

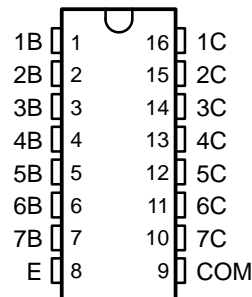
# ULN2001A, ULN2002A, ULN2003A, ULN2004A, ULQ2003A, ULQ2004A HIGH-VOLTAGE HIGH-CURRENT DARLINGTON TRANSISTOR ARRAY

SLRS027F – DECEMBER 1976 – REVISED FEBRUARY 2003

The ULN2001A is obsolete  
and is no longer supplied.

- 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
- Designed to Be Interchangeable With Sprague ULN2001A Series

ULN2001A . . . D OR N PACKAGE  
ULN2002A . . . N PACKAGE  
ULN2003A, ULN2004A . . . D, N, OR NS PACKAGE  
ULQ2003A, ULQ2004A . . . D OR N PACKAGE  
(TOP VIEW)



## description/ordering information

The ULN2001A, ULN2002A, ULN2003A, ULN2004A, ULQ2003A, and ULQ2004A are high-voltage, high-current Darlington transistor arrays. Each 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. For 100-V (otherwise interchangeable) versions of the ULN2003A and ULN2004A, see the SN75468 and SN75469, respectively.

## ORDERING INFORMATION

T <sub>A</sub>	PACKAGE†		ORDERABLE PART NUMBER	TOP-SIDE MARKING
-20°C to 70°C	PDIP (N)	Tube of 25	ULN2002AN	ULN2002AN
			ULN2003AN	ULN2003AN
			ULN2004AN	ULN2004AN
	SOIC (D)	Tube of 40	ULN2003AD	ULN2003A
			ULN2003ADR	
		Reel of 2500	ULN2004AD	ULN2004A
			ULN2004ADR	
	SOP (NS)	Reel of 2000	ULN2003ANSR	ULN2003A
ULN2004ANSR			ULN2004A	
-40°C to 85°C	PDIP (N)	Tube of 25	ULQ2003AN	ULQ2003A
			ULQ2004AN	ULQ2004AN
	SOIC (D)	Tube of 40	ULQ2003AD	ULQ2003A
			ULQ2003ADR	ULQ2003A
		Reel of 2500	ULQ2004AD	ULQ2004A
			ULQ2004ADR	ULQ2004A

† 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).



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 **TEXAS  
INSTRUMENTS**

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# ULN2001A, ULN2002A, ULN2003A, ULN2004A, ULQ2003A, ULQ2004A HIGH-VOLTAGE HIGH-CURRENT DARLINGTON TRANSISTOR ARRAY

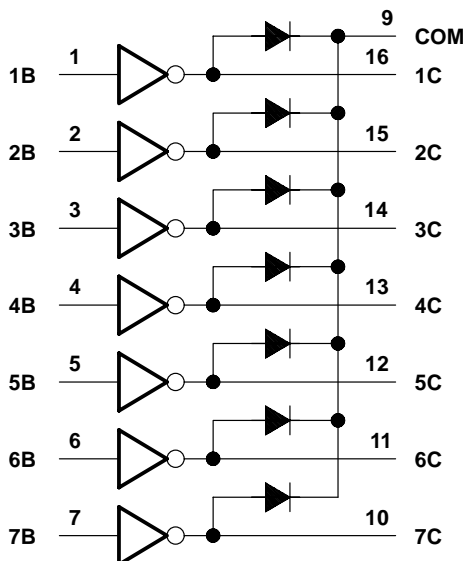
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The ULN2001A is obsolete  
and is no longer supplied.

## description/ordering information (continued)

The ULN2001A is a general-purpose array and can be used with TTL and CMOS technologies. The ULN2002A is designed specifically for use with 14-V to 25-V PMOS devices. Each input of this device has a Zener diode and resistor in series to control the input current to a safe limit. The ULN2003A and ULQ2003A have a 2.7-k $\Omega$  series base resistor for each Darlington pair for operation directly with TTL or 5-V CMOS devices. The ULN2004A and ULQ2004A have a 10.5-k $\Omega$  series base resistor to allow operation directly from CMOS devices that use supply voltages of 6 V to 15 V. The required input current of the ULN/ULQ2004A is below that of the ULN/ULQ2003A, and the required voltage is less than that required by the ULN2002A.

## logic diagram

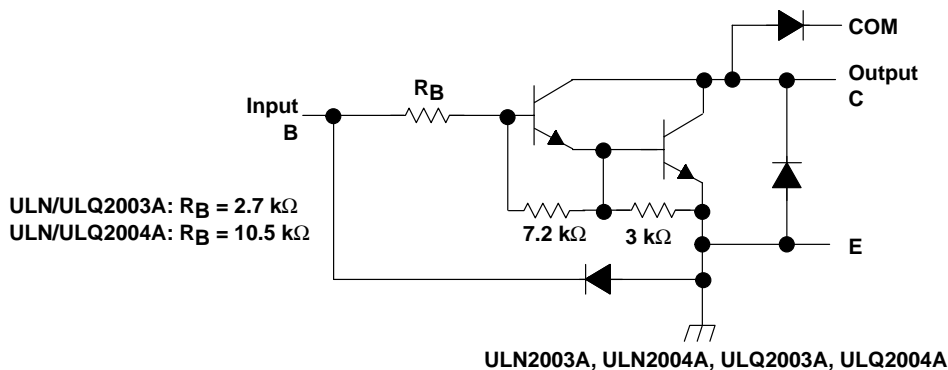
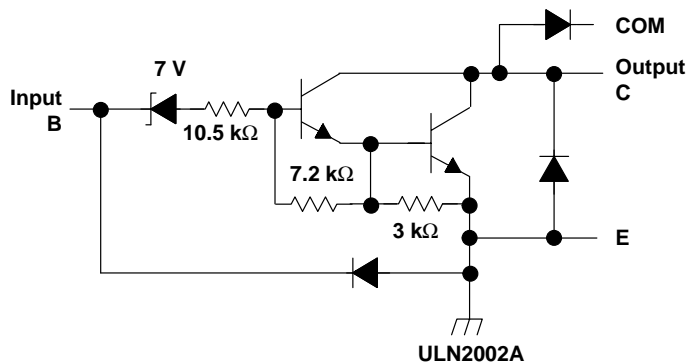
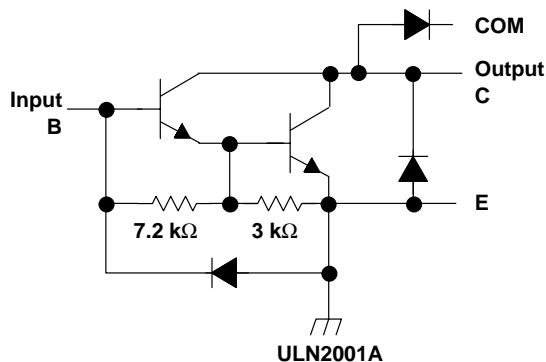


