



ULN200x, ULQ200x High-Voltage, High-Current Darlington Transistor Arrays

1 Features

- 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

2 Applications

- Relay Drivers
- Stepper and DC Brushed Motor Drivers
- Lamp Drivers
- Display Drivers (LED and Gas Discharge)
- Line Drivers
- Logic Buffers

3 Description

The ULx200xA devices 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 ULx2003A devices, see the [SLRS023](#) data sheet for the SN75468 and SN75469 devices.

The ULN2002A device 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 ULx2003A devices have a 2.7-k Ω series base resistor for each Darlington pair for operation directly with TTL or 5-V CMOS devices.

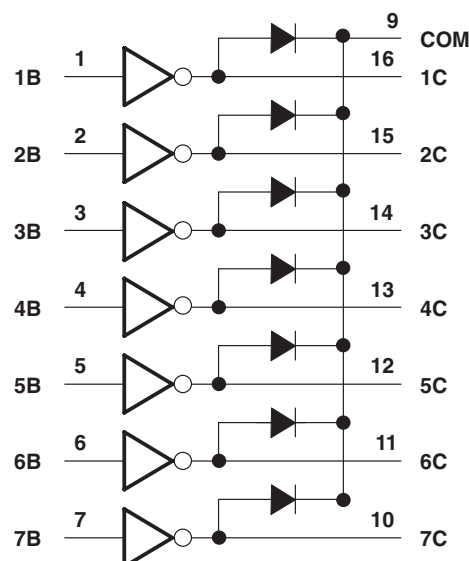
The ULx2004A devices have a 10.5-k Ω series base resistor to allow operation directly from CMOS devices that use supply voltages of 6 V to 15 V. The required input current of the ULx2004A device is below that of the ULx2003A devices, and the required voltage is less than that required by the ULN2002A device.

Device Information⁽¹⁾

PART NUMBER	PACKAGE	BODY SIZE (NOM)
ULx200xD	SOIC (16)	9.90 mm × 3.91 mm
ULx200xN	PDIP (16)	19.30 mm × 6.35 mm
ULN200xNS	SOP (16)	10.30 mm × 5.30 mm
ULN200xPW	TSSOP (16)	5.00 mm × 4.40 mm

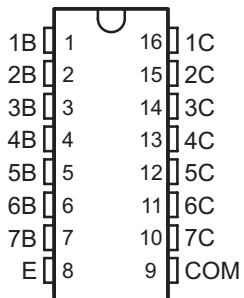
(1) For all available packages, see the orderable addendum at the end of the data sheet.

Simplified Block Diagram



5 Pin Configuration and Functions

**D, N, NS, and PW Package
16-Pin SOIC, PDIP, SO, and TSSOP
Top View**



Pin Functions

PIN		I/O ⁽¹⁾	DESCRIPTION
NAME	NO.		
1B	1	I	Channel 1 through 7 Darlington base input
2B	2		
3B	3		
4B	4		
5B	5		
6B	6		
7B	7		
1C	16	O	Channel 1 through 7 Darlington collector output
2C	15		
3C	14		
4C	13		
5C	12		
6C	11		
7C	10		
COM	9	—	Common cathode node for flyback diodes (required for inductive loads)
E	8	—	Common emitter shared by all channels (typically tied to ground)

(1) I = Input, O = Output

6 Specifications

6.1 Absolute Maximum Ratings

at 25°C free-air temperature (unless otherwise noted)⁽¹⁾

			MIN	MAX	UNIT	
V _{CC}	Collector-emitter voltage		50		V	
	Clamp diode reverse voltage ⁽²⁾		50		V	
V _I	Input voltage ⁽²⁾		30		V	
	Peak collector current, See Figure 4 and Figure 5		500		mA	
I _{OK}	Output clamp current		500		mA	
	Total emitter-terminal current		−2.5		A	
T _A	Operating free-air temperature range		ULN200xA	−20	70	°C
			ULN200xAI	−40	105	
			ULQ200xA	−40	85	
			ULQ200xAT	−40	105	
T _J	Operating virtual junction temperature		150		°C	
	Lead temperature for 1.6 mm (1/16 inch) from case for 10 seconds		260		°C	
T _{stg}	Storage temperature		−65	150	°C	

- (1) 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.
- (2) All voltage values are with respect to the emitter/substrate terminal E, unless otherwise noted.

6.2 ESD Ratings

			VALUE	UNIT
V _(ESD)	Electrostatic discharge	Human body model (HBM), per ANSI/ESDA/JEDEC JS-001 ⁽¹⁾	±2000	V
		Charged device model (CDM), per JEDEC specification JESD22-C101 ⁽²⁾	±500	

- (1) JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process.
- (2) JEDEC document JEP157 states that 250-V CDM allows safe manufacturing with a standard ESD control process.

6.3 Recommended Operating Conditions

over operating free-air temperature range (unless otherwise noted)

		MIN	MAX	UNIT
V _{CC}	Collector-emitter voltage (non-V devices)	0	50	V
T _J	Junction temperature	–40	125	°C

6.4 Thermal Information

THERMAL METRIC ⁽¹⁾		ULx200x				UNIT
		D (SOIC)	N (PDIP)	NS (SO)	PW (TSSOP)	
		16 PINS	16 PINS	16 PINS	16 PINS	
R _{θJA}	Junction-to-ambient thermal resistance	73	67	64	108	°C/W
R _{θJC(top)}	Junction-to-case (top) thermal resistance	36	54	n/a	33.6	°C/W
R _{θJB}	Junction-to-board thermal resistance	n/a	n/a	n/a	51.9	°C/W
ψ _{JT}	Junction-to-top characterization parameter	n/a	n/a	n/a	2.1	°C/W
ψ _{JB}	Junction-to-board characterization parameter	n/a	n/a	n/a	51.4	°C/W

- (1) For more information about traditional and new thermal metrics, see the *Semiconductor and IC Package Thermal Metrics* application report, [SPRA953](#).

6.5 Electrical Characteristics: ULN2002A

 $T_A = 25^\circ\text{C}$

PARAMETER	TEST FIGURE	TEST CONDITIONS	ULN2002A			UNIT
			MIN	TYP	MAX	
$V_{I(on)}$ ON-state input voltage	Figure 14	$V_{CE} = 2\text{ V}$, $I_C = 300\text{ mA}$			13	V
V_{OH} High-level output voltage after switching	Figure 18	$V_S = 50\text{ V}$, $I_O = 300\text{ mA}$	$V_S - 20$			mV
$V_{CE(sat)}$ Collector-emitter saturation voltage	Figure 12	$I_I = 250\text{ }\mu\text{A}$, $I_C = 100\text{ mA}$		0.9	1.1	V
		$I_I = 350\text{ }\mu\text{A}$, $I_C = 200\text{ mA}$		1	1.3	
		$I_I = 500\text{ }\mu\text{A}$, $I_C = 350\text{ mA}$		1.2	1.6	
V_F Clamp forward voltage	Figure 15	$I_F = 350\text{ mA}$		1.7	2	V
I_{CEX} Collector cutoff current	Figure 9	$V_{CE} = 50\text{ V}$, $I_I = 0$			50	μA
	Figure 10	$V_{CE} = 50\text{ V}$, $T_A = 70^\circ\text{C}$, $I_I = 0$			100	
		$V_I = 6\text{ V}$			500	
$I_{I(off)}$ OFF-state input current	Figure 10	$V_{CE} = 50\text{ V}$, $I_C = 500\text{ }\mu\text{A}$	50	65		μA
I_I Input current	Figure 11	$V_I = 17\text{ V}$		0.82	1.25	mA
I_R Clamp reverse current	Figure 14	$V_R = 50\text{ V}$, $T_A = 70^\circ\text{C}$			100	μA
		$V_R = 50\text{ V}$			50	
C_i Input capacitance		$V_I = 0$, $f = 1\text{ MHz}$			25	pF

6.6 Electrical Characteristics: ULN2003A and ULN2004A

 $T_A = 25^\circ\text{C}$

PARAMETER	TEST FIGURE	TEST CONDITIONS	ULN2003A			ULN2004A			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
$V_{I(on)}$ ON-state input voltage	Figure 14	$V_{CE} = 2\text{ V}$						5	V
								6	
					2.4				
					2.7				
								7	
					3				
V_{OH} High-level output voltage after switching	Figure 18	$V_S = 50\text{ V}$, $I_O = 300\text{ mA}$	$V_S - 20$			$V_S - 20$			mV
$V_{CE(sat)}$ Collector-emitter saturation voltage	Figure 13	$I_I = 250\text{ }\mu\text{A}$, $I_C = 100\text{ mA}$		0.9	1.1		0.9	1.1	V
		$I_I = 350\text{ }\mu\text{A}$, $I_C = 200\text{ mA}$		1	1.3		1	1.3	
		$I_I = 500\text{ }\mu\text{A}$, $I_C = 350\text{ mA}$		1.2	1.6		1.2	1.6	
I_{CEX} Collector cutoff current	Figure 9	$V_{CE} = 50\text{ V}$, $I_I = 0$			50			50	μA
	Figure 10	$V_{CE} = 50\text{ V}$, $T_A = 70^\circ\text{C}$, $I_I = 0$			100			100	
		$V_I = 6\text{ V}$						500	
V_F Clamp forward voltage	Figure 16	$I_F = 350\text{ mA}$		1.7	2		1.7	2	V
$I_{I(off)}$ Off-state input current	Figure 11	$V_{CE} = 50\text{ V}$, $T_A = 70^\circ\text{C}$, $I_C = 500\text{ }\mu\text{A}$	50	65		50	65		μA
I_I Input current	Figure 12	$V_I = 3.85\text{ V}$		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	Figure 15	$V_R = 50\text{ V}$			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

6.7 Electrical Characteristics: ULN2003AI

$T_A = 25^\circ\text{C}$

PARAMETER	TEST FIGURE	TEST CONDITIONS		ULN2003AI			UNIT
				MIN	TYP	MAX	
$V_{I(on)}$ ON-state input voltage	Figure 14	$V_{CE} = 2\text{ V}$	$I_C = 200\text{ mA}$			2.4	V
			$I_C = 250\text{ mA}$			2.7	
			$I_C = 300\text{ mA}$			3	
V_{OH} High-level output voltage after switching	Figure 18	$V_S = 50\text{ V}, I_O = 300\text{ mA}$		$V_S - 50$			mV
$V_{CE(sat)}$ Collector-emitter saturation voltage	Figure 13	$I_I = 250\text{ }\mu\text{A}, I_C = 100\text{ mA}$		0.9	1.1		V
		$I_I = 350\text{ }\mu\text{A}, I_C = 200\text{ mA}$		1	1.3		
		$I_I = 500\text{ }\mu\text{A}, I_C = 350\text{ mA}$		1.2	1.6		
I_{CEX} Collector cutoff current	Figure 9	$V_{CE} = 50\text{ V}, I_I = 0$				50	μA
V_F Clamp forward voltage	Figure 16	$I_F = 350\text{ mA}$			1.7	2	V
$I_{I(off)}$ OFF-state input current	Figure 11	$V_{CE} = 50\text{ V}, I_C = 500\text{ }\mu\text{A}$		50	65		μA
I_I Input current	Figure 12	$V_I = 3.85\text{ V}$			0.93	1.35	mA
I_R Clamp reverse current	Figure 15	$V_R = 50\text{ V}$				50	μA
C_i Input capacitance		$V_I = 0, f = 1\text{ MHz}$			15	25	pF

