TECHNICAL REFERENCE NOTE

ARTESYN
AIT02ZPFC SERIES

720 Watts Power Factor Correction

PRODUCT DESCRIPTION

Advanced Energy's AIT02ZPFC Power Factor Correction module is part of Artesyn family of advanced High Density modular power supply components. Featuring high reliability and convenient control and monitoring functions, these modules are designed to reduce product development time and enhance system performance. The PFC is designed to work over all typical line voltages used worldwide, and provide unity power factor with very low levels of harmonic distortion in line current. The AIT02ZPFC is TRCA-DO-160D harmonic compliant at 115Vac input and also IEC1000-3-2 compliance at 50Hz and 800Hz input.

AT A GLANCE

Total Power

720 Watts

Input Voltage

85 to 264 Vac

# of Outputs

Single

RoHS

SPECIAL FEATURES

- Unity power factor
- High efficiency up to 93%
- Universal input voltage and frequency range
- Up to 720W output power
- Conforming to IEC 1000-3-2 compliance at 50Hz
- TRCA-DO-160D harmonic compliant at 115Vac input, full load @ 400Hz and 800Hz
- 100 ^{O}C baseplate operating temperature
- Internal active switch bypassing external inrush current components
- High Reliability - over 1 million hours MTBF @ baseplate temperature 50^{O}C

SAFETY

- UL/cUL 60950 Recognized
- TUV EN60950 Licensed

TYPICAL APPLICATIONS

- Industrial

MODEL NUMBERS

Standard	Input Voltage	Output Voltage	Output Power	Efficiency*
AIT02ZPFC-01NL	85-180Vac	393Vdc	320W	93%
	180-264Vac	393Vdc	720W	

Note*: Efficiency measured @230Vac input, 720W output power

Order Information

AIT	02	ZPFC	-	01	N	L
①	②	③		④	⑤	⑥

①	Model series	AIT series.
②	Output current	02: 1.84A rated output current
③	Output voltage	ZPFC: Power factor correction module
④	Model variant	01: The 01 variant
⑤	Remote on/off logic	N: Negative enable
⑥	RoHS status	L: RoHS R6

Options

None

ELECTRICAL SPECIFICATIONS

Absolute Maximum Ratings

Stress in excess of those listed in the “Absolute Maximum Ratings” may cause permanent damage to the power supply. These are stress ratings only and functional operation of the unit is not implied at these or any other conditions above those given in the operational sections of this TRN. Exposure to any absolute maximum rated condition for extended periods may adversely affect the power supply’s reliability.

Table 1. Absolute Maximum Ratings

Parameter	Model	Symbol	Min	Typ	Max	Unit
Input Voltage Operating - Continuous	AIT02ZPFC-01NL	$V_{IN,AC}$	85	-	264	Vac
Input Frequency Operating -Continuous	AIT02ZPFC-01NL		50	-	800	Hz
Maximum Output Power	AIT02ZPFC-01NL	$P_{O,max}$	-	-	720	W
Isolation Voltage Input to Baseplate Output to Baseplate	AIT02ZPFC-01NL		- -	- -	2700 2700	Vdc Vdc
Insulation Resistance 500Vdc	AIT02ZPFC-01NL		100	-	-	MΩ
Operating Temperature (Baseplate)	AIT02ZPFC-01NL	T_A	-20	-	100[1]	^{O}C
Start Up Temperature	AIT02ZPFC-01NL	T_S	-40	-	100	^{O}C
Storage Temperature	AIT02ZPFC-01NL	T_{STG}	-40	-	110	^{O}C
Humidity (non-condensing) Operating Non-operating	AIT02ZPFC-01NL		15 0	- -	90 95	% %

Note 1 - PFC module have a thermal sensor to monitor its internal temperature and will shut down when temperature is detected to be above 105 ^{O}C. PFC module will resume normal operation when the temperature is detected to have fallen back to below 95 ^{O}C.

