

V2 Power Supply Specification

Version 2.0

AC/DC PSU 3.3kW @ 12.6V_{DC}

FB PN: 03-000661



OPEN
Compute Project

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1-Feb-2015	Rev 1.0	OCP version (PSU, Shelf, Communication specification all buddle together.)
8-Oct-2018	Rev 2.0	Updated version. More specific details and re-organized. Does not include communication or shelf specification.

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Summary

This specification defines the requirement for a 3300W hot-swappable single-phase power module which is capable of producing 3300W at 12.6V_{DC}, 270W at 52.5V_{DC} for battery charging, and has a step-up boost converter which uses the Li-ion battery pack (52.5V_{DC}) as an input to the bulk voltage. Three of these modules are placed inside the V2 Power Shelf which can house a maximum of three PSUs and three BBUs in a 2+1 redundancy configuration to provide 12.6V_{DC} both online and back-up power functions to power the IT loads.

In this document PSU refers to the power supply unit module and BBU refers to the battery backup unit pack.

V2 Reference Specifications:

V2 Power Shelf specification, Rev 2.0
 V2 BBU specification, Rev 3.4
 V2 Communication Manual, Rev4.6a

Mechanical PSU Dimensions:	65mm x 165mm x 529.5mm (HxWxD)
AC Input Range (rated):	200V _{AC} to 277V _{AC}
Outputs:	12.6V _{DC} /265A (droop) 52.5V _{DC} /5A (0.2% output precision)
Efficiency:	Titanium+ Efficiency (230V _{AC} , fan powered internally, and connector losses included) 90% at 10% of the load 94% at 20% of the load 96% at 50% of the load 91% at 100% of the load
Holdup Time:	20ms @100% loading (worst case scenario)
Sharing:	±5% when load >20% ±1% when load at 100%
Redundancy:	Output ORing device for 12.6V _{DC} Hot Swappable
Communication:	RS485-Modbus PSU output SMBus between PSU and BBU CANbus between PSUs
Protection:	OCP, OTP, OVP, UVP, BBU Protection Signals
LEDs:	Green/Amber Bi-color LED for PWR OK / BKP Red LED for FAIL

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2 Mechanical Requirements

2.1 Module Mechanical

The section below outlines the mechanical chassis of the PSU which shall be placed in any of the three slots of the V2 power shelf.

- Please refer to the separate mechanical 2D and 3D drawings provided for all the mechanical dimensions, tolerances, and mechanical highlighted notes.
- The weight of the PSU shall also not be greater than 20 lbs.

2.2 Latch, Retention and Keying

A mechanical latch should be used to securely fasten the PSU within the Power Shelf. All touch points, including the latch should be colored green (Pantone 375C). The latch shall have a backstop to prevent damage to the latch during actuation and should only lock into place when a good electrical contact is made on the rear connectors. A sturdy handle should be implemented which makes removal and insertion of the PSU as smooth as possible. Both the latch and handle should be implemented in a way such that it does not obscure any LEDs or silkscreens. Please note that the PSU will be heavy and the handle should be sturdy enough to carry the entire weight of the PSU. The handle shall also have enough clearance between the handle and the front surface of the PSU module so that the operator can wrap their hand around handle and carry the PSU vertically. This scheme will allow a quick installation of the power supply in its appropriate bay, and without the need of using any tools. The PSU shall be keyed so that it cannot be inserted upside down in the V2 Power Shelf. Also, when placed upside down or incorrectly, there should be no damage to the PSU connector or power shelf mating connector.

2.3 12.6V_{DC} Output Blades

The power supply module will output the main 3300W at 12.6V_{DC} with a pair of busbar blades, which are soldered onto the PSU PCB. The output busbar blades will mate with the Tyco Crown Clip II connector (TE P/N: 1643903-3) which will be attached to the internal shelf output busbar.

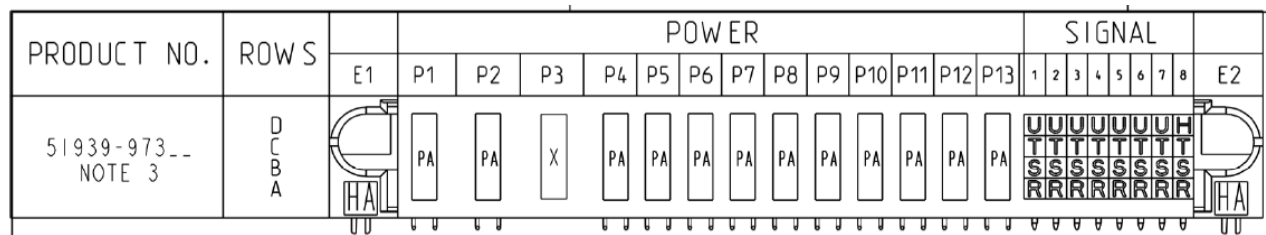
- The busbar blades suggested plated shall be nickel plated (3-5um) with silver (5-7um) on top. The Vendor is free to propose alternate plating thickness, Facebook approval needed.
- The negative busbar should be premating and mate first with the mating connector. The negative busbar blade should be offset by 3.1mm in length.

2.4 Inlet/Signals Connector

There shall be one male connector located below the 12.6V_{DC} output blades which is right angle soldered directly onto the PSU PCB (FCI part number, 51939-973, right angle STB header, 4ACP + 9DCP + 32S). This connector shall supply the single-phase AC input, BBU input, a 52.5V_{DC} BBU charging output, as well as all the 32 signal pins.

A spacer is advised between AC line and the signals to ensure enough safety clearance. Note, that ground pins should mate first as well as some signal pins should be shorter than the other pins (pin #8 below PS_KILL is recessed).

Pins highlighted in *blue* (italics) are to/from the BBU, via the shelf PCB.



Line	Neutral/ Line2	Not Connected	Ground	3x Batt (+)	3x Batt (-)	Aux 54V (-)	Aux 54V (+)	BBU Charger (+)	1	2	3	4	5	6	7	8
									9	10	11	12	13	14	15	16
									17	18	19	20	21	22	23	24
									25	26	27	28	29	30	31	32

Figure 1: Male PSU input connector (looking at the male connector head on).

Connector Pin Definition (detailed definition of each pin can be found in [Section 11](#)):

1. *Battery Sense (positive)*
2. *Sleep Signal*
3. *Protection Signal*
4. *Shelf Address 2*
5. *Current Share*
6. *Redundancy_Lost_L*
7. *R-485a*
8. *PS_Kill (short pin)*
9. *Battery Sense (negative)*
10. *12V(-) to BBU*
11. *12V(+) to BBU (3A fused, 12.6V_{DC} before the ORing MOSfet)*
12. *Rack Address 3*
13. *S_RTN*
14. *Power_Fail_L*
15. *RS-485b*
16. *BBU_I2C_SCL*
17. *Fail BBU*
18. *12V(-) Fan to BBU*
19. *12V(+) Fan to BBU (a second pair of pins similar to pins 10/11)*
20. *Rack Address 4*
21. *S_RTN / Insert BBU*
22. *PSM_Sync-off/ON*
23. *Can Bus CAN_H*
24. *12V5 for opto (12.6V_{DC} after or-ing which is used to power optocouplers in the shelf to supply the 9V signals, max 40mA)*
25. *Stop Discharge*
26. *EOL for BBU*
27. *SOH check for BBU*
28. *Charge Enable for BBU*
29. *PS Address 0*
30. *PS Address 1*
31. *CAN Bus Can_L*
32. *BBU I2C SDA*

2.5 Airflow Requirements

The PSU is cooled using one or two internal efficient fan pulling cold air inside the PSU. The fan guard shall be built into the chassis housing.

The fan mechanical mounting method shall be such that propagation of vibrations to the PSU chassis caused by the fan rotation is limited; damping soft rubber material may be used for this purpose between the fan housing and the sheet metal chassis. All airflow shall pass through the power supply and not over the exterior surfaces of the power supply.

