HPM therm

Comprehensive CATALOGUE

Power electronics

Heatsinks • Heat exchangers • Accessories

Company introduction

HPM therm, s.r.o. is dynamically developing company focused on machine engineering production in the field of thermal technology. The products are applicable in the products for air conditioning, heating and cooling. The company was established in 1998. The experience of management and the substantial group of employees of HPM therm, s.r.o. in design, construction and production of heat exchangers dates back to 1982. The company has 52 employees. The production activity is carried out in own premises. The company belongs to the major local employees.

The composition of the products produced by the company is as follows:

- Heat exchangers,
- Radiators,
- Heatsinks with heat pipes,
- Liquid cooled heatsinks, and
- Accessories for liquid distribution.

Almost 80% of the company production is exported. In addition to already established markets in Germany, Austria, Czech Republic and Slovakia in technology modernisation, the activities on the markets in Switzerland, France, England, Norway, Poland and Russia grow.

Thanks to its many-year experience in the field of cooling, HPM therm, s.r.o. successfully develops its production program. High quality and reliability of the products is ensured by quality management system pursuant to EN ISO 9001. The products of HPM therm, s.r.o. also meet the strict requirements as for the contents of risky and dangerous substances (RoHS) pursuant to the European Union Directives No. 2002/95/EU and 76/769/EEC.

The fundamental priority for HPM therm, s.r.o. is the quality of products, reliability, observation of the term of delivery and price. It has developed all supporting activities (purchase, supply, input/output inspection warehouse management, transport, safe handling, internal audits, etc.) in order to ensure the priorities.

The engagement of all employees in the process of management and quality improvement is considered to be the decisive way towards prosperity.
We carry out the working activity in accordance with the needs and wishes of our customers. The improvement of quality of our products is achieved thanks to our customer and supplier relationship.

The ultimate satisfaction of our customers is one of the main objectives of our business.

"YOUR SATISFACTION IS OUR OBJECTIVE"

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Heatsinks in general

A heatsink for power semiconductor devices is the device leading away loss power transformed to heat from the place of its origin to the cooling environment (air, liquid). As long as the transfer of heat originated from loss power in a silicon plate of power semiconductor device is not ensured, temperature of PN transitions shall permanently rise, till it comes to the deterioration of the function properties of the power semiconductor device or even its destruction when reaching a certain value. The generated heat cannot be transferred to the environment by casing surface in the case of the power semiconductor device, the device must be fixed to a suitable heatsink.

According to the applied principle of the transfer of loss power from the power semiconductor device to the environment, the heatsinks can be divided to two basic types:
- Air cooled heatsink
- Liquid cooled heatsink

Air heatsinks are further classified according to the method of heat transfer.
Classic - they use thermal conductivity of the material of a heat sink and they are sub-classified according to the production technology to printed, cast, bonded, sheet-metal, etc.
With heat pipes - the cooling part uses the principle of heat pipe for the achievement of the cooling effect. It is the heat-transforming element with closed internal space that is partially filled with heat-transferring substance and its vapours.
Liquid heatsinks use liquid for heat transfer. The properties of the liquid must correspond with the type of application.
Water– very good cooling effects, no or almost no dielectric strength.
Industrial – purified water free from all coarser impurities, very good cooling effects, very small dielectric strength.
Demineralised, deionised water – water free from all minerals, salts or ions. It attacks all materials that may release their ions to water. It must be continuously cleaned and regenerated. Aluminium or copper heatsinks shall be eventually corroded (approximately after years). Very good cooling effects, food dielectric strength.
Transformer oil – very good dielectric strength (ca 26kV/2.5mm), cooling effects worse than in the case of water. It must be dried prior to use. It has high capillary attraction oil distributions are hard to seal.
Fluoroiner - very good dielectric strength (ca 52kV/2.5mm), cooling effects worse than in the case of water. It is very heavy and cannot withstand large flow speeds. The liquid does not endure materials comprising Teflon.

According to the application method, the heatsinks are classified as the heatsinks for one side, double side and column cooling:

Heatsinks for one side cooling

They are applicated at power semiconductor devices in casings of the stud type, tablet type or modular type.
For the power semiconductor devices of stud type, the mechanical connection of the device and the heatsink shall be achieved by screwing to the heatsink. The derivation of necessary mounting force for the provision of defined contact resistance shall be achieved by observing the prescribed tightening torque.
For power semiconductor devices of tablet type with connection with a heatsink and the derivation of the necessary mounting force shall be achieved using special mounting clamp.
In both cases, the heatsink fulfils both thermal and electric function. The heatsink is at potential, thus it must be separated from the carrying structure by an insulation element (e.g. insulator, insulation board made of textit, etc).
For power semiconductor devices of the modular type with connection with a heatsink and the derivation of the necessary mounting force shall be achieved using bolts alongside the module circumference.
Then the heatsink shall fulfil just the thermal function. It is not at potential, thus it doesn`t need to be separated from the carrier structure by insulation.

Heatsinks for double side cooling

They are used for power semiconductor devices of the tablet casing.
The mechanical connection of the power semiconductor device with the heatsink and the derivation of necessary mounting force shall be achieved using special clamping structure. The heatsinks of the type are composed of two parts, out of which every one leads the loss heat away from one side of the power semiconductor device. The properties of the heatsink, as a unit, shall be always specified. Current is lead to the device by contact surfaces of the heatsinks that are modified in such a way the size and stability of transition resistors would be ensured. The heatsink is at potential thus it must be separated from the carrier structure by insulation.

Heatsinks for Column Arrangement

They are used for power semiconductor devices of the tablet casing.

The mechanical connection of the power semiconductor device with the heatsink and the derivation of necessary mounting force shall be achieved using special clamping structure. The heatsinks of the type are fit for assembly in a column. Every heatsink shall lead loss heat away from two power semiconductor devices. Current is lead to the part by inserted outlet or by suitable shaping of the contact block. The heatsink is at potential thus it must be separated from the carrier structure and other heatsinks by insulation.

Design of suitable heatsink

The fault-free operation of semiconductor devices depends upon sufficient cooling.
The following is decisive for cooling design:
- Thermal resistance of the power semiconductor device R_{thjc}
  - it depends upon the structure (type) of the semiconductor device
- Thermal resistance of contact R_{thch} - it depends upon the dimensions and quality of contact area
- Thermal resistance of heatsink R_{thha} - it depends upon:
  - the selection of coolant (air, water, oil)
  - the quantity of coolant
  - size of surface, shape and structure of the heatsink
  - surface treatment of the heatsink

The smallest possible values of the auxiliary thermal resistances shall be achieved by:
- using the entire contact area of the device,
- cleanliness and smoothness of contact areas,
- deriving the prescribed pressure to semiconductor devices,
- covering the contact areas with heat leading contact grease or a contact foil,
- the power semiconductor devices would be placed directly onto the heatsink without using outlets, if possible (by placing the outlet between the power semiconductor device and the heatsink, thermal resistance of the contact shall be doubled).

