NOVUS PRODUTOS ELETRÔNICOS LTDA
RUA ALVARO CHAVES, 155
PORTO ALEGRE – RS – BRASIL
90220-040
TEL: +55 (51) 3323 3600
FAX: +55 (51) 3323 3644
info@novus.com.br

RS485 & RS422 Basics

INTRODUCTION

The 422 and 485 standards, as they are known today, are balanced data-transmission schemes that offer robust solutions for transmitting data over long distances and noisy environments. These standards don't specify a logical communication protocol, and are used as the physical layer specification by many protocols such as Modbus, Profibus, DIN-Measurement-Bus and many others.

All Novus products that have serial bus communication follow RS485 standard, due to the advantages it shows in industrial environments. For being so well known all over the world, it is easily accepted.

Besides they have been used for a long while, it is still common to find users with some unanswered questions about RS485 and RS422 based networks. Due to this, we propose this document to present a brief explanation on important topics for the design, analysis and installation of a communication networks using the RS485 and RS422 standards.

TIA/EIA-422

The TIA/EIA-422 standard, known as RS422, describes a communication interface that uses balanced data transmission over multiple pairs of wires to establish communication from one transmitter to up to 10 receivers. At least two twisted-pairs of wires are used, one for communication from the transmitter (usually the master) to the receivers (usually the slaves), and the other for transmission from the slaves back to the master. Since multiple slaves share the same wires for transmission, they must keep their line drivers turned off (in high impedance state) most of the time. When data from a slave is requested, it turns on its line driver, transmit data and turn it off again to allow transmission from another slave. Use of two pairs of wires allows master and one slave to transmit data at the same time, which is called full-duplex operation.

TIA/EIA-485

The TIA/EIA-485 standard, known as RS485, describes a communication interface that uses balanced data transmission over one or two pairs of wires to establish communication between 32 "load units". Usually, each network device (transmitter and receiver) corresponds to one "unit load", thus resulting in a 32 devices network. New devices can have fractional "unit loads", increasing the allowed number of networked devices. RS485 networks usually communicate using a twisted-pair of wires, where data flows in both directions. Each device turns on its line driver only when transmitting data, and keeps it off (in high impedance state) for the remaining time to allow other devices to transmit. Only one device can transmit at a time, which is called a half-duplex operation.

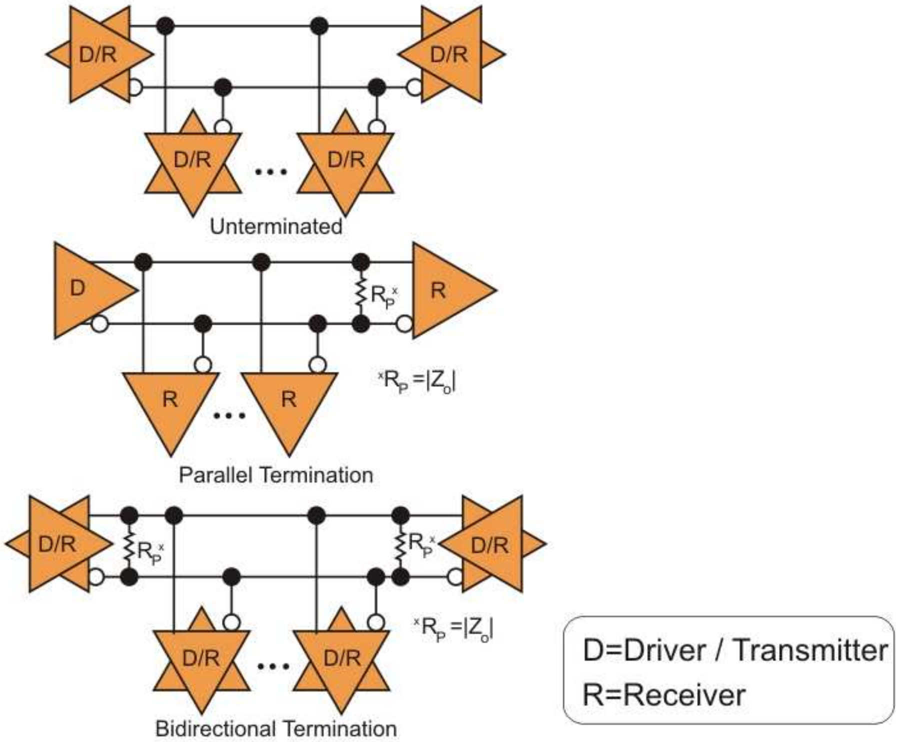
RS485 networks can also operate using 2 pairs of wires, in full-duplex mode, as described for RS422.