6.8 Electrical Characteristics: ULN2003AI

$T_A = -40^\circ\text{C}$ to 105°C

PARAMETER	TEST FIGURE	TEST CONDITIONS		ULN2003AI			UNIT
				MIN	TYP	MAX	
$V_{I(on)}$ ON-state input voltage	Figure 14	$V_{CE} = 2\text{ V}$	$I_C = 200\text{ mA}$			2.7	V
			$I_C = 250\text{ mA}$			2.9	
			$I_C = 300\text{ mA}$			3	
V_{OH} High-level output voltage after switching	Figure 18	$V_S = 50\text{ V}, I_O = 300\text{ mA}$		$V_S - 50$			mV
$V_{CE(sat)}$ Collector-emitter saturation voltage	Figure 13	$I_I = 250\text{ }\mu\text{A}, I_C = 100\text{ mA}$		0.9	1.2		V
		$I_I = 350\text{ }\mu\text{A}, I_C = 200\text{ mA}$		1	1.4		
		$I_I = 500\text{ }\mu\text{A}, I_C = 350\text{ mA}$		1.2	1.7		
I_{CEX} Collector cutoff current	Figure 9	$V_{CE} = 50\text{ V}, I_I = 0$				100	μA
V_F Clamp forward voltage	Figure 16	$I_F = 350\text{ mA}$			1.7	2.2	V
$I_{I(off)}$ OFF-state input current	Figure 11	$V_{CE} = 50\text{ V}, I_C = 500\text{ }\mu\text{A}$		30	65		μA
I_I Input current	Figure 12	$V_I = 3.85\text{ V}$			0.93	1.35	mA
I_R Clamp reverse current	Figure 15	$V_R = 50\text{ V}$				100	μA
C_i Input capacitance		$V_I = 0, f = 1\text{ MHz}$			15	25	pF

6.9 Electrical Characteristics: ULQ2003A and ULQ2004A

over recommended operating conditions (unless otherwise noted)

PARAMETER	TEST FIGURE	TEST CONDITIONS		ULQ2003A			ULQ2004A			UNIT
				MIN	TYP	MAX	MIN	TYP	MAX	
$V_{I(on)}$ ON-state input voltage	Figure 14	$V_{CE} = 2\text{ V}$	$I_C = 125\text{ mA}$						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				
			$I_C = 350\text{ mA}$						8	
V_{OH} High-level output voltage after switching	Figure 18	$V_S = 50\text{ V}$, $I_O = 300\text{ mA}$		$V_S - 50$			$V_S - 50$			mV
$V_{CE(sat)}$ Collector-emitter saturation voltage	Figure 13	$I_I = 250\text{ }\mu\text{A}$, $I_C = 100\text{ mA}$		0.9	1.2		0.9	1.1		V
		$I_I = 350\text{ }\mu\text{A}$, $I_C = 200\text{ mA}$		1	1.4		1	1.3		
		$I_I = 500\text{ }\mu\text{A}$, $I_C = 350\text{ mA}$		1.2	1.7		1.2	1.6		
I_{CEX} Collector cutoff current	Figure 9	$V_{CE} = 50\text{ V}$, $I_I = 0$				100			50	μA
	Figure 10	$V_{CE} = 50\text{ V}$, $T_A = 70^\circ\text{C}$	$I_I = 0$						100	
			$V_I = 6\text{ V}$						500	
V_F Clamp forward voltage	Figure 16	$I_F = 350\text{ mA}$		1.7	2.3		1.7	2		V
$I_{I(off)}$ OFF-state input current	Figure 11	$V_{CE} = 50\text{ V}$, $T_A = 70^\circ\text{C}$, $I_C = 500\text{ }\mu\text{A}$		65			50	65		μA
I_I Input current	Figure 12	$V_I = 3.85\text{ V}$		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	Figure 15	$V_R = 50\text{ V}$, $T_A = 25^\circ\text{C}$				100			50	μA
		$V_R = 50\text{ V}$				100			100	
C_i Input capacitance		$V_I = 0$, $f = 1\text{ MHz}$		15	25		15	25		pF

6.10 Switching Characteristics: ULN2002A, ULN2003A, ULN2004A

$T_A = 25^\circ\text{C}$

PARAMETER	TEST CONDITIONS	ULN2002A, ULN2003A, ULN2004A			UNIT
		MIN	TYP	MAX	
t_{PLH} Propagation delay time, low- to high-level output	See Figure 17		0.25	1	μs
t_{PHL} Propagation delay time, high- to low-level output	See Figure 17		0.25	1	μs

6.11 Switching Characteristics: ULN2003AI

$T_A = 25^\circ\text{C}$

PARAMETER	TEST CONDITIONS	ULN2003AI			UNIT
		MIN	TYP	MAX	
t_{PLH} Propagation delay time, low- to high-level output	See Figure 17		0.25	1	μs
t_{PHL} Propagation delay time, high- to low-level output	See Figure 17		0.25	1	μs

6.12 Switching Characteristics: ULN2003AI

$T_A = -40^\circ\text{C}$ to 105°C

PARAMETER	TEST CONDITIONS	ULN2003AI			UNIT
		MIN	TYP	MAX	
t_{PLH}	Propagation delay time, low- to high-level output		1	10	μs
t_{PHL}	Propagation delay time, high- to low-level output		1	10	μs

6.13 Switching Characteristics: ULQ2003A, ULQ2004A

over recommended operating conditions (unless otherwise noted)

PARAMETER	TEST CONDITIONS	ULQ2003A, ULQ2004A			UNIT
		MIN	TYP	MAX	
t_{PLH}	Propagation delay time, low- to high-level output		1	10	μs
t_{PHL}	Propagation delay time, high- to low-level output		1	10	μs

6.14 Typical Characteristics

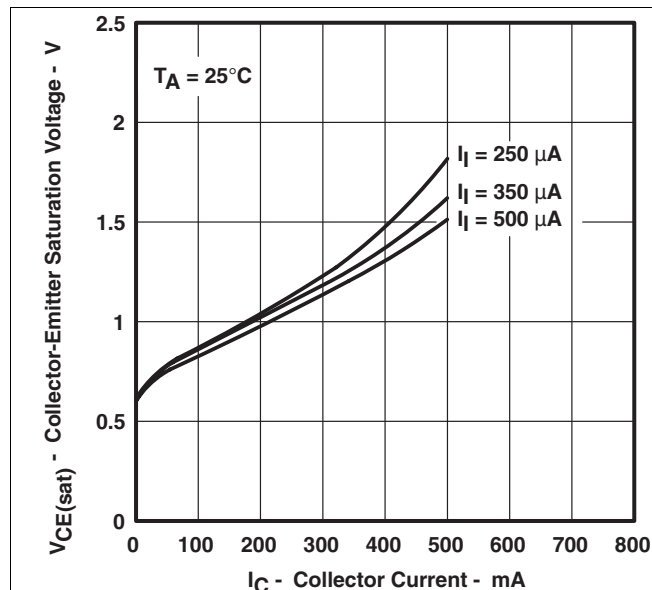


Figure 1. Collector-Emitter Saturation Voltage vs Collector Current (One Darlington)

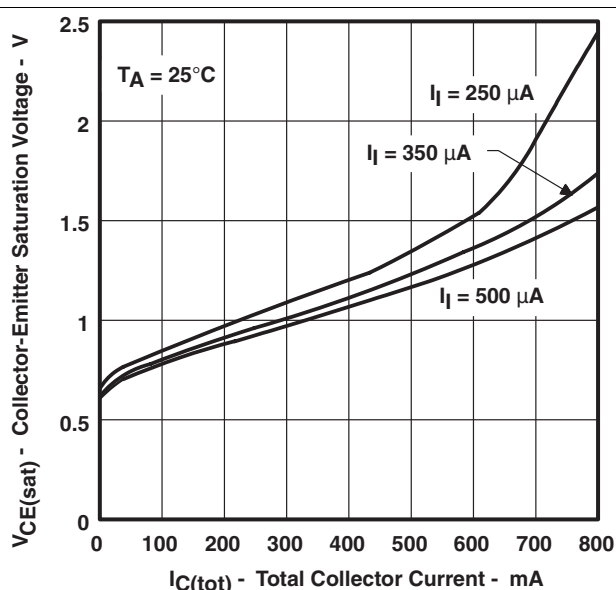


Figure 2. Collector-Emitter Saturation Voltage vs Total Collector Current (Two Darlings in Parallel)

Typical Characteristics (continued)