ELECTRICAL SPECIFICATIONS

Input Specifications

Table 2. Input Specifications

Parameter	Condition	Symbol	Min	Typ	Max	Unit
Input Voltage Operating – Continuous	All	$V_{IN,DC}$	85	115	264	Vdc
Operating Input Frequency	All	f_{IN}	47	-	800	Hz
Maximum Input Current ($I_O = I_{O,max}$)	$V_{IN,AC}$ = 115Vac $V_{IN,AC}$ = 230Vac	$I_{IN,max}$	- -	2.98 3.32	3.42 3.52	A_{RMS}
No Load Input Current (V_O On, I_O = 0A)	$V_{IN,AC}$ = 115Vac	I_{IN,no_load}	-	-	0.1	A_{RMS}
Harmonic Line Currents	All	THD	RTAC-DO 160			
Power Factor@ Different AC Frequency (Io=0.19A)	$V_{IN,AC}$ = 115Vac f_{IN} = 50Hz	PF	0.99	-	-	
	$V_{IN,AC}$ = 115Vac f_{IN} = 360Hz	PF	0.98	-	-	
	$V_{IN,AC}$ = 115Vac f_{IN} = 800Hz	PF	0.97	-	-	
Startup Surge Current (Inrush) @ 25°C	$V_{IN,AC}$ = 264Vac $V_{IN,AC}$ = 115Vac	$I_{IN,surge}$	- -	- -	40 25	A_{PK} A_{PK}
Input AC Low Line Start-up Voltage	$I_O = I_{O,max}$	$V_{IN,AC}$	79	82.5	85	Vac
Input AC Under Voltage Lockout	$I_O = I_{O,max}$	$V_{IN,AC}$	74	77.5	80	Vac
Operating Efficiency @ 25°C	$I_O = I_{O,max}$ $V_{IN,AC}$ = 230Vac	η	-	93	-	%
Leakage Current	f = 800Hz		-	3	-	mA

ELECTRICAL SPECIFICATIONS

Output Specifications

Table 3. Output Specifications

Parameter	Condition	Symbol	Min	Typ	Max	Unit
Output Voltage VADJ pin short to S_GND VADJ pin open	V_{IN} = 230Vac V_{IN} = 115Vac	V_O	389 300	393 303	397 306	Vdc Vdc
Maximum Output Power	V_{IN} = 115Vac V_{IN} = 230Vac	$P_{O,max}$	- -	- -	320 720	W W
Output Adjust Range @ V_ADJ pin open @ V_ADJ pin shorted to GND	V_{IN} = 115Vac; I_O = 0.5A V_{IN} = 230Vac; I_O = 1A	V_O	300 389	303 393	306 397	Vdc Vdc
V_O Load Capacitance	Start up	-	-	440	-	uF
Output Regulation	V_{IN} > 180Vac I_O = 1.832A I_O = 0.814A I_O = 0.1A	V_O	389 393 389	393 393 393	397 397 400	Vdc Vdc Vdc
Output Current, continous	All	I_O	0	-	1.84	A
Output Rise	V_{IN} = 115Vac V_{IN} = 230Vac	Trise	50 50	300 150	400 300	mSec mSec
Over Temperature Protection	All	Auto Recovery				

ELECTRICAL SPECIFICATIONS

Protection Function Specifications

Input Fuse

AIT02ZPFC-01NL module do not have an in-line fuse fitted internally. In order to comply with CSA, VDE and UL safety regulations, it is recommended that a fuse of 250Vac, 10A be fitted at the module's input.

Input Under Voltage Protection

An input under voltage protection circuit protects the module under low input voltage conditions. Hysteresis is built into the PFC Series module to allow for high levels of variation on the input supply voltage without causing the module to cycle on and off. PFC modules will operate when the input exceeds 82Vac and turn off below 77Vac (normal).

Over Voltage Protection (OVP)

The maximum over voltage point is 430V. The power supply latches off during output over voltage with the AC line recycled to reset the latch.

