HydroSink™: a smart and more efficient way to cool power electronics

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Abstract
Air systems have some limitations when cooling concentrated or transient heat. Aavid designed a liquid cooling system, “HydroSink™”, to replace traditional cooling, which is cheaper and performs better.
It is made using the most reliable components on the market, while the liquid cold plate is fully customizable.
HydroSink™ has a simple but efficient control system and is available in two sizes: “Small” and “Medium”; it can be supplied ready installed in a cabinet or as separated components. The nominal dissipated powers are 3.0 kW and 9.9 kW respectively, while they can work in a wide range of thermal resistances by acting on fan and pump speed (“Small” size: 7.0÷21.0 °C/kW and “Medium” size: 2.9÷9.0 °C/kW).

1. Introduction
Power electronics can be cooled by using air or liquid systems. Air systems are very common, but they are unable to efficiently cool concentrated heat sources or transient load conditions: the result is that performance is poor (thermal resistance is high).
The way to improve the situation is to work with high exchange surfaces or high air speed, but in the case of the latter the acceptance of high pressure drop will be required and the use of expensive, bulky and noisy fans will be necessary.
Aavid Thermalloy aims to replace traditional air cooling by using a liquid cooling system which is cheaper, more reliable, efficient, effective, flexible, compact and with high performance (as shown in figure 1).

Fig. 1. Air system vs liquid system

2. Development of the system
2.1. Components selection
The focus during the design phase has been to look for the most reliable and cost effective components available on the market. The system includes: pump, fan, heat exchanger, small tank,
valves, fittings, tubes, sensors and control board. It is possible to customize the liquid cold plate(s) to be assembled with it in order to ensure the best performance and to fulfill all the specifications of the application it is to be used with.

Concerning the single components, the biggest one (in terms of dimensions) is the heat exchanger; it is a common aluminum one, with a small customization to better integrate it into the whole system. The pump has ultra-hard wearing resistant ceramics ball support, self-realigning rotor with magnetic support; it’s life is longer than any fan used in electronic cooling. It means that the most critical component is the fan and one which has been homologated for automotive applications has been selected, with a life-span of more than 50,000 hours.

The small tank has been selected by looking at the available products in the market, considering its suitability in the desired assembly position. An air filter has to be provided in the final application in order to keep the air (and consequently the fan) clean.

Other components (such as the fittings, valves and tubes) have been identified by considering the normal operating conditions: the purpose is not to work in hard external environmental conditions, so plastic (PPH - polypropylene homopolymer) and silicon are suitable.

The system has components working in AC that can be used both in US and Europe without any adaptor being needed.

### 2.2. Control board and monitor system (Controller)

The control system has been studied in order to have specific characteristics: the idea is to have a simple and efficient controller, able to monitor the operating conditions and to modify them when and if needed.

The controller allows the fan and the pump to slow down when ambient temperature or power dissipated permits, in order to increase the components life-span. With this approach, it is possible to guarantee a stable cooling condition with different ambient temperatures and power dissipations. The controller also monitors the sensor signals, in order to facilitate the system maintenance and prevent failures. Sensors have been selected looking at two basic criteria: efficiency and simplicity.

**HydroSink™** has the following sensors:

- Liquid pressure
- Air pressure
- Liquid temperature (incoming in the liquid cold plate)
- Liquid flow rate
- Temperature (one for every liquid cold plates)
- Air temperature
- Coolant level in the small tank

Based on the above measured values, the system is able to modify fan and pump speed and to check if the air filter has to be cleaned.

### 2.3. Other generic features

The way the system has been studied provides additional benefits: one is the possibility to work with a very flexible installation, as the components can be arranged in different ways and positions, according to the application.

The liquid cold plate(s) can be located inside a sealed customer’s cabinet, with remote location for pump and heat exchanger; otherwise, it is possible to have them close to the other components, for a more compact solution. For the same reason (to have a compact system), a version already assembled inside a metal cabinet has been studied.
The control board is able to manage the maintenance and thanks to the selected components, this operation is very simple (it’s just about filter and cooling media refilling). Board, display and the other components of the controller are sealed inside a plastic box and can be easily connected to the other machine controls.

Based on the control system, noise level is lower than air cooling systems and it can be defined according to the desired thermal performance.

2.4. Layout

The schematic layout of HydroSink™ is shown in figure 2; it represents all the hydraulic and electronic connections which guarantee that operating conditions are respected.

3. Results

3.1. HydroSink™ features

Operating conditions

HydroSink™ has been developed to work in moderately hard environmental conditions (because of the materials and components). The coolant will be a mixture of water plus ethylene glycol (ethylene glycol percentage depends on the ambient conditions); even though the thermal conductivity of ethylene glycol is not as high as water, glycol provides freeze protection during use or shipping. Glycols with proper inhibitors, easily available on the market, are highly recommended over non-inhibited glycols.

