

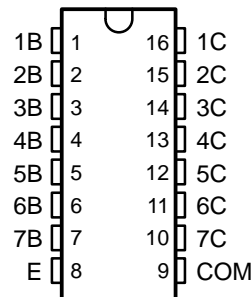
# ULN2001A, ULN2002A, ULN2003A, ULN2004A, ULQ2003A, ULQ2004A HIGH-VOLTAGE HIGH-CURRENT DARLINGTON TRANSISTOR ARRAY

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The ULN2001A is obsolete  
and is no longer supplied.

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

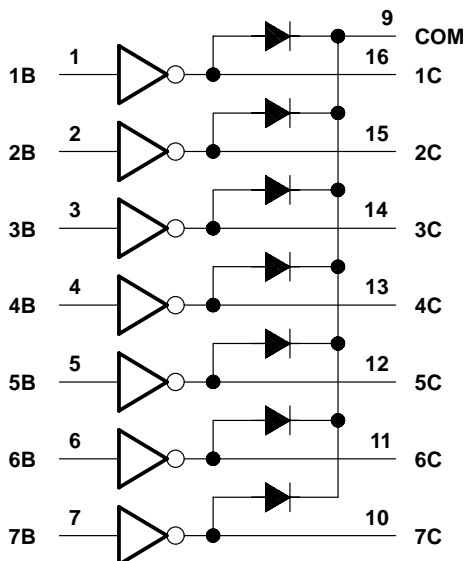
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and is no longer supplied.

## 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-kΩ 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-kΩ 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

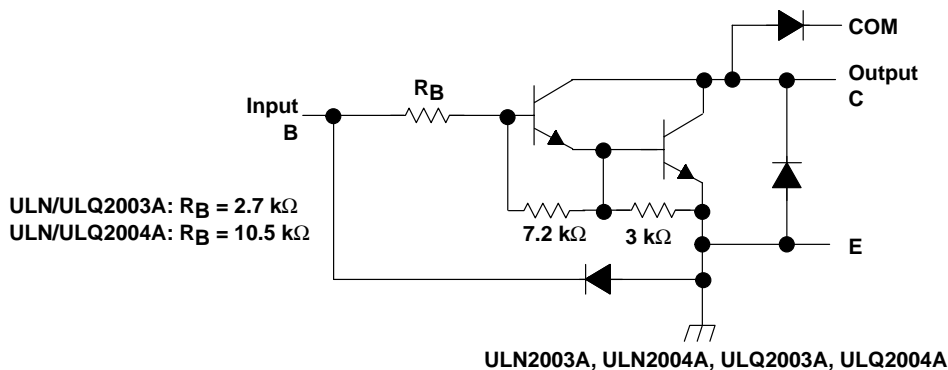
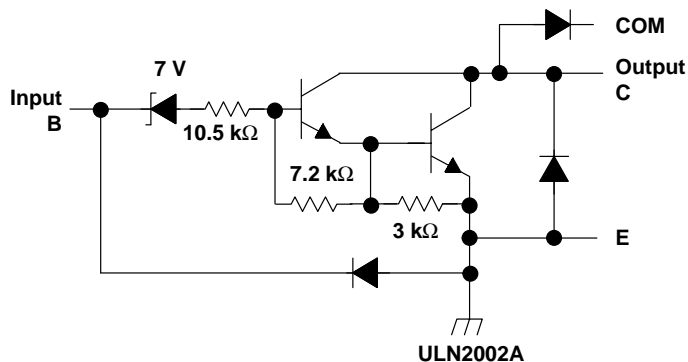
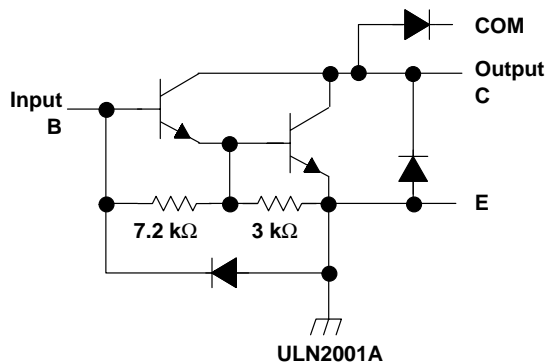


# ULN2001A, ULN2002A, ULN2003A, ULN2004A, ULQ2003A, ULQ2004A HIGH-VOLTAGE HIGH-CURRENT DARLINGTON TRANSISTOR ARRAY

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## schematics (each Darlington pair)



All resistor values shown are nominal.

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

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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 |               |
| $I_{I(off)}$ 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  
TRANSISTOR ARRAY**

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and is no longer supplied.

