

THVD4431 120Ω の切り替え可能終端抵抗と IEC-ESD 保護機能を内蔵したマルチプロトコル (RS-232、RS-422、RS485) トランシーバ

1 特長

- TIA/EIA-485A および TIA/EIA-232F 規格の要件に適合またはそれを上回る性能
- RS-232 仕様のトランスミッタ 3 個とレシーバ 5 個
- RS-485 仕様のトランスミッタ 1 個とレシーバ 1 個
- RS-485 モード用のオンチップの切り替え可能な 120Ω 終端抵抗
- RS-232 信号伝送用チャージポンプを内蔵
- 電源電圧: 3V~5.5V
- ロジックデータおよび制御信号用の 1.65V~5.5V 電源
- 5V 電源で 2.1V を超える RS-485 差動出力により PROFIBUS に準拠
- RS-232 モードでの大きな出力スイング (代表値 ±9V)
- SLR ピンで選択可能なデータレート:
 - RS-232 3T5R モード: 250kbps、1Mbps
 - RS-485 の半二重および全二重モード: 500kbps、20Mbps
- バス I/O 保護
 - ±16kV HBM ESD
 - ±8kV IEC 61000-4-2 接触および ±15kV 気中放電
 - ±4kV IEC 61000-4-4 高速過渡バースト
- RS-232 と RS-485 の両方のモードに対応する診断ループバック
- ディスエーブル状態でシャットダウンピンを使用して消費電流を低減 (代表値 10μA)
- グリッチなしの電源オン/オフによるホットプラグイン機能
- RS-485 仕様の 1/8 単位負荷 (最大 256 個のバスノード)
- RS-485 レシーバに対する開放、短絡、アイドルバスのフェイルセーフ
- バス短絡保護、サーマル シャットダウン
- 拡張周囲温度範囲: -40°C~125°C
- 省スペースで熱効率の高い 6mm × 6mm VQFN-40 パッケージ

2 アプリケーション

- 産業用 PC
- ファクトリ・オートメーションおよび制御
- HVAC システム
- ビル・オートメーション
- POS 端末
- グリッド・インフラ
- 産業用輸送

3 概要

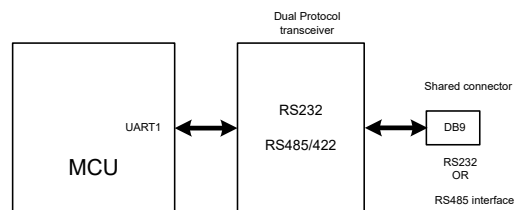
THVD4431 は、RS-232、RS-422、RS-485 の各物理層をサポートする、高集積で堅牢なマルチプロトコルトランシーバです。このデバイスは、3 つのトランスミッタと 5 つのレシーバを搭載しており、3T5R RS-232 ポートを有効にできます。また、このデバイスには 1 つのトランスミッタと 1 つのレシーバが内蔵されており、半二重と全二重の RS-485 ポートを実現できます。モード選択ピンにより、プロトコルの共有バスおよびロジックピンが共通の単一のコネクタを共有できるようになります。RS-485 バスピンと RS-232 レシーバ入力の終端が統合されているため、外付け部品なしで完全な機能を持つ通信ポートを実現できます。このデバイスはスルーレート選択機能を備えており、これを使うと、SLR ピンの設定に基づいて 2 つの最大速度でこのデバイスを使うことができます。

このデバイスは、レベル 4 の IEC ESD 保護機能を内蔵しているため、システムレベルの外付け保護部品は不要です。RS-232 と RS-485 の両方に、ロジックからバスおよびバスからロジックパスに向う機能安全性をチェックし、ケーブルとコネクタの短絡をチェックする、診断ループバックモードが搭載されています。さらに、RS-485 レシーバのフェイルセーフ機能は、バス入力が開放または短絡しているとき、またはバスがアイドル状態のときに、受信したロジック出力をロジック High に駆動します。シャットダウンモードの消費電流は非常に小さく (代表値 10μA)、消費電力の制約が厳しいアプリケーションに最適です。このデバイスには、RS-232 用のチャージポンプ、および RS-232 と RS-485 の両方のドライバ/レシーバに電力を供給する 3~5.5V の電源が必要です。独立したロジック電源 V_{IO} (1.65V~5.5V) により、低レベルのマイクロコントローラとのインターフェイスが可能です。

パッケージ情報

| 部品番号 | パッケージ (1) | パッケージ サイズ (2) |
|----------|-----------|---------------|
| THVD4431 | VQFN (40) | 6mm × 6mm |

- (1) 詳細については、[セクション 11](#) を参照してください。
- (2) パッケージ サイズ (長さ×幅) は公称値であり、該当する場合はピンも含まれます。



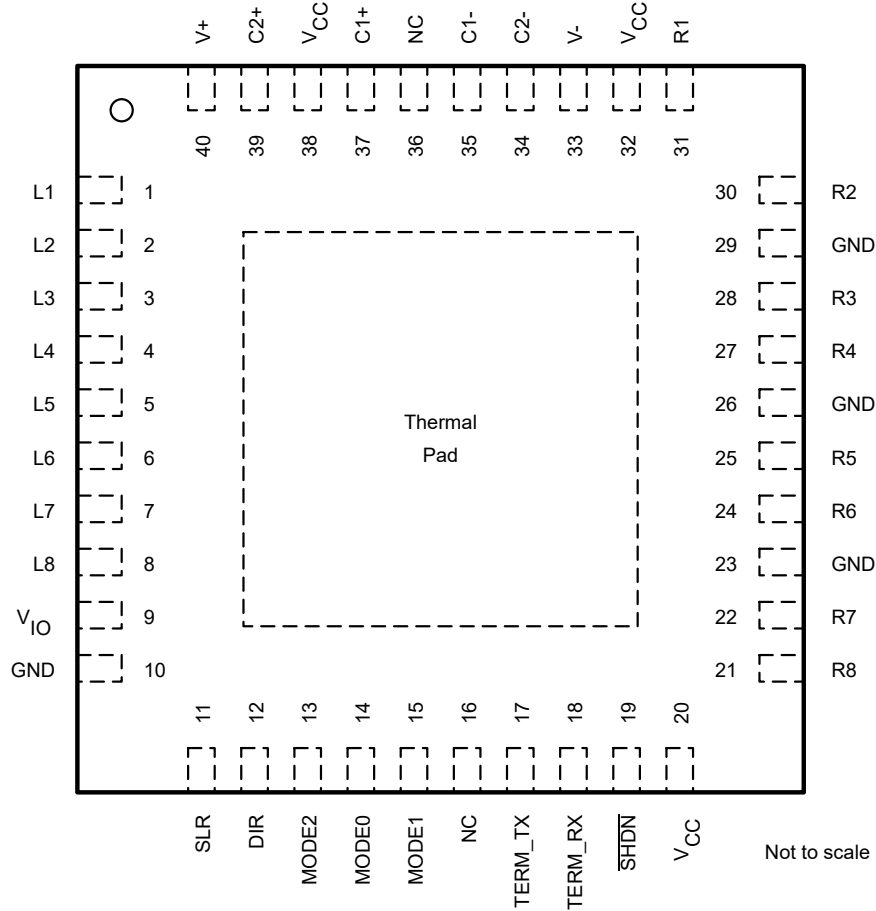
THVD4431 の概略回路図



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4 Pin Configuration and Functions



**図 4-1. 40-Pin VQFN Package (RHA)
Top View**

表 4-1. Pin Functions

| NAME | NO. | TYPE | DESCRIPTION |
|-----------------|-----|------|---|
| L1 | 1 | O | Logic output (RS-232) |
| L2 | 2 | O | Logic output (RS-232/RS-485) |
| L3 | 3 | I | Logic input (RS-232/RS-485). Integrated weak pull-up resistor . |
| L4 | 4 | I | Logic input. Integrated weak pull-up resistor |
| L5 | 5 | O | Logic output |
| L6 | 6 | I | Logic input, Integrated weak pull-up resistor |
| L7 | 7 | O | Logic output |
| L8 | 8 | O | Logic output |
| V _{IO} | 9 | P | 1.65 V to 5.5 V logic supply voltage |

表 4-1. Pin Functions (続き)

| NAME | NO. | TYPE | DESCRIPTION |
|--------------------|-----|------|--|
| GND ⁽¹⁾ | 10 | G | Ground |
| SLR | 11 | I | Slew rate control, internal pull-down resistor. SLR=H enables slow speed |
| DIR | 12 | I | RS-485 TX/RX enable/disable. Internal pull-down resistor. |
| MODE2 | 13 | I | MODE control pins, Integrated weak pull-down resistor |
| MODE0 | 14 | I | |
| MODE1 | 15 | I | |
| NC | 16 | NC | Not connected internally. Can be connected to supply, ground or left open on PCB. |
| TERM_TX | 17 | I | 120 Ω Termination enable/disable across R1/R2 terminals. Internal Pull down resistor |
| TERM_RX | 18 | I | 120 Ω Termination enable/disable across R3/R4 terminals. Internal Pull down resistor |
| SHDN | 19 | I | Device enable/disable. Internal pull-down resistor |
| V _{CC} | 20 | P | 3 to 5.5V supply voltage |
| R8 | 21 | I | RS-232 receiver input |
| R7 | 22 | I | RS-232 receiver input |
| GND ⁽¹⁾ | 23 | G | Ground |
| R6 | 24 | O | RS-232 driver output |
| R5 | 25 | I | RS-232 receiver input |
| GND | 26 | G | Ground |
| R4 | 27 | I/O | RS-232 driver output or RS-485 inverting receiver input (B) |
| R3 | 28 | I/O | RS-232 driver output or RS-485 non-inverting receiver input (A) |
| GND ⁽¹⁾ | 29 | G | Ground |
| R2 | 30 | I/O | RS-232 receiver input or RS-485 bus pin (Y or A) |
| R1 | 31 | I/O | RS-232 receiver input or RS-485 bus pin (Z or B) |
| V _{CC} | 32 | P | 3 to 5.5 V supply voltage |
| V- | 33 | | Negative charge pump rail |
| C2- | 34 | | Negative terminal of charge pump capacitor |
| C1- | 35 | | Negative terminal of charge pump capacitor |
| NC | 36 | NC | Not connected internally. Can be left open or Grounded on PCB. |
| C1+ | 37 | | Positive terminal of charge pump capacitor |
| V _{CC} | 38 | P | 3 to 5.5V supply voltage |
| C2+ | 39 | | Positive terminal of charge pump capacitor |
| V+ | 40 | | Positive charge pump rail |

(1) GND pins 10, 23, 26, 29 all must be grounded on PCB.

5 Specifications

5.1 Absolute Maximum Ratings

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

| | | MIN | MAX | UNIT |
|--|--|------|-----------------------|------|
| Bus supply voltage | V _{CC} to GND | -0.5 | 6 | V |
| Logic supply voltage | V _{IO} to GND | -0.5 | V _{CC} + 0.2 | V |
| Charge pump positive-output supply voltage | V+ to GND | -0.3 | 14 | V |
| Charge pump negative-output supply voltage | V- to GND | -14 | 0.3 | V |
| Bus voltage | Voltage at any bus pin (R1, R2, R3, R4, R5, R6, R7, R8) with respect to GND | -16 | 16 | V |
| Differential bus voltage | (R1-R2) or (R2-R1), (R3-R4) or (R4-R3) with termination disbled | -22 | 22 | V |
| Differential bus voltage RS485 mode | (R1-R2) or (R2-R1), (R3-R4) or (R4-R3) with termination enabled | -6 | 6 | V |
| Input voltage | Range at any logic pin (L3, L4, L6, SLR, SHDN, TERM_TX, TERM_RX, MODE0, MODE1, MODE2, DIR) | -0.3 | V _{IO} + 0.2 | V |
| Receiver output current | I _O (L1, L2, L5, L7, L8) | -8 | 8 | mA |
| Storage temperature | T _{stg} | -65 | 150 | °C |
| Junction temperature | T _J | -40 | 170 | °C |

- (1) Operation outside the Absolute Maximum Ratings may cause permanent device damage. Absolute Maximum Ratings do not imply functional operation of the device at these or any other conditions beyond those listed under Recommended Operating Conditions. If used outside the Recommended Operating Conditions but within the Absolute Maximum Ratings, the device may not be fully functional, and this may affect device reliability, functionality, performance, and shorten the device lifetime.

5.2 ESD Ratings

| | | | VALUE | UNIT | |
|--------------------|-------------------------|--|--|---------|---|
| V _(ESD) | Electrostatic discharge | Human-body model (HBM), per ANSI/ESDA/ JEDEC JS-001 ⁽¹⁾ | Bus terminals (R1, R2, R3, R4, R5, R6, R7, R8) and GND | ±16,000 | V |
| | | | All pins except bus terminals and GND | ±4,000 | V |
| | | Charged-device model (CDM), per JEDEC specification JESD22-C101 ⁽²⁾ | ±1,500 | V | |

- (1) JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process.
(2) JEDEC document JEP157 states that 250-V CDM allows safe manufacturing with a standard ESD control process.

5.3 ESD Ratings [IEC]

| | | | VALUE | UNIT |
|--------------------|--|--------------------------------------|---------|------|
| V _(ESD) | | Contact discharge, per IEC 61000-4-2 | ±8,000 | V |
| | | Air-gap discharge, per IEC 61000-4-2 | ±15,000 | |
| V _(EFT) | Electrical fast transient in RS485 HD or FD mode | Per IEC 61000-4-4 | ±4,000 | V |

5.4 Recommended Operating Conditions

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

| | | MIN | NOM | MAX | UNIT |
|-------------------------------|---|----------------------------------|-----|---------------------|------|
| V _{CC} | Supply voltage | 3 | | 5.5 | V |
| V _{IO} | I/O supply voltage | 1.65 | | V _{CC} | V |
| V _{I(RS-485)} | Input voltage at any bus terminal (R1, R2, R3, R4) in RS-485 mode ⁽¹⁾ | -7 | | 12 | V |
| V _{ID} | Differential input voltage in RS-485 receive mode [(R1-R2) or (R2-R1), (R3-R4) or (R4-R3)] with on-chip termination resistor disabled | -12 | | 12 | V |
| V _{ID} | Differential input voltage in RS-485 receive mode [(R1-R2) or (R2-R1), (R3-R4) or (R4-R3)] with on-chip termination resistor enabled | -5.5 | | 5.5 | V |
| V _{I(RS-232)} | Receiver input voltage in RS-232 mode | -15 | | 15 | V |
| V _{IH} | High-level input voltage (L3, L4, L6, SLR, SHDN, TERM_TX, TERM_RX, MODE0, MODE1, MODE2, DIR inputs) | 0.7*V _{IO} | | V _{IO} | V |
| V _{IL} | Low-level input voltage (L3, L4, L6, SLR, SHDN, TERM_TX, TERM_RX, MODE0, MODE1, MODE2, DIR inputs) | 0 | | 0.3*V _{IO} | V |
| I _O | Output current, driver in RS-485 mode | -60 | | 60 | mA |
| I _{OR} | Output current, receiver | V _{IO} = 1.8 V or 2.5 V | | 2 | mA |
| I _{OR} | Output current, receiver | V _{IO} = 3.3 V or 5 V | | 4 | mA |
| R _L | Differential load resistance in RS-485 mode | 54 | 60 | | Ω |
| 1/t _{UI} | Signaling rate in RS-485 mode | SLR = V _{IO} | | 500 | kbps |
| | | SLR = GND or floating | | 20 | Mbps |
| | Signaling rate in RS-232 mode | SLR = V _{IO} | | 250 | kbps |
| | | SLR = GND or floating | | 1 | Mbps |
| 1/t _{UI(loopback)} | Signaling rate in RS-485 loopback mode | | | 0.5 | Mbps |
| | Signaling rate in RS-232 loopback mode | | | 1 | Mbps |
| T _A ⁽²⁾ | Operating ambient temperature | -40 | | 125 | °C |

- (1) The algebraic convention, in which the least positive (most negative) limit is designated as minimum is used in this data sheet.
 (2) Operation is specified for internal (junction) temperatures upto 150°C. Self-heating due to internal power dissipation should be considered for each application. Maximum junction temperature is internally limited by the thermal shut-down (TSD) circuit which disables the driver and receiver when the junction temperature reaches 170°C.

5.5 Thermal Information

| THERMAL METRIC ⁽¹⁾ | | THVD4431 | UNIT |
|-------------------------------|--|-----------|------|
| | | RHA (QFN) | |
| | | 40 PINS | |
| R _{θJA} | Junction-to-ambient thermal resistance | 27.4 | °C/W |
| R _{θJC(top)} | Junction-to-case (top) thermal resistance | 16.8 | °C/W |
| R _{θJB} | Junction-to-board thermal resistance | 9.8 | °C/W |
| ψ _{JT} | Junction-to-top characterization parameter | 0.2 | °C/W |
| ψ _{JB} | Junction-to-board characterization parameter | 9.8 | °C/W |
| R _{θJC(bot)} | Junction-to-case (bottom) thermal resistance | 2.7 | °C/W |

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

5.6 Power Dissipation

| PARAMETER | | TEST CONDITIONS | | | Typical | Max | UNIT |
|------------------------|---|--|---------|----------|---------|-----|------|
| P _{D(RS-485)} | Full Duplex mode with DIR = V _{IO} , MODE2, MODE1, MODE0 = 011, R2/R1 are externally connected to R3/R4 in loopback fashion; V _{IO} = V _{CC} = 5.5 V, T _A = 125 °C, L3 = square wave 50% duty | Unterminated, TERM_TX = L, TERM_RX = L | SLR = H | 500 kbps | 160 | 200 | mW |
| | | | SLR = L | 20Mbps | 390 | 450 | |
| | | TERM_TX = TERM_RX = V _{IO} | SLR = H | 500 kbps | 430 | 500 | mW |
| | | | SLR = L | 20Mbps | 500 | 575 | |

5.6 Power Dissipation (続き)

| PARAMETER | | TEST CONDITIONS | | | Typical | Max | UNIT |
|-------------------------|--|---|---------|----------|---------|-----|------|
| P _D (RS-232) | RS-232 mode with MODE2, MODE1, MODE0 = 001 | V _{CC} = V _{IO} = 5.5V, R3, R4, R6 bus lines loaded with 3 kΩ, R3 load cap = 1000 pF, L3 toggling | SLR = L | 1 Mbps | 320 | 500 | mW |
| | | V _{CC} = V _{IO} = 5.5V, R3, R4, R6 bus lines loaded with 3 kΩ, R3 load cap = 2500 pF, L3 toggling | SLR = H | 250 kbps | 185 | 200 | mW |

5.7 Electrical Characteristics

over operating free-air temperature range (unless otherwise noted). All typical values are at 25°C and supply voltage of V_{CC} = 5 V, V_{IO} = 3.3 V, unless otherwise noted.

| PARAMETER | | TEST CONDITIONS | | | MIN | TYP | MAX | UNIT |
|------------------------|---|--|--|--|-----------------------------|-----------------------|------|------|
| Driver_RS-485 | | | | | | | | |
| V _{OD} | Driver differential output voltage magnitude | R _L = 60 Ω, -7 V ≤ V _{test} ≤ 12 V (See 6-1) | | | 1.5 | 2 | | V |
| | | R _L = 60 Ω, -7 V ≤ V _{test} ≤ 12 V, 4.5 V ≤ V _{CC} ≤ 5.5 V (See 6-1) | | | 2.1 | 3 | | V |
| | | R _L = 100 Ω (See 6-2) | | | 2 | 2.5 | | V |
| | | R _L = 54 Ω, 4.5 V ≤ V _{CC} ≤ 5.5 V (See 6-2) | | | 2.1 | 3.3 | | V |
| | | R _L = 54 Ω (See 6-2) | | | 1.5 | 3.3 | | V |
| Δ V _{OD} | Change in magnitude of differential output voltage | R _L = 54 Ω or 100 Ω (See 6-2) | | | -50 | | 50 | mV |
| V _{OC} | Common-mode output voltage | R _L = 54 Ω or 100 Ω (See 6-2) | | | | V _{CC} /2 | 3 | V |
| ΔV _{OC(SS)} | Change in steady-state common-mode output voltage | R _L = 54 Ω or 100 Ω (See 6-2) | | | -50 | | 50 | mV |
| I _{OS} | Short-circuit output current (bus terminals) | DIR = V _{IO} , -7 V ≤ (V _{R2} or V _{R1}) ≤ 12 V, or R1 shorted to R2 | | | -250 | | 250 | mA |
| I _{OZD} | Driver High impedance output leakage current on R1 and R2 in Full duplex mode | MODE2, MODE1, MODE0 = 011, TERM_TX = GND, DIR = GND, V _{CC} = GND or 5.5V, V _O = -7V, +12V | | | -125 | | 125 | μA |
| | | MODE2, MODE1, MODE0 = 011, TERM_TX = V _{IO} , DIR = GND, V _{CC} = 5.5V, V _O = -7V, +12V | | | -325 | | 350 | μA |
| Receiver_RS-485 | | | | | | | | |
| I _I | Bus input current (termination disabled) | Half and full duplex modes, DIR = 0 V, V _{CC} and V _{IO} = 0 V or 5.5 V | | | | 75 | 125 | μA |
| | | | | | V _I = 12 V | | | μA |
| I _{RXT} | Receiver bus input leakage current with termination enabled | Full duplex mode, V _{CC} and V _{IO} = 5.5 V, TERM_RX = V _{IO} | | | | | 325 | μA |
| | | | | | V _I = -7 to 12 V | -325 | | μA |
| V _{TH+} | Positive-going input threshold voltage ⁽¹⁾ | Over common-mode range of -7 V to 12 V | | | | -70 | -40 | mV |
| V _{TH-} | Negative-going input threshold voltage ⁽¹⁾ | | | | | -200 | -150 | mV |
| V _{HYS} | Input hysteresis | | | | | 25 | 80 | mV |
| C _{A,B} | Input differential capacitance | Measured between R3 and R4, f = 1 MHz | | | | 45 | | pF |
| V _{OH} | Output high voltage, L2 pin | I _{OH} = -4 mA, V _{IO} = 3 to 3.6 V or 4.5 V to 5.5 V | | | V _{IO} - 0.4 | V _{IO} - 0.2 | | V |
| V _{OL} | Output low voltage, L2 pin | I _{OL} = 4 mA, V _{IO} = 3 to 3.6 V or 4.5 V to 5.5 V | | | | 0.2 | 0.4 | V |
| V _{OH} | Output high voltage, L2 pin | I _{OH} = -2 mA, V _{IO} = 1.65 to 1.95 V or 2.25 V to 2.75 V | | | V _{IO} - 0.4 | V _{IO} - 0.2 | | V |
| V _{OL} | Output low voltage, L2 pin | I _{OL} = 2 mA, V _{IO} = 1.65 to 1.95 V or 2.25 V to 2.75 V | | | | 0.2 | 0.4 | V |
| I _{OZ} | Output high-impedance current, L2 pin | V _O = 0 V or V _{IO} , DIR = V _{IO} , MODE2, MODE1, MODE0 = 010 (half duplex mode) | | | -2 | | 2 | μA |
| Driver_RS-232 | | | | | | | | |
| V _{OH} | High-level output voltage | All DOUT (R3, R4, R6) at R _L = 3 kΩ to GND, DIN (L3, L4, L6) = GND; V _{CC} = 3 V to 3.6 V | | | 5 | 5.5 | 7.2 | V |
| V _{OL} | Low-level output voltage | All DOUT (R3, R4, R6) at R _L = 3 kΩ to GND, DIN (L3, L4, L6) = V _{IO} ; V _{CC} = 3 V to 3.6 V | | | -7.2 | -5.5 | -5 | V |

