DESIGN SOLUTIONS

INTERFACE

RS-485: Overcome the Speed vs. Distance Challenge

Introduction

As modern industrial environments become ever larger and more complex, production engineers are presented with more challenges in the design and layout of automated industrial process control systems (Figure 1).

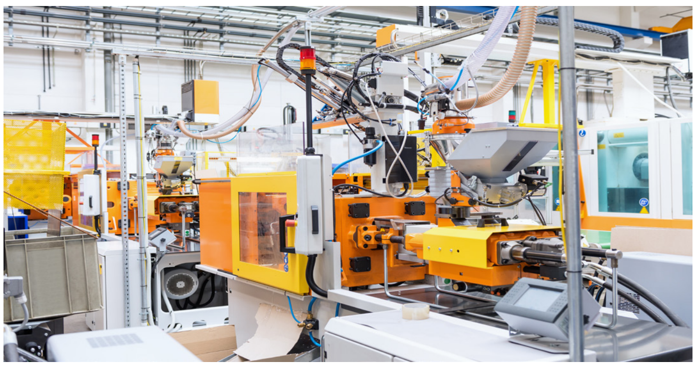

Figure 1. Automated Process Control System

The distance and speed at which control and measurement signals must travel continue to increase. For over twenty years, common industrial network protocols such as PROFIBUS have used the RS-485 standard for transmission of electrical signals across physical media. However, as these network protocols have developed and evolved, the original RS-485 specification is being pushed to its limits (and beyond). In this design solution, we briefly review the original RS-485 specification, consider its relative strengths and weaknesses and present a new solution which allows RS-485 to meet the demands of modern industrial network protocols, thereby extending its usefulness for the foreseeable future.

The Original RS-485 Specification

The ANSI/TIA/EIA-485-A-1998 (commonly known as RS-485) standard was approved in March 1998. RS-485 is a bidirectional, half-duplex standard featuring multiple "bussed" drivers and receivers, in which each driver can relinquish the bus. RS-485 is an electrical-only standard (physical layer) using differential signaling for noise immunity, typically on a balanced transmission cable such as unshielded twisted pair (UTP). With a -7V to +12V bus common-mode range, receiver input sensitivity is ±200mV, which means that to recognize a "mark" (logical 1) or "space" (logical 0), a receiver must see signal levels above +200mV or below -200mV. Maximum receiver input impedance is 12kΩ, and the driver output voltage is ±1.5V minimum, ±5V maximum. Table 1 lists the key specifications in the original RS-485 standard.

RS-485 Standard	
Mode of operation	Differential, Half and Full Duplex, Multipoint
Allowed no. of Tx and Rx	32 Tx, 32 Rx
Maximum cable length	4000ft (1.2km)
Maximum data rate	10Mbps
Minimum driver output range	±1.5V
Maximum driver output range	±5V
Maximum driver short-circuit current	250mA
Tx load impedance	54Ω
Rx input sensitivity	±200mV
Maximum Rx input resistance	12kΩ
Rx input voltage range	-7V to +12V
Rx logic-high	>200mV
Rx logic-low	<200mV

Table 1. Original RS-485 Specification

RS-485 Advantages and Disadvantages

RS-485 is commonly used for signal transmission between equipment in industrial environments because of its differential nature, which ensures high noise immunity in the harsh and noisy electric/magnetic fields in a factory setting. However, while the original standard was defined to operate at speeds up to 10Mbps, and at distances up to 1.2km, these could not be simultaneously achieved. The maximum data rate is achievable over relatively short distances (10m to 15m). A rule of thumb to estimate the trade-off between the data rate and distance is that the product of the data rate, in bits-persecond, and distance, in meters, should not exceed 1 × 10^8. The requirement of industrial network protocols to operate at increasing data rates means that designers of modern RS-485 transceivers have pushed the original specification well beyond its original limit. It is not uncommon for modern transceivers to work at speeds that are multiples of the original specification, for example 30Mbps to 40Mbps. These data rates are only achievable over relatively short distances (on the order of a few meters). However, the scale and complexity of modern process control systems requires signals to travel at higher speeds over medium distances (up to 100 meters). This has not been achievable using RS-485.

Higher Speeds Over Longer Distances

The MAX22500E RS-485/RS-422 transceiver (Figure 2) has quite literally changed the accepted status quo of what has been achievable with RS-485 by at least an order of magnitude. As illustrated by the differential voltage levels of approximately ±2V (measuring well above the minimum ±200mV specified in the standard) in the eye diagram illustrated in Figure 3, the MAX22500E achieves an unprecedented data rate of 100Mbps over ten meters of Cat5e cable (and potentially over even longer distances depending on the choice of cable selected).

