PAH75D24 SERIES

THERMAL DESIGN

LAMBDA

DENSEI-LAMBDA

POWER MODULE

DRAWING NO. : PA565-04-02A		
NLS R&D		
PREPARED	CHECKED	APPROVED
7/6/02	7/6/02	7/6/02
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The thermal design are in the followings next few pages. Before that please read the caution below for installation of heatsink.

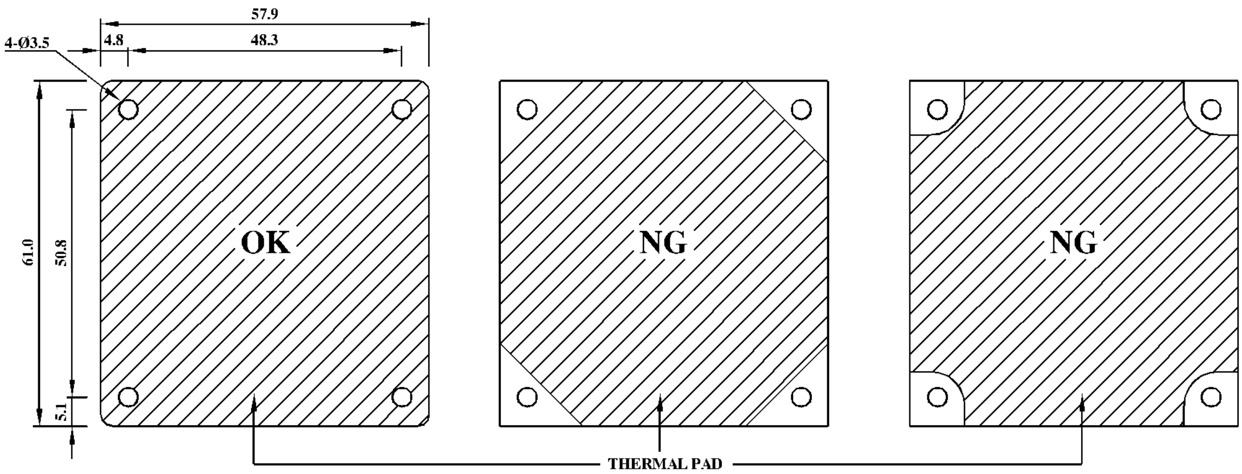
Caution for Heatsink Installation

1) The power module is fixed to the heatsink by 4 position through the M3 mounting tapped holes provided on the baseplate. It is recommended that the sequence to screw the 4 screws is in a diagonally manner and the recommended torque is 5.5kgcm.

2) Recommended hole diameter for heatsink = 3.5mm.

3) Use thermal grease or thermal sheet in between heatsink and baseplate to minimize the contact thermal resistance. However, make sure that the thermal grease or sheet is evenly applied and using no-warped heatsink in order to avoid any warpage on the baseplate.

4) Recommended thermal sheet is as shown below. Cutting the corner of thermal sheet is NOT advisable.



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1. THERMAL DESIGN

To ensure proper operation of power module, it is necessary to keep the baseplate temperature within the allowable temperature limit. The reliability of the system is determined by design of the baseplate temperature.
The process of thermal design is described through an example of PAH75D24 Series. The flow chart is shown in Figure1-1.

