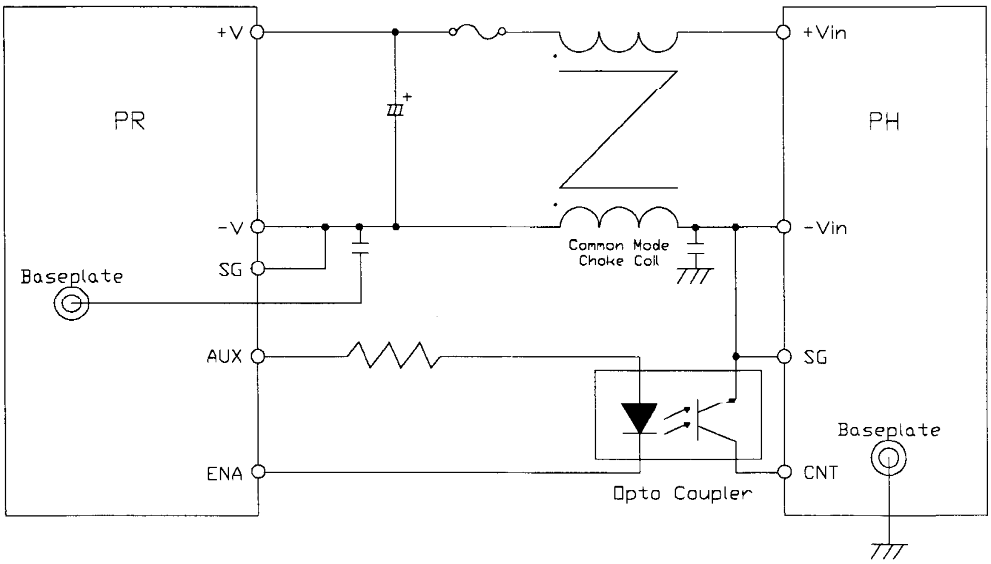
PR Series Application Notes

- **PH Series Connection**

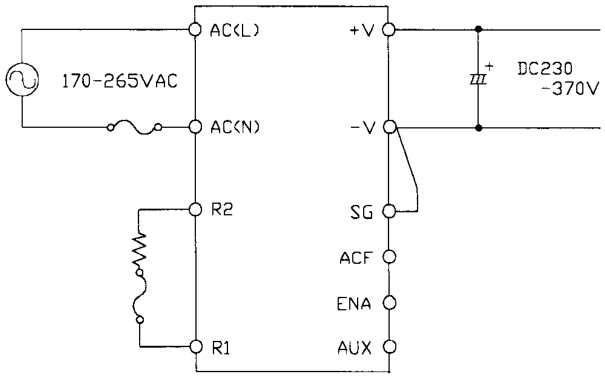


*Add the circuit so that CNT turns on when IOG and ENA signals are both LOW.

1. **External Components**

- Place a common mode choke coil across the input section of the PH series (for each module).
  Common Mode Choke Coil Inductance Value: 2mH
- Place a 4700pF capacitor on the input side of the PH series between the −V terminal and baseplate (FG).
  (attach to each module)
- Place a 4700pF capacitor on the output side of the PR series between the −V terminal and baseplate (FG).
  (attach to each module)
- Please use (for each PH module) a opto coupler for the ON/OFF control circuit between the PR series and the PH series. Further, please use a opto coupler with the transistor output having no base terminal. Also place the transistor as close to the PH series CNT and SG (or −V) terminals as possible.
- Short the SG terminal to the −Vin on the PH series and to the −Vout on the PR series. Do not connect them directly together.
- Attach the PH series input fuse to the +V side, do not place it on the −V side.

■ Basic Connection



2. Input Voltage Range

The PR module accepts a world wide 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 the Voltage Doubler Figure. The PR module should be configured as a full wave bridge rectifier for 220VAC operation as in the Basic Connection Figure.

