CASE STUDY
Intel® Core™2 Duo Processor
Intel® X38 Express Chipset
Intel® 82575EB Gigabit Ethernet Controller
Robotics

Build a better robot, and automation gets easy

Using Intel® multi-core technology, KUKA Roboter engineers a groundbreaking robot controller and raises the bar on industrial safety

KUKA

KUKA has just released its first PC-based robot controller with an IEC61508 SIL2 Safety Soft-PLC using an off-the-shelf Intel dual-core platform.

Overview

The field of robotics is still relatively young compared to other technology innovations, but KUKA Roboter GmbH is busy charting the course for its future. Based in Augsburg, Germany, KUKA develops world-class robot and control technology to enable increasingly more complex and faster-working industrial automation applications. From the automotive sector to the entertainment industry, and from medical technology to meat-cutting, if something moves in automation, KUKA probably has a robotic hand in it.

As one of the world's leading suppliers of industrial robots, controllers, software, and linear units, KUKA recognizes that robots can be used to automate essentially any industrial process: They can stack, sort, bend, polish, weld, inspect, saw, drill, glue, and grind—plus a whole lot more. But regardless of the task or industry, robotics is an intense application area that requires massive amounts of calculation, coordination, and control. And for that, KUKA's product developers need all the performance they can get.

For example, using Intel® multi-core processor technology, KUKA can build more powerful, higher-performance robot controllers for high-end applications. KUKA recently took new advantage of Intel multi-core technology in the development of its next-generation robot controllers. The just-launched KUKA KR C4 control system addresses the growing emphasis on functional safety in industrial automation—especially crucial in work environments where humans and robots interact. KUKA, a pioneer of PC-based controllers for robots since 1996, bills its newest product as the world's first PC-based robot controller with an integrated safety PLC (programmable logic controller).

KUKA's KR C4 offers strong evidence that designing with commercial off-the-shelf technologies—including Intel dual-core processors, Intel chipsets, and Intel Ethernet controllers—can help accelerate new product time to market. Equally important, KUKA engineers have demonstrated that by taking advantage of Intel multi-core technology, safety functions can co-exist with control functions on a single CPU.

The Challenge: Reinventing Robotics

KUKA Roboter aims to equip its customers for the challenges of the 21st century and position them for sustainable business success. The company recently set out to develop a next-generation robot controller that couples utmost performance with optimal safety, ease of operation with maximum flexibility and functionality, and unprecedented efficiency with virtually limitless openness.

Developers at KUKA had some specific customer needs and design parameters in mind when they embarked on their latest effort in innovation. For example, they recognized the benefits of consolidating hardware in the PC instead of using external components to implement a safety controller and closed loop controller, as in earlier products. Heinrich Munz, senior software developer at KUKA Roboter, says less hardware has two key benefits: If it's not there, it doesn't cost money, and if it's not there, it can't fail. Developers reasoned that if they could implement certain functions in software instead of hardware, KUKA could offer customers a lower-priced robot controller with a better Mean Time Before Failure (MTBF).

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– Heinrich Munz, Senior Software Developer, KUKA Roboter

KUKA engineers also recognized that developing and maintaining software is much easier and more efficient within a PC-based architecture than in external embedded controllers. In addition, they sought to take advantage of Intel processors because they can deliver much higher performance than external embedded controllers, such as the digital signal processors (DSPs) used in prior-generation products. Developers also insisted on equipping the robot controller with a highly intuitive human-machine interface (HMI) that customers could easily learn.

This vision of a new-generation robot controller posed some tricky design and engineering challenges for KUKA developers. Munz cites a trio of especially tough challenges: One, supporting a cycle time of 8 kHz (8,000 cycles per second) for the closed loop controller; two, communicating several Ethernet telegrams within each of those cycles; and three, fulfilling the requirements of the international IEC 61508 SIL2 safety specification on a standard PC motherboard with an Intel dual-core processor.

The Solution: Go Mainstream

Choosing commercial, off-the-shelf technologies such as an Intel architecture platform helped KUKA bring a groundbreaking new robot controller to market quickly—and stay a big step ahead of its competitors.

"Our experience shows that by using mainstream technologies and nothing else, our time to market is 25 to 50 percent better compared to proprietary technologies," Munz says. "The Intel architecture components and PC technology are an important part of that, but using Ethernet exclusively also made the development of this new generation easier."

The new KR C4 robot controller is designed to control any of the more than 100 robot types that KUKA produces. KUKA views it as a leap in technology that will make automation much easier, thus changing the face of industrial robotics. Based on Intel architecture, its key components include the Intel® Core™2 Duo Processor, the Intel® X38 Express Chipset and the Intel® 82575EB Gigabit Ethernet Controller.

