Heat Exchange Solutions - White Paper
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ThermoKey®
Heat Exchange Solutions

TKMicro

Multi System Dual Flow

A solution of heat recovery and enhanced performance

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A Revolution for heat recovery

Despite approaching an environmental crisis, we continue to release 2,860 TWh/y of heat into the atmosphere in Europe alone [1], which is almost the same amount of thermal energy used for heating and hot water. Across the Atlantic Ocean, the US produces 43·109 GJ (11,944 TWh) of waste heat over 30°C per year [2]. This number is meant to increase considering that the global chiller market is expected to grow at a 3% CAGR from 2022 to 2029 [3]. Thus, **heat recovery in the field of industrial HVAC&R is imperative in order to reduce greenhouse gas emissions and the effects of global warming**.

After a few years of studies and experiments, **Thermokey is ready to offer its innovative solution of Multi System Dual Flow**. This new version of a Microchannel Heat Exchanger (MCHX) provides an up to 50% increase of power and a warm coolant that can be used for many applications discussed in this paper. In addition, the noise of fans may be reduced by 8 to 10 dB(A). Prototypes are available to trail for a higher performance and heat recovery.

PAPER CONTENT

KEY TAKEAWAYS

The actual unsustainable system

EUROPE

2,860 TWh
of waste heat into the atmosphere per year

US

11,944 TWh
of waste heat over 30°C are produced every year

Thermokey solution for heat recovery in the field of industrial HVAC&R

Thermokey is ready to offer its innovative solution of Multi System Dual Flow to cope with this urgency and improve the performance of air-cooled MCHX.

Up to **+50%** of power and a warm coolant

Up to **-30%** of the absorbed ventilation power

Up to **-10**dB(A) of fan noise

Up to **-32%** of number of core units

REFERENCES

[1] D. Connolly, . B. V. Mathiesen, P. A. Østergaar, B. Möller, S. Nielsen, H. Lund, U. Persson, S. Werner, J. Grözinger, T. Boermans, M. Bosquet e D. Trier, «Heat Roadmap Europe 2: Second Pre-Study for the EU27» Department of Development and Sustainable Energy Planning Research Group, Aalborg University, 2013.

[2] A. S. Rattner e S. Garimella, «Energy harvesting, reuse and upgrade to reduce primary energy usage in the USA» Energy, vol. 36, n. 10, pp. 6172-6183, 2011.

[3] Exactitude Consultancy, «Chillers Market by Type, Power Range, and End User and Region, Global trends and forecast from 2022 to 2029» 2022.

A new integrated solution, more compact and versatile

Several Chillers and ventilated unit producers are pushing towards sustainability and, in particular, towards heat recovery. Indeed, conventional coolers and condensers dissipate heat into the atmosphere or into neighboring bodies of water. Although in many applications this heat is considered a waste, it can be recycled for many purposes. Generally, **waste heat can be reused to supply heat and warm water to neighboring homes and industries through a district energy system, as well as all-process heating**. Thermal energy storage is a technology already being utilized for these applications in order to choose when to employ this resource, as well as thermodynamic cycles that change the operating temperature. Alternatively, **waste heat can improve the efficiency of machines or HVAC&R plants**. A simple example is the modern system of ventilation that uses discharged air to warm the fresh air coming into the building. To this end, the whole air conditioning system will consume less energy to provide the target ambient temperature. In addition, coolant heated to the designed temperature may serve for evaporator defrosting.

In free-cooling and condensation, heat is removed from the working fluid and transferred to a coolant or to the ambient air. In the case of a liquid coolant as working fluid, this heat can be used directly into the nearby utilities. On the other hand, when air is the working coolant, this heat is released directly into the atmosphere. In order to take advantage of this, energy needs to be transferred to a denser fluid, in general water or a mixture of water and glycols. Nowadays, a plate-type heat exchanger is placed upstream of an air-cooled cooler/condenser, introducing an additional component to the HVAC&R plant. Furthermore, in the case of a condensing refrigerant, the plate heat exchanger can only operate in the superheating zone and/or it must be placed higher than the air-cooled condenser.

> This new technology makes use of an additional coolant to recover heat from a refrigerant at higher temperature

However, these complications may cease to exist due to the integrated solution proposed by Thermokey in this article. This patented technology of **Multi System Dual Flow**, also world-wide patent pending, is supported by a structured portfolio of IP rights. It is a solution between an air-cooled and a water-cooled heat exchanger, more compact than an air-cooled exchanger but more versatile than the water-cooled. As in a typical air-cooled MCHX, it has the capability of using an additional coolant for heat recovery. MCHX are composed of MPE tubes that can be fed with more than one fluid. By allowing a coolant to run inside dedicated ports, part of **the heat can be transferred from the hot refrigerant to the cold liquid** (*Figure 1*). **The high conductivity of these aluminum tubes was expected to deflect a significant amount of energy towards the cold ports**. In order to assess the amount of heat transferred to the coolant, a numerical model has been developed for this innovative MCHX geometry.

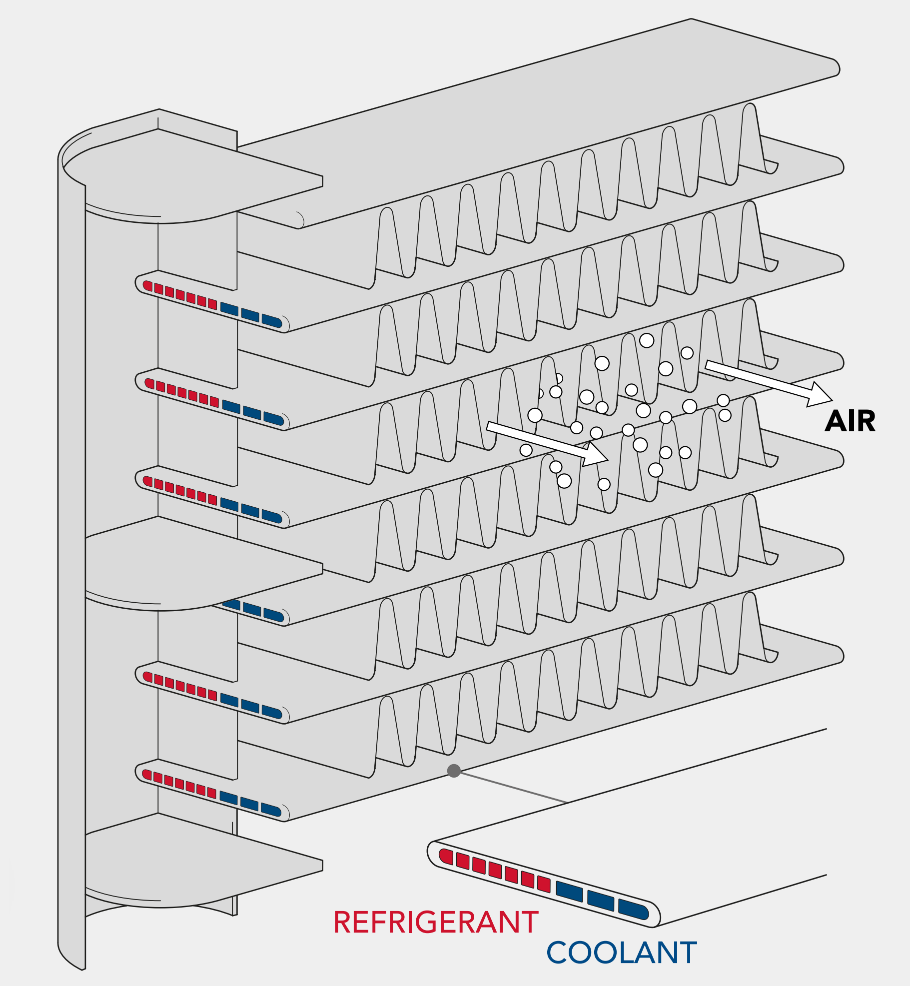

Figure 1 – Multi System Dual Flow working principle.

The CFD study

The configuration depicted in *Figure 1* needed to be tested to estimate how much heat could be transferred to the coolant and for this purpose the finite element CFD code COMSOL Multiphysics® was used to provide the required information. In order to limit the computational effort, the model solves the steady state conduction in the metal for the smallest possible periodic volume of the heat exchanger. On the surfaces exposed to the fluids a convective heat transfer coefficient was applied whereas the symmetrical surfaces were considered adiabatic.