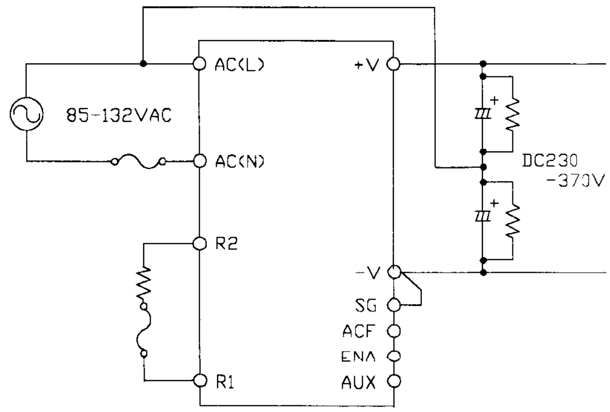
3. Input Current

The input current is specified as the effective value supplied to the power module. This is expressed in the specifications as the input current at standard input and output.

4. Standard Output Voltage

The output voltage range for the PR module

■ Voltage Doubler



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 110VAC mode, the PR module should be configured as a voltage doubler (Voltage Double Figure). The average output voltage is calculated as follows.

Equation 1: 110VAC Operation - Voltage Doubler Operation

$$V_o = (\sqrt{2} \times V_{in}) \times 2 - V_f \text{ (VDC)}$$

Vo = Output Voltage (DC)
Vin = Input Voltage (AC)
Vf = Internal Voltage Drop
Vf approx. 5V

Example: For 110VAC

$V_o = (\sqrt{2} \times 110) - 5$

$V_{oavg} = 306\text{VDC}$

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 220VAC mode, the PR module is configured as a full bridge rectifier (Basic Connection). The average output voltage is calculated as follows.

Equation 2: **220VAC Operation- Full Bridge Rectification**

$$Voavg = \sqrt{2} \times Vin - Vf \quad (VDC)$$

Example: For 220VAC

$$Vo = \sqrt{2} \times 220 - 5$$
$$Vo = 306VDC$$

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 (line impedance), the distorted value must be subtracted from the calculated values shown in the examples for a true DC rectified voltage.

● **Selection of External Output Capacitor**

The external output capacitor value is determined by the following factors:

- Peak to Peak Output Ripple Voltage
- Required Holdup Time
- Expected Lifetime of the Capacitor
- Peak to Peak Ripple Current

The maximum allowable output ripple of the PR module is 40V. If a voltage above this is used, malfunction or breakdown could occur in the PR module.

$$Vrpl(max) \leqq 40V$$

Further, the maximum external output capacitance nominal value is 2450μF. This is the total capacitance attached between the output terminals. Even when using the voltage doubler rectification, the value is the same. A value above this can cause the module to malfunction or even breakdown.

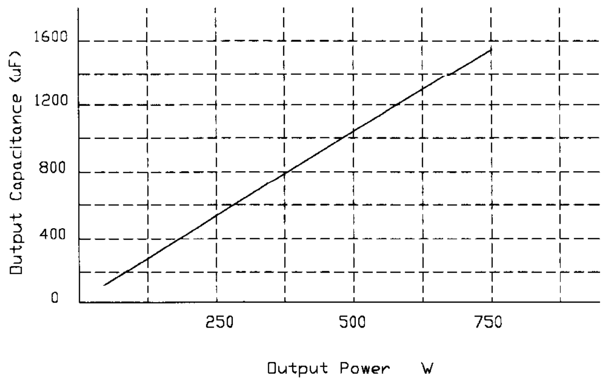
$$C(max) \leqq 2450\mu F \text{ (Nominal Value)}$$

Here, an example of the selection of the external output capacitor is given with the 280VDC input type PH series.

A. **Minimum Required Capacitance**

The minimum capacitance value is determined by the input power, the allowable ripple voltage of the PH module (20Vpk-pk), the minimum input voltage 170VAC and the minimum input frequency (47Hz).

Below shows the minimum capacitor values for the criteria mentioned above. In particular, when there is no specification for the PH module holdup time, the capacitance can be determined by the graph below.



Example

The minimum capacitance required for an output power of 750W is 1150μF.

B. Capacitance Required to Fulfill the PH Module Holdup Time

○ 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

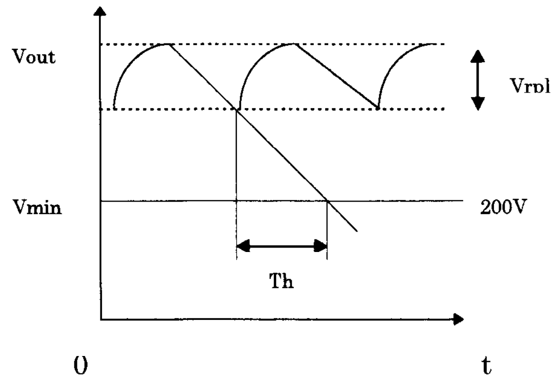
Note: This applies to the DC-DC converter (PH Series) that is connected to the input module.

