Lambda's FE Power Shelf Series is a compact, flexible source of 24/48 VDC and an excellent choice for front end distributed power in data processing and communications applications

FE POWER SHELF SERIES

Application Manual

IMFERS
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LAMBDA ELECTRONICS INC.

NOTICE PAGE

SAFETY WARNING

The FE Power Shelf system is intended for use as a component of other equipment. Therefore, adhere to national and local safety standards (including EN60950, IEC950, UL1950 and CSA22.2-950) when installing this system. In particular, creepage and clearance distances and distances through insulation between primary power and ground or between primary and secondary power must be maintained.

Connect the protective ground terminal of this Safety Class 1 instrument to ground (earth) through a power source equipped with an appropriate grounding system. For ground fault protection, the unit must be protected in the final installation by suitable overcurrent protection means. If protection relies upon building wiring, the end product installation must ensure that the necessary protection is provided.

In systems with a Low Voltage Disconnect (LVD) Module, safety standards require that the battery can be completely disconnected from the power system, including the battery system ground.

Before installation or operation, review this manual and check the power system for safety markings and instructions.

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1.0 DOCUMENT DESCRIPTION

This Application Manual provides information about the FE (Front End) Power Shelf Series. The FE Series contains modular AC-DC distributed-power front end supplies which convert AC input voltages of 85-265 VAC (170-265 VAC for model FE2000) to a power factor corrected, regulated DC bus of either 24 VDC or 48 VDC, nominal.

For detailed information about individual components, refer to their respective specifications. In the event of a conflict between this manual and individual specifications, the individual specifications shall govern.

In this document the terms CAUTION and WARNING will be listed before any step or operation to alert personnel of dangers in any procedure. The terms will be used in situations and in the format as follows:

CAUTION

Placed before any step or operation to alert personnel of possibility of damage to equipment or product when performing procedure.

WARNING

Placed before any step or operation to alert personnel of possibility of injury or death when performing procedure.

2.0 SYSTEM DESCRIPTION

The FE Power Shelf Series is a compact, flexibly configured source of 24V$_{DC}$ or 48V$_{DC}$ power. It is an excellent choice as a front end source of distributed power in telecommunications and high-end computer applications. It is comprised of FE power modules and an FE racking system. The FE power modules are available in four different power levels: 500, 1000, 1500, and 2000 watts. The FE racking system is produced in three different styles, as follows.

X Version. This low cost option allows the system to attain increased power density.

N Version. Features internal filtering to comply with FCC Class B conducted emissions standards. Includes front panel circuit breakers.

L Version. Monitors battery output voltage and automatically disconnects battery from load under preset conditions.

The FE Power Shelf Series is designed to be stable for all ranges of capacitive, battery, and negative incremental impedance converter loads such as DC to DC converters. The Series is capable of N + N operation, including power float battery voltages in a telecom power plant.

Each FE shelf is a 3U (5.25 in. high) enclosure designed to mount in a standard 19-in. rack (24 in. with NEBS option). (See Appendix A for outline dimensions.). The maximum depth, not including service loop for the AC input wiring, is 14.5 in. for FE4KXE, FE4KNE, FE5KXE, FE5KNE, FE6KXE, and 16.0 in. for FE6KNE and FE6KLE racks..

The FE power modules (see Appendix A for outline dimensions) install into the FE power shelf from the front. The AC input module of the -N and -L versions, and the LVD module of the L version, are installed in the factory and are not user replaceable. All power and signal connections are made at the rear of the shelf.

CAUTION

Multiple AC input supply sources are used on all configurations. Service personnel must disconnect all sources before servicing equipment.

Cooling is provided by fans within the FE power modules. The airflow direction is from front to back. A minimum plenum space of 6 in. is required behind the shelf for proper cooling. There are no fans in the shelf chassis. No external fans are required.

3.0 SUMMARY SPECIFICATIONS

3.1 Input Capabilities

3.1.1 Power. The ratings listed in Table 1 reflect the maximum capabilities of each FE power shelf. The exact capability will depend on the number of FE power modules installed.

3.1.2 Voltage. Table 1 lists the input voltage capability per shelf type.

NOTE

Safety Agency approvals apply only for operation between 100 VAC and 250 VAC.

3.1.3 Current. The FE Power Shelf Series can accommodate input line ratings up to 30 A per terminal block.

NOTE

The input terminal blocks are suitable for internal wiring only, not for primary power connection (power supply cord/conduit termination).

3.1.4 Frequency. Per Table 1.

CAUTION

The FE Power Shelf Series is not designed to operate from DC or 400-440 Hz sources.

3.1.5 Single and Three Phase Operation. All FE Power Shelf Series configurations can operate from single phase sources. In addition, only FE6KXE and FE6KNE, with three FE1500 or three FE2000 power modules, can operate from three phase power and maintain load balance across the phases.

Table 1. Power Shelf Maximum Capabilities

SYSTEM DESCRIPTION	V_{in}	*Frequency*	PFC_{min}*	η_{min}	$P_{IN\ max}$	$I_{IN\ max}$
FE4K-LE	85-265 Vac	47-63 Hz	0.95	76%	3289 W	39 A
FE4K-NE					4605 W	54 A
FE4K-XE					5263 W	62 A
FE5K-LE					3947 W	46 A
FE5K-NE					5263 W	62 A
FE5K-XE					6579 W	77 A
FE6K-LE FE1500					3947 W	46 A
FE6K-NE FE1500					5921 W	70 A
FE6K-XE FE1500						
FE6K-LE FE2000	170-265 Vac			82%	4878 W	29 A
FE6K-NE FE2000					7317 W	43 A
FE6K-XE FE2000						

** At Full load per IEC1000 down to 10% load minimum for total harmonic line current.*

3.2 Output Capabilities

3.2.1 Voltage. The FE power shelf series has a single output. The voltage of this output is set by the installed FE power modules . Within the shelf, the output voltage is configured at the factory to sense on the output bus bars. This assures that the output voltage will be no more than 100mV less than the power module setpoint.

3.2.2 Current. The output bus bars of the FE power shelf are rated for continuous operation with output currents up to 300A. See paragraph 8.2 for maximum rated output currents of shelf configurations. Refer to Appendix B for current share calibration of FE power modules

3.2.3 Output Power Derating. The FE power shelf can operate continuously from -40°C to +70°C. To maintain maximum output power, ambient temperature of the operating environment must not exceed 50 ° C. (See Figure 1.) Table 2 lists the output power derating for all shelf configurations and power modules.

NOTE

A thirty minute warmup is required at -40°C.

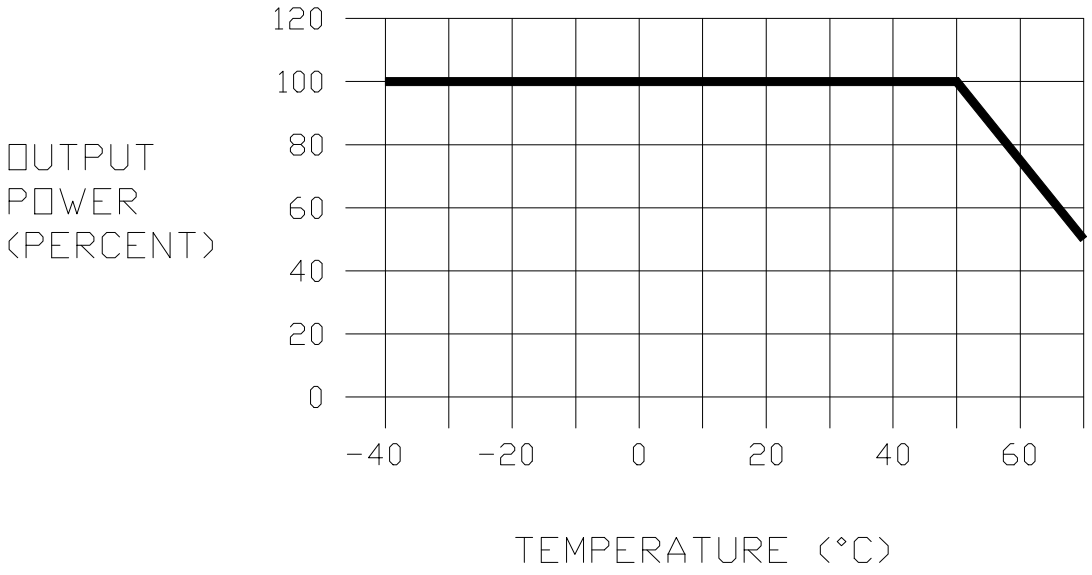


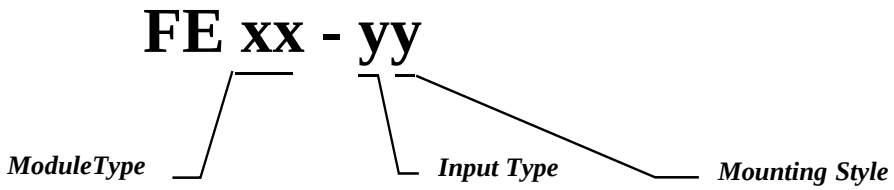
Figure 1. Output Power Derating for Ambient Temperature

Table 2. Maximum Output Power for Shelf Configurations

	Output Power @		
Model	***< 50°C***	***60°C***	***70°C***
FE4K-XE	4000w	3000w	2000w
FE4K-NE	3500w	2625w	1750w
FE4K-LE	2500w	1875w	1250w
FE5K-XE	5000w	3750w	2500w
FE5K-NE	4000w	3000w	2000w
FE5K-LE	3000w	2000w	1500w
FE6K-XE with FE1500	4500w	3375w	2250w
FE6K-XE with FE2000	6000w	4500w	3000w
FE6K-NE with FE1500	4500w	3375w	2250w
FE6K-NE with FE2000	6000w	4500w	3000w
FE6K-LE with FE1500	3000w	2250w	1500w
FE6K-LE with FE2000	4000w	3000w	2000w

4.0 FE RACK SYSTEM IDENTIFICATION

The FE rack system is numbered and identified according to the following:



4K= FE0500	N= EMI & Breakers	N= NEBS/Telcom (24”)
5K= FE1000	X= w/o EMI & Breakers	E = EIA (19”)
6K= FE1500/2000	L= EMI, Breakers & Low voltage disconnect module	

The FE power modules can be configured in the FE Power Shelf Series according to Table 3.

Table 3. Maximum Module Capacity Per Power Shelf

Model	*FE0500*	*FE1000*	*FE1500/2000*
FE4K-XE	8		
FE4K-NE	7		
FE4K-LE	5		
FE5K-XE		5	
FE5K-NE		4	
FE5K-LE		3	
FE6K-XE			3
FE6K-NE			3
FE6K-LE			2

5.0 AC INPUT OPTIONS

The EMI module with input circuit breakers is located on the right side of the shelf chassis (front view), in the FE4K-NE and FE5K-NE shelves. This option is factory installed and requires the shelf to be removed from its mounted rack for service or replacement. In the event of a fault, the magneto-thermal breakers will break the line to protect the wiring within the shelf. A single circuit breaker is associated with each AC inlet connector. No circuit breakers are included with the -XE option.

In all cases, ground connections from the FE power shelf AC connector to the shelf chassis are made according to the requirements of the applicable safety agencies. Maximum resistance from the ground point on the FE power shelf chassis to the ground connection of the FE power module, when measured with the 30A, 12V test, is no more than 50 mΩ.

WARNING

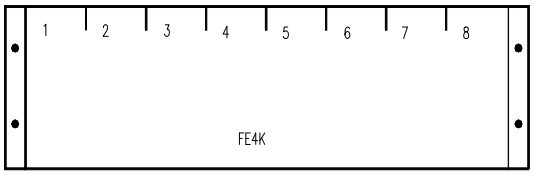
Restrict access to the AC input of the power shelf to trained service personnel only.

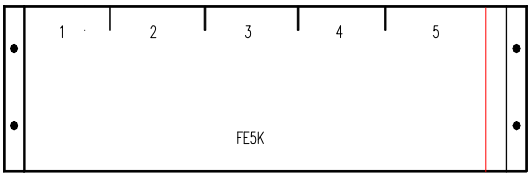
5.1 XE Option

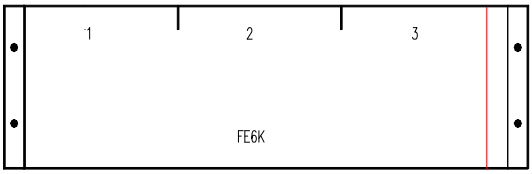
With this option the AC input wiring is brought into the FE power shelf and wired via the AC input connector to the FE power modules. This option is not available with line filters and circuit breakers. The user is required to provide adequate means of input protection through the use of fusing or circuit breakers. The AC input connector, when viewed from the rear, is wired to the corresponding "bay" as shown in the Table 4.

Table 4. AC Input Wiring for XE Option

	AC Input "A"	*AC Input "B"*	*AC Input "C"*	*# of Modules*
FE4K	1,2,3	4,5,6	7,8	8
FE5K	1,2	3,4	5	5
FE6K	1	2	3	3





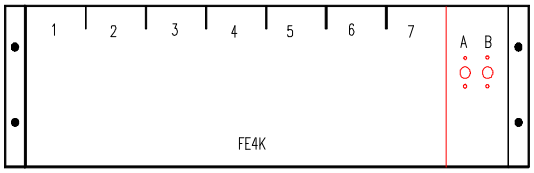


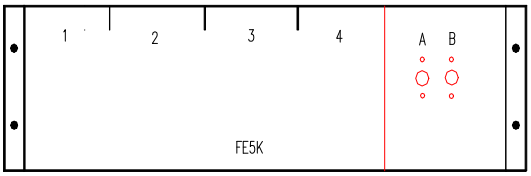
5.2 NE Option

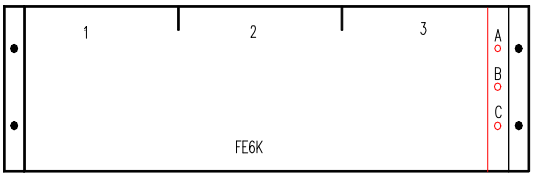
With this option the AC input wiring is brought into the FE power shelf and wired through the EMI module and input circuit breakers to the AC input connector. The connector, when viewed from the rear, is wired to the corresponding "bay" as shown in Table 5.

Table 5. AC Input Wiring for NE Option

	AC Input "A"	*AC Input "B"*	*AC Input "C"*	*# of Modules*
FE4K	1,2,3	4,5,6,7	N/A	7
FE5K	1,2	3,4	N/A	4
FE6K	1	2	3	3





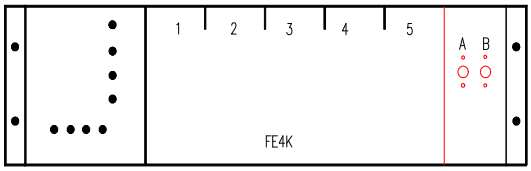


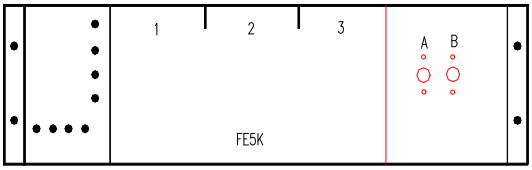
5.3 LE Option

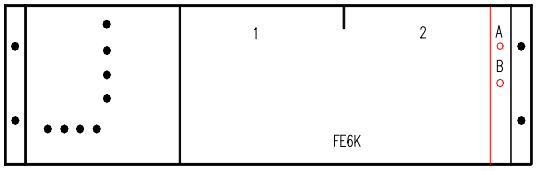
With this option the AC input wiring is brought into the FE power shelf and wired through the EMI module with input circuit breakers to the AC input connector. The connector, when viewed from the rear, is wired to the corresponding "bay" as shown in Table 6.

Table 6. AC Input Wiring for LE Option

	AC Input "A"	*AC Input "B"*	*# of Modules*
FE4K	1,2	3,4,5	5
FE5K	1	2,3	3
FE6K	1	2	2







5.3.1 Low Voltage Disconnect (LVD) Module. This module option occupies the left bay in the FExK-LE power shelf. The LVD circuit monitors operating conditions in the battery shelf and provides four monitor signals which indicate the conditions. As listed in Table 7, the monitor signals are available both as visual indicators on the front panel and as TTL levels in the 14 pin IDC connector in the rear of the power shelf.

Under normal operating condition the relay inside the LVD is closed, and current is flowing into the battery (IB>0). If the FE power shelf bus fails, the battery begins to supply current to the load (battery discharge). When the battery voltage falls below a predetermined voltage threshold, the relay opens and disconnects the battery from the load, preventing damage to the battery.

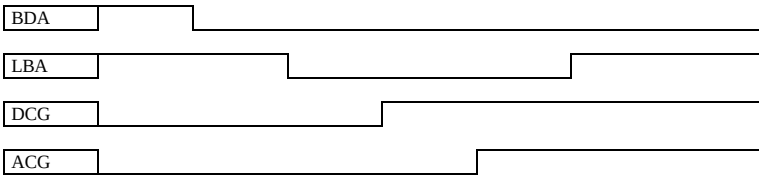
To maintain the charge and extend the life of the battery, the output voltage on the FE power shelf is adjusted by the temperature compensation circuit inside the LVD module. Depending on the battery temperature, the temperature compensation circuit adjusts the output voltage on the FE power shelf, via the sense lines.

Table 7. Battery Condition Indicators

Visual/TTL Indicators

CURRENT GOOD (Green)
LOW BATTERY (Yellow)
AC LINE FAILURE (Red)
SYSTEM DC FAULT (Red)

CASE	A	B	C	D	E	F
LED						
GREEN	OFF	ON	ON	ON	ON	ON
YELLOW	OFF	OFF	ON	ON	ON	OFF
RED	OFF	OFF	OFF	ON	ON	ON
RED	OFF	OFF	OFF	OFF	ON	ON



Case A: The system is OFF.
Case B: The system is working normally.
Case C: The batteries are discharging and either the output voltage of the Fe's is programmed at or below 24.72V (or 49.44V) or the load malfunctions.
Case D: The batteries are discharging and one or more of the FE's is not providing output power.
Case E: The batteries are discharging and one or more of the FE's has lost the AC input power.
Case F: One or more of the FE's has been removed from the system or lost the AC input power.

Temperature Compensation. This is the procedure of varying the charging voltage applied to a battery according to its temperature. At temperatures below 25° C, batteries require a higher charging voltage than normally specified; at temperatures above 25° C, they require a lower charging voltage than normal.

The temperature compensating circuit in the LVD module prevents overcharging of the batteries at higher temperatures and also optimizes their charge capacity at lower temperatures. Thus temperature compensation helps to prolong the battery life. Figure 2 illustrates the response of the indicators and TTL levels over a range of battery voltages.

CAUTION

Any loads connected to the FE power shelf will see temperature-compensated voltages which could be as high as 63 VDC at -40° C and as low as 45 VDC at 50° C for 48 VDC units.

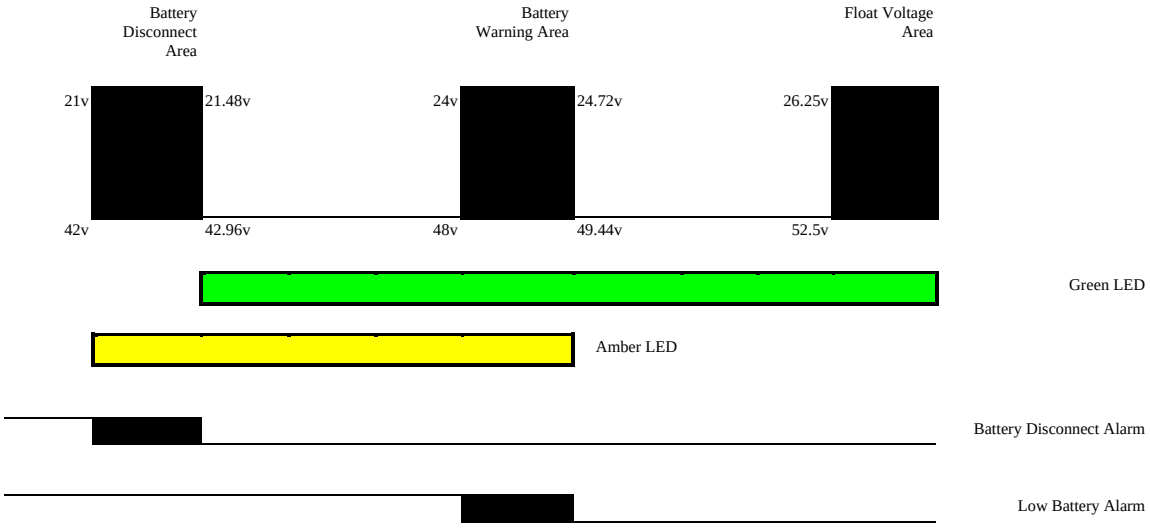


Figure 2. Indicator and TTL Level Response to Battery Voltage Events

6.0 MAINS INPUT CONNECTION

6.1 Single-Phase Configuration

For single-phase operation the terminals LA, LB, and LC as well as NA, NB, and NC at the female end of the input connector should be connected together as shown in Figure 3.

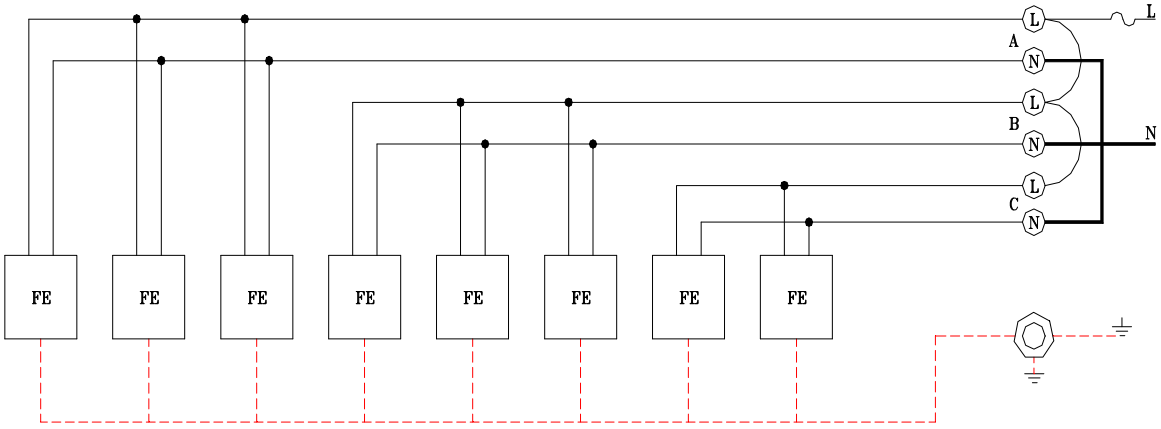


Figure 3. Single-Phase Configuration L, N 120V or 230V Mains

6.2 Phase-to-Phase Configuration

Phase-to-phase connections are shown in Figure 4.

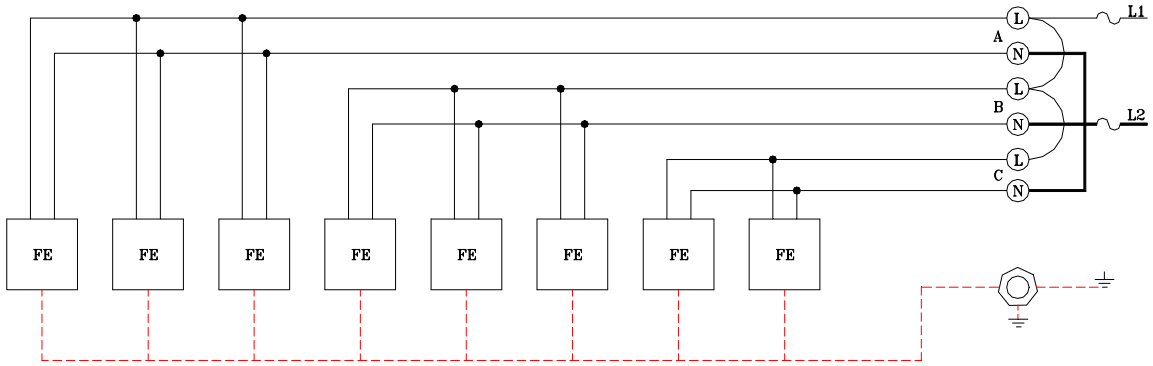


Figure 4. Phase to Phase Configuration L1, L2, 120V/208V Mains

6.3 Three-Phase (Y) Configuration

The three-phase (Y) configuration can be applied to FE6K-XE and FE6K-NE power shelf units only, as shown in Figure 5.

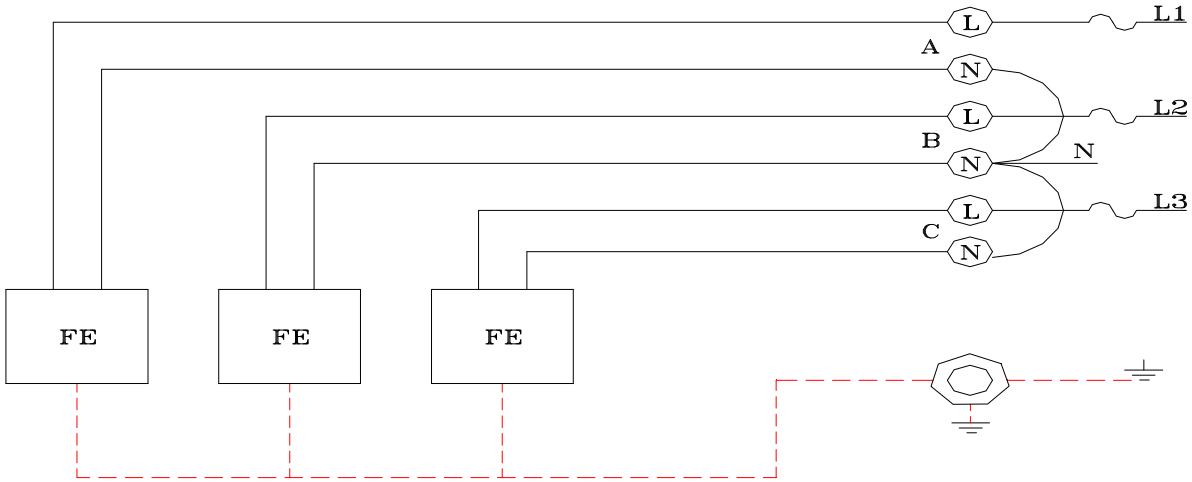


Figure 5. Three-Phase (Y) Configuration L1, L2, L3, N 120/208V Mains

6.4 Three-Phase (Δ) Configuration

The input AC section of the FE6K-XE or FE6K-NE is wired in a Δ connection, enabling full power of the FE power modules at low mains input voltage of 120/208 VAC. (See Figure 6.) An input AC section in three-phase (Δ) configuration is available on request. Modifications to the back plane in the field from (Y) to (Δ) configuration is not recommended.

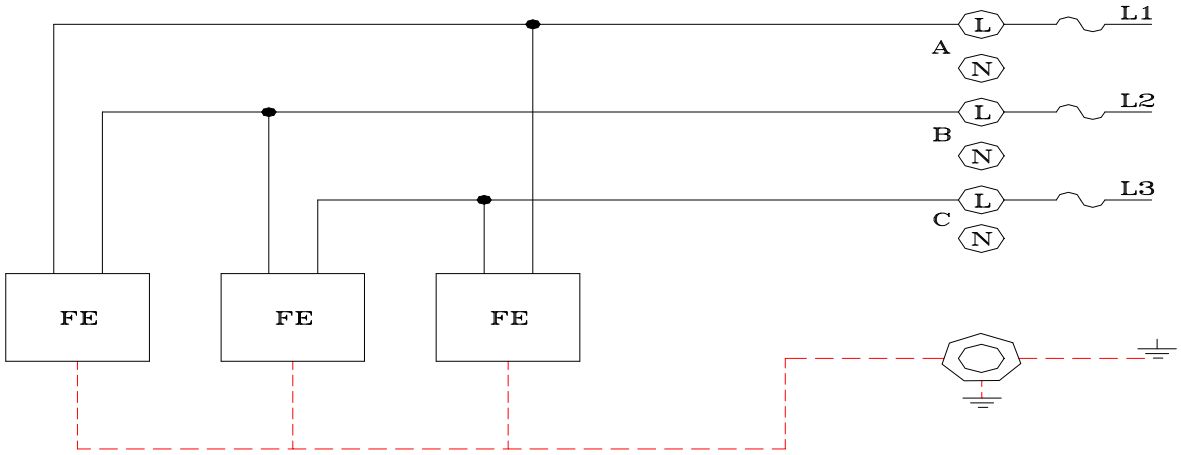


Figure 6. Three-Phase (Δ) Configuration L1, L2, L3, 120/208V Mains

CAUTION

Maximum nominal input is 230Vrms + 10%, phase to phase.
Higher voltages may damage the FE power modules.

Connection to the mains should be done strictly according to Figure 5. Wrong connection at the input may damage the FE power modules. An external fuse needs to be installed into each line.

7.0 AC SERVICE REQUIREMENT CALCULATIONS

Power available to a system is limited by the input service line, and safety regulations require that no single piece of equipment draw more than 80 percent of a branch circuit's rated current. To assure that the agency requirements will be met, calculate the input AC current. as follows:

- Sum the end load power.
- Divide the load powers by the DC-DC converter efficiencies to calculate the required distribution bus power;
- Divide the distribution bus power by the FE power module efficiency to calculate the required AC input power;
- Divide the AC input power by the power factor to calculate the required input volt-amperes (VA).
- Divide the VA by the input voltage to calculate the input current.

Make this calculation at each voltage at which the input current will be checked. Do not simply use the specified minimum value of power factor and efficiency without regard to the conditions under which they are specified.

The efficiency of an FE power module varies inversely with voltage. For a given power output, the input current will decrease as the voltage increases. This results in reduced losses and greater efficiency. The power factor, however, behaves just the opposite. The power factor will be the highest at the lowest input voltages and will decrease slightly as the voltage approaches the maximum input value.

Specifications for efficiency and power factor, however, are often given in terms of an absolute minimum. But these minimums occur at opposite ends of the input voltage range. So calculating input line current at these minimum values overstates the input current. In fact, the variations of these two parameters tend to cancel each other so that the ratio of output power to input VA remains nearly constant over the input voltage range.

Therefore, to provide the maximum power from a given input line without exceeding its rating, FE power shelf specifications give a maximum input current versus line voltage at

full rated output. Based on these specifications, the tables in Appendix D give the maximum input current for all combinations of FE power modules and shelves.

8.0 DC OUTPUT

8.1 Output Voltage

The FE power shelf is designed to supply a single distribution output voltage (contact factory for multiple bus options). Depending on the exact selection of FE power module which is capable of providing one of the following output voltages:

48 VDC output voltage with an adjustment range between 40 VDC and 58 VDC
24 VDC output voltage with an adjustment range between 20 VDC and 29 VDC

8.2 Output Current

Each slot in the power shelf has the capability for two sets of contacts (+V, -V) for output current. Each contact is capable of continuously carrying 50 A. (Output busbar current max is 300 A.) Table 8 gives the power shelf's maximum rated output current.

NOTE

For operation at 85 VAC, derate the output of the rack to 80 percent of Iout.

8.3 Output Voltage and Connection To Chassis Ground

The FE power shelf DC output connection is available on two tabs that are an integral part of the output busbar. These tabs have clearance holes that accept ¼-in. hardware (not included). The user is free to terminate the output voltages as desired. Strapping together +V and GND makes a negative voltage supply; strapping together -V and GND makes a positive voltage supply. The outputs may also be left unstrapped for an output that "DC floats with respect to" and is "RF shorted to" ground.

8.4 Monitoring and Control Signals

The FE power shelf has one monitoring and one control signal connector for each FE power module. The pinout is identical on all connectors and is listed in Tables 9 - 12.

Table 8. Power Shelf Maximum Rated Output Current

Shelf Version	*Power Module*	*# of Modules*	*Io_{MAX} / Module*	*Io_{MAX} / Shelve*
FE4K-XE	FE-500-24	8	25A	200A
	FE-500-48	8	12.5A	100A
FE4K-NE	FE-500-24	7	25A	175A
	FE-500-48	7	12.5A	87.5A
FE4K-LE	FE-500-24	5	25A	125A
	FE-500-48	5	12.5A	62.5A
FE5K-XE	FE-1000-24	5	50A	250A
	FE-1000-48	5	25A	125A
FE5K-NE	FE-1000-24	4	50A	200A
	FE-1000-48	4	25A	100A
FE5K-LE	FE-1000-24	3	50A	150A
	FE-1000-48	3	25A	75A
FE6K-XE	FE-1500-24	3	75A	225A
	FE-1500-48	3	37.5A	112.5A
	FE-2000-24	3	91A	273A
	FE-2000-48	3	50A	150A
FE6K-NE	FE-1500-24	3	75A	225A
	FE-1500-48	3	37.5A	112.5A
	FE-2000-24	3	91A	273A
	FE-2000-48	3	50A	150A
FE6K-LE	FE-1500-24	2	75A	150A
	FE-1500-48	2	37.5A	75A
	FE-2000-24	2	91A	182A
	FE-2000-48	2	50A	100A

Table 9. Monitoring Signal Connector (Jx3)

Pin #	*Designation*	*Description*
1	***Imon (+)***	Output Current monitoring terminal. A 0 to 1Volt signal with respect to Imon (-) indicating 0% to 100% Output Current for the Power Module
2	***Imon (-)***	Return Pin for the Imon(+).
3	***+Vaux***	A +12Vdc @ 50mA auxiliary power supply intended to support external housekeeping circuitry (Alarms, LED's etc.).
4	***-Vaux***	Return Pin for the +Vaux
5	***AC Good 1***	Open Collector signal indicating that a Fault condition has occurred on the AC Line. This pin represents the collector of the internal opto-transistor capable of sinking up to 5mA with 20Vdc maximum applied from collector to emitter.
6	***AC Good 2***	Represents the emitter of the internal opto-transistor.
7	***DC Good 1***	Conductance signal optically coupled which indicates that delivered output voltage, as measured at the +V & -V output terminals. This pin represents the collector of the internal opto-transistor capable of sinking up to 5mA with 20Vdc maximum applied from collector to emitter.
8	***DC Good 2***	Represents the emitter of the internal opto-transistor.
9	***OT Shut 1***	Open Collector signal indicating that an Over-temperature condition has occurred. This pin represents the collector of the internal opto-transistor capable of sinking up to 5mA with 20Vdc maximum applied from collector to emitter.
10	***OT Shut 2***	Represents the emitter of the internal opto-transistor.
11	***+ LS***	Sensing connection to +V terminal of the Power Module.
12	***- LS***	Sensing connection to -V terminal of the Power Module.
13	***N/C***	No Connection
14	***N/C***	No Connection

Table 10. Control Signal Connector (Jx2)

Pin #	*Designation*	*Description*
1	***+ LS***	Sensing connection to +V terminal of the Power Module.
2	***- LS***	Sensing connection to -V terminal of the Power Module.
3	***+ S***	Sense connection to +V terminal. This connection is already made in the factory between Pin #3 and Pin #1 for Local Sense. (*****)
4	***- S***	Sense connection to -V terminal. This connection is already made in the factory between Pin #4 and Pin #2 for Local Sense. (*****)
5	***N/C***	No Connection
6	***-S***	Sense connection to -V terminal.
7	***Ishare***	Current Share Bus. This connection is already made between each slot in the factory to ensure current sharing between all slots within the same shelve. Connect this pin between shelves to ensure current sharing between shelves.
8	***PROG***	This pin allows for Remote/External resistive Programming. This pin is jumped to pin #6 (-S) in the Factory for Front Panel Programming.
9	***LOCK 1***	Remote ON/OFF feature. This pin is jumped to LOCK 2 in the factory A logic level Low or a direct short to LOCK 2 will enable the output. A logic level High or an open circuit to LOCK 2 will disable the output.
10	***LOCK 2***	Return Pin for the LOCK 1

(*) The output Voltage will regulate when all the Sense Jumpers are installed.

Table 11. Low Voltage Disconnect Monitoring Signal Connector (Jx5)

Pin #	*Designation*	*Description*
1	***Battery +Vs***	Sense connection to Positive Battery terminal.
2	***Battery -Vs***	Return Pin for the ***Battery +Vs***
3	***System Current 1***	System Current connection to Positive Shunt terminal.
4	***System Current 2***	Return Pin for the ***System Current 1***
5	***Bat. Dis. Alarm 1***	Open Collector signal indicating that the Battery has been disconnected from the Load. This pin represents the collector of the internal opto-transistor capable of sinking up to 5mA with 20Vdc maximum applied from collector to emitter.
6	***Bat. Dis. Alarm 2***	Represents the Emitter of the internal opto-transistor.
7	***Low Bat. Alarm 1***	Open Collector signal indicating that the Battery Voltage has fallen bellow the float voltage range and is between 2.00 to 2.06 volts per cell. This pin represents the collector of the internal opto-transistor capable of sinking up to 5mA with 20Vdc maximum applied from collector to emitter.
8	***Low Bat. Alarm 2***	Represents the Emitter of the internal opto-transistor.
9	***Battery Maint. 1***	This signal is an optically isolated pair that mimics a relay contact closure. Leaving the signal open has no effect on the output. For 5.0 volts into this terminals floating with respect to chassis reduces output voltage to a level set by the operator that is bellow the normal output voltage. A trim pot in the front panel is provided for battery maintenance set voltage.
10	***Battery Maint. 2***	Return Pin for the ***Battery Maint. 1***
11	***AC Fail 1***	Open Collector signal indicating a global warning in the case of a single or multiple AC failures of any FE power module in the system. This pin represents the collector of the internal opto-transistor capable of sinking up to 5mA with 20Vdc maximum applied from collector to emitter.
12	***AC Fail 2***	Represents the Emitter of the internal opto-transistor.
13	***DC Fail 1***	Open Collector signal indicating a global warning in the case of a single or multiple DC failures of any FE power module in the system. This pin represents the collector of the internal opto-transistor capable of sinking up to 5mA with 20Vdc maximum applied from collector to emitter.
14	***DC Fail 2***	Represents the Emitter of the internal opto-transistor.

Table 12. Power Module Monitoring and Control Connector (Px1)

Pin #	*Designation*	*Description*
1	***+S***	+ Sense Connection. Connect to +V terminal of Load for Remote sensing. Connect to +LS for Local sensing.
2	***- LS***	Sensing connection to -V terminal of the Power Module.
3	***PROG***	Jumper to Pin 15 (-S) for front panel programming. For remote, external programming via insertion of resistor between the Programming pin and pin 15 (-S).
4	***Imon (+)***	Output Current monitoring terminal. A 0 to 1Volt signal with respect to Imon (-) indicating 0% to 100% Output Current for the Power Module
5	***+Vaux***	A +12Vdc @ 50mA auxiliary power supply intended to support external housekeeping circuitry (Alarms, LED's etc.).
6	***LOCK 1***	Functions to enable and disable the inverter of the power supply. A Logic Level low from zero to 1.5 volts or a direct short to pin 19 (LOCK 2) through a contact closure will enable the unit. A Logic Level high from a minimum 3.8 volts or higher or an open circuit to pin 19 (LOCK 2) will disable the power supply.
7	***N/C***	No Connection
8	***N/C***	No Connection
9	***N/C***	No Connection
10	***N/C***	No Connection
11	***AC Good 2***	Represents the emitter of the internal opto-transistor.
12	***DC Good 2***	Represents the emitter of the internal opto-transistor.
13	***OT Shut 2***	Represents the emitter of the internal opto-transistor.
14	***+ LS***	Sensing connection to +V terminal of the Power Module.
15	***-S***	- Sense Connection. Connect to -V terminal of Load for Remote sensing. Connect to -LS for Local sensing.
16	***ISHARE***	Current Share Bus.
17	***Imon (-)***	Return Pin for the Imon(+).
18	***-Vaux***	Return Pin for the +Vaux
19	***LOCK 2***	Return Pin for the LOCK 1
20	***CH GND***	Represents the Chassis Ground Terminal.
21	***N/C***	No Connection
22	***N/C***	No Connection
23	***AC Good 1***	Open Collector signal indicating that a Fault condition has occurred on the AC Line. This pin represents the collector of the internal opto-transistor capable of sinking up to 5mA with 20Vdc maximum applied from collector to emitter.
24	***DC Good 1***	Conductance signal optically coupled which indicates that delivered output voltage, as measured at the +V & -V output terminals. This pin represents the collector of the internal opto-transistor capable of sinking up to 5mA with 20Vdc maximum applied from collector to emitter.
25	***OT Shut 1***	Open Collector signal indicating that an Over-temperature condition has occurred. This pin represents the collector of the internal opto-transistor capable of sinking up to 5mA with 20Vdc maximum applied from collector to emitter.

9.0 SAFETY

The FE power shelf is designed to allow operator access from the front of the unit only. Access to the rear of the power shelf must be restricted to skilled service personnel. There are no shock hazards accessible from an empty, partially filled or completely filled shelf for any configuration of power modules.

Energy hazards, however, are accessible on the rear of the power shelf wherever the output bus is available. Any covers, removed for servicing, must be replaced before system is put into operation.

WARNING

Precautions must be taken to prevent unskilled personnel access to these areas.

9.1 Leakage Current

WARNING

High leakage current. Earth connection essential before connecting supply.

All leakage current specifications are with an AC input voltage of 265 $V_{AC_{RMS}}$, at a line frequency of 50Hz and a temperature of 25°C. See Table 13.

Table 13. Leakage Current Maximums

FE Power Shelf	*Maximum Leakage Current*
FE4K	22.40mA
FE5K	15.75mA
FE6K	10.20mA

10.0 AGENCY APPROVALS

10.1 Underwriter's Laboratories

The FE Power Shelf Series is recognized to UL-1950.

10.2 Canadian Standards Association

The FE Power Shelf Series is certified to CSA 22.2 No. 950-95.

10.3 European Approval

The FE Power Shelf Series is approved to EN 60 950 through TUV Rheinland.

10.4 Other

CE marking, when applied to a product covered by this manual, indicates compliance with the Low Voltage Directive (73/23/EEC) as modified by the CE Marking Directive (93/68/EEC) in that it complies with EN60950/IEC60950.

11.0 EMISSIONS

11.1 Conducted

11.1.1 Federal Communications Commission (FCC). The FE power shelf complies with FCC-CFR, Part 15, subpart B, Class B in the -NE version and FCC-CFR, part 15, Class A in the -XE version.

11.1.2 CISPR. The FE power shelf complies with CISPR 22, Class B in the -NE version and CISPR 22, Class A in the -XE version..

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11.2 Radiated

11.2.1 FCC. The FE power shelf complies with FCC-CFR, Part 15, subpart B, Class A. *Exception Note: The present design of the power shelf has not been certified to this specification. Please contact the factory for the latest information.*

APPENDIX A

OUTLINE DRAWINGS

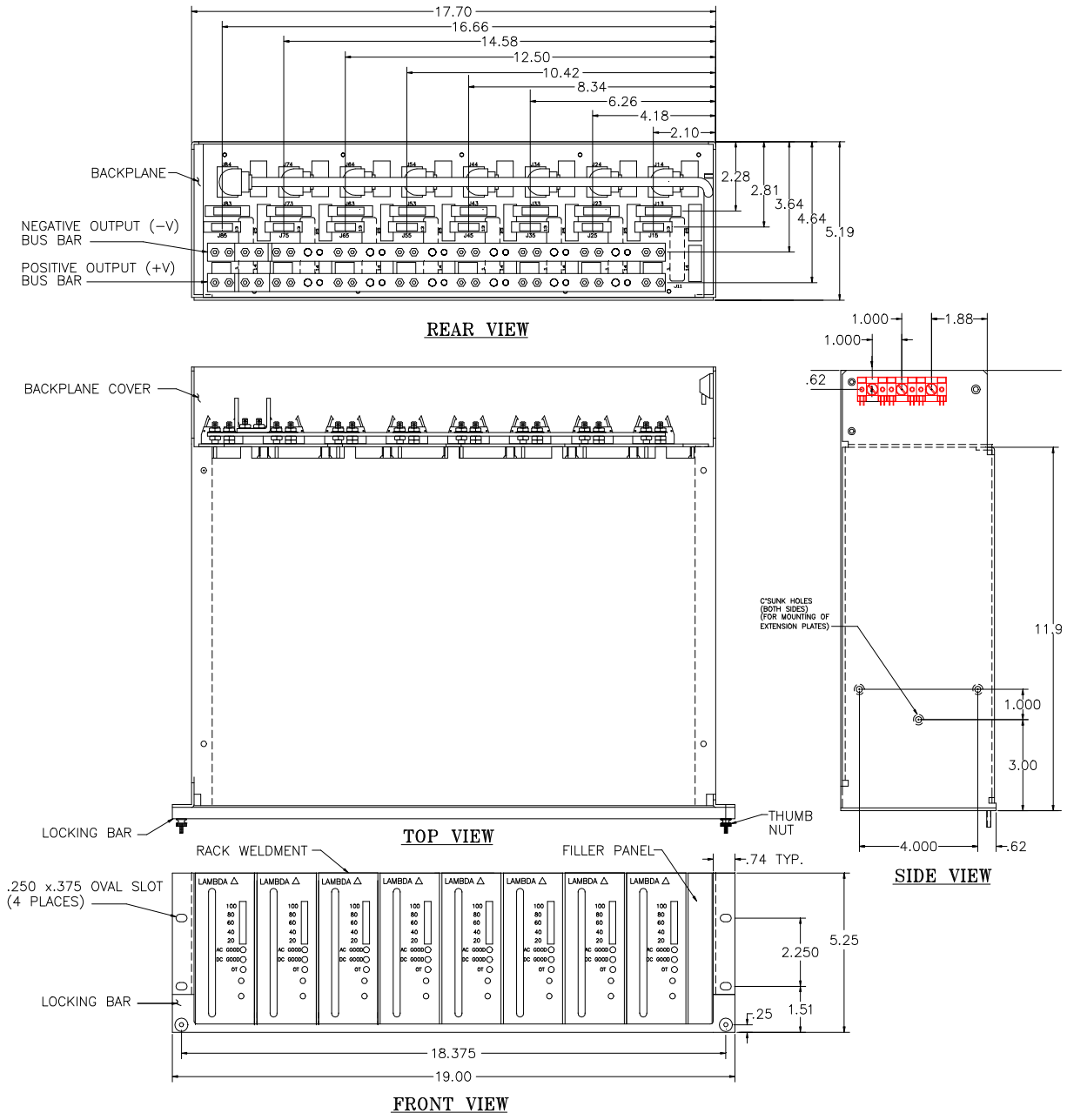


Figure A-1. Outline Drawing of FE4K-XE Power Shelf

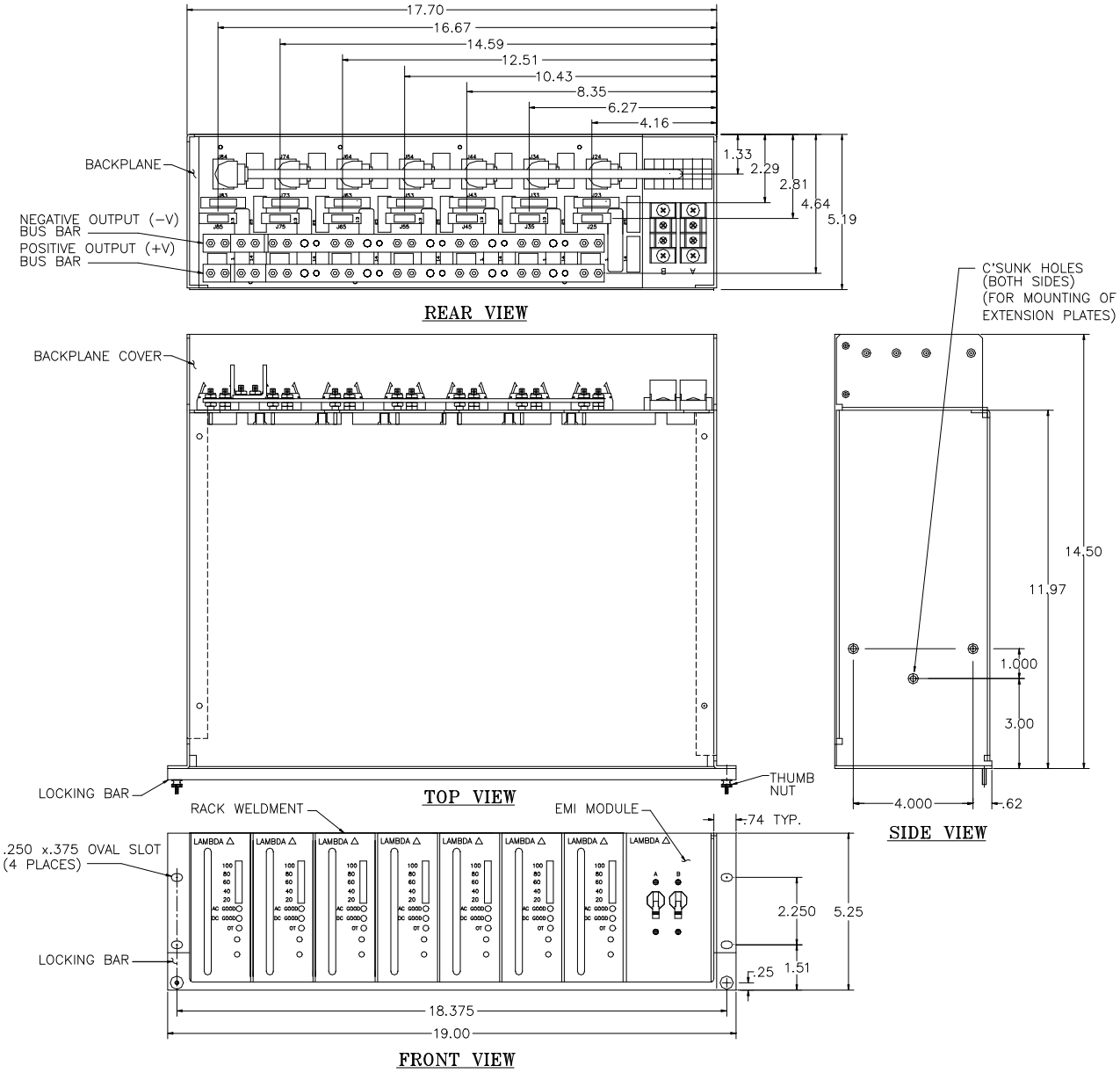


Figure A-2. Outline Drawing of FE4K-NE Power Shelf

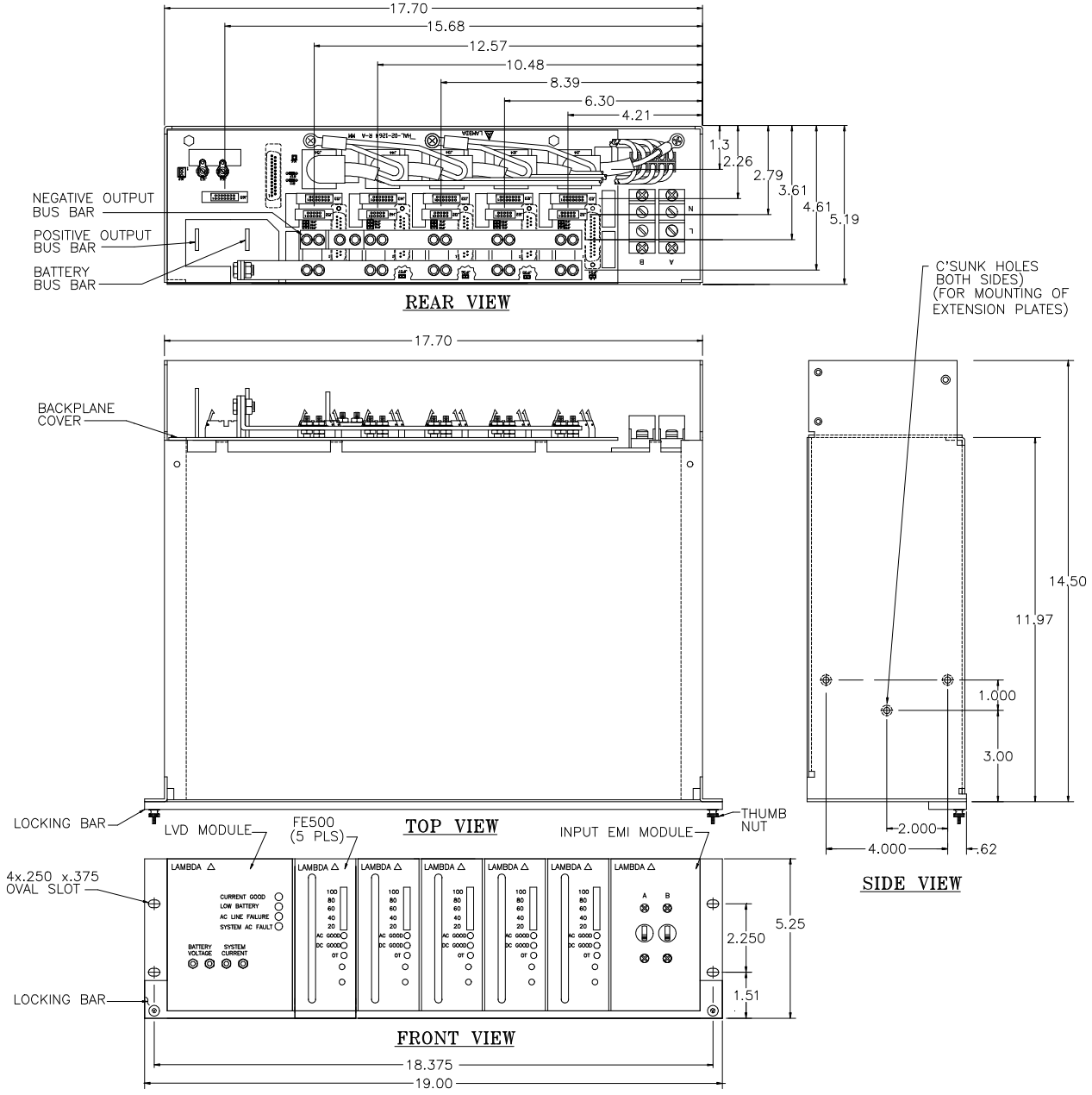


Figure A-3. Outline Drawing of FE4K-LE Power Shelf

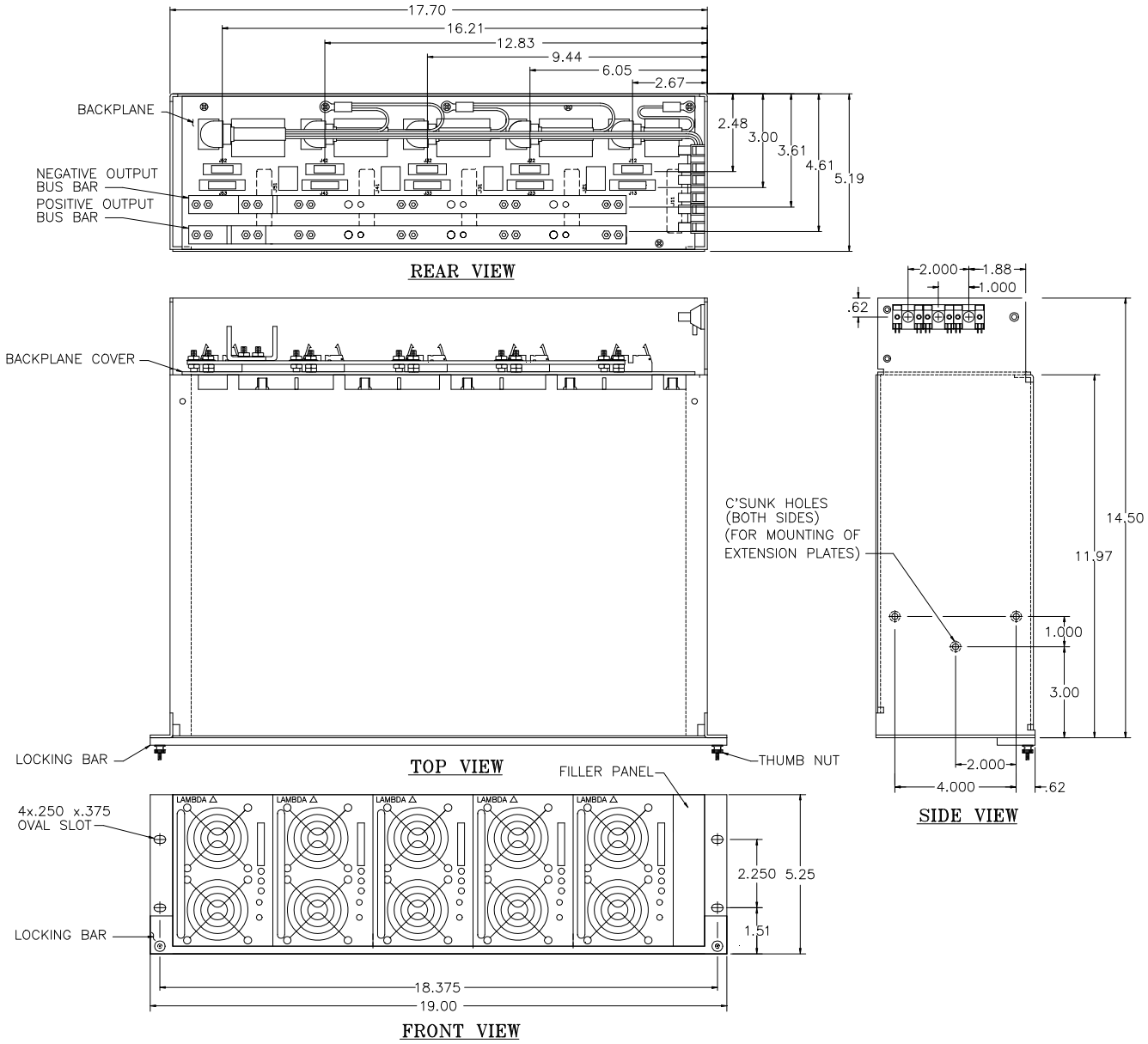


Figure A-4. Outline Drawing of FE5K-XE Power Shelf

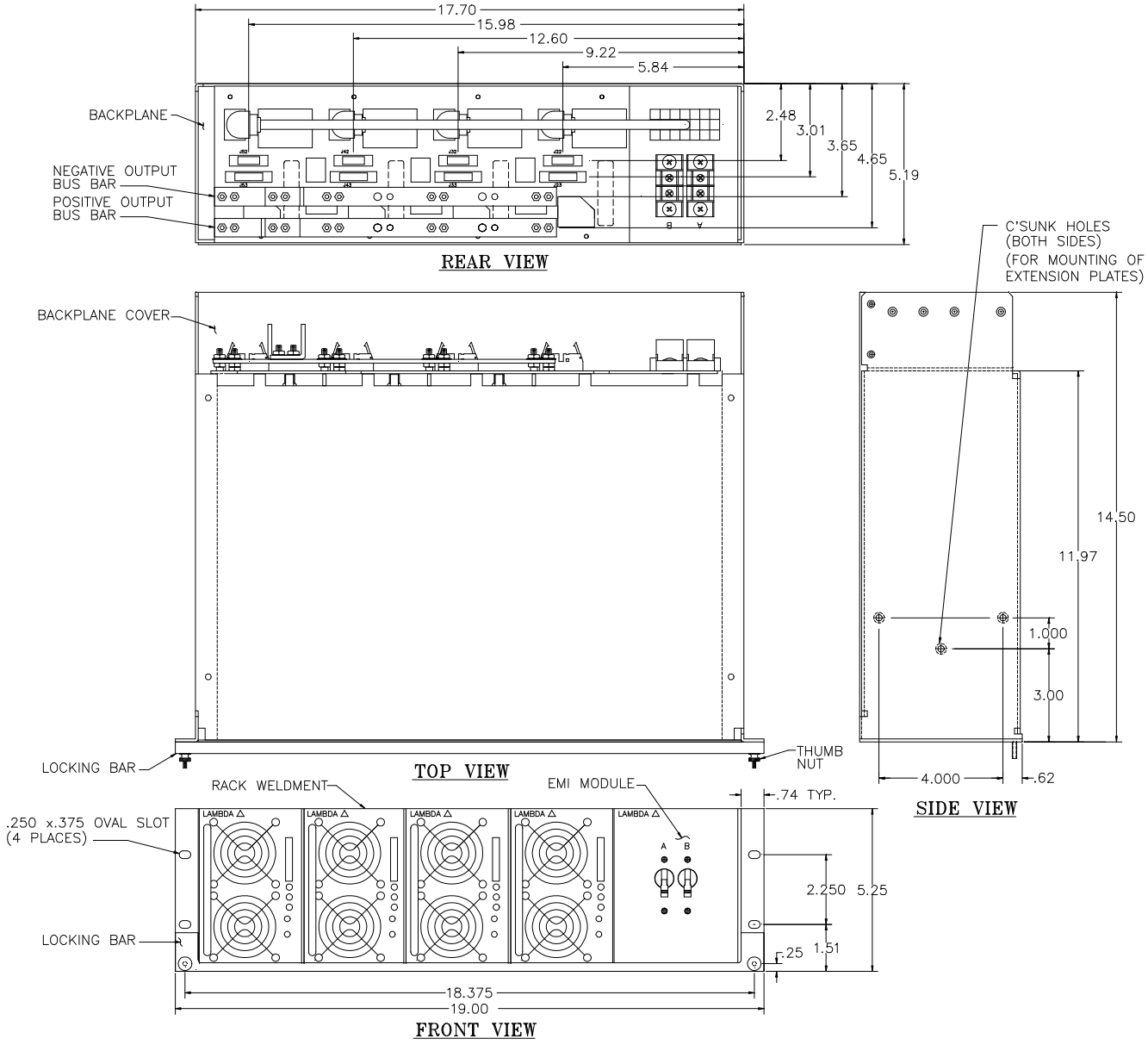


Figure A-5. Outline Drawing of FE5K-NE Power Shelf

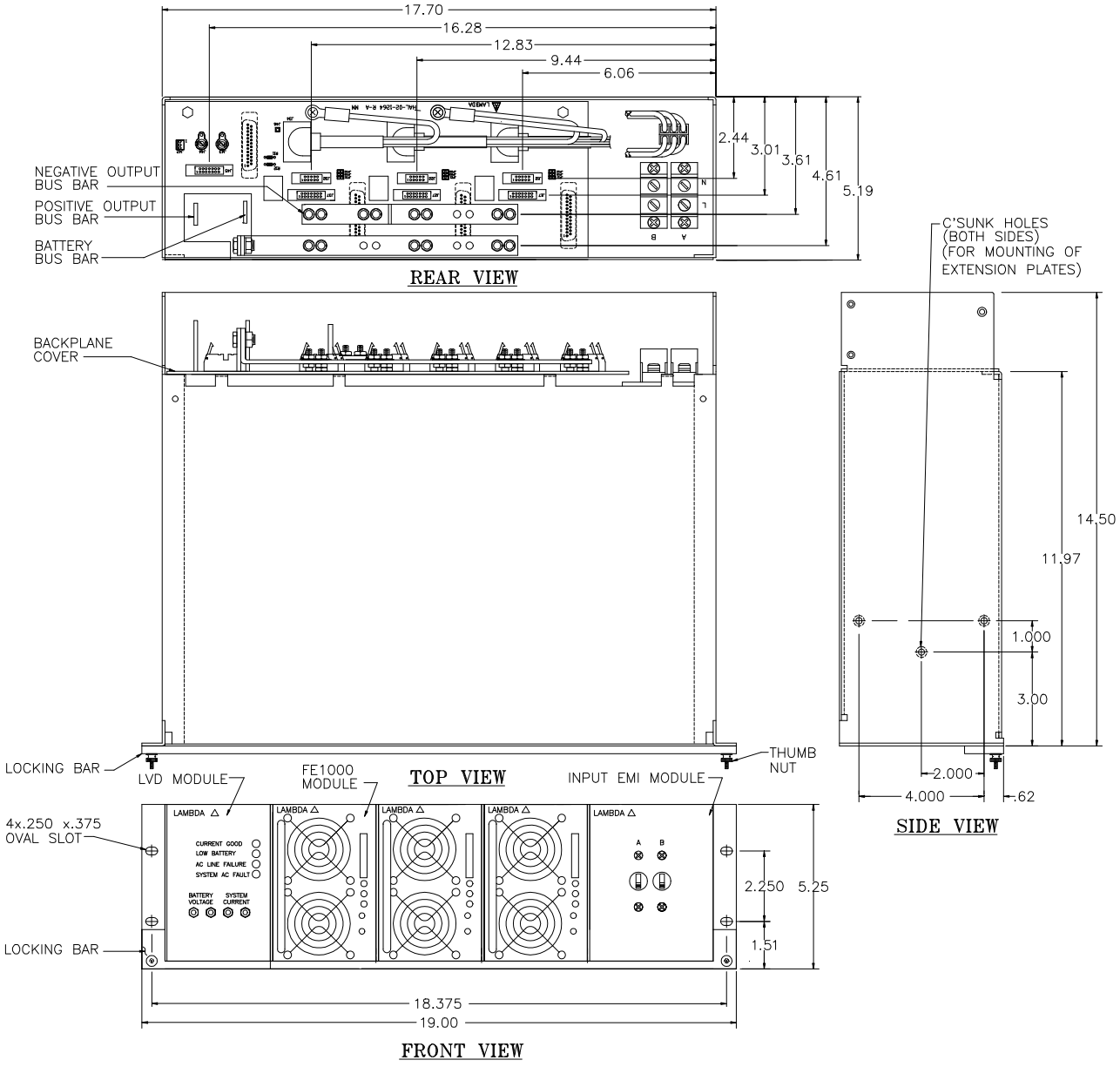


Figure A-6. Outline Drawing of FE5K-LE Power Shelf

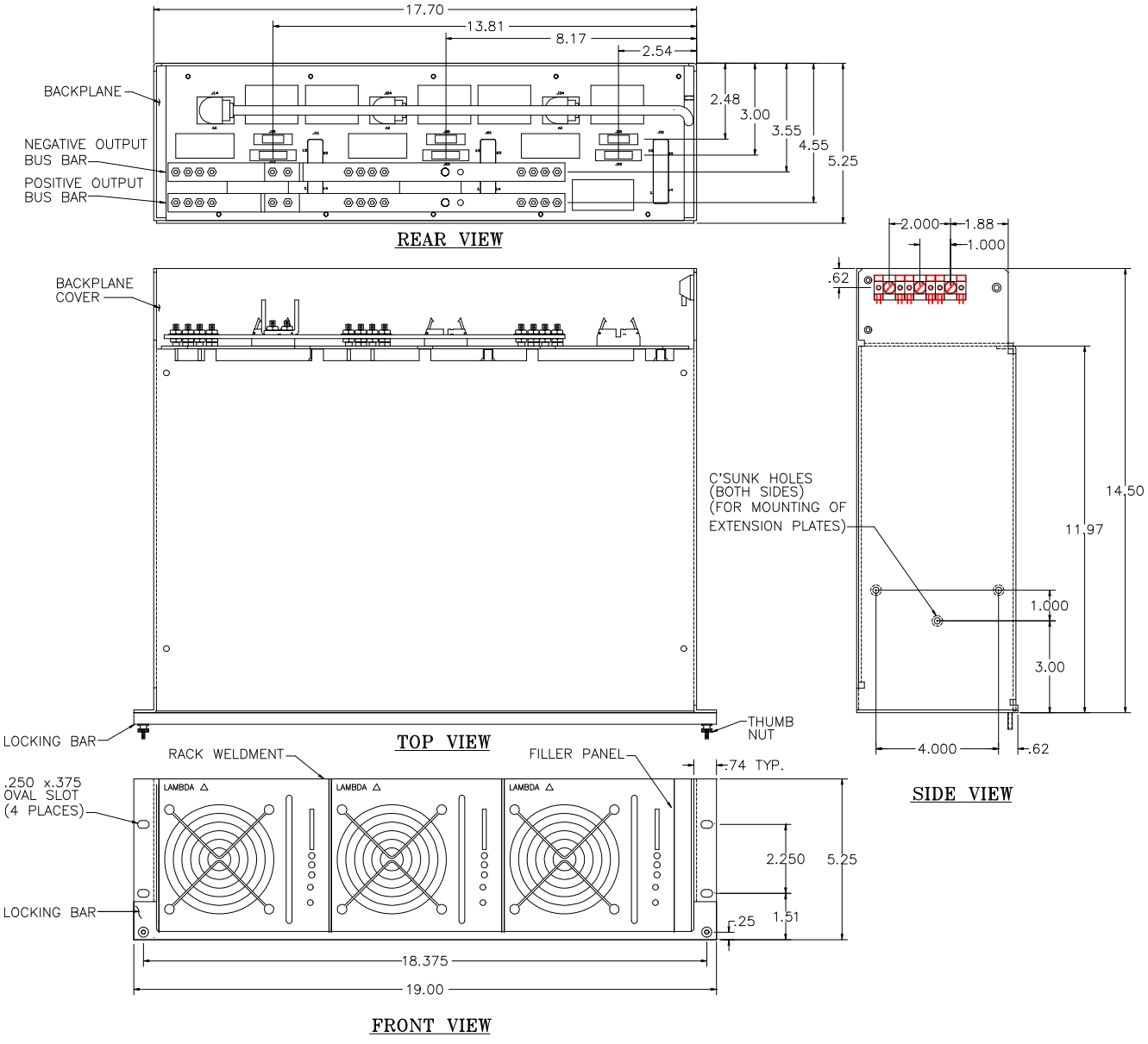


Figure A-7. Outline Drawing of FE6K-XE Power Shelf

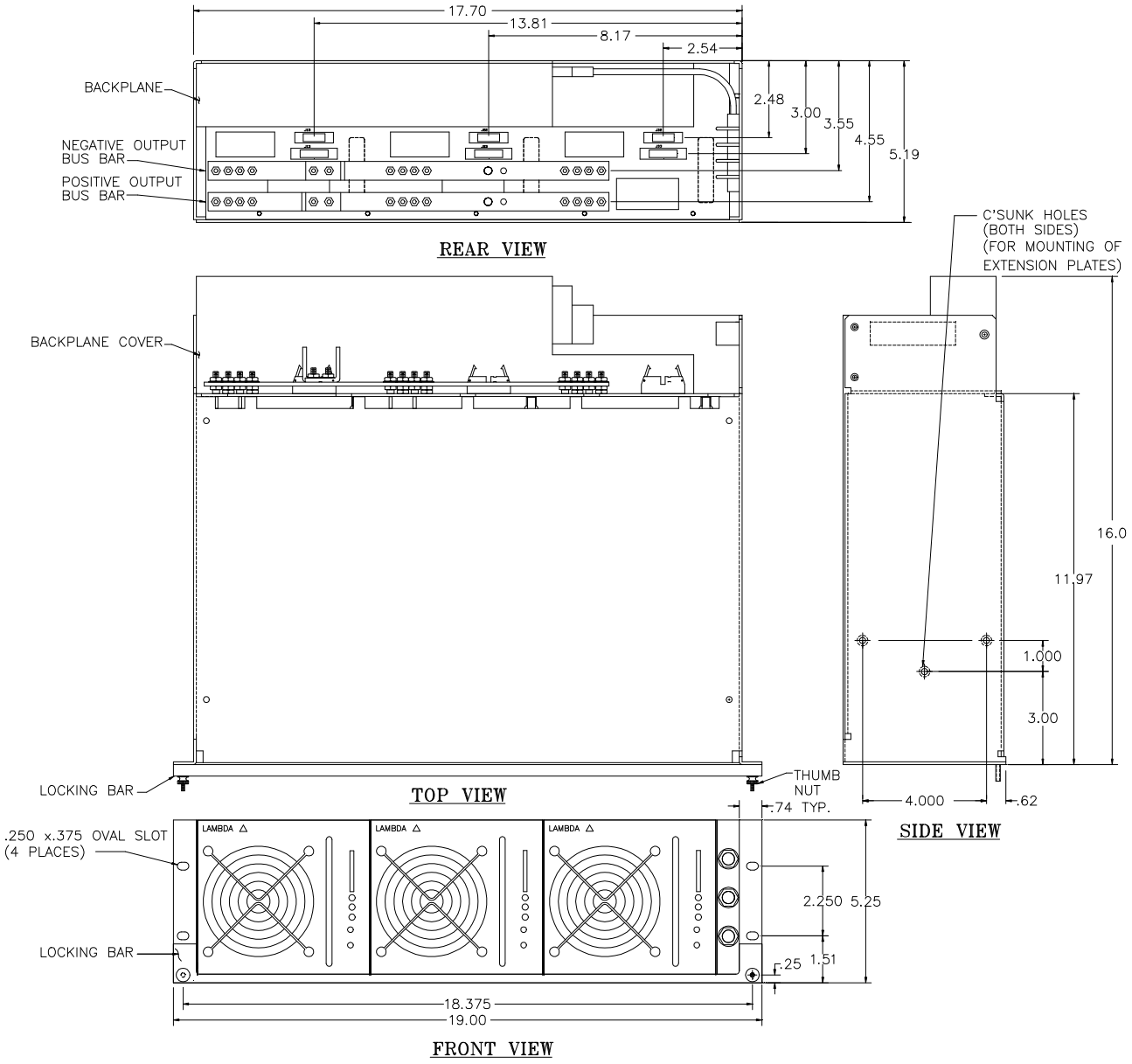


Figure A-8. Outline Drawing of FE6K-NE Power Shelf

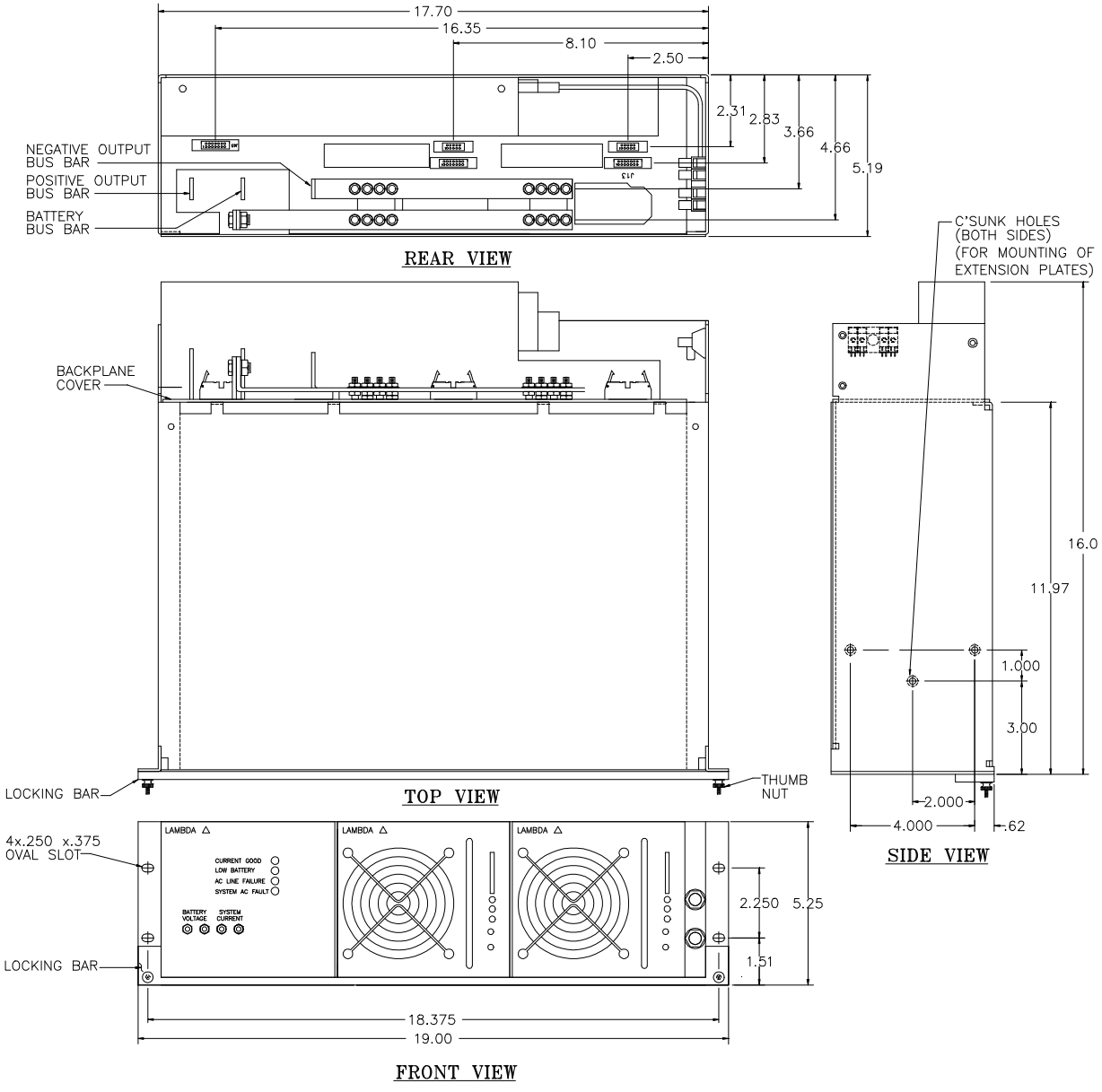


Figure A-9. Outline Drawing of FE6K-LE Power Shelf

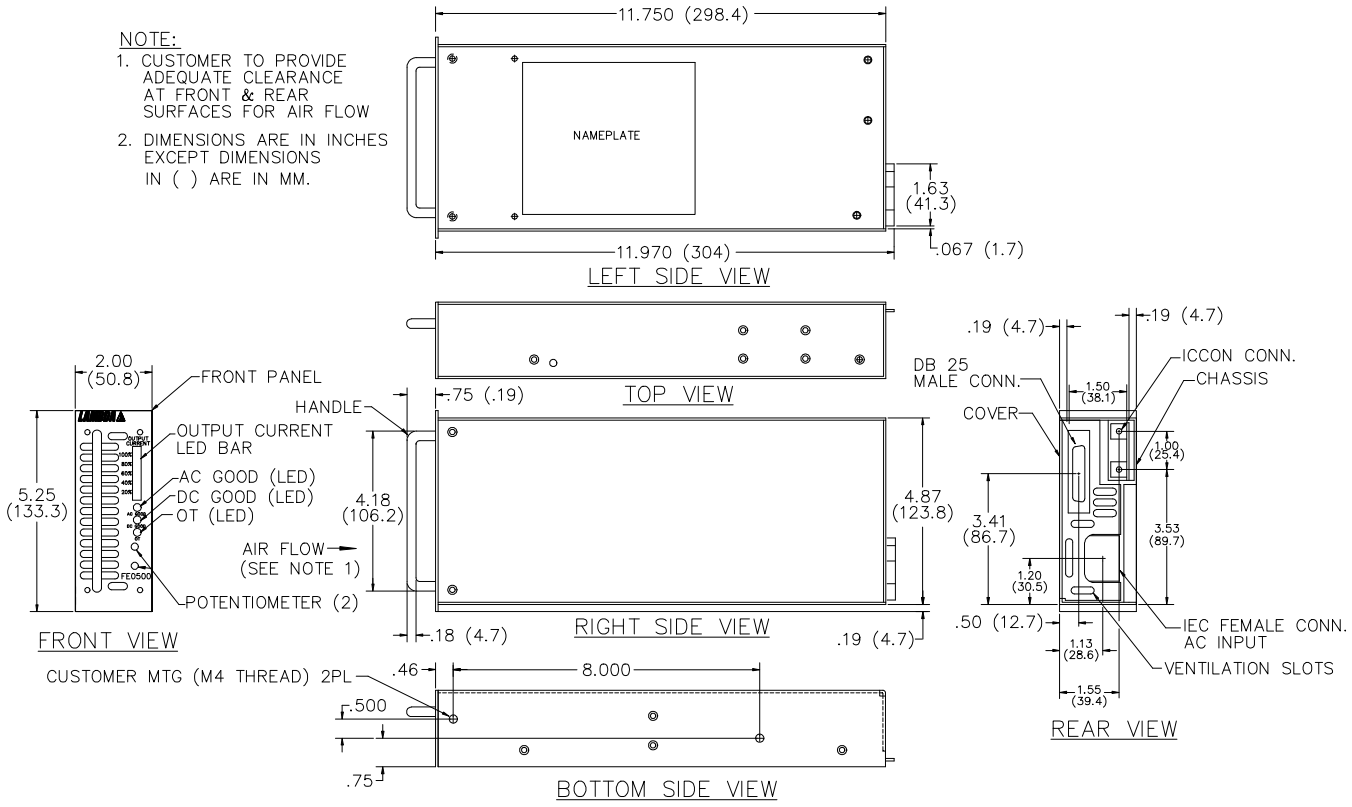


Figure A-10. Outline Drawing of FE500 Power Module

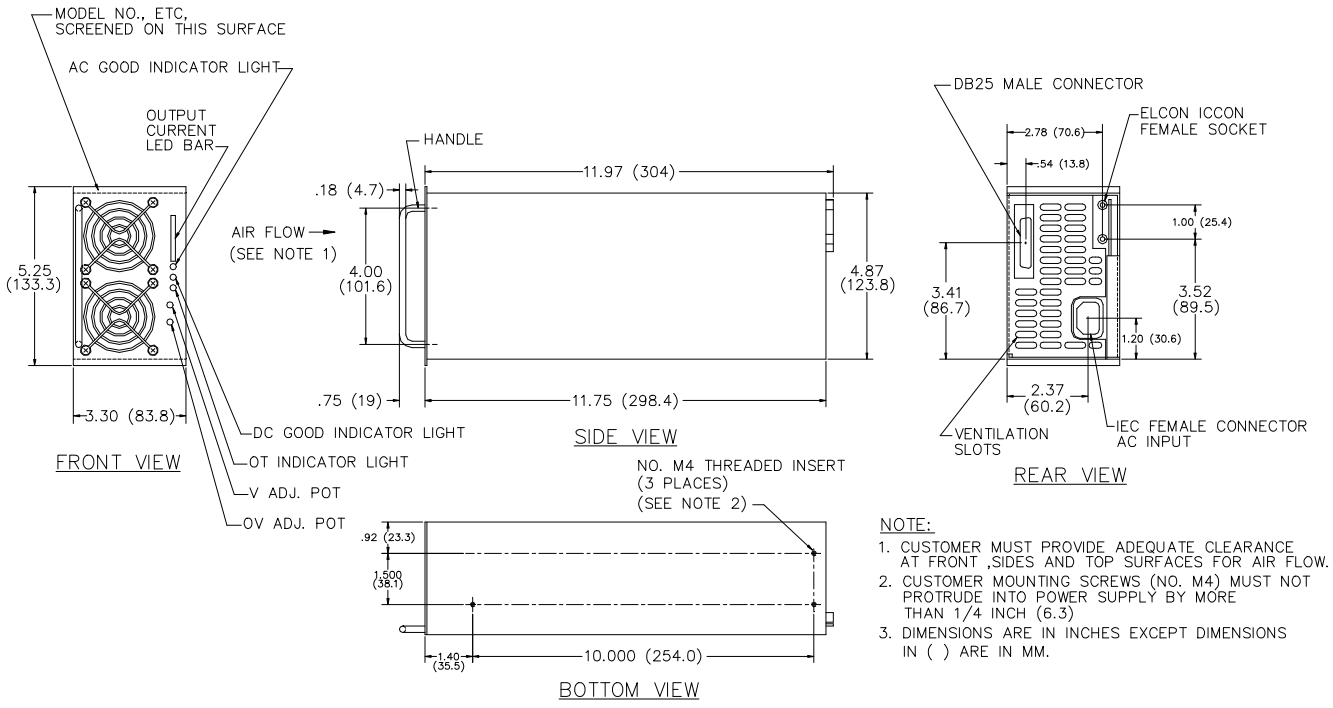


Figure A-11. Outline Drawing of FE1000 Power Module

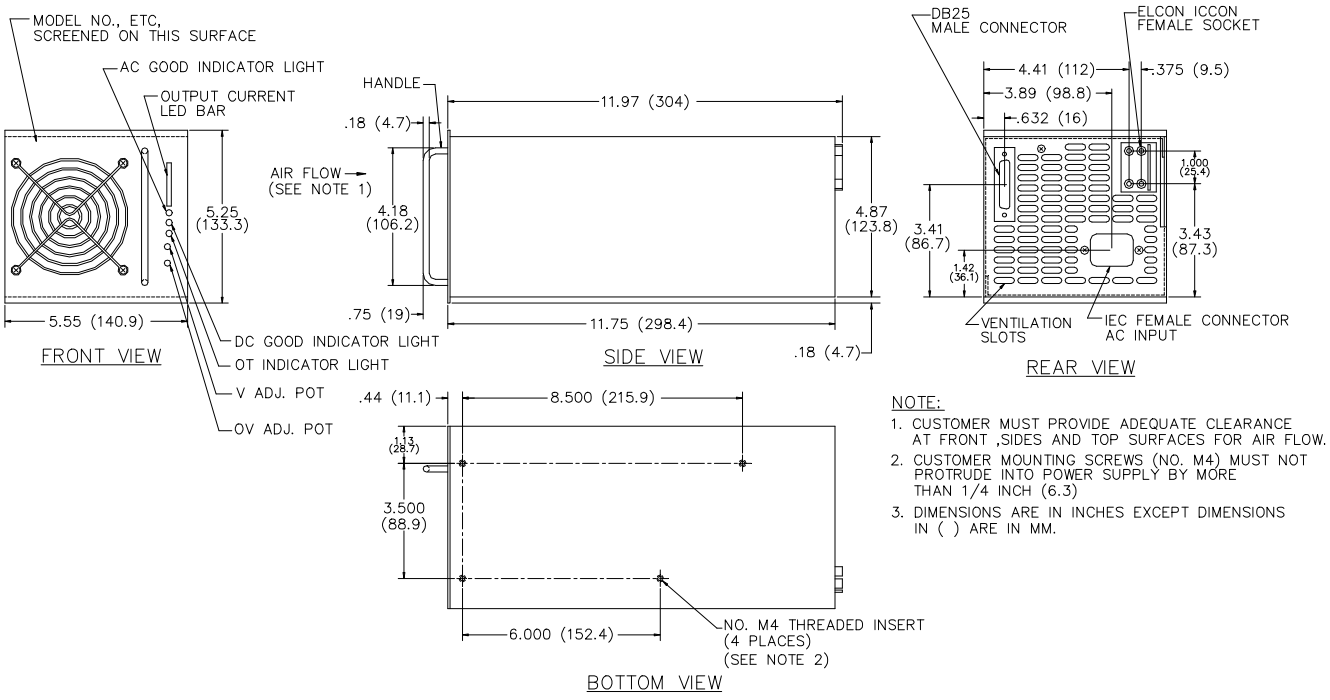
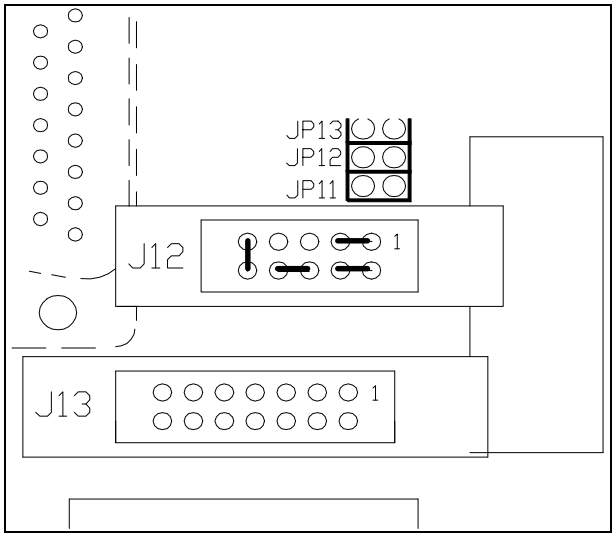


Figure A-12. Outline Drawing of FE1500/2000 Power Module

APPENDIX B

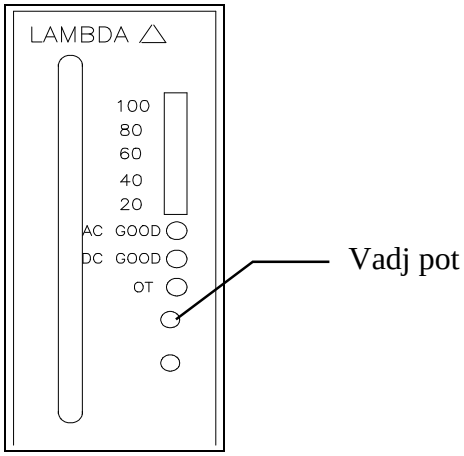
CURRENT SHARE CALIBRATION OF FE POWER MODULES

When operating FE power modules in parallel it is necessary to calibrate the FE power module output voltages as close to each other as possible in order to ensure proper current sharing.
The output voltages must be calibrated separately under the same load to within +/- 100mV. Follow the procedures below to calibrate the FE power shelf:
Configure Control Signal Connector **(Jx2)** as shown.



Connect a load to the output bus bars. Be sure that it is within the ratings of the (single) FE power module being calibrated.
Apply AC and monitor the voltage on the output bus bars on the backplane of the FE power shelf.

Adjust the voltage via the Vadj pot on the front panel of the FE power module being calibrated to +/-100mV of nominal output voltage.



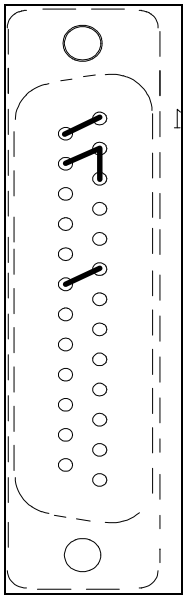
Remove the calibrated FE power module and apply these steps to all FE power modules being used in the same FE power shelf.

Note: -Once the units are calibrated separately do not attempt to adjust their output
-If another voltage is desired on the output, the system must be recalibrated.

APPENDIX C

FE POWER MODULE TROUBLESHOOTING PROCEDURE

1. If troubleshooting a standalone unit, configure the DB25 connector on back of the FE power module as shown. If troubleshooting in the FE power shelf, the shelf is already configured properly from the factory. (Do not attempt to change configuration of connectors on back panel of rack.)



2. Insert one FE power module into slot 1 (left slot) if using shelf.

3. Apply AC power to unit under test (FE power module or FE power shelf) with no load connected.

a. Observe the AC GOOD and DC GOOD LED's on front panel of FE power module.
b. Observe that the fans are rotating.
c. Measure voltage on the output bus bars and adjust the output voltage to a nominal 24V or 48V output (depending on output rating).
d. If the output voltage is steady and adjustable and all features function properly, the FE power module is operational.
e. If the FE power module does not seem to be functioning properly, the FE power module may be damaged

NOTE

If the unit was tested in the FE power shelf, then the unit must be tested out of the shelf to confirm if the FE power module or FE power shelf is bad.

f. If the output is out of range, try turning the bottom pot on the front panel clockwise and observe output voltage. If nothing happens, then turn counter clockwise, at the same time, adjust the upper pot to see if the output is adjustable.

4. Apply a known load to the unit under test, verify the output voltage and the current bar on the front panel of the FE power module. It should indicate load percentage,

5. If testing is performed in the shelf and the module in slot 1 seems to be working, use the same module to test the rest of the slots.
a. Repeat step 3 for all slots, this will indicate an operational FE power shelf.
b. Then repeat step 3 in slot 1 for all modules. This will indicate if the modules are operational.

6. When all modules have tested OK, then repeat step 4 for multiple modules in parallel in the FE power shelf with a known good load. Be sure that the output voltages are set individually to the same nominal voltage (leave as adjusted in step 3).

Note:
If the module does not operate properly external to ***FE*** power shelf, this indicates an internal failure to the ***FE*** power module.
If the module does not operate in the ***FE*** power shelf, it must be tested external to confirm internal failure to the ***FE*** power module.
If the module works external to the shelf, but not in the shelf, this indicates a ***FE*** power shelf failure.
If the modules and the ***FE*** power shelf check out OK, this indicates load failure.

APPENDIX D

MAXIMUM AC INPUT CURRENT

Tables D-1 through D-3 list the maximum AC input current at full rated output for all FE power module and shelf combinations. The currents have been calculated for worst case conditions: 85 VAC input and worst case efficiency.

Table D-1. Maximum AC Input Current for FE4K Power Shelf Combinations

SYSTEM DESCRIPTION	*Input Line A*		*Input Line B*		*Input Line C*	
	No. of Modules	*Iin max*	*No. of Modules*	*Iin max*	*No. of Modules*	*Iin max*
FE4K-LE	2	15.5A	3	23.3A		
	2	15.5A	2	15.5A		
	2	15.5A	1	7.7A		
	1	7.7A	3	23.3A		
	1	7.7A	2	15.5A		
	1	7.7A	1	7.7A		
FE4K-NE	3	23.3A	4	31A		
	3	15.5A	3	23.3A		
	3	15.5A	2	15.5A		
	3	23.3A	1	7.7A		
	2	15.5A	4	31A		
	2	15.5A	3	23.3A		
	2	15.5A	2	15.5A		
	2	15.5A	1	7.7A		
	1	7.7A	4	31A		
	1	7.7A	3	23.3A		
	1	7.7A	2	15.5A		
	1	7.7A	1	7.7A		
FE4K-XE	3	23.3A	3	23.3A	2	15.5A
	3	23.3A	2	15.5A	2	15.5A
	3	23.3A	1	7.7A	2	15.5A
	2	15.5A	3	23.3A	2	15.5A
	2	15.5A	2	15.5A	2	15.5A
	2	15.5A	1	7.7A	2	15.5A
	1	7.7A	3	23.3A	2	15.5A
	1	7.7A	2	15.5A	2	15.5A
	1	7.7A	1	7.7A	2	15.5A
	3	23.3A	3	23.3A	1	7.7A
	3	23.3A	2	15.5A	1	7.7A
	3	23.3A	1	7.7A	1	7.7A
	2	15.5A	3	23.3A	1	7.7A
	2	15.5A	2	15.5A	1	7.7A
	2	15.5A	1	7.7A	1	7.7A
	1	7.7A	3	23.3A	1	7.7A
	1	7.7A	2	15.5A	1	7.7A
	1	7.7A	1	7.7A	1	7.7A

Table D-2. Maximum AC Input Current for FE5K Power Shelf Combinations

SYSTEM DESCRIPTION	*Input Line A*		*Input Line B*		*Input Line C*	
	No. of Modules	*Iin max*	*No. of Modules*	*Iin max*	*No. of Modules*	*Iin max**
FE5K-LE	1	15.4	2	30.8		
	1	15.4	1	15.4		
FE5K-NE	2	30.8	2	30.8		
	2	30.8	1	15.4		
	1	15.4	2	30.8		
	1	15.4	1	15,4		
FE5K-XE	2	30.8	2	30.8	1	15.4
	2	30.8	1	15.4	1	`5.4
	1	15.4	2	30.8	1	15.4
	1	15.4	1	15.4	1	15.4

** Maximum input current calculated under worst case efficiency and minimum AC line.*

Table D-3. Maximum AC Input Current for FE6K Power Shelf Combinations

SYSTEM DESCRIPTION	*Input Line A*		*Input Line B*		*Input Line C*	
	No. of Modules	*Iin max*	*No. of Modules*	*Iin max*	*No. of Modules*	*Iin max**
FE6K-LE w/ FE1500	1	23.3A	1	23.3A		
FE6K-NE w/ FE1500	1	23.3A	1	23.3A	1	23.3A
FE6K-XE w/ FE1500	1	23.3A	1	23.3A	1	23.3A
FE6K-LE w/ FE2000	1	14.3A	1	14.3A		
FE6K-NE w/ FE2000	1	14.3A	1	14.3A	1	14.3A
FE6K-XE w/ FE2000	1	14.3A	1	14.3A	1	14.3A

***** *Maximum input current calculated under worst case efficiency and minimum input AC line.*

APPENDIX E

MONITORING SIGNALS

The monitoring signals of the FE power shelf are all optically coupled conductance outputs. Each output is the transistor output stage of an optocoupler which conducts during a "good" status and opens in failure mode. Each output is isolated from the power supply output and from each other for voltages up to 500 VDC and from the AC input for voltages up to 3000 VAC.

The operation of the Monitoring Signals is as follows:

AC Good Signal: Indicates adequate input capacitor voltage to provide 5 milliseconds of holdup time when the supply is at Po max. This threshold is independent of the AC input line.

DC Good Signal: Indicates power supply's inverter is functional and output voltage is within specified limits.

With the addition of a few external components, custom monitoring of the power supply can be accomplished. A simple approach to fault monitoring is shown in Figure E-1. In this figure, a "daisy chain" circuit has been implemented which uses a minimum number of external components. Alternatively, a separate limiting resistor and LED can be used for each alarm, or the conductance output can be used to drive external circuitry.

The LED in the figure will remain illuminated as long as all the failure alarms remain in conducting "good" state. If a fault of any kind should occur within the power supply, the LED will extinguish.

This same approach can be used in a parallel/redundant application for "N" number of power supplies. Figure E-2 illustrates this approach where one fault signal indicates the status of multiple power supplies.

The auxiliary power supply in the figure must be chosen with a high enough output voltage to overcome the voltage drops created by each transistor output stage. The voltage drop of each output can be as high as 0.4 VDC. Assuming an LED drop of 1.0 Volt, the output voltage of the auxiliary supply should be set greater than three times the individual voltage drop of each optocoupler (0.4 volts), multiplied by the number of supplies used (N), plus the LED drop.

The optocouplers used in the power supply have a maximum VCEO of 30 volts. This limits Vout of the bias supply to less than 30 volts. Due to this limitation, the maximum

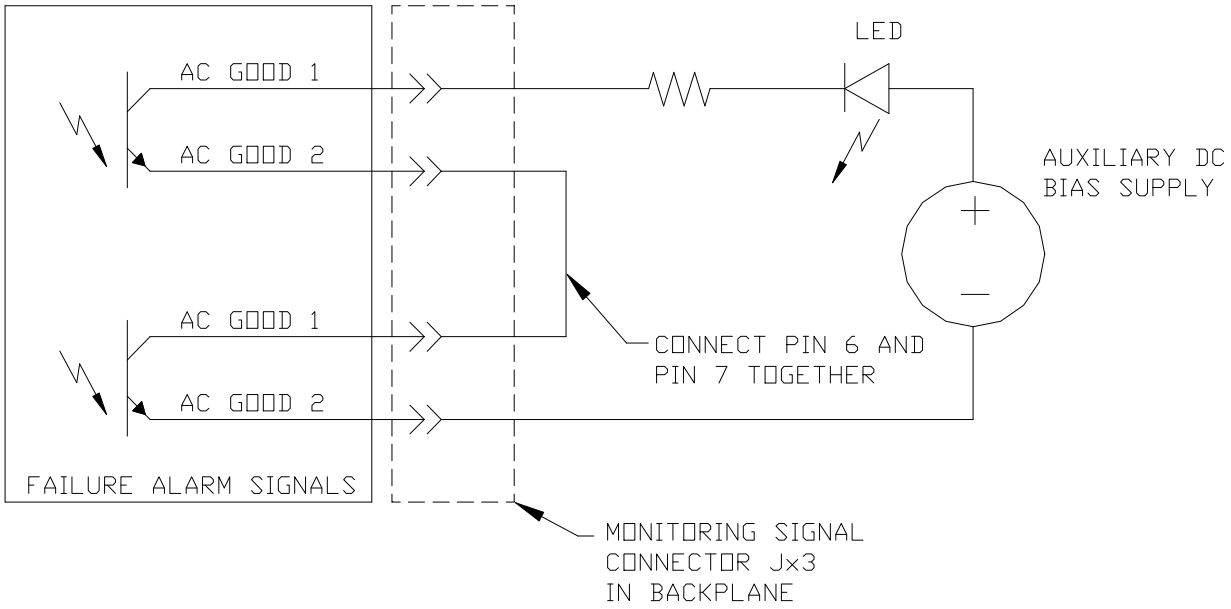


Figure E-1. Basic Fault Monitoring Circuit

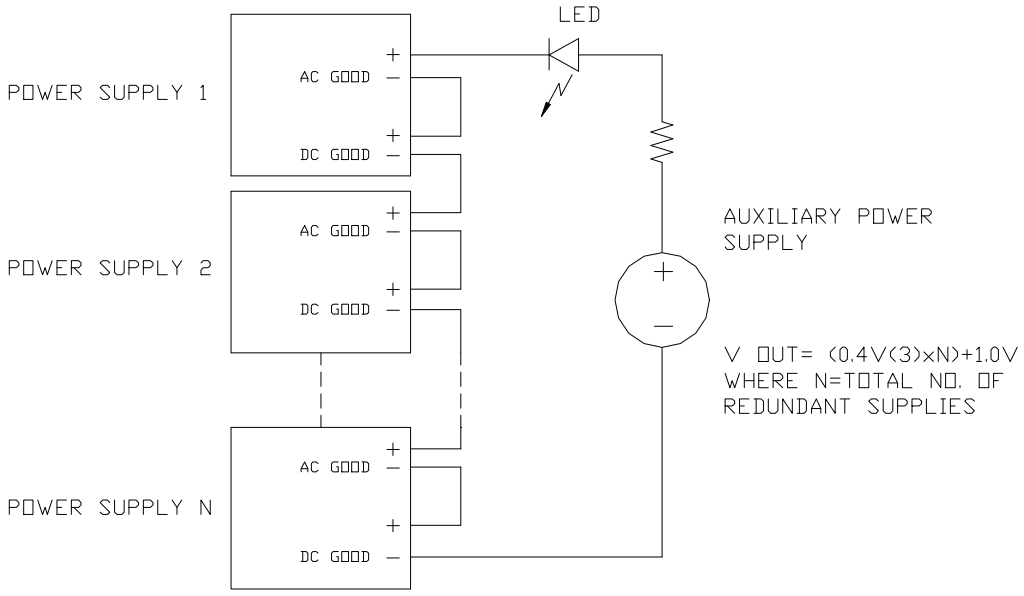


Figure E-2. Fault Monitoring of Multiple Power Supplies

number of power supplies that may be employed using this method is eight. The resistor can be used to limit the current through the LED and optocoupler outputs. The current should be limited to no more than 5 mA.

Another approach, which is not limited by the maximum current allowed by the optocouplers, is illustrated in Figure E-3. By adding a PNP transistor and biasing resistors, the daisy chain circuit illustrated previously in Figure E-2 can be expanded to drive greater loads. The LED shown in the figure can easily be replaced with a lamp, relay, or audible alarm, if Q1 and the bias supply can handle the current load.

If individual indicators for each failure signal are desired, either circuit approach can be used for individual failure alarm output. The failure monitoring circuitry integrated into the FE power module provides the flexibility for a system designer to easily customize the power supply application.

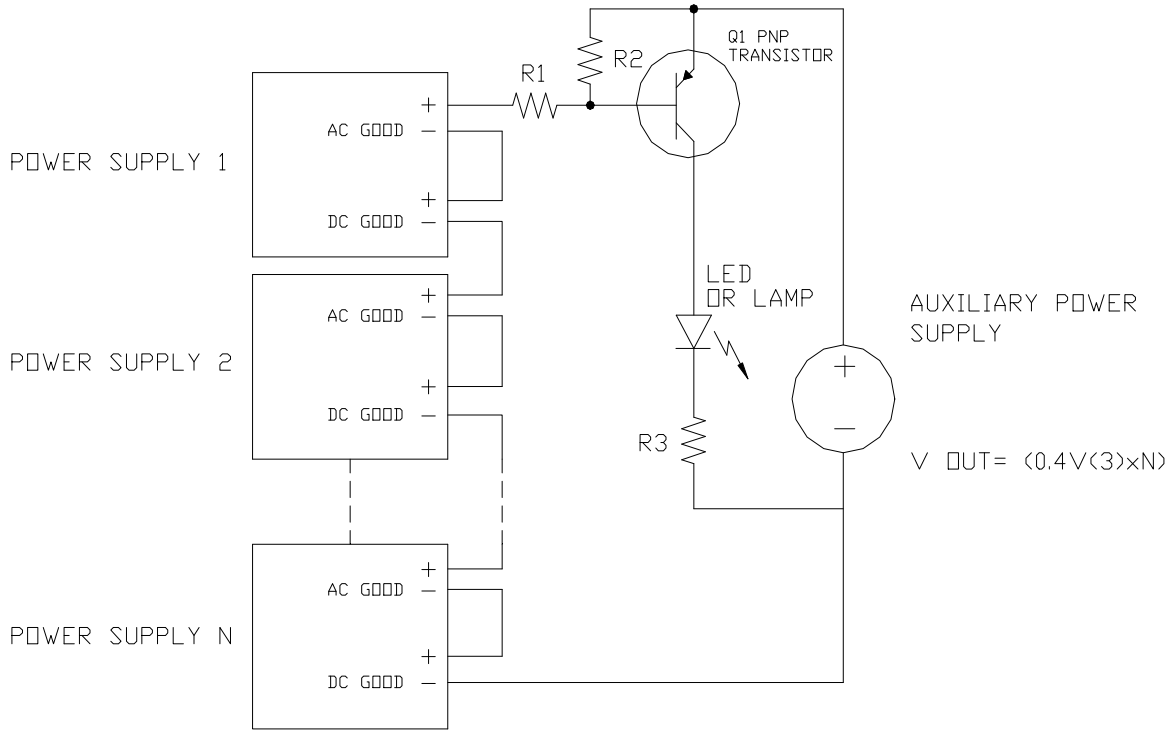


Figure E-3. Heavy-Load Fault Monitoring Circuit

APPENDIX F

INTERLOCK / REMOTE ON/OFF

Figure F-1 shows a typical INTERLOCK / REMOTE ON/OFF circuit utilizing the LOCK 1 and LOCK 2 signals from three FE power modules. LOCK 1 and LOCK 2 are isolated from the primary circuit by an optocoupler.

LOCK 1 and LOCK 2 provide a remote ON/OFF feature by enabling or disabling the inverter of the power supply. They are jumped together at the factory. For remote operation, as shown, a Logic Level low from zero to 1.5 volts or a direct short to LOCK 2 through a contact closure will enable the unit. A Logic Level high from a minimum of 3.8 volts or an open circuit to LOCK 2 will disable the power supply.

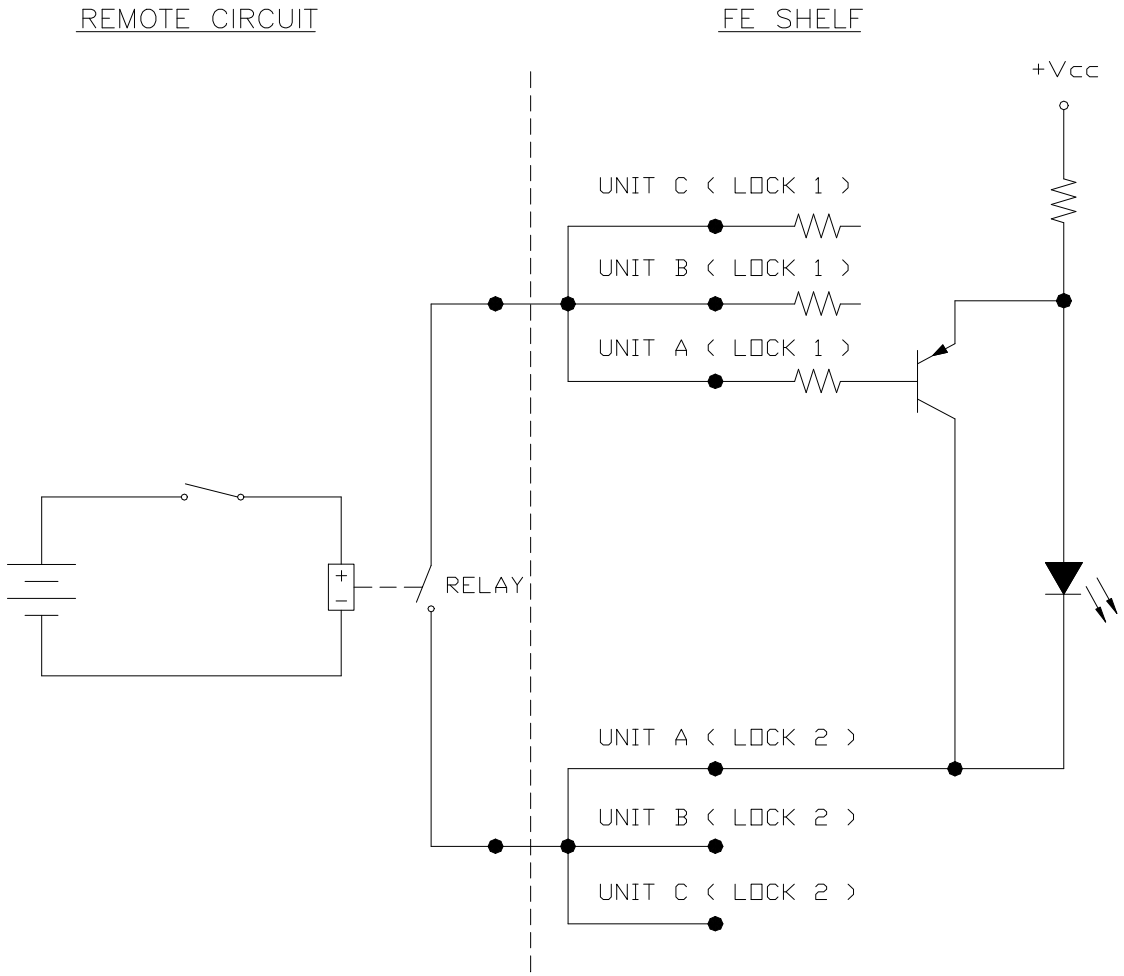


Figure F-1. Interlock/Remote ON/OFF Circuit

APPENDIX G

REMOTE RESISTIVE PROGRAMMING

The output voltage of the FE power shelf can be Local (Trim pot in the front panel of each FE power module) or Remote programmed. The shelf has been pre-configured in the factory for Local programming.

For Remote Resistive Programming, perform the following:

1. Pre-adjust the output voltage of each FE power module to the maximum range (29V on 24V models, 58V on 48V models), via the Vadj pot on the front panel. (Calibrate all output voltages to +/- 100mV of each other).

1. Turn off power to system.

2. Remove the shunt jumper from pin 6 to pin 8 on all 10-pin Control Signal Connectors **(Jx2)** located on the backplane of the FE power shelf.

3. Daisy chain pin 6 on all 10-pin Control Signal Connectors **(Jx2)** on the backplane of the FE power shelf.

4. Daisy chain pin 8 on all 10-pin Control Signal Connectors **(Jx2)** on the backplane of the FE power shelf.

5. Connect a 25KΩ Potentiometer between pin 6 and pin 8 of one of the 10-pin Control Signal Connectors **(Jx2)** on the backplane of the ***FE*** power shelf.

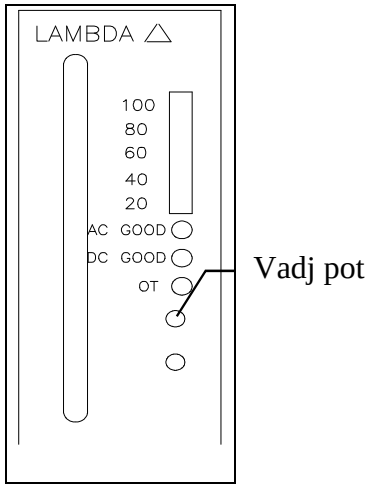


Figure G-1.

6. At this point the operator is ready to adjust the output voltage of the entire ***FE*** power shelf from a single remote point.

8. Re-apply power to system.

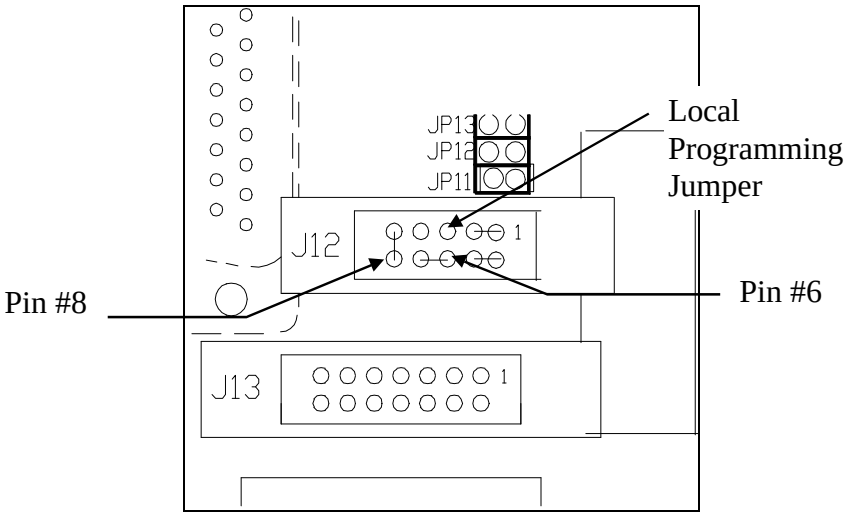


Figure G-2.

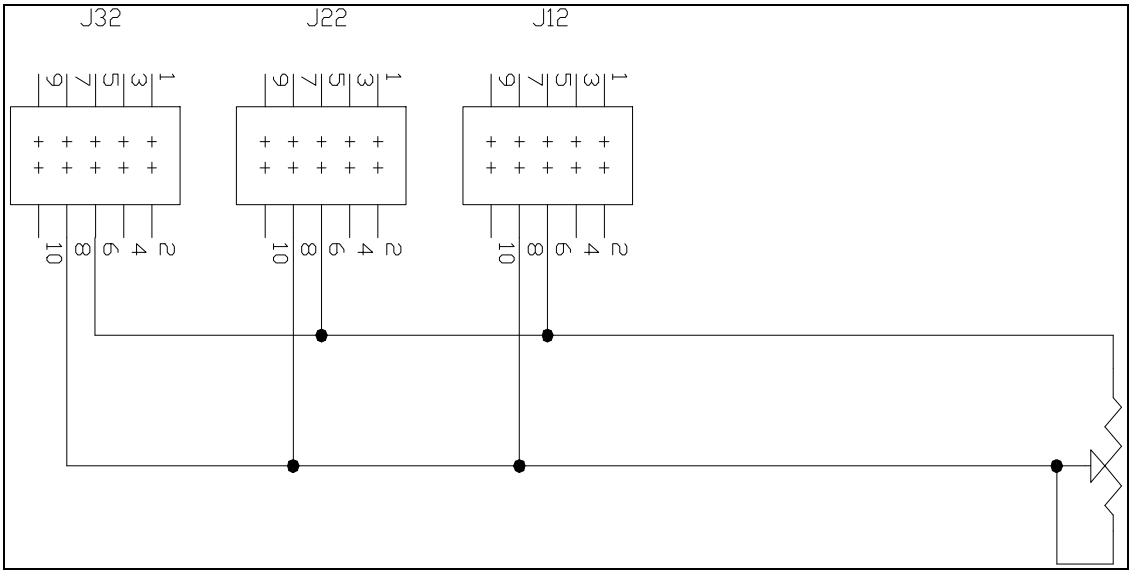


Figure G-3.

Schematic of remote resistive programming for three modules. Clockwise rotation of potentiometer will increase the output voltage.

APPENDIX H

POWER MODULE BLOCK DIAGRAMS

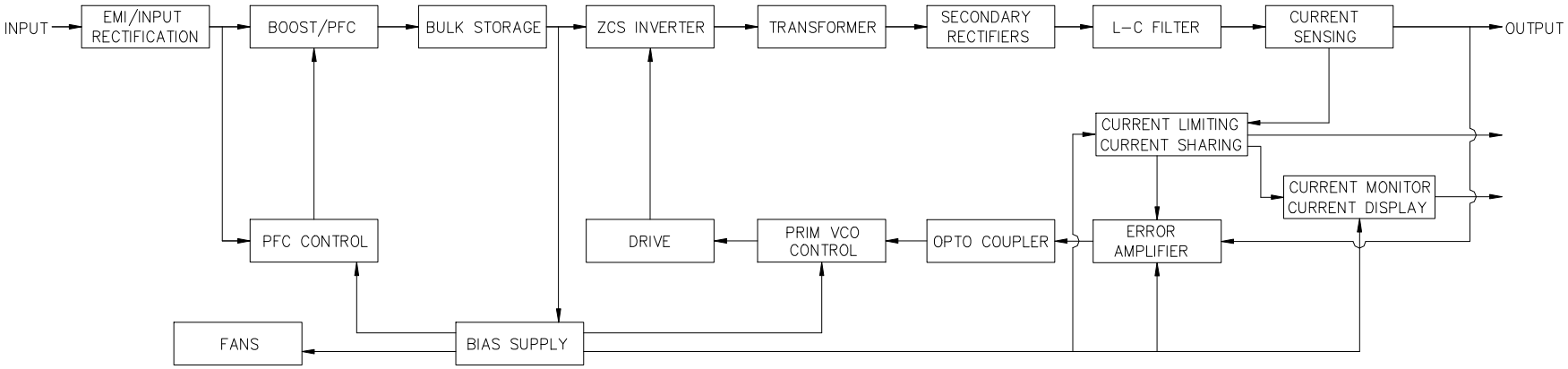


Figure H–1. Block Diagram of FE500/FE1000 Power Module

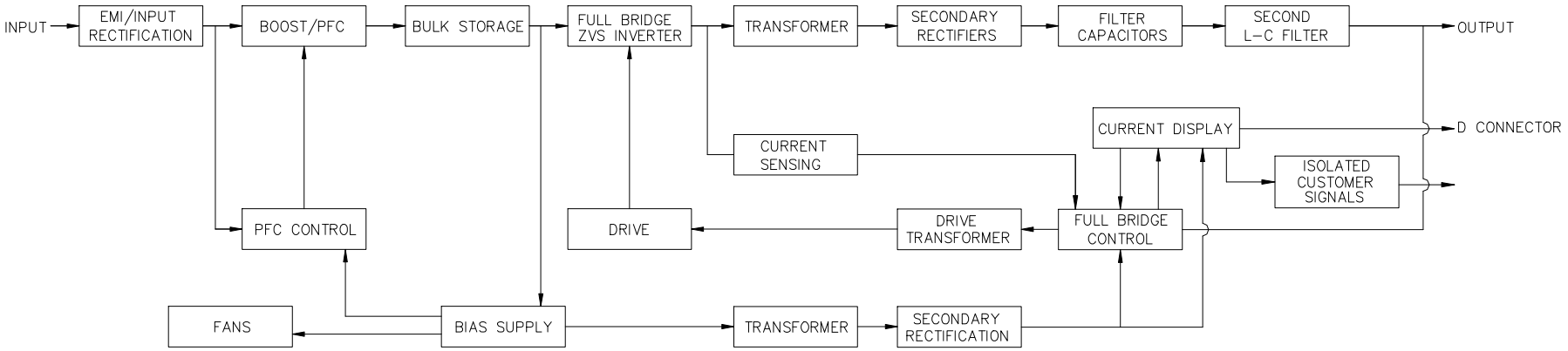


Figure H–2. Block Diagram of FE1500/FE2000 Power Module

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