![Texas Instruments logo] TEXAS INSTRUMENTS
www.ti.com

ULN2003AI
HIGH-VOLTAGE, HIGH-CURRENT
DARLINGTON TRANSISTOR ARRAY

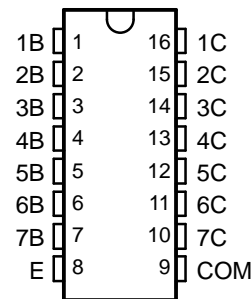SLRS054B−JULY 2003−REVISED FEBRUARY 2005

FEATURES

- **500-mA-Rated Collector Current (Single Output)**
- **High-Voltage Outputs . . . 50 V**
- **Output Clamp Diodes**
- **Inputs Compatible With Various Types of Logic**
- **Relay-Driver Applications**

D, N, OR PW PACKAGE
(TOP VIEW)

1B	1	16	1C
2B	2	15	2C
3B	3	14	3C
4B	4	13	4C
5B	5	12	5C
6B	6	11	6C
7B	7	10	7C
E	8	9	COM

DESCRIPTION/ORDERING INFORMATION

The ULN2003AI is a high-voltage, high-current Darlington transistor array. This device consists of seven npn Darlington pairs that feature high-voltage outputs with common-cathode clamp diodes for switching inductive loads. The collector-current rating of a single Darlington pair is 500 mA. The Darlington pairs can be paralleled for higher current capability. Applications include relay drivers, hammer drivers, lamp drivers, display drivers (LED and gas discharge), line drivers, and logic buffers.

The ULN2003AI has a 2.7-kΩ series base resistor for each Darlington pair for operation directly with TTL or 5-V CMOS devices.

ORDERING INFORMATION
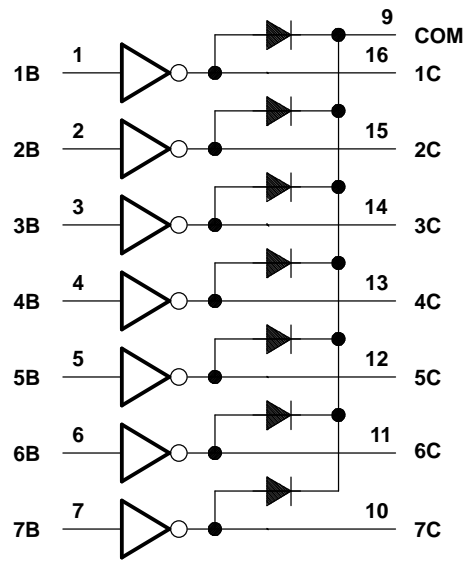
T_A	PACKAGE		ORDERABLE PART NUMBER	TOP-SIDE MARKING
−40°C to 105°C	PDIP (N)	Tube of 425	ULN2003AIN	ULN2003AIN
	SOIC (D)	Tube of 40	ULN2003AID	ULN2003AI
		Reel of 2500	ULN2003AIDR	
	TSSOP (PW)	Reel of 2000	ULN2003AIPWR	UN2003AI

LOGIC DIAGRAM

SCHEMATICS (EACH DARLINGTON PAIR)
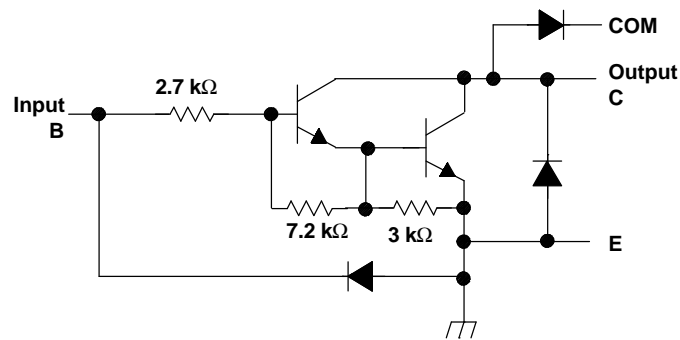
All resistor values shown are nominal.

www.ti.com

ULN2003AI
HIGH-VOLTAGE, HIGH-CURRENT
DARLINGTON TRANSISTOR ARRAY
SLRS054B – JULY 2003 – REVISED FEBRUARY 2005

Absolute Maximum Ratings[(1)]

at 25°C free-air temperature (unless otherwise noted)

			MIN	MAX	UNIT
V_{CC}	Collector-emitter voltage			50	V
	Clamp diode reverse voltage [(2)]			50	V
V_I	Input voltage [(2)]			30	V
	Peak collector current [(3)(4)]			500	mA
I_{OK}	Output clamp current			500	mA
	Total emitter-terminal current			−2.5	A
T_A	Operating free-air temperature range		−40	105	°C
θ_{JA}	Package thermal impedance [(3)(4)]	D package		73	°C/W
		N package		67	
		PW package		108	
T_J	Operating virtual junction temperature			150	°C
T_{stg}	Storage temperature range		−65	150	°C

(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 are with respect to the emitter/substrate terminal E, unless otherwise noted.
(3) Maximum power dissipation is a function of T_J(max), θ_{JA}, and T_A. The maximum allowable power dissipation at any allowable ambient temperature is $P_D = (T_J(\text{max}) − T_A)/\theta_{JA}$. Operating at the absolute maximum T_J of 150°C can affect reliability.
(4) The package thermal impedance is calculated in accordance with JESD 51-7.

