Application Report

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RS-422 and RS-485 Standards Overview and System Configurations

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ABSTRACT

ANSI TIA/EIA-422 and TIA/EIA-485 standards, commonly known as RS-422 and RS-485, respectively, specify balanced data-transmission schemes for transmitting data over long distances in noisy environments. These standards are compared, and their basic differences and similarities are discussed. Techniques for impedance matching to minimize line reflections in several applications are presented, with laboratory test results.

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1 Introduction

The RS-422 and RS-485 standards, as they are known today, are balanced data-transmission schemes that offer robust solutions for transmitting data over long distances and noisy environments. The official titles for these two standards are ANSI TIA/EIA-422 and TIA/EIA-485, respectively, and are revised periodically by the TR-30.2 DTE-DCE Interfaces and Protocols Subcommittee to the Telecommunications Industry Association (TIA) TR-30 Data Transmission Systems and Equipment Committee. For identification, RS-422 and RS-485 suffice.

This application report offers an overview of the RS-422 and RS-485 standards. While many specifications are described in the official ANSI documents, only the most prevalent are discussed in this application report. The purpose of this application report is to not duplicate the official documents, but to outline basic differences and similarities between the RS-422 and RS-485 standards. Major specifications are described in detail and the two standards are compared. Because impedance matching is an important aspect of differential data transmission in minimizing line reflections due to transmission-line effects, techniques for terminating different system applications are presented. Also, typical system configurations are taken into consideration for optimal application performance and cost constraints.

2 Overview of RS-422 and RS-485 Standards

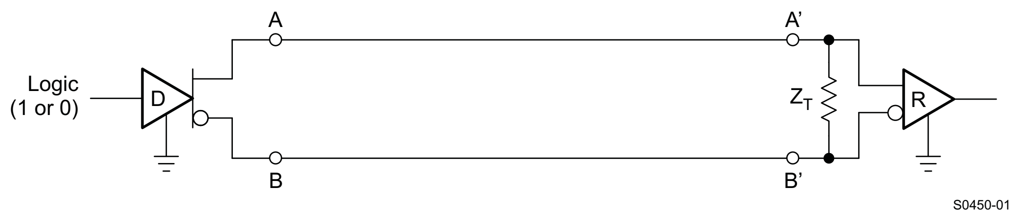
Officially, the RS-422 standard's title is *Electrical Characteristics of Balanced Voltage Digital Interface Circuits*, and is published by the ANSI Telecommunication Industry Association/Electronic Industries Association (TIA/EIA). In the industry, the term RS-422 is commonly used rather than the official name, and this document does the same. RS-422 is specified as a simplex multidrop standard, which means only one driver and up to ten receivers can be attached to a bus.

The RS-485 standard's title is *Electrical Characteristics of Generators and Receivers for Use in Balanced Digital Multipoint Systems*. RS-485 is commonly used, rather than its official title. If more than one driver is required, devices conforming to RS-485 are recommended. RS-485 specifications allow only one driver to send data at a time, and up to 32 unit loads (U.L.) can be placed on the bus. The U.L. concept is described in this application report in the Selected RS-485 Electrical Specifications section.

RS-422 and RS-485 initially might appear to be similar, but are distinct, and interchangeability is determined by the bus architecture. The RS-485 standard is written to be electrically compatible with RS-422. To illustrate their basic differences, a condensed description of each standard is presented in the following subsections.

2.1 Selected RS-422 Electrical Specifications

The balanced-voltage digital interface is shown in Figure 1. The driver (or generator) is labeled D, the receiver is labeled R, and the termination impedance is Z_T. The termination impedance should be equal to the characteristic impedance of the cable, Z_o, and is used only once at the end of the cable. Because matching termination impedance to Z_o often is difficult to achieve and is application dependent, typically, ±20% is sufficient. Also, up to nine additional receivers can be placed along the cable from points A and B to points A' and B', respectively. No restriction on maximum cable length is imposed by the RS-422 standard. Taking this into account, systems of up to 1 km are not uncommon, with signaling rates no higher than about 100 kbps. Speed and cable lengths work against each other. In other words, the longer the cable, the slower the signaling rate must be, while data can be transmitted faster on shorter cables. As a rule of thumb, the data signaling rate (in bps) multiplied by the cable length (in meters) should not exceed 10^8. For example, a system with a cable measuring 500 m should not transmit data at speeds greater than 200 kbps (10^8/500).



A D = driver (or generator)

B R = receiver

C Z_T = termination impedance

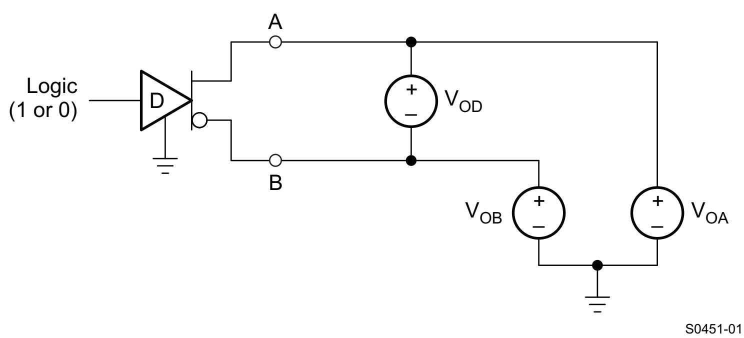
Figure 1. RS-422 Balanced-Voltage Digital-Interface Circuit

Although the input electrical characteristics of the RS-422-compliant receiver are identical to those of the RS-423-compliant receiver (ANSI TIA/EIA-423 standard), the RS-423 specifies an unbalanced signaling scheme, which is not within the scope of this application report.

Descriptions of selected specified parameters are presented in the following paragraphs.

2.1.1 Open-Circuit Output Voltage (V_{OD}, V_{OA}, and V_{OB} Measured)

The output voltage shall not exceed ±6 V under unloaded conditions, and the differential voltage [measured as the difference between an output voltage, V_{OA} (V_{OB}), and its complementary output voltage, V_{OB} (V_{OA})] is no greater than ±10 V. See Figure 2 for the test circuit.



A $|V_{OD}| \le 10$ V, $|V_{OA}| \le 6$ V, and $|V_{OB}| \le 6$ V

B V_{OA} = voltage on A output

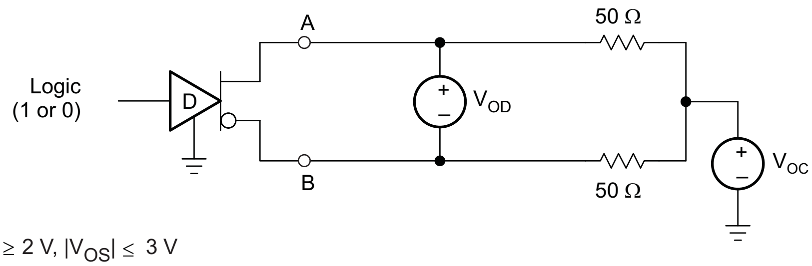
C V_{OB} = voltage on B output

D V_{OD} = differential output voltage

Figure 2. RS-422 Open-Circuit Test Circuit

2.1.2 Differential and Offset Output Voltage (V_{OD} and V_{OC} Measured)

To ensure proper drive strength, a minimum of ±2-V V_{OD} and a maximum of ±3-V V_{OS} are measured (see Figure 3). Furthermore, a check on driver output-voltage balance between the differential output voltages is put in place to measure the change in these voltages (not to exceed 400 mV). The maximum limit of 400 mV most often is approached during transients when driver outputs are switching states.

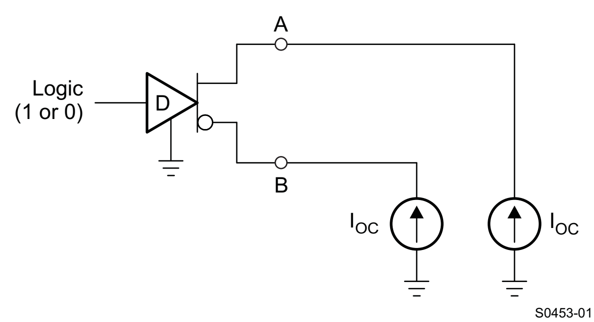


A. VOD| ≥ 2 V, $|V_{OS}| \leq$ 3 V
B. $|\Delta V_{OD}| = ||V_{OD}| - \overline{V_{OD}}|| \leq 0.4$ V
C. $|\Delta V_{OC}| = ||V_{OC}| - \overline{V_{OC}}|| \leq 0.4$ V

Figure 3. RS-422 Output-Voltage Test Circuit

2.1.3 Short-Circuit Output Current (I_{OS} Measured)

With the driver shorted to ground, the magnitude of the output current shall not exceed 150 mA, regardless of the state of the driver output (high or low) at the time of the short. This test ensures that the device is not destroyed by excessive current flowing through the output stage. Figure 4 shows the test circuit.

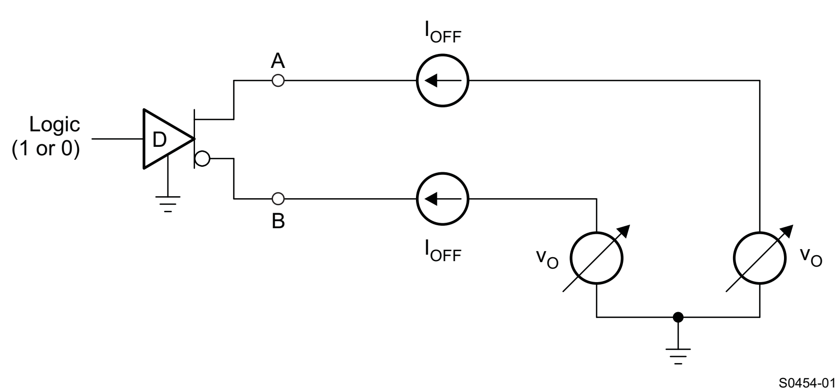


A $|I_{OC}|$ to ground ≤ 150 mA

Figure 4. RS-422 Short-Circuit Output-Current Test Circuit

2.1.4 Power-Off Measurement (I_{OFF} Measured; V_O Applied)

As shown in Figure 5, with the driver powered down, the magnitude of the output leakage current shall not exceed 100 µA for output voltages ranging from –0.25 V to 6 V. Currents higher than 100 µA can disrupt the bus potential and lead to erroneous data at the receiver.

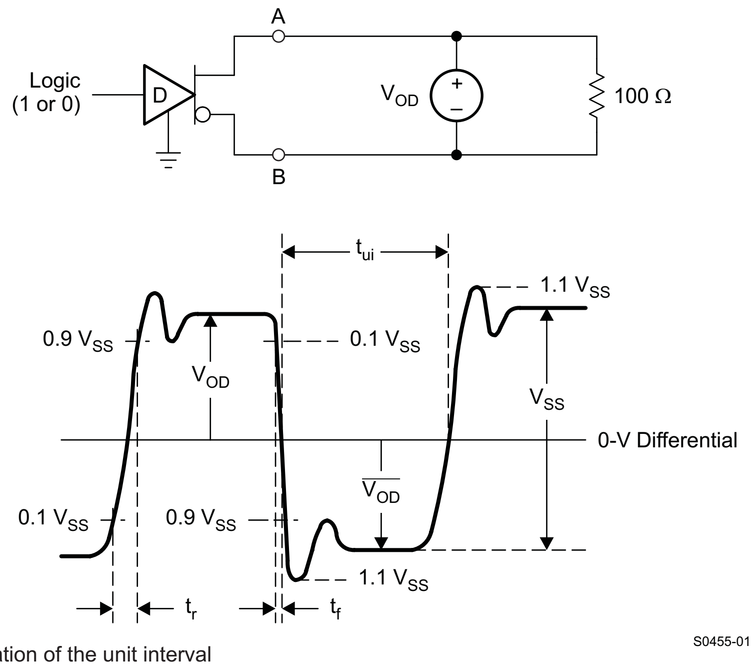


A $|I_{off}|$ ≤ 100 µA for –0.25 ≤ VO ≤ 6 V

Figure 5. RS-422 Power-Off Output-Current Test Circuit

2.1.5 Output-Signal Waveform (V_{OD} Measured)

Basically, this test ensures good signal quality on the bus. With a 100-Ω resistor across the differential output, the voltage monotonically changes between 10% and 90% of V_{SS} within a tenth of the unit interval, t_{ui}, or 20 ns, whichever is greater. Figure 6 shows the test circuit and resultant waveform. In addition, the resultant voltage shall not change more than 10% of V_{SS} after a transition has occurred (limits overshoots and undershoots).



A. t_{ui} = time duration of the unit interval

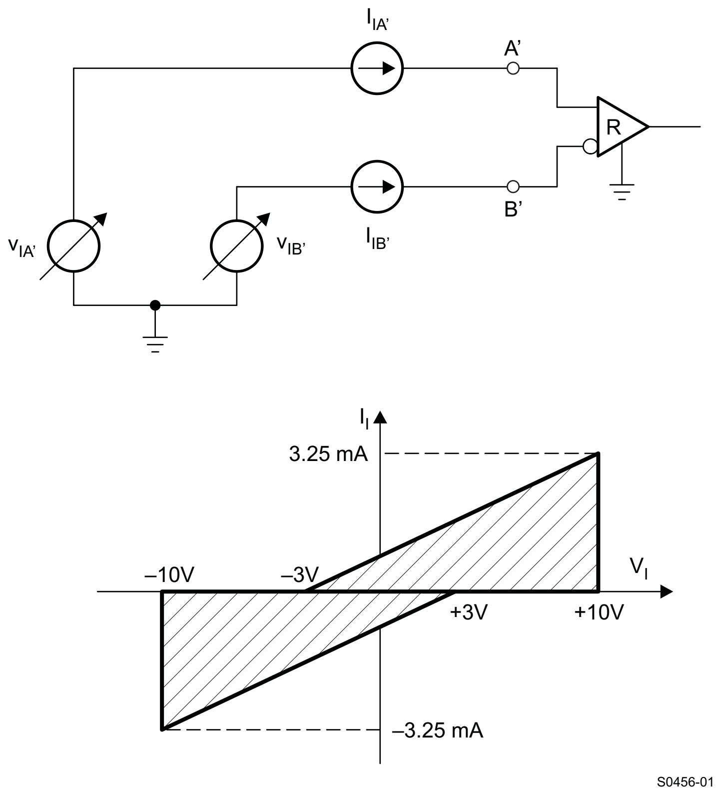
B. $V_{SS} = |V_{OD} - \overline{V_{OD}}|$

C. $2\ V \leq |V_{OD}| \leq 10\ V$

Figure 6. RS-422 Test Circuit and Output-Signal Waveform

2.1.6 Input I/V Characteristics (V_{IA}, and VI_B, Applied; I_{IA}, and I_{IB}, Measured)

A maximum limit on the input characteristic must be placed on the receiver to ensure a maximum load on the bus when all ten receivers are placed on it. With the common-mode voltage V_{IA}, (V_{IB}) ranging from +10 V to –10 V while V_{IB}, (V_{IA},) is held to 0 V, the resultant input current should remain within the shaded region (see Figure 7) in both the power-on and power-off conditions. A device with input characteristics within the shaded region reveals that the input impedance is no smaller than 4 kΩ, as defined by the calculation. The inverse of the slope of the upper and lower bounds is exactly the minimum input impedance allowed for the input.

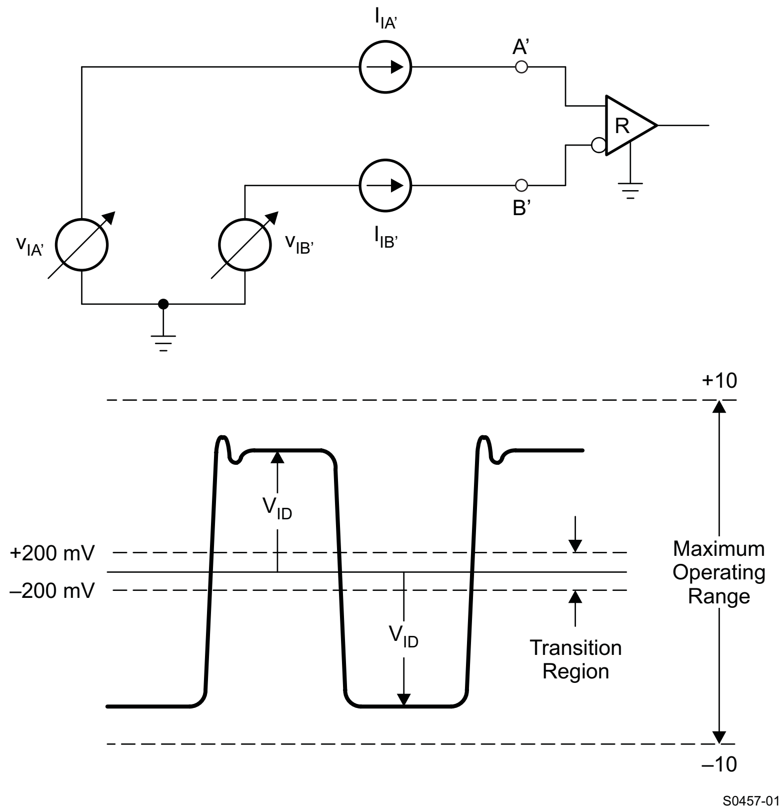


A R = ΔV/ΔI = 13 V/3.25 mA = 4 kΩ

Figure 7. RS-422 Input Receiver Test Circuit and I/V Plot

2.1.7 Input Sensitivity (V_{CM}, V_{IA}, and V_{IB}, Applied; V_{ID} Measured)

Figure 8 shows the test circuit used to determine a receiver's input sensitivity. To ensure functionality over the full common-mode range, suggested test voltages for both inputs and the purpose of the measurements are given in Table 1.



A 200 mV < $|V_{ID}|$ < 10 V

Figure 8. RS-422 Input-Sensitivity Test Circuit and Resultant Waveform

For a common-mode voltage varying from –7 V to 7 V, V_{ID} need not be greater than ±200 mV to correctly assume the intended state. As specified in the standard, the magnitude of the differential input voltage, V_{ID}, varying from 200 mV to 10 V, is required to maintain correct operation over this range.

Table 1. Input Sensitivity and Resultant Voltages of 422-Compliant Devices

APPLIED VOLTAGE		RESULTING V_{ID} (1)	RESULTING V_{CM} (2)	RECEIVER OUTPUT STATE	PURPOSE OF MEASUREMENTS
$V_{IA'}$ (3)	$V_{IB'}$ (3)				
+10 V	–2 V	+12 V	+4 V	Q	Ensures correct operation with maximum differential voltage supply
–10 V	+2 V	–12 V	–4 V	$\overline{Q}$	
+10 V	+4 V	+6 V	+7 V	Q	Ensures correct operation with maximum common mode voltage supply
–10 V	–4 V	–6 V	–7 V	$\overline{Q}$	
+100 mV	–100 mV	+200 mV	0 V	Q	200 mV threshold test across common mode voltage supply
–100 mV	+100 mV	–200 mV	0 V	$\overline{Q}$	
+7.1 V	+6.9 V	+200 V	+7 V	Q	
–7.1 V	–6.9 V	–200 V	–7 V	$\overline{Q}$	

