# SN74LVC16T245
## 16-bit Dual-Supply Bus Transceiver With Configurable Voltage Translation and Tri-State Outputs

## 1 Features

- Control Inputs $V_{IH}/V_{IL}$ Levels are Referenced to $V_{CCA}$ Voltage
- $V_{CC}$ Isolation Feature – If Either $V_{CC}$ Input is at GND, Both Ports are in the High-Impedance State
- Overvoltage-Tolerant Inputs and Outputs Allow Mixed Voltage-Mode Data Communications
- Fully Configurable Dual-Rail Design Allows Each Port to Operate Over the Full 1.65-V to 5.5-V Power-Supply Range
- $I_{off}$ Supports Partial-Power-Down Mode Operation
- Latch-Up Performance Exceeds 100 mA Per JESD 78, Class II
- ESD Protection Exceeds JESD 22

## 2 Applications

- Personal Electronics
- Industrial
- Enterprise
- Telecom

## 3 Description

This 16-bit noninverting bus transceiver uses two separate configurable power-supply rails. The A port is designed to track $V_{CCA}$. $V_{CCA}$ accepts any supply voltage from 1.65 V to 5.5 V. The B port is designed to track $V_{CCB}$. $V_{CCB}$ accepts any supply voltage from 1.65 V to 5.5 V. This allows for universal low-voltage bidirectional translation between any of the 1.8-V, 2.5-V, 3.3-V, and 5-V voltage nodes.

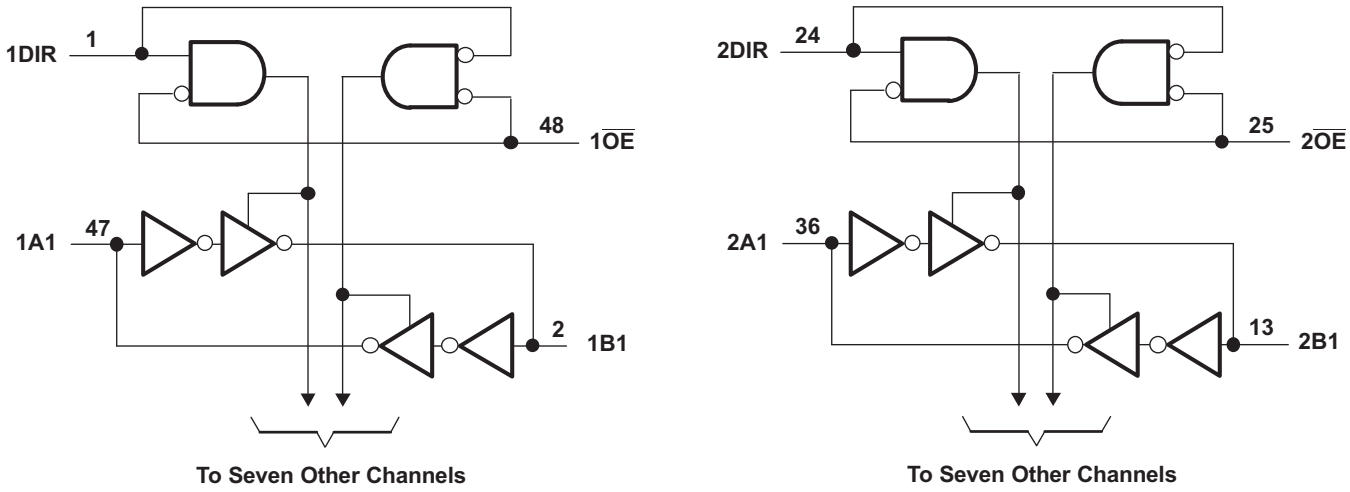
The SN74LVC16T245 device is designed for asynchronous communication between two data buses. The logic levels of the direction-control (DIR) input and the output-enable ($\overline{OE}$) input activate either the B-port outputs or the A-port outputs or place both output ports into the high-impedance mode. The device transmits data from the A bus to the B bus when the B-port outputs are activated, and from the B bus to the A bus when the A-port outputs are activated. The input circuitry on both A and B ports always is active and must have a logic HIGH or LOW level applied to prevent excess $I_{CC}$ and $I_{CCZ}$.

**Device Information**[1]

| PART NUMBER | PACKAGE | BODY SIZE (NOM) |
|---|---|---|
| SN74LVC16T245 | TSSOP (48) | 12.50 mm × 6.10 mm |
| | TVSOP (48) | 9.70 mm × 4.40 mm |
| | SSOP (48) | 15.88 mm × 7.49 mm |
| | BGA MICROSTAR JUNIOR (56) | 7.00 mm × 4.50 mm |

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

**Logic Diagram (Positive Logic)**



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## 4 Revision History

**Changes from Revision A (October 2005) to Revision B** **Page**

- Added *Pin Configuration and Functions* section, *ESD Ratings* table, *Feature Description* section, *Device Functional Modes*, *Application and Implementation* section, *Power Supply Recommendations* section, *Layout* section, *Device and Documentation Support* section, and *Mechanical, Packaging, and Orderable Information* section ... 1

## 5 Description (continued)

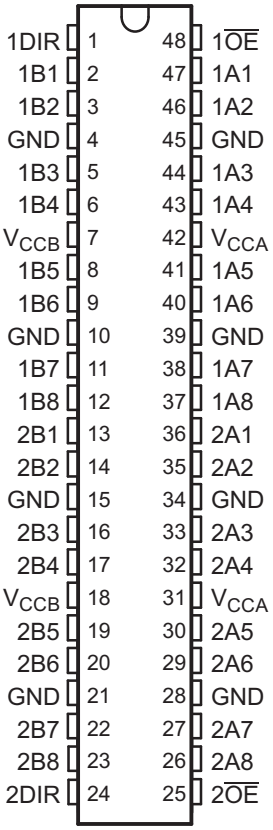
The SN74LVC16T245 control pins (1DIR, 2DIR, $1\overline{OE}$, and $2\overline{OE}$) are supplied by $V_{CCA}$.

This device is fully specified for partial-power-down applications using $I_{off}$. The $I_{off}$ circuitry disables the outputs, preventing damaging current backflow through the device when it is powered down.

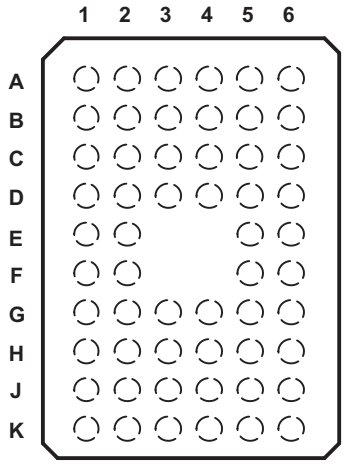
The $V_{CC}$ isolation feature ensures that if either $V_{CC}$ input is at GND, then both ports are in the high-impedance state. To ensure the high-impedance state during power up or power down, $\overline{OE}$ should be tied to $V_{CC}$ through a pullup resistor; the minimum value of the resistor is determined by the current-sinking capability of the driver.

# 6 Pin Configuration and Functions

**DGG and DGV Packages**
**48-Pin TSSOP and TVSOP**
**(Top View)**




**GQL and ZQL Packages**
**56-Pin BGA**
**(Top View)**




**Pin Functions**

| PIN | | | I/O | DESCRIPTION |
|---|---|---|---|---|
| NAME | DGG / DGV | GQL / ZQL | | |
| 1A1 | 47 | B5 | I/O | Input/Output. Referenced to $V_{CCA}$ |
| 1A2 | 46 | B6 | I/O | Input/Output. Referenced to $V_{CCA}$ |
| 1A3 | 44 | C5 | I/O | Input/Output. Referenced to $V_{CCA}$ |
| 1A4 | 43 | C6 | I/O | Input/Output. Referenced to $V_{CCA}$ |
| 1A5 | 41 | D5 | I/O | Input/Output. Referenced to $V_{CCA}$ |
| 1A6 | 40 | D6 | I/O | Input/Output. Referenced to $V_{CCA}$ |
| 1A7 | 38 | E5 | I/O | Input/Output. Referenced to $V_{CCA}$ |
| 1A8 | 37 | E6 | I/O | Input/Output. Referenced to $V_{CCA}$ |
| 1B1 | 2 | B2 | I/O | Input/Output. Referenced to $V_{CCB}$ |
| 1B2 | 3 | B1 | I/O | Input/Output. Referenced to $V_{CCB}$ |
| 1B3 | 5 | C2 | I/O | Input/Output. Referenced to $V_{CCB}$ |
| 1B4 | 6 | C1 | I/O | Input/Output. Referenced to $V_{CCB}$ |
| 1B5 | 8 | D2 | I/O | Input/Output. Referenced to $V_{CCB}$ |
| 1B6 | 9 | D1 | I/O | Input/Output. Referenced to $V_{CCB}$ |
| 1B7 | 11 | E2 | I/O | Input/Output. Referenced to $V_{CCB}$ |
| 1B8 | 12 | E1 | I/O | Input/Output. Referenced to $V_{CCB}$ |
| 1DIR | 1 | A1 | I | Direction-control signal |

