FARM™
FARMxxxx



Actual size:
2.28 x 2.2 x 0.5in
[57,9 x 55,9 x 12,7mm]

Filter/Autoranging Rectifier Module Up to 1000 Watts

Features & Benefits

- RoHS compliant (with F or G pin style)
- EMI filtering
- Choice of 500W or 750W modules
- 96% efficiency
- Autoranging 115/230V_{AC} 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 500/750W or 750/1000W models in a mini sized package measuring only 2.28 x 2.2 x 0.5in.

The FARM interfaces directly with worldwide AC mains and may be used with Vicor 300V 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.

Absolute Maximum Rating

Parameter	Rating	Unit	Notes
L to N voltage	264	V_{AC}	Continuous
	280	V_{AC}	100ms
+OUT to –OUT voltage	400	V_{DC}	
B OK to –OUT voltage	16	V_{DC}	
EN to –OUT voltage	16	V_{DC}	
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]	<5sec; wave solder
	750 [390]	°F [°C]	<7sec; 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
with thermal pad (P/N 20264)		0.14		°C/Watt
Baseplate to ambient				
Free convection		8.0		°C/Watt
1000LFM		1.9		°C/Watt

Part Numbering

FARM | **1** | **C** | **1** | **1**

Product

Type
1 = *500/750W*
2 = *750/1000W*

Product Grade Temperatures (°C)

Grade	Operating	Storage
E =	–10 to +100	–20 to +125
C =	–20 to +100	–40 to +125
T =	–40 to +100	–40 to +125
H =	–40 to +100	–55 to +125

Pin Style
1 = *Short Pin*
2 = *Long Pin*
S = *Short ModuMate* [a]
N = *Long ModuMate* [a]
F = *Short RoHS* [a]
G = *Long RoHS* [a]
K = *Extra Long RoHS* [b]

Baseplate
1 = *Slotted*
2 = *Threaded*
3 = *Thru hole*

[a] Pin styles S, N, F & G are compatible with the ModuMate interconnect system for socketing and surface mounting.
[b] Not intended for socket or Surfmate mounting.

Note: Product images may not highlight current product markings.

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	V_{AC}	Autoranging (doubler mode)
high range	180		264	V_{AC}	Autoranging (bridge mode)
Input undervoltage			90	V_{AC}	No damage
AC line frequency	47		63	Hz	C-Grade
	47		880	Hz	T-Grade, H-Grade
Power factor		0.60			Dependent on line source impedance, hold-up capacitance and load.
Inrush current			30	Amps	$264V_{AC}$ peak line

Output Specifications

	FARM1xxx			FARM2xxx				
Parameter	Min	Typ	Max	Min	Typ	Max	Unit	Notes
Output power	0		500	0		750	Watts	$90 – 132V_{AC}$
	0		750	0		1000	Watts	$180 – 264V_{AC}$
Efficiency	94	96		94	96		%	$120/240V_{AC}$
Output voltage	250		370	250		370	V_{DC}	$90 – 264V_{AC}$
External hold-up capacitance						1,750	µF	2 – 3,300µF in series; HUB3300-S
			1,100				µF	2 – 2,200µF 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	V_{DC}	Bus normal 50mA max.
High-state voltage	14.0	15.0	15.4	V_{DC}	Bus abnormal, 27kΩ internal pull up to $15V_{DC}$ (see Figure11)
B OK true threshold	235	240	245	V_{DC}	Output Bus voltage (see Figure 8)
B OK false threshold	200	205	210	V_{DC}	Output Bus voltage
Module Enable (EN)					
Low-state resistance			15	Ω	To negative output – Converters disabled
Low-state voltage			0.1	V_{DC}	50mA max.
High-state voltage	12	14	16	V_{DC}	150kΩ internal pull up to $15V_{DC}$ (see Figure 10)
Enable threshold	235	240	245	V_{DC}	Output bus voltage (see Figure 8)
Disable threshold	185	190	195	V_{DC}	Output bus voltage
AC Bus OK - Module Enable, differential error*	12	14	16	V_{DC}	AC Bus OK and Module Enable thresholds track

* Tracking error between Bus OK and Enable thresholds

Electrical Characteristics (Cont.)

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.

Electromagnetic Compatibility

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

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			V_{DC}	Baseplate earthed
Leakage current		1.5		mA	264 V_{AC}

Agency Approvals

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

General Specifications

Parameter	Min	Typ	Max	Unit	Notes
MTBF		>1,000,000		Hours	25˚C, Ground Benign, MIL-HDBK-217F
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

