81357 Series PFC Boost Module
Application 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.

RTCA/DO160E section 16 requires minimization of individual harmonic distortion content up to the 40th harmonic (16kHz at 400Hz fundamental frequency) for all equipment that draws more than 35VA. 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. 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

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.

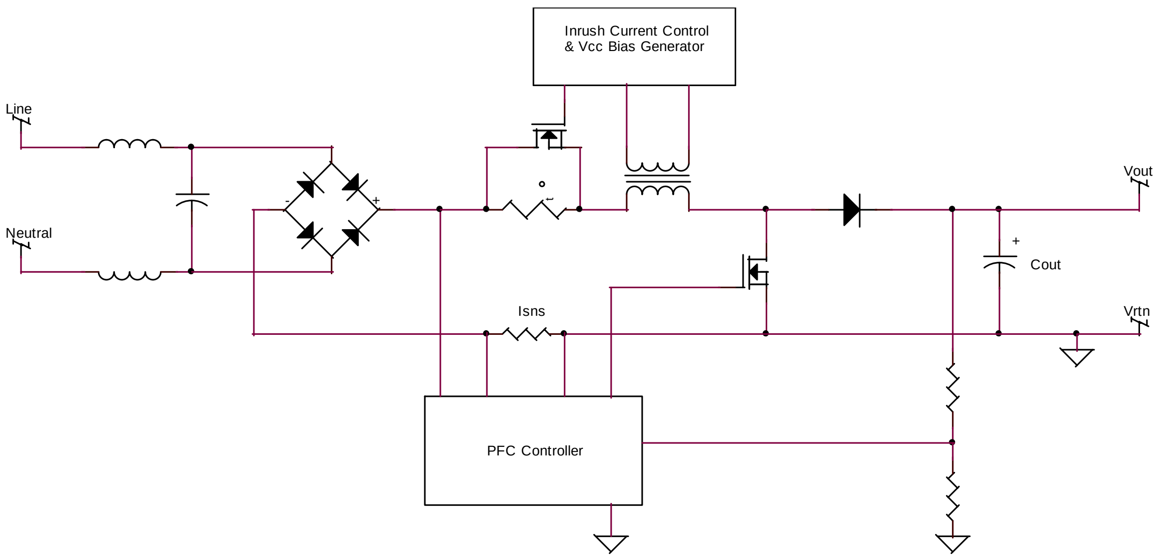

Figure 1. PFC Boost Converter Block Diagram

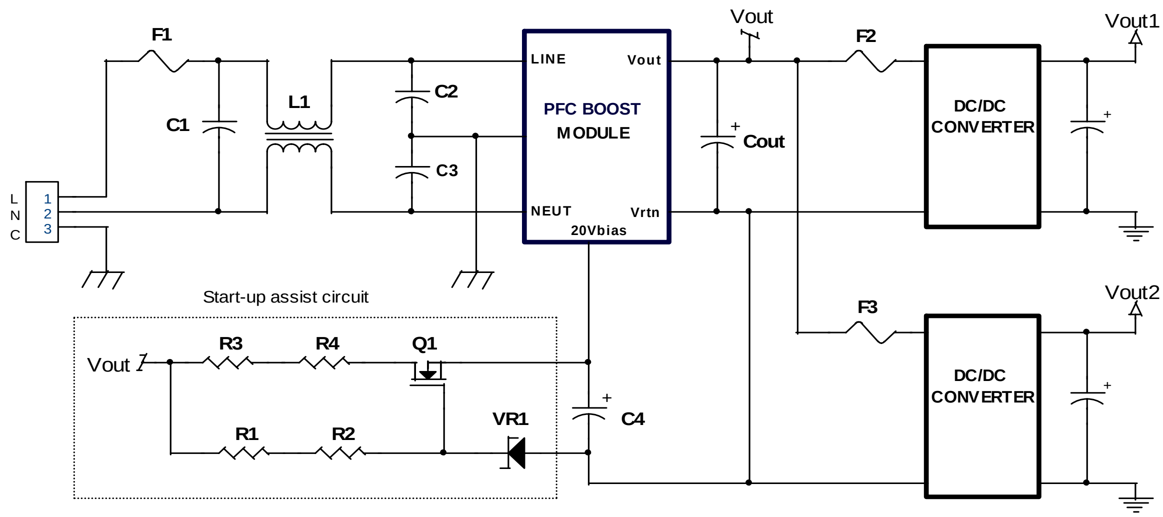

Figure 2. Typical Application Circuit, PFC Corrected Dual Output Modular Power Supply

Designator	Typical p/n or Description
F1	3A, 125Vac, Slow-Blow
F2, F3	2.5A, 450V, PC-Tron
L1	JW Miller #7109 or #7116
C1	0.068uF, 275Vac, “X2”
C2, C3	3300pF, 250Vac, “Y1/Y2”
C4	470uF, 25V, Alum
R1, R2	365k, 1/8W, 1206
R3, R4	12k, 3W, 5%, 350V
Q1	FDD6N50FTFCT, 500V, Vgs=+/-30V, DPAK
VR1	MMSZ5248BT1, 18V, 1/2W

Reference figure 2 for a typical application circuit of a dual output modular supply.

