



Introduction to RS 422 & RS 485

1. What is RS 422, RS 485, comparison with RS 232.

RS 232 is well known due to popularity of today's PC's, unlike the RS422 and RS 485. These are used in industry for control systems and data transfers (small volumes, NO hundreds of Mb/s). So, what is the main difference between RS 232 and RS 422 & 485? Voltage levels with respect to ground represent the RS 232 signals. There is a wire for each signal, together with the ground signal (reference for voltage levels). This interface is useful for point-to-point communication at slow speeds. For example, port COM1 in a PC can be used for a mouse, port COM2 for a modem, etc. This is an example of point-to-point communication: one port, one device. Due to the way the signals are connected, a common ground is required. This implies limited cable length - about 30 to 60 meters maximum. (Main problems are interference and resistance of the cable.) Shortly, RS 232 was designed for communication of local devices, and supports one transmitter and one receiver.

RS 422 & 485 uses a different principle: Each signal uses one twisted-pair (TP) line - two wires twisted around themselves. We're talking 'Balanced data transmission', or 'Differential voltage transmission'. Simply, let's label one of the TP wires 'A' and the other one 'B'. Then, the signal is inactive when the voltage at A is negative and the voltage at B is positive. Otherwise, the signal is active, A is positive and B is negative. Of course, the difference between the wires A and B matters. For RS 422 & 485 the cable can be up to 1200 meters (4000 feet) long.

What is the difference between RS 422 and RS 485? Electrical principle is the same: both use differential transmitters with alternating voltages 0 and 5V. However, RS 422 is intended for point-to-point communications, like RS 232. RS 422 uses two separate TP wires; data can be transferred in both directions simultaneously. RS 422 is often used to extend a RS 232 line, or in industrial environments. RS 485 is used for multipoint communications: more devices may be connected to a single signal cable - similar to e.g. ETHERNET networks, which use coaxial cable. Most RS 485 systems use Master/Slave architecture, where each slave unit has its unique address and responds only to packets addressed to this unit. These packets are generated by Master (e.g. PC), which periodically polls all connected slave units.

In Master/Slave architecture, slave never starts the communication. It is critical for Master to send correct addresses.

RS 485 exists in two versions: 1 Twisted Pair or 2 Twisted Pairs.

Single Twisted Pair RS 485

In this version, all devices are connected to a single Twisted Pair. Thus, all of them must have drivers with tri-state outputs (including the Master). Communication goes over the single line in both directions. It is important to prevent more devices from transmitting at once (software problem).

Double Twisted Pair RS 485

Here, Master does not have to have tri-state output, since Slave devices transmit over the second twisted pair, which is intended for sending data from Slave to Master. This solution often allows implementing multipoint communication in systems, which were originally designed (HW as well as SW) for RS232. Of course, Master software needs to be modified, so that Master periodically sends query packets to all Slave devices. Increased data throughput is evident in large volumes.

Sometimes you can see a RS 485 system in a point-to-point system. It is virtually identical to RS 422; the high impedance state of the RS 485 output driver is not used. The only difference in hardware of the RS 485 and RS 422 circuits is the ability to set the output to high impedance state.

2. Balanced differential signals



First, let's talk about advantages and disadvantages of RS 422/485. For a basic RS 422/485 system, we need an I/O driver with differential outputs and an I/O receiver with differential inputs. Noise and interference is introduced into the line; however, since the signal is transferred via a twisted pair of wires, the voltage difference (between A and B) of this interference is almost zero. Due to the differential function of the RS 422/485 input amplifier of the receiver, this interference is eliminated. The same is true for cross-talk from neighboring lines, as well as for any other source of interference, as long as the absolute maximum voltage ratings of the receiver circuits are not exceeded. Differential inputs ignore different earth potentials of the transmitter and the receiver. This is very important for communications of diverse systems, where great problems would otherwise arise - e.g. different power sources, etc. Twisted Pair cables, together with correct terminations (to eliminate reflections), allow data transfer rate of over 10Mbit/s with cables up to 1 km long.

However, all of these advantages come at a cost. RS 422/485 circuits are more complex, and thus more expensive. Higher data transfer speeds require correctly connected and matched terminations, which can be a problem in systems where the number of connected devices changes. And, of course, Twisted Pair cables are required.

