## Description

The ULN2002A, ULN2003A, and ULN2004A are high-voltage, high-current Darlington arrays each containing seven open collector common emitter pairs. Each pair is rated at 500mA. Suppression diodes are included for inductive load driving. The inputs and outputs are pinned in opposition to simplify board layout.

Device options are designed to be compatible with common logic families:

- ULN2002A (14V to 25V PMOS)
- ULN2003A (5V TTL, CMOS)
- ULN2004A (6V to15V CMOS, PMOS)

These devices are capable of driving a wide range of loads including solenoids, relays, DC motors, LED displays, filament lamps, thermal print-heads, and high-power buffers.

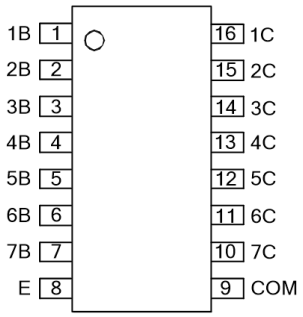
The ULN2002A, ULN2003A, and ULN2004A are available in both a small outline 16-pin package (SO-16) and a PDIP-16 package. The ULN2003A has an additional TSSOP-16 (Type CJ) package available for small footprint requirements.

## Features

- 500mA Rated Collector Current (Single Output)
- High-Voltage Outputs: 50V
- Output Clamp Diodes
- Inputs Compatible with Popular Logic Types
- Relay Driver Applications
- "Green" Molding Compound (No Br, Sb)
- **Totally Lead-Free & Fully RoHS Compliant (Notes 1 & 2)**
- **Halogen and Antimony Free. "Green" Device (Note 3)**
- **For automotive applications requiring specific change control (i.e. parts qualified to AEC-Q100/101/104/200, PPAP capable, and manufactured in IATF 16949 certified facilities), please contact us or your local Diodes representative. https://www.diodes.com/quality/product-definitions/**

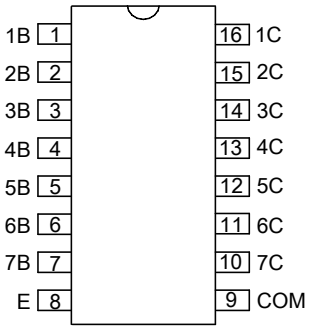
## Pin Assignments

(Top View)




SO-16
TSSOP-16 (Type CJ) (ULN2003A Only)

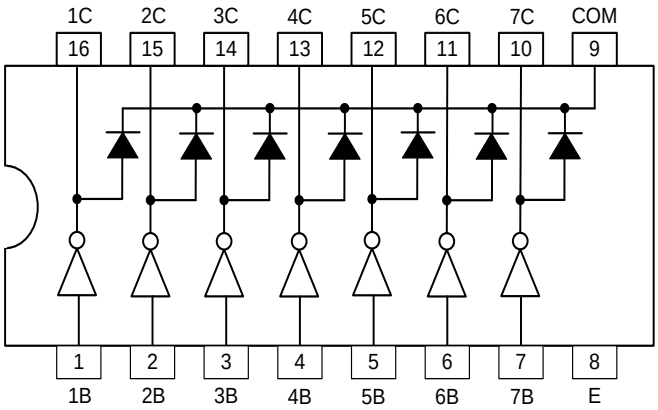
(Top View)




PDIP-16

Notes:
1. No purposely added lead. Fully EU Directive 2002/95/EC (RoHS), 2011/65/EU (RoHS 2) & 2015/863/EU (RoHS 3) compliant.
2. See https://www.diodes.com/quality/lead-free/ for more information about Diodes Incorporated's definitions of Halogen- and Antimony-free, "Green" and Lead-free.
3. Halogen- and Antimony-free "Green" products are defined as those which contain <900ppm bromine, <900ppm chlorine (<1500ppm total Br + Cl) and <1000ppm antimony compounds.

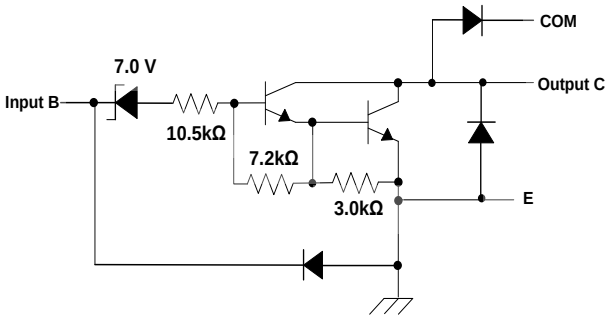
## Connection Diagram



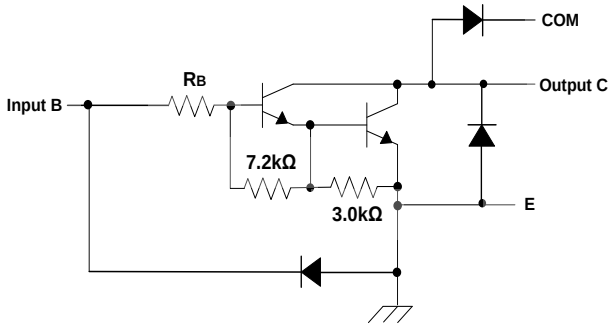

## Pin Descriptions

| Pin Number<br>SO-16/PDIP-16/TSSOP-16 (Type CJ) | Pin Name | Function |
|---|---|---|
| 1 | 1B | Input Pair 1 |
| 2 | 2B | Input Pair 2 |
| 3 | 3B | Input Pair 3 |
| 4 | 4B | Input Pair 4 |
| 5 | 5B | Input Pair 5 |
| 6 | 6B | Input Pair 6 |
| 7 | 7B | Input Pair 7 |
| 8 | E | Common Emitter (Ground) |
| 9 | COM | Common Clamp Diodes |
| 10 | 7C | Output Pair 7 |
| 11 | 6C | Output Pair 6 |
| 12 | 5C | Output Pair 5 |
| 13 | 4C | Output Pair 4 |
| 14 | 3C | Output Pair 3 |
| 15 | 2C | Output Pair 2 |
| 16 | 1C | Output Pair 1 |

