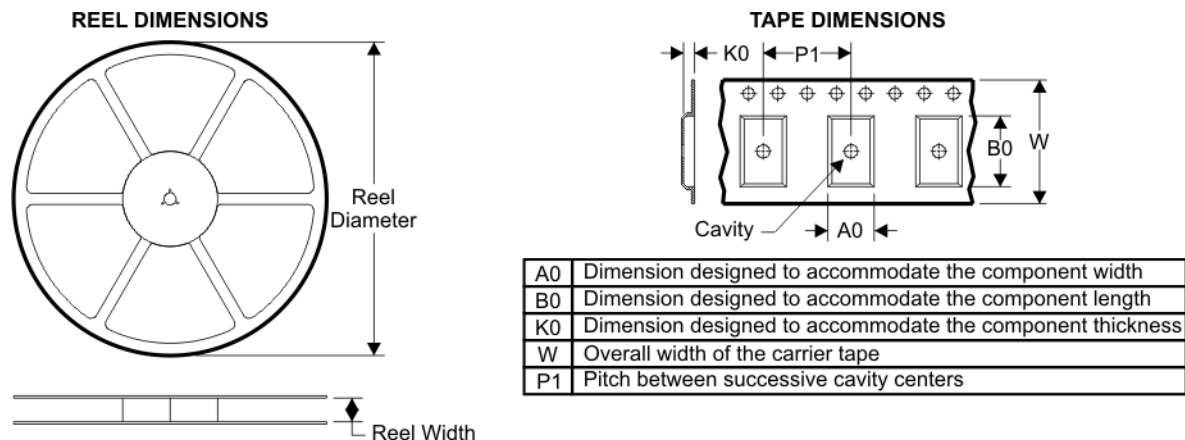
**Green (RoHS & no Sb/Br):** TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

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

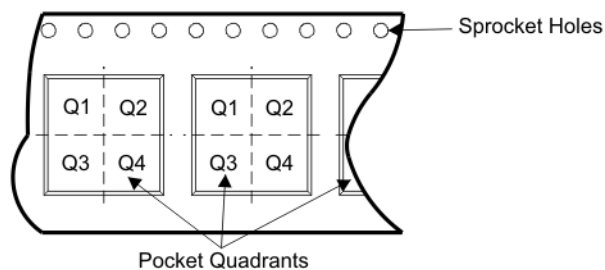
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In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.

## TAPE AND REEL BOX INFORMATION



### QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



Device	Package	Pins	Site	Reel Diameter (mm)	Reel Width (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
TL971IDR	D	8	SITE 27	330	12	6.4	5.2	2.1	8	12	Q1
TL972IDR	D	8	SITE 27	330	12	6.4	5.2	2.1	8	12	Q1
TL972IPWR	PW	8	SITE 41	330	12	7.0	3.6	1.6	8	12	Q1
TL974IPWR	PW	14	SITE 41	330	12	7.0	5.6	1.6	8	12	Q1

## TAPE AND REEL BOX DIMENSIONS



Device	Package	Pins	Site	Length (mm)	Width (mm)	Height (mm)
TL971IDR	D	8	SITE 27	342.9	336.6	20.64
TL972IDR	D	8	SITE 27	342.9	336.6	20.64
TL972IPWR	PW	8	SITE 41	346.0	346.0	29.0
TL974IPWR	PW	14	SITE 41	346.0	346.0	29.0

## 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

For the latest package information, go to [http://www.ti.com/sc/docs/package/pkg\\_info.htm](http://www.ti.com/sc/docs/package/pkg_info.htm)



POST OFFICE BOX 655303 • DALLAS, TEXAS 75265

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

16 PINS SHOWN

## PLASTIC DUAL-IN-LINE PACKAGE



PINS **	14	16	18	20
DIM				
A MAX	0.775 (19,69)	0.775 (19,69)	0.920 (23,37)	1.060 (26,92)
A MIN	0.745 (18,92)	0.745 (18,92)	0.850 (21,59)	0.940 (23,88)
MS-001 VARIATION	AA	BB	AC	AD



4040049/E 12/2002

- NOTES:
- A. All linear dimensions are in inches (millimeters).
  - B. This drawing is subject to change without notice.
  - Falls within JEDEC MS-001, except 18 and 20 pin minimum body length (Dim A).
  - The 20 pin end lead shoulder width is a vendor option, either half or full width.

