Application Note for Power Module Products

Description

This document provides various application hint for Power Module Products which employs mechanical structure using aluminum PCB* as baseplate.
Please refer and utilize this contents when using these products.

Note) * Printed Circuit Board

Object Products (Series Name)

CN-A, PAF, PAH, PF-A, PFE-F(A), PFE-SA, PH-A

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Note)

Please refer the instruction manual for each individual product usage. Some part of this document overlaps with the instruction manual for individual products.
In addition, the products name on this document are as of December, 2021.

As of Dec. 2021

1. Parallel Operation Application

1-1. Description

Output parallel operation by Current Share Method (using PC function) is available for a part of Power Module PS Products. By connecting PC terminal each other, the products operate to evenly share the output current of each power module. There are 2 types of current sharing operation: basic Power-up Parallel operation, and N+1 Redundant Parallel operation.

Note) Although the CN200A, PF500A, PF1000A, PFE700SA series are also available for parallel operation, no target of this document because parallel method is different. Please refer each product instruction manual in detail.

(Products Name are as December, 2021.)

(1) Power-up Parallel Operation

This operation is applied for (a) power-up for high power load which cannot supply by single module, or (b) reliability improvement by reducing the output power per product and suppressing heat generation.

a) Power-up (example)

If the power supply is 500W and the load is700W, it cannot be supplied due to insufficient power, but if it is paralleled for 2 power supplies, it can be supplied because the burden is 350W each.

b) Reducing power & higher reliability (example)

If the load is 400W for a 500W power supply, there is a power supply capability, but if another unit is placed in parallel and distributed to 200W each, the heat generation per power supply can be reduced and reliability can be improved.

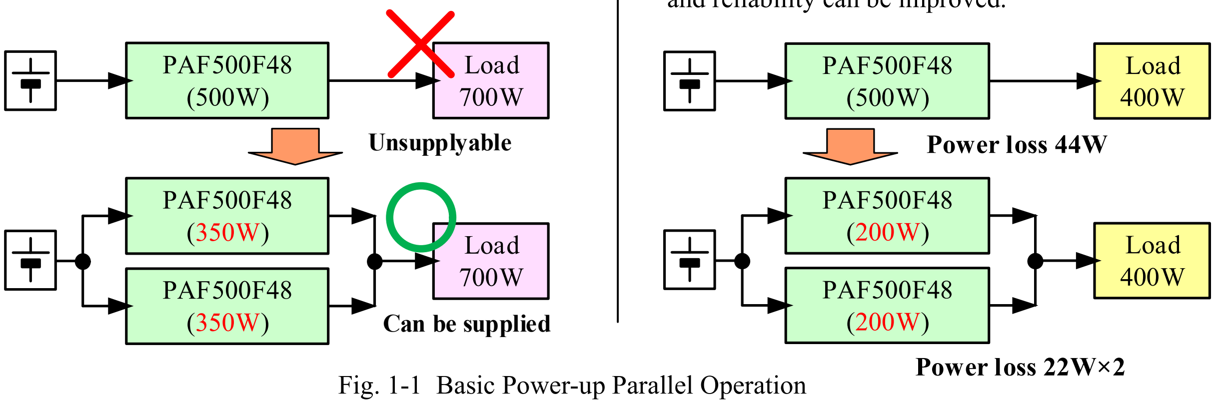
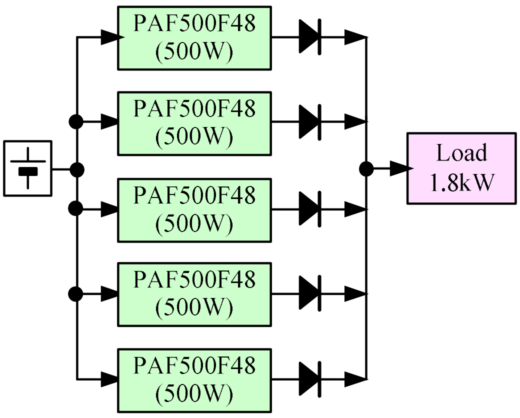


Fig. 1-1 Basic Power-up Parallel Operation

(2) N+1 Parallel Redundant Operation

On the higher reliability in a power supply system, it is possible to improve reliability by using N+1 pcs power modules for the load of N pcs modules. Even if one power module breaks down when operating N+1 pcs in parallel, other N pcs power modules will bear load power, then the system function is held.



For example, when N+1 redundant operating by using 5 pcs of 500W power modules, possible output power is: 500W x 5 x 95% = 2,375W. Then if the 1.8kW load is driven by using it, the power is distributed with 5pcs power modules. And if one pc module breaks down, remaining 4 pcs modules operates on distribution supply. Even if 4 pcs, power supply ability is : 500W x 4 x 95% = 1,900W, therefore available to supply. In addition, inserted diodes at output line are backflow preventer for the module break-down.

Fig. 1-2 N+1 Parallel Redundant Operation

1-2. Parallel Operation Requirements

The requirements of parallel operation by PC (Parallel Control) terminal on power modules are as following.

(1) Available Products for Parallel Operation
The product which having PC terminal, and same series or model each other only.

(2) When Adjusting Output Voltage on Parallel Operation
Please apply pre-trimming to required output voltage accuracy (example: ±1%) before parallel operation.

(3) Maximum Output current on Parallel Operation
It is needed to reduce than the current which maximum 1 unit current x quantity of units (Ex. 95% for PAF).
This reduction rate depends on the product. So, please refer the instruction manual of each product.

(4) Notice for Load Wiring Method
Please align the length or thickness of wiring between (plural) power modules and the load.

(5) Notice for PC terminal
Electrical operating reference point of PC terminal (signal GND.) is -S or COM terminal on the PC circuit.
If a switching noise is superimposed on this circuit, parallel operation becomes unstable or unbalanced.
Therefore, please avoid using load line (-V) and PC_GND (-S or COM) as shared usage.

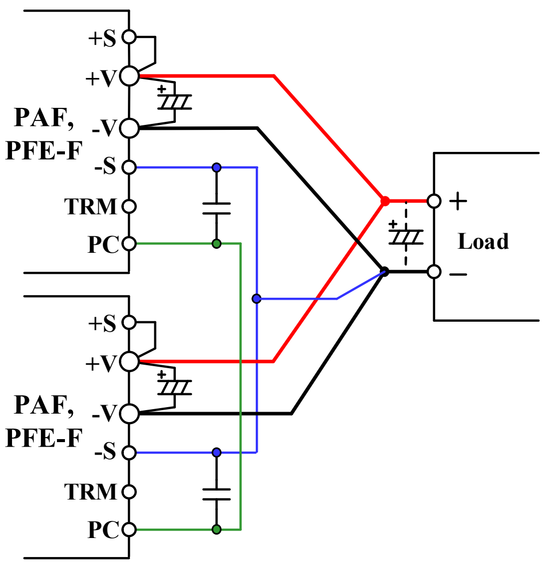
* Especially, tend to that above if a distance is large among each power modules. For the countermeasure, please study adding by-pass capacitor (0.01~0.1uF) between PC and GND (-S or COM).

(6) Another notice (Countermeasure EMI)
Parallel operation will be unstable by mutual interference among paralleled power modules input line.
As a countermeasure, please insert Common Mode Choke coil at input at each power module.
In addition, please refer the instruction manual when using IOG, AUX terminal, etc., in detail.

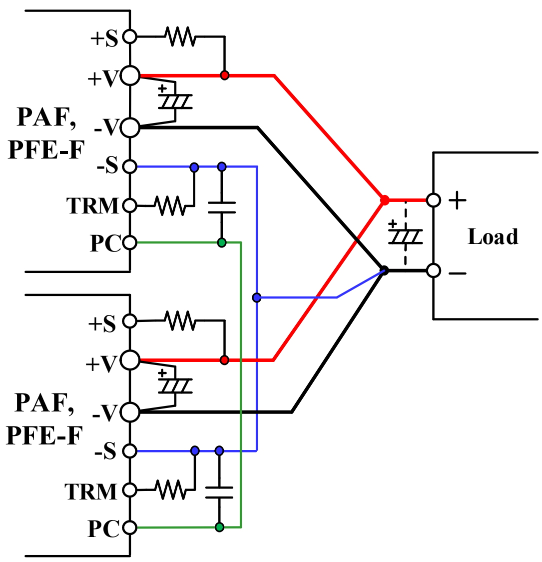
1-3. Power-up Parallel Operation Example

Here, parallel operation for power-up example with symbolic wired schematic diagram is shown below.
The example is for 2 pcs parallel, but 3 pcs or more is also same. For good performance, the PC signal line should be wired with closing to the -S (Signal GND), and grounded on -V (Load) at one point.

(a) Basic Parallel Operation for Power-up



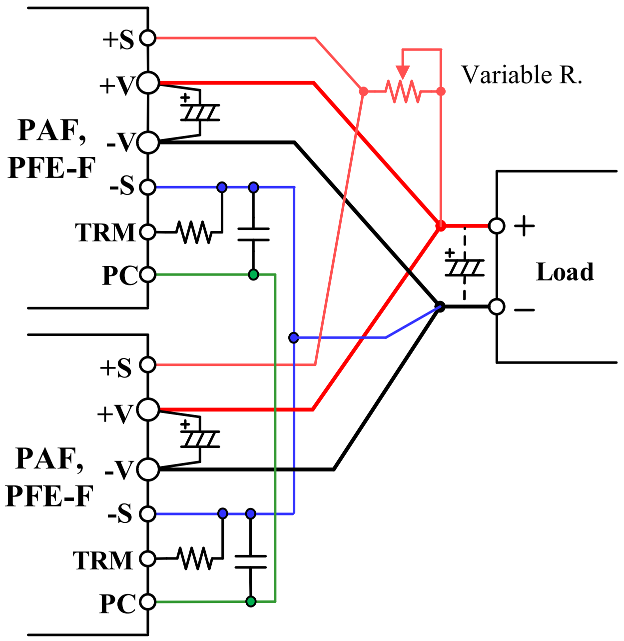
(b) Parallel Operation with Output Adjusting



* On the example above, bypass capacitor between PC and -S terminal is connected for each module.
Electrolytic capacitor connection nearby the load is effective for output stabilization and noise reduction.

1-3. Power-up Parallel Operation Example (Continued)

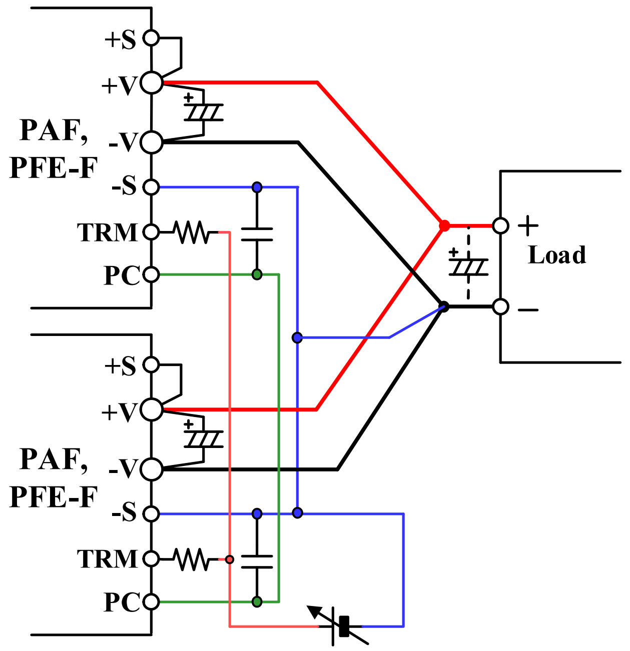
(c) Output Voltage Adjustment in Parallel Operation (Using variable R.)



The left side circuit shows collaboration using resistor at +S line for plural modules, furthermore changed it to variable resistor.

Its variable resistor value (range) is 1/N of the value written in the instruction manual, here the N is number (quantity) of modules in parallel

(d) Output Voltage Adjustment in Parallel Operation (By applying external control voltage)



This circuit example is output voltage adjustment by applying external voltage on TRM terminal through a resistor for each power module.
It is arranged circuit of previous circuit (a).

For current-share type parallel operation, the circuit diagram like this is required, because of controlling (fine tuning) TRM terminal voltage based on PC signal.

Caution) Please evaluate enough on actual equipment when applying parallel operation.

1-4. N+1 Redundant Operation Example

N+1 redundant operation example is shown below. Circuit diagram is pattern one with equal length of load line. The difference point from previous paragraph is as following (1) and (2), then it can be used for high reliability system power supply that does not allow output down.

