



## TXS0104E-Q1 4-Bit Bidirectional Voltage-Level Translator for Open-Drain and Push-Pull Applications

### 1 Features

- Qualified for Automotive Applications
- AEC-Q100 Qualified With the Following Results:
  - Device Temperature Grade 1: –40°C to 125°C Ambient Operating Temperature Range
  - Device HBM ESD Classification Level 2
  - Device CDM ESD Classification Level C6
- No Direction-Control Signal Required
- Maximum Data Rates
  - 24 Mbps Maximum (Push Pull)
  - 2 Mbps (Open Drain)
- 1.65 V to 3.6 V on A port and 2.3 V to 5.5 V on B port ( $V_{CCA} \leq V_{CCB}$ )
- No Power-Supply Sequencing Required— $V_{CCA}$  or  $V_{CCB}$  Can Be Ramped First
- ESD Protection Exceeds JESD 22
  - A Port
    - 2000-V Human-Body Model (A114-B)
    - 1000-V Charged-Device Model (C101)
  - B Port
    - 15-kV Human-Body Model (A114-B)
    - 1000-V Charged-Device Model (C101)
- IEC 61000-4-2 ESD (B Port)
  - $\pm 8$ -kV Contact Discharge
  - $\pm 10$ -kV Air-Gap Discharge

### 2 Applications

- Automotive infotainment, advance driver assistance systems (ADAS)
- Isolates and Level Translates Between Main Processor and Peripheral Modules
- I<sup>2</sup>C or 1-Wire Voltage-Level Translation

### 3 Description

The TXS0104E-Q1 device connects an incompatible logic communication from chip-to-chip due to voltage mismatch. This auto-direction translator can be conveniently used to bridge the gap without the need of direction control from the host. Each channel can be mixed and matched with different output types (open-drain or push-pull) and mixed data flows (transmit or receive) without intervention from the host. This 4-bit noninverting translator uses two separate configurable power-supply rails. The A and B ports are designed to track  $V_{CCA}$  and  $V_{CCB}$  respectively. The  $V_{CCB}$  pin accepts any supply voltage from 2.3 V to 5.5 V while the  $V_{CCA}$  pin accepts any supply voltage from 1.65 V to 3.6 V such that  $V_{CCA}$  is less than or equal to  $V_{CCB}$ . This tracking allows for low-voltage bidirectional translation between any of the 1.8-V, 2.5-V, 3.3-V, and 5-V voltage nodes.

When the output-enable (OE) input is low, all outputs are placed in the high-impedance state.

The TXS0104E-Q1 device is designed so that the OE input circuit is supplied by  $V_{CCA}$ .

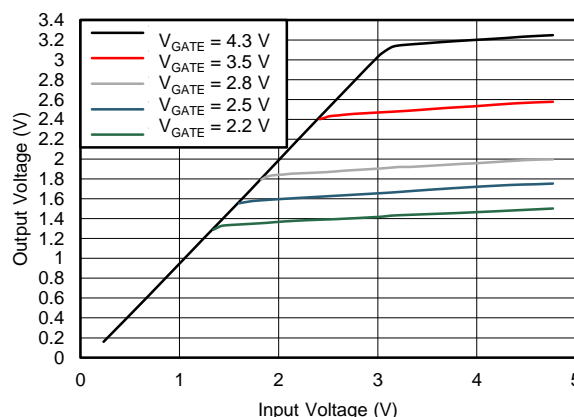
To ensure the high-impedance state during power up or power down, the OE pin must be tied to the GND pin through a pulldown resistor; the minimum value of the resistor is determined by the current-sourcing capability of the driver.

#### Device Information<sup>(1)</sup>

| PART NUMBER | PACKAGE    | BODY SIZE (NOM)   |
|-------------|------------|-------------------|
| TXS0104E-Q1 | TSSOP (14) | 5.00 mm x 4.40 mm |

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

#### Transfer Characteristics of an N-Channel Transistor



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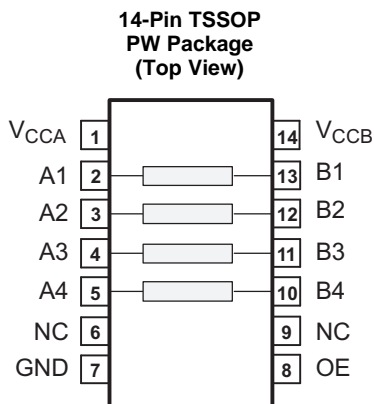
## 4 Revision History

### Changes from Revision A (April 2014) to Revision B

Page

- Changed device status from *Product Preview* to *Production Data* 1

## 5 Pin Configuration and Functions



NC - No internal connection

### Pin Functions

| PIN       |        | I/O | DESCRIPTION   |
|-----------|--------|-----|---|
| NAME      | NUMBER |     |   |
| A1        | 2      | I/O | Input-output 1 for the A port. This pin is referenced to $V_{CCA}$ .  |
| A2        | 3      | I/O | Input-output 2 for the A port. This pin is referenced to $V_{CCA}$ .  |
| A3        | 4      | I/O | Input-output 3 for the A port. This pin is referenced to $V_{CCA}$ .  |
| A4        | 5      | I/O | Input-output 4 for the A port. This pin is referenced to $V_{CCA}$ .  |
| B1        | 13     | I/O | Input-output 1 for the B port. This pin is referenced to $V_{CCB}$ .  |
| B2        | 12     | I/O | Input-output 2 for the B port. This pin is referenced to $V_{CCB}$ .  |
| B3        | 11     | I/O | Input-output 3 for the B port. This pin is referenced to $V_{CCB}$ .  |
| B4        | 10     | I/O | Input-output 4 for the B port. This pin is referenced to $V_{CCB}$ .  |
| GND       | 7      | —   | Ground  |
| NC        | 6      | —   | No connection   |
|           | 9      |     |   |
| OE        | 8      | O   | Tri-state output-mode enable. Pull the OE pin low to place all outputs in tri-state mode. This pin is referenced to $V_{CCA}$ . |
| $V_{CCA}$ | 1      | I   | A-port supply voltage. $1.65\text{ V} \leq V_{CCA} \leq 3.6\text{ V}$ and $V_{CCA} \leq V_{CCB}$ .                              |
| $V_{CCB}$ | 14     | I   | B-port supply voltage. $2.3\text{ V} \leq V_{CCB} \leq 5.5\text{ V}$ .  |

## 6 Specifications

### 6.1 Absolute Maximum Ratings<sup>(1)</sup>

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

|  |   |                    | MIN  | MAX                    | UNIT |
|--|---|--------------------|------|------------------------|------|
| Supply voltage   | V <sub>CCA</sub>  |                    | −0.5 | 4.6                    | V    |
|  | V <sub>CCB</sub>  |                    | −0.5 | 6.5                    |      |
| Input-output pin voltage, V <sub>IO</sub> <sup>(2)</sup>                     | A1, A2, A3, A4  | A port             | −0.5 | 4.6                    | V    |
|  | B1, B2, B3, B4  | B port             | −0.5 | 6.5                    |      |
| Output voltage, V <sub>O</sub>   | Voltage range applied to any output in the high-impedance or power-off state <sup>(2)</sup> | A port             | −0.5 | 4.6                    | V    |
|  |   | B port             | −0.5 | 6.5                    |      |
|  | Voltage range applied to any output in the high or low state <sup>(2)(3)</sup>              | A port             | −0.5 | V <sub>CCA</sub> + 0.5 | V    |
|  |   | B port             | −0.5 | V <sub>CCB</sub> + 0.5 |      |
| Input clamp current, I <sub>IK</sub>   |   | V <sub>I</sub> < 0 | −50  |                        | mA   |
| Output clamp current, I <sub>OK</sub>  |   | V <sub>O</sub> < 0 | −50  |                        | mA   |
| Continuous output current, I <sub>O</sub>                                    |   |                    | ±50  |                        | mA   |
| Continuous current through each V <sub>CCA</sub> , V <sub>CCB</sub> , or GND |   |                    | ±100 |                        | mA   |
| Operating virtual junction temperature range, T <sub>J</sub>                 |   |                    | −40  | 125                    | °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 and output negative-voltage ratings may be exceeded if the input and output current ratings are observed.
- (3) The value of  $V_{CCA}$  and  $V_{CCB}$  are provided in the recommended operating conditions table.