- During normal AC operation mode, the ΔT shall be greater than 12.5°C , if $T_{\text{inlet}} \leq 35^{\circ}\text{C}$ and loading is less than 67% loading.
 - Except for conditions where fan operates at absolute minimum speed, ΔT requirement shall be met at any AC operation mode when $T_{\text{inlet}} \leq 35^{\circ}\text{C}$.
- ΔT shall be calculated based on airflow rate and power dissipation; it applies to both sea level and high-altitude conditions.
- $T_{\text{outlet}} \leq 60^{\circ}\text{C}$ at any operating temperature range.
- During BBU backup mode and State of Health battery test (SoH), the PSU fan must run at full speed and does not have to conform to the requirements stated above during the AC operation mode.
- The air must flow in the direction from the front surface of the PSU to the back. Where the front surface is where the handles and LEDs are located.
- The fan speed algorithm of the PSU should be computed while the PSUs are installed in the shelf and using the PSU that is inserted in the 'worst case' slot, which is the PSU with the highest back pressure (highest air flow impedance).
- At PSU turns on, the fan should start up at full speed and then settle down to the self-regulated speed value.
- The fan is a 12V_{DC} component and so it can be powered directly by the output voltage. A 'C-L-C' filter may be used to power the fan to reduce injection of spikes to the main 12.6V_{DC} supply output. In fact, the brushless fan generates significant amounts of ripple and noise to their DC supply. The electrolytic capacitor connected directly in parallel to the fan must be selected to endure the low frequency ripple current with extra margin (low ESR and long-life component).
 - **Layout rule:** at board level, the fan's positive and negative terminals are connected directly to the main output capacitors before any further PSU output filters, using independent dedicated copper traces routed away from any noise sensitive circuitry (e.g. the main feedback loop circuitry, etc.).
- The fan must stay on at full speed for at least 1 minute after a backup lasting more than 30 seconds or a battery test before going back to normal self-regulated speed.
- If two fans are used and one fan fails, it should be treated as a fan failure and the PSU should turn off.

Note: The battery back-up (SoH test) can last up to 5 minutes at 2200W constant power or the backup converter can provide constant power for 3300W for up to 90 seconds. Regardless, during battery back up the fan should run at full speed.

Temperature sensors shall be placed on critical components as well as input and output PSU locations so that they can provide accurate inlet and outlet temperature information via the Modbus communication.

Temperature sensor	Temp Range	Accuracy
Inlet sensor	-5°C to 45°C	±2°C
Outlet sensor		N/A

2.6 Acoustic Requirements

Acoustic requirement shall follow ISO7779 Section 8.8, mean sound pressure level at the bystander positions shall not exceed 78dBA at any operating condition. Worst case condition might be at full fan speed.

2.7 Temperature Requirements

The power supply shall operate within the following temperature range, -5°C to 45°C.

- Operating temperature range: -5°C to +45°C
- PSU is able to 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 +70°C (short-term storage)
- Operating altitude with no de-ratings: 3000m (10 000 feet)
- The maximum temperature of any touchable part of the PSU during normal operation or when servicing shall be below 70°C.

2.8 LEDs and Silkscreen

Two 3mm LEDs are used for indication of the power supply status. They are located on the front panel face plate on the middle left area with a vertical distance of 8mm between them. The top LED is a bi-color green/amber led and the second LED is red.

Color	Ideal Wavelength (nm)	Wavelength Range (nm)	Intensity
Amber	590	583-593	-
Green	525	505-535	-
Red	630	615-650	-

Silkscreen text is located next to each LED in black Arial condensed bold, with ~2.5mm of font size. The text to the right of the green/amber LED should be “PWR OK / BKP” and the text to the right of the red LED should be “FAIL”.

The drawing below shows a typical location and silkscreen for the LEDs. Final proposed location is subject to Facebook’s approval.

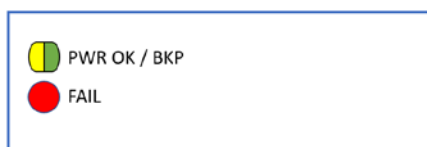


Figure 2: PSU silkscreen and LED placement

Please see more LED information in [Section 10.9](#)

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3 Power Supply Block Diagram

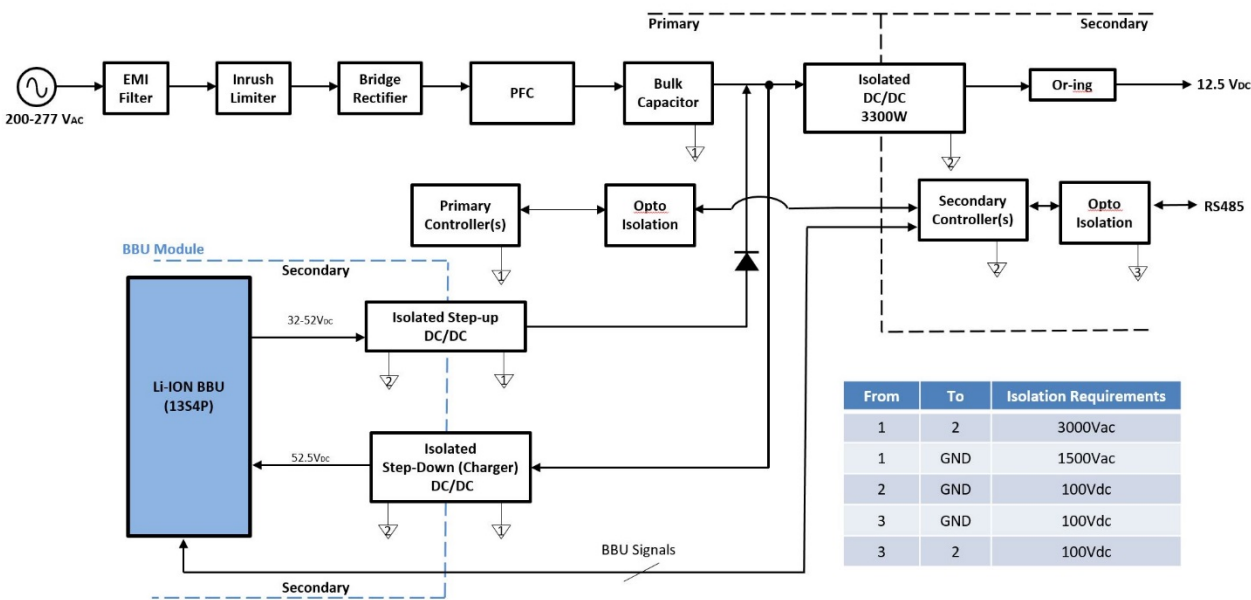


Figure 3: High level PSU block diagram

Note: This is a high-level block diagram and just a suggestion on the topology for the actual implementation. Isolation voltage levels are also listed.

4 AC Input Requirements

4.1 AC Input Voltage

The power supply unit must be able to operate at 180V_{AC} to 305V_{AC} RMS auto-ranging input. The power module must withstand continuous exposure to 305V_{AC} RMS input with no damage, while at this voltage level is not expected to meet the power factor and THD requirements. The front-end circuitry must be able to detect any AC loss within 5mS after the actual occurrence, at any AC input level and at any phase of the input AC sinusoidal waveform (from 1° to 360°, wherever the AC loss event occurs).

No hiccups or on/off oscillations are allowed under any conditions and the power supply must not be damaged when exposed to this under voltage. The maximum input current under a continuous brownout shall not blow the fuse.

The housekeeping circuit shall turn on when AC input voltage is greater than 100V_{AC} to report PSU AC under voltage, signal fail LED, and trigger other signals.

	Min	Rated	Max	Start Up	Turn Off	Max input current	UVP/UFP	OVP/OFP	Hysteresis
Voltage (V_{AC})	180	200-277	305	186±4	175±4	At rated voltage max is 22 A	<180V _{AC} go into backup	>330V _{AC} for 12 cycles go into backup*	315V _{AC} back into AC mode
Frequency (Hz)	40	50-60	70	-	-	-	≤39Hz go into backup	≥71Hz go into backup	3Hz

*If input V_{AC} is greater than 330V_{AC}, after the 90 second backup, the PSU shall turn off the 12.6V_{DC} and assert a red fail LED.

4.2 AC Line Fuse

The AC input fuse will be placed in each of the power modules. The fuse is used for safety and extreme protection in case of catastrophic failures. The fuse shall be placed on both line and return path so that the PSU can be used in both Line-Neutral configuration or Line-Line configuration. The fuse rating is 25A, 'fast blow' type; it shall never blow during inrush or any AC input current transients. The fuse shall be a safety approved component (acceptable for all safety agency requirements) with rating of at least 400V_{AC} RMS (may be a larger size due to the high AC voltage involved). At system level, the PSU is powered by a custom AC PDU connected directly to the tap box without any extra protection: a proper I²T coordination shall be verified when the PSU is powered by the PDU (e.g. in the event that the AC input stage of the power supply fails, such as in a short circuit, then the power supply input AC fuse should blow while the breaker in the tap box should not trip).

4.3 AC Line Dropout/Holdup/Power Recovery

The holdup time is defined as the time the 12.6V_{DC} remains in regulation after the AC input drops to 0V_{AC} at any phase angle without any extra capacitance added to the output at ambient temperature.