In a RS 232 unbalanced data transmission system, a voltage level with respect to ground represents each signal. For example, the TxD signal of a PC COMx port is negative when idle, and switches between positive and negative level when transmitting data. Amplitude ranges between -15 to -5V in negative state, and between +5 to +15V in positive state.

In a balanced differential system, the transmitter generates a voltage between 2 to 7V (approx.) between the A and B outputs. Although the transmitter and the receiver are connected with a ground wire (GND) as well, it is never used to determine logic levels at the AB wires. This implies already mentioned tolerance of different ground potentials of the transmitter and the receiver. RS 485 transmitters have an Enable input, allowing setting the outputs to high impedance state, allowing several devices to share a single TP. RS 422 transmitters usually don't provide such input. Voltage level of most commonly sold transmitters is 0 and 5V. When idle, there is +5V on B and 0V on A.

RS422/485 receivers react to voltage difference between the A and B inputs. If V_{ab} is greater than 200mV, a logic level is defined on the receiver output. For V_{ab} less than 200mV, the logic level is opposite.

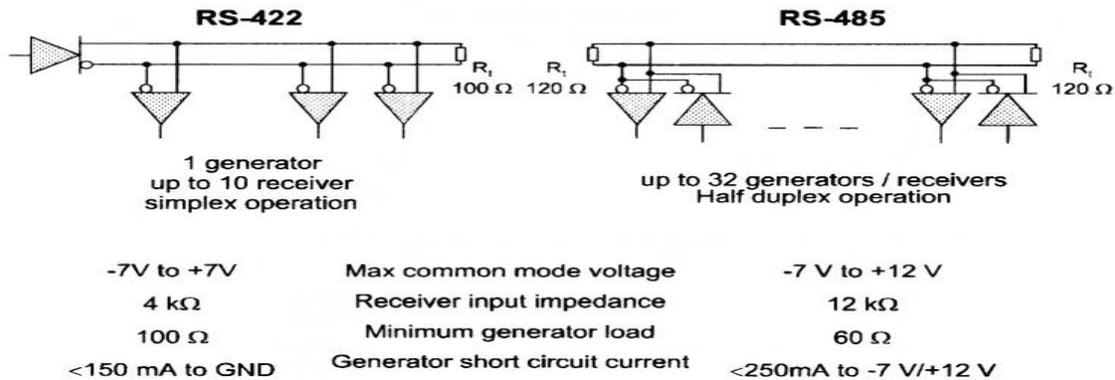
EIA STANDARD RS 422 & RS 485

There are two standards describing balanced interface circuits: EIA-RS 422 (international standard ITU-T V.11) defines point-to-point interfaces with up to 10 receivers for a single transmitter. The limiting parameter is the receiver input impedance $R_i=4k\Omega$. 10 receivers + termination resistor 100 Ohm give the maximum transmitter load.

EIA-RS 485 (ISO 8482) defines the input impedance of RS 485 circuits $R_i = 12k\Omega$. Then, up to 32 transmitters, receivers, or combination, can be connected to a single line. Since the data transfer is bi-directional, the line needs to have a terminating resistor at both ends.



Comparison RS422 - RS485



This picture compares the standards RS 485 and RS 422, summarizes individual values and shows connections of termination resistors.

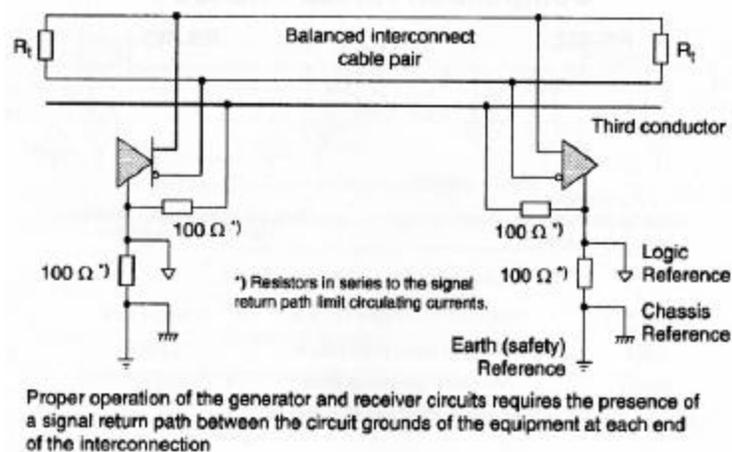
Ground potential difference between different devices is +/- 7V max, according to EIA-RS 422. EIA-RS 485 defines maximum voltage range at the receiver input (ground potential difference + alternating signal voltage) from -7V to +12V. RS 422/485 circuits have a short-circuit protection. Point-to-point (EIA-RS 422) defines short circuit as a current greater than 150mA, between A and B or against the ground. Multipoint (EIA-RS 485) defines short circuit as current greater than 150mA against the ground, or more than 250 mA between A and B.

