82505 Series (-ICL and -800) PFC Boost Module
Application's Information

OVERVIEW

Implementing power factor correction (PFC) into switch mode power supplies maximizes the power handling capability of the power supply and current handling capacities of power distribution networks. Input power factor (PF) is defined as real power (Watts) divided by apparent power (VA) and is expressed as decimal number between 0 and 1. A non-corrected power supply with a typical PF equal to 0.65 will draw approximately 1.5 times greater input current as a PFC supply (PF=0.99) for the same output loading. The non-corrected supply requires additional AC current to be generated which is not consumed by the load, creating I^2R losses in the power distribution network.

Ideally, PFC power supplies "look" like a resistor to the driving voltage source; the current drawn by the supply matches the voltage in waveshape and phase. Power factor will approach unity when the input current drawn by the power supply matches and is in phase with the input voltage. For a sine wave voltage source, the input current of a well designed PFC supply will also be a sine wave. A perfect sine wave contains no harmonic distortion (all individual higher order harmonics have zero magnitude). As a result, a derivative of active power factor corrected power supplies, when subjected to a non-distorted input source, is minimization of input current harmonic distortion content.

Airborne equipment must comply with stringent standards regarding input power factor and input current harmonic distortion content. RTCA/DO160D section 16 and Boeing's D6-44588 (AA) require minimization of individual harmonic distortion content up to the 40^{th} harmonic (16kHz at 400Hz fundamental frequency) for all equipment that draws more than 35VA. Limits set forth in these specifications mandate active PFC correction for most airborne equipment power supplies. For a non-distorted single phase AC voltage source, individual input current harmonic distortion requirements are:

Harmonic Order	Limits
Odd triplen harmonics; (h = 3, 9, 15, 21, 27, 33, 39)	Ih = 0.15(If) / h
Odd non triplen harmonics; (h = 5, 7, 11, 13, 17, 19, 23, 25, 29, 31, 35, 37)	Ih = 0.3(If) / h
Even harmonics 2 & 4; (h = 2 and 4)	Ih = 0.01(If) / h
Even harmonics > 4; (h = 6, 8, … 40)	Ih = 0.0025 (If)

Where:
h = order of harmonic
Ih = maximum harmonic current of order h obtained during min, max and steady state operation
If = fundamental current obtained during min, max and steady state operation

Recently, requirements have been added to these specifications that require test and compliance with input harmonic distortion for variable frequency generators from the minimum input line frequency of 360Hz through the maximum input line frequency of 800Hz.

A block diagram of an active PFC boost converter is shown in figure 1. The input stage of this type of converter is the same as a conventional non-corrected power supply; the input AC is filtered and rectified. In order to boost the output and to control the input current, the large input capacitor that would normally be associated with the AC to DC conversion function has been moved to the output of the boost converter; Cout in the diagram. The PFC controller circuitry programs the input current to track the input voltage by varying the main MOSFET duty cycle based on two feedback and one feedforward signals: output voltage, rectified line current and rectified AC voltage. The output of the boost regulator is a constant voltage but the input current is programmed to be a half sine wave. The power flow into Cout is a sine wave at twice the line frequency

