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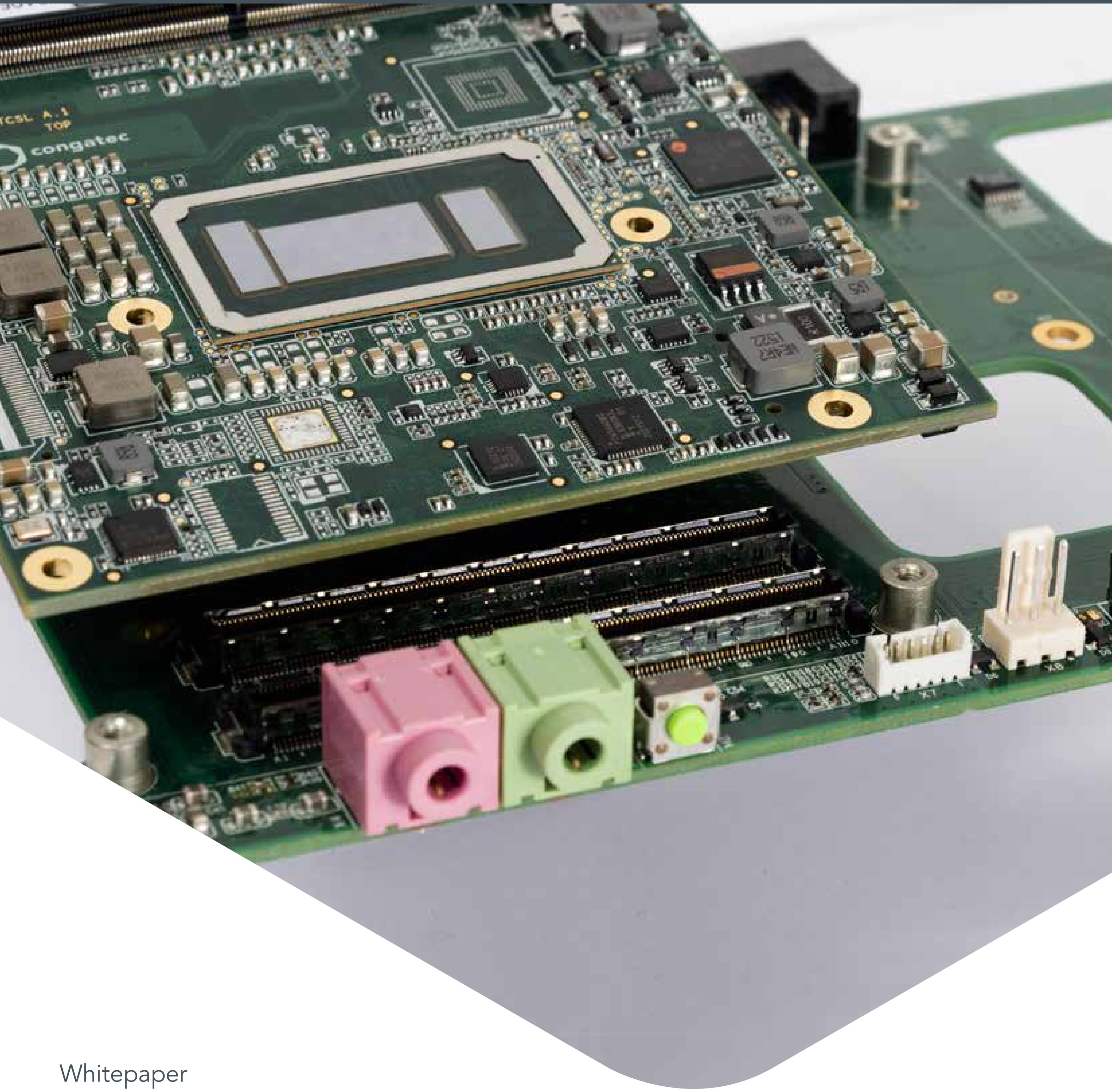


Whitepaper

Pros and Cons of Computer-on-Modules

Embedded system design considerations

Pros and Cons of Computer-on-Modules

Computer-on-Modules are world-leading platforms for embedded system designs. What makes them so attractive and what are their limitations?

Studies from IHS Markit state that Computer-on-Modules are leading the global ranking of embedded form factors followed by standalone boards and VME/VPX solutions. They also forecast a growth of 8.6% CAGR during the period 2015-2020, which is impressive as market leading technology is generally well established and market volume tends to be stable rather than dynamic. Similar studies from Research and Markets paint an even healthier growth perspective, forecasting that the global Computer-on-Module market will be growing at a CAGR of 17.97% during the period 2016-2020. The large difference between these two forecasts may be caused by the highly uncertain market dynamics in the IoT segment where these modules will get massively deployed. IHS Markit identifies the needs of industrial automation and Industry 4.0 as a major driver of growth in coming decades. So from a bird's eye view of the market perspectives, there is no doubt that Computer-on-Modules are suitable candidates to evaluate for embedded system designs. But what makes them so attractive?

Made for customization

Computer-on-Modules are building blocks for custom system designs. Custom designs are often demanded in the embedded computing area as off-the-shelf motherboards cannot be used for all embedded applications. Commercial boards don't necessarily fit the available box space nor meet customers' interface demands, which are almost always individual in terms of number, configuration and board location. Also, a motherboard with expansion cards may not offer the required resistance against mechanical or thermal stress. All these individual demands lead to the question: Shall I build my own design from scratch with all efforts and costs involved, or are there other options available that can help me design my dedicated system faster and more efficiently? Computer-on-Modules were invented exactly to help with this 'build or buy' question and with the intention to simplify the use of embedded processor technologies in customized designs.

Application ready super components

Computer-on-Modules are application ready super components that offer engineers high design efficiency. One benefit for purchase departments is the fact that the bill of material (BOM) is reduced from many components to a single module for the processing core – but this is only the smaller part of the efficiency gain. More important are the reduced efforts required both to design-in the complex processor, RAM and high-speed interfaces; and to build the entire board support package with all the necessary drivers, libraries and APIs. All this work is already done and modules can be deployed with the same effort as a new processor on a motherboard, making upgrading processor technology far easier.

Great scalability

Computer-on-Modules offer tremendous scalability. While a processor change can only be executed with pin compatible processors that are generally only available within a certain processor generation, Computer-on-Modules can basically host all processors from all leading embedded processor vendors. One example is the update from the 5th generation of Intel Core processors to the 6th generation, where the grid array and memory interface changed. When leveraging a customized board, designers would have to re-design their PCB. With Computer-on-Modules, a switch between processor generations and vendors is much simpler and always possible. A new product generation can be launched just by switching the module. Another advantage of this scalability feature is that it extends the long term availability of applications; when the seven or ten year product life cycle of an embedded processor ends, a successor is often available that can be used as a retrofit.

The benefits of standardization

Scalability can only be secured by interface standardization. Computer-on-Modules achieve this by standardizing the footprints as well as the interface to the custom designed carrier boards of the modules. The benefits of standardization are tremendous: It leads to highest design security as designers can rely on the future availability of modules with the same interfaces. They can also develop second source strategies and are not dependent on a single vendor. This increases design security and provides commercial advantages due to competitive pricing. Standardization further delivers the capabilities to offer a broad ecosystem of commercially available accessories, ranging from heat spreaders and carrier boards to cable sets and housings. This makes it easy to purchase components from third parties, reducing NRE costs to a minimum. Finally, a large community of designers working with the form factor ensures continuous standard improvements. The vendor independent standardization bodies PICMG and SGET e.V. help fend off proprietary solutions.

Custom specific carrier boards

Even though Computer-on-Modules are true super components, there is still some customization required. But the good news is that the design effort is reduced to the application specific needs on the carrier boards for the modules. Designing such a customized carrier board is far less complex than a full custom design but offers identical benefits: Custom specific carrier boards are not restricted as regards footprint and interfaces. There is no limit for the footprint – it can be quadrangular, round or have a completely asymmetric form factor. This offers perfect conditions to tailor the PCB to the system and yields many benefits, from optimized cooling and more rugged mounting to the advantage that I/Os can be located exactly where required. This avoids the need for internal cabling or conventional expansion boards, which are often prone to mechanical stress and can reduce system reliability while increasing BOM and cost.

There is no need to manipulate the computing cores such as the processor and RAM or the standardized module interfaces to the carrier boards. Engineers can consequently focus on routing the Computer-on-Modules' interconnects and implement the required additional controllers and physical interfaces on the carrier boards. This way, they can fully concentrate on the customization, which simplifies and accelerates the design process.

Less interfaces, more benefits

Compared to standard motherboards, designs with COMs (Computer-on-Modules) and carrier boards only integrate what the application actually needs. This brings cost gains, as the design does not feature unnecessary components. This also helps to increase security, because an interface that is not there cannot be corrupted or hacked. Take, for example, the many USB ports that standard systems offer, which represent an open door for data theft and malware.

Computer-on-Module based designs get the customization via the carrier boards. This offers the same benefits as full custom designs but incurs far less engineering costs.

Carrier board design guides

Both the PICMG and SGET standard bodies provide verified design guides for carrier board development, so that OEMs get guidance on all the required best practices of designing application specific carrier boards. These carrier board design guides are a great educational base for embedded computing engineers and their availability has lead to advanced standardization: Most of the custom specific carrier boards are designed in line with the latest best practices described in the guides. With many vendors delivering their blueprints to OEM customers in appropriate files, engineers can also leverage considerable efficiency gains by re-using existing carrier board layouts. As embedded and IoT system engineers are increasingly faced with the design challenge of having to deliver more new product designs in ever shorter time frames, these carrier board design guides greatly help to get best quality designs to market faster.

Reduced complexity of accompanying tasks

Compared to a full custom design, not only the engineering and design efforts are reduced; there are also other accompanying tasks that can be fulfilled more easily:

- The evaluation and verification of building blocks is limited to components that are not provided by the modules and evaluation carrier boards.
- OEMs can utilize the documentation of Computer-on-Modules that are already finalized and only need to tweak the evaluation carrier board documentation to their final carrier board documentation, which means that for this component of a system at least 60% of the documentation effort is already done which frees engineers from this unloved task.
- Tests and certifications carried out for the components simplify the certification demands of the entire system as well.

Training and support

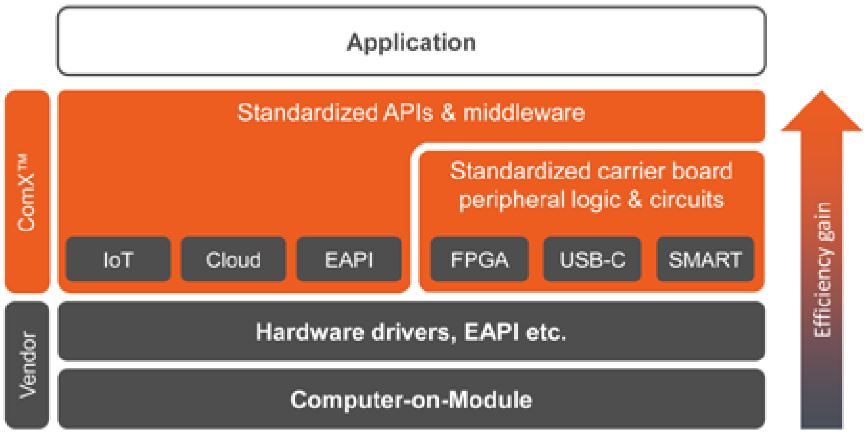
As Computer-on-Module vendors strive to offer best services and support for their modules, customers have access to various offerings ranging from online tutorials and carrier board design training to integration services. congatec offers premium support in this area as the company has installed a personal service for OEMs that is designed to further simplify the use of embedded computing technologies. OEM customers around the globe benefit from a single point of contact to get all their design-in questions answered. There is no need to wait in an impersonal hotline or speak to constantly changing contact persons. congatec’s premium service for OEM customers is simple, straightforward and comfortable for engineers, unique for the embedded computing market and globally available at no extra costs. Do vendors of standard motherboards offer such services? No! And who should developers of full custom designs contact to get quality help with their design challenges? So it will most likely be down to the Computer-on-Module vendors to offer best in class services and support.

Reduced efforts for devices in place

As devices get more and more connected, embedded systems can no longer be deployed with a frozen configuration of OS and application. Full custom designs are faced with the problem that OEMs assume responsibility for managing all security updates for any component inside the system. With Computer-on-Modules, OEMs find a strong partner in their module vendor who offers regular updates for the computing core and its standard BIOS, firmware and drivers.

Advanced standardization in sight

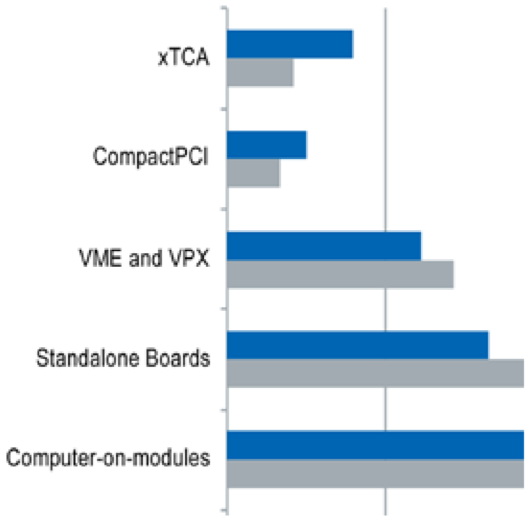
As the Computer-on-Module market has been mature for many years, new initiatives are underway to further advance standardization to simplify the use of Computer-on-Modules even more. One of these activities is the ComX™ standardization initiative, which goes beyond the current specifications for Computer-on-Modules and carrier board design guides. The ComX standardization targets two pillars: The API and middleware standardization, including APIs for IoT gateways or embedded features of COM Express Type 7 Server-on-Modules; and approved circuit diagrams and logic for demanded carrier board implementations such as FPGA integration, switching logic for USB-C, or for SMART battery logic. The goal of the ComX standardization is to establish an additional design-in and API standardization on top of the existing core standards to further simplify the development of custom specific applications based on standardized embedded computing building blocks.



ComX standardization addresses everything beyond the existing module centric standards.

Don't dismiss single board solutions

With all the outlined benefits of Computer-on-Module based designs, it's all too easy to forget that sometimes, they are not the best solution for the given requirements. Engineers consequently need to check the specifications and market trends of other embedded form factors before choosing a module approach. As the forecast from IHS indicates, checking the availability of standalone boards which directly fit the application is important. The relevant



The world market for embedded computer boards, modules and systems by product type, by Brian Arbuckle, Senior Market Analyst, IHS Markit
Source: https://technology.ihs.com/587541?utm_campaign=PC9477-1_eT3_JM%20_MT_TMT_GLOBAL_NEWSLETTER_Semis_Feb2017_Engaged&utm_medium=email&utm_source=Eloqua

form factors in this growth cluster are the Mini-ITX and Pico-ITX boards as well as the new eNUC standard as they offer small form factors perfectly suited for space constrained embedded system designs. In the market segment of passive backplane based systems, only VME/VPX shows good growth perspectives – due to intensified spending in the military market – while Compact PCI and xTCA technologies are declining.

High volume productions

If the project size reaches ultra-high levels, then it should also be checked whether a full custom design might ultimately be a better fit. While a single module connector may cost only 1 dollar, when you've got 500,000 pieces this adds up to half a million dollars, and mounting the module is a cost factor too. So when it comes to very high volume productions, the breakeven point between a COM/carrier concept as opposed to a full custom design needs to determined. Calculating this breakeven point is complex as R&D costs and investments in future upgrades also need to be taken into account. Module vendors can help OEMs with these calculations, and in most cases they also offer embedded design and manufacturing services for full custom boards

Rich choice of module standards to pick from

After having evaluated all the options and finding that a Computer-on-Module approach fits best, engineers need to choose the right Computer-on-Module standard. Today's state-of-the-art technologies include the specifications from two worldwide standardization bodies: The PCI Industrial Computer Manufacturers Group (PICMG) hosting the COM Express standard, and the Standardization Group for Embedded Technologies e.V. (SGET), which is responsible for Qseven and SMARC.

COM Express

The COM Express standard defines a family of different module sizes and pinout types covering a broad range of designs from low power small form factor devices up to powerful embedded servers. Introduced by the PICMG back in 2005, it is the longest existing among the Computer-on-Module standards featured here. All COM Express designs leverage the same reliable and rugged connector to the carrier board. Dedicated pinouts allow designs to be optimized for their specific tasks while remaining within the standard. COM Express focuses on x86 processor technology. Besides the modules themselves, the COM Express specification also defines a unifying cooling solution to further standardize and simplify module integration as well as interchangeability. From a footprint point of view, COM Express is available in 4 different sizes. But size is not the only decisive factor. The pinout of the connector is at least as important. There are currently three state-of-the art pinouts that comply with the latest COM Express 3.0 specification launched in 2017.

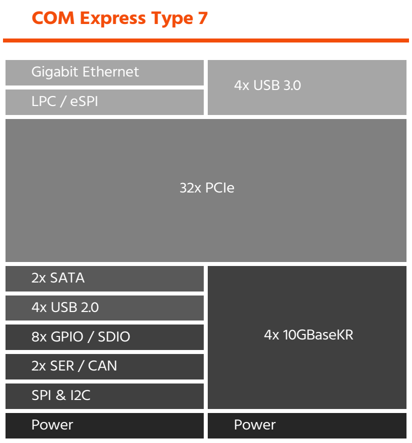
COM Express Sizes

- Mini 84 x 55 mm²
- Basic 95 x 125 mm²
- Compact 95 x 95 mm²
- Extended 110 x 155 mm²

COM Express Type 7

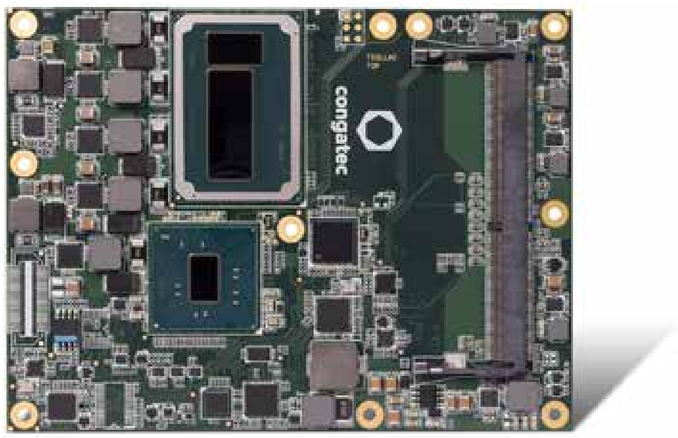
Brand new is PICMG's COM Express Type 7 specification. It is tailored for modular server designs, which are being deployed at the edge of the IoT and Industry 4.0 applications as cloud and fog servers, or in cloudlets at the edge of the carriers' base stations for high-bandwidth mobile communications. What is most interesting from a feature set point of view is the support of up to 4x 10 GbE bandwidth and up to 32x high-speed PCIe for high performance storage, and dedicated interfaces supported by 440 signal pins to the carrier board. Target processors that can be found on the Basic sized 95 x 125 mm² modules include the Intel Xeon D processors and the upcoming successors from both x86 server processor vendors, Intel and AMD. Larger modules are also possible as COM Express already specifies the Extended format measuring 110 × 155 mm². This larger footprint can be leveraged for increased RAM and/or for higher cooling demands above 65 W TDP to avoid hot spots that are harder to handle. As server processors don't integrate a graphics unit, graphics signals are not part of the Type 7 pinout, instead offering more Ethernet and PCIe connectivity. If graphics or GPGPUs are required, these can be integrated via the carrier board.

The COM Express Type 7 Server-on-Modules provide up to 4x 10 Gbit Ethernet and up to 32 PCIe Lanes. The conga-B7XD Server-on-Module integrates latest Intel Xeon D processors with up to 16 cores and 48 GByte of DDR4 RAM.



COM Express Type 6

COM Express Compact Type 6
95 x 95 mm²

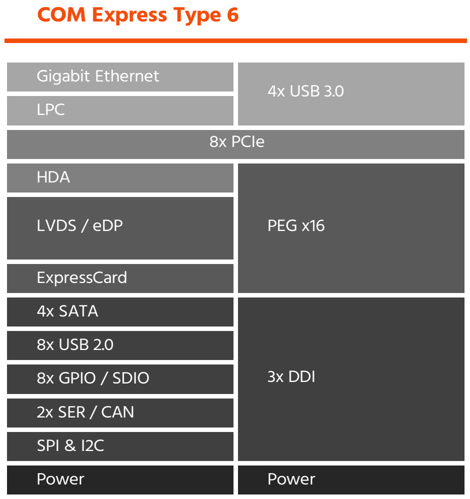


COM Express Basic Type 6
125 x 95 mm²

Latest COM Express Type 6 modules like the conga-TC-175 and the conga-TS175 with state-of-the-art Intel® Core™ processors provide PC-like interfaces including multiple graphics, USB 3.0 and 2.0 as well as PCIe outputs and many typical embedded I/Os.

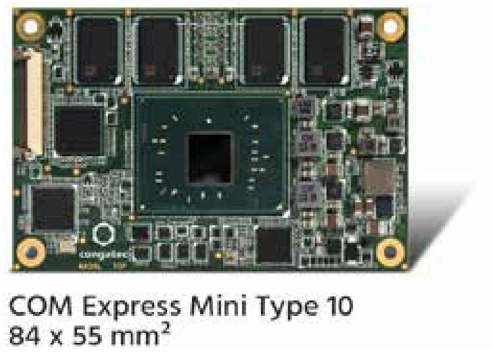
The established PICMG COM Express Type 6 specification is state-of-the-art for the high-end sector of embedded computer systems with implemented processors ranging from Intel Core, Pentium and Celeron to the AMD Embedded R-Series.

These modules measure 95 x 125 mm² (Basic) or 95 x 95 mm² (Compact), provide 440 pins to the carrier board and offer a comprehensive set of state-of-the-art computer interfaces. They support up to four independent displays, 24 PCIe lanes, USB 2.0 and USB 3.0 as well as Ethernet, CAN bus and serial interfaces, thus providing everything needed to build powerful PLCs, HMIs, shop floor systems or SCADA workstations in control rooms. Further application areas are high-end digital signage systems, high-end gaming machines and complex kiosk systems.



COM Express Type 10

PICMG's small form factor COM Express Type 10 rounds off the set of COM Express specifications. It comes with the credit card sized Mini form factor. These modules measure only 55 x 84 mm², offer 220 pins and are dedicated for low power x86 SoC processors such as Intel Atom and Celeron as well as AMD G-Series processors. Thanks to the unified connector technology and design guides used within the entire PICMG COM Express ecosystem, developers can re-use as many features as possible. Designers have one standard they can leverage to scale their designs on the basis of COM Express, from Mini Type 10 modules with Intel Atom processors up to Intel Xeon D processors for the server segment.



The conga-MA5 with latest low-power Intel® Atom™, Celeron® and Pentium® processors in the COM Express Mini footprint with Type 10 pinout extends COM Express scalability to small form factor designs.

Qseven and SMARC

Engineers that are targeting not only x86 but also ARM-based designs are best served with Qseven or SMARC 2.0 modules as they incorporate both processor architectures. The difference between Qseven and SMARC 2.0 can quite easily be explained: On the connector side, Qseven offers 230 pins and SMARC 2.0 offers 314 pins. SMARC is more orientated towards feature rich multimedia applications whereas Qseven offers more I/Os as required by the deeply embedded and industrial arena. All the other benefits are comparable. Both standards enable slimmer designs compared to COM Express because of their flat edge connectors; and both have reliable connector vendors: The Qseven connector is currently supported by three and the SMARC 2.0 connector by two vendors.

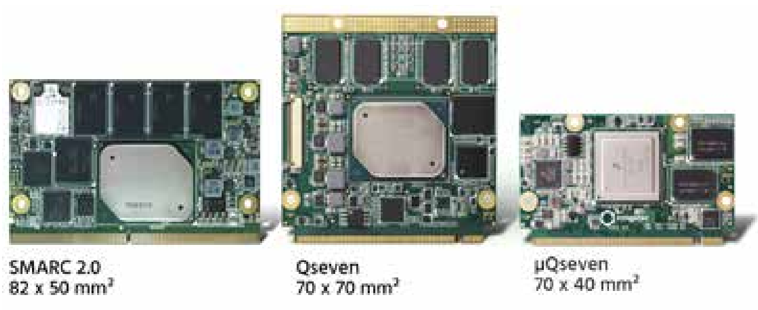
As mentioned above, Qseven ideally suits industrial and deeply embedded designs. For these, it provides outstanding industrial peripheral support via up to 2x USB 3.0, 8x USB 2.0 as well as up to 4x serial interfaces or CAN bus. Additionally, up to two MIPI CSI cameras can be connected via a flat foil connector on the module. For internet connectivity it further features one Gigabit Ethernet port; as for display support, Qseven modules can drive up to three independent displays.

SMARC 2.0 modules offer nearly the same overall feature set, but balance the I/O count more towards multimedia applications for markets like digital signage, vending and infotainment. Compared to Qseven, SMARC supports up to four independent displays. Also, audio is extended with High Definition Audio and I²S in parallel, which is common for many handheld consumer devices. In contrast to Qseven, the camera inputs are executed via the connector.

