Limitations of long distance data links

DESIGN BRIEFING

RS232 is the dominant standard for serial data transmission. But its limitations have been highlighted by attempts to use it over longer distances, at higher data rates and in electrically noisy environments. Martin O'Hara reports.

The simplest form of serial data link is single ended (unbalanced) using a signal wire and a ground return, like RS232. This system is susceptible to the effects of line impedance and signal loss and hence is usually restricted in its maximum cable length and data transmission rate (see table 1). Despite these limitations, the system is easily and cheaply implemented and maintained, since it requires only two wires – hence its popularity.

In RS232, the signal voltage level is typically ±12V (up to ±15V). However, the interface circuitry must differentiate between +3V as a high data value (logic '1') and -3V as a low data value (logic '0'). The first problem of RS232, therefore, is generating the necessary supply rails from a cmos or ttl system. There are several possible solutions. If a low drive current is required, typically over a short shielded serial connection, a high sided charge pump circuit can be used. Several serial interface ics for RS232 have charge pump circuits integrated with the interface buffers (Maxim's MAX232 or Linear Technology's LT1180, for example). If a long cable and a high data rate are required, a dedicated dc/dc converter may be a better solution to generate ±12V (Newport's NMA0512M, for instance).

On paper, the RS423 single ended interface standard looks superior to RS232 since it uses the signal common as a differential input at the receiver. However, there are other design constraints to be considered.

The RS423 is also an unbalanced standard: slew rate control may have to be used to limit cross talk at high data rates. The extra design considerations and expense that this involves have limited RS423's popularity.

In differential serial data transmission, two wires act as signal and return.

The difference between the signals at the receiver defines the state. Absolute voltage values are less important than in single ended systems.

The benefits of using a differential signal are that noise immunity is improved, transmission length can be extended, higher data rates can be achieved and common mode ground voltage shift rejection is superior.

One of the first standards for differential serial data interfacing was the RS422. This is unidirectional but is not suitable for party lines since there is no inherent driver control circuit.

The RS485 standard is a development from RS422 (in general, most RS485 compatible circuits would satisfy RS422 standards also). The major advantages over RS422 are higher common mode rejection at both driver and receiver and the facility to connect up to 32 drivers and receivers on a party line. Having a driver control allows the interface to be easily wired as a transceiver and operate under half duplex conditions. For unidirectional communication the cabling cost of RS485 is half that of RS422.

For correct operation of a differential line, there must be a common ground reference between receivers and transmitters to prevent the receiver circuits saturating. Therefore, with twisted pair cabling, a grounded

