Wiring of RS485 Communications Networks

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Summary

This document attempts to explain correct methods of wiring RS485 communication networks in industrial environments based on various application notes and technical articles.

Keywords

RS485 RS-485 COMMUNICATIONS EIA/TIA-485

Details

1. RS-485 (EIA/TIA-485) Differential Data Transmission System Basics

The RS-485 standard was developed jointly by two trade associations: the Electronic Industries Association (EIA) and the Telecommunications Industry Association (TIA). The original prefix "RS" stands for "Recommended Standard" and has been officially replaced with "EIA/TIA" to help identify the origin of its standards.

<table>
<thead>
<tr>
<th>RS-485 Standard Specifications</th>
<th>Differential</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mode of operation</td>
<td>Differential</td>
</tr>
<tr>
<td>Allowed no. of Tx and Rx</td>
<td>32 Tx 32 Rx</td>
</tr>
<tr>
<td>Maximum cable length</td>
<td>4000ft length</td>
</tr>
<tr>
<td>Maximum data rate</td>
<td>10Mbps</td>
</tr>
<tr>
<td>Minimum driver output range</td>
<td>±1.5V</td>
</tr>
<tr>
<td>Maximum driver output range</td>
<td>±5V</td>
</tr>
<tr>
<td>Minimum drive capability</td>
<td>±55mA</td>
</tr>
<tr>
<td>Maximum driver short-circuit current</td>
<td>250mA</td>
</tr>
<tr>
<td>Tx load impedance</td>
<td>54 Ω</td>
</tr>
<tr>
<td>Rx input sensitivity</td>
<td>±200mV</td>
</tr>
<tr>
<td>Maximum Rx input resistance</td>
<td>12kΩ</td>
</tr>
<tr>
<td>Rx input voltage range</td>
<td>-7V to +12V</td>
</tr>
<tr>
<td>Rx logic high</td>
<td>&gt;200mV</td>
</tr>
<tr>
<td>Rx logic low</td>
<td>&lt;200mV</td>
</tr>
<tr>
<td>Max common mode voltage</td>
<td>-7V to +12V</td>
</tr>
</tbody>
</table>
Full duplex implementation requires 4 wires. This may be necessary for some applications involving legacy devices. In half-duplex implementation 2 wires are used – this is the recommended configuration for most Schneider Electric PMC devices.

All products manufactured by Schneider Electric PMC support half-duplex, 2 wire configuration. The 4 wire interface is usually implemented in order to avoid creating a T (tee) or star connections or to support full duplex connections.

A twisted pair type of cable should be used in order to reduce radiated emissions and improve immunity of the communications system to any external electromagnetic interference.

The National Electrical Code and all applicable local regulations must be followed when installing the communications wiring.

Cable examples:
- Belden 9841 or Alpha 6412 or equivalent cable may be used for applications under 300V that are indoors or outdoors in conduit above grade.

- Belden 3074F or equivalent cable may be used for applications greater than 300V which are indoors or outdoors in conduit above grade.

In all devices the RS485 ports are opto-isolated from the internal device electronics. All devices with RS485 port have a “shield” terminal, which may be connected to the chassis ground (e.g. on 7X50, 880, 8600) or to the isolated reference of the RS485 port (i.e. no connection to the chassis ground as in 6200, 6300, 6100)
2. Network Configuration

2.1 Topology
Several types of network topologies are possible, but the daisy-chain bus configuration is the most efficient. Typically, one of the units is the master controlling the network traffic and prevents multiple drivers from being active at the same time (bus contention). A shielded twisted pair cable is the physical medium. The cable impedance should be within 100-120Ω range. In the “Backbone with Studs” technology, no studs should be left unconnected at the device end. Otherwise, such a stud will act as an antenna and introduce a significant amount of noise on the RS485 bus, to such a point that comms may become impossible. This is actually a fairly common source of problems.

