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RS-485 Cable Lengths against Data Signaling Rate

Application Note

Revision History

Document No.	Release Date	Change Description
292ANR01	July 15, 2022	**Updated:** ■ In "RS-485 Differential Output Voltages (V_{OD})" figure, 50ΩF replaced with 50Ω. ■ In "RS-485 Cable Lengths" section. "10Mbps RS-485 driver" replaced with "1Mbps RS-485 driver".
292ANR00	April 6, 2022	Initial release.

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Introduction

This document describes how you can transmit an RS-485 signal without data loss.

When you interconnect an equipment with RS-485's drivers and receivers, you can get problems due to the cable characteristics, cable terminations, grounding arrangements, and RS-485 failsafe method.

Related Documentation

- *TIA/EIA-485, Electrical Characteristics of Generators and Receivers for Use in Balanced Multipoint Systems. (known as RS-485 Standard).*
- *TIA/EIA-422-B, Electrical Characteristics of Balanced Voltage Digital Interface Circuits. (known as RS-422 Standard).*

RS-485 Cable Lengths

Per the *RS-485* standard, the minimum drive strength (or V_{OD}) is 1.5V. If you need to use longer cable length, a RS-485 transceiver with a drive strength that exceed the RS-485 standard can offer better performance. MaxLinear offers RS-485/RS-422 transceivers with drive strength capability (V_{OD}) above 1.5V with 54Ω load in parallel with 50pF.

In general, a higher drive strength helps to counter the DC-parasitic resistance of the interconnecting cable and support further communication distances at low data rates.

The following figure shows RS-485 differential output voltages.

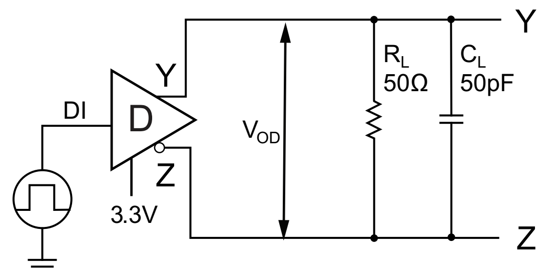


Figure 1: RS-485 Differential Output Voltages (V_{OD})

The maximum permissible length between a RS-485 driver and receiver is 4000ft (or 1200 meters). However, both cable quality and data rates impact this distance. As data rates increase, the signal is increasingly attenuated by the parasitic RC-filter created by the cable.

For more information about cable length versus data rate when you design RS-485, refer to the *TIE/EIA-422-B Annex-A guideline.* See also Figure 2.

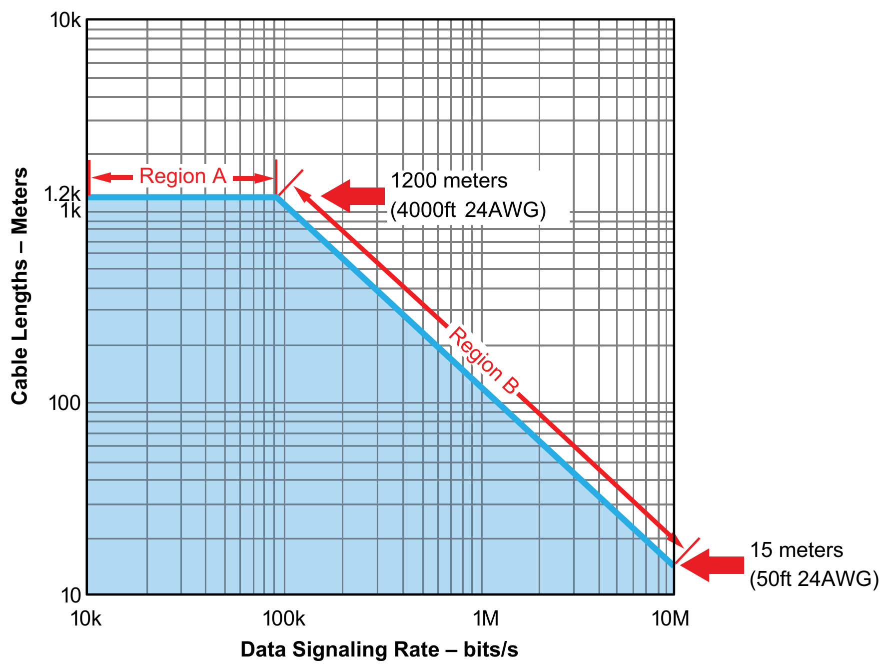
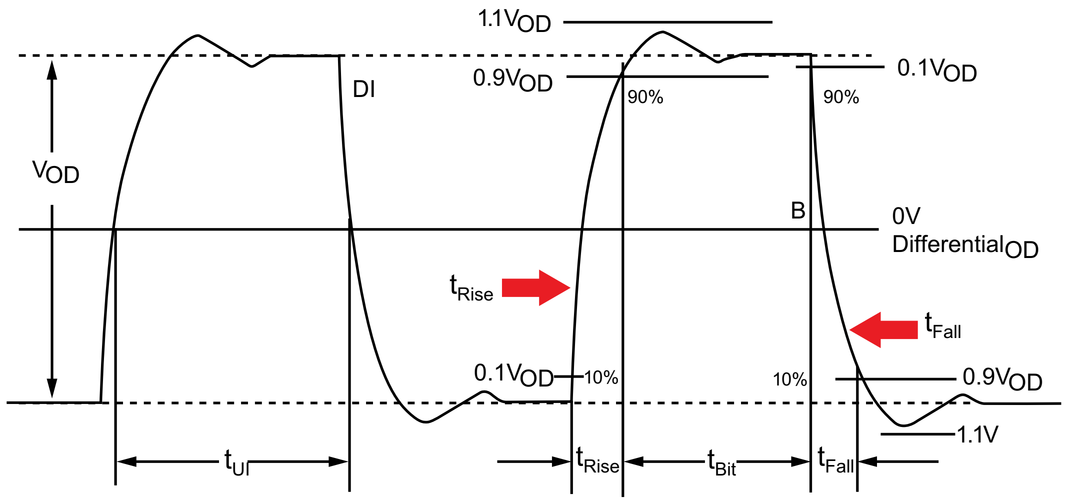