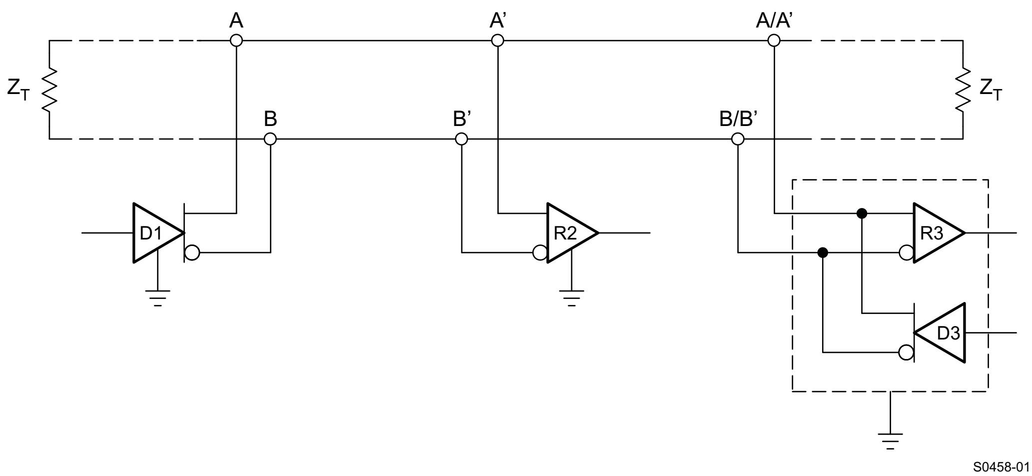
(1) $|V_{ID}|$ < 12 V (maximum input differential voltage without damaging device)
(2) V_{CM} is measured as the arithmetic average of $V_{IA'}$ and $V_{IB'}$, or $(V_{IA'} + V_{IB'})/2$.
(3) $|V_{IA'}|$ < 10 V, $|V_{IB'}|$ < 10 V (maximum input voltages to ensure correct operation)

2.1.8 Cable Termination

Cable termination is required, unless the data rate of the application is less than 200 kbps or the signal rise/fall time at the load end of the cable is greater than four times the one-way cable delay. The latter rule-of-thumb typically is used to describe a system that does not behave like a transmission line. In most other applications, cable termination is recommended. Cable termination for a RS-422-compliant system always is placed at the load end of the cable. Two options for cable termination are recommended in the standard. The first option is to match the termination resistance to the characteristic impedance of the cable, Z_o, while the second option is to place an additional capacitor in series with the termination resistance for designers that are concerned with power dissipation. These two options are discussed in detail in the *Suggested Termination and Grounding Techniques* section.

2.2 Selected RS-485 Electrical Specifications

By comparing Figure 1 and Figure 9, it is evident that RS-422 and RS-485 system topologies are different. The RS-485 can operate in balanced digital multipoint systems, whereas the RS-422 can support only one driver per bus line (multidrop). Parameter values specified in 485 are similar to those specified in RS-422. Furthermore, RS-485-compliant receiver and driver electrical characteristics are specified such that they cover requirements of RS-422. This allows RS-485-compliant drivers and receivers to be used in most RS-422-compliant applications.



A D1 = driver

B D3/R3 = transceiver

C R2 = receiver

D Z_T = termination impedance

E Up to 32 U.L.s [receiver, driver (off state), transceiver]

Figure 9. RS-485 Balanced-Voltage Digital-Interface Circuit

Although RS-485 specifies that only one driver can talk at any given time (half-duplex operation), fault conditions might occur (caused by inadvertent shorts on output drivers or line contention). Therefore, RS-485-compliant devices must provide for this. For example, consider the case when driver D1 in Figure 9 is intended to send a signal to receiver R2, but driver D3 still is enabled. If the designer did not disable driver D3 before initiating the transmission, a fault condition occurs and erroneous data might be transmitted to receiver R2. This condition also is known as line contention (see *Summary Comparison of the Standards* section).

The maximum recommended cable length is about 1200 m. Usually, the amount of noise a designer is willing to tolerate is the deciding factor in choosing the cable length. The same relationship of speed versus cable length applies to RS-485-compliant systems, as well as to RS-422-compliant systems.

2.2.1 U.L. Concept (V_{IA} and V_{IB} Applied; I_{IA} and I_{IB} Measured)

As with the RS-422, a maximum limit on the I/V characteristic must be placed on the receiver, driver (off state), and transceiver to ensure a maximum load on the bus when all 32 U.L.s are used. With the voltage V_{IA} (V_{IB}) ranging from –7 V to 12 V, while V_{IB} (V_{IA}) is grounded, the resulting input current IIA (IIB) should remain within the shaded region in both power-on and power-off conditions (see Figure 10). A device with input characteristics that fall within the shaded region conforms to having a 1-U.L. characteristic. The

RS-485 standard specifies the capability to sustain up to 32 U.L.s. The RS-485 often is thought of as a 12-kΩ load standard. Because the output current of the driver is dependent on loading, a design that requires a large number of stations (drivers, receivers, or transceivers) attached to the bus needs a larger load resistance to allow more connections. For example, a 0.5-U.L. transceiver can be placed up to 64 times on a bus, because this configuration complies with the maximum 32-U.L. specification.

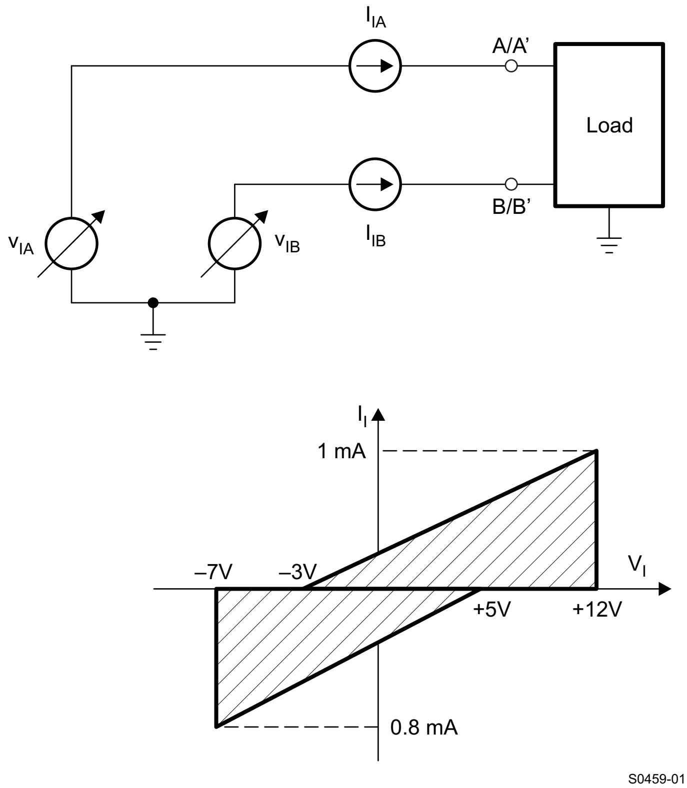
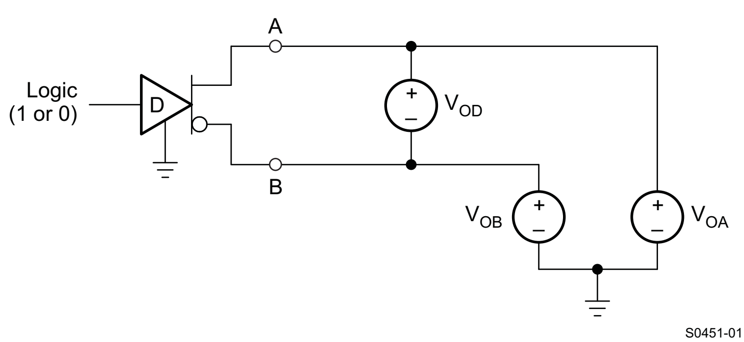


Figure 10. RS-485 U.L. Test Circuit and I/V Relationship

2.2.2 Open-Circuit Output Voltage (V_{OD}, V_{OA}, and V_{OB} Measured)

The output voltage shall not exceed ±6 V under unloaded conditions, and the differential voltage generated will be no smaller than ±1.5 V and no greater than ±6 V. Figure 11 shows the test circuit used.



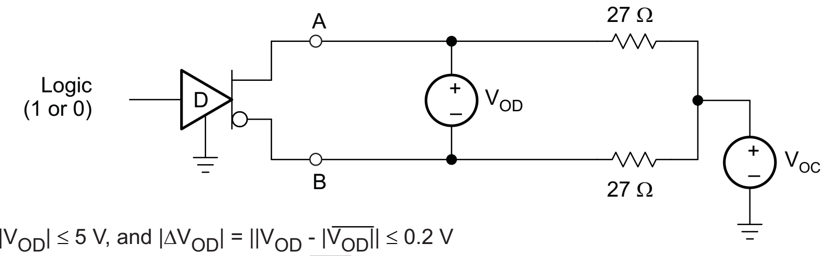
A $1.5\ V \le |V_{OD}| \le 6\ V$

B $|V_{OA}| \le 6\ V$; $|V_{OB}| \le 6\ V$

Figure 11. RS-485 Open-Circuit Test Circuit

2.2.3 Differential and Offset Output Voltage (V_{OD} and V_{OC} Measured)

Similar to the RS-422, RS-485 also specifies a minimum output voltage to ensure proper drive strength, but also places a maximum limit. Figure 12 shows the limitations that have been placed on the differential and offset voltages. It also shows the magnitude in the change in these voltages shall not exceed 200 mV.

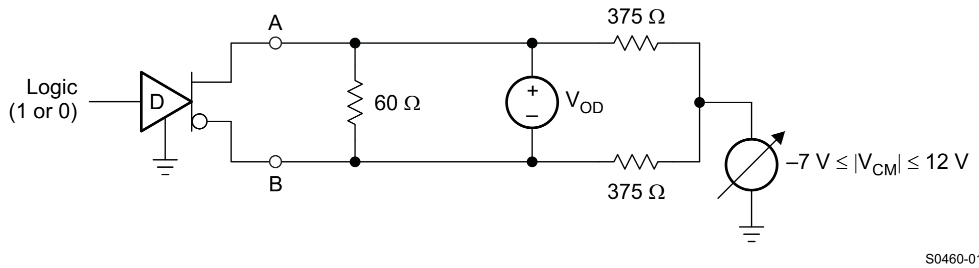


A. $1.5\ V \le |V_{OD}| \le 5\ V$, and $|\Delta V_{OD}| = ||V_{OD} - |\overline{V_{OD}}|| \le 0.2\ V$
B. $-1\ V \le |V_{OC}| \le 3\ V$, and $|\Delta V_{OC}| = ||V_{OC} - |\overline{V_{OC}}|| \le 0.2\ V$

Figure 12. RS-485 Output-Voltage Test Circuit

2.2.4 Differential Output Voltage With Common-Mode Loading (V_{OD} Measured; V_{CM} Applied)

With the test circuit shown in Figure 13, the magnitude of the differential output voltage falls within 1.5 V and 5 V.



