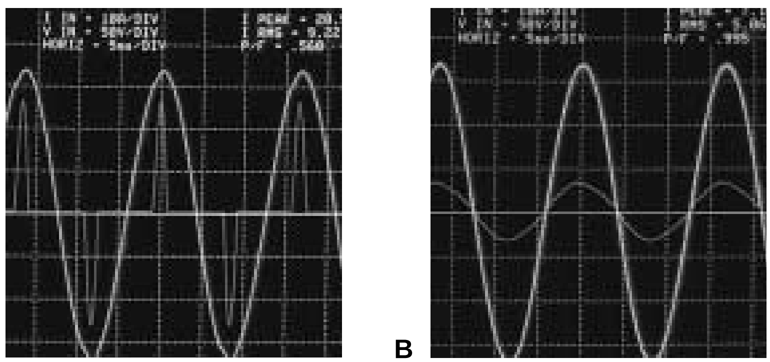
VI-HAM Harmonic Attenuator Module
(includes VI-HAM, VI-HAMD and VI-BAMD)

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.

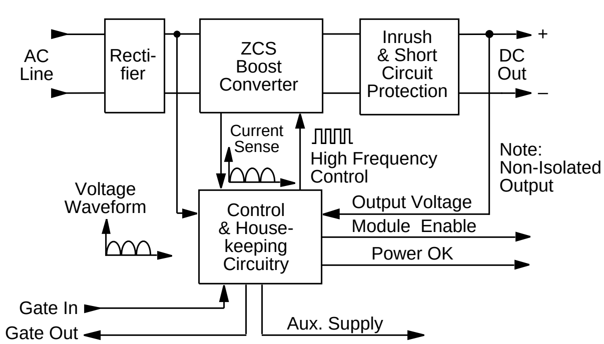
Figure 1. Oscilloscope Photos Showing Input Voltage and Current Without Power Factor Correction (A) and With Power Factor Correction (B).



A 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



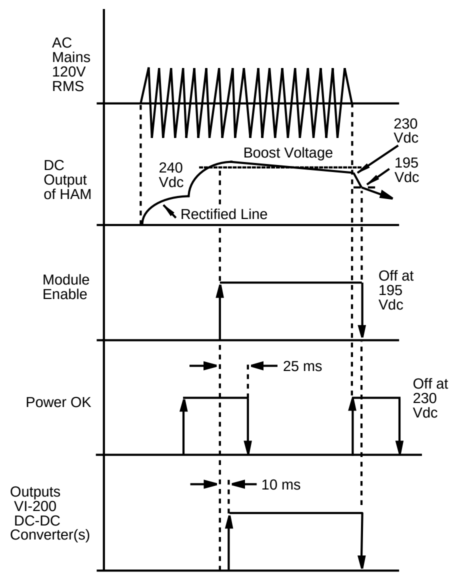
NOTE: No input to output isolation.

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 high. 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.

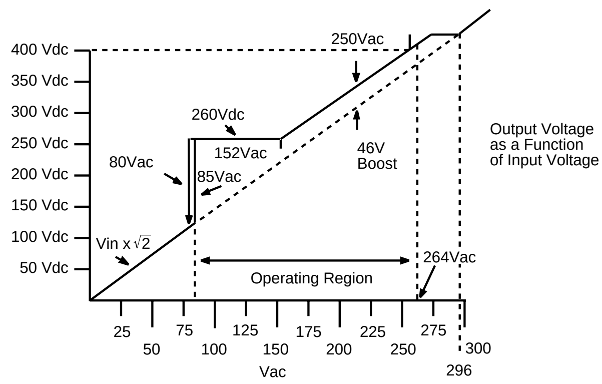
Figure 3. Functional Timing Diagram



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

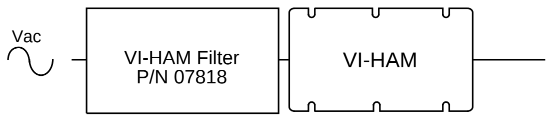


Vicor overcomes the "domestic disadvantage" by varying the output voltage of the VI-HAM as a function of incoming AC line voltage. On a nominal 120Vac line the output voltage of the VI-HAM is 260Vdc — well within the input operating voltage range of standard Vicor converters. As input line increases, 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.

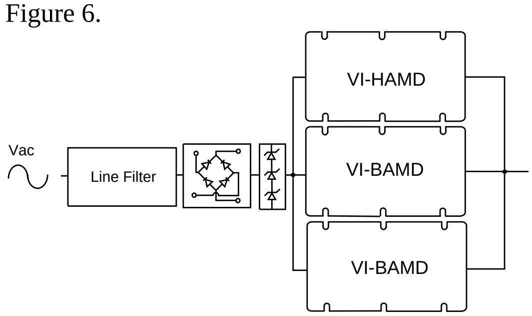
VI-HAMD-CM — Driver VI-HAM: No internal bridge rectifier or synchronization diodes.

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.