### 6.2 Handling Ratings

|             |                           |   | MIN  | MAX | UNIT |
|-------------|---------------------------|---|------|-----|------|
| $T_{stg}$   | Storage temperature range |   | −65  | 150 | °C   |
| $V_{(ESD)}$ | Electrostatic discharge   | Human body model (HBM), per AEC Q100-002 <sup>(1)</sup> | −2.5 | 2.5 | kV   |
|             |                           | Charged device model (CDM), per AEC Q100-011, all pins  | −1.5 | 1.5 |      |

- (1) AEC Q100-002 indicates HBM stressing is done in accordance with the ANSI/ESDA/JEDEC JS-001 specification.

### 6.3 Recommended Operating Conditions

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

|                            |                                    |                                | $V_{CCA}$      | $V_{CCB}$    | MIN                   | MAX                   | UNIT |
|----------------------------|------------------------------------|--------------------------------|----------------|--------------|-----------------------|-----------------------|------|
| $V_{CCA}$                  | Supply voltage <sup>(1)</sup>      |                                |                |              | 1.65                  | 3.6                   | V    |
| $V_{CCB}$                  | Supply voltage <sup>(1)</sup>      |                                |                |              | 2.3                   | 5.5                   |      |
| $V_{IH(Ax)}$               | High-level input voltage           | A-port I/Os                    | 1.65 to 1.95 V | 2.3 to 5.5 V | $V_{CCA} - 0.2$       | $V_{CCA}$             | V    |
|                            |                                    |                                | 2.3 to 3.6 V   |              | $V_{CCA} - 0.4$       | $V_{CCA}$             |      |
| $V_{IH(Bx)}$               | High-level input voltage           | B-port I/Os                    | 1.65 to 3.6 V  | 2.3 to 5.5 V | $V_{CCB} - 0.4$       | $V_{CCB}$             |      |
| $V_{IH(OE)}$               | High-level input voltage           | OE input                       |                |              | $V_{CCA} \times 0.65$ | 5.5                   |      |
| $V_{IL(Ax)}$               | Low-level input voltage            | A-port I/Os                    | 1.65 to 3.6 V  | 2.3 to 5.5 V | 0                     | 0.15                  | V    |
| $V_{IL(Bx)}$               | Low-level input voltage            | B-port I/Os                    |                |              | 0                     | 0.15                  |      |
| $V_{IL(OE)}$               | Low-level input voltage            | OE input                       |                |              | 0                     | $V_{CCA} \times 0.35$ |      |
| $\Delta t/\Delta v_{(Ax)}$ | Input transition rise or fall rate | A-port I/Os, push-pull driving | 1.65 to 3.6 V  | 2.3 to 5.5 V |                       | 10                    | ns/V |
| $\Delta t/\Delta v_{(Bx)}$ | Input transition rise or fall rate | B-port I/Os, push-pull driving |                |              |                       | 10                    |      |
| $\Delta t/\Delta v_{(OE)}$ | Input transition rise or fall rate | OE input                       |                |              |                       | 10                    |      |
| $T_A$                      | Operating free-air temperature     |                                |                |              | -40                   | 125                   | °C   |

(1)  $V_{CCA}$  must be less than or equal to  $V_{CCB}$ , and  $V_{CCA}$  must not exceed 3.6 V.

### 6.4 Thermal Information

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

| THERMAL METRIC <sup>(1)</sup> |  | PW<br>(14-PINS) | UNIT |
|-------------------------------|--|-----------------|------|
| $R_{\theta JA}$               | Junction-to-ambient thermal resistance       | 120.1           | °C/W |
| $R_{\theta JC(top)}$          | Junction-to-case (top) thermal resistance    | 49.1            |      |
| $R_{\theta JB}$               | Junction-to-board thermal resistance         | 61.8            |      |
| $\Psi_{JT}$                   | Junction-to-top characterization parameter   | 6.2             |      |
| $\Psi_{JB}$                   | Junction-to-board characterization parameter | 61.2            |      |
| $R_{\theta JC(bot)}$          | Junction-to-case (bottom) thermal resistance | —               |      |

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

## 6.5 Electrical Characteristics<sup>(1)</sup>

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

| PARAMETER                          |   | TEST CONDITIONS   | V <sub>CCA</sub>                         | V <sub>CCB</sub> | T <sub>A</sub> = 25°C |     |     | T <sub>A</sub> = 25°C to 125°C |      | UNIT |
|------------------------------------|---|---|--|------------------|-----------------------|-----|-----|--------------------------------|------|------|
|                                    |   |   |  |                  | MIN                   | TYP | MAX | MIN                            | MAX  |      |
| V <sub>OH(Ax)</sub>                | High-level output voltage, A port                 | I <sub>OH</sub> = –20 μA, V <sub>I(Bx)</sub> ≥ V <sub>CCB</sub> – 0.4 V | 1.65 to 3.6 V                            | 2.3 to 5.5 V     |                       |     |     | V <sub>CCA</sub> × 0.75        |      | V    |
| V <sub>OL(Ax)</sub>                | Low-level output voltage, A port                  | I <sub>OL</sub> = 1 mA, V <sub>I(Bx)</sub> ≤ 0.15 V                     | 1.65 to 3.6 V                            | 2.3 to 5.5 V     |                       |     |     | 0.4                            |      | V    |
| V <sub>OH(Bx)</sub>                | High-level output voltage, B port                 | I <sub>OH</sub> = –20 μA, V <sub>I(Ax)</sub> ≥ V <sub>CCA</sub> – 0.2 V | 1.65 to 3.6 V                            | 2.3 to 5.5 V     |                       |     |     | V <sub>CCB</sub> × 0.75        |      | V    |
| V <sub>OL(Bx)</sub>                | Low-level output voltage, B port                  | I <sub>OL</sub> = 1 mA, V <sub>I(Ax)</sub> ≤ 0.15 V                     | 1.65 to 3.6 V                            | 2.3 to 5.5 V     |                       |     |     | 0.4                            |      | V    |
| I <sub>I(OE)</sub>                 | Input current                                     | OE  | V <sub>I</sub> = V <sub>CCI</sub> or GND | 1.65 to 3.6 V    |                       |     | ±1  |                                | ±2   | μA   |
| I <sub>OZ</sub>                    | Off-state output current                          | A or B port   | OE = V <sub>IL</sub>                     | 1.65 to 3.6 V    |                       |     | ±1  |                                | ±3   | μA   |
| I <sub>CCA</sub>                   | Supply current, A port                            | V <sub>I</sub> = V <sub>O</sub> = Open, I <sub>O</sub> = 0              | 1.65 to V <sub>CCB</sub>                 | 2.3 to 5.5 V     |                       |     |     |                                | 4    | μA   |
|                                    |   |   | 3.6 V                                    | 0                |                       |     |     |                                | 2.2  |      |
|                                    |   |   | 0  | 5.5 V            |                       |     |     |                                | –1   |      |
| I <sub>CCB</sub>                   | Supply current, B port                            | V <sub>I</sub> = V <sub>O</sub> = Open, I <sub>O</sub> = 0              | 1.65 to V <sub>CCB</sub>                 | 2.3 to 5.5 V     |                       |     |     |                                | 21   | μA   |
|                                    |   |   | 3.6 V                                    | 0                |                       |     |     |                                | –1   |      |
|                                    |   |   | 0  | 5.5 V            |                       |     |     |                                | 5    |      |
| I <sub>CCA</sub> +I <sub>CCB</sub> | Supply current, A port plus B port supply current | V <sub>I</sub> = V <sub>O</sub> = Open, I <sub>O</sub> = 0              | 1.65 V to V <sub>CCB</sub>               | 2.3 to 5.5 V     |                       |     |     |                                | 25   | μA   |
| C <sub>I(OE)</sub>                 | Input capacitance                                 | OE  |  | 3.3 V            |                       |     | 2.5 |                                | 4    | pF   |
| C <sub>IO(Ax)</sub>                | Input-output capacitance                          | A port  | 3.3 V                                    | 3.3 V            |                       |     | 5   |                                | 6.5  | pF   |
| C <sub>IO(Bx)</sub>                |   | B port  |  |                  |                       |     | 12  |                                | 16.5 |      |

(1) V<sub>CCA</sub> must be less than or equal to V<sub>CCB</sub>, and V<sub>CCA</sub> must not exceed 3.6 V.