If the AC line dropout is longer than the holdup time, the PSU shall recover automatically (assuming no BBU input) and meet all turn on requirements. The PSU shall meet the AC dropout requirements over the full AC input range and frequency without the DC input applied from the BBU.

The PSU shuts down during an AC input under voltage condition and can automatically restart when a minimum voltage level is reached.

AC input Voltage	Frequency	Phase Angle	Temp	Loading	Holdup/ Dropout Time
200V _{AC} - 277V _{AC}	50-60Hz	0-360°	25°C	100%	20mS (1 AC cycle)

4.4 AC Loss Detection

The PSUs front end circuitry must be able to detect any AC loss within 5mS after the actual occurrence, at any AC input level and at any phase of the AC sinusoidal waveform (from 1° to 360°, wherever the AC loss event occurs).

4.5 AC Inrush

The inrush current shall never exceed 30A peak at cold start, $V_{input} = 290V_{AC}$ RMS, $T_{amb} = 35^{\circ}C$. The PFC start-up current peak shall be lower compared to the AC inrush current peak. The AC inrush current during the main 12.6V_{DC} soft start up shall be less than 16A RMS at 230V_{AC}. The spikes of current due to the charging of the X2 EMI capacitors should not be considered. The inrush sequence will have to repeat after any AC interruptions of sufficient duration to cause the PSU to enter back-up status, including dips and sags (i.e. multiple input dropouts).

AC input Voltage	Frequency	Phase Angle	Temp	Loading	Requirement
290V _{AC}	50-60Hz	0-360° (worst case angle)	35°C	100%	Input AC current <30A peak

The inrush MOSFET or relay will be driven by the microprocessor. The relay must open, and the sequence should be repeated every time the AC input voltage falls below a certain threshold.

Suggestion: The inrush-limiting component (power resistor or NTC) can be placed in series to the input AC power train, before the input bridge rectifier (this topology will provide the best performance vs. the surge test).

4.6 AC Line Isolation

The power supply shall meet all safety requirements for dielectric strength.

- The PSU will support safety reinforced isolation between high voltage AC primary section and any secondary section (3000V_{AC} RMS of isolation).
- Isolation between high voltage AC primary section and chassis GND is 1500V_{AC} RMS.

4.7 AC Line Leakage Current

The leakage current per module shall be in compliance with applicable EN/IEC standards, and shall not exceed 3.5mA RMS at 60 Hz and 277V_{AC}.

4.8 Power Factor Correction

If a bridgeless type power factor correction (PFC) is chosen, it must have at least two high voltage silicon diodes (in series) from the AC grid. This is for safety reasons. If the bulk voltage is energized by the li-ion BBU during an AC outage, the bulk voltage (supplied by the BBU) must not be able to discharge to the AC input line after a single failure (e.g. in the event where one of the two diodes fail and create a short circuit).

4.8.1 Bulk Tracking

When AC input voltage goes above $300V_{AC}$, the PFC shall slowly ramp up the bulk voltage to maintain a $\sim 15V_{DC}$ difference between the input rectified voltage and the bulk voltage. Bulk voltage shall stay less than $470V_{DC}$.

4.9 Power Quality

Power factor and iTHD (total harmonic distortion of the AC input current, with order of the harmonics up to and including 40) at rated voltage:

	Voltage	Loading	Requirement
Power Factor	200-277	>10%	PF > 0.95
iTHD	200-277	>10%	iTHD < 10%

- Power supply should not shutdown with 10% harmonic AC input voltage for full working range (180-305V_{AC})

The Vendor is encouraged to propose solutions exceeding the above limits if they make cost sense for a 3300W power supply. Note that efficiency is priority.

4.10 EMI Filter

The EMI filter should not make use of more than two cells with low series DC resistance. The design should preferably use bulky choke components to reduce the copper losses and maximize the efficiency. Smart design of common mode windings able to include some differential mode (DM) impedance (DM leakage) is welcomed because it helps EMI suppression. As already mentioned, all the components used in the AC input power section must be rated at least 305V_{AC} RMS (e.g. AC input connector, protection fuse, X2 EMI caps, surge protection devices, bleeder resistors, etc.).

4.11 Primary MOSFETS and Bulk Capacitors

- The bulk capacitor shall be rated at 500V_{DC} 105°C and shall be long life components. For each bulk capacitor, a single component rated at 500V_{DC} is required (compared to the potential alternative of having two capacitors rated at 250V_{DC} each and connected in series). Voltage stress, especially when the positive peak of the low frequency ripple voltage at worst conditions is included, is not negligible, while at the same time a reliable design, fully working up to 290V_{AC} RMS input, must be guaranteed (305V_{AC} RMS peak).
- The 500V_{DC} rating gives enough margin for a nominal bulk voltage that likely shall be in the range 430V_{DC} ~ 450V_{DC}.
- All of the high voltage power MOSFETs used in the primary side must be rated 600V (minimum), 650V preferred.

5 DC Input Requirements

An external battery pack will be connected directly to the power supply module and will use the power from the battery during an AC outage or during the battery State of Health check (SoH).

5.1 DC Input Voltage

The DC input voltage will range from $28V_{DC}$ to $55V_{DC}$, which will be provided from the battery pack. The normal working range is from $31.85V_{DC}$ to $52.5V_{DC}$, but the PSU shall be able to work in the lower range for a short amount of time without any issues.

Min	Rated	Max	Max input current
$28V_{DC}$	$31.85-52.5V_{DC}$	$55V_{DC}$	140A

5.2 DC Input Fuse

No DC input fuse is required since the battery pack will have its own internal fuse.

5.3 Emission Standards Compliance

Needs to meet same compliance standards in [Section 13](#).

5.4 DC Input Isolation

The power supply shall meet all safety requirements for dielectric strength.

- The PSU will support safety reinforced isolation between high voltage AC primary section and any secondary section ($3000V_{AC}$ RMS of isolation).
- Isolation between high voltage AC primary section and chassis GND is $1500V_{AC}$ RMS.
- Isolation between BBU and chassis GND is $100V_{DC}$

5.5 DC Inrush

The inrush shall be less than 20A to limit any spikes of current that occur when a charged BBU is installed in the shelf.

The maximum peak of the start-up output current during an AC outage, while the PSU is switching to backup mode, shall never exceed +20% of the related steady-state output current, tested at any input voltages ranging from $30V_{DC}$ to $55V_{DC}$ (with 2V step increments), and at all valid loads. The max peak of the startup current shall never last more than 5ms.

5.6 DC Leakage Current

The leakage current at $52.5V_{DC}$ main output blades (including the sense lines) from the BBU input should be a maximum of 2mA (lower the better) regardless of what state the power supply is in (ex. on, off, sleep, failed, etc.).

5.7 BBU Signals

Various, open collector signals are sent from the BBU to the PSU. The various actions that the PSU must take for each signal is listed below in [Section 10.3](#). Also, more information can be found in the V2 BBU specifications document.

6 DC Output

There are two main DC outputs out of the PSU, the main 12.6V_{DC} and the 52.5V_{DC} charger. There may be other internal DC outputs connected to the bulk voltage such as the boost converter to convert the battery voltage to the bulk voltage.

6.1 Output Power

Below are the normal output power requirements for both the main 12.6V_{DC} and 52.5V_{DC} charger output. The power supply shall also be able to support above the max rating for a short duration. Average power shall always be less than 100% of the rated power. Thermal shutdown may occur if PSU is running over 100% for a long period of time (ex. 118% loading for greater than 18 seconds may cause a thermal shutdown).

Voltage	Min	Max	Peak / Time	Slew Rate
12.6V _{DC}	0A	265A	120% / 18 secs 170% / 3ms	1A / μ S
52.5V _{DC} charger	0A	5A \pm 2%	-	-

6.2 Internal Bias Supply

The internal DC bias supply (auxiliary supply) is intended for housekeeping functions only (no externally available standby voltage is required). The implementation of an independent bias supply is the preferred solution and it should work from a minimum of 100V_{AC} RMS. The bias supply should be implemented with a high efficiency scheme; the Vendor shall propose the best solution.

A back bias connection is needed that takes the 12.6V_{DC} from the common output busbar in the shelf, which is powered by the other PSUs. In the event of a PSU failure, the back bias will provide power to the failed PSU's LEDs, secondary logic, and communication circuits. The 12.6V_{DC} back bias shall not power any the PSU under normal condition (only when the PSU has a failure and cannot produce its own 12.6V_{DC}). The BBU shall never receive power from the back bias (if the PSU fails, the BBU will not see the 12.6V_{DC} and therefore it will go into sleep mode). Also, a thermal fuse should be used as an internal short circuit protection in conjunction with a resistor to limit the inrush current.

