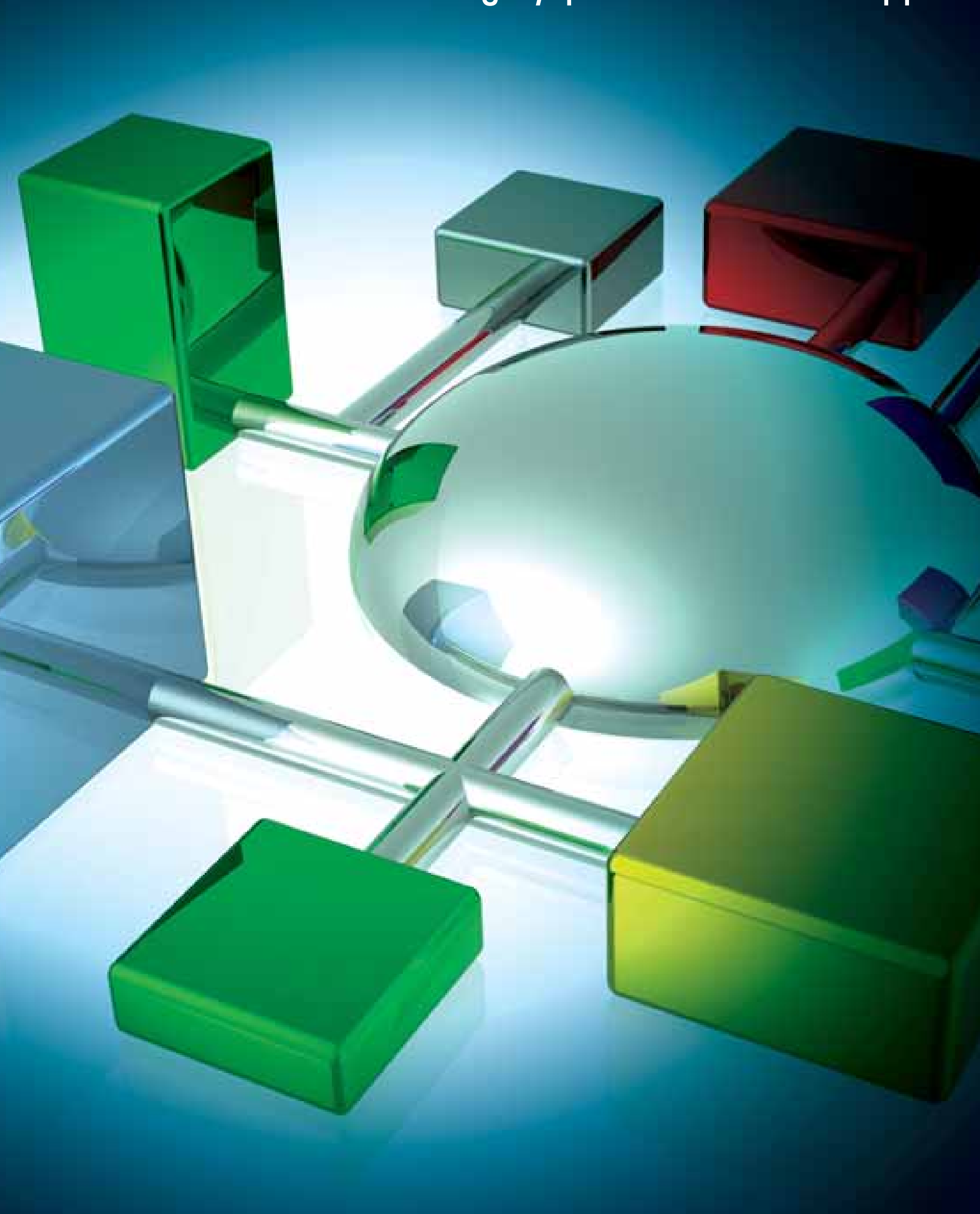
# Designing Efficient, Synchronized and Reliable Motion Networks

## Real-time Ethernet-based SERCOS III offers an innovative networking solution for fast and highly precise industrial applications.