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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           | $V_{CE} = 50\text{ V}$ , $T_A = 70^\circ\text{C}$<br>$V_I = 1\text{ V}$       |                       |          | 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           | $V_{CE} = 50\text{ V}$ , $T_A = 70^\circ\text{C}$<br>$I_C = 500\ \mu\text{A}$ | 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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## 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  |          |      | 50   | 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**

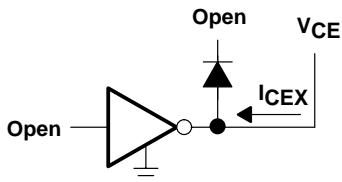


Figure 1.  $I_{CEX}$  Test Circuit

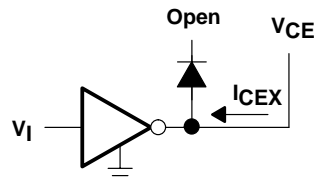


Figure 2.  $I_{CEX}$  Test Circuit

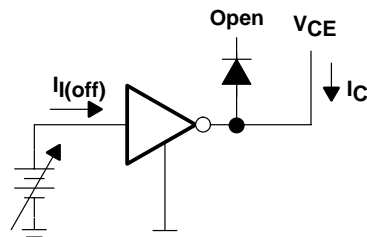


Figure 3.  $I_{I(off)}$  Test Circuit

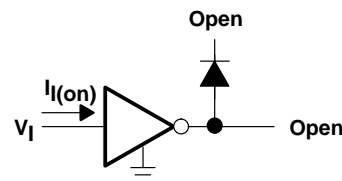
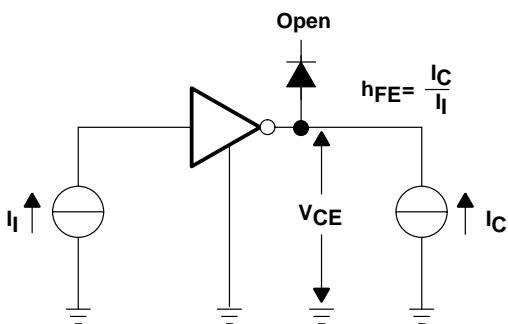


Figure 4.  $I_I$  Test Circuit



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

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

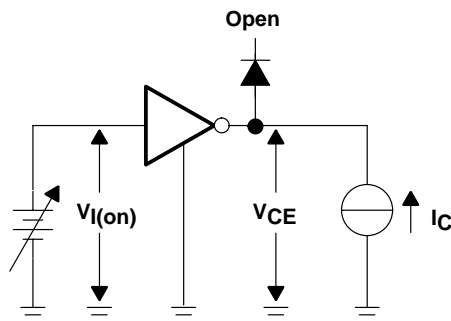


Figure 6.  $V_{I(on)}$  Test Circuit

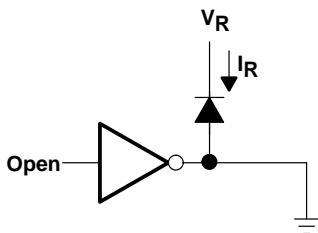


Figure 7.  $I_R$  Test Circuit

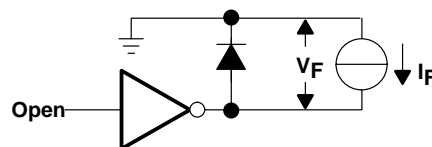


Figure 8.  $V_F$  Test Circuit

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

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## PARAMETER MEASUREMENT INFORMATION

