KUKA KR C4 robot controller uses EtherCAT

Since 2010 KUKA has relied on EtherCAT technology as a system bus in all KUKA robot controllers. The compact controller for the new KR AGILUS robot and the LBR iiwa lightweight robots is also implemented on the basis of EtherCAT. Industrial Ethernet-based EtherCAT from Beckhoff is thus universally integrated as a foundational technology throughout the current KUKA controller range.

In 1996 KUKA Roboter GmbH became the first robot manufacturer to introduce a robot controller exclusively based on Windows PCs. The success of this first generation of controllers can be largely attributed to the intuitive operator guidance using Windows technology as it is familiar from the office world and accepted by customers, and to the high performance of PC technology. Leveraging IT products from consumer markets enables a high degree of innovation and high performance at low cost. When it came to planning a new generation of KUKA robot controllers, it was an obvious progression to adopt further matured technologies from the IT world in addition to Windows and PCs – namely universal communication via Ethernet. A very powerful, fast and deterministic bus system is required for the internal communication inside the controller. For this reason KUKA has relied on EtherCAT since 2010 as the system bus for the KR C4 controller series to ensure high-performance and open standards.

A standardized fieldbus is generally used for the outward communication of the robot controller into the I/O, cell and plant levels in order to fully integrate the robot into an automation system. The fieldbus system is usually specified by the customer and the robot controller must be able to connect to the selected technology.

However, complex data traffic between the different components such as drives and position encoders is also necessary inside a robot controller so that control and regulation tasks with high requirements for real-time performance can be implemented. Furthermore, internal devices must exchange information for the safety technology and control infrastructure, not to mention display and operation. Different communication technologies were used for this in the previous version of the KR C4 robot controller, resulting in a large number of different plugs and cables.

In the planning phase of the current KUKA controller this issue was considered in great detail, taking also into account the ability of current Ethernet technologies to support real-time and safety requirements with very high data rates, all with the characteristics familiar from IT. In addition, Ethernet has the advantage that different protocols can be transmitted over a single line, which contributes enormously towards the reduction of cables in the system.

With the aid of the fully integrated “KUKA VisionTech” vision system, robots can also be used flexibly in unstructured environments.
One important goal of the project development was to use the fewest possible number of different communication technologies, both outwards to the fieldbus level and inwards, in order to achieve a more streamlined design. KUKA’s aim was to avoid the use of proprietary technologies in favor of the most accepted and open industry standards possible. In addition, performance-limiting hardware was to be replaced by intelligent software functions, and this was made possible due to the high computing performance of modern multi-core PCs. Less hardware meant an improved MTBF (mean time between failures) as well as lower development costs, price per unit and logistic costs. These standardizations led to a reduction in the number of required hardware assemblies by 33 % and in the case of plug connectors and cables by as much as 50 %.

**Communication to the field level: software stacks or gateways?**

With the pre-existing Ethernet equipment in the PC, the fieldbus connections to Ethernet-based fieldbuses such as PROFINET or EtherNet/IP could be entirely realized in software instead of using more expensive, specialized hardware. Thus, connections to conventional fieldbuses such as PROFIBUS or DeviceNet are not integrated by installing plug-in cards in the controller, but rather via EtherCAT communication gateways in the I/O system.

**Ethernet and EtherCAT for internal communication and communication with sensors, actuators and I/O**

All internal communication and the communication to the lower-level I/O level take place via standard Ethernet or EtherCAT. Therefore, only two different, yet standard communication protocols are used in the universal bus physics (cables, plugs and Ethernet controller chips) in the KR C4 robot controller.

Standard Ethernet is used internally for addressing the KUKA hand-held controller, for connecting and synchronizing several robot controllers within a KUKA RoboTeam group or for connecting an engineering laptop, for example.
The use of EtherCAT communication technology in addition to standard Ethernet was necessary because standard Ethernet technology cannot meet the requirements to deliver real-time capability and support of industrial safety protocols. EtherCAT functions as an internal drive bus for controlling and monitoring the drives of the robot and the position encoders. In addition, EtherCAT is used to control the internal safety assemblies for robot safety or for the safety-relevant operating elements of the SmartPad. Furthermore, an EtherCAT master interface to conventional fieldbuses is integrated for the user to address local I/O modules or gateways.

**Why EtherCAT?**

EtherCAT, as a real-time Industrial Ethernet and safety communication technology, was chosen because in comparison with other real-time Ethernet technologies it offers a series of benefits that were ideally suited to KUKA’s development goals. For example, EtherCAT requires no special hardware connection in the master, but only in the slaves. In the master, a standard Ethernet controller suffices, which is present in large numbers in the PC of the KR C4. The plugs and cables required are also identical to standard Ethernet, which lowers costs and increases simplicity.

Thanks to its special “processing on-the-fly” technique, EtherCAT enables very high data throughput rates, which can almost completely utilize the maximum possible net Ethernet data rate of 100 Mbits/s. That made it possible to execute many functions in software on the control PC that otherwise would have had to be outsourced to expensive proprietary hardware assemblies.

The EtherCAT-specific safety protocol, Safety over EtherCAT (FSoE) can be communicated over both EtherCAT and Ethernet. FSoE enables the PC-based and centralized KR C4 safety controller, which is similarly executed exclusively in software, to control all safety-related peripheral devices such as local safety modules for robot safety or the safety-relevant operating elements of the SmartPad.

Along with PROFINET and EtherNet/IP fieldbuses, EtherCAT is among the most widely used Ethernet-based industrial communication technologies in the world with a large community of users. Accordingly, it is possible to use the numerous EtherCAT slave devices that are available on the market from EtherCAT Technology Group (ETG) members. This makes countless new EtherCAT-based automation solutions possible that use high performance devices from a great many vendors. Continuity is also an argument in favor of EtherCAT, since no “version changes” have been made to the standards, protocols or ASICs since the system was established.