

# 24-Bit Dual-Supply Bus Transceiver with Configurable Voltage Translation And 3-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, All Outputs Are in the High-Impedance State
- Overvoltage-Tolerant Inputs/Outputs Allow Mixed-Voltage-Mode Data Communications
- Fully Configurable Dual-Rail Design Allows Each Port to Operate Over Full 1.2-V to 3.6-V Power-Supply Range
- $I_{off}$  Supports Partial-Power-Down Mode Operation
- I/Os Are 4.6-V Tolerant
- Max Data Rates
  - 380 Mbps (1.8-V to 3.3-V Translation)
  - 200 Mbps (<1.8-V to 3.3-V Translation)
  - 200 Mbps (Translate to 2.5 V or 1.8 V)
  - 150 Mbps (Translate to 1.5 V)
  - 100 Mbps (Translate to 1.2 V)
- Latch-Up Performance Exceeds 100 mA Per JESD 78, Class II
- ESD Protection Exceeds JESD 22
  - 8000-V Human-Body Model (A114-A)
  - 200-V Machine Model (A115-A)
  - 1000-V Charged-Device Model (C101)

## 2 Applications

- Personal Electronics
- Industrial
- Enterprise
- Telecom

## 3 Description

This 24-bit noninverting bus transceiver uses two separate configurable power-supply rails. The SN74AVC24T245 is optimized to operate with  $V_{CCA}/V_{CCB}$  set at 1.4 V to 3.6 V. It is operational with  $V_{CCA}/V_{CCB}$  as low as 1.2 V. The A port is designed to track  $V_{CCA}$ .  $V_{CCA}$  accepts any supply voltage from 1.2 V to 3.6 V. The B port is designed to track  $V_{CCB}$ .  $V_{CCB}$  accepts any supply voltage from 1.2 V to 3.6 V. This allows for universal low-voltage bidirectional translation between any of the 1.2-V, 1.5-V, 1.8-V, 2.5-V, and 3.3-V voltage nodes.

The SN74AVC24T245 is designed for asynchronous communication between data buses. The device transmits data from the A bus to the B bus or from the B bus to the A bus, depending on the logic level at the

direction-control (DIR) input. The output-enable ( $\overline{OE}$ ) input can be used to disable the outputs so the buses are effectively isolated.

The SN74AVC24T245 is designed so that the control pins (1DIR, 2DIR, 3DIR, 4DIR, 5DIR, 6DIR, 1  $\overline{OE}$ , 2  $\overline{OE}$ , 3  $\overline{OE}$ , 4  $\overline{OE}$ , 5  $\overline{OE}$ , and 6  $\overline{OE}$ ) 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.

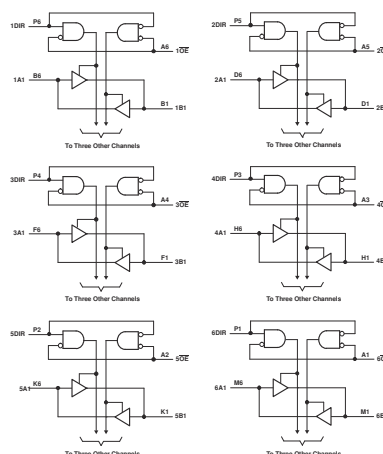
The  $V_{CC}$  isolation feature ensures that if either  $V_{CC}$  input is at GND, then both ports are in the high-impedance state.

To ensure the high-impedance state during power up or power down,  $\overline{OE}$  should be tied to  $V_{CCA}$  through a pullup resistor; the minimum value of the resistor is determined by the current-sinking capability of the driver.

### Device Information

| PART NUMBER          | PACKAGE <sup>(1)</sup> | BODY SIZE (NOM)    |
|----------------------|------------------------|--------------------|
| SN74AVC24T245GRG/ZRG | LFBGA                  | 10.00 mm × 4.50 mm |
| SN74AVC24T245NMU     | nFBGA                  | 10.00 mm × 4.50 mm |

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



**Figure 3-1. Logic Diagram**



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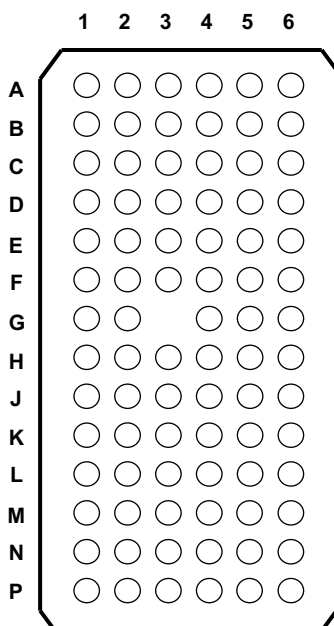
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## 4 Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

| <b>Changes from Revision D (August 2005) to Revision E (August 2020)</b>              | <b>Page</b> |
|---------------------------------------------------------------------------------------|-------------|
| • Updated document to current TI data sheet format.....                               | 1           |
| • Removed Ordering Information table.....                                             | 1           |
| • Added Applications list, Device Information table.....                              | 1           |
| • Added NMU package option to Device Information table.....                           | 1           |
| • Added NMU package to pinout drawing.....                                            | 3           |
| • Added <a href="#">ESD Ratings</a> table.....                                        | 6           |
| • Added <a href="#">Thermal Information</a> table.....                                | 8           |
| • Added NMU package to <a href="#">Thermal Information</a> table.....                 | 8           |
| • Added <a href="#">Typical Characteristics</a> section.....                          | 13          |
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## 5 Pin Configuration and Functions



**Figure 5-1. GRG/ZRG, NMU Package 83-Pin LFBGA, nFBGA Top View**

**Table 5-1. Pin Assignments**

|          | 1                        | 2                        | 3                        | 4                        | 5                        | 6                        |
|----------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|
| <b>A</b> | 6 $\overline{\text{OE}}$ | 5 $\overline{\text{OE}}$ | 4 $\overline{\text{OE}}$ | 3 $\overline{\text{OE}}$ | 2 $\overline{\text{OE}}$ | 1 $\overline{\text{OE}}$ |
| <b>B</b> | 1B1                      | 1B2                      | $\text{V}_{\text{CCB}}$  | $\text{V}_{\text{CCA}}$  | 1A2                      | 1A1                      |
| <b>C</b> | 1B3                      | 1B4                      | GND                      | GND                      | 1A4                      | 1A3                      |
| <b>D</b> | 2B1                      | 2B2                      | $\text{V}_{\text{CCB}}$  | $\text{V}_{\text{CCA}}$  | 2A2                      | 2A1                      |
| <b>E</b> | 2B3                      | 2B4                      | GND                      | GND                      | 2A4                      | 2A3                      |
| <b>F</b> | 3B1                      | 3B2                      | GND                      | GND                      | 3A2                      | 3A1                      |
| <b>G</b> | 3B3                      | 3B4                      |                          | GND                      | 3A4                      | 3A3                      |
| <b>H</b> | 4B1                      | 4B2                      | $\text{V}_{\text{CCB}}$  | $\text{V}_{\text{CCA}}$  | 4A2                      | 4A1                      |
| <b>J</b> | 4B3                      | 4B4                      | GND                      | GND                      | 4A4                      | 4A3                      |
| <b>K</b> | 5B1                      | 5B2                      | GND                      | GND                      | 5A2                      | 5A1                      |
| <b>L</b> | 5B3                      | 5B4                      | $\text{V}_{\text{CCB}}$  | $\text{V}_{\text{CCA}}$  | 5A4                      | 5A3                      |
| <b>M</b> | 6B1                      | 6B2                      | GND                      | GND                      | 6A2                      | 6A1                      |
| <b>N</b> | 6B3                      | 6B4                      | $\text{V}_{\text{CCB}}$  | $\text{V}_{\text{CCA}}$  | 6A4                      | 6A3                      |
| <b>P</b> | 6DIR                     | 5DIR                     | 4DIR                     | 3DIR                     | 2DIR                     | 1DIR                     |

**Table 5-2. Pin Functions**

| PIN |                          | I/O   | DESCRIPTION                                                                                                                                     |
|-----|--------------------------|-------|-------------------------------------------------------------------------------------------------------------------------------------------------|
| NO. | NAME                     |       |                                                                                                                                                 |
| A1  | 6 $\overline{\text{OE}}$ | Input | Tri-State output-mode enables. Pull $\overline{\text{OE}}$ high to place all outputs in Tri-State mode. Referenced to $\text{V}_{\text{CCA}}$ . |
| A2  | 5 $\overline{\text{OE}}$ | Input | Tri-State output-mode enables. Pull $\overline{\text{OE}}$ high to place all outputs in Tri-State mode. Referenced to $\text{V}_{\text{CCA}}$ . |
| A3  | 4 $\overline{\text{OE}}$ | Input | Tri-State output-mode enables. Pull $\overline{\text{OE}}$ high to place all outputs in Tri-State mode. Referenced to $\text{V}_{\text{CCA}}$ . |
| A4  | 3 $\overline{\text{OE}}$ | Input | Tri-State output-mode enables. Pull $\overline{\text{OE}}$ high to place all outputs in Tri-State mode. Referenced to $\text{V}_{\text{CCA}}$ . |

**Table 5-2. Pin Functions (continued)**

| PIN |                   | I/O          | DESCRIPTION                                                                                                                |
|-----|-------------------|--------------|----------------------------------------------------------------------------------------------------------------------------|
| NO. | NAME              |              |                                                                                                                            |
| A5  | 2 $\overline{OE}$ | Input        | Tri-State output-mode enables. Pull $\overline{OE}$ high to place all outputs in Tri-State mode. Referenced to $V_{CCA}$ . |
| A6  | 1 $\overline{OE}$ | Input        | Tri-State output-mode enables. Pull $\overline{OE}$ high to place all outputs in Tri-State mode. Referenced to $V_{CCA}$ . |
| B1  | 1B1               | Input/Output | Referenced to $V_{CCB}$ .                                                                                                  |
| B2  | 1B2               | Input/Output | Referenced to $V_{CCB}$ .                                                                                                  |
| B3  | $V_{CCB}$         | —            | B-port supply voltage. $1.2\text{ V} \leq V_{CCB} \leq 3.6\text{ V}$ .                                                     |
| B4  | $V_{CCA}$         | —            | A-port supply voltage. $1.2\text{ V} \leq V_{CCA} \leq 3.6\text{ V}$ .                                                     |
| B5  | 1A2               | Input/Output | Referenced to $V_{CCA}$ .                                                                                                  |
| B6  | 1A1               | Input/Output | Referenced to $V_{CCA}$ .                                                                                                  |
| C1  | 1B3               | Input/Output | Referenced to $V_{CCB}$ .                                                                                                  |
| C2  | 1B4               | Input/Output | Referenced to $V_{CCB}$ .                                                                                                  |
| C3  | GND               | —            | Ground.                                                                                                                    |
| C4  | GND               | —            | Ground.                                                                                                                    |
| C5  | 1A4               | Input/Output | Referenced to $V_{CCA}$ .                                                                                                  |
| C6  | 1A3               | Input/Output | Referenced to $V_{CCA}$ .                                                                                                  |
| D1  | 2B1               | Input/Output | Referenced to $V_{CCB}$ .                                                                                                  |
| D2  | 2B2               | Input/Output | Referenced to $V_{CCB}$ .                                                                                                  |
| D3  | $V_{CCB}$         | —            | B-port supply voltage. $1.2\text{ V} \leq V_{CCB} \leq 3.6\text{ V}$ .                                                     |
| D4  | $V_{CCA}$         | —            | A-port supply voltage. $1.2\text{ V} \leq V_{CCA} \leq 3.6\text{ V}$ .                                                     |
| D5  | 2A2               | Input/Output | Referenced to $V_{CCA}$ .                                                                                                  |
| D6  | 2A1               | Input/Output | Referenced to $V_{CCA}$ .                                                                                                  |
| E1  | 2B3               | Input/Output | Referenced to $V_{CCB}$ .                                                                                                  |
| E2  | 2B4               | Input/Output | Referenced to $V_{CCB}$ .                                                                                                  |
| E3  | GND               | —            | Ground.                                                                                                                    |
| E4  | GND               | —            | Ground.                                                                                                                    |
| E5  | 2A4               | Input/Output | Referenced to $V_{CCA}$ .                                                                                                  |
| E6  | 2A3               | Input/Output | Referenced to $V_{CCA}$ .                                                                                                  |
| F1  | 3B1               | Input/Output | Referenced to $V_{CCB}$ .                                                                                                  |
| F2  | 3B2               | Input/Output | Referenced to $V_{CCB}$ .                                                                                                  |
| F3  | GND               | —            | Ground.                                                                                                                    |
| F4  | GND               | —            | Ground.                                                                                                                    |
| F5  | 3A2               | Input/Output | Referenced to $V_{CCA}$ .                                                                                                  |
| F6  | 3A1               | Input/Output | Referenced to $V_{CCA}$ .                                                                                                  |
| G1  | 3B3               | Input/Output | Referenced to $V_{CCB}$ .                                                                                                  |
| G2  | 3B4               | Input/Output | Referenced to $V_{CCB}$ .                                                                                                  |
| G4  | GND               | —            | Ground.                                                                                                                    |
| G5  | 3A4               | Input/Output | Referenced to $V_{CCA}$ .                                                                                                  |
| G6  | 3A3               | Input/Output | Referenced to $V_{CCA}$ .                                                                                                  |
| H1  | 4B1               | Input/Output | Referenced to $V_{CCB}$ .                                                                                                  |
| H2  | 4B2               | Input/Output | Referenced to $V_{CCB}$ .                                                                                                  |
| H3  | $V_{CCB}$         | —            | B-port supply voltage. $1.2\text{ V} \leq V_{CCB} \leq 3.6\text{ V}$ .                                                     |
| H4  | $V_{CCA}$         | —            | A-port supply voltage. $1.2\text{ V} \leq V_{CCA} \leq 3.6\text{ V}$ .                                                     |
| H5  | 4A2               | Input/Output | Referenced to $V_{CCA}$ .                                                                                                  |
| H6  | 4A1               | Input/Output | Referenced to $V_{CCA}$ .                                                                                                  |