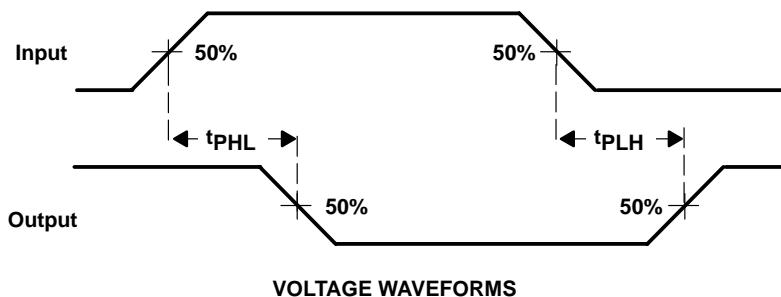
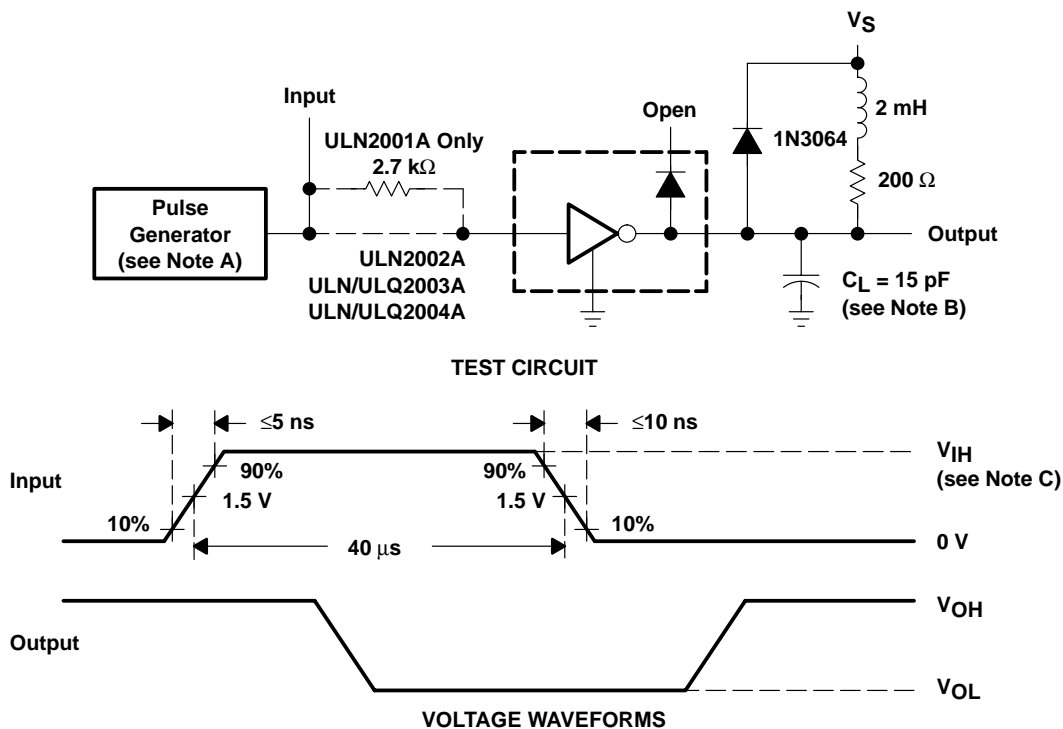


Figure 9. Propagation Delay-Time Waveforms



- 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,  $V_{IH} = 8 \text{ V}$ .

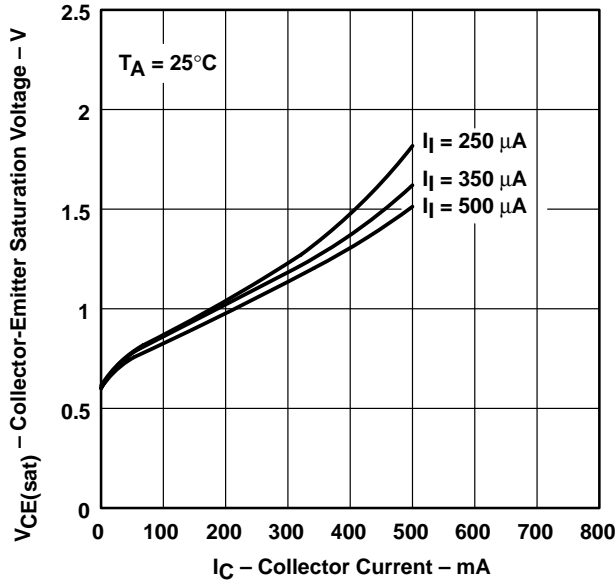
Figure 10. Latch-Up Test Circuit and Voltage Waveforms



The ULN2001A is obsolete  
 and is no longer supplied.

