

PAF500F24 SERIES

Instruction Manual

■ Before using this product

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

■ Precautions

- Avoid touching the baseplate and the case of this product because they get hot.
- 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 burn.
- To avoid unexpected accid from placing hands or face near the unit during operation.
- Verify that connection to input, output ents, refrain and signal terminnals are correct as indicated in this instruction manual.
- For acquisition of various Safety Standards and safety improvement, be sure to use an external fuse. This product is designed for installation on electronic equipment.
- For input terminals of 24 V input models, apply a voltage from a primary source with reinforced or double insulation.
- Output voltage of this product is considered to have hazardous energy level (voltage of 2V and above with power of 240W and above) and must not have physical contact with operator. Protection must be provided on this module when installed on equipment to prevent physical contact with service technician himself or accidentally dropped tools during repair. Before repair, be sure to turn off the input source and confirm that input and output voltage have drop down to a safe level.
- Application circuit or component values described in this instruction manual are for reference only. When designing circuit, be sure to verify actual circuit operation before determining final application circuit or component values. Contents of this instruction manual are subject to change without notice. When using this product, please refer to latest data sheet to satisfy this product specification.
- No part of this instruction manual may be reproduced, or transmitted in any form or by any other means without prior consent of TDK-Lambda.

Table of Contents

■ Block Diagram

■ Sequence Time Chart

■ Terminal Explanation

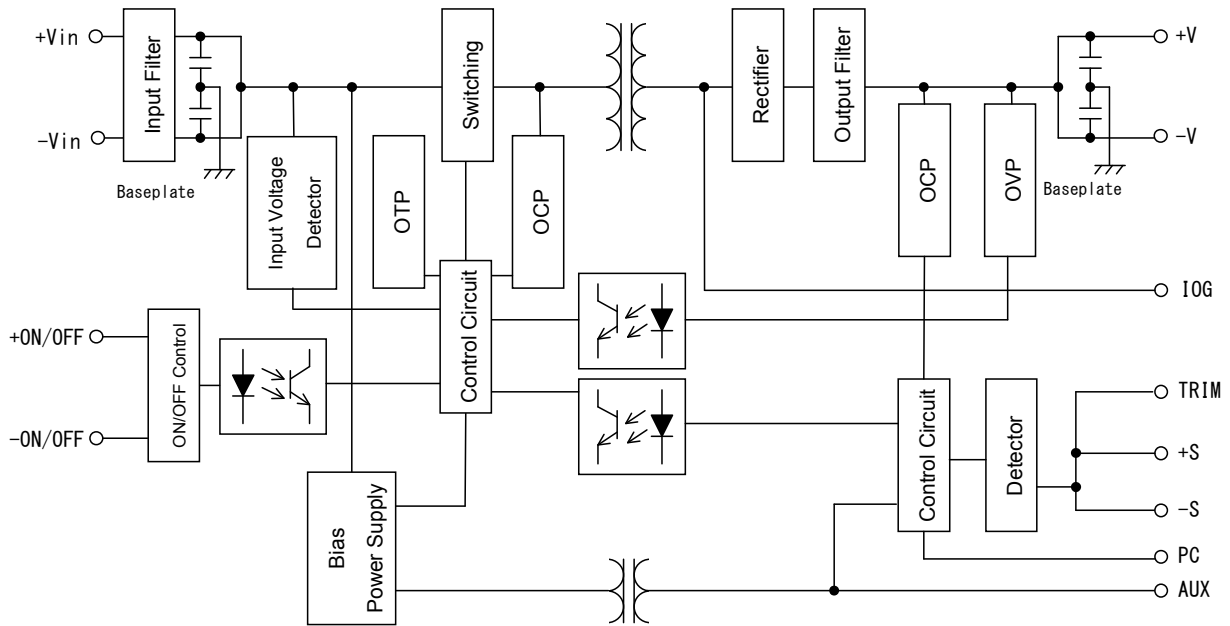
■ Explanation on Specifications

1. Input Voltage Range
2. Output Voltage Adjust Range
3. Maximum Output Ripple and Noise
4. Maximum Line Regulation
5. Maximum Load Regulation
6. Over Current Protection (OCP)
7. Over Voltage Protection (OVP)
8. Over Thermal Protection
9. Remote Sensing (+S, -S terminal)
10. ON/OFF Control (+ON/OFF, -ON/OFF terminal)
11. Parallel Operation (PC terminal)
12. Series Operation
13. I.O.G. signal (IOG terminal)
14. Auxiliary power supply for external signals
(AUX terminal)
15. Operating Ambient Temperature
16. Operating Ambient Humidity
17. Storage Ambient Temperature
18. Storage Ambient Humidity
19. Cooling Method
20. Baseplate temperature vs. output voltage drift
21. Withstand Voltage
22. Insulation Resistance
23. Withstand Vibration
24. Withstand Shock