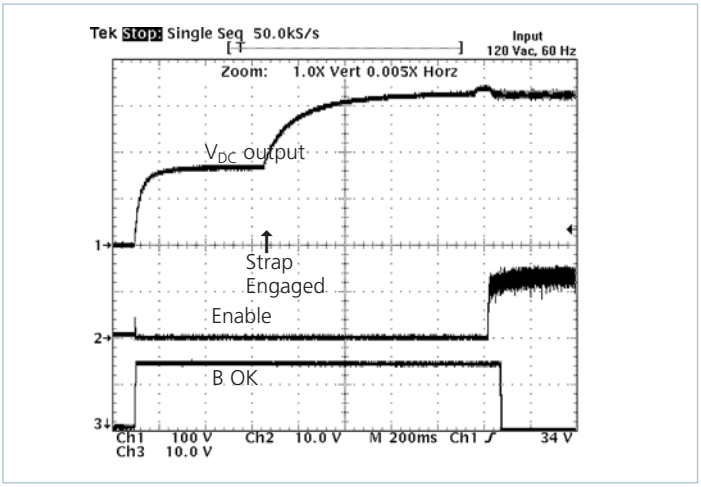


***Figure 1** — Start up at 120V_{AC} input*

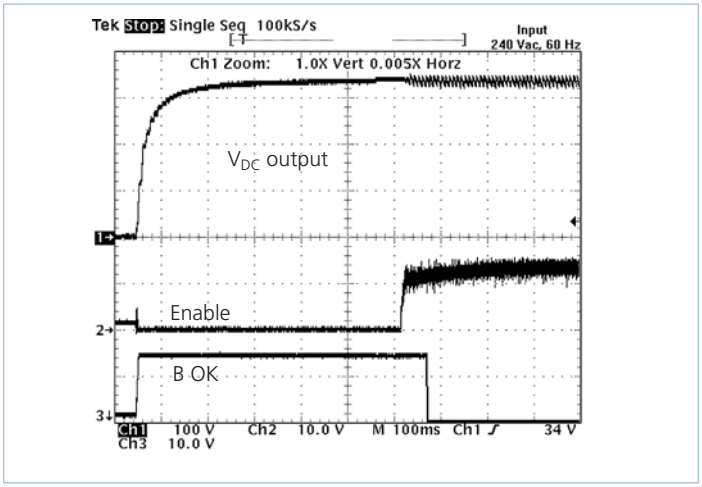


***Figure 2** — Start up at 240V_{AC} input*

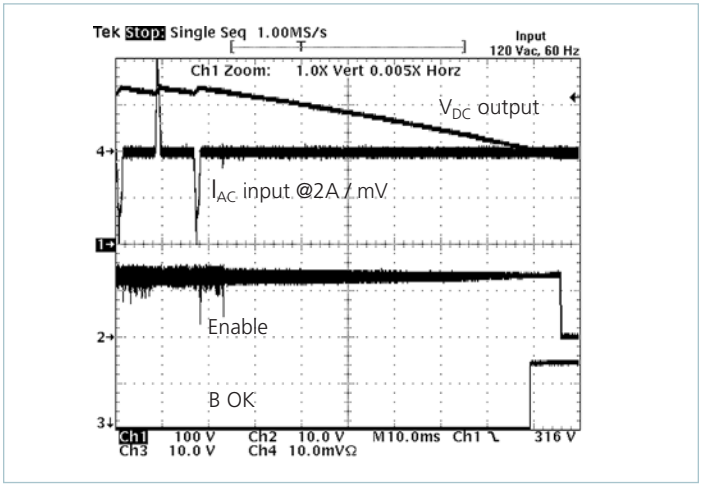


***Figure 3** — Power down, from 120V_{AC}*

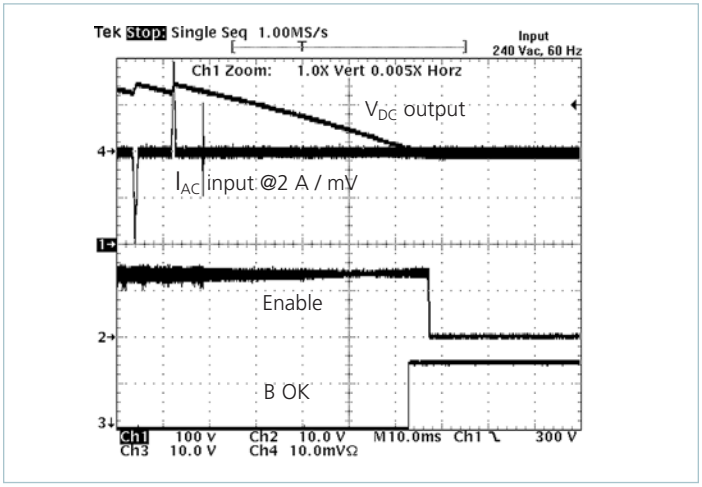


***Figure 4** — Power down, from 240V_{AC}*

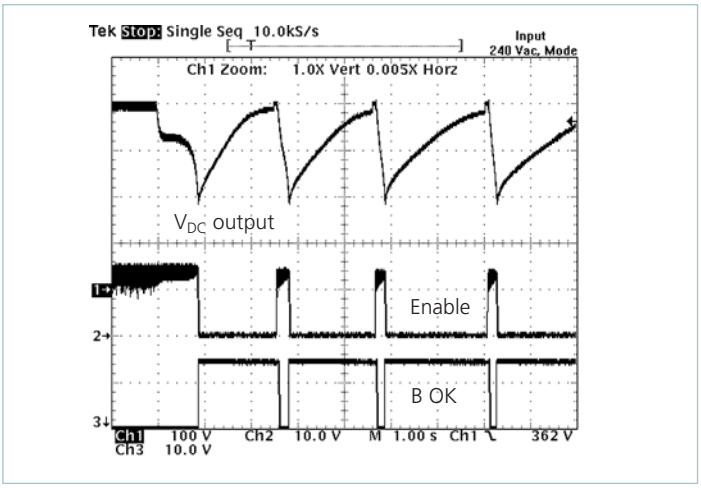


***Figure 5** — Output overvoltage protection 240V_{AC} range*

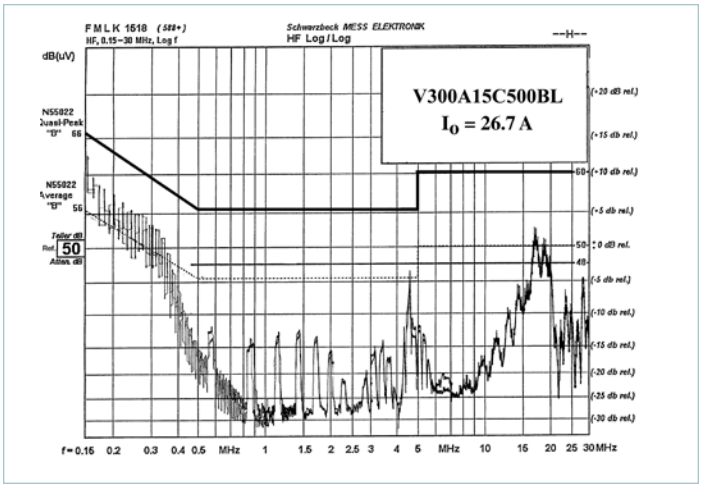


***Figure 6** — Typical conducted emissions*

Application Note

The Filtered, Autoranging Rectifier Module (FARM) 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.