## Functional Block Diagram




ULN2002A




ULN2003A: $R_B$ = 2.7k
ULN2004A: $R_B$ = 10.5k

ULN2003A/ULN2004A

## Absolute Maximum Ratings (Note 4) (@$T_A$ = +25°C, unless otherwise specified.)

| Symbol | Parameter | | Rating | Unit |
|---|---|---|---|---|
| $V_{CC}$ | Collector to Emitter Voltage | | 50 | V |
| $V_R$ | Clamp Diode Reverse Voltage (Note 5) | | 50 | V |
| $V_I$ | Input Voltage (Note 5) | | 30 | V |
| $I_{CP}$ | Peak Collector Current | | 500 | mA |
| $I_{OK}$ | Output Clamp Current | | 500 | mA |
| $I_{TE}$ | Total Emitter Current | | -2.5 | A |
| $\theta_{JA}$ | Thermal Resistance Junction-to-Ambient (Note 6) | SO-16 | 63.0 | °C/W |
| | | TSSOP-16 (Type CJ) (ULN2003A) | 98 | |
| | | PDIP-16 | 50.0 | |
| $\theta_{JC}$ | Thermal Resistance Junction-to-Case (Note 7) | SO-16 | 12.0 | °C/W |
| | | TSSOP-16 (Type CJ) (ULN2003A) | 31 | |
| | | PDIP-16 | 15.0 | |
| ESD | HBM | | 2 | kV |
| | CDM | | 2 | kV |
| $T_J$ | Junction Temperature | | +150 | °C |
| $T_{STG}$ | Storage Temperature | | -65 to +150 | °C |

Notes:
4. Stresses greater than those listed under *Absolute Maximum Ratings* can 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 Ratings* for extended periods can affect device reliability.
5. All voltage values are with respect to the emitter/substrate terminal E, unless otherwise noted.
6. 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.
7. Maximum power dissipation is a function of $T_J$(max), $\theta_{JC}$ and $T_A$. The maximum allowable power dissipation at any allowable ambient temperature is $P_D = (T_J(max) – T_C)/\theta_{JC}$. Operating at the absolute maximum $T_J$ of +150°C can affect reliability.

## Recommended Operating Conditions

| Symbol | Parameter | Min | Max | Unit |
|---|---|---|---|---|
| $V_{CC}$ | Collector to Emitter Voltage | 0 | 50 | V |
| $T_A$ | Operating Ambient Temperature | -40 | +105 | °C |

## Electrical Characteristics (@$T_A$ = +25°C, unless otherwise specified.)

**ULN2002A**

| Symbol | Parameter | Test Figure | Test Conditions | | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|---|---|
| $V_{I(ON)}$ | On-State Input Voltage | 6 | $V_{CE}$ = 2V, $I_C$ = 300mA | | — | — | 13 | V |
| $V_{CE(SAT)}$ | Collector Emitter Saturation Voltage | 5 | $I_I$ = 250µA, $I_C$ = 100mA | | — | 0.9 | 1.1 | V |
| | | | $I_I$ = 350µA, $I_C$ = 200mA | | — | 1 | 1.3 | |
| | | | $I_I$ = 500µA, $I_C$ = 350mA | | — | 1.2 | 1.6 | |
| $V_F$ | Clamp Forward Voltage | 8 | $I_F$ = 350mA | | — | 1.7 | 2 | V |
| $I_{CEX}$ | Collector Cut-Off Current | 1 | $V_{CE}$ = 50V, $I_I$ = 0 | | — | — | 50 | µA |
| | | 2 | $V_{CE}$ = 50V, $T_A$ = +105°C | $I_I$ = 0 | — | — | 100 | |
| | | | | $V_I$ = 6V | — | — | 500 | |
| $I_{I(OFF)}$ | Off-State Input Current | 3 | $V_{CE}$ = 50V, $I_C$ = 500µA | | 50 | 65 | — | µA |
| $I_I$ | Input Current | 4 | $V_I$ = 17V | | — | 0.82 | 1.25 | mA |
| $I_R$ | Clamp Reverse Current | 7 | $V_R$ = 50V | $T_A$ = +105°C | — | — | 100 | µA |
| | | | | — | — | — | 50 | |
| $C_I$ | Input Capacitance | — | $V_I$ = 0, f = 1MHz | | — | — | 25 | pF |

## Electrical Characteristics (continued) (@$T_A$ = +25°C, unless otherwise specified.)

**ULN2003A**

| Parameter | | Test Figure | Test Conditions | | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|---|---|
| $V_{I(ON)}$ | On-State Input Voltage | 6 | $V_{CE}$ = 2V | $I_C$ = 200mA | — | — | 2.4 | V |
| | | | | $I_C$ = 250mA | — | — | 2.7 | |
| | | | | $I_C$ = 300mA | — | — | 3 | |
| $V_{CE(SAT)}$ | Collector Emitter Saturation Voltage | 5 | $I_I$ = 250µA, $I_C$ = 100mA | | — | 0.9 | 1.1 | V |
| | | | $I_I$ = 350µA, $I_C$ = 200mA | | — | 1 | 1.3 | |
| | | | $I_I$ = 500µA, $I_C$ = 350mA | | — | 1.2 | 1.6 | |
| $V_F$ | Clamp Forward Voltage | 8 | $I_F$ = 350mA | | — | 1.7 | 2 | V |
| $I_{CEX}$ | Collector Cut-Off Current | 1 | $V_{CE}$ = 50V, $I_I$ = 0 | | — | — | 50 | µA |
| | | 2 | $V_{CE}$ = 50V<br>$T_A$ = +105°C | $I_I$ = 0 | — | — | 100 | |
| $I_{I(OFF)}$ | Off-State Input Current | 3 | $V_{CE}$ = 50V, $I_C$ = 500µA | | 50 | 65 | — | µA |
| $I_I$ | Input Current | 4 | $V_I$ = 3.85V | | — | 0.93 | 1.35 | mA |
| $I_R$ | Clamp Reverse Current | 7 | $V_R$ = 50V | $T_A$ = +105°C | — | — | 100 | µA |
| | | | | — | — | — | 50 | |
| $C_I$ | Input Capacitance | — | $V_I$ = 0, f = 1MHz | | — | 15 | 25 | pF |