Serial interface interconnection diagrams

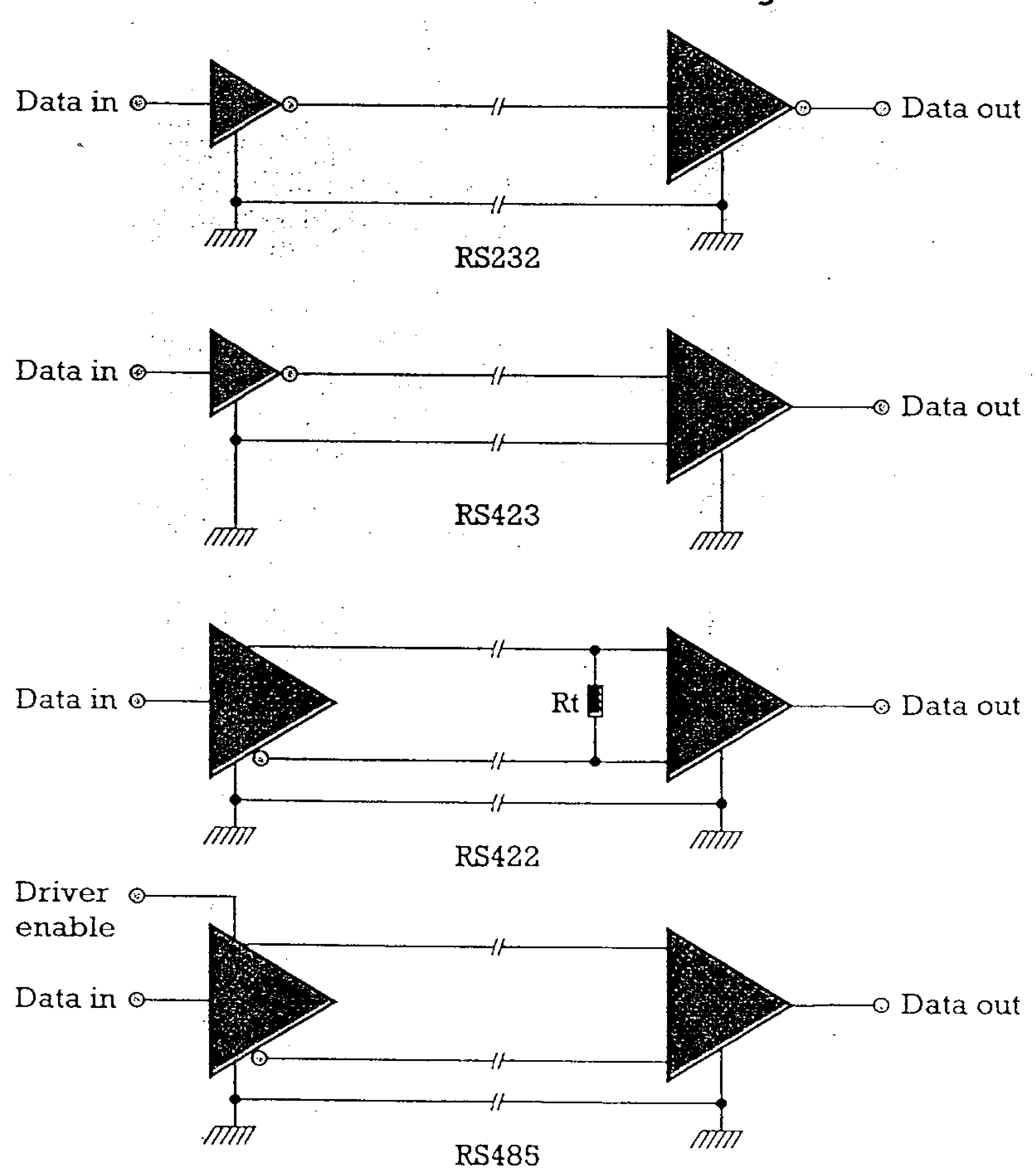

Table 1: Interface Standards Comparison

Parameter	RS232	RS423	RS422	RS485
Mode of operation	single ended	single ended	differential	differential
Number of drivers & receivers allowed on line	1 driver 1 receiver	1 driver 10 receivers	1 driver 10 receivers	32 drivers 32 receivers
Maximum cable length (m)	15*	1200	1200	1200
Maximum data rate (Bits/sec)	20k	100k	10M	10M
Maximum common mode voltage	±25V	±6V	+6V −0.025V	+12V −7V
Driver output signal	±5V min ±15V max	±3.6V min ±6.0V max	±2V min	±1.5V min
Driver load Resistance Capacitance	3kΩ - 7kΩ 250pF max	450Ω min	100Ω	60Ω
Driver slew rate	30V/μs max	Determined by cable length & data rate	N/A	N/A
Driver output resistance	300Ω min	N/A	N/A	N/A
High Z state	300Ω min	±100nA max	±100nA max	±100nA max
Receiver resistance	3kΩ - 7kΩ	<4kΩ	<4kΩ	<12kΩ
Receiver sensitivity	±3V	±200mV	±200mV	±200mV

*typical value determined by cable capacitance per unit length.

Design Tips

Methods of reducing noise in serial data links:

- An isolated RS232 (such as Newport's NM232DD or Maxim's MAX252) can give a cheap wiring method for local data transfer in noisy environments and provides a simple single chip solution.
- In a multipoint system isolate any party terminals in a noisy environment, as these might otherwise pollute the line.
- Isolating signal wires at transmitter and receiver means that only common mode noise can affect the system.
- Limiting slew rate reduces induced cross talk between lines
- Restricing line length effectively reduces the receiving aerial which may pick up radiated interference and reduces capacitive coupling.
- Shielding signal conductors will reduce the level of noise reaching the signal conductor.
- Using low impedance ground wires reduces system noise and ground voltage offset.

shield should also be connected. Consequently differential serial data interfaces require at least a 3 wire cable.

Table 1 (above) illustrates the choice of a standards. For long distance transmission at high data rate, a differential standard is best, whereas for short distance links a cheaper solution may be possible using an unbalanced interface standard. However, as with most things in life, there are always exceptions to the rule.

In a relatively noise free electrical environment (most offices, for example), an unbalanced serial interface should be adequate. Links up to 15m in length are tolerable even using relatively cheap cable, providing adequate drive power is available at the transmitter. Longer lengths may be possible by using cable with low capacitance and resistance. However, there is a trade off between the cost of the high quality wire and that of a differential system which can use cheaper cable.

In theory, the RS423 single ended standard should be capable of transmitting on cables up to 1200m in length. The reality is that this can only be achieved at a low data rate (less than 6kbits/s). A more practical distance, for the 100kbits/s full data rate, is 80m with linear wave shaping.

The extra cost of high quality cable and the reduction in achievable baud rate often eliminate single ended standards from long distance use. If cable cost is a major factor and a low data transfer rate can be tolerated RS423, may be a possible solution in a quiet environment up to 1200m.

The choice of differential techniques for long distance transmission (typically up to 1200m) will depend on the requirement for party line or a non-reversible systems. Since the cost differences are often small, RS485 is preferred as this has the potential for multipoint systems at a later date while allowing the RS422 standard to be implemented immediately (note: the common mode performance of most receivers is better for RS485 than RS422). The major problem with a very long distance differential system will be differences in localised ground voltages (the problem is even more critical in single ended systems). Over the full length of a serial data line, ground voltage differences will reduce the signal levels at the receivers. This increases the signal susceptibility to electromagnetic interference.

In an electrically noisy environment (close to rotating equipment, switch gear or high voltage cabling, for instance) a differential standard is preferable due to its inherent common mode rejection. There are some instances where the lower sensitivity of RS232 is sufficient and there are several methods that can be employed to improve the noise immunity of whichever standard is used. (See panel on left) □

Martin O'Hara is development manager at Newport Components, Milton Keynes

Newport Components, Milton Keynes	Enter 230
Linear Technology, Camberley	Enter 231
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