Technical White Paper

THVD44xx: Multiprotocol Transceivers With Advanced Integration and Flexibility Enable Diverse Applications

Vikas Kumar Thawani, Mani Ray, and Jitender Kapil

ABSTRACT

RS-232 and RS-422/RS-485 wired interfaces have been popular in industrial applications because of the simplicity, low cost and robustness offered by them. Applications such as industrial and factory automation, industrial PCs (also known as single board computers), barcode scanners, point-of-sale terminals, building security systems and industrial transport use one or both of these interfaces.

Multiprotocol (MP) transceivers integrate RS-232, RS-422 and RS-485 into one chip and offer flexible configuration options for the user. Multiprotocol transceivers can be used as standalone RS-232 or RS-422 or RS-485 transceiver by allowing seamless switching between either interface based on control pins. MP transceivers usually combine charge pump for RS-232 signaling and termination resistor for RS-232 receiver (5kΩ) and for RS-422/RS-485 (120Ω), making the overall system compact and eliminating costly and space-consuming external circuitry.

Texas Instruments THVD44xx family of multiprotocol transceivers offer an unprecedented level of integration and flexibility. This paper describes multiprotocol transceivers and compares them to the discrete implementation. Article then describes in detail the THVD44xx devices by diving into the operational modes and waveforms. The paper concludes by showcasing benefits THVD44xx devices offer compared to available devices in the market.

Table of Contents

Trademarks

1 Introduction

RS-232 is prevalent in low-cost, low-speed, point-to-point industrial applications. RS-232 is typically used for factory equipment diagnostics or programming. This interface utilizes large signal amplitudes to increase signal-to-noise ratio and work in harsh industrial environments. RS-232 is a full duplex wired interface and a communication port design can be implemented with a single driver and single receiver, or the interface can have multiple drivers and receivers to account for handshake control signals to control the data flow between the sender and the receiver.

The RS-232 standard uses inverse logic in which a high-level digital signal from the microcontroller (MCU) is translated to negative analog signal (less than or equal to -5V). Conversely, a low-level digital signal is translated to positive analog signal (greater than or equal to +5V). Receiver thresholds are defined as ±3V so there is some margin between lowest RS-232 driver output and receiver thresholds. From data rate perspective, RS-232 standard asks for up to 20kbps signaling rate with a max limit on slew rate of transmitted signal to control emissions. Modern day devices can support up to 1Mbps data rate while keeping slew rate in check. Maximum data rate is subjected to maximum capacitive loading that arises from the cable capacitance between the sender and the receiver.

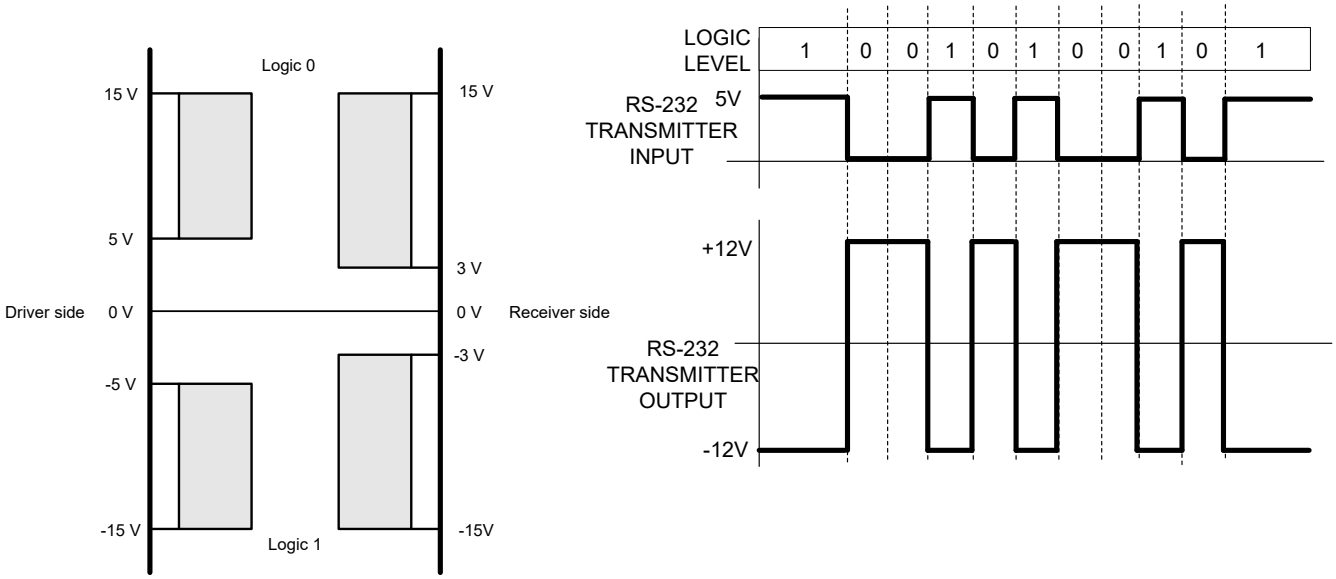


Figure 1-1. RS-232 Signaling and Range of Amplitudes for Driver and Receiver

RS-485 has been the most used wired communications interface in industrial applications for more than two decades now. Balanced differential signaling of RS-485 allows for reduced emissions and rejection of common mode noise increases immunity. Communications over long distances in noisy industrial environments is feasible. RS-485 allows multipoint network where multiple communicating nodes can talk through same bus, reducing cable cost. RS-485 networks can be implemented in either half duplex (2 wire) or full duplex (4 wire) fashion. Both networks are terminated at farthest ends- termination matching to cable characteristic impedance reduces reflections and improves signal quality.