Electrical Characteristics

$T_A = 25°C$

PARAMETER		TEST FIGURE	TEST CONDITIONS		MIN	TYP	MAX	UNIT
$V_{I(on)}$	On-state input voltage	5	$V_{CE} = 2$ V	$I_C = 200$ mA			2.4	V
				$I_C = 250$ mA			2.7	
				$I_C = 300$ mA			3	
$V_{CE(sat)}$	Collector-emitter saturation voltage	4	$I_I = 250$ µA,	$I_C = 100$ mA		0.9	1.1	V
			$I_I = 350$ µA,	$I_C = 200$ mA		1	1.3	
			$I_I = 500$ µA,	$I_C = 350$ mA		1.2	1.6	
I_{CEX}	Collector cutoff current	1	$V_{CE} = 50$ V,	$I_I = 0$			50	µA
V_F	Clamp forward voltage	7	$I_F = 350$ mA			1.7	2	V
$I_{I(off)}$	Off-state input current	2	$V_{CE} = 50$ V,	$I_C = 500$ µA	50	65		µA
I_I	Input current	3	$V_I = 3.85$ V			0.93	1.35	mA
I_R	Clamp reverse current	6	$V_R = 50$ V				50	µA
C_i	Input capacitance		$V_I = 0$,	$f = 1$ MHz		15	25	pF

ULN2003AI
HIGH-VOLTAGE, HIGH-CURRENT
DARLINGTON TRANSISTOR ARRAY

SLRS054B−JULY 2003−REVISED FEBRUARY 2005

TEXAS INSTRUMENTS
www.ti.com

Electrical Characteristics

$T_A = -40°C$ to $105°C$

PARAMETER		TEST FIGURE	TEST CONDITIONS		MIN	TYP	MAX	UNIT
$V_{I(on)}$	On-state input voltage	5	$V_{CE} = 2$ V	$I_C = 200$ mA			2.7	V
				$I_C = 250$ mA			2.9	
				$I_C = 300$ mA			3	
$V_{CE(sat)}$	Collector-emitter saturation voltage	4	$I_I = 250$ μA,	$I_C = 100$ mA		0.9	1.2	V
			$I_I = 350$ μA,	$I_C = 200$ mA		1	1.4	
			$I_I = 500$ μA,	$I_C = 350$ mA		1.2	1.7	
I_{CEX}	Collector cutoff current	1	$V_{CE} = 50$ V,	$I_I = 0$			100	μA
V_F	Clamp forward voltage	7	$I_F = 350$ mA			1.7	2.2	V
$I_{I(off)}$	Off-state input current	2	$V_{CE} = 50$ V,	$I_C = 500$ μA	30	65		μA
I_I	Input current	3	$V_I = 3.85$ V			0.93	1.35	mA
I_R	Clamp reverse current	6	$V_R = 50$ V				100	μA
C_i	Input capacitance		$V_I = 0$,	$f = 1$ MHz		15	25	pF

Switching Characteristics

$T_A = 25°C$

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
t_{PLH}	Propagation delay time, low- to high-level output	See Figure 8			0.25	1	μs
t_{PHL}	Propagation delay time, high- to low-level output	See Figure 8			0.25	1	μs
V_{OH}	High-level output voltage after switching	$V_S = 50$ V,	$I_O \approx 300$ mA, See Figure 9	$V_S - 20$			mV

Switching Characteristics

$T_A = -40°C$ to $105°C$

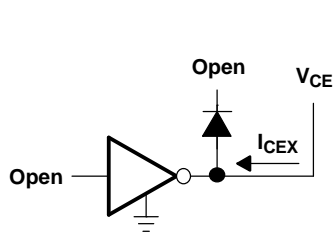| PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
t_{PLH}	Propagation delay time, low- to high-level output	See Figure 8			1	10	μs
t_{PHL}	Propagation delay time, high- to low-level output	See Figure 8			1	10	μs
V_{OH}	High-level output voltage after switching	$V_S = 50$ V,	$I_O \approx 300$ mA, See Figure 9	$V_S - 50$			mV

PARAMETER MEASUREMENT INFORMATION

Figure 1. I_{CEX} Test Circuit
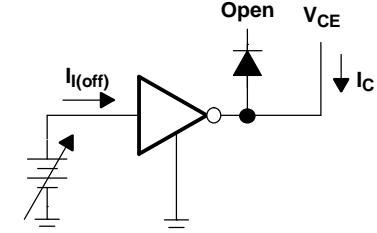
Figure 2. $I_{I(off)}$ Test Circuit

Figure 3. I_I Test Circuit

$$h_{FE} = \frac{I_C}{I_I}$$
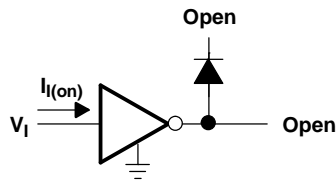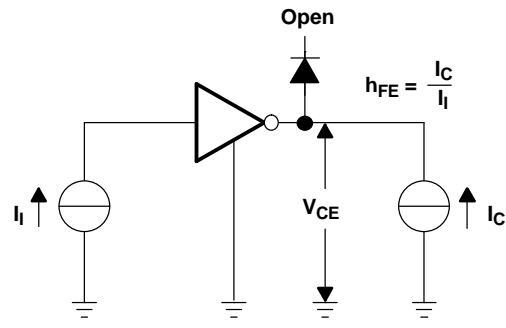
NOTE: I_I is fixed for measuring $V_{CE(sat)}$, variable for measuring h_{FE}.

Figure 4. h_{FE}, $V_{CE(sat)}$ Test Circuit

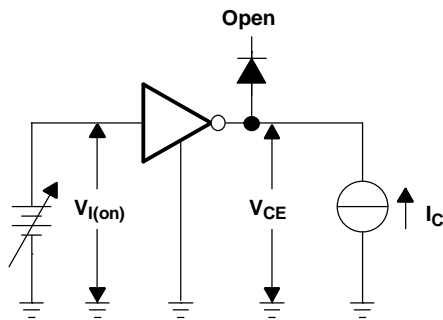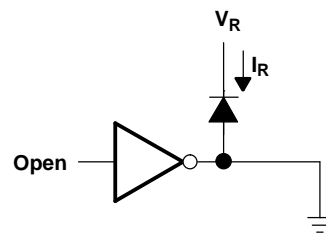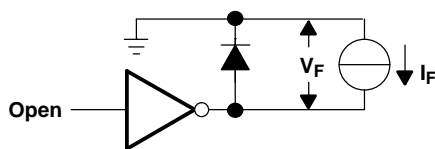**Figure 5. $V_{I(on)}$ Test Circuit**