## Pin Functions (continued)

| PIN | | | I/O | DESCRIPTION |
|---|---|---|---|---|
| NAME | DGG / DGV | GQL / ZQL | | |
| 1$\overline{OE}$ | 48 | A6 | I | Tri-State output-mode enables. Pull $\overline{OE}$ high to place all outputs in Tri-State mode. Referenced to $V_{CCA}$ |
| 2A1 | 36 | F6 | I/O | Input/Output. Referenced to $V_{CCA}$ |
| 2A2 | 35 | F5 | I/O | Input/Output. Referenced to $V_{CCA}$ |
| 2A3 | 33 | G6 | I/O | Input/Output. Referenced to $V_{CCA}$ |
| 2A4 | 32 | G5 | I/O | Input/Output. Referenced to $V_{CCA}$ |
| 2A5 | 30 | H6 | I/O | Input/Output. Referenced to $V_{CCA}$ |
| 2A6 | 29 | H5 | I/O | Input/Output. Referenced to $V_{CCA}$ |
| 2A7 | 27 | J6 | I/O | Input/Output. Referenced to $V_{CCA}$ |
| 2A8 | 26 | J5 | I/O | Input/Output. Referenced to $V_{CCA}$ |
| 2B1 | 13 | F1 | I/O | Input/Output. Referenced to $V_{CCB}$ |
| 2B2 | 14 | F2 | I/O | Input/Output. Referenced to $V_{CCB}$ |
| 2B3 | 16 | G1 | I/O | Input/Output. Referenced to $V_{CCB}$ |
| 2B4 | 17 | G2 | I/O | Input/Output. Referenced to $V_{CCB}$ |
| 2B5 | 19 | H1 | I/O | Input/Output. Referenced to $V_{CCB}$ |
| 2B6 | 20 | H2 | I/O | Input/Output. Referenced to $V_{CCB}$ |
| 2B7 | 22 | J1 | I/O | Input/Output. Referenced to $V_{CCB}$ |
| 2B8 | 23 | J2 | I/O | Input/Output. Referenced to $V_{CCB}$ |
| 2DIR | 24 | K1 | I | Direction-control signal |
| 2$\overline{OE}$ | 25 | K6 | I | Tri-State output-mode enables. Pull $\overline{OE}$ high to place all outputs in Tri-State mode. Referenced to $V_{CCA}$ |
| GND | 4 | B3 | — | Ground |
| | | B4 | | |
| | 10 | D3 | | |
| | 15 | D4 | | |
| | 21 | G3 | | |
| | 28 | G4 | | |
| | 34 | J3 | | |
| | 45 | J4 | | |
| NC(1) | — | A2 | — | |
| | | A3 | | |
| | | A4 | | |
| | | A5 | | |
| | | K2 | | |
| | | K3 | | |
| | | K4 | | |
| | | K5 | | |
| $V_{CCA}$ | 31 | C4 | — | A-port supply. 1.65 V ≤ $V_{CCA}$ ≤ 5.5 V |
| | 42 | H4 | | |
| $V_{CCB}$ | 7 | C3 | — | B-port supply. 1.65 V ≤ $V_{CCB}$ ≤ 5.5 V |
| | 18 | H3 | | |

(1) NC – No internal connection

# 7 Specifications

## 7.1 Absolute Maximum Ratings

over operating free-air temperature range (unless otherwise noted)(1)

| | | | MIN | MAX | UNIT |
|---|---|---|---|---|---|
| $V_{CCA}$<br>$V_{CCB}$ | Supply voltage | | –0.5 | 6.5 | V |
| $V_I$ | Input voltage(2) | I/O ports (A port) | –0.5 | 6.5 | V |
| | | I/O ports (B port) | –0.5 | 6.5 | |
| | | Control inputs | –0.5 | 6.5 | |
| $V_O$ | Voltage applied to any output in the high-impedance or power-off state(2) | A port | –0.5 | 6.5 | V |
| | | B port | –0.5 | 6.5 | |
| $V_O$ | Voltage applied to any output in the high or low state(2) (3) | A port | –0.5 | $V_{CCA}$ + 0.5 | V |
| | | B port | –0.5 | $V_{CCB}$ + 0.5 | |
| $I_{IK}$ | Input clamp current | $V_I$ < 0 | | –50 | mA |
| $I_{OK}$ | Output clamp current | $V_O$ < 0 | | –50 | mA |
| $I_O$ | Continuous output current | | | ±50 | mA |
| | Continuous current through each $V_{CCA}$, $V_{CCB}$, and GND | | | ±100 | mA |
| $T_J$ | Junction temperature | | -40 | 150 | °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, which do not imply functional operation of the device at these or any other conditions beyond those indicated under *Recommended Operating Conditions*. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.
(2) The input ($V_I$ ) and output ($V_O$) negative-voltage ratings may be exceeded if the input and output current ratings are observed.
(3) The output positive-voltage rating may be exceeded up to 6.5 V maximum if the output current rating is observed.

## 7.2 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) | ±1000 | |
| | | Machine model (A115-A) | ±200 | |

(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

See (1)(2)(3)(4)

| | | | $V_{CCI}$ | $V_{CCO}$ | MIN | MAX | UNIT |
|---|---|---|---|---|---|---|---|
| $V_{CCA}$ | Supply voltage | | | | 1.65 | 5.5 | V |
| $V_{CCB}$ | | | | | 1.65 | 5.5 | |
| $V_{IH}$ | High-level input voltage | Data inputs(5) | 1.65 V to 1.95 V | | $V_{CCI}$ × 0.65 | | V |
| | | | 2.3 V to 2.7 V | | 1.7 | | |
| | | | 3 V to 3.6 V | | 2 | | |
| | | | 4.5 V to 5.5 V | | $V_{CCI}$ × 0.7 | | |
| $V_{IL}$ | Low-level input voltage | Data inputs(5) | 1.65 V to 1.95 V | | | $V_{CCI}$ × 0.35 | V |
| | | | 2.3 V to 2.7 V | | | 0.7 | |
| | | | 3 V to 3.6 V | | | 0.8 | |
| | | | 4.5 V to 5.5 V | | | $V_{CCI}$ × 0.3 | |
| $V_{IH}$ | High-level input voltage | Control inputs (referenced to $V_{CCA}$)(6) | 1.65 V to 1.95 V | | $V_{CCA}$ × 0.65 | | V |
| | | | 2.3 V to 2.7 V | | 1.7 | | |
| | | | 3 V to 3.6 V | | 2 | | |
| | | | 4.5 V to 5.5 V | | $V_{CCA}$ × 0.7 | | |
| $V_{IL}$ | Low-level input voltage | Control inputs (referenced to $V_{CCA}$)(6) | 1.65 V to 1.95 V | | | $V_{CCA}$ × 0.35 | V |
| | | | 2.3 V to 2.7 V | | | 0.7 | |
| | | | 3 V to 3.6 V | | | 0.8 | |
| | | | 4.5 V to 5.5 V | | | $V_{CCA}$ × 0.3 | |
| $V_I$ | Input voltage | Control inputs | | | 0 | 5.5 | V |
| $V_{I/O}$ | Input/output voltage | Active state | | | 0 | $V_{CCO}$ | V |
| | | Tri-State | | | 0 | 5.5 | |
| $I_{OH}$ | High-level output current | | | 1.65 V to 1.95 V | | –4 | mA |
| | | | | 2.3 V to 2.7 V | | –8 | |
| | | | | 3 V to 3.6 V | | –24 | |
| | | | | 4.5 V to 5.5 V | | –32 | |
| $I_{OL}$ | Low-level output current | | | 1.65 V to 1.95 V | | 4 | mA |
| | | | | 2.3 V to 2.7 V | | 8 | |
| | | | | 3 V to 3.6 V | | 24 | |
| | | | | 4.5 V to 5.5 V | | 32 | |
| Δt/Δv | Input transition rise or fall rate | Data inputs | 1.65 V to 1.95 V | | | 20 | ns/V |
| | | | 2.3 V to 2.7 V | | | 20 | |
| | | | 3 V to 3.6 V | | | 10 | |
| | | | 4.5 V to 5.5 V | | | 5 | |
| $T_A$ | Operating free-air temperature | | | | –40 | 85 | °C |