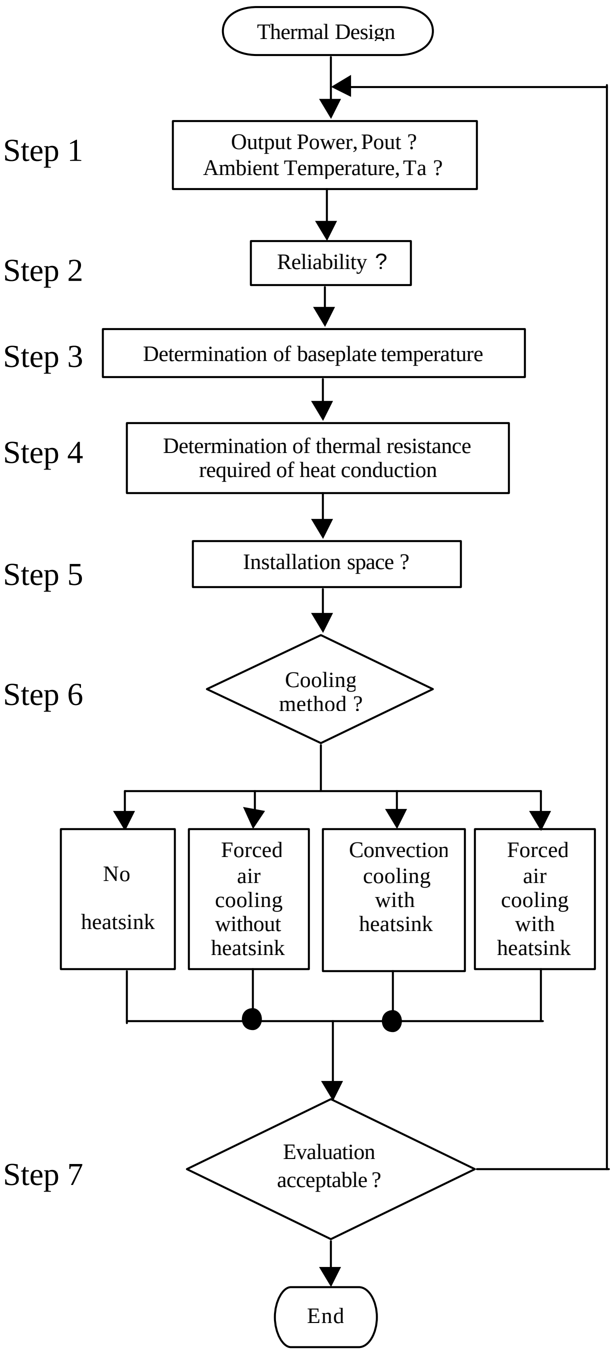

Figure1-1 Flow Chart of Thermal Design

- **STEP 1**

Determine the required output power (P_{out}) and ambient temperature (T_a) of power module.

Model :- PAH75D24-5033 Pout = 75W Ta = 30°C

- **STEP 2, 3**

The baseplate temperature is determined by the required reliability. Table 1-1 shown below is the baseplate temperature required by the application and the grade.

Application	Baseplate Temperature	Equivalent Grade
Public	below 70°C	G1
Industrial	below 80°C	G2
General	below 85°C	G3
General	below 100°C	G4

Table1-1 Baseplate Temperature and Reliability

Assuming the apparatus is for general, the baseplate temperature is set up to below 100°C.

- **STEP 4**

Determine the required thermal resistance of the heatsink.

(1) Calculate the internal power dissipation

$$P_d = \frac{1-h}{h} \times P_{out} \qquad \text{(Equation1-1)}$$

P_d : Internal Power Dissipation (W)
P_{out} : Output Power (W)
η : Efficiency (%)

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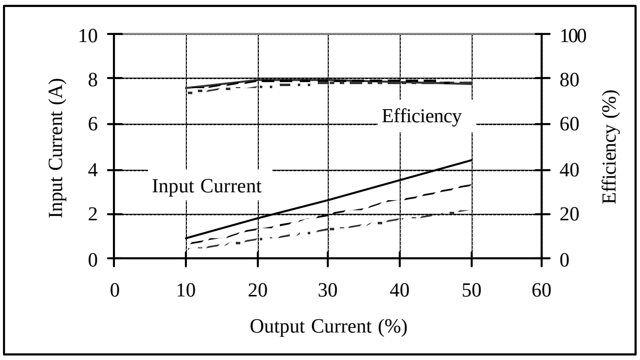
Efficiency is calculated by following equation.

$$h = \frac{Pout}{Pin} \times 100\% \quad \text{(Equation1-2)}$$

η	: Efficiency (%)
P_{out}	: Output Power (W)
P_{in}	: Input Power

Efficiency changes with input voltage and output current and every model have their own efficiency characteristic. For examples, the efficiency data of PAH75D24-5033 is shown in Figure 1-2.
To determine the internal power dissipation, give 1~2 % margin of the efficiency value which is obtained from the Characteristics of Efficiency vs. Output Current.



— 18VDC --- 24VDC -·-·-36VDC

Figure1-2 PAH75D24-5033 Characteristics of Efficiency vs. Output Current

From Figure 1-2, the efficiency at 24VDC nominal voltage with both output current at 50% is 78.5%. To give 2% margin, the efficiency will be as follow.
Efficiency, η = 76.5%

$$P_d = \frac{1 - 0.765}{0.765} \times 75$$
$$= 23.04W$$

(2) Calculate the required thermal resistance of the heatsink.

$$q_{bp-a} = \frac{T_{bp} - T_a}{P_d} \quad \text{(Equation1-3)}$$

θ_{bp-a}	: Thermal Resistance (°C/W) (baseplate - Air)
P_d	: Internal Power Dissipation (W)
T_a	: Ambient Temperature (°C)
T_{bp}	: Baseplate Temperature (°C)