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SERCOS (SErial Real-time COmmunications System), the digital drive interface specified by international standard IEC 61491, has become a globally accepted real-time networking standard for demanding motion-control applications over the last decade. SERCOS is particularly interesting because of outstanding technical features like real-time capabilities, high performance, noise immunity, and last but not least, a very large variety of products and suppliers.

The third SERCOS generation combines the proven mechanisms of the SERCOS interface with Ethernet's physics and protocol. This combination offers new and innovative options for the automation technology of the future (Figure 1).

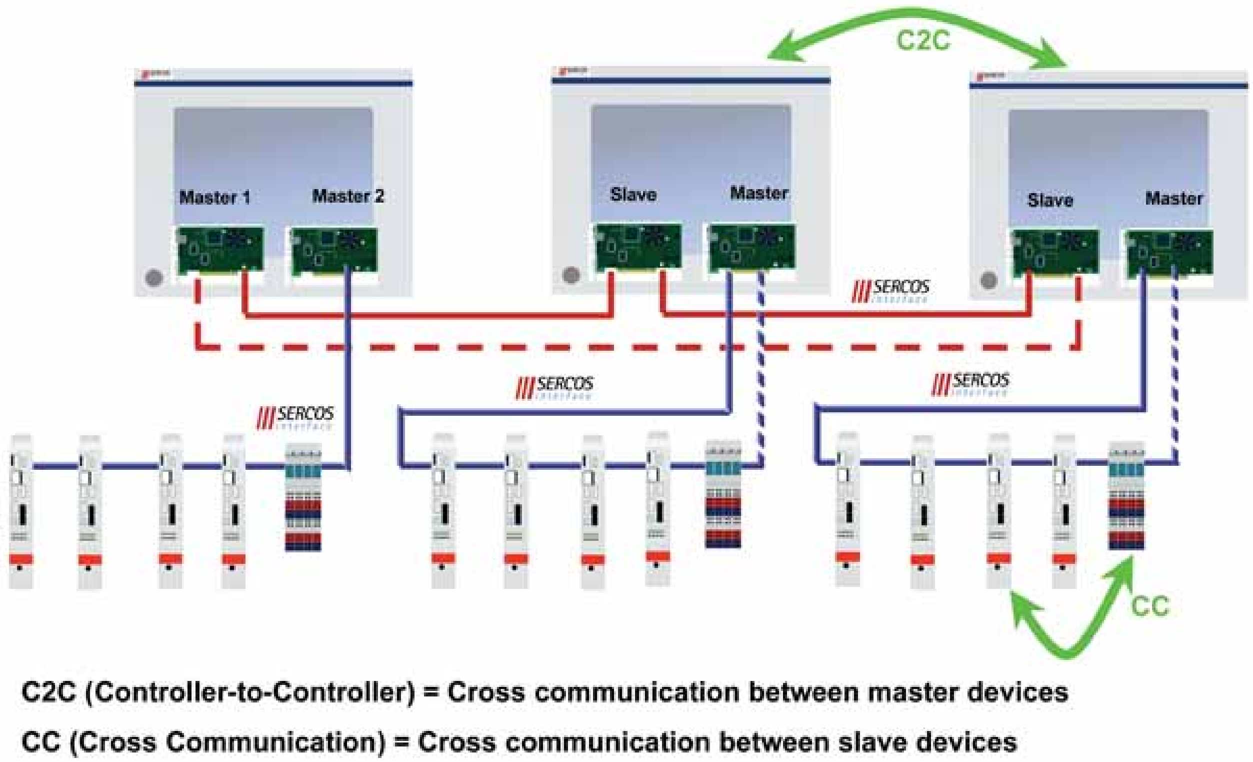


*Figure 1 – Universal real-time communication with real-time, Ethernet-based SERCOS III*

### Why Combine Ethernet and SERCOS?

Industrial Ethernet has become the de facto standard for manufacturing information networking, and the market has begun to request Ethernet connectivity for servo drives. Ethernet is characterized by high bandwidth and low hardware costs, but is not deterministic. The SERCOS interface, on the other hand, is optimized for high-speed deterministic motion control where the exact synchronization of multiple drives is required.

