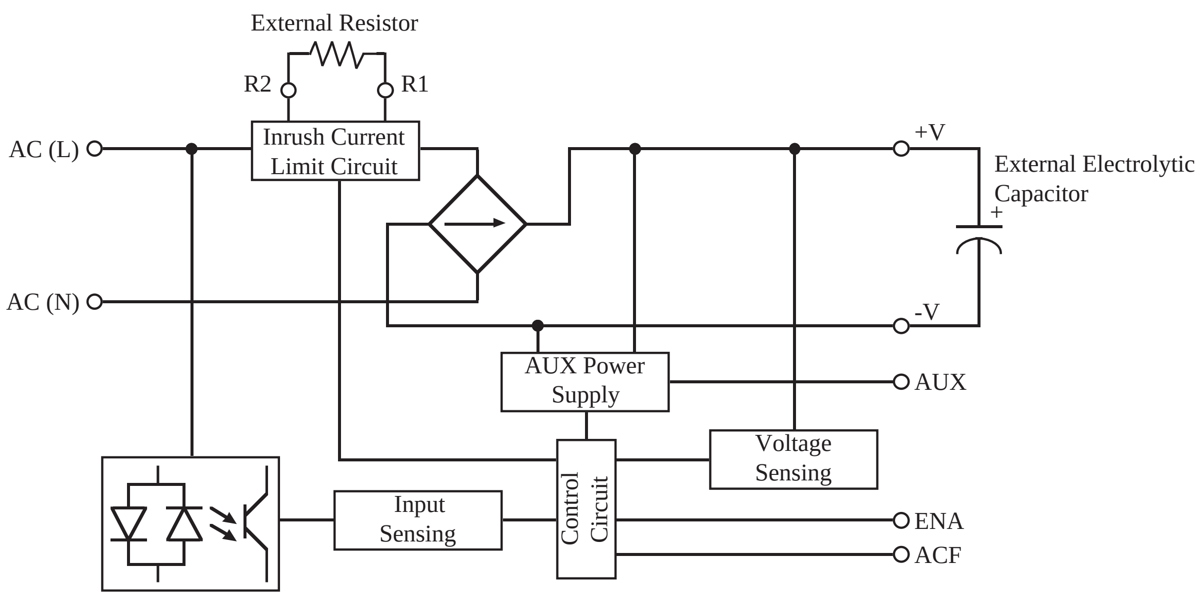
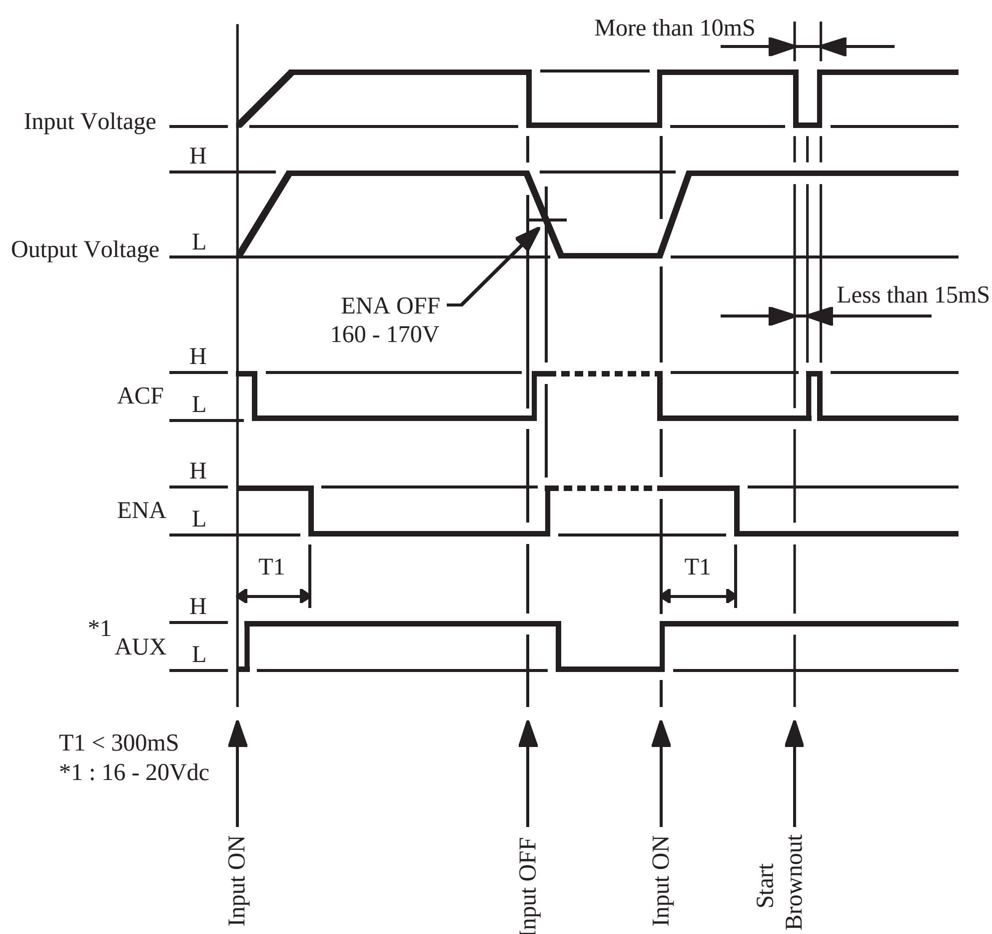
PR500-280 Rectifier Module