Figure 6. I_R Test Circuit

Figure 7. V_F Test Circuit

ULN2003AI
HIGH-VOLTAGE, HIGH-CURRENT
DARLINGTON TRANSISTOR ARRAY
SLRS054B−JULY 2003−REVISED FEBRUARY 2005

TEXAS
INSTRUMENTS
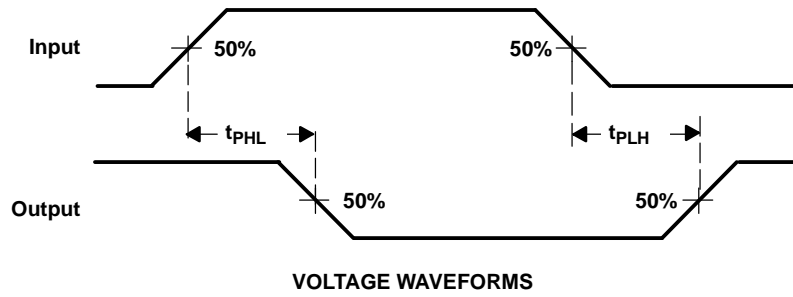**www.ti.com**

PARAMETER MEASUREMENT INFORMATION

Figure 8. Propagation Delay-Time Waveforms
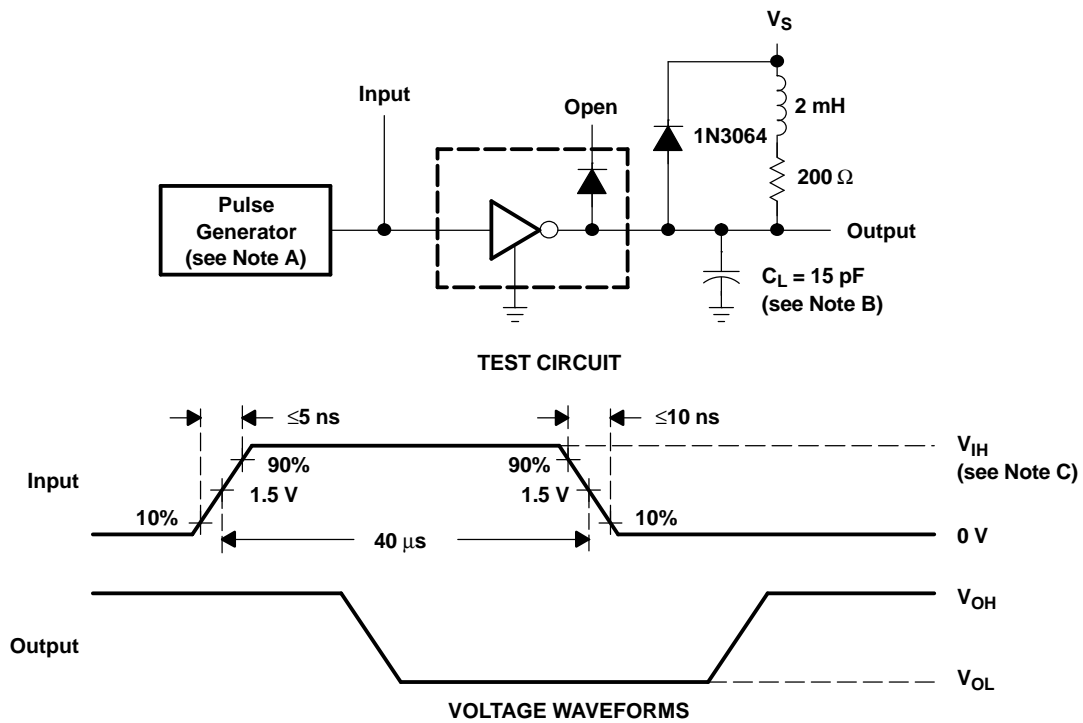
NOTES: A. The pulse generator has the following characteristics: PRR = 12.5 kHz, Z_O = 50 Ω.
B. C_L includes probe and jig capacitance.
C. For testing, V_{IH} = 3 V

Figure 9. Latch-Up Test Circuit and Voltage Waveforms

TYPICAL CHARACTERISTICS

COLLECTOR-EMITTER
SATURATION VOLTAGE
vs
COLLECTOR CURRENT
(ONE DARLINGTON)
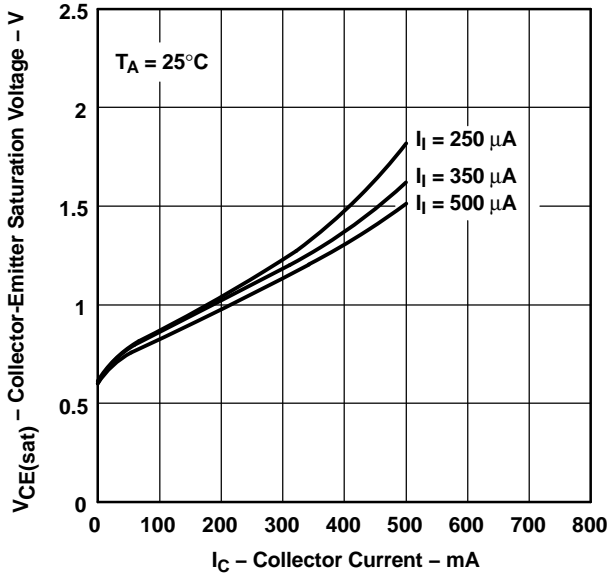
Figure 10