■ Before concluding module damage

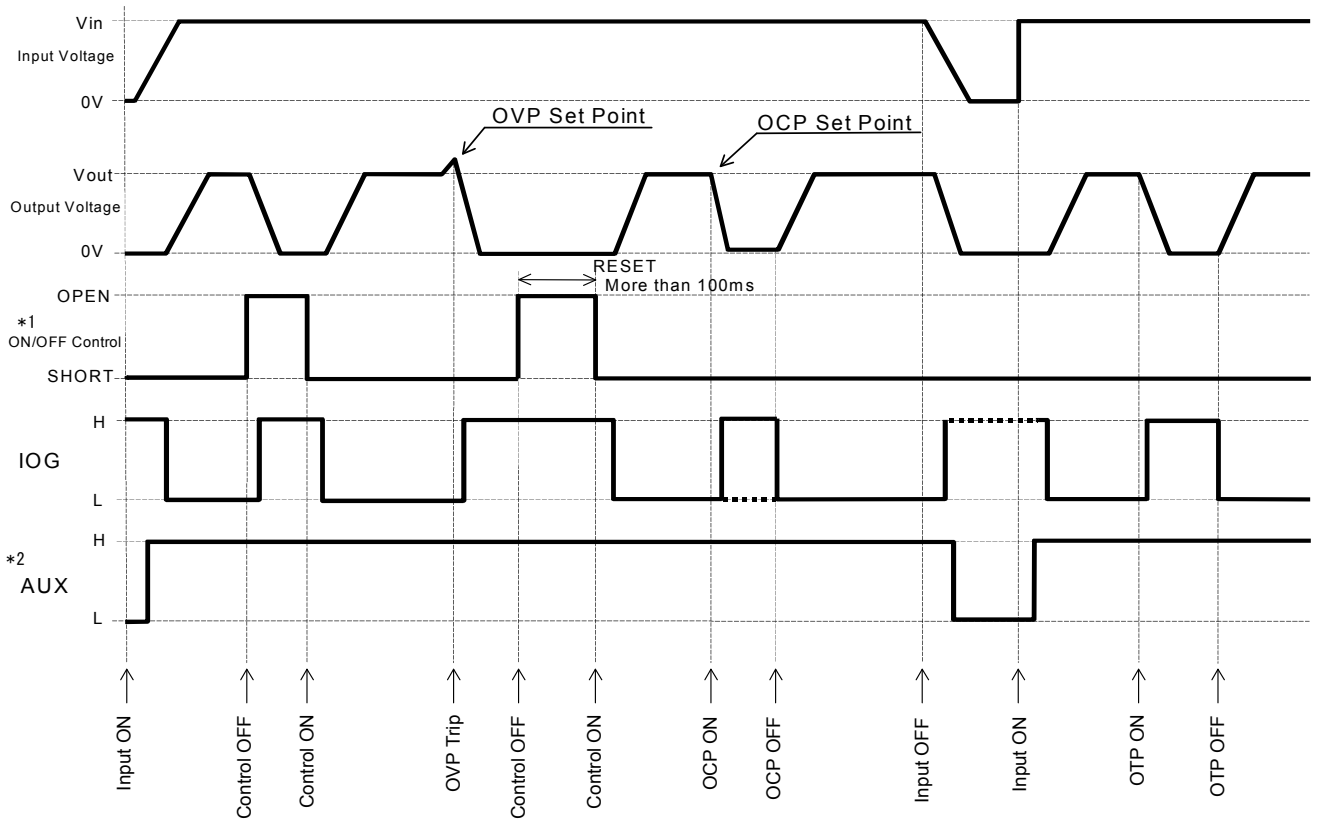
PAF500F24-SERIES

Block Diagram



Switching Frequency : 330kHz

Sequence Time Chart

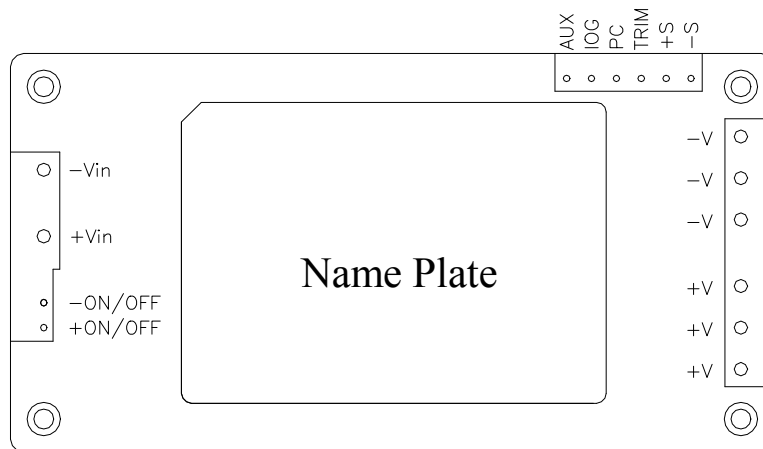


*1 SHORT : $1\text{mA} \leq I(\text{ON/OFF}) \leq 5\text{mA}$

*2 H Level : 7~10VDC

PAF500F24-SERIES

Terminal Explanation



[Input Side Terminals]

