Application Note

NOVOSENSE

RS485 Transceiver Reference Design

AN-13-0012

Author: Zhe Zhang

AN-13-0012

NOVOSENSE

RS485 Transceiver Reference Design

ABSTRACT

In industrial applications that often need to transmit data in multiple systems, RS485 transceiver based on the TIA/EIA-485-A standard is often the ideal choice. It has the advantages of long-distance communication, two-way communication, wide common-mode voltage range, etc. This application note mainly introduces the reference design of RS485 transceiver and does not introduce the communication protocol.

INDEX

1.RS485 transceiver application topology

The standard recommends using bus topologies to connect nodes. In this topology, the transceiver used is connected to the bus via a stub, as shown in Figure 1.1. The bus can be designed for full-duplex or half-duplex transmission.

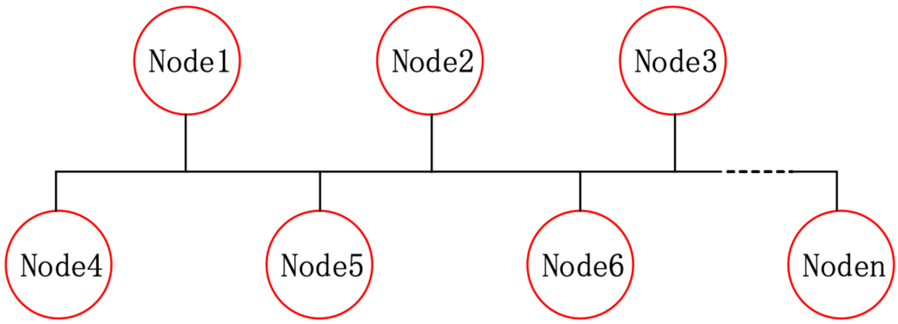

Figure 1.1 RS485 bus topology

The implementation of full-duplex transmission requires two pairs of signal lines, and the full-duplex mode allows nodes to send data on one pair of signal lines and receive data on the other pair of signal lines.

