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Ethernet in Machine Construction

Part 3: Data traffic with high performance and tested reliability

Maximum efficiency is the goal of every machine manufacturer. Every project has to be judged in terms of how far it offers an optimum balance between results and costs. Therefore, new technologies are not taken up simply because they are new but because they improve efficiency without raising costs unnecessarily.

To be able to assess the efficiency of a technology, a precise understanding of the application is required. This is because the more tasks that a solution can fulfill, the more criteria it has to meet. Top results in one discipline can be ruined by weaknesses in another. Only those that can offer top results in all areas will meet engineers' and users' requirements for verifiable efficiency.

Networks of the future

The complexity of the considerations involved can be illustrated by the nervous system of modern production systems. Twenty years ago all that was required was for simple field buses to transfer measurement values reliably within a process and activate modules with precision. The more multi-layered the tasks, such as coordinating several drives (Motion Control), the greater the requirements became, and not every field bus was able to handle them effectively. Modern production systems demand networks which are also capable of enabling data to be exchanged between different processes and machines. Industrial Ethernet is the answer to the need for homogeneous vertical communication within companies, from the planning to the field level. As described in the first two parts of this series, the TCP/IP protocol was selected as the preferred option for enabling computers, control systems and machines to exchange information both within and outside the company.

Ethernet in accordance with IEEE Standard 802.3 is not suitable for horizontal communication in production because it allows a single device to block the network traffic even when another device needs to send an urgent message. In the finely-tuned process typical of an extruding machine, any such delay in a signal to a valve would produce scrap parts. Industrial Ethernet is therefore the ideal solution because it offers real-time communication. This means that it guarantees that every device in the network can receive and send data at any time.

At the same time, however, there is real-time communication and there is real-time communication. In order to enable a hydraulic system and stopper valve to work together to optimum effect in an injection molding machine, for example,

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the control data has to be transferred to several devices in precise cycles. In this case the synchronization and cycle time will determine whether the network offers the required performance level for all applications.

Guaranteed data transmission

SERCOS III, like previous SERCOS generations, is based on the field-proven hardware synchronization solution as it offers the greatest reliability. Every module comes with a special logic module (ASIC) which coordinates the SERCOS nodes with each other. This eliminates any need for additional expensive control points in the form of hubs and switches, and the network coordinates itself automatically. Synchronization is therefore one of the basic features of every SERCOS solution, not a feature which has to be added on each time with additional modules or protocols.

Thanks to this guaranteed network synchronization, SERCOS III can take real-time operation into whole new dimensions. The data transmission rate of 100 MBit per second (Fast Ethernet) in full-duplex mode along with the high protocol efficiency results in minimal cycle times of just 31.25 microseconds. One µs equates to one-millionth of a second. By way of comparison, the Space Shuttle can achieve a maximum speed of 27,875 km/h, but in the time it takes for a single SERCOS III cycle it would travel no further than just 0.2 millimeters, or the width of two hairs.

At the same time the cycle time of 31.25 µs in real-time mode does not mean that one individual module would take up the complete range for itself alone. Instead, it is possible for up to eight drives in Motion Control applications to be supplied with 8 bytes of cyclical data and for them to send the same number of diagnoses as well. This is sufficient for the most demanding tasks currently conceivable in mechanical engineering. Even high-precision CNC machines currently “only” have minimal cycle times of 1,000 µs. Thanks to the greater efficiency of SERCOS technology it will not be long before there will be no applications which would make it necessary to have a higher network speed. Moreover, Fast Ethernet also offers sufficient reserves for TCP/IP communication in production – especially because SERCOS is very efficient in the use of resources.

Flexible network structure

Flexibility is a success factor in production and Industrial Ethernet is a protocol which allows planning and production to be coordinated with each other without long lead times. In practice, however, a modern network is expected to be able to do even more than this. Flexibility also means being able to combine individual modules to form new solutions at low cost. Intelligent control systems turn

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machines into reusable modular systems, the components of which can be combined anew as requirements dictate.

The network therefore has to be highly flexible. As a general rule individual components (slaves) are controlled by a controller (master). This results in the typical linear bus structure of a section of production. In turn, the individual controllers can communicate with each other via a joint network, or gateway, segment.

