

High Precision and Low Cost for Industrial Automation: POWERLINK and the Intel® Ethernet Controller I210

Standards-based networking solutions now deliver the high predictability and performance needed for motion control and industrial automation, without the higher costs associated with proprietary field-programmable gate arrays (FPGAs).



Industrial applications require performance and precision for high-speed, predictable timing of events. For example, a robot arm must be in exactly the right place at exactly the right time to perform an operation on a manufacturing line, and the control system that robot is connected to must be able to process data fast enough to accurately control the overall process.

Industrial protocols such as POWERLINK deliver high predictability, but increasing demands for predictability and performance tend to drive up the cost of the underlying hardware. Typical off-the-shelf Ethernet controllers, even when used in a real-time OS, are not capable of the levels of predictability (low jitter) required for demanding industrial applications, and as a result, expensive FPGA-based solutions are typically used. The Intel® Ethernet Controller I210 stands apart from other off-the-shelf Ethernet controllers, delivering both high performance and high predictability while lowering the implementation cost for even highly demanding usages of POWERLINK.

ETHERNET POWERLINK

The Ethernet POWERLINK Standardization Group (EPSG) is an independent organization founded in 2003 by leading companies from the fields of motion control and automation technology.

The organization's goals are to standardize and further develop the POWERLINK protocol first introduced by B&R in 2001. The

EPSG cooperates with leading standardization organizations such as CAN in Automation (CiA) and the IEC. Stefan Schoenegger is the organization's general manager.

POWERLINK is a completely patent-free, vendor-independent, and purely software-based communication system that delivers hard real-time performance. POWERLINK is well suited to a broad range of automation applications, including I/O, motion control, robotics tasks, communication between programmable logic controllers, and visualization. Initially developed by B&R, POWERLINK was introduced in 2001. The Ethernet POWERLINK Standardization Group (EPSG), an independent user organization with a democratic charter, took charge of the further development of the technology in 2003. An open-source version was made available free of charge in 2008.

POWERLINK uses the IEEE 802.3 Ethernet standard—the same protocol that provides all standard Ethernet features and allows for flexible deployment of various network topologies. POWERLINK is standardized by the International Electrotechnical Commission (IEC) as international standards IEC 61158 and IEC 61784-2. POWERLINK is also the Industrial Ethernet National Standard in China (GB/T-27960-2011).

Until recently, the best, lowest-jitter POWERLINK performance required a discrete FPGA, which added cost to the overall solution. Optimization for industrial automation in the Intel Ethernet Controller I210 eliminates this requirement while delivering better performance than software-only-based industrial Ethernet solutions.

POWERLINK: Ethernet Built for Industrial Automation

POWERLINK is a deterministic real-time protocol based on standard Ethernet. It uses a mixture of time-slot and polling procedures to achieve the transfer of time-critical data. Part of the network bandwidth is reserved for non-real-time data, with asynchronous communication between network nodes.

A POWERLINK device can be a managing node (MN) or a controlled node (CN). A POWERLINK network has exactly one MN, which regulates activity on the network. All other devices in the network are CNs. A POWERLINK cycle, which is illustrated in Figure 1, consists of three periods:

- 1. During the Start Period**, the MN sends a Start of Cycle (SoC) frame to all CNs to synchronize the devices. The SoC is sent as a multicast packet and can be received and processed by all other POWERLINK nodes in the network. No application data is transported in the SoC; it is used only for synchronization.
- 2. During the Cyclic Period**, cyclic isochronous data exchange takes place. In the course of one clock cycle, the MN sends Poll Requests to one CN after another in a fixed sequence. Every CN replies immediately to this request with a Poll Response, on which all other nodes can listen in.

- 3. The asynchronous phase** enables the transfer of large, non-time-critical data packets, such as user data or TCP/IP frames, which may be scattered between the asynchronous phases of several cycles.

POWERLINK cycle times as short as 500 microseconds are relatively common, although cycle length is user-configurable and will vary according to the specific implementation. The precision demanded by high-speed industrial automation makes SoC jitter a critical timing parameter in POWERLINK communication cycles, which are initiated by SoC frames that are generated by the MN, as shown in Figure 2. For a software solution, the accuracy of the SoC generation is usually determined by the OS, network stack, and network driver. A high-resolution timer is also usually required to provide accurate cycle timing.

To date, where higher performance (lower jitter) than possible with a software solution is required, FPGAs have been used to implement POWERLINK master stacks. These FPGA implementations are capable of very low jitter, but they add cost to the system. The Intel Ethernet Controller I210 provides some key features, described below, which enable very low jitter operation without requiring FPGAs.