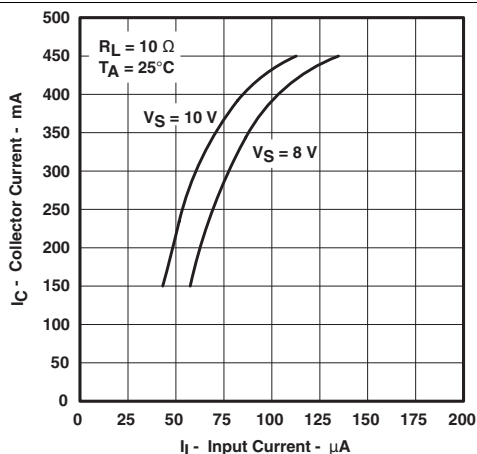


Figure 3. Collector Current vs Input Current

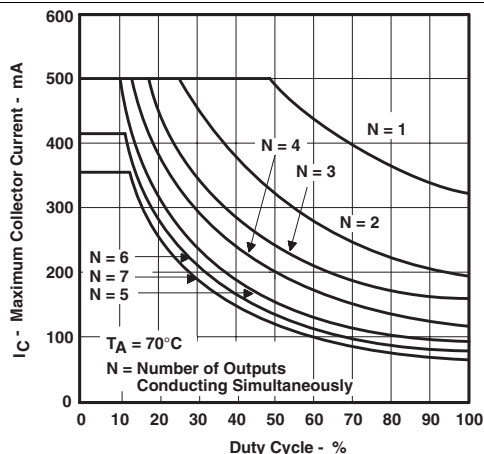


Figure 4. D Package Maximum Collector Current vs Duty Cycle

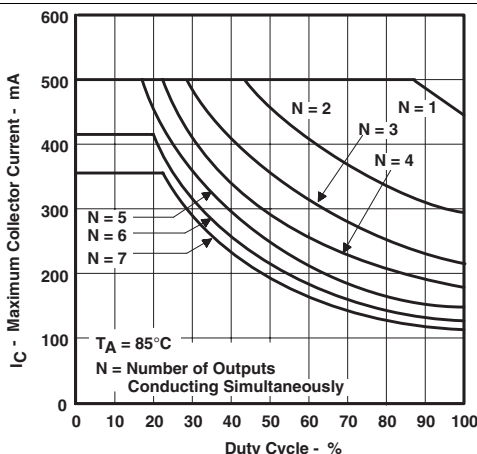


Figure 5. N Package Maximum Collector Current vs Duty Cycle

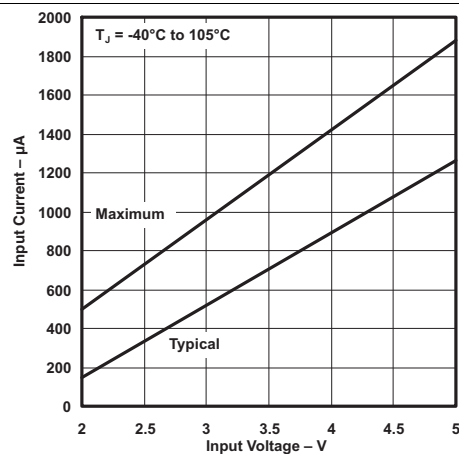


Figure 6. Maximum and Typical Input Current vs Input Voltage

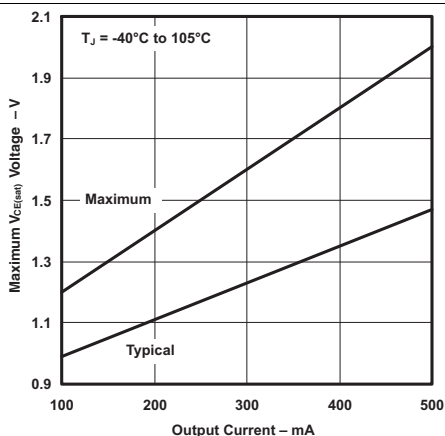


Figure 7. Maximum and Typical Saturated V_{CE} vs Output Current

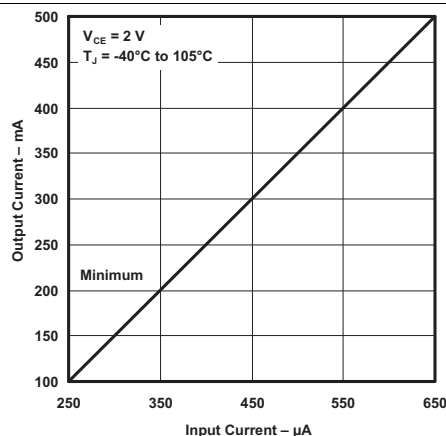


Figure 8. Minimum Output Current vs Input Current

7 Parameter Measurement Information

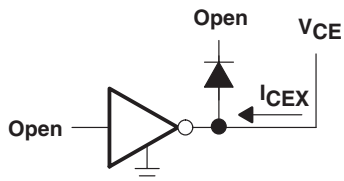


Figure 9. I_{CEX} Test Circuit

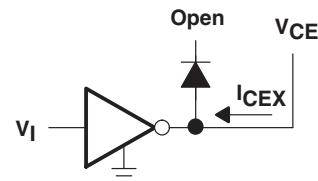


Figure 10. I_{CEX} Test Circuit

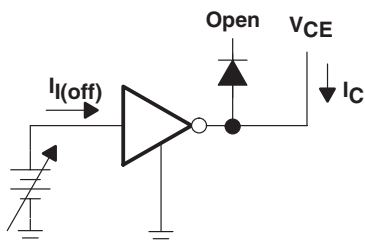


Figure 11. $I_{I(off)}$ Test Circuit

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

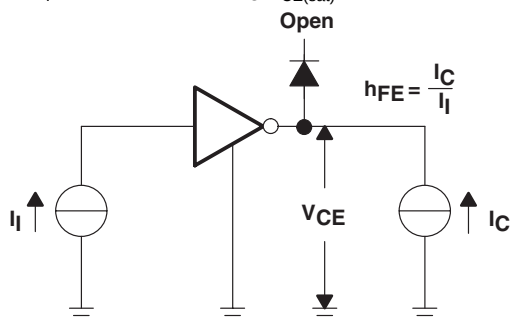


Figure 13. h_{FE} , $V_{CE(sat)}$ Test Circuit

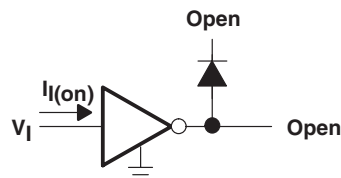


Figure 12. I_I Test Circuit

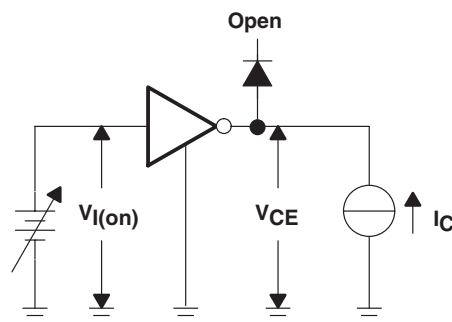


Figure 14. $V_{I(on)}$ Test Circuit

Parameter Measurement Information (continued)

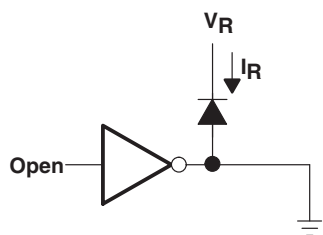


Figure 15. I_R Test Circuit

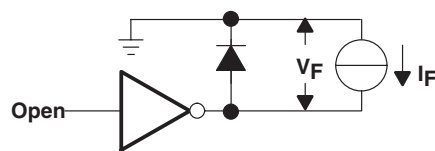
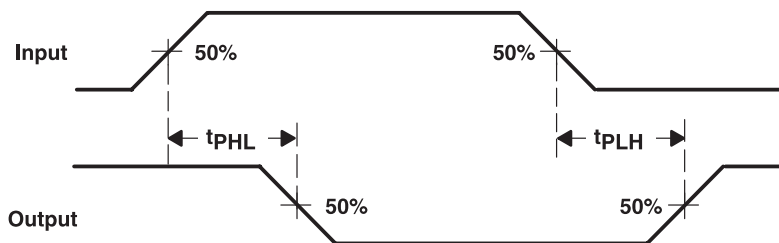
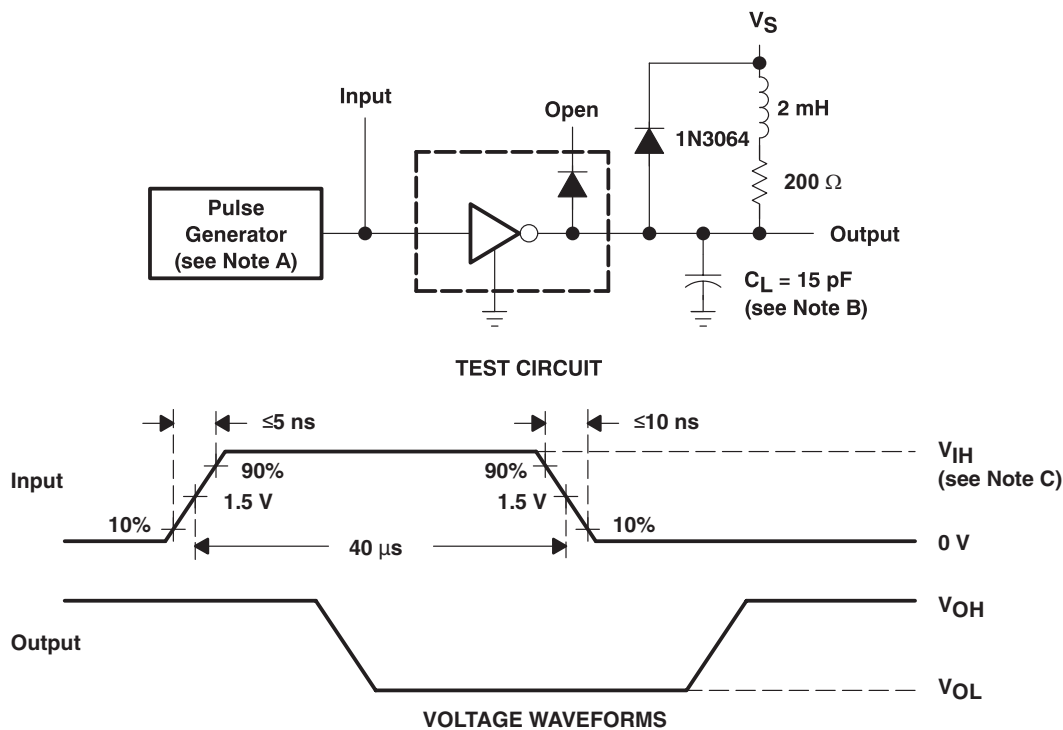


Figure 16. V_F Test Circuit



VOLTAGE WAVEFORMS

Figure 17. Propagation Delay-Time Waveforms



VOLTAGE WAVEFORMS

The pulse generator has the following characteristics: PRR = 12.5 kHz, $Z_O = 50 \Omega$.

C_L includes probe and jig capacitance.

For testing the ULN2003A device, ULN2003AI device, and ULQ2003A devices, $V_{IH} = 3 \text{ V}$; for the ULN2002A device, $V_{IH} = 13 \text{ V}$; for the ULN2004A and the ULQ2004A devices, $V_{IH} = 8 \text{ V}$.

Figure 18. Latch-Up Test Circuit and Voltage Waveforms

8 Detailed Description

8.1 Overview

This standard device has proven ubiquity and versatility across a wide range of applications. This is due to integration of 7 Darlington transistors of the device that are capable of sinking up to 500 mA and wide GPIO range capability.

The ULN2003A device comprises seven high-voltage, high-current NPN Darlington transistor pairs. All units feature a common emitter and open collector outputs. To maximize their effectiveness, these units contain suppression diodes for inductive loads. The ULN2003A device has a series base resistor to each Darlington pair, thus allowing operation directly with TTL or CMOS operating at supply voltages of 5 V or 3.3 V. The ULN2003A device offers solutions to a great many interface needs, including solenoids, relays, lamps, small motors, and LEDs. Applications requiring sink currents beyond the capability of a single output may be accommodated by paralleling the outputs.

This device can operate over a wide temperature range (-40°C to 105°C).

8.2 Functional Block Diagrams

All resistor values shown are nominal. The collector-emitter diode is a parasitic structure and should not be used to conduct current. If the collectors go below GND, an external Schottky diode should be added to clamp negative undershoots.

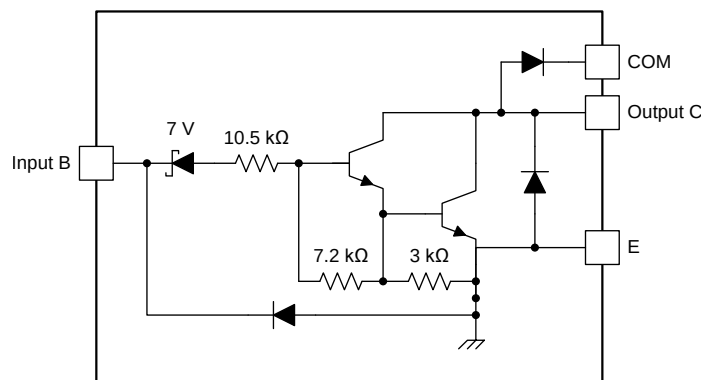


Figure 19. ULN2002A Block Diagram

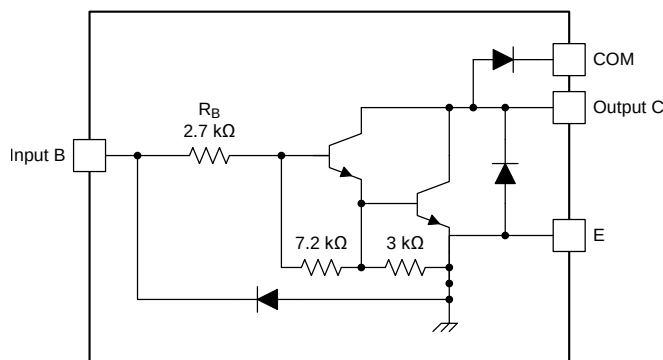


Figure 20. ULN2003A, ULQ2003A and ULN2003AI Block Diagram

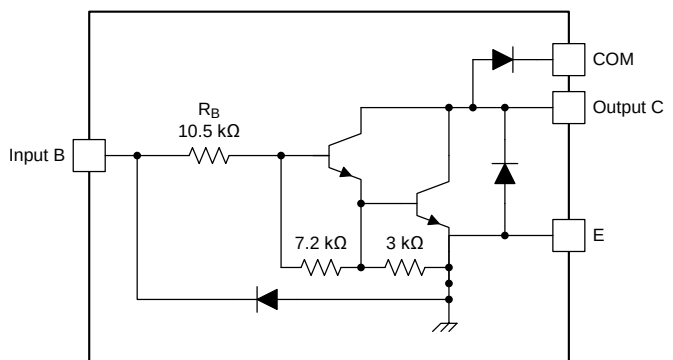


Figure 21. ULN2004A and LQ2004A Block Diagram

9 Application and Implementation

NOTE

Information in the following applications sections is not part of the TI component specification, and TI does not warrant its accuracy or completeness. TI's customers are responsible for determining suitability of components for their purposes. Customers should validate and test their design implementation to confirm system functionality.

