

TLIN2021-Q1 Fault-Protected LIN Transceiver with Inhibit and Wake

1 Features

- AEC-Q100 qualified for automotive applications
- Compliant to LIN 2.0, LIN 2.1, LIN 2.2, LIN 2.2A and ISO 17987–4 Electrical physical layer (EPL) specification (See [SLLA493](#))
- Compliant to SAE J2602-1 LIN Network for Vehicle Applications and SAE J2602-2 LIN Network for Vehicle Applications Conformance Test (See [SLLA493](#))
- Support for 12-V and 24-V applications
- Wide input operational voltage range:
 - V_{SUP} range from 4.5 V to 45 V
- LIN transmit data rate up to 20 kbps
- LIN receive data rate up to 100 kbps
- Operating modes:
 - Normal mode
 - Low-power standby mode
 - Low-power sleep mode
- Low-power mode wake-up support with source recognition:
 - Remote wake-up over the LIN bus
 - Local wake-up via the WAKE pin
 - Local wake-up via EN
- 5-V tolerant input-level support
- Integrated 45-k Ω LIN pull-up resistor
- Control of system-level power using the INH pin
- Power-up/down glitch-free operation on LIN bus and RXD output
- Protection features: ± 60 -V LIN bus fault tolerant, 42-V load dump support, IEC ESD protection, undervoltage protection on V_{SUP} input, TXD dominant state time-out, thermal shutdown, unpowered node or ground disconnection fail-safe at system level
- Junction temperatures from -40°C to 150°C
- Available in the SOIC (8) and VSON (8) package with improved automated optical inspection (AOI) capability

2 Applications

- [Body Electronics and Lighting](#)
- [Infotainment and Cluster](#)
- [Hybrid Electric Vehicles and Power Train Systems](#)
- [Passive Safety](#)
- [Appliances](#)

3 Description

The TLIN2021-Q1 is a local interconnect network (LIN) physical layer transceiver. LIN is a low speed universal asynchronous receiver transmitter (UART) communication protocol that supports automotive in-vehicle networking.

The TLIN2021-Q1 transmitter supports data rates up to 20 kbps and the receiver supports data rates up to 100 kbps for faster end-of-line programming. The TLIN2021-Q1 controls the state of the LIN bus via the TXD pin and reports the state of the bus on its open-drain RXD output pin. The device has a current-limited wave-shaping driver to reduce electromagnetic emissions (EME).

The TLIN2021-Q1 is designed to support 24-V applications with a wide input voltage operating range and also supports low-power sleep mode. The device supports wake-up from low-power mode via wake over LIN, the WAKE pin, or the EN pin. The device allows for system-level reductions in battery current consumption by selectively enabling the various power supplies that may be present on a node through the TLIN2021-Q1 INH output pin.

The TLIN2021-Q1 integrates a resistor for LIN slave applications, ESD protection, and fault protection which allow for a reduced amount of external components in the applications. The device prevents back-feed current through LIN to the supply input in case of a ground shift or supply voltage disconnection.

Device Information⁽¹⁾

| PART NUMBER | PACKAGE | BODY SIZE (NOM) |
|-------------|------------|-------------------|
| TLIN2021-Q1 | SOIC (D) | 4.90 mm x 3.91 mm |
| | VSON (DRB) | 3.00 mm x 3.00 mm |

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

Simplified Master Node Schematic

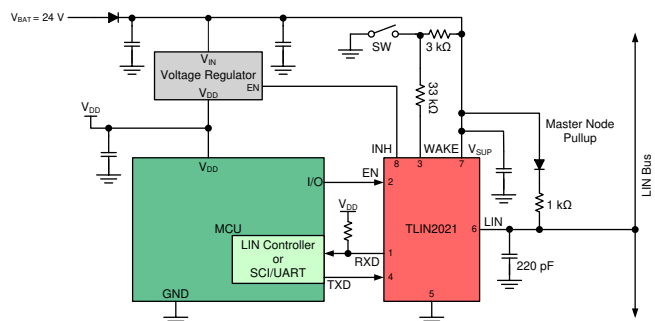


Table of Contents

| | |
|---|--|
| 1 Features 1 2 Applications 1 3 Description 1 4 Revision History 2 5 Description (continued) 3 6 Pin Configuration and Functions 4 7 Specifications 5 7.1 Absolute Maximum Ratings 5 7.2 ESD Ratings..... 6 7.3 Thermal Information 6 7.4 Recommended Operating Conditions 7 7.5 Power Supply Characteristics 7 7.6 Electrical Characteristics..... 7 7.7 AC Switching Characteristics 10 7.8 Typical Characteristics 11 8 Parameter Measurement Information 12 9 Detailed Description 21 9.1 Overview 21 | 9.2 Functional Block Diagram 22 9.3 Feature Description..... 22 9.4 Device Functional Modes..... 25 10 Application and Implementation 30 10.1 Application Information..... 30 10.2 Typical Application 30 11 Power Supply Recommendations 31 12 Layout 32 12.1 Layout Guidelines 32 12.2 Layout Example 32 13 Device and Documentation Support 33 13.1 Documentation Support 33 13.2 Support Resources 33 13.3 Trademarks 33 13.4 Electrostatic Discharge Caution..... 33 13.5 Glossary 33 14 Mechanical, Packaging, and Orderable Information 33 |
|---|--|

4 Revision History

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

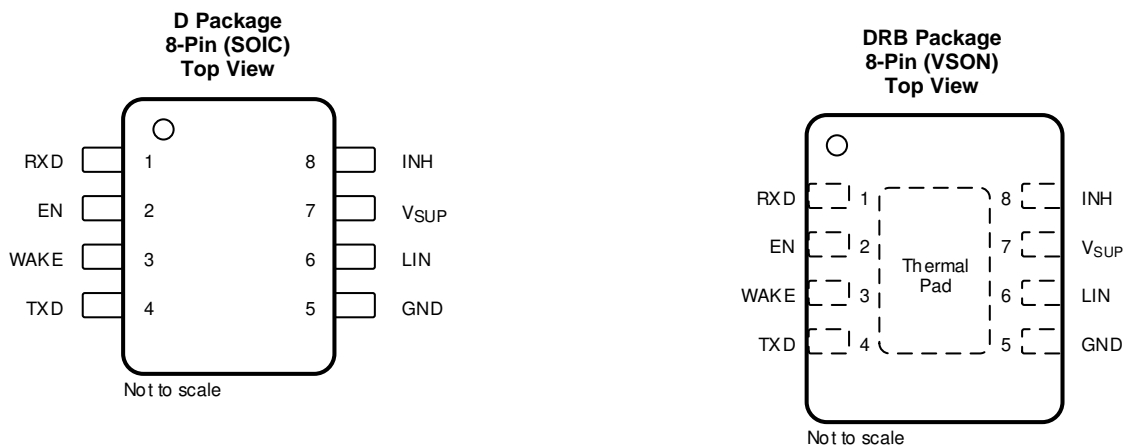
| Changes from Revision A (May 2020) to Revision B | Page |
|--|------|
| • Added: (See SLLA493) to the <i>Features</i> list..... | 1 |
| • Added : See errata TLIN1021-Q1 and TLIN2021-Q1 Duty Cycle Over V_{SUP} | 9 |

| Changes from Original (December 2019) to Revision A | Page |
|--|------|
| • Changed note 3 to: Results given here are specific to the SAE J2962-1 Communication Transceivers Qualification Requirements - LIN. Testing performed by OEM approved independent 3 rd party up to $\pm 35V$, EMC report available upon request. $\pm 85V$ verified internally during characterization..... | 6 |
| • Changed C_{LIN} max value from 45pF to 25pF | 8 |
| • Changed text in the <i>WAKE</i> section from: The WAKE pin is a high-voltage reverse-blocked input used for the local wake-up (LWU) function. To: The WAKE pin is a high-voltage input used for the local wake-up (LWU) function. | 24 |
| • Changed text in the <i>Local Wake-Up (LWU) via WAKE Input Terminal</i> section From: The WAKE terminal is a bi-directional high-voltage reverse battery protected input To: The WAKE terminal is a bi-directional high-voltage input | 27 |

5 Description (continued)

The TLIN2021-Q1 also includes undervoltage detection, temperature shutdown protection, and loss-of-ground protection. In the event of a fault condition, the transmitter is immediately switched off and remains off until the fault condition is removed.

6 Pin Configuration and Functions



Pin Functions

| PIN | | TYPE | DESCRIPTION |
|------------------|-----|--------------|---|
| NAME | NO. | | |
| RXD | 1 | Digital | LIN receive data output, open-drain |
| EN | 2 | Digital | Sleep mode control input, integrated pull-down |
| WAKE | 3 | High Voltage | Local wake-up input, high voltage |
| TXD | 4 | Digital | LIN transmit data input, integrated pulled down - active low after a local wake-up event |
| GND | 5 | GND | Ground connection |
| LIN | 6 | Bus IO | LIN bus input/output line |
| V _{SUP} | 7 | Supply | High-voltage supply from the battery |
| INH | 8 | High Voltage | Inhibit output to control system voltage regulators and supplies, high voltage |
| Thermal Pad | — | — | Electrically connected to GND, connect the thermal pad to the printed circuit board (PCB) ground plane for thermal relief |

7 Specifications

7.1 Absolute Maximum Ratings

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

| | | MIN | MAX | UNIT |
|---------------------|---|------|---------------------------------|------|
| V_{SUP} | Supply voltage range (ISO 17987) | -0.3 | 60 | V |
| V_{LIN} | LIN Bus input voltage (ISO 17987) | -60 | 60 | V |
| V_{WAKE} | WAKE pin input voltage | -0.3 | 60 | V |
| V_{INH} | INH pin output voltage range | -0.3 | 60 and $V_O \leq V_{SUP} + 0.3$ | V |
| V_{LOGIC_INPUT} | Logic input voltage | -0.3 | 6 | V |
| V_{LOGIC_OUTPUT} | Logic output voltage | -0.3 | 6 | V |
| I_O | Digital pin output current | | 8 | mA |
| $I_{O(INH)}$ | Inhibit output current | | 4 | mA |
| $I_{O(WAKE)}$ | WAKE output current due to ground shift ($V_{WAKE} \leq V_{GND} - 0.3$ V thus current out of the WAKE pin must be limited) | | 3 | mA |
| T_J | Junction Temp | -55 | 165 | °C |
| T_{stg} | Storage temperature | -65 | 150 | °C |

- (1) Stresses beyond those listed under *Absolute Maximum Ratings* may cause permanent damage to the device. These are stress ratings only, which do not imply functional operation of the device at these or any other conditions beyond those indicated under *Recommended Operating Conditions*. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

7.2 ESD Ratings

| | | | VALUE | UNIT | | |
|-------------------|-------------------------------------|---|---|------------------------------------|-------|--|
| V _{ESD} | Electrostatic discharge | Human body model (HBM) classification level 3B: V _{SUP} , INH, and WAKE with respect to ground | ±8000 | | | |
| | | Human body model (HBM) classification level 3B: LIN with respect to ground | ±10000 | | | |
| | | Human body model (HBM) classification level 3A: all other pins, per AEC Q100-002 ⁽¹⁾ | ±4000 | | | |
| | | Charged device model (CDM) classification level C5, per AEC Q100-011 | All pins | | ±750 | |
| | | LIN, V _{SUP} , WAKE terminal to GND ⁽²⁾ | IEC 62228-3 per ISO 10605 Contact discharge R = 330 Ω, C = 150 pF (IEC 61000-4-2) | | ±8000 | |
| | | LIN terminal to GND ⁽²⁾ | IEC 62228-3 per ISO 10605 Indirect contact discharge R = 330 Ω, C = 150 pF (IEC 61000-4-2) | | ±8000 | |
| | | LIN terminal to GND ⁽³⁾ | SAE J2962-1 per ISO 10605 Contact discharge | | ±8000 | |
| | LIN terminal to GND ⁽³⁾ | SAE J2962-1 per ISO 10605 Air discharge | ±25000 | | | |
| V _{TRAN} | Non-synchronous transient injection | LIN, V _{SUP} , WAKE terminal to GND ⁽²⁾ | IEC 62228-3 per IEC 62215-3 12 V electrical systems Pulse 1 | -100 | V | |
| | | | IEC 62215-3 24 V electrical systems ⁽⁴⁾ Pulse 1 | -450 | | |
| | | | IEC 62228-3 per IEC 62215-3 12 V electrical systems 24 V electrical systems ⁽⁴⁾ Pulse 2 | 75 | | |
| | | | IEC 62228-3 per IEC 62215-3 12 V electrical systems Pulse 3a | -150 | | |
| | | | IEC 62215-3 24 V electrical systems ⁽⁴⁾ Pulse 3a | -225 | | |
| | | | IEC 62228-3 per IEC 62215-3 12 V electrical systems Pulse 3b | 150 | | |
| | | | IEC 62215-3 24 V electrical systems ⁽⁴⁾ Pulse 3b | 225 | | |
| | | | Direct capacitor coupling | LIN terminal to GND ⁽³⁾ | | SAE J2962-1 per ISO 7637-3 DCC - Slow transient pulse |

- (1) AEC Q100-002 indicates that HBM stressing shall be in accordance with the ANSI/ESDA/JEDEC JS-001 specification.
- (2) Results given here are specific to the IEC 62228-2 Integrated circuits – EMC evaluation of transceivers – Part 2: LIN transceivers. Testing performed by OEM approved independent 3rd party, EMC report available upon request.
- (3) Results given here are specific to the SAE J2962-1 Communication Transceivers Qualification Requirements - LIN. Testing performed by OEM approved independent 3rd party up to ±35V, EMC report available upon request. ±85V verified internally during characterization.
- (4) Verified during characterization

7.3 Thermal Information

| THERMAL METRIC ⁽¹⁾ | | TLIN2021 | | UNIT |
|-------------------------------|--|----------|------------|------|
| | | D (SOIC) | DRB (VSON) | |
| | | PINS | PINS | |
| R _{θJA} | Junction-to-ambient thermal resistance | 125.3 | 53.3 | °C/W |
| R _{θJC(top)} | Junction-to-case (top) thermal resistance | 65.4 | 60 | °C/W |
| R _{θJB} | Junction-to-board thermal resistance | 68.7 | 25.6 | °C/W |
| Ψ _{JT} | Junction-to-top characterization parameter | 17.6 | 1.8 | °C/W |
| Ψ _{JB} | Junction-to-board characterization parameter | 68.0 | 25.5 | °C/W |

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

Thermal Information (continued)

| THERMAL METRIC ⁽¹⁾ | | TLIN2021 | | UNIT |
|-------------------------------|--|----------|------------|------|
| | | D (SOIC) | DRB (VSON) | |
| | | PINS | PINS | |
| $R_{\theta JC(bot)}$ | Junction-to-case (bottom) thermal resistance | – | 9.8 | °C/W |

7.4 Recommended Operating Conditions

parameters valid across $-40^{\circ}\text{C} \leq T_J \leq 150^{\circ}\text{C}$ (unless otherwise noted)

| | | MIN | NOM | MAX | UNIT |
|---------------|--|-----|-----|------|------|
| V_{SUP} | Supply Voltage | 4.5 | | 45 | V |
| V_{LIN} | LIN Bus input voltage | 0 | | 45 | V |
| V_{LOGIC} | Logic Pin Voltage | 0 | | 5.25 | V |
| T_J | Operating virtual junction temperature range | -40 | | 150 | °C |
| T_{SDR} | Thermal shutdown rising | 160 | | | °C |
| T_{SDF} | Thermal shutdown falling | | | 150 | °C |
| $T_{SD(HYS)}$ | Thermal shutdown hysteresis | | 10 | | °C |

7.5 Power Supply Characteristics

parameters valid across $-40^{\circ}\text{C} \leq T_J \leq 150^{\circ}\text{C}$ (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|--|--|---|-----|------|------|---------------|
| Supply Voltage and Current | | | | | | |
| V_{SUP} | Operational supply voltage ISO 17987 Param 10,53 | Device is operational beyond the LIN defined nominal supply voltage range. See Figure 8 and Figure 9 | 4.5 | | 45 | V |
| | Nominal supply voltage ISO 17987 Param 10, 53 | Normal and standby modes ⁽¹⁾ See Figure 8 and Figure 9 | 4.5 | | 45 | V |
| | | Sleep mode | 4.5 | | 45 | V |
| I_{SUP} | Supply current Bus dominant | Normal mode $EN = V_{CC}$, $R_{LIN} \geq 500 \Omega$, $C_{LIN} \leq 10 \text{ nF}$, $INH = WAKE = V_{SUP}$ | | 1.8 | 7.5 | mA |
| | | Standby mode $EN = 0 \text{ V}$, $R_{LIN} \geq 500 \Omega$, $C_{LIN} \leq 10 \text{ nF}$, $INH = WAKE = V_{SUP}$ | | 1 | 2.1 | mA |
| | Supply current Bus recessive | Normal mode $EN = V_{CC}$, $INH = WAKE = V_{SUP}$ | | 400 | 850 | μA |
| | | Standby mode $EN = 0 \text{ V}$, $INH = WAKE = V_{SUP}$ | | 20 | 55 | μA |
| | Supply current Sleep mode | $4.5 \text{ V} < V_{SUP} \leq 27 \text{ V}$, $T_J = 125^{\circ}\text{C}$ $EN = 0 \text{ V}$, $LIN = WAKE = V_{SUP}$, TXD and RXD floating | | 12 | 20 | μA |
| $27 \text{ V} < V_{SUP} \leq 45 \text{ V}$, $T_J = 125^{\circ}\text{C}$ $EN = 0 \text{ V}$, $LIN = WAKE = V_{SUP}$, TXD and RXD floating | | | | | 26 | μA |
| UV_{SUPR} | Under voltage V_{SUP} threshold | Ramp up | | 4.15 | 4.45 | V |
| UV_{SUPF} | Under voltage V_{SUP} threshold | Ramp down | 3.5 | 4 | | V |
| U_{VHYS} | Delta hysteresis voltage for V_{SUP} under voltage threshold | | | 0.13 | | V |

(1) Normal mode ramp V_{SUP} while LIN signal is a 10 kHz square wave with 50% duty cycle and 18 V swing.

