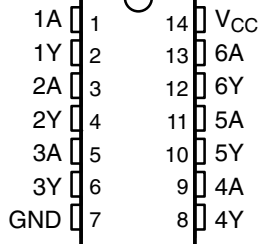


# SN54AHC04, SN74AHC04 HEX INVERTERS

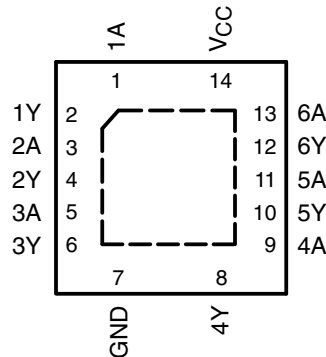
SCLS234K – OCTOBER 1995 – REVISED JULY 2003

- Operating Range 2-V to 5.5-V  $V_{CC}$
- Unbuffered Outputs
- Latch-Up Performance Exceeds 250 mA Per JESD 17
- ESD Protection Exceeds JESD 22
  - 2000-V Human-Body Model (A114-A)
  - 200-V Machine Model (A115-A)
  - 1000-V Charged-Device Model (C101)

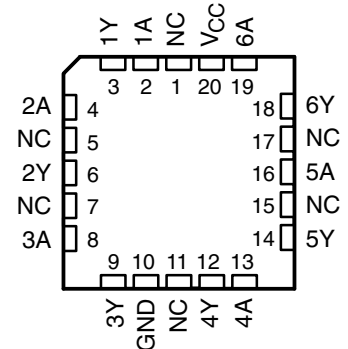
SN54AHC04 . . . J OR W PACKAGE  
SN74AHC04 . . . D, DB, DGV, N, NS,  
OR PW PACKAGE  
(TOP VIEW)



SN74AHC04 . . . RGY PACKAGE  
(TOP VIEW)



SN54AHC04 . . . FK PACKAGE  
(TOP VIEW)



NC – No internal connection

## description/ordering information

The 'AHC04 devices contain six independent inverters. These devices perform the Boolean function  $Y = \bar{A}$ . Internal circuitry consists of single-stage inverters that can be used in analog applications such as crystal oscillators.

## ORDERING INFORMATION

$T_A$	PACKAGE†		ORDERABLE PART NUMBER	TOP-SIDE MARKING
–40°C to 85°C	QFN – RGY	Tape and reel	SN74AHC04RGYR	HD04
	PDIP – N	Tube	SN74AHC04N	SN74AHC04N
	SOIC – D	Tube	SN74AHC04D	AHC04
		Tape and reel	SN74AHC04DR	
	SOP – NS	Tape and reel	SN74AHC04NSR	AHC04
	SSOP – DB	Tape and reel	SN74AHC04DBR	HD04
	TSSOP – PW	Tube	SN74AHC04PW	HD04
Tape and reel		SN74AHC04PWR		
–55°C to 125°C	TVSOP – DGV	Tape and reel	SN74AHC04DGVR	HD04
	CDIP – J	Tube	SNJ54AHC04J	SNJ54AHC04J
	CFP – W	Tube	SNJ54AHC04W	SNJ54AHC04W
	LCCC – FK	Tube	SNJ54AHC04FK	SNJ54AHC04FK

† Package drawings, standard packing quantities, thermal data, symbolization, and PCB design guidelines are available at [www.ti.com/sc/package](http://www.ti.com/sc/package).



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**

POST OFFICE BOX 655303 • DALLAS, TEXAS 75265

Copyright © 2003, Texas Instruments Incorporated  
On products compliant to MIL-PRF-38535, all parameters are tested unless otherwise noted. On all other products, production processing does not necessarily include testing of all parameters.

