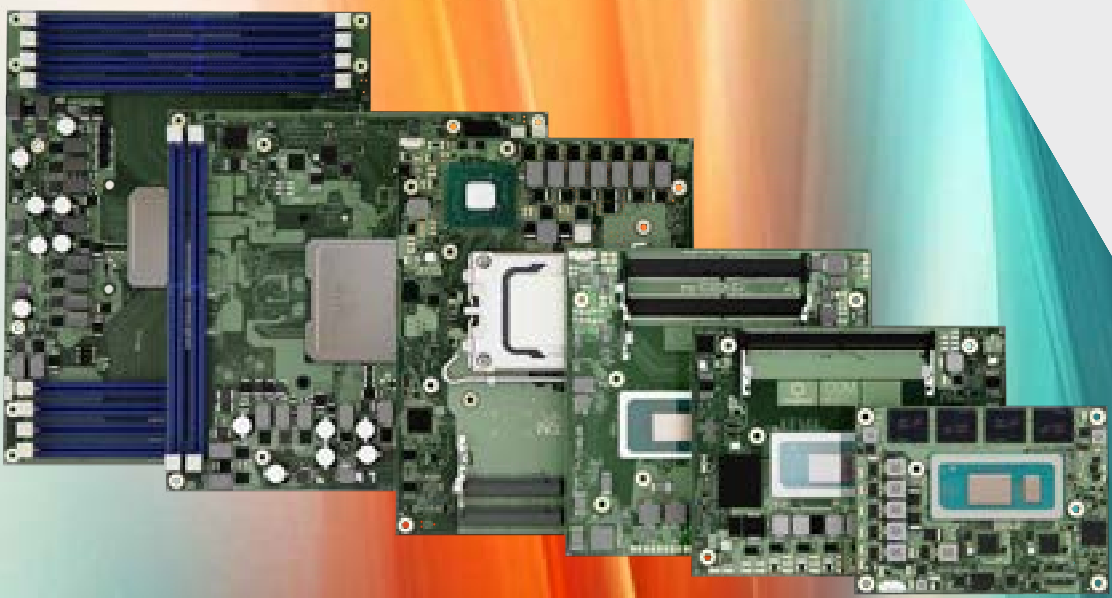
Computer-on-Modules – the Compendium

What, when, why, where and how?

Whitepaper



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Computer-on-Modules – a short introduction

There are many different types of computer modules, referred to by names like System-on-Modules (SoMs) and Computer-on-Modules (COMs). Since the latter is more common and more precise, this paper will stick to Computer-on-Modules or COMs. But in general, both mean the same: A circuit board that contains the core building blocks of an embedded computer.

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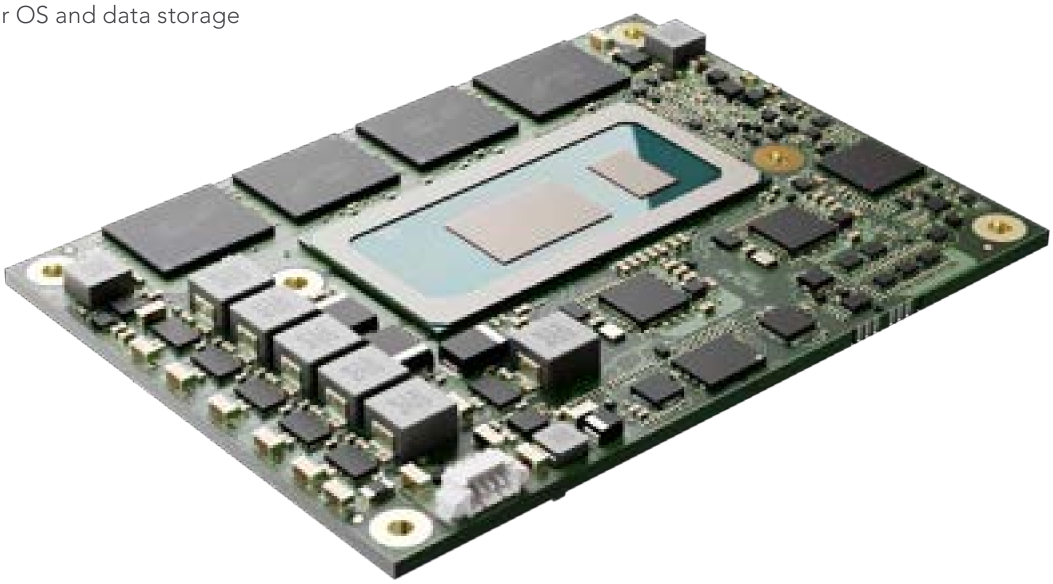
Off-the-shelf super-component

The beauty of Computer-on-Modules is that they are available off-the-shelf as application-ready super-components. In a single, function-validated package they feature all key building blocks and interfaces of an embedded computer including:

- Processing unit (CPU), sometimes with integrated graphics and AI accelerators
- RAM, memory modules or soldered down for the rugged versions,
- Graphics, Ethernet, USB, GPIO, etc.
- Controllers for additional interfaces including real-time Ethernet, CAN bus, MIPI CSI, Thunderbolt on selected SKUs, etc.
- Non-volatile memory for OS and data storage on selected SKUs

OEMs can buy Computer-on-Modules with all required board support packages including drivers and software tools. Optional accessories like tailored cooling solutions and evaluation carrier boards are often also offered.

Designers can choose between proprietary COMs and modules following open standards. It is highly recommended to leverage COMs based on open standards as they make full use of the modular approach and offer unique advantages.



Evolution of open Computer-on-Module standards

Moore's Law for Computer-on-Modules
The number of transitions that fit on a specific Computer-on-Module form factor doubles approximately every 2 years.

1993

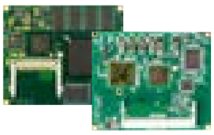
ModulAT
- AT/ISA96 bus
- 120 pins
- Intel 80C88

1999

Intel Pentium III
- Cracks 1 GHz limit

2000

ETX XTX



ETX/XTX
- ISA/PCI bus
- 400 pins

Intel Pentium 4

2001

Foundation of ETX-IG
Open specifications enable COM

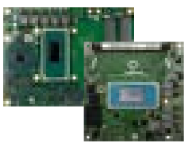
VIA Eden

2003

Intel Pentium M
The COM milestone processor

2005

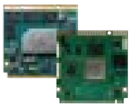
COM Express
- Pure serial PCIe bus
- 440 pins a quantum leap
- Basic & Compact dominate



COM Express®

2008

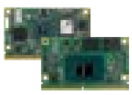
QSEVEN



Qseven
- 70 mm × 70 mm
- Industrial grade interfaces
- 230 pin MXM 2 connector
- For Arm and x86

2013

SMARC Module
- Industrial grade interfaces
- 314 pin MXM 3 connector
- For Arm and x86
- Extended industrial I/O



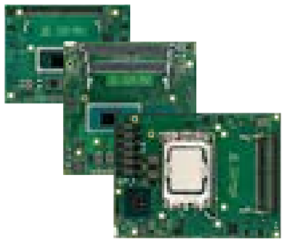
SMARC module

2016

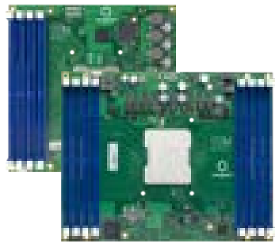
Server-on-Modules
Introduction of COM Express Type 7

2021

COM-HPC



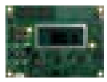
COM-HPC/Client
- Up to PCIe Gen 5
- 800 pins
- Video/audio interfaces
- Up to 4 SODIMM memory



COM-HPC/Server
- Up to 64 × PCIe Gen 5
- 800 pins
- Headless
- 8 DIMM memory

2023

COM-HPC Mini
- Up to 16 × PCIe Gen 6
- 400 pins
- Video/audio interfaces
- Soldered RAM



COM benefits at a glance

Faster time-to-market

COMs save time as they separate the application-specific design work from the underlying embedded computing technology. Designers can fully concentrate on their core competencies and leave the computing functionality to the COM.

Lower development cost

COMs save money compared to full-custom designs by reducing the non-recurring engineering costs for development and upgrades. With standardized COMs, developers don't have to spend time on a complex design in process.

Reduced design risk

COMs minimize risk. Basic changes during the design phase, or in the middle of a product's lifecycle, are easily managed. Simply plug in the next-generation computer module and continue. Easily design whole product families using different COMs from one basic design.

Increased agility

COMs are highly scalable to meet all performance requirements, from low power to high performance, and from Arm technology to x86. Conquer the challenges of rapid technological evolution with a simple module change to implement more performance and new possibilities like AI.

High investment security

COMs enable seamless migration to newer technologies and different providers, making your applications independent from technological changes, obsolescence issues, and technology provider. This preserves compatibility and software investments.

Maximized ROI & sustainability

COMs increase the lifetime of your application. Existing designs can easily be upgraded to fulfill new and unforeseen demands with a simple module change. Even systems that have been in use for several years can be upgraded, extending the lifespan of your hardware.

The COM approach – buy and build

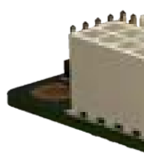
One of the fundamental questions regarding the embedded computing technology when developing a new application is: Shall I build, or shall I buy?

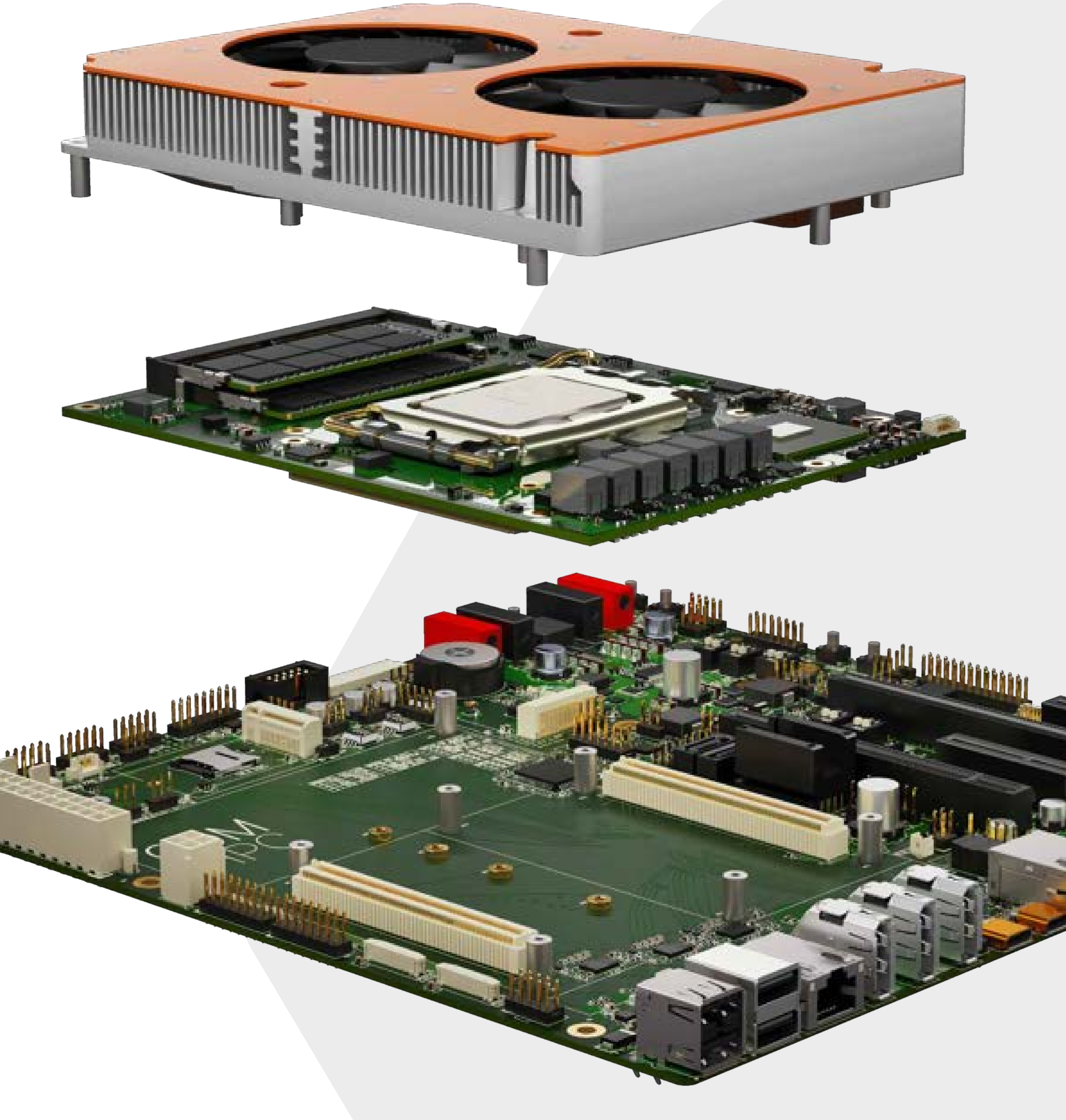
Pros and cons for build

Building a full-custom design leads to a highly optimized solution. The shape and features can be tailored to meet the exact requirements of the application in a cost-optimized package. But a full-custom design requires substantial upfront investments in development resources, monetary costs, and time. Moreover, future upgrades, for example with more powerful and energy-efficient processors, often require a complete re-design of the existing solution. But in many cases, the biggest trade-offs are missing expertise and/or resources to design-in the complex core PC components.

Pros and cons for buy

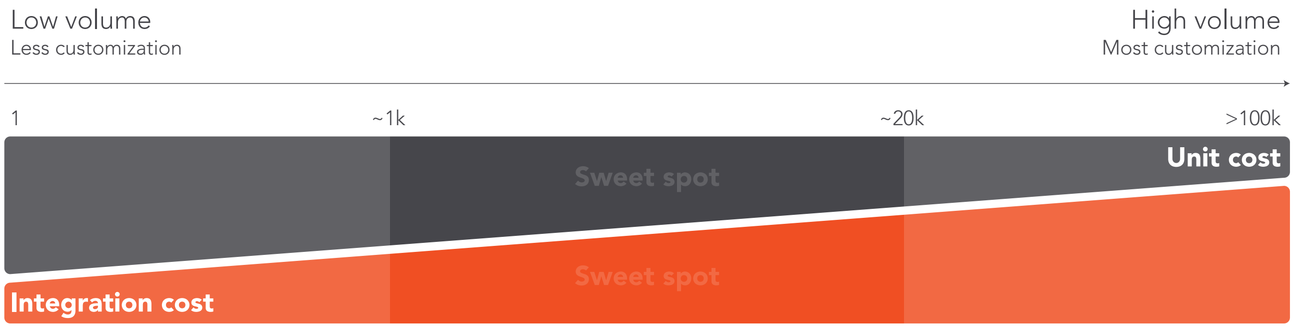
At the other end of the scale are off-the-shelf motherboards. Buying a commercial motherboard is typically the fastest way to the application. Moreover, this route also comes with high design security as customers purchase a fully verified and reliable design. However, there are some drawbacks to this approach. Designers frequently pay for more features than they really need. The boards may not fit the available box space nor provide the required number of interfaces in the right configuration or board location. Utilizing PCIe expansion cards on the board may not provide the required resistance against mechanical or thermal stress. And sometimes, standardized boards just don't offer the required scalability due to unavailable processor options.





COMs – the golden design choice

Between these two designs paths, Computer-on-Modules provide the optimal route for designers. COMs decouple the application-specific design work from the underlying, highly complex embedded computing technology.



In contrast to full-custom designs, engineers neither have to integrate complex processors, RAM and high-speed interfaces, nor build entire board support packages with all associated drivers, libraries and APIs themselves. Instead, all these components come off-the-shelf from the respective module vendor. This enables engineers to concentrate fully on optimizing the dedicated application, which after all is their core competency.

Besides R&D, purchasing departments also benefit from COMs since the bill of materials (BOM) is reduced from multiple components to a single module for the processing core. Admittedly, this is a smaller but nevertheless important part of the efficiency gains from Computer-on-Modules.

Highest scalability

Computer-on-Modules offer tremendous scalability for upgrading processing power. With a full-custom design, a direct processor change can only be executed using pin-compatible processors. However, in most cases, successor processors are not pin-compatible. 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 exchanging the module. Another advantage is the long-term availability of applications. When the multi-year product lifecycle of an embedded processor ends, a module with a successor is often available for a seamless retrofit.

Open standards are a must

However, high scalability can only be secured through standardization. Computer-on-Modules achieve this by utilizing open standards. These define aspects such as module footprints, type and number of connectors, signals routed to the carrier board, and maximum power consumption.

The benefits of open standards for COMs are tremendous. Standardization leads to highest design security as it guarantees future availability of modules with the same interfaces. Designers can also develop second source strategies and are not dependent on a single vendor. This increases both design security and availability as disruptions in the supply chain can be compensated for by other vendors.

PICMG	SGET
COM Express	SMARC
COM-HPC	Qseven

Standardization further delivers the capability 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 most important vendor-independent computer module standards are COM-HPC® and COM Express® from the PCI Industrial Computer Manufacturers Group (PICMG), and SMARC and Qseven from the Standardization Group for Embedded Technologies e. V. (SGET).

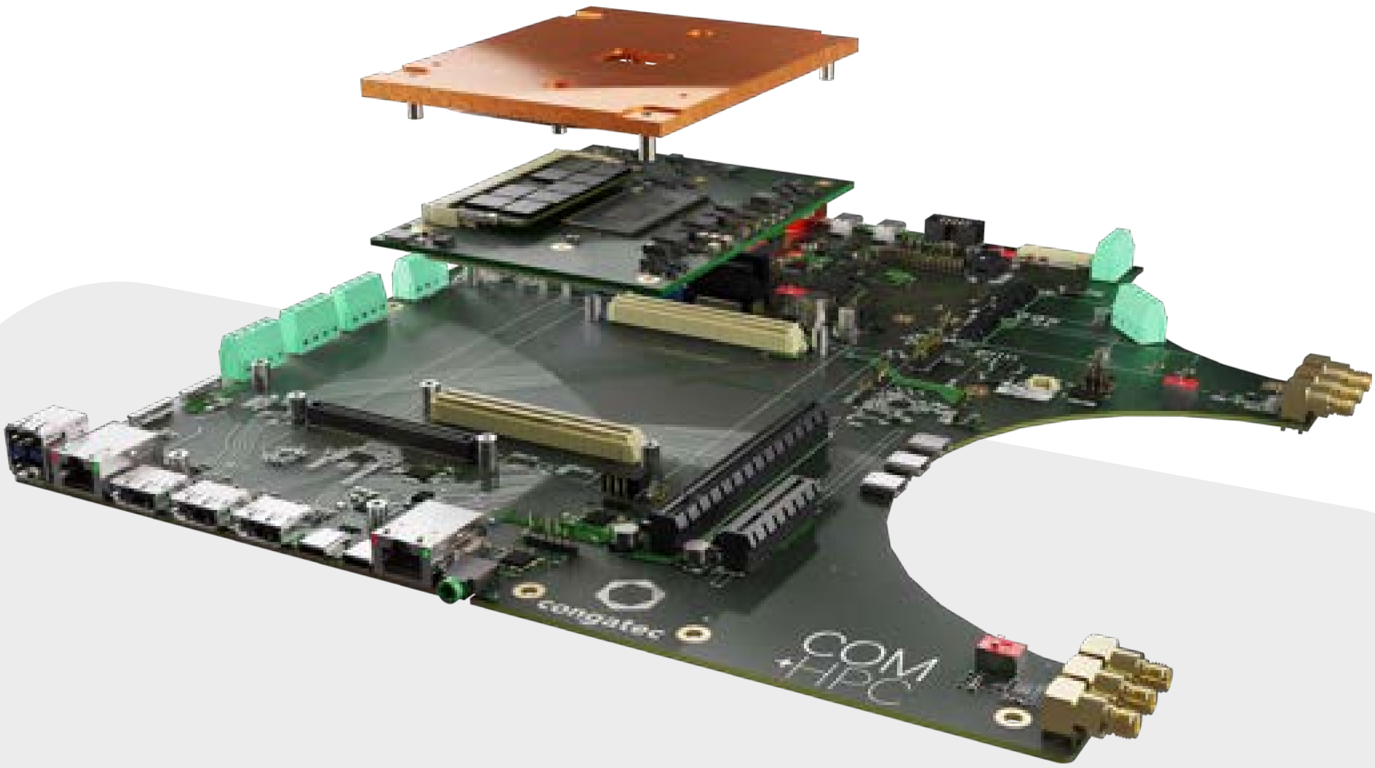
Standardized cooling

These standards go beyond defining modules alone. They also cover corresponding heat spreaders, which act as thermal interfaces between modules and system cooling solutions. All heat-generating components thermally conduct to these heat spreaders to avoid hot spots. Moreover, the standards define an overall z-height for conformity. The heat spreaders level out variances in CPU and component heights on the modules. As a result, the overall height from cage top to heat spreader top is always the same within a given standard. This ensures that modules are interchangeable even when directly coupled to system housings for passive heat dissipation.

Simplified customization via carrier boards

As previously mentioned, Computer-on-Modules derive their greatest strength from following standards. But how do you customize COM designs, and how do they compare against off-the-shelf motherboards or SBCs?

With COMs, customization is implemented via carrier boards. Designing a customized carrier is far less complex than designing a full-custom board, yet provides identical benefits. Compared to standard motherboards, carrier boards offer complete footprint and interface flexibility. The footprint can be quadrangular, round, or entirely asymmetric. This offers perfect conditions for tailoring the PCB to the system and yields many benefits, from optimized cooling and more rugged mounting to the ability to position I/Os exactly where required. This eliminates the need for complex internal cabling, which improves reliability and system design. Additional controllers for application-specific peripherals are easily implemented via the carrier, too. This eliminates the need for conventional expansion boards, which are often prone to mechanical stress and can reduce system reliability while increasing BOM and cost. This way, engineers can fully concentrate on the customization, which simplifies and accelerates the design process.



Less interfaces, more benefits

In contrast to conventional SBCs and motherboards, COM-based carrier boards only integrate what the application 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 compromised or hacked. Take for example external USB ports, which may not be required by the application but are standard in motherboards. These ports represent an open door for data theft and malware.

Reduced complexity of associated tasks

Compared to a full-custom design, the COM approach reduces not only the engineering and design efforts; other associated tasks are also easier to fulfil:

- Evaluation and verification are limited to components that are not provided by the modules and evaluation carrier boards. All other components are pre-validated by the board vendor.
- OEMs can utilize the already finalized documentation for the Computer-on-Modules, only needing to tweak the evaluation carrier board specifics to arrive at their own final carrier board documentation. This means that at least 60% of the documentation effort for this system component is completed out-of-the-box, which frees engineers from this unloved task.
- Tests and certifications are limited to the application-specific components, which simplifies certification of the overall system.

Carrier design guides

Both the PICMG and SGET standard bodies provide verified design guides for carrier board development, guiding OEMs through 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 led to advanced standardization: Most custom-specific carrier boards are designed in line with the best practices described in the guides. With many vendors delivering the blueprints of their evaluation carrier designs to OEM customers in appropriate files, engineers can also leverage considerable efficiency gains by re-using existing carrier board layouts. With embedded and edge system engineers having to navigate ever shorter design cycles, these carrier board design guides are a great help to get high-quality designs to market faster.

You can find the carrier design guides for COM-HP and COM Express at PICMG website
www.picmg.org/resources/design-guides

You can find the carrier design guide for SMARC Module at: sget.org/standards/smarc

Training and support

As Computer-on-Module vendors strive to provide the 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, having 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 in the embedded computing market, and globally available at no extra costs. Do vendors of standard motherboards offer such services? No! So, who should developers of full-custom designs contact to get quality help with their design challenges? It will most likely be down to the Computer-on-Module vendors to offer best-in-class services and support.

Checklist for the COM approach

COMs are a good fit when your application requires at least one of the following features:

- ☐ Application-specific I/O set
- ☐ Customized form and size
- ☐ High scalability
- ☐ Long-term availability
- ☐ Upgradability
- ☐ High design security
- ☐ Fast time-to-market
- ☐ Optimized development cost
- ☐ High design agility
- ☐ High re-use of existing designs

You should consult a COM vendor when you run into one of the following challenges:

- ☐ Your required processing unit is not available on standard modules, not even on the processor-agnostic COM-HPC standard
- ☐ Your required z-height is lower than COMs provide
- ☐ You require very high production volumes

But even in those cases, the COM approach and vendor will likely be able to help, for instance by designing a dedicated module solution with the required processing unit on a project basis. This can be done via the processor-agnostic COM-HPC standard. For the last two demands, a COM and carrier fusion can be helpful. Here, the required COM and carrier combination is transferred into a single board solution to find the financial sweet spot.

Finding the sweet spot

Calculating this breakeven point is complex as R&D costs and future upgrade investments must also be taken into account. congatec can help OEMs with these calculations, and it can also provide embedded design and manufacturing services for full-custom boards.

Reduced efforts for deployed devices

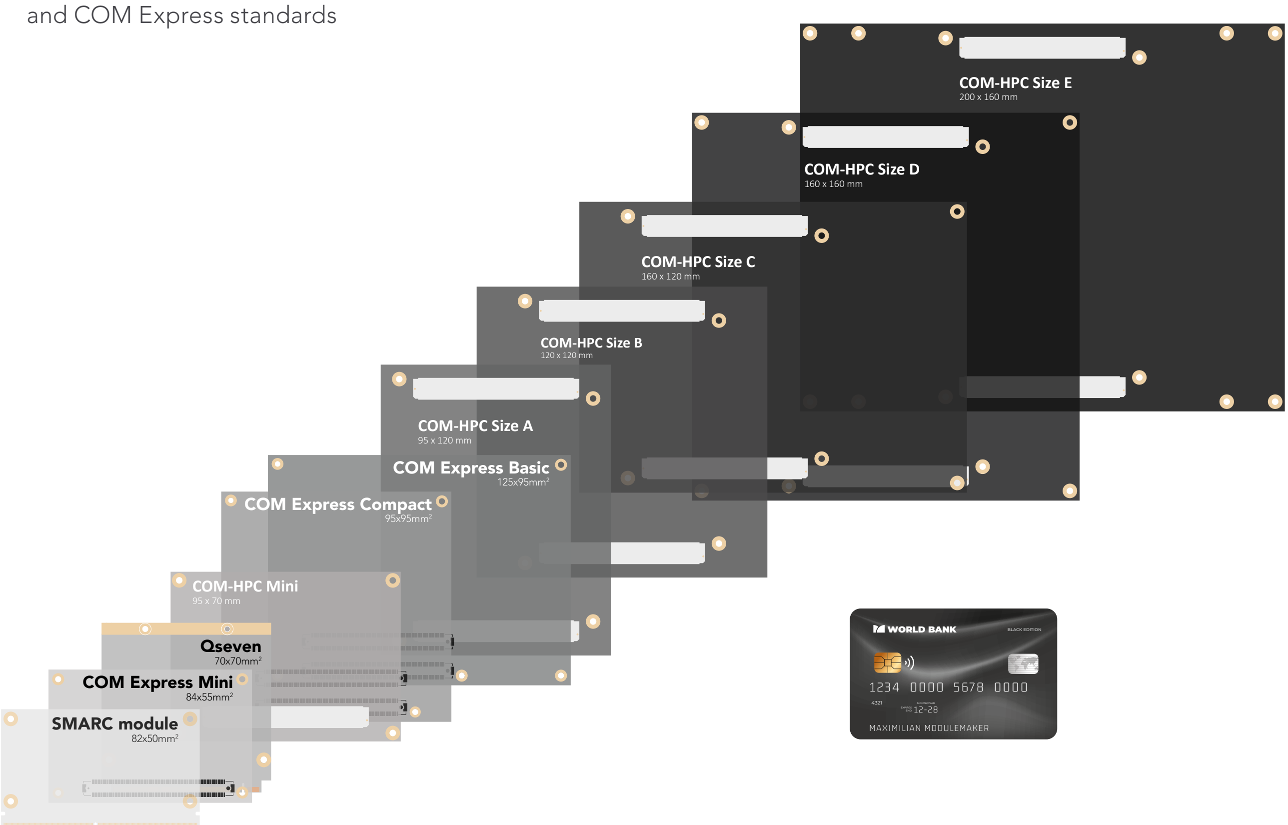
As device connectivity increases, embedded systems can no longer deploy with frozen OS and application configurations. Full-custom designs place the burden of managing security updates for all components in the system on OEMs. With Computer-on-Modules, OEMs find a strong partner in their module vendor who offers regular updates for the computing core and its standard BIOS, firmware and drivers.

