

Dual Protocol Transceivers

Dual Protocol Transceivers Simplify Interface Design

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Abstract

The industrial PC design trend towards smaller form factors and more communication versatility is driving the development of modern bus transceivers. New transceivers win over legacy designs due to their high grade of integration, dual protocol capability supporting the RS-232 and RS-485 standards, and ample configuration features.

To help understand the benefits of this new generation of transceivers, this document starts with an overview of the industry's most commonly used interface standards, RS-232 and RS-485, then describes the functionality and features of a dual-protocol transceiver, and concludes discussing various application examples.

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1. The RS-232 Standard

Developed in the early 60s RS-232 was the first interface standard for digital communication between Data Terminal Equipment (DTE), commonly a PC, and Data Communication Equipment (DCE), typically a modem. The standard comprises a total of 24 signal lines for data, control, synchronization, and ground. However, the most common application at the time, the data modem, required only nine signal connections ([Figure 1](#)).

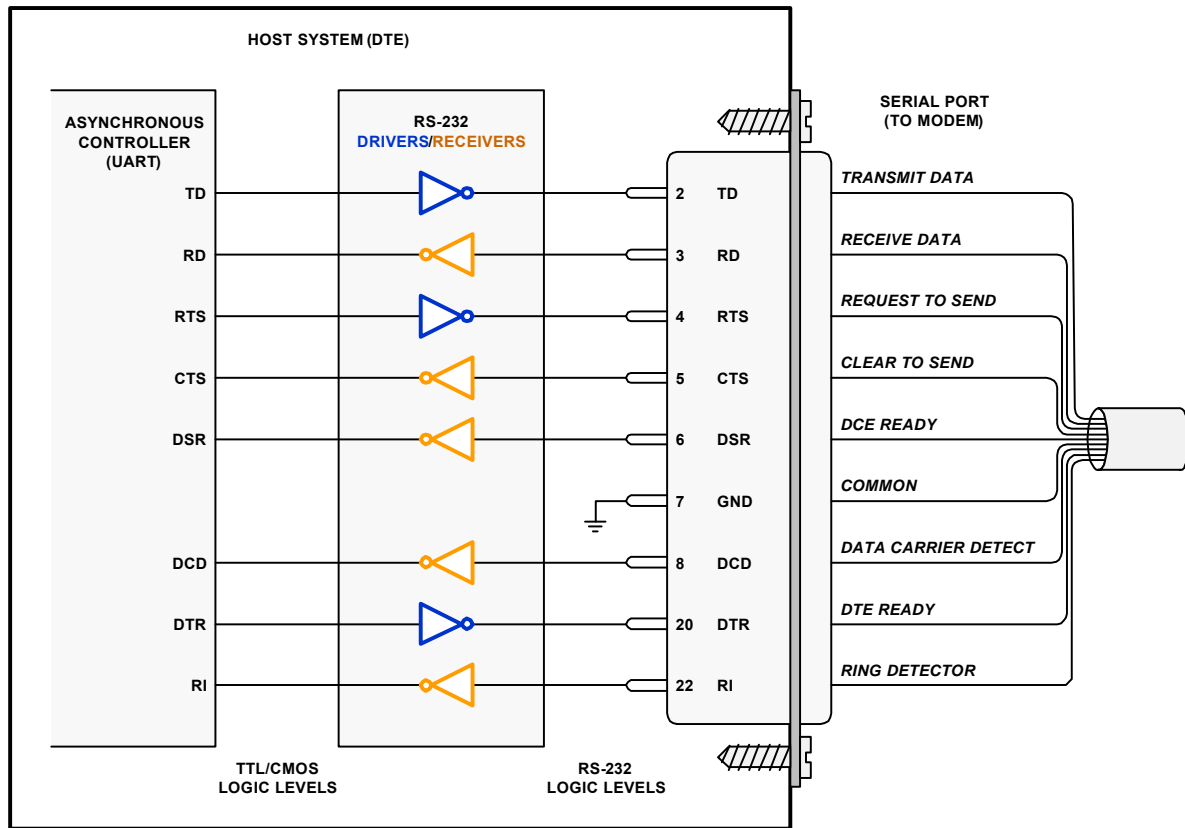


Figure 1. Typical RS-232 Link Between PC and Data Modem Using Only Nine of the Specified 24 Signals

Most of today's RS-232 designs use only one or two data channels. Each channel consists of a transmit and a receive signal pair. Transceivers providing two channels often use one channel for data transmission and the other for handshake control, using the Request to Send (RTS) and Clear to Send (CTS) handshake control signals. Single-channel devices however, must resort to software flow control using XON and XOFF (Transmit On/Off) commands.

RS-232 is a single-ended, full-duplex interface, defined for point-to-point communication only. This means that one driver connects to one receiver, and vice versa, one receiver connects to one driver. The interface requires a ground wire connection between the driver and receiver grounds to provide a common reference for transmit and receive signals ([Figure 2 on page 3](#)).

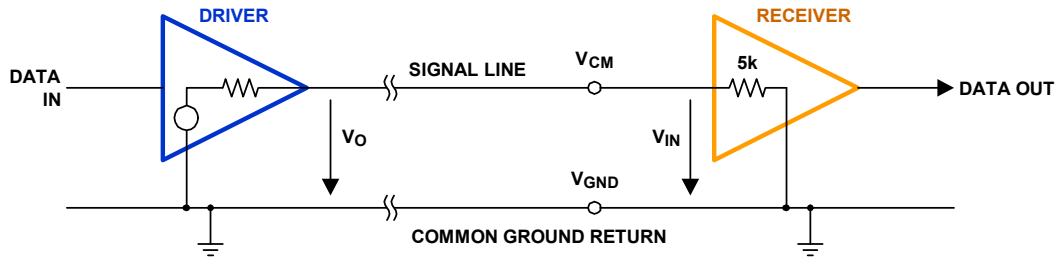


Figure 2. Single-Ended, Point-to-Point Data Link

RS-232 is sensitive to noise pick-up, because noise induced into the signal or ground paths adds to the receiver input. This can cause false receiver triggering. RS-232 tries to counteract external noise through the use of high signal amplitudes. The standard uses inverse logic and specifies a logic zero, as a bus voltage from +3V to +15V, and a logic one from -3V to -15V (Figures 3 through 5). The range from +3V to -3V is undetermined, or simply not allowed.

DRIVER OUTPUT	RS-232 STANDARD	RECEIVER INPUT
+9V	+15V	+15V
LOGIC 0 OUT	LOGIC 0	LOGIC 0 IN
+5V	+3V	+2V
	-0V - -	+0.8V
-5V	-3V	LOGIC 1 IN
LOGIC 1 OUT	LOGIC 1	
-9V	-15V	-15V

Figure 3. RS-232 Signal Levels

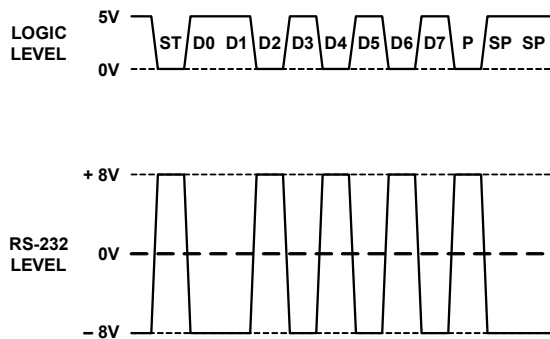


Figure 4. RS-232 Conversion from Logic Signals

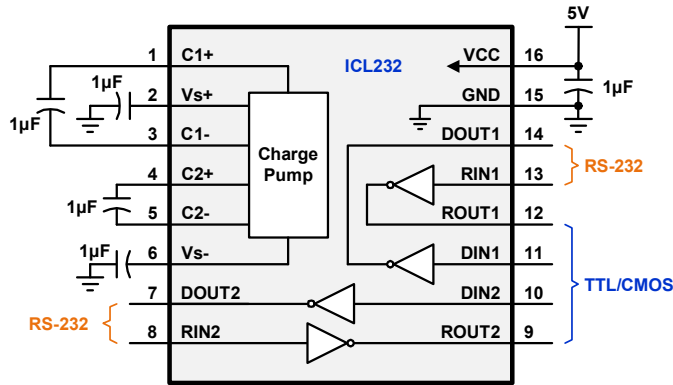


Figure 5. Integrated Transceiver Performing the Signal Conversion

An RS-232 transceiver inverts the input signals from both directions. It also converts logic I/O levels (0 to 5V) into bipolar high-voltage bus levels ($\pm 8V$) through an internal charge pump.