COLLECTOR-EMITTER
SATURATION VOLTAGE
vs
TOTAL COLLECTOR CURRENT
(TWO DARLINGTONS IN PARALLEL)
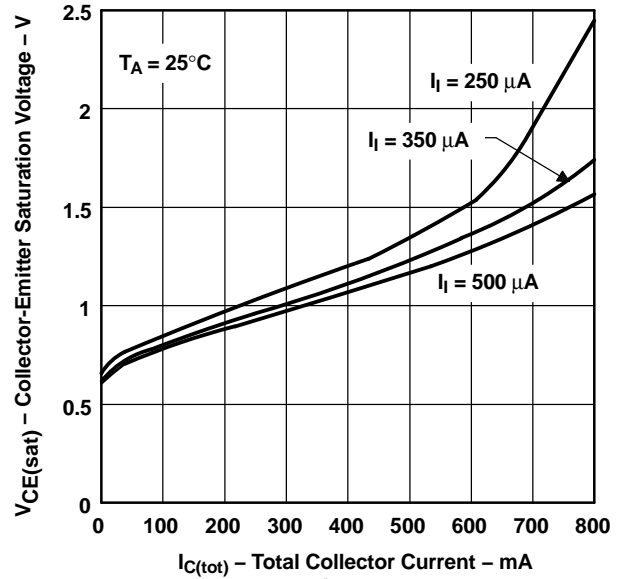
Figure 11

COLLECTOR CURRENT
vs
INPUT CURRENT

Figure 12

ULN2003AI
HIGH-VOLTAGE, HIGH-CURRENT
DARLINGTON TRANSISTOR ARRAY

SLRS054B−JULY 2003−REVISED FEBRUARY 2005

TEXAS
INSTRUMENTS
www.ti.com
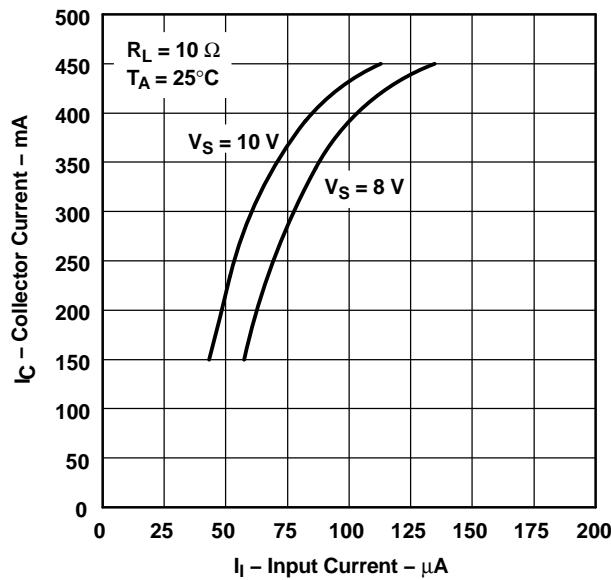
THERMAL INFORMATION

D PACKAGE
MAXIMUM COLLECTOR CURRENT
vs
DUTY CYCLE
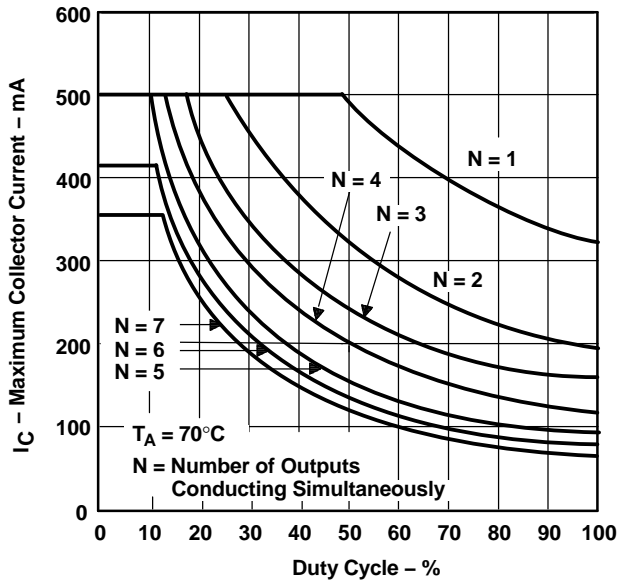
Figure 13