Figure 2: Cable Lengths versus Data Signaling Rate

This curve is based on empirical data that use a 24AWG unshielded twisted-pair copper conductor with a capacitance of 16pF/foot (or 52.4pF/meter) and terminated into a 100Ω resistive load.

- The region A shows the maximum distance determined by the DC resistance of the cable. As the data signaling rate is reduced below 90Kbps, the maximum cable length is limited at 4000ft (or 1200 meters) by the assumed maximum allowable 66% signal loss at the receiver end.
- The region B shows the inverse relationship between the cable length and data rate. At a higher data signaling rates (from 90Kbps to 10Mbps), the cable length is decreased when the data rate is increased to maintain the rise-time and fall-time requirements. The maximum allowable distance between a driver and receiver is limit to about 50ft (or 15 meters) for signaling rate speeds above 10Mbps.

For a reliable communication, the maximum rise-time or fall-time of the driver should not exceed one third of the unit interval (t_{UI}) at a given data rate. For example, a 1Mbps RS-485 driver has a unit interval (t_{UI}) of 1000ns. The maximum rise-time (t_{Rise}) and fall-time (t_{Fall}) should not exceed one third of unit interval (t_{UI}) (1000ns/3 = 333.33ns).



Output Signal Waveform (Signal Transition Time)

Figure 3: t_{Rise}, t_{Fall} and t_{UI} Signal Transition Time Requirements

Eye-diagrams show the attenuation affect caused by the transmission cable.

Example 1

In this example, a 4000ft of 24AWG-CAT5e cable is used between the driver output and the receiver input. Figure 4 shows the input signal DI at 90Kbps as well as the output of the driver Y and Z, which shows an almost instantaneous rising and falling edge.

On the right-hand side after the 4000ft cable, the receiver sees rising and falling edges that look like RC-delay due to long cable pairs. However, the receiver can still successfully transmit the signal with no data errors because the receiver is seeing rising and the falling edges that fall within the 1/3 rule previously described. Note that the rise-time is about 584ns and the fall-time is about 619.25ns at the receiver input. Both are well under the 1/3 of unit interval requirement of 3703.67ns (11111/3 = 3703.67ns).

