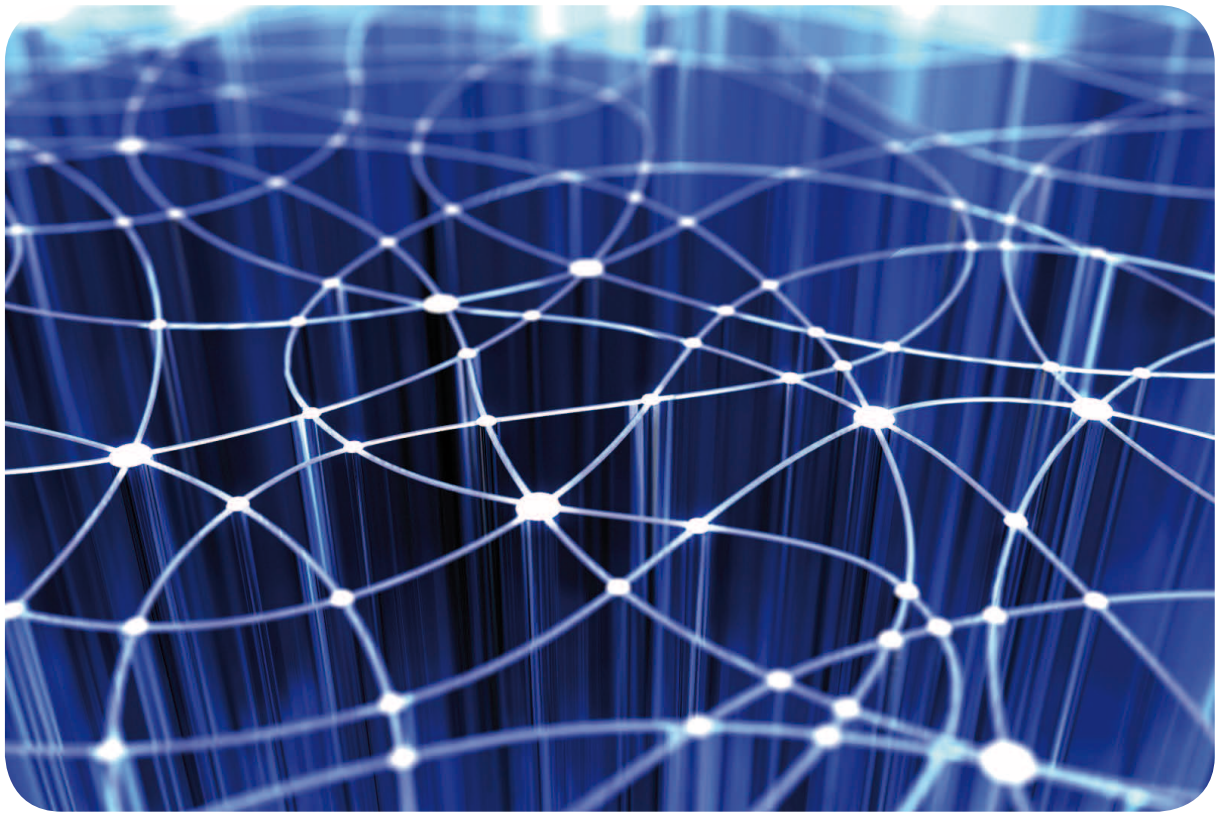# x86 meets FPGA - endless possibilities

Intel® Atom™ E6x5C processor with integrated Altera FPGA marks a new era in embedded computing

x86 meets FPGA - endless possibilities
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The Intel® Atom™ E6x5C processor series pairs an Intel® Atom™ E6x5 series processor with an Altera Field Programmable Gate Array (FPGA) in a single package. This is an entirely new approach to embedded x86 technologies with the potential to dramatically change the way in which embedded devices are designed in the future. It opens a new window for x86 technologies to become even more dedicated on a common technology platform.

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Increasing attractiveness of x86 for embedded markets

In the past, performance was the decisive factor for developing new x86 processor technology. However, recently two new factors have –risen in importance to x86 technology; an increasingly high degree of integration and energy efficiency. As an example, the Intel® Atom™ processor, manufactured in 45nm technology with a TDP of less than two watts at 1.6 GHz performance, has achieved a never before seen performance per watt ratio. Low energy consumption was also present in the waste heat which has enabled fan-less designs and completely closed housings. This has also led to the flexible x86 technology becoming more deeply integrated into embedded applications.