COM standards – not all COMs are created equal

While COMs are as close to a unified, one-size-fits-all design approach as you can get, there is no single, universal COM standard.

Currently, there are three state-of-the-art standards from two worldwide standardization bodies:

1. The PCI Industrial Computer Manufacturers Group (PICMG) hosting the performance-oriented COM-HPC and COM Express standards
2. The Standardization Group for Embedded Technologies e. V. (SGET), which maintains the low-power-optimized SMARC module and Qseven specifications

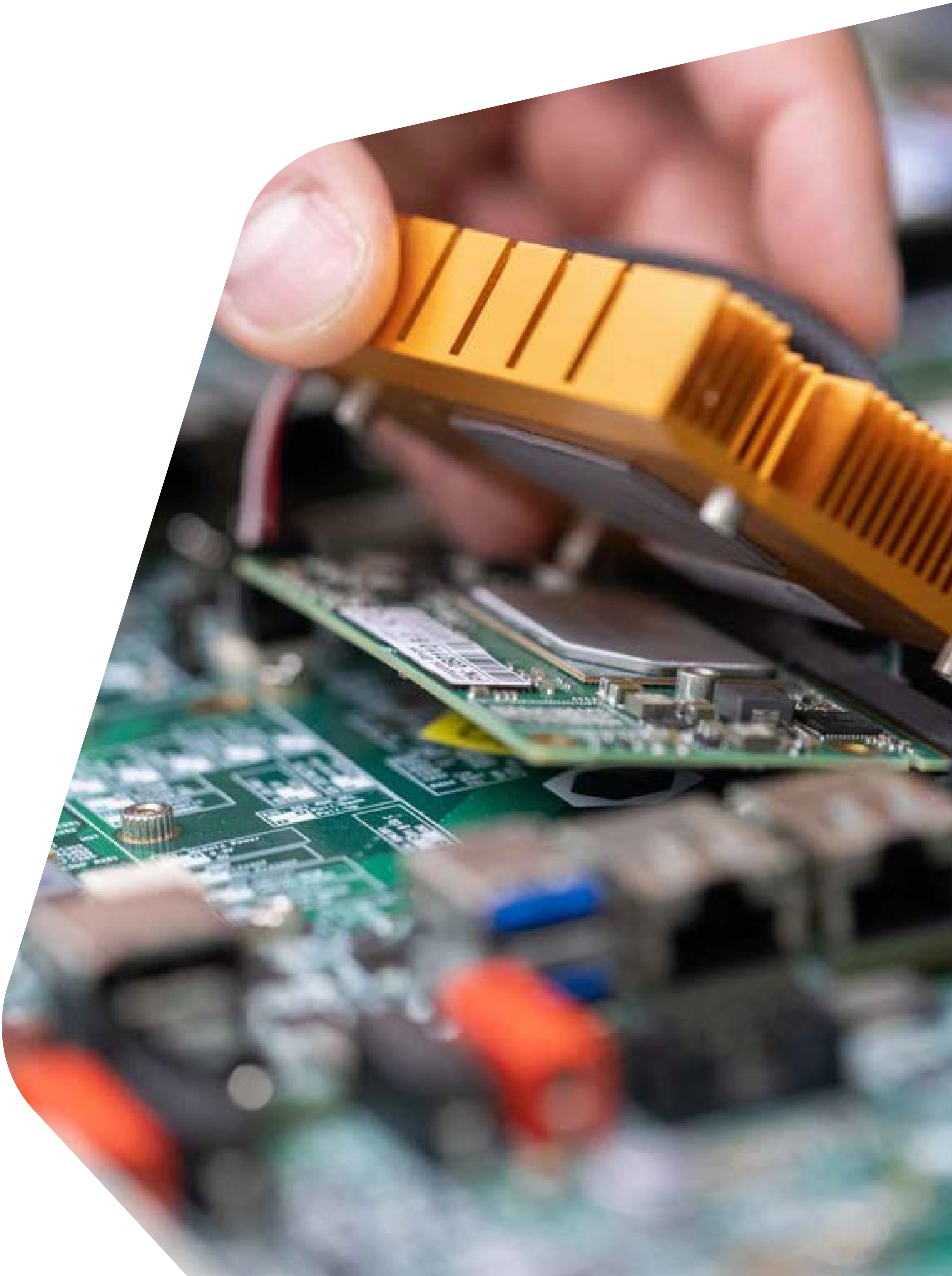


All available form factors as defined by the COM-HPC, COM Express, SMARC module, and Qseven specifications.

The current standards

	COM-HPC	COM Express®	SMARC module	Qseven[1]
Low-Power Class	✓	✓	✓	✓
Performance Class	✓	✓	–	–
Server Class	✓	✓	–	–
CPU Support				
x86	✓	✓	✓	✓
Arm	✓	–	✓	✓
Other (FPGA, GPGPU, etc.)	✓	–	–	–
Scalability				
Performance	+++	++	+	–
Footprint	+++	++	+	+
I/Os				
Range and number	+++	+	++	–
Bandwidth	+++	+	+	–

[1] Although still actively supported, developers should not base their new SFF applications on Qseven. With COM-HPC Mini and SMARC module there are two highly capable new standards that offer more benefits. This paper will therefore not address Qseven in detail.



COM-HPC – the game changer

COM-HPC is the youngest of all COM standards, officially launched in 2021. It is specifically designed to address the ever-increasing performance demands and bandwidth needs of all the new and upcoming edge and embedded server applications that cannot be met by other existing standards. COM-HPC is positioned above COM Express. It is not replacing it – it extends the possibilities for Computer-On-Module based solutions!

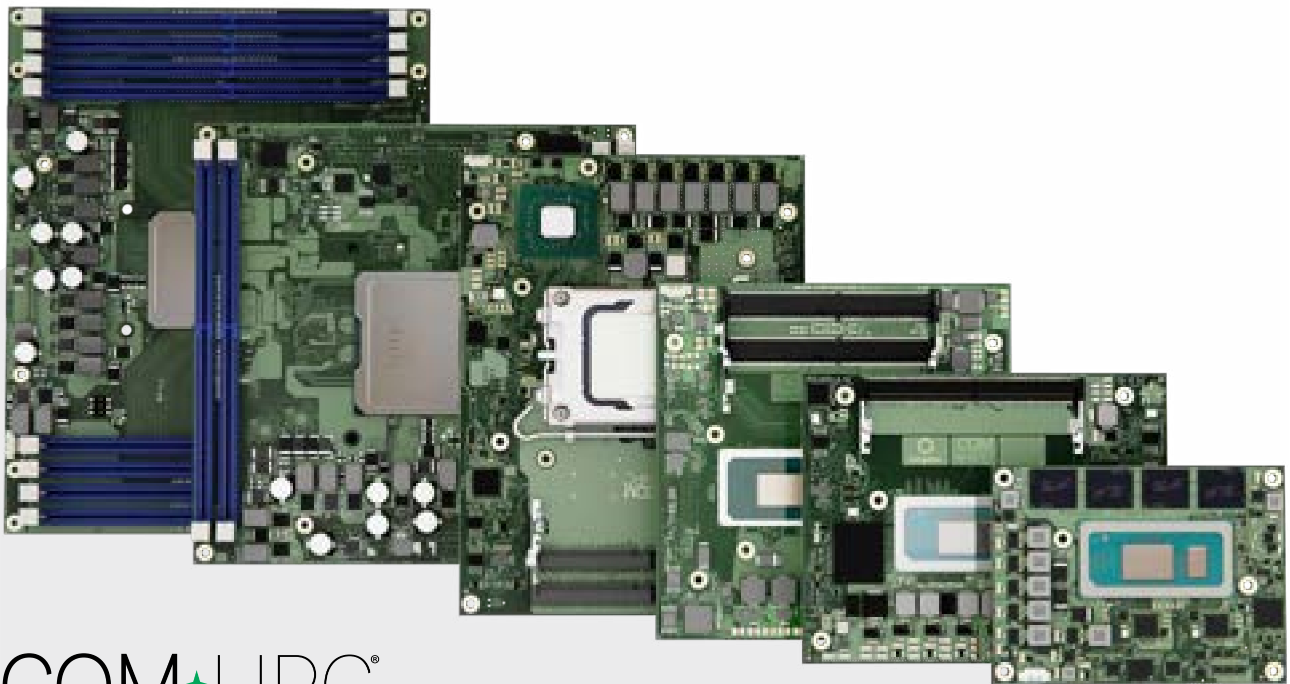
COM-HPC Computer-on-Modules are available in three application classes (Mini, Client, and Server) and 6 sizes (Mini, Size A, B, C, D, E). This makes COM-HPC the most broadly scalable Computer-on-Module specification, covering a wide range of applications from ultra-compact designs to edge servers.

All COM-HPC modules use the same high-performance 400-pin connector. COM HPC Client and Server modules use two connectors, for a total of 800 pins. COM-HPC Mini leverages a single connector with 400 pins. The connector system allows binary signaling rates (NRZ) of up to 56 Gtps suitable for PCIe Gen 5, and even supports 4-level pulse-amplitude modulation (PAM-4) for data rates of up to 112 Gtps, suitable for PCIe Gen 6. The connector system allows for 10 mm or 5 mm stack heights.

COM-HPC modules are processor agnostic. They can host x86 and Arm processors as well as further computing units including GPGPUs, ASICs, and FPGAs. Another unique feature of COM-HPC is the master and slave capability. This enables combining different COM-HPC modules and footprints on one carrier board. Furthermore, COM-HPC features a platform management interface (PMI) specification for easy remote management, even when the system is turned off. It leverages a simplified feature set of the common intelligent platform management interface (IPMI) technology.

At the COM-HPC page www.picmg.org/openstandards/com-hpc from PICMG designers can find the following assets:

- COM-HPC Module Base Specification Revision 1.2
- COM-HPC Module Base Preview specification
- Carrier Design Guide
- Embedded EEPROM specification for COM-HPC
- Platform Management Interface specification for COM-HPC



COM-HPC®

COM-HPC Mini

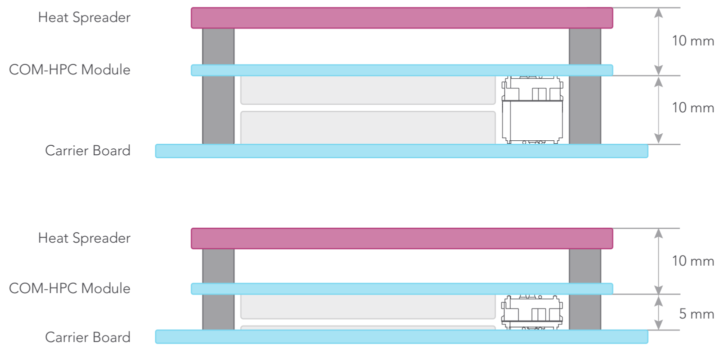
Maximum performance on a mini form factor

With the ratification of the COM-HPC 1.2 specification in October 2023, PICMG has officially introduced the COM-HPC Mini form factor. It extends the usage model of COM-HPC to extremely compact applications that previously could not be addressed due to size restrictions.

Size & form factor

With its footprint of just 95 mm × 70 mm, COM HPC Mini is significantly smaller than the smallest COM-HPC Client footprint Size A. The construction height of COM-HPC Mini measures either 5 mm or 10 mm from carrier board top to module bottom, depending on the used connector.

Together with the standardized cooling solution it features a total height of 15 mm or 20 mm. COM-HPC Mini modules shall use soldered memory as defined by the specification.



Connector & interfaces

COM-HPC Mini uses one connector instead of two as Client and Server modules do. Furthermore, the pinout has been changed to provide an optimized feature set. Therefore COM HPC Mini can transfer the full range of latest high-bandwidth interfaces via its 400 signal pins – including fully featured USB 4.0, Thunderbolt, PCIe Gen 4/5 as well as 10 Gbit/s Ethernet and much more.

Compared to COM-HPC Client, the specified maximum heat dissipation of the Mini standard is reduced. Yet the maximum power consumption of up to 76 Watt offers ample headroom for performance-oriented processors. This enables COM-HPC Mini to provide small form factor (SFF) designs with unprecedented performance levels as delivered by the latest multicore processor technologies.

Mini modules operate on a wide-range input power voltage over a range of 8–20 Volt.

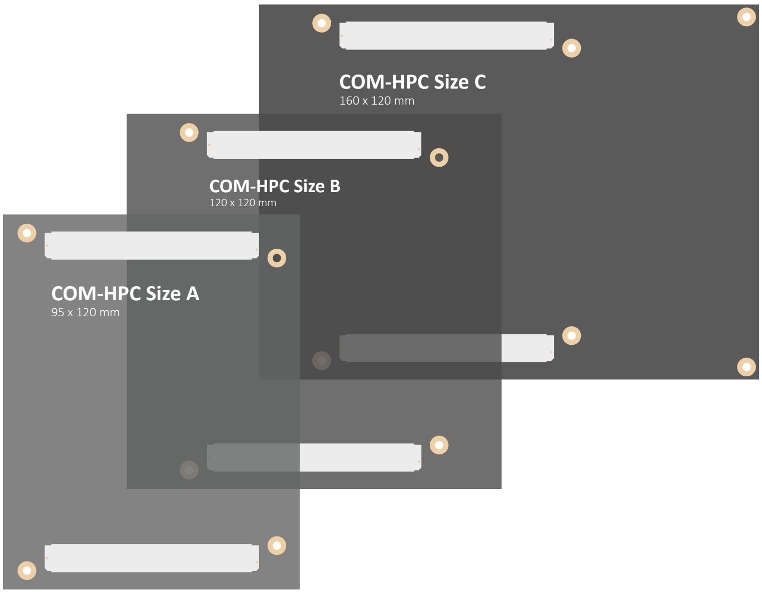
COM-HPC Mini
16x PCIe[3] with Target Support
4x USB 4.0[1]
4x USB 3.2x1[1] / 2x USB 3.2 x1[1]
8x USB 2.0[2]
2x SATA[3]
12x GPIO, 2x UART, 1x CAN
eSPI, 2x SPI, SMB, 2x I2C
2x MIPI-CSI[4]
HDA/I2S, 2x SoundWire
FuSa
2x NBaseT, 2x NBaseT Serdes[3]
2x DDI[1], 1x eDP
Power 8-20V DC

[1] Alternative use for DDI or USB 3.x possible
[2] Also needed for USB4 and USB 3.2
[3] Alternative to PCIe Lanes
[4] 2x Flatfoil Connector

COM-HPC Client

Unmatched features and performance for next-gen edge computing designs

COM-HPC Client modules are designed for high-performance embedded systems with integrated graphics. Client modules can be combined with other Client or Server modules in one multi-module system design for ultra-high-performance designs featuring dedicated CPUs or accelerators like GPGPUs, ASICs, or FPGAs.

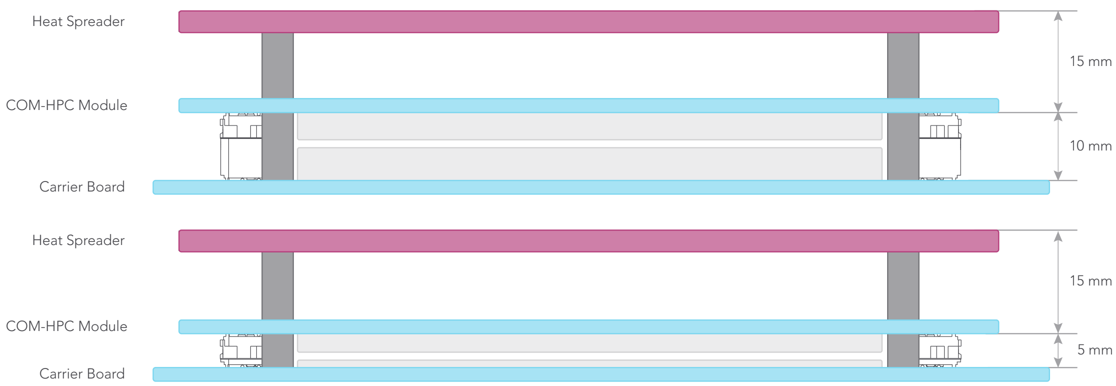


Size & form factor

For COM-HPC Client modules PICMG specifies three sizes: Size A with 120 mm × 95 mm, Size B measuring 120 mm × 120 mm, and Size C with 120 mm × 160 mm for exceptionally powerful processors. Just like COM-HPC Mini, Client modules also feature construction heights of 5 mm or 10 mm from carrier board top to module bottom, depending on the connector.

For both heights, the unifying heat spreader adds another 15 mm. This height is required to support more powerful and socketed processors on COM-HPC Client. Consequently, COM-HPC Client modules feature total design heights of 20 mm or 25 mm including heat spreader.

COM-HPC Client modules can accommodate a maximum of three SDRAM sockets or soldered memory as defined by the specification.

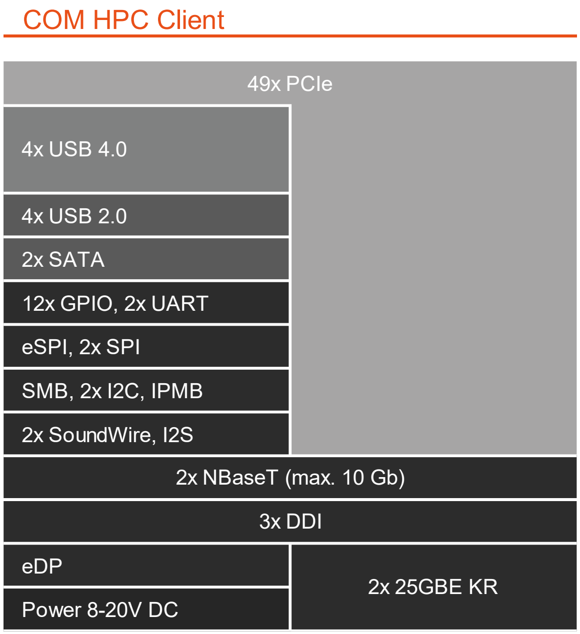


Connector & interfaces

COM-HPC Client uses two connectors with 400 signal pins each to the carrier board, just like Server modules. However, the distance between the connectors differs. This protects the modules, preventing that Client and Server modules, which are electrically incompatible, are accidentally plugged in the wrong carrier board. The total of 800 pins allows COM HPC Client to use more power lanes as well as significantly more I/Os.

With 49 PCIe lanes, COM-HPC Client features three times the bandwidth of COM HPC Mini and 4 display interfaces. Client modules also have two MIPI CSI camera inputs. Unlike Mini, however, the signal lanes of Client modules are executed directly via the connector to the carrier board. COM-HPC Client modules can host up to four SO-DIMM sockets for currently up to 128 GByte of RAM.

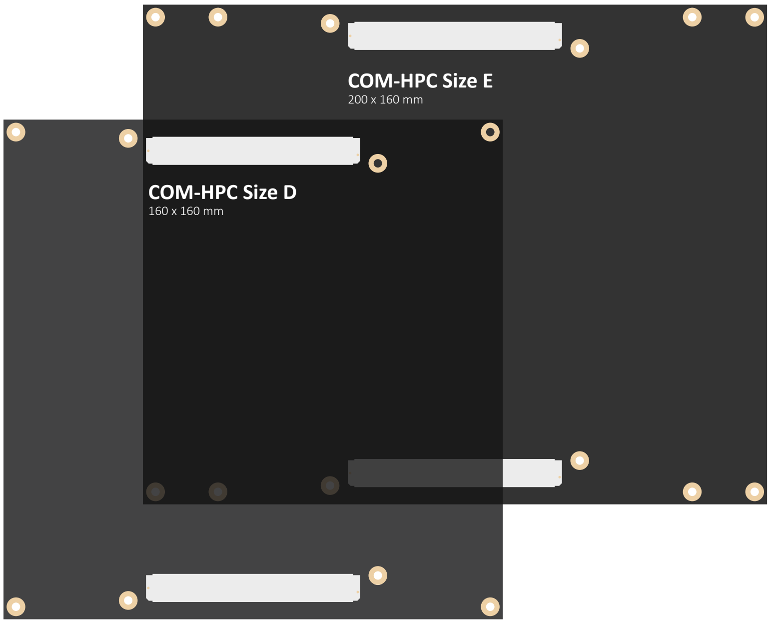
Client modules operate from either a fixed 12 Volt power source, or a wide-range input power supply of 8 to 20 Volt. The maximum power budget of COM-HPC Client modules is as high as 251 Watt at the minimum DC input voltage of 8 Volt.



COM-HPC Server

Brings datacenter-grade performance to the industrial edge

COM-HPC Server is the first standard that has been designed from the ground up for powerful edge servers. COM-HPC Server allows edge server installations to break free from the tight thermal constraints of air-conditioned server rooms. Server modules can be combined with other COM-HPC modules in one multi-module system.



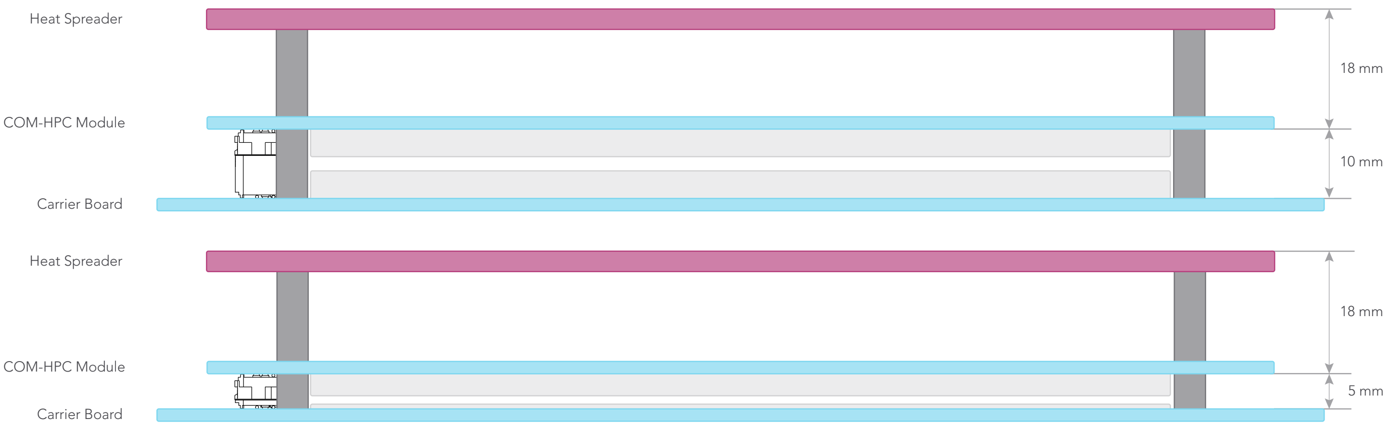
Size & form factor

The COM-HPC Server standard specifies two footprints – Size D (160 mm × 160 mm) and Size E (200 mm × 160 mm). These dimensions provide enough headroom for current and upcoming server processors with massive core count.

Just like COM-HPC Client, Server modules also feature construction heights of either 5 mm or 10 mm from carrier board top to module bottom, depending on the connector.

For both heights, the unifying heat spreader adds another 18 mm. The extra height of 3 mm compared to COM-HPC Client is required to support more powerful and socketed server processors. In total, COM-HPC Server modules feature total design heights of 23 mm or 28 mm including heat spreader.

COM-HPC Server modules can host up to 4 SDRAM sockets on Size D, and up to 8 on Size E for highest memory capacities with fastest data transfer rates.



Connector & interfaces

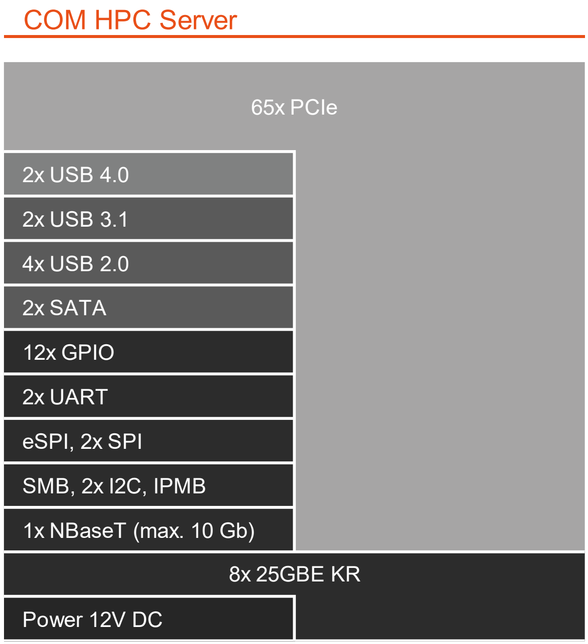
COM-HPC Server uses two connectors with 400 signal pins each to the carrier board, just like the Client modules. However, the distance between the connectors differs. This protects the modules, preventing that Client and Server modules, which are electrically incompatible, are accidentally plugged in the wrong carrier board.

With 800 pins, COM-HPC Server modules offer the highest PCIe lane capacity and networking bandwidth currently available on Computer-on-Modules. COM-HPC Server omits the graphic interfaces of Client in favor of more and higher-performing networking interfaces and PCIe lanes. These are required to accelerate intersystem communication, as well as to handle immense amounts of raw data, connect additional compute accelerators like GPGPUs, ASICs, or FPGAs, and save information on fast NVMe SSD clusters.

The up to 8 × Ethernet interfaces are designed as 25GBASE-KR. This allows designers to choose their preferred PHY and implement it on the carrier board. It also gives them full freedom to define whether the data is transmitted via copper or fiber optic cables. For even more flexibility, the PHY can be implemented as exchangeable SFP+ modules, which makes it possible to delay the decision whether to transfer via copper or fiber optics until installation on site.

To ensure compliance with IEEE 1588, the feature set of the COM-HPC Server 25GBASE-KR interfaces also includes a software-defined pin to specify if the interface acts as input or output. It is controlled by the corresponding Ethernet controller. This enables the implementation of a hardware-based timing protocol in accordance with IEEE 1588 for high-performance real-time applications.

Other than the Client and Mini modules, the Server modules operate from a fixed 12 Volt power source. The maximum power budget of COM-HPC Server modules is as high as 358 Watt.



COM Express

COM Express is the very first vendor-independent COM standard defined by the PICMG. It was officially launched in 2005 as a successor of ETX modules (hosted by an industry group). The widespread introduction of the new PCI Express bus and the elimination of ISA support in processors and chipsets in the early 2000s laid the foundation for COM Express, which in the first versions also supported the PCI bus. Since its introduction, COM Express has undergone many improvements, adapting it to the latest state-of-the-art technologies. One example is the introduction of the Type 7 Server-on-Module pinout for high-bandwidth networking.

COM Express Computer-on-Modules are available in three application classes defined by their respective pinout: Type 10 for extremely small low-power applications, Type 6 for client designs with graphics, and Type 7 for headless server designs. Just like COM-HPC, COM Express also offers extraordinary scalability.

