Application Brief

How to Implement Power over Data Lines (PoDL) for Automotive Ethernet

Fabian Barth *System Engineering and Marketing*

Overview

Future automotive architectures are characterized by centralized gateway systems that serve as a communication and control point for various subsystems such as Advanced Driver Assistance Systems (ADAS), powertrain, infotainment, and body or comfort. These systems offer flexibility, scalability, and efficiency by combining multiple functions into one integrated platform. This reduces costs, improves reliability, and increases the performance of automotive systems.

These centralized architectures generate large amounts of data that need to be processed by powerful processors like the TDA4 Jacinto™ processor family and securely transmitted through high-speed interfaces such as Automotive Ethernet or Low-Voltage-Differential-Signaling (LVDS) SerDes FPD-Link™. Automotive Ethernet is a high-speed network technology that was specifically developed for the transmission of large amount of data in vehicles. Automotive Ethernet is based on the proven Ethernet standards (IEEE802.3) and enables the transmission of data through single twisted pair (STP) cables.

Power over Data Lines (PoDL) is a remarkable technology that makes it possible to transmit power through the data cable in Single Pair Ethernet (SPE) systems. This eliminates the need for separate power cables, which simplifies cabling, reduces weight, and cuts costs. PoDL plays an important role in the integration of electronic components and sensors in the vehicle and supports efficient and scalable implementations of centralized gateway systems.

Use Cases

There are many possible applications for PoDL in the automotive sector. From a technical point of view, power of up to 15W can be transmitted efficiently with stabilized 12V or up to 30W using 24V. This makes PoDL particularly interesting for the integration of remote sensors such as cameras, Radar, or LiDAR systems, as well as for displays with high-bandwidth requirements. With the introduction of 10Base-T1S (10Mbit/s) for the automotive sector, PoDL now gains even more application areas. This includes applications in the area of door modules, actuators, and any sensor technology in the body electronics and lighting area.

Setup of a PoDL Device

It is highly important that the data integrity is not disturbed by the transmission of power over the SPE cable. A coupling network is used for this purpose, which couples in or couples out the power from the data at both ends of the cable. Furthermore, classic melting fuses will cease to exist, which means that an alternative design of protecting the cable and device is required. Texas Instruments (TI) provides high-side switches or so-called eFuses which are primarily used here. These devices enable additional diagnostic functions such as power measurements.

Status of the Implementation

Both automotive manufacturers (OEM) and suppliers (tier 1) show a strong interest in this technology. Several manufacturers of passive components already offer coupling networks. Intensive work is being done on the implementation and development of this technology. Evaluation results show that TI automotive Ethernet PHYs are capable of this technology and ready to be used in the next generation of vehicles.

Development of Bus Architecture in the Vehicle

The ongoing evolution of bus systems in vehicles plays a key role in the progressive development of vehicle technology and capabilities. The overarching goal of improving vehicle safety and increasing driving comfort remains a key driver of this development. The following sections describe the development of the vehicle bus architecture which acts as an essential foundation for the effective implementation of PoDL technology.

Classic Architecture

The classic architecture of vehicles distributes electronic control units (ECU) throughout the vehicle, which manage functions such as engine control, braking system, and infotainment. A complex network of different communication interfaces enables data exchange between the ECUs and sensors but leads to extensive cabling and costs. The data rates are between 0.01Mbit/s and 10Mbit/s through Controller Area Network (CAN) and Local Interconnect Network (LIN). In comparison, the star topology of FlexRay® is more flexible, but more expensive than CAN and LIN.

Domain Architecture

Modern vehicles are equipped with an increasing number of ECUs, on average around 100 in mid-range vehicles and over 150 in luxury vehicles. Connecting these ECUs is a challenge for car manufacturers and has led to the development of domain architecture. In this architecture, ECUs with similar functions are grouped together in domain controllers, reducing complexity and cost. The domains include infotainment systems, powertrain, body or comfort, and ADAS, which are connected through a gateway. Each domain uses different bus systems, communicating through Ethernet to provide a secure and reliable connection between all domains.

Zone Architecture

In response to the increasing complexity and requirements of autonomous driving, a shift from a domain-based to a zone-based architecture was developed. In this new approach, sensors or actuators in a vehicle are connected to the physically-closest zone controller, which offers additional functions such as localized power distribution and higher network bandwidth for in-vehicle communication. A central controller, connected to each zone controller through a high-speed data bus, manages sensor fusion and higher-level decision making. The architecture requires higher speed and higher throughput bus systems as a large amount of data is exchanged between ECUs and a connection to external high-speed networks is required. The higher bandwidth is necessary to enable data aggregation in the zones, communication with the central compute unit, and the use of more sensors with higher data rate and resolution, as future vehicles are expected to have 10–14 cameras compared to the 1 to 5 cameras today.