7.6 Electrical Characteristics

parameters valid across $-40^{\circ}\text{C} \leq T_J \leq 150^{\circ}\text{C}$ (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|----------------------------|--------------------------------------|--|-----|-----|-----|---------------|
| RXD Output Terminal | | | | | | |
| V_{OL} | Low-level voltage | Based upon external pull-up to V_{CC} ⁽¹⁾ | | | 0.6 | V |
| I_{OL} | Low-level output current, open drain | $LIN = 0 \text{ V}$, $RXD = 0.4 \text{ V}$ | 1.5 | | | mA |
| I_{LKG} | Leakage current, high-level | $LIN = V_{SUP}$, $RXD = V_{CC}$ | -5 | | 5 | μA |

(1) RXD uses open drain output structure therefore V_{OL} level is based upon microcontroller supply voltage.

Electrical Characteristics (continued)

 parameters valid across $-40^{\circ}\text{C} \leq T_J \leq 150^{\circ}\text{C}$ (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|--|---|--|-------|-----|-----------------|---------------|
| TXD Input Terminal | | | | | | |
| V_{IL} | Low-level input voltage | | | | 0.8 | V |
| V_{IH} | High-level input voltage | | 2 | | | V |
| I_{LKG} | Low-level input leakage current | TXD = 0 V | -5 | | 5 | μA |
| $I_{TXD(WAKE)}$ | Local wake-up source recognition TXD ⁽²⁾ | Standby mode after a local wake-up event $V_{LIN} = V_{SUP}$, WAKE = 0 V or V_{SUP} , TXD = 1 V | 1.3 | | 8 | mA |
| R_{TXD} | Internal pull-down resistor value | | 125 | 350 | 800 | k Ω |
| EN Input Terminal | | | | | | |
| V_{IL} | Low-level input voltage | | -0.3 | | 0.8 | V |
| V_{IH} | High-level input voltage | | 2 | | 5.25 | V |
| V_{HYS} | Hysteresis voltage | By design and characterization | 30 | | 500 | mV |
| I_{IL} | Low-level input current | EN = 0 V | -5 | | 5 | μA |
| R_{EN} | Internal pull-down resistor | | 125 | 350 | 800 | k Ω |
| LIN Terminal (Referenced to V_{SUP}) | | | | | | |
| V_{OH} | LIN recessive high-level output voltage | TXD = V_{CC} , $I_O = 0$ mA, $V_{SUP} = 7$ V to 45 V | 0.85 | | | V_{SUP} |
| V_{OH} | LIN recessive high-level output voltage | TXD = V_{CC} , $I_O = 0$ mA, 4.5 V $\leq V_{SUP} \leq 7$ V | 3 | | | V |
| V_{OL} | LIN dominant low-level output voltage | TXD = 0 V, $V_{SUP} = 7$ V to 45 V | | | 0.2 | V_{SUP} |
| V_{OL} | LIN dominant low-level output voltage | TXD = 0 V, 4.5 V $\leq V_{SUP} \leq 7$ V | | | 1.2 | V |
| $V_{SUP_NON_OP}$ | V_{SUP} where impact of recessive LIN bus < 5% ISO 17987 Param 54/56 | TXD & RXD open LIN = 4.5 V to 60 V | -0.3 | | 60 | V |
| $I_{BUS(LIM)}$ | Limiting current ISO 17987 Param 57 | TXD = 0 V, $V_{LIN} = 36$ V, $R_{MEAS} = 480$ Ω , $V_{SUP} = 36$ V, $V_{BUSdom} < 10.224$ V See Figure 13 | 75 | 120 | 300 | mA |
| $I_{BUS_PAS_dom}$ | Receiver leakage current, dominant ISO 17987 Param 58 | Driver off/recessive, LIN = 0 V, $V_{SUP} = 24$ V See Figure 14 | -1 | | | mA |
| $I_{BUS_PAS_rec1}$ | Receiver leakage current, recessive ISO 17987 Param 59 | Driver off/recessive, LIN $\geq V_{SUP}$, 4.5 V $\leq V_{SUP} \leq 45$ V See Figure 15 | | | 20 | μA |
| $I_{BUS_PAS_rec2}$ | Receiver leakage current, recessive ISO 17987 Param 59 | Driver off/recessive, LIN = V_{SUP} See Figure 15 | -5 | | 5 | μA |
| $I_{BUS_NO_GND}$ | Leakage current, loss of ground ISO 17987 Param 60 | GND = $V_{SUP} = 27$ V, 0 V $\leq V_{LIN} \leq 36$ V See | -1.5 | | 1.5 | mA |
| $I_{BUS_NO_BAT}$ | Leakage current, loss of supply ISO 17987 Param 61 | $V_{SUP} = \text{GND}$, 0 V $\leq V_{LIN} \leq 36$ V See | | | 5 | μA |
| V_{BUSdom} | Low-level input voltage ISO 17987 Param 62 | LIN dominant (including LIN dominant for wake up) See Figure 10 and Figure 11 | | | 0.4 | V_{SUP} |
| V_{BUSrec} | High-level input voltage ISO 17987 Param 63 | Lin recessive See Figure 10 and Figure 11 | 0.6 | | | V_{SUP} |
| V_{BUS_CNT} | Receiver center threshold ISO 17987 Param 64 | $V_{BUS_CNT} = (V_{BUSrec} + V_{BUSdom})/2$ See Figure 10 and Figure 11 | 0.475 | 0.5 | 0.525 | V_{SUP} |
| V_{HYS} | Hysteresis voltage ISO 17987 Param 65 | $V_{HYS} = V_{BUSrec} - V_{BUSdom}$ See Figure 10 and Figure 11 | | | 0.175 | V_{SUP} |
| V_{SERIAL_DIODE} | Serial diode LIN termination pull-up path | $I_{SERIAL_DIODE} = 10$ μA | 0.4 | 0.7 | 1.0 | V |
| R_{SLAVE} | Pull-up resistor to V_{SUP} | Normal and standby modes | 20 | 45 | 60 | k Ω |
| I_{RSLEEP} | Pull-up current source to V_{SUP} sleep mode | $V_{SUP} = 27$ V, LIN = GND | -20 | | -1.5 | μA |
| C_{LIN} | Capacitance of the LIN pin | | | | 25 | pF |
| INH Output Terminal | | | | | | |
| ΔV_H | High level voltage drop INH with respect to V_{SUP} | $I_{INH} = -0.5$ mA | | 0.5 | 1 | V |
| $I_{LKG(INH)}$ | Leakage current sleep mode | INH = 0 V | -0.5 | | 0.5 | μA |
| WAKE Input Terminal | | | | | | |
| V_{IH} | High-level input voltage | Standby and sleep mode | | | $V_{SUP} - 1.8$ | V |

(2) Open drain-drive

Electrical Characteristics (continued)

 parameters valid across $-40^{\circ}\text{C} \leq T_J \leq 150^{\circ}\text{C}$ (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|---|---|-------|-------|------------------|---------------|
| V_{IL} | Low-level input voltage | Standby and sleep mode | | | $V_{SUP} - 3.85$ | V |
| I_{IH} | High-level input leakage current | WAKE = $V_{SUP} - 1$ V | -25 | -12.5 | | μA |
| I_{IL} | High-level input leakage current | WAKE = 1 V | | 15 | 25 | μA |
| t_{WAKE} | WAKE hold time | Wake up time from sleep mode | 5 | | 50 | μs |
| Duty Cycle Characteristics⁽³⁾ | | | | | | |
| $D1_{12V}$ | Duty Cycle 1 ISO 17987 Param 27 ⁽⁴⁾ | $TH_{REC(MAX)} = 0.744 \times V_{SUP}$, $TH_{DOM(MAX)} = 0.581 \times V_{SUP}$, $V_{SUP} = 7$ V to 18 V, $t_{BIT} = 50$ μs (20 kbps), $D1 = t_{BUS_rec(min)}/(2 \times t_{BIT})$ See Figure 17 and Figure 18 | 0.396 | | | |
| $D1_{12V}$ | Duty Cycle 1 | $TH_{REC(MAX)} = 0.625 \times V_{SUP}$, $TH_{DOM(MAX)} = 0.581 \times V_{SUP}$, $V_{SUP} = 4.5$ V to 7 V, $t_{BIT} = 50$ μs (20 kbps), $D1 = t_{BUS_rec(min)}/(2 \times t_{BIT})$ See Figure 17 and Figure 18 | 0.396 | | | |
| $D2_{12V}$ | Duty Cycle 2 ISO 17987 Param 28 | $TH_{REC(MIN)} = 0.422 \times V_{SUP}$, $TH_{DOM(MIN)} = 0.284 \times V_{SUP}$, $V_{SUP} = 4.5$ V to 18 V, $t_{BIT} = 50$ μs (20 kbps), $D2 = t_{BUS_rec(MAX)}/(2 \times t_{BIT})$ See Figure 17 and Figure 18 | | | 0.581 | |
| $D3_{12V}$ | Duty Cycle 3 ISO 17987 Param 29 ⁽⁵⁾ | $TH_{REC(MAX)} = 0.778 \times V_{SUP}$, $TH_{DOM(MAX)} = 0.616 \times V_{SUP}$, $V_{SUP} = 7$ V to 18 V, $t_{BIT} = 96$ μs (10.4 kbps), $D3 = t_{BUS_rec(min)}/(2 \times t_{BIT})$ See Figure 17 and Figure 18 | 0.417 | | | |
| $D3_{12V}$ | Duty Cycle 3 | $TH_{REC(MAX)} = 0.645 \times V_{SUP}$, $TH_{DOM(MAX)} = 0.616 \times V_{SUP}$, $V_{SUP} = 4.5$ V to 7 V, $t_{BIT} = 96$ μs (10.4 kbps), $D3 = t_{BUS_rec(min)}/(2 \times t_{BIT})$ See Figure 17 and Figure 18 | 0.417 | | | |
| $D4_{12V}$ | Duty Cycle 4 ISO 17987 Param 30 | $TH_{REC(MIN)} = 0.389 \times V_{SUP}$, $TH_{DOM(MIN)} = 0.251 \times V_{SUP}$, $V_{SUP} = 7$ V to 18 V, $t_{BIT} = 96$ μs (10.4 kbps), $D4 = t_{BUS_rec(MAX)}/(2 \times t_{BIT})$ See Figure 17 and Figure 18 | | | 0.59 | |
| $D4_{12V}$ | Duty Cycle 4 | $TH_{REC(MIN)} = 0.422 \times V_{SUP}$, $TH_{DOM(MIN)} = 0.284 \times V_{SUP}$, $V_{SUP} = 4.5$ V to 7 V, $t_{BIT} = 96$ μs (10.4 kbps), $D4 = t_{BUS_rec(MAX)}/(2 \times t_{BIT})$ See Figure 17 and Figure 18 | | | 0.59 | |
| $D1_{24V}$ | Duty Cycle 1 ISO 17987 Param 72 | $TH_{REC(MAX)} = 0.710 \times V_{SUP}$, $TH_{DOM(MAX)} = 0.554 \times V_{SUP}$, $V_{SUP} = 15$ V to 36 V, $t_{BIT} = 50$ μs , $D1 = t_{BUS_rec(MIN)}/(2 \times t_{BIT})$ See Figure 19 and Figure 20 | 0.330 | | | |
| $D2_{24V}$ | Duty Cycle 2 ISO 17987 Param 73 | $TH_{REC(MIN)} = 0.446 \times V_{SUP}$, $TH_{DOM(MIN)} = 0.302 \times V_{SUP}$, $V_{SUP} = 15.6$ V to 36 V, $t_{BIT} = 50$ μs , $D2 = t_{BUS_rec(MAX)}/(2 \times t_{BIT})$ See Figure 19 and Figure 20 | | | 0.642 | |
| $D3_{24V}$ | Duty Cycle 3 ISO 17987 Param 74 | $TH_{REC(MAX)} = 0.744 \times V_{SUP}$, $TH_{DOM(MAX)} = 0.581 \times V_{SUP}$, $V_{SUP} = 7$ V to 36 V, $t_{BIT} = 96$ μs , $D3 = t_{BUS_rec(min)}/(2 \times t_{BIT})$ See Figure 19 and Figure 20 | 0.386 | | | |

(3) See errata [TLIN1021-Q1](#) and [TLIN2021-Q1 Duty Cycle Over \$V_{SUP}\$](#)

(4) Duty cycle LIN driver bus load conditions (C_{LINBUS} , R_{LINBUS}): Load1 = 1 nF; 1 k Ω / Load2 = 6.8 nF; 660 Ω / Load3 = 10 nF; 500 Ω .

(5) Duty cycles 3 and 4 are defined for 10.4-kbps operation. The TLIN2029 meets these lower data rate requirements while it is also capable of the higher speed 20-kbps operation as specified by duty cycles 1 and 2. SAE J2602 derives propagation delay equations from the LIN 2.0 duty cycle definitions, for details see the SAE J2602 specification.

Electrical Characteristics (continued)

 parameters valid across $-40^{\circ}\text{C} \leq T_J \leq 150^{\circ}\text{C}$ (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|-------------------|------------------------------------|--|-------|-----|-------|------|
| D3 _{24V} | Duty Cycle 3 | $TH_{REC(MAX)} = 0.645 \times V_{SUP}$, $TH_{DOM(MAX)} = 0.581 \times V_{SUP}$, $V_{SUP} = 4.5\text{ V to }7\text{ V}$, $t_{BIT} = 96\ \mu\text{s}$, $D3 = t_{BUS_rec(min)}/(2 \times t_{BIT})$ See Figure 19 and Figure 20 | 0.386 | | | |
| D4 _{24V} | Duty Cycle 4 ISO 17987 Param 75 | $TH_{REC(MIN)} = 0.422 \times V_{SUP}$, $TH_{DOM(MIN)} = 0.284 \times V_{SUP}$, $V_{SUP} = 4.5\text{ V to }36\text{ V}$, $t_{BIT} = 96\ \mu\text{s}$, $D4 = t_{BUS_rec(MAX)}/(2 \times t_{BIT})$ See Figure 19 and Figure 20 | | | 0.591 | |

7.7 AC Switching Characteristics

 parameters valid across $-40^{\circ}\text{C} \leq T_J \leq 150^{\circ}\text{C}$ (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|--|---|-----|-----|-----|---------------|
| Device Switching Characteristics | | | | | | |
| t_{rx_pdr} | Receiver rising propagation delay time ISO 17987 Param 31 | $R_{RXD} = 2.4\text{ k}\Omega$, $C_{RXD} = 20\text{ pF}$ See Figure 19 and Figure 20 | | | 6 | μs |
| t_{rx_pdf} | Receiver falling propagation delay time ISO 17987 Param 31 | | | | 6 | μs |
| t_{rs_sym} | Symmetry of receiver propagation delay time Receiver rising propagation delay time ISO 17987 Param 32 | Rising edge with respect to falling edge $t_{rx_sym} = t_{rx_pdf} - t_{rx_pdr}$, $R_{RXD} = 2.4\text{ k}\Omega$, $C_{RXD} = 20\text{ pF}$ See Figure 19 and Figure 20 | -2 | | 2 | μs |
| t_{LINBUS} | Minimum dominant time on LIN bus for wake-up | See Figure 23 , Figure 25 and Figure 26 | 25 | 65 | 150 | μs |
| t_{CLEAR} | Time to clear false wake-up prevention logic if LIN bus had a bus stuck dominant fault (recessive time on LIN bus to clear bus stuck dominant fault) | See Figure 26 | 8 | 25 | 50 | μs |
| t_{MODE_CHANGE} | Mode change delay time | Time to change from normal mode to sleep mode through EN pin See Figure 21 | 2 | | 15 | μs |
| t_{NOMINT} | Normal mode initialization time ⁽¹⁾ | Time for normal mode to initialize and data on RXD pin to be valid, includes t_{MODE_CHANGE} for standby to normal mode. See Figure 21 | | | 45 | μs |
| t_{PWR} | Power-up time | Time it takes for valid data on RXD upon power-up | | | 1.5 | ms |
| t_{TXD_DTO} | Dominant state time out | | 20 | 50 | 80 | ms |

 (1) The transition time from sleep mode to normal mode includes both t_{MODE_CHANGE} and t_{NOMINT} .