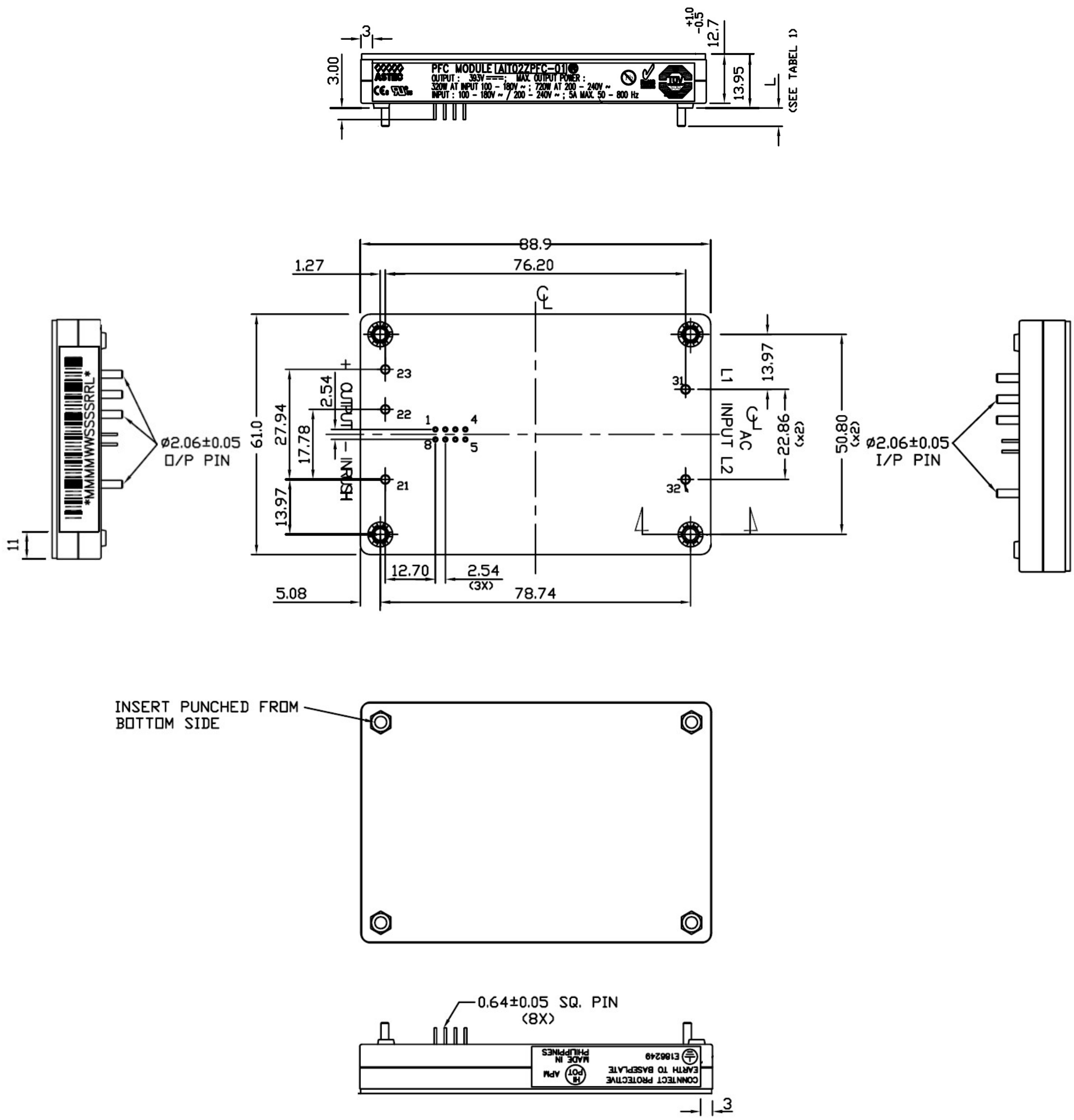
Parameter	Min	Nom	Max	Unit
V_O Output Overvoltage	400	-	430	Vdc

Over Temperature Protection (OTP)

The power supply have a thermal sensor to monitor its internal temperature. AIT02ZPFC will be internally disabled when the Base Plate temperature reaches 115^{O}C maximum, and will recover automatically when the temperature drops to below 99^{O}C.