"The very fast cores of the Intel dual-core processor with virtually no interrupt latency time made it possible to bring the cycle time up to 8 kHz for the closed loop controller," Munz says. "The high-performance Intel Gigabit Ethernet Controller with virtually no communication delay helped in sending and receiving Ethernet telegrams within the 125-microsecond cycles. And the two fully independent cores of the processor supported the implementation of an IEC 61508 SIL2 Safety Soft PLC."

The KR C4 is considered an industry first: a PC-based robot controller with functional safety integrated as a Soft PLC. This software-only safe PLC means that for the first time, the complete safety controller is seamlessly integrated into the KR C4 control system without proprietary hardware. Safety functions and safety-oriented communication are implemented on the basis of Ethernet-based protocols.

KUKA's insistence on mainstream technologies also includes Microsoft* Windows* XP Embedded as the HMI operating system—which offers customers a familiar interface for telling a robot what to do—and Wind River* VxWorks* as the real-time controller operating system. The two operating systems share a single core of the Intel Core 2 Duo processor using KUKA's real-time virtualization technology. The safety PLC also runs on the dual-core processor, using one core for each of the PLC's two channels.

Communication to the actuators—robot drives, safety switches and so forth—and the sensors—positioning sensor, safety emergency stop and so forth—occurs exclusively via real-time Ethernet using the EtherCAT protocol for Control Automation Technology. Munz explains that using Ethernet vs. proprietary field bus technology, as in previous controller generations, enables faster data communication and can save customers money if they want to connect automation devices.

"So we have VxWorks on that Intel Core 2 Duo processor, we have Windows on that processor, we have a safety PLC on that processor and we have an 8 kHz closed loop controller on that processor," Munz says. "These are the four big building blocks, all running on those two cores. This is unreached until now in the robotics community."

More to the point, Munz adds, "Thanks to the powerful Intel Core 2 Duo processor, we could eliminate three plug-in boards—a safety controller, which was external in the previous generation; the closed loop controller, which was also a separate processor; and a general controller that performed the PC management. By implementing those three functions in software only, we are saving hardware cost and saving MTBF."

KUKA's new systematic approach to implementing control processes as software functions in the KR C4 robot controller reduced the number of hardware modules by 35 percent and the connectors and cables by 50 percent.

Raising the Bar on Safety

The field of robotics is growing faster than ever as industrial robots spread into more areas and become increasingly affordable, thereby extending the marketplace to mid-sized and small companies. To KUKA, this trend means safety will be the most critical issue in industrial automation over the next several years.

The just-launched KR C4 robot controller addresses safety head on, recognizing that as customers expect humans and robots to work more closely together, vendors need to deliver safe solutions. For example, a robot capable of carrying 1000 kg could easily injure humans if programmed incorrectly. An emergency stop is a critical function that must be implemented in safe technology, but in environments where people share the robot's work area, an emergency stop is not enough; robots must have sensors that detect human proximity and automatically stop or slow down accordingly.

HARDWARE CONSOLIDATION

Intel Multi-Core Processor for **Efficiency, Performance,** and **Flexibility**

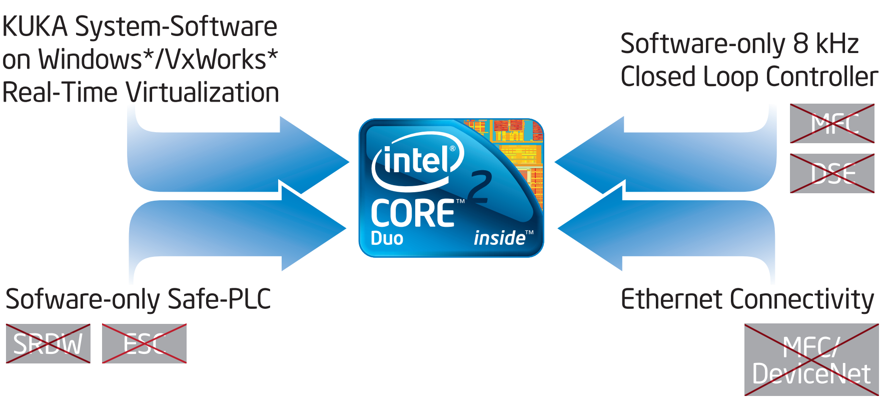

Figure 1. The power of the Intel Core 2 Duo processor enables consolidation of hardware.

