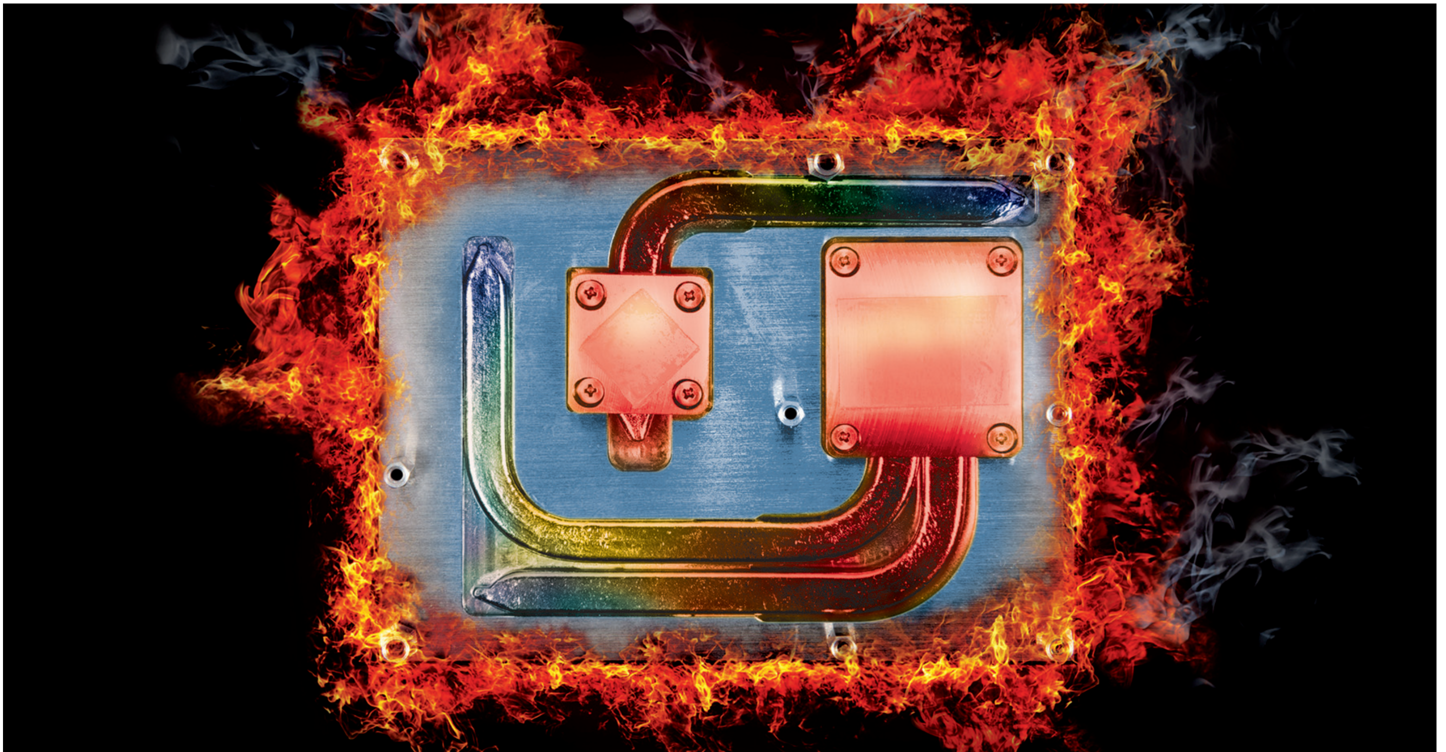
congatec
the rhythm of embedded computing

Whitepaper

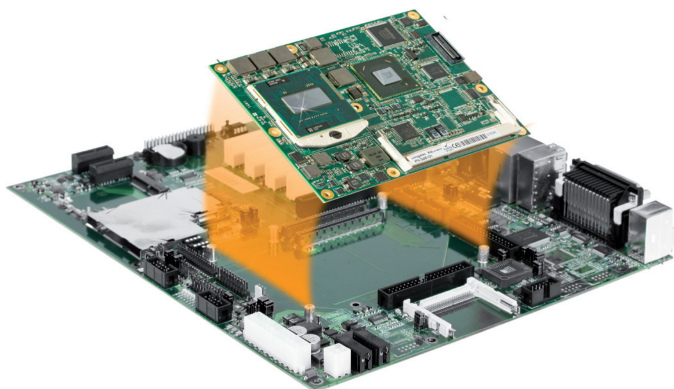
Full speed ahead while keeping a cool head: A smart cooling solution for unbridled processor performance



Electronics are getting smaller and more and more powerful. But as component functionalities and packing densities on the chip and board increase, more heat is produced per unit area. congatec's new, patent-pending cooling concept for COM Express modules paves the way for future performance growth.