# ULN2001A, ULN2002A, ULN2003A, ULN2004A, ULQ2003A, ULQ2004A HIGH-VOLTAGE HIGH-CURRENT DARLINGTON TRANSISTOR ARRAY

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## schematics (each Darlington pair)



All resistor values shown are nominal.

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## absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)†

Collector-emitter voltage	50 V
Clamp diode reverse voltage (see Note 1)	50 V
Input voltage, $V_I$ (see Note 1)	30 V
Peak collector current (see Figures 14 and 15)	500 mA
Output clamp current, $I_{OK}$	500 mA
Total emitter-terminal current	-2.5 A
Operating free-air temperature range, $T_A$ , ULN200xA	-20°C to 70°C
ULQ200xA	-40°C to 85°C
ULQ200xAT	-40°C to 105°C
Package thermal impedance, $\theta_{JA}$ (see Notes 2 and 3): D package	73°C/W
N package	67°C/W
NS package	64°C/W
Package thermal impedance, $\theta_{JC}$ (see Notes 4 and 5): D package	36°C/W
N package	54°C/W
Operating virtual junction temperature, $T_J$	150°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds	260°C
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:
- All voltage values are with respect to the emitter/substrate terminal E, unless otherwise noted.
  - Maximum power dissipation is a function of  $T_J(\max)$ ,  $\theta_{JA}$ , and  $T_A$ . The maximum allowable power dissipation at any allowable ambient temperature is  $P_D = (T_J(\max) - T_A)/\theta_{JA}$ . Operating at the absolute maximum  $T_J$  of 150°C can affect reliability.
  - The package thermal impedance is calculated in accordance with JESD 51-7.
  - Maximum power dissipation is a function of  $T_J(\max)$ ,  $\theta_{JC}$ , and  $T_C$ . The maximum allowable power dissipation at any allowable case temperature is  $P_D = (T_J(\max) - T_C)/\theta_{JC}$ . Operating at the absolute maximum  $T_J$  of 150°C can affect reliability.
  - The package thermal impedance is calculated in accordance with MIL-STD-883.

## electrical characteristics, $T_A = 25^\circ\text{C}$ (unless otherwise noted)

PARAMETER	TEST FIGURE	TEST CONDITIONS	ULN2001A			ULN2002A			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
$V_{I(on)}$ On-state input voltage	6	$V_{CE} = 2\text{ V}$ , $I_C = 300\text{ mA}$						13	V
$V_{CE(sat)}$ Collector-emitter saturation voltage	5	$I_I = 250\ \mu\text{A}$ , $I_C = 100\text{ mA}$		0.9	1.1		0.9	1.1	V
		$I_I = 350\ \mu\text{A}$ , $I_C = 200\text{ mA}$		1	1.3		1	1.3	
		$I_I = 500\ \mu\text{A}$ , $I_C = 350\text{ mA}$		1.2	1.6		1.2	1.6	
$V_F$ Clamp forward voltage	8	$I_F = 350\text{ mA}$		1.7	2		1.7	2	V
$I_{CEX}$ Collector cutoff current	1	$V_{CE} = 50\text{ V}$ , $I_I = 0$			50			50	$\mu\text{A}$
	2	$V_{CE} = 50\text{ V}$ , $T_A = 70^\circ\text{C}$ , $I_I = 0$ , $V_I = 6\text{ V}$			100			100	
								500	
$I_{I(off)}$ Off-state input current	3	$V_{CE} = 50\text{ V}$ , $T_A = 70^\circ\text{C}$ , $I_C = 500\ \mu\text{A}$	50	65		50	65		$\mu\text{A}$
$I_I$ Input current	4	$V_I = 17\text{ V}$					0.82	1.25	mA
$I_R$ Clamp reverse current	7	$V_R = 50\text{ V}$ , $T_A = 70^\circ\text{C}$			100			100	$\mu\text{A}$
		$V_R = 50\text{ V}$			50			50	
$h_{FE}$ Static forward-current transfer ratio	5	$V_{CE} = 2\text{ V}$ , $I_C = 350\text{ mA}$	1000						
$C_i$ Input capacitance		$V_I = 0$ , $f = 1\text{ MHz}$		15	25		15	25	pF



**ULN2001A, ULN2002A, ULN2003A, ULN2004A, ULQ2003A, ULQ2004A  
HIGH-VOLTAGE HIGH-CURRENT DARLINGTON  
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**electrical characteristics,  $T_A = 25^\circ\text{C}$  (unless otherwise noted) (continued)**