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

Power-Up Sequence (See Figure 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.

2.1. 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.

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 Figure 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 $205V_{DC}$ (typical).

2.2. The converters are disabled when the bus voltage falls below $190V_{DC}$. 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.

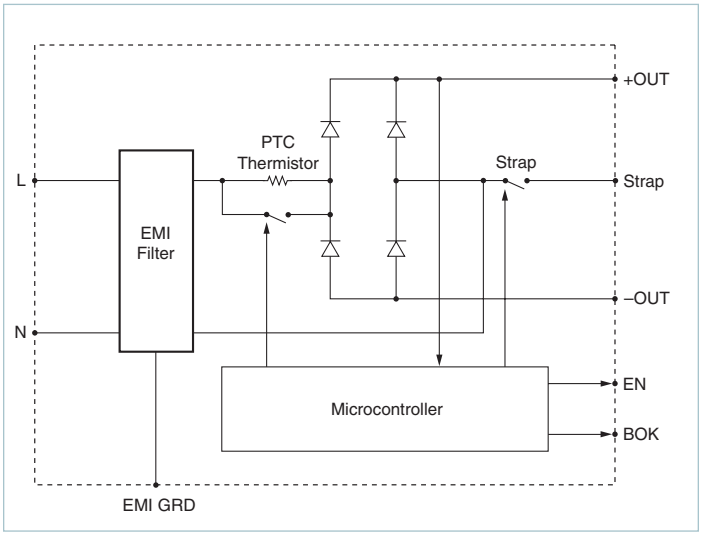


Figure 7 — *Functional block diagram: autoranging rectifier*

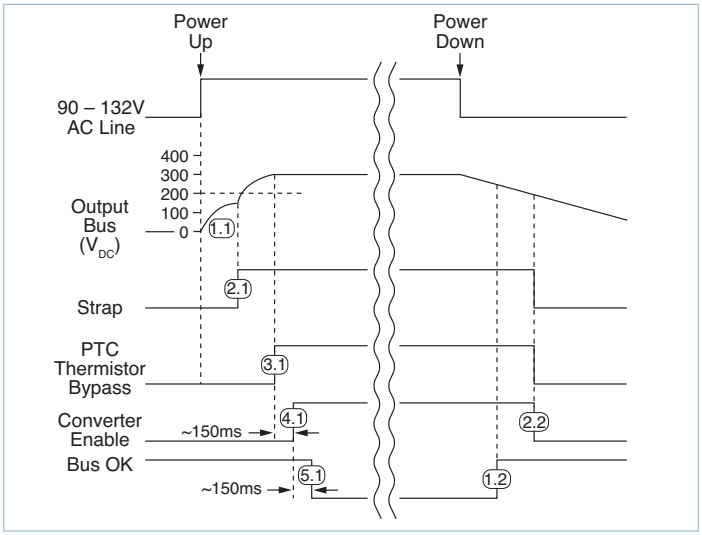


Figure 8 — *Timing diagram: power up/down sequence*

Application Note (Cont.)