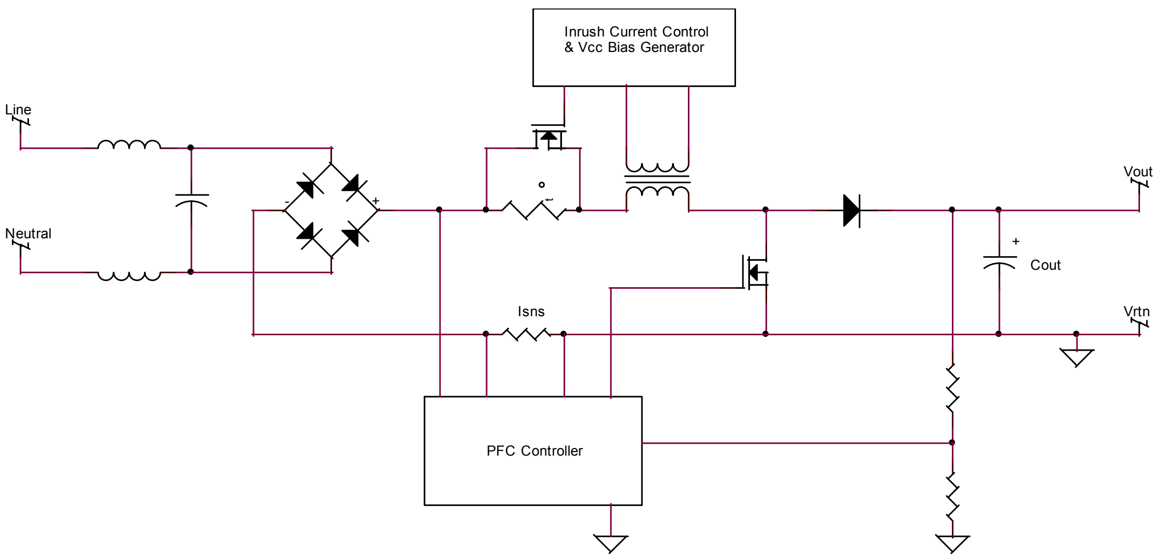

Figure 1.PFC Boost Converter Block Diagram

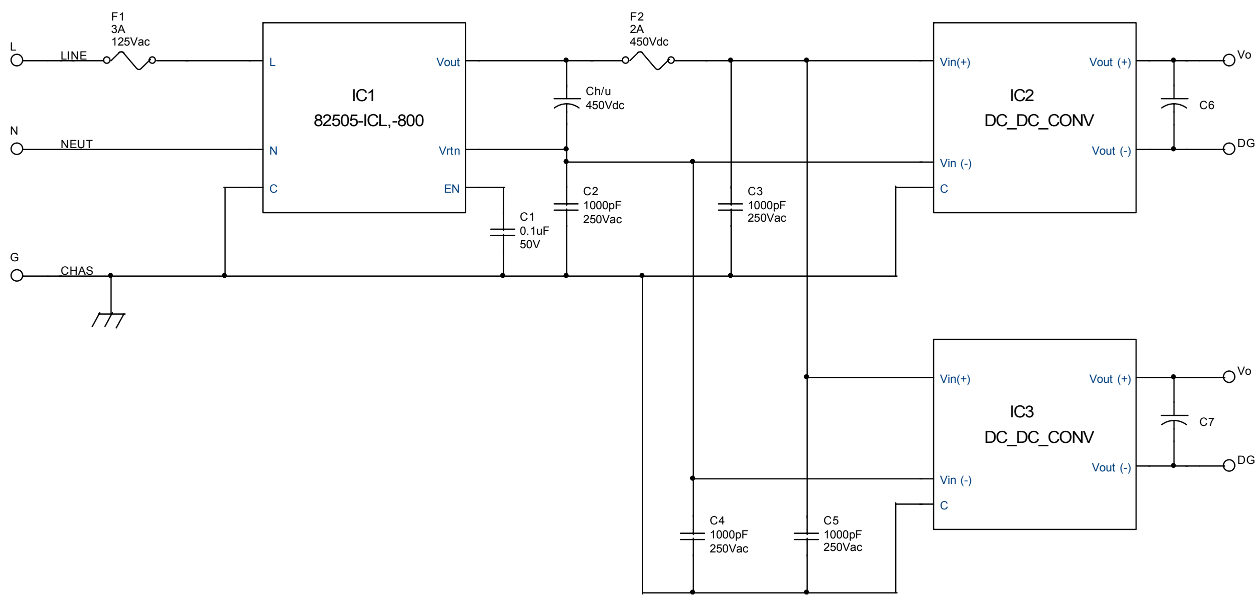

Figure 2. Typical Application Circuit

EXTERNAL FILTER

No external line filter is necessary with the 82505-ICL,-800 modules for specification compliance.

HOLD-UP TIME

The 82505-ICL,-800 PFC boost modules require a minimum output capacitance of 100uF installed between Vout and Vrtn for proper module operation. Typical values will be larger due to the hold-up time requirements of the particular application. The maximum output capacitance is 4,800uF. The maximum value is specified in order not to over stress the active inrush current limiter within the boost module.

In order to extend configured power supply hold-up time, polarized 450V (minimum) electrolytic capacitors must be connected externally between the module's Vout and Vrtn pins. Required external capacitance can be determined using the following formula:

$$E = P * (t + t_{restart}) = \{½\, C_{h/u}\, (Vi^2 - Vf^2)\}$$

Where,

P = External (downstream) DC/DC converter input power (Watts)
t = Desired hold-up time (Seconds)
$t_{restart}$ = Warm start delay of ~20mSec upon reapplication of input AC
$C_{h/u}$ = External hold-up capacitance (Farads)
Vi = Minimum PFC output voltage = 325 Volts – 3% = 315V
Vf = Undervoltage shutdown level for downstream DC/DC converter (typically 180 Volts)

In order to hold up 250W boost converter output power for 200mSec requires:
$C_{h/u} = \{(250W)\ (200mSec + 20mSec)\} \div \{(1/2)\ (315V^2 - 180V^2)\} = 1650uF$

Use of 105°C, 450Vdc, 20% tolerance snap-mount aluminum electrolytic capacitors is recommended. For the example above, a total nominal capacitance of 2060uF would be necessary to assure the required capacitance of 1650uF was achieved. Warm start delay occurs for AC power interrupts less than ~400mSec as a result of combination of time to reactivate PFC control circuitry, reinitiation of PFC soft-start cycle and reaching module power limit.

