4th Generation Intel Core processors for embedded systems: Better energy efficiency thanks to new microarchitecture

Intel has recently launched the 4th Generation Core processors (codenamed Haswell). The focus for the embedded models is on high performance; without incurring an increase in power consumption. Some impressive improvements have been achieved, particularly with regards to vector processing, floating point calculations and graphics performance.

With the introduction of the 4th Generation Core i series processors, Intel has remained faithful to its “tick-tock” model. This refers to the successive introduction of a new processor generation by first announcing the process technology (“tick”), and then bringing a new architecture (“tock”) to market a year later. The recent introduction of the 4th Generation line of processors is a “tock”, signifying the optimization and development of the architecture, especially the microcode. The 22nm manufacturing process, first introduced with Intel’s 3rd Generation Ivy Bridge, is maintained until the introduction of 14 nm process technology as the next milestone.

Benefits of the new Haswell microarchitecture

In the long term, the improvements to the existing architecture will result in efficiency gains of up to 10%. However, it will take some time before firmware, compilers, operating systems and applications can utilize the full advantages of the new processor generation. This is more of an evolution than a revolution, unlike the introduction of the predecessor which led to a significant reduction in power dissipation thanks to the new manufacturing technology. In embedded systems these efficiency gains are primarily used to increase performance. This is particularly evident in the embedded on-chip graphics which provides significantly higher performance but has a slightly higher power draw, at least at full loads. Therefore, and thanks to the newly integrated voltage regulator units, the TDP specified by Intel increases slightly, at least for the first series of embedded quad core processors that have been released: 47 Watt TDP for the Core i7-4700EQ as compared to 45 Watt for the predecessor, bearing in mind that the latter’s 2 Watt advantage is lost through the implementation of voltage regulators on the module. The maximum system clock rate (with Turbo Boost) for cores and graphics is roughly the same as that of previous models, while the basic clock rate (without Turbo Boost) is somewhat lower.

Since these TDP values are weighted averages and not maximum values, the increase in power consumption is likely to be even more significant when operating at maximum power. This requires more sophisticated cooling concepts, such as the patented heat pipe based cooling solution from congatec. This ensures that the peak performance can actually be utilized and prevents the protective circuitry from downclocking the processor performance due to overheating. In addition, Intel has reduced the maximum permissible surface temperature from 105 to 100 degrees Celsius.

What’s new?

The most exciting new feature is the introduction of the AVX2 vector unit to replace AVX (Advanced Vector Extensions), itself a successor of SSE. AVX was already used instead of SSE in Intel’s previous processor generation to significantly improve performance for floating-point computations by extending the instruction sets from 128 bit to 256 bit vectors and by providing more powerful buffers, especially a bigger reorder buffer. In 4th Generation Core processors, Intel enlarged the buffers further; added an integer ALU and a second branch unit to the execution unit; and expanded the instruction set with FMA (Fused Multiple Add) and TSX (Transactional Synchronization Extension). As a result, the vector unit achieves twice the computing power of earlier models for large fixed and floating point computations.

Not exactly new, but more relevant than ever for current applications, is Intel® AES-NI (Advanced Encryption Standard
New Instructions). This refers to the offloading of particularly compute-intensive packaging and encryption routines of the well-known cryptographic algorithm AES (Advanced Encryption Standard) into hardware. This enables high performance encryption without putting a significant burden on the CPU cores.

There have also been major improvements to power management – a key point for many embedded users as it is the only way to keep power draw low while increasing performance at the same node. The integrated graphics unit supports the latest versions of DirectX (11.1), OpenGL (4.0) and OpenCL (1.2) plus a native 4K2K resolution (up to 3840 x 2160 pixels with DisplayPort and 4096 x 2304 pixels with HDMI). Thanks to a new multi format codec, SVC (Scalable Video Coding) is now supported in addition to MPEG-1, -2, -4, AVC, and VC1.

Who needs all this?

With the growing trend towards cloud services and industry 4.0, encryption is increasingly important for modern, intelligent embedded systems. Full disk and endpoint encryption is becoming standard for mobile systems with sensitive data and is indispensable for SSDs (Solid State Disks) where it’s virtually impossible to completely erase data, unlike hard drives. Remote maintenance, storing data in the cloud or communicating with external systems and partners without data encryption is grossly negligent and practically inconceivable. Other applications where cryptography is key are databases, data compression and backup. AES-NI is already supported by most operating systems and many leading applications. With Intel AES-NI, smaller embedded systems can now also benefit from powerful and secure cryptography without sacrificing performance during application.

Intel is clearly focussing on performance with the introduction of 4th Generation Core processors. This is underlined by the expansion of the instruction sets and the vector unit which almost double the already high performance. Applications that benefit directly from this increased performance include demanding scientific calculations such as simulations and CAD, as well as image processing applications such as tomography and radar or optical inspection.