9.1 Application Information

Typically, the ULN2003A device drives a high-voltage or high-current (or both) peripheral from an MCU or logic device that cannot tolerate these conditions. This design is a common application of ULN2003A device, driving inductive loads. This includes motors, solenoids and relays. Figure 22 shows a model for each load type.

9.2 Typical Application

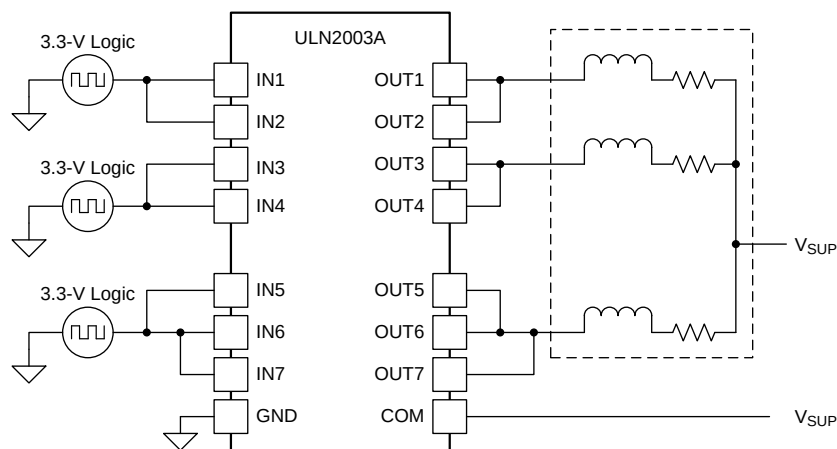


Figure 22. ULN2003A Device as Inductive Load Driver

9.2.1 Design Requirements

For this design example, use the parameters listed in Table 1 as the input parameters.

Table 1. Design Parameters

DESIGN PARAMETER	EXAMPLE VALUE
GPIO voltage	3.3 V or 5 V
Coil supply voltage	12 V to 48 V
Number of channels	7
Output current (R_{COIL})	20 mA to 300 mA per channel
Duty cycle	100%

9.2.2 Detailed Design Procedure

When using ULN2003A device in a coil driving application, determine the following:

- Input voltage range
- Temperature range
- Output and drive current
- Power dissipation

9.2.2.1 Drive Current

The coil voltage (V_{SUP}), coil resistance (R_{COIL}), and low-level output voltage ($V_{CE(SAT)}$ or V_{OL}) determine the coil current.

$$I_{COIL} = (V_{SUP} - V_{CE(SAT)}) / R_{COIL} \quad (1)$$

9.2.2.2 Low-Level Output Voltage

The low-level output voltage (V_{OL}) is the same as $V_{CE(SAT)}$ and can be determined by, [Figure 1](#), [Figure 2](#), or [Figure 7](#).

9.2.2.3 Power Dissipation and Temperature

The number of coils driven is dependent on the coil current and on-chip power dissipation. The number of coils driven can be determined by [Figure 4](#) or [Figure 5](#).

For a more accurate determination of number of coils possible, use the below equation to calculate ULN2003A device on-chip power dissipation P_D :

$$P_D = \sum_{i=1}^N V_{OLi} \times I_{Li}$$

where

- N is the number of channels active together
- V_{OLi} is the OUT_i pin voltage for the load current I_{Li} . This is the same as $V_{CE(SAT)}$

To ensure reliability of ULN2003A device and the system, the on-chip power dissipation must be lower than or equal to the maximum allowable power dissipation ($PD_{(MAX)}$) dictated by below equation [Equation 3](#).

$$PD_{(MAX)} = \frac{(T_{J(MAX)} - T_A)}{\theta_{JA}}$$

where

- $T_{J(max)}$ is the target maximum junction temperature
- T_A is the operating ambient temperature
- $R_{\theta JA}$ is the package junction to ambient thermal resistance

Limit the die junction temperature of the ULN2003A device to less than 125°C. The IC junction temperature is directly proportional to the on-chip power dissipation.

9.2.3 Application Curves

The characterization data shown in Figure 23 and Figure 24 were generated using the ULN2003A device driving an OMRON G5NB relay and under the following conditions: $V_{IN} = 5\text{ V}$, $V_{SUP} = 12\text{ V}$, and $R_{COIL} = 2.8\text{ k}\Omega$.

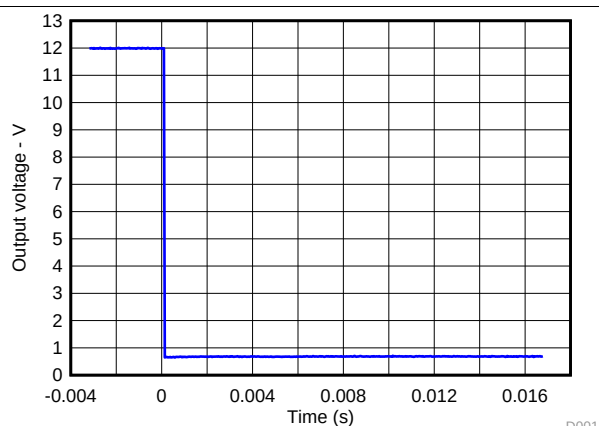


Figure 23. Output Response With Activation of Coil (Turnon)

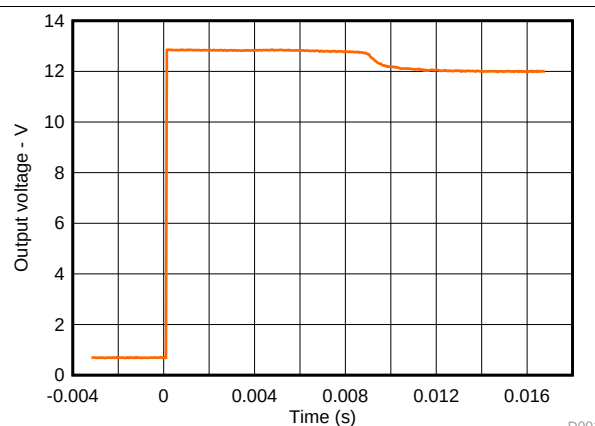


Figure 24. Output Response With De-activation of Coil (Turnoff)