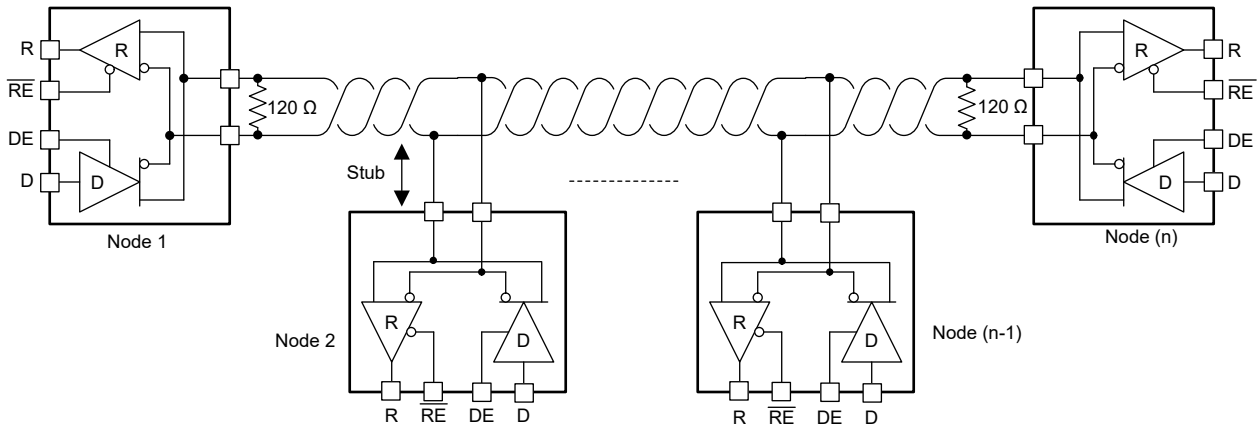


Figure 1-2. RS-485 Half Duplex Network

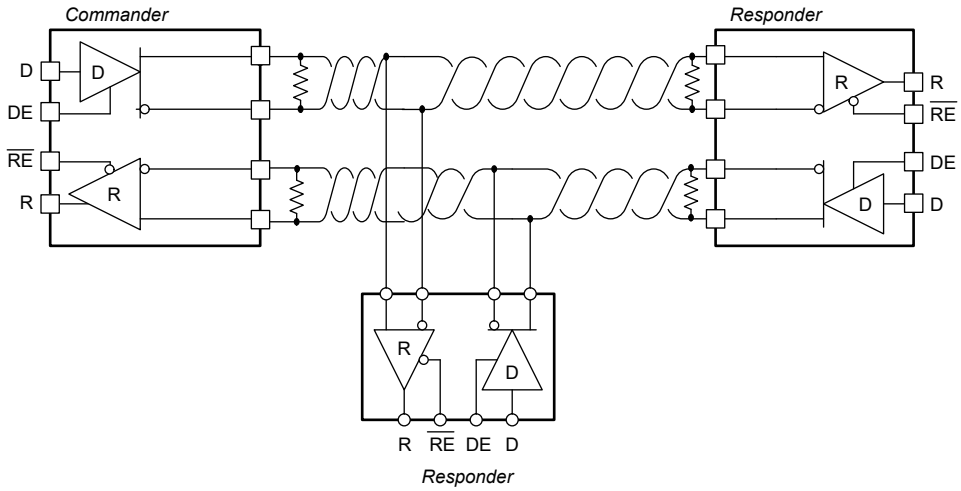


Figure 1-3. RS-485 Full Duplex Network

RS-422 is similar to RS-485, except that RS-422 allows multidrop network with only one driver and multiple receivers. RS-485 compliant transceivers are designed in a manner to be compliant to RS-422 as well.

Multiprotocol transceivers, as the name suggests, can support multiple wired protocols or interfaces. MP transceivers combine RS-232 and RS-422/RS-485 interface into one package. Thus, a communication port in an end application can be configured in any of the below fashions:

- Point-to-point RS-232 interface
- As a multidrop single driver-multiple receivers RS-422 interface
- As a multipoint multiple drivers-multiple receivers RS-485 network

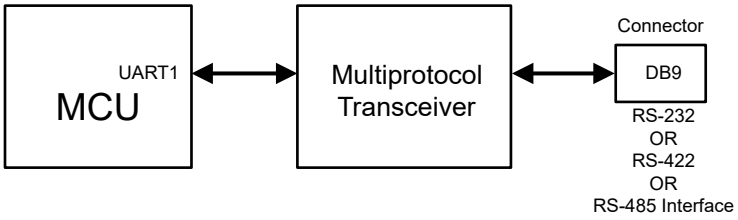


Figure 1-4. Multiprotocol Transceiver in RS-232, RS-422 or RS-485 Application

2 Application Use-Case of Multiprotocol Transceivers

One of the main applications that utilizes multiprotocol transceivers are Industrial PCs (IPC, also known as single board computers). Modern industrial manufacturing and automation have proliferated IPC into multiple fields including factories, medical, automotive, and retail. Main requirements for IPC design are:

- Robustness against transients to support harsh industrial environment
- Communication versatility- IPC needs to support large number of communication interfaces such as USB, Ethernet, display port, RS-232 and RS-485
- Small form factor. High power dissipation on board necessitates support for higher ambient temperature for semiconductors used

There are pre-dominantly two ways a multiprotocol transceiver is used by system designers:

- Single communication port needing one interface at a time via shared bus/logic lines. So, the port is either a RS-232 or a RS-422/RS-485 interface at one time. Main benefit for the application is there is no need for two physical connectors- same connector can be used as RS-232 or RS-485, so overall space needed on PCB is drastically reduced.
- Two port requiring both interfaces at the same time, but with each port configurable for either RS-232 or RS-422/RS-485.

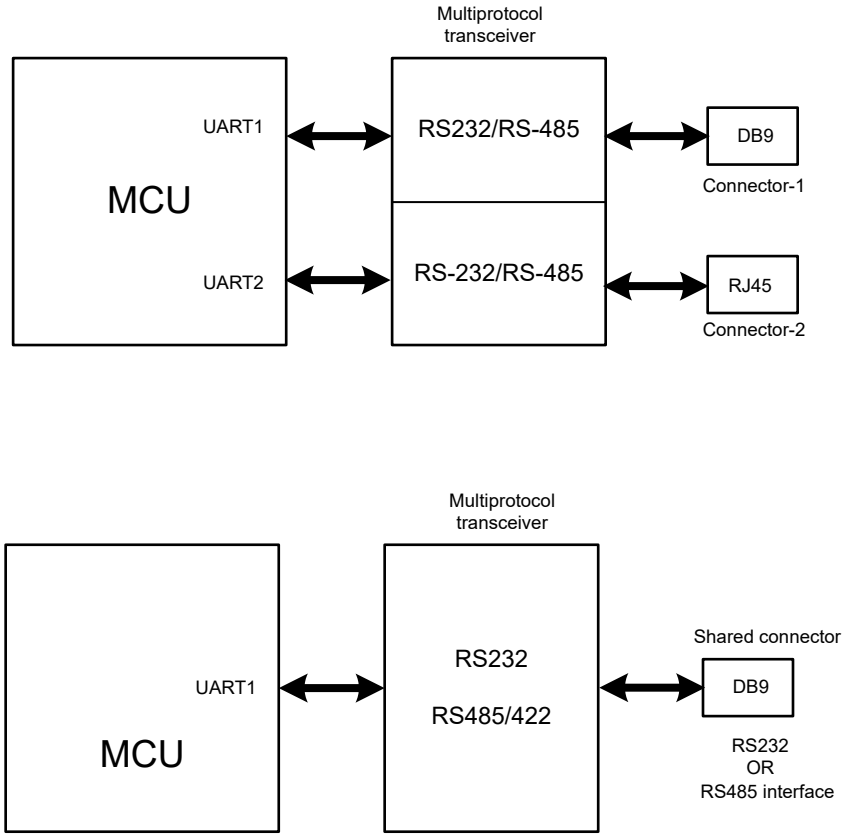


Figure 2-1. Single Port vs Two Port MP Use-Case Method

These usage methods are aimed towards mainly three application scenarios detailed below

