

**THE HARMONIC ATTENUATOR MODULE  
COMPATIBLE WITH VI-26x AND VI-J6x FAMILIES**

The Harmonic Attenuation Module (HAM) consists of a full-wave rectifier, a high-frequency zero-current-switching (ZCS) boost converter, active inrush current limiting, short-circuit protection, control, and housekeeping circuitry (Figure 13–1). The incoming AC line is rectified and fed to the boost converter. The control circuitry varies the operating frequency of the boost converter to regulate and maintain the output voltage of the HAM above the peak of the incoming line, while forcing the input current to follow the waveshape and phase of the line voltage. A power factor better than 0.99 is achieved (Figure 13–2). Operating efficiency of the boost converter is optimized at any incoming line voltage by an adaptive output voltage control scheme.

The output voltage of the HAM varies as a function of incoming AC line voltage (Figure 13-3). On a nominal 120 Vac line the output voltage of the HAM is 260 Vdc — well within the input operating voltage range of Vicor VI-26x and VI-J6x converters. As input line increases, so does the HAM output voltage; at 220 Vac the delivered voltage will be about 350 V. For any given input line voltage, the 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.

The HAMD version does not contain an internal bridge rectifier and is intended for configuring higher power arrays with Booster versions, referred to as the VI-BAMD (Figure 13–5).

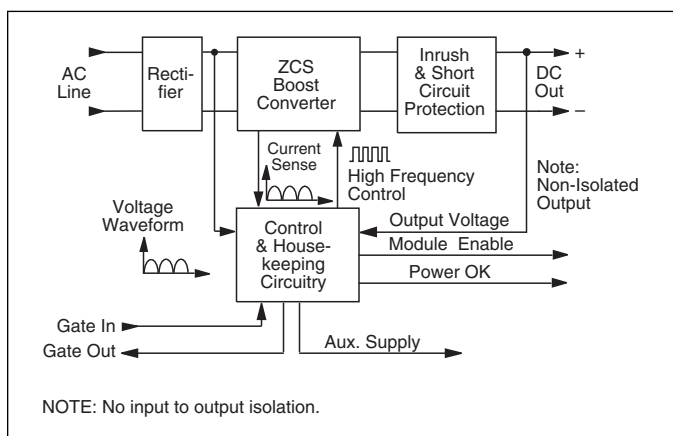


Figure 13–1 — HAM block diagram (HAMD version has the rectifier block deleted.)

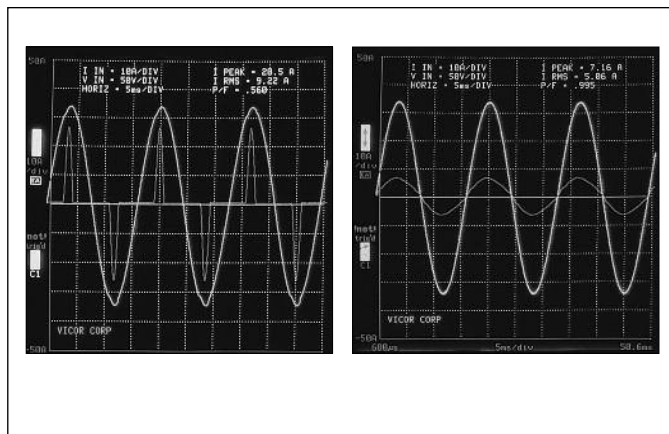


Figure 13–2 — Input voltage and current wave forms, without and with power factor correction.

