Understanding Some Basic Recommended Standards for Serial Data Communications - A comparison of RS-232, RS-422 and RS-485

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A friend recently remarked that the RS-232 serial port should be dead by now, especially with the proliferation of faster ports such as USB, Firewire, RS-422 and RS-485. Aged it is, dead it is not. RS-232 still has its place and uses and probably will for some time to come. Its low cost and ease of implementation still make RS-232 attractive for relatively low data rate, short-run, applications usually associated with handheld devices and instruments. USB and Firewire fill the gap for high-speed, relatively short-run, heavy-data-handling applications while RS-422 and RS-485 satisfy those high-speed, longer run, applications found most often in industrial settings for plant-wide security and equipment networking.

Because we often discard or overlook what we don't fully understand, it might be a good exercise to take a quick comparative tour of the three widely used serial data communications standards, RS-232, RS-422 and RS-485, each a recommended standard (RS-XXX) of the Electronic Industry Association (EIA) and more recently rebranded as EIA-232, EIA-422 and EIA-485. We will leave USB and Firewire for another venue.

Each of the three mentioned serial data communications standards is unique in performance and application. Distance and data rate have already been mentioned as distinctions of these standards. Other distinguishing factors include electrical signaling techniques, communications modes and network complexity. These will be used to compare and explain the standards as each is considered.

RS-232 (EIA-232)
EIA Recommended Standard 232 was first introduced in 1962 to help ensure connectivity and compatibility across manufacturers for simple serial data communications. Its strongest application was, and still is, peripheral connectivity for PCs, which went beyond modems and printers to many different handheld devices and instruments of today. RS-232's capabilities have been stretched somewhat from the original slow data rate of up to 20 kbps to over 1 Mbps for some applications today. Still, RS-232 is intended for short cable runs, or local data transfers in a range up to 50 feet.

A factor that limits the distance of reliable data transfer using RS-232 is the signaling technique that it uses. It is often referred to as "single-ended". That means that communications occurs over a single wire referenced to ground, the ground wire serving as a second wire. Over that single wire, data bits are represented using negative and positive voltages to create the data low and high states, sometimes called marks and spaces. While this is very adequate for intended applications, it is not suitable for faster and longer applications. Single-ended systems become vulnerable to induced noise, ground loops and ground shifts, a ground at one end not the same potential as at the other end of the cable.

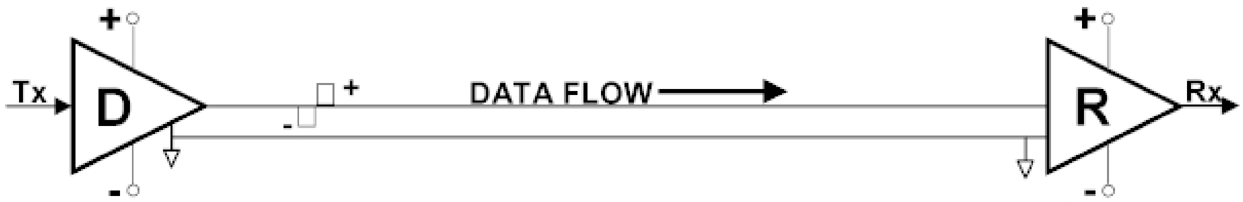

Figure 1: RS-232 – Single-Ended, Unidirectional, Half Duplex

As illustrated in Figure 1, RS-232 is designed for a unidirectional half-duplex communications mode. That simply means you can have a transmitter (driver) feeding data to a receiver over a copper line. Naturally, the data always goes one direction over that line, from driver to receiver. If return transmission is desired, another set of driver, receiver and wires is needed. In other words, if bidirectional or full-duplex capabilities are needed, two separate communications paths are required.

Most applications for RS-232 today are for data connectivity between portable handheld devices and a PC. Such devices require that the RS-232 IC be very small, have low current drain, operate from a +3 to +5-V supply and provide ESD protection on all transmit and receive pins. For example, Intersil's ISL4221E is specifically designed for handheld devices. It supports data rates greater than 250 kbps, operates down to +2.7 V, automatically goes into a standby mode drawing only 150 nA when not in use, provides 15 kV ESD protection on data pins and is in the near-chip-scale 5 X 5 mm quad flat no-lead package.

Today's RS-232 ICs are far more sophisticated and capable than what was first introduced in 1962. New handheld apparatus applications have kept RS-232 employed. To that point, Intersil's family of RS-232 transceivers offers a wide range of selection that includes variations in functions, supply voltage and driver/receiver configurations, all to support new applications.

Thus, you have seen that RS-232 is alive and well, especially for portable and handheld applications. It is for short runs and relatively low data rates, is single-ended and operates half duplex to a single receiver over a two-wire connection. But suppose you need a higher data rate or a greater distance while possibly transmitting to more than one receiver in a fixed, non-portable, application. That's when you might consider RS-422.