PARAMETER	TEST FIGURE	TEST CONDITIONS		ULN2003A			ULN2004A			UNIT
				MIN	TYP	MAX	MIN	TYP	MAX	
$V_{I(on)}$ On-state input voltage	6	$V_{CE} = 2\text{ V}$	$I_C = 125\text{ mA}$						5	V
			$I_C = 200\text{ mA}$			2.4			6	
			$I_C = 250\text{ mA}$			2.7				
			$I_C = 275\text{ mA}$						7	
			$I_C = 300\text{ mA}$			3				
			$I_C = 350\text{ mA}$						8	
$V_{CE(sat)}$ Collector-emitter saturation voltage	5	$I_I = 250\ \mu\text{A}$ , $I_C = 100\text{ mA}$		0.9	1.1	0.9	1.1		V	
		$I_I = 350\ \mu\text{A}$ , $I_C = 200\text{ mA}$		1	1.3	1	1.3			
		$I_I = 500\ \mu\text{A}$ , $I_C = 350\text{ mA}$		1.2	1.6	1.2	1.6			
$I_{CEX}$ Collector cutoff current	1	$V_{CE} = 50\text{ V}$ , $I_I = 0$			50			50	$\mu\text{A}$	
	2	$V_{CE} = 50\text{ V}$ , $T_A = 70^\circ\text{C}$ , $V_I = 1\text{ V}$			100			100		
$V_F$ Clamp forward voltage	8	$I_F = 350\text{ mA}$		1.7	2	1.7	2		V	
$I_{I(off)}$ Off-state input current	3	$V_{CE} = 50\text{ V}$ , $T_A = 70^\circ\text{C}$ , $I_C = 500\ \mu\text{A}$	50	65		50	65		$\mu\text{A}$	
$I_I$ Input current	4	$V_I = 3.85\text{ V}$		0.93	1.35				mA	
		$V_I = 5\text{ V}$				0.35	0.5			
		$V_I = 12\text{ V}$				1	1.45			
$I_R$ Clamp reverse current	7	$V_R = 50\text{ V}$			50			50	$\mu\text{A}$	
		$V_R = 50\text{ V}$ , $T_A = 70^\circ\text{C}$			100			100		
$C_i$ Input capacitance		$V_I = 0$ , $f = 1\text{ MHz}$		15	25	15	25		pF	



# ULN2001A, ULN2002A, ULN2003A, ULN2004A, ULQ2003A, ULQ2004A HIGH-VOLTAGE HIGH-CURRENT DARLINGTON TRANSISTOR ARRAY

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The ULN2001A is obsolete  
and is no longer supplied.

## electrical characteristics over recommended operating conditions (unless otherwise noted)

PARAMETER	TEST FIGURE	TEST CONDITIONS	ULQ2003A			ULQ2004A			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
V <sub>I(on)</sub> On-state input voltage	6	V <sub>CE</sub> = 2 V	I <sub>C</sub> = 125 mA					5	V
			I <sub>C</sub> = 200 mA					6	
			I <sub>C</sub> = 250 mA					2.7	
			I <sub>C</sub> = 275 mA					2.9	
			I <sub>C</sub> = 300 mA					7	
			I <sub>C</sub> = 350 mA					3	
								8	
V <sub>CE(sat)</sub> Collector-emitter saturation voltage	5	I <sub>I</sub> = 250 μA, I <sub>C</sub> = 100 mA		0.9	1.2		0.9	1.1	V
		I <sub>I</sub> = 350 μA, I <sub>C</sub> = 200 mA		1	1.4		1	1.3	
		I <sub>I</sub> = 500 μA, I <sub>C</sub> = 350 mA		1.2	1.7		1.2	1.6	
I <sub>CEX</sub> Collector cutoff current	1	V <sub>CE</sub> = 50 V, I <sub>I</sub> = 0						100	μA
	2	V <sub>CE</sub> = 50 V	I <sub>I</sub> = 0					100	
			V <sub>I</sub> = 1 V					500	
V <sub>F</sub> Clamp forward voltage	8	I <sub>F</sub> = 350 mA		1.7	2.3		1.7	2	V
I <sub>I(off)</sub> Off-state input current	3	V <sub>CE</sub> = 50 V, I <sub>C</sub> = 500 μA		65			50	65	μA
I <sub>I</sub> Input current	4	V <sub>I</sub> = 3.85 V		0.93	1.35				mA
		V <sub>I</sub> = 5 V					0.35	0.5	
		V <sub>I</sub> = 12 V					1	1.45	
I <sub>R</sub> Clamp reverse current	7	V <sub>R</sub> = 50 V, T <sub>A</sub> = 25°C			100			50	μA
		V <sub>R</sub> = 50 V			100			100	
C <sub>i</sub> Input capacitance		V <sub>I</sub> = 0, f = 1 MHz		15	25		15	25	pF

## switching characteristics, T<sub>A</sub> = 25°C

PARAMETER	TEST CONDITIONS	ULN2001A, ULN2002A, ULN2003A, ULN2004A			UNIT
		MIN	TYP	MAX	
t <sub>PLH</sub> Propagation delay time, low- to high-level output	See Figure 9		0.25	1	μs
t <sub>PHL</sub> Propagation delay time, high- to low-level output	See Figure 9		0.25	1	μs
V <sub>OH</sub> High-level output voltage after switching	V <sub>S</sub> = 50 V, I <sub>O</sub> ≈ 300 mA, See Figure 10		V <sub>S</sub> -20		mV

## switching characteristics over recommended operating conditions (unless otherwise noted)

PARAMETER	TEST CONDITIONS	ULQ2003A, ULQ2004A			UNIT
		MIN	TYP	MAX	
t <sub>PLH</sub> Propagation delay time, low- to high-level output	See Figure 9		1	10	μs
t <sub>PHL</sub> Propagation delay time, high- to low-level output	See Figure 9		1	10	μs
V <sub>OH</sub> High-level output voltage after switching	V <sub>S</sub> = 50 V, I <sub>O</sub> ≈ 300 mA, See Figure 10		V <sub>S</sub> -500		mV



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**PARAMETER MEASUREMENT INFORMATION**

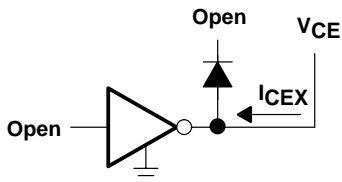


Figure 1.  $I_{CEX}$  Test Circuit

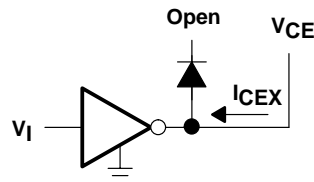


Figure 2.  $I_{CEX}$  Test Circuit

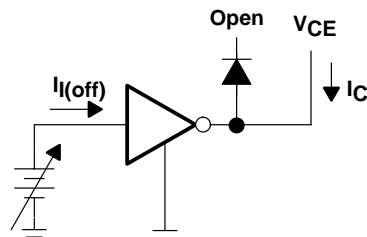


Figure 3.  $I_{I(off)}$  Test Circuit

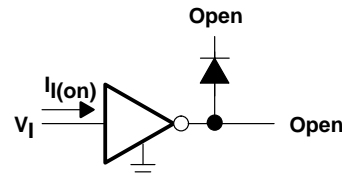
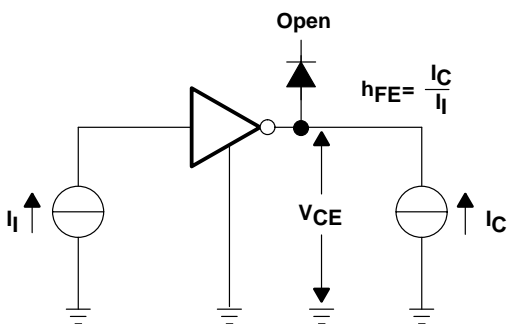