## 6.6 Timing Requirements—V<sub>CCA</sub> = 1.8 V ± 0.15 V

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

|                |                                |                    |  | V <sub>CCB</sub> = 2.5 V<br>± 0.2 V |     | V <sub>CCB</sub> = 3.3 V<br>± 0.3 V |     | V <sub>CCB</sub> = 5 V<br>± 0.5 V |     | UNIT |
|----------------|--------------------------------|--------------------|--|-------------------------------------|-----|-------------------------------------|-----|-----------------------------------|-----|------|
|                |                                |                    |  | MIN                                 | MAX | MIN                                 | MAX | MIN                               | MAX |      |
| Data rate      |                                | Push-pull driving  |  | 18                                  |     | 21                                  |     | 23                                |     | Mbps |
|                |                                | Open-drain driving |  | 2                                   |     | 2                                   |     | 2                                 |     |      |
| t <sub>w</sub> | Pulse duration<br>See Figure 7 | Push-pull driving  |  | 55                                  |     | 47                                  |     | 43                                |     | ns   |
|                |                                | Open-drain driving |  | 500                                 |     | 500                                 |     | 500                               |     |      |

## 6.7 Timing Requirements—V<sub>CCA</sub> = 2.5 V ± 0.2 V

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

|                |                                |                    |             | V <sub>CCB</sub> = 2.5 V<br>± 0.2 V |     | V <sub>CCB</sub> = 3.3 V<br>± 0.3 V |     | V <sub>CCB</sub> = 5 V<br>± 0.5 V |     | UNIT |
|----------------|--------------------------------|--------------------|-------------|-------------------------------------|-----|-------------------------------------|-----|-----------------------------------|-----|------|
|                |                                |                    |             | MIN                                 | MAX | MIN                                 | MAX | MIN                               | MAX |      |
| Data rate      | Push-pull driving              |                    |             | 20                                  |     | 22                                  |     | 24                                |     | Mbps |
|                | Open-drain driving             |                    |             | 2                                   |     | 2                                   |     | 2                                 |     |      |
| t <sub>w</sub> | Pulse duration<br>See Figure 7 | Push-pull driving  | Data inputs | 50                                  |     | 45                                  |     | 41                                |     | ns   |
|                |                                | Open-drain driving |             | 500                                 |     | 500                                 |     | 500                               |     |      |

## 6.8 Timing Requirements— $V_{CCA} = 3.3\text{ V} \pm 0.3\text{ V}$

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

|                |  |                    |  | V <sub>CCB</sub> = 3.3 V<br>± 0.3 V |     | V <sub>CCB</sub> = 5 V<br>± 0.5 V |     | UNIT |
|----------------|--|--------------------|--|-------------------------------------|-----|-----------------------------------|-----|------|
|                |  |                    |  | MIN                                 | MAX | MIN                               | MAX |      |
| Data rate      |  | Push-pull driving  |  | 22                                  |     | 24                                |     | Mbps |
|                |  | Open-drain driving |  | 2                                   |     | 2                                 |     |      |
| t <sub>w</sub> | Pulse duration<br>See <a href="#">Figure 7</a> | Push-pull driving  |  | 45                                  |     | 41                                |     | ns   |
|                |  | Open-drain driving |  | 500                                 |     | 500                               |     |      |

## 6.9 Switching Characteristics— $V_{CCA} = 1.8\text{ V} \pm 0.15\text{ V}$

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

| PARAMETER  |   |  | TEST CONDITIONS    | V <sub>CCB</sub> = 2.5 V<br>± 0.2 V |     | V <sub>CCB</sub> = 3.3 V<br>± 0.3 V |     | V <sub>CCB</sub> = 5 V<br>± 0.5 V |     | UNIT |
|--|---|--|--------------------|-------------------------------------|-----|-------------------------------------|-----|-----------------------------------|-----|------|
|  |   |  |                    | MIN                                 | MAX | MIN                                 | MAX | MIN                               | MAX |      |
| t <sub>PHL(A-B)</sub>                              | Propagation delay time<br>(high to low)<br>See <a href="#">Figure 8</a> | From <b>A</b> (input) to <b>B</b> (output)                 | Push-pull driving  | 6                                   |     | 5.8                                 |     | 5.8                               |     | ns   |
|  |   |  | Open-drain driving | 8.8                                 |     | 9.6                                 |     | 10                                |     |      |
| t <sub>PHL(B-A)</sub>                              | Propagation delay time<br>(high to low)<br>See <a href="#">Figure 8</a> | From <b>B</b> (input) to <b>A</b> (output)                 | Push-pull driving  | 4.4                                 |     | 4.5                                 |     | 4.7                               |     |      |
|  |   |  | Open-drain driving | 5.3                                 |     | 4.4                                 |     | 4                                 |     |      |
| t <sub>PLH(A-B)</sub>                              | Propagation delay time<br>(low to high)<br>See <a href="#">Figure 8</a> | From <b>A</b> (input) to <b>B</b> (output)                 | Push-pull driving  | 7.7                                 |     | 6.8                                 |     | 7                                 |     | ns   |
|  |   |  | Open-drain driving | 50                                  |     | 26                                  |     | 33                                |     |      |
| t <sub>PLH(B-A)</sub>                              | Propagation delay time<br>(low to high)<br>See <a href="#">Figure 8</a> | From <b>B</b> (input) to <b>A</b> (output)                 | Push-pull driving  | 5.3                                 |     | 4.5                                 |     | 0.5                               |     |      |
|  |   |  | Open-drain driving | 36                                  |     | 16                                  |     | 20                                |     |      |
| t <sub>en</sub> (OE-A)<br>t <sub>en</sub> (OE-B)   | Enable time   | From <b>OE</b> (input) to <b>A</b><br>or <b>B</b> (output) |                    | 200                                 |     | 200                                 |     | 200                               |     | ns   |
| t <sub>dis</sub> (OE-A)<br>t <sub>dis</sub> (OE-B) | Disable time  | From <b>OE</b> (input) to <b>A</b><br>or <b>B</b> (output) |                    | 200                                 |     | 200                                 |     | 200                               |     | ns   |
| t <sub>r</sub> (A <sub>x</sub> )                   | Rise time, A port   |  | Push-pull driving  | 9.5                                 |     | 9.3                                 |     | 15                                |     | ns   |
|  |   |  | Open-drain driving | 38                                  | 199 | 30                                  | 150 | 22                                | 109 |      |
| t <sub>r</sub> (B <sub>x</sub> )                   | Rise time, B port   |  | Push-pull driving  | 10.8                                |     | 9.1                                 |     | 7.6                               |     | ns   |
|  |   |  | Open-drain driving | 34                                  | 186 | 23                                  | 112 | 10                                | 58  |      |
| t <sub>f</sub> (A <sub>x</sub> )                   | Fall time, A port   |  | Push-pull driving  | 5.9                                 |     | 6                                   |     | 13.3                              |     | ns   |
|  |   |  | Open-drain driving | 6.9                                 |     | 6.4                                 |     | 6.1                               |     |      |
| t <sub>f</sub> (B <sub>x</sub> )                   | Fall time, B port   |  | Push-pull driving  | 7.6                                 |     | 7.5                                 |     | 8.8                               |     |      |
|  |   |  | Open-drain driving | 13.8                                |     | 16.2                                |     | 16.2                              |     |      |
| t <sub>sk</sub>                                    | Channel-to-channel skew   |  |                    | 1                                   |     | 1                                   |     | 1                                 |     | ns   |
| Maximum data rate                                  |   |  | Push-pull driving  | 18                                  |     | 21                                  |     | 23                                |     | Mbps |
|  |   |  | Open-drain driving | 2                                   |     | 2                                   |     | 2                                 |     |      |