When designing a suitable heatsink, proceed as follows:

1. For the selected type of power semiconductor device search for the following in the catalogue:
a) The highest allowable temperature of transition T_{jmax} (°C),
b) Internal thermal resistance of the power semiconductor device R_{thjc} (K/W),
c) Contact thermal resistance R_{thch} (K/W),
d) Read the loss power P_z (W), corresponding with the operating current load of the device from the curves of loss power for the used power semiconductor device.

Note: medium loss power P_z (W) can be calculated also using the following method:
- look for the following in the catalogue - threshold voltage V_{TO} (V),
- differential resistance r_T (Ω),
- according to the connection (Table 2) the power semiconductor devices shall work in, you shall determine constants K1, K2 or K3 (Table 1)
- medium current through power semiconductor device I_d (A)

From the formula $P_z=K1*I_d^{2}*r_T+I_d*V_{TO}$ for sine-wave course – where resistance load prevails
or
from the formula $P_z=K2*I_d^{2}*r_T+I_d*V_{TO}$ for rectangular course – where induction load prevails
or
from the formula $P_z=K3*I_d^{2}*r_T+I_d*V_{TO}$ for thyristors with phase control – where induction load prevails
we shall compute the loss power P_z(W)
from the formula $P_z=K4*I_d^{2}*r_T+I_d*V_{TO}$ for thyristors with phase control – where resistance load prevails
we shall compute the loss power P_z (W)

Table 1 - Konstanty K1 a K2

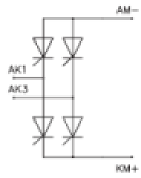
	B6	B2	M6	M3	W1	E1	M2	E1 DC
K1	3,007	2,47	6,015	3,1	2,47	2,47	2,47	1
K2	3	2	6	3	2	2	2	1
K3	$2*\pi/\psi$							
K4	$\pi/(1+\cos\alpha)^2*(\pi-\alpha+\sin(2*\alpha)/2)$							

ψ - angle of thyristor opening
α - angle of thyristor turning on

Table 2 - Basic connection of power semiconductor device

B2

B2C



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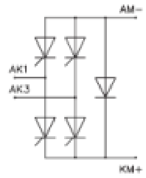

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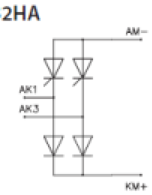

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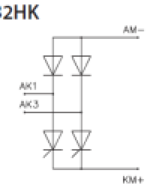

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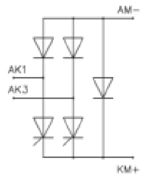

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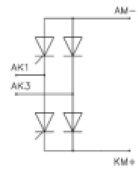

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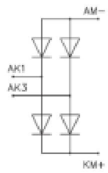

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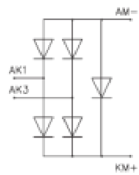
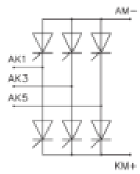


B6

B6C



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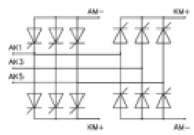

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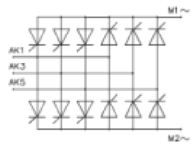

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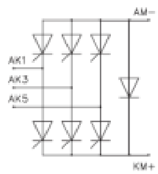

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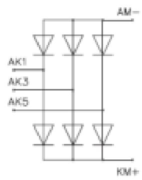

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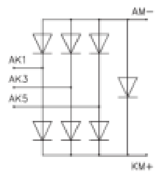
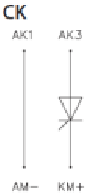


E1

E1CK



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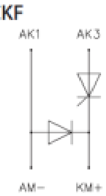

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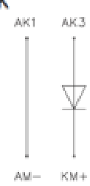

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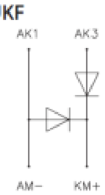
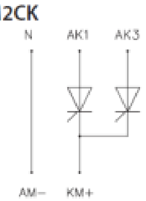
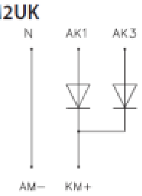


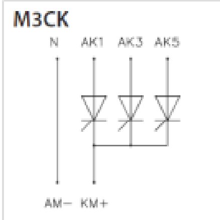
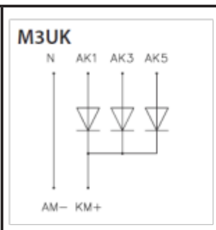
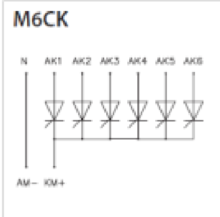
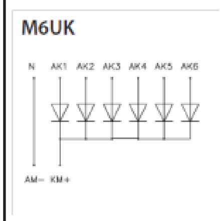
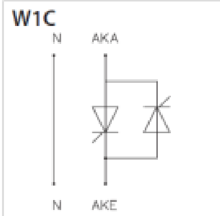
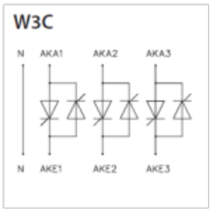
M2

M2CK



M2UK



M3				
M6				
W1				
W3				

2. Ambient temperature T_a (°C) shall be selected, for which there is a presumption the power semiconductor device shall work. Unless otherwise specified, we can consider:

For natural air cooling $T_a = 45°C$
For forced air cooling $T_a = 35°C$
For liquid cooling $T_a = 45°C$

3. The overall heating and thermal resistance of the heatsink based on the fundamental relationship shall be calculated from the obtained values:

$\mathbf{R_{thja} = dT_{ja}/P_z}$ **(K/W = K/W)** where $\mathbf{R_{thja} = R_{thjc} + R_{thch} + R_{thja}}$ **(K/W = K/W+ K/W+ K/W)**
$\mathbf{dT_{ja} = T_{jmax} - T_a}$ **(K = °C - °C)**

by entering the values to the fundamental relationship, rearrangement of the equation and entering the known values we shall calculate R_{thha} (K/W).

You must be careful in the calculation and consider whether it is one side, double side or column arrangement of cooling and how many power semiconductor devices is on one heatsink (e.g. 2 power semiconductor devices - modules on a common heatsink).
For power semiconductor device, R_{thjc} it is usually distinguished between one side cooling, cooling through cathode or anode side. In the case it is not stated and just one value is specified, in the majority of cases it shall be the value for double side cooling, the value for one side cooling shall be achieved by entering the values to the formula:
$\mathbf{R_{thjc\ anode\ (cathode)} = R_{thjc}*2}$ **(K/W)**

Difference between anode and cathode can be neglected since the substantial part of R_{th} is in the heatsink.
For power semiconductor device of a modular type, you must take care whether R_{thjc} is specified for the entire module or for the individual semiconductor chips. The module can comprise from 2 to 6 chips according to the internal wiring. In the majority of cases, R_{thjc} is specified for the entire module. As long as just one chip shall be used in the module, R_{thjc} can be modified.

