Application Note

NOVOSENSE

Relationship between Data Rate and Cable Length in RS485 Applications

AN-13-0006

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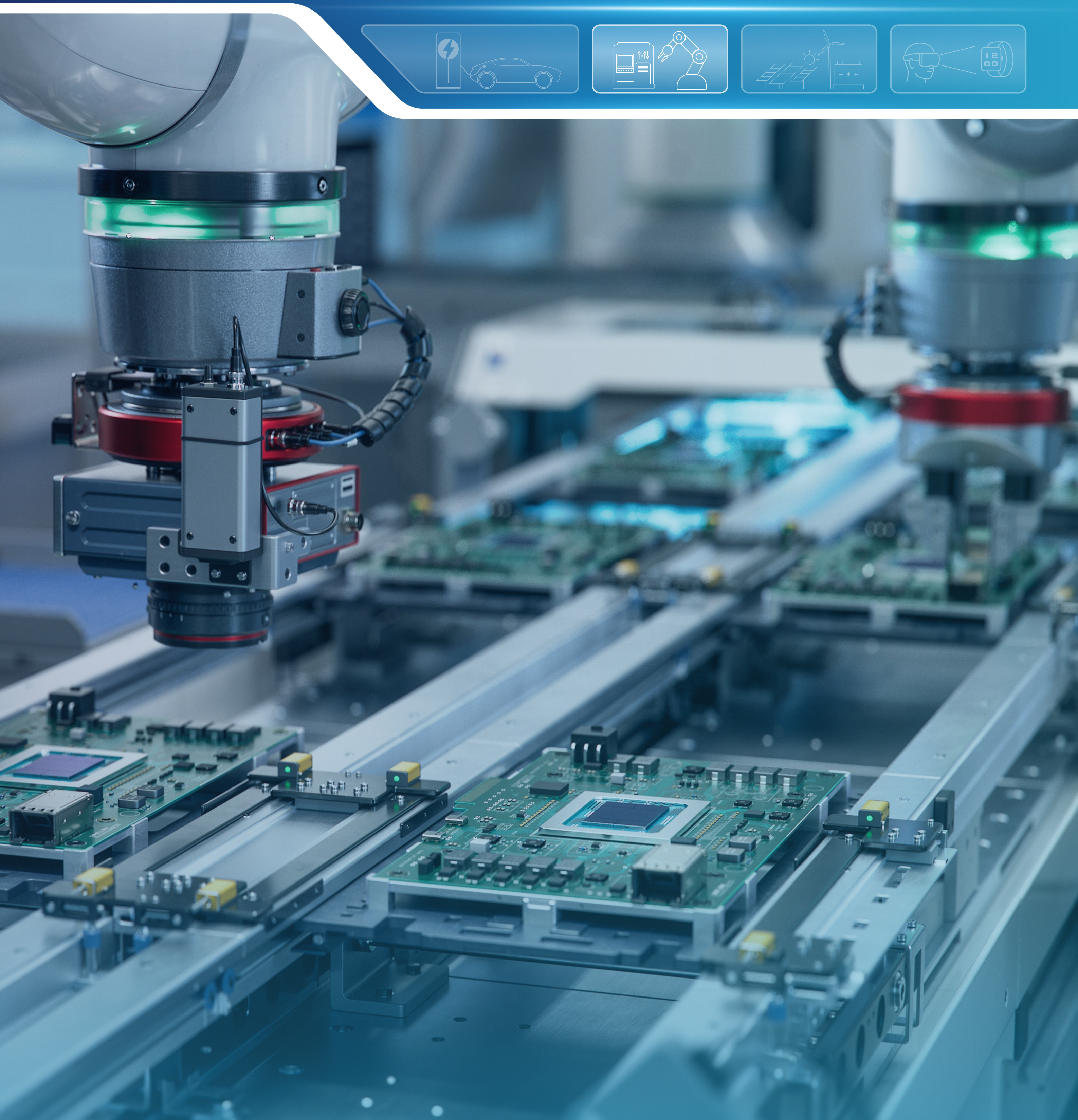

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ABSTRACT

In industrial applications that often need to transmit data in multiple systems over long distances, RS485 based on the TIA/EIA-485-A standard is often the ideal choice. The accuracy and stability of data transmission are generally related to the performance of RS485 transceiver, transmission distance, cable selection and the choice of communication protocol. This application note mainly introduces the performance parameters of RS485 transceiver, the relationship between transmission rate and cable length, and does not introduce the communication protocol.