9.3 System Examples

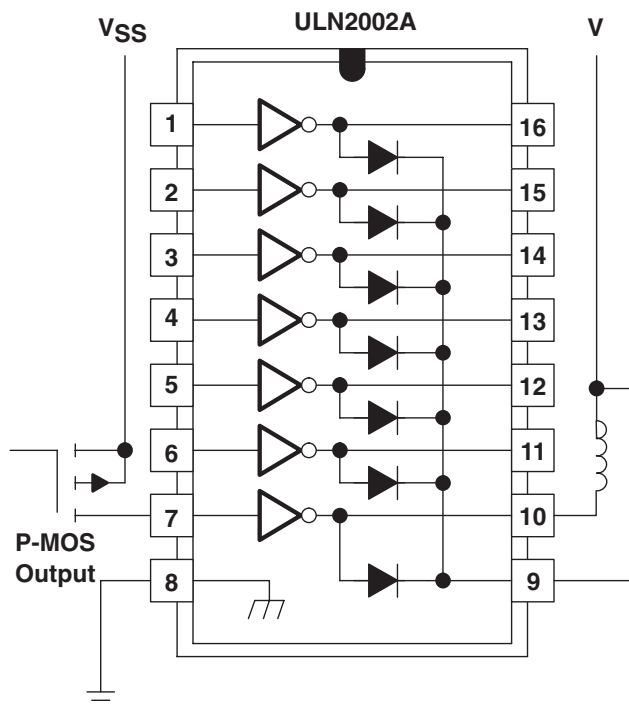


Figure 25. P-MOS to Load

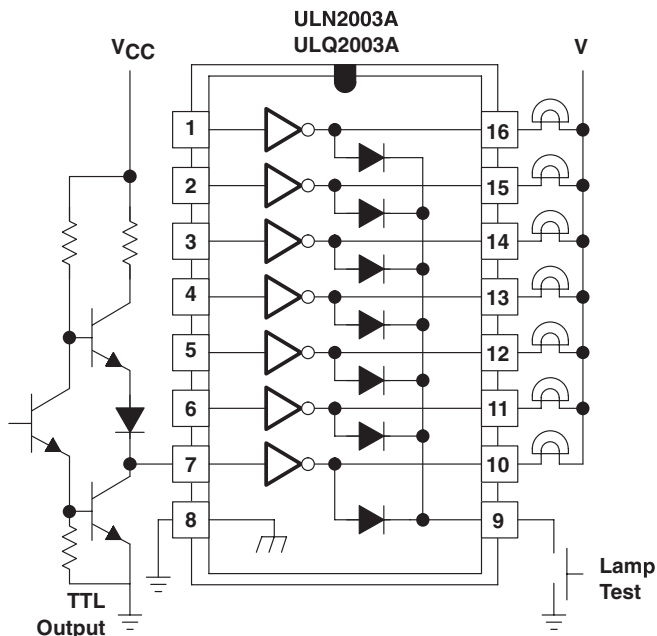


Figure 26. TTL to Load

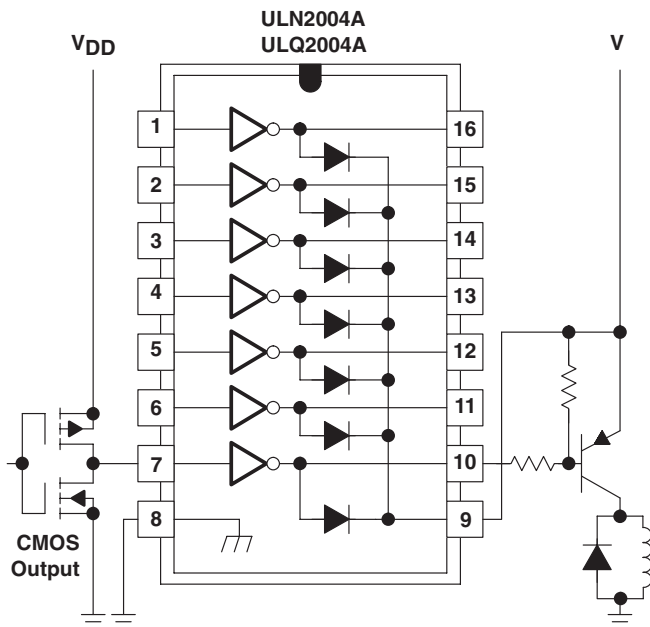


Figure 27. Buffer for Higher Current Loads

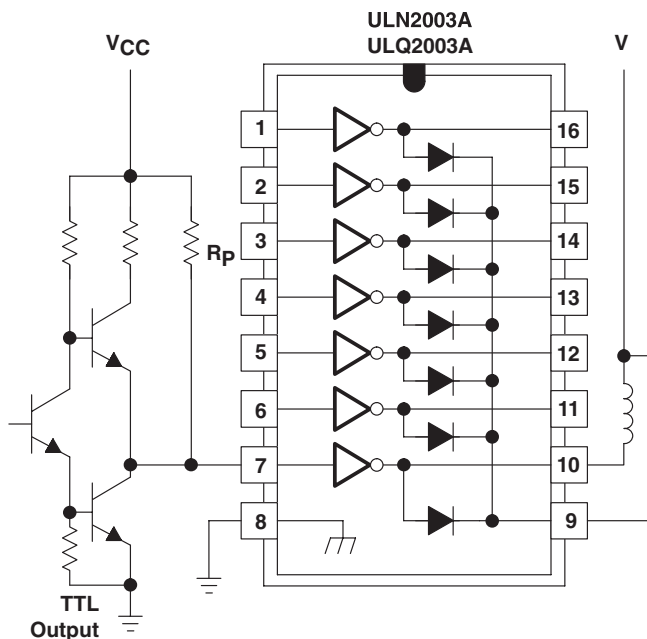


Figure 28. Use of Pullup Resistors to Increase Drive Current

10 Power Supply Recommendations

This device does not need a power supply. However, the COM pin is typically tied to the system power supply. When this is the case, it is very important to ensure that the output voltage does not heavily exceed the COM pin voltage. This discrepancy heavily forward biases the fly-back diodes and causes a large current to flow into COM, potentially damaging the on-chip metal or over-heating the device.

11 Layout

11.1 Layout Guidelines

Thin traces can be used on the input due to the low-current logic that is typically used to drive ULN2003A device. Take care to separate the input channels as much as possible, as to eliminate crosstalk. TI recommends thick traces for the output to drive whatever high currents that may be needed. Wire thickness can be determined by the current density of the trace material and desired drive current.

Because all of the channels currents return to a common emitter, it is best to size that trace width to be very wide. Some applications require up to 2.5 A.

11.2 Layout Example

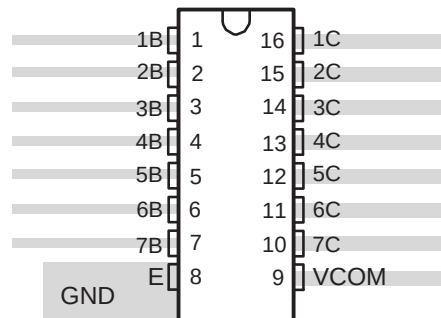


Figure 29. Package Layout

12 Device and Documentation Support

12.1 Documentation Support

12.1.1 Related Documentation

For related documentation, see the following:

SN7546x Darlington Transistor Arrays, [SLRS023](#)

12.2 Related Links

The table below lists quick access links. Categories include technical documents, support and community resources, tools and software, and quick access to sample or buy.

Table 2. Related Links

PARTS	PRODUCT FOLDER	SAMPLE & BUY	TECHNICAL DOCUMENTS	TOOLS & SOFTWARE	SUPPORT & COMMUNITY
ULN2002A	Click here	Click here	Click here	Click here	Click here
ULN2003A	Click here	Click here	Click here	Click here	Click here
ULN2003AI	Click here	Click here	Click here	Click here	Click here
ULN2004A	Click here	Click here	Click here	Click here	Click here
ULQ2003A	Click here	Click here	Click here	Click here	Click here
ULQ2004A	Click here	Click here	Click here	Click here	Click here

12.3 Community Resources

The following links connect to TI community resources. Linked contents are provided "AS IS" by the respective contributors. They do not constitute TI specifications and do not necessarily reflect TI's views; see TI's [Terms of Use](#).

TI E2E™ Online Community *TI's Engineer-to-Engineer (E2E) Community*. Created to foster collaboration among engineers. At [e2e.ti.com](#), you can ask questions, share knowledge, explore ideas and help solve problems with fellow engineers.

Design Support *TI's Design Support* Quickly find helpful E2E forums along with design support tools and contact information for technical support.

12.4 Trademarks

E2E is a trademark of Texas Instruments.
All other trademarks are the property of their respective owners.

12.5 Electrostatic Discharge Caution



These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

12.6 Glossary

[SLYZ022](#) — *TI Glossary*.

This glossary lists and explains terms, acronyms, and definitions.

13 Mechanical, Packaging, and Orderable Information

The following pages include mechanical packaging and orderable information. This information is the most current data available for the designated devices. This data is subject to change without notice and revision of this document. For browser based versions of this data sheet, refer to the left hand navigation.

PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
ULN2002AN	ACTIVE	PDIP	N	16	25	Pb-Free (RoHS)	CU NIPDAU	N / A for Pkg Type	-20 to 70	ULN2002AN	Samples
ULN2002ANE4	ACTIVE	PDIP	N	16	25	Pb-Free (RoHS)	CU NIPDAU	N / A for Pkg Type	-20 to 70	ULN2002AN	Samples
ULN2003AD	ACTIVE	SOIC	D	16	40	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-20 to 70	ULN2003A	Samples
ULN2003ADE4	ACTIVE	SOIC	D	16	40	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-20 to 70	ULN2003A	Samples
ULN2003ADG4	ACTIVE	SOIC	D	16	40	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-20 to 70	ULN2003A	Samples
ULN2003ADR	ACTIVE	SOIC	D	16	2500	Green (RoHS & no Sb/Br)	CU NIPDAU CU SN	Level-1-260C-UNLIM	-20 to 70	ULN2003A	Samples
ULN2003ADRE4	ACTIVE	SOIC	D	16	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-20 to 70	ULN2003A	Samples
ULN2003ADRG3	ACTIVE	SOIC	D	16	2500	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	-20 to 70	ULN2003A	Samples
ULN2003ADRG4	ACTIVE	SOIC	D	16	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-20 to 70	ULN2003A	Samples
ULN2003AID	ACTIVE	SOIC	D	16	40	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 105	ULN2003AI	Samples
ULN2003AIDE4	ACTIVE	SOIC	D	16	40	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 105	ULN2003AI	Samples
ULN2003AIDG4	ACTIVE	SOIC	D	16	40	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 105	ULN2003AI	Samples
ULN2003AIDR	ACTIVE	SOIC	D	16	2500	Green (RoHS & no Sb/Br)	CU NIPDAU CU SN	Level-1-260C-UNLIM	-40 to 105	ULN2003AI	Samples
ULN2003AIDRE4	ACTIVE	SOIC	D	16	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 105	ULN2003AI	Samples
ULN2003AIDRG4	ACTIVE	SOIC	D	16	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 105	ULN2003AI	Samples
ULN2003AIN	ACTIVE	PDIP	N	16	25	Pb-Free (RoHS)	CU NIPDAU CU SN	N / A for Pkg Type	-40 to 105	ULN2003AIN	Samples
ULN2003AINE4	ACTIVE	PDIP	N	16	25	Pb-Free (RoHS)	CU NIPDAU	N / A for Pkg Type	-40 to 105	ULN2003AIN	Samples

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
ULN2003AINSR	ACTIVE	SO	NS	16	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 105	ULN2003AI	Samples
ULN2003AIPW	ACTIVE	TSSOP	PW	16	90	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 105	UN2003AI	Samples
ULN2003AIPWE4	ACTIVE	TSSOP	PW	16	90	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 105	UN2003AI	Samples
ULN2003AIPWG4	ACTIVE	TSSOP	PW	16	90	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 105	UN2003AI	Samples
ULN2003AIPWR	ACTIVE	TSSOP	PW	16	2000	Green (RoHS & no Sb/Br)	CU NIPDAU CU SN	Level-1-260C-UNLIM	-40 to 105	UN2003AI	Samples
ULN2003AIPWRG4	ACTIVE	TSSOP	PW	16	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 105	UN2003AI	Samples
ULN2003AN	ACTIVE	PDIP	N	16	25	Pb-Free (RoHS)	CU NIPDAU CU SN	N / A for Pkg Type	-20 to 70	ULN2003AN	Samples
ULN2003ANE4	ACTIVE	PDIP	N	16	25	Pb-Free (RoHS)	CU NIPDAU	N / A for Pkg Type	-20 to 70	ULN2003AN	Samples
ULN2003ANSR	ACTIVE	SO	NS	16	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-20 to 70	ULN2003A	Samples
ULN2003ANSRE4	ACTIVE	SO	NS	16	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-20 to 70	ULN2003A	Samples
ULN2003ANSRG4	ACTIVE	SO	NS	16	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-20 to 70	ULN2003A	Samples
ULN2003APW	ACTIVE	TSSOP	PW	16	90	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-20 to 70	UN2003A	Samples
ULN2003APWG4	ACTIVE	TSSOP	PW	16	90	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-20 to 70	UN2003A	Samples
ULN2003APWR	ACTIVE	TSSOP	PW	16	2000	Green (RoHS & no Sb/Br)	CU NIPDAU CU SN	Level-1-260C-UNLIM	-20 to 70	UN2003A	Samples
ULN2003APWRG4	ACTIVE	TSSOP	PW	16	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-20 to 70	UN2003A	Samples
ULN2004AD	ACTIVE	SOIC	D	16	40	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-20 to 70	ULN2004A	Samples
ULN2004ADE4	ACTIVE	SOIC	D	16	40	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-20 to 70	ULN2004A	Samples
ULN2004ADG4	ACTIVE	SOIC	D	16	40	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-20 to 70	ULN2004A	Samples