- **Shared port with on-the-fly configurability:** Certain applications need configurable communication port. For example, an industrial equipment's port is configured as RS-485 for long distance multipoint communications. But during downtime, that port needs to be converted to RS-232 for diagnostics or firmware upgrade. Multiprotocol transceivers benefit such applications by requiring just one device instead of having separate RS-232 and RS-485 transceivers. Additional discrete circuitry to implement seamless switching between both interfaces and enabling/disabling termination for either interface is eliminated as that functionality is now integrated into the Multiprotocol transceiver, shrinking solution size considerably.
- **Single port fixed interface:** Multiprotocol transceivers comprising of RS-232 and RS-422/RS-485 benefit the applications which just need one interface. Customers can select, test and qualify multiprotocol transceiver, and configure it for either interface. Main benefit is reduced development time and effort, and lower inventory cost of management since now the customers do not have to select different devices for different applications.
- **Protocol translation:** Multiprotocol transceivers that enable both RS-232 and RS-485 interfaces simultaneously can be used as protocol translator. Certain application scenarios need an equipment's legacy RS-232 port to be converted as RS-485 for long distance communications. RS-485 inputs and outputs can be connected to RS-232 outputs and inputs to enable RS-232 communication distance extension.

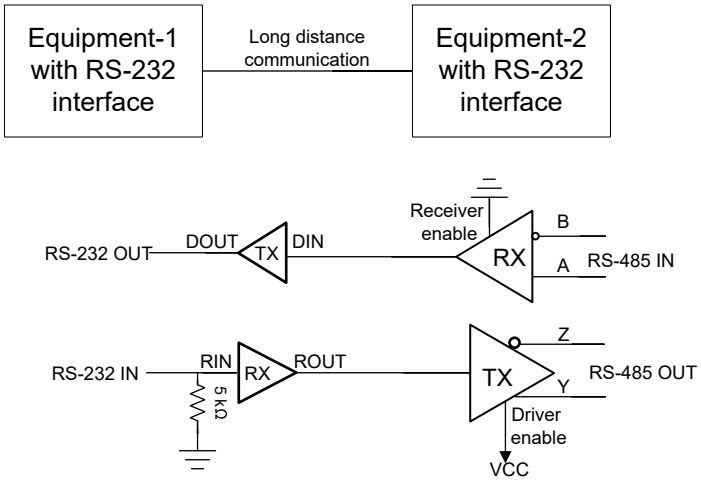


Figure 2-2. Protocol Translation

3 Key Design Goals of a Versatile Multiprotocol Transceiver

An versatile multiprotocol transceiver can have below features:

- Support of both RS-485 and RS-232 interface, with MODE configuration pins. If logic and bus pins are shared between both interfaces, no interference/loading from unused interface to the active interface must be supported.
- Support switching between half duplex and full duplex RS-485 configurations.
- Support integrated 120Ω switchable termination for bus pins in RS-485 configuration.
- Support integrated 5kΩ resistor for RS-232 receivers.
- Support integrated charge pump for RS-232 signaling that can operate from either 3.3V or 5V supply. This enables overall small solution size without the need for additional voltage rails and the device can just run off a single low voltage bus supply.
- Additional features such as slew rate control for both RS-232 and RS-485 drivers, shutdown pin to achieve ultra-low (µA) current consumption, and diagnostic loopback modes can benefit the applications.

4 Discrete Multiprotocol Transceiver Implementation

With the above design goals in mind, discrete multiprotocol implementation can be realized as shown in Figure 4-1.