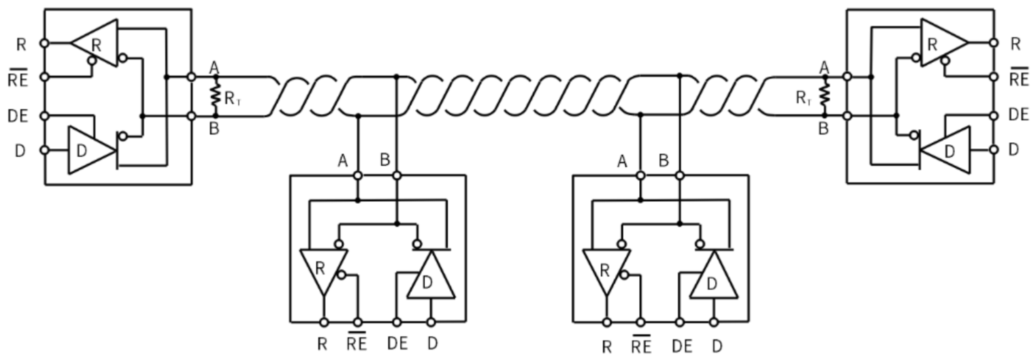

Figure 1.2 Typical RS-485 Network with Half-Duplex Transceivers

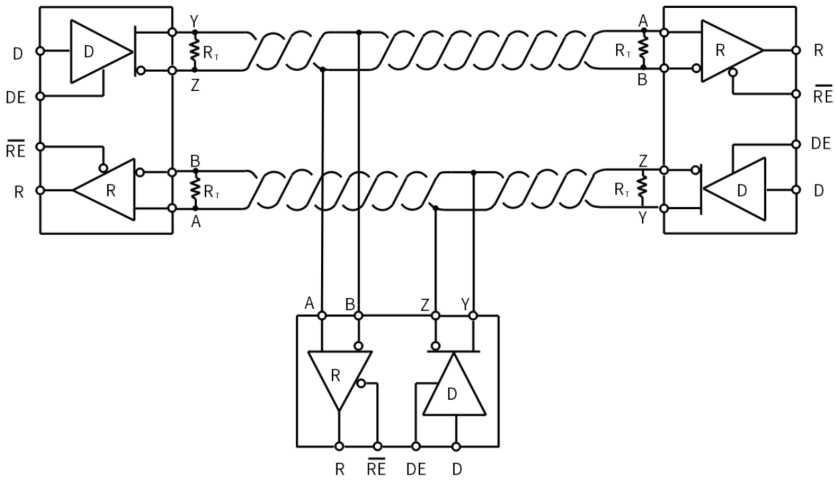

Figure 1.3 Typical RS-485 Network With Full-Duplex Transceivers

Half duplex communication requires only a pair of signal lines, but the sending and receiving cannot be carried out at the same time. Whether it is half duplex or full duplex, all nodes on the bus need to be controlled by a control signal (the enable signal of the driver or receiver), ensuring that only one node on the bus is working at any one time. The situation where multiple node drivers send signals to the bus at the same time must be avoided by software control.

2.Cable type

Twisted pair is usually used in RS485 applications to transmit differential signals, because the common mode interference of the external interference source coupled to the signal line through the twisted pair will be filtered out by the differential receiver. The cables used in RS485 applications use twisted pair cables that meet the 22-24AWG wire gauge, as shown in the Figure 2.1.

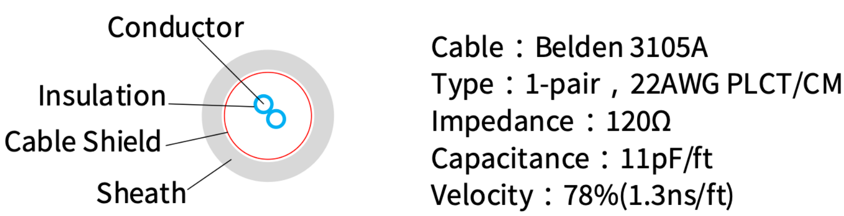

Figure 2.1 Example of an RS-485 cable

NOVOSENSE

3.Bus termination

In order to avoid impedance mismatch resulting in signal reflection, the bus needs to have terminal resistors at both ends as shown in the Figure 1.2 and Figure 1.3. The resistance value of the terminal resistance is determined by the characteristic impedance of the selected transmission cable and needs to match the characteristic impedance of the cable. The RS485 standard recommends that a cable with a characteristic impedance of 120Ω be used, so the terminal resistance value should also be 120Ω.

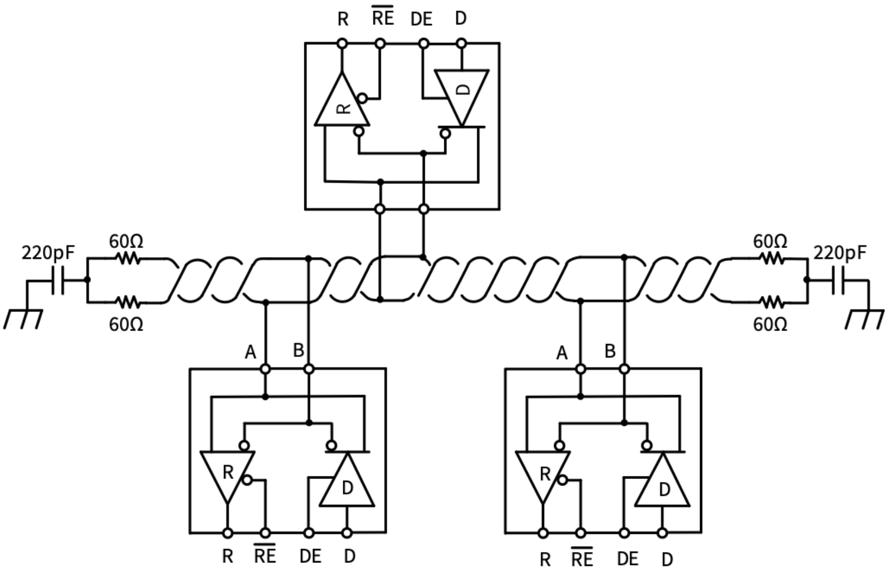

Figure 3.1 RS-485 terminal resistor design reference

When the RS485 system is used in a noisy environment, the 120Ω resistor can be replaced with two 60Ω resistors, while increasing the intermediate capacitance to form a low-pass filter to provide an additional common-mode noise filtering capability, as shown in the Figure 3.1. In order to avoid the difference in filtering performance between the two filters, and common-mode noise is converted into differential mode noise, resulting in the reduction of the receiver's immunity affecting the communication quality. Be sure to ensure that the resistance values match (it is advisable to use a resistor with a precision of 1%). The choice of capacitance value can be determined according to different transition frequency requirements.

