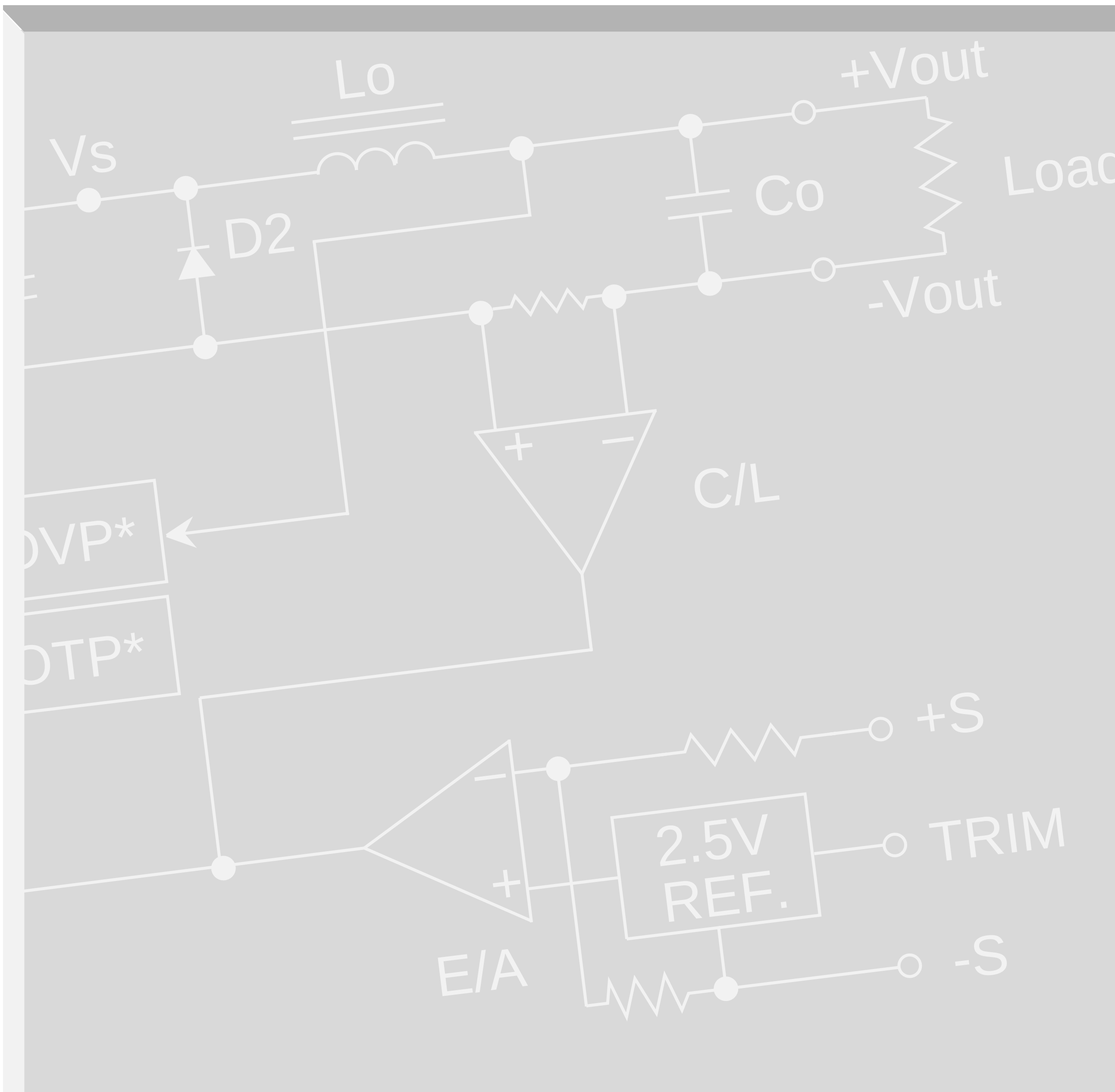
Applications Manual

First Generation Converters and Accessory Modules

Eighth Edition



Component Solutions For Your Power System

Total Power Solutions

Vicor Corporation produces families of compact, economical, high performance power components and systems that offer the system designer a "total solution" to most power system requirements.

This publication provides a review of Vicor's zero-current-switching technology and helpful applications information as it applies to Vicor's first generation of DC-DC converters (VI-200, VI-J00) and accessory modules (VI-IAM, VI-RAM, VI-AIM,VI-HAM). For information on Vicor's 2nd generation products visit our website at vicr.com. Additionally, a glossary of technical terms has been included for your convenience.

System architects are being asked to squeeze more and more power into ever-shrinking spaces. This applications manual is designed to help system designers make the most of their available space using Vicor power components.

Please contact Vicor's Applications Engineering Department at (800) 927-9474, or one of Vicor's Technical Support Centers, listed below, if further clarification of the topics presented is required.

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Note: This Application does not relate to Vicor's 2nd Generation Products.

Zero-Current-Switching

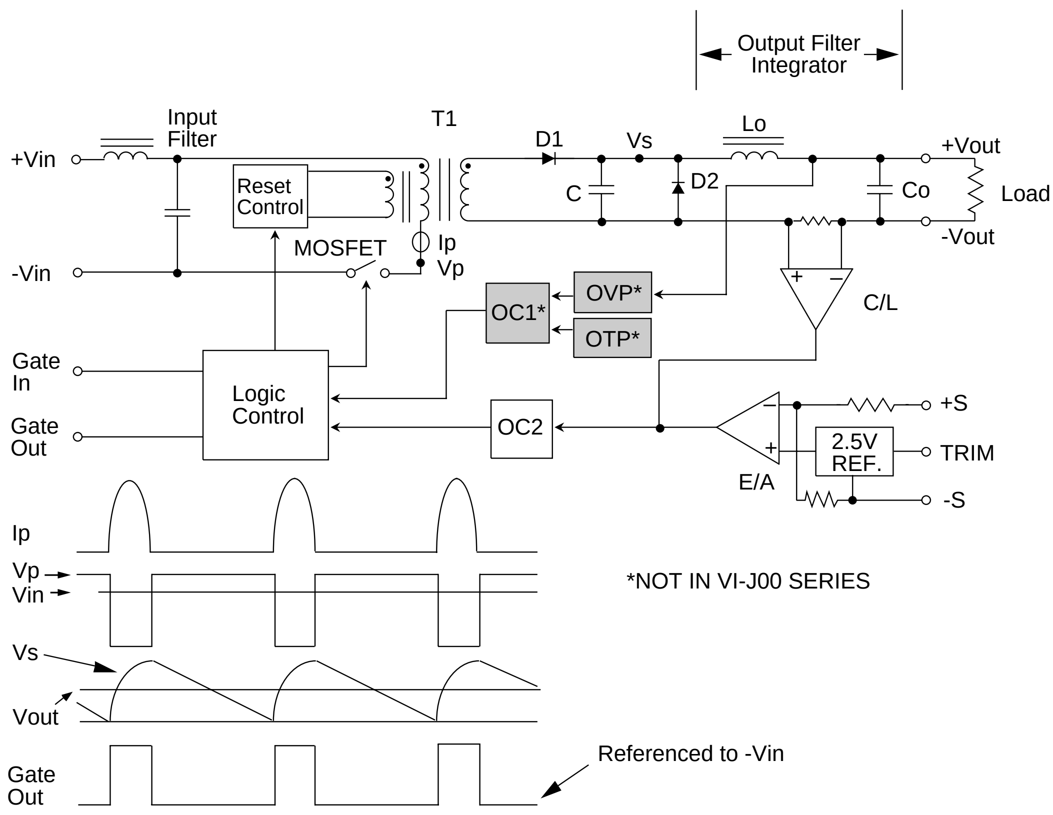
Overview

The heart of Vicor's module technology, zero-current-switching, allows Vicor converters to operate at frequencies in excess of 1 MHz, with efficiencies greater than 80% and power densities ten or more times those of conventional converters.

Lossless Energy Transfer

Switch turn-on of the MOSFET switch transfers a quantized energy packet from the input source to an LC "tank" circuit, composed of inherent transformer leakage inductance of T1 and a capacitive element, C, in the secondary. Simultaneously, an approximately half-sinusoidal current flows through the switch, resulting in switch turn-on at zero current and turn-off when current returns to zero. Resonance, or bidirectional energy flow, cannot occur because D1 will only permit unidirectional energy transfer. A low-pass filter (Lo, Co) following the capacitor produces a low ripple DC output. The result is a virtually lossless energy transfer from input to output with greatly reduced levels of conducted and radiated noise.

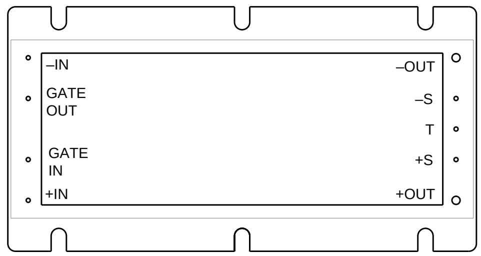
1st Generation Zero-Current-Switching Block Diagram

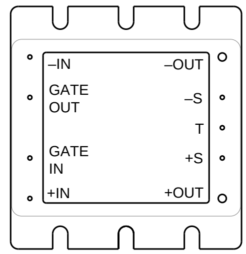


DC-DC Converter Pinouts

Pinout Description

VI-200, VI-J00 Modules





–IN, +IN:
DC voltage inputs. See tables below for nominal input voltages and ranges for the VI-200, VI-J00, MI-200 and MI-J00 Family modules (data sheets contain Brownout and Transient ratings).

VI-200, VI-J00 Input Voltage Ranges			
Designator	**Low**	**Nominal**	**High**
0	10V	12V	20V
1	21V	24V	32V
W	18V	24V	36V
2	21V	36V	56V
3	42V	48V	60V
N	36V	48V	76V
4	55V	72V	100V
T	66V	110V	160V
5	100V	150V	200V
6	200V	300V	400V
7	100V	150/300V	375V

MI-200, MI-J00 Input Voltage Ranges			
Designator	**Low**	**Nominal**	**High**
2	18V	28V	50V
5	100V	155V	210V
6	125V	270V	400V
7	100V	165V	310V

GATE OUT, GATE IN:
Gate Out: The pulsed signal at the Gate Out terminal of a regulating driver module is used to synchronously drive the Gate In terminal of a companion booster module to effect power sharing between the driver and the booster. Daisy-chaining additional boosters (connecting Gate Out of one unit to Gate In of a succeeding unit) leads to a virtually unlimited power expansion capability.

Gate In: The Gate In pin on a driver module may be used as a logic Enable/Disable input. When Gate In is pulled low (<0.65V @ 6 mA, referenced to $-V_{in}$), the module is turned off; when Gate In is floating (open collector), the module is turned on. The open circuit voltage of the Gate In pin is less than 10V.

–OUT, +OUT:
DC output pins. See the table below for output voltages and power levels of VI-200, VI-J00, MI-200 and MI-J00 Family modules.

Output Voltage	Power Level		Power Level	
	VI-200	**VI-J00**	**MI-200**	**MI-J00**
<5Vdc	10-40A	5-20A	10-30A	5-10A
≥5Vdc	50-200W	25-100W	50-100W	10-50W

Special output voltages from 1 to 95V; consult factory.

Pinout Description (cont)

T (Trim):
Allows fixed or variable adjustment of the module output.
Trimming Down: Allows output voltage of the module to be trimmed down, with a decrease in efficiency. Ripple as a percent of output voltage goes up and input range widens since input voltage dropout (loss of regulation) moves down.
Trimming Up: Reverses the above effects.

–S, +S (–Sense, +Sense):
Maintains specified output voltage to the load. Overvoltage protection will be activated in the VI-200/MI-200 and module will shut down if remote sense tries to boost output voltage above 110% of nominal. Do not exceed 0.25V drop in negative return; if the voltage drop exceeds 0.25V in the negative return path, the current limit setpoint will increase. Connect + sense to + out and –sense to –out at the module if remote sensing is not desired (see figure 4, pg 9-2).

Module Do's and Don'ts

Electrical Considerations

Gate In and Gate Out Terminals: Logic Disable

When the Gate In terminal of a driver module is pulled low with respect to $-V_{in}$ **(CAUTION: with off-line applications $-V_{in}$ is not earth ground)**, the module shuts off (see Figure 1, page 9-1). In Logic Disable mode, the Gate In terminal should be driven from either an "open collector" or electromechanical switch that can sink 6 mA when on (Gate In voltage less than 0.65V). If driven from an electromechanical switch or relay, a 1 µF capacitor should be connected from Gate In to $-V_{in}$ to eliminate the effects of switch "bounce". The 1 µF capacitor may be required in all applications to provide a "soft start" if the unit is disabled and enabled quickly. This terminal is not intended for repetitive on/off/on operation.

High Power Arrays

The pulsed signal at the Gate Out terminal of a regulating driver module is used to synchronously drive the Gate In terminal of a companion booster module to effect power sharing between the driver and the booster (refer to Figure 5, page 9-2). Daisy-chaining additional boosters (i.e., connecting Gate Out to Gate In of a succeeding unit) leads to a virtually unlimited power expansion capability. MI/VI-200 series modules of the same family and power level can be paralleled (i.e., DRIVER, VI-260-CU with BOOSTER, VI-B60-CU).

In general:

- Don't drive the Gate In terminal from an "analog" voltage source.
- Don't leave Gate In terminals of booster modules unterminated.
- Don't overload Gate Out; limit load to a single Vicor module Gate In connection, or 1 Kohm, minimum, in parallel with 100 pF, maximum.
- Don't skimp on traces that interconnect module $-V_{in}$ terminals in high power arrays. Gate In and Gate Out are referenced to $-V_{in}$; heavy, properly laid out traces will minimize parasitic impedances that could interfere with proper operation.
- Do use a decoupling capacitor across each module's input (see *Input Source Impedance* below).
- Do use a fuse or breaker on each module's input to prevent fire in the event of module failure.

Input Source Impedance

The converter should be connected to an input source that exhibits low AC impedance. A small electrolytic capacitor should be mounted close to the module's input pins if source impedance is questionable. This will restore low AC impedance, while avoiding the potential resonance associated with "high-Q" film capacitors. The minimum value of the capacitor, in microfarads, should be C (µF) = 400 ÷ V_{in} minimum. Example: V_{in}, minimum, for a VI-260-CV is 200V. The minimum capacitance would be 400 ÷ 200 = 2 µF. For applications involving long line or high inductance additional capacitance will be required.

Input Transients

Don't exceed the transient input voltage rating of the converter. Input Attenuator Modules or surge suppressors, in combination with appropriate filtering, should be used in off-line applications or in applications where source transients may be induced by load changes, blown fuses, etc.

NOTE: On any converter module with a high line rating in excess of 250Vdc, do not allow the rate of change of input voltage to exceed 10V/µs for any input voltage change in excess of 250V.

The level of transient suppression required will depend on the severity of the transients. A zener diode, TRANSZORB™ or the like will provide suppression of transients of under 100 µs, act as

Electrical Considerations (cont)

a voltage clipper for DC input transients and provide reverse input protection. It may be necessary to incorporate an LC filter for larger energy transients. This LC filter will integrate the transient energy while the zener clips the peak voltages. The Q of this filter should be kept low to avoid potential resonance problems. Please see Section 14, *VI-IAM/MI-IAM Input Attenuator Module*, for additional information on transient suppression.

Output OVP

Each module, with the exception of VI-J00s and MI-J00s, has an internal overvoltage protection circuit that monitors the voltage across the output power terminals. It is designed to latch the converter off at 115% to 135% of rated output voltage. It is not a crowbar circuit, and if a module is trimmed above 110% of rated output voltage, OVP may be activated. **CAUTION**: **when trimming up VI-J00 or MI-J00 modules, additional care should be taken as an improper component selection could result in module failure. Improper connection of the sense leads on VI-J00 or MI-J00 can also result in an over voltage condition and module failure.**

Input Reverse Voltage Protection

The module may be protected against reverse input voltages by the addition of a diode in series with the positive input, or a reverse shunt diode with a fuse in series with the positive input. Input Attenuator Modules (VI-IAMs) provide input reverse voltage protection when used with a current limiting device (fuse).

Thermal/Mechanical Considerations

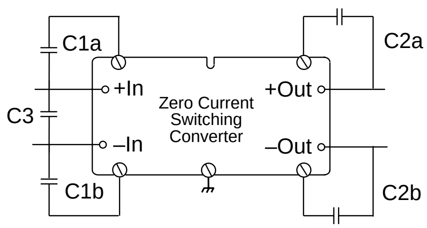
Baseplate

Operating temperature of the baseplate, as measured at the center mounting slot on the $–V_{in}$, $–V_{out}$ side, cannot exceed rated maximum. Thermal compound or a thermal pad should be used when mounting the module baseplate to a chassis or heatsink. All six mounting holes should be used. Number six (#6) machine screws should be torqued to 5-7 in.-lbs., and use of Belville washers is recommended.

EMC Considerations

All applications utilizing DC-DC converters should be properly bypassed, even if no EMC standards need to be met. Bypass V_{in} and V_{out} pins to each module baseplate as shown in Figure 1 below. Lead length should be as short as possible. Recommended values vary depending on the front end, if any, that is used with the modules, and are indicated on the appropriate data sheet. In most applications, C1 is a 4700 pF “Y” capacitor (Vicor P/N 01000) carrying the appropriate safety agency approval; C2 is a 4700 pF “Y” capacitor (Vicor P/N 01000) or a .01 µF ceramic capacitor rated at 500V. In PC board-mount applications, each of these components is typically small enough to fit under the module baseplate flange.

Figure 1.



Safety Considerations

Shock Hazard
Agency compliance requires that the baseplate be grounded or made inaccessible.

Fusing
Internal fusing is not provided in Vicor DC-DC converters. To meet safety agency conditions, a fuse is required. This fuse should be placed in the +input lead, not the –input lead, as opening of the –input lead will cause the gate terminals to rise to the potential of the +input lead, causing possible damage to other modules or circuits that share common Gate In or Gate Out connections.

Safety agency conditions of acceptability require module input fusing. The VI-x7x, VI-x6x and VI-x5x require the use of a Buss PC-Tron fuse, or other DC-rated fuse. See below for suggested fuse ratings. This fuse should be inserted in the (+) input lead, as opening of the (–) input lead will cause the gate terminals to rise to the voltage of the (+) input lead, possibly causing destruction of the connected modules or devices.

VI-27X	PC-Tron 2.5A	VI-J7X	PC-Tron 2.5A
VI-26X	PC-Tron 3A	VI-J6X	PC-Tron 3A
VI-25X	PC-Tron 5A	VI-J5X	PC-Tron 5A
VI-2TX	PC-Tron 5A	VI-JTX	PC-Tron 5A
VI-24X	6A/125V	VI-J4X	PC-Tron 5A
VI-2NX	8A/125V	VI-JNX	PC-Tron 5A
VI-23X	8A/125V	VI-J3X	PC-Tron 5A
VI-22X	8A/60V	VI-J2X	PC-Tron 5A
VI-2WX	12A/50V	VI-JWX	8A/60V
VI-21X	12A/32V	VI-J1X	8A/60V
VI-20X	12A/32V	VI-J0X	8A/60V

MegaMod Family
Please consult Vicor’s Applications Engineering Department for MegaMod fuse values.

This fuse should be inserted in the (+) input lead, as opening of the (–) input lead will cause the gate terminals to rise to the voltage of the (+) input lead, possibly causing destruction of connected modules or devices.

Notes

Module Packaging Options

Up to 50 Watts/Cubic Inch
SlimMod™

Vicor's PC-mountable power components are available in flangeless "SlimMod" package configurations that provide users with the highest power density available in printed circuit mount applications.

To order the SlimMod configuration, add the suffix "S" to the standard part number. Example: VI-260-CV-S.

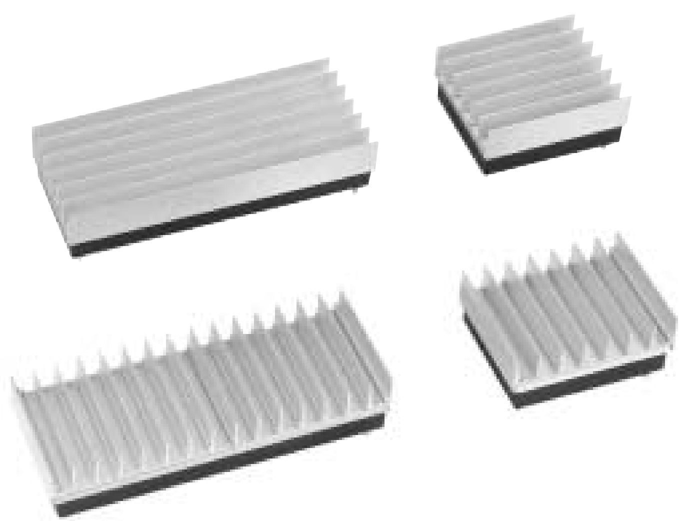
Full- and Half-Size SlimMods

FinMod™

Vicor's PC-mountable power components are also available in flangeless "FinMod" package configurations with integral finned heatsinks. FinMods eliminate the need for secondary heatsink assembly operations.

The full-size and half-size module components are available in .25 and .5 inch longitudinal or transverse fin versions. To order the longitudinal fin configurations add the suffix "F1" (.25 inch) or "F2" (.5 inch) to the standard part number.* For transverse fins, add the suffix "F3" (.25 inch) or "F4" (.5 inch) to the standard part number.

Longitudinal and Transverse FinMods



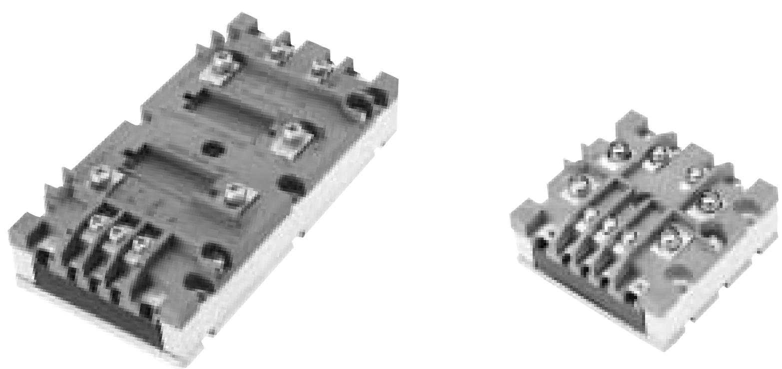
*F1 and F2 FinMods are now 7-fin products as shown. A 14-fin version is available by specifying F5 or F6.

BusMod™

The BusMod is a rugged module housing assembly that combines convenient chassis mounting with a screw/lug wiring interface for all electrical connections. To order the BusMod option, add “B1” to the standard part number.

NOTE: The BusMod may be used with any of Vicor’s full-size modules, with the exception of the VI-HAM.

BusMod Module Housing Assembly



Output Voltage Trimming

Overview

Specifications such as efficiency, ripple and input voltage range are a function of output voltage settings. As the output voltage is trimmed down, efficiency goes down; ripple as a percent of V_{out} goes up and the input voltage range widens since input voltage dropout (loss of regulation) moves down. As the units are trimmed up, the reverse of the above effects occurs.

All converters have a fixed current limit. The overvoltage protection setpoint is also fixed; trimming the output voltage does not alter its setting. As the output voltage is trimmed down, the current limit setpoint remains constant. Therefore, in terms of output power, if the unit is trimmed down, available output power drops accordingly.

The output voltage of all Vicor converters can be trimmed ±10%. Certain modules can be trimmed down to 50% of nominal output.

Do not attempt to trim the module output voltage more than +10%, as overvoltage shutdown may occur. Do not exceed maximum rated output power when the module is trimmed up. **CAUTION**: **when trimming up VI-J00 or MI-J00 modules, additional care should be taken as an improper component selection could result in module failure. Improper connection of the sense leads on VI-J00 or MI-J00 can also result in an over voltage condition and module failure.**

The following procedures describe methods for output voltage adjustment (–50 to +10% of nominal) of the VI-200, MI-200, VI-J00, MI-J00, ComPAC, FlatPAC and Mega Modules.

*** Modules with nominal 3.3V outputs and above have the 2.5V precision reference and 10k internal resistor. For trim resistor calculations on modules with 2.0V outputs use 0.97V in place of the 2.5V reference and substitute 3.88 kΩ for the internal 10 kΩ resistor.**

NOTE: Resistors are 1/4W. When trimming down any module, always maintain a preload of 1% of rated output power. For more specific information on trimming down a specific module, please consult Vicor's Applications Engineering Department.

Resistive Adjustment Procedure

To achieve a variable trim range, an external resistor network must be added. Refer to Figure 1.

Example 1.
For trimming –20% to +10% with a standard off-the-shelf 10 kΩ potentiometer (R7), values for resistors R6 and R8 need to be calculated.

Resistor R6 limits the trim down range. For a given percentage, its value is independent of output voltage. Refer to Table 1, page 5-4, for limiting resistor values.

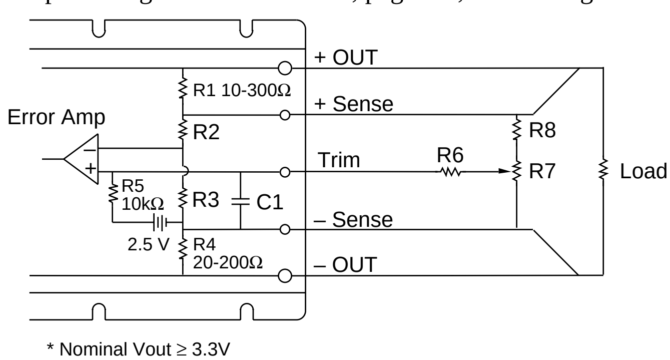
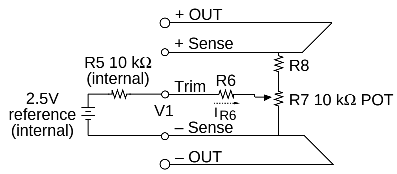


Figure 1. External Resistive Network for Variable Trimming

Trimming Down –20%

A 20% drop of the 2.5V reference at the trim pin is needed to effect a 20% drop in the output voltage. Refer to Figure 2.

Figure 2.
Circuit Diagram
"Trim Down"



$V_1 = 2.5V - 20\% = 2V$

Therefore:

$$I_{R5} = \frac{(2.5V - 2V)}{10\ k\Omega} = 50\ \mu A$$

Since $I_{R5} = I_{R6} = 50\ \mu A$:

$$R6 = \frac{2V}{50\ \mu A} = 40\ k\Omega$$

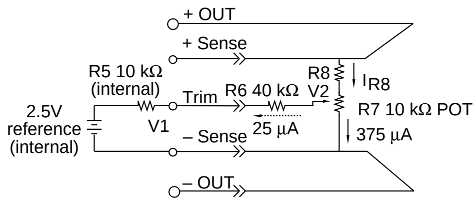
This value will limit the trim down range to –20% of nominal output voltage.

Trimming Up +10%

To trim +10% above nominal output voltage, the following calculations are needed to determine the value of R8. This calculation is dependent on the output voltage of the module. A 12V output will be used as an example. Refer to Figure 3.

It is necessary for the voltage at the trim pin to be 10% greater than the 2.5V reference. This offset will cause the error amplifier to adjust the output voltage up 10% to 13.2V.

Figure 3.
Circuit Diagram
"Trim Up"



$V_1 = 2.5V + 10\% = 2.75V$

$$I_{R5} = \frac{(2.75V - 2.5V)}{10\ k\Omega} = 25\ \mu A$$

Since $I_{R5} = I_{R6}$, the voltage drop across R6 = (40 kΩ) (25 µA) = 1V.

Therefore, V_2 = 2.75V + 1V = 3.75V. The current through R7 (10 kΩ pot) is:

$$I_{R7} = \frac{V_2}{R7} = \frac{3.75}{10\ k} = 375\ \mu A$$

Trimming Up +10% (cont)

Using Kirchoff's current law:

$I_{R8} = I_{R7} + I_{R6} = 400\ \mu A$

Thus, knowing the current and voltage, R8 can be determined:

$V_{R8} = (V_{out} + 10\%) - V_2 = 13.2V - 3.75V = 9.45V$

$$R8 = \frac{(9.45V)}{400\ \mu A} = 23.63\ k\Omega$$

This resistor configuration allows a 12V output module to be trimmed up to 13.2V and down to 9.6V. Follow this procedure to determine resistor values for other output voltages.

Fixed Trim

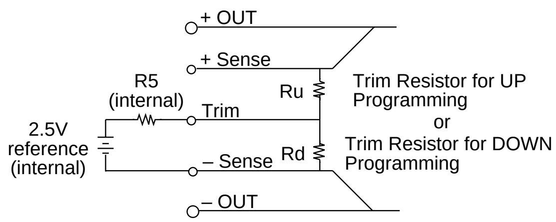
Converters can be trimmed up or down with the addition of one external resistor, either Ru for programming up or Rd for programming down. Refer to Figure 4 below.

Example 2.
Fixed Trim Up (12V to 12.6V)

To determine Ru, the following calculation must be made:

$2.5V + 5\% = 2.625V$
$V_{R5} = V_{trim} - V_{ref}$
$V_{R5} = 2.625 - 2.5 = 0.125V$

Figure 4.
Fixed Trimming



Knowing this voltage, the current through R5 can be found:

$$I_{R5} = \frac{V_{R5}}{R5} = \frac{.125V}{10\ k\Omega} = 12.5\ \mu A$$

$V_{Ru} = 12.6V - 2.625V = 9.975V$

$$Ru = \frac{9.975V}{12.5\ \mu A} = 798\ k\Omega$$

Connect Ru from the trim pin to the positive sense. Be sure to connect the resistor to the positive sense, not the positive output, or drops in the positive output lead as a function of load will cause apparent load regulation problems.

Fixed Trim (cont)

Example 3.
–25% Fixed Trim Down (24V to 18V)

The trim down methodology is identical to that used in Example 2, except that it is utilized to trim the output of a 24V module down 25% to 18V. The voltage on the trim pin must be reduced 25% from its nominal setting of 2.5V. This is accomplished by adding a resistor from the trim pin to negative sense.

2.5V – 25% = 1.875V
$V_{R5} = V_{bandgap} - V_{trim}$
= 2.5V – 1.875V = .625V

Knowing this voltage, the current through R5 can be found:

$$I_{R5} = \frac{V_{R5}}{R5} = \frac{.625V}{10\ k\Omega} = 62.5\ \mu A$$

The voltage across the resistor, Rd, and the current flowing through it are known:

$$Rd = \frac{(2.5V - .625V)}{62.5\ \mu A} = 30\ k\Omega$$

Connect Rd (Figure 4) from the trim pin to the negative sense of the module. Be sure to connect the resistor to the negative sense, not the negative output, or drops in the negative output lead as a function of load will cause apparent load regulation problems.

Table 1.
Values for Trim Down by Percentage
(Refer to product data sheet for allowable trim ranges)

Percent	Resistance
–5%	190 kΩ
–10%	90 kΩ
–15%	56.7 kΩ
–20%	40 kΩ
–25%	30 kΩ
–30%	23.3 kΩ
–35%	18.6 kΩ
–40%	15 kΩ
–45%	12.2 kΩ
–50%	10 kΩ

Tables 2a and 2b.
Values for Fixed Trim Down and Trim Up by Voltage

Fixed Trim Down		
Vnom	**V (Desired)**	**Trim Resistor***
5V	4.5V	90.9 kΩ
	3.3V	19.6 kΩ
	2V	6.65 kΩ
15V	13.8V	115 kΩ
24V	20V	49.9 kΩ
48V	40V	49.9 kΩ
	36V	30.1 kΩ

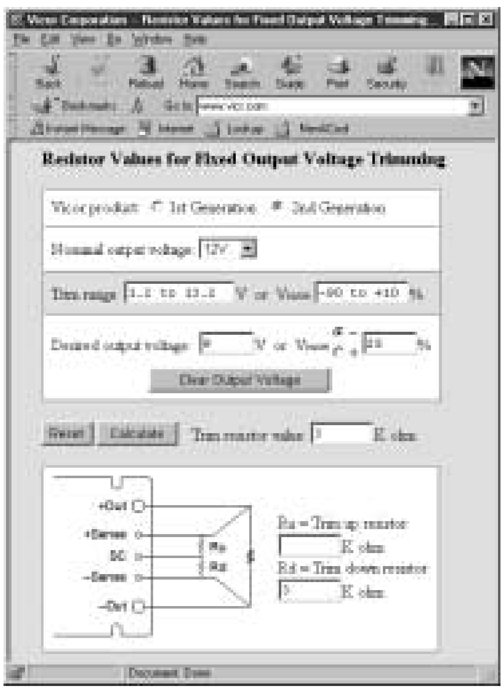
Fixed Trim Up		
Vnom	**V (Desired)**	**Trim Resistor***
5V	5.2V	261 kΩ
	5.5V	110 kΩ
12V	12.5V	953 kΩ
	13.2V	422 kΩ
15V	15.5V	1.62 MΩ
	16.5V	562 kΩ
24V	25V	2.24 MΩ
48V	50V	4.74 MΩ

*Values listed in the table are the closest standard 1% resistor values.

Dynamic Adjustment Procedure

Output voltage can also be dynamically programmed by driving the trim pin from a voltage or current source; programmable power supplies and power amplifier applications can be addressed in this way. For dynamic programming, drive the trim pin from a source referenced to the negative sense lead, and keep the drive voltage in the range of 1.25-2.75V. Applying 1.25 to 2.5V on the trim pin corresponds to 50% to 100% of nominal output voltage. Voltages in excess of 2.75V (+10% over nominal) may cause overvoltage protection to be activated. For applications where the module will be programmed on a continuous basis the operating frequency should be limited to 30 Hz.

Trimming on the Web



Trim values calculated automatically:

Resistor trim calculators are available on Vicor's web site at URL: www.vicr.com/tools.html or by requesting a copy of Vicor's Applications Manual on a CD ROM.

Resistor values can be calculated for fixed trim up, fixed trim down and for variable trim up or down cases for both 1st and 2nd Generation DC-DC converters.

In addition to trimming information, the web site and the applications manual on CD ROM, also includes design tips, applications circuits, EMC suggestions, thermal design guidelines and PDF data sheets for all available Vicor products.

Notes

Using Boosters to Expand Output Power

Overview

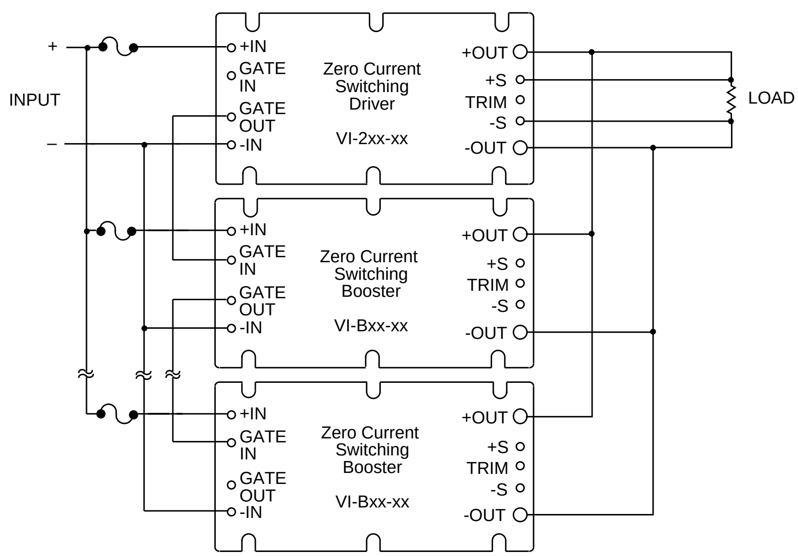
The VI-200 and MI-200 Family of DC-DC converters are available as driver or booster modules. The driver can be used as a standalone module, or in multi-kilowatt arrays by adding parallel boosters. Booster modules do not contain feedback or control circuitry, so it is necessary to connect the booster Gate In pin to the preceding driver or booster Gate Out, to synchronize operation. Drivers and boosters have identical power trains, although drivers close the voltage loop internally while boosters do not.

The concept behind driver/booster operation is that two power trains driven at the same frequency will inherently load-share if their outputs are tied together. Slaved modules require only one connection between units when their outputs are connected together; no trimming, adjustments or external components are required to achieve load sharing. The load sharing is dynamic and typically within 5 percent.

For additional information, see the heading *Electrical Considerations-High Power Arrays* in the *Chapter Module Do's and Don'ts*.

IMPORTANT: ***IT IS IMPORTANT TO REMEMBER THAT WHEN USING BOOSTERS, THE INPUT VOLTAGE, OUTPUT VOLTAGE AND OUTPUT POWER OF THE BOOSTERS MUST BE THE SAME AS THE DRIVER.***

Using Drivers with Boosters



Notes

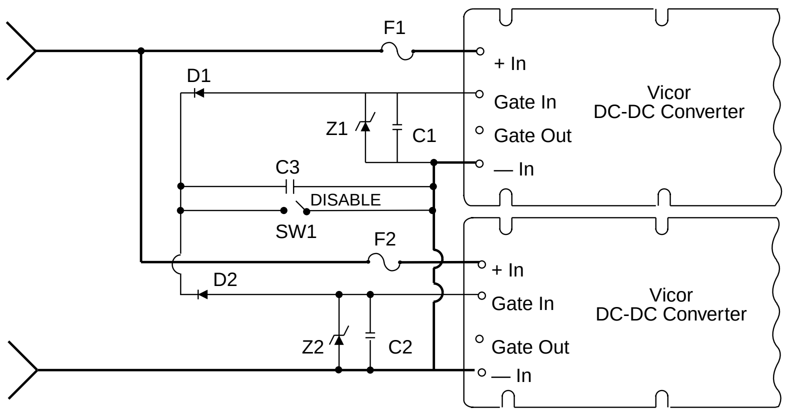
Multiple Gate-In Connections

Overview

A number of Gate In terminals may be connected for remote shutdown and logic disable (Figure 1). Diodes D1 and D2 provide isolation and prevent multiple failures if the Gate In of a module becomes shorted to the +input. The zener diodes Z1 and Z2 and capacitors C1 and C2 attenuate transient voltage spikes caused by differential inductance in the –input leg. Capacitors C1 and C2 will also lengthen turn-on time. SW1 is a mechanical or solid state switch that is used to disable both driver modules. C3 is used to minimize the effects of “switch bounce” associated with mechanical devices.

NOTE: Gate In voltage needs to be <0.65V referenced to $–V_{in}$ to ensure modules are disabled.

Figure 1.
Protection for Multiple Gate In Connections



C1, C2, C3 = 1 µF
Z1, Z2 = 15V (1N965A)
D1, D2 = Small signal diode (1N4148)*

*For bus voltages greater than 75V, a 1N4006 diode should be used.

NOTE: –Input leg should be kept as short as possible to minimize differential inductance. Heavy lines indicate power connections. Use suitably sized conductors.

Notes

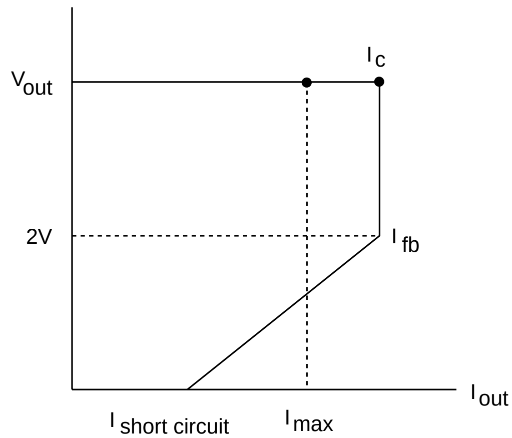
Overcurrent Protection

Foldback Current Limiting

The MI/VI-200 units with output voltages of 5V or less incorporate foldback current limiting (Figure 1). In this mode, the output voltage remains constant up to the current knee, $I_{current\ limit}$ (I_C), which is 5-25% greater than full-rated current, I_{max}. Beyond I_C, the output voltage falls along the vertical line I_C-I_{fb} until approximately 2V. At ≤2V, the voltage and current fall back along the foldback line I_{fb} to $I_{short\ circuit}$ (20% to 80% of I_{max}). Units will automatically recover when overcurrent is removed.

When bench testing modules with foldback current limiting, use a constant resistance load as opposed to a constant current load. Some constant current loads have the ability to pull full current to near zero Volts. This may cause a latchup condition.

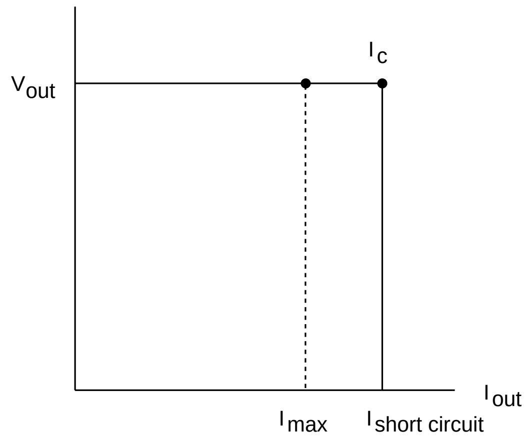
Figure 1. Foldback Current Limiting



Straight Line Current Limiting

The MI/VI-200s with output voltages greater than 5V and all MI/VI-J00s incorporate a straight-line type current limit (Figure 2). As output current is increased beyond I_{max}, the output voltage remains constant and within its specified limits up to a point, I_C, which is 5-25% greater than rated current, I_{max}. Beyond I_C, the output voltage falls along the vertical line to I_{SC}. Units will automatically recover after overcurrent is removed.

Figure 2. Straight-Line Current Limiting



Notes

Applications Circuits

Figure 1. Logic Disable

The Gate In pin of the module may be used to turn the module on or off. When Gate In is pulled low (<.65V @ 6 mA, referenced to $-V_{in}$), the module is turned off. When Gate In is floating (open collector), the module is turned on. The open circuit voltage of the Gate In pin is less than 10V. This applies to VI-200, VI-J00 and M modules (see Product Application Legend, page 9-3).

Figure 1.

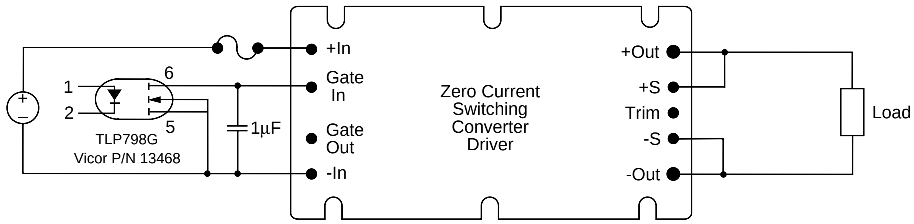


Figure 2. Output Voltage Programming

$$V_{out} = \frac{V_{trim} \times V_{nom}}{2.5V}$$

NOTE: Consult Vicor's Applications Engineering Department before attempting large signal applications at high repetition rates due to ripple current considerations in the output capacitors. This applies to VI-200, VI-J00, C, F and M modules (see Product Application Legend, page 9-3).

Figure 2.

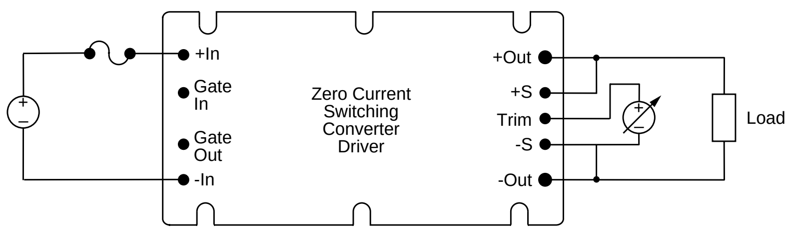


Figure 3. Negative Inputs (with positive ground)

NOTE: Vicor modules have isolated inputs and outputs making negative input configurations easy. Fusing the negative input instead of the positive is possible, provided any connections to the gate in /gate out are isolated. Refer to safety considerations in chapter 3 for more information.

Figure 3.

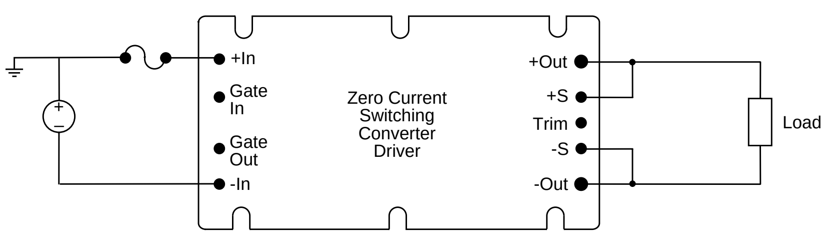


Figure 4. Remote Sensing

NOTE: Output voltage between +Out and –Out must be maintained below 110% of nominal. Do not exceed 0.25V drop in negative return as the current limit setpoint is moved out proportionately to the drop >0.25V. The sense must be closed at the module if remote sensing is not desired. Applies to VI-200, VI-J00, C, F, M, and MP modules (see page 9-3 for Product Application Legend).Long sense leads and/or capacitance at the load can result in module instability. Please consult Vicor applications for compensation methods.

Figure 4.

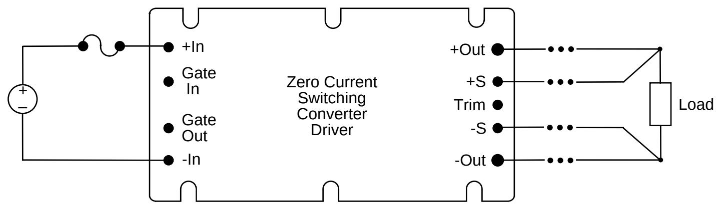


Figure 5. Parallel Boost

U.S. Patent #4,648,020 — other patents pending.

NOTE: To retain accurate power sharing between a driver and (n) number of boosters, provide adequate input and output power bussing. This applies to VI-200 and M modules (see page 9-3 for Product Application Legend). See module Do's and Don'ts (section 3) for recommended external components.

Figure 5.

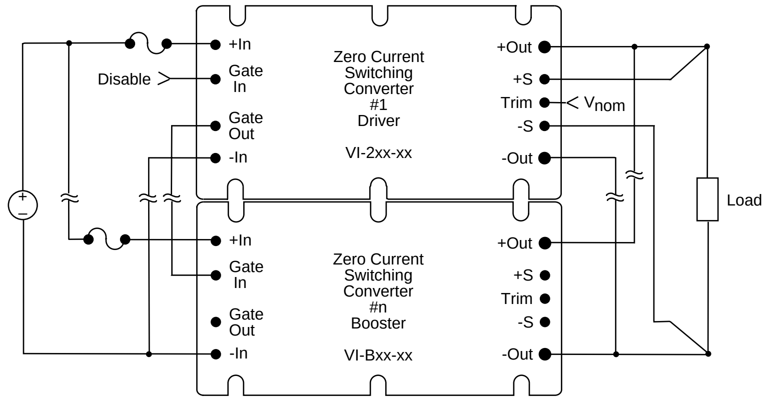
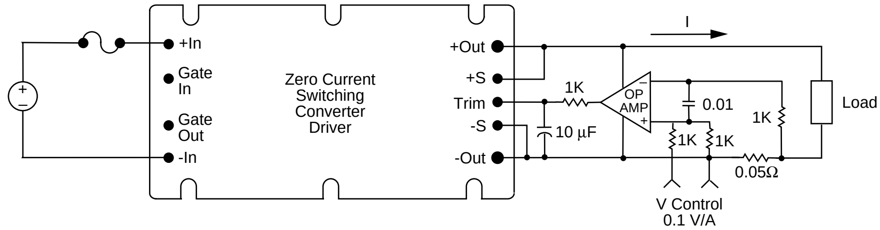


Figure 6. Programmable Current Source

V_{nom} not to exceed the rated voltage of the operational amplifier. This applies to VI-200, VI-J00, C, F and M modules (see page 9-3 for Product Application Legend).*

Figure 6.

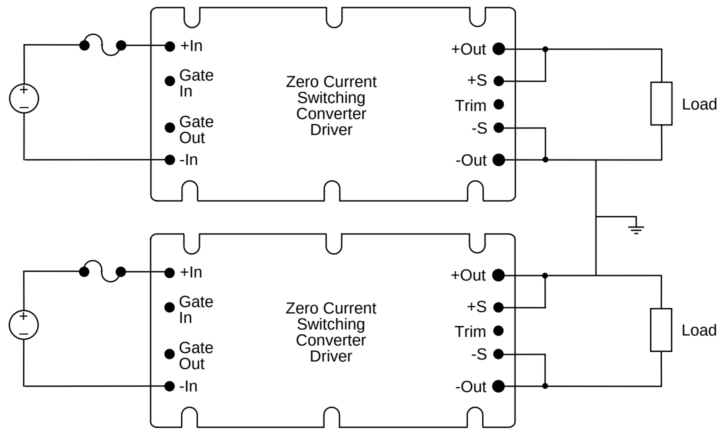


*When using a VI-J00 family module, the Trim pin voltage should be clamped to 2.75V to avoid damage to the module. This corresponds to the maximum trim up voltage.

Figure 7. Dual Output Voltage

Vicor modules have isolated outputs so they can easily be referenced to a common node creating positive and negative rails.

Figure 7.



Legend:

VI-200 (VI- and MI-200)
VI-J00 (VI- and MI-J00)
C (ComPAC and MI- ComPAC)
F (FlatPAC)
M (Mega Module and MI-Mega Module)
MP (MegaPAC and Mini MegaPAC)

Current Sharing in Power Arrays

Whenever power supplies or converters are operated in a parallel configuration—for higher output power, fault tolerance, or both—current sharing is an important consideration. Most current-sharing schemes employed with power converters involve analog approaches. One analog method artificially increases the output impedance of the converter modules, while another actually senses the output current of each module and forces all of the currents to be equal by feedback control.

Synchronous current sharing offers an alternative to analog techniques. In a synchronous scheme, there is no need for a current-sensing or current-measuring device on each module. Nor is there a need to artificially increase output impedance, which compromises load regulation.

There are advantages and disadvantages associated with each approach to current sharing. In choosing the best approach for a given application, designers should be aware of the tradeoffs as well as tips for implementing a successful design.

Most paralleled power components, such as transistors, rectifiers, power conversion modules, and offline power supplies, will not inherently share the load. With power converters, one or more of the converters will try to assume a disproportionate or excessive fraction of the load unless forced current-sharing control is designed into the system.

One converter, typically the one with the highest output voltage, may deliver current up to its current limit setting, which is beyond its rated maximum. Then, the voltage will drop to the point where another converter in the array—the one with the next highest voltage—will begin to deliver current. All of the converters in an array may deliver some current, but the load will be shared unequally. With built-in current limiting, one or more of the converters will deliver current up to the current limit (generally 15% or 20% above the module's rated maximum), while other converters in the array supply just a fraction of load.

Consider a situation where one module in a two-module array is providing all of the load. If it fails, the load on the second module must go from no load to full load. During that time, the output voltage is likely to droop temporarily. This could result in system problems, including shutdown or reset.

On the other hand, if both modules were sharing the load and one failed, the surviving module would experience a much less severe transient (one-half to full load). Also, the output voltage would be likely to experience no more than a slight momentary droop. The dynamic response characteristic of all forward converters, resonant or pulse-width modulated, is degraded when the load is stepped from zero (no load) where the output inductor current is discontinuous.

In the same two-module array example, the module carrying all of the load also is generating all of the heat. That results in a much lower mean time between failure for that module. An often-quoted rule of thumb says that for each 10°C increase in operating temperature, average component life is cut in half.

Current Sharing in Power Arrays (cont)

In a current-sharing system, the converters or supplies all run at the same temperature. This temperature is lower than that of the hot-running (heavily loaded) modules in a system without current sharing. Furthermore, same-temperature operation means that all of the modules in a current-sharing arrangement age equally.

Current sharing, then, is important because it improves system performance. It optimizes transient and dynamic response and minimizes thermal problems, which improves reliability and helps extend the lifetimes of all of the modules in an array. Current sharing is an essential ingredient in most systems that use multiple power supplies or converters to achieve higher output power or fault tolerance.

When parallel supplies or converters are used to increase power, current sharing is achieved through a number of approaches. One scheme simply adds resistance in series with the load. A more practical variant of that is the “droop-share” method, which actively causes the output voltage to drop in response to increasing load. Nevertheless, the two most commonly used approaches to paralleling converters for power expansion are driver/booster arrays and analog current-sharing control. They appear to be similar, but the implementation of each is quite different.

Driver/booster arrays usually contain one intelligent module or driver, and one or more power-train-only modules or boosters. Analog current-sharing control involves paralleling two or more identical modules, each containing intelligence.

One of the common methods of forcing load sharing in an array of parallel converters is to sense the output current of each converter and compare it to the average current. Then, the output of a given converter is adjusted so that its contribution is equal to the average. This is usually accomplished by current-sense resistors in series with the load, a sensing amplifier for each converter module, and a summing amplifier. Load sharing is accomplished by actively trimming the output voltage using trim or sense pins.

Occasionally, a designer is tempted to avoid the expense of a current-sense resistor by using the IR drops in the wire as a means of sensing the current. Unfortunately, there are a number of negative issues associated with that idea. First of all, there’s the temperature coefficient of copper. As the wire heats up, its resistance increases, negating its value as a stable current-sensing device. Second, there are oxidation and corrosion issues, which also cause parametric changes. Consequently, a high-precision current-sensing device, such as a precision resistor, is a must.

The resistor values typically range from a few milliohms up to about 100 mΩ, depending on the power level or current range of operation. Selecting the right value requires a tradeoff between power dissipation and sensitivity (signal-to-noise ratio or noise immunity). The larger the resistor value, the better the noise immunity—and the greater the power dissipation.

Determining the size of the resistor needed to generate a signal above the noise can be a bit tricky. Another potential pitfall with this (or, for that matter, any other) approach is the need for good electrical and mechanical design and layout. This requires adequate trace widths, minimized trace lengths, and decoupling to reduce noise. An experienced designer should have no difficulty with this, but it is an area rich with opportunities for error.

Current Sharing in Power Arrays (cont)

The droop-share method artificially increases the output impedance to force the currents to be equal. It's accomplished by injecting an error signal into the control loop of the converter, causing the output voltage to vary as a function of load current. As load current increases, output voltage decreases. All of the modules will deliver approximately the same current because they are all being summed into one node.

If one supply is delivering more current than another supply, its output voltage will be forced down a little so that it will be delivering equal current for an equal voltage at the summing node. A simple implementation of the droop-share scheme uses the voltage dropped across an auctioneering diode, which is proportional to current, to adjust the output voltage of the associated converter (Fig. 1).

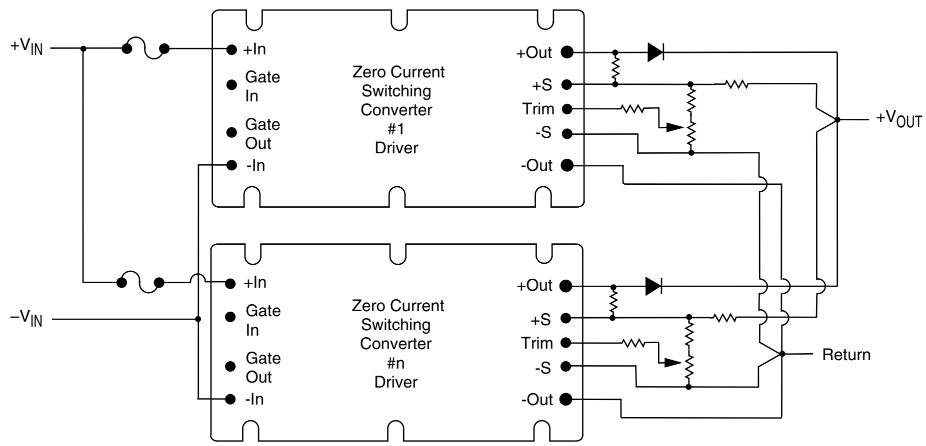


Figure 1. Droop-share current sharing artificially increases converter output impedance to force the currents to be equal. Diodes on the output of each converter provide current sensing and fault protection.

Droop share has advantages and disadvantages. One of the advantages is that it can work with any topology. It's also fairly simple and inexpensive to implement. A major drawback, though, is that it requires that the current be sensed. A current-sensing device is needed in each of the converters or power supplies. Additionally, a small penalty is paid in load regulation, though in many applications this isn't an issue.

In general, mixing and matching converters isn't recommended—especially those with incompatible current-sharing schemes. The droop-share method, however, is more forgiving in this regard than any of the other techniques. With a little external circuitry, current sharing can be achieved using arrays constructed from different converter models or even from different suppliers.

Current Sharing in Power Arrays (cont)

Most systems can employ the driver/booster (or master/slave) array for increased power (Fig. 2). The driver is used to set and control output voltage, while booster modules, as slaves to the master, are used to extend output power to meet system requirements.

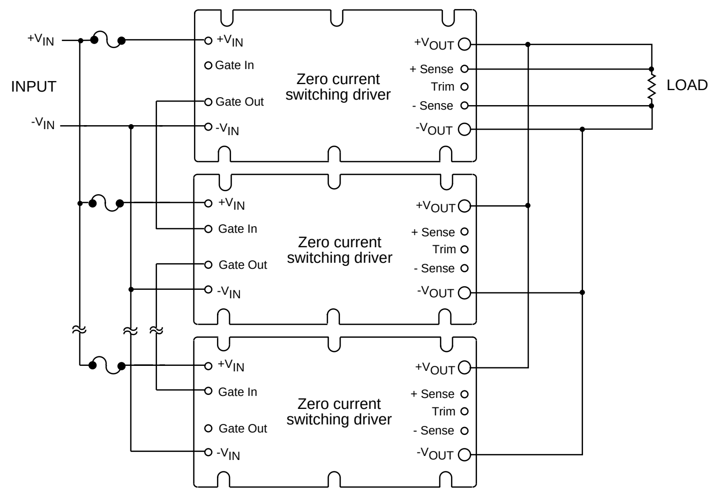


Figure 2. Most converters can use the driver/booster array to increase output power. Driver/booster arrays usually contain one intelligent module or driver, and one or more power-train-only modules or boosters.

Driver/booster arrays of quasi-resonant converters with identical power trains inherently current share because the per-pulse energy of each converter is the same. If the inputs and outputs are tied together and the units operate at the same frequency, all modules will deliver equal current (within component tolerances).

The single intelligent module in the array determines the transient response, which does not change as modules are added. Slaved modules require only one connection between units when their outputs are connected. No trimming, adjustments, or external components are required to achieve load sharing. The load sharing is dynamic and usually guaranteed within 5%. It's important to remember that when using boosters, the input and output voltage and output power specifications of the boosters must be the same as the driver.

Driver/booster arrays have two advantages. They have only a single control loop, so there are no loop-within-a-loop stability issues. And, they have excellent transient response. However, this arrangement isn't fault tolerant. If the driver module fails, the array won't maintain its output voltage.

Analog current-sharing control involves paralleling two or more identical modules, each containing intelligence. The circuit actively adjusts the output voltage of each supply so the multiple supplies deliver equal currents. This method, though, has a number of disadvantages. Each converter in the array has its own voltage regulation loop, and each requires a current-sensing device and current-control loop.