Design obstacle number 1: Tailoring

In addition, more interfaces are moving away from dedicated controllers into the chipsets. In the meantime, nearly all the relevant interfaces PC technology has to offer, are integrated in chipsets. However, this leads to a certain overhead, as the deeper an embedded PC has to be embedded, the more dedicated and specific the necessary interfaces become. Therefore, many of the available standard PC interfaces are no longer necessary at this stage.

Design obstacle number 2: Backward Compatibility

On the other hand older interfaces such as ISA bus are no longer supported by the new processors. However, there are still applications which rely on the old, but proven, ISA bus in order to protect investments. At one time, the most cost-efficient solution was to work with PCI to ISA implementations rather than porting ISA-based I/O cards to PCI or PCI Express. That was not only costly, but also required additional space-consuming components.

Figure: The Intel® Atom™ processor E6x5C series delivers the benefits of the Intel® Atom™ E6x5C processor series combined with a Field Programmable Gate Array (FPGA) from Altera in a single package.

Furthermore it is only a matter of time until PCI is no longer supported by standard chipsets.

## Design obstacle number 3: Diversification

If it is a matter of designing a dedicated selection of standard and proprietary interfaces, developers soon meet the limits of what standard x86 chipsets are capable of. For example, if it is a question of putting together a global offer of industrial Panel PCs with country-specific field buses – including as small a Bill of Material as possible. To date, diversification such as this was more or less only possible by using extension components. Rather than this costly and time-intensive extra effort, it would be ideal if alternative access to an interface, which is fully configurable, was possible. In addition, these interfaces would include the option on which all field busses could be implemented in order to profit from a single, globally applicable hardware platform while using a minimum of components.

Design obstacle number 4: Sustainability

Several other factors to consider are the occasional changes in standards for interfaces, newly published specifications and individual adjustments to specific protocols. Developers are faced with the challenge of not being able to carry this out with standard components without having to permanently change the hardware design. This can lead to significantly increased costs due to the need to carry out test and certification work.

Increasing I/O flexibility with FPGAs

One way of providing the right interfaces, without any unnecessary overhead, is utilizing flexible interfaces on the basis of Field Programmable Gate Arrays (FPGAs). These programmable circuits have the advantage of functions that can always be re-defined. This is possible due to reusable units of logic, called IP cores, which lend to the individual functionality of the FPGA. In this way, the FPGA can take on the functionalities of serial interfaces, Industrial Ethernet controllers, user-defined I/Os or even the entire chipset functionality. A chipset which is defined like this can also execute the necessary proprietary interfaces. It's this fact that distinguishes the Intel® Atom™ E6x5C processor series and makes it a new milestone of x86 technologies. Instead of a chipset with a fixed definition, this processor series combines the Intel® Atom™ E6x5 processor with a flexible and programmable Altera FPGA on a single compact multi-chip module. This is possible due to the fact that the Intel® Atom™ E6x5 series connects the chipset via PCI Express instead of via the Intel® specific Front Side Bus. With PCI Express, it became possible to connect an FPGA directly to the processor rather than a dedicated chipset which results in maximum flexibility and long-term design security.
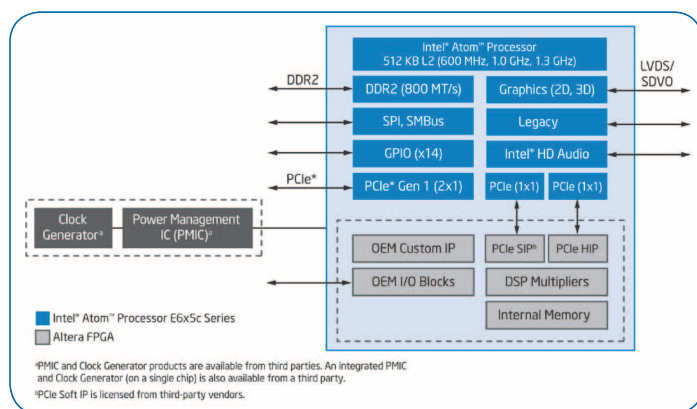
FEATURE SET OF THE INTEL® ATOM™ E6X5C PROCESSOR
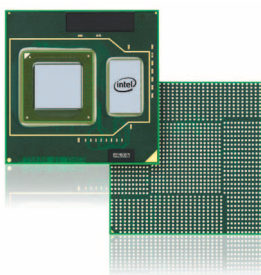
The Intel® Atom™ E6x5C processor series features an energy-efficient 45nm Intel® Atom™ E6x5 processor core with a 512KB L2 cache plus 3-D graphics, display, memory and a PCI Express controller paired with an Altera FPGA in a single package. The integrated Intel® Graphics Media Accelerator (Intel® GMA) 600 is a power-optimized 2-D/3-D graphics engine that supports OpenGL 2.0, OpenGL 2.1 and OpenVG 1.1, along with hardware-accelerated HD video decode (MPEG4 part 2, H.264, WMV and VC1) and encode (MPEG4 part 2, H.264). Its core TDP is as low as 3.6 watt for the 1GHz version and only 2.7 watt for the 600MHz version. It features LVDS and SDVO for connecting displays. Intel® Hyperthreading technology provides support for multi-threaded applications, delivering increased performance and system responsiveness in today's multi-tasking environments by enabling the processor to execute two instruction threads in parallel. Furthermore, with the integrated, hardware-assisted Intel® Virtualization technology, it enables greater flexibility and maximum system utilization to be achieved by consolidating multiple environments into a hardware platform. With support from the processor, BI/OS and enabling software, Intel® VT improves traditional software-only virtualization.