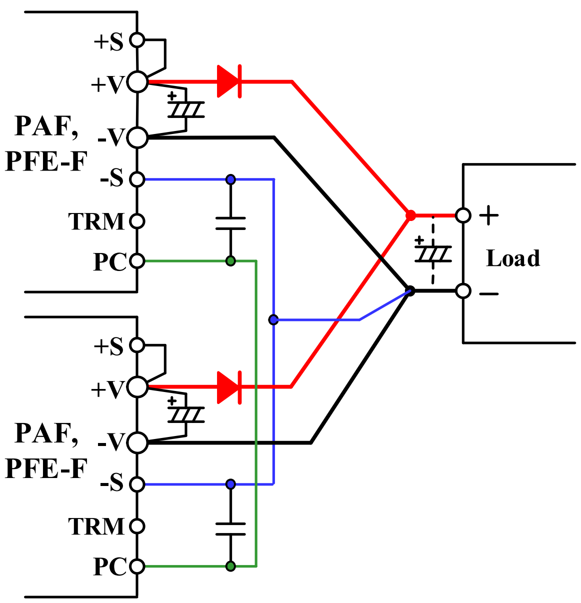
(1) Output Diode is inserted on +V line for each module

By this treatment, load current back-flow, output voltage drop is prevented even if short failure inside modules. However, fine tuning is needed to treat forward voltage and power-loss of diodes.

(2) Setting Enough Output Power when faluring

For example, 90% load at 10 pcs parallel of PAF500F48 can supply 4.5kW output power. And if load power is 3.5kW, redundant operation PAF-module can supply it even if fail up to 2 pcs, then output supply is kept and this system is high reliability.

(a) Basic N+1 Redundant connection Example



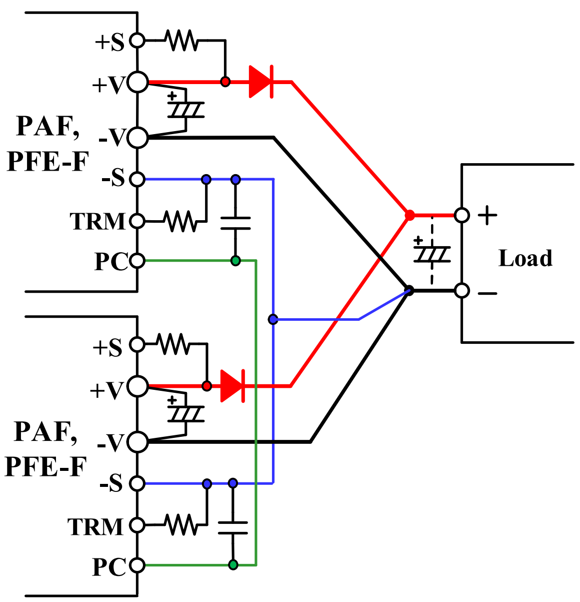
N+1 redundant circuit is the construction that diodes are inserted at output line for power-up parallel operation configuration.

To prevent damage risk of failure, +S should be connected at +V, i.e., anode side of the diode. (Below, it is the same)

The notice for PC terminal wiring, bypass capacitor connection, or electrolytic capacitor (terminated at load) are same as power-up parallel operation.

* For convenience, 2 pcs power modules are shown at left side circuit diagram, however it is the same for 3 pcs or more.

(b) N+1 Redundant Connection with Output Voltage Fixed Adjustment

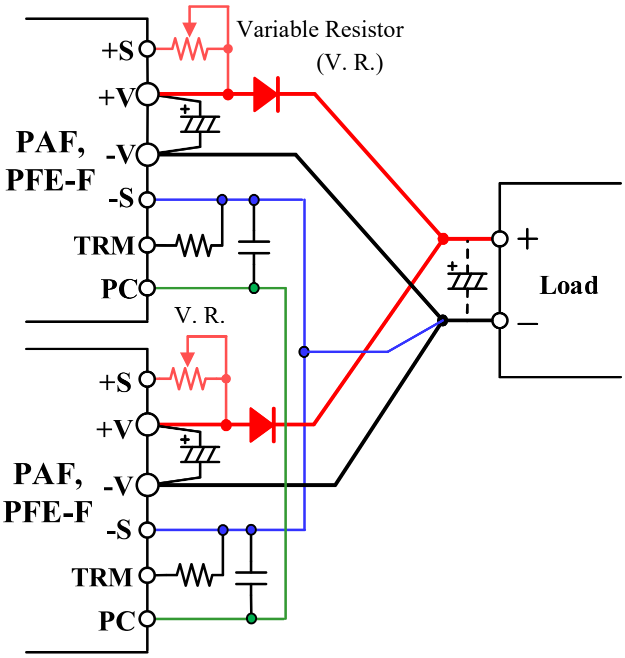


This example is output voltage adjustment circuit with N+1 redundant operation. Its circuit configuration is additional diodes with power-up parallel operation for output voltage adjustment type.

Output voltage setting should be within specified output range between +V and -V, not at both load ends.

1-4. N+1 Redundant Operation Example (Continued)

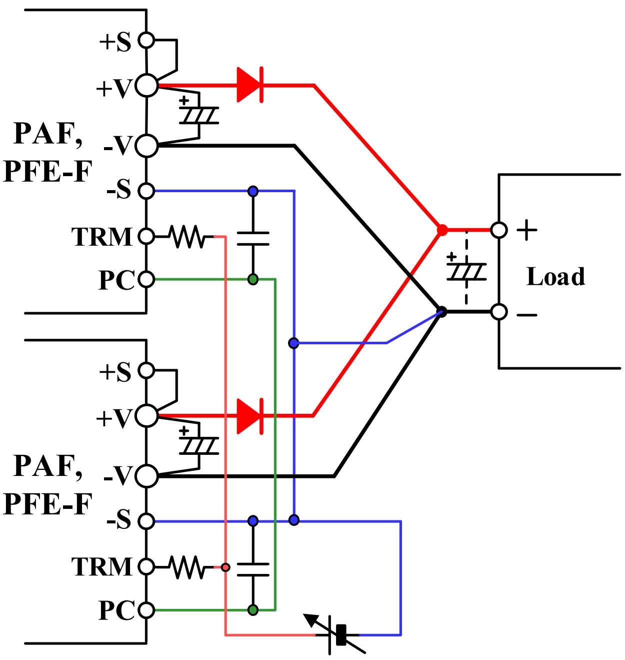
(c) N+1 Redundant Operation with Adjustable Output Voltage by Using Variable Resistors



This circuit is output voltage adjustable by using variable resistors on N+1 redundant operation, which is added output diode on power-up parallel operation.

For stable operation, please apply local sensing (sensing at anode of diode), and the variable resistor should be inserted between +S and +V for each power module.

(d) N+1 Redundant Operation with Output Voltage Adjustment by Applying Ext. Voltage



This circuit is also added diodes at each output line of power module to power-up parallel operation with output voltage adjustment by applying external voltage.

For current share type parallel operation, each TRM terminal voltage is tuned based on PC signal level, so, the connection like this is required.

Note) Please evaluate enough on redundant parallel operation at actual application equipment.

2. Thermal Design for Power Modules

2-1. Thermal Radiation Concept

Power Module Products that employs a mechanical structure using Aluminum PCB as baseplate requires attachment of Heatsink, etc. for Conduction Cooling. Therefore, Thermal Radiation Design is required when using these power modules. Thermal dissipation conditions vary depending on the structure of the equipment or the installation environment where the power module is to be mounted. Therefore, end-user need to perform a suitable thermal design, to ensure that the baseplate temperature of the power module is within allowable maximum specification before using. As shown in Fig. 2-1, there are various types of thermal radiation (dissipation) method, providing a certain degree of freedom for equipment design to suit end-user application. In this document, thermal design of Fig. (2) and (4) is explained below.

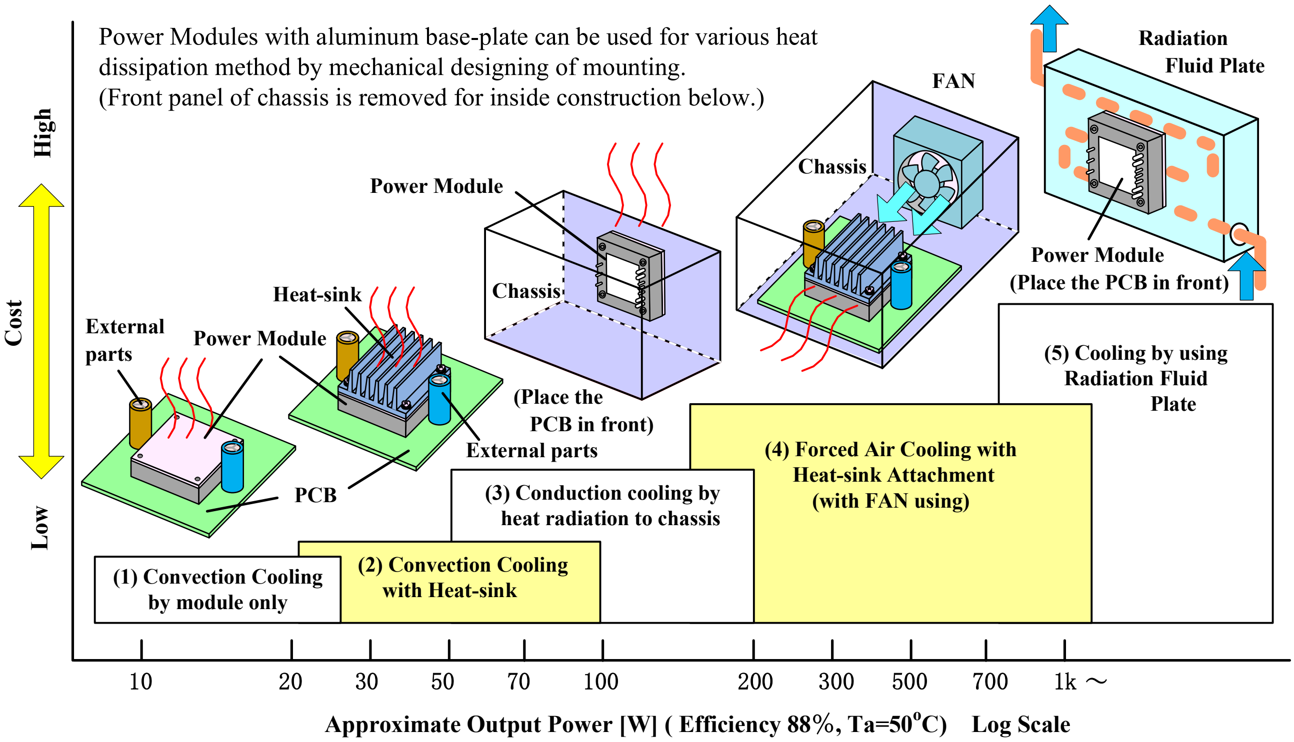


Fig. 2-1　Variation Example for Heat Dissipation Design

(1) Convection cooling by module only - - - - - - - Applicable in the case approximate 20W output or less.
(2) Convection cooling with Heat-sink - - - - - - - - Applicable up to 100W level with standard Heat-sink.
(3) Conduction cooling by heat radiation to chassis - - - Need to consider whole chassis heat and its influence.
(4) Forced air cooling with heat-sink attachment - - - - It is very general cooling. FAN power supply is needed.
(5) Cooling by using fluid plate radiator - - - - - - It is needed in the case of large power output as some kW.

About optional standard Heat-sink

TDK-Lambda prepared some heat-sinks which forms are adopted the base-plate of power module products. They are assumed forced air cooling, so in many cases radiation amount is insufficient for convection cooling. Therefore please prepare large size heat-sink when applying convection cooling by the customer themselves.

No.	Adoptive Power Module	Tp max	Heat-sinl Type Name	Rth (convection)
1	PF500A	85°C	HAA-083	2.7°C/W
2	PF1000A	85°C	HAA-146	1.7°C/W
3,4,5	PAH, CN200A, PH-A(300-600)	100°C	HAH-10L, HAH-10T, HAH-15L	4.6°C/W, 4.5°C/W, 3.4°C/W
6,7,8	PAF, PFE-SA(300-700)	100°C	HAF-10L, HAF-15L, HAF-15T	2.2°C/W, 1.9°C/W, 1.5°C/W
9	PFE500F	100°C	HAL-F12T	0.97°C/W
10	PFE1000FA	100°C	HAM-F10T	0.78°C/W
11	CN-A(30-100), PH-A(50-150)	100°C	HAQ-10T	7.5°C/W

Table 2-1　Standard Heat-sink List

2-2. Heat Radiation by Heat-sink

Flexible design system power supply can be constructed by studying and designing as Fig.2-2 below with using power module supply products. Here, some actual example explanation is shown about radiating heat issue, In addition, left side items in Fig.2-2 are explained for heat radiating especially.