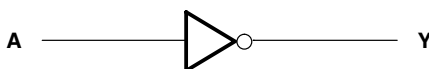
# SN54AHC04, SN74AHC04 HEX INVERTERS

SCLS234K – OCTOBER 1995 – REVISED JULY 2003

**FUNCTION TABLE**  
(each inverter)

INPUT A	OUTPUT Y
H	L
L	H

## logic diagram (positive logic)



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

Supply voltage range, $V_{CC}$ .....	-0.5 V to 7 V
Input voltage range, $V_I$ (see Note 1) .....	-0.5 V to 7 V
Output voltage range, $V_O$ (see Note 1) .....	-0.5 V to $V_{CC} + 0.5$ V
Input clamp current, $I_{IK}$ ( $V_I < 0$ ) .....	-20 mA
Output clamp current, $I_{OK}$ ( $V_O < 0$ or $V_O > V_{CC}$ ) .....	$\pm 20$ mA
Continuous output current, $I_O$ ( $V_O = 0$ to $V_{CC}$ ) .....	$\pm 25$ mA
Continuous current through $V_{CC}$ or GND .....	$\pm 50$ mA
Package thermal impedance, $\theta_{JA}$ (see Note 2): D package .....	86°C/W
(see Note 2): DB package .....	96°C/W
(see Note 2): DGV package .....	127°C/W
(see Note 2): N package .....	80°C/W
(see Note 2): NS package .....	76°C/W
(see Note 2): PW package .....	113°C/W
(see Note 3): RGY package .....	47°C/W
Storage temperature range, $T_{stg}$ .....	-65°C to 150°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. The input and output voltage ratings may be exceeded if the input and output current ratings are observed.  
 2. The package thermal impedance is calculated in accordance with JESD 51-7.  
 3. The package thermal impedance is calculated in accordance with JESD 51-5.

# SN54AHC04, SN74AHC04 HEX INVERTERS

SCLS234K – OCTOBER 1995 – REVISED JULY 2003

## recommended operating conditions (see Note 4)

		SN54AHC04		SN74AHC04		UNIT
		MIN	MAX	MIN	MAX	
V <sub>CC</sub>	Supply voltage	2	5.5	2	5.5	V
V <sub>IH</sub>	High-level input voltage	V <sub>CC</sub> = 2 V		1.7	1.7	V
		V <sub>CC</sub> = 3 V		2.4	2.4	
		V <sub>CC</sub> = 5.5 V		4.4	4.4	
V <sub>IL</sub>	Low-level input voltage	V <sub>CC</sub> = 2 V		0.3	0.3	V
		V <sub>CC</sub> = 3 V		0.6	0.6	
		V <sub>CC</sub> = 5.5 V		1.1	1.1	
V <sub>I</sub>	Input voltage	0	5.5	0	5.5	V
V <sub>O</sub>	Output voltage	0	V <sub>CC</sub>	0	V <sub>CC</sub>	V
I <sub>OH</sub>	High-level output current	V <sub>CC</sub> = 2 V		-50	-50	μA
		V <sub>CC</sub> = 3.3 V ± 0.3 V		-4	-4	mA
		V <sub>CC</sub> = 5 V ± 0.5 V		-8	-8	
I <sub>OL</sub>	Low-level output current	V <sub>CC</sub> = 2 V		50	50	μA
		V <sub>CC</sub> = 3.3 V ± 0.3 V		4	4	mA
		V <sub>CC</sub> = 5 V ± 0.5 V		8	8	
T <sub>A</sub>	Operating free-air temperature	-55	125	-40	85	°C

NOTE 4: All unused inputs of the device must be held at V<sub>CC</sub> or GND to ensure proper device operation. Refer to the TI application report, *Implications of Slow or Floating CMOS Inputs*, literature number SCBA004.

## electrical characteristics over recommended operating free-air temperature range (unless otherwise noted)

PARAMETER	TEST CONDITIONS	V <sub>CC</sub>	T <sub>A</sub> = 25°C			SN54AHC04		SN74AHC04		UNIT
			MIN	TYP	MAX	MIN	MAX	MIN	MAX	
V <sub>OH</sub>	I <sub>OH</sub> = -50 μA	2 V	1.8	2	1.8	1.8	V			
		3 V	2.7	3	2.7	2.7				
		4.5 V	4	4.5	4	4				
	I <sub>OH</sub> = -4 mA	3 V	2.58		2.48	2.48				
	I <sub>OH</sub> = -8 mA	4.5 V	3.94		3.8	3.8				
V <sub>OL</sub>	I <sub>OL</sub> = 50 μA	2 V			0.2	0.2	0.2	V		
		3 V			0.3	0.3	0.3			
		4.5 V			0.5	0.5	0.5			
	I <sub>OL</sub> = 4 mA	3 V			0.36	0.5	0.44			
	I <sub>OL</sub> = 8 mA	4.5 V			0.36	0.5	0.44			
I <sub>I</sub>	V <sub>I</sub> = 5.5 V or GND	0 V to 5.5 V			±0.1	±1*	±1	μA		
I <sub>CC</sub>	V <sub>I</sub> = V <sub>CC</sub> or GND, I <sub>O</sub> = 0	5.5 V			2	20	20	μA		
C <sub>i</sub>	V <sub>I</sub> = V <sub>CC</sub> or GND	5 V		2	10		10	pF		

\* On products compliant to MIL-PRF-38535, this parameter is not production tested at V<sub>CC</sub> = 0 V.