A $1.5\ V \le |V_{OD}| \le 5\ V$

Figure 13. RS-485 Output-Voltage Test Circuit With Common-Mode Loading

2.2.5 Short-Circuit Output Current (I_{OS} Measured; V_O Applied)

With the driver shorted to a voltage source that is varied from –7 V to 12 V, current shall not exceed 250 mA, and the driver shall not be damaged (see Figure 14). Texas Instruments incorporates into all its RS-485-compliant devices a circuit that meets this requirement.

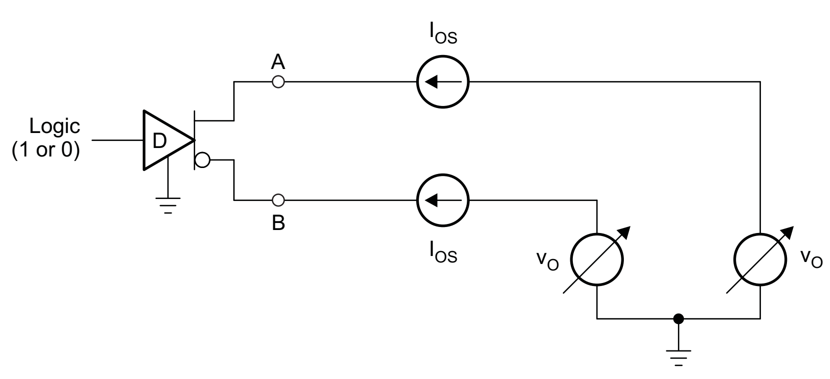


Figure 14. RS-485 Short-Circuit Output-Current Test Circuit

Although the internal circuitry limits the amount of current flowing from the output driver, complying with the full range from –7 V to 12 V for an indefinite time is a very stringent test. For customers seeking devices with various levels of robustness, TI offers products that comply fully (indeterminate time period and full voltage range) and partially with this specification. Partially compliant devices may limit the current over the full range, but cannot sustain the current over a long period of time. Another example of partial compliance is the capability to keep the current within specification for long periods, but at a smaller voltage range.

2.2.6 Output-Signal Waveform (V_{OD} Measured)

To ensure signal quality, RS-485 also places a constraint on the output-signal waveform. The output-signal waveform is identical to the one described for the RS-422, but a different test circuit is necessary (see Figure 15). The output voltage should change monotonically between 0.1 V_{SS} and 0.9 V_{SS} within 0.3 t_{ui}. Thereafter, the output voltage shall not change more than 10% of V_{SS}, and |VOD| ≤ 5 V.

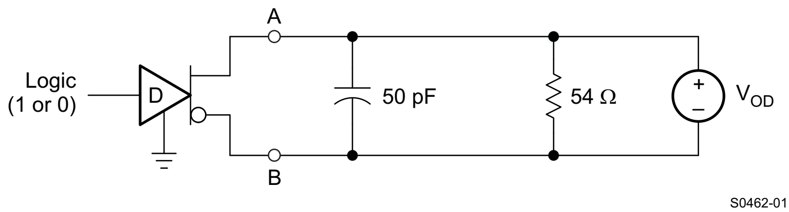


Figure 15. RS-485 Output-Signal Test Circuit

2.2.7 Input Sensitivity (V_{CM}, VI_A, and V_{IB}, Applied; V_{ID} Measured)

Using the same test circuit as in RS-422, Table 2 shows the operating voltage extremes of the receiver and the purpose of each measurement.

Table 2. Input Sensitivity and Resultant Voltages of 485-Compliant Devices

APPLIED VOLTAGE		RESULTING V_{ID}	RESULTING V_{CM}	RECEIVER OUTPUT STATE	PURPOSE OF MEASUREMENTS
$V_{IA'}$	$V_{IB'}$				
–7 V	–6.8 V	–200 V	–6.9 V	$\overline{Q}$	Minimum V_I at extreme – VCM
+12 V	+11.8 V	+200 V	+11.9 V	Q	Minimum V_I at extreme + VCM
–7 V	–2 V	–5 V	–4.5 V	$\overline{Q}$	Maximum V_I at extreme – VCM
+12 V	+7 V	+5 V	+9.5 V	Q	Maximum V_I at extreme + VCM

3 Failsafe Operation

The feature of receiver failsafe is a benefit in many RS-422 and RS-485 applications; however, its usefulness needs to be considered and understood at an application level.

3.1 The Need for Failsafe Protection

In any party-line interface system with multiple driver/receivers, long periods of time may occur when all the driving devices are inactive. This state is known as line idle or bus idle and occurs when all drivers place their outputs into a high-impedance state. During bus idle, the differential bus voltage is left floating (i.e., indeterminate: neither logic-high nor logic-low state) if there is no termination resistors, and the differential bus voltage is close to zero in the case where termination resistors are used. In both cases, as a result, the receiver can be falsely triggered into either a logic-high or logic-low state, depending on the presence of noise and the last polarity of the floating lines. Obviously, this is undesirable, as the circuitry following the receiver could interpret this as valid information. It is best to detect such a situation and place the receiver outputs into a known and predetermined state. The name given to methods that ensure this condition is receiver failsafe. An additional, desirable feature that a failsafe provides is to protect the receiver from shorted line conditions, which can again cause erroneous processing of data.

3.2 Internal Failsafe

TI and other manufacturers have devices with failsafe design by including some form of open-circuit, short-circuit, and idle-bus failsafe circuitry within the integrated circuits, which simplify the system design. Further discussion of internal failsafe is found in references SLYT080 and SLYT064.

3.3 External Failsafe

External failsafe uses external circuitry together with termination to provide a defined voltage across the receiver's input, regardless of whether the signal pair is shorted together or is left open circuited. It is recommended to use when there is no internal failsafe circuit, or to reinforce the effect of internal failsafe circuits in applications where extremely high levels of noise are possible. Further discussion of internal failsafe is found in reference SLYT324.

4 Suggested Termination and Grounding Techniques

When designing a system that uses drivers, receivers, and transceivers that comply with RS-422 or RS-485, proper cable termination is essential for highly reliable applications with reduced reflections in the transmission line. Because RS-422 allows only one driver on the bus, if termination is used, it is placed only at the end of the cable near the last receiver. In general, RS-485 requires termination at both ends of the cable.

Factors to consider when determining the type of termination usually are performance requirements of the application and the ever-present factor, cost. The different types of termination techniques discussed are unterminated lines, parallel termination, ac termination, and multipoint termination. Laboratory waveforms for each termination technique (except multipoint termination) illustrate the usefulness and robustness of RS-422 (and, indirectly, RS-485). Similar results can be obtained if 485-compliant devices and termination techniques are used. For laboratory experiments, 100 feet of 100-Ω, 24-AWG, twisted-pair cable (Bertek) was used. A single driver and receiver, TI AM26C31C and AM26C32C, respectively, were tested at room temperature with a 5-V supply voltage. Two plots per termination technique are shown. In each plot, the top waveform is the driver input and the bottom waveform is the receiver output. To show voltage waveforms related to transmission-line reflections, the first plot shows output waveforms from the driver at the start of the cable; the second plot shows input waveforms to the receiver at the far end of the cable.

Resistor and capacitor (if used) termination values are shown for each laboratory experiment, but vary from system to system. For example, the termination resistor, ZT, must be within 20% of the characteristic impedance, Z_o, of the cable and can vary from about 90 Ω to 120 Ω.

4.1 No Termination

Figure 16 shows a configuration with no termination. Figure 17 and Figure 18 show that, although reflections are present at the receiver inputs at a data signaling rate of 200 kbps with no termination, the RS-422-compliant receiver reads only the input differential voltage and produces a clean signal at the output.

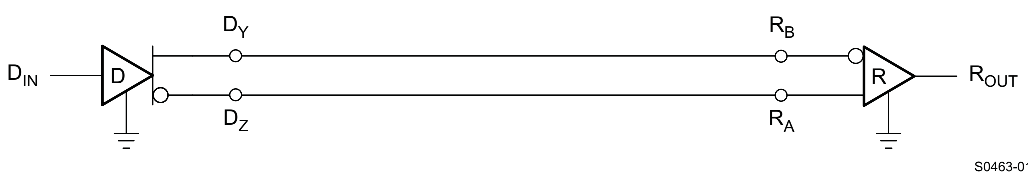


Figure 16. Differential Unterminated Configuration

- Advantages
  - Driver is only required to source a minimal amount of current to produce a signal at the receiver.
  - Minimizes the driver's on-chip power dissipation
  - Ensures that the receiver's output is in a known state if the receiver internally features open-line fail safe
- Disadvantage
  - Signal reflections due to mismatched line impedance at high data signaling rates (should be used

only in applications with data rates ≤200 kbps and short distances) (If $t_r > 4t_{delay}$, the cable is not considered a transmission line.)

