Designing High Power Single and Three-Phase Isolated Supplies using the Granite Power GP-MPFC1H21 PFC Front End

Mike DeGaetano
VI Brick Application Engineering
October 2013

Contents **Page**

Introduction

The MIL-COTS GP-MPFC1H21 PFC Front End from Granite Power Technologies is a single phase AC input front-end module that can accept a wide input voltage range and operate at line frequencies from 47 to 440 Hz delivering up to 1400 W of output power. Using Maxi, Mini, or Micro modules with their inherent load-sharing characteristic, allows the user to create a high power parallel array that can be operated from either a single-phase or three-phase AC power source. This application note will detail the necessary design considerations for creating a high-power array using the PFC front end and Vicor Maxi, Mini, Micro series DC-DC converters that can be can be operated from either a single or three-phase power source.

The following types of sources are applicable to the setup described in this application note:

- Single phase 120 VAC (L-N)
- Single phase 240 or 208 VAC (L-L or L-N*)
- Three phase 120/208 VAC (L-N or L-L)
- Three phase 230 VAC (L-L)
- Three phase 230/400 VAC (L-N) **WARNING:** L-N connection only. To ensure product and user safety, the 230/400 VAC three-phase source must have a low impedance and a reliable neutral connection, only a L-N connection is permissible.

NOTE: (L = line, N = neutral)

*Single phase power derived from a L–N connection from the following systems:
240/400 VAC three phase Y.
240 VAC three phase corner grounded delta.
240/120 VAC three phase delta with 208 V high leg.

Single-Phase Setup

A schematic diagram is shown in Figure 1 for a single-phase input application. A filter must be used at the input of the PFC front end and in this application note a JMK FF-2137B-13 was utilized. This filter provides sufficient EMI suppression to meet MIL-STD-461F. Two Vicor V375A48C600BL Maxi modules are used downstream from the PFC front end to convert the 384 Vdc from the PFC front end to an isolated bus voltage of 48 Vdc. The two paralleled V375 modules are able to deliver up to 25 A of output current or 1,200 W output power.

Multiple arrays of the setup, shown in Figure 1, can be paralleled to increase output current and power, and/or operate off of a three phase distribution. A bill of materials is included in the Appendix for the components used in Figure 1. Figure 2 shows the single-phase array setup of Figure 1 applied to a US 120 VAC single-phase source.