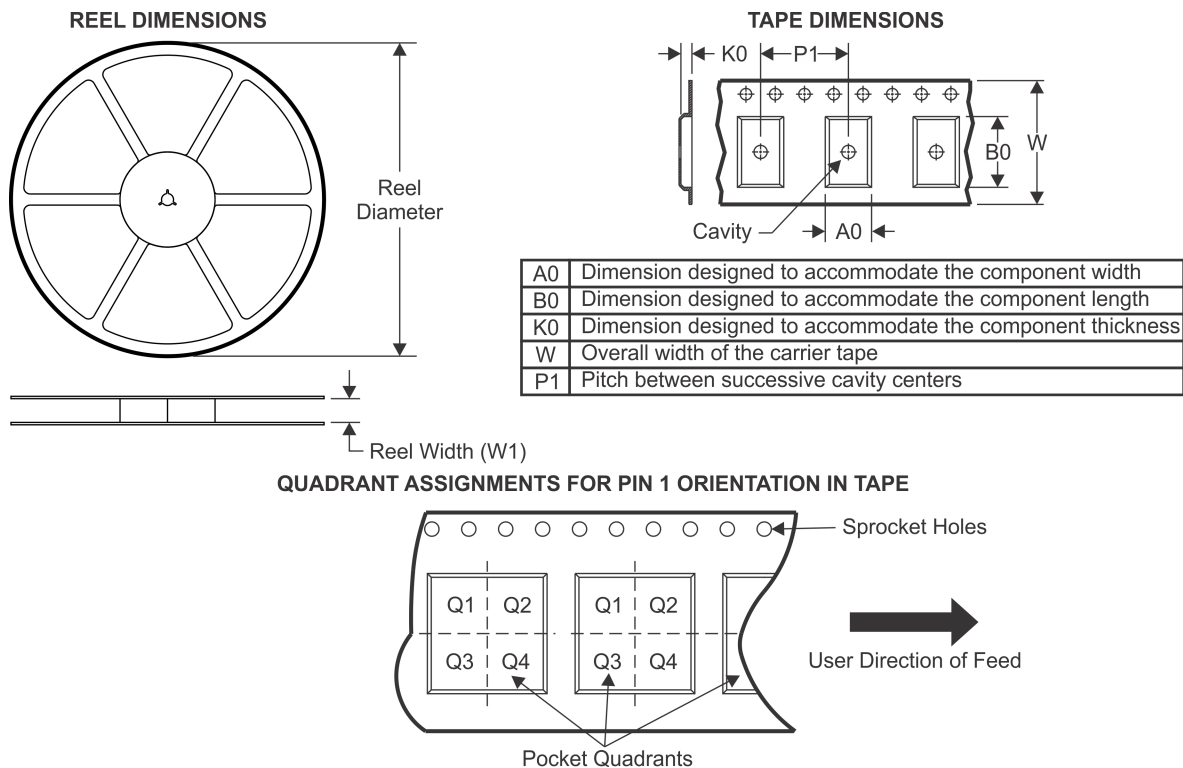
Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
ULN2004ADR	ACTIVE	SOIC	D	16	2500	Green (RoHS & no Sb/Br)	CU NIPDAU CU SN	Level-1-260C-UNLIM	-20 to 70	ULN2004A	Samples
ULN2004ADRE4	ACTIVE	SOIC	D	16	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-20 to 70	ULN2004A	Samples
ULN2004ADRG4	ACTIVE	SOIC	D	16	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-20 to 70	ULN2004A	Samples
ULN2004AN	ACTIVE	PDIP	N	16	25	Pb-Free (RoHS)	CU NIPDAU	N / A for Pkg Type	-20 to 70	ULN2004AN	Samples
ULN2004ANE4	ACTIVE	PDIP	N	16	25	Pb-Free (RoHS)	CU NIPDAU	N / A for Pkg Type	-20 to 70	ULN2004AN	Samples
ULN2004ANSR	ACTIVE	SO	NS	16	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-20 to 70	ULN2004A	Samples
ULQ2003AD	ACTIVE	SOIC	D	16	40	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 85	ULQ2003A	Samples
ULQ2003ADG4	ACTIVE	SOIC	D	16	40	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM		ULQ2003A	Samples
ULQ2003ADR	ACTIVE	SOIC	D	16	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 85	ULQ2003A	Samples
ULQ2003ADRG4	ACTIVE	SOIC	D	16	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM		ULQ2003A	Samples
ULQ2003AN	ACTIVE	PDIP	N	16	25	Pb-Free (RoHS)	CU NIPDAU	N / A for Pkg Type	-40 to 85	ULQ2003A	Samples
ULQ2004AD	ACTIVE	SOIC	D	16	40	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 85	ULQ2004A	Samples
ULQ2004ADG4	ACTIVE	SOIC	D	16	40	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM		ULQ2004A	Samples
ULQ2004ADR	ACTIVE	SOIC	D	16	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 85	ULQ2004A	Samples
ULQ2004ADRG4	ACTIVE	SOIC	D	16	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM		ULQ2004A	Samples
ULQ2004AN	ACTIVE	PDIP	N	16	25	Pb-Free (RoHS)	CU NIPDAU	N / A for Pkg Type	-40 to 85	ULQ2004AN	Samples

⁽¹⁾ The marketing status values are defined as follows:

ACTIVE: Product device recommended for new designs.

LIFEBUY: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.

NRND: Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.

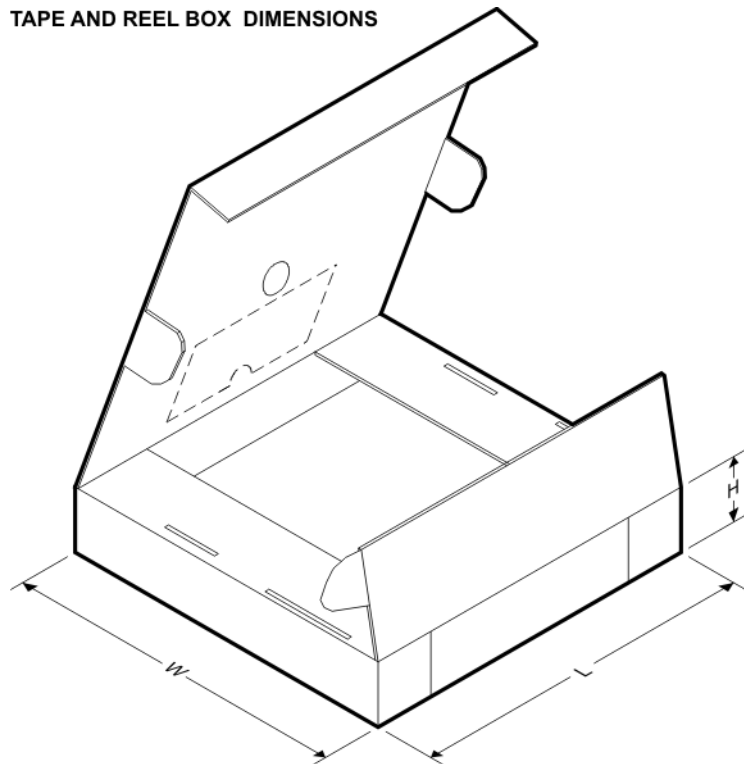
TAPE AND REEL INFORMATION


*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
ULN2003ADR	SOIC	D	16	2500	330.0	16.4	6.5	10.3	2.1	8.0	16.0	Q1
ULN2003ADR	SOIC	D	16	2500	330.0	16.8	6.5	10.3	2.1	8.0	16.0	Q1
ULN2003ADR	SOIC	D	16	2500	330.0	16.4	6.5	10.3	2.1	8.0	16.0	Q1
ULN2003ADRG3	SOIC	D	16	2500	330.0	16.8	6.5	10.3	2.1	8.0	16.0	Q1
ULN2003ADRG4	SOIC	D	16	2500	330.0	16.4	6.5	10.3	2.1	8.0	16.0	Q1
ULN2003AIDR	SOIC	D	16	2500	330.0	16.4	6.5	10.3	2.1	8.0	16.0	Q1
ULN2003AIDR	SOIC	D	16	2500	330.0	16.8	6.5	10.3	2.1	8.0	16.0	Q1
ULN2003AIDRG4	SOIC	D	16	2500	330.0	16.4	6.5	10.3	2.1	8.0	16.0	Q1
ULN2003AIPWR	TSSOP	PW	16	2000	330.0	12.4	6.9	5.6	1.6	8.0	12.0	Q1
ULN2003AIPWR	TSSOP	PW	16	2000	330.0	12.4	6.9	5.6	1.6	8.0	12.0	Q1
ULN2003AIPWRG4	TSSOP	PW	16	2000	330.0	12.4	6.9	5.6	1.6	8.0	12.0	Q1
ULN2003APWR	TSSOP	PW	16	2000	330.0	12.4	6.9	5.6	1.6	8.0	12.0	Q1
ULN2003APWR	TSSOP	PW	16	2000	330.0	12.4	6.9	5.6	1.6	8.0	12.0	Q1
ULN2003APWRG4	TSSOP	PW	16	2000	330.0	12.4	6.9	5.6	1.6	8.0	12.0	Q1
ULN2004ADR	SOIC	D	16	2500	330.0	16.4	6.5	10.3	2.1	8.0	16.0	Q1
ULN2004ADR	SOIC	D	16	2500	330.0	16.4	6.5	10.3	2.1	8.0	16.0	Q1
ULN2004ADR	SOIC	D	16	2500	330.0	16.8	6.5	10.3	2.1	8.0	16.0	Q1
ULN2004ADRG4	SOIC	D	16	2500	330.0	16.4	6.5	10.3	2.1	8.0	16.0	Q1

Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
ULN2004ADRG4	SOIC	D	16	2500	330.0	16.4	6.5	10.3	2.1	8.0	16.0	Q1
ULQ2003ADR	SOIC	D	16	2500	330.0	16.4	6.5	10.3	2.1	8.0	16.0	Q1
ULQ2003ADRG4	SOIC	D	16	2500	330.0	16.4	6.5	10.3	2.1	8.0	16.0	Q1

TAPE AND REEL BOX DIMENSIONS



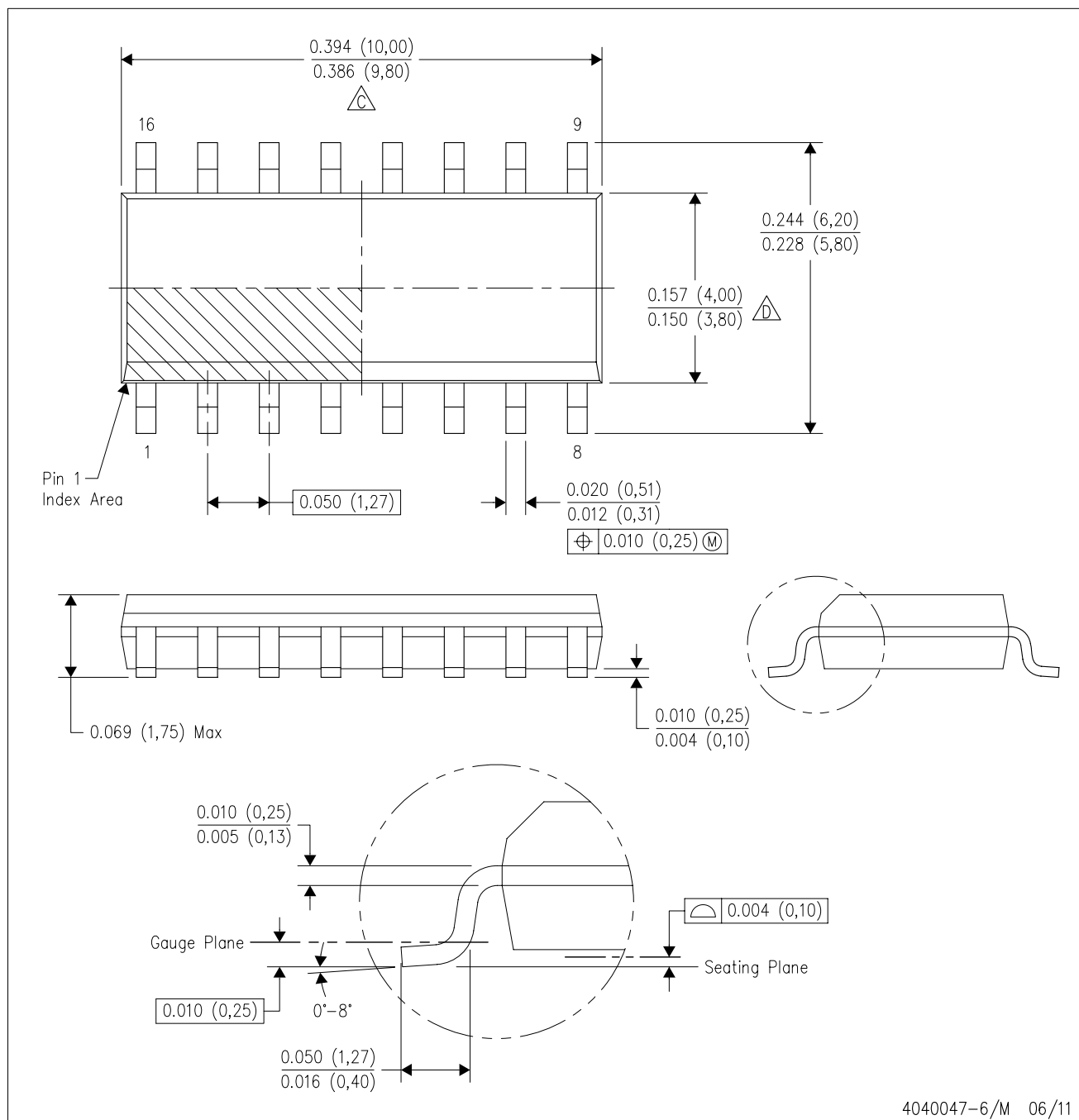
*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
ULN2003ADR	SOIC	D	16	2500	333.2	345.9	28.6
ULN2003ADR	SOIC	D	16	2500	364.0	364.0	27.0
ULN2003ADR	SOIC	D	16	2500	367.0	367.0	38.0
ULN2003ADRG3	SOIC	D	16	2500	364.0	364.0	27.0
ULN2003ADRG4	SOIC	D	16	2500	333.2	345.9	28.6
ULN2003AIDR	SOIC	D	16	2500	333.2	345.9	28.6
ULN2003AIDR	SOIC	D	16	2500	364.0	364.0	27.0
ULN2003AIDRG4	SOIC	D	16	2500	333.2	345.9	28.6
ULN2003AIPWR	TSSOP	PW	16	2000	364.0	364.0	27.0
ULN2003AIPWR	TSSOP	PW	16	2000	367.0	367.0	35.0
ULN2003AIPWRG4	TSSOP	PW	16	2000	367.0	367.0	35.0
ULN2003APWR	TSSOP	PW	16	2000	364.0	364.0	27.0
ULN2003APWR	TSSOP	PW	16	2000	367.0	367.0	35.0
ULN2003APWRG4	TSSOP	PW	16	2000	367.0	367.0	35.0

