

# PAE-S48 SERIES

## Instruction Manual

### ■ Before Using This Power Module

Be sure to take note of precautions and warnings indicated in this manual when using this product. Improper usage may lead to electric shock or fire. Be sure to read this instruction manual thoroughly before using this product.

### ■ Caution

- There are high voltage and high temperature components within this product. Refrain from disassembling this product or touching its internal components as this may lead to electric shock or burned.
- When the unit is operating, keep your hands and face away from the unit. You may get injured by accident.
- Confirm connections to input/output terminals and signal terminals are correct as indicated in the instruction manual.
- Attach a fast blow type external fuse to each module to ensure safety operation and compliance to each safety standard approval.
- This power module is designed for professional installation within the end user equipment.
- Use isolated voltage by reinforced or double insulation as input power source.
- Do not inject abnormal voltage to output terminal and signal terminal from the outside.  
The injection of reverse voltage or over voltage exceeding nominal output voltage to output terminals might cause damage to internal circuit.
- The application circuits and their parameter are for reference only. Be sure to verify effectiveness of application circuits and their parameters before finalizing circuit design.
- The information in this document is subject to change without prior notice. For actual design-in, please refer to the latest publications of data sheet, etc., for the most up-to date specifications of the unit.
- No part of this document may be copied or reproduced in any for, or by any mean without prior written consent of Densai-Lambda.
- This product is not authorized for use as critical components in life support devices or systems without prior written consent of Densai-Lambda. As used herein:
  1. Life support devices or systems are devices or systems which, (a) are intended for surgical implant into the body, or (b) support or sustain life, and whose failure to perform when properly used in accordance with instructions for use provided in the labeling, can be reasonably expected to result in a significant injury to the user.
  2. A critical component is any component of a life support device or system whose failure to perform can be reasonably expected to cause the failure of the life support device or system, or to affect its safety or effectiveness.

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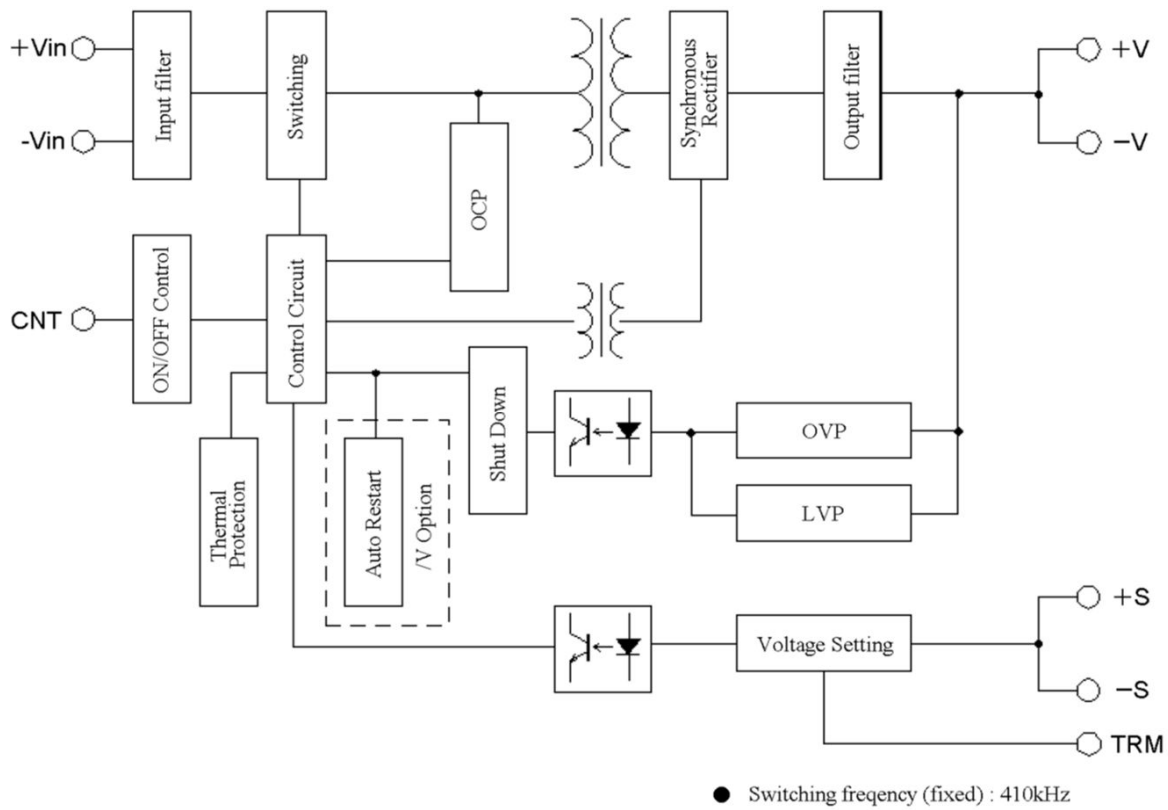
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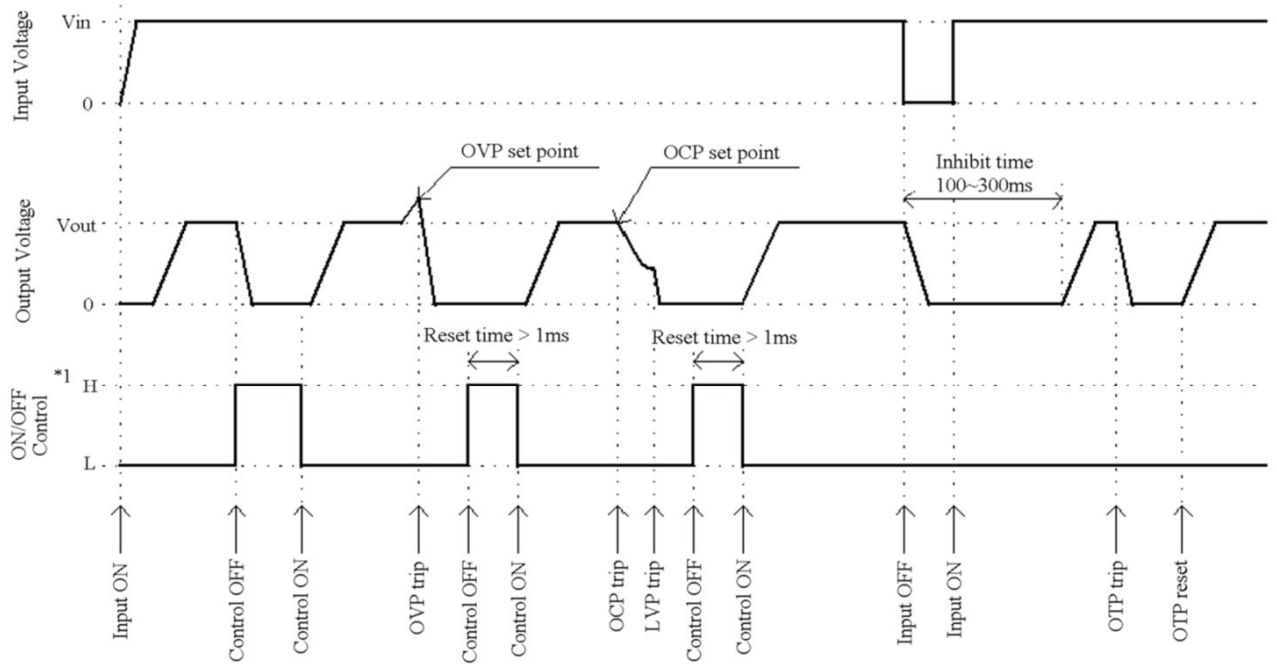
### ■ Before concluding module damage