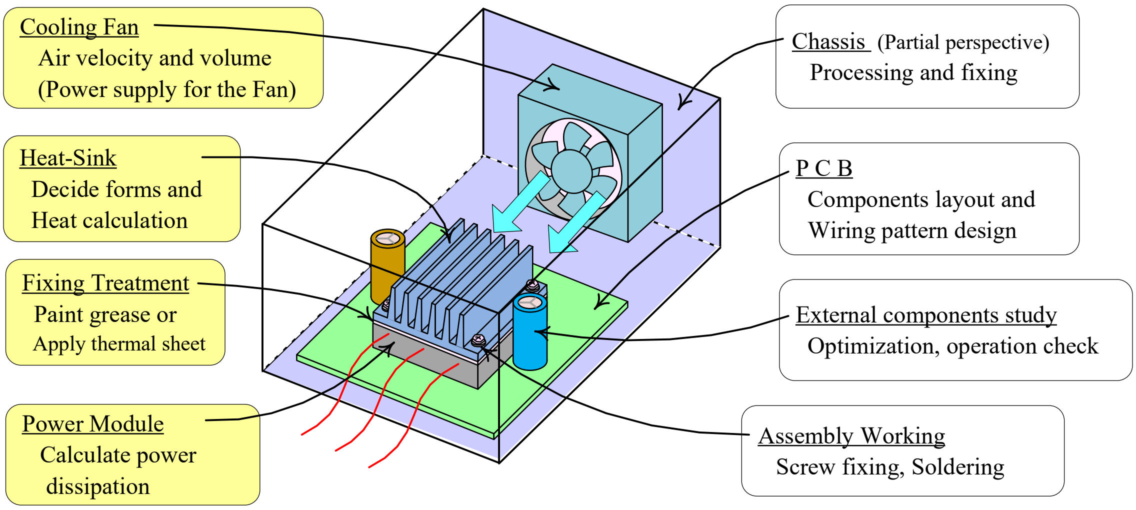


Fig. 2-2 Studying item example for system power supply with power module

For the forced air cooling heat-sink selection, there are two possibilities below, and each has own characteristics.
(1) Standard Heat-sinks (Option item)
TDK-Lambda prepared some heat-sinks as option item, they are adopted base-plate size for power modules. And they also have screw holes, can be used heat-sinks to power modules. Their form or volume are limited, so that radiating ability are limited, but can be used quickly after purchasing and no need tooling to manufacture.
(2) Custom Heat-sinks (Made-to-order)
The customers need to design heatsinks by themselves - construction, manufacturer selection, preparing tooling. And initial investment is needed, however, they can get flexible equipment design.
* Please ask about custom heat-sink to heat-sink manufacturer, because TDK-Lambda does not treat them.

No.	Item	Outline Form	Heat Radiation Ability	Mechanical Design	Tooling	Development Priod	Cost
1	Standard Heat-sink (Option item)	Fixed forms as a base-plate size of power module	Limited	No need	No need	No need	Low
2	Made-to-Order Heat-sink (Custom Type)	Free size or forms to fit user's system equipment	Not Limited	Needed	Often needed, but can be used maker's extrude tooling	Needed	High

Table 2-2 Features for Air-cooling Heat-sink

Note) Please take care when fixing a heat-sink to power module below.
Apply the thermal grease or sheet between a baseplate of a power module and a heat-sink in close contact.
And a M3 screw is used to fixture. Please prepare these items by the customers themselves.
In detail, please refer Fixing Method corner.

2-3. Thermal Design Flowchart and Example

Here, thermal design process is explained of Power Module with concrete example of the PH600A280-24. Thermal design flowchart is shown in Fig.2-3-1. Hereinafter, each step is described in order.

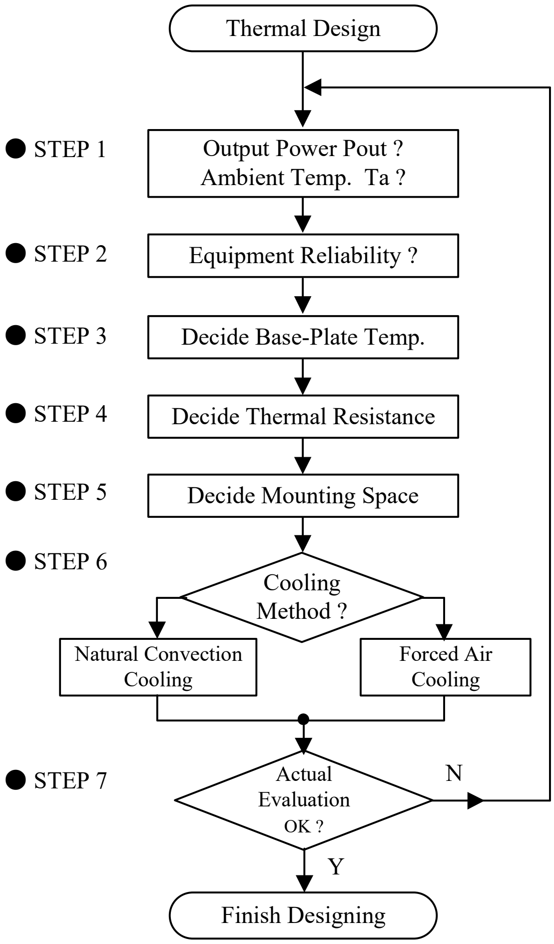


Fig. 2-3-1 Thermal Design Flowchart

● STEP 1

Decide output power (Pout) and ambient temperature (Ta) for using power module product.

* Applied Product : PH600A280-24
* Output Power : Pout=504[W] (24V, 21A) (84% Load)
* Ambient Temp. : Ta=50 (°C)

(Actual example is shown in the frame, same as below.)

● STEP 2

Next, decide maximum base-plate temperature with considering reliability as the Table 3-3 below. Generally, if the electronic equipment temperature is lowered at using, the components stress is reduced, then the reliability is improved.

Reliability	Base-plate Temp.	Use
Very High Reliability	70°C or less	Public or Unmanned Control Equipment
Industrial	80°C or less	General Industry or Manufacturing Equipment
Consumer	100°C or less (*85°C or less)	General Purpose Equipment

Note) * PF500A-360, PF1000A-360 only

Table 3-3. Example for Reliability, Temperature and Use

● STEP 3

Here, assuming for general industrial equipment use, Base-plate temperature setting is 80°C or less.

● STEP 4

Calculate thermal resistance for heat-sink

(1) Power dissipation Pd for power module

$$Pd = Pout \times \left(\frac{1}{\eta} - 1\right) \quad \cdots (3\text{-}1)$$

Where efficiency η is defined as follows.

$$\eta = \frac{Pout}{Pin} \times 100 \quad \cdots\cdots\cdots (3\text{-}2)$$

Pout [W] :Output Power, Pin [W] :Input Power

Pd [W] :Power Dissipation, η [%]: Efficiency

Efficiency changes by input or output conditions, and it is different for products. So please refer each products efficiency data and estimate its power dissipation.

From Fig. 2-3-2, η=92%, therefore Pd is (Formula 3-1)

$$Pd = 504[W] \times \left(\frac{1}{0.92} - 1\right) = 44\ [W]$$

24V

Using condition: Vin=360VDC or less, and its efficiency is 92%, with 1% margin with the data

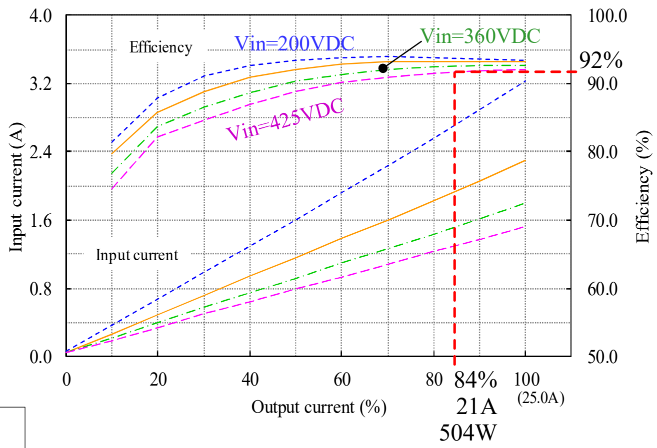


Fig. 2-3-2 Efficiency of PH600A280-24
(Reference from Evaluation Data)

● STEP 4 (Continued)

(2) Calculate Thermal Resistance for Heatsink

Thermal resistance composition is shown on Fig. 2-3-3, and thermal resistance between heatsink and ambient atmosphere ($\theta_{hs\text{-}a}$) can be calculated as follows.

$$\theta_{hs\text{-}a} = \theta_{bp\text{-}a} - \theta_{bp\text{-}hs} \quad \cdots\cdots \text{(3-3)}$$

$\theta_{bp\text{-}a}$: Thermal resistance between base-plate and ambient
$\theta_{bp\text{-}hs}$: Contact thermal resistance between base-plate and heat sink

Here, $\theta_{bp\text{-}a}$ is :

$$\theta_{bp\text{-}a} = \frac{Tp - Ta}{Pd} \quad \cdots\cdots \text{(3-4)}$$

Tp : Base-plate temperature、 Ta : Ambient temperature,
Pd: Power dissipation of power module

Contact Resistance ($\theta_{bp\text{-}hs}$) is defined as the thermal resistance that exists between the contact surfaces of the power module baseplate and heatsink. Large power application requires enhancement measures to reduce heat such as applying Coolant Grease or inserting thermal pads in-between surfaces. Without these enhancement measures, surface gap in-between will degrade heat dissipation performance.

Thermal Resistance for Heat dissipation $\theta_{bp\text{-}hs} + \theta_{hs\text{-}a} = \theta_{bp\text{-}a}$
(Formula 3-3 is transformed)

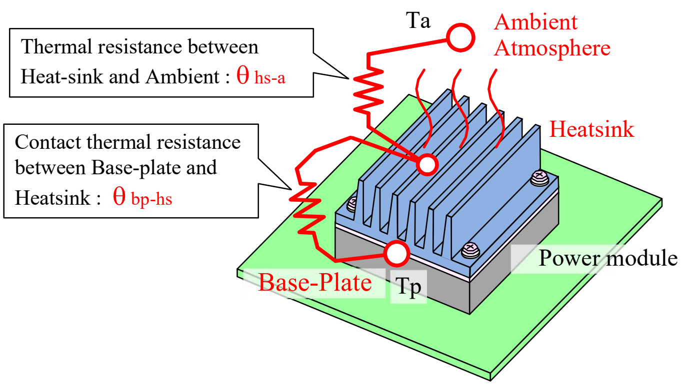


Fig. 2-3-3 Thermal resistance for designing calculation

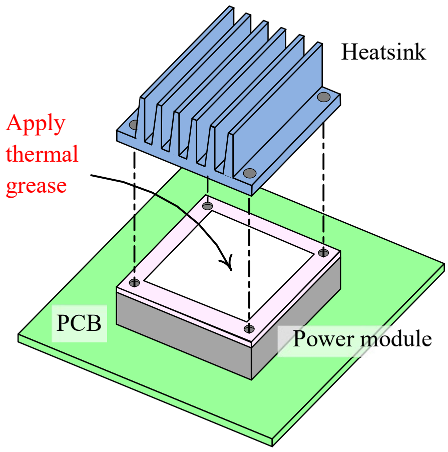


Fig. 2-3-4 Thermal grease application

In first assumed condition of PH600A280-24, from Formula 3-4, thermal resistance between base-plate and ambient is calculated as: $\theta_{bp\text{-}a} = (80^{\circ}C - 50^{\circ}C)/44W = 0.68\ [^{\circ}C/W]$. Next, regarding contact heat resistance (mentioned above) is considered under the condition with applying general thermal grease.

For thermal grease example, general type with thermal conductivity K=0.9 [W/(m·K)] is used, and it is applied as thickness and area : t=0.1 [mm] , L×W=50[mm]×50[mm] (it is a little smaller than PHs area). Then, contact thermal resistance can be calculated as follows.

$$\theta_{bp\text{-}hs} = \frac{t}{K \times L \times W} = \frac{0.1\ [mm]}{0.9\ [W/(m\cdot K)] \times 50\ [mm] \times 50\ [mm]} = 0.05\ [^{\circ}C/W] \quad \cdots\cdots \text{(3-5)}$$

Then the thermal resistance for a heat-sink can be calculated from the formula (3-3) as follows,

$$\theta_{hs\text{-}a} = \theta_{bp\text{-}a} - \theta_{bp\text{-}hs} = 0.68 - 0.05 = \underline{0.63\ [^{\circ}C/W]}$$

Note) Thermal conductivity of a grease above is an example. In detail, please refer thermal material manufacturer catalog. Recently, higher thermal conductivity grease than the example above are popular. Actually, after applying a thermal grease, it stretches thinly less than 0.1mm by fixing heat-sink to power-module. However, in this column, the value 0.1mm is used for consideration with margin calculation. And here, the unit K (Kelvin) and °C (Celsius degree) is treated as same unit (dimension).