Figure 1.
Schematic diagram of single array

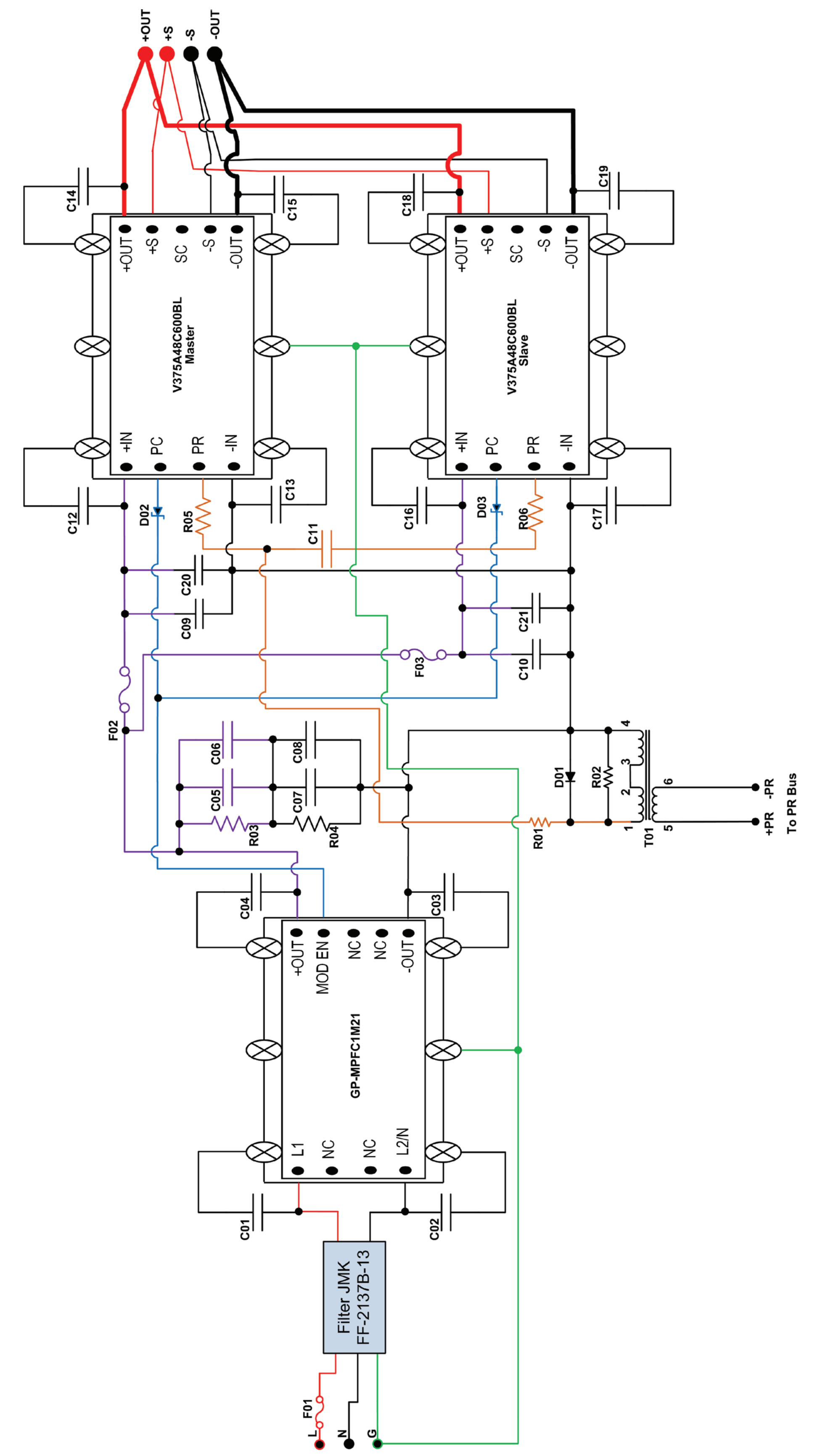


Figure 2.

Connection diagram of a US 120 VAC single-phase setup using one PFC front end and two Maxi modules