With regards to data rate and transition times, RS-232 specifies a maximum signal rate of up to 19.8kbps and a maximum slew rate of $30V/\mu s$. By reducing the bus voltage amplitudes, however, modern transceivers can support data rates of up to 1Mbps without violating the slew-rate specification. Although RS-232 does not specify a specific cable type whose characteristic impedance requires matched terminations, the commonly applied cable length is limited to 30m.

2. The RS-485 Standard

Developed in the early 80s, RS-485 remains a drastically improved standard for robust data transmission in noisy environments and across long distances. The standard uses differential signaling across a signal-pair of two conductors, A and B. It specifies a differential bus voltage swing between the two conductors of 1.5V minimum when loaded with a 54Ω differential load.

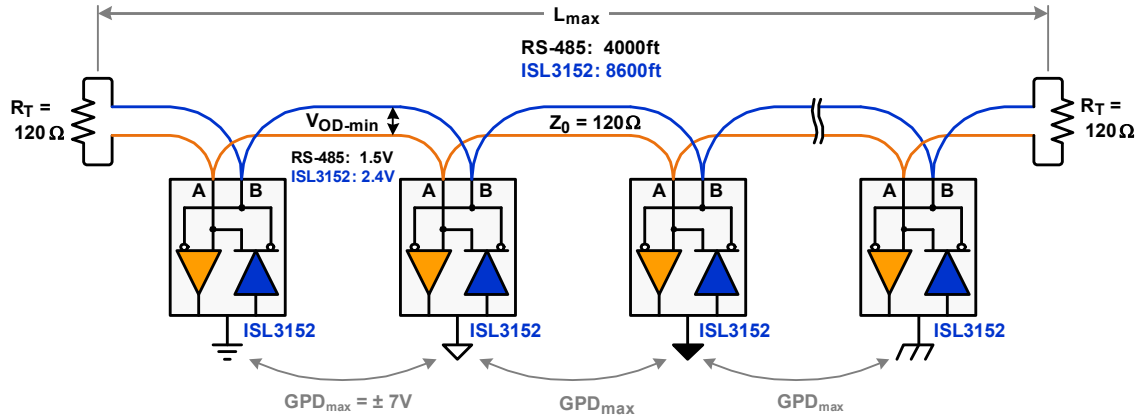


Figure 6. Typical RS-485 Network with Daisy-Chained Bus Nodes and Terminated Cable Ends

RS-485 supports networking of up to 32 unit loads using a multi-point bus topology. Bus nodes are daisy-chained (Figure 6) to one another through a twisted pair cable. The recommended characteristic cable impedance of 120Ω requires termination resistors at both cable ends, whose values should match the cable impedance.

As the receiver inputs are internally referenced to ground, a separate ground connection between drivers and receivers is not required. That is, as long as the receiver input voltages do not exceed the specified common-mode voltage range of -7V to +12V.

RS-485 supports cable lengths up to 4000ft (1200m) and data rates up to 10Mbps, but not both at the same time. The maximum applicable cable length for a given data rate follows a conservative cable-length-versus-data-rate characteristic, established over 30 years ago. (Figure 7).

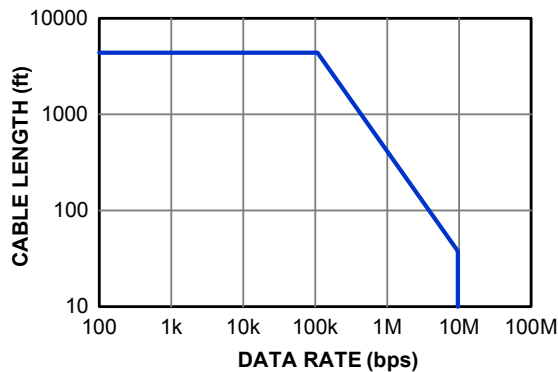


Figure 7. RS-485 Cable Length vs Data Rate Characteristic

Dual Protocol Transceivers

RS-485 supports a multi-point topology in which each bus node can either transmit or receive data. Two types of multipoint buses exist: a half-duplex and a full-duplex version (Figure 8). A half-duplex bus uses two wires across which one node may transmit while another node receives data. In a full-duplex bus, two signal pairs (four wires) are used. One pair connects the driver of a master node to the receivers of multiple slave nodes. The other pair connects the drivers of the slave nodes to the receiver of the master node. This topology allows the master to either broadcast data to all slaves or address a specific slave node, while simultaneously receiving data from the slave nodes, one slave at a time. A full-duplex both increases data throughput but is substantially more expensive than a half-duplex bus due to increased wiring effort.