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.

<u>Equation 3</u>

$$Co \geqq \frac{2 \times Po}{(Vo - Vpk\text{-}pk/2)^2 - (Vmin)^2} \times Th \quad (F)$$

Co = Output Capacitance
Po = Max Output Power
Th = Required holdup time of AC/DC power supply
Vo = PR output voltage (Equation 1)
Vpk-pk = Output ripple voltage (less than 20Vpk-pk)
Vmin = Minimum Input Voltage of PH Module (200VDC)



Determine the capacitance from the results of A and B above. The larger value should be used to obtain the desired holdup and peak to peak ripple voltage requirements.

Note:

1. Electrolytic capacitors of low ESR type should be used.

C. Electorlytic Capacitor 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 typ.) components. Due to this, the calculation for the ripple current becomes complicated. As a standard the input current can be used. Assume a power factor of 0.5~0.6

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

5. **PH/PR Integration**

When using long connections (high inductance) between the PH module and the PR module or in the case of multiple module use, please take note of the PR module output capacitance. Please refer to the PH Application Notes.

That is, determine the PR output capacitance by including the input capacitance required for the PH module.

6. **Maximum Output Current**

The maximum output current that the module can continuously supply to the load. However, this value will differ depending on the input voltage (100VAC/200VAC).

7. **Maximum Output Power**

The maximum output power that the module can continuously supply to the load. However, this value will differ depending on the input voltage (100VAC/200VAC).

8. **Efficiency**

Efficiency is expressed as the ratio of the output power to the effective input power. The efficiency in the specifications is the value when there is standard input and output. Efficiency will vary depending on the input voltage and output power. Please take note when creating the thermal design.

9. **Input Frequency**

This is the PR series input frequency range.

10. **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 cannot operate without an external inrush limiting resistor.

● **Selection of an External Inrush Limiting Resistor**

A. **Resistor Value Determination**

<u>**Equation 5**</u>

$$R = \frac{Vinpk}{I(inrush)} \quad (\Omega)$$

R = External Resistor Value (Ω)

Vin = AC RMS Input Voltage (VAC)
$Vinpk = Vin \times \sqrt{2}$
I(inrush) = Inrush Current (Apk)

Further, please establish the external resistor and output capacitor time constant to above 1600µS.

CoR ≧ 1600 µS.

Co = Output Smoothing Capacitance
R = External Resistor

B. 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 manufacturers rating. The I^2t value can be computed as follows:

Equation 6

$$I^2t = \frac{Co \times (Vinpk)^2}{2 \times R} \ (A^2s)$$

I^2t = Product of the current squared and time
Co = Output Smoothing Capacitor
$Vinpk = Vin \times \sqrt{2}$
R = External Inrush Limiting Resistor

From the above calculations the external resistor should be selected. It is recommended to use a thermally fused inrush limiting resistor or a resistor with a thermal fuse in series for safety protection.

● 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

The standard current rating of the fuse is determined by the maximum input current.

Equation 7

$$Iin(max) = \frac{Pout}{Vin(min) \times \eta \times PF} \ (Arms)$$

Iin(max) = Maximum Input Current
Pout = Maximum output power of PR module
η = Efficiency
PF = Power Factor $\frac{\text{apparent power}}{\text{real power}}$

Vin = AC Input Voltage

Although power factor changes with line impedance, output capacitance, and output power, in general the power factor can be assumed to be 0.5~0.6. Please confirm this value with the actual equiptment being used.

C. Calculating the Required Surge Energy

Concerning the inrush withstand current, brownout (reinput) must be considered. If the output is above 160V, when the input shuts down, the inrush current protection will not function. Under these conditions, the inrush limitor is only the line impedance. The surge energy that the input fuse will be exposed to at this time can be calculated using the following equation.

Equation 8

$$I^2t = \frac{Co \times (Vin - 160)^2}{2 \times r} \quad (A^2s)$$

I^2t = Product of the current squared and time

Co = Output Smoothing Capacitance

Vinpk = Vin × $\sqrt{2}$

I(inrush) = Inrush Current (Apk)

r = Line Impendace

Under actual usage conditions the line impedance will change. However, in the case calculating please make the line impedance 0.5 Ω.