## Block Diagram



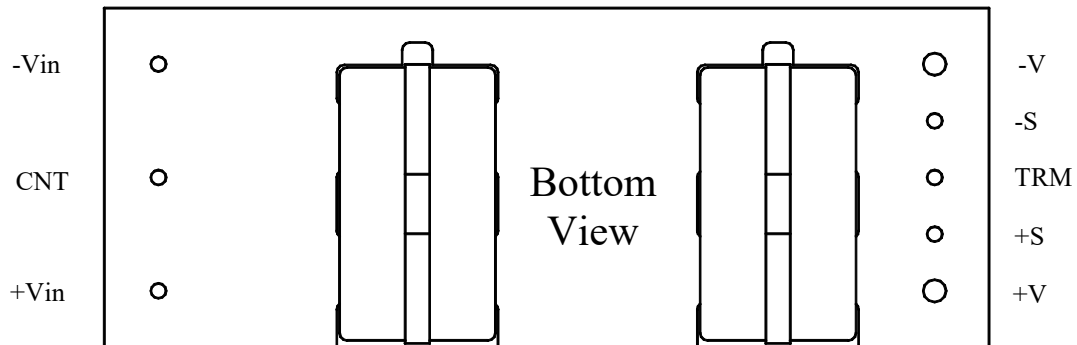
## Sequence Time Chart

(for Standard Model with Latch type OVP & OCP)



\*1 Level :  $4V \leq H \leq 35V$  or Open,  $0V \leq L \leq 0.8V$  or Short

## ■ Terminal Explanation



Input and Output Terminal Configurations (Bottom View)

[Input Terminal]

-Vin : -Input Terminal  
CNT : ON/OFF Control Terminal  
+Vin : +Input Terminal

[Output Terminal]

-V : -Output Terminal  
-S : -Remote Sensing Terminal  
TRM : Output Voltage Trimming Terminal  
+S : +Remote Sensing Terminal  
+V : +Output Terminal

## ■ Explanation on Specifications

### 1. Input Voltage Range

Input Voltage Range for PAE\_S48 Series is indicated below.

**Input Voltage Range : 36~76VDC**

Basically, ripple voltage ( $V_{rpl}$ ) which results from rectification and filtering of commercial AC line might be included within the input voltage as shown in Fig.1-1.

Ripple voltage must be limited within the voltage described below.

**Allowable input ripple voltage : 2Vp-p**

When this value is exceeded, the output ripple voltage might become large.

Note that sudden input voltage change may cause variation of output voltage transitionally.

Also, input voltage waveform peak value must not exceed above input voltage range.

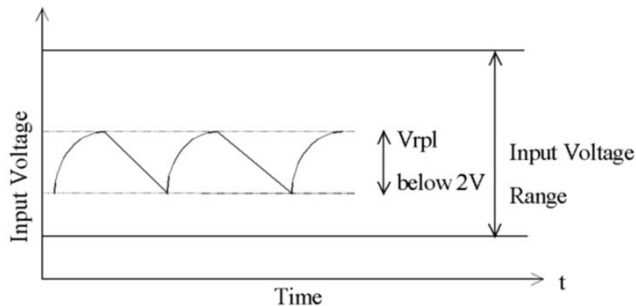


Fig.1-1 Input Ripple Voltage

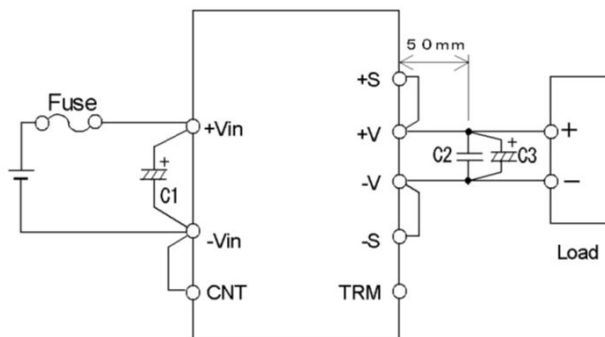


Fig.1-2 Basic Connection

### Input Fuse

PAE\_S48 Series module is not internally fused. To ensure safe operation and to receive each Safety Standards approval, please connect an external fuse (fast-blow type) as shown in Fig.1-2.

Fuse must be connected to the  $+Vin$  side if  $-Vin$  side is used as ground, or fuse must be connected to  $-Vin$  side if  $+Vin$  side is used as a ground.

**Recommended input fuse current rating:**

**PAE100S48 : 6.3A**

**PAE50S48 : 5A**

### C1 :

Input capacitor  $C1$  is recommended to stabilize the module when the module is powered from a high impedance source.

Select the electrolytic capacitor with low ESR and sufficient allowable ripple current.

Verify actual ripple current value by actual measurement.

**Recommended capacitor value : 33  $\mu$ F and above (Voltage rating : 100V and above)**

### Note)

- 1 Use low impedance electrolytic capacitor with excellent temperature characteristics. (Nippon Chemicon LXV Series or equivalent)
- 2 When input line inductance becomes excessively high due to insertion of choke coil operation of the power module could become unstable. For this case, increase  $C1$  value more than the value indicated above.
- 3 When ambient temperature becomes lower than  $-20^{\circ}\text{C}$ , connect ceramic capacitors.

**C2, C3**

To reduce spike noise voltage at the output, connect  $1\ \mu\text{F}$  ceramic capacitor and  $10\ \mu\text{F}$  electrolytic capacitor or tantalum capacitor between +V and -V within 50mm distance from the output terminals. Also, take note that output spike noise voltage could vary according to PCB wiring design.

**Recommended capacitor value**

- C2 :  $1\ \mu\text{F}$**
- C3 :  $10\ \mu\text{F}$**

Maximum capacitance (ceramic capacitor) that can be connected between +V and -V, is shown below.

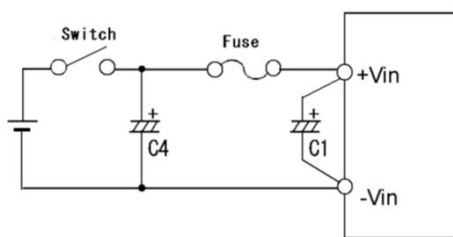
**Maximum capacitance of output capacitor  
 $10,000\ \mu\text{F}$  ( ALL Model )**

**C4 :**

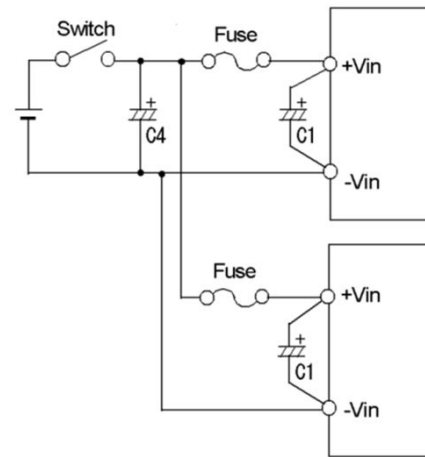
When switches or connectors are used between input source and PAE\_S48 Series input terminals, impulse surge voltage is generated due to input throw-in by switch on/off or due to inserting/removing of power module from the active line. For this case, connect an additional electrolytic capacitor C4 as shown in fig.1-3 and fig.1-4.