6.3 Voltage Regulation

Output	Tolerance	Min	Nominal	Max	Comments
12.6V _{DC}	\pm 10mV	12.421	-	12.630	Droop share
52.5V _{DC} (charger)	\pm 0.2%	52.395	52.5	52.605	At no load condition

6.3.1 Voltage Droop Regulation Values

Load	Min	Nominal	Max
0%	12.560	12.620	12.680
50%	12.466	12.526	12.586
100%	12.372	12.432	12.492

6.4 Dynamic Loading

The power supply shall meet voltage regulation specified in the above section during the dynamic loading conditions below. The measurement shall be from the new steady state value (due to droop) to the voltage spike/dip peaks during a transient-load and be within $\pm 300\text{mV}$, under the following conditions:

- Electronic load set in “constant current” mode.
- Load step of 0%-25% with $0.1\text{A}/\mu\text{S}$ slew rate, 50hz to 50kHz, 10% duty cycle to 90% duty cycle
- Load step of 10%-90% with $1\text{A}/\mu\text{S}$ slew rate, 50hz to 50kHz, 10% duty cycle to 90% duty cycle
- Load step of 50%-120% with $1\text{A}/\mu\text{S}$ slew rate duty cycle & load step of 50%-170% with $1\text{A}/\mu\text{S}$ slew rate duty cycle
- Transient requirements shall be met with (or without) the max allowed capacitive load connected to the output terminations.

6.5 Capacitive Loading

A single PSU is able to startup properly and, more importantly, is unconditionally stable when such a capacitance (or lesser value) is connected to the output (in parallel to any resistive loads, or just the capacitance).

Output	Min	Max
12.6 V _{DC}	0	200 000 μF
52.5V _{DC} (charger)	-	-

6.6 Stability

- The power supply shall be unconditionally stable, under any conditions and combinations of resistive and capacitive loading, constant power loading, temperature, aging, etc. Feedback loop control (analog or digital) shall never cause the error amplifier to enter a non-linear status during extreme transients.
- Bode plot will show a phase margin greater than 45 degrees at worst conditions and the dynamic step-load plots will show no ringing but rather a smooth recovery shape similar to a second order system with damping factor $\sigma > 0.7$.
- The stability criteria shall be met with and without the max allowed capacitive load.
- The stability margin should not be excessive because exaggerated reductions of the line frequency ripple or slow transient response time are not desired.
- The PSU is able to start properly under no load conditions or overload conditions.

6.7 Ripple/Noise

The max ripple and noise shall meet the requirements in the table below.

- No external capacitive load is connected to the output terminals during this test.
- Measurements are performed at the output connector at PCB level, with the board installed in the chassis, a safety ground connected through an AC power cord, 180V_{AC} input and full load.
- A digital oscilloscope is used for this measurement, with acquisition set to peak detect mode.
- The probe will be used without its cap to minimize the length of the return connection in order to achieve a reliable R&N reading (negative return is directly connected to the metal body of the probe).
 - A small 1uF X7R 0805 SMT ceramic capacitor may be connected locally to the probe tip during this measurement.
- As a design note, the 12.6V_{DC} output stage may include a small CM choke added very near the output connector, for CM noise suppression.

Output	Ripple Spec	Bandwidth/Test
12.6V _{DC}	120mV pk-pk	20MHz
52.5V _{DC} (charger)	300mV pk-pk at CC mode	
	300mA pk-pk	

6.8 Hot Swap Requirements

The power supply modules will be placed in a shelf that has the capabilities to support up to three PSUs. The shelf is designed as a 2+1 redundancy configuration. Therefore, any PSUs can be removed and installed in the shelf during operation. During insertion and removal all voltage regulations shall remain within their limit.

6.9 Current Sharing / Droop

The power module shares the current with the remaining two or one modules in the shelf using a current share topology that shall allow excellent sharing at light load. Different loading conditions on the battery charger should not affect the overall output sharing.

- A further droop-share is added on top of the regular current share, to help the current share functionality during transients: -0.15V from 10% load to 90% load (0% loading-12.61875, 100%-12.43125).

PSU Loading	Share Accuracy	Comments
>20% rated load of the shelf 6.6kW	±5%	-
100% rated load rated load of the shelf 6.6kW	±1%	Can be tested with only 2 PSUs in a shelf.

Sharing Accuracy for 2 PSUs installed in the V2 Shelf						
Shelf Load		Positive Accuracy		Negative Accuracy		Total Accuracy
%	(A)	%	(A)	%	(A)	(A)
0%	0	-	-	-	-	-
10%	53	-	-	-	-	-
20%	106	5%	2.65	5%	2.65	5.3
30%	159	5%	3.975	5%	3.975	7.95
40%	212	5%	5.3	5%	5.3	10.60
50%	265	5%	6.625	5%	6.625	13.25
60%	318	5%	7.95	5%	7.95	15.90
70%	371	4%	7.42	4%	7.42	14.84
80%	424	3%	6.36	3%	6.36	12.72
90%	477	2%	4.77	2%	4.77	9.54
100%	530	1%	2.65	1%	2.65	5.3

The sharing accuracy spec is percentage of average current, $I_{AVG} = \frac{1}{2}(I_1 + I_2)$ when 2 PSUs are installed in the shelf. When 3 PSUs are working in parallel, each PSUs should be within +/- (the same accuracy in the table above) of the theoretical average current.

Each PSU calculated its output voltage set point using a linear equation $V_{out_set} = f(i_{out})$ valid for its own internal V_{sense} point. Below graph represents the passive droop characteristics.

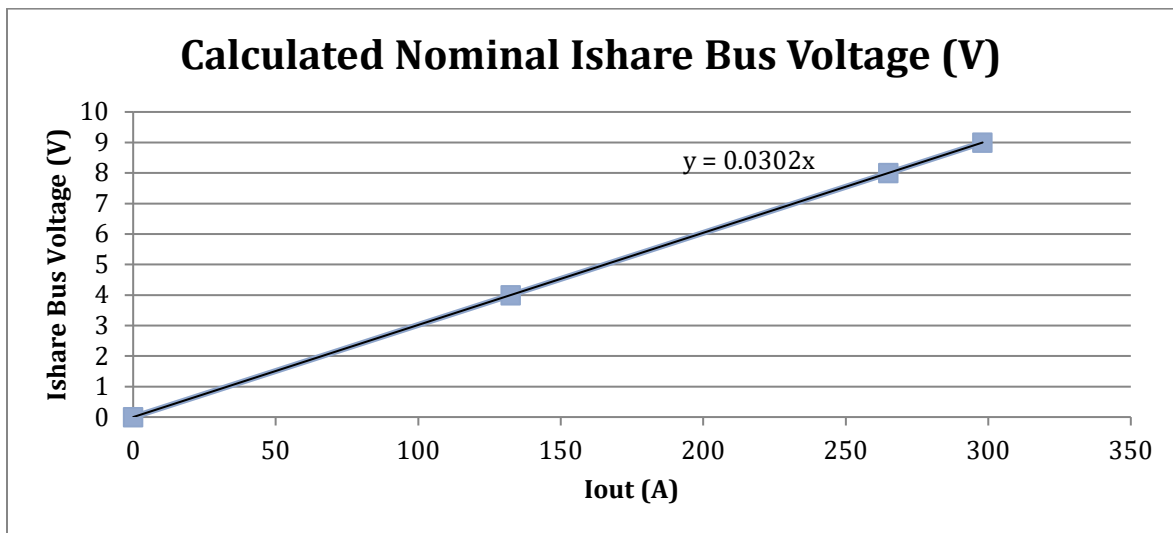


Figure 4: Passive droop characteristic (i-share bus)

6.10 DC Isolation

- Both positive and negative 12.6V_{DC} output terminations are floating with respect to the chassis GND, with galvanic isolation of 100V_{DC}.
- The charger and boost converters should also have the same reinforced isolation between primary and secondary side (3000V_{AC}). As a reminder, the negative returns of the 270W charger are electrically connected to the 12.6V_{DC} negative return.

6.11 Battery Charger Information

This converter connects directly to the li-Ion BBU battery module with ORing diode/MOSFET, to avoid spikes of current that occur when a charged BBU is installed in the shelf (it blocks the voltage from the BBU).

The battery charger constant current level can be adjustable between 1A to 5A. Two methods can be implemented to set the value of the constant current level. Firstly, the PSU will determine its own default constant current charger output level through an equation, based on various parameters, outage duration, output loading, and battery voltage. Facebook will work with the Vendor to define this calculation and implementation of various corner case scenarios (ex. SoH test, first time BBU insertion, periodical charging, etc). Secondly, the charge current level can be overwritten by writing a value to a defined register (0xA4, W/R, 1 word length) via Modbus protocol. Please refer to the communication specification for detailed register address for this read/write register.