The second-generation SERCOS interface, SERCOS II, operates at up to 16 Mbps, which is more than adequate for most applications (although there is still a demand for higher speeds). Also, the SERCOS interface has been most effective in 1 kW and above drives because the cost of its optical components has limited its adoption in lower power drives, a large segment of the market.

The SERCOS interface not only defines the protocol structure but also includes an ample variety of profile definitions (parameters and functionalities), which are already successfully used in a great number of applications. This facilitated the idea of combining the proven mechanisms and properties of the SERCOS interface with Ethernet physics to create SERCOS III, reducing costs and creating an advanced version of the successful open motion-control communication interface.

### How Does SERCOS III Work?

Our challenge was to create the best of both worlds and combine the deterministic performance of SERCOS with the low cost and high bandwidth of the non-deterministic Ethernet. Our solution was to put the standard Ethernet TCP/IP under control of the motion bus and use Ethernet hardware. This maintains the deterministic motion control of SERCOS, allows links to existing manufacturing communications infrastructure, provides for the possibility of new features, and lowers hardware costs.

The real-time Ethernet concept of SERCOS is based on the following mechanisms:

- A ring comprises one master and multiple slaves – drives, I/O, and sensors. Multiple rings can be used in a network.
- The communication is based on a time-slot protocol using fixed and distinct communication cycles. A communication cycle is divided into two channels with a timing control.
- In the real-time channel, collective SERCOS III telegrams are transferred as broadcast data. This increases the bandwidth and improves protocol efficiency. The addressing of the SERCOS III devices is achieved by pre-defined addresses or by addresses assigned by the master (remote addressing). SERCOS III telegrams are processed on the fly to reduce network delay times.
- In the non-real-time channel, any non-real-time Ethernet frames can be sent as individual telegrams to any device in the network. The addressing for this is carried out directly through the MAC address allocated to the master and slave devices.

## SERCOS III halves the minimum cycle time of the current SERCOS interface from 62.5 µs down to 31.25 µs.

- Any device can thus be connected individually or integrated in a network through any standard Ethernet hardware such as a notebook computer. Common protocol stacks such as TCP/IP are used for this. This mechanism works both in the offline mode (without the SERCOS III protocol running) as well as in the online mode (during real-time SERCOS III operation). Because the SERCOS III hardware ensures that the real-time channel cannot be disturbed by asynchronous Ethernet communication, any "non-SERCOS III" Ethernet devices can be connected directly to any free SERCOS III port without additional hardware and without a special software driver.

**SERCOS III Features**

SERCOS III has a ring structure like the traditional, fiber optic-based SERCOS interface. Conditional on the full-duplex characteristic of Ethernet physics, however, it is a double ring structure, which offers the possibility of redundant data transfer. In case of a break at any point in the ring, communication will continue. This switchover takes 25 µs at the most, which means only one communication cycle of data can get lost. Manufacturing can continue at a plant while the integrated diagnostics tool signals the break, which can be repaired without interfering with that plant's performance.

In addition to the ring structure, a linear structure is also possible. It does not offer the redundancy advantage but does save a wire connection. SERCOS III does not use the star topology of the standard Ethernet. There are no hubs or switches needed, which reduces delay times in the network and also reduces cost.

SERCOS III halves the minimum cycle time of the current SERCOS interface from 62.5 µs down to 31.25 µs. Because of the greater bandwidth of Ethernet physics, it is still possible to connect an adequate number of slaves despite the short cycle time. Thus, it is possible to implement both decentralized drive concepts and centralized signal processing concepts. With a decentralized drive concept, all control loops are closed in the drive. With centralized concepts, only the current loop is closed in the drive, whereas all other loops of several axes are implemented in the central control electronics.