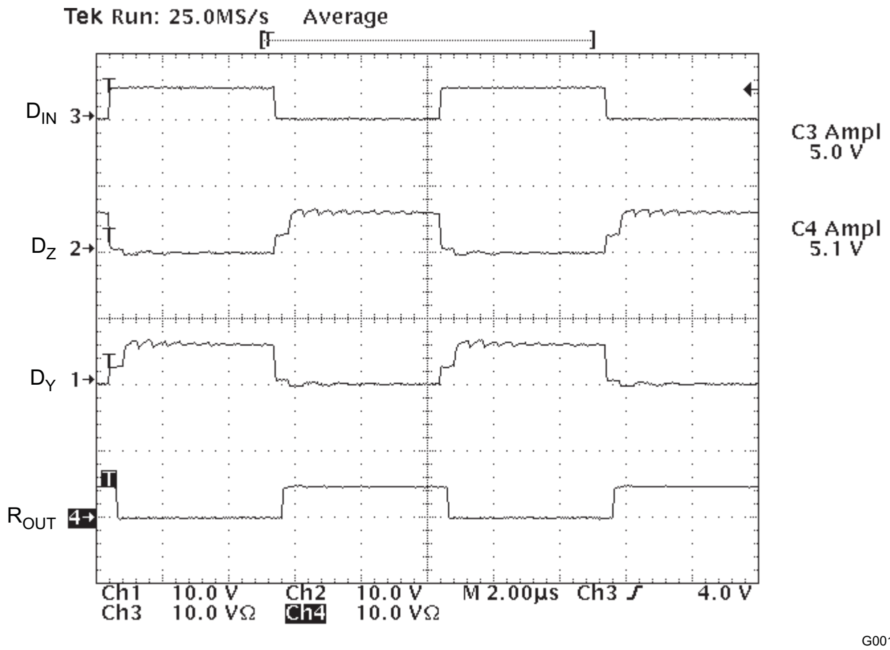


Figure 17. Differential Unterminated-Driver Output Waveforms

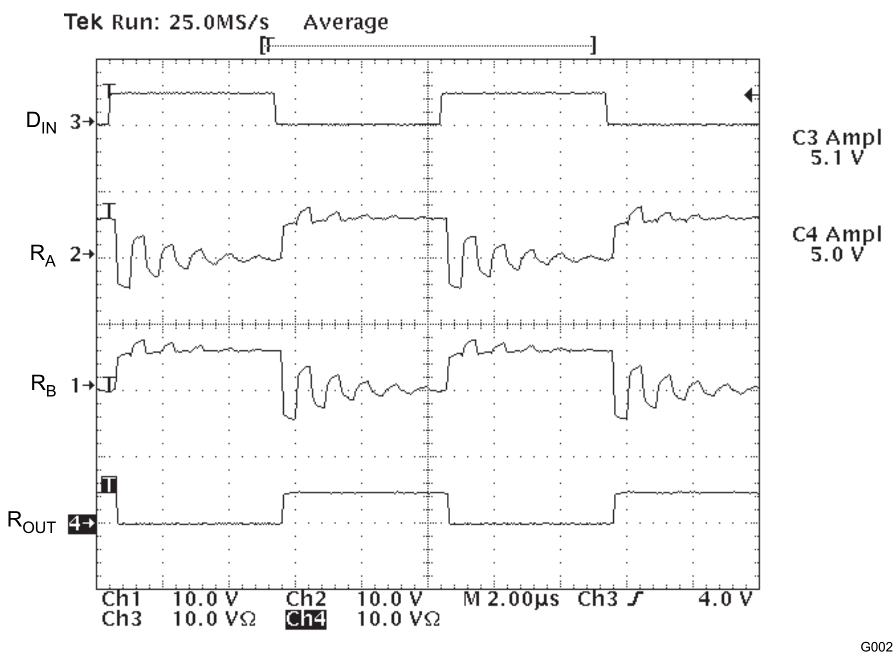
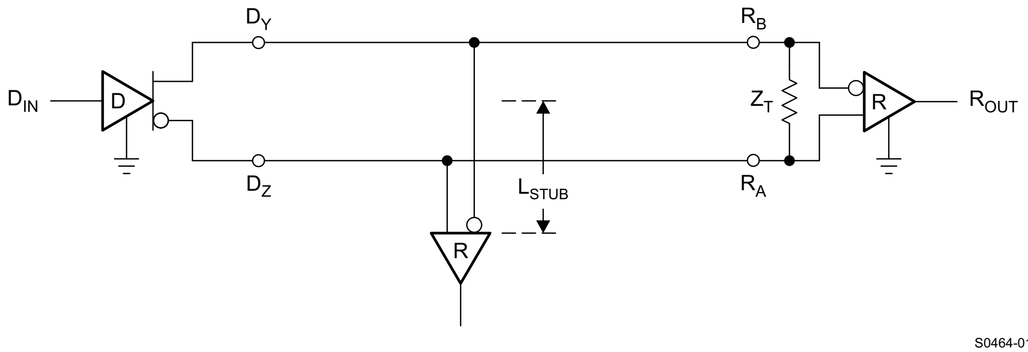


Figure 18. Differential Unterminated-Receiver Input Waveforms

4.2 Parallel Termination

Figure 19 shows a typical configuration using an impedance termination across the differential inputs at the far-end receiver. As shown in Figure 20 and Figure 21, parallel termination ensures that there are no impedance mismatches and eliminates reflections. A termination resistance of 100 Ω was applied, and only one receiver was used in this experiment, while transmitting at a data signaling rate of 1 Mbps.



A $Z_T = Z_o$

Figure 19. Differential Parallel-Terminated Configuration

- Advantages
  - Elimination of reflections: higher data rates and longer cables
  - Multidrop applications are also supported.
- Disadvantages
  - Long stub lengths (L_{STUB}) reintroduce reflections.
  - Increase in driver's power dissipation (when compared to the unterminated case)
  - Receiver's differential input is zero when all drivers are idle.

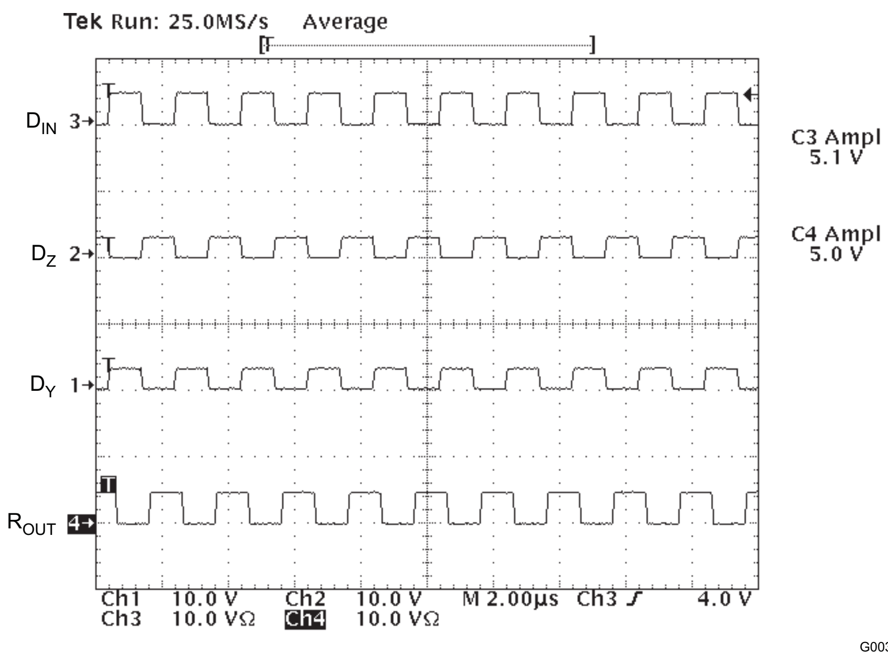


Figure 20. Differential Parallel-Terminated Driver Output Waveforms

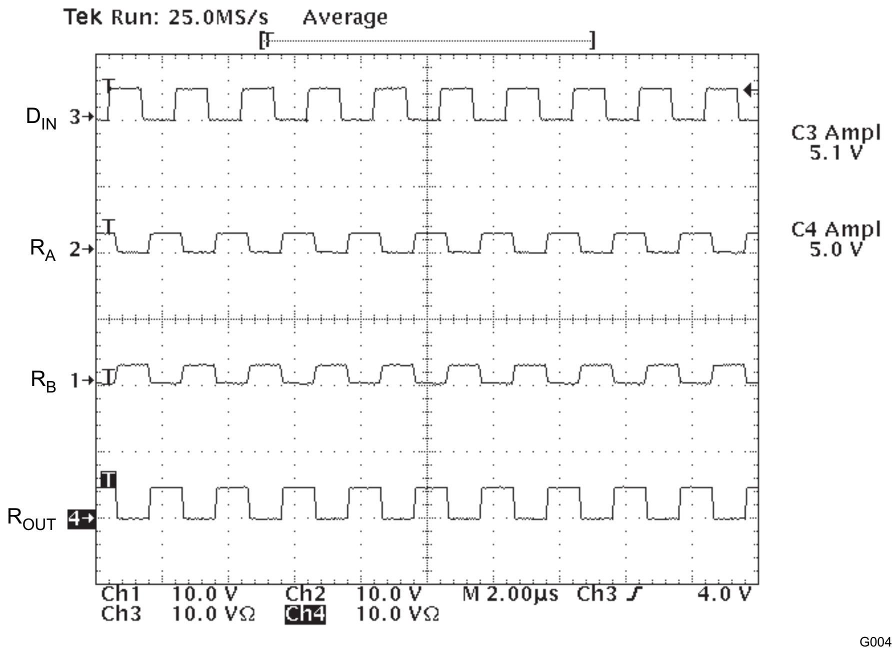


Figure 21. Differential Parallel-Terminated Receiver Input Waveforms

4.3 AC Termination

Because the differential outputs are complementary when the driver is activated, one output is in the high state, while the other is in the low state. Current flows from the high-state output to the low-state output through the termination resistor, as in the parallel configuration. A capacitor and resistor are used for ac termination to eliminate the dc current path from one differential output to the other. Figure 22 shows the connectivity. However, this added RC time-constant delay significantly reduces transmission speeds. Figure 23 and Figure 24 illustrate acceptable receiver input and output waveforms using an ac termination of Z_T = 100 Ω and a 1000-pF capacitor. The data rate was limited to 200 kbps in laboratory measurements. If a RS-485-system with multiple drivers is used, place another Z_T and C_T across the balanced line at the other end of the cable.