Figure 4.  $I_I$  Test Circuit



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

Figure 5.  $h_{FE}$ ,  $V_{CE(sat)}$  Test Circuit

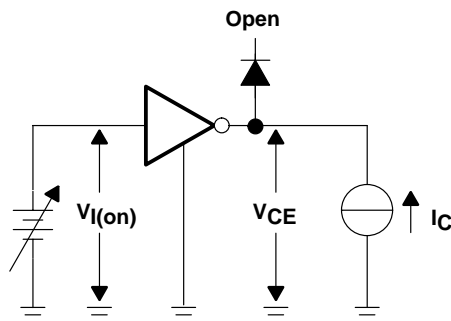


Figure 6.  $V_{I(on)}$  Test Circuit

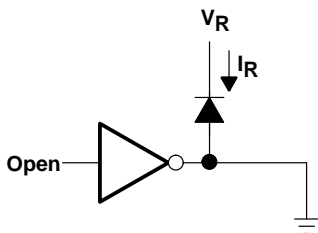


Figure 7.  $I_R$  Test Circuit

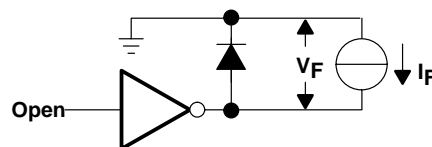


Figure 8.  $V_F$  Test Circuit

# ULN2001A, ULN2002A, ULN2003A, ULN2004A, ULQ2003A, ULQ2004A HIGH-VOLTAGE HIGH-CURRENT DARLINGTON TRANSISTOR ARRAY

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## PARAMETER MEASUREMENT INFORMATION

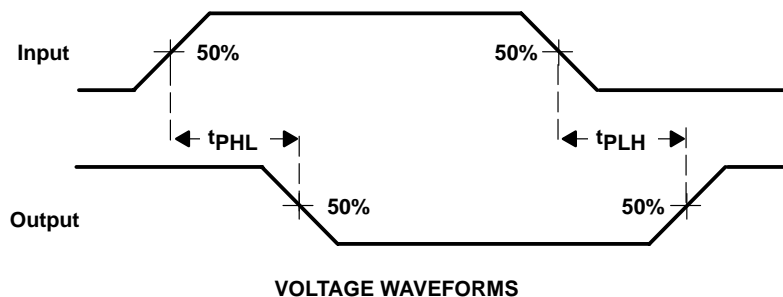
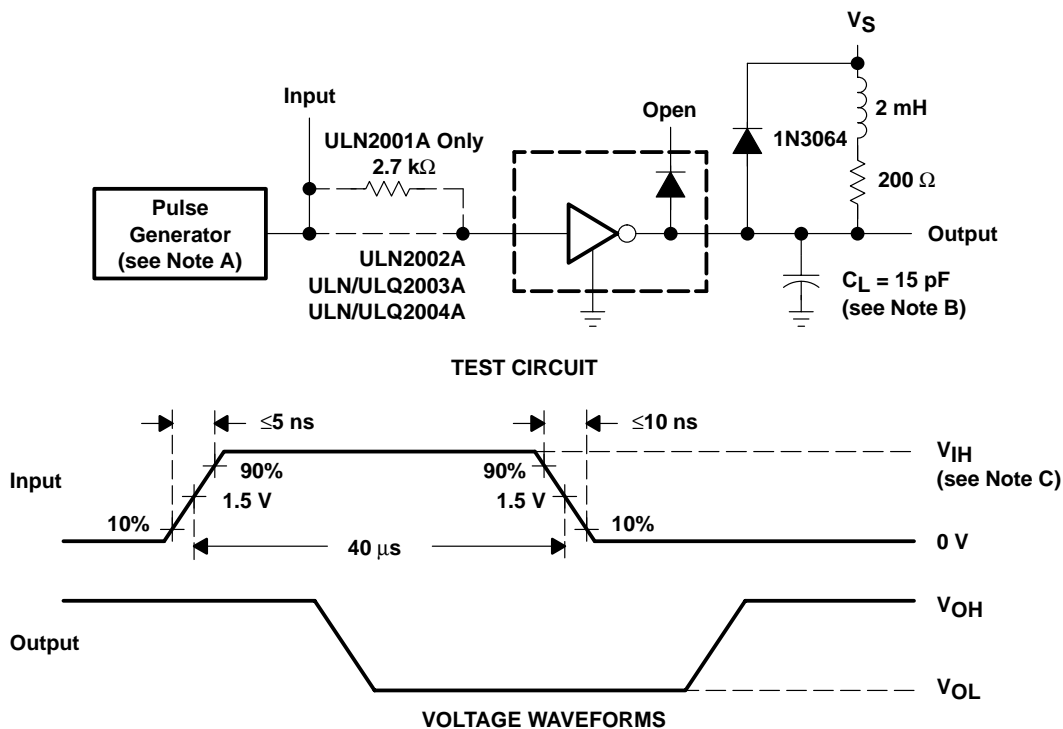


Figure 9. Propagation Delay-Time Waveforms



- NOTES: A. The pulse generator has the following characteristics: PRR = 12.5 kHz,  $Z_O = 50 \Omega$ .  
 B.  $C_L$  includes probe and jig capacitance.  
 C. For testing the ULN2001A, the ULN2003A, and the ULQ2003A,  $V_{IH} = 3 \text{ V}$ ; for the ULN2002A,  $V_{IH} = 13 \text{ V}$ ; for the ULN2004A and the ULQ2004A,  $V_{IH} = 8 \text{ V}$ .

