



# Data Sheet

## FARM™



### Filter/Autoranging Rectifier Module

### Up to 1000 Watts

#### Features

- RoHS compliant (with F or G pin style)
- EMI filtering
- Choice of 500 W or 750 W modules
- 96% efficiency
- Autoranging 115/230 Vac input
- Microprocessor controlled
- Inrush current limiting
- Mini sized package
- Power fail signal
- Module enable

#### Product Highlights

The FARM (Filter/Autoranging Rectifier Module) is an AC front-end module which provides EMI filtering, autoranging line rectification and inrush current limiting. The FARM is available in either 500/750 W or 750/1000 W models in a mini sized package measuring only 2.28" x 2.2" x 0.5".

The FARM interfaces directly with worldwide AC mains and may be used with Vicor 300 V input DC-DC converters to realize an autoranging, high density, low profile switching power supply. The FARM includes a microcontroller that continuously monitors the AC line to control bridge / doubler operation. The user need only provide external capacitance to satisfy system hold-up requirements.

Vicor 2nd Generation packaging technology offers flexible mounting options for various manufacturing processes. The FARM may be installed as a conventional leaded device for onboard applications, inboard for low profile, height restricted applications, socketed or surface mounted with optional ModuMate interconnect products.

Shown actual size:  
2.28 x 2.2 x 0.5 in  
57,9 x 55,9 x 12,7 mm



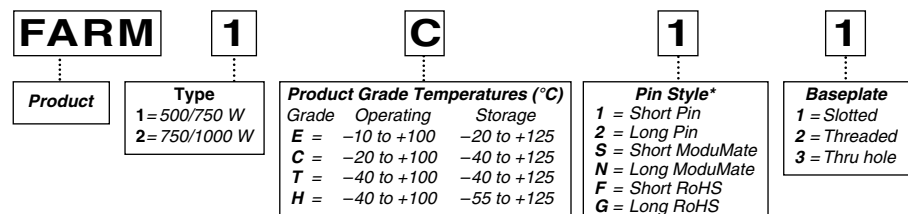
#### Absolute Maximum Rating

Parameter	Rating	Unit	Notes
L to N voltage	264	Vac	Continuous
	280	Vac	100 ms
+Out to -Out voltage	400	Vdc	
B OK to -Out voltage	16	Vdc	
EN to -Out voltage	16	Vdc	
Mounting torque	4 – 6(0.45 – 0.68)	in-lbs (N-m)	6 each, 4-40 screw
Operating temperature	-40 to 100	°C	H-Grade
Storage temperature	-55 to 125	°C	H-Grade
Pin soldering temperature	500 (260)	°F (°C)	<5 sec; wave solder
	750 (390)	°F (°C)	<7 sec; hand solder
Output current	3.5	A	
Baseplate temperature	100	°C	

#### Thermal Resistance and Capacity

Parameter	Min	Typ	Max	Unit
Baseplate to sink flat, greased surface		0.16		°C/Watt
		0.14		°C/Watt
Baseplate to ambient Free convection		8.0		°C/Watt
	1000 LFM	1.9		°C/Watt

#### Part Numbering



\*Pin styles S, N, F & G are compatible with the ModuMate interconnect system for socketing and surface mounting.

## ELECTRICAL CHARACTERISTICS

Electrical characteristics apply over the full operating range of input voltage, output power and baseplate temperature, unless otherwise specified. All temperatures refer to the operating temperature at the center of the baseplate. Specifications apply for AC mains having up to 5% total harmonic distortion.

### ■ INPUT SPECIFICATIONS (FARM1xxx, FARM2xxx)

Parameter	Min	Typ	Max	Unit	Notes
Operating input voltage					
low range	90		132	Vac	Autoranging (doubler mode)
high range	180		264	Vac	Autoranging (bridge mode)
Input undervoltage			90	Vac	No damage
AC line frequency	47		63	Hz	C-Grade
	47		880	Hz	T-Grade, H-Grade
Power factor	0.60		0.65		Dependent on line source impedance
Inrush current			30	Amps	264 Vac peak line

### ■ OUTPUT SPECIFICATIONS

Parameter	FARM1xxx			FARM2xxx			Unit	Notes
	Min	Typ	Max	Min	Typ	Max		
Output power	0		500	0		750	Watts	90 – 132 Vac
	0		750	0		1000	Watts	180 – 264 Vac
Efficiency	94	96		94	96		%	120/240 Vac
Output voltage	250		370	250		370	Vdc	90 – 264 Vac
External hold-up capacitance						1,750	μF	2 - 3,300 μF in series; HUB3300-S
			1,100				μF	2 - 2,200 μF in series; HUB2200-S

### ■ CONTROL PIN SPECIFICATIONS

Parameter	Min	Typ	Max	Unit	Notes
AC Bus OK (B OK)					
Low state resistance			15	Ω	To negative output – Bus normal
Low state voltage			0.1	Vdc	Bus normal 50 mA max.
High state voltage	14.0	15.0	15.4	Vdc	Bus abnormal, 27 K internal pull up to 15 Vdc (see Fig.11)
B OK true threshold	235	240	245	Vdc	Output Bus voltage (see Fig. 8)
B OK false threshold	200	205	210	Vdc	Output Bus voltage
Module Enable (EN)					
Low state resistance			15	Ω	To negative output – Converters disabled
Low state voltage			0.1	Vdc	50 mA max.
High state voltage	14.0	15.0	15.4	Vdc	150 K internal pull up to 15 Vdc (see Fig. 10)
Enable threshold	235	240	245	Vdc	Output bus voltage (see Fig. 8)
Disable threshold	185	190	195	Vdc	Output bus voltage
AC Bus OK - Module Enable, differential error*	15		17	20	Vdc AC Bus OK and Module Enable thresholds track