# SN54AHC04, SN74AHC04 HEX INVERTERS

SCLS234K – OCTOBER 1995 – REVISED JULY 2003

**switching characteristics over recommended operating free-air temperature range,  
V<sub>CC</sub> = 3.3 V ± 0.3 V (unless otherwise noted) (see Figure 1)**

PARAMETER	FROM (INPUT)	TO (OUTPUT)	LOAD CAPACITANCE	T <sub>A</sub> = 25°C			SN54AHC04		SN74AHC04		UNIT
				MIN	TYP	MAX	MIN	MAX	MIN	MAX	
t <sub>PLH</sub>	A	Y	C <sub>L</sub> = 15 pF	5*	7.1*	1*	8.5*	1	8.5	ns	
t <sub>PHL</sub>				5*	7.1*	1*	8.5*	1	8.5		
t <sub>PLH</sub>	A	Y	C <sub>L</sub> = 50 pF	7.5	10.6	1	12	1	12	ns	
t <sub>PHL</sub>				7.5	10.6	1	12	1	12		

\* On products compliant to MIL-PRF-38535, this parameter is not production tested.

**switching characteristics over recommended operating free-air temperature range,  
V<sub>CC</sub> = 5 V ± 0.5 V (unless otherwise noted) (see Figure 1)**

PARAMETER	FROM (INPUT)	TO (OUTPUT)	LOAD CAPACITANCE	T <sub>A</sub> = 25°C			SN54AHC04		SN74AHC04		UNIT
				MIN	TYP	MAX	MIN	MAX	MIN	MAX	
t <sub>PLH</sub>	A	Y	C <sub>L</sub> = 15 pF	3.5*	5.5*	1*	6*	1	6.5	ns	
t <sub>PHL</sub>				3.5*	5.5*	1*	6*	1	6.5		
t <sub>PLH</sub>	A	Y	C <sub>L</sub> = 50 pF	5	7	1	8	1	8	ns	
t <sub>PHL</sub>				5	7	1	8	1	8		

\* On products compliant to MIL-PRF-38535, this parameter is not production tested.

**noise characteristics, V<sub>CC</sub> = 5 V, C<sub>L</sub> = 50 pF, T<sub>A</sub> = 25°C (see Note 5)**

PARAMETER		SN74AHC04			UNIT
		MIN	TYP	MAX	
V <sub>OL(P)</sub>	Quiet output, maximum dynamic V <sub>OL</sub>		0.5		V
V <sub>OL(V)</sub>	Quiet output, minimum dynamic V <sub>OL</sub>		-0.5		V
V <sub>OH(V)</sub>	Quiet output, minimum dynamic V <sub>OH</sub>		4.3		V
V <sub>IH(D)</sub>	High-level dynamic input voltage		4		V
V <sub>IL(D)</sub>	Low-level dynamic input voltage			1	V

