

ULN2003B 高电压、高电流达灵顿晶体管阵列

1 特性

- 输出泄漏电流 (I_{CEX}) 超过 ULN2003A 的四倍
- 500mA 额定集电极电流 (单路输出)
- 高压输出 50V
- 钳位二极管输出
- 可兼容各类逻辑的输入
- 继电器驱动器应用

2 应用

- 继电器驱动器
- 锤式驱动器
- 灯驱动器
- 显示屏驱动器 (LED 和气体放电元件)
- 线路驱动器
- 逻辑缓冲器

3 说明

ULN2003B 是一款高电压、高电流达灵顿晶体管阵列。这个器件包含 7 个高压输出型 NPN 达灵顿晶体管对，这些晶体管具有针对电感负载开关的共阴极钳位二极管。单个达灵顿对的集电极电流额定值为 500mA。将达灵顿对并联可以提供更高的电流。

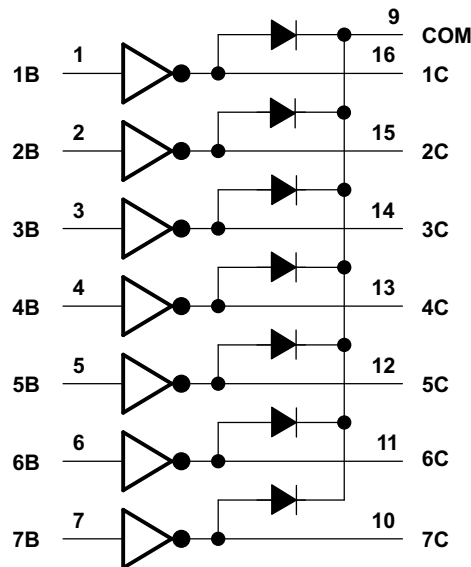
ULN2003B 的每个达灵顿对具有一个 2.7k Ω 基极串联电阻器，可直接用于晶体管逻辑 (TTL) 或互补金属氧化物半导体 (CMOS) 器件。

器件信息⁽¹⁾

部件号	封装	封装尺寸 (标称值)
ULN2003B	PDIP (16)	19.30mm x 6.35mm
	SOIC (16)	9.90mm x 3.91mm
	TSSOP (16)	5.00mm x 4.40mm

(1) 如需了解所有可用封装，请见数据表末尾的可订购产品附录。

4 简化电路原理图



目录

1	特性	1	9	Detailed Description	9
2	应用	1	9.1	Overview	9
3	说明	1	9.2	Functional Block Diagram	9
4	简化电路原理图	1	9.3	Feature Description	9
5	修订历史记录	2	9.4	Device Functional Modes	10
6	Pin Configuration and Functions	3	10	Application and Implementation	10
7	Specifications	4	10.1	Application Information	10
7.1	Absolute Maximum Ratings	4	10.2	Typical Application	10
7.2	Handling Ratings	4	11	Power Supply Recommendations	12
7.3	Recommended Operating Conditions	4	12	Layout	12
7.4	Thermal Information	4	12.1	Layout Guidelines	12
7.5	Electrical Characteristics, $T_A = 25^\circ\text{C}$	5	12.2	Layout Example	12
7.6	Electrical Characteristics, $T_A = -40^\circ\text{C}$ to 105°C	5	13	器件和文档支持	13
7.7	Switching Characteristics, $T_A = 25^\circ\text{C}$	5	13.1	商标	13
7.8	Switching Characteristics, $T_A = -40^\circ\text{C}$ to 105°C	5	13.2	静电放电警告	13
7.9	Typical Characteristics	6	13.3	术语表	13
7.10	Thermal Information	7	14	机械封装和可订购信息	13
8	Parameter Measurement Information	8			

5 修订历史记录

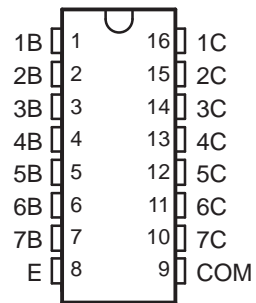
Changes from Original (June 2014) to Revision A

Page

• 完整版的最初发布版本。	1
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6 Pin Configuration and Functions

**D, N, OR PW PACKAGE
(TOP VIEW)**



Pin Functions

PIN		I/O	DESCRIPTION
NAME	NO.		
<1:7>B	1 - 7	Input	Channel 1 through 7 darlington base input
<1:7>C	16 - 10	Output	Channel 1 through 7 darlington collector output
E	7	–	Common Emmitter shared by all channels (typically tied to ground)
COM	8	Input/Output	Common cathode node for flyback diodes (required for inductive loads)