EXTERNAL COMPONENT SELECTION

FUSES

F1 = 3A, 125Vac, Slow-Blow, LittleFuse PICO-II Series
F2 = F3 = 450V/2.5A, DC Fuse, Bussmann, PC-TRON, PCB SERIES

COMMON MODE CHOKE (L1)
Used for suppression of conducted emissions as a result of PCB trace lengths from input power connector to boost converter module input. F1 and L1 should be placed as close as possible to AC entry point within assembly (i.e., @ power connector). The inclusion of L1 will have minimal impact on harmonic distortion performance of boost module.

Typical L1 values are 1 - 5 mH @ 2 - 4 Arms

Suggested manufacturers:

JW Miller
www.bourns.com/bourns_jwmiller_cobranding.html
P/N's 7109, 7116

Coilcraft
www.coilcraft.com
P/N F5593A

OUTPUT CAPACITOR(S) (Cout)
The 81357 series boost modules require a minimum output capacitance of 100uF installed between Vout and Vrtn for proper module operation (200uF for –HP1 module). Typical values will be larger due to the hold-up time requirements of the particular application. The maximum output capacitance varies slightly with each module but is typically 1000uF (see individual module data sheets). The maximum value is specified in order not to over stress the active inrush current limiter within the boost module.

If implementing greater than 470uF output capacitance (Cout), the start-up assist circuit provided in the application schematic above may be required to assure the PFC module starts properly for all line and load conditions.

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

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

<u>Placement</u>:

Output capacitor(s) should be placed within several inches of the boost module output prior to the DC/DC converter input fuses F2 and F3.

<u>Output Capacitor Ripple Requirements</u>:

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 (125kHz for –HP1 version) ripple current content is generated as a function of the boost module's normal operation. The maximum 100kHz ripple current for the 81357 series boost modules is 900mApk-pk and occurs at the internal switching frequency of the converter.

Hold-up Time Calculations:

Output capacitance (Cout) vs. hold-up time (t) can be calculated by the following formula:

$E = Pt = 1/2 Cout(Vi^2 - Vf^2)$

where:
P = Power delivered to DC/DC converters
Vi = Normal operating DC output voltage of boost converters
Vf = Minimum operating voltage of DC/DC converter

START-UP ASSIST CIRCUIT & 20Vbias OUTPUT

If implementing greater than 470uF output capacitance (Cout), the start-up assist circuit provided in the application schematic above is required to assure the PFC module starts properly for all line and load conditions.

A low current bias output ("20Vbias output") is available from the 81357 series boost modules to use for auxiliary sense and control circuitry. This output is capable of sourcing up to 5mArms of current and will maintain an RMS voltage level of 17.8Vrms ± 1.2Vrms. This output is referenced to Vrtn. When using this low current bias supply, it is usually required to implement the start-up assist circuit regardless of the value of Cout.

EMI CONSIDERATIONS

Although the 81357 series boost modules complies with RTCA/DO-160 EMI requirements as a stand-alone unit, often times circuit implementation (i.e., component placement, DC/DC converter selection, PCB layout and grounding, supply enclosure, power trace/wire lengths) enter into the spectrum. Certain precautions should be taken to assure successful EMI compliance. Among these are:

- Use of solid chassis ground plane on power supply PCB
- Solid mechanical interconnection from chassis ground to module frame (#4 hardware, 4 places)
- Incorporation of suggested common mode choke (L1) and filter capacitors (C1, C2 & C3)
- Observance of EMI guidelines for specific DC/DC converters chosen
- Avoid routing traces directly under module

Should the configured modular power supply fail preliminary conducted emissions scans, most likely the emissions are coupling around the boost module input filter. Try inserting 50 - 100uH toroidal inductors at the nearest AC power point of entry in both line and neutral leads. This technique usually provides an additional 20dB attenuation of input current in the frequency range of interest (150kHz - 5MHz). Implementation of input toroidal inductors will have minimal impact on the harmonic distortion/ power factor performance of the configured power supply. Several manufacturers (Pulse Engineering, TMC Magnetics and Coilcraft) offer "off-the-shelf" toroidal inductors for AC power line filter applications. These devices are typically powdered iron cores and can be as small as 0.7" OD.

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 81357 series boost 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.