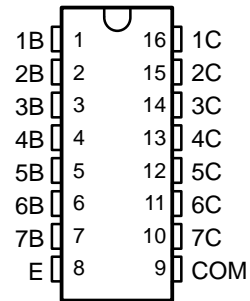


HIGH-VOLTAGE HIGH-CURRENT DARLINGTON TRANSISTOR ARRAYS

- 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

D OR N PACKAGE
(TOP VIEW)

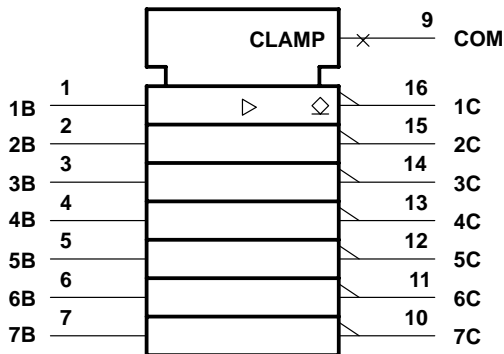


description

The ULN2001A, ULN2002A, ULN2003A, ULN2004A, ULQ2003A, and ULQ2004A are monolithic 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 may 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, see the SN75465 through SN75469.

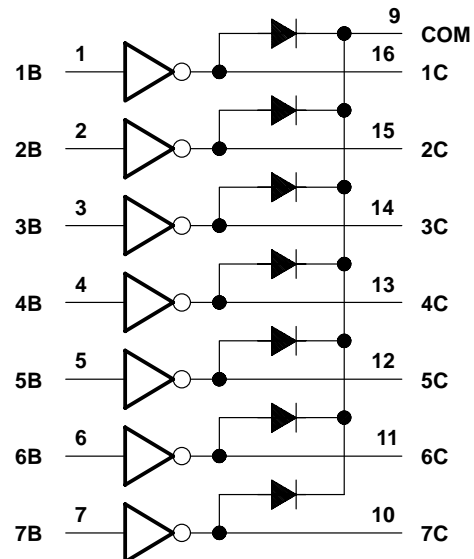
The ULN2001A is a general-purpose array and can be used with TTL and CMOS technologies. The ULN2002A is specifically designed for use with 14- to 25-V PMOS devices. Each input of this device has a zener diode and resistor in series to control the input current to a safe limit. The ULN2003A and ULQ2003A 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 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 symbol†



† This symbol is in accordance with ANSI/IEEE Std 91-1984 and IEC Publication 617-12.

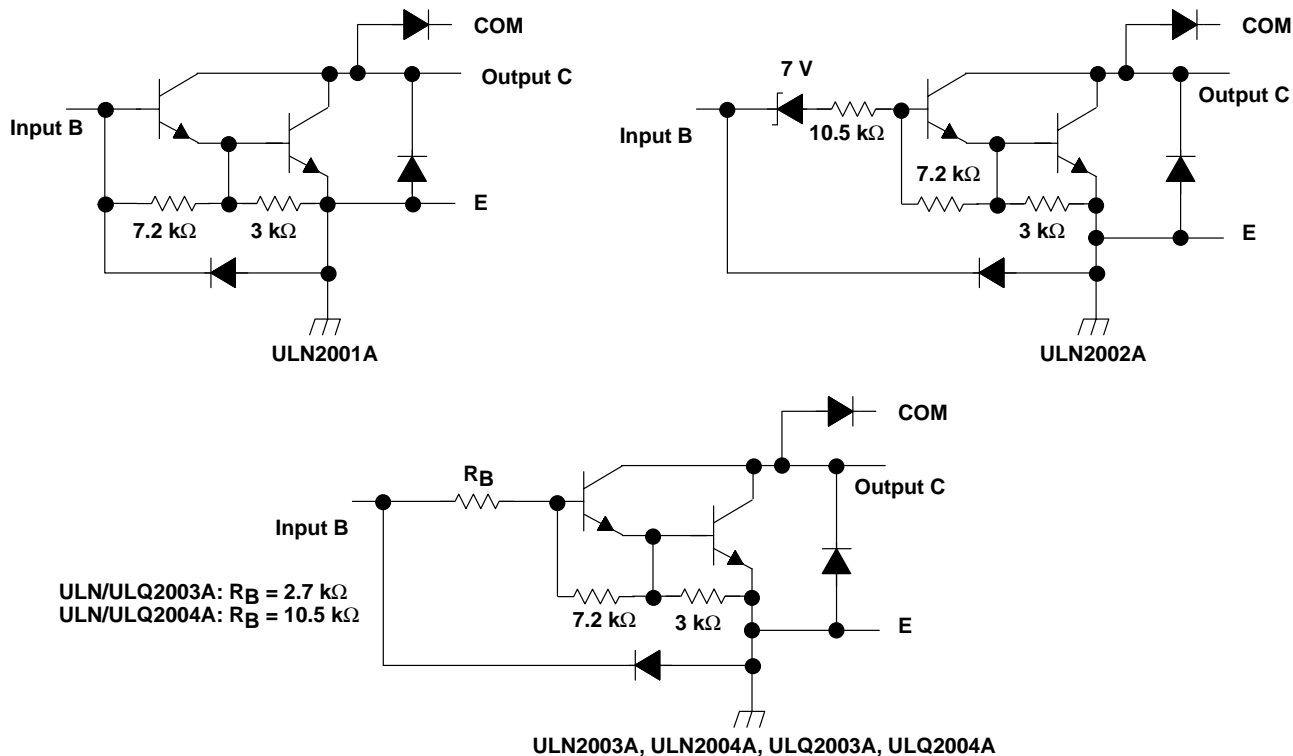
logic diagram



ULN2001A, ULN2002A, ULN2003A, ULN2004A, ULQ2003A, ULQ2004A DARLINGTON TRANSISTOR ARRAY

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schematics (each Darlington pair)



All resistor values shown are nominal.

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 |
| Continuous total power dissipation | See Dissipation Rating Table |
| Operating free-air temperature range, T_A , ULN200xA | -20°C to 85°C |
| ULQ2003A | -40°C to 85°C |
| ULQ2004A | -40°C to 70°C |
| Operating junction temperature range, T_J | -40°C to 105°C |
| Storage temperature range, T_{stg} | -65°C to 150°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds | 260°C |

NOTE 1: All voltage values are with respect to the emitter/substrate terminal E, unless otherwise noted.

DISSIPATION RATING TABLE

| PACKAGE | $T_A = 25^\circ\text{C}$ POWER RATING | DERATING FACTOR ABOVE $T_A = 25^\circ\text{C}$ | $T_A = 85^\circ\text{C}$ POWER RATING |
|---------|--|---|--|
| D | 950 mW | 7.6 mW/°C | 494 mW |
| N | 1150 mW | 9.2 mW/°C | 598 mW |

**ULN2001A, ULN2002A, ULN2003A, ULN2004A,
ULQ2003A, ULQ2004A
DARLINGTON TRANSISTOR ARRAY**
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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 | μA |
| | 2 | $V_{CE} = 50\text{ V}$, $T_A = 70^\circ\text{C}$, $V_I = 6\text{ V}$, $I_I = 0$ | | | 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 | | μA |
| 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 | μA |
| | | $V_R = 50\text{ V}$ | | | 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 |

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

| 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 | | | 7 | | |
| | | | $I_C = 275\text{ mA}$ | | | | | | | | |
| | | | $I_C = 300\text{ mA}$ | | | 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 | μA | | |
| | 2 | $V_{CE} = 50\text{ V}$, $T_A = 70^\circ\text{C}$, $V_I = 1\text{ V}$, $I_I = 0$ | | | 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 | | μA | | |
| 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 | μA | | |
| | | $V_R = 50\text{ V}$, $T_A = 70^\circ\text{C}$ | | | 100 | | | 100 | | | |
| C_i Input capacitance | | $V_I = 0$, $f = 1\text{ MHz}$ | | 15 | 25 | | 15 | 25 | pF | | |



**ULN2001A, ULN2002A, ULN2003A, ULN2004A,
ULQ2003A, ULQ2004A**

DARLINGTON TRANSISTOR ARRAY

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electrical characteristics, $T_J = -40^{\circ}\text{C}$ to 105°C (unless otherwise noted)

| PARAMETER | TEST FIGURE | TEST CONDITIONS | | ULQ2003A | | | ULQ2004A | | | 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 | |
| | | | $I_C = 200\text{ mA}$ | | | 2.7 | | | 6 | | |
| | | | $I_C = 250\text{ mA}$ | | | 2.9 | | | | | |
| | | | $I_C = 275\text{ mA}$ | | | | | | 7 | | |
| | | | $I_C = 300\text{ mA}$ | | | | | 3 | | | |
| $V_{CE(sat)}$ Collector-emitter saturation voltage | 5 | | $I_I = 250\ \mu\text{A}, I_C = 100\text{ mA}$ | | 0.9 | 1.2 | | 0.9 | 1.1 | V | |
| | | | $I_I = 350\ \mu\text{A}, I_C = 200\text{ mA}$ | | 1 | 1.4 | | 1 | 1.3 | | |
| | | | $I_I = 500\ \mu\text{A}, I_C = 350\text{ mA}$ | | 1.2 | 1.7 | | 1.2 | 1.6 | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| I_{CEX} Collector cutoff current | 1 | $V_{CE} = 50\text{ V}, I_I = 0$ | | | | | | 100 | μA | | |
| | 2 | | $V_{CE} = 50\text{ V}, T_A = 70^{\circ}\text{C}, V_I = 1\text{ V}$ | | | | | 500 | | | |
| V_F Clamp forward voltage | 8 | $I_F = 350\text{ mA}$ | | 1.7 | 2.2 | | 1.7 | 2 | V | | |
| $I_{I(off)}$ Off-state input current | 3 | $V_{CE} = 50\text{ V}, T_A = 70^{\circ}\text{C}, I_C = 500\ \mu\text{A}$ | 30 | 65 | | 50 | 65 | | μA | | |
| 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 | $V_R = 50\text{ V}, T_A = 70^{\circ}\text{C}$ | | | 100 | | | 50 | μA | | |
| | | | | | 100 | | | 100 | | | |
| C_i Input capacitance | | $V_I = 0, f = 1\text{ MHz}$ | | 15 | 25 | | 15 | 25 | pF | | |

switching characteristics, $T_A = 25^{\circ}\text{C}$

| PARAMETER | TEST CONDITIONS | ULN2001A, ULN2002A, ULN2003A, ULN2004A | | | UNIT |
|--|--|--|------|-----|---------------|
| | | MIN | TYP | MAX | |
| t_{PLH} Propagation delay time, low-to-high-level output | See Figure 9 | | 0.25 | 1 | μs |
| t_{PHL} Propagation delay time, high-to-low-level output | | | 0.25 | 1 | μs |
| V_{OH} High-level output voltage after switching | $V_S = 50\text{ V}, I_O \approx 300\text{ mA},$ See Figure 10 | $V_S - 20$ | | | mV |

switching characteristics, $T_J = -40^{\circ}\text{C}$ to 105°C

| PARAMETER | TEST CONDITIONS | ULQ2003A, ULQ2004A | | | UNIT |
|--|--|--------------------|-----|-----|---------------|
| | | MIN | TYP | MAX | |
| t_{PLH} Propagation delay time, low-to-high-level output | See Figure 9 | | 1 | 10 | μs |
| t_{PHL} Propagation delay time, high-to-low-level output | | | 1 | 10 | μs |
| V_{OH} High-level output voltage after switching | $V_S = 50\text{ V}, I_O \approx 300\text{ mA},$ See Figure 10 | $V_S - 500$ | | | mV |



PARAMETER MEASUREMENT INFORMATION

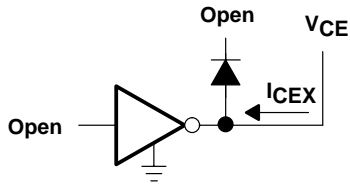


Figure 1. I_{CEX} Test Circuit

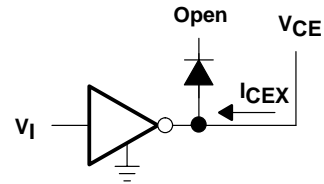


Figure 2. I_{CEX} Test Circuit

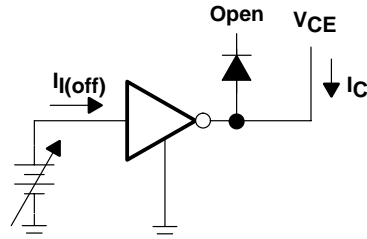


Figure 3. $I_{I(off)}$ Test Circuit

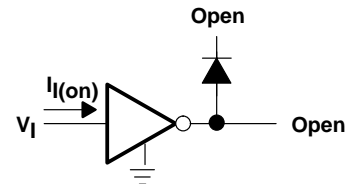
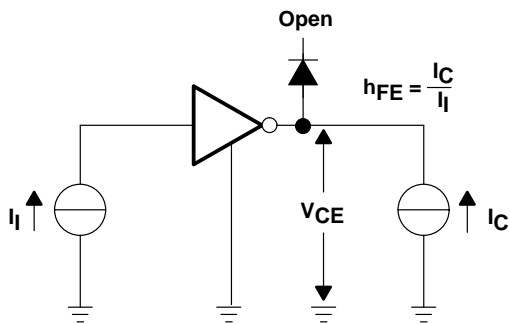


Figure 4. I_I Test Circuit



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

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

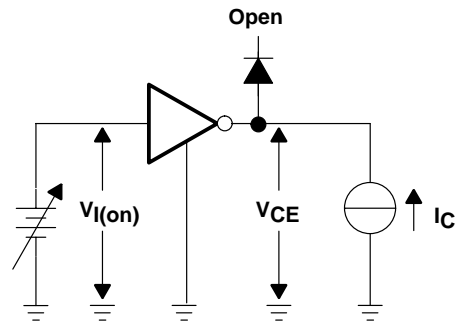


Figure 6. $V_{I(on)}$ Test Circuit

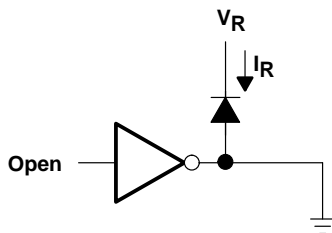


Figure 7. I_R Test Circuit

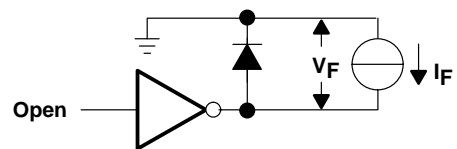


Figure 8. V_F Test Circuit

**ULN2001A, ULN2002A, ULN2003A, ULN2004A,
ULQ2003A, ULQ2004A
DARLINGTON TRANSISTOR ARRAY**

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PARAMETER MEASUREMENT INFORMATION

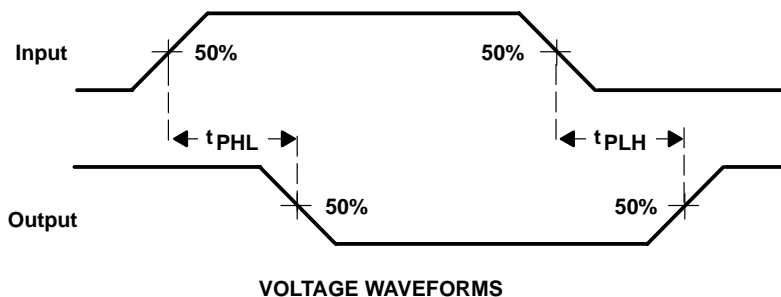
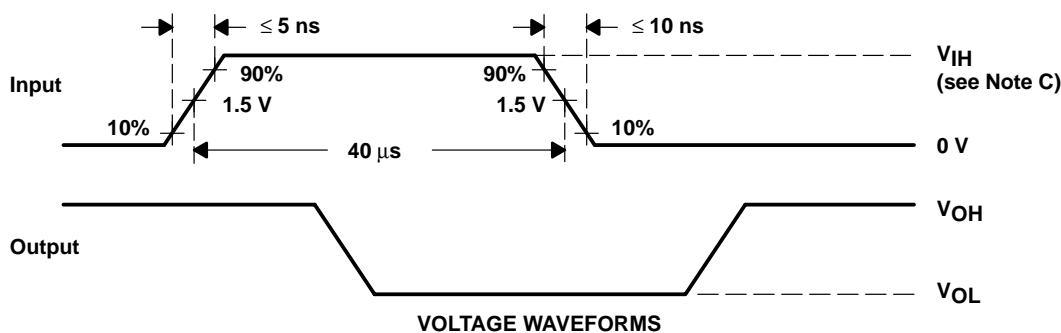
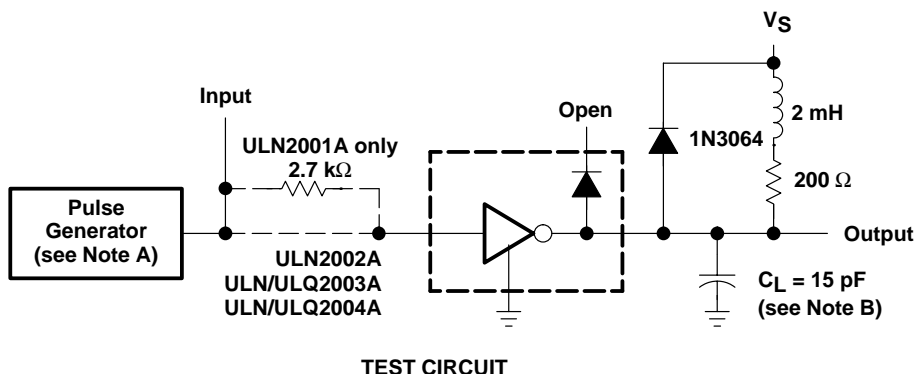


Figure 9. Propagation Delay Time Waveforms



- 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

TYPICAL CHARACTERISTICS

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

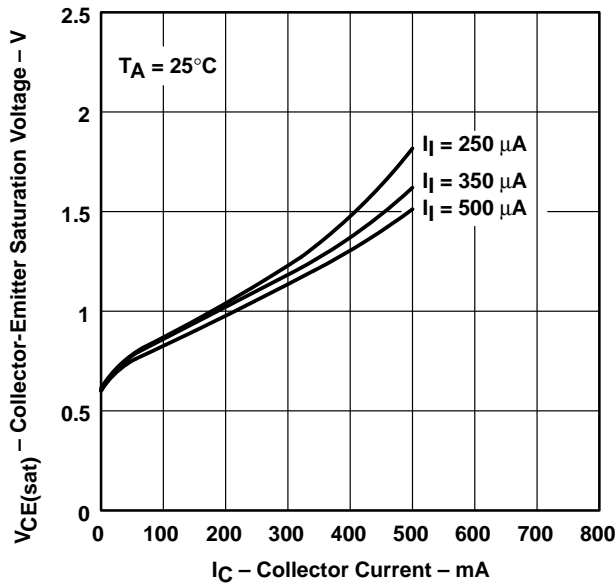


Figure 11

COLLECTOR-EMITTER SATURATION VOLTAGE vs TOTAL COLLECTOR CURRENT (TWO DARLINGTONS PARALLELED)

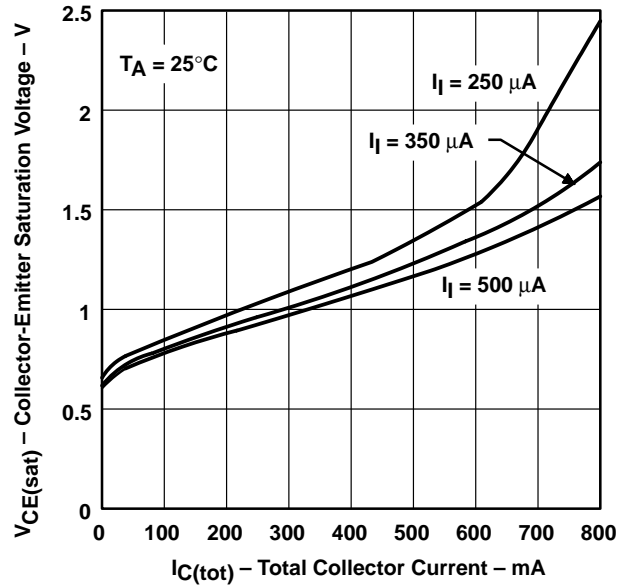


Figure 12

COLLECTOR CURRENT vs INPUT CURRENT

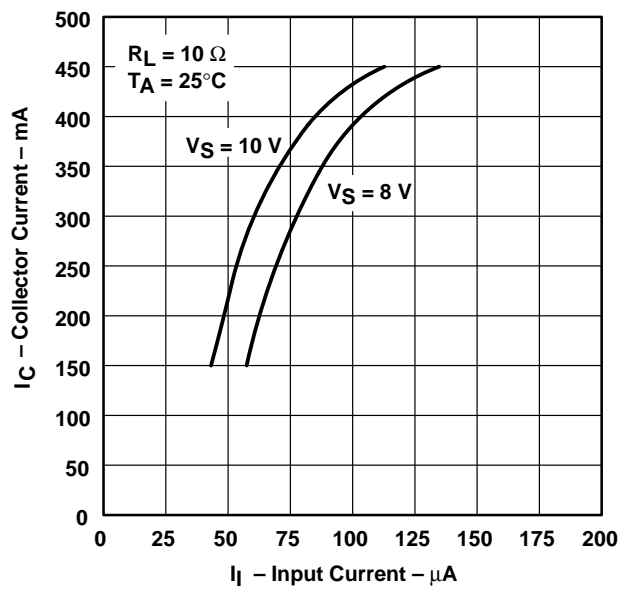


Figure 13

THERMAL INFORMATION

D PACKAGE
 MAXIMUM COLLECTOR CURRENT
 VS
 DUTY CYCLE

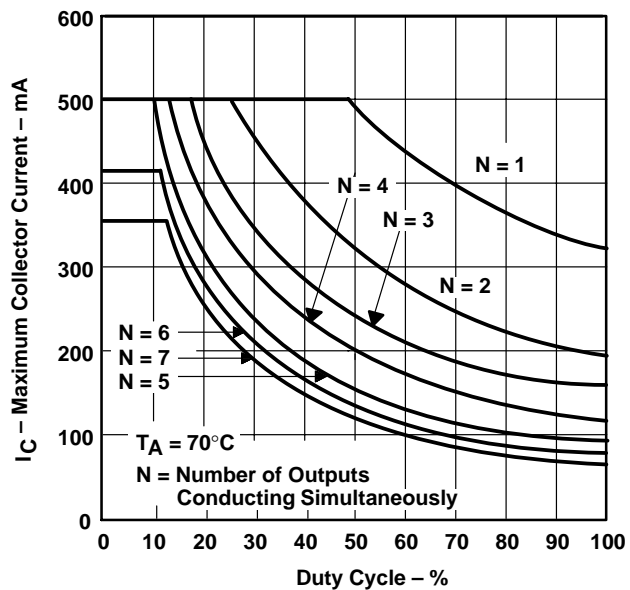


Figure 14

N PACKAGE
 MAXIMUM COLLECTOR CURRENT
 VS
 DUTY CYCLE

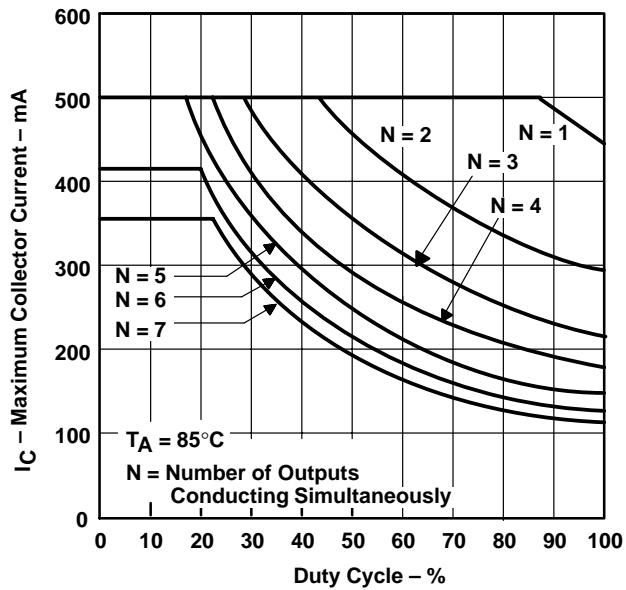


Figure 15

APPLICATION INFORMATION

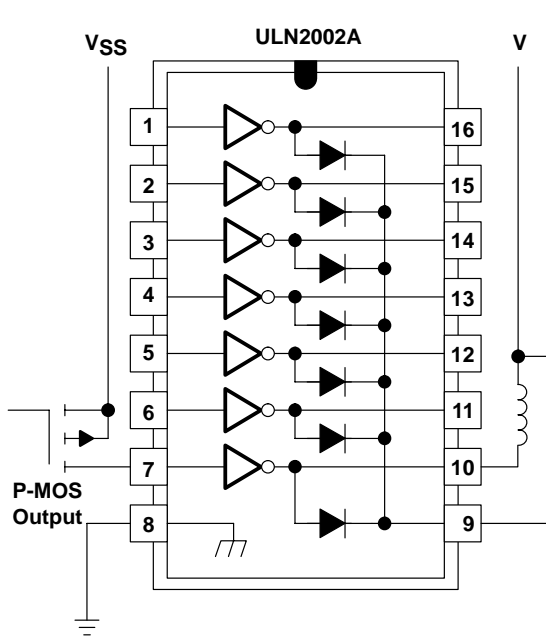


Figure 16. P-MOS to Load

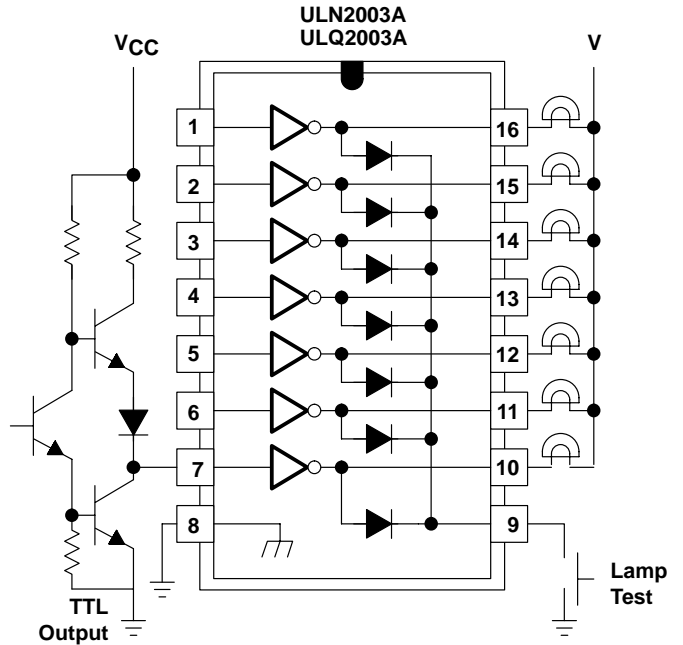


Figure 17. TTL to Load

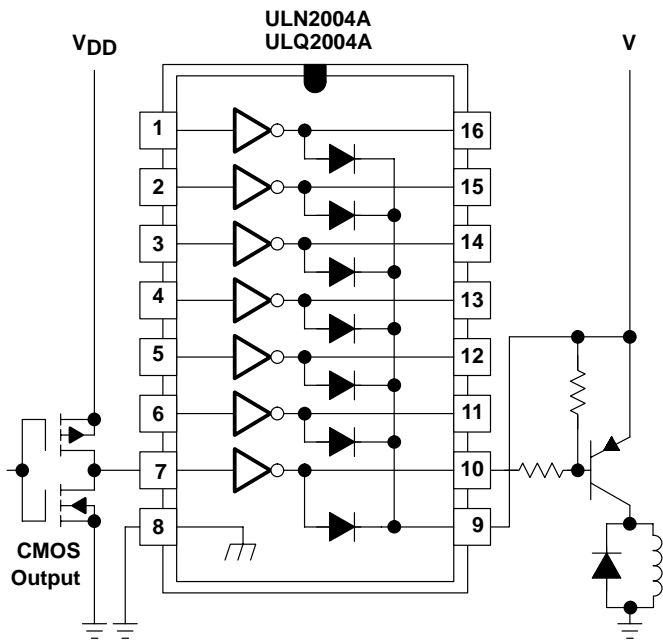


Figure 18. Buffer for Higher Current Loads

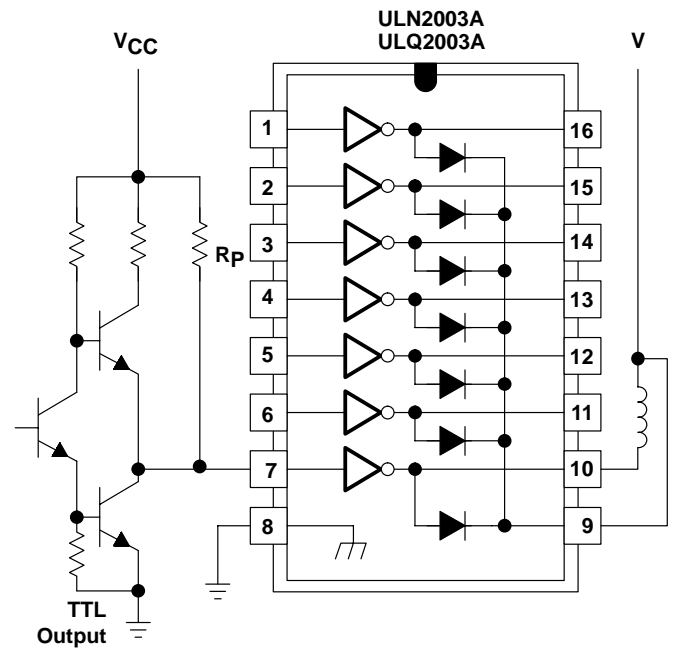


Figure 19. Use of Pullup Resistors to Increase Drive Current

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