## 6.10 Switching Characteristics— $V_{CCA} = 2.5 \text{ V} \pm 0.2 \text{ V}$

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

| PARAMETER                          |  |   | TEST CONDITIONS    | $V_{CCB} = 2.5 \text{ V} \pm 0.2 \text{ V}$ |     | $V_{CCB} = 3.3 \text{ V} \pm 0.3 \text{ V}$ |     | $V_{CCB} = 5 \text{ V} \pm 0.5 \text{ V}$ |      | UNIT |
|------------------------------------|--|---|--------------------|---|-----|---|-----|---|------|------|
|                                    |  |   |                    | MIN   | MAX | MIN   | MAX | MIN                                       | MAX  |      |
| $t_{PHL(A-B)}$                     | Propagation delay time (high to low)<br>See Figure 8 | From <b>A</b> (input) to <b>B</b> (output)              | Push-pull driving  |   | 3.2 |   | 3.3 |   | 3.4  | ns   |
|                                    |  |   | Open-drain driving |   | 6.3 |   | 6   |   | 5.8  |      |
| $t_{PHL(B-A)}$                     | Propagation delay time (high to low)<br>See Figure 8 | From <b>B</b> (input) to <b>A</b> (output)              | Push-pull driving  |   | 3   |   | 3.6 |   | 4.3  | ns   |
|                                    |  |   | Open-drain driving |   | 4.7 |   | 4.2 |   | 4    |      |
| $t_{PLH(A-B)}$                     | Propagation delay time (low to high)<br>See Figure 8 | From <b>A</b> (input) to <b>B</b> (output)              | Push-pull driving  |   | 3.5 |   | 4.1 |   | 4.4  | ns   |
|                                    |  |   | Open-drain driving |   | 3.5 |   | 4.1 |   | 4.4  |      |
| $t_{PLH(B-A)}$                     | Propagation delay time (low to high)<br>See Figure 8 | From <b>B</b> (input) to <b>A</b> (output)              | Push-pull driving  |   | 2.5 |   | 1.6 |   | 0.7  | ns   |
|                                    |  |   | Open-drain driving |   | 2.5 |   | 1.6 |   | 1    |      |
| $t_{en(OE-A)}$<br>$t_{en(OE-B)}$   | Enable time  | From <b>OE</b> (input) to <b>A</b> or <b>B</b> (output) |                    |   | 200 |   | 200 |   | 200  | ns   |
| $t_{dis(OE-A)}$<br>$t_{dis(OE-B)}$ | Disable time   | From <b>OE</b> (input) to <b>A</b> or <b>B</b> (output) |                    |   | 200 |   | 200 |   | 200  | ns   |
| $t_{r(Ax)}$                        | Rise time, A port                                    |   | Push-pull driving  |   | 7.4 |   | 6.6 |   | 5.6  | ns   |
|                                    |  |   | Open-drain driving | 34  | 180 | 28  | 150 | 24  | 105  |      |
| $t_{r(Bx)}$                        | Rise time, B port                                    |   | Push-pull driving  |   | 8.3 |   | 7.2 |   | 6.1  | ns   |
|                                    |  |   | Open-drain driving | 35  | 170 | 24  | 120 | 12  | 64   |      |
| $t_{f(Ax)}$                        | Fall time, A port                                    |   | Push-pull driving  |   | 5.7 |   | 5.5 |   | 5.3  | ns   |
|                                    |  |   | Open-drain driving |   | 6.9 |   | 6.2 |   | 5.8  |      |
| $t_{f(Bx)}$                        | Fall time, B port                                    |   | Push-pull driving  |   | 7.8 |   | 6.7 |   | 6.6  | ns   |
|                                    |  |   | Open-drain driving |   | 8.8 |   | 9.4 |   | 10.4 |      |
| $t_{sk}$                           | Channel-to-channel skew                              |   |                    |   | 1   |   | 1   |   | 1    | ns   |
|                                    | Maximum data rate                                    |   | Push-pull driving  |   | 20  |   | 22  |   | 24   | Mbps |
|                                    |  |   | Open-drain driving |   | 2   |   | 2   |   | 2    |      |

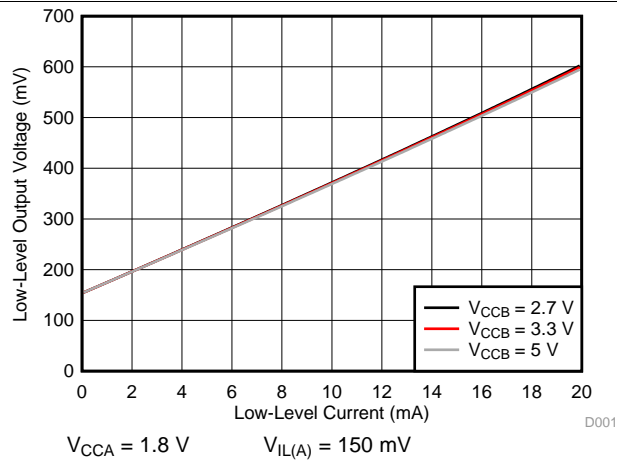


## 6.11 Switching Characteristics— $V_{CCA} = 3.3\text{ V} \pm 0.3\text{ V}$

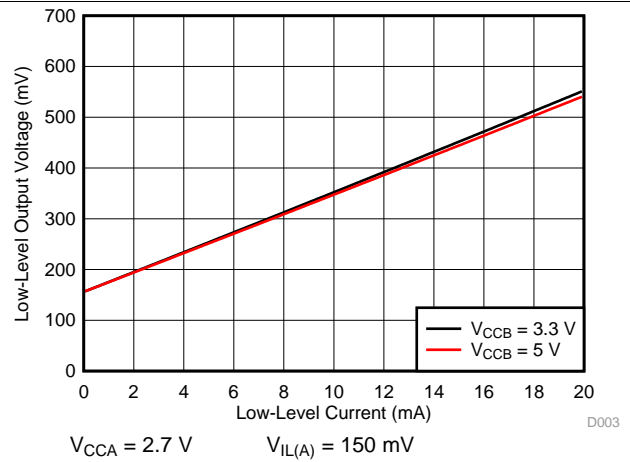
over recommended operating free-air temperature range (unless otherwise noted)

