

Technologies  
**Single Pair Ethernet**  
for Device Manufacturers

Whitepaper



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# 1. Introduction to Single Pair Ethernet

Single Pair Ethernet (SPE) is a groundbreaking technology that simplifies Ethernet communication by utilizing a single twisted pair of wires instead of the traditional two or four pairs. This approach supports fast data transmission rates on long distances, Multidrop applications and can also deliver power over the same pair of wires. SPE is particularly advantageous for applications where weight, space, and cost are critical considerations, making it ideal for industrial and commercial use.

## Key Benefits of SPE

- **Enhanced Data Transmission:** With the ability to transmit data at high speeds for long distances, SPE ensures fast and reliable communication essential for real-time data processing and control in various applications. At the same time the standards supports multidrop applications.
- **Simplified Network Architecture:** By reducing the complexity of network architecture, SPE makes network management and maintenance easier and more reliable, leading to more efficient troubleshooting. No additional gateways are required to bring Ethernet on the sensor and field device level.
- **Power Over Data Line (PoDL):** SPE's capability to deliver power alongside data eliminates the need for separate power lines, which is particularly useful for powering remote sensors, actuators and IoT devices.
- **Efficient installation:** SPE minimizes the amount of cabling needed, which lowers material and installation expenses. This is especially beneficial in settings requiring extensive cabling, such as manufacturing plants or large commercial buildings.

## 2. SPE Standards and Specifications

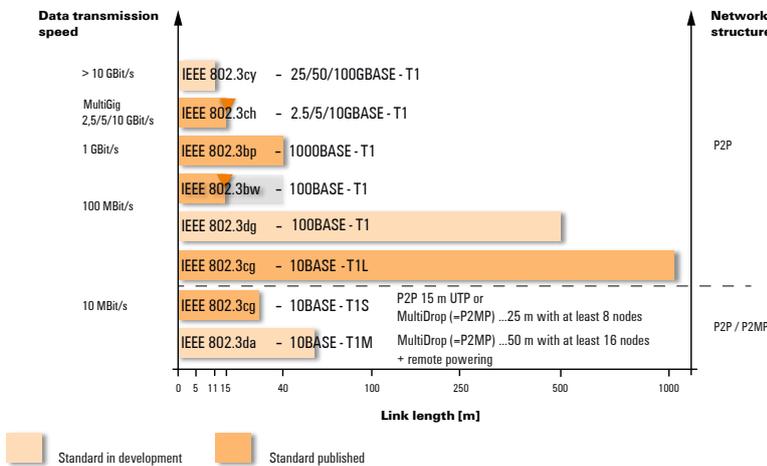
### SPE Standards and Specifications

Single Pair Ethernet standards refer to a set of guidelines and specifications established for the use of Ethernet technology over a single pair of twisted copper wires. The specifications include every aspect of SPE, like Ethernet interfaces, wiring, and data transfer. The standard for SPE is defined as IEEE 802.3. This specification sets the technical parameters for Ethernet-based data communication over a single pair of wires.

The following table gives an overview of the different SPE protocols. These standards differ in their transmission speeds and distances and ensure interoperability and provide guidelines for designing compliant products. The currently most relevant standards for the industry are 10BASE-T1L up to 1,000 m and 10BASE-T1S for Multidrop applications. 100BASE-T1 enables 100 Mbit/s up to 100 m and 1000BASE-T1 even 1 Gbit/s up to 40 m. When being available, it is estimated that also 100BASE-T1L (IEEE802.3dg) will be very important for the industry.

### Overview IEEE802.3 SPE protocols

Further SPE standards in progress - Forecast 2025



The IEC standard IEC 63171 considers the standardization of the connection technology of Single Pair Ethernet. This defines basic information, testing techniques and requirements for SPE connectors and includes electrical and transmission properties as well as different mating faces. In addition, the MICE concept (Mechanical, Ingress, Climatic and Electromagnetic) is integrated into the standard, which deals with environmental conditions and areas of application.

Recently, international automation communities have highlighted the need for a standardized connector for Single Pair Ethernet, which has been submitted for international standardization based on essential application requirements. With the agreement on a uniform connector face for Single Pair Ethernet, the industry is now making a significant step towards the future. The new SPE connector system provides a consistent mating face for applications in control cabinets, in the field, and for hybrid installations. Numerous manufacturers have already announced their plans to implement it soon. As a key driver of this technology, Weidmüller will also be expanding its product range to include connectors featuring the new design based on the IEC 63171-7 standard.

### 3. Key Benefits for Device Manufacturers

Device Manufacturers of industrial devices are responsible for the entire lifecycle of their products, from research and development, design, and prototyping to production, quality control, and distribution. They must adhere to industry standards and regulations, ensuring that their products are safe, reliable, and meet the needs of their customers.