The openness to be dedicated

The universal x86 technology now offers even more openness and flexibility. For example, owing to the flexible I/O execution, OEMs can also develop designs very efficiently which in terms of I/O requirements have to be tailored to precisely meet the needs of the target applications. On the other hand FPGAs can also take on tasks that otherwise only dedicated controller components could carry out. For example, signal processing of real time video data for quality control on manufacturing lines. With the increasing digitization of end devices such as cameras, sensors, actuators or servo drives, these devices can be connected directly to the x86 hardware without the need for dedicated I/O cards. Furthermore, the x86/FPGA tandem can also carry out Motion Control for servo drives which include characteristic mapping and individual parameterization. By using a fast field bus, even calculation of the path (trajectory) can be shifted away from the servo regulator to the control and calculated there.

However, the precondition for this is fast industrial busses which are already available through different industrial Ethernet variants. The various industrial Ethernet variants indeed require specific processing mechanisms that can differ according to target application. But even this challenge is easy to deal with by means of an FPGA-based Ethernet connection. All industrial Ethernet protocols can thus be supported with only one hardware unit and also long-term, because the FPGA configuration required for the respective protocol can also be easily and flexibly adapted to future protocol developments by loading the software along with the suitable protocol stack into the FPGA.

Long-term availability and sustainability

FPGAs also provide a solid technological basis for processing raw data delivered from ultrasonic probes in medical applications. The first reason for this is due to the highly dedicated computing power they offer depending on the required design and second, because of the guaranteed long-term availability of the whole solution in comparison to a solution with logic set in hardware. Even when "end of life" announcements for components are made, this is no longer an issue thanks to programmable logic, as the soft IP (Intellectual Property) remains and can be ported to a new FPGA component with little effort. Therefore, instead of keeping track of several different controller components, only the IP cores have to be maintained. Since the FPGA market is stable and expects a CAGR rate of at least 8.6 percent according to Loring Wirbel at FPGA Gurus , with a US$7.5 billion worldwide size until 2015, it is one of the most stable technologies that embedded engineers can rely on next to x86. So FPGA technology delivers nearly the same benefits that x86 technologies have: multi-functionality, a wide ecosystem and countless target applications.

Reduced BOM and increased IP protection

The symbiosis of both technologies provides double the benefits to developers. Because the programmable FPGA comes integrated into the processor this translates into less work for integrating a separate FPGA. Now simple "daughter cards" suffice to carry out the required physical interfaces. This not only reduces costs of developing I/O

cards, but also the downsized parts list and the higher integration level enable more compact constructions. Application engineers also profit from the FPGA which can take on the complete chipset functionality. Developers are no longer dependent on the chipset functionalities which the processor manufacturer has defined, but are completely free to choose which functionalities and interfaces they require. Company-specific knowledge in FPGAs can be protected more reliably than is the case with normal software as a re-engineering of the FPGA code, which is encoded in Hardware Description Language (HDL), can be encrypted and thus not simply copied or processed in any way.

Huge base of established IP cores

Commercial-off-the-Shelf IP cores and stacks are widely available from the FPGA and processor vendors and many other third party vendors with specialized knowledge in I/O requirements. These include standard PC functions such as USB, PCI Express or SATA as well as application-specific I/Os like CAN bus, serial interfaces (SPI Master / UART), I2C and GPI/O. Also, all major variants of industrial Ethernet are available as IP cores and stacks for Real Time Ethernet (RTE) protocols such as PROFINET, EtherCat, EtherNet/IP and MODBUS TCP. In regards to this versatility, it is not a real challenge to find the right service partners for the preferred I/Os. OEMs can purchase them more or less like software. Only the individual configuration is a task that needs attention, but service providers are also available for tasks like this.