7.8 Typical Characteristics

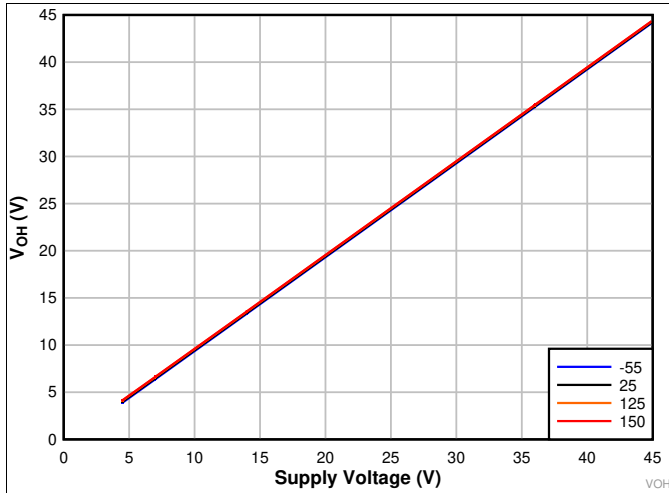


Figure 1. V_{OH} vs V_{SUP} and Temperature

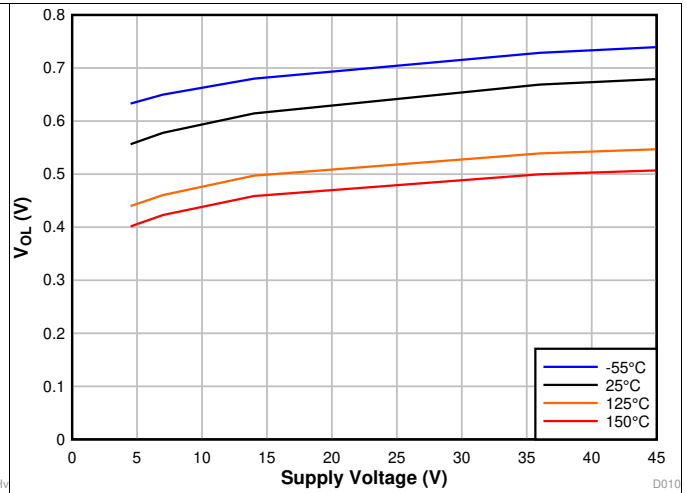


Figure 2. V_{OL} vs V_{SUP} and Temperature

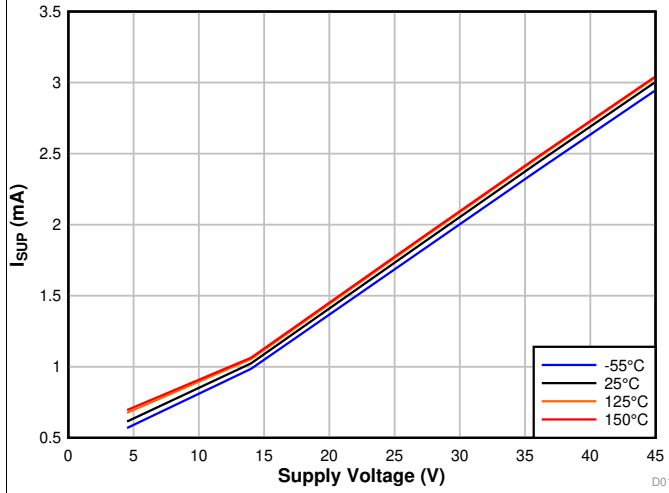


Figure 3. I_{SUP} Dominant vs V_{SUP} and Temperature

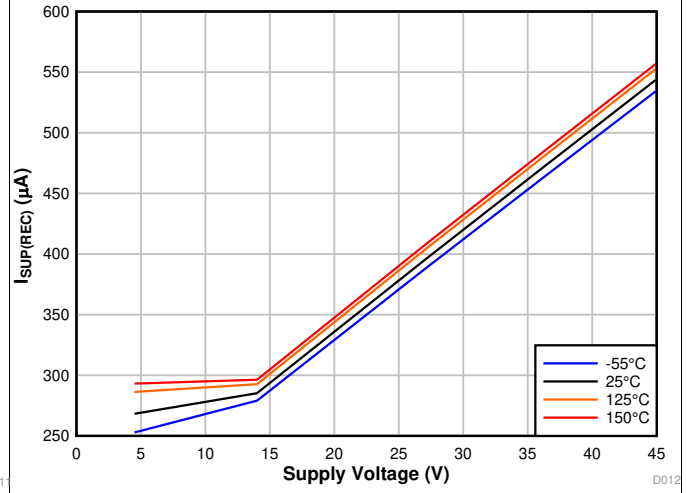


Figure 4. I_{SUP} Recessive vs V_{SUP} and Temperature

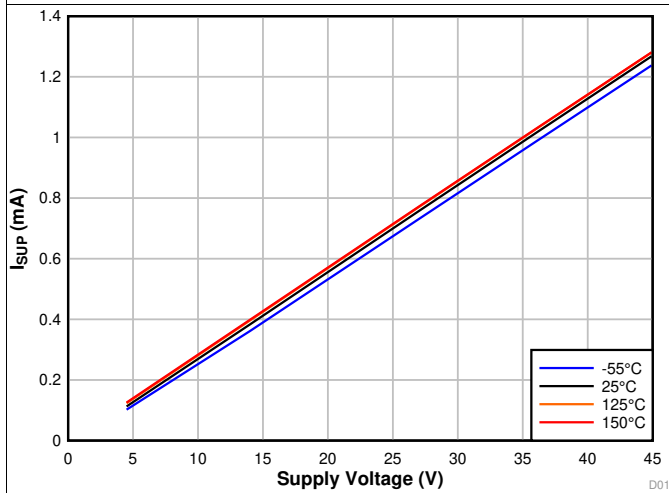


Figure 5. Standby Mode I_{SUP} Dominant vs V_{SUP} and Temperature

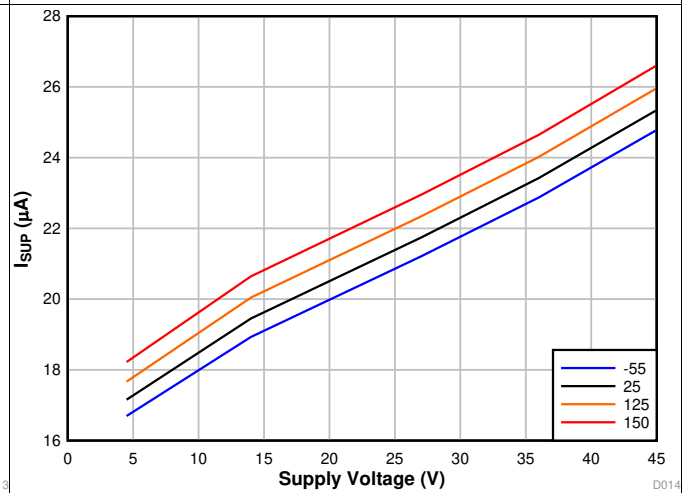
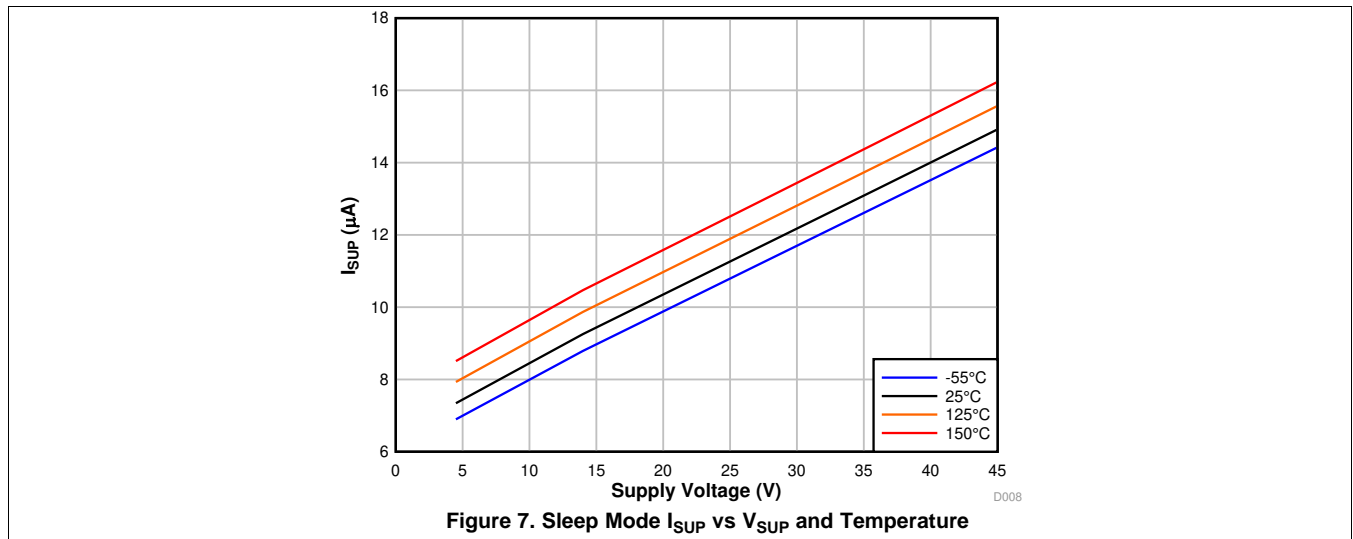
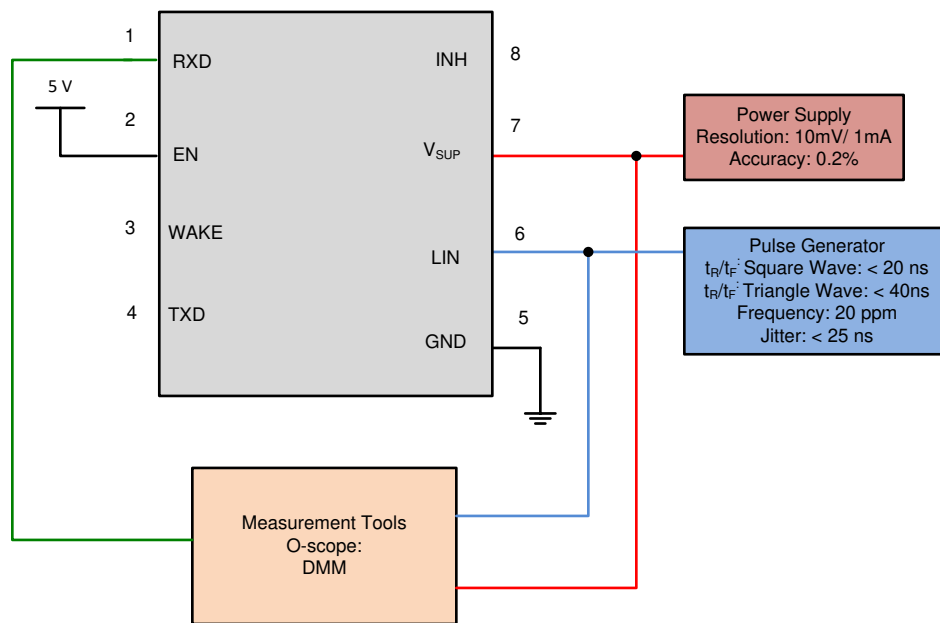


Figure 6. Standby Mode I_{SUP} Recessive vs V_{SUP} and Temperature

Typical Characteristics (continued)



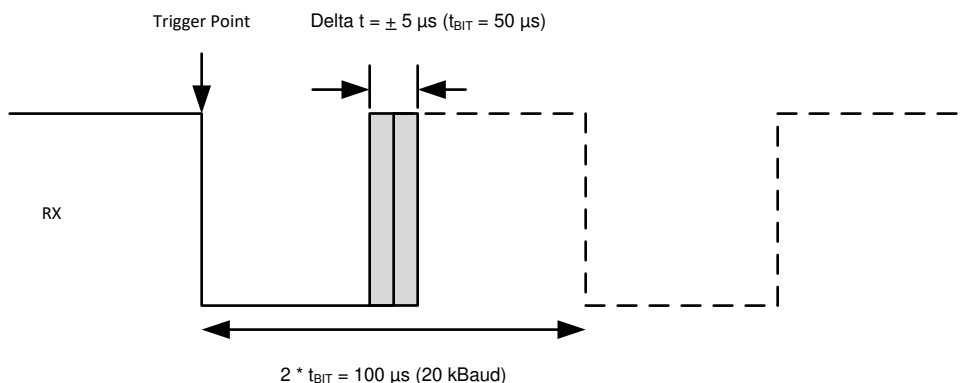
8 Parameter Measurement Information



Copyright © 2019, Texas Instruments Incorporated

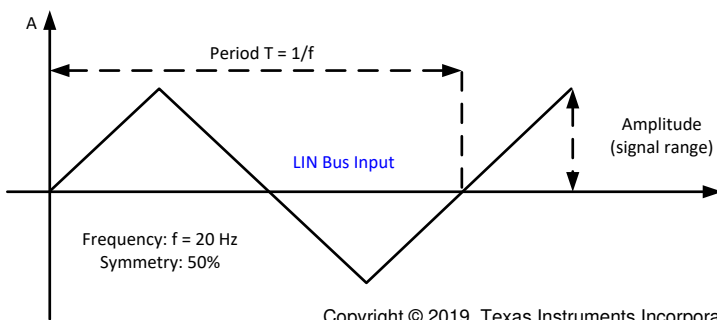
Figure 8. Test System: Operating Voltage Range with RX and TX Access: Parameters 9, 10

Parameter Measurement Information (continued)



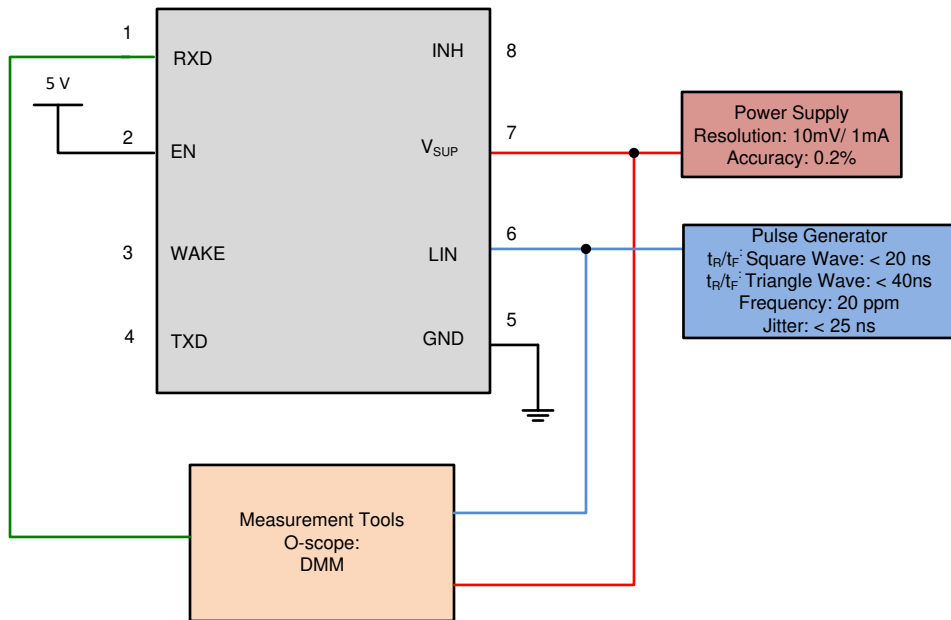
Copyright © 2019, Texas Instruments Incorporated

Figure 9. RX Response: Operating Voltage Range



Copyright © 2019, Texas Instruments Incorporated

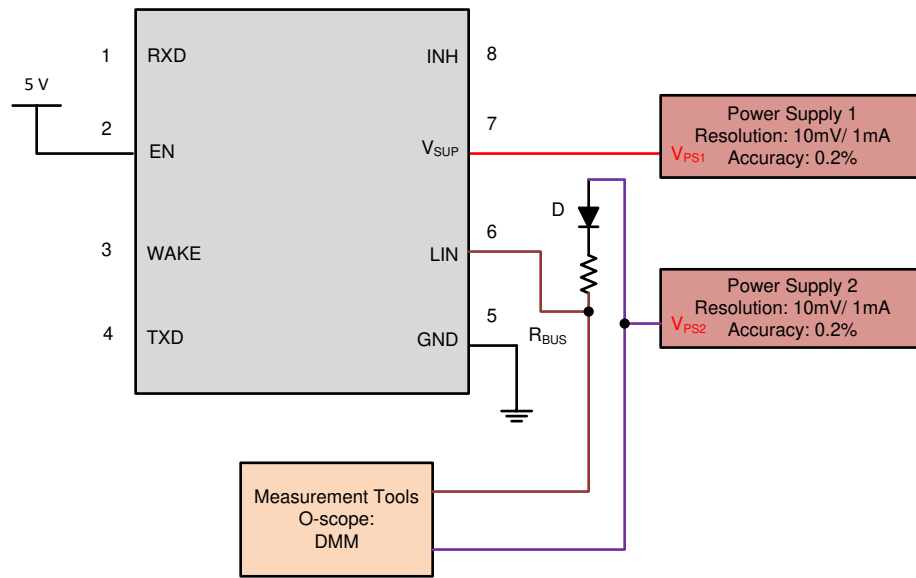
Figure 10. LIN Bus Input Signal



Copyright © 2019, Texas Instruments Incorporated

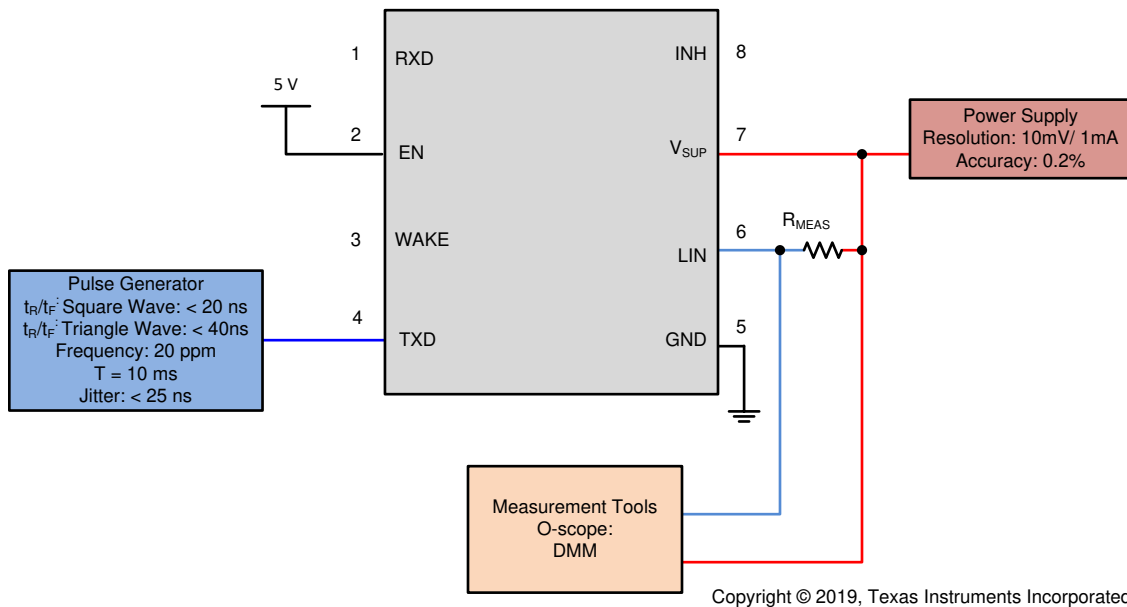
Figure 11. LIN Receiver Test with RX access Param 17, 18, 19, 20