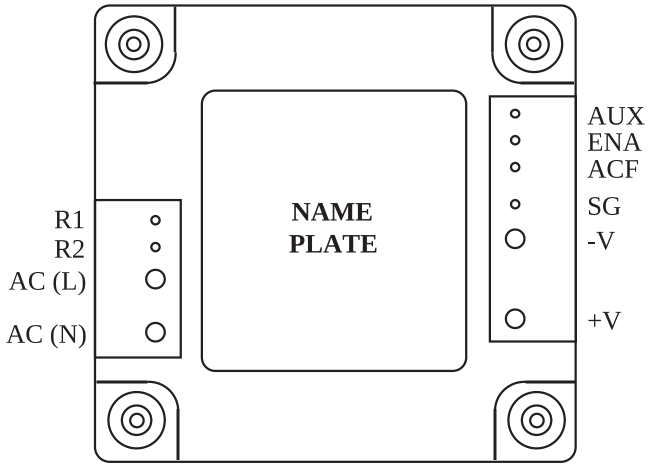
Block Diagram



Sequency Timing Diagram



PR500-280 Terminal Layout



Primary Referenced Terminals :

Pin Name	Function	Refer to Page(s)
R1	Inrush Current Limit Resistor	3, 6
R2	Inrush Current Limit Resistor (Live Line Side)	3, 6
AC (N)	AC Input Terminal (Neutral Line)	3
AC (L)	AC Input Terminal (Live Line)	3

Secondary Referenced Terminals :

Pin Name	Function	Refer to Page(s)
AUX	Auxiliary Power Supply	7
ENA	Power ON Signal	7
ACF	Alarm Signal	7
SG	Signal Ground	7
-V	Negative Output Voltage	3 - 4
+V	Positive Output Voltage	3 - 4

1.0 Input Voltage Range

The PR Module accepts a worldwide input range from 85 - 265Vac, and functions to provide an unregulated DC voltage bus to support operation of the PH DC-DC converter modules. For "110Vac" operation, the PR module should be configured as a voltage doubler, shown in Figure 1-1. The PR module should be configured as a full wave bridge rectifier for "220Vac" operation as in Figure 1-2.

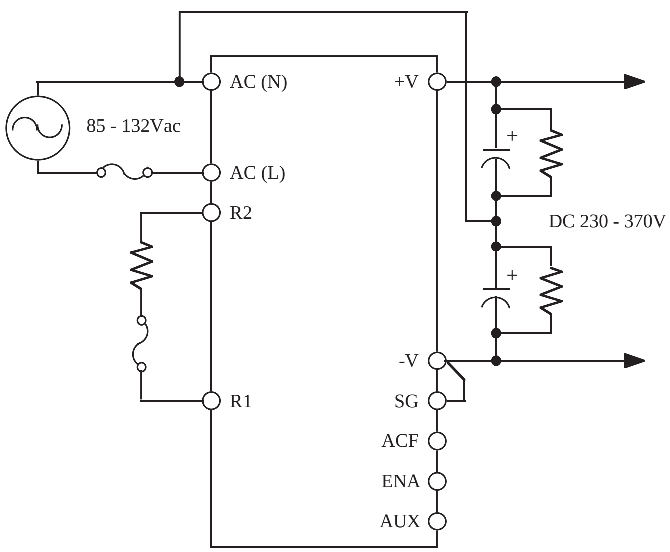


Figure 1-1 Voltage Doubler Connection

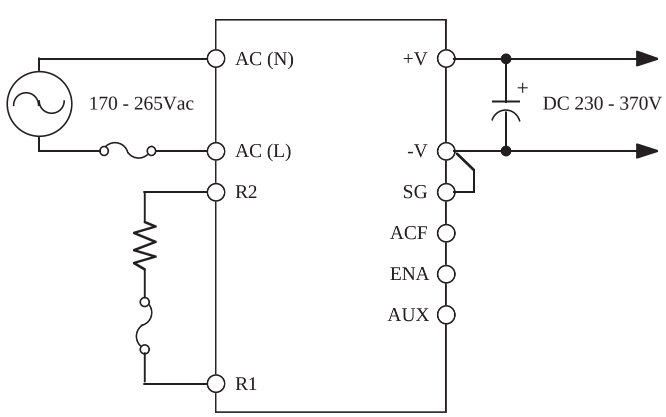


Figure 1-2 Basic Connection

2.0 Input Current

The input current is specified as a typical value needed to sustain the desired input power necessary for system operation. By design, a switch mode power supply will maintain its output voltage constant for a wide range of input voltages. Since the output voltage is fixed under steady loading conditions, the output power will remain constant as the input voltage varies. In order to maintain constant input power at constant efficiency, the input current must vary inversely proportional to the input voltage. Therefore, at minimum input voltage (85Vac) maximum input current will exist.

3.0 Rated Output Voltage

The output voltage range for the PR module is rated from 230 - 370Vdc at a nominal value of 280Vdc. This unregulated DC Voltage can be achieved through the voltage doubler mode (110) and full bridge mode (220) of operation.

When operating in "110" mode, the PR module should be configured as a voltage doubler (refer to Figure 1-1). The average output voltage is calculated as follows:

110 Operation - Voltage Doubler Operation

Equation 3-1

$V_{OAVG} = [(\sqrt{2} \times V_{IN}) \times 2] - V_F$

Vo = Output Voltage (D.C.)

Vin = Input Voltage (A.C.)

V_F = Internal Voltage Drop

V_F approx. 5V

Example:

For 110Vdc

$V_O = \sqrt{2} \times 110 - 5$

$V_{OAVG} = 306\text{Vdc}$

Note : In order to maintain a balanced voltage applied to the capacitors when using a voltage doubler hookup, bleeder resistors (of the same value, proper power level) are recommended.

When operating in "220" mode, the PR module is configured as a full bridge rectifier (see Figure 1-2). The average output voltage is calculated as follows:

220 Mode Operation - Full Bridge Rectification

Equation 3-2

$V_{OAVG} = \sqrt{2} \times Vin - V_F$

Example:

For 220Vdc

$Vo = \sqrt{2} \times 220 - 5$

$Vo = 306Vdc$

Note : The above DC rectified voltage assumes a non-distorted input sine wave applied at the input of the rectifier module. If the input waveform is distorted or clamped due to poor input line capability, the distorted value must be subtracted from the calculated values shown in the examples on the previous page for a true DC rectified voltage.

4.0 Selection of the Output Capacitor

External output capacitors are needed to form an unregulated DC input section. Output capacitor selection is composed of the following criteria:

1. Peak to peak output ripple voltage
2. Desired holdup time of the system
3. Peak to peak ripple current that each capacitor must meet
4. Expected lifetime of the capacitors

Definition of Holdup Time

The time under worst case conditions during which a power supply's output voltage remains within the specified limits following the loss or removal of input power (Note : This applies to the DC-DC converter (PH Series) that is connected to the input module).

