Development of a cooling system for a COM carrier system

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During the development process of the Pentair Schroff COM carrier system, thermal simulations were used to optimize passive cooling through the cooling element. The result is a modular system that can be modified to meet various customer requirements through selection from a series of available cooling elements.

Figure 1. The COM carrier system: 1) removable cooling element; 2) adapter plate; 3) removable front and top covers for easy access to the electronics.

■ Increasing electronics density and higher power dissipation require continuous improvement of heat dissipation solutions for electronic components and systems. This is why the cooling design for the Schroff COM carrier from Pentair was integrated into the development process and monitored in parallel from the start of development. Using state-of-the-art simulation methods, a wide range of solutions can be validated before actual development starts. The result is a modular set of components that makes it possible to support a wide range of customer requirements while still presenting the right solutions quickly.

■ In the past, an iterative development process in the test lab using prototypes achieved satisfactory cooling results. However, this method is no longer practical due to the high cost and development time (time to market). The specific problem is that prototypes and samples are usually not available until very late in the development process. There is always a risk of design changes in later project phases, which may cause delays and higher costs.

Computational development methods, on the other hand, have made tremendous advances in recent decades with respect to accuracy and user-friendliness. Thanks to the computing capacity of state-of-the-art hardware, these methods have become an efficient tool. This method does require that developers make a few simplifications and design assumptions, requiring in turn that the simulations be validated using measurements and trials of the physical cooling devices. Using simulations, the number of trials and versions can be significantly reduced. This is why a combined method was used for developing the cooling concept of the Schroff COM carrier. The system was designed with the aid of thermal simulations and a series of measurements were then carried out on the real parts to validate simulation results.

The goal is for the Schroff COM carrier to support COM express modules up 45W using only thermal conduction and convection air flow. In this design, the exposed surface of a heat sink must not have a temperature over 50°C in order to prevent burn injuries. In addition, demand is growing for easy module replacement, which requires an easy-to-open case with simple cooling device removal. For this reason, an adapter plate is used (figure 1). This plate is permanently connected to the heat spreader of the COM module, sealing the case against the ingress of dirt, water and electromagnetic waves. In addition, the plate establishes the thermal connection between the heat spreader and the cooling element. Thermal gap fillers compensate for tolerances and unevenness.

The cooling elements are specially designed for the carrier system at the beginning of the process with the help of simulations. In order to efficiently achieve a wide range of variants for the test series, additional cooling elements from standard profiles are procured from suppliers. Because the positions of the primary heat sources vary on different COM modules, dummy modules with load resistors and heat spreaders with easily adjustable thermal loads are created for the measurements. The components in the thermal conduction path (modules, heat spreaders, adapter plates and cooling elements) are equipped with temperature sensors at all four corners and on both sides. The sensors are sunk into grooves made in the surface and glued in with thermal adhesives to ensure that they do not interfere with heat transfer. The trials are carried out in a climate chamber with the option of adjusting the ambient temperature. In addition, potential disturbance variables are evaluated and minimized at the beginning of the test series. Each individual measurement is carried out for as long as it takes to achieve a steady state.

At the beginning of the measurements, it was shown that the thermal inertia of the cooling element is very high and that the measurements must be prolonged over several hours before the cooling element reaches a steady state. This is due in particular to the high

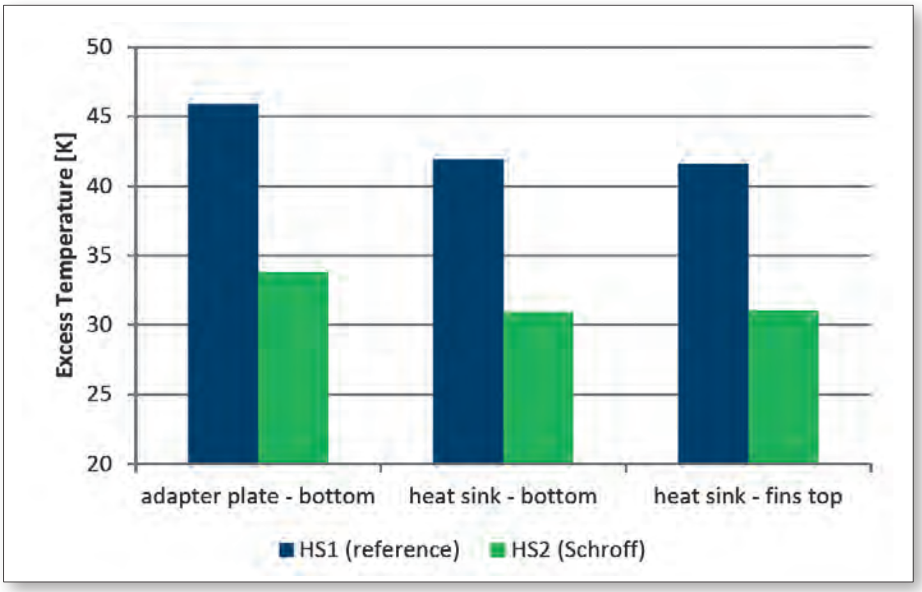

Figure 2. Measurement results for the over-temperature (measured temperature relative to the ambient temperature) for the comparison element (KK1) and the series-oriented Schroff cooling element (KK2).

