# Single Pair Ethernet Poised to Power up Industrial Automation

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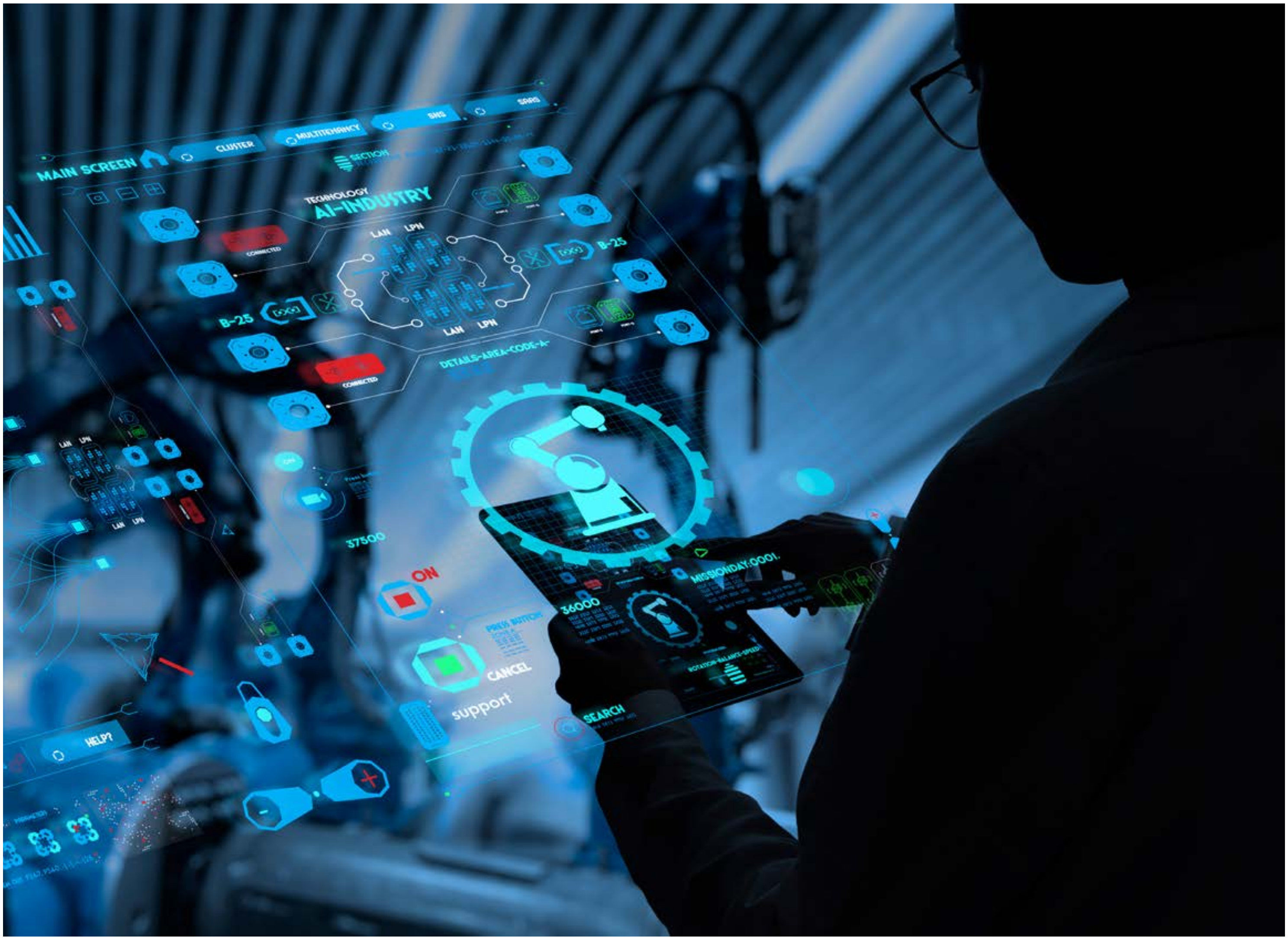