Off-Line Power Supply Configuration

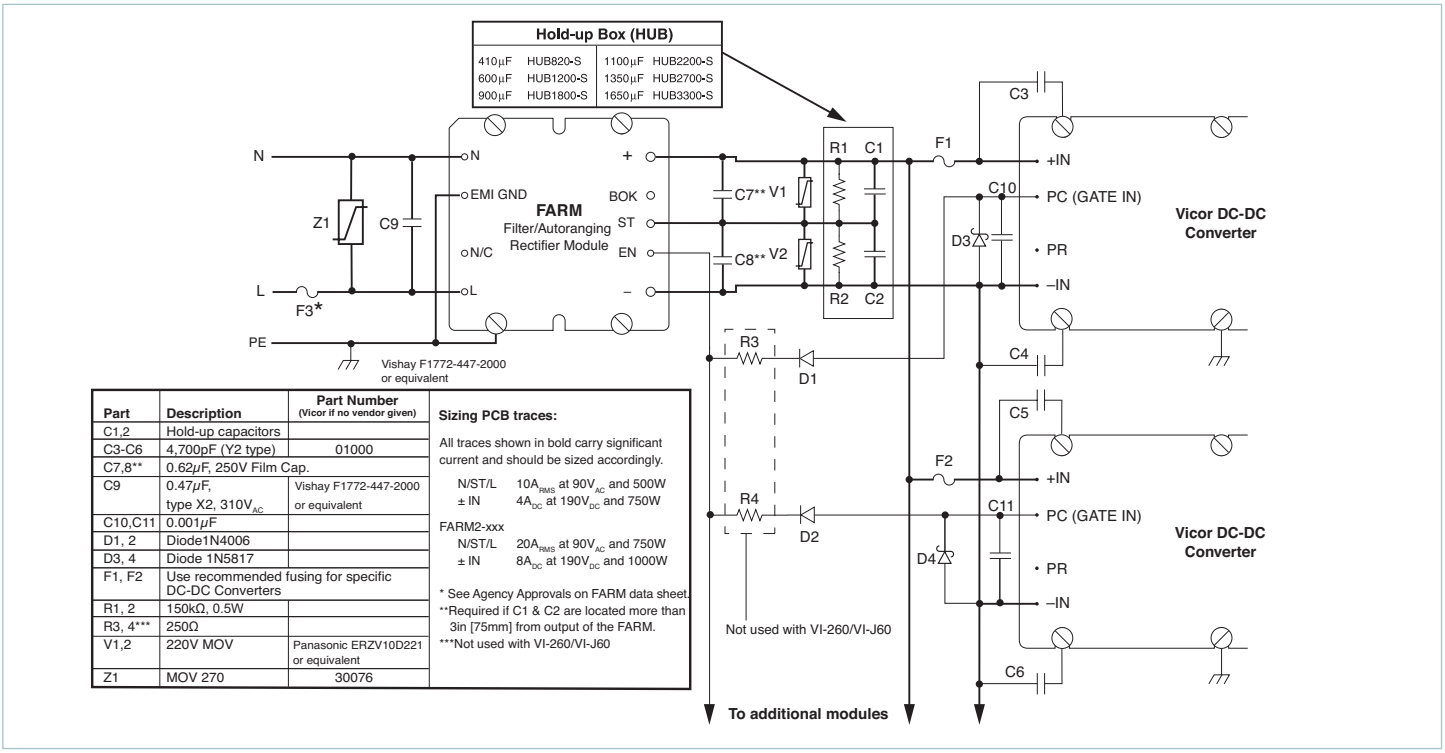
The FARM maintains the DC output bus voltage between 250 and 370V_{DC} over the entire input voltage range, which is compatible with Vicor 300V input converters. The FARM automatically switches to the proper bridge or doubler mode depending on the input voltage, eliminating the possibility of damage due to improper line connection. The FARM1xxx is rated at 500W in the low range (90 – 132V_{AC} input), and 750W in the high range (180 – 264V_{AC} input). The FARM2xxx is rated for 750W and 1000W 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 Figure 9) for proper (autoranging) operation. Metal oxide varistors, V1 and V2 provide capacitor protection. The bleeder resistors (R1, R2, see Figure 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 3in [75mm] from the FARM output pins.

Enable (EN) Pin: (See Figure 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 15V through a 150kΩ 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 (15V) 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 400V_{DC}. 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 180V_{DC}.

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.



Part	Description	Part Number (Vicor if no vendor given)
C1,2	Hold-up capacitors	
C3-C6	4,700pF (Y2 type)	01000
C7,8**	0.62µF, 250V Film Cap.	
C9	0.47µF, type X2, 310V_{AC}	Vishay F1772-447-2000 or equivalent
C10,C11	0.001µF	
D1, 2	Diode1N4006	
D3, 4	Diode 1N5817	
F1, F2	Use recommended fusing for specific DC-DC Converters	
R1, 2	150kΩ, 0.5W	
R3, 4***	250Ω	
V1,2	220V MOV	Panasonic ERZV10D221 or equivalent
Z1	MOV 270	30076

Sizing PCB traces:

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

N/ST/L ± IN: 10A_{RMS} at 90V_{AC} and 500W; 4A_{DC} at 190V_{DC} and 750W

FARM2-xxx N/ST/L ± IN: 20A_{RMS} at 90V_{AC} and 750W; 8A_{DC} at 190V_{DC} and 1000W

* See Agency Approvals on FARM data sheet.
**Required if C1 & C2 are located more than 3in [75mm] from output of the FARM.
***Not used with VI-260/VI-J60

Figure 9 — *Offline power supply configuration*

Application Note (Cont.)