Single Pair Ethernet is set to become an industry standard that customers will soon demand, as the adoption of this technology is inevitable. With an increasing number of devices and networks relying on SPE in the future, now is the ideal time to consider integrating this technology into new generations of devices.

The use of a single pair of wires in device design brings several advantages, particularly in creating more compact and lightweight devices. This is especially beneficial in fields like automotive and aerospace, where space and weight are critical concerns. Comparing to a standardized RJ45 jack, the SPE jack will save a lot of space on the PCB.

At the same time SPE allows a direct access to the field level, also for long distances. Connecting different sensors via SPE far away, the information is directly available via the IIoT, without the need of additional gateways. This allows a diagnosis function, which leads to a higher plant availability.

Single Pair Ethernet serves as another physical layer, allowing Ethernet-based protocols such as Modbus TCP, PROFINET, Ethernet/IP, and HTTP to communicate seamlessly over it. This high level of compatibility makes SPE a versatile and efficient solution for numerous applications. By supporting existing Ethernet protocols, SPE ensures easy integration into current network infrastructures. Consequently, adopting SPE can streamline network design. Performance and reliability are also improved with SPE-based devices. Utilizing the robust and high-speed data transmission capabilities of Ethernet, these devices offer superior performance and reliability compared to traditional fieldbus systems.

Additionally, SPE enhances product versatility as well as cost efficiency. Its ability to handle both data and power over a single pair of wires simplifies the design of versatile devices, suitable for various settings, from industrial environments to smart homes. SPE helps reduce production costs by minimizing material usage and simplifying manufacturing processes. The need for multiple connectors and cables is reduced, making products more cost-effective overall. With fewer types of cables and connectors needed, inventory and logistics are simplified, reducing overhead and easing supply chain management.

Moreover, adopting SPE allows device manufacturers to future-proof their products. As Single Pair Ethernet becomes more prevalent, having compatible devices ensures continued market relevance, aligning with emerging industry standards and trends.

Finally, SPE supports sustainability by decreasing the amount of cabling and materials required. The lighter and less bulky cables reduce transportation emissions and energy use during installation, contributing to more sustainable manufacturing practices.

## 4. Applications of SPE – Perspectives for Device Manufacturers

Single Pair Ethernet finds its origin in the automotive industry, where smaller devices with highest performance are needed. Today there are multiple use-cases for SPE, as it is ideal for various applications in Industry 4.0 (IIoT), building, factory or process automation. For these fields Device Manufacturers have a lot of options to consider SPE when designing their new device generations.

### 1. Industrial automation

As automation advances, a growing number of sensors and actuators are used in all areas of manufacturing. A consistent, scalable and time-critical network from IIoT devices to the cloud is required, which needs reliable components. This allows Ethernet across all automation levels down to the individual sensor/actuator level.

Especially where intelligent devices are communicating, sensing or monitoring, several use cases for SPE can be found. Typical applications Barcode Readers, Cameras, User Terminals or any Detection Sensors.



In the industrial automation long distances up to 1,000 m need to be bridged with high transmission speeds, but without any additional gateways. The different sensors, actuators and field devices inside the factories require a power supply. Thanks to PoDL (power over Data Line) a simultaneous power and data supply is possible just via the two wires – without separate power supply lines.

### 2. Robotics

Single Pair Ethernet offers significant advancements in the miniaturization of communication infrastructure, making it possible to develop more sophisticated end-of-arm tools for robots. Unlike conventional protocols, SPE provides greater bandwidth, allowing communication between a robot's arm and its controller to handle larger data frames efficiently. The Power over Data Line (PoDL) feature simplifies cabling along the robot's body by transmitting both data and power through a single cable.



SPE supports high-resolution 2D or 3D robot vision systems by enabling data transmission at speeds of up to 1 Gbit/s over distances of up to 40 meters. Additionally, SPE cables have a smaller bending radius compared to traditional automation cables, which can lead to a reduction in the overall dimensions of the robot body and arm. This compact and efficient cabling solution enhances the performance and design flexibility of robotic systems.

### 3. Process industry with Ethernet-APL

In the process industry, Ethernet-compatible interfaces are increasingly needed to access data from the field via IIoT. There's the challenge that information is required from sensors and devices in the field, with large distances to be bridged. In addition, various IIoT devices must be integrated into the network infrastructure. The Single Pair Ethernet for the process industry is called Ethernet-APL, which is a dedicated definition of 10Base-T1L enriched with functional safety, which requires qualified components for a reliable data transmission at 10 Mbit/s and simultaneous power supply via twisted pair cable up to 1,000 m.