Comfortable tools for FPGAs

OEMs, who wish to develop a highly individual IP core on their own in order to implement, not only dedicated interfaces but also their own algorithms, can make use of a huge base of FPGA-orientated development environments. For the Intel® Atom™ E6x5C series for example, Altera's Quartus II design software is a good example of a tool for building the dedicated FPGA logic. There are also Third Party Development tools which are partly available as Open Source and which generate HDL code. FPGA cores can also be generated in Matlab Simulink and transformed via Altera's DSP into HDL code. For engineers who want work with FPGA itself, there is a broad software environment available.

INTEL® ATOM™ E6X5C BASED COTS AND EVALUATION PLATFORMS

The Kontron Microspace® MSMST is the world's first PCIe/104™ embedded single board computer based on the Intel® Atom™ E6X5C processor series with industrial temperature range, which pairs an Intel® Atom™ E6X5 series processor in an Altera Field Programmable Gate Array (FPGA) in a single package.

The Kontron PCIe/104™ SBC MICROSPACE® MSMST can be seen as a new milestone of this integration, as it is currently the only available solution on the market with the highly integrated multi-chip module is already implemented. This symbiosis of both technologies on one compact SBC means that application developers profit from a simplified application design and reduced development effort. As a long-term available standard component, this type of platform fulfils all requirements regarding reduced development effort, minimized design risk and Total-Cost-of-Ownership (TCO). The Kontron PCIe/104™ MICROSPACE® MSMST is equipped with the Intel® Atom™ E6x5C processor series ranging up to 1.3 GHz with up to 2 GB onboard DRAM system memory. The power optimized Intel® Graphics Media Accelerator (Intel® GMA 600) with up to 128 MByte, 18/24 Bit LVDS and SDVO interface is integrated in the processor. Video signals are carried out by optional media boards for VGA or DVI. Optional SPDIF (out) and two analog stereo connections for line-out and mic-in take care of the high-definition audio signals. Storage media can be connected by 2x SATA300. 2 x USB 2.0 and an optional 1x Gigabit LAN are also available. The integration of numerous customer-specific I/O options is enabled via the PCI Express bus of the PCIe/104™ SBC or via the HSMC interface. The Trusted Platform Module (TPM) is responsible for the high level of security and reliability by carrying out the hardware encryption of all the transmitted data.
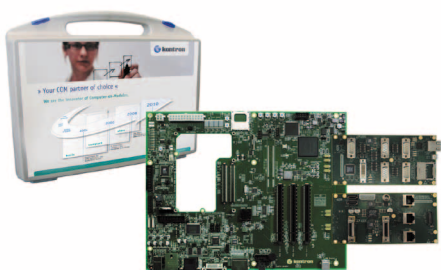
*The ideal development platform for FPGA-based x86 designs:
The Kontron COM Express™ FPGA Starterkit.*

Parallel to this, the COM Express® FPGA Starterkit with Altera Cyclone IV GX FPGA is available which allows developers to make an immediate start on developing dedicated FPGA-based applications. The Starterkit includes all the components required for evaluating new board designs with user-definable I/Os. The components of the Starterkit and the Computer-on-Module which have been selected plus individual High Speed Mezzanine Cards (HSMC) with additional physical interfaces can be put together in a matter of minutes. If the required logic for a hardware interface has been implemented, the FPGA acts like an interface realized in hardware and is addressed by application programs like an API (Application Programming Interface). The application evaluation can therefore begin after a few installation steps, and software developers can immediately start the actual programming of the platform.

Outsourcing hardware development and manufacturing

An alternative to using a company's own R&D efforts for the "hardware only" functionality would be outsourcing the hardware design to partners so that OEMs can concentrate on their application development. This could result in a higher innovation potential, shorter development cycles and improved quality. With COTS platforms available, they are the best technological basis for customization or full custom designs due to the reduced design efforts compared to an entirely new design. However, from the generic x86/ FPGA platform (from PCB / board design point of view) to an application-ready x86-FPGA platform, in the majority of cases a lot of FPGA development efforts have to be carried out. Hardware vendors need to build up design expertise in order to carry out all the different needs OEMs have. Therefore, OEMs should take a close look into the FPGA strategies and resources embedded platform vendors can offer.
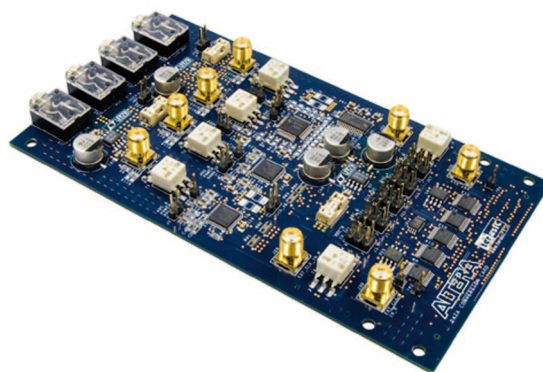
Image: High-Speed Mezzanine Cards (HSMC) carry out the interfaces from the FPGA.