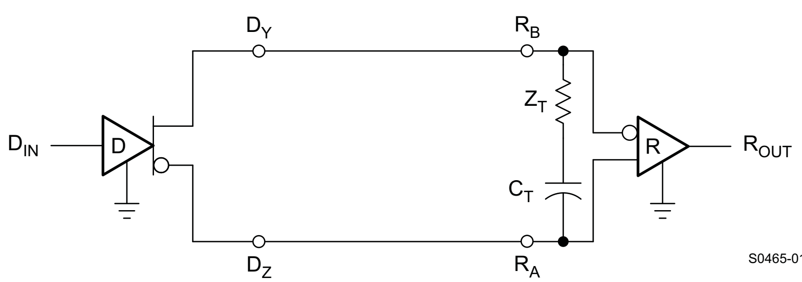


Figure 22. Differential AC-Terminated Configuration

- Advantages
  - Driver power dissipation is decreased compared to parallel termination, but not as much as in the unterminated case.
  - Line reflections are reduced.
  - Ensures that the receiver's output goes to a known state if the receiver internally features open-line fail-safe
- Disadvantage
  - Limitation on maximum data signaling rate and cable distance due to RC time constant (typically used on low-speed control lines)

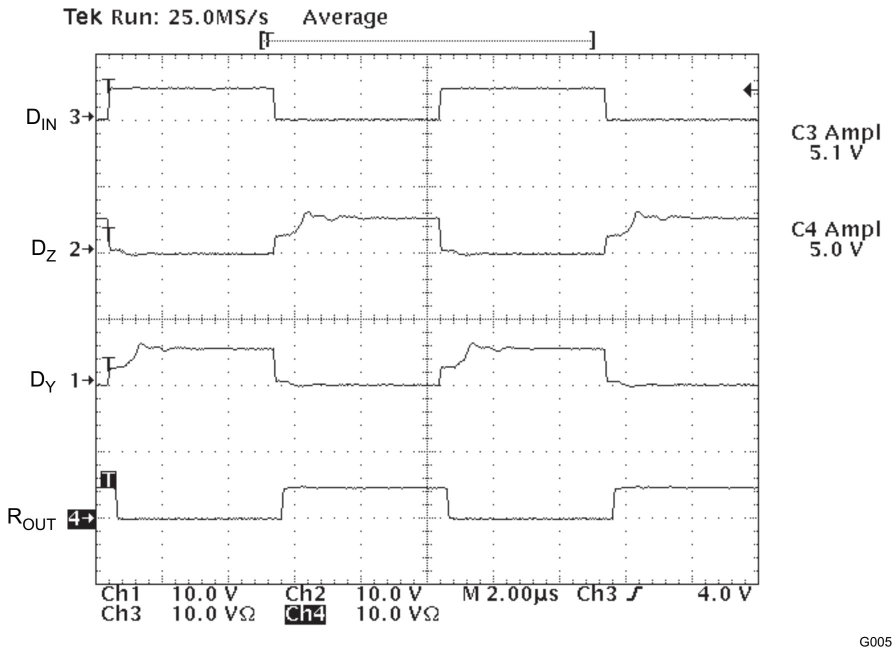


Figure 23. Differential AC-Terminated Driver Output Waveforms

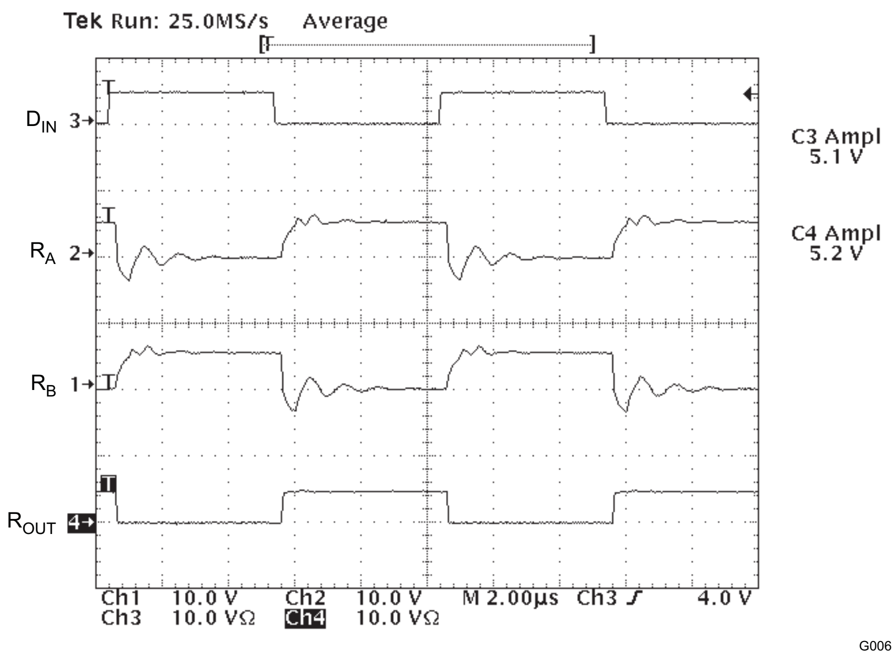
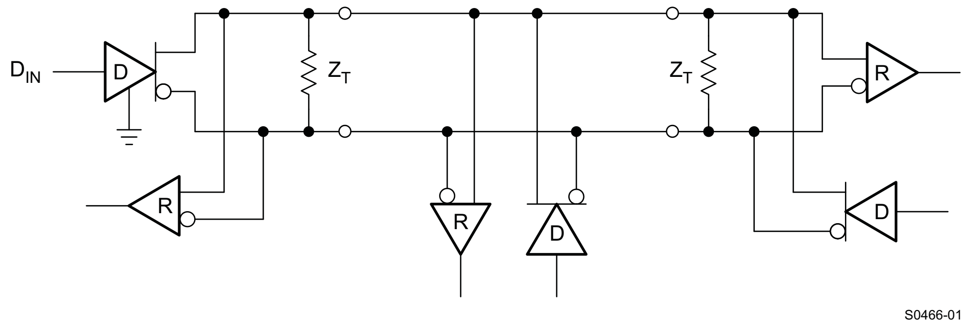


Figure 24. Differential AC-Terminated Receiver Input Waveforms

4.4 Multipoint Termination

Multipoint configurations are supported by RS-485, but not RS-422. Figure 25 shows a typical RS-485-compliant configuration, with a transceiver at both ends of the cable and drivers/receivers placed along the length of the cable. RS-485 requires termination at both ends of the cable (see Figure 25). No waveforms are provided for this configuration, but performance similar to that of the parallel-termination case can be expected.



A $Z_T = Z_o$

Figure 25. Differential Multipoint-Terminated Configuration

- Advantages
  - Same as parallel termination
  - Optimum signal quality
- Disadvantage
  - Same as parallel termination, but two termination resistors are required, one at each end of the cable, which adds more loading to the drivers.

Table 3. Summary of Termination Techniques

TECHNIQUE	POWER DISSIPATION	OPEN-LINE FAIL-SAFE	SHORTED-LINE FAIL-SAFE	SPEED	SIGNAL INTEGRITY
No termination	Low	Supported if available on receiver	Supported if available on receiver	Low	Good at low signaling rates, Poor at high speeds
Parallel termination	Medium	Supported if available on receiver	Supported if available on receiver	High	Excellent
AC termination	Low	Supported if available on receiver	Supported if available on receiver	Medium	Good
Multipoint termination	Medium	Supported if available on receiver	Supported if available on receiver	High	Excellent

4.5 Ground Connections

Commonly RS-422 and RS-485 system configurations are presented without a separate ground wire. Laws of physics, however, still require a solid ground connection to ensure error-free communication between drivers and receivers.

4.5.1 Local Ground and Protective Earth Is Not Connected

If all the power supplies for all the transceivers and related processing circuitry are isolated and have disconnected local ground and PE (Protective Earth), no ground loop exists. Local ground of each transceiver can be connected directly (Figure 26).

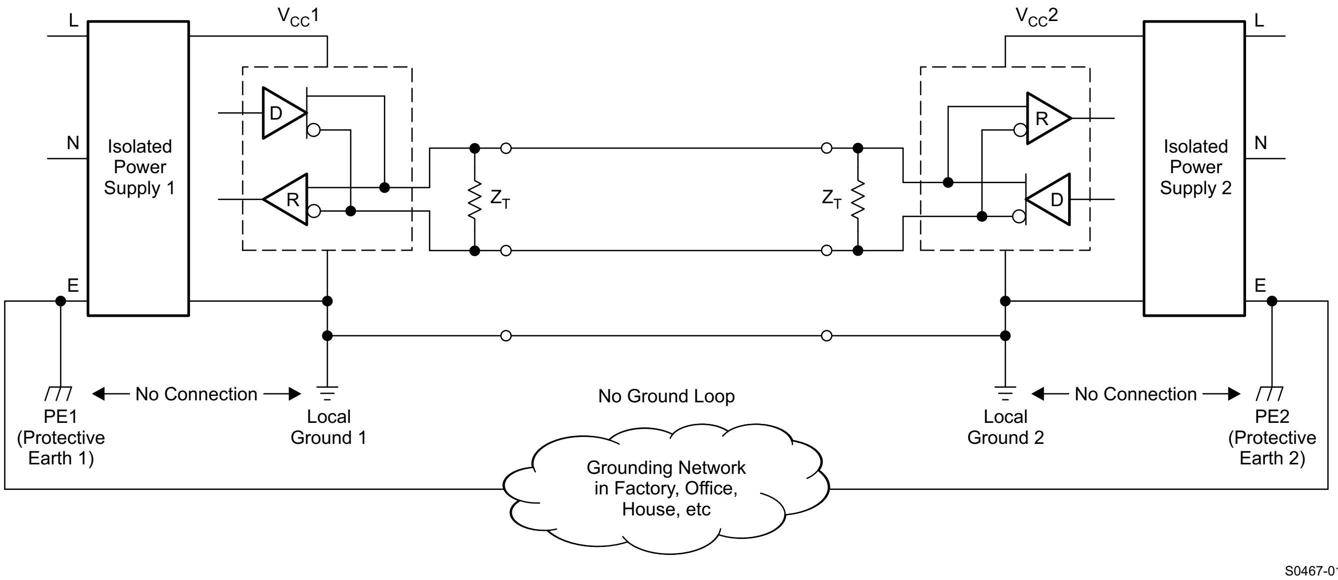


Figure 26. Grounding Configuration with Isolated Local Ground and PE

4.5.2 Local Ground and Protective Earth Is Connected

In many cases, local ground and PE are connected by wire, chassis, or leakage for many reasons, such as lowest cost or simplest power supply design. Thus, if a high-voltage potential difference exists between remote grounds, especially during transients, then current flows through the remote ground because a ground loop does exist. If the ground loop has no resistance , then the ground current is large and creates some problems. For this reason, the RS-485 standard recommends adding some resistance between logic and chassis ground to avoid excess ground-loop currents (Figure 27).