Alternatively or additionally, the integrated graphics processing units can be used via OpenCL. Thanks to the new variable coder and 4K2 support, it is possible to realize even demanding multimedia and gaming applications.

The hardware continues to be based on the power-saving 22nm architecture introduced with the 3rd Generation. The integrated GT2 graphics of the current embedded processors is equipped with additional execution units: 16 now and later 20. The standard embedded chipset consists of two components as before, however one of the new features includes integrated voltage regulators, reducing the bill of materials and space requirements of the solution. With a specified TDP of 47 Watt, the top Core i7-4700EQ model presents a challenge for small, fanless embedded systems. A high performance cooling concept is therefore even more important than for earlier processor generations – in particular because of the internal voltage regulators, the reduction in the maximum permissible temperature levels and the associated hot spot issues. In addition to efficient cooling, heat spreading and rapid heat dissipation are key. This is however difficult to achieve without complicated technologies such as heat pipes and large cooling surfaces.
conga-TS87: The first COM implementations

The conga-TS87 COM Express module with pin out Type 6 takes full advantage of the integrated graphics with extended digital display interfaces, high USB 3.0 bandwidths and PCIe 3.0 with additional PCI Express lanes. The COM Express module is currently available for the embedded quad core Intel® Core™ i7-4700EQ processor with 6MB L2 cache and can be powered by 4x 2.4 GHz and a TDP of 47 Watt. In Turbo Boost mode, the clock rate is increased to 3.4 GHz. Should the processor start to overheat the mode is downclocked. An efficient cooling solution with fast heat dissipation can therefore significantly increase overall performance.

The COM is equipped with the mobile Intel® QM87 Express chipset, but can alternatively be kitted out with various future i3, i5 and i7 dual core and quad core processors as soon as they become available. The module features up to 16 GB, 1600 MT/s fast LV 1.35V dual channel DDR3 memory. The integrated graphics is significantly more powerful than previous models and supports Intel® Flexible Display Interface (FDI), DirectX 11.1, OpenGL 4, OpenCL 1.2 and high-performance, flexible hardware decoding for parallel decoding of multiple high-resolution full HD videos. 4K2K pixel resolution of up to 3840 x 2160 with DisplayPort, and 4096 x 2304 with HDMI is supported natively. It is also possible to connect up to three independent display interfaces via DVI as well as LVDS and VGA. Native USB 3.0 support ensures fast data transmission with low power draw.

A total of eight USB ports are provided, four of which can support SuperSpeed USB 3.0. Seven PCI Express 2.0 lanes, PCI Express 3.0 graphics (PEG) x16 lanes for high-performance external graphics cards, four SATA ports with up to 6 Gb/s and RAID support and one Gigabit Ethernet interface enable fast and flexible system extensions. Fan control, LPC bus for easy integration of legacy I/O interfaces and Intel® High Definition Audio complete the feature set.
An absolute must: Appropriate cooling

In compact embedded systems, there’s no simple way of dissipating the defined TDP of 47 Watts of the top Intel Core i7-4700EQ models. A solution is provided by congatec’s patent-pending modular high-performance cooling solution for COM systems. Independent thermal couplers, each equipped with their own independent heat pipe, dissipate the heat from the CPU and chipset away from the components to a special heatspreader block. From there, the heat is then discharged directly into the ambient air at lower power levels of about 37 Watts and under normal cooling conditions by means of an integrated heat sink. For larger TDPs and in the extended temperature range, the heatspreader can be mounted directly onto a larger metal housing or a suitable device wall.

Summary and outlook

With 4th Generation Core processors Intel has manifested its leadership in high-performance embedded systems and is setting new performance standards for floating point and vector calculations with the AVX2, FMA and TSX instruction set extensions. For users, it comes as an invaluable benefit that they can take advantage of the power increase without having to change their application software or concept – the necessary adjustments are made by the operating system manufacturers and the compiler designers.

In the first launch phase of the 4th Generation Core processors, the focus is on the new architecture and its high performance. This platform benefits users of power-hungry applications such as numerical computation and simulation, image processing, tomography and radar and, thanks to increased graphics performance, the manufacturers of multimedia and gaming systems.

Things will get even more interesting for classic embedded applications once Intel releases energy-optimized quad core and dual core processors in a second launch phase at a yet unspecified date.

Overall, Intel has achieved another major success. Thanks to early supporters, such as congatec with the conga-TS87, there are already powerful computer modules on the market that provide sophisticated firmware and excellent driver support, enabling early but risk-free customer design-ins. Modular COM Express technology also ensures that future technology improvements in processors and chipsets can be easily and quickly integrated.

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