

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

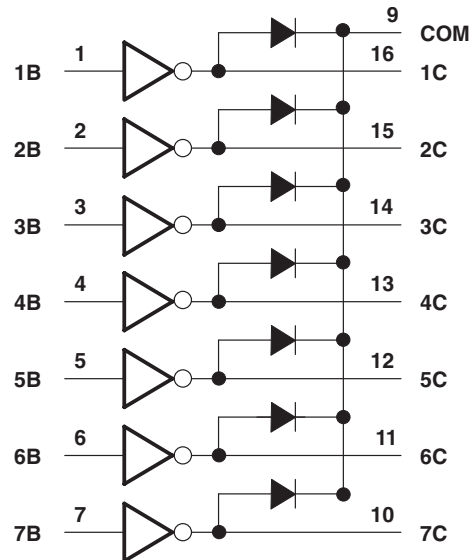
The XD/L200X devices are high-voltage, high-current Darlington transistor arrays. Each consists of seven NPN Darlington pairs that feature high-voltage outputs with common-cathode clamp diodes for switching inductive loads.

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 2003 devices, see the SLRS023 data sheet for the SN75468 and SN75469 devices.

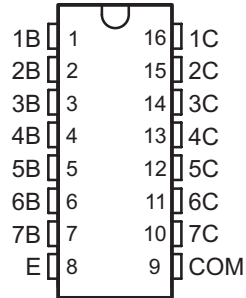
The XD/L200X device is designed specifically for use with 14-V to 25-V PMOS devices. Each input of this device has a Zener diode and resistor in series to control the input current to a safe limit. The 2003 devices have a 2.7-k Ω series base resistor for each Darlington pair for operation directly with TTL or 5-V CMOS devices.

The 2004 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 2004 device is below that of the 2003 devices, and the required voltage is less than that required by the XD/L200X device.

4 Simplified Block Diagram



5 Pin Configuration and Functions



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 | XD/L200X | -20 | 70 | °C |
| | | | -40 | 105 | |
| | | | -40 | 85 | |
| | | | -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 |
| | | 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⁾ | XD/L200X | | | | 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.

6.5 Electrical Characteristics: XD/L2002

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

| PARAMETER | TEST FIGURE | TEST CONDITIONS | XD/L2002 | | | 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 | $I_I = 250\ \mu\text{A}, I_C = 100\text{ mA}$ | 0.9 | 1.1 | 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 | | |
| 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 | | 500 |
| $I_{I(off)}$ | OFF-state input current | Figure 10 | $V_{CE} = 50\text{ V}, I_C = 500\ \mu\text{A}$ | | 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: 2003 and 2004

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

| PARAMETER | TEST FIGURE | TEST CONDITIONS | 2003 | | | 2004 | | | 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 | |
| | | | | $I_C = 200\text{ mA}$ | | | | | 2.4 | | 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_{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 | $I_I = 250\ \mu\text{A}, I_C = 100\text{ mA}$ | 0.9 | 1.1 | 0.9 | 1.1 | V | | | |
| | | | $I_I = 350\ \mu\text{A}, I_C = 200\text{ mA}$ | 1 | 1.3 | 1 | 1.3 | | | | |
| | | | $I_I = 500\ \mu\text{A}, I_C = 350\text{ mA}$ | 1.2 | 1.6 | 1.2 | 1.6 | | | | |
| I_{CEX} | Collector cutoff current | 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 | $V_{CE} = 50\text{ V}, T_A = 70^\circ\text{C}, I_C = 500\ \mu\text{A}$ | | 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: 2003

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

| PARAMETER | TEST FIGURE | TEST CONDITIONS | 2003 | | | 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 | $I_I = 250\ \mu\text{A}, I_C = 100\text{ mA}$ | 0.9 | 1.1 | 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_{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 | $V_{CE} = 50\text{ V}, I_C = 500\ \mu\text{A}$ | 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: 2003