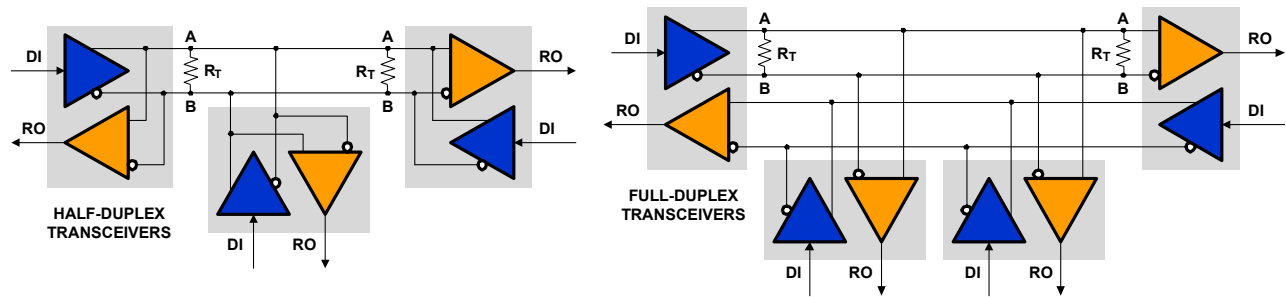


Figure 8. Half- and Full-Duplex Multi-Point Bus Topologies in RS-485

3. Short Summary

Though RS-232 is a simple and cost-effective solution, it is limited to low data rates, short distances, and point-to-point data links. In strong contrast to this, RS-485 allows for the design of multi-point networks with up to several hundreds of nodes connected to a single bus segment. It supports data rates of up to 100kbps at 4000ft (1200m) of cable length, and up to 50Mbps across short distances of up to 20m. Differential signaling through balanced transmission lines assures low emissions and high noise immunity.

4. Dual Protocol Transceivers

Modern transceiver designs are capable of supporting both the designs of new industrial PCs as well as the designs of RS-232 to RS-485/422 interface converters. The latter one is needed in existing RS-232 equipment, such as legacy PCs, instrumentation equipment, and industrial machinery, whose interfaces must either be connected to a single network, or be extended over long distances.

Figure 9 shows the block diagram of such a transceiver. The device incorporates two RS-232 transmit and receive channels and one full-duplex RS-485 transceiver. Notice the transceiver's flow-through pinout with bus pins on one side and logic pins on the other. This allows for easy routing of signal traces to the local controller and presents a great advantage over legacy transceivers (see Figures 3 through 5), whose pinouts required the crossing of signal traces from the bus to the controller side and vice versa.

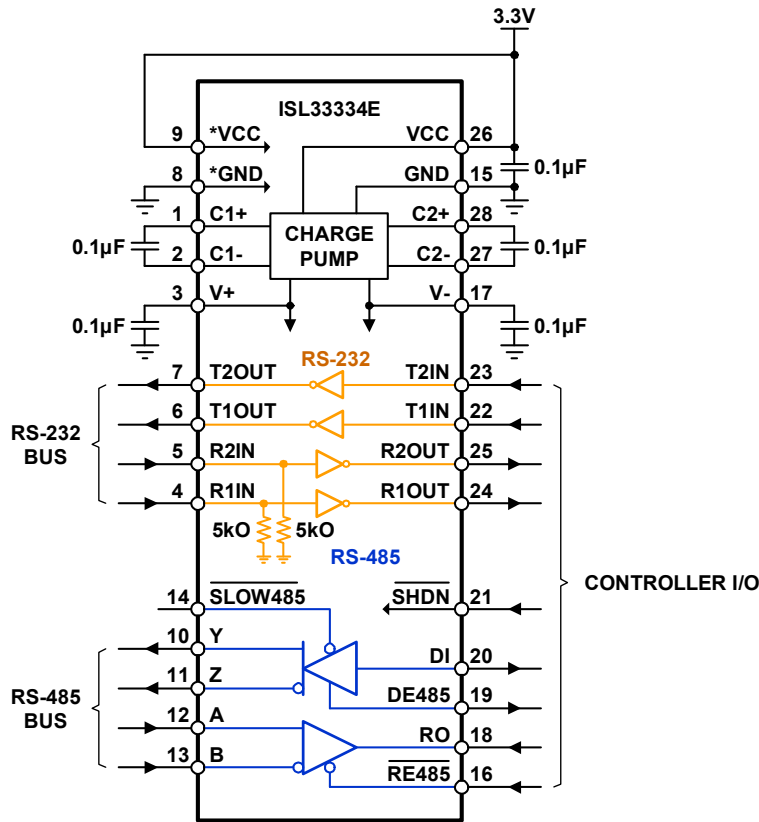


Figure 9. Dual Protocol Transceiver Incorporating One RS-485 and Two RS-232 Transceivers