UNDERSTANDING FUNCTIONAL SAFETY

Functional safety is an industry term that's getting a lot of attention today, but what exactly does it mean? Stated simply, functional safety refers to a system or piece of equipment that is inherently designed for operational integrity. A system that conforms to specified functional safety standards is designed to respond appropriately and operate correctly if certain functional issues occur, thereby minimizing the risk of physical injury or property damage. For example, in the event of an operator error, a software or hardware failure, or a change in the environment with which the system interacts, the system detects the potential danger and actively manages the event by shutting down, slowing its speed, restarting, performing some type of recovery action and so forth.

Functional safety is an inclusive concept; in other words, it requires that all of a system's subcomponents meet the level of integrity associated with the system as a whole. Functional safety also implies active systems, such as sensors that detect smoke and activate a fire suppression system, or sensors that detect a dangerously high level of a flammable liquid and close a valve to prevent a tank from overflowing.

Regulations and customer demand have led to certain recognized functional safety standards; in the European Union, the primary functional safety standard is IEC EN 61508. This standard defines four Safety Integrity Levels (SILs) that relate to the level of risk-reduction provided by a safety function, with SIL 4 being the highest level.

Munz says the power of the Intel Core 2 Duo processor gave KUKA a much higher degree of flexibility around functional safety because it enabled developers to implement safety as a PLC—an approach that was unthinkable in previous robot controllers. He explains that in robotics, safety requires a two-channel technology for redundancy. Everything is computed twice, and the two channels are constantly compared against each other to ensure that safety mechanisms don't fail. Like the calculations needed to control a robot's six motors, those safety calculations are extremely compute-intensive, requiring a high-performance processor.

"You need a lot of computing power to detect if a human is approaching a robot, and then slow down the speed, and you need it in safe technologies," Munz explains. "And for that, dual-core processors are the ideal solution."

Using multi-core technology ensures the dual-channel system required for safety applications. Moreover, the KR C4 system offers more than just monitoring functions; KUKA's approach to safety also makes it possible to influence the motion and velocity of the robot safely.

Besides delivering the requisite performance for complex safety-related calculations, the Intel Core 2 Duo processor allows KUKA to integrate safety and control functions on a single CPU. The pioneering approach of using a software-only Safe-PLC instead of an external safety controller sets a safety milestone for human-machine interaction and signals to the rest of the industry where trends in safety technology are headed.

"With the PLC, the customer now has the flexibility to program the robot not only for movement but also for the safety environment," Munz says.

Benefits for the Shop Floor and the Top Floor

Advanced features, high-end performance, functional safety flexibility, and lower development time aren't the only reasons that KUKA prefers Intel components over other options. Munz points out that Intel architecture technology—and especially multi-core technology—offers a number of other advantages, including low prices, good development tools, better educated developers, and a large pool of prospective employees who are currently at universities studying to be engineers.

Equally important, he says, Intel support is excellent, and hardware drivers for Windows XP Embedded and VxWorks have been available for all of the Intel components incorporated in KUKA's new robot controller. Munz concludes by noting that all of the Intel products used in the new KR C4 are also on the Intel embedded roadmap, which assures KUKA they will be available for at least seven years.

"Intel has stated clearly that it will continue to support the embedded market, which is important for us as a machinery vendor because our products will live for 10 to 15 years," Munz says. " We absolutely rely on Intel to deliver these kinds of processors and this kind of technology to us for at least the next 15 years."

For More Information
www.intel.com/go/industrial
www.kuka-robotics.com
www.automation-becomes-easy.com/en/home.html

SOLUTION PROVIDED BY:

FUNCTIONAL SAFETY, MULTI-CORE TECHNOLOGY, AND VIRTUALIZATION

Safety-related architectures are becoming more complex with the increasing demand for new features and the escalating requirements of regulatory compliance.

One trend driving complexity is the need for industrial devices to interface with more networks and systems, including the Internet, the shop floor and the top floor. This trend requires devices to support more types of application software (such as security and protocol stacks) with various levels of criticality. In addition, as system complexity increases, regulatory bodies are enforcing more formal certification methods and processes to help safeguard systems.

The combination of multi-core processors and virtualization technology can help device manufacturers in industrial control, process automation, energy, and transportation protect their development investments. These technologies enable systems to run more applications simultaneously and safely, so it's possible to upgrade an existing multi-core platform incrementally with respect to performance, security, scalability, certifiability, and usability.

The enhanced performance of Intel multi-core processors can also be used to consolidate control and acquisition applications, visualization, and network security onto a single board with minimal software changes. In addition, a virtualization layer can protect software investments by reducing direct hardware dependencies. This makes it easier for developers to port and upgrade to new device types while managing the migration to commercial off-the-shelf technologies more effectively.

A white paper that discusses how developers are applying multi-core and virtualization technologies to industrial and safety-related applications to guard against unintended software interactions and outside breaches can be found at: **http://download.intel.com/platforms/applied/indpc/321410.pdf**

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