**Recommended capacitor value:  $33\ \mu\text{F}$  and above  
(Voltage Rating : 100V and above)**

Also, in-rush current flows at line throw-in. Therefore, be sure to verify capability of switch or fuse to withstand  $I^2t$  at line throw-in.



**Fig.1-3 Input filter (C4) with Switch**



**Fig.1-4 Input Filter with Switch  
when Plural Power Modules are connected**

**Reverse input connections**

Reverse input polarity would cause module damage. For cases where reverse connections are possible, connect a protective diode and fuse. Use protective diode with higher voltage rating than the input voltage, and with higher surge current rating than the fuse.



**Fig.1-5 Protection for Reversed Input Connection**

**2. Output Voltage Adjustment Range**

Output voltage could be adjusted within the range described below by external resistor or variable resistor. However, take note that OVP might trigger when output voltage adjustment exceeds the ranges indicated below.

**Output Voltage Adjustment Range**

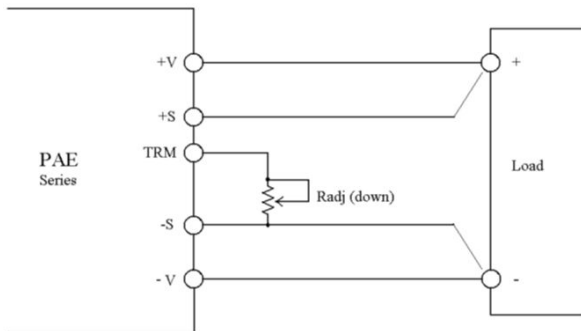
- 1.8V, 2.5V, 3.3V :**  
-20% ~ +10% of nominal output Voltage
- 5V:**  
-15% ~ +15% of nominal output Voltage

When increasing the output voltage, reduce the output current accordingly so as not to exceed the maximum output power.

Remote sensing is possible even when output voltage is varied. For details on remote sensing function, please refer to "9.Remote Sensing."

**Output Voltage Adjustment by external resistor or by variable resistor**

- (1) In case of adjusting output voltage lower
  - (1-1) Available maximum output current = rated output current
  - (1-2) Connect an external resistor R<sub>adj(down)</sub> between the TRM terminal and -S terminal.



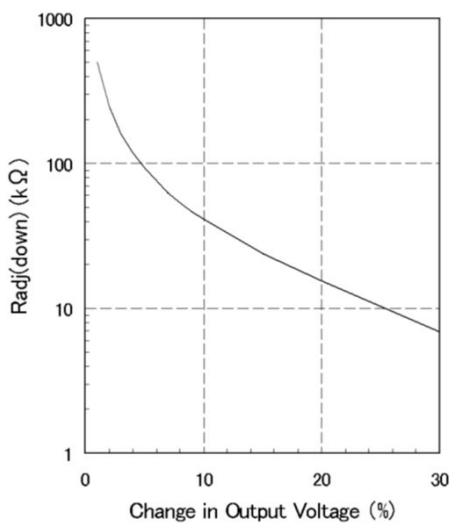
**Fig.2-1 Connection for output voltage trim down**

- (1-3) Equation of external resistor and output voltage

$$R_{adj(down)} = \left( \frac{5.11 \times 100(\%)}{\Delta(\%)} - 10.22 \right) [k\Omega]$$

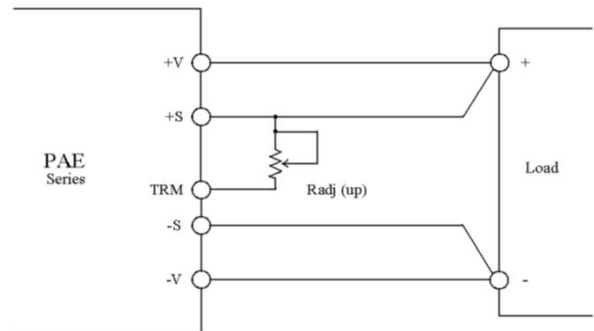
R<sub>adj(down)</sub> : Value of external resistor  
 Δ (%) : Output voltage change rate against nominal output voltage

Below graph is relation Δ (%) and value of external resistor.



**Fig.2-2 Δ (%) vs. Radj(down)**

- (2) In case of adjusting output voltage higher
  - (2-1) Allowable maximum output current = value of output power ÷ output voltage (reduce maximum output current in specification.)
  - (2-2) Connect an external resistor R<sub>adj(up)</sub> between TRM terminal and +S terminal



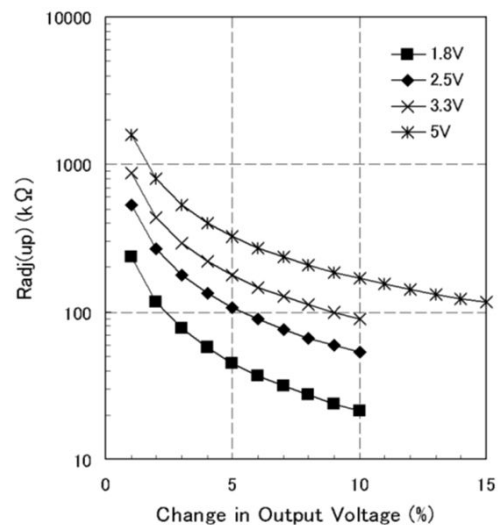
**Fig.2-3 Connection for output voltage trim up**

- (2-3) Equation of external resistor and output voltage

$$R_{adj(up)} = \left( \frac{5.11 \times V_o(100(\%) + \Delta(\%))}{1.225 \times \Delta(\%)} - \frac{5.11 \times 100(\%)}{\Delta(\%)} - 10.22 \right) [k\Omega]$$

V<sub>o</sub> : nominal output value of module  
 R<sub>adj (up)</sub> : external adjustment resistor  
 Δ (%) : Output voltage change rate against nominal output voltage

Below graph is relation Δ (%) and value of external resistor.



**Fig.2-4 Δ (%) vs. Radj(up)**

(3) To adjust output voltage for whole range Resister values, as well as, connecting methods for external resistor (R1) and external variable resistor(VR) are described below.