When operating the bus systems independently, each RS-232 port can support data rates of up to 400kbps without exceeding the maximum slew rate of $30\text{V}/\mu\text{s}$, specified in the RS-232 standard.

The RS-485 section however, allows for the selection of a 20Mbps high-speed mode and a 115kbps slew-rate limited mode through the /SLOW485 pin. In High-Speed mode the driver output is not slew-rate limited. This mode should only be applied for short distance of 100ft (30m) maximum. High-Speed mode also requires the implementation of termination resistors at both cable ends, where the resistor values must match the characteristic cable impedance of either 120Ω for RS-485 cable or 100Ω for CAT-5 cable.

In addition to versatility and configurability, modern transceivers must be able to operate efficiently at low power supply. This is accomplished through an optimized charge pump design. The above charge pump creates the bipolar power supplies ($V+$, $V-$) for the RS-232 drivers by only requiring four small $0.1\mu\text{F}$ capacitors. Two capacitors are used for the actual charge pump action converting the initial 3.3V at V_{CC} into $+5\text{V}$ for $V+$ and -5.3V for $V-$. The other two capacitors are used for buffering $V+$ and $V-$ to ensure sufficient supply current for the RS-232 driver during switching action.

While total transceiver supply current is less than 4mA , further power savings can be achieved by driving the entire chip into a shut-down mode. This is accomplished by pulling the $\overline{\text{SHDN}}$ pin low. In Shutdown mode, the charge pump operation ceases, and the remaining supply current only consists of the leakage currents flowing into the logic inputs. Thus, total leakage current depends on the device configuration but can be as low as $40\mu\text{A}$.

When re-enabling the device by taking $\overline{\text{SHDN}}$ high, the charge pump takes up to $25\mu\text{s}$ to stabilize. During this time RS-232 communication is not possible. Because the charge pump does not supply the RS-485 transceiver, RS-485 communication can already start $2\mu\text{s}$ after $\overline{\text{SHDN}}$ is taken high. This timing is much faster than in legacy transceivers, which require the charge pump for all modes of operation.

5. Dual Protocol Applications

The integration of one RS-485 and two RS-232 transceivers into one IC makes the interface design of an industrial PC extremely versatile because the local controller can either drive the various bus systems independently, or act as an interface converter. Figure 10 shows such a design. When operated as an RS-232 to RS-485 converter, the RS-232 signals of either Channel 1 or Channel 2, or both can be converted into logic levels and then transmitted through the RS-485 bus. Using address coding, the controllers on both sides of the RS-485 link can distinguish (multiplex) between the two RS-232 channels.

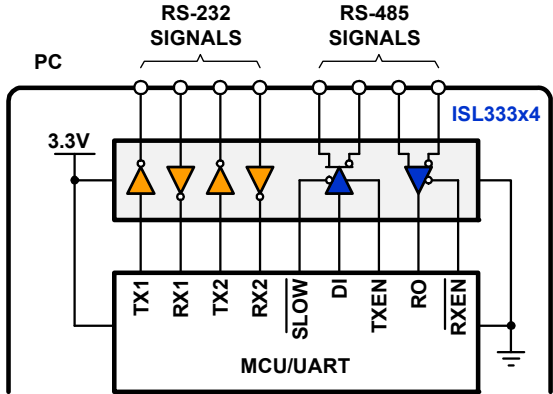


Figure 10. Networking Multiple RS-232 Equipment Using RS-232 to RS-485 Converters

To connect a legacy PC (here as master node), only equipped with RS-232 ports, with another remote located RS-232 equipment in a point-to-point link, the dual protocol transceiver is configured as a stand-alone RS-232 to RS-485 converter. Two converters are needed, one at each cable end. This ensures that the RS-232 signals from a data source are converted into RS-485 bus signal and back converted into RS-232 signals at the data sink. The configuration is simple as the enable inputs for driver and receiver can be fixed wired to their respective voltage rails to remain the transceiver constantly active (Figure 11).