For contact thermal resistance R_{thch}, the value for double side cooling is stated in the majority of cases. Unless otherwise stated, the value for unilateral cooling shall be obtained by entering the values to the formula:
$\mathbf{R_{thch\ anode\ (cathode)} = R_{thch}*2.}$

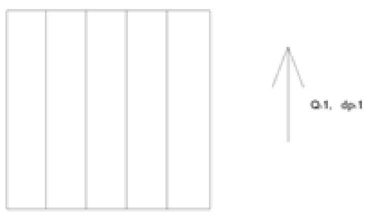
The value of R_{thha} is specified for heatsinks by manufacturers or suppliers according to the type of the heatsink and its application. They distinguish one side, double side and column arrangement of heatsinks. Thus it shall be possible to look for the relevant heatsink according to the specified value. In general, we can say the following relationship applies to the individual values of R_{thha}:

$R_{thha\ double\ side} \cdot 2 = R_{thha\ one\ side} = R_{thha\ column} \cdot 1{,}31$ až 1,05 (lower values apply to natural cooling)

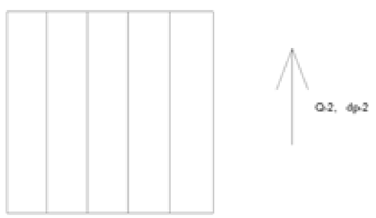
4. The suitable heatsink and speed (quantity) of coolant shall be determined according to the catalogue using the calculated necessary value of thermal resistance R_{thha} . The found heatsink must have the value of R_{thha} identical or smaller than the calculated value.

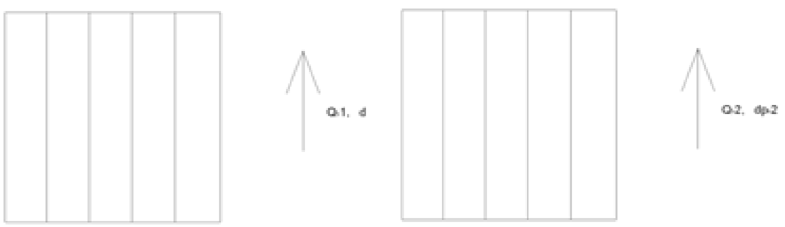
For natural cooling, we consider the size of loss power that have the significant impact on the cooling effect of the heatsink. The profile heatsinks must be located in the devices in such a way their fins would be in vertical position. As long as the heatsinks are located in the devices directly above each other, the sucked cooling air of the upper heatsink shall be warmer than that one of the lower ones. When designing the applications, it shall be necessary to consider the fact. In addition, the effects of the other heat sources may not be neglected in a closed space. It is helpful to use a suitable shaping of the air tunnel, when it is possible to make use of so called chimney effect and thus improve cooling by 25% already. As long as we get the heatsink eloxal-coated in black, cooling shall be improved by another up to 20% since we add emitting component to the radiation component.

As for forced cooling, in addition to the functionality of thermal resistance and the speed of coolant, the functionality of pressure loss and speed or the quantity of coolant is important as well. The quantity of coolant and pressure loss are usually specified for one heatsink. As long as there are n profile heatsinks connected in the device in parallel, then the overall quantity of cooling air to be supplied by a fan shall be equal to the n-multiple of the quantity for one heatsink. Likewise, as long as there are n profile heatsinks connected in series (above - behind each other), the overall pressure loss shall be equal to the n-multiple of pressure loss for one heatsink. However, this holds true only supposing the quantity of air necessary for cooling is identical for every heatsink.



$Q_h1 = Q_h2$; $dph = dp_h1 + dp_h2$





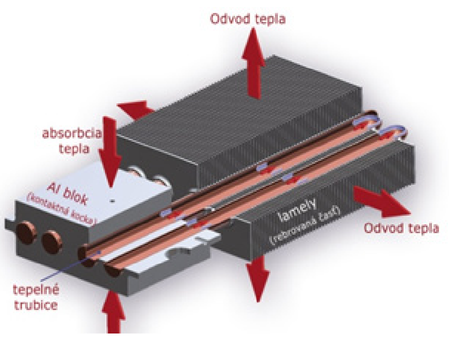
$Q_h = Q_h1 + Q_h2$; $dp_h1 = dp_h2$

The given procedure of heatsink design is intended in particular for the stable operation condition of the device. When designing cooling for devices in pulse operation or with operation overload, one must come from the curves of transient impedance of the power semiconductor device, heatsinks and contact resistors, the course of which is stated in the catalogues or specifications.

Air cooled heatsinks with heat pipes

Thanks to their parameters, the heatsinks with heat pipes squeezed between the classic air heatsinks and liquid heatsinks. They use the basic principle of the classic air heatsinks - blasting of the fins with air and the principle of liquid heatsinks - transfer of heat away from the semiconductor device using liquid and vapours.
The heatsinks use the principle of heat pipe for the achievement of the cooling effect. It is the heat-transforming element with closed internal space that is partially filled with heat-transferring substance and its vapours. Heat pipe is a closed system using high intensity of heat sharing upon the phase transformation of the heat-transferring substance. The loss power from semiconductor device is transferred via the contact block to the evaporator part of the heat pipe where it comes to the evaporation of the heat-transferring substance. The intensive thermal flow from the evaporator part to the condensation part of the heatsink is transferred by the vapour phase of the heat-transferring substance. The reversible flow of the condensate takes place due to the temperature difference of the condensation and evaporator end of the heat pipe. The transfer of heat from the condensation end equipped with fins is achieved by air flow.

The heatsink with heat pipes is composed of 3 basic parts that are not demountable from each other:
Contact block – aluminium block serving for the mechanical, electric and thermal connection of power semiconductor device to the heatsink. Heat from the semiconductor device aims to the heat pipes and it balances possible irregularities in the heat transfer. It is the part that may be designed by the user themselves after an agreement.
Heat pipe – a copper pipe with a liquid the function of which can be described in a layman manner as follows - there is a liquid in the copper pipe that shall start boiling due to the impact of the loss power. Vapours rise up in the centre of the pipe to the finned part. There is a heatsink environment, so they shall start condensing on walls. The drops flow due to gravitation and vapour pressure downwards to warmer place, where they shall again vaporize and the cycle repeats. The speed of the cycle approximates the sound speed.
Finned part – the part of the heatsink serving for the transfer of heat to environment - air. Fins forming the finned part are strongly mechanically joined with heat pipe. Size, shape and number of fins are given by the production technology and power that must be cooled by the heatsink.



Properties of heatsinks with heat pipes:

- Savings in built-up volume and weight. Classic aluminium heatsink with the same parameters shall be much larger and heavier.

- High operating reliability. The heatsinks can withstand even rather “rude” handling. There is no risk they would disintegrate or become leaky (the leak of heat-carrying liquid).

