# PH300S, 600S Thermal Design

## 1. Thermal Design

## 2. Standard Heatsink

| DWG NO. : C113-04-13 | | |
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NEMIC-LAMBDA

# PH300S,600S-SERIES Thermal Design

## 1. Thermal Design

To ensure proper operation of power modules, 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 PH300S280-5. The flow chart of the thermal design is shown as below.

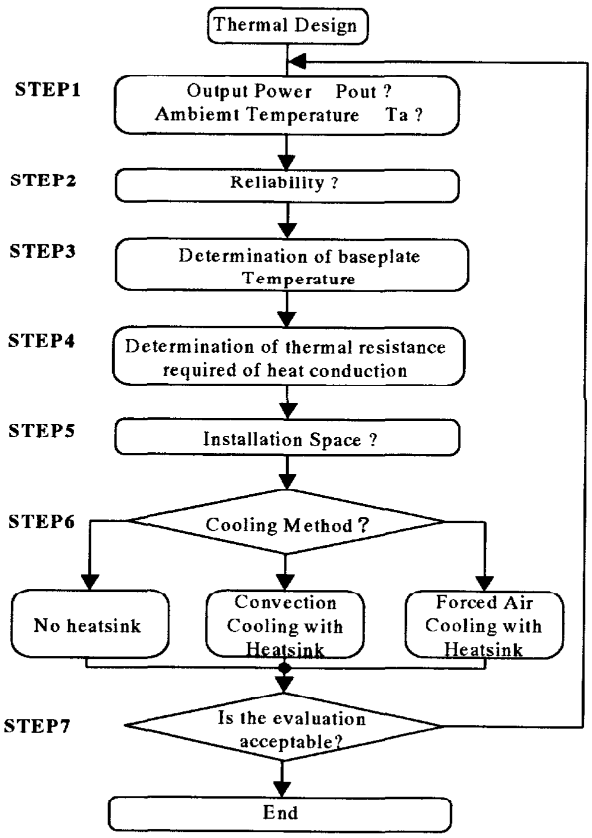


**Figure1-1** Flow Chart of Thermal Design

### ● STEP1

Determine the required output power (Pout) and ambient temperature (Ta) of power module.

| Model : PH300S280-5 |
|---|
| Pout=250 (W) |
| Ta=40 (°C) |

### ● STEP2, 3

The baseplate temperature is determined by the required reliability.
Determine the baseplate temperature with refer to a table of baseplate temperature and reliability required by the application and grade shown as below.

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

**Table1-1** Baseplate Temperature and Reliability

| Assuming the apparatus is for general industrial, the baseplate temperature is set up below 80°C. |
|---|

### ● STEP4

Determine the required thermal resistance of heatsink.

(1) Calculate the internal power dissipation.

$$Pd = \frac{1-\eta}{\eta} \times Pout \qquad \text{(Equation 1-1)}$$

Pd : Internal Power Dissipation (W)
Pout : Output Power (W)
$\eta$ : Efficiency (%)

Efficiency is calculated by following Equation.

$$\eta = \frac{Pout}{Pin} \times 100 \qquad \text{(Equation 1-2)}$$

$\eta$ : Efficiency (%)
Pout : Output Power (W)
Pin : Input Power

Efficiency varies with input voltage and output current. Because it depends on each model, refer to individual data indicated in 2-1 Steady Data of Evaluation Data. For examples, the efficiency date

of PH300S280-5 is shown in Figure1-2.
To determine the internal power dissipation, give 1 ~2% margin of efficiency value calculated by Characteristic of Efficiency vs. Output Current.

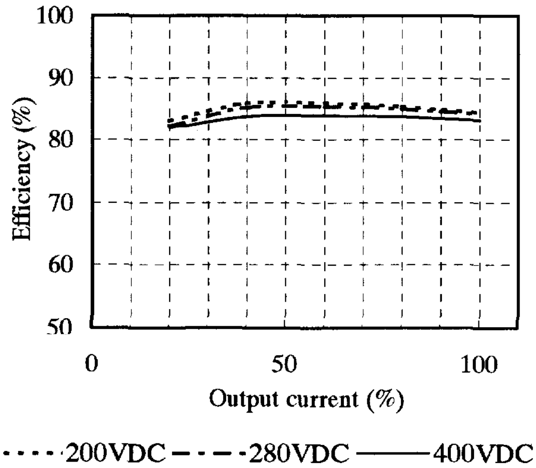


**Figure1-2** Efficiency vs. Output Current of PH300S280-5

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|---|
| Efficiency is obtained by Figure1-2.<br>The efficiency of PH300S280-5 is obtained by operating in 280VDC nominal voltage.<br>Its efficiency by Figure1-2 in 280VDC input voltage at 100% output current is 84.5%.<br>To give 2% margin, the efficiency will be as follow.<br>Efficiency, $\eta$ = 82.5%<br>$Pd = \frac{1-0.825}{0.825} \times 250 = 53$ (W) |