RS-422 (EIA-422)

EIA Recommended Standard 422 was designed specifically to overcome the distance and speed limitations of RS-232 and to accommodate multiple receivers. This fits well in process control applications in which instructions are sent out to many actuators or responders. Data lines can be up to 4,000 feet with a data rate around 100 kbps. The maximum data rate is around 10 Mbps for short runs, trading off distance for speed. So, how does RS-422 overcome the speed and distance limitations of RS-232?

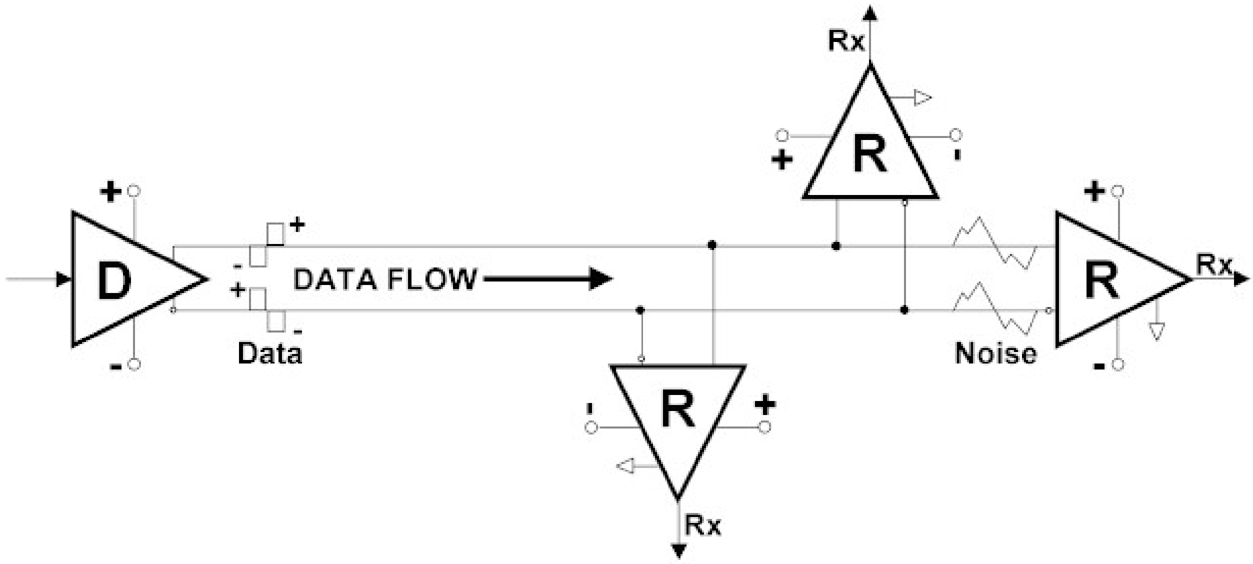

Figure 2: RS-422 – Differential Signaling, Unidirectional, Half Duplex, Multi-drop

As shown in Figure 2, the key is differential data communications, also referred to as balanced differential signaling. The driver uses two wires over which the signal is transmitted. However, each wire is driven and floating separate from ground, meaning, neither is grounded as in a single-ended system. Correspondingly, the receiver has two inputs, each floating above ground and electrically balanced with the other when no data is being transmitted. Data on the line causes a desired electrical imbalance, which is recognized and amplified by the receiver. So called common-mode signals, such as induced electrical noise on the lines caused from machinery or radio transmissions, are, for the most part, canceled by the receiver. That is because the induced noise is identical on each wire and the receiver inverts the signal on one wire to place it out of phase with the other causing a subtraction to occur which results in a 0 difference. Thus, noise picked up by long data lines is eliminated at the receiver and does not interfere with data transfer. Also, because the line is balanced and separate from ground, there is not problem associated with ground shifts or ground loops.

Unlike RS-232, an RS-422 driver can service up to 10 receivers on the same line (bus). This is often referred to as a half-duplex single-source multi-drop network, not to be confused with multi-point networks associated with RS-485 – more on that in a moment. Like RS-232, however, RS-422 is still half-duplex one-way data communications over a two-wire line. If bidirectional or full-duplex operation is desired, another set of driver, receiver(s) and two-wire line is needed. In which case, RS-485 is worth considering.