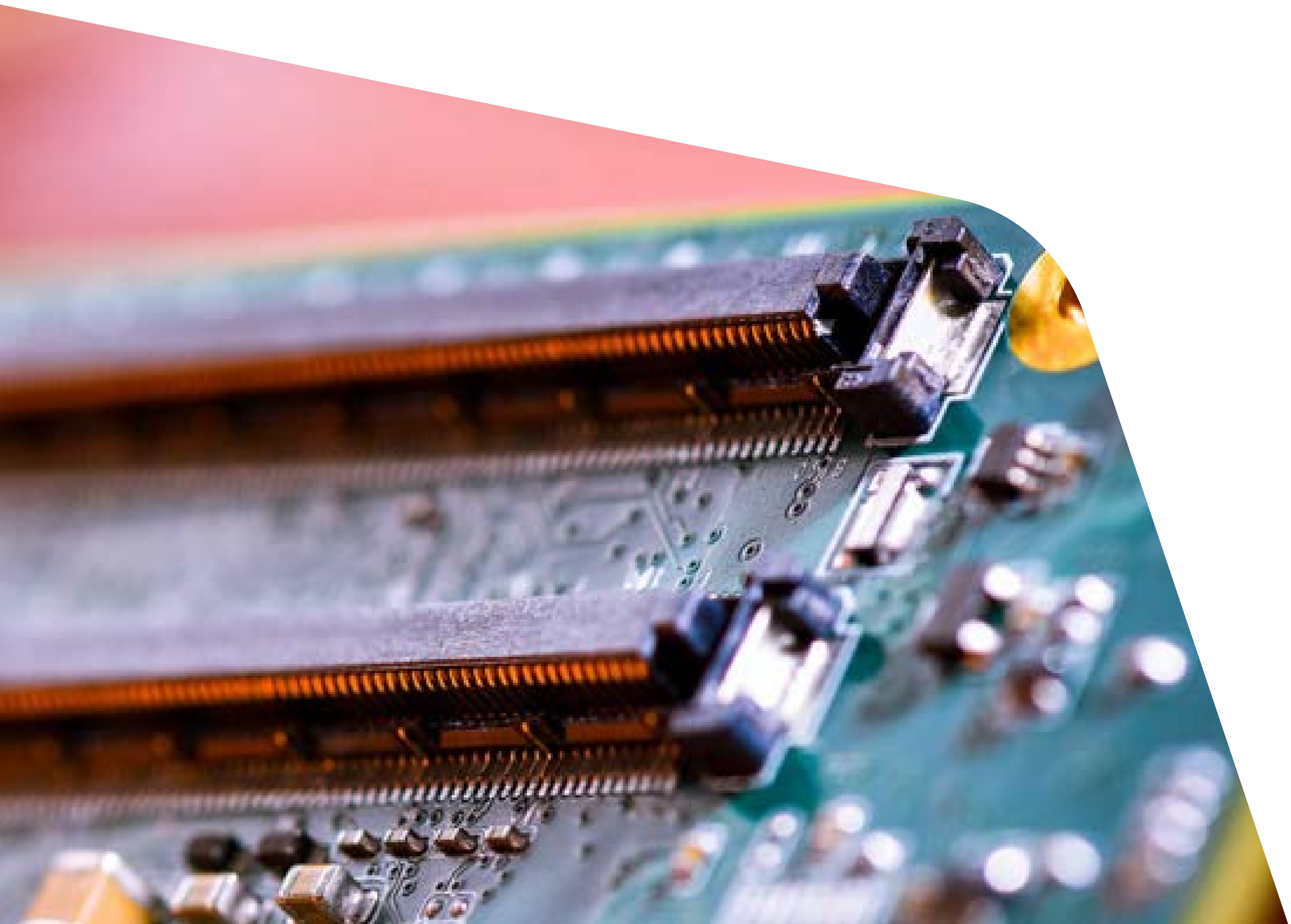
All COM Express modules use the same high-pin connector with 220 pins. COM Express Type 6 and Type 7 modules use two of those connectors, for a total of 440 pins. COM Express Mini with the Type 10 pinout leverages a single connector with 220 pins.

Unlike COM-HPC or SMARC, COM Express modules are optimized for x86 technology alone. COM Express is the best example of the long-term benefits of Computer-on-Modules. Developed back in 2005, it is still up to date today, featuring the latest processor and interface technologies and serving as a great basis for powerful embedded designs.

At the COM Express page www.picmg.org/openstandards/com-express designers can find the following assets:

- COM Express® Module Base Specification Rev 3.1
- Embedded EEPROM specification for COM Express

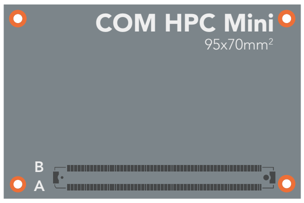
The Carrier Board Design guide can be downloaded for free: www.picmg.org/resources/design-guides



COM Express Type 10 (Mini)

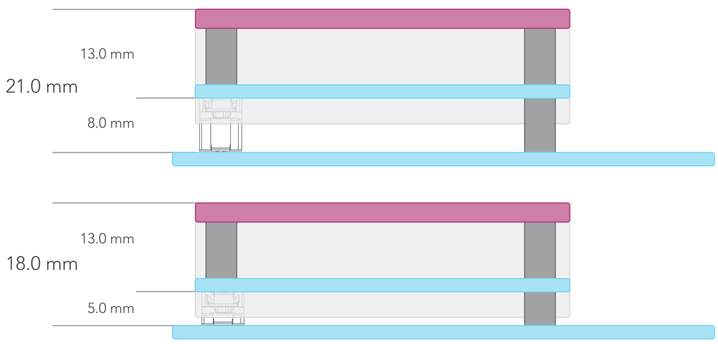
PICMG's smallest Computer-on-Module standard

The COM Express Type 10 pinout is directly connected to the COM Express Mini form factor. It has been specifically developed to enable SFF designs based on power-saving x86 technology. The COM Express Type 10 pinout and Mini form factor were introduced in 2012.



Size & form factor

COM Express Mini is the smallest Computer-on-Module footprint specified by PICMG, measuring only 84 mm × 55 mm. It targets extremely compact and/or mobile applications that require the highest level of integration and powerful graphics combined with longer battery life. Designers can choose between 5 mm and 8 mm stack height options (module bottom surface to carrier board top surface). Together with the standardized cooling solution, COM Express Mini designs feature total construction heights of 18 mm or 23 mm. COM Express Mini modules shall use soldered memory to save space on the PCB.



Connector & interfaces

COM Express Mini is based on the same proven connector as the other footprints. But Type 10 specifies only one connector with an optimized pinout to feature all relevant interfaces for space-constrained applications. MIPI CSI cameras can be connected via up to two dedicated connectors on the module.

Compared to COM Express Type 6 modules, the Mini specification offers the same range of interfaces, only their number is reduced. In keeping with the smaller footprint, COM Express Mini modules also feature a small power budget totaling 68 Watt. This limit provides still far more headroom than most designs require. Unique to Type 10 COM Express Mini modules is the optional wide-range power input from 4.75 to 20 Volt. This enables easy integration in battery-powered devices as well as in-vehicle applications. The normal operating voltage is 12 Volt.

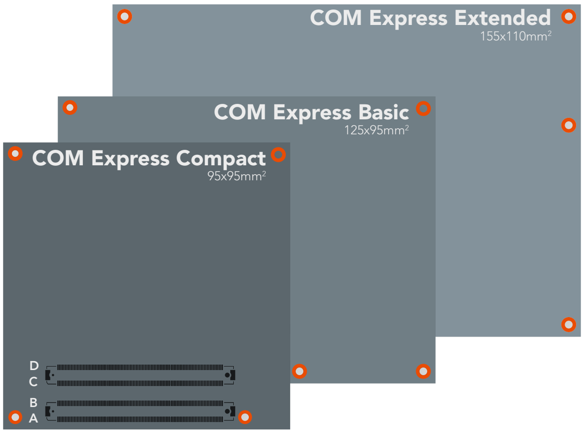
Type 10

- Gigabit Ethernet
- LPC
- 4x PCIe
- HDA
- LVDS 1x24 / eDP
- DDI
- 2x SATA
- 8x USB 2.0 / 2x USB 3.0
- 8x GPIO / SDIO
- 2x SER / CAN
- SPI & I2C
- Power

COM Express Type 6

The most successful multi-purpose standard

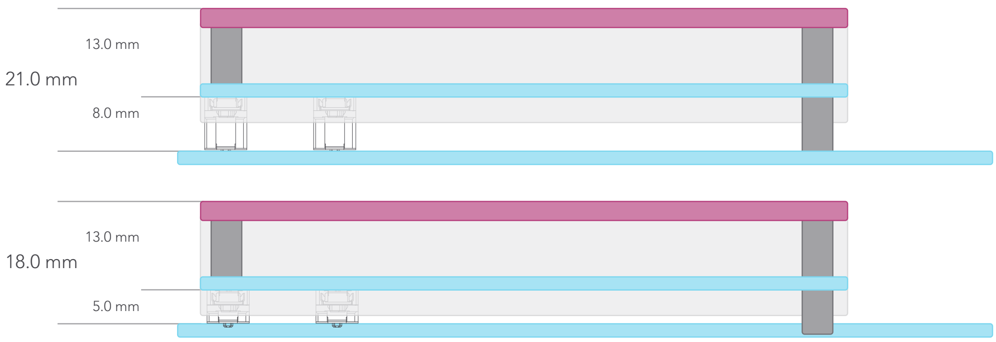
COM Express Type 6 modules cover a broad range of multi-purpose embedded applications. With their extensive interface range, they provide everything needed to build powerful PLCs, HMIs, shop floor systems, or SCADA workstations. Further application areas are high-end digital signage systems, complex kiosk systems, as well as autonomous mobile robots.



Size & form factor

For COM Express Type 6 modules PICMG specifies three sizes: Extended with 155 mm × 110 mm, Basic measuring 125 mm × 95 mm, and Compact with 95 mm × 95 mm. The most common form factors are Compact and Basic, whereas Extended modules typically feature the most powerful and usually socketed processors. Just like COM Express Mini, the Compact, Basic and Extended modules also feature stack heights of 5 mm or 10 mm from carrier board top to module bottom. For both heights, the unifying heat spreader adds another 13 mm.

COM Express Basic and Compact modules typically offer one or two stacked SO DIMM sockets for memory. Rugged versions can also feature soldered memory or a combination for even higher capacities. The larger Extended modules can also carry full-size DIM modules with higher bandwidth.



Connector & interfaces

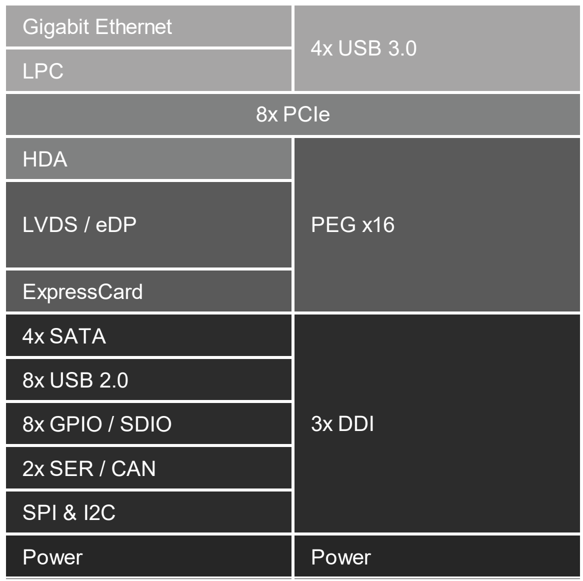
COM Express Type 6 uses two connectors with 220 signal pins each to the carrier board, just like Type 7 modules. Although Type 6 and Type 7 modules are electrically incompatible, the modules are protected against damage if a module is plugged onto the wrong carrier.

The total of 440 pins allows COM Express Type 6 modules to use more power lanes as well as significantly more I/Os than Mini modules.

With 24 PCIe lanes, Type 6 modules feature six times the bandwidth of COM Express Mini and offer 4 display interfaces instead of one. Just like with Mini, two MIPI CSI cameras can be connected via dedicated connectors on the module. COM Express Compact and Basic modules typically host up to two SO-DIMM sockets or soldered memory for rugged designs.

COM Express Compact and Basic modules operate from a 12 Volt power source. The maximum power budget of these footprints is as high as 137 Watt.

