RS-485 Serial Data Communication
Physical Layer for Factory Automation and Process Control Networks

by Mark E. Hazen, High Performance Analog
Intersil Corporation

Today, there are some predominant and widely-deployed factory automation and process control networks, such as PROFIBUS and Field Bus, which employ RS-485 (EIA-485) serial data communications transceivers, and the 485 standard, in the physical layer. These transceivers enable control of manufacturing and other processes over a wide area, such as the factory floor (field), from a central computer control station. The simple twisted-copper-pair network wire (bus) snakes its way around the plant (field) throughout the machinery to a host of sensors and actuators that the computer uses to direct and syncopate a myriad of operations that yield a final product. Already you can see the derivation behind the popular network name, Field Bus.

The elegance of such a network is found in its low cost, simplicity, extensibility and very high noise immunity, in addition to the tremendous selection of sensors and actuators readily available to bring the network online quickly. PROFIBUS is an industry name coined from Process Field Bus. The PROFIBUS association is made up of over 1200 members internationally and is responsible for thousands of software and hardware network automation products.

The Electronics Industry Association (EIA) Recommended Standard (RS) number 485 is the foundational hardware fabric for Field Bus networks. It is designed to provide bi-directional half-duplex multi-point data communications over a single two-wire bus. Full-duplex operation is accomplished using a four-wire, two-bus, network that completes the process loop from sensor to processor to actuator, and so on. The data bus can be up to 4000 feet in length with a data rate at approximately 100 kbit/s. The maximum data rate is 10 Mbit/s, or so, for short runs, trading off distance for speed.

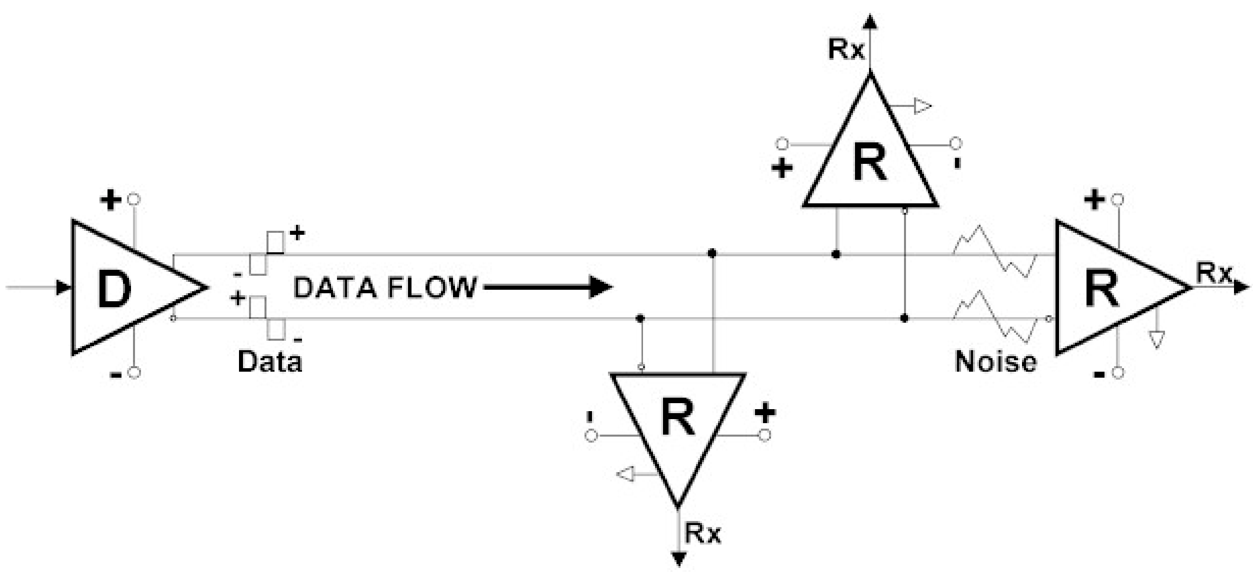

Fig. 1: Differential Signaling In A Multi-Drop RS-485-Based Network

As shown in Fig. 1, RS-485 drivers and receivers use 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.

Differential 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 virtually 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 yields a zero net result, or noise signal cancellation. Thus, noise picked up by long data lines is eliminated in the receiver and does not interfere with data transfer. Also, because the line is balanced and separate from ground, there are no problems associated with ground shifts or ground loops that would normally occur in unbalanced systems.

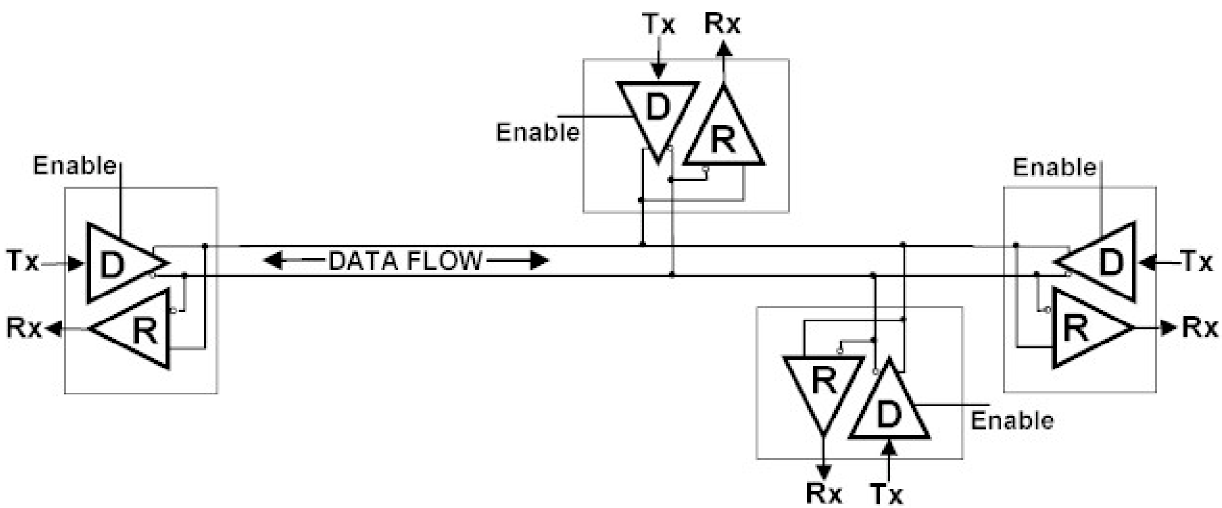

Fig. 2: RS-485; Differential Signaling, Bi-directional, Half-Duplex, Multi-point

The RS-485 standard allows multiple drivers (Tx) and receivers (Rx) on the same bus. As depicted in Fig. 2 each node on the bus can, but may not always, include both a driver and receiver forming a half-duplex multi-point star network. Each driver at each node remains in a disabled high-impedance state until called upon to transmit.

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. Behind the hardware is a software protocol that prevents bus contention, two transmitters fighting for the line at the same time. As mentioned earlier, if full-duplex operation is desired, a four-wire dual-bus network is used and separated drivers and receivers form the nodes. Those transceivers shown in Fig. 2 are not suited for full duplex because bus pins to the IC are shared between Tx and Rx, making it impossible for them to perform both functions at the same time.

In many applications, 32 nodes are insufficient. To avoid the cost and complexity of laying in additional network buses, fractional-unit load transceivers can be used to expand the number of nodes across the field (on the bus) without threatening bus operation or data integrity. Fractional-unit load transceivers have receivers whose input impedance is higher than the standard single-unit load (>12 kΩ) and, therefore, offer less loading to the bus. For example, Intersil's LinearLink ISL81487 is a one-eighth ($1/8^{th}$) fractional-unit load transceiver that, if used exclusively on the bus, will allow up to 256 nodes (8 X 32). This IC provides a cost-effective means of expanding an installed network or of designing an extended network.

Many networks today, such as PROFIBUS, require higher data rates than specified by RS-485. Recently, IC manufacturers have started to offer faster transceivers to satisfy this need. As an example, Intersil has introduced an ultra-high-speed half-duplex transceiver family starting with the ISL4486 that provides data rates as high as 40 Mbit/s and the industry's widest voltage differential of 2.5 V, as measured across a standard 54-Ω load. That is 0.4 V higher than the PROFIBUS standard requires, which enhances data integrity over longer runs at higher speeds. Intersil's ISL81486 is a 30 Mbit/s transceiver that offers a pin-for-pin performance upgrade from other products of similar nomenclature. Both transceivers are 0.6 fractional-unit load devices with a minimum input resistance of 20 kΩ that allows up to 50 nodes on the bus.

The modern automation and process control network has evolved from a cumbersome and inflexible centralized multi-wired bird's-nest-meshed nightmare to a sleek, streamlined and easily extensible network based on the RS-485 physical layer standard. Recent RS-485 transceiver performance improvements have further enhanced expandability and network speed. Building from these foundational hardware products, associations and manufacturers have developed standard software protocols and a myriad of plug-and-play products to rapidly implement automation and process control networks.

About The Author

Mark Hazen is an electronics engineer and author of several college-level engineering textbooks such as *Exploring Electronic Devices*. He is currently a manager serving Intersil's High Performance Analog Products Group.

Further Information

Intersil Interface Products: http://www.intersil.com/interface/
PROFIBUS International: http://www.profibus.com
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Intersil Corporation
2401 Palm Bay Rd. NE
Palm Bay, FL 32905
1-888-468-3774

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