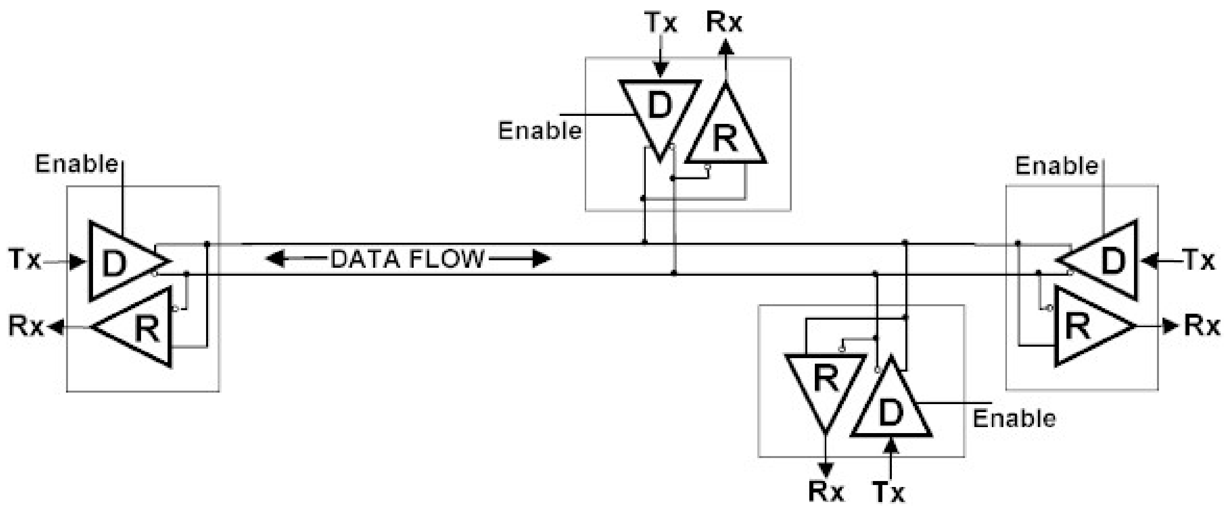

Figure 3: RS-485 – Differential Signaling, Bidirectional, Half Duplex, Multi-point

RS-485 (EIA-485)
EIA Recommended Standard 485 is designed to provide bidirectional half-duplex multi-point data communications over a single two-wire bus. Like RS-232 and RS-422, full-duplex operation is possible using a four-wire, two-bus network but the RS-485 transceiver ICs must have separate transmit and receive pins to accomplish this. RS-485 has the same distance and data rate specifications as RS-422 and uses differential signaling but, unlike RS-422, allows multiple drivers on the same bus. As depicted in Figure 3, each node on the bus can include both a driver and receiver forming a multi-point star network. Each driver at each node remains in a disabled high-impedance state until called upon to transmit. This is different than drivers made for RS-422 where there is only one driver and it is always enabled and cannot be disabled.

Behind the hardware is a protocol that prevents bus contention, two transmitters fighting for the line at the same time. The standard itself specifies up to 32 drivers and 32 receivers on the same bus. That can translate into literally 32 driver/receiver nodes, 1 driver and 32 receivers, 32 drivers and 1 receiver or any combination thereof. With automatic repeaters and tri-state drivers the 32-node limit can be greatly exceeded. It's interesting to note that ANSI-based SCSI-2 and SCSI-3 bus specifications use RS-485 for the physical (hardware) layer.

Table 1 provides a direct comparison of these three serial data communications standards.

	RS-232	RS-422	RS-485
Signaling Technique	Single-Ended (unbalanced)	Differential (balanced)	Differential (balanced)
Drivers and Receivers on Bus	1 Driver 1 Receiver	1 Driver 10 Receivers	32 Drivers 32 Receivers
Maximum Cable Length	50 feet	4000 feet	4000 feet
Original Standard Maximum Data Rate	20 kbps	10 Mbps down to 100 kbps	10 Mbps down to 100 kbps
Minimum Loaded Driver Output Voltage Levels	+/-5.0 V	+/-2.0 V	+/-1.5 V
Driver Load Impedance	3 to 7 kΩ	100 Ω	54 Ω
Receiver Input Impedance	3 to 7 kΩ	4 kΩ or greater	12 kΩ or greater

Table 1: Quick Comparison

Some of today's RS-485 drivers and receivers have capabilities that exceed the original standard. As applications demand higher data rates, manufacturers such as Intersil offer RS-485 transceiver ICs that meet the challenge. Intersil's new ISL4485 provides data rates up to 20 Mbps, twice the standard specification and can be used for both RS-422 and RS-485 for short-run applications. For long-run applications in the thousands of feet, the data rate is slowed and slew-rate limited drivers are often used to preserve signal shaping and to ensure communications reliability. Intersil's ISL8483 is an example of a slew-rate limited RS-485/422 transceiver IC that offers a data rate of 250 kbps for long runs or for modest applications.

	RS-232	RS-422	RS-485
Multi-drop		**X**	**X**
Multi-point			**X**
Low Rate Short Run	**X**		
High Rate		**X**	**X**
Long Run		**X**	**X**
Noise Immune (differential)		**X**	**X**
Unidirectional	**X**	**X**	
Bidirectional			**X**
Two-Wire Bus Half Duplex	**X**	**X**	**X**
Two-Wire Bus Full Duplex			
Four-Wire Bus Full Duplex	**X**	**X**	**X**

Table 2: Applying the Standards

This brings us back to where we began. The application dictates which serial data communications standard to employ. Table 2 summarizes and relates the standards to application requirements. Choosing which standard to use isn't difficult if you understand the merits of each. And yes, there is still plenty of room for the elder statesman, RS-232.