In addition, SERCOS III offers the following features:

- High compatibility with previous SERCOS interfaces (topology, profiles, telegram structures, synchronization) to protect investments
- Reduced hardware costs by using off-the-shelf Ethernet hardware and FPGA devices

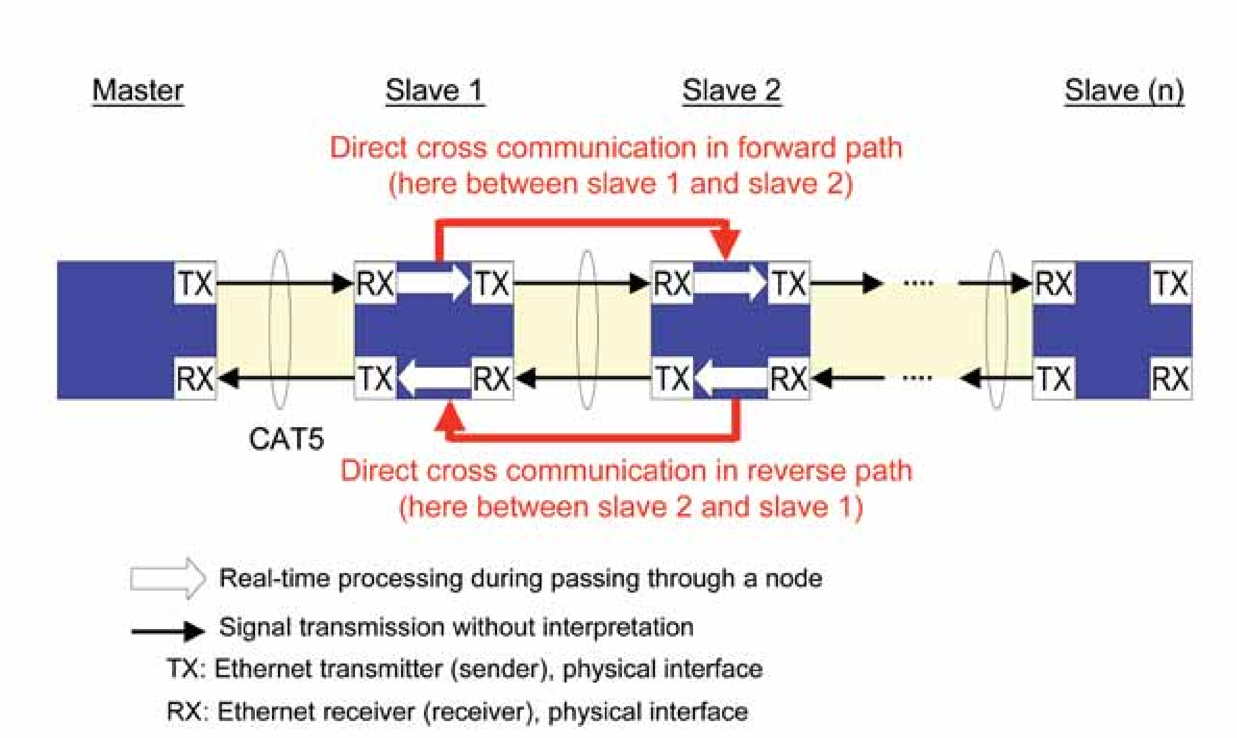


*Figure 2 – Direct cross-communication between SERCOS III slave devices*

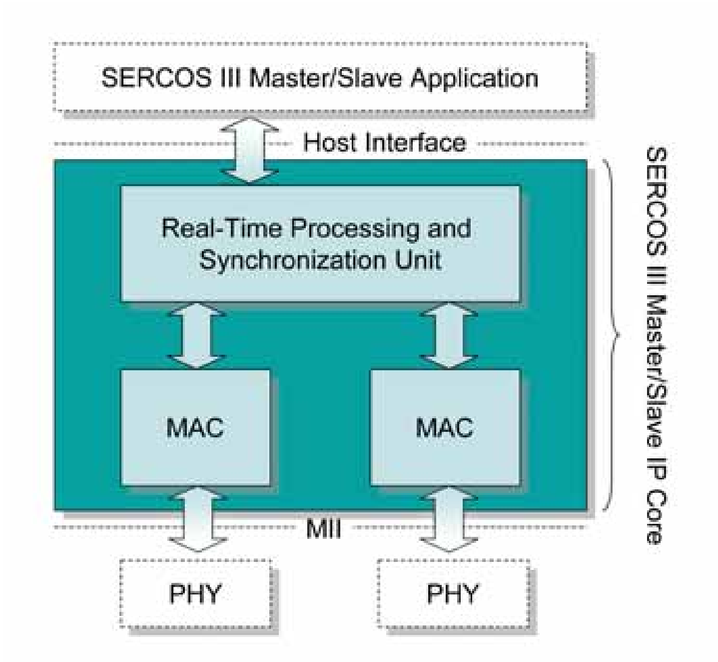


*Figure 3 – Real-time processing and synchronization unit of SERCOS III hardware*

- Integration with any Ethernet-based protocol – UDP/IP, TCP/IP, HTTP
- Direct cross communication between slaves (Figure 2)
- Synchronization of several motion controls
- Safe and non-safe data transmission through one network
- Hot-plugging and hot-swapping of devices during normal operation
- Fault tolerance in case of a break in the ring

### CIP Safety on SERCOS

Control Information Protocol (CIP) Safety on SERCOS is a safety concept for centralized and decentralized safety applications that is compatible with established SERCOS transmission mechanisms. It is based on a producer/consumer model supporting single- and multi-cast connections. Because of the routing capability of the CIP safety protocol, a safety network can stretch across several underlying and diverse communication networks: DeviceNet, Ethernet/IP, SERCOS III, and SERCOS II.

According to the CIP safety specification, the safe data container embedded in the SERCOS frame can contain between 2 and 250 bytes of safe user data. Thus, the SERCOS interface can be used within safety applications up to SIL 3 (safety integrity level) according to IEC61508, even with the shortest cycle times. Independent of the type of data – command values, logical signals, or safe logic or process information – the SERCOS interface provides a homogeneous, continuous solution for modern automation concepts.

### Performance

As described earlier, SERCOS III achieves very high performance because of its high protocol efficiency and direct cross communication. This has the advantage that data – even in case of longer cycle times – can always be transferred between slaves within a communication cycle with a minimum delay time. With homogeneous synchronization points, the target values are