**ULN2004A**

| Parameter | | Test Figure | Test Conditions | | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|---|---|
| $V_{I(ON)}$ | On-State Input Voltage | 6 | $V_{CE}$ = 2V | $I_C$ = 125mA | — | — | 5 | V |
| | | | | $I_C$ = 200mA | — | — | 6 | |
| | | | | $I_C$ = 275mA | — | — | 7 | |
| | | | | $I_C$ = 350mA | — | — | 8 | |
| $V_{CE(SAT)}$ | Collector Emitter Saturation Voltage | 5 | $I_I$ = 250µA, $I_C$ = 100mA | | — | 0.9 | 1.1 | V |
| | | | $I_I$ = 350µA, $I_C$ = 200mA | | — | 1 | 1.3 | |
| | | | $I_I$ = 500µA, $I_C$ = 350mA | | — | 1.2 | 1.6 | |
| $V_F$ | Clamp Forward Voltage | 8 | $I_F$ = 350mA | | — | 1.7 | 2 | V |
| $I_{CEX}$ | Collector Cut-Off Current | 1 | $V_{CE}$ = 50V, $I_I$ = 0 | | — | — | 50 | µA |
| | | 2 | $V_{CE}$ = 50V<br>$T_A$ = +105°C | $I_I$ = 0 | — | — | 100 | |
| | | | | $V_I$ = 6V | — | — | 500 | |
| $I_{I(OFF)}$ | Off-State Input Current | 3 | $V_{CE}$ = 50V, $I_C$ = 500µA | | 50 | 65 | — | µA |
| $I_I$ | Input Current | 4 | $V_I$ = 5V | | — | 0.35 | 0.5 | mA |
| $I_R$ | Clamp Reverse Current | 7 | $V_R$ = 50V | $T_A$ = +105°C | — | — | 100 | µA |
| | | | | — | — | — | 50 | |
| $C_I$ | Input Capacitance | — | $V_I$ = 0, f = 1MHz | | — | 15 | 25 | pF |

## Electrical Characteristics (@$T_A$ = -40°C to +105°C, unless otherwise specified.)

| ULN2003A | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Parameter** | | **Test Figure** | **Test Conditions** | **Min** | **Typ** | **Max** | **Unit** |
| $V_{I(ON)}$ | On-State Input Voltage | 6 | $V_{CE}$ = 2V, $I_C$ = 200mA | — | — | 2.7 | V |
| | | | $V_{CE}$ = 2V, $I_C$ = 250mA | — | — | 2.9 | |
| | | | $V_{CE}$ = 2V, $I_C$ = 300mA | — | — | 3 | |
| $V_{CE(SAT)}$ | Collector Emitter Saturation Voltage | 5 | $I_I$ = 250µA, $I_C$ = 100mA | — | 0.9 | 1.2 | V |
| | | | $I_I$ = 350µA, $I_C$ = 200mA | — | 1 | 1.4 | |
| | | | $I_I$ = 500µA, $I_C$ = 350mA | — | 1.2 | 1.7 | |
| $V_F$ | Clamp Forward Voltage | 8 | $I_F$ = 350mA | — | 1.7 | 2.2 | V |
| $I_{CEX}$ | Collector Cut-Off Current | 1 | $V_{CE}$ = 50V, $I_I$ = 0 | — | — | 100 | µA |
| $I_{I(OFF)}$ | Off-State Input Current | 3 | $V_{CE}$ = 50V, $I_C$ = 500µA | 30 | 65 | — | µA |
| $I_I$ | Input Current | 4 | $V_I$ = 3.85V | — | 0.93 | 1.35 | mA |
| $I_R$ | Clamp Reverse Current | 7 | $V_R$ = 50V | — | — | 100 | µA |
| $C_I$ | Input Capacitance | — | $V_I$ = 0, f = 1MHz | — | 15 | 25 | pF |

## Switching Characteristics (@$T_A$ = +25°C, unless otherwise specified.)

| ULN2002A/ULN2003A/ULN2004A | | | | | | |
|---|---|---|---|---|---|---|
| **Parameter** | | **Test Figure** | **Min** | **Typ** | **Max** | **Unit** |
| $t_{PLH}$ | Propagation Delay Time, Low to High-Level Output | 9 | — | 0.25 | 1 | µs |
| $t_{PHL}$ | Propagation Delay Time, High to Low-Level Output | 9 | — | 0.25 | 1 | µs |
| $V_{OH}$ | High-Level Output Voltage after Switching | 9 ($V_S$ = 50V, $I_O$ = 300mA) | $V_S$-20 | — | — | mV |

## Switching Characteristics (@$T_A$ = -40 to +105°C, unless otherwise specified.)

| ULN2003A | | | | | | |
|---|---|---|---|---|---|---|
| **Parameter** | | **Test Figure** | **Min** | **Typ** | **Max** | **Unit** |
| $t_{PLH}$ | Propagation Delay Time, Low to High-Level Output | 9 | — | 1 | 10 | µs |
| $t_{PHL}$ | Propagation Delay Time, High to Low-Level Output | 9 | — | 1 | 10 | µs |
| $V_{OH}$ | High-Level Output Voltage after Switching | 9 ($V_S$ = 50V, $I_O$ = 300mA) | $V_S$-50 | — | — | mV |

## Parameter Measurement Circuits

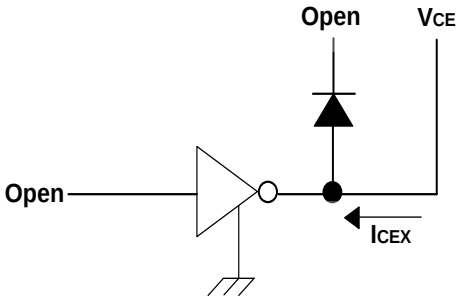



Fig.1 $I_{CEX}$ Test Circuit

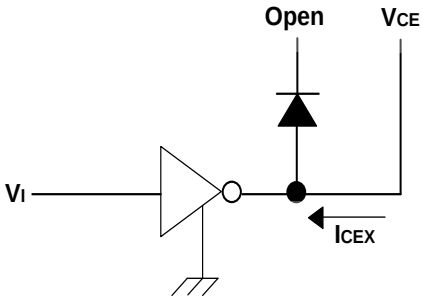



Fig.2 $I_{CEX}$ Test Circuit

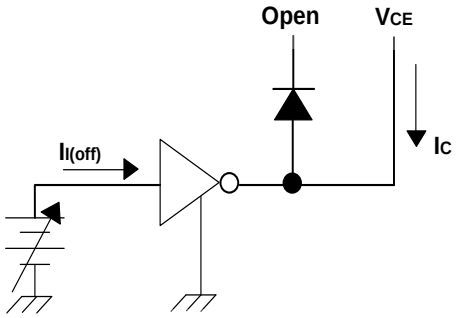



Fig.3 $I_{I(off)}$ Test Circuit

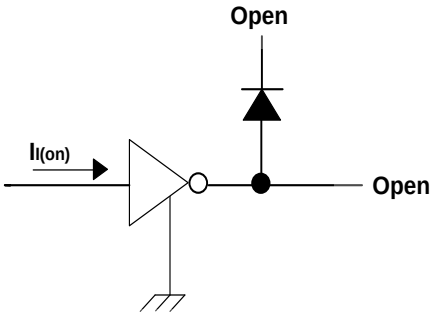



Fig.4 $I_I$ Test Circuit

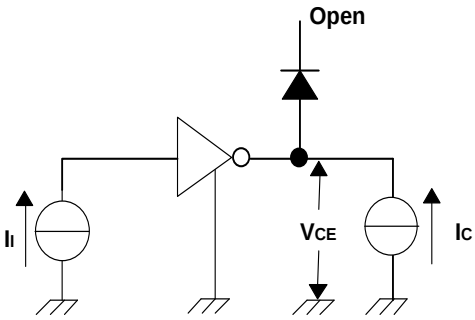



Fig. 5 $h_{FE}$ , $V_{CE(sat)}$ Test Circuit

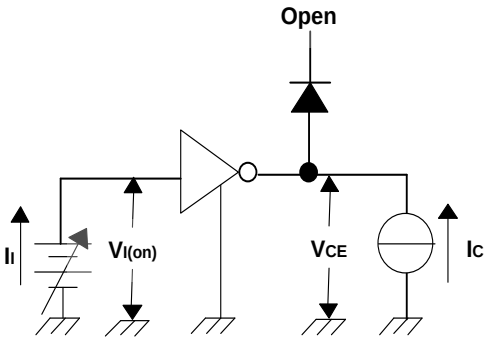



Fig. 6 $V_{I(on)}$ Test Circuit

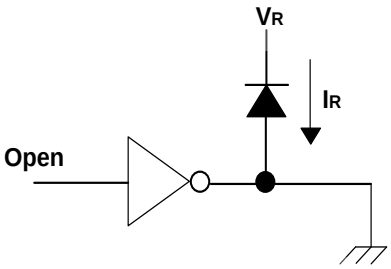



Fig. 7 $I_R$ Test Circuit

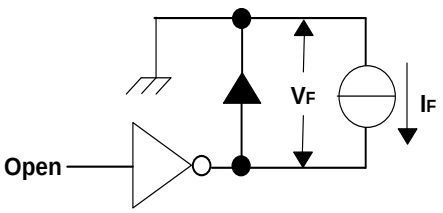



Fig. 8 $V_F$ Test Circuit