5.7 Electrical Characteristics (続き)

over operating free-air temperature range (unless otherwise noted). All typical values are at 25°C and supply voltage of $V_{CC} = 5\text{ V}$, $V_{IO} = 3.3\text{ V}$, unless otherwise noted.

| PARAMETER | | TEST CONDITIONS | | MIN | TYP | MAX | UNIT |
|---------------------------|---|---|-------------------------|---------------------------------------|----------------|-----------|--------------------|
| V_{OH} | High-level output voltage | All DOUT (R3, R4, R6) at $R_L = 3\text{ k}\Omega$ to GND, DIN (L3, L4, L6) = GND; $V_{CC} = 4.5\text{ V}$ to 5.5 V | | 7.8 | 9 | 11 | V |
| V_{OL} | Low-level output voltage | All DOUT (R3, R4, R6) at $R_L = 3\text{ k}\Omega$ to GND, DIN (L3, L4, L6) = V_{IO} ; $V_{CC} = 4.5\text{ V}$ to 5.5 V | | -11 | -9 | -7.8 | V |
| I_{OS} | Short-circuit output current (2) | $V_{CC} = 3.6\text{ V}$ | $V_O = 0\text{ V}$ | | ± 35 | ± 60 | mA |
| | | $V_{CC} = 5.5\text{ V}$ | $V_O = 0\text{ V}$ | | | | |
| r_o | Output resistance on R3, R4, R6 | $V_{CC} = 0\text{ V}$, $V_+ = 0\text{ V}$, and $V_- = 0\text{ V}$ | | 300 | 10M | | Ω |
| I_{off} | Output leakage current on R3, R4, R6 | SHDN = GND | $V_O = \pm 12\text{ V}$ | $V_{CC} = 3\text{ to }3.6\text{ V}$ | | ± 125 | μA |
| | | | $V_O = \pm 10\text{ V}$ | $V_{CC} = 4.5\text{ to }5.5\text{ V}$ | | ± 125 | μA |
| Receiver_RS-232 | | | | | | | |
| V_{OH} | High-level output voltage L1/L2/L5/L7/L8 | $I_{OH} = -4\text{ mA}$, $V_{IO} = 3\text{ to }3.6\text{ V}$ or 4.5 V to 5.5 V | | $V_{IO} - 0.5$ | $V_{IO} - 0.2$ | | V |
| | | $I_{OH} = -2\text{ mA}$, $V_{IO} = 1.65\text{ to }1.95\text{ V}$ or 2.25 V to 2.75 V | | $V_{IO} - 0.48$ | $V_{IO} - 0.2$ | | V |
| V_{OL} | Low-level output voltage L1/L2/L5/L7/L8 | $I_{OL} = 4\text{ mA}$, $V_{IO} = 3\text{ to }3.6\text{ V}$ or 4.5 V to 5.5 V | | | | 0.4 | V |
| | | $I_{OL} = 2\text{ mA}$, $V_{IO} = 1.65\text{ to }1.95\text{ V}$ or 2.25 V to 2.75 V | | | | 0.4 | V |
| V_{IT+} | Positive-going input threshold voltage on RS-232 receiver inputs (R1, R2, R5, R7, R8) | $V_{CC} = 3.3\text{ V}$ | | | 1.6 | 2.4 | V |
| | | $V_{CC} = 5\text{ V}$ | | | 1.9 | 2.4 | V |
| V_{IT-} | Negative-going input threshold voltage on RS-232 receiver inputs (R1, R2, R5, R7, R8) | $V_{CC} = 3.3\text{ V}$ | | 0.6 | 1.1 | | V |
| | | $V_{CC} = 5\text{ V}$ | | 0.8 | 1.4 | | V |
| V_{hys} | Input hysteresis on receiver inputs ($V_{IT+} - V_{IT-}$) | | | 0.4 | 0.5 | | V |
| I_{off} | Output leakage current on receiver output pins L1/L2/L5/L7/L8 | SHDN = 0 V | | | ± 0.05 | ± 10 | μA |
| r_i | Input resistance on receiver input pins | $-15\text{ V} \leq V_i \leq 15\text{ V}$ | | 3 | 5 | 7 | k Ω |
| Thermal Protection | | | | | | | |
| T_{SHDN} | Thermal shutdown threshold | Temperature rising | | 150 | 170 | | $^{\circ}\text{C}$ |
| T_{HYS} | Thermal shutdown hysteresis | | | | 15 | | $^{\circ}\text{C}$ |
| Supply | | | | | | | |
| UV_{VCC} (rising) | Rising under-voltage threshold on V_{CC} | | | | 2.5 | 2.8 | V |
| UV_{VCC} (falling) | Falling under-voltage threshold on V_{CC} | | | 1.9 | 2.1 | | V |
| $UV_{VCC(hys)}$ | Hysteresis on under-voltage of V_{CC} | | | 100 | 400 | | mV |
| UV_{VIO} (rising) | Rising under-voltage threshold on V_{IO} | | | | 1.5 | 1.6 | V |
| UV_{VIO} (falling) | Falling under-voltage threshold on V_{IO} | | | 1.2 | 1.4 | | V |
| $UV_{VIO(hys)}$ | Hysteresis on under-voltage of V_{IO} | | | 85 | 100 | | mV |

5.7 Electrical Characteristics (続き)

over operating free-air temperature range (unless otherwise noted). All typical values are at 25°C and supply voltage of $V_{CC} = 5\text{ V}$, $V_{IO} = 3.3\text{ V}$, unless otherwise noted.

| PARAMETER | | TEST CONDITIONS | | MIN | TYP | MAX | UNIT |
|--|---|---|--|-----|--------------------|--------------------|---------------|
| I_{CC_SHDN} | Supply current in shutdown mode | $V_{CC} = 4.5\text{ V to } 5.5\text{ V}$, $\overline{SHDN} = \text{GND}$, All other logic input pins floating, no load on bus, $T_A \leq 125^\circ\text{C}$ | | | 5 | 20 | μA |
| | | $V_{CC} = 3\text{ V to } 3.6\text{ V}$, $\overline{SHDN} = \text{GND}$, All other logic input pins floating, no load on bus, $T_A \leq 125^\circ\text{C}$ | | | 3 | 15 | μA |
| | | $V_{CC} = 4.5\text{ V to } 5.5\text{ V}$, $\overline{SHDN} = \text{GND}$, All other logic input pins floating, no load on bus, $T_A \leq 105^\circ\text{C}$ | | | 5 | 15 | μA |
| | | $V_{CC} = 3\text{ V to } 3.6\text{ V}$, $\overline{SHDN} = \text{GND}$, All other logic input pins floating, no load on bus, $T_A \leq 105^\circ\text{C}$ | | | 3 | 10 | μA |
| I_{IO_SHDN} | Logic supply current in shutdown mode | $V_{IO} = 1.65\text{ V to } 5.5\text{ V}$, $\overline{SHDN} = \text{GND}$, All other logic input pins floating | | | | 2 | μA |
| I_{CC_485} | Supply current (quiescent), $V_{CC} = 4.5\text{ V to } 5.5\text{ V}$ TERM_RX, TERM_TX = Floating or low, SLR = X | Driver and receiver enabled, DIR = V_{IO} , MODE2, MODE1, MODE0 = 011 (Full duplex) | No load | | 1.7 | 3.4 | mA |
| | | Driver enabled, receiver disabled, DIR = V_{IO} , MODE2, MODE1, MODE0 = 010 (Half duplex) | No load | | 1.3 | 2.8 | mA |
| | | Driver disabled, receiver enabled, DIR = GND, MODE2, MODE1, MODE0 = 010 (Half duplex) | No load | | 0.8 | 1.5 | mA |
| I_{CC_485} | Supply current (quiescent), $V_{CC} = 3\text{ V to } 3.6\text{ V}$ TERM_RX, TERM_TX = Floating or low, SLR = X | Driver and receiver enabled, DIR = V_{IO} , MODE2, MODE1, MODE0 = 011 (Full duplex) | No load | | 1.5 | 2.8 | mA |
| | | Driver enabled, receiver disabled, DIR = V_{IO} , MODE2, MODE1, MODE0 = 010 (Half duplex) | No load | | 1 | 2.3 | mA |
| | | Driver disabled, receiver enabled, DIR = GND, MODE2, MODE1, MODE0 = 010 (Half duplex) | No load | | 0.7 | 1.3 | mA |
| I_{IO_485} | Logic supply current (quiescent), $V_{IO} = 3\text{ to } 3.6\text{ V}$ TERM_RX, TERM_TX = Floating | Driver disabled, Receiver enabled, SLR = GND, DIR = GND; MODE2, MODE1, MODE0 = 010 (half duplex) | No load | | 7 | 17 | μA |
| | | Driver disabled, Receiver enabled, SLR = V_{IO} ; DIR = GND; MODE2, MODE1, MODE0 = 010 (half duplex) | No load | | 8 | 21 | μA |
| I_{CCDT_485} | Supply current in RS-485 driver termination mode | Driver enabled with termination ON; MODE2, MODE1, MODE0 = 011 (full duplex) | DIR = V_{IO} , TERM_TX = V_{IO} | | 38 | 50 | mA |
| I_{CCRT_485} | Supply current in RS-485 receiver termination mode | Receiver enabled with termination ON; MODE2, MODE1, MODE0 = 011 (full duplex) | DIR = GND, TERM_RX = V_{IO} | | 1 | 1.5 | mA |
| I_{CC_RS232} | Supply current in RS-232 mode | MODE2, MODE1, MODE0 = 001, $\overline{SHDN} = V_{IO}$; other logic inputs floating | No load | | 4 | 6 | mA |
| $I_{CC_RS232_LB}$ | Supply current in RS-232 loopback mode | MODE2 = x, MODE1 = 0, MODE0 = 0; L3 = L4 = L6 = static logic high, $-40^\circ\text{C} \leq T_A \leq 85^\circ\text{C}$ | No extra load on RS-232 drivers or on logic output | | 25 | 31 | mA |
| $I_{CC_RS485_LB}$ | Supply current in RS-485 loopback mode | MODE2 = MODE1 = MODE0 = V_{IO} ; L3 = static logic high | No load on bus or logic output | | 3 | 4 | mA |
| On-Chip termination resistor_RS-485 | | | | | | | |
| R_{TERM_TX} | 120 Ω termination across Driver output R1/R2 terminals | MODE2, MODE1, MODE0 = 011 (Full duplex) or 010 (half duplex); DIR = GND, TERM_TX = V_{IO} , $V_{R2R1} = 2\text{ V}$, $V_{R1} = -7\text{ V}$, 0 V, 10 V; See 6-9 | | 102 | 120 | 138 | Ω |
| R_{TERM_RX} | 120 Ω termination across receiver output R3/R4 terminals | MODE2, MODE1, MODE0 = 011 (Full duplex); TERM_RX = V_{IO} , $V_{R3R4} = 2\text{ V}$, $V_{R4} = -7\text{ V}$, 0 V, 10 V; See 6-9 | | 102 | 120 | 138 | Ω |
| Logic | | | | | | | |
| I_{IN} | Input current (L3, L4, L6, DIR, \overline{SHDN} , SLR, TERM_TX, TERM_RX, MODE2, MODE1, MODE0) | $1.65\text{ V} \leq V_{IO} \leq 5.5\text{ V}$, $0\text{ V} \leq V_{IN} \leq V_{IO}$ | | -20 | | 5 | μA |
| $V_{IT+(IN)}$ | Rising threshold: logic inputs | $1.65\text{ V} \leq V_{IO} \leq 5.5\text{ V}$ | | | $0.6 \cdot V_{IO}$ | $0.7 \cdot V_{IO}$ | V |
| $V_{IT-(IN)}$ | Falling threshold: logic inputs | | | | $0.3 \cdot V_{IO}$ | $0.4 \cdot V_{IO}$ | V |
| $V_{IN(HYS)}$ | Input threshold: logic inputs | | | | $0.1 \cdot V_{IO}$ | $0.2 \cdot V_{IO}$ | V |

- Under any specific conditions, V_{TH+} is assured to be at least V_{HYS} higher than V_{TH-} .
- Short-circuit durations should be controlled to prevent exceeding the device absolute power dissipation ratings, and not more than one

output should be shorted at a time.

5.8 Switching Characteristics_RS-485_500kbps

500-kbps (with SLR = V_{IO}) over recommended operating conditions. All typical values are at 25°C and supply voltage of $V_{CC} = 5\text{ V}$, $V_{IO} = 3.3\text{ V}$, unless otherwise noted. ⁽¹⁾

| PARAMETER | TEST CONDITIONS | | MIN | TYP | MAX | UNIT | |
|--------------------------|--|---|--|-----|-----|------|---------------|
| Driver | | | | | | | |
| t_r, t_f | Differential output rise/fall time | $R_L = 54\ \Omega, C_L = 50\text{ pF}$ See 6-3 | $V_{CC} = 3\text{ to }3.6\text{ V}$, Typical at 3.3V | 210 | 300 | 600 | ns |
| | | | $V_{CC} = 4.5\text{ to }5.5\text{ V}$, Typical at 5 V | 250 | 300 | 600 | ns |
| t_{PHL}, t_{PLH} | Propagation delay | | $V_{CC} = 3\text{ to }3.6\text{ V}$, Typical at 3.3V | | 250 | 450 | ns |
| | | | $V_{CC} = 4.5\text{ to }5.5\text{ V}$, Typical at 5 V | | 250 | 450 | ns |
| $t_{SK(P)}$ | Pulse skew, $ t_{PHL} - t_{PLH} $ | | $V_{CC} = 3\text{ to }3.6\text{ V}$, Typical at 3.3V | | 2 | 15 | ns |
| | | | $V_{CC} = 4.5\text{ to }5.5\text{ V}$, Typical at 5 V | | 2 | 15 | ns |
| t_{PHZ}, t_{PLZ} | Disable time | MODE2, MODE1, MODE0 = 010 (half duplex) or 011 (full duplex) | See 6-4 and 6-5 | | 80 | 150 | ns |
| t_{PZH}, t_{PZL} | Enable time | MODE2, MODE1, MODE0 = 011 (full duplex): receiver enabled | | 200 | 650 | ns | |
| Receiver | | | | | | | |
| t_r, t_f | Output rise/fall time | $C_L = 15\text{ pF}$ | | | 5 | 10 | ns |
| t_{PHL}, t_{PLH} | Propagation delay | | See 6-6 | | 700 | 1200 | ns |
| $t_{SK(P)}$ | Pulse skew, $ t_{PHL} - t_{PLH} $ | | | | 10 | 45 | ns |
| t_{PHZ}, t_{PLZ} | Disable time in half duplex mode | MODE2, MODE1, MODE0 = 010, TERM_TX = V_{IO} | See 6-7 | | 30 | 80 | ns |
| $t_{PZH(1)}$ | Enable time in half duplex mode | | | | 60 | 155 | ns |
| $t_{PZL(1)}$ | | | | | 450 | 1250 | ns |
| $t_{PZH(2)}, t_{PZL(2)}$ | Enable time from shutdown with TX disabled in full duplex mode | DIR = 0 V; MODE2, MODE1, MODE0 = 011 | See 6-8 | | 7 | 16 | μs |

(1) R3, R4 are RX input, R2/R1 are driver output terminals in Full duplex mode

5.9 Switching Characteristics_RS-485_20Mbps

20-Mbps (SLR = GND) over recommended operating conditions. All typical values are at 25°C and supply voltage of $V_{CC} = 5\text{ V}$, $V_{IO} = 3.3\text{ V}$. ⁽¹⁾

| PARAMETER | TEST CONDITIONS | | MIN | TYP | MAX | UNIT | |
|--------------------|------------------------------------|---|--|-----|-----|------|----|
| Driver | | | | | | | |
| t_r, t_f | Differential output rise/fall time | $R_L = 54\ \Omega, C_L = 50\text{ pF}$ See 6-3 | $V_{CC} = 3\text{ to }3.6\text{ V}$, Typical at 3.3 V | 5 | 10 | 15 | ns |
| | | | $V_{CC} = 4.5\text{ to }5.5\text{ V}$, Typical at 5 V | 5 | 10 | 15 | ns |
| t_{PHL}, t_{PLH} | Propagation delay | | $V_{IO} = 1.65\text{ V to }1.95\text{ V}$ | 14 | 25 | 58 | ns |
| | | | $V_{IO} = 3\text{ V to }3.6\text{ V}$ | 9 | 20 | 46 | ns |
| $t_{SK(P)}$ | Pulse skew, $ t_{PHL} - t_{PLH} $ | | $V_{CC} = 3\text{ to }3.6\text{ V}$, Typical at 3.3 V | | 1 | 3.5 | ns |
| | | | $V_{CC} = 4.5\text{ to }5.5\text{ V}$, Typical at 5 V | | 1 | 3.5 | ns |
| t_{PHZ}, t_{PLZ} | Disable time | MODE2, MODE1, MODE0 = 010 (half duplex) or 011 (full duplex) | See 6-4 and 6-5 | | 11 | 65 | ns |
| t_{PZH}, t_{PZL} | Enable time | MODE2, MODE1, MODE0 = 011 (full duplex): receiver enabled | | 8 | 80 | ns | |
| Receiver | | | | | | | |

5.9 Switching Characteristics_RS-485_20Mbps (続き)

20-Mbps (SLR = GND) over recommended operating conditions. All typical values are at 25°C and supply voltage of $V_{CC} = 5$ V, $V_{IO} = 3.3$ V. ⁽¹⁾

| PARAMETER | | TEST CONDITIONS | | MIN | TYP | MAX | UNIT |
|--------------------------|---|--|-------------------------|-----|-----|-----|---------|
| t_r, t_f | Output rise/fall time | $C_L = 15$ pF | See 6-6 | | 5 | 10 | ns |
| t_{PHL}, t_{PLH} | Propagation delay | | | | 40 | 70 | ns |
| $t_{SK(P)}$ | Pulse skew, $ t_{PHL} - t_{PLH} $ | | | | | 10 | ns |
| t_{PHZ}, t_{PLZ} | Disable time in half duplex mode | MODE2, MODE1, MODE0 = 010, TERM_TX = V_{IO} | See 6-7 | | 20 | 80 | ns |
| $t_{PZH(1)}, t_{PZL(1)}$ | Enable time in half duplex mode (includes driver disable time as per setup) | | | | 50 | 160 | ns |
| $t_{PZH(2)}, t_{PZL(2)}$ | Enable time from shutdown with TX disabled in full duplex mode | DIR = 0 V; MODE2, MODE1, MODE0 = 011 | See 6-8 | | 4 | 15 | μ s |

(1) R3, R4 are RX input, R2/R1 are driver output terminals in Full duplex mode.

5.10 Switching Characteristics, Driver_RS232

over recommended ranges of supply voltage and operating free-air temperature(unless otherwise noted)⁽¹⁾

| PARAMETER | | TEST CONDITIONS | | MIN | TYP ⁽²⁾ | MAX | UNIT |
|--------------------|---------------------------------------|--|---|------|--------------------|-----|------------|
| 250 kbps | | | | | | | |
| | Maximum data rate | $R_L = 3$ k Ω One DOUT switching | $C_L = 2500$ pF See 6-16 | 250 | 500 | | kbps |
| t_{PHL}, t_{PHL} | Transmitter propagation delay | $R_L = 3$ k Ω to 7 k Ω | $C_L = 150$ pF to 2500 pF See 6-16 | | 0.8 | 2 | μ s |
| $t_{sk(p)}$ | Transmitter Pulse skew ⁽³⁾ | | | | 220 | 600 | ns |
| SR(tr) | Slew rate, transition region | $V_{CC} = 3.3$ V \pm 10%, 5 V \pm 10% , $R_L = 3$ k Ω to 7 k Ω , See 6-17 | $C_L = 150$ pF to 1000 pF | 6 | | 30 | V/ μ s |
| | | | $C_L = 150$ pF to 2500 pF | 4 | | 30 | |
| 1 Mbps | | | | | | | |
| | Maximum data rate | $R_L = 3$ k Ω One DOUT switching, See 6-16 | $C_L = 250$ pF, $V_{CC} = 3$ to 3.6 V | 1000 | | | kbps |
| | | | $C_L = 1000$ pF, $V_{CC} = 4.5$ to 5.5 V | 1000 | | | kbps |
| t_{PLH}, t_{PHL} | Transmitter propagation delay | $R_L = 3$ k Ω to 7 k Ω , See 6-16 | $C_L = 150$ pF to 1000 pF | | 300 | 800 | ns |
| $t_{sk(p)}$ | Pulse skew ⁽³⁾ | | | | 25 | 150 | ns |
| SR(tr) | Slew rate, transition region | $R_L = 3$ k Ω to 7 k Ω , $V_{CC} = 4.5$ V to 5.5 V $R_L = 3$ k Ω to 7 k Ω , $V_{CC} = 3$ V to 3.6 V | $C_L = 150$ pF to 1000 pF See 6-17 | 18 | | 150 | V/ μ s |
| | | | | 15 | | 150 | V/ μ s |

(1) Test conditions are $C1-C4 = 0.1$ μ F at $V_{CC} = 3.3$ V + 0.3 V; $V_{CC} = 5$ V \pm 0.5 V.

(2) All typical values are at $V_{CC} = 3.3$ V or $V_{CC} = 5$ V, and $T_A = 25^\circ$ C.

(3) Pulse skew is defined as $|t_{PLH} - t_{PHL}|$ of each channel of the same device.