\* Tracking error between BUS OK and Enable thresholds

### ■ ELECTROMAGNETIC COMPATIBILITY

Parameter	Standard	Notes
Transient / surge immunity	EN61000-4-5	2 kV – 50 μs Line or neutral to earth 1 kV – 50 μs Line to neutral
Line disturbance / immunity	EN61000-4-11	Interruptions and brownouts
Flicker / inrush	EN61000-3-3	

## ELECTRICAL CHARACTERISTICS (CONT.)

### ■ SAFETY SPECIFICATIONS (FARM1xxx, FARM2xxx)

Parameter	Min	Typ	Max	Unit	Notes
Isolation voltage (in to out)		None			Isolation provided by DC-DC converter(s)
Dielectric withstand (I/O to baseplate)	2,121			Vdc	Baseplate earthed
Leakage current		1.5		mA	264 Vac

### ■ AGENCY APPROVALS

Safety Standards	Agency Markings	Notes
FARM1 xxx UL60950, EN60950, CSA 60950	cTÜVus CE Marked	Baseplate earthed, fast acting line fuse, Bussman ABC10 or Wickman 10 A 194 series Low voltage directive
FARM2 xxx UL60950, EN60950, CSA 60950	cTÜVus CE Marked	Baseplate earthed, fast acting line fuse, Bussman ABC15 or Wickman 16 A 194 Series Low voltage directive

### ■ GENERAL SPECIFICATIONS

Parameter	Min	Typ	Max	Unit	Notes
MTBF		>1,000,000		Hours	25°C, Ground Benign, Mil, HDBK, 2 17 F
Baseplate material					Aluminum
Cover					Ends: Zenite® 6130 Center section: Kapton insulated aluminum
Pin Material					
Style 1 & 2					Copper, Tin / Lead plated
Styles S & N (ModuMate compatible)					Copper, Nickel / Gold plated
Styles F & G (RoHS compliant)					Copper, Nickel / Gold plated
Weight		3.1 (88)		Ounces (grams)	
Size		2.28 x 2.2 x 0.5 (57,9 x 55,9 x 12,7)		Inches (mm)	