However, sometimes it is more efficient for one component to inform another one directly. SERCOS III therefore permits cross-communication between masters and/or slaves. This makes it possible for data to be exchanged directly between a sensor and a drive which are controlled by separate controllers. This reduces the load on the central control system and also cuts data flows in the network. This so-called C2C (control-to-control) cross-communication between masters, such as two PLCs, for example, provides the basis for the distributed control of complex production lines. This flexibility in communication, which leads to reduced reaction times between master or slave devices and, therefore, in the overall process, permits the synchronous actuation of axes at any time, even where several SERCOS networks are involved.

More safety in operation

The technology which makes cross-communication between the individual nodes possible not only contributes to the efficiency and flexibility of SERCOS solutions, it also increases safety because it enables a SERCOS III network to be organized on the basis of a ring structure. In the event of a cable failure, therefore, a redundant signal route is available. This is not the case in the classical Ethernet which uses switches and routers for coordinating data flows. The SERCOS network, in contrast, coordinates itself and offers flexible strategies: a classical linear structure in order to save materials or a redundant ring structure for greater safety. The engineers have the choice of selecting the most suitable cabling to meet requirements without having to think about additional elements for the network infrastructure.

The same applies to the safety of data transmission. SERCOS offers a certified security protocol as standard to ensure that information is safely transferred. SERCOS safety complies with the requirements of safety standard IEC 61508 up to Safety Integrity Level 3 (SIL 3). This covers risks arising out of or in connection with system failures and which may pose a risk to the health of employees, to the environment, etc. For example, a sensor used for detecting a dangerous axis movement or an overheated drive is also supposed to ensure that the machine is made safe in a controlled manner and also switched off. Previously this required separate cables. SERCOS III allows all safety-related

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information to be transferred via the existing data cables so that in the event of an emergency it can be guaranteed that the power supply will be shut off if the emergency stop button is actuated. The elimination of additional hardware reduces costs without any compromise on safety.

SERCOS safety is protected against potential errors such as repeats, losses, insertions, incorrect sequences, corruption, delays and the confusion of secure and standard data. The security protocol is certified in accordance with IEC 61508 and was also tested by the German TÜV in respect of safety requirements. To ensure that data is transmitted securely SERCOS safety uses the CIP safety protocol of the ODVA. It is used by a range of communication standards such as DeviceNet, ControlNet and Ethernet/IP and allows users to use the same safety mechanisms on different platforms. This makes it possible to connect several CIP-based networks together on a consistent basis.

Reliability in every situation

Offering a combination of high performance, flexibility and verifiable safety, SERCOS III meets all the requirements of a modern, consistent automation network. It offers the required everyday suitability thanks to the field-proven capabilities of the SERCOS protocol and the forward compatibility of a real-time Ethernet solution. Thanks to Fast Ethernet and synchronous cycle times of 31.25 µs, the third generation of SERCOS not only delivers impressive performance data at the top end, it also masters complex automation tasks. For example, it can allow up to 330 drives with 4 byte input/output data and 8 digital I/Os each to communicate with each other in a cycle of a single millisecond. SERCOS III therefore delivers a level of performance which more than meets the requirements of today’s highly developed production machines. In addition, it also permits the rapid processing of process data via distributed I/O modules in central control systems.

SERCOS III also offers efficiency in Ethernet communication with standard TCP/IP protocols. Thanks to the full-duplex mode, every node can call on the full range of 100 MBit per second in real-time mode. Full TCP/IP consistency is guaranteed at the same time because non-real-time data packets are forwarded through via a special NRT channel (non-real-time), without compromising the guaranteed cycle times of the real-time data. This allows parameterization to be undertaken, for example, without the control system running using a standard notebook and Ethernet interface.
In October 2007 SERCOS III was incorporated in the binding standards IEC 61784-2 (Digital data communication for measurement and control) and IEC 61158 (Field buses for industrial control systems). In addition, the IEC 61491 SERCOS drive profile, which has existed since 1995, was also transferred to the new IEC 61800-7 standard. All three SERCOS generations are therefore now

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covered by the international IEC standards. For users and developers this means maximum efficiency, forward compatibility and planning certainty for investments in both new and existing machine systems.

Note: this Ethernet series has four parts which address different aspects of the technology. (The publication date publication is shown in parentheses).
The parts that have already been published are available at www.boschrexroth.de/press

Part 1 More flexibility in machine construction through Industrial Ethernet (31.10.2007)
Part 2 Trends and challenges in industrial automation (19.11.2007)
Part 3 Data traffic with high performance and tested reliability (07.12.2007)
Part 4 How companies can master the conversion safely and systematically (14.12.2007)

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