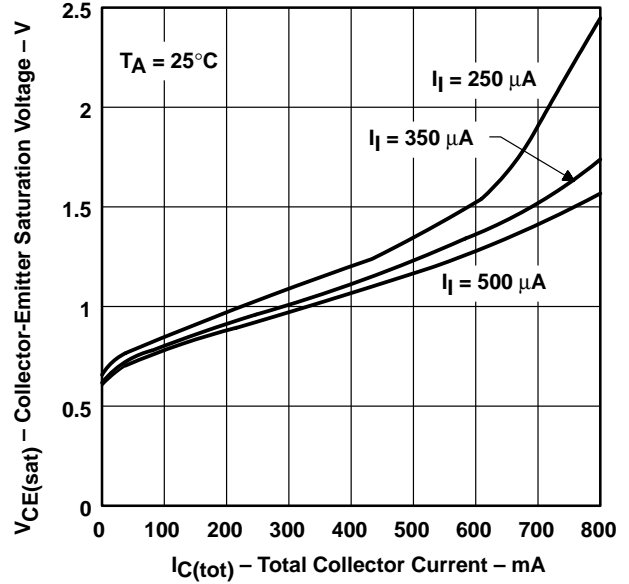
**TYPICAL CHARACTERISTICS**

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



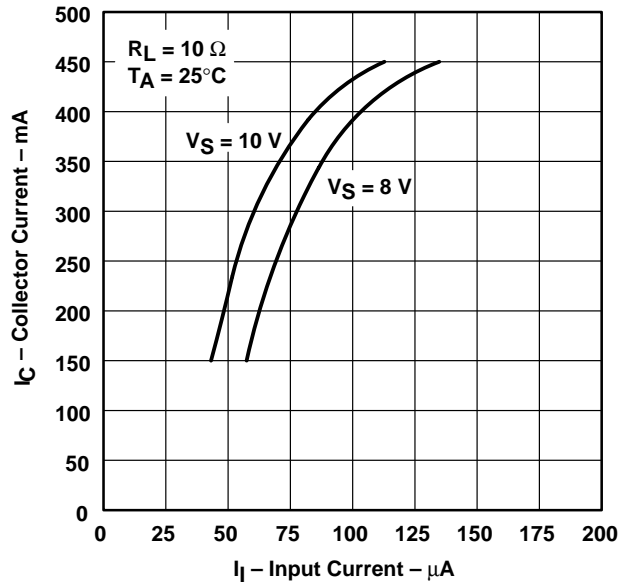
**Figure 11**

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



**Figure 12**

**COLLECTOR CURRENT  
 vs  
 INPUT CURRENT**



**Figure 13**

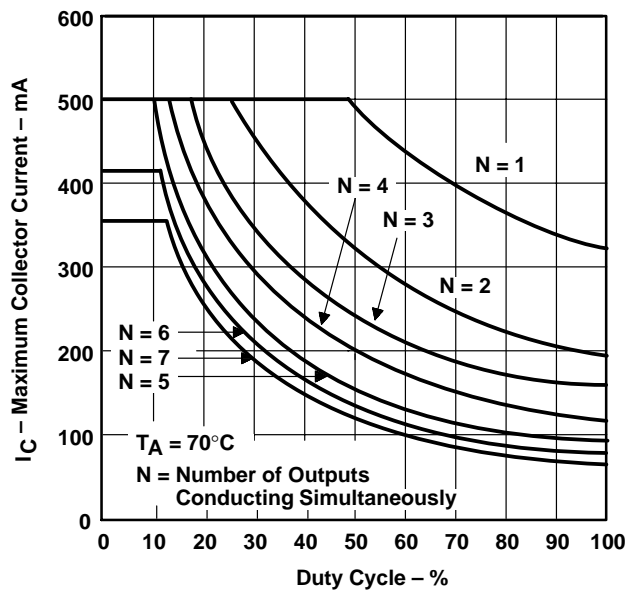
**ULN2001A, ULN2002A, ULN2003A, ULN2004A, ULQ2003A, ULQ2004A**  
**HIGH-VOLTAGE HIGH-CURRENT DARLINGTON**  
**TRANSISTOR ARRAY**

SLRS027F – DECEMBER 1976 – REVISED FEBRUARY 2003

The ULN2001A is obsolete  
 and is no longer supplied.

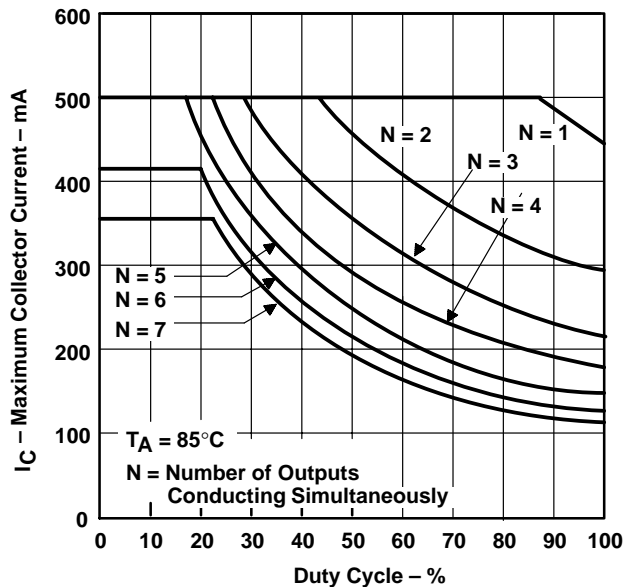
**THERMAL INFORMATION**

**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

The ULN2001A is obsolete  
and is no longer supplied.