4.1 Peak to Peak Output Ripple Voltage

The maximum allowable ripple voltage out (Vpp) of the PR module is 40Vpp. Operation above this voltage does not guarantee operation within specified limits, and should be avoided.

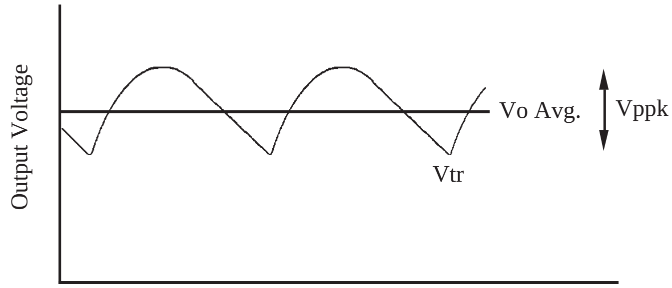


Figure 4-1

4.2 Capacitor Value Needed for Output Holdup Time Requirements

The total effective capacitance value needed to comply with the desired holdup is derived from the energy stored in the output capacitors. The capacitor value required is provided by the following formula:

Equation 4-1

$$Co_{(EFF)} = \frac{2 \times P_{IN} \times T_H}{[(Vo - Vp\text{-}p)^2 - (V_{DO})^2]}$$

$Co_{(EFF)}$ = Total effective capacitance value
P_{IN} = Total system input power requirements
Vo = DC output rectified unregulated voltage
$Vp\text{-}p$ = Ripple voltage
V_{DO} = Dropout voltage of the PH module
T_H = Output holdup time

Note 1 : V_{DO} = 180Vdc.

Note 2 : Electrolytic capacitors of low ESR type are recommended as input capacitors.

Example

Determine the required capacitance for the following parameters:

- Total system input power = 500W
- Holdup requirement = 1 line cycle @ 60Hz
- Minimum Input Voltage (90Vac)
- Vp-p Output Ripple Voltage = 25V

Calculate the effective capacitance:

$Vo = [90 \times \sqrt{2} \times 2] - 5$

$Vo = 249$

$$C_{O(EFF)} = \frac{2 \times 500 \times 16.6mS}{[(249 - 25)^2 - (180)^2]}$$

$C_{O(EFF)} = 933\mu F$

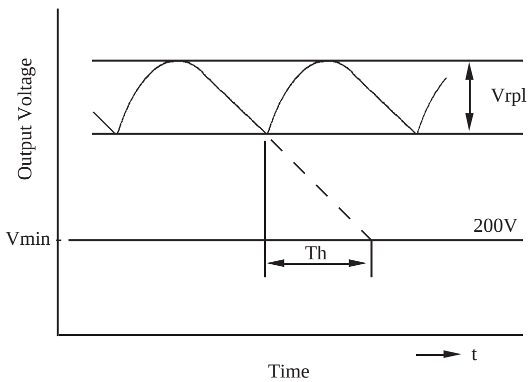


Figure 4-2 Ripple Voltage vs. Holdup Time

4.3 Minimum Capacitance Value for Unspecified Holdup

The minimum capacitance value is determined by the input power, the allowable ripple voltage of the PH module (25Vp-p), the minimum input voltage and the minimum input frequency (47Hz).

Figure 4-3 shows the minimum capacitor values for the criteria mentioned above.

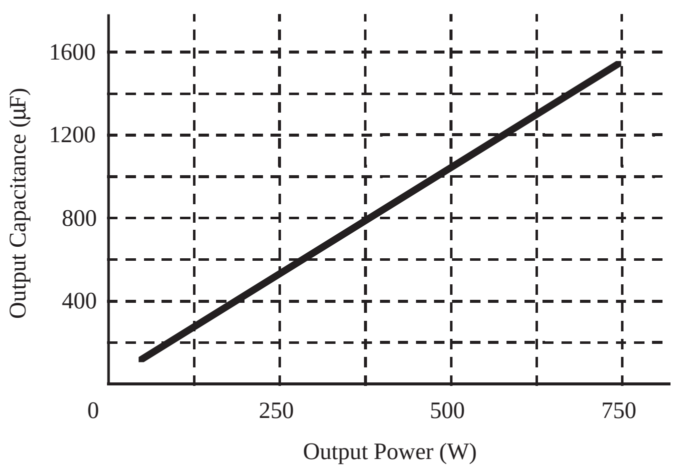


Figure 4-3 Minimum Capacitor Values vs. Output Power

Note : The maximum effective capacitance value must be less than or equal to 2450µF.