**Table 5-2. Pin Functions (continued)**

| PIN |           | I/O          | DESCRIPTION                                                            |
|-----|-----------|--------------|------------------------------------------------------------------------|
| NO. | NAME      |              |                                                                        |
| J1  | 4B3       | Input/Output | Referenced to $V_{CCB}$ .                                              |
| J2  | 4B4       | Input/Output | Referenced to $V_{CCB}$ .                                              |
| J3  | GND       | —            | Ground.                                                                |
| J4  | GND       | —            | Ground.                                                                |
| J5  | 4A4       | Input/Output | Referenced to $V_{CCA}$ .                                              |
| J6  | 4A3       | Input/Output | Referenced to $V_{CCA}$ .                                              |
| K1  | 5B1       | Input/Output | Referenced to $V_{CCB}$ .                                              |
| K2  | 5B2       | Input/Output | Referenced to $V_{CCB}$ .                                              |
| K3  | GND       | —            | Ground.                                                                |
| K4  | GND       | —            | Ground.                                                                |
| K5  | 5A2       | Input/Output | Referenced to $V_{CCA}$ .                                              |
| K6  | 5A1       | Input/Output | Referenced to $V_{CCA}$ .                                              |
| L1  | 5B3       | Input/Output | Referenced to $V_{CCB}$ .                                              |
| L2  | 5B4       | Input/Output | Referenced to $V_{CCB}$ .                                              |
| L3  | $V_{CCB}$ | —            | B-port supply voltage. $1.2\text{ V} \leq V_{CCB} \leq 3.6\text{ V}$ . |
| L4  | $V_{CCA}$ | —            | A-port supply voltage. $1.2\text{ V} \leq V_{CCA} \leq 3.6\text{ V}$ . |
| L5  | 5A4       | Input/Output | Referenced to $V_{CCA}$ .                                              |
| L6  | 5A3       | Input/Output | Referenced to $V_{CCA}$ .                                              |
| M1  | 6B1       | Input/Output | Referenced to $V_{CCB}$ .                                              |
| M2  | 6B2       | Input/Output | Referenced to $V_{CCB}$ .                                              |
| M3  | GND       | —            | Ground.                                                                |
| M4  | GND       | —            | Ground.                                                                |
| M5  | 6A2       | Input/Output | Referenced to $V_{CCA}$ .                                              |
| M6  | 6A1       | Input/Output | Referenced to $V_{CCA}$ .                                              |
| N1  | 6B3       | Input/Output | Referenced to $V_{CCB}$ .                                              |
| N2  | 6B4       | Input/Output | Referenced to $V_{CCB}$ .                                              |
| N3  | $V_{CCB}$ | —            | B-port supply voltage. $1.2\text{ V} \leq V_{CCB} \leq 3.6\text{ V}$ . |
| N4  | $V_{CCA}$ | —            | A-port supply voltage. $1.2\text{ V} \leq V_{CCA} \leq 3.6\text{ V}$ . |
| N5  | 6A4       | Input/Output | Referenced to $V_{CCA}$ .                                              |
| N6  | 6A3       | Input/Output | Referenced to $V_{CCA}$ .                                              |
| P1  | 6DIR      | Input        | Direction-control signal. Referenced to $V_{CCA}$ .                    |
| P2  | 5DIR      | Input        | Direction-control signal. Referenced to $V_{CCA}$ .                    |
| P3  | 4DIR      | Input        | Direction-control signal. Referenced to $V_{CCA}$ .                    |
| P4  | 3DIR      | Input        | Direction-control signal. Referenced to $V_{CCA}$ .                    |
| P5  | 2DIR      | Input        | Direction-control signal. Referenced to $V_{CCA}$ .                    |
| P6  | 1DIR      | Input        | Direction-control signal. Referenced to $V_{CCA}$ .                    |

## 6 Specifications

### 6.1 Absolute Maximum Ratings

over operating free-air temperature range (unless otherwise noted)<sup>(1)</sup>

|                        |                                                                                             | MIN                | MAX  | UNIT            |
|------------------------|---------------------------------------------------------------------------------------------|--------------------|------|-----------------|
| $V_{CCA}$<br>$V_{CCB}$ | Supply voltage range                                                                        | –0.5               | 4.6  | V               |
| $V_I$                  | Input voltage range <sup>(2)</sup>                                                          | I/O ports (A port) | –0.5 | 4.6             |
|                        |                                                                                             | I/O ports (B port) | –0.5 | 4.6             |
|                        |                                                                                             | Control inputs     | –0.5 | 4.6             |
| $V_O$                  | Voltage range applied to any output in the high-impedance or power-off state <sup>(2)</sup> | A port             | –0.5 | 4.6             |
|                        |                                                                                             | B port             | –0.5 | 4.6             |
| $V_O$                  | Voltage range applied to any output in the high or low state <sup>(2) (3)</sup>             | A port             | –0.5 | $V_{CCA} + 0.5$ |
|                        |                                                                                             | 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              |
| $T_{stg}$              | Storage temperature range                                                                   | –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) The input voltage and output 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 4.6-V maximum if the output current rating is observed.

### 6.2 ESD Ratings

|             |                         | VALUE                                                                        | UNIT  |
|-------------|-------------------------|------------------------------------------------------------------------------|-------|
| $V_{(ESD)}$ | Electrostatic discharge | Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001 <sup>1</sup>              | ±8000 |
|             |                         | Charged-device model (CDM), per JEDEC specification JESD22-C101 <sup>2</sup> | ±1000 |

### 6.3 Recommended Operating Conditions

| (1) (2) (3)      |                                    |                                                         | V <sub>CCI</sub> | V <sub>CCO</sub> | MIN                     | MAX              | UNIT |
|------------------|------------------------------------|---------------------------------------------------------|------------------|------------------|-------------------------|------------------|------|
| V <sub>CCA</sub> | Supply voltage                     |                                                         |                  |                  | 1.2                     | 3.6              | V    |
| V <sub>CCB</sub> | Supply voltage                     |                                                         |                  |                  | 1.2                     | 3.6              | V    |
| V <sub>IH</sub>  | High-level input voltage           | Data inputs <sup>(4)</sup>                              | 1.2 V to 1.95 V  |                  | V <sub>CCI</sub> × 0.65 |                  | V    |
|                  |                                    |                                                         | 1.95 V to 2.7 V  |                  | 1.6                     |                  |      |
|                  |                                    |                                                         | 2.7 V to 3.6 V   |                  | 2                       |                  |      |
| V <sub>IL</sub>  | Low-level input voltage            | Data inputs <sup>(4)</sup>                              | 1.2 V to 1.95 V  |                  | V <sub>CCI</sub> × 0.35 |                  | V    |
|                  |                                    |                                                         | 1.95 V to 2.7 V  |                  | 0.7                     |                  |      |
|                  |                                    |                                                         | 2.7 V to 3.6 V   |                  | 0.8                     |                  |      |
| V <sub>IH</sub>  | High-level input voltage           | DIR<br>(referenced to V <sub>CCA</sub> ) <sup>(5)</sup> | 1.2 V to 1.95 V  |                  | V <sub>CCA</sub> × 0.65 |                  | V    |
|                  |                                    |                                                         | 1.95 V to 2.7 V  |                  | 1.6                     |                  |      |
|                  |                                    |                                                         | 2.7 V to 3.6 V   |                  | 2                       |                  |      |
| V <sub>IL</sub>  | Low-level input voltage            | DIR<br>(referenced to V <sub>CCA</sub> ) <sup>(5)</sup> | 1.2 V to 1.95 V  |                  | V <sub>CCA</sub> × 0.35 |                  | V    |
|                  |                                    |                                                         | 1.95 V to 2.7 V  |                  | 0.7                     |                  |      |
|                  |                                    |                                                         | 2.7 V to 3.6 V   |                  | 0.8                     |                  |      |
| V <sub>I</sub>   | Input voltage                      |                                                         |                  |                  | 0                       | 3.6              | V    |
| V <sub>O</sub>   | Output voltage                     | Active state                                            |                  |                  | 0                       | V <sub>CCO</sub> | V    |
|                  |                                    | 3-state                                                 |                  |                  | 0                       | 3.6              |      |
| I <sub>OH</sub>  | High-level output current          |                                                         |                  | 1.2 V            |                         | –3               | mA   |
|                  |                                    |                                                         |                  | 1.4 V to 1.6 V   |                         | –6               |      |
|                  |                                    |                                                         |                  | 1.65 V to 1.95 V |                         | –8               |      |
|                  |                                    |                                                         |                  | 2.3 V to 2.7 V   |                         | –9               |      |
|                  |                                    |                                                         |                  | 3 V to 3.6 V     |                         | –12              |      |
| I <sub>OL</sub>  | Low-level output current           |                                                         |                  | 1.2 V            |                         | 3                | mA   |
|                  |                                    |                                                         |                  | 1.4 V to 1.6 V   |                         | 6                |      |
|                  |                                    |                                                         |                  | 1.65 V to 1.95 V |                         | 8                |      |
|                  |                                    |                                                         |                  | 2.3 V to 2.7 V   |                         | 9                |      |
|                  |                                    |                                                         |                  | 3 V to 3.6 V     |                         | 12               |      |
| Δt/Δv            | Input transition rise or fall rate |                                                         |                  |                  |                         | 5                | ns/V |
| T <sub>A</sub>   | Operating free-air temperature     |                                                         |                  |                  | –40                     | 85               | °C   |

(1) V<sub>CCI</sub> is the V<sub>CC</sub> associated with the data input port.

(2) V<sub>CCO</sub> is the V<sub>CC</sub> associated with the output port.

(3) All unused data inputs of the device must be held at V<sub>CCI</sub> or GND to ensure proper device operation. Refer to the TI application report, *Implications of Slow or Floating CMOS Inputs*, literature number SCBA004.