# OPERATING CHARACTERISTICS

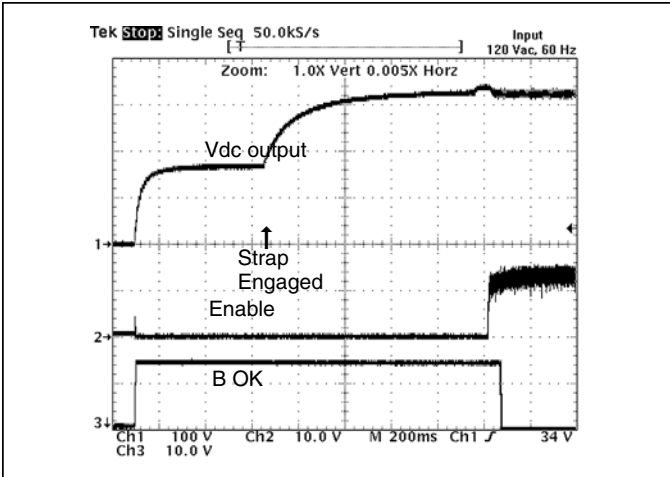


Figure 1 — Start up at 120 Vac input

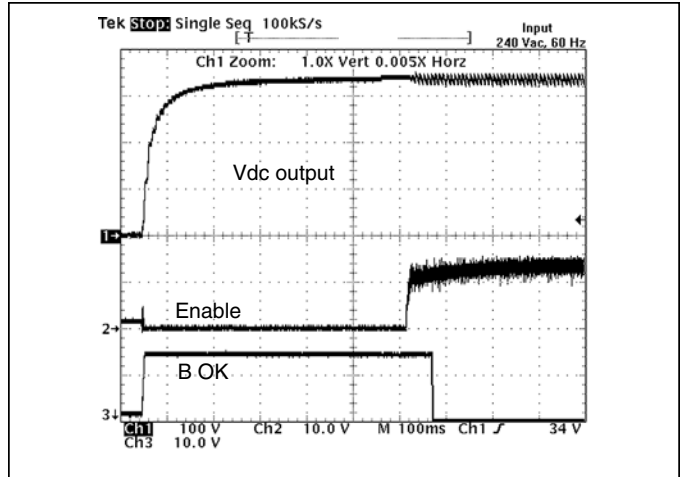


Figure 2 — Start up at 240 Vac input

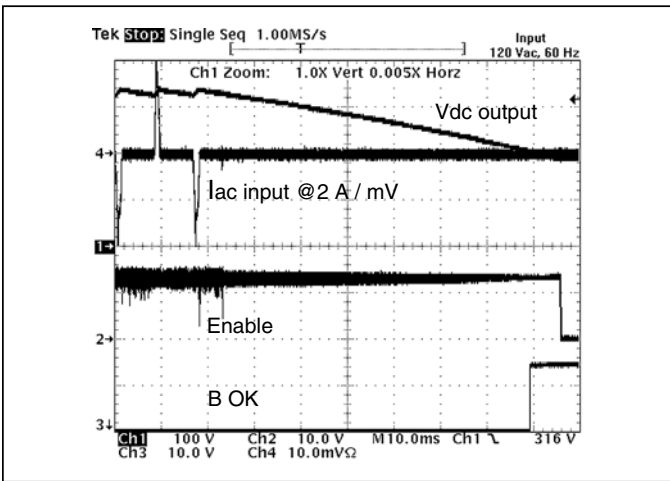


Figure 3 — Power down, from 120 Vac

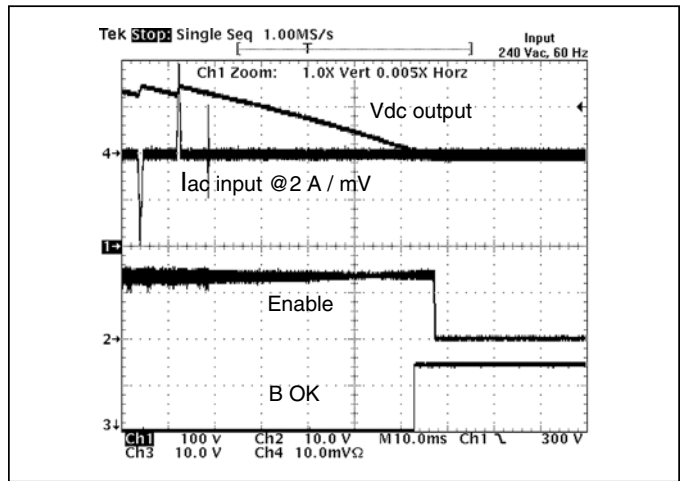


Figure 4 — Power down, from 240 Vac

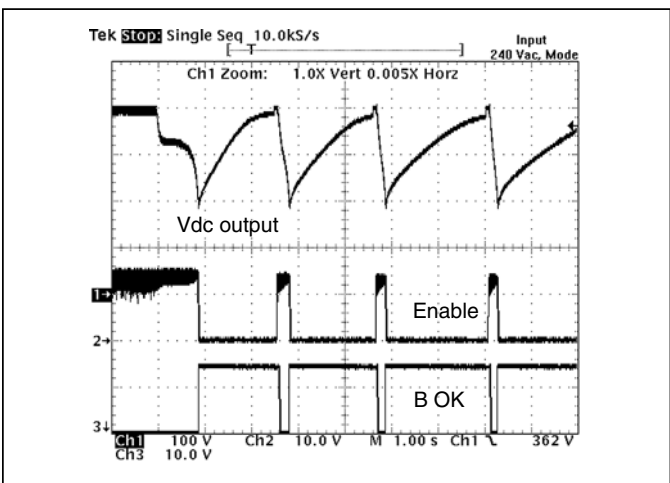


Figure 5 — Output overvoltage protection 240 Vac range

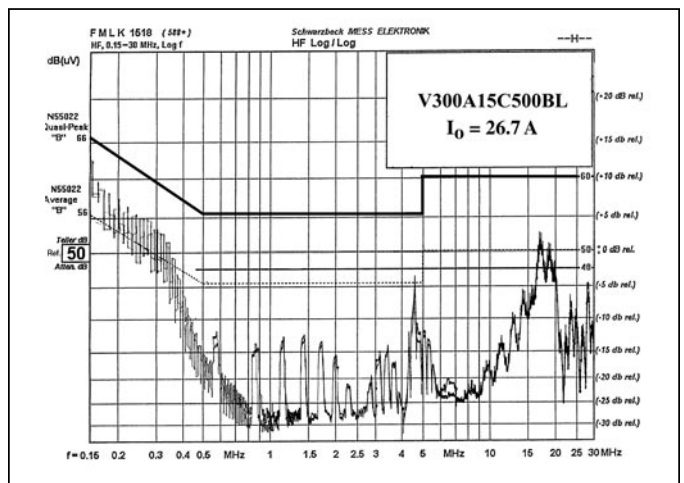


Figure 6 — Typical Conducted Emissions

## APPLICATION NOTE

The Filtered, Autoranging Rectifier Module (FARM) provides an effective solution for the AC frontend 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.

In addition to providing transient/surge immunity and EMI filtering, the FARM 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 only needs to add hold-up capacitors, and a few discrete components.

### Functional Description

#### Initial Condition

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 Fig. 7). In addition, the converter modules are disabled via the Enable (EN) line, and Bus-OK (BOK) is high.

#### Power Up Sequence. (see Fig. 8):

- 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 hold-up capacitor value and the thermistor cold resistance. The slope (dv/dt) of the capacitor voltage versus time approaches zero as the capacitors become charged to the peak of the AC line voltage.

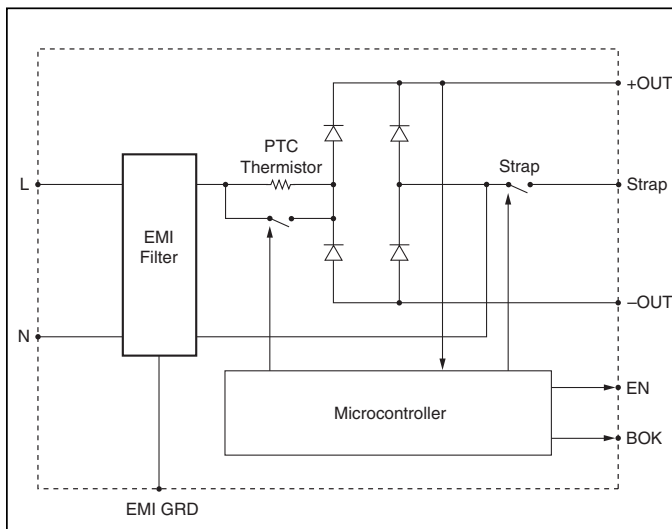


Figure 7 — Functional block diagram: autoranging rectifier

- 2.1** If the bus voltage is greater than 200 V, the doubler is not activated.
- 3.1** If the bus voltage is greater than 235 V as the slope approaches zero, the inrush limiting thermistor is bypassed. Below 235 V, it is not bypassed.
- 4.1** The converters are enabled ~150 milliseconds after the thermistor bypass switch is closed.
- 5.1** Bus-OK is asserted after an additional ~150 millisecond delay to allow the converter outputs to settle within specification.