***Source:*** greenbutterfly/Shutterstock.com

Single Pair Ethernet (SPE) is rapidly becoming a desirable and more cost-effective alternative to traditional Ethernet in a wide range of implementations spanning across an array of different industries. SPE utilizes a single twisted pair of wires to simultaneously transmit data and power, making it smaller in scale and more energy-efficient than the standard 4-pair Ethernet cabling. SPE can transmit up to 10Mbit/sec of data over distances up to 1000m and up to 1Gbit/sec of data over distances up to 40m, all while delivering up to 52W of DC power. SPE evolved out of the automotive industry's desire to add more Ethernet-based devices and systems to newer vehicles, like the motion and proximity sensors that enable LIDAR (light detection and range) in self-driving automobiles and the high-definition displays in infotainment systems. The space limitations in modern automotive environments created the need for lighter-weight cables with smaller profiles—and in some cases needed a single cable to perform the job that in previous vehicle generations was done using multiple cables.

As it has developed, SPE has found a more robust market in industrial automation and manufacturing implementations. SPE's lightweight and simplicity is an optimal solution for networking the kinds of industrial robotics and monitoring systems typically found in modern manufacturing settings. Upgrading from existing cabling to SPE cables is as simple as disconnecting the existing Ethernet networking cable and replacing it with an SPE cable—the existing infrastructure can be easily upgraded to SPE without any additional retrofitting or equipment upgrades.

## Industrial Automation and Manufacturing

Industrial automation for material processing and transportation is a rapidly growing field with many key application areas. Some examples of these are fixed location track-based material movement and processing systems in modern factories and flexible and autonomous warehouse robots for item storage, tracking, retrieval, and processing. Industrial automation is the lifeblood of the increasingly critical production and transport chain of today's modern economy. Although seemingly disparate use cases, this assortment of applications share many common elements.

At the "edge" of all these systems are sensors implemented to track materials, provide quality control and inspection, monitor processes, and otherwise observe the critical system elements that need regulation. In advanced systems, video is implemented (in conjunction with artificial intelligence algorithms) to track processes and materials—and to adapt to changes in requirements or the local environment when necessary. Thus, video can have significant advantages over fixed-function sensors like scanners or position sensors and can even allow the system to evolve and improve as it learns from previous operations (video does require higher communications bandwidth, however).

Once the sensors have collected the relevant data, the control system "sifts" through that data and uses it to alter the operations of the processes or material transport system to optimize efficiency. Data collection can require a robust communications interface that supports various bandwidths—from periodic process sensors that change slowly over time to higher speed sensors for measuring position and movement to the highest bandwidths, such as for real-time HD video feeds. Typically, a variety of industry-standard interfaces and protocols need to be supported, sometimes due to the need to include legacy sub-systems or to differences between newly developed, more advantageous sub-systems.

Changing the operation of an industrial automation system often requires dealing with motors—whether for a robotic arm or the speed or direction of a track-based material control system. Just about every industrial automation system needs a host of motors or other electromechanical elements to control the system's operation. Advanced motor control systems can use artificial intelligence algorithms (using historical data hosted in the cloud) for predictive maintenance to avoid costly system downtime and extend the system's overall operating lifetime. High-level data collection can require additional bandwidth but can also dramatically reduce overall system costs.

Industrial applications often have a set of high-level standard requirements as well. For example, reliability can be critical when controlling expensive processes and materials. Any system downtime can be costly, so consistent performance is essential in keeping costs down. Safety is even more critical when human operators are on the factory floor or in the warehouse. Other high-level standard requirements may include:

- Low startup costs
- Low maintenance costs
- Long system lifetimes
- Easy updates to the system hardware and software modules
- The use of industry standard communications protocols
- Low power requirements
- System and subsystem flexibility

## SPE in Industrial Implementations

A more detailed look at a specific implementation can help identify how trade-offs in critical requirements can be avoided. For example, let's examine a mid-range industrial robot suitable for warehouse operation that has autonomous movement. The robot has one or more arms used for grasping, scanning, picking and placing, and moving small objects. Focusing on implementing the robot arm or arms can help illustrate how SPE can help satisfy the competing requirements mentioned above.