(1) $V_{CCI}$ is the $V_{CC}$ associated with the input port.
(2) $V_{CCO}$ is the $V_{CC}$ associated with the output port.
(3) All unused or driven (floating) data inputs (I/Os) of the device must be held at logic HIGH or LOW (preferably $V_{CCI}$ or GND) to ensure proper device operation and minimize power. Refer to the TI application report, *Implications of Slow or Floating CMOS Inputs*, literature number SCBA004.
(4) All unused data inputs of the device must be held at $V_{CCA}$ or GND to ensure proper device operation.
(5) For $V_{CCI}$ values not specified in the data sheet, $V_{IH}$ min = $V_{CCI}$ × 0.7 V, $V_{IL}$ max = $V_{CCI}$ × 0.3 V.
(6) For $V_{CCA}$ values not specified in the data sheet, $V_{IH}$ min = $V_{CCA}$ × 0.7 V, $V_{IL}$ max = $V_{CCA}$ × 0.3 V.

## 7.4 Thermal Information

| THERMAL METRIC[1] | | SN74LVC16T245 | | | | UNIT |
|---|---|---|---|---|---|---|
| | | DL (SSOP) | DGG (TSSOP) | DGV (TVSOP) | GQL / ZQL (BGA) | |
| | | 48 PINS | 48 PINS | 48 PINS | 56 PINS | |
| $R_{\theta JA}$ | Junction-to-ambient thermal resistance | 92.9 | 60 | 82.5 | 64.6 | °C/W |
| $R_{\theta JC(top)}$ | Junction-to-case (top) thermal resistance | 29.5 | 13.9 | 34.2 | 16.6 | °C/W |
| $R_{\theta JB}$ | Junction-to-board thermal resistance | 35.5 | 27.1 | 45.1 | 30.8 | °C/W |
| $\psi_{JT}$ | Junction-to-top characterization parameter | 8.1 | 0.5 | 2.7 | 0.9 | °C/W |
| $\psi_{JB}$ | Junction-to-board characterization parameter | 34.9 | 26.8 | 44.6 | 64.6 | °C/W |

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

## 7.5 Electrical Characteristics

over recommended operating free-air temperature range (unless otherwise noted)[1] [2]

| PARAMETER | | TEST CONDITIONS | $V_{CCA}$ | $V_{CCB}$ | $T_A$ = 25°C | | | $T_A$ = –40°C to 85°C | | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | MIN | TYP | MAX | MIN | MAX | |
| $V_{OH}$ | | $I_{OH}$ = –100 µA, $V_I = V_{IH}$ | 1.65 V to 4.5 V | 1.65 V to 4.5 V | | | | $V_{CCO}$ – 0.1 | | V |
| | | $I_{OH}$ = –4 mA, $V_I = V_{IH}$ | 1.65 V | 1.65 V | | | | 1.2 | | |
| | | $I_{OH}$ = –8 mA, $V_I = V_{IH}$ | 2.3 V | 2.3 V | | | | 1.9 | | |
| | | $I_{OH}$ = –24 mA, $V_I = V_{IH}$ | 3 V | 3 V | | | | 2.4 | | |
| | | $I_{OH}$ = –32 mA, $V_I = V_{IH}$ | 4.5 V | 4.5 V | | | | 3.8 | | |
| $V_{OL}$ | | $I_{OL}$ = 100 µA, $V_I = V_{IL}$ | 1.65 V to 4.5 V | 1.65 V to 4.5 V | | | | | 0.1 | V |
| | | $I_{OL}$ = 4 mA, $V_I = V_{IL}$ | 1.65 V | 1.65 V | | | | | 0.45 | |
| | | $I_{OL}$ = 8 mA, $V_I = V_{IL}$ | 2.3 V | 2.3 V | | | | | 0.3 | |
| | | $I_{OL}$ = 24 mA, $V_I = V_{IL}$ | 3 V | 3 V | | | | | 0.55 | |
| | | $I_{OL}$ = 32 mA, $V_I = V_{IL}$ | 4.5 V | 4.5 V | | | | | 0.55 | |
| $I_I$ | Control inputs | $V_I = V_{CCA}$ or GND | 1.65 V to 5.5 V | 1.65 V to 5.5 V | | | ±1 | | ±2 | µA |
| $I_{off}$ | A or B port | $V_I$ or $V_O$ = 0 to 5.5 V | 0 V | 0 to 5.5 V | | | ±1 | | ±2 | µA |
| | | | 0 to 5.5 V | 0 V | | | ±1 | | ±2 | |
| $I_{OZ}$ | A or B port | $V_O = V_{CCO}$ or GND, $\overline{OE} = V_{IH}$ | 1.65 V to 5.5 V | 1.65 V to 5.5 V | | | ±1 | | ±2 | µA |
| $I_{CCA}$ | | $V_I = V_{CCI}$ or GND, $I_O$ = 0 | 1.65 V to 5.5 V | 1.65 V to 5.5 V | | | | | 20 | µA |
| | | | 5 V | 0 V | | | | | 20 | |
| | | | 0 V | 5 V | | | | | –2 | |
| $I_{CCB}$ | | $V_I = V_{CCI}$ or GND, $I_O$ = 0 | 1.65 V to 5.5 V | 1.65 V to 5.5 V | | | | | 20 | µA |
| | | | 5 V | 0 V | | | | | –2 | |
| | | | 0 V | 5 V | | | | | 20 | |
| $I_{CCA} + I_{CCB}$ | | $V_I = V_{CCI}$ or GND, $I_O$ = 0 | 1.65 V to 5.5 V | 1.65 V to 5.5 V | | | | | 30 | µA |
| $\Delta I_{CCA}$ | A port | One A port at $V_{CCA}$ – 0.6 V, DIR at $V_{CCA}$, B port = open | 3 V to 5.5 V | 3 V to 5.5 V | | | | | 50 | µA |
| | DIR | DIR at $V_{CCA}$ – 0.6 V, B port = open, A port at $V_{CCA}$ or GND | | | | | | | 50 | |
| $\Delta I_{CCB}$ | B port | One B port at $V_{CCB}$ – 0.6 V, DIR at GND, A port = open | 3 V to 5.5 V | 3 V to 5.5 V | | | | | 50 | µA |
| $C_i$ | Control inputs | $V_I = V_{CCA}$ or GND | 3.3 V | 3.3 V | | 4 | | | 5 | pF |

(1) $V_{CCO}$ is the $V_{CC}$ associated with the output port.
(2) $V_{CCI}$ is the $V_{CC}$ associated with the input port.

## Electrical Characteristics (continued)

over recommended operating free-air temperature range (unless otherwise noted)(1) (2)

| PARAMETER | | TEST CONDITIONS | $V_{CCA}$ | $V_{CCB}$ | $T_A$ = 25°C | | | $T_A$ = –40°C to 85°C | | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | MIN | TYP | MAX | MIN | MAX | |
| $C_{io}$ | A or B port | $V_O = V_{CCA/B}$ or GND | 3.3 V | 3.3 V | | 8.5 | | | 10 | pF |

## 7.6 Switching Characteristics: $V_{CCA}$ = 1.8 V ±0.15 V

over recommended operating free-air temperature range, $V_{CCA}$ = 1.8 V ± 0.15 V (unless otherwise noted) (see Figure 3)

| PARAMETER | FROM (INPUT) | TO (OUTPUT) | $V_{CCB}$ = 1.8 V ±0.15 V | | $V_{CCB}$ = 2.5 V ±0.2 V | | $V_{CCB}$ = 3.3 V ±0.3 V | | $V_{CCB}$ = 5 V ±0.5 V | | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX | |
| $t_{PLH}$ / $t_{PHL}$ | A | B | 1.7 | 21.9 | 1.3 | 9.2 | 1 | 7.4 | 0.8 | 7.1 | ns |
| $t_{PLH}$ / $t_{PHL}$ | B | A | 0.9 | 23.8 | 0.8 | 23.6 | 0.7 | 23.4 | 0.7 | 23.4 | ns |
| $t_{PHZ}$ / $t_{PLZ}$ | $\overline{OE}$ | A | 1.6 | 29.6 | 1.5 | 29.4 | 1.5 | 29.3 | 1.4 | 29.2 | ns |
| $t_{PHZ}$ / $t_{PLZ}$ | $\overline{OE}$ | B | 2.4 | 32.2 | 1.9 | 13.1 | 1.7 | 12 | 1.3 | 10.3 | ns |
| $t_{PZH}$ / $t_{PZL}$ | $\overline{OE}$ | A | 0.4 | 24 | 0.4 | 23.8 | 0.4 | 23.7 | 0.4 | 23.7 | ns |
| $t_{PZH}$ / $t_{PZL}$ | $\overline{OE}$ | B | 1.8 | 32 | 1.6 | 16 | 1.2 | 12.6 | 0.9 | 10.8 | ns |