7 Specifications

7.1 Absolute Maximum Ratings⁽¹⁾

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

		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 ⁽³⁾⁽⁴⁾		500	mA
I _{OK}	Output clamp current		500	mA
	Total emitter-terminal current		-2.5	A
T _A	Operating free-air temperature range	-40	105	°C
θ _{JA}	Package thermal impedance ⁽³⁾⁽⁴⁾	D package	81	°C/W
		N package	49.7	
		PW package	105	
T _J	Operating virtual junction temperature		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.
- (3) Maximum power dissipation is a function of T_{J(max)}, θ_{JA}, and T_A. The maximum allowable power dissipation at any allowable ambient temperature is P_D = (T_{J(max)} - T_A)/θ_{JA}. Operating at the absolute maximum T_J of 150°C can affect reliability.
- (4) The package thermal impedance is calculated in accordance with JESD 51-7.

7.2 Handling Ratings

		MIN	MAX	UNIT
T _{stg}	Storage temperature range	-65	150	°C
V _(ESD)	Electrostatic discharge	Human body model (HBM), per ANSI/ESDA/JEDEC JS-001, all pins ⁽¹⁾	2000	V
		Charged device model (CDM), per JEDEC specification JESD22-C101, all pins ⁽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.

7.3 Recommended Operating Conditions

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

		MIN	MAX	UNIT
V _I		0	5	V
V _{CC}		0	50	V
T _J	Junction Temperature	-40	125	°C

7.4 Thermal Information

THERMAL METRIC ⁽¹⁾	ULN2003B		UNIT	
	PW	D		
	16 PINS	16 PINS		
R _{θJA}	Junction-to-ambient thermal resistance	105.4	81.2	°C/W
R _{θJctop}	Junction-to-case (top) thermal resistance	32.9	40.3	
R _{θJB}	Junction-to-board thermal resistance	51.3	38.9	
ψ _{JT}	Junction-to-top characterization parameter	2.1	10.9	
ψ _{JB}	Junction-to-board characterization parameter	50.6	38.7	

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

7.5 Electrical Characteristics, $T_A = 25^\circ\text{C}$

PARAMETER	TEST FIGURE	TEST CONDITIONS		ULN2003B			UNIT
				MIN	TYP	MAX	
$V_{I(on)}$ On-state input voltage	图 12	$V_{CE} = 2\text{ V}$	$I_C = 200\text{ mA}$			2.4	V
			$I_C = 250\text{ mA}$			2.7	
			$I_C = 300\text{ mA}$			3	
$V_{CE(sat)}$ Collector-emitter saturation voltage	图 11		$I_I = 250\text{ }\mu\text{A}$, $I_C = 100\text{ mA}$		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	图 8	$V_{CE} = 50\text{ V}$, $I_I = 0$				10	μA
V_F Clamp forward voltage	图 14	$I_F = 350\text{ mA}$			1.7	2	V
$I_{I(off)}$ Off-state input current	图 9	$V_{CE} = 50\text{ V}$, $I_C = 500\text{ }\mu\text{A}$		50	65		μA
I_I Input current	图 10	$V_I = 3.85\text{ V}$		0.93	1.35		mA
I_R Clamp reverse current	图 13	$V_R = 50\text{ V}$				50	μA
C_i Input capacitance		$V_I = 0$, $f = 1\text{ MHz}$		15	25		pF

7.6 Electrical Characteristics, $T_A = -40^\circ\text{C}$ to 105°C

PARAMETER	TEST FIGURE	TEST CONDITIONS		ULN2003B			UNIT
				MIN	TYP	MAX	
$V_{I(on)}$ On-state input voltage	图 12	$V_{CE} = 2\text{ V}$	$I_C = 200\text{ mA}$			2.7	V
			$I_C = 250\text{ mA}$			2.9	
			$I_C = 300\text{ mA}$			3	
$V_{CE(sat)}$ Collector-emitter saturation voltage	图 11		$I_I = 250\text{ }\mu\text{A}$, $I_C = 100\text{ mA}$		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	图 8	$V_{CE} = 50\text{ V}$, $I_I = 0$				20	μA
V_F Clamp forward voltage	图 14	$I_F = 350\text{ mA}$			1.7	2.2	V
$I_{I(off)}$ Off-state input current	图 9	$V_{CE} = 50\text{ V}$, $I_C = 500\text{ }\mu\text{A}$		30	65		μA
I_I Input current	图 10	$V_I = 3.85\text{ V}$		0.93	1.35		mA
I_R Clamp reverse current	图 13	$V_R = 50\text{ V}$				100	μA
C_i Input capacitance		$V_I = 0$, $f = 1\text{ MHz}$		15	25		pF