| PARAMETER                          |  |                                    | TEST CONDITIONS    | $V_{CCB} = 3.3\text{ V} \pm 0.3\text{ V}$ |     | $V_{CCB} = 5\text{ V} \pm 0.5\text{ V}$ |     | UNIT |
|------------------------------------|--|------------------------------------|--------------------|---|-----|---|-----|------|
|                                    |  |                                    |                    | MIN                                       | MAX | MIN                                     | MAX |      |
| $t_{PHL(A-B)}$                     | Propagation delay time (high to low)<br>See Figure 8 | From A (input) to B (output)       | Push-pull driving  |   | 2.4 |   | 3.1 | ns   |
|                                    |  |                                    | Open-drain driving |   | 4.2 |   | 4.6 |      |
| $t_{PHL(B-A)}$                     | Propagation delay time (high to low)<br>See Figure 8 | From B (input) to A (output)       | Push-pull driving  |   | 2.5 |   | 3.3 | ns   |
|                                    |  |                                    | Open-drain driving |   | 124 |   | 97  |      |
| $t_{PLH(A-B)}$                     | Propagation delay time (low to high)<br>See Figure 8 | From A (input) to B (output)       | Push-pull driving  |   | 4.2 |   | 4.4 | ns   |
|                                    |  |                                    | Open-drain driving |   | 4.2 |   | 4.4 |      |
| $t_{PLH(B-A)}$                     | Propagation delay time (low to high)<br>See Figure 8 | From B (input) to A (output)       | Push-pull driving  |   | 2.5 |   | 2.6 | ns   |
|                                    |  |                                    | Open-drain driving |   | 2.5 |   | 3.3 |      |
| $t_{en(OE-A)}$<br>$t_{en(OE-B)}$   | Enable time  | From OE (input) to A or B (output) |                    |   | 200 |   | 200 | ns   |
| $t_{dis(OE-A)}$<br>$t_{dis(OE-B)}$ | Disable time   | From OE (input) to A or B (output) |                    |   | 200 |   | 200 | ns   |
| $t_{r(Ax)}$                        | Rise time, A port                                    |                                    | Push-pull driving  |   | 5.6 |   | 5   | ns   |
|                                    |  |                                    | Open-drain driving | 25  | 140 | 19                                      | 102 |      |
| $t_{r(Bx)}$                        | Rise time, B port                                    |                                    | Push-pull driving  |   | 6.4 |   | 7.4 | ns   |
|                                    |  |                                    | Open-drain driving | 26  | 130 | 14                                      | 75  |      |
| $t_{f(Ax)}$                        | Fall time, A port                                    |                                    | Push-pull driving  |   | 5.4 |   | 5   | ns   |
|                                    |  |                                    | Open-drain driving |   | 6.1 |   | 5.7 |      |
| $t_{f(Bx)}$                        | Fall time, B port                                    |                                    | Push-pull driving  |   | 7.4 |   | 7.6 | ns   |
|                                    |  |                                    | Open-drain driving |   | 7.6 |   | 8.3 |      |
| $t_{sk}$                           | Channel-to-channel skew                              |                                    |                    |   | 1   |   | 1   | ns   |
|                                    | Maximum data rate                                    |                                    | Push-pull driving  | 22  |     | 24                                      |     | Mbps |
|                                    |  |                                    | Open-drain driving | 2   |     | 2                                       |     |      |

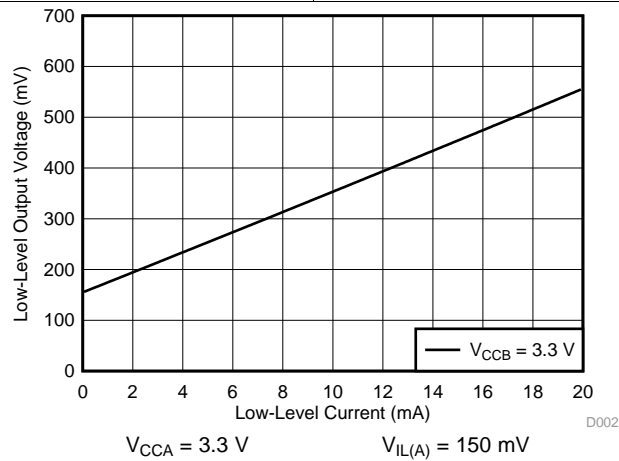
## 6.12 Typical Characteristics



**Figure 1. Low-Level Output Voltage ( $V_{OL(Ax)}$ ) vs Low-Level Current ( $I_{OL(Ax)}$ )**



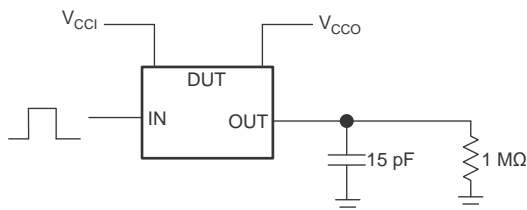
**Figure 2. Low-Level Output Voltage ( $V_{OL(Ax)}$ ) vs Low-Level Current ( $I_{OL(Ax)}$ )**



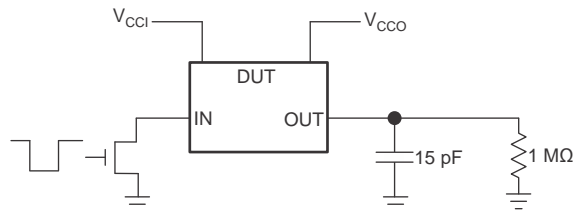
**Figure 3. Low-Level Output Voltage ( $V_{OL(Ax)}$ ) vs Low-Level Current ( $I_{OL(Ax)}$ )**

## 7 Parameter Measurement Information

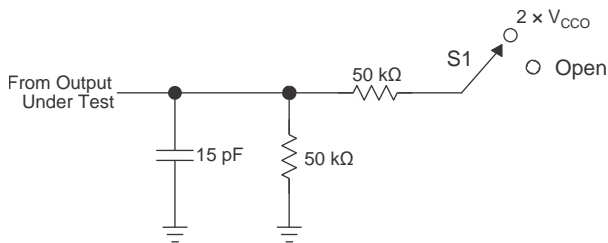
### 7.1 Load Circuits



**Figure 4. Data Rate, Pulse Duration, Propagation Delay, Output Rise-Time and Fall-Time Measurement Using a Push-Pull Driver**



**Figure 5. Data Rate, Pulse Duration, Propagation Delay, Output Rise-Time and Fall-Time Measurement Using an Open-Drain Driver**

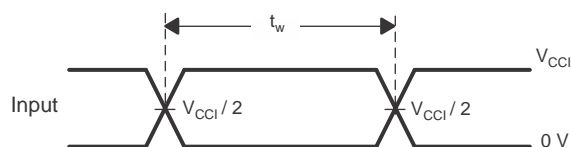


| TEST                                 | S1                 |
|--------------------------------------|--------------------|
| $t_{PZL} / t_{PLZ}$<br>( $t_{dis}$ ) | $2 \times V_{CCO}$ |
| $t_{PHZ} / t_{PZH}$<br>( $t_{en}$ )  | Open               |

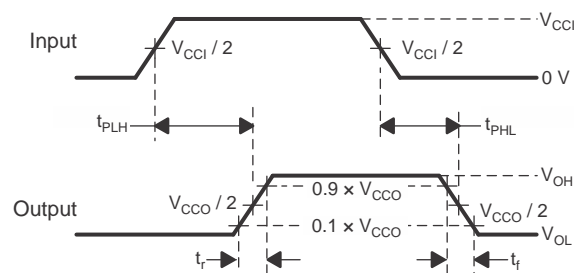
**Figure 6. Load Circuit for Enable-Time and Disable-Time Measurement**

1.  $t_{PLZ}$  and  $t_{PHZ}$  are the same as  $t_{dis}$ .
2.  $t_{PZL}$  and  $t_{PZH}$  are the same as  $t_{en}$ .
3.  $V_{CCI}$  is the  $V_{CC}$  associated with the input port.
4.  $V_{CCO}$  is the  $V_{CC}$  associated with the output port.