- Excellent cooling properties

- Very fast response to the change of the load of semiconductor device. Very fast start-up and stabilisation of temperature of heatsink. The stabilised value of the heatsink shall be achieved in minutes.

- Time of heating the heatsink from ambient temperature to the stabilised condition shall be the same as the time of cooling from the stabilised value to the ambient temperature.
Note: as long as you know the system shall be pulse overloaded, you must consider the overload.

- Heat pipe is functioning only in the position where the contact block is below finned part. The working tilt of the heatsink is from 10° to 170°. R_{thha} shall change with position just slightly
Note: There are exceptions when heat pipe is equipped with sinter sieve, etc. The working tilt of the heatsink is from -10° to 190°.

- The construction of the heatsink itself implies the finned part is at potential.
Note: There is an exception again where the heat pipe is interrupted between the contact block and finned part by ceramic insertion and filled with non-conductive heat-carrying substance.

- According to the used heat-carrying substance, the heatsink with heat pipes can be operated just for ambient temperatures above 1°C (water), -40°C (alcohol), -60°C (fluoroinert).

- The optimum highest ambient temperature is recommended, 45°C for natural cooling and 35°C for forced cooling. However, they successfully work also at ambient temperature of up to 80°C. R_{thha} shall change in dependence upon temperature. Thermal resistance R_{thha} of the heatsink with heat pipes is specified as a standard for ambient temperature of 20 - 35°C. In the direction towards negative and positive temperatures, R_{thha} shall be increased.

- The thermal power of the heatsink with heat pipes ranges from several W to kW. There is a small paradox. As long as strongly oversized heatsink is used e.g. standardized for 800 W for leading away loss heat of 40W, the heatsink shall not be functioning or would perform badly. The delivered heath would not transform the heat-carrying substance (liquid) to vapours, since it is lead away by the wall of heat pipe. Thus the heatsink shall perform as the classic aluminium one or even worse.

- The number of heat pipes and their diameter provides us with the idea of the thermal power of the heatsink.

- The heatsinks are well suitable for systems in column arrangement. It has an advantage there are minimal distances, due to the parasitic inductance. Take care after the shifted length. It must not come to the sagging of the column and max. and min. mounting force at the semiconductor device cannot be exceeded.

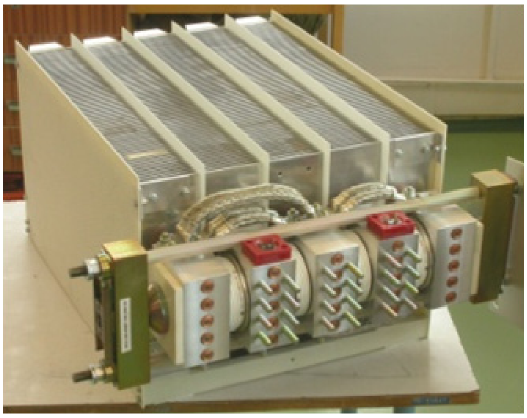
- The heatsinks with heat pipes can be used in both stationary applications (rectifier stations, distribution centres, etc.) and rail applications (trains, trolleybuses, etc.)

- They do not present any environmental load, when observing the act on waste.

- The area with semiconductor device can be well-separated from the area with cooling air flowing. This brings about greater cleanliness of environment for semiconductor device.

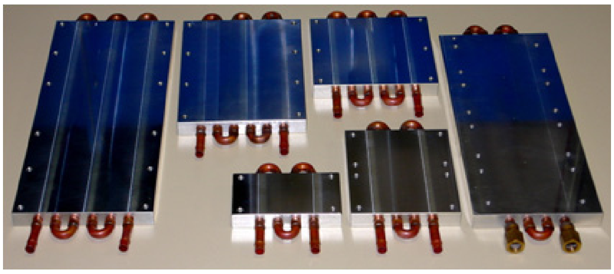
- The heatsinks can be divided to the heatsinks for natural cooling and forced cooling. They can be differentiated according to several characteristics. The heatsinks for natural flow have stronger and larger fins with greater distance from each other and they work almost in horizontal position in the majority of cases. The heatsinks for forced cooling have smaller and more compact fins

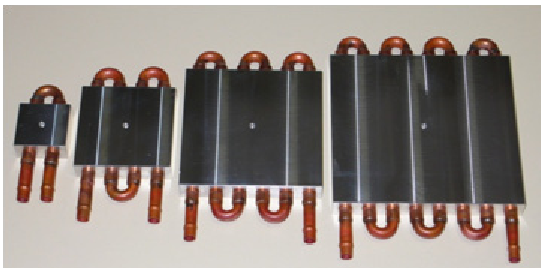
- An air tunnel for leading cooling air and separation of the individual potentials – finned heatsinks in the system is always made around the evaporator part. For forced cooling, the cooling air shall be directed in the desired direction and a tunnel shall be made for natural cooling in order to enlarge the chimney effect.
Note: in the case of natural cooling, temperature of cooling air leaving the system can be even 160°C



Liquid cooled heatsinks

Liquid cooled heatsinks represent the most powerful heatsinks that can be used for cooling of power semiconductor device. They make use of the principle of heat transfer from solid substance to the cooling medium - coolant, liquid, leading heat away from the semiconductor device. They are characterized by solid structure with small built-up volume per unit of outlet power and they are intended for forced flow of the coolant. In addition, they are designed in such a way they would facilitate a simple arrangement in various electrically connected groups according to the need of a customer.