Parameter Measurement Information (continued)



Copyright © 2019, Texas Instruments Incorporated

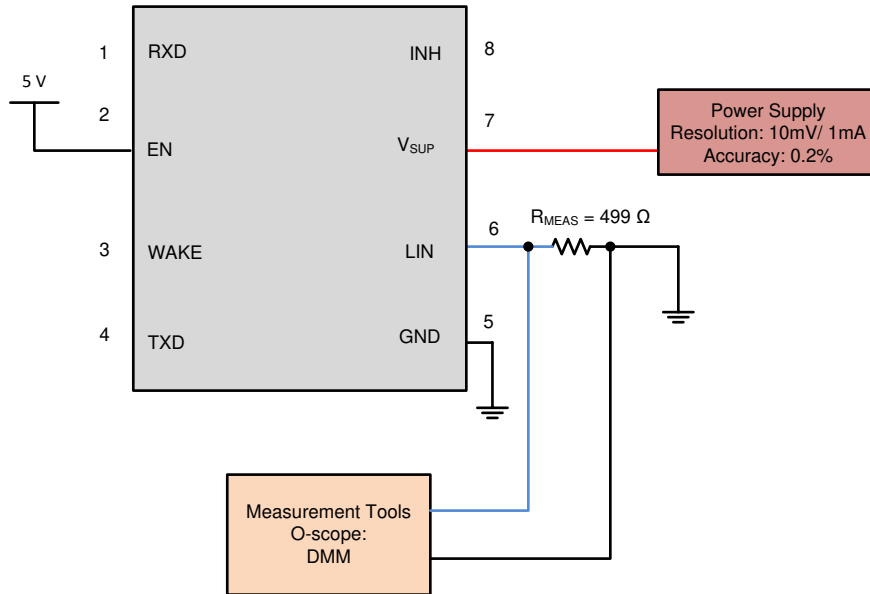
Figure 12. $V_{SUP_NON_OP}$ Param 1154/56



Copyright © 2019, Texas Instruments Incorporated

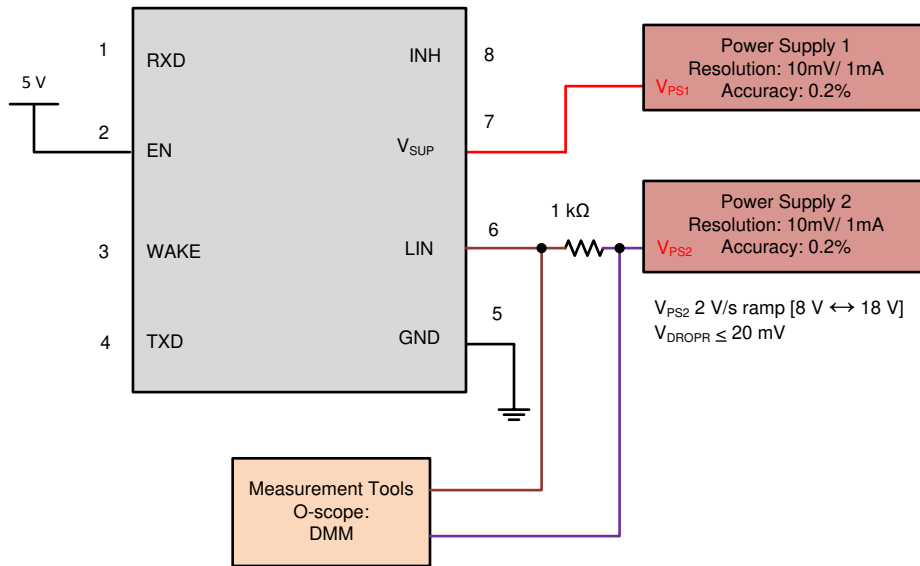
Figure 13. Test Circuit for I_{BUS_LIM} at Dominant State (Driver on) Param 12

Parameter Measurement Information (continued)



Copyright © 2019, Texas Instruments Incorporated

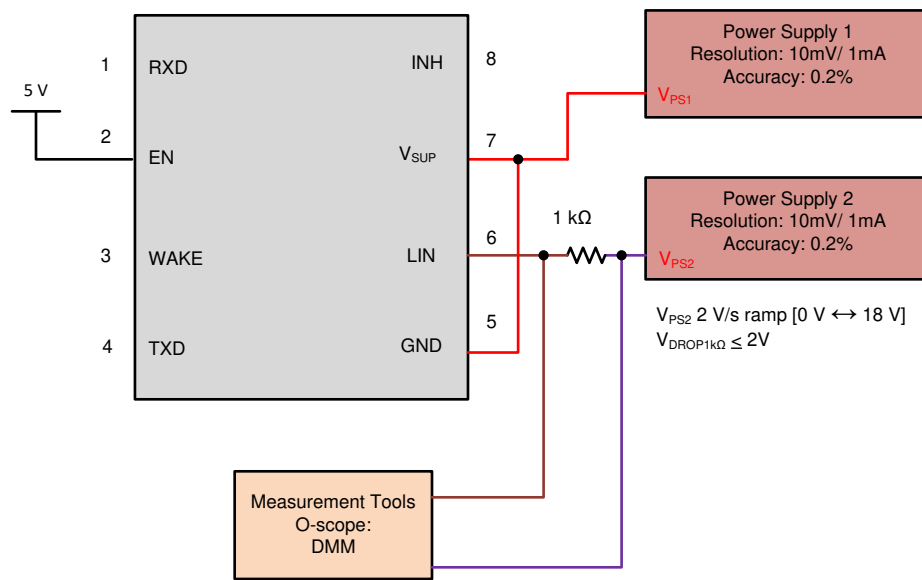
Figure 14. Test Circuit for $I_{BUS_PAS_dom}$; TXD = Recessive State $V_{BUS} = 0\text{ V}$, Param 13



Copyright © 2019, Texas Instruments Incorporated

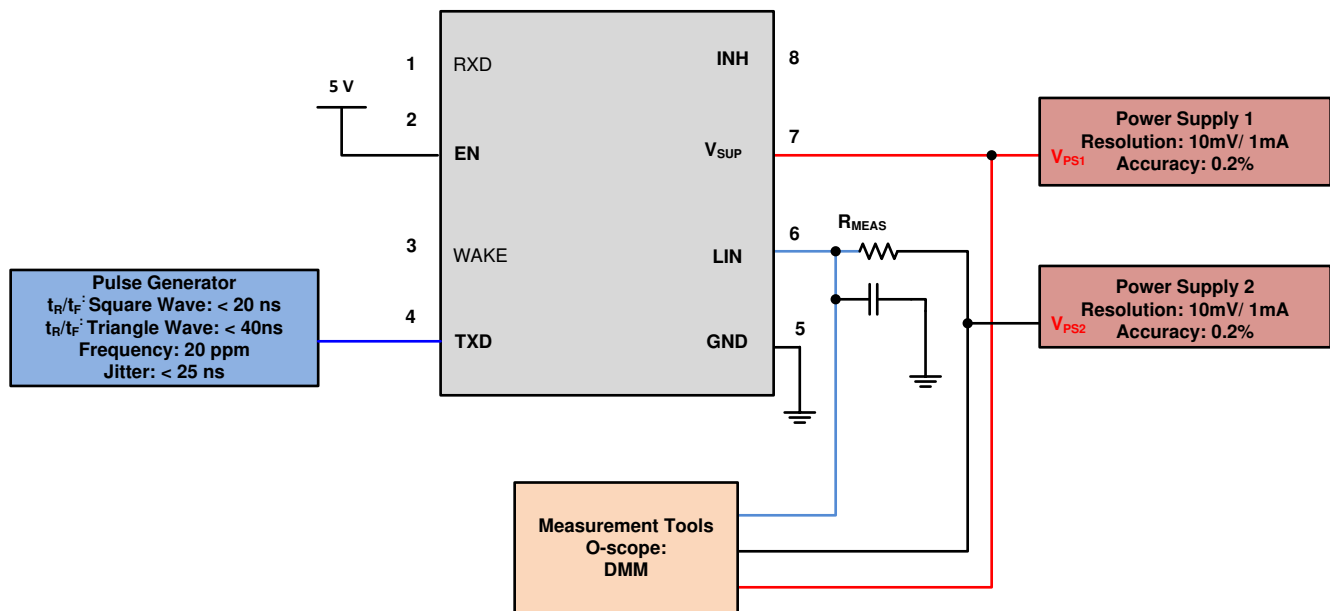
Figure 15. Test Circuit for $I_{BUS_PAS_rec}$ Param 14

Parameter Measurement Information (continued)



Copyright © 2019, Texas Instruments Incorporated

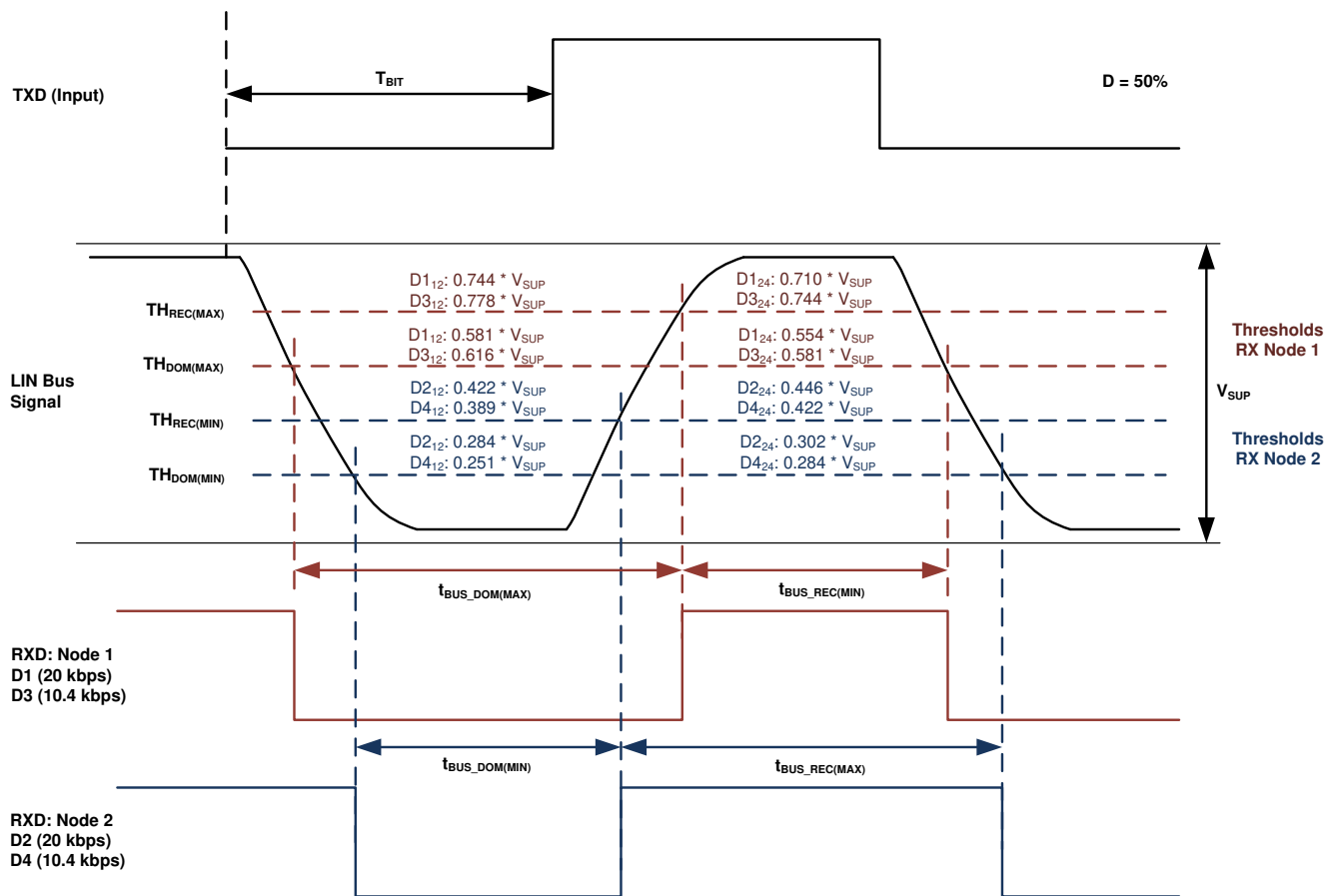
Figure 16. Test Circuit for $I_{BUS_NO_GND}$ Loss of GND



Copyright © 2019, Texas Instruments Incorporated

Figure 17. Test Circuit Slope Control and Duty Cycle Param 27, 28, 29, 30, 72, 73, 74, 75

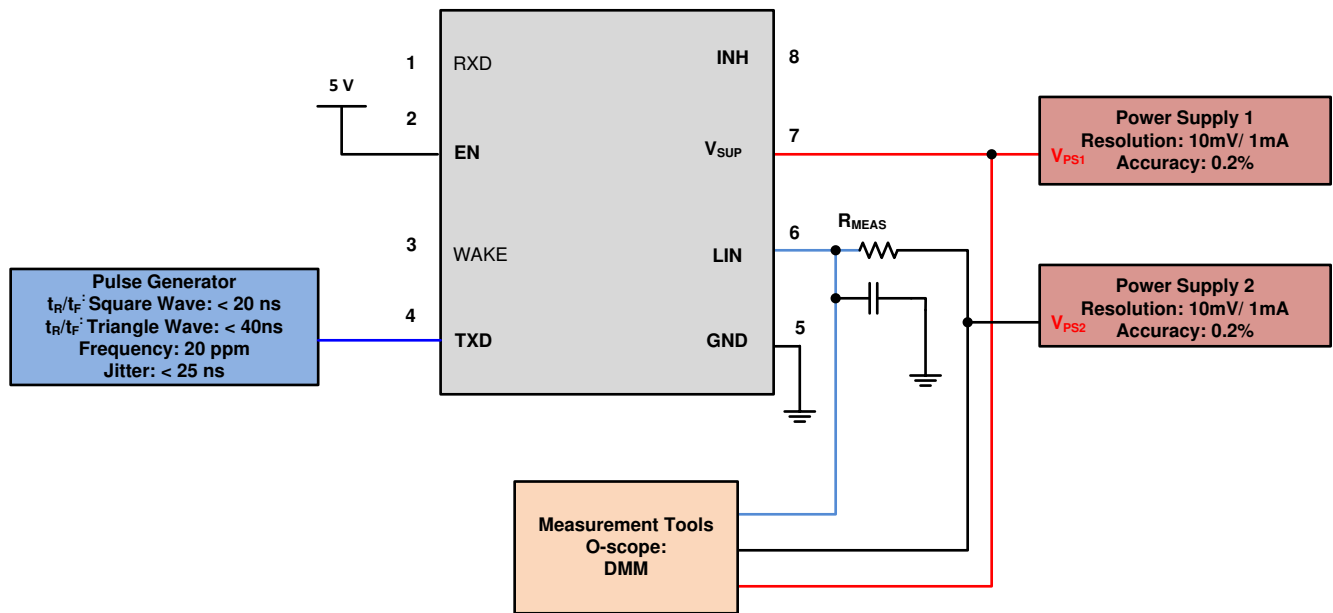
Parameter Measurement Information (continued)



Copyright © 2019, Texas Instruments Incorporated

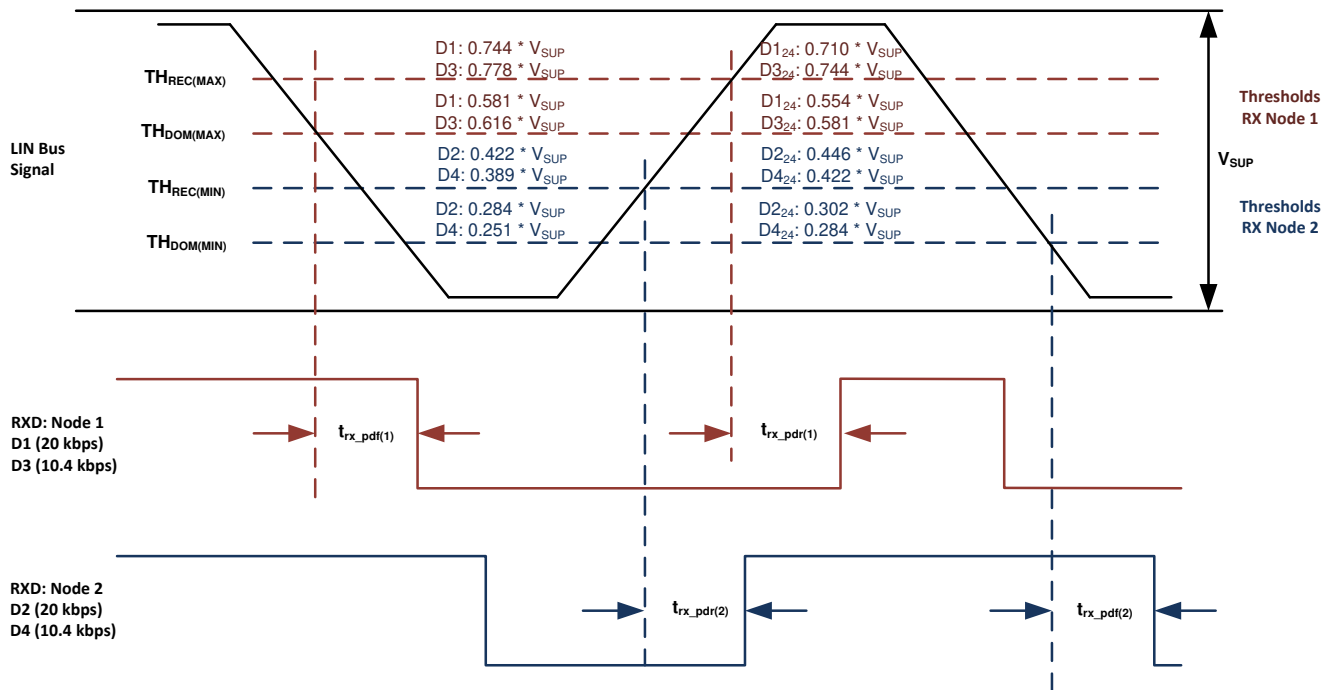
Figure 18. Definition of Bus Timing Parameters