## 7.7 Switching Characteristics: $V_{CCA}$ = 2.5 V ±0.2 V

over recommended operating free-air temperature range, $V_{CCA}$ = 2.5 V ± 0.2 V (unless otherwise noted) (see Figure 3)

| PARAMETER | FROM (INPUT) | TO (OUTPUT) | $V_{CCB}$ = 1.8 V ±0.15 V | | $V_{CCB}$ = 2.5 V ±0.2 V | | $V_{CCB}$ = 3.3 V ±0.3 V | | $V_{CCB}$ = 5 V 0.5 V | | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX | |
| $t_{PLH}$ / $t_{PHL}$ | A | B | 1.6 | 21.4 | 1.2 | 9 | 0.8 | 6.2 | 0.6 | 4.8 | ns |
| $t_{PLH}$ / $t_{PHL}$ | B | A | 1.2 | 9.3 | 1 | 9.1 | 1 | 8.9 | 0.9 | 8.8 | ns |
| $t_{PHZ}$ / $t_{PLZ}$ | $\overline{OE}$ | A | 1.4 | 9 | 1.4 | 9 | 1.4 | 9 | 1.4 | 9 | ns |
| $t_{PHZ}$ / $t_{PLZ}$ | $\overline{OE}$ | B | 2.3 | 29.6 | 1.8 | 11 | 1.7 | 9.3 | 0.9 | 6.9 | ns |
| $t_{PZH}$ / $t_{PZL}$ | $\overline{OE}$ | A | 1 | 10.9 | 1 | 10.9 | 1 | 10.9 | 1 | 10.9 | ns |
| $t_{PZH}$ / $t_{PZL}$ | $\overline{OE}$ | B | 1.7 | 28.2 | 1.6 | 12.9 | 1.2 | 9.4 | 1 | 6.9 | ns |

## 7.8 Switching Characteristics: $V_{CCA}$ = 3.3 V ±0.3 V

over recommended operating free-air temperature range, $V_{CCA}$ = 3.3 V ± 0.3 V (unless otherwise noted) (see Figure 3)

| PARAMETER | FROM (INPUT) | TO (OUTPUT) | $V_{CCB}$ = 1.8 V ±0.15 V | | $V_{CCB}$ = 2.5 V ±0.2 V | | $V_{CCB}$ = 3.3 V ±0.3 V | | $V_{CCB}$ = 5 V ±0.5 V | | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX | |
| $t_{PLH}$ / $t_{PHL}$ | A | B | 1.5 | 21.2 | 1.1 | 8.8 | 0.8 | 6.1 | 0.5 | 4.4 | ns |
| $t_{PLH}$ / $t_{PHL}$ | B | A | 0.9 | 7.2 | 0.8 | 6.2 | 0.7 | 6.1 | 0.6 | 6 | ns |
| $t_{PHZ}$ / $t_{PLZ}$ | $\overline{OE}$ | A | 1.6 | 8.2 | 1.6 | 8.2 | 1.6 | 6.2 | 1.6 | 8.2 | ns |
| $t_{PHZ}$ / $t_{PLZ}$ | $\overline{OE}$ | B | 2.1 | 29 | 1.7 | 10.3 | 1.5 | 8.6 | 0.8 | 6.3 | ns |
| $t_{PZH}$ / $t_{PZL}$ | $\overline{OE}$ | A | 0.8 | 7.8 | 0.8 | 7.8 | 0.8 | 7.8 | 0.8 | 7.8 | ns |
| $t_{PZH}$ / $t_{PZL}$ | $\overline{OE}$ | B | 1.6 | 27.7 | 1.4 | 12.4 | 1.1 | 8.5 | 0.9 | 8.4 | ns |

## 7.9 Switching Characteristics: $V_{CCA}$ = 5 V ±0.5 V

over recommended operating free-air temperature range, $V_{CCA}$ = 5 V ± 0.5 V (unless otherwise noted) (see Figure 3)

| PARAMETER | FROM (INPUT) | TO (OUTPUT) | $V_{CC}$ = 1.8 V ±0.15 V | | $V_{CC}$ = 2.5 V ±0.2 V | | $V_{CC}$ = 3.3 V ±0.3 V | | $V_{CC}$ = 5 V ±0.5 V | | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX | |
| $t_{PLH}$ / $t_{PHL}$ | A | B | 1.6 | 21.4 | 1 | 8.8 | 0.7 | 6 | 0.4 | 4.2 | ns |
| $t_{PLH}$ / $t_{PHL}$ | B | A | 0.7 | 6.8 | 0.4 | 4.8 | 0.3 | 4.5 | 0.3 | 4.3 | ns |
| $t_{PHZ}$ / $t_{PLZ}$ | $\overline{OE}$ | A | 0.3 | 5.4 | 0.3 | 5.4 | 0.3 | 5.4 | 0.3 | 6.4 | ns |
| $t_{PHZ}$ / $t_{PLZ}$ | $\overline{OE}$ | B | 2 | 28.7 | 1.6 | 9.7 | 1.4 | 8 | 0.7 | 5.7 | ns |
| $t_{PZH}$ / $t_{PZL}$ | $\overline{OE}$ | A | 0.7 | 5.5 | 0.7 | 5.5 | 0.7 | 5.5 | 0.7 | 5.5 | ns |
| $t_{PZH}$ / $t_{PZL}$ | $\overline{OE}$ | B | 1.6 | 27.6 | 1.3 | 11.4 | 1 | 8.1 | 0.9 | 6 | ns |

## 7.10 Operating Characteristics

$T_A$ = 25°C

| PARAMETER | | TEST CONDITIONS | $V_{CCA}$ = $V_{CCB}$ = 1.8 V | $V_{CCA}$ = $V_{CCB}$ = 2.5 V | $V_{CCA}$ = $V_{CCB}$ = 3.3 V | $V_{CCA}$ = $V_{CCB}$ = 5 V | UNIT |
|---|---|---|---|---|---|---|---|
| | | | TYP | TYP | TYP | TYP | |
| $C_{pdA}$ (1) | A-port input, B-port output | $C_L$ = 0, f = 10 MHz, $t_r$ = $t_f$ = 1 ns | 2 | 2 | 2 | 3 | pF |
| | B-port input, A-port output | | 18 | 19 | 19 | 22 | |
| $C_{pdB}$ (1) | A-port input, B-port output | | 18 | 19 | 20 | 22 | |
| | B-port input, A-port output | | 2 | 2 | 2 | 2 | |

(1) Power dissipation capacitance per transceiver. Refer to the TI application report, *CMOS Power Consumption and Cpd Calculation*, SCAA035

