

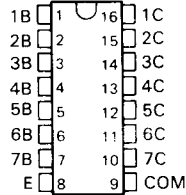
# ULN2001A THRU ULN2005A DARLINGTON TRANSISTOR ARRAYS

D2624, DECEMBER 1976—REVISED SEPTEMBER 1986

## 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)

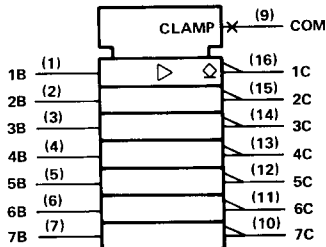


### description

The ULN2001A, ULN2002A, ULN2003A, ULN2004A, and ULN2005A are monolithic high-voltage, high-current Darlington transistor arrays. Each consists of seven n-p-n 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.

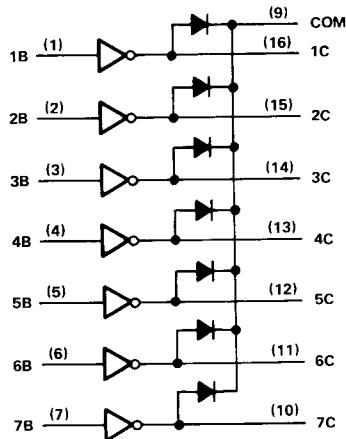
The ULN2001A is a general-purpose array and may be used with TTL, P-MOS, CMOS, and other MOS technologies. The ULN2002A is specifically designed for use with 14- to 25-V P-MOS devices. Each input of this device has a zener diode and resistor in series to control the input current to a safe limit. The ULN2003A has a 2.7-k $\Omega$  series base resistor for each Darlington pair for operation directly with TTL or 5-V CMOS devices. The ULN2004A has a 10.5-k $\Omega$  series base resistor to allow its operation directly from CMOS or P-MOS devices that use supply voltages of 6 to 15 V. The required input current of the ULN2004A is below that of the ULN2003A, and the required voltage is less than that required by the ULN2002A. The ULN2005A has a 1050- $\Omega$  series base resistor and is specifically designed for use with TTL devices where higher output current is required and loading of the driving source is not a concern.

### logic symbol†



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

### logic diagram



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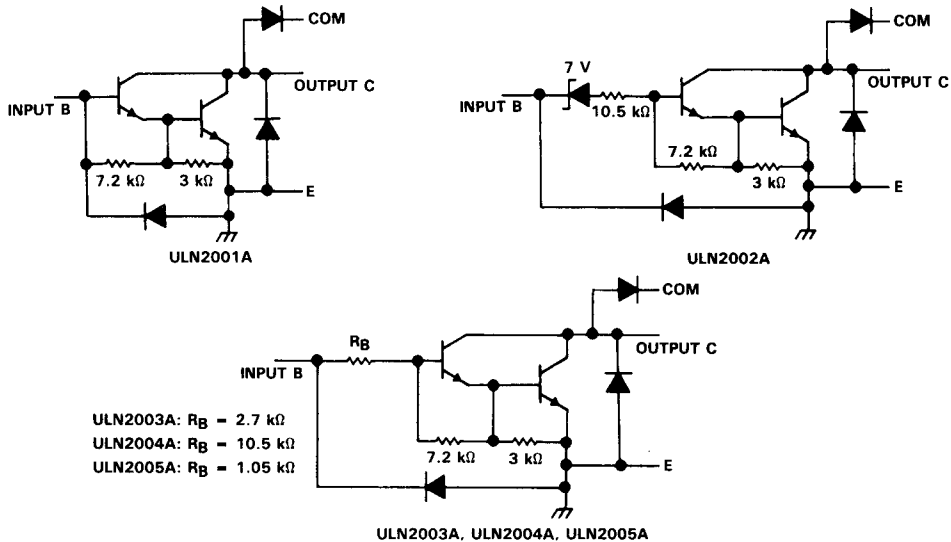
**TEXAS  
INSTRUMENTS**

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# ULN2001A THRU ULN2005A DARLINGTON TRANSISTOR ARRAYS

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
Input voltage (see Note 1): ULN2002A, ULN2003A, ULN2004A	30 V
ULN2005A	15 V
Peak collector current (see Figures 14 and 15)	500 mA
Output clamp diode current	500 mA
Total emitter-terminal current	-2.5 A
Continuous total power dissipation	See Dissipation Rating Table
Operating free-air temperature range	-20°C to 85°C
Storage temperature range	-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	$T_A = 25^\circ\text{C}$	DERATING FACTOR	$T_A = 85^\circ\text{C}$
	POWER RATING	ABOVE $T_A = 25^\circ\text{C}$	POWER RATING
D	950 mW	7.6 mW/°C	494 mW
N	1150 mW	9.2 mW/°C	598 mW

# ULN2001A THRU ULN2005A DARLINGTON TRANSISTOR ARRAYS

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

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

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

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

**ULN2001A THRU ULN2005A  
DARLINGTON TRANSISTOR ARRAYS**

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

PARAMETER	TEST FIGURE	TEST CONDITIONS	ULN2005A			UNIT
			MIN	TYP	MAX	
$I_{CEX}$ Collector cutoff current	1	$V_{CE} = 50 \text{ V}, I_I = 0$			50	$\mu\text{A}$
		$V_{CE} = 50 \text{ V}, I_I = 0, T_A = 70^\circ\text{C}$			100	
$I_{I(off)}$ Off-state input current	3	$V_{CE} = 50 \text{ V}, I_C = 500 \mu\text{A}, T_A = 70^\circ\text{C}$	50	65		$\mu\text{A}$
$I_I$ Input current	4	$V_I = 3 \text{ V}$		1.5	2.4	$\text{mA}$
$V_{I(on)}$ On-state input voltage	6	$V_{CE} = 2 \text{ V}, I_C = 350 \text{ mA}$			2.4	$\text{V}$
$V_{CE(sat)}$ Collector-emitter saturation voltage	5	$I_I = 250 \mu\text{A}, I_C = 100 \text{ mA}$		0.9	1.1	$\text{V}$
		$I_I = 350 \mu\text{A}, I_C = 200 \text{ mA}$		1	1.3	
		$I_I = 500 \mu\text{A}, I_C = 350 \text{ mA}$		1.2	1.6	
$I_R$ Clamp diode reverse current	7	$V_R = 50 \text{ V}$			50	$\mu\text{A}$
		$V_R = 50 \text{ V}, T_A = 70^\circ\text{C}$			100	
$V_F$ Clamp diode forward voltage	8	$I_F = 350 \text{ mA}$		1.7	2	$\text{V}$
$C_i$ Input capacitance		$V_I = 0, f = 1 \text{ MHz}$		15	25	$\text{pF}$

**switching characteristics at 25 °C free-air temperature**

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

PARAMETER MEASUREMENT INFORMATION

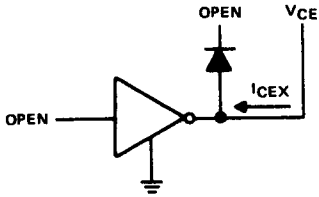


FIGURE 1.  $I_{CEX}$

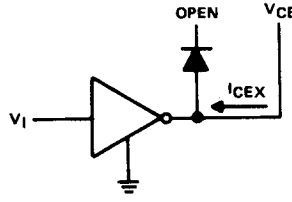


FIGURE 2.  $I_{CEX}$

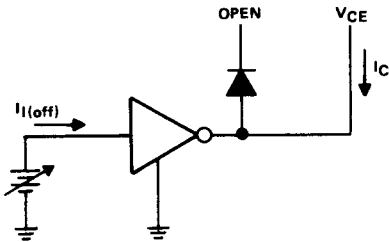


FIGURE 3.  $I_1(off)$

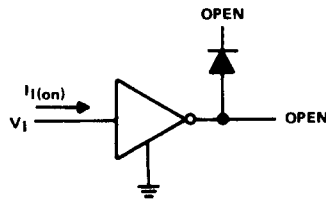
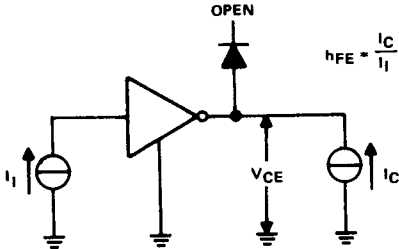


FIGURE 4.  $I_1$



NOTE:  $I_1$  is fixed for measuring  $V_{CE(sat)}$ , variable for measuring  $h_{FE}$ .

FIGURE 5.  $h_{FE}$ ,  $V_{CE(sat)}$

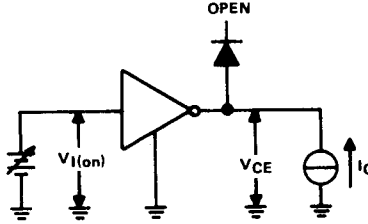


FIGURE 6.  $V_1(ON)$

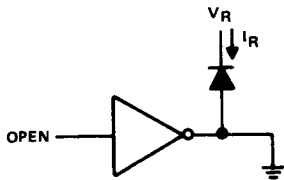


FIGURE 7.  $I_R$

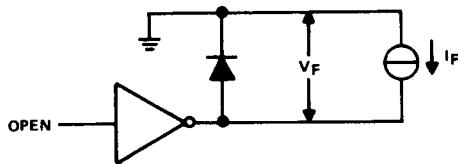
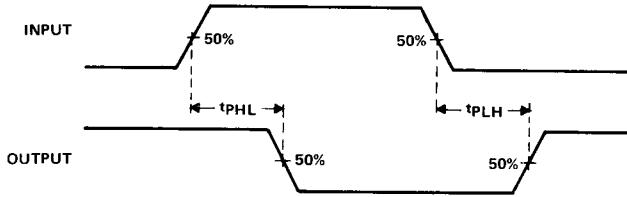


FIGURE 8.  $V_F$

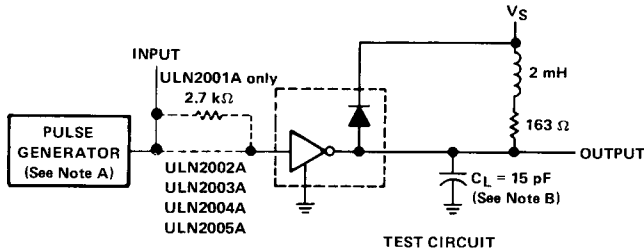
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**PARAMETER MEASUREMENT INFORMATION**

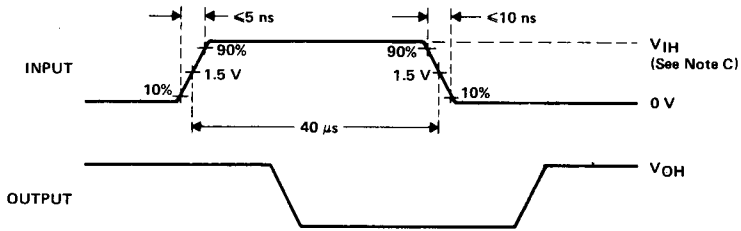


**VOLTAGE WAVEFORMS**

**FIGURE 9. PROPAGATION DELAY TIMES**



**TEST CIRCUIT**



**VOLTAGE WAVEFORMS**

- NOTES: A. The pulse generator has the following characteristics: PRR = 12.5 kHz,  $Z_0 = 50 \Omega$ .  
 B.  $C_L$  includes probe and jig capacitance.  
 C. For testing the ULN2001A, ULN2003A, and the ULN2005A,  $V_{IH} = 3 \text{ V}$ ; for the ULN2002A,  $V_{IH} = 13 \text{ V}$ ; for the ULN2004A,  $V_{IH} = 8 \text{ V}$ .

**FIGURE 10. LATCH-UP TEST**

TYPICAL CHARACTERISTICS

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

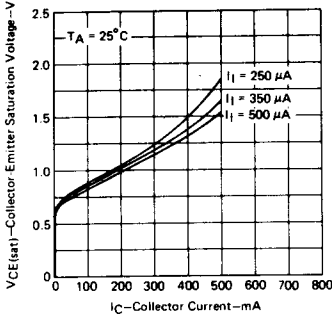


FIGURE 11

COLLECTOR-EMITTER SATURATION VOLTAGE  
VS  
COLLECTOR CURRENT  
(TWO DARLINGTONS PARALLELED)

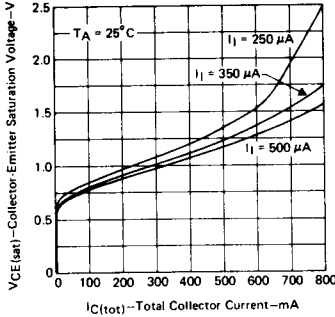


FIGURE 12

COLLECTOR CURRENT VS  
INPUT CURRENT

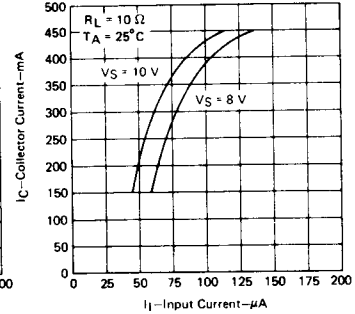


FIGURE 13

THERMAL INFORMATION

D PACKAGE  
MAXIMUM COLLECTOR CURRENT  
VS  
DUTY CYCLE

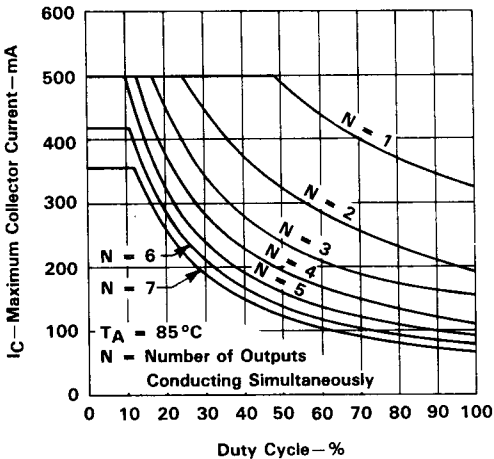


FIGURE 14

N PACKAGE  
MAXIMUM COLLECTOR CURRENT  
VS  
DUTY CYCLE

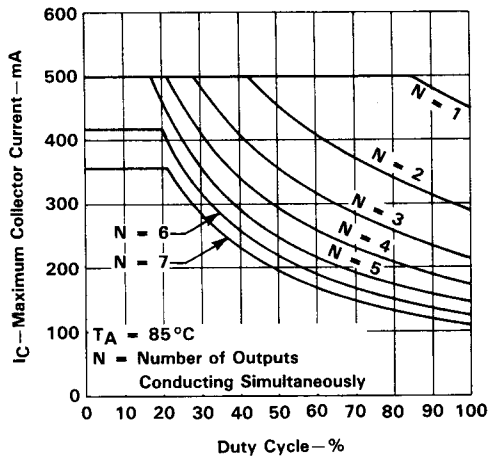


FIGURE 15

**ULN2001A THRU ULN2005A  
DARLINGTON TRANSISTOR ARRAYS**

**APPLICATION INFORMATION**