	1.8V	2.5V	3.3V	5V
R1	2.2k	4.7k	10k	3.3k
VR	2k	2k	2k	5k

unit : [  $\Omega$  ]

**Table 2-1 Values of External Resistor and Variable Resistor**

$V_o$  -20%, +10% (1.8V, 2.5V, 3.3V)  
 $V_o$   $\pm$ 15% (5V)

	1.8V	2.5V	3.3V	5V
R1	33k	18k	27k	18k
VR	500	1k	1k	2k

unit : [  $\Omega$  ]

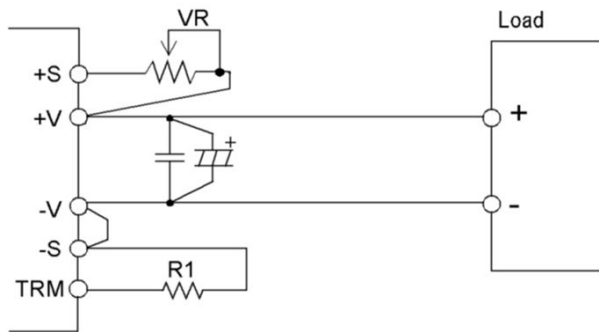
**Table 2-2 Values of External Resistor and Variable Resistor**

( $\pm$ 10% Variable)

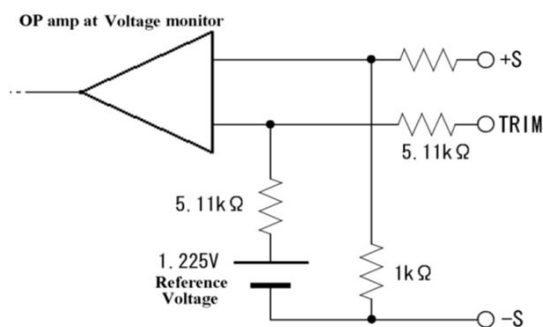
R1 :  $\pm$ 5% Tolerance

VR :  $\pm$ 20% Tolerance

with end resistance below 1%



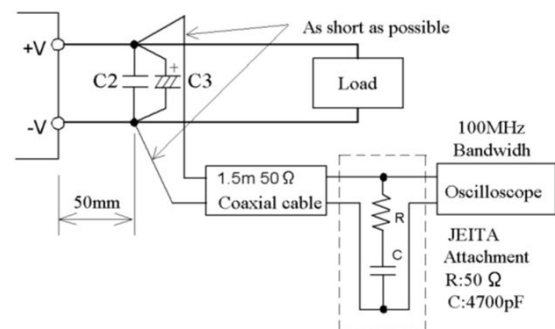
**Fig.2-5 Example connection of external resistor**



**Fig.2-6 Trim circuit composition**

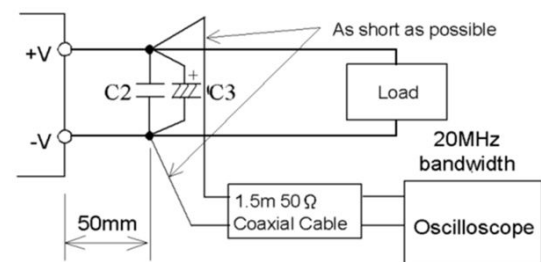
### 3. Maximum Ripple and Noise

(1) Measurement based on JEITA RC-9141  
 Measure according to the specified methods (Fig.3-1) based on JEITA RC-9141(Clause 7.12 and 7.13) which is described in the following. Connect capacitors (C2:ceramic capacitor 1  $\mu$  F, C3: electrolytic capacitor 10  $\mu$  F) at 50mm distance from the output terminals. Measure at ceramic capacitor (C2) leads as shown in fig.3-1 using coaxial cable with JEITA attachment. Use oscilloscope with 100MHz frequency bandwidth or equivalent.



**Fig.3-1 Measurement of Maximum Output Ripple & Noise Based on JEITA RC-9141**

(2) Measurement using coaxial cable  
 Measure according to fig.3-2. Connect capacitors (C2:ceramic capacitor 1  $\mu$  F, C3: electrolytic capacitor 10  $\mu$  F) at 50mm distance from the output terminals. Measure at ceramic capacitor (C2) leads using coaxial cable. Use oscilloscope with 20MHz frequency bandwidth or equivalent.



**Fig.3-2 Measurement of Maximum Output Ripple & Noise Using coaxial cable**

Take note that output ripple voltage and output spike noise may vary depending on PCB wiring design. Generally, output ripple voltage and output spike noise can be reduced by increasing value of external capacitor.



#### 4. Maximum Line Regulation

Maximum line regulation is the maximum value of output voltage change when input voltage is gradually varied within specified input voltage range. The measurement point for the input and output voltage are  $\pm V_{in}$  and  $\pm S$  (sense point) respectively

#### 5. Maximum Load Regulation

Maximum value of output voltage change when output current is gradually varied within specified output current range. The measurement point for the input and output voltage are  $\pm V_{in}$  and  $\pm S$  (sense point) respectively. When using at dynamic load mode, audible noise may be heard from the power module and output voltage fluctuation might increase.

#### 6. Over Current Protection (OCP)

This power module has built-in OCP function.

When output current is overload conditions, output voltage lowers.

Output will recover when short circuit or overload conditions are released.

OCP setting value is fixed and therefore, can not be externally adjusted. Also, take note, when output voltage drops down below lower side of adjustment range by output short circuit or over load conditions, output might be shut down.

Output can be recovered by manual reset of the control ON/OFF terminal or by turning input line off and then turning it on again .

#### 7. Over Voltage Protection (OVP)

This power module has built-in OVP function.

OVP set point is relative to the rated output voltage value. When output voltage exceed OVP set point, output voltage shut down. OVP set point is fixed and therefore can not be changed. When OVP is triggered, output can be recovered by turning input line off and then turning it on again after lowering the input voltage below the voltage value indicated below or by manual reset of the control ON/OFF terminal.

Verifying OVP function shall be done by increasing output voltage with external resistor. For verifying OVP function, avoid applying external voltage to output terminal because this will cause power module damage.

**Input voltage for OCP & OVP reset : 8VDC and below**

#### /V Option (automatically recovery)

The /V optional model will re-start with delay of 100ms~300ms after shutdown by OCP & OVP triggering.

When over current & over voltage are removed, output will recover normally.

#### 8. Over Temperature Protection (OTP)

This power module has built-in OTP function. This function operates and shuts down the output when temperature of the power module rises abnormally. Output voltage will re-start when PCB temperature drops down. Take note that OTP will operate again unless the cause of abnormal heat of the power module is eliminated.

#### 9. Remote Sensing (+S、-S Terminal)

Remote sensing terminal is provided to compensate for voltage drop across the wirings from the power module output terminal to the load input terminal. When remote sensing function is not used (local sensing), short +S terminal to +V terminal and, -S terminal to -V terminal.

When using remote sensing function, output power of power module should be within maximum output power. Also, use within maximum output adjustable voltage at output terminal.

When wire is long, Power Supply operation might be unstable due to noise. Moreover, please do enough prior evaluation for remote sensing function by using shielded wire, twist pair, or parallel pattern.