Ground connection for RS 422/485

For correct operation of the transmitter and the receiver, a return signal path between the grounding of individual devices is required. It may be realized either by a third wire, or by grounding each device (third pole in the mains

socket). If a third (ground) wire is used, resistors (approx. 1kOhm) should be connected in series to eliminate unwanted currents resulting from ground potential differences.

Grounding Arrangement



Proper operation of the generator and receiver circuits requires the presence of a signal return path between the circuit grounds of the equipment at each end of the interconnection

3. Terminations, capacities, cable lengths, and data transfer speed

RS 422/485 line termination is essential, especially for faster data transfer rates and long cables. Main reasons for correct termination are reflections at the ends of the line, and the minimum transmitter load requirement. For RS 422, the termination is fairly simple (see picture comparing RS 422 and RS 485). A terminating resistor of 100Ohm is connected to the end of the line. If there are more RS 422 receivers connected to the line, the resistor can be a little bigger. The value can be calculated since the input impedance of the receivers is known.

For RS 485, the termination is somewhat more complex (again, see the comparison picture). Since each device communicates bi-directionally (single TP version), we are unable to determine where is the transmitter and where is the receiver - this changes constantly, according to which device transmits at the moment. So, both ends of the line have to be terminated with a 120Ohm terminator. However, it is not that



easy. Since all devices have tri-state outputs, situations occur (very often - every time the transmitting device or data direction changes), when all transmitters are in high impedance state, and the line, due to termination resistors, is in undefined state ($V_{ab} > 200mV$). It is, however, desirable to define idle state in this situation ($V_{ab} < -200mV$).

The comparison picture shows a circuit solving this problem with termination resistor values. The values are calculated to allow maximum number of devices (32) with input impedances 12kOhm to be connected to a single line. It is important that there are only two R_t resistors at the end of the cable (they may be inside the last device connected).

Maximum data transfer speeds

Graph showing the dependence of transfer speed on several basic conditions.

1) Maximum data transfer rate over short distances, where the line influence can be neglected, is determined by the output parameters of the transmitter. The duration of the rising and falling edges matters. Standard assumes speed of 10Mbit/s; today's fastest chips, e.g. SN76ALS176, can achieve up to 25 MBit/s.

2) When the line length exceeds 10m, we have to take into consideration losses caused by capacities and the so-called skin effect, when the current begins to flow only on the surface of the conductors. The rule for standard TP cables says, that data transfer speed (Mbit/s) multiplied by cable length (m) is less than 10^8 . So, for example, if a cable is 100m long, we get maximum data transfer speed of 1Mbit/s.

3) Last limitation applies to very long cables. The ohm resistance of the line, and following the signal loss limits speed. Maximum cable length is determined by its resistance, which should be less than the line impedance - 100Ohm. Standard TP cable, diameter 2x0.6mm has a resistance of around 100W/Km. Capacity of the cable needs to be considered as well.

This table is for orientation only, but still very useful:

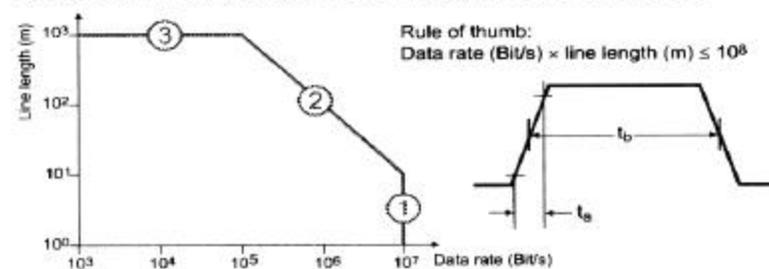
Data transfer speed	1200bd	2400bd	4800bd	9600bd	19200bd	38400bd	57600bd	115200bd
Max. Cable capacity	250nF	120nF	60nF	30nF	15nF	750pF	500pF	250pF

4. Protocols, software

This chapter is short because software is custom-designed for each individual application, including the transfer protocols. RS 422, as a point-to-point connection, operates similarly to the RS 232 serial port. However, there are certain things software needs to take into account. First, the communication media (TP line) needs to be assigned to individual stations, so that there are no collisions and that responses are fast enough.