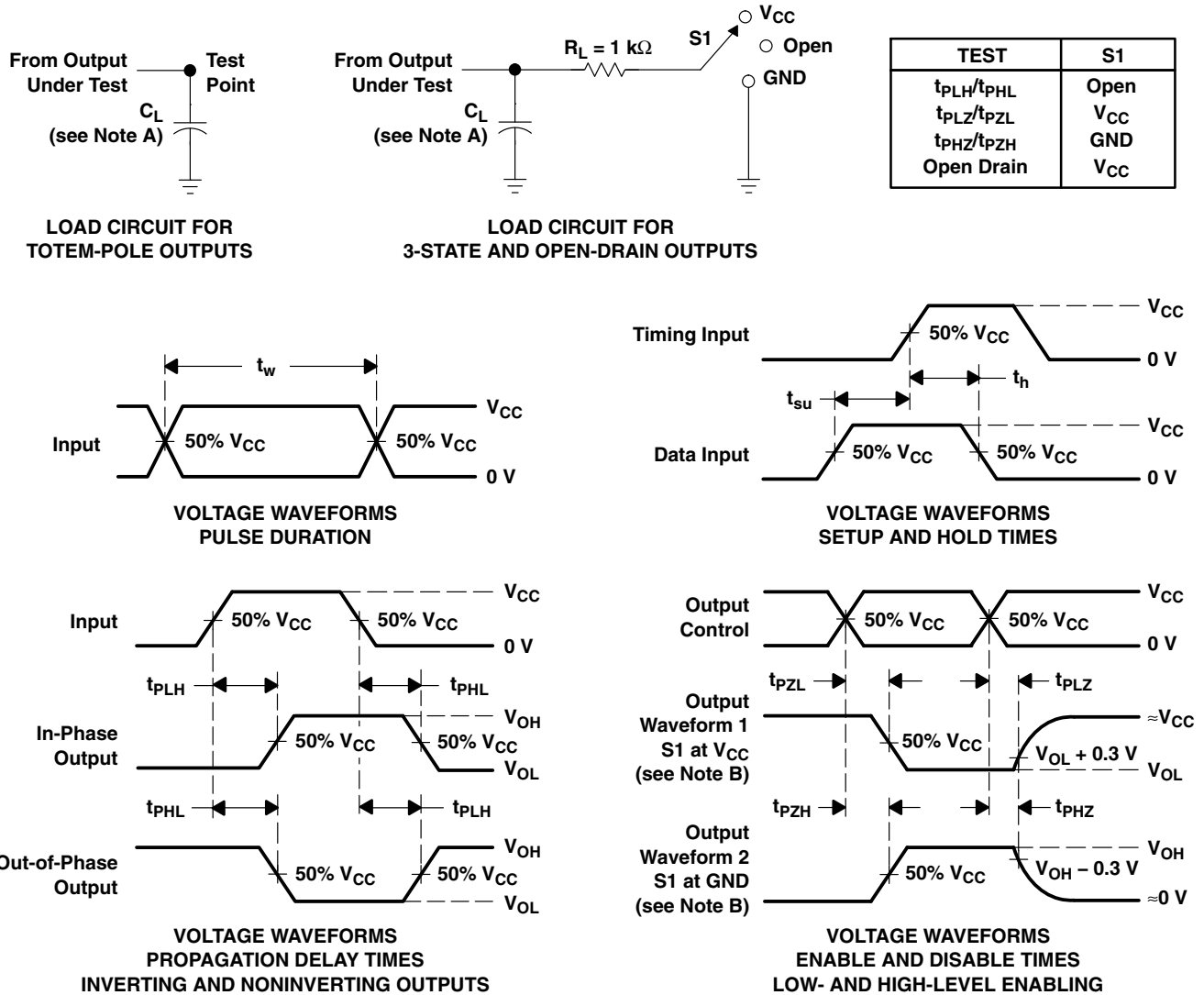
NOTE 5: Characteristics are for surface-mount packages only.

**operating characteristics, V<sub>CC</sub> = 5 V, T<sub>A</sub> = 25°C**

PARAMETER	TEST CONDITIONS	TYP	UNIT
C <sub>pd</sub> Power dissipation capacitance	No load, f = 1 MHz	7.3	pF



PARAMETER MEASUREMENT INFORMATION



- NOTES: A.  $C_L$  includes probe and jig capacitance.  
 B. Waveform 1 is for an output with internal conditions such that the output is low except when disabled by the output control. Waveform 2 is for an output with internal conditions such that the output is high except when disabled by the output control.  
 C. All input pulses are supplied by generators having the following characteristics: PRR  $\leq$  1 MHz,  $Z_O = 50 \Omega$ ,  $t_r \leq 3$  ns,  $t_f \leq 3$  ns.  
 D. The outputs are measured one at a time with one input transition per measurement.  
 E. All parameters and waveforms are not applicable to all devices.