7.7 Switching Characteristics, $T_A = 25^\circ\text{C}$

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
t_{PLH} Propagation delay time, low- to high-level output			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	$V_S = 50\text{ V}$, $I_O \approx 300\text{ mA}$	$V_S - 20$			mV

7.8 Switching Characteristics, $T_A = -40^\circ\text{C}$ to 105°C

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
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
V_{OH} High-level output voltage after switching	$V_S = 50\text{ V}$, $I_O \approx 300\text{ mA}$	$V_S - 50$			mV

7.9 Typical Characteristics

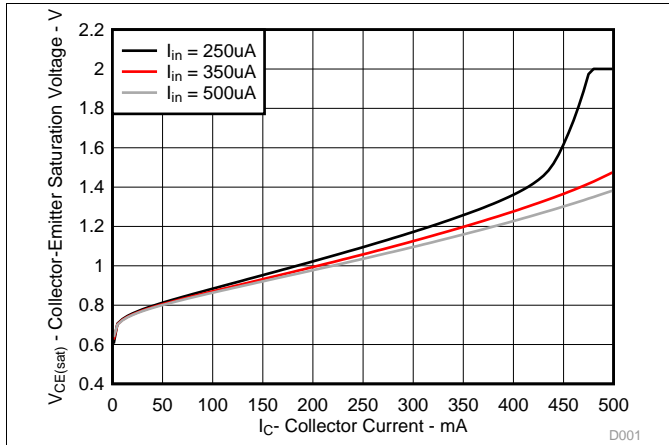


图 1. Collector-Emitter Saturation Voltage vs Collector Current (One Darlington)

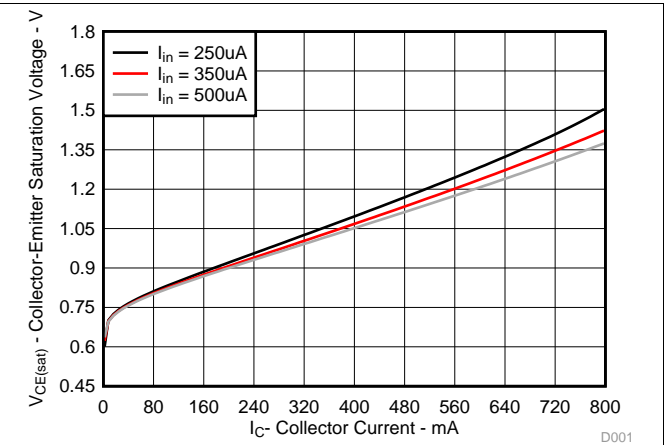


图 2. Collector-Emitter Saturation Voltage vs Total Collector Current (Two Darlings in Parallel)