BALANCED DIFFERENTIAL LINES

Both RS485 and RS422 use balanced differential lines for communication, usually twisted pairs of wires. Line drivers and receivers for these interfaces use as data information the voltage difference between the two lines of the same pair. Binary data are identified by the polarity of this voltage difference, defining that the data is a logical '1' when the polarity is positive (voltage level in "+" wire is higher than in "-" wire) and '0' when the polarity is negative (voltage level in "-" wire is higher than in "+" wire). A noise margin of ±0.2 V level is defined to enhance noise immunity. The balanced data transmission cancels the induced noise, since the same noise is induced in both conductors of the pair, preserving the voltage difference that carries the information. The radiated noise of a balanced communication bus is also lower than the one of a non-differential bus.

TERMINATION RESISTORS

Communications theory states that a transmission line must be terminated by an impedance that is equal to the line characteristic impedance. Proper termination attenuates signal reflections that degrade transmitted data, increasing the maximum allowed cable length and/or data rate. Some termination methods are presented in the next figure.



Unterminated networks are low power, low cost, and simple to build. The disadvantage, of course, is that data rates must be quite slow or cable length must be short for the network to operate reliably. A network up to 100 m long and communicating at 19,200 bps is expected to be reliable even when no termination resistors are installed.

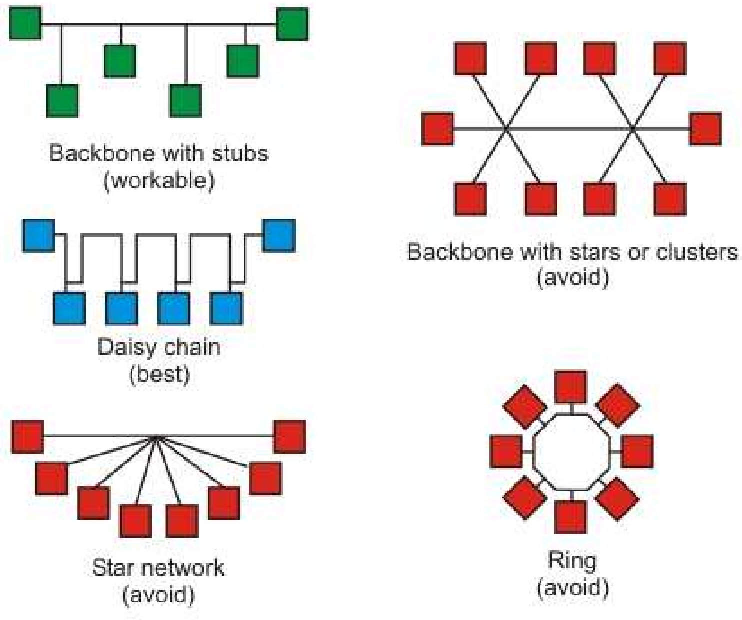
A parallel termination offers excellent data rates but is limited to networks that only have one driver. The driver must be located on one end of the network and the termination resistor must be located on the far end. This is the case for each pair of a RS422 or full-duplex RS485 network.

The third termination technique is a bidirectional termination, which offers excellent signal integrity. With this technique, the line drivers can be anywhere on the network. The disadvantage is power consumption. This technique is probably the most reliable RS-485 termination technique.