SLRS027F – DECEMBER 1976 – REVISED FEBRUARY 2003

## APPLICATION INFORMATION

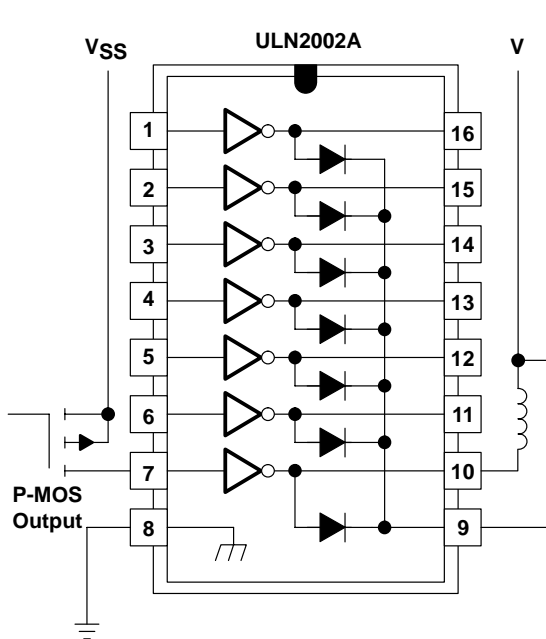


Figure 16. P-MOS to Load

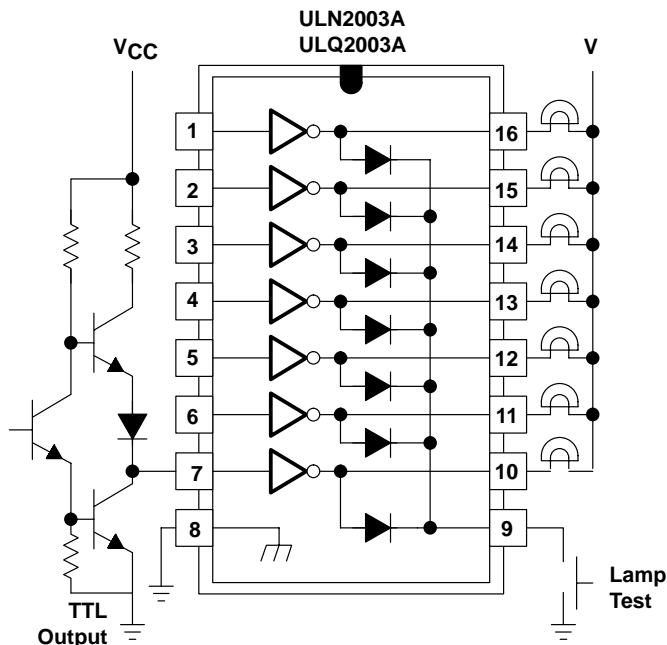