4.4 Electrolytic Capacitors Selection, Ripple Current

The ripple current that the capacitors are exposed to is comprised of both low frequency (line frequency 60Hz) and high switching frequency (250KHz typical) components. Typical ripple current can be estimated by assuming a power factor of 0.5 - 0.6.

<u>Example</u>

if Iin = 2A

$I_{CAP(RIP)} = 2 \times .6 = 1.2$Ap-p/per bank

Actual ripple current should be measured to confirm the selection of the capacitors.

4.5 Expected Lifetime Calculation of Selected Capacitors

Most capacitor vendors provide two methods for calculating the expected lifetime of input capacitors. The first uses ambient temperature, operating RMS current and ambient temperature multipliers to project life at a given temperature and RMS current. This method is only effective for free air, or non-fan cooling. The other method involves measuring the can temperature. The manufacturer specifies a table of expected hot spot temperature rise and measured can temperature rise versus can diameter. For a 50mm can diameter, this ratio is 2. The following is a modified life expectancy equation:

<u>Equation 4-2</u>

$Lx = Lo \times [\, 2^{((To - Ta / 10)}] \times [\, 4^{((\Delta To - \Delta Tx) / 10)}]$

To = The speced operating temperature for life expectancy Lo.

Ta = Operating Ambient Temperature

ΔTo = Normal expected hot spot to ambient temperature rise with rated RMS current

ΔTx = Extrapolated hot spot temperature rise based on measured ΔT_{CASE}.

Lo = Capacitor Load Life

<u>Example - Life Expectancy Calculation</u>

- Measured temperature rise on capacitors is 12°C.
- Speced operating temperature is 105°C.

- $T_a = 40°C$.
- $\Delta T_o = 5°C$.
- L_o = 2000 Hours

$L_x = 2000 \times 2^{\{(105 - 40) / 10\}} \times 4^{\{(5 - 12) / 10\}}$
L_x = 68,593 Hours or 7.9 Years.

5.0 Inrush Current

Inrush current is defined as the initial peak input current drawn by the input capacitors during turn-on. This current can be very large depending on the source impedance, and can cause such problems as external fuse brown-out, melting of the contacts of a relay or tripping of a circuit breaker.

The inrush current at turn-on can be limited by connecting an external resistor between the R1 and R2 terminals on the PR module. This allows flexibility for the user to reduce the inrush current to meet his or her design conditions.

Note : The PR module can not operate without an external inrush limiting resistor.

5.1 Selection of an External Inrush Limiting Resistor

A. Determination of Resistor Value

Equation 5-1

$$R = \frac{Vinpk}{I_{(INRUSH)}}\ \Omega$$

R = External Resistor Value (Ω)
Vin = AC RMS Input Voltage (Vac)
$Vin_{PK} = Vin \times \sqrt{2}$
$I_{(INRUSH)}$ = Inrush Current (Apk)

By adding an inrush resistor, a time constant is developed between the product of the total effective capacitance at the output of the PR module and the inrush resistor value. This time constant must be equal to or greater than 1600mS.

Equation 5-2

$$Co_{(EFF)} \times R \geq 1600\mu S$$

$Co_{(EFF)}$ = Effective Output Capacitance
R = External Resistor

5.2 I^2t Rating of Inrush Limiting Resistor

When selecting an inrush limiting resistor value, its I^2t rating must be limited to less than the manufacturer's rating. The I^2t value can be computed as follows:

Equation 5-3

$$I^2t = \frac{Co_{(EFF)} \times (Vin_{PK})^2}{2R}$$

I^2t = Product of the current squared and time
$Co_{(EFF)}$ = Total Effective Input Capacitance
$Vin_{PK} = Vin \times \sqrt{2}$
R = External Inrush Limiting Resistor

It is recommended to use a thermally fused inrush limiting resistor or a thermistor with a thermal fuse in series for safety protection.