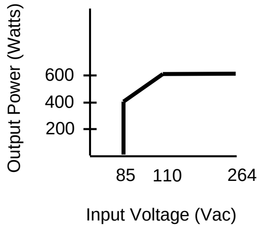
Figure 6. VI-HAMD with Booster VI-HAMs (VI-BAMDs) (No Internal Bridge Rectifier)



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.

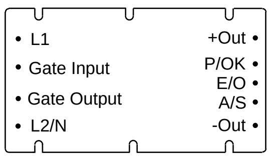
Derating Curves, Pinout — VI-HAM/VI-HAMD

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

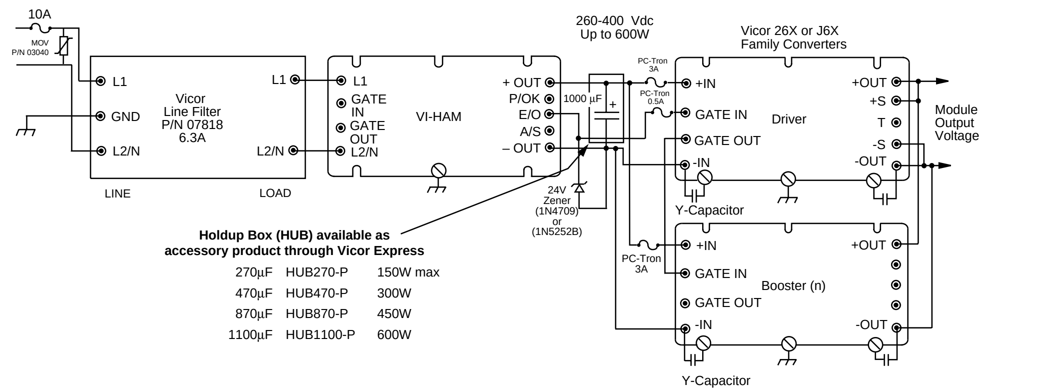


Figure 10.
Connection Diagram,
VI-HAM

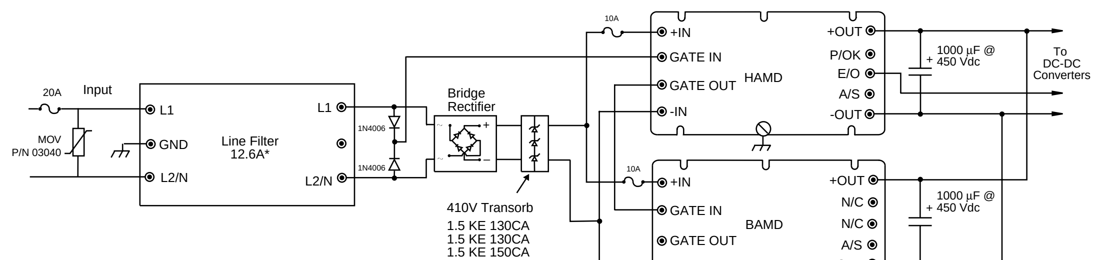


Figure 11.
Connection Diagram,
HAMD/BAMD

* Please consult Vicor's Application Engineering Department for specific VI-HAMD/VI-BAMD filtering information.

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.

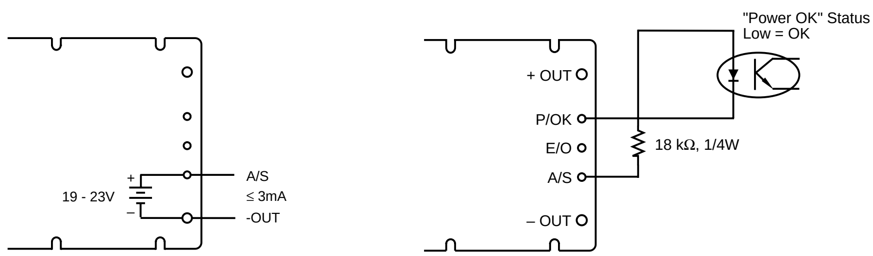


Figure 12.
Auxiliary Supply (A/S)

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.

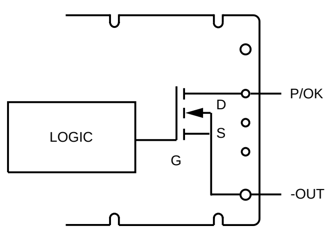


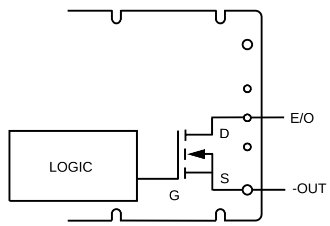
Figure 13.
Power OK (P/OK)

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

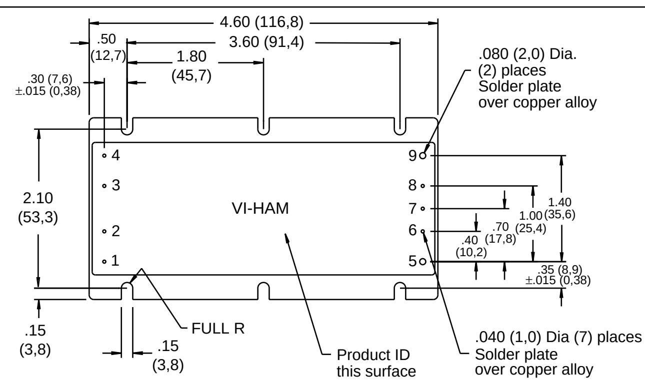
Over the full range of input voltages (85 to 264Vac), the output varies from 260 to 415Vdc. Therefore the DC-DC Converters modules used with the VI-HAM are from the VI-260 and VI-J60 families.