The Ethernet-APL (Advanced Physical Layer) technology enables direct access down to the field and device level via an internationally standardised two-wire solution. This requires powerful IIoT devices with qualified components. By this you will get an increased plant availability and production data: The collection, use and analysis of data from devices in the field is possible easily to ensure and increase plant availability and to implement new solutions.



### 4. Building automation

The integration of the Internet of Things (IoT) into building automation has become a critical aspect of the ongoing digital transformation, with its importance expected to rise further. By adopting the IP protocol, building automation becomes more streamlined and effective, as sensors, controllers, and other building technologies can be seamlessly connected to the building's system technology, even over long distances. This method replaces traditional proprietary fieldbus systems with standardized Ethernet cabling, thereby removing the need for expensive and intricate programming and parameterization. With the use of Single Pair Ethernet, additional gateways are no longer necessary.



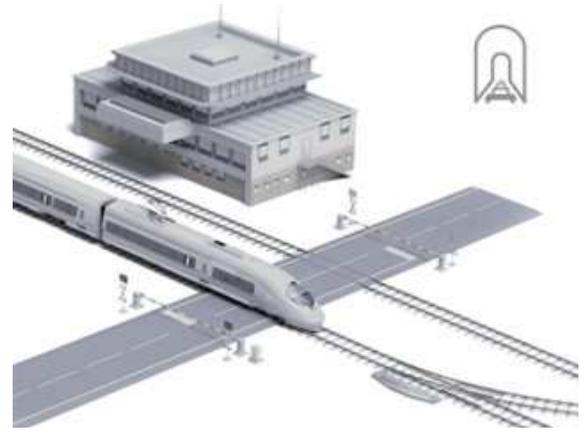
In designing and developing smart buildings, there is a clear trend towards minimizing the energy consumption of all connected devices. Single Pair Ethernet is crucial in this context. It allows for the simultaneous transmission of high-performance data and power over a single pair of wires using Power over Data Line (PoDL). Additionally, SPE components, including connectors and cables, are engineered to be smart, durable, and efficient. SPE enables the integration

of building systems like lighting, HVAC, and security into a unified network that is easy to install and maintain. The ability to support various transmission distances and rates, coupled with high packing density, makes this connection technology highly adaptable for nearly any system. SPE is transformative for IoT devices, allowing for compact, power-efficient designs with reliable Ethernet connectivity. This is vital for applications such as smart grids, smart cities, and home automation.

## 5. Infrastructure

Thanks to the ability to transmit data over longer distances compared to traditional Ethernet like 10BASE-T1L with 10 Mbit/s up to 1,000 m, also infrastructure applications can benefit from Single Pair Ethernet. This makes SPE particularly useful for large-scale infrastructure projects like tunnels and railroad crossings, which require extended reach and high data rates. It can be used for signal controlling and powering, sensor connectivity and powering as well as actuator controlling. In extensive installations like trackside systems and traffic control networks, SPE simplifies cabling complexity. By delivering both power and data over the same pair of wires (Power over Data Line), SPE makes the installation and maintenance of devices such as sensors and cameras for traffic control and monitoring systems more straightforward.

SPE's compatibility with existing Ethernet-based systems ensures seamless integration, enabling efficient deployment of intelligent infrastructure solutions that need real-time data exchange and monitoring. Additionally, SPE's scalability makes it ideal for expanding existing infrastructure projects, as it can easily accommodate increasing data demands and the addition of new devices without requiring major changes to the existing setup.



## 6. Energy



Single Pair Ethernet also offers numerous advantages for the energy sector. Its capability to support high-speed data communication over extended distances makes it ideal for monitoring and controlling remote energy assets such as wind turbines, solar farms, and substations. With Power over Data Line (PoDL) SPE simplifies the deployment of smart grid devices, sensors, and actuators, facilitating the integration of IoT technologies. Additionally, the real-time data exchange and monitoring provided by SPE are crucial for efficient energy management, predictive maintenance, and ensuring the stability and reliability of the power grid.

## 5. Design Considerations for SPE Devices

When designing SPE-compatible products, manufacturers should consider several points regarding components, conformity, testing and system architecture.

Regarding the **Connector Design**, it is necessary to consider that SPE connectors are smaller and simpler than traditional Ethernet connectors, reducing size and cost. They must be designed for robustness and reliability in specific application environments. Different connectors are described under IEC 63171, which allows the use of standardized components for the devices. Besides Standardized components also qualified SPE Terminals can be used to ensure a reliable transmission. Especially for device manufacturers that need to transmit power, signal and data, hybrid connectors can play an essential role. Weidmüller's OMNIMATE® 4.0 is a perfect example, how to solve such a transmission in a compact and convenient way.