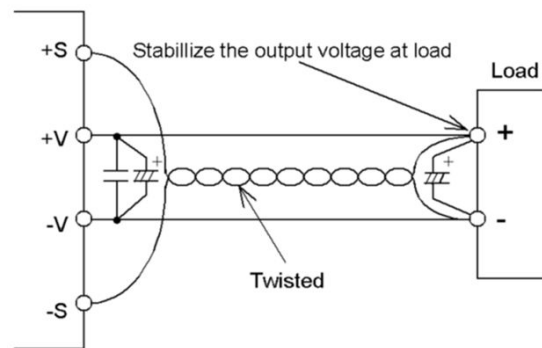


Fig.9-1 Remote Sensing in Use

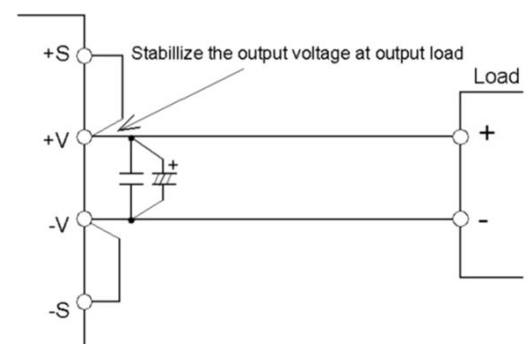


Fig.9-2 Remote Sensing Not in Use  
(Local Sensing)

## 1 0 . ON/OFF Control (CNT Terminal)

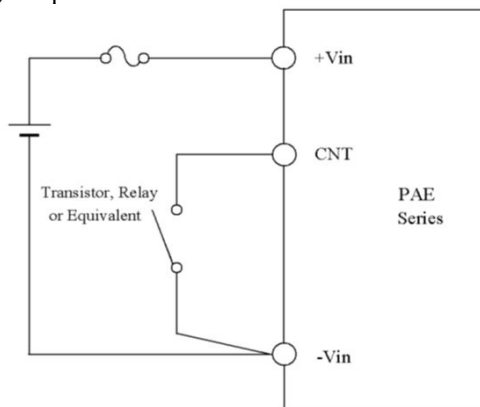
Without turning the input supply on and off, the output can be enabled and disabled using this function. This function also can be used for output sequence of plural modules.

ON/OFF control circuit is on the primary side (the input side), CNT Terminal pin. For secondary control, isolation can be achieved through the use of an opto coupler or a relay.

CNT Terminal Level to -Vin Terminal	Output Status
H Level ( $4V \leq H \leq 35V$ ) or Open	OFF
L Level ( $0V \leq L \leq 0.8V$ ) or Short	ON

- ※ When control function is not used ,CNT terminal is shorted to  $-V_{in}$  terminal.
- ※ When using long wiring, for prevention of noise , attach a 4,700pF capacitor between CNT Terminal and  $-V_{in}$  terminal.
- ※ At L level, maximum source current from CNT Terminal to  $-V_{in}$  terminal is 0.5mA.
- ※ The maximum CNT Terminal voltage when it is opened is 35V.

### (1) Output ON/OFF control



### (2) Secondary (output side) control

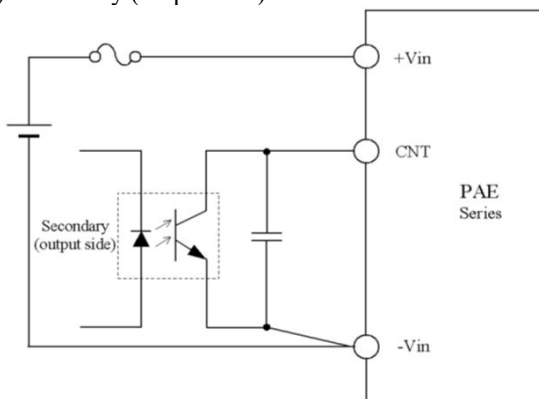


Fig.10-1 CNT connection

## 1 1 . Parallel Operation

Parallel Operation can not be used.

## 1 2 . Series Operation

Series operation is possible for PAE\_48 series. Connections shown in fig.12-1 and fig.12-2 are possible.

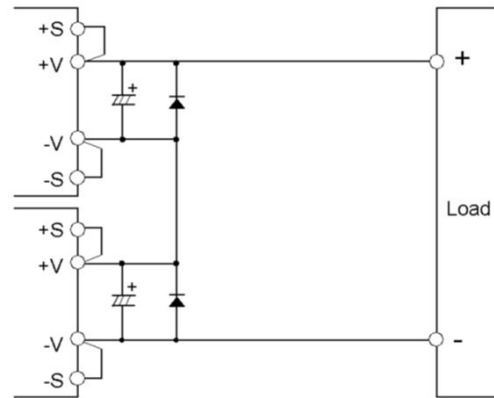


Fig.12-1 Series Operation for High Output Voltage Application

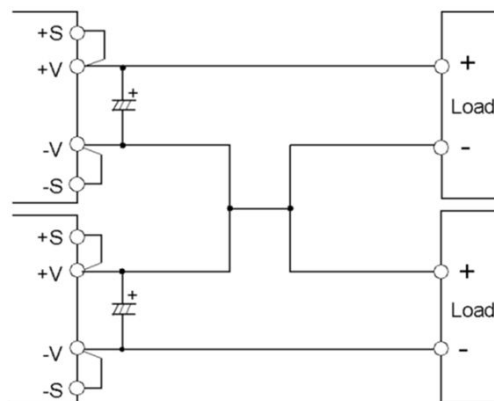


Fig.12-2 ±Output Series Operation

## 1 3 . Operating Ambient Temperature

According to ambient temperature, output load should derated accordingly (refer to Mounting Method & Terminal Condition). There is no restriction on mounting direction but there should be enough consideration for airflow so that heat does not accumulate around the power module vicinity. Determine external components configuration and mounting direction on PCB such that air could flow through power module at forced air cooling or convection cooling. For better reliability, derating of ambient temperature is recommended. For details on derating, refer to “Mounting Method & Thermal Condition”

#### 1 4 . Operating Ambient Humidity

Take note that moisture could lead to power module abnormal operation or damage.

#### 1 5 . Storage Ambient Temperature

Abrupt temperature change would cause condensation built-up that leads to poor solderability of terminals of the power module.

#### 1 6 . Storage Ambient Humidity

High temperature and humidity can cause the terminals on the module to oxidize. The quality of the solder will become worse.

#### 1 7 . Cooling Method

Forced air cooling is recommended. Convection cooling is also possible. For the details of derating, refer to “Mounting Method and Thermal condition “

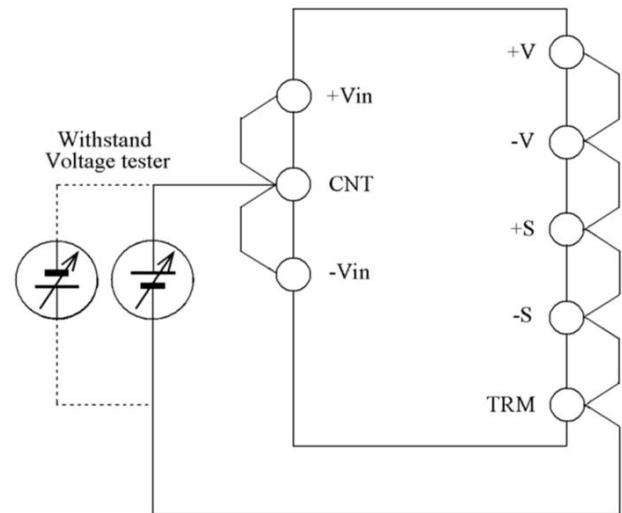
#### 1 8 . Ambient Temperature vs. Output Voltage Drift

Temperature coefficient is defined as the rate of voltage change when ambient temperature is changed during operation.

#### 1 9 . Withstand Voltage

This power module is designed to have a withstand voltage of 1.5kVDC between input to output. When conducting withstand voltage test during incoming inspection, be sure to apply DC voltage. Also, set the current limit value of the withstand voltage testing equipment to 10mA. Be sure to avoid conducting test with AC voltage because this would cause power module damage. Furthermore, avoid throw in or shut off of the testing equipment when applying or when shutting down the test voltage. Instead, gradually increase or decrease the applied voltage. Take note especially not to use the timer of the test equipment because when the timer switches the applied voltage off, impulse voltage which has several times the magnitude of the applied voltage is generated causing damage to the power module.