Recommended coolants

The manufacturer of heatsinks lets a customer to select the coolant, since it fully relates to the design of the cooling circuit of the alternator or the entire substation. The following coolants are suitable:
Industrial water (electric resistivity of ca 10^3 Ωm) not treated, slightly polluted water. When using it, it comes to the sediments of scales in heatsinks, sensors, therefore it shall be necessary to more frequently clean the hydraulic circuit so that the cooling conditions would not be deteriorated and to make the check for the correct function of sensors. Dielectric strength is minimal. Suitable for cooling of power semiconductor modules and power semiconductor devices of tablet type in the applications with very low voltage and sufficiently long connection hoses (electroplating industry, etc.). The range of application temperatures is from 5°C to 95°C at normal pressure.
Distilled water pure, treated water with the residues of minerals and ions. When using it, scales sediment to the minimum extent. The hydraulic circuit is very stable and the functionality of sensors is problem-free. Suitable for cooling of power semiconductor modules and power semiconductor devices of tablet type in the applications with low voltage and sufficiently long connection hoses. The range of application temperatures is from 5°C to 95°C at normal pressure.
Demineralized water (electric resistivity of ca 10^5 Ωm) pure, treated water with the residues of ions. When using it, the material of the hydraulic circuit is slightly attacked. Despite that, the hydraulic circuit is very stable and the functionality of sensors is problem-free. With regards to the gradual reduction of water quality, it shall be necessary to insert a filter to the circuit. Suitable for cooling of power semiconductor devices of tablet type in the applications with low voltage and sufficiently long connection hoses. The range of application temperatures is from 5°C to 95°C at normal pressure.
Deionised water (electric resistivity of ca 10^6 Ωm) pure, treated water with no ions at all. When using it, the material of the hydraulic circuit is heavily attacked (corrosion). Deionised water is aggressive at room temperature to all metal materials. It becomes strongly corrosive also for noble metals, such as stainless steel at the temperature above 45°C. It cannot be operated above 80°C due to the compactness of filters the hydraulic circuit must be equipped with in order to maintain the quality of water and thus its dielectric strength (ionisation filters). Filters must be regularly replaced. The material of the hydraulic circuit must be selected with regards to the strong corrosive properties of deionised water. In majority of cases, the heatsinks are made of copper, less frequently from aluminium and stainless steel. They select such a material that belongs to the noble metals from the point of view of corrosive properties. We can prolong the operation life of the hydraulic circuit by the selection; however we cannot prevent the corrosion of material the hydraulic circuit is made of. It is suitable to design the main distributions from plastic, which is not attacked by deionised water, pump from stainless steel and heatsinks from stainless steel or copper, it shall be necessary to replace the heatsinks more frequently. It is suitable for cooling of power semiconductor devices of tablet type in the applications with high voltage and sufficiently long connection hoses. The range of application temperatures is from 5°C to 95°C at normal pressure.
Transformer oil (electric resistivity of ca 10^9 Ωm). When using it, the value of thermal resistance R_{thha} of the heatsink and distribution must be modified. You must consider the change of viscosity of oil in dependence upon operating temperature and to amend the pump parameters accordingly. The hydraulic circuit is very stable and the functionality of sensors is problem-free. Transformer oil can bind water. For this reason, it must be dried before use and operated in a closed hydraulic circuit so that its dielectric strength would not deteriorate. It has high capillarity and the hydraulic circuit must be well sealed. Suitable for cooling of power semiconductor devices of tablet type in the applications with high and very high voltage and sufficiently long connection hoses. The range of application temperatures is from -40°C to 150°C at normal pressure.

Fluoroinerts (electric resistivity of ca 10^8 Ωm). When using them, the value of thermal resistance R_{thha} of the heatsink and distribution must be modified. You must consider the change of viscosity of liquid in operating temperature and to amend the pump parameters accordingly. The hydraulic circuit is very stable and the functionality of sensors is problem-free. Fluoroinerts can vaporize even at room temperature. Thus it must be operated in a closed hydraulic circuit so that it would not vaporize to air. They are health-safe, very heavy and have very low value of specific heath. They are hard to transport in the hydraulic circuit by a pump without being heated. They require especially careful procedure when designing the hydraulic circuit. They are suitable for cooling of power semiconductor devices of tablet type in the applications with high and very high voltage and sufficiently long connection hoses. The range of application temperatures is from -80°C to 200°C at normal pressure. In the case of leakage from cooling circuit, they do not damage the electric device. They cannot come to the contact with material comprising teflon. When exposed to the impact of fluoroinert, teflon shall swell and becomes leaky.
Non-freezing mixtures (electric resistivity of ca 10^1 Ωm) treated distilled water with an admixture of sugars and other substances for the achievement of suitable properties at low temperatures. When used, the value of thermal resistance R_{thha} of heatsink and distributions must be modified. You must consider the change of viscosity and density of liquid depending upon the operating temperature and to amend the pump parameters accordingly. Some types of liquids start separating - decomposing at temperature over 60°C. This phenomenon is irreversible. The hydraulic circuit is very stable and the functionality of sensors is problem-free. Suitable for cooling of power semiconductor modules and power semiconductor devices of tablet type in the applications with very low voltage and sufficiently long connection hoses. The range of application temperatures is from -40°C to (60°C) 95°C at normal pressure.

Liquid cooled heatsink design

Liquid heatsinks are designed in the similar way as the air ones. The majority of manufacturers states the thermal resistance of a heatsink R_{thha} (K/W) for water. As long as the user wants to use another cooling agent, it shall be necessary to modify the value of thermal resistance R_{thha}. Using a fast and simple method, just for informative purposes the value of thermal resistance R_{thha} can be calculated using specific heath c (J/kg/K)

$$\mathbf{R_{thha\ coolant} = R_{thha\ water} * c_{water} / c_{coolant}}$$

The table specifies the specific heat c of some liquids at 20°C

Liquid	Specific heat c (J/kg/K)
water	4183
transformer oil	1892
methyl alcohol	2470
glycerol	2428
ethylene glycol	2382
ethyl alcohol	2470
fluoroinerts	1100

Connection Hoses

The connection hoses are suggested according to the particular application. Their task is to deliver cooling medium to liquid heatsink in a sufficient quantity, to balance mechanical inaccuracies of distribution during assembly, facilitate thermal dilatation so that the possible forced would not stress the system with semiconductor devices and electrically insulate potential on the heatsinks from earthed hydraulic circuit.
Diameter of connection hoses should be selected according to the sockets on heatsinks and it should have the internal diameter asimilar to the internal diameter of the socket. Never use hose with internal diameter smaller than the internal diameter of the socket.
End-pieces of hoses can be presser and they must correspond with the end-piece on a heatsink it shall be screwed in afterwards. You may use hose without end-pieces. It should be pulled over the socket of the heatsink equipped with a protrusion preventing slipping down and secured with hose clamp.
Length of hoses should be selected in such a way the heatsink could easily dilate against the mounted collector, i.e. the connection shall form S shape - consider the radius of hose bending. A loop can be made as well, but pay your attention to pressure loss. The length of hoses shall depend also upon the used cooling liquid and the required dielectric strength.
Version of hoses should be selected with regards to the operation pressure, testing pressure, operating temperature, testing temperature radius of hose bending. It is suitable to use raided or double-layered hoses for normal application, armour-plated where there is a risk of mechanical damage and it does not matter they are electrically conductive. CAUTION - some hose types are filled with carbon particles and they are electrically conductive.

Pump

The design of the pump comes from the concept of a hydraulic circuit and the requirement of power semiconductor devices.
- Coolant flow rate - to be determined according to the quantity and connection of liquid heatsinks.
- Overall pressure hydraulic loss - is the sum of pressure hydraulic losses of liquid heatsinks according to the quantity and connection, heat exchanger, connection hoses lengths and shape of distribution, sensors, height difference, etc.

The flow rate of heatsink and the overall pressure hydraulic loss determines the working point of the pump. The pump shall be designed pursuant to the working point. The parameters of the pump are usually stated for water. As long as other coolant shall be used in the hydraulic circuit and not water, you must consider density, viscosity and the range of operating temperatures of the coolant when designing it.