(4) For V<sub>CCI</sub> values not specified in the data sheet, V<sub>IH</sub> min = V<sub>CCI</sub> × 0.7 V, V<sub>IL</sub> max = V<sub>CCI</sub> × 0.3 V.

(5) For V<sub>CCI</sub> values not specified in the data sheet, V<sub>IH</sub> min = V<sub>CCA</sub> × 0.7 V, V<sub>IL</sub> max = V<sub>CCA</sub> × 0.3 V.

## 6.4 Thermal Information

| THERMAL METRIC <sup>(1)</sup> |                                              | SN74AVC24T245 |      |      | UNIT |
|-------------------------------|----------------------------------------------|---------------|------|------|------|
|                               |                                              | GRG           | ZRG  | NMU  |      |
|                               |                                              | 83            | 83   | 83   |      |
| $R_{\theta JA}$               | Junction-to-ambient thermal resistance       | 38.1          | 38.1 | 44.3 | °C/W |
| $R_{\theta JC(top)}$          | Junction-to-case (top) thermal resistance    | 22.8          | 22.8 | 24.5 | °C/W |
| $R_{\theta JB}$               | Junction-to-board thermal resistance         | 17.0          | 17.0 | 29.1 | °C/W |
| $\Psi_{JT}$                   | Junction-to-top characterization parameter   | 0.44          | 0.44 | 0.5  | °C/W |
| $\Psi_{JB}$                   | Junction-to-board characterization parameter | 16.9          | 16.9 | 29.2 | °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

over recommended operating free-air temperature range (unless otherwise noted)<sup>(2) (3)</sup>

| PARAMETER                           | TEST CONDITIONS           | V <sub>CCA</sub>                                                                                                                   | V <sub>CCB</sub> | T <sub>A</sub> = 25°C |     |        | –40°C to 85°C          |      | UNIT  |
|-------------------------------------|---------------------------|------------------------------------------------------------------------------------------------------------------------------------|------------------|-----------------------|-----|--------|------------------------|------|-------|
|                                     |                           |                                                                                                                                    |                  | MIN                   | TYP | MAX    | MIN                    | MAX  |       |
| V <sub>OH</sub>                     | I <sub>OH</sub> = –100 µA | V <sub>I</sub> = V <sub>IH</sub>                                                                                                   | 1.2 V to 3.6 V   | 1.2 V to 3.6 V        |     |        | V <sub>CCO</sub> – 0.2 |      | V     |
|                                     | I <sub>OH</sub> = –3 mA   |                                                                                                                                    | 1.2 V            | 1.2 V                 |     | 0.95   |                        |      |       |
|                                     | I <sub>OH</sub> = –6 mA   |                                                                                                                                    | 1.4 V            | 1.4 V                 |     |        | 1.05                   |      |       |
|                                     | I <sub>OH</sub> = –8 mA   |                                                                                                                                    | 1.65 V           | 1.65 V                |     |        | 1.2                    |      |       |
|                                     | I <sub>OH</sub> = –9 mA   |                                                                                                                                    | 2.3 V            | 2.3 V                 |     |        | 1.75                   |      |       |
|                                     | I <sub>OH</sub> = –12 m   |                                                                                                                                    | 3 V              | 3 V                   |     |        | 2.3                    |      |       |
| V <sub>OL</sub>                     | I <sub>OL</sub> = 100 µA  | V <sub>I</sub> = V <sub>IL</sub>                                                                                                   | 1.2 V to 3.6 V   | 1.2 V to 3.6 V        |     |        |                        | 0.2  | V     |
|                                     | I <sub>OL</sub> = 3 mA    |                                                                                                                                    | 1.2 V            | 1.2 V                 |     | 0.15   |                        |      |       |
|                                     | I <sub>OL</sub> = 6 mA    |                                                                                                                                    | 1.4 V            | 1.4 V                 |     |        |                        | 0.35 |       |
|                                     | I <sub>OL</sub> = 8 mA    |                                                                                                                                    | 1.65 V           | 1.65 V                |     |        |                        | 0.45 |       |
|                                     | I <sub>OL</sub> = 9 mA    |                                                                                                                                    | 2.3 V            | 2.3 V                 |     |        |                        | 0.55 |       |
|                                     | I <sub>OL</sub> = 12 mA   |                                                                                                                                    | 3 V              | 3 V                   |     |        |                        | 0.7  |       |
| I <sub>I</sub>                      | Control inputs            | V <sub>I</sub> = V <sub>CCA</sub> or GND                                                                                           | 1.2 V to 3.6 V   | 1.2 V to 3.6 V        |     | ±0.025 | ±0.25                  |      | ±1 µA |
| I <sub>off</sub>                    | A or B port               | V <sub>I</sub> or V <sub>O</sub> = 0 to 3.6 V                                                                                      | 0 V              | 0 to 3.6 V            |     | ±0.1   | ±2.5                   |      | µA    |
|                                     | A or B port               |                                                                                                                                    | 0 to 3.6 V       | 0 V                   |     | ±0.1   | ±2.5                   |      |       |
| I <sub>OZ</sub> <sup>(1)</sup>      | A or B port               | V <sub>O</sub> = V <sub>CCO</sub> or GND,<br>V <sub>I</sub> = V <sub>CCI</sub> or GND,<br>$\overline{\text{OE}}$ = V <sub>IH</sub> | 3.6 V            | 3.6 V                 |     | ±0.5   | ±2.5                   |      | ±5 µA |
| I <sub>CCA</sub>                    |                           | V <sub>I</sub> = V <sub>CCI</sub> or GND,<br>I <sub>O</sub> = 0                                                                    | 1.2 V to 3.6 V   | 1.2 V to 3.6 V        |     |        |                        | 40   | µA    |
|                                     |                           |                                                                                                                                    | 0 V              | 3.6 V                 |     |        |                        | –5   |       |
|                                     |                           |                                                                                                                                    | 3.6 V            | 0 V                   |     |        |                        | 40   |       |
| I <sub>CCB</sub>                    |                           | V <sub>I</sub> = V <sub>CCI</sub> or GND,<br>I <sub>O</sub> = 0                                                                    | 1.2 V to 3.6 V   | 1.2 V to 3.6 V        |     |        |                        | 40   | µA    |
|                                     |                           |                                                                                                                                    | 0 V              | 3.6 V                 |     |        |                        | 40   |       |
|                                     |                           |                                                                                                                                    | 3.6 V            | 0 V                   |     |        |                        | –5   |       |
| I <sub>CCA</sub> + I <sub>CCB</sub> |                           | V <sub>I</sub> = V <sub>CCI</sub> or GND,<br>I <sub>O</sub> = 0                                                                    | 1.2 V to 3.6 V   | 1.2 V to 3.6 V        |     |        |                        | 75   | µA    |
| C <sub>i</sub>                      | Control inputs            | V <sub>I</sub> = 3.3 V or GND                                                                                                      | 3.3 V            | 3.3 V                 |     | 3.5    |                        |      | pF    |
| C <sub>io</sub>                     | A or B port               | V <sub>O</sub> = 3.3 V or GND                                                                                                      | 3.3 V            | 3.3 V                 |     | 7      |                        |      | pF    |

(1) For I/O ports, the parameter I<sub>OZ</sub> includes the input leakage current.

(2) V<sub>CCO</sub> is the V<sub>CC</sub> associated with the output port.

(3) V<sub>CCI</sub> is the V<sub>CC</sub> associated with the input port.

## 6.6 Switching Characteristics

over recommended operating free-air temperature range,  $V_{CCA} = 1.2\text{ V}$  (see [Figure 7-1](#))

| PARAMETER | FROM<br>(INPUT) | TO<br>(OUTPUT) | $V_{CCB} = 1.2\text{ V}$ | $V_{CCB} = 1.5\text{ V}$ | $V_{CCB} = 1.8\text{ V}$ | $V_{CCB} = 2.5\text{ V}$ | $V_{CCB} = 3.3\text{ V}$ | UNIT |
|-----------|-----------------|----------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|------|
|           |                 |                | TYP                      | TYP                      | TYP                      | TYP                      | TYP                      |      |
| $t_{PLH}$ | A               | B              | 4.1                      | 3.3                      | 3                        | 2.8                      | 3.2                      | ns   |
| $t_{PHL}$ |                 |                | 4.1                      | 3.3                      | 3                        | 2.8                      | 3.2                      |      |
| $t_{PLH}$ | B               | A              | 4.4                      | 4                        | 3.8                      | 3.6                      | 3.5                      | ns   |
| $t_{PHL}$ |                 |                | 4.4                      | 4                        | 3.8                      | 3.6                      | 3.5                      |      |
| $t_{PZH}$ | $\overline{OE}$ | A              | 6.4                      | 6.4                      | 6.4                      | 6.4                      | 6.4                      | ns   |
| $t_{PZL}$ |                 |                | 6.4                      | 6.4                      | 6.4                      | 6.4                      | 6.4                      |      |
| $t_{PZH}$ | $\overline{OE}$ | B              | 6                        | 4.6                      | 4                        | 3.4                      | 3.2                      | ns   |
| $t_{PZL}$ |                 |                | 6                        | 4.6                      | 4                        | 3.4                      | 3.2                      |      |
| $t_{PHZ}$ | $\overline{OE}$ | A              | 6.6                      | 6.6                      | 6.6                      | 6.6                      | 6.8                      | ns   |
| $t_{PLZ}$ |                 |                | 6.6                      | 6.6                      | 6.6                      | 6.6                      | 6.8                      |      |
| $t_{PHZ}$ | $\overline{OE}$ | B              | 6                        | 4.9                      | 4.9                      | 4.2                      | 5.3                      | ns   |
| $t_{PLZ}$ |                 |                | 6                        | 4.9                      | 4.9                      | 4.2                      | 5.3                      |      |

## 6.7 Switching Characteristics

over recommended operating free-air temperature range,  $V_{CCA} = 1.5\text{ V} \pm 0.1\text{ V}$  (see [Figure 7-1](#))

| PARAMETER | FROM<br>(INPUT) | TO<br>(OUTPUT) | $V_{CCB} = 1.2\text{ V}$ | $V_{CCB} = 1.5\text{ V} \pm 0.1\text{ V}$ |      | $V_{CCB} = 1.8\text{ V} \pm 0.15\text{ V}$ |      | $V_{CCB} = 2.5\text{ V} \pm 0.2\text{ V}$ |      | $V_{CCB} = 3.3\text{ V} \pm 0.3\text{ V}$ |      | UNIT |
|-----------|-----------------|----------------|--------------------------|-------------------------------------------|------|--------------------------------------------|------|-------------------------------------------|------|-------------------------------------------|------|------|
|           |                 |                | TYP                      | MIN                                       | MAX  | MIN                                        | MAX  | MIN                                       | MAX  | MIN                                       | MAX  |      |
| $t_{PLH}$ | A               | B              | 3.6                      | 0.5                                       | 6.2  | 0.5                                        | 5.2  | 0.5                                       | 4.1  | 0.5                                       | 3.7  | ns   |
| $t_{PHL}$ |                 |                | 3.6                      | 0.5                                       | 6.2  | 0.5                                        | 5.2  | 0.5                                       | 4.1  | 0.5                                       | 3.7  |      |
| $t_{PLH}$ | B               | A              | 3.3                      | 0.5                                       | 6.2  | 0.5                                        | 5.9  | 0.5                                       | 5.6  | 0.5                                       | 5.5  | ns   |
| $t_{PHL}$ |                 |                | 3.3                      | 0.5                                       | 6.2  | 0.5                                        | 5.9  | 0.5                                       | 5.6  | 0.5                                       | 5.5  |      |
| $t_{PZH}$ | $\overline{OE}$ | A              | 4.3                      | 1                                         | 10.1 | 1                                          | 10.1 | 1                                         | 10.1 | 1                                         | 10.1 | ns   |
| $t_{PZL}$ |                 |                | 4.3                      | 1                                         | 10.1 | 1                                          | 10.1 | 1                                         | 10.1 | 1                                         | 10.1 |      |
| $t_{PZH}$ | $\overline{OE}$ | B              | 5.6                      | 1                                         | 10.1 | 0.5                                        | 8.1  | 0.5                                       | 5.9  | 0.5                                       | 5.2  | ns   |
| $t_{PZL}$ |                 |                | 5.6                      | 1                                         | 10.1 | 0.5                                        | 8.1  | 0.5                                       | 5.9  | 0.5                                       | 5.2  |      |
| $t_{PHZ}$ | $\overline{OE}$ | A              | 4.5                      | 1.5                                       | 9.1  | 1.5                                        | 9.1  | 1.5                                       | 9.1  | 1.5                                       | 9.1  | ns   |
| $t_{PLZ}$ |                 |                | 4.5                      | 1.5                                       | 9.1  | 1.5                                        | 9.1  | 1.5                                       | 9.1  | 1.5                                       | 9.1  |      |
| $t_{PHZ}$ | $\overline{OE}$ | B              | 5.5                      | 1.5                                       | 8.7  | 1.5                                        | 7.5  | 1                                         | 6.5  | 1                                         | 6.3  | ns   |
| $t_{PLZ}$ |                 |                | 5.5                      | 1.5                                       | 8.7  | 1.5                                        | 7.5  | 1                                         | 6.5  | 1                                         | 6.3  |      |