Figure 10. Latch-Up Test Circuit and Voltage Waveforms

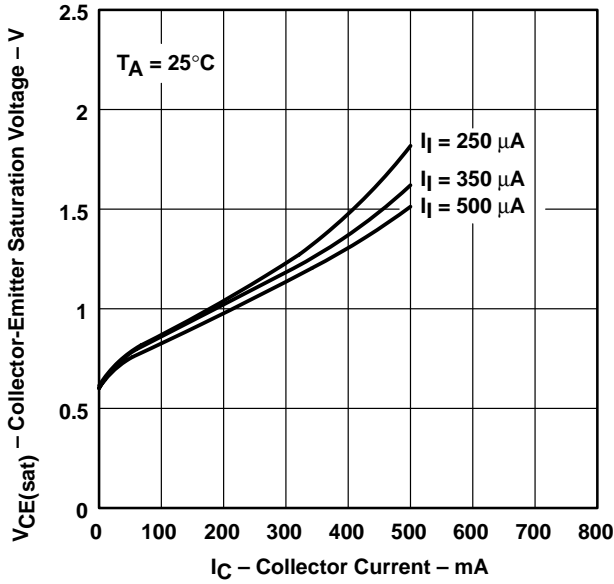


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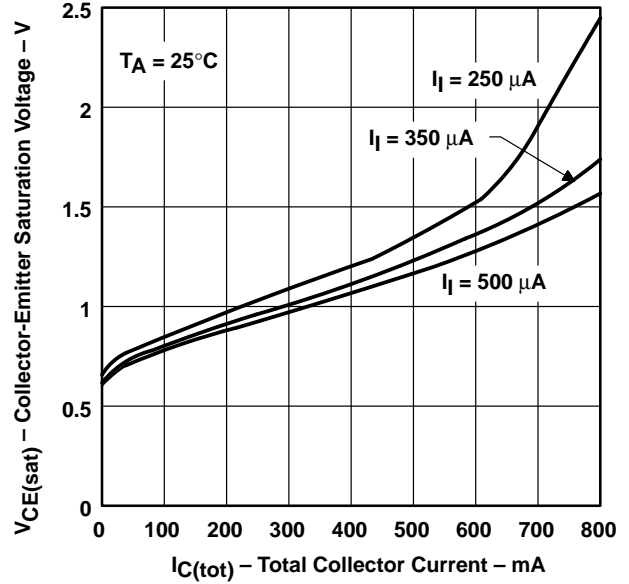
**TYPICAL CHARACTERISTICS**

**COLLECTOR-EMITTER  
 SATURATION VOLTAGE  
 vs  
 COLLECTOR CURRENT  
 (ONE DARLINGTON)**



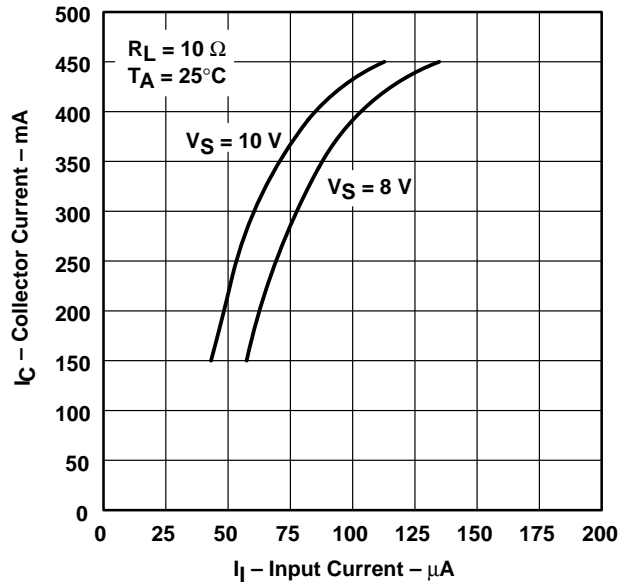
**Figure 11**

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



**Figure 12**

**COLLECTOR CURRENT  
 vs  
 INPUT CURRENT**



**Figure 13**

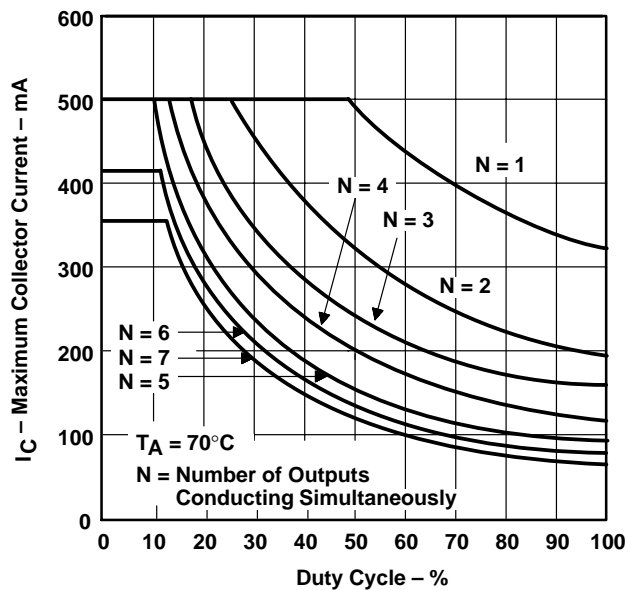
**ULN2001A, ULN2002A, ULN2003A, ULN2004A, ULQ2003A, ULQ2004A**  
**HIGH-VOLTAGE HIGH-CURRENT DARLINGTON**  
**TRANSISTOR ARRAY**

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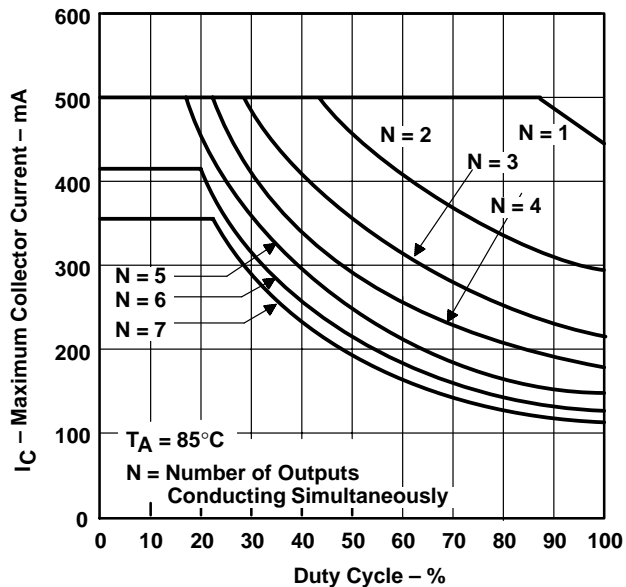
**THERMAL INFORMATION**