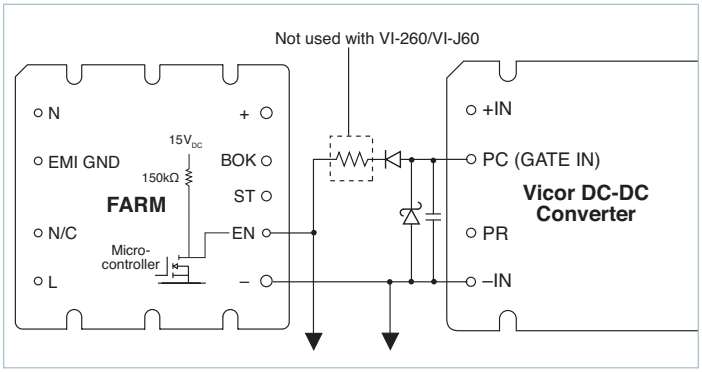


Figure 10 — *Enable (EN) function*

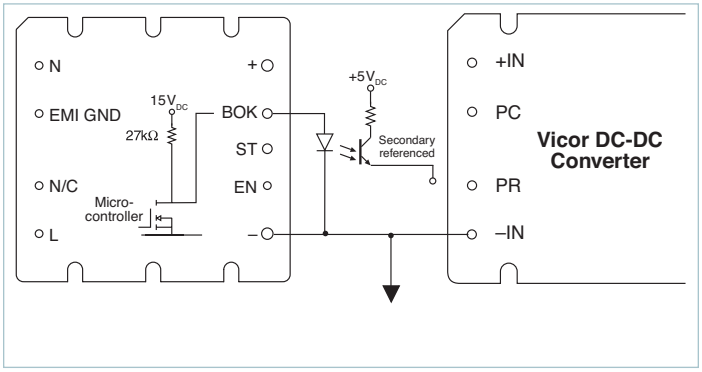


Figure 11 — *Bus OK (BOK) isolated power status indicator*

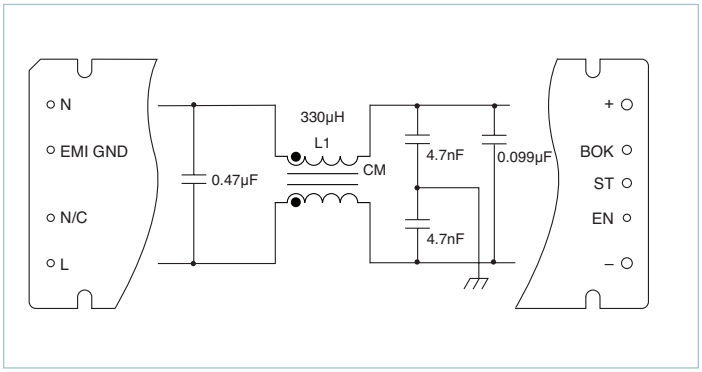


Figure 12 — *Internal filter*

Bus OK (BOK) Pin: (See Figure 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 Figure 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 100kHz and 30MHz 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 Figure 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:

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

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:

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

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:

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

Application Note (Cont.)

The power fail warning time (Δt) is defined as the interval between B OK and converter shut down (EN) as illustrated in Figure 13. The Bus-OK and Enable thresholds are 205V and 190V, 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 Figure 9) requires each capacitor to be twice the calculated value, but the required voltage rating of each capacitor 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.

For example, a converter whose output is 15V and nominal input is 300V will provide approximately 56dB ripple rejection, i.e., $10V_{P-P}$ of input ripple will produce $15mV_{P-P}$ of output ripple (See Figure 17). Equation 3 is again used to determine the required capacitance. In this case, V1 and V2 are the instantaneous values of bus voltage at the peaks and valleys (See Figure 13) 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:

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

Where: f = *line frequency*
θ = *rectifier conduction angle*

The approximate conduction angle is given by:

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

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:

$$I_{RMS} = 2P / V_{AC} \qquad (6)$$

Where: P = *operating power level*
V_{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 $12V_{DC}$ at 320W. Therefore, the output power from the FARM would be 375W (assuming a converter efficiency of 85%). The desired hold-up time is 9ms over an input range of 90 – $264V_{AC}$.

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 820µF. Since two capacitors are used in series, each capacitor must be at least 1,640µF. 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.

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 $90V_{AC}$, ride-through would be 68ms. 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 $12V_{P-P}$.

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 60dB for a 12V output. Since the ripple on the bus voltage is $12V_{AC}$ and the ripple rejection of the converter is 60dB, the output ripple of the converter due to ripple on its input (primarily 120Hz) will be $12mV_{P-P}$.

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.