● STEP 5

Decide cooling method with considering mounting space of power-module. Here, 2 examples are shown below.
(1) Mounting space has margin for power-module, so forced air cooling with optional standard heatsink is applied.
(2) Formerly chassis box size is fixed, and apply custom made heatsink for convection cooling is applied.

● STEP 6

(1) Forced Air Cooling by Using Standard Optional Heatsink

Optional standard heatsinks are prepared by TDK-Lambda, which are same size with power module base-plate. Their cooling ability is limited because of same size with base-plate, so in many case, forced air cooling is needed by using blowing fan (cannot be used convection cooling). And a kinds of standard heat-sink is also limited, then the equipment or chassis form has also a restriction. But it is convenience because of no need tooling design like custom heatsink, and can be used promptly after purchasing them.

In the actual example, considering large power dissipation 44W on PH600A280-24, largest heatsink of half brick power module HAH-15L is selected, and calculate air velocity for cooling. (Fig. 2-3-5)
From $\theta_{hs\text{-}a}$ = 0.63 [°C/W] on the STEP 4, average air velocity 5m/s is needed for forced air cooling.

Here, the definition of "average Air velocity" is the average value of the inflow and outflow air velocities before and after the radiator (Fig. 2-3-6). Therefore, it is necessary to set the wind speed with an external fan, etc., to be stronger than the wind speed obtained here.

[Reference] When blowing air by a general axial fan, the size will be 60 to 80 mm square, 24 V, 5 W, and the air volume is 1.0 m3 / min. It is thought that a fan of about is required. (For details, refer to the fan manufacturer's catalog.)

* When applying this example to the equipment, its size is determined by the fan size (60 to 80 mm square). Please note that a separate power supply is required to drive the fan.
* In this example, the heat radiation and cooling method were decided above, so next proceed to STEP 7 to check the actual machine. If the base plate temperature is below the specified value, there is no problem and the examination is completed.

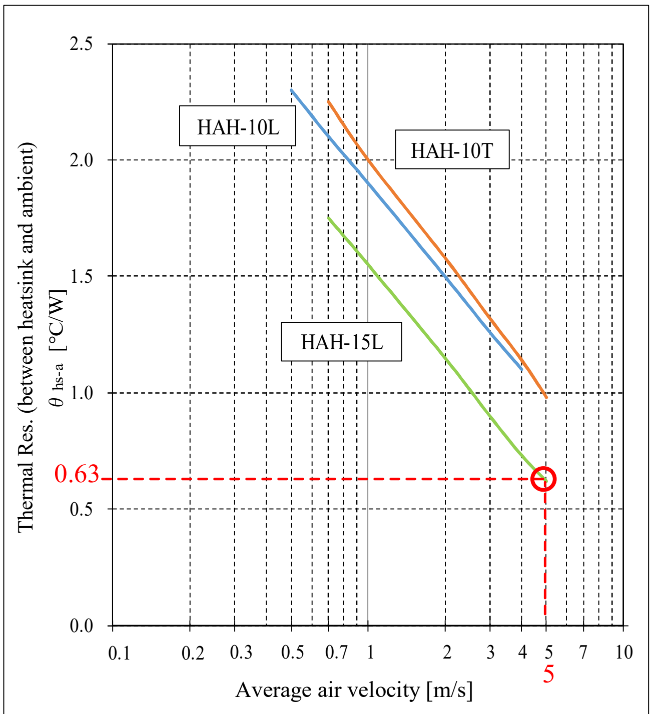
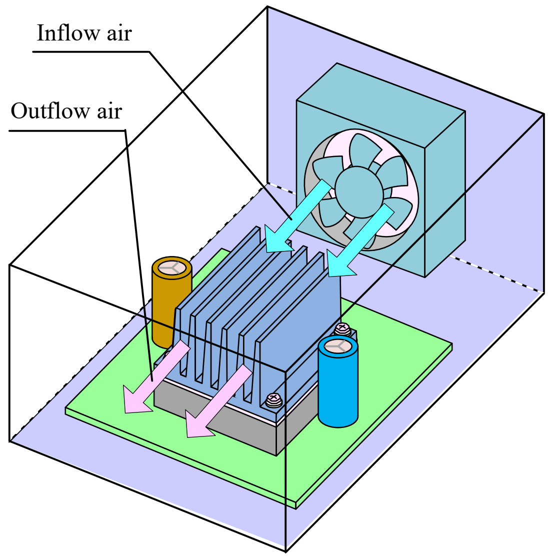


Fig. 2-3-5 "HAH" type Heatsink Thermal Resistance



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

Fig. 2-3-6 Forced airflow cooling configuration and Definition of Average air velocity

Note) Fig. 2-3-6 is a conceptual diagram, so the shape and color may differ from the actual products or parts. The lineup and outline of the standard heatsinks are listed on the last page of this document.

● STEP 6 (Continued)

(2) Determine the housing shape and use a custom-made radiator for natural convection cooling

Here, first decide the mounting space for the power module, and consider the radiator that will enter that space. First, when considering the shape of the device, the minimum required thickness for mounting is as follows.

-Power module height (13 mm), -Mounting PCB thickness (1.6 mm),

-Distance between the bottom of the PCB and the housing (6 mm)

The total thickness of these is 20.6 mm, but let's set it to 21 mm with a margin. This thickness is a required dimension for all our power modules and needs to be checked and set for each product. To fix the board, insert a spacer with a length of 6 mm and screw it to the housing. If it is necessary to secure the withstand voltage of the device, insert an insulating plate.

For the actual example, the mounting space for the PH600A280-24 is : W=250, H=60, D=180 [mm]. Here, assuming a size housing. The radiator space is reduced by the height from the above issue, and the bottom is also smaller. W=240, H=45, D=170 [mm] can be secured, so consider using a radiator of this size (Fig. 2-3-7).

Next, obtain the approximate volume required for natural convection cooling from Fig. 2-3-8 "Relation between the envelope volume of the radiator and the thermal resistance". This diagram is for a general heatsink, composed of aluminum material with appropriate blade spacing. The "envelope volume" is the volume occupied by the contour of the radiator, and it is the approximate size of the radiator required for natural convection cooling. However, the thermal resistance also depends on the shape of the radiator and the ease with which the surrounding air can pass. For details, refer to the catalog for radiator manufacturers.

Find the thermal resistance of the radiator required for natural convection cooling using an actual example. From Fig. 3-3-8, 1.4 x 106 [mm3] or more is required. On the other hand, the volume of the radiator set in STEP 5 is W×H×D=240×45×170=1.8×106 [mm3]. Therefore, in this example, natural air cooling is possible, so proceed to Step 7, check the temperature of the base plate with the actual machine, and there is a problem. If not, the design is complete. The radiator shown here is different from the standard radiator in that the shape is a power module. Please note that it is larger than the base plate and limits the mounting height of external parts.

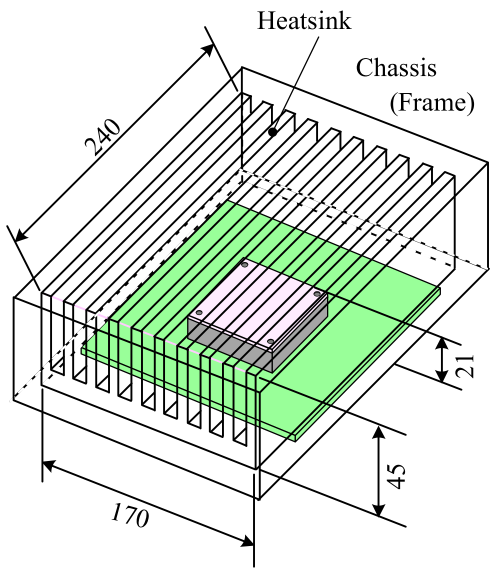


Fig. 2-3-7 Large Heatsink Configulation
(Perspective View)

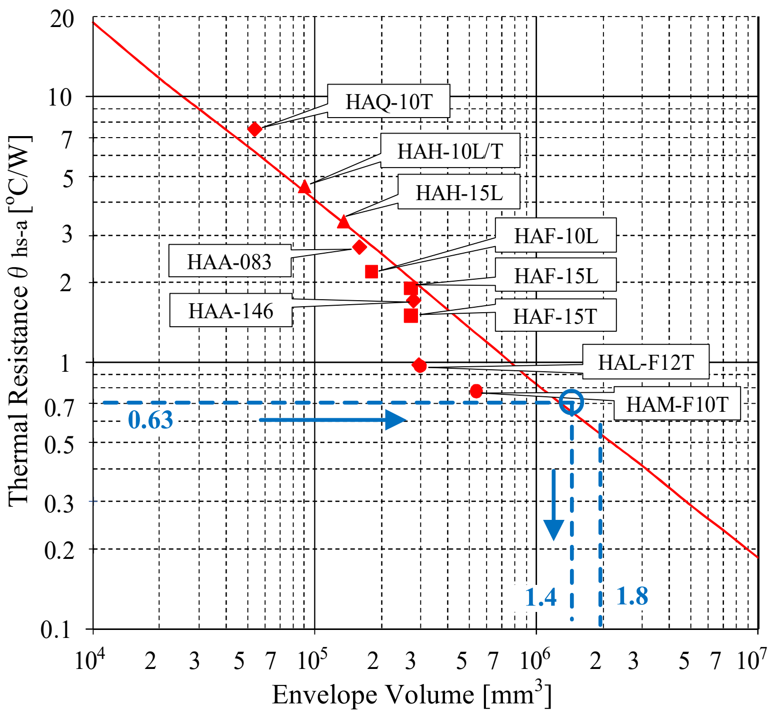


Fig. 2-3-8 Envelope Volume vs Thermal Resistance Relation

Note) The thermal resistance of TDK-Lambda's standard radiator (optional item) on natural convection cooling is also shown. The shape whose cross section is longer than the blade of the radiator improves heat dissipation performance and tends to swing below the straight line.

(3) <Supplement> Forced air cooling with a Custom-made Heatsink

In the previous example, if space is insufficient or a smaller equipment is required, it is also needed to study forced air cooling with a custom-made Heatsink. The following can be considered as the advantages and disadvantages of adopting forced air cooling.

[Strong Points]

* The heat radiation ability of the heatsink (compared with same shape) is improved to several times of convection cooling. (If forced air cooling with 3m/s Airflow, it leads about 1/3 thermal resistance of natural air cooling.)
* Even in spaces where natural air cooling cannot be expected, cooling is possible by forcibly discharging hot air.

[Disadvantages]

* A fan and its power supply are required, and consideration For a fan installation, its noise, air filter, etc.
* It is also needed to make a prototype Heatsink, and check whether the expected cooling effect can be obtained.

In the actual example on the previous page, it was possible to handle it by convection cooling. Now, in order to make the heatsink a little smaller and lighter, let's consider what kind of cooling conditions are required for forced air cooling when the heatsink is halved. First, if the length of the heatsink blade shown in Fig. 2-3-7 is halved (120 mm) from 240 mm, the thermal resistance will be almost doubled. It goes from about 0.63°C/W to 1.26°C/W. Therefore, if forced air cooling with a wind speed of 3 m/s is applied, the thermal resistance will be 50% or less. Since it is expected to be reduced to about 0.63oC / W, the original thermal resistance can be secured and cooling is possible. However, a power supply (Note *) for driving the fan is also required, and if this power is taken from PH600A280-24, the load factor and power loss and heat generation will increase, so it will be necessary to reset the amount that takes these factors into account.

Note)* It is assumed that two 24V, 5W class, 60mm square (air volume 1.0 m^3/min) are lined up as a fan.
(Since this is a simple calculation, we do not consider the decrease in wind power due to the air filter.)

● STEP 7

Check whether the heat radiation is as designed by actual evaluation. The baseplate temperature equation is:

$$Tp = Ta + Pd \times \theta_{bp\text{-}a} = Ta + Pd \times (\theta_{bp\text{-}hs} + \theta_{hs\text{-}a}) \cdots\cdots\cdots\cdots\cdots \text{Formula 3-6}$$

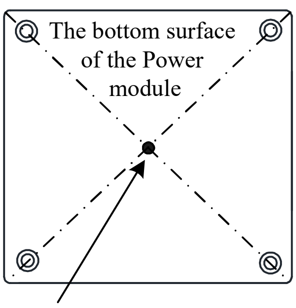
Tp: Baseplate Temperature [°C]	$\theta_{bp\text{-}a}$: Thermal resistance between BP and ambient [°C/W]
Ta: Ambient Temperature [°C]	$\theta_{bp\text{-}hs}$: Contact Thermal Resistance between BP and HS [°C/W]
Pd: Power dissipation of Power Module [W]	$\theta_{hs\text{-}a}$: Thermal resistance between HS and ambient [°C/W]

(Abbreviation : BP is Baseplate, HS is Heatsink.)