collected in a synchronous and simultaneously valid manner and the actual values across the entire network are collected in a synchronous and simultaneous manner. SERCOS III achieves a synchronization precision of < 20 ns and simultaneity values of < 100 ns. Furthermore, real-time data are available synchronously; that is, related to a joint communication cycle at any point within the network. This allows for very efficient and flexible network diagnosis and monitoring.

### SERCOS III Implementation

The original SERCOS interface was supported by a communication ASIC. A more flexible and cost-efficient hardware solution is implemented in SERCOS III. A SERCOS core (SERCOS-III IP) allows the use of FPGA devices to connect automation equipment to a SERCOS III network. SERCOS III controllers can be used on the master and the slave side, which not only supports the on-the-fly processing of real-time telegrams plus ring redundancy, but also provides an error- and jitter-free synchronization signal (Figure 3).

To support an easy migration from traditional SERCOS, a replacement for the SERCON816 ASIC has been defined. The SERCON100M/S/SL is a binary file that can be loaded on Xilinx® Spartan™-3 devices to create SERCOS III communication controllers for master and slave automation devices. In addition, the SERCOS III functionality is offered as a netlist, allowing component and system manufacturers to combine the SERCOS III hardware and other logic functionality into one common FPGA. Such concepts even allow the implementation of single-chip devices for low-cost automation peripherals.

### Conclusion

SERCOS III represents an important evolution in the SERCOS interface. Experts from SERCOS member companies are continuously finding new ways to improve and expand motion control using the interface.

For example, SERCOS International recently introduced Easy-I/O, a free IP core software for low-cost Spartan-3 XC3S250E FPGA devices. This allows SERCOS III to be integrated into basic I/O slave devices with minimal development and integration effort. This is another milestone in the establishment of SERCOS III as a universal, low-cost, real-time Ethernet solution for motion and I/O.

For more information on SERCOS, see *www.sercos.de* and *www.sercos.com*.