A hot performance

Heat is not distributed evenly across a circuit board. Hot spots occur in the vicinity of the processors and chipsets, since these components generate the most heat. For this reason, the processors feature integrated mechanisms to protect against overheating and consequent damage. Users want to take advantage of the full performance potential. Downclocking the CPU, or shutting the processor down, can only be an emergency solution. New cooling concepts are needed to allow users to exploit the available computing power to the fullest. Existing cooling solutions have already reached their limits while the trend towards more performance continues unabated.



Computer-on-Module concept, carrier board and computer module

The modular COM Express concept can pave the way for future performance growth. Newer and more powerful modules are easily mounted on an existing customer-specific carrier board. While this scalable design solution helps customers to quickly and inexpensively create a wide variety of applications, full performance depends on the processor staying cool.

Cooling solution composition: heat pipes

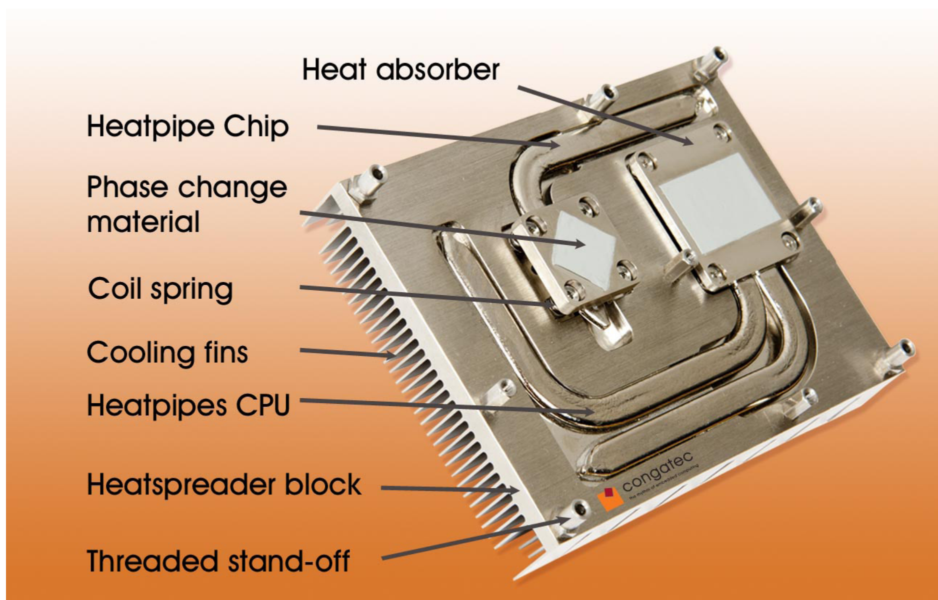
Classic cooling designs for up to 35W TDP

The classic COM cooling design resembles a sandwich with the different functions layered on top of each other. A copper or aluminium block is mounted on the chip to absorb heat. Between the chip and copper or aluminium block, an optional phase-change material can be placed to mitigate the effects of thermal peaks. To account for different component heights and manufacturing tolerances, the next layer is a height-balancing, thermally conductive material, the so-called gap filler. The last layer consists of a heatspreader, an approximately 3mm thick aluminium or copper plate. All heat generated by the module is distributed across the complete heatspreader.