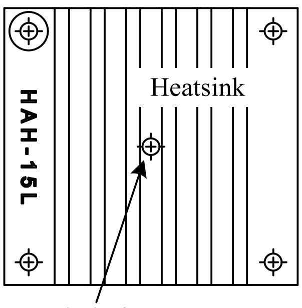
In the actual evaluation, confirm the baseplate temperature is below the temperature determined in STEP 3.
If there are no problems, the design is complete. But if the performance is not as designed, redesign it.

When checking the baseplate temperature, please use a thermocouple as shown in the right figure below. The Other measurement method does not provide accurate data. In addition, the temperature measurement point differs for each power module product, so please refer to the catalog for confirmation.

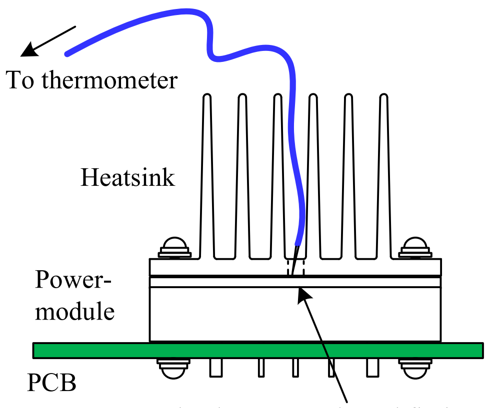
For optional standard heatsink, there is a hole near the center of the heatsink for temperature measurement.



Temperature measurement Point (Half-brick Type)



A hole for Temperature measurement (3ϕ)



Insert the thermocouple and fix it with adhesive. (Avoid applying thermal grease in the center area.)

2-4. Standard Heatsinks

Standard optional heatsinks are available according to the size of the base plate of the power module products. Model names, Compatible products, Outlines, and Cooling characteristics examples are sown here below, under the condition that silicon grease is applied between baseplate and heatsink.

Note) * Natural convection cooling

(1) Heatsink for [T83]

HAA-083

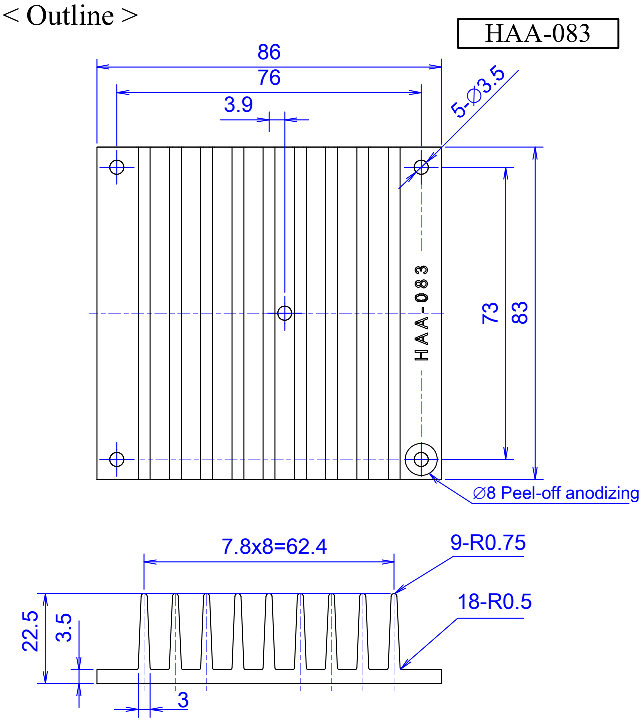
Size : 86(W)×22.5(H)×83(D)[mm]
Module to be applied : PF500A-360
Thermal Resistance * : 2.7 [°C/W]

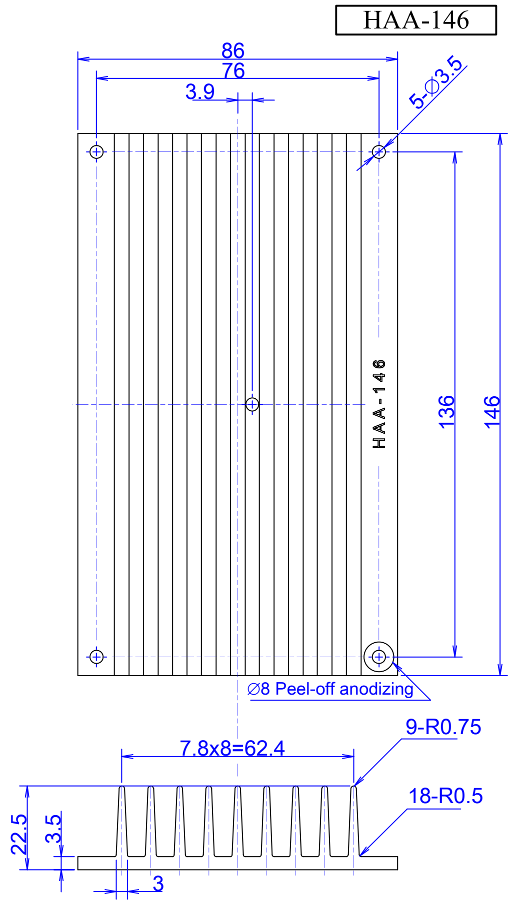
(2) Heatsink for [T146]

HAA-146

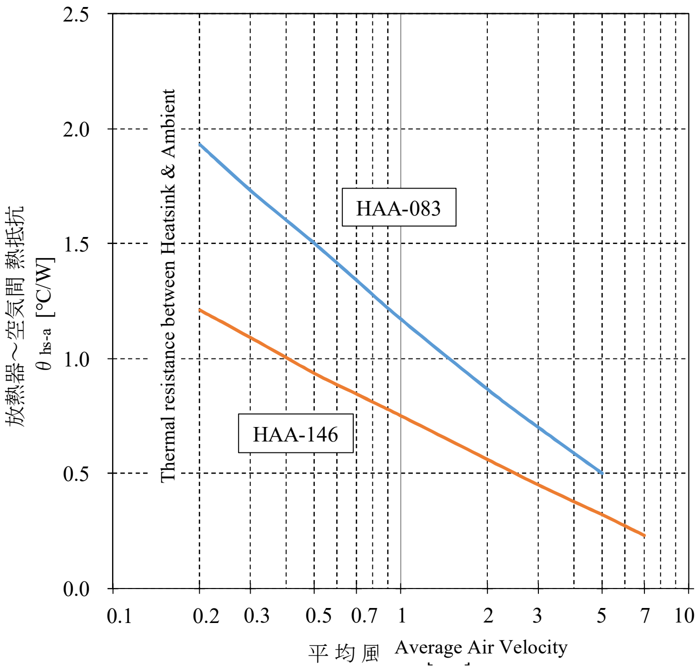
Size : 86(W)×22.5(H)×146(D)[mm]
Module to be applied : PF1000A-360
Thermal Resistance * : 1.7 [°C/W]

< Outline >





< Characteristics on Forced Air Cooling >



Material : Aluminum A6063-T5, with
Black-Anodized Surface Treatment
(Commonly used.)

(3) Heatsink for Half Brick ①

HAH-10L

Size : 61(W)×25.4(H)×57.9(D)[mm]
Modules to be applied to :
PAH, CN200A110,
PH300A280, PH600A280
Thermal Resistance * : 4.6 [°C/W]

(4) Heatsink for Half Brick ②

HAH-10T

Size : 57.9.(W)×25.4(H)×61(D)[mm]
Modules to be applied to :
PAH, CN200A110,
PH300A280, PH600A280
Thermal Resistance * : 4.5 [°C/W]

(5) Heatsink for Half Brick ③

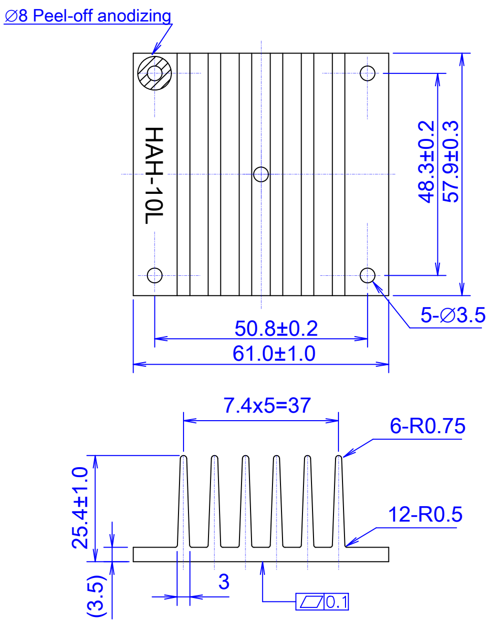
HAH-15L

Size : 61(W)×38.1(H)×57.9(D)[mm]
Modules to be applied to :
PAH, CN200A110,
PH300A280, PH600A280
Thermal Resistance * : 3.4 [°C/W]

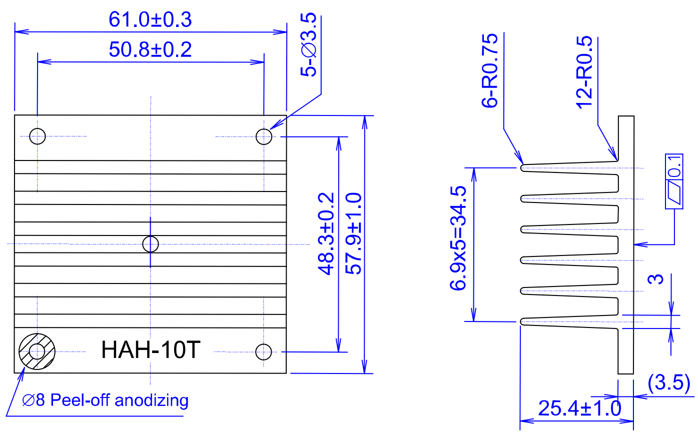
< Outline >

Note) * Natural convection cooling

HAH-10L



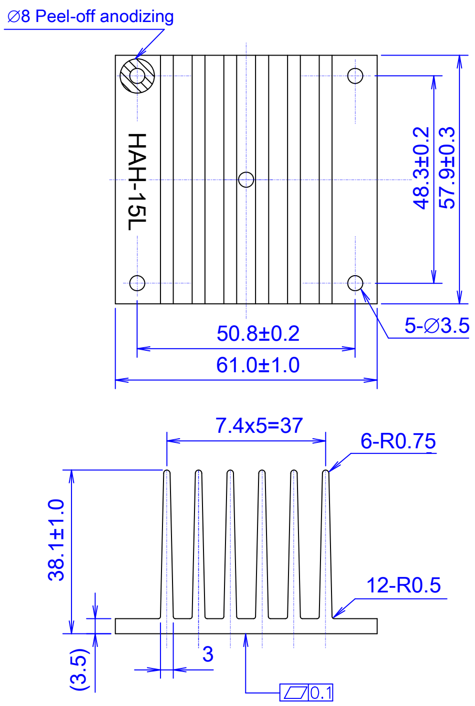
HAH-10T



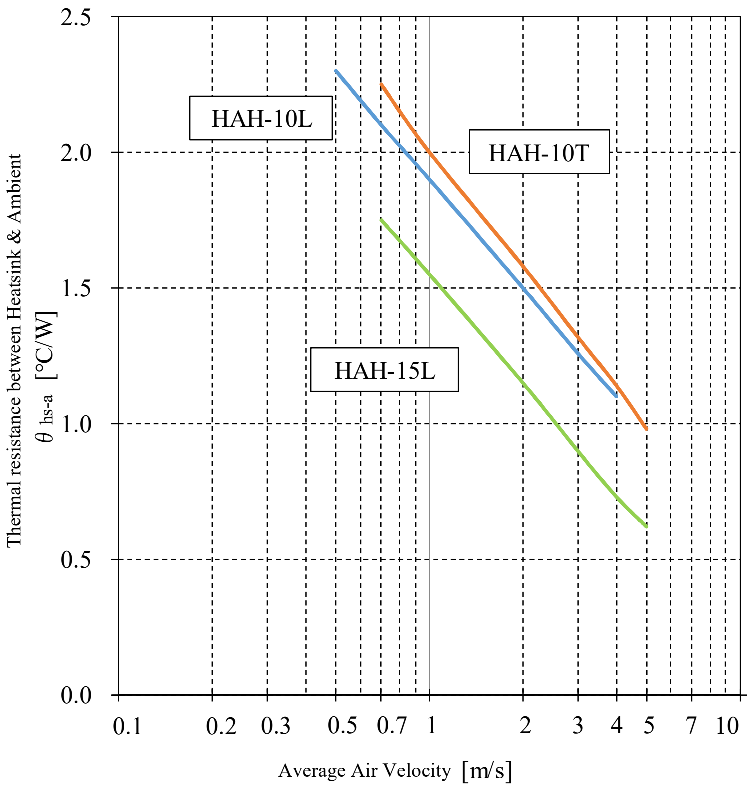
Material : Aluminum A6063-T5, with Black-Anodized
Surface Treatment (Commonly used.)