4.Fail-safe protection

Fail-safe protection is to ensure that the receiver has the ability to output a definite state in the absence of an input signal. There are three possible reasons for bus signal loss:

- 1.Bus open: The cable is disconnected or the transceiver is disconnected from the bus
- 2. Bus short circuit: Twisted pair contact due to insulation failure
- 3. Bus idle: All bus drivers are not working

The requirement for the receiver in the RS485 standard is to be able to identify differential voltages greater than 200mV or less than -200mV, which leads to an uncertain state of the receiver's output when the input signal is 0. The RS485 series transceivers from Novosns can recognize differential voltages greater than -10mv to ensure a constant high level output in the event of signal loss resulting in a zero input signal. But if it rely only on the chip's own receiver capabilities to cope with signal loss, The worst case noise tolerance is only 10mv. Therefore, in the environment with large interference, it is recommended to increase the fail-safe protection circuit to increase the noise tolerance, as shown in the Figure 4.1.

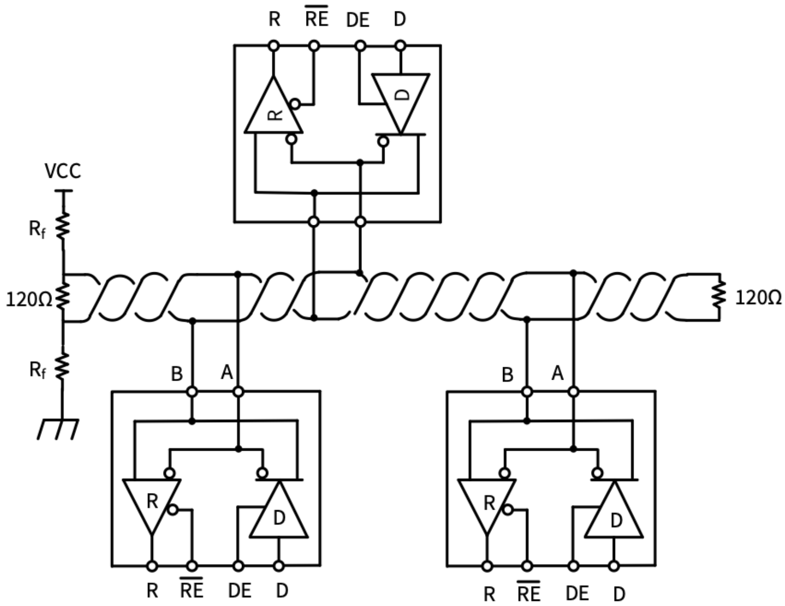

Figure 4.1 Fail-safe protection circuit

The fail-safe protection circuit may consist of a resistor divider circuit to ensure that sufficient bus differential voltage can be generated. The desired differential voltage value can be selected according to the actual situation, but ensure that it is greater than the input threshold of the receiver to ensure that a definite output state can be produced. The resistance value of the partial voltage resistor can be calculated by reference to the following formula:

$$\left(\frac{\frac{Rin}{n}\times 60}{\frac{Rin}{n}+60}\right)\times VCC = VAB\times\left(\frac{\frac{Rin}{n}\times 60}{\frac{Rin}{n}+60}+2Rf\right)$$

R_{in} is the differential resistance of the RS485 transceiver, n is the number of nodes on the bus, VCC is the chip power supply voltage, and V_{AB} is the required differential voltage. Here, the need to generate 0.2V differential voltage as an example, two nodes on the bus, NCA3176 differential resistance is considered to be 96KΩ, VCC power supply is 5V, then the calculated resistance value R_f is 720Ω.