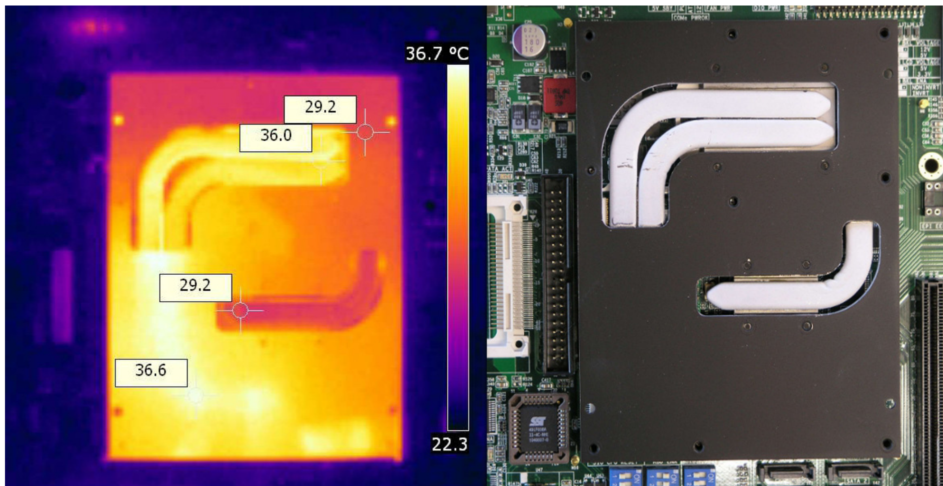
The module dimensions and interfaces are defined by the COM Express specification. While this standardization guarantees compatibility, size specifications may mean that the heat sink cannot necessarily be as large as desired. As a consequence this cooling structure is only suitable for modules with a maximum power dissipation of 35W.

Hot spots unwelcome

Modern COM Express modules such as the conga-TS77 feature a 3rd Generation Intel® Core™ i7 or i5. The power dissipation of these processors is significantly higher than 35W and hot spots around the processor and chipset become a real problem. An improved cooling concept is needed to lower CPU temperature, which is crucial when utilizing the 2nd generation Turbo Boost technology in order to achieve maximum performance and energy efficiency. As a result, the processor can operate above the maximum permitted thermal design power (TDP) levels.



Description of the individual components of congatec's cooling pipe solution



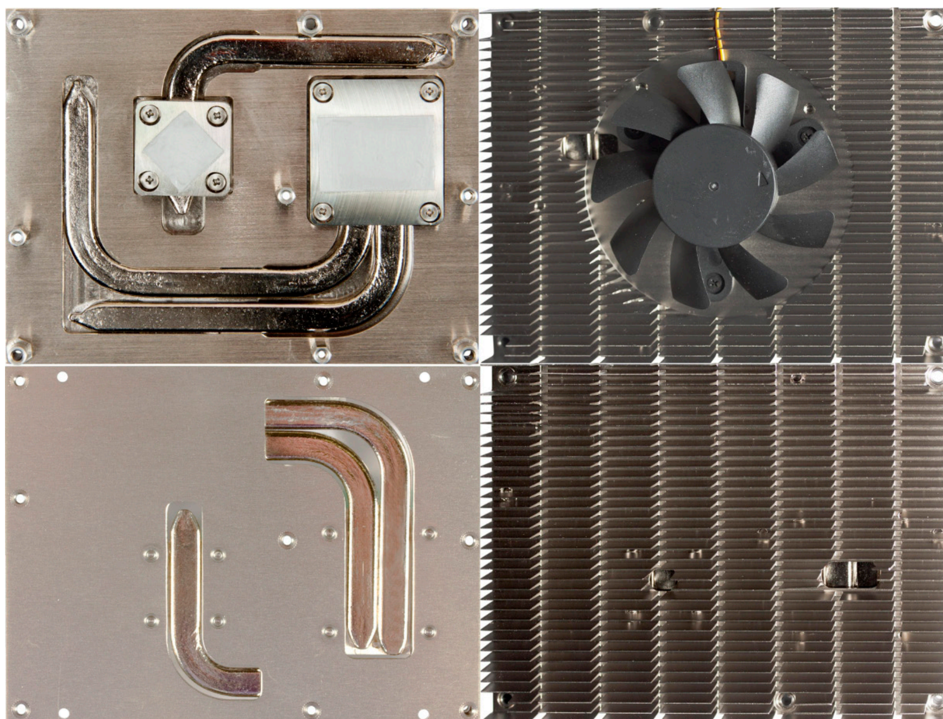
Explosion graphic: Basic structure of the optimized cooling solution for Computer-on-Modules

Limitations of the conventional solution

For the best heat dissipation results, a perfect thermal connection to the cooling system is required. The thermal conductivity of the gap filler material is limited. When power losses are high, the gap filler layer inevitably gets thinner. Thin gap filler layers have lower mechanical tolerances. To compensate for differences in component height more pressure must be applied. At a certain pressure the PCB will bend, which in turn leads to mechanical damage to the connections. Solder joints of ball grid array (BGA) casings or vias on the board can break. The cooling capacity depends to a large degree on the amount of heat-absorbing material used and the heat dispensing surface area. Copper is expensive; large heat sinks are heavy and require space that is generally not available. Simply increasing the size of the heat sink is therefore not a viable long-term solution.