Current Sharing in Power Arrays (cont)

Analog current-sharing control does support a level of redundancy. But it's susceptible to single-point failures within the current-sharing bus that at best can defeat current sharing, and at worst can destroy every module in the array. The major reason for this is the single-wire galvanic connection between modules.

Current sharing is an essential element in fault-tolerant arrays. Yet regardless of the approach, there is an inherent cost incurred by the addition of at least one redundant converter or supply.

Incidentally, most applications today that require fault tolerance or redundancy also require hot-swap capability to ensure continuous system operation. Hot-swappable cards must be designed so the operator won't come in contact with dangerous potentials and currents.

It's also essential that when a module fails, the failure is detected and identified by an alarm or notice to provide service. A hot-swap system must ensure that during swap-out, there is minimal disturbance of the power bus. Specifically, the affected voltage bus must not drop enough to cause errors in the system, either on the input bus or the output bus.

A power-supply failure can cripple an entire system, so the addition of a redundant converter or supply is often justified by the need to keep the system operating. Adding an extra module (N+1) to a group of paralleled modules will significantly increase reliability with only a modest increase in cost.

The implementation of redundant converters is determined in part by the available space and cost requirements. For example, two 200W full-size modules could be used to provide a 400W output with an additional 200W module for 2+1 redundancy (a total of 600W in a volume of about 16.5 in.^{3}).

Alternatively, four 100W half-size modules might be used with a fifth 100W module to provide 4+1 redundancy (a total of 500W and 14 in.^{3}). Although the second solution uses less space, it increases the accumulated failure rate because it employs more converters, more OR'ing diodes, more monitoring circuitry, and more assembly.

OR'ing diodes may be inserted in series with the output of each module in an N+1 array to provide output fault tolerance (Fig.1). They're important in a redundant power system to maintain fault isolation. Without them, a short-circuit failure in the output of one converter could bring down the entire array.

But OR'ing diodes add losses to the power system, reducing overall efficiency and decreasing reliability. To ameliorate the negative effect on efficiency, OR'ing diodes should run hot, thereby reducing forward voltage drop and increasing efficiency. Reverse leakage current will be an issue only if the output of a converter shorts and the diode is reverse biased. This is an important consideration with regard to operating temperature.

EMC Considerations

VI-200/MI-200, VI-J00/MI-J00, Mega Modules

The DC Source

Vicor's DC-DC converters have several input ranges and are designed to accommodate the dynamic conditions common in computers, industrial control systems, military products, telecommunications products, and a variety of other applications. This section of Vicor's *Applications Manual* covers:

Conducted Noise

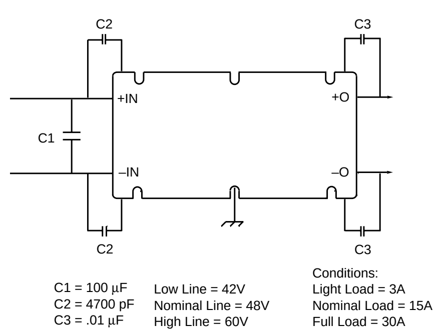
Conducted noise is the AC current flowing between the source voltage and the power supply. It includes both common mode and normal mode noise. Vicor zero-current-switching converters are 20 to 40 dB lower in conducted noise than a traditional board-mounted PWM converter; however, if a specific EMC specification such as FCC or VDE must be met, additional filtering may be required.

Since the noise generated is 10 to 100 times lower than fixed frequency converters, an existing filter should provide equal or better performance when the *Do's and Don'ts* in Section Three of this manual are adhered to.

In the event the system does not contain an existing filter, the following will provide valuable information relative to the attainment of system conducted noise objectives. System requirements, such as Tempest (military) or UL544/EN60601 (medical), require a somewhat different approach. Medical requirements vary as a function of the application and country — please call Vicor Applications Engineering for additional details.

Common Mode Noise

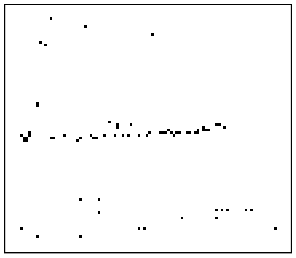
Figure 1.
Conducted Input Noise, No Additional Filtering



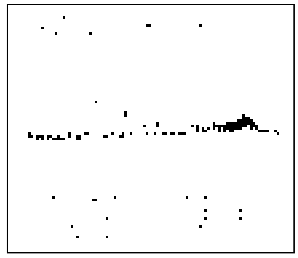
No Filtering
Typical Vicor Module, VI-230-CV
48V Input, 5V Output
Conducted Noise vs. Load

Conducted Noise (cont)

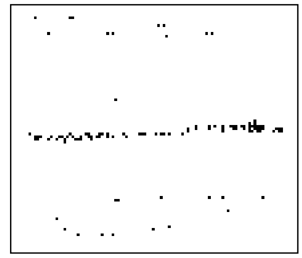
3 Amp Load



15 Amp Load



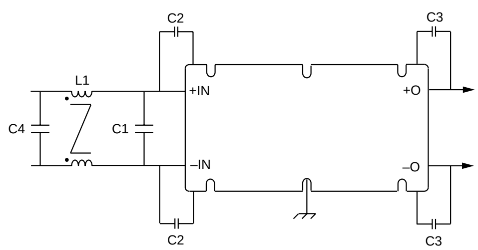
30 Amp Load



Common mode conducted noise current is the unidirectional (in phase) component in both the positive and negative inputs to the module. This current circulates from the converter via the power input leads to the DC source and returns to the converter via the grounded baseplate or output lead connections. This represents a potentially large loop cross-sectional area which, if not effectively controlled, can generate magnetic fields. Common mode noise is a function of the dv/dt across the main switch in the converter and the effective input to baseplate and input to output capacitance of the converter.

The most effective means to reduce common mode current is to bypass both input leads to the baseplate with "Y" capacitors (C2), keeping the leads short to reduce parasitic inductance. Additionally, a common mode choke (L1) is usually required to meet FCC/VDE A or B.

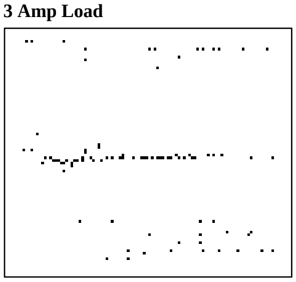
Figure 2.
Conducted Input Noise, with Common Mode Choke



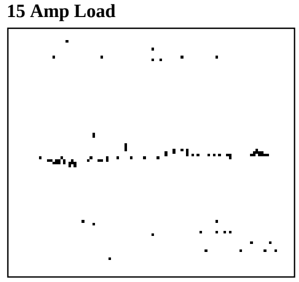
	Vicor Part #	Conditions:
C1 = 100 µF		
C2 = 4700 pF	01000	Light Load = 3A
C3 = .01 µF	04872	Nominal Load = 15A
C4 = 2.2 µF		Full Load = 30A
L1 = 3 mH	02133	

Common Mode Filter
Typical Vicor Module, VI-230-CV
48V Input, 5V Output
Conducted Noise vs. Load

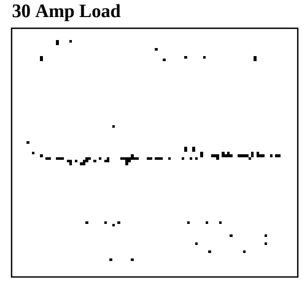
3 Amp Load



15 Amp Load



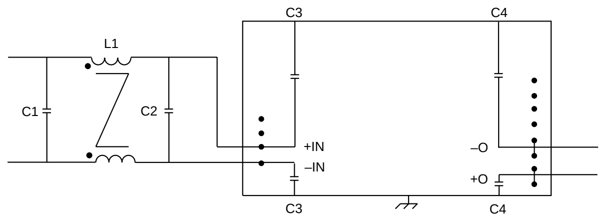
30 Amp Load



There are no special precautions that must be exercised in the design of input filters for Vicor converters. In fact, if the system contains an EMC filter designed for typical fixed frequency converters, it should be sufficient as is (although not optimal in terms of size), as zero-current-switching converters inherently generate significantly less conducted noise.

Conducted Noise (cont)

Figure 3.
Conducted Input Noise, Typical Fixed Frequency Converter with Filter



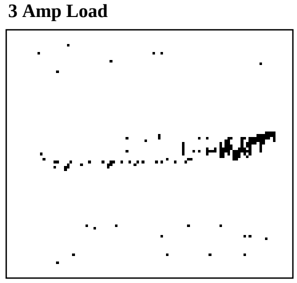
C1 = 2.2 µF
C2 = 100 µF
C3 = Internal
C4 = Internal
L1 = 3 mH

Conditions:

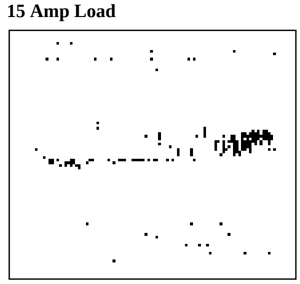
Light Load = 3A
Nominal Load = 15A
Full Load = 30A

Common Mode Filter
Typical Fixed Frequency Converter
48V Input, 5V Output
Conducted Noise vs. Load

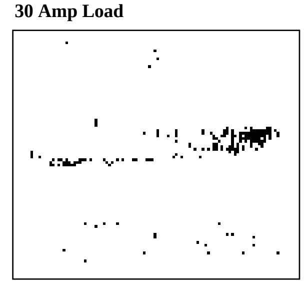
3 Amp Load



15 Amp Load



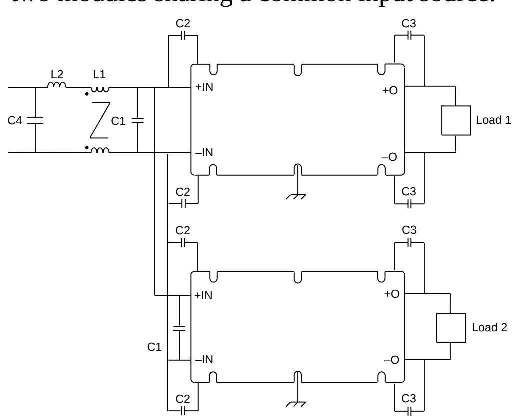
30 Amp Load



The previous plots are representative of fixed frequency converters with input filtering. Note that a fixed frequency converter generates more input conducted noise with a filter than Vicor's zero-current-switching converter without a filter. Also note that fixed frequency converters using a construction technique involving control circuitry on the same metal plate as power processing components will generate significantly more input noise than shown.

Conducted Noise with More than One Module
No special precautions are needed when using two or more modules. The filter required will have the same characteristics as a single module filter, however the wire size on the magnetics will need to reflect the increased input current. Shown below is the input conducted noise for two modules sharing a common input source.

Figure 4.
Conducted Noise, Multiple Zero-Current-Switching Converters



Vicor Part #

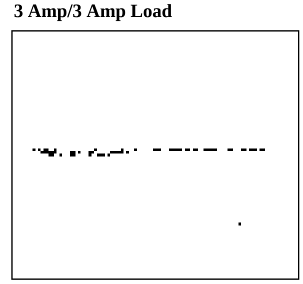
Conditions:

C1 = 47 µF
C2 = 4700 pF — 01000
C3 = .01 µF — 04872
C4 = 2.2 µF
L1 = 3 mH — 02133
L2 = 20 µH

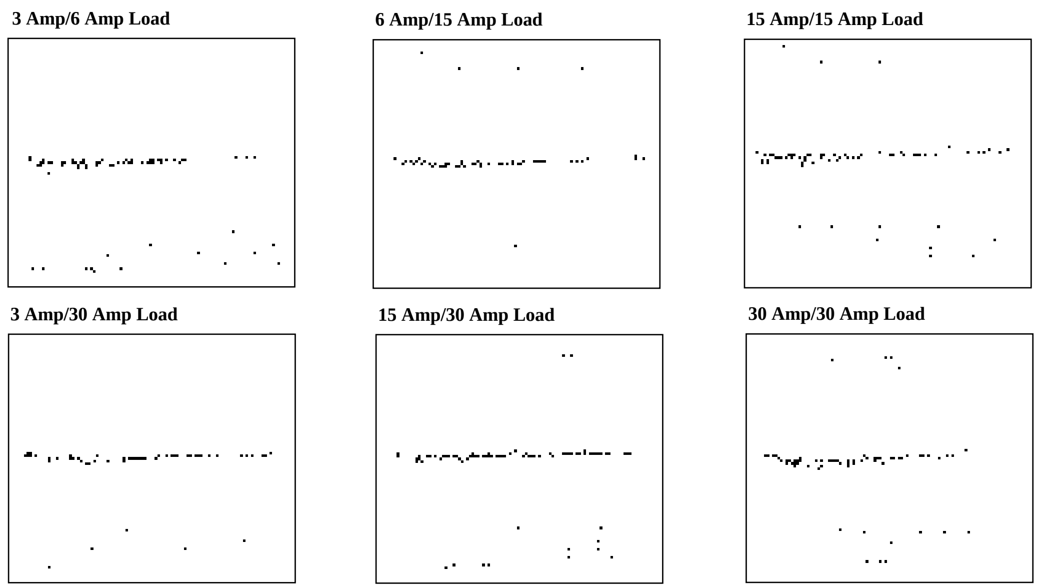
Light Load = 3A
Nominal Load = 15A
Full Load = 30A

Differential and Common Mode Filter
Two Vicor VI-230-CV Modules
48V Inputs, 5V Outputs
Conducted Noise vs. Load

3 Amp/3 Amp Load



Conducted Noise (cont)



Vicor offers three common mode chokes as standard accessories:

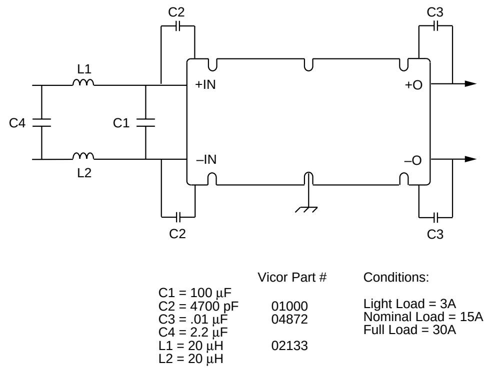
Part Number	Inductance Each Winding	Max. DC Current	Resistance Each Winding
02134	1000 µH	12 Amperes	6.5 mOhm
02133	3000 µH	7 Amperes	18 mOhm
05071	2163µH	1 Ampere	42 mOhm

Common mode filters may be common to one or more modules, but only one should be used with modules interconnected via Gate In's or, Gate Out to Gate In. As an example, driver/booster arrays or drivers with Gate Ins tied together to provide a common disable function.

Normal Mode Noise

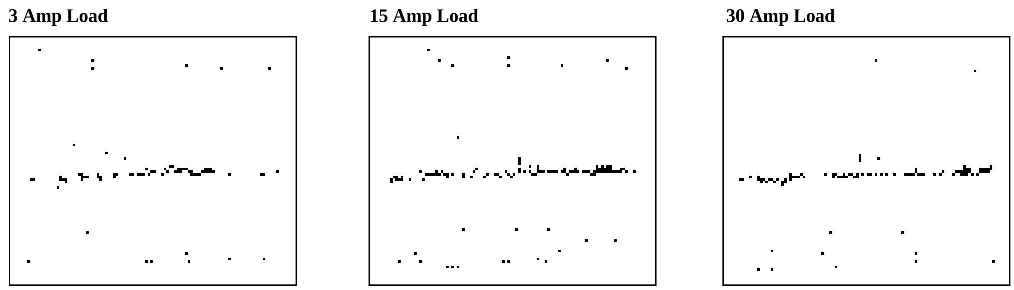
Normal mode conducted noise current is the component of current, at the input power terminal, which is opposite in direction or phase with respect to each other.

Figure 5. Conducted Noise, Normal Mode Filtering



Normal Mode Filter
Typical Vicor Module, VI-230-CV
48V Input, 5V Output
Conducted Noise vs. Loading

Conducted Noise (cont)



All Vicor converters have an internal normal mode LC filter which, in conjunction with a small external capacitor C1 (minimum value in µF = $400/V_{in}$), reduces normal mode conducted noise. The external capacitor should be placed close to the module to reduce loop cross-sectional area.

Care should be taken to reduce the loop cross-sectional area of normal mode current flowing between the source and C1. Since differential mode input current is by definition opposite in phase, twisting the input leads causes noise cancellation. PCB power planes can reduce radiated noise if the traces are on opposite sides of the PCB directly over one another. If normal mode inductance is used, it may be common to one or more modules.

Radiated Noise

Radiated noise may be either electric field or magnetic field. Magnetic radiation is caused by high di/dt's and is generally what is measured by FCC, VDE or MIL-STD-461. Vicor converters utilize zero-current-switching topologies, with the advantage over pulsewidth modulated non-zero-current-switching being that zero-current-switching topologies contain minimal discontinuities in the switched current waveforms, resulting in lower di/dt's. Electric field radiation (caused by dv/dt's) is "near-field," i.e., it decays quickly as a function of distance and as a result does not usually affect radiated measurements.

Radiation can be minimized by proper board layout. Keep all leads with AC current short, twisted or run as ground planes to minimize loop cross-sectional area.

Also keep in mind the effects of capacitive coupling — even when not expected. Don't put an unshielded filter on the opposite side of the PCB from the module. Conducted noise can be capacitively coupled around the filter. Don't run input and output leads in the same cable bundle — they'll end up talking to each other. Don't put a filter on each PCB and then run 20 feet of unshielded cable back to the power entrance. Again, no special precautions, just good design practices.

Noise Considerations

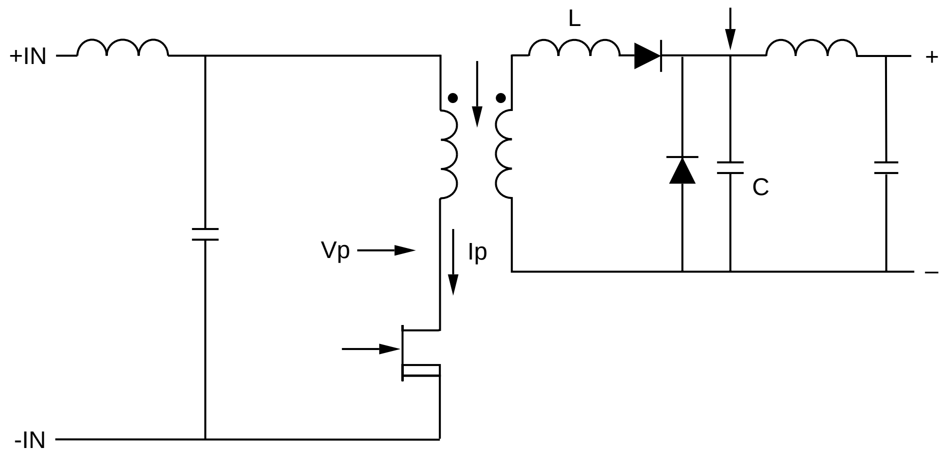
All switchmode power supplies generate a certain amount of "noise", yet it remains one of the least understood parameters in power conversion.

VI-200s and VI-J00s both use the same topology, so their operation is very similar. These products are zero-current-switching converters — i.e., the current is zero when the main switch is turned on or off. While the switch is on, the current through the switch or the primary of the

Noise Considerations (cont)

transformer is a half-wave rectified sine wave. Similar in operation to a resonant converter, these products are commonly referred to as quasi-resonant converters. The LC resonant frequency is fixed so the on-time of the switch is about 500 ns. When the switch turns on, energy builds up in the leakage inductance of the transformer (L) and then "transferred" into the capacitor on the secondary side of the module (C, Figure 6). The energy processed in each pulse is fixed, and is ultimately the energy stored in this capacitor, 1/2 CV^2. Since the energy in every pulse is fixed, the repetition rate of the pulse train is varied as a function of load to regulate the output voltage. Maximum repetition rate occurs at minimum line, full load and is approximately twice the LC time period or 1 µs. If the load drops by 50%, then the repetition rate is approximately one-half of maximum (since the energy in every pulse is fixed). Therefore the pulse repetition rate varies linearly with load, to a first order approximation.

Figure 6.



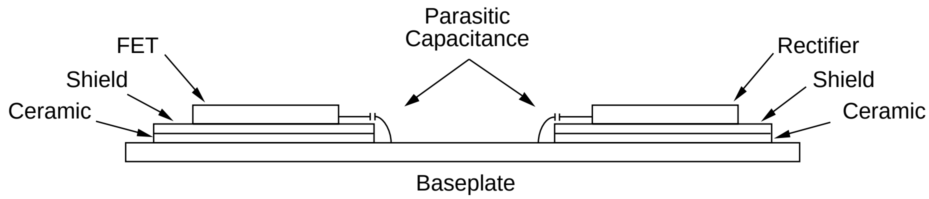
Since the energy in every pulse is related to the square of the applied voltage (CV^2), the pulse repetition rate varies as approximately the square of the line voltage. For example, a 300V input unit can vary from 200V to 400V, or a factor of two, therefore it follows that the repetition rate must vary by approximately a factor of four to regulate the output. As previously established, the current in the primary is a half-wave rectified sine wave, but the voltage on the primary is a square wave. Since this voltage is a square wave, it contains harmonics of the fundamental frequency. It also includes frequencies, that extends to 50 and 70 MHz.

These frequencies can be of interest in the following circumstances. Rapidly changing voltages (high dv/dt's) can generate E-fields (primarily near-field) which do not usually cause system noise problems since they decay quickly as a function of distance. For this reason, E-fields are not measured by agencies such as the FCC or VDE. These agencies do, however, measure the magnetic radiation caused by currents high frequency in a conductor electro. The half-wave rectified sine wave in the transformer is an example of this, but since there are no discontinuities in the current waveform and the loop cross-sectional area is very small, the resultant E-field is very small. E-fields can be a problem if sensitive circuitry is located near the module. In this case, a shield can be positioned under the epoxy side of the module as a discrete element or as a ground

Noise Considerations (cont)

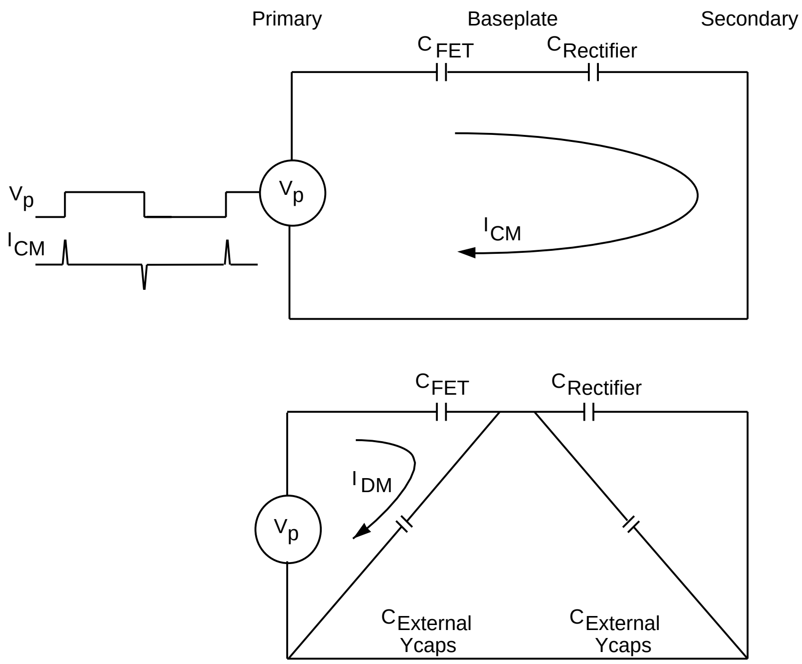
plane on the PC card under the base of the module. The other effect that occurs as a result of the 50-70 MHz component on the main switch is common-mode noise. This is best explained by the drawings below.

Figure 7. The shield layer serves to reduce the capacitance



The dv/dt of the switch (FET) is a generator. This FET is mounted on a two layer insulating and shielding assembly which is attached to the baseplate. Since ceramic is a dielectric, there is capacitance from the FET to the baseplate (Figure 7). The output rectifiers are also tied to the baseplate with ceramic insulators, adding additional capacitance. The dv/dt of the FET is differentiated by these two series capacitors, resulting in a spike of noise current at 50-70 MHz that flows from primary to secondary (Figure 8). This noise current is common-mode as opposed to differential, and therefore should not affect the operation of the system. It should be noted, however, that oscilloscopes have a finite ability to reject common-mode signals, and these signals can be worsened by the use of long ground leads on the scope probe.

Figure 8. Noise Coupling Model

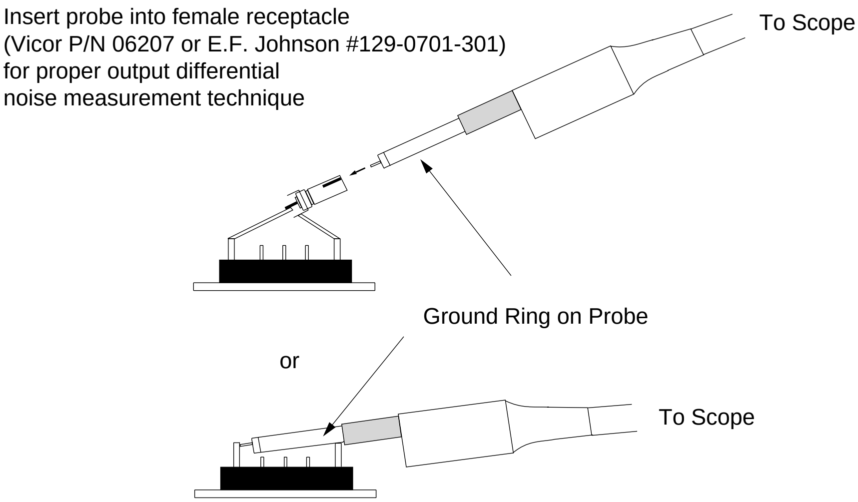


Noise Considerations (cont)

Long ground leads adversely impact the common-mode rejection capability of oscilloscopes because the ground lead has inductance not present on the signal lead. These differing impedances take common-mode signals and convert them to differential signals that show up on the trace. To check for common-mode noise, put the oscilloscope probe on the ground lead connection of the probe while the ground lead is tied to either output return or positive output (Figure 9). If the noise is common-mode, you will still see “noise” even though you are looking at the same point.

The capacitor that we recommend from the $-V_{in}$ to the baseplate shunts the common-mode current from $-V_{in}$ to the baseplate thus reducing noise current on the input power lines. Again, the capacitor must have very short leads since the frequency is high. It must also be a good capacitor (i.e., ceramic or other material that has a low ESR/ESL). This type of capacitor is most important on high input voltage units since the dv is larger, but is generally recommended for all units.

Figure 9.



We recommend a capacitor from $-V_{out}$ to the baseplate, since the output rectifier has a changing voltage on it, and, like the FET, can generate common-mode noise. This capacitor is similarly most important for high output voltage units (48V).

Again, common-mode noise is not differential with respect to the output. It does, however, flow in both input and output leads of the power supply and is a noise parameter that is measured by the FCC or VDE. It can cause power systems to fail conducted radiation tests, so it must be dealt with. We recommend bypass capacitors to the baseplate and a common-mode filter on the input of the module or the main input of the power supply.

The common-mode filter should be placed on the input side as opposed to the output side. Theoretically, since this current flows from primary to secondary, the choke could be placed in either the input or the output, but is usually placed in the input leads for the following reasons: 1) input currents are smaller since the input voltage is usually higher; 2) line regulation of the module can correct for voltage drops across the choke; and 3) if the choke is in the output and the senses are connected to the other side of it, the stability of the loop can be impacted.

Noise Considerations (cont)

Differential output noise is the AC component of the output voltage that is not common to both outputs. The noise is comprised of both low frequency, line-related noise (typically 120 Hz) and high frequency switching noise.

High Frequency Switching Noise

Peak-to-peak output voltage ripple is typically 2% or less (1% for 12V outputs and above). Hence additional output filtering is generally not required. Digital systems rarely need additional filtering. However some analog systems, such as front end ultrasound systems, will probably require additional output filtering. Additional output filter choices are as follows:

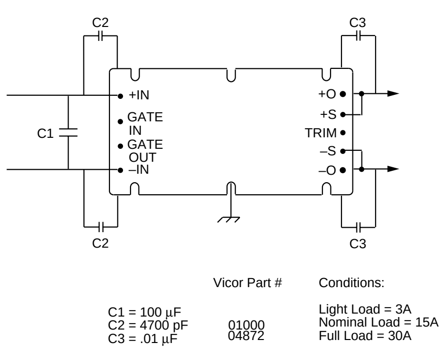
	5V Outputs	**12-15V Outputs**	**24-48V Outputs**
No Additional Filter	2% p-p Typ.	1% p-p Typ.	0.2% p-p Typ.
Low ESR Output Cap.	1% p-p Typ.	0.5% p-p Typ.	0.1% p-p Typ.
LC Output Filter	0.4% p-p Typ.	0.2% p-p Typ.	0.05% p-p Typ.
VI-RAM Filter(VI-200)	<3 mV p-p Max.	<3 mV p-p Max.	<3 mV p-p Max.
VI-RAM Filter(VI-J00)	<10 mV, any output	<10 mV, any output	<10 mV, any output

Line Related Output Noise

Line related output noise can be determined from the converter specification — Input Ripple Rejection. As an example, a VI-260-CV (300Vin to 5Vout) has a rejection specification at 120 Hz of 30 + 20 Log(V_{in}/V_o). V_{in} = 300 and V_o = 5, hence its rejection is 30 + 35.56 = 65.56 dB, which provides an attenuation factor of 1.89 k. Therefore if the input to the converter has 30V p-p of ripple, the output p-p ripple would be 15.8 mV. It is not practical to attenuate this component further with passive filtering due to its low frequency, hence active filtering is required. The VI-RAM contains both a passive filter for high frequency noise and an active filter for low frequency noise.

Differential Output Noise

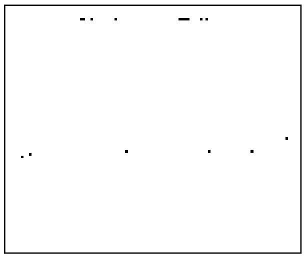
Figure 10. Output Noise, No Additional Output Filtering



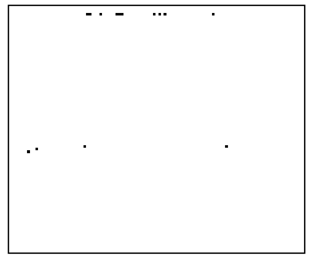
Normal Filtering
Typical Vicor Module
VI-230-CV
48V Input, 5V Output
Output Ripple vs. Load

Noise Considerations (cont)

3 Amp Load



15 Amp Load



30 Amp Load

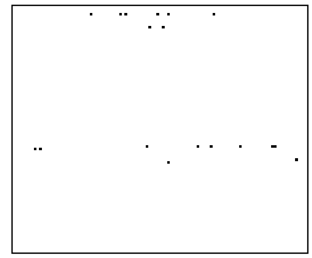
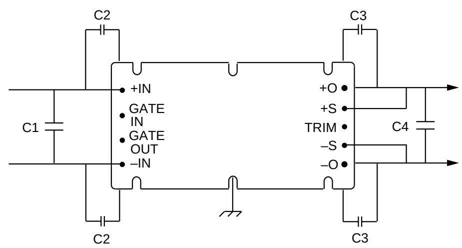


Figure 11. Output Noise, Additional Output Capacitance



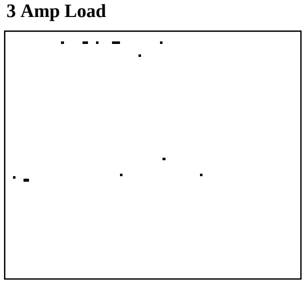
C1 = 100 µF
C2 = 4700 pF
C3 = .01 µF
C4 = 270 µF (Tant.)

Vicor Part #
01000
04872

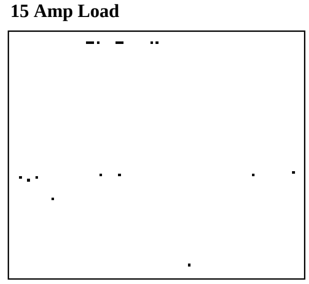
Conditions:
Light Load = 3A
Nominal Load = 15A
Full Load = 30A

Additional Output Capacitor
Typical Vicor Module
VI-230-CV
48V Input, 5V Output
Output Ripple vs. Load

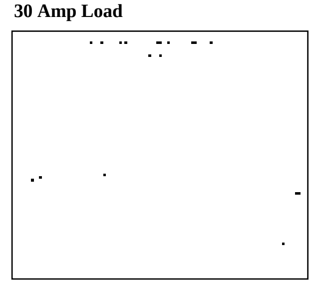
3 Amp Load



15 Amp Load



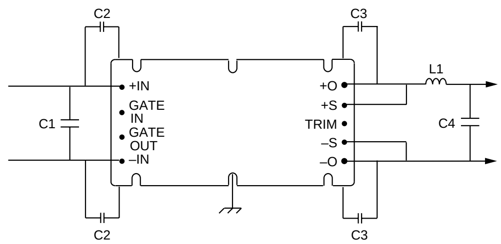
30 Amp Load



NOTE: A low ESR capacitor should be used, preferably tantalum.

Noise Considerations (cont)

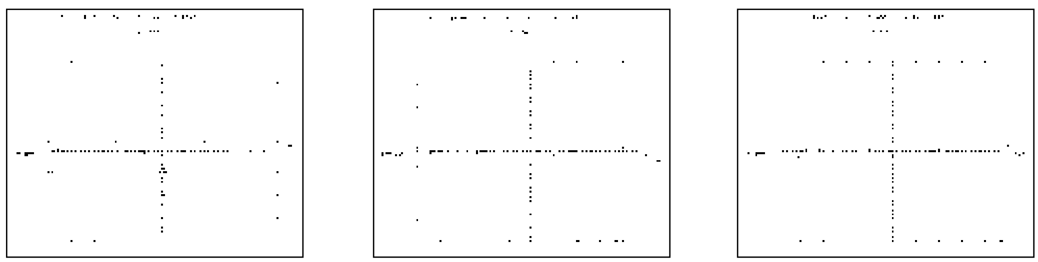
Figure 12.
Output Noise,
Additional Output
Inductor and Capacitor
(LC)



	Vicor Part #	Conditions:
C1 = 100 µF		Light Load = 3A
C2 = 4700 pF	01000	Nominal Load = 15A
C3 = .01 µF	04872	Full Load = 30A
C4 = 270 µF (Tant.)		
L1 = 110 nH	05298	

LC Output Filter
Typical Vicor Module
VI-230-CV
48V Input, 5V Output
Output Ripple vs. Load

3 Amp Load **15 Amp Load** **30 Amp Load**



NOTE: The inductor is Vicor P/N 05298 and the capacitor, preferably tantalum, should have a low ESR.

VI-RAM / MI-RAM Operation

The VI-RAM attenuates output noise in two ways. First, an LC filter in the VI-RAM attenuates high frequency components associated with the switching frequency. Secondly, the VI-RAM contains an active filter that attenuates low frequency components associated with the input to the converter. These frequencies are on the order of 60-120 Hz and harmonics would require very large output LCs if a passive approach were to be used. Essentially, the active circuit looks at the output ripple from the converter, multiplies it by –1 (inverts it) and adds it to the output. This effectively cancels out low frequency components.

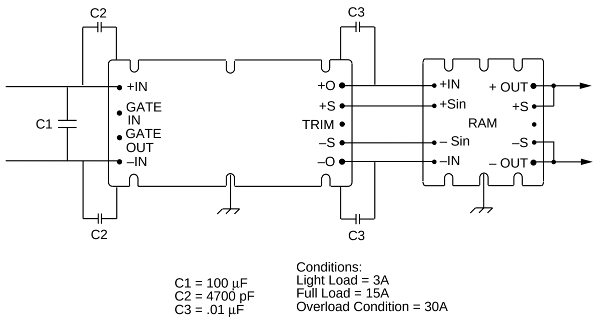
The VI-RAM does not contain any common-mode filtering, so whatever common-mode noise is present is passed through. It only provides differential filtering of noise that is present on one output pin relative to the other.

The use of the VI-RAM is very straightforward, but a couple of cautions should be noted. First, the LC filter is in the positive output leg, so that if that leg is shorted you will lose high frequency attenuation. Additionally, the active circuit is in the negative leg, so that if you short that leg, you will lose low frequency attenuation.

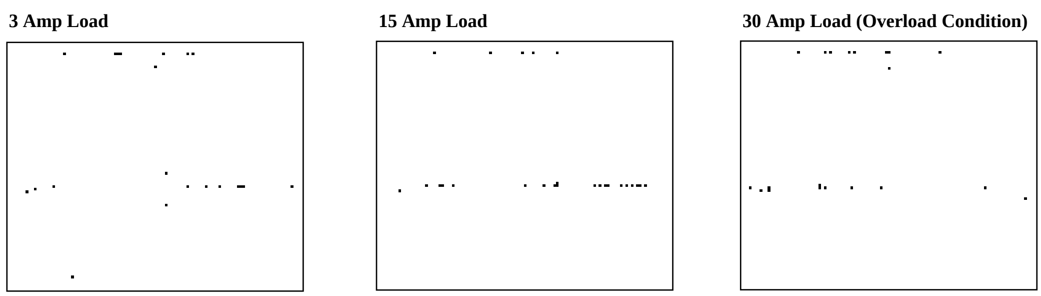
The VI-RAM is intended to be used with the Vicor VI-200, and VI-J00, and the MI-RAM is intended to be used with Vicor MI-200 and MI-J00 family of DC-DC converters.

VI-RAM Operation (cont)

Figure 13. Output Noise, with VI-RAM Ripple Attenuator Module



RAM Output Filter
Typical Vicor Module
VI-230-CV
48V Input, 5V Output
Output Ripple vs. Load
with VI-RAM-C2



NOTE: In addition to a passive filter similar to the above, the VI-RAM / MI-RAM contains an active filter to attenuate low frequencies associated with line harmonics. See section 15 for additional information on the VI-RAM / MI-RAM.

The BatMod™

Overview

The BatMod is a programmable current source module that can also be used as a constant voltage converter. It can be controlled externally to meet a wide range of charging parameters: voltage, current, charge rate and charge time.

The BatMod is comparable to the VI-200 voltage module with a variable current limit. It has three output terminals that differ from conventional voltage output converters: Current Control, Voltage Adjust and Current Monitor. All of these terminals are referenced to the –Out pin.

Although the BatMod is primarily intended for battery charge applications it can be used as a programmable current source for resistive loads or CW laser diodes. The BatMod will not function properly at zero output voltage and current simultaneously. It follows therefore that the current can not be adjusted to zero with a resistive load. *Refer to Safe Operating Area Curves on the BatMod spec sheet.*

Following is a description of the BatMod's pinout.

CURRENT ADJUST: CURRENT TRIM (ITRIM). An input signal with an analog voltage of 1 to 5V that can adjust the sourced current rating 0 to maximum rating.

5 Vdc		100% of Rating
↑	=	↑
1 Vdc		0 Amps

VOLTAGE ADJUST: VOLTAGE TRIM (VTRIM): An input signal that can be set for a maximum voltage with a fixed resistor or adjusted by an external voltage source. A source voltage referenced to the –Out of 1.25 to 2.5V for a 50% to 100% of rated voltage adjustment.

2.5 Vdc		Max. V_{out}
↑	=	↑
1.25 Vdc		50% of V_{out}

CURRENT MEASUREMENT: CURRENT MONITOR (IMON): An output signal that indicates the amount of current being sourced. It is a linear voltage/current relationship where one Volt corresponds to 0% of sourced current and 5V corresponds to 100% of sourced current.

5 Vdc		100% of Rating
↑	=	↑
1 Vdc		0 Amps

For DC input current sources (Figure 1, page 11-2), the modules have the same wide range input rating as VI-200 Family voltage converters for 48 and 300V inputs. BatMods can be used for higher current sources with a driver booster scheme (Figure 2, page 11-2).

NOTE: Inductance to the load should be limited to 20 µH to avoid possible loop instabilities.

Overview (cont)

Figure 1.
DC Input
Single Module

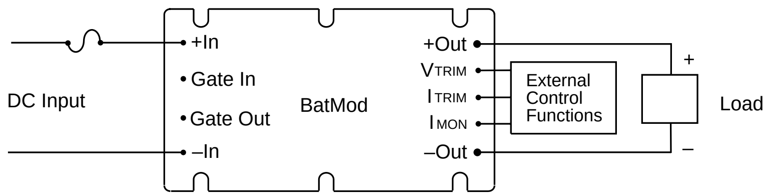
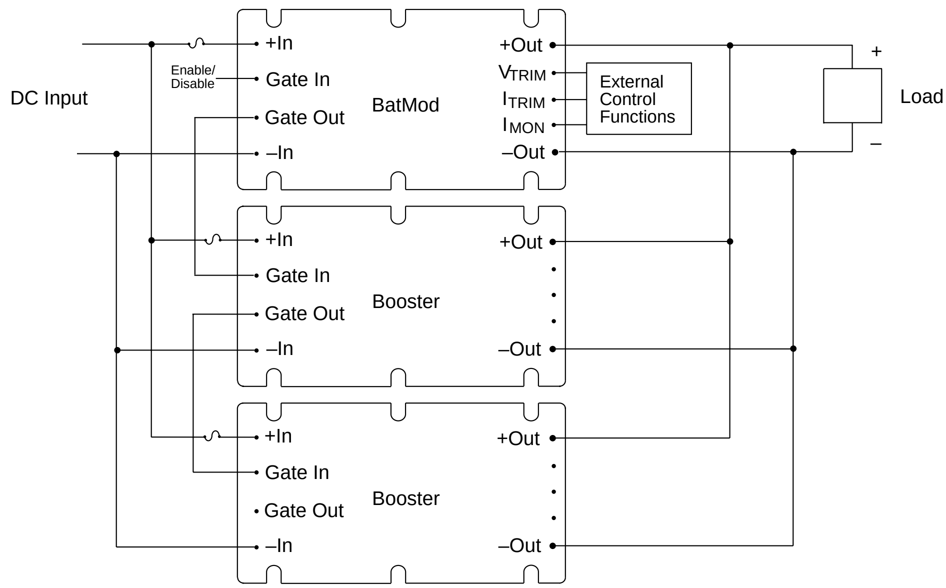


Figure 2.
DC Input
High Power Array



Designing a Battery Charger

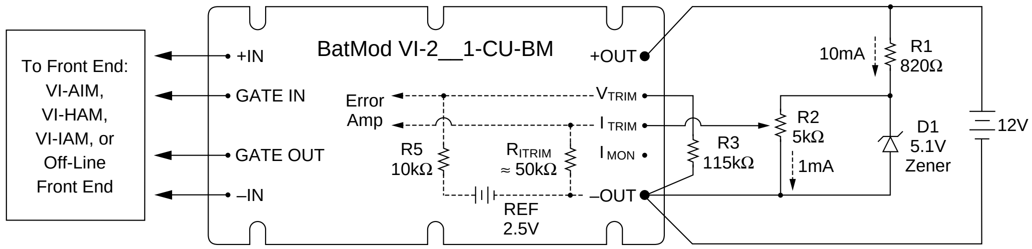
Vicor's BatMod current source module enables designers to easily build a compact, lightweight battery charging system with commonly available parts. The BatMod module provides programmable controlled current and voltage outputs and is ideal for applications involving standard input and output voltages. Because the BatMod allows the output voltage and the charge current to be set independently, the system design is greatly simplified.

Basic Battery Charger
Figure 3, page 11-3, shows a basic charging circuit with a BatMod module for the following system requirements:
Battery voltage: 12V
Float voltage: 13.8V
Charge current: Adjustable 0–14.5A

Setting the float voltage: Since the open circuit output of a 12V BatMod module (VI-2__1-CU-BM) is 15V, a trimming resistor (R3) is necessary to set a float voltage of 13.8V.

Designing a Battery Charger (cont)

Figure 3. Basic Charging Circuit Using a BatMod Current Source Module



To determine the value of R3, follow these steps:

Solve for V_{TRIM}:

$$\left(\frac{V_{FLOAT}}{V_{NOM}}\right) V_{REF} = V_{TRIM}$$

$$\left(\frac{13.8V}{15V}\right) 2.5V = 2.3V$$

• Solve for V_{R5}:

$V_{REF} – V_{TRIM} = V_{R5}$

2.5V – 2.3V = 0.2V

• Solve for I_{R5}:

$$I_{R5} = \frac{V_{R5}}{R5} = \frac{0.2V}{10\ k\Omega} = 20\ \mu A$$

• Solve for R3:

$$\frac{V_{TRIM}}{I_{R5}} = R3$$

$$\frac{2.3V}{20\ \mu A} = 115\ k\Omega$$

A 13.8V output requires a 115 kΩ resistor.

Setting the charge current: The charge current can be programmed from 0 to maximum (14.5A) by applying 1 to 5V to the I_{TRIM} pin. To determine the voltage required to produce a particular charge current, 10A for example, use the following formula:

$$4\left(\frac{\text{Desired Charge Current}}{\text{Maximum Output Current}}\right) + 1 = V_{ITRIM}$$

$$4\left(\frac{10A}{14.5A}\right) + 1 = 3.76V$$

To set the input to I_{TRIM} to 3.76V, adjust the potentiometer (R2) accordingly.

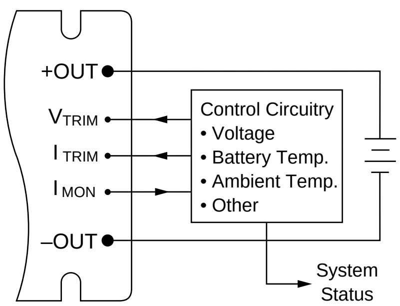
Designing a Battery Charger (cont)

The Figure 3 configuration will charge the battery at a maximum of 10A with a 13.8V float voltage. Other charge rates and float voltages may be similarly calculated. If a fixed charge current is desired, the potentiometer can be replaced with two fixed resistors. In applications requiring tight control over the charging current, D1 can be replaced with a precision reference.

Advanced Battery Charger

Many new battery technologies require sophisticated charging and monitoring systems to preserve their high performance and to extend their life. The BatMod serves as an ideal building block for constructing an advanced battery management system, which typically incorporates a microprocessor-based control circuit that is easily adapted for a variety of battery chemistries and monitoring functions (see Figure 4).

Figure 4.
The BatMod in an Advanced Battery Charging System



To maintain the optimum charge on the battery, the control circuit independently adjusts the float voltage and charge current in response to conditions during the charge: the battery's voltage, current, temperature and pressure, and other pertinent parameters. It can also relay battery status information such as capacity, charge and discharge history, and cause of failure.

With its wide range of outputs, the BatMod offers designers a simple, cost-effective solution to battery charging for all major battery types.

VI-AIM™/MI-AIM™ Alternating Input Module

Overview

In combination with VI-200 and VI-J00 Family modules and configured families of DC-DC converters, the Alternating Input Module provides a high density, low profile, universal AC input off-line switching power supply for systems requiring up to 200W of total output power. The VI-AIM accepts 85-264Vac, with a DC output voltage proportional to the peak value of the AC line. The input voltage required for the VI-AIM module to start operating is between 82V and 90Vrms (non-distorted).

Features of the VI-AIM

• Line Rectification	• Transient Protection	• Surge Protection
• EMC Filtering	• Inrush Limiting	• UL, CSA, TÜV Approval

The DC output of the VI-AIM is the peak rectified line ($Vac_{RMS} \times \sqrt{2}$), thus, 85Vac corresponds to 120Vdc and 264Vac corresponds to 373Vdc. Since the DC output range is wide, a “7” series DC-DC converter is normally used. However, the “5” series DC-DC converter is available for domestic AC inputs only and the “6” series for European AC inputs only, potentially reducing the number of modules required in some applications.

Summary of Compatible Modules

Use VI-x7x for inputs of 85-264Vac; VI-x6x for inputs of 170-264Vac; or VI-x5x for inputs of 85-135Vac. EMC filtering specifications of FCC level A are met by adding a 0.47 µF “X-type” capacitor to the input of the VI-AIM (Vicor Part #03047); “Y-type” bypass capacitors must also be added from the +/– inputs of the DC-DC converters to their respective baseplates, which are grounded (Vicor Part #00770, 1500 pF; Vicor Part #01000, 4700 pF). To select the capacitor appropriate for your application, (see *Selecting Capacitors for VI-AIM Modules* page 12-2).

The output ripple of the VI-AIM is a function of output load. It is necessary to keep the ripple less than 20V p-p to ensure the under/overvoltage protection circuits don’t trigger. A fully loaded VI-AIM (200W of module output power) requires a minimum of 680 µF of capacitance; holdup requirements can be met with this capacitor and maximum total capacitance should not exceed 1200 µF (refer to *Selecting Capacitors for VI-AIM Modules* on page 12-2). The voltage rating of this capacitor will be determined by the input operating voltage.

It is necessary to connect all DC-DC converter driver Gate In pins to the Gate In pin of the VI-AIM. This Gate In to Gate In connection is used to disable the converters at turn-on to allow proper start-up of the VI-AIM. The DC-DC converters are then enabled through the Gate In pin when the output bus voltage is in the range of 113-123Vdc. Input overvoltage conditions cause the Gate In pin of the VI-AIM to disable the converters when the output bus voltage is in the range of 406-423Vdc. Input undervoltage conditions cause the Gate In to disable the converters when the output bus voltage drops to 68-89Vdc.

CAUTION: The VI-AIM is not isolated. Do not put scope probes on input and output of VI-AIM simultaneously.

Summary of Compatible Modules (cont)

The Gate Out of the VI-AIM must be connected to the Gate Out of only one DC-DC converter. This input signal to the VI-AIM controls a charge pump (D1, D2, C2) that biases the gate of Q1, 10V above its source, which turns on Q1 to shunt out a PTC thermistor that limits inrush. Multiple DC-DC converters operating from an VI-AIM may make it impossible to guarantee a 10% load on the DC-DC converter that provides the Gate Out signal to the VI-AIM. In this instance, other DC-DC converters can charge pump the FET through the parallel pin, with the addition of two diodes and a capacitor to each driver module.

Figure 1. Block Diagram, VI-AIM

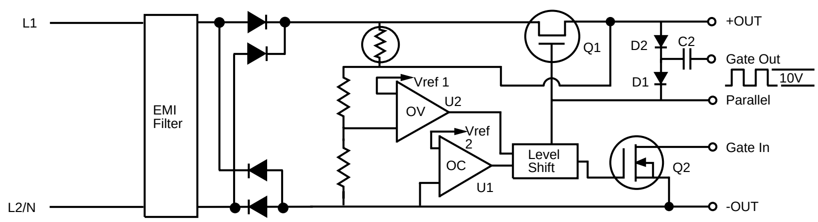
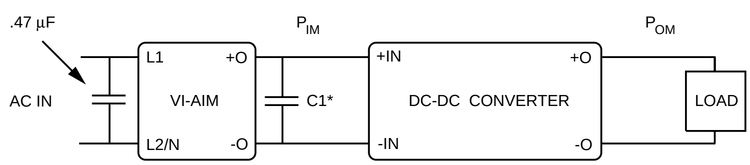


Figure 2. System Block Diagram (supervisory connections not shown)



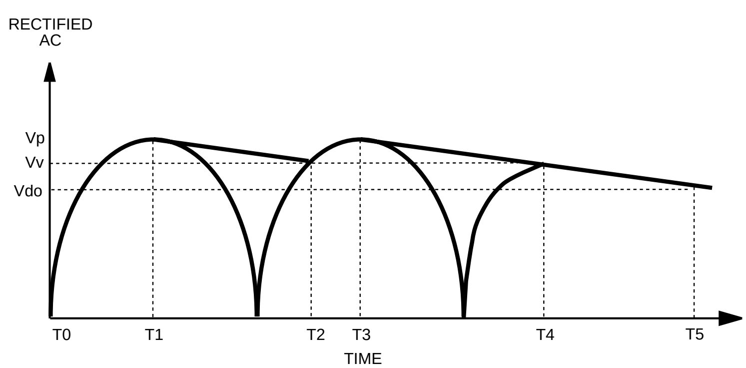
*C1 is a holdup capacitor necessary for proper operation of the VI-AIM. Holdup capacitors are available through Vicor Express.

Selecting Capacitors for VI-AIM

Holdup Time — General

For maximum flexibility, an external capacitor (Figure 2, C1) is used to set the system's holdup requirements. Holdup time, for purposes of this application note, is defined as the time interval from loss of AC power to the time a DC-DC converter begins to drop out of regulation (Figure 3, T4 to T5). Holdup time is a function of line voltage, holdup capacitance, output load, and that point on the AC waveform where the line drops out. For example, if the AC line fails just after the holdup capacitors were recharged, holdup time will be much greater (Figure 3, T3 to T5) than if the AC line fails just prior to another recharge (Figure 3, T4 to T5).

Figure 3. AC Waveforms



Selecting Capacitors for VI-AIM (cont)

The basic equations involved in calculating holdup time are:

$$\frac{1}{2} \times C1 \times V_p2 - \frac{1}{2} \times C1 \times V_{do}2 = P_{IM} \times (T5 - T3) \qquad (1)$$

solving for C1:

$$C1 = 2 \times \frac{P_{IM} \times (T5 - T3)}{V_p2 - V_{do}2} \qquad (2)$$

Where P_{IM} is power delivered from the VI-AIM:

$$P_{IM} = \frac{\text{Module Output Power}}{\text{Module Efficiency}} = \frac{P_{OM}}{\text{Eff }\%/100} \qquad (3)$$

The energy (Joules) delivered from the VI-AIM from the time power is lost (T4), until loss of an output (Figure 2, T5):

$$\text{Energy (Joules)} = P_{IM} \times (T5 - T4) \ \ (\text{Watt} - \text{Seconds}) \qquad (4)$$

where:
P_{OM} = Output power from all the modules
P_{IM} = Input power to the modules (output power from the VI-AIM)
Eff = Weighted average efficiency of all modules

The input power to the converter(s) during normal operation is supplied from the AC line during the conduction time of the rectifiers (T2 to T3) internal to the VI-AIM and by the energy stored in C1 when the rectifiers in the VI-AIM are reverse biased (T1 to T2). In the event of an AC failure (T4), C1 must continue to provide energy to the converters until either AC returns or the converter drops out (T5).

The energy stored in C1 at the peak of the AC is:

$$\frac{1}{2} \times C1 \times V_p2 = \text{Joules} \qquad (5)$$

The energy stored in C1 when the converter drops out of regulation is:

$$\frac{1}{2} \times C1 \times V_{do}2 = \text{Joules} \qquad (6)$$

The energy delivered by C1 to the converters during normal operation is:

$$P_{IM} \times (T2 - T1) = \text{Joules} \qquad (7)$$

Choosing Appropriate Values

Sample Calculation:

- Converter Output Power (P_{OM}) = 100W
- Line Frequency = 60 Hz
- Line Range = 105Vac to 264Vac
- Efficiency = 82%
- Desired Holdup Time = 5 ms Minimum

therefore:

- $P_{IM} = \frac{100}{0.82} = 122$ Watts
- T5 – T3 = 5 ms + 8.3 ms = 13.3ms (minimum holdup time plus half cycle)
- $V_p = 105 \times \sqrt{2} = 148V$
- $V_{do} = 100V$

and:

$$C1 = 2 \times \frac{122 \times .0133}{148^2 - 100^2}$$

C1 = 270 µF

where:

V_p = The peak of the rectified AC line or $\sqrt{2}$ x Vac_{in}. For an input range of 85 to 264Vac, this voltage will vary from 120V to 373V.

V_v = The low point of the rectified AC line under normal operating conditions. This “valley” voltage is a function of C1, P_{IM} and line frequency. The peak-to-peak ripple across C1 is Vp – V_v and determines the ripple current in C1. It is important to verify the rms ripple current in C1 with a current probe.

V_{do} = Voltage at which the DC-DC converter(s) begin(s) to drop out of regulation. This voltage is from the data sheet of the appropriate module, which for the VI-270 Family is 100Vdc. Under normal operating conditions, V_v must exceed V_{do}.

T1 = The peak of the rectified AC line or the point at which C1 is fully charged. For an input range of 85 to 264Vac, this voltage will vary from 120V to 373V.

T2 = The low point of the rectified AC line under normal operating conditions and the point at which C1 is about to be “recharged”. This is the point of lowest energy in C1.

T4 = The low point of the rectified AC line; the point of lowest energy in C1; the point at which if the AC line fails, holdup time is shortest, i.e., “worst case”.

T5 = The time at which the converter(s) drop out of regulation.

T5 – T4 = Minimum holdup time. Actual holdup time may vary up to a maximum of T5 – T3.

(T3 – T1) x 2 = One line cycle.

Choosing Appropriate Values (cont)

The following values are calculated in a similar manner:

Table 1.

Module(s)	60 Hz		50 Hz	
Delivered Power	90Vac	105Vac	90Vac	105Vac
50W	270 µF	135 µF	300 µF	150 µF
75W	400 µF	200 µF	440 µF	230 µF
100W	525 µF	270 µF	600 µF	300 µF
150W	800 µF	400 µF	890 µF	455 µF
200W	1000 µF	540 µF	1180 µF	600 µF

C1 values as a function of line voltage, frequency and delivered power, for use with 7-Series (90-264Vac) or 5-Series (90-132Vac) modules.

NOTE: With 7-Series modules operated over the line range from 90 to 264Vac, 400V capacitors **must be used** (Vicor P/N 08377). 5-Series modules used over the range of 90 to 132Vac should use 200V capacitors (Vicor P/N 08376).

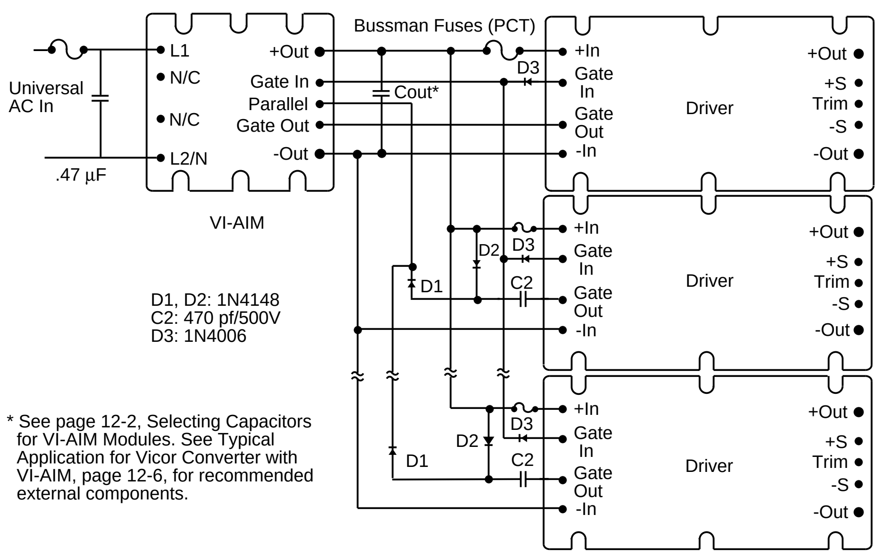
Table 2.