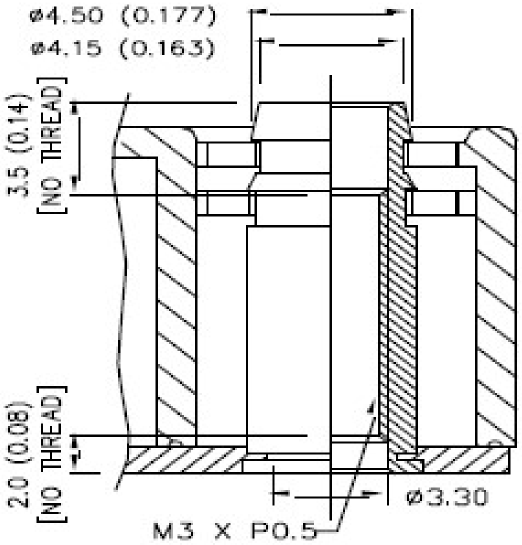
MECHANICAL SPECIFICATIONS

Mechanical Outlines (unit: mm)



MECHANICAL SPECIFICATIONS

Mechanical Outlines (unit: mm)



MECHANICAL SPECIFICATIONS

Pin Assignments

Pin Assignments		
Input (AC)	Output (DC)	Control Pin
31. L1	21. Inrush	1. NC
32. L2	22. NEGATIVE	2. NC
	23. POSITIVE	3. LE_ADJ
		4. TEMP_MON
		5. LD_ENABLE
		6. V_ADJ
		7. PF_ENABLE
		8. GND

MECHANICAL SPECIFICATIONS

Weight

The AIT02ZPFC-01NL weight is 155g approx.

ENVIRONMENATAL SPECIFICATIONS

Safety Certifications

The AIT02ZPFC-01NL power supply is intended for inclusion in other equipment and the installer must ensure that it is in compliance with all the requirements of the end application. This product is only for inclusion by professional installers within other equipment and must not be operated as a stand alone product.

Table 6. Safety Certifications for AIT02ZPFC-01NL Series Module

Document	Description
UL, cUL 60950	US and Canada Requirements
EN60950	Europe Requirements

POWER AND CONTROL SIGNAL DESCRIPTIONS

AC Input Pin

These pins provide the AC Mains to the AIT02ZPFC-01NL power supply.

Pin 31 - AC Input Line / Return
Pin 32 - AC Input Line / Return

DC Output Pin

The three connectors provide the main output for the AIT02ZPFC-01NL. The "+" and the "-" pins are the output positive and output negative rails. The Output (V_O) connectors are electrically isolated from the power supply chassis.

Pin 23 - (+) 393V Output (Vo)
Pin 22 - (-) 393V Output (Vo)
Pin 21 - INRUSH

A power inrush resistor or thermistor of 10 to 40 Ohm of 10 watt or above (depending on the output capacitance) should be connected from INRUSH pin to the output positive pin. An internal MOSFET bypasses this external thermistor/resistor during normal operation.

Control Signals

The AIT02ZPFC contains a 6 pins control signal header providing an analogue control interface, temperature monitor and PFC module status warning interface.

LE_ADJ - (pin 3)

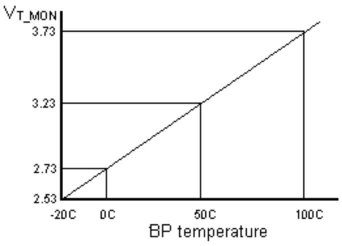
This pin is used to program the operation point of the LD_ENABLE pin signal. When LE_ADJ is shorted to GND, the LD_EN will turn off when V_O drops to 250V. When LE_ADJ is open, the LD_ENABLE will turn off when V_O drops to 180V. A resistor connected to ground the LD_ENABLE signal can be programmed to turn-off when the output voltage falls to a desired voltage between these two limits of 180V and 250V.

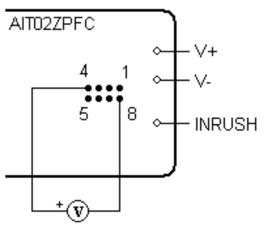
TEMP MON - (pin 4)

The TEMP MON pin provides an indication of the module's internal temperature. The voltage at the TEMP MON pin is proportional to the temperature of the module baseplate at 10mV per ^{O}C. Where:

Module temperature (^{O}C) = (V_TEMP_MON * 100) - 273

The temperature monitor signal can be used by thermal management systems (e.g. to control a variable speed fan). It can also be used for over temperature warning circuits and for thermal design verification of prototype power supplies and heatsink.