5.11 Switching Characteristics, Receiver_RS232

over recommended ranges of supply voltage and operating free-air temperature (unless otherwise noted)⁽¹⁾

| PARAMETER | | TEST CONDITIONS | | MIN | TYP ⁽²⁾ | MAX | UNIT |
|--------------------------|--|--|--|---|--------------------|-----|------|
| 250 kbps | | | | | | | |
| t_{PLH} | Propagation delay time, low- to high-level output | $C_L = 150$ pF, See 6-18 | | | 150 | 550 | ns |
| t_{PHL} | Propagation delay time, high- to low-level output | | | | 150 | 550 | ns |
| t_{PLH} | Propagation delay time, low- to high-level output | $C_L = 15$ pF, See 6-18 | | | 130 | 520 | ns |
| t_{PHL} | Propagation delay time, high- to low-level output | | | | 130 | 520 | ns |
| t_{R_232}, t_{F_232} | Rise/fall time (receiver buffer output), $V_{IO} = 3$ to 5.5 V | $C_L = 150$ pF, See 6-18 | | | 20 | 50 | ns |
| | | | | $C_L = 15$ pF, See 6-18 | | 5 | 10 |
| | Rise/fall time (receiver buffer output), $V_{IO} = 1.65$ to 2.75 V | $C_L = 150$ pF, See 6-18 | | | 40 | 90 | ns |
| | | | | $C_L = 15$ pF, See 6-18 | | 10 | 20 |

5.11 Switching Characteristics, Receiver_RS232 (続き)

over recommended ranges of supply voltage and operating free-air temperature (unless otherwise noted)⁽¹⁾

| PARAMETER | | TEST CONDITIONS | MIN | TYP ⁽²⁾ | MAX | UNIT |
|--------------------------------|---|---|---|--------------------|-----|------|
| t_{en} | Output enable time | $C_L = 150 \text{ pF}$, $R_L = 3 \text{ k}\Omega$, See 6-19 | | 6 | 14 | us |
| t_{dis} | Output disable time | | | 100 | 200 | ns |
| $t_{sk(p)}$ | Pulse skew ⁽³⁾ | $C_L = 150 \text{ pF}$, See 6-18 | | 50 | 135 | ns |
| | | $C_L = 15 \text{ pF}$, See 6-18 | | 50 | 135 | ns |
| 1 Mbps | | | | | | |
| t_{PLH} | Propagation delay time, low- to high-level output | $C_L = 150 \text{ pF}$, See 6-18 | | 150 | 550 | ns |
| t_{PHL} | Propagation delay time, high- to low-level output | | | 150 | 550 | ns |
| t_{PLH} | Propagation delay time, low- to high-level output | $C_L = 15 \text{ pF}$, See 6-18 | | 130 | 520 | ns |
| t_{PHL} | Propagation delay time, high- to low-level output | | | 130 | 520 | ns |
| t_{R_232} , t_{F_232} | Rise/fall time (receiver buffer output), $V_{IO} = 3 \text{ to } 5.5 \text{ V}$ | $C_L = 150 \text{ pF}$, See 6-18 | | 20 | 50 | ns |
| | | $C_L = 15 \text{ pF}$, See 6-18 | | 5 | 10 | ns |
| | | Rise/fall time (receiver buffer output), $V_{IO} = 1.65 \text{ to } 2.75 \text{ V}$ | $C_L = 150 \text{ pF}$, See 6-18 | | 40 | 90 |
| | | $C_L = 15 \text{ pF}$, See 6-18 | | 10 | 20 | ns |
| t_{en} | Output enable time | $C_L = 150 \text{ pF}$, $R_L = 3 \text{ k}\Omega$, See 6-19 | | 6 | 14 | us |
| t_{dis} | Output disable time | | | 100 | 200 | ns |
| $t_{sk(p)}$ | Pulse skew ⁽³⁾ | $C_L = 150 \text{ pF}$, See 6-18 | | 50 | 125 | ns |
| | | $C_L = 15 \text{ pF}$, See 6-18 | | 50 | 125 | ns |

(1) Test conditions are C_1 – $C_4 = 0.1 \mu\text{F}$ at $V_{CC} = 3.3 \text{ V} \pm 0.3 \text{ V}$; $C_1 = 0.047 \mu\text{F}$, C_2 – $C_4 = 0.33 \mu\text{F}$ at $V_{CC} = 5 \text{ V} \pm 0.5 \text{ V}$.

(2) All typical values are at $V_{CC} = 3.3 \text{ V}$ or $V_{CC} = 5 \text{ V}$, and $T_A = 25^\circ\text{C}$.

(3) Pulse skew is defined as $|t_{PLH} - t_{PHL}|$ of each channel of the same device.

5.12 Switching Characteristics_MODE switching

Parameters over recommended operating conditions. All typical values are at 25°C and supply voltage of $V_{CC} = 5 \text{ V}$, $V_{IO} = 3.3 \text{ V}$, unless otherwise noted.

| PARAMETER | | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|-----------------|---|---|-----|------|-----|---------------|
| t_{RDY} | Time from Shutdown to RS-232 ready | MODE2, MODE1, MODE0 = 000 or floating; SHDN = GND to V_{IO} ; rest of logic input pins floating, $V_{CC} = 4.5 \text{ V to } 5.5 \text{ V}$ Time from 50% of rising SHDN to charge pump V- supply reaching -8 V; See 6-11 | | 0.05 | 0.1 | ms |
| | | MODE2, MODE1, MODE0 = 000 or floating; SHDN = GND to V_{IO} ; rest of logic input pins floating, $V_{CC} = 3 \text{ V to } 3.6 \text{ V}$ Time from 50% of rising SHDN to charge pump V- supply reaching -5 V; See 6-11 | | 0.1 | 0.4 | ms |
| t_{R2_R4} | Time to switch from RS-232 3T5R mode to RS-485 Full duplex mode | $L_3 = V_{IO}$, MODE2 = GND, MODE1 from GND to V_{IO} , MODE0 = V_{IO} ; SHDN = DIR = V_{IO} ; SLR, TERM_TX, TERM_RX = floating; Time from 50% of MODE1 rising edge to R2 reaching 2V; See 6-12 | | 0.04 | 0.1 | μs |
| t_{R4_R2} | Time to switch from RS-485 full duplex mode to RS-232 3T5R mode | $L_3 = V_{IO}$, MODE2 = GND, MODE1 from V_{IO} to GND, MODE0 = V_{IO} ; SHDN = DIR = V_{IO} ; SLR, TERM_TX, TERM_RX = floating; Time from 50% of MODE1 falling edge to R2 reaching 300 mV; See 6-12 | | 2 | 2.1 | μs |
| t_{LP_RS232} | Time to switch from RS-232 loopback mode to normal RS-232 mode | MODE2 = MODE1 = GND, MODE0 from GND to V_{IO} ; SHDN = V_{IO} , $L_3 = \text{GND}$; Time from 50% of MODE0 rising edge to L2 50% rising edge, $-40^\circ\text{C} \leq T_A \leq 85^\circ\text{C}$; See 6-13 | | 2 | 2.4 | μs |
| t_{RS232_LP} | Time to switch from normal RS-232 mode to RS-232 loopback mode | MODE2 = MODE1 = GND, MODE0 from V_{IO} to GND; SHDN = V_{IO} , $L_3 = \text{GND}$; Time from 50% of MODE0 falling edge to L2 50% falling edge, $-40^\circ\text{C} \leq T_A \leq 85^\circ\text{C}$; See 6-13 | | 2 | 15 | μs |
| t_{LP_RS485} | Time to switch from RS-485 loopback mode to RS-485 full duplex mode | MODE1 = MODE0 = V_{IO} ; MODE2 from V_{IO} to GND; SHDN = V_{IO} , SLR, TERM_TX, TERM_RX = floating; $L_3 = \text{GND}$; Time from 50% of MODE2 falling edge to 50% of rising L2; See 6-14 | | 40 | 50 | μs |

5.12 Switching Characteristics_MODE switching (続き)

Parameters over recommended operating conditions. All typical values are at 25°C and supply voltage of $V_{CC} = 5\text{ V}$, $V_{IO} = 3.3\text{ V}$, unless otherwise noted.

| PARAMETER | | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|------------------|---|--|-----|-----|-----|---------------|
| t_{RS485_LP} | Time to switch from RS-485 full duplex mode to RS-485 loopback mode | MODE1 = MODE0 = V_{IO} ; MODE2 from GND to V_{IO} ; SHDN = V_{IO} ; SLR, TERM_TX, TERM_RX = floating; L3 = GND, Time from 50% of MODE2 rising edge to 50% of falling L2; See 6-14 | | 1 | 2 | μs |
| t_{FHD_RS485} | Time to switch from RS-485 full duplex to half duplex mode | DIR = V_{IO} , MODE2 = GND, MODE1 = V_{IO} ; MODE0 from V_{IO} to GND; SHDN = V_{IO} , SLR, TERM_TX, TERM_RX = floating; L3 = GND, 10k pull down resistor on L2, Time from 50% of MODE0 falling edge to 50% falling edge on L2; See 6-15 | | 0.5 | 1 | μs |
| t_{HFD_RS485} | Time to switch from RS-485 half duplex to full duplex mode | DIR = V_{IO} , MODE2 = GND, MODE1 = V_{IO} ; MODE0 from GND to V_{IO} ; SHDN = V_{IO} , SLR, TERM_TX, TERM_RX = floating; L3 = GND, 10k pull down resistor on L2, Time from 50% of MODE0 rising edge to 50% rising edge on L2; See 6-15 | | 0.5 | 1 | μs |

5.13 Switching Characteristics_RS-485_Termination resistor

Parameters over recommended operating conditions. All typical values are at 25°C and supply voltage of $V_{CC} = 5\text{ V}$, $V_{IO} = 3.3\text{ V}$, unless otherwise noted.

| PARAMETER | | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|------------|--|---|-----|------|------|------|
| t_{DTEN} | Driver terminal Termination resistor turn-on time | MODE2, MODE1, MODE0 = 011; $V_{IO} = 3$ to 3.6 V, DIR = GND, $V_{R2R1} = 2\text{ V}$, $V_{R1} = 0\text{ V}$; See 6-10 | | 1000 | 2200 | ns |
| t_{DTZ} | Driver terminal Termination resistor turn-off time | MODE2, MODE1, MODE0 = 011; $V_{IO} = 3$ to 3.6 V, DIR = GND, $V_{R2R1} = 2\text{ V}$, $V_{R1} = 0\text{ V}$; See 6-10 | | 2000 | 7200 | ns |
| t_{RTEN} | Receiver terminal Termination resistor turn-on time | MODE2, MODE1, MODE0 = 011; $V_{IO} = 3$ to 3.6 V, $V_{R3R4} = 2\text{ V}$, $V_{R4} = 0\text{ V}$; See 6-10 | | 1000 | 2200 | ns |
| t_{RTZ} | Receiver terminal Termination resistor turn-off time | MODE2, MODE1, MODE0 = 011; $V_{IO} = 3$ to 3.6 V, $V_{R3R4} = 2\text{ V}$, $V_{R4} = 0\text{ V}$; See 6-10 | | 2000 | 7200 | ns |

5.14 Switching Characteristics_Loopback mode

Parameters over recommended operating conditions. All typical values are at 25°C and supply voltage of $V_{CC} = 5\text{ V}$, $V_{IO} = 3.3\text{ V}$, unless otherwise noted.

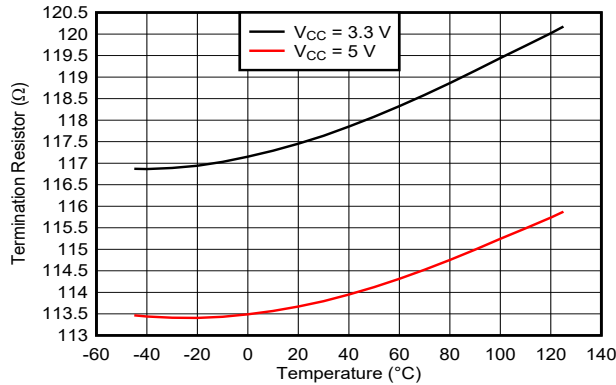
| PARAMETER | | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|--------------------------|--|---|-----|-----|------|------|
| $t_{LB_RS232_rising}$ | Delay from Logic input rising edge to logic output rising edge in RS-232 Loopback mode | MODE2 = X, MODE1, MODE0 = GND; SLR = GND, Delay from 50% of L3/L4/L6 rising edge to 50% L2/L1/L5, L7, L8 rising edge, SHDN = V_{IO} , TERM_TX and TERM_RX float, Load capacitance on output buffers = 15 pF, R_L on all 3 driver outputs = 3k Ω , $-40\text{ }^\circ\text{C} \leq T_A \leq 85\text{ }^\circ\text{C}$ | | 410 | 920 | ns |
| | | MODE2 = X, MODE1, MODE0 = GND; SLR = V_{IO} , Delay from 50% of L3/L4/L6 rising edge to 50% L2/L1/L5, L7, L8 rising edge, SHDN = V_{IO} , TERM_TX and TERM_RX float, Load capacitance on output buffers = 15 pF, R_L on all 3 driver outputs = 3k Ω , $-40\text{ }^\circ\text{C} \leq T_A \leq 85\text{ }^\circ\text{C}$ | | 640 | 1100 | ns |
| $t_{LB_RS232_falling}$ | Delay from Logic input falling edge to logic output falling edge in RS-232 Loopback mode | MODE2 = X, MODE1, MODE0 = GND; SLR = GND, Delay from 50% of L3/L4/L6 falling edge to 50% L2/L1/L5, L7, L8 falling edge, SHDN = V_{IO} , TERM_TX and TERM_RX float, Load capacitance on output buffers = 15 pF, R_L on all 3 driver outputs = 3k Ω , $-40\text{ }^\circ\text{C} \leq T_A \leq 85\text{ }^\circ\text{C}$ | | 570 | 760 | ns |
| | | MODE2 = X, MODE1, MODE0 = GND; SLR = V_{IO} , Delay from 50% of L3/L4/L6 falling edge to 50% L2/L1/L5, L7, L8 falling edge, SHDN = V_{IO} , TERM_TX and TERM_RX float, Load capacitance on output buffers = 15 pF, R_L on all 3 driver outputs = 3k Ω , $-40\text{ }^\circ\text{C} \leq T_A \leq 85\text{ }^\circ\text{C}$ | | 600 | 1460 | ns |
| $t_{SKEW_RS232_LB}$ | Pulse skew from logic input to logic output in RS232 loopback mode | $ t_{LB_RS232_rising} - t_{LB_RS232_falling} $, SLR = V_{IO} , $-40\text{ }^\circ\text{C} \leq T_A \leq 85\text{ }^\circ\text{C}$ | | 100 | 860 | ns |
| | | $ t_{LB_RS232_rising} - t_{LB_RS232_falling} $, SLR = GND, $-40\text{ }^\circ\text{C} \leq T_A \leq 85\text{ }^\circ\text{C}$ | | 70 | 250 | ns |

5.14 Switching Characteristics_Loopback mode (続き)

Parameters over recommended operating conditions. All typical values are at 25°C and supply voltage of $V_{CC} = 5\text{ V}$, $V_{IO} = 3.3\text{ V}$, unless otherwise noted.

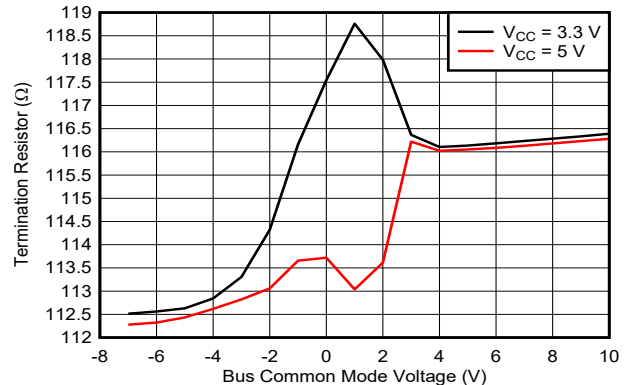
| PARAMETER | | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|--------------------------|--|--|-----|------|------|------|
| $t_{LB_RS485_rising}$ | Delay from Logic input rising edge to logic output rising edge in RS-485 Loopback mode | MODE2 = MODE1 = MODE0 = Vio; SLR = Vio, Delay from 50% of L3 rising edge to 50% L2 rising edge, $\overline{SHDN} = Vio$, TERM_TX and TERM_RX float, Load cap on L2 = 15 pF, Load on Driver output terminals (R2-R1) = 54 Ω | | 1060 | 1770 | ns |
| $t_{LB_RS485_falling}$ | Delay from Logic input falling edge to logic output falling edge in RS-485 Loopback mode | MODE2 = MODE1 = MODE0 = Vio; SLR = Vio, Delay from 50% of L3 falling edge to 50% L2 falling edge, $\overline{SHDN} = Vio$, TERM_TX and TERM_RX float, Load cap on L2 = 15 pF, Load on Driver output terminals (R2-R1) = 54 Ω | | 1060 | 1770 | ns |
| $t_{SKEW_RS485_LB}$ | Pulse skew from logic input to logic output in RS485 loopback mode | $ t_{LB_RS485_rising} - t_{LB_RS485_falling} $, SLR = Vio | | 5 | 50 | ns |

5.15 Typical Characteristics



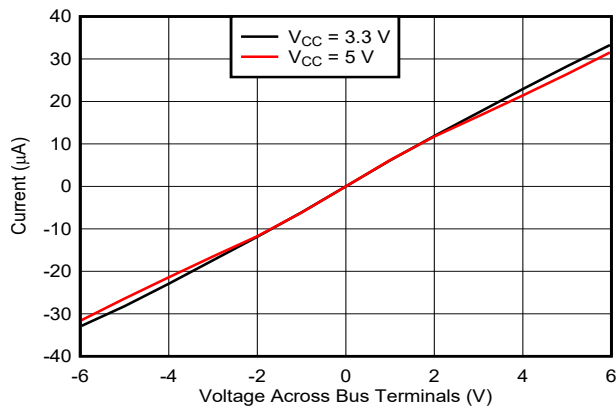
RS-485 Full Duplex mode $V(R3-R4) = 2V$

5-1. RS-485 Termination Resistor vs Temperature



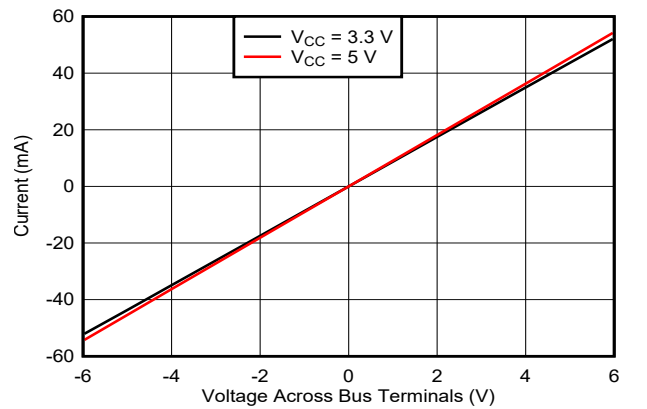
RS-485 Full Duplex mode $V(R3-R4) = 2V$

5-2. Termination Resistor vs Bus Common Mode Voltage



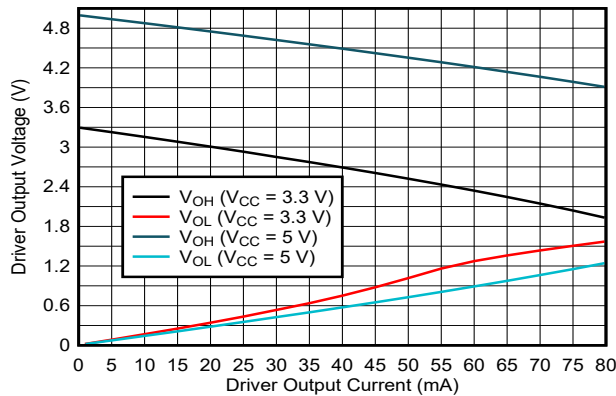
TERM_TX = GND DIR = GND $T_A = 25^\circ C$

5-3. Voltage vs Current across R2-R1 Bus Pins with Termination OFF



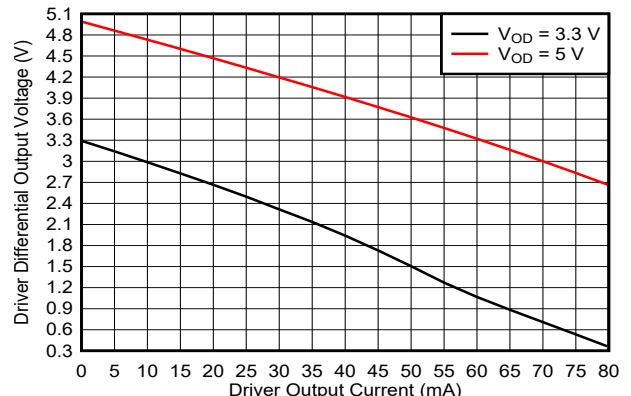
TERM_TX = V_{IO} DIR = GND $T_A = 25^\circ C$