Short the output side as shown in the diagram below.

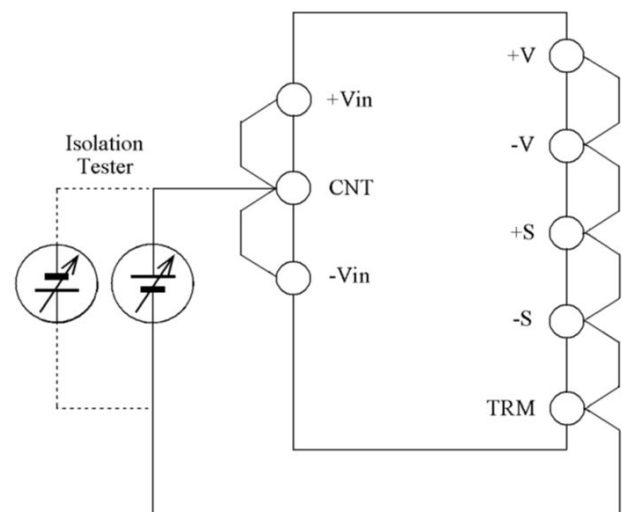


1.5kVDC 1minute (10mA)

Fig.19-1 Withstand Voltage Test for Input-Output

#### 2 0 . Insulation Resistance

Use DC insulation tester (MAX 500V) between output and input. Insulation resistance value is 100MΩ and above at 500VDC applied voltage. Make sure that during testing, the isolation testers does not produce a high pulse when the applied voltage is varied. Ensure that the tester is fully discharged after the test.



500VDC 100MΩ and above

Fig.20-1 Isolation test

## **2 1 . Vibration**

Vibration of power module is defined in case of mounting on PCB.

## **2 2 . Shock**

Value for the conditions of out shipping and packaging.

## **2 3 . CE MARKING / UKCA MARKING**

### **CE MARKING**

CE Marking, when applied to a product or packing material for a product covered by this handbook, indicates compliance with the Low Voltage Directive and RoHS Directive.

### **UKCA MARKING**

UKCA Marking, when applied to a product or packing material for a product covered by this handbook, indicates compliance with the Electrical Equipment (Safety) Regulations and Restriction of the Use of Certain Hazardous Substances in Electrical & Electronic Equipment Regulations.

## ■ Mounting Method and Thermal Condition

### 1. Output derating

There is no restriction on mounting direction but there should be enough consideration for airflow so that heat does not accumulate around the power module vicinity. Determine external components configuration and mounting direction on PCB such that air could flow through power module at forced air cooling or convection cooling. Take note, output power derating is needed as shown in followings. (Refer to output derating by ambient temperature). The derating curves provided is based on the below set-up condition. For actual application with difficulty of air flow measurement, find of PCB temperature is recommended to ensure the power module operates within derating curve.(refer to Output derating by PCB temperature)

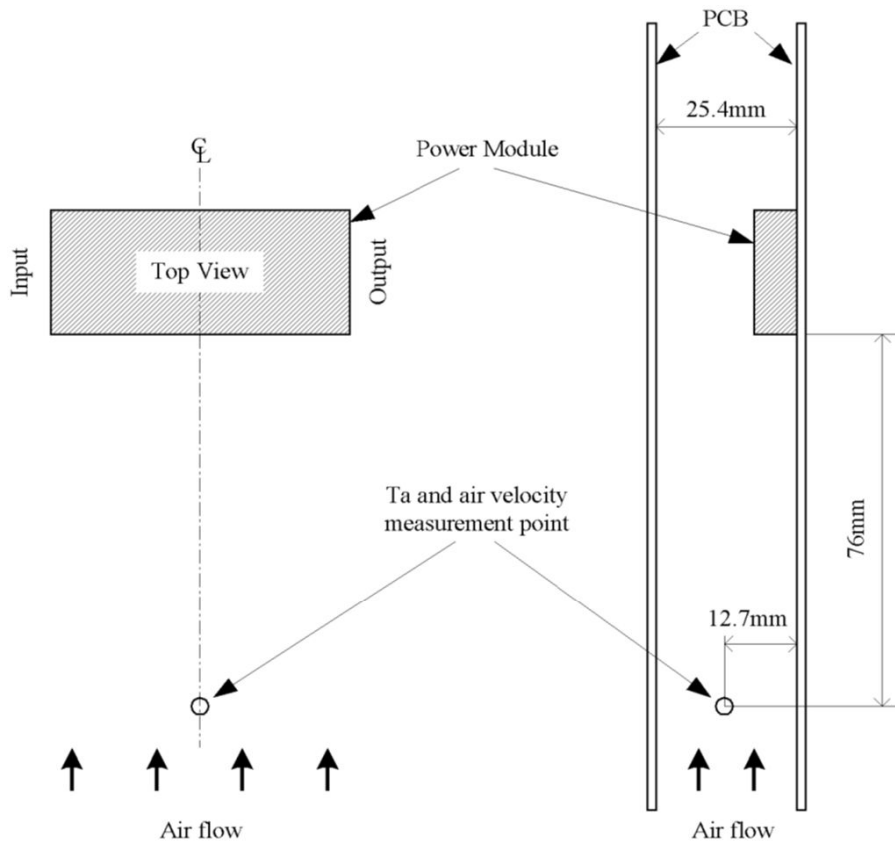


Fig.1-1

(1) Output Derating by ambient temperature  
PAE100S48 (including /V option)