## 7.11 Typical Characteristics

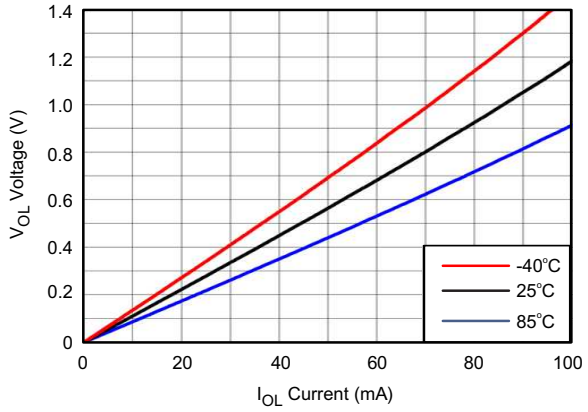



**Figure 1. $V_{OL}$ Voltage vs $I_{OL}$ Current**

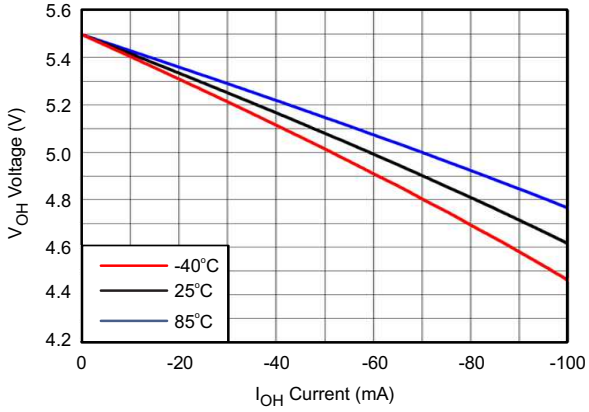
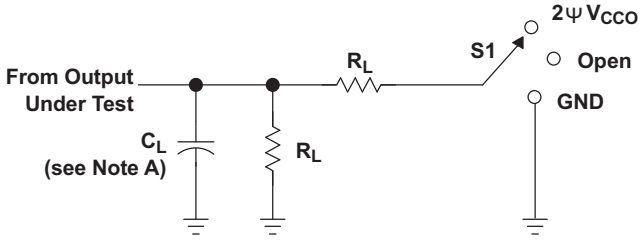



**Figure 2. $V_{OH}$ Voltage vs $I_{OH}$ Current**

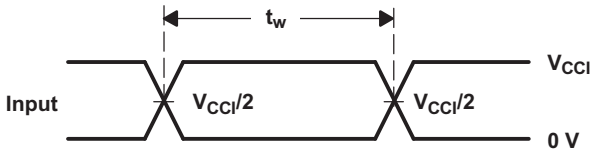
# 8 Parameter Measurement Information



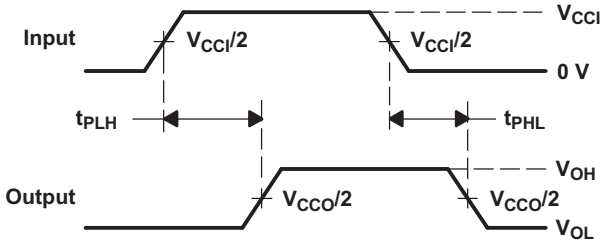

LOAD CIRCUIT

| TEST | S1 |
|---|---|
| $t_{pd}$ | Open |
| $t_{PLZ}/t_{PZL}$ | $2\psi V_{CCO}$ |
| $t_{PHZ}/t_{PZH}$ | GND |

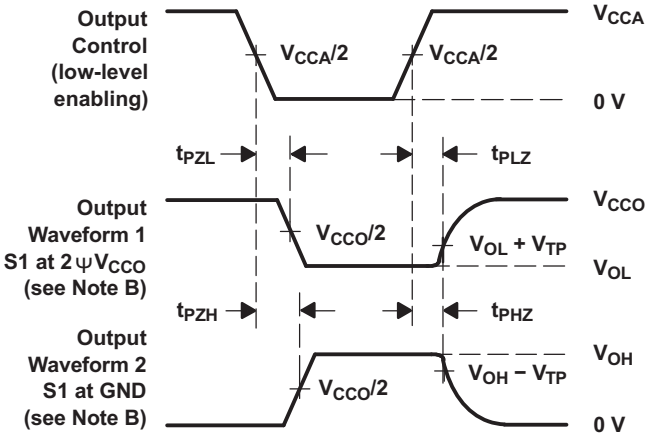
| $V_{CCO}$ | $C_L$ | $R_L$ | $V_{TP}$ |
|---|---|---|---|
| 1.8 V ± 0.15 V | 15 pF | 2 kΩ | 0.15 V |
| 2.5 V ± 0.2 V | 15 pF | 2 kΩ | 0.15 V |
| 3.3 V ± 0.3 V | 15 pF | 2 kΩ | 0.3 V |
| 5 V ± 0.5 V | 15 pF | 2 kΩ | 0.3 V |




VOLTAGE WAVEFORMS
PULSE DURATION




VOLTAGE WAVEFORMS
PROPAGATION DELAY TIMES




VOLTAGE WAVEFORMS
ENABLE AND DISABLE TIMES

NOTES: A. $C_L$ includes probe and jig capacitance.
B. Waveform 1 is for an output with internal conditions such that the output is low, except when disabled by the output control. Waveform 2 is for an output with internal conditions such that the output is high, except when disabled by the output control.
C. All input pulses are supplied by generators having the following characteristics: PRR ≤ 10 MHz, $Z_O$ = 50 Ω, dv/dt ≥ 1 V/ns.
D. The outputs are measured one at a time, with one transition per measurement.
E. $t_{PLH}$ and $t_{PHL}$ are the same as $t_{pd}$.
F. $V_{CCI}$ is the $V_{CC}$ associated with the input port.
G. $V_{CCO}$ is the $V_{CC}$ associated with the output port.
H. All parameters and waveforms are not applicable to all devices.

**Figure 3. Load Circuit and Voltage Waveforms**

# 9 Detailed Description

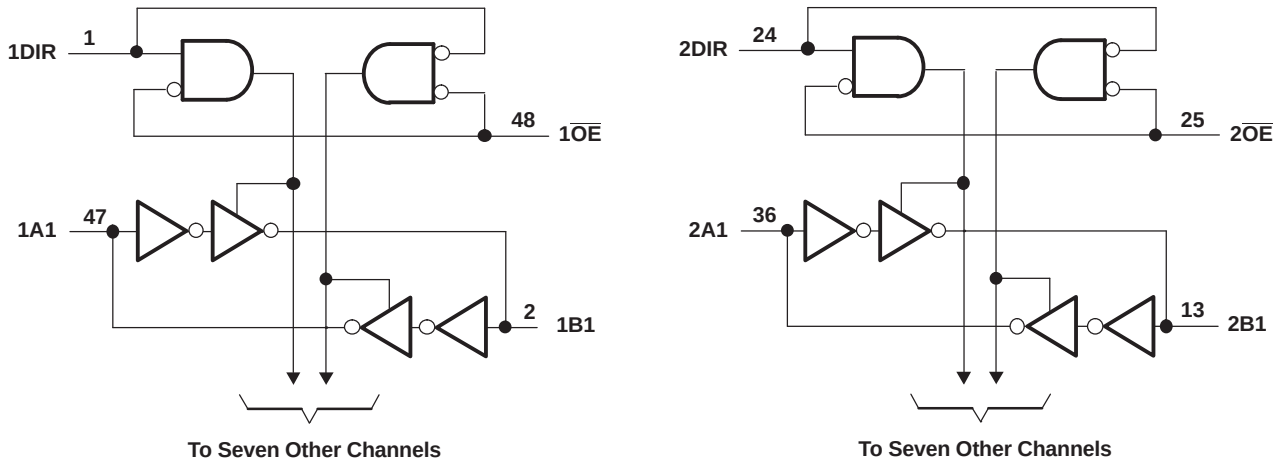
## 9.1 Overview

The SN74LVC16T245 is a 16-bit, dual-supply noninverting bidirectional voltage level translation. Pins A and control pins (DIR and $\overline{OE}$) are supported by $V_{CCA}$ and pins B are supported by $V_{CCB}$. The A port is able to accept I/O voltages ranging from 1.65 V to 5.5 V, while the B port can accept I/O voltages from 1.65 V to 5.5 V. A high on DIR allows data transmission from A to B and a low on DIR allows data transmission from B to A when $\overline{OE}$ is set to low. When $\overline{OE}$ is set to high, both A and B are in the high-impedance state.

This device is fully specified for partial-power-down applications using off output current ($I_{off}$).

The $V_{CC}$ isolation feature ensures that if either $V_{CC}$ input is at GND, both ports are put in a high-impedance state.

## 9.2 Functional Block Diagram




## 9.3 Feature Description

### 9.3.1 Fully Configurable Dual-Rail Design Allows Each Port to Operate Over the Full 1.65-V to 5.5-V Power-Supply Range

Both $V_{CCA}$ and $V_{CCB}$ can be supplied at any voltage from 1.65 V to 5.5 V making the device suitable for translating between any of the low voltage nodes (1.8-V, 2.5-V, and 3.3-V).

### 9.3.2 Support High-Speed Translation

SN74LVC16T245 can support high data rate application. Data rates can be calculated form the maximum propagation delay. This is also dependant on the output load. For example, for a 3.3-V to 5-V conversion, the maximum frequency is 200 MHz.

### 9.3.3 Partial-Power-Down Mode Operation

This device is fully specified for partial-power-down applications using off output current ($I_{off}$). $I_{off}$ will prevent backflow current by disabling I/O output circuits when device is in partial power-down mode.

### 9.3.4 $V_{CC}$ Isolation

The $V_{CC}$ isolation feature ensures that if either $V_{CCA}$ or $V_{CCB}$ are at GND, both ports will be in a high-impedance state ($I_{OZ}$ shown in *Electrical Characteristics*). This prevents false logic levels from being presented to either bus.

## 9.4 Device Functional Modes

The functional modes for the SN74LVC16T245 device are shown in Table 1.

**Table 1. Function Table(1)**
**(Each Transceiver)**

| CONTROL INPUTS | | OUTPUT CIRCUITS | | OPERATION |
|---|---|---|---|---|
| $\overline{OE}$ | DIR | A PORT | B PORT | |
| L | L | Enabled | Hi-Z | B data to A bus |
| L | H | Hi-Z | Enabled | A data to B bus |
| H | X | Hi-Z | Hi-Z | Isolation |

(1) Input circuits of the data I/Os always are active.

# 10 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.

## 10.1 Application Information

The SN74LVC16T245 device can be used in level-shifting applications for interfacing devices and addressing mixed voltage incompatibility. The SN74LVC16T245 device is ideal for data transmission where direction is different for each channel.

### 10.1.1 Enable Times

Calculate the enable times for the SN74LV16T245 using the following formulas:

$$t_{PZH} \text{ (DIR to A)} = t_{PLZ} \text{ (DIR to B)} + t_{PLH} \text{ (B to A)} \quad (1)$$

$$t_{PZL} \text{ (DIR to A)} = t_{PHZ} \text{ (DIR to B)} + t_{PHL} \text{ (B to A)} \quad (2)$$

$$t_{PZH} \text{ (DIR to B)} = t_{PLZ} \text{ (DIR to A)} + t_{PLH} \text{ (A to B)} \quad (3)$$

$$t_{PZL} \text{ (DIR to B)} = t_{PHZ} \text{(DIR to A)} + t_{PHL} \text{ (A to B)} \quad (4)$$

In a bidirectional application, these enable times provide the maximum delay from the time the DIR bit is switched until an output is expected. For example, if the SN74LVC16T245 initially is transmitting from A to B, then the DIR bit is switched; the B port of the device must be disabled before presenting it with an input. After the B port has been disabled, an input signal applied to it appears on the corresponding A port after the specified propagation delay.

## 10.2 Typical Application

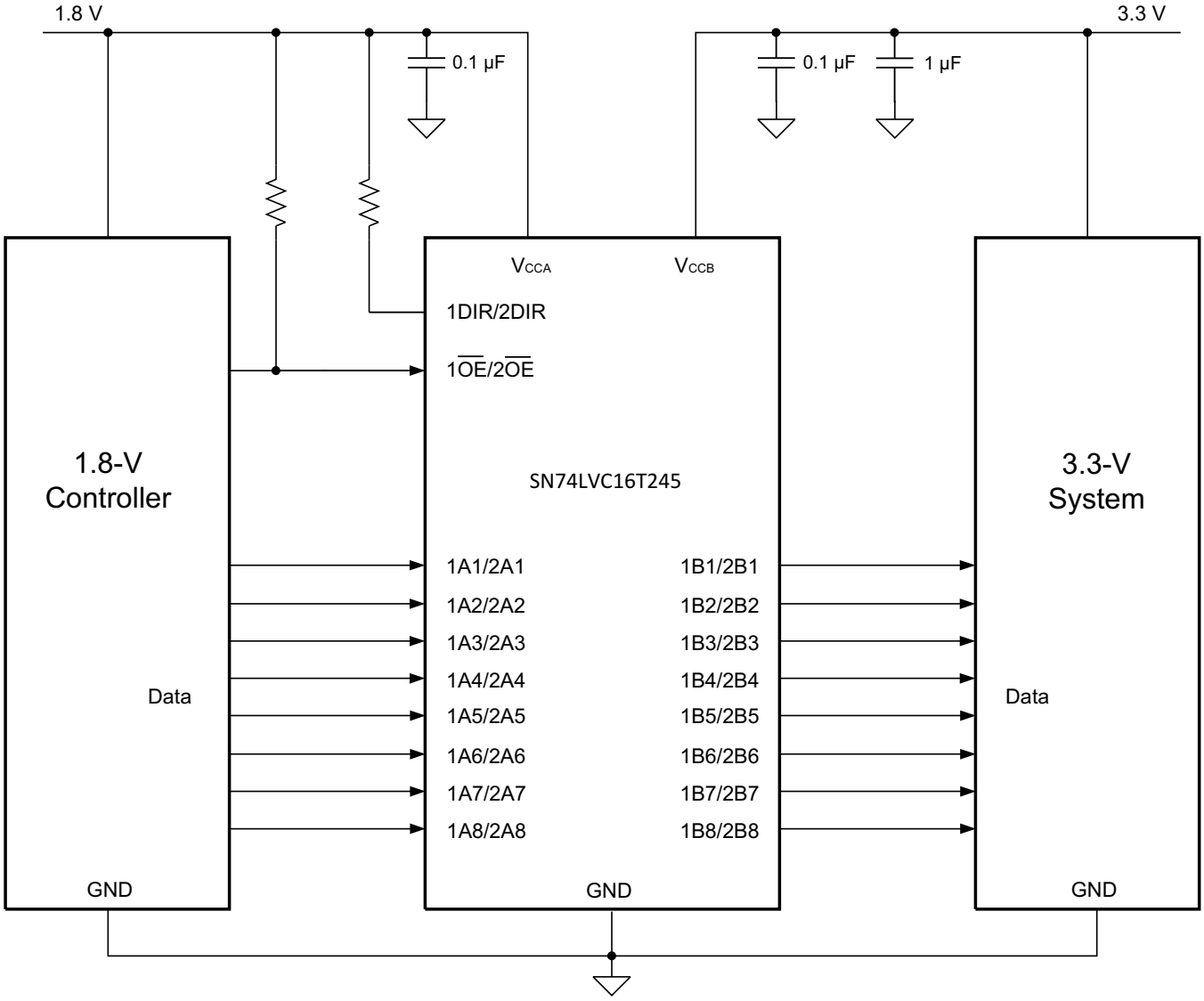



**Figure 4. Typical Application Schematic**

### 10.2.1 Design Requirements

This device uses drivers which are enabled depending on the state of the DIR pin. The designer must know the intended flow of data and take care not to violate any of the high or low logic levels. It is important that unused data inputs not be floating, as this can cause excessive internal leakage on the input CMOS structure. Make sure to tie any unused input and output ports directly to ground. For this design example, use the parameters listed in Table 2.

**Table 2. Design Parameters**

| DESIGN PARAMETERS | EXAMPLE VALUE |
|---|---|
| Input voltage range | 1.65 V to 5.5 V |
| Output voltage | 1.65 V to 5.5 V |

### 10.2.2 Detailed Design Procedure

To begin the design process, determine the following:

- Input voltage range
  - Use the supply voltage of the device that is driving the SN74LVC16T245 device to determine the input voltage range. For a valid logic high the value must exceed the $V_{IH}$ of the input port. For a valid logic low the value must be less than the $V_{IL}$ of the input port.
- Output voltage range
  - Use the supply voltage of the device that the SN74LVC16T245 device is driving to determine the output voltage range.

### 10.2.3 Application Curve

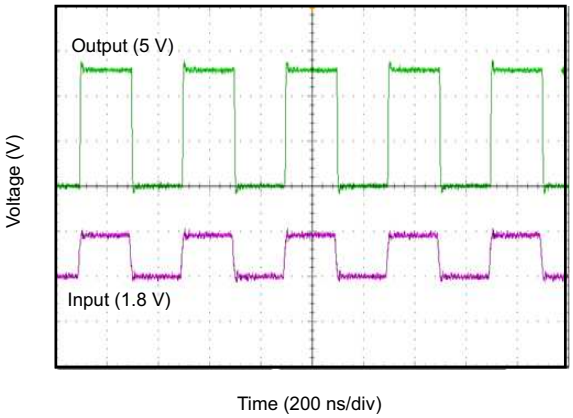



**Figure 5. Translation Up (1.8 V to 5 V) at 2.5 MHz**

## 11 Power Supply Recommendations

The SN74LVC16T245 device uses two separate configurable power-supply rails, $V_{CCA}$ and $V_{CCB}$. $V_{CCA}$ accepts any supply voltage from 1.65 V to 5.5 V and $V_{CCB}$ accepts any supply voltage from 1.65 V to 5.5 V. The A port and B port are designed to track $V_{CCA}$ and $V_{CCB}$, respectively, allowing for low-voltage bidirectional translation between any of the 1.8-V, 2.5-V and 3.3-V voltage nodes.

The output-enable $\overline{OE}$ input circuit is supplied by $V_{CCA}$ and when the $\overline{OE}$ input is high, all outputs are placed in the high-impedance state. To ensure the high-impedance state of the outputs during power up or power down, the $\overline{OE}$ input pin must be tied to $V_{CCA}$ through a pullup resistor and must not be enabled until $V_{CCA}$ and $V_{CCB}$ are fully ramped and stable. The minimum value of the pullup resistor to $V_{CCA}$ is determined by the current-sinking capability of the driver.

## 12 Layout

### 12.1 Layout Guidelines

To ensure reliability of the device, following common printed-circuit-board layout guidelines is recommended.

- Bypass capacitors should be used on power supplies.
- Short trace lengths should be used to avoid excessive loading.
- Placing pads on the signal paths for loading capacitors or pullup resistors to help adjust rise and fall times of signals depending on the system requirements.

## 12.2 Layout Example

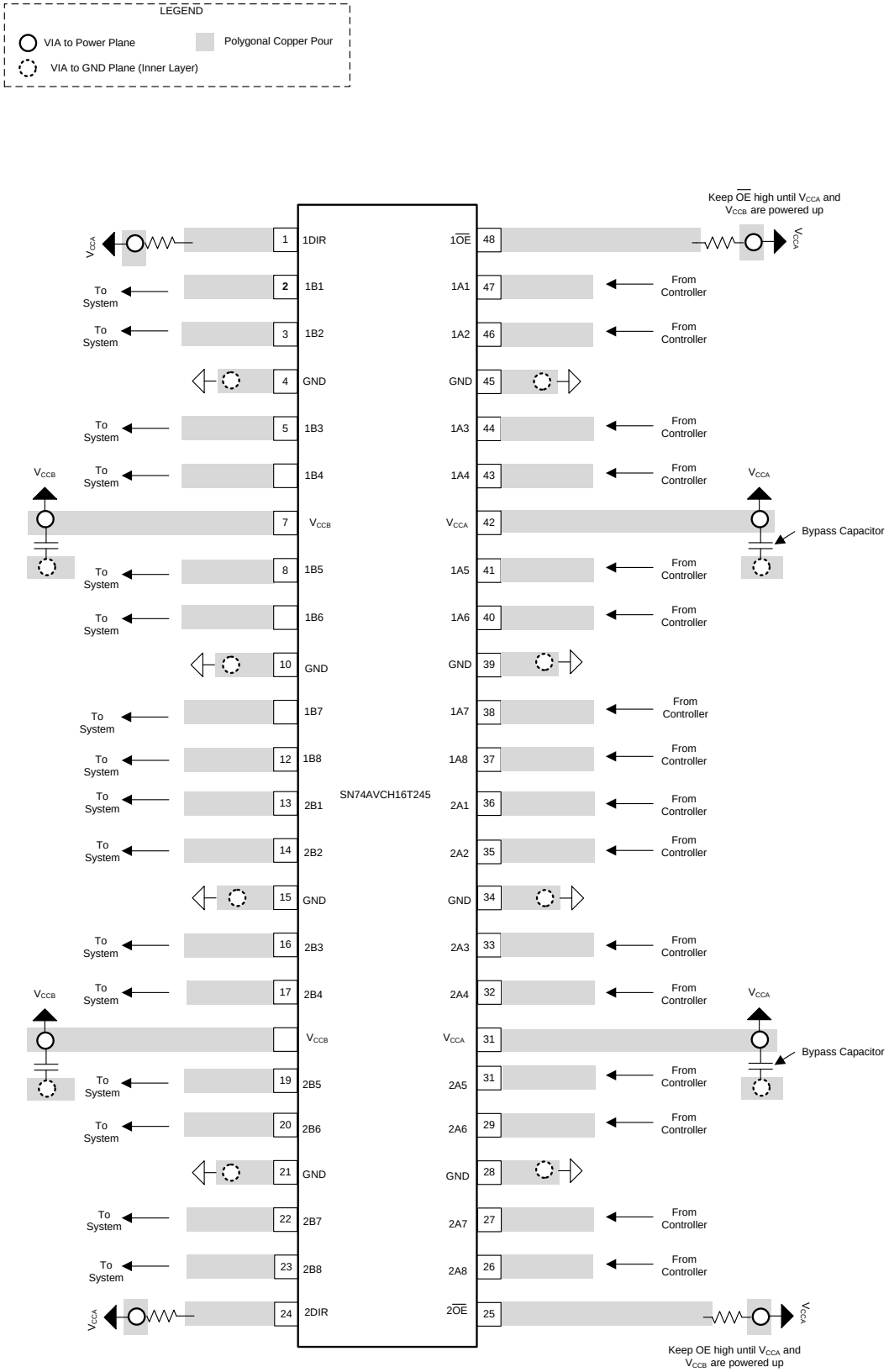



**Figure 6. SN74LVC16T245 Layout Example**

# 13 Device and Documentation Support

## 13.1 Documentation Support

### 13.1.1 Related Documentation

For related documentation see the following:

- *CMOS Power Consumption and Cpd Calculation*, SCAA035
- *Implications of Slow or Floating CMOS Inputs*, SCBA004

## 13.2 Trademarks

All trademarks are the property of their respective owners.

## 13.3 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.

## 13.4 Glossary

SLYZ022 — *TI Glossary*.

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

# 14 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 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 74LVC16T245DGGRE4 | ACTIVE | TSSOP | DGG | 48 | 2000 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM | -40 to 85 | LVC16T245 | Samples |
| 74LVC16T245DGGRG4 | ACTIVE | TSSOP | DGG | 48 | 2000 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM | -40 to 85 | LVC16T245 | Samples |
| 74LVC16T245DGVRG4 | ACTIVE | TVSOP | DGV | 48 | 2000 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM | -40 to 85 | LDT245 | Samples |
| SN74LVC16T245DGGR | ACTIVE | TSSOP | DGG | 48 | 2000 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM | -40 to 85 | LVC16T245 | Samples |
| SN74LVC16T245DGVR | ACTIVE | TVSOP | DGV | 48 | 2000 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM | -40 to 85 | LDT245 | Samples |
| SN74LVC16T245DGVRG | ACTIVE | TVSOP | DGV | 48 | | TBD | Call TI | Call TI | -40 to 85 | | Samples |
| SN74LVC16T245DL | ACTIVE | SSOP | DL | 48 | 25 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM | -40 to 85 | LVC16T245 | Samples |
| SN74LVC16T245DLG4 | ACTIVE | SSOP | DL | 48 | 25 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM | -40 to 85 | LVC16T245 | Samples |
| SN74LVC16T245DLR | ACTIVE | SSOP | DL | 48 | 1000 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM | -40 to 85 | LVC16T245 | Samples |
| SN74LVC16T245GQLR | ACTIVE | BGA MICROSTAR JUNIOR | GQL | 56 | 1000 | TBD | SNPB | Level-1-240C-UNLIM | -40 to 85 | LDT245 | Samples |
| SN74LVC16T245ZQLR | ACTIVE | BGA MICROSTAR JUNIOR | ZQL | 56 | 1000 | Green (RoHS & no Sb/Br) | SNAGCU | Level-1-260C-UNLIM | -40 to 85 | NK245 | 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.
**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) Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check http://www.ti.com/productcontent for the latest availability information and additional product content details.
**TBD:** The Pb-Free/Green conversion plan has not been defined.