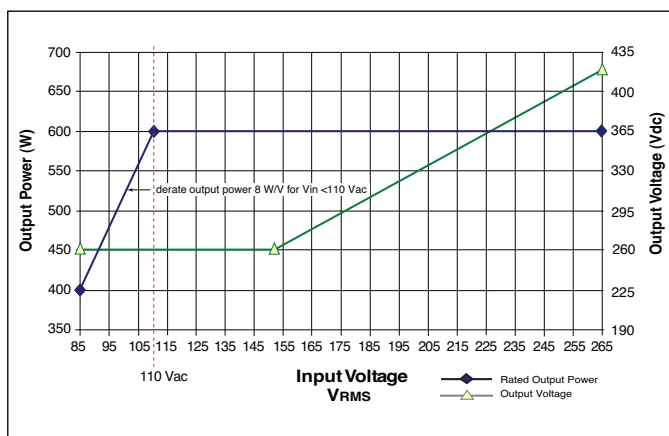


Figure 13–3 — Output voltage and power rating vs. input voltage

**L1 and L2/IN (HAM) Pin.** An appropriate line filter is required to limit conducted emissions and ensure reliable operation of the HAM, see page 40. Connect single phase AC mains to the input of the line filter via a 10 A, 250 V fuse. Connect the output of the filter to L1 and L2/IN of the HAM. Do not put an X-capacitor across the input of the HAM or use a line filter with an X-capacitor on its output as power factor correction may be impacted.

**+IN, -IN (HAMD, BAMD) Pin.** These pins are connected to the output of the external bridge rectifier in HAMD / BAMD configurations (Figure 13–5).

**GATE IN (HAM) Pin.** The user should not make any connection to this pin.

**GATE IN (HAMD) Pin.** This pin provides line voltage envelope and phase information for power factor correction. This connection must be made through the synchronization diodes between the line filter and bridge rectifier (Figure 13–5).

**GATE IN (BAMD) Pin.** The Gate In pin is an interface pin to the Gate Out pin of a HAMD or BAMD depending on configuration. The user should not make any other connection to this pin.

**GATE OUT Pin.** The Gate Out pin is a synchronization pin for HAMD/BAMD arrays; the user should not make any other connection to this pin.

**+OUT and -OUT Pin.** Connect the +OUT of the HAM to the +IN of the respective Vicor DC-DC converters with the recommended fuse. Connect the -OUT of the HAM to the -IN of the converters. In addition, an external hold-up capacitor of 1,000  $\mu\text{F}$  with a minimum voltage rating of 450 Vdc, is required (across the output of the HAM) for 16 ms ride through time at full power (500  $\mu\text{F}$  for half power, etc). This capacitor must be in close proximity to the HAM. Do not exceed 3,000  $\mu\text{F}$  of total output capacitance. Lower values of capacitance may be used for reduced hold up requirements, but not less than 500  $\mu\text{F}$ . Lower capacitance values may degrade power factor specifications.

**Auxiliary Supply (A/S) Pin.** The HAM provides a low voltage non isolated output Auxiliary Supply (A/S) that may be used to power primary side control and monitoring circuitry. This output is 19 – 23 Vdc, referenced to -OUT, at 3 mA max. Do not overload or short this output as the HAM will fail. A typical use for A/S is to power an optical coupler that isolates the Power OK signal (Figure 13–6).

**Enable Output (E/O) Pin.** The Enable Output (E/O) is used to inhibit the DC-DC converters at start up until the hold up capacitors are charged, at which time Enable is asserted high (open state, Figure 13–8). If the AC line fails, E/O goes low when the DC output of the HAM drops below 195 Vdc.

E/O must be connected to the Gate Input of all VI-26x and VI-J6x drivers (Figure 13–4); failure to do so may cause the converters to toggle on and off. It is not necessary to connect this pin to boosters as they are controlled by their respective driver. If an external load is connected directly to the output of the HAM, do not apply the load until the output hold up capacitor(s) are fully charged.

The E/O pin ancillary circuitry illustrated in Figures 13–4 and 13–5 provides transient immunity. The illustrated circuitry is the minimum required, see Figures 13–4 and 13–5.

**Power OK (P/OK) Pin.** Power OK is a monitor signal that indicates the status of the AC mains and the DC output voltage of the HAM. P/OK is asserted (active low) when the output bus voltage is within normal operating range 20 – 25 ms after DC-DC converters are enabled by the

E/O signal of the HAM. This provides sufficient time for the converters to turn on and their output(s) to stabilize prior to P/OK being asserted (Figure 13–9). For momentary interruptions of AC power, the HAM will provide at least 16 ms of ride through or hold up time (with 1,000  $\mu\text{F}$  output capacitor). On loss of power or brownout, (when the HAM output voltage drops below 230 Vdc) the P/OK signal will go to an open circuit state (see Figure 13–7), signaling an impending loss of input power to the converter modules. P/OK will provide power fail warning at least 1 ms prior to converter shut down. When the HAM output voltage drops below 195 Vdc the converters are disabled via Enable Output (E/O).

**NOTE: Acoustic Noise.** Audible noise may be emitted from the module under no load, light load, or dynamic loading conditions. This is considered normal operation of the module.

### SAFETY NOTES

Each HAM, HAMD or BAMD module must be preceded by a safety agency recognized fast-blow 10A 3AG fuse.

The HAM is not isolated from the line – either input or output; a line isolation transformer must be used when making scope measurements. HAMs do not provide input to output isolation. Differential probes should be used when probing the input and output simultaneously to avoid destructive ground loops.

### PROTECTIVE FEATURES

**Over Temperature Shut Down.** The HAM is designed to shut down when the temperature of the baseplate exceeds 90°C. Do not operate the HAM above its maximum operating temperature of 85°C.

**Short Circuit Protection.** The HAM contains output short circuit protection. Operation of this function does not clear the input fuse and the output will resume normal operation after removal of the fault. A short period of time may be required to allow for cooling of an internal temperature sensor.

**Output Over Voltage Protection.** The HAM contains output over voltage protection. In the event the output voltage exceeds approximately 420 Vdc, the boost will decrease to maintain 420 Vdc on the output. When the peak of the AC line exceeds 420 V (approximately 293 Vac) the boost will have been reduced to zero and the E/O line will be pulled low shutting down the converters. Beyond this the protection circuit will be enabled and the output voltage will decrease.