**Power Down Sequence.** (see Fig. 8) When input power is turned off or fails, the following sequence occurs as the bus voltage decays:

- 1.2** Bus-OK is de-asserted when the bus voltage falls below 205 Vdc (Typical).
- 2.2** The converters are disabled when the bus voltage falls below 190 Vdc. 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 re-established before the bus reaches the disable threshold, the power up sequence is not repeated, i.e., the power conversion system “rides through” the momentary interruption.

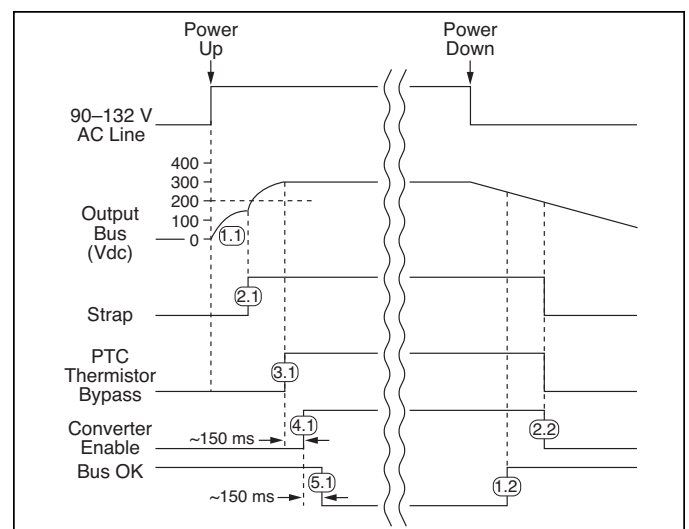


Figure 8 — Timing diagram: power up/down sequence

## APPLICATION NOTE (CONT.)

### OffLine Power Supply Configuration

The FARM maintains the DC output bus voltage between 250 and 370 Vdc over the entire input voltage range, which is compatible with Vicor 300 V input converters. The FARM automatically switches to the proper bridge or doubler mode depending on the input voltage, eliminating the possibility of damage due to improper line connection. The FARM1xxx is rated at 500 W in the low range (90-132 Vac input), and 750 W in the high range (180-264 Vac input). The FARM2xxx is rated for 750 W and 1000 W 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 center junction of the series hold-up capacitors (C1, C2, see Fig. 9) for proper (autoranging) operation. Metal oxide varistors, V1 and V2 provide capacitor protection. The bleeder resistors (R1, R2, see Fig. 9) discharge the hold-up capacitors when power is switched off. Capacitors C7 and C8 are recommended if the hold-up capacitors are located more than 3 inches (75 mm) from the FARM output pins.

**Enable (EN) Pin.** (see Fig. 10) The Enable pin must be connected to the PC or Gate-In 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 current limiting 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.

A signal diode should be placed close to and in series with the PC or (Gate-In) 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 varistors conduct. The thermistor bypass switch also opens if a fault or overload reduces the bus voltage to less than 180 Vdc.

**CAUTION:** There is no input to output isolation in the FARM, hence the -Out of the FARM and thus the -In of the downstream DC-DC converter(s) are at a high potential. If it is necessary to provide an external enable / disable function by controlling the DC-DC converter's PC pin (referenced to the -In) of the converter an opto-isolator or isolated relay should be employed.