Storage

Vicor products, when not installed in customer units, should be stored in ESD safe packaging in accordance with ANSI/ESD S20.20, "Protection of Electrical and Electronic Parts, Assemblies and Equipment" and should be maintained in a temperature controlled factory/ warehouse environment not exposed to outside elements controlled between the temperature ranges of 15°C and 38°C. Humidity shall not be condensing, no minimum humidity when stored in an ESD compliant package.

Application Note (Cont.)

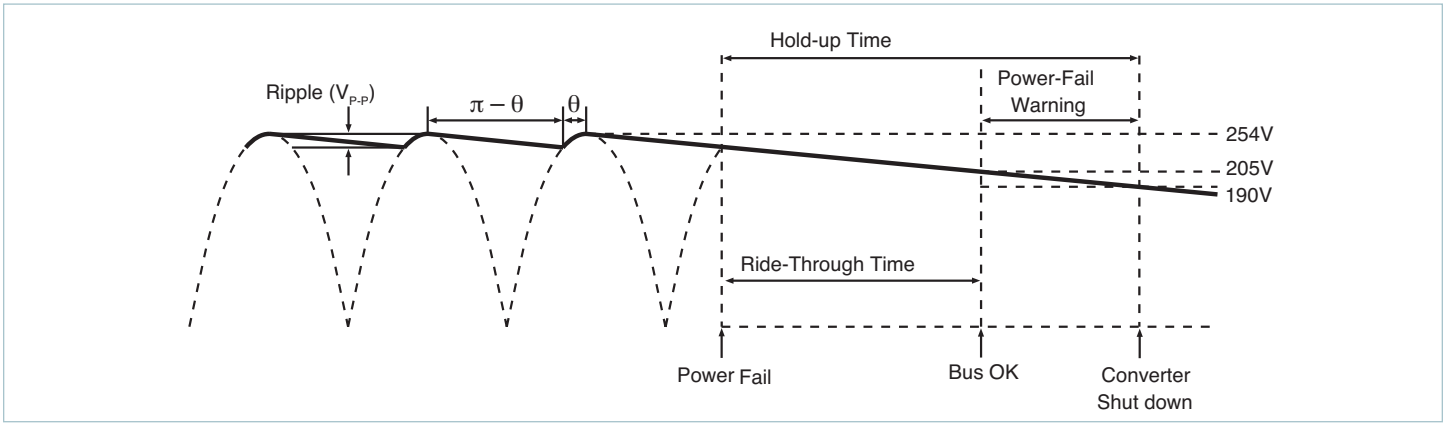


Figure 13 — *Hold-up time*

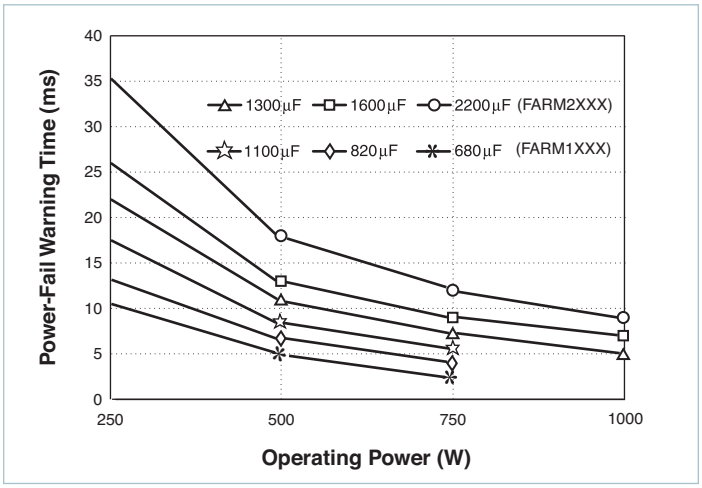


Figure 14 — *Power fail warning time vs. operating power and total bus capacitance, series combination of C1, C2 (see Figure 9)*