The last subject related to termination is what to do with unused conductors in a data cable. Unused conductors will self-resonate and couple noise into the data wires. If the unused cables are left opened, they will resonate at all sorts of strange frequencies. If they are grounded at one end, they will resonate at L/2 (“L” is the cable length). If they are grounded at both ends, they resonate at L/4. The best method for minimizing energy on an unused conductor is to dissipate the energy as heat. In short, terminate both ends of the unused conductor to ground with resistors (a bidirectional termination). The resistors should be equal to the characteristic impedance of the line. Other option is to use a cable with no extra wires.

TOPOLOGY

If the signals on the network are slow, the bit edges are long, and the cable runs are short, topology is not an issue. As soon as transmission-line effects begin to show up, there is only one simple topology for managing them. The following figure shows several network topologies. To avoid signal reflections that cause communication errors, the Daisy Chain topology is recommended.



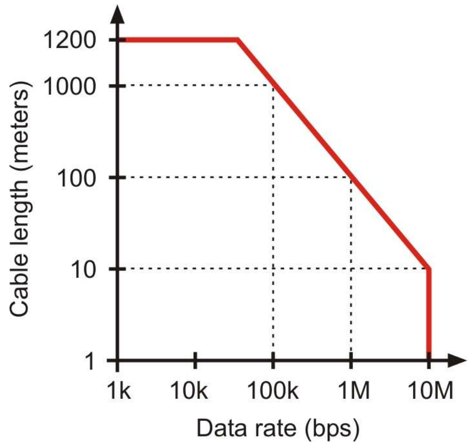
This is not to say, for example, that it's impossible to implement a star configuration with RS-485 devices. Keeping reflections under control in a star topology is more art than science in a practical network. The best way to ensure a robust and reliable RS-485 network is to build it around a daisy-chain configuration.

When a backbone with stubs topology is used, the stub length should be much shorter than the main bus length.

CABLE LENGTH AND DATA RATE

RS422 and RS485 specified maximum cable length is 1200 meters. The maximum working data rate (in bits per second – bps) depends on network devices characteristics, cable capacitance and installed termination resistors. The longer the communication cables, the lower the maximum data rate. As a rule of thumb, no problems are expected when the cable length (in meters) multiplied by the data rate (in bps) is lower than 10^8 (100,000,000), for a well designed and installed system.

The following figure illustrates the length x rate trade-off. System performance will change depending on the cable type, termination, network topology, environment electrical noise and quality of line drivers and receivers in each device.



MAXIMUM NUMBER OF DEVICES IN A RS485 BUS

RS485 standard does not specify the maximum number of devices attached to a bus, but it does a lot of parameters that can be used for calculating this limit. Some of these parameters are:

- Low limit for bus resulting load resistance.
- Load (resistance) value that each device presents to the bus, called “Unit Load” (15 kΩ).
- Minimum current value that the driver (transmitter) of a RS485 device must be able to supply.

Based on these data and considering the need of termination resistors in both ends of the bus (corresponding to 60 Ω), it can be calculated the limit of 32 unit load devices for a RS485 communication bus.

Many new RS485 devices have less than one unit load, usually 1/2, 1/4 and 1/8 of a unit load. By using only 1/8th load devices in a network, it is possible to have up to 256 devices in a terminated RS485 bus.

In smaller applications, where the cable lengths are short and/or the data rate is low, it may be possible to eliminate the termination resistors. This allows the bus device capacity to increase from 32 to 282 devices! Of course, a reliable operation in such condition is not guaranteed at all.

GROUNDING / COMMON WIRE

This topic is the least understood issue in RS485 networking, and cause of most failures and communication errors. Data in differential communication lines is transmitted as a potential difference between the 2 wires of a twisted pair. Binary data is represented as a positive or negative voltage difference between the 2 wires. The voltage difference between any of the wires to a common reference is not important, if maximum limits are respected. This allows that distinct systems communicate even when no common potential is established.

Transmitters and receivers may get damaged if high voltage is applied from any of the wires to a common reference (ground). TIA/EIA-485 specifies this maximum common-mode voltage from –7 V to +12 V, while TIA/EIA-422 specifies limits from –7 V to +7 V. Voltage above these limits are usual when only the communication pair connects multiple isolated devices.