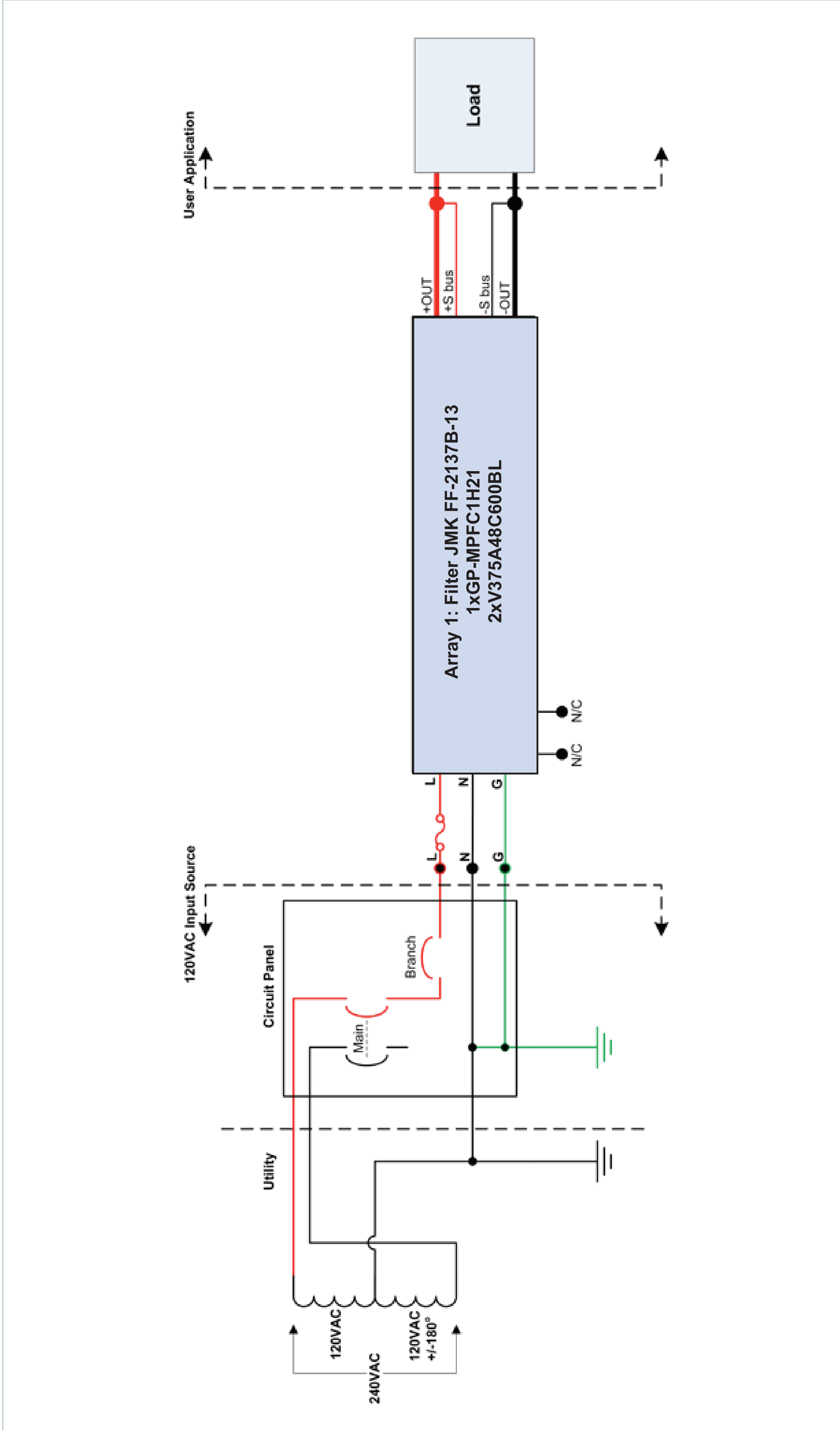
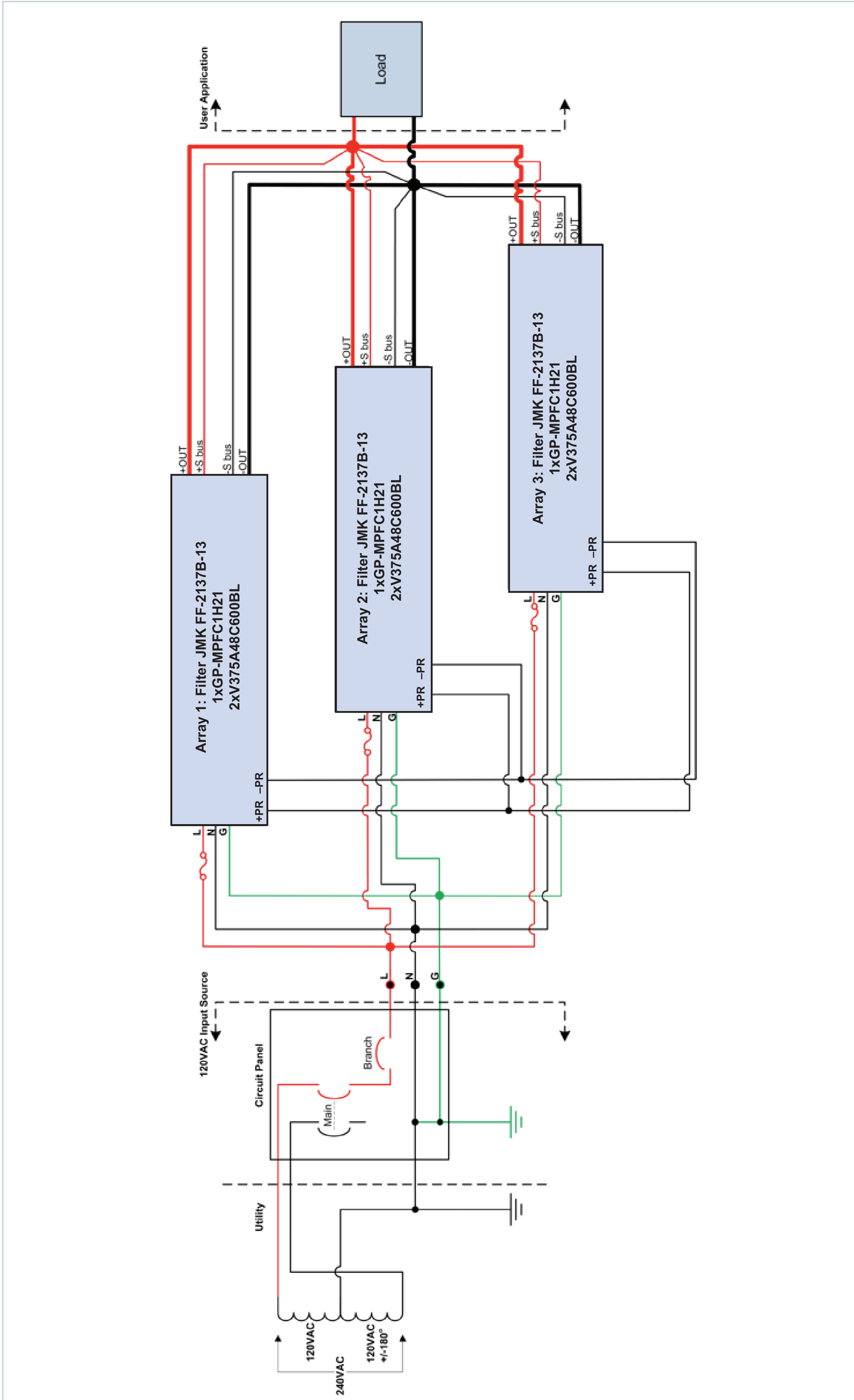


Figure 3.

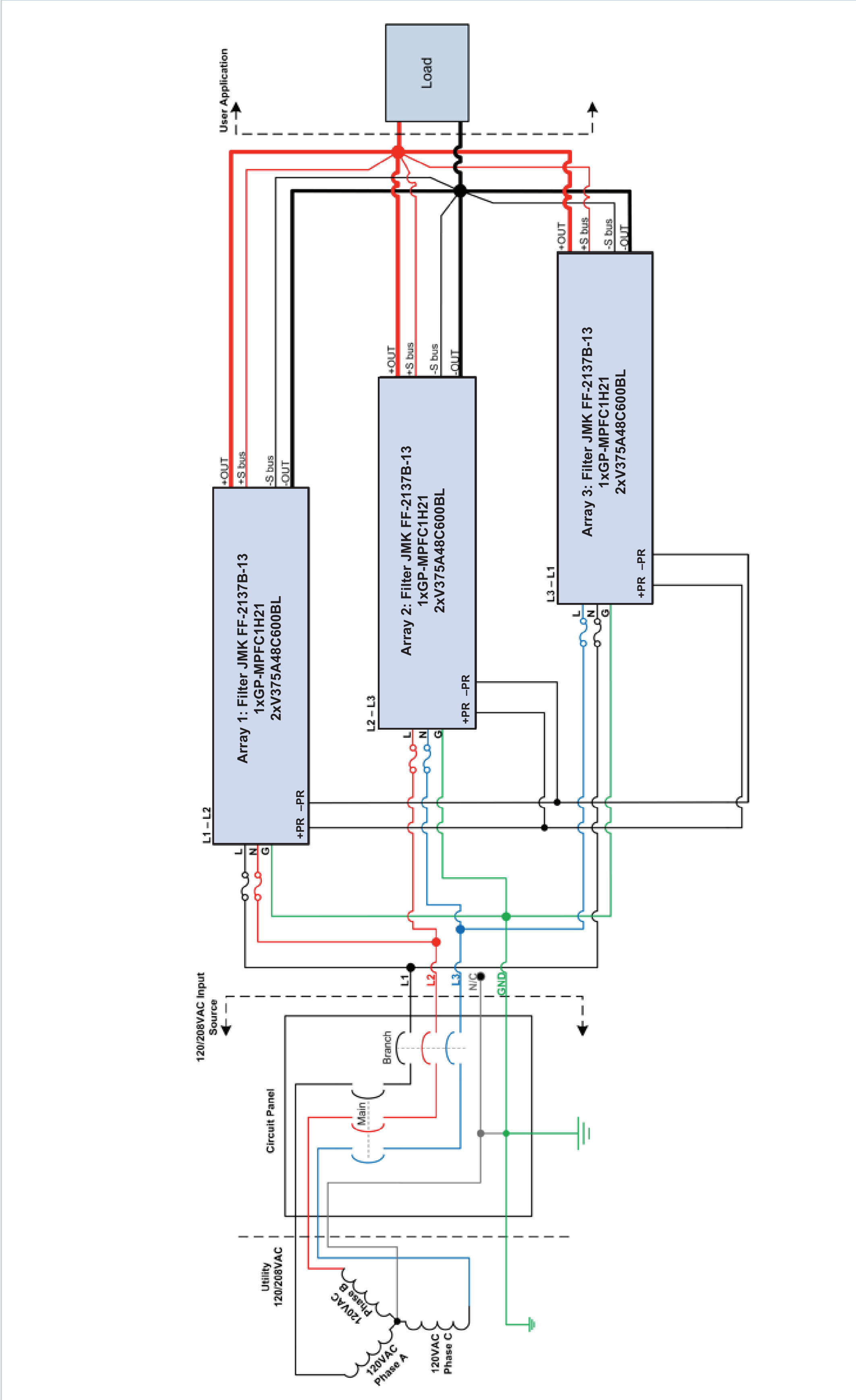
Connection diagram of a US 120 VAC high power single phase setup using one PFC front end and two Maxi modules in three arrays



NOTE: Sense bus and PR bus should be twisted pair, coaxial cable should not be used.

Figure 4.

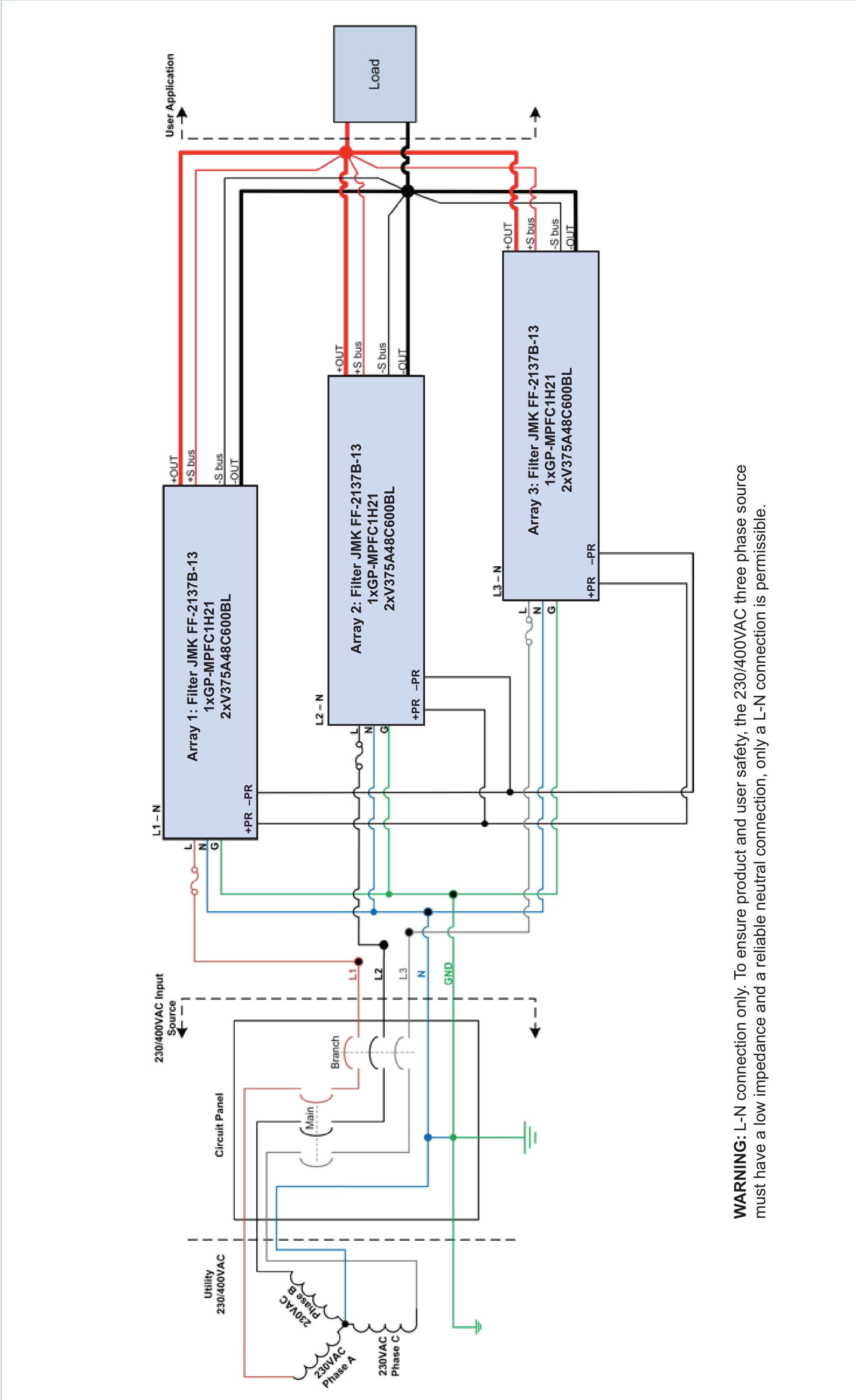
Connection diagram of a US 208 VAC three phase setup using one PFC front end and two Maxi modules in three arrays



NOTE: Sense bus and PR bus should be twisted pair, coaxial cable should not be used.