![Diagram of network topologies](image)

*Figure 5—Many common network topologies exist, but the daisy chain is the most reliable for RS-485 networks.*

The longer the cable, the lower the data rate:
2.2 Termination

Termination resistors that match the cable’s characteristic impedance are essential for minimizing reflections and consequently communication error rates and electromagnetic emissions. For common RS-485 cables (a twisted pair of 24AWG wires), this means a 100-120Ω resistor at both ends. Termination resistors should be used especially with long cable length to ensure data integrity. Note that, on very long cable length, adding termination resistors can sometime cause an additional drop of voltage that will cause a loss of communication on the devices that are furthest from the master. In this case, adding a repeater or removing some termination resistors can restore comms.

2.3 Fails-Safe Biasing

Open bus condition:

When a node is disconnected from the bus, the state of the bus, as seen by the receiver, is undetermined and may result in random output from the receiver. A weak failsafe biasing is recommended to ensure that the receiver does not enter undetermined state under open bus conditions.

Idle bus condition:

When no drivers are active on a bus with termination resistors, those resistors will decrease the differential bus voltage to zero, which according to the RS485 standard, is an undefined bus condition. Biasing resistors should be used in order to generate a valid bus logic state under idle-bus conditions. Biasing resistors are only needed at one node (usually the master), hence configuration switches must be used if the biasing resistors are incorporated into every node. Only one device on the bus should be providing the biasing. The biasing resistors may be external or internal to the device. Some products e.g.8800, 7X50 have internal resistors which may be connected with internal switches to provide biasing of the bus. The Com 32 and Com 128 have permanently connected biasing resistors.

2.4 Unit Load (U.L.)

A one RS485 transceiver represent a load of 1U.L. The RS485 standard specifies the bus loading as 32 U.L.
2.5 Shielding and Grounding

The RS485 interface standard does not specify a ground wire, but such wire is needed to provide a return path for common mode currents and consequently reduce emissions. It may be possible to operate the RS485 loop without a ground wire, but such systems may radiate high levels of EMI.

A shield limits coupling of external interference and noise onto the bus. Generally the shield should be connected to the chassis ground (installation ground) at one end of the cable. In case of ground potential differences between nodes (common in industrial locations) this arrangement prevents the flow of DC ground loop currents in the shield. Ground loop currents flowing in the shield will induce noise in the communications cable. A capacitor or an RC network may be used between the other end and ground.

The RS485 nodes can tolerate from -7V to +12V of common mode voltage. When this voltage is exceeded the nodes are no longer guaranteed to function and may even be damaged. Due to significant differences in ground potentials that may and will be present between nodes in industrial locations, ground should not be used as a reference. In installations where ground is used as return path 100-120Ω resistors may be used to limit the ground currents flowing due to ground potential differences between devices.
The figure below illustrates the grounding concepts.

**Figure 4a**—A dedicated conductor to reference signal grounds is the best method of controlling $V_{org}$. **b**—The 100-ohm resistors limit current but allow larger $V_{org}$ to develop. **c**—As a last resort, earth ground can be used to reference signal grounds.
Connection Example: 6300 meter, terminated daisy chain bus.

The shield terminal is not connected to chassis ground of the meter. Installer must ensure low impedance connection to the system ground at one end of the cable. The 4 wire port on the 6300 is intended to help the installer avoid making T (or stub) connections. Note the use of termination resistors RT.

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**6300 RS-485 Connection**

- Terminal Strip
- RS-485 Cable: 22 gauge shielded twisted pair
- Shield

**RS-485 Wire Colors**

<table>
<thead>
<tr>
<th>Color</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black</td>
<td>Shield</td>
</tr>
<tr>
<td>Blue/White</td>
<td>Data - (minus)</td>
</tr>
<tr>
<td>Orange/White</td>
<td>Data + (minus)</td>
</tr>
<tr>
<td>White/Blue</td>
<td>Data + (plus)</td>
</tr>
<tr>
<td>White/Orange</td>
<td>Data + (plus)</td>
</tr>
</tbody>
</table>

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**RS-485 STRAIGHT-LINE TOPOLOGY**

- COM128 RS-232 to RS-485 Converter
- Computer or Modem
- RS-485 Cable: AWG 22 shielded twisted pair. Overall length: 4000 ft. maximum.
- Last RS-485 Device (End Point)
- Termination Resistor

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Example: third party devices:
Examples of improper networks – Do NOT do this:

Unterminated cable:

Incorrect location of termination resistor:

Multiple cables in a “star” configuration
Backbone cable with long stubs: