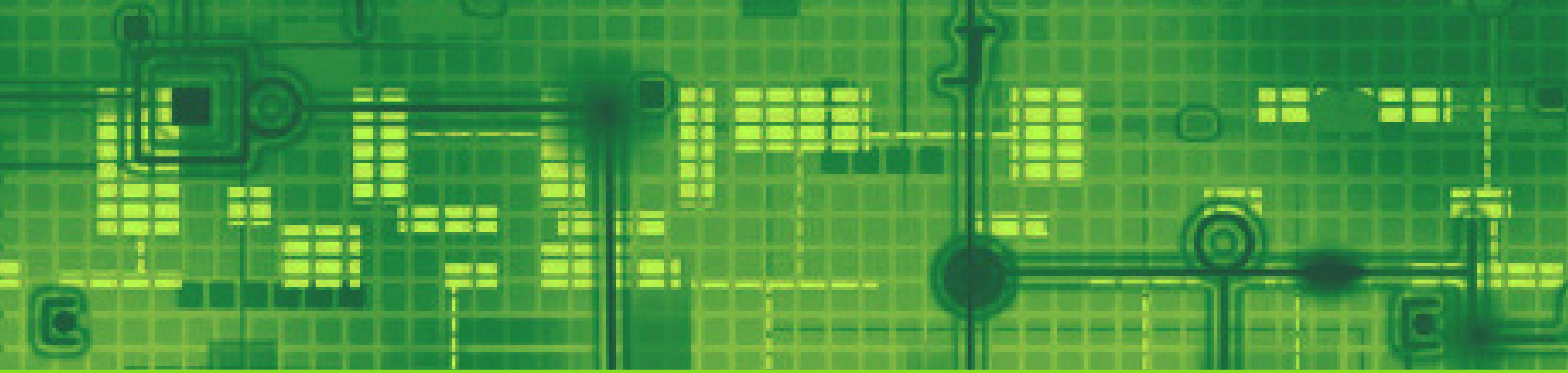

Application of TEC Using a Heat Exchanger

for Sub-Ambient Liquid Cooling

Thermoelectrics are solid-state devices capable of transferring heat across a temperature gradient. As a solid-state technology, there are no moving parts and no working fluids, which translates into simple integration, essentially no maintenance, quiet operation, and acceptable reliability. For applications involving relatively steady state cooling and low humidity with a continuous and uniform supply of DC voltage, thermoelectric module reliability is extremely high. Mean Time between Failures (MTBFs) in excess of 200,000 hours are not uncommon in such cases and it is generally considered to be an industry standard [6]. In addition, the degree of cooling may be readily controlled by means of the current supplied to the thermoelectrics.

Thermoelectric modules offer the potential to augment the cooling of electronic module packages to: 1) reduce chip operating temperatures at a given module heat load, or 2) allow higher module heat loads at a given chip temperature level. Compounds such as Bi_2Te_3 which is currently used in thermoelectric modules, made possible the development of practical thermoelectric devices for attaining temperatures below ambient without the use of vapor-compression refrigeration which carries the risk of cooling failure due to the mechanical nature of the compressor and electronic expansion valve.

Though sub-ambient temperatures can be achieved with the application of TEM's (thermoelectric modules), they come with the limitation of heat flux resulting in lower coefficient of performance. This limitation can be overcome by use of Thermoelectric Chiller as shown in figure 1, which consists of Thermoelectric heat exchanger, water loop routing cooling the electronic modules and rejecting the overall heat load to air.

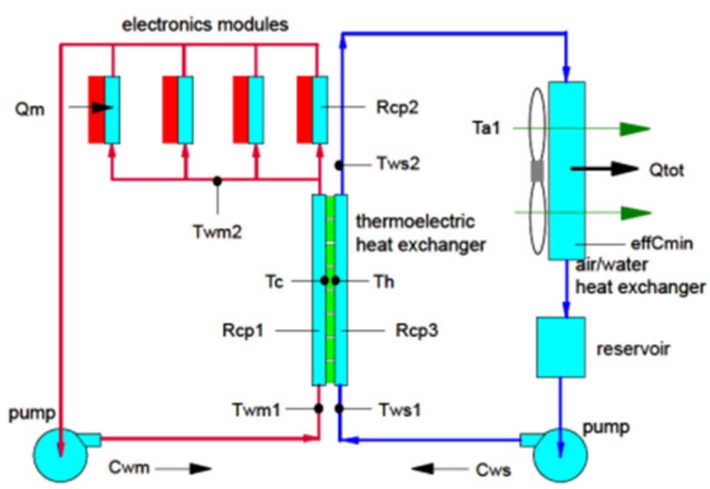

Figure 1. Hybrid Air to Water Cooling Loops with Thermoelectric Heat Exchanger [1]

Liquid Cooling Using a Thermoelectric Heat Exchanger

In this section, three different thermoelectric heat exchanger arrangements (Segregated water loop, Series water loop and Parallel water loop) with respect to pumps and power generating module is explained and a comparative analysis is done to determine the best out of three configurations [1]

The thermoelectric heat exchanger arrangement is as shown in figure 2, where 6 TEMs are sandwiched between two machined copper cold plates. Dow Corning 340 is used as interface material between cold plates and thermoelectric heat exchanger. The springs and bolt assemblies seen on the left side are provided to achieve uniform compressive loading.

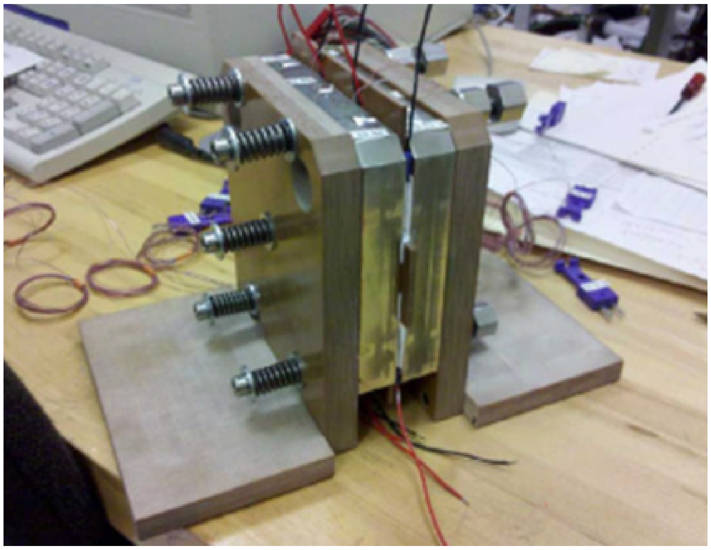

Figure 2. Thermoelectric Heat Exchanger Photograph [1]

Segregated Water Loop(SGWL):

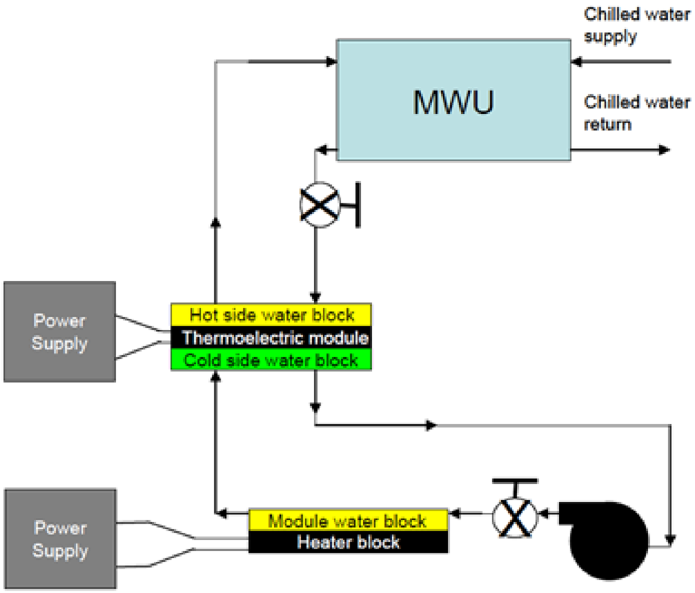

Figure 3. Thermoelectric Heat Exchanger Schematic with Segregated TEM Hot and Cold Side Loops [1]

This arrangement shows two separate water loops; one running on the hot side and other on the cold side of the thermoelectric heat exchanger. The hot side of the thermoelectric module is associated with the ultimate heat sink, i.e. MWU in this case which is a Modular water Unit supplying conditioned water at a specified flow and temperature whereas a separate water loop runs through cold side of the thermoelectric which services electronics module.

Segregated Water Loop(SGWL):

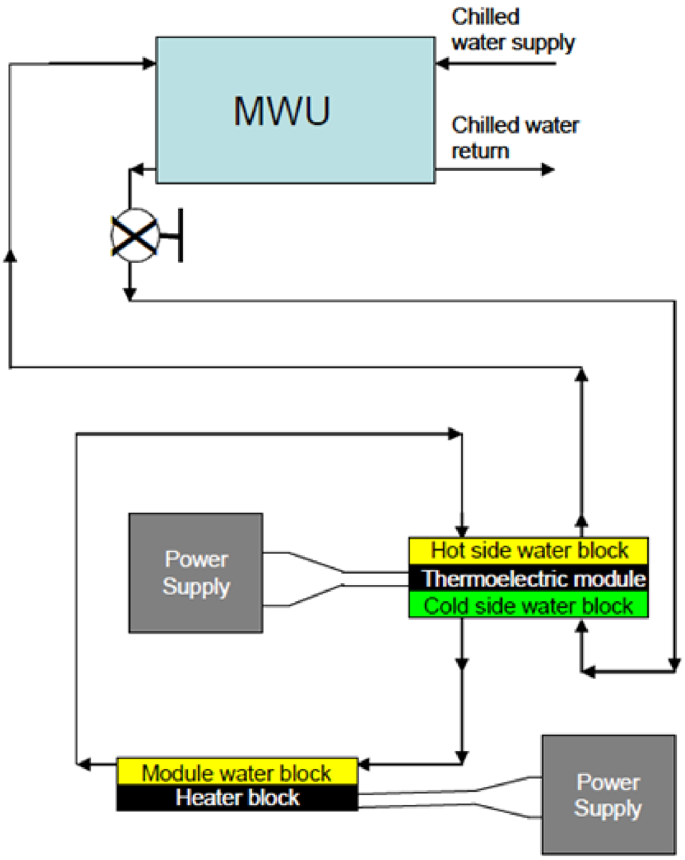

Figure 4. Thermoelectric Heat Exchanger Schematic With the Water Flow in Series for the TEM Hot and Cold Side [1]

The MWU shown supplies water to the cold side of the thermoelectric, to be chilled to a specified temperature value and further passes on to cool the electronic module. Finally, the water circulates through the hot side of the thermoelectric and dissipates the system heat to the final sink.

Parallel Water Loop:

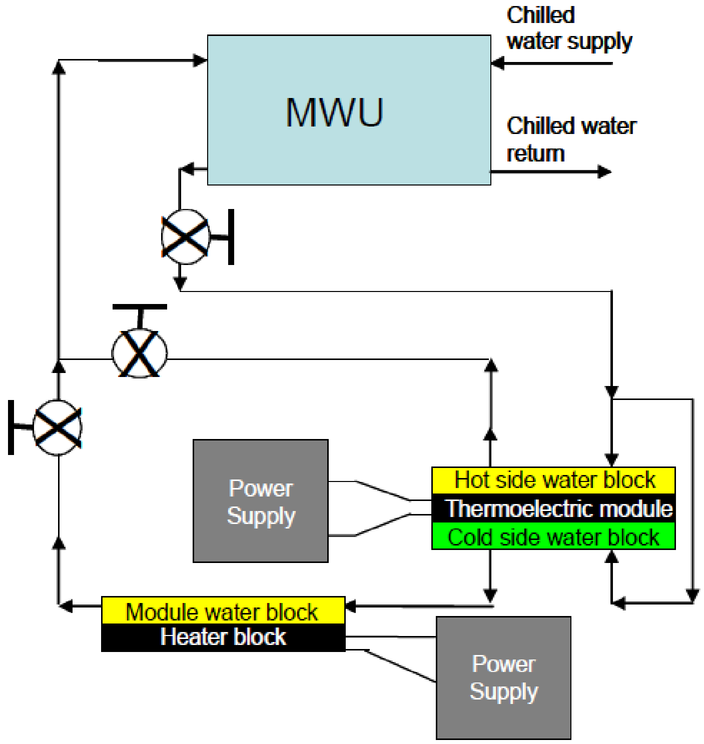

Figure 5. Thermoelectric Heat Exchanger Schematic with the Water Flow in Parallel for the TEM Hot and Cold Side [1]

The MWU shown contains a pump, liquid to liquid heat exchanger, and a reservoir; its function is to serve as the heat sink for the loop and to provide the process flow. The liquid- to-liquid heat exchanger interfaces with the loop and with a controllable flow of chilled water (using an electronic proportional valve)[2].