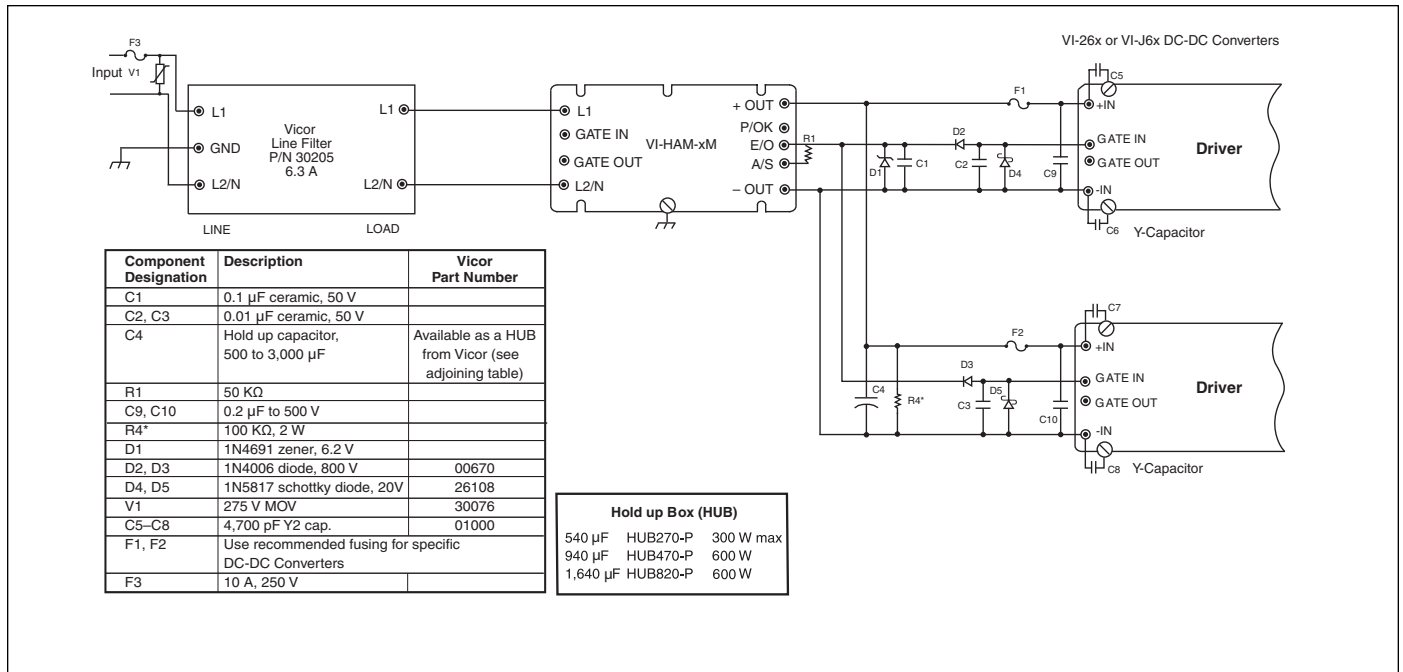


Figure 13-4 — Connection diagram HAM / DC-DC converter

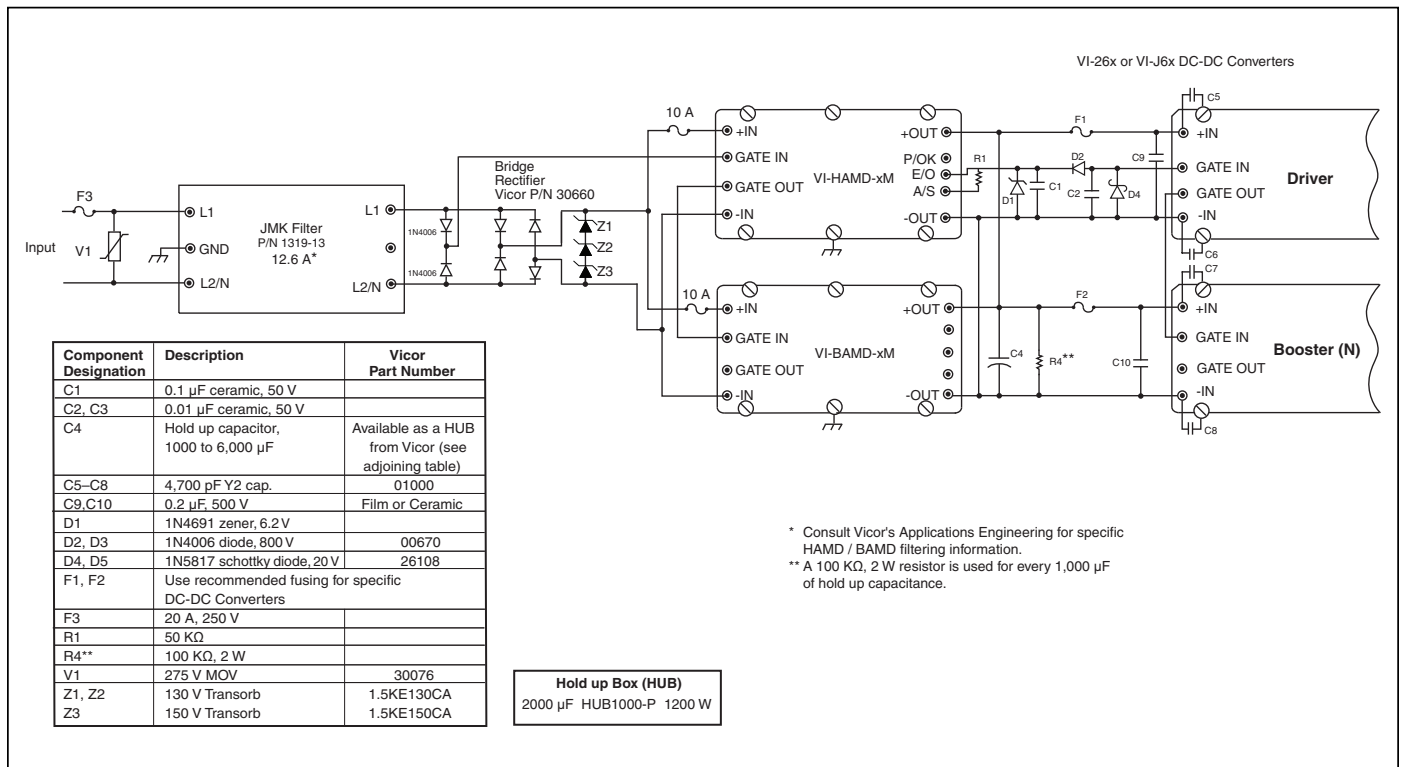


Figure 13-5 — Connection Diagram, HAMD / BAMD / VI-26x or VI-J6x DC-DC Converters

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