In terms of **cabling**, SPE-specific cables are optimized to support high data rates and power transmission over longer distances with minimal interference and signal loss. At the same time the bending radius can be increased, which can be a big advantage for the device design.

Choosing appropriate physical layer (PHY) and transceivers that comply with SPE standards is crucial for converting digital data to the electrical signals needed for transmission. Also Ethernet controllers must support SPE technology, ensuring efficient data traffic management and compatibility with the necessary protocols.

Setting up SPE in the **network infrastructure** requires network components like switches and routers. For 10BASE-T1L applications Weidmüller has a suitable switch in the portfolio, which fulfils all SPE requirements. The network infrastructure components like must support SPE to ensure seamless integration and efficient data routing. Manufacturers building these kinds of devices need to make sure that the suitable chips are used and they need to decide, whether they want to design them with or without PoDL (Power over Data Line) and which PoDL classification to be considered. Especially with PoDL effective **power management** and delivery are crucial. Devices should be designed to handle data and power transmission efficiently. Within the devices also **EMI and EMC Compliance** need to be considered. Ensuring electromagnetic interference (EMI) and electromagnetic compatibility (EMC) compliance is essential, particularly in industrial applications where electrical noise is common.

Last, but not least, **testing and certification** of devices and components is necessary. Adherence to SPE standards and obtaining relevant certifications ensure interoperability and reliability. Rigorous testing validates performance under various conditions.



Broad SPE portfolio of Weidmüller according to IEC 63171-2

## 6. Future Trends and Developments

The adoption of Single Pair Ethernet is ready for substantial growth as more industries come to understand its numerous benefits. Future advancements are anticipated to include higher data rates, enhanced power delivery capabilities, and further miniaturization of connectors and components, making SPE an increasingly compelling choice for ambitious applications.

As the ecosystem of SPE-compatible devices continues to expand, we can expect a significant boost in innovation and the emergence of new opportunities for device manufacturers. This growing ecosystem will not only improve existing technologies but also facilitate the development of groundbreaking applications and systems. By leveraging the advantages of SPE, industries can maintain a competitive edge in an increasingly interconnected and technologically advanced world. As SPE technology continues to advance, it will undoubtedly play a crucial role in various applications, from automotive networks over industrial automation, process industry, building automation, and IoT applications to smart grids. The technology's inherent flexibility and efficiency make it a key enabler for the next generation of connected devices, driving innovation and allowing for new functionalities that were previously unattainable.

### Conclusion

Single Pair Ethernet marks a significant advancement in Ethernet technology, ready to transform networking across various industries. It offers numerous benefits, especially for device manufacturers looking to innovate and optimize their products.

In industrial automation and the process industry, the high-speed data communication and power delivery over long distances is particularly beneficial. It enables the creation of more intelligent and responsive industrial networks, facilitating real-time data monitoring and control from sensors far away for optimizing production processes and enhancing operational efficiency. In building automation, SPE supports the deployment of smart building technologies, including advanced HVAC systems, lighting controls, and security systems, all benefiting from streamlined connectivity and improved data handling capabilities.

By dramatically reducing cabling complexity, SPE not only cuts material costs but also simplifies installation and maintenance, crucial for large-scale deployments such as industrial automation and building management systems. Device manufacturers who embrace SPE will be well-positioned to leverage these advantages and drive the next generation of connected devices.

The enhanced data transmission capabilities, coupled with its power delivery integration via Power over Data Line (PoDL), make it an ideal solution for the expanding Internet of Things (IoT) ecosystem. This integration allows devices to be powered and connected through a single twisted pair cable, streamlining design considerations and minimizing the physical footprint required for connectivity infrastructure. As IoT devices continue to grow, the demand for efficient, compact, and reliable connectivity solutions like SPE becomes increasingly apparent.

For device manufacturers, adopting SPE technology opens new opportunities for innovation and competitiveness. Manufacturers can create products that are more efficient, easier to deploy, and future-proof, thanks to the technology's scalability and compatibility with existing Ethernet standards. This compatibility ensures that devices can seamlessly integrate into current and future network environments, providing a robust foundation for long-term technological advancements.

In conclusion, Single Pair Ethernet represents a groundbreaking development in Ethernet technology, offering significant benefits to device manufacturers and end-users alike. Its ability to simplify cabling, enhance data transmission, and integrate power delivery positions it as a vital enabler for the future of industrial automation, building automation, and IoT applications. Device manufacturers who embrace SPE will be at the forefront of technological innovation, ready to lead in developing the next wave of connected devices that are smarter, more efficient, and more capable than ever before.

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