The I^2t value of the manufacturers rating must be greater than the calculated value from Equation 8 The fuse must also be able to support the AC RMS input current as well as the AC RMS input voltage.

The input fuse can be selected from the above results.

11. Alarm Signal

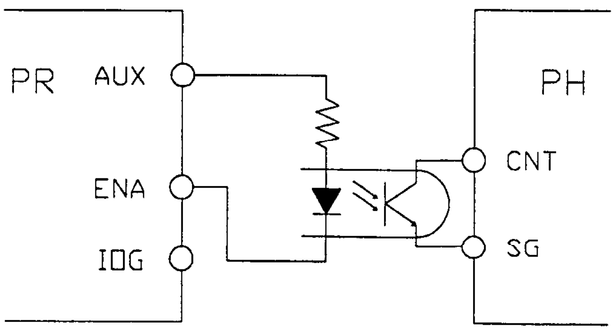
The PR module is equipped with an AC Fail Signal (ACF) of open collector type. This signal can sink up to a maximum current of 5mA, and can support a maximum applied voltage of 35V. Under normal operation the status of the ACF signal is low. When a fault condition occurs the output of the ACF signal is in the high condition. Under a fault condition (such as input shutdown) of over 10mS, the AC Fail signal is outputted (refer to Sequence Time Chart).

Note: The return for the ACF signal is at the SG terminal.

12. 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, the power ON signal is in its low state (maximum sink current: 5mA, maximum applied voltage: 35V). Please refer to the sequence time chart.

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 below should be added when combining PR and PH modules.



The optically isolated circuit shown above 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: This circuit can also be controlled via an external 0 - 5V TTL signal in place of the auxiliary supply.

The return of the ENA pin is the SG terminal.

13. Auxiliary Power Supply for External Signal (AUX Terminal)

The PR module is equipped with an auxiliary power supply (AUX terminal) to provide power for external system or "housekeeping" circuitry. The output voltage range is from 16~20VDC at an output current of 10mA. The return for the AUX signal is the signal ground terminal (SG). A 0.1μF film capacitor is recommended between the AUX and SG terminals for reduction of high frequency noise pickup when in use. In the case of attaching an output capacitor, please make sure that the capacitance is below 220μF.

Please do not connect to another PR module in parallel.

14. Operating Temperature

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

15. Operating Humidity

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

16. Storage Temperature

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

17. Storage Humidity

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

18. Cooling Method

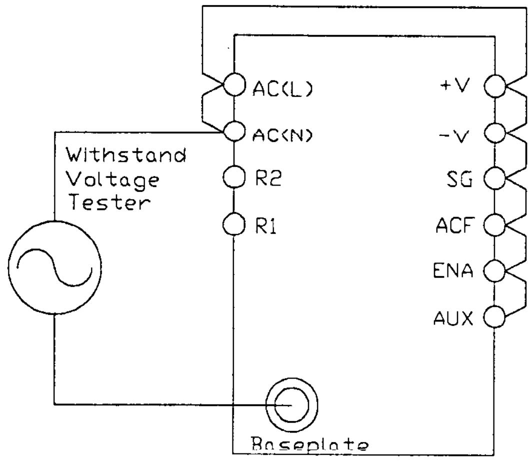
The operating temperature is specified by the baseplate temperature (limited to 85℃). Various heatsink designs are possible. For detailed heatsink design, refer to the Application Note "Thermal Design".

19. Withstand Voltage

The power module is designed to withstand 3.0kVAC between the input and the baseplate, and between the input and output for 1 minute.

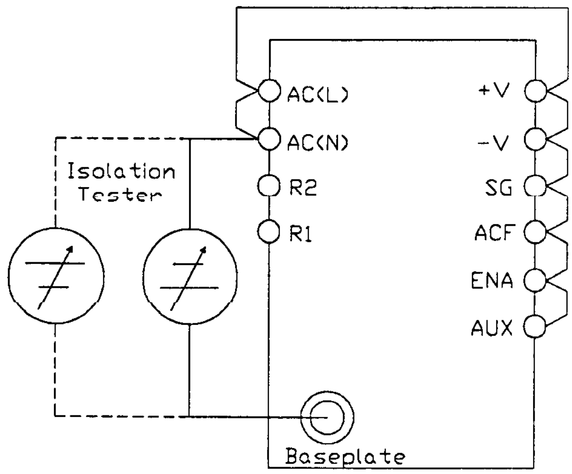
In the case that the withstand voltage is tested in the incoming goods test, etc., please set the limit of the withstand voltage test equipment to 20mA. The applied voltage must be increased gradually from zero to the testing value, and then decreased gradually at shut down. Especially stay away from use of a timer, where a pulse of several times the applied voltage can be generated. This could cause damage to the module. Be sure to short the output side as shown below.