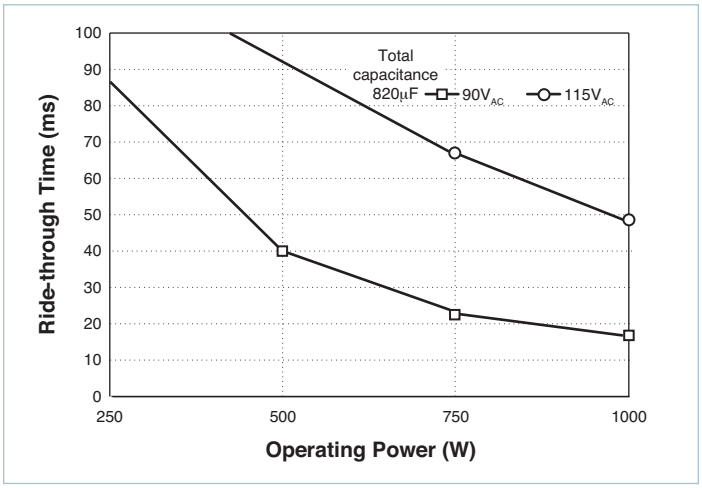


Figure 15 — *Ride-through time vs. operating power*

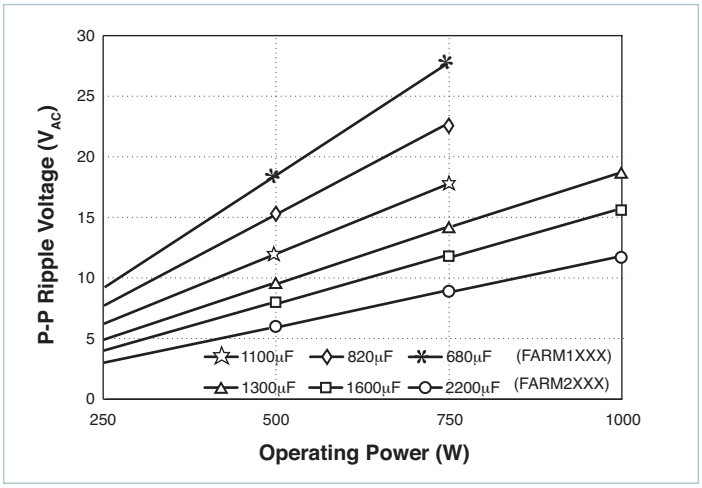


Figure 16 — *Ripple voltage vs. operating power and bus capacitance, series combination of C1, C2 (see Figure 9)*

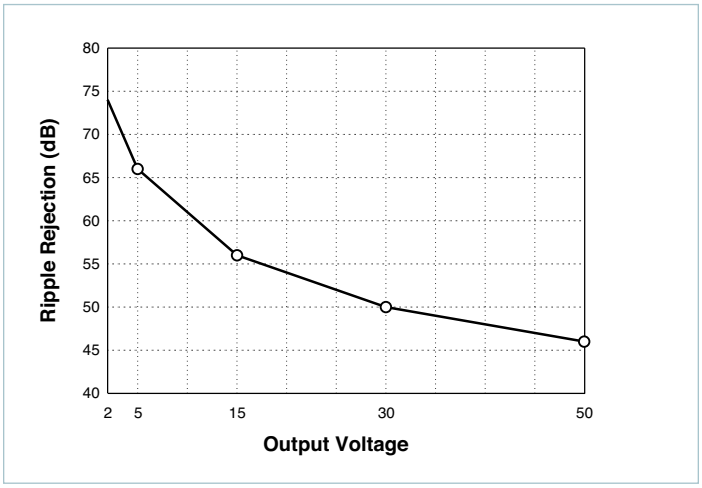
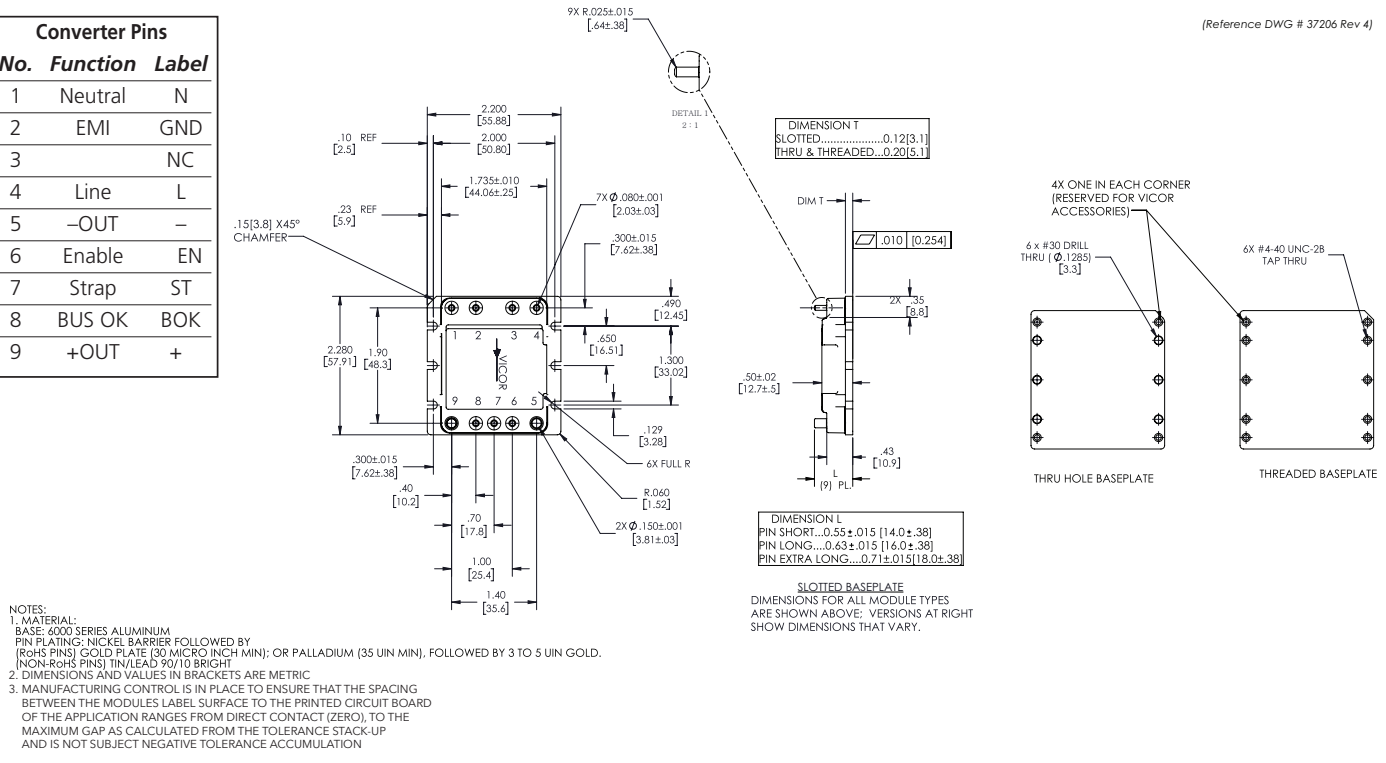