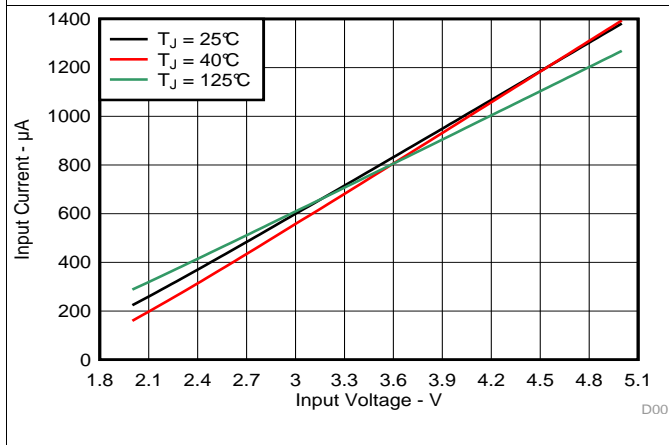


图 3. Input Current vs Input Voltage

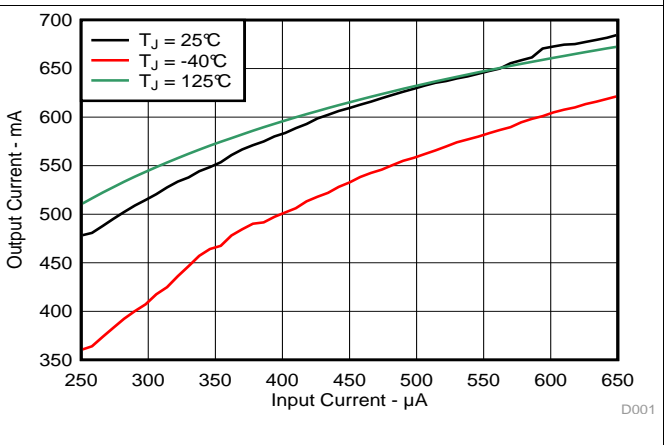


图 4. Output Current vs Input Current

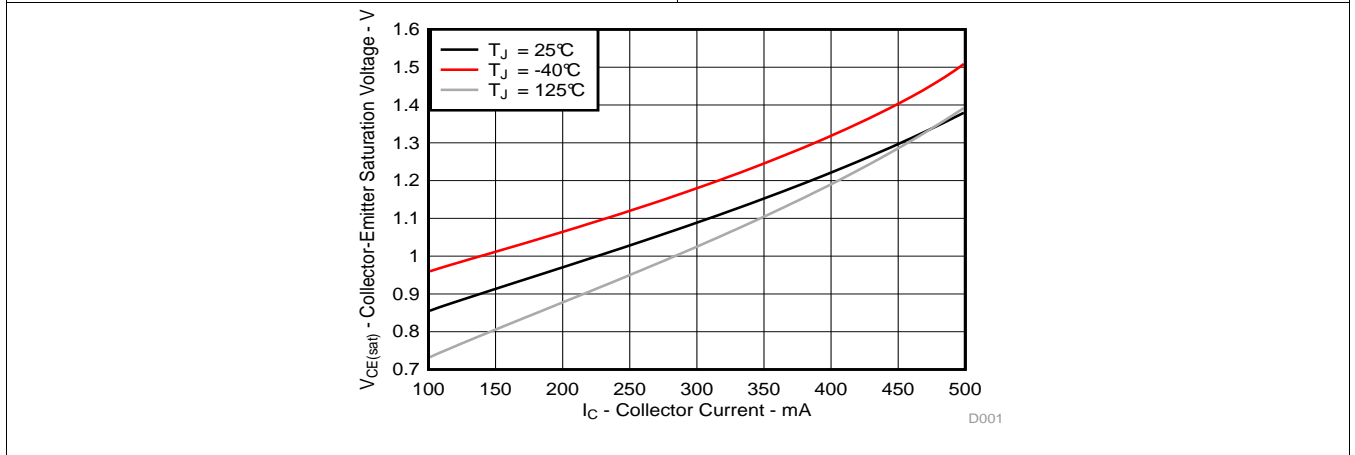
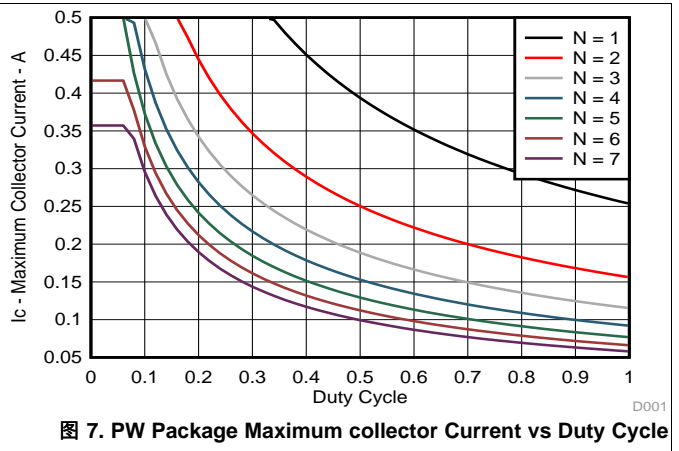
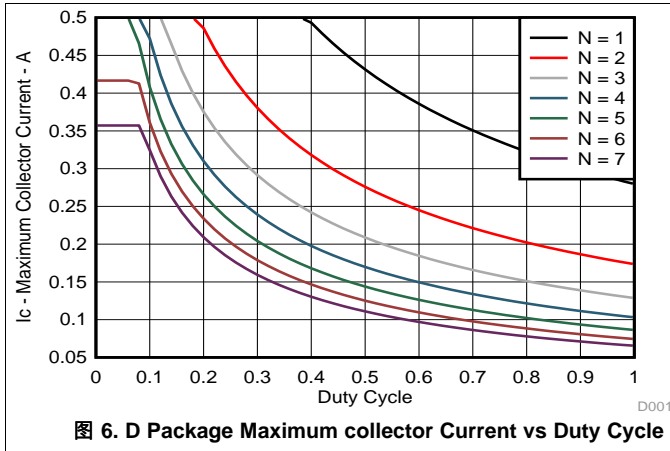