$V_{in}=48V_{dc}$

PAE100S48-1R8

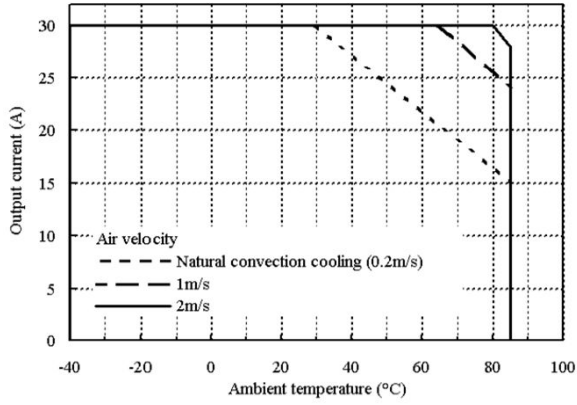


Fig.1-2

PAE100S48-2R5

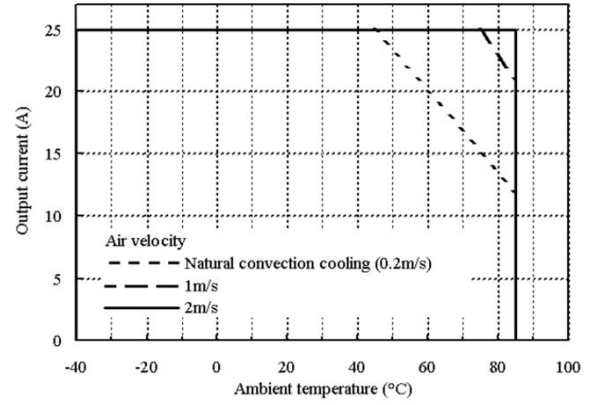


Fig.1-3

PAE100S48-3R3

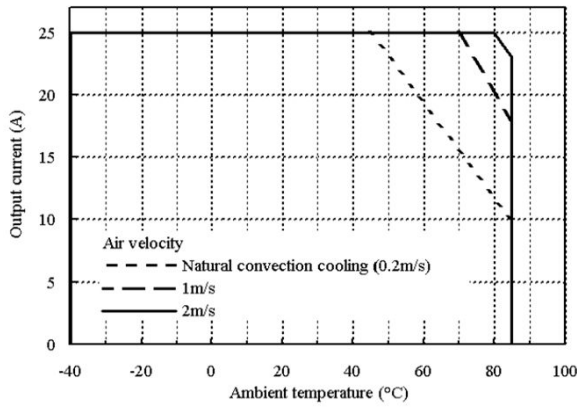


Fig.1-4

PAE100S48-5

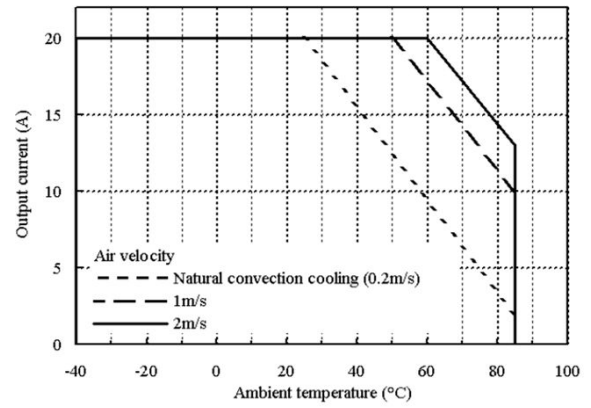


Fig.1-5

PAE100S48-3R3/H

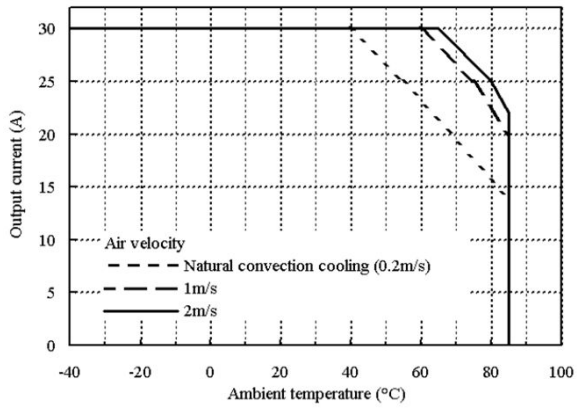


Fig.1-6

**PAE50S48 (including /V option)**

Vin=48Vdc

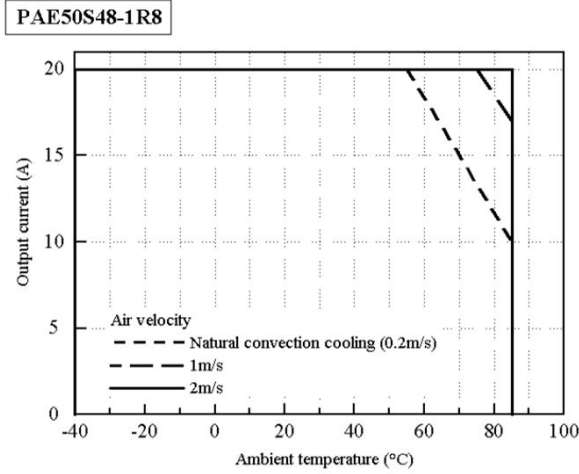


Fig.1-7

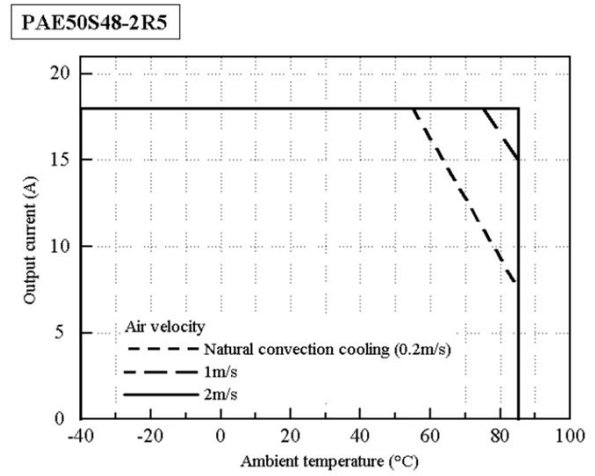


Fig.1-8

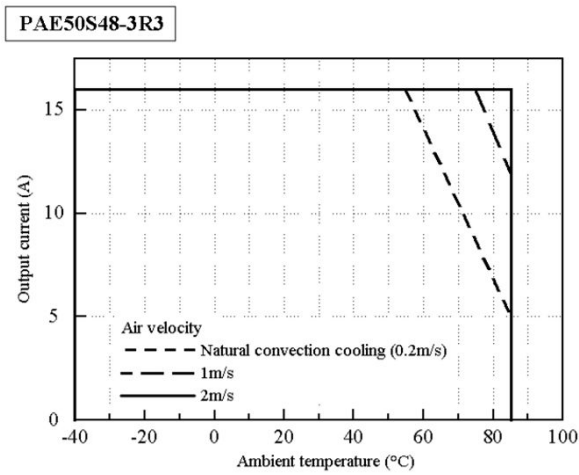


Fig.1-9

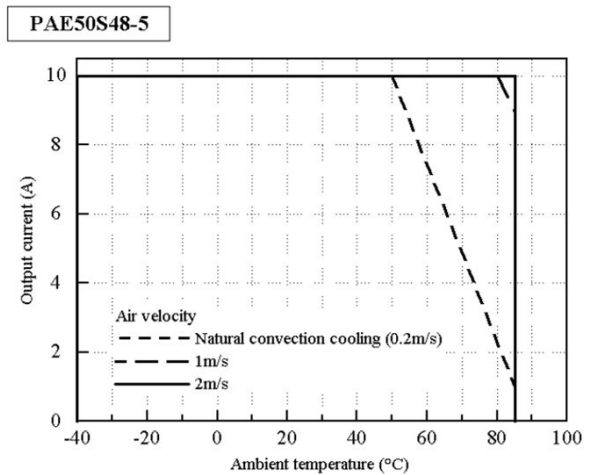
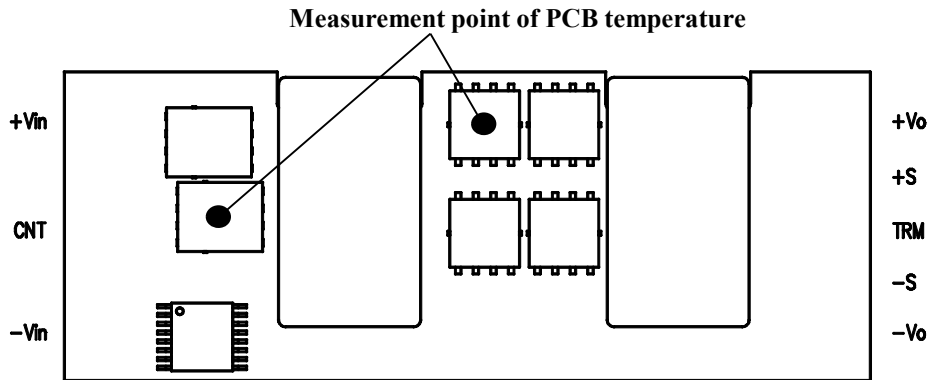