Figure 17 — *Converter ripple rejection vs. output voltage (typical)*

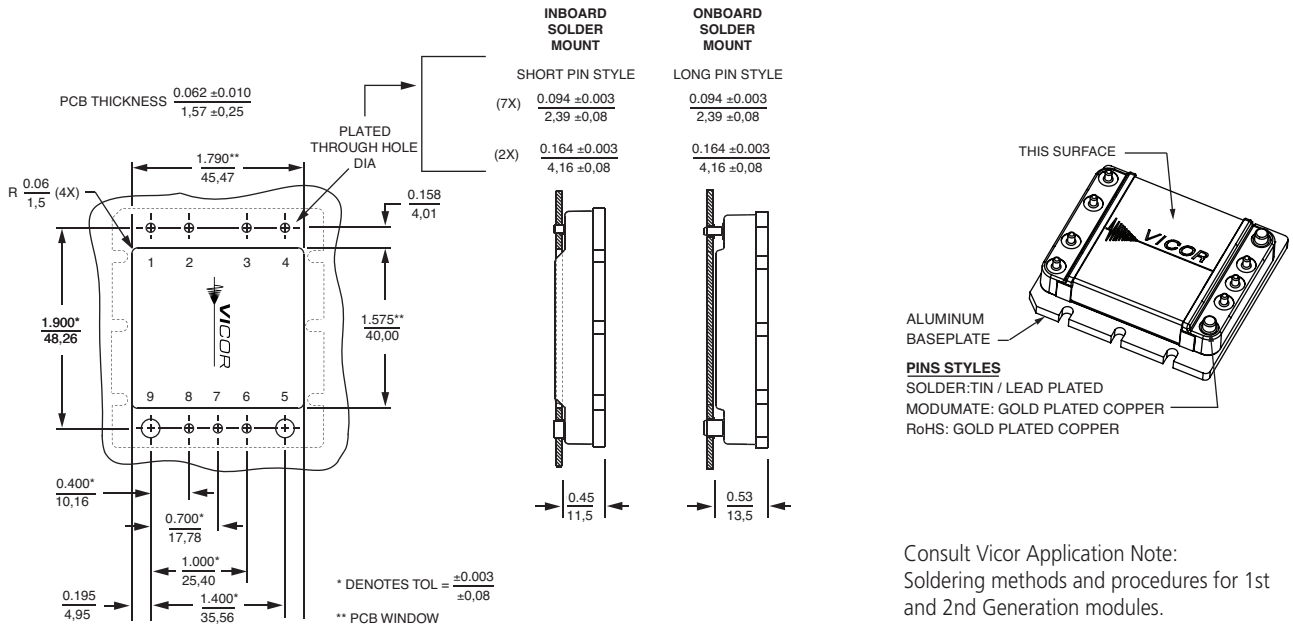
Mechanical Drawings

Converter Pins		
No.	***Function***	***Label***
1	Neutral	N
2	EMI	GND
3		NC
4	Line	L
5	–OUT	–
6	Enable	EN
7	Strap	ST
8	BUS OK	BOK
9	+OUT	+



NOTES:
1. MATERIAL:
BASE: 6000 SERIES ALUMINUM
PIN PLATING: NICKEL BARRIER FOLLOWED BY (RoHS PINS) GOLD PLATE (30 MICRO INCH MIN); OR PALLADIUM (35 UIN MIN), FOLLOWED BY 3 TO 5 UIN GOLD. (NON-RoHS PINS) TIN/LEAD 90/10 BRIGHT
2. DIMENSIONS AND VALUES IN BRACKETS ARE METRIC
3. MANUFACTURING CONTROL IS IN PLACE TO ENSURE THAT THE SPACING BETWEEN THE MODULES LABEL SURFACE TO THE PRINTED CIRCUIT BOARD OF THE APPLICATION RANGES FROM DIRECT CONTACT (ZERO), TO THE MAXIMUM GAP AS CALCULATED FROM THE TOLERANCE STACK-UP AND IS NOT SUBJECT NEGATIVE TOLERANCE ACCUMULATION

Module outline



Consult Vicor Application Note: Soldering methods and procedures for 1st and 2nd Generation modules.

PCB mounting specifications

Vicor's comprehensive line of power solutions includes high density AC-DC and DC-DC modules and accessory components, fully configurable AC-DC and DC-DC power supplies, and complete custom power systems.

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