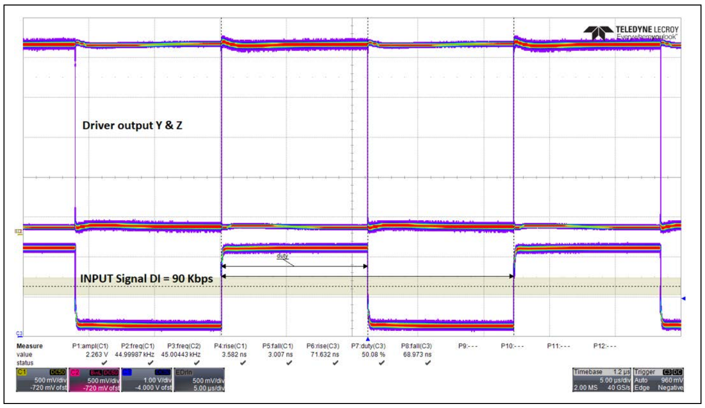


Figure 4: Eye-Diagram at Driver Output

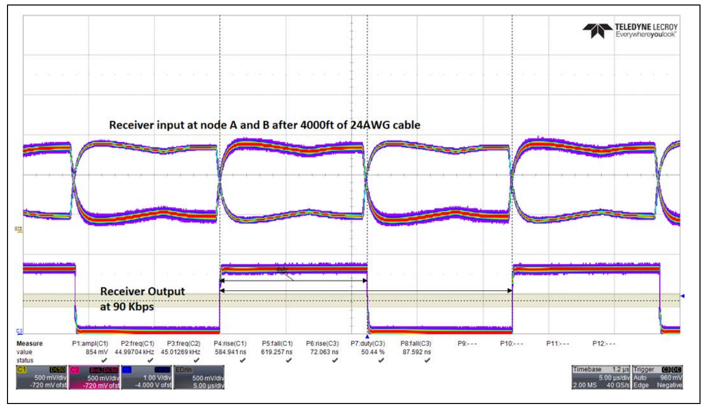


Figure 5: Eye-Diagram at Receiver Input after 4000ft Cable @90Kbps

Example 2

In this example, the data rate is increased to 2Mbps and 4Mbps respectively. The cycle-to-cycle distortion is seen at the receiver RO output at 2Mbps and 4Mbps. The rise and fall times in both case exceed the 1/3 UI rule. Data loss at the receiver end is guaranteed to occur at these data rates over 1200m of cable.

The data signaling rate against the cable length graph (Figure 2 on page 2) indicates a maximum of 60m at 2Mbps and about 30m at 4Mbps for a successful transmission.

To operate the RS-485 driver at a maximum speed of 10Mbps and beyond, the maximum cable length between driver and receiver should be limited to a maximum of 15 meters (or 50 ft) of 24AWG cable.

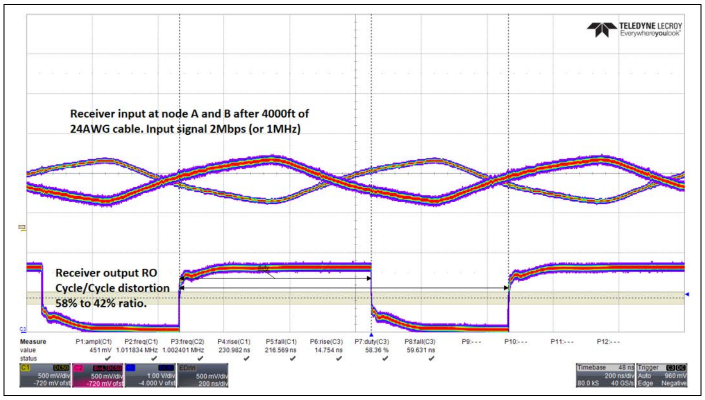


Figure 6: Eye-Diagram at Receiver Input after 4000ft Cable @2Mbps

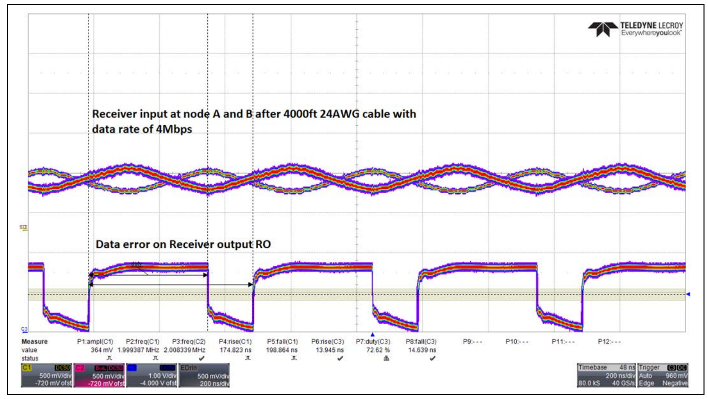


Figure 7: Eye-Diagram at Receiver Input after 4000ft Cable @4Mbps

In summary, the following tips help you to maintain a successful RS-485 link:

- Tip 1: Use the TIE/EIA-422-B graph as a guidelines to determine the maximum cable length between a RS-485 driver and a RS-485 receiver at a given data signaling rate.
- Tip 2: Obey the 1/3 rule (1/3 rise-time, 1/3 fall-time, and 1/3 bit-time) to guarantee no data loss. In a noisy environment, use the 1/4 rule (1/4 rise-time, 1/4 fall-time and 1/2 bit-time) for a better performance.
- Tip 3: Use a larger diameter cable to reduce the DC-parasitic loss and improve the signal performance over long distances. A 19-AWG cable perform better than a 24-AWG cable at the same length.
- Tip 4: Whenever possible, choose a RS-485's driver (or transmitter) with a higher V_{OD} than the standard RS-485 specification of 1.5V with load 54Ω parallel with 50pF. A higher drive strength driver perform better than a standard drive strength RS-485 driver at the same cable length.

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