The actual thermal resistance of heatsink is calculated by the following equation.

$$\theta_{hs-a} = \theta_{bp-a} - \theta_{bp-hs} \quad \text{(Equation1-4)}$$

θ_{hs-a}	: Actual Thermal Resistance of Heatsink (°C/W) (Heatsink -Air)
θ_{bp-hs}	: Actual Contact Thermal Resistance (°C/W) (Baseplate - Heatsink)

Contact thermal resistance is thermal resistance of surface between baseplate and heatsink. To decrease the contact thermal resistance, silicone grease is using.
Recommended torque of screws to fix the power module is 5.5 kgcm.

Ambient Temperature (Ta)

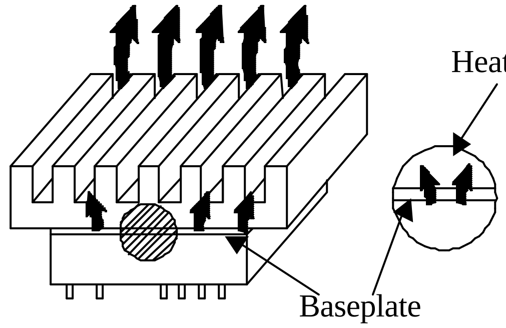


Figure 1-3 Contact Thermal Resistance

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- **STEP 5**

$\theta_{bp\text{-}a}$ = (100 – 30) / 23.04
= 3.0382 °C/W
Assume the contact thermal resistance
($\theta_{bp\text{-}hs}$) to be 0.2 °C/W,
then thermal resistance of heatsink shall be
$\theta_{hs\text{-}a}$ = 3.0382 °C/W – 0.2 °C/W
= 2.8382 °C/W

Below shown the calculation for heatsink space when the power module is mounted.

Assume mounting space to be
61.0 mm (W) x 60.0mm (L) x 25.7mm (H)
The size of PAH75D24 is
61.0mm (W) x 57.9mm (L) x 12.7 mm (H)
Hence, the available thermal space is approximately
61.0mm (W) x 60.0mm (L) x 13.0 mm (H)

- **Step 6**

Investigate cooling method, which satisfies the power module in allowable mounting space.
(1) Convection Cooling
Figure1-4 show the relation of enveloping volume of heatsink and thermal resistance by natural convection cooling without any blockage from neighbouring structures. The thermal resistance data is obtained from the Thermalloy's datasheet.
This characteristic is for aluminum heatsink that has proper fin intervals (if the intervals are too narrow, ventilation resistance increases and also heat dissipation decreased.) Enveloping volume is the volume occupied by the outline of heatsink. This is calculated here, is the approximate volume of required heatsink of convection cooling. However, thermal resistance would be influenced by shape of heatsink; therefore, refer to the detailed thermal resistance data supplied by the manufacturer prior to the selection.
In most cases, the thermal resistance data from the manufacturer is data of vertical mounting. Hence, be noticed that cooling efficiency would