Proper grounding of the networked devices may help, but don’t always solve the problem. In a typical industrial installation, ground potential difference in two locations may be of many volts, rising to hundreds of volts during lightning. The best solution to avoid damage to communication circuits is the use of an additional wire that interconnects all common terminals (ground) of the networked devices.

Use of shielded cable is recommended when cable cost is not an important issue. A properly grounded shielded cable has high noise immunity against external interference (EMI), even when the cable is close to electrical interference sources like frequency inverters, weld machines, contactor coils and AC power cables.

To reduce cabling costs, a non-shielded twisted pair cable may be used, but it should be installed away from these EMI sources.

CONNECTIONS

The appropriate connection of the devices depends on the type of serial network: RS422, 2-wire RS485 or 4-wire RS485. A shielded twisted-pairs cable is recommended for wiring the communication bus from the converter to all network devices. The shield should be grounded and/or connected to the common terminals of all devices. The minimum recommended wire gauge is 24 AWG (0.2 mm^2).

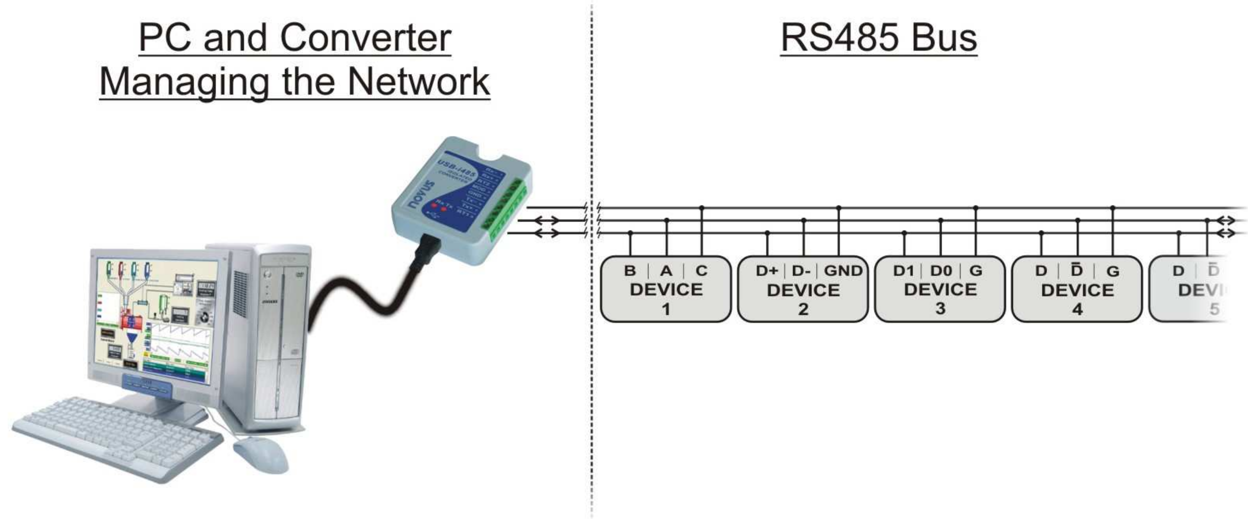
Use of a wire connecting all devices common terminals is highly recommended. Damage of the networked devices may result if this recommendation is not followed.

RS485 or RS422 devices from different vendors or of different models may identify the communication terminals using distinct notation. The following table shows some of these notations and its equivalences.

POPULAR RS485 AND RS422 CONNECTION IDENTIFICATION	D	$\overline{D}$
	D1	D0
	B	A
	D+	D-

HALF-DUPLEX RS485 (2 WIRES)

This is the usual RS485 connection. A single twisted pair is used for data transmission and reception. Multiple RS485 devices are connected in a single bus, as shown in the next figure. Devices from different vendors may use different names for the data signal terminals. In the following figure, different identification schemes are presented for each device.