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1.Relationship between RS485 transceiver parameters and transmission rate, transmission distance

1.1.Relationship between voltage parameter performance and transmission distance

The TIA/EIA-485-A standard requires that the receiver of an RS485 transceiver must be able to effectively detect any signal with a differential voltage amplitude greater than 200 mV as a valid data signal. Thus, the receiver's worst-case input differential amplitude is 200mV. At the same time, the TIA/EIA-485-A standard requires that the driver of the RS485 transceiver must be able to produce a differential voltage greater than 1.5V. Taking the typical application of half duplex given in Figure 1.1 as an example, when the master node sends the differential signal to the bus and then the slave node receives the differential signal from the bus, the DC attenuation of the bus voltage can reach 1.3V. This is also one of the reasons why RS485 is the preferred choice when communicating over long distances.

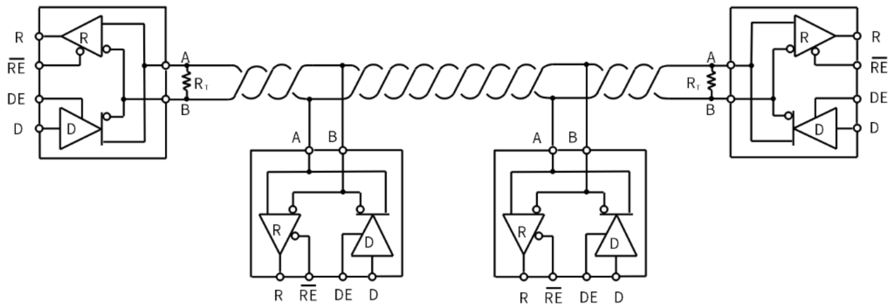

Figure 1.1 Typical half-duplex 485 applications

In theory, the greater the bus voltage attenuation that an RS485 transceiver can produce, the greater the transmission distance it can support. The RS485 transceiver series products launched by Novosense can generate differential voltage greater than 1.5V in the full voltage range, while the receiver can recognize differential voltage greater than -10mV as high, and the performance is better than the requirements of TIA/EIA-485-A standard. And the wide common-mode voltage range (-7V to 12V) allows for a ground potential difference between the driver and the receiver. Therefore, it is possible to support long-distance communication requirements in 485 application systems.

1.2.Relationship between timing parameter performance and transmission rate

The TIA/EIA-485-A standard requires that when the driver of the RS485 transceiver has a level switch, the conversion time of the bus voltage from 10% to 90% of the voltage should be limited to less than 30% of the bit time, as shown in Figure 1.2. Take the data rate of 20 Mbps as an example. If t_{bit}=50ns, t_r and t_f must not exceed 30% of 50n, that is 15ns. The RS485 transceiver series products launched by Novosense, t_r and t_f do not exceed 10ns. Therefore, the data rate of 20 Mbps can be met.

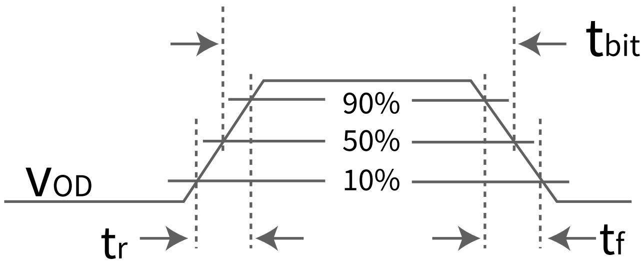

Figure 1.2 Timing reference diagram

2.Data rate and cable length

When determining the possible data rate for a particular cable length, it is not enough to select an RS485 transceiver that meets the performance requirements. The effect of the cable parameters on the signal also needs to be considered. TIA/EIA-568-B.2 standard makes a certain specification of twisted pair parameters, and provides a reference for analyzing the influence of DC and AC parameters of the cable on the signal quality of RS485. This note will introduce the relationship between data rate and cable length based on TIA/EIA-568-B.2 standard.