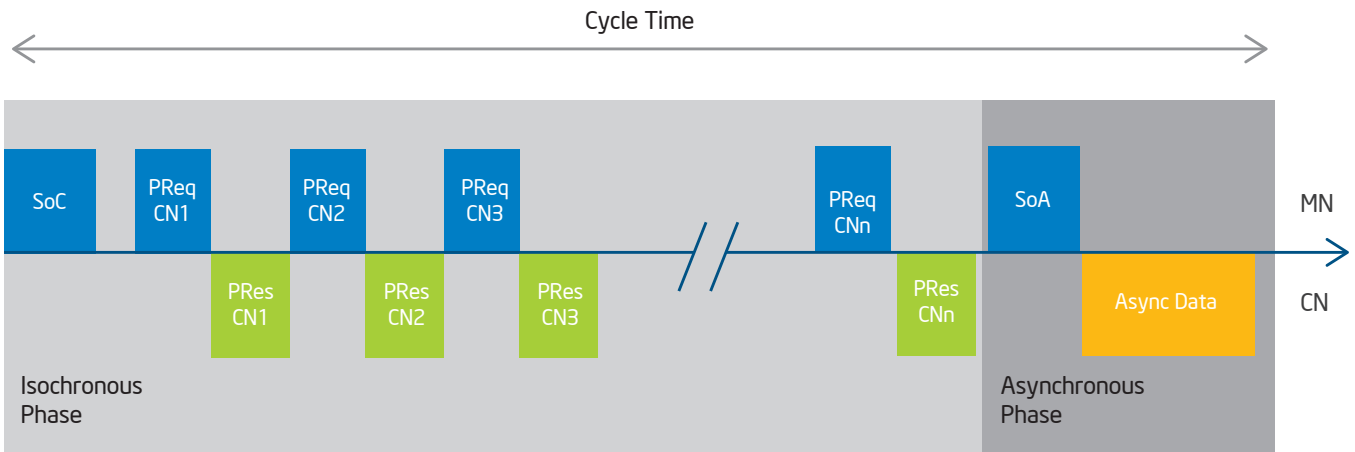


Figure 1. POWERLINK cycle.

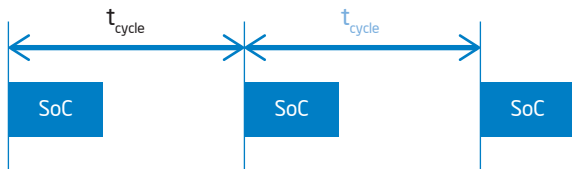


Figure 2. POWERLINK Start of Cycle (SoC) timing.

Intel® Ethernet Controller I210: High Performance and Low Jitter

The Intel Ethernet Controller I210 provides outstanding connectivity for POWERLINK masters. It effectively balances the requirements for highly accurate and low-jitter transmission with low cost. While standard Ethernet controllers are used today for software implementations of POWERLINK masters, the long control cycles of these solutions exclude their use in demanding applications such as motion control. For these types of applications, POWERLINK masters typically use FPGA-based Ethernet controllers, which are significantly more expensive than off-the-shelf standard Ethernet controllers such as the Intel Ethernet Controller I210.

The key advancement within the Intel Ethernet Controller I210 that enables high accuracy is the ability to specify the time at which packets should be transmitted. Most systems with standard Ethernet controllers exhibit very high jitter for transmitted packets, mostly due to a lack of determinism in the OS and network stack. To address this issue, Intel added several capabilities to the Intel Ethernet Controller I210:

- **Separation of time-critical traffic and best-effort traffic** into separate queues
- **Ability to specify the launch time of packets from time-critical queues** based on a high-precision hardware clock with 8-nanosecond resolution
- **Programmable packet-data prefetch** to ensure that packet data is ready to send at the specified launch time
- **Programmable hold-off for best-effort traffic** to ensure conflict-free transmit of time-critical packets

If the Ethernet controller begins to send a best-effort packet too close to the time when the SoC needs to be sent, transmission of the best-effort packet may still be in progress when it is time to send the SoC frame. Setting a hold-off time allows best-effort frames to be delayed until after the SoC frame is sent.

These features allow POWERLINK SoC frames to be sent at very specific times with very low jitter, effectively removing uncertainty associated with the OS and network stack, as shown in Figure 3.

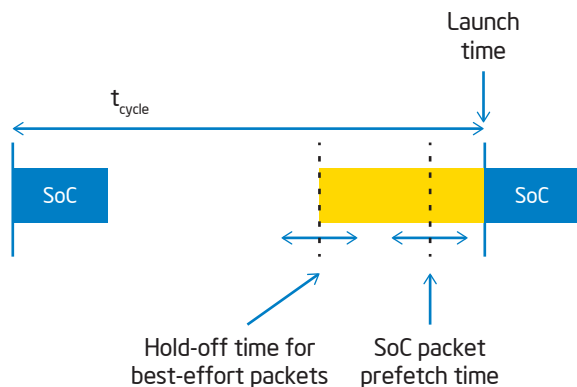


Figure 3. Intel® Ethernet Controller I210 timing features related to POWERLINK Start of Cycle (SoC) frames.

The key features of the Intel Ethernet Controller I210 enable high-performance POWERLINK master systems to realize the advantages of standard off-the-shelf Ethernet controllers, including the following:

- Low cost
- Superior energy efficiency
- Small footprint, compatible with the Intel® 82574L Gigabit Ethernet Controller
- Integrated triple-speed BASE-T PHY
- SerDes/SGMII interfaces available
- Industrial temperature support available
- Production availability for seven or more years

POWERLINK and Intel Ethernet: A Viable Standards-Based Solution

The POWERLINK master used for performance validation is a standard industrial PC running Linux* and the open-source POWERLINK software stack, as shown in Figure 4. The timing precision of the POWERLINK network was measured by a real-time network analyzer from B&R (X20ET8819).