## 6.8 Switching Characteristics

over recommended operating free-air temperature range,  $V_{CCA} = 1.8 \text{ V} \pm 0.15 \text{ V}$  (see [Figure 7-1](#))

| PARAMETER | FROM<br>(INPUT) | TO<br>(OUTPUT) | $V_{CCB} = 1.2 \text{ V}$ | $V_{CCB} = 1.5 \text{ V} \pm 0.1 \text{ V}$ |     | $V_{CCB} = 1.8 \text{ V} \pm 0.15 \text{ V}$ |     | $V_{CCB} = 2.5 \text{ V} \pm 0.2 \text{ V}$ |     | $V_{CCB} = 3.3 \text{ V} \pm 0.3 \text{ V}$ |     | UNIT |
|-----------|-----------------|----------------|---------------------------|---------------------------------------------|-----|----------------------------------------------|-----|---------------------------------------------|-----|---------------------------------------------|-----|------|
|           |                 |                | TYP                       | MIN                                         | MAX | MIN                                          | MAX | MIN                                         | MAX | MIN                                         | MAX |      |
| $t_{PLH}$ | A               | B              | 3.4                       | 0.5                                         | 5.9 | 0.5                                          | 4.8 | 0.5                                         | 3.7 | 0.5                                         | 3.3 | ns   |
| $t_{PHL}$ |                 |                | 3.4                       | 0.5                                         | 5.9 | 0.5                                          | 4.8 | 0.5                                         | 3.7 | 0.5                                         | 3.3 |      |
| $t_{PLH}$ | B               | A              | 3                         | 0.5                                         | 5.2 | 0.5                                          | 4.8 | 0.5                                         | 4.5 | 0.5                                         | 4.4 | ns   |
| $t_{PHL}$ |                 |                | 3                         | 0.5                                         | 5.2 | 0.5                                          | 4.8 | 0.5                                         | 4.5 | 0.5                                         | 4.4 |      |
| $t_{PZH}$ | $\overline{OE}$ | A              | 3.4                       | 1                                           | 7.8 | 1                                            | 7.8 | 1                                           | 7.8 | 1                                           | 7.8 | ns   |
| $t_{PZL}$ |                 |                | 3.4                       | 1                                           | 7.8 | 1                                            | 7.8 | 1                                           | 7.8 | 1                                           | 7.8 |      |
| $t_{PZH}$ | $\overline{OE}$ | B              | 5.4                       | 1                                           | 9.2 | 0.5                                          | 7.4 | 0.5                                         | 5.3 | 0.5                                         | 4.5 | ns   |
| $t_{PZL}$ |                 |                | 5.4                       | 1                                           | 9.2 | 0.5                                          | 7.4 | 0.5                                         | 5.3 | 0.5                                         | 4.5 |      |
| $t_{PHZ}$ | $\overline{OE}$ | A              | 4.2                       | 1.5                                         | 7.7 | 1.5                                          | 7.7 | 1.5                                         | 7.7 | 1.5                                         | 7.7 | ns   |
| $t_{PLZ}$ |                 |                | 4.2                       | 1.5                                         | 7.7 | 1.5                                          | 7.7 | 1.5                                         | 7.7 | 1.5                                         | 7.7 |      |
| $t_{PHZ}$ | $\overline{OE}$ | B              | 5.2                       | 1.5                                         | 8.4 | 1.5                                          | 7.1 | 1                                           | 5.9 | 1                                           | 5.7 | ns   |
| $t_{PLZ}$ |                 |                | 5.2                       | 1.5                                         | 8.4 | 1.5                                          | 7.1 | 1                                           | 5.9 | 1                                           | 5.7 |      |

## 6.9 Switching Characteristics

over recommended operating free-air temperature range,  $V_{CCA} = 2.5 \text{ V} \pm 0.2 \text{ V}$  (see [Figure 7-1](#))

| PARAMETER | FROM<br>(INPUT) | TO<br>(OUTPUT) | $V_{CCB} = 1.2 \text{ V}$ | $V_{CCB} = 1.5 \text{ V} \pm 0.1 \text{ V}$ |     | $V_{CCB} = 1.8 \text{ V} \pm 0.15 \text{ V}$ |     | $V_{CCB} = 2.5 \text{ V} \pm 0.2 \text{ V}$ |     | $V_{CCB} = 3.3 \text{ V} \pm 0.3 \text{ V}$ |     | UNIT |
|-----------|-----------------|----------------|---------------------------|---------------------------------------------|-----|----------------------------------------------|-----|---------------------------------------------|-----|---------------------------------------------|-----|------|
|           |                 |                | TYP                       | MIN                                         | MAX | MIN                                          | MAX | MIN                                         | MAX | MIN                                         | MAX |      |
| $t_{PLH}$ | A               | B              | 3.2                       | 0.5                                         | 5.6 | 0.5                                          | 4.5 | 0.5                                         | 3.3 | 0.5                                         | 2.8 | ns   |
| $t_{PHL}$ |                 |                | 3.2                       | 0.5                                         | 5.6 | 0.5                                          | 4.5 | 0.5                                         | 3.3 | 0.5                                         | 2.8 |      |
| $t_{PLH}$ | B               | A              | 2.6                       | 0.5                                         | 4.1 | 0.5                                          | 3.7 | 0.5                                         | 3.3 | 0.5                                         | 3.2 | ns   |
| $t_{PHL}$ |                 |                | 2.6                       | 0.5                                         | 4.1 | 0.5                                          | 3.7 | 0.5                                         | 3.3 | 0.5                                         | 3.2 |      |
| $t_{PZH}$ | $\overline{OE}$ | A              | 2.5                       | 0.5                                         | 5.3 | 0.5                                          | 5.3 | 0.5                                         | 5.3 | 0.5                                         | 5.3 | ns   |
| $t_{PZL}$ |                 |                | 2.5                       | 0.5                                         | 5.3 | 0.5                                          | 5.3 | 0.5                                         | 5.3 | 0.5                                         | 5.3 |      |
| $t_{PZH}$ | $\overline{OE}$ | B              | 5.2                       | 0.5                                         | 9.4 | 0.5                                          | 7.3 | 0.5                                         | 5.1 | 0.5                                         | 4.5 | ns   |
| $t_{PZL}$ |                 |                | 5.2                       | 0.5                                         | 9.4 | 0.5                                          | 7.3 | 0.5                                         | 5.1 | 0.5                                         | 4.5 |      |
| $t_{PHZ}$ | $\overline{OE}$ | A              | 3                         | 1                                           | 6.1 | 1                                            | 6.1 | 1                                           | 6.1 | 1                                           | 6.1 | ns   |
| $t_{PLZ}$ |                 |                | 3                         | 1                                           | 6.1 | 1                                            | 6.1 | 1                                           | 6.1 | 1                                           | 6.1 |      |
| $t_{PHZ}$ | $\overline{OE}$ | B              | 5                         | 1                                           | 7.9 | 1                                            | 6.6 | 1                                           | 6.1 | 1                                           | 5.2 | ns   |
| $t_{PLZ}$ |                 |                | 5                         | 1                                           | 7.9 | 1                                            | 6.6 | 1                                           | 6.1 | 1                                           | 5.2 |      |

## 6.10 Switching Characteristics

over recommended operating free-air temperature range,  $V_{CCA} = 3.3 \text{ V} \pm 0.3 \text{ V}$  (see Figure 7-1)

| PARAMETER | FROM<br>(INPUT) | TO<br>(OUTPUT) | $V_{CCB} = 1.2 \text{ V}$ | $V_{CCB} = 1.5 \text{ V} \pm 0.1 \text{ V}$ |     | $V_{CCB} = 1.8 \text{ V} \pm 0.15 \text{ V}$ |     | $V_{CCB} = 2.5 \text{ V} \pm 0.2 \text{ V}$ |     | $V_{CCB} = 3.3 \text{ V} \pm 0.3 \text{ V}$ |     | UNIT |
|-----------|-----------------|----------------|---------------------------|---------------------------------------------|-----|----------------------------------------------|-----|---------------------------------------------|-----|---------------------------------------------|-----|------|
|           |                 |                | TYP                       | MIN                                         | MAX | MIN                                          | MAX | MIN                                         | MAX | MIN                                         | MAX |      |
| $t_{PLH}$ | A               | B              | 3.2                       | 0.5                                         | 5.5 | 0.5                                          | 4.4 | 0.5                                         | 3.2 | 0.5                                         | 2.7 | ns   |
| $t_{PHL}$ |                 |                | 3.2                       | 0.5                                         | 5.5 | 0.5                                          | 4.4 | 0.5                                         | 3.2 | 0.5                                         | 2.7 |      |
| $t_{PLH}$ | B               | A              | 2.8                       | 0.5                                         | 3.7 | 0.5                                          | 3.3 | 0.5                                         | 2.8 | 0.5                                         | 2.7 | ns   |
| $t_{PHL}$ |                 |                | 2.8                       | 0.5                                         | 3.7 | 0.5                                          | 3.3 | 0.5                                         | 2.8 | 0.5                                         | 2.7 |      |
| $t_{PZH}$ | $\overline{OE}$ | A              | 2.2                       | 0.5                                         | 4.3 | 0.5                                          | 4.2 | 0.5                                         | 4.1 | 0.5                                         | 4   | ns   |
| $t_{PZL}$ |                 |                | 2.2                       | 0.5                                         | 4.3 | 0.5                                          | 4.2 | 0.5                                         | 4.1 | 0.5                                         | 4   |      |
| $t_{PZH}$ | $\overline{OE}$ | B              | 5.1                       | 0.5                                         | 9.3 | 0.5                                          | 7.2 | 0.5                                         | 4.9 | 0.5                                         | 4   | ns   |
| $t_{PZL}$ |                 |                | 5.1                       | 0.5                                         | 9.3 | 0.5                                          | 7.2 | 0.5                                         | 4.9 | 0.5                                         | 4   |      |
| $t_{PHZ}$ | $\overline{OE}$ | A              | 3.4                       | 0.5                                         | 5   | 0.5                                          | 5   | 0.5                                         | 5   | 0.5                                         | 5   | ns   |
| $t_{PLZ}$ |                 |                | 3.4                       | 0.5                                         | 5   | 0.5                                          | 5   | 0.5                                         | 5   | 0.5                                         | 5   |      |
| $t_{PHZ}$ | $\overline{OE}$ | B              | 4.9                       | 1                                           | 7.7 | 1                                            | 6.5 | 1                                           | 5.2 | 0.5                                         | 5   | ns   |
| $t_{PLZ}$ |                 |                | 4.9                       | 1                                           | 7.7 | 1                                            | 6.5 | 1                                           | 5.2 | 0.5                                         | 5   |      |