Module(s)	60 Hz		50 Hz	
Delivered Power	180Vac	210Vac	180Vac	210Vac
50W	66 µF	34 µF	74 µF	38 µF
75W	100 µF	50 µF	110 µF	60 µF
100W	130 µF	67 µF	150 µF	75 µF
150W	200 µF	100 µF	220 µF	115 µF
200W	262 µF	135 µF	300 µF	150 µF

Cl values as a function of line voltage, frequency and delivered power, for use with 6-Series (180-264Vac) modules.

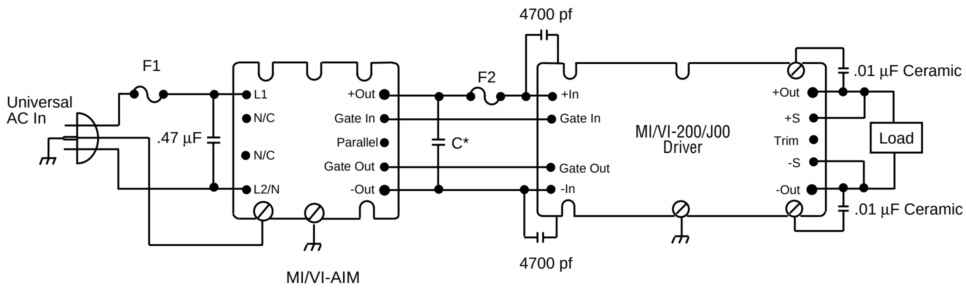
NOTE: With 6-Series modules operated over the line range from 180 to 264Vac, 400V capacitors **must be used** (Vicor P/N 08377).

Figure 4. VI-AIM Connection Diagram, Multiple Driver Modules



Choosing Appropriate Values (cont)

Figure 5.
Typical Application for Vicor Converter with VI-AIM



* Consult factory or see Vicor's Applications Manual, page 12-2, Selecting Capacitors for VI-AIM Modules.

Fuse 1: 6.3A/250V (IEC 5X20 mm) Buss GDB-6.3 or 7A/250V (3AG 1/4" x 1 1/4") Littlefuse 314-007
Fuse 2: For VI-X7X-XX — Buss PC-Tron 2.5A (250V)
For VI-X6X-XX — Buss PC-Tron 3A (250V)
For VI-X5X-XX — Buss PC-Tron 5A

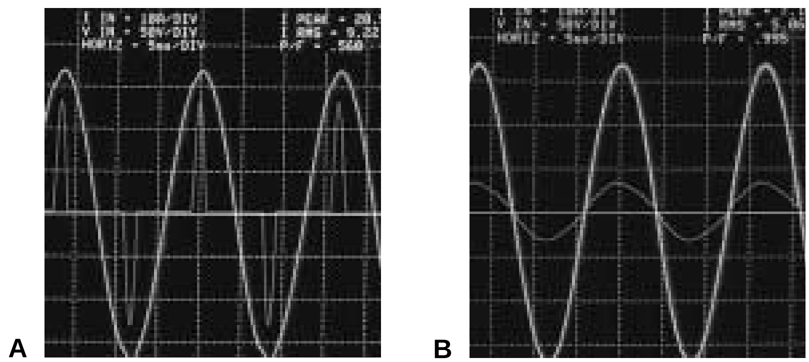
VI-HAM Harmonic Attenuator Module

(includes VI-HAM, VI-HAMD and VI-BAMD)

Overview

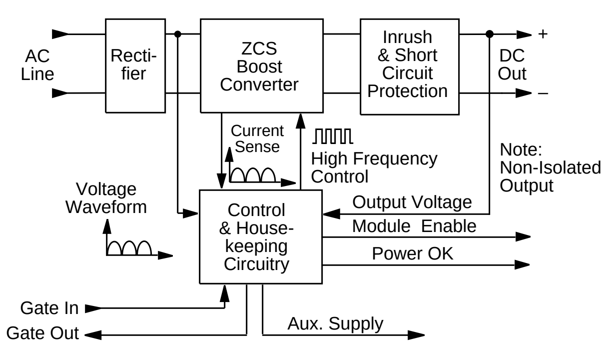
Conventional capacitive-input front ends draw energy from the AC line in short bursts of current at the peaks of the line voltage waveform. These current bursts are characterized by high peak currents and high harmonic content. The effect of the distorted line current can be appreciated by measuring the rms line current drawn by a conventional front end: the product of the measured rms current and the rms line voltage — the "apparent power" being delivered by the line — will be significantly greater (typically 1.6X) than the DC power delivered by the front end. The "extra" rms current at the input is circulating harmonic currents which deliver no power to the load but which flow in the delivery system and contribute to losses. Only the fundamental component of the line current contributes to "real" power flow. Power factor — the ratio of "real" to "apparent" power — is a measure of the effectiveness with which an AC load can extract usable power from an AC source.

Figure 1. Oscilloscope Photos Showing Input Voltage and Current Without Power Factor Correction (A) and With Power Factor Correction (B).



The VI-HAM (see Figure 2) consists of a full-wave rectifier, a proprietary high-frequency zero-current switching boost regulator, active inrush and short-circuit protection circuitry, and control and housekeeping circuitry. The incoming AC line is rectified and fed to the ZCS boost converter. The control circuitry varies the operating frequency of the ZCS boost converter so as to simultaneously maintain the output voltage of the VI-HAM at a DC voltage value above the peak of the incoming line, while forcing the input current to the ZCS converter to follow the waveshape of the rectified line. By this means, the AC input current follows the AC voltage waveform and a power factor better than 0.99 is achieved. Operating efficiency of the ZCS boost converter is optimized at any incoming line voltage by a proprietary adaptive output voltage control scheme.

Figure 2. VI-HAM Block Diagram



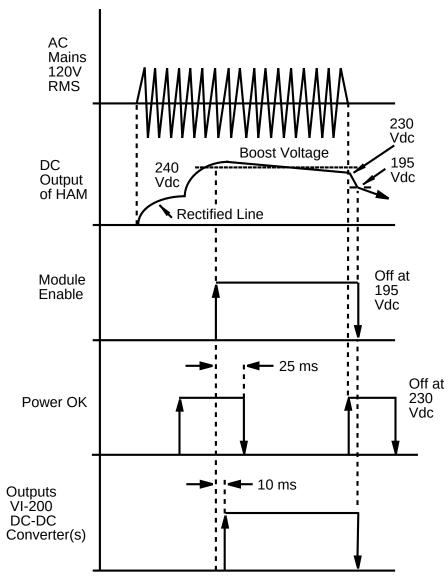
NOTE: No input to output isolation.

The VI-HAM also includes active circuitry which controls inrush currents when power is applied and active short circuit protection circuitry — features not normally found in conventional power factor correctors.

Overview (cont)

Housekeeping circuitry provides two signals of use to the system designer (see Figure 2): Module Enable and Power OK. Referencing the timing diagram below, the Module Enable signal, which is connected to the Gate In inputs of the Vicor DC-DC converters powered by the VI-HAM, will come high and enable the DC-DC converters when the VI-HAM output voltage exceeds 240Vdc. The DC-DC converter voltage outputs will be up approximately 10 ms after Module Enable goes high. Typically, 20 ms after Module Enable goes high the VI-HAM Power OK signal, which can be used by the system designer to enable circuitry powered by the DC-DC converter modules, also goes low. On loss of power or brownout, the Power OK signal will go low when the VI-HAM DC output voltage drops below 230V, signaling an impending loss of input power to the converter modules. When the DC output dips below 195V, the Module Enable signal will toggle low, disabling the converter modules and unloading the VI-HAM. The VI-HAM will provide at least 16 ms of ride-through or holdup time, and at least 5 ms of AC fail warning time with a 1000 µF output capacitor.

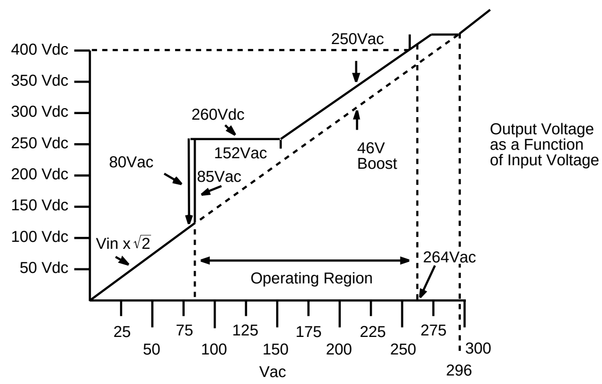
Figure 3.
Functional Timing Diagram



Active power factor correctors incorporate a boost regulator which must operate over a range of incoming AC line voltages. Conventionally, the output voltage of the boost regulator is set to a value greater than the maximum anticipated peak value of the incoming AC line. Thus, if the power factor corrector must operate on line voltages up to 264V rms, the boost regulator output might typically be set to a value greater than 373V ($\sqrt{2}$ x 264); for example, 415V. Unfortunately, while this works well for operation on most European lines (e.g. 220Vac), a penalty is paid when such a unit is operated on domestic lines (120Vac). This is because the efficiency of any boost regulator can be shown to be first-order dependent upon the degree to which it must boost. In other words, the greater the difference between the input and output voltage the poorer the efficiency of the boost regulator. Operating a power factor corrector with an output voltage setting of 415V on a 120Vac line will result in significant efficiency degradation — and more heat losses and thermal stresses — than if the unit were operated on a 220Vac line. We call this the “domestic disadvantage”; it translates directly into wasted energy!

Overview (cont)

Figure 4.
Input Voltage vs.
Output Voltage

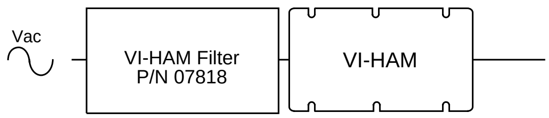


Vicor overcomes the "domestic disadvantage" by varying the output voltage of the VI-HAM as a function of incoming AC line voltage. On a nominal 120Vac line the output voltage of the VI-HAM is 260Vdc — well within the input operating voltage range of standard Vicor converters. As input line increases, so does the VI-HAM output voltage; at 220Vac the delivered voltage will be about 350V. For any given input line voltage, the VI-HAM maintains enough headroom between the output voltage and peak input voltage to ensure high quality active power factor correction without unnecessarily sacrificing operating efficiency and wasting energy. Another good reason for not running at a constant high value of output voltage is that since the DC-DC converter loads can operate off of a wide voltage range, reducing the power factor corrector output voltage as a function of line voltage also reduces voltage stresses on DC-DC converter circuitry.

Filter Requirements

The VI-HAM requires an external filter (Figure 5) or equivalent design. In addition this filter enables the VI-HAM to meet the following international standards EN55022, VDE 0878 and VFG243. To meet IEC 60801-5 Level 3 requires the addition of MOV, P/N 03040. Other filters are in development.

Figure 5.
VI-HAM-CM



Safety Note: All VI-HAM configurations must be preceded by an appropriately rated fast-blow 3AG fuse ahead of the line filter. This fuse would be a 10A for a single VI-HAM connected to line. For fusing information on other VI-HAM configurations, please contact Vicor's Applications Engineering Department.

VI-HAM Configurations

VI-HAM-CM — Driver VI-HAM: Fully configured power factor correcting front end.

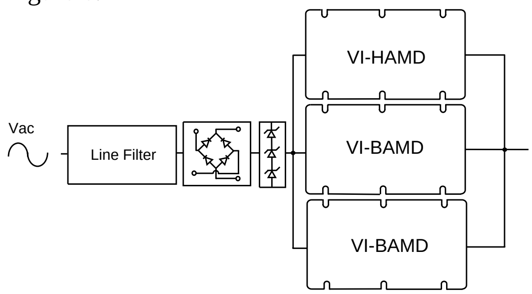
VI-HAMD-CM — Driver VI-HAM: No internal bridge rectifier or synchronization diodes.

VI-BAMD-CM — Booster VI-HAM: Companion module to VI-HAMD-CM used for additional output power. No internal bridge rectifier.

VI-HAM Configurations (cont)

Use the VI-HAM-CM for applications requiring up to 600W from the front end. For applications in excess of 600W, power can be added in 600W increments with booster VI-HAMs. It is not possible to simply parallel two driver VI-HAMs due to conflicting control loops. Gate Out to Gate In connections on respective driver/boosters are used to ensure that the power train of the VI-HAMs current-share. However, this does not ensure that the diodes in the lower half of the bridge rectifier will current-share. A solution for this situation is illustrated in Figure 6.

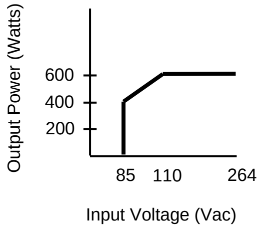
Figure 6. VI-HAMD with Booster VI-HAMs (VI-BAMDs) (No Internal Bridge Rectifier)



A solution to bridge current sharing issues is to remove the bridge rectifier from each VI-HAM and use one diode bridge sized to handle the entire load. Approximately 25% of the heat is removed from the VI-HAM in this approach; use a VI-HAMD-CM with one or more VI-BAMD-CMs.

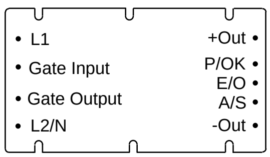
Derating Curves, Pinout — VI-HAM/VI-HAMD

Figure 8.
VI-HAM/VI-HAMD
Derating Curve



Prod. Grade	Baseplate Temp.	Storage Temp.	Model
E	-10°C to +85°C	-20°C to +100°C	VI-HAM-EM
C	–25˚C to +85˚C	–40˚C to +100˚C	VI-HAM-CM
I	–40˚C to +85˚C	–55˚C to +100˚C	VI-HAM-IM
M	–55˚C to +85˚C	–65˚C to +100˚C	VI-HAM-MM

Figure 9.
VI-HAM Pinout
*(Top View)**



* See page 13-9 for pin ID of VI-HAMD and VI-BAMD.

Pin	Description/Status (VI-HAM Only)
L1	AC mains; must be connected
Gate Input	Turns boost on/off; no connection necessary
Gate Output	Synchronizing function; may be connected
L2/N	AC mains neutral; must be connected
+Output (+Out)	Positive DC output; must be connected
Power OK (P/OK)	AC status indicator; may be connected
Enable (E/O)	Disables converter; must be connected
Aux. Supply (A/S)	Output of 20V@ 3 mA; may be connected
–Output (–Out)	Negative DC output; must be connected

Connecting the VI-HAM/VI-HAMD

The VI-HAM must be used in conjunction with a specific line filter, Vicor’s P/N 07818 or equivalent (consult factory), appropriate output holdup capacitor(s) and Vicor DC-DC converters (Figure 10). Connect single phase AC mains to the input of the line filter via a standard 10 Amp AC fuse. Connect the output of the filter to L1 and L2/N of the VI-HAM. Do not put an X capacitor across the input of the VI-HAM or use a line filter with an X capacitor on its output as power factor correction may be impacted. Connect the +Output of the VI-HAM to the +Input of the converters via a 3 Amp PC Tron DC fuse. Connect the –Output of the VI-HAM to the –Input of the converters. Connect a 1000 µF electrolytic capacitor rated at a minimum of 450Vdc across the + and –Output of the VI-HAM (or 500 µF for 300W, etc). This capacitor must be in close proximity to the VI-HAM. Connect the Enable Output of the VI-HAM to the Gate Input of each driver converter to disable the converters until the output of the VI-HAM is within normal operating range. Please refer to Section 3, *Module Do’s and Don’ts*, for information on the proper connection of the DC-DC converters.

The above connections are the minimum required. In addition, there are other features available. The Auxiliary Supply output is approximately 20V at 3 mA max. This output is usually used in conjunction with the Power OK signal. Care must be taken not to overload or short the Aux. Supply output. Power OK provides an indication of the status of the DC output and the AC mains. See *Functional Description*, page 13-6, for a more detailed discussion of these features.

Connecting the VI-HAM, VI-HAMD/VI-BAMD

Figure 10.
Connection Diagram,
VI-HAM

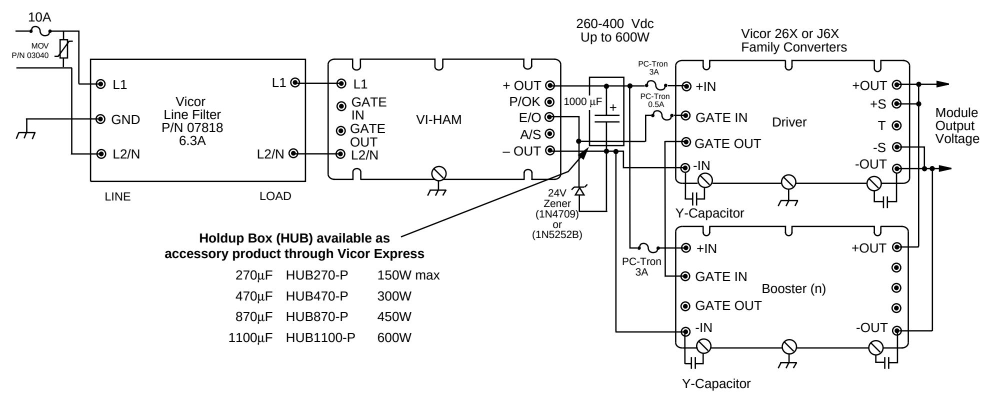
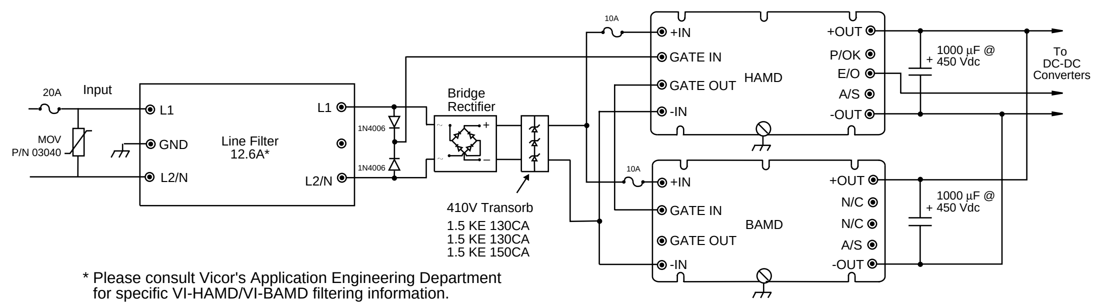


Figure 11.
Connection Diagram,
HAMD/BAMD



Functional Description

L1 and L2/N (VI-HAM):
These pins are to be connected to the AC mains output of a suitable EMC filter. Do not connect an X capacitor across these pins as power factor correction will be slightly degraded.

+IN, –IN (VI-HAMD, VI-BAMD):
These pins are connected to the output of the external bridge rectifier.

Gate Input (VI-HAM):
This pin disables the boost converter only. Rectified line voltage may still be present at the module output. *This pin does not provide the same function as the gate input pin of I-200/VI-J00 modules.* The user should not make any connection to this pin.

Gate Input (VI-HAMD):
This pin serves as a line voltage reference pin for power factor correction and synchronization to line. Connection must be made through diodes between the line filter and bridge rectifier (see Figure 10).

Gate Input (VI-BAMD):
The Gate Input pin is an interface pin to the Gate Out pin of a VI-HAMD or VI-BAMD depending on configuration. The user should not make any other connection to this pin. It is necessary to connect the VI-BAMD Gate In pin to the Gate Out pin of the preceding VI-HAMD or VI-BAMD.

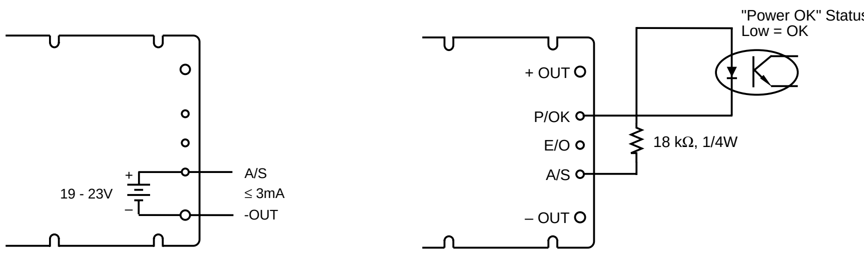
Functional Description (cont)

Gate Output (VI-HAMD, VI-BAMD):
The Gate Output pin is an interface pin to BAMDs, depending on configuration. The user should not make any other connection to this pin. No connection for VI-HAM.

+Output and –Output and Holdup Capacitor:
These outputs should be connected to the respective inputs of Vicor DC-DC converters. In addition, an external holdup capacitor of 1000 µF with a minimum voltage rating of 450Vdc, is required across the output for 20 ms holdup time at 600W (500 µF for 300W, etc). Do not exceed 3000 µF of total output capacitance. Lower values of capacitance may be used for reduced holdup requirements, but not less than 330 µF. Lower capacitance values may degrade power factor specifications. Holdup capacitors and holdup boxes are available through Vicor Express.

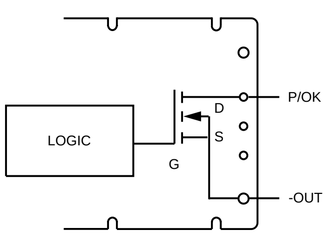
Auxiliary Supply (A/S):
The VI-HAM and VI-BAMD contain an internal low voltage output (A/S) that may be used to power primary side logic. This output is 19-23Vdc, referenced to –Out, at 3 mA max. **Do not overload or short this output** as the VI-HAM will fail. A typical use for A/S is to power an optical coupler that isolates the Power OK signal.

Figure 12.
Auxiliary Supply (A/S)



Power OK (P/OK)
P/OK is a monitor signal that indicates the status of the AC mains and the DC output voltage of the VI-HAM. P/OK, during normal operation, is an active low (see Figure 13, below). In the event AC mains or DC output fails, this pin goes to an open circuit state. P/OK is asserted when the output bus voltage is within normal operating range and 20-25 ms after DC-DC converters are enabled by the Module Enable output of the VI-HAM. This provides sufficient time for the converters to turn on and their outputs to stabilize prior to P/OK being asserted. When the AC mains is removed and the output of the VI-HAM drops below 230V, P/OK goes to an open circuit state. When the output voltage drops below 195V the converters are disabled via Module Enable.

Figure 13.
Power OK (P/OK)

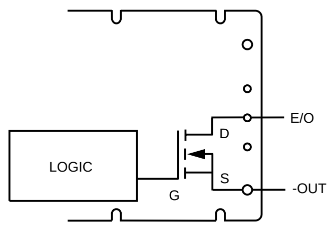


Module Enable (E/O)
The Module Enable output is used to disable the DC-DC converters until there is sufficient energy in the holdup capacitor (240V) to support normal operation, while limiting inrush current. Module Enable must be connected to the Gate Input of all driver DC-DC converters. It is not necessary to connect this pin to boosters as they are controlled by their respective driver. If the AC mains fail, Module Enable goes low when the DC output of the VI-HAM drops below 195V. Failure to connect Module Enable may result in the output of the VI-HAM latching low during turn-on.

Functional Description (cont)

Overtemperature Shutdown
The VI-HAM incorporates overtemperature shutdown. It is designed to shut down when the temperature of the baseplate exceeds 90-100°C. This does not mean that it is safe to run the VI-HAM for extended periods above its maximum operating temperature of 85°C. The temperature sensor is monitoring the average internal temperature of the VI-HAM. If the temperature of the VI-HAM increases at a very rapid rate, there can be a large thermal gradient inside the device and as a result, areas of the VI-HAM can exceed safe temperatures even though the temperature shutdown has not tripped. This can occur when small heatsinks are cooled by fans which malfunction.

Figure 14. Module Enable (E/O)



VI-HAM Protection Features

Short Circuit Protection
The VI-HAM contains a short circuit shutdown function. Operation of this function does not blow the input fuse and the output will resume normal operation after removal of the short. A short period of time may be required to allow for cooling of an internal PTC. Overcurrent protection is provided by the Vicor DC-DC converters. It is not recommended to exceed the power rating when the VI-HAM is not connected to Vicor DC-DC converters.

Output Overvoltage Protection
The VI-HAM contains output overvoltage protection. In the event the output voltage exceeds approximately 415Vdc, the boost will decrease to maintain 415Vdc on the output. When the peak of the AC line hits 415V (approximately 293Vac), the boost will have been reduced to zero. Beyond this the protection circuit will be enabled and the output voltage will decrease. Vicor modules have a transient input voltage specification of 425V for 1 second or approximately 300Vac.

Inrush Current Limit
The VI-HAM contains inrush current protection in the form of a PTC and a shunt device. The same PTC is used for overcurrent protection on the output.

Input Overvoltage Protection
This function is included in all VI-HAM compatible filters. If any other filter is used this function must be provided externally, typically by a transient suppressor.

Compatible Modules

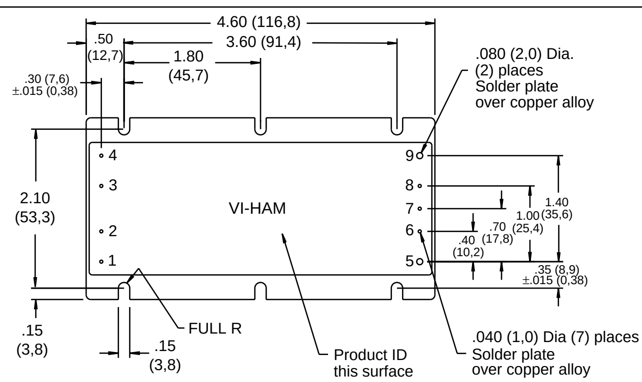
Over the full range of input voltages (85 to 264Vac), the output varies from 260 to 415Vdc. Therefore the DC-DC Converters modules used with the VI-HAM are from the VI-260 and VI-J60 families.

VI-200 Family*					
2V	**3.3V**	**Output**	**5V**	**10V**	**Output**
VI-26Z-CU	VI-26Y-CU	40A	VI-260-CU	VI-26M-CU	200W
VI-26Z-CV	VI-26Y-CV	30A	VI-260-CV	VI-26M-CV	150W
VI-26Z-CW	VI-26Y-CW	20A	VI-260-CW	VI-26M-CW	100W
VI-26Z-CX	VI-26Y-CX	15A	VI-260-CX	VI-26M-CX	75W
VI-26Z-CY	VI-26Y-CY	10A	VI-260-CY	VI-26M-CY	50W
12V	**15V**	**24V**	**28V**	**48V**	**Output**
VI-261-CU	VI-262-CU	VI-263-CU	VI-26L-CU	VI-264-CU	200W
VI-261-CV	VI-262-CV	VI-263-CV	VI-26L-CV	VI-264-CV	150W
VI-261-CW	VI-262-CW	VI-263-CW	VI-26L-CW	VI-264-CW	100W
VI-261-CX	VI-262-CX	VI-263-CX	VI-26L-CX	VI-264-CX	75W
VI-261-CY	VI-262-CY	VI-263-CY	VI-26L-CY	VI-264-CY	50W

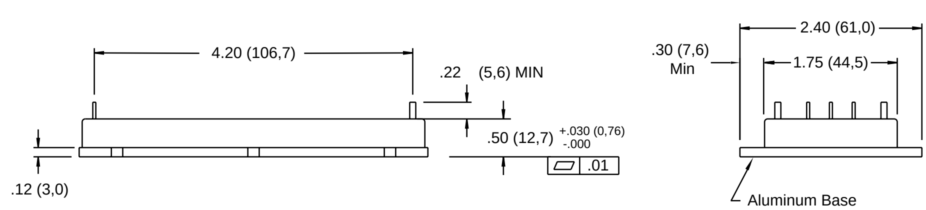
High Power modules available as boosters. Change VI-2**xx-xx to VI-**B**xx-xx.*

VI-J00 Family					
2V	**3.3V**	**Output**	**5V**	**10V**	**Output**
VI-J6Z-CW	VI-J6Y-CW	20A	VI-J60-CW	VI-J6M-CW	100W
VI-J6Z-CX	VI-J6Y-CX	15A	VI-J60-CX	VI-J6M-CX	75W
VI-J6Z-CY	VI-J6Y-CY	10A	VI-J60-CY	VI-J6M-CY	50W
			VI-J60-CZ	VI-J6M-CZ	25W
12V	**15V**	**24V**	**28V**	**48V**	**Output**
VI-J61-CW	VI-J62-CW	VI-J63-CW	VI-J6L-CW	VI-J64-CW	100W
VI-J61-CX	VI-J62-CX	VI-J63-CX	VI-J6L-CX	VI-J64-CX	75W
VI-J61-CY	VI-J62-CY	VI-J63-CY	VI-J6L-CY	VI-J64-CY	50W
VI-J61-CZ	VI-J62-CZ	VI-J63-CZ	VI-J60-CZ	VI-J6M-CZ	25W

Mechanical Diagram



Pin #	HAM	HAMD	BAMD
1	L1	+IN	+IN
2	Gate In	Gate In	Gate In
3	Gate Out	Gate Out	Gate Out
4	L2/N	–IN	–IN
5	+Out	+Out	+Out
6	P/OK	P/OK	N/C
7	E/O	E/O	N/C
8	A/S	A/S	A/S
9	–Out	–Out	–Out



VI-HAM Do's and Don'ts

The following cautions should be observed before applying power to the VI-HAM.

- It is important that the output of the VI-HAM not be loaded until the input voltage has exceeded 85Vac and the output has begun to boost to 260Vdc. This means that if the load on the VI-HAM is a Vicor converter, the Enable Output of theVI- HAM must be connected to the Gate Input of all driver modules. The VI-HAM will then disable the module output until the input exceeds 85Vac and the output has been boosted to 260Vdc. If an external load is connected directly to the output of the VI-HAM, do not apply the load until the output of the VI- HAM is in boost mode.

• SAFETY NOTE •

All VI-HAM configurations must be preceded by an appropriately rated fast-blow 3AG fuse ahead of the line filter. This fuse would be a 10A for a single VI-HAM connected to line. For fusing information on other VI-HAM configurations, please contact Vicor's Application Engineering Department.

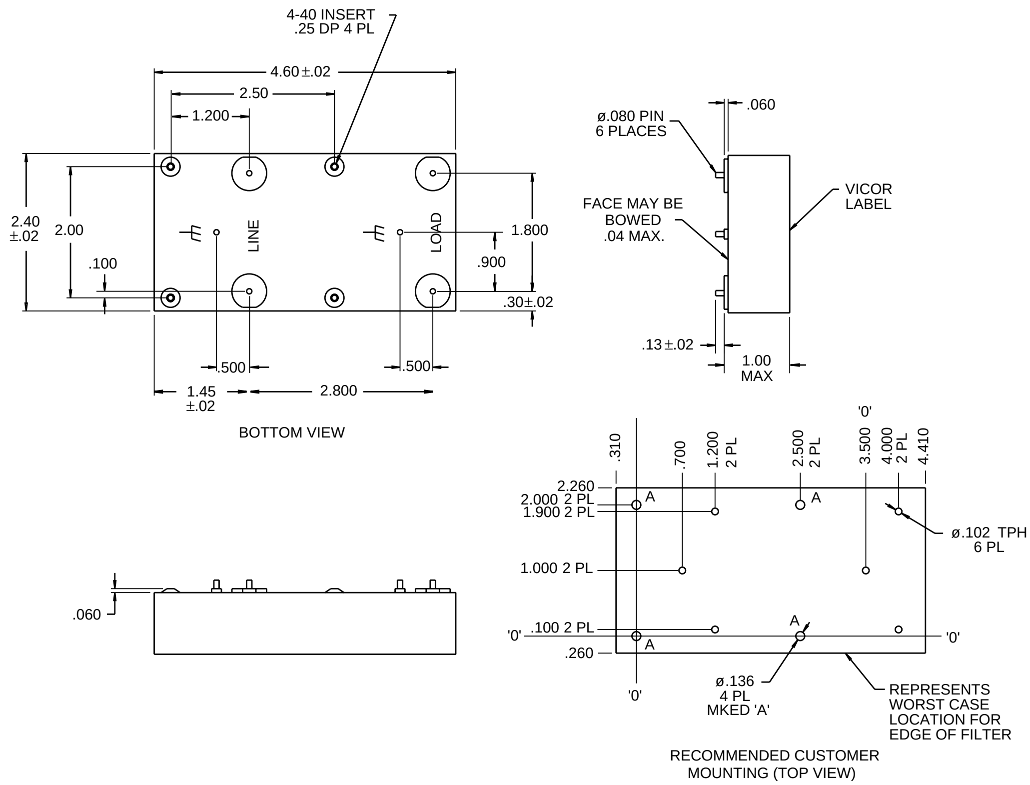
- Although the efficiency of the VI-HAM is quite high, it still dissipates significantly more power than a VI-200 DC-DC converter. Care should be taken to cool it. Do not rely on the internal overtemperature shutdown to take the place of adequate planning relative to the cooling of the VI-HAM. Thermal compound should be used between the heatsink and baseplate of the VI-HAM, VI-HAMD or VI-BAMD.

- When making any connections to the VI-HAM for measurement purposes, remember that it is not isolated from the line — either input or output. A line isolation transformer must be used when making scope measurements.

- Power factor is .997 at 120Vac and .995 at 240Vac. Harmonic content at 240Vac is therefore somewhat higher than at 120Vac. Remember that harmonic content measured can not be any lower than the harmonic content of the AC mains. A precision AC source is required for accurate power factor measurements.

- The input voltage range of the VI-HAM is 85 to 264Vac; however it may not start boosting until the AC mains has exceeded 87Vac. Once the VI-HAM has started, it will operate down to 85Vac. The VI-HAM contains 2.5 to 6V of input hysteresis, therefore if the AC line impedance is high, i.e., when using a variable autotransformer, the VI-HAM may start, but the AC line may then fall enough to drop below undervoltage lockout. When this happens the AC line will go up, the VI-HAM starts and the cycle repeats. Therefore avoid soft AC lines at or near low line.

Mechanical Diagram, Vicor Line Filter P/N 07818



Notes

VI-IAM™/MI-IAM™ Input Attenuator Module

Overview

The VI-IAM is a component-level, DC input front end filter that when used in conjunction with Vicor converters provides a highly efficient, high density power system with outputs from 1 to 95Vdc and power expansion from 25 to 800W.

- EMC Filtering
- Transient Protection
- Reverse Polarity Protection
- Inrush Current Limiting
- UL, CSA, TÜV Approval

There are five input attenuator modules available for the commercial market that comply with telecommunication and industrial control EMC specifications: Refer to data sheets for applicable standards.

Model	Input Voltage Range	Max. Output Power* of Converter Combinations
VI-A11-CU	24V (21-32V)	200W
VI-AWW-CU	24V “W” (18-36V)	200W
VI-A33-CQ	48V (42-60V)	400W
VI-ANN-CQ	48V “N” (36-76V)	400W
VI-A66-CQ	300V (200-400V)	400W

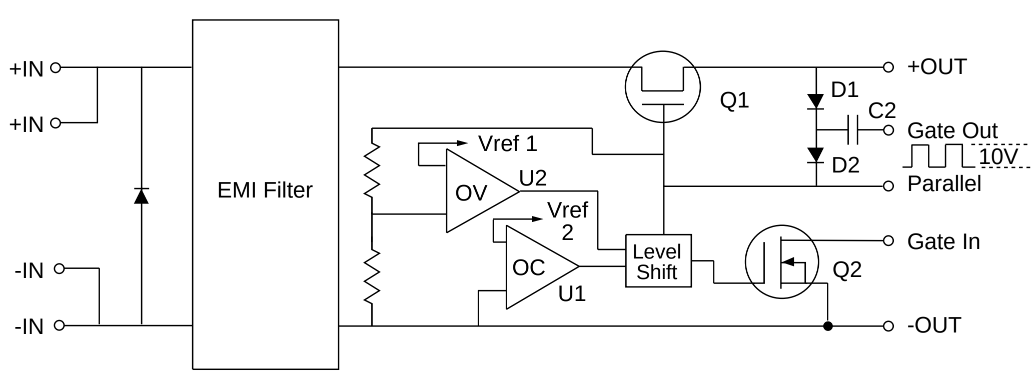
*Based on 5V output and above converters.

There are two input attenuator modules available for the defense market that comply with military EMC specifications, transient specifications and spike specifications. Refer to product datasheet for applicable standards.

Model*	Input Voltage Range	Max. Output Power of Converter Combinations
MI-A22-MU	28V (18-50V)	200W
MI-A66-MU	270V (125-400V)	200W

*I temperature grade is available.

Figure 1. Block Diagram of Input Attenuator Module (VI-IAM)



EMC

EMC performance is guaranteed when the VI-IAM is used in conjunction with Vicor converters within the permissible power rating and in accordance with the recommended installation procedure (Figure 2, page 14-4). The capacitor shown across the input of the converter, bypass capacitors and series resistors shown on the –In and +In of the DC-DC converters to ground are required to meet EMC specifications. The capacitors should be Y-rated (interference suppression). These capacitors have high voltage breakdown ratings to meet the isolation characteristics of the module's input to baseplate specification plus self-healing properties, and have safety agency approvals.

Input Reverse Polarity Protection

A zener diode in the EMC filter provides reverse polarity protection when used with a current limiting device external to the VI-IAM. The characteristics of the recommended input line fuses permit normal full load operation with protection in the event of a reverse polarity; see table below.

Input Transient Protection

A zener diode, inductor and capacitor in the EMC filter protect against short term transients. Transient voltages that persist beyond these limits are dropped across an N-channel enhancement FET, Q1. It is necessary that the FET be kept in saturation mode during normal operation. Thus it is necessary to connect the DC-DC converters' Gate Out to the VI-IAM's Gate Out to charge pump the gate of the FET to a voltage in excess of its source. In the case where multiple DC-DC driver modules are connected to one VI-IAM, an external charge pump through the parallel pin (connected to the gate of the FET) must be added to ensure that the FET remains enhanced in the event Gate Out enhancement is lost (Figure 3, page 14-4). The additional circuitry, C2, D1 and D2 are added externally to charge pump through the parallel pin.

Shutdown of the DC-DC converters is accomplished by saturating Q2 during an input over-voltage to prevent possible damage to the converters. The VI-IAM will automatically restart when the input overvoltage is reduced to within the input voltage range.

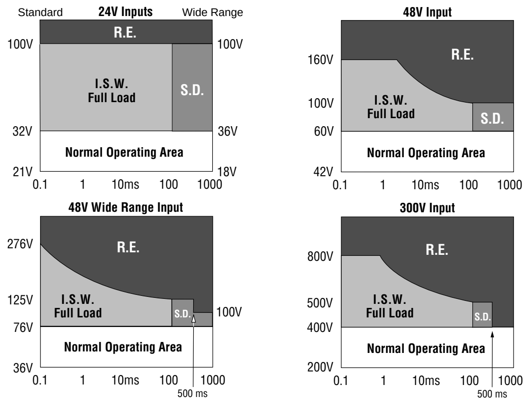
If the long term transient withstand specifications are exceeded, the recommended external fuse will clear.

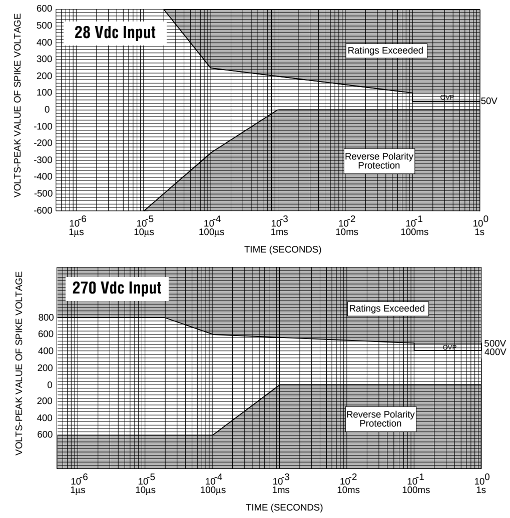
Input Voltage	Recommended Fuse
24V	20A/32V (AGC-20)
24V "W"	20A/36V (AGC-20)
48V	20A/60V (3AB-20)
48V "N"	20A/80V (3AB-20)
300V	5A/250V Bussman PC-Tron
28V	20A/250V (3AB-20 or F03A, 125V, 20A)
270V	5A/250V Bussman PC-Tron or F03A, 250V, 4A

Input Transient Protection (cont)

Safe Operating Area

(1% duty cycle max., Z_S = .5Ω, for short duration transient capability refer to specifications)





I.S.W.: Input Surge Withstand (no disruption of performance)
R.E.: Ratings Exceeded
S.D.: Shut Down

Input Current

Inrush current is a function of the number of DC-DC converters that are connected to the input attenuator module (modules are not gated off at turn-on) and the amount of external capacitance added between the input attenuator module and the DC-DC converter. The inrush current specification is 125% of steady state input current for 10 ms. To avoid excessive dissipation in the element controlling the inrush (Q1), the following maximum values of external capacitance must be adhered to:

Input Voltage	Max. Capacitance*
24Vdc (21-32V)	470 µF
24Vdc (18-36V)	470 µF
28Vdc (18-50V)	390 µF
48Vdc (42-60V)	220 µF
48Vdc (36-76V)	120 µF
270Vdc (125-400V)	27 µF
300Vdc (200-400V)	27 µF

*Capacitance should be distributed across the input of each DC-DC converter (see Figure 2, page 14-4 to reference C1).

Output Overcurrent/Short Circuit Protection

Output overcurrent protection is a foldback type, followed by a timed latched shutdown should the overcurrent persist beyond 2 ms. If the overcurrent condition is removed before the timeout interval, autorestart shall occur. Should latched shutdown occur, input power must be recycled to restart.

Output Overcurrent Threshold	
24Vin "W", 28Vin, 48Vin "N"	20A ± 5%
24Vin, 48Vin	15A ± 5%
270Vin, 300Vin	4A ± 5%

Expansion Capabilities

The input attenuator module incorporates a parallel pin permitting power expansion as long as the total output power from the DC-DC converters does not exceed the power rating of each input attenuator module (EMC specifications are guaranteed for up to two input attenuators in parallel). It is necessary to include a 100 ohm, 1/4W resistor between the minus outputs of the attenuator modules to ensure equal potential at these points when paralleling input attenuator modules, so as not to impact the effectiveness of the internal common-mode choke.

Figure 2.
External Components for EMC Requirements

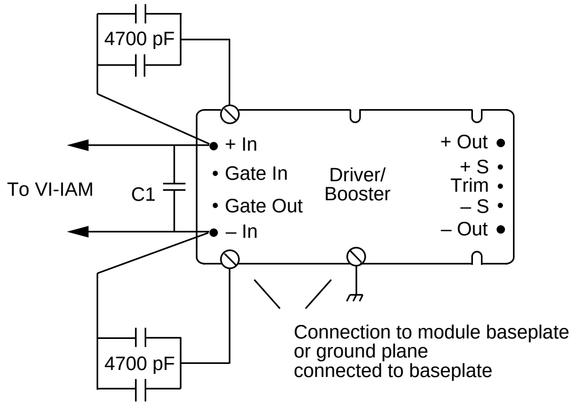
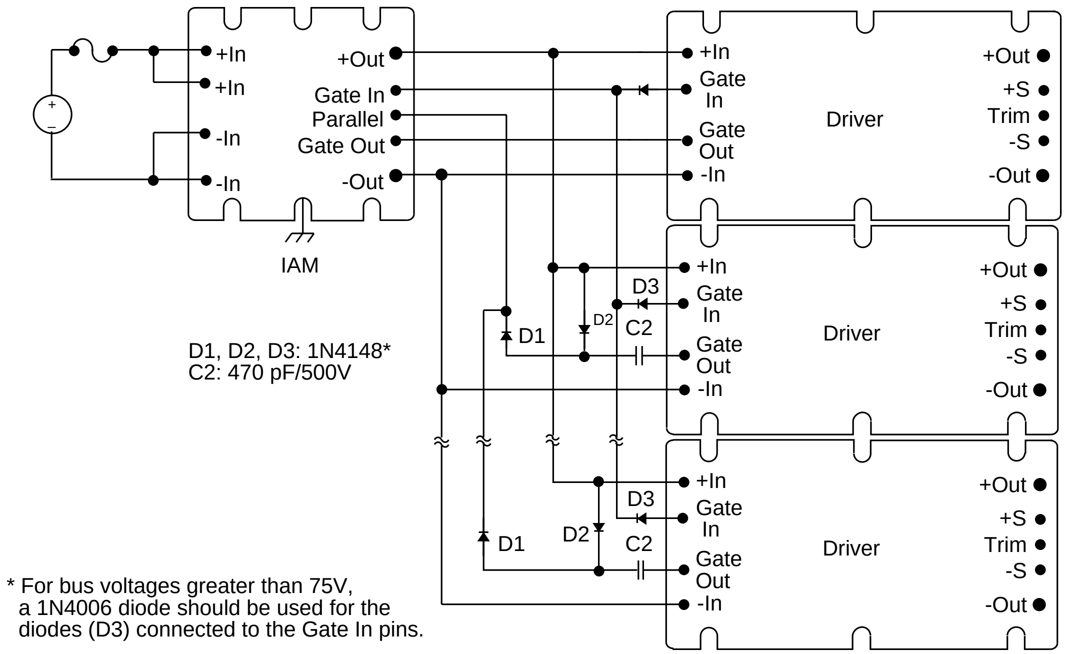
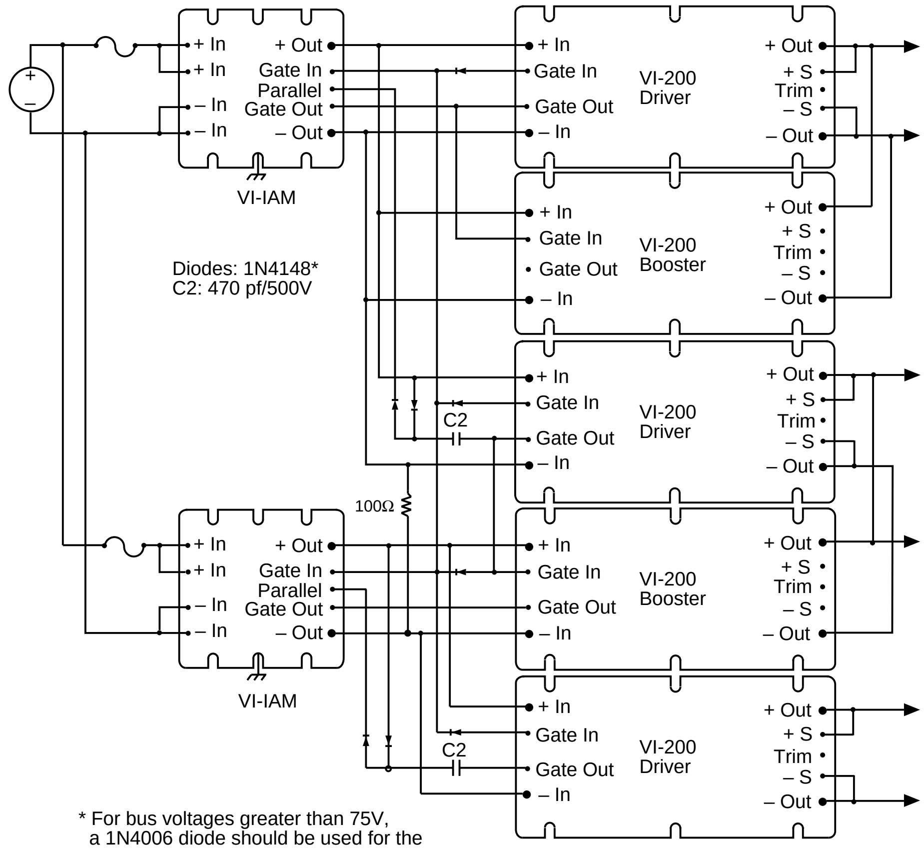


Figure 3.
IAM Multiple Driver Interconnection



Expansion Capabilities (cont)

Figure 4.
Paralleling
Connections
for the VI-IAM



* For bus voltages greater than 75V, a 1N4006 diode should be used for the diodes connected to the Gate In pins.

Safety Considerations

SHOCK HAZARD
Agency compliance requires that the baseplate be grounded or made inaccessible.

FUSING
Safety agency conditions of acceptability require module input fusing. See table on page 14-2 for recommended fuse ratings.

Notes

VI-RAM™ / MI-RAM™ Ripple Attenuator Module

Overview

The VI-RAM is an accessory product for VI-200, VI-J00 and Mega Modules, ComPAC DC-DC switchers, and FlatPAC AC-DC switching power supplies. It reduces line frequency related ripple and converter switching noise to less than 3 mV p-p (10 mV p-p on VI-J00 modules).

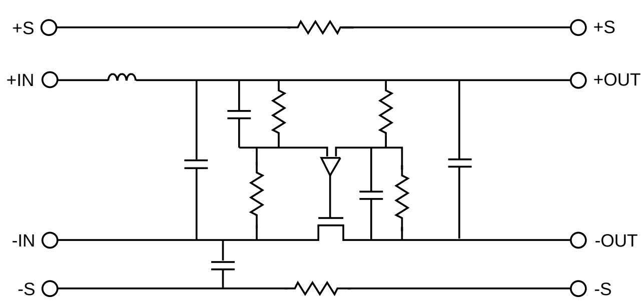
Features include:

- Reduced Differential Noise (<3 mV p-p at loads up to 20A)
  The input of the VI-RAM must be between 5 and 50Vdc.
- Active and Passive Filtering
- Attenuation of Low Frequency Input Power Source Harmonics and High Frequency Switching Components from DC-20 MHz
- Efficiencies of 95-99%
- Remote Sense, Trim, Overvoltage Protection and Overcurrent Protection Features Retained

Applications for the VI-RAM include medical diagnostic and automated test equipment, radio receivers, transmitters and communication products, and other products requiring the noise performance of a linear supply.

The patented VI-RAM module is a combination active/passive filter. A simplified block diagram is shown in Figure 1. The output of the switcher feeds directly into a high frequency passive filter which attenuates the switching noise. Low frequency, line related ripple attenuation is via a FET series regulator that maintains a constant average forward voltage drop of about 350 mV. The FET gate is modulated to maintain the AC component of the FET drain-source voltage equal to the ripple component of the incoming DC voltage, effectively cancelling it out.

Figure 1.



The power supply's sense leads feed through the VI-RAM for connection at the VI-RAM output, for local sense, or at the load, for remote sense (converter compensation is .5V maximum). The attenuation and insertion loss are constant up to 10A or 20A, depending on model. In overload (above 10A or 20A), the voltage drop will increase as the current increases. A single VI-RAM can be used on any output from 5Vdc to 50Vdc and will maintain the original output setpoint of the converter within 0.5% at the sense connection. Care should be taken not to connect In to Out terminals (i.e., through scope probe returns, grounds, etc.) as attenuation will be adversely affected.

The VI-RAM is intended to be used with the Vicor VI-200 and VI-J00, and the MI-RAM is intended to be used with the MI-200 and MI-J00 family of DC-DC converters.

Overview (cont)

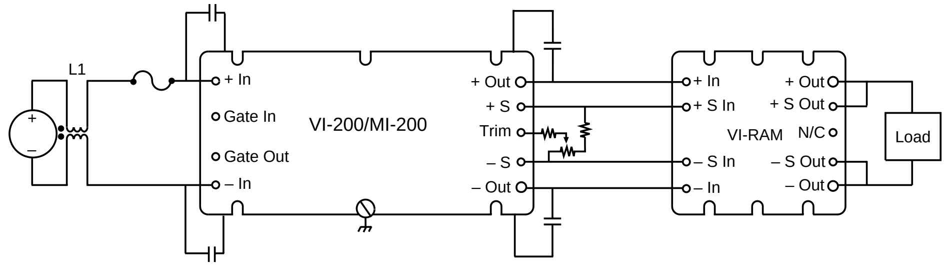


Figure 2.
VI-RAM with Optional Trimming Circuit and Optional Common Mode Choke for Conducted Noise (see Ch. 10 for more details)

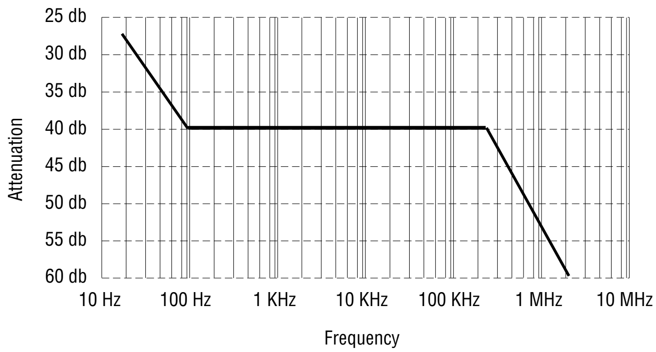


Figure 3.
Attenuation vs. Frequency (Typical)

VI-ARM™ Autoranging Rectifier Module

Overview

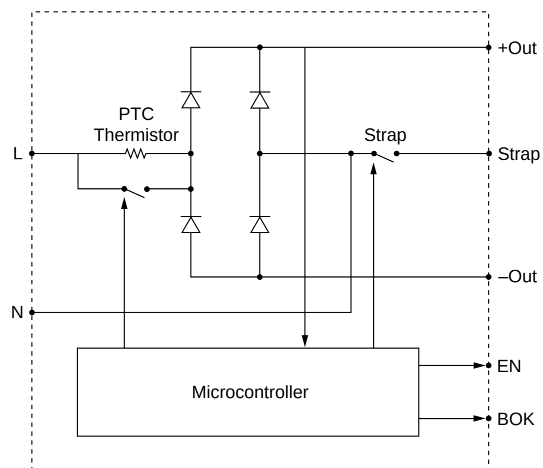
The VI-ARM (Autoranging Rectifier Module) provides an effective solution for the AC front end of a power supply built with Vicor DC-DC converters. This high performance power system building block satisfies a broad spectrum of requirements and agency standards.

The VI-ARM contains all of the power switching and control circuitry necessary for autoranging rectification, inrush current limiting, and overvoltage protection. This module also provides converter enable and status functions for orderly power up/down control or sequencing. To complete the AC front end configuration, the user needs only to add holdup capacitors and a suitable input filter with transient protection.

Functional Description

The switch that bypasses the inrush limiting PTC (positive temperature coefficient) thermistor is open when power is applied, as is the switch that engages the strap for voltage doubling. (See Figure 1.) In addition, the converter modules are disabled via the Enable (EN) line, and Bus-OK (BOK) is high.

Figure 1. Functional block diagram



Power-Up Sequence. (See Figure 2.):

1.1 Upon application of input power, the output bus capacitors begin to charge. The thermistor limits the charge current, and the exponential time constant is determined by the holdup capacitor value and the thermistor cold resistance. The slope (dv/dt) of the capacitor voltage approaches zero as the capacitors become charged to the peak of the AC line voltage.

2.1 If the bus voltage is less than 200V as the slope nears zero, the voltage doubler is activated, and the bus voltage climbs exponentially to twice the peak line voltage. If the bus voltage is greater than 200V, the doubler is not activated.

3.1 If the bus voltage is greater than 235V as the slope approaches zero, the inrush limiting thermistor is bypassed. Below 235V, it is not bypassed.

Functional Description (cont)

4.1 The converters are enabled 50 milliseconds after the thermistor bypass switch is closed.

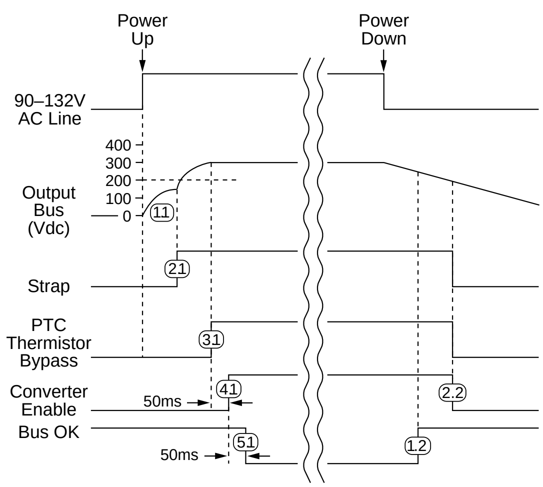
5.1 Bus-OK is asserted after an additional 50 millisecond delay to allow the converter outputs to settle within specification.

Power-Down Sequence. (See Figure 2.) When input power is turned off or fails, the following sequence occurs as the bus voltage decays:

1.2 Bus-OK is deasserted when the bus voltage falls below 210Vdc.

2.2 The converters are disabled when the bus voltage falls below 190Vdc. If power is reapplied after the converters are disabled, the entire power-up sequence is repeated. If a momentary power interruption occurs and power is reestablished before the bus reaches the disable threshold, the power-up sequence is not repeated.

Figure 2. Timing diagram: power up/down sequence



Off-Line Supply Configuration

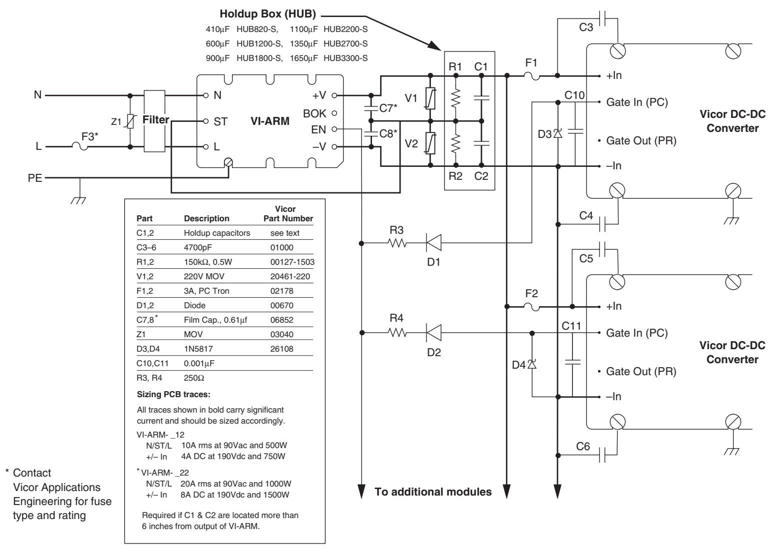
The VI-ARM maintains the DC output bus voltage between 200 and 375Vdc over the specified input range, which is compatible with Vicor VI-260 series and VI-J60 series DC-DC converters, as well as next-generation 300V input Vicor converters. The VI-ARM automatically switches to the proper rectification mode (doubled or undoubled) depending on the input voltage, eliminating the possibility of damage due to improper line connection. The VI-ARM-C12 is rated at 500W in the low range (90-132Vac input), and 750W in the high range (180-264Vac input). The VI-ARM-C22 is rated for 1000W and 1500W for the low and high input ranges, respectively. Either of these modules can serve as the AC front end for any number and combination of compatible converters as long as the maximum power rating is not exceeded.

Strap (ST) Pin. In addition to input and output power pin connections, it is necessary to connect the Strap pin to the junction of the series holdup capacitors (C1, C2, Figure 3) for

Offline Supply Configuration (cont)

proper (autoranging) operation. Gas tubes across the capacitors provide input transient protection. The bleeder resistors (R1, R2, Figure 3) discharge the hold-up capacitors when power is switched off.

Figure 3.
Converter connections



Part	Description	Vicor Part Number
C1,2	Holdup capacitors	see text
C3–6	4700pF	01000
R1,2	150kΩ, 0.5W	00127-1503
V1,2	220V MOV	20461-220
F1,2	3A, PC Tron	02178
D1,2	Diode	00670
C7,8*	Film Cap., 0.61µf	06852
Z1	MOV	03040
D3,D4	1N5817	26108
C10,C11	0.001µF	
R3, R4	250Ω	

Sizing PCB traces:

All traces shown in bold carry significant current and should be sized accordingly.

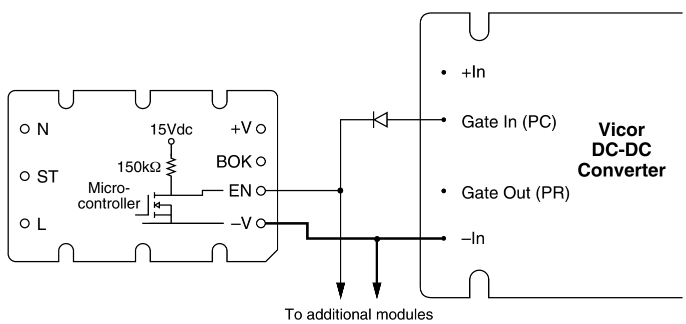
VI-ARM- _12
N/ST/L 10A rms at 90Vac and 500W
+/– In 4A DC at 190Vdc and 750W

*VI-ARM- _22
N/ST/L 20A rms at 90Vac and 1000W
+/– In 8A DC at 190Vdc and 1500W

Required if C1 & C2 are located more than 6 inches from output of VI-ARM.

Enable (EN) Pin. (See Figure 4.) The Enable pin must be connected to the Gate-In or PC pin of all converter modules to disable the converters during power-up. Otherwise, the converters would attempt to start while the hold-up capacitors were being charged through an unbypassed thermistor preventing the bus voltage from reaching the thermistor bypass threshold thus disabling the power supply. The Enable output (the drain of an N channel MOSFET) is internally pulled up to 15 V through a 150 kΩ resistor.

Figure 4.
Enable (EN) function



A signal diode should be placed close to and in series with the Gate-In (or PC) pin of each converter to eliminate the possibility of control interference between converters. The Enable pin switches to the high state (15 V) with respect to the negative output power pin to turn on the converters after the power-up inrush is over. The Enable function also provides input overvoltage protection for the converters by turning off the converters if the DC bus voltage exceeds 400 Vdc. The thermistor bypass switch opens if this condition occurs, placing the thermistor in series with the input voltage, which reduces the bus voltage to a safe level while limiting input current in case the gas tubes fire. The thermistor bypass switch also opens if a fault or overload reduces the bus voltage to less than 180 Vdc.

Off-Line Power Supply Configuration (cont)

Bus-OK (BOK) Pin. (See Figure 5.) The Bus-OK pin is intended to provide early-warning power fail information and is also referenced to the negative output pin.

Caution: There is no input to output isolation in the VI-ARM. It is necessary to monitor Bus-OK via an optoisolator if it is to be used on the secondary (output) side of the converters. A line isolation transformation should be used when performing scope measurements. Scope probes should never be applied simultaneously to the input and output as this will destroy the unit.

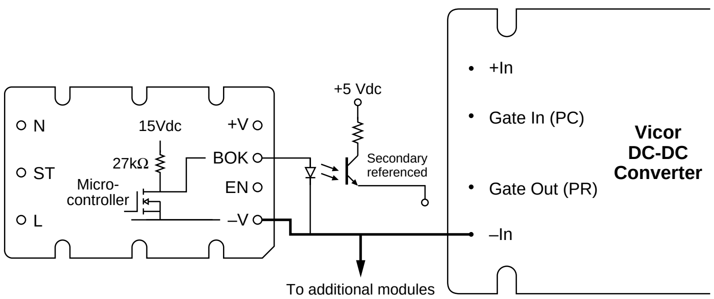
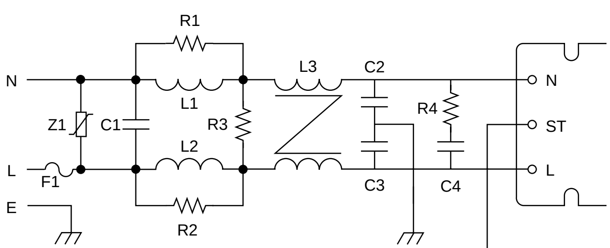


Figure 5.
Bus OK (BOK) isolated power status indicator

Filter. (See Figure 6.) The recommended input filter consists of a common mode choke and Y rated capacitors (line-ground) plus two additional inductors and an X rated capacitor (line-line). This filter configuration provides sufficient common mode and differential mode insertion loss in the frequency range between 100kHz and 30MHz to comply with the Level B conducted emissions limit.



Part	Description	Vicor Part Number
C1	1.0µF	02573
C2, C3	4700pF	01000
C4	0.15µF	03269
F1	12A fuse	05147
L1, L2	27µH	14563
L3	1.3mH	15016
R1, R2	10Ω	
R3	150kΩ, 0.5W	00127-1503
R4	2.2Ω	
Z1	MOV	03040

Figure 6.
Filter connections

Selecting Capacitors for the VI-ARM (Visit vicr.com for an online holdup capacitor calculator.)

Holdup Capacitors. Holdup capacitor values should be determined according to output bus voltage ripple, power fail holdup time, and ride-through time. (See Figure 7.) Many applications require the power supply to maintain output regulation during a momentary power failure of specified duration, i.e., the converters must holdup or ride through such an event while maintaining undisturbed output voltage regulation. Similarly, many of these same systems require notification of an impending power failure in order to allow time to perform an orderly shutdown.

The energy stored on a capacitor which has been charged to voltage V is:

(1) $$\varepsilon = 1/2(CV^2)$$

Where: ε = stored energy
C = capacitance
V = voltage across the capacitor

Energy is given up by the capacitors as they are discharged by the converters. The energy expended (the power-time product) is:

(2) $$\varepsilon = P\Delta t = C(V_1^2 – V_2^2) / 2$$

Where: P = operating power
Δt = discharge interval
V_1 = capacitor voltage at the beginning of Δt
V_2 = capacitor voltage at the end of Δt

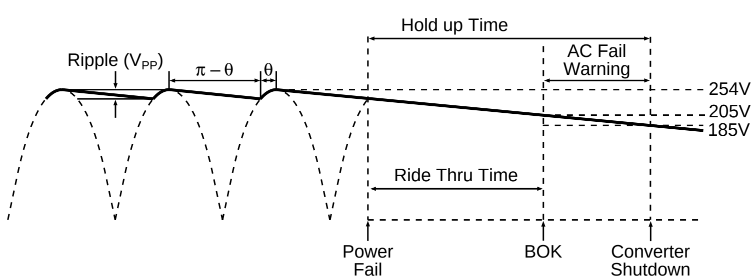
Rearranging Equation 2 to solve for the required capacitance:

(3) $$C = 2P\Delta t / (V_1^2 – V_2^2)$$

The AC fail warning time (Dt) is defined as the interval between power fail warning (BOK) and converter shutdown (EN) as illustrated in Figure 7. The Bus-OK and Enable thresholds are 205V and 185V, respectively. A simplified relationship between AC fail warning time, operating power, and bus capacitance is obtained by inserting these constants:

$$C = 2P\Delta t / (205^2 – 185^2)$$
$$C = 2P\Delta t / (7,800)$$

Figure 7.
Holdup time



Selecting Capacitors for the VI-ARM (cont)

It should be noted that the series combination C1, C2, (Figure 3) requires each capacitor to be twice the calculated value, but the required voltage rating is reduced to 200V.

Allowable ripple voltage on the bus (or ripple current in the capacitors) may define the capacitance requirement. Consideration should be given to converter ripple rejection and resulting output ripple voltage. The ripple rejection (R) of many Vicor converters is specified as a function of the input/output voltage ratio:

(4) $$R = 30 + 20\log(V_{IN} / V_{OUT})$$

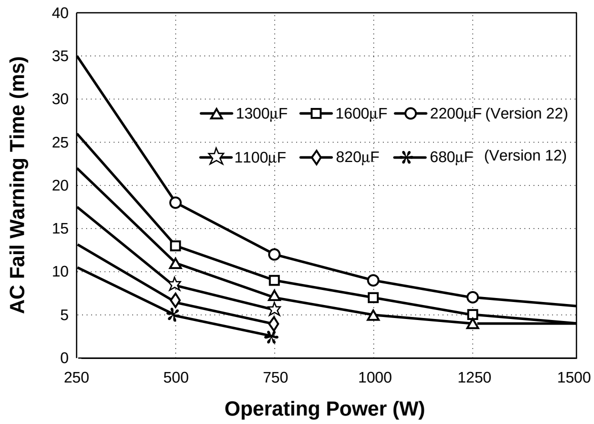


Figure 8. AC fail warning time vs. operating power and total bus capacitance, series combination on C1, C2 (Figure 3)

For example, a converter whose output is 15V and nominal input is 300V will provide 56dB ripple rejection, i.e., $10V_{PP}$ of input ripple will produce $15mV_{PP}$ of output ripple. (See Figure 11.) Equation 3 is again used to determine the required capacitance. In this case, V_1 and V_2 are the instantaneous values of bus voltage at the peaks and valleys (Figure 7) of the ripple, respectively. The capacitors must hold up the bus voltage for the time interval (Δt) between peaks of the rectified line as given by:

(5) $$\Delta t = (\pi - \theta) / 2\pi f$$

Where: f = line frequency
θ = rectifier conduction angle

The approximate conduction angle is given by:

(6) $$\theta = \mathrm{Cos}^{-1} V_2/V_1$$

Another consideration in holdup capacitor selection is their ripple current rating. The capacitors' rating must be higher than the maximum operating ripple current. The approximate operating ripple current (rms) is given by:

(7) $$I_{RMS} = 2P/V_{ac}$$

Where: P = operating power level
V_{ac} = operating line voltage

Selecting Capacitors for the Vi-ARM (cont)

Calculated values of bus capacitance for various holdup time, ride-through time, and ripple voltage requirements are given as a function of operating power level in Figures 8, 9, and 10, respectively.

Figure 9.
Hold up time vs. operating power

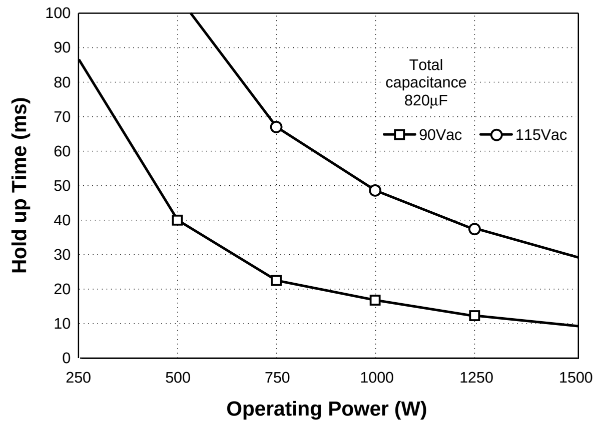
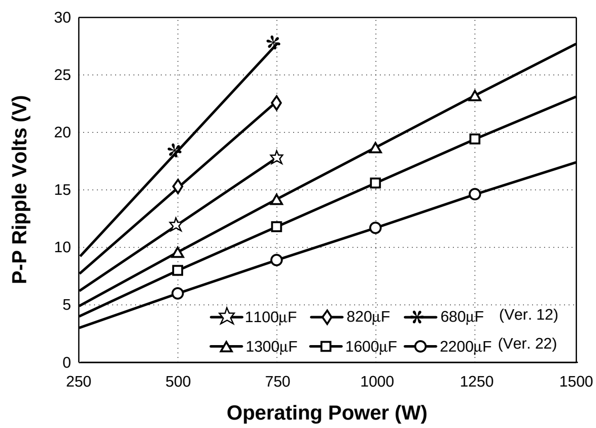


Figure 10.
Ripple voltage vs. operating power and bus capacitance, series combination of C1, C2 (Figure 3)



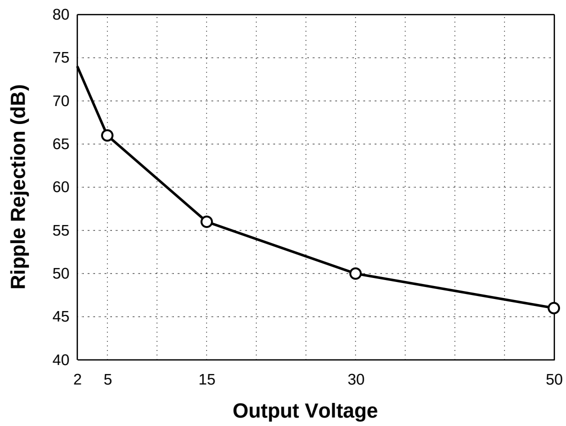
Example
In this example, the output required at the point of load is 12Vdc at 320W. Therefore, the output power from the VI-ARM would be 375W (assuming a converter efficiency of 85%). The desired holdup time is 9 ms over an input range of 90 to 264Vac.

Determining Required Holdup Capacitance. Figure 8 is used to determine holdup capacitance for a given AC fail warning time and power level, and shows that the total bus capacitance must be at least 820 µF. Since two capacitors are used in series, each capacitor must be at least 1,640 µF. Note that AC fail warning time is not dependent on line voltage.

Selecting Capacitors for the VI-ARM (cont)

Determining Ride-through Time. Figure 9 illustrates hold up time as a function of line voltage and output power, and shows that at a nominal line of 115Vac, ride-through would be 68 ms. Hold up time is a function of line voltage.

Figure 11. Converter ripple rejection vs. output voltage



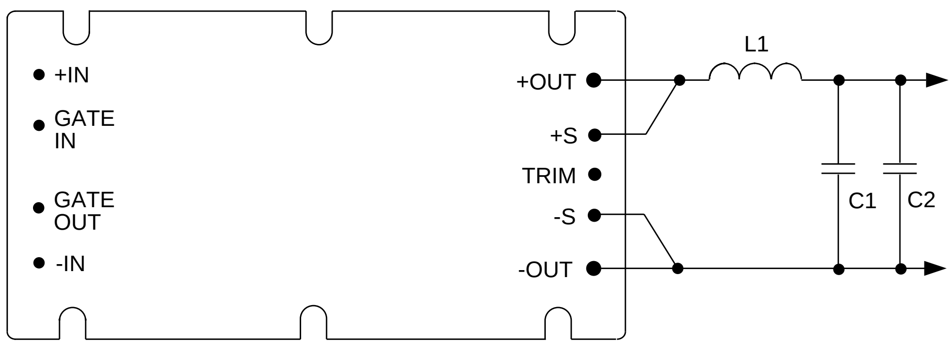
Determining Ripple Voltage on the Holdup Capacitors. Figure 10 is used to determine ripple voltage as a function of operating power and bus capacitance, and shows that the ripple voltage across the holdup capacitors will be 12Vac.

Determining the Ripple on the Output of the DC-DC Converter. Figure 11 is used to determine the ripple rejection of the DC-DC converter and indicates a ripple rejection of approximately 60 dB for a 12V output. Since the ripple on the bus voltage is 12Vac and the ripple rejection of the converter is 60 dB, the output ripple of the converter due to ripple on its input (primarily 120 Hz) will be 12 mV p-p. Note that 2nd Generation converters have greater ripple rejection than either VI-200s or VI-J00s.

Optional Filters for Attenuation of Output Ripple

Overview

The LC filter design below is a comparatively simple solution for reducing ripple on the outputs of Vicor's 200/J00 Families. These components are small and provide significant peak-to-peak noise attenuation. Since an output filter capacitor is already present in the DC-DC converter, adding an inductor and capacitor to the output creates a pi filter. It is important that the inductor wire be of a size sufficient to carry the load current, including a safety factor, and that the core does not saturate. LC filters are generally needed only where very accurate analog signals are involved, and the system power supply rejection is poor at the ripple frequency. The VI-RAM (Vicor Ripple Attenuator Module) should be used if greater attenuation of output ripple is required.



All standard outputs will function with either remote sense or local sense. Lower ESR is achieved with capacitors in parallel. Ripple value measured @ 20 MHz bandwidth limit.

Filter Components for VI-260-CV (5 V Output)
L1 — Vicor P/N 05298 or Micrometals #T38-26/90, 2T #14 (110 nH)
C1, C2 — Vicor P/N 24252, 270 μF/10V solid tantalum
Typical data at high line input (worst case):
With full load, ripple = 11 mV p-p
With 50% load, ripple = 8 mV p-p

Filter Components for VI-261-CW (12 V Output)
(Also applicable for a 15 V output)
L1 — Vicor P/N 05298 or Micrometals #T38-26/90, 2T #14 (110 nH)
C1, C2 — Vicor P/N 24253, 120 μF/20 V solid tantalum
Typical data at high line input (worst case):
With full load, ripple = 5 mV p-p
With 10% load, ripple = 15 mV p-p

Filter Components for VI-263-CW (24 V Output)
L1 — Vicor P/N 05298 or Micrometals #T38-26/90, 2T #14 (110 nH)
C1, C2 — Vicor P/N 24254, 68 μF/30 V solid tantalum
Typical data at high line input (worst case):
With full load, ripple = 6 mV p-p
With 10% load, ripple = 18 mV p-p

Notes

The ComPAC™ Family

DC-DC Switching Power Supplies

Overview

The ComPAC is a low profile, highly efficient, high density configurable DC-DC power solution with EMC filtering, transient protection and reverse polarity protection. It has an isolated master disable input for remote shutdown, and provides outputs from 1-95Vdc and power up to 600W.

Features

- EMI Filtering
- Transient Protection
- Reverse Polarity Protection
- Inrush Limiting
- UL, CSA, TÜV, VDE Approval
- CE Marked

There are five input voltages available which comply with telecommunication and industrial control EMC specifications: Refer to datasheet for applicable standards.

Nominal Input Voltage	Input Designator	Input Voltage Range
24	1	21.7-32
24 (wide)	W	18.7-36
48	3	42-60
48 (wide)	N	36-76
300	6	200-400

There are two military input voltages available which comply with military EMC specifications and the transient and spike specifications. Refer to datasheet for applicable standards.

Nominal Input Voltage	Input Designator	Input Voltage Range
28	2	18-50
270	6	125-400

ComPACs can be configured in 1-up, 2-up or 3-up packages with total output power limited to the maximum power of individual VI-200 or MI-200 series converters. Output voltages may be trimmed by the user.

Output Power
The maximum total power which is delivered from the ComPAC is:

Nominal	Total Output Power		
Input Voltage	1-Up	2-Up	3-Up
24V and 24V (wide)	150W	300W	450W
28V, 270V (military)	100W	200W	300W
48V and 48V (wide), 300V	200W	400W	600W

Dimensions and Mechanical Mounting
See page 18-6.

Features (cont)

Weight
1-up: 1.2 lbs (540g); 2-up: 2.4 lbs (1080g); 3-up: 3.6 lbs (1630g)

Operating Case Temperature
E-Grade = -10˚C to +85˚C
C-Grade = -25˚C to +85°C
I-Grade = -40˚C to +85°C
M-Grade = -55˚C to +85°C

Thermal Data
Operating Ambient Temperature: Depends on factors such as output power, availability of forced air, and mounting technique. Do not allow the ComPAC to exceed its maximum operating temperature, which is reached when the case is 85˚C. (Full power can be delivered up to this temperature.) Refer to Section 24, *Thermal Curves*, to determine the maximum ambient temperature for your application.

NOTE: To ensure proper heat transfer from the internal module(s) to the heatsink, the mounting holes through the heatsink must be properly torqued at all times during operation. If the unit is operated unmounted, insert a #4-40 or metric M3 flathead screw through each hole from below and secure with a nut on top, torqued to 6 lb-in (0.83 N-m).

Thermal Impedance, Free Convection
Thermal resistance baseplate to air (˚C/W):

	1-Up	2-Up	3-Up
Vertical Mounting	2.44	1.17	0.76
Horizontal Mounting	3.6	1.7	1.35

Forced Convection
Thermal resistance baseplate to air (horizontal mount):

Thermal Resistance (°C/W)			Airflow (LFM)
1-Up	**2-Up**	**3-Up**	
3.6	1.7	1.35	0
2.7	1.4	1.26	50
2.3	1.3	1.11	100
1.6	0.97	0.82	250
1.15	0.70	0.58	500
0.9	0.54	0.46	750
0.78	0.45	0.38	1000

NOTE: A higher heatsink, option H1, is available; consult factory.

Overall Efficiency
The overall efficiency of the ComPAC is approximately 1% less than the efficiency of the Vicor DC-DC converters (typical efficiencies: 77% for 2V output, 81% for 5V output and 83% for 12V-48V output).

Features (cont)

EMC Performance, Conducted EMC
The ComPAC will conform to the following conducted EMC specifications on the input power leads:

Telecom (24V and 48V inputs): Bellcore TR-TSY-000513, Issue 2 July 1987 and Rev. 1, December 1988. British Telecom Document BTR2511, Issue 2.
Commercial (300V input): FCC Pt. 15 Subpt. J, Class A/VDE 0871 Class A.
Military (28V, 270V): MIL-STD-461C Conducted Emissions: CE01, CE03, CE07
Conducted Susceptibility: CS01, CS02, CS06

Radiated EMC
The ComPAC will conform to the following radiated specifications:

Military: Radiated Emissions: RE02; Radiated Susceptibility: MIL-STD-461C, RS02, RS03.

Input Transient Protection
The input transient protection will suppress short term transients appearing on the input line. Refer to datasheet for applicable standards.

Input Surge Withstand
The 24V, 48V and 300V input ComPAC shall withstand, without damage or interruption of power, an input line surge shown below for a duration of 100 ms from a source impedance of 500 milliohms.

Extended Input OV Shutdown
Surge protection shall also shut down the ComPAC in the presence of sustained input surges (>100 ms) which would cause excessive dissipation or damage. The ComPAC will auto restart when the input overvoltage is removed.

Input Reverse Polarity Protection
The input of the ComPAC is protected against reverse polarity. No damage will occur provided that external current limiting is present (i.e., fuse).

Output Short Circuit Protection
Output short circuit protection is provided by the current limiting of the Vicor DC-DC converters.

Undervoltage Lockout
The ComPAC incorporates an undervoltage lockout which will inhibit the output of all converters until the input line exceeds the brownout voltage specified for the converter input range.

Features (cont)

Nominal Input	UV Lockout (Vdc, typical)
24	19
24 (wide)	17
28 (military)	17
48	41
48 (wide)	35
270 (military)	121
300	188

Following startup, the undervoltage lockout will inhibit the converter output(s) should the input drop roughly 8-10V below the UV lockout limits stated above.

Recommended Input Line Fusing
The ComPAC must be fused externally. The table below lists the fuse ratings for one-, two- and three-up units (max. output 200, 400 and 600W).

Input Voltage	Fuse Rating		
	1-Up	2-Up	3 Up
24V	10A/32V	20A/32V	30A/32V
24V (wide)	12A/32V	20A/32V	30A/32V
28V (military)	10A/250V	20A/250V	30A/125V
48V	8A/60V	15A/60V	25A/60V
48V (wide)	6A/100V	15A/100V	25A/100V
270V (military)	2A/250V	4A/250V	6A/250V
300V	2A/250V	4A/250V	6A/250V

Recommended Input Wiring and Torque

1 up	#16 AWG	10 in-lb
2 up, 3 up	#14 AWG	15 in-lb

Recommended Output Wiring
Use the output wire gauge that corresponds to the output current of the ComPAC unit:

105A-160A: #4	26A-40A: #10	7A-10A: #16
66A-104A: #6	16A-25A: #12	4A-6A: #18
41A-65A: #8	11A-15A: #14	0A-3A: #20

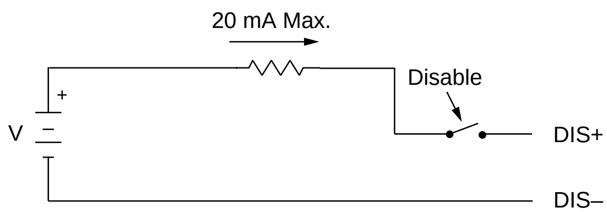
Grounding
For safe operation, the ComPAC unit must be grounded. Connect a ground lead to the terminal marked (GND). Use the same wire gauge as that specified for your ComPAC unit's input voltage connections.

Features (cont)

Master Disable

The ComPAC incorporates an optically isolated Master Disable input which will shut down the ComPAC output when a current is driven through the disable terminals.

Figure 1. ComPAC Module Disable



Disable Current

• 4 mA DC minimum for 1 Up ComPAC
• 8 mA DC minimum for 2 Up ComPAC
• 12 mA DC minimum for 3 Up ComPAC

Trimming

The nominal output voltage of the ComPAC can be adjusted from 110% to 50% of nominal voltage. Refer to *Output Voltage Trimming*, Section 5, for external resistor values. Do not trim the outputs higher than 110% of their nominal output power (output overvoltage protection may trigger). When the output is trimmed up, do not exceed its maximum rated output power.

NOTE: 10V, 12V, and 15V outputs, standard trim range ±10%. Consult factory for wider trim range.

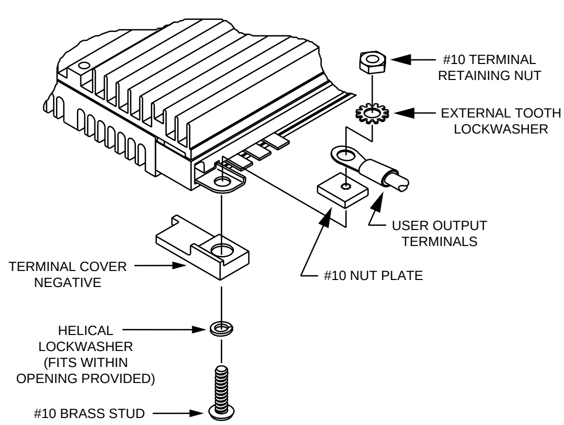
Remote Sensing

+Sense and -Sense must be connected locally or remotely.

Output Terminal Connections

A hardware kit with parts for output terminal connections is provided with each ComPAC unit. The following drawing shows the assembly of those parts for the proper connection of metal power terminals. Assembly for PCB power terminals is the same except that they do not require an external tooth lockwasher. Consult the table below for the recommended torque level for each stud size.

Figure 2. Output Terminal Connections

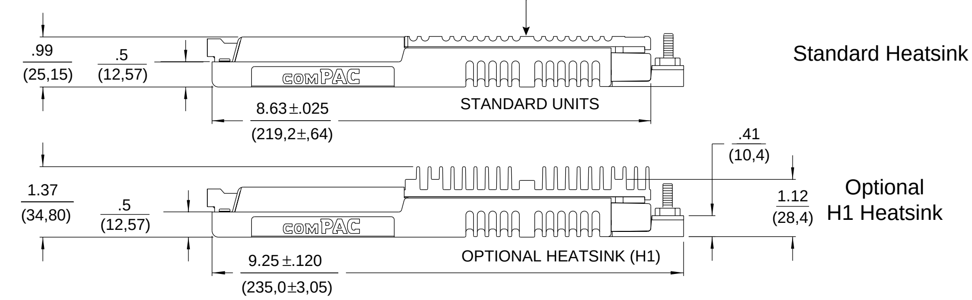


Terminal and Product Model	Terminal Style	Stud Size	Recommended Torque
-Output, +Output			
LC, PC, RC Series	PCB	8-32 UNC	10 in-lbs (1.1 N-m)
MC and NC Series	Metal	10-32 UNC	15 in-lbs (1. 7 N-m)
QC Series	PCB Metal	8-32 UNC 10-32 UNC	10 in-lbs (1.1 N-m) 15 in-lbs (1.7 N-m)
Supervisory: All Models	Sized to accept Amp Faston© insulated receptacle #2-520184-2.		

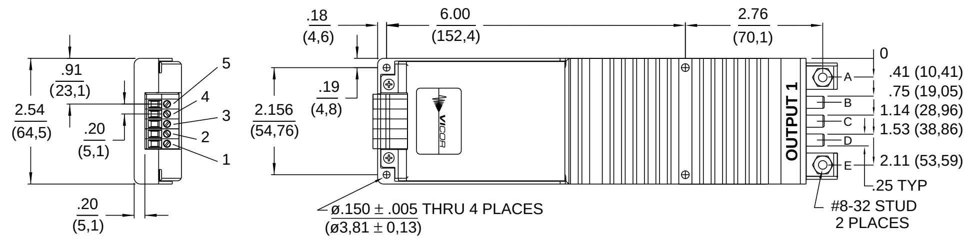
Mechanical Drawings

All Models

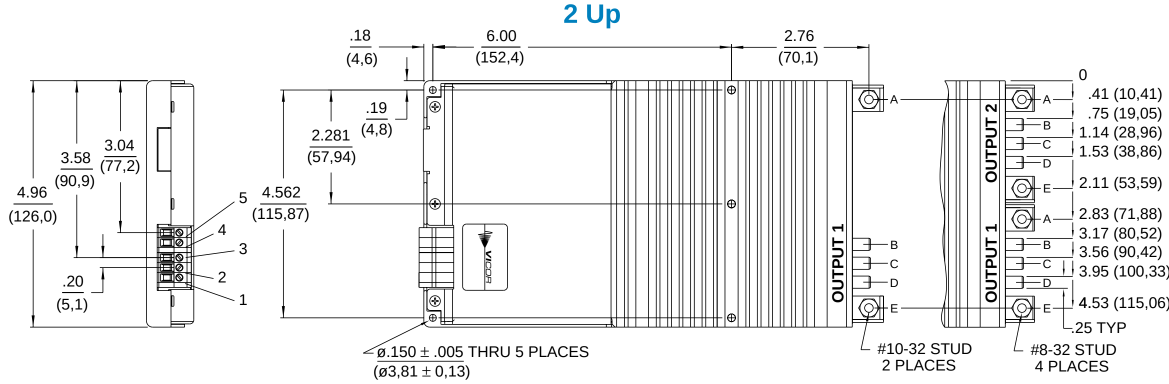
INPUTS	
1	Ground
2	-Input
3	+Input
4	Disable-
5	Disable+
OUTPUTS	
A	+Output
B	+Sense
C	Trim
D	-Sense
E	-Output



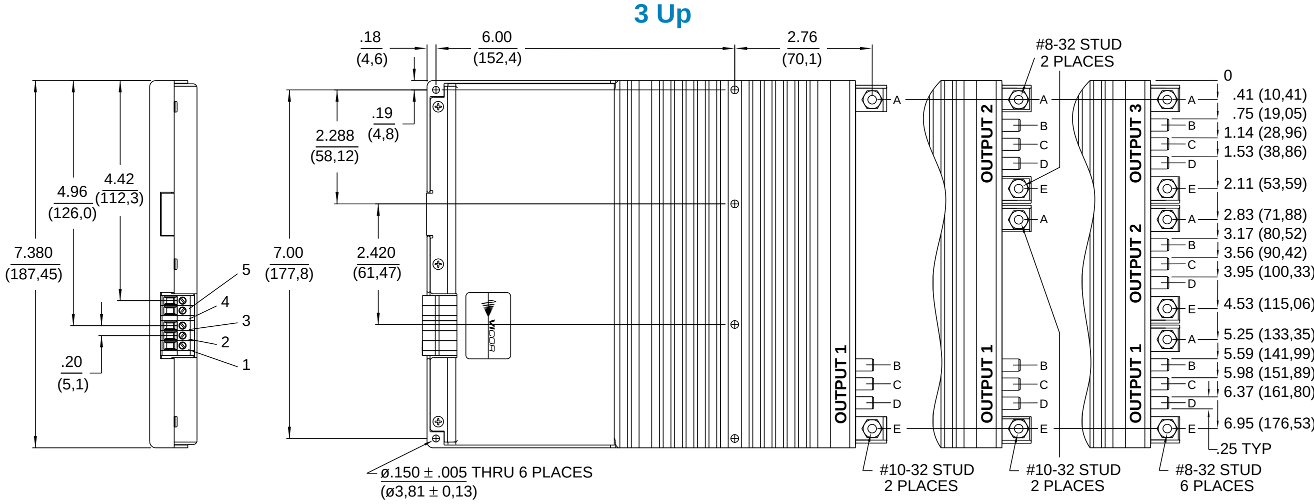
1 Up



2 Up



3 Up



Supervisory: All Models	Sized to accept Amp Faston© insulated receptacle #2-520184-2.

FlatPAC™ Technical Description

Overview

Vicor’s FlatPAC consists of an off-line single phase AC front end and one, two or three VI-26x/VI-B6x Family DC-DC converter modules (1-up, 2-up, 3-up), combined in an integrated mechanical assembly. This assembly provides a complete, high efficiency, off-line switching power supply delivering power up to 600W. The off-line front end provides rectification and filtering of the AC input, delivering a nominal unregulated 300Vdc bus as input to the VI-26x/VI-B6x Family converter modules. The front end control circuit will automatically strap the bridge as a voltage doubler for 115Vac operation or as a full bridge for 230Vac operation.

Circuit Operation

AC line voltage is applied via an agency-approved terminal block providing AC mains (L1, L2/N and GND). Current in the L1 lead is applied to a 15A/250V fuse for the 3-up FlatPAC, a 12A/250V fuse for the 2-up FlatPAC and a 7A/250V fuse for the 1-up FlatPAC. This current is interrupted only in the event of a catastrophic failure of a main power component internal to the FlatPAC.

The input current beyond the fuse is passed through an EMC filter designed to meet conducted noise limits of FCC Part 15 EN55022 Class B for the 2 up and 3 up versions. At start-up, AC inrush current is limited by a PTC thermistor prior to being passed to the main energy storage capacitors. This PTC thermistor serves as both an inrush current limiter on power-up and a current limiting shutdown device in the event of a line overvoltage condition. The PTC is shunted out shortly after initial power-up by a pair of inverse parallel SCRs on the 3-Up FlatPAC (TRIAC for the 1-up and 2-up FlatPAC), controlled by an opto-TRIAC coupler driven by a DC bus voltage sense circuit. The main rectifiers and filter capacitors are arranged in a conventional selectable configuration and act as either a full wave bridge or voltage doubler, delivering a nominal 300Vdc to the converter modules.

At initial power-up, the front end is configured for 230V operation and the PTC inrush limiter permits the main storage capacitors to charge up at a controlled rate toward full operating DC bus potential. If the bus voltage is below the operating threshold for the converter, the unit will autostrap for 115V operation. The autostrapping function is performed by a control circuit and TRIAC* which configures the front end from a full wave bridge to a voltage doubler. Once the unit autostraps for 230V operation, it will be necessary to recycle the AC power to allow operation at 115V. If the unit is operating in the 115V mode and a long duration transient is applied to the FlatPAC (>150Vac for 50 ms), the unit will autostrap for 230V operation.

The control circuit maintains the converter Gate In pins low, the PTC shunt inactive and the AC-OK and BUS-OK outputs in FAIL status until the DC bus potential reaches a minimum threshold at which full power and holdup can be delivered. The Gate In terminals of all driver modules internal to the FlatPAC are FET-controlled by a logical replica of the BUS-OK status line, and as such will inhibit converter operation at power-up until the DC bus potential has settled to full operating level. The converters are then enabled and the PTC shunt activated.

*Dual SCRs on 3-up unit.

Circuit Operation (cont)

The AC-OK and BUS-OK status lines go to their respective active states almost simultaneously on initial power-up. AC-OK will de-assert prior to BUS-OK on loss of AC input, providing advance warning of impending DC failure should the AC line not return prior to the expiration of the ride thru time (a function of both load and line voltage).

The front end output is bled down automatically after loss of AC input, as the logic circuit operating power is derived from a bleed path across the DC output bus. Input voltage to the converters is made via fast-acting 3A/250V Buss PC-Tron fuses in each positive input lead. The fuse will clear rapidly and protect the front end from damage in the event of a module input short.

Input overvoltage sensing and protection is performed by a voltage sensing circuit connected across the DC bus. In the event of an overvoltage condition, a SCR/PTC combination will simultaneously disable the drive for the TRIAC/SCR PTC shunt, disable the converters and apply a load across the DC bus. Normal operation resumes when the input voltage falls within the normal operating range.

A master disable function is incorporated in the two- and three-up FlatPAC (MOD DIS+, MOD DIS–). This optically isolated input will disable the output of all converters simultaneously. Applying a current to this input will disable the converters. This disable current should be limited to 30 mA maximum by an external control element.

FlatPAC AC-OK and BUS-OK Status Outputs, MOD-DIS Input (2-up and 3-up only)

The BUS-OK and AC-OK outputs provide the user with both an optically isolated status indication of the internal DC bus condition and advance warning of pending DC bus drop-out due to AC line loss. These outputs, in system applications, can provide power supply status, switch in (standby) backup sources or initiate “power down” sequences to save volatile memory contents in the event of AC line loss. The MOD-DIS input is an optically coupled input and allows for remote disabling of the outputs of 2-up- and 3-up FlatPACs.

BUS-OK

An internal replica of BUS-OK is wired to the Gate In input of all internal driver modules. The modules will be disabled (no DC output) during initial power-up of the FlatPAC until the internal DC input bus voltage to the DC-DC converters is sufficient to support fully-loaded operation. The BUS-OK status output reflects the status of this inhibit function. This same logic circuit will shut down the converters when the internal DC bus voltage is insufficient to support proper loaded operation. This shutdown will occur during normal power down, AC line dropouts of duration exceeding the holdup time, or internal faults causing the internal DC bus voltage at the input of the converters to collapse.

AC-OK

This output is provided primarily as an advance warning of a potential DC BUS-OK shutdown due to loss of AC line or an internal fault. A minimum advance warning time of 5 ms is provided at 90Vac and full load.

MOD-DIS+, MOD-DIS–

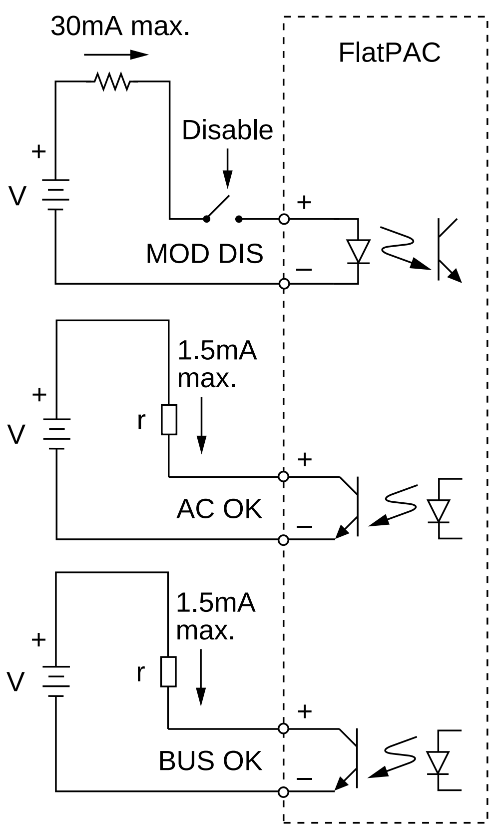
The module disable function will disable the output(s) of the 2-up- and 3-up FlatPACs. The supply is disabled by applying current to the MOD-DIS+/MOD-DIS– input. The minimum input current for disabling the supplies is 1 mA. The maximum allowable current is 30 mA.

Electrical Connections

Status output pairs AC-OK+, AC-OK– and BUS-OK+, BUS-OK– are the collectors (+) and emitters (–) of NPN optoisolator output transistors (one optoisolator per status signal). The collector terminals AC-OK+ and BUS-OK+ of the optocouplers, in a typical application, can be connected via current limiting resistors to a source no greater than 70Vdc. These resistors should limit the maximum current to the optocoupler output transistors to 1.5 mA. The emitter terminals AC-OK– and BUS-OK– are connected to the return of the external source. The status OK condition will set the optocoupler output transistors in saturation and are capable of sinking up to 1.5 mA with a Vce saturation voltage of 0.4V. Users should be cautioned that although the output of the FlatPAC can be used as the pull-up source, shortly after BUS-OK changes from OK (saturated) to NOT OK (high Z), the pull-up voltage will be shut down. It is thus advisable to provide a capacitive reservoir, if the pull-up source is one of the FlatPAC's outputs, in order to maintain the pull-up potential after loss of DC current output. Use edge sensing logic to detect assertion of logic outputs, or a separate source of bias supply voltage (i.e., backup batteries) to provide a safe pull-up voltage source regardless of the AC line status.

MOD DIS Input. *Apply a current of 1 – 30mA to disable output. Forward voltage drop of internal opto diode is 1.65V max. at 30mA max.*

AC OK and BUS OK Status Outputs. *Outputs low when OK. Vce sat. = < 0.4V @ 1.5mA. Maximum external pullup is 70Vdc. AC OK and BUS OK signals are isolated and can have different reference levels.*



Notes

The MegaPAC™ Family

AC-DC, DC-DC Switching Power Supplies

Overview

The MegaPAC family is a line of field configurable switching power supplies that leverage Vicor's DC-DC converters to provide maximum flexibility. Developing a custom power supply is as easy as selecting a MegaPAC chassis and sliding in the appropriate output assemblies, called ConverterPACs. With five different chassis, five different ConverterPAC styles and thousands of voltage and power combinations, there is a MegaPAC to fit almost any need.

Designing a customized power supply begins with selecting a chassis from the MegaPAC family; the PFC MegaPAC, Autoranging MegaPAC, Mini MegaPAC, Three Phase MegaPAC or DC MegaPAC. One or more can accept input voltages from 85 to 264Vac, 208/240 three phase, or 10 to 380Vdc. Maximum output power ranges up to 4000W, and all five are fan cooled. Standard features include output sequencing, general shutdown, AC OK and overcurrent protection.

Customized design continues by selecting the ConverterPACs that meet your requirements. Each ConverterPAC can be configured to provide one or two separate output voltages and up to 400W of power. Multiple ConverterPACs can be connected in parallel to achieve higher power levels. Best of all, ConverterPACs can be added or replaced with the turn of just one screw.

MegaPAC Family Products

PFC MegaPAC Technical Description

The PFC MegaPAC chassis consists of an off-line single phase, power factor corrected front end, EMC filter, cooling fan, customer interface and associated housekeeping circuits.

Input AC mains voltage (L1, L2/N and GND) is applied to a terminal block. The input current is passed through an EMC filter designed to meet conducted noise limit “B” specifications of FCC Part 15 and VDE 0871 and EN55022 level “B”. At start-up, inrush current is limited by a PTC thermistor prior to being passed to the power rectifiers. The PTC is shunted out shortly after initial power-up by a DC bus voltage sense circuit driving a relay. After rectification, the input voltage is put through a boost converter that keeps the AC input current sinusoidal and synchronized with the input AC voltage (in compliance with EN61000 at nominal line voltages). The boost converter delivers an unregulated 370Vdc to the hold-up capacitors and a high voltage backplane. The backplane supplies power to a variety of ConverterPAC assemblies that provide the desired low voltage, regulated outputs.

At initial power-up, the PFC MegaPAC outputs are disabled to limit the inrush current and to allow the DC bus potential to settle out to the correct operating level. A low-power flyback converter operating with PWM current-mode control converts the high voltage DC bus into regulated low voltage to power the internal housekeeping circuits and DC cooling fan. The internal housekeeping Vcc comes up within 1 sec after the application of input power. Once the high voltage bus is within its limits, the AC Power OK signal asserts to a TTL “1” indicating that the input power is OK, and allows the power outputs to come up within 15-30 ms. An auxiliary Vcc output of 5Vdc sourcing up to 0.3A is provided for peripheral use on interface connector J10-9.

An output Enable/Disable function is provided by using an optocoupler to control the Gate In pins of the ConverterPAC assemblies. If the Enable/Disable control pin is pulled low, the optocoupler turns on, pulling the Gate In pin low and disabling the ConverterPAC output. The nominal delay associated for an output to come up when measured from release of the Enable/Disable pin is 5-10 ms. The General Shutdown function controls all outputs simultaneously, and works in a similar manner.

The ride-through (holdup) time is the amount of time the load can be supported before loss of output regulation after the loss of input power. Detecting the loss of input power takes a finite time period after which the AC Power OK signal goes from a TTL “1” to “0”. This signal is available for use within 1.2 seconds after initial power-up and may be used to indicate an impending loss of power. Approximately 3 ms of warning time is obtained. Following the loss of input power, the outputs are disabled after AC Power OK goes low.

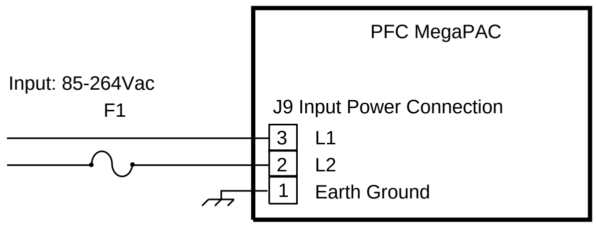
A fault-clearing device such as a fuse is required per safety agency conditions of acceptability. It should be sized to handle the specific load conditions but not to exceed 20A. 6 to 20A fast-acting ceramic body type fuses should be used, 3AB-6 to 3AB-20 respectively. For current ratings less than 6A, use a 3AB slow-blow type fuse. Fuses should be sized with sufficient voltage rating as well as current rating.

PFC MegaPAC Interface Connections

Chassis Input Power Terminals (J9)

Input AC power is applied to terminal block J9, using a pressure screw terminal that accepts a maximum wire size of 12 AWG. The maximum torque recommended is 10 in-lbs. J9-1 (GND) is Earth Ground for safety; J9-2 (L2) is the Hot connection; J9-3 (L1/N) is the other Hot or input Neutral connection.

Figure 1.
Input Connector J9

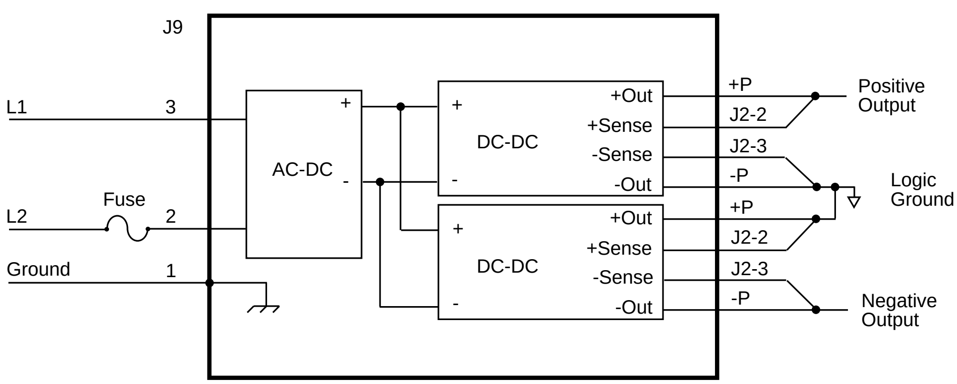


Chassis Output Power Terminals

Depending on the ConverterPAC used, there are two types of output power terminals available in the PFC MegaPAC. For single output assemblies (ModuPAC/RamPAC/BatPAC), these terminals are two 1/4-20 plated steel bolts. The positive polarity of the output is the upper bolt. For DualPACs there is a 6-pin Molex connector for each output (J1A, J1B). For both connectors pins 1 and 4 are the +Output, and pins 2 and 5 are the –Output. Pins 3 and 6 are duplicates of the remote sense pins present on J2A and J2B. The top connector, J1B, provides the first voltage listed on the DualPAC, while the bottom connector, J1A, provides the second voltage. Each power output is isolated; thus outputs of positive or negative polarity may be configured by the user through proper selection of an output reference terminal.

In order to minimize parasitic cable inductance and reduce EMC, the output power cables should be routed in close proximity to one another, and large current loops should be avoided. To avoid excessive voltage drop, do not undersize power cables, especially for high current outputs. Excessive cable inductance coupled with large capacitive loading can introduce instability in switching power supplies. This problem can be avoided with proper system design. Consult Vicor's Applications Engineering Department for assistance with applications that use long cable lengths and excessive load capacitance.

Figure 2.
Output Power Connections

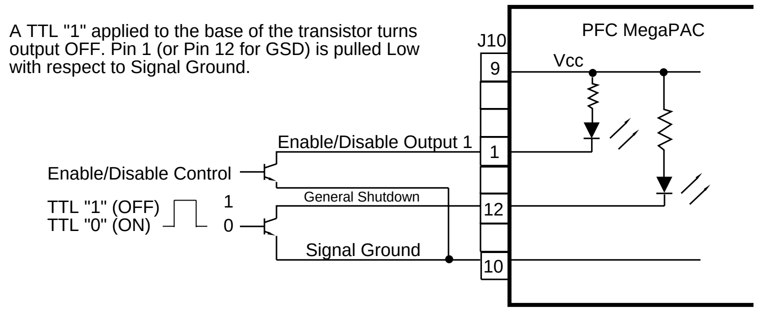


PFC Interface Connections (cont)

Signal Ground (J10-10)
Signal Ground on J10-10 is an isolated secondary ground reference for all J10 interfacing signals, and for ModuPAC output status signals such as Power Good. This is not the same as Earth Ground on input power connector J9.

Enable/Disable (J10-8)
The Enable/Disable control pins allow ConverterPAC outputs to be sequenced either on or off. J10-1 through J10-8 are the control pins for output positions 1 through 8, respectively. For DualPACs, both outputs are sequenced. In parallel arrays, only the driver ModuPAC need be controlled. The Enable/Disable pins should be pulled low to less than 0.7V with respect to Signal Ground to disable the outputs. They will source 10mA maximum. These pins should be open circuited or allowed to exceed 4.5V when enabled. Do not apply more than 5V to these inputs at any time.

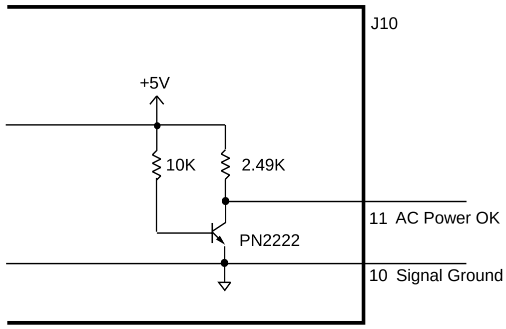
Figure 3. Enable/Disable and General Shutdown



General Shutdown GSD (J10-12)
The GSD control pin on J10-12 allows simultaneous shutdown of all ConverterPAC outputs. This pin must be pulled down to less than 0.7V, and will source 13 mA maximum to shut down all outputs. The GSD pin should be open circuited or allowed to exceed 4.5V when not in use, or when the outputs are to be enabled. Do not apply more than 5V to this input at any time. Normal open circuit voltage is 1.5 to 3V with respect to Signal Ground.

AC Power OK (J10-11)
This is an active high TTL compatible signal, and provides a status indication of the AC input power. It is capable of sinking 20 mA maximum. This signal switches to a TTL “1” when the high voltage bus exceeds low-line condition during turn-on, and switches to a TTL “0” 3 ms (typical) before loss of output regulation due to the loss of input AC power. This signal may be used to warn external control circuits of an impending loss of power.

Figure 4. AC Power OK

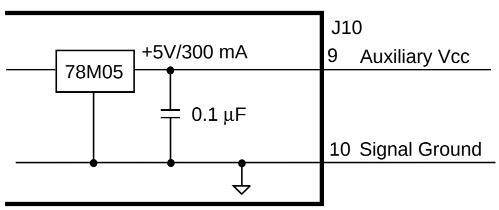


PFC Interface Connections (cont)

Auxiliary Vcc +5V/0.3A (J10-9)
The Vcc on J10-9 is an auxiliary 5V regulated power source. It is +5Vdc +/–5% with respect to Signal Ground, and can supply 300 mA maximum. It is short circuit proof, but if shorted all outputs will shut down through the Enable/Disable circuitry.

The Auxiliary Vcc is typically used with the Power Good circuitry to provide a pull-up reference for the outputs of the DC Power Good circuit on a ModuPAC (Figure 5, below). If used for this purpose, then the Signal Ground on J10-10 must also be connected to the J3-4 Signal Ground pin of the ModuPAC.

Figure 5. Auxiliary Vcc



PFC MegaPAC Output Power Derating

Figure 6. Maximum Output Power vs. AC Input Voltage

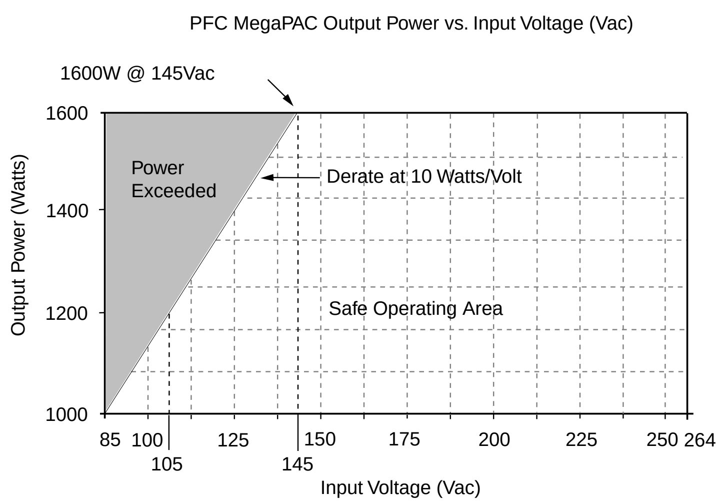
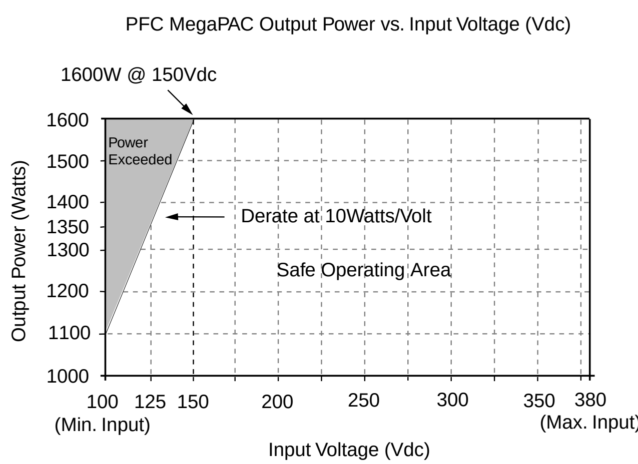


Figure 7. Maximum Output Power vs. DC Input Voltage

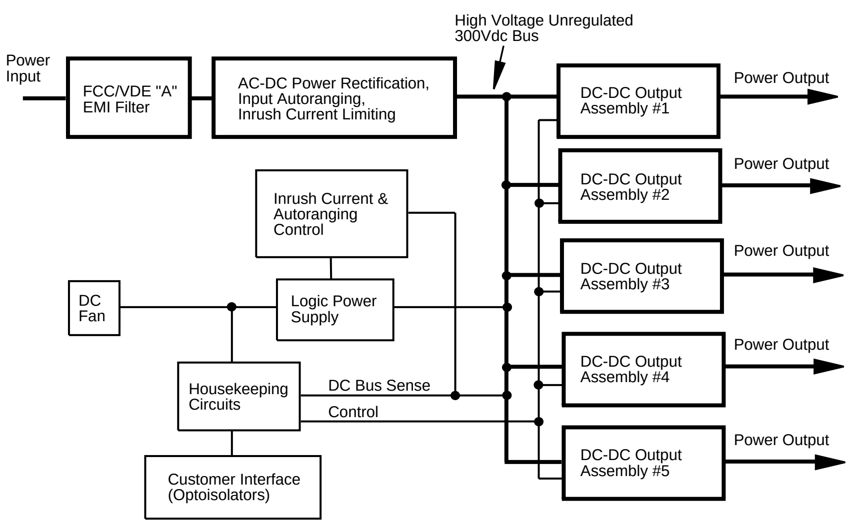


Autoranging MegaPAC/Mini MegaPAC Technical Description

The MegaPAC and Mini MegaPAC chassis consist of an off-line single phase AC front end, EMC filter, cooling fan, customer interface and associated housekeeping circuits.

Input AC mains voltage (L1, L2/N and GND) is applied to a terminal block. The input current is passed through an EMC filter designed to meet conducted noise limit “A” specifications of FCC Part 15 and VDE 0871. At start-up, inrush current is limited by an NTC thermistor prior to being passed to the power rectifiers. The NTC is shunted out shortly after initial power-up by a relay driven by a DC bus voltage sense circuit. The sense circuit also controls the input autoranging selection relay on the autoranging MegaPAC. The power rectifiers and filter capacitors are arranged in a conventional full wave bridge rectifier/voltage doubler configuration. This operates as a full wave bridge rectifier on 230Vac, and voltage doubler on 115Vac, delivering unregulated 300Vdc to a high voltage backplane. The backplane supplies power to a variety of ConverterPAC assemblies that provide the desired low voltage, regulated outputs.

Figure 8. MegaPAC and Mini MegaPAC Architecture



At initial power-up, the MegaPAC outputs are disabled to limit the inrush current, reduce peak currents in the autoranging relay contacts, and to allow the DC bus potential to settle out to the correct operating level. A low-power flyback converter operating with PWM current-mode control converts the high voltage DC bus into regulated low voltage to power the internal housekeeping circuits and DC cooling fan. When operating on 115Vac, the internal housekeeping Vcc comes up within 1,000 ms after the application of input power. On 230Vac, it comes up within 500 ms. The input range selection circuit in the Autoranging MegaPAC may take up to 200 ms to select the range if 115Vac is applied. When 230Vac is applied, the circuit immediately selects for operation on 230Vac. The Mini MegaPAC must be manually strapped for 115Vac or 230Vac operation. Once the input range selection has taken place, the AC Power OK signal asserts to a TTL “1” indicating that the input power is OK, and allows the power outputs to come up within 15-30 ms later. An auxiliary Vcc output of 5Vdc sourcing up to 0.3A is provided for peripheral use on interface connector J10-9.

Autoranging MegaPAC/Mini MegaPAC Interface Connections

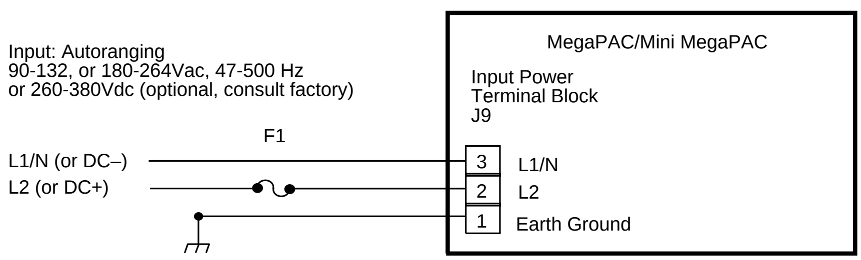
An output Enable/Disable function is provided by using an optocoupler to control the Gate In pins of the ConverterPAC assemblies. If the Enable/Disable control pin is pulled low, the optocoupler turns on, pulling the Gate In pin low and disabling the ConverterPAC output. The nominal delay associated for an output to come up when measured from release of the Enable/Disable pin is 5-10 ms. The General Shutdown function controls all outputs simultaneously, and works in a similar manner.

The ride-through (holdup) time is the amount of time the load can be supported before loss of output regulation after the loss of input power. Detecting the loss of input power takes a finite time period after which the AC Power OK signal goes from a TTL “1” to “0”. This signal is available for use within 1.2 seconds after initial power-up and may be used to indicate an impending loss of power. Approximately 3 ms of warning time is obtained. Following the loss of input power, the outputs are disabled after AC Power OK goes low.

Chassis Input Power Terminals (J9)
Input AC power is applied to terminal block J9, using a pressure screw terminal that accepts a maximum wire size of 10 AWG. The maximum torque recommended is 10 in-lbs. J9-1 (GND) is Earth Ground for safety; J9-2 (L2) is the Hot connection; J9-3 (L1/N) is the other Hot or input Neutral connection.

A fault clearing device such as a fuse is required per safety agency conditions of acceptability. It should be sized to handle the specific load conditions. The Autoranging MegaPAC should use a max. 30A fast-blow fuse for 1200W, 115Vac operation and a max. 25A fast-blow fuse for 1600W, 230Vac operation. The Mini MegaPAC should use a 25A max. fast blow fuse. For current ratings less than 6A, use a 3AB slow-blow type fuse. Fuses should be sized with sufficient voltage rating as well as current rating.

Figure 9. Input Power Connections



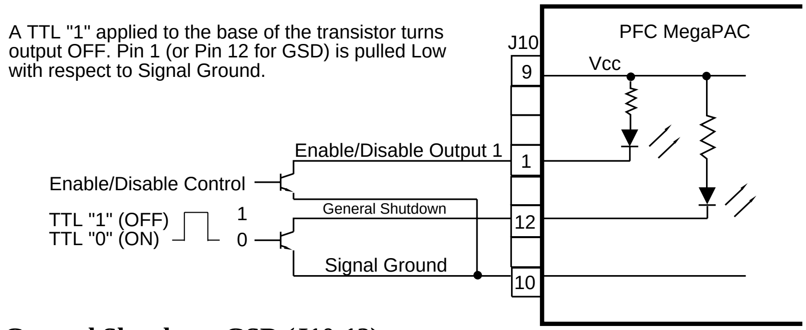
Note: An input fault clearing device, such as fuse F1 or a circuit breaker is recommended.

Signal Ground (J10-10)
Signal Ground on J10-10 is an isolated secondary ground reference for all J10 interfacing signals, and for ModuPAC output status signals such as Power Good. This is not the same as Earth Ground on input power connector J9.

Enable/Disable (J10-1 to 8)
The Enable/Disable control pins allow ConverterPAC outputs to be sequenced either on or off. For the Autoranging MegaPAC, J10-1 through J10-8 are the control pins for output positions 1 through 8, respectively. For the Mini MegaPAC, J10-1 through J10-5 control the outputs for position 1 through 5. For DualPACs, both outputs are sequenced together. In parallel arrays, only the driver ModuPAC need be controlled. The Enable/Disable pins should be pulled low to less than 0.7V with respect to Signal Ground to disable the outputs. They will source 10 mA maximum. These pins should be open circuited or allowed to exceed 4.5V when enabled. Do not apply more than 8V to these inputs at any time.

Autoranging MegaPAC/Mini MegaPAC Interface Connections (cont)

Figure 10.
Enable/Disable General Shutdown



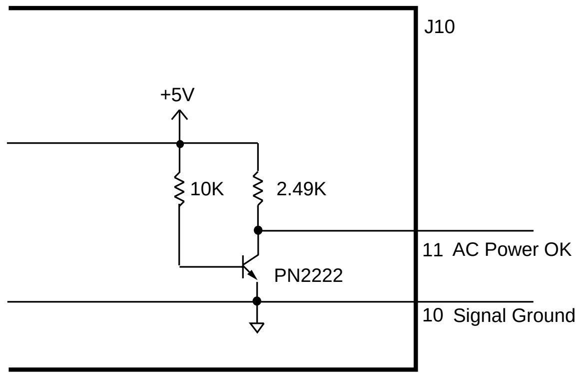
General Shutdown GSD (J10-12)
The GSD control pin on J10-12 allows simultaneous shutdown of all ConverterPAC outputs. This pin must be pulled down to less than 0.7V, and will source 13 mA maximum to shut down all outputs. The GSD pin should be open circuited or allowed to exceed 4.5V when not in use, or when the outputs are to be enabled. Do not apply more than 8V to this input at any time. Normal open circuit voltage is 1.5 to 3V with respect to Signal Ground.

AC Power OK (J10-11)
This is an active high TTL compatible signal, and provides a status indication of the AC input power. It is capable of sinking 20 mA maximum. This signal switches to a TTL “1” when the high voltage bus exceeds low-line condition during turn-on, and switches to a TTL “0” 3 ms (typical) before loss of output regulation due to the loss of input AC power. This signal may be used to warn external control circuits of an impending loss of power.

Auxiliary Vcc +5V/0.3A (J10-9)
The Vcc on J10-9 is an auxiliary 5V regulated power source. It is +5Vdc +/–5% with respect to Signal Ground, and can supply 300 mA maximum. It is short circuit proof, but if shorted all outputs will shut down through the Enable/Disable circuitry.

The Auxiliary Vcc is typically used with the Power Good circuitry to provide a pull-up reference for the outputs of the DC Power Good circuit on a ConverterPAC (Figure 11, below). If used for this purpose, then the Signal Ground on J10-10 must also be connected to the J3-4 Signal Ground pin of the ModuPAC.

Figure 11.
AC Power OK



Autoranging MegaPAC/Mini MegaPAC Interface Connections (cont)

Vcc (J3-1)
The Vcc on J3-1 is an input that requires +5V either from the Auxiliary Vcc on J10-9, or from another source. Input current to this pin is limited by an internal resistor to 3 mA. If the Auxiliary Vcc on J10-9 is connected to Vcc on J3-1, then Signal Ground J10-10 must also be connected to Signal Ground on J3-4.

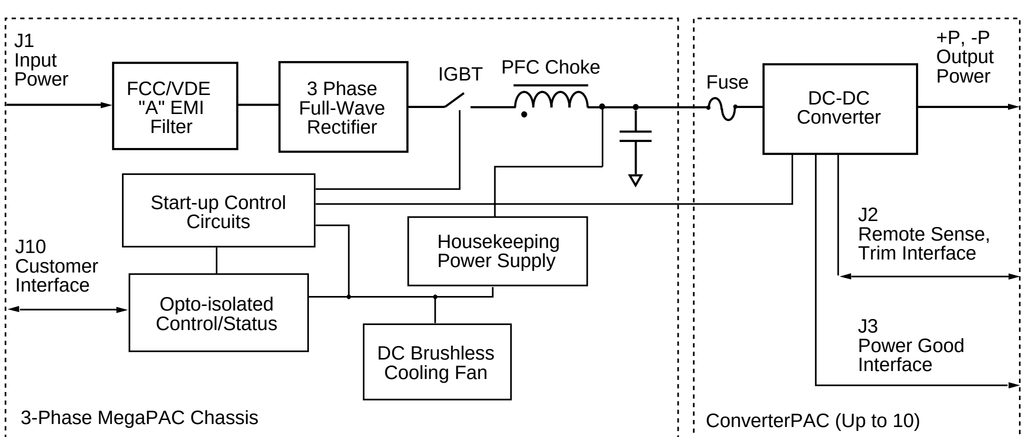
Three Phase MegaPAC Technical Description

A Three Phase MegaPAC is configured by installing DC-DC ConverterPAC assemblies into a three phase front-end chassis. The chassis takes three phase AC input power and performs filtering and rectification functions. The ConverterPACs plug into a high-voltage backplane and provide low-noise, independently regulated and fully isolated outputs.

Three Phase MegaPAC Chassis
Input AC mains voltage (L1, L2, L3 and GND) is applied to an agency-approved mating plug. The input current is passed through an EMC filter designed to meet conducted noise limit "A" specifications of FCC Part 15 and VDE 0871, before it is passed to a three-phase full-wave bridge rectifier. The rectifier charges-up storage capacitors and delivers unregulated 300Vdc to a backplane after passing through a large choke that improves input power factor. The power factor typically exceeds 0.9 depending upon load, line voltage, frequency and line balance. Inrush current is actively controlled with an IGBT and never exceeds 30A peak regardless of hot or cold starts. The backplane supplies power to a variety of ConverterPAC assemblies that provide the desired low-voltage, regulated outputs.

A housekeeping supply, isolated from the AC input, powers the brushless DC cooling fan and other input monitoring circuits, in addition to providing an auxiliary +5V power source for the user. Excessive input currents caused by loss of a phase, or excessive output loading in single phase operation, will safely shut down the unit and provide a phase fail indication until input power is recycled. This occurs when the peak input current reaches 30A. Analog and digital temperature monitors are provided, as well as overtemperature shutdown. An active-high TTL compatible, Enable control is included for each ConverterPAC assembly, as well as an active-low General Shutdown control; the polarities, active-high or active-low, are factory set. Three Phase MegaPACs can be safely paralleled with accurate current sharing for high power systems. All interface signals are safety-isolated using a common floating return.

Figure 12. Three-Phase MegaPAC Architecture



Three Phase MegaPAC Technical Description (cont)

Upon power-up, all outputs are first disabled to limit the inrush current, and to allow the unregulated 300Vdc to reach correct operating levels for ConverterPAC assemblies. The internal housekeeping supply comes up within 500 ms after input power is applied, at which time the AC Power OK signal asserts to a TTL "1," indicating that the input power is OK. The low-voltage power outputs come up within 10-20 ms after the AC Power OK asserts to a TTL "1." Output ramp-up time from Enable or General Shutdown is 10-20 ms. Output fall time from Disable is dependent on load, but typically a few hundred microseconds.

Three Phase MegaPAC Interface Connections

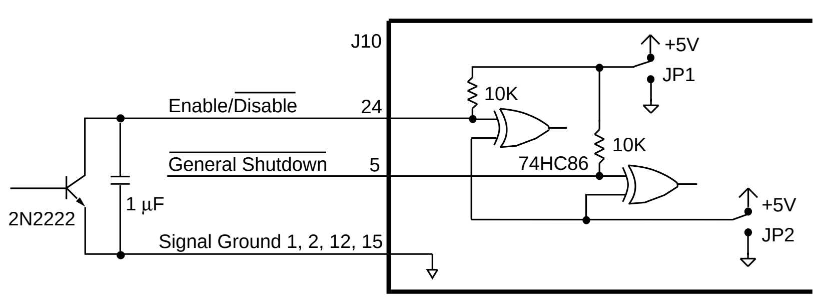
Input Power Connections (J1)
Input AC power is applied to a plug-in connector, J1, that accepts soldered terminals with a maximum wire size of 12 AWG. For operation on high voltage DC input, input power may be connected to any two input lines. A fault-clearing device, such as a fuse, at the power supply input is required per safety agency conditions of acceptability. A user-accessible input fuse is not present within the unit. For an output of 2000W with operation on 208Vac, 3Ø input, a 20A slow-blow fuse in each input line is acceptable. Input power cables should be shielded to minimize radiated noise effects.

The Three Phase MegaPAC can also operate from a single phase 230Vac input; however, the output power must be limited to 1200W.

Signal Ground (J10)
Signal Ground on J10 pins 1, 2, 12, and 15 is an isolated secondary ground reference for all J10 interface signals. This is not the same as Earth Ground on input power connector J1.

Enable/Disable and General Shutdown (GSD) (J10)
The Enable/Disable control lines allow individual ConverterPAC outputs to be sequenced either on or off via TTL compatible HCMOS control inputs. For DualPACs, both outputs are sequenced together. In parallel arrays, only the driver ModuPAC needs to be sequenced. The GSD control line on J10-5 allows simultaneous shutdown of all ConverterPAC outputs. An internal jumper, JP2, selects polarity, either active-high or active-low. A jumper, JP1, selects a pull-up or pull-down source for the HCMOS control inputs.

Figure 13. Enable/Disable and General Shutdown

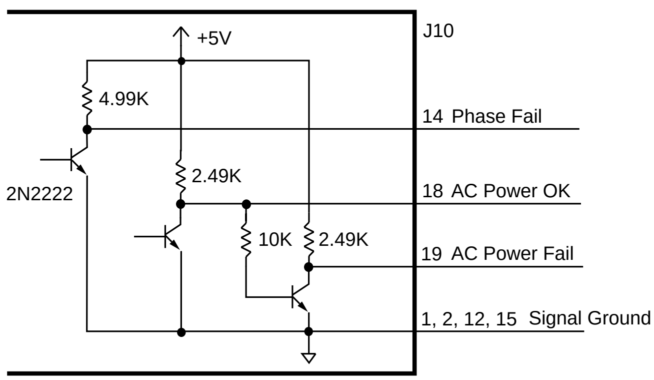


Three Phase MegaPAC Interface Connections (cont)

For standard Three Phase MegaPACs, the Enable/Disable controls are configured as active-high with internal pull-up; outputs are enabled when these pins are open-circuited or allowed to exceed 4.5V with respect to Signal Ground. Outputs are disabled when the Enable/Disable control lines are pulled low to less than 0.7V. The GSD control line is configured to be active-low with internal pull-up; all outputs are simultaneously inhibited when the GSD control line is pulled low to less than 0.7V. All outputs are enabled when GSD is open circuited or allowed to exceed 4.5V. Do not apply more than 5V to these inputs at any time. If driven from an electromechanical switch or relay, a small capacitor should be connected between the control line and Signal Ground to eliminate latch-up due to the effects of switch bounce (1 µF, typical).

AC Power OK (J10-18)
This signal on J10-18 provides a status of the AC input power. It is active high, TTL compatible and capable of sinking 10 mA maximum. This signal switches to a TTL “1” when the high voltage bus exceeds low-line condition during turn-on, and switches to a TTL “0” 3 ms (typical) before loss of output regulation due to the loss of input AC power. This signal may be used to warn external control circuits of an impending loss of power.

Figure 14. AC Power OK, AC Power Fail and Phase Fail



AC Power Fail (J10-19)
J10-19 is the inverse of AC Power OK, and goes to a TTL “1” when the input AC power is not OK. It is capable of sinking 10 mA maximum. The fan out is 20.

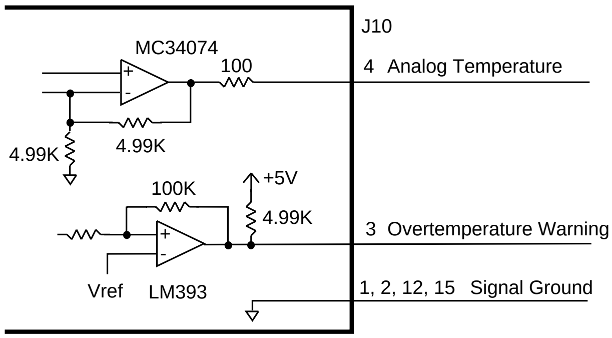
Phase Fail (Input Overcurrent) (J10-14)
J10-14 is a TTL level active-high signal, that is asserted when the peak input current reaches 30A due to the loss of an input phase, or severe line imbalance. This occurs when one input phase is lost with approximately 1400W output loading. Maximum current that can be sourced is 10 mA.

Analog Temperature (J10-4)
J10-4 provides an analog DC voltage between 0V and 10V, representing an inlet air temperature of 0˚C to 100˚C, respectively. The temperature is monitored close to the fan.

Overtemperature Warning (J10-3)
J10-3 asserts a TTL level “1” if the inlet air temperature exceeds the following factory set levels. For standard units, the warning trip point is between 65˚C to 76˚C. The recovery point is 1˚C lower than the actual trip point.

Three Phase MegaPAC Interface Connections (cont)

Figure 15.
Analog Temperature and Overtemperature Warning



Overtemperature Shutdown

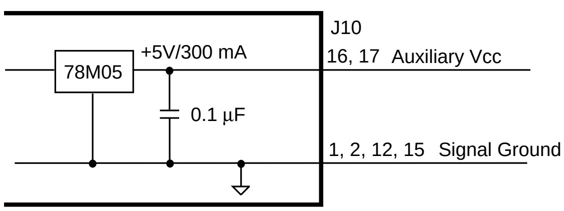
If the inlet ambient air temperature exceeds the following factory set levels, then all outputs are disabled. For standard units the shutdown trip point is between 70˚C to 81˚C. The recovery point is 10˚C lower than the actual trip point.

Auxiliary Vcc (J10-16,17)

J10 pins 16 and 17 provide an auxiliary regulated power source. It is +5Vdc +/–5% with respect to Signal Ground, and can supply 300 mA maximum. It is short circuit proof, but if shorted, all outputs will shut down.

The Auxiliary Vcc can be used to provide a pull-up reference for the Power Good circuit on ConverterPACs. In this case, Signal Ground on J10 must also be connected to Signal Ground on J3-4 of the ConverterPAC Power Good connector.

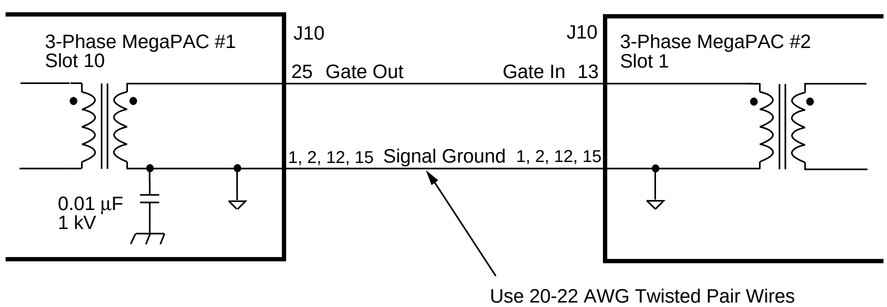
Figure 16.
Auxiliary Vcc



Gate-In, Gate-Out (J10-13,25)

Gate-In and Gate-Out signals are used for paralleling Three Phase MegaPACs for high power systems using a proprietary driver/booster technique that provides accurate current sharing between units. One channel may be paralleled, i.e., one output voltage from unit #1 may be connected to unit #2. The Three Phase MegaPAC #1 provides a signal from output slot #10 at J10-25, to slot #1 in the Three-Phase MegaPAC #2 at J10-13. These signals are referenced to Signal Ground on J10. Use twisted pair 20-22 AWG wires. Do not separate the units by more than six feet.

Figure 17.
Gate-In and Gate-Out

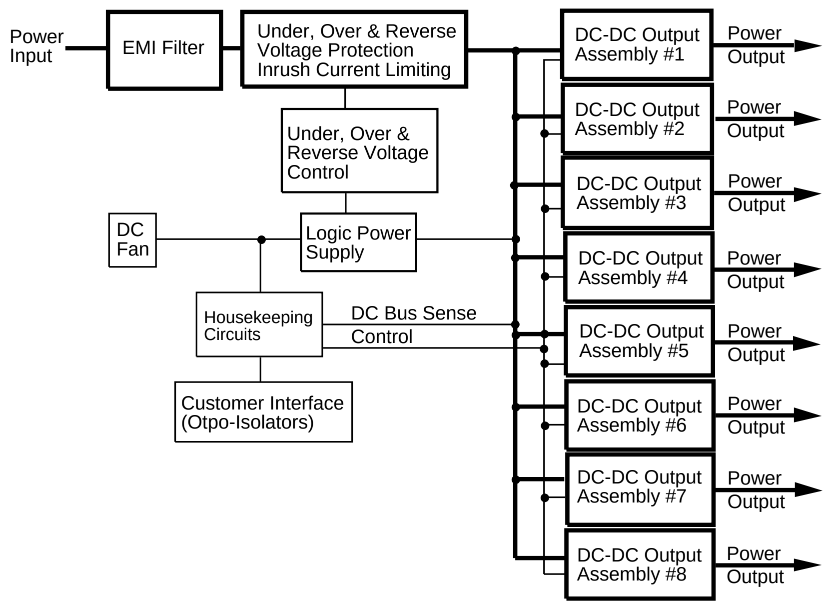


DC MegaPAC Technical Description

The DC MegaPAC chassis consists of an EMC filter, cooling fan, customer interface and associated housekeeping circuits.

Input DC voltage (+Vin, –Vin and GND) is applied to the input connectors. The input current is passed through an EMC filter designed to meet British Telecom specifications. At start-up, inrush current is limited by a thermistor. The thermistor is shunted out shortly after initial power-up by a relay driven by a DC bus voltage sense circuit. The DC voltage is then fed to the backplane. The backplane supplies power to a variety of ConverterPAC assemblies that provide the desired voltage, regulated outputs.

Figure 18.
DC MegaPAC Architecture



At initial power-up, the DC MegaPAC outputs are disabled to limit the inrush current and to allow the DC bus potential to charge to the operating level. A low-power flyback converter operating with PWM current-mode control converts the voltage DC bus into regulated low voltage to power the internal housekeeping circuits and DC cooling fan. The internal housekeeping Vcc comes up within three seconds after the application of input power. Once the input range is within specification, the Vin OK signal asserts to a TTL "1" indicating that the input voltage is OK, and allows the power outputs to be enabled. The power outputs will be in regulation 500 ms after the Vin OK signal asserts to a TTL "1". An auxiliary Vcc output of 5Vdc sourcing up to 0.3A is provided for peripheral use on interface connector J10-16 and J10-17.

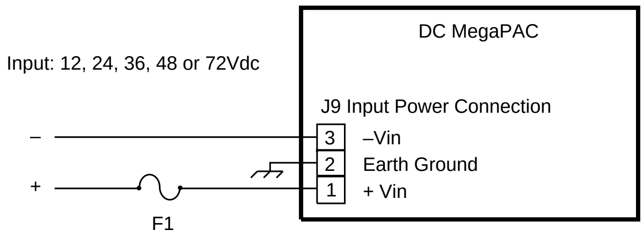
DC MegaPAC Interface Connections

Chassis Input Power Terminals (J9)
Input DC power is applied to solderless lugs J9, using a wire size of 2 AWG. J9-1 is the +DC Voltage IN connection and J9-3 is the -DC Voltage IN connection. The Earth Ground is accessed via J9-2, a size 10-32 self-locking PEM nut. Max. torque recommended is 25 in-lbs. A fault clearing device such as a fuse or circuit breaker at the power supply input is strongly recommended. For an output of 1600W with operation on 48Vdc (and low line operation

DC MegaPAC Interface Connections (cont)

of 42V), a fast-blow fuse of 50 Amps is recommended. Start-up inrush current is limited by a 10Ω thermistor and in most cases will be less than nominal line current during operation. Start-up inrush current can be calculated by I = MaxVin/10 (where MaxVin is the maximum operating voltage, see Table 1, page 20-16). Example: for a nominal 48V input, the maximum operating voltage is 60V, therefore, I = 60V/10 = 6 Amps.

Figure 19. Input Connector J9

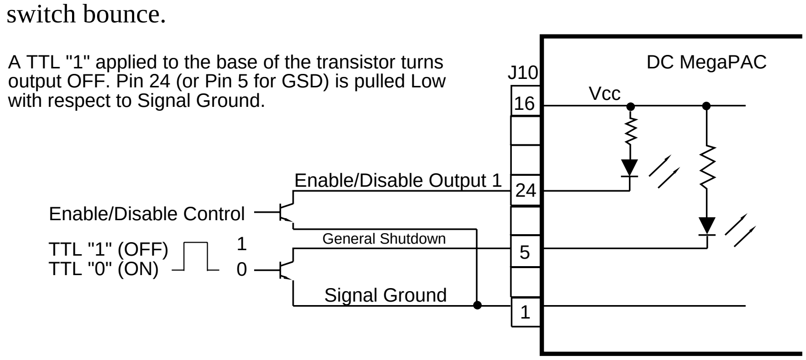


NOTE: An input fault clearing device such as fuse F1, or a circuit breaker is required per safety agency conditions of acceptability.

Signal Ground (J10-1,2,12,15)
Signal Ground on J10-1, 2, 12 and 15 are isolated secondary ground references for all J10 interfacing signals. This is not the same as Earth Ground on input power connector J9.

Enable/Disable (J10)
The Enable/Disable control pins allow ConverterPAC outputs to be sequenced either on or off; see outline drawing for locations. For DualPACs, both outputs are sequenced together. In parallel arrays, only the driver ConverterPAC need be controlled. The Enable/Disable pins should be pulled low to less than 0.7V with respect to Signal Ground to disable the outputs. They will source 8 mA maximum. These pins should be open circuited or allowed to exceed 4.5V when enabled. Do not apply more than 8V to these inputs at any time. If driven from an electromechanical switch or relay, a capacitor should be connected to eliminate the effects of switch bounce.

Figure 20. Enable/Disable and General Shutdown



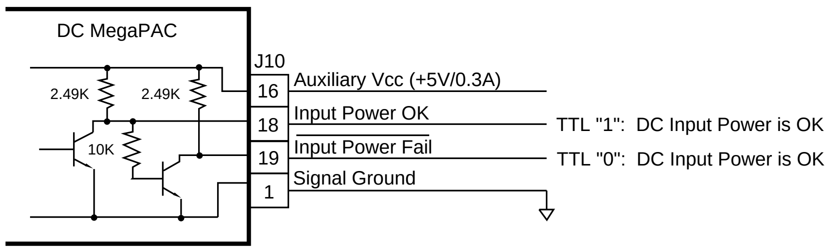
General Shutdown (GSD) (J10-5)
The GSD control pin on J10-5 allows simultaneous shutdown of all ConverterPAC outputs. This pin must be pulled low to less than 0.7V, and will source 8 mA maximum to shut down all outputs. The GSD pin should be open circuited or allowed to exceed 4.5V when not in use, or when the outputs are to be enabled. Do not apply more than 8V to this input at any time. Normal open circuit voltage is 1.5 to 3V with respect to Signal Ground. If driven from an electromechanical switch or relay, a capacitor should be connected to eliminate the effects of switch bounce.

DC MegaPAC Interface Connections (cont)

Input Power OK (J10-18)
This is an active high TTL compatible signal on pin J10-18, and provides a status indication of the DC input power. It is capable of sinking 20 mA maximum. This signal switches to a TTL “1” when Vin voltage is within specification. See Table 1, page 20-16 for specifications.

Input Power Fail (J10-19)
The Input Power Fail signal on pin J10-19 is the inverse of the Input Power OK signal on J10-18, and goes to a TTL “0” when the input DC power is OK. It is capable of sinking 20 mA maximum.

Figure 21.
Input Power OK,
Input Power Fail



Analog Temperature (J10-4)
This signal on J10-4, referenced to Signal Ground, provides an analog DC voltage output between 0V and 10V that represents the air temperature of 0˚C to 100˚C, respectively, inside the power supply. The inlet air temperature is monitored close to the fan.

Overtemperature Warning (J10-3)
J10-3 is a signal that asserts a TTL level “1” if the air temperature exceeds the following factory set levels. The warning trip point is 65˚C to 76˚C typically and the recovery point is 1˚C lower than the actual trip point.

Overtemperature Shutdown
If the inlet ambient air temperature exceeds the following factory set levels, then the outputs are disabled. The shutdown trip point is 70˚C to 81˚C typically and the recovery point is 10˚C lower than the actual trip point.

Gate In/Gate Out (J10-13,25)
The Gate In and Gate Out signals are used for paralleling DC MegaPACs for power expansion. The Gate Out signal, J10-25, of the driver DC MegaPAC should be connected to the Gate In, J10-13, of the Booster DC MegaPAC; J10 signal ground of the driver DC MegaPAC also needs to be connected to J10 signal ground of the booster DC MegaPAC.

The driver DC MegaPAC (ModuPAC, slot #8) generates the Gate Out signal and sends it to the booster DC MegaPAC (ModuPAC, slot #1). Vicor’s zero-current-switching Booster technology provides for accurate, dynamic power sharing within arrays, without the need for trimming, module “matching” or external components.

Auxiliary Vcc +5V/0.3A (J10-16,17)
The Vcc on J10-16, 17 is an auxiliary 5V regulated power source. It is +5Vdc +/–5% with respect to Signal Ground, and can supply 300 mA maximum. It is short circuit protected, but if shorted all outputs will shut down through the Enable/Disable circuitry.

The Auxiliary Vcc can be used with the Power Good circuitry to provide a pull-up reference for the outputs of the DC Power Good circuit on a ConverterPAC. If used for this purpose, then the Signal Ground on J10-1, 2, 12 or 15 must also be connected to the J3-4 Signal Ground pin of the ConverterPAC.

DC MegaPAC Input Voltage Range and Vin OK Limits

Table 1.

	Operating Range			Vin OK Trigger	
Code	Nominal Vdc	Low Line	High Line	Low Line Cut off	High Line Cut off
0	12V	10V	20V	6V to 10V	20V to 23V
1	24V	21V	32V	16V to 21V	32V to 36V
W	24V Wide	18V	36V	12V to 18V	36V to 41V
2	36V	21V	56V	11V to 21V	56V to 63V
3	48V	42V	60V	34V to 42V	60V to 68V
N	48V Wide	36V	76V	23V to 36V	76V to 86V
4	72V	55V	100V	40V to 55V	100V to 112V*

*Do not apply greater than 100V to the input of the DC MegaPAC.

ConverterPAC Functional Descriptions

A brief description of the standard output assemblies and the power and interface connections is provided. Please refer to the MegaPAC Family data sheet for technical specifications and mechanical details.

ModuPAC
The ModuPAC output assembly consists of a VI-200 DC-DC converter that converts the unregulated high voltage bus to the desired regulated output voltage. The converter is fused with a PC-Tron 3A fast-acting fuse in the positive input terminal. The output of the converter contains a passive LC filter to reduce output ripple/noise down to 1% (typ.), and 2% (max.) when measured peak to peak up to a 20 MHz bandwidth from 10% to 100% of rated load of the converter. To meet VXI noise level standards the “V2” option can be selected for outputs up to 15Vdc, and the “V1” option can be selected for 24Vdc outputs. Option “V2” limits output ripple/noise to 50 mV peak to peak, and option “V1” limits output ripple/noise to 150 mV peak to peak. An optional DC Power Good signal and/or output voltage adjustment potentiometer may be specified.

The ModuPAC contains output overvoltage protection (OVP), overcurrent protection (OCP), and overtemperature protection (OTP). The OCP has automatic recovery when the overcurrent condition is removed. The OVP and OTP are latching functions, and require recycling of the AC input power to restart.

JuniorPAC
The JuniorPAC consists of one VI-J00 DC-DC converter that converts the unregulated input voltage to the desired regulated output voltage. The assembly is fused with a single PC-Tron fast-acting fuse. The output contains a passive LC filter to reduce output ripple/noise to 1% (typ.), and 2% (max.) when measured peak to peak up to a 20 MHz bandwidth from 10% to 100% of rated load of the converters. To meet VXI noise level standards the “V2” option can be selected for outputs up to 15Vdc, and the “V1” option can be selected for 24Vdc outputs.

Option “V2” limits output ripple/noise to 50 mV peak to peak and option “V1” limits output ripple/noise to 150 mV peak to peak. An optional DC Power Good signal and/or output voltage adjustment potentiometer may be specified.

ConverterPAC Functional Descriptions (cont)

The JuniorPAC contains output overcurrent protection which recovers automatically when the overcurrent condition is removed. Overvoltage and overtemperature protection are not available.

DualPAC

This output assembly consists of two VI-J00 DC-DC converters that convert the unregulated high voltage bus to the desired regulated output voltages. The assembly is fused with a single PC-Tron 3A fast-acting fuse. The output of each converter contains a passive LC filter to reduce output ripple/noise to 1% (typ.), and 2% (max.) when measured peak to peak up to a 20 MHz bandwidth from 10% to 100% of rated load of the ConverterPACs. To meet VXI noise level standards the "V2" option can be selected for outputs up to 15Vdc, and the "V1" option can be selected for 24Vdc outputs. Option "V2" limits output ripple/noise to 50 mV peak to peak and option "V1" limits output ripple/noise to 150 mV peak to peak. An optional output voltage adjustment potentiometer may be specified for each output. DC Power Good signal is not available. When using the Enable/Disable feature on any MegaPAC, both outputs on a DualPAC are controlled simultaneously.

The DualPAC contains output overcurrent protection which recovers automatically when the overcurrent condition is removed. Overvoltage and overtemperature protection are not available.

RAMPAC

This output assembly consists of a VI-J00 DC-DC converter with a Ripple Attenuator Module (VI-RAM) and is often used in applications requiring low output ripple/noise. The RAMPAC attenuates the ripple/noise down to 10 mV when measured peak to peak over a 20 MHz bandwidth from 10% to 100% of rated load of the converter. The converter is also fused at the input with a PC-Tron 3A fast-acting fuse. An optional DC Power Good signal, or output voltage adjustment potentiometer may be specified.

The RAMPAC contains output overcurrent protection which recovers automatically when the overcurrent condition is removed. Overvoltage and overtemperature protection are not available.

BatPAC

The BatPAC output assembly consists of a VI-200 BatMod current source that converts the unregulated input voltage to the desired regulated output current or voltage. The converter is fused with a PC-Tron fast-acting fuse in the positive input terminal. This is a programmable current source that may be configured as a battery charger. Overvoltage and overtemperature protection are not available. Maximum current and voltage settings are made using potentiometers that come as a standard feature. An option to control these maximum settings externally is also available.

Table 2. Summary of ConverterPAC Features

ConverterPAC	OVP	OCP	OTP	RS	LS	PG	TrimPot
ModuPAC	Std.	Std.	Std.	Std.	Opt.	Opt.	Opt.
DualPAC	N/A	Std.	N/A	Std.	Opt.	N/A	Opt.
JuniorPAC	N/A	Std.	N/A	Std.	Opt.	Opt.	Opt.
RAMPAC	N/A	Std.	N/A	Std.	Opt.	Opt.	Opt.
BatPAC	N/A	Std.	N/A	N/A	Std.	N/A	Std.

OVP: Overvoltage Protection
OCP: Overcurrent Protection
OTP: Overtemperature Protection
RS: Remote Sense
LS: Local Sense
PG: Power Good

ConverterPAC Functional Descriptions (cont)

Power Good (J3-3)
The optional Power Good signal on J3-3 is referenced to Signal Ground on J3-1, and indicates the status of the output voltage. It is capable of sinking 20 mA maximum when 5V is used as Vcc. This signal is asserted a TTL “1” when the output voltage is above 95% of nominal. It is a TTL “0” when the output voltage is below 85% of nominal.

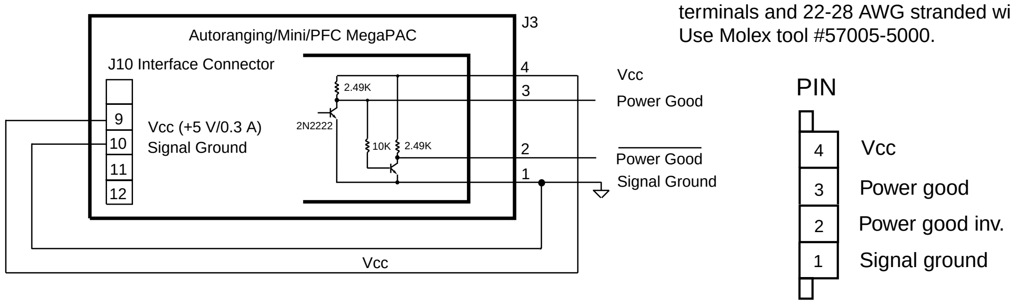
Power Good Inverted (J3-2)
This is the inverse of the Power Good signal on J3-3, referenced to Signal Ground on J3-1.

Signal Ground (J3-1)
Signal Ground on J3-1 is an isolated secondary ground reference for all J3 status signals. It is used to provide a reference point for the Power Good circuitry, and is not the same as Earth Ground on input power connector J9.

Vcc (J3-4)
The Vcc on J3-1 is an input that requires +5V either from the Auxiliary Vcc on J10-9, or from another source. Input current to this pin is limited by an internal resistor to 3 mA. If the Auxiliary Vcc on J10-9 is connected to Vcc on J3-4, then Signal Ground J10-10 must also be connected to Signal Ground on J3-1.

J3 "Power good" connector (optional). Mating receptacle is Molex #39-01-0043 housing using #39-00-0031 terminals and 22-28 AWG stranded wire. Use Molex tool #57005-5000.

Figure 22. Power Good and Vcc



ConverterPAC Remote Sense and Trim Interface
(J2 for Single Outputs or J2A and J2B for Dual Outputs)

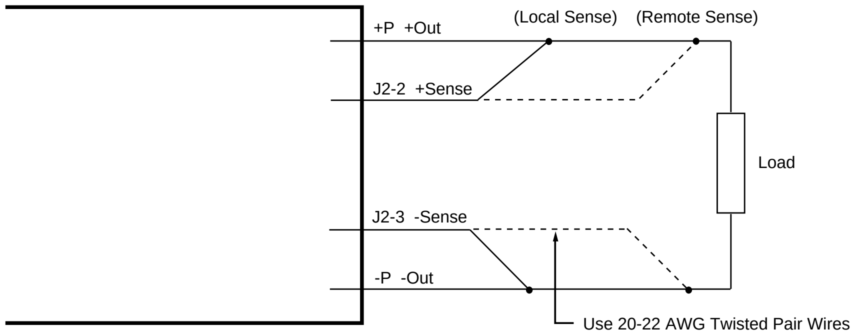
+Sense/–Sense (J2)
The +Sense on J2-2 should be connected to the +Power Out, and the –Sense on J2-3 to the –Power Out terminal. Do not leave the Sense pins open.

These pins may be terminated locally at the output of the power supply, in which case the power supply will provide regulation at the output terminals. The voltage appearing at the load may drop slightly due to voltage drop in the power cables. If it is necessary to compensate for voltage drop along the output power cables, this termination should be made close to the output load. Compensation of up to 0.5V can be obtained. Use twisted pair 20-22 AWG wire for this purpose.

For DualPACs, the +Sense pins are available on connectors designated as J2A-2 and J2B-2 for outputs A and B, respectively. –Sense pins are on J2A-3 and J2B-3, respectively. These pins are also duplicated on power connectors J1A and J1B.

ConverterPAC Functional Descriptions (cont)

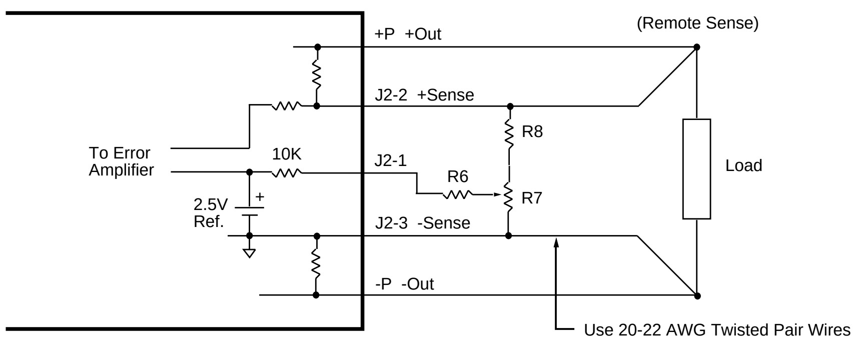
Figure 23.
Sense Leads



Trim (J2)
The Trim pin on J2-1 may be used to control the output voltage. It is referenced to the –Sense pin on J2-3. For DualPACs, the Trim pins are available on connectors designated as J2A-1 and J2B-1 for outputs A and B, respectively.

Trimming is accomplished by using the techniques shown earlier in Section 5, *Output Voltage Trimming*. These techniques show how a potentiometer placed external to the power supply may be used to adjust the output voltage (Figure 24, below). Alternatively, a digital-to-analog converter (DAC) may be used to program the output voltage from 50% to 110% of nominal as the DAC output is controlled from 1.25 to 2.75Vdc.

Figure 24.
External Trim



MegaPAC Mechanical Considerations

The MegaPAC Family may be mounted on any of four surfaces using standard 8-32/M4 size screws. The chassis comes with four mounting points on each surface; maximum allowable torque is 20 in.-lbs. The maximum penetration is 0.15 in (3.7 mm).

When selecting a mounting location and orientation, the unit should be positioned so that air flow is not restricted. Maintain a 2" minimum clearance at both ends of the MegaPAC and route all cables so that airflow is not obstructed. The standard unit draws air in at the fan side and exhausts air out the load side. If airflow ducting is used, pay attention as sharp turns could present back pressure to the MegaPAC. The fan moves approximately 30 CFM of air (38 CFM for Three-Phase MegaPAC).

MegaPAC Mechanical Considerations (cont)

Avoid excessive bending of output power cables after they are connected to the MegaPAC. For high-current outputs, use cable-ties to support heavy cables to minimize mechanical stress on output studs. Be careful to not short-out to neighboring output studs. The MegaPAC is supplied with serrated, flanged hex-nuts on all output studs, therefore, Loc-tite® or lock washers are not required. The maximum torque recommended on flanged nuts is 45 in.- lbs.

Avoid applications in which the unit is exposed to excessive shock or vibration levels. In such applications, a shock absorption mounting design is required.

MegaPAC Do’s and Don’ts

- **Do not leave ConverterPAC sense line open. Always terminate them locally or at the load. Use twisted pair 20-22 AWG wire.**
- **Insert proper fault protection at power supply input terminals (i.e., a fuse).**
- **Use proper size wires to minimize voltage drop.**
- **Always fill all output slots of the MegaPAC. If a slot is not filled with a ConverterPAC it should be filled with an Airblock. Failure to do so may result in overheating and damage to the power supply.**
- **Never loosen the inner nut on a ConverterPAC.**
- Do not unplug ConverterPAC while input power is applied. They are not designed for hot plug applications.
- Do not restrict airflow to the unit. The cooling fan draws air into the unit and forces it out of the output power terminals.
- For power expansion use booster ModuPACs. Viewing the unit from the output terminal side, always insert boosters to the right of the driver.
- Run the output power cables next to each other to minimize inductance.
- Wait 5 minutes after shutting off power to insert or remove ConverterPACs.
- Do not attempt to repair or modify the power supply in any manner other than the exchange of ConverterPACs as described.

ConverterPAC Derating Curves

Figure 25.

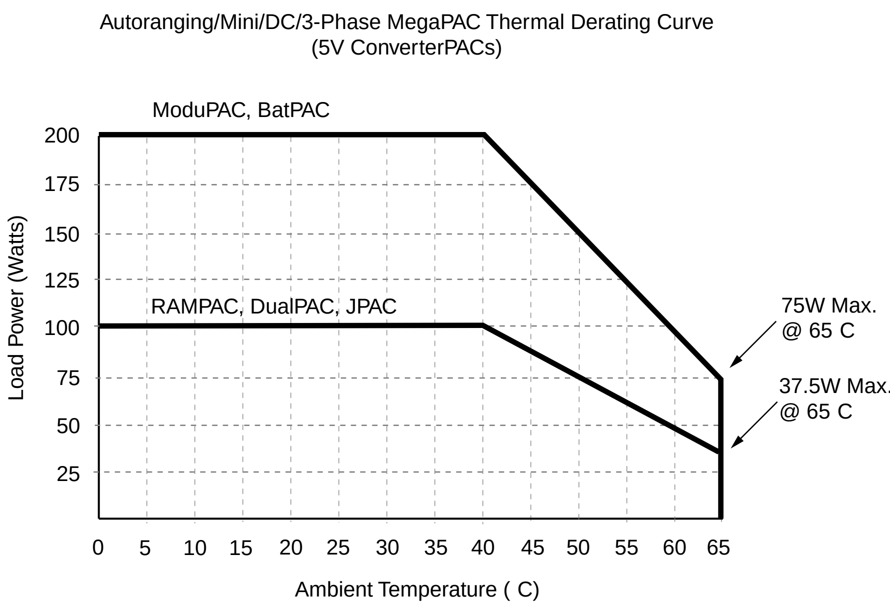
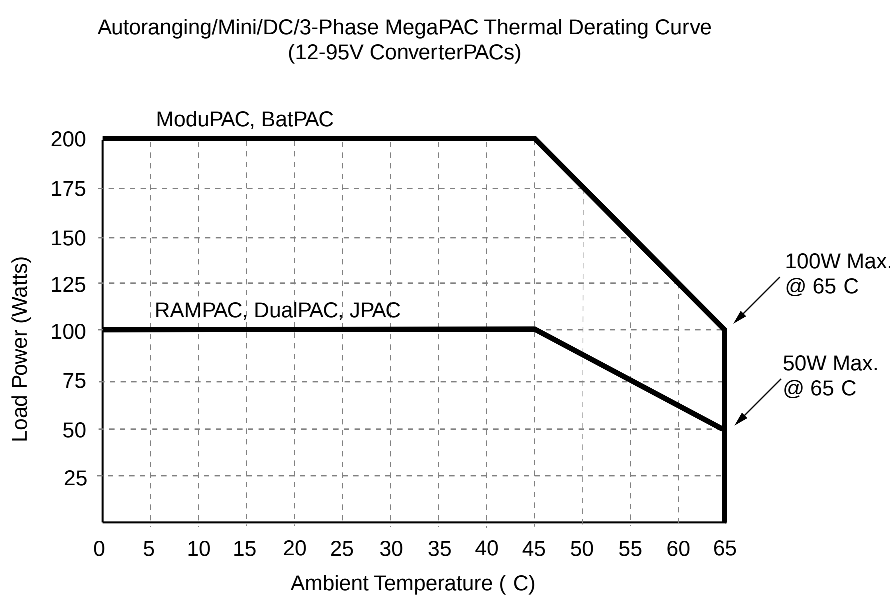


Figure 26.



ConverterPAC Derating Curves (cont)

Figure 27.

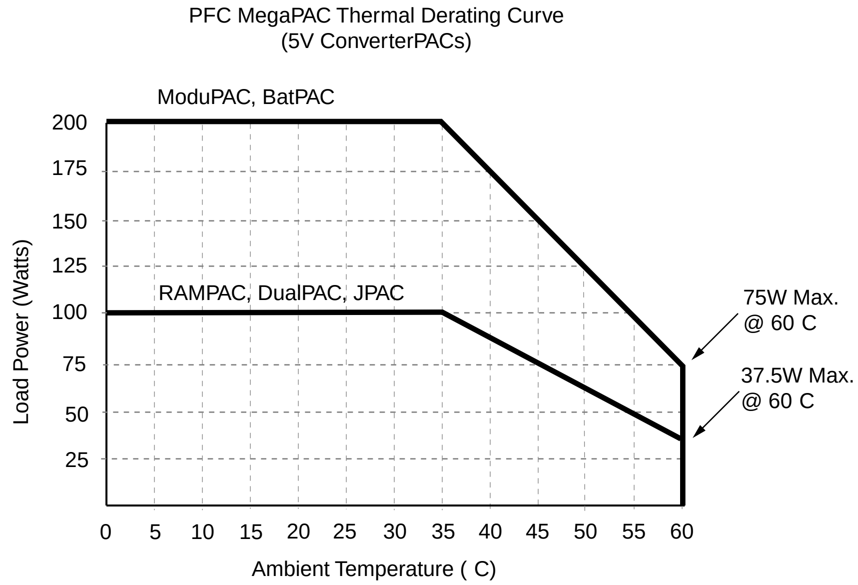
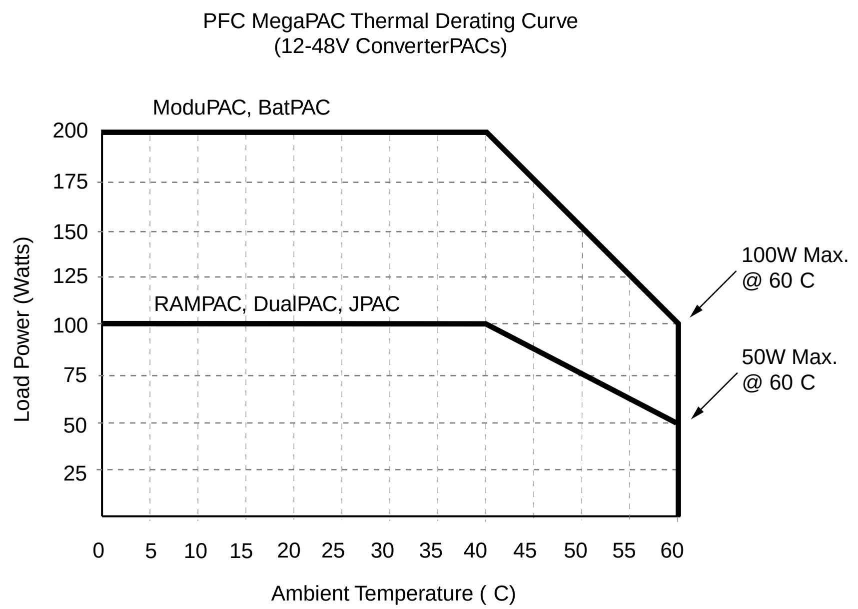


Figure 28.



PFC Mini ™

Power Factor Corrected AC-DC Switchers

Overview

The PFC Mini is an extremely low profile switching power supply that combines the advantages of power factor correction, power density, and user selected isolated outputs. Accepting input voltages of 85Vac to 264Vac, and 100 to 380Vdc, the PFC Mini can provide up to 1500W in a package size of 1.75" x 6" x 12". The PFC Mini can provide up to 6 isolated outputs and is factory configured to meet user requirements. Its inherent flexibility comes from the use of Vicor's family of DC-DC converters. Creating a customized power supply is as easy as choosing a converter and plugging it in.

Technical Description

The PFC Mini consists of an off-line single phase, power-factor-corrected front end, EMC filter, cooling fan, customer interface, associated housekeeping circuits, and a selection of Vicor's DC-DC converters.

Input AC mains voltage is applied to a terminal block. The input current is passed through an EMC filter designed to meet conducted noise limit "B" specifications of FCC Part 15 and EN55022 level "B."

At start-up, inrush current is limited by a PTC thermistor. The PTC is shunted out shortly after initial power-up by a DC bus voltage sense circuit driving a relay. After rectification, the input voltage is put through a boost converter that keeps the AC input current sinusoidal and synchronized with the input AC voltage (in compliance with EN61000). The boost converter delivers an unregulated 370Vdc to the hold-up capacitors and a high voltage backplane. The backplane supplies power to the DC-DC converters that provide the desired low voltage, regulated outputs.

Voltage conversion is achieved by Vicor's family of Zero-Current-Switching (ZCS) DC-DC converters. These are forward converters in which the main switching element switches at zero current. This patented topology has a number of unique attributes: Low switching losses; high frequency operation, resulting in reduced size for magnetics and capacitors; excellent line and load regulation; wide adjustment range for output; low EMC emission and high efficiencies.

At initial power-up, the PFC Mini outputs are disabled to limit the inrush current and to allow the DC bus potential to settle out to the correct operating level. A low-power flyback converter operating with PWM current-mode control converts the high voltage DC bus into regulated low voltage to power the internal housekeeping circuits and DC cooling fans.

The internal housekeeping Vcc comes up within 1 sec after the application of input power. Once the high voltage bus is within operating limits, the AC Power OK signal asserts to a TTL "1," indicating the input power is OK, and allows the power outputs to come up 15-30 ms later. An auxiliary Vcc output of 5Vdc sourcing up to 0.3A is provided for peripheral use.

An output Enable/Disable function is provided by using an optocoupler to control Vicor's DC-DC converters. If the Enable/Disable control pin is pulled low, the optocoupler turns on and disables the output. The nominal delay associated for an output to come up when measured from release of the Enable/Disable pin is 5-10 ms. The General Shutdown function controls all outputs simultaneously and works in a similar manner.

Interface Connections

Chassis Input Power Terminals (J1)
Input AC power is applied to terminal block J1 using a pressure screw terminal that accepts a maximum wire size of 10 AWG. The maximum torque recommended is 10 in-lbs. J1-1 (GND) is Earth Ground for safety; J1-2 (L2) and J1-3 (L1) are the other Hot connections.

A fault clearing device, such as a fuse or circuit breaker, with a maximum 15A rating at the power supply input is required for safety agency compliance. It should be sized to handle the start-up inrush current of 30A at 115Vac and 60A at 230Vac.

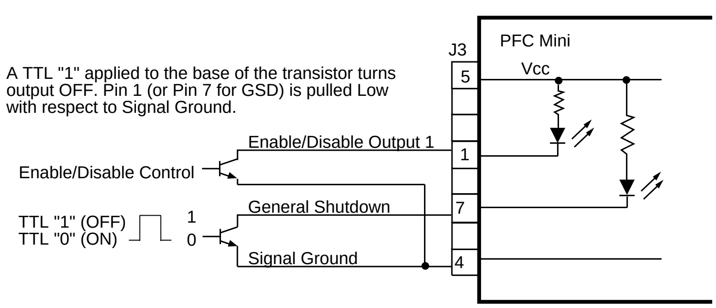
Output Power Connections
There are two types of output power terminals available in the PFC Mini. Outputs from full-sized converters are terminated in two 1/4-20 plated steel bolts. The positive polarity of the output is the right bolt when viewed from the output end. Outputs from half-sized converters terminate in a Molex connector. Each power output is isolated, so outputs of positive or negative polarity can be configured through proper selection of the output reference terminal.

In order to minimize parasitic cable inductance and reduce EMC, the output power cables should be routed in close proximity to one another, and large current loops should be avoided. To avoid excessive voltage drop, do not undersize power cables, especially for high current outputs. Excessive cable inductance coupled with large capacitive loading can introduce instability in switching power supplies. This problem can be avoided with proper system design. Consult Vicor's Applications Engineering Department for assistance with applications that use long cable lengths and excessive load capacitance.

Signal Ground (J3-4)
Signal Ground on J3-4 is an isolated secondary ground reference for all J3 interfacing signals. This is **not** the same as Earth Ground on input power connector J1.

Enable/Disable (J3-1 to J3-3)
The Enable/Disable control pins allow outputs to be sequenced either on or off. J3-1 through J3-3 are the control pins for output cards 1 through 3, respectively. For 2-output cards, both outputs are enabled or disabled with a single control. The Enable/Disable pins should be pulled low to less than 0.7V with respect to Signal Ground to disable the outputs. They will source 3mA maximum. These pins should be open circuited or allowed to exceed 4.5V when enabled. Do not apply more than 5V to these inputs at any time.

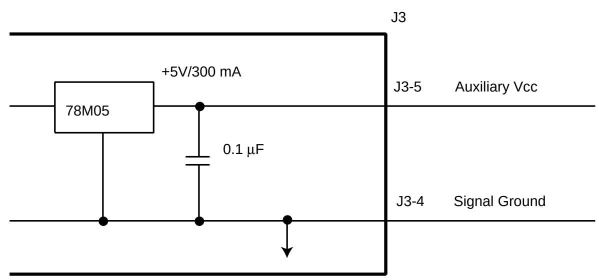
Figure 1. Enable/Disable Control



Interface Connections (cont)

General Shutdown /GSD (J3-7)
The GSD control pin on J3-7 allows simultaneous shutdown of all outputs. This pin must be pulled down to less than 0.7V, and will source 3 mA maximum to shut down all outputs. The GSD pin should be open circuited or allowed to exceed 4.5V when not in use, or when the outputs are to be enabled. Do not apply more than 5V to this input at any time. Normal open circuit voltage is 1.5 to 3V with respect to Signal Ground.

Figure 2. AC OK

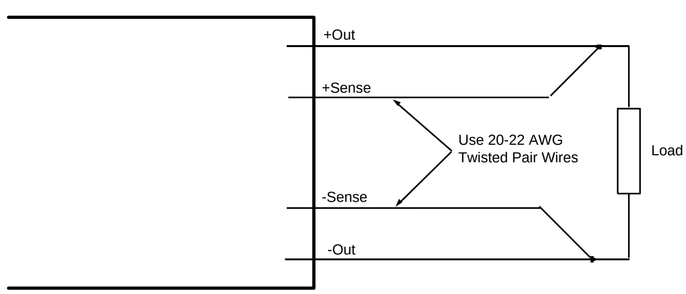


AC OK (J3-6)
AC OK is an active high TTL compatible signal, and provides a status indication of the AC input power. It is on pin J3-6 and is capable of sinking 16 mA maximum. This signal switches to a TTL "1" when the high voltage bus exceeds low-line condition during turn-on.

Auxiliary Vcc +5V/0.3A (J3-5)
The Vcc on J3-5 is an auxiliary 5V regulated power source. It is +5Vdc +/–5% with respect to Signal Ground and can supply 300 mA maximum. It is short-circuit-proof, but if shorted, all outputs will shut down through the Enable/Disable circuitry.

+Sense/–Sense (J2)
The Sense lines for the outputs are shipped from the factory with Local Sense installed. If Remote Sense is desired the Local Sense jumpers can be removed for individual outputs. If the Local Sense jumpers are removed, the Sense lines must be connected for Remote Sense. Leaving the Sense lines open will prevent proper output regulation and can damage the unit.

Figure 3.



When Local Sense is used, the power supply will regulate the output at the output terminals. The voltage appearing at the load may drop slightly due to voltage drop in the power cables. If it is necessary to compensate for voltage drop along the output power cables, the output can be trimmed up or configured for Remote Sense. Use twisted pair 20-22 AWG wire for the Remote Sense lines. Remote Sense can compensate for a voltage drop of up to 0.5V, or 0.25V on each leg.

Interface Connections (cont)

Installing Remote Sense requires the Local Sense jumpers to be removed. On single output cards, the Local Sense jumpers are located behind the Sense connector at J1. To remove the jumpers, pull them off the four pins at J1. On dual output cards, the Local Sense jumpers are on either side of the output connector at J1 and J3. The jumpers at J1 are for output #1, and the jumpers at J3 are for output #2.

Note: PFC Mini units built after 12/2000 have been equipped with a new feature called Autosense. With Autosense, the PFC Mini will automatically operate in a Remote Sense mode when Remote Sense connections are made. In the event that the Remote Sense is not connected or needed, no Local Sense selection is necessary –simply hook up the output and the PFC Mini will automatically operrate in the Local Sense.

The Sense connector for a single output board is a 3 pin connector providing the +Sense connection on J2-2 and the –Sense connection on J2-3. The Sense connector for a dual output board is a 14 pin connector that also provides the output and trim connections. +Sense and –Sense for the first output are located on J2-1 and J2-8, respectively. +Sense and –Sense for the second output are located on J2-7 and J2-14, respectively.

External Trim (J2)
The Trim pin on J2 can be used to control the output voltage. It is referenced to the –Sense pin. For dual output cards, the Trim pins are available on J2-4 and J2-11 for outputs 1 and 2, respectively. To trim the output up, it is necessary for the voltage at the Trim pin to be greater than the 2.5V bandgap. A 10% increase to 2.75V results in a 10% increase in output voltage. Bringing the voltage at the trim pin below 2.5V trims the output down. A 50% reduction to 1.25V causes the output to decrease by 50%.

Refer to Section 5 for further information on trimming Vicor's DC-DC converters.

CONSULT APPLICATIONS ENGINEERING WHEN TRIMMING OUTPUTS BELOW 5V.

Mechanical Considerations

The PFC Mini can be mounted on either of two surfaces using standard 6-32 size screws. The chassis comes with four mounting points on two surfaces; maximum allowable torque is 20 in.-lbs. The maximum penetration is 0.19 in. (4.8 mm).

When selecting a mounting location and orientation, the unit should be positioned so air flow is not restricted. Maintain a 2"(50,8 mm) minimum clearance at both ends of the PFC Mini, and route all cables so airflow is not obstructed. The power supply draws air in at the fan side/AC input side and exhausts air out the load side. If airflow ducting is used, avoid sharp turns that could create back pressure. The fans move approximately 30 CFM of air.

Avoid excessive bending of output power cables after they are connected to the output terminals. For high-current outputs, use cable-ties to support heavy cables and minimize mechanical stress on connectors. Be careful not to short-out to neighboring outputs. The maximum torque recommended on output nuts is 18 in.-lbs.

Avoid applications in which the unit is exposed to excessive shock or vibration levels. In such applications, a shock absorbing mount design is required.

PFC Mini Do's and Don'ts

- **If Sense jumpers are removed, do not leave Sense lines open. Use twisted pair 20-22 AWG wire when installing Remote Sense.**
- Do not restrict airflow to the unit. The cooling fan draws air into the unit and forces it out at the output power terminals.
- Run the output (+/–) power cables next to each other to minimize inductance.
- Do not attempt to repair or modify the power supply in any manner.
- Insert proper fault protection at power supply input terminals (i.e., a fuse).
- Use proper size wires to avoid overheating and excessive voltage drop.

Notes

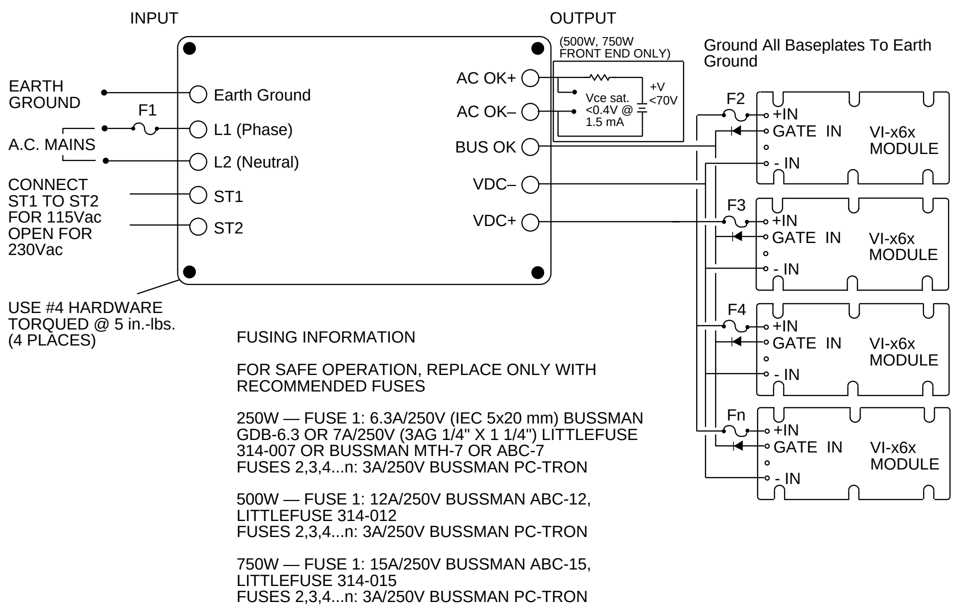
Front End Application Notes

Single Phase Front Ends

Vicor's single phase non-isolated AC front ends are available in both PCB and chassis mount versions, and deliver reliable DC bus voltage to VI-x6x converter modules or Mega Modules at power levels up to 250, 500 and 750W. These front ends are strappable to provide operation from either 115Vac or 230Vac single phase lines, and provide conducted EMC filtering to VDE/FCC Level B. They also offer transient surge protection, active inrush limiting, AC OK (AC fail indicator), and a BUS-OK status output suitable for controlling Vicor modules via the Gate In pin.

Vicor's front ends have been designed to comply with the requirements of major safety agencies when used in conjunction with recommended mains switching and input fusing.

Figure 1.
250W, 500W, 750W
Front Ends



Notes:

1. Ambient temperature must be less than 50˚C in free air. Temperature may exceed 50˚C with moving air (refer to derating curves on page 22-2).
2. Do not obstruct vent holes.
3. Observe module installation requirements (refer to Vicor's Component Power User Guide).
4. Minimize length of all unshielded line cord.
5. Minimum conductor size for supply is 16 AWG (250W), 14 AWG (500W) and 12 AWG (750W) including the 115/230 strap.
6. If the DC output bus is shorted, the fuse may not blow, and the unit will not turn on.
7. If wire distance from front end to modules is greater than 3 feet, (.91m) install a TRANSZORB (P/N 1.5KE 400A) across the input of each module.
8. If unit is strapped for 115V operation and 230V is applied, the input fuse will clear. Replace fuse, strap correctly and reapply power.
9. To control EMC most effectively, the return path to ground from either the front end or modules should be made via a good RF ground (i.e., a braided wire) if possible.
10. The BUS-OK, Vdc– and Vdc+ lines should be run in close proximity to one another or as a twisted group between the front end and modules.
11. Bypass the baseplates of the modules to –IN and –OUT (refer to *EMC Considerations*, page 10-1).

250W, 500W, and 750W Front Ends (cont)

Thermal Considerations

Free Convection Derating

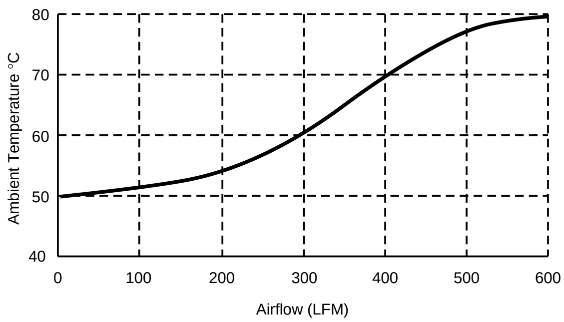
- 250W: Derate output power linearly at 7.2W/˚C over 50˚C.
- 500W: Derate output power linearly at 14.3W/˚C over 50˚C.
- 750W: Derate output power linearly at 18.8W/˚C over 45˚C.

Forced Convection

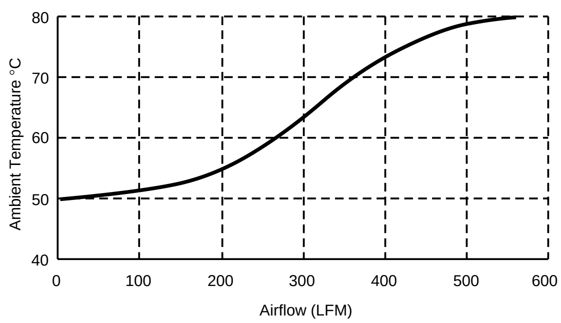
The curves below represent worst case data for chassis mounted (enclosed) front ends; i.e., low line, full load. System conditions such as higher line voltage, lighter load or PC mount versions of the front ends will increase reliability if the following data is used as the nominal design criteria.

The sigmoid shape of the curves at low air flow is due to the chassis mount cover restricting the airflow to the inboard components. When an airflow of approximately 200 LFM is achieved, the velocity of air rushing over the cover causes air to be pulled in through the side perforations, resulting in a rapid improvement in the cooling of internal components.

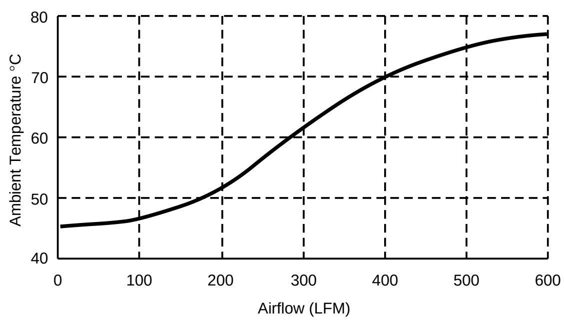
Figure 2. Max. Ambient Temperature vs. Airflow (LFM) Over Cover (Full Load, 90Vac Input, Chassis Mount) 250W



500W



750W



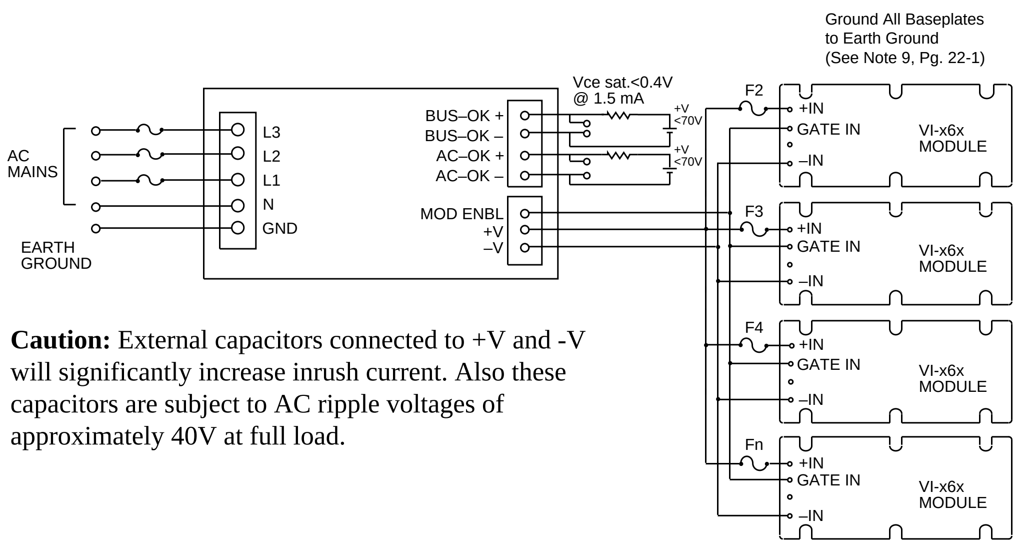
Three-Phase Front Ends

Vicor's three-phase front ends are available as chassis mount products that deliver reliable DC bus voltage to x6x family (nominal 300Vdc input) converters up to 1.5 kW, 3 kW and 5 kW.

Front ends operate from 3-phase (4-wire delta or 4 or 5-wire wye) AC mains input and provide conducted EMC filtering to VDE/FCC Class A, transient surge protection, inrush current limiting and ENABLE output suitable for controlling an array of Vicor converters via the Gate In pin. Isolated AC-OK and BUS-OK outputs are also provided for advance warning of DC bus dropout due to AC line failure and indication of internal DC bus integrity in the user system, respectively.

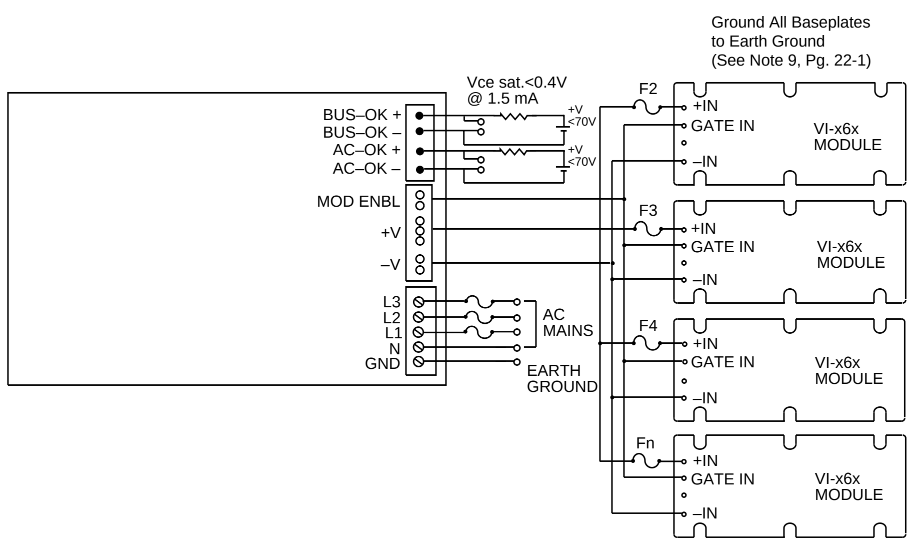
These front ends have been designed to comply with the requirements of major safety agencies when used in conjunction with the recommended mains switching and input fusing.

Figure 3.
1.5, 3.0 kW Front End



Caution: External capacitors connected to +V and -V will significantly increase inrush current. Also these capacitors are subject to AC ripple voltages of approximately 40V at full load.

Figure 4.
5.0 kW Front End



Three-Phase Front Ends (cont)

Fusing Information

1.5 kW Front End

7A/250V normal blow in all three phases of the AC line (Bussman ABC-7 or Littlefuse 314-007).

3 kW Front End

12A/250V normal blow in all three phases of the AC line (Bussman ABC-12 or Littlefuse 314-012).

5 kW Front End

20A/250V normal blow in all three phases of the AC line (Bussman ABC-20).

Environmental Data

• Operating temperature (no load to full load): –20˚C to +50˚C, free convection
• Non operating temperature: –40˚C to +80˚C
• Operating/non operating humidity: 95% relative, non-condensing

Electrical Data — AC Line Input Voltage Connections (phase to phase)

• Three-phase delta: (4 wire): 208Vac (nominal) +20%/–10%.
Connect the three phases (L1, L2, L3) and GND (earth) to the five terminal barrier block marked as such.
• Three-phase Wye Distribution (5-wire): 208Vac (nominal) +20%/–10%.
Connect the three phases (L1, L2, L3), N (neutral), and GND (earth) to the five terminal barrier block marked as such.
• Line Frequency: 47-440 Hz

DC Output Connections and Module Enable

A three terminal barrier block labeled V–, V+ and En provides both the DC input enable and Enable control line for Vicor converters.

• V–: Negative DC input terminal to all Vicor converters.
• V+: Positive DC input terminal to all Vicor converters.
• En: Connect to the Gate In terminal of all driver modules. This connection must be made to guarantee proper enabling of the converter array on power up and proper shutdown of the converter array on power loss, loss of phase or output fault.

Cautions

• This product is designed to operate with Vicor x6x Family (300Vdc input) converters and Mega Modules only.
• This product is not intended for use with European 380-415Vac three phase distribution.
• This product is an off-line AC-DC power supply. It is not isolated from the AC mains.
• Proper grounding is mandatory for safe operation.

Thermal Considerations

Overview

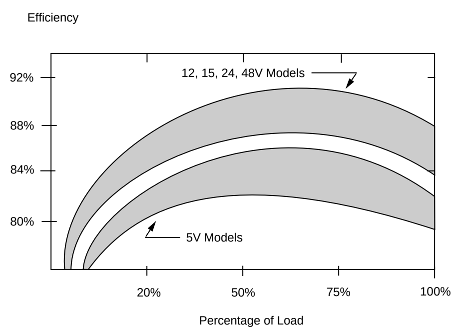
Simplified thermal management is one of the benefits of using Vicor converters. High operating efficiency minimizes heat loss, and the low profile package features an easily accessible, electrically isolated thermal interface surface.

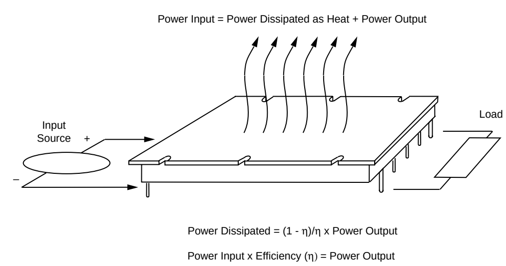
Proper thermal management pays dividends in terms of improved converter and system MTBFs, smaller size and lower product life-cycle costs. The following pages provide guidelines for achieving effective thermal management of Vicor converters.

Efficiency and Dissipated Power

A DC-DC converter takes power from an input source and converts it into regulated output power for delivery to a load. Not all of the input power is converted to output power however; some is dissipated as heat within the converter. The ratio of delivered output power to converter input power is defined as the converter's efficiency. Efficiency is a basic figure of merit that can be used to relate power dissipation directly to converter output power, as illustrated in Figures 1a and 1b.

Figures 1a, 1b.





The first step in evaluating cooling requirements is to calculate worst-case dissipation based on converter efficiency and worst-case anticipated load power. Clearly, higher efficiency will translate into lower power dissipation and simplify the cooling problem. Vicor converters are among the most efficient converters available, with full load efficiencies typically in excess of 80%.

Removing Heat From Vicor Converters

Heat is removed from Vicor converters through the flat metal baseplate on top of the module. The baseplate is thermally coupled to, but electrically isolated from, all internal heat-generating components. The basic thermal design problem is to transfer heat from the baseplate into the surrounding environment as a means of maintaining baseplate temperature at or below rated maximum.

Heat energy is transferred from regions of high temperature to regions of low temperature via three basic mechanisms: radiation, conduction and convection.

Radiation: Electromagnetic transfer of heat between masses at different temperatures.
Conduction: Transfer of heat through a solid medium.
Convection: Transfer of heat through the medium of a fluid; typically air.

Removing Heat From Vicor Converters (cont)

All three of these heat transfer mechanisms are active to some degree in every application. Convection will be the dominant heat transfer mechanism in most applications. Nondominant effects will provide an added contribution to cooling; in some cases, however, they may result in undesirable and unanticipated thermal interactions between components and subassemblies. All three of these mechanisms should be given consideration when developing a successful cooling strategy.

Radiation

Radiant heat transfer occurs continuously between objects at different temperatures that are exposed to each other. The net effect on the temperature of an individual part is dependent on a great many factors, including its temperature relative to other parts, relative part orientations, surface finishes and spacing. The difficulty in quantifying many of these factors, combined with the universal presence of radiant energy exchange, makes calculation of radiational temperature effects both a complex and generally imprecise task.

Temperature differentials encountered in practical applications of Vicor converters are never large enough to cause radiational cooling to be the dominant heat transfer mechanism. Radiation will account for less than 10% of total heat transfer in the majority of cases. For these reasons, the presence of radiant cooling is often assumed to provide safety margins over and above the dominant cooling mechanism, and detailed consideration of its effects are neglected. A valid assumption, in most cases, is that the converter will be warmer than its surroundings and radiant energy transfer will aid cooling. In some cases, however, nearby objects (PC boards, power resistors, etc.) may be much hotter than the converter and net radiant energy transfer may actually increase the converter’s temperature.

Surveying the relative positions and estimated temperatures of converters and surrounding parts is advisable as a means of anticipating the potential effects of radiant transfer. In cases where hot components are in close proximity to the converter, the use of interposing barriers can generally moderate undesirable radiational heating effects.

Conduction

In most applications, heat will be conducted from the baseplate into an attached heatsink or heat conducting member. Heat conducted across the interface between the baseplate and mating member will result in a temperature drop which must be controlled. As shown in Figure 2, the interface can be modeled as a “thermal resistance” in series with the dissipated power flow. The baseplate temperature will be the sum of the temperature rise in the interface and the temperature of the member to which the baseplate is attached.

Conduction (cont)

Figure 2.

Temperature rise across a surface interface can be significant if not controlled. The area of the interface should be as large as possible, and the surface flatness of the attached member should be within 5 mils. Thermal compound or a thermal pad should be used to fill surface irregularities. Thermal resistance across surface interfaces can be held to under 0.1˚C/Watt with proper measures.

Many applications require that heat be conducted from the baseplate of the converter to a “remote” dissipative surface via a thermally conductive member. The resulting baseplate temperature will be the sum of the temperature of the dissipative surface, the temperature rise in the heat conducting member, and the rises across the two surface interfaces. The thermal resistance of the conductive member is proportional to its length, and inversely proportional to both its cross-sectional area and thermal conductivity (Figure 3). Minimizing total temperature rise is dependent on controlling interface resistance, as described above, and controlling the thermal resistance of the transfer member through appropriate material selection and dimensioning.

Figure 3.

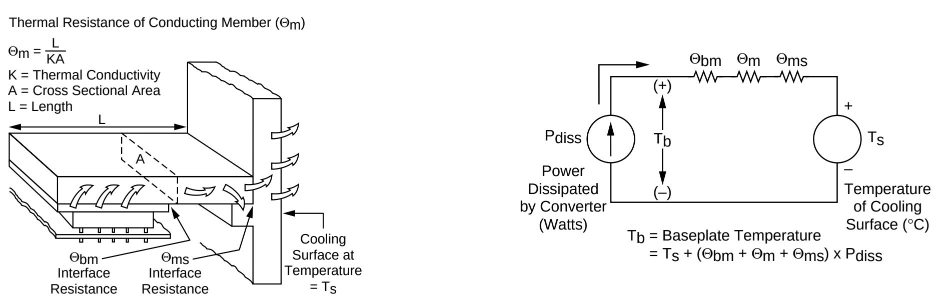
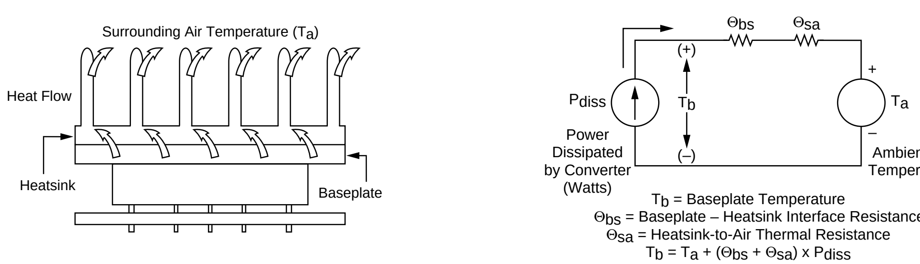


Figure 4.



Convection

Convective heat transfer into air is a common method for cooling Vicor converters. “Free” or “natural” convection refers to heat transfer from a dissipative surface into a cooler surrounding mass of otherwise still air; forced convection refers to heat transfer into a moving air stream.

The convection cooling model is shown in Figure 4, page 23-3. Baseplate temperature depends on the temperature of the air, total dissipated power and the values of two thermal resistances: the thermal resistance of the surface interface between the baseplate and the heatsink, and the heatsink-to-air thermal resistance. Surface interface resistance can be minimized as discussed under Conduction. The heatsink-to-air resistance is dependent on a variety of factors including heatsink material and geometry, air temperature, air density and air flow rate. Fortunately, thermal resistance data is available for a very wide range of standard heatsinks (from Vicor, Wakefield Engineering, Aavid, and others) for use in both free and forced convection applications. The following sections will provide guidelines for both free and forced convection cooling of Vicor converters.

Free Convection

The benefits of free convection include low cost of implementation, no need for fans, and the inherent reliability of the cooling process. Compared to forced air cooling, however, free convection will require more heatsink volume to achieve an equivalent baseplate temperature.

To select a suitable heatsink for free convection cooling, follow these steps:

1. Determine the power to be dissipated by the heatsink. This should be based upon converter efficiency and worst-case converter power output using the formula given in the section on Efficiency and Dissipated Power.

2. Estimate or experimentally determine the surface interface thermal resistance. Use of thermal compound or a thermal pad is recommended to minimize this resistance. An estimate of 0.2˚C/Watt should provide an adequate safety margin.

3. Referencing Figure 4, we can derive the following formula for heatsink-to-air thermal resistance:

$$\theta_{sa} = \left(\frac{T_b - T_a}{P_{diss}}\right) - \theta_{bs}$$

T_a = Worst case anticipated operating ambient air temperature.
θ_{bs} = Surface interface thermal resistance, from Step 2, above.
P_{diss} = Worst-case power dissipation, from Step 1, above.
T_b = Baseplate temperature.

Start with a value of T_b = 85˚C or 100˚C (VI-J00) to determine the maximum acceptable heatsink-to-air thermal resistance.

Free Convection (cont)

4. Select several heatsinks that appear physically acceptable for the application. Using data provided, obtain values for their free convection thermal resistance, preferably at worst-case ambient temperature, T_a. If values obtained are less than the value calculated in Step 3, go on to Step 5. If the values are greater, then either a physically larger heatsink will be required or a different cooling method will need to be used (i.e., forced air, etc.).

5. Select the heatsink with the lowest available thermal resistance consistent with space and cost limits. Keep in mind that small reductions in baseplate temperature produce dramatic improvements in MTBF.

6. Baseplate temperature can be estimated by using the following formula:

$$T_b = T_a + P_{diss} \times (\theta_{bs} + \theta_{sa})$$

7. Test to verify that performance is in line with expectations.

Keep in mind the following:

Heatsink data is almost always given for vertical fin orientation. Orienting the fins horizontally will reduce cooling effectiveness. If horizontal mounting is mandatory, obtain relevant heatsink performance data or use forced convection cooling.

Free convection depends on air movement caused by heat-induced density changes. Thermal resistance data is dependent on the heatsink fins being completely exposed to the ambient air without any significant interference to air flow at the ends of or along the length of the fins. If packaging will tend to block or baffle air movement over the fins, a larger heatsink might be required. In the worst case, free convection may be ineffective. Make sure that the fins are well exposed to ambient air.

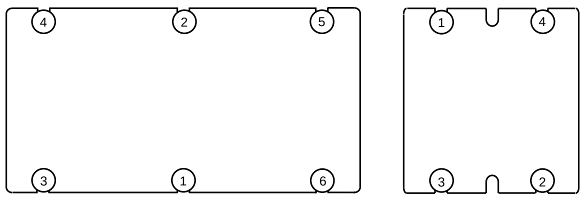
It is not necessary to limit the size of the heatsink to the size of the baseplate. Heatsinks with footprints larger than the baseplate area can often be used to advantage. In the latter case, heat must be conducted along the base surface of the heatsink to get to the outer fins, so don’t count on achieving full cooling capability. Also, several modules can be mounted to a common heatsink, but cooling calculations must now take into account total power dissipation with consideration given to possible localized overheating if worst-case converter power dissipations are greatly imbalanced. When securing a PC board containing two or more converters to a heatsink, it is good practice to use sockets on the converter pins to allow for mechanical alignment. If sockets are not used, be sure to mount the converters first mechanically, then solder the units in place. A fixture should be used to maintain alignment if soldering must be performed before attachment.

When mounting heatsinks to Vicor modules, use #6 screws torqued uniformly through the mounting slots provided. The following tightening sequence should be used:

- Lightly finger-tighten all screws
- Torque screws to 5-7 in.-lbs. per Figure 5, page 23-6.

Free Convection (cont)

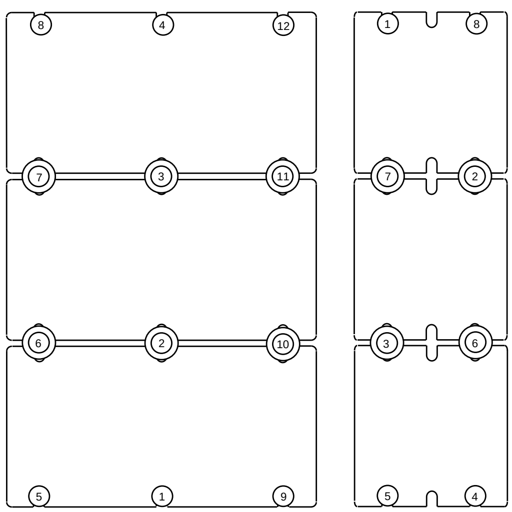
Figure 5. Heatsink Torquing Sequence VI-200/VI-J00



Multiple Modules Using Common Fasteners

The following mounting scheme should be used to attach modules to a heatsink for two or more modules. A large, heavy washer should be used on the common fasteners to distribute the mounting force equally between modules. The torquing sequence shown in Figure 6 can easily be expanded from two to any number of modules. An array of three is shown.

Figure 6. Torquing Sequence, Multiple VI-200/VI-J00 Converters



Forced Convection

Forced air can make a great difference in cooling effectiveness. Heatsink-to-air thermal resistance can be improved by as much as an order of magnitude when compared to free convection performance, by using suitable heatsinks. Consider the following data for baseplate-to-air thermal resistance (no heatsink) of a VI-200 or VI-J00 module at various air flow rates:

Air Flow	VI-200 Baseplate to Air Thermal Resistance	VI-J00 Baseplate to Air Thermal Resistance
Free Air	5.1˚C/W	8.1˚C/W
200 LFM	2.8˚C/W	5.1˚C/W
400 LFM	1.8˚C/W	2.7˚C/W
600 LFM	1.4˚C/W	2.3˚C/W
800 LFM	1.2˚C/W	1.7˚C/W
1000 LFM	1.0˚C/W	1.4˚C/W

Forced Convection (cont)

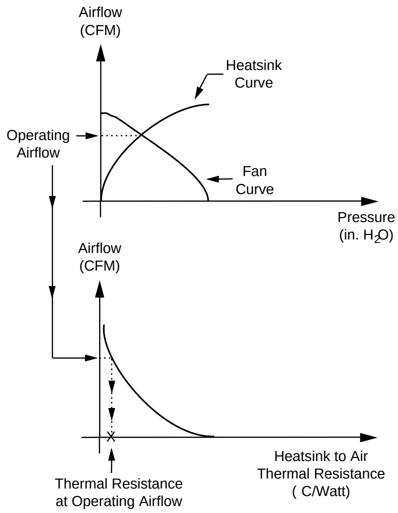
Forced air implies the use of fans. Many applications require that fans be used to achieve some desired combination of overall system reliability and packaging density. In other applications, however, fans are considered taboo. “Dirty” environments will require filters that must be changed regularly to maintain cooling efficiency, and neglecting to change a filter or the failure of the fan could cause the system to shut down or malfunction.

The steps involved in selecting a heatsink/fan combination for forced convection are essentially the same as those followed for free convection, with the additional requirement that the heatsink and fan be matched to achieve desired heatsink-to-air thermal resistance. Attention must also be paid to proper channeling of fan airflow so that maximum utilization of its cooling capability is realized. Selection of a heatsink/fan combination involves the following steps:

1. Determine maximum acceptable heatsink-to-air thermal resistance by following the first three steps of the heatsink selection procedure given in the Free Convection section.

2. Selection of a heatsink/fan combination requires that forced convection data for both the heatsink and fan be available. Forced convection characteristics for heatsinks define both heatsink-to-air thermal resistance and pressure drop through the heatsink as a function of airflow. Fan characteristics define airflow as a function of pressure drop. The intersection point of the airflow versus pressure curves for the fan and heatsink will define the operating airflow through the heatsink (Figure 7). The heatsink-to-air thermal resistance for this airflow may be read directly off the airflow versus resistance curve for the heatsink.

Figure 7.



Finding and interpreting the operating point requires consideration of the following:

Units of pressure drop are generally given in inches of water. Units of fan airflow are in cubic feet per minute (CFM). Occasionally metric units are used, but conversion is straightforward.

Heatsink airflows may be given either in CFM or LFM (linear feet per minute). The conversion between LFM and CFM is dependent on the cross-sectional area through which air is flowing:

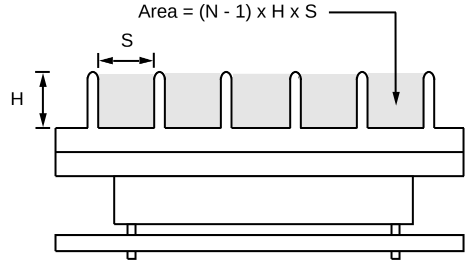
CFM = LFM x Area

Forced Convection (cont)

The cross-sectional area between the fins is the area through which the total airflow must pass (Figure 8). Correct interpretation of heatsink data requires that only the airflow through this area be considered. Simply pointing a fan at a heatsink will clearly not result in all of the flow going through the cooling cross-section of the sink; some channeling of air is usually required to get the full benefit of fan output.

The fan curves give output in CFM versus pressure drop. Fan pressure drop is the total of all drops encountered by the fan airflow. The heatsink, any ducting that is used, and air entry and exit channels all contribute to pressure drop. Pressure drop represents the work done by the fan in moving air through a region, so care should be taken to minimize unproductive pressure losses. Ensure that air entry and exit locations and internal air channels are not unduly constricted, and avoid sharp turns in airflow paths.

Figure 8.



The thermal resistance that was determined by overlapping the fan and heatsink curves will represent an optimistic estimate since it assumes that all the fan output flows through the heatsink cooling cross-section, and that all the pressure drop occurs along the heatsink. If the estimated thermal resistance is close to the minimum value determined in Step 1, then it is likely that a larger fan or different heatsink is required. This will not be a problem in most cases; relatively modest heatsinks and fans usually provide ample cooling.

Careful channeling and ducting of airflow as a means of both maximizing flow through the cooling cross-section of the heatsink and minimizing extraneous flow of air around the sink is well worth the small extra design effort required. Every degree of improvement in baseplate temperature results in significant improvement in MTBF. If you are paying for a fan, you may as well leverage it for all that it is worth.

3. Steps 5 through 7 in the Free Convection section will complete the heatsink selection process. Select the fan/heatsink combination with the lowest thermal resistance consistent with cost and space constraints, calculate the estimated baseplate temperature and test to verify.

DC-DC Converters and Off-Line Power Supplies

These products fall into three categories: full size modules, 4.6" x 2.4" x 0.5"; half size modules, 2.28" x 2.4" x 0.5"; and configurable products. Modules are offered in several different package styles: standard, with mounting flanges; SlimMod, without mounting flanges; and FinMod, flangeless package (Fl/F3, .25" integral heatsink, F2/F4, .50" integral heatsink).

DC-DC Converters and Off-Line Power Supplies (cont)

Consideration should be given to module baseplate temperature during operation. The most common cause of power supply failure is thermal stress beyond maximum rating. Refer to the product data sheet for the maximum baseplate temperature specification. The operating baseplate temperature is the sum of the ambient or environmental temperature and the module temperature rise due to internal power dissipation as given by;

$$Tbp = Ta + \theta Pd \qquad (1)$$

θ is the thermal impedance between the baseplate and the environment to which the heat is transferred (C/W), and is primarily a function of heat sink geometry and air flow rate as illustrated in the tables below. Internal power dissipation depends on conversion efficiency and output power according to the following expression;

$$Pd = Po(1/n-1) \qquad (2)$$

Where n is the converter efficiency which is also available from the product data sheet.

If cooling is by conduction as opposed to convection, the temperature rise is again the product of internal dissipation and the thermal impedance of the member that is in contact with the baseplate.

Thermal Impedance Charts (˚C/W)

VI-200 MI-200 θbm = 0.2	Base-plate	2111 0.9"L Fins	6927 .7"L Fins	2113 .9"T Fins	2092 1.45"L Fins	4431 .7"T Fins	2112 .4"T Fins	Slim-Mod	FinMod -F1/-F3	FinMod -F2/-F4
	θsa	θsa	θsa	θsa	θsa	θsa	θsa	θsa	θsa	θsa
Free Air	5.10	3.40	4.08	2.70	2.60	3.15	3.80	5.40	5.00	3.70
200 LFM	2.80	1.50	1.80	1.10	1.00	1.28	1.55	3.20	2.40	1.80
400 LFM	1.80	1.00	1.20	0.80	0.60	0.93	1.13	2.20	1.50	1.20
600 LFM	1.40	0.80	0.96	0.60	0.50	0.70	0.84	1.60	1.10	0.90
800 LFM	1.20	0.60	0.72	0.50	0.40	0.58	0.70	1.30	0.90	0.70
1000 LFM	1.00	0.50	0.60	0.40	0.30	0.47	0.56	1.20	0.80	0.60

VI-J00 MI-J00 θbm = 0.4	Base-plate	4306 .9" L Fins	4307 .9" T Fins	5738 .4" T Fins	Slim-Mod	FinMod -F1/-F3	FinMod -F2/-F4
	θsa	θsa	θsa	θsa	θsa	θsa	θsa
Free Air (H)	8.10	4.20	4.00	5.63	8.50	8.00	7.00
Free Air (V)	7.60	4.00	3.90	5.49	8.40	7.30	6.70
200 LFM	5.10	1.60	1.60	2.25	5.50	5.00	2.70
400 LFM	2.70	1.30	1.30	1.83	3.60	2.50	1.50
600 LFM	2.30	0.90	0.90	1.27	2.90	2.10	1.20
800 LFM	1.70	0.70	0.70	0.99	2.30	1.30	0.80
1000 LFM	1.40	0.60	0.60	0.84	2.00	1.10	0.70

Configurables (also applies to MI-products)	FlatPAC*			ComPAC*			Mega Module*		
	1 Up	2 Up	3 Up	1 Up	2 Up	3 Up	1 Up	2 Up	3 Up
	θbm	θbm	θbm	θbm	θbm	θbm	θbm	θbm	θbm
	0.1	0.05	0.03	0.1	0.05	0.03	0.1	0.05	0.03
	θsa	θsa	θsa	θsa	θsa	θsa	θsa	θsa	θsa
Free Air	2.1	1.3	1.0	3.6	1.7	1.4	4.4	2.1	1.7
50 LFM	1.5	1.1	0.9	2.7	1.4	1.3	3.3	1.7	1.6
100 LFM	1.2	0.9	0.7	2.3	1.3	1.1	2.8	1.6	1.3
250 LFM	0.7	0.5	0.4	1.6	1.0	0.8	2.0	1.2	1.0
500 LFM	0.4	0.3	0.3	1.2	0.7	0.6	1.5	0.9	0.7
750 LFM	0.3	0.2	0.2	0.9	0.5	0.5	1.1	0.6	0.6
1000 LFM	0.2	0.2	0.2	0.8	0.4	0.4	1.0	0.5	0.5

*Assumes uniform loading of 2- and 3- output units.

Table Usage: The forced convection thermal impedance data shown in the table above assumes airflow through the heatsink fins. Actual airflow through the fins should be verified. For purposes of heatsink calculation, assume efficiencies of 81% for 5V outputs and 85% for 12V and above.

Typical Examples — Thermal Equations

T_{max} = maximum baseplate temperature (From product specifications.)

T_a = ambient temperature

η = efficiency = $\dfrac{P_{out}}{P_{in}}$ (Assume efficiencies of 81% for 5V outputs and 85% for 12V out and above.)

θ_{bm} = baseplate -to-heatsink thermal resistance (From thermal impedance tables in section above)

θ_{sa} = baseplate -to-heatsink thermal resistance (From thermal impedance tables in section above)

$$P_{diss} = \text{dissipated power} = P_{out}\left(\frac{1}{\eta} - 1\right)$$

$$\text{Airflow (LFM)} = \left(\frac{\text{CFM}}{\text{Area}}\right)$$

$$\text{Maximum Output Power} = \frac{T_{max} - T_a}{\theta_{sa}\left(\frac{1}{\eta} - 1\right)}$$

$$\text{Maximum Thermal Impedance} = \frac{T_{max} - T_a}{P_{out}\left(\frac{1}{\eta} - 1\right)}$$

$$\text{Maximum Ambient Temperature} = T_{max} - \theta_{sa} \times P_{out}\left(\frac{1}{\eta} - 1\right)$$

$$\text{Temperature Rise} = \theta_{sa} \times P_{out}\left(\frac{1}{\eta} - 1\right)$$

$$\text{Thermal Drop} = \theta_{bm} \times P_{out}\left(\frac{1}{\eta} - 1\right)$$

Typical Examples — Thermal Equations (cont)

EXAMPLE 1. Determine the maximum output power for a 100W, VI-200 converter, no heat sink, delivering 5V in 400 LFM at a maximum ambient temperature of 45°C.

$$\text{Maximum Output Power} = \frac{T_{max} - T_a}{\theta_{sa}\left(\frac{1}{\eta} - 1\right)}$$

$T_{max} = 85°C$

$T_a = 45°C$

$\theta_{sa} = 1.8°C/W$

$\eta = 81\% = (.81)$

$$\text{Maximum Output Power} = \frac{85 - 45}{1.8\left(\frac{1}{0.81} - 1\right)}$$

= 95W max.

EXAMPLE 2. Determine the **maximum thermal impedance** of a 50W, VI-J00 converter, no heat sink, delivering 24V at 45W in free air convection at 55°C ambient.

$$\text{Maximum Thermal Impedance} = \frac{T_{max} - T_a}{P_{out}\left(\frac{1}{\eta} - 1\right)}$$

$T_{max} = 100°C$

$T_a = 55°C$

$P_{out} = 45W$

$\eta = 85\% = (.85)$

$$\text{Maximum Thermal Impedance} = \frac{100 - 55}{45\left(\frac{1}{0.85} - 1\right)}$$

= 5.7˚C/W Min.

Typical Examples — Thermal Equations (cont)

EXAMPLE 3. Determine the **maximum ambient temperature** of a 3-up FlatPAC delivering 12V at 600W in 500 LFM with no additional conduction cooling to the chassis.

$$\text{Maximum Ambient Temperature} = T_{max} - \theta_{sa} \times P_{out}\left(\frac{1}{\eta} - 1\right)$$

$T_{max} = 85°C$

$\theta_{sa} = 0.3°C/W$

$P_{out} = 600W$

$\eta = 85\% = (.85)$

$$\text{Maximum Ambient Temp.} = 85 - 0.3 \times 600\left(\frac{1}{0.85} - 1\right)$$

$= 53°C$

EXAMPLE 4. Determine the **temperature rise** of a 150W, VI-200 converter delivering 5V at 132W with a 02113 heatsink in 200 LFM.

$$\text{Temperature Rise} = \theta_{sa} \times P_{out}\left(\frac{1}{\eta} - 1\right)$$

$\theta_{sa} = 1.1°C/W$

$P_{out} = 132W$

$\eta = 81\% = (0.81)$

$$\text{Temperature Rise} = 1.1 \times 132\left(\frac{1}{0.85} - 1\right)$$

$= 34°C$ Over Ambient Temperature

EXAMPLE 5. Determine the baseplate to coldplate thermal drop for an MI-200 converter delivering 5V at 50W with a thermal pad.

$$\text{Thermal Drop} = \theta_{bm} \times P_{out}\left(\frac{1}{\eta} - 1\right)$$

$\theta_{bm} = 0.2°C/W$

$P_{out} = 50W$

$\eta = 81\% = 0.81$

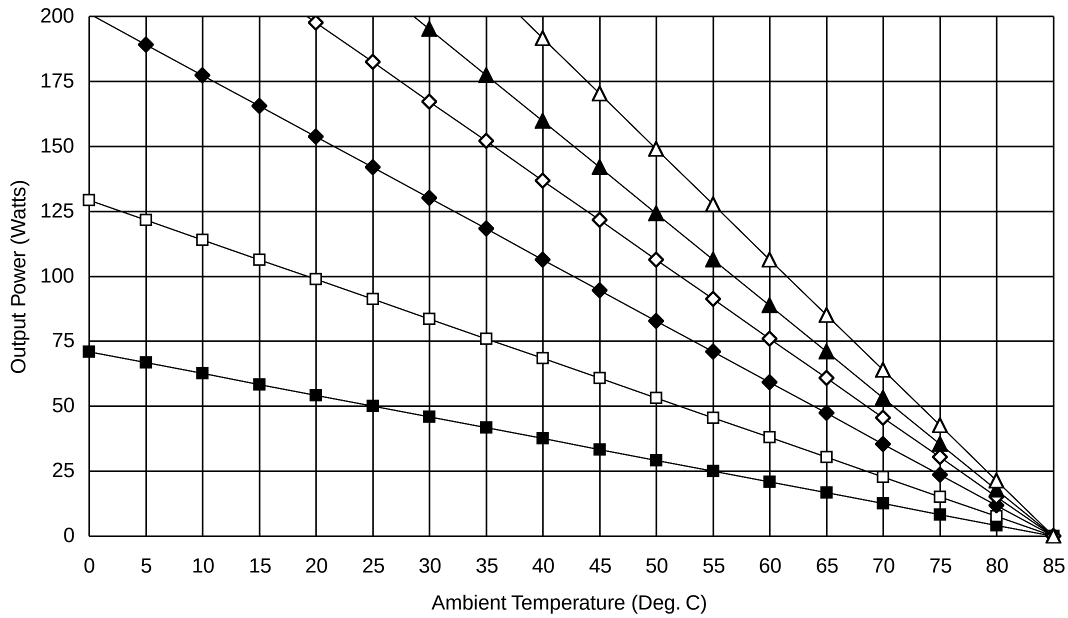
$$\text{Temperature Rise} = 0.2 \times 50\left(\frac{1}{0.85} - 1\right)$$

$= 2.34°C$

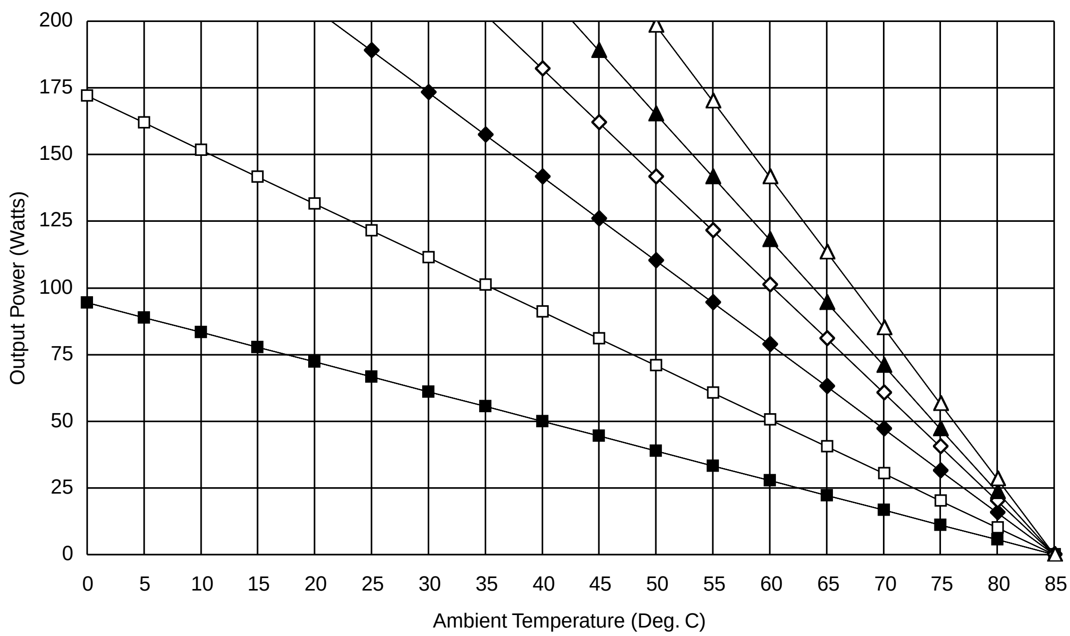
Thermal Curves

Thermal Curves **(Use as a design guide only. Verify final design by actual temperature measurement.)**

VI-200 Family
Baseplate-to-Air
(No Heatsink)
5V Output



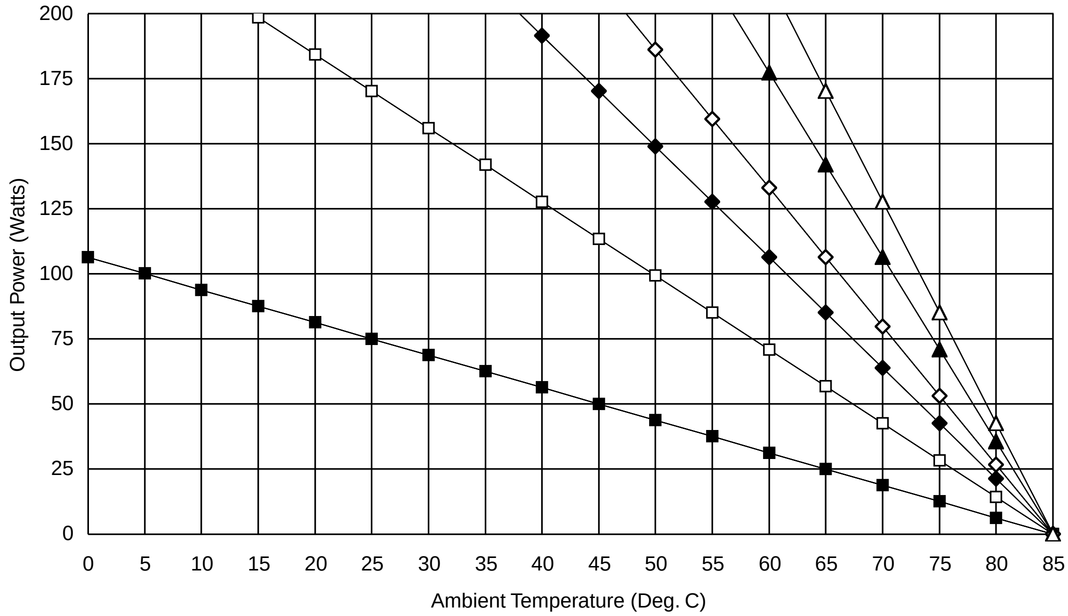
VI-200 Family
Baseplate-to-Air
(No Heatsink)
12-48V Output



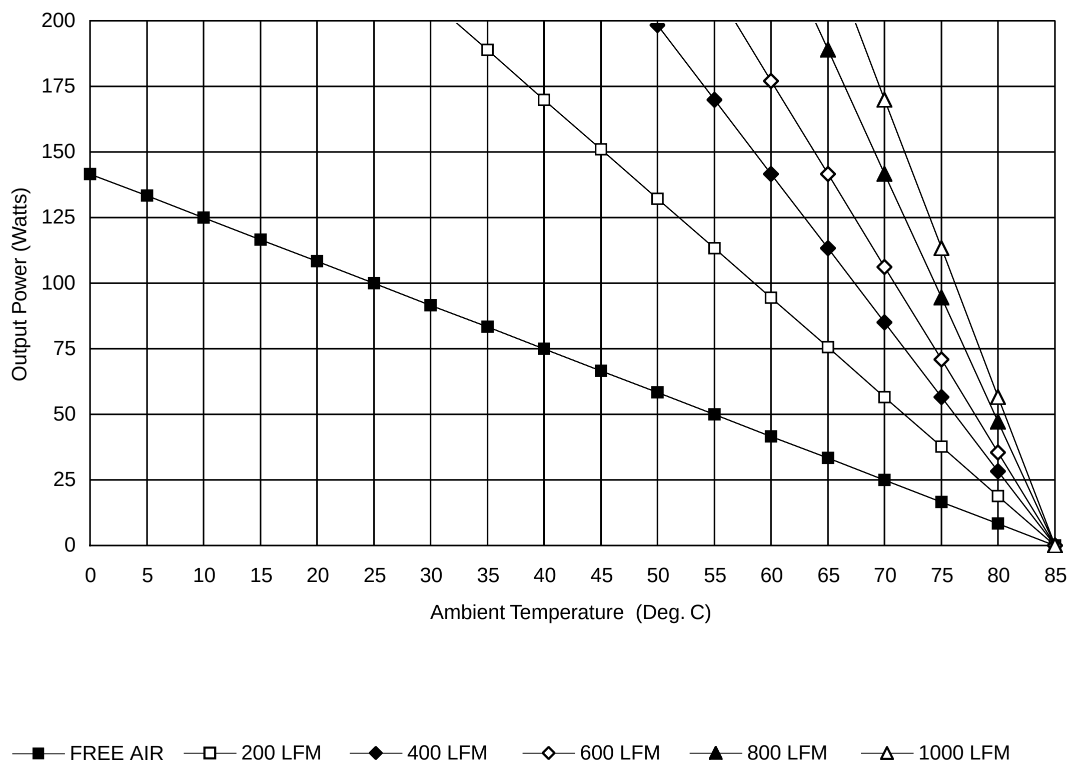
FREE AIR 200 LFM 400 LFM 600 LFM 800 LFM 1000 LFM

Thermal Curves (cont)

VI-200 Family
2111 Heatsink,
5V Output

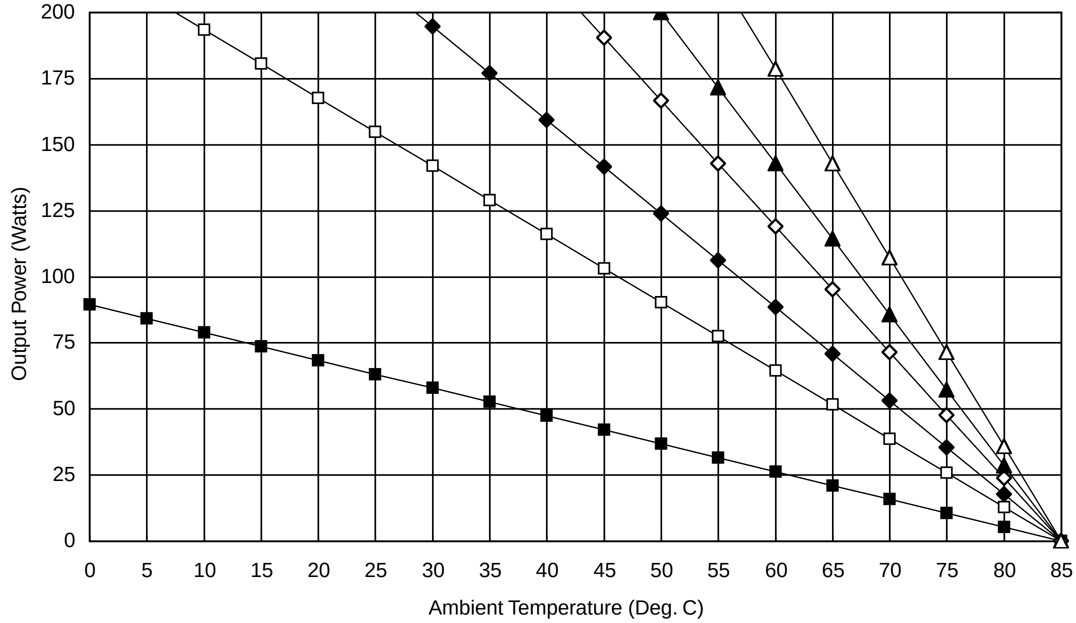


VI-200 Family
2111 Heatsink,
12-48V Output

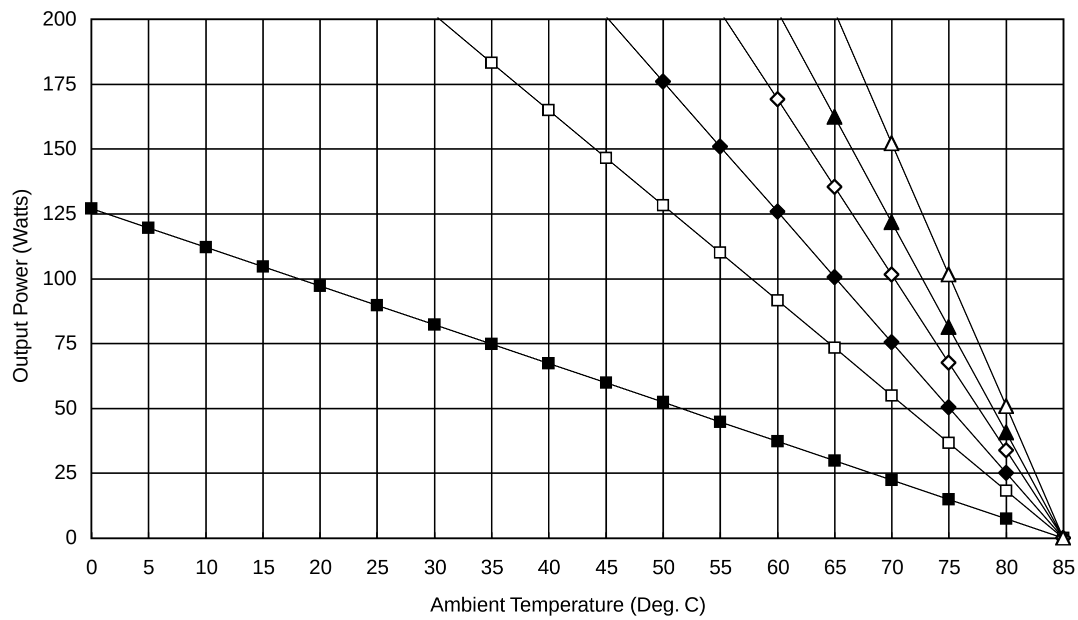


Thermal Curves (cont)

VI-200 Family
2112 Heatsink
5V Output



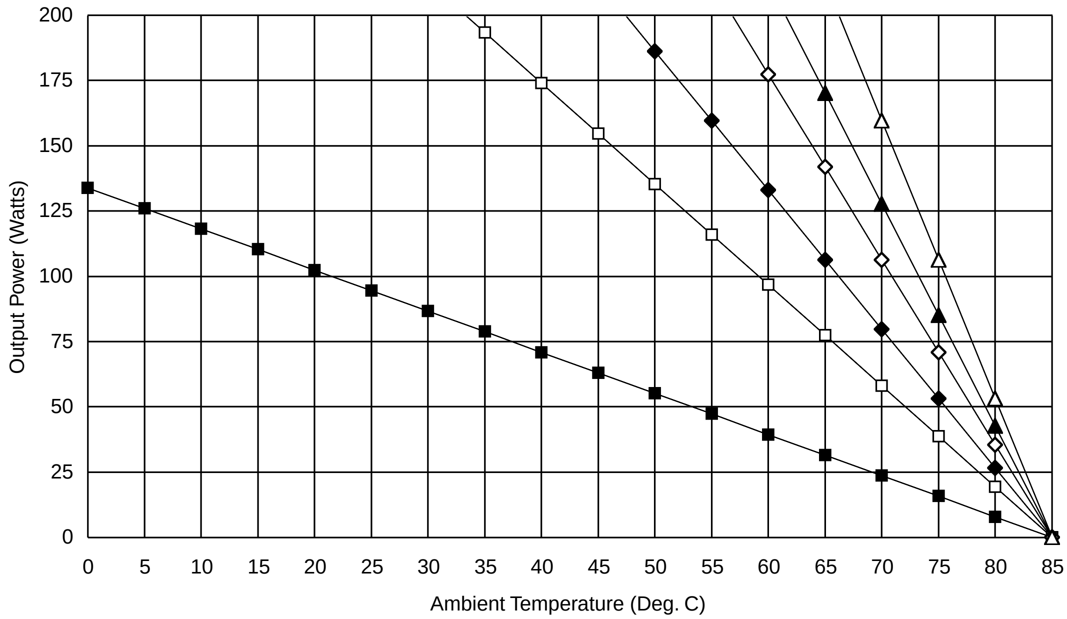
VI-200 Family
2112 Heatsink
12-48V Output



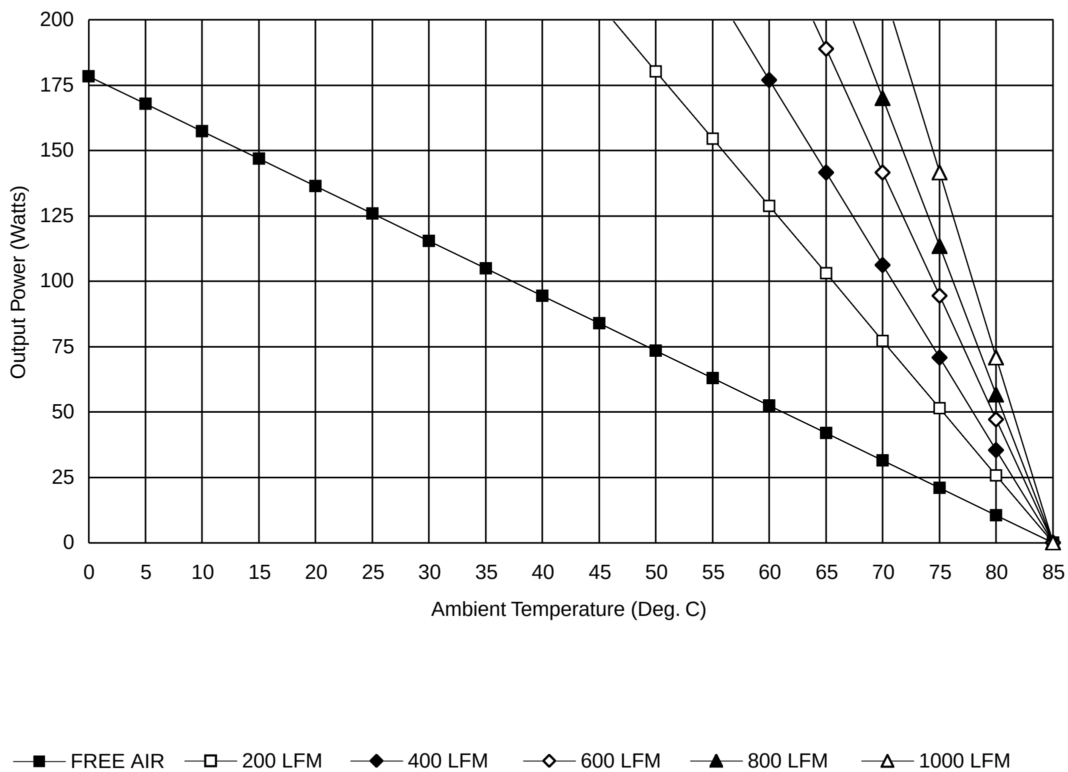
FREE AIR — 200 LFM — 400 LFM — 600 LFM — 800 LFM — 1000 LFM

Thermal Curves (cont)

VI-200 Family
2113 Heatsink,
5V Output

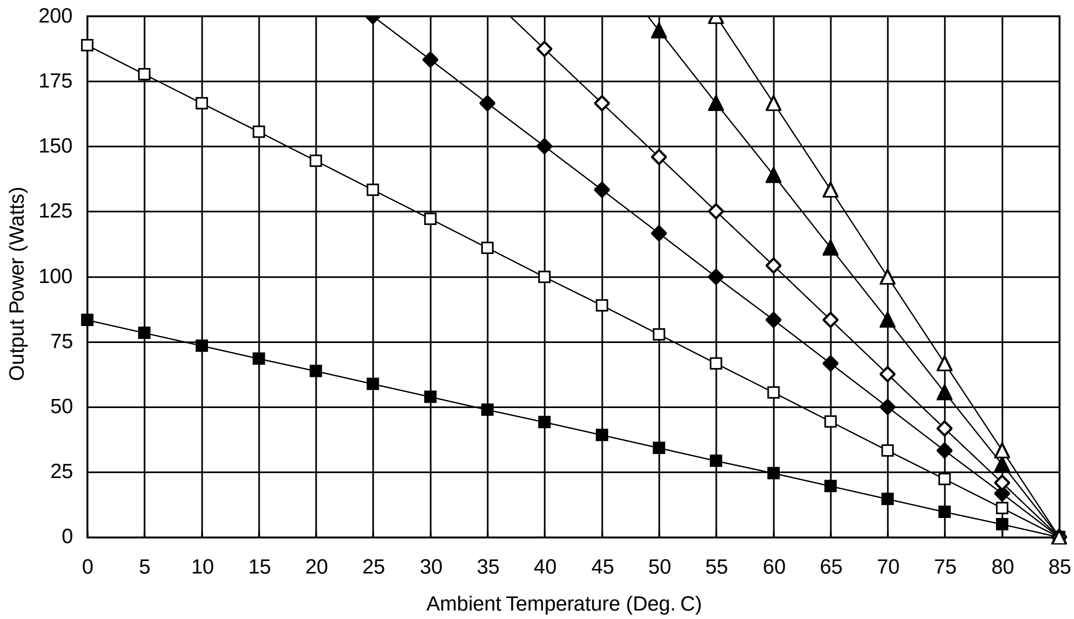


VI-200 Family
2113 Heatsink,
12-48V Output

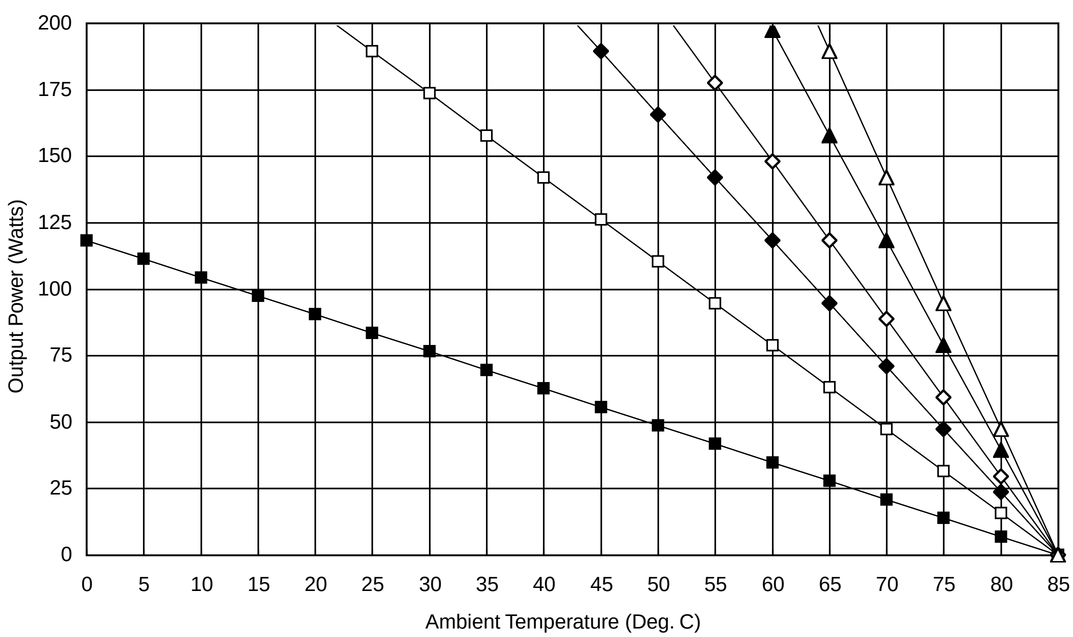


Thermal Curves (cont)

VI-200 Family
6927 Heatsink
5V Output



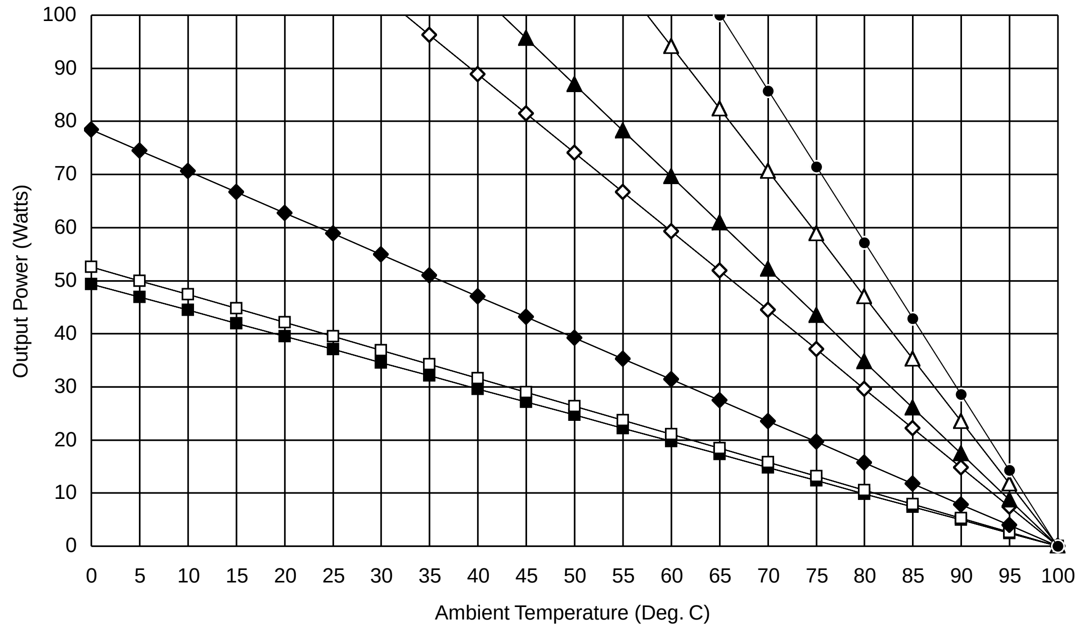
VI-200 Family
6927 Heatsink
12-48V Output



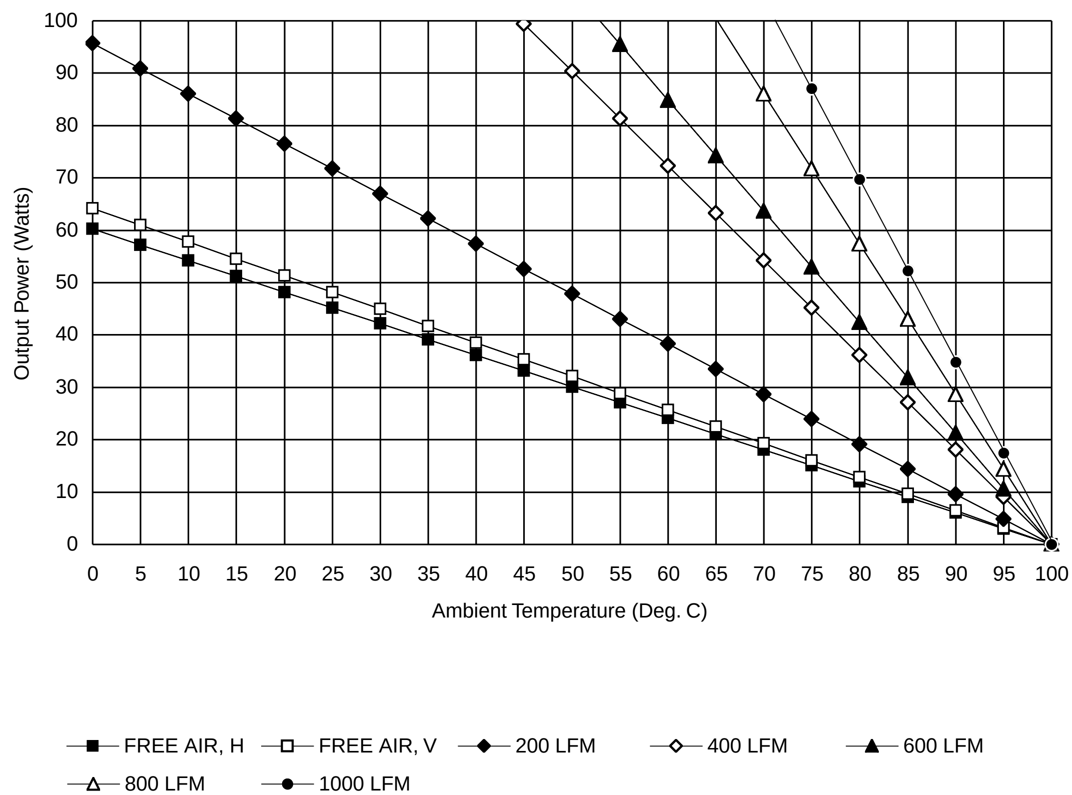
FREE AIR 200 LFM 400 LFM 600 LFM 800 LFM 1000 LFM

Thermal Curves (cont)

VI-J00 Family
Baseplate-to-Air
(No Heatsink)
5V Output

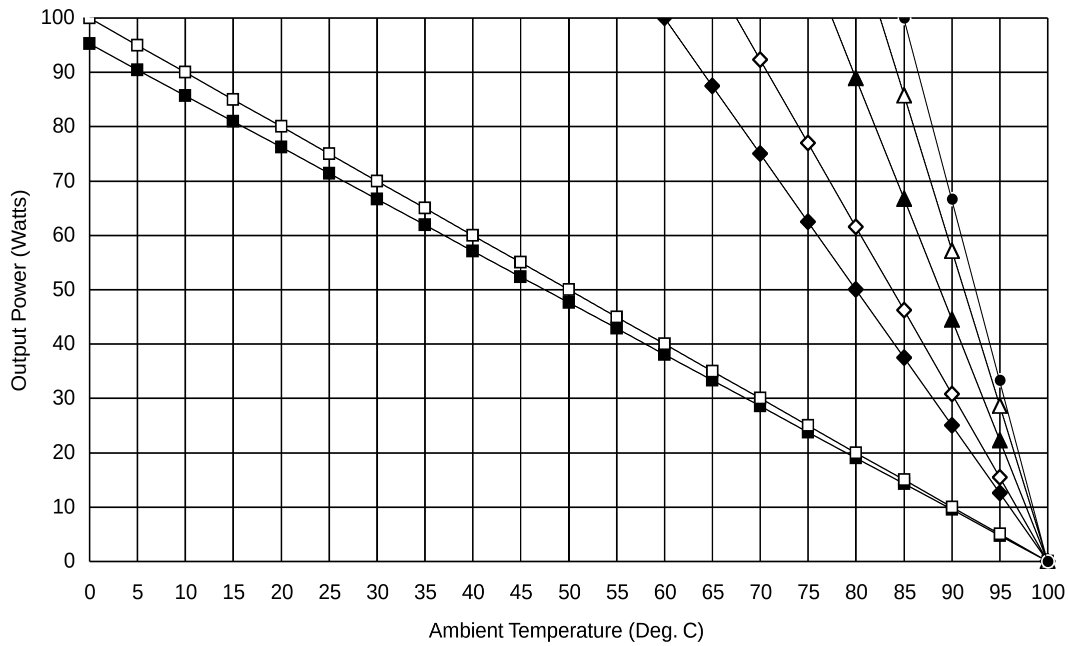


VI-J00 Family
Baseplate-to-Air
(No Heatsink)
12-48V Output

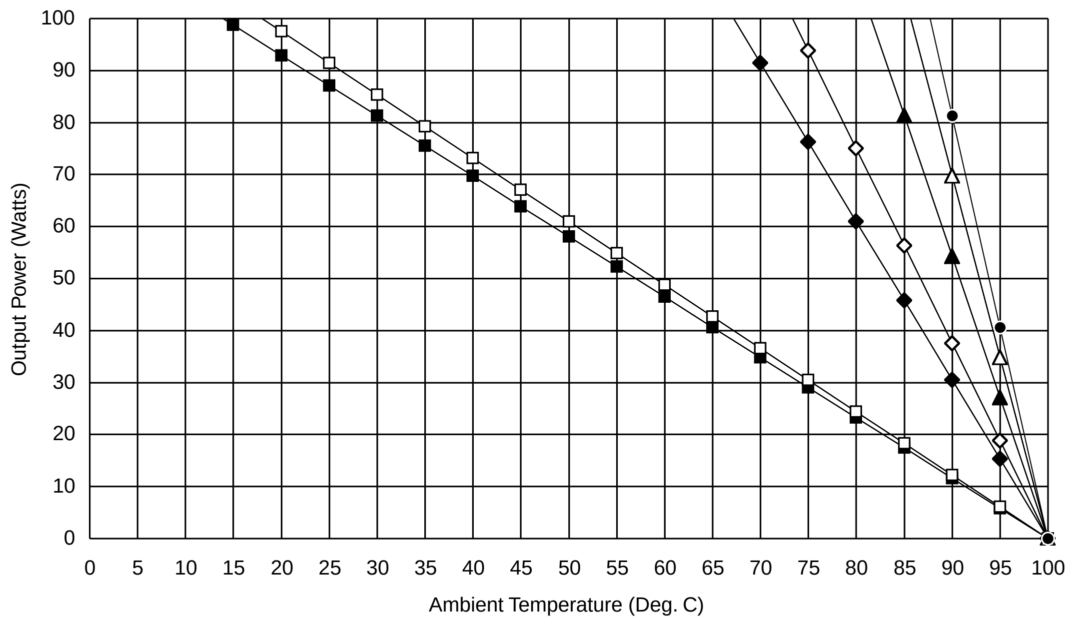


Thermal Curves (cont)

VI-J00 Family
4306 Heatsink,
5V Output



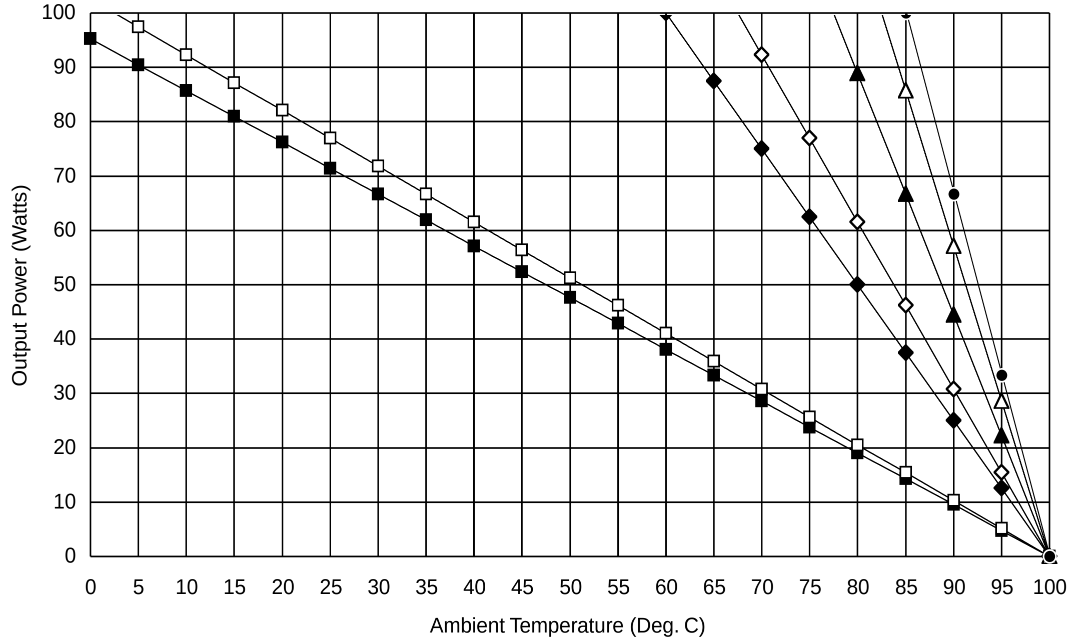
VI-J00 Family
4306 Heatsink,
12-48V Output



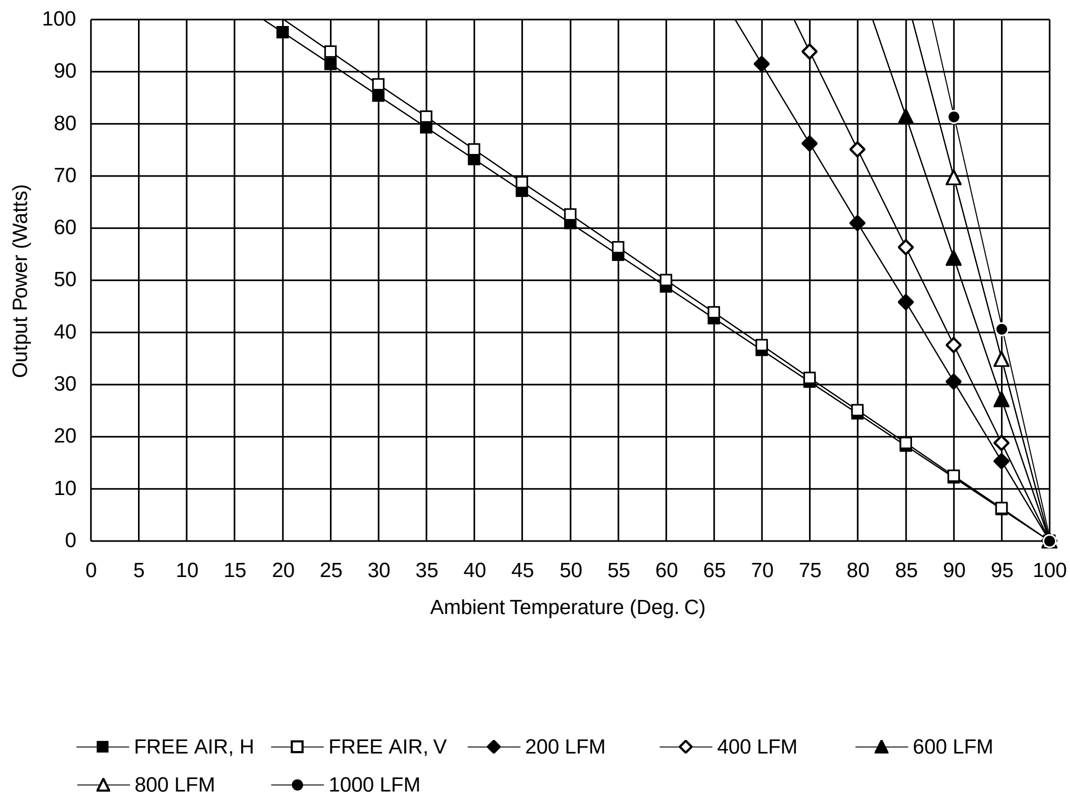
FREE AIR, H — FREE AIR, V — 200 LFM — 400 LFM — 600 LFM
800 LFM — 1000 LFM

Thermal Curves (cont)

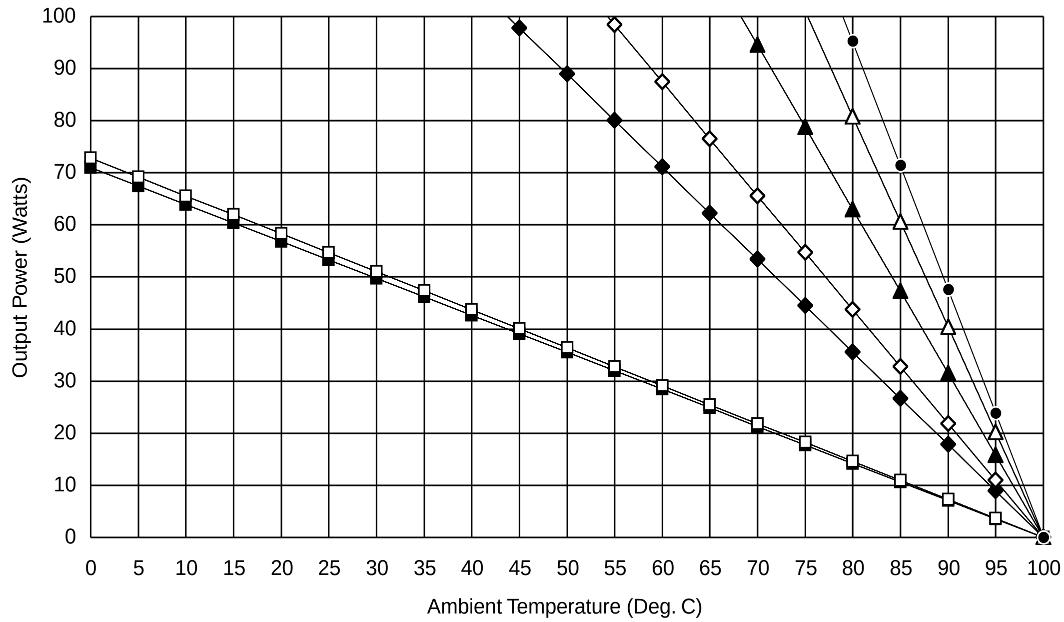
VI-J00 Family
4307 Heatsink,
5V Output



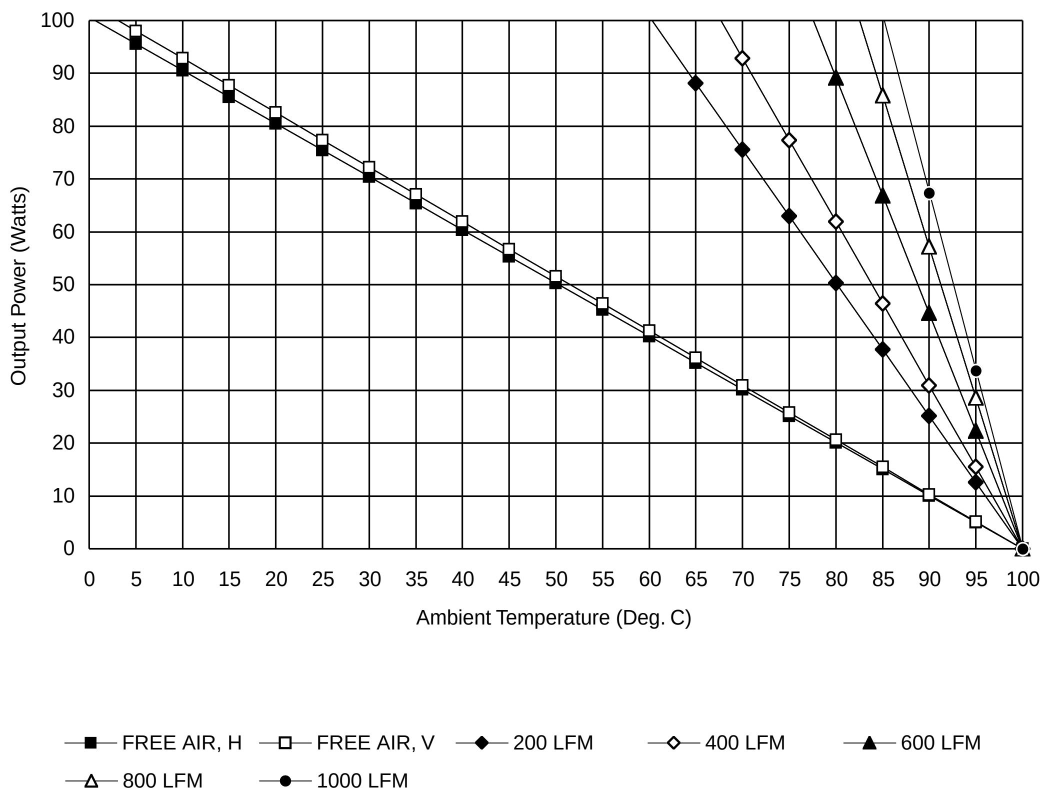
VI-J00 Family
4307 Heatsink,
12-48V Output



VI-J00 Family
5738 Heatsink
5V Output

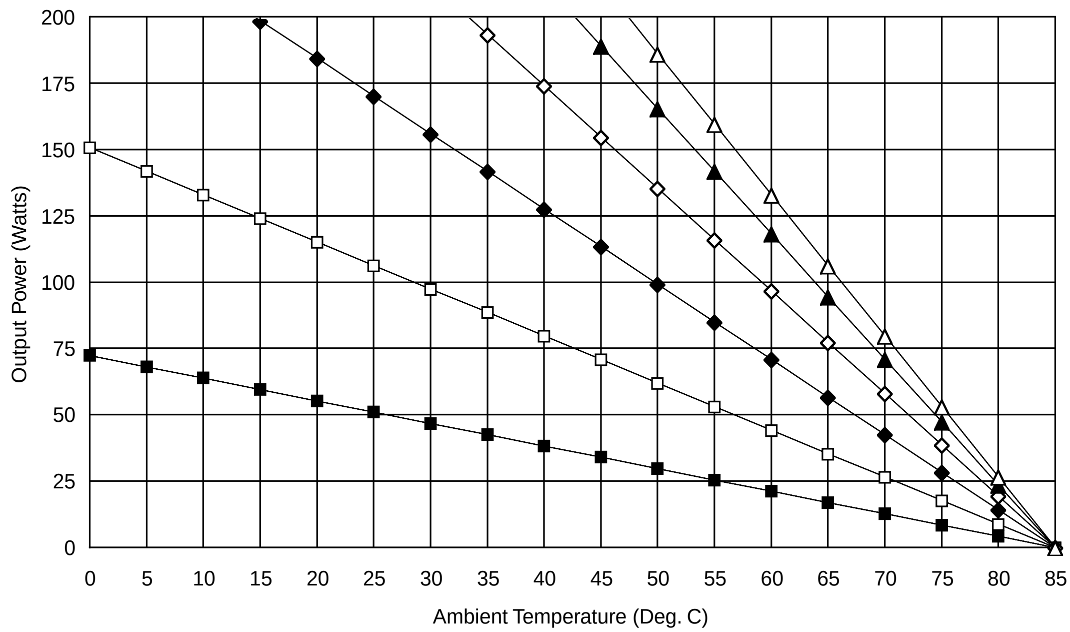


VI-J00 Family
5738 Heatsink
12-48V Output

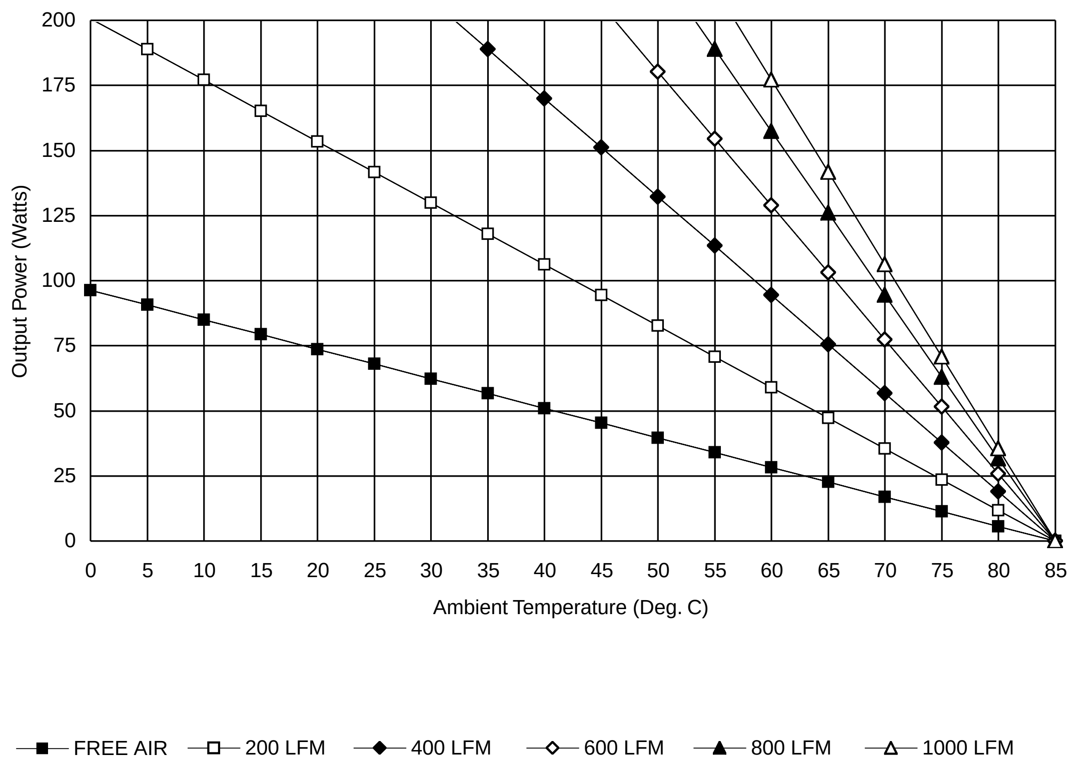


Thermal Curves (cont)

FinMod
VI-200 Family
F1/F3
Configuration
5V Output

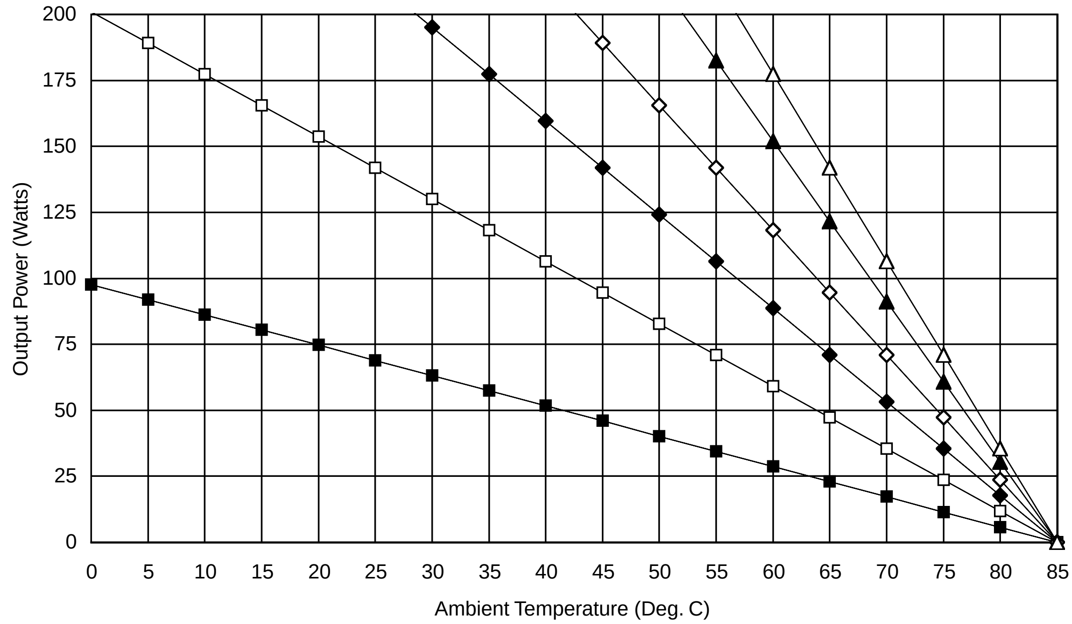


FinMod
VI-200 Family
F1/F3
Configuration
12-48V Output

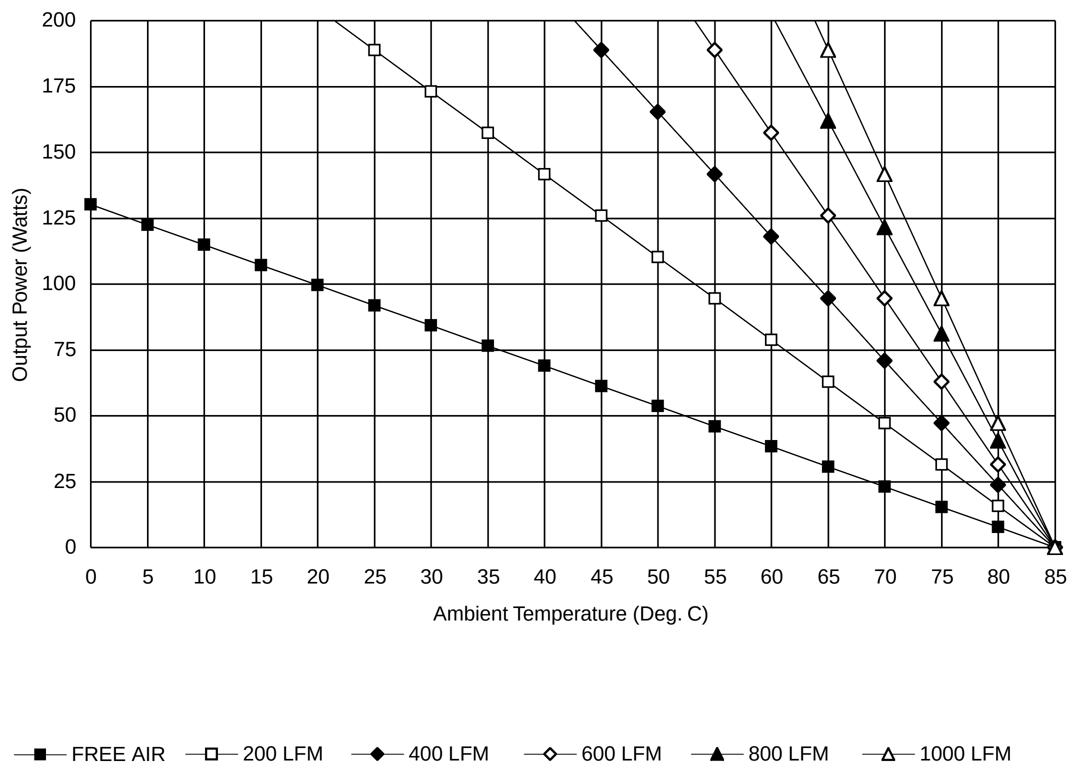


Thermal Curves (cont)

FinMod
VI-200 Family
F2/F4 Configuration
5V Output

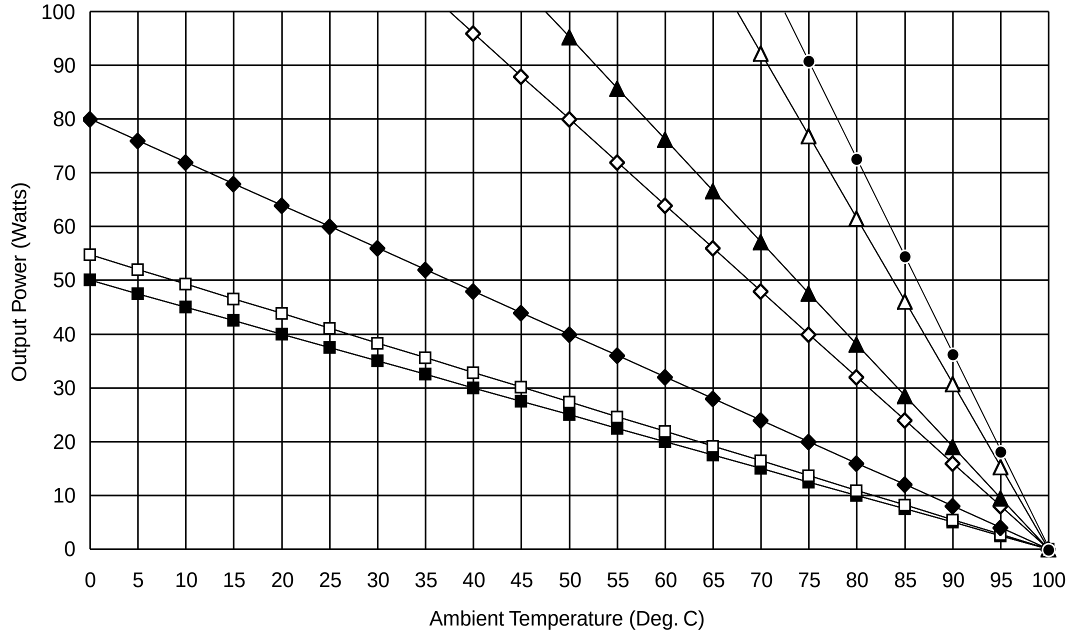


FinMod
VI-200 Family
F2/F4 Configuration
12-48V Output

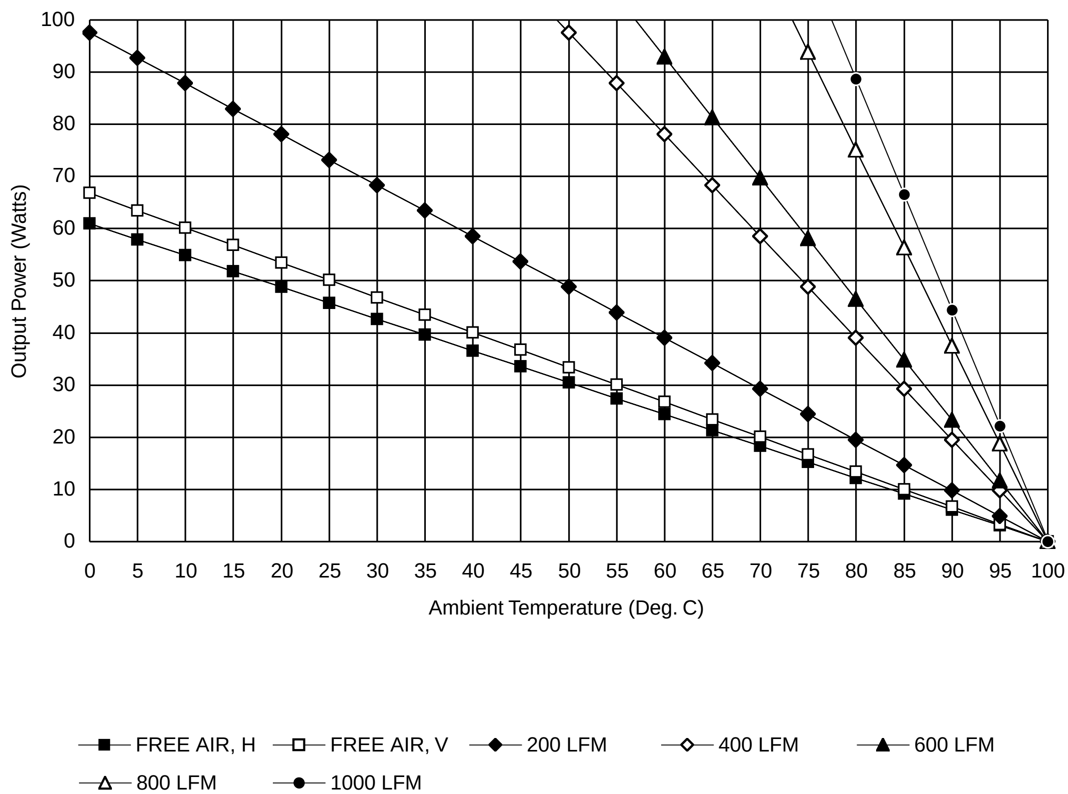


Thermal Curves (cont)

FinMod
VI-J00 Family
F1/F3 Configuration
5V Output

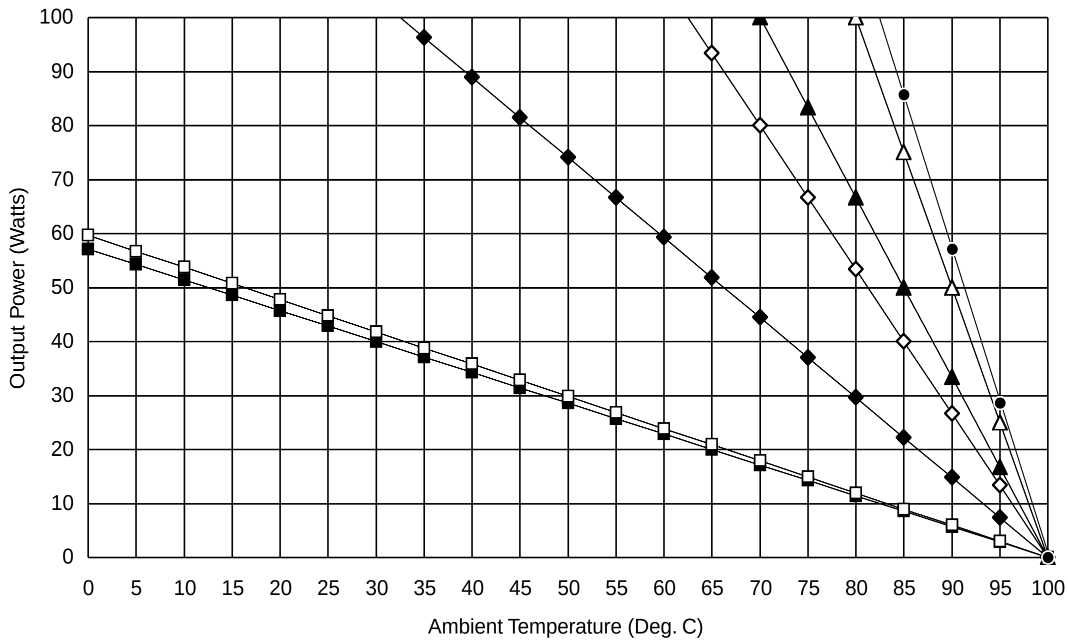


FinMod
VI-J00 Family
F1/F3 Configuration
12-48V Output

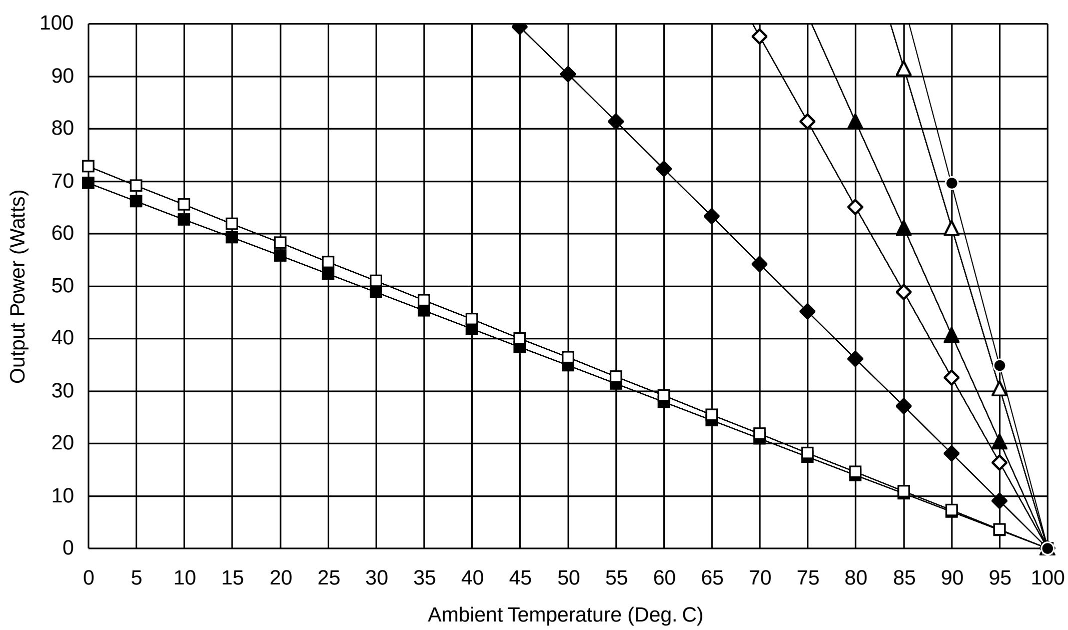


Thermal Curves (cont)

FinMod
VI-J00 Family
F2/F4 Configuration
5V Output



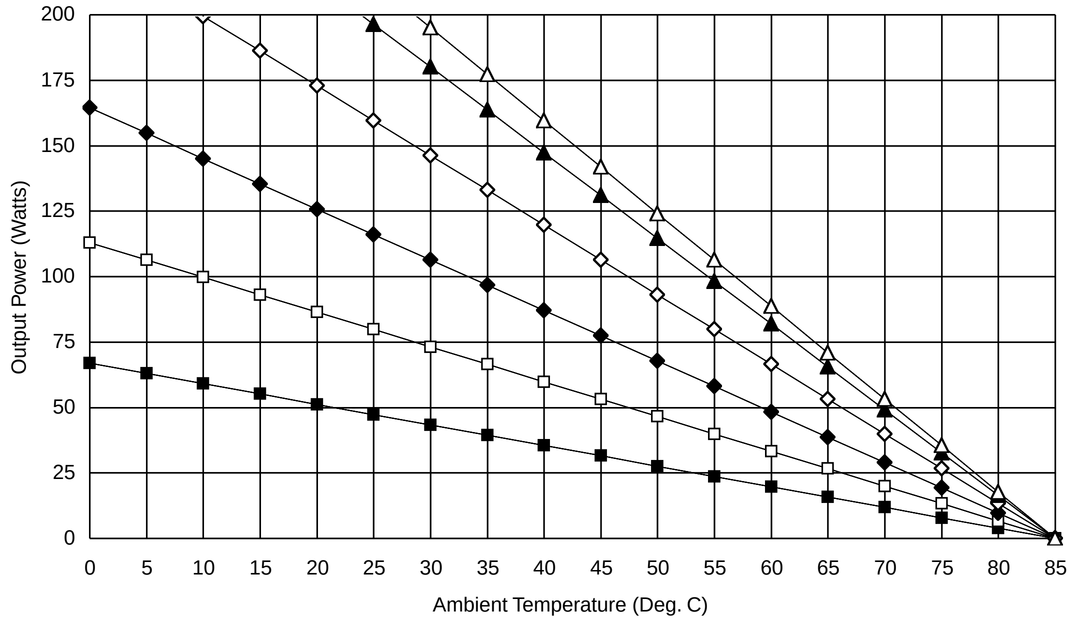
FinMod
VI-J00 Family
F2/F4 Configuration
12-48V Output



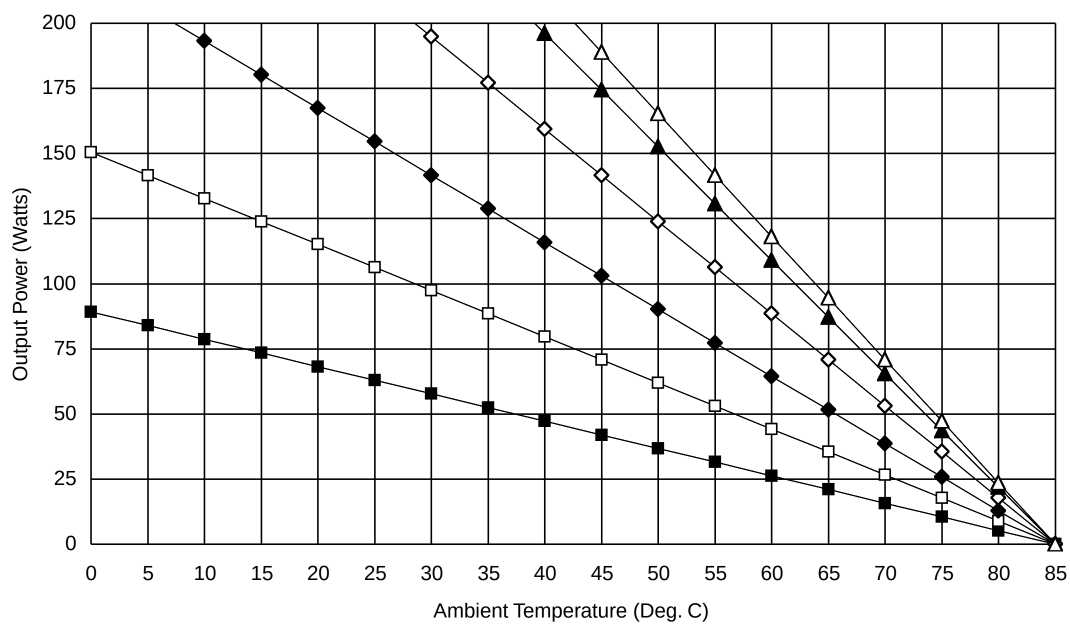
FREE AIR, H FREE AIR, V 200 LFM 400 LFM 600 LFM
800 LFM 1000 LFM

Thermal Curves (cont)

SlimMod
VI-200 Family
5V Output



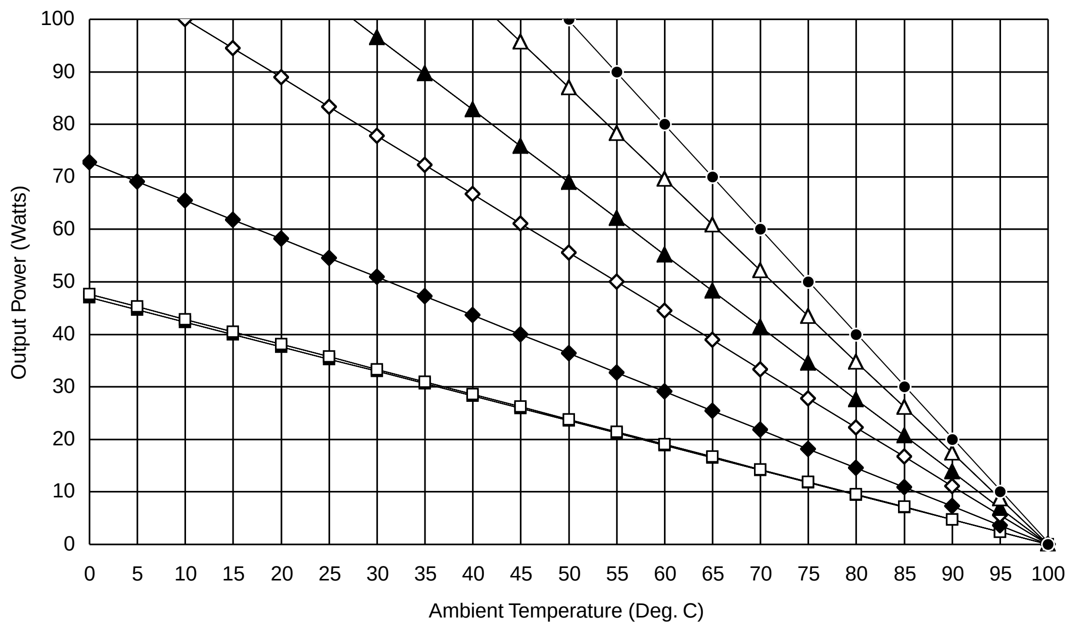
SlimMod
VI-200 Family
12-48V Output



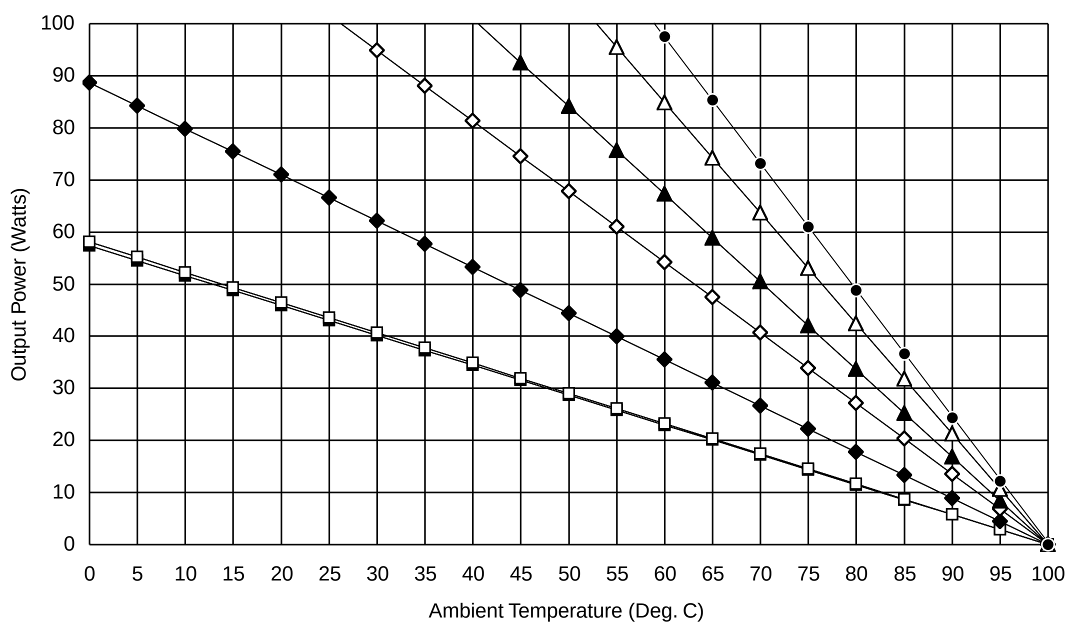
FREE AIR   200 LFM   400 LFM   600 LFM   800 LFM   1000 LFM

Thermal Curves (cont)

SlimMod
VI-J00 Family
5V Output



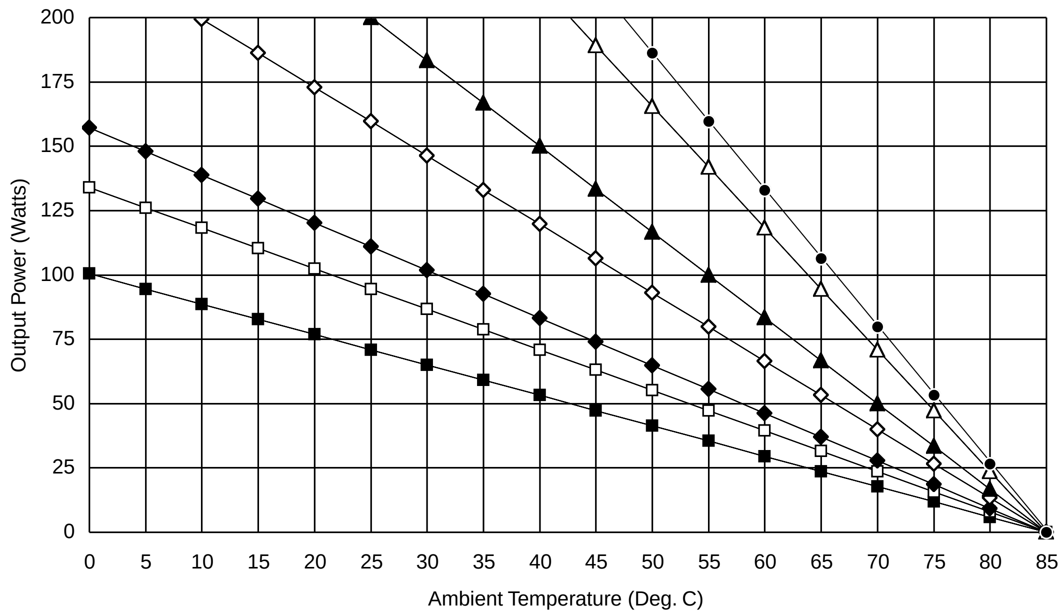
SlimMod
VI-J00 Family
12-48V Output



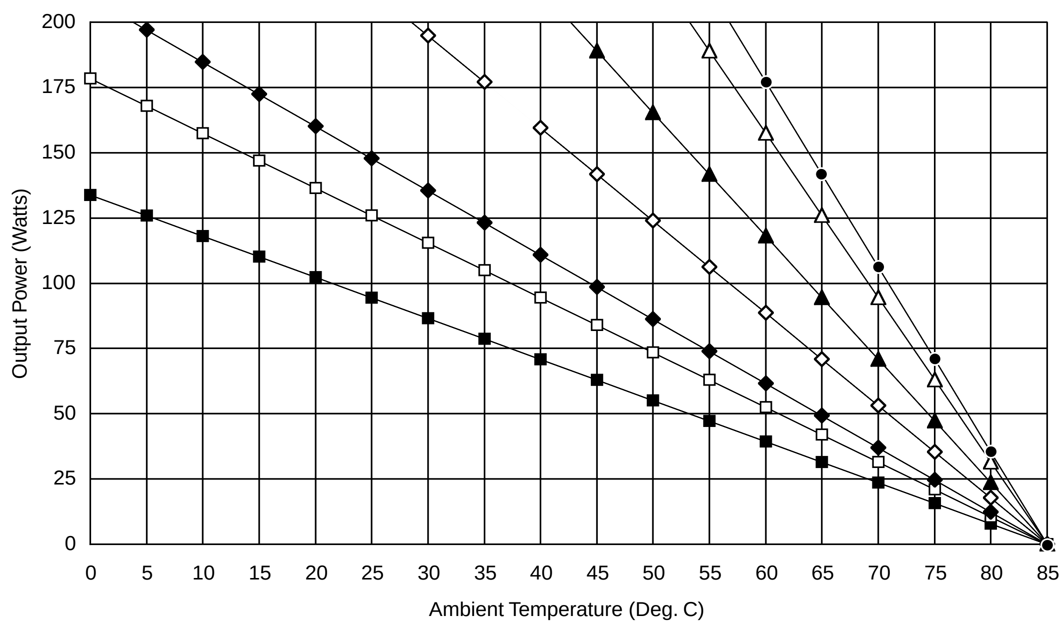
FREE AIR, H FREE AIR, V 200 LFM 400 LFM 600 LF
800 LFM 1000 LFM

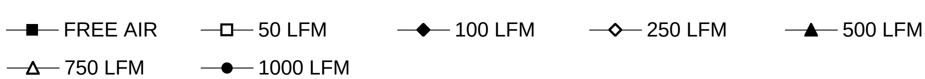
Thermal Curves (cont)