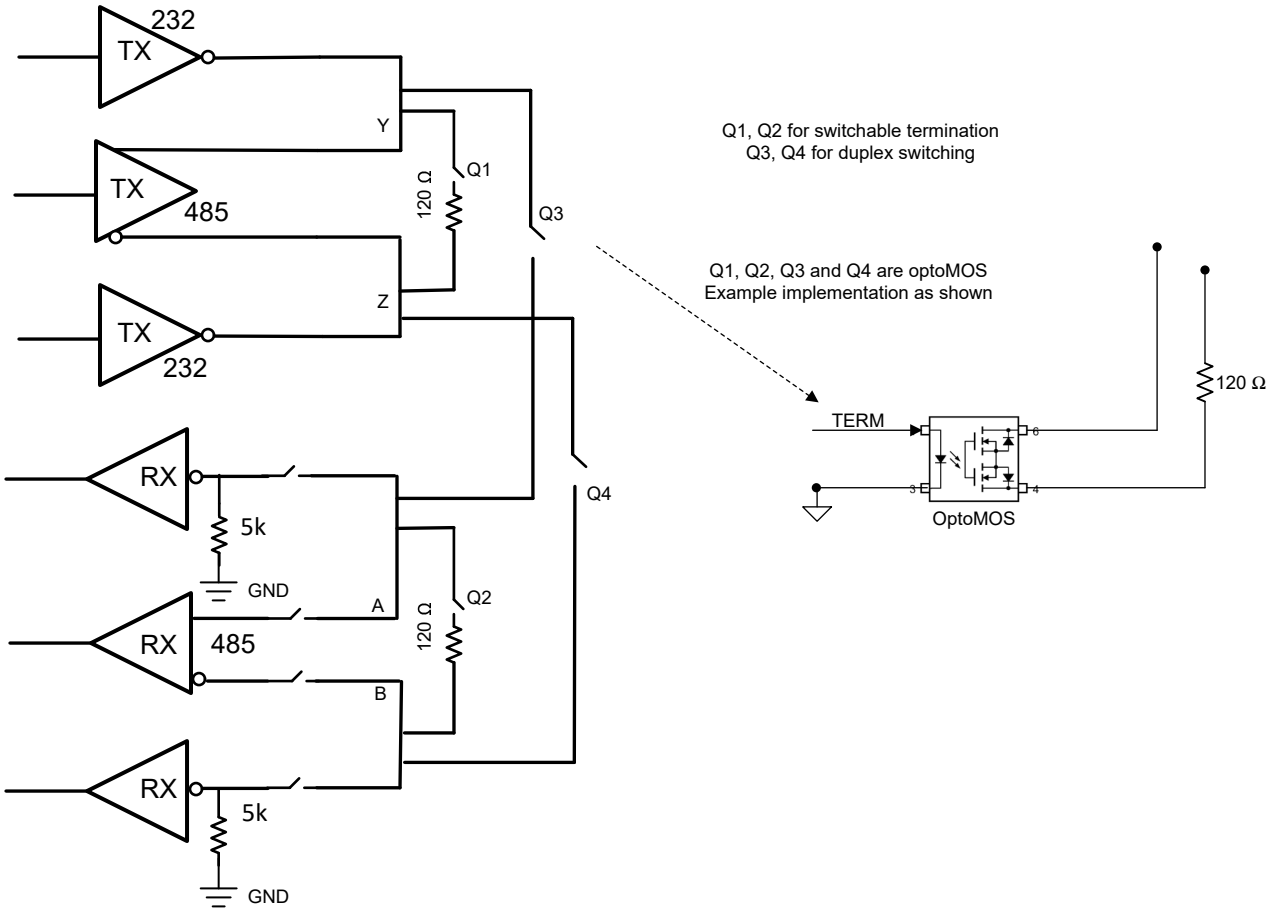


Figure 4-1. Discrete Multiprotocol Solution Implementation

The OptoMOS that connects driver and receiver non-inverting terminals together (Q3) and inverting terminals together (Q4) are used to make the solution switch between half and full duplex. Q1 and Q2 OptoMOS are used to switch ON or OFF the 120Ω termination resistor to make the node either a terminal node or a middle node. The solution can look functionally OK, but there is one issue that degrades the performance of the RS-485 system. Integrated RS-232 devices in the market have 5kΩ resistor on RS-232 receiver pins to ground which are still present even if the solution is configured as RS-485. This loads the RS-485 receiver and reduces the number of nodes supported by RS-485. Clearly, a discrete solution is tricky to design, requires considerable external components and occupies a lot of board space, making the overall solution expensive and bulky.

5 TI's THVD44xx Multiprotocol Transceiver Family

Texas Instruments has released a family of Multiprotocol transceivers THVD44xx. All three devices in this family are for single communication port needing one interface (RS-232 or RS-422/RS-485) at a time via shared bus/ logic lines.

THVD4431: three transmitters and five receivers for RS-232, one transmitter and one receiver for RS-485 in 40-QFN (6mm*6mm).

THVD4421: two transmitters and two receivers for RS-232, one transmitter and one receiver for RS-485 in 32-QFN (5mm*5mm).

THVD4411: one transmitter and one receiver for RS-232, one transmitter and one receiver for RS-485 in 24-QFN (4mm*4mm).

Figure 5-1 through Figure 5-3 show the block diagrams for each of the device. For more details into the pinout, functionality and application schematic, see the device-specific data sheets.

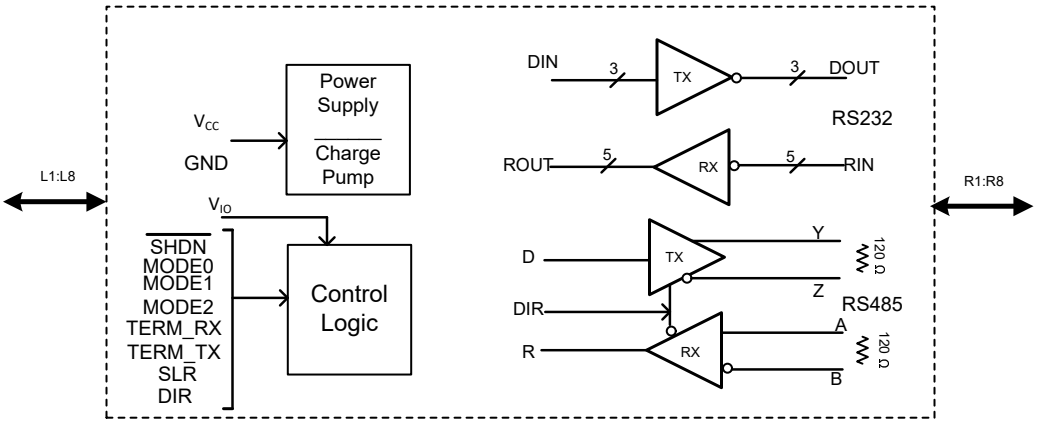


Figure 5-1. THVD4431 Block Diagram

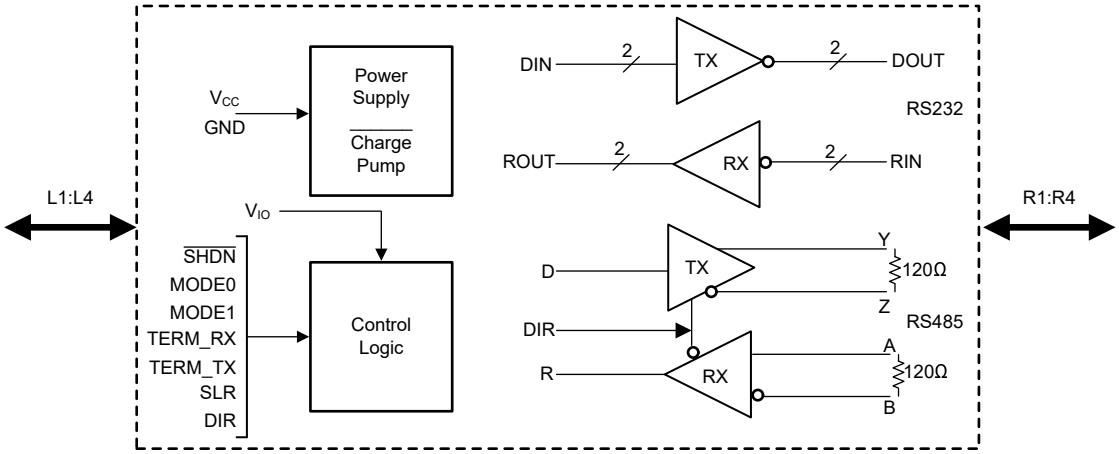


Figure 5-2. THVD4421 Block Diagram

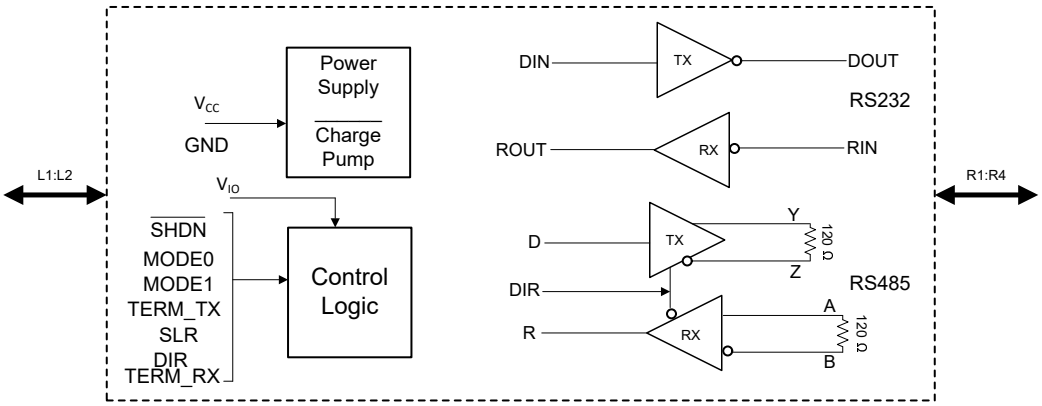


Figure 5-3. THVD4411 Block Diagram

Below features are common to all three devices:

- Integrated Level-4 (8kV contact discharge, 15kV air-gap discharge) IEC-ESD protection (per IEC 61000-4-2) on all bus pins.
- Integrated 120-Ω switchable termination on both RS-485 driver and RS-485 receiver bus pins. These can be engaged ON/OFF from TERM_TX/TERM_RX pins providing complete flexibility to the system designer to use the device on any node (middle or end) in any type of network (half duplex or full duplex).

- Integrated high-efficiency low-noise charge pump for driving RS-232 voltage levels. This charge pump produces regulated ±5.5V (nominal) output from $3.3V_{CC}$, or ±9V (nominal) from $5V_{CC}$.
- Ultra-low power shutdown mode where all blocks are switched off and device consumes less than 20uA of leakage current.
- Slew rate control for RS-232 and RS-485 that enables same device to be used in two max signaling rate scenarios.
- Logic supply (1.65V to 5.5V) support to enable different MCU interface supply and bus supply voltages.
- Ample configuration options such as RS-485 half duplex mode, RS-485 full-duplex mode, RS-422 mode, RS-232, and some devices have diagnostic loopback modes as well.
- Extended ambient temperature range supported: -40°C to 125°C
- Integrated protection features such as RS-485 and RS-232 driver short-circuit, RS-485 receiver failsafe operation, under-voltage and thermal shutdown to enable robust operation.
- Space-saving thermally efficient QFN package.

6 MODE Configurations for THVD4431

THVD4431 can be configured into various modes through the MODE pins. Below are the diagrams that explain those modes. THVD4431 greatly benefits the application by reducing test and qualification time and re-use of schematics and layout, as the device can be used for any mode via pin control. Notice that same bus and logic pins are used whether the device is operating in any RS-232 or in any RS-485 modes.