Figure 17. TTL to Load

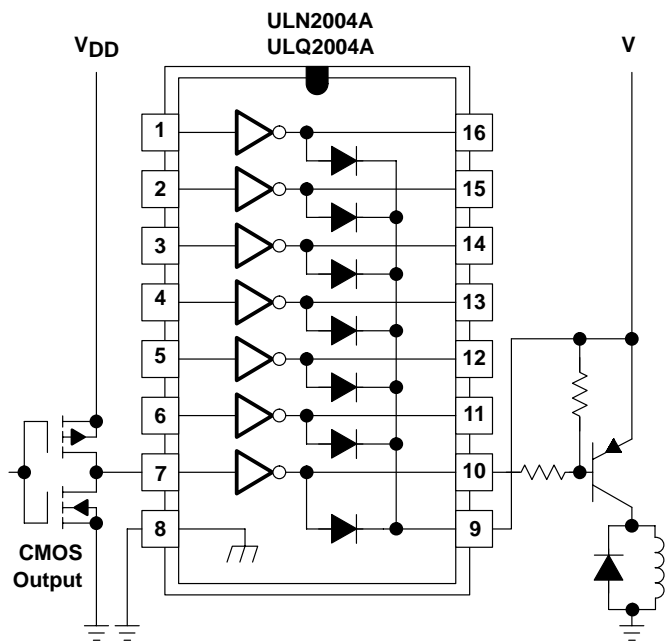


Figure 18. Buffer for Higher Current Loads

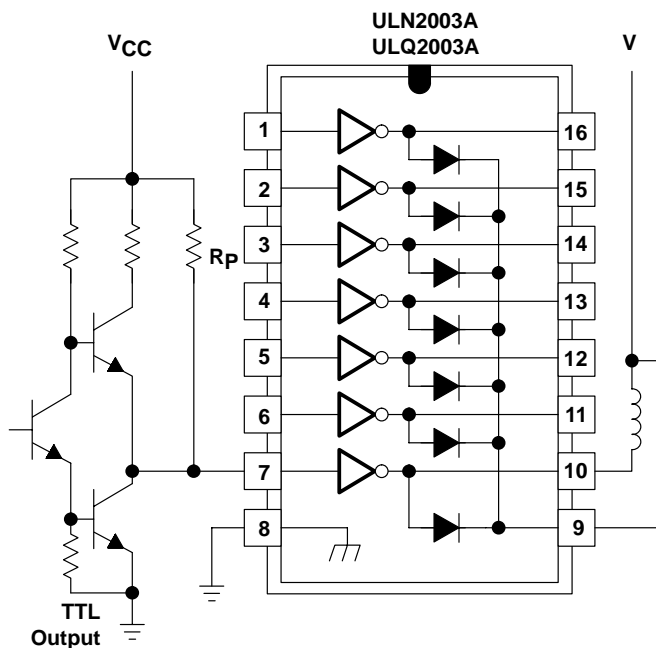
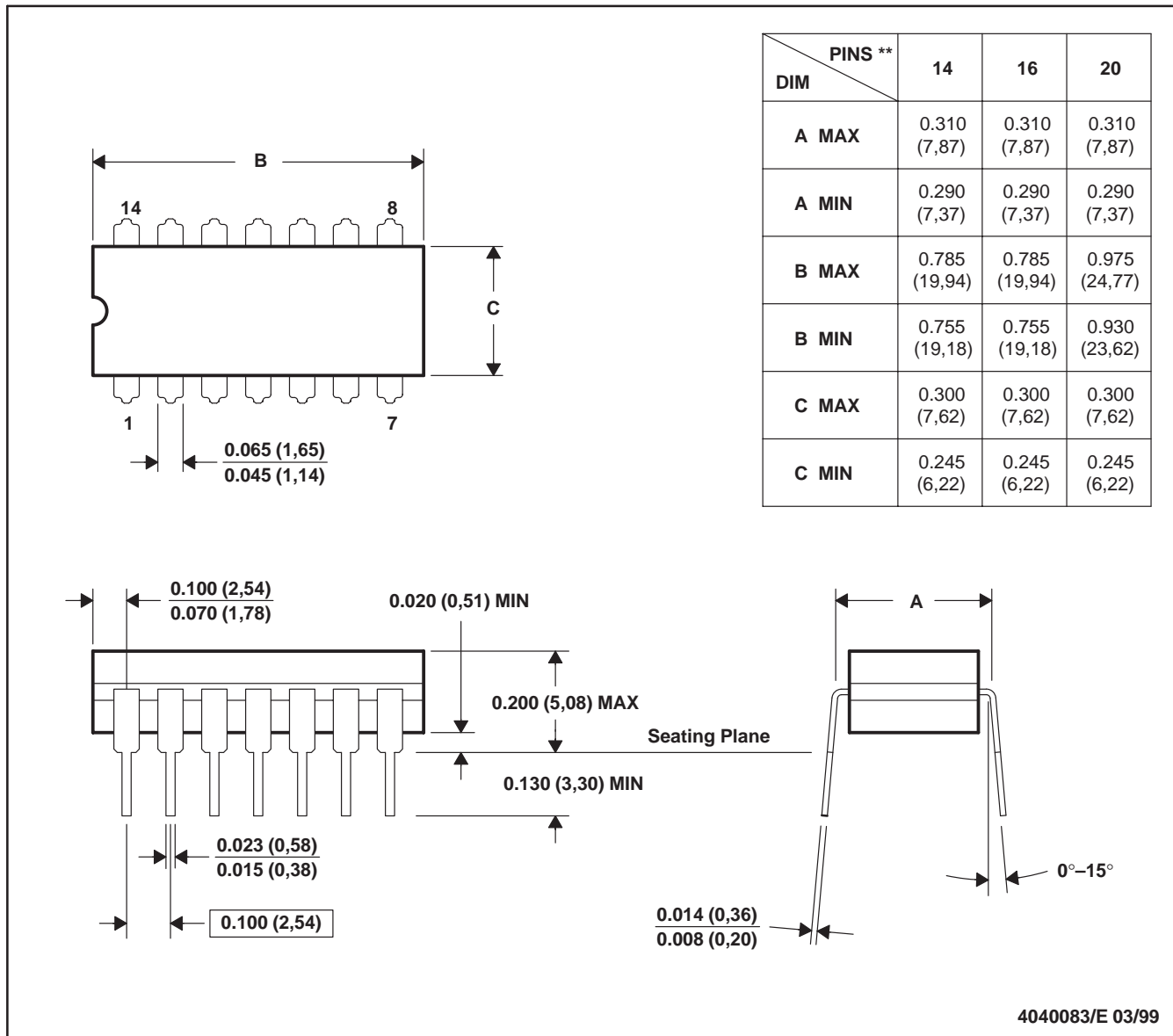