$T_A = -40^\circ\text{C}$ to 105°C

| PARAMETER | TEST FIGURE | TEST CONDITIONS | 2003 | | | 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 | $I_I = 250\ \mu\text{A}, I_C = 100\text{ mA}$ | 0.9 | 1.2 | V | |
| | | $I_I = 350\ \mu\text{A}, I_C = 200\text{ mA}$ | 1 | 1.4 | | |
| | | $I_I = 500\ \mu\text{A}, I_C = 350\text{ mA}$ | 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 | $V_{CE} = 50\text{ V}, I_C = 500\ \mu\text{A}$ | 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: 2003 and 2004

over recommended operating conditions (unless otherwise noted)

| PARAMETER | TEST FIGURE | TEST CONDITIONS | 2003 | | | 2004 | | | 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 | $V_{CE} = 50\text{ V}, T_A = 70^\circ\text{C}$ | | | | 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: XD/L2002, 2003, 2004

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

| PARAMETER | TEST CONDITIONS | XD/L2002, 2003, 2004 | | | 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: 2003

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

| PARAMETER | TEST CONDITIONS | 2003 | | | 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: 2003

$T_A = -40^\circ\text{C}$ to 105°C

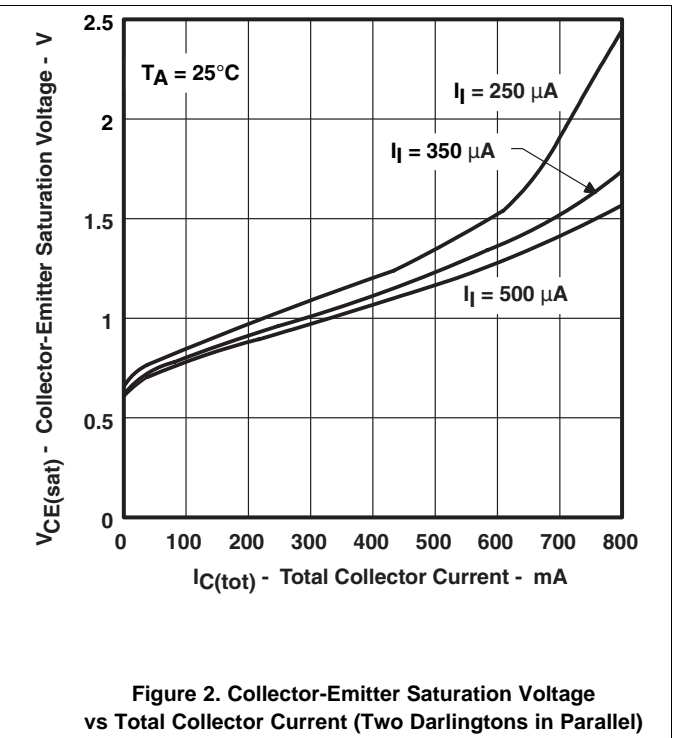
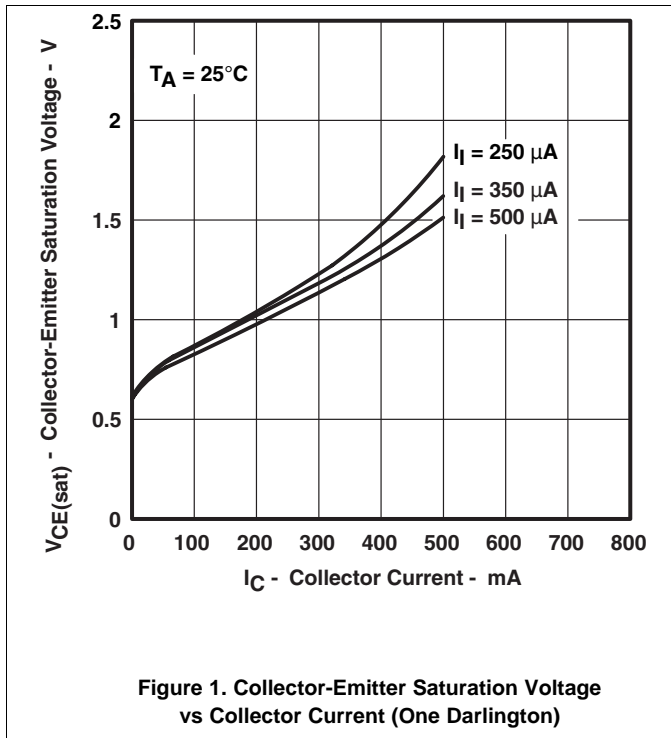
| PARAMETER | TEST CONDITIONS | 2003 | | | UNIT |
|-----------|---|------|-----|-----|---------------|
| | | MIN | TYP | MAX | |
| t_{PLH} | Propagation delay time, low- to high-level output | | 1 | 10 | μs |
| t_{PHL} | Propagation delay time, high- to low-level output | | 1 | 10 | μs |