图 5. Collector-Emitter Saturation Voltage vs Collector Current

7.10 Thermal Information



8 Parameter Measurement Information

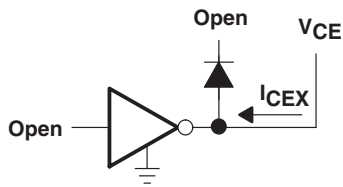


图 8. I_{CEX} Test Circuit

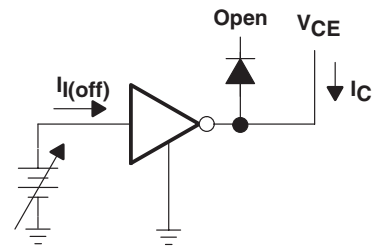


图 9. $I_{I(off)}$ Test Circuit

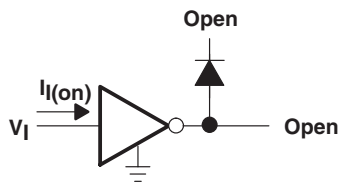


图 10. I_I Test Circuit

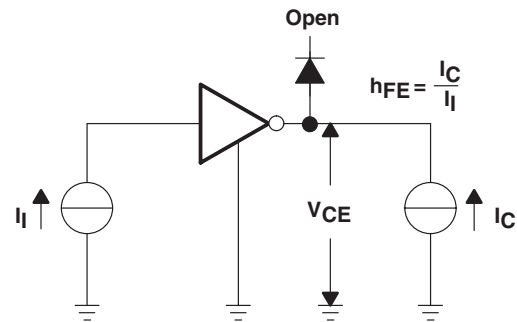


图 11. h_{fe} , $V_{CE(sat)}$ Test Circuit

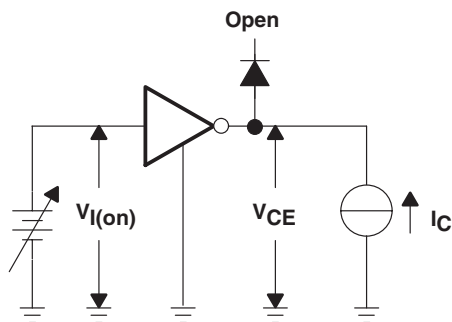


图 12. $V_{I(on)}$ Test Circuit

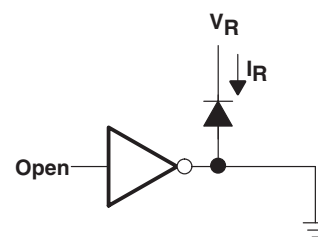


图 13. I_R Test Circuit

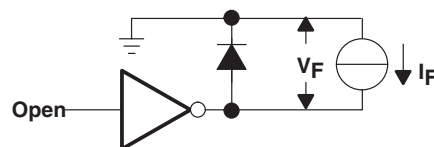


图 14. V_F Test Circuit

9 Detailed Description

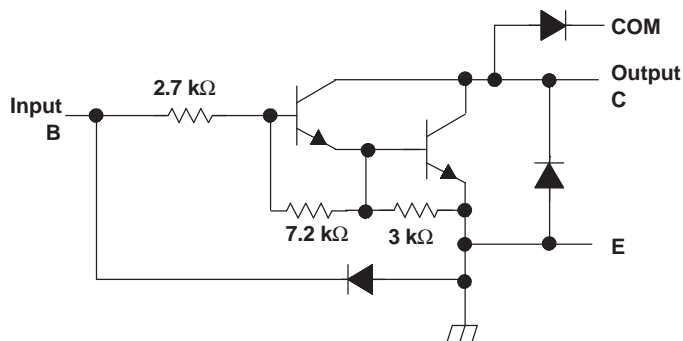
9.1 Overview

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

The ULN2003B 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 ULN2003B has a series base resistor to each Darlington pair, thus allowing operation directly with TTL or CMOS operating at supply voltages of 5.0 V or 3.3 V. The ULN2003B 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).