Figure 19. Use of Pullup Resistors  
to Increase Drive Current

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

CERAMIC DUAL-IN-LINE

14 LEADS SHOWN

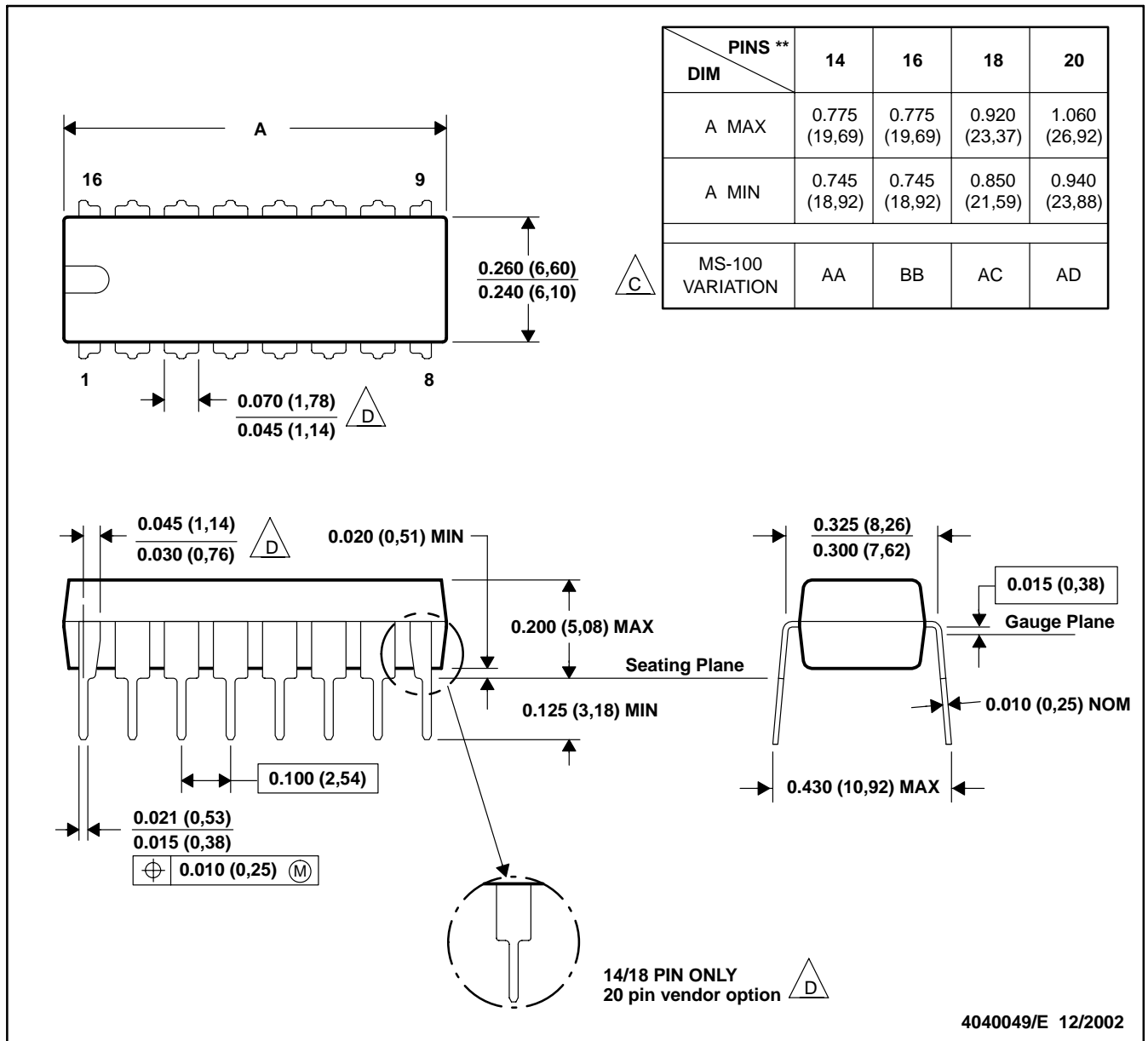


- NOTES: A. All linear dimensions are in inches (millimeters).  
 B. This drawing is subject to change without notice.  
 C. This package is hermetically sealed with a ceramic lid using glass frit.  
 D. Index point is provided on cap for terminal identification.  
 E. Falls within MIL STD 1835 GDIP1-T14,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