6.13 Switching Characteristics: 2003, 2004

over recommended operating conditions (unless otherwise noted)

| PARAMETER | TEST CONDITIONS | 2003, 2004 | | | 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



Typical Characteristics (continued)

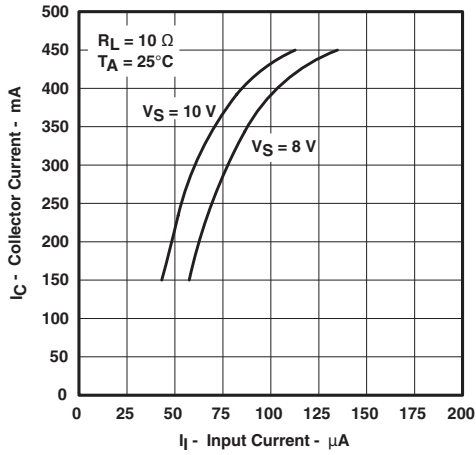


Figure 3. Collector Current vs Input Current

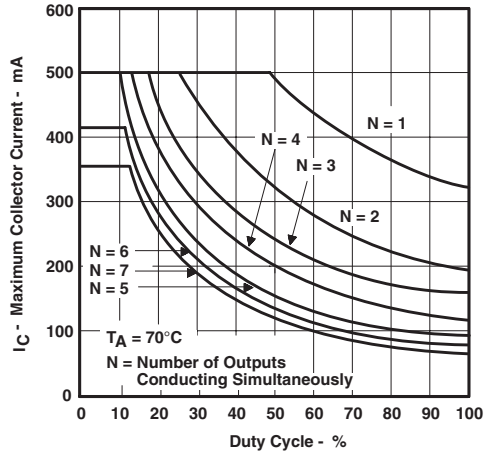


Figure 4. D Package Maximum Collector Current vs Duty Cycle

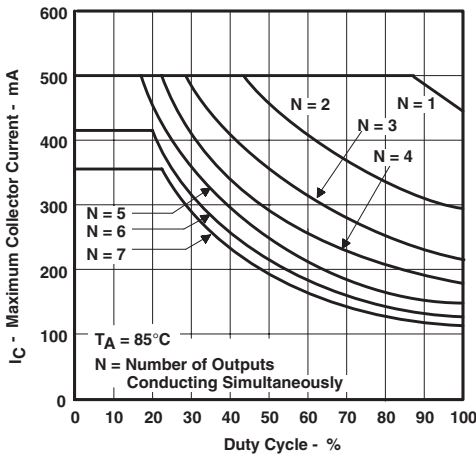


Figure 5. N Package Maximum Collector Current vs Duty Cycle

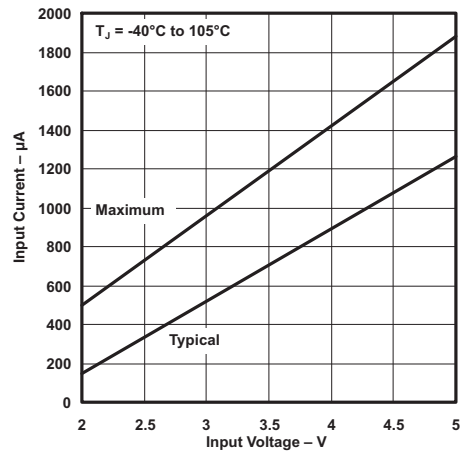


Figure 6. Maximum and Typical Input Current vs Input Voltage

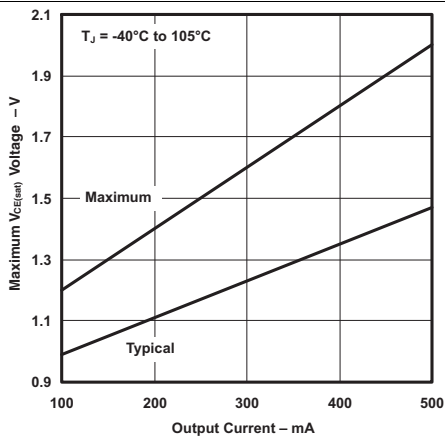


Figure 7. Maximum and Typical Saturated V_{CE} vs Output Current