(2) Calculate the required thermal resistance of heatsink.

$$\theta\ \text{bp-a} = \frac{Tp - Ta}{Pd} \qquad \text{(Equation1-3)}$$

$\theta$ bp-a : Thermal Resistance (°C/W) (Baseplate - Air)
Pd : Internal Power Dissipation (W)
Ta : Ambient Temperature (°C)
Tp : Baseplate Temperature (°C)

Actual thermal resistance of heatsink can be calculated by the following equation.

$$\theta\ \text{hs-a} = \theta\ \text{bp-a} - \theta\ \text{bp-hs} \qquad \text{(Equation1-4)}$$

$\theta$ hs-a : Actual Thermal Resistance of Heatsink (°C/W) (Baseplate - Air)
$\theta$ bs-hs : *Actual Contact Thermal Resistance (°C/W)* (Baseplate - Heatsink)

Contact Thermal resistance is the thermal resistance of surface in between baseplate and heatsink. To decrease this contact thermal resistance, use silicon grease.
Recommended torque of screws to fix the power module is 5.5kg·cm.

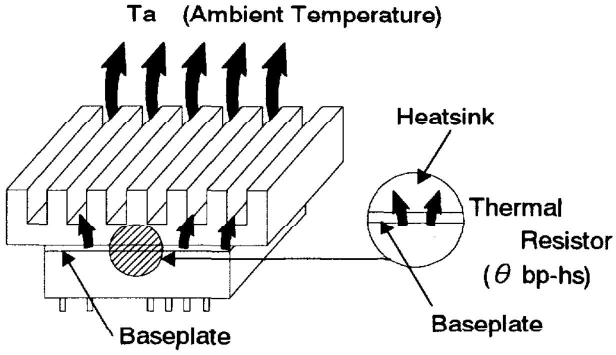



**Figure1-3** Contact Thermal Resistance

- **STEP5**

| |
|---|
| $\theta$ bp-a = (80-40) / 53<br>= 0.75 (°C/W)<br>Assume the contact thermal resistance ($\theta$ bp-hs) to be 0.2 °C/W,<br>then thermal resistance of heatsink shall be:<br>$\theta$ hs-a = 0.75 − 0.2<br>= 0.55 (°C/W) |

See how much space can be kept for heatsink when the power module is mounted.

| |
|---|
| Assume mounting space to be<br>90 (W) × 50 (H) × 90 (D) mm<br>*then size of PH300S is*<br>83 (W) × 12.7 (H) × 86 (D) mm.<br>Hence, the available thermal space is approximately<br>90 (W) × 37 (H) × 90 (D) mm. |

● **STEP6**

Investigate cooling method to be fit into the mounting space.

(1) Convection Cooling

The required volume of heatsink to obtain the thermal resistance calculated in STEP4 at convection cooling is given by relation of enveloping volume of heatsink and thermal resistance shown in Figure 1-4.

This characteristic is for the heatsink made of aluminum that has proper fin interval (if the interval is too narrow, ventilation resistance enlarges and also heat dissipation decreased.) Enveloping volume is the volume occupied by the outline of heatsink. The enveloping volume which is calculated here is approximate volume of required heatsink of convection cooling. However, thermal resistance would be influenced by the shape of heatsink; therefore, refer to the detailed thermal resistance data supplied by the manufacturer prior to the selection.

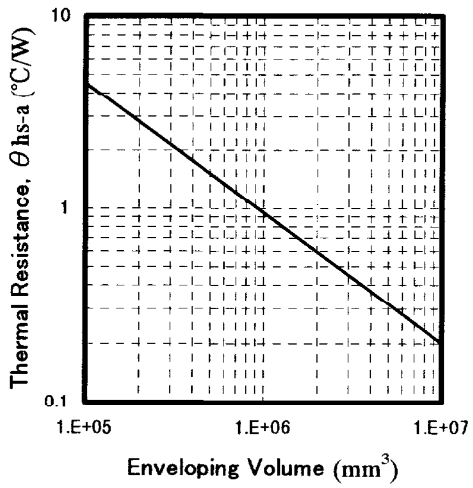



**Figure1-4** Enveloping Volume of Heatsink vs. Thermal Resistance

In the most of cases, the thermal resistance data from manufacturer is the data of vertical mounting. Hence, be noticed that cooling efficiency would be greatly decreased in case that the heatsink horizontally mounted.