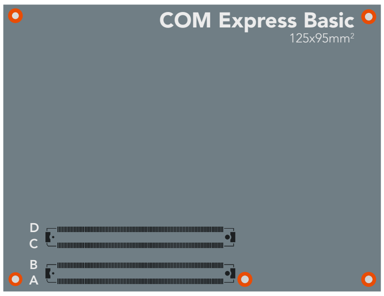
COM Express Type 6



COM Express Type 7

The entry point for rugged edge servers

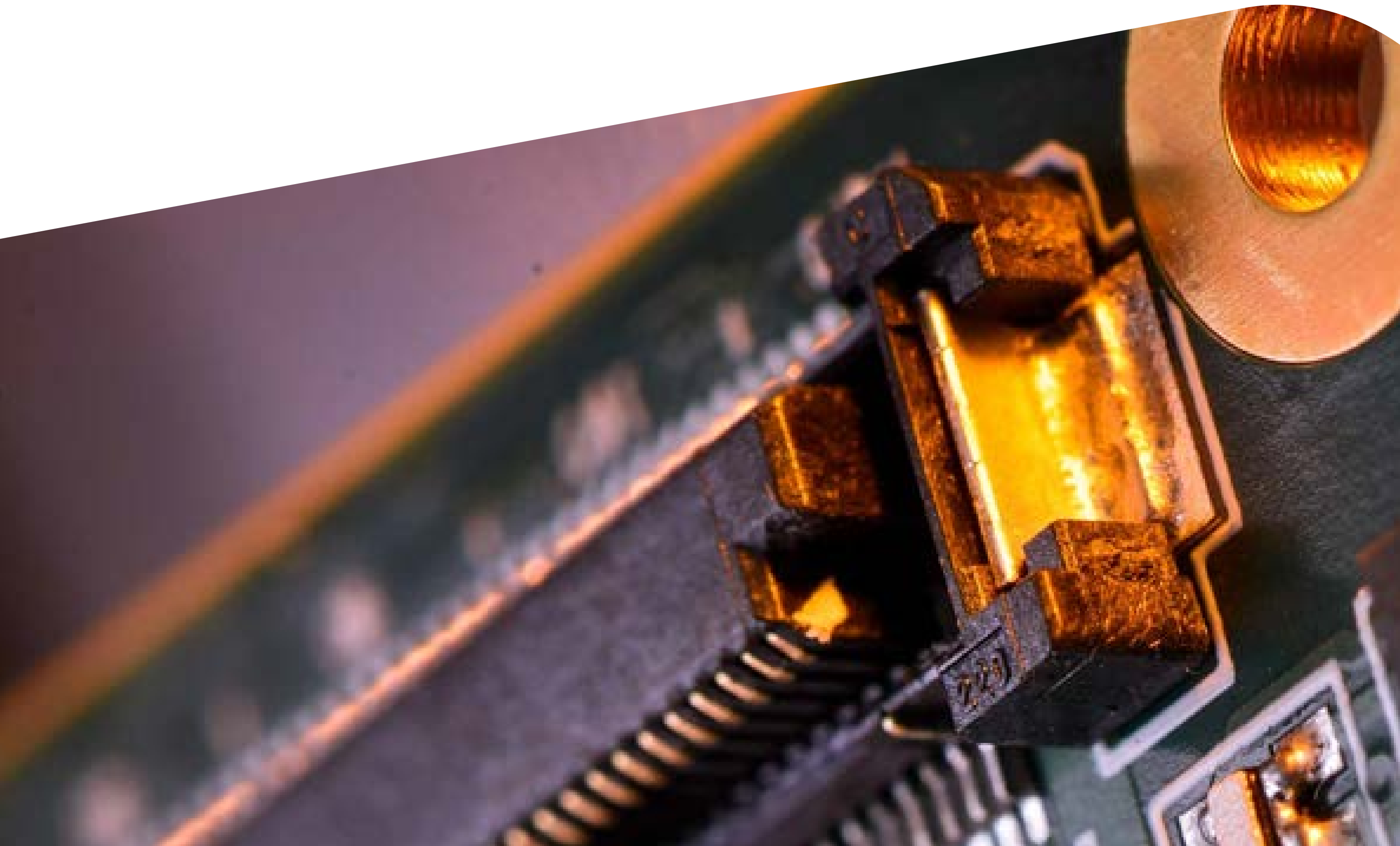
The COM Express Type 7 Server-on-Modules were added to the COM.0 specification in 2017. These modules extend the use cases for COM Express to modular edge server designs, which are being deployed at the rugged edge of the IoT and Industry 4.0.



Size & form factor

COM Express Type 7 modules are typically available in the Basic footprint (125 mm × 95 mm). These dimensions provide enough space even for the typically larger embedded server processors that require a greater surface for effective heat dissipation.

COM Express Type 7 Server-on-Modules also feature stack heights of 5 mm or 10 mm from carrier board top to module bottom, but overall heights with heat spreader measure 18 mm or 23 mm. COM Express Type 7 Server-on-Modules typically offer two stacked SO-DIMM sockets for memory. Here too, the extended form factor is rarely used as the increased space is not required by today's CPUs, which must stay within the defined power range of COM Express.

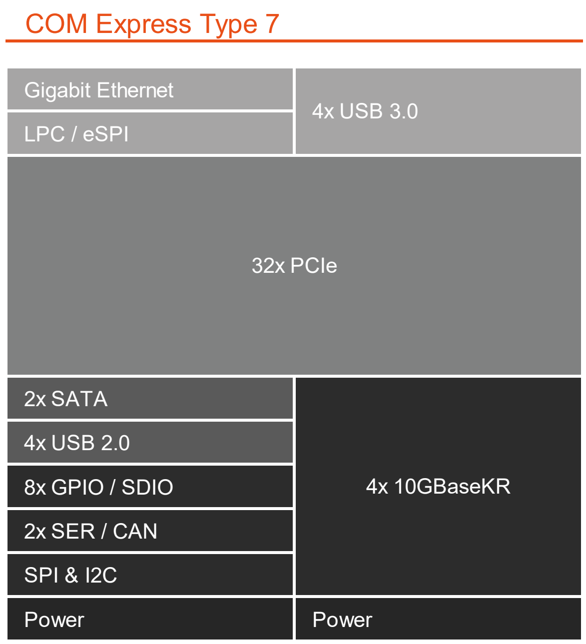


Connector & interfaces

COM Express Type 7 uses the same connectors as Type 6 modules. However, the supported interfaces have been optimized to the high bandwidth demands of today's edge server designs. Compared to Type 6, the Type 7 Server-on-Modules omit all graphics, sound, and camera interfaces in favor of more and higher bandwidth interfaces. A major change is the addition of 8 more PCIe lanes, summing up to 32 lanes in total, to connect more storage and compute accelerators like GPGPUs. Moreover, Type 7 supports up to 4 × 10 Gb Ethernet with side band signals. Also, to address the demands of embedded server technology, COM Express Type 7 reserves pins for an intelligent platform management bus (IPMB) interface.

Just like COM-HPC Server, the 10 GbE interfaces on COM Express Type 7 are designed as 10GBASE-KR single backplane lanes (see also IEEE 802.3 / 49). The PHY is to be implemented on the carrier board, which gives designers the freedom to define whether the data is transmitted via copper or fiber optic cables. For even more flexibility, the PHY can be implemented as exchangeable SFP+ modules, which makes it possible to delay the decision whether to transfer via copper or fiber optics until installation on site.

To ensure compliance with IEEE 1588, the feature set of the COM Express 10GBASE-KR interfaces also includes a software-defined pin for each of the four interfaces. This physical pin can be configured as input or output and is controlled by the corresponding Ethernet controller. This enables the implementation of a hardware-based timing protocol in accordance with IEEE 1588 for high-performance real-time applications.



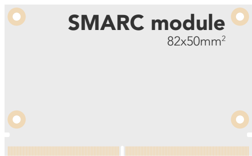
Just like Type 6 modules, Type 7 Server-on-Modules also operate from a 12 Volt power source. The maximum power budget of these footprints is as high as 137 Watt.

SMARC module

For size, weight, power and cost-optimized AI applications at the rugged edge

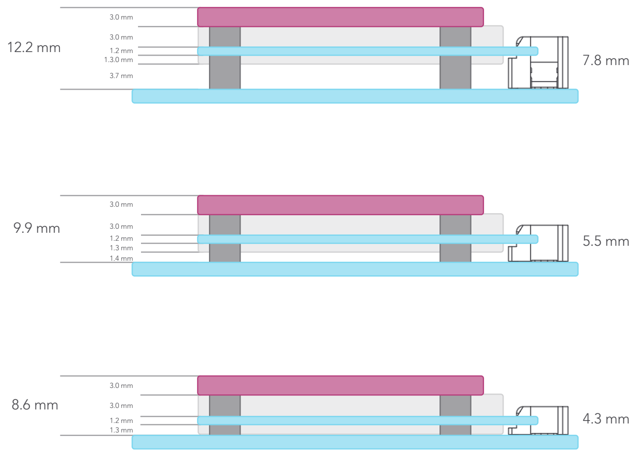
SMARC (Smart Mobility ARChitecture) Module is an open standard specifically designed for low-power credit-card-sized Computer-on-Modules. It was introduced in 2012 by the SGET. SMARC module is designed to enable digital transformation even at the outer edge for size, weight, power and cost (SWaP-C) sensitive applications.

The SMARC module specification is available for free download at SGET:
sget.org/standards/smarc



Size & form factor

SMARC defines two module sizes measuring 82 mm × 50 mm and 82 mm × 80 mm. The larger size is defined but is practically not in use today. Compared to COM Express Type 10 and COM-HPC Mini, SMARC modules offer a very low-profile solution. The defined z-height from carrier top to module bottom is as low as 1.5 mm. Together with the specified heat spreader, SMARC designs feature an overall height of only 11.7 mm. This is by far the lowest construction height of all open COM standards.



Connector & interfaces

SMARC module builds upon the common MXM 3 connector, which is backed by broad industry support due to its use with notebook graphics cards. Thanks to this card-edge connector, SMARC enables exceptionally slim and rugged designs.

Despite its space-saving design, the MXM 3 connector features 314 signal pins. This provides ample room for a broad range of interfaces tailored to state-of-the-art industrial, medical, in-vehicle, and robotics applications that integrate powerful imaging features for situational awareness. Consequently, SMARC features a rich set of graphics-oriented interfaces including 3 display outputs, up to 4 MIPI CSI inputs for cameras, as well as 4 PCIe lanes, 6 USB ports, and 2 CAN bus interfaces to connect to further peripherals. 2 Gigabit Ethernet ports with TSN support allow for vertical and horizontal integration in industrial networks.

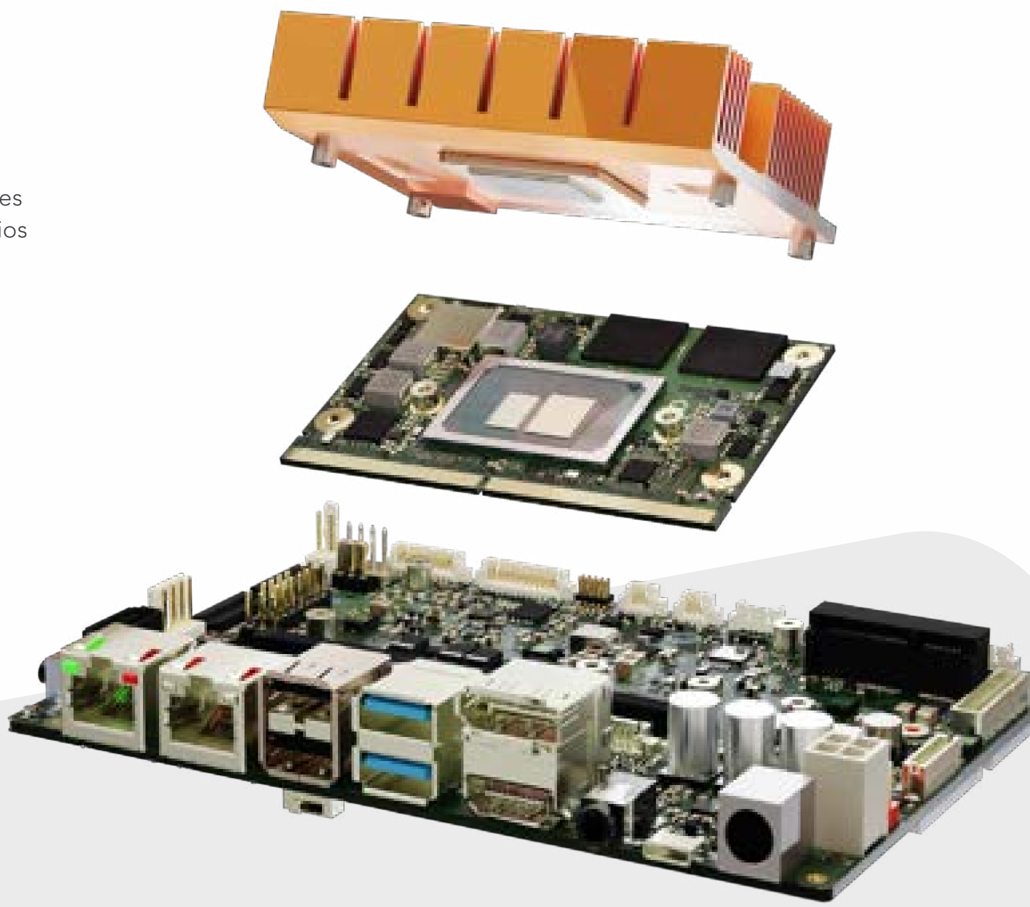
SMARC 2.0
2x Gigabit Ethernet
eSPI
4x PCIe
HDA / 2x I2S
LVDS 2x24 / eDP / MIPI DSI
2x MIPI CSI
HDMI & DP++
1x SATA
6x USB 2.0 / 2x USB 3.0
12x GPIO / SDIO
4x SER / CAN
SPI / I2C
Power

Processors & special features

SMARC module is designed to host both leading processor architectures x86 and ARM. Besides the modules themselves, SMARC module also defines a unifying heat spreader to further standardize and simplify module integration as well as interchangeability.

With its focus on low-power designs, SMARC module defines an input voltage between 3.0 and 5.25 Volt, and a maximum power consumption of 25 Watt (maximum peak power). However, ARM designs are typically in the range of only 6 Watt, and x86 designs between 5 and 12 Watt. Consequently, SMARC module features one of the best interface-per-watt ratios among all current COM standards.

A unique feature of SMARC module is the optional on-module wireless functionality with a designated area for antenna connections. This simplifies the implementation of wireless connectivity in mobile and other applications as no additional controllers are needed on the carrier.



