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PHY Holds the Key to Robust Industrial Ethernet Applications

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Ethernet has a long history of successful application in the office and commercial environments. Over the past several years, Ethernet found a new home in industrial applications, including automotive.

Thanks to its wide availability and low cost and proven performance, Ethernet is ideally suited to industrial applications. However, its adoption in industry has not gone without some challenges. Meeting these challenges centers on having a hearty physical layer (PHY) of the network, which includes the Ethernet transceiver and the physical cabling. What follows is a solution that meets the limitations of standard Ethernet and makes it a great fit for industrial use.

Industrial Ethernet

The industrial use of Ethernet includes interconnections between computers and other networked devices like robots, CNC machine tools, production-line equipment, motors and controllers, switch gear, programmable logic controllers (PLCs), human interface devices (HIDs), and many others. Another use case is the smart grid. Gradually, Ethernet has replaced older networking technology due to its speed and easy-to-deploy nature.

Ethernet is also working its way into automotive applications. Today's vehicles contain a wide variety of electronic subsystems that have to be networked. Sensors, engine controllers, braking and stability systems, infotainment centers, navigation, and other subsystems must talk to one another. Some of the newer subsystems include backup cameras, lane departure warning, automatic braking, adaptive cruise control, and the forthcoming autonomous driving equipment. The on-board diagnostics (OBD II) port is also networked.

In the recent past, networking was handled by the controller area network (CAN) and its faster cousin CAN-FD. This is another arena where Ethernet is gradually replacing older technology—CAN, in this case—because it's faster and offers lower latency.

Overall, Ethernet is becoming the de facto networking technology in industry and automotive applications. One main factor behind its surge is that chip and equipment vendors have learned how to overcome the problems encountered in the industrial environment.

EMI/EMC Compliant 10/100 Mbps Ethernet Brick with Fiber or Twisted Pair Interface Reference Design

The Perils of the Industrial Environment

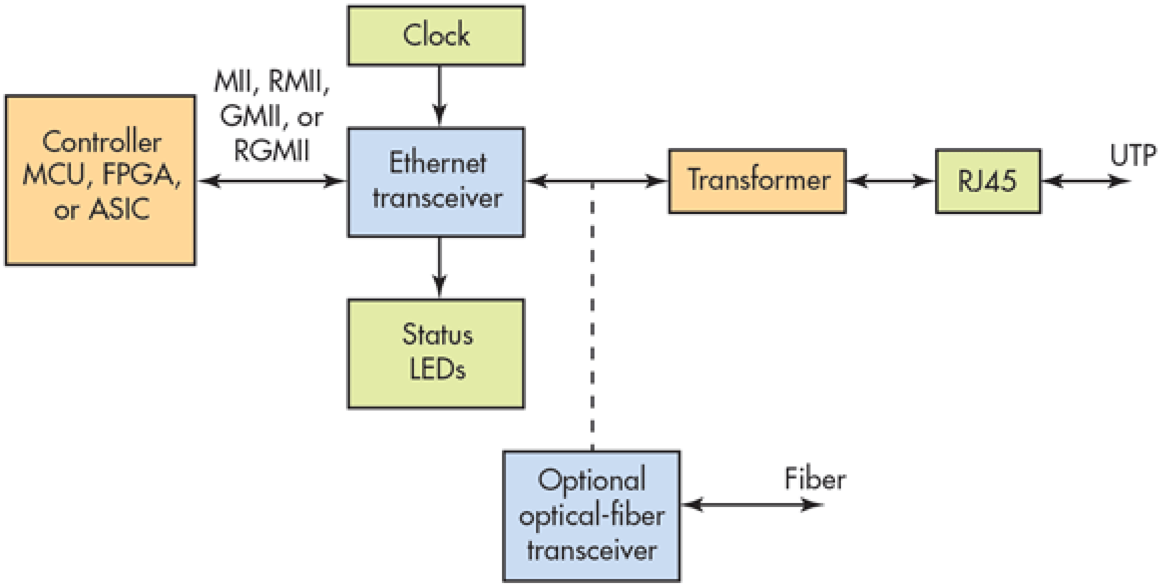
The industrial and automotive environments are severe. Many times, their surroundings involve elevated temperatures, mechanical stress, dirty conditions, and potential exposure to toxic substances. And the industrial environment also often endures electrical noise and very high voltages. Hardware vendors have learned to harden the components and equipment in order for them to survive. The PHY components of Ethernet must also handle these conditions plus meet other needs. Key requirements of a modern Ethernet PHY include:

• *ESD protection:* Electrostatic discharge is a pulse of current that often occurs in industrial settings. Not only can it disrupt the flow of data in the network, but it may damage the electronics. ESD pulses can reach many thousands of volts, potentially resulting in invisible but catastrophic destruction of electronic equipment. A good Ethernet PHY will include external or internal ESD suppression components.

• *EMI mitigation:* Electromagnetic interference is noise that's produced by the flow of current in cables and equipment and the ensuing magnetic radiation. EMI is generated by anything digital, switch-mode power supplies, and by cabling. In cabling, inductive and capacitive coupling can easily transfer signals from one entity to another, causing data errors and other disruptions. This is otherwise known as crosstalk. Good grounding, shielding, cable placement, and filtering practices can minimize EMI.