N PACKAGE
MAXIMUM COLLECTOR CURRENT
vs
DUTY CYCLE

Figure 14

APPLICATION INFORMATION

Figure 15. TTL to Load

Figure 16. Use of Pullup Resistors to Increase Drive Current

PACKAGING INFORMATION

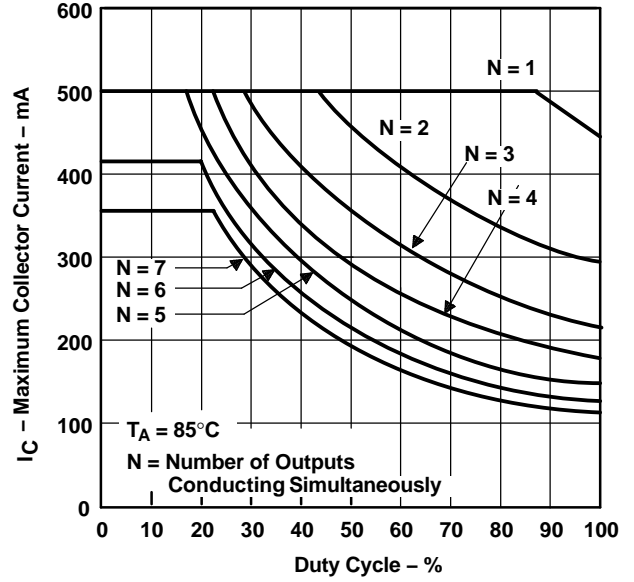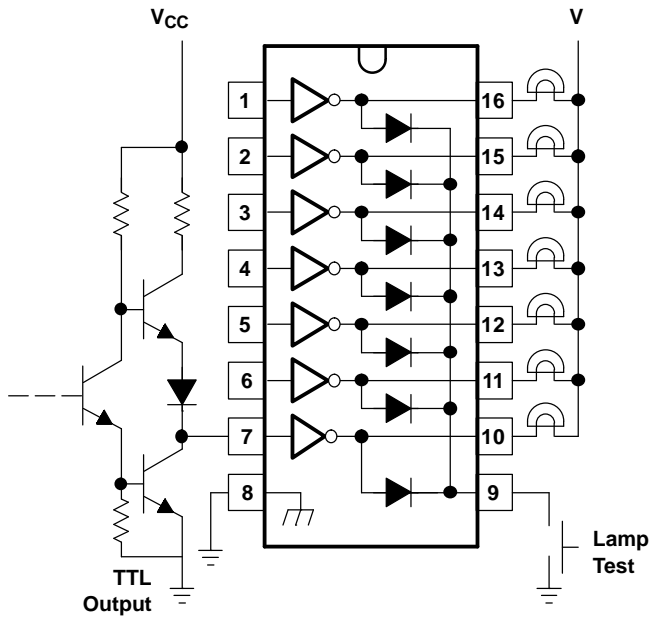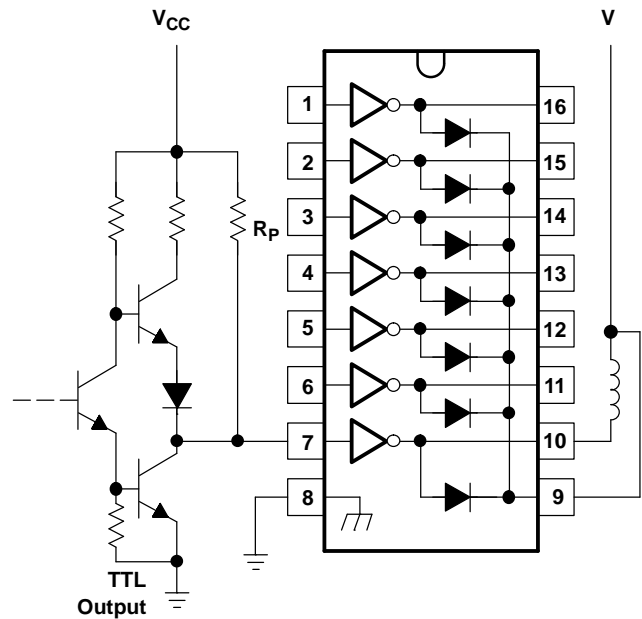| Orderable Device	Status [1]	Package Type	Package Drawing	Pins	Package Qty	Eco Plan [2]	Lead/Ball Finish	MSL Peak Temp [3]
ULN2003AID	ACTIVE	SOIC	D	16	40	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
ULN2003AIDE4	ACTIVE	SOIC	D	16	40	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
ULN2003AIDG4	ACTIVE	SOIC	D	16	40	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
ULN2003AIDR	ACTIVE	SOIC	D	16	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
ULN2003AIDRE4	ACTIVE	SOIC	D	16	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
ULN2003AIDRG4	ACTIVE	SOIC	D	16	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
ULN2003AIN	ACTIVE	PDIP	N	16	25	Pb-Free (RoHS)	CU NIPDAU	N / A for Pkg Type
ULN2003AINE4	ACTIVE	PDIP	N	16	25	Pb-Free (RoHS)	CU NIPDAU	N / A for Pkg Type
ULN2003AIPW	ACTIVE	TSSOP	PW	16	90	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
ULN2003AIPWE4	ACTIVE	TSSOP	PW	16	90	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
ULN2003AIPWG4	ACTIVE	TSSOP	PW	16	90	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
ULN2003AIPWR	ACTIVE	TSSOP	PW	16	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
ULN2003AIPWRE4	ACTIVE	TSSOP	PW	16	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
ULN2003AIPWRG4	ACTIVE	TSSOP	PW	16	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM

[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.

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.

TAPE AND REEL INFORMATION

REEL DIMENSIONS

TAPE DIMENSIONS

A0	Dimension designed to accommodate the component width
B0	Dimension designed to accommodate the component length
K0	Dimension designed to accommodate the component thickness
W	Overall width of the carrier tape
P1	Pitch between successive cavity centers
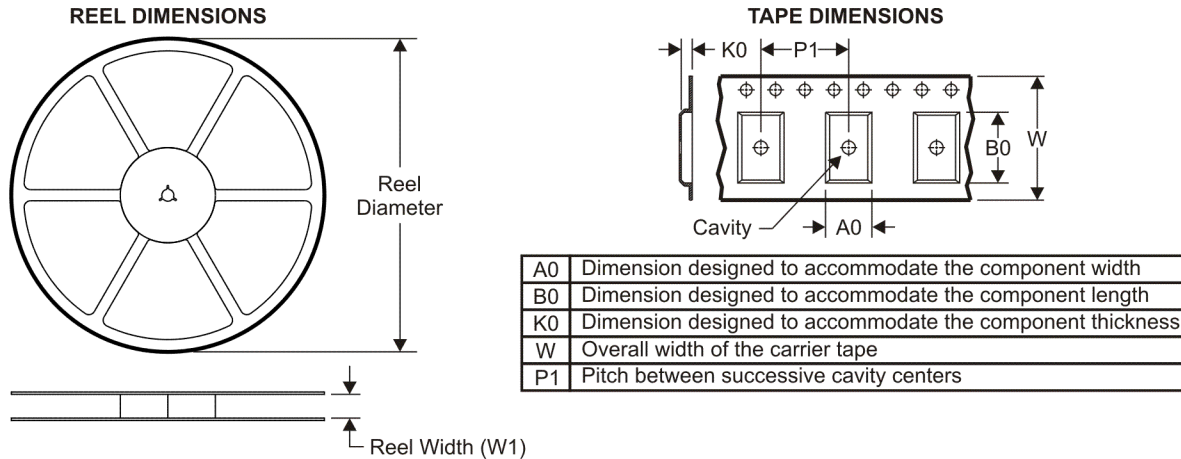
QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE

User Direction of Feed

*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
ULN2003AIDR	SOIC	D	16	2500	330.0	16.4	6.5	10.3	2.1	8.0	16.0	Q1
ULN2003AIPWR	TSSOP	PW	16	2000	330.0	12.4	7.0	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)
ULN2003AIDR	SOIC	D	16	2500	333.2	345.9	28.6
ULN2003AIPWR	TSSOP	PW	16	2000	346.0	346.0	29.0

PW (R-PDSO-G**)   PLASTIC SMALL-OUTLINE PACKAGE

14 PINS SHOWN

0,65

0,30 / 0,19   ⊕ 0,10 Ⓜ

14   8

4,50 / 4,30   6,60 / 6,20

1   7

A

0,15 NOM

Gage Plane

0°–8°

0,25

0,75 / 0,50

1,20 MAX

0,15 / 0,05

Seating Plane   ⌒ 0,10

DIM \ PINS **	8	14	16	20	24	28
A MAX	3,10	5,10	5,10	6,60	7,90	9,80
A MIN	2,90	4,90	4,90	6,40	7,70	9,60
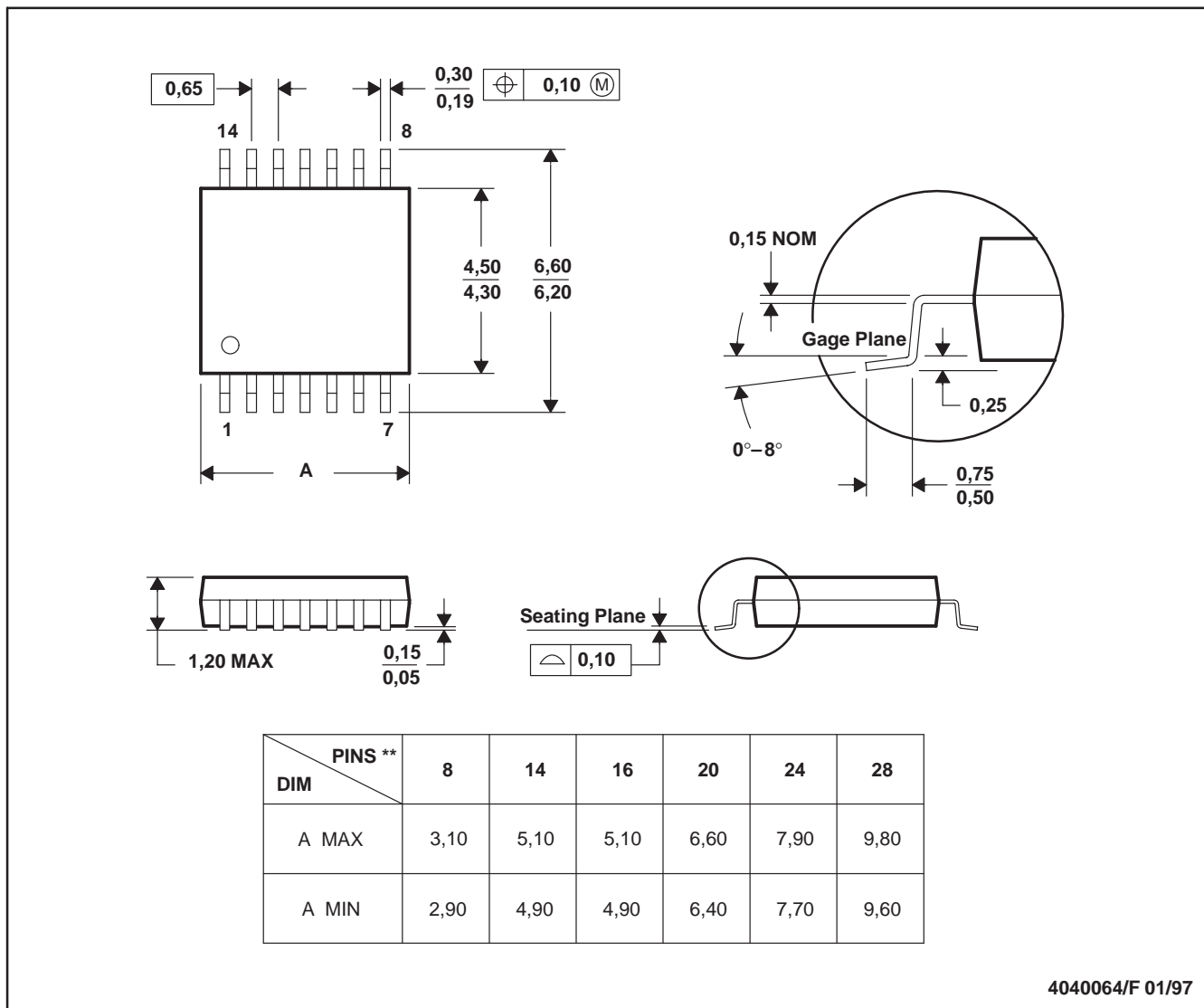
4040064/F 01/97