+Vin : +Input Terminal

-Vin : -Input Terminal

[Control Terminals]

+ON/OFF : +ON/OFF Control

-ON/OFF : -ON/OFF Control

[Output Side Terminals]

+V : +Output Terminal

-V : -Output Terminal

+S : +Remote Sensing Terminal

-S : -Remote Sensing Terminal

TRIM : Output Voltage Trimming Terminal

PC : Output Current Balance Terminal

IOG : Inverter Operation Monitor terminal

AUX : Auxiliary Power Supply

for External Signals

Baseplate can be connected to FG through M3 mounting tapped holes.

Connect +Vin, -Vin, +V, -V with consideration of contacting resistance.

PAF500F24-SERIES

■ Explanations on Specifications:

1. Input Voltage Range

Input voltage range for PAF500F24 Series is indicated below.

Input Voltage Range :

PAF500F24-12 19~36VDC
PAF500F24-28 18~36VDC

Basically, ripple voltage (V_{rpl}) which results from rectification and filtering of commercial AC line is 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 becomes large.

Note that abrupt input voltage change could cause the output voltage to fluctuate excessively.

Also, input voltage waveform peak value for high and low must not exceed above input voltage range.

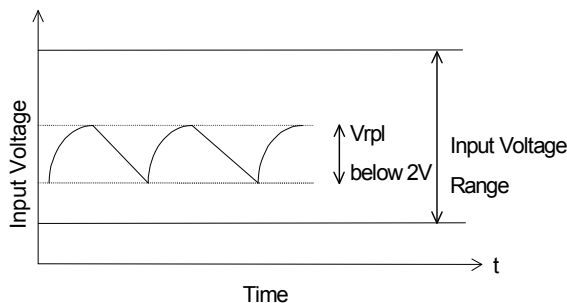


Fig.1-1 Ripple Voltage

● Basic Connection

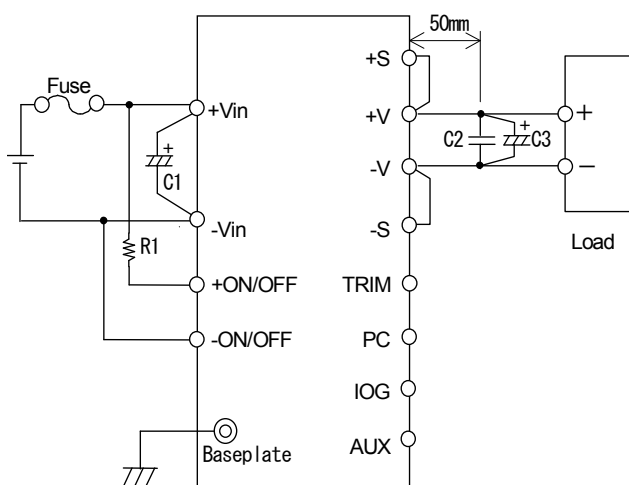


Fig.1-2 Basic Connection

Input Fuse

This power module has no built-in fuse. Use external fuse to acquire various Safety Standards and to improve safety. Also, use fast-blow type for every module.

Furthermore, 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.

Input Fuse recommended current rating: 50A

C1 :

To prevent the effect of input line inductance to the power module, connect electrolytic capacitor or ceramic capacitor between +Vin and -Vin terminals.

Furthermore, use electrolytic capacitor with small ESR value. Especially take note that during line turn off at low ambient temperature, power module output will not normally shut down due to unstable C1 voltage.

Also, ripple current flows across this capacitor. Therefore, verify maximum allowable ripple current this capacitor when selecting component. Verify actual ripple current value by actual measurement.

Recommended capacitor value : 560 μ F \times 2 pcs and above (parallel connect) (voltage rating 50V and above)

Note) 1. Use low impedance electrolytic capacitor with excellent temperature characteristics. (Nippon Chemicon LXY 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°C , connect 4 more and above capacitors indicate above in parallel to reduce ESR.

C2 : 10 μ F

To reduce spike noise voltage at the output, connect a ceramic 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.

C3 :

For stable operation, connect an electrolytic capacitor between +V and -V within 50mm distance from the output terminals.

Take note that output ripple and output shutdown could be affected by electrolytic capacitor, equivalent impedance and inductance characteristics of wiring.

Take note that output ripple voltage could vary according to PCB wiring design.

For cases of abrupt changes in load current or input voltage, increasing capacitance value of the external capacitors could reduce the voltage fluctuation.

Vout	C3
12V	25V 470 μ F \times 2 (*1)
28V	50V 220 μ F \times 2 (*1)

*1 parallel connect

Table1-1 C3:Recommended Values of External Output Capacitor

Note)1. Use low impedance electrolytic capacitor with excellent temperature characteristics.

(Nippon Chemicon LXY Series or equivalent)

2. Use 4 more and above capacitors indicated above in parallel when ambient temperature becomes lower than -20°C to reduce ESR.

3. Take note of the allowable ripple current of the capacitor to be used. Especially, when load adding capacitors for abrupt current changes, be sure to verify that ripple current does not exceed allowable ripple current before use.

C4 :

When switches or connectors are used between input source and PAF500F24 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 Capacitance Value : 560 μ F and above (Voltage Rating 50V 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.

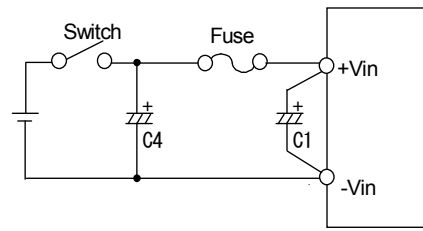


Fig.1-3 Input Filter with Input Switch

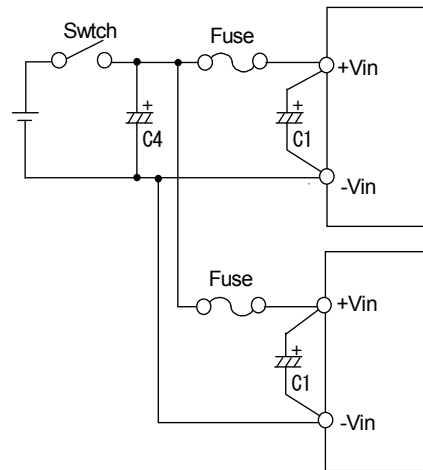


Fig.1-4 Input Filter when Plural Power

Reverse input connections

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

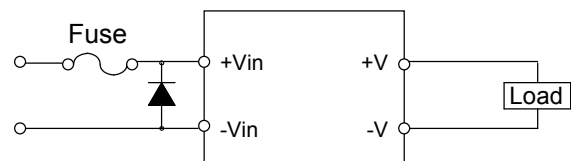


Fig.1-5 Protection for Reversed Connection of Input

- Recommended input filter as EMI counter-measure (conforms to VCCI Class 1, FCC class A)

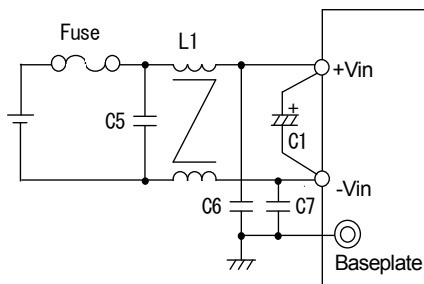


Fig.1-6 Recommended input filter as EMI countermeasure

Recommended Values:

- C1 : 560 μ F (Electrolytic Capacitor) \times 2 pcs in parallel**
- C5 : 2.2 μ F (Ceramic Capacitor)**
- C6,C7 : 0.1 μ F (Ceramic Capacitor)**
- L1 : 1 mH (Common mode choke coil)**

Note)

1. For the power module output, connect output capacitors described in the basic circuit connection.
2. VCCI Class 1, FCC Class A limits can be satisfied with the above recommended filter at TDK-Lambda measuring conditions. However, there are cases where above limits might not be satisfied due to input and output wiring method, as well as, peripheral circuits. When selecting input filter, be sure to verify actual EMI characteristics (CE and RE) before finalizing the filter. Refer to PAF500F24-* Evaluation Data for details.

2. Output Voltage Adjustment Range

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

**Output Voltage Adjustment Range
-40%~ +10% of Nominal Output Voltage**

Furthermore, when increasing the output voltage reduce the output current so as not to exceed the maximum output power.

Also, take note that when output voltage is increased, input voltage range is limited as shown in Fig. 2-1.

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

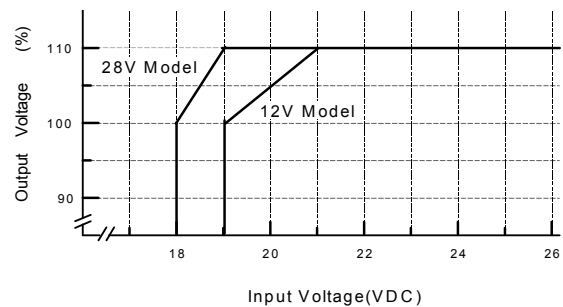


Fig.2-1 Limit of Input Voltage

Output Voltage Adjustment by external resistor or by variable resistor

Resistor values, as well as, connecting methods for external resistor (R2) and external variable resistor (VR) are described below.

In this case, using VR as remote programming resistor, remote programming of output voltage can be possible.

Output voltage rate of change versus VR resistor value is approximately 1V/k Ω . (Sensing current : about 1mA)

Also, be sure to connect remote programming resistor between +S terminal and +V terminal.

	12V	28V
R2	6.8k	6.8k
VR	20k	50k

Unit : [Ω]

- External Resistor : below \pm 5% Tolerance
- Variable Resistor : below \pm 20% Tolerance
below 1% Remain

**Table2-1 Values of External Resistor and Variable Resistor
(-40%~+10% Variable)**

	12V	28V
R2	43k	43k
VR	5k	10k

Unit : [Ω]

- External Resistor : below \pm 5% Tolerance
- Variable Resistor : below \pm 20% Tolerance
below 1% Remain

**Table2-2 Values of External Resistor and Variable Resistor
(\pm 10% Variable)**

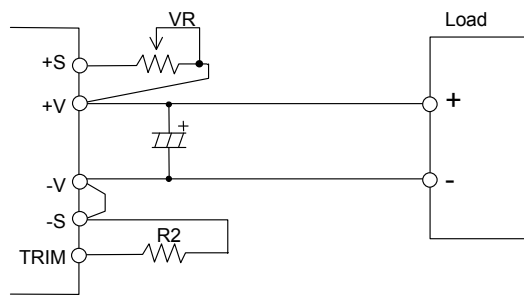


Fig.2-2 Example Connection of External Resistor

Output Voltage Adjustment by applying external voltage

By applying external voltage at the TRIM terminal, output voltage can be adjusted within the same output voltage adjustment range as the output voltage adjustment by external resistor or variable resistor. For this case, output voltage can be determined by the formula shown below.

$$\text{Output Voltage} = \text{TRIM Terminal Voltage} \times \text{Nominal Output Voltage}$$

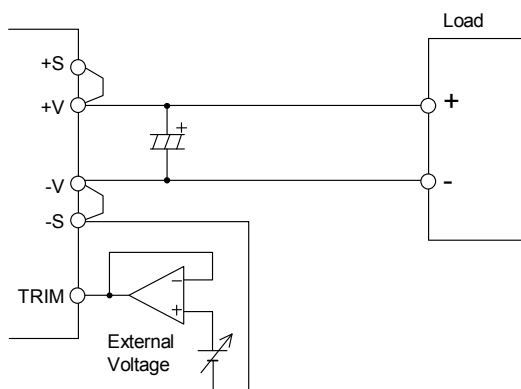


Fig.2-3 Output Voltage Adjustment by applying external voltage

For applications other than the above, refer to the trim circuit below and determine external circuit and component values.

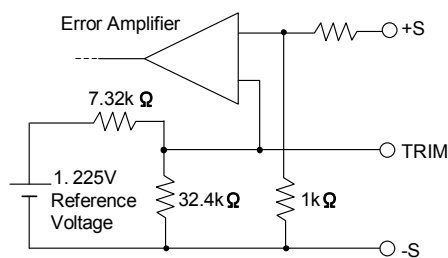


Fig.2-4 TRIM Circuit (For the Reference)

3. Maximum Ripple and Noise

Measured value according to the specified methods based on JEITA-9141 (Clause 7.12 and clause 7.13) which is described in the following.

Connect according to Fig.3-1 and measure. Connect capacitors (C2: ceramic capacitor 10 μF, C3: refer to table 1-1 for electrolytic capacitor values) 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.

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 capacitance value of external capacitor.

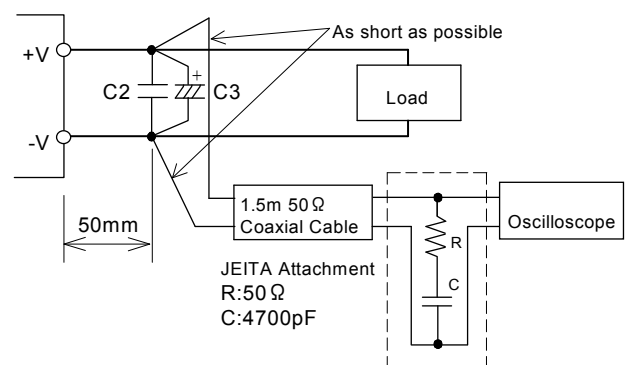


Fig.3-1 Measurement of Maximum Output Ripple & Noise

4. Maximum Line Regulation

Maximum value of output voltage change when input voltage is gradually varied (steady state) within specified input voltage range.

5. Maximum Load Regulation

Maximum value of output voltage change when output current is gradually varied (steady state) within specified output current range.

When using at dynamic load mode, audible noise could be heard from the power module and output voltage fluctuation might increase. A thorough pre-evaluation must be performed before using this power module.

6. Over Current Protection (OCP)

This power module has built-in OCP function.

Output will recover when short circuit or overload conditions are released. OCP setting value is fixed and therefore, cannot be externally adjusted.

Also, take note that power module might be damaged continuing output short circuit or over load conditions depending on thermal conditions.

7. Over Voltage Protection (OVP)

This power module has built-in OVP function.

As this set point is fixed, so adjustment voltage from the outside is impossible.

OVP set point is relative to the rated output voltage value.

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. Reset time for ON/OFF terminal is 100ms or longer.