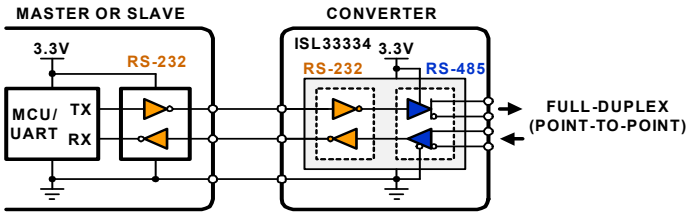


Figure 11. Networking Two RS-232 Nodes Through a Full-Duplex RS-485 Link

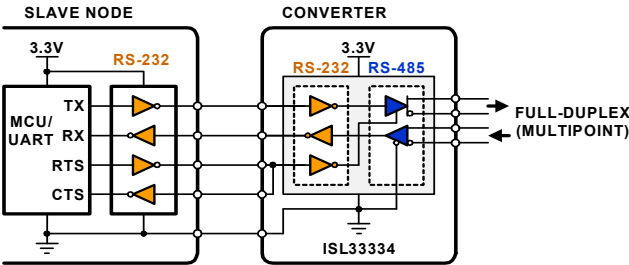


Figure 12. Networking Multiple RS-232 Nodes Through a Full-Duplex RS-485 Link

Networking multiple RS-232 equipment over a full-duplex RS-485 bus however, requires a minor configuration change for the converters in slave nodes. The driver and receiver in the master node (PC) can remain active all the time, so can the receivers in the slave nodes. The drivers in the slave nodes however, must be timely controlled to prevent two or more slaves from accessing the bus at the same time. For this purpose, the driver of the second RS-232 channel in a converter design is used to enable and disable the RS-485 driver with the RTS flow control signal (Figure 12). Note that within the converter the RTS must be looped back to the CTS input of the controller, which is known as null-modem configuration.

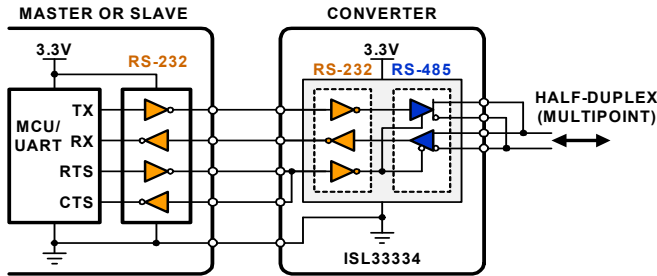


Figure 13. Networking Multiple RS-232 Nodes Through a Half-Duplex RS-485 Link Using RTS Flow-Control

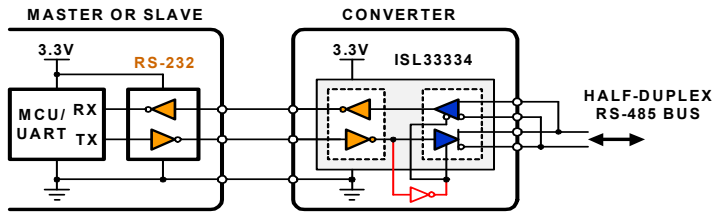


Figure 14. Networking RS-232 Nodes Through a Half-Duplex RS-485 Link Using Data Dependent Flow-Control

Networking multiple RS-232 equipment over a half-duplex, RS-485 bus requires the configuration shown in Figure 13. Here the RTS signal controls the enable functions of both driver and receiver. This configuration is required in all nodes, master and slaves, as a half-duplex bus can only transmit or receive data, but never both at the same time.

In some PCs, the RTS and CTS control signals can be up to 10ms out of sync with the data to be transmitted. In this case, it is best to make the enable signals data-driven. This is accomplished by implementing a Schmitt-trigger inverter between the Driver Input (DI) and the enable pins (DE485 and RE485). This puts the transceiver in transmit mode when DI = low, and in receive mode when DI = high, thus collapsing the bus voltage to 0V. Because the RS-485 receiver is a full-failsafe device, all dual protocol transceivers on the bus will indicate a zero bus voltage as a logic high at the receiver output, RO.

6. Conclusion

Modern dual protocol transceivers simplify the design of industrial interfaces due to their high grade of integration, support of RS-232 and RS-485 protocols, programmable data rates, and power-saving configuration features.

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