5-4. Voltage vs Current across R2-R1 Bus Pins with Termination ON



DIR = V_{IO} $T_A = 25^\circ C$

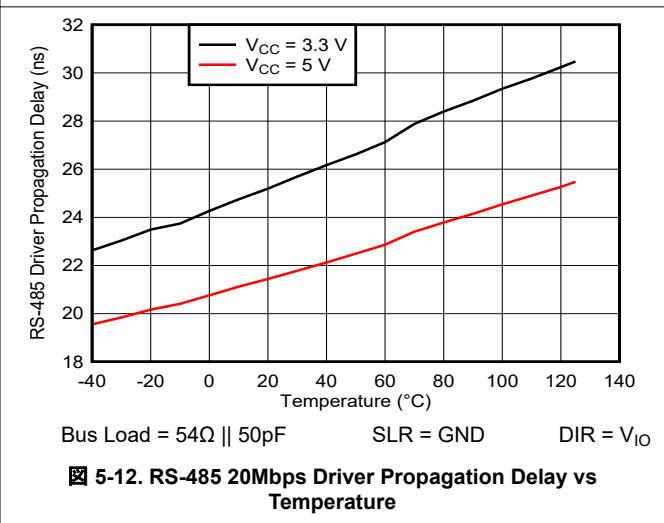
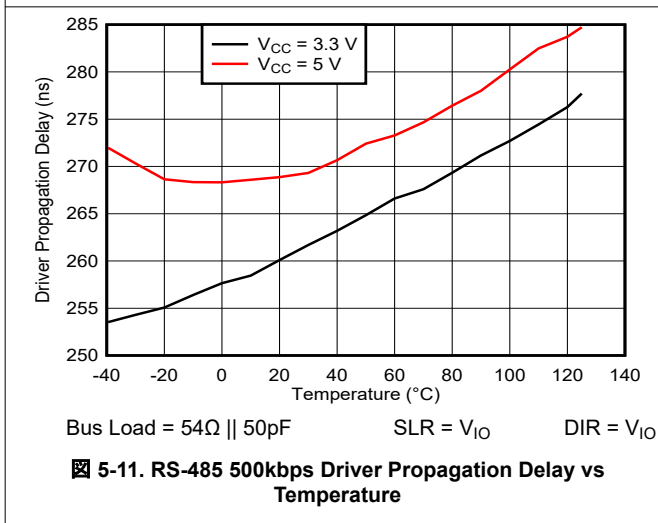
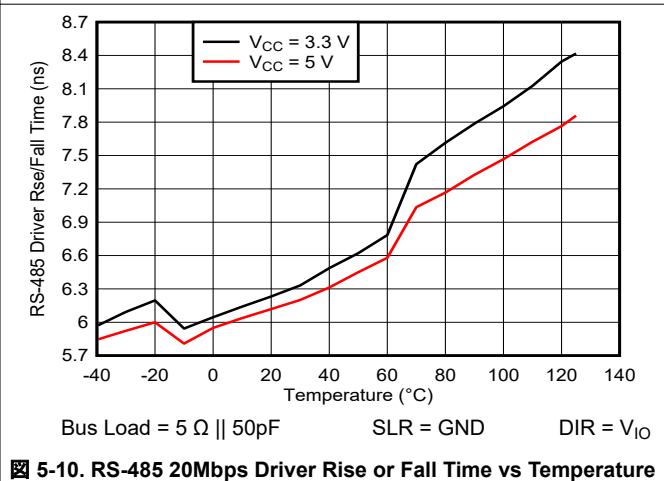
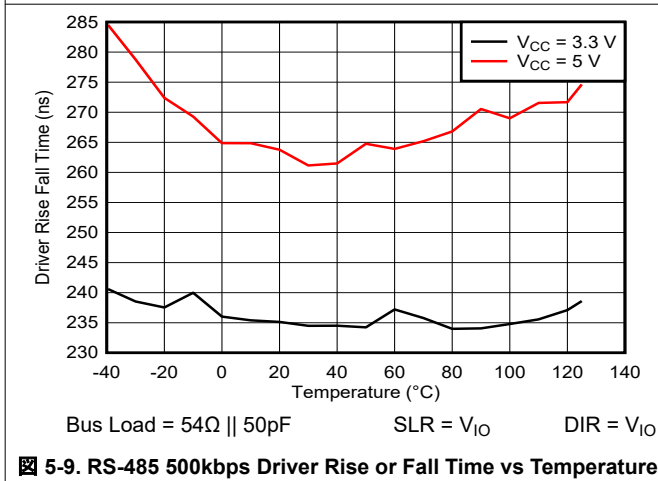
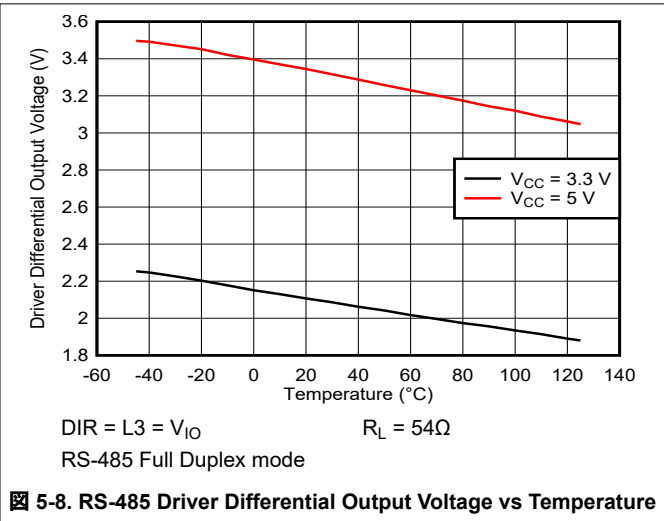
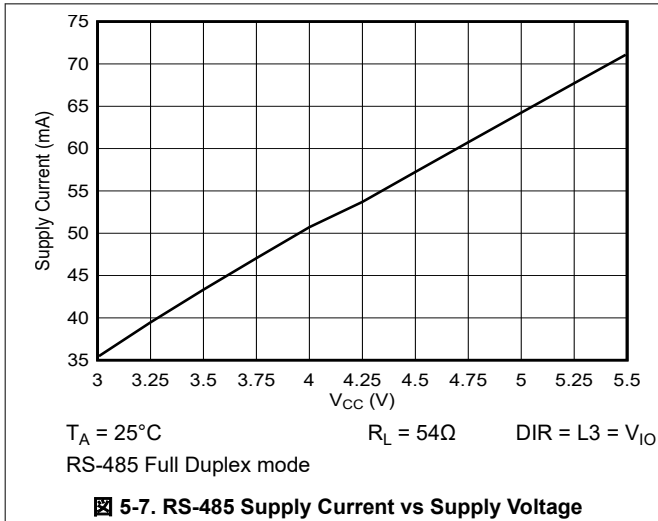
5-5. RS-485 Driver Output Voltage vs Driver Output Current



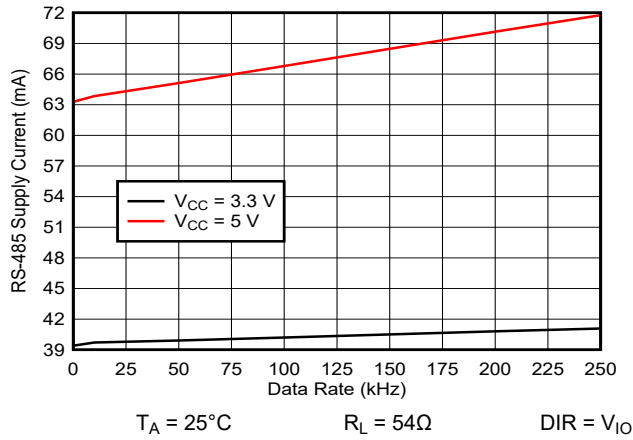
DIR = V_{IO} $T_A = 25^\circ C$

5-6. RS-485 Driver Differential Output Voltage vs Driver Output Current

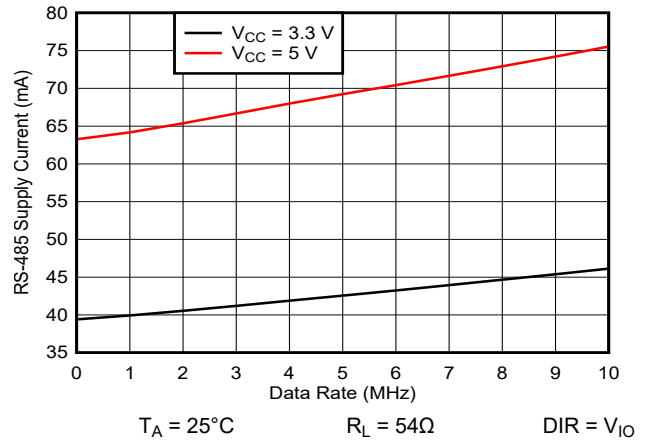
5.15 Typical Characteristics (continued)



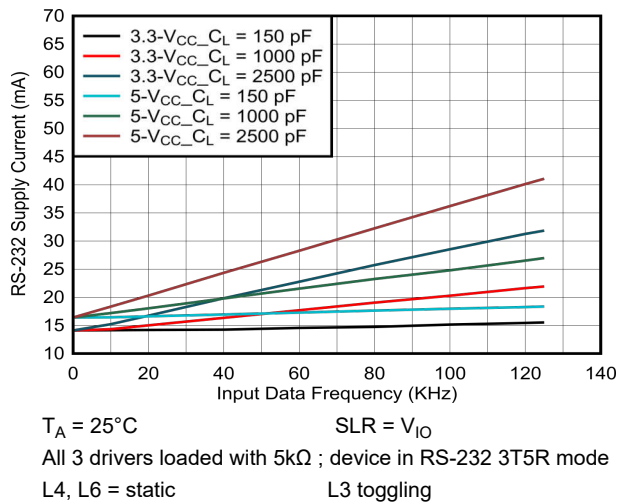
5.15 Typical Characteristics (continued)



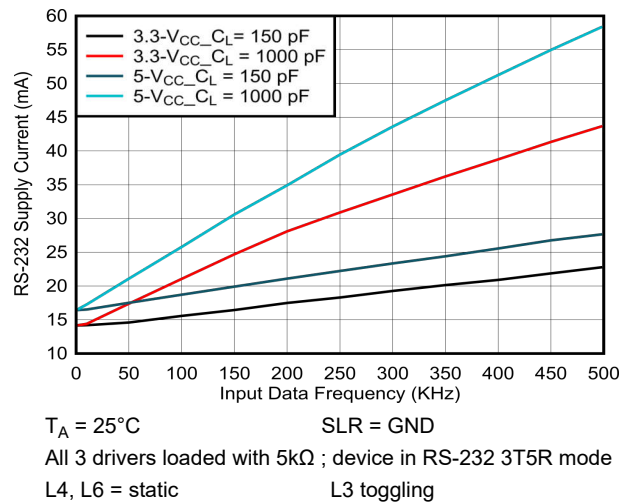
5-13. RS-485 500kbps Supply Current vs Signaling Rate



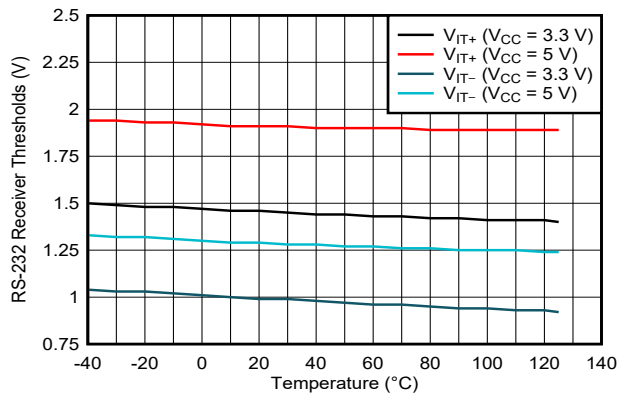
5-14. RS-485 20Mbps Supply Current vs Signaling Rate



5-15. RS-232 Supply Current vs Signaling Rate for 250kbps Mode



5-16. RS-232 Supply Current vs Signaling Rate for 1Mbps Mode



5-17. RS-232 Receiver Thresholds vs Temperature

6 Parameter Measurement Information

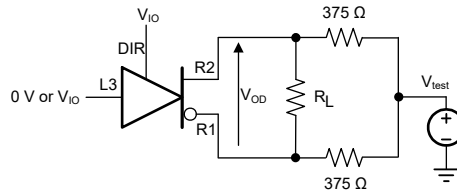


Figure 6-1. Measurement of RS-485 Driver Differential Output Voltage With Common-Mode Load

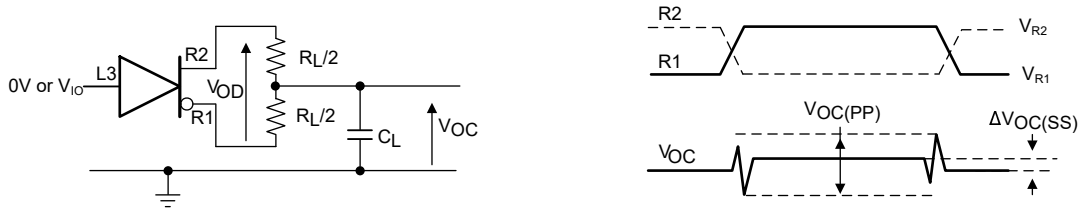


Figure 6-2. Measurement of RS-485 Driver Differential and Common-Mode Output With RS-485 Load

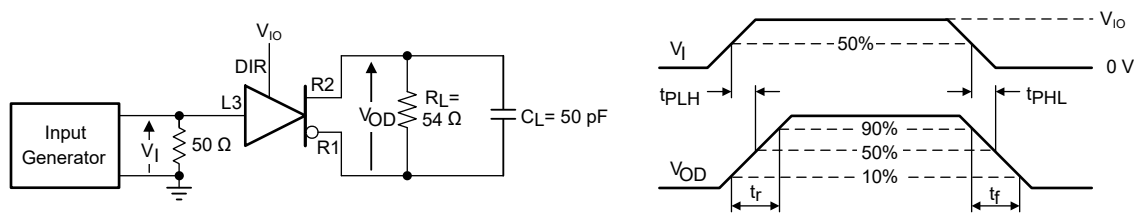


Figure 6-3. Measurement of RS-485 Driver Differential Output Rise and Fall Times and Propagation Delays

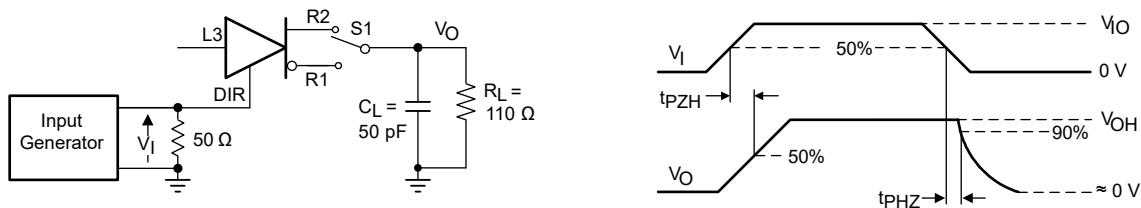


Figure 6-4. Measurement of RS-485 Driver Enable and Disable Times With Active High Output and Pull-Down Load

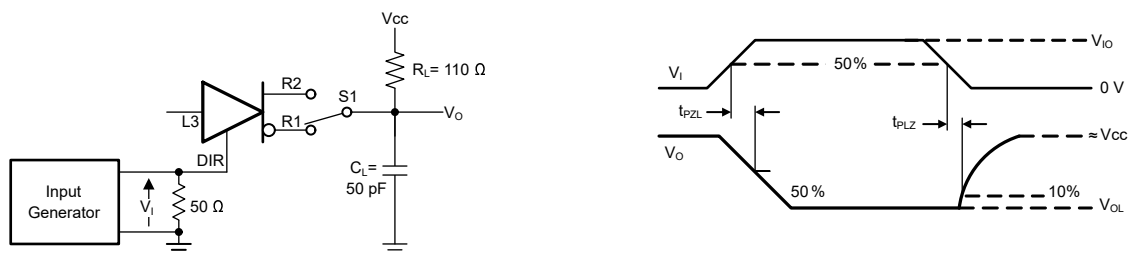


Figure 6-5. Measurement of RS-485 Driver Enable and Disable Times With Active Low Output and Pull-up Load

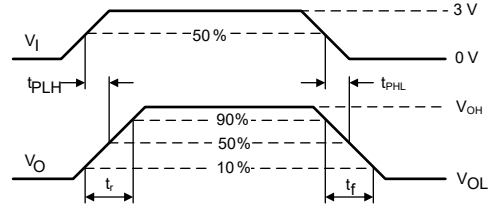
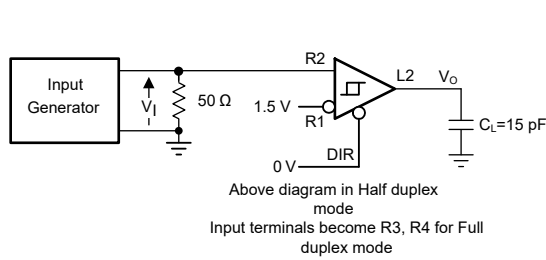


Figure 6-6. Measurement of RS-485 Receiver Output Rise and Fall Times and Propagation Delays

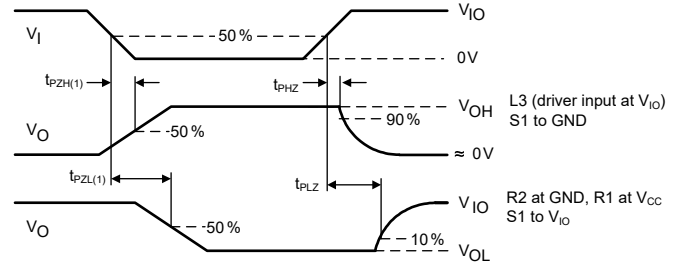
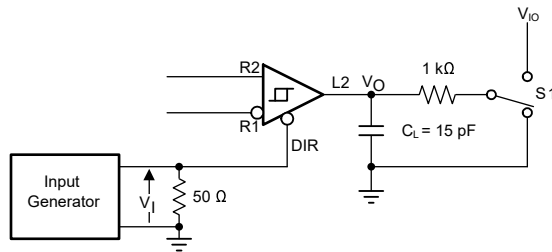


Figure 6-7. Measurement of RS-485 Receiver Enable and Disable Times in Half Duplex Mode

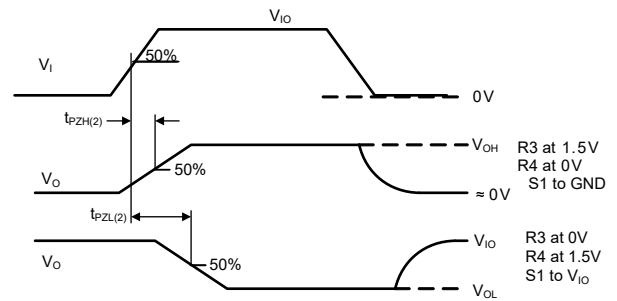
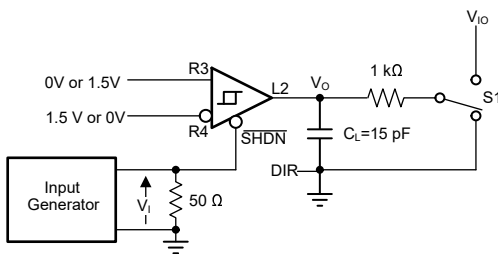


Figure 6-8. Measurement of RS-485 Receiver Enable Time from Shutdown with TX Disabled: Full Duplex Mode

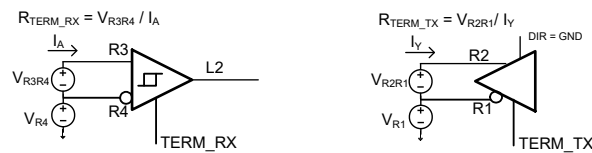


Figure 6-9. Termination Resistor Measurement

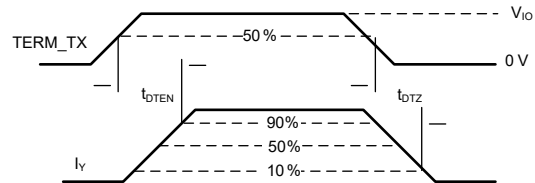
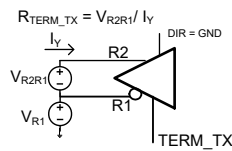
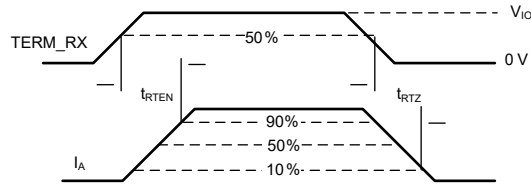
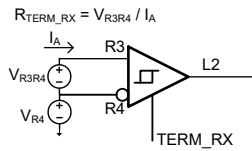


图 6-10. Termination Resistor Switching Measurement

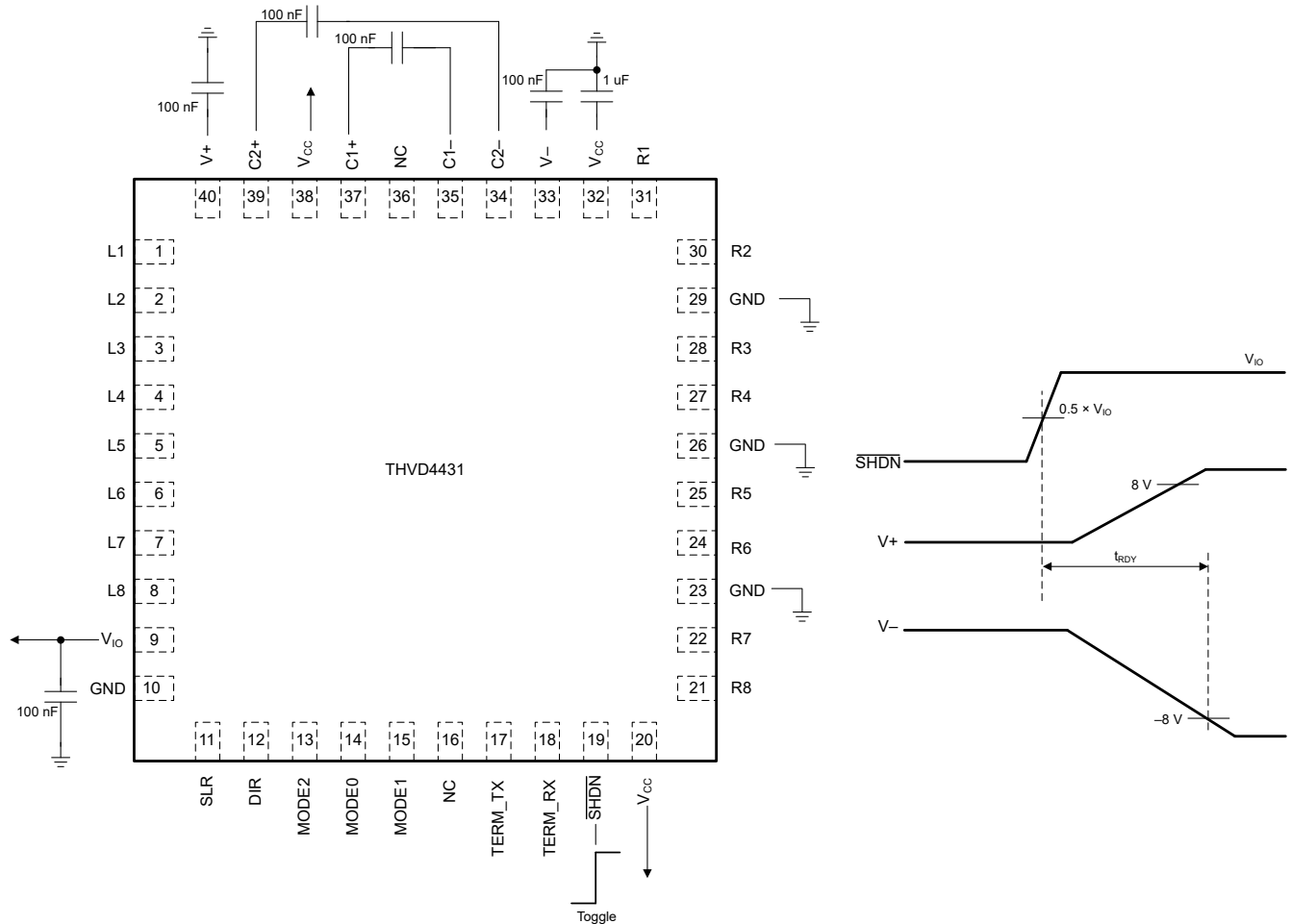
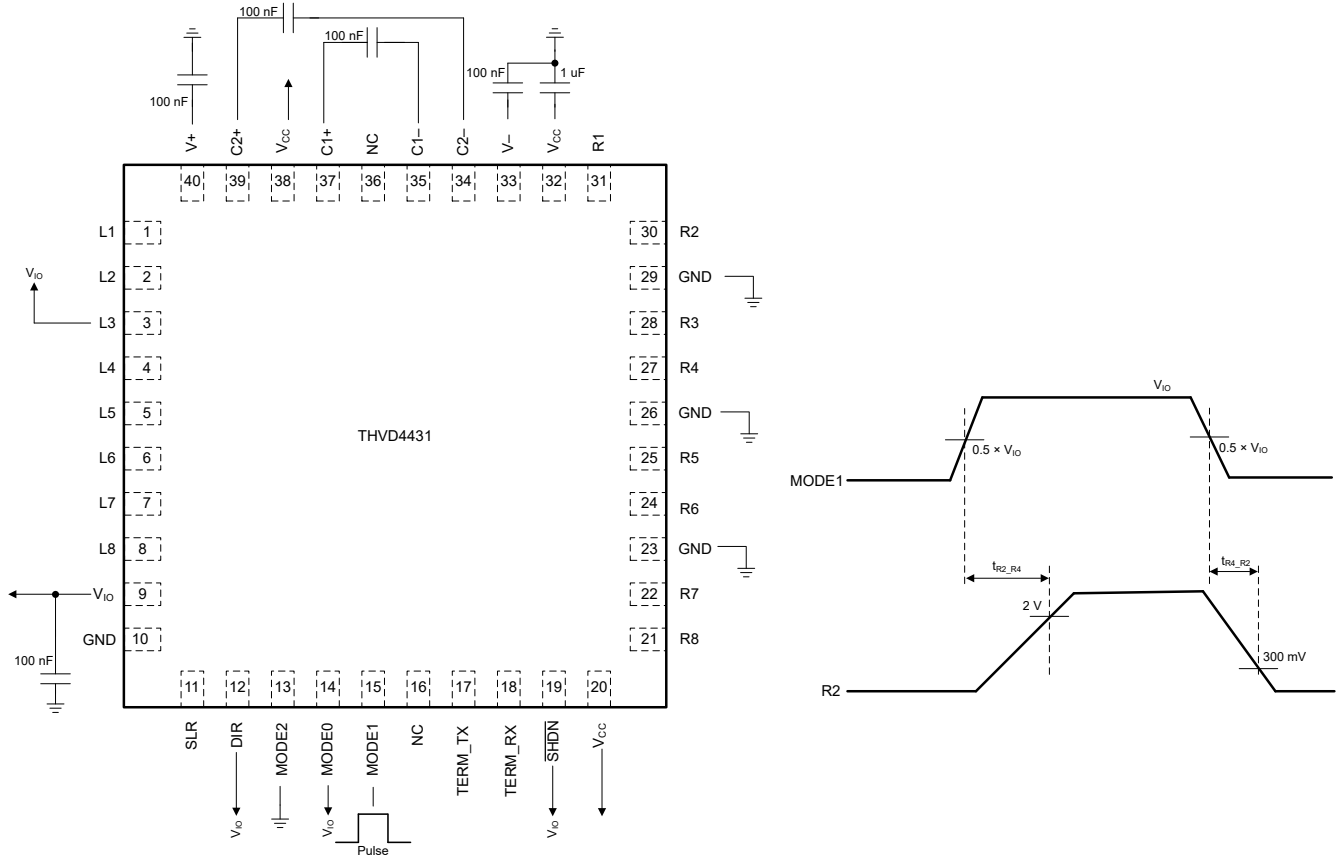


图 6-11. Time from Shutdown to RS-232 Ready



6-12. Time to Switch from RS-232 3T5R Mode to RS-485 Full Duplex Mode and Back

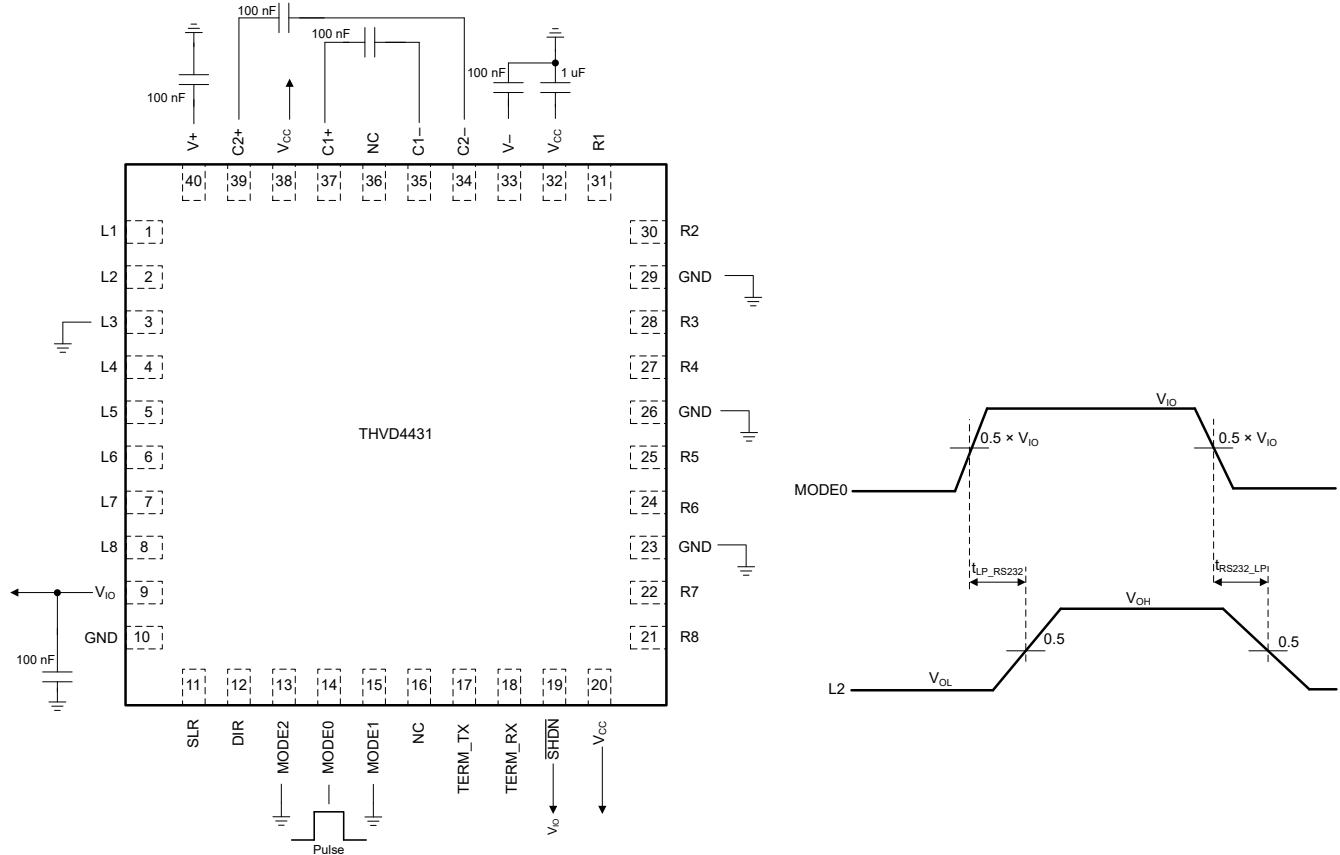
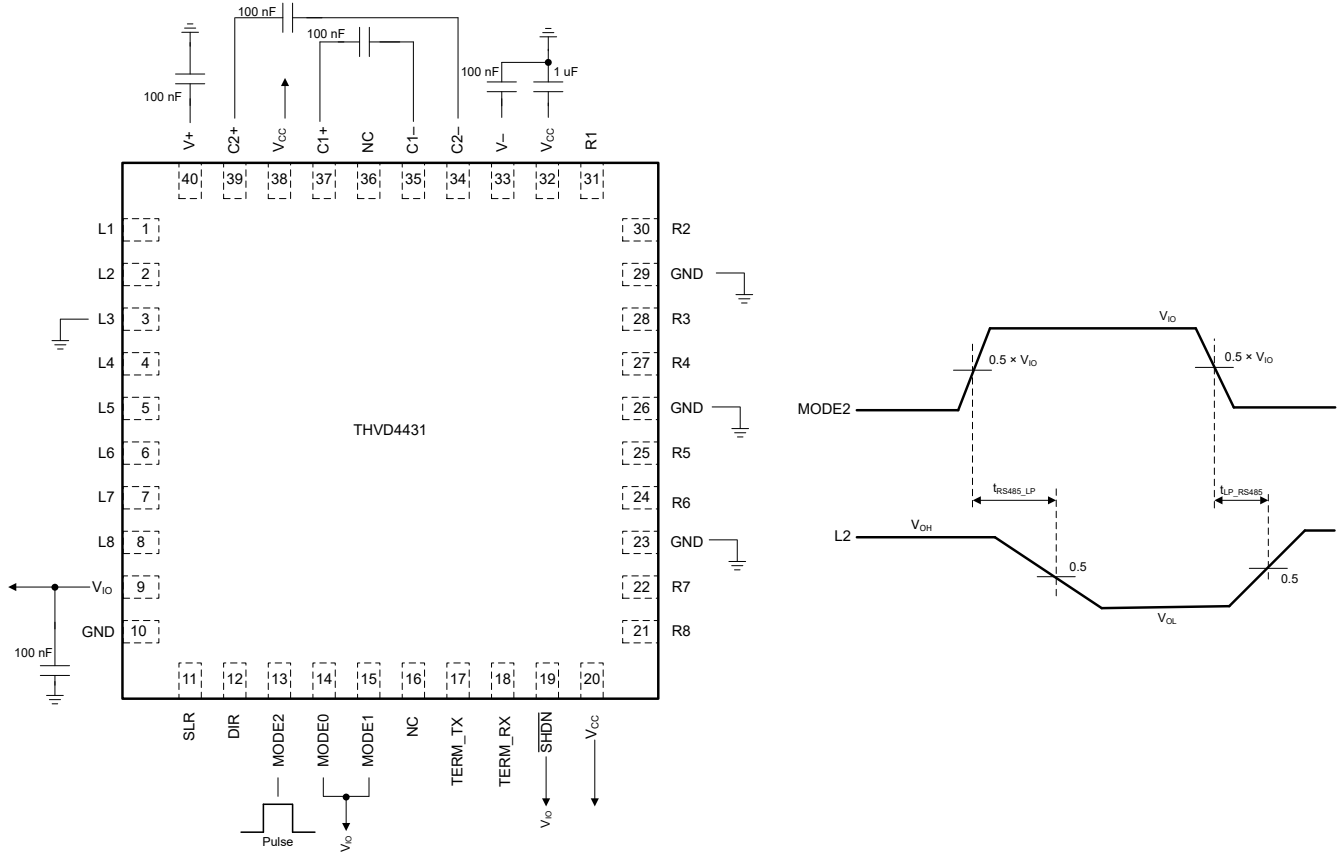


图 6-13. Time to Switch from RS-232 Loopback to Normal RS-232 3T5R Mode and Back



 **6-14. Time to Switch from RS-485 Loopback Mode to RS-485 Full Duplex Mode and Back**

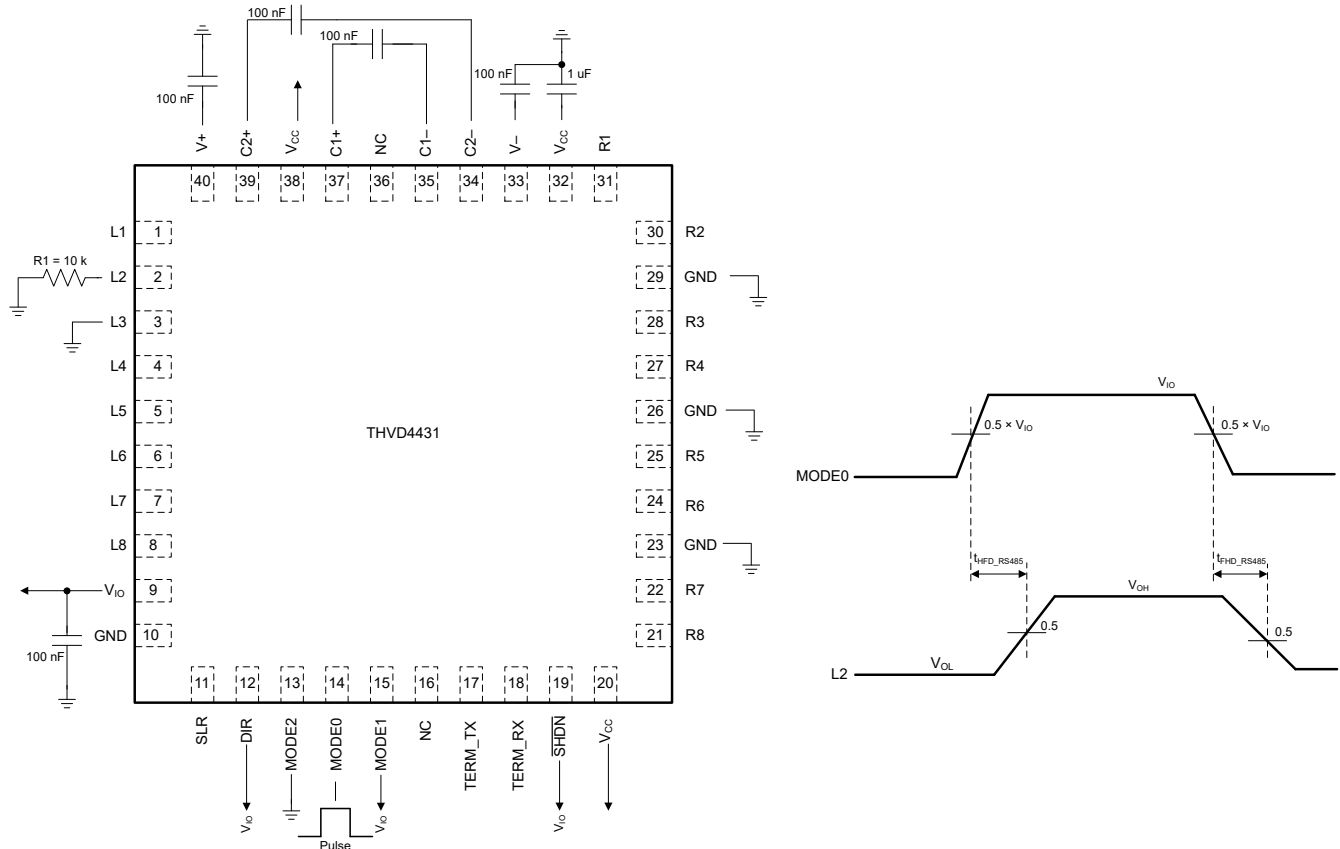
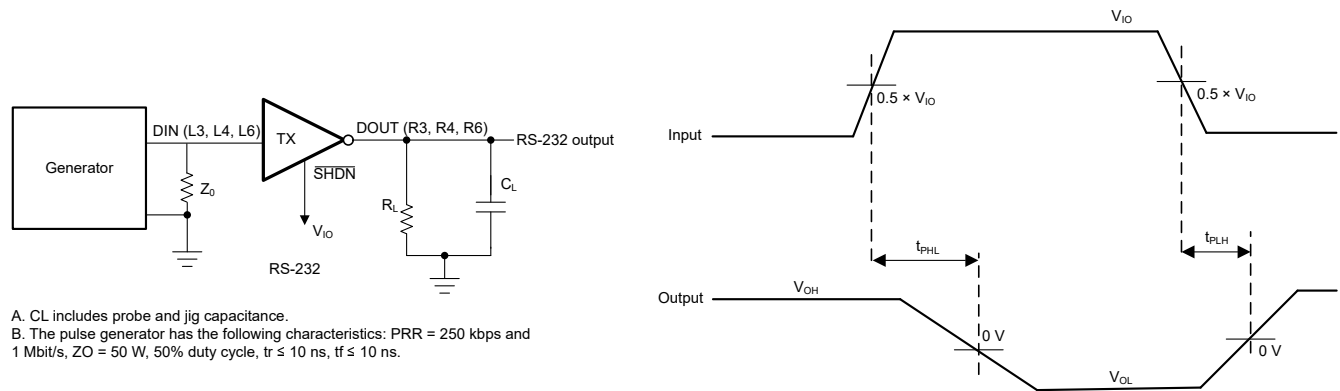
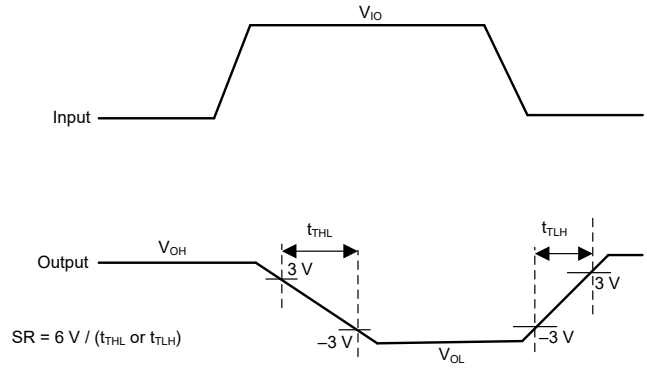
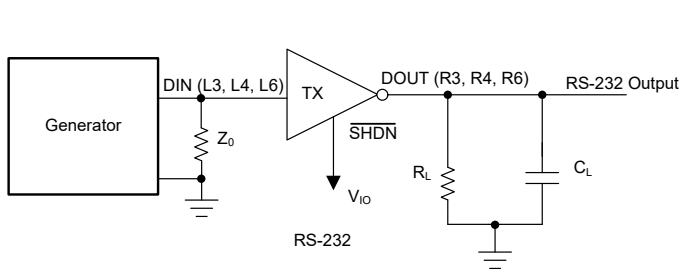


图 6-15. Time to Switch from RS-485 Full Duplex to Half Duplex and Back



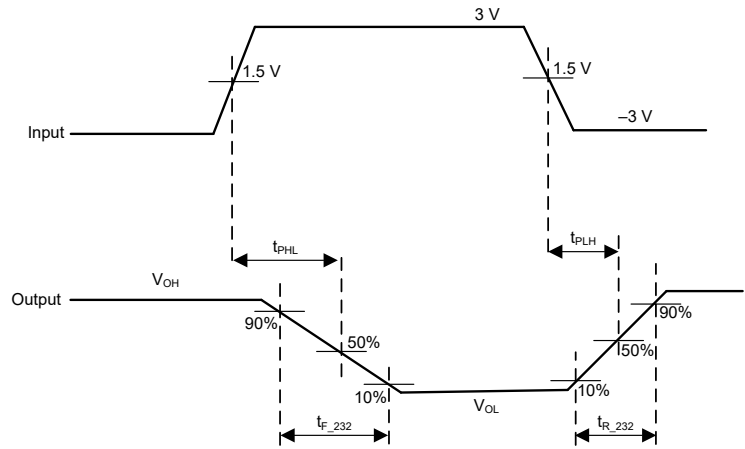
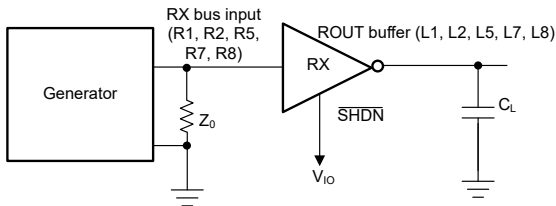
A. CL includes probe and jig capacitance.
 B. The pulse generator has the following characteristics: PRR = 250 kbps and 1 Mbit/s, ZO = 50 W, 50% duty cycle, tr ≤ 10 ns, tf ≤ 10 ns.

图 6-16. RS-232 Driver Prop Delay, Pulse Skew



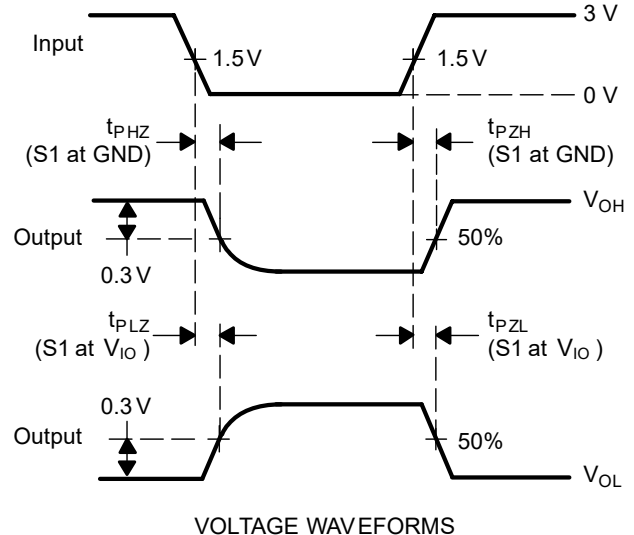
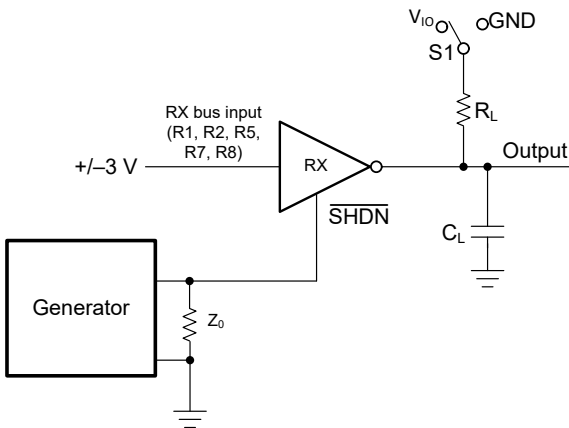
- A. CL includes probe and jig capacitance.
- B. The pulse generator has the following characteristics: PRR = 250 kbps and 1 Mbit/s, $Z_0 = 50 \Omega$, 50% duty cycle, $t_r \leq 10$ ns, $t_f \leq 10$ ns.

6-17. RS-232 Driver Slew Rate



- A. CL includes probe and jig capacitance.
- B. The pulse generator has the following characteristics: $Z_0 = 50 \Omega$, 50% duty cycle, $t_r \leq 10$ ns, $t_f \leq 10$ ns.