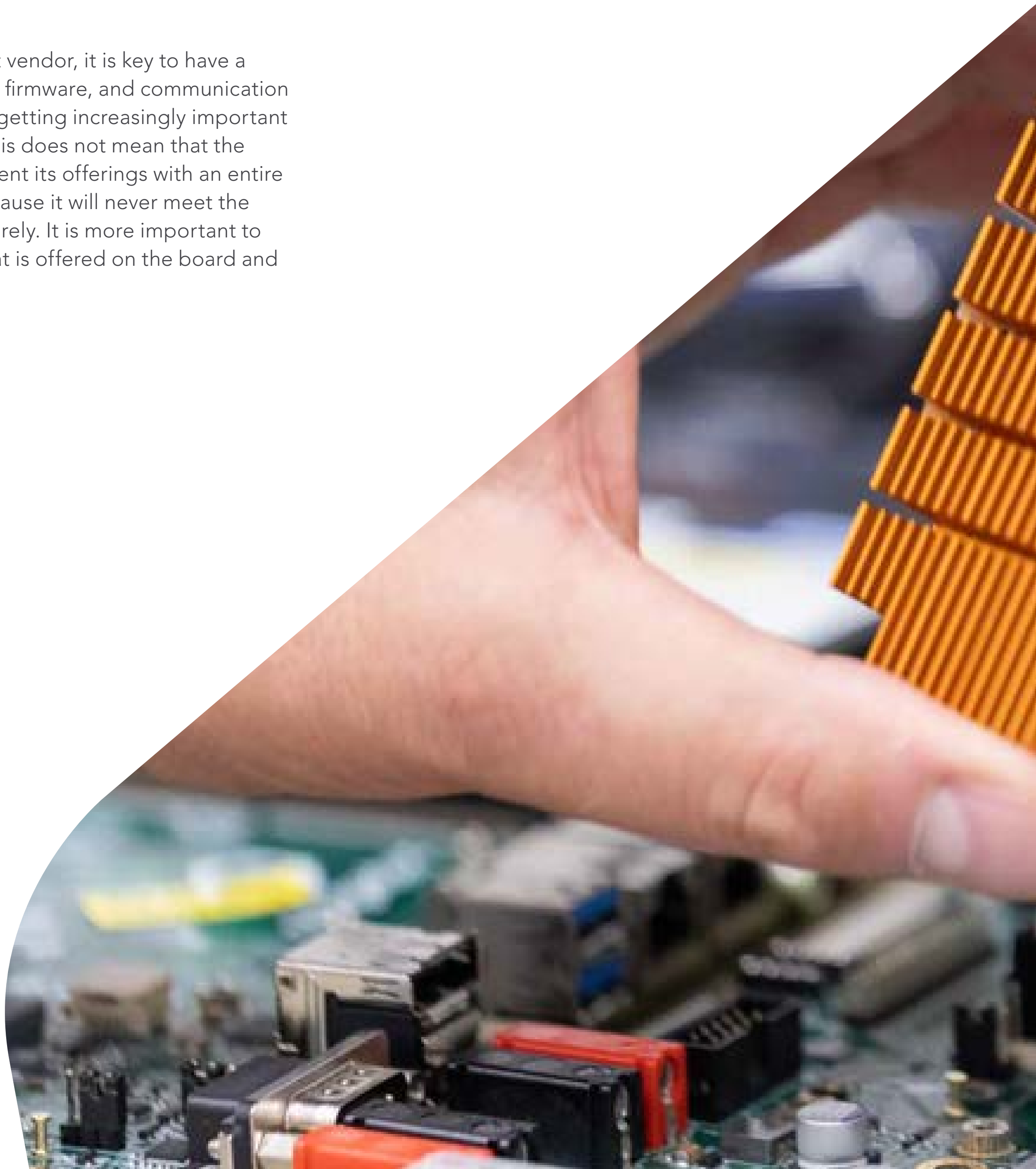
Conclusion

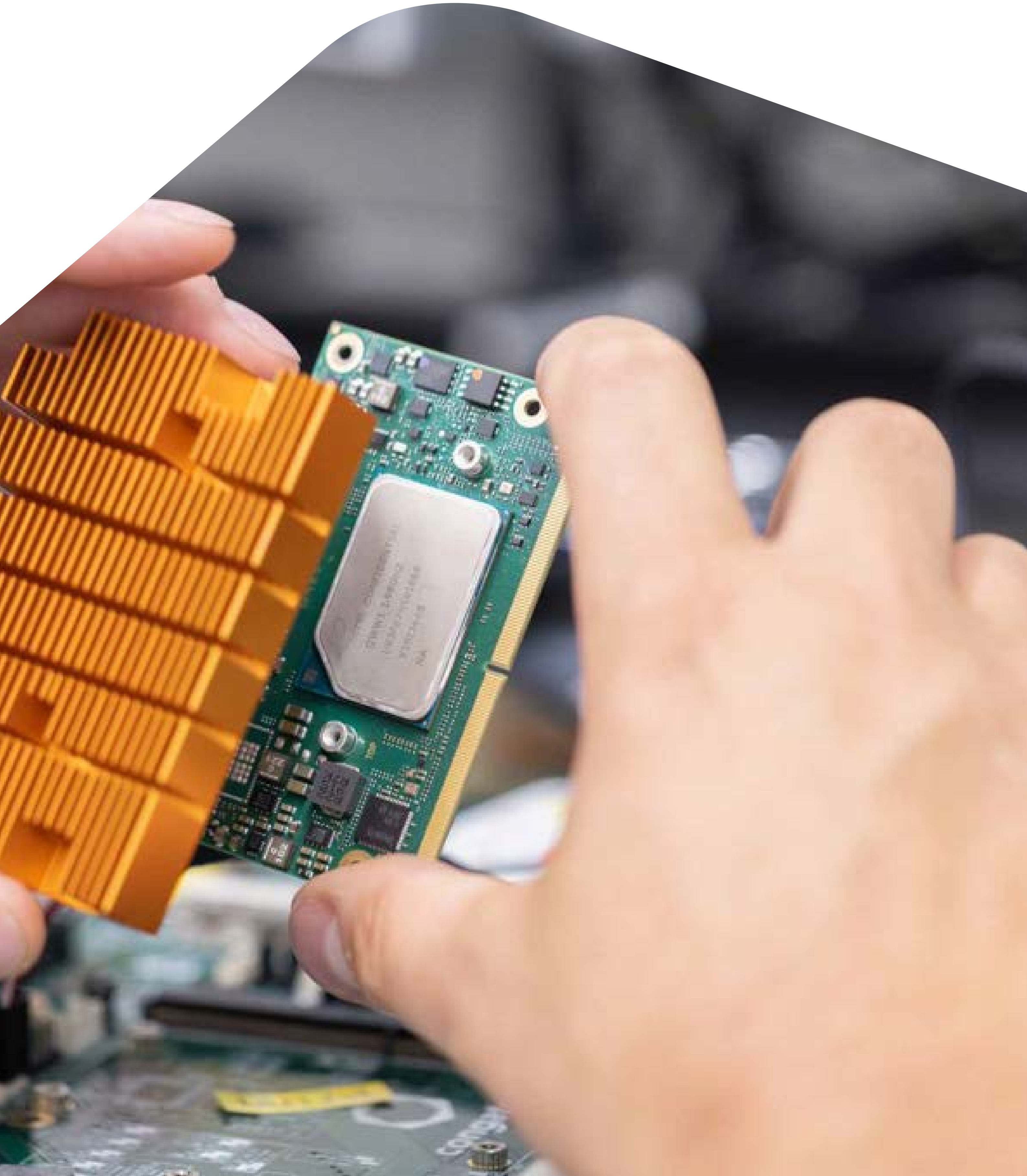
Computer-on-Modules offer substantial benefits over full-custom designs, including reduced development costs, a scalable product range, and faster time-to-market as developers can focus on the system features. This enables OEMs to react to market trends faster. Moreover, by utilizing Computer-on-Modules they can leverage a second source philosophy and minimize inventory costs.

Identifying the best form factor is a major step within the design evaluation process. Module vendors that offer all the relevant form factors can help by providing expert consultancy as well as best options to migrate from one form factor to another.

When choosing the right vendor, it is key to have a look at the offered BSPs, firmware, and communication middleware, as they are getting increasingly 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.

Check that integration support is offered for Arm and x86, because it is better to employ one engineer who supports both architectures for a unified product family instead of two engineers for two separate product lines. This also requires unified APIs. Finally, check the provided documentation. It is better to have extensive content instead of only a bare minimum. And think also about relying on local manufacturing capacities wherever you or your customers reside.





aReady.

High-performance building blocks from COM to cloud simplify development

congatec's aReady. strategy is specifically designed to simplify the implementation and utilization of modern base technologies. With aReady. high-performance embedded building blocks, designers can focus on their core competencies and become an innovation driver in their industry. congatec's constantly growing aReady. portfolio includes aReady.COM, aReady.IOT and aReady.VT, covering the most relevant use cases.

aReady.COM

Application-ready Computer-on-Modules from congatec

aReady.COM reduces complexity of COM-based designs by seamlessly integrating hardware and software building blocks for unparalleled performance and flexibility.

Benefits

- Optimize time-to-market and design efforts by combining existing hardware and software building blocks.
- Optimized cost and efficiency by reducing efforts for installation, compatibility testing and licensing.
- Increased security by pre-evaluated hardware and software building blocks.
- Reduced system size, weight, power, and cost by system consolidation.
- Increased flexibility and scalability by simple extension with further building blocks.

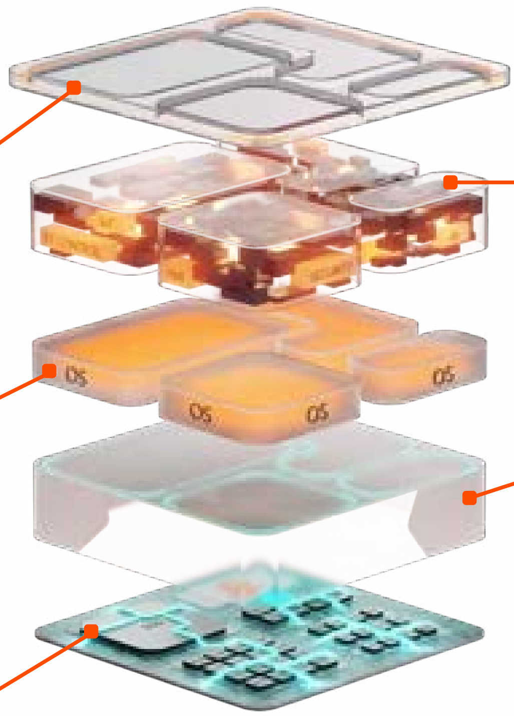
Customer Application
Applications built on aReady.COMs are more agile and responsive.

Software Layer
Pre-evaluated functional software building blocks minimize design efforts and compatibility concerns

Operating Systems Layer
Every aReady.COM comes with pre-installed and licensed operating systems fitted to your needs.

Virtualization Layer
Hypervisor-on-Module enables the consolidation of multiple applications to make full use of all resources.

Hardware-Layer
aReady.COMs facilitate flexible integration, enable easy upgrades to extend product lifecycles, and improve return on investment.



aReady.VT

Virtualization technology from congatec – consolidate what belongs together

aReady.VT enables the full utilization of today's multi-core performance. It allows for the consolidation of functionality that previously required multiple dedicated systems onto a single hardware platform.

Benefits

- Improved time-to-market and agility.
- Reduced system size, weight, power and cost.
- Full flexibility in system functionality.
- Support from low-power modules to high-performance server designs.

Hypervisor-on-Modules

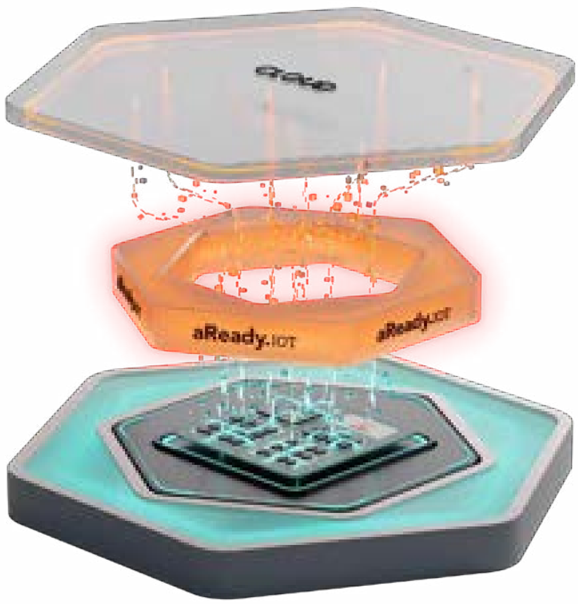
At congatec, the hypervisor is now standard in all new x86-based Computer-on- Modules. With the free trial license, designers can immediately start evaluating the advantages of virtualization. Find more information here.

Hypervisor

Additionally, the industry leading Hypervisor from Real-Time Systems is also available as a stand-alone software.

aReady.IOT

IoT technology from congatec – for secure OT/IT connection from COM to cloud



aReady.IOT Building Blocks are designed for secure IoT connectivity from COM to cloud. Developers use them for secure connection between Operational Technology (OT) and Information Technology (IT).

Benefits

- High security by physical network separation VPN gateway function adds another security layer.
- Enhanced communication via wireless and wired connectivity options.
- Pre-configured for fast and easy roll-out.
- High scalability enables digitization even across multiple locations.
- High integration level ideal for system integrators.

Small form factor module standards in comparison

	COM-HPC Mini	COM Express 3.1 Type 10 (Mini)
Dimensions	95 mm × 70 mm	84 mm × 55 mm
Connector height (module bottom to carrier board top)	5 mm or 10 mm	5 mm or 10 mm
Stack height (carrier board top to heat-spreader top)	15 mm or 20 mm	18 mm or 23 mm
Max. power dissipation	91 W	68 W
Input voltage range	8–20 V	12 V, optional wide-range input power of 4.75 to 20 V
Signal pins	400	220
PCIe[1]	16 × PCIe Gen 6	4 × PCIe Gen 4
Graphics[1]	3 × DDi + 1 × eDP	1 × DDI +1 LVDS/eDP
Sound[1]	HDA + SoundWire + I2S	1 × HDA/SoundWire
Camera in[1]	2 × MIPI CSI via dedicated connectors on the module	2 × MIPI CSI via dedicated connectors on the module
Ethernet[1]	2 × 10 GbitE with TSN + 2 × 10 GbitE (SERDES) with TSN	1 × 1 GbE with TSN
Wireless	Not supported	Not supported
USB[1]	4 × USB 4.0, 4 × USB 3.2 ×1 / USB 3.2 ×1 + 8 × USB 2.0	2 × USB 3.2 + 8 × USB 2.0
SATA[1]	2 × SATA Gen 3	2 × SATA Gen 3
CAN bus[1]	1 ×	2 ×
UART[1]	2 ×	-
GPIO	12 ×	8 ×
Other	eSPI, 2 × SPI, SMB, 2 × I2C	LPC/eSPI

[1] Not all I/Os are available in parallel; some pins are shared.

