Wiring Guidelines for RS-485 networks

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Overview

The RS-485 standard allows for very robust communications over distances of up to 4000 feet on networks wired with relatively inexpensive cable types.

This document serves as a guide to wiring RS485 controllers in RS485 MS/TP networks.

Operation

RS-485 networks use the convention 'A+' and 'B-' to represent lines 'A' and 'B', defined by the RS-485 standard, respectively.
Two-wire RS-485 networks operate in half-duplex mode on one twisted pair plus a ground wire. Data may only travel in one direction at a time. All devices on the network can be transmitters or receivers, but only one may transmit at any given time. On the same network bus, there may be multiple master devices and multiple slave devices. Each device has a **Device ID** to identify the controller in the same segment of the network and a **Network ID** to identify the network segment in the network bus. Device ID and Network ID are set by the user. Using the MS/TP communication protocol, controllers on the network configure/reconfigure themselves automatically in the network, so hot plugging/unplugging is allowed. All devices on the same network segment receive any transmitted data. The device for which the data is intended responds if necessary.

On the same network segment there can be up to 32 controllers. For more complex networks, with more than 32 controllers and multiple network segments, router devices are used to interconnect the network segments and allow for complex configurations.

Network Topology

A network segment consists of multiple controllers (up to 32) connected with a cable. For robust data communications a **daisy chain topology** is recommended between controllers in the same segment. The following diagram shows the daisy chain topology.

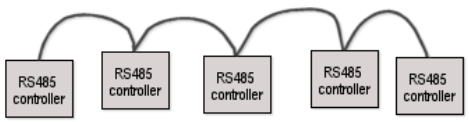

Fig. 1 – Daisy chain topology

For complex applications with more than 32 devices, a **router device** is used to connect between different network segments. Router devices can also link RS-485 networks with other networks, like TCP/IP over Ethernet.

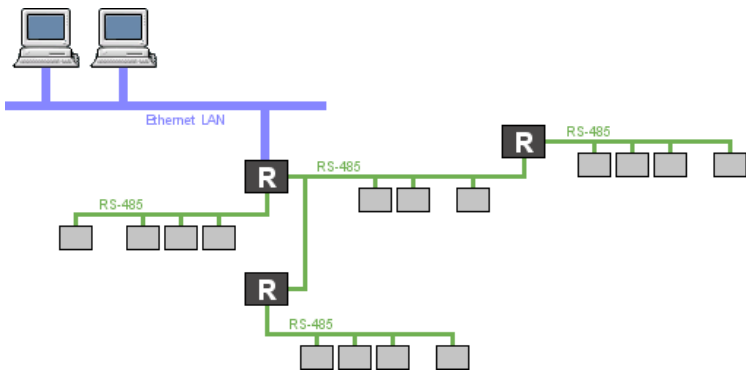

Fig. 2 – Complex RS485 network

Daisy chain connection

In practice, the wiring of a daisy chain topology is most easily implemented by using the MS/TP connector on the device to link the network to the upstream and downstream nodes. This could lead to incorrect wiring, so care should be taken to avoid inadvertently connecting the network in a star configuration. All controllers use the same type of connector for the MS/TP network, a two piece terminal block connector with 3 positions. The connector pinout is shown in the following drawing, as seen from above, with the wire screw input at the bottom side.

Fig. 3 – MS/TP terminal block connector pinout

RS-485 always requires at least **3 conductors**: 2 signal wires (A+ and B-) and 1 signal return path (GND).

In case multi pair twisted pair cable is used, one pair shall be used for A+ and B- signals (blue and white/blue) and one pair for GND (orange + white/orange). Unused wires should be terminated with 100 ohm resistors to ground at both ends of the cable. Connect the A+ wire from the upstream device into the local A+ connector and connect the A+ line for the downstream device into the same pin of the connector. Repeat this procedure for the B– line and GND. See the following diagram for more details:

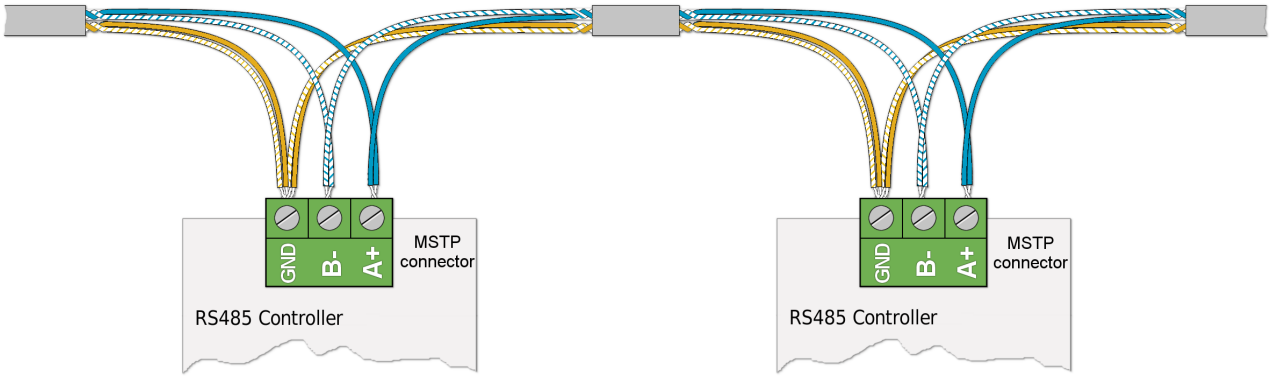

Fig. 4 – Correct daisy chaining arrangement

The length of the untwisted wires from a twisted pair that links to the terminal block connector, should be kept as short as possible.

To wire the connections, carefully strip away about ¼ inch of the conductor insulation, twist tight the two striped wires together, insert them into the correct terminal slot and then fasten the screw. The screws should never be over-tightened as the conductors may thus be damaged.

When controllers shall be interconnected with third party RS-485 devices or integrated in third party MS/TP networks, with different signals naming conventions, '**A+**' is equivalent to '**+**', '**B-**' is equivalent to '**–**' and '**Ground**', '**r**', '**return**' or '⊥' is equivalent to '**GND**'. Care should be taken to avoid incorrectly connecting the 3-wire network. Some third party devices may have different signal naming convention and also different pinout for the MSTP connector (e.g.: " + ⊥ - " instead of "A+ B- GND"). The following diagram shows the correct wiring system according to the EIA-485 standard:

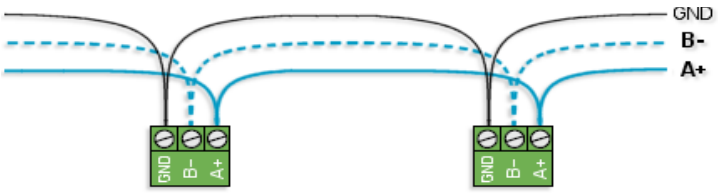

Fig. 5 – "Three wire" wiring for the RS-485 bus

Grounding

Grounding is essential to reliable operation of any RS-485 network. EIA-485 is a three-wire system. The third wire is required so that all nodes on the bus, share a common ground reference connection. This ground wire could be a separate wire or a pair of the twisted pair cable. If shielded twisted pair cable is used (recommended), the shield shall be connected to earth ground only at one end. Recommended bus wiring is shown in the following diagram:

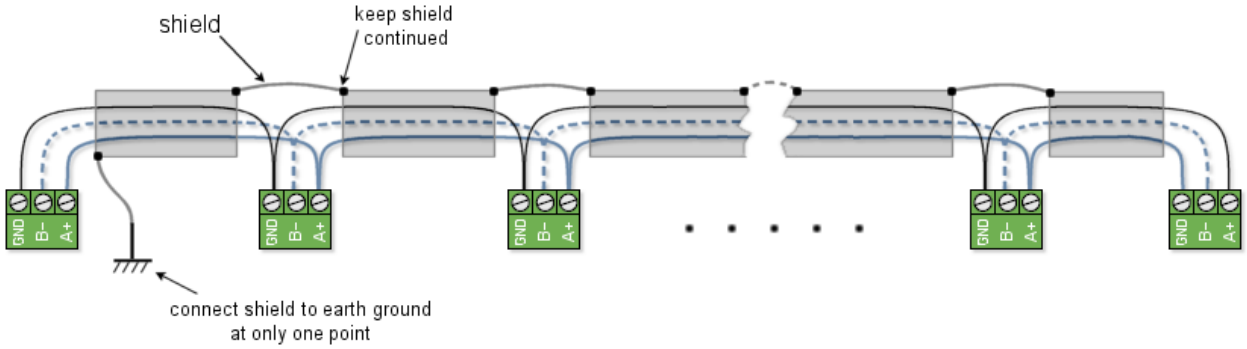

Fig. 6 – Recommended bus wiring

Blue and white/blue conductors must be in the same twisted pair. The black ground wire could be a separate wire or another twisted pair. Preferred method for wiring is a shielded one pair cable with and extra wire used specifically for a ground wire. The advantage to using this wiring method (3 conductor cabling) is you would reduce noise induced through ground potential differences. If the shield is grounded in more than one point, a ground loop is created and leakage ground currents may corrupt data communications.