6-18. RS-232 Receiver Propagation Delay, Pulse Skew



- A. CL includes probe and jig capacitance.
- B. The pulse generator has the following characteristics: $Z_0 = 50 \Omega$, 50% duty cycle, $t_r \leq 10$ ns, $t_f \leq 10$ ns.
- C. t_{PLZ} and t_{PHZ} are same as t_{DIS}
- D. t_{PZL} and t_{PZH} are same as t_{EN}

6-19. RS-232 Receiver Enable and Disable Time

7 Detailed Description

7.1 Overview

THVD4431 is a highly integrated and robust multiprotocol transceiver supporting RS-232, RS-422 and RS-485 physical layers. The device has three transmitters and five receivers to enable 3T5R RS-232 port. Device also integrates one transmitter and one receiver to enable half and full duplex RS-485 port. MODE selection pins enable shared bus and logic pins for the protocols to share a common single connector.

The device has SLR pin which allows it to be used for two different maximum speed settings for RS-232 and for RS-485. This is beneficial as customers can qualify one device and use it in two separate end-applications. The devices also have flexible I/O supply pin V_{IO} which enables digital interface voltage range, from 1.65V to 5.5V, different from bus voltage supply 3V to 5.5V.

7.2 Functional Block Diagrams

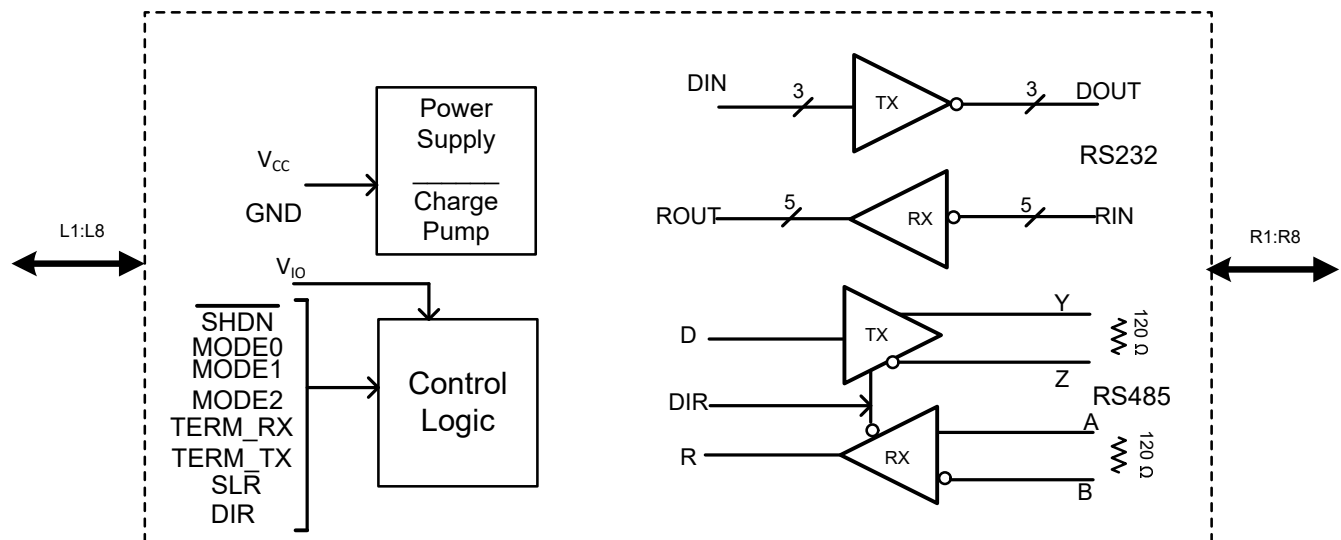


图 7-1. THVD4431 Block Diagram

7.3 Feature Description

7.3.1 Integrated IEC ESD and EFT Protection

Internal ESD protection circuits protect all the transceiver bus pins (driver and receiver) against electrostatic discharges (ESD) according to IEC 61000-4-2 up to ± 8 kV for contact discharge and ± 15 kV for air discharge for all operating modes. Bus lines in RS-485 mode can also withstand electrical fast transients (EFT) according to IEC 61000-4-4 for up to ± 4 kV.

7.3.2 Protection Features

The THVD4431 bus pins are protected against any DC supply shorts in the range of -16 V to +16 V. In the RS-485 mode, the short circuit current is limited to ± 250 mA to comply with the TIA/EIA-485A standard. In RS-232 mode, current limiting of ± 60 mA is applicable for scenarios where bus pins can short to ground.

The device also features thermal shutdown protection that disables the driver and the receiver if the junction temperature exceeds the T_{SHDN} threshold due to excessive power dissipation on-chip.

Supply undervoltage protection is present on both V_{CC} and V_{IO} supplies. This maintains the bus output and receiver logic output in known driven state when both the supplies are above their rising undervoltage thresholds. Table below describes the device behavior in various scenarios of supply levels.

表 7-1. Supply Function Table

| V _{CC} | V _{IO} | Driver Output | Receiver Output |
|-------------------------------|-------------------------------|---|---|
| > UV _{VCC} (rising) | > UV _{VIO} (rising) | For RS-485 mode, determined by DIR and L3 inputs. For RS-232 mode, determined by L3, L4, L6 inputs. For shutdown mode, Hi-Z | For RS-485 mode, determined by DIR and (R1-R2) or (R3-R4) inputs. For RS-232 mode, determined by R1, R2, R5, R7, R8 inputs. For shutdown mode, Hi-Z |
| < UV _{VCC} (falling) | > UV _{VIO} (rising) | High impedance | Undetermined |
| > UV _{VCC} (rising) | < UV _{VIO} (falling) | High impedance | High impedance |
| < UV _{VCC} (falling) | < UV _{VIO} (falling) | High impedance | High impedance |

7.3.3 RS-485 Receiver Fail-Safe Operation

The RS-485 differential receiver of the THVD4431 is *failsafe* to invalid bus states caused by the following:

- Open bus conditions, such as a disconnected connector
- Shorted bus conditions, such as cable damage shorting the twisted-pair together
- Idle bus conditions that occur when no driver on the bus is actively driving

In any of these cases, the differential receiver outputs a failsafe logic high state so that the output of the receiver is not indeterminate.

Receiver failsafe is accomplished by offsetting the receiver thresholds such that the *input indeterminate* range does not include zero volts differential. To comply with the RS-422 and RS-485 standards, the receiver output must output a high when the differential input V_{ID} is more positive than 200 mV, and must output a low when V_{ID} is more negative than –200 mV. The receiver parameters which determine the failsafe performance are V_{TH+}, V_{TH-}, and V_{HYS} (the separation between V_{TH+} and V_{TH-}). As shown in the *Receiver Function table*, differential signals more negative than –200 mV always causes a low receiver output, and differential signals more positive than 200 mV always causes a high receiver output.

When the differential input signal is close to zero, it is still above the V_{TH+} threshold, and the receiver output is high. Only when the differential input is more than V_{HYS} below V_{TH+} does the receiver output transition to a low state. Therefore, the noise immunity of the receiver inputs during a bus fault conditions includes the receiver hysteresis value, V_{HYS}, as well as the value of V_{TH+}.

7.3.4 Low-Power Shutdown Mode

Driving the $\overline{\text{SHDN}}$ pin low puts the device into the shutdown mode. This is the lowest power mode of the device and current consumption is 10 uA typical. All the blocks get disabled in this mode.

7.3.5 On-chip Switchable Termination Resistor

THVD4431 has 2 termination resistors of nominal 120 Ω , one across R1/R2 and another across R3/R4 in RS-485 mode. Both termination resistors are enabled or disabled using pins as described in 表 7-2. Both the termination resistors can be enabled or disabled independent of the state of driver or receiver. Termination is OFF in RS-232 loopback, RS-232 3T5R, RS-485 loopback, unpowered and thermal shutdown modes.

表 7-2. On-chip Termination Function

| Signal state | Device mode | Function | Comments |
|--|------------------|---|--|
| TERM_TX = V _{IO} | Full duplex mode | 120 Ω enabled between R1 and R2 | Termination between R1/R2 is disabled by default |
| TERM_TX = GND or floating | Full duplex mode | 120 Ω disabled between R1 and R2 | |
| TERM_RX = V _{IO} | Full duplex mode | 120 Ω enabled between R3 and R4 | Termination between R3/R4 is disabled by default |
| TERM_RX = GND or floating | Full duplex mode | 120 Ω disabled between R3 and R4 | |
| TERM_RX = X, TERM_TX = V _{IO} | Half duplex mode | 120 Ω enabled between R1 and R2 | In half duplex mode, TERM_RX is don't care and TERM_TX has higher priority |
| TERM_RX = X, TERM_TX = GND | Half duplex mode | 120 Ω disabled between R1 and R2 | |

The on-chip 120 Ω termination resistor is designed for minimum variation across temperature and across common mode voltage on bus pins. The termination block offers a resistive load to the bus, and does not alter the magnitude or phase of the bus signals from DC to 20Mbps signaling. See the typical characteristic curves for variation of termination resistor with voltage and temperature.

7.3.6 Operational Data Rate

THVD4431 can be used in slow speed or fast speed RS-485 and RS-232 applications by configuring Slew rate control (SLR) pin. 表 7-3 describes slew rate control function.

表 7-3. Slew Rate Control Function

| Signal state | Driver | Receiver | Comment |
|-----------------------|---|---|--|
| SLR = V _{IO} | Maximum speed of operation for RS-485 = 500kbps. Maximum speed of operation in RS-232 mode is 250kbps | Maximum speed of operation for RS-485 = 500kbps. Maximum speed of operation in RS-232 mode is 250kbps | Active high slew rate limiting applied on driver output. In this configuration, glitch filter in receiver path for RS-485 is enabled |
| SLR = GND or floating | Maximum speed of operation for RS-485 = 20Mbps. Maximum speed of operation in RS-232 mode is 1Mbps | Maximum speed of operation for RS-485 = 20Mbps. Maximum speed of operation in RS-232 mode is 1Mbps | Slew rate limiting on driver output disabled. |

For RS-485 half and full duplex modes, receiver path in the slow speed mode (500 kbps) provides additional noise filtering. To attenuate high frequency noise pulses from the bus which can be wrongly interpreted as valid data, SLR = V_{IO} enables a low pass filter to filter out pulses with frequency higher than typical 700 kHz.

7.3.7 Diagnostic Loopback

THVD4431 provides complete path diagnostic loopback modes for both RS-232 and RS-485. These modes internally short bus outputs to bus inputs. So, if data is toggled from logic input, data reaches bus and is reflected back on logic buffer output. This enables MCU to detect bus side short (due to connector/cable) by comparing logic input and logic output.

In RS-232 loopback mode, L3 reflects on L2/R2/R3; L4 reflects on L1/R4/R1; L6 reflects on L5, L7, L8, R5, R6, R7 and R8 enabling to detect short to ground on all bus pins from R1 through R8. RS-232 loopback mode is optimized for -40°C to 85°C ambient temperature. RS-232 diagnostic loopback can be performed on a node (DUT1) even with another node (DUT2) connected via cable, but listening node (DUT2) is not allowed to transmit anything on the RS232 lines while loopback check by DUT1 is ongoing.

In RS-485 loopback mode, internally R2 gets connected to R3 and R1 gets connected to R4. L3 input data is routed to driver output terminals and receiver input terminals and reflects on L2. DIR and TERM_RX are not supported in this mode. Specific to this mode, external termination on R3/R4 is not supported, but R1/R2 can have internal or external termination. This is able to detect short between R1/R2 and between R3/R4 bus terminals. Recommended maximum data rate for RS-485 diagnostic loopback to detect cable or connector shorts is 500kbps with $SLR = V_{IO}$.

7.3.8 Integrated Charge pump for RS-232

THVD4431 has integrated high-efficiency and low-noise charge pump to generate large output voltages for RS-232 signals. Charge pump consists of a voltage doubler and an inverter to regulate the voltage to nominal ± 5.5 V or to ± 9.5 V for 3.3 V or 5-V V_{CC} operation respectively. Charge pump needs four external ceramic capacitors (2 flying capacitors and 2 storage capacitors) and allows for single supply operation for RS-232. For a generic description of RS-232 charge pump operation, please refer to the blog: [How the RS-232 transceiver's regulated charge-pump circuitry works.](#)

7.4 Device Functional Modes

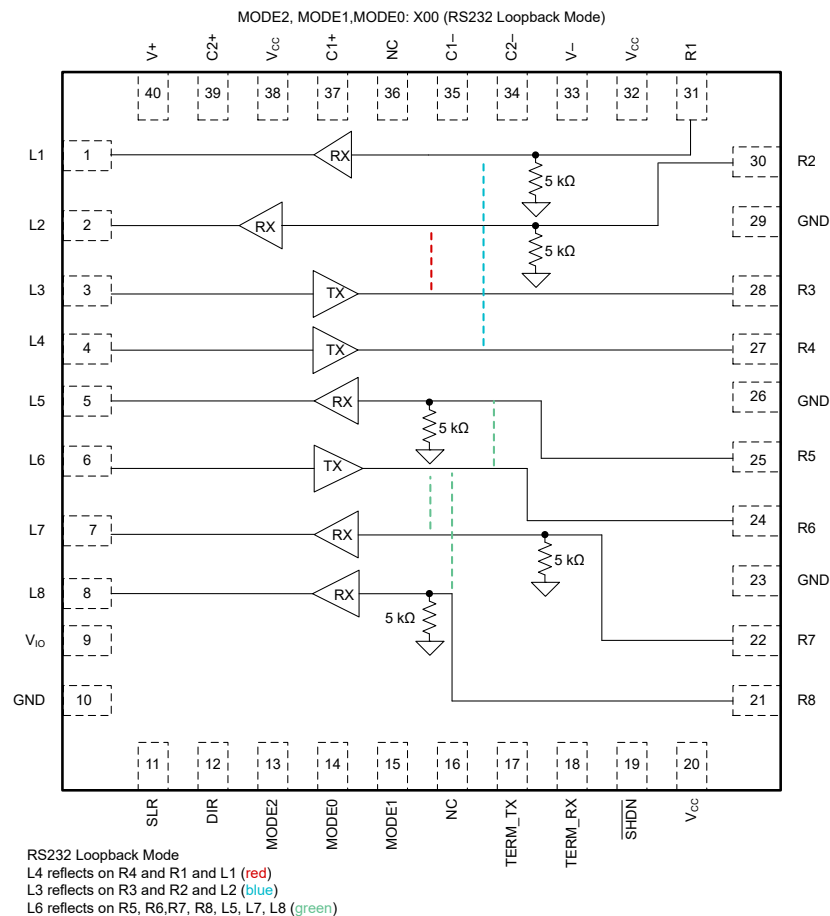


図 7-2. RS-232 Loopback Mode

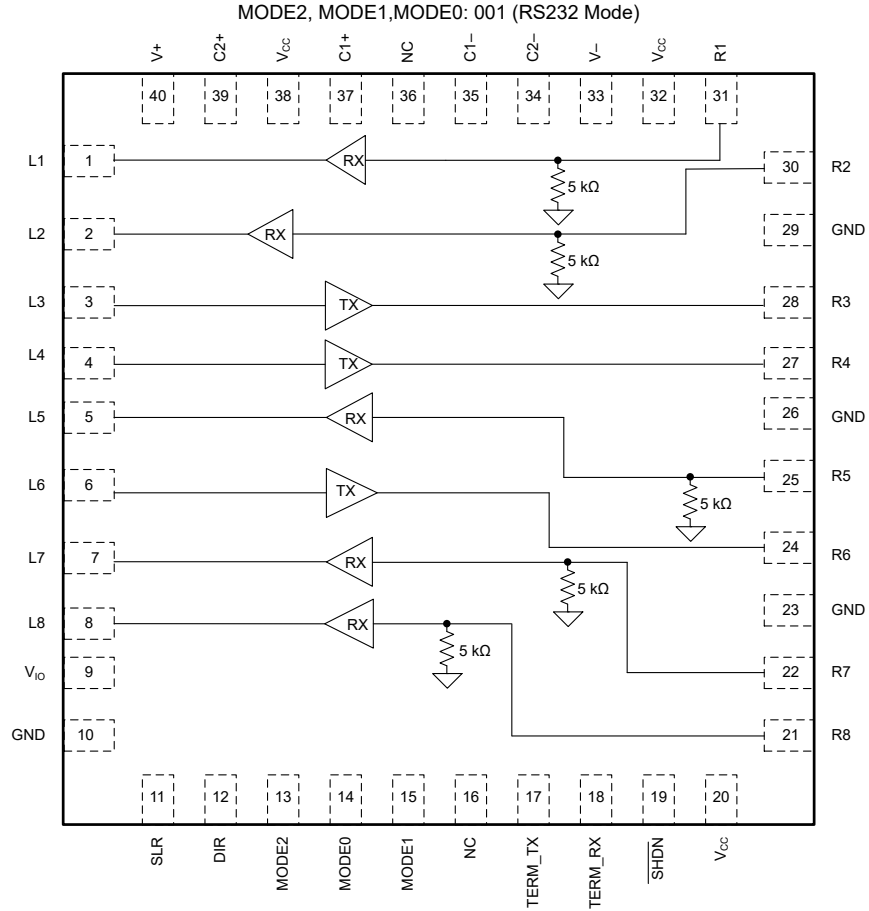


図 7-3. RS-232 3T5R Mode

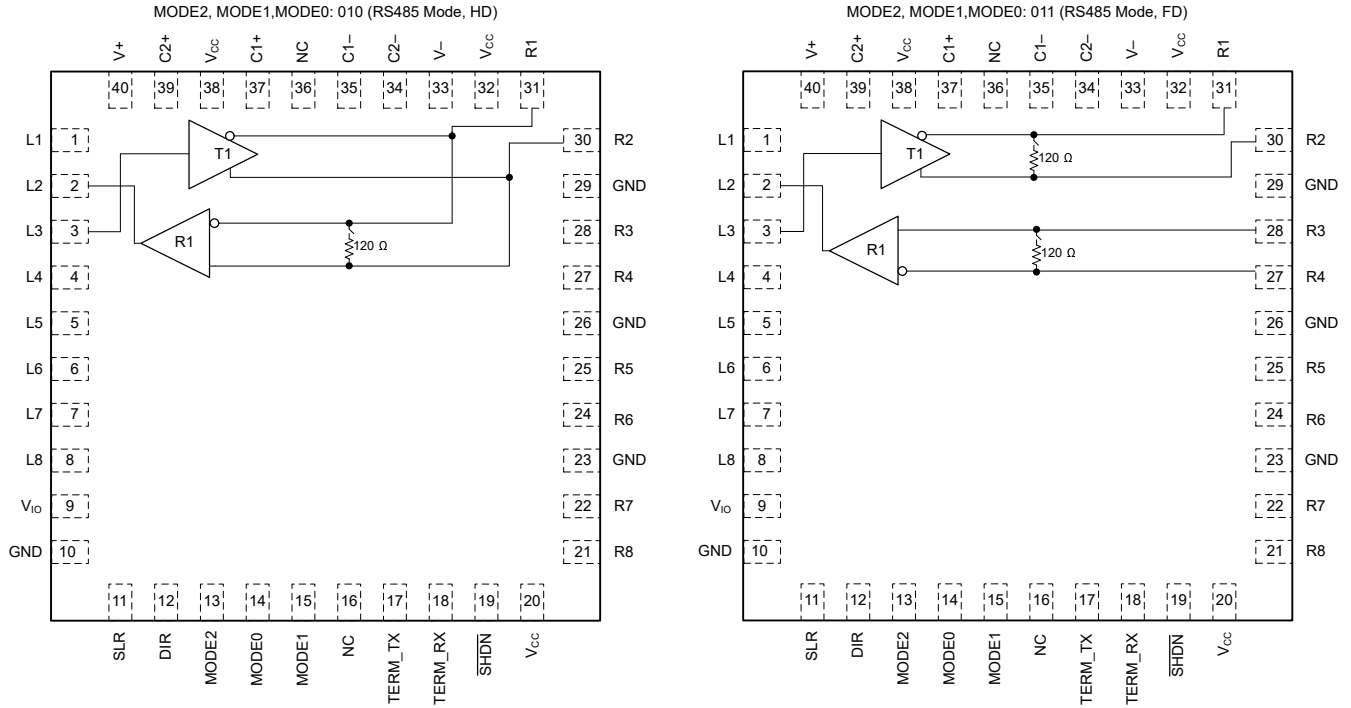
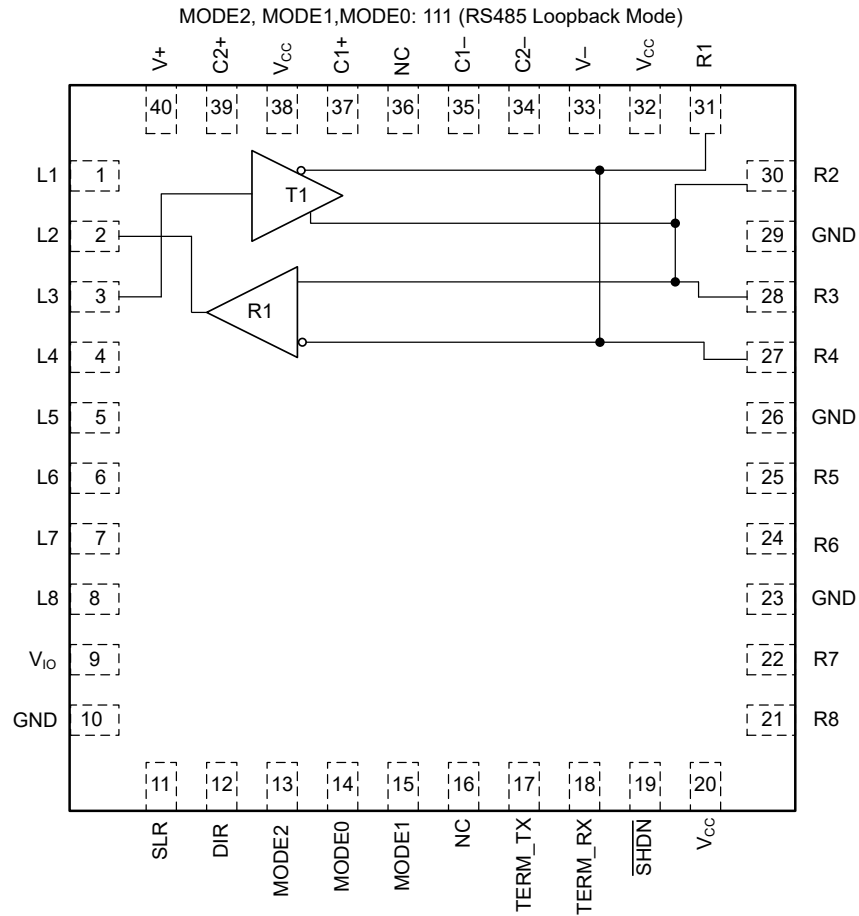


図 7-4. RS485 Half duplex and Full duplex mode



7.4.1 RS-485 Functionality

When the driver enable pin, DIR, is logic high, the differential outputs R2 and R1 follow the logic states at data input L3. A logic high at L3 causes R2 to turn high and R1 to turn low. In this case, the differential output voltage defined as $V_{OD} = V_{R2} - V_{R1}$ is positive. When L3 is low, the output states reverse: R1 turns high, R2 becomes low, and V_{OD} is negative.