9.2 Functional Block Diagram



All resistor values shown are nominal.

图 15. Schematic (Each Comparator)

9.3 Feature Description

Each channel of ULN2003B consists of Darlington connected NPN transistors. This connection creates the effect of a single transistor with a very high current gain (β_2). This can be as high as 10,000 A/A at certain currents. The very high β allows for high output current drive with a very low input current, essentially equating to operation with low GPIO voltages.

The GPIO voltage is converted to base current via the 2.7 k Ω resistor connected between the input and base of the pre-driver Darlington NPN. The 7.2 k Ω & 3.0 k Ω resistors connected between the base and emitter of each respective NPN act as pull-downs and suppress the amount of leakage that may occur from the input.

The diodes connected between the output and COM pin is used to suppress the kick-back voltage from an inductive load that is excited when the NPN drivers are turned off (stop sinking) and the stored energy in the coils causes a reverse current to flow into the coil supply via the kick-back diode.

In normal operation the diodes on base and collector pins to emitter will be reversed biased. If these diode are forward biased, internal parasitic NPN transistors will draw (a nearly equal) current from other (nearby) device pins.

9.4 Device Functional Modes

9.4.1 Inductive Load Drive

When the COM pin is tied to the coil supply voltage, ULN2003B is able to drive inductive loads and suppress the kick-back voltage via the internal free wheeling diodes.

9.4.2 Resistive Load Drive

When driving a resistive load, a pull-up resistor is needed in order for ULN2003B to sink current and for there to be a logic high level. The COM pin can be left floating for these applications.

10 Application and Implementation

注

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.

10.1 Application Information

ULN2003B will typically be used to drive a high voltage and/or current peripheral from an MCU or logic device that cannot tolerate these conditions. The following design is a common application of ULN2003B, driving inductive loads. This includes motors, solenoids & relays. Each load type can be modeled by what's seen in [图 16](#).

10.2 Typical Application

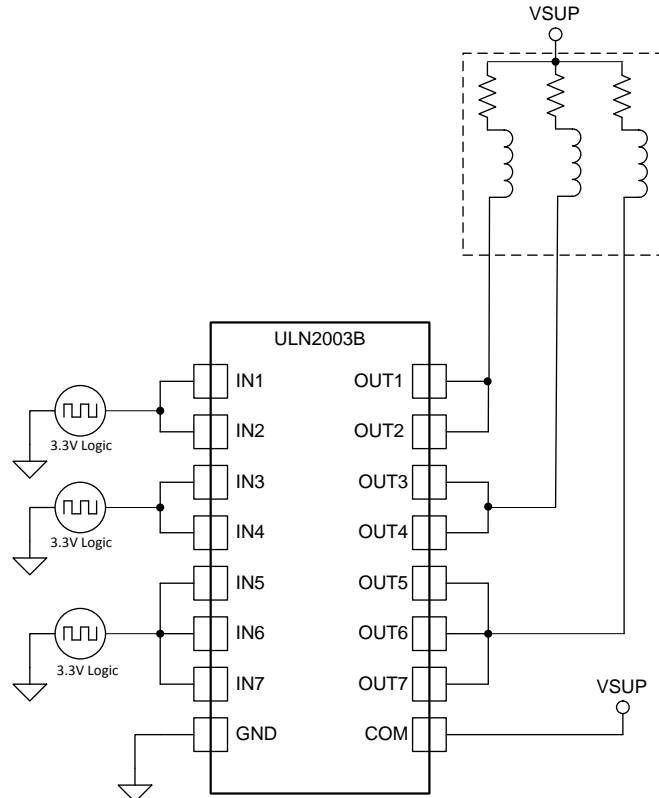


图 16. ULN2003B as Inductive Load Driver

Typical Application (接下页)

10.2.1 Design Requirements

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

表 1. Design Parameters

DESIGN PARAMETER	EXAMPLE VALUE
GPIO Voltage	3.3 V or 5.0 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%

10.2.2 Detailed Design Procedure

When using ULN2003B in a coil driving application, determine the following:

- Input Voltage Range
- Temperature Range
- Output & Drive Current
- Power Dissipation

10.2.2.1 Drive Current

The coil current is determined by the coil voltage (V_{SUP}), coil resistance & output low voltage (V_{OL} or V_{CE(SAT)}).

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

10.2.2.2 Output Low Voltage

The output low voltage (V_{OL}) is the same thing as V_{CE(SAT)} and can be determined by, 图 1, 图 2, or 图 5.