5.Bus load

In order to estimate the maximum load of the bus, RS485 specifies the concept of unit load. One unit load (U_L) is equivalent to 1 mA of input leakage current at +12 V. This load represents a single-ended load with respect to ground. Another easy way to think of the unit load is the equivalent of a 12 kΩ resistance from either the A or B bus pins (and the Y and Z pins for full-duplex transceivers) to ground. The RS485 standard requires the transceiver to be able to drive 32unit loads, guaranteeing an output differential voltage of 1.5V in the presence of two 120ohm terminal resistors. The NCA3176 series transceiver itself carries one-eighth of the unit load, so it can theoretically connect 256 nodes on the bus. If the fault safe protection circuit is introduced, the circuit itself will introduce about 20 units of load current, so a maximum of 96 nodes can be connected to the bus.

6.Data rate and communication length

The following figure shows the conservative estimated curve of cable length and data rate with the signal jitter not exceeding 10% as the basis.

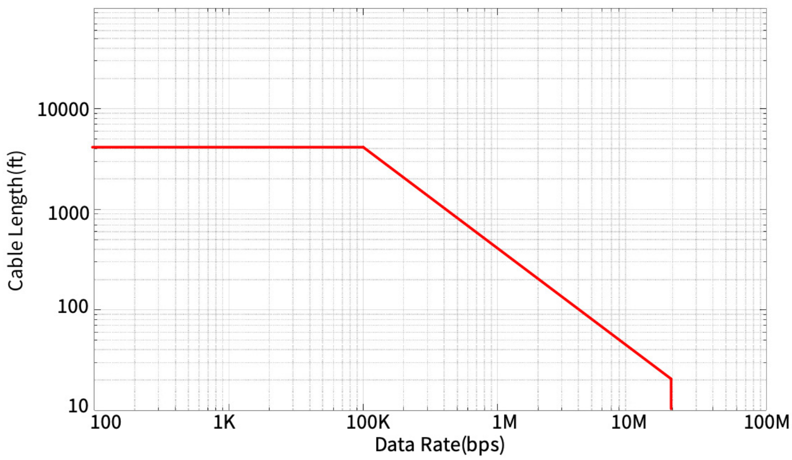

Figure 5.1 Estimated cable length and data rate

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.

7.TVS Diode selection

In automotive or industrial applications, for some systems with external connection interfaces, protecting the interface transceivers from all kinds of electrical overstress events is a major concern. Transient voltage suppressor (TVS) diodes are common devices for this purpose, since they can clamp the voltage spikes by generating a low-impedance current path. For the selection of TVS, in addition to considering their instantaneous response characteristics, which can quickly release large instantaneous energy. we should also pay attention to the following parameters:

- **Reverse Stand-off Voltage (V_{RWM})**

The reverse stand-off voltage parameter characterizes the maximum withstand voltage of a TVS transistor in a nonconducting state. Under normal operation of the RS485 bus, the TVS should be in the cut-off state. When the RS485 bus experiences abnormal overvoltage and reaches the TVS breakdown voltage, the TVS changes from a high resistance state to a low resistance state, releasing the instantaneous overcurrent caused by the abnormal overvoltage to the ground. So the reverse stand-off voltage of the TVS should be higher than the normal working voltage of the RS485 bus. The reverse stand-off voltage of a general TVS should be higher than the common mode voltage operating range of the RS485 transceiver bus.

- **Breakdown Voltage (V_{BR})**

V_{BR} characterizes the voltage at both ends of TVS when passing through a certain current. At this voltage, the TVS exhibits low impedance characteristic, and in general, VBR is slightly higher than V_{RWM}.

- **Clamping Voltage (V_{CL})**

V_{CL} characterizes the maximum clamping voltage of TVS under peak pulse current. In RS485 system applications, the V_{CL} of the TVS should not exceed the absolute maximum rated voltage (AMR) of the bus, otherwise it may damage the RS485 transceiver.

- **Peak Pulse power (P_{PP})**

The peak pulse power is the product of the peak pulse current and the clamping voltage. The larger the P_{pp}, the greater the transient surge current absorption capacity of TVS under the given maximum clamping voltage condition, and the better the protection of TVS. So, under the selecting of fixed V_{CL}, TVS with larger P_{pp} should be chosen.

The TVS should be placed at the external connection of the module for quickly releasing external energy to the ground. The PCB routing of TVS should be as short as possible to reduce parasitic inductance and impedance effects. Parasitic inductance may cause an increase in V_{CL} voltage, while routing impedance will reduce the ability to release surge energy.

NOVOSENSE

8.Revision History

Revision	Description	Author	Date
1.0	Initial version	Zhe Zhang	2025/09/05