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

PLASTIC SMALL-OUTLINE PACKAGE

8 PINS SHOWN

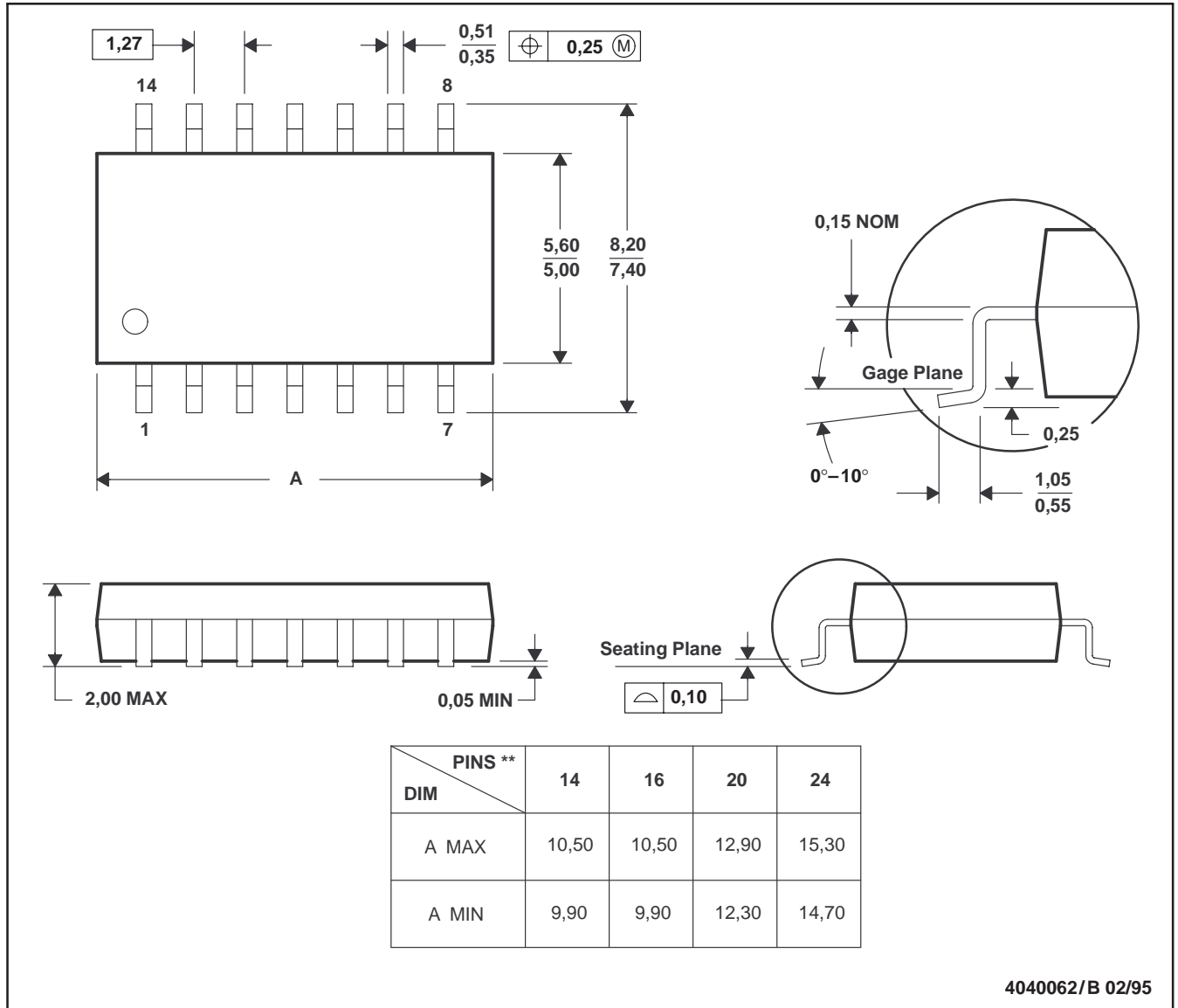


- NOTES: A. All linear dimensions are in inches (millimeters).  
 B. This drawing is subject to change without notice.  
 C. Body dimensions do not include mold flash or protrusion, not to exceed 0.006 (0,15).  
 D. Falls within JEDEC MS-012

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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Texas Instruments  
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