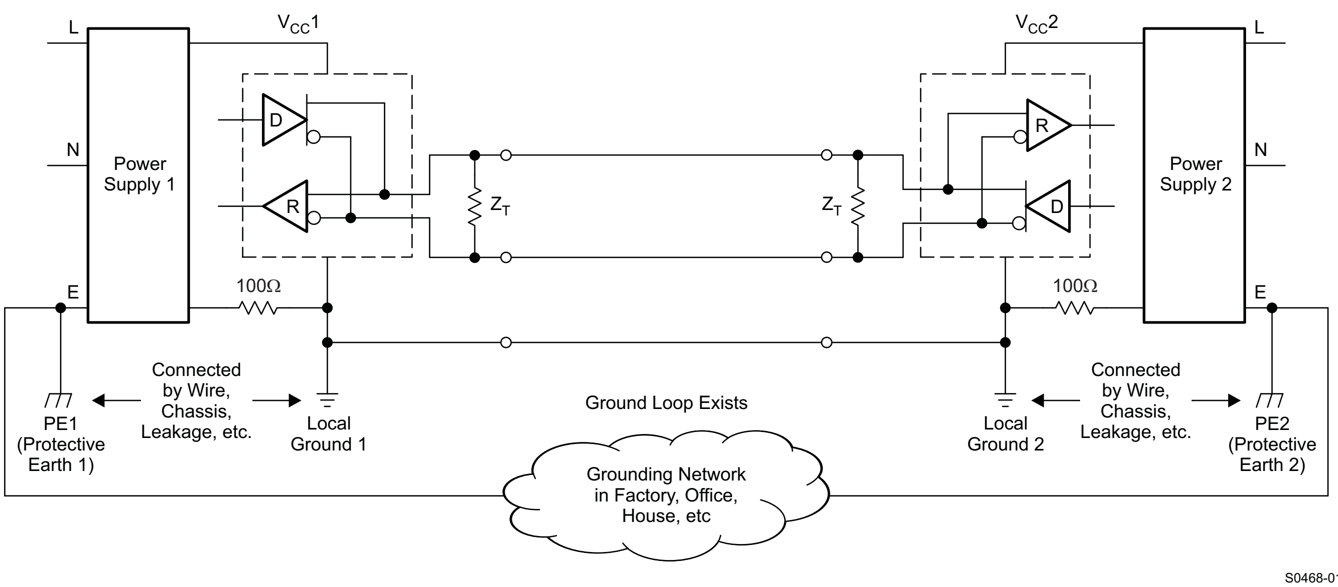


Figure 27. Grounding Configuration with Connected Local Ground and PE

This approach reduces loop current, but the existence of a large ground loop keeps the data link sensitive to noise generated somewhere else along the loop.

The approach to tolerate ground potential differences up to several kilovolts across a robust RS-485 data link and over long distance is the galvanic isolation of the signal and supply lines of a bus transceiver from its local signal and supply sources (Figure 28).

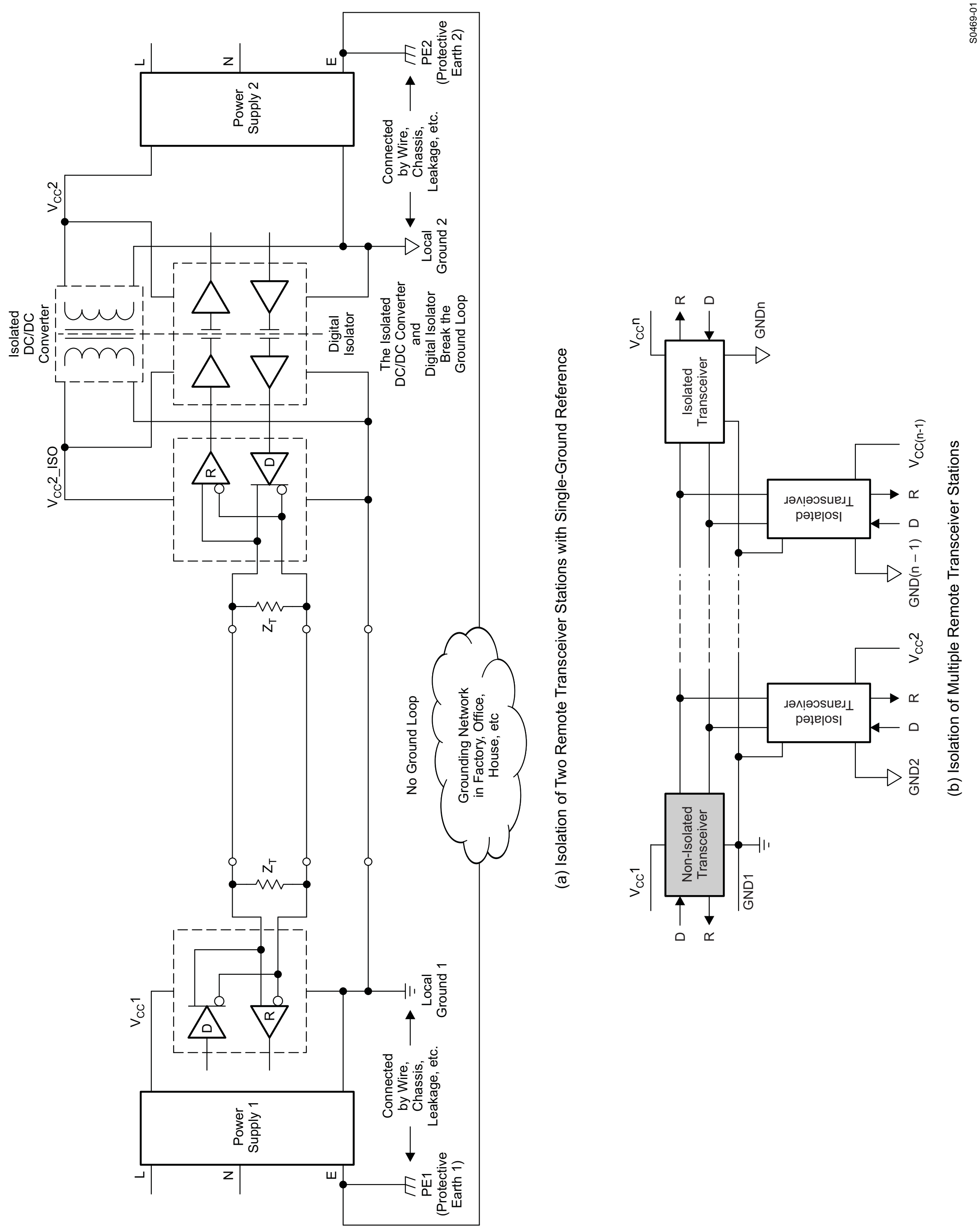


Figure 28. Isolated Configuration

In this case, supply isolators, such as isolated DC/DC converters, and signal isolators, such as digital capacitive isolators, prevent current flow between remote system grounds and avoid the creation of current loops. The non-isolated transceiver on the left provides the single-ground reference for the entire bus.

5 Typical System Configurations

This section presents a general idea about connecting balanced differential drivers, receivers, and transceivers in different situations. Properly connecting the devices greatly reduces reflections.

The following discussions on system configurations apply only to RS-485-compliant system designs. Conversion to a RS-422-compliant system is straightforward, knowing that the termination impedance, Z_T, is placed only once in close proximity to the last receiver at the end of the cable farthest from the driver. Also, only one driver is required, with up to nine additional receivers allowed in a RS-422-compliant system design.

5.1 Daisy-Chain Configuration

One widely used connectivity scheme is called daisy-chaining. In this topology, each station is attached successively as close to the input/output as possible (see Figure 29). The idea is to make the main bus seem like only one transmission line.