OVP release input voltage value : 5VDC and below

When verifying OVP function by applying external voltage at the output terminals, applied voltage value should not exceed specified OVP maximum value. Refer to specification table for OVP maximum value. Avoid applying external voltage that exceeds OVP maximum value because this will cause power module damage.

8. Over Thermal Protection

This power module has built-in OTP function. This function operates and shuts down the output when ambient temperature or internal temperature of power module abnormally rises. OTP operates at 105°C to 130°C baseplate temperature. Output shutdown due to OTP can be released when baseplate temperature drops down approximately to within 80°C to 95°C. However, 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

Take note that voltage compensation range for line drop

(voltage drop due to wiring) is determined such that output voltage at the output terminals is within output voltage range and that voltage between -V and -S terminals is within 2V or less. Even for remote sensing case, use power module such that output power is within specified maximum output power. Furthermore, reduce noise effect by using shield wire, twist pair, or parallel pattern.

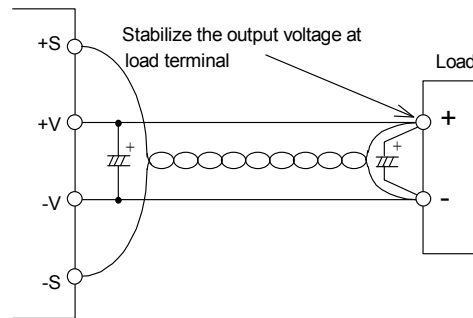


Fig.9-1 Remote Sensing at Use

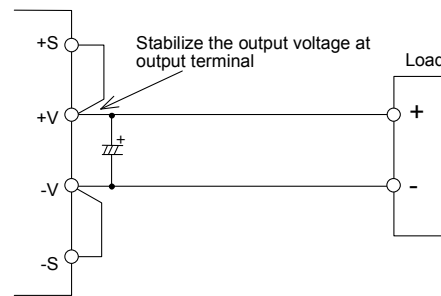


Fig.9-2 Remote Sensing Not in Use

10. ON/OFF Control

(+ON/OFF, -ON/OFF terminal)

Output can also be turned ON/OFF even without turning the input line ON/OFF. An ON/OFF control circuit is provided which is isolated from the input side, as well as, the output side. (Isolation withstand voltage : 1.5kVDC) .

Connection of ON/OFF terminal is as follows. As shown in the Figure below, output voltage turns ON when current is made to flow through ON/OFF terminal. ON/OFF terminal can be controlled by opening or closing connections (with switch or relay), or by photo-coupler ON/OFF.

Maximum source current for ON/OFF terminal is 5mA. Therefore, set current limiting resistor value such that this maximum source current value is not exceeded. Also, the allowable maximum reverse current flow is 10mA.

A. Controlling the ON/OFF terminal from the input side

Connect current limiting resistor R1 as shown in Fig 10-1.

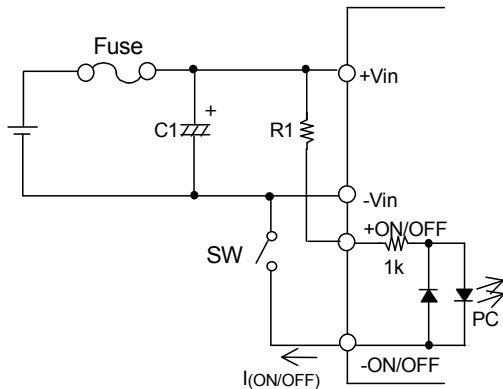


Fig.10-1 Connection of ON/OFF Control (A)
R1 Recommended Resistor value : 15kΩ (1/4W)

B. Controlling the ON/OFF terminal from the output side

Connect the current limiting resistor R4 as shown in Fig. 10-2.

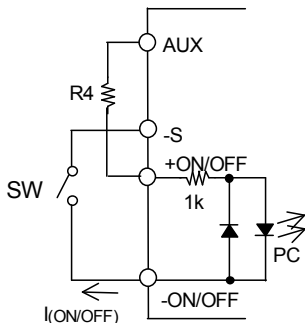


Fig.10-2 Connection of ON/OFF Control (B)
R4 Recommended Resistor Value: 2kΩ (1/6W)

C. Controlling the ON/OFF terminal by an external power supply

If necessary connect a current limiting resistor R5 as shown in Fig.10-3.

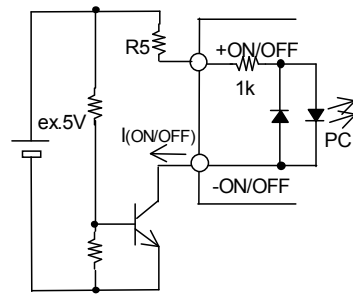


Fig.10-3 Connection of ON/OFF Control (C)

Note)

1. When wiring becomes long, connect a capacitor of about $0.1 \mu\text{F}$ value between the +ON/OFF terminal and -ON/OFF terminal at a nearest distance.
2. Current limiting resistor can also be connected to the -ON/OFF terminal side.

ON/OFF Level	Output Status	
	Standard	Option(* 1)
Open	OFF	ON
$1\text{mA} \leq I(\text{ON/OFF}) \leq 5\text{mA}$	ON	OFF

* 1 For option models, inquire to TDK-Lambda.

Table10-1 ON/OFF Control Mode

11. Parallel Operation (PC terminal)

By connecting the PC terminal of each power module, output current can be equally drawn from each module. A maximum of 11 units of the same model can be connected.

Furthermore, be sure that the output power of every module does not exceed the maximum output power value.

By setting output voltage accuracy of each module in a parallel operation to within $\pm 1\%$, the maximum value of the output current that can be drawn is 95% of the total rated output current.

Refer to "Parallel Operation" of the Power Module Application Notes for details.

12. Series Operation

Series operation is possible for PAF500F24 series. Connections shown Fig. 12-1 and Fig. 12-2 is possible.

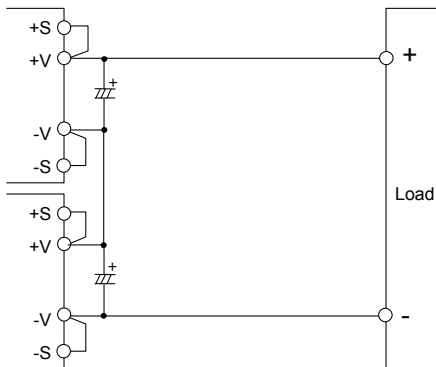


Fig.12-1 Series Operation in High Output Voltage

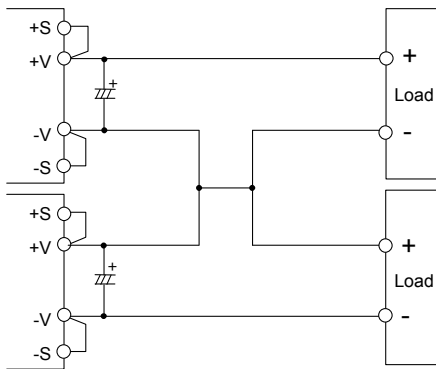


Fig.12-2 ± Output Series Operation

13. I.O.G. signal (IOG terminal)

Normal or abnormal operation of the power module can be monitored by using the IOG terminal. Output of this signal monitor is located at secondary side (output side) and is an open collector output.

This signal is LOW when inverter is normally operating and HIGH when inverter stops or when inverter is operating abnormally. (maximum sink current is 5mA, maximum applied voltage is 35V)

Ground for the IOG terminal is the -S terminal.

Also note that IOG becomes unstable for following conditions:

- Operation of Over Current Protection (OCP)
- Light load conditions at parallel operation
- Dynamic load operation

14. Auxiliary power supply for external signals (AUX terminal)

For AUX terminal, output voltage value is within 7 ~ 10VDC range, maximum output current is 20mA.

Ground for the AUX terminal is -S terminal.

Avoid short circuit of AUX terminal with other terminals as this would lead to power module damage.

15. Operating ambient temperature

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 the heatsink at forced cooling and conventional cooling.

By maintaining actual baseplate temperature below 100°C, operation is possible.

For details on thermal design, refer to Application Notes "Thermal Design".

Note) 1. Maximum baseplate temperature is 100°C.

For worst case operating condition, verify baseplate temperature at measurement point indicated in Fig. 15-1.

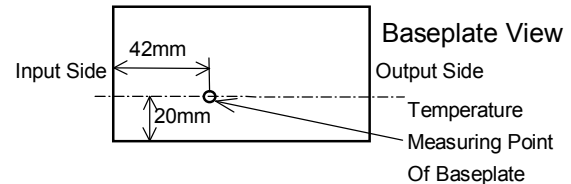


Fig.15-1 Temperature Measurement Point of Baseplate

For better improvement of power module reliability, derating of baseplate temperature when using is recommended.

16. Operating Ambient Humidity

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

17. Storage Ambient Temperature

Abrupt temperature change would cause moisture formation that leads to poor solderability of each terminal of the power module.

18. Storage Ambient Humidity

Take enough care when storing the power module because rust which causes poor solderability would form in each terminal when stored in high temperature, high humidity environment.

19. Cooling Method

Operating temperature range is specified by the baseplate temperature. Therefore, several method of heat dissipation is possible.

For details on thermal design, refer to Application Notes “Thermal Design”.

20. Baseplate Temperature vs. Output Voltage Drift

Output voltage drift is defined as the rate of voltage change when baseplate temperature only is changed during operation.

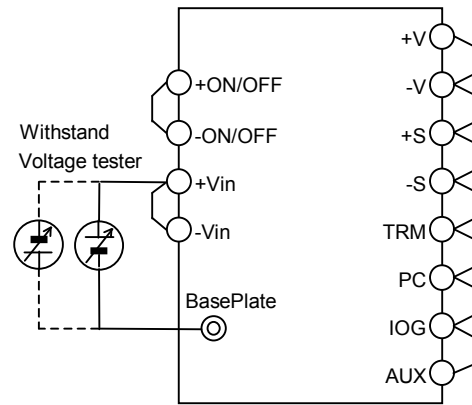
21. Withstand Voltage

This power module is designed to have a withstand voltage of 1.5kVDC between input to baseplate, 1.5kVDC between input to output, 1.5kVDC between the control terminals to input/output and 500VDC between output to baseplate for 1 minute. 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.

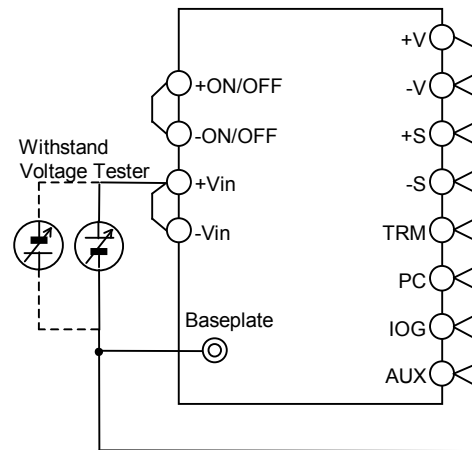
Be sure to avoid conducting test with AC voltage because this would cause power module damage.

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.

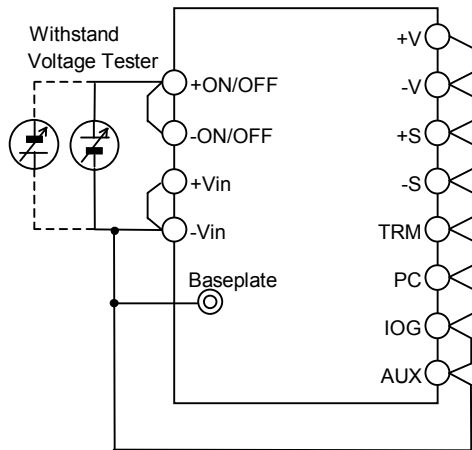
Short the output side as shown in the diagram below.



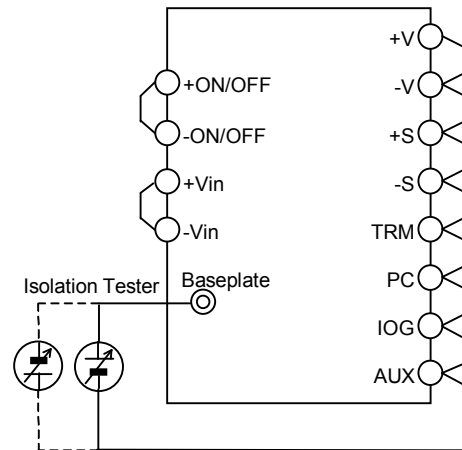
1.5kVDC 1minute (10mA)
Fig.21-1 Withstand Voltage Tester for Input-Baseplate



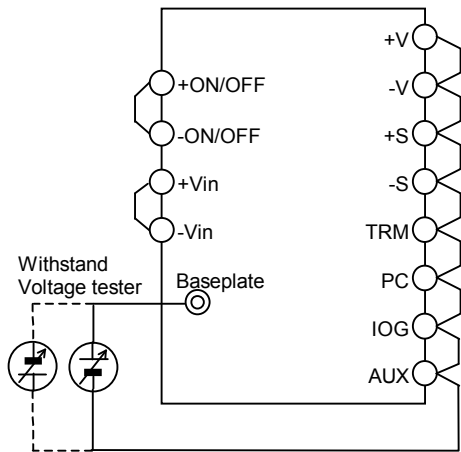
1.5kVDC 1minute (10mA)
Fig.21-2 Withstand Voltage Tester for Input-Output



1.5kVDC 1minute (10mA)
Fig.21-3 Withstand Voltage Tester for ON/OFF-Input/Output



Over 100MΩ at 500VDC
Fig.22-1 Isolation Test



500VDC 1minute (10mA)
Fig.21-4 Withstand Voltage Tester for Output-Baseplate

22. Insulation Resistance

Use DC insulation tester (MAX 500V) between output and baseplate. Insulation resistance value is 100MΩ and above at 500VDC applied voltage. Also take note that depending on the insulation tester used, some testers generate high voltage pulse. Discharge the power module after test using a resistor, etc.

23. Withstand Vibration

Refer to Application Notes “Mounting Method” section.

24. Withstand Shock

Withstand shock value is defined to be the value at TDK-Lambda shipment and packaging conditions.

■ Before concluding power module damage

Verify following items before concluding power module damage.

1) No output voltage

- Is specified input voltage applied?
- Are the ON/OFF control terminal (+ON/OFF, -ON/OFF), remote sensing terminal (+S, -S), output voltage trimming terminal (TRIM) correctly connected?
- Is output current of the auxiliary power supply for external signals terminal (AUX) within the specified value ?
- 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 baseplate 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) Output 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?