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Electronic Design

Industrial Ethernet Adapts to the Times

Sponsored by Texas Instruments: A smaller, less-expensive, faster, and lower-power Industrial Ethernet PHY widens the technology's reach.

If you're planning to install a new wired network, most of you would agree that the only viable choice is Ethernet. Over the past 45 years, this IEEE 802.3 standard has outlasted all other computer networks to achieve worldwide dominance. Because of its variety and flexibility, Ethernet covers just about every networking need.

Thanks to the IEEE 802.3 working group, the standard has been continuously developed and updated. And the presence of multiple vendors of Ethernet gear continues to keep prices of components and equipment reasonable.

One special version of Ethernet receiving fresh attention is Industrial Ethernet. While Ethernet isn't perfect, the Industrial version is growing and finding its way into new environments like building automation. On top of that, the availability of new ICs helps mitigate one of Ethernet's toughest problems—latency—making it ever more useful.

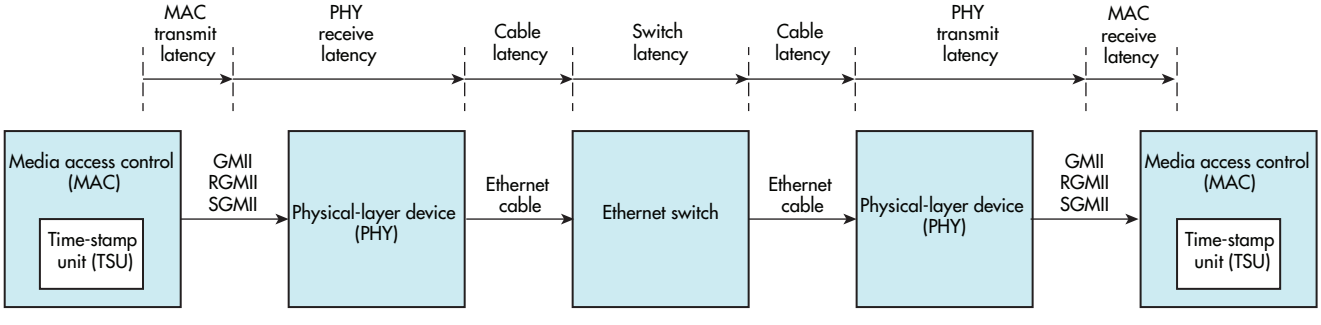
Industrial Ethernet Overview

Industrial Ethernet is primarily a ruggedized and heavy-duty version of standard Ethernet. Typical Ethernet equipment is made for offices and general uses. Industrial Ethernet employs cabling and equipment that's protected from the harsh conditions.

The factory floor, process control plants and industrial settings in general are dirty and loaded with other troublesome problems—extreme temperatures both hot and cold, dust, moisture, hazardous chemicals, and occasional exposure to physical stresses and vibrations. Industrial Ethernet overcomes these problems with special wiring and connectors (IP67 shielded RJ45 or M12) that keep out moisture and dirt. Ethernet switches and other equipment are packaged to withstand the punishing conditions of industrial settings.

Most Industrial Ethernet uses the 100Base-TX 100-Mb/s version (802.3u) on CAT5e or CAT6 cable. Some systems use the 1000Base-T (802.3ab) version, where the 1-Gb/s rate is needed. Network topology is typically a star. All operations are half duplex using the CSMA-CD access method. This access method makes Ethernet non-deterministic, a quality undesirable in some industrial applications.

During the past few decades, Industrial Ethernet has gradually replaced older industrial networks and a variety of fieldbuses deployed throughout industry. Another adaption of Industrial Ethernet uses standard Ethernet as described above, but with the addition of special protocols that implement determinism. Some of these protocols include Modbus/TCP, PROFINET, EtherNet/IP, EtherCAT, Sercos III, and POWER-



The diagram illustrates the main factors of latency.

LINK, among others. This article will not be discussing those industrial protocols—the focus here will be plain standard Industrial Ethernet.

Top 3 Issues with Industrial Ethernet

The industrial environment is very different from the commercial office environment, posing its own set of challenges. Industrial environments often include harsh conditions like higher temperature ranges and voltages, higher noise, mechanical stress, etc. An industrial-grade Ethernet physical layer (PHY) must perform according to the requirements of Ethernet standards. Let's discuss the three most important aspects to consider when selecting Ethernet PHYs for your system.

Latency

Latency is the delay time between giving a command to piece of equipment and the actual response time. That time is responsible for Ethernet being non-deterministic. The term refers to the ability to accurately predict when some operation will take place.