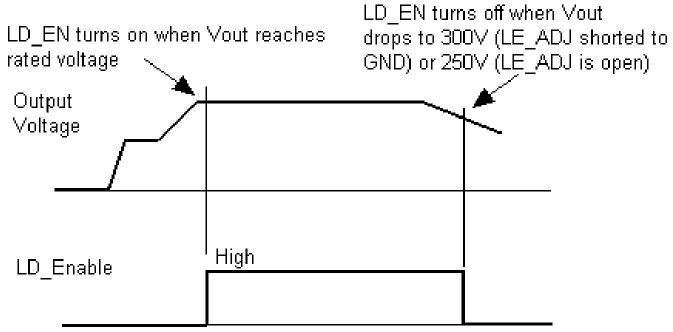




POWER AND CONTROL SIGNAL DESCRIPTIONS

LD_ENABLE - (pin 5)

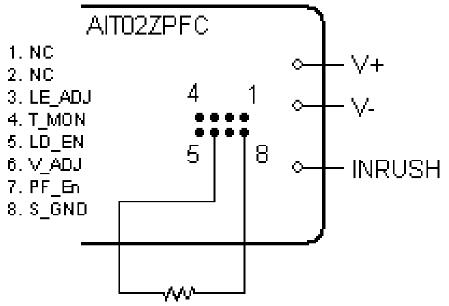
After the PFC power up sequence, the power to the load can be enabled. This can be performed manually or the PFC can automatically enable the load using the LD ENABLE signal.



Initially the load is disabled and the LD ENABLE (pin 5) is at 0.4V (LOW). When the PFC power up sequence has completed, the LD ENABLE voltage goes HIGH. And the LD ENABLE will stay high as long as Vin is above 175Vac or V_O is above 250V, even if PF_ENABLE is in disable mode.

V_ADJ - (pin 6)

The output voltage of the module may be accurately adjusted from 79% to 100% of the nominal output voltage. Adjustment can be made using a resistor connected as below.



Vout = Vr * (1 + Rh / (R2 + 1 / (1 / (R3 + R) + 1 / R1)))

Where (all units are in K ohm) – R is the resistor connected between the V_ADJ pin to S_GND

Vr = 3

Rh = 1356

R1 = 4.53

R2 = 9.058

R3 = 1.98

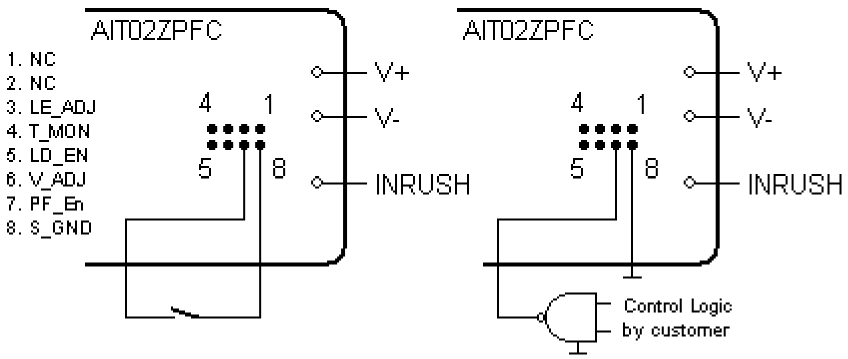
POWER AND CONTROL SIGNAL DESCRIPTIONS

V_O Required	Resistor to V_ADJ	Unit
305	160	K ohm
310	56	K ohm
315	30	K ohm
320	20	K ohm
325	15	K ohm
330	11	K ohm
332	9.1	K ohm
335	6.8	K ohm
340	5.6	K ohm
350	4.7	K ohm
355	3.6	K ohm
360	3	K ohm
365	2.2	K ohm
370	1.8	K ohm
375	1.2	K ohm
380	0.82	K ohm
385	0.47	K ohm
390	0.16	K ohm

PF_ENABLE - (pin 7)

The enable pin is a TTL compatible input used to turn the output of the module on or off.