**D PACKAGE**  
**MAXIMUM COLLECTOR CURRENT**  
**vs**  
**DUTY CYCLE**



**Figure 14**

**N PACKAGE**  
**MAXIMUM COLLECTOR CURRENT**  
**vs**  
**DUTY CYCLE**



**Figure 15**

# ULN2001A, ULN2002A, ULN2003A, ULN2004A, ULQ2003A, ULQ2004A HIGH-VOLTAGE HIGH-CURRENT DARLINGTON TRANSISTOR ARRAY

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## APPLICATION INFORMATION

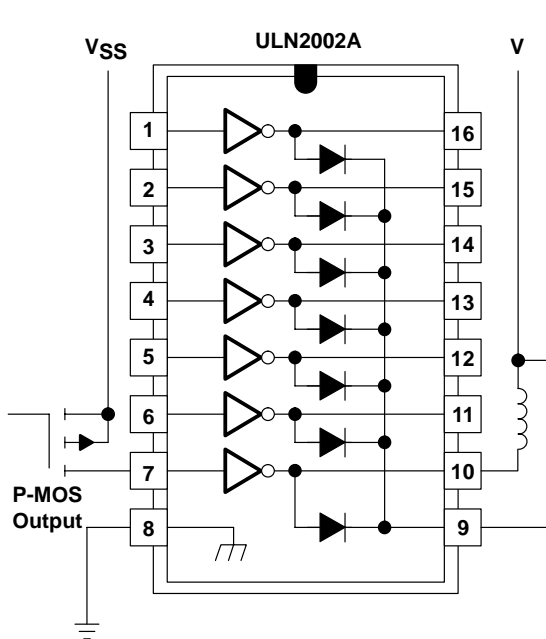


Figure 16. P-MOS to Load

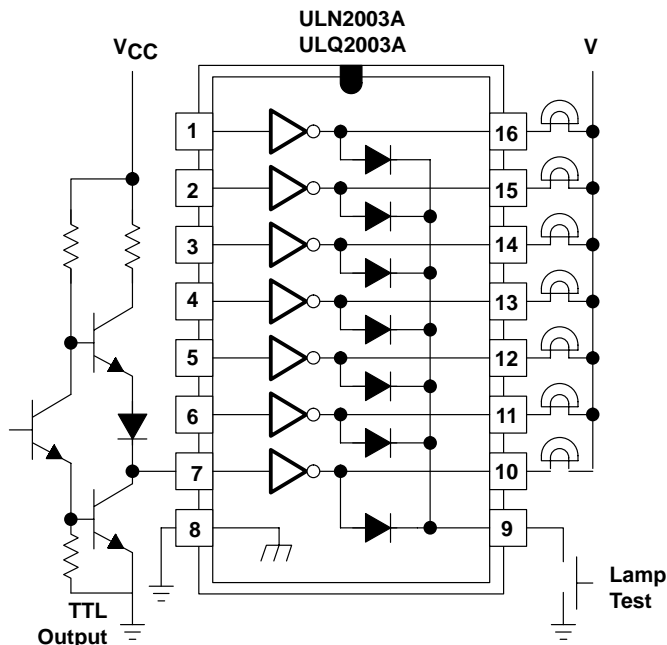


Figure 17. TTL to Load

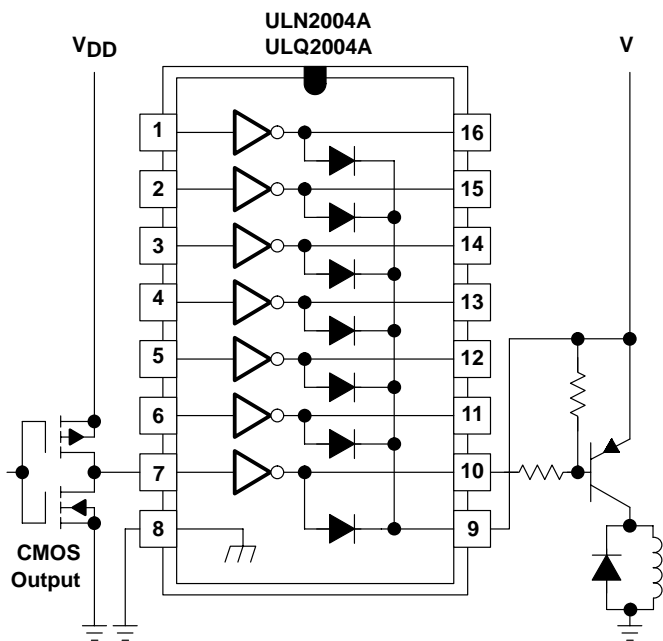


Figure 18. Buffer for Higher Current Loads

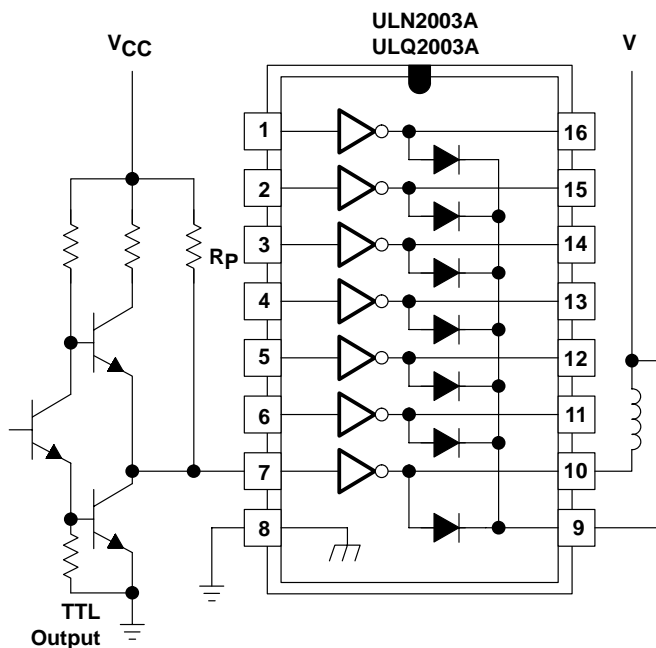
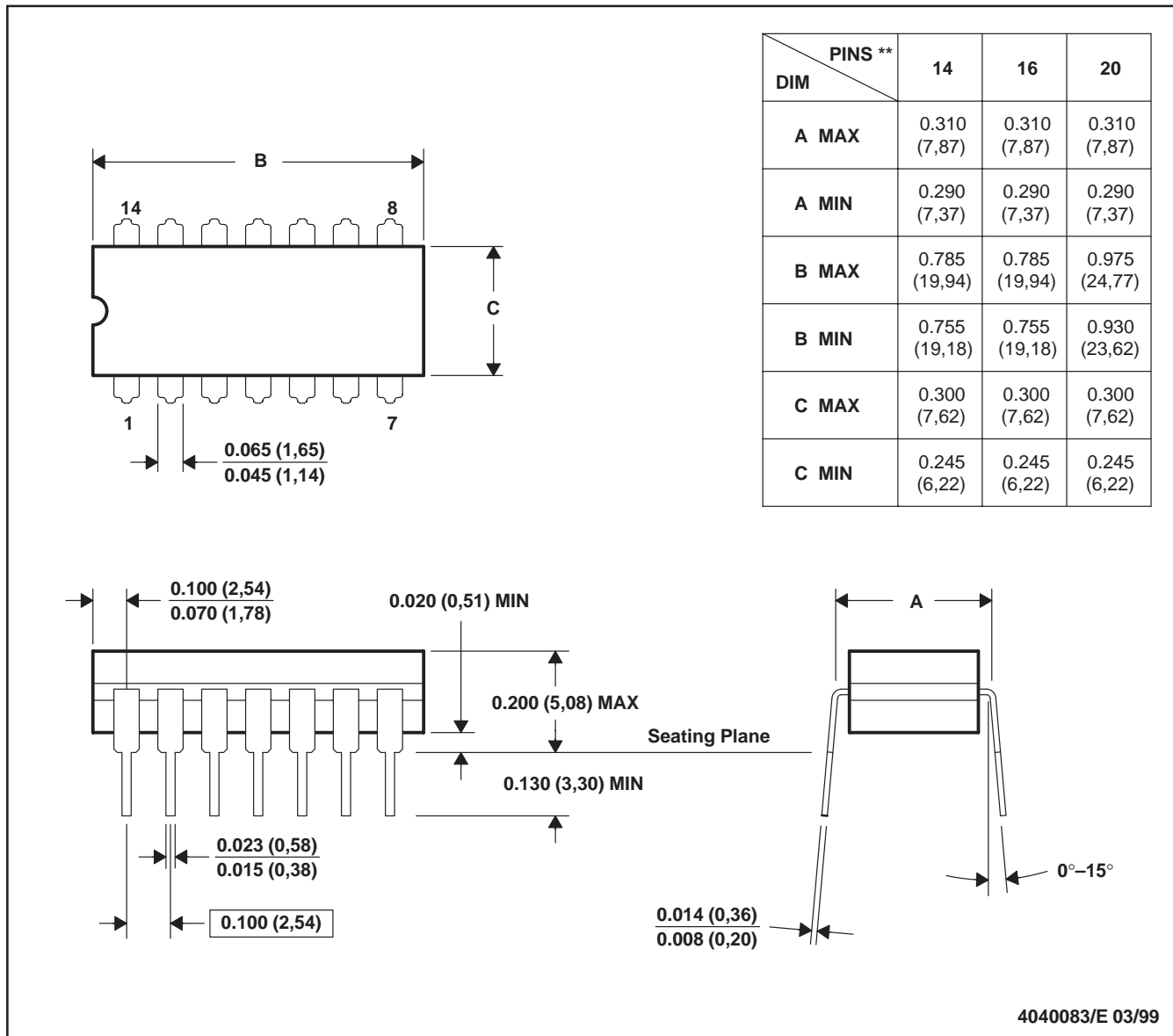


Figure 19. Use of Pullup Resistors  
to Increase Drive Current

J (R-GDIP-T\*\*)