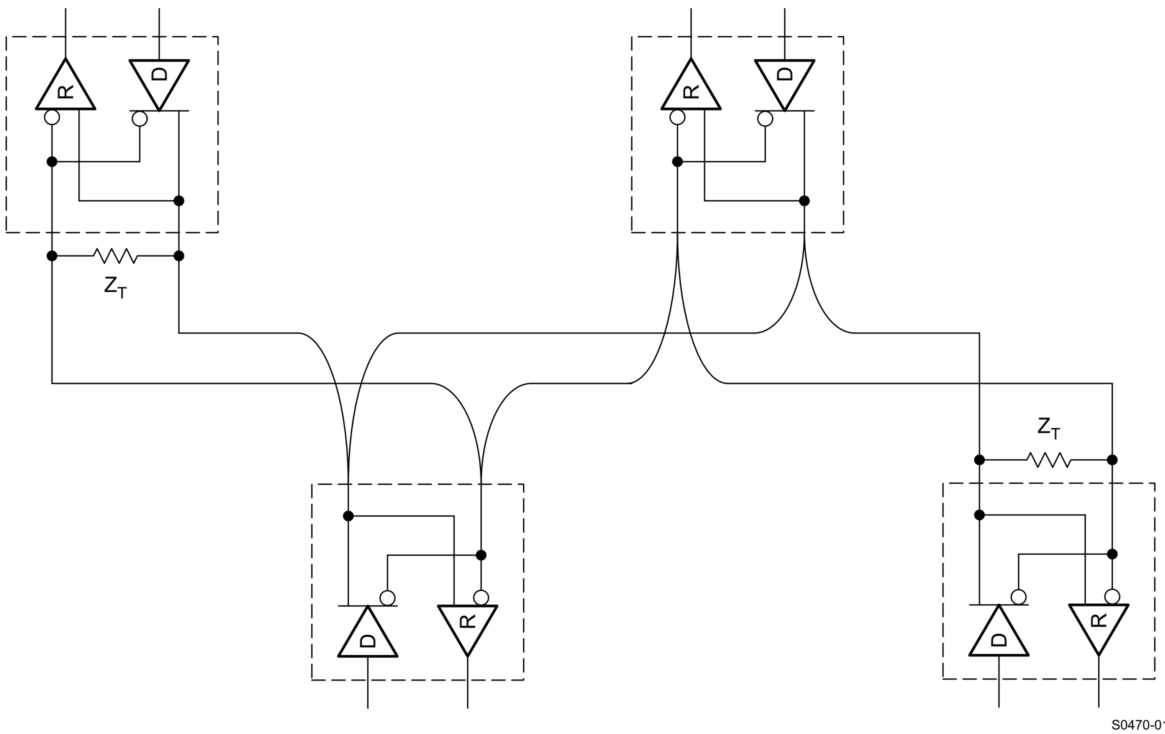


Figure 29. Daisy-Chain Connection

5.2 Bus and Stub Configuration

Another popular connection scheme (shown in Figure 30) is connecting stations directly to the main bus (referred to as a backbone). To reduce line reflections, it is essential to keep the stubs (cable distance from main bus line) as short as possible. Again, the intent is for the driver to see only one transmission line.

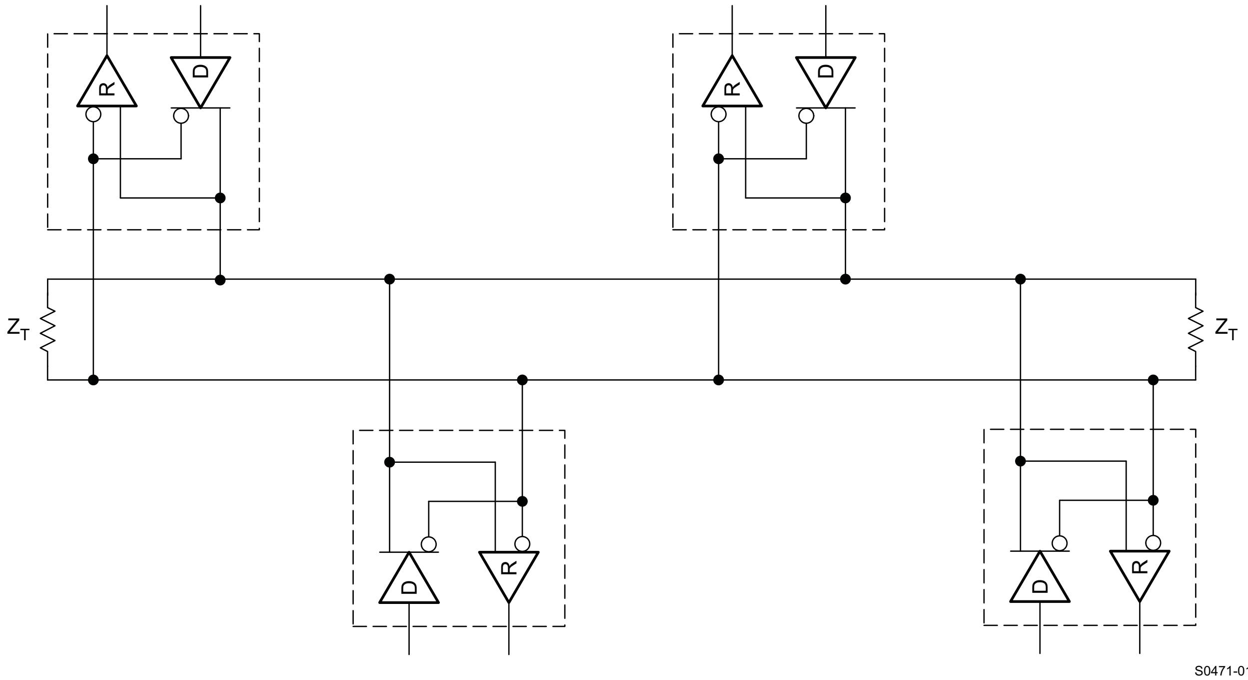


Figure 30. Stub Cables Connected to the Main Backbone

5.3 *Point-to-Point Configuration*

Point-to-point connectivity, in its simplest form of data transmission, is shown in Figure 31.

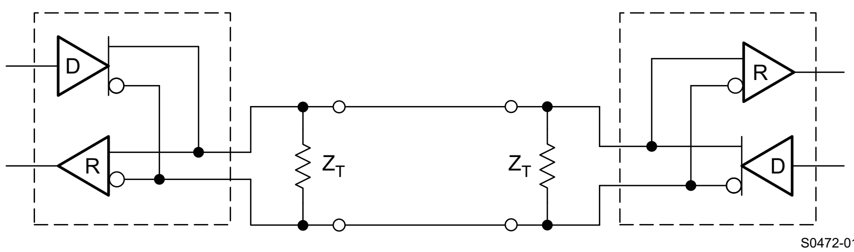


Figure 31. Point-to-Point Connection

6 Summary Comparison of the Standards

As discussed previously, RS-422 and RS-485 have similar requirements. RS-485-compliant drivers and receivers generally are interchangeable with those compliant to RS-422, but the reverse is not necessarily true. RS-422-compliant drivers used in multipoint applications have at least three major problems: common-mode range, line contention, and output drive current.

6.1 *Common-Mode Range*

RS-485-compliant drivers and receivers are specified for operation with a common-mode range of -7 V to 12 V. RS-422-compliant drivers are specified over the range of only 0.25 V to 6 V. RS-422-compliant receivers are specified regarding the 200-mV threshold levels over the common-mode range of -7 V to +7 V, but are specified regarding bus pin leakage over the common-mode range -10 V to +10 V.

6.2 Line Contention

Line contention, as discussed previously, is caused when two or more drivers are turned on at the same time. For example, if driver 1 is driving VA > VB while driver 2 also is turned on and driving VB > VA, a line-contention situation arises. Both RS-422 and RS-485 require driver output current limits that protect against high currents in these situations. However, the data on the bus lines is unreliable during line contention.

Thermal shutdown disables the output driver when it senses a high temperature and turns it back on after the device cools. If line contention still is present after the driver is re-enabled, thermal shutdown disables the driver again as soon as the temperature reaches a certain point. The output cycles in and out of thermal shutdown indefinitely until line contention no longer is present.

The problem with line contention is exacerbated when the ground potential between the remote grounds is stretched to its maximum limit of ±7 V. If driver 2 is connected to the ground that is 7 V lower than the ground for driver 1, a potential close to +12 V can exist on the output of driver 2 (assuming VCC = 5 V). If driver 2 is connected to the ground that is 7 V higher than the ground for driver 1, a potential close to –7 V can exist on the output of driver 2. The RS-485 standard, as noted, limits the current out of the output when a voltage ranging from –7 V to 12 V is applied. Therefore, the standard does require protection against the effects of line contention by limiting the output current.

6.3 Drive Current

Because RS-485 requires two termination resistors, but RS-422 requires only one termination resistor, RS-485 outputs typically are stronger. Furthermore, RS-422 allows driving up to 10 4-kΩ loads (equivalent to 400 Ω), whereas RS-485 allows driving up to 32 12-kΩ loads (equivalent 375 Ω). Therefore, with the same output drive strength, a RS-485-compliant driver can handle triple the number of loads.

Table 4 summarizes the main differences between RS-422 and RS-485; Table 3 summarizes attributes for each termination technique discussed.

Table 4. Summary Comparison of RS-485 and RS-422 Specifications

PARAMETER	RS-422	RS-485	UNIT
Number of drivers and receivers	1 driver / 10 receivers	32. U.L.s	
Maximum theoretical cable length	1200	1200	m
Maximum data rate	10	> 10[1]	Mbps
Maximum common-mode voltage	±7	–7 to +12	V
Driver differential output level	$2 \le \lvert V_{OD}\rvert \le 10$	$1.5 \le \lvert V_{OD}\rvert \le 5$	V
Driver load	≥100	≥60	Ω
Driver output short-circuit current limit	150 to GND	250 to –7 V or 12 V	mA
High-impedance state, power off	60	12	kΩ
Receiver input resistance	4	12	kΩ
Receiver sensitivity	±200	±200	mV

(1) TI devices operating at up to 50 Mbps.

7 Conclusion

Although similarities exist between RS-422 and RS-485, board designers must consider distinct differences between devices specified for one standard or the other. This application report has outlined the major differences and provided suggested connection schemes. RS-485-compliant devices can be used in RS-422-compliant systems, but the opposite is not true.

TI offers a variety of devices that meet or exceed requirements of RS-422 and RS-485. TI's main competitive advantage is its extensive selection of bipolar and BiCMOS differential devices that are available at competitive prices, allowing the board designer to reduce system costs. For a complete listing of available devices from each standard, data sheets are available on the Internet at http://www.ti.com under interface products.

8 Glossary

BiCMOS	Bipolar and complementary metal-oxide-semiconductor process
bps	Bits per second
Line contention	At least two drivers on the same bus inadvertently enabled simultaneously
Multidrop	Multiple receivers driven by a single driver per bus line
Multipoint	Multiple transceivers, drivers, or receivers per bus line
U.L.	Unit load

9 Acknowledgment

Technical assistance was provided by Kevin Gingerich and Frank Dehmelt, both of the TI Advanced Analog Products Group.

10 References

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5. *Comparing EIA-485 and EIA-422-A Line Drivers and Receivers in Multipoint Applications*, John Goldie, National Semiconductor, Application Note AN-759

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