The effect of the air temperature increase through the heat exchanger is considered by the approach of Model Coupling. An additional one-dimensional dummy model simulates this phenomenon by solving the heat transfer in the air by imposing a heat source term that accounts for the heat exchanged with the air in the main model. By solving the two models iteratively, the heat transfer through the metal is calculated until convergence is reached. The results provide a 3D map of the temperature field inside the metal and the local amount of heat exchanged between refrigerant, water and air.

The CDF investigation shows a significant heat flux along the horizontal direction

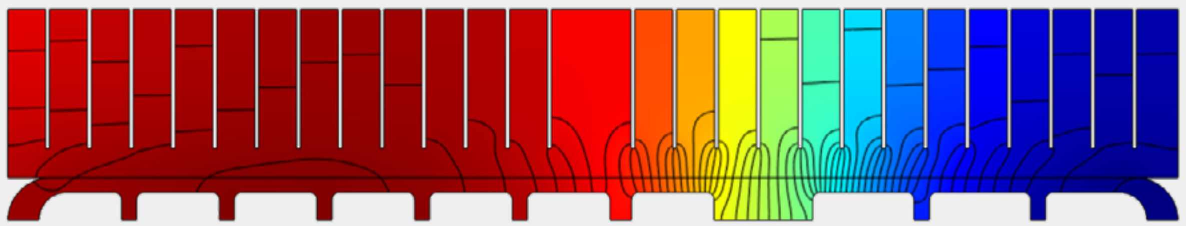

Figure 2 – Iso-thermal contour of a 2D section of a 2D section of tube and fin.

As an example, a 2D section of the geometry was extrapolated and the iso-thermal contours plotted in *Figure 2*. The proximity of all contour lines between the hot and cold ports is an indicator of **a significant heat flux along the horizontal direction**. The local heat exchanged by the three fluids can be adjusted as required by changing flow rates and fluid temperatures. The heat recovered from the coolant can even match the one released by the refrigerant; in such an extreme case the inlet air temperature is equal to the outlet temperature. Lastly, it may also be possible to **significantly reduce the action of the fans**.

Core Calculating Engine

Since the CFD capabilities of this geometry in terms of local heat transfer are known, the next step was to simulate an entire exchanger core rather than a small part of the tube. To this purpose, **a numerical procedure was developed for the analysis of the whole heat exchanger**. For each small element, the heat fluxes between the fluids are inferred by interpolation from a dataset obtained through the CFD simulations described in the previous section. The solution to the problem, i.e. the air temperatures, as well as refrigerant and coolant throughout the MCHX, is calculated by iteratively solving a system of linear equations accounting for the energy balance in every element. The numerical procedure was implemented in Fortran to ensure high calculation speed. The performances of the entire heat exchanger were, then, needed to be compared and validated with experimental data. Thus, **Thermokey produced a prototype** to work with hot and cold water that was sent to an external laboratory for some experimental tests.

Experiments and Numerical Validation

A detailed measurement campaign was commissioned by Thermokey and performed by the heat pump laboratory of EURAC Research (Bolzano, Italy) in order to evaluate the performance of its prototype and to validate the numerical model aforementioned. The machine was built with a baffle in the middle of both manifolds in order to separate the top and both sections (*Figure 3*). It was therefore possible to test the heat exchanger as a single pass or two passes and with the hot and cold water in counter-flow or co-current modes. Temperature and pressure sensors were positioned in the connections brazed on the manifolds while the mass flow meters were located about 1 m upstream of the entry in the manifold. The inlet hot water temperature varied from 45°C to 71°C while the cold water and ambient air (both at inlet conditions) were kept constant at about 15°C and 35°C respectively.

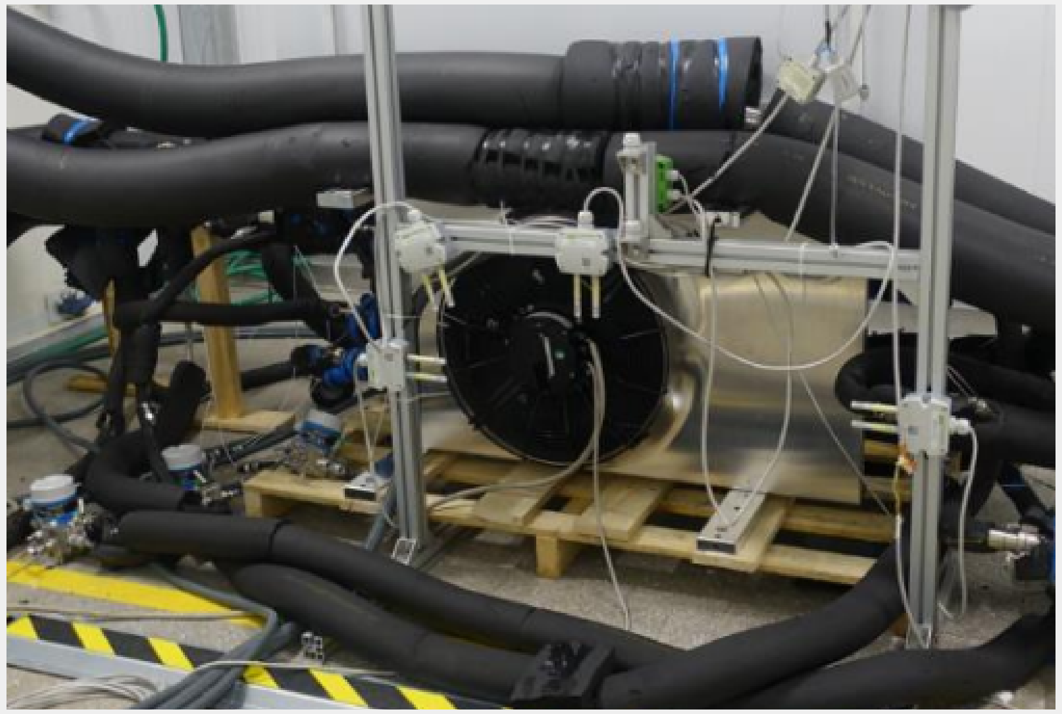

Figure 3 – Image of the test facility (courtesy of EURAC Research).

The results showed supported the numerical data obtained in the same working conditions, demonstrating the accuracy of the numerical tool in spite of the simplifying

Experimental and numerical results are in very good agreement

assumptions of the model. *Figure 4* and *Figure 5* show the comparison of the calculated heat flux (abscissa) versus the heat flux obtained by the experiments (ordinate) respectively for the hot water and the cold water circuits. In terms of standard deviation these differences are about ± 10.4% for a 95% confidence level, assuming a gaussian distribution of the error. In reality, the experimental results are slightly underestimated compared to the numerical ones. However, this might be due to some differences between the measurement set-up and the numerical calculating engine that doesn't take into account any heat transfer in the manifolds and inlet/outlet connections. The figures also show vertical error bars calculated with the theory of error propagation for the measured temperatures and mass flow rates.

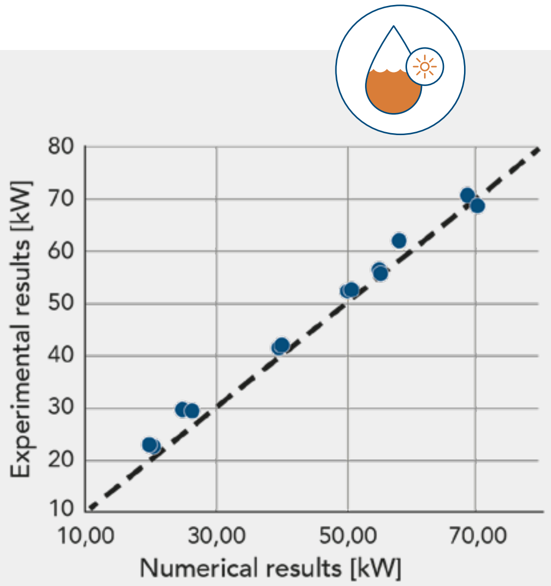

Figure 4 – Heat fluxes comparison for the **hot water** circuit.

