

PFH500F-28-xxx Series

Instruction Manual

BEFORE USING THE POWER SUPPLY UNIT

Be sure to read and understand this instruction manual thoroughly before using this product. Pay attention to all cautions and warnings before using this product. Incorrect usage could lead to an electrical shock, damage to the unit or a fire hazard.

⚠ DANGER

Never use this product in locations where flammable gas or ignitable substances are present. There are risks of igniting these substances and exploding by an arcing.

⚠ WARNING

- Do not touch this product or its internal components while circuit is live, or shortly after shut down. There may be high voltage or high temperature present and you may receive an electric shock or burn.
- While this product is operating, keep your hands and face away from it as you may be injured by an unexpected situation.
- Do not make unauthorized changes to this product, otherwise you may receive an electric shock and void your warranty.
- Do not drop or insert anything into the product. It might lead to a failure, fire and electric shock.
- Do not use this product under unusual conditions such as emission of smoke and/or abnormal smell or audible noise, etc. It might lead to fire and/or electric shock. In such cases, please contact TDK Lambda. Do not attempt repair by yourself, as it is dangerous for the user.
- Do not operate these products in the presence of condensation. It might lead to fire and electric shock.

⚠ CAUTION

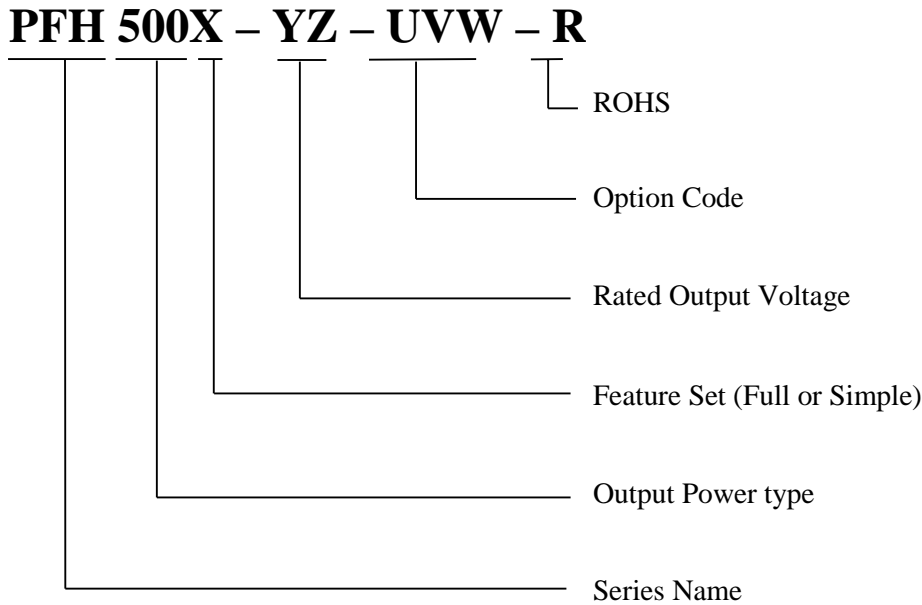
- This power supply is designed and manufactured for use within an end product such that it is accessible only to trained SERVICE ENGINEERS.
- Confirm that the connections to input/output terminals, and signal terminals are correct as specified in this instruction manual before turning on the power.
- Input voltage, Output current, Output power, ambient temperature, case temperature, and ambient humidity should be kept within the specifications, otherwise the product may be damaged.
- Do not operate and store this product in an environment where condensation might occur. In such case, waterproof treatment is necessary.
- The equipment has been evaluated for use in a Pollution Degree 2 environment.
- Do not use this product in environment with a strong electromagnetic field, corrosive gas or conductive substances.
- For applications, which require very high reliability, such as nuclear related equipment, medical equipment, traffic control equipment, etc., it is necessary to provide a fail-safe mechanism in the end equipment.
- Do not inject abnormal voltages into the output terminal or signal terminal of this product. The injection of reverse voltage or over voltage exceeding nominal output voltage into the output terminal or signal terminal might cause damage to internal components.
- Never operate the product under the over-current or short circuit conditions. The failure or other damages may occur.
- The output voltage of this power supply unit is considered to be a hazardous energy level (The voltage is 2V or more and the electric power is 240W or more). It must not be made accessible to users. Protection must be provided for Service Engineers against indirect contact with the output terminals and/or to prevent tools being dropped across them. While working on this product, the AC input power must be switched off, and the input, output, +VBus, and -VBus terminal voltages should be at safe level.
- The application circuits and their parameters are for reference only. Be sure to verify effectiveness of these circuits and their parameters before finalizing the circuit design.
- Use a Fast-Blow external fuse to each module to ensure safe operation and compliance with the safety standards to which it is approved. The recommended input fuse rating within the instructions is as follows: 10A, 250V fast acting fuse. The breaking capacity and voltage rating of this fuse may be subject to the end use application.

⚠ CAUTION

- This information in this document is subject to change without prior notice. Please refer to the latest version of the data sheet, etc., for the most up-to date specifications of the product.
- No part of this document may be copied or reproduced in any form without prior written consent TDK-Lambda.



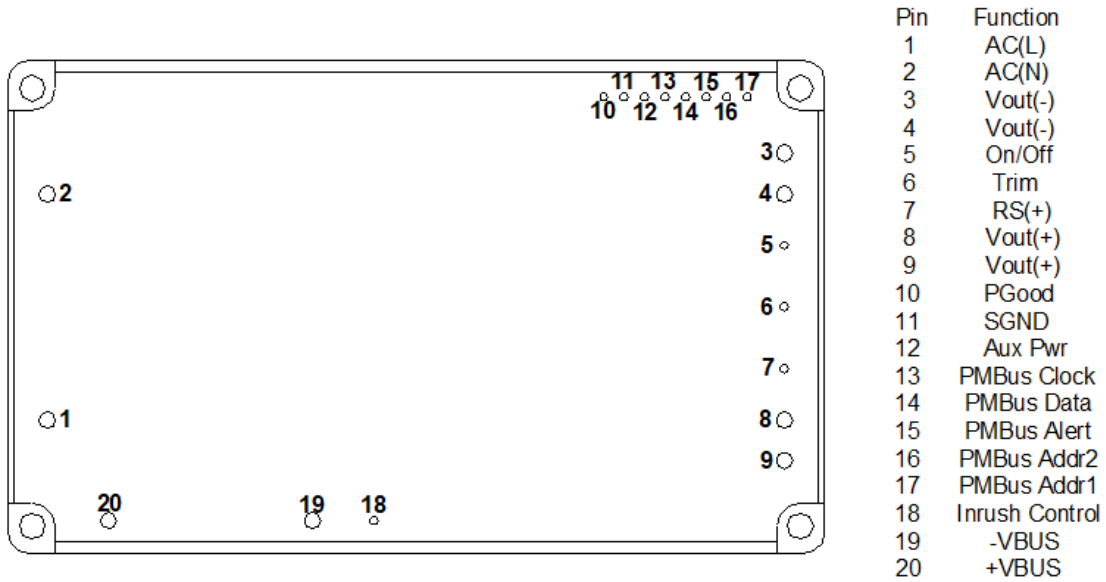
1. Model name identification scheme:



1-1. Ordering Table:

X	YZ	U	OVP	OCP	OTP	Pin Length	Parallel Operation
Module Feature	Output (V)	Case Mounting	(Latch)	(Non-Latch)	(Non-Latch)	(0.240")	(Droop Load Share)
F: Full Features S: Simple Features	28: 28V 12: 12V 48: 48V	0: Thru-hole 1: Threaded	Standard: Latch	Standard: Non-Latch	Standard: Non-Latch	Standard: 0.240"	0: No Droop Load Share D: Droop Load Share
-UVW (Option Codes)							
-000		Thru-hole	Latch	Non-Latch	Non-Latch	0.240"	No Droop Load Share
-0D0		Thru-hole	Latch	Non-Latch	Non-Latch	0.240"	With Droop Load Share
-100		Threaded	Latch	Non-Latch	Non-Latch	0.240"	No Droop Load Share
-1D0		Threaded	Latch	Non-Latch	Non-Latch	0.240"	With Droop Load Share

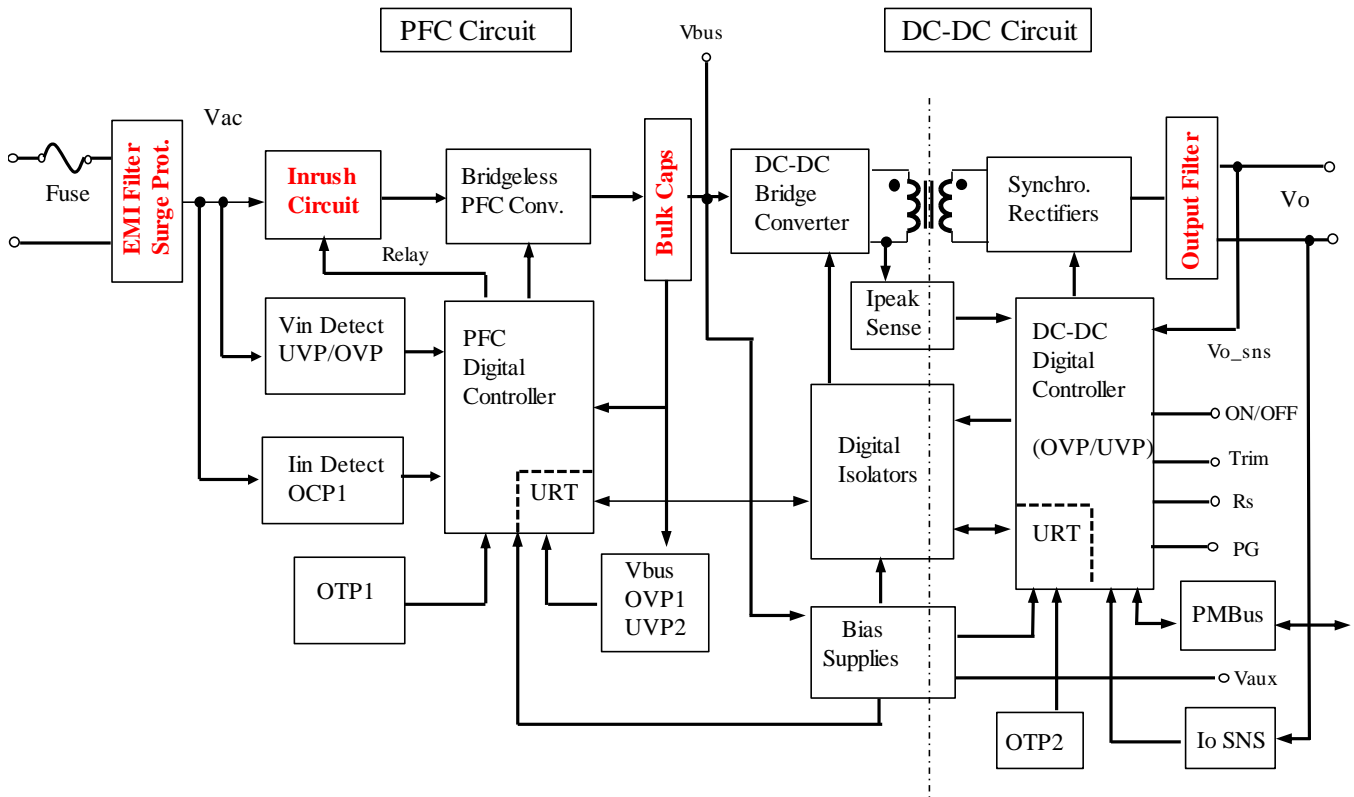
2. Module Pinout:



PIN	FUNCTION	PIN	FUNCTION
1	AC Input (Line)	11	Secondary Signal GND
2	AC Input (Neutral)	12	Aux Power Supply
3	Vout (-)	13	PMBus Clock
4	Vout (-)	14	PMBus Data
5	ON/OFF	15	PMBus Alert
6	Trim	16	PMBus Address 2
7	Remote Sense (+)	17	PMBus Address 1
8	Vout (+)	18	Inrush Control
9	Vout (+)	19	- Boost Voltage Bus (-VBUS)
10	Power Good	20	+ Boost Voltage Bus (+VBUS)

- Module case can be connected to Frame Ground through M3 mounting threaded hole(s).
- Consider terminal contact resistance when connecting AC(L), AC(N), +VBUS, -VBUS, Vout(+), Vout(-).
- Note that +VBUS and -VBUS terminals are primary voltage with high voltage rating (385VDC).
- Do not connect any load(s) across +VBUS and -VBUS terminals. Otherwise, it may damage the module.

3. Circuit Block Diagram

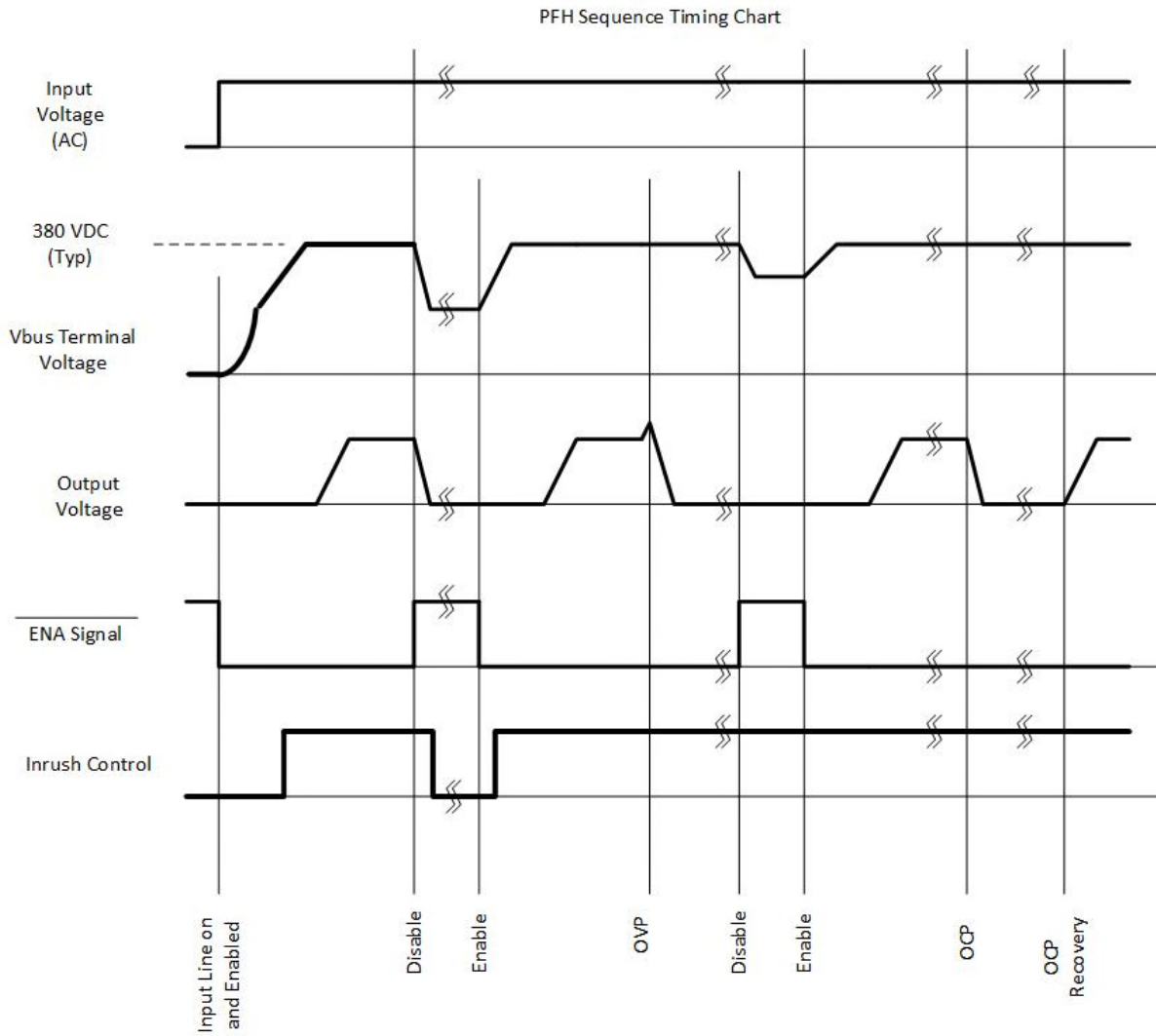


NOTE: The blocks with red font are the external components required for the operation of PFH module.

Switching Frequency:

- a) PFC Converter (fixed) : 145kHz
- b) DC/DC Converter (fixed):
 - 28Vo : 145kHz (primary), 290kHz (secondary ripple)
 - 12Vo & 48Vo : TBD
- c) Bias Converter (fixed): 135kHz

4. Sequence Timing Diagram



Note: PFH series product has a remote ON/OFF pin that is referenced to output return.

5. Terminal connecting method

In order to use the PFH500 series, this module must be connected with external components according to Figure 5-1.

Pay attention to the wiring details. If PFH module is connected to wrong terminal(s), the power module will be damaged.

PFH500 series employs conduction cooling method. Use a heat sink and fan(s) to remove the heat generated by heavy load operation.

For selection of heat sink(s) and the heat sink heat transfer method, refer to the Power Module Application Note.

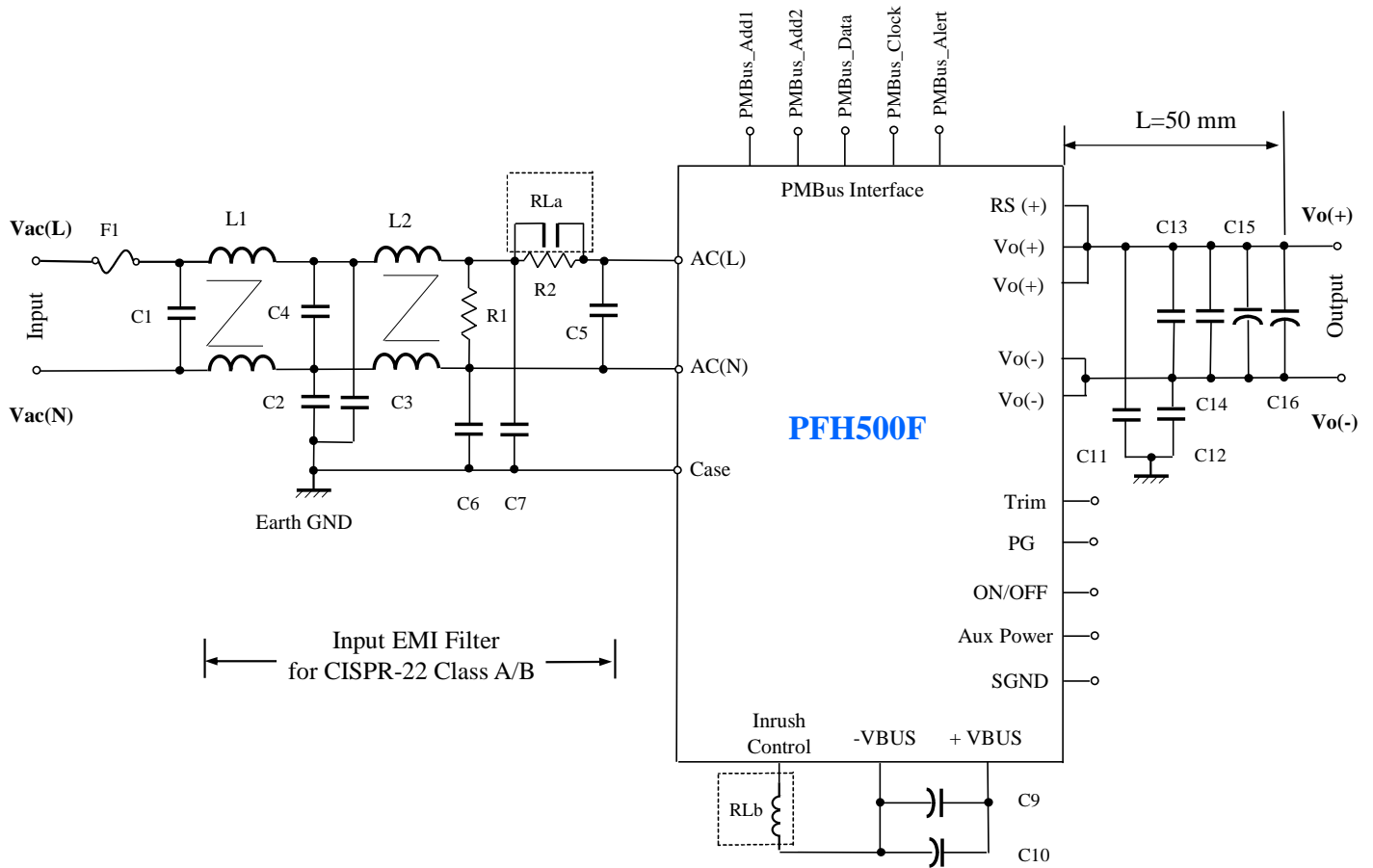


Fig.5-1 Basic connection

F1 : External Input Fuse

PFH500 series module has no internal fuse. Use external fuse to meet Safety Agency requirement.

PFH500 series modules were tested for safety agency certifications (UL, cUL, VDE, etc.) using 10A, 250Vac, Fast-Acting line fuse. Furthermore, the Fast-Acting type fuse selected must be used with one fuse per each module.

Also, the line inrush surge current will flow through the PFH module during initial line power application (or line power switch in). Be sure to check I^2t rating of external power switch (or circuit breaker), and external line fuse to make sure that the fuse will not blow, and/or the circuit breaker will not trip.

Recommended External Fuse : **10A, 250V (Fast Acting)**

Note) Select fuse based on rated voltage, rated current and surge current capability.

(1) Voltage Ratings

100VAC line : AC125V

200VAC line : AC250V

(2) Current Ratings

Rated current is determined by the maximum input current based on operating conditions and can be calculated by the following formula.

$$I_{in} (\text{max}) = \frac{P_{out}}{V_{in} (\text{min}) \times \eta \times PF} (\text{Arms}) \quad (\text{Formula 5-1})$$

$I_{in} (\text{max})$: Maximum Input Current
 P_{out} : Maximum Output Power
 $V_{in} (\text{min})$: Minimum Input Voltage
 η : Efficiency
 PF : Power Factor

For Efficiency and Power Factor values, refer to separate document “PFH500F Series Evaluation Data”.

C1 and C4: 1uF; C5: 2.2uF (Film Capacitor or Class X Safety Capacitor)

These capacitors are connected across the lines to protect against differential mode interference. Their failure does not create conditions for electric shock, although it can generate a fire risk if failed. Since the X cap is connected across the line and neutral, the current flowing through the cap can be high. When selecting X capacitor, be sure to check the allowable maximum ripple current rating of this capacitor.

TDK Lambda Americas recommends the customers to verify the actual ripple current flowing through each X capacitor by measuring the capacitor actual current.

Connect C5 as close to the input terminals of PFH500 series power module [i.e. AC(L) and AC(N)] as possible.

Recommended Voltage Rating of X - Capacitors: 250VAC

L1 and L2 : 6.3mH (Common Mode Choke)

Add common mode chokes as EMI noise countermeasure to protect the EMI noise generated by PFH500 series module flowing into the ac mains. When using multiple PFH500 series modules in parallel, it is important to insert the EMI filter stages (including X caps, Y caps, and common mode chokes) for each PFH500 module.

Note: An in-proper designed common mode choke may not help the noise reduction, in fact, it may actually cause PFH500 series module malfunction due to filter resonance. Consult TDK Lambda for technical assistance in selecting a right EMI filter.

C2, C3 : 3300pF (Ceramic Capacitor or Class Y Capacitor)

Y-capacitors are designed to enhanced electrical and mechanical reliability standards. Y-capacitors are used in applications where failure of the capacitor could lead to the danger of electrical shock to the user, if the ground connection is lost.

Y capacitance values are limited to reduce the current flowing through the capacitor when AC line voltage is applied. Low capacitance helps to reduce the energy stored to a safe limit when DC voltage is applied. Y capacitors must be tested to applicable safety standards to qualify them for use as Y-capacitors.

Y capacitors are used to protect against common mode noise generated from the PFH500 series module. Be sure to consider leakage current requirement of your equipment or instrument when selecting this capacitor.

High withstand voltage are applied across this capacitor depending on the application. Select capacitor with high withstand voltage rating such as Y2 capacitor (rated voltage: 150Vac to 300vac, peak tested voltage: 5kV).

R1: 470 kΩ, 2W

Connect bleeder resistor R1 across ac input terminals as shown in Figure 5-1.

C6, C7: 1000pF (Ceramic Capacitor or Class Y Capacitor)

Add these Y capacitors as EMI common-mode noise countermeasure. Be sure to consider leakage current of your equipment when selecting these capacitors.

High withstand voltage are applied across this capacitor depending on the application. Select capacitor with high withstand voltage rating such as Y2 capacitor

Connect C6 as close as possible to AC(L) terminal, C7 as close as possible to AC(N) terminal.

C9, C10: Electrolytic Capacitors

PFH500X: 470μF / 450V/ 105 °C x 2 in parallel

Refer to “Selection Method of External Bulk Capacitor for Boost Converter” below.

Allowable maximum external capacitance at nominal capacitance value is shown below.

Recommended Voltage Rating: 450VDC (105 °C rated capacitor)

Recommended Maximum Total Capacitance: 940 μF - 1410 μF

- Notes:
1. Do not connect capacitors with more than the above capacitance value as this could lead to PFH Series power module damage. Consult TDK Lambda for higher bulk capacitance requirement.
 2. When using module below -20°C ambient temperature, AC ripple of boost voltage, output ripple voltage might be affected by ESR characteristics of the bulk capacitors. Therefore, be sure to verify characteristics by actual evaluation.
 3. One or two high value (e.g. 1 MΩ) bleeder resistors are required to be connected across C9 or C10 to discharge the bulk cap voltage to a safe level after the Power Off.

C11, C12 : 470 pF to 1000 pF

Connect Y class ceramic or film capacitors as EMI noise countermeasure to reduce high frequency noise.

Capacitors with high voltage rating are needed since a very high test voltage is applied across this capacitor (between the output terminals and the module metal case) during the Hipot test depending on the application, and if the metal case is connected to earth ground or equipment frame ground. Connect C11 as close to Vo(+) terminal as possible, and C12 as close to Vo(-) terminal as possible.

C13: 0.1 μF, 50V ~ 100V (Ceramic Capacitor)

Add this ceramic capacitor 50 mm away from the PFH series module output terminals to help reducing the high frequency output ripple noise.

C14: 40 μF, 50V ~ 100V or four (4) 10 μF capacitors in parallel (Ceramic Capacitor)

Add this ceramic capacitor 50 mm away from the PFH series module output terminals to help reducing the high frequency output ripple noise, and also to help the load transient response speed.

C15, C16: Refer to Table 5-1

Connect C15 and C16 at 50mm from the output terminals Vo(+) and Vo(-) of the PFH series power module to stabilize the module operation.

Note that the output noise ripple and the characteristics of the power module during input line turn off might be affected by the ESR and ESL values of the selected electrolytic capacitors.

Also, note that output ripple voltage may vary depending on layout of the printed circuit board.

Sudden change in output voltage due to sudden load change or sudden input line voltage change can be reduced by increasing external output capacitance value.

Table 5-1 Recommended external output capacitance for C15 and C16

Module Output Voltage	C15	C16
28V	220 μF, 50V	220 μF, 50V
48V	220 μF, 100V	220 μF, 100V
12V	220 μF, 25V	220 μF, 25V

- Notes:
1. Use low-impedance electrolytic capacitors with excellent temperature characteristics. (Nihon Chemi-con LXY Series or Nichicon PM Series or equivalent rated at least 105 °C)

2. For module operation at ambient temperature below $-20\text{ }^{\circ}\text{C}$, the output ripple voltage will be affected by ESR characteristics of the electrolytic capacitors. Increase the recommended capacitance values as shown in table below.

Table 5-2 Recommended external output capacitance (when Ambient Temperature $\leq -20\text{ }^{\circ}\text{C}$)

Module Output Voltage	C15	C16
28V	470 μF , 50V	470 μF , 50V
48V	470 μF , 50V	470 μF , 50V
12V	470 μF , 25V	470 μF , 25V

3. Take note of the maximum allowable ripple current of the electrolytic capacitor used. Especially, for sudden load current changes, verify actual ripple current and make sure that allowable maximum ripple current of the external capacitor is not be exceeded.

For connection other than recommended capacitance, be sure to connect the polarity right.

● Selection Method of External Bulk Capacitor for Boost Converter

Boost converter bulk capacitor is determined by intermediate bus voltage ripple, ripple current, and hold-up time. Select a right capacitor value such that Boost converter bus voltage ripple does not exceed 15Vp-p.

Note: When the ambient temperature is $\leq -20\text{ }^{\circ}\text{C}$, the ripple voltage of Boost converter output will increase due to ESR characteristics. Therefore, verify above characteristics by actual evaluation in the circuit.

For output hold-up time, refer to separate document “PFH500 Series Evaluation Data”, and use appropriate capacitor up to 1410 μF maximum. It is recommended that actual verification is performed.

For allowable capacitor ripple current value, refer to Fig. 5-2.

Use of a capacitor with higher ripple current rating is highly recommended.

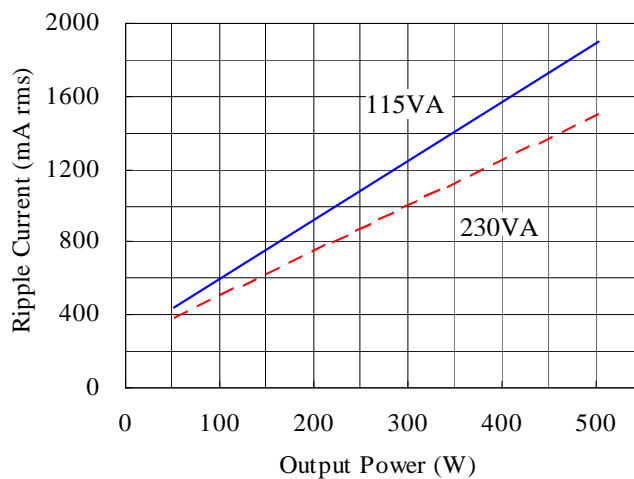


Fig. 5-2 Allowable ripple current value

The recommended Boost output bulk capacitance value is ranged from 960 μF to 1410 μF .

Note that reduction of the bulk capacitance affects the module output hold-up time, dynamic line transient response, and dynamic load transient response characteristics. It is recommended that the verification test is performed for the entire operating temperature range.

R2: 20Ω - 30Ω

By inserting a thermal fuse inrush resistor between the line filter and the input terminal, AC(L) as shown in Fig. 5-1, the inrush current can be limited to a pre-determined level to avoid the external line fuse from being blown or the input circuit breaker from being tripped or the bulk capacitors and/or PFH series module internal parts from being damaged or to avoid the oscillation between the input inductor and the bulk capacitors.

The maximum allowable resistance value is limited by the bulk capacitor bank charging time, and the PFC boost voltage ramp-up time. A 20Ω thermal resistor is recommended.

Note that PFH500 series module will not operate if this external inrush resistor is not present.

•Selection Method of External Resistor

(1) Calculating Resistance Value for R2:

Resistance can be calculated by the formula below.

$$R2 = \frac{Vin_pk}{Irush} (\Omega) \quad (\text{Formula 5-2})$$

R2 : Minimum Resistance Value Required for External Thermal Resistor, R2
 Vin_pk : Maximum Input Voltage Peak Value = Maximum Input Voltage (rms) x $\sqrt{2}$
 Irush : Allowed Input Inrush Current Peak Value during Initial Power Switch ON

(2) Required Surge Current Rating:

Sufficient surge current withstanding capability is required for external R2 thermal resistor.

Required Surge Current Rating of R2 can be determined by I^2t . (Current squared multiplied by time)

$$I^2t = \frac{Cb \times (Vin_pk)^2}{2 \times R2} (A^2s) \quad (\text{Formula 5-3})$$

I^2t : Thermal Resistor current-squared multiplied by time rating
 Cb : Maximum Boost Output Bulk Capacitance
 Vin_pk : Maximum Input Voltage Peak Value = Input Voltage (rms) x $\sqrt{2}$
 R2 : Resistance Value for External Thermal Resistor, R2, Chosen

(3) R2 Maximum Value Limitation:

R2 maximum value is limited by R-C charging time. The higher R2 value, the lower inrush current, but the longer start-up time will be (also see section 6-3 discussion). PFH series module does not have the second inrush event. When the ac line is switched on, the ac power source charges the bulk capacitor bank via the inrush resistor. Once the Boost converter output voltage (or bulk capacitor voltage) reaches about

70V, the internal bias circuitry starts to work. After a short delay, the PFC controller starts to enable the PFC converter, which charges the bulk capacitor bank to the regulated voltage level about 385V. The value of the thermal resistor, R2, limits the PFC converter ramp –up time, especially at low line case.

RL: Inrush Relay, 10A/277Vac (16A/125Vac), 12V coil

The inrush relay is connected in parallel with R2 resistor. As soon as the PFC bus voltage reaches the pre-set value (close to the peak of the maximum ac line voltage), the PFC controller will enable the inrush control pin to energize the relay. This method mitigates or even eliminates the second inrush current event during the relay closing. It is very important to make sure that the relay contacts are opened before applying AC power. Otherwise, the unwanted inrush current surge will damage PFH series module.

The inrush relay chosen must have the maximum switching voltage $\geq 265\text{Vac}$. A relay with minimum of 10A, 277Vac rating, and 12V / (15mA to 20mA) nominal coil operating voltage and current is recommended.

6. Explanation of Functions and Precautions

6-1. Input Voltage Range

Input ac voltage source should be a single phase power, ranged from 85 - 265Vrms (47-63Hz).

Connect the PFH series module to any power source that is outside this specified range (above) may lead to the permanent damages of the power module.

PFH500 series power module is certified by various safety agencies with a certified label indicating “**100-240Vac, 50-60Hz, 8A**”.

6-2. Output Voltage Adjustment Range

PFH series module output voltage can be adjusted up and down by connecting a trim resistor to Vout(+) pin or Vout(-) pin. Care must be taken to prevent the trim up voltage not to exceed 20% of the nominal voltage. Otherwise, it may activate the module OVP protection function.

Output Voltage Adjustment Range: +/-20% of the nominal output voltage setting

When trimming up the output voltage, the output current needs to be reduced to maintain maximum output power to be 500W or less. Otherwise, the module can be damaged permanently.

The trim-up and the trim down connections using external resistor are shown in Fig. 6-2, and Figure 6-4. If the remote sensing feature is NOT used, RS(+) pin needs to be connected to Vout(+) for local sensing. For details on Remote Sensing function, refer to “6-7. Remote Sensing”.

- **Output Voltage Adjustment using Fixed Trim Resistors**

With a trim resistor connected between the trim pin and Vout (+) pin, the output voltage is adjusted up. To adjust the output voltage up a percentage of Vout ($\Delta\%$) from $V_{o,nom}$, the trim resistor (in k Ω) should be chosen according to the following equation:

$$R_{trim_up} = 5.11 \times \left(\frac{V_{0,nom} \times (100 + \Delta\%)}{V_{ref} \times \Delta\%} - \frac{100}{\Delta\%} - 2 \right) \quad (\text{Formula 5-4})$$

$$\Delta\% = 100 \times (V_{o,nom} - V_{desired}) / V_{o_nom}$$

$$V_{ref} = 1.22V$$

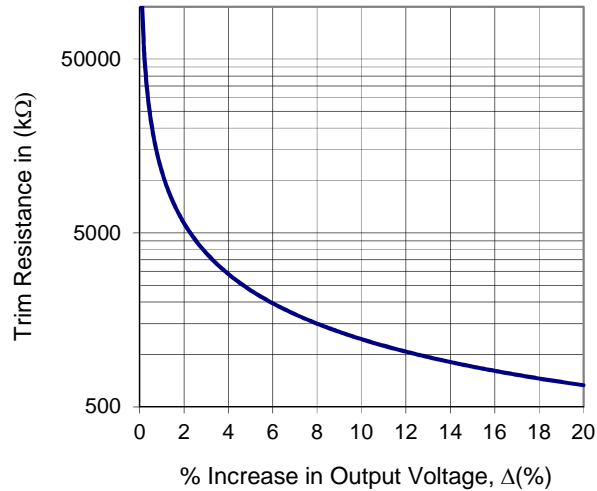


Figure 6-1 Trim-up Resistance vs. Percentage Voltage Trim-up

The trim-up resistor (R_{t_up}) values from +5% to +20%, can be found in Table 6-1. The trim-up circuit connection is shown in Figure 6-2. Recommended trim resistor should have +/-1% or better tolerance.

Table 6-1 External Trim-up Resistor Value for Various Output Voltage Adjustment

% Trim-up of V_{o_nom} (V)	Trim-Up Resistance (KΩ)	Measured Value (V)	Calculated Value (V)
+ 5%	2391.4K	29.3V	29.4V
+ 10%	1250.3K	30.6V	30.8V
+ 15%	869.8K	31.9V	32.2V
+ 20%	679.6K	33.1V	33.6V

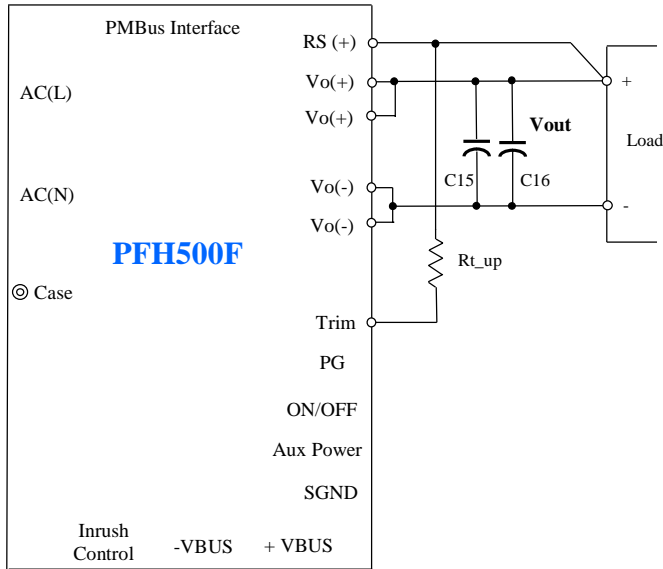


Figure 6-2 External Trim-up Circuit Connection

With a resistor connected between the trim pin and Vout (-) pin, the output voltage can be adjusted down. To adjust the output voltage down a percentage of Vout ($\Delta\%$) from $V_{o,nom}$, the trim resistor should be chosen according to the following equation (in $k\Omega$).

$$R_{trim_down} = 5.11 \times \left(\frac{100}{\Delta\%} - 2 \right) \quad (\text{Formula 5-5})$$

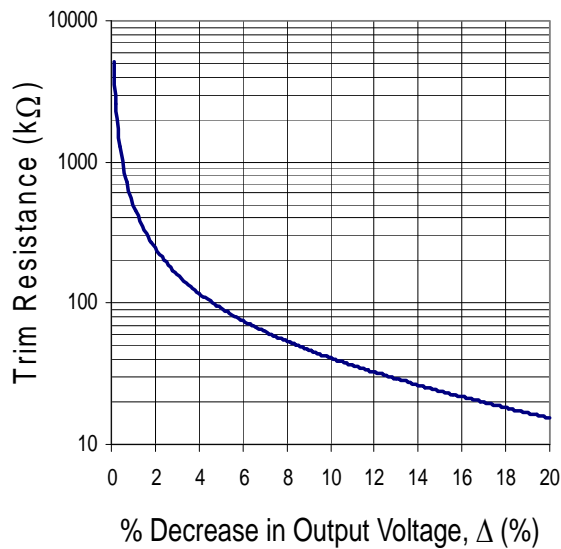


Figure 6-3 Trim-down Resistance vs. Percentage Voltage Trim-down

The trim-down resistor (R_{t_down}) values for the trim-down voltage range from -5% to -40% can be found in Table 6-2. The trim down connection diagram is shown in Figure 6-4.

Table 6-2 External Trim-down Resistor Value for Various Output Voltage Adjustment

% Trim-down of V_{o_nom} (V)	Trim-down Resistance ($K\Omega$)	Measured Value (V)	Calculated Value (V)
- 5%	92K	26.8V	26.6V
- 10%	40.9K	25.5V	25.2V
- 15%	23.9K	23.8V	23.8V
- 20%	15.3K	22.3V	22.4V
- 30%	6.81K	19.1V	19.6V
- 40%	2.56K	16.9V	16.8V

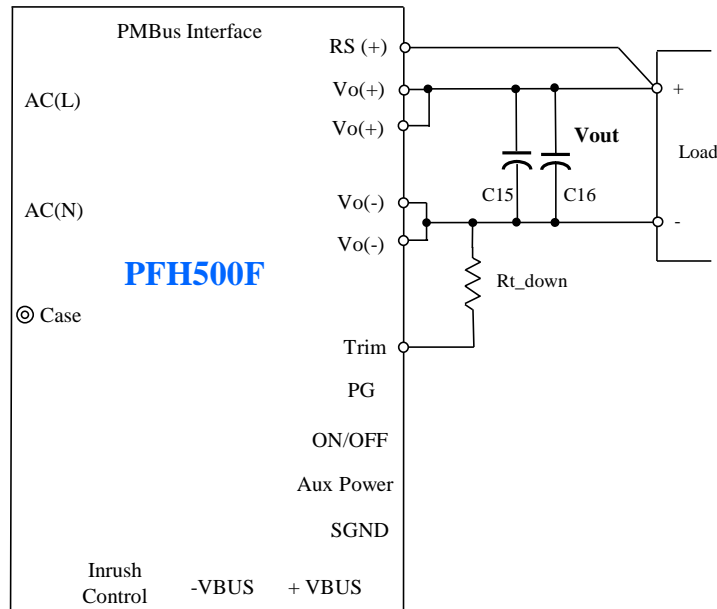


Fig.6-4 External Trim-down Circuit Connection

6-3. Inrush Current

Input inrush or surge current changes with the thermal fuse resistor (R_2) value and the external boost converter bulk capacitance value (C_9 and C_{10}). It is recommended that the actual evaluation test to be performed to confirm the inrush current value.

The inrush current peak values shown in the specification or data sheet are measured at nominal lines (115Vac and 230Vac), at 25 °C using the basic connection as shown in Figure 5-1.

The external line fuse should be chosen based on the PFH product label, which can handle the measured inrush peak current. The circuit breaker if used should be selected in additional to the line fuse.

6-4. Output Over-Voltage Protection (OVP)

PFH series module is equipped with OVP protection function. The OVP function activates when $V_o >$ the pre-set OVP trip set-point. When the OVP triggers, the module output will be shut down either with latch or auto-recovery depending on the option code specified. The standard option of PFH series modules has a latched OVP protection.

When the OVP function activates, first, cut off input ac line power. Afterwards, verify the boost bus voltage has dropped below 10V. Check for any abnormal conditions. Then, recover output by cycling input line switch on. The OVP latch can also be reset by turning off the module use of the On/Off pin or PMBus command.

The OVP set-point can be changed via PMBus if a full featured PFH series module is used. On the other hand, the maximum allowed module output voltage is limited by the pre-set Boost converter bus voltage. Without increasing this intermediate bus voltage setting, the OVP setting can only be lowered via PMBus. Otherwise, the module will never be able to reach the OVP triggering point unless it is applied externally.

Care must be taken to avoid applying higher voltage externally to the output terminals of PFH series module. Otherwise, it may cause the permanent damage to the module.

6-5. Boost (or Bus) Output Over-Voltage and Under-Voltage Protections (BOVP/BUVP)

PFH series module also monitors the Boost Bus voltage to protect it from the over-voltage and the under-voltage operations. In case it reaches these pre-set points, the module will be shut down, and the PFC converter will also be shutdown. The module will try to auto-restart after the shutdown. The inhibiting time depends on the value of the bulk caps and bleeder resistor values used.

6-6. Output Over-Current Protection (OCP)

PFH series module is equipped with various OCP protection functions including input PFC over-current protection, DC-DC primary side peak current cycle-by-cycle over-current protection, module over-load protection, and short circuit protection. In normal operation condition as specified by the specification and derating curves, the OCP protection will not be activated.

The module OCP function triggers when the output current exceeds 105% to 120% of maximum rated DC output current of specification. The OCP triggering point is also module temperature dependent since the power module PWB traces are used for the output current sensing. The OCP set-point is temperature compensated, and is also calibrated during the manufacturing test process.

The module output will automatically recover when the over-load condition or the short circuit is removed.

For the module with non-latching OCP, the module will enter a 2-second hiccup retry sequence once an OCP condition is detected. The module will try to re-start for 6 times at 2-second hiccup rate. If the over-load condition remains after the module tried to re-start 6 times, then it will enter a 6-minute hiccup retry sequence. Once the module enters the 6-minute hiccup mode, it will stay there until the over-load condition is removed, and the module can operate for at least 7 minutes without any OCP alarms. After that, the module will reset back to a standard 2-second hiccup time OCP protection mode in case an OCP alarm is detected again after 7 minutes.

When the PFH series module is operated outside the specified input voltage range, the input OCP function may also be activated to protect the module from drawing excessive input current to damage the module.

PFH series module OCP set-point is fixed, but it can be lowered from its maximum value by PMBus if a full featured module is used.

Note that continuous short circuit or overload condition might result in power supply over-heating or damage.

6-7. Module Over-Temperature Protection (OTP)

PFH series module is equipped with internal OTP protection function. There are four (4) OTP protection devices located at various key locations of the potted module. There are two (2) NTC thermistors, one located on the hot spot of the PFC converter side, and another on the hot spot of the DC-DC converter side. The digital controller chip (for both PFC and DC-DC) also has its own internal thermal sensor. The digital controller reads back the temperature sensed, and disables the operation based on the pre-set OTP reading(s).

When any one of these components hits the temperature trigger point(s), the OTP protection will be activated, and the module will shut down. The module will re-start after the internal temperature drops below the re-start point, usually 20 °C below the trip point. The non-latching auto-restart OTP protection is a standard feature for PFH series module.

PFH series module OTP set-point(s) also varies with the input line voltage range. The trip point at low line range is set lower than the trip set-point of high line operation since the module efficiency at low line operation is lower than the case of high line operation.

The latched OVP protection is possible, but is not recommended since it requires either to cycle the input power or to cycle the ON-OFF switch to reset the OTP fault providing the measured hot spot temperature dropped 20 °C or more. Usually, this reset operation requires operators' action, which takes time and cost money in most cases.

6-8. Remote Sensing (+RS Terminals)

PFH series module has one remote sensing terminal, RS(+), to compensate for the line drop from the output terminals to the output load. When the remote sensing is not required, i.e. using local sensing, be sure to short RS(+) pin to Vo(+) pins. Note that the line drop (the voltage drop due to long wirings) voltage compensation range must be within the output voltage adjustment range. At any conditions, the maximum output power of PFH module should not be exceeded.

Before using remote sensing feature, do adequate evaluation to make sure that the module does not have noise impact at the load terminals. Should a noise filter inductor be inserted between Vo(+) pin(s) and the load terminal, the RS(+) sense must be connected as local sense, i.e. to Vo(+) terminal. Some precaution in the layout may be needed. Contact TDK Lambda Customer Support for the helps if needed.

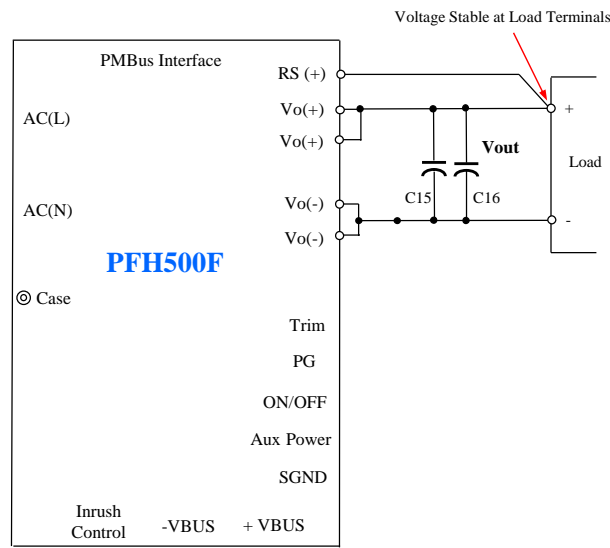


Fig.6-5 Remote Sensing is used

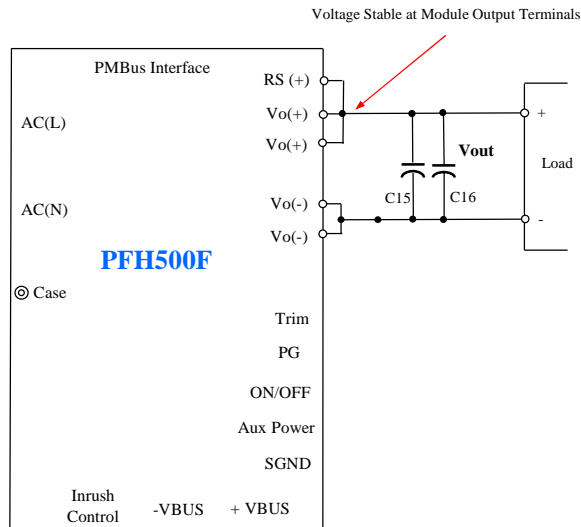


Fig.6-6 Remote Sensing is not used (Local Sensing)

6-9. ON-OFF Control (ENA Terminal)

PFH series module has an ON-OFF control pin, which is used to enable (or turn on) or disable (or turn off) the module. When this pin is low, the PFH module is enabled. Internally, this pin is connecting to a 10KΩ pull-up resistor that is in series with 3.3V source. A 0.01uF filter cap is also connected across this pin to the GND.

- Maximum sink current of ON-OFF pin: 300μA
- Maximum low status voltage for Enable: 1V
- Maximum high voltage of ON-OFF Pin: 3.4V

ON-OFF pin references to Vout(-) Signal Ground.

The digital controller inside the module will remember the ON-OFF control status. Should the module be enabled by ON-OFF pin, then it must be turned off by ON-OFF pin. Try to turn off the module by PMBus (if equipped) will be ignored. If the module is enabled by PMBus control, then ON-OFF pin control function will be overridden.

Various ON-OFF pin connection schemes are shown below, Figure 6-7a to Figure 6-7d.

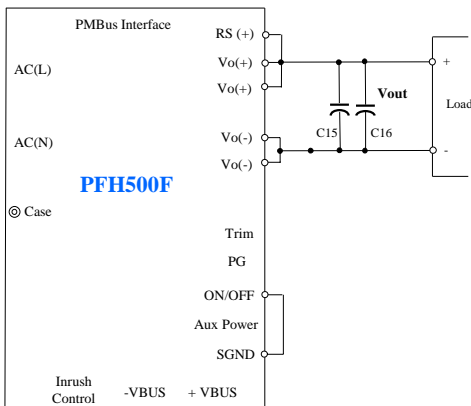


Fig.6-7a ON-OFF Pin Tied “Active”

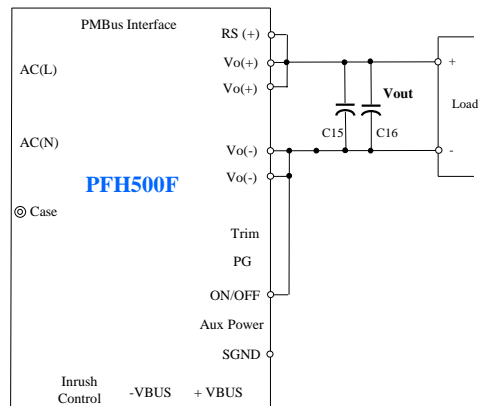


Fig.6-7b ON-OFF Pin Tied “Active”

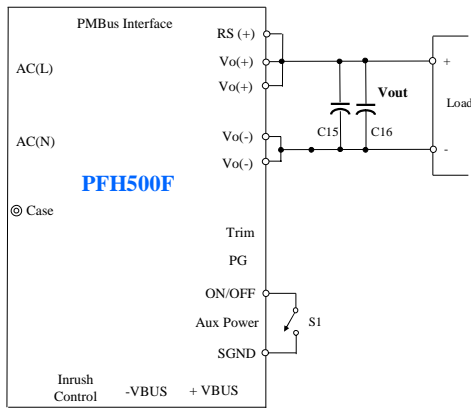


Fig.6-7c ON-OFF Control Using Switch

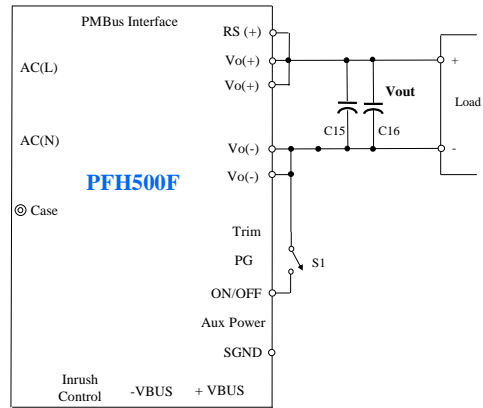


Fig.6-7d ON-OFF Control Using Switch”

6-10. Power Good Signal

PFH series module has a Power Good pin to allow the customer to use this pin to either turn on or off their load(s) or to communicate with their controller and signaling system to monitor the status of PFH module.

When the output voltage of PFH module is within the specified output voltage regulation band together with the PWM switching of the module, a Power Good signal is activated. An active “Low level” indicates Power Good.

Maximum sink current of Power Good pin:	200mA
Maximum voltage of Power Good Pin:	60V

Some filtering (hardware or software) of the Power Good pin is recommended for the application where a large load transient taking place constantly. Care must also be taken for the application where multiple PFH modules are connected in parallel without the ORing diodes or Oring FETs.

Since PFH series module uses a droop load share scheme, a reasonable well load sharing is expected, which should not complicate the Power Good signal status.

6-11. Auxiliary Bias / Power

The full featured PFH series module also has an Auxiliary Bias Supply pin, references to Vout(-). This auxiliary bias is internally over-current protected. It is capable of providing a loosely regulated 12V bias (10V ~ 14V, and 200mA maximum current). This bias supply can be used for powering customers’ on-board POLs loads, and other low power devices such as LEDs, amplifiers, relays, drivers, etc.

6-12. Droop Load Share (Parallel Operation)

The droop load share scheme is used in PFH series module for the optional load sharing needs. The droop load share scheme senses the module output load current, and then intentionally lowers the output voltage reference, which then in turns reduces the regulated output voltage as shown in Figure 6-8a.

Use of Oring diodes (Schottky diodes) with same forward voltage drops and same temperature rise characteristics is required. The use of the Oring diodes is to prevent any negative current from flowing back to the PFH module(s) due to the synchronous rectification of the secondary side FETs together with the use of the full digital control.

In a two-module load share system, if Unit #2 provides the load current, I_{o2} , is higher than what Unit #1 provides, i.e. $I_{o2} > I_{o1}$, then the output voltage of Unit #2, V_{o2} , will be lower than the output voltage of Unit #1, i.e. $V_{o2} < V_{o1}$. If $R1 \cong R2$ and Schottky diodes voltage drops are the same, then the higher V_{o1} will force the Unit #1 to contribute more current to the total load current. In the steady state and with a perfect sharing, each PFH series module will provide close to 50% of the total load current. Figure 6-8b depicts two PFH units running at 18A load, and then one of the units shut down.

The load share accuracy is the function of the module initial output voltage setting accuracy, load current sensing accuracy, multiple modules output wiring impedance difference, and the forward voltage drop difference of the external Oring diodes (or Oring FETs). A dual-pack Schottky diodes with the same forward voltage drop and temperature characteristics will help boosting the load share accuracy.

If more than 2 PFH modules are connected in parallel, a higher droop rate may be required for better accuracy. The RS(+) needs to be connected at local sense mode, i.e. to $V_{o}(+)$ pin(s).

Since PFH series module has a hiccup type OCP protection scheme, in a multiple modules paralleling system, start-up load current must be the same or less than one PFH module's maximum allowed current to avoid the difficulty of starting.

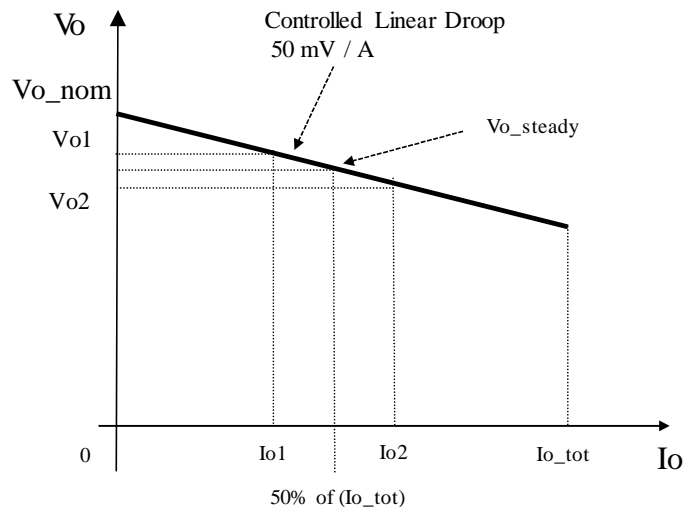
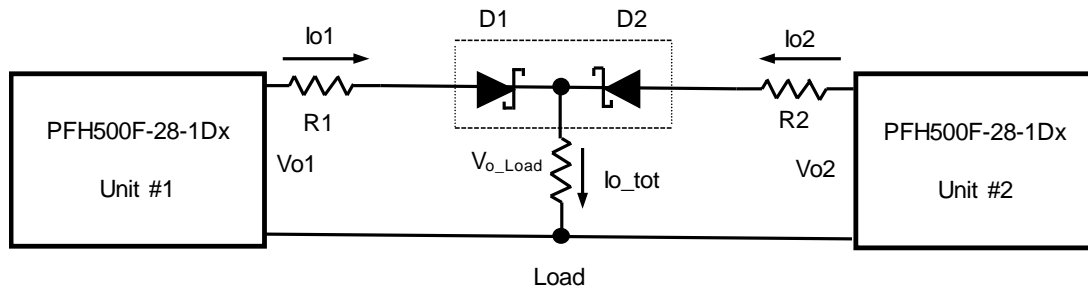


Fig.6-8a Two PFH Modules in Droop Load Share Mode (with Oring Diodes)

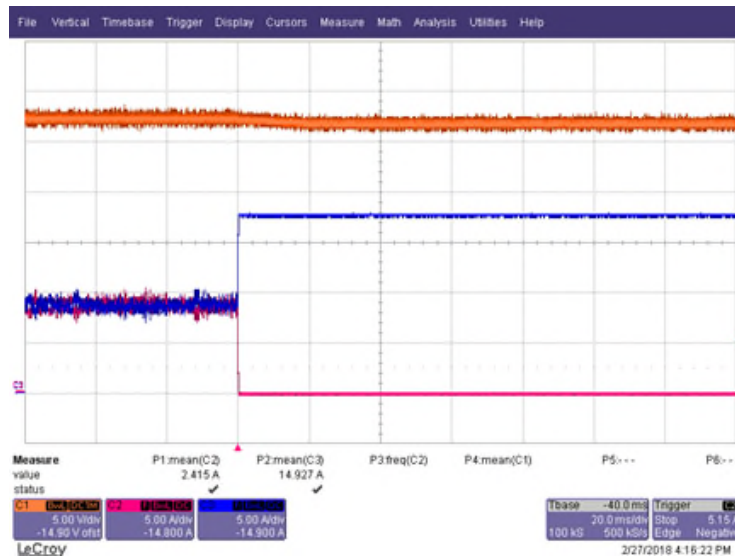


Fig.6-8b Two PFH Modules Running at 18A Load, and then One PFH Unit Shutdown

6-13. PMBus Communication

The full featured PFH series module has equipped five (5) PMBus pins (Pin 13 to Pin 17), which allows the host computer to communicate with the PFH module controller to read out and/or command (or set) the module operating parameters.

PFH series module operating status such as V_{in} , I_{in} , Internal sensed temperature (4 of them), DC-DC switching frequency, V_{out} , output droop rate, I_o , PFC bulk capacitor voltage, output OCP limit setting, output OVP limit setting, and output UVP setting, etc. PMBus can also be used to modify some of the operation parameters and/or limit setting, etc. For the details, please refer to TDK Lambda “PFH PMBus Specification and Application Note”.

As an additional safety feature, the firmware is designed to shut down the module if the communications between the two controller chips (PFC and DC-DC) stops functioning. This type of fault is very rare, and the module shutdown requires re-cycling the input ac power to restart the module.

6-14. Maximum Ripple and Noise

The output noise is measured according to the description below in accordance with industrial standard.

The output noise measurement connection can be found in the basic connection diagram shown in Fig. 5-1, and the simplified connection diagram shown in Figure 6-9 below.

A 0.1 μ F ceramic capacitor, C13, and four (4) 10 μ F ceramic capacitors, C14, are connected across the PFH module output bus located 50mm away from the module output terminals. Connect a 50 Ω coaxial cable with JEITA attachment across the ceramic capacitors electrodes (see Figure 6-9) to measure the output noise. Use 20MHz bandwidth digital oscilloscope setting to measure peak-peak and RMS values.

Note that the measured actual output ripple noise and the output spikes may vary depending on the wiring pattern of the printed circuit board, and the contact impedance of the scope coaxial cable connection.

In general, the module output ripple noise, and the output spike noise can be reduced by increasing external ceramic capacitor numbers and values.

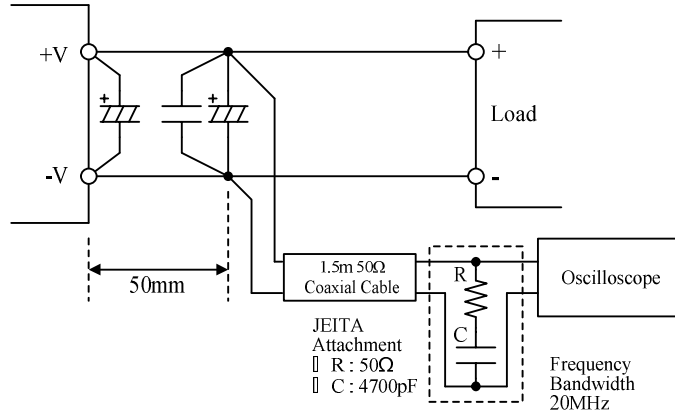


Fig.6-9 Output Noise or Ripple (including Spike Noise) Measurement Method

6-15. Series Operation

To double the output voltage of PFH series module output, it is possible to connect two or more PFH500 series modules in series. For two modules connected in series configuration, the connection diagrams are shown in Figure 6-10a and Figure 6-10b. The output voltage from each module can be set (or trimmed) to different level to form various combination of the total output voltage. The maximum allowable modules to be connected in series are 3 units. The RS(+) pin needs to be connected at local sense mode, i.e. to Vo(+) pin(s). Care must be taken for the use of the ON-OFF feature in this operation. Opto-couplers or other isolated devices are needed. Contact TDK Lambda Customer Support for the helps if needed.

$$V_{out_tot} = V_{out1} + V_{out2}$$

(Formula 5-6)

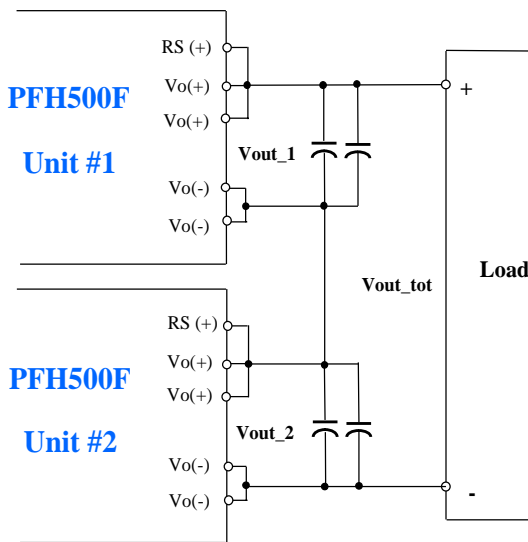


Fig.6-10a Series Operation #1
(Higher Output Voltage)

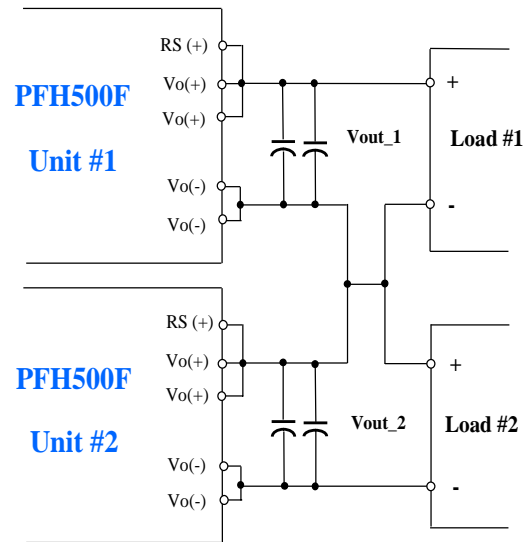


Fig.6-10b Series Connection #2
(Different Load with Different Output Voltage)

6-16. Isolation Resistance

The isolation resistance between Output and PFH module case should be more than 100MΩ with 500VDC applied.

For safety concern, the isolation resistance test must be done first before Hipot test and/or powering on the module with ac power. Ensure that the unit is fully discharged after the isolation resistance test.

Output – Case: 100MΩ or more at 500Vdc

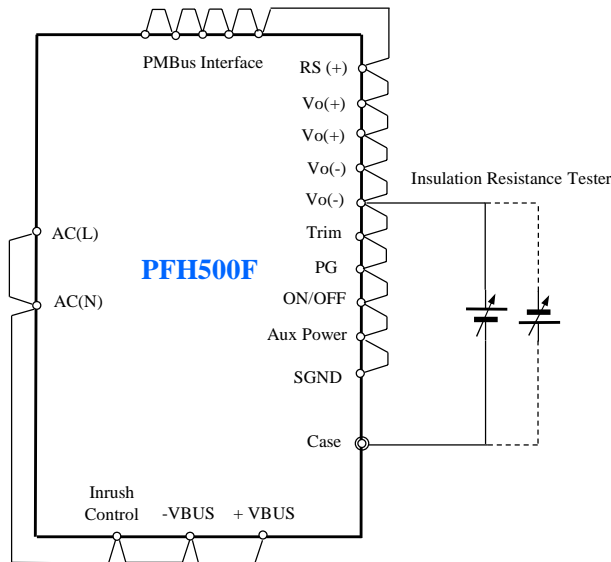


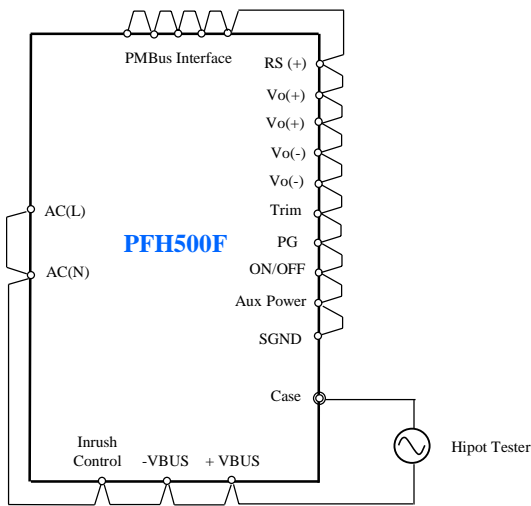
Fig.6-11 Isolation Resistance Test Method

6-17. Withstand Voltage Test (Hipot Test)

PFH series module is designed to withstand 2.5kVac between input and module case, 3.0kVac (reinforced voltage) between input and output, and 1.5kVdc between output and case, each for 1 minute long. When testing withstand voltage (or Hipot test), set the current limit of the withstand voltage tester (or Hipot tester) equipment at 20mA.

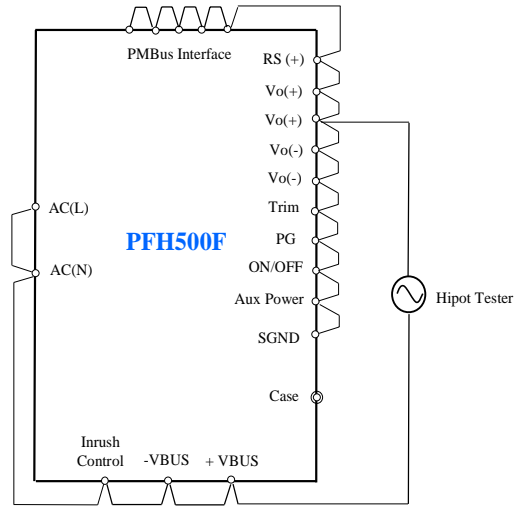
Be sure to apply DC Hipot test voltage between output and case. Avoid applying AC testing voltage during this test. Otherwise, it may damage the PFH series power module.

The applied voltage must be gradually increased from zero-volt to preset testing level, and then gradually decreased to zero-volt. The ramp rate must not exceed 300Vrms/sec, the dwell time should be 1 sec in mass production, and 60 seconds during the safety qualification test. Connect each terminal of PFH module according to the circuit diagrams as shown in Figure 6-12a, Figure 6-12b, and Figure 6-12c.