CERAMIC DUAL-IN-LINE

14 LEADS SHOWN

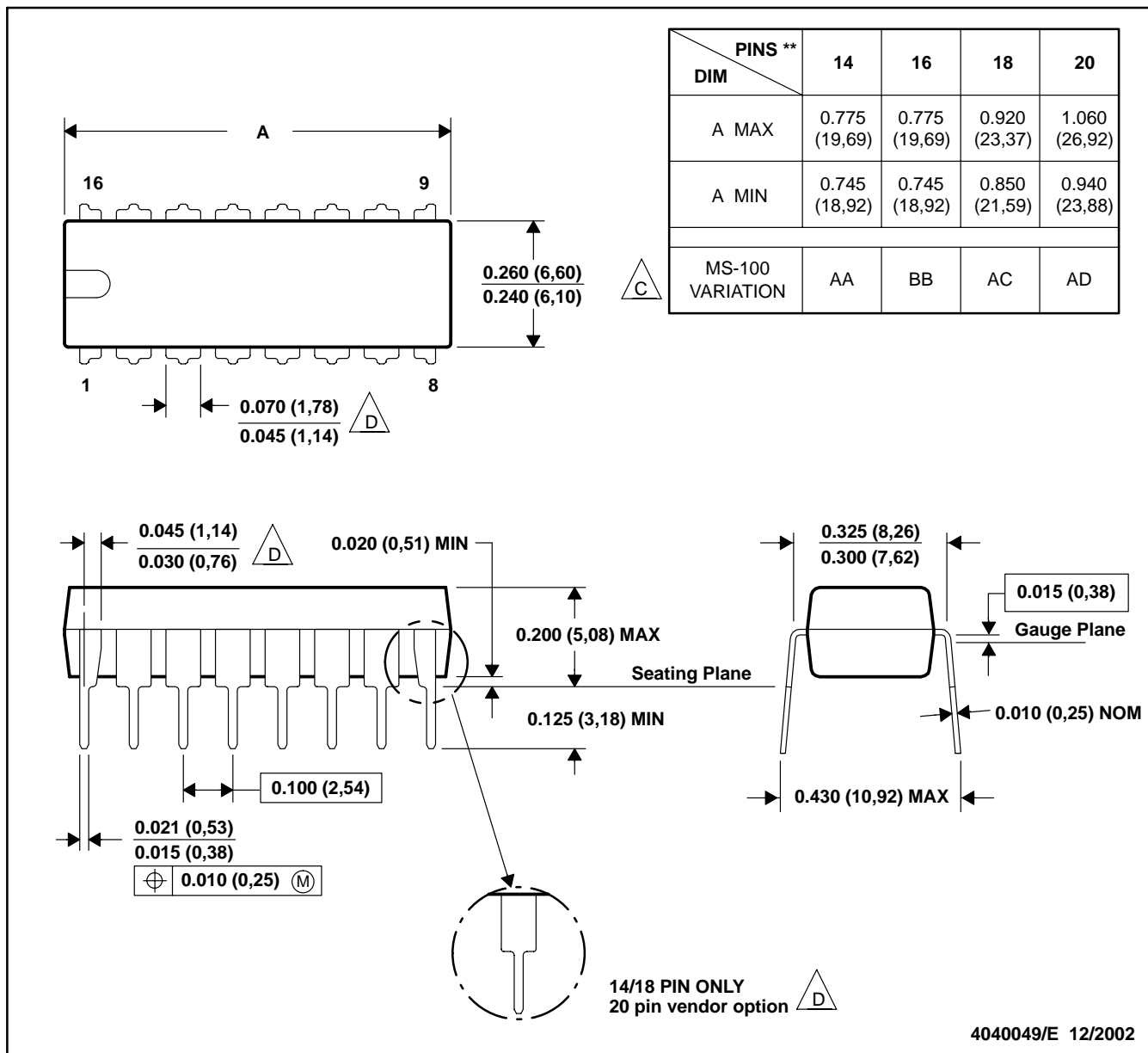


- NOTES: A. All linear dimensions are in inches (millimeters).  
 B. This drawing is subject to change without notice.  
 C. This package is hermetically sealed with a ceramic lid using glass frit.  
 D. Index point is provided on cap for terminal identification.  
 E. Falls within MIL STD 1835 GDIP1-T14, GDIP1-T16, and GDIP1-T20

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.  
 C Falls within JEDEC MS-001, except 18 and 20 pin minimum body length (Dim A).  
 D The 20 pin end lead shoulder width is a vendor option, either half or full width.

4040049/E 12/2002

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

PLASTIC SMALL-OUTLINE PACKAGE

8 PINS SHOWN



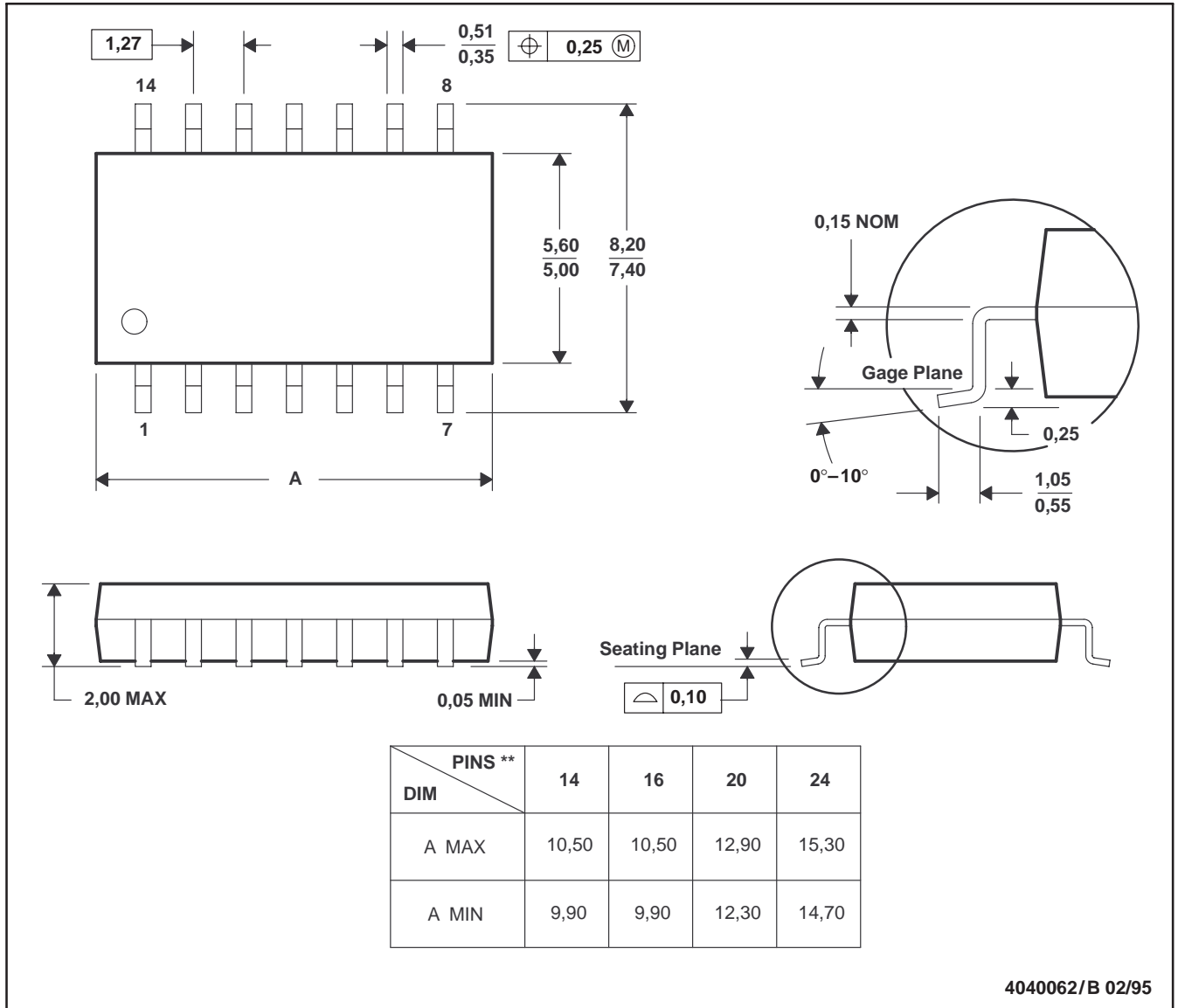
4040047/E 09/01

- 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).  
 D. Falls within JEDEC MS-012

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.

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