The AIT02ZPFC-01NL is a negative logic module, the output is enabled when the PF ENABLE is connected to S GND or driven to a logic low < 0.8V (but not negative). The output is disabled when the PF ENABLE is open or driven to a logic high > 2.2V.



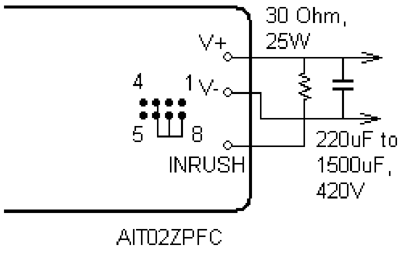
GND - (pin 8)

The GND pin is connected to the internal common ground of the module. It is also internally connected to the –O/P terminals. When connecting S GND to external circuitry care must be taken to ensure that the current flowing through this pin is kept below 25mA.

APPLICATION NOTES

Output Capacitor

The PFC requires an output hold-up capacitor of between 220uF and 1500uF to prevent the module from disabling due to fluctuations in output voltage. Ideally the capacitor should be connected directly to the PFC output pins. If this is not possible the connection must be less than 50mm from the pins.



Selecting an External Output Capacitor

The output capacitor value is determined by the following factors:

1. RMS ripple current.
2. Peak-to-peak output ripple voltage.
3. Hold-up time.
4. Expected lifetime of the capacitor.

RMS ripple current

The maximum permissible RMS ripple current for the output capacitor should be greater than the RMS ripple current for the application. The ripple current for the PFC module can be approximated as

$$I_{rms} = (P_O/Eff) \times 1/\sqrt{(V_O \times V_{rms})}$$

where :

P_O = output power (W)

Eff = efficiency

V_O = output voltage (V)

V_{rms} = input RMS voltage (V)

This gives the ripple current at 125KHz. The maximum ripple current for capacitors is usually specified at 120Hz. To convert from 125KHz to 120Hz the Irms figure should be divided by 1.3.

APPLICATION NOTES

Peak to Peak Output Ripple Voltage

The AC input causes a ripple on the output voltage. The size of the ripple is inversely proportional to the size of the capacitor. Therefore the maximum allowable ripple voltage should be decided in order to calculate the size of capacitor required. This may be calculated using the following equation:

$$C_O = P_O / (2\pi f \times Eff \times V_O \times V_{ripple})$$

Where:
C_O = output capacitance (µF)
Eff = efficiency
f = input voltage frequency (Hz)
V_O = output voltage (V)
V_{ripple} = output ripple voltage (V)

Hold-Up Time Requirement

The output capacitor value is different for different hold-up time requirements. The minimum capacitance corresponding to the required hold-up time of a system comprised of Artesyn DC/DC power modules and an PFC module can be calculated as follows:

$$C_{O\ min} = (2 \times P_O \times T_{hold}) / [(V_O - V_{ripple})^2 - (V_{min})^2]$$

where :
C_O min = output capacitance (µF)
P_O = output power (W)
T_{hold} = hold up time (sec)
V_O = output voltage (V)
V_{ripple} = output ripple voltage (V)
V_{min} = minimum input voltage for DC/DC module

For example:
A PFC module driving 3 AIF80A300 400W modules @ 5V. Efficiency of the AIF80A300 module is 88%, the minimum input voltage is 250V, the output voltage of the PFC is 380V, the required hold-up time is 20mS and the peak-to-peak voltage V_{ripple} is chosen to be 16V.

$$C_{O\ min} = \frac{2 \times (3 \times 400/0.88) \times 0.02}{[(380-16)^2 - 250^2]} = 390\mu F \quad (470\ \mu F \pm 20\%)$$