Figure 1. Load Circuit and Voltage Waveforms

**PACKAGING INFORMATION**

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
5962-9680301QDA	ACTIVE	CFP	W	14	1	TBD	Call TI	N / A for Pkg Type	-55 to 125	5962-9680301QD A SNJ54AHC04W	<a href="#">Samples</a>
SN74AHC04D	ACTIVE	SOIC	D	14	50	Green (RoHS & no Sb/Br)	NIPDAU	Level-1-260C-UNLIM	-40 to 85	AHC04	<a href="#">Samples</a>
SN74AHC04DBR	ACTIVE	SSOP	DB	14	2000	Green (RoHS & no Sb/Br)	NIPDAU	Level-1-260C-UNLIM	-40 to 85	HD04	<a href="#">Samples</a>
SN74AHC04DE4	ACTIVE	SOIC	D	14	50	Green (RoHS & no Sb/Br)	NIPDAU	Level-1-260C-UNLIM	-40 to 85	AHC04	<a href="#">Samples</a>
SN74AHC04DR	ACTIVE	SOIC	D	14	2500	Green (RoHS & no Sb/Br)	NIPDAU	Level-1-260C-UNLIM	-40 to 85	AHC04	<a href="#">Samples</a>
SN74AHC04N	ACTIVE	PDIP	N	14	25	Green (RoHS & no Sb/Br)	NIPDAU	N / A for Pkg Type	-40 to 85	SN74AHC04N	<a href="#">Samples</a>
SN74AHC04NSR	ACTIVE	SO	NS	14	2000	Green (RoHS & no Sb/Br)	NIPDAU	Level-1-260C-UNLIM	-40 to 85	AHC04	<a href="#">Samples</a>
SN74AHC04PW	ACTIVE	TSSOP	PW	14	90	Green (RoHS & no Sb/Br)	NIPDAU	Level-1-260C-UNLIM	-40 to 85	HD04	<a href="#">Samples</a>
SN74AHC04PWR	ACTIVE	TSSOP	PW	14	2000	Green (RoHS & no Sb/Br)	NIPDAU	Level-1-260C-UNLIM	-40 to 85	HD04	<a href="#">Samples</a>
SN74AHC04PWRG4	ACTIVE	TSSOP	PW	14	2000	Green (RoHS & no Sb/Br)	NIPDAU	Level-1-260C-UNLIM	-40 to 85	HD04	<a href="#">Samples</a>
SNJ54AHC04W	ACTIVE	CFP	W	14	1	TBD	Call TI	N / A for Pkg Type	-55 to 125	5962-9680301QD A SNJ54AHC04W	<a href="#">Samples</a>

(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.

**OBSELETE:** TI has discontinued the production of the device.

(2) **RoHS:** TI defines "RoHS" to mean semiconductor products that are compliant with the current EU RoHS requirements for all 10 RoHS substances, including the requirement that RoHS substance do not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, "RoHS" products are suitable for use in specified lead-free processes. TI may reference these types of products as "Pb-Free".

**RoHS Exempt:** TI defines "RoHS Exempt" to mean products that contain lead but are compliant with EU RoHS pursuant to a specific EU RoHS exemption.

---

**Green:** TI defines "Green" to mean the content of Chlorine (Cl) and Bromine (Br) based flame retardants meet JS709B low halogen requirements of  $\leq 1000$ ppm threshold. Antimony trioxide based flame retardants must also meet the  $\leq 1000$ ppm threshold requirement.

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

(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

(5) Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

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

**Important Information and Disclaimer:** The information provided on this page represents TI's knowledge and belief as of the date that it is provided. TI bases its knowledge and belief on information provided by third parties, and makes no representation or warranty as to the accuracy of such information. Efforts are underway to better integrate information from third parties. TI has taken and continues to take reasonable steps to provide representative and accurate information but may not have conducted destructive testing or chemical analysis on incoming materials and chemicals. TI and TI suppliers consider certain information to be proprietary, and thus CAS numbers and other limited information may not be available for release.

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.