6.0 Selection of an External Input Fuse

A. Voltage Rating of the External Fuse

Rating	Input Voltage
125Vac	100Vac Input
250Vac	200Vac Input

B. Current Rating of the External Fuse

Equation 6-1

$$Iin_{(MAX)} = \frac{Pout}{Vin_{(MIN)} \times \eta \times PF}$$

$Iin_{(MAX)}$ = Maximum Input Current
Pout = Maximum output power of PR module
η = Efficiency (95% typ.)
PF = Power Factor $\frac{\text{apparent power}}{\text{real power}}$
$Vin_{(MIN)}$ = Minimum AC Input Voltage

The power factor varies with the following factors:

1. Line Impedance
2. Effective Input Capacitance
3. Output Power

Typical power factor is normally between 0.5-0.6 for the PH modules. Ideally, the power factor and Iin should be measured to confirm theoretical results and ensure proper system design.

During a condition where the AC line is recycled, such as brownout, the average DC voltage may appear above 160Vdc upon recycling. Under this operating condition (160Vdc or above at turn-on), the inrush limiting circuit internal to the PR module is disabled. Inrush current during this condition is limited only by the input line impedance, which tends to be quite low in value (approximately 0.5Ω), producing a very high peak inrush current.

The product of the current squared and time for this case is given as follows:

Equation 6-2

$$I^2t = \frac{Co_{(EFF)}\,(Vin_{PK} - 160)^2}{2\,Rin}$$

I^2t = Product of Square Current and Time
$Co_{(EFF)}$ = Total Effective Input Current
Vin_{PK} = Peak AC Input Voltage
$Vin_{PK} = Vin \times \sqrt{2}$
Rin = Input Line Impedance (approximately 0.5Ω)

The I^2t of the external input fuse can also be calculated by using Equation 6-2. Note : The I^2t value of the manufacturer's rating must be greater than the calculated value. The fuse must also be able to support the AC RMS input current as well as the AC RMS voltage.

7.0 Alarm Signal

The PR module is equipped with an AC Fail Signal (ACF) of open collector type. This signal can sink up to a maximum current of 5mA, and can support a maximum applied voltage of 35V. Under normal operation the status of the ACF signal is low. When a fault condition occurs the output of the ACF signal is in the high condition. Under a fault condition (such as input shutdown), the AC Fail signal is output for a minimum of 10mS (see the Sequency Time Chart on Page 1). Note the return for the ACF signal is at the SG terminal.

8.0 PR/PH Integration

8.1 Power ON Signal (ENA Terminal)

The PR series is furnished with a power ON monitoring signal (ENA terminal) that is supplied as an open collector type. This signal monitors the output voltage of the PR module and indicates when it is at a high enough voltage to support proper operation. When the output voltage is at its proper level (greater than 350Vdc), the power ON signal is in its low state (maximum sink current : 5mA, maximum applied voltage : 35V). Refer to the Timing Sequence chart on Page 1.

The power ON signal functions to ensure that the load of the PR module (ie: PH module) remains in the off state until the module reaches its appropriate output voltage. At initial turn on of a power supply, there exists a high peak inrush current that charges up the input capacitors. If a load is drawn from the bulk storage capacitors before the PR module reaches its normal operating voltage, the DC bus voltage can drop, causing a possible undervoltage lockout condition. This can prohibit the PH module from operating properly. To prevent this from happening, the following circuitry shown in Figure 8-1 should be added when combining PR and PH modules.

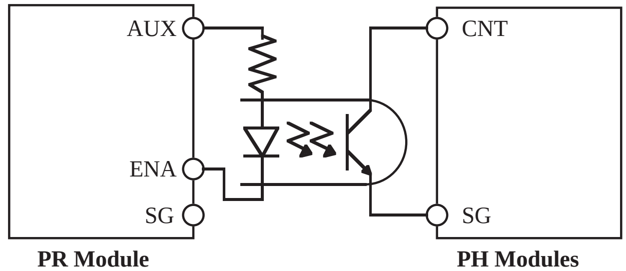


Figure 8-1 Recommended Circuitry for PR/PH Integration

This optically isolated circuit uses the auxiliary bias supply of the PR module to "hold off" the PR module until sufficient voltage at the output of the PR module is reached.