Parameter Measurement Information (continued)



Copyright © 2019, Texas Instruments Incorporated

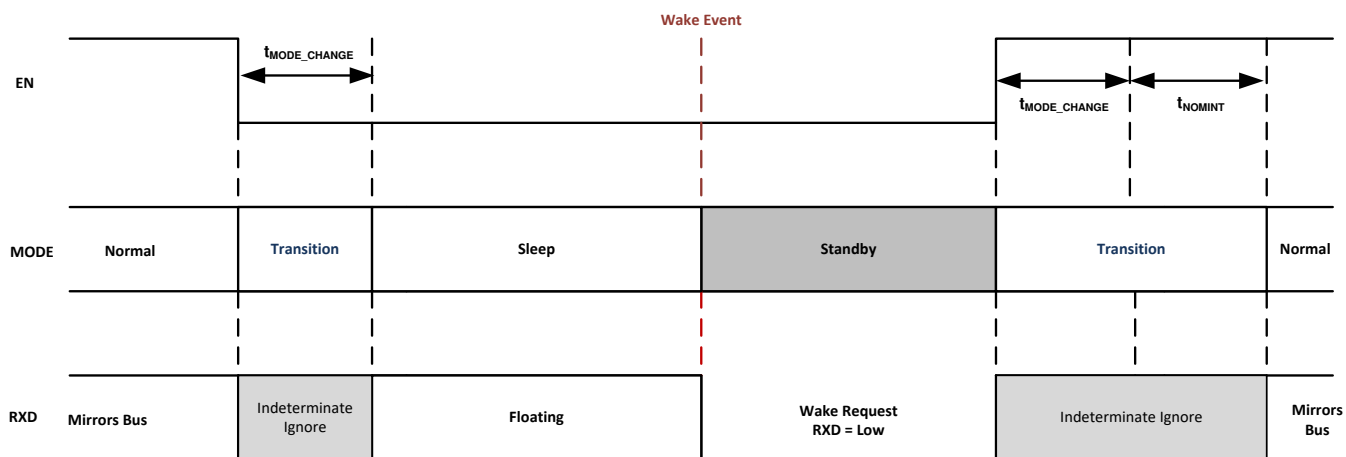
Figure 19. Propagation Delay Test Circuit; Param 31, 32



Copyright © 2019, Texas Instruments Incorporated

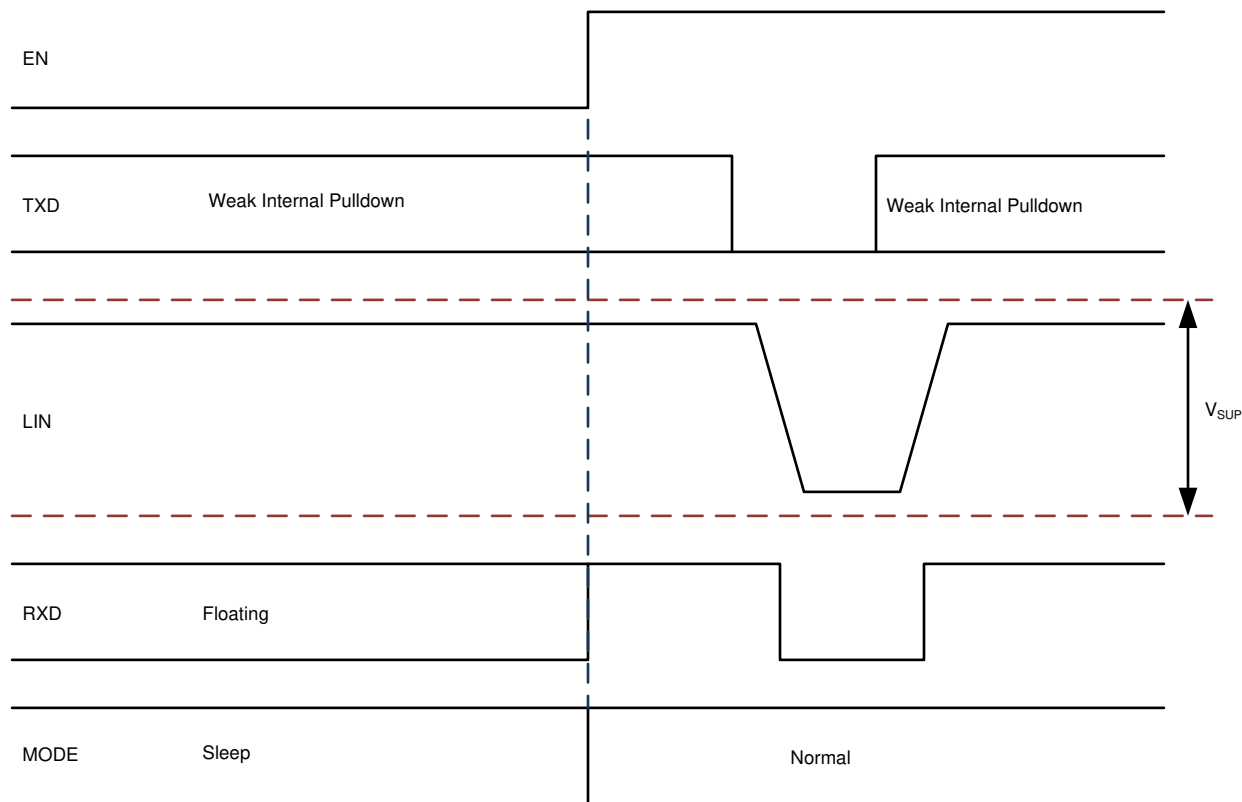
Figure 20. Propagation Delay

Parameter Measurement Information (continued)



Copyright © 2019, Texas Instruments Incorporated

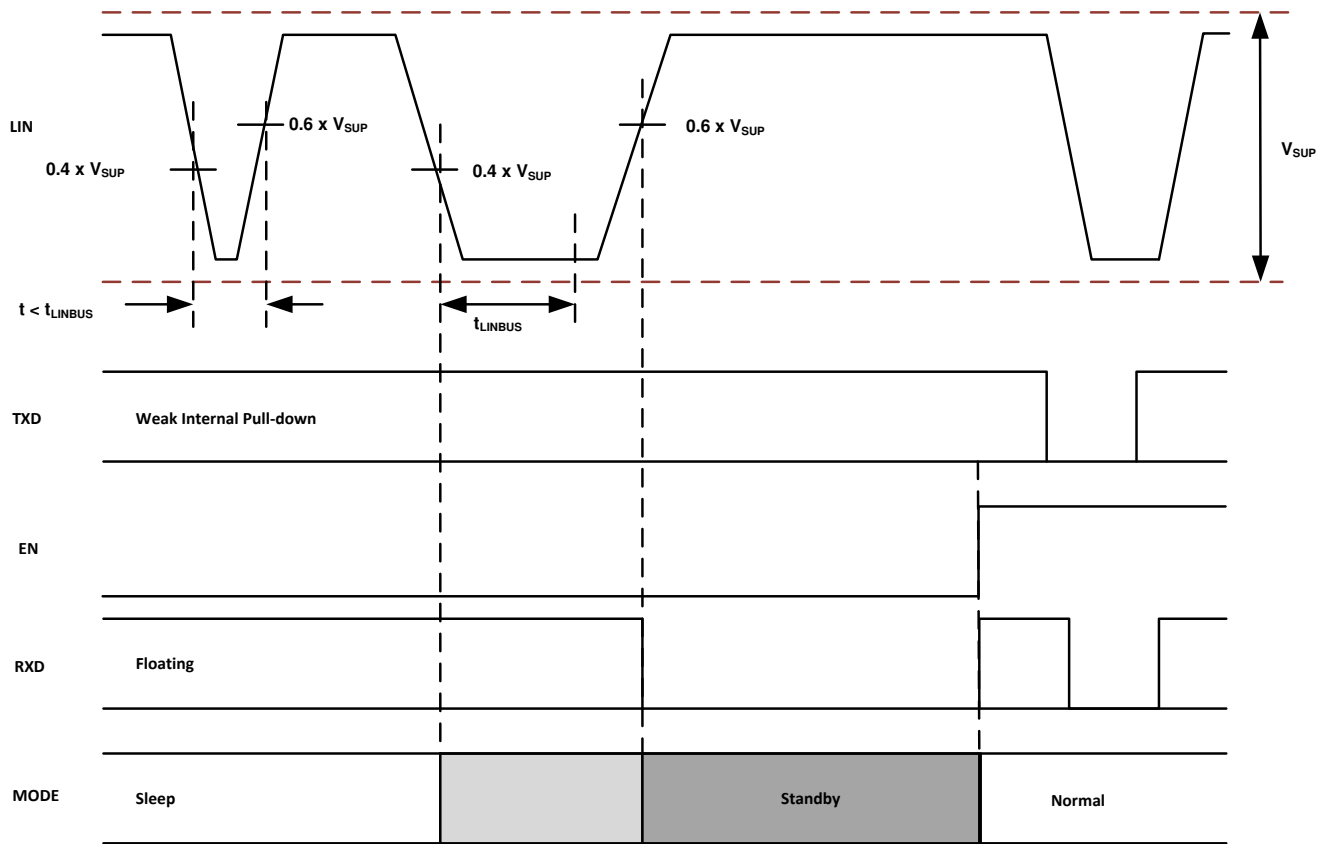
Figure 21. Mode Transitions



Copyright © 2019, Texas Instruments Incorporated

Figure 22. Wake-up Through EN

Parameter Measurement Information (continued)



Copyright © 2019, Texas Instruments Incorporated

Figure 23. Wake-up through LIN

9 Detailed Description

9.1 Overview

The TLIN2021-Q1 is a local interconnect network (LIN) physical layer transceiver, compliant to LIN 2.0, LIN 2.1, LIN 2.2, LIN 2.2A, SAE J2602-1, SAE J2602-2, ISO 17987-4, and ISO 17987-7 standards. LIN is a low-speed universal asynchronous receiver transmitter (UART) communication protocol focused on automotive in-vehicle networking.

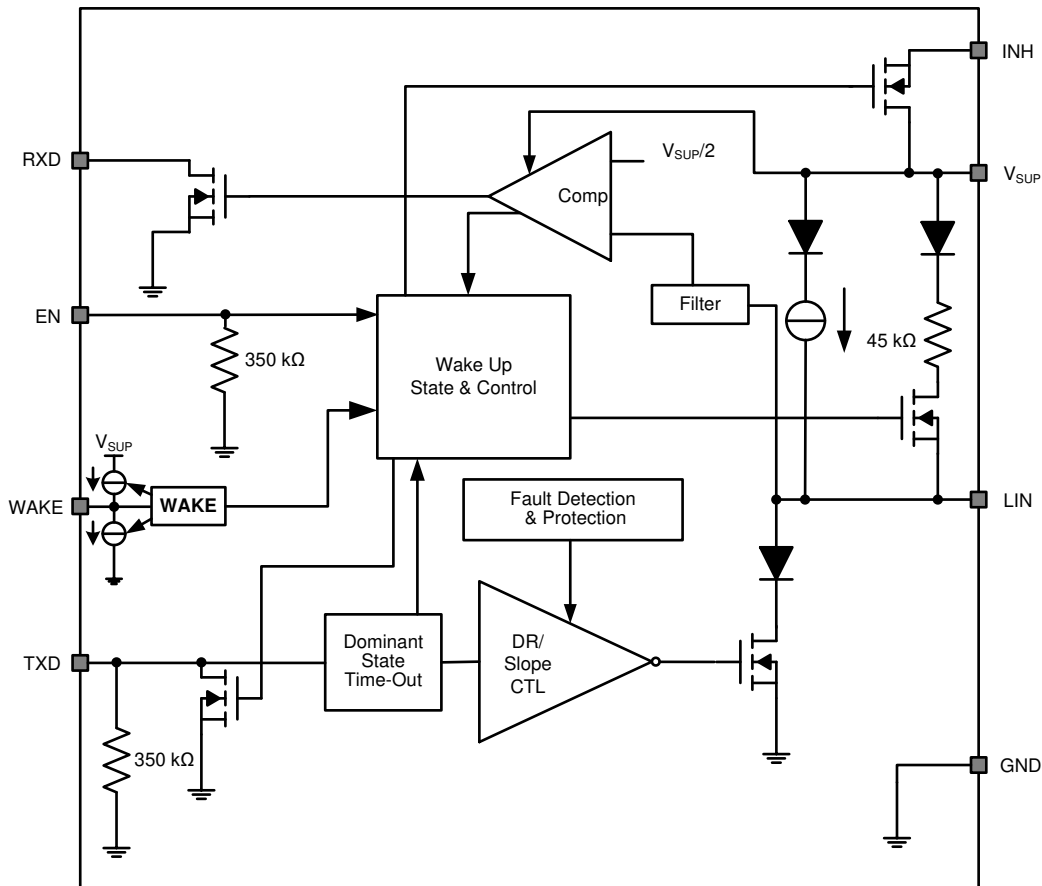
The TLIN2021-Q1 transmitter supports data rates from 2.4 kbps to 20 kbps and the receiver supports data rates up to 100 kbps for end-of-line programming. The TLIN2021-Q1 controls the state of the LIN bus via the TXD pin and reports the state of the bus via its open-drain RXD output pin. The LIN protocol data stream on the TXD input is converted by the TLIN2021-Q1 into a LIN bus signal using an optimized electromagnetic emissions current-limited wave-shaping driver as outlined by the LIN physical layer specification. The receiver converts the data stream to logic-level signals that are sent to the microcontroller through the open-drain RXD pin. The LIN bus has two states: dominant state (voltage near ground) and recessive state (voltage near battery). In the recessive state, the LIN bus is pulled high by the transceivers internal pull-up resistor (45 k Ω) and a series diode. No external pull-up components are required for slave applications. Master applications require an external pull-up resistor (1 k Ω) plus a series diode per the LIN specification.

The TLIN2021-Q1 is designed to support 24 V applications with a wide input voltage operating range and also supports low-power sleep mode. The device supports wake-up from low-power mode via wake over LIN, the WAKE pin, or the EN pin. The device allows for system-level reductions in battery current consumption by selectively enabling the various power supplies that may be present on a node through the TLIN2021-Q1 INH output pin.

The TLIN2021-Q1 integrates ESD protection and fault protection which allow for a reduction in the required external components in the applications. The device prevents back-feed current through LIN to the supply input in case of a ground shift or supply voltage disconnection.

The TLIN2021-Q1 also include undervoltage detection, temperature shutdown protection, and loss-of-ground protection. In the event of a fault condition, the transmitter is immediately switched off and remains off until the fault condition is removed.

9.2 Functional Block Diagram



Copyright © 2019, Texas Instruments Incorporated

9.3 Feature Description

9.3.1 LIN

This high voltage input/output pin is the single-wire LIN bus transmitter and receiver. The LIN pin can survive transient voltages up to 60 V. Reverse currents from the LIN to supply (V_{SUP}) are minimized with blocking diodes, even in the event of a ground shift or loss of supply (V_{SUP}).

9.3.1.1 LIN Transmitter Characteristics

The LIN transmitter has thresholds and AC switching parameters according to the LIN specification. The transmitter is a low side transistor with internal current limitation and thermal shutdown. During a thermal shutdown condition, the transmitter is disabled to protect the device. There is an internal pull-up resistor with a serial diode structure to V_{SUP} , so no external pull-up components are required for LIN slave applications. An external pull-up resistor and series diode to V_{SUP} must be added when the device is used for in a master application per the LIN specification.

9.3.1.2 LIN Receiver Characteristics

The receiver characteristic thresholds are proportional to the device supply pin in accordance to the LIN specification.

The receiver is capable of receiving higher data rates, > 100 kbps, than supported by LIN or SAEJ2602 specifications. This allows the TLIN2021-Q1 to be used for high-speed downloads at the end-of-line production or other applications. The actual data rate achievable depends on system time constants (bus capacitance and pull-up resistance) and driver characteristics used in the system.

Feature Description (continued)

9.3.1.2.1 Termination

There is an internal pull-up resistor with a serial diode structure to V_{SUP} , so no external pull-up components are required for the LIN slave applications. An external pull-up resistor (1 k Ω) and a series diode to V_{SUP} must be added when the device is used for master node applications as per the LIN specification.