## 7.2 Voltage Waveforms

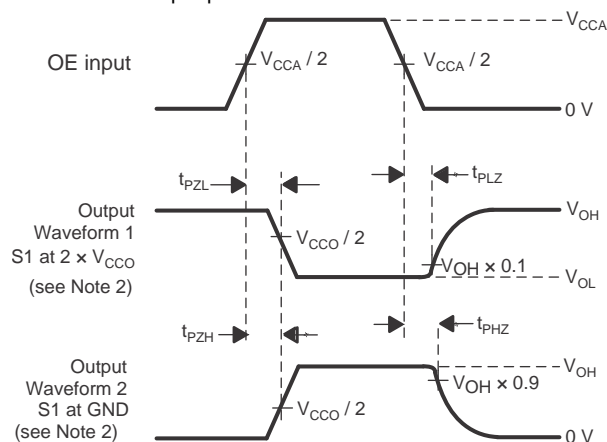


**Figure 7. Pulse Duration**



**Figure 8. Propagation Delay Times**

1.  $C_L$  includes probe and jig capacitance.
2. Waveform 1 in Figure 9 is for an output with internal such that the output is high, except when OE is high (see Figure 6). Waveform 2 in Figure 9 is for an output with conditions such that the output is low, except when OE is high.
3. 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.
4. The outputs are measured one at a time, with one transition per measurement.
5.  $t_{PLZ}$  and  $t_{PHZ}$  are the same as  $t_{dis}$ .
6.  $t_{PZL}$  and  $t_{PZH}$  are the same as  $t_{en}$ .
7.  $t_{PLH}$  and  $t_{PHL}$  are the same as  $t_{pd}$ .
8.  $V_{CCI}$  is the  $V_{CC}$  associated with the input port.
9.  $V_{CCO}$  is the  $V_{CC}$  associated with the output port.



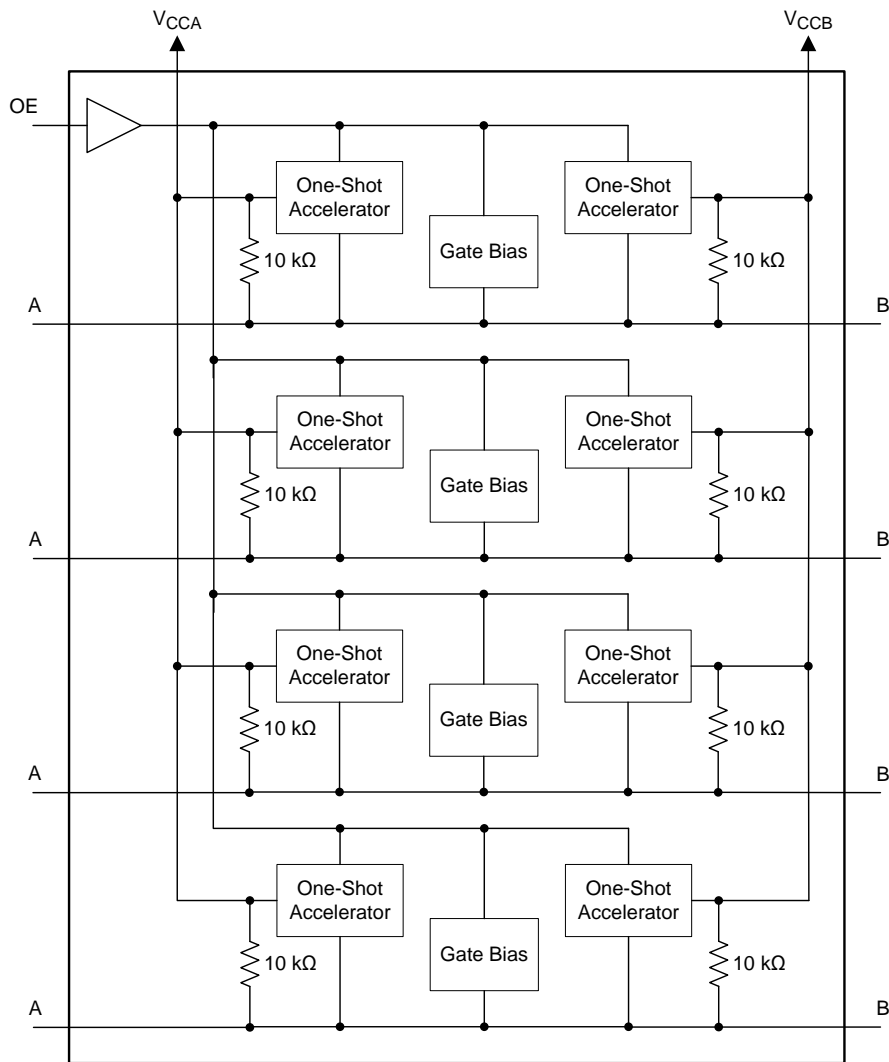
**Figure 9. Enable and Disable Times**

## 8 Detailed Description

### 8.1 Overview

The TXS0104E-Q1 device is a directionless voltage-level translator specifically designed for translating logic voltage levels. The A port is able to accept I/O voltages ranging from 1.65 V to 3.6 V, while the B port can accept I/O voltages from 2.3 V to 5.5 V. The device is a pass gate architecture with edge rate accelerators (one shots) to improve the overall data rate. 10-k $\Omega$  pullup resistors, commonly used in open drain applications, have been conveniently integrated so that an external resistor is not needed. While this device is designed for open drain applications, the device can also translate push-pull CMOS logic outputs.

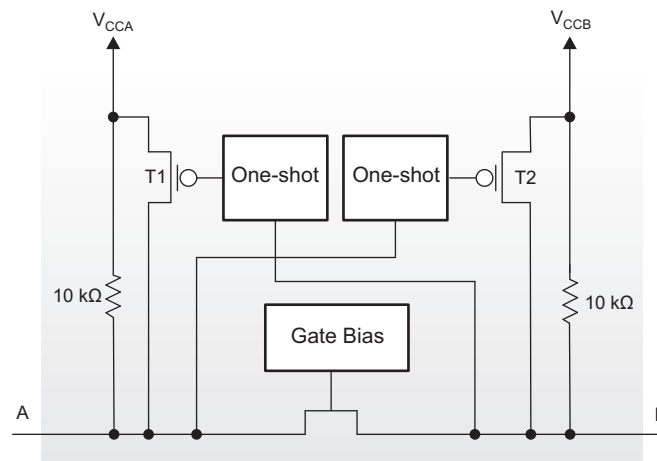
### 8.2 Functional Block Diagram



## 8.3 Feature Description

### 8.3.1 Architecture

The TXS0104E-Q1 architecture (see [Figure 10](#)) does not require a direction-control signal in order to control the direction of data flow from A to B or from B to A.



**Figure 10. Architecture of a TXS01xx Cell**

Each A-port I/O has an internal 10-kΩ pullup resistor to  $V_{CCA}$ , and each B-port I/O has an internal 10-kΩ pullup resistor to  $V_{CCB}$ . The output one-shots detect rising edges on the A or B ports. During a rising edge, the one-shot turns on the PMOS transistors (T1, T2) for a short duration which speeds up the low-to-high transition.

### 8.3.2 Input Driver Requirements

The fall time ( $t_{fA}$ ,  $t_{fB}$ ) of a signal depends on the output impedance of the external device driving the data I/Os of the TXS0104E-Q1 device. Similarly, the  $t_{PHL}$  and maximum data rates also depend on the output impedance of the external driver. The values for  $t_{fA}$ ,  $t_{fB}$ ,  $t_{PHL}$ , and maximum data rates in the data sheet assume that the output impedance of the external driver is less than 50 Ω.

### 8.3.3 Power Up

During operation, ensure that  $V_{CCA} \leq V_{CCB}$  at all times. During power-up sequencing,  $V_{CCA} \geq V_{CCB}$  does not damage the device, so any power supply can be ramped up first.