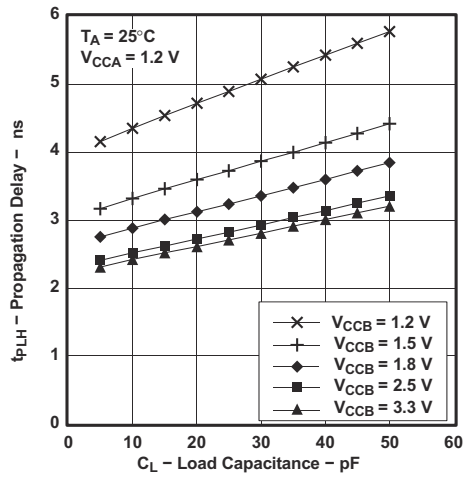
## 6.11 Operating Characteristics

$V_{CCA}$  and  $V_{CCB} = 3.3 \text{ V}$ ,  $T_A = 25^\circ\text{C}$

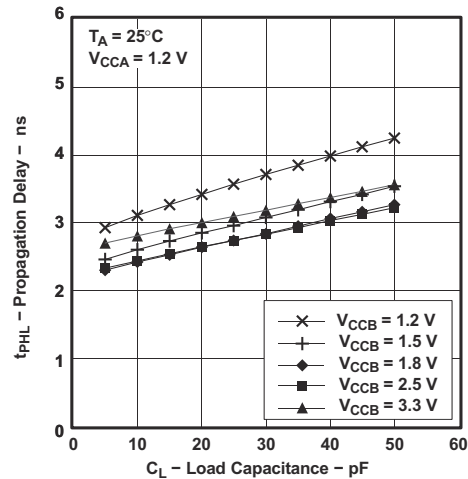
| PARAMETER                |        |                  | TEST<br>CONDITIONS                                                  | $V_{CCA} =$<br>$V_{CCB} = 1.5 \text{ V}$ | $V_{CCA} =$<br>$V_{CCB} = 1.2 \text{ V}$ | $V_{CCA} =$<br>$V_{CCB} = 1.8 \text{ V}$ | $V_{CCA} =$<br>$V_{CCB} = 2.5 \text{ V}$ | $V_{CCA} =$<br>$V_{CCB} = 3.3 \text{ V}$ | UNIT |
|--------------------------|--------|------------------|---------------------------------------------------------------------|------------------------------------------|------------------------------------------|------------------------------------------|------------------------------------------|------------------------------------------|------|
|                          |        |                  |                                                                     | TYP                                      | TYP                                      | TYP                                      | TYP                                      | TYP                                      |      |
| $C_{pdA}$ <sup>(1)</sup> | A to B | Outputs enabled  | $C_L = 0$ ,<br>$f = 10 \text{ MHz}$ ,<br>$t_r = t_f = 1 \text{ ns}$ | 1                                        | 1                                        | 1                                        | 2                                        | 2                                        | pF   |
|                          |        | Outputs disabled |                                                                     | 1                                        | 1                                        | 1                                        | 1                                        | 2                                        |      |
|                          | B to A | Outputs enabled  |                                                                     | 19                                       | 19                                       | 20                                       | 21                                       | 22                                       |      |
|                          |        | Outputs disabled |                                                                     | 1                                        | 1                                        | 1                                        | 1                                        | 1                                        |      |
| $C_{pdB}$ <sup>(1)</sup> | A to B | Outputs enabled  | $C_L = 0$ ,<br>$f = 10 \text{ MHz}$ ,<br>$t_r = t_f = 1 \text{ ns}$ | 19                                       | 19                                       | 20                                       | 21                                       | 22                                       | pF   |
|                          |        | Outputs disabled |                                                                     | 1                                        | 1                                        | 1                                        | 1                                        | 1                                        |      |
|                          | B to A | Outputs enabled  |                                                                     | 1                                        | 1                                        | 1                                        | 2                                        | 2                                        |      |
|                          |        | Outputs disabled |                                                                     | 1                                        | 1                                        | 1                                        | 1                                        | 2                                        |      |

(1) Power dissipation capacitance per transceiver

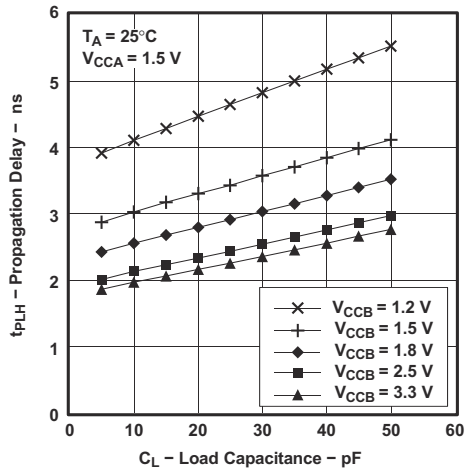
## 6.12 Typical Characteristics



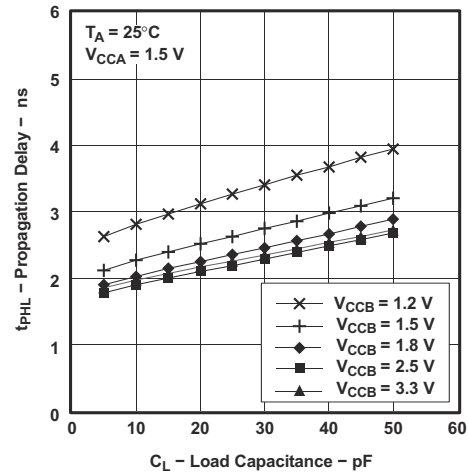
**Figure 6-1. Propagation Delay vs Load Capacitance**



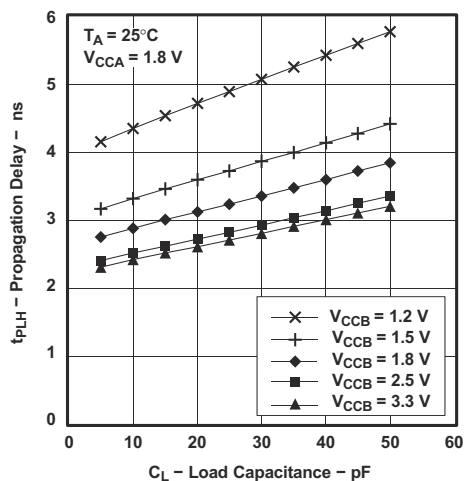
**Figure 6-2. Propagation Delay vs Load Capacitance**



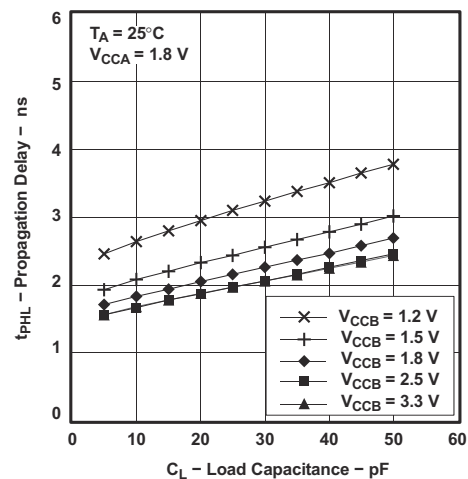
**Figure 6-3. Typical Propagation Delay  $t_{PLH}$  (A to B) vs Load Capacitance**



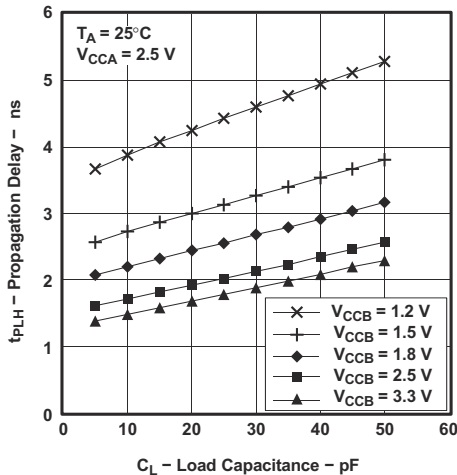
**Figure 6-4. Typical Propagation Delay  $t_{PLH}$  (A to B) vs Load Capacitance**



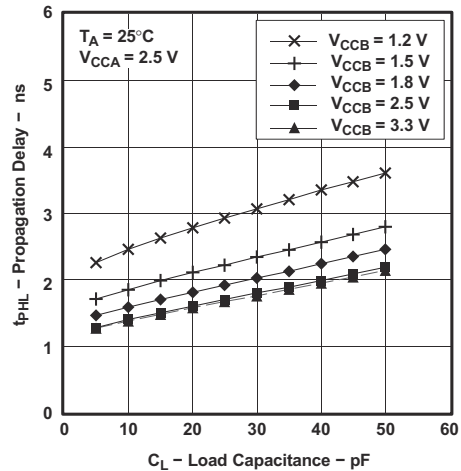
**Figure 6-5. Typical Propagation Delay  $t_{PLH}$  (A to B) vs Load Capacitance**



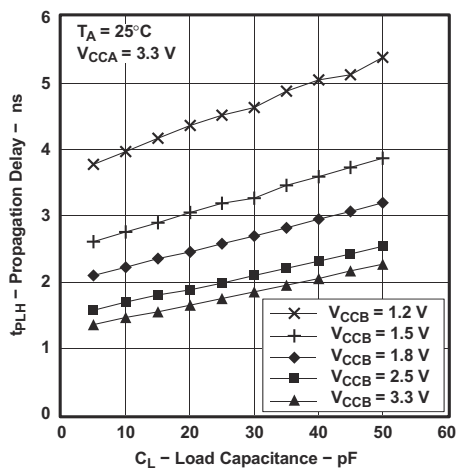
**Figure 6-6. Typical Propagation Delay  $t_{PLH}$  (A to B) vs Load Capacitance**



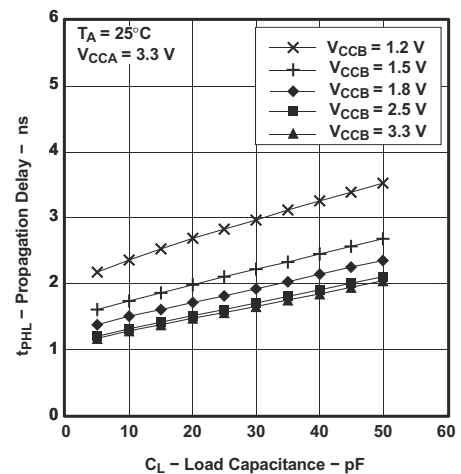
**Figure 6-7. Typical Propagation Delay  $t_{PLH}$  (A to B) vs Load Capacitance**