Further, the Withstand Voltage Test is basically a breakdown test. Please limit the number of tests to as few as possible.



20. Isolation Resistance

The isolation resistance is more than 100M Ω at 500VDC when tested with a DC isolation tester between output and baseplate and input and baseplate. Note when testing, some isolation testers can produce a high pulse when the applied voltage is changed over. Ensure to discharge the module with a resistor after the test.



21. Vibration

Please refer to the "Installation" application note.

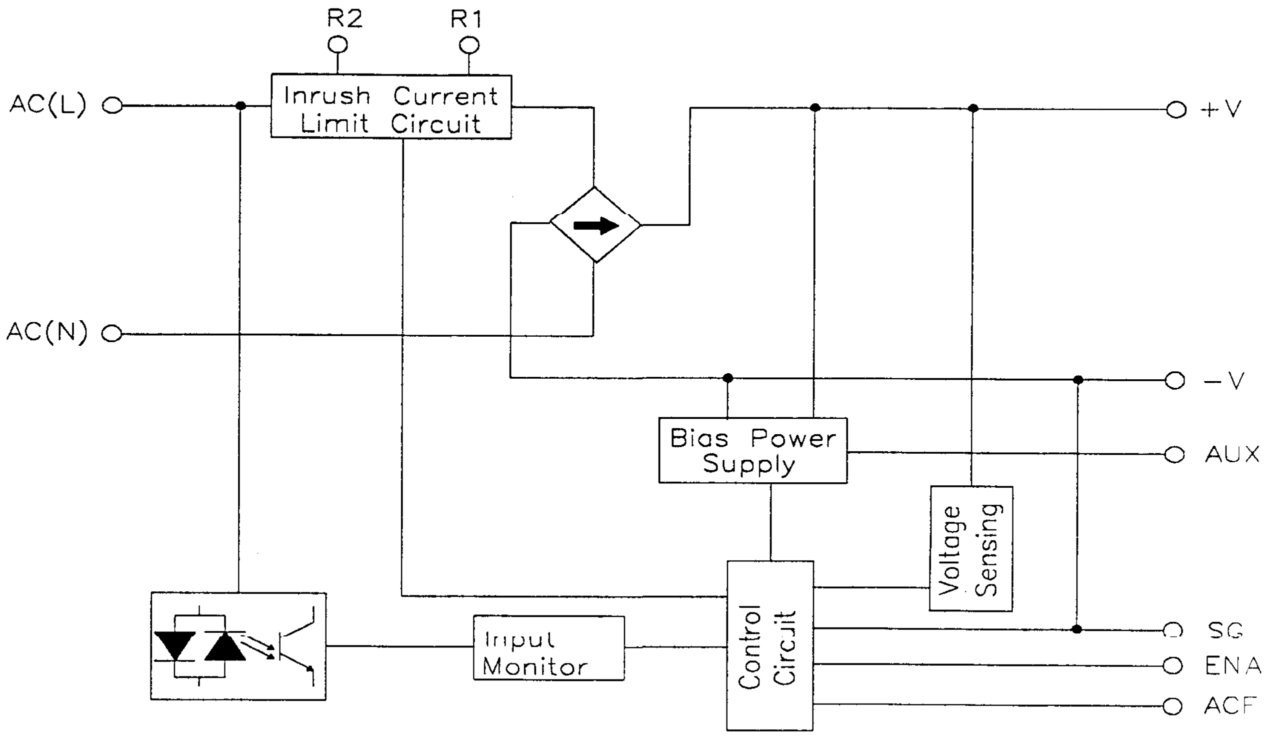