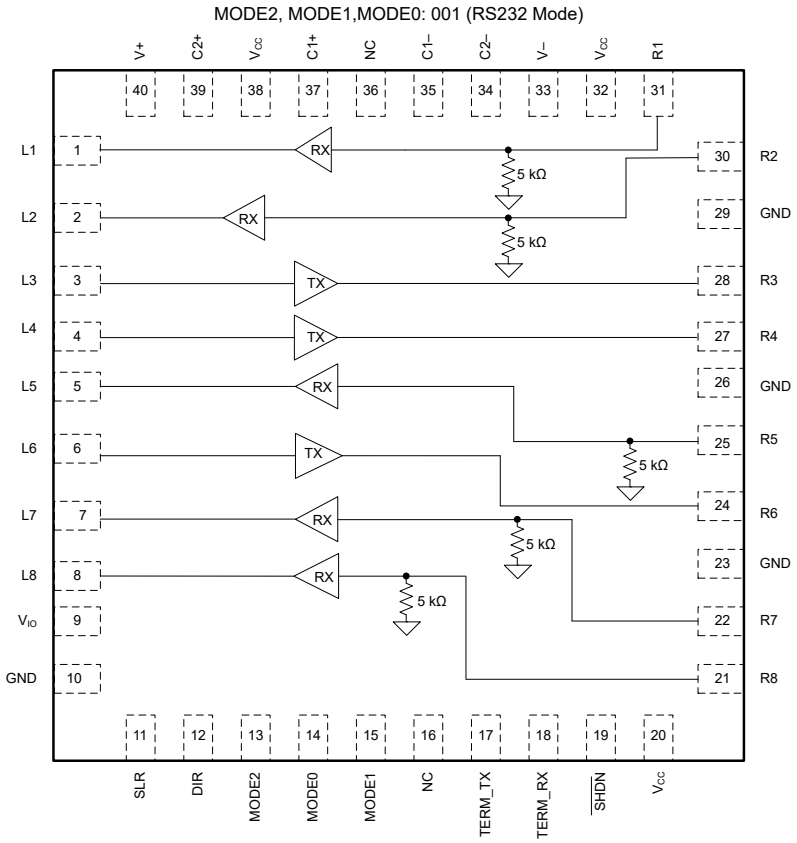


Figure 6-1. THVD4431 in RS-232 3T5R Mode

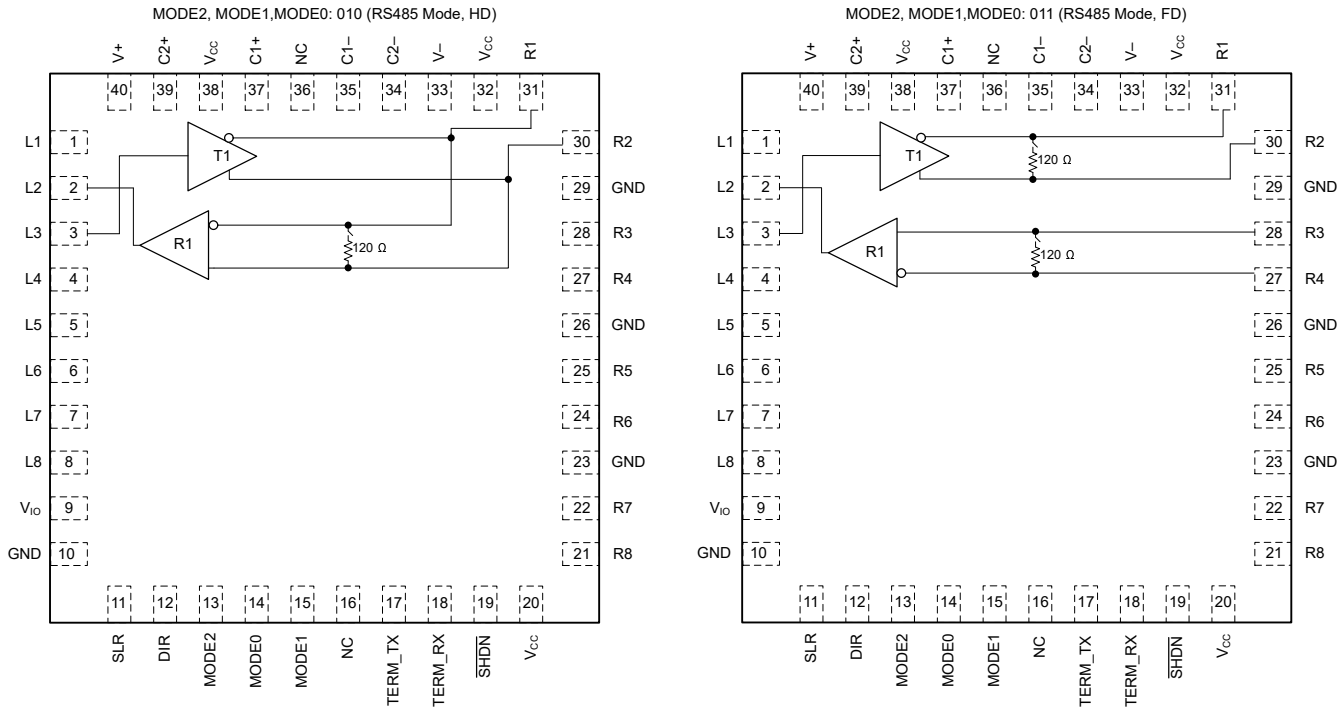


Figure 6-2. THVD4431 in RS-485 Half-Duplex and Full-Duplex Mode

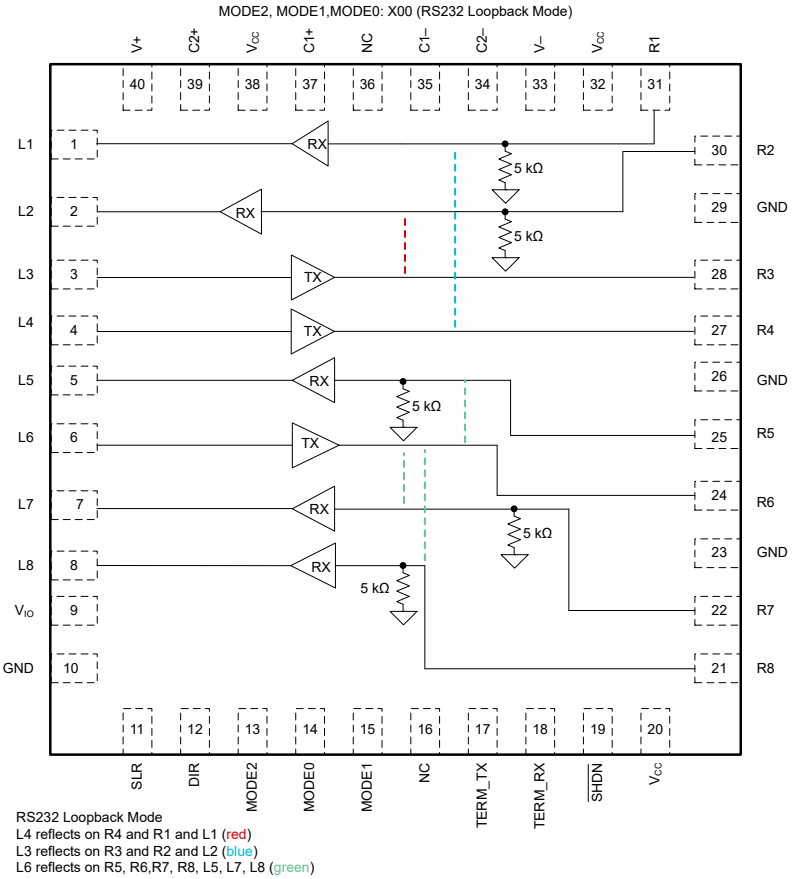


Figure 6-3. THVD4431 in RS-232 Loopback Mode

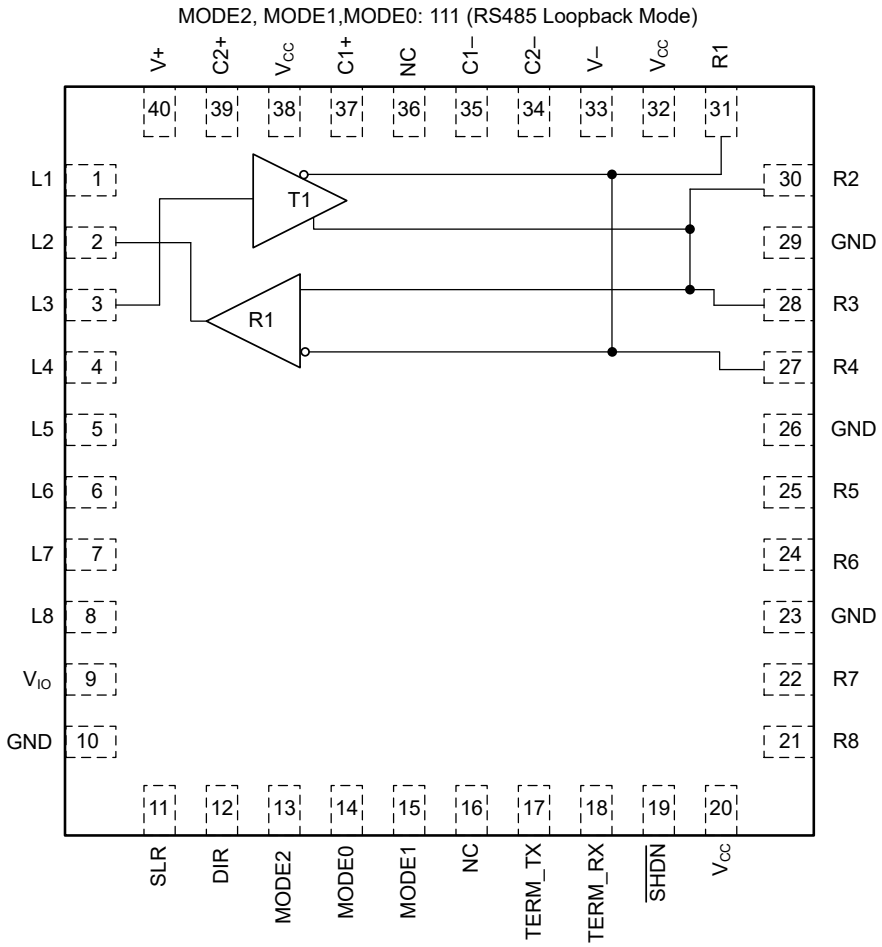


Figure 6-4. THVD4431 in RS-485 Loopback Mode

7 Application Diagrams for THVD4431

As described earlier, THVD4431 can be configured for RS-485 half duplex network, RS-485 full duplex network or RS-232 3T5R point-to-point communication. Notice how each node in the RS-485 network uses THVD4431, end nodes with on-chip termination engaged and middle nodes with on-chip termination switched off.