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

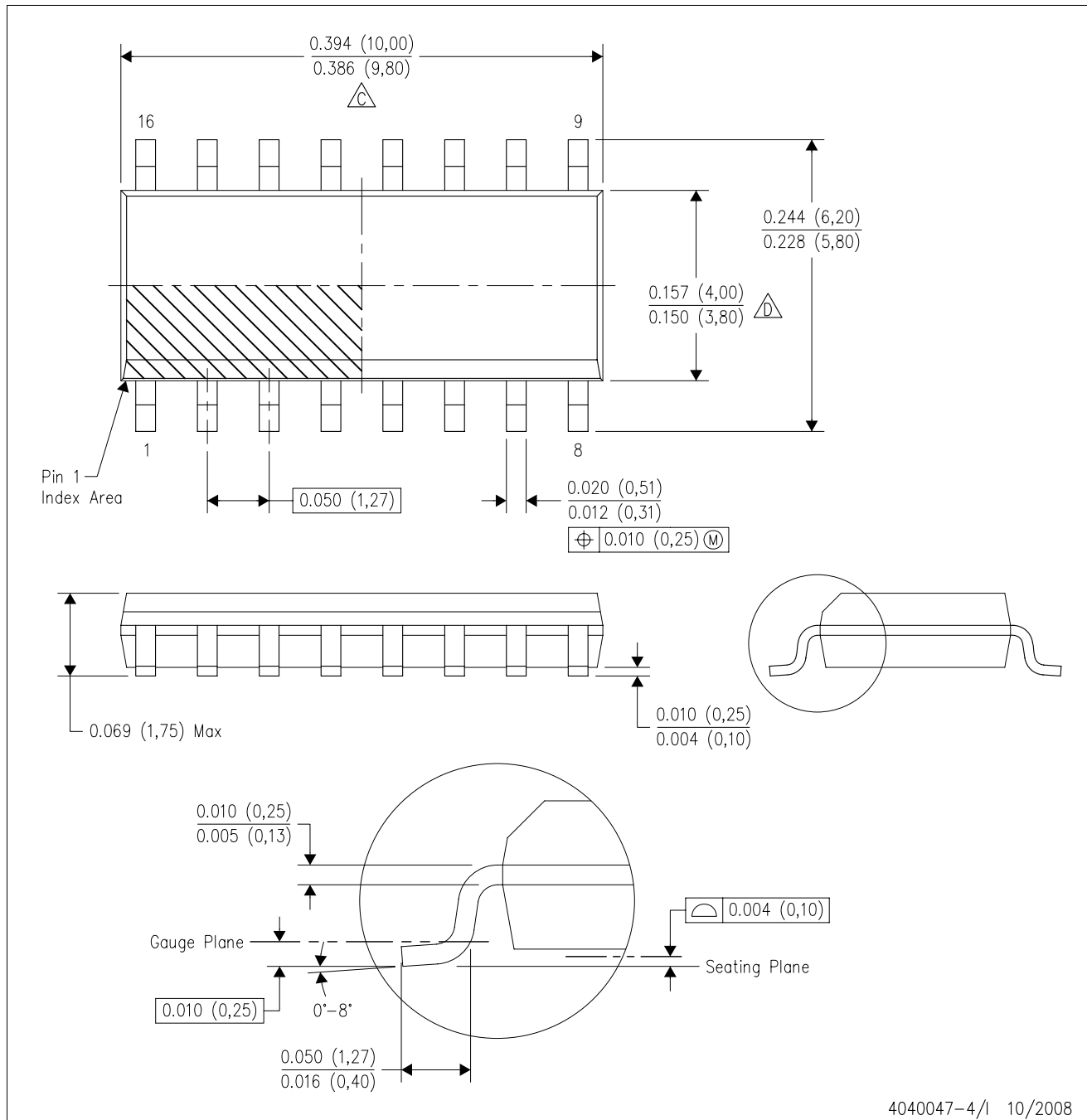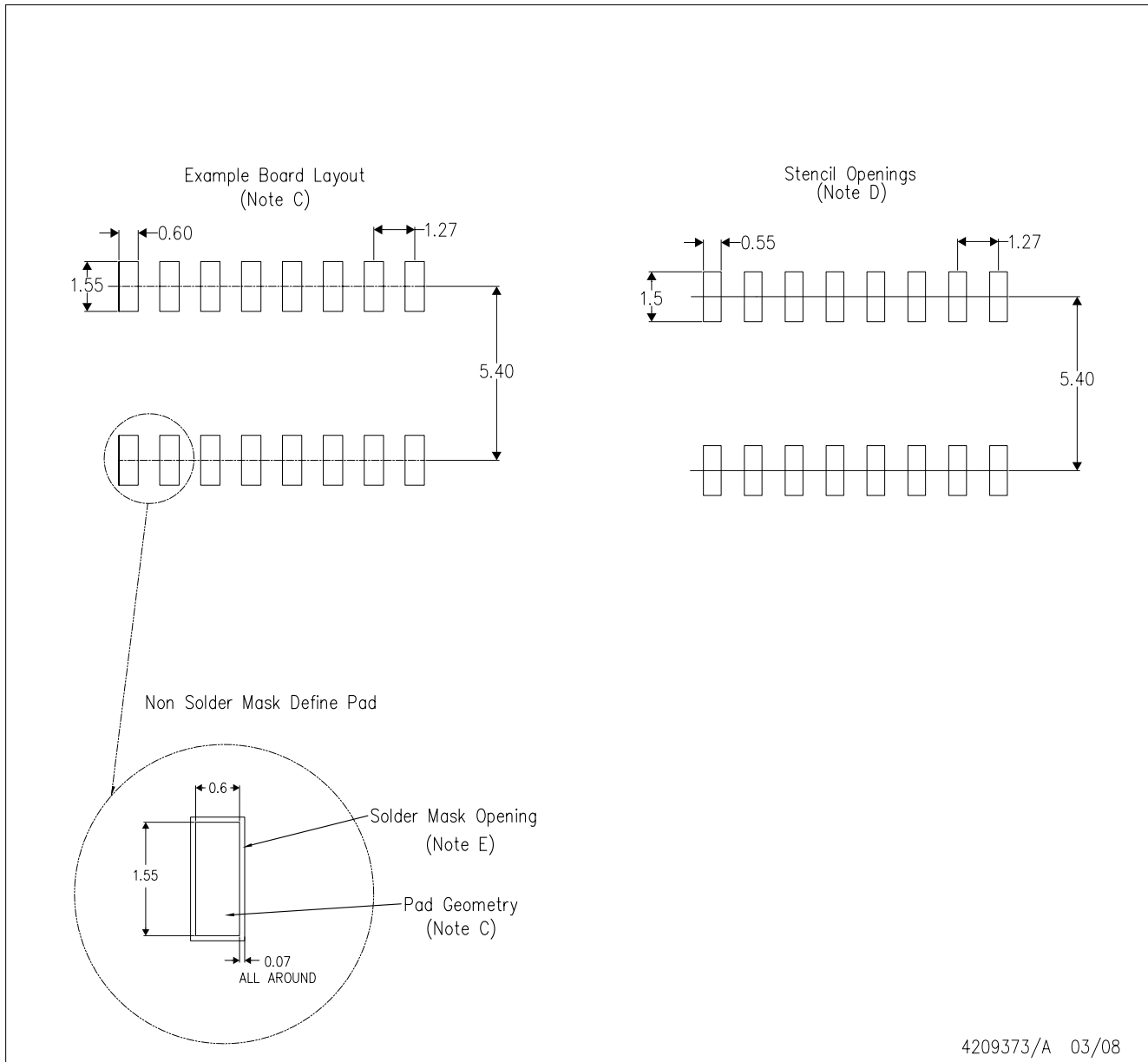D (R−PDSO−G16)   PLASTIC SMALL−OUTLINE PACKAGE