When DIR is low, both outputs turn high-impedance. In this condition, the logic state at L3 is irrelevant. The DIR pin has an internal pull-down resistor to ground, thus when left open the driver is disabled (high-impedance) by default. The L3 pin has an internal pull-up resistor to V_{IO} , thus, when left open while the driver is enabled, output R2 turns high and R1 turns low.

表 7-4 is valid for both half duplex and full duplex modes, and is independent of state of TERM_TX, TERM_RX and SLR pins.

表 7-4. Driver Function Table

| INPUT | ENABLE | OUTPUTS | | FUNCTION |
|-------|--------|----------------|----------------|------------------------------------|
| L3 | DIR | R2 | R1 | |
| H | H | H | L | Actively drive bus high |
| L | H | L | H | Actively drive bus low |
| X | L | High impedance | High impedance | Driver disabled |
| X | OPEN | High impedance | High impedance | Driver disabled by default |
| OPEN | H | H | L | Actively drive bus high by default |

In full duplex mode, if \overline{SHDN} is high, receiver is always enabled. In half duplex mode, receiver is enabled if DIR = Low/floating and disabled if DIR = V_{IO} . When the differential input voltage defined as $V_{ID} = V_{R2} - V_{R1}$ or $V_{R3} - V_{R4}$ is higher than the positive input threshold, V_{TH+} , the receiver output, L2, turns high. When V_{ID} is lower than the negative input threshold, V_{TH-} , the receiver output, L2, turns low. If V_{ID} is between V_{TH+} and V_{TH-} the output is indeterminate.

Internal biasing of the receiver inputs causes the output to go failsafe-high when the transceiver is disconnected from the bus (open-circuit), the bus lines are shorted to one another (short-circuit), or the bus is not actively driven (idle bus).

In half duplex mode, when DIR is high, the receiver output is high-impedance and the magnitude and polarity of V_{ID} are irrelevant.

表 7-5 is valid irrespective of state of TERM_TX, TERM_RX and SLR pins. Other logic outputs L1, L5, L7 and L8 remain high in RS-485 mode.

表 7-5. Receiver Function Table

| DIFFERENTIAL INPUT | OUTPUT | FUNCTION |
|---|---|--|
| $V_{ID} = V_{R2} - V_{R1}$ (Half duplex mode) or $V_{R3} - V_{R4}$ (Full duplex mode) | L2 | |
| $V_{TH+} < V_{ID}$ | H | Receive valid bus high |
| $V_{TH-} < V_{ID} < V_{TH+}$ | ? | Indeterminate bus state |
| $V_{ID} < V_{TH-}$ | L | Receive valid bus low |
| X | High impedance for DIR = V_{IO} in Half duplex mode | Receiver disabled in half duplex mode for DIR = V_{IO} |
| Open-circuit bus | H | Fail-safe high output |
| Short-circuit bus | H | Fail-safe high output |
| Idle (terminated) bus | H | Fail-safe high output |

7.4.2 RS-232 Functionality

In RS-232 mode, only way to disable driver is to go in shutdown mode by pulling $\overline{\text{SHDN}}$ pin low. A logic high at inputs for driver L3, L4 and L6 causes driver outputs R3, R4 and R6 to be driven low towards negative charge pump output V-. A logic low at inputs for driver L3, L4 and L6 causes driver outputs R3, R4 and R6 to be driven high towards positive charge pump output V+. If logic inputs are left floating due to the pull-up resistors on driver logic inputs, the driver outputs are driven low towards V-.

表 7-6 is valid irrespective of the state of SLR pin.

表 7-6. Driver Function Table

| INPUT | ENABLE | OUTPUTS | FUNCTION |
|------------|--------------------------|-------------------------|--|
| L3, L4, L6 | $\overline{\text{SHDN}}$ | R3, R4, R6 | |
| H | H | Low (driven towards V-) | Normal operation with inverting logic |
| L | H | H (Driven towards V+) | Normal operation with inverting logic |
| X | L | High impedance | TX and RX are disabled in shutdown mode |
| Open | H | Low (driven towards V-) | Since pull-up on logic input pin, output driven low by default |

For the RS-232 receiver, if the receiver bus inputs are above rising threshold V_{IT+} , corresponding received logic output goes low. Also, if the receiver bus inputs are below falling threshold V_{IT-} , corresponding received logic output goes high.

表 7-7 is valid irrespective of the state of SLR pin.

表 7-7. Receiver Function Table

| RS-232 BUS INPUT | LOGIC OUTPUT | FUNCTION |
|---|--|---------------------------------------|
| V_{IRx} (voltage on R1, R2, R5, R7 or R8) | L1, L2, L5, L7, L8 | |
| $V_{IT+} < V_{IRx}$ | L | Normal operation with inverting logic |
| $V_{IT-} < V_{IRx} < V_{IT+}$ | ? | Indeterminate bus state |
| $V_{IRx} < V_{IT-}$ | H | Normal operation with inverting logic |
| X | High impedance for $\overline{\text{SHDN}} = \text{GND}$ | Receiver disabled in shutdown mode |
| Open-circuit bus | H | Fail-safe high output |

7.4.3 Mode Control

RS-232 3T5R to RS-232 loopback mode transition and RS-232 loopback mode to RS-232 3T5R direct mode transition is not allowed. These 2 mode transitions must go through shutdown mode in between. Rest all combination of mode transitions are allowed.

表 7-8. MODE Control Function Table

| MODE2 | MODE1 | MODE0 | Operating mode | Function |
|--------------------|------------|------------|--|--|
| X | Logic low | Logic low | RS-232 loopback, charge pump is ON, V+/V- are regulated | L3 reflects on L2/R2/R3; L4 reflects on L1/R4/R1; L6 reflects on L5, L7, L8, R5, R6, R7 and R8 |
| X | Logic low | Logic high | RS-232 3T5R mode, charge pump is ON, V+/V- are regulated | 3T5R mode; L3, L4, L6 are Logic inputs for RS232 driver; L1, L2, L5, L7, L8 are Logic outputs |
| X | Logic high | Logic low | RS-485 half duplex mode (charge pump is off) | L2 is RX Logic output; L3 is Driver Logic input; R1 R2 are Bus inverting and non-inverting terminals respectively |
| Logic low or float | Logic high | Logic high | RS-485 full duplex mode (charge pump is off) | R1R2 are inverting and non-inverting driver terminals; R3R4 are non-inverting and inverting receiver terminals. |
| Logic high | Logic high | Logic high | RS-485 loopback mode (charge pump is off) | R1, R2, R3, R4 continue to be bus terminals and reflect data on L3; DIR is don't care in this mode; TERM_RX not supported. External termination on R3/R4 not supported. R1/R2 can have internal or external termination. |

8 Application and Implementation

注

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.

8.1 Application Information

THVD4431 is a highly integrated multiprotocol transceiver supporting RS-232, RS-422 and RS-485 physical layer and is used for asynchronous data transmissions. MODE pins allow for the configuration of different operating modes. Device allows point-to-point RS-232 communication port and multipoint RS-485 communication port over common connector. The device also features integrated 120Ω switchable termination resistor on RS-485 bus lines which enables same device to be used for middle nodes or end nodes in an RS-485 network. When the device is configured in RS-232 mode, RS-485 circuits and 120Ω termination are disabled and do not interfere in RS-232 communication. For RS-232 communication, charge pump and $5k\Omega$ resistor to ground on receiver bus pins is integrated in the device. This $5k\Omega$ resistor and charge pump is automatically disabled in RS-485 mode. Slew rate limiting pin is provided so that same device can be used in slow speed or fast speed RS-485 and RS-232 applications. When ultra low power consumption is needed, device can be put in shutdown mode using $\overline{\text{SHDN}}$ pin. All these features make the device completely flexible and suitable for various application needs. Integration of termination resistor saves significant PCB area compared to discrete implementation.

8.2 Typical Application

An RS-485 bus consists of multiple transceivers connecting in parallel to a bus cable. To eliminate line reflections, each cable end is terminated with a termination resistor, R_T , whose value matches the characteristic impedance, Z_0 , of the cable. This method, known as parallel termination, generally allows for higher data rates over longer cable length.

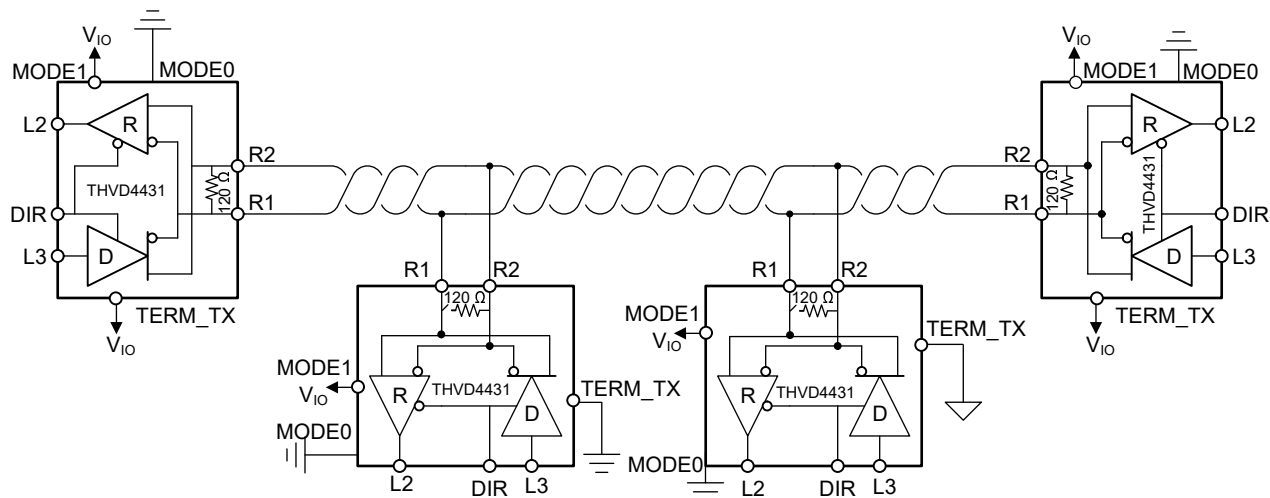


図 8-1. Typical RS-485 Network With Half-Duplex Transceivers

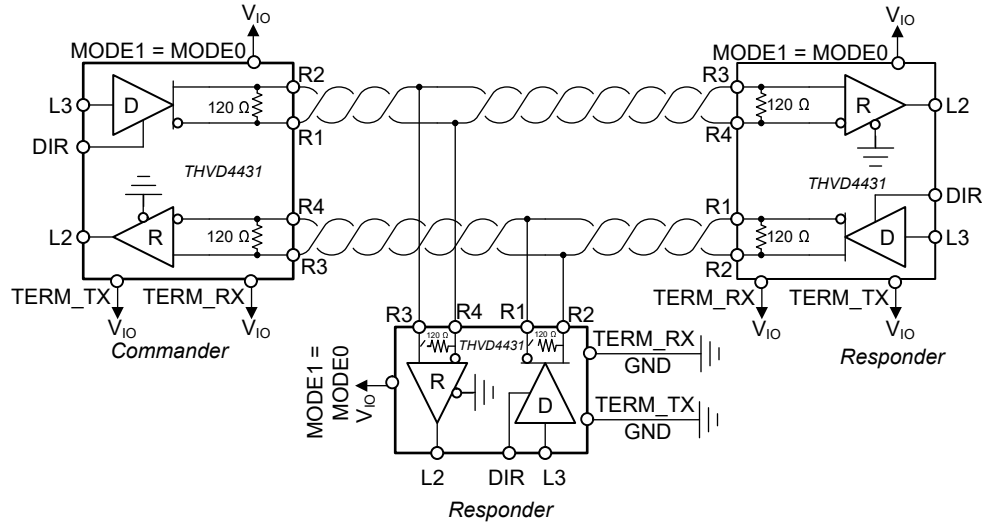


図 8-2. Typical RS-485 Network With Full-Duplex Transceivers

THVD4431 can be used in both networks (half and full duplex) and at all nodes (end node or middle nodes) since device has the configurability based on MODE2, MODE1, MODE0 pins and TERM_TX, TERM_RX pins.

THVD4431 also consists of three line drivers, five line receivers and dual charge pump circuit to enable RS-232 point-to-point serial communication. Full duplex transmission with hardware flow control is feasible with this device. This device provides the electrical interface between an asynchronous communication controller and the serial-port connector.

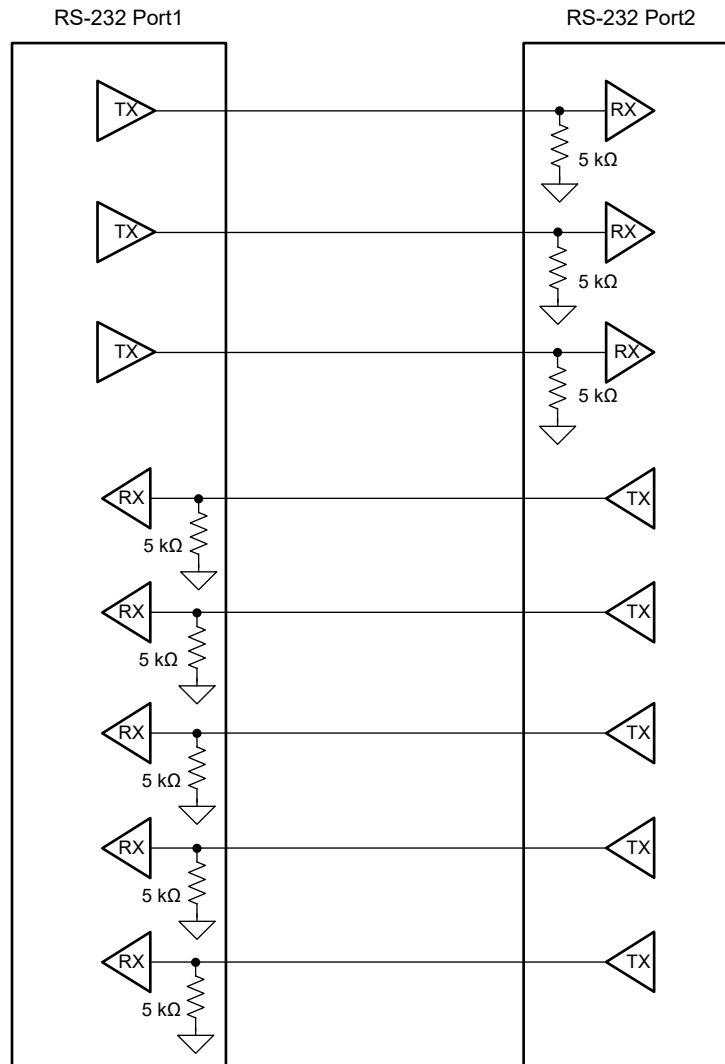


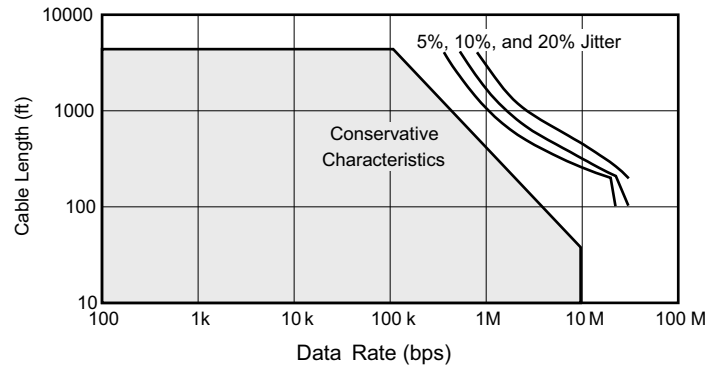
図 8-3. RS-232 serial communication

8.2.1 Design Requirements

RS-485 is a robust electrical standard suitable for long-distance networking that may be used in a wide range of applications with varying requirements, such as distance, data rate, and number of nodes. RS-232 is more suitable for debug or configuration point to point applications.

8.2.1.1 Data Rate and Bus Length for RS-485

There is an inverse relationship between data rate and cable length, which means the higher the data rate, the shorter the cable length. Conversely, the lower the data rate, the longer the cable length. While most RS-485 systems use data rates between 10 kbps and 100 kbps, some applications require data rates up to 250 kbps at distances of 4000 feet and longer. Longer distances are possible by allowing for small signal jitter of up to 5 or 10%.



☒ 8-4. Cable Length vs Data Rate Characteristic

8.2.1.2 Stub Length for RS-485 Network

When connecting a node to the bus, the distance between the transceiver inputs and the cable trunk, known as the stub, should be as short as possible. Stubs present a non-terminated piece of bus line which can introduce reflections of varying phase as the length of the stub increases. As a general guideline, the electrical length, or round-trip delay, of a stub should be less than one-tenth of the rise time of the driver, thus giving a maximum physical stub length as shown in 式 1.

$$L_{(\text{STUB})} \leq 0.1 \times t_r \times v \times c \quad (1)$$

where

- t_r is the 10/90 rise time of the driver
- c is the speed of light (3×10^8 m/s)
- v is the signal velocity of the cable or trace as a factor of c

8.2.1.3 Bus Loading for RS-485 Network

The RS-485 standard specifies that a compliant driver must be able to drive 32 unit loads (UL), where 1 unit load represents a load impedance of approximately 12 kΩ. Because the THVD4431 in RS-485 half and full duplex mode consists of 1/8 UL transceivers which represents load resistance of approximately 96 kohm, connecting up to 256 receivers to the bus is possible for a limited common mode range of - 7 V to 12 V.

8.2.2 Detailed Design Procedure

☒ 8-5 suggests an application schematic for THVD4431. The device has all logic pins on one side and bus side pins on other side to enable a flow-through layout in end application.

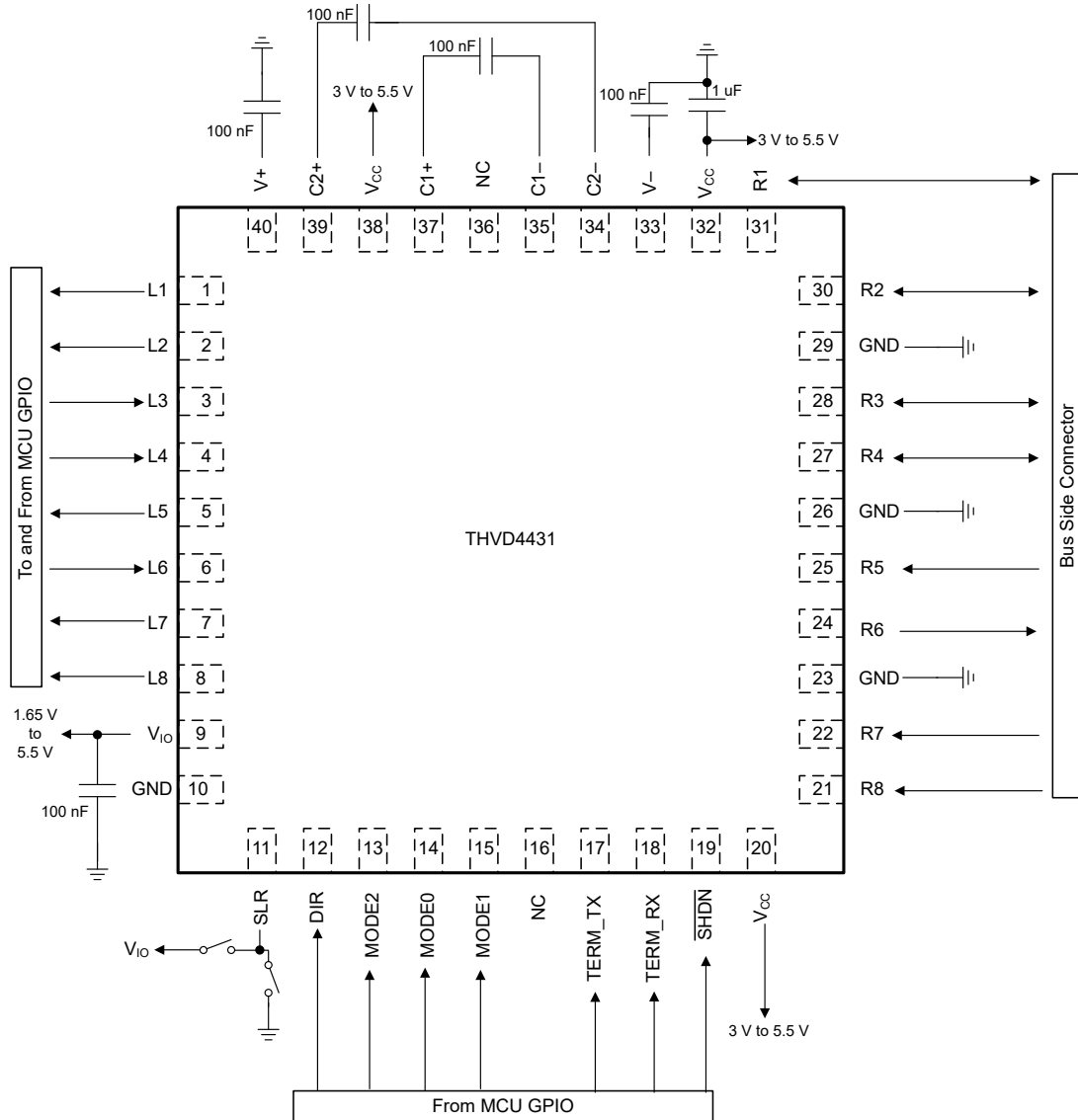
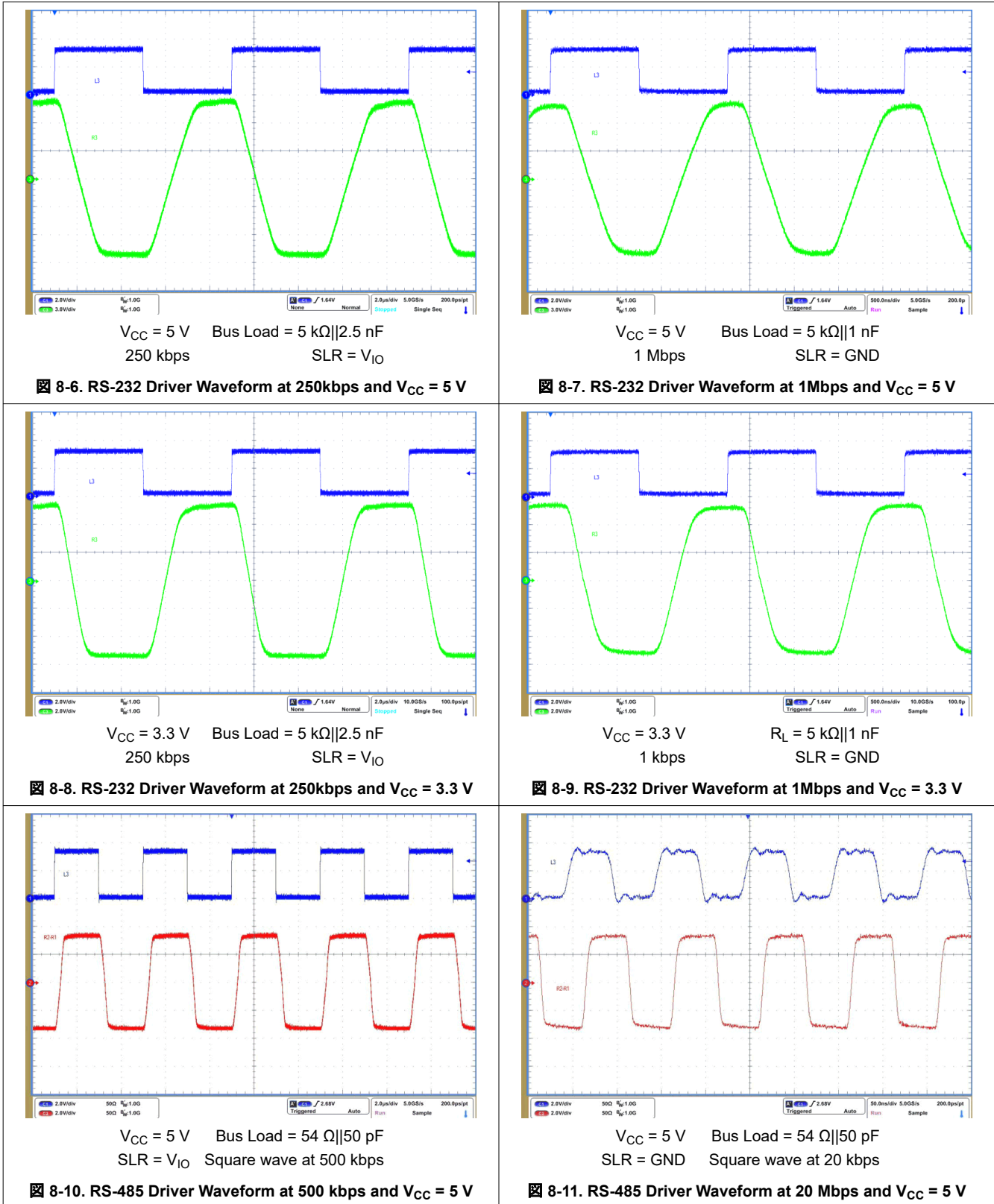