There should be no overshoot; the output voltage must rise monotonically. During turn-off, the output voltage must fall monotonically.

The leakage of the ORing diode/MOSFET shall be less than 0.5mA and two 100kΩ resistors in parallel before the ORing shall be placed in parallel to the output capacitors so that the output capacitors do not become charged to 52.5V_{DC} and do not 'fake' the converter into seeing a correct voltage if the charger converter does not work.

The feedback for the step-down charger shall be taken at the (3) power blades of the negative connector of the battery and the (1) charge blade with a differential amplifier.

The sense lines provided from the BBU will be also connected to a differential amplifier used for monitoring the battery voltage.

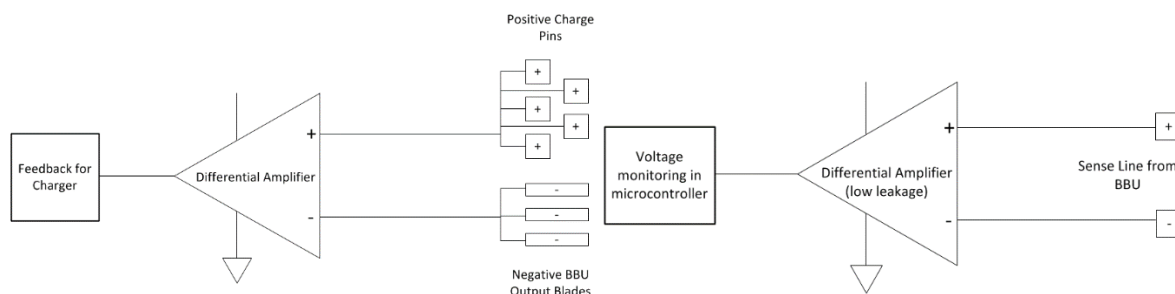


Figure 5: Charger feedback diagram

6.11.1 Charger Failure

- If the current given by the charger from the PSU is less than 500mA and if the voltage is less than 52.5V_{DC} -2% for 2 consecutive seconds (at the BBU sense lines) then the charger shall be shut down and the fail LED on the PSU shall be asserted. This will subsequently cause the BBU to go into sleep mode (since it won't see any charge current for 5 minutes) and the BBU will then open its charging MOSFETs.
- If the battery charger is on (charge_enable signal low) for more than 5 consecutive hours, then the battery charger should be considered failed and assert the fail LED on the PSU.
- A failure of the battery charger should not latch off the main 12.6V_{DC} output.

Note, if the BBU does not see any current for 5 consecutive minutes, after it asserts the charge_enable signal low, then the BBU will go into sleep mode and assert its Sleep signal high.

Charger Voltage	Timing	Charger output current	Sense Method	Outcome
$< 52.5V_{DC} - 2\%$ ($< 51.45V_{DC}$)	2 seconds	$< 500mA$	BBU sense lines	PSU Fail LED = ON, $12.6V_{DC}$ still present
-	> 5 hours	-	-	PSU Fail LED = ON, $12.6V_{DC}$ still present

6.12 Timing Requirements

Under any conditions of dissipative load, capacitive load, temperature, with or without backup voltage connected to the PSU:

- The PSU shall turn on when a valid AC input is provided. Stand-by switch and/or on/off signal are not required. The design of the PFC & DC-DC circuitry, soft starts, etc., will be such that the total time, from when a valid AC input is applied to when the DC output voltage reaches regulation, is a maximum of 4.3 seconds under any conditions with $V_{in} > 200V_{AC}$ RMS, which includes the 2 second random timer.
- During first AC turn on the PFC shall be randomized with 0-2 second window to give each power shelf a random turn on time (three PSU turn on is synchronized).
- The $12.6V_{DC}$ rise time should be less than 20ms from 10% to 90% of the $12.6V_{DC}$ output at any loading.
- For any loads (from 'no-load' to 'max-load'), the output voltage will rise monotonically from $0V_{DC}$ to $12.6V_{DC}$, without overshoot or ringing, at any turn on following application of AC input voltage, and anytime when the PSU resumes functionalities after an automatic protection condition (including parallel operations). The output voltage will fall monotonically from $12.6V_{DC}$ to $0V_{DC}$, without undershoot or ringing, at any AC loss, and at any turn off caused by an automatic protection condition (including parallel operations). The backup voltage is not applied for this test, but the same performances are expected regardless of whether the input is supplied by AC or DC (via the BBU).
- Output voltage shall never reverse polarity at the turn off (all conditions and converters).
- The PSU shall include a soft-start that promptly resets at any input AC loss $> 20ms$, or after any automatic protection conditions.
- See timing diagram below for PSU behavior on AC loss, when a valid backup voltage is connected to the PSU.
- The power shelf shall turn on with only 1 PSU inserted into any slot.

Item	Description	Min	Max	Units
T_{on_random}	0-2 second initial turn on random delay	0	2	seconds
T_{ON}	Time $12.6V_{DC}$ turns on after shelf receives AC input	-	4.3	seconds
T_{SYNC}	After all PSUs in the shelf are ready to start till when $12.6V_{DC}$ will start	5	8	msec
T_{RISE}	$12.V_{DC}$ rise time	-	20	msec
$T_{charger}$	Charger turns on after it sees the charge_enable signal	2	5	seconds
T_{Holdup}	$12.6V_{DC}$ holdup time	20	-	
T_{AC_1sec}	Minimum 1 sec AC return	0.9	1.1	seconds

T_{random}	Random timing window after AC outage	0	8	seconds
T_{BACKUP}	Time the PSU can be in DC backup mode	0	90	seconds
$T_{\text{detection}}$	AC loss detection	0	5	msec

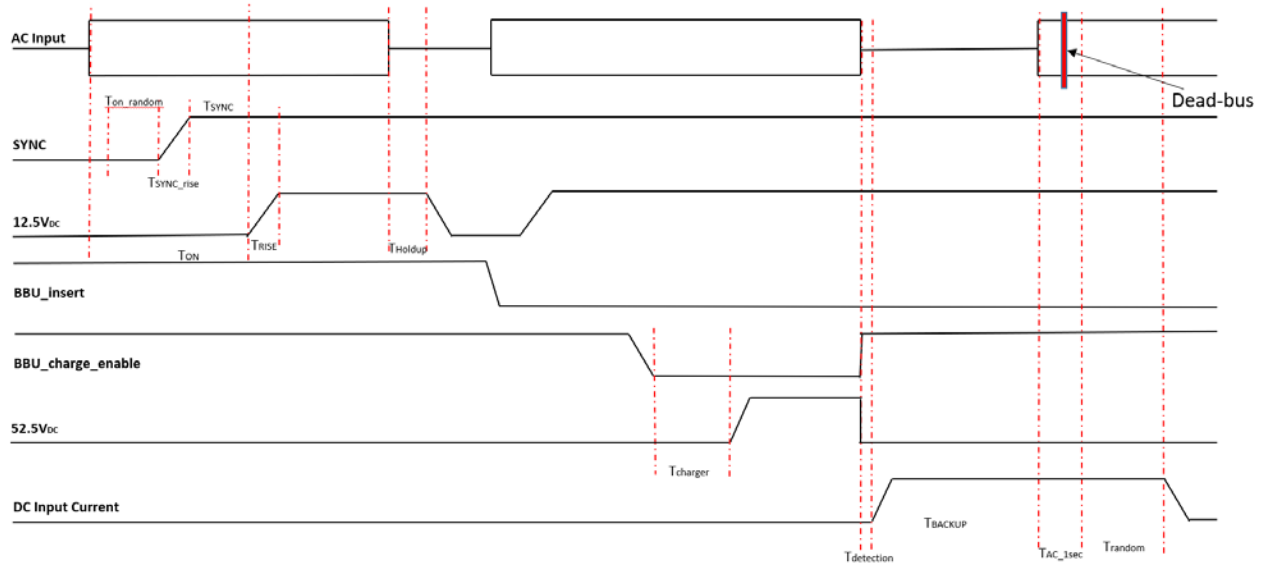


Figure 6: PSU timing diagram

6.12.1 Power Supply Turn-On Sequence

Normal conditions: after a valid AC input is applied, the internal bias supply turns on and the entire circuitry gets powered. There is always a turn on sequence requirement when the AC input voltage is applied to the power supply, regardless of whether the DC backup BBU is installed.