Graphics Interfaces	Max. 3 independent	Max. 4 independent
LVDS	2x dual channel LVDS/eDP	2x dual channel LVDS/eDP/MIPI DSI
DDI	1x DVI/HDMI/DP	1x HDMI/DP++ & 1x DP++
Camera inputs	2x MIPI CSI (flat foil connector on module)	2x MIPI CSI
Audio	1x HDA/I²S	1x HDA & 2x i²S
Connectivity	1x Gbit Ethernet	2x Gbit Ethernet
Wireless	-	Bluetooth & WLAN optional
Storage	2x SATA	1x SATA
Expansions		
PCI Express	4 lanes	4 lanes
USB	8x USB 2.0 / 2x USB 3.0	6x USB 2.0 / 2x USB 3.0
Industrial I/Os	4x SER/CAN bus	2x SER/CAN bus
GPIO	8x	12x
SPI	1x	1x
LPC	1x	1x eSPI
SMB	1x	1x
I²C	1x	1x

The major difference between Qseven and SMARC 2.0 is the number of interfaces which divides the application areas into more deeply embedded applications for Qseven and more multimedia focused designs for SMARC 2.0.

One unique feature that SMARC 2.0 provides is support for wireless technologies on the module itself. For that task, the specification reserves a special area on the module that is dedicated to the placement of the miniature RF connectors. All SMARC 2.0 modules with wireless functionality have these connectors in the same position to ensure consistent interchangeability. Ideally, the connectivity for logic devices like WLAN and Bluetooth is integrated in



SMARC modules like the conga-SA5 with Intel® Atom™, Celeron® and Pentium® processors target feature rich multimedia applications whereas Qseven is intended for the deeply embedded and industrial arena. Both form factors can host x86 as well ARM processor technology.

a modular way and in line with the M.2 1216 interface specification. This allows a wide choice of radio protocols which in turn makes customizations for end user applications highly flexible.

The difference in the number of interfaces between Qseven and SMARC 2.0 is also kind of a price indicator: Qseven is designed for less complex designs and SMARC for the high-end of small form factor applications that demand credit card sized modules. In general, any decision therefore depends on what the task of an embedded system will be.

Conclusion

The benefits of Computer-on-Modules are so substantial that a majority of embedded system designs are already using these application ready building blocks. Compared to full custom designs, they offer reduced development costs, a scalable product range and faster time to market as developers can focus on the system features. This enables OEMs to react to market trends faster. Moreover, with Computer-on-Modules they can leverage a second source philosophy and minimize inventory costs.

As the number of IoT and Industry 4.0 applications multiplies, many new designs are forecast to be based on Computer-on-Modules and the new class of Server-on-Modules for edge computing. Identifying the best form factor is the next major step within the design evaluation process where module vendors can help. As long as they offer all the relevant form factors, they can provide better consultancy as well as better options to migrate from one form factor to the other. When choosing the right vendor, it is key to have a look at the BSPs, firmware and communication middleware, as they are getting more and more important in a connected world. This does not mean that the vendor should complement its offerings with an entire cloud for the system because it will never meet the needs of a customer entirely. It is more important to have a closer look at what is offered on the board and module level itself. For example, is the board management controller proprietary? Then take care as it could prove to be a dead end. Better to choose open, non-proprietary APIs because openness and standards are the fundament for most efficient and simplified re-use of existing engineering efforts.

Check that integration support is offered for ARM and x86, because it is better to get one engineer who supports both architectures for a unified product family instead of two different engineers with two different product lines. This also requires unified APIs. Finally, check the provided documentation. It is better to have more pages of content instead of only the bare minimum. And think also about relying on local manufacturing capacities wherever you or your customer reside. This will not only allow you or your customer to buy local but can also help with potential government trade restrictions. Fabless board-level vendors such as congatec with subsidiaries all over the world can offer you all these advantages.

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About congatec AG

Headquartered in Deggendorf, Germany, congatec AG is a leading supplier of industrial computer modules using the standard form factors COM Express, Qseven and SMARC as well as single board computers and EDM services. congatec's products can be used in a variety of industries and applications, such as industrial automation, medical, entertainment, transportation, telecommunication, test & measurement and point-of-sale. Core knowledge and technical know-how includes unique extended BIOS features as well as comprehensive driver and board support packages. Following the design-in phase, customers are given support via extensive product lifecycle management. The company's products are manufactured by specialist service providers in accordance with modern quality standards. Currently congatec has entities in the USA, Taiwan, China, Japan and Australia as well as the United Kingdom, France and the Czech Republic. More information is available on our website at www.congatec.com or via Facebook, Twitter and YouTube.

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