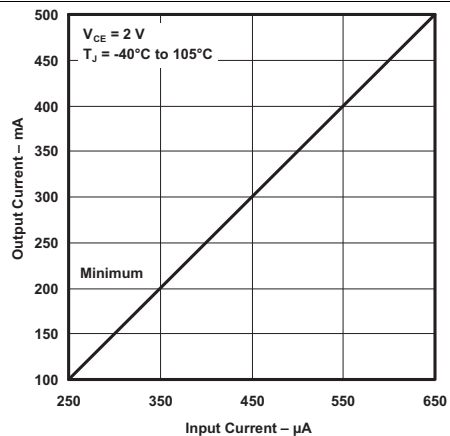


Figure 8. Minimum Output Current vs Input Current

7 Parameter Measurement Information

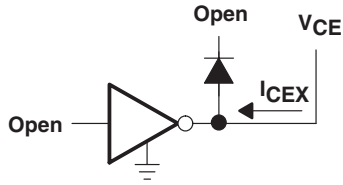


Figure 9. I_{CEX} Test Circuit

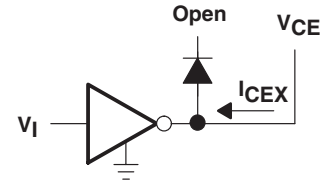


Figure 10. I_{CEX} Test Circuit

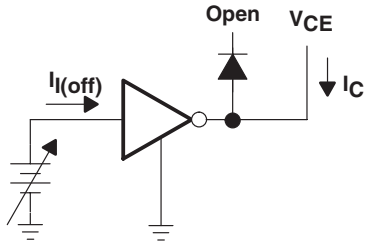


Figure 11. $I_{I(off)}$ Test Circuit

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

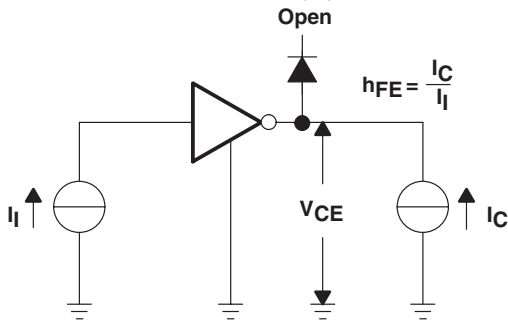


Figure 13. h_{FE} , $V_{CE(sat)}$ Test Circuit

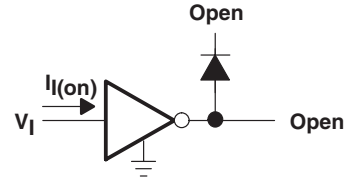


Figure 12. I_I Test Circuit

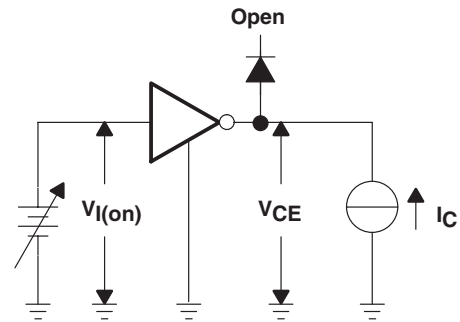


Figure 14. $V_{I(on)}$ Test Circuit

Parameter Measurement Information (continued)