**Pb-Free (RoHS):** TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.
**Pb-Free (RoHS Exempt):** This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.
**Green (RoHS & no Sb/Br):** TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

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



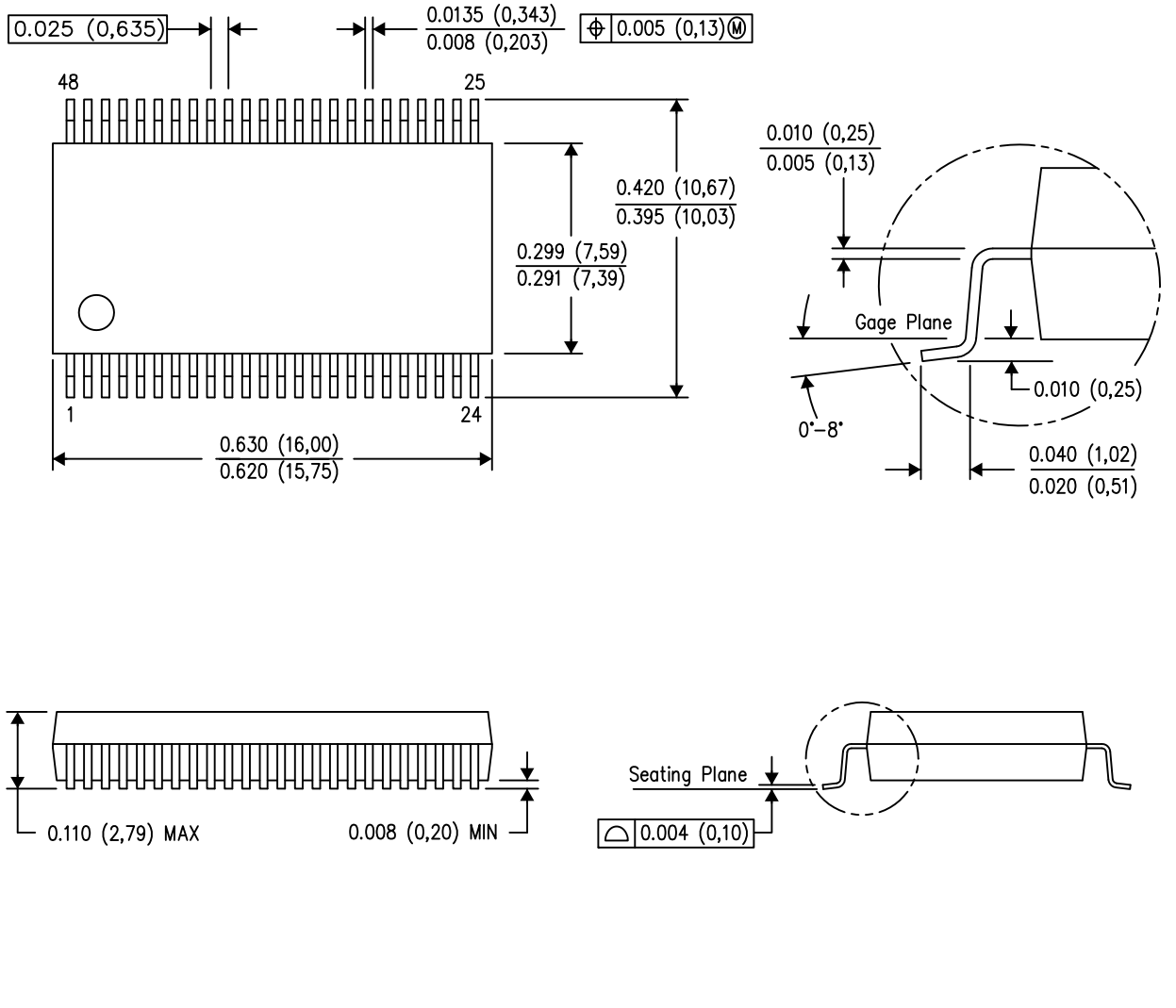
**OTHER QUALIFIED VERSIONS OF SN74LVC16T245 :**

- Enhanced Product: SN74LVC16T245-EP

NOTE: Qualified Version Definitions:

- Enhanced Product - Supports Defense, Aerospace and Medical Applications

DL (R–PDSO–G48) PLASTIC SMALL–OUTLINE PACKAGE

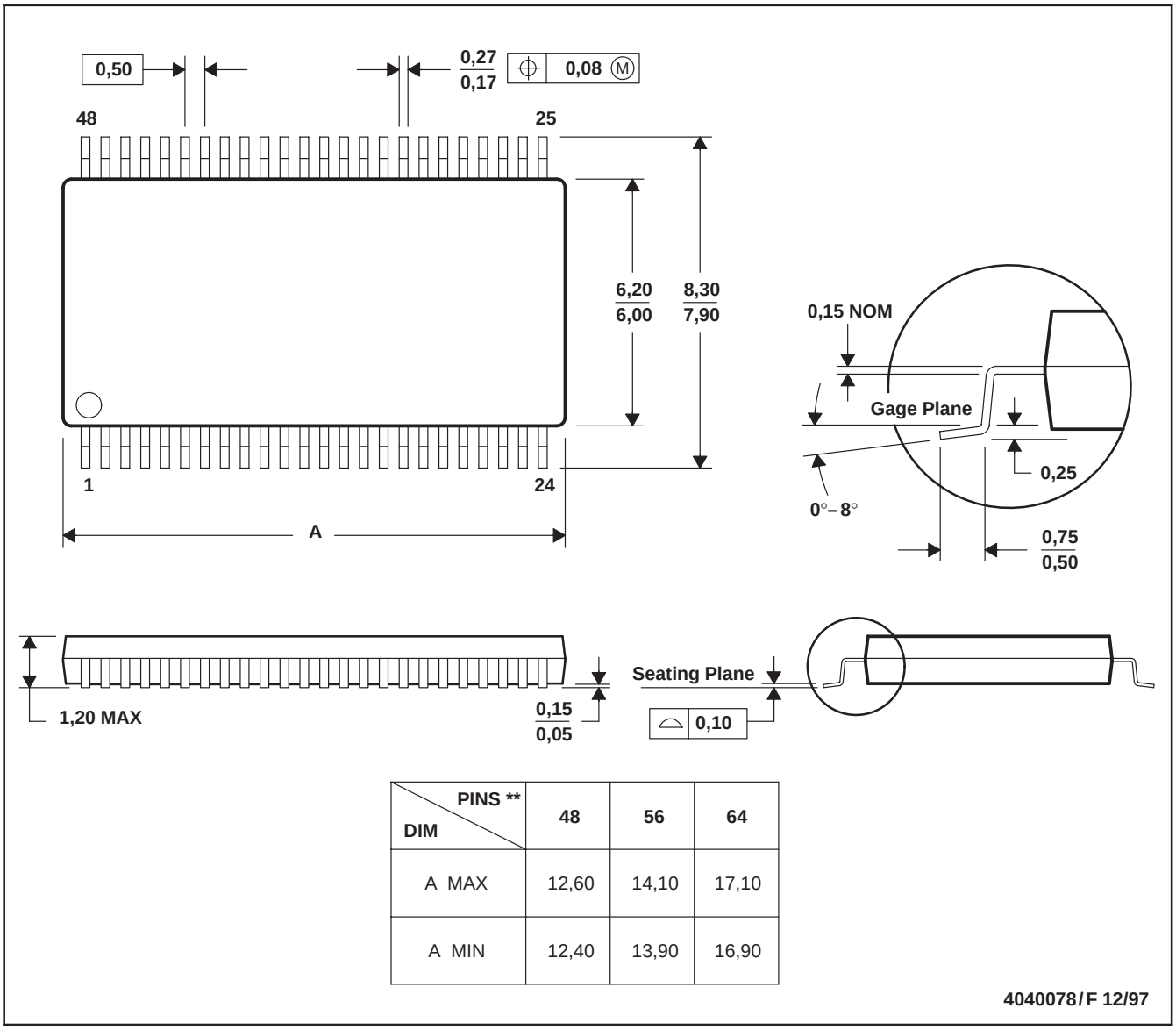



NOTES:
A. All linear dimensions are in inches (millimeters).
B. This drawing is subject to change without notice.
C. Body dimensions do not include mold flash or protrusion not to exceed 0.006 (0,15).
D. Falls within JEDEC MO–118

PowerPAD is a trademark of Texas Instruments.

**DGG (R-PDSO-G**)** **PLASTIC SMALL-OUTLINE PACKAGE**

**48 PINS SHOWN**




| DIM \ PINS ** | 48 | 56 | 64 |
|---|---|---|---|
| A MAX | 12,60 | 14,10 | 17,10 |
| A MIN | 12,40 | 13,90 | 16,90 |

NOTES: A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Body dimensions do not include mold protrusion not to exceed 0,15.
D. Falls within JEDEC MO-153

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