Note) For PH600A280 on high power output, HAH-15L with large blade use is recommended, because it has large heat radiation.

HAH-15L



< Characteristics on Forced Air Cooling >



(6) Heatsink for Full Brick ①

HAF-10L

Size : 61(W)×25.4(H)×116.8(D)[mm]
Modules to be applied to : PAF, PFE-SA
Thermal Resistance * : 2.2 [°C/W]

(7) Heatsink for Full Brick ②

HAF-15L

Size : 61(W)×38.1(H)×116.8(D)[mm]
Modules to be applied to : PAF, PFE-SA
Thermal Resistance * : 1.9 [°C/W]

(8) Heatsink for Full Brick ③

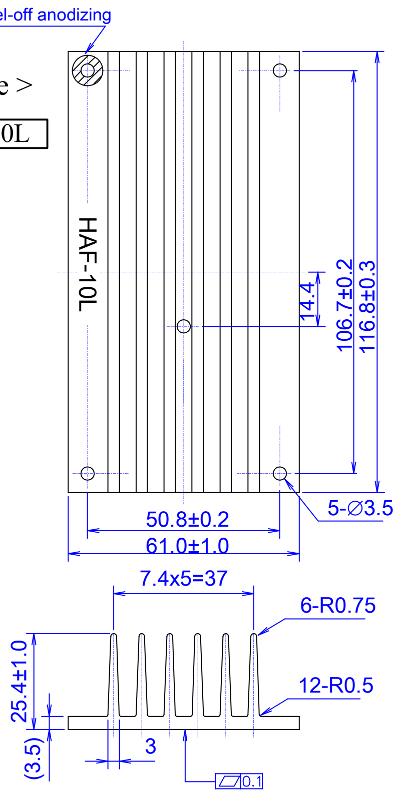
HAF-15T

Size : 116.8(W)×38.1(H)×61(D)[mm]
Modules to be applied to : PAF, PFE-SA
Thermal Resistance * : 1.5 [°C/W]

Note) * Natural convection cooling

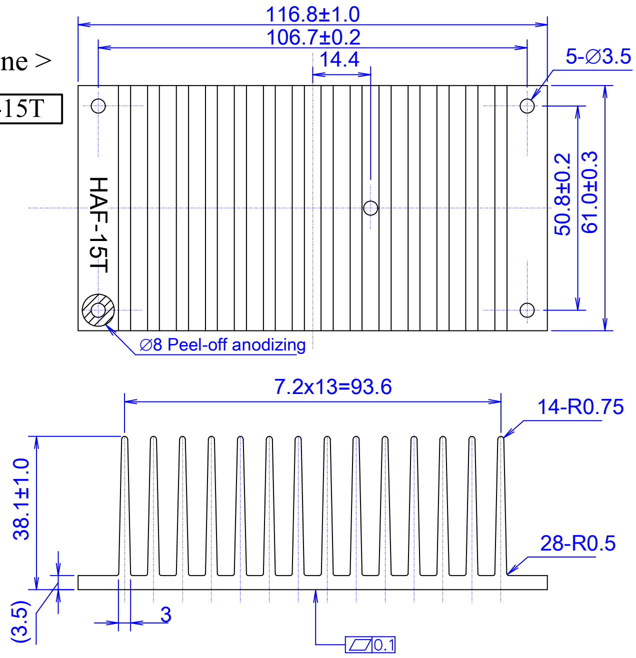
< Outline >

HAF-10L



< Outline >

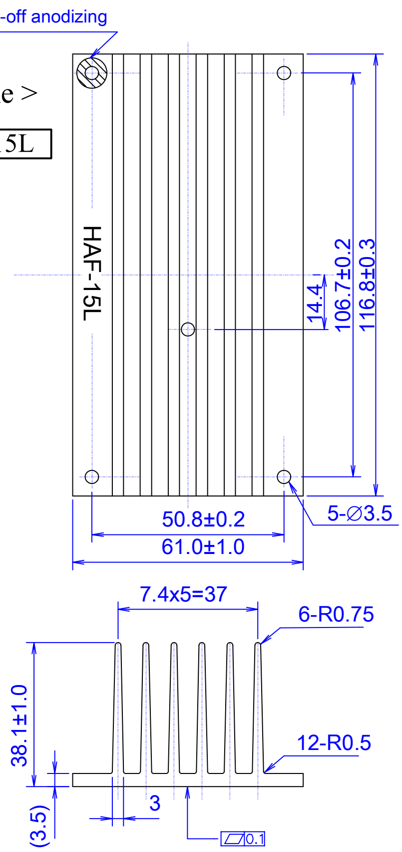
HAF-15T



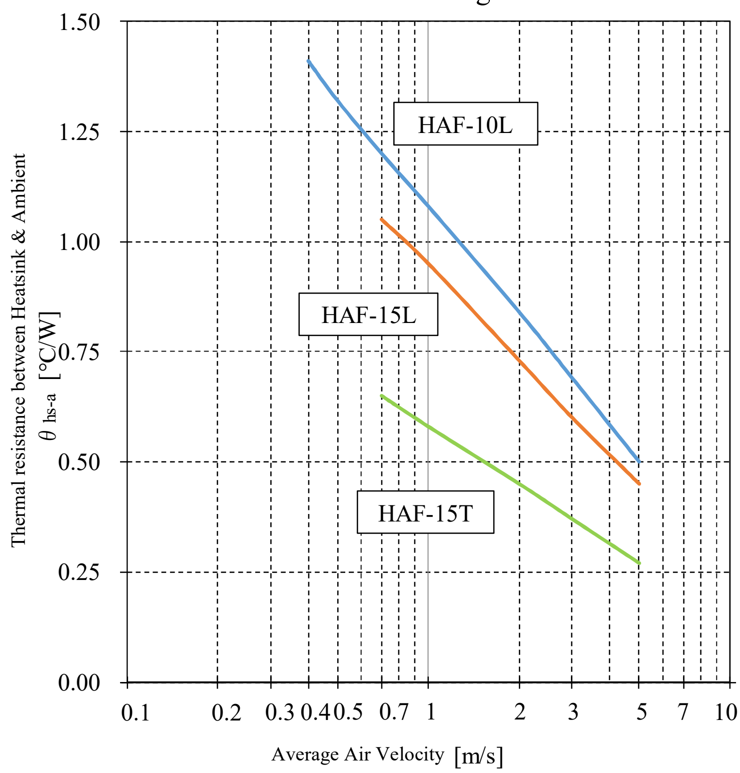
Material : Aluminum A6063-T5, with Black-Anodized Surface Treatment (Commonly used.)

< Outline >

HAF-15L



< Characteristics on Forced Air Cooling >



(9) Heatsink for PFE500F only

HAL-F12T

Size : 122(W)×35(H)×69.9(D)[mm]
Modules to be applied to : PFE500F
Thermal Resistance * : 0.97 [°C/W]

(10) Heatsink for PFE1000FA only

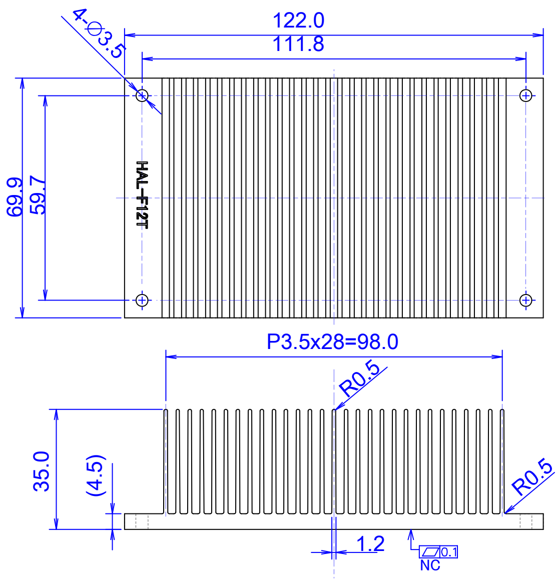
HAM-F10T

サイズ: 160(W)×33.4(H)×100(D)[mm]
Modules to be applied to : PFE1000FA
Thermal Resistance * 0.78 [°C/W]

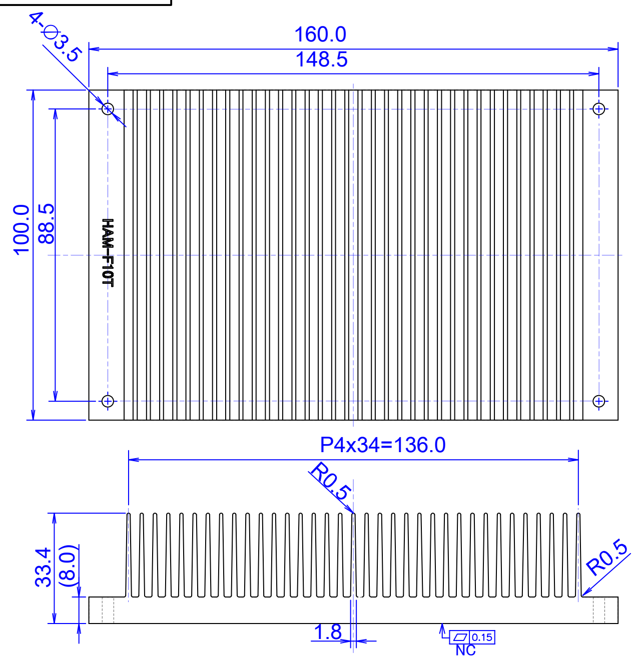
Note) * Natural convection cooling

< Outline >

HAL-F12T

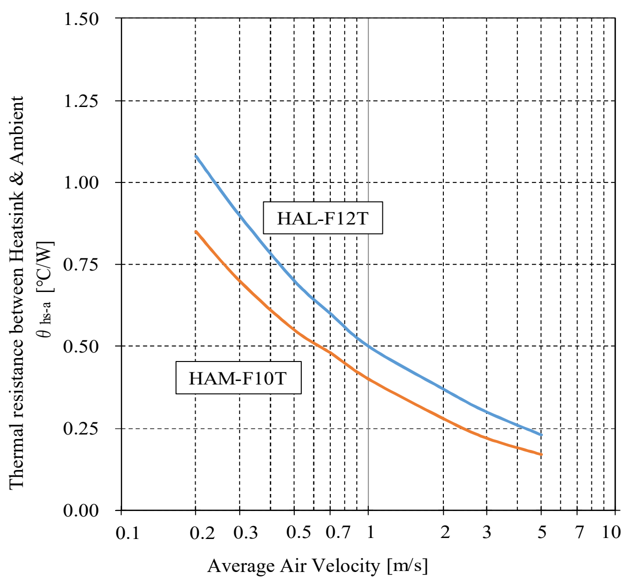


HAM-F10T



Material : Aluminum A6063-T5, without Anodized
Surface Treatment (Commonly used.)

< Characteristics on Forced Air Cooling >



Note) HAL and HAM do not have holes for temperature measurement (through thermocouples).
Customers are requested to make holes by themselves before using or evaluation.