**OTHER QUALIFIED VERSIONS OF SN54AHC04, SN74AHC04 :**

- Catalog: [SN74AHC04](#)
- Automotive: [SN74AHC04-Q1](#), [SN74AHC04-Q1](#)
- Enhanced Product: [SN74AHC04-EP](#), [SN74AHC04-EP](#)
- Military: [SN54AHC04](#)

NOTE: Qualified Version Definitions:

- Catalog - TI's standard catalog product
- Automotive - Q100 devices qualified for high-reliability automotive applications targeting zero defects
- Enhanced Product - Supports Defense, Aerospace and Medical Applications

- Military - QML certified for Military and Defense Applications

## 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
SN74AHCU04DR	SOIC	D	14	2500	330.0	16.4	6.5	9.0	2.1	8.0	16.0	Q1
SN74AHCU04NSR	SO	NS	14	2000	330.0	16.4	8.2	10.5	2.5	12.0	16.0	Q1
SN74AHCU04PWR	TSSOP	PW	14	2000	330.0	12.4	6.9	5.6	1.6	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)
SN74AHCU04DR	SOIC	D	14	2500	367.0	367.0	38.0
SN74AHCU04NSR	SO	NS	14	2000	367.0	367.0	38.0
SN74AHCU04PWR	TSSOP	PW	14	2000	367.0	367.0	35.0

## MECHANICAL DATA

**NS (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.

W (R-GDFP-F14)

CERAMIC DUAL FLATPACK



- NOTES:
- A. All linear dimensions are in inches (millimeters).
  - B. This drawing is subject to change without notice.
  - C. This package can be hermetically sealed with a ceramic lid using glass frit.
  - D. Index point is provided on cap for terminal identification only.
  - E. Falls within MIL STD 1835 GDFP1-F14

D (R-PDSO-G14)

PLASTIC SMALL OUTLINE



- NOTES:
- A. All linear dimensions are in inches (millimeters).
  - B. This drawing is subject to change without notice.
  -  Body length does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.006 (0,15) each side.
  -  Body width does not include interlead flash. Interlead flash shall not exceed 0.017 (0,43) each side.
  - E. Reference JEDEC MS-012 variation AB.

D (R-PDSO-G14)

PLASTIC SMALL OUTLINE

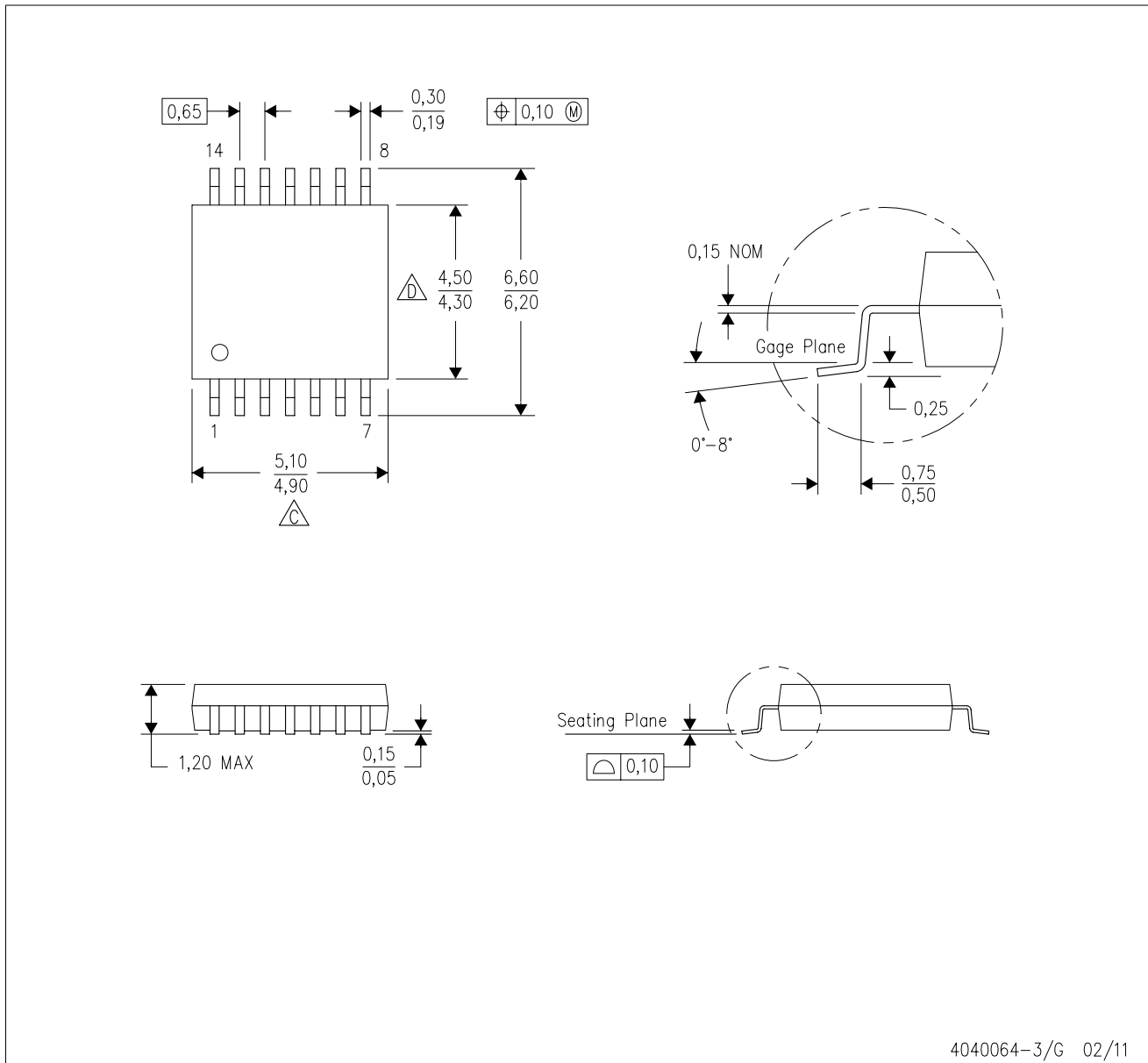




4211283-3/E 08/12

- NOTES:
- A. All linear dimensions are in millimeters.
  - B. This drawing is subject to change without notice.
  - C. Publication IPC-7351 is recommended for alternate designs.
  - D. Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Refer to IPC-7525 for other stencil recommendations.
  - E. Customers should contact their board fabrication site for solder mask tolerances between and around signal pads.

PW (R-PDSO-G14)

PLASTIC SMALL OUTLINE



- NOTES:
- A. All linear dimensions are in millimeters. Dimensioning and tolerancing per ASME Y14.5M-1994.
  - B. This drawing is subject to change without notice.
  -  Body length does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0,15 each side.
  -  Body width does not include interlead flash. Interlead flash shall not exceed 0,25 each side.
  - E. Falls within JEDEC MO-153

PW (R-PDSO-G14)

PLASTIC SMALL OUTLINE



- NOTES:
- All linear dimensions are in millimeters.
  - This drawing is subject to change without notice.
  - Publication IPC-7351 is recommended for alternate designs.
  - Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Refer to IPC-7525 for other stencil recommendations.
  - Customers should contact their board fabrication site for solder mask tolerances between and around signal pads.

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

PLASTIC DUAL-IN-LINE PACKAGE

16 PINS SHOWN



- 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.

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

PLASTIC SMALL-OUTLINE

28 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-150

## IMPORTANT NOTICE AND DISCLAIMER

TI PROVIDES TECHNICAL AND RELIABILITY DATA (INCLUDING DATASHEETS), DESIGN RESOURCES (INCLUDING REFERENCE DESIGNS), APPLICATION OR OTHER DESIGN ADVICE, WEB TOOLS, SAFETY INFORMATION, AND OTHER RESOURCES "AS IS" AND WITH ALL FAULTS, AND DISCLAIMS ALL WARRANTIES, EXPRESS AND IMPLIED, INCLUDING WITHOUT LIMITATION ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

These resources are intended for skilled developers designing with TI products. You are solely responsible for (1) selecting the appropriate TI products for your application, (2) designing, validating and testing your application, and (3) ensuring your application meets applicable standards, and any other safety, security, or other requirements. These resources are subject to change without notice. TI grants you permission to use these resources only for development of an application that uses the TI products described in the resource. Other reproduction and display of these resources is prohibited. No license is granted to any other TI intellectual property right or to any third party intellectual property right. TI disclaims responsibility for, and you will fully indemnify TI and its representatives against, any claims, damages, costs, losses, and liabilities arising out of your use of these resources.

TI's products are provided subject to TI's Terms of Sale ([www.ti.com/legal/termsofsale.html](http://www.ti.com/legal/termsofsale.html)) or other applicable terms available either on [ti.com](http://ti.com) or provided in conjunction with such TI products. TI's provision of these resources does not expand or otherwise alter TI's applicable warranties or warranty disclaimers for TI products.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265  
Copyright © 2020, Texas Instruments Incorporated