FPGA CONFIGURATION SERVICES
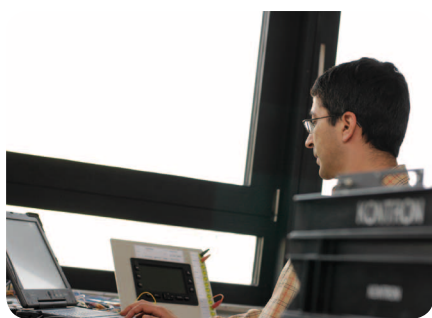
Kontron has introduced finished development platforms at the launch of Intel®'s Atom™ E6x5C multi-chip module including a range of FPGA configurations with HSMC cards and corresponding IP cores. These configurations consist of various form factors which include the processors, FPGAs, IP cores, HSMC daughter cards, drivers, board support packages (BSPs) as well as installation and support of various operating systems (e.g. Windows, VxWorks, Linux, etc.) and are available as COTS platforms.

Besides these platforms, Kontron also offers complete custom design and production services for individual FPGA-based solutions. So the offerings are by far not limited to the available platforms but are directed to all those OEM solutions that can benefit from the x86-FPGA tandem. This includes also custom-specific systems such as Panel PCs or Box PCs to name just a few system level solutions.

The major focus of Kontron's service is the implementation of standard I/Os into the FPGA. Kontron is continually expanding its offer of FPGA I/O products. A recent example is the cooperation with Softing Industrial Automation GmbH. Softing's IP cores and stacks forPROFINET, EtherCat, EtherNet/IP and MODBUS TCP, which are application-ready implementations into FPGA-based I/O hubs.

This way customers profit from complete solutions from one source which includes licensing of FPGA stacks and IP cores. This saves customers valuable time when planning their individual FPGA configurations. Additionally Kontron's Global Software Design Center offers FPGA programming as an optional software service for customers who want to save the R&D time and effort for the custom-specific IP core development and implementation. This service is mainly focused on custom-specific standard I/O configurations for the FPGA but is not limited to this. So especially for companies thinking about using FPGAs for the first time it is an option to move towards suppliers offering application-ready solutions because in most cases the implemented logic will be still the "basic technology" for the OEM application.

These investments will help customers to get best-in-class services related to their hardware platform including all the required IP know-how and hardware-near software services so that they can use the hardware platform vendor as a real development partner for any questions occuring while designing in their dedicated embedded computing platform. And even if a customer only asks for the barebone platform they at least will get a partner who can offer best-in-class services for any question that one day might eventually arise.

Conclusion

Due to the fact that it is now possible to use an x86 processor with an FPGA, an embedded computer's feature set is no longer "set in stone". Thanks to FPGA technology, developers are given the freedom to program the required interfaces and the functions as required. The combination of the Intel® Atom™ E6x5C processor with an Altera Arria II FPGA on pre-integrated embedded platforms will bring universal x86 technology one large step further towards more openness and flexibility.

With the availability of board level products, the entire design supply chain changes too. The technology shifts towards a one-stop-shop where OEMs can purchase their entire x86-FPGA design including all standard interfaces required. So there is a tremendous change taking place which requires OEMs to think about cooperating with board level vendors who provide application-ready platforms including all the required "standard" IP cores.

About Kontron

Kontron is a global leader in embedded computing technology. With more than 30% of its employees in Research and Development, Kontron creates many of the standards that drive the world's embedded computing platforms. Kontron's product longevity, local engineering and support, and value-added services, helps create a sustainable and viable embedded solution for OEMs and system integrators. Kontron works closely with its customers on their embedded application-ready platforms and custom solutions, enabling them to focus on their core competencies. The result is an accelerated time-to-market, reduced total-cost-of-ownership and an improved overall application with leading-edge, highly-reliable embedded technology.

Kontron is listed on the German TecDAX stock exchange under the symbol "KBC".
For more information, please visit: **www.kontron.com**

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