Recommended capacitor type and placement:
450V, Aluminum Electrolytic, Snap-mount, 105°C

Panasonic, TS series
United Chemi-Con, KMQ series
Cornell Dubilier, 381LX series

Placement:

Output capacitor(s) should be placed within several inches of the boost module output prior to the DC/DC converter input fuses.

Output Capacitor Ripple Requirements:

Observe capacitor ripple current requirements at 800Hz and 100kHz. Normal (full load) 800Hz ripple current can be approximated by:

I (800) ~ P in / V in (rms)

100kHz ripple current content is generated as a function of the boost module's normal operation. The maximum 100kHz ripple current for the 82505-ICL, -800 modules is ~1.2Apk-pk and occurs at the internal switching frequency of the converter.

EMI CONSIDERATIONS

Use of a chassis ground plane or aluminum surface beneath the non-metallic (silicon) module side is recommended. Although the 82505-ICL,-800 modules contain a differential mode input filter and common-mode suppression capacitors, the use of an external line filter is required for compliance with conducted emissions. See application circuit for suggested external filter.

If using an external filter comprised of discrete components, assure the current ratings of the differential and common mode inductors are sufficient. Avoid adding excessive line-to-line capacitance at lower output power levels (<125W output) as this may have an adverse effect on input current harmonic distortion when running distorted input testing (Vthd > 5%).

One or more of the external hold-up capacitors should be installed in close proximity to the module’s output terminals (within 2 – 3 inches is recommended).

SAFETY CONSIDERATIONS

The 82505-ICL,-800 modules do not contain internal overcurrent protection. An external fuse installed in the line is required to assure proper protection in the event of a short circuit or low impedance fault condition on the modules output terminals or within the module's input EMI filter. A properly rated fuse should be selected and tested within the application to assure it protects the module and wiring in the event of a fault while not nuisance tripping when cycling input AC power (as a result of charging output hold up capacitors).

THERMAL CONSIDERATIONS

There is no derating required for module output power up to the module's maximum baseplate temperature of 85°C. Beyond this temperature the module will shutdown (AC is switched out during a fault with this module). In order to assure the baseplate temperature remains below 85°C additional heatsinking or forced airflow may be required. In order to estimate baseplate temperature and whether external heatsinking or airflow is necessary, apply the following formula:

$T_{baseplate} = T_{ambient} + (P_{diss})(\Theta_{s\text{-}a})$

Where:
$T_{baseplate}$ = Module baseplate temperature in °C,
$T_{ambient}$ = Ambient air temperature in °C,
$\Theta_{s\text{-}a}$ = Thermal resistance from module baseplate to ambient air in °C/W without external airflow or heatsink,
eff = Module efficiency from appropriate curve,
$P_{diss} = \{(P_{out} \div eff) – P_{out}\}$ in watts

As an example,
Assume a desired output power of 250W at nominal line operation (115Vrms) with a maximum ambient temperature of 55°C. The following formula would apply:

$T_{baseplate}$ = 55°C + {(250W / 0.89) – 250W)} (1.3°C/W) = 95.6°C

Therefore either an external heatsink or forced air cooling would be required such that $\Theta_{s\text{-}a}$ was reduced to:

$\Theta_{s\text{-}a} < \{(T_{baseplate} - T_{ambient}) \div P_{diss}\}$

$\Theta_{s\text{-}a}$ < {85°C - 55°C} ÷ {(250W / 0.89) – 250W)} < 0.971°C/W

PRECAUTIONS

a) PPI PFC boost modules are non-isolated. The DC output is a differential potential but not with respect to chassis ground. The Vrtn line is not at chassis potential. Isolation (primary to secondary) is accomplished within the DC/DC converters. Special care must be exercised when monitoring the module's DC output on an oscilloscope. Either the oscilloscope must be floated from chassis ground or the input neutral line disconnected from chassis ground. Typical aircraft application is to tie neutral and chassis ground together. Failure to isolate neutral from Vrtn can permanently damage the boost module device. Proper input fusing of the AC high line should protect the boost module in the event the neutral is inadvertently tied to Vrtn.

b) When incorporating large values of output capacitors (Cout) and using DC/DC converters that turn-on at voltages well below the module's rated output voltage, verify proper modular supply start-up at low line input voltages. The module’s output power limit set point can be exceeded (due to the combination of charging the output capacitor bank and driving the DC/DC converter load) causing cyclic on/off of the boost module when starting at low line. This condition can be corrected by delaying the DC/DC converter at start-up until the boost module is at or near its specified output voltage and/or incorporating the start-up assist circuit provided in the application schematic.

c) The 82505-ICL,-800 modules are contained within an aluminum enclosure. If the module is mounted on a printed wiring board (PWB), avoid routing the interconnecting signal traces on the component layer of the PWB directly beneath and in contact with the module’s enclosure.