The robot arms will need to be as light as possible while still retaining the strength needed to handle the objects it moves, sorts, scans, etc. The robot also needs to be able to support any sensors, motors, or tools required in its normal operation. Communications between the sensors, control system, and motors need a robust and reliable wired interface to support high bandwidth video sensors used for object detection and scanning. Suppose a single cable can be used to connect to all the sensors, motors, and tools on the robot arm. In that case, it can provide a significant advantage over a system requiring individual wires for each sensor and motor sub-system. The number of cables will be further reduced by providing power over the same cable as data communications, lowering the overall cable weight. Combined power and communications can also reduce the size and weight of sensor and motor electronics, as separate sub-systems for electronics power delivery are no longer required. A single lightweight cable for power and data can also simplify cable management, a significant benefit in keeping multi-axis arm movement from over-twisting cables. Cable replacement is also a simpler process when only a single cable needs to be accessed.

## The Three Key SPE Levels: The MAC/PHY Layer, Signal Transformer, and Cabling System

Many of the essential requirements for an industrial application like the one described above can be satisfied using an SPE-based implementation. Delving into the key SPE sub-system levels—the MAC/PHY, the signal transformer, and the cable and connectors—can help illustrate why.

The MAC/PHY layer of an SPE implementation provides a standard protocol for moving data across the physical interface. The MAC/PHY is connected to an MCU or an MPU that provides data transfer control and implements higher-level application features. In an industrial robotic system, the local MCU can also be responsible for insuring reliable communications, and sensor interface or data filtering or aggregation. The MAC/PHY must also support the bandwidth needed and can range from a high of 1Gbit/s to a low of 10Mbit/s. Let's look at a specific MAC/PHY device, like the low power integrated 10BASE-T1 Ethernet PHY and Ethernet MAC/PHY from Analog Devices. For this application we will select the integrated MAC/PHY device, which is best suited for the arms distributed MCU-based sub-systems, the ADIN1110.

The Low Power Integrated MAC/PHY (ADIN1110) has several features that address the requirements for the robotic arms, sensors, and motors found in automated manufacturing environments. The ADIN1110 has a small board footprint by virtue of the number of features combined on a single device -- features such as the on-chip FIFO memory, integrated voltage monitor, and on-chip power-on reset circuitry. The simple interface also reduces signal count, further reducing the size of the device. The low power requirements of the ADIN1110 reduces overall system power, increases operating time, and reduces battery weight. Finally, providing a range of communication speeds—from 10Mbit to 1Gbit—supports both low bandwidth sensors and high bandwidth video data on the same physical interface. Our example design will use the 100BASE-T standard, which will be sufficient for the data bandwidth needed for the sensors and motors.

The MAC/PHY connects to a signal transformer and further passive filters that provide isolation, noise attenuation, ESD protection, and EMC improvement. This element of the SPE standard can be critical in industrial applications where a robust design is a necessary element in reliability, safety, and longevity. We will select the **Würth Elektronik** SPE devices for our example application: The **WE-STST signal transformer**, the **WE-CNSW common mode line filter**, the **WE-TVS diode**, and the **WCAP-CSMH/CSGP ceramic capacitors**. The solution provides 1.5kV isolation according to IEC 62368-1, ESC protection up to 15kV according to IEC 6100-4-2, signal stability up to 1000m, and supports 10BASE-T1 and 100BASE-T1 speeds. **Figure 1** shows an example of an industrial SPE implementation and the resulting smaller PCB footprint.

A robotic arm can use the implementation we've just described to provide a very small footprint for standard compliant (from SPE 10Base-T1 to 1000Base-T1) communications. This approach saves over 50% onboard space, a critical requirement when using a collection of distributed sensors and motors. Operation over an extended temperature range is also beneficial for industrial IoT applications in which overall reliability is important.