22. Shock

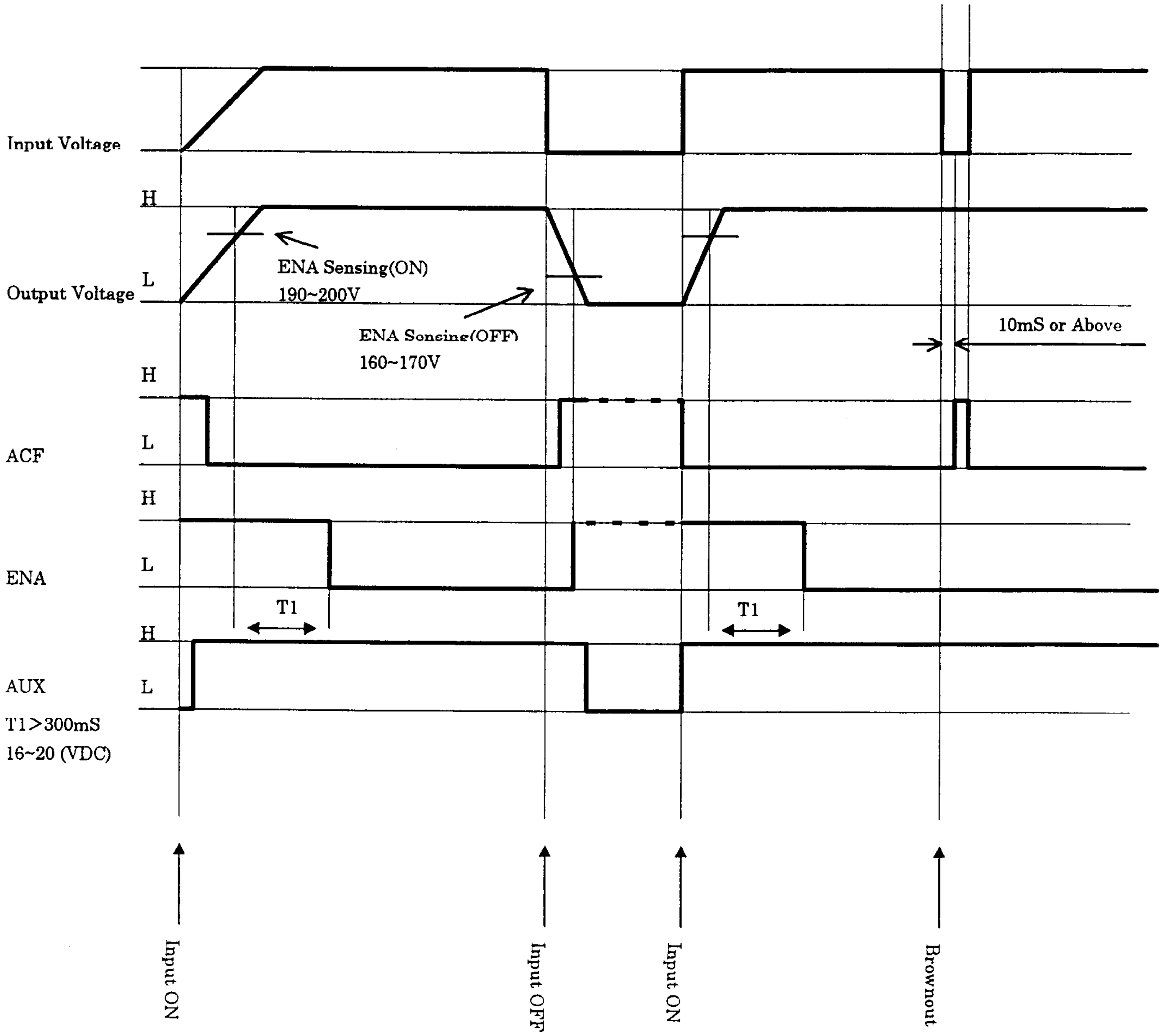
Value for the conditions of our shipping and packaging.

23. CE Marking

CE Marking, when applied to a product covered by this handbook, indicates compliance with the low voltage directive (73/23/EEC) as modified by the CE Marking Directive (93/68/EEC) in that it complies with EN60950.

24. Block Diagram - Sequence Chart




Input Voltage
H
L
Output Voltage
ENA Sensing(ON)
190~200V
ENA Sensing(OFF)
160~170V
10mS or Above
H
L
ACF
H
L
ENA
T1
T1
H
L
AUX
T1>300mS
16~20 (VDC)
Input ON
Input OFF
Input ON
Brownout