If the selected heatsink satisfied the mounting space, proceed to STEP7. Otherwise, investigate forced air method .

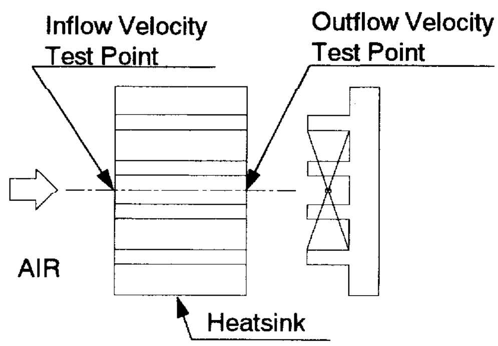
(2) Forced Air Cooling

Using forced air cooling method, heat dissipation ability of heatsink improves much higher than convection cooling.

Thermal design with forced air cooling can not be calculated so easily because air inside of chassis is not uniformly convected. This is causes of complicated shape and construction of chassis and disheveled convection inside of chassis by fans and high density of mounted component. Moreover, many literature introduce the calculation method, nevertheless, most of them are not so utility for many specified conditions.

Therefore, a method that measures wind velocity of chassis model and then estimates the thermal resistance.

At first, make a chassis model that is considered with shape of chassis, number of fans and its disposition, direction wind blows 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 shown as Figure1-5. In 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.




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

**Figure1-6** Flow Velocity Test Point

# PH300S,600S-SERIES Thermal Design

● **[T83] Standard Heatsink (HAA-083)**

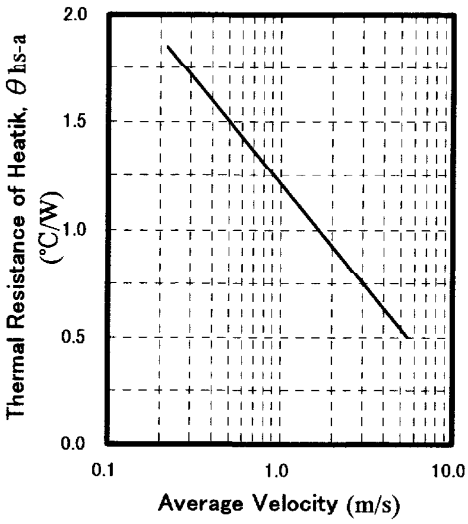



**Figure1-6** Thermal Resistance of Heatsink vs. Flow velocity Characteristics

Thermal resistance is presumed by assigning the measured wind velocity to characteristics of heatsink.
Confirm this thermal resistance would be less than the calculated thermal resistance in STEP4. If the thermal resistance is not obtained as required, change the number and/or characteristic of fans or reconsider the structure of chassis to obtain the required thermal resistance.

| |
|---|
| Calculate the required enveloping volume of heatsink in convection cooling. According to Figure1-4, The enveloping volume of the required thermal resistance suppose to be larger than $2.2 \times 10^6$ mm$^3$.<br>For the mounting space condition, volume of heatsink is approximately $3 \times 10^5$ mm$^3$; hence, it can not be fitted. Therefore, the forced air cooling method is required. To satisfy above condition, our standard heatsink is used in this model.<br>To obtain the thermal resistance below 0.55°C/W on the characteristics of heatsink shown as Figure1-6, it is necessary to keep the wind velocity<br>more than 5.0 m/s. Confirm it obtained the required wind velocity by using the model. |

To use forced air cooling, protections against failure fans, countermeasures against noise and dusts of fans and air flow management must be definitely concerned.
If the forced air cooling is acceptable, proceed to STEP7. If it is impossible, reconsider another cooling method such as water cooling or redesign.

● **STEP7**

Confirm the performance designed by experience. Using the following equation, estimate the baseplate temperature.