Figure 5.

Connection diagram of a European 230/400 VAC three-phase setup using one PFC front end and two Maxi modules in three arrays



NOTE: Sense bus and PR bus should be twisted pair, coaxial cable should not be used.

General Considerations for High Power Arrays

Proper fusing is important, and each module must have a fuse before it. Safety Certifications on the Vicor web site should always be consulted for the latest fusing requirements and also refer to relevant safety standards (UL, IEC, CAS, etc).

A twisted pair wire should be used for the Sense bus on each array to the load.

WARNING: Do not connect the –In of the PFC front ends to one another.

NOTE: Do not apply the load until all PFC front ends are under normal operation and the holdup capacitors are fully charged.

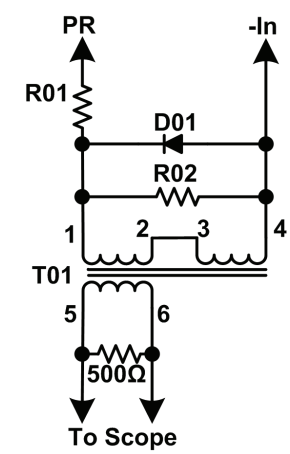
Vicor PR transformers must be used to interface the PR bus between arrays.
The PR transformers keep interconnect impedance between boards from corrupting the PR signal and also isolates the common return (-In) of each array from the parallel bus. The PR bus should also utilize a twisted pair to retain the fidelity of the PR pulse. Please refer to Converter PR Pin Facilitates Parallel Operation for Power Expansion or Redundancy application note for detailed information on the paralleled bus.

During initial design qualification, ensure that the fidelity of the PR pulse is adequate (see Figure 8), and all of the DC-DC modules are current sharing.

NOTE: A PR coupling transformer must be used to make any measurements on the on the PR bus as the –In of each array is not isolated from the AC mains. Probing the PR bus without a transformer could form a destructive ground loop. A 500 Ω resistor should be used to terminate the PR transformer when probing the PR bus (refer to Figure 6). The waveform will need to be scaled (2x) due to the 2:1 turns ratio of the PR transformer.

Figure 6.

PR Transformer with 500 Ω termination



Single-Phase and Three-Phase Considerations

For three-phase input applications, three PFC front ends are used and each front end operates off of two lines of the three-phase source. Each of the single-phase arrays from Figure 1 can be paralleled to create high power systems (refer to Figure 3). For supplies using more than one array, each array should be individually tested on single-phase power to ensure proper operation. The arrays can then be configured for parallel operation for high power and/or three-phase applications.

Please refer to the Maxi, Mini, Micro Design Guide and the Designing High-Power Arrays Using Maxi, Mini and Micro Family DC-DC Converters application note for paralleling Micro modules and for general paralleling information. Please contact Vicor Applications Engineering with any questions.

Paralleling the Arrays

Figure 4 shows the US 208 VAC three-phase setup and Figure 5 shows the European 230/400 VAC setup. Each setup uses three arrays of the setup shown in Figure 1 where each array runs off of a single phase (L-L for US 208 VAC and L-N for the European 230/400 VAC input system).

WARNING (For the 230/400 VAC source): L-N connection only. To ensure product and user safety, the 230/400 VAC three phase source must have a low impedance and a reliable neutral connection, only a L-N connection is permissible.

The US 208 VAC system was utilized for this application note. Each array is powered by the line-to-line 208 VAC voltage where each line is 120° out of phase in reference to another line. One Maxi module in the center array was configured as the master while the other five modules were configured as slave modules by shorting SC to –S.

TVS diodes (D01 in Figure 1) were used between +PR and –In on each board to clamp PR voltage overshoot due to the lead inductance of the twisted pair. A 10 Ω resistor (R01 in Figure 1) was added in series to the PR pin on each board for to improve damping. A 250 Ω (R02 in Figure 1) resistor was also added in parallel with the TVS diode on the board with the master module for additional damping. The value of R02 should be selected during qualification testing and is dependent on the number of arrays used in the system.