## Parameter Measurement Circuits (continued)

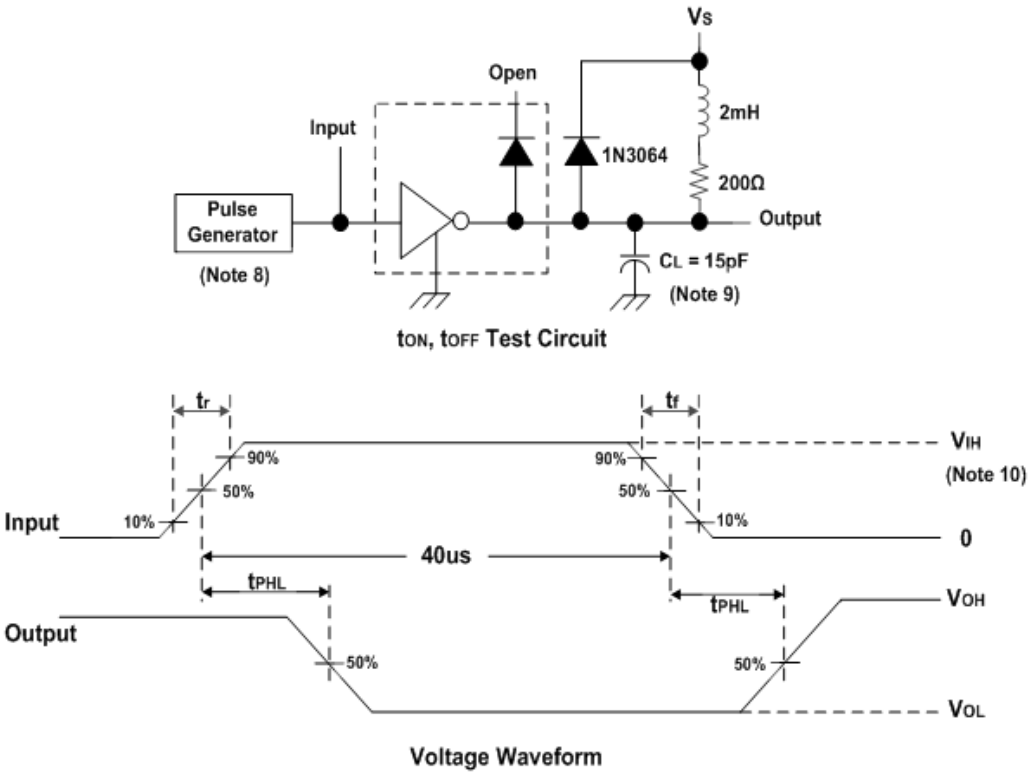
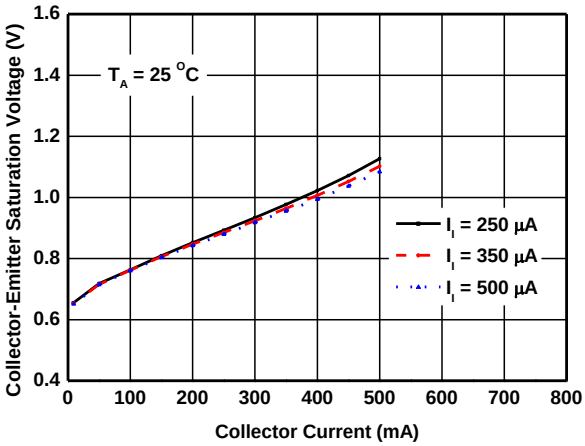



**Fig. 9 Latchup Test Circuit and Voltage Waveform**

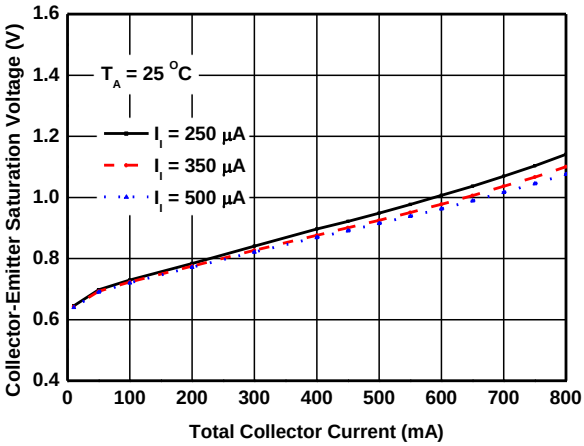
Notes: 8. The pulse generator has the following characteristics: Pulse width = 12.5Hz, output impedance 50Ω, tr ≤ 5ns, tr ≤ 10ns.
9. $C_L$ includes prove and jig capacitance.
10. For testing the ULN2002A, $V_{IH}$ = 13V; for the ULN2003A, $V_{IH}$ = 3V; for the ULN2004A, $V_{IH}$ = 8V.

## Typical Performance Characteristics

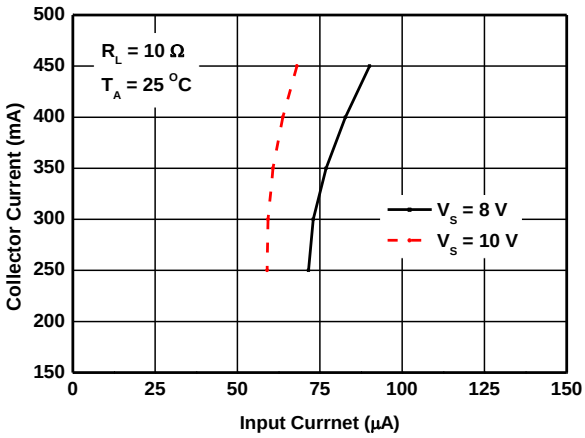
**Collector-Emitter Saturation Voltage vs. Collector Current (One Darlington)**