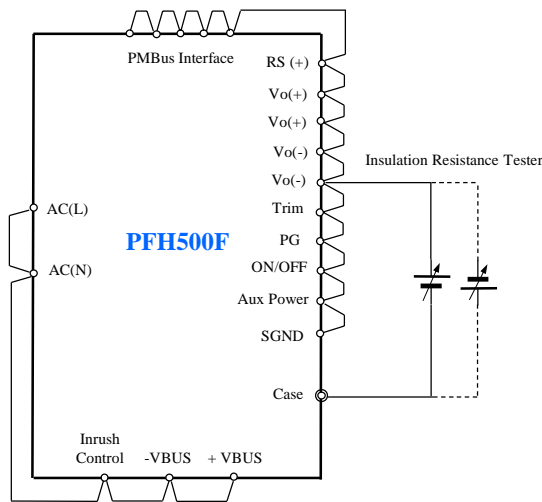
2.5kVac 1 minute (3mA)

Fig. 6-12a Input to Case Hipot Test Method



3kVac 1 minute (3mA)

Fig. 6-12b Input to Output Hipot Test Method



1.5kVdc 1 minute (3mA)

Fig.6-12c Output to Case Hipot Test Method

Withstand Voltage Testing with External Supporting Circuitry

The aforementioned Withstand Voltage Testing (or Hipot testing) only applies to PFH series power module as a stand-alone unit. For the Withstand Voltage Testing performed in a system level with the supporting circuitry such as shown in Fig. 5-1, care must be taken to check and verify the voltage rating of the selected external capacitors (and/or MOVs, and spike gaps for line surge protection) between the Input terminals and Case, and Output terminals and Case.

Capacitor: Input terminals to Case (or Frame GND):

C2, C3, C6, C7

Capacitor: Output terminals to Case (or Frame GND):

C11, C12

MOVs and Spike Gaps: Input terminals to Case (not shown in Fig. 5-1):

MOVs 3-6, SG1, SG2

7. Thermal Considerations and Mounting Method

7-1. Thermal Considerations

The PFH series module is designed for both convection and conduction cooling applications.

This product can be mounted in any orientation, but for forced convection applications, be sure to provide adequate airflow around power supply to avoid heat accumulation. Consider layout of surrounding components and orient the PFH such that air flow across module is optimized.

It is recommended that this product operate when case temperature is maintained at or below the derating curves as shown in Figure 7-2. The maximum case temperature should be 100°C or less regardless of the input operating line voltage and/or frequency. For any technical issues related to thermal derating, thermal test set-up, mounting, the heat sink attachment, and use of the thermal interface material, contact TDK Lambda Americas technical support.

Case temperature thermal measurement location is shown in Fig. 7-1.

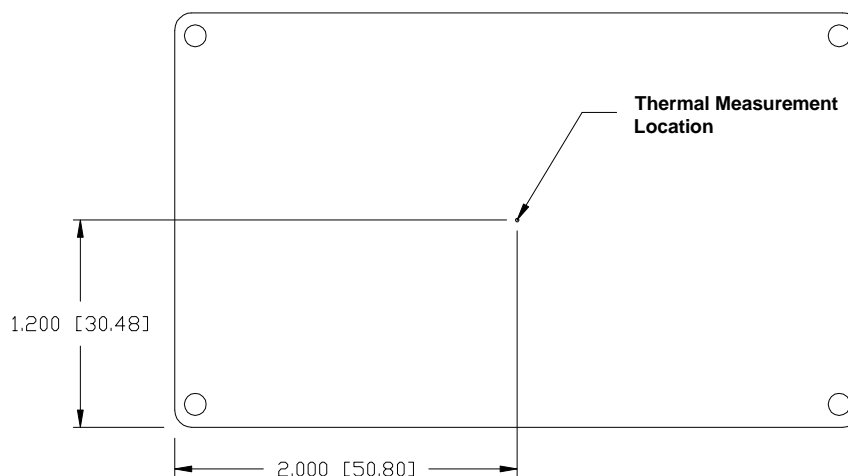


Fig.7-1 Base-plate Temperature Measuring Point

To achieve a more rugged physical design and minimize common mode noise, the PFH series module is constructed **without** an Insulated Metal Substrate (IMS) board. Instead the PFH construction comprises of a multi-layer, heavy Cu PCB enclosed within a 5-sided insulated case.

Because of the different heat transfer nature of PFH series module, operation at 100 °C case temperature can be done only if output power is derated slightly depending on the **input** line condition. In most applications, the case temperature requirement is lower than 100 °C. A lower case temperature requirement does not suggest poor thermal performance since the module can deliver the same or even more power at the same given ambient temperature due to higher conversion efficiency, and less internal power losses (i.e. heat) generated. Furthermore, PFH is a 2.4 x 4.0" compact brick size module, which is the smallest ac-dc brick that can deliver 500W in the market-place.

However, for applications where 100 °C case temperature operation is required, the output current of the module may need to be derated as shown in Fig. 7-2, especially for low input line voltage operations.

7-2. Output Current/Case Temperature Thermal Derating

PFH500F-28 module is derated according to Figure 7-2. Derating varies based on AC input voltage and desired case temperature/output current.

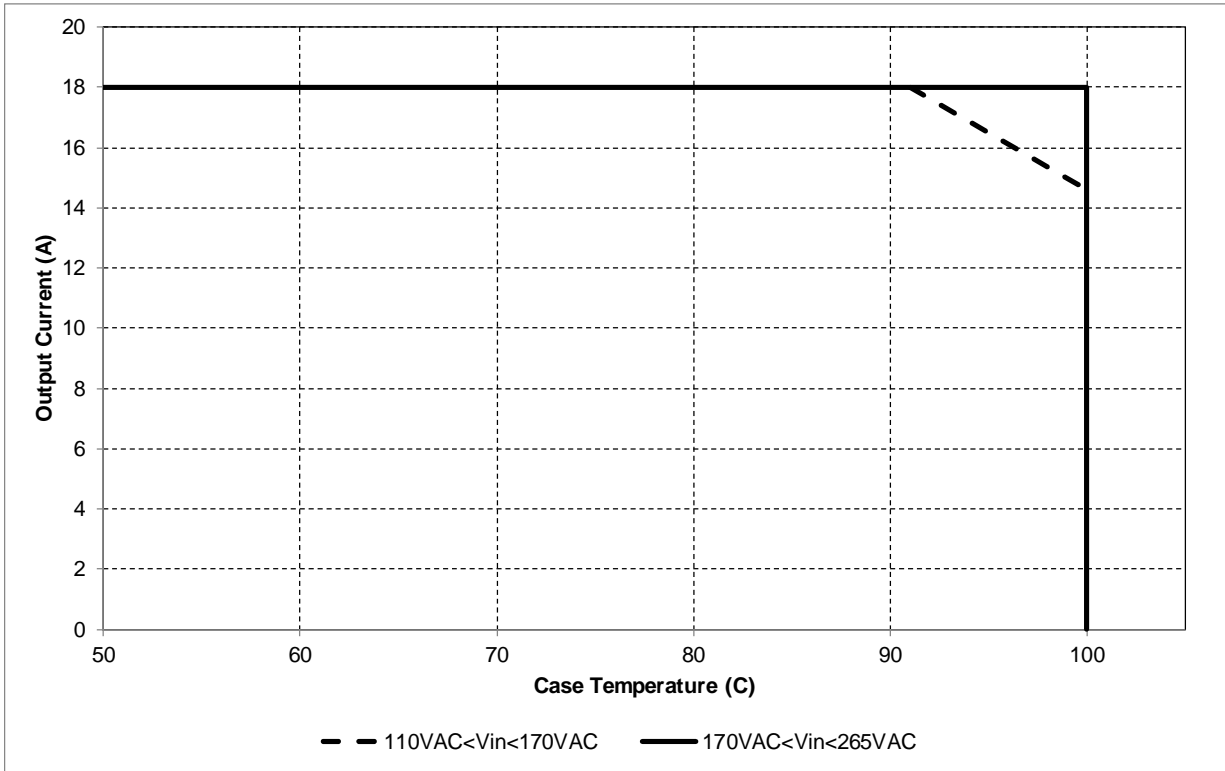


Fig.7-2 PFH500F-28-xxx Derating Curves

For the sake of the components long term reliability, it is recommended to use PFH series power module strictly according to these derating curves or derating guidelines. For any technical issues related to thermal derating, thermal test set-up, mounting, the heat sink attachment, and use of the thermal interface material, contact TDK Lambda Americas technical support.

7-3. Recommended Soldering Condition

Recommended soldering temperature is as follows:

Soldering Dip: 260 °C, within 10 seconds
Preheat: 130 °C, within 60 seconds

7-4. Recommended Washing Condition.

After soldering, following washing condition is recommended.

For other washing conditions, consult TDK Lambda Americas Technical Support.

(1) Recommended washing solution

- IPA (Isopropyl Alcohol)

(2) Washing method

In order to avoid penetration inside the power module, washing should be done with brush.
Then, dry up thoroughly after washing.

8. Damaged Power Module

Verify following items before concluding power module damage.

(1) No output voltage

- Is specified input voltage applied?
- During output voltage adjustment, is the fixed resistor used correct?
- Is the power module attempting to re-start (hiccup mode) ?
- Is there no abnormality with the output load?
- Is the actual case temperature within the specified operating temperature of this module?

(2) Output voltage is too high

- Is the remote sensing terminals RS(+) correctly connected?
- Is the measurement done at the sensing points?
- During output voltage adjustment, is the fixed resistor used correct?

(3) Output voltage is too low

- Is specified input voltage applied?
- Is the remote sensing terminals RS(+) correctly connected?
- Is the measurement done at the sensing points?
- During output voltage adjustment, is the fixed resistor used correct?
- Is there no abnormality with the output load?

(4) Load regulation or line regulation is out of specification

- Is specified input voltage applied?
- Are the input or output terminals firmly connected?
- Is the measurement done at the sensing points?

- Are the input and output wires too thin?
- Is the recommended output capacitance within the range?

(5) Large output ripple

- Is the measurement done according to methods described in the Instruction Manual?
- Is the recommended ceramic capacitance used?
- Is the measuring probe contact resistance too large (dirty or greasy)?

9. Warranty Period

Warranty period is 3 years or whatever is specified on the purchasing agreement.

For damages occurring at normal operation (as recommended by this Instruction Manual including the derating curves) during this warranty period, repair is free of charge.

Following cases are not covered by warranty

- (1) Improper use like dropping products, applying shock, and/or dropping/spilling fluid to the module
- (2) Operating the PFH series module outside the specification or not following this Instruction Manual
- (3) Defects resulting from natural disaster (fire, flood, earthquake, tornado, hurricane, etc.)
- (4) Unauthorized modifications or repair by the buyers/customers