Heat pipe – a suitable alternative?

In laptops heat pipes are used to solve the problem. Heat pipes transport about 100 to 1000 times more heat than an equivalent pipe made of solid copper. The secret lies in the physical fact that energy is absorbed during evaporation and released during condensation. The heat pipe is connected both to a hot and cold interface and filled with a working fluid. This evaporates at the hot end and condenses at the cold end. The condensate returns to the hot interface by capillary action and the cycle begins again. Since the heat pipe contains a vacuum, the working fluid evaporates even at low temperatures. The capillary forces depend on the structure of the heat pipe. Geometry and location influence how fast the working fluid is transferred, hence also affecting the cooling performance. Bend radius, the diameter of the heat pipe and mounting position also need to be considered. A laptop provides a comparatively large space to accommodate a heat pipe solution. By contrast, COM modules must always be connected to the cooling solution at the same geometrical position in the system, because the modules are interchangeable.



Thermogram comparing a standard COM cooling solution with congatec's optimized cooling pipe solution. The distribution of the point-shaped heat sources is clearly visible.

Classic cooling meets heat pipe

Fast spot cooling, good thermal connection, elimination of mechanical stress and greater cooling performance while retaining geometric dimensions – achieving all these requirements sounds like asking the impossible. However, congatec has mastered the challenge by skilfully combining the classical solution with a structurally modified heat pipe. Unlike the classical design, a flattened heat pipe is used to transfer heat from the chip to the heat spreader plate. The heat pipe is attached directly to the cooling blocks on the chip and the heatspreader plate. As a result, more heat is transported from the processor environment to the heatspreader, hot spots are cooled more quickly and the processor is cooled more optimally. Spiral springs with defined spring tension, as well as the heat pipe itself with its flexible height, put optimum pressure on the processor chip.

Manufacturing tolerances in the soldering process or height differences of the chips can be balanced in every direction, making a gap filler layer unnecessary. This is another advantage because when gap filler materials heat up they can leak silicone oil,which can lead to negative consequences elsewhere in the system. Recesses in the heatspreader accommodate the flattened heat pipe, thereby maintaining the height. At the hot interface the heat pipe rests freely in a recess; at the condensation end it is placed in a wide groove on the heatspreader plate. This ensures there is plenty of room to deflect the pipe while guaranteeing perfect thermal connection at both ends.

New cooling module inspires innovative customer ideas

congatec's new cooling solution provides scope for innovative customer ideas. For example, the heat pipe can be designed in such a way that it can be connected to a customer-specific heat sink. Fanless designs are possible provided the casing is equipped with appropriately sized cooling fins. Ultimately, the design depends on the specific application. The key features of the concept are equally applicable to other electronic circuits. Hot spots also occur in power modules. Semiconductor circuits in rectifiers and inverters, for instance, could benefit from this effective, inexpensive, small-scale cooling solution.

Extended life spans thanks to thermal reserves

The new cooling solution is also suitable for systems with low power dissipation. The modules have a higher thermal reserve, which increases their life span and reliability. Average temperature reductions of only 5 Kelvin can double the statistical life span – a convincing argument when considering the total cost over the lifetime of a system.

The advantages at a glance:

- Rapid spot cooling for full performance
- Elimination of gap filler layer
- Elimination of mechanical stress leads to higher quality
- Better cooling extends the life span of the module
- Heat pipe principle enables innovative customer-specific cooling concepts

Summary:

congatec's new patent-pending cooling solution for COM modules paves the way for new dimensions of performance.

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Konrad Pfaffinger studied electrical and mechanical engineering before joining congatec in 2006. His main role at congatec is the development of computer modules and their mechanics and this role has produced innovative products and solutions.