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

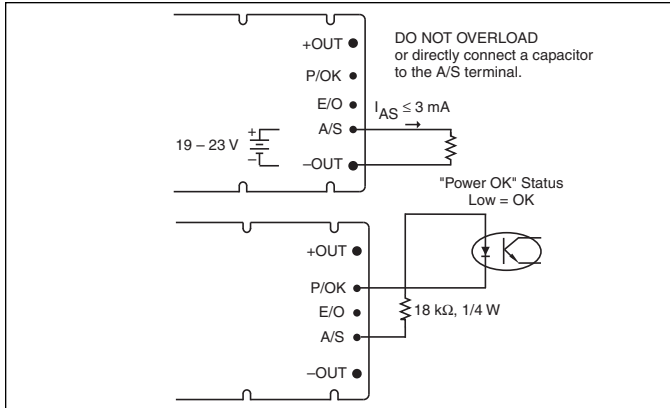


Figure 13-6 — Auxiliary Supply (A/S)

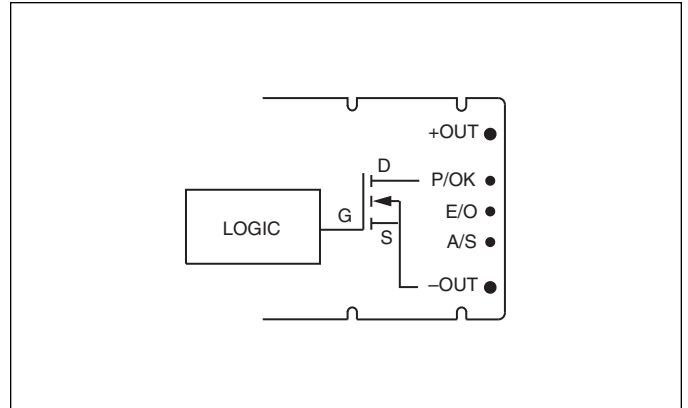


Figure 13-7 — Power OK (P/OK)

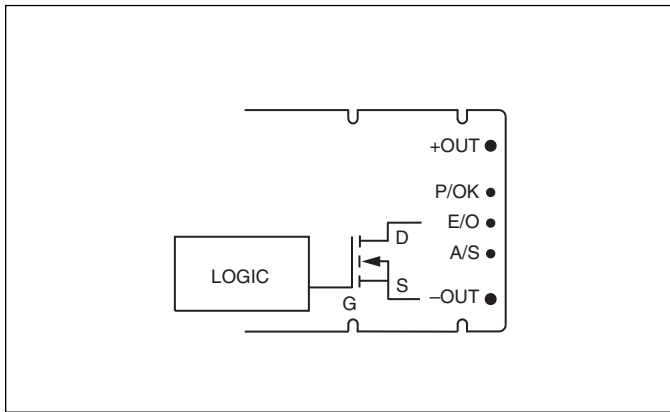


Figure 13-8 — Enable Output (E/O)