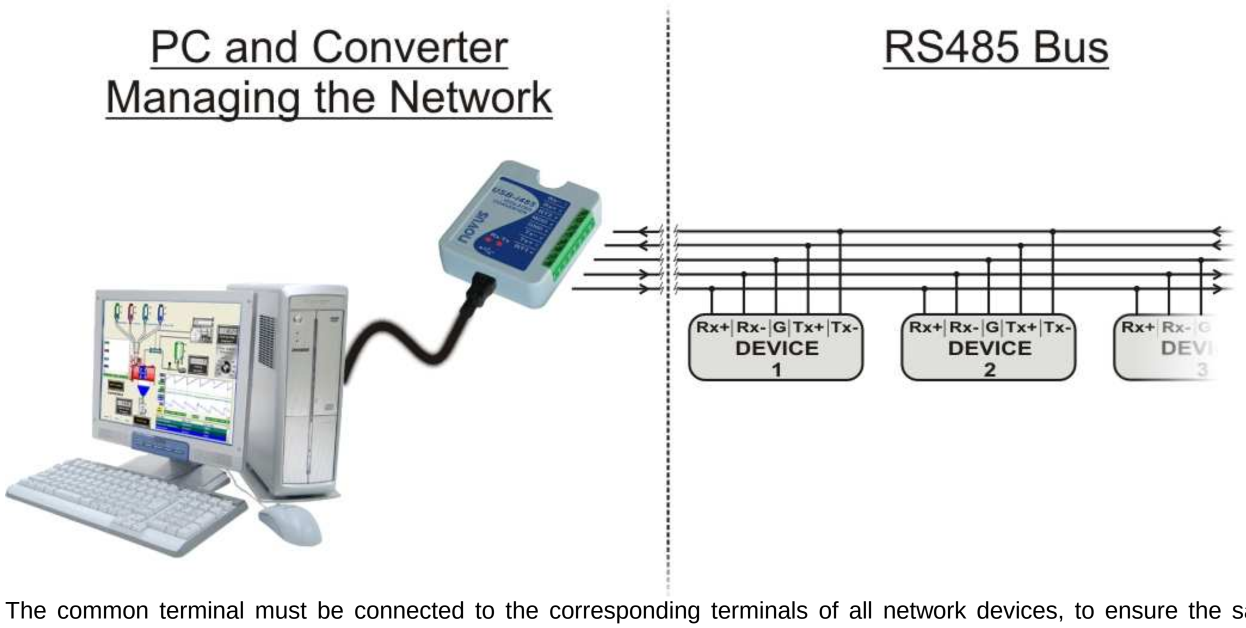


The common terminal must be connected to the corresponding terminals of all network devices, to ensure the same potential in all devices. If a common wire is not connected to all devices, all must be properly grounded according to the manufacturer recommendation. This demand results in using a third wire that, although not being part of the communication process, is essential to ensure the electrical integrity of the network devices.

The need to install termination resistors depends on the total length of the communication bus and the communication speed (baud rate).

RS485 FULL-DUPLEX (4 WIRES)

In this mode two pairs of wires are used. Data from the RS485 converter to the networked devices are transmitted through one pair, and the other pair carries data from the devices to the RS485 converter. Multiple devices are connected as shown in the next figure.



The common terminal must be connected to the corresponding terminals of all network devices, to ensure the same potential in all devices. If a common wire is not connected to all devices, all must be properly grounded according to the manufacturer recommendation. This demand results in using a fifth wire that, although not being part of the communication process, is essential to ensure the electrical integrity of the network devices.

The need to install termination resistors depends on the total length of the communication bus and the communication speed (baud rate).

RS422

Full-Duplex RS485 specification supersedes RS422. The same connection instructions shown for Full-Duplex RS485 apply for RS422 connection.

TECHNICAL REFERENCES

Some parts of this document are based on the following references, where additional information can be obtained:

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Dallas/Maxim Semiconductor. ***Guidelines for Proper Wiring of an RS-485 (TIA/EIA-485-A) Network***. Application Note 763, Jul. 2001.

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Gingerich, Kevin. ***The RS-485 unit load and maximum number of bus connections***. Texas Instruments, 2004.

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