**Figure 6-8. Typical Propagation Delay  $t_{PLH}$  (A to B) vs Load Capacitance**

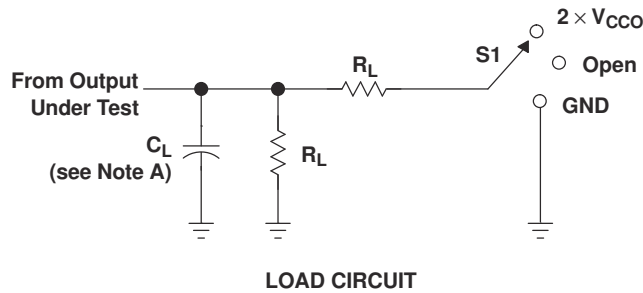


**Figure 6-9. Typical Propagation Delay  $t_{PLH}$  (A to B) vs Load Capacitance**



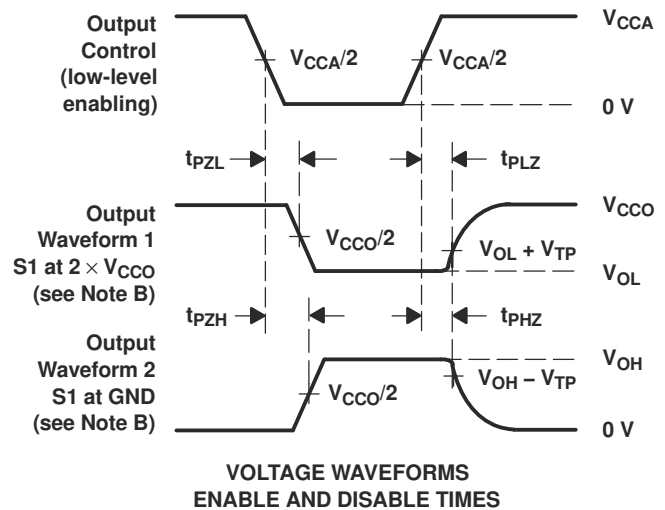
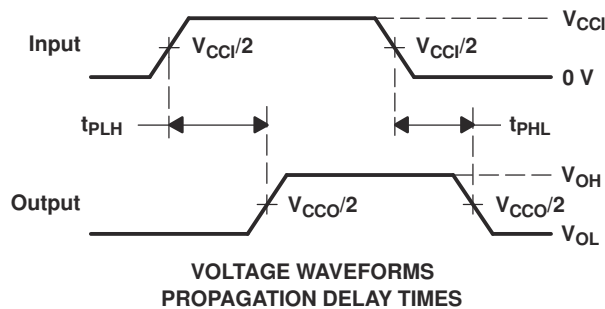
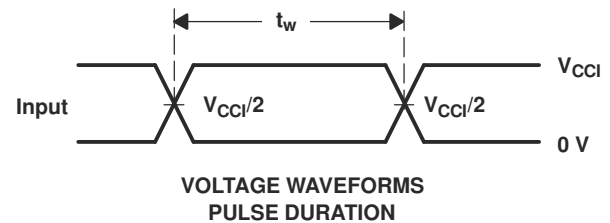
**Figure 6-10. Propagation Delay vs Load Capacitance**

## 7 Parameter Measurement Information



| $V_{CCO}$          | $C_L$ | $R_L$        | $V_{TP}$ |
|--------------------|-------|--------------|----------|
| 1.5 V $\pm$ 0.1 V  | 15 pF | 2 k $\Omega$ | 0.1 V    |
| 1.8 V $\pm$ 0.15 V | 15 pF | 2 k $\Omega$ | 0.15 V   |
| 2.5 V $\pm$ 0.2 V  | 15 pF | 2 k $\Omega$ | 0.15 V   |
| 3.3 V $\pm$ 0.3 V  | 15 pF | 2 k $\Omega$ | 0.3 V    |

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



- 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:  $PRR \leq 10$  MHz,  $Z_O = 50 \Omega$ ,  $dv/dt \geq 1$  V/ns.
  - D. The outputs are measured one at a time, with one transition per measurement.
  - E.  $t_{PLZ}$  and  $t_{PHZ}$  are the same as  $t_{dis}$ .
  - F.  $t_{PZL}$  and  $t_{PZH}$  are the same as  $t_{en}$ .
  - G.  $t_{PLH}$  and  $t_{PHL}$  are the same as  $t_{pd}$ .
  - H.  $V_{CCI}$  is the  $V_{CC}$  associated with the input port.
  - I.  $V_{CCO}$  is the  $V_{CC}$  associated with the output port.

Figure 7-1. Load Circuit and Voltage Waveforms

## 8 Detailed Description

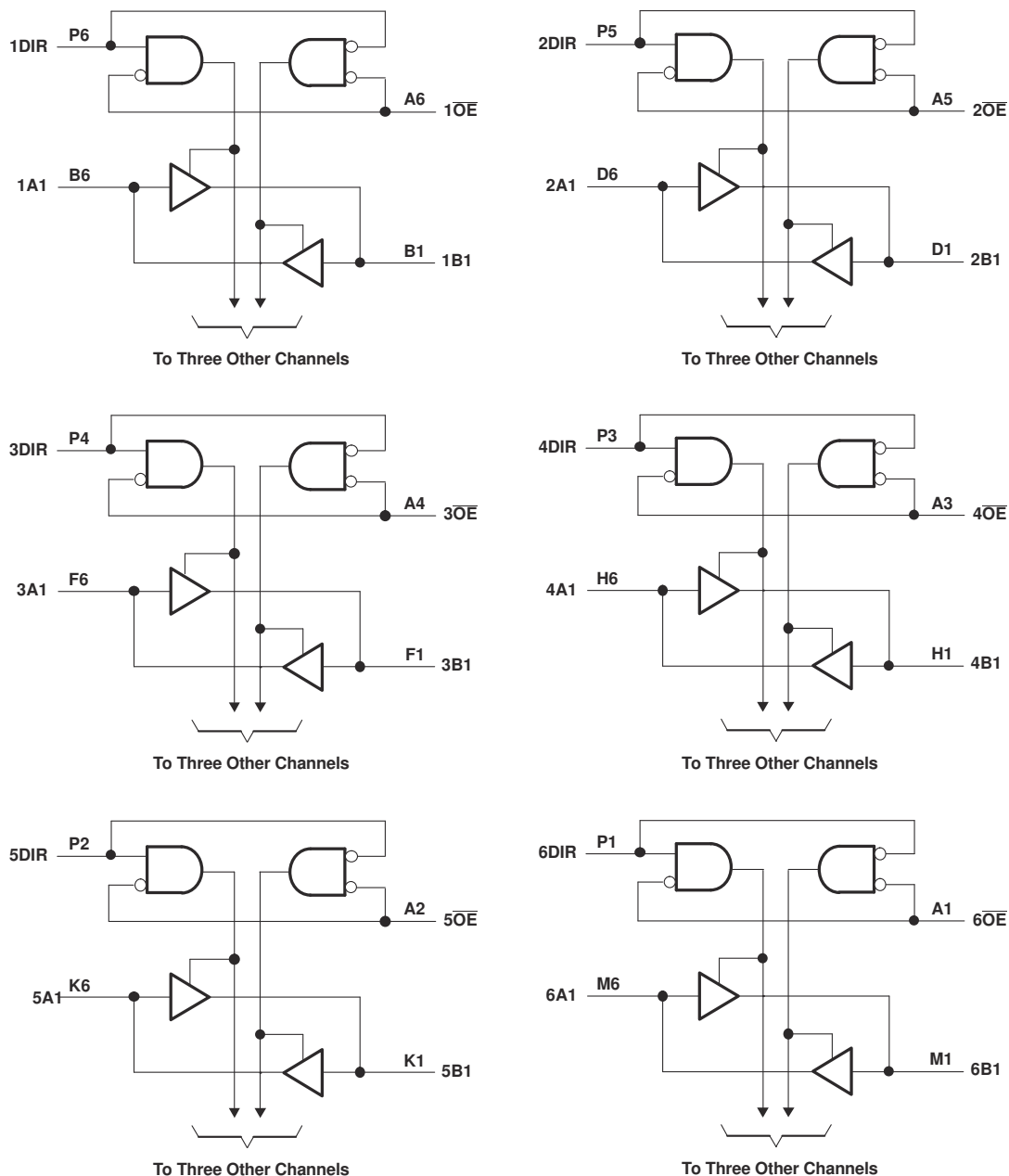
### 8.1 Overview

The SN74AVC24T245 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 can accept I/O voltages ranging from 1.2 V to 3.6 V, while the B port can accept I/O voltages from 1.2 V to 3.6 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.

### 8.2 Functional Block Diagram





## 8.3 Feature Description

### 8.3.1 Fully Configurable Dual-Rail Design Allows Each Port to Operate Over the Full 1.2-V to 3.6-V Power-Supply Range

Both  $V_{CCA}$  and  $V_{CCB}$  can be supplied at any voltage from 1.2 V to 3.6 V which makes the device suitable for translating between any of the low voltage nodes (1.2 V, 1.8 V, 2.5 V, and 3.3 V).

### 8.3.2 Partial-Power-Down Mode Operation

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

### 8.3.3 $V_{CC}$ 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 ( $I_{OZ}$ ). This prevents false logic levels from being presented to either bus.

## 8.4 Device Functional Modes

The SN74AVC24T245 is a voltage level translator that can operate from 1.2 V to 3.6 V ( $V_{CCA}$ ) and 1.2 V to 3.6 V ( $V_{CCB}$ ). The signal translation between 1.2 V and 3.6 V requires direction control and output enable control. When  $\overline{OE}$  is low and DIR is high, data transmission is from A to B. When  $\overline{OE}$  is low and DIR is low, data transmission is from B to A. When  $\overline{OE}$  is high, both output ports will be high-impedance.

**Table 8-1. Function Table  
(Each 4-Bit Section)**

| INPUTS          |     | OPERATION       |
|-----------------|-----|-----------------|
| $\overline{OE}$ | DIR |                 |
| L               | L   | B data to A bus |
| L               | H   | A data to B bus |
| H               | X   | Isolation       |

## 9 Application and Implementation

### Note

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

### 9.1 Application Information

The SN74AVC24T245 device can be used in level-shifting applications for interfacing devices and addressing mixed voltage incompatibility. The SN74AVC24T245 device is ideal for data transmission where direction is different for each channel.

### 9.2 EnableTimes

Calculate the enable times for the SN74AVC24T245 using the following formulas:

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

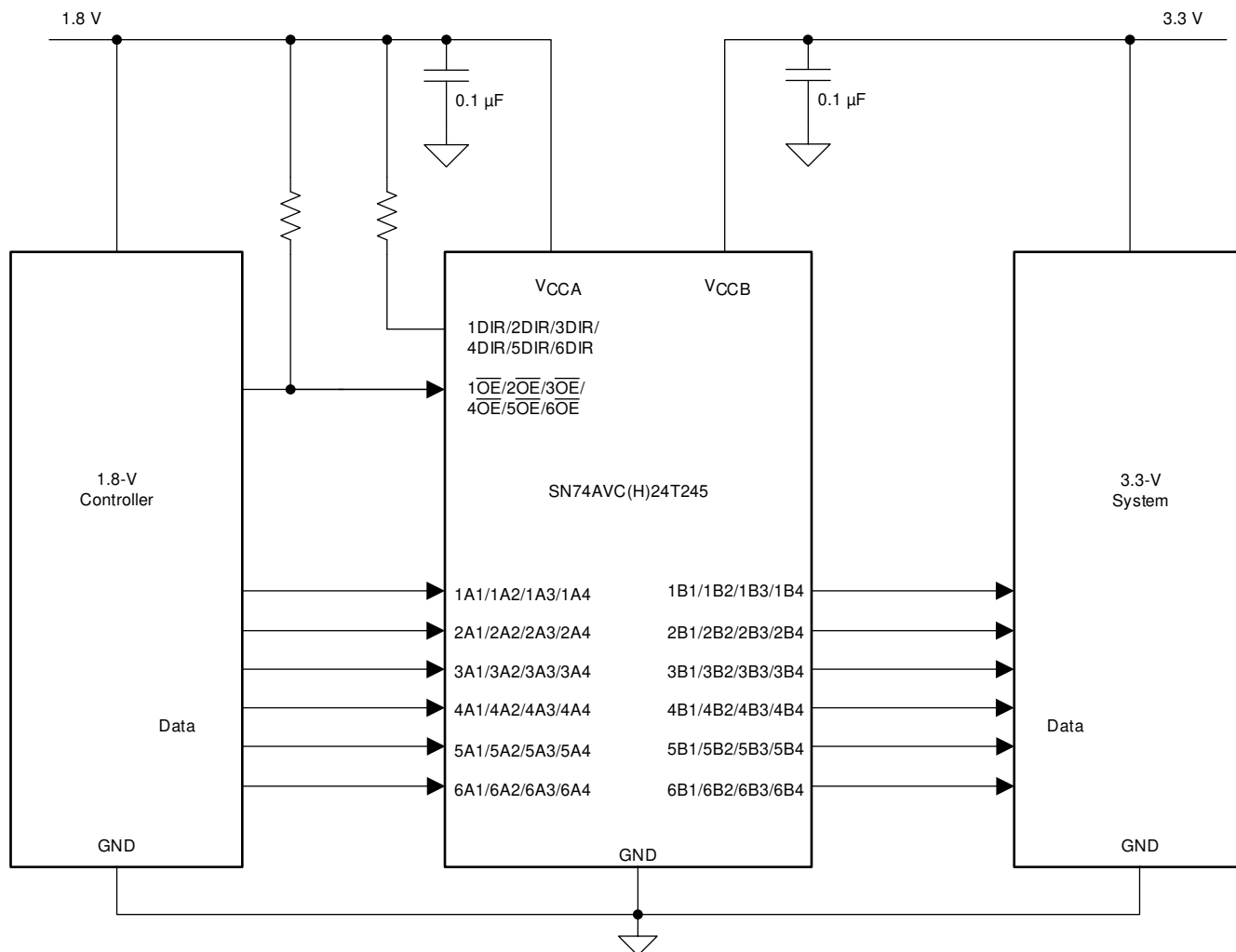
$$t_{PZL} \text{ (DIR to A)} = t_{PHZ} \text{ (DIR to B)} + t_{PHL} \text{ (B to A)} \quad (2)$$

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

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

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 SN74AVC24T245 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.