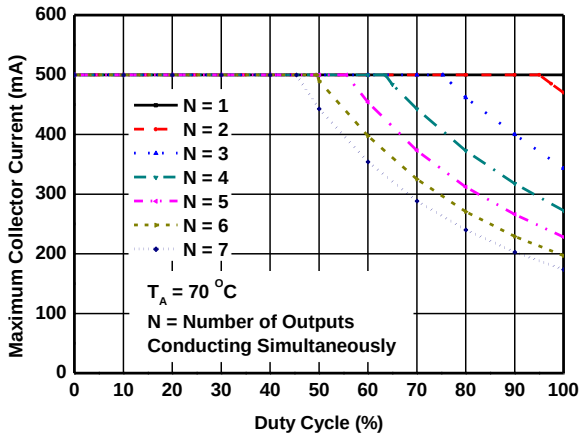

**Collector-Emitter Saturation Voltage vs. Collector Current (Two Darlington in Parallel)**



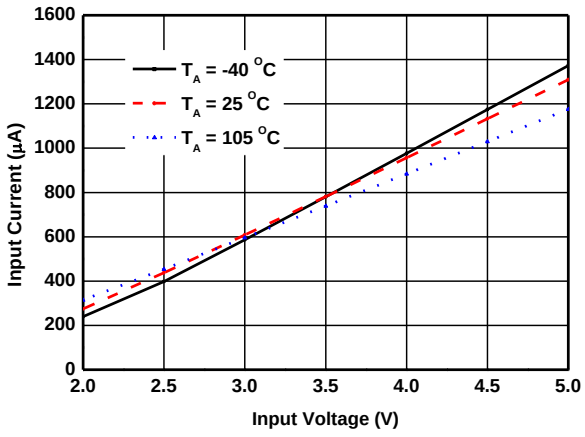

**Collector Current vs. Input Current**



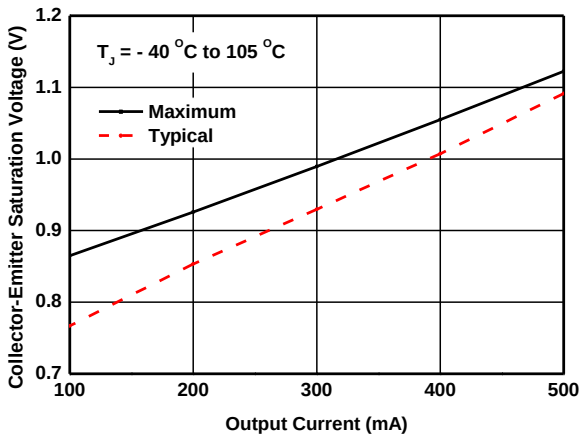

**Maximum Collector Current vs. Duty Cycle**




**Input Current vs. Input Voltage**

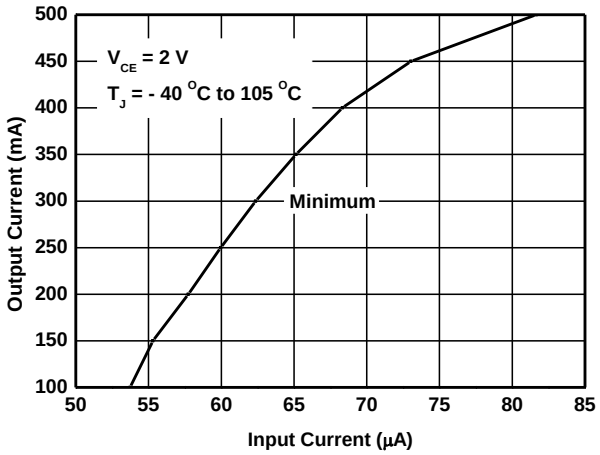



**Collector-Emitter Saturation Voltage vs. Output Current**

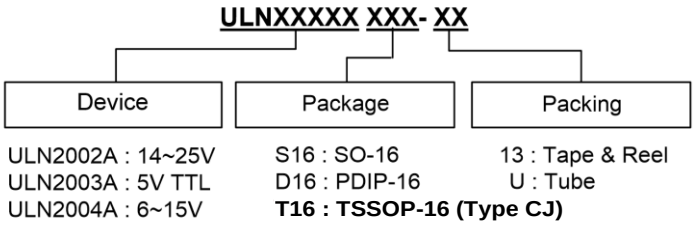


## Typical Performance Characteristics (continued)

**Output Current vs. Input Current**



## Ordering Information



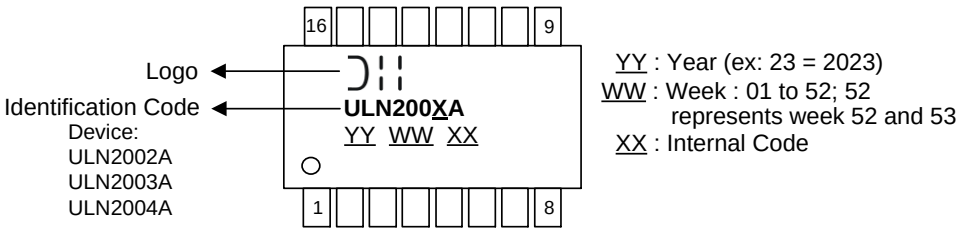

| Part Number | Part Number Suffix | Package Code | Package | Status | Packing | |
|---|---|---|---|---|---|---|
| | | | | | Qty. | Carrier |
| ULN2002AS16-13 | -13 | S16 | SO-16 | Production | 2,500 | 13” Tape and Reel |
| ULN2003AS16-13 | -13 | S16 | SO-16 | Production | 2,500 | 13” Tape and Reel |
| ULN2004AS16-13 | -13 | S16 | SO-16 | Production | 2,500 | 13” Tape and Reel |
| ULN2002AD16-U | -U | D16 | PDIP-16 | EOL* | 25 | Tube |
| ULN2003AD16-U | -U | D16 | PDIP-16 | EOL* | 25 | Tube |
| ULN2004AD16-U | -U | D16 | PDIP-16 | EOL* | 25 | Tube |
| ULN2003AT16-13 | -13 | T16 | TSSOP-16 (Type CJ) | Production | 2,500 | 13” Tape and Reel |

* EOL = End of life. Please contact us.