Every time AC is applied to the shelf including after the 90 second backup timeout: the shelf (3 PSU units) turns on synchronously. Sequence: after AC voltage is applied, the internal bias supply starts, the microcontroller boots and keeps the PFC off as well as the step-up and step-down converters. Then the microcontroller closes the inrush relay and turns on all the converters. Note, the step-down BBU charger is turned on 2 seconds after the main 12.6V_{DC} is within regulation. (LED = solid green or solid yellow).

6.12.2 Charger Timer / Information

The earliest the BBU charger turns on is 2 seconds (max delay is 5 seconds) after the main 12.6V_{DC} is turned on.

7 Efficiency

7.1 AC Mode Efficiency

Should meet Titanium 80 plus standard at 230V_{AC} at 25°C, at the loading condition for 30 minutes and the reading should be taken after the female mating connector and fan powered by the PSU. Therefore, the loss of the 12.6V_{DC} connector interface and the fan power loss is included into the efficiency measurement.

A further efficiency target requirement is as follows, efficiency > 95% between 30% load to 90% loading.

AC input Voltage	≥ 230V _{AC}				
Load	10%	20%	30-90%	50%	100%
Efficiency	90%	94%	95%	96%	91%

7.2 Backup Mode Efficiency

The efficiency from the DC input to the 12.6V_{DC} output shall follow the table below. (Note that the fans may be at full speed during DC mode operation and therefore the fan power will be included in the efficiency measurement.) All other measurement parameters should follow the below [Section 7.3](#).

DC input Voltage	33.8V _{DC}	45V _{DC}
Load	100%	100%
Efficiency	>89%	>92%

7.3 Test Parameters/M Measurement Setup

- Input AC power voltage of 230V_{AC} RMS (50Hz and 60Hz).
- A power analyzer with reading accuracy better than 0.1% will be used for the measurements.
- A precise low distortion AC power source supplies the input voltage during the measurement.
- The PSU board is correctly installed in the chassis, with the cover and with the safety chassis GND connected through the AC power connector.
- AC- and DC-power input voltages are measured just before the mating connector, therefore input connector mating loss is incorporated.
- Fans should be powered internally.
- The 52.5V_{DC} battery charger can be completely disabled for testing purposes.
- The output 12.6V_{DC} measurement shall be made at the tabs on the TE connector (PN: 1643903-3) therefore to incorporate the mating losses as well.
- The ambient temperature should be around 25°C.
- The measurement load step shall be an increment of 5%. Take measurements after 30 minutes under initial 75% load, over five samples (they all need to pass).
- Measurements shall be valid over 25 insertions of the PSU into any Vendor's shelf.

NOTE: The PFC may include interleaved topology with phase management in order to maximize the efficiency at light load (phase shedding).

8 Protection Circuits

The protection circuitry of the PSU shall cause the output of its converter to shut down in the event of an OCP, OVP, UVP, OTP. If the PSU latches off due to one of the following protection limits is reached, then an AC cycle for greater than 1 second can reset the power supply. If the charger or step-up boost converter fail the PSU shall not turn off the 12.6V_{DC} output.

8.1 Over Current Protection (OCP)

- Output voltage must shutdown when a short circuit condition is detected. After 5 seconds the output will try once to turn on. If the short circuit condition is still there, the output will latch off.
- A hard short lasting more than 2 seconds latches off the 12.6V_{DC} output (and all secondary converters) and an AC recycle (≥ 1 second) is needed to resume the PSU.
- If a latched OCP PSU is in the shelf which experiences an AC outage, when AC returns this satisfies as an AC recycle (≥ 1 second) and can try to turn on again if the short is removed.
- The PSU is sized (thermally and electrically) to indefinitely stand a short circuit, without damage, under any conditions.
- The PSU is able to start under overload or short circuit conditions.
- The power supply shall also be able to support above the max rating for a short duration. Average power shall always be less than 100% of the rated power.
 - Thermal shutdown may occur if PSU is running over 100% for a long period of time (ex. 118% loading for greater than 18 seconds may cause a thermal shutdown which is allowed).

Output	Over current Limit	
12.6V _{DC}	120% > 18 seconds shutdown (latched shutdown)	170% > 3ms shutdown (auto recover after 5 seconds)
52.5V _{DC} (charger)	Shall not go above 5.4A (charger latched shutdown)	

8.2 Over/Under Voltage Protection (OVP/UVP)

- The protection mode is the latch off type, so an AC input recycle (≥ 1 seconds) is needed when attempting to resume operations after an over-voltage event.
- The over-voltage circuitry is independent and includes a separate voltage reference device. The microprocessor may be notified in case of an over-voltage event, if necessary.
- Analog protection circuit is required for OVP.

Output	Over voltage Limit		Time
	Min	Max	
12.6V _{DC}	13.9 V _{DC}	15.03V _{DC}	
52.5V _{DC} (charger)	52.984V _{DC}	54.816V _{DC}	<100ms

8.3 Over Temperature Protection (OTP)

The PSU shall work without any issues at 45°C ambient temperature. The PSU is protected against overheating to prevent damage or degradation. The PSU may overheat for many reasons, including (but not only) internal failing conditions, environmental factors, or because of improper use, such as air obstruction.

- If inlet sensor goes above its OTP limit, all the PSUs outputs shut down and will be able to automatically resume operations once the temperature falls below the OT recovery point.
- If any component sensor goes above its OTP limit, all the PSUs outputs turn off and PSU asserts the fail LED. The PSU should latch.
- If charger experiences an OTP, it is a latched shutdown but 12.6V_{DC} is still available with a red fail LED.
- The OTP limit should be set as high as possible to maintain safe operation (at least 55°C).
- No components shall be over stressed at the temperature shutdown threshold level.
- There should be enough temperature sensors within the PSU to guarantee safe operation.
- An OTP alarm for one PSU shall not force any of the other two PSUs in the shelf to also turn off. Each PSU shall act independently for OTP.

For example:

- Primary thermal switch (e.g., normally closed for primary heat sink OT protection).
- Secondary thermal switch (e.g., normally closed for secondary heat sink OT protection).
- The BBU step-up and step-down BBU charger, converters should stay within their temperature range.
- All of the thermal sensors should be routed to the microprocessor (primary sensors are opto- isolated, reinforced isolation). The vendor is free to propose the best solution for OTP.

8.4 Battery Protection Signal

An analog, active low signal (“Protection Pin” from BBU) will be provided by the BBU to alert if an over temperature condition has occurred. This signal will be one of two inputs to a logic OR circuit. The second signal will be generated if an under-voltage condition is seen via the BBU sense lines. A comparator should be placed after the amplification circuit of the BBU sense voltage lines and referred to a voltage which is equivalent to 28V_{DC} (2.154V_{DC} x 13 per cell). A small delay of 100ms, should be implemented (to ensure valid signal and not just noise) after the comparator before the signal is ORed, with the active low signal (“Protection”) from the BBU. The OR logic output of these two signals shall be used to immediately turn off the step-up (backup) converter’s MOSFETs in case of any one of those two conditions are met. The step-up converter’s MOSFET driver shall be enabled again when the voltage at the sense lines increases back to 43V_{DC} (3.3V_{DC} per cell).

Therefore, if the sense lines is $\geq 43V_{DC}$ then the PSU shall discharge that BBU now if an AC outage occurred.

Output	Low voltage protection	Sensing/Signals	Timing	Action
Boost Step-up Converter Disabled	$28V_{DC}$	(BBU sense lines) OR'd with (Protection signal from BBU)	100mS	Step-up converter MOSFET drivers disabled (enabled again at $43V_{DC}$)

9 Battery Backup

9.1 Battery Backup Sequence

9.1.1 Battery Backup Timing

The PSUs shall go into backup individually when they detect an AC outage (assuming BBU is also healthy) based on the AC input voltage threshold. The BBU should never be used as long as there is a valid AC input, except during an SoH test and/or command sent for force backup mode operation via Modbus.

Switching into backup will be detected by a fast AC_OK signal which can detect a bad AC input voltage within half a cycle AND together with BULK_OK signal. If AC_OK is bad and BULK_OK is still good, after 100mS the PSU should go into backup regardless of BULK_OK is still good (for light loading conditions). The output of these two signals can be OR'd together with any other power monitoring signal for better accuracy.

After AC voltage restores, the microcontroller keeps the PFC converter OFF. Then the microcontroller generates a random number 'N' between 0 and 8000 turning ON the PFC converter with that delay in milliseconds. The PSU module in SLOT#1 then sends a sync command via the CANbus that is dictated by the random number generated by itself. If the PSU in SLOT #1 is failed (or not even installed) at the time of AC is restored, the remaining two units start up synchronously at the end of "TAC_1sec" (with no random timing), when AC becomes available and is present for at least 1 second.

- The time in DC backup mode shall end once AC returns for 1 second plus random timing. Example, if AC outage lasts for example 88 seconds, the PSU shall not shut down once 90 seconds is reached. At the 90 second timer mark, if AC is available the PSU shall automatically switch back to AC power.
- The 90 second counter shall reset once the PSU returns on AC mode. Therefore the worst case condition would be that the previous AC outage lasted 89 seconds, the PSU then switched back to AC mode for 1 second, this would cause the 90 second timer to reset.

9.1.2 Random Number Generation

The random restart command is assigned to the power module installed in SLOT #1 (left most slot if looking at the front of the shelf): it enables the transition back to AC power for itself and to the two remaining modules, for a shelf synchronized random restart after AC restores (after outage). This is performed via the CANbus.

- The random numbers above shall be dynamically generated immediately after each AC recycle, and not generated one time and then stored in the EEPROM for future usages.
- As long as all three PSUs are installed in the shelf and all three PSUs are active on the CANbus, there will be a random timer implemented.
- If a BBU or PSU fail there will still be a random timer implemented as long as the PSU is active on the CANbus.
- If any BBU fails before or during an outage so that the PSU is not delivering 12.6V_{DC} during back up, when AC returns there should be a random timing and shall bring the shelf back synchronously out of back up. The PSU with the failed BBU during back up shall not turn on right away when AC returns.
 - If any PSU is running an SoH test, and an AC outage happens, then when AC returns the PSU in the other slots shall turn on synchronously with the random timing and the PSU running an SoH test should continue its test if it is not finished.
 - Also the 90 second timer should start when AC is lost and not start when the one PSU started the SoH test.

9.1.3 Dead-Bus Event

As described above, when AC power is restored during a backup phase after an AC outage, the PSU will randomly restart in the 8 second window. In the case that the DC input BBU fails, stop_discharge, sleep, protection signals are asserted or the BBU is physically removed from the shelf, during that 1 second validation and 8 second window, in which the AC mains is actually available, start of the “TAC_1sec” interval before the PFC starts delivering power (see Backup Sequence, interval “TAC_1sec”), then the PFC shall take over and provide power to the main converter. The backup sequence chart shows the exact point where to test the DEAD-BUS event: see PSU timing diagram in Figure 6 above, interval “TAC_1sec”. The PSU’s 12.6V_{DC} output must stay within regulation at full load and meet the DEAD-BUS requirement.

9.2 Battery State of Health (SoH) Check

The BBU will determine internally (with random logic) when the BBU needs to be tested. Please refer to the V2 BBU Specification for more information. The logic of how a BBU test should be implemented once the SoH signal is low, is below.

The PSU will turn on the step-up converter when the SoH signal from the BBU is low and all preconditions are valid and the PSU will turn off the step-up converter and stop using the BBU as a source of power once the SoH signal is high. At any time during the battery test, when the SoH signal is low, if the BBU gives the ‘stop_discharge’, ‘fail’, or ‘protection’ signals the PSU shall stop using the BBU as a power source and revert back to AC power (similar to the deadbus event in [Section 9.1.3](#)).

- 1) CHECK: Make sure all three PSUs and BBUs are installed and communication is available.
- 2) CHECK: Are any BBUs currently running a self-test? This is determined via internal communication.
 - YES: Queue the test
 - No: Continue
- 3) CHECK: Are the shelf level AC_OK and BULK_OK signal valid (AC power is present to all three PSUs)
 - YES: Continue
 - No: Queue the test

- 4) CHECK: Are there
 - Any failed PSUs or BBUs
 - Any BBUs displaying the following low signals:
 - Stop_Discharge, EoL, Protection
 - Any BBUs displaying the following signals high:
 - Sleep or Insert
 - Any PSUs in the shelf performing a FW update (bootloader)
 - YES: Queue the test
 - No: Continue
- 5) CHECK: Are there any BBUs being charged at the moment via the Charge_Enable signal or are there any BBU packs with a voltage less than $50.7V_{DC}$ (BBU sense lines)?
 - YES: Queue the test
 - No: Continue
- 6) CHECK: Is the load for that PSU greater than 500W for at least one minute (consecutively)?
 - YES: Continue (if load decreases during the test, continue. Once you perform a test you must commit to it)
 - No: Queue the test
- 7) START self-test
 - IF another BBU fails or another PSU in that shelf fails
 - i. THEN continue the test as normal
 - IF the shelf goes into backup mode
 - i. IF the SoH signal goes back high, the PSU shall continue to discharge that BBU until AC returns (the go second timer for that PSU/BBU pair shall start when the AC outage happened).
 - IF the BBU is physically removed
 - i. THEN end the test. The BBU will consider this as a failed test and wait for the next scheduled test. The PSU will seamlessly transition back to AC power without interruption to the output $12.6V_{DC}$ (similar to the deadbus event in [Section 9.1.3](#)).
 - IF the PSU whose battery is being tested asserts the Fail, Stop_Discharge, or Protection signals, then the PSU will stop discharging the BBU and seamlessly transition back to AC power without interruption to the output $12V_{DC}$ (similar to the deadbus event in [Section 9.1.3](#)).
 - i. THEN ABORT test and switch back to AC power, similar to Deadbus event (BBU goes into sleep mode)
- 8) IF SoH re-asserts high then stop discharging the BBU and switch back to AC power
 - Determine if the test is valid:
 - i. The BBU will determine the validity of the test data. If valid, it will begin its open circuit voltage (OCV) period and will determine if the BBU has reached EoL at the end of this period. During this period the BBU will not be recharged. The charge_enable signal will remain high.
 1. IF for any reason during this OCV period the battery asks to be charged ('Charge_enable' is low) this means that the test data was not useful and the BBU has aborted the test.

2. IF an AC power outage occurs during this OCV period, the outage is always given priority and the PSU can use the BBU as a power source, until the stop_discharge signal is given. The BBU will abort its battery test data.
 - Once that BBU has been fully recharged, the PSU will consider the test complete and will allow another BBU to be tested if it was in queue.
- 9) During a battery test the internal CANbus informs the other power modules installed in the shelf that they cannot perform any battery tests until:
 - The current test completes and
 - The BBU performing the battery test recharges back to full voltage ($>50.7V_{DC}$ and Charge_Enable signal back high)

9.2.1 SoH Queue

- If a PSU is in queue for an SoH test, the blocking conditions can be checked every x minutes (suggested to use 10 minutes) to see if all the conditions are valid now to start the SoH.
- During startup of the power shelf a 1-minute delay should be added to avoid an SoH at first turn on.
- If multiple BBUs are in queue at the same time, base the priority of the battery tests should be first in first out (FIFO).
- If an SoH signal was low for a BBU prior to an AC outage then the PSU should go into battery backup.
 - Once the outage is over, the PSU shall return to AC power, regardless if the SoH signal is still low for that BBU. Once, all the BBUs are charged back to $>50.7V_{DC}$ and all other precondition checks are satisfied, IF the SoH signal is still low you can then conduct an SoH for that BBU.

Conditions	Proceed to Queueing
A PSU is not Present	Yes
A BBU is not Present (Insert signal high)	Yes
BBU Fail signal (low)	Yes
BBU Sleep signal (high)	Yes
PSU Fail	Yes
BBU Voltage	If less than $50.7V_{DC}$
BBU Eol signal (low)	Yes
BBU Protection signal (low)	Yes
BBU Stop Discharge signal (low)	Yes
BBU Charge Enable signal (low)	Yes
PSU Bootloading	Yes
PSU performing another BBU SoH test	Yes
Invalid AC	Yes
PSU load	If load is $\leq 500W$ for at least 1 minute

NOTE: Use the following flow chart, Figure 7, below as a high-level reference. Please follow the detailed checks mentioned above.

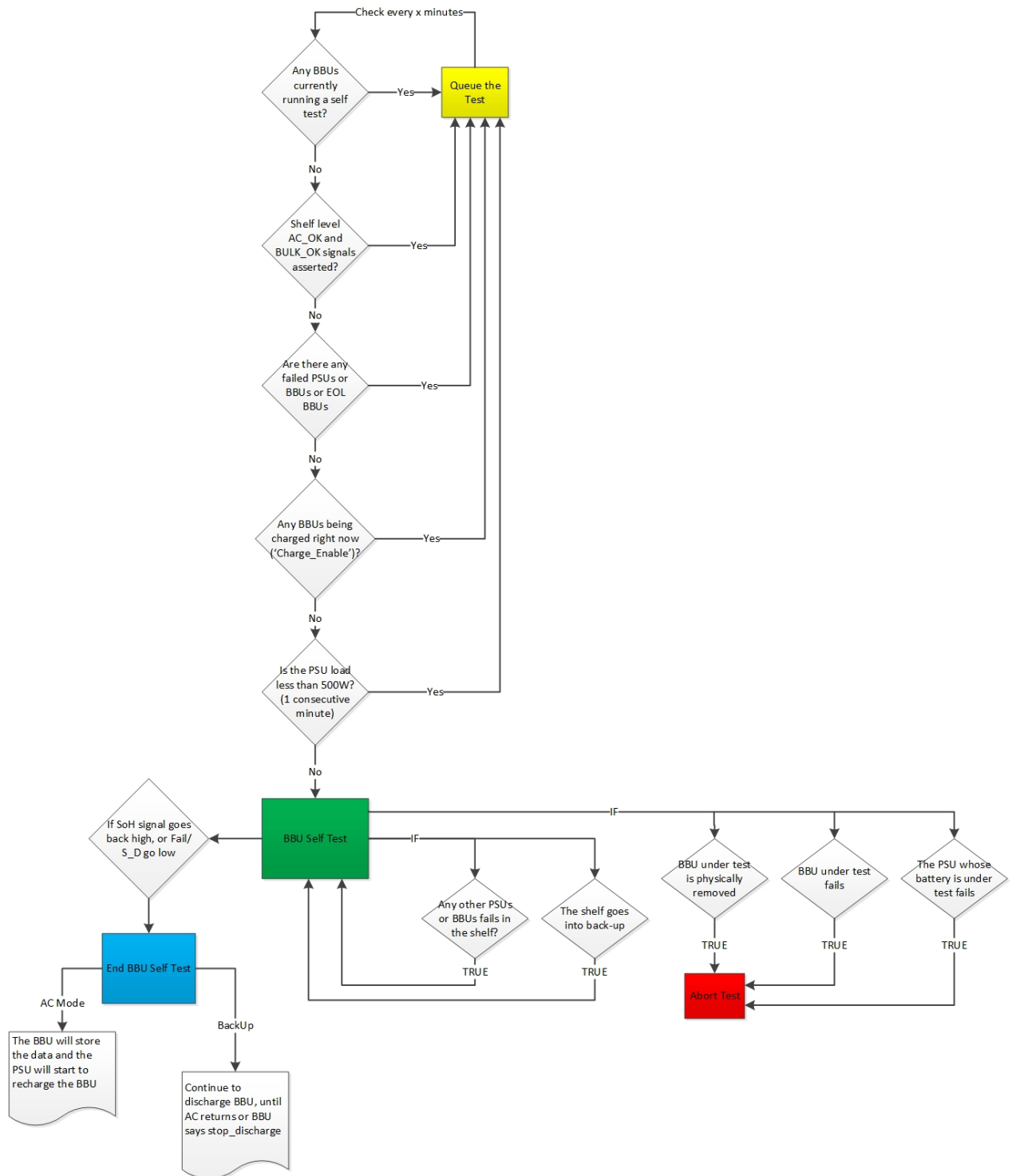


Figure 7: SoH test conditions flow chart

10 Control and External Signals

10.1 Signals

All signals out of the shelf shall require isolation.

10.1.1 PS_Kill

Short pin on the PSU connector which should engage last and disengage first. The PS_Kill prevents arcing and shuts down the PSU. The PS_KILL signal shall be connected to ground of the PSU. The PS_Kill turns off all outputs of the PSU (12.6V_{DC} and charger).

10.1.2 PSM_SYNC-OFF/ON

This is the synchronization signal to turn on the PSUs in the shelf together during first turn on. This signal is not used to perform the synchronization turn on after an AC outage. The random synchronization timing is done via the CANbus.

10.1.3 S_RTN

S_RTN, is used as signal ground for I2C communication and I/O signals (sync turn on, etc).

10.2 FB Server Signals

The two signals below shall be isolated (100V_{DC}, which can be done in the power shelf) and their definitions are defined below. Also these two signals will be used to produce 9V_{DC} on the output of the shelf.

10.2.1 Redundancy_Lost_L

This is an active low open collector signal, normally high. This signal indicates to the data center that the power shelf has lost some form of redundancy. This signal is sent low out of the shelf, within 5 seconds, via pin 3 on the RJ45 connector and output 9V_{DC} on the 9V_{DC} connector every time the following condition below happens:

- When the PowerShelf loses redundancy. This means that at least one power module in the shelf has failed (red fail LED on PSU), a BBU in the shelf has failed or the sleep/insert signal are high, or a PSU/BBU is not inserted/removed from the shelf.
- The REDUNDANCY_LOST _L signal should be asserted when the PSU is performing a bootload or when the BBU voltage is below 31.85V_{DC}.
 - The signal should **not** get asserted low when any BBUs in the shelf have the Stop_Discharge, Protection, or EoL signal low.
 - An AC outage/backup or one BBU performing a battery test (SoH) should **not** make the REDUNDANCY_LOST_L signal go low.
 - A PSU charger fail should not assert the signal.

Note: The REDUNDANCY_LOST_L signal may go low if any of the requirements above are met while in AC outage mode, for example if a PSU fails during an AC outage the REDUNDANCY_LOST_L signal should go low.

Conditions	Cause Redundancy Lost?
A PSU is not Present	Yes
A BBU is not Present	Yes
BBU Fail	Yes
BBU Sleep	Yes
PSU Fail	Yes
PSU (Charger) Fail	No
BBU Voltage	If less than 31.85V _{DC}
BBU Eol	No
BBU Protection	No
BBU Stop Discharge	No
BBU Charge Enable	No
PSU Bootloading	Yes
PSU performing BBU SoH	No
Invalid AC	No
PSU loading value	No

10.2.2 Power_Fail_L

This is an active low open collector signal, normally high. The purpose of this signal is to indicate to the data center that an imminent failure is about to occur, and the shelf has a high probability of turning off. This signal is sent low out of the shelf via pin 2 on the RJ45 connector every time the following condition happens below. If for example AC returns at 60 seconds, the signal goes back high when the PSU returns back to AC mode.

- At the 45 seconds mark during backup mode and if AC_OK is still not present for all the PSUs installed in the shelf, then assert the POWER_FAIL_L signal low.
 - If only 1 PSU is installed (or working) in the shelf, then once AC is lost for 45 seconds it should assert the signal.
 - If only 2 PSUs are installed (or working) in the shelf, then once one or more PSU has lost AC for 45 seconds it should assert the signal.
 - If 3 PSUs are installed in the shelf and only 2 PSUs are in backup for 45 seconds then the signal shall still assert, once the first 2 PSUS reach the 45 seconds mark.
 - If 3 PSUS are installed in the shelf and only 1 PSU is in backup for more than 45 seconds then the signal should **not** get asserted.
- SoH testing of a BBU should not cause the POWER_FAIL_L to be asserted.
- Bootloading a PSU shall not assert the POWER_FAIL_L signal (open collector signal remains high, 9V low) and shall not get asserted in any conditions since the PSU doesn't go into backup.

Note: The POWER_FAIL_L signal is not for a sudden failure, sudden over current condition, or lack of energy in the BBUs which may cause shelf shut down.

10.3 BBU Signals

The signals that come from the BBU shall only be used by the PSU that is directly connected above it. For example, if BBU in slot #1 asserts "stop_discharge" low, it should not affect the other two PSU/BBU pairs. All signals below shall have a 1 second persistence delay, except the protection signal (100mS) and the insert signal to avoid triggering on any noise.

10.3.1 Charge_Enable

When the PSU sees this signal go low (for 1 second), wait 2 seconds then turn on the charger and start charging the BBU until Charge_Enable signal goes back high.

- If Charge_Enable is low for some reason during a BBU discharge (outage/self test) the PSU shall not charge the BBU and keep the step-down converter off.
- If the current given by the charger is less than 500mA and if the voltage is not within $52.5\text{Vdc} \pm 2\%$ (at the sense lines) then the fail signal on the PSU shall be asserted to indicate that the charger has failed (PSU Fail LED).
- If the BBU does not see any current for 5 consecutive minutes then the BBU will go into sleep mode and assert its Sleep signal high (please see BBU specification).
- If the battery charger is on for more than 5 consecutive hours then the battery charger should be considered failed and assert the fail LED on the PSU.
 - Note: At the 4 consecutive hour the BBU will consider itself failed, if for some reason this doesn't happen we have a 5 hour timer on the PSU.
- If one of the Charge_Enable signals is low for any of the three BBUs then it should block