Hydraulic Circuit

The cooling circuit is composed of and outlined according to the application it should cool down.
Single-circuited - its task is to transport the coolant using the pump from the tank to the heatsinks where the coolant shall take heat, further to the heat exchanger, where heat is delivered to the ambient environment and it returns back to the tank under the defined conditions.
Multi-circuited – one common tank is the reservoir of the coolant for several single-circuited hydraulic circuits.
Complex single-circuited – hydraulic circuit composed of two pumps, when one pump delivers the coolant from the tank to the heatsinks, where the coolant takes heat and returns back to the tank under the defined conditions and the other pump transports the coolant from the tank to the heat exchanger, where heat is delivered to the ambient environment and it shall return back to the tank under the defined conditions.
Complex multi-circuited – one common tank is the reservoir of the coolant for several complex single-circuited hydraulic circuits, where just one pump delivers the coolant from the tank to the heat exchanger, where heat is delivered to the ambient environment and it shall return back to the tank under the defined conditions.
Separated single-circuited – the same principle as in the case of a complex single-circuited hydraulic circuit, but there is a heat exchanger of liquid-liquid type in the tank. Second pump transporting other coolant to the heat exchanger, cooling tower shall thus be hydraulically separated from first pump.
Multi-circuited, complex separated - the same principle as in the case of composed multi-circuited hydraulic circuit, but there is a heat exchanger of liquid-liquid type in the tank where just one pump transports another liquid to the heat exchanger, cooling tower and it is thus hydraulically separated from the other pumps.

The cooling circuit must be able to respond to sudden situations such as the loss of liquid, sudden increase in temperature of liquid, unusual pressure or flow rate of coolant in the cooling circuit.
In the majority of cases, it shall be composed of:

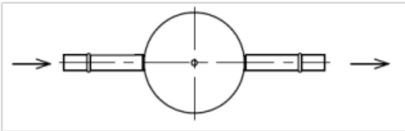
pump,
heatsinks,
mounted collector,
leads and hoses,
heat exchanger with a fan (liquid-liquid heat exchanger)
liquid reservoir,
temperature, flow, pressure, level sensors,
discharge valve, bleeder valve, emergency pressure valve, feeding valve, and
control unit.

Arrangement of the hydraulic circuit should be selected in such a way it would facilitate simple venting, filling up, drainage, assembly, maintenance, replacement of the hydraulic circuit components, thermal dilatation, prevented possible liquid leakage to the electric part or outside the area of the entire device.
In majority of cases, the pump and tank are located in the lowermost part of the hydraulic circuit; there are usually heatsinks with mounted collectors in the central section and a heat exchanger in the upper section. Pressure and flow sensor should be included to the pump delivery. Thermal sensor to the tank, before and behind the heatsinks.
Design of the hydraulic circuit is governed by hydraulic and thermal laws. All the branches of the hydraulic circuit must have the same pressure loss. Thus you shall ensure the same flow rate for liquid heatsinks.

The pump and the power of heatsinks shall be dimensioned according to the type of the connection of heatsinks:

Simple Connection

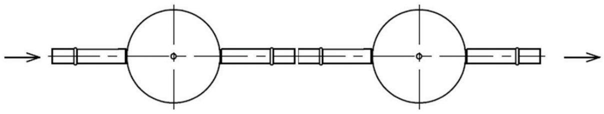
Q_h, Δp_h, T_{a1}



T_{a2}

When dimensioning the pump, the flow rate of the coolant via heatsink corresponds with the flow rate of the coolant supplied by the pump. The pressure of coolant supplied by the pump is the sum of the pressure loss of the heatsink and the losses in the coolant distributions.

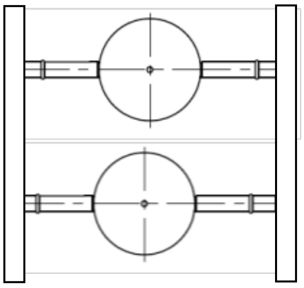
Connection in Series



Q_h, 2x Δp_h, T_{a1} **T_{a2}** **T_{a3}**

In the connection, T_{a2} must meet the condition $T_{a2} = T_a$ prescribed by the manufacturer.
When dimensioning the pump, the flow rate of the coolant via heatsink corresponds with the flow rate of the coolant supplied by the pump. The pressure of coolant supplied by the pump is the sum **n** x pressure loss of the heatsink and the losses in the coolant distributions.

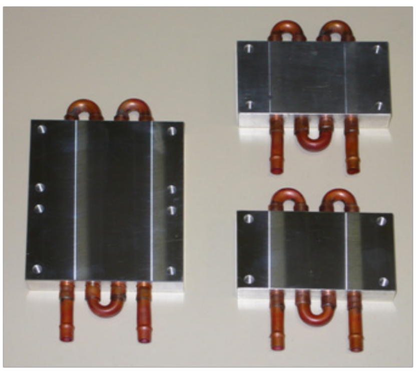
Connection in Parallel

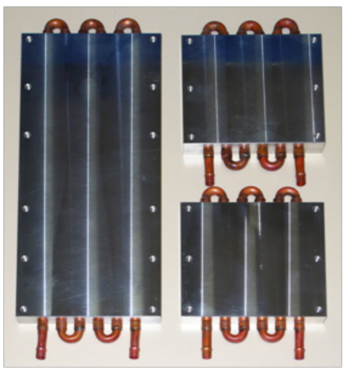


2xQ_h, Δp_h, T_{a1} **T_{a2}**

When dimensioning the pump, the overall flow rate of the coolant is **n** x flow rate of the coolant via the heatsink. The pressure of coolant supplied by the pump is the sum of the pressure loss of the heatsink and the losses in the coolant distributions.

Note: **n** - No. of heatsinks in circuit

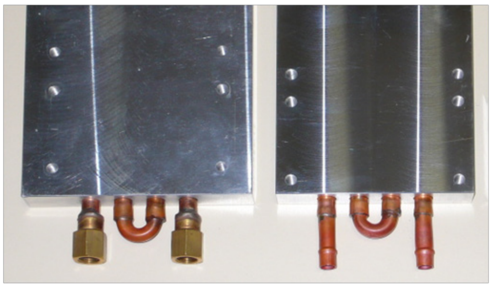




Accessories for liquid cooled heatsinks

Accessories for liquid heatsinks are parts facilitating electric and hydraulic connection of liquid heatsinks in the assembly with power semiconductor device. This is the basic accessories in offer. In the case of the other requirements for the parts, it is possible to make the modification of the existing parts or the fabrication of absolutely new parts.

- All liquid heatsinks are completed without fitting. By selecting the type of the fitting according to the habits of the user, it is possible to connect the hoses to the liquid heatsink with distribution of coolant
- Using the mounted collectors of coolant the heatsinks can be controlled in parallel supposing the total hydraulic losses of the individual liquid heatsinks connected in parallel are identical.
- When using the power semiconductor device of a lozenge type with liquid heatsink, outlet for easier connection of strap steel and cables can be included in the electric circuit. The outlet should not be included between the semiconductor device and the heatsink, but after the heatsink.