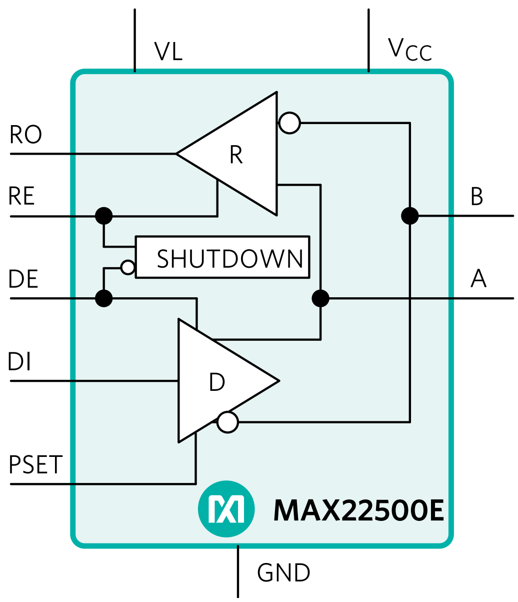

Figure 2. Functional Diagram of the MAX22500E

While this level of speed is impressive by itself, Figure 4 illustrates that not only are high speeds possible over relatively short distances (on the order of tens of meters), but the MAX22500E is also capable of data transmission rates of up to 50Mbps over 100 meters of cable. Although not quite as distinct as in Figure 3, the opening of the eye (approximately ±0.7V) is still greater than the minimum voltage levels defined by the original RS-485 standard.

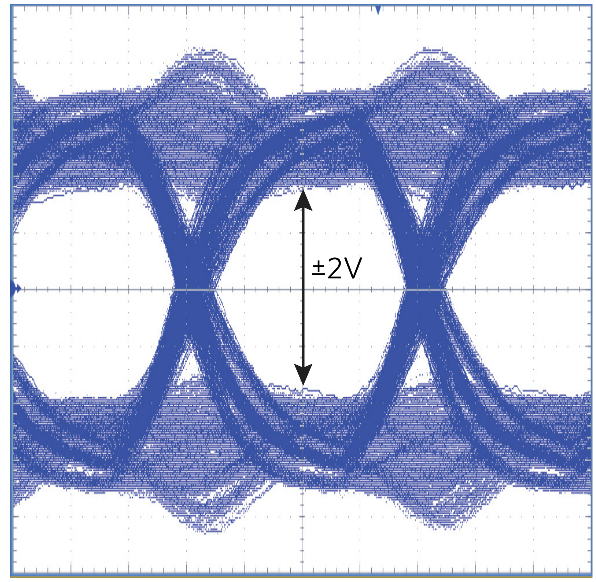

Figure 3. MAX22500E Operating at 100Mbps Over 10m Cat5e (Scale of 2.5ns/div)

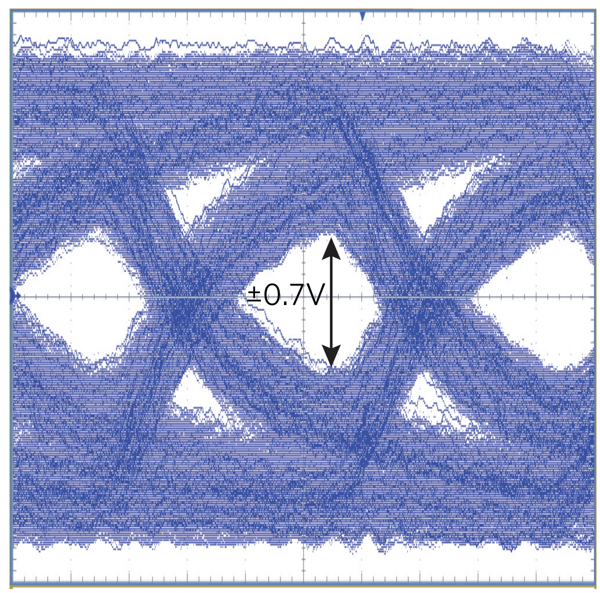

Figure 4. MAX22500E Operating at 50Mbps Over 100m Cat5e (Scale at 5ns/div)

By using a technique called "pre-emphasis," the performance of the transceiver over longer distances can be improved further, as illustrated in Figure 5. The speed and distance is the same as for Figure 4, but enabling the pre-emphasis feature increases the voltage levels so that the opening of the eye in the diagram is visibly more distinct.