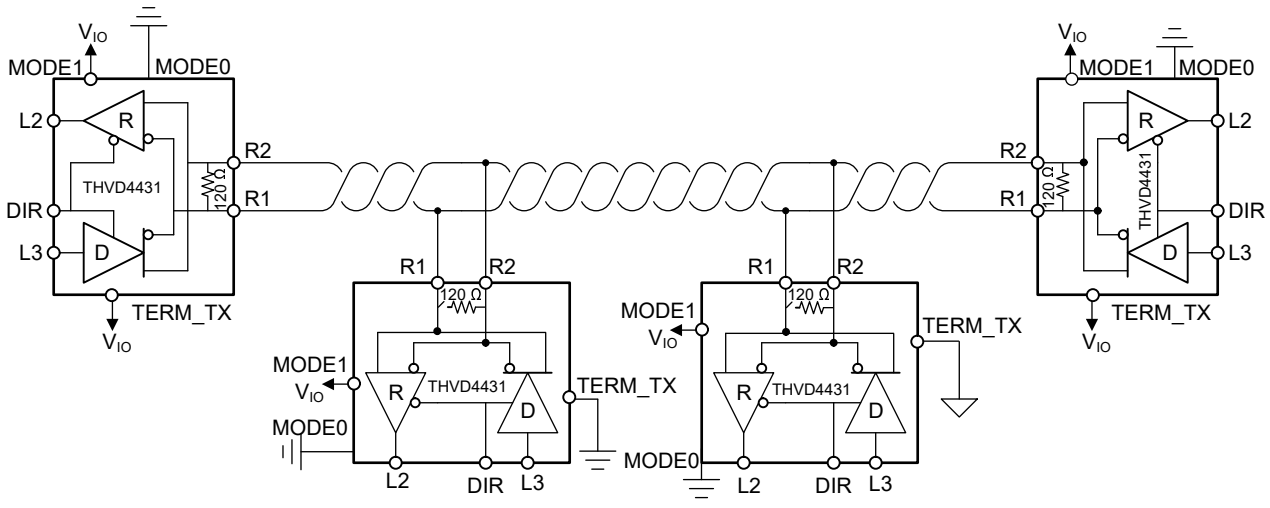


Figure 7-1. THVD4431 in RS-485 Half Duplex Network

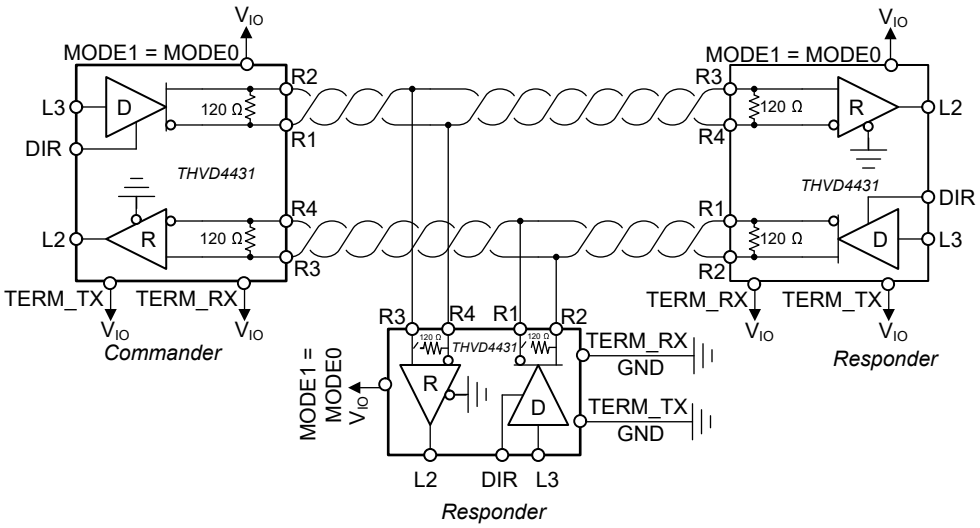


Figure 7-2. THVD4431 in RS-485 Full-Duplex Network

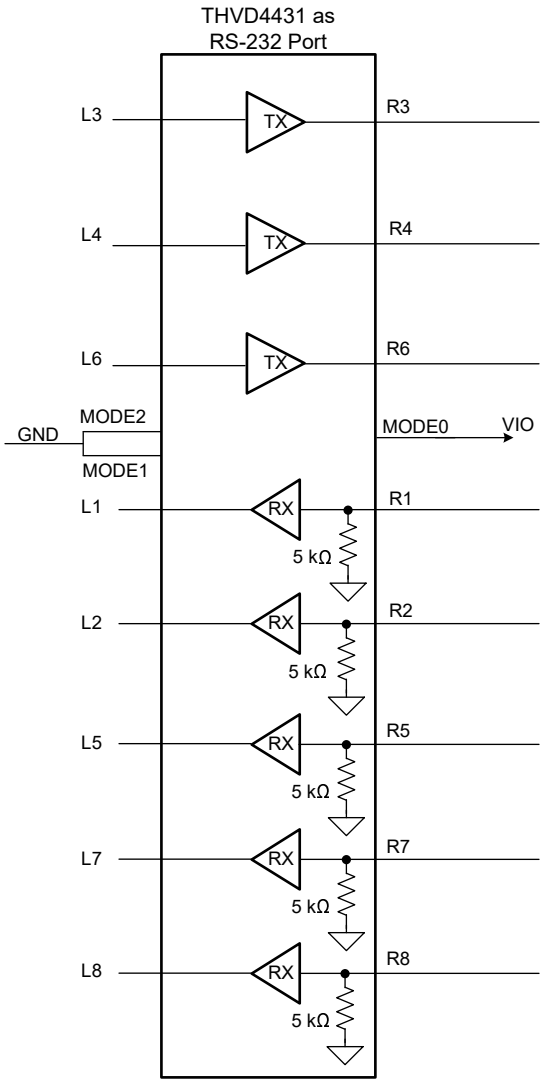
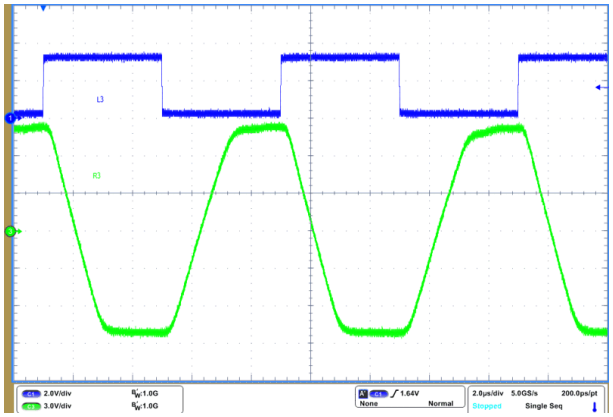