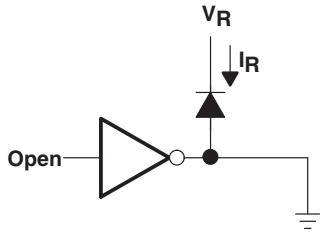


Figure 15. I_R Test Circuit

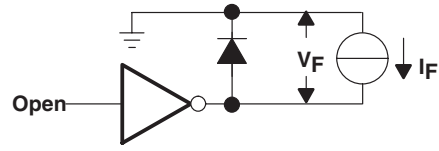
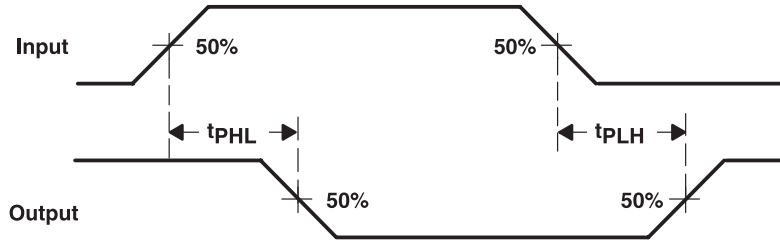
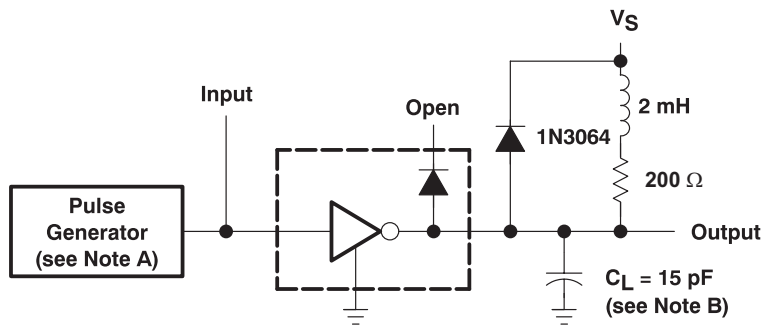


Figure 16. V_F Test Circuit

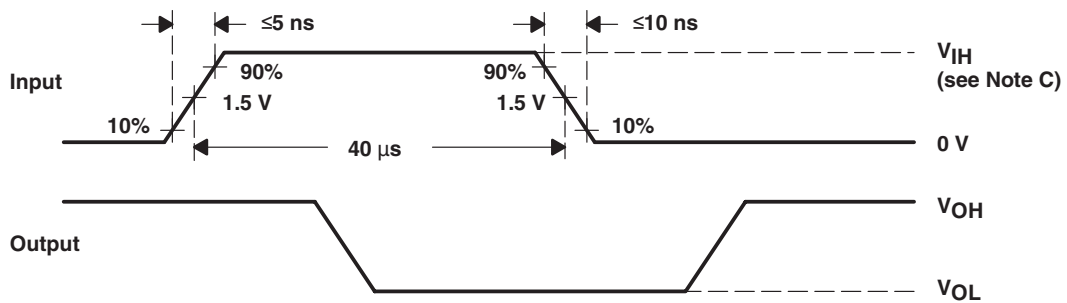


VOLTAGE WAVEFORMS

Figure 17. Propagation Delay-Time Waveforms



TEST CIRCUIT



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 2003 device, 2003 device, and 2003 devices, $V_{IH} = 3\text{ V}$; for the XD/L2002 device, $V_{IH} = 13\text{ V}$; for the 2004 and the 2004 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 2003 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 2003 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 2003 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.