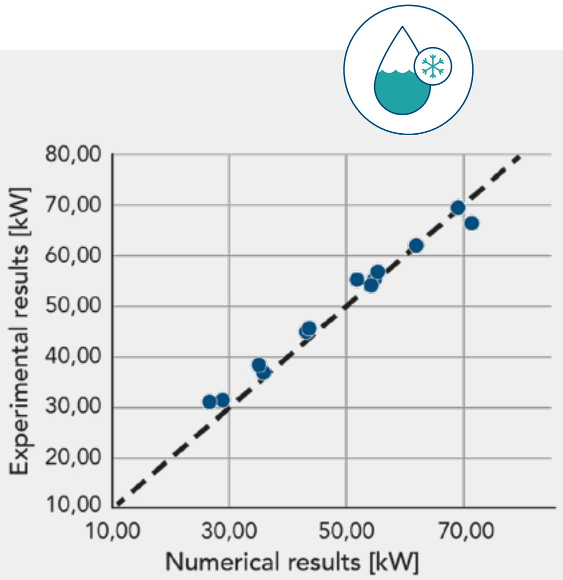

Figure 5 – Heat fluxes comparison for the **cold water** circuit.

Benefits, Performance and Applications

In line with these results, air-cooled cores can be provided with a double flow system that can boost the heat transfer. **Prototypes of Multi System Dual flows have been tested by two external laboratories as well as by a client. Compared to the same heat exchanger with zero coolant flow, these data show capacities up to 50% higher in standard conditions and even higher for specific applications.** This technology provides an air-cooled heat exchanger with the addition of another variable that can control the working condition of the machine where the product is used. The specific power of the latter can be largely improved with the introduction of a coolant. The benefits in terms of the performance of the single MCHX are represented by a reduction of the dimensions or a higher power output. Another positive side effect is the potential to reduce air ventilation which may reduce noise pollution.

For instance, the graph of *Figure 6* shows the reduction in frontal area, which is also an indication of the volume of the heat exchanger, while varying the coolant flow rate in respect of the constant refrigerant flow rate. In this case, the power output was kept the same and it can be concluded that increasing the coolant flow rate to the maximum allowed for this geometry, **the core dimensions may be reduced by 32%**. On the other hand, if the geometry and the subcooling are kept constant, increasing the refrigerant flow rate, **the capacity increases by over 50%** (*Figure 7*), which is also supported by the performed experiments. Consequently, for a standard module size, **fewer modules can be used to meet the required capacity**. Instead of using 6 modules of 80 kW each, the designer could use 4 modules of 120 kW.

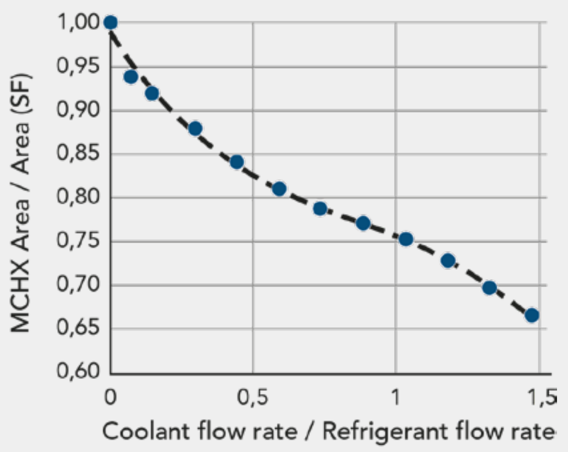

Figure 6 – Decrease of the required heat exchanger dimension in terms of front surface increasing the coolant flow rate.

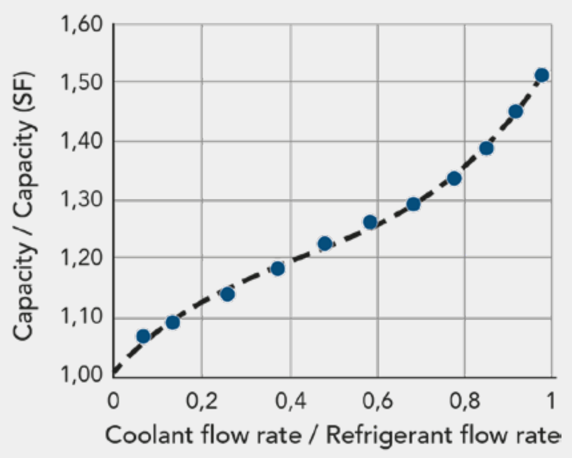

Figure 7 – Capacity increase of a MCHX with the same dimension when increasing the coolant flow rate.