Equipment must meet EMI and electromagnetic-compatibility (EMC) standards set by regulatory bodies like the Federal Communications Commission (FCC), European Committee for Standardization (CEN), and Comité International Spécial des Pertubations Radioélectriques (CISPR). EMC refers to the equipment's ability to operate successfully in a high EMI environment and simultaneously not generate EMI of its own that could interfere with others.

• *Low latency:* Latency is the time it takes for packets on the network to travel from transmitter to receiver. Latency is determined in the PHY transceiver, the physical medium, switches, and hubs, as well as by the inherent operation of the network. It can vary widely, but, unfortunately, many industrial applications require critical timing. Any delays should be short and deterministic. Machines must respond quickly to commands or be synchronized for proper operation. Long, unpredictable delays cannot, in general, be tolerated.



As it turns out, Ethernet is non-deterministic thanks to its inherent characteristics and access method—carrier-sense multiple access with collision detection (CSMA/CD). Fortunately, this problem has been corrected by incorporating the IEEE 1588 Precision Time Protocol (PTP). It's a combined hardware/software solution that must be supported by the PHY transceivers.

• *Power consumption:* Ethernet transceivers are notoriously power hungry. A common 10/100-Mb/s transceiver can consume up to 300 mW, and a typical 10/100/1000-Mb/s transceiver can eat up over a watt. If many Ethernet ports are involved, power consumption can become a problem. However, modern equipment addresses this problem in two distinct ways:

1. Implementation of the Energy-efficient Ethernet (EEE) standard, IEEE 802.3az. EEE is a method that involves both the PHY and the Ethernet Media Access Control (MAC) network layers. It eliminates idle signaling during times of low channel usage. Parts of the circuitry are shut down during quiet periods of transmission by avoiding the practice of continuously transmitting idle symbols during low traffic periods.

2. The Wake-on-LAN (WoL) protocol keeps the PHY transceiver active but shuts down connected components, such as any MCU, FPGA, or ASIC, to save power. An active PHY can then notify and wake up the support devices upon detection of activity.

A Look at the PHY

The PHY is the cabling medium and the transceiver. The Ethernet 802.3 standard offers multiple connection media, including unshielded twisted pair (UTP), coax, backplanes, and fiber. The most widely used is UTP, which comes in multiple versions such as CAT5, CAT5e, CAT6, and CAT7. The choice depends on the speed version of Ethernet. Because the 10/100-Mb/s standard is most, CAT5 UTP is the most common in industrial applications. Gigabit Ethernet is also used when there's a need for higher speed, although the 10G and 100G versions don't come into play.

Inexpensive and easy to work with, UTP can function at distances to 100 meters. However, it's susceptible to crosstalk and noise over the longer cable runs. When longer distances must be covered, fiber is the best option. It can reliably transmit packets up to around 1000 meters, and is totally immune to any EMI.

With regard to the transceiver, it must of course meet the full 802.3 standards. It has to comply with the 10Base-T, 100Base-TX, and 100Base-FX configurations to ensure the interoperability of equipment. Furthermore, the nsceiver must have low power consumption, energy-saving features like EEE and WoL, EMI minimization and D protection, and low-latency characteristics. The *figure* shows a typical PHY transceiver application.

The transceiver is a single IC that connects to the controller with its MCU, FPGA, or ASIC by way of the media-independent interface (MII). MII is defined in several versions that dictate the number of parallel connections and the clock speeds: original base MII, reduced MII (RMII), Gigabit MII (GMII), and reduced Gigabit MII (RGMII). The network MAC function is implemented in the controller.

A 25-MHz clock operates the transceiver; external LEDs indicate several operational conditions. The transceiver connects to the UTP medium by way of a transformer and the RJ45 connector. For a fiber medium, one can opt for a fiber-optic transceiver module.

A transceiver IC that meets all of these requirements is Texas Instruments' DP83822. The DP83822 was designed to meet the needs of rugged and high-performance applications while still offering a wide range of options for minimizing power consumption. Core features include:

• Compliance to 10/100 Mb/s Ethernet standards

• MII, RMII, and RGMII MAC interfaces

• Single supply of 1.8 or 3.3 V

• Low power consumption: < 120 mW (1.8 V) or < 220 mW (3.3 V)

• Industrial temperature range of –40 to +125°C

• ±8-kV and ±16-kV ESD protection

• Start frame detect support for IEEE 1588 PTP

• Energy-savings support with EEE and WoL

Other variations of this IC are available featuring different MAC interface options, package types, a One Gig 1000-Mb/s version, and a dual-port device.

TI also offers an EMI/EMC-compliant 10/100-Mb/s reference design called the Ethernet Brick. The Brick reference design provides a simplified solution that eliminates the need to have multiple boards for copper or fiber interfaces. It uses the DP83822 10/100-Mb/s Ethernet transceiver to reduce board size for a cost-optimized and scalable solution with reduced power consumption in high-temperature industrial applications.

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