Technologies

Single Pair Ethernet
for Device Manufacturers

Whitepaper

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1. Introduction to Single Pair Ethernet

Single Pair Ethernet (SPE) is rapidly emerging as a groundbreaking technology for modern industrial and commercial applications. By transmitting data over a single twisted pair of wires—rather than the traditional two or four pairs—SPE enables high-speed communication over extended distances, supports multi-drop network topologies, and allows simultaneous power transmission via Power over Data Line (PoDL).
These capabilities make SPE particularly attractive for applications where space, weight, and cost efficiency are critical. Device manufacturers can leverage SPE to design more compact, intelligent, and flexible devices without compromising performance, while also simplifying network architecture and reducing cabling complexity. Its versatility and efficiency position SPE as a key enabler for industrial automation, building technology, robotics, infrastructure, and energy applications.

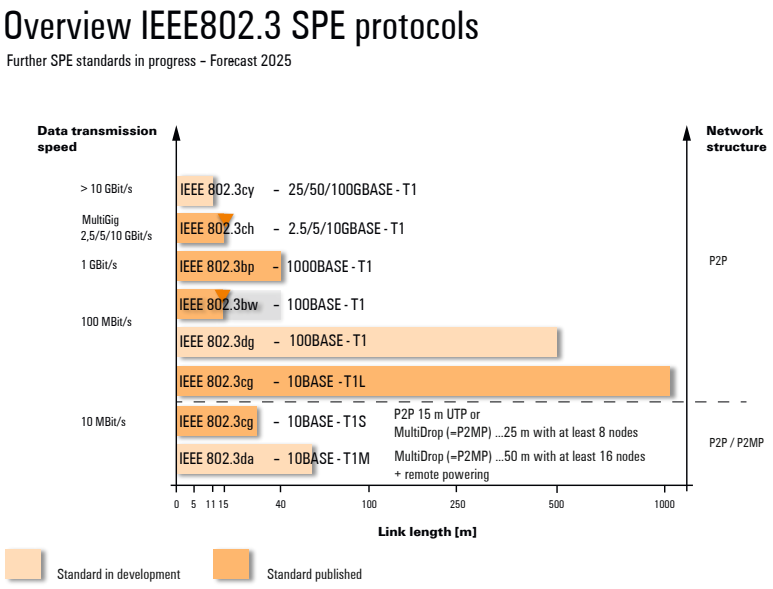
Key Benefits of SPE

- **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.



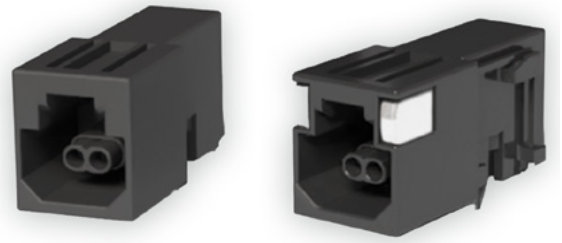
The IEC standard IEC 63171 considers the standardization of the connection technology of Single Pair Ethernet. This defines basic information, testing techniques and requirements for SPE connectors and includes electrical and transmission properties as well as different mating faces. In addition, the 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.

The New IEC 63171 7 Standard: Harmonized SPE Interfaces

To support device manufacturers in adopting SPE, Weidmüller has aligned its portfolio with the new IEC 63171 7 Edition 2 standard. This harmonized interface provides a unified mating face across IP20, IP67 and Hybrid connectors, enabling seamless interoperability across different vendors and network devices.

Compliance with IEC 63171 7 (Ed. 2) not only ensures devices meet all necessary certification requirements but also reduces engineering risks, simplifies planning, and accelerates time-to-market. For PROFINET over SPE, IEC 63171 7 is already recognized as a standard, providing clear guidance for device and system manufacturers. Simultaneously, organizations such as PROFINET International, ODVA, OPC Foundation, and FieldComm Group are driving consistent SPE standardization—including PoDL power classes and standardized connectors—to guarantee interoperable, vendor-independent solutions from the field level to IT.

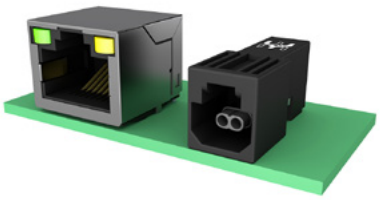
This standardization creates market certainty, giving device manufacturers confidence that SPE-based designs developed today will remain compatible with future network infrastructures.



3. Key Benefits for Device Manufacturers

Device Lifecycle and Market Relevance
Device manufacturers are responsible for the entire lifecycle of their products, from research and development and prototyping to production, quality control, and distribution. Adhering to industry standards and regulations is essential to ensure that devices are safe, reliable, and meet customer requirements. With Single Pair Ethernet (SPE) becoming increasingly adopted across industrial and commercial applications, manufacturers now have the opportunity to integrate a future-proof connectivity solution that will meet evolving customer demands and network requirements.

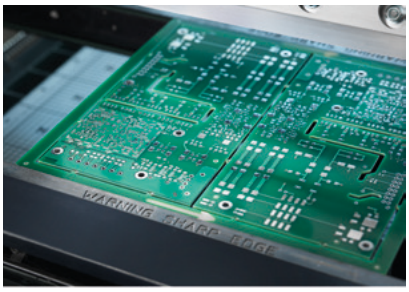
Compact, Efficient, and Versatile Device Design
SPE uses a single twisted pair of wires, enabling highly compact and lightweight device designs. Compared to traditional RJ45 connectors, SPE components occupy only 67 % of the space, allowing up to 33 % more ports on the same PCB. This miniaturization is especially valuable for applications where space and weight are critical, such as automotive, aerospace, and industrial devices. Consolidating power and data via Power over Data Line (PoDL) further reduces cabling complexity and minimizes the number of connectors, simplifying the device architecture and lowering material and assembly costs. Two signal traces instead of four twisted pairs make PCB routing easier, free up board space, and support faster, more reliable automated assembly, while high coplanarity, tight pin tolerances, and tapered pin tips ensure robust mechanical performance over 750 mating cycles.



Future-Proof Connectivity and Operational Reliability
SPE serves as an additional physical layer, supporting Ethernet-based protocols such as PROFINET, Modbus TCP, EtherNet/IP, and HTTP. This high level of compatibility ensures seamless integration into existing networks and guarantees interoperability across vendors. Simplified cabling and fewer connectors reduce potential failure points, while optional LED indicators provide visual feedback for installation, commissioning, and maintenance, facilitating troubleshooting and minimizing downtime. Optimized signal integrity, controlled impedance, and robust shielding maintain consistent performance even in electrically noisy industrial environments, while familiar RJ45-like haptics make installation and servicing intuitive.

Economic and Strategic Advantages Across the Product Lifecycle

Adopting SPE offers both technical and economic benefits throughout the entire product lifecycle. High-temperature-resistant materials ensure robust soldering in THT and THR assembly, while the reduced footprint and simplified routing lower PCB manufacturing costs. By integrating data and power transmission into a single interface, manufacturers can design versatile, cost-effective devices suitable for industrial and commercial applications. Early adoption of SPE allows companies to future-proof their products, streamline production, reduce material usage, and improve sustainability through lighter, less bulky cabling. Together, these advantages provide a strategic edge, enabling faster innovation, optimized device performance, and long-term compatibility with emerging industrial standards.



4. Applications of SPE – Perspectives for Device Manufacturers

Single Pair Ethernet finds it 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, an increasing number of sensors and actuators are deployed across all areas of manufacturing. This growth requires a consistent, scalable, and time-critical network from IIoT devices to the cloud, with reliable components that can deliver Ethernet connectivity down to the individual sensor or actuator level. Single Pair Ethernet (SPE) is ideally suited for these applications, enabling direct, high-speed connections for devices such as barcode readers, cameras, user terminals, and detection sensors.

SPE eliminates the need for additional gateways, allowing uniform and interoperable networks that simplify system architecture and streamline data acquisition. Long distances of up to 1,000 m can be bridged while maintaining high transmission speeds, and with Power over Data Line (PoDL), both power and data can be delivered over the same two wires, removing the need for separate power lines. The result is faster and more reliable process control, higher plant availability, and a simplified, cost-efficient network infrastructure.

2. Robotics

Single Pair Ethernet (SPE) enables significant advancements in the miniaturization of communication infrastructure, making it possible to develop more sophisticated robotic systems, including end-of-arm tools. SPE supports high-resolution 2D and 3D robot vision systems by providing data transmission at speeds of up to 1 Gbit/s over distances of up to 40 meters.
Compared to conventional protocols, SPE offers greater bandwidth, allowing efficient communication between a robot's arm and its controller to handle larger data frames.
The Power over Data Line (PoDL) feature simplifies cabling by transmitting both data and power over a single cable, reducing complexity and enabling flexible placement of devices. Additionally, SPE cables have smaller bending radii than traditional automation cables, contributing to a more compact communication infrastructure and allowing for reduced overall dimensions of robotic arms and systems.

This combination of high-speed data, integrated power delivery, and compact cabling enhances both performance and design flexibility in automated production environments, supporting advanced robotics and efficient, space-saving installations.

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.

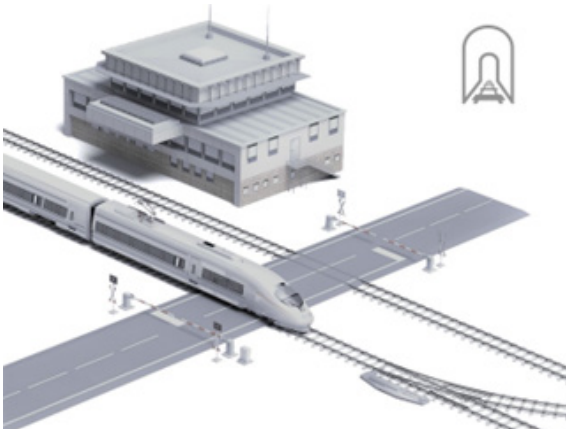
4. Building automation

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.



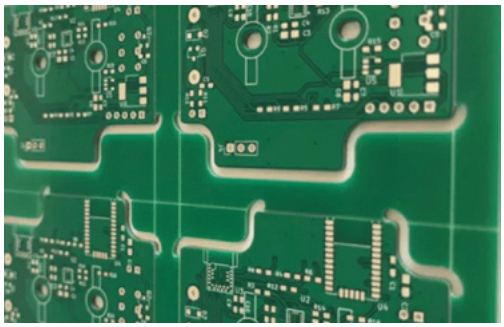
SPE's compatibility with existing Ethernet-based systems ensures seamless integration, enabling efficient deployment of intelligent infrastructure solutions that need real-time data exchange and monitoring. Additionally, SPE's scalability makes it ideal for expanding existing infrastructure projects, 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.

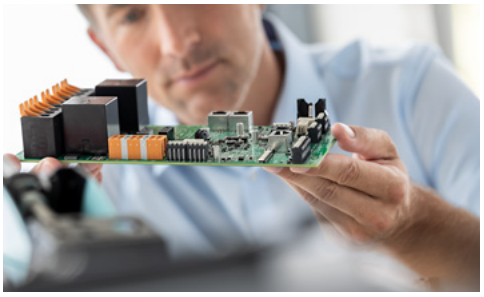
5. Design Considerations for SPE Devices

When designing SPE-compatible products, manufacturers must carefully consider components, conformity, system architecture, and testing to ensure reliable, high-performance devices.



SPE connectors are smaller and simpler than traditional Ethernet connectors, reducing PCB space and cost, which is relevant for PCB Layout and Connector Design. They must be robust and reliable for specific application environments. The IEC 63171 standard defines various connector types, allowing the use of standardized components and qualified SPE terminals to ensure dependable transmission. The reduced number of signal traces allows for compact board layouts, while Weidmüller's high coplanarity, precise pin tolerances, and tapered pin tips ensure reliable automated assembly. SPE connectors maintain RJ45-like handling, supporting intuitive installation and maintenance.

SPE devices are engineered for robust signal integrity, with controlled impedance, optimized shielding, and carefully managed creepage and clearance distances. This ensures consistent performance even in electrically noisy industrial environments and supports long-distance communication with real-time data acquisition. EMC compliance must also be addressed to maintain reliable operation in demanding conditions.



Power over Data Line (PoDL) enables simultaneous transmission of power and data over a single pair of wires, simplifying cabling and reducing the number of connectors. Device designers should select the appropriate PoDL class to ensure safe and efficient energy delivery. Integrating power and data management into device architecture allows streamlined designs while maintaining high reliability and performance.