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
ULN2004ADR	SOIC	D	16	2500	367.0	367.0	38.0
ULN2004ADR	SOIC	D	16	2500	333.2	345.9	28.6
ULN2004ADR	SOIC	D	16	2500	364.0	364.0	27.0
ULN2004ADRG4	SOIC	D	16	2500	367.0	367.0	38.0
ULN2004ADRG4	SOIC	D	16	2500	333.2	345.9	28.6
ULQ2003ADR	SOIC	D	16	2500	333.2	345.9	28.6
ULQ2003ADRG4	SOIC	D	16	2500	367.0	367.0	38.0

D (R-PDSO-G16)

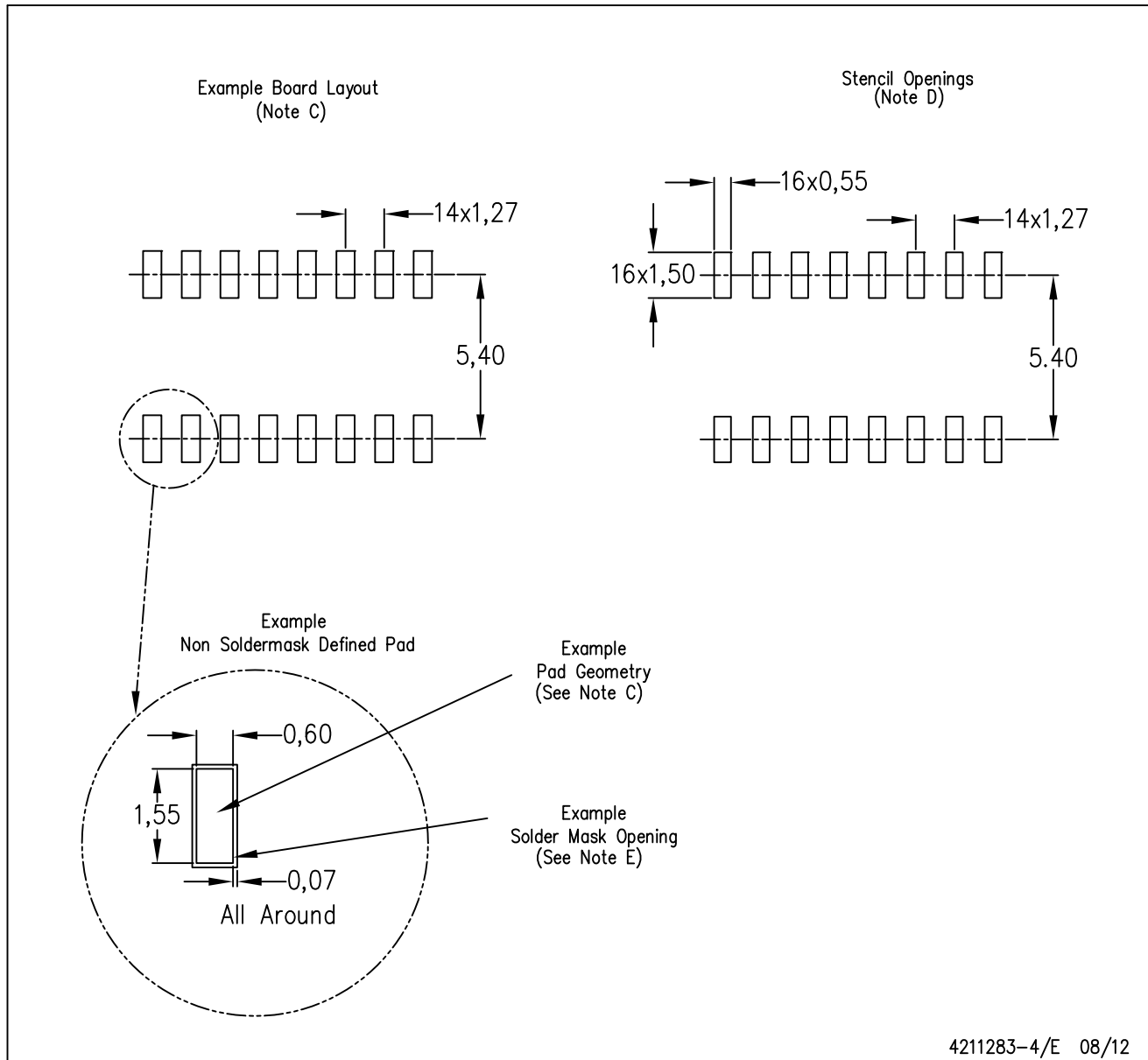
PLASTIC SMALL OUTLINE



- NOTES:
- A. All linear dimensions are in inches (millimeters).
 - B. This drawing is subject to change without notice.
 - C. Body length does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.006 (0,15) each side.
 - D. Body width does not include interlead flash. Interlead flash shall not exceed 0.017 (0,43) each side.
 - E. Reference JEDEC MS-012 variation AC.

D (R-PDSO-G16)

PLASTIC SMALL OUTLINE



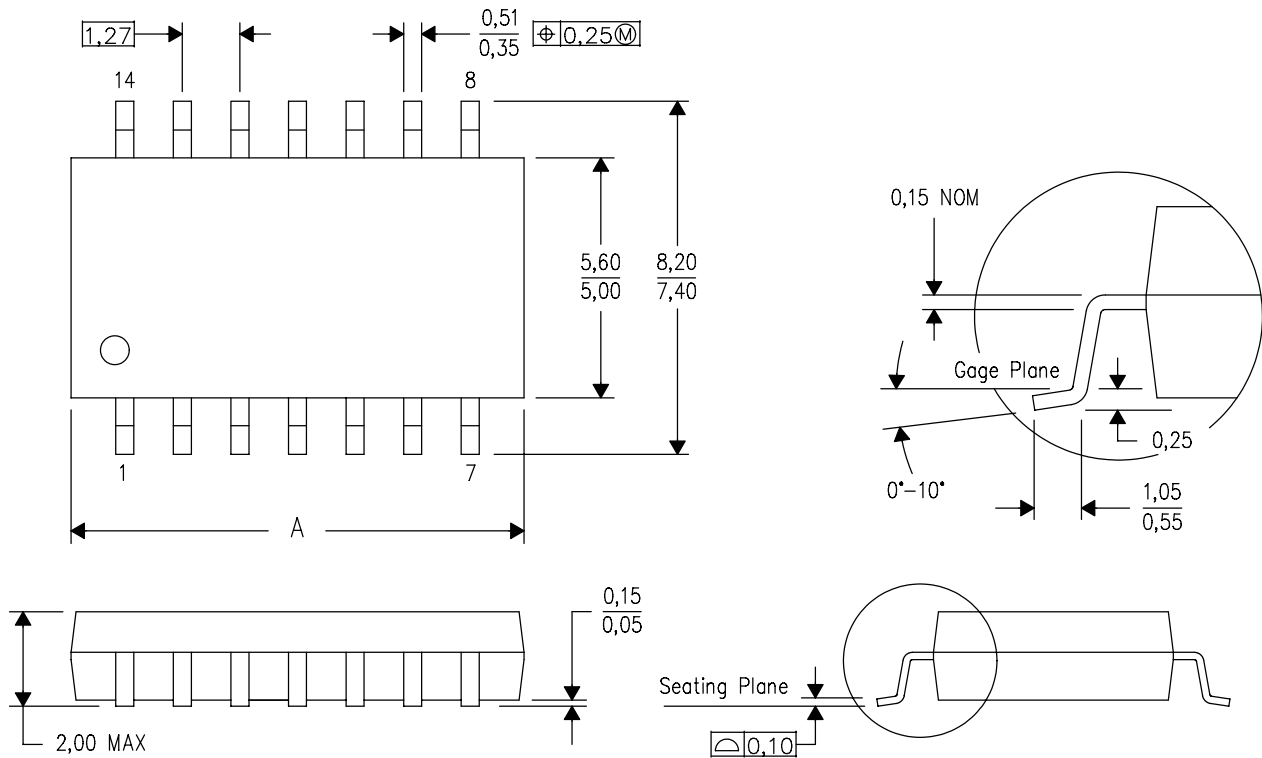
- NOTES:
- A. All linear dimensions are in millimeters.
 - B. This drawing is subject to change without notice.
 - C. Publication IPC-7351 is recommended for alternate designs.
 - D. Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Refer to IPC-7525 for other stencil recommendations.
 - E. Customers should contact their board fabrication site for solder mask tolerances between and around signal pads.