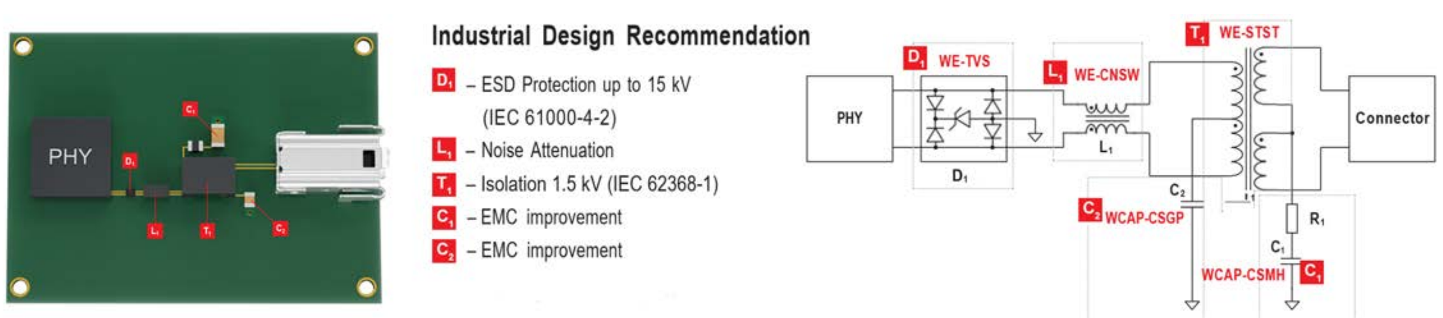


***Figure 1:*** *Single Pair Ethernet Solution for Industrial applications. (Source: Würth Elektronik)*

The SPE connector and cabling for the robotic arm are critical in delivering small size, low weight, and power delivery over the single pair of wires used in SPE. Our example can use the Harting T1 SPE (AH IP20) jack, Figure 2. This SPE jack is 80% smaller than the RJ25 implementation and has a lower profile and a smaller panel cut-out, hence a smaller PCB footprint. The SPE 2 wire connection provided by the jack supports up to 50W of power over the data line (PoDL) at the full range of standard speeds -- 1Gbit/s, 100Mbit/s, and 10Mbit/s. The compatible Harting receptacle, the T1 SPR (SL-C IP20), also supports the SPE industry standard (and offers smaller and lighter cabling) in addition to providing the same PoDL and speeds as the companion plug. Using the Harting devices is instrumental in reducing the number of cables in the system and the weight of the resulting implementation -- this also makes cable management and harnessing simpler and further reduces weight. The reduced number of cables simplifies testing, maintenance, and repair and improves overall system reliability while extending system lifetime.

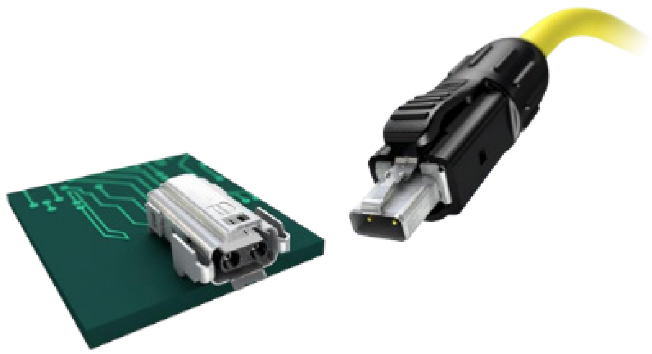

***Figure 2:*** *The Harting jack and plug offer end-to-end compatibility of devices, cables and connectors. (Source:* **https://www.mouser.com/new/harting/harting-t1-industrial/***)*

## Conclusion

SPE allows plant engineers and industrial operations professionals to design and build cost- and energy-efficient automation networks and cabling structures without costly retrofitting or redesigning of manufacturing facilities or processes. SPE can communicate over existing Ethernet protocols—Ethernet/IP, EtherCat, and Profinet—without the need for proprietary protocols or fieldbuses. The SPE benefits vary according to the specific application, but reducing complexity and overall size and weight is a recipe that will reduce costs and improve efficiency to a wide range of industrial applications and networking technologies. As industrial automation and the Industrial Internet of Things (IIoT) continues to propagate, SPE is poised to become the preferred networking solution.