SPE-specific cabling is optimized for high data rates and PoDL over long distances with minimal interference, and their smaller bending radius supports compact device designs. Choosing appropriate physical layer (PHY) components and transceivers that comply with SPE standards is crucial for converting digital data into electrical signals. Ethernet controllers must support SPE technology to ensure efficient data management and protocol compatibility. For network infrastructure, devices must integrate seamlessly with switches, routers, and other components. For 10BASE-T1L applications, Weidmüller offers suitable switches fulfilling SPE requirements.

Last, but not least, rigorous testing and certification are essential to ensure devices meet SPE standards, achieve interoperability, and perform reliably under various conditions. Adherence to standards validates the design, confirms compatibility across vendors, and guarantees long-term operational reliability.

6. Weidmüller SPE Portfolio: Expanding to IEC 63171 7

Building on its existing IEC 63171 2 portfolio, Weidmüller will expand its SPE offering to IEC 63171 7-compliant components by mid-2026. The portfolio addresses the needs of industrial device manufacturers and system integrators, offering both IP20 and IP67-rated solutions.

Components include PCB sockets and connectors, IP20 patch cables, IP67 circular connectors, field-attachable IP20 connectors for on-site assembly, and new switches supporting SPE networks and 10BASE-T1L applications. Future portfolio expansions will cover M8 connectors, additional PCB connectors, wall feed-throughs, DIN rail outlets, media converters, and other network infrastructure components, enabling manufacturers to gradually adopt the new standard while maintaining compatibility with existing SPE solutions.

By broadening the portfolio in line with IEC 63171 7, Weidmüller supports manufacturers in creating future-proof, flexible, and reliable devices, simplifying integration and accelerating the design-in process.

7. Future Trends and Developments

The adoption of Single Pair Ethernet (SPE) is poised for substantial growth as industries increasingly recognize its benefits. Future advancements are expected 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 expands, innovation will accelerate, creating new opportunities for device manufacturers. This growing ecosystem not only enhances existing technologies but also enables 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. The technology's inherent flexibility and efficiency position it as a key enabler for a wide range of applications, from automotive networks and industrial automation to the process industry, building automation, IoT applications, and smart grids.
The harmonization of SPE through IEC 63171 7 provides device manufacturers with clarity and market confidence. The standardized interface, widely supported by PROFINET and other industrial protocols, ensures that devices designed today remain compatible with future network infrastructures. SPE is set to become a cornerstone of industrial and commercial networking, enabling compact, energy-efficient, and high-performance devices across factory automation, building technology, robotics, infrastructure, and energy. Early adoption offers manufacturers a strategic advantage, allowing them to shape the next generation of connected devices.

Next to the right products, Weidmüller supports this journey with comprehensive design-in resources, including 3D models, sample components, technical drawings, STEP and EDA data, soldering profiles, and expert consultation on connector selection, cabling, PoDL, and system architecture. By leveraging these resources, manufacturers can confidently implement SPE, accelerate development cycles, and deliver devices that are future-proof, interoperable, and optimized for industrial performance.

Conclusion:
SPE's combination of high-speed data transmission and integrated power delivery via Power over Data Line (PoDL) simplifies device design and connectivity, reduces cabling complexity, and minimizes the physical footprint of infrastructure. This makes it an ideal solution for industrial automation, building automation, and IoT ecosystems, supporting real-time monitoring, intelligent control, and energy-efficient operations. Devices can be powered and connected through a single twisted pair cable, streamlining design considerations while ensuring future-proof interoperability with existing and emerging Ethernet networks.

As the SPE ecosystem continues to mature, it will unlock new design possibilities, enable simplified cabling, and allow more efficient network architectures, delivering long-term value for device manufacturers and system integrators. Manufacturers embracing SPE today are positioned to lead the development of smarter, more efficient, and highly capable connected devices, securing their relevance in the evolving landscape of Industry 4.0 and the Industrial Internet of Things (IIoT).

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Torben Schoeneberg is Product Manager in the field of device connection technology and responsible for data connectors. He has been working for Weidmüller since 2018.
Through his previous activities in Sales Support and Business Administration, he was able to gain experience from the international market environment in various industries.

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