10.2.2.3 Power Dissipation & 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 图 6 or 图 7.

For a more accurate determination of number of coils possible, use the below equation to calculate ULN2003B on-chip power dissipation P_D:

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

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)} (2)

In order to guarantee reliability of ULN2003B 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 公式 3.

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

Where:

T_{J(MAX)} is the target maximum junction temperature.

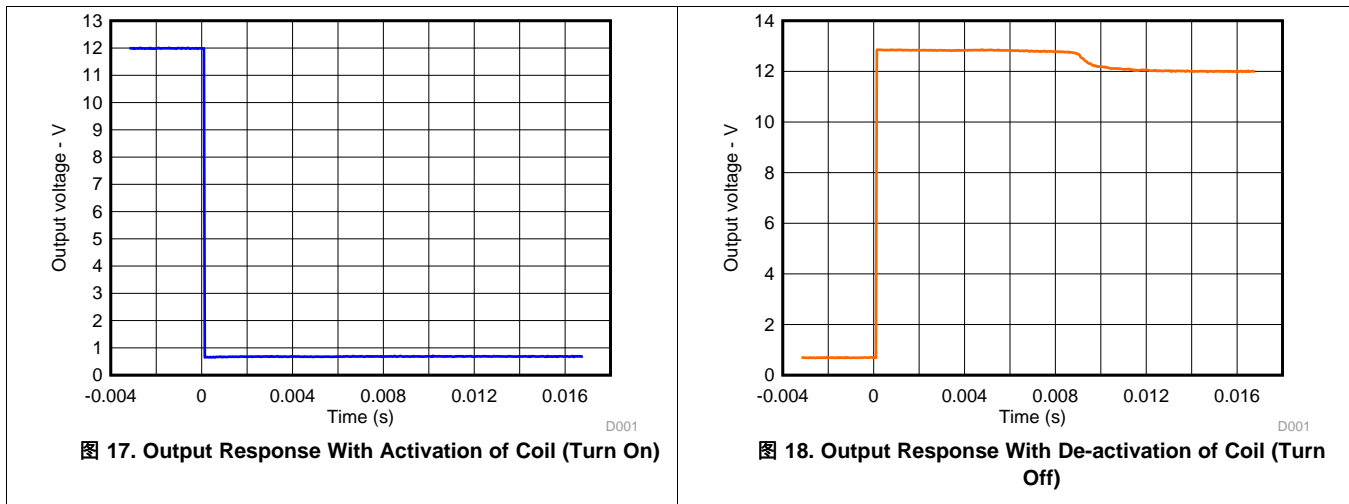
T_A is the operating ambient temperature.

θ_{JA} is the package junction to ambient thermal resistance. (3)

It is recommended to limit ULN2003B IC's die junction temperature to less than 125°C. The IC junction temperature is directly proportional to the on-chip power dissipation.

10.2.3 Application Curves

The following curves were generated with ULN2003B driving an OMRON G5NB relay – $V_{in} = 5.0V$; $V_{sup} = 12 V$ & $R_{COIL} = 2.8 k\Omega$



11 Power Supply Recommendations

This part 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 make sure that the output voltage does not heavily exceed the COM pin voltage. This will heavily forward bias the fly-back diodes and cause a large current to flow into COM, potentially damaging the on-chip metal or over-heating the part.

12 Layout

12.1 Layout Guidelines

Thin traces can be used on the input due to the low current logic that is typically used to drive UNL2003B. Care must be taken to separate the input channels as much as possible, as to eliminate cross-talk. Thick traces are recommended for the output, in order to drive whatever high currents that may be needed. Wire thickness can be determined by the trace material's current density and desired drive current.

Since 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.

12.2 Layout Example

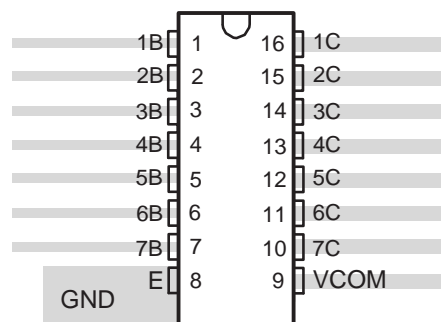


图 19. Package Layout

13 器件和文档支持

13.1 商标

All trademarks are the property of their respective owners.