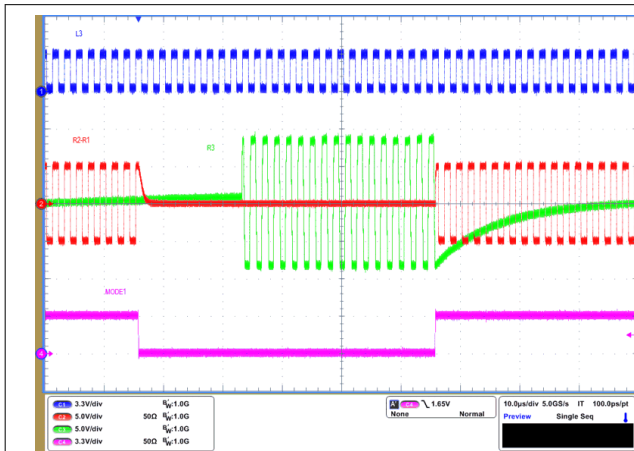
图 8-5. Typical application diagram for THVD4431

All V_{CC} power pins should have 1 μF decoupling capacitor close to the respective device pins. RS-232 charge pump is designed such that 100 nF charge pump capacitors work for both 3.3 V and 5 V operating V_{CC} supply.

8.2.3 Application Curves

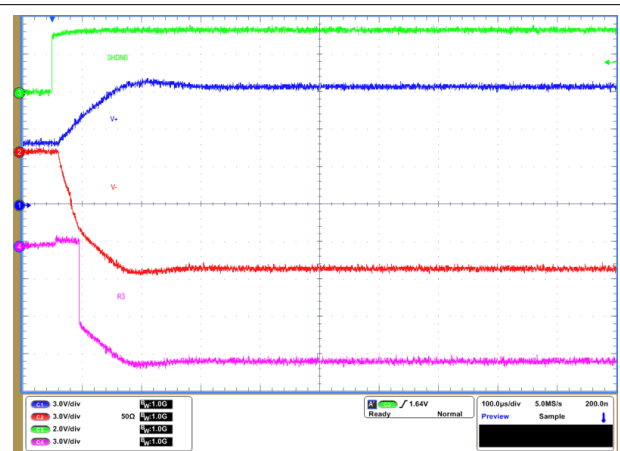


8.2.3 Application Curves (continued)



$V_{CC} = 5\text{ V}$ L3 = 1 Mbps square wave
SLR = GND MODE1 toggled at 10 kHz

8-12. RS-232 to RS-485 Mode Switching Waveform



$V_{CC} = 5\text{ V}$ L3 = GND
SHDN toggled

8-13. Mode Switching Waveform From Shutdown to RS-232 Mode

8.3 Power Supply Recommendations

For reliable operation at all data rates and supply voltages, each supply should be decoupled with a ceramic capacitor located as close to the supply pins as possible. Recommended bypass capacitor for V_{CC} is 1 μF , for V_{IO} is 100 nF, for $V+$, $V-$ charge pump voltage supplies is 100 nF. Besides this, two charge pump flying capacitors of 100 nF each are needed between $C1+$, $C1-$ terminals and between $C2+$, $C2-$ terminals. For $V_{CC} = 3.3\text{V} \pm 10\%$, $V+$ and $V-$ voltages are regulated to +5.5V and -5.5V typically. If an application needs larger RS-232 output voltages, $V_{CC} = 5\text{V} \pm 10\%$ is recommended because $V+$ and $V-$ are regulated to $\pm 9.5\text{V}$.

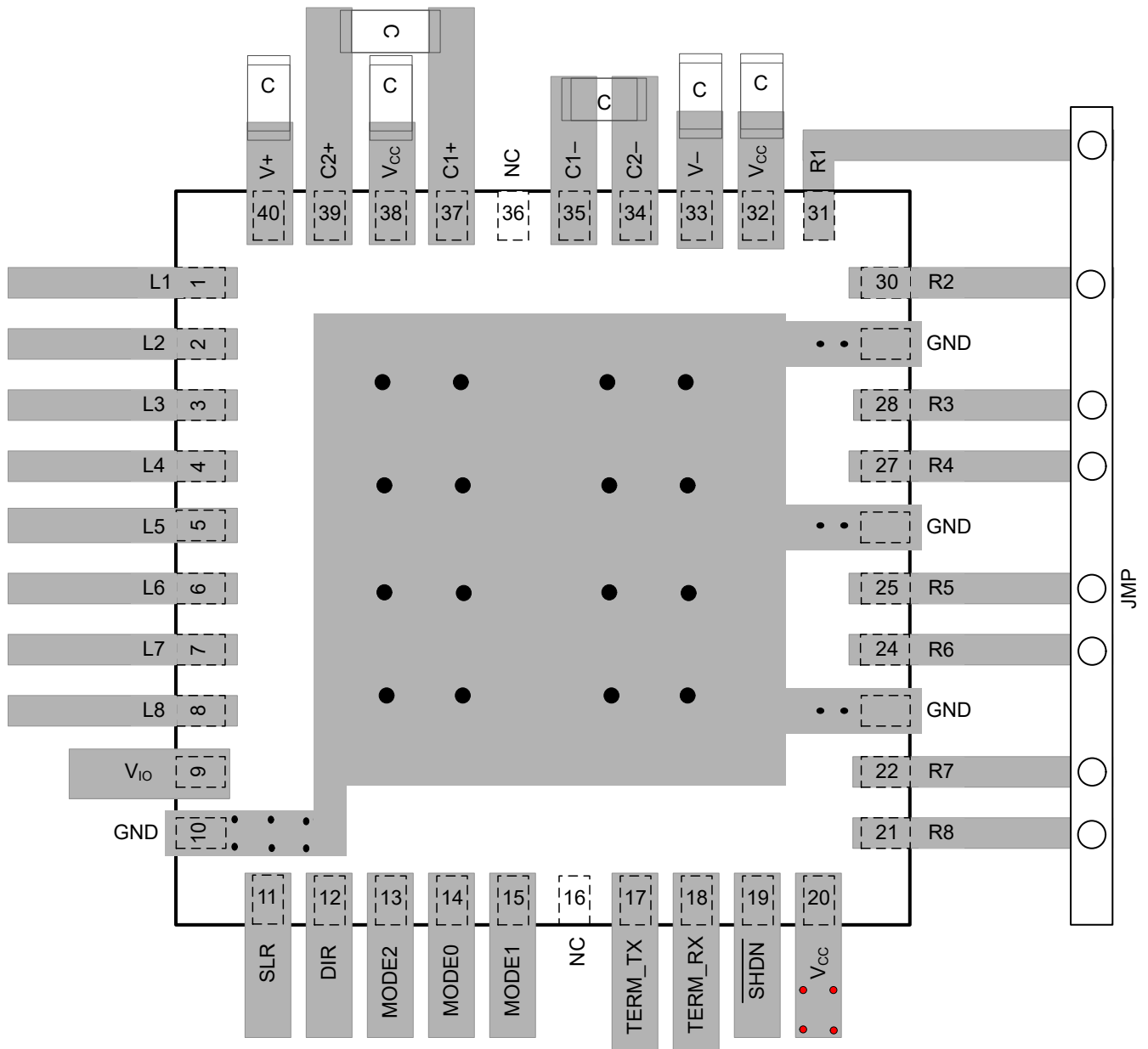
8.4 Layout

8.4.1 Layout Guidelines

Robust and reliable bus node design often requires the use of external transient protection devices to protect against surge transients that may occur in industrial environments. THVD4431 has integrated IEC ESD and EFT protection. So if the application does not need IEC Surge protection, external transient protection may not be needed. Since these transients have a wide frequency bandwidth (from approximately 3 MHz to 300 MHz), high-frequency layout techniques should be applied during PCB design.

1. Place the external protection circuitry close to the bus connector to prevent noise transients from propagating across the board.
2. Use V_{CC} and ground planes to provide low inductance. Note that high-frequency currents tend to follow the path of least impedance and not the path of least resistance.
3. Design the protection components into the direction of the signal path. Do not force the transient currents to divert from the signal path to reach the protection device.
4. Apply decoupling capacitors and charge pump capacitors as close as possible to the respective device pins such as V_{CC} , V_{IO} , $V+$, $V-$, $C1+$ to $C1-$, $C2+$ to $C2-$ pins of transceiver.
5. Use at least two vias for V_{CC} and ground connections of decoupling capacitors and protection devices to minimize effective via inductance.
6. Optionally, use 1-k Ω to 10-k Ω pull-up and pull-down resistors for control lines to limit noise currents in these lines during transient events.

8.4.2 Layout Example



8-14. Layout Example

9 Device and Documentation Support

9.1 Device Support

9.1.1 サード・パーティ製品に関する免責事項

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9.6 用語集

テキサス・インスツルメンツ用語集

この用語集には、用語や略語の一覧および定義が記載されています。

10 Revision History

Changes from Revision A (November 2023) to Revision B (April 2024)

Page

- Changed values from nF to pF in [図 5-15](#) and [図 5-16](#) 15

Changes from Revision * (August 2023) to Revision A (November 2023)

Page

- ドキュメントのステータスを「事前情報」から「量産データ」に変更 1

11 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.

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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 |
|------------------|---------------|--------------|-----------------|------|-------------|-----------------|--------------------------------------|----------------------|--------------|-------------------------|---------|
| THVD4431RHAR | ACTIVE | VQFN | RHA | 40 | 4000 | RoHS & Green | NIPDAU | Level-1-260C-UNLIM | -40 to 125 | THVD 4431 | 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.

OBSELETE: 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.

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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 |
|--------------|--------------|-----------------|------|------|--------------------|--------------------|---------|---------|---------|---------|--------|---------------|
| THVD4431RHAR | VQFN | RHA | 40 | 4000 | 330.0 | 16.4 | 6.3 | 6.3 | 1.1 | 12.0 | 16.0 | Q2 |

TAPE AND REEL BOX DIMENSIONS


*All dimensions are nominal

| Device | Package Type | Package Drawing | Pins | SPQ | Length (mm) | Width (mm) | Height (mm) |
|--------------|--------------|-----------------|------|------|-------------|------------|-------------|
| THVD4431RHAR | VQFN | RHA | 40 | 4000 | 367.0 | 367.0 | 35.0 |

GENERIC PACKAGE VIEW

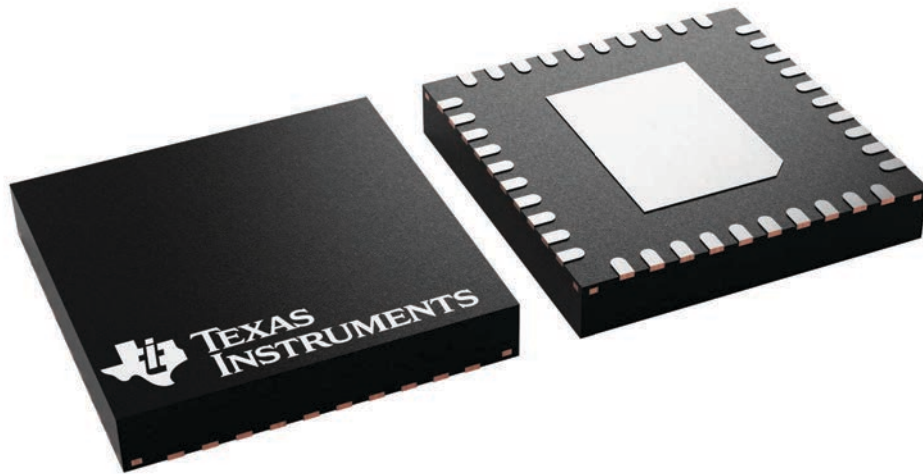
RHA 40

VQFN - 1 mm max height

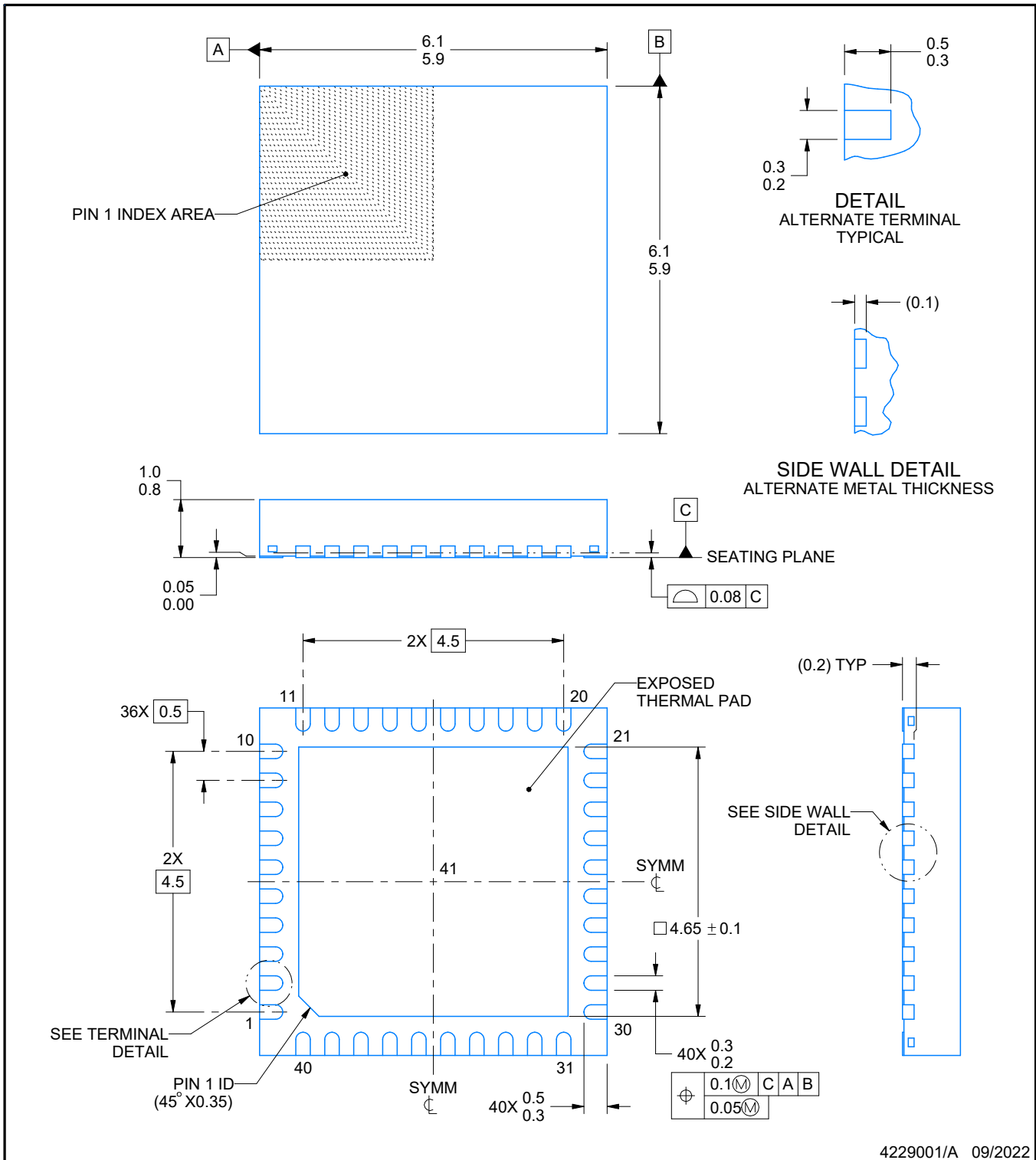
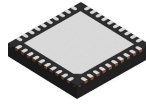
6 x 6, 0.5 mm pitch

PLASTIC QUAD FLATPACK - NO LEAD

This image is a representation of the package family, actual package may vary.
Refer to the product data sheet for package details.



4225870/A



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NOTES:

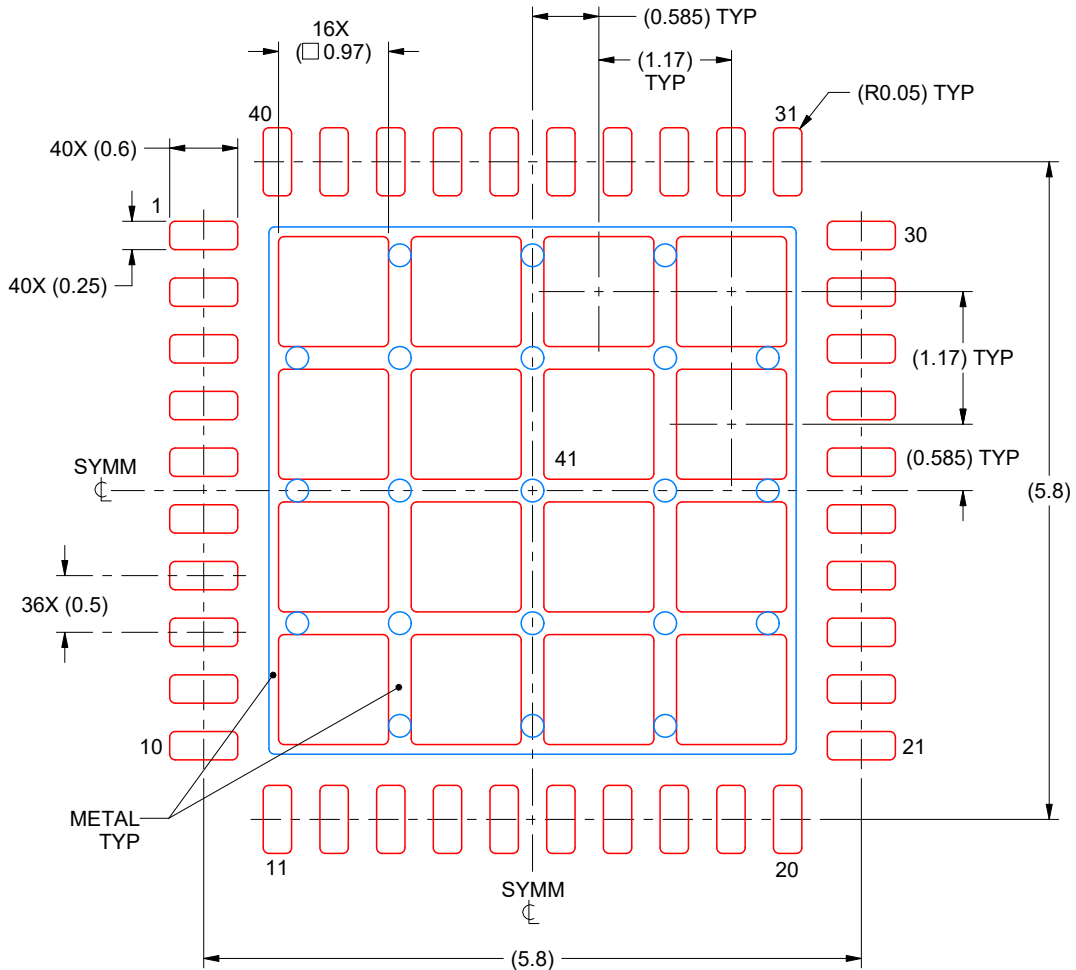
1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. The package thermal pad must be soldered to the printed circuit board for thermal and mechanical performance.

EXAMPLE STENCIL DESIGN

RHA0040R

VQFN - 1 mm max height

PLASTIC QUAD FLATPACK - NO LEAD



SOLDER PASTE EXAMPLE
BASED ON 0.125 mm THICK STENCIL

EXPOSED PAD 41:
69% PRINTED SOLDER COVERAGE BY AREA
SCALE:15X

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NOTES: (continued)

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

REVISIONS

| REV | DESCRIPTION | ECR | DATE | ENGINEER / DRAFTSMAN |
|-----|---------------------|---------|------------|---------------------------|
| A | RELEASE NEW DRAWING | 2201054 | 09/01/2022 | S. KUMMERL / K. SINCERBOX |

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