The ability to enable pre-emphasis for data transmission over longer distances provides equipment designers with an extra degree of flexibility in achieving their desired level of speed-vs-distance performance using the RS-485 interface.

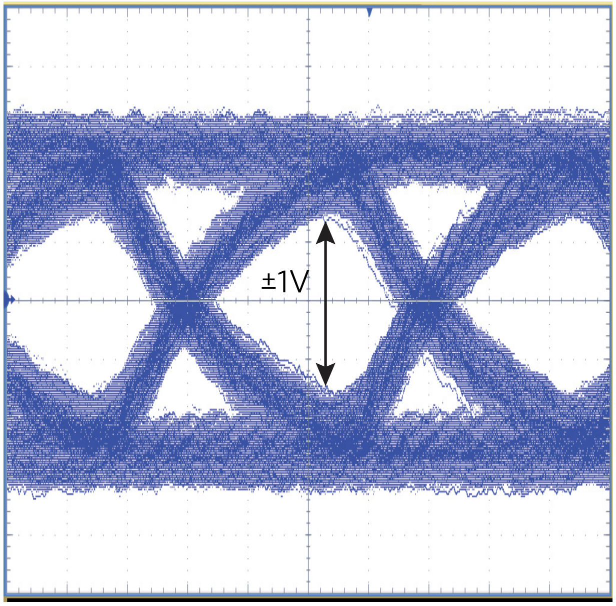

Figure 5. MAX22500E Operating at 50Mbps Over 100m Cat5e with Pre-emphasis Enabled (Scale at 5ns/div)

Features of the MAX22500E

Apart from the MAX22500E's increased speed times distance product (at 10^9, which is a factor of 10 improvement over previous transceivers), other notable benefits of this IC include integrated protection to increase its immunity to ESD. This includes a -15V to +15V common-mode range, ±15kV ESD protection (Human Body Model), ±7kV IEC 61000-4-2 Air-Gap ESD protection, ±6kV IEC 61000-4-2 contact discharge ESD protection, and short-circuit protection of the driver outputs. The device operates over a 3V to 5.5V supply range to maintain compatibility with legacy systems. It also operates with a low-voltage logic supply down to 1.6V for easy interfacing to low-voltage microcontrollers without the need for voltage translation. A variation of the MAX22500E without pre-emphasis is the MAX22501E, available for applications that do not have the same distance requirements. Another member of this family, the MAX22502E, provides full-duplex data transmission, if required. In addition to industrial control systems and fieldbus networks, these ICs are also suitable for applications that include motion control, encoder interfaces, and backplane buses.

Conclusion

In this design solution, we have reviewed the strengths and limitations of the RS-485 standard as a physical layer communications standard. We can conclude that although it is robust and reliable, there is a significant trade-off to be made between the speed and distances attainable using RS-485. The MAX22500E RS-485 transceiver (and other similar parts in the family) provides reliable transmission of data up to 100Mbps over 10 meters of cable and up to 50Mbps over 100 meters in either full- or half-duplex mode. This means that designers of industrial automation and control equipment can confidently plan for the continued use of RS-485 as a communications interface for the foreseeable future.

Glossary

PROFIBUS: (Process field bus) is a standard for fieldbus communication in automation technology and was first promoted in 1989 by BMBF (German department of education and research) and then used by Siemens.

ESD: Electrostatic discharge. Release of stored static electricity. Most commonly, the potentially damaging discharge of many thousands of volts that occurs when an electronic device is touched by a charged body.

Pre-emphasis: In some transmission and recording systems (e.g. vinyl records, FM radio, analog magnetic tape), there is more noise at higher frequencies. To offset this, the audio signal is "pre-emphasized" at the transmitter—filtered with a highpass filter to boost the higher audio frequencies. A matching lowpass filter is used at the receiver to return to an overall flat audio-frequency response. The filter at the receiver reduces the high-frequency noise introduced by the transmission process.

IC: Integrated circuit

Learn more:

MAX22500E 100Mbps Half-Duplex RS-485/RS-422 Transceiver with Pre-Emphasis for Long Cables

MAX22501E 100Mbps Half-Duplex RS-485/RS-422 Transceiver for Long Cables

MAX22502E 100Mbps Full-Duplex RS-485/RS-422 Transceiver with Pre-Emphasis for Long Cables

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