The openPOWERLINK stack is published under the open-source BSD license. It contains the POWERLINK protocol stack for the Managing Node (master) and for the Controlled Nodes (slaves). It runs on Linux, VxWorks*, Microsoft Windows* and other OSs and platforms. With the openPOWERLINK stack, which is available at <http://openpowerlink.sourceforge.net/>, a pure software-based solution is available that runs on a standard PC without proprietary hardware.

Measurement results confirm the high accuracy that can be achieved using POWERLINK and the Intel Ethernet Controller I210. With a series of approximately one million tests running POWERLINK at 500µs cycle time, an accuracy of 6 nanoseconds was measured. Figure 5 shows the measured POWERLINK cycle time during a CPU load test. Even during this heavy stress test, an absolute maximum network jitter of just 240 nanoseconds was measured.¹ These results demonstrate that the combination of the Intel Ethernet Controller I210 and POWERLINK is a viable alternative to more expensive FPGA solutions.

“The combination of the Intel® Ethernet Controller I210 and POWERLINK now offers customers a more cost-effective, standards-based alternative to proprietary ASICs for many industrial applications.”

– Stéphane Potier, Technology Marketing Manager, EPSG

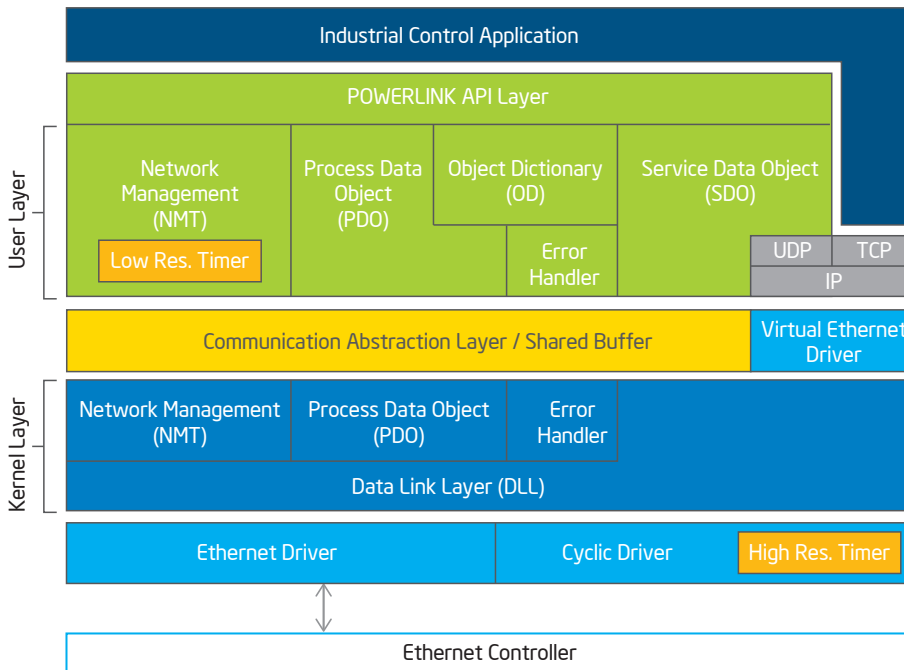


Figure 4. The openPOWERLINK software stack.

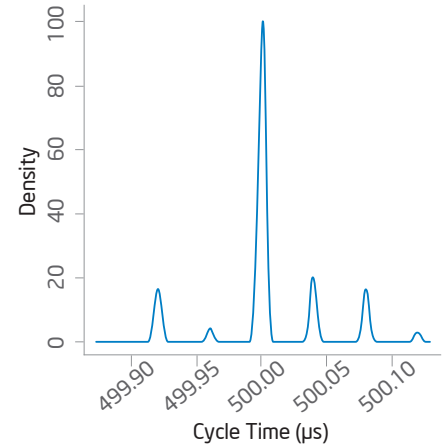


Figure 5. High regularity (low jitter) in POWERLINK cycle times.¹

Conclusion

POWERLINK masters can achieve very high performance at a lower cost point than ever with the Intel Ethernet Controller I210. Eliminating the requirement for proprietary network controllers allows a typical low-cost Industrial PC to be used as a POWERLINK master for systems implementing motion control or high-speed drives.

Industrial PCs based on Intel® processors take advantage of continuing advances in performance and energy efficiency while also benefiting from the broad ecosystem of development tools available for Intel® architecture-based systems.

For more about POWERLINK, see www.ethernet-powerlink.org

For more about Intel® Ethernet, see www.intel.com/go/ethernet

SOLUTION PROVIDED BY:



¹ Industrial PC, Pentium® Dual-Core Processor E5700 @ 3.00GHz; Linux® kernel 2.6.31-11-rt; openPOWERLINK v1.8.2; Intel® Ethernet controller I210-AT; POWERLINK cycle time: 500µs.

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