Figure 7-3. THVD4431 in RS-232 Point-to-Point Communication

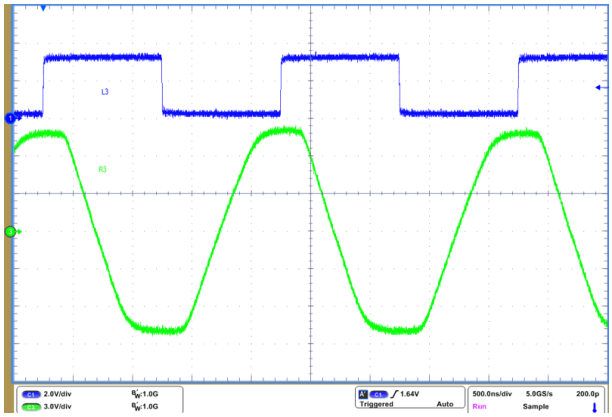
8 Waveforms for THVD4431

This section displays some waveforms captured on THVD4431 configured in RS-232 and in RS-485 modes, while also showing mode switch waveform:



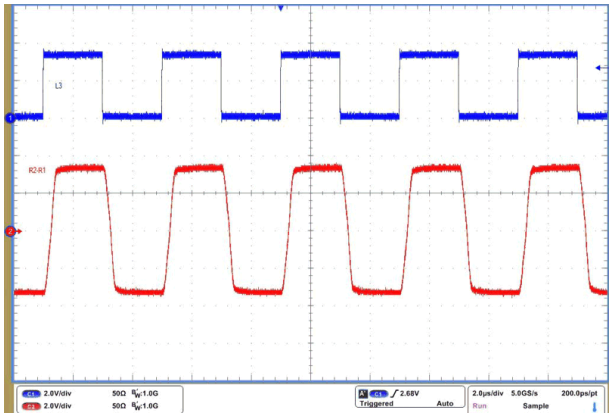
V_{CC} = 5V, Bus load = 5 kΩ || 2.5 nF

Figure 8-1. RS-232 Waveform in 250kbps Mode



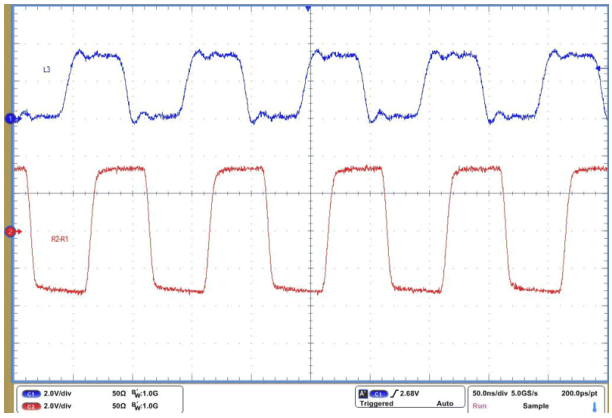
V_{CC} = 5V, Bus load = 5 kΩ || 1 nF

Figure 8-2. RS-232 Waveform in 1Mbps Mode



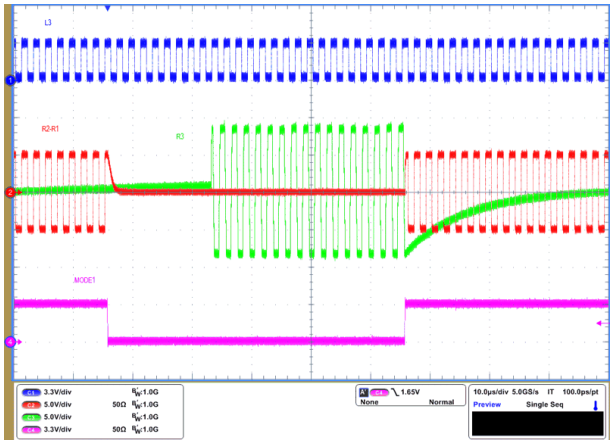
V_{CC} = 5V, Bus load = 54 Ω || 50 pF

Figure 8-3. RS-485 Waveform in 500kbps Mode



V_{CC} = 5V, Bus load = 54 Ω || 50 pF

Figure 8-4. RS-485 Waveform in 20Mbps Mode



V_{CC} = 5V, L3 = 1 Mbps square wave, SLR = GND, MODE1 toggled at 10 khz

Figure 8-5. RS-232 to RS-485 Mode Switch Waveform

9 Benefits of THVD4431 Over Competition Devices

Table 9-1. Benefits of THVD4431 Over Competition Devices

Parameter	THVD4431	Competition A	Competition B	Competition C	System Implication
Logic level support	1.65V -5.5V	1.7V-5.5V	Not supported	Not supported	TI is future proof with logic level support to interface to 1.8V MCU
Typical RS-232 output voltage level @5Vcc	±9V (regulated)	±5.5V	±9V (unregulated)	±9V (unregulated)	TI's RS232 output will be regulated across data rate and varying cap load. Higher amplitude = better SNR in noisy industrial environment
Diagnostic loopback mode	Full path loopback for both RS-232 and RS-485	Logic loopback only	Logic loopback only	Not supported	TI supports chip health monitoring and cable/connector short detection
Integrated 120Ω switchable termination for RS-485	Yes for both TX and RX pins	Yes for both TX and RX pins	Only RX pins	Only RX pins	TI device has more flexibility for RS-485 network placement as termination on individual bus pins can be turned on/off
Operating ambient temperature	-40°C to 125°C	-40°C to 125°C	-40°C to 85°C	-40°C to 85°C	TI supports higher ambient temperature enabling smaller PCB's/end systems
Flow through layout	Yes	Yes	Yes	No	All left side pins in THVD4431 are MCU logic pins, right side are bus (connector) side pins enabling clean PCB layout

10 Conclusion

Texas Instruments THVD44xx Multiprotocol transceivers offer compelling differentiation compared to incumbent solutions in the market. These devices only need four charge pump capacitors and two bypass capacitors to operate. Different customers and applications can select from any of the three devices available in this family based on the number of transmitters and receivers needed. Advance level of integration in these devices help enable new applications which were not possible with discrete or currently available competing multiprotocol solutions. Evaluation boards are available for all 3 devices in this family for quick evaluation and head-start into the design.

IMPORTANT NOTICE AND DISCLAIMER

TI PROVIDES TECHNICAL AND RELIABILITY DATA (INCLUDING DATA SHEETS), 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, regulatory 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 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.

TI objects to and rejects any additional or different terms you may have proposed.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265