We have to be aware of the fact, that only a single channel is available for communication. It has to transfer both data and the bit and byte synchronization. For transferring of individual bits, one of the data network modulations can be used, e.g. coding NRZ, NRZI, phase modulation NRZ, or differential phase modulation. These modulations are not covered in this article; they are a topic of network and protocol theory.

Maximum Data Rate in a Balanced Interface



- ① Data rate is limited by the rise time of the output signal of the generator (ITU-T V.11: $t_r \leq 0.1 \times t_b$; ISO8482: $t_r \leq 0.3 \times t_b$).
- ② Data rate is limited due to signal distortion caused by losses on the transmission line (e.g. skin effect).
- ③ Data rate is limited due to the attenuation caused by the ohmic resistance of the wires (a 1000 m twisted pair cable with wires of 0.6 mm diameter has a resistance of $\approx 100 \Omega$).



For byte synchronization, several options are available. Maybe the simplest is to reserve one byte to be a sync character. Software then needs to convert data bytes equal to the sync byte to a sequence of different bytes. Or, protocols SLDC/HLDC, suitable for high-speed transfers, may be used. When an application requires only slower data transfer rates (115200bd, or up to 2Mb/s with special UART circuits), we can take advantage of the RS 232 format for both bit and byte synchronization. This solution saves a lot of effort, especially when a PC is used as Master, and Slave is equipped with a micro controller containing its own UART, e.g. 8051 compatibles.

From a network point of view, the RS 485 incorporates a bus topology. Since Slave stations have no means of starting the communication without a risk of collision, they need to be assigned a 'right to transmit' by the Master station. Assignment is done centrally via pooling, where the central (Master) station periodically asks all Slaves whether they have data to transmit. If so, the questioned station sends the data immediately; otherwise, it replies with a confirmation packet only, or does not reply at all. This method is good for Multipoint systems with smaller number of Slave stations (approx. up to 100). For more stations, the reply would become too slow. Of course, individual system requirements need to be considered. Mentioned 100 stations is for an "on-line" system, where stations have to interactively react to user requests, thus the reply delay needs to be less than 0.5 sec (considered for 115200bd data transfer rate, which is seldom available in industrial environments).

Of course, in systems where the Master has no priority function, or due to other factors (e.g. large number of stations with low frequency of data transfers), different access methods may be used. For example, the random access method ALOHA. Here, any station sends its data regardless of the transfer channel status. If a collision occurs, the station does not receive a confirmation, and repeats transmission. However, this method utilizes on average only about 18% of available bandwidth, and with larger volumes of data the throughput decreases rapidly due to larger number of collisions. With RS 485, where transmitters can at the same time "listen" for the channel status, the ALOHA method can be improved by a "carrier" (data activity) detection. In this case, stations begin transmission only if the channel is idle. Both methods essentially require a transfer protocol with error detection.

In any data transfer, including the RS 485, there is no way to 100% guarantee that a transmitted packet has been successfully received. Especially with the ALOHA methods, collisions may occur; interference, cable length, etc. causes errors too. It is advisable for the communication software to take such situations into consideration. In the central assignment method it is useful for slave stations to send a reply packet with information of last packet received. Several options are available, choice depends on individual use.

5. More than 32 nodes, handy tips, recommended parts

In case an application requires more than 32 devices, there are basically two options. The simpler is to use transmitters with 4 times the input impedance (48k), allowing connecting up to 128 devices at the same time; these are commonly available nowadays. In this case, we have to adapt the whole termination system. The other option is to use a RS 485 repeater. Such a device has two TP ports. When data appear on one of them, the repeater sends them to the other port, and vice versa. In this way, we can connect another 31 (or 127) stations. Data activity detection can be very simple, using the RS 485 definition - $V_{ab} > 200\text{mV}$; or, such a repeater may incorporate its own processor and work as a router as well - like in computer networks.

Several hints:

Don't know which wire is A and B? When idle, B is more positive than A.

You don't always have to use TP cables. For small distances and low speeds, common telephone cables are good enough.

Termination is not critical for small distances and low speeds.