## 9.3 Typical Application



**Figure 9-1. Application Schematic**

### 9.3.1 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. Unused data inputs must not be floating, as this can cause excessive internal leakage on the input CMOS structure. Tie any unused input and output ports directly to ground.

For this design example, use the parameters listed in the *Electrical Characteristics*.

**Table 9-1. Design Parameters**

| DESIGN PARAMETER     | EXAMPLE VALUE  |
|----------------------|----------------|
| Input voltage range  | 1.2 V to 3.6 V |
| Output voltage range | 1.2 V to 3.6 V |

### 9.3.2 Detailed Design Procedure

To begin the design process, determine the following:

#### 9.3.2.1 Input Voltage Ranges

Use the supply voltage of the device that is driving the SN74AVC24T245 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.

#### 9.3.2.2 Output Voltage Range

Use the supply voltage of the device that the SN74AVC24T245 device is driving to determine the output voltage range.

### 9.3.3 Application Curve

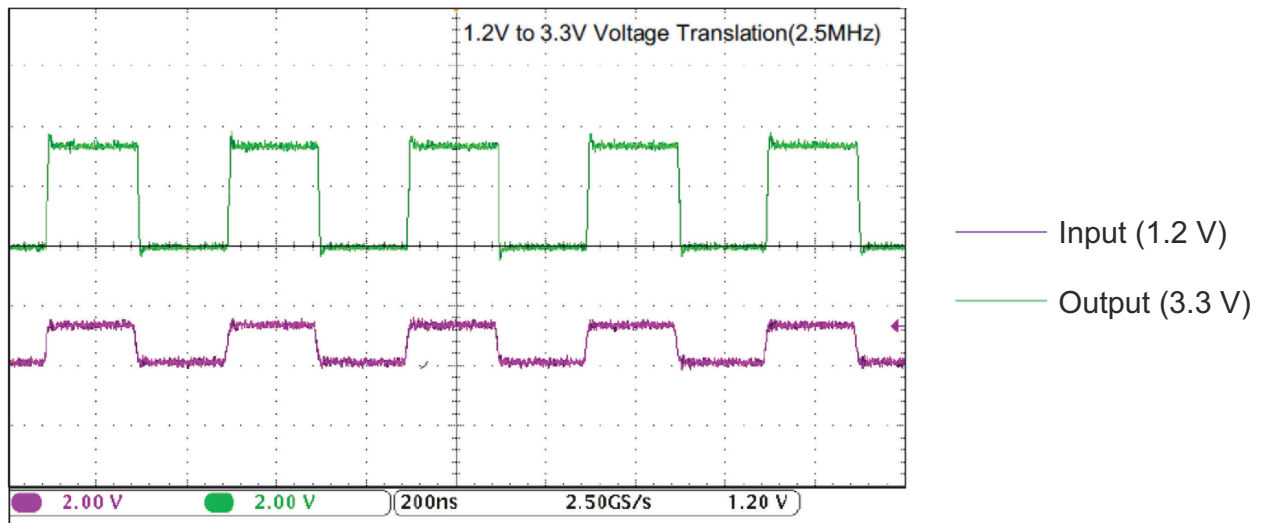


Figure 9-2. Translation Up (1.2 V to 3.3 V) at 2.5 MHz

## 10 Power Supply Recommendations

The SN74AVC24T245 device uses two separate configurable power-supply rails,  $V_{CCA}$  and  $V_{CCB}$ .  $V_{CCA}$  accepts any supply voltage from 1.2 V to 3.6 V and  $V_{CCB}$  accepts any supply voltage from 1.2 V to 3.6 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 1.2-V, 1.5-V, 1.8-V, 2.5-V and 3.3-V voltage nodes.

The output-enable  $\overline{OE}$  input circuit is designed so that it 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.

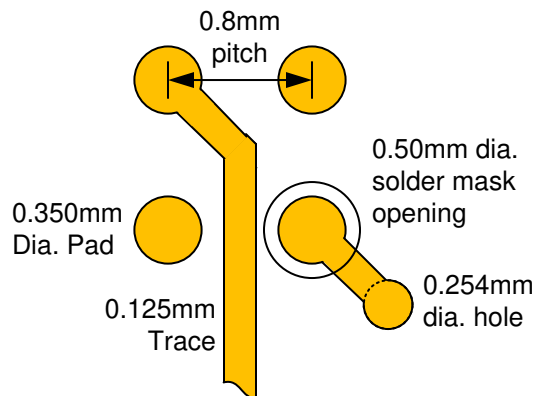
## 11 Layout

### 11.1 Layout Guidelines

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

- Bypass capacitors must be used on power supplies.
- Short trace lengths must be used to avoid excessive loading.
- Place 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.

### 11.2 Layout Example



**Figure 11-1. BGA Layout Example**

## 12 Device and Documentation Support

### 12.1 Documentation Support

### 12.2 Related Documentation

For related documentation, see the following:

<http://www.ti.com/lit/an/scea014/scea014.pdf>

### 12.3 Trademarks

All other trademarks are the property of their respective owners.

### 12.4 Electrostatic Discharge Caution



This integrated circuit can be damaged by ESD. Texas Instruments recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

### 12.5 Glossary

#### [TI Glossary](#)

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

## 13 Mechanical, Packaging, and Orderable Information

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

PACKAGING INFORMATION

| Orderable part number | Status<br>(1) | Material type<br>(2) | Package   Pins   | Package qty   Carrier | RoHS<br>(3) | Lead finish/<br>Ball material<br>(4) | MSL rating/<br>Peak reflow<br>(5) | Op temp (°C) | Part marking<br>(6) |
|-----------------------|---------------|----------------------|------------------|-----------------------|-------------|--------------------------------------|-----------------------------------|--------------|---------------------|
| SN74AVC24T245NMUR     | Active        | Production           | NFBGA (NMU)   83 | 1000   LARGE T&R      | Yes         | SNAGCU                               | Level-3-260C-168 HR               | -40 to 85    | 2CPW                |
| SN74AVC24T245NMUR.B   | Active        | Production           | NFBGA (NMU)   83 | 1000   LARGE T&R      | Yes         | SNAGCU                               | Level-3-260C-168 HR               | -40 to 85    | 2CPW                |

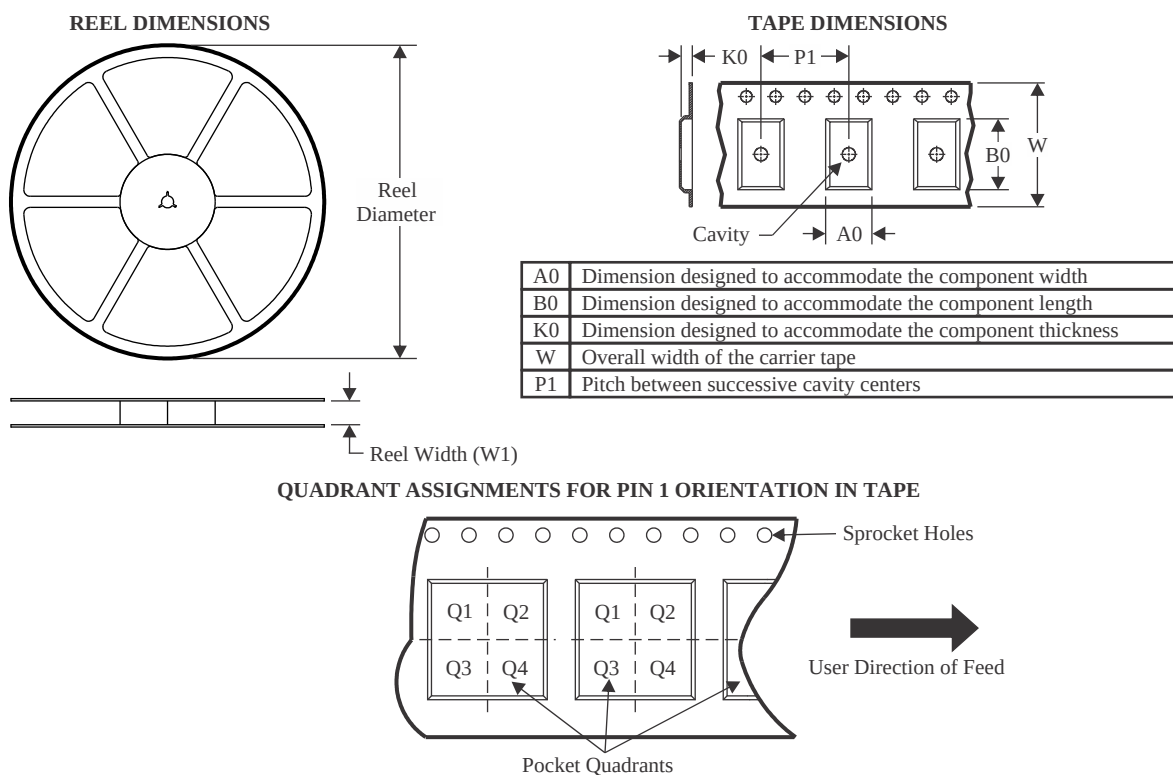
- <sup>(1)</sup> **Status:** For more details on status, see our [product life cycle](#).
- <sup>(2)</sup> **Material type:** When designated, preproduction parts are prototypes/experimental devices, and are not yet approved or released for full production. Testing and final process, including without limitation quality assurance, reliability performance testing, and/or process qualification, may not yet be complete, and this item is subject to further changes or possible discontinuation. If available for ordering, purchases will be subject to an additional waiver at checkout, and are intended for early internal evaluation purposes only. These items are sold without warranties of any kind.
- <sup>(3)</sup> **RoHS values:** Yes, No, RoHS Exempt. See the [TI RoHS Statement](#) for additional information and value definition.
- <sup>(4)</sup> **Lead finish/Ball material:** Parts 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.
- <sup>(5)</sup> **MSL rating/Peak reflow:** The moisture sensitivity level ratings and peak solder (reflow) temperatures. In the event that a part has multiple moisture sensitivity ratings, only the lowest level per JEDEC standards is shown. Refer to the shipping label for the actual reflow temperature that will be used to mount the part to the printed circuit board.
- <sup>(6)</sup> **Part marking:** There may be an additional marking, which relates to the logo, the lot trace code information, or the environmental category of the part.

Multiple part markings will be inside parentheses. Only one part marking contained in parentheses and separated by a "~" will appear on a part. If a line is indented then it is a continuation of the previous line and the two combined represent the entire part marking for that device.