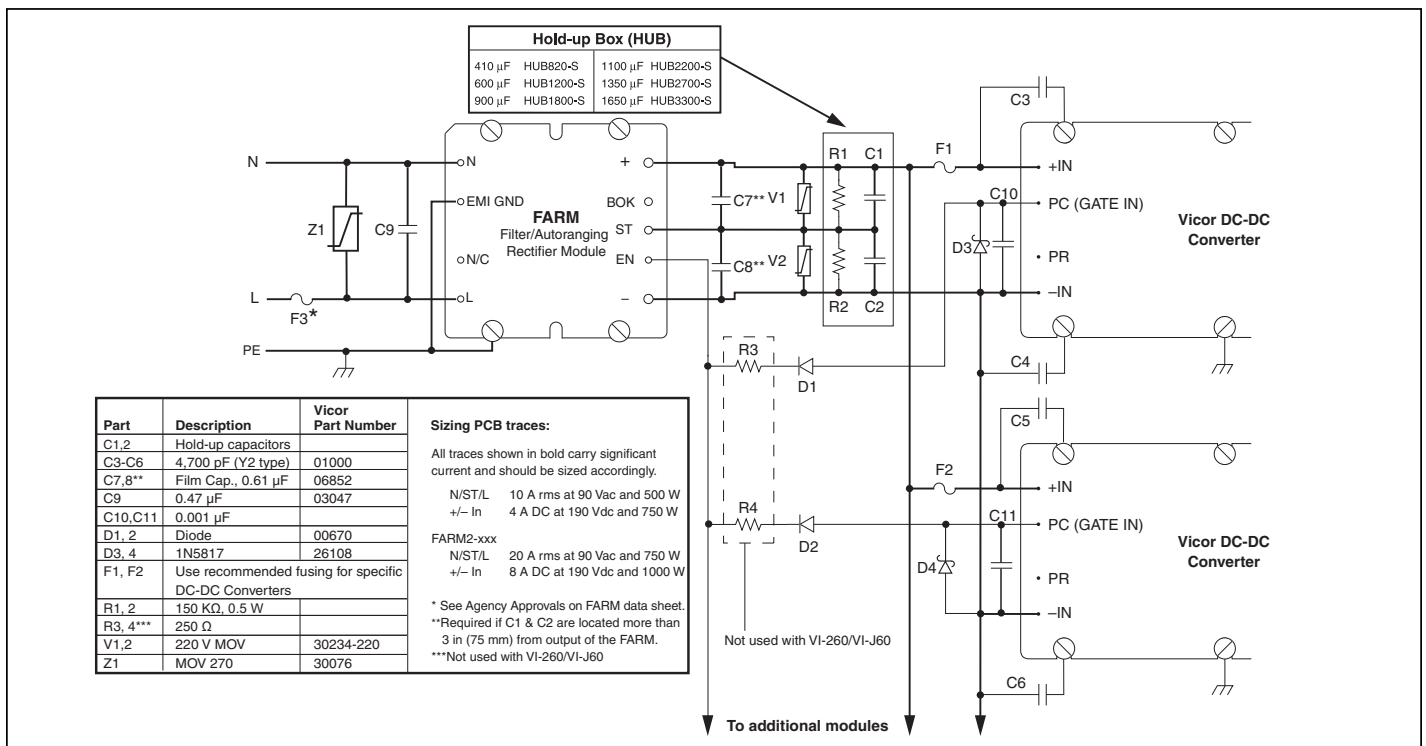


Figure 9 — Offline Power Supply Configuration

## APPLICATION NOTE (CONT.)

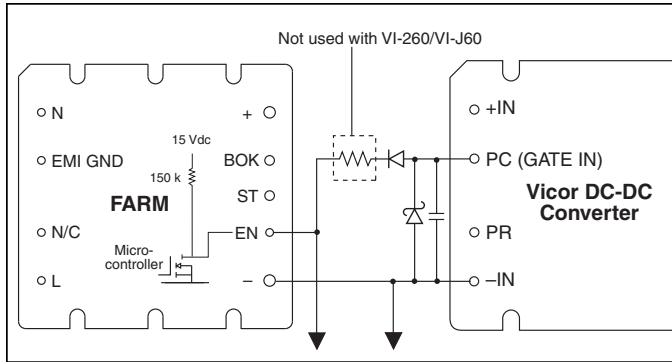


Figure 10 — Enable (EN) function

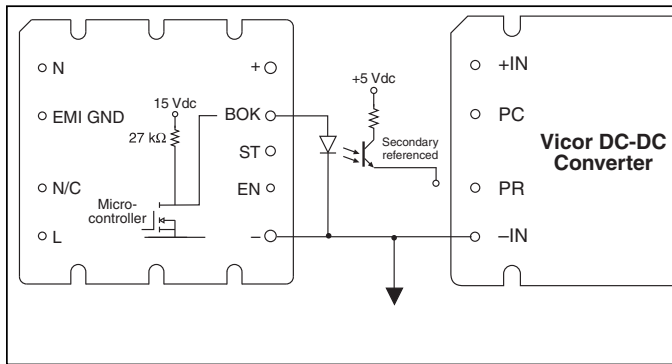


Figure 11 — Bus OK (BOK) isolated power status indicator

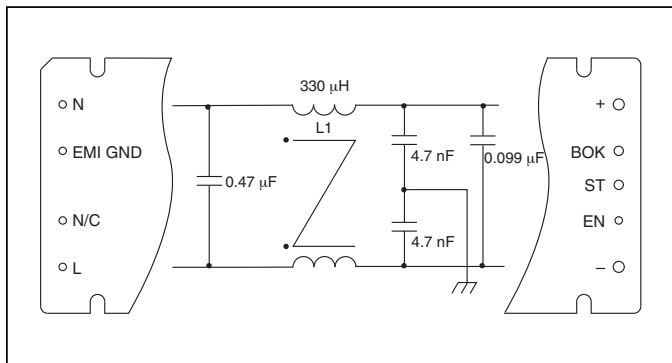


Figure 12 — Internal filter

**Bus-OK (BOK) Pin.** (see Fig. 11) 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 FARM. 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 transformer should be used when performing scope measurements. Scope probes should never be applied simultaneously to the input and output as this will damage the module.

**Filter.** (see Fig. 12) An integral input filter consists of a common mode choke and Y rated capacitors (line-ground) plus two X rated capacitors (line-line). This filter configuration provides common mode and differential mode insertion loss in the frequency range between 100 kHz and 30 MHz as illustrated in Figure 6.

**Hold-up Capacitors.** Hold-up capacitor values should be determined according to output bus voltage ripple, power fail hold-up time, and ride-through time (see Fig. 13). Many applications require the power supply to maintain output regulation during a momentary power failure of specified duration, i.e., the converters must hold-up 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 shut down.

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

$$\mathcal{E} = 1/2(CV^2) \quad (1)$$

Where:  $\mathcal{E}$  = 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:

$$\mathcal{E} = P\Delta t = C(V_1^2 - V_2^2) / 2 \quad (2)$$

Where:  $P$  = operating power  
 $\Delta t$  = discharge interval  
 $V_1$  = capacitor voltage at the beginning of  $\Delta t$   
 $V_2$  = capacitor voltage at the end of  $\Delta t$

Rearranging Equation 2 to solve for the required capacitance:

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

## APPLICATION NOTE (CONT.)

The power fail warning time ( $\Delta t$ ) is defined as the interval between B OK and converter shut down (EN) as illustrated in Fig. 13. The Bus-OK and Enable thresholds are 205 V and 190 V, respectively. A simplified relationship between power fail warning time, operating power, and bus capacitance is obtained by inserting these constants:

$$C = 2P\Delta t / (205^2 - 190^2)$$
$$C = 2P\Delta t / (5,925)$$

It should be noted that the series combination ( $C1$ ,  $C2$ , see Fig. 9) requires each capacitor to be twice the calculated value, but the required voltage rating of each capacitor is reduced to 200 V. 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.