2.1.Attenuation of the signal by the cable

Insertion loss refers to signal attenuation due to the insertion of a length of cable between the driver and the receiver, expressed in dB. TIA/EIA-568-B.2 (Section 4.3.4.7) refers to the formula for calculating the insertion loss of a cable at any frequency:

$$Insertion\ loss \leq k1\sqrt{f} + k2 \times f + \frac{k3}{\sqrt{f}} dB/100m(328ft)$$

k1, k2 and k3 are the formula constants of cable insertion loss. TIA/EIA-568-B.2 standard provides two types of cable related parameters, category 5e and Category 3, as shown in the following table. f is the transmission frequency of the data on the cable.

	k1	k2	k3
Category3	2.32	0.238	0.000
Category5e	1.967	0.023	0.05

The TIA/EIA-568-B.2 standard also specifies that Category 5e cables are suitable for use up to 100MHz, and Category 3 cables are suitable for use up to 16MHz. According to this, this note gives the signal attenuation curve of category 5e and Category 3 in the specified frequency range.

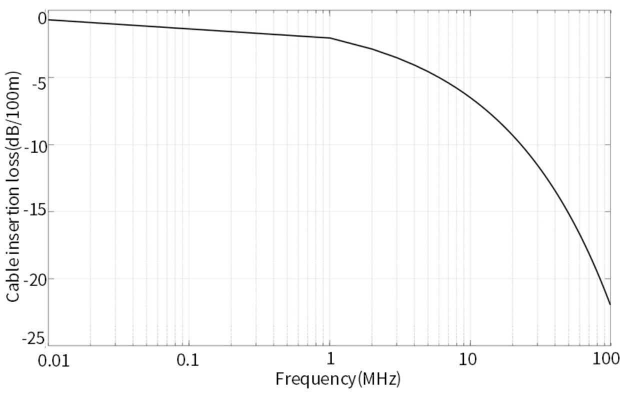

Figure 2.1 category 5e attenuation curve

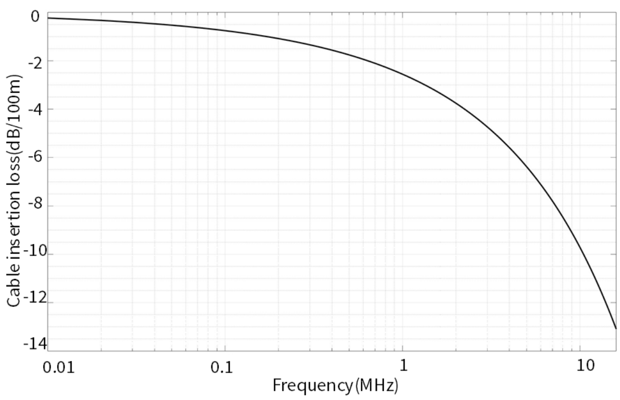

Figure 2.2 category 3 attenuation curve

In signal attenuation, dB is equivalent to power attenuation, that is dB=10*log10(P/P_r), where P is the actual power and P_r is the reference power. Assuming the impedance is fixed, P=U^2/R, then dB=20*log10(U/U_r). Taking category 5e as an example, 100m cabling is achieved at a data rate of 10MHz, and the cable attenuation is -5.8 dB, so the voltage attenuation at the receiving end is about 51% of that at the sending end. The above formula can therefore be used to estimate the data rate and cable length.

2.2.Effect of cable on timing

In addition to the attenuation of the signal, the cable will also affect the signal timing, thus affecting the signal quality. For high data rate, the AC effect of the cable limits the quality of the signal and limits the cable length to a short distance. Therefore, when determining the reliable data rate in the actual system, it is also necessary to consider the influence of the cable on the signal propagation delay and the rise and fall time. Sections 4.3.4.12 and 4.3.4.13 of the TIA/EIA-568-B.2 standard give the maximum propagation delay and rise-fall time offset allowed by the cable, respectively. The relationship between maximum propagation delay time and frequency is allowed to be introduced:

$$delay \le (534 + \frac{36}{\sqrt{f}})\text{ns}/100\text{m}(328ft)$$

Where f is the data transmission frequency. Taking category 5e as an example, Figure 2.3 shows the maximum propagation delay allowed by the cable at different transmission rates.