Final Setup and Measurements

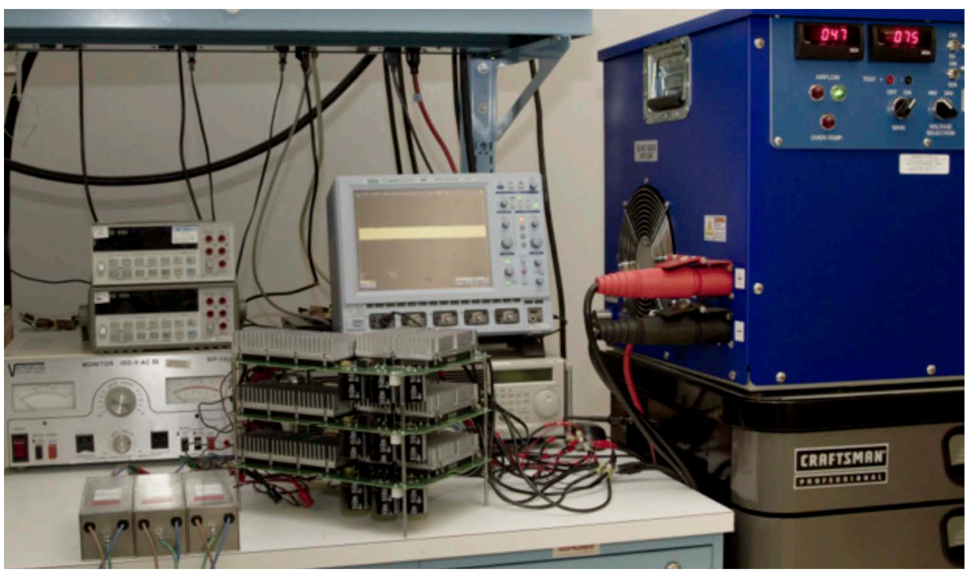


Figure 7.
US 208 VAC
Three-phase setup

Figure 7 shows the setup for evaluating the US 208 VAC three-phase distribution and implements the block diagram shown in Figure 4. Three JMK FF-2137B-13 filters were used in front of each array (seen in the lower left of the setup). Each array consists of a Granite Power PFC Evaluation Board that has one PFC front end and two Maxi modules mounted on it. The system was operating at full power in Figure 7, and a resistive DC load bank was used to sink the 75 A of output current.