1-Up ComPAC, 5V Output



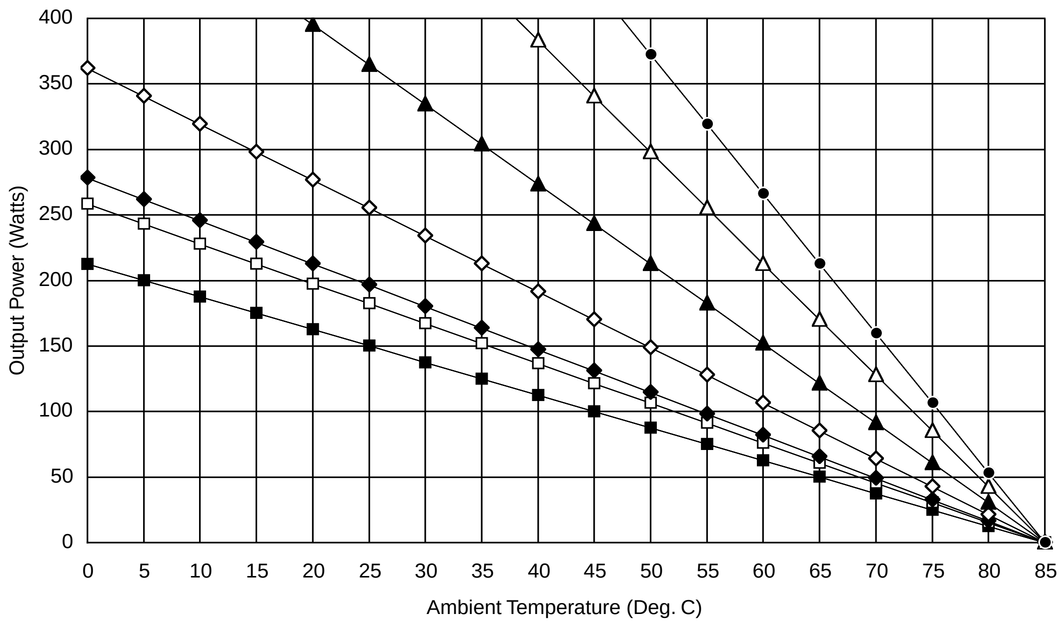
1-Up ComPAC, 12-48V Output



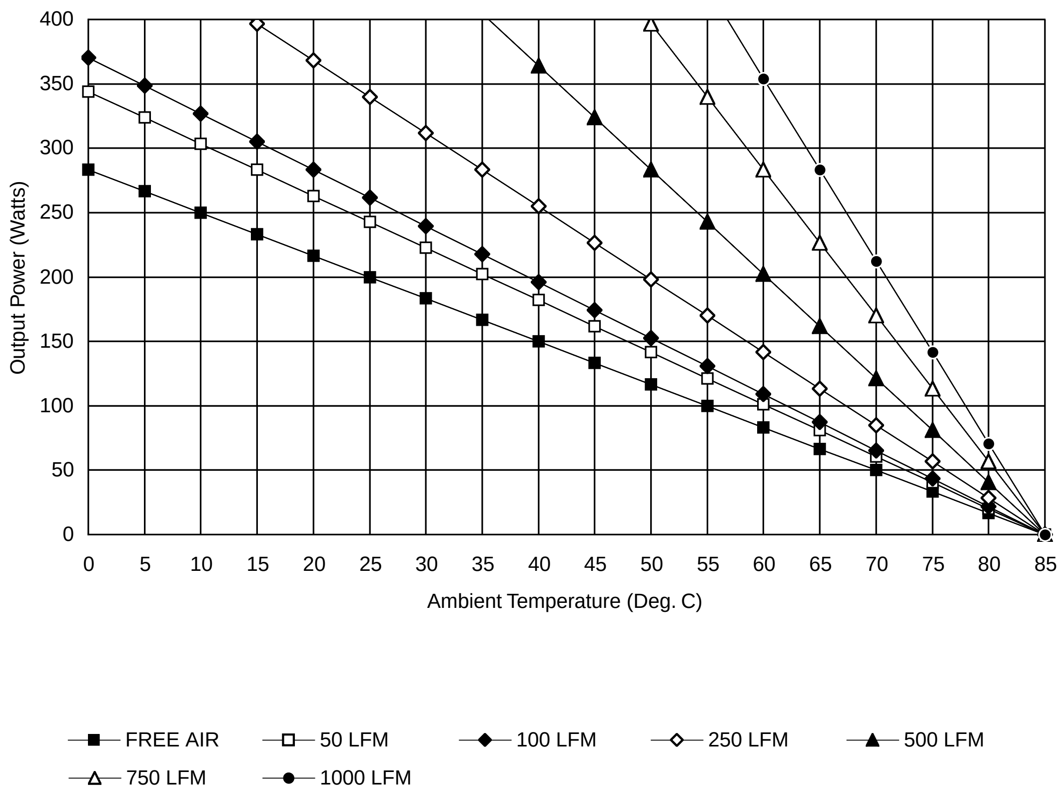


Thermal Curves (cont)

2-Up ComPAC,
5V Output

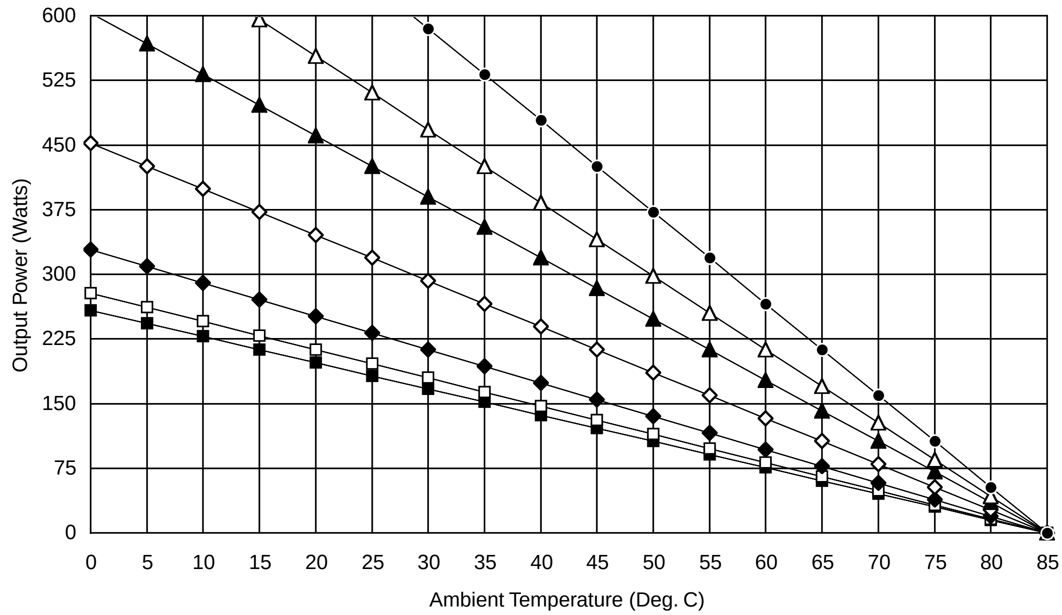


2-Up ComPAC,
12-48V Output

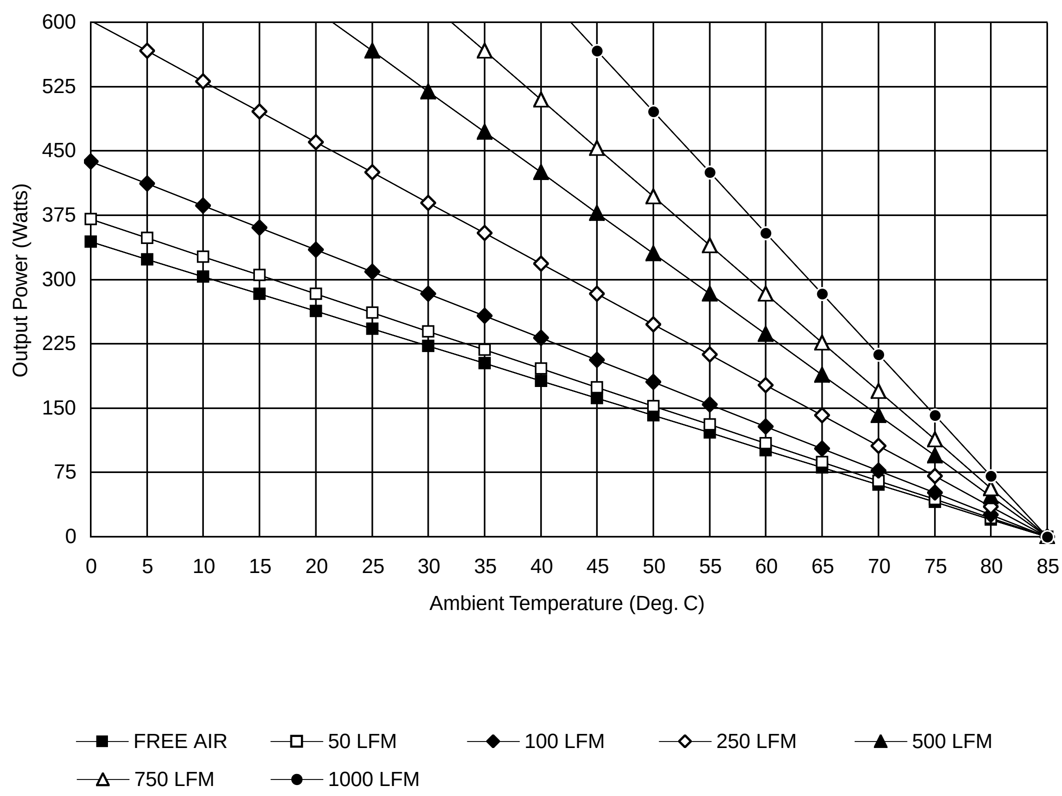


Thermal Curves (cont)

3-Up ComPAC,
5V Output

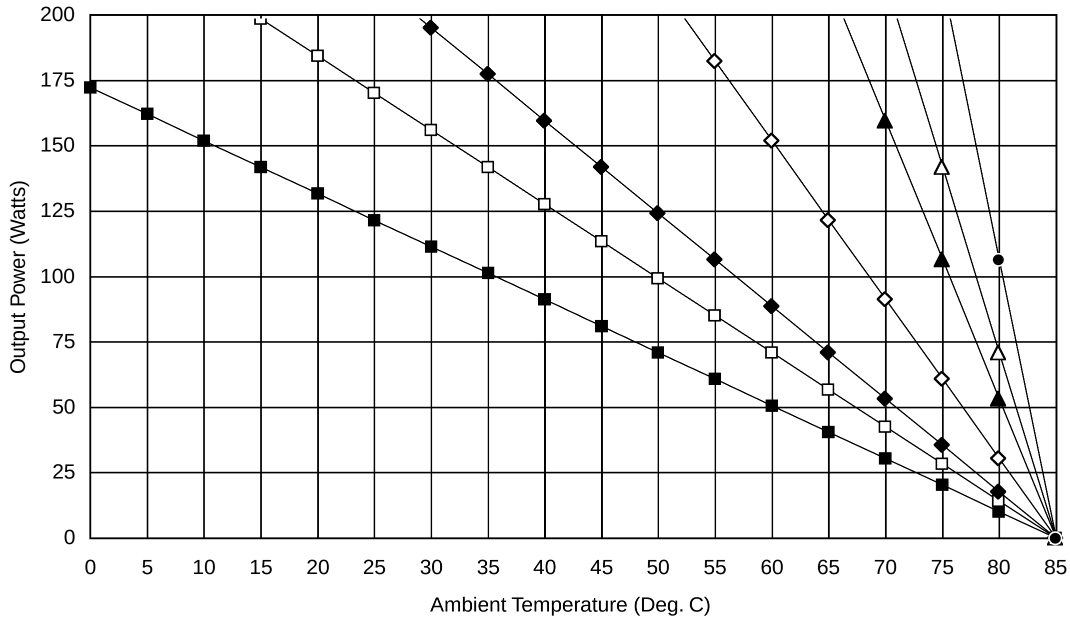


3-Up ComPAC,
12-48V Output

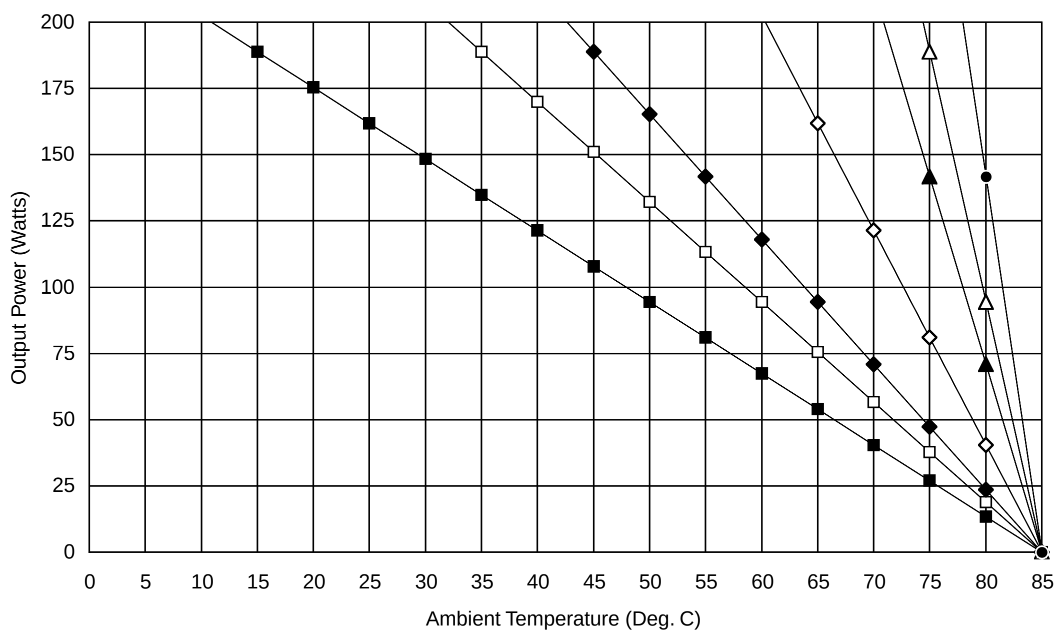


Thermal Curves (cont)

1-Up FlatPAC, 5V Output



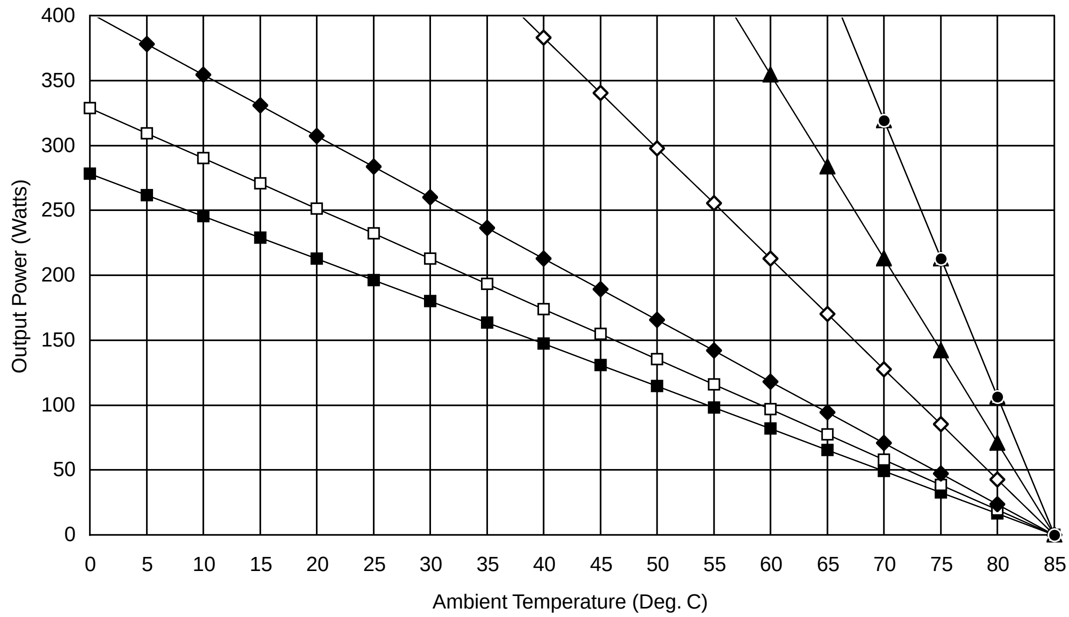
1-Up FlatPAC, 12-48V Output



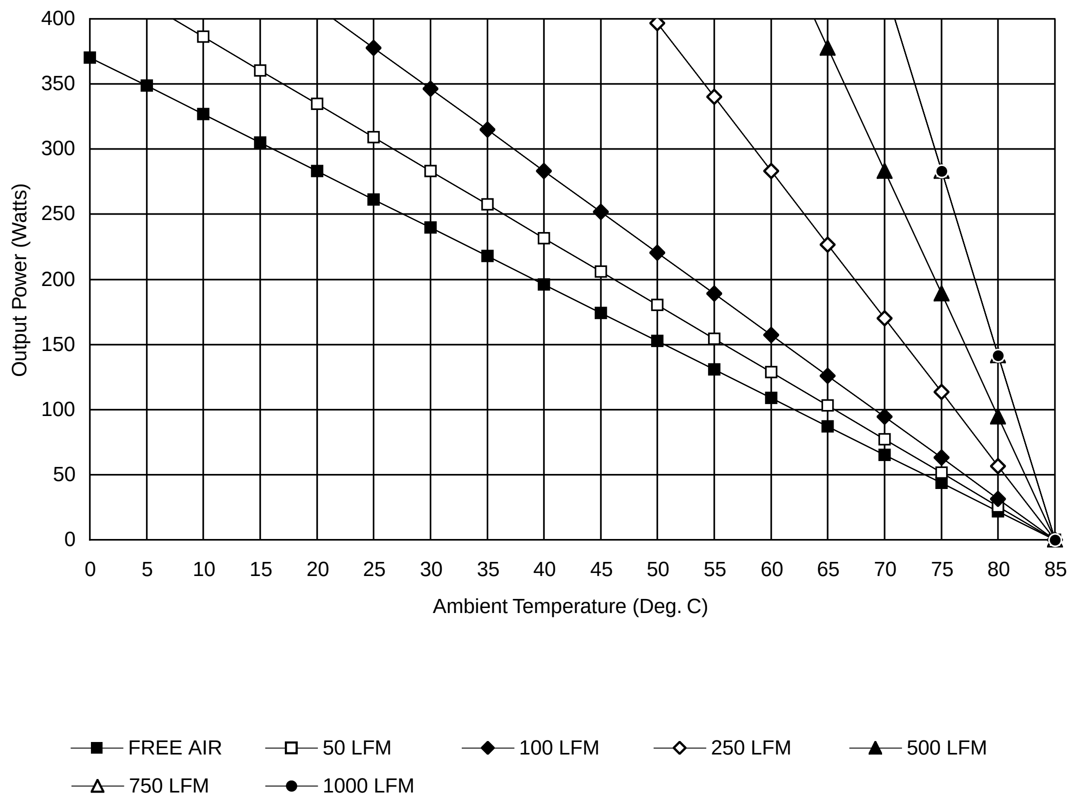
FREE AIR | 50 LFM | 100 LFM | 250 LFM | 500 LFM | 750 LFM | 1000 LFM

Thermal Curves (cont)

2-Up FlatPAC, 5V Output

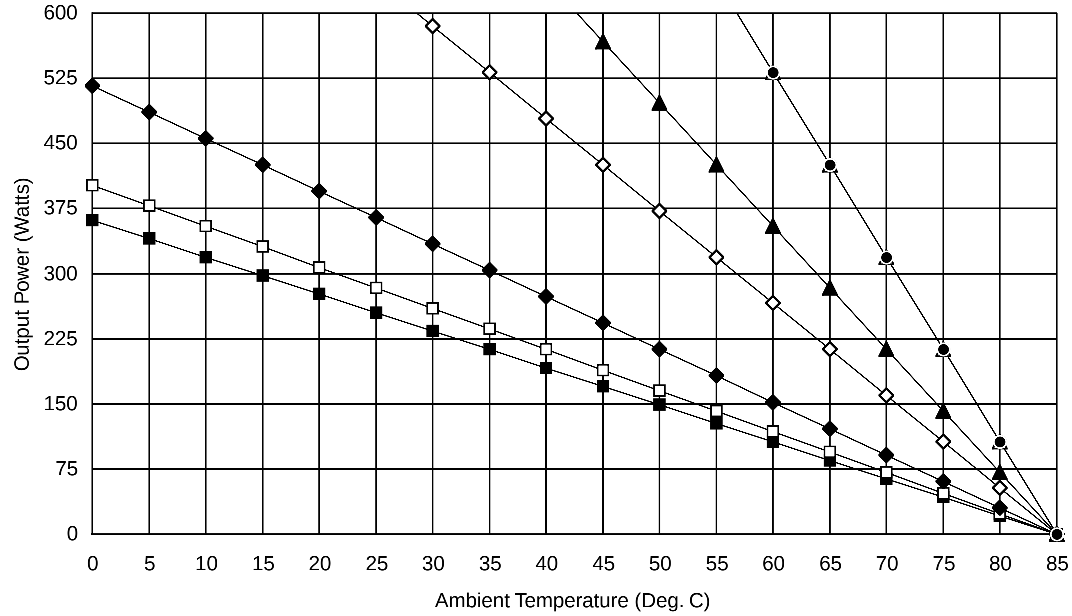


2-Up FlatPAC, 12-48V Output

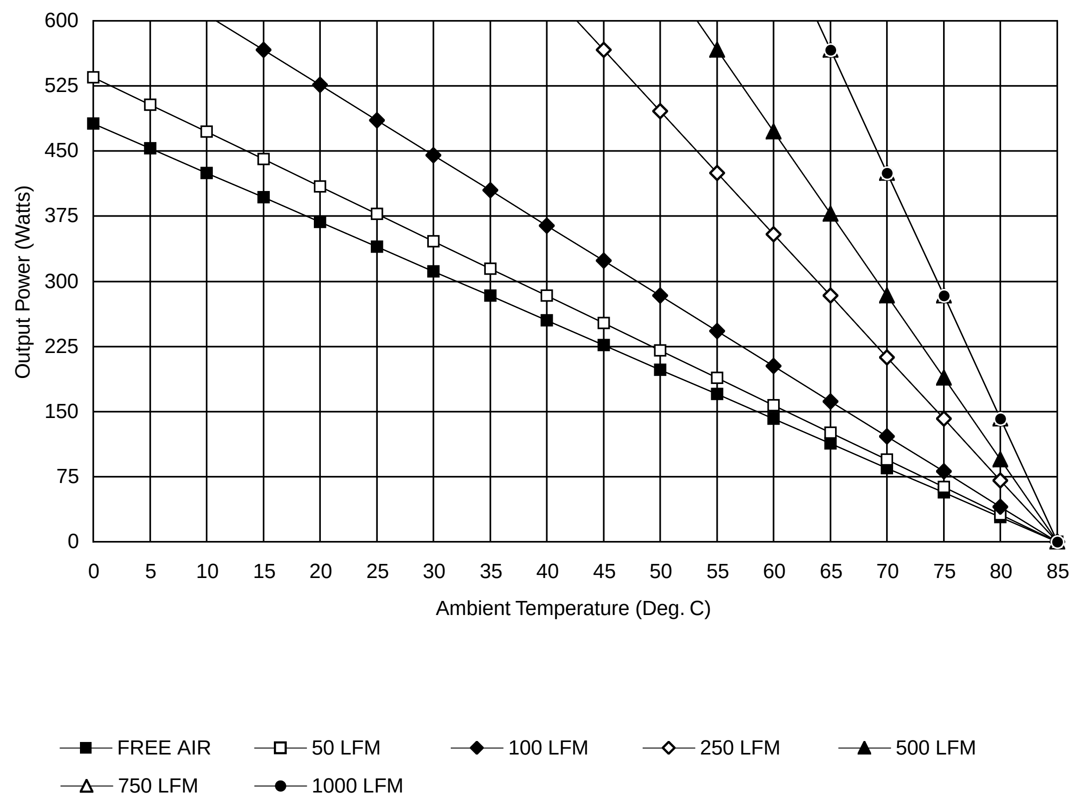


Thermal Curves (cont)

3-Up FlatPAC, 5V Output



3-Up FlatPAC, 12-48V Output



Notes

Agency Approvals

Overview

Below are the agency approvals received on Vicor products as of 1/98. Please consult the factory for the approvals on our more recent product introductions.

DC-DC Products

	Approvals
VI-200 Family	UL: 544, 1012, 1950, 2601-1 CSA: 0, 0.4, 0.7, 125, 142, 220, 234, 950; 1402C, 556B TÜV: EN 60950 VDE: IEC 60950, EN 60950, VDE 0805, IEC 60601, EN 60601, VDE 0750 BSI: BS 6301, IEC 60950, BS 7002, EN 60950 BABT: EN 41003, EN 60950 Austel: TS001, AS3260 Bellcore: (NEBS) Flammability Requirements CE: Low Voltage Directive (73/23/EEC, 93/68/EEC)
VI-J00 Family	UL: 1012, 1950 CSA: 0, 0.4, 142, 220, 234, 950; 1402C, 556B TÜV: EN 60950 VDE: IEC 60950, EN 60950, VDE 0805 BSI: IEC 60950, BS 7002, EN 60950 BABT: EN 41003, EN 60950 Austel: TS001, AS3260 Bellcore: (NEBS) Flammability Requirements CE: Low Voltage Directive (73/23/EEC, 93/68/EEC)
2nd Generation DC-DC (Selected Models)	UL: 1012, 1950 CSA: 0, 0.4, 142, 234, 950; 1402C TÜV: EN 60950 VDE: IEC 60950, EN 60950, VDE 0805 BABT: EN 41003, EN 60950 Austel: TS001, AS3260 Bellcore: (NEBS) Flammability Requirements CE: Low Voltage Directive (73/23/EEC, 93/68/EEC)
MegaModules	UL: 544, 1012, 1950 CSA: 0, 0.4, 234, 950; 1402C TÜV: EN 60950 VDE: VDE 0805, IEC 60950, EN 60950 BABT: EN 41003, EN 60950 CE: Low Voltage Directive (73/23/EEC, 93/68/EEC)
MegaModule Juniors	UL: 1012, 1950 CSA: 0, 0.4, 234, 950; 1402C TÜV: EN 60950 BABT: EN 41003, EN 60950 CE: Low Voltage Directive (73/23/EEC, 93/68/EEC)

DC-DC Products (Cont)

ComPAC

UL: 1012, 1950, 1604
CSA: 0, 0.4, 0.7, 220, 234, 950; 1402C
TÜV: EN 60950
VDE: VDE 0805, IEC 60950, EN 60950
BABT: EN 41003, EN 60950
CE: Low Voltage Directive (73/23/EEC, 93/68/EEC)

ConverterPACs

UL: 1012, 1950
CSA: 0, 0.4, 234, 950; 1402C
TÜV: EN 60950

DC MegaPAC

UL: 1950
CSA: 0, 0.4, 0.7, 142, 234, 950; 1402C
TÜV: EN 60950
CE: Low Voltage Directive (73/23/EEC, 93/68/EEC)

AC-DC Products

Front Ends 250, 500, 750 Watts

UL: 1244, (UL 544 with -LL), 1950
CSA: 0, 0.4, 234, 950; 1402C
TÜV: EN 60950
VDE: VDE 0805, IEC 60950, EN 60950
BABT: EN 41003, EN 60950
CE: Low Voltage Directive (73/23/EEC, 93/68/EEC)

Three Phase Front Ends

UL: 1012, 1950
CSA: 0, 0.4, 234, 950
TÜV: EN 60950
BABT: EN 41003, EN 60950
CE: Low Voltage Directive (73/23/EEC, 93/68/EEC)

PFC Mini

UL: 1950
CSA: 0, 0.4, 950
TÜV: EN 60950
VDE: VDE 0805, IEC 60950, EN 60950
CE: Low Voltage Directive (73/23/EEC, 93/68/EEC)

FlatPAC

UL: 1950 (UL 544 with -LL), 1604
CSA: 0, 0.4, 234, 950; 1402C
TÜV: EN 60950
VDE: VDE 0805, IEC 60950, EN 60950
BABT: EN 41003, EN 60950
CE: Low Voltage Directive (73/23/EEC, 93/68/EEC)

VI-AIM

UL: 544, 1950
CSA: 0, 0.4, 234, 950
TÜV: EN 60950
VDE: VDE 0805, IEC 60950, EN 60950
BABT: EN 41003, EN 60950
CE: Low Voltage Directive (73/23/EEC, 93/68/EEC)

AC-DC Products

VI-ARM	UL: 544, 1950 CSA: 0, 0.4, 234, 950 TÜV: EN 60950 VDE: VDE 0805, IEC 60950, EN 60950 BABT: EN 41003, EN 60950 CE: Low Voltage Directive (73/23/EEC, 93/68/EEC)
VI-HAM	UL: 544, 1950 CSA: 0, 0.4, 234, 950; 1402C TÜV: EN 60950 BABT: EN 41003, EN 60950 CE: Low Voltage Directive (73/23/EEC, 93/68/EEC)
Mini MegaPAC	UL: 1950 CSA: 0, 0.4, 950 TÜV: EN 60950 CE: Low Voltage Directive (73/23/EEC, 93/68/EEC)
Autoranging MegaPAC	UL: 1950 CSA: 0, 0.4, 950 TÜV: EN 60950 CE: Low Voltage Directive (73/23/EEC, 93/68/EEC)
PFC MegaPAC	UL: 1950 CSA: 0, 0.4, 950 TÜV: EN 60950 CE: Low Voltage Directive (73/23/EEC, 93/68/EEC)
3 Phase MegaPAC	UL: 1950 CSA: 0, 0.4, 950 TÜV: EN 60950 CE: Low Voltage Directive (73/23/EEC, 93/68/EEC)

Filters

VI-HAM (P/N 07818)	UL: 1283 CSA: C22.2 No. 8 TÜV: VDE 0565
VI-IAM	UL: 544, 1950 CSA: 0, 0.4, 234, 950 TÜV: EN 60950 VDE: VDE 0805, IEC 60950, EN 60950 BABT: EN 60950, EN 41003 CE: Low Voltage Directive (73/23/EEC, 93/68/EEC)

Agency Classifications

United States			
UL (Underwriters Laboratories, Inc.)	1950	3rd Edition	Safety of Information Technology Equipment
	544	2nd Edition	Medical and Dental Equipment
	1012	5th Edition	Power Supplies
	1244	1st Edition	Electric and Electronic Measuring Equipment
	478	5th Edition	Information Processing and Business Equipment (replaced by UL1950 3rd)
	1459	2nd Edition	Telephone Equipment (replaced by UL1950 3rd)
	2601-1/A2		Medical Electrical Equipment
Canada			
CSA (Canadian Standards Association)	0-M82		Canadian Electrical Code Part II
	0.4-M82		Bonding and Grounding of Electrical Equipment
	0.7-M82		Equipment Connected to a Telecommunication Network
	Bulletin 1402C		Power Supplies for Use with Information Processing and Business Equipment
	Bulletin 556B		Electronic Instruments and Scientific Apparatus
	142-M87		Process Control Equipment
	125-M84		Electromedical Equipment
	220-M86		Information Processing and Business Equipment
	234-M90		Safety of Component Power Supplies
	950-M95		Safety of Information Technology Equipment
Germany			
VDE (Verband Deutsche Elektrotechniker)	IEC 60950 VDE 0805 EN 60950		Safety of Information Technology Equipment
TÜV Product Service (Technischer Uberwachungs-Verein)	IEC 61010		Laboratory Equipment
	IEC 60601 VDE 0750 EN 60601		Medical Electrical Equipment

Agency Classifications

United Kingdom		
BSI (British Standards Institute)	IEC 60950/BS 7002 EN 60950, BS 6301	Safety of Information Technology Equipment
BABT (British Approvals Board for Telecommunications)	EN 41003/EN 60950	Connect to Telecom Networks
Bellcore	Network Equipment Building System (NEBS)	TR-EOP-000063 Issue 3 Flame Requirements
Australia		
Austel (Australian Telecom)	TS001/AS3260	Telecommunications and ITE

Product Weights

Overview

The following is a list of typical weights for Vicor products.

DC-DC Products

VI-200/MI-200 Family (Including SlimMod)	6.0 oz.	170 g
VI-J00/MI-J00 Family	3.0 oz.	85 g
BatMod	6.0 oz.	170 g
BusMod		
VI-2XX-XX-B1	12.6 oz.	357 g
MI-2XX-XX-B1	12.6 oz.	357 g
VI-JXX-XX-B1	6.4 oz.	181 g
MI-JXX-XX-B1	6.4 oz.	181 g
FinMod		
VI-2XX-XX-F1, MI-2XX-MX-F1	7.0 oz.	198 g
VI-2XX-XX-F2, MI-2XX-MX-F2	7.5 oz.	213 g
VI-JXX-XX-F1, MI-JXX-MX-F1	3.5 oz.	99 g
VI-JXX-XX-F2, MI-JXX-MX-F2	4.0 oz.	113 g
MI/VI-MegaModFamily		
L Family (1-up)	9.0 oz.	255 g
M and P Family (2-up)	1.2 lbs.	545 g
N, Q, R Family (3-up)	1.7 lbs	772 g
MI/VI-MegaMod Jr. Family		
L Family (1-up)	4.5 oz.	127 g
P Family (2-up)	8.8 oz.	250 g
R Family (3-up)	13.3 oz.	377 g

MI/VI-ComPAC	**STD**	**CC**	**HI**	**STD**	**CC**	**HI**
LC Family (1-up)	1.2 lbs.	1.4 lbs.	1.3 lbs.	545 g	636 g	590 g
MC Family (2-up	2.4 lbs.	2.8 lbs.	2.7 lbs.	1.248 kg	1.27 kg	1.23 kg
NC Family (3-up)	3.6 lbs.	4.2 lbs.	4.0 lbs.	1.633 kg	1.91 kg	1.82 kg

BusMod		
VI-2XX-XX-Bl	12.6 oz	357 g
MI-2XX-XX-Bl	12.6 oz	357 g
VI-JXX-XX-Bl	6.4 oz	181 g
MI-JXX-XX-Bl	6.4 oz	181 g

AC/DC Products

MI-/VI-AIM AC Input Module	3.0 oz.		85 g	
VI-ARM Autoranging Rectifier Module	2.1 oz.		60 g	
VI-HAM Harmonic Attenuator Module	6.0 oz.		170 g	
FlatPAC	**STD**	**CL**	**STD**	**CL**
LU Family (1-up)	1.4 lbs.	1.8 lbs.	652 g	817 g
PU, MU Family (2-up)	2.75 lbs.	3.5 lbs.	1.248 kg	1.59 kg
NU, QU, RU Family (3-up)	4.0 lbs.	5.1 lbs.	1.843 kg	2.32 kg
Offline Front-ends (Includes Industrial Grade)				
VI-FPE6-CUX (250 W PC Mount)	6.5 oz.		184 g	
VI-FKE6-CUX (250 W Chassis Mount)	12.0 oz.		340 g	
VI-FPE6-CQX (500 W PC Mount	13.8 oz.		391 g	
VI-FKE6-CQX (500 W Chassis Mount)	1.3 lbs.		610 g	
VI-FPE6-CMX (750 W PC Mount)	1.1 lbs.		496 g	
VI-FPE6-CMX (750 W Chassis Mount)	1.6 lbs.		737 g	
Three-Phase Front Ends				
VI-TKY6-CHX (1500 W)	1.9 lbs.		862 g	
VI-TKY6-CEX (3000 W)	3.3 lbs.		1.497 kg	
VI-TRY6-CCX (5000 W)	6.3 lbs.		2.857 kg	
ConverterPAC	0.7 lbs.		226 g	
MegaPAC (Fully Configured)	9.0 lbs.		4.114 kg	
Mini MegaPAC (Fully Configured)	6.25 lbs.		2.857 kg	
PFC MegaPAC (Fully Configured)	9.75 lbs.		4.43 kg	
PFC Mini	4.5 lbs.		2.025 kg	
Three Phase MegaPAC (Fully Configured)	17 lbs.		7.698 kg	

Filters

MI-/VI-IAM Input Attenuator Module	3.2 oz.	91 g
MI-/VI-RAM Ripple Attenuator Module	2.8 oz.	79 g
HAM Filter P/N 07818	13.6 oz.	85 g

Glossary of Technical Terms

Glossary

AC-OK SIGNAL. The signal used to indicate the loss of AC input voltage from the 115/230V line.

ALTITUDE TESTING. Generally performed to determine the proper functionality of equipment in airplanes and other flying objects. MIL-STD-810.

AMBIENT TEMPERATURE. The temperature of the environment, usually the still air in the immediate proximity of the power supply.

APPARENT POWER. A value of power for AC circuits that is calculated as the product of rms current times rms voltage, without taking power factor into account.

BANDWIDTH. A range of frequencies over which a certain phenomenon is to be considered.

BASEPLATE. All modular products have an aluminum mounting base at which Vicor specifies operating temperatures and which should be affixed to a thermally conductive surface for cooling.

BELLCORE SPECIFICATION. A telecommunications industry standard developed by Bellcore.

BIPOLAR TRANSISTOR. A transistor that operates by the action of minority carriers across a P/N junction; and is a current controlled device as opposed to a voltage controlled device.

BLEEDER RESISTOR. A resistor added to a circuit for the purpose of providing a small current drain, to assure discharge of capacitors.

BOBBIN. A device upon which the windings of a transformer or inductor are wound, it provides a form for the coil and insulates the windings from the core.

BOOSTER CONVERTER. A “slave” module in a driver/booster combination, connected to the driver module. Several boosters can be connected to a driver module.

BREAKDOWN VOLTAGE. A voltage level at which dielectric insulation fails by excessive leakage current or arcing. In reference to power supplies the breakdown voltage is the maximum AC or DC voltage that can be applied from input to output and/or chassis.

BRIDGE CONVERTER. A DC-DC converter topology (configuration) employing two or four active switching components in a bridge configuration across a power transformer.

BRIDGE RECTIFIER. A full wave rectifier circuit employing four rectifiers in a bridge configuration.

BRITISH TELECOM STANDARDS. A telecommunications industry standard developed by the British PTT authorities.

BROWNOUT. A reduction of the AC mains distribution voltage, usually caused deliberately by the utility company to reduce power consumption when demand exceeds generation or distribution capacity.

Glossary (cont)

BURN-IN. Operating a newly manufactured power supply, usually at rated load, for a period of time in order to force component infant mortality failures or other latent defects.

CAPACITIVE COUPLING. Coupling of a signal between two circuits, due to discrete or parasitic capacitance between the circuits.

CENTER TAP. An electrical connection made at the center of a transformer or inductor winding, usually so as to result in an equal number of turns on either side of the tap.

C-GRADE. Industry standard where the operating temperature of a device does not drop below –20 degrees Celsius.

CHASSIS MOUNT CONFIGURATION. A configuration where the modules or AC front ends are mounted directly to the chassis.

COMMON MODE NOISE. Noise present equally on two conductors with respect to some reference point; often used specifically to refer to noise present on both the hot and neutral AC lines with respect to ground.

COMPAC. A Vicor DC input power supply that provides EMC filtering and transient suppression for industrial, military and telecommunications markets.

CONSTANT CURRENT POWER SUPPLY. A power supply designed to regulate output current for changes in line, load, ambient temperature and drift resulting from time.

CONSTANT VOLTAGE POWER SUPPLY. A power supply designed to regulate output voltage for changes in line, load, ambient temperature and drift resulting from time.

CONTROL CIRCUIT. A circuit in a closed-loop system, typically containing an error amplifier, that controls the operation of the system to achieve regulation.

CONVERTER. An electrical circuit that accepts a DC input and generates a DC output of a different voltage usually achieved by high frequency switching action employing inductive and capacitive filter elements.

CREST FACTOR. In an AC circuit, the mathematical ratio of the peak to rms values of a waveform. Crest factor is sometimes used for describing the current stress in AC mains supply wires, since for a given amount of power transferred, the RMS value, and hence the losses, become greater with increasing peak values. Crest factor gives essentially the same information as power factor, and is being replaced by power factor in power supply technology.

CROSS REGULATION. The effect of a load change on one output to the regulation of another output. It usually only applies to non postregulated (quasi) outputs.

CROWBAR. An overvoltage protection method that shorts the power supply output to ground in order to protect the load when an overvoltage fault is detected.

Glossary (cont)

CSA. Canadian Standards Association. Defines the standards and safety requirements for power components.

CURRENT LIMITING. An overload protection circuit that limits the maximum output current of a power supply in order to protect the load and/or the power supply.

CURRENT MODE. A control method for switch-mode converters where the converter adjusts its regulating pulsewidth in response to measured output current and output voltage, using a dual loop control circuit.

CURRENT MONITOR. An analog power supply signal that is linearly proportional to output current flow.

DC-OK SIGNAL. Signal used to monitor the status of the DC output.

DERATING. A reduction in an operating specification to improve reliability. For power supplies it is usually a specified reduction in output power to facilitate operation at higher temperatures.

DESIGN LIFE. The expected lifetime of a power supply during which it will operate to its published specifications.

DIFFERENTIAL MODE NOISE. Noise that is measured between two lines with respect to a common reference point excluding common-mode noise. The resultant measurement is the difference of the noise components of the two lines. The noise between the DC output and DC return is usually measured in power supplies.

DISTRIBUTED POWER ARCHITECTURE. A central power source that is delivered to a local site, usually in the form of DC.

DRIFT. The change in an output voltage, after a warm-up period, as a function of time when all other variables such as line, load, and operating temperature are held constant.

DRIVER MODULE. The controlling module in a standalone or driver/booster configuration. The driver module contains all the control circuitry.

DROPOUT. The lower limit of the AC input voltage where the power supply just begins to experience insufficient input to maintain regulation. The dropout voltage for linears is largely line dependent, whereas for most switchers it is largely load dependent, and to a smaller degree line dependent.

DYNAMIC LOAD REGULATION. The delta in output voltage when the output load is rapidly changed.

EFFICIENCY. The ratio of total output power to input power expressed as a percentage. Normally specified at 75% full load and nominal input voltage.

Glossary (cont)

ELECTRONIC LOAD. An electronic device designed to provide a load to the outputs of a power supply, usually capable of dynamic loading, and frequently programmable or computer controlled.

EMC. Electromagnetic Compatibility, relating to compliance with electromagnetic emissions and susceptibility standards.

EMI. Electromagnetic Interference, which is the generation of unwanted noise during the operation of a power supply or other electrical or electronic equipment.

ESR. Equivalent Series Resistance. The value of resistance in series with an ideal capacitor that duplicates the performance characteristics of a real capacitor.

FAULT TOLERANT CONFIGURATION. A method of parallel operation, using output isolating diodes, in which the failure of a single supply (module) will not result in a loss of power. The total current of the parallel system must not exceed the load requirements to a point where the failure of a single unit will not result in a system overload.

FET. Field Effect Transistor, a majority carrier-voltage controlled transistor.

FINMOD. A flangeless/finned packaging option available on Vicor's VI / MI Family converters and accessory modules.

FLATPAC. A Vicor AC-DC switcher available with one, two or three outputs, with total power rating from 50 to 600W.

FLOATING OUTPUT. An output of a power supply that is not connected or referenced to any other output, usually denoting full galvanic isolation. Floating outputs can generally be used as either positive or negative outputs. Non floating outputs share a common return line and are hence DC referenced to one another.

FOLDBACK CURRENT LIMITING. A type of protection circuit where the output current decreases as the overload increases. The output current reaches a minimum as the load approaches a short circuit condition.

FORWARD CONVERTER. A switching power supply in which the energy is transferred from the input to the output during the "on" time of the primary switching device.

GATE IN. The Gate In pin of the module may be used to turn the module on or off. When Gate In is pulled low (<1 Volt @ 4 mA, referenced to $-V_{in}$), the module is turned off. When Gate In is floating (open collector) the module is turned on. The open circuit voltage of the Gate In pin is less than 10 Volts, referenced to $-V_{in}$. A Gate In/Gate Out connection is necessary to run driver/booster configurations.

GATE OUT. The Gate Out pin is the clock pulse of the converter. It is used to synchronize booster modules to a driver module for high power arrays.

GROUND. An electrical connection to earth or some other conductor that is connected to earth. Sometimes the term "ground" is used in place of "common," but such usage is not correct unless the connection is also connected to earth.

Glossary (cont)

GROUND LOOP. An unintentionally induced feedback loop caused by two or more circuits sharing a common electrical ground.

HAM (VI-HAM Harmonic Attenuator Module). The VI-HAM is a component level front end that accommodates universal input voltage (85-264), provides line rectification, filtering, transient protection, unity power factor, inrush limiting and a DC output compatible with the 300V input families of DC-DC converters.

HAVERSINE. A waveform that is sinusoidal in nature, but consists of a portion of a sine wave superimposed on another waveform. The input current waveform to a typical off-line power supply has the form of a haversine.

HEADROOM. Used in conjunction with series pass regulators, headroom is the difference between the input and output voltages.

HEATSINK. A medium of high thermal mass that can absorb (sink) heat indefinitely with negligible change in temperature. Heatsinks are not necessarily needed with Vicor modules, and their use is highly dependent on the individual application, power and ambient temperature.

HIGH LINE INPUT. The maximum steady-state input voltage on the input pin.

HIPOT. Abbreviation for high potential, and generally refers to the high voltages used to test dielectric withstand capability for regulatory agency electrical safety requirements.

HOLDUP CAPACITOR. A capacitor whose energy is used to provide output voltage for a period after the removal of input voltage.

HOLDUP TIME. The length of time a power supply can operate in regulation after failure of the AC input. Linears have very short holdup times due to the CV^2 energy storage product of their low voltage secondary side output capacitors. Switchers have longer times due to higher voltage primary side energy storage capacitors.

HOT SWAP. Insertion and extraction of a power supply into a system while power is applied.

IAM (VI-IAM Input Attenuator Module). A Vicor filter module used to provide EMC conducted noise filtering and transient protection.

I-GRADE. Industry standard where the operation temperature of a device does not drop below –40 degrees Celsius.

IMPEDANCE. The ratio of voltage to current at a specified frequency.

INDUCED NOISE. Noise generated in a circuit by varying a magnetic field produced by another circuit.

INPUT LINE FILTER. An internally or externally mounted lowpass or band-reject filter at the power supply input that reduces the noise fed into the power supply.

Glossary (cont)

INPUT LINE FILTER. An internally or externally mounted lowpass or band-reject filter at the power supply input that reduces the noise fed into the power supply.

INRUSH CURRENT. The peak current flowing into a power supply the instant AC power is applied. This peak may be much higher than the steady state input current due to the charging of the input filter capacitors.

INRUSH CURRENT LIMITING. A circuit that limits the amount of inrush current when a power supply is turned on.

ISOLATION. Two circuits that are completely electrically separated with respect to DC potentials, and almost always AC potentials. In power supplies, it is defined as the electrical separation of the input and output via the transformer.

ISOLATION VOLTAGE. The maximum AC or DC voltage that may be continuously applied from input to output and/or chassis of a power supply.

LEAKAGE CURRENT. A term relating to current flowing between the AC supply wires and earth ground. The term does not necessarily denote a fault condition. In power supplies, leakage current usually refers to the 60 Hz current that flows through the EMC filter capacitors connected between the AC lines and ground (Y caps).

LINEAR REGULATOR. A regulating technique where a dissipative active device such as a transistor is placed in series with a power supply output to regulate the output voltage.

LINE REGULATION. The change in output voltage when the AC input voltage is changed from minimum to maximum specified.

LINE VOLTAGE (Mains). The sine wave voltage provided to the power supply, usually expressed in volts rms.

LOAD REGULATION. The change in output voltage when the load on the output is changed.

LOCAL SENSING. Using the voltage output terminals of the power supply as sense points for voltage regulation.

LONG TERM STABILITY. Power supply output voltage change due to time with all other factors held constant. This is expressed in percent and is a function of component aging.

LOW LINE. The minimum steady state voltage that can be applied between the + and - input pins of a converter and still maintain output regulation.

MAINS. The utility AC power distribution wires.

MARGINING. Adjusting a power supply output voltage up or down from its nominal setting in order to verify system performance margin with respect to supply voltage. This is usually done electrically by a system-generated control signal.

Glossary (cont)

MEGA MODULES. A chassis mount packaging option that incorporates one, two or three VI/MI-200 Family converters for single, dual or triple outputs having a combined power of up to 600W.

M-GRADE. An industry standard where the operating temperature of a device does not drop below –55 degrees Celsius.

MIL-SPECS. Military standards that a device must meet to be used in military environments.

MINIMOD. A junior size (VI-J00) version of the VI/MI-200 Family of DC-DC converters offering up to half the power in a 2.28" x 2.4" x 0.5" package.

MINIMUM LOAD. The minimum load current/power that must be drawn from the power supply in order for the supply to meet its performance specifications. Less frequently, a minimum load is required to prevent the power supply from failing.

MODULE EVALUATION BOARD. A test fixture used to evaluate Vicor DC modules. AC and DC input versions are available.

MTBF (Mean Time Between Failure). MTBF is the point at which 63% of a given population no longer meet specification. It can either be calculated or demonstrated. The usual calculation is per MIL-STD-217 Rev. E. Demonstrated reliability is usually determined by temperature accelerated life testing and is usually greater than calculated MTBF.

NOMINAL INPUT. The center value for the input voltage range.

NOMINAL VALUE. A usual, average, normal, or expected operating condition. This stated value will probably not be equal to the value actually measured.

OFF LINE. A power supply that receives its input power from the AC line, without using a 50/60 Hz power transformer prior to rectification and filtering, hence the term “off line” power supply.

OPEN FRAME. A power supply where there is no external metal chassis; the power supply is provided to the end user essentially as a printed circuit board that provides mechanical support as well as supporting the components and making electrical connections.

OPERATING TEMPERATURE. The range of temperatures in which a unit can operate within specifications.

OPTOISOLATOR. An electro-optical device that transmits a signal across a DC isolation boundary.

OR’ING DIODES. Diodes used to isolate supplies from one another under a fault condition.

OUTPUT FILTERING. Filter used to reduce switching power supply noise and ripple.

Glossary (cont)

OUTPUT GOOD. A power supply status signal that indicates the output voltage is within a certain tolerance. An output that is either too high or too low will deactivate the Output Good signal.

OUTPUT IMPEDANCE. The ratio of change in output voltage to change in load current.

OUTPUT NOISE. The AC component that may be present on the DC output of a power supply. Switch-mode power supply output noise usually has two components: a lower frequency component at the switching frequency of the converter and a high frequency component due to fast edges of the converter switching transitions. Noise should always be measured directly at the output terminals with a scope probe having an extremely short grounding lead.

OUTPUT POWER RATING. The maximum power in watts that the power supply can provide and still maintain safety agency approvals.

OUTPUT VOLTAGE ACCURACY. See Setpoint Accuracy.

OVERLOAD PROTECTION. A power supply protection circuit that limits the output current under overload conditions.

OVERSHOOT. A transient output voltage change exceeding the high limit of the voltage accuracy specification caused by turning the power supply on or off, or abruptly changing line or load conditions.

OVERTEMP WARNING. A TTL compatible signal that indicates an overtemperature condition exists in the power supply.

OVERVOLTAGE PROTECTION (OVP). A circuit that either shuts down the power supply or crowbars the output in the event of an output overvoltage condition.

PARALLEL BOOST. VI/MI-200 Family booster modules may be added to a driver to create multi-kilowatt arrays. Boosters do not contain any feedback or control circuitry.

PARALLEL OPERATION. Connecting the outputs of two or more power supplies together for the purpose of obtaining a higher output current. This requires power supplies specially designed for load sharing.

PARD. Periodic And Random Deviation, referring to the sum of all ripple and noise components on the DC output of a power supply, regardless of nature or source.

PEAK POWER. The absolute maximum output power that a power supply can produce without immediate damage. Peak power capability is typically well beyond the continuous output power capability and the resulting average power should not exceed rated specifications.

PI FILTER. A commonly used filter at the input of a switching supply or DC-DC converter to reduce reflected ripple current. The filter usually consists of two shunt capacitors with inductance between them.

Glossary (cont)

POST REGULATOR. A secondary regulating circuit on an auxiliary output of a power supply that provides regulation on that output.

POWER FAIL. A power supply interface signal that gives a warning that the input voltage will no longer sustain full power regulated output.

POWER FACTOR. The ratio of true power to apparent power in an AC circuit. In power conversion technology, power factor is used in conjunction with describing AC input current to the power supply.

PRELOAD. A small amount of current drawn from a power supply to stabilize its operation.

PRIMARY. The input section of an isolated power supply, it is connected to the AC mains and hence has dangerous voltage levels present.

PRODUCT GRADE. The environmental and acceptance tests performed on Vicor products.

PULSE WIDTH MODULATION (PWM). A switching power conversion technique where the on-time (or width) of a duty cycle is modulated to control power transfer for regulating power supply outputs.

PUSH-PULL CONVERTER. A switch mode power supply topology that utilizes a center-tapped transformer and two power switches. The two switches are alternately driven on and off.

QUASI-REGULATED OUTPUT. The regulation of an auxiliary output that is accomplished by regulation of the main output. A transformer turns ratio, commensurate with the desired auxiliary output voltage, is used in conjunction with the output around which the main control loop is closed. Quasi-regulated outputs are significantly affected by second order effects in the converter.

RATED OUTPUT CURRENT. The maximum load current that a power supply can provide at a specified ambient temperature.

REFLECTED RIPPLE CURRENT. The rms or peak-to-peak AC current present at the input of the power supply that is a result of the switching frequency of the converter.

REGULATION. The ability of a power supply to maintain an output voltage within a specified tolerance as referenced to changing conditions of input voltage and/or load.

REGULATION BAND. The total error band allowable for an output voltage. This includes the effects of all of the types of regulation: line, load, temperature and time.

REGULATORY AGENCIES. CSA: Canadian Standards Association; FCC: Federal Communications Commission; FTZ: Fernmelde Technisches Zentralamt; TÜV: Technischer Überwachungs Verein; U.L.: Underwriters Laboratory; VDE: Verband Deutscher Electrotechniker.

Glossary (cont)

REMOTE INHIBIT. A power supply interface signal, usually TTL compatible, that commands the power supply to shut down one or all outputs.

REMOTE ON/OFF. Enables power supply to be remotely turned on or off. Turn-on is typically performed by open circuit or TTL logic “1”, and turn-off by switch closure or TTL logic “0”.

REMOTE SENSE. Wires connected in parallel with power supply output cables such that the power supply can sense the actual voltage at the load to compensate for voltage drops in the output cables and/or isolation devices.

RETURN. The designation of the common terminal for the power supply outputs. It carries the return current for the outputs.

REVERSE VOLTAGE PROTECTION. A protection circuit that prevents the power supply from being damaged in the event that a reverse voltage is applied at the input or output terminals.

RFI. An abbreviation for Radio Frequency Interference, undesirable noise produced by a power supply or other electrical or electronic device during its operation. In power supply technology, RFI is usually taken to mean the same thing as EMC.

RIPPLE AND NOISE. The amplitude of the AC component on the DC output of a power supply usually expressed in millivolts peak-to-peak or rms. For a linear power supply it is usually at the frequency of the AC mains. For a switching power supply, it is usually at the switching frequency of the converter stage.

SAFETY GROUND. A conductive path to earth that is designed to protect persons from electrical shock by shunting away any dangerous currents that might occur due to malfunction or accident.

SECONDARY. The output section of an isolated power supply, it is isolated from the AC mains and specially designed for safety of personnel who might be working with power on the system.

SELV. An acronym for Safety Extra Low Voltage, a term generally defined by the regulatory agencies as the highest voltage that can be contacted by a person and not cause injury. It is often specifically defined as 30Vac or 42.4Vdc.

SETPOINT ACCURACY. Ratio of actual to specified output voltage.

SEQUENCING. The technique of establishing a desired order of activating the outputs of a multiple output power supply.

SOFT START. A technique for gradually activating a power supply circuit when the power supply is first turned on. This technique is generally used to provide a gradual rise in output voltages and inrush current limiting.

Glossary (cont)

SOFT LINE. A condition where there is substantial impedance present in the AC mains feeding input power to a power supply. The input voltage to the power supply drops significantly with increasing load.

SPLIT BOBBIN WINDING. A transformer winding technique where the primary and secondary are wound side-by-side on a bobbin with an insulation barrier between them.

STANDBY CURRENT. The input current drawn by a power supply when shut down by a control input (remote inhibit) or under no load.

STIFF LINE. A condition where there is no significant impedance present in the AC mains feeding input power to a power supply. The input voltage to the power supply does not change appreciably with load.

SWITCHING FREQUENCY. The rate at which the DC voltage is switched on and off in a switching power supply.

TEMPERATURE COEFFICIENT. The average output voltage change expressed as a percent per degree Celsius of ambient temperature change. This is usually specified for a predetermined temperature range.

TEMPERATURE DERATING. Reducing the output power of a power supply with increasing temperature to maintain reliable operation.

THERMAL PAD. A graphite laminate used as a thermal interface between the converter and a heatsink or chassis.

THERMAL PROTECTION. A power supply protection circuit that shuts the power supply down in the event of unacceptably high internal temperatures.

TOPOLOGY. The design type of a converter, indicative of the configuration of switching transistors, utilization of the transformer, and type of filtering. Examples of topologies are the Flyback, Forward, Half Bridge, Full Bridge, Resonant and Zero-Current-Switching.

TRACKING. A characteristic in a multiple output power supply where any changes in the output voltage of one output caused by line, load, and/or temperature are proportional to similar changes in accompanying outputs.

TRANSIENT RECOVERY TIME. The time required for an output voltage to be within specified accuracy limits after a step change in line or load conditions.

TRUE POWER. In an AC circuit, true power is the actual power consumed. It is distinguished from apparent power by eliminating the reactive power component that may be present.

UNDERSHOOT. A transient output voltage change which does not meet the low limit of the voltage accuracy specification and is caused by turning the power supply on or off, or abruptly changing line or load conditions.

Glossary (cont)

UNIVERSAL INPUT. An AC input capable of operating from major AC lines worldwide, without straps or switches.

VOLTAGE BALANCE. The difference in magnitudes, in percent, of two output voltages that have equal nominal voltage magnitudes but opposite polarities.

VOLTAGE MODE. A method of closed loop control of a switching converter to correct for changes in the output voltage.

WARM-UP DRIFT. The initial change in the output voltage of a power supply in the time period between turn-on and when the power supply reaches thermal equilibrium at 25 degrees Celsius, full load and nominal line.

WARM-UP TIME. The time required after initial turn-on for a power supply to achieve compliance to its performance specifications.

X-CAPACITOR. A capacitor connected across the supply lines to suppress normal mode interference.

Y-CAPACITOR. Power conversion modules generally require bypass capacitors from line to chassis (earth ground) to shunt common mode noise currents and keep them local to the converter. In cases where the converters are operating from rectified AC line voltage, the failure of a bypass capacitor could result in excessive leakage current to the equipment chassis thus creating a ground fault and shock hazard. For this reason, a special classification of capacitor, referred to as a Y-capacitor, is recommended. These capacitors contain a dielectric with unique “self-healing” properties to help prevent against excessive leakage.

To meet general EMC requirements (see chapter 10 of the Vicor Applications Manual), Vicor recommends the use of Y-capacitors with all power conversion modules. Y-capacitors meet IEC384-14, EN132400, an UL 1283 standards.

ZERO-CURRENT-SWITCHING. The turn-on and turn-off of a switch at zero current, resulting in essentially lossless switching. The zero-current-switching topology allows Vicor converters to operate at frequencies in excess of 1 MHz, with efficiencies greater than 80% and power densities ten or more times greater than conventional topologies.

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