(11) Heatsink for Quarter Brick

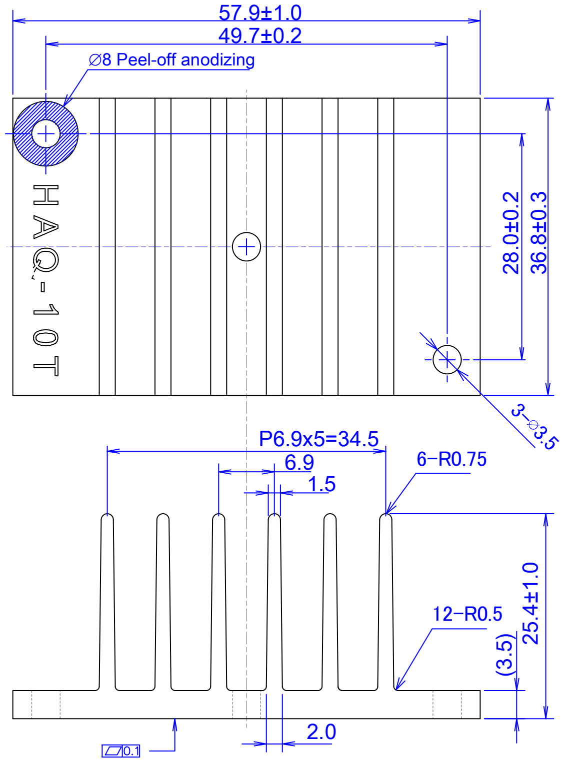
HAQ-10T

Size : 57.9(W)×25.4(H)×36.8(D)[mm]
Modules to be applied to : CN-A (30-100W), PH-A280 (50-150W)
Thermal Resistance * : 7.5 [°C/W]

Note) * Natural convection cooling

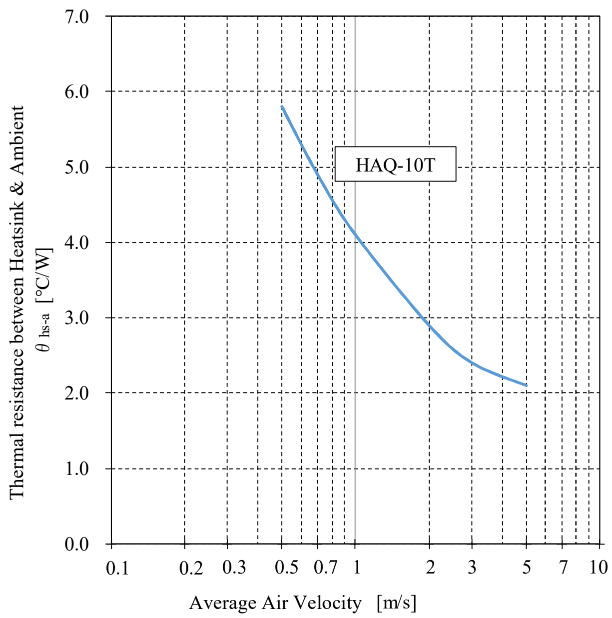
< Outline >

HAQ-10T



Material : Aluminum A6063-T5, with
Black-Anodized Surface Treatment

< Characteristics on Forced Air Cooling >



2-5. Forced Air Cooling Example by Using Optional Standard Heatsink (For Reference)

Here, typical output power, efficiency, power loss, thermal resistance, and average wind speed required for standard radiators are shown for power modules. A calculation example Are shown on the table below. This is the case when the base plate is coated with silicone grease for heat radiation and the heatsink is mounted. When the average wind speed exceeds 5 m/s (axial fan: 60 mm square 5W, 1.0 m^3/min class) or more, it is necessary to pay attention to audible noise.

1. DC-DC Power Moduule		Common Condition : Ta=50°C				(1) Tp=80°C (ΔTp=30°C)		(2) Tp=90°C (ΔTp=40°C)	
Series	Model	Output Power Po [W]	Efficiency η [%]	Power Loss Pd [W]	Heat-sink	Required Thermal Res. θbp-a1 [°C/W]	Average Air Velocity V1 [m/s]	Required Thermal Res. θbp-a2 [°C/W]	Average Air Velocity V2 [m/s]
CN-A	CN50A24-5 or 12	50	81	11.7	HAQ-10T	2.56	2.6	3.41	1.4
	CN50A24-15 or 24	50	82	11.0	↑	2.73	2.3	3.64	1.3
	CN50A110-*	50	81	11.7	↑	2.56	2.6	3.41	1.4
	CN100A110-5	100	86	16.3	↑	1.84	4.9	2.46	2.8
	CN100A110-12,15,24	100	85	17.6	↑	1.70	5.8	2.27	3.3
	CN200A110-*	150	85	26.5	HAH-15L	1.13	2.2	1.51	1.2
		200	86	32.6	↑	0.92	3.1	1.23	1.8
PAH	PAH300S24-12	100	85	17.6	HAH-10L	1.70	1.4	2.27	0.5
		200	86	32.6	HAH-15L	0.92	3.1	1.23	1.8
		300	85	52.9	↑	0.57	5.5	0.76	4.0
	PAH300S48-28	100	86	16.3	HAH-10L	1.84	1.1	2.46	0.4
		200	88	27.3	HAH-15L	1.10	2.3	1.47	1.2
		300	87	44.8	↑	0.67	4.6	0.89	3.2
	PAH450S48-48	300	90	33.3	↑	0.90	3.2	1.20	1.9
		400	90	44.4	↑	0.68	4.6	0.90	3.2
		450	90	50.0	↑	0.60	5.2	0.80	3.7
PAF	PAF500F24-12	400	87	59.8	HAF-10L	0.50	4.9	0.67	3.1
		500	86	81.4	HAF-15T	0.37	3.1	0.49	1.6
	PAF500F48-28	400	88	54.5	HAF-10L	0.55	4.3	0.73	2.6
		500	88	68.2	HAF-15T	0.44	2.1	0.59	1.0
	PAF700F48-12	500	89	61.8	HAF-10L	0.49	5.2	0.65	3.3
		700	87	104.6	HAF-15T	0.29	4.8	0.38	2.9
	PAF700F48-28	500	89	61.8	HAF-10L	0.49	5.2	0.65	3.3
		700	89	86.5	HAF-15T	0.35	3.5	0.46	1.9
	PAF600F280-48	450	90	50.0	↑	0.60	0.9	0.80	0.3
		600	90	66.7	↑	0.45	2.0	0.60	0.9
PH-A	PH50A280-5	30	81	7.0	HAQ-10T	4.26	0.9	5.68	0.5
		50	84	9.5	↑	3.15	1.7	4.20	1.0
	PH100A280-48	75	86	12.2	↑	2.46	2.8	3.28	1.6
		100	87	14.9	↑	2.01	4.2	2.68	2.3
	PH150A280-24	120	88	16.4	↑	1.83	5.0	2.44	2.8
		150	88	20.5	↑	1.47	7.8	1.96	4.4
	PH300A280-48	200	88	27.3	HAH-10L	1.10	4.0	1.47	2.1
		300	89	37.1	HAH-15L	0.81	3.7	1.08	2.4
	PH600A280-24	450	91	44.5	↑	0.67	4.6	0.90	3.2
		600	92	52.2	↑	0.58	5.4	0.77	3.9

2-5. Forced Air Cooling Example by Using Optional Standard Heatsink (For Reference) < Continued >

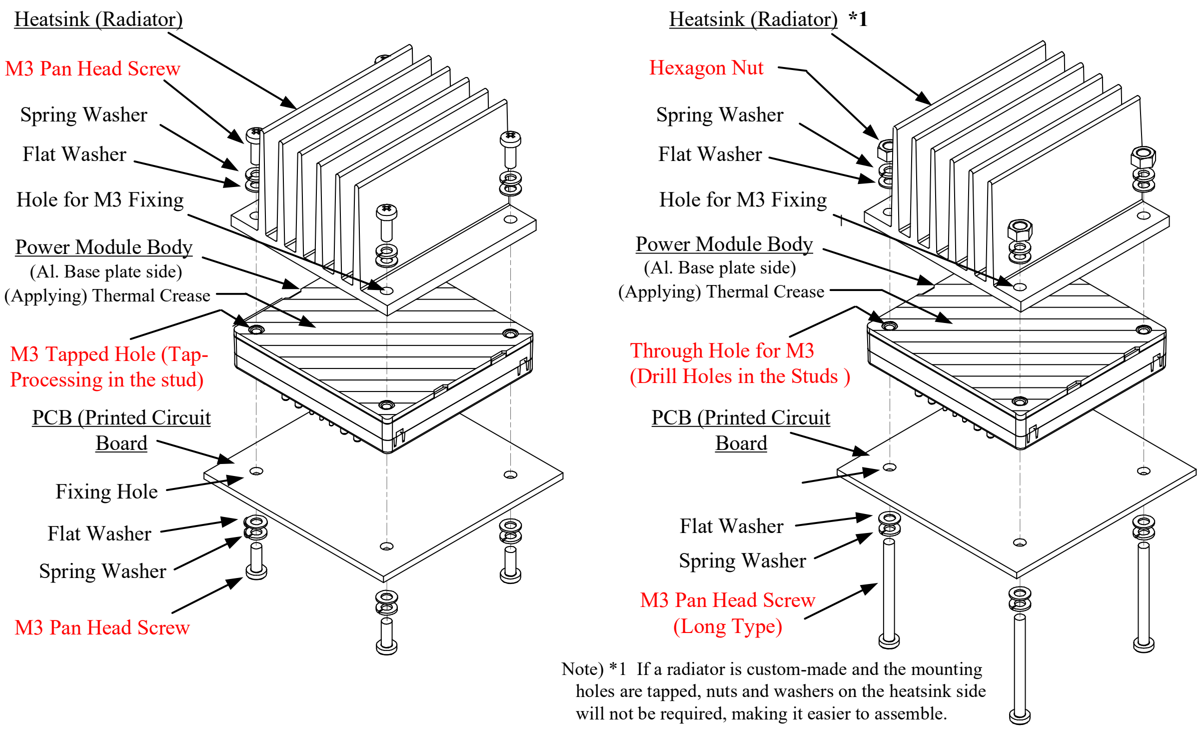
2. PFHC Power Moduule		Common Condition : Ta=50°C				(1) Tp=80°C (ΔTp=30°C)		(2) Tp=85°C (ΔTp=35°C)	
Series	Model	Output Power Po [W]	Efficiency η [%]	Power Loss Pd [W]	Heat-sink	Required Thermal Res. θbp-a1 [°C/W]	Average Air Velocity V1 [m/s]	Required Thermal Res. θbp-a2 [°C/W]	Average Air Velocity V2 [m/s]
PF-A	PF500A-360 (Vin=100VAC)	300	92	26.1	HAA-083	1.15	1.1	1.34	0.7
		400	92	34.8	↑	0.86	2.2	1.01	1.6
		500	91	49.5	↑	0.61	3.9	0.71	3.1
	PF500A-360 (Vin=200VAC)	600	95	31.6	↑	0.95	1.8	1.11	1.2
		750	95	39.5	↑	0.76	4.0	0.89	3.2
	PF1000A-360 (Vin=100VAC)	600	94	38.3	HAA-146	0.78	0.9	0.91	3.1
		800	94	51.1	↑	0.59	1.9	0.69	1.3
		1000	94	63.8	↑	0.47	2.9	0.55	2.2
	PF1000A-360 (Vin=200VAC)	1200	94	76.6	↑	0.39	3.8	0.46	3.0
		1500	94	95.7	↑	0.31	5.1	0.37	4.2

3. AC-DC Power Module		Common Condition : Ta=50°C				(1) Tp=80°C (ΔTp=30°C)		(2) Tp=90°C (ΔTp=40°C)	
Series	Model	Output Power Po [W]	Efficiency η [%]	Power Loss Pd [W]	Heat-sink	Required Thermal Res. θbp-a1 [°C/W]	Average Air Velocity V1 [m/s]	Required Thermal Res. θbp-a2 [°C/W]	Average Air Velocity V2 [m/s]
PFE-SA	PFE500SA-48 (Vin=100VAC)	300	86	48.8	HAF-10L	0.61	3.6	0.82	2.1
		500	88	68.2	HAF-15T	0.44	2.1	0.59	1.0
	PFE500SA-48 (Vin=200VAC)	300	89	37.1	HAF-10L	0.81	2.1	1.08	1.0
		500	91	49.5	HAF-15T	0.61	0.9	0.81	0.3
	PFE700SA-48 (Vin=100VAC)	400	88	54.5	HAF-10L	0.55	4.3	0.73	2.6
		700	89	86.5	HAF-15T	0.35	3.5	0.46	1.9
	PFE700SA-48 (Vin=200VAC)	400	90	44.4	HAF-10L	0.68	3.1	0.90	1.6
		700	92	60.9	HAF-15T	0.49	1.6	0.66	0.7
PFE-F	PFE500F-28 (Vin=100VAC)	300	82	65.9	HAL-F12T	0.46	1.2	0.61	0.7
		500	84	95.2	↑	0.32	2.4	0.42	1.4
	PFE500F-28 (Vin=200VAC)	300	85	52.9	↑	0.57	0.7	0.76	0.4
		500	86	81.4	↑	0.37	1.8	0.49	1.0
PFE-FA	PFE1000FA-48 (Vin=100VAC)	700	86	114.0	HAM-F10T	0.26	2.2	0.35	1.2
		1000	87	149.4	↑	0.20	3.8	0.27	2.1
	PFE1000FA-48 (Vin=200VAC)	700	88	95.5	↑	0.31	1.5	0.42	0.9
		1000	89	123.6	↑	0.24	2.6	0.32	1.5

3. Power Module Assembling on the PCB

3-1. Mounting Method on the PCB

When mounting the power module on the PCB, refer to the method in Fig. 3-1 before mounting. The example in the figure shows the combination of PH300A280 / PH600A280 and the standard radiator "HAH-15L".