Fig.1-10

**(2) Output derating by PCB temperature**

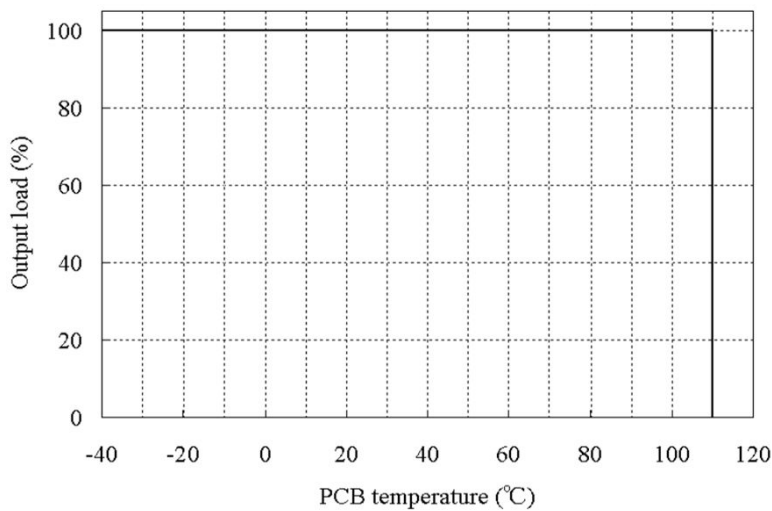
When use with different measurement conditions from output derating by ambient temperature, use output derating by PCB temperature as in Fig.1-12. PCB temperature is decided by temperature of the component surface in below Fig.1-11. Measurement of PCB temperature is recommended to ensure the module to operate within the derating curve.



**Fig.1-11 Measurement point of PCB temperature**

**Output Derating by PCB temperature**

**PAE100S48 & PAE50S48**



**Fig.1-12 Output Derating by PCB Temperature**



## 2. Mounting Method

### (1) Prohibition area of pattern wiring

▨ Avoid wiring pattern on PCB in shaded area as shown in Figure 2-1 as it may cause insulation problem. Since the power module may influence by noise, care must be taken when wire the signal line on the non-shaded area.

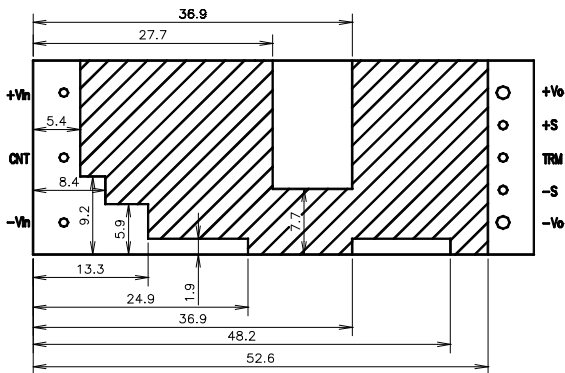


Fig.2-1 Prohibition area of wiring pattern

### (2) Mounting hole on PCB

Refer to below table for the diameter of hole and land of PCB.

Type	PAE S48
Input Terminal Pin	φ 1.0mm
Hole Diameter	φ 1.3mm
Land Diameter	φ 2.6mm
Output Terminal Pin	φ 1.5mm
Hole Diameter	φ 1.8mm
Land Diameter	φ 3.6mm
Signal Terminal Pin	φ 1.0mm
Hole Diameter	φ 1.3mm
Land Diameter	φ 2.6mm

For position of the holes, see outline drawing of the power module.

### (3) Recommended Material of PCB

Recommended materials of the printed circuit board is 4 layers glass epoxy with through holes. (thickness :t=1.6mm)

### (4) Output Pattern Width

When several to tens amperes of current flows to output pattern, voltage would drop and heat generation would be higher for narrow pattern. Relationship between current and pattern width changes depending on material of printed circuit board, thickness of conductor, temperature rise allowance. 35mm copper

glass epoxy printed circuit board is shown in Figure2-2 as an example.

For example, when 5A of current flows and temperature rise below 10°C are expected, pattern width shall be more than 4.2mm with 35μm copper plate (generally 1mm/A is standard).

Confirmation is definitely necessary for designing because characteristics shown in figure 2-2 depend on manufactures of printed circuit board.

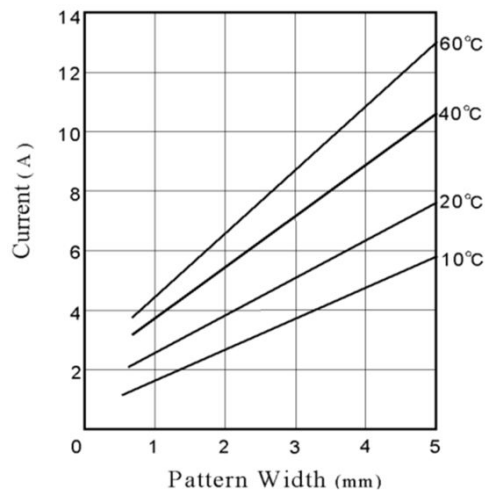


Fig.2-2 Characteristic of current allowance

## 3. Recommended Soldering Method

Recommended soldering temperature is as follows.

### (1) Soldering dip

260°C within 10 seconds

Pre-heat condition

110°C 30~40 seconds

### (2) Soldering iron.

350°C within 3 seconds

## 4. Recommended Cleaning Condition

It is recommended not to clean the board after soldering, but if cleaning is required, perform it under the following conditions.

- Cleaning solvent

IPA (isopropyl alcohol)

- Cleaning Procedure

Brush only the terminals so that the cleaning liquid does not adhere to the product. Then, dry up thoroughly after washing.

## ■ Before concluding power module damage

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Verify following items before concluding power module damage.

- 1) No output voltage
  - Is specified input voltage applied?
  - Are the ON/OFF control terminal (CNT terminal), remote sensing terminal (+S, -S), output voltage trimming terminal (TRM) correctly connected?
  - For cases where output voltage adjustment is used, is the resistor or variable resistor setting, connections correctly done?
  - Are there no abnormalities in the output load used?
  - Is the ambient temperature within the specified temperature range?
- 2) Output voltage is high.
  - Are the remote sensing terminals (+S, -S) correctly connected?
  - Is the measurement done at the sensing points?
  - For cases where output voltage adjustment is used, is the resistor or volume setting, connections correctly done?
- 3) Output voltage is low
  - Is specified input voltage applied?
  - Are the remote sensing terminals (+S, -S) correctly connected?
  - Is the measurement done at the sensing points?
  - For cases where output voltage adjustment is used, is the resistor or variable resistor setting, connections correctly done?
  - Are there no abnormalities in the output load used?
- 4) Load regulation and line regulation is large
  - Is specified input voltage applied?
  - Are the input terminals and the output terminals firmly connected?
  - Is the measurement done at the sensing points?
  - Is the input or output wire too thin?
- 5) Out put ripple voltage is large
  - Is the measuring method used the same or equivalent with the specified method in the Application Notes?
  - Is the input ripple voltage value within the specified value?