0.394 (10,00)
0.386 (9,80)
⚠C

16   9

0.244 (6,20)
0.228 (5,80)

0.157 (4,00)
0.150 (3,80) ⚠D

1   8

Pin 1
Index Area

0.050 (1,27)

0.020 (0,51)
0.012 (0,31)

⊕ | 0.010 (0,25) Ⓜ

0.069 (1,75) Max

0.010 (0,25)
0.004 (0,10)

0.010 (0,25)
0.005 (0,13)

0.004 (0,10)

Gauge Plane

Seating Plane

0.010 (0,25)   0°−8°

0.050 (1,27)
0.016 (0,40)

4040047−4/I 10/2008

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 AC.

TEXAS INSTRUMENTS
www.ti.com

D(R−PDSO−G16)

Example Board Layout
(Note C)

Stencil Openings
(Note D)

0.60

1.27

1.55

5.40

0.55

1.27

1.5

5.40

Non Solder Mask Define Pad

0.6

Solder Mask Opening
(Note E)

1.55

Pad Geometry
(Note C)

0.07
ALL AROUND

4209373/A 03/08

NOTES: A.   All linear dimensions are in millimeters.
         B.   This drawing is subject to change without notice.
         C.   Refer to IPC7351 for alternate board design.
         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
         E.   Customers should contact their board fabrication site for solder mask tolerances between and around signal pads.

IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, modifications, enhancements, improvements, and other changes to its products and services at any time and to discontinue any product or service without notice. Customers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All products are sold subject to TI's terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its hardware products to the specifications applicable at the time of sale in accordance with TI's standard warranty. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by government requirements, testing of all parameters of each product is not necessarily performed.

TI assumes no liability for applications assistance or customer product design. Customers are responsible for their products and applications using TI components. To minimize the risks associated with customer products and applications, customers should provide adequate design and operating safeguards.

TI does not warrant or represent that any license, either express or implied, is granted under any TI patent right, copyright, mask work right, or other TI intellectual property right relating to any combination, machine, or process in which TI products or services are used. Information published by TI regarding third-party products or services does not constitute a license from TI to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

Reproduction of TI information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. Reproduction of this information with alteration is an unfair and deceptive business practice. TI is not responsible or liable for such altered documentation. Information of third parties may be subject to additional restrictions.

Resale of TI products or services with statements different from or beyond the parameters stated by TI for that product or service voids all express and any implied warranties for the associated TI product or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

TI products are not authorized for use in safety-critical applications (such as life support) where a failure of the TI product would reasonably be expected to cause severe personal injury or death, unless officers of the parties have executed an agreement specifically governing such use. Buyers represent that they have all necessary expertise in the safety and regulatory ramifications of their applications, and acknowledge and agree that they are solely responsible for all legal, regulatory and safety-related requirements concerning their products and any use of TI products in such safety-critical applications, notwithstanding any applications-related information or support that may be provided by TI. Further, Buyers must fully indemnify TI and its representatives against any damages arising out of the use of TI products in such safety-critical applications.

TI products are neither designed nor intended for use in military/aerospace applications or environments unless the TI products are specifically designated by TI as military-grade or "enhanced plastic." Only products designated by TI as military-grade meet military specifications. Buyers acknowledge and agree that any such use of TI products which TI has not designated as military-grade is solely at the Buyer's risk, and that they are solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI products are neither designed nor intended for use in automotive applications or environments unless the specific TI products are designated by TI as compliant with ISO/TS 16949 requirements. Buyers acknowledge and agree that, if they use any non-designated products in automotive applications, TI will not be responsible for any failure to meet such requirements.

Following are URLs where you can obtain information on other Texas Instruments products and application solutions:

Products		**Applications**	
Amplifiers	amplifier.ti.com	Audio	www.ti.com/audio
Data Converters	dataconverter.ti.com	Automotive	www.ti.com/automotive
DSP	dsp.ti.com	Broadband	www.ti.com/broadband
Clocks and Timers	www.ti.com/clocks	Digital Control	www.ti.com/digitalcontrol
Interface	interface.ti.com	Medical	www.ti.com/medical
Logic	logic.ti.com	Military	www.ti.com/military
Power Mgmt	power.ti.com	Optical Networking	www.ti.com/opticalnetwork
Microcontrollers	microcontroller.ti.com	Security	www.ti.com/security
RFID	www.ti-rfid.com	Telephony	www.ti.com/telephony
RF/IF and ZigBee® Solutions	www.ti.com/lprf	Video & Imaging	www.ti.com/video
		Wireless	www.ti.com/wireless

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265
Copyright © 2008, Texas Instruments Incorporated