Standard Type (M3 Tapped) Assembly Method

/T, /PI Type (Through Hole) Assembly Method

Fig. 3-1 Power Module Assembly Method on the PCB

(1) How to Fixing

When fixing the power module to the PCB, use the mounting holes on the body to screw it in. Refer to the next (2) section for the details of the mounting holes. M3 is suitable for screws. And the recommended tightening torque is 0.54 N・m (about 5.5 kg F・cm). The number of places to fix with screws varies depending on the product size and is as follows.

2 places ... 1/4 Brick or less size, 4 places ... 1/2 Brick or more size

Use all the mounting holes for the power module and screw them in. If only a part of it is used, stress will be applied to the base plate during fixing, which may damage the internal parts, which is dangerous.

* If a washer built-in screw (sems screw) that combines a screw and a washer is used, workability will be improved.

(2) M3 Tapped Hole for fixing

M3 screw mounting holes are made by drilling in the metal studs built into the power module (Fig. 3-2), and there are two types: tapped products and through-hole products (through holes, without tapping). The standard product is a tapped product. Through-hole types are distinguished by adding / T or / PI after the product type name.
Below are variations of mounting holes and examples of product names.
Standard product: M3 tap (thread cutting) processed product (PAH450S48-48, etc.),
Through hole: φ3.3 through hole product (PH600A280-24 / T, etc.),
Through hole: φ3.2 through hole product (PF1000A-360 / PI, PF-A series only)
If you need a through-hole product, please specify it when ordering.

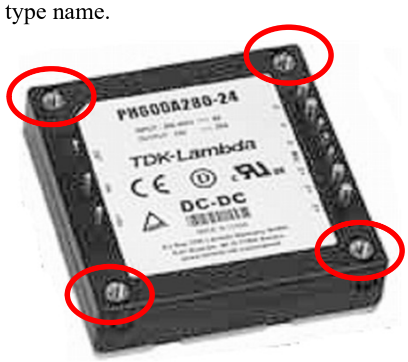


Fig. 3-2 Support and hole processing (inside the round frame) (Example of PH600A280, photo seen from the front seal side)

(3) Mounting holes of the PCB / Land diameter of Copper wiring pattern

Refer to the sizes in the table below to determine the mounting holes and land diameter of the PCB. These can be arranged as appropriate as long as they meet the requirements of equipment performance and safety standards.
For the position and number of mounting holes (pins), please refer to the external view of each product.

Function		AC-DC				DC-DC		
Site \ Prdn. Name		PF-A360	PFE-SA	PFE500F	PFE1000FA	PAF-F	CN50~100A24, CN30~100A110 PH50~150A280	CN200A110, PH300A280, PH600A280
Diameter of Input Pins ϕ [mm]	Pin	2.0	1.0		2.0		1.0	
	PCB Hole	2.5	1.5		2.5		1.5	
	Land	5.0	3.5		5.0		2.5	
Diameter of Output Pins ϕ [mm]	Pin			2.0			1.5	2.0
	PCB Hole			2.5			2.0	2.5
	Land			5.0			3.5	5.0
Diameter of Signal Pins ϕ [mm]	Pin	0.6	1.0	□ 0.64 *		1.0	1.0	
	PCB Hole	1.0	1.5	1.0		1.5	1.5	
	Land	2.0	3.5	1.8		3.5	2.5	
Tap Diameter in Studs (FG) ϕ [mm]	Screw	M3.0 (Common for All Power Modules)						
	PCB Hole	3.5 (Common for All Power Modules)						
	Land	7.0 (Common for All Power Modules)						

Note) * PFE-F (A) series signal pins are square pins.

(4) Recommended PCB material

A glass epoxy PCB with double-sided through holes, thickness 1.6 mm, copper foil thickness 35 mm or more.

(5) PCB copper pattern width

A several 10A current flowing through the input / output line, so please design the PCB pattern in consideration of copper loss and heat radiation.

The relation between the current and the pattern width depends on the PCB material, copper thickness, and the allowable temperature rise of the pattern. Here, as an example of a general glass epoxy board with a copper thickness of 35 mm, the relation between the conductor width and the allowable current is shown in Fig. 3-3. For example, if a current of 5A is applied and the temperature rise is 10°C or less, the pattern width must be 4.2mm or more. (As an easy-to-use guide, consider a width of 1mm per 1A of current.) The characteristics shown in Fig. 3-3 differ depending on the board manufacturer, so at the time of design. Please be sure to check with the applicable board manufacturer.

In addition, if necessary, apply a multi-layer board, and consider making the pattern thicker or connecting in parallel where a large current flows.

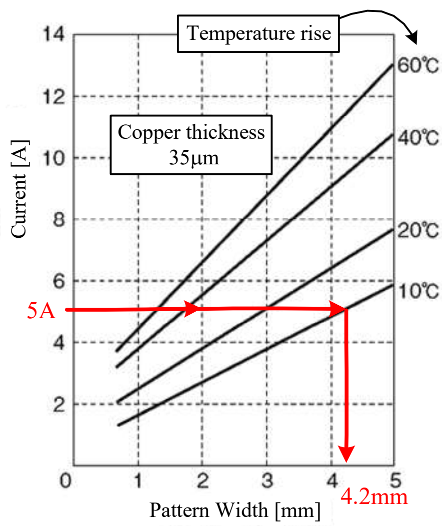


Fig. 3-3 Relation between pattern width and allowable current (example)

(6) Terminal wiring and pattern routing method

Input / output terminal pins (+ Vin, -Vin, AC (L), AC (N), + R, + V (out), -V (out), etc.) and FG (mounting tap) can be connected in (5) above.) To deal with large currents and to prevent noise, make the contact resistance smaller.
And please consider noise suppression for small signal wiring (terminal names: CNT, SG, ON / OFF, PC, IOG, ENA, AUX, + S, TRM, -S, etc.). As an example, it is effective to separate it from the input / output system wiring, wire it according to the -S pattern on the output side, or use a multilayer board to make -S or FG a shield layer.

* Please note that the pin length differs by the product. For details, please refer to the external view of each product.

3-2. Heatsink Assembly

(1) Fixing Method (Refer to Fig. 3-1)

(1-1) Standard Type

To fix the heatsink, use the M3 tap screw on the base plate side. M3 is suitable for screws. Consider the length of the screws so that they do not interfere with the screws installed from the opposite PCB side. The length of the tapped column is 12.7 mm (typ.), which is the same as the height (thickness) of the power module, so it is a rough guideline that the screw can be inserted into the column by about 3 to 5 mm. The recommended tightening torque for screws is 0.54 [N・m] (approx. 5.5 [kg F・cm]).

(1-2) Through Hole Type (/T, /PI)

A long screw Must be used through the printed circuit board with the power module mounted, and it is fastened together with the heatsink. M3 is suitable for screws. The screw length is the sum of the board thickness, power module height (thickness), and radiator thickness. For example, if the board thickness is 1.6 mm, the power module height is 12.7 mm, the heat dissipation grease thickness is 0.2 mm, and the heat dissipation device mounting part thickness is 3.0 mm, the total on the left is 17.5 mm. Then, need to use a matching long screw.

When using a through-hole product, temporarily fix the power module body in advance before soldering him. Please note that if the solder is screwed after flow soldering without temporary fixing, stress will be applied to the soldered part, which may affect the reliability.

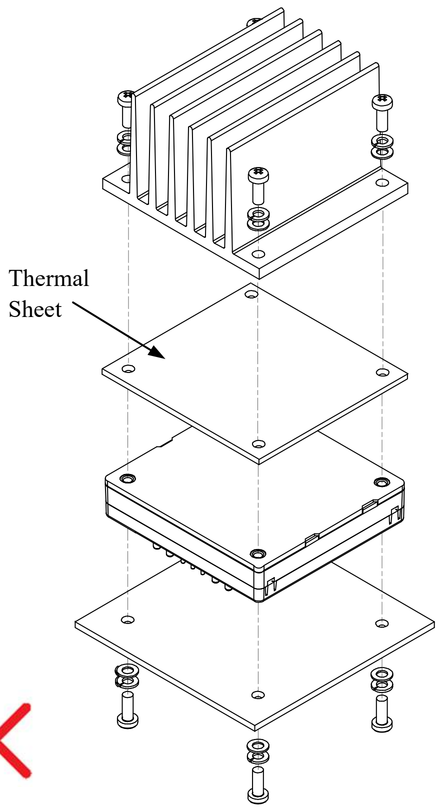
(2) Mounting Holes of Heatsink

The standard (optional) Heatsinks of TDK-Lambda Have also mounting holes for standard products only. They have through holes according to the mounting tap position of the power module product, and the hole diameter are ϕ 3.5 mm. If a customer uses the / T, / PI type of power module and design the heatsinks by himself, tapping (threading) the heatsink with M3 will improve workability. (See Figure 3-1 / T, / PI type implementation method)

(3) Notice for Thermal Sheet

In order to ensure thermal radiation performance, it is necessary to improve the heat coupling between the power module product and the radiator and install the radiator. A common method is to apply thermal grease to the base plate of the power module and fix the radiator on it. As a result, the gap between the base plate and the radiator is filled, so high heat radiation performance can be obtained.

Recently, there is an example of using a heat dissipation sheet as shown in Fig. 3-4 at right side, but please install it so that the above gap is not created. Also, when processing the thermal sheet, make a hole according to the position of the screw. If only diagonal cuts are used as shown in the figure below, stress may be applied to the edges of the base plate during fixing, which may damage the built-in parts, so avoid such processing.



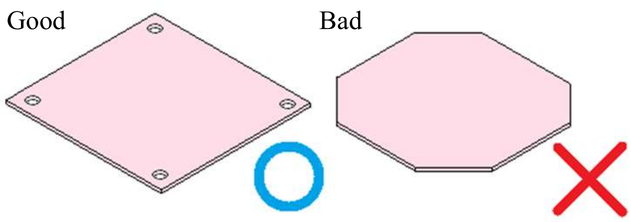


Fig. 3-4 Image of using thermal sheet and precautions when processing

3-3. Vibration and Shock Resistant

The vibration or shock resistant specification value of the power module is the value when only the power module is mounted on the PCB* (without a heatsink). Therefore, when using a large radiator, fix the radiator to the housing of the device separately from fixing the power module so that excessive stress is not applied to the power supply body or the PCB*. (*PCB : Printed circuit board)

3-4. Recommended Soldering Conditions

(1) Flow Soldering (for solder dip tank)

Preheat conditions : 110°C、30~40sec. or less, Dip Condition：260°C、10sec. or less
Note) Reflow soldering is not possible. (Because the solder of the built-in parts melts and falls off or is damaged.)

(2) Soldering Iron (for manual soldering)

The iron tip temperature : 350°C max. Soldering Time：3 sec. or less

Note) It is necessary to adjust the soldering time depending on the heat capacity of the soldering iron used, the board pattern, etc. Please arrange by The customer himself based on the above conditions.

3-5. Recommended Cleaning (Flux) Conditions (After assembly the power module)

(1) Recommended Cleaning Liquid

IPA (Iso-Propyl alcohol), but no cleaning and corresponding flux are also recommended.

(2) Cleaning Method

Please clean the brush so that the cleaning liquid does not penetrate inside the power module product.
And after cleaning, please dry it sufficiently. Please do not soak and wash.

Note) There is a risk that the resin parts inside the product will be deformed or deteriorated if it is soaked and washed.

3-6. Storage Condition and Period (Before Mounting with Soldering on PCB)

(1) Storage Condition

* Temperature Range : 5°C ~ 30°C, * Humidity Range : 40% ~ 60%RH (No Dew Condensation)

Please keep the product in the packaged state at purchasing, and also avoid direct sunlight.
And please handle the product without excessive vibration, shock or weight load.

Note) Please keep away from the places where temperature and humidity change drastically, because there is the risk for occurrence of dew condensation and deterioration.

(2) Storage Period

It is recommended for use within 2 years after delivery. However, if 1 year passed after delivery, to make sure, please check the lead pins of the product whether oxidation or rust occurs or not, and use after checking their solderability.

Note) In the case for long-term Storage

The oxidation factor (oxygen or moisture) countermeasure is recommended by applying degassed packing with using desiccant (for example, silica-gel) to store with an emphasis on not oxidizing the terminal pins.

3-7. Saving Conditions and Periond (After Mounting with Soldering on PCB)

(1) Saving Conditions

* Temperature Range : -40°C ~ 85°C, * Humidity Range : 5% ~ 95%RH (No Dew Condensation)

(2) Saving Period

There is no particular regulation, but it is recommended to use the products in about 2 years as a guide.
In addition, if a limited life-time component (such as electrolytic capacitor) is mounted externally, please also check that it is not deteriorated.