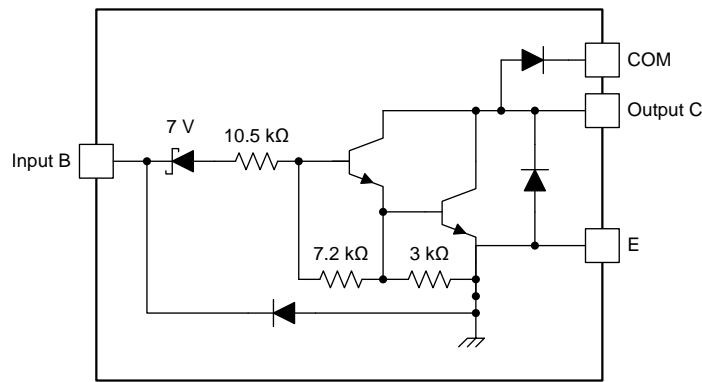


Figure 19. XD/L2002 Block Diagram

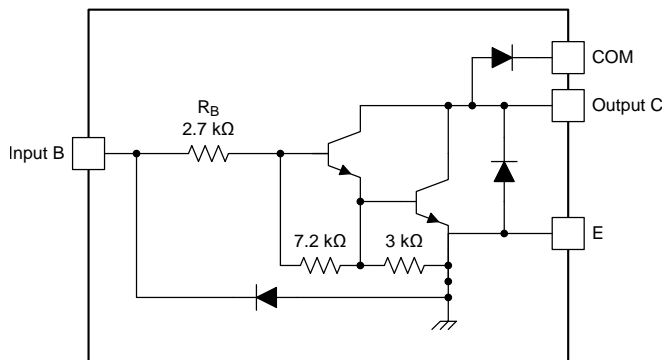


Figure 20. 2003 Block Diagram

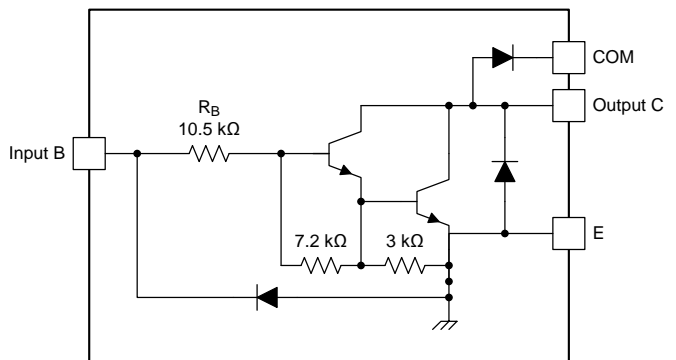


Figure 21. 2004 Block Diagram

8.3 Feature Description

Each channel of the 2003 device 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 through the 2.7-k Ω resistor connected between the input and base of the predriver Darlington NPN. The 7.2-k Ω and 3-k Ω resistors connected between the base and emitter of each respective NPN act as pulldowns 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 through the kick-back diode.

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

8.4 Device Functional Modes

8.4.1 Inductive Load Drive

When the COM pin is tied to the coil supply voltage, 2003 device is able to drive inductive loads and suppress the kick-back voltage through the internal free-wheeling diodes.

8.4.2 Resistive Load Drive

When driving a resistive load, a pullup resistor is needed in order for 2003 device to sink current and for there to be a logic high level. The COM pin can be left floating for these applications.

9 Application and Implementation

9.1 Application Information

Typically, the 2003 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 2003 device, driving inductive loads. This includes motors, solenoids and relays. Figure 22 shows a model for each load type.

9.2 Typical Application

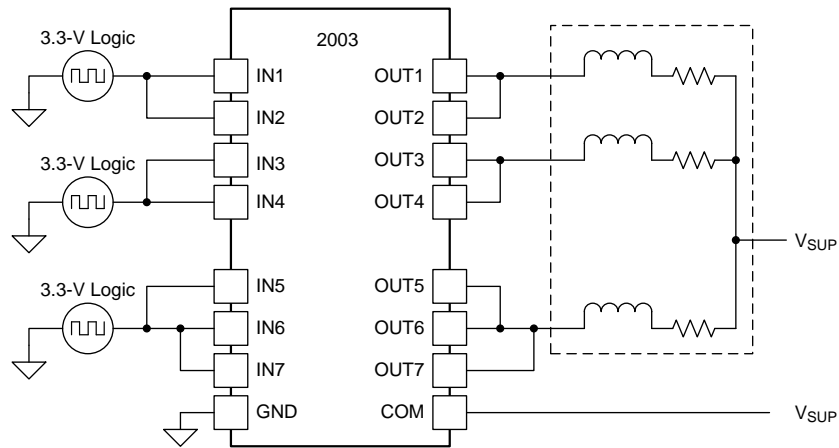


Figure 22. 2003 Device as Inductive Load Driver

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 2003 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 2003 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 $V_{CE(SAT)}$ (2)

To ensure reliability of 2003 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 (3)

Limit the die junction temperature of the 2003 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 2003 device driving an OMRON G5NB relay and under the following conditions: $V_{IN} = 5\text{ V}$, $V_{SUP} = 12\text{ V}$, and $R_{COIL} = 2.8\text{ k}\Omega$.