Heat exchangers

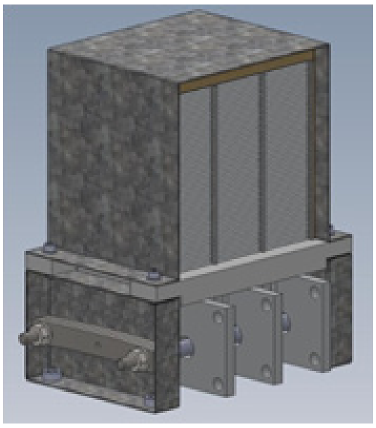
The heat exchangers of liquid-air type are a separate group of accessories for liquid heatsinks. A heat exchanger is the device serving for the exchange of thermal energy between liquid and air. Their fundamental activity is the cooling of liquid (coolant) heated up by heat loss from power semiconductor devices to the temperature of ca 45°C. Unless otherwise stated, the temperature is considered to be max. input temperature of coolant for liquid heatsinks.
The heat exchangers are tubular, finned in a steel frame ready for building-in.

The application of heatsinks with heat pipes and liquid cooled heatsinks:

The heatsinks with heat pipes and liquid heatsinks are suitable for every power semiconductor device. By connecting the heatsink, power semiconductor device, or down-force, outlet, etc. a heatsink assembly shall be formed. The heatsink assemblies are designed in so called “blocks” (column arrangement of heatsinks with air tunnel or liquid distribution, down-force and power semiconductor device of the tablet casing) with advantage, however they may be used also separately (a heatsink with the module). The shape and size of the contact block shall adapt to the power semiconductor device and the mechanical method of electric connection.

The heatsinks are thus suitable for all known power semiconductor devices in any casing:

- Diodes,
- Thyristors,
- IGCT, and
- IGBT



Heaters

Heaters are devices capable of heating the relevant element using electric energy. They are used for tempering of systems (heatsink - semiconductor device) at very low temperatures, maintenance of minimal operating temperature of heatsinks for the removal of large temperature cycles of modules, etc. The advantage of the heaters is the contact heating by frontal area. They do not require any special modification of the heated element. They have the same requirements for the contact area of the heatsink and assembly as power semiconductor devices. The heater may be screwed or pressed to the heated element. It may be the part of the assembly with clamping structure.
The body of the heater is made of stainless steel. The non-contact area is thermally insulated by the pair of insulation boards.
Every heater is equipped with:

- Thermocouple for the control of internal temperature
- Electric outlets for easy supply of electric energy.

Supply voltage is selectable from 24 V to 230 V AC or DC.
Operating temperature of the heater is max. 300°C.

Heatsink testing laboratory

HPM therm s.r.o. has its own testing laboratory of air heatsinks and liquid heatsinks. The testing laboratory is equipped for the execution of development, type tests or piece tests in the case of small series.

Testing laboratory parameters:

- Cross-section of air tunnel	600 x 600 mm (max. diameter)
- Quantity of cooling air	0 – 4200 m^3/hour / 1000 – 0 Pa
- Power of the source imitating the loss power	0 - 5 kW
- Quantity of cooling liquid	2 – 40 l/min

Equipment of the testing laboratory:
60-channel measuring, recording and evaluating device
Pressure loss measurement
Coolant flow rate measurement
Measurement of temperature by thermocouples of T type

The company offers the possibility of measurement of tailored air and liquid heatsinks, semiconductor assemblies, heat exchangers, etc.

Contact data for design, heatsink selection

As long as you need the consultation regarding the selection of the heatsink or the design of a heatsink not specified in the catalogue, answer the following questions or describe your requirements in brief.

- Cooling type
    - liquid cooled
    - air cooled
        - natural
        - forced

- Operational temperature conditions
    - min. ambient temperature
    - max. ambient temperature

- Type (casing dimensions) of the power semiconductor device

- Method of semiconductor device cooling
    - One side,
    - Double side,
    - Column.

- Thermal resistor of the heatsink or loss power of the power semiconductor device (in the case of doubts enter the type of connection and required output current)

- Space restriction - size of the area the heatsink should be located in

- Location (distribution room, rail application, chemical operation, etc.)

- Quantity of coolant (as long as it is predetermined)

- Structural arrangement of the assembly (position electric and hydraulic outlets, etc.)

- Requirement for insulation strength

<u>Your requirements should be sent to the address:</u>

office@hpmtherm.eu

or

kalcik@hpmtherm.eu

Explanatory notes

Every catalogue sheet describes the basic heatsink properties in a comprehensive way. More detailed information are stated in specification of the particular heatsink.

<table>
<tr><td colspan="2">HPM therm</td><td colspan="3">Identification</td><td rowspan="4">Power</td></tr>
<tr><td colspan="5">Name</td></tr>
<tr><td colspan="2">Photo</td><td colspan="3">Drawing</td></tr>
<tr><td>Symbol</td><td colspan="2">Parameter, data</td><td>Value</td><td>Unit</td></tr>
</table>

The contents and acronyms used in the catalogue sheet:

Identification – heatsink drawing number
Name – heatsink type
Power – orientation value of heatsink power
Photo – product photograph
Drawing – drawing of the product with main dimensions
Symbol – symbol of the particular parameter
Parameter, data – the given parameter with data regarding the condition of its validity
Value – the value of the parameter in the form of numerical data or in the form of a graphic representation.
Unit – parameter unit
R_{thha} - thermal resistance heatsink - ambient. Supplemented by the method of product heating up the size of the casing of the semiconductor device and a reference to the recommended quantity of coolant.
Q_h - Recommended quantity of coolant (liquid, air - valid for the given direction of flow according to STP
STP – Volume flows of gases transported in the piping are converted to the internationally recognized state values STP (Standard Temperature Pressure), ti.e. temperature 0 oC and pressure 101,325 kPa (pursuant to ISO 10780)
$Q_{h\ dle\ STP} = Q_h * p_{st}/p_n * T_n/T_a$ **(m^3/hod = m^3/hod * Pa/Pa * K/K)**

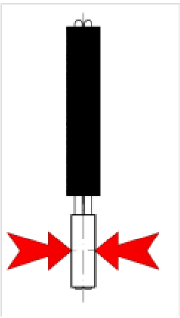
where p_n - standard pressure (STP) - 101 325 Pa
T_n - absolute standard temperature (STP) - 273,15 K
T_a - air temperature
p_{st} - static air pressure before the heatsink

T_{amax} - T_{amin} - Coolant operating temperature range
Δp_h - Hydraulic loss for recommended amount of coolant
G_h - Heatsink weight
α - Working position - tilt the heatsink works in

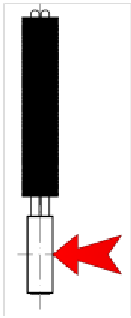
Unless otherwise specified, the following values applied to the products:
Climatic resistance acc. ČSN EN 60068-2 and related standards - 40/110/21
Vibration resistance acc. ČSN EN 60068-2-6, Test Fc 4/55/0,75/6 - 3 g
Shock resistance acc. ČSN EN 60068-2-75, Test Eb 25/6/1000 - 3g
Surface treatment - no
Heatsink colour - natural metal
Working environment for heatsink (typical) acc. ČSN 332000-3
- AA2/AA5, AC1, AD1, AE1, AF1, AG2, AH2, AK1, AL1, BA5