MECHANICAL DATA

NS (R-PDSO-G**)

PLASTIC SMALL-OUTLINE PACKAGE

14-PINS SHOWN



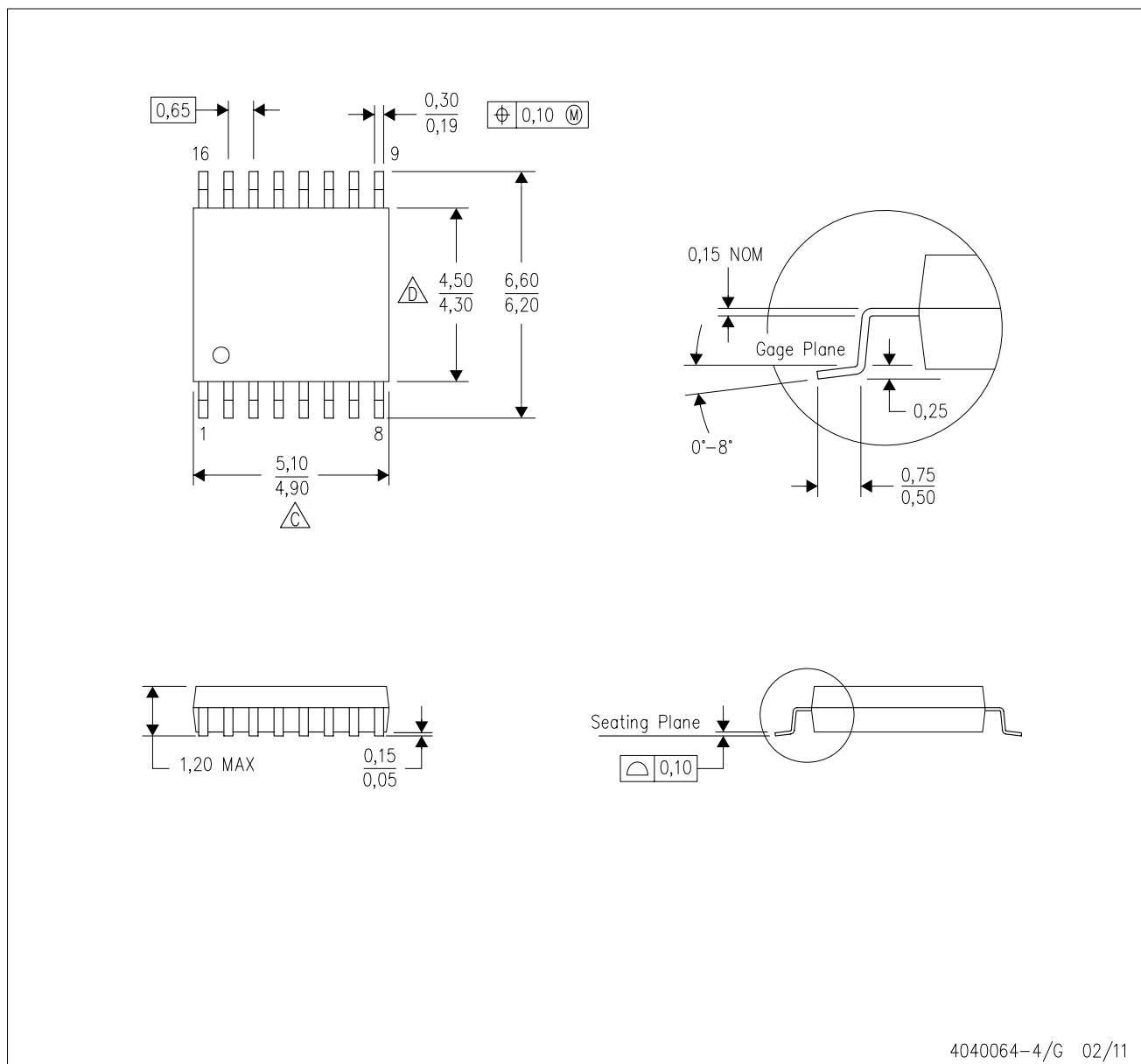
DIM \ PINS **	14	16	20	24
A MAX	10,50	10,50	12,90	15,30
A MIN	9,90	9,90	12,30	14,70

4040062/C 03/03

- 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.

PW (R-PDSO-G16)

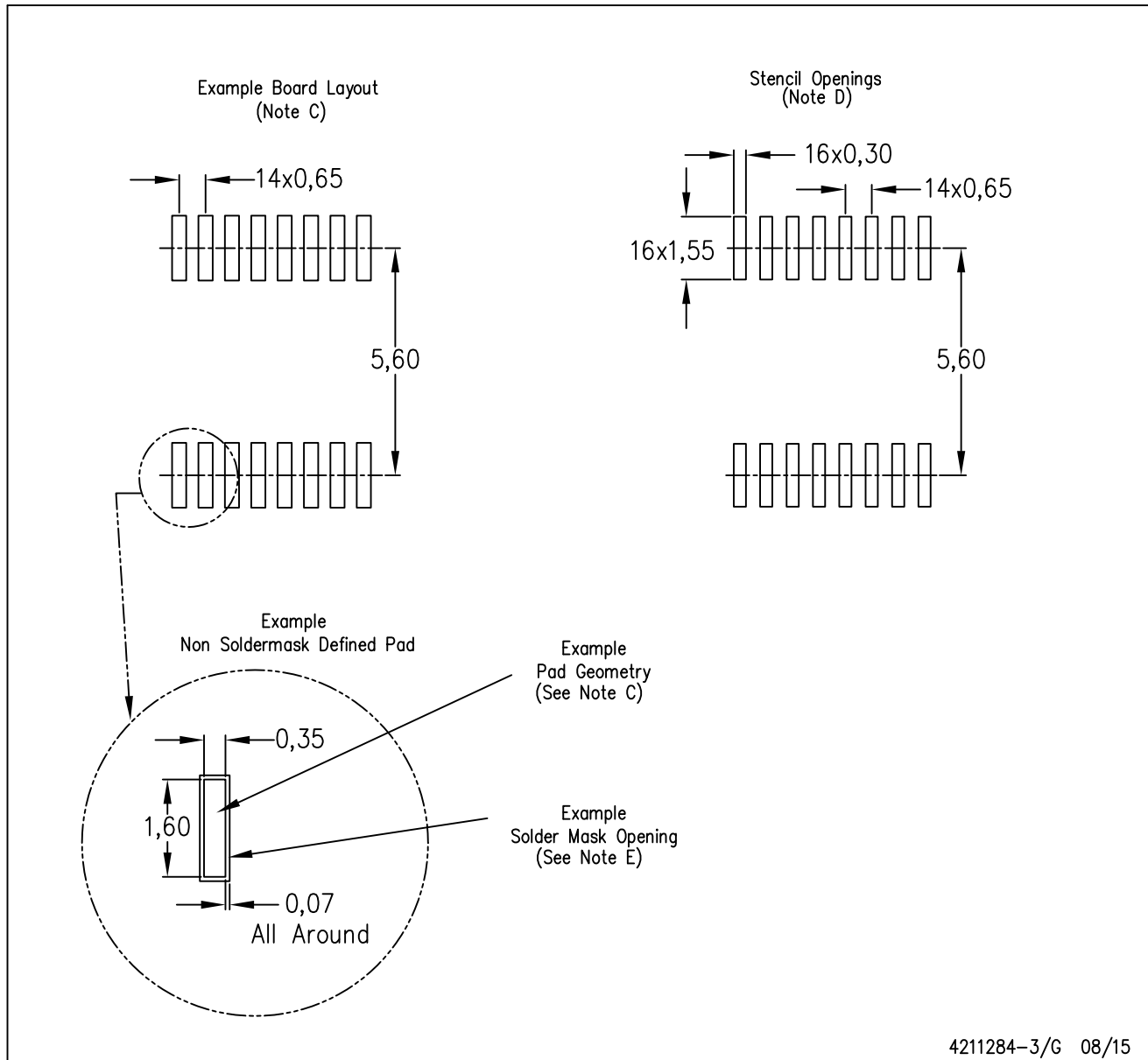
PLASTIC SMALL OUTLINE



- NOTES:
- A. All linear dimensions are in millimeters. Dimensioning and tolerancing per ASME Y14.5M-1994.
 - B. This drawing is subject to change without notice.
 - C. Body length does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0,15 each side.
 - D. Body width does not include interlead flash. Interlead flash shall not exceed 0,25 each side.
 - E. Falls within JEDEC MO-153

PW (R-PDSO-G16)

PLASTIC SMALL OUTLINE

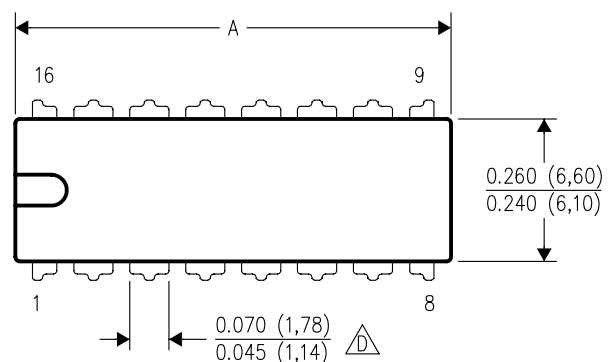


- NOTES:
- A. All linear dimensions are in millimeters.
 - B. This drawing is subject to change without notice.
 - C. Publication IPC-7351 is recommended for alternate designs.
 - D. Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Refer to IPC-7525 for other stencil recommendations.
 - E. Customers should contact their board fabrication site for solder mask tolerances between and around signal pads.

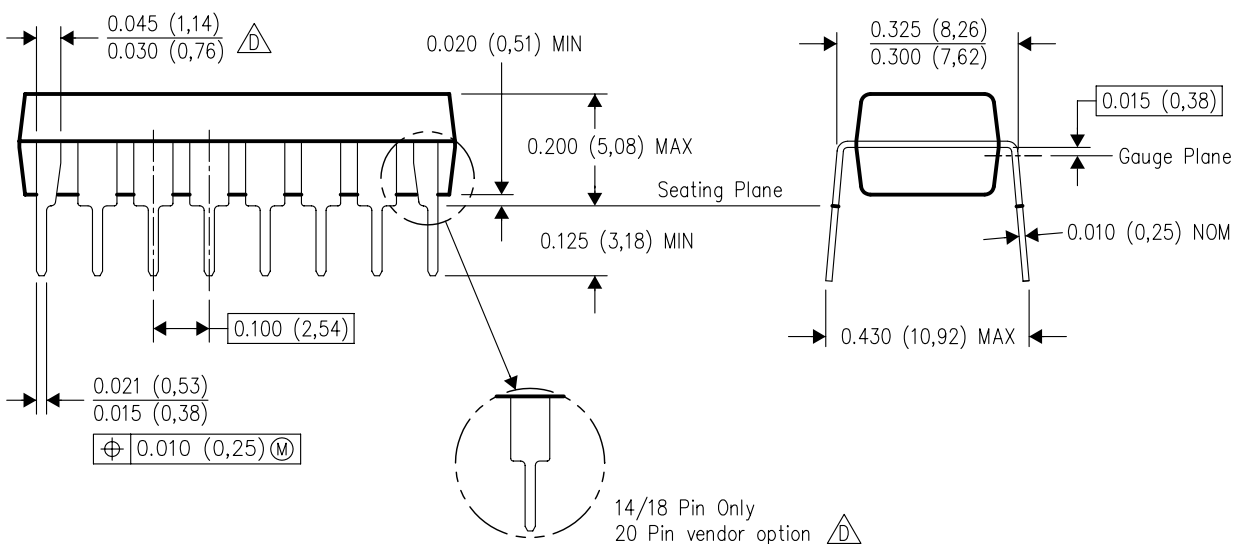
N (R-PDIP-T**)

16 PINS SHOWN

PLASTIC DUAL-IN-LINE PACKAGE



PINS ** DIM	14	16	18	20
A MAX	0.775 (19,69)	0.775 (19,69)	0.920 (23,37)	1.060 (26,92)
A MIN	0.745 (18,92)	0.745 (18,92)	0.850 (21,59)	0.940 (23,88)
MS-001 VARIATION	AA	BB	AC	AD



4040049/E 12/2002

NOTES:

- A. All linear dimensions are in inches (millimeters).
B. This drawing is subject to change without notice.
-  Falls within JEDEC MS-001, except 18 and 20 pin minimum body length (Dim A).
 The 20 pin end lead shoulder width is a vendor option, either half or full width.