### 8.3.4 Enable and Disable

The TXS0104E-Q1 device has an OE input that disables the device by setting OE low, which places all I/Os in the high-impedance state. The disable time ( $t_{dis}$ ) indicates the delay between the time when the OE pin goes low and when the outputs actually enter the high-impedance state. The enable time ( $t_{en}$ ) indicates the amount of time the user must allow for the one-shot circuitry to become operational after the OE pin is taken high.

### 8.3.5 Pullup and Pulldown Resistors on I/O Lines

Each A-port I/O has an internal 10-kΩ pullup resistor to  $V_{CCA}$ , and each B-port I/O has an internal 10-kΩ pullup resistor to  $V_{CCB}$ . If a smaller value of pullup resistor is required, an external resistor must be added from the I/O to  $V_{CCA}$  or  $V_{CCB}$  (in parallel with the internal 10-kΩ resistors).

## 8.4 Device Functional Modes

The TXS0104E-Q1 device has two functional modes, enabled and disabled. To disable the device set the OE input low, which places all I/Os in a high impedance state. Setting the OE input high will enable the device.

## 9 Application and Implementation

### 9.1 Application Information

The TXS0104E-Q1 device can be used in level-translation applications for interfacing devices or systems operating at different interface voltages with one another. The TXS0104E-Q1 device is ideal for use in applications where an open-drain driver is connected to the data I/Os. The TXS0104E-Q1 device can also be used in applications where a push-pull driver is connected to the data I/Os, but the TXB0104-Q1 device might be a better option for such push-pull applications.

### 9.2 Typical Application

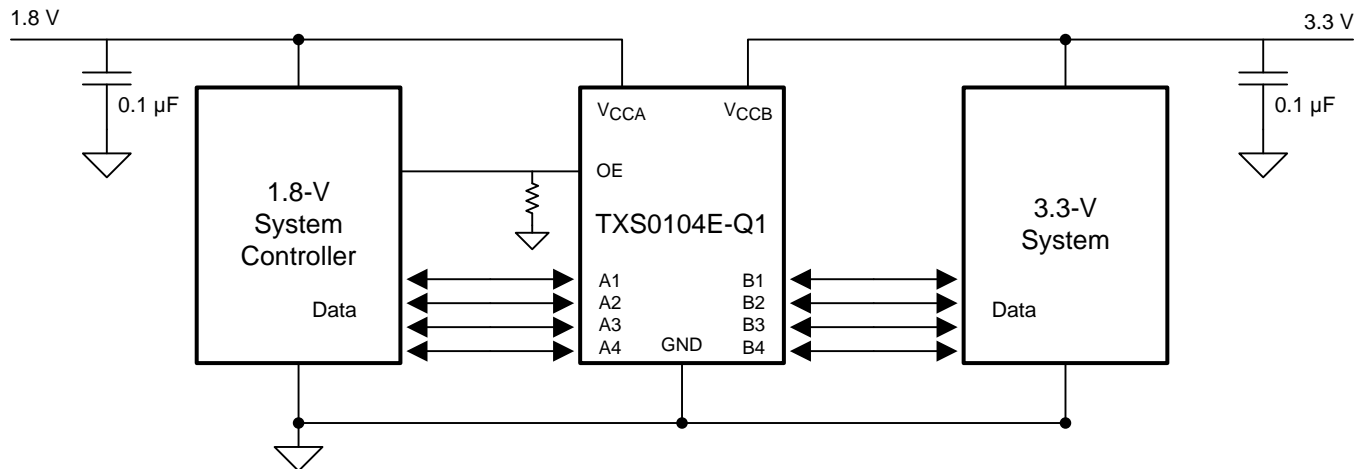


Figure 11. Application Schematic

#### 9.2.1 Design Requirements

For this design example, use the parameters listed in [Table 1](#).

Table 1. Design Parameters

| DESIGN PARAMETER     | EXAMPLE VALUE |
|----------------------|---------------|
| Input voltage range  | 1.65 to 3.6 V |
| Output voltage range | 2.3 to 5.5 V  |

#### 9.2.2 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 TXS0104E-Q1 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 TXS0104E-Q1 device is driving to determine the output voltage range.
  - The TXS0104E-Q1 device has 10-k $\Omega$  internal pullup resistors. External pullup resistors can be added to reduce the total RC of a signal trace if necessary.

- An external pull down resistor decreases the output  $V_{OH}$  and  $V_{OL}$ . Use Equation 1 to calculate the  $V_{OH}$  as a result of an external pull down resistor.

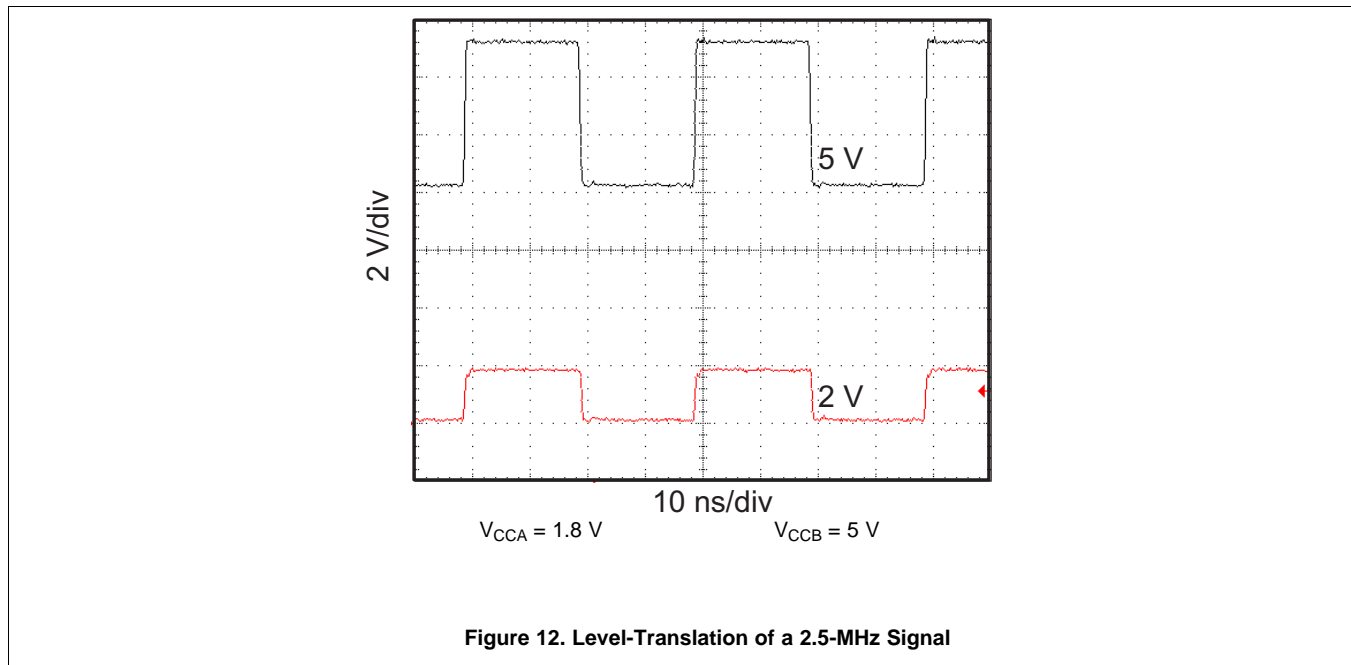
$$V_{OH} = V_{CCx} \times R_{PD} / (R_{PD} + 10 \text{ k}\Omega)$$

where

- $V_{CCx}$  is the supply voltage on either  $V_{CCA}$  or  $V_{CCB}$
- $R_{PD}$  is the value of the external pull down resistor

(1)

### 9.2.3 Application Curve



## 10 Power Supply Recommendations

The TXS0104E-Q1 device uses two separate configurable power-supply rails,  $V_{CCA}$  and  $V_{CCB}$ .  $V_{CCB}$  accepts any supply voltage from 2.3 V to 5.5 V and  $V_{CCA}$  accepts any supply voltage from 1.65 V to 3.6 V as long as  $V_S$  is less than or equal to  $V_{CCB}$ . 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, 3.3-V, and 5-V voltage nodes.