SMARC 2.1 Module	Qseven
82 mm × 50 mm	70 mm × 70 mm / 40 mm × 70 mm (µQseven)
1.5 mm	5 mm
11.7 mm	
25 W	12 W
3.0V to 5.25V	4.75V to 5.25V
314	230
4 × PCIe Gen 3	4 × PCIe Gen 3
DP++/HDMI + 1 × DP++ + 2 × LVDS/eDP/MIPI DSI	eDP/HDMI + 2 × LVDS
HDA + I2S	1 × HDA/I2S
2 × MIPI CSI + 2 × MIPI CSI via dedicated connectors on the module	–
4 × 1 GbE with TSN	1 × 1 GbE with TSN
Antenna connector for WiFi & Bluetooth	Not supported
2 × USB 3.0 + 6 × USB 2.0	2 × USB 3.0 + 8 × USB 2.0
1 × SATA Gen 3	2 × SATA Gen 3
2 ×	1 ×
4 ×	1 ×
14 ×	8 ×
eSPI, SPI, I2C	SPI, LPC, I2C, SDI

Performance class modules in comparison

	COM-HPC Mini	COM-HPC Client
Dimensions	95 mm × 70 mm	120 mm × 95 mm (Size A) 120 mm × 120 mm (Size B) 120 mm × 160 mm (Size C)
Connector height (module bottom to carrier board top)	5 mm or 10 mm	5 mm or 10 mm
Stack height (carrier board top to heat-spreader top)	15 mm or 20 mm	20 mm or 25 mm
Max. power dissipation	91 W	251 W
Input voltage range	8–20 V	8–20 V
Signal pins	400	800
PCIe lanes[1]	16 × PCIe Gen 6	49 × PCIe Gen 6
Graphics[1]	3 × DDi + 1 × eDP	3 × DDI + 1 × eDP
Sound[1]	SoundWire / HDA / I2S	2 × SoundWire / I2S / HDA
Camera in[1]	2 × MIPI CSI via dedicated connectors on the module	2 × MIPI CSI
Ethernet[1]	2 × 10 GbitE with TSN + 2 × 10 GbitE (SERDES) with TSN	2 × 25 GbE KR + 2 × BaseT (up to 10 Gb) with TSN
USB[1]	4 × USB 4.0, 4 × USB 3.2 ×1 / USB 3.2 ×1 + 8 × USB 2.0	4 × USB 4.0 + 8 × USB 2.0
SATA[1]	2 × SATA Gen 3	2 × SATA Gen 3
CAN bus[1]	1 ×	–
UART[1]	2 ×	2 ×
GPIO[1]	12 ×	12 ×
Other[1]	eSPI, 2 × SPI, SMB, 2 × I2C	SMB, 2 × I2C, IPMB

[1] Not all I/Os are available in parallel; some pins are shared.

COM Express Type 6 (Spec 3.1)
125 mm × 95 mm (Basic) 95 mm × 95 mm (Compact)
5 mm or 10 mm
18 mm or 23 mm
137 W
12 V
440
24 × PCIe Gen 4
3 × DDI + 1 × LVDS/eDP / VGA
HDA (1 × SoundWire optional)
2 × MIPI CSI via dedicated connectors on the module
1 × GbE with TSN
4 × USB 3.2 or 2 × USB 4.0 multiplexed with 2 × DDI + 8 × USB 2.0
4 × SATA Gen 3
2
–
8 ×
LPC/eSPI

Server-class module standards in comparison

	COM-HPC Server	COM Express Type 7 (Spec 3.1)
Dimensions	160 mm × 160 mm (Size D) 200 mm × 160 mm (Size E)	125 mm × 95 mm (Basic)
Connector height (module bottom to carrier board top)	5 mm or 10 mm	5 mm or 10 mm
Stack height (carrier board top to heat-spreader top)	20 mm or 25 mm	18 mm or 23 mm
Max. power dissipation	358 W	137 W
Input voltage range	12 V	12 V
Signal pins	800	440
PCIe lanes[1]	65 × PCIe Gen 6	32 × PCIe Gen 4
Graphics[1]	Headless	Headless
Sound[1]	–	–
Camera in[1]	–	–
Ethernet[1]	8 × 25 GbE KR + 1 × 1 GbE with NCSI	4 × 10 GbE KR + 1 × GbE
USB[1]	2 × USB 4.0 + 2 × USB 3.1 + 8 × USB 2.0	4 × USB 3.0 + 4 × USB 2.0
SATA[1]	2 × SATA Gen 3	2 × SATA Gen 3
CAN bus[1]	–	2 × (multiplexed with UART)
UART[1]	2	2
GPIO[1]	12	8
Other[1]	eSPI, 2 × SPI, SMB, 2 × I2C	LPC/eSPI, I2C, SPI
Platform Management Interface	IPMB	NCSI + IPMB

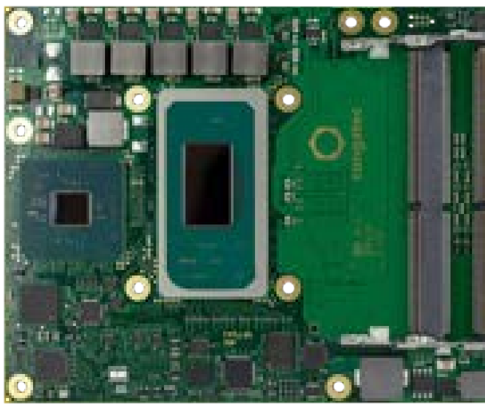
[1] Not all I/Os are available in parallel; some pins are shared.

COM Express module types in comparison

	COM Express 3.1 Type 10 (Mini)	COM Express Type 6 (Spec 3.1)
Dimensions	84 mm × 55 mm	125 mm × 95 mm (Basic) 95 mm × 95 mm (Compact)
Connector height (module bottom to carrier board top)	5 mm or 10 mm	5 mm or 10 mm
Stack height (carrier board top to heat-spreader top)	18 mm or 23 mm	18 mm or 23 mm
Max. power dissipation	68 W	137 W
Input voltage range	12 V, optional wide-range input power of 4.75 to 20 V	12 V
Signal pins	220	440
PCIe lanes[1]	4 × PCIe Gen 4	24 × PCIe Gen 4
Graphics[1]	1 × DDI + 1 LVDS/eDP	3 × DDI + 1 × LVDS/eDP / VGA
Sound[1]	1 × HDA/SoundWire	HDA (1 × SoundWire optional)
Camera in[1]	2 × MIPI CSI via dedicated connectors on the module	2 × MIPI CSI via dedicated connectors on the module
Ethernet[1]	1 × 1 GbE with TSN	1 × GbE with TSN
USB[1]	2 × USB 3.2 + 8 × USB 2.0	4 × USB 3.2 or 2 × USB 4.0 multiplexed with 2 × DDI + 8 × USB 2.0
SATA[1]	2 × SATA Gen 3	4 × SATA Gen 3
CAN bus[1]	2 ×	2 ×
UART[1]	2 ×	–
GPIO[1]	8 ×	8 ×
Other[1]	LPC/eSPI	LPC/eSPI

[1] Not all I/Os are available in parallel; some pins are shared.

COM Express Type 7 (Spec 3.1)
125 mm × 95 mm (Basic)
5 mm or 10 mm
18 mm or 23 mm
137 W
12 V
440
32 × PCIe Gen 4
Headless
–
–
4 × 10 GbE KR with NCSI + 1 × GbE
4 × USB 3.0 + 4 × USB 2.0
2 × SATA Gen 3
2 × (multiplexed with UART)
2
8
LPC/eSPI, I2C, SPI

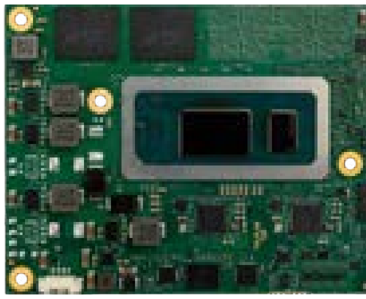


COM-HPC module types in comparison

	COM-HPC Mini	COM-HPC Client
Dimensions	95 mm × 70 mm	120 mm × 95 mm (Size A) 120 mm × 120 mm (Size B) 120 mm × 160 mm (Size C)
Connector height (module bottom to carrier board top)	5 mm or 10 mm	5 mm or 10 mm
Stack height (carrier board top to heat-spreader top)	15 mm or 20 mm	20 mm or 25 mm
Max. power dissipation	91 W	251 W
Input voltage range	8–20 V	12 V
Signal pins	400	800
PCIe lanes[1]	16 × PCIe Gen 6	49 × PCIe Gen 6
Graphics[1]	3 × DDi + 1 × eDP	3 × DDI + 1 × eDP
Sound1	SoundWire / HDA / I2S	2 × SoundWire / I2S / HDA
Camera in[1]	2 × MIPI CSI via dedicated connectors on the module	2 × MIPI CSI
Ethernet1	2 × 10 GbitE with TSN + 2 × 10 GbitE (SERDES) with TSN	2 × 25 GbE KR + 2 × BaseT (up to 10 Gb) with TSN
USB[1]	4 × USB 4.0, 4 × USB 3.2 ×1 / USB 3.2 ×1 + 8 × USB 2.0	4 × USB 4.0 + 8 × USB 2.0
SATA[1]	2 × SATA Gen 3	2 × SATA Gen 3
CAN bus[1]	1 ×	-
UART1	2 ×	2 ×
GPIO[1]	12 ×	12 ×
Other[1]	eSPI, 2 × SPI, SMB, 2 × I2C	SMB, 2 × I2C, IPMB

[1] Not all I/Os are available in parallel; some pins are shared.

COM-HPC Server
160 mm × 160 mm (Size D) 200 mm × 160 mm (Size E)
5 mm or 10 mm
20 mm or 25 mm
358 W
12 V
800
65 × PCIe Gen 6
Headless
–
–
8 × 25 GbE KR + 1 × 1 GbE with NCSI
2 × USB 4.0 + 2 × USB 3.1 + 8 × USB 2.0
2 × SATA Gen 3
-
2 ×
12 ×
eSPI, 2 × SPI, SMB, 2 × I2C, IPMB



COM-HPC ecosystem

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SMARC Module ecosystem

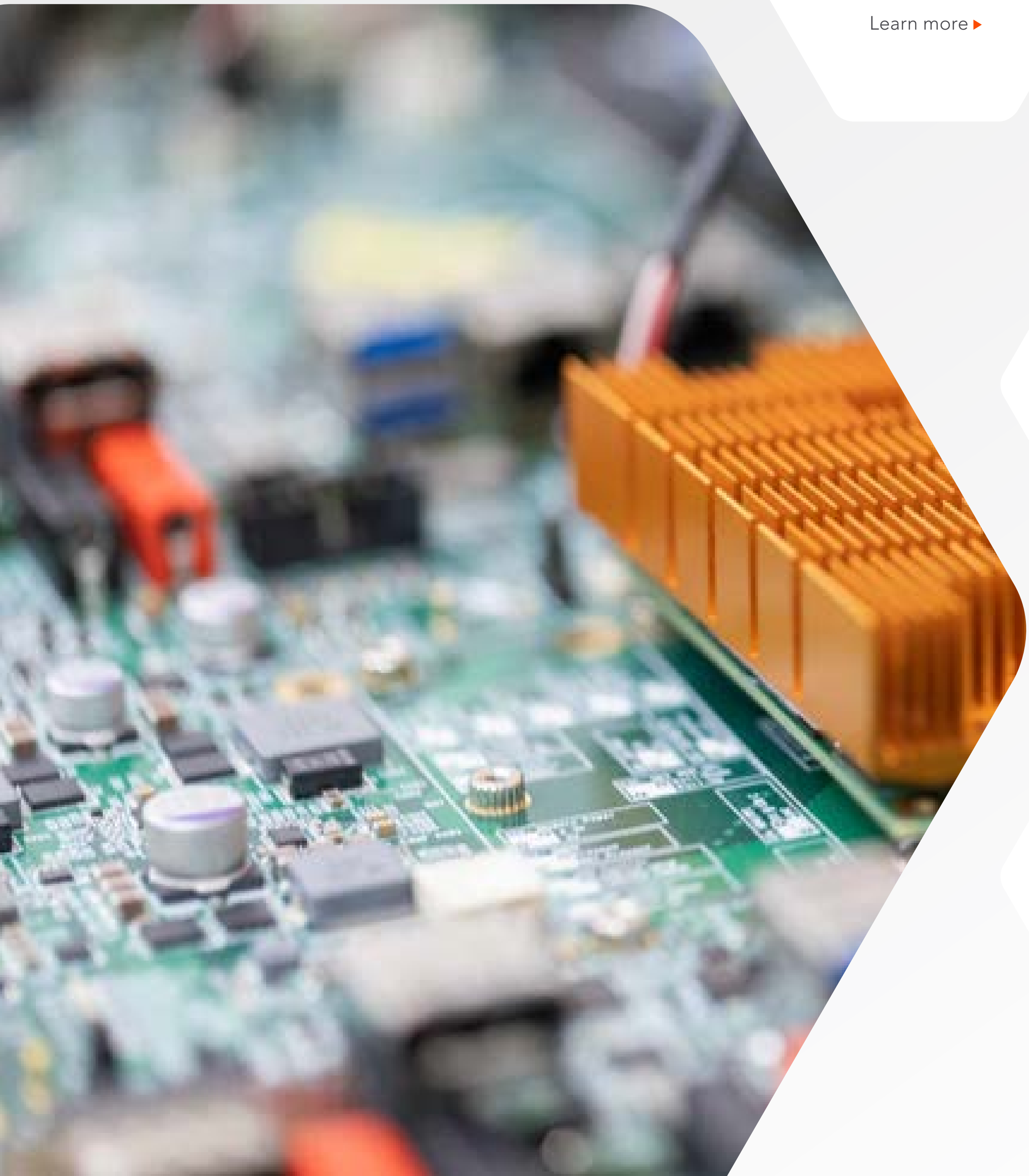
Learn more ▸

COM Express ecosystem

Learn more ▸

Qseven ecosystem

Learn more ▸



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About congatec

congatec is a leading global provider of high-performance hardware and software building blocks for embedded and edge computing solutions based on Computer-on-Modules (COMs). These advanced computer modules drive systems and devices across industries such as industrial automation, medical technology, robotics, telecommunications, and more. congatec's high-performance aReady. ecosystems simplify and accelerate the solution development, from COM to cloud. This application-ready approach combines COMs with services and customizable technologies that enable cutting-edge advancements in system consolidation, IoT, security, and artificial intelligence. Supported by its majority shareholder, DBAG Fund VIII – a German mid-market fund focused on driving growth for industrial enterprises – congatec has the financial backing and M&A expertise to capitalize on expanding market opportunities.

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