The benefits of this technology are represented by a reduction of core size or a smaller number of units (up to 32%)

Considering the complexity of finding the best working conditions, the air-flow rate may play an important role. Compared to a single flow MCHX, the ventilation power can be strongly reduced. In the extreme condition of a constant power and size of the core, increasing the coolant rate to the maximum, the fans can be turned off (*Figure 8*). This is how this technology can switch from an air-cooled to a liquid-cooled condenser. In a more real situation, either a solution with smaller cores or less modules is possible, and both of them allow a reduction of the absorbed ventilation power and its related noise. While **the ventilation power can be decreased by 30%, the noise may be reduced from a standard level of 70dB (A) to an estimated value of 62-63 dB(A)**. It is important to underline that the reduction in power consumption of the fans is coming at the expense of the power needed to push the coolant through the tubes; however, this is the side effect of any heat recovery system. The energy saved needs to provide a benefit that can be considered worthy, and this depends on the specific application.

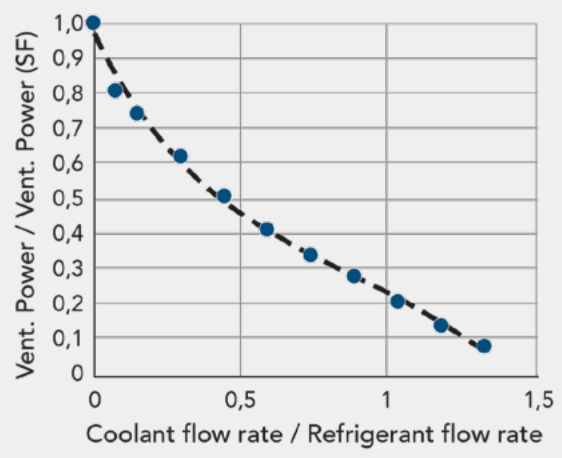

Figure 8 – Ventilation power reduction for different coolant flow rates obtained keeping capacity and size of the core constant.

Each application for the energy saved with this device requires a certain amount of coolant at a certain temperature. Thermal-energy storage may also play an important role. In general, relatively low mass-flows are used to defrost evaporators and heated glycols can be stored and pre-mixed with non-heated glycols for this purpose. When the heated coolant can be used directly in neighboring homes/offices, the amount of heat needs to match the one required by the district. The working temperature may be changed through a thermodynamic cycle when convenient. In contrast, a relatively small closed circuit of coolant flow is able to improve the performance of reverse cycle machines. The latter is possible by decreasing the condensation temperature, also observed in some experiments.

Conclusions

The **Multi System Dual Flow technology developed by Thermokey** can have **multiple applications** as mentioned and most likely even more. The preliminary local CFD simulations showed promising results that were followed by a global analysis of a double flow MCHX by means of a numerical model of the entire core. The company produced in the last years a few prototypes that were tested in research laboratories and in the field. The experimental results of EURAC research are in very good agreement with the numerical results; the Core Calculating Engine, specially developed for the analysis of this innovative MCHX, can therefore be considered validated.
A data analysis has been carried out changing the coolant flow showing some benefits linked to a greater specific power. This solution, indeed, represents the possibility for **a good compromise between an air-cooled heat exchanger and a liquid-cooled heat exchanger**. **This great advantage allows us to a fine control of the output and the efficiency by altering the flow rates of the three fluids involved**: warm/hot refrigerant, the coolant and the air.

Multi System Dual Flow technology allows us to a fine control of the performance in most of HVAC&R applications while providing free warm water to our utilities

This technology can be optimized for the specific application depending on the required amount of coolant and its optimum temperature. Looking towards the future, **Thermokey provides a system of heat recovery that is not only beneficial for the environment but can also improve the performance of HVAC&R machines**.

For more information on **TKMicro Multi System Dual Flow** or to request a test please refer to our contacts:

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Established in 1991, ThermoKey has been manufacturing heat exchangers of various types for over 30 years.
All products are completely engineered, developed and manufactured within the company, with the cooperation of international certification institutions. Alongside the broad range of exchangers present in our catalogue, there are special exchangers, engineered following the specific needs of the customer. ThermoKey is a leading company in the production of microchannel cores in Europe. The state-of-the-art production process of TKMicro cores makes ThermoKey the ideal partner both for large-scale production and for smaller and more customized orders based on the customer's specific needs.