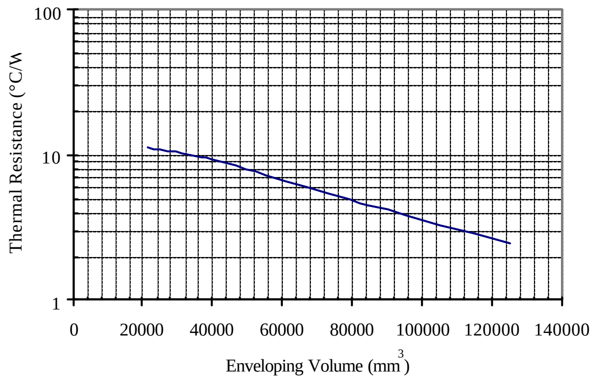

Figure1-4 Enveloping Volume of Heatsink vs. Thermal Resistance

be greatly decreased in a case that the heatsink horizontally mounted.
If the selected heatsink satisfied into the mounting space, proceed to STEP 7. Otherwise, investigate forced air method
(2) Forced Air Cooling
Using open flow forced air cooling method, heat dissipation ability of heatsink improves much higher than convection cooling. And a ducted air cooling system helps to further improve heat dissipation; lower thermal resistance. The data published in this application note is based on open flow system.
Thermal design with forced air-cooling cannot be calculated easily because the air inside of chassis is not uniformly convected. This is caused by complicated shape and construction of chassis. A simplified method to measure wind velocity and to calculate the thermal resistance of a chassis model is as shown below.
Firstly, make a chassis model that take into consideration the shape of chassis, number of fans and its disposition, wind blows direction against heatsink, and layout of components around heatsink. Then measure the velocity of inflow and outflow wind by anemometer while the fans are operating. It shall be measured at the center of heatsink as shown in Figure 1-5. Consequently, average velocity of inflow and outflow winds is assigned as the velocity in the graph of thermal resistance and wind velocity characteristics of heatsink.
In general, the customers are recommended to conduct their own measurement so as to make sure the module operates below the desired base plate temperature.

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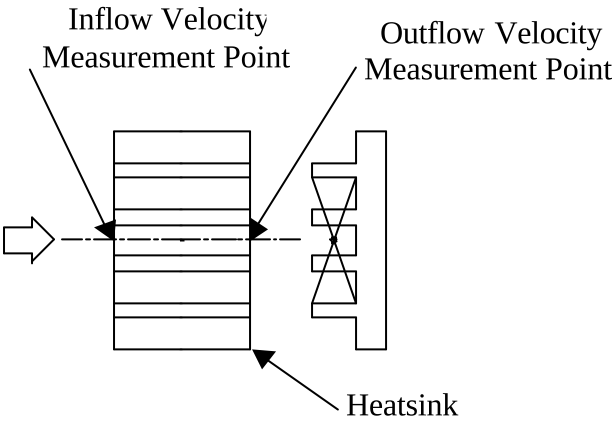

Figure1-5 Flow Velocity Test Point

$$\text{Velocity Average} = \frac{(\text{Inflow} + \text{Outflow})}{2}$$

- **Standard Heatsink (6515B) [Thermalloy]**

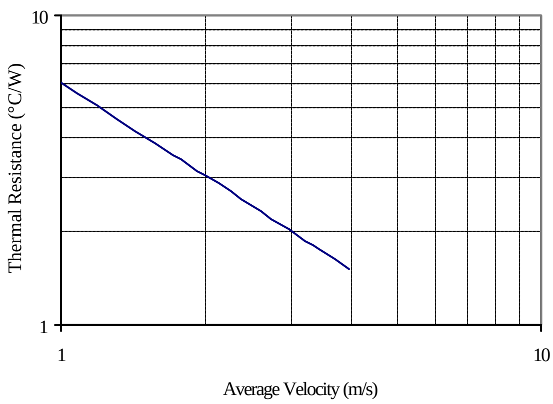

Figure1-6 Thermal Resistance of Heatsink vs. Flow Velocity Characteristics

Thermal resistance can be obtained by assigning the measured wind velocity to characteristics of heatsink.
Confirm this thermal resistance would be less than the calculated thermal resistance in STEP 4. If the thermal resistance does not meet the requirement, change the number and/or characteristic of fans or reconsider the structure of chassis to obtain the required thermal resistance.
In forced air open flow (non-ducted) cooling method, protections against failure fans, countermeasures against noise and dust of fans, and air flow management must be taken into consideration.
If forced air open flow (non-ducted) cooling method is accepted, proceed to Step 7. If not, redesign again.

> Calculate the required enveloping volume of heatsink in convection cooling. According to Figure 1-4, the enveloping volume of the required thermal resistance suppose to be larger than 120×10^3 mm^3.
> For the mounting space condition, volume of heatsink is approximately 47.58×10^3 mm^3; hence, it can not be fitted. Therefore, the forced air cooling method is required. To satisfy above condition, Thermalloy (vendor) standard heatsink is used in this model.
> From Figure 1-6, in order to obtain the thermal resistance below 2.8382°C/W, it is necessary to keep the wind velocity more than 2.0m/s.

- **Step 7**

Confirm the design by experiment. Estimate the baseplate temperature by following equation.

$$T_p = T_a + P_d \times \theta_{bp\text{-}a}$$
$$= T_a + P_d \times (\theta_{bp\text{-}hs} + \theta_{hs\text{-}a}) \quad \text{(Equation1-6)}$$

T_p : Baseplate Temperature (°C)
T_a : Ambient Temperature (°C)
Pd : Internal Power Dissipation (W)
$\theta_{bp\text{-}a}$: Thermal Resistance (°C/W) (Baseplate - Air)
$\theta_{bp\text{-}hs}$: Contact Thermal Resistance (°C/W) (Baseplate - Heatsink)
$\theta_{hs\text{-}a}$: Thermal Resistance of Heatsink (°C/W) (Heatsink - Air)

Confirm the baseplate temperature is lower than its target temperature in Step 3. If it is achieved, the thermal design is completed. If not, redesign.
Measure the baseplate temperature at the center of the baseplate. If it is impossible such as structural problem of the heatsink, measure at a point as close as possible to the center.