For example, a converter whose output is 15 V and nominal input is 300 V will provide approximately 56 dB ripple rejection, i.e., 10 V p-p of input ripple will produce 15 mV p-p of output ripple (see Fig. 17). 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 (see Fig. 13) of the ripple, respectively. The capacitors must hold-up the bus voltage for the time interval ( $\Delta t$ ) between peaks of the rectified line as given by:

$$\Delta t = (\pi - \theta) / 2\pi f \quad (4)$$

Where:  $f$  = line frequency  
 $\theta$  = rectifier conduction angle

The approximate conduction angle is given by:

$$\theta = \text{Cos}^{-1}(V_2/V_1) \quad (5)$$

Another consideration in hold-up 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:

$$I_{\text{rms}} = 2P/V_{\text{ac}} \quad (6)$$

Where:  $P$  = total output power  
 $V_{\text{ac}}$  = operating line voltage

Calculated values of bus capacitance for various hold-up time, ride-through time, and ripple voltage requirements are given as a function of operating power level in Figures 14, 15, and 16, respectively.

## Example

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

### Determining Required Capacitance for Power Fail

**Warning.** Figure 14 is used to determine capacitance for a given power fail warning time and power level, and shows that the total bus capacitance must be at least 820  $\mu\text{F}$ . Since two capacitors are used in series, each capacitor must be at least 1,640  $\mu\text{F}$ . Note that warning time is not dependent on line voltage. A hold-up capacitor calculator is available on the Vicor website, at [vicorpower.com/hubcalc](http://vicorpower.com/hubcalc).

**Determining Ride-through Time.** Figure 15 illustrates ride-through time as a function of line voltage and output power, and shows that at a nominal line of 90 Vac, ride-through would be 68 ms. Ride-through time is a function of line voltage.

### Determining Ripple Voltage on the Hold-up Capacitors.

Figure 16 is used to determine ripple voltage as a function of operating power and bus capacitance, and shows that the ripple voltage across the hold-up capacitors will be 12 V p-p.

### Determining the Ripple on the Output of the DC-DC

**Converter.** Figure 17 is used to determine the approximate ripple rejection of the DC-DC converter and indicates a ripple rejection of approximately 60 dB for a 12 V output. Since the ripple on the bus voltage is 12 Vac 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.

*For more information about designing an autoranging AC input power supply using the FARM and Vicor DC-DC converter modules, contact Vicor Applications Engineering at the nearest Vicor Technical Support Center, or send email to [apps@vicorpower.com](mailto:apps@vicorpower.com).*

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# APPLICATION NOTE (CONT.)

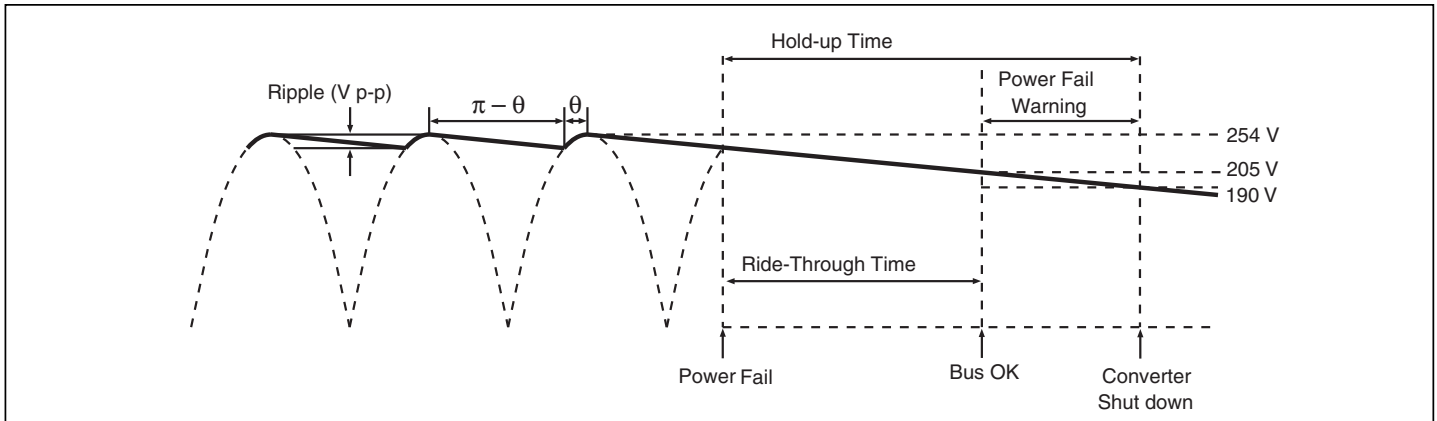


Figure 13 — Hold-up time

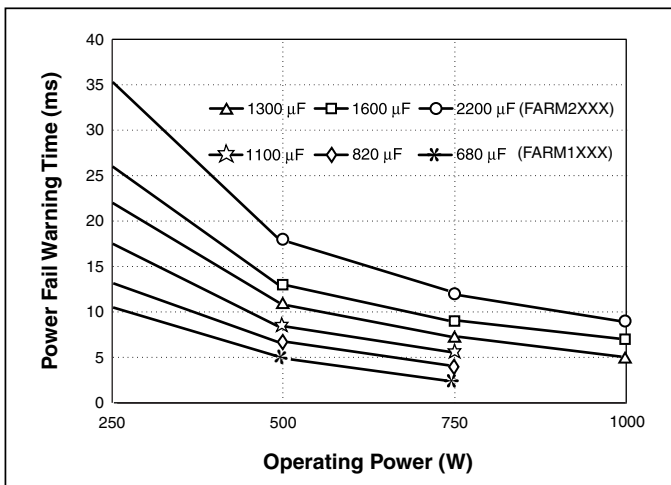


Figure 14 — Power fail warning time vs. operating power and total bus capacitance, series combination of C1, C2 (see Fig. 9)