Though not recommended, the shield of the twisted pair cable could be used to implement the common ground wire (GND).

Termination and fail-safe biasing

The interconnect media for the RS-485 is a transmission line, so reflections may occur due to impedance discontinuity that a traveling wave sees as it propagates down the line. This happens mostly at the end of the cable. A reflection of sufficient magnitude and polarity can result in data corruption and possible damage to the interface circuitry. For this reason, the RS-485 bus must be terminated at both ends of the cable. The termination can be a simple resistor or more elaborate circuit to provide other functions.

RS-485 is a multi-drop bus, meaning that more devices can transmit data, but not in the same time. Thus, an idle line state may occur, when no device is transmitting, placing the line in an unknown logic state. In this idle state, the line could be affected by external noise that could trigger false frame start conditions and affect the overall data communication on the bus. The idle line is even more noise sensitive when terminators are present. Controllers may implement a fail-safe circuit to bias the line to a known state in case of idle line.

Both, the termination and fail-safe bias circuits, are included on each controller and can be enabled/disabled by jumpers. Termination and fail-safe circuits can't be enabled/disabled individually, but only together. Only controllers at both ends of the line shall have the '**TE**' jumpers set to enable those circuits. All the other intermediate controllers on the line shall have the 'TE' jumpers clear, thus the termination and fail-safe bias circuits disabled. The following diagram shows the correct enabling of TE jumpers:

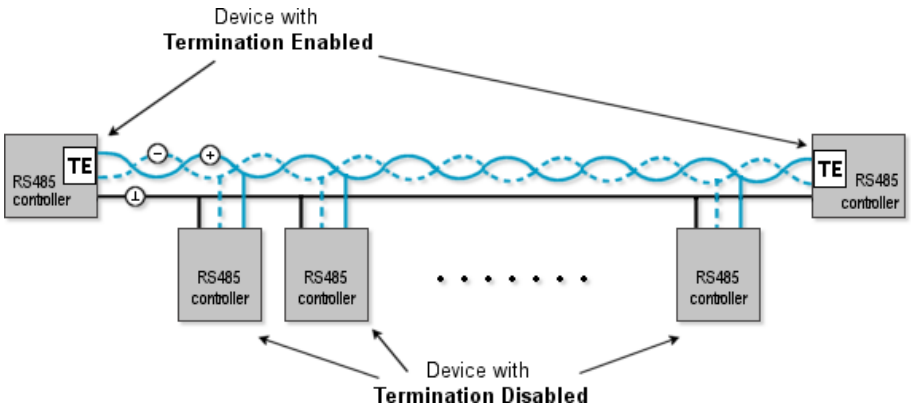

Fig. 7 – RS-485 bus terminated at both ends

Both controllers with termination enabled must be powered on for the fail-safe circuit to work. Line must be terminated at both ends. If one or both controllers with termination enabled are powered off or only one end controller is terminated, may lead to overall communication failure on the RS-485 bus. This situation may occur also if termination is enabled on intermediate devices on the bus. Termination jumpers must be **disabled** for those **intermediate nodes** and **enabled** only for the **two end nodes**. This rule applies also to router devices connected on the bus.

Network segment length in the daisy chain

Minimum cable length between adjacent devices shall be **more than 1 ft** and maximum cable length for a network segment shall **not exceed 4000 ft**. This is required in order to maintain signal integrity, thus keeping the guaranteed high data communication rate.

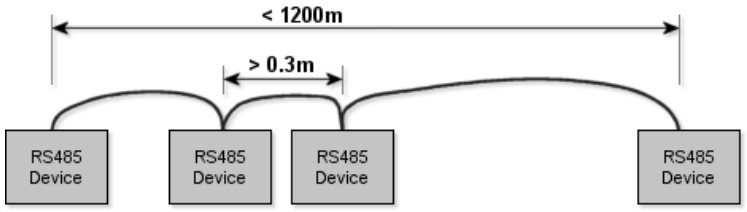

Fig. 12 – Minimum and maximum length requirements for the MSTP daisy chain

For longer cable runs, two network segments of up to 4000 ft each, shall be connected to a router device.

Recommended cable parameters

Cable type	2 pairs
Conductor gauge	≤ AWG 24 stranded
Insulation	foam-polyethylene
Shielded	YES, braided > 80% coverage
Mutual capacitance	< 20 pF/ft @ 1 KHz
Ground capacitance	< 30 pF/ft @ 1 KHz
Characteristic impedance	100 Ω -120 Ω
Conductor DCR	≤ 26 Ω / 1000 ft @ 20°C
Shield DCR	≤ 2.5 Ω / 1000 ft @ 20°C