4200W @ 12V (N + 1) Redundant Power Shelf Hardware v0.3
OR-draco-cinnabari-0.3

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1 Scope

This specification defines the requirement for a 4900W standalone power shelf, with single-voltage 12V nominal output, powered from single-phase AC line, hosting up to seven 700W power modules, and used for IT systems for both online and backup power functions. This device works in conjunction with the *Open Compute Project Battery Cabinet*.

2 Contents

3 Overview

When data center design and hardware design move in concert, they can improve efficiency and reduce power consumption. To this end, the Open Compute Project is a set of technologies that reduces energy consumption and cost, increases reliability and choice in the marketplace, and simplifies operations and maintenance. One key objective is openness—the project is starting with the opening of the specifications and mechanical designs for the major components of a data center, and the efficiency results achieved at facilities using Open Compute technologies.

One component of this project is a custom power shelf. This document lists the requirements for the power shelf and the 700W power module. The power module uses the 700W-SH power supply design scheme,, technology, and specification; refer to the OCP 700W-SH Power Supply v1.0 specification as the master reference document for the power shelf.

This specification lists the differences between the above 700W-SH reference specification, plus the new shelf requirements. The power shelf is a 3xOpenU power shelf hosting up to seven modules in parallel, each one with 700W of nominal output rating, hot-swap, droop current share, normally (6 + 1) redundant for a total of 4.2KW of redundant power output.

Note: 1xOpenU = 48mm. Sheet metal thickness for the shelf is 1.2mm, and 1mm for the module. Specifications herein are for the V1 power shelf, unless the power module is mentioned specifically. Throughout this specification, the power shelf is referred to as a *shelf*, the power module as *module*, and the shelf populated with a minimum of 3 modules as either a *power station* or a *station*.

3.1 Accessibility

The power shelf must be physically installed in a restricted (controlled) area with service accessibility exclusively permitted to authorized personnel only; certified and trained personnel only can have access to the power shelf, its components, and its interconnections.

3.2 License

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4 Compliance Requirements

The power shelf complies with the same related safety and compliance specifications as the OCP 700W-SH power supply, and is certified and labeled accordingly. The power module has its own label. Both labels must follow the same rules as described in the OCP 700W-SH label. The acceptable label areas on the power shelf and power module are included in the mechanical drawings.

4.1 EMI Compliance and Limits

The AC test are conducted as standalone unit at both 200Vac and 277Vac, full load 4900W, and for any number of modules installed in the shelf (4 to 7). A minimum number of 4 modules can be installed in the shelf; blanking panels are available for the unused slots.

- FCC Part 15, EN55022, CISPR 22: Conducted Emission, Class B (3db margin on peak).
- FCC Part 15, EN55022, CISPR 22: Radiated Emission, Class B (3db margin on peak).
- When the shelf works in backup phase, it meets Class A (3 dB margin on peak), at 48Vdc input and full load (conducted and radiated).
- At system level, the power shelf complies with Class A limits for both conducted and radiated emissions, with a 3 dB margin on peak, for both AC and DC inputs/converters, with any number of modules installed in the shelf.

4.2 AC Mains Leakage Current of Power Station

AC leakage current complies with applicable EN/IEC standards, and does not exceed 15mA RMS at 60Hz and 277Vac, with seven modules installed in the shelf.

4.3 Input and Output Connectors, Fuses, EMI filter

4.3.1 Shelf AC Input

The AC input voltage inlet is a 3 positions Positronic (RoHS part) male socket connector (part number PLB3W3M4BN0A1/AA-PA161), board-mount right-angle, hot-pluggable, solder type preferred, and is mechanically secured to the PCB and to the shelf chassis base near the rear panel. The general requirements for the AC connector are:

- Must be locked-in type.
- Must include a pre-mating pin (centered long pin, for GND connection).
- Must be at least 30A rated, and 600V rated.
- Its connector counterpart (carrying the AC voltage from the grid) must have a custom molded strain-relief custom built on the housing, for safety and for mechanical strength.
- The AC cord carries three wires: Line, Neutral, and GND.

The AC input fuse is a replaceable component installed on PCB mounting clips, accessible from the rear side of the shelf through a small window. The perforated door on the fuse window is secured with M4 captive Phillips screws, and fixed with hinges on the lower side (door is not detachable); see the mechanical drawings for more details and for the yellow warning label. The fuse is used for safety and extreme protection in case of catastrophic failures.

The AC input connector is polarized; the fuse is connected in series to the hot conductor (Line). The fuse is rated 35A @ 480Vac (or 600Vac), and is a *slow blow* type (it never trips during AC inrush or any AC input current transients that the shelf is designed to withstand under normal conditions). Approved components are Bussmann SC fuse series or Littelfuse SLC fuse series (both are Class G fuses).

The further EMI filter at shelf level, if installed on the board, should not make use of more than two cells, with low series DC resistance. The design uses bulky choke components to reduce the copper losses and so to maximize the efficiency. All the components used in the AC input power section (AC input connector, protection fuse, X2 EMI caps, surge protection devices, bleeder resistors, and so forth) must be rated at least 305Vac RMS.

Any AC cabling inside the shelf should be AWG 12, or at least AWG 14, and 600V rated.

4.3.2 Shelf DC Input

The input DC connector used for backup functions is APP SB120, wire crimp type for an AWG 4 cable. Any potential DC cabling inside the shelf should be min AWG 6; AWG 4 is preferred.

There is no EMI filter through the DC input, provided that EMC is passing.

No fuse is used through the DC input path.

During operation, the maximum input DC current is 120 Amps for a maximum of 90 seconds. The input DC paths are designed with very low resistance and impedance to avoid voltage losses that may compromise the backup performances of the shelf at full load, reduce the efficiency of the DC-DC power conversion, and generate negative voltage spikes when the backup engages.

4.3.3 Shelf DC Output

The 12V nominal output is made available to the rear panel of the shelf with three pairs of copper *bus bars*, blades placed vertically and in parallel. Two M8 PEMs allow for installation of the cables for 12V connections at system level. The reference component is stainless steel, PEM part number CLS-M8-2. Refer to the mechanical drawing for more details. Reference cables are AWG 2/0 for the left and right output, and AWG 4/0 for the centered output. The reference lug is Burndy part number YAZV272TC38FX, while FusionLUG technology is the preferred choice for these cables. X and/or Y caps may be used on the 12V output to reduce DC and CM noise in the shelf. The preferred method to connect in parallel the 7 power modules inside the shelf is by using bus bars built inside the shelf. No capacitance should be connected to the output of each power module after their OR-ing MOS (inside the module) to avoid glitches on the 12V shelf bus during hot plugs.

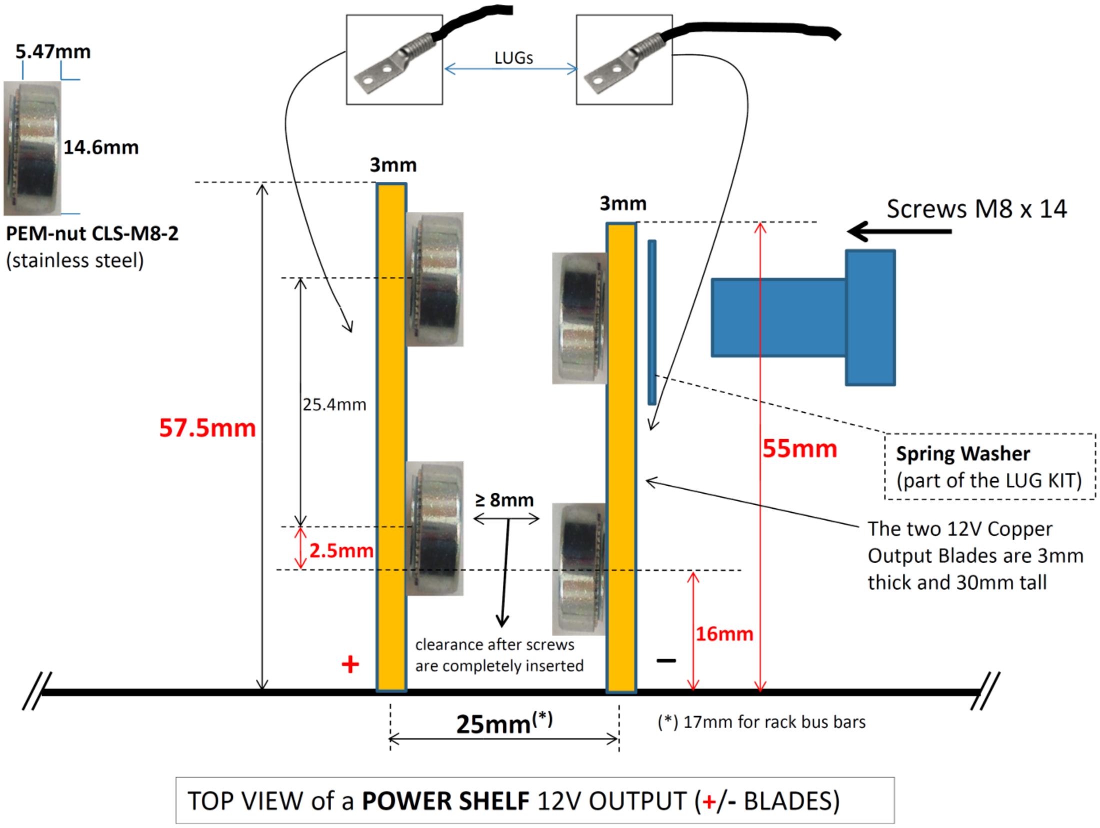


Figure 1 Top View Power Shelf Output (1 of 3)

During normal online mode, the output voltage is generated by the AC main converter in the power modules; during backup mode, the voltage is generated by the DC backup converter in the power modules. The modules share the output current in both AC and DC modes, and are also able to share during AC transitions and during AC random restarts, where AC converters of some modules can share the output current with DC converters of other modules.

The three bus bar outputs inside the shelf include three common mode high-permeability ferrites, clamping directly the three +/- output bars. They are installed near where the bars exit from the rear panel. They help to reduce common mode noise through the three DC outputs, and help to decouple them at high frequency.

Looking at the rear panel of the shelf:

- The left side and right side bus bars can each deliver 3KW maximum continuous when used alone.
- The central bus bar can deliver full load 4900W continuous when used alone, and 4200W at system level, to preserve the redundancy
- At rack level, each bus bar is connected to its independent load. The three outputs may not be externally electrically paralleled again at system level, somewhere in the rack power zone (shorted again outside the shelf), because this would unbalance the currents in the Open Rack bas bars, cause unwanted recirculating currents through the chassis installed in the power zones, and cause instant saturation of the 12V common mode ferrites installed in the shelf.

4.4 AC Inrush Current, Preferred Topology

The inrush current is equivalent to the OCP 700W-SH inrush limit, depending on the number of modules installed in the shelf: 56A peak at cold start, Vin = 290Vac RMS, Tamb = +35C, when the shelf is fully populated with seven modules.

4.5 Power Factor and THD

The power module complies with EN61000-3-2 up to 290Vac RMS input.

At the power shelf level: Power Factor and iTHD (Total Harmonic Distortion of AC input current, with order of the harmonics up to and including 40):

- PF > 0.95 (>20% of full load)
- THD < 10% (>20% of full load)

Note: The shelf is fully populated (full load is 4900W).

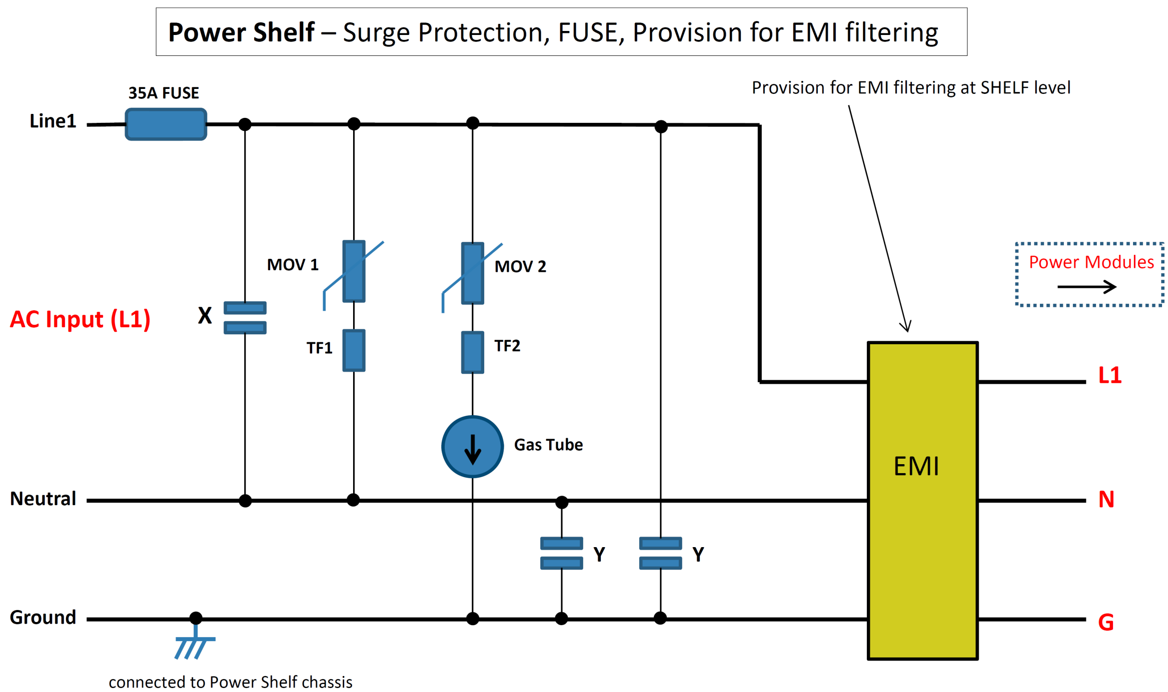
4.6 Input AC Surge

Additional surge protection circuitry is implemented inside the shelf. The shelf complies with EN61000-4-5 with the following limits (for any configuration of the shelf with a minimum of 3 modules to a maximum of 7 modules, when it is off):

- 2KV DM (differential mode is Line to Neutral)
- 4KV CM (common mode is Line/Neutral to Ground)

The shelf is protected against surge events and will not get damaged in such occurrences. The shelf continues to operate without functional failures or hiccups during surge tests per the above limits, and the output voltage is not affected by the surge pulses under any conditions. Surge events cannot reset the system when the shelf is used to power the IT chassis at rack system level. The usage of a gas tube in the surge circuitry is mandatory for the common mode connection. A minimum of 4 power modules are installed in the shelf for any application.

A typical approach for the surge protection circuitry at shelf level looks like this:



- **MOV1 to MOV3:** leaded Varistor EPCOS 'S20K385' (thermal fuse installed on the body with shrink- tubing)
- **TF1 to TF3:** reference thermal fuse is: JAPAN ANZEN DENGU Co 'N4F' (1A 250V 127C)
- **2.5KV Gas Tube:** reference component is a leaded Gas Discharge Tube EPCOS 'A71H25X'
- **35A FUSE:** Littelfuse SLC-35 or Bussmann SC-35

Figure 2 Surge Protection, Fuse, Provision for EMI Filtering

4.6.1 Isolation Requirements

Under any configuration, the shelf supports 3000Vac RMS of safety-reinforced insulation between the high-voltage AC primary section and any secondary sections.

Isolation between the high-voltage AC primary section and chassis GND is 1500Vac RMS.

Both positive and negative 12Vdc output terminations are floating with respect to the chassis GND, with a galvanic isolation of 100Vdc.

The input of the DC backup converter is a safe voltage, so its DC input section supports reinforced insulation with the AC input primary section.

The DC BACKUP CONVERTER is isolated with at least 500Vdc of insulation between its primary section and the secondary of the shelf (12Vdc output).

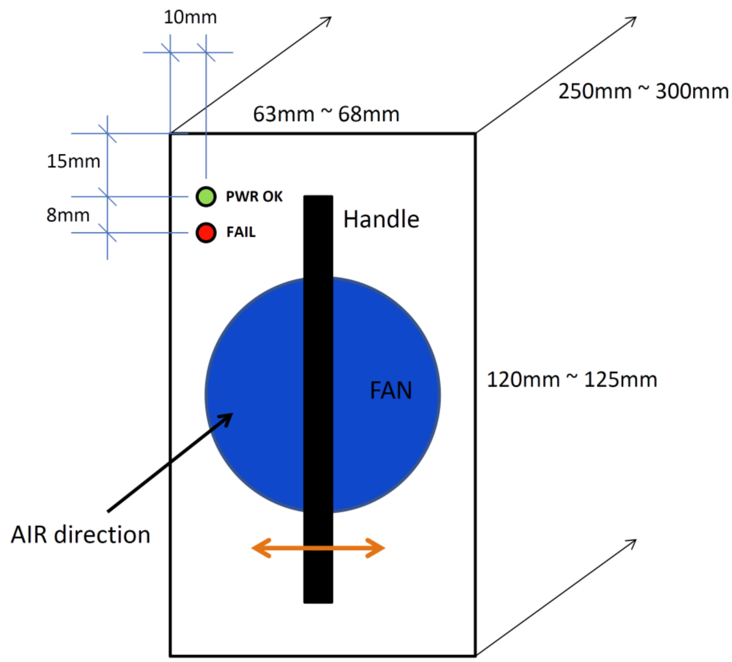
5 Power Module and Shelf General Requirements

5.1 Output Voltage, Power, SHARE

The shelf hosts up to seven modules single-voltage power converters, for (N + 1) redundancy.

- The power module uses the OCP 700W-SH power supply design scheme, board, technology, and specifications. It includes an output OR-ing MOS, so the module is hot swappable (a handle installed in the faceplate). The droop current SHARE function is permanently active. The 2 second random startup window at first AC application is also permanently disabled. This corresponds to the combination (B1 = 0) and (B2 = 1) in the SHARE Select Table in the 700W-SH specification (figure 5 in the v1.0 specification). Software will adapt without the need to use signals to select the functions anymore.
- The nominal output voltage of each module is 12.75V (~ 22.5% of full load; see Figure 4), and 12.40V at nominal output power (700W continuous).
- The peak power of each module is 800W when working in AC or DC mode (over current threshold is > 65A). A higher than normal over current threshold ensures that a fully installed power shelf never shuts down during transient, due to potential current share inaccuracy.
- Typical dimensions of each module are (63mm ~ 68mm) x (120mm ~ 125mm) x (< 300mm).
- The modules are hot swappable from the front of the shelf, and cannot be installed upside down.
- Blanking panels are provided and can be installed on the shelf to block the airflow in the unused slots, for any (N + 1) redundant configurations (minimum N = 3). Power modules and blanking panels lock in inside the shelf slot, once fully installed — a small leverage on the faceplate is used to uninstall the power module or the blanking panel from the shelf. The blanking panel can be either plastic or metallic material.
- The module faceplate is an air intake.
- The fan is the same as the model used in the OCP 700W-SH power supply, and is installed on the faceplate, inside the module. Minimum baseline PWM is 40%.
- The output current internal reading of the power module, used for the droop-share functionality, is calibrated at 56A and at 28A prior to the final test in the manufacturing line, with an accuracy of ±0.2%.
- The output voltage is calibrated to 12.40V at 56A in the manufacturing line, with an accuracy of ±0.2%.
- The -8mV/Amp droop-share is ±0.2% accurate from full load to half load. Refer to Figure 4 below.
- The share accuracy target when all the seven modules are installed in the shelf is better than 4% at a full load of 4900W. The maximum unbalance output current vs. the theoretical value is ±4% when working at 4900W with seven modules; each module delivers 56A ±4% or better.
- The shelf can withstand a no-load condition for indefinite time, without damage and with (or without) the maximum allowed capacitive load connected to the output terminations (for any configuration).
- The output voltage rising is always monotonic, under all conditions.
- The output voltage falling is always monotonic and never reverses polarity, under all conditions.

- The nominal continuous output power of the shelf is 4200W (6 x 700W, where 4800W is the peak power).
- The one extra 700W module (6 + 1) is normally used for redundancy. However, the shelf can deliver a maximum 4900W of continuous power from the centered bus bar, and still perform AC backup transitions under this configuration.
- Output OR-ing MOS are installed inside each module for hot swap, redundancy, and parallel operations. Efficiency will not drop by more than 0.2% at full load (target), after the OR-ing devices are added. The hot-swap functionality is enhanced by using a short pin in the module in order to anticipate the shutdown of the module while pulling out the module from the shelf.
- The power module faceplate has the same LEDs as the OCP 700W-SH power supply, and in the same location: on the top left or top right corner. Figure 3 shows the top-left layout for the LEDs. The distance between the LEDs is 8mm.
- The red and green LEDs are never on at the same time.
- The handle is vertically displaced; it does not have to be centered with the faceplate.



V1 Power Shelf – 700W module (faceplate)

Figure 3 V1 Power Shelf Faceplate

- A power module ON signal is available to the shelf to enable a synchronized startup of all the power modules installed in the shelf at first AC application (Vout rise is monotonic), and behaves the same way for backup transitions and restarts.
- The shelf can engage the backup phase under any conditions and configuration, with clean backup sequences, at full nominal power without redundancy (4900W). For example, seven modules are used, load is 4900W, input AC voltage is 200Vac, input DC voltage is 39Vdc; the output voltage shows no glitch below 11.5V (worst case) during multiple AC outages and restore.
- Rapid AC cycles without input DC applied do not reset and latch the power shelf.

- The AC main converter of one module in the shelf can share the output current with a DC backup converter of another module installed in the shelf (under all possible shelf configurations), to be able to keep using the random restart functionality already implemented at the module level (see the OCP 700W-SH specification), without engaging a new function to randomize the whole shelf at AC restart.
- In the power module, the bandwidth of the droop-share loop control of the AC main converter and the bandwidth of the droop-share loop control of the DC backup converter (dynamics), are similar to prevent different speeds of the Vout recovery of the main converter vs. the backup converter, when they work in parallel (and share the current) during rapid dynamic loads.
- The fully-populated shelf can start up under overload or short circuit conditions.
- During the backup phase, the time counter of each of the individual power module is synchronized (yellow LEDs will blink synchronized). This can be achieved by using a X-TAL crystal as a reference clock for the microprocessor installed in the power module.

5.1.1 Droop-Share Table

Current Share Functions
Droop-Share Table for the 700W Power Module

Table & parameters avalid for both Main Converter & Backup Converter

			1 MODULE		1 SHELF	
Pout [W] nominal	**Vout [V]**	**Iout [A]**	**Pout [W] nominal**	**Pout [W] actual**	**Pout [W]**	
0	12.85	0	0	0	0	No Load
156.25	**12.75**	12.5	156.25	159.38	956	~ 22.5% of Full Load
225	12.71	18	225	228.71	1372	
350	12.63	28	350	353.53	2121	
450	12.56	36	450	452.23	2713	
700	**12.40**	56	700	694.51	4167	Full Load 4.2KW

Vout shall be set to **12.40V** ± 0.2% at 56A load (AC Main Converter and DC Backup Converter)
Droop-Share is -8mV / Amp (± 0.2% accuracy from Full Load to Half Load)
Output Current Reading for both converters is calibrated at 56A and 28A, with ± 0.2% accuracy
6 modules in the SHELF (#4 module is not installed)

Figure 4 Droop-Share Table

The actual maximum output current for the maximum power delivery of 700W is 56A (12.40V).

The over current protection threshold to allow 800W peak power is ≥ 65A .

5.2 Output Voltage Ripple and Noise

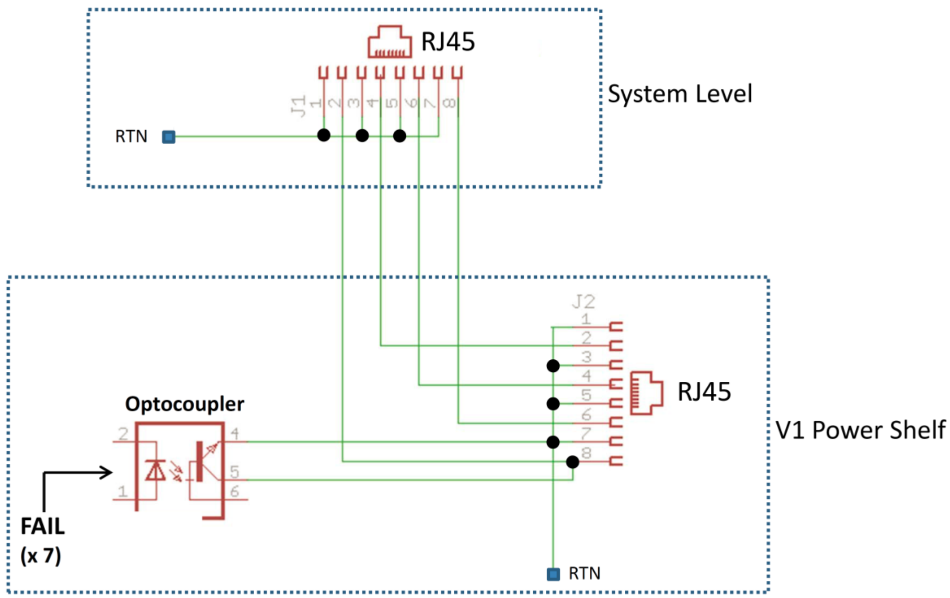
The maximum ripple and noise never exceeds 200mV peak-peak at 20Mhz bandwidth.

No external capacitive load is connected to the output terminations during this test.

5.3 Output Signals, Shelf LED

There is one opto-isolated output signal for the shelf, described in Figure 5 below. It is routed to the RJ45 connector installed on the rear panel of the power shelf.

One RJ45 connector in a 'V1 Power Shelf'



Optocoupler is driven by the modules 'FAIL signals'. Logic in the module is powered by 12V bus

FAIL signal is a latch-OFF type, asserted after 5 sec of persistent fail condition (module **RED LED** turns-ON when signal is asserted)
- Power Module general failure (directly related with the internal fail signal of the 700W-SH board)
- Voltage at the Anode of a Power Module OR-ing MOS is < 11.3V
- FAN failure (or LOW FAN SPEED), Over Temperature
- AIR Temperature Sensor failure (open or shorted). This will also cause the FAN to run full speed
- Power Module shuts down once FAIL signal is asserted, also during backup mode, and stays latched OFF

Figure 5 Optocoupler

The optocoupler is driven by the open collector latched-OFF FAIL signals coming from up to 7 power modules, one for each module, all connected together in the shelf.

There is another output present in the rear panel of the shelf, near to the RJ45 port. It is a (2 + 2) small Molex Microfit SD-43650 series board-mount connector. Pins 1 and 2 are the negative, pins 3 and 4 are the positive. Normally, at 0V, the voltage across the pins (3=4) and (1=2) changes to +9V under the following conditions:

- The FAIL_S signal is asserted.
- The shelf is working in DC backup mode.

The implementation makes use of a simple 9V (1A) regulator (or 0.5A regulator), driven by the external 12V bus, and activated by the logic present in the shelf.

Note on the 700W-SH: The available signals in the 700W-SH design are A2, B1, B2, C1, C2, D1, D2; they can now be used to implement new functions needed in the power shelf, like the synchronized startup at first AC application or AC return. They are either output or input signals, routed to the power module microprocessor logic, inside the module. The +5V at pin D2 is no longer necessary; the corresponding components, including the small IC regulator, are no longer needed.

5.3.1 Fail Signal at Shelf Level

This signal, called **FAIL_S**, is an open collector signal generated by an optocoupler installed inside the shelf. The collector and the emitter of this optocoupler are directly connected to the RJ45 socket (port) installed in the rear panel of the shelf, and not connected anywhere else; it is a floating output. Proper ESD simple circuitry is included in the shelf to protect those terminations at the RJ45 connector.

At the system level, collector and emitter terminations are routed to an external digital monitoring box (a separate device for power failure monitoring at the rack level), with the emitter grounded to the local negative termination and the collector pulled up to +5V with a 10K resistor.

The optocoupler is driven by the open collector signals coming from the (up to 7) power modules in the shelf, called **FAIL_M** (up to 7 signals, one per module). When at least one open collector signal from a power module in the shelf goes low, then the signal FAIL_S goes low, signaling to the external world that at least one power module in the shelf failed. The signal FAIL_S is normally open (high state), meaning normal conditions (no failures). The FAIL_M signal is also at a high state under normal conditions, and turns low after 2 seconds of persistence of any failure condition in the corresponding power module. Then it stays latched off indefinitely.

When at least one power module failure occurs, the FAIL_S gets low latched-off because the corresponding FAIL_M signal coming from a failed module gets low latched-off by the power module logic. The red LEDs of the modules are directly driven by their corresponding FAIL_M signals and powered by the 12V bus. The microprocessor and logic within the power modules is back-biased by the 12V bus at the shelf level. It is always alive and can guarantee a permanent latch-off of the FAIL_M signals (and then of the FAIL_S signal) at all times, as long as the 12V bus at shelf level is present.

The fan fail LED signaling typical of the OCP power supply (a red LED blinking at 1 Hz when the power supply fan fails) is not used in the power shelf; the internal to the power module new fan fail signal (or low speed fan signal) drives low the FAIL_M signal of the module like any other failure, but after 5 seconds of persistence.

Reset of FAIL_M signal latched-off: When a unit asserts low its FAIL_M signal latched-off, then the unit shuts down latched off. The attempt to recover the unit is done by performing a reset of the FAIL_M signal. This can be achieved by swapping the unit from the shelf (at least a 2 second swapping time), or by recycling the AC input (at least a 2 second recycling time), in an attempt to recover functionality.

A FAIL_M signal triggers for these latching-off conditions, where the power module also latches off:

- General power supply failure
- The output 12V before the OR-ing MOS goes out of regulation
- Fan fail or fan low speed (5 second delay on persistence)
- Over current protection (2 second delay on persistence)
- Over temperature protection (2 second delay on persistence)
- Over voltage protection
- AC fuse failure (5 to 30 second delay)

Failure signals for a power module while working in a running shelf:

- When 150V is mentioned, it indicates either 150V or "any voltage below 170V but high enough to activate the auxiliary bias supply inside the power module." Voltages are intended to be applied to the shelf.
  - **277V APPLIED, 48VDC NOT APPLIED**: If the 277V applied to the shelf suddenly drops to 150V, or 0V, the shelf shuts down. Power module LEDs turn off and the FAIL_M signal stays high.
  - **277V APPLIED, 48VDC APPLIED:** If the 277V applied to the shelf suddenly drops to 150V, or 0V, the shelf enters backup for 90 seconds and then shuts down. Power module LEDs turn off and the FAIL_M signal stays high.
  - **277V APPLIED, 48VDC NOT APPLIED:** If the AC fuse of a power module suddenly fails, after 5 to 30 seconds its red LED turns on and its FAIL_M signal turns low latched-off.
  - **277V APPLIED, 48VDC APPLIED**: If the AC fuse of a power module suddenly fails, the module enters the backup phase and, after 90 seconds, shuts down for a backup timeout. Then, 5 seconds later, its red LED turns on and its fail signal turns low latched-off.
  - **277VAC APPLIED, 48VDC APPLIED OR NOT APPLIED**: If a power module with a failed AC fuse is installed in the running shelf, after 5to 30 seconds the red LED on the unit turns on and its FAIL_M signal turns low latched-off.
- The green LED is driven by the power module board in the same way it is driven in the OCP 700W-SH power supply. However, fan fail does not result in the green LED blinking, which happens in the 700W-SH supply. Instead, the power module shuts down and shows the failure (as described above).
- If a power module fails during the backup phase, the module shuts down, the red LED turns on and its FAIL_M signal turns low latched-off. When the AC restores, the unit does not resume functioning because the FAIL_M signal stays latched-off. For example, a shelf with 7 units is working in AC mode when an AC outage occurs, so the shelf enters backup mode. A few seconds later, while working in DC backup mode, one power module fails. This module shows a red LED and shuts down latched-off. When AC resumes, the shelf will transition to AC mode for the 6 functioning units, while the units that failed during backup mode still show a red LED, the FAIL_M signal asserted, and it stays latched-OFF indefinitely. This unit will need replacement, as the digital monitoring device will report the failure of the shelf redundancy.

Failure signals of a power module when working standalone:

- Voltages are intended to be applied to the power module standalone.
  - **277V APPLIED, 48VDC NOT APPLIED**: If the 277V applied to the module suddenly drops to 150V, or 0V, the module shuts down. The power module LEDs turn off and the FAIL_M signal stays high.
  - **277V APPLIED, 48VDC APPLIED**: If the 277V applied to the module suddenly drops to 150V, or 0V, the module enters backup for 90 seconds and then shuts down. The power module LEDs turn off and the FAIL_M signal stays high.
  - **277V APPLIED, 48VDC NOT APPLIED**: If the AC fuse of a power module suddenly fails, the module shuts down. The power module LEDs turn off and the FAIL_M signal stays high.

- **277V APPLIED, 48VDC APPLIED**: If suddenly the AC fuse of a power module fails, the module enters backup for 90 seconds and then shuts down. The power module LEDs turn off and the FAIL_M signal stays high
- **277VAC APPLIED, 48VDC APPLIED OR NOT APPLIED**: If a power module with a failed AC fuse is suddenly provided AC and DC inputs, nothing happens.

Shelf LED: A 5mm green LED installed on the rear panel of the shelf near the +9V connector turns on when the 12V shelf output voltage is present. This is a 12V "power good" indicator.

5.3.2 Power Shelf Efficiency (AC Main Converter)

Efficiency exceeds the Climate Savers Computing Initiative's Platinum rating (as of September, 2009). Those limits are:

- Efficiency > 90% at 20% load
- Efficiency > 94% at 50% load
- Efficiency > 91% at full load

Methodology for the measurement follows the CSCI directive at 230Vac RMS input.

Additional target efficiency requirements include:

- Efficiency > 94.5% (between 40% and 80% of full load).
- Wider than above load range is desired, but not a target at this time.
- Only the centered bus bar output is loaded for the efficiency measurements.
- Full load is defined as 4200W (6 x 700W).
- Six modules are installed, symmetrically; the center slot is empty.

Measurements are performed as follows:

- Input AC voltage is 277Vac RMS (50Hz or 60Hz).
- AC and DC input voltage are measured directly at the respective connectors; output voltage is measured at the centered bus bar output.
- The cooling fans are powered using an external generator but with the speed controlled by the power module logic, as occurs during normal operations.
- Ambient temperature is +25°C.
- Measurements are taken after 30 minutes under initial 75% load, over five samples.

5.3.3 Stability

The power shelf is unconditionally stable, under any conditions and combinations of resistive and capacitive loading, constant power loading, input voltage, temperature, aging, and under any configurations of modules inserted in the shelf.

5.4 DC Inrush Current, DC Leakage Current

The DC inrush never exceeds 35A peak under any conditions, with seven modules installed in the shelf.

The DC input leakage current is less than 70mA at 54Vdc (battery leakage at system level) under any conditions, with seven modules installed in the shelf, with (or without) the presence of a valid AC input, and after the shelf shuts down when the 90 second backup timeout is reached. In case of input voltage reverse polarity, the DC input leakage current is also less than 70mA.

5.4.1 Clean, Uninterruptible Output Voltage

The shelf provides a seamless output voltage level no matter what happens to the AC input voltage, if a valid DC Backup Voltage is applied to the shelf DC input, under any conditions, and any configurations of the modules installed in the shelf.

6 Power Shelf Efficiency (DC Backup Converter)

The efficiency of the backup converter is as follows, with seven modules in the shelf:

- Efficiency > 90% (> 40% of full load, up to 90% of full load)

Measurements are performed as follows

- Input DC voltage is 48Vdc.
- DC voltages are measured directly at the respective shelf connectors.
- The cooling fan is running at full speed during the backup phase. The fan is not powered using an external generator, but self-powered by the power module.
- Ambient temperature is +25°C.
- Measurements are taken over five samples, after 30 minutes under initial 75% load with AC present.
- Only the centered bus bar output is used for the efficiency measurements.
- Full load is defined as 4200W (6 x 700W).

6.1 Shelf Isolation Requirements

The backup converter supports galvanic insulation between DC input and shelf output, and supports reinforced safety insulation with the main AC input. Detailed isolation requirements are equivalent to the requirements for the OCP 700W-SH power supply.

7 Environmental Requirements

- Gaseous contamination: severity level G1 per ANSI/ISA 71.04-1985
- Ambient operating temperature range: -5°C to +45°C
- Power shelf can start at -15°C of ambient temperature
- Operating and storage relative humidity: 10% to 90% (non-condensing)
- Storage temperature range: -40°C to +70°C
- Transportation temperature range: -55°C to +85°C (short-term storage)
- Operating altitude with no deratings: 3000m (10,000 feet)
- The shelf PCB board is partially conformal coated on the AC input area
- The total shelf weight with 7 modules installed does not exceed 25kg (65 pounds)

7.1 Vibration and Shock

An empty power shelf, power module, and power shelf fully populated with seven modules, meets shock and vibration tests per IEC78-2-(*) & IEC721-3-(*) Standard & Levels, with the specifications listed below.

	Operating	Non-Operating
Vibration	0.5g acceleration, 1.5mm amplitude, 5 to 500 Hz, 10 sweeps at 1 octave / minute for each of the three axes (one sweep is 5 to 500 to 5 Hz)	1g acceleration, 3mm amplitude, 5 to 500 Hz, 10 sweeps at 1 octave / minute for each of the three axes (one sweep is 5 to 500 to 5 Hz)
Shock	6g, half-sine 11mS, 5 shocks for each of the three axes	12g, half-sine 11mS, 10 shocks for each of the three axes

Figure 6 Vibration and Shock Requirements

8 Mechanical Requirements

Refer to the mechanical drawing in Figure 8.

8.1 Bus Bar Plating

The copper bus bars used inside the shelf are nickel-plated, including the output 12V blade pairs. The electro-plating process can be either:

- Minimum 10 microns of nickel plating, or,
- Minimum of 5 microns of nickel plating, on top minimum 10 microns of tin plating

The final look (smooth or grain) depends on the finish of the copper blade base material. The plating finish itself can be matte (smooth finish), brush (grain finish), or semi-bright; whatever is best for the cables terminal LUGs interface resistance once the output cables or bars are installed.

9 Prescribed Materials

9.1 Disallowed Components

- Trimmers and/or potentiometers
- Tantalum capacitors
- Dip switches
- High-side driver integrated circuits
- Paralleled power MOS are allowed, provided the design prevents parasitic oscillations
- Phase-shift topology
- SMT ceramic capacitors are allowed with a case size smaller than 1206. The size 1206 can still be used when SMT capacitors are placed far from the PCB edge, and with a correct orientation that minimizes risks of cracks
- Allowed ceramics materials for SMT capacitors are X7R or better material

The COG or NP0 types should be used in critical portions of the design, such as feedback loop, PWM clock settings, and so forth.

The use of any electro-mechanical relays should be discussed up front before any approval is given to include them in the design.

9.2 Capacitors

All electrolytic capacitors are rated 105°C, and are made by high quality manufacturers only. All capacitors have a predicted lifespan of at least 50,000 hours at 45°C inlet air temperature, under worst conditions.

10 V1 Power Shelf Mechanical Drawing

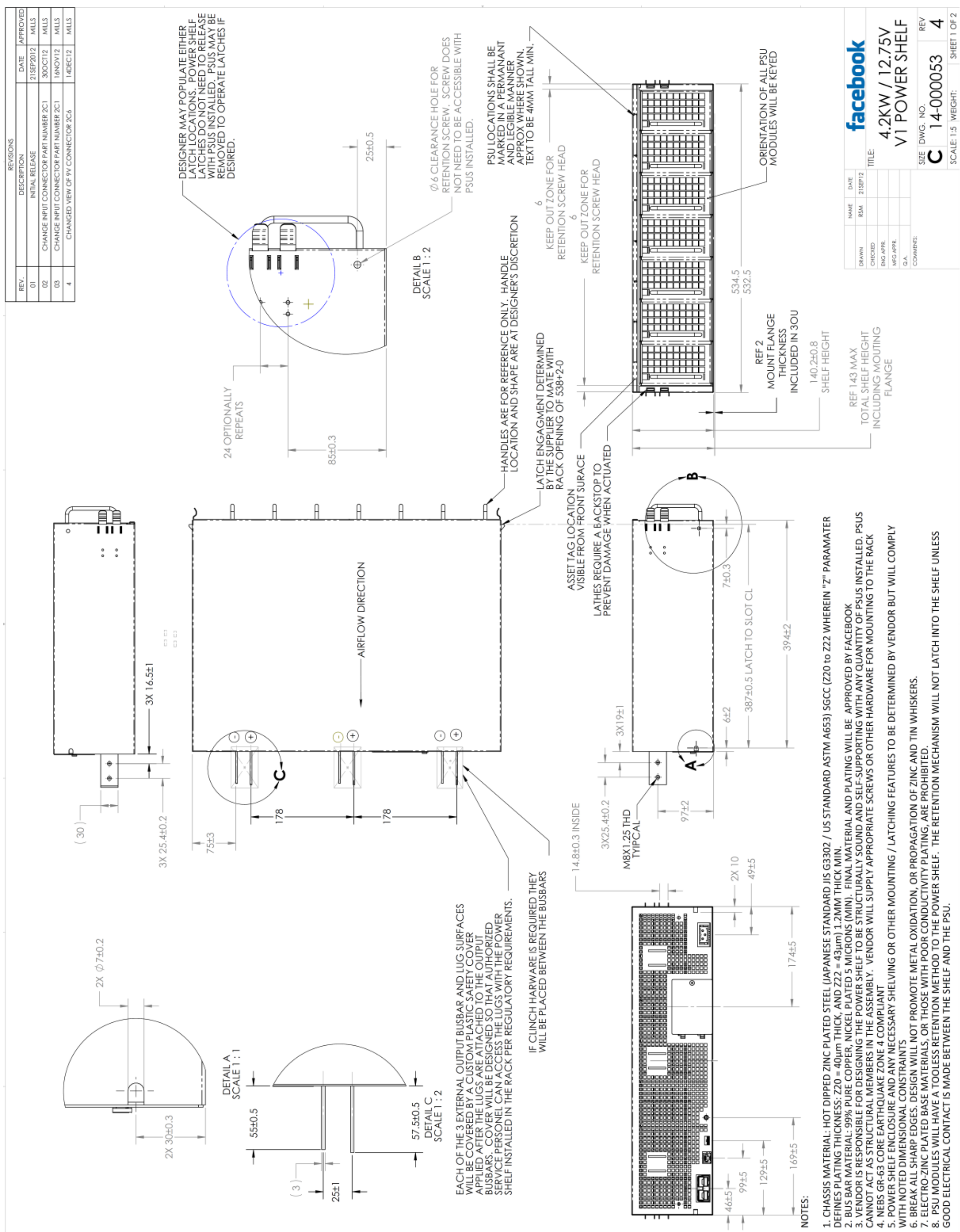


Figure 7 V1 Power Shelf Mechanical Drawing

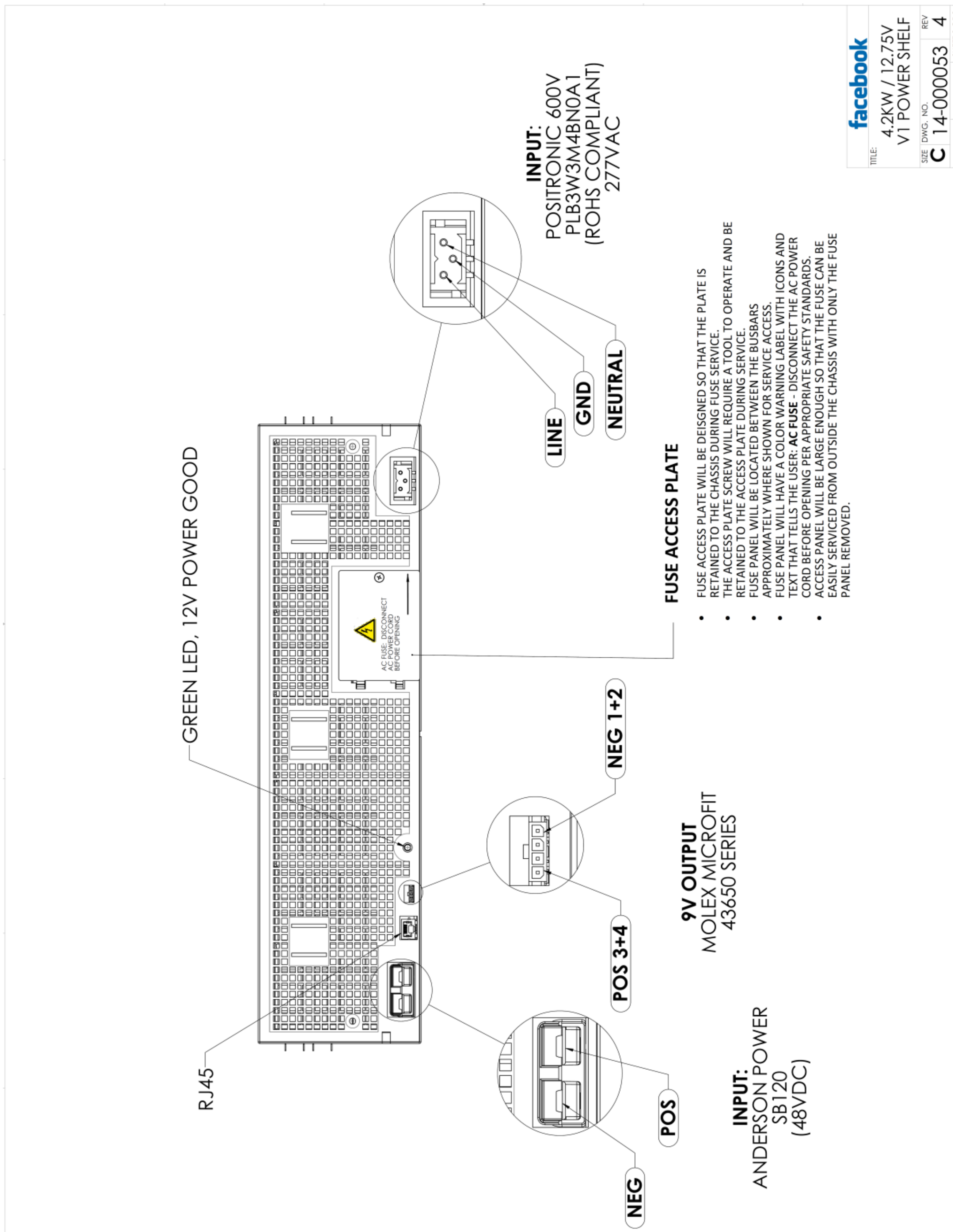


Figure 8 V1 Power Shelf Mechanical Drawing