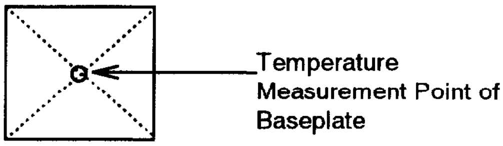
$$Tp = Ta + Pd \times \theta\,bp\text{-}a = Ta + Pd \times (\theta\,bp\text{-}hs + \theta\,hs\text{-}a)$$

(Equation1-6)

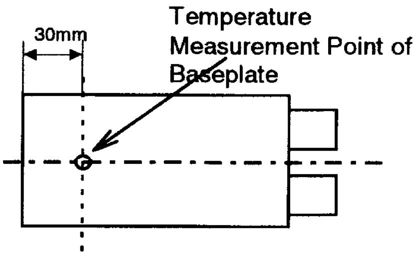
Tp : Baseplate Temperature (°C)
Ta : Ambient Temperature (°C)
Pd : Internal Power Dissipation (W)
θ bp-a : Thermal Resistance (°C/W) [Baseplate - Ambient]
θ bp-hs : Contact Thermal Resistance (°C/W) [Baseplate - Heatsink]
θ hs-a : Thermal Resistance of Heatsink (°C/W) [Heatsink - Ambient]

Confirm the baseplate temperature is lower than its calculated temperature in STEP3 before using.
If it is achieved, the thermal design is completed.
If the performance is not as designed, redesign.
Measure the baseplate temperature at the center of the baseplate as shown as Figure1-7. If it is impossible such as structural problem of heatsink, measure at a point as close as possible to the center point.

2) The maximum baseplate temperature is 100°C. Confirm the baseplate temperature at a measurement point shown as Figure1-7 in the worst condition.




**(PH300S)**




**(PH600S)**

**Figure1-7** Temperature Measurement Point of Baseplate

| |
|---|
| Experiment shall be conducted with PH300S280-5.<br>Measure the baseplate temperature at the actual condition (Pout=250W、Ta=40°C).<br>Then confirm the baseplate temperature has been kept below 80°C.<br>The thermal design is completed. |

# PH300S,600S-SERIES Thermal Design

## 2. Standard Heatsink

Our various standard heatsinks are prepared in each power module package.
The thermal resistance value is that of with silicon grease.

(1) [T83] Standard Heatsink (HAA-083)
Size : 86 (W) × 83 (D) × 22.5 (H) mm
Applied Module : PH300S

<Convection Cooling>
Thermal Resistance : approx. 2.7 (°C/W)

<Forced Air Cooling>

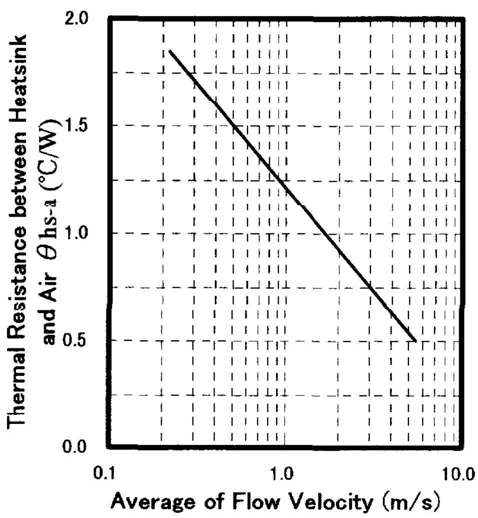



**Figure2-1 Thermal Resistance of Heatsink [T83] vs. Flow Velocity Chracteristics**

(2) [T146] Standard Heatsink (HAA-146)

Size : 86 (W) × 146 (D) × 22.5 (H) mm
Applied Module : PH600S

<Convection Cooling>
Thermal Resistance : approx. 1.7 (°C/W)

<Forced Air Cooling>

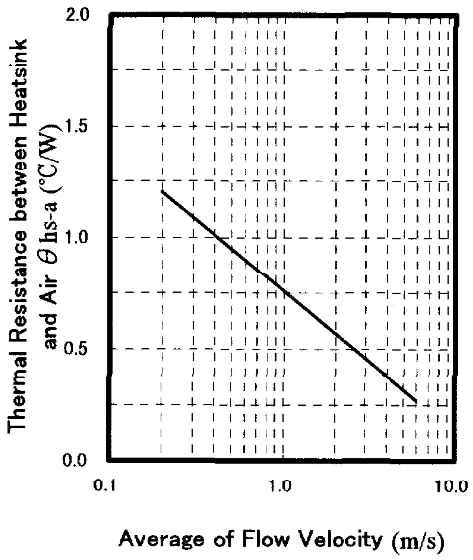



**Figure2-2 Thermal Resistance of Heatsink [T146] vs. Flow Velocity Characteristics**