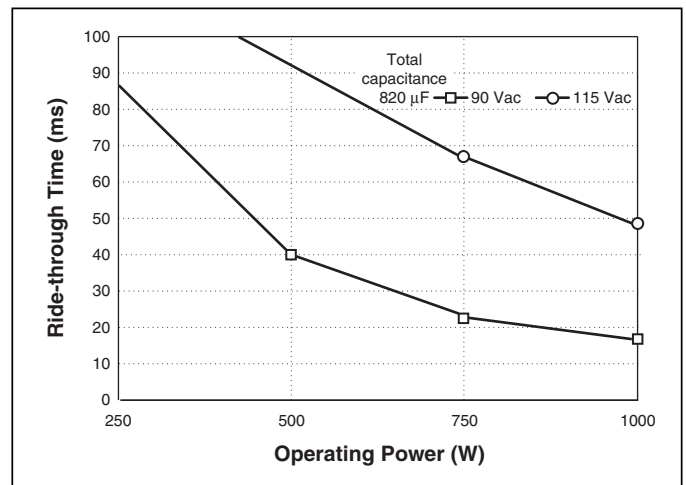


Figure 15 — Ride-through time vs. operating power

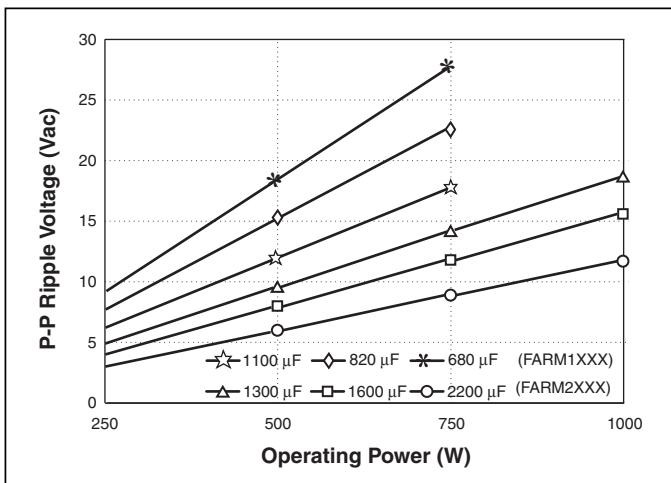


Figure 16 — Ripple voltage vs. operating power and bus capacitance, series combination of C1, C2 (see Fig. 9)

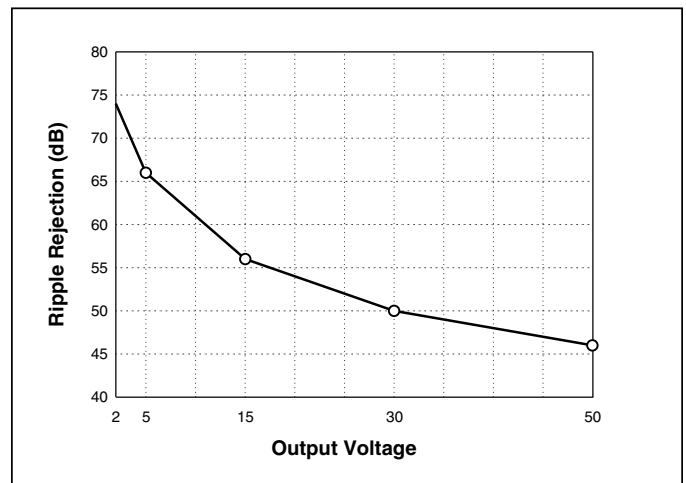
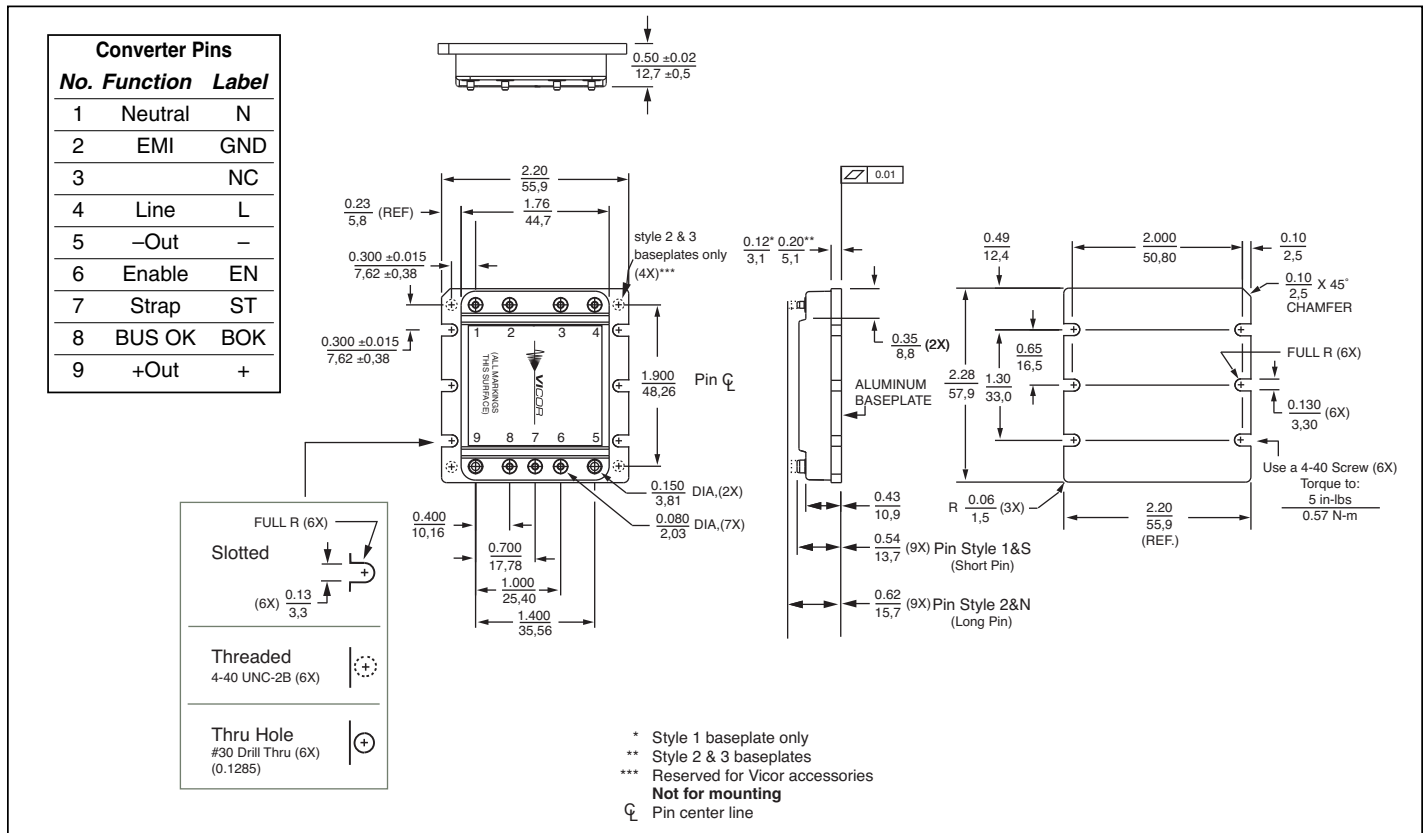
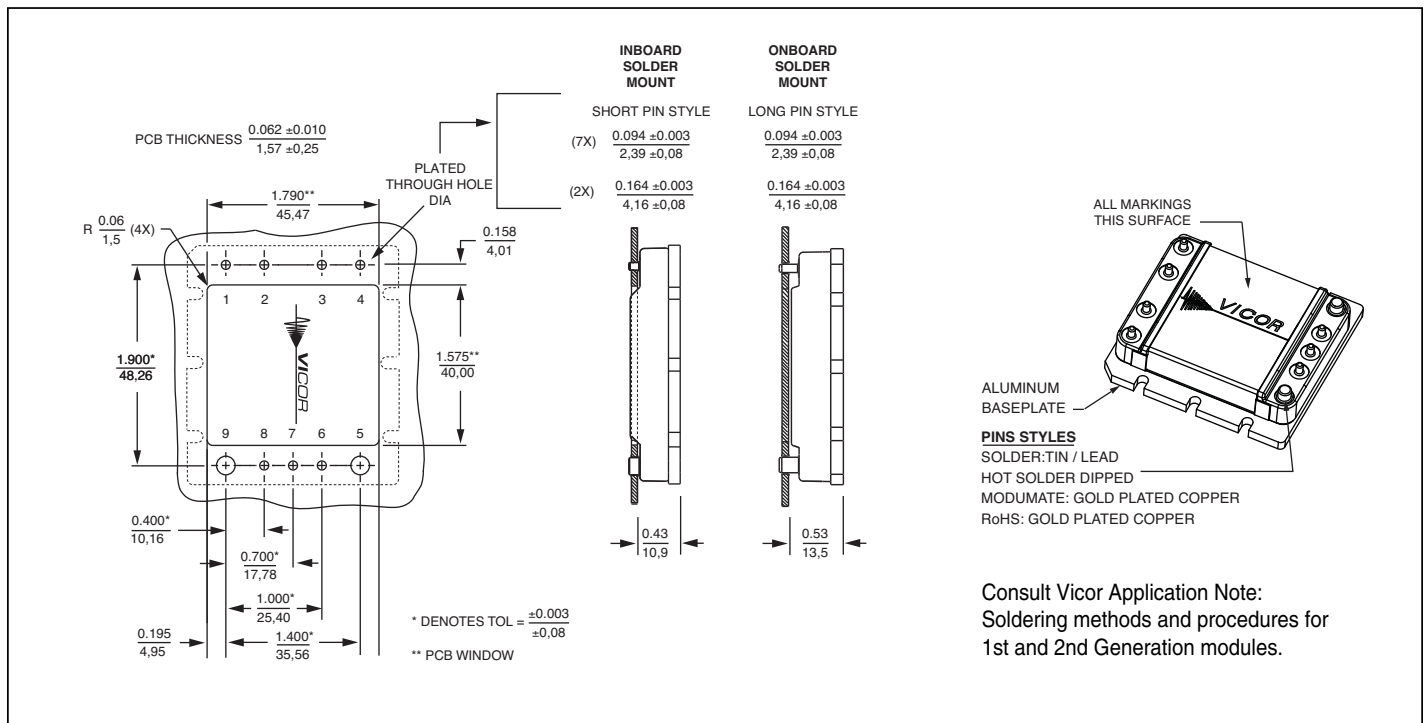


Figure 17 — Converter ripple rejection vs. output voltage (typical)

# Mechanical Diagram



# PCB Mounting Specifications



## Warranty

Vicor products are guaranteed for two years from date of shipment against defects in material or workmanship when in normal use and service. This warranty does not extend to products subjected to misuse, accident, or improper application or maintenance. Vicor shall not be liable for collateral or consequential damage. This warranty is extended to the original purchaser only.

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**Specifications are subject to change without notice.**

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