Figure 24 shows a Master Node configuration and how the voltage levels are defined

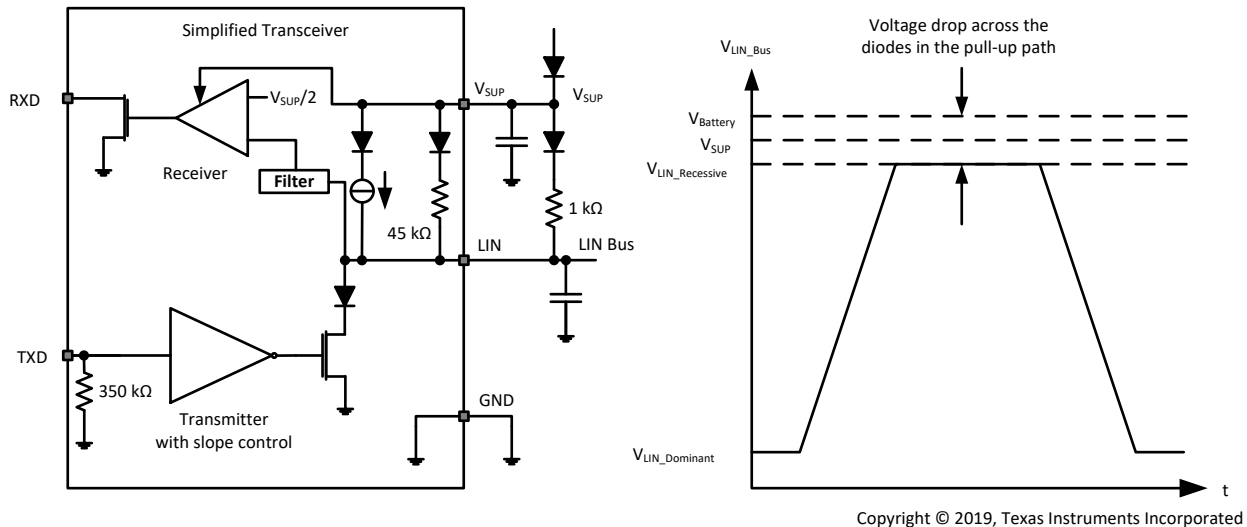


Figure 24. Master Node Configuration with Voltage Levels

9.3.2 TXD

TXD is the interface to the MCU LIN protocol controller or SCI and UART that is used to control the state of the LIN output. When TXD is low the LIN output is dominant (near ground) and when TXD is high the LIN output is recessive (near V_{SUP}), see Figure 24.

The TXD input structure is compatible with 3.3 V and 5 V microcontrollers and integrates a weak pull-down resistor. The LIN bus is protected from being stuck dominant through a system failure driving TXD low through the dominant state timer-out timer. When a change of state on the WAKE pin initiates a local wake-up event, the TXD pin is pulled hard to ground indicating a local wake-up event. The hard pull to ground is released upon the rising edge on the EN pin. If an external pull-up resistor is added to the TXD pin to the microcontrollers IO voltage then TXD is pulled high to indicate a remote wake-up event.

9.3.3 RXD

RXD is the interface to the MCU's LIN protocol controller or SCI and UART, which reports the state of the LIN bus voltage. LIN recessive (near V_{SUP}) is represented by a high level on the RXD and LIN dominant (near ground) is represented by a low level on the RXD pin. The RXD output structure is an open-drain output stage. This allows the device to be used with 3.3 V and 5 V microcontrollers. If the microcontrollers RXD pin does not have an integrated pull-up, an external pull-up resistor to the microcontrollers IO supply voltage is required. In standby mode, the RXD pin is driven low to indicate a wake-up request.

9.3.4 V_{SUP}

V_{SUP} is the power supply pin. V_{SUP} is connected to the battery through an external reverse-blocking diode, see Figure 24. If there is a loss of power at the ECU level, the device has extremely low leakage from the LIN pin, which does not load the bus down. This is optimal for LIN systems in which some of the nodes are unpowered (ignition supplied) while the rest of the network remains powered (battery supplied).

Feature Description (continued)

9.3.5 GND

GND is the device ground connection. The device can operate with a ground shift as long as the ground shift does not reduce the V_{SUP} below the minimum operating voltage. If there is a loss of ground at the ECU level, the device has extremely low leakage from the LIN pin, which does not load the bus down. This is optimal for LIN systems in which some of the nodes are unpowered (ignition supplied) while the rest of the network remains powered (battery supplied).

9.3.6 EN

EN controls the operational modes of the device. When EN is high the device is in normal operating mode allowing a transmission path from TXD to LIN and from LIN to RXD. When EN is low, the device is put into sleep mode and there are no transmission paths available. The device can enter normal mode only after wake-up. EN has an internal pull-down resistor to ensure the device remains in low power mode even if EN floats.

9.3.7 WAKE

The WAKE pin is a high-voltage input used for the local wake-up (LWU) function. This function is explained further in [Local Wake-Up \(LWU\) via WAKE Input Terminal](#) section. The pin is defaulted to bidirectional edge trigger, meaning it recognizes a local wake-up (LWU) on a rising or falling edge of WAKE pin transition.

9.3.8 INH

The TLIN2021-Q1 inhibit, INH, output pin can be used to control the enable of system power-management devices allowing for a significant reduction in battery quiescent current consumption while the application is in sleep mode. The INH pin has two states: driven high and high impedance. When the INH pin is driven high, the terminal shows V_{SUP} minus a diode voltage drop. In the high impedance state the output is left floating. The INH pin is high in the normal and standby modes and is low when in sleep mode. A 100 k Ω load can be added to the INH output to ensure a fast transition time from the driven high state to the low state and to also force the pin low when left floating.

The INH terminal should be considered a high-voltage logic terminal and not a power output. Thus should be used to drive the EN terminal of the systems power-management device and not used as a switch for the power-management supply itself. This terminal is not reverse battery protected and thus should not be connected outside the system module.

9.3.9 Local Faults

The TLIN2021-Q1 has several protection features that are described as follows.

9.3.10 TXD Dominant Time-Out (DTO)

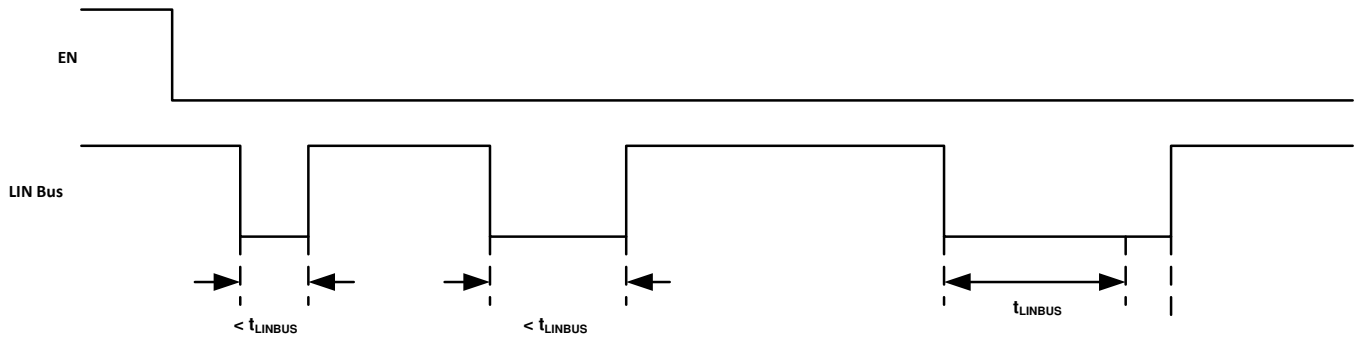
While the LIN driver is in active mode a TXD DTO circuit prevents the local node from blocking network communication in event of a hardware or software failure where TXD is held dominant longer than the time-out period t_{TXD_DTO} . The TXD DTO circuit is triggered by a falling edge on TXD. If no rising edge is seen before the time-out constant of the circuit, t_{TXD_DTO} , expires the LIN driver is disabled releasing the bus line to the recessive level. This keeps the bus free for communication between other nodes on the network. The LIN driver is re-activated on the next dominant to recessive transition on the TXD terminal, thus clearing the dominant time-out. During this fault, the transceiver remains in normal mode, the integrated LIN bus pull-up termination remains on, and the LIN receiver and RXD terminal remain active reflecting the LIN bus data.

The TXD pin has an internal pull-down to ensure the device fails to a known state if TXD is disconnected. If EN pin is high at power-up, the TLIN2021-Q1 enters normal mode. With the internal TXD connected low, the DTO timer starts. To avoid a t_{TXD_DTO} fault, a recessive signal should be put onto the TXD pin before the t_{TXD_DTO} timer expires, or the device should be into sleep mode by connecting EN pin low.

9.3.11 Bus Stuck Dominant System Fault: False Wake-Up Lockout

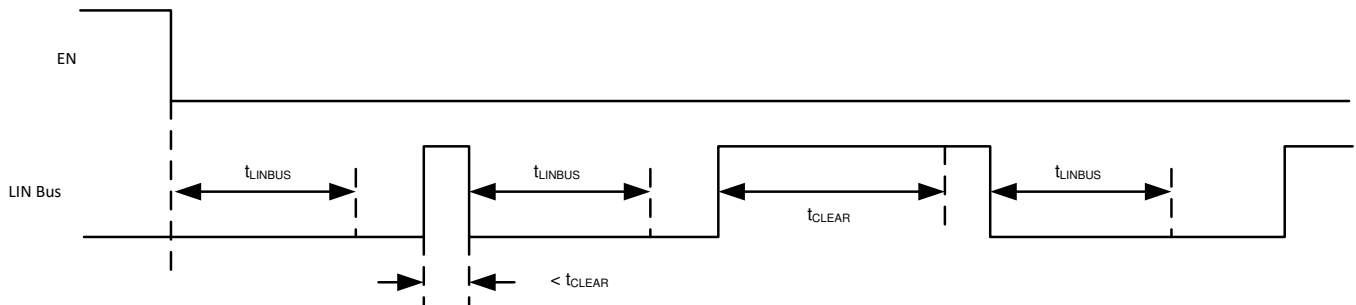
The TLIN2021-Q1 contains logic to detect bus stuck dominant system faults and prevents the device from waking up falsely during the system fault. Upon entering sleep mode, the device detects the state of the LIN bus. If the bus is dominant, the wake-up logic is locked out until a valid recessive on the bus clears the bus stuck dominant fault, preventing excessive current use, see [Figure 25](#) and [Figure 26](#).

Feature Description (continued)



Copyright © 2019, Texas Instruments Incorporated

Figure 25. No Bus Fault: Entering Sleep Mode with Bus Recessive Condition and Wake-up



Copyright © 2019, Texas Instruments Incorporated

Figure 26. Bus Fault: Entering Sleep Mode With Bus Stuck Dominant Fault, Clearing, and Wake-up

9.3.12 Thermal Shutdown

The TLIN2021-Q1 transmitter is protected by limiting the current. If the junction temperature, T_J , of the device exceeds the thermal shutdown threshold, $T_J > T_{SDR}$, the device puts the LIN transmitter into the recessive state. Once the over temperature fault condition has been removed and the junction temperature has cooled beyond the hysteresis temperature, the transmitter is re-enabled. During this fault, the transceiver remains in normal mode, the integrated LIN bus pull-up termination remains on, the LIN receiver and RXD terminal remain active reflecting the LIN bus data.

9.3.13 Under Voltage on V_{SUP}

The TLIN2021-Q1 contains a power on reset circuit to avoid false bus messages during under voltage conditions when V_{SUP} is less than UV_{SUP} .

9.3.14 Unpowered Device

In automotive applications, some LIN nodes in a system can be unpowered, ignition supplied, while others in the network remains powered by the battery. The TLIN2021-Q1 has extremely low unpowered leakage current from the bus so an unpowered node does not affect the network or load it down.

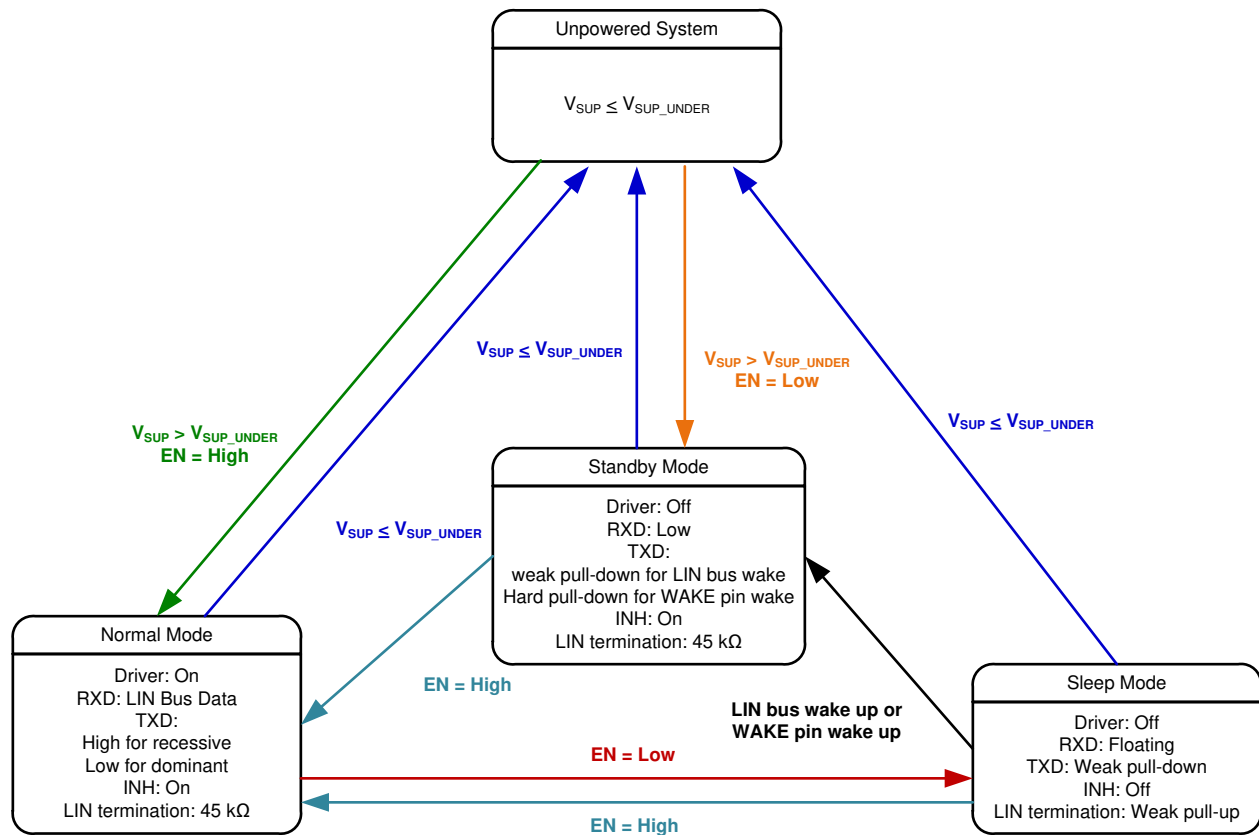
9.4 Device Functional Modes

The TLIN2021-Q1 has three functional modes of operation: normal, sleep, and standby. The next sections describe these modes and how the device transitions between the different modes. Figure 27 graphically shows the relationship while Table 1 shows the state of pins.

Device Functional Modes (continued)

Table 1. Operating Modes

| MODE | EN | TXD | RXD | INH | LIN BUS TERMINATION | TRANSMITTER | COMMENT |
|---------|------|---|--------------|----------|----------------------|-------------|--|
| Sleep | Low | Weak pull-down | Floating | Floating | Weak current pull-up | Off | |
| Standby | Low | weak pull-down if LIN bus wake-up; Strong pull-down if a local wake-up event (WAKE pin) | Low | High | 45 kΩ | Off | Wake-up event detected, waiting on MCU to set EN |
| Normal | High | High: recessive state Low: dominant state | LIN Bus Data | High | 45 kΩ | On | LIN transmission up to 20 kbps |



Copyright © 2019, Texas Instruments Incorporated

Figure 27. Operating State Diagram

9.4.1 Normal Mode

The EN pin controls the mode of the device. If the EN pin is high at power-up the device powers-up in normal mode, if the EN is low at power-up the device powers-up in standby mode. In normal mode the receiver and transmitter fully operational. The LIN transmitter transmits data from the LIN controller to the LIN bus up to the LIN specified maximum data rate of 20 kbps. The LIN receiver detects the data stream on the LIN bus up to data rates of 100 kbps and outputs the data on RXD output for the LIN controller. Upon an EN pin transition from from low to high the TLIN2021-Q1 transitions from sleep mode to normal mode in $t \geq t_{NOMINT}$.

9.4.2 Sleep Mode

Sleep mode is the lowest power mode of the TLIN2021-Q1 and is only entered from normal mode when the EN pin transitions from high to low for $t > t_{\text{MODE_CHANGE}}$. In sleep mode, the LIN driver and receiver are switched off, the LIN bus is weakly pulled up, an the transceiver cannot send or receive data. The INH pin is switched to a floating output in sleep mode causing any system power elements controlled by the INH pin to be switched off thus reducing the system power consumption. While the device is in sleep mode, the following conditions exist:

- The LIN bus driver is disabled and the internal LIN bus termination is switched off to minimize power loss if LIN is short circuited to ground.
- A weak current pull-up is active to prevent false wake-up events in case an external connection to the LIN bus is lost.
- The normal receiver is disabled.
- EN input, WAKE pin and LIN wake-up receiver are active.

The TLIN2021-Q1 supports three methods for wake-up from sleep mode:

- Wake-up over the LIN bus via the LIN wake-up receiver.
- Local wake-up via the WAKE pin.
- Local wake-up via the EN pin. The EN pin must be set high for $t > t_{\text{NOMINT}}$ in order for the device to wake-up.

9.4.3 Standby Mode

Standby mode is entered whenever a wake-up event occurs through LIN bus or the WAKE pin while the device is in sleep mode. In standby mode, the LIN bus slave termination circuit, 45 k Ω , is on. When a wake-up event occurs and the TLIN2021-Q1 enters standby mode the RXD pin is driven low signaling the wake-up event to the LIN controller.

The TLIN2021-Q1 exits standby mode and transitions to normal mode when the EN pin is set high for longer than $t_{\text{MODE_CHANGE}}$ where the normal LIN transmitter and receiver are fully operational and bi-directional communication is possible.

9.4.4 Wake-Up Events

There are three ways to wake-up the TLIN2021-Q1 from sleep mode:

- Remote wake-up initiated by the falling edge of a recessive-to-dominant state transition on the LIN bus where the dominant state is held than t_{LINBUS} filter time. After the t_{LINBUS} filter time has been met a rising edge on the LIN bus going from dominant-to-recessive initiates a remote wake-up event. The pattern and t_{LINBUS} filter time used for the LIN wake-up prevents noise and bus stuck dominant faults from causing false wake requests.
- A local wake-up event due to the EN pin being set high for $t > t_{\text{MODE_CHANGE}}$.
- A local wake-up event due to a change in voltage level on the WAKE pin for $t > t_{\text{WAKE}}$

9.4.4.1 Local Wake-Up (LWU) via WAKE Input Terminal

The WAKE terminal is a bi-directional high-voltage input which can be used for local wake-up (LWU) requests via a voltage transition. A LWU event is triggered on either a low-to-high or high-to-low transition since it has bi-directional input thresholds. The WAKE pin could be used with a switch to V_{SUP} or to ground. If the terminal is unused it should be pulled to V_{SUP} or ground to avoid unwanted parasitic wake-up events. When a LWU event takes place the TXD pin is pulled hard to GND letting the LIN controller know that the wake-up event was due to the WAKE pin and not a wake over LIN event.

The LWU circuitry is active in standby mode and sleep mode. If a valid LWU event occurs in standby mode, the device remains in standby mode and drive the RXD output low. If a valid LWU event occurs in sleep mode, the device transitions to standby mode and drive the RXD output low. The LWU circuitry is not active in normal mode. To minimize system level current consumption, the internal bias voltages of the terminal follows the state on the terminal with a delay of $t_{\text{WAKE(MIN)}}$. A constant high level on WAKE has an internal pull-up to V_{SUP} , and a constant low level on WAKE has an internal pull-down to GND.

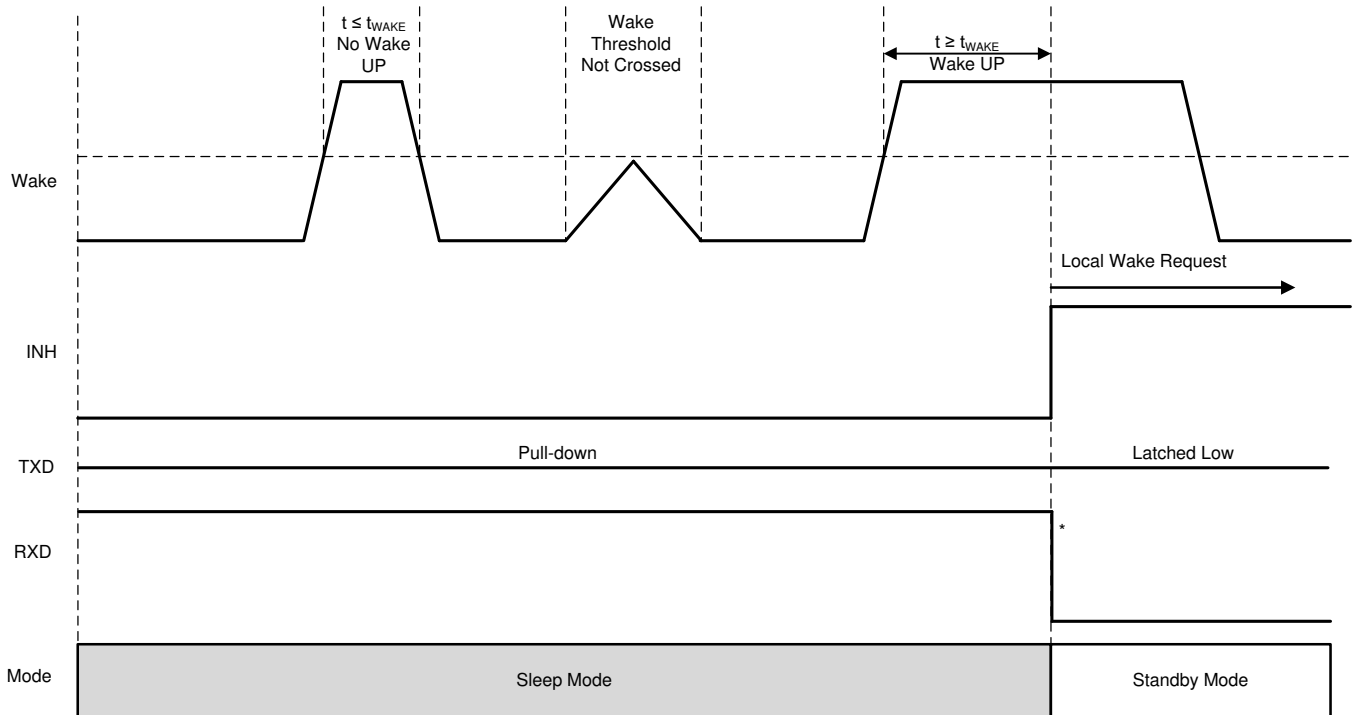


Figure 28. Local Wake-Up – Rising Edge

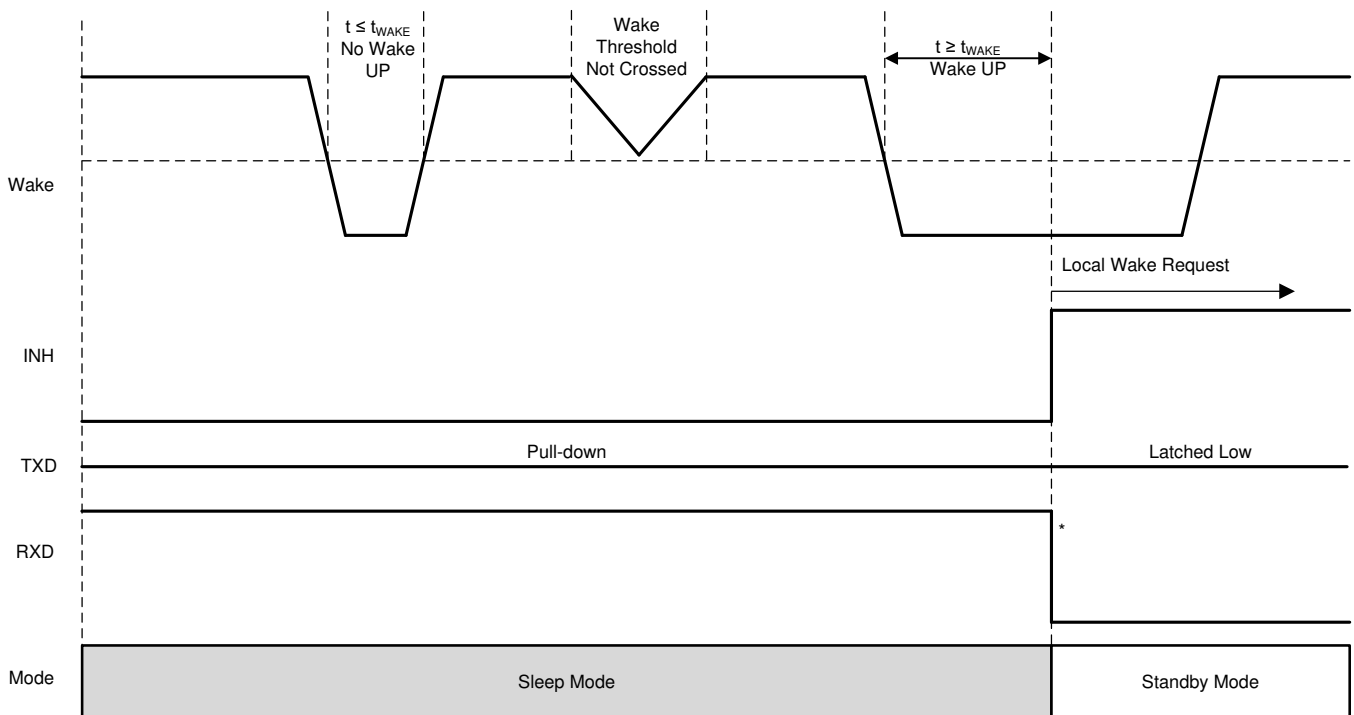


Figure 29. Local Wake-Up – Falling Edge

Copyright © 2019, Texas Instruments Incorporated

9.4.4.2 Wake-Up Request (RXD)

When the TLIN2021-Q1 encounters a wake-up event from the WAKE pin, or the LIN bus the RXD output is driven low until EN is asserted high, the device enters normal mode. Once the device enters normal mode, the wake-up event is cleared, and the RXD output is released. The RXD output is fully operation and reflects the receiver output from the LIN bus.

10 Application and Implementation

NOTE

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

10.1 Application Information

The TLIN2021-Q1 can be used in both a slave application and a master application in a LIN network.

10.2 Typical Application

The device integrates a 45 kΩ pull-up resistor and series diode for slave applications. For master applications, an external 1 kΩ pull-up resistor with series blocking diode can be used. shows the device being used in both master and slave applications.

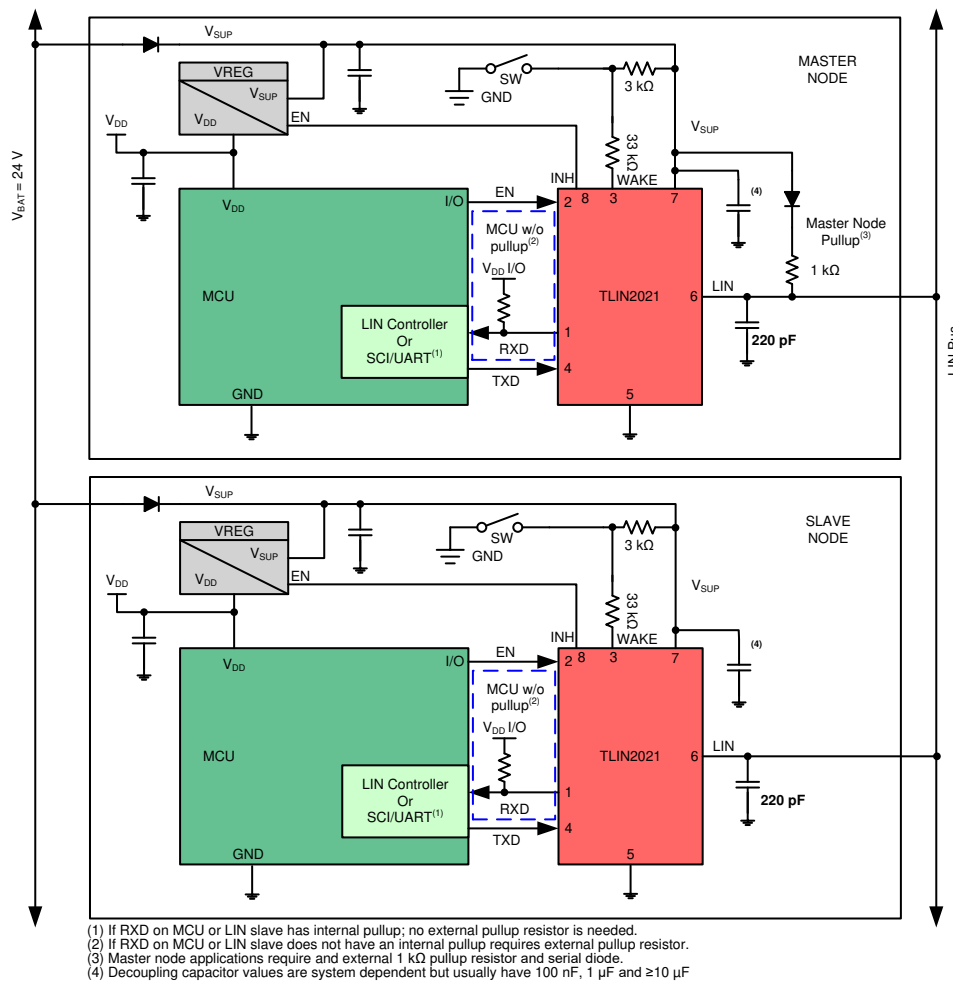


Figure 30. Typical LIN Bus

Typical Application (continued)

10.2.1 Design Requirements

The RXD output structure is an open-drain output stage which allows the TLIN2021-Q1 to be used with 3.3-V and 5-V controllers. If the RXD pin of the controller does not have an integrated pull-up, an external pull-up resistor to the controllers IO voltage is required. The external pull-up resistor value should be between 1 kΩ to 10 kΩ. The V_{SUP} pin of the device should be decoupled with a 100-nF capacitor by placing it close to the V_{SUP} supply pin. The system should include additional decoupling on the V_{SUP} line as needed per the application requirements.

10.2.2 Detailed Design Procedures

10.2.2.1 Normal Mode Application Note

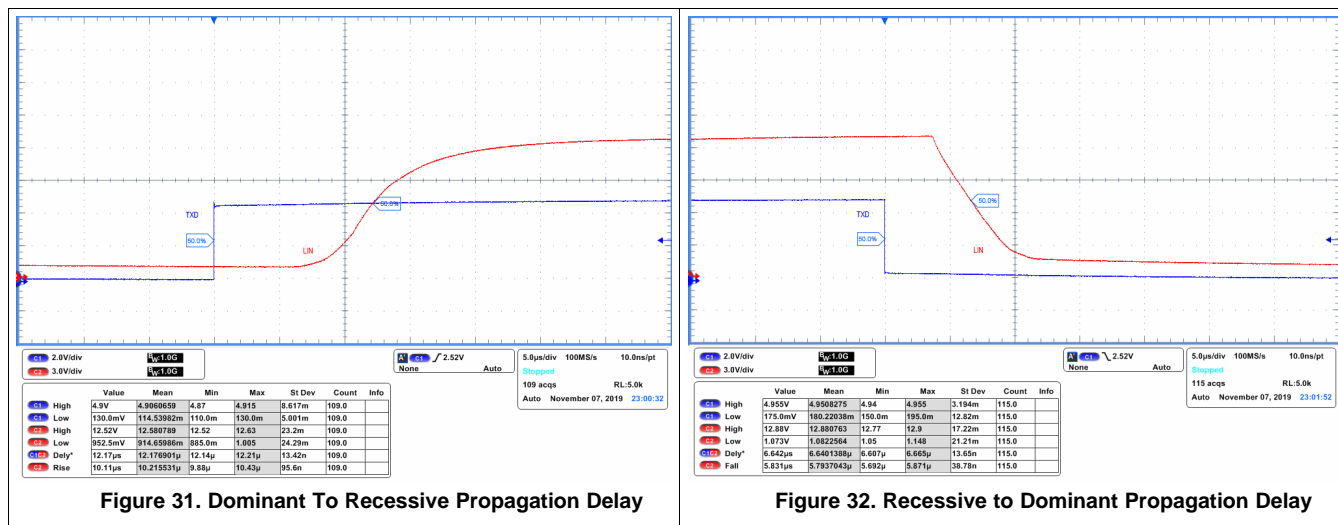
When using the TLIN2021-Q1 in systems which are monitoring the RXD pin for a wake-up request, special care should be taken during the mode transitions. The output of the RXD pin is indeterminate for the transition period between states as the receivers are switched. The application software should not look for an edge on the RXD pin indicating a wake-up request until t_{MODE_CHANGE} has been met. This is shown in Figure 21

10.2.2.2 TXD Dominant State Time-Out Application Note

The maximum dominant TXD time allowed by the TXD dominant state time-out limits the minimum possible data rate of the device. The LIN protocol has different constraints for master and slave applications thus there are different maximum consecutive dominant bits for each application case thus different minimum data rates.

10.2.3 Application Curves

Figure 31 and Figure 32 show the propagation delay from the TXD pin to the LIN pin for the dominant to recessive and recessive to dominant edges.



11 Power Supply Recommendations

The TLIN2021-Q1 was designed to operate directly from a car battery, or any other DC supply ranging from 4.5 V to 45 V. The V_{SUP} pin of the device should be decoupled with a 100-nF capacitor by placing it close to the V_{SUP} supply pin. The system should include additional decoupling on the V_{SUP} line as needed per the application requirements.

12 Layout

For the PCB design to be successful, start with design of the protection and filtering circuitry. Because ESD transients have a wide frequency bandwidth from approximately 3 MHz to 3 GHz, high frequency layout techniques must be applied during PCB design. Placement at the connector also prevents these noisy events from propagating further into the PCB and system.

12.1 Layout Guidelines

- **Pin 1 (RXD):** The RXD pin is an open-drain output and requires an external pull-up resistor in the range of 1 kΩ and 10 kΩ to function properly. If the controller paired with the transceiver does not have an integrated pull-up, an external resistor should be placed between RXD and the supply voltage for the controller.
- **Pin 2 (EN):** EN is an input pin that is used to place the device in low-power sleep mode. If this feature is not used the pin should be connected to the supply voltage for the controller through a series resistor using a pull-up value between 1 kΩ and 10 kΩ. Additionally, a series resistor may be placed on the pin to limit current on the digital lines in the case of an over-voltage fault.
- **Pin 3 (WAKE):** SW1 is oriented in a low-side configuration which is used to implement a local WAKE event. The series resistor R5 is needed for protection against over current conditions as it limits the current into the WAKE pin when the ECU has lost its ground connection. The pull-up resistor R4 is required to provide sufficient current during stimulation of a WAKE event. In this layout example R4 is set to 3 kΩ and R5 is set to 33 kΩ.
- **Pin 4 (TXD):** The TXD pin is the transmit input signal to the device from the controller. A series resistor can be placed to limit the input current to the device in the case of an over-voltage on this pin. A capacitor to ground can be placed close to the input pin of the device to help filter noise.
- **Pin 5 (GND):** This is the ground connection for the device. This pin should be tied to the ground plane through a short trace with the use of two vias to limit total return inductance.
- **Pin 6 (LIN):** The LIN pin connects to the TLIN2021-Q1 to the LIN bus. For slave applications a 220 pF capacitor to ground is implemented. For master applications an additional series resistor and blocking diode should be placed between the LIN pin and the V_{SUP} pin, see [Figure 30](#).
- **Pin 7 (V_{SUP}):** This is the supply pin for the device. A 100-nF capacitor should be placed close to the V_{SUP} supply pin for local power supply decoupling.
- **Pin 8 (INH):** The INH pin is used for system power-management. A 100 kΩ load can be added to the INH output to ensure a fast transition time from the driven high state to the low state and to also force the pin low when left floating.