The TXS0104E-Q1 device does not require power sequencing between  $V_{CCA}$  and  $V_{CCB}$  during power-up so the power-supply rails can be ramped in any order. A  $V_{CCA}$  value greater than or equal to  $V_{CCB}$  ( $V_{CCA} \geq V_{CCB}$ ) does not damage the device, but during operation,  $V_{CCA}$  must be less than or equal to  $V_{CCB}$  ( $V_{CCA} \leq V_{CCB}$ ) at all times.

The output-enable (OE) input circuit is designed so that it is supplied by  $V_{CCA}$  and when the (OE) input is low, 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 OE input pin must be tied to GND through a pulldown resistor and must not be enabled until  $V_{CCA}$  and  $V_{CCB}$  are fully ramped and stable. The minimum value of the pulldown resistor to ground is determined by the current-sourcing capability of the driver.



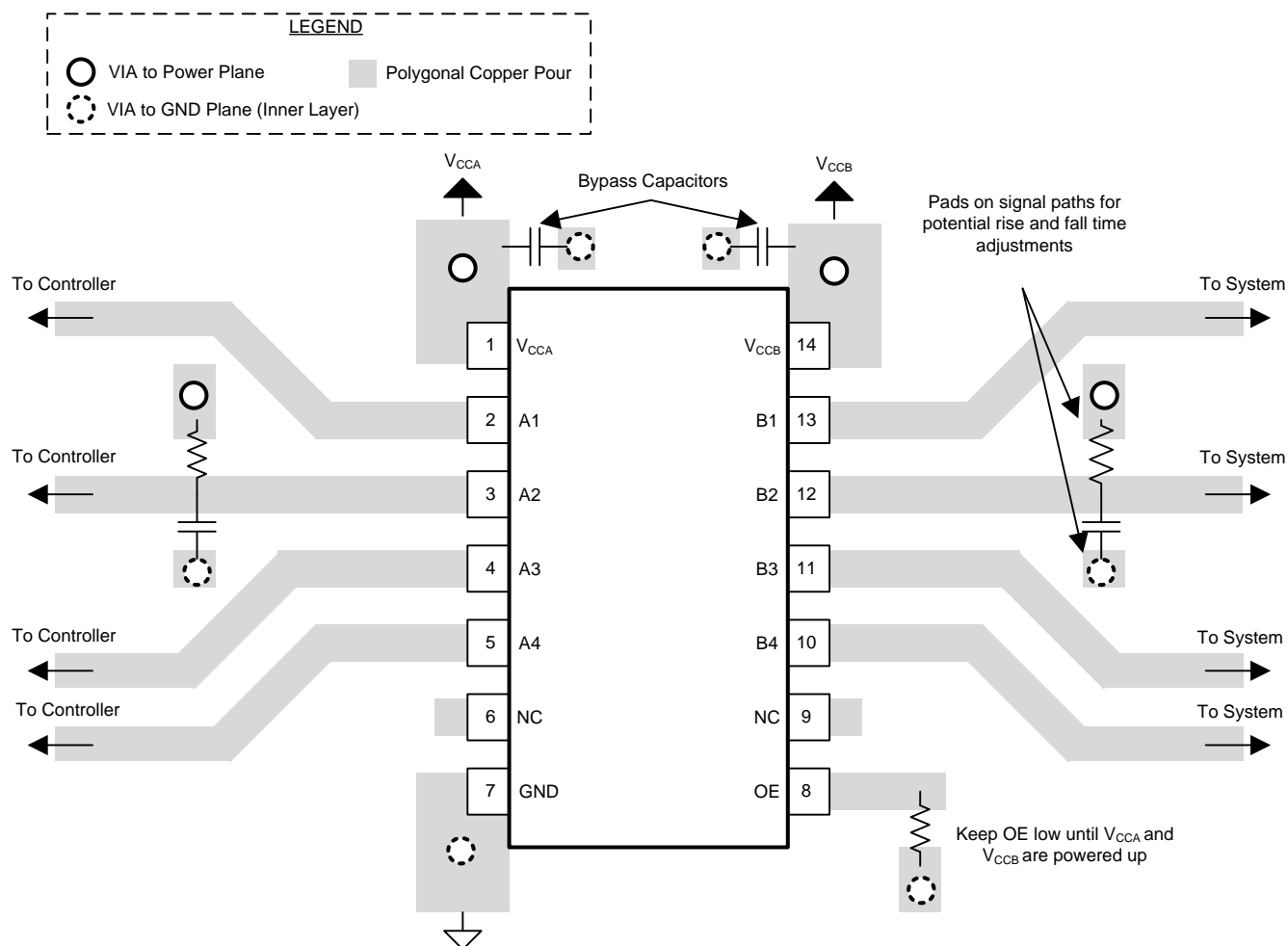
## 11 Layout

### 11.1 Layout Guidelines

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

- Bypass capacitors should be used on power supplies.
- Short trace lengths should be used to avoid excessive loading.
- PCB signal trace-lengths must be kept short enough so that the round-trip delay of any reflection is less than the one shot duration, approximately 30 ns, ensuring that any reflection encounters low impedance at the source driver.
- 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

### 11.2 Layout Example



**Figure 13. TXS0104E-Q1 Layout Example**

## 12 Device and Documentation Support

### 12.1 Trademarks

All trademarks are the property of their respective owners.

### 12.2 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.

### 12.3 Glossary

[SLYZ022](#) — *TI Glossary*.

This glossary lists and explains terms, acronyms and definitions.

## 13 Mechanical, Packaging, and Orderable Information

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

## PACKAGING INFORMATION

| Orderable Device | Status<br>(1) | Package Type | Package<br>Drawing | Pins | Package<br>Qty | Eco Plan<br>(2)            | Lead/Ball Finish<br>(6) | MSL Peak Temp<br>(3) | Op Temp (°C) | Device Marking<br>(4/5) | Samples                 |
|------------------|---------------|--------------|--------------------|------|----------------|----------------------------|-------------------------|----------------------|--------------|-------------------------|-------------------------|
| TXS0104EQPWRQ1   | ACTIVE        | TSSOP        | PW                 | 14   | 2000           | Green (RoHS<br>& no Sb/Br) | CU NIPDAU               | Level-3-260C-168 HR  | -40 to 125   | 04EQ1                   | <a href="#">Samples</a> |

(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.

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In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.

**OTHER QUALIFIED VERSIONS OF TXS0104E-Q1 :**

- Catalog: [TXS0104E](#)

**NOTE:** Qualified Version Definitions:

- Catalog - TI's standard catalog product

**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 |
|----------------|--------------|-----------------|------|------|--------------------|--------------------|---------|---------|---------|---------|--------|---------------|
| TXS0104EQPWRQ1 | TSSOP        | PW              | 14   | 2000 | 330.0              | 12.4               | 6.9     | 5.6     | 1.6     | 8.0     | 12.0   | Q1            |

## TAPE AND REEL BOX DIMENSIONS



\*All dimensions are nominal

| Device         | Package Type | Package Drawing | Pins | SPQ  | Length (mm) | Width (mm) | Height (mm) |
|----------------|--------------|-----------------|------|------|-------------|------------|-------------|
| TXS0104EQPWRQ1 | TSSOP        | PW              | 14   | 2000 | 367.0       | 367.0      | 35.0        |

PW (R-PDSO-G14)

PLASTIC SMALL OUTLINE



4040064-3/G 02/11

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

PW (R-PDSO-G14)

PLASTIC SMALL OUTLINE



4211284-2/F 12/12

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



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