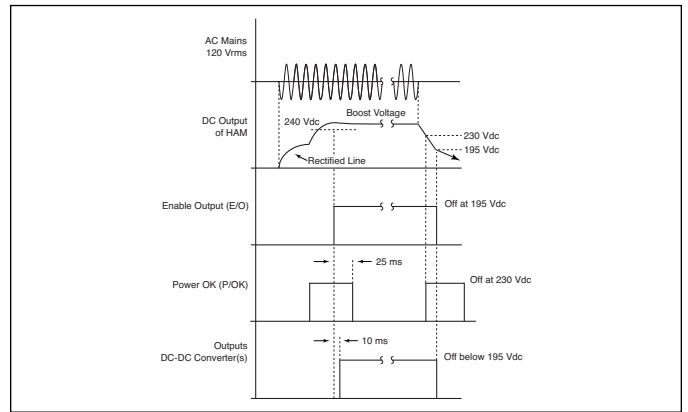


Figure 13-9 — Start-up / shut-down timing diagram

**LINE FILTER FOR HIGH BOOST HAM**

A line filter is required to provide attenuation of conducted emissions generated by the HAM module and to protect it from line transients. It also presents a well defined high frequency AC line impedance to the input of the HAM. To meet the listed specifications, Vicor’s P/N 30205 line filter/transient suppressor or equivalent must be used (Figure 13-10). The addition of a MOV external to this filter is required to meet normal mode transient surge requirements.

For applications using HAMD + BAMD or where the user desires to construct a custom HAM filter, the filter should be designed following Figure 13-10, the schematic of Vicor’s P/N 30205 filter. The current carrying capability of the inductors must be scaled proportionally to the number of HAM modules used. Inductance values must be selected according to Table 13-1. These limits are to ensure proper operation of the HAM and do not guarantee a system will meet conducted emissions specifications.

For applications requiring magnetic field shielding, do not place a ferrous EMI shield over the plastic cover of the HAM module. This can cause thermal problems due to induction heating effects.

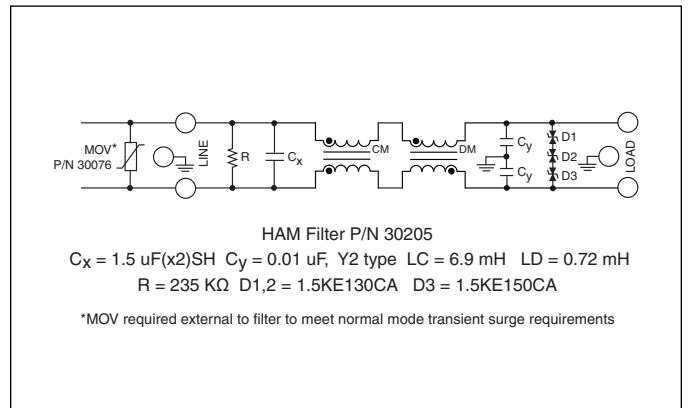


Figure 13-10 — Recommended HAM filter

Parameter	Min	Typ	Max	Unit
Differential Mode Inductance (LD)	0.2	0.35	0.75	mH
Common Mode Inductance (LC)	3	6		mH