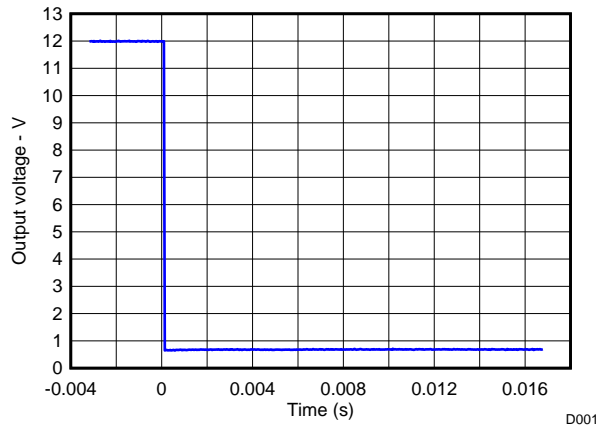


Figure 23. Output Response With Activation of Coil (Turnon)

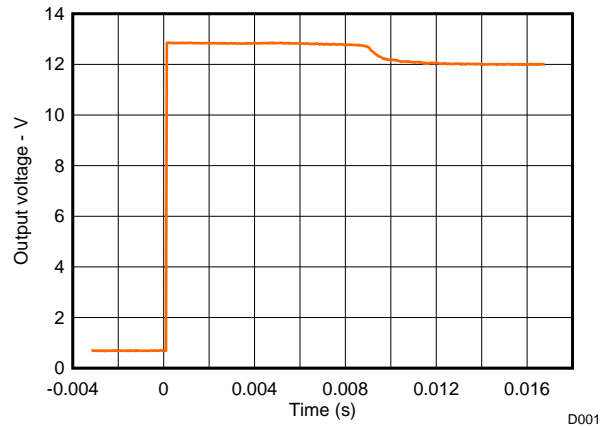


Figure 24. Output Response With De-activation of Coil (Turnoff)