Ethernet's response time is determined by the time it takes to transmit variable length frames over different lengths of cable at different speeds and not being able to predict when the delay of a CSMA-CD access procedure will take place. This affectation of Ethernet makes it a real problem in some industrial applications that require real-time processes. Without the ability to time operations to some degree means that some types of machine operations could go haywire. Robots, production-line equipment, and some machine tools regularly require timing knowledge to prevent malfunctions and downtime. More on latency later.

EMI/EMC Issues

An industrial Ethernet network can be compromised by electromagnetic interference (EMI), which includes emissions from the noisy power line; switching transients from motors, relays, and solenoids; and any radio emissions from Wi-Fi, Bluetooth, cell phones, and other radio equipment. In addition, the network itself is probably a significant emitter of interference to other sensitive equipment.

ESD Problems

Electrostatic discharge (ESD) refers to a huge surge of electrical energy that produces very high voltage or current. Lightning is a good example. Some industrial equipment can generate ESD. Other equipment must be ESD free or close to it.

Mitigating Latency in Factory Automation

Many industrial applications require real-time operations or at least predictable timing. Couple that with the fact that standard Ethernet is non-deterministic. Often, latency is thought of as the major problem to contend with. This causes some confusion about applying Ethernet in an industrial application. For that reason, it's essential you fully understand the terminology. Let's get the definitions straight in your head.

- *Deterministic:* This is the characteristic of a process or device to always react within a specific time or less. It means that the response time will consistently be a specific value and no more.
- *Latency:* This is the amount of time it takes for an action to occur after it's initiated. It's the response time between originating a process and the time that it begins.
- *Repeatability:* A related term is repeatability, or the consistency of the response time. This term may actually quote a window of solution timing.

Taking these definitions and mentally applying them to your application will help you determine the next steps. Maybe the problem isn't as bad as you think. One conclusion you can draw is if you had a PHY layer with a latency that was short enough, predictable, and consistent, it would work with many applications without resorting to special protocols.

Latency through the Ethernet physical layer is a critical parameter in Ethernet networks *(see figure)*. Latency consists of the delay through the MAC layer operations plus the latency of the cabling and other equipment (switches, et al). The delay also varies depending on the version of Ethernet, what MAC interface (GMII, RGMII, or SGMII) is deployed, and whether the mode is transmit or receive.

You can measure that latency by time-stamping the start frame delimiter (SFD) in a transmitted packet and then time-stamping when it's received. By generally knowing that latency, you can subsequently select a PHY transceiver that always delivers a delay less than the required minimum.

One solution is low-latency Ethernet PHYs. Latency is the delay that occurs between the transmission of a frame and the time it's received, and a desired action is to take place. A corollary problem is different transmit and receive latencies.

Texas Instruments' DP83826E and DP8367 Industrial Ethernet PHY transceivers feature a fixed delay time through the device on up to 150 meters of cable. The delay is repeatable on power-ups and from link to link. The delay is always less than 400 ns. And being consistent or repeatable regardless of the operation means that the devices can be used in many real-time deterministic applications without special protocols.

Ethernet in Building Automation

As Industrial Ethernet continues to grow, it's also being adopted for other uses. One new application is in building automation. Many of the characteristics of a large building are similar to those of a factory-automation facility. As new buildings are being designed and built, they're getting wired with Cat5e or Cat6 cabling. This allows designers to connect and use a wide range of sensors and actuators in addition to the usual Ethernet switches, routers, and servers.

Another movement is retrofitting older buildings with In-

dustrial Ethernet to bring in all of the positive features just discussed. Though the retrofitting is difficult, it's usually worth the cost due to the potential lower energy usage and high-efficiency operation. Using TI's DP838251 PHY IC will enable interoperability of all Ethernet devices and help resolve even basic latency problems.

One more benefit is the ability of the designers to take advantage of the Power over Ethernet (PoE) feature that delivers dc power over the cable data lines to operate the equipment. Some of the expected benefits include energy management by controlling building heating, cooling and lighting, security, fire protection and building access control. All types of sensors can be used to detect fire, smoke, and gas presence, with Internet Protocol network cameras (IPNCs) included.

Ethernet-based automation is on the rise as designers recognize that buildings can benefit from some of the industrial applications, and thus make buildings smarter. New construction routinely plans for building-automation networks, however retrofitting existing buildings to accommodate networked sensors and controls has its challenges. Read the referenced article to learn how to overcome those challenges with the industry's smallest, lowest-power Ethernet PHY.

Conclusion

Learn more about Industrial Ethernet so you can implement its benefits in your work. Part of that learning is discovering relevant products like TI's DP83837 and DP838251 to incorporate into future designs.