Table 13-1 — HAM filter inductance range

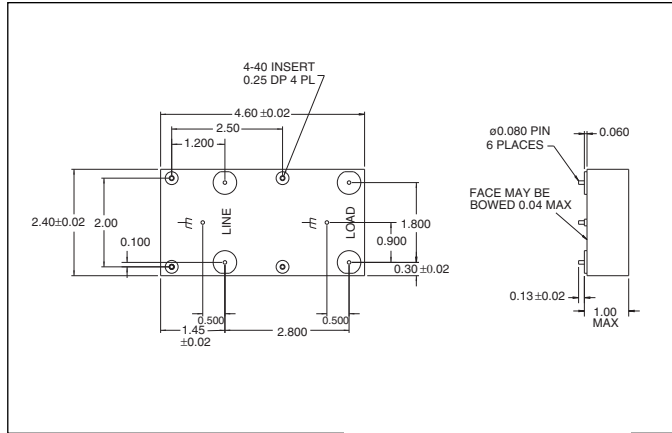


Figure 13-11 — HAM filter mechanical diagram

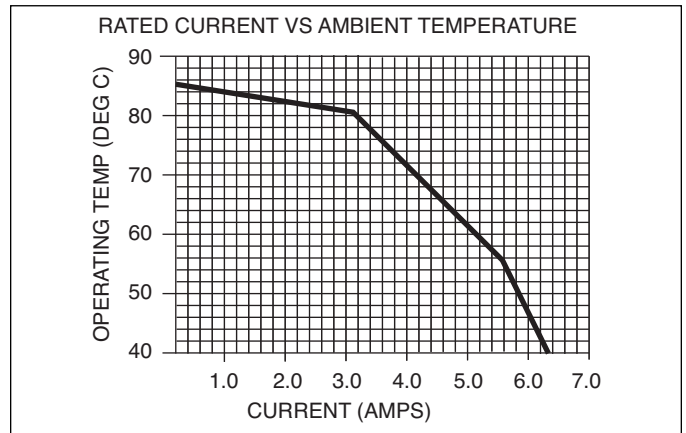


Figure 13-12 — HAM filter's current rating vs. temperature

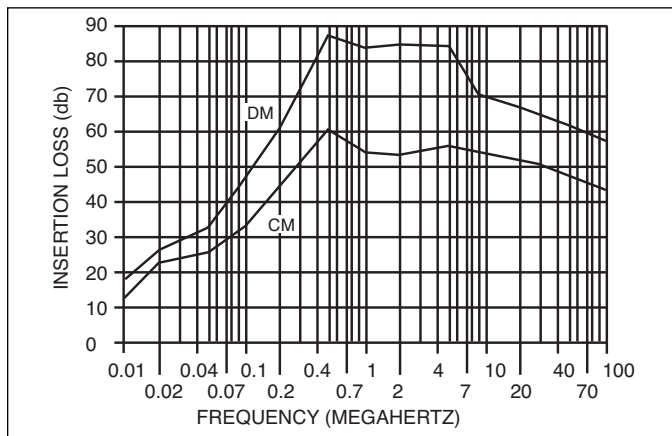


Figure 13-13 — HAM filter insertion loss vs. frequency

Parameter	Min	Typ	Max	Unit
Operating voltage	85		250	Vac
Operating temperature (See Fig.13-12)	-20		50	°C
Leakage current at 264 Vac, 63 Hz (Either line to earth)			1.2	mA
Operating current			6.3	A
Dielectric withstand (line – case)			1500	Vac
Residual voltage after 1 sec.			34	V
Operating frequency	50		60	Hz

Table 13-2 — HAM filter part #30205 specifications

### HAM DO'S AND DON'TS

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

- It is important that the output of the HAM not be loaded until the input voltage has exceeded 85 Vac and the output has begun to boost to 260 Vdc. This means that if the load on the HAM is a Vicor converter, the ENABLE Output of the HAM must be connected to the GATE IN of all Driver modules. The HAM will then disable the module output until the input exceeds 85 Vac and the output has been boosted to 260 Vdc. If an external load is connected directly to the output of the HAM, do not apply the load until the output of the HAM is stabilized in boost mode.
- Although the efficiency of the HAM is quite high, it still dissipates significantly more power than a VI-26x DC-DC converter. Care should be taken to cool it. Do not rely on the internal overtemperature shut down to take the place of adequate planning relative to the cooling of the HAM. Thermal compound should be used between the heat sink and baseplate of the HAM, HAMD and BAMD.
- Power factor is 0.997 at 120 Vac and 0.995 at 240 Vac. Harmonic content at 240 Vac is therefore somewhat higher than at 120 Vac. Remember that harmonic content measured cannot 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 HAM is 85 – 264 Vac; however it may not start boosting until the AC mains has exceeded 87 Vac. Once the HAM has started, it will operate down to 85 Vac. The HAM contains 2.5 – 6 V of input hysteresis, therefore if the AC line impedance is high, i.e., when using a variable autotransformer, the 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 HAM starts and the cycle repeats. Therefore avoid soft AC lines at or near low line.