![Fig. 2. Layout of HydroSink™](image)

The customization of the liquid cold plate has to take into consideration material compatibility issues: as the heat exchanger is a full aluminum one, the flow path must be made with aluminum...
alloys or stainless steel tubes. Neither copper nor its alloys can be used in order to prevent any possible electrochemical corrosion phenomena.

**Performances**

HydroSink™ is available in two different sizes: “Small” and “Medium”. The nominal dissipated power is 3.0 kW for the “Small” and 9.9 kW for the “Medium”, while they can work in a wide range of thermal resistances by changing the fan and pump speed.

Thermal resistance is a better parameter for the classification, as it gives an immediate understanding of the system’s capability: if the available temperature rise \((T_{\text{MAX,LCP}} - T_{\text{AIR,AMBIENT}})\) is higher, it will be possible to dissipate more power. Thermal resistance is defined as follows:

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\text{Thermal resistance} = \frac{1}{\text{Power dissipated}}
\]

HydroSink™ performance is a combination of the performance of the liquid cold plate (LCP) and of the heat exchanger (HEX):

Both parameters have the same relevance: if the power loss doubles, the available temperature raise will be half.

Based on the above definitions, the “Small” size is able to work from 7.0 to 21.0 °C/kW, while the “Medium” one can work from 2.9 to 9.0 °C/kW.

Performance curves are shown in figure 3 and figure 4.

![Fig. 3. Performance curve of the Small HydroSink™](image-url)
HydroSink™ performance has been obtained by means of experimental activities and tests have been carried out using tap water without antifreeze.

3.2. Advantages

The system which has been developed is characterized by high thermal performances; its design makes it suitable for concentrated heat sources. These two characteristics overcome two of the main limits of traditional air cooled systems.

The main advantages are related to its flexibility, making it adjustable in existing design, and being made up of standard components combined with customized LCP(s): in this way it is possible to offer a high level of performances mixed with defined components. Even with this high flexibility, the system remains compact.

HydroSink™ is intelligent, thanks to its control board managing all the components and sensor signals. The system is continuously monitored and all the information regarding its state is readily available.

3.3. Reliability and maintenance

Reliability is the main characteristic of HydroSink™. It is based on some design choices related to the main components (pump, fan and controller).

The model of pump and fan are able to guarantee a life span of more than 50,000 hours, while the controller allows the fan and pump to slow down when ambient temperature or power dissipated allows it. The control board also monitors the sensor signals to facilitate maintenance and prevent failures.

On the other hand, a detailed and accurate FMA is the base and guideline of reliable planned maintenance, as it is essential to avoid unplanned service interruptions and to reach the life
expectation. Planned maintenance is mainly related to two aspects: to keep the air filter clean and to refill the refrigerant properly. The air filter permits the fan to work well and protects it from dirtiness, while the refilling of refrigerant will be needed in order to compensate changes over the time. The sophisticated controller assembled on it will guide the operators to facilitate and guarantee the planned maintenance, even if all the relevant information is provided in a maintenance guide: it outlines, highlights and points out all aspects, features, weaknesses, actions and operations that have to be made in order to make the system work correctly.

The basic principle to be followed is that prevention and planned maintenance is the most safe and less expensive way to run a liquid cooling system and to assure long life to the electronic components.

### 3.4. Available versions

HydroSink™ can be provided already installed inside a cabinet (as shown in figure 5 and figure 6) or as separate components: in the case of the latter, the components can be arranged in different ways and positions, according to customer’s needs, giving high installation flexibility (see figure 7).

The above versions are available both for the “Small” and “Medium” size; in the case with cabinet, the maximum dimensions (for the stand alone system, without any LCPs mounted) are respectively:
- 465x400x525 mm (Small)
- 610x400x680 mm (Medium)

The version without cabinet allows different arrangements; there are many possible configurations, with different maximum dimensions. The basic idea is that the final layout can be established by considering the application in terms of requirements (that could be hydraulic, electrical or purely dimensional).

The liquid cold plate(s) can be located inside a customer’s sealed cabinet, with remote location for pump and heat exchanger or close to them, for a more compact solution; the solutions mentioned are available for both versions with and without cabinet.
**HydroSink™**: a smart and more efficient way to cool power electronics

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Fig. 7. Medium HydroSink™ inside a cabinet

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Fig. 8. Small and Medium HydroSink™ without a cabinet – the above arrangement is just an example

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Every version is available with two heat exchanger models: one with low pressure drop (and higher Rth) and another one with better thermal performances (and higher pressure drop).
3.5. Certifications

HydroSink™ (cabinet version) is CE certified (Bologna, 16/02/2015); UL certification is ongoing.

4. Conclusions

HydroSink™ is a high thermal performance system, suitable for concentrated heat sources, flexible and easy to be fitted in with existing designed applications. It is basically a standard system combined with customized liquid cold plates, with a smart controller and cost convenient: a 3 kW air cooling system is more expensive than an equivalent HydroSink™, since the components are considerably more effective.

5. References


6. Contacts

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