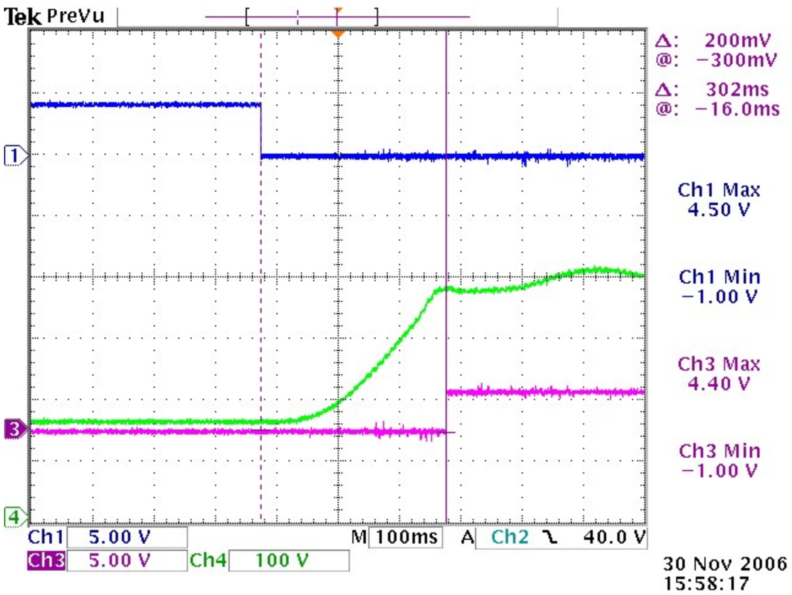
This figure is the minimum capacitance. To allow for capacitor tolerances and aging effects the actual value should generally be around 1.5 times greater.

APPLICATION NOTES

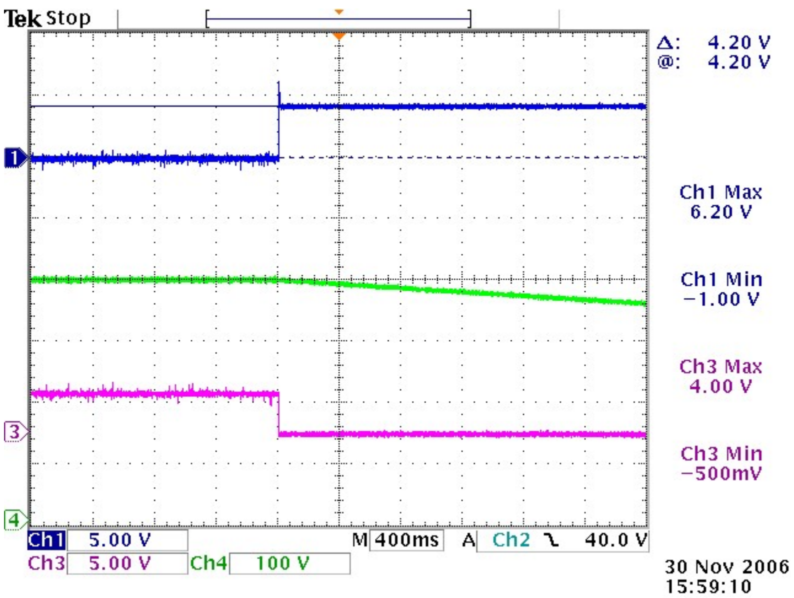
PF & Load Enable Connections and Timing

The PFC module must be supplied with a PF ENABLE signal to initiate the start-up sequence. The output of the LD ENABLE pin goes HIGH (ON) once the PFC has completed the start-up sequence.

It is recommended that the LD ENABLE signals is always used to enable the load, however, if the load is to be enabled manually it is essential that the ton time has expired before enabling occurs.



PF_ENABLE and LD_ENABLE @PF turn-on (Ch1: PF_ENABLE, Ch3: LD_ENABLE)

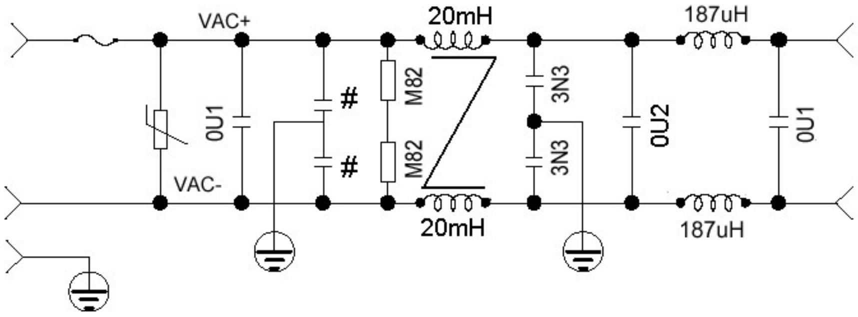


PF_ENABLE and LD_ENABLE @ PF turn-off (Ch1: PF_ENABLE, Ch3: LD_ENABLE)