13.2 静电放电警告



这些装置包含有限的内置 ESD 保护。存储或装卸时，应将导线一起截短或将装置放置于导电泡棉中，以防止 MOS 门极遭受静电损伤。

13.3 术语表

[SLYZ022](#) — TI 术语表。

这份术语表列出并解释术语、首字母缩略词和定义。

14 机械封装和可订购信息

以下页中包括机械封装和可订购信息。 这些信息是针对指定器件可提供的最新数据。 这些数据会在无通知且不对本文档进行修订的情况下发生改变。 欲获得该数据表的浏览器版本，请查阅左侧的导航栏。

PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead finish/ Ball material (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
ULN2003BDR	OBSOLETE	SOIC	D	16		TBD	Call TI	Call TI	-40 to 105	ULN2003B	
ULN2003BN	OBSOLETE	PDIP	N	16		TBD	Call TI	Call TI	-40 to 105	ULN2003BN	
ULN2003BPWR	OBSOLETE	TSSOP	PW	16		TBD	Call TI	Call TI	-40 to 105	UN2003B	

(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.

PREVIEW: Device has been announced but is not in production. Samples may or may not be available.

OBSOLETE: TI has discontinued the production of the device.

(2) **RoHS:** TI defines "RoHS" to mean semiconductor products that are compliant with the current EU RoHS requirements for all 10 RoHS substances, including the requirement that RoHS substance do not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, "RoHS" products are suitable for use in specified lead-free processes. TI may reference these types of products as "Pb-Free".

RoHS Exempt: TI defines "RoHS Exempt" to mean products that contain lead but are compliant with EU RoHS pursuant to a specific EU RoHS exemption.

Green: TI defines "Green" to mean the content of Chlorine (Cl) and Bromine (Br) based flame retardants meet JS709B low halogen requirements of <=1000ppm threshold. Antimony trioxide based flame retardants must also meet the <=1000ppm threshold requirement.

(3) MSL, Peak Temp. - The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

(5) Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

(6) Lead finish/Ball material - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material values may wrap to two lines if the finish value exceeds the maximum column width.

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N (R-PDIP-T**)

PLASTIC DUAL-IN-LINE PACKAGE

16 PINS SHOWN



- NOTES:
- A. All linear dimensions are in inches (millimeters).
 - B. This drawing is subject to change without notice.
 - 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.

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.



4220204/A 02/2017

NOTES:

1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.15 mm per side.
4. This dimension does not include interlead flash. Interlead flash shall not exceed 0.25 mm per side.
5. Reference JEDEC registration MO-153.

EXAMPLE BOARD LAYOUT

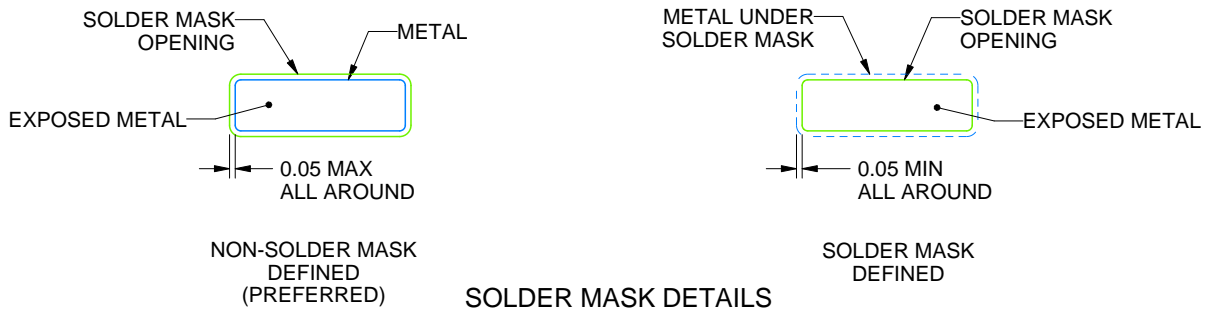
PW0016A

TSSOP - 1.2 mm max height

SMALL OUTLINE PACKAGE



LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE: 10X



4220204/A 02/2017

NOTES: (continued)

- 6. Publication IPC-7351 may have alternate designs.
- 7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.

EXAMPLE STENCIL DESIGN

PW0016A

TSSOP - 1.2 mm max height

SMALL OUTLINE PACKAGE



SOLDER PASTE EXAMPLE
BASED ON 0.125 mm THICK STENCIL
SCALE: 10X

4220204/A 02/2017

NOTES: (continued)

8. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
9. Board assembly site may have different recommendations for stencil design.

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