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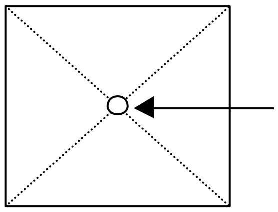
The maximum baseplate temperature is 100°C. Confirm the baseplate temperature at a measurement point shown as Figure 1-7 in the worst condition.



Temperature measurement point of Baseplate

(PAH75D24 SERIES)

Figure1-7 Temperature Measurement Point of Baseplate

Experiment shall be conducted with PAH75D24 SERIES. Measure the baseplate temperature at the actual condition (Pout = 75W, Ta = 30°C). Then confirm the baseplate temperature has been kept below 100°C. The thermal design is completed.

2. STANDARD HEATSINK

Standard heatsink is provided in each power module package.
The thermal resistance value is more precise when heatsink is apply with silicone grease.

- **Standard Heatsink [Termalloy]**

Application :- PAH75D24 Series.

<Size>
(1) 6517B – 57.91mm (L) x 60.96mm (D) x 35.56mm (H)
(2) 6516B – 57.91mm (L) x 60.96mm (D) x 24.13mm (H)
(3) 6515B – 57.91mm (L) x 60.96mm (D) x 11.43mm (H)
(4) 6514B – 57.91mm (L) x 60.96mm (D) x 6.10mm (H)

<Convection cooling>
(1) 6517B – 2.4°C/W
(2) 6516B – 4.4°C/W
(3) 6515B – 9.1°C/W
(4) 6514B – 11.0°C/W

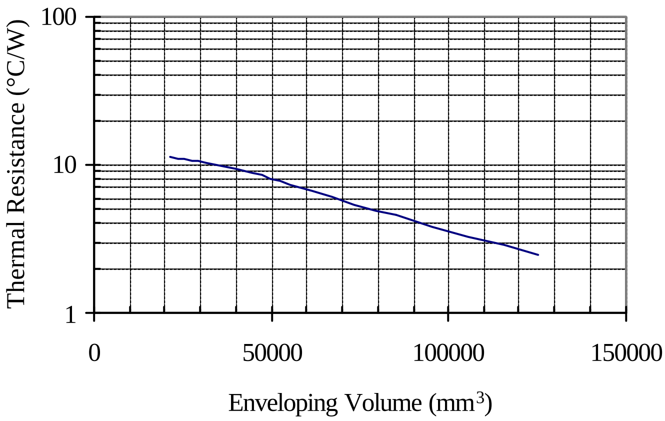


Figure2-1 Characteristics of Thermal Resistance vs. Volume For Standard Heatsink

<Forced Air Cooling>

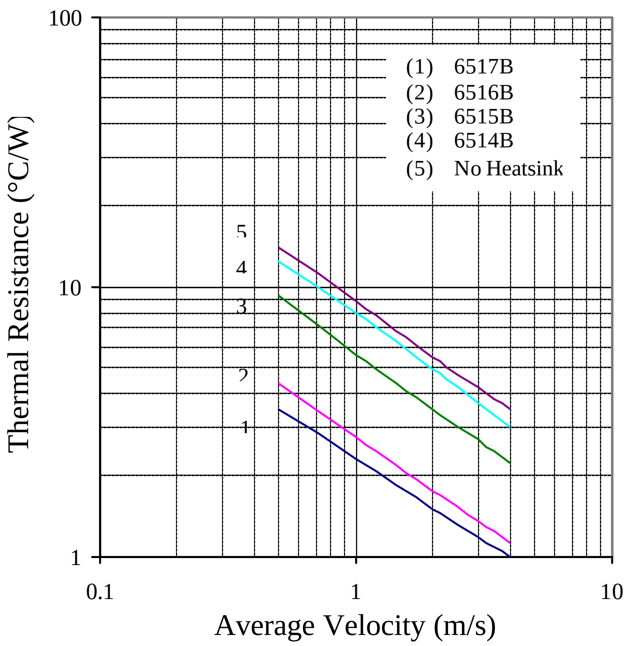


Figure2-2 Characteristics of Thermal Resistance vs. Wind Velocity for Standard Heatsink