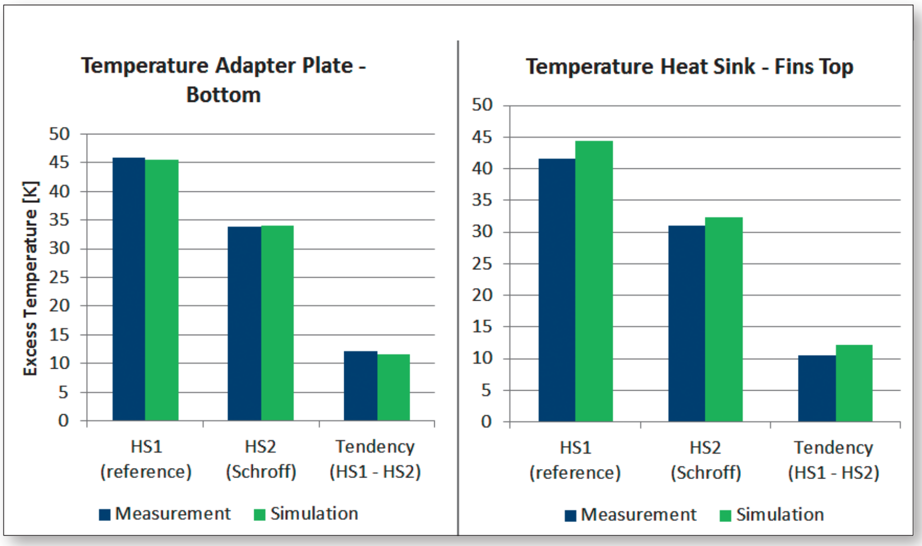

Figure 3. Comparison of the measurement results on the adapter plate and the fin temperature for the two cooling elements

thermal storage capacity of the heavy cooling element in comparison to the relatively low power of 45W dissipation of the COM express module. Even small disturbances, such as the entrance of laboratory personnel into the climate chamber, are evident on the measurement curves. The conditioning system of the climate chamber proves to be a major interference factor.

This conditioning system uses multiple fans to circulate the climate chamber air, resulting in an air temperature distribution that is as homogeneous as possible. Air movements caused by this process increase the heat transfer on the cooling element, which results in trials that achieve very low temperatures for the electronic components during conditioned operation. For this reason, the additional tests are carried out in the climate chamber with protection from outside influences and with the conditioning system switched off. Measured values attained this way for the cooling system and, in particular, for the thermal resistance of the cooling element are a better match with the manufacturer specifications and simulation results. The measurement results are visualized using the example of two different cooling elements that have significantly different shapes. On one hand, clear differences in the measured values are to be expected, which simplifies the comparison with simulations. Secondly, this setup allows for observation of how well the simulation tool deals with the unique features of the various components. The Schroff-manufactured flat and wide cooling element featuring even fins is a production-oriented model that roughly meets the cooling requirements mentioned. The comparison model is a tall and short element from the market with shaped fins. Based on the manufacturer specifications, it is clear from the beginning that this model will provide substantially lower cooling performance. However, it will be interesting to use this element to learn whether the simulations are able to reproduce the cooling effect of the fins with sufficient accuracy. According to the data sheet from the manufacturer, the cooling element has a thermal resistance of approximately 0.8K/W, assuming horizontal mounting and unobstructed convection.

An initial look at the test results (figure 2) for the series-oriented cooling element makes it clear that the surface temperature at the top of the fins is just over the 50°C required at an ambient temperature of 20°C, the same result that was inferred from looking at the design calculations. The comparison cooling element very clearly exceeds this requirement. The surface temperature at the end of the fins would reach more than 65°C. It is also important to note here that the thermal resistance of the comparison cooling element is below the specified value of 0.8K/W. The measurements yielded a resistance of a little more than 0.9K/W. This is presumably due to the fact that the entire bottom side of the element is not connected to the heat source, and instead the element is connected only through the surface of the adapter plate. It is interesting to note here that the glass-fiber-reinforced gap filler between the cooling element and the adapter plate causes differences in the temperature reduction between the versions. Obviously, it is difficult to guarantee the same heat termination over the foil in all cases. Lower fluctuations can be achieved when softer foils without glass-fiber reinforcement are used. The differences for the reinforced foils, however, are reduced to a low enough level overall that the advantages of working with them outweigh the aforementioned disadvantage.

Figure 3 shows a comparison of the simulation results and physical measurements for the versions described. It is easy to see that the simulations are quite capable of predicting the physical measurements. This is only possible using an adequate configuration of the material properties in the simulation model. This means that the simulation model is capable of reproducing the tendencies accurately with a maximum deviation of 1.5K, which is crucial for variant comparison. It is also capable of calculating the absolute values of the temperatures with sufficient accuracy and with an absolute deviation below 3K, which corresponds to a relative tolerance of maximum 7%. This allows for a precise design of the system to meet specific requirements. ■