1) Method of heatsink stressing (heating up)

double side heatsink heating

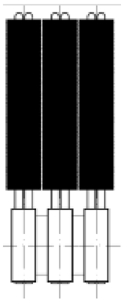


one side heatsink heating

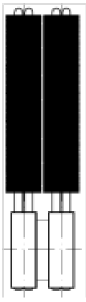


2) Method of semiconductor device cooling

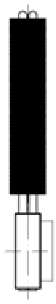
Column arrangement of cooling



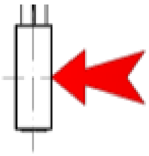
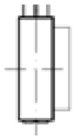
double side cooling

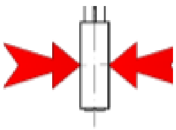
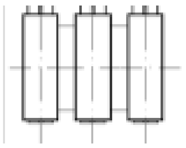


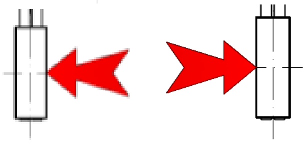
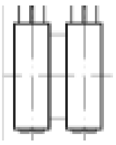
one side cooling



Method of heatsink stressing (heating up) / Methods of semiconductor device cooling

one side heatsink heating  = one side cooling 

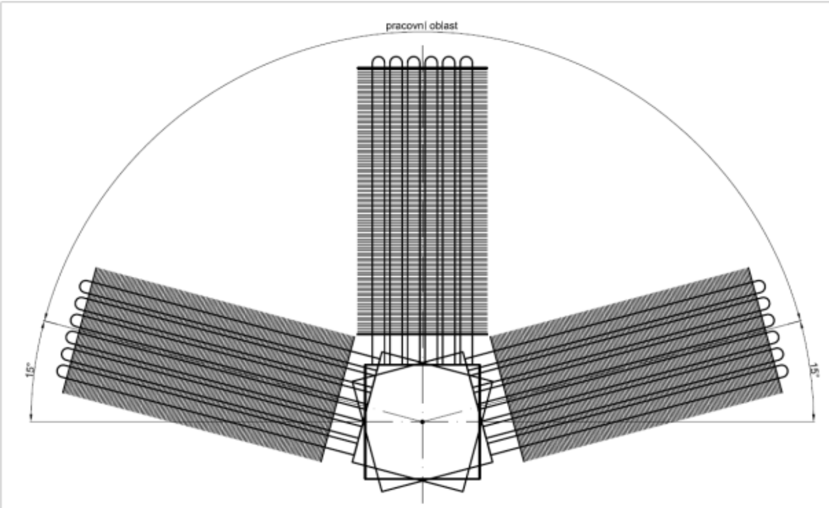
double side heatsink heating  = column arrangement of cooling 

half of one side heatsink heating  = double side cooling 

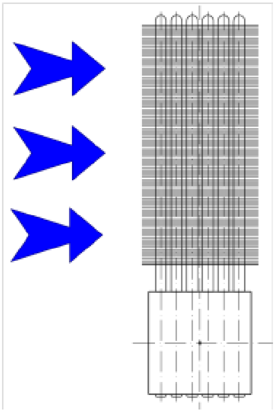
Application:

- For one side cooling of semiconductor device, the value of thermal resistance R_{thha} for one side heatsink heating shall be considered
- For double side cooling of semiconductor device, the half of the value of thermal resistance R_{thha} for one side heatsink heating shall be considered
- For column cooling of semiconductor device, the value of thermal resistance R_{thha} for double side heatsink heating shall be considered

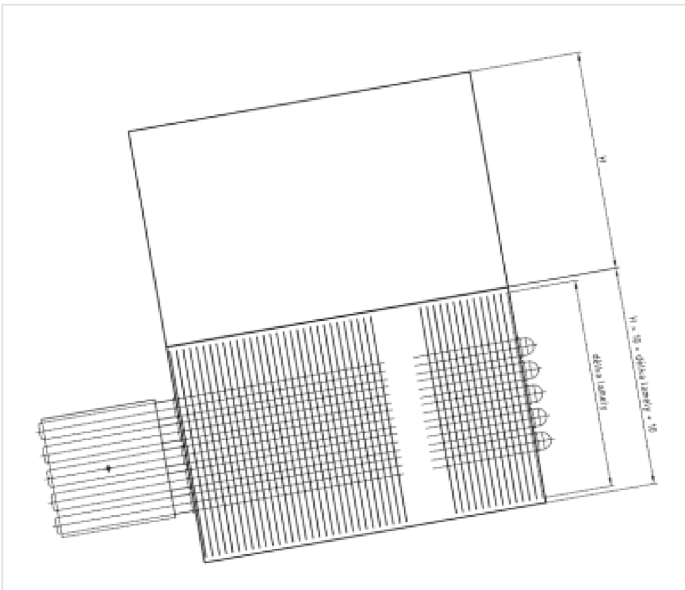
3) Working position of the heatsink (example)



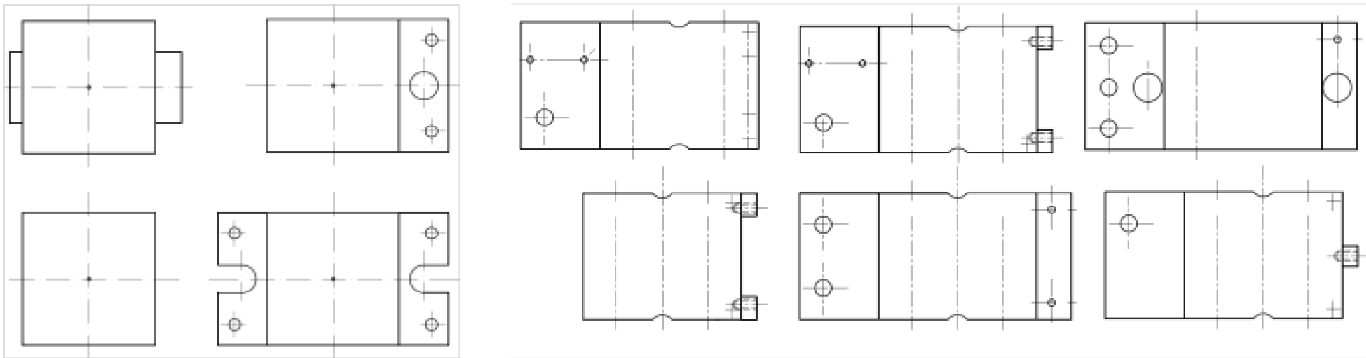
4) Recommended coolant flow direction



4a) Height of air tunnel for natural cooling



5) Structural possibilities – we offer various types of contact blocks facilitating the variability of electric connection:



The examples of contact block types.

NOTES