Note 1 : This circuit can also be controlled via an external 0 - 5V TTL signal in place of the auxiliary supply.

Note 2 : The return of the ENA pin is the SG terminal.

8.2 PR/PH Parallel Operation

When paralleling power modules, the following diagram is recommended for system configuration.

Note : To prevent unwanted noise pickup at the remote ON/OFF pin, it is recommended to use an optocoupler that does not bring the base of the transistor out to a pin on the device. Noise pickup at the remote ON/OFF point (CNT could cause the output of the module to oscillate.

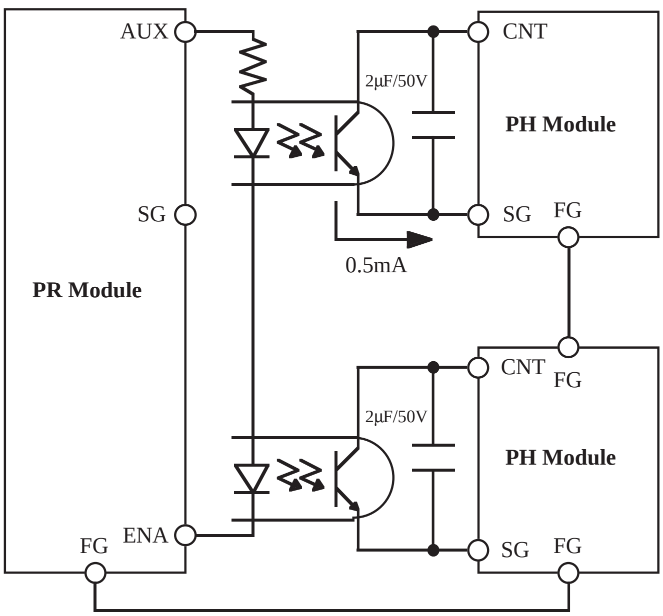


Figure 8-2 Recommended Circuitry for Parallel Operation of PR/PH Integration

8.3 PR/PH System Connections

When using long connections (high inductance) between the PH module and the PR module, it is recommended to place a capacitor at the input terminals of the PH module as explained in the application note for the PH 280 Volt Series of power modules (Application Note *ANPH280*).

Consideration of this capacitor in accordance with the output capacitor values for the PR module must be noted.

9.0 Auxiliary Power Supply

The PR module has an auxiliary power supply (16 - 20Vdc at 10mA max.) for external signal monitoring and for support of system circuitry. A .1µF film capacitor is recommended between the AUX and SG terminals for reduction of high frequency noise pickup.

10.0 Operating Temperature

The baseplate temperature must be limited to less than 85°C. For details on the thermal design, please refer to the Application Note ANPH-2, "Thermal Design".

11.0 Operating Humidity

Avoid the buildup of condensation on or in the rectifier module.

12.0 Storage Temperature (-40°C - +85°C)

Sudden temperature changes can cause condensation buildup and possible rectifier module failure.

13.0 Storage Humidity (10% - 95%)

High temperature and humidity can cause the terminals on the module to oxidize.

14.0 Cooling Method

The operating temperature is specified by the baseplate temperature (limited to 85°C). Various heatsink designs are possible. For detailed heatsink design, refer to the Application Note ANPH-2, "Thermal Design".

15.0 Withstand Voltage

The rectifier module is designed to handle 3KVac between the input/output and the baseplate for 1 minute. The unit is tested at a leakage current limited to 20mA. The applied voltage must be increased gradually from zero to the testing value, and then decreased gradually at shut down.

16.0 Isolation Resistance

The isolation resistance is more than 100mΩ at 500Vdc when tested with a DC isolation tester between the input/output and the baseplate. Note when testing that some isolation testers can produce a high pulse when the applied voltage is varied. Ensure that the tester is fully discharged after the test.

17.0 Vibration

10 - 55Hz amplitude, 1 minute sweep, 5G maximum, 1 hour along X, Y, Z axis. For more information, refer to the Application Note ANPH-10, "Installation".

18.0 Shock

Less than 20G.

Table of Contents

Application Note

PR500-280 Rectifier Module

Lambda Error-free Action Process

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