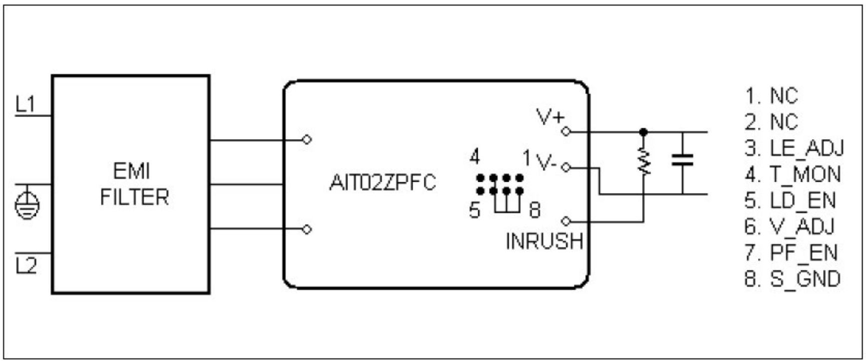
APPLICATION NOTES

Conducted EMI

The PFC modules will require additional EMI filtering to enable the system to meet relevant EMI standards. PFC modules have an effective input to ground (baseplate) capacitance of 1600pF. This should be accounted for when calculating the maximum EMI 'Y' capacitance to meet ground leakage current specifications. An example filter circuit is shown below.



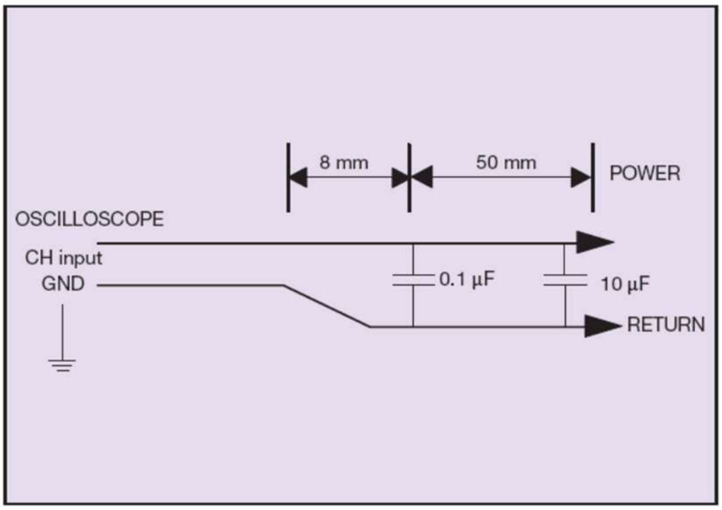
PFC Module Connection Example



APPLICATION NOTES

Output Ripple and Noise Measurement

The setup outlined in the diagram below has been used for output voltage ripple and noise measurements on the AIT02ZPFC-01NL module. When measuring output ripple and noise, a scope jack in parallel with a 0.1uF ceramic chip capacitor, and a 10uF aluminum electrolytic capacitor should be used. Oscilloscope should be set to 20MHz bandwidth for this measurement.



RECORD OF REVISION AND CHANGES

Issue	Date	Description	Originators
1.0	05.29.2018	First Issue	K. Wang
1.1	07.02.2018	Updated the inrush resistor error	K. Wang
1.2	02.26.2020	Update the 115Vac to 230Vac at Efficiency test	K. Wang
1.3	10.10.2022	Update error for input from “85 to 100” to “85 to 180” on page 2	K. Wang

ABOUT ADVANCED ENERGY

Advanced Energy (AE) has devoted more than three decades to perfecting power for its global customers. AE designs and manufactures highly engineered, precision power conversion, measurement and control solutions for mission-critical applications and processes.

Our products enable customer innovation in complex applications for a wide range of industries including semiconductor equipment, industrial, manufacturing, telecommunications, data center computing, and medical. With deep applications know-how and responsive service and support across the globe, we build collaborative partnerships to meet rapid technological developments, propel growth for our customers, and innovate the future of power.

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