From MWU, the water stream breaks into two paths, one is diverted to the hot side of TEM and the remainder is chilled by the cold side of the TEM. Heat is transferred from the water to the hot side via the thermoelectric modules, resulting in a lower water temperature entering the Module water block. Similarly, the water flows through the hot side of the thermoelectric heat exchanger, thus pulling out the heat. The hot and cold side streams meet downstream of the load (heater block), and finally the water is returned to the MWU pump and heat exchanger thus dissipating the system load at the ultimate sink.

Comparison Between Segregated, Serial and Parallel TEC Heat Exchanger Arrangement

The application under investigation is a 500W load, with the thermoelectric heat exchanger hot side inlet temperature (T_{whi}) set as nearly as possible to 20.8°C and the water flow through the heat source fixed at 3.79 l/min (1.0 gpm). The temperature of the water supplied to the heater block (module water block), is considered as benchmark to gauge the relative effectiveness of the three arrangements. [1]

As shown in figure (6), for each arrangement, the thermoelectric modules were operated at four power levels. The benchmarking point discussed above is a function of this power supplied to TEM's.

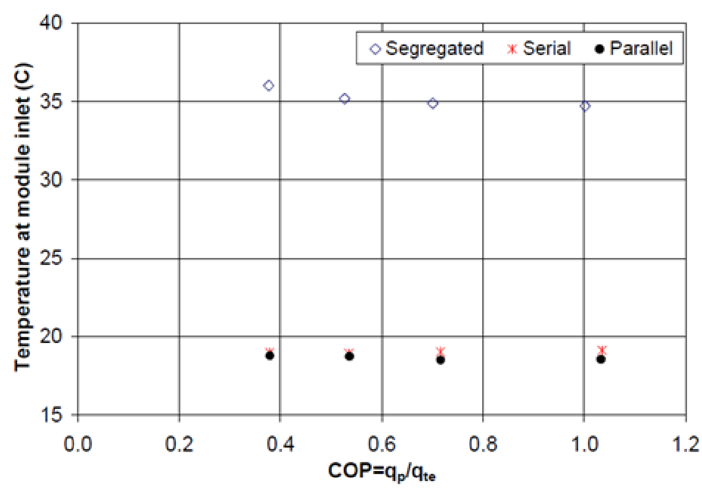

Figure 6. Comparison of Heat Load Inlet Temperature as a Function of Loop Arrangement and Ratio of Heater Power to TEM Power [1]

The results show that, Serial and Parallel configuration provides lower water temperature to the heater block. In addition to this, the parallel and serial loops require only one pump in comparison to two pumps required by segregated loop.

In serial loop, the arrangement causes the Thermoelectric Heat exchanger hot and cold side flows to be equal, and this approach requires higher water flow rate as compared to Segregated and Parallel loop. Additionally, the hot side thermoelectric heat exchanger water is preheated by heat from the heater block. With these shortcomings, the arrangements of Figure 3 and Figure 4, both results in a lower thermodynamic efficiency at the thermoelectric heat exchanger to achieve a target water temperature to the module. Parallel flow architecture overcomes these shortcomings and is the most sophisticated, which allows separate control and optimization of the water flow on the hot and cold sides of the thermoelectric heat exchanger. In Parallel flow architecture, some adjustments with respect to water flow parameters and heat transfer quantities, helps to maximize thermoelectric heat exchanger cold side temperature reduction (or conversely minimize electrical current to the thermoelectric heat exchanger for a specified temperature reduction). Adjustments such as, providing the lowest cold side flow rate at which the module will be sufficiently cooled can be one way or conversely providing the highest hot side flow rate within the system pump capabilities can be other way. Also, lowering thermal resistances on the thermoelectric hot and cold side cold plates can improve the thermoelectric heat exchanger cold side temperature reduction. These advantages along with better control features, makes the parallel arrangement the most attractive for an electronics cooling application.

More work and data are needed to correlate the performance of the TEC with various parameters such as water block thermal resistance, flow rates and chilled water supply temperature.

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