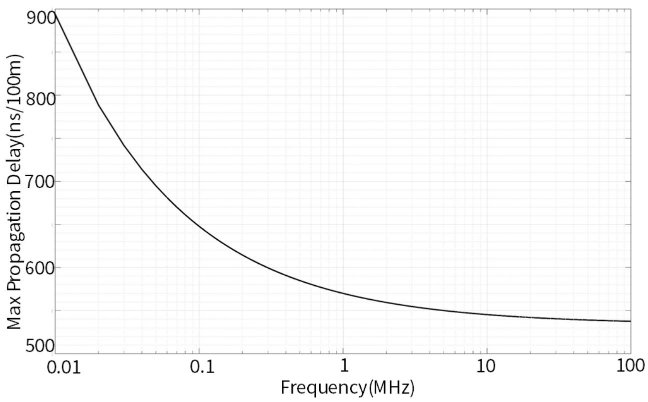

Figure 2.3 Relationship between data rate and the maximum allowable delay

Taking 10MHz data transmission frequency as an example, it can be calculated that the maximum allowable propagation delay per 100m is 545ns, and the maximum allowable rising and falling edge time offset per 100m is 45ns according to the TIA/EIA-568-B.2 standard. In practical applications, you can refer to the above data to evaluate the performance of the cable. If the timing requirements of the TIA/EIA-568-B.2 standard are met, the cable can be considered to meet the communication requirements.

2.3.Non-ideal working conditions

The above two sections are all analyses under ideal conditions. In practical applications, the appearance of non-ideal conditions is inevitable, which may affect the accuracy and stability of communication. The following table shows common non-ideal conditions and their possible effects on the system.

Non-ideal condition	The influence of non-ideal conditions on the system
External noise sources exist on the RS485 bus	Potential noise sources such as IEC61000-4-2 electrostatic discharge ESD, IEC610004-4 electrical fast transient EFT, IEC61000-4-5 surge may reduce system reliability and effective data transmission
There are differences between the two wires of twisted pair cable	Excessive deviation of rising and falling edge may occur, resulting in abnormal communication
Crosstalk exists between twisted pairs	Error codes may be generated, affecting communication
Multi-node long distance communication	Multi-node long distance communication may cause signal reflection due to impedance mismatch, thus generating error codes

Based on the effect of the above non-ideal conditions on the communication, the following figure shows the conservative estimated curve of cable length and data rate with the signal jitter not exceeding 10% as the basis.

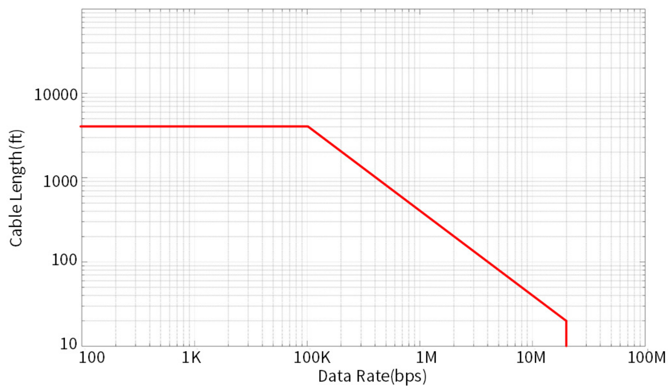

Figure 2.4 Estimated cable length and data rate

Generally, when the RS485 data rate is below 100Kbps, the maximum cable length is about 4000 feet (1200m). As the length of the cable is reduced, the data rate can be further improved. The estimated value given in this note is much more conservative than the current cable performance, so the actual support distance should be larger than the given reference value at a given data rate.

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3.Revision History

Revision	Description	Author	Date
1.0	Initial version	Zhe Zhang	19/9/2024

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