With the introduction of the domain or zone architecture, there is not only a change in the data network, but also in the power network, which is now organized in domains or zones. This change already enables high-power provisioning in the domain controllers or zone controllers. The power is distributed from these locations, which reduces the number of cables and therefore the overall weight. This is achieved by using existing Ethernet cables to transmit power. Ultimately, this leads to a reduction in cost.

Fundamentals of Automotive Ethernet

Ethernet was developed in the 1980s and is a widely-used communication system for connecting devices in a local area network (LAN). Ethernet is based on various standards defined by the IEEE, which specify different transmission media and speeds. Over time, Ethernet has evolved to meet the different requirements of various industries and applications. In the automotive sector in particular, new standards were introduced to meet specific requirements such as higher electromagnetic compatibility (EMC), electromagnetic interference (EMI), shorter cable lengths, and lower power consumption. These adaptations make sure that Ethernet can be used effectively in different environments and meet the challenges and advances of the automotive industry.

Various Ethernet technologies are used in the automotive sector, including IEEE802.3cg (10Base-T1S), IEEE802.3bw (100Base-T1), and IEEE802.3bp (1000Base-T1). While 100Base-T1 and 1000Base-T1 are point-to-point connections, meaning that a direct connection is established between two endpoints, 10Base-T1S supports both multidrop and point-to-point topology. This means that several devices can be connected through the same cable, like the classic bus topology as with the CAN bus.

To enable a processor or microcontroller to communicate through Ethernet, an Ethernet physical layer transceiver (PHY) is required. The Ethernet PHY acts as a transceiver and translates Ethernet frames between the media-independent interface (MII) and the media-dependent interface (MDI) through the transmission medium. The Ethernet PHY provides error-free communication. The Ethernet PHY is configured through the Serial Management Interface (SMI), also known as Management Data Input/Output (MDIO) using one clock and one signal line. Register access is used for configuration and diagnostics of the Ethernet PHY. The MDI represents the physical transmission medium between the network devices, with Automotive Ethernet using a single twisted pair as the transmission medium.

Figure 1 illustrates the position of the Ethernet PHY in the system.

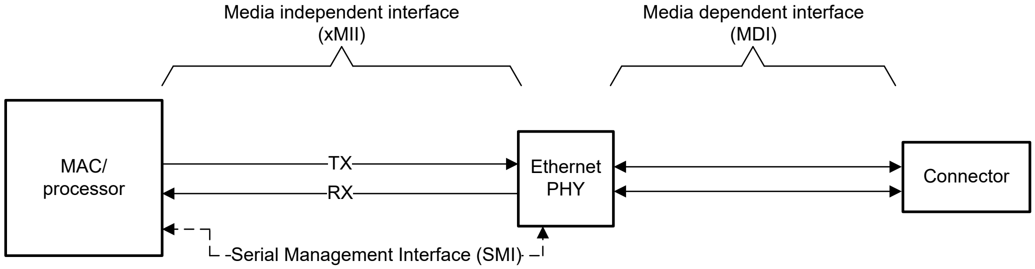

Figure 1. Position of an Ethernet PHY in a System

Power over Data Lines

While Power over Ethernet (PoE) is applicable to standard Ethernet, that is, cables consisting of four twisted pairs of wires, PoDL is only applicable to SPE.

Figure 2 shows a typical PoDL system consisting of a power sourcing equipment (PSE), a connection section, and a powered device (PD). In the automotive sector, SPE uses capacitive data coupling due to lower isolation requirements. The PSE, usually part of an ECU, domain or zone controller, provides the required power for the PD. The PSE couples the power to the data lines through a differential-mode inductor (DMI). The network, consisting of the common-mode choke (CMC), DMI and the DC blocking capacitors (DC), is called a coupling-decoupling network (CDN).