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## TAPE AND REEL INFORMATION

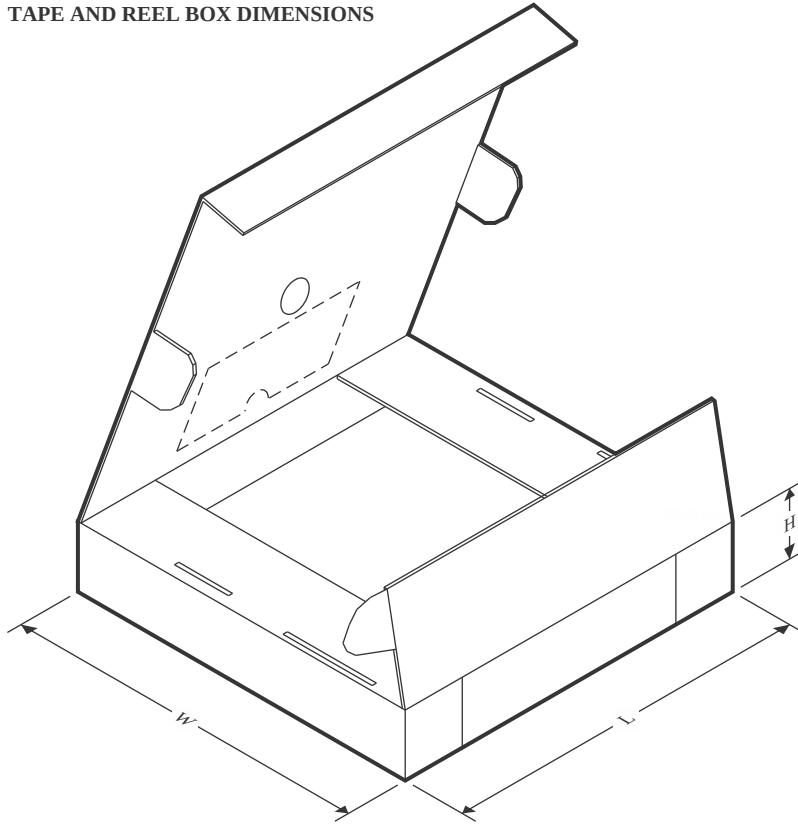


\*All dimensions are nominal

| Device            | Package Type | Package Drawing | Pins | SPQ  | Reel Diameter (mm) | Reel Width W1 (mm) | A0 (mm) | B0 (mm) | K0 (mm) | P1 (mm) | W (mm) | Pin1 Quadrant |
|-------------------|--------------|-----------------|------|------|--------------------|--------------------|---------|---------|---------|---------|--------|---------------|
| SN74AVC24T245NMUR | NFBGA        | NMU             | 83   | 1000 | 330.0              | 24.4               | 4.8     | 10.3    | 1.8     | 8.0     | 24.0   | Q1            |

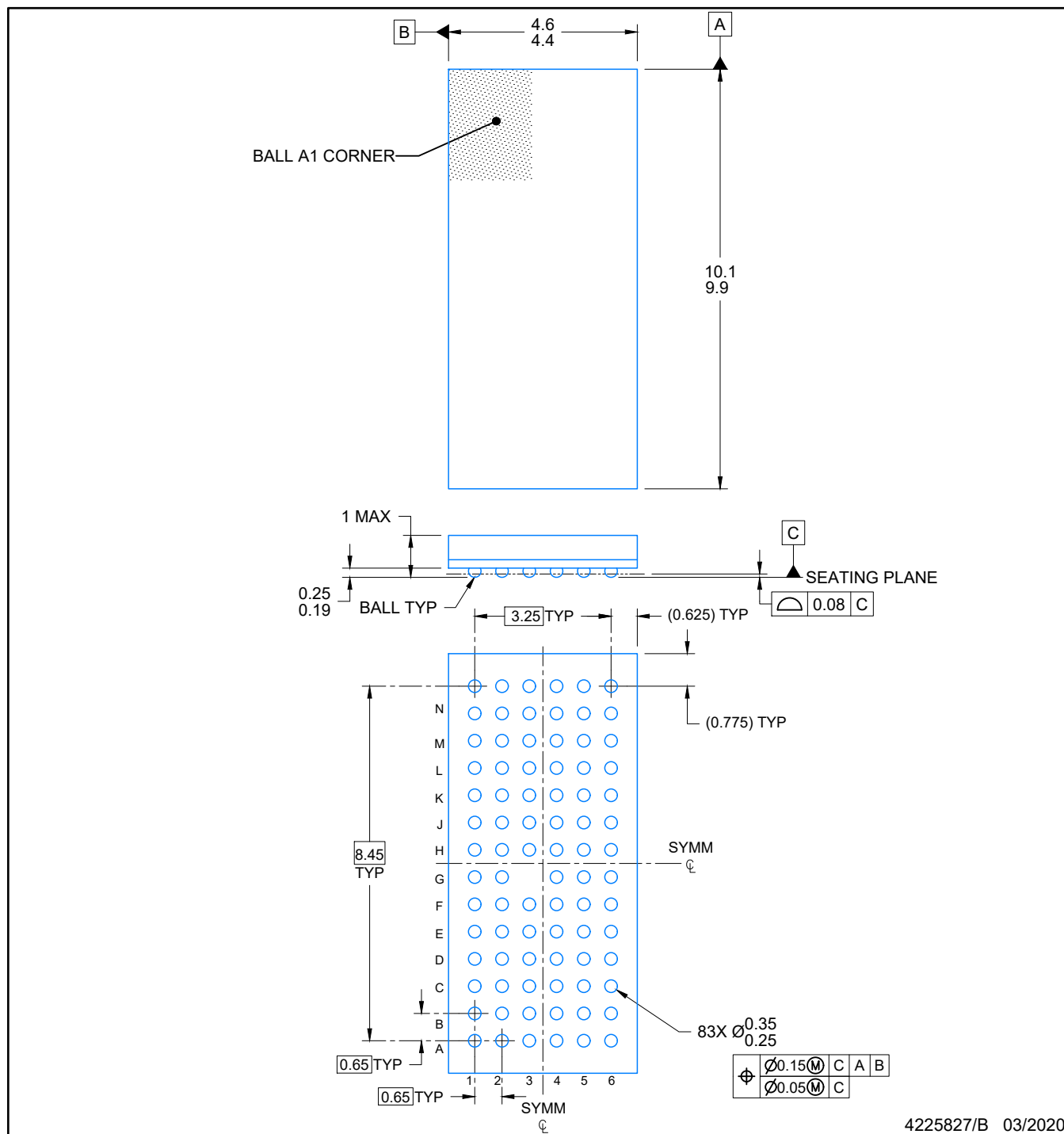


## TAPE AND REEL BOX DIMENSIONS



\*All dimensions are nominal

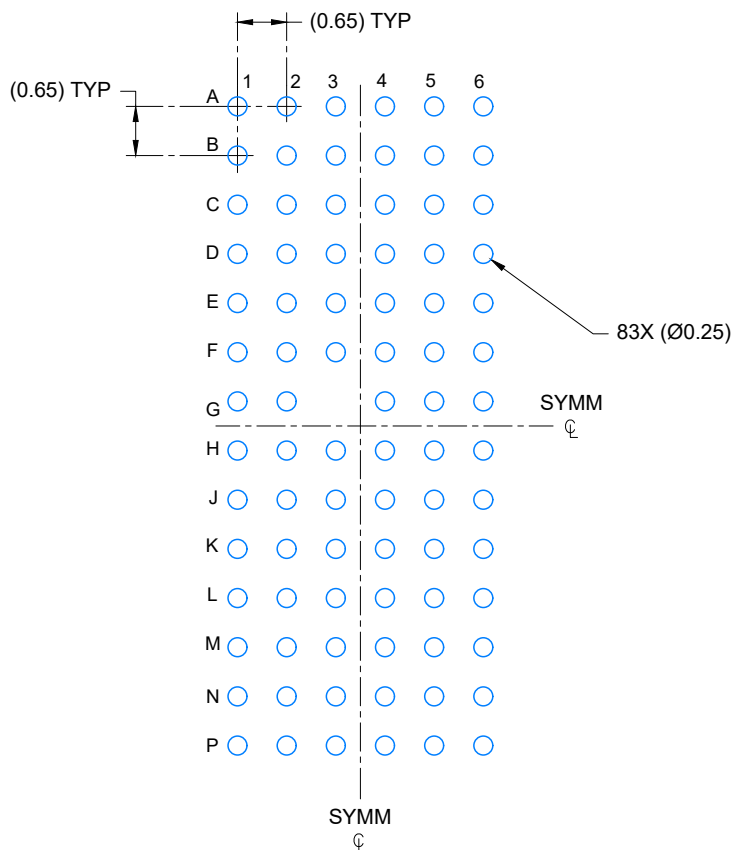
| Device            | Package Type | Package Drawing | Pins | SPQ  | Length (mm) | Width (mm) | Height (mm) |
|-------------------|--------------|-----------------|------|------|-------------|------------|-------------|
| SN74AVC24T245NMUR | NFBGA        | NMU             | 83   | 1000 | 350.0       | 350.0      | 43.0        |



NOTES:

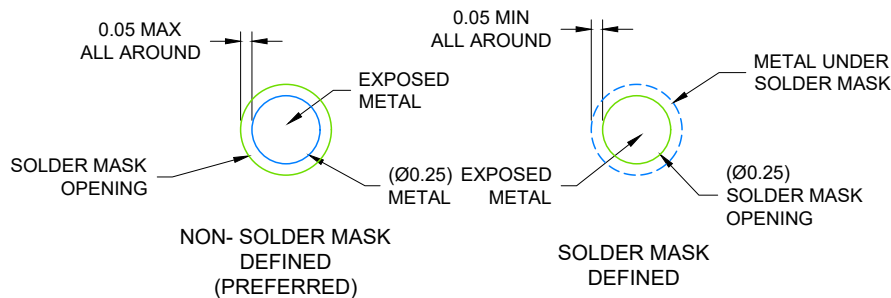
NanoFree is a trademark of Texas Instruments.

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.



LAND PATTERN EXAMPLE

SCALE: 10X



SOLDER MASK DETAILS

NOT TO SCALE

4225827/B 03/2020

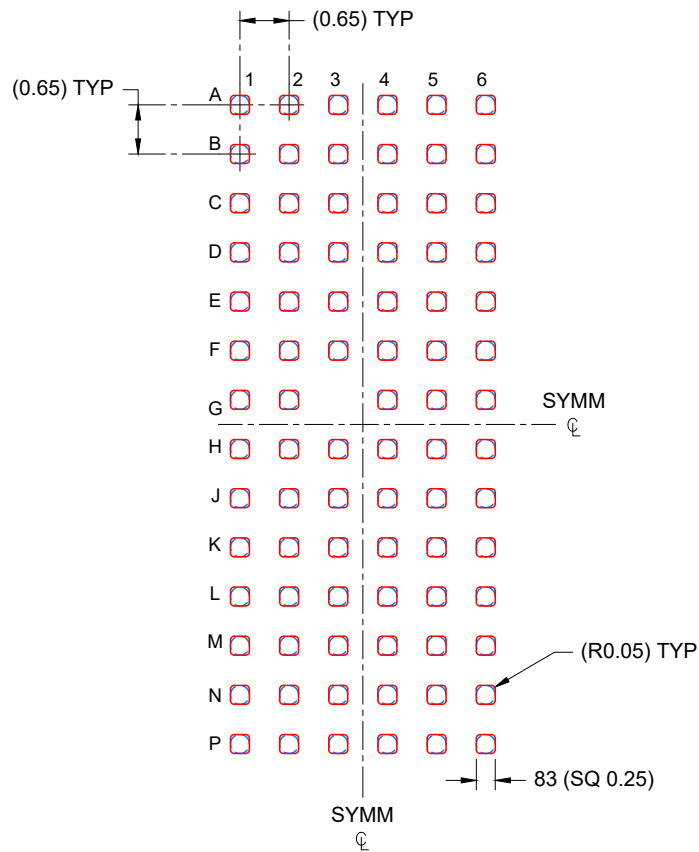
NOTES: (continued)

- Final dimensions may vary due to manufacturing tolerance considerations and also routing constraints. Refer to Texas Instruments Literature number SNVA009 ([www.ti.com/lit/snva009](http://www.ti.com/lit/snva009)).

**NMU0083A**

## NFBGA - 1 mm max height

## PLASTIC BALL GRID ARRAY



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

4225827/B 03/2020

NOTES: (continued)

4. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release.

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