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

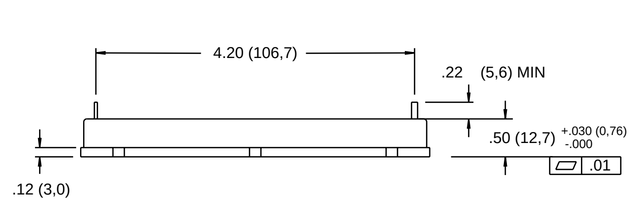
High Power modules available as boosters. Change VI-2**xx-xx to VI-**B**xx-xx.*

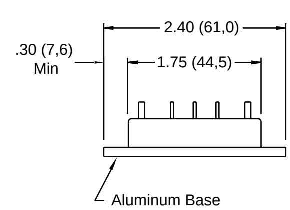
VI-J00 Family					
2V	**3.3V**	**Output**	**5V**	**10V**	**Output**
VI-J6Z-CW	VI-J6Y-CW	20A	VI-J60-CW	VI-J6M-CW	100W
VI-J6Z-CX	VI-J6Y-CX	15A	VI-J60-CX	VI-J6M-CX	75W
VI-J6Z-CY	VI-J6Y-CY	10A	VI-J60-CY	VI-J6M-CY	50W
			VI-J60-CZ	VI-J6M-CZ	25W
12V	**15V**	**24V**	**28V**	**48V**	**Output**
VI-J61-CW	VI-J62-CW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

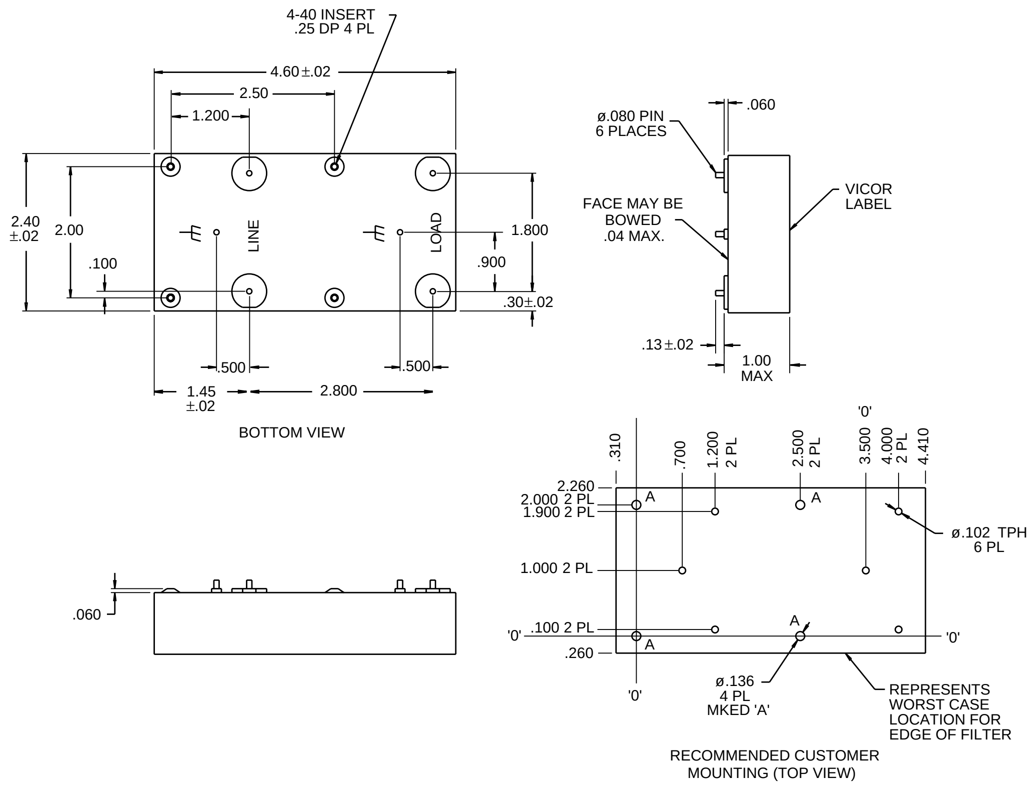
- Although the efficiency of the VI-HAM is quite high, it still dissipates significantly more power than a VI-200 DC-DC converter. Care should be taken to cool it. Do not rely on the internal overtemperature shutdown to take the place of adequate planning relative to the cooling of the VI-HAM. Thermal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