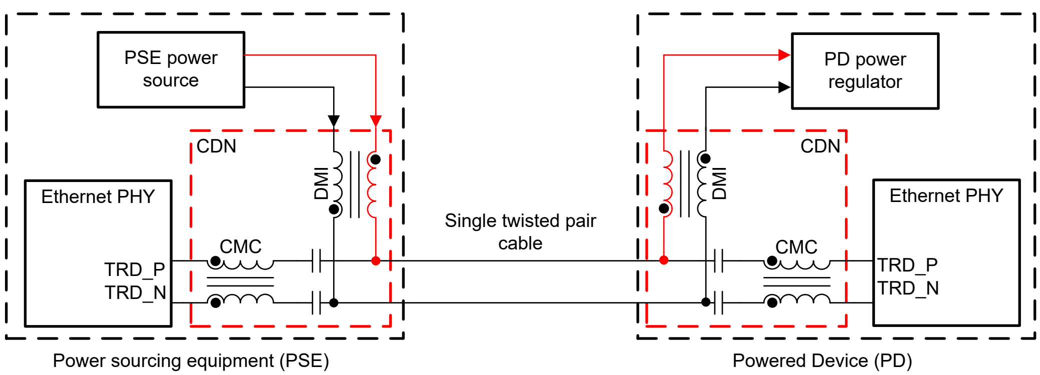

Figure 2. Fundamental Overview of a PoDL System

PoDL is defined in IEEE802.3bu for 100/1000Base-T1 and can support a power of up to 50W. The standard specifies a series of safety measures designed to protect the Power Sourcing Equipment (PSE) and the Powered Device (PD) from damage. The standard describes the implementation of the requirements of industrial applications. However, the requirements of the automotive industry differ enormously from those of industrial applications.

Automotive-Specific Requirements for Power over Data Lines

The Ethernet network in the automotive sector differs fundamentally from that in industrial applications. The methods required in IEEE802.3bu for the interoperability of devices are not required in the automotive sector. This is based on the assumption that OEMs are defining which devices are being used in the vehicle. Compared to industrial applications, devices are not added or removed during the lifetime of the vehicle. An implementation completely in compliance with IEEE802.3bu is not required. This enables a dramatic reduction in complexity and, similar to already implemented *power over* designs for other physical transmission media, leads to a reduction in costs and weight.

Automotive-Specific Use Cases for Power over Data Lines

A wide range of applications are opening for PoDL in the automotive sector. In particular, ADAS sensors already connected through automotive Ethernet, such as radar, LiDAR, and cameras, are predestined for the use of PoDL. Sensors in the range of 1W to 10W at 12V can be operated through PoDL without any problems. For higher power requirements above 10W, a voltage of at least 24V is recommended.

Advantages of PoDL Compared to Power Supply Through Power Cables

The use of PoDL compared to classic power transmission through separate cables offers several significant advantages. A central point is the possibility of de-energizing entire sensor nodes through a high-side switch (HSS), which leads to considerable energy savings.

The implementation of PoDL not only reduces power costs, but also the overall costs of the wiring harness. The installation of the wiring harness becomes simpler and more cost-effective, as separate cables, crimp contacts, and fuses can be dispensed with. In some cases, eFuses are already used today, so there are no additional costs for implementation.

The infrastructure required for PoDL, consisting of two DMIs and possibly a high-side switch, is less complex and less expensive than conventional cabling elements. This results in an efficient and economically advantageous design for power transmission in automotive applications.

Challenges

Ground loops occur when there are multiple paths for electrical current to flow between the ground points of interconnected devices, potentially leading to unwanted voltage differences. These voltage differences can introduce noise and ultimately cause saturation of one of the DMIs, resulting in loss of signal integrity. To prevent this, there is only one economically feasible option which is to isolate the PD local ground from the chassis ground.

A key design challenge is to make sure that the signal integrity of the data is not reduced when using PoDL. The signal integrity depends strongly on the selection of the coupling network. Tests with TI's latest automotive Ethernet PHYs have shown that the signal-to-noise ratio (SNR) of the communication using PoDL compared to a non-PoDL design does not significantly reduce the SNR. These tests are based on scenarios like radar applications which generate high load dumps. The key here is a combination of an already well performing Ethernet PHY without PoDL and the correct selection of the impedance of the DMI.

Conclusion

The integration of PoDL in an automotive system can offer significant advantages in terms of cost reduction and weight savings compared to the use of a separate cable for power supply. To realize these advantages, it is not necessary to implement PoDL completely according to IEEE802.3bu, but rather to focus on the dimension and selection of the filter network (CDN). TI shows that it is possible to implement PoDL cost-optimized and design-optimized using the current Automotive Ethernet PHYs: DP83TG720S-Q1 and DP83TC812S-Q1.

The industry has determined that the relevant components of the filter network, consisting of common-mode choke (CMC) and differential-mode inductor (DMI), must comply with the specifications of IEEE802.3bu to provide signal integrity. Leading suppliers of passive components show that this is feasible. The measures required in IEEE802.3bu for the interoperability of devices are not necessary in the automotive sector, as the OEM defines exactly which devices must be able to work together.

The power classes, defined in IEEE802.3bu, serve as a recommendation or reference. Implementation outside of these classes can increase system efficiency. The introduction of cable and PD protection is highly recommended to eliminate the need for a classic melting fuse. Overall, PoDL offers a customized design that is tailored to the specific requirements and optimizations in the automotive sector.

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