## D (R-PDSO-G14)

## PLASTIC SMALL-OUTLINE PACKAGE

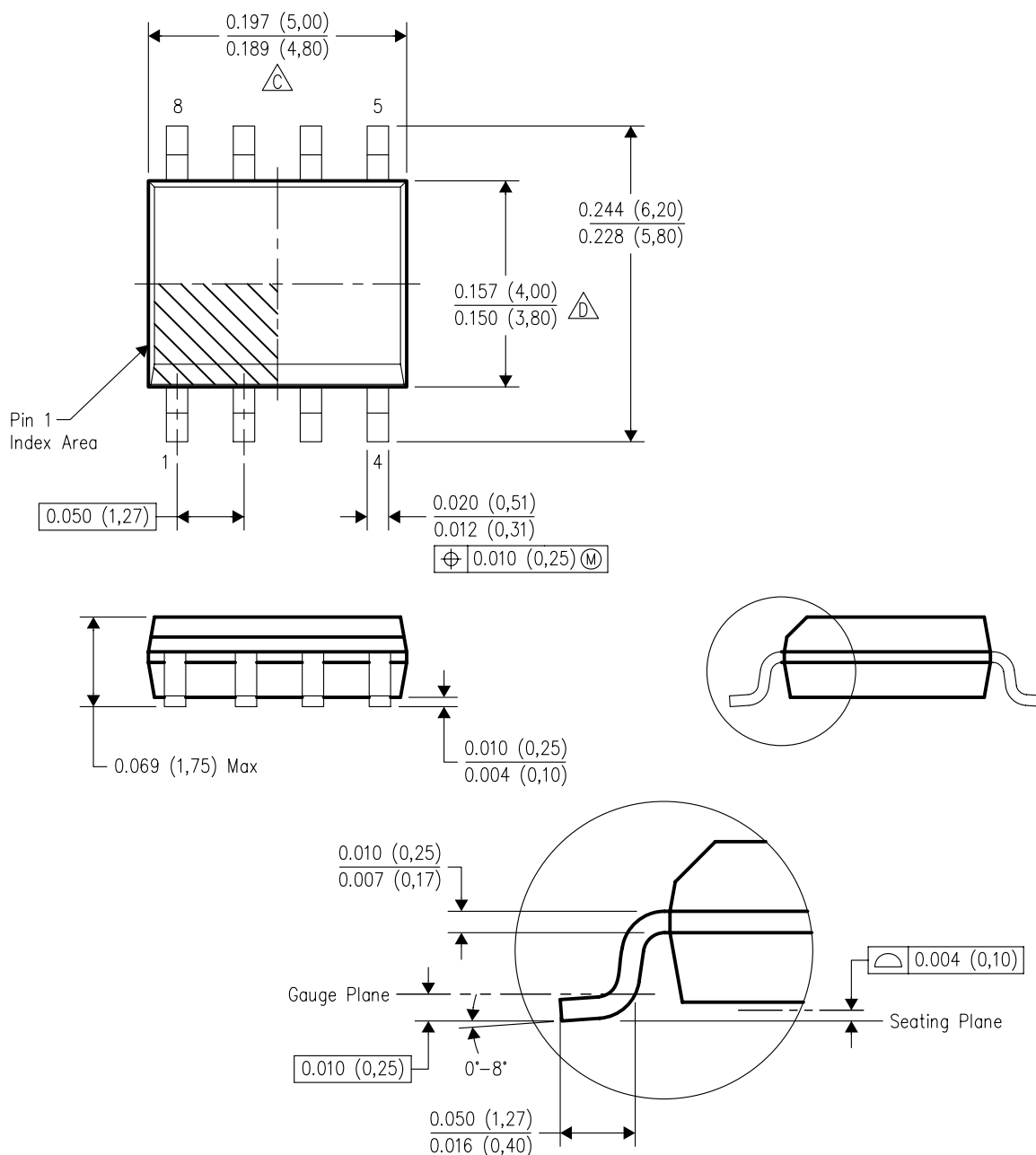


## NOTES:

- 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.

## D (R-PDSO-G8)

# PLASTIC SMALL-OUTLINE PACKAGE



4040047-2/H 11/2006

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.



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

## PLASTIC SMALL-OUTLINE PACKAGE

14 PINS SHOWN



- 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

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