## Marking Information

**(1) SO-16, TSSOP-16 (Type CJ)**

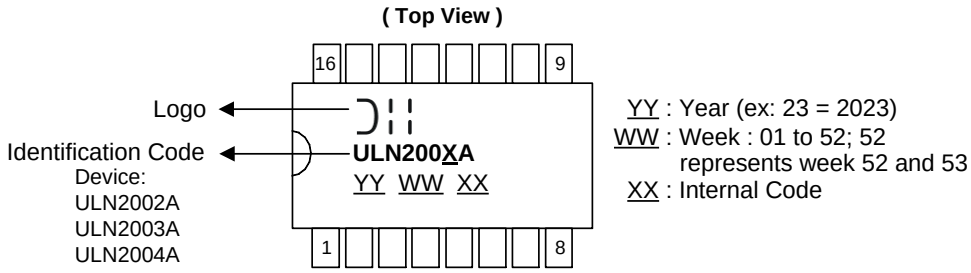
**( Top View )**




| Part Number | Package | Identification Code |
|---|---|---|
| ULN200xAS16-13 | SO-16 | ULN200xA |
| ULN2003AT16-13 | TSSOP-16 (Type CJ) | ULN2003A |

**(2) PDIP-16**

**( Top View )**

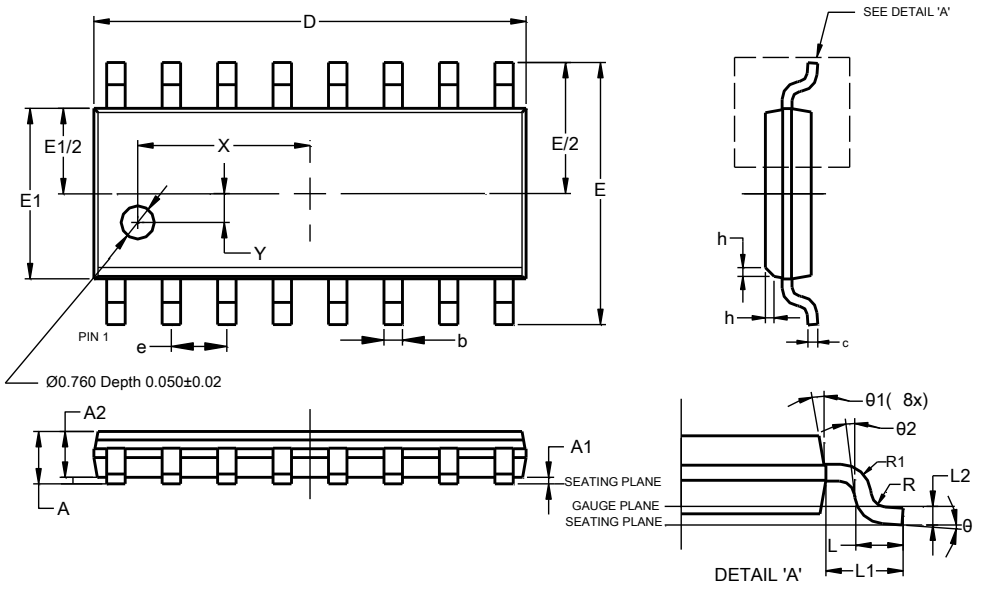



| Part Number | Package | Identification Code |
|---|---|---|
| ULN200xAD16-U | PDIP-16 | ULN200xA |

## Package Outline Dimensions

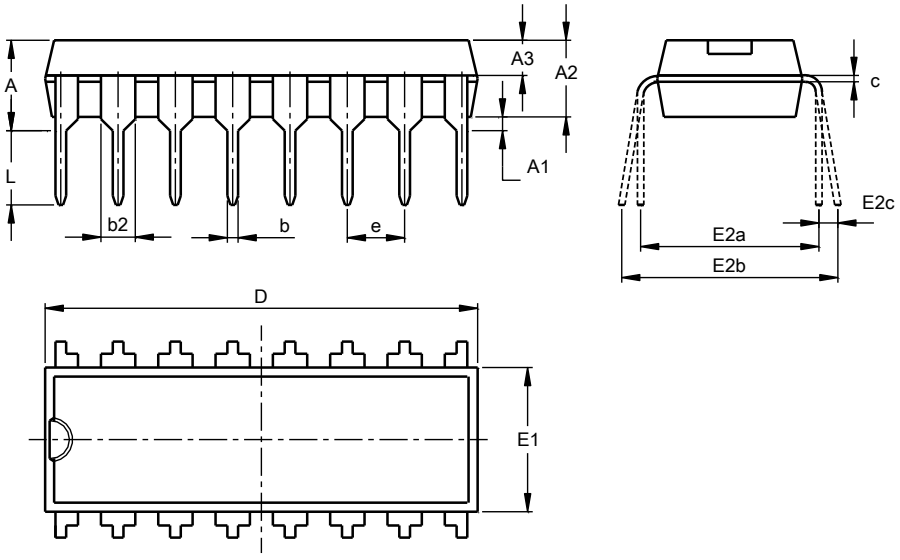
Please see http://www.diodes.com/package-outlines.html for the latest version.

**SO-16**




| SO-16 | | | |
|---|---|---|---|
| **Dim** | **Min** | **Max** | **Typ** |
| **A** | -- | 1.260 | -- |
| **A1** | 0.10 | 0.23 | -- |
| **A2** | 1.02 | -- | -- |
| **b** | 0.31 | 0.51 | -- |
| **c** | 0.10 | 0.25 | -- |
| **D** | 9.80 | 10.00 | -- |
| **E** | 5.90 | 6.10 | -- |
| **E1** | 3.80 | 4.00 | -- |
| **e** | 1.27 BSC | | |
| **h** | 0.15 | 0.25 | 0.20 |
| **L** | 0.40 | 1.27 | -- |
| **L1** | 1.04 REF | | |
| **L2** | 0.25 BSC | | |
| **R** | 0.07 | -- | -- |
| **R1** | 0.07 | -- | -- |
| **X** | 3.945 REF | | |
| **Y** | 0.661 REF | | |
| **θ** | 0° | 8° | -- |
| **θ1** | 5° | 15° | -- |
| **θ2** | 0° | -- | -- |
| **All Dimensions in mm** | | | |