Figure 8.
PR Bus Signal

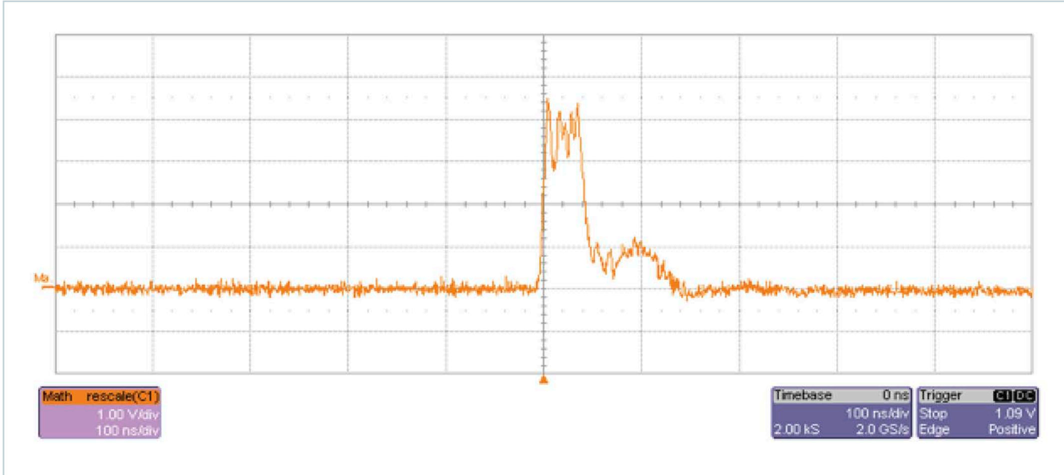


Figure 9.
V_{OUT} at no load

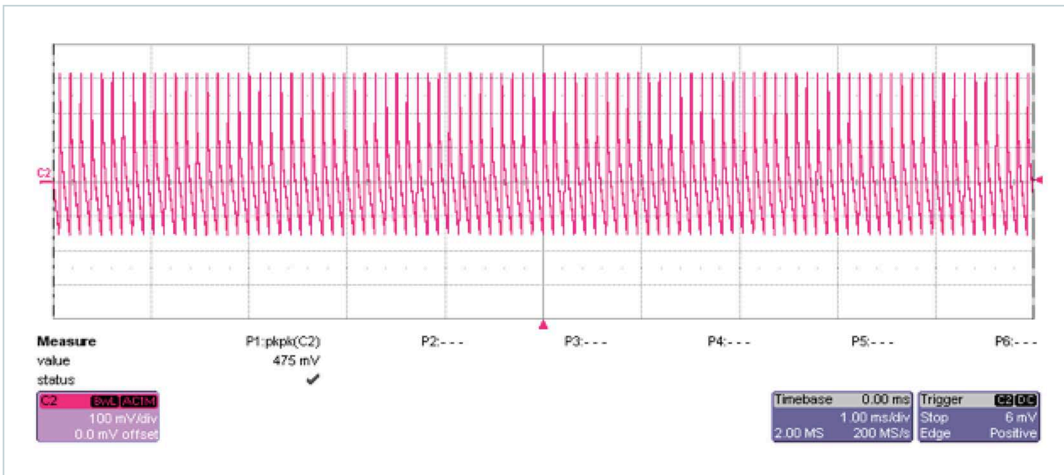


Figure 10.
V_{OUT} at 50% load

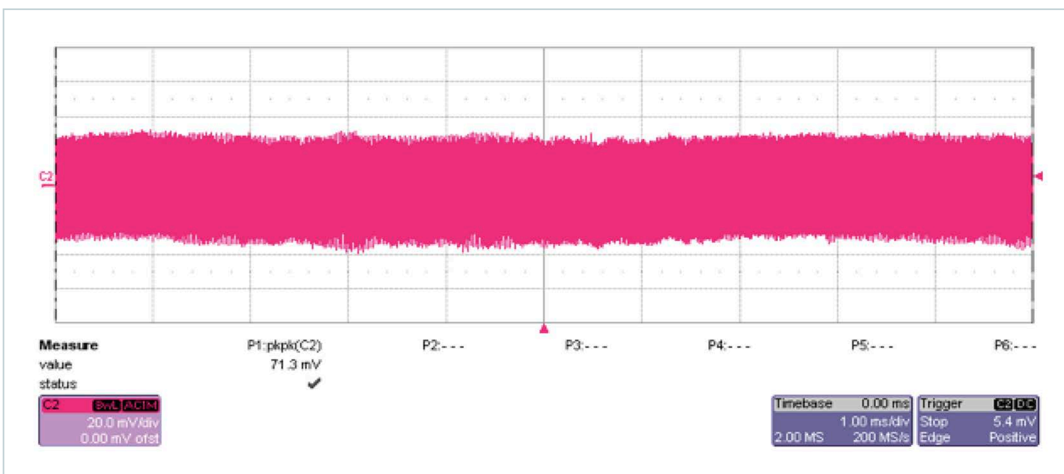


Figure 8 captures the PR bus signal scaled to 2x to show the waveform as seen by the modules due to the PR transformer stepping the signal down by the turns ratio (2:1).

The voltage ripple of the system at no load is shown in Figure 9.

Figure 10 shows the output voltage ripple when the system is operating at 50% load.

Conclusion

For high power and three-phase power applications, a Granite Power GP-MPFC1H21 Front End and two Vicor V375A48C600BL modules can be used in three parallel arrays to provide 3,200 W of power.

Appendix

Bill of Materials (for single array shown in Figure 1)

Reference Designator	Description	Manufacturer	Manufacturer Part Number
C01, C02, C03, C04, C12, C13, C16, C17	CAP Y RATED 4,700 pF 2,000 V	TDK or similar	C5750X7S3D472K200KA
C05, C06, C07, C08	CAP 1,200 µF 200 V	Panasonic or similar	EET-ED2D122EA
C09, C10, C14, C15, C18, C19	CAP 0.1 µF 1,000 V	Vishay or similar	VJ2225Y104KXGAT
C11	CAP .01 µF 50 V 0805	Murata Electronics or similar	GRM2195C1H103JA01D
C20, C21	CAP 0.33 µF 760 V	Kemet or similar	PHE840MX6330MB11R17
D01	TVS DIODE	NXP Semiconductors	PESD3V3U1UT,215
D02, D03	SCHOTTKEY DIODE	DIODES INC or similar	B0540W-7
F01	FUSE 15 A 250 V	Cooper Bussmann	BK/ABC-15
F02, F03	FUSE 5 A 250 V	Cooper Bussmann	BK/PCI-5-R
R01	RES 10 OHM 1/4 W*	Generic	Generic
R02	RES 250 OHM 1/4 W*	Generic	Generic
R03, R04	RES 499 K 1 W 2512	Generic	Generic
R05, R06	RES 4R99 1/4 W 1206	Generic	Generic

* Values selected during initial qualification testing

The Power Behind Performance