9.3 System Examples

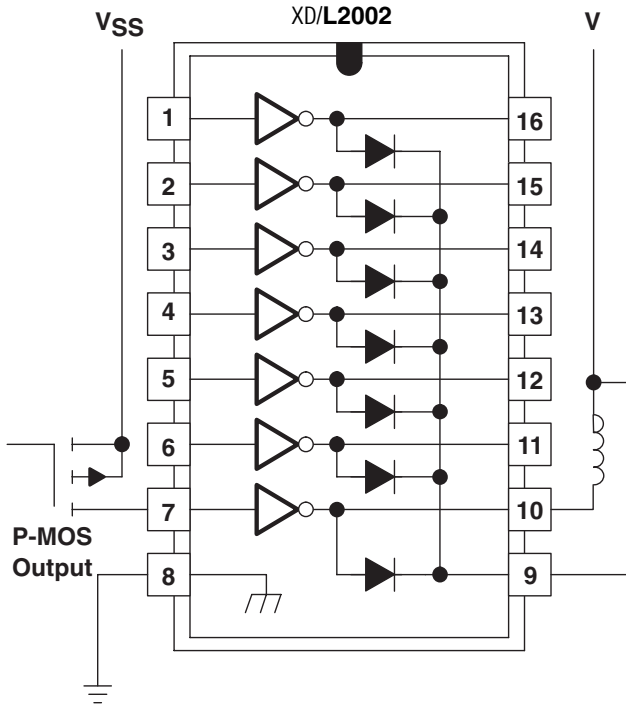


Figure 25. P-MOS to Load

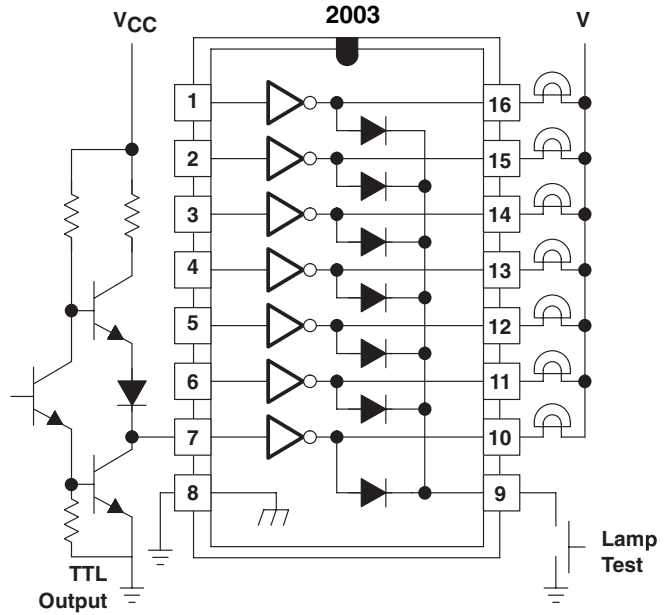


Figure 26. TTL to Load

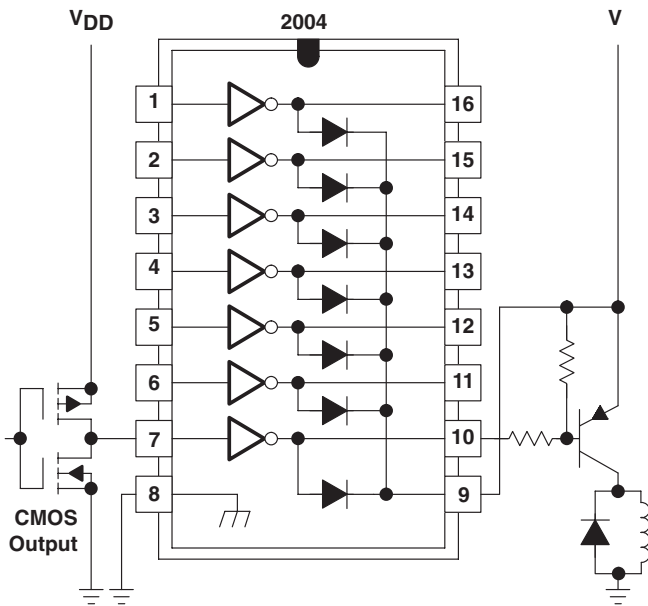


Figure 27. Buffer for Higher Current Loads

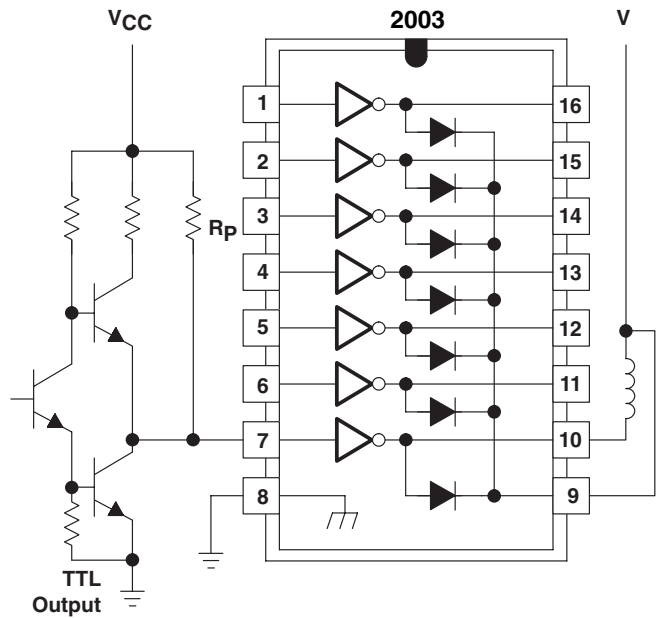


Figure 28. Use of Pullup Resistors to Increase Drive Current

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