NOTE

All ground and power connections should be made as short as possible and use at least two vias to minimize the total loop inductance.

12.2 Layout Example

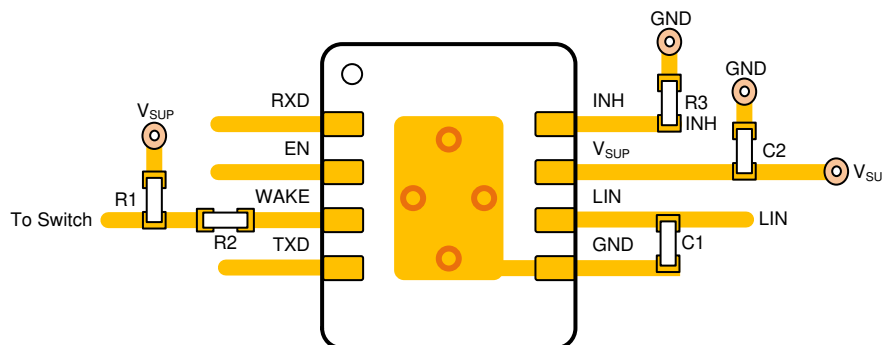


Figure 33. Layout Example

13 Device and Documentation Support

13.1 Documentation Support

13.1.1 Related Documentation

[TLIN1021-Q1 and TLIN2021-Q1 Duty Cycle Over \$V_{SUP}\$](#)

13.2 Support Resources

TI E2E™ [support forums](#) are an engineer's go-to source for fast, verified answers and design help — straight from the experts. Search existing answers or ask your own question to get the quick design help you need.

Linked content is provided "AS IS" by the respective contributors. They do not constitute TI specifications and do not necessarily reflect TI's views; see TI's [Terms of Use](#).

13.3 Trademarks

E2E is a trademark of Texas Instruments.

13.4 Electrostatic Discharge Caution



These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

13.5 Glossary

[SLYZ022](#) — *TI Glossary*.

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

14 Mechanical, Packaging, and Orderable Information

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

PACKAGING INFORMATION

| Orderable Device | Status (1) | Package Type | Package Drawing | Pins | Package Qty | Eco Plan (2) | Lead finish/ Ball material (6) | MSL Peak Temp (3) | Op Temp (°C) | Device Marking (4/5) | Samples |
|------------------|---------------|--------------|-----------------|------|-------------|-----------------|--------------------------------------|----------------------|--------------|-------------------------|-------------------------|
| TLIN2021DRBRQ1 | ACTIVE | SON | DRB | 8 | 3000 | RoHS & Green | NIPDAU | Level-2-260C-1 YEAR | -40 to 125 | TL021 | Samples |
| TLIN2021DRQ1 | ACTIVE | SOIC | D | 8 | 2500 | RoHS & Green | NIPDAU | Level-1-260C-UNLIM | -40 to 125 | TL021 | Samples |

(1) The marketing status values are defined as follows:

ACTIVE: Product device recommended for new designs.

LIFEBUY: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.

NRND: Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.

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

OBSOLETE: TI has discontinued the production of the device.

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

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

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

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

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

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

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

Important Information and Disclaimer:The information provided on this page represents TI's knowledge and belief as of the date that it is provided. TI bases its knowledge and belief on information provided by third parties, and makes no representation or warranty as to the accuracy of such information. Efforts are underway to better integrate information from third parties. TI has taken and continues to take reasonable steps to provide representative and accurate information but may not have conducted destructive testing or chemical analysis on incoming materials and chemicals. TI and TI suppliers consider certain information to be proprietary, and thus CAS numbers and other limited information may not be available for release.

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.

TAPE AND REEL INFORMATION



QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*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 |
|----------------|--------------|-----------------|------|------|--------------------|--------------------|---------|---------|---------|---------|--------|---------------|
| TLIN2021DRBRQ1 | SON | DRB | 8 | 3000 | 330.0 | 12.4 | 3.3 | 3.3 | 1.1 | 8.0 | 12.0 | Q1 |
| TLIN2021DRQ1 | SOIC | D | 8 | 2500 | 330.0 | 12.4 | 6.4 | 5.2 | 2.1 | 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) |
|----------------|--------------|-----------------|------|------|-------------|------------|-------------|
| TLIN2021DRBRQ1 | SON | DRB | 8 | 3000 | 367.0 | 367.0 | 35.0 |
| TLIN2021DRQ1 | SOIC | D | 8 | 2500 | 533.4 | 186.0 | 36.0 |

DRB 8

GENERIC PACKAGE VIEW

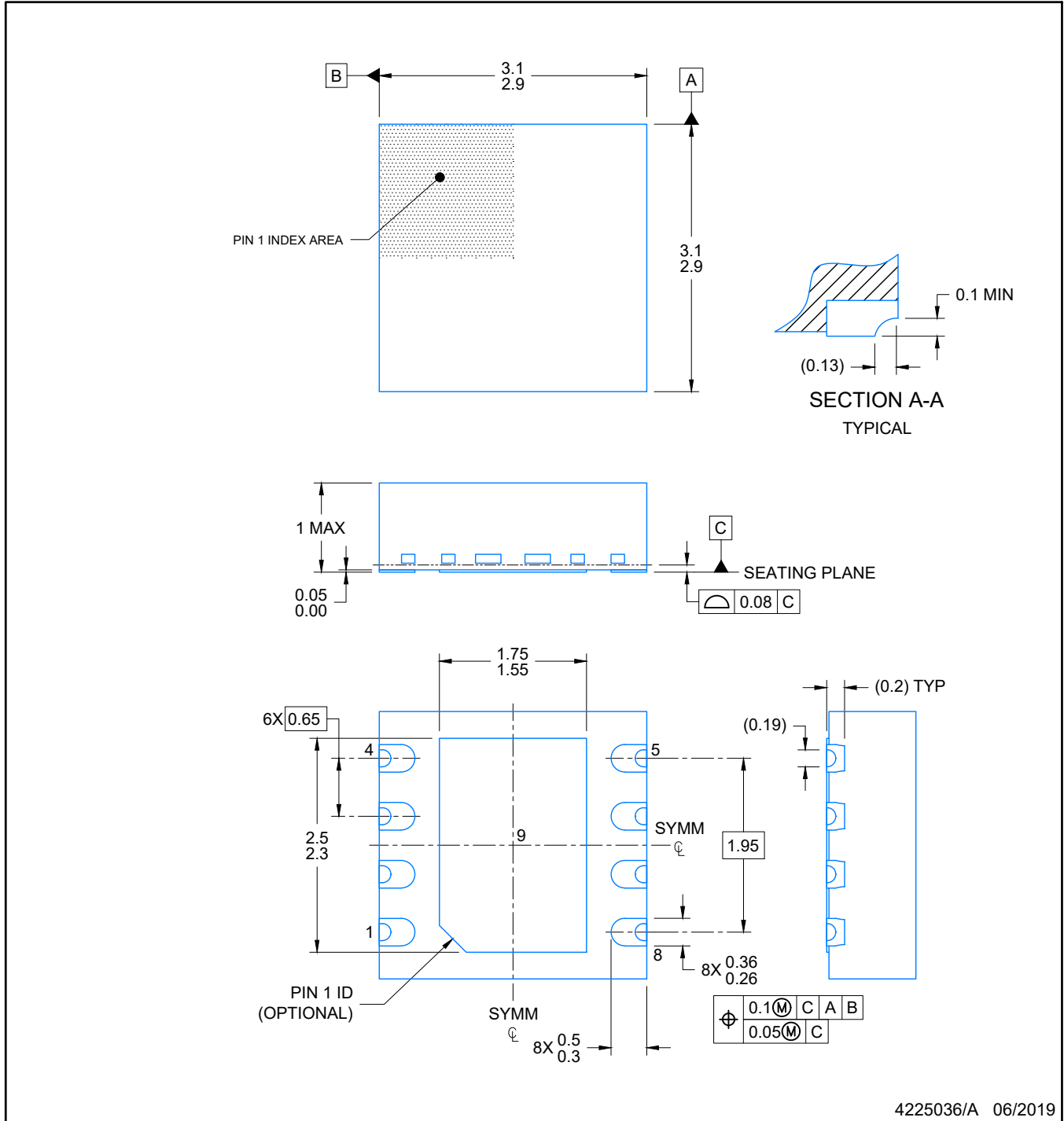
VSON - 1 mm max height

PLASTIC SMALL OUTLINE - NO LEAD



Images above are just a representation of the package family, actual package may vary.
Refer to the product data sheet for package details.

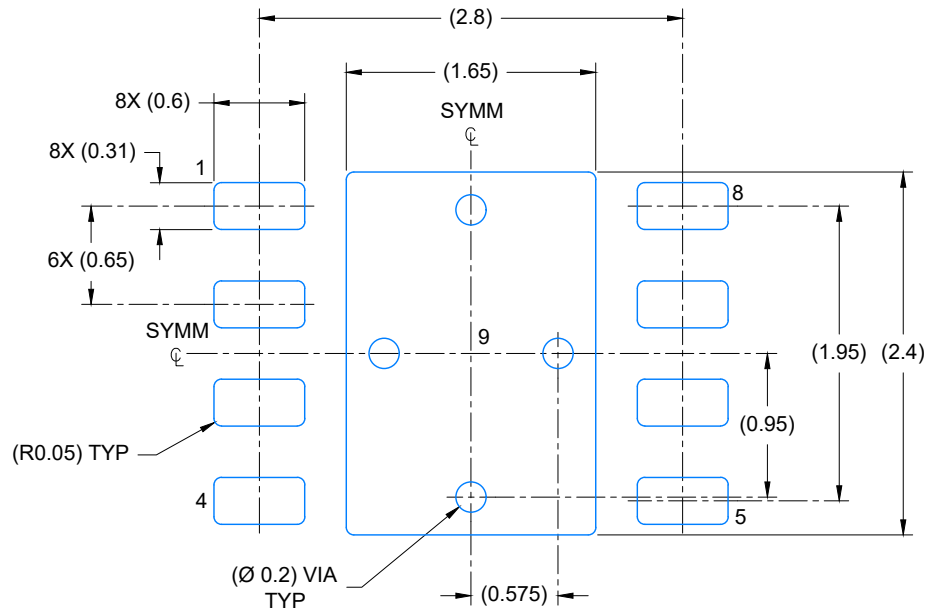
4203482/L



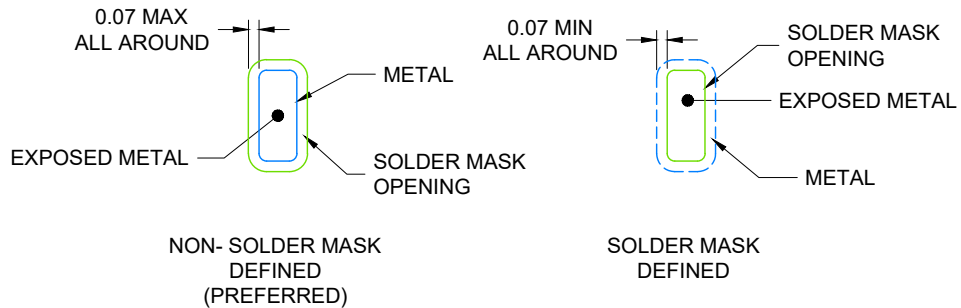
4225036/A 06/2019

NOTES:

1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. The package thermal pad must be soldered to the printed circuit board for optimal thermal and mechanical performance.



LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE: 20X

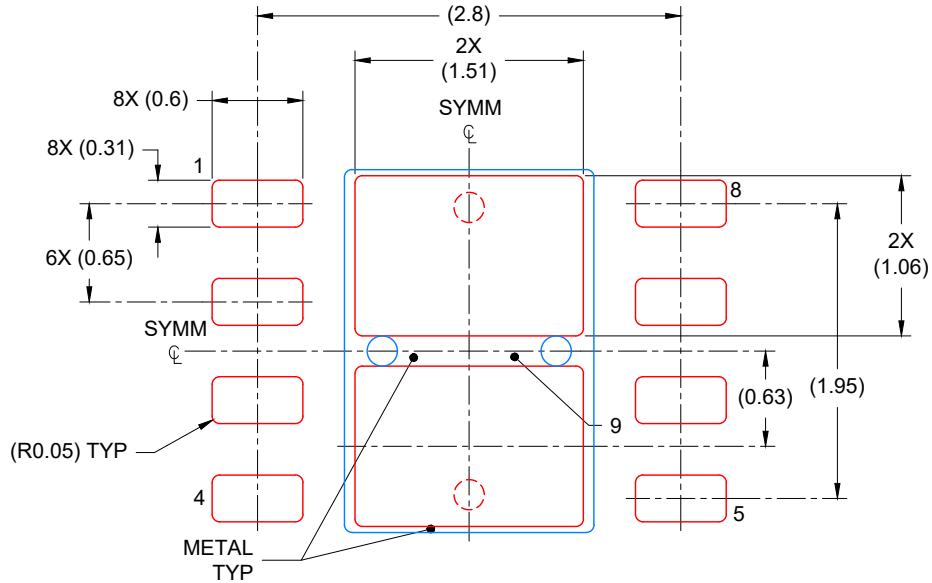


SOLDER MASK DETAILS

4225036/A 06/2019

NOTES: (continued)

4. This package is designed to be soldered to a thermal pad on the board. For more information, see Texas Instruments literature number SLUA271 (www.ti.com/lit/slua271).
5. Vias are optional depending on application, refer to device data sheet. If any vias are implemented, refer to their locations shown on this view. It is recommended that vias under paste be filled, plugged or tented.



SOLDER PASTE EXAMPLE
 BASED ON 0.125 mm THICK STENCIL

EXPOSED PAD
 81% PRINTED COVERAGE BY AREA
 SCALE: 20X

4225036/A 06/2019

NOTES: (continued)

6. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.



D0008A

PACKAGE OUTLINE

SOIC - 1.75 mm max height

SMALL OUTLINE INTEGRATED CIRCUIT



4214825/C 02/2019

NOTES:

- Linear dimensions are in inches [millimeters]. Dimensions in parenthesis are for reference only. Controlling dimensions are in inches. Dimensioning and tolerancing per ASME Y14.5M.
- This drawing is subject to change without notice.
- This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed $.006$ [0.15] per side.
- This dimension does not include interlead flash.
- Reference JEDEC registration MS-012, variation AA.

EXAMPLE BOARD LAYOUT

D0008A

SOIC - 1.75 mm max height

SMALL OUTLINE INTEGRATED CIRCUIT



LAND PATTERN EXAMPLE
 EXPOSED METAL SHOWN
 SCALE:8X



SOLDER MASK DETAILS

4214825/C 02/2019

NOTES: (continued)

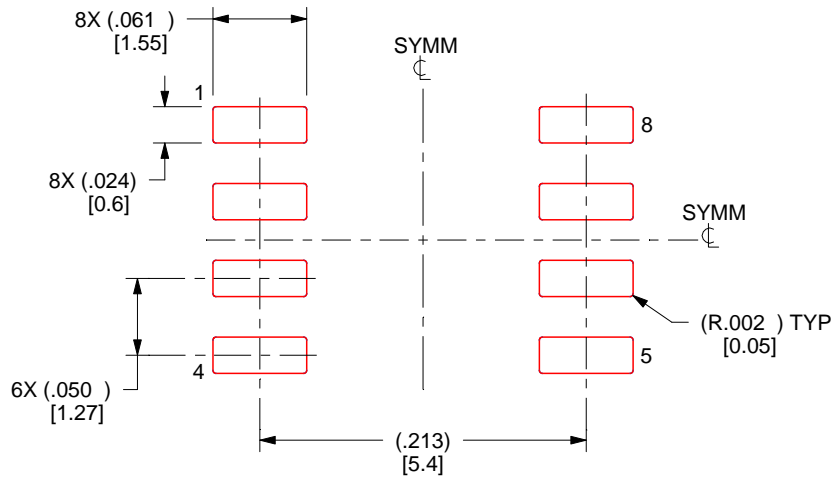
- 6. Publication IPC-7351 may have alternate designs.
- 7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.

EXAMPLE STENCIL DESIGN

D0008A

SOIC - 1.75 mm max height

SMALL OUTLINE INTEGRATED CIRCUIT



SOLDER PASTE EXAMPLE
BASED ON .005 INCH [0.125 MM] THICK STENCIL
SCALE:8X

4214825/C 02/2019

NOTES: (continued)

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

IMPORTANT NOTICE AND DISCLAIMER

TI PROVIDES TECHNICAL AND RELIABILITY DATA (INCLUDING DATASHEETS), DESIGN RESOURCES (INCLUDING REFERENCE DESIGNS), APPLICATION OR OTHER DESIGN ADVICE, WEB TOOLS, SAFETY INFORMATION, AND OTHER RESOURCES "AS IS" AND WITH ALL FAULTS, AND DISCLAIMS ALL WARRANTIES, EXPRESS AND IMPLIED, INCLUDING WITHOUT LIMITATION ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

These resources are intended for skilled developers designing with TI products. You are solely responsible for (1) selecting the appropriate TI products for your application, (2) designing, validating and testing your application, and (3) ensuring your application meets applicable standards, and any other safety, security, or other requirements. These resources are subject to change without notice. TI grants you permission to use these resources only for development of an application that uses the TI products described in the resource. Other reproduction and display of these resources is prohibited. No license is granted to any other TI intellectual property right or to any third party intellectual property right. TI disclaims responsibility for, and you will fully indemnify TI and its representatives against, any claims, damages, costs, losses, and liabilities arising out of your use of these resources.

TI's products are provided subject to TI's Terms of Sale (www.ti.com/legal/termsofsale.html) or other applicable terms available either on ti.com or provided in conjunction with such TI products. TI's provision of these resources does not expand or otherwise alter TI's applicable warranties or warranty disclaimers for TI products.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265
Copyright © 2020, Texas Instruments Incorporated