**PDIP-16**

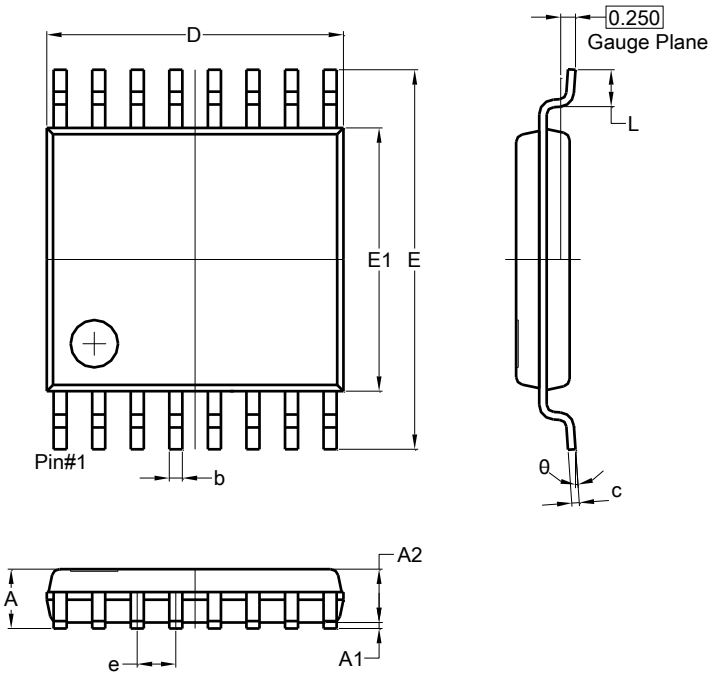



| PDIP-16 | | | |
|---|---|---|---|
| **Dim** | **Min** | **Max** | **Nom** |
| **A** | 3.60 | 4.00 | 3.80 |
| **A1** | 0.51 | - | - |
| **A2** | 3.20 | 3.40 | 3.30 |
| **A3** | 1.47 | 1.57 | 1.52 |
| **b** | 0.44 | 0.53 | - |
| **b2** | 1.52BSC | | |
| **c** | 0.25 | 0.31 | - |
| **D** | 18.90 | 19.30 | 19.10 |
| **E1** | 6.15 | 6.55 | 6.35 |
| **E2a** | 7.62 BSC | | |
| **E2b** | 7.62 | 9.30 | - |
| **E2c** | 0.00 | 0.84 | - |
| **e** | 2.54BSC | | |
| **L** | 3.00 | - | - |
| **All Dimensions in mm** | | | |

## Package Outline Dimensions (continued)

Please see http://www.diodes.com/package-outlines.html for the latest version.

**TSSOP-16 (Type CJ)**

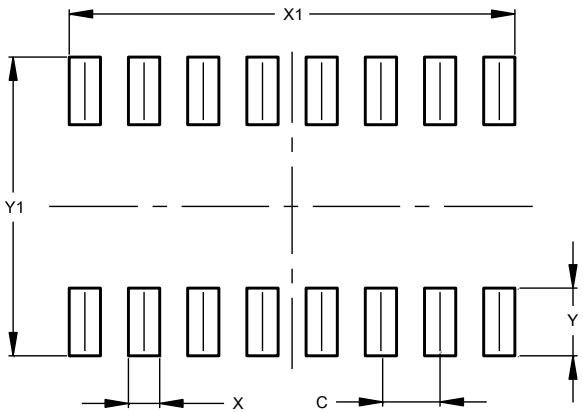



| TSSOP-16 (Type CJ) | | | |
|---|---|---|---|
| **Dim** | **Min** | **Max** | **Typ** |
| **A** | -- | 1.200 | -- |
| **A1** | 0.020 | 0.100 | -- |
| **A2** | 0.800 | 1.000 | -- |
| **b** | 0.190 | 0.300 | -- |
| **c** | 0.090 | 0.200 | |
| **D** | 4.900 | 5.100 | -- |
| **E** | 6.250 | 6.550 | -- |
| **E1** | 4.300 | 4.500 | -- |
| **e** | 0.650 BSC | | |
| **L** | 0.500 | 0.700 | -- |
| **θ** | 1° | 7° | -- |
| **All Dimensions in mm** | | | |

## Suggested Pad Layout

Please see http://www.diodes.com/package-outlines.html for the latest version.

**SO-16**

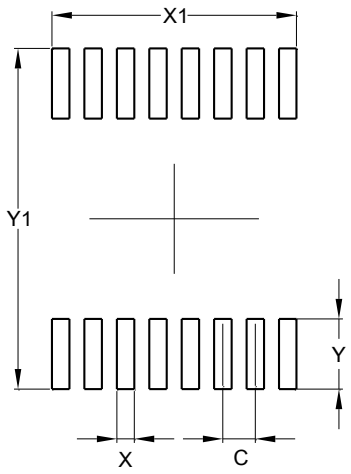



| Dimensions | Value (in mm) |
|---|---|
| **C** | 1.270 |
| **X** | 0.670 |
| **X1** | 9.560 |
| **Y** | 1.450 |
| **Y1** | 6.400 |

## Suggested Pad Layout (continued)

Please see http://www.diodes.com/package-outlines.html for the latest version.

**TSSOP-16 (Type CJ)**




| Dimensions | Value (in mm) |
|---|---|
| C | 0.650 |
| X | 0.350 |
| X1 | 4.900 |
| Y | 1.400 |
| Y1 | 6.800 |

## Mechanical Data

- Moisture Sensitivity:
  - SO-16: Level 1 per J-STD-020
  - TSSOP-16 (Type CJ): Level 1 per J-STD-020
- Terminals: Finish—Matte Tin Plated Leads, Solderable per MIL-STD-202, Method 208 e3
- Weight:
  - SO-16: 0.13 grams (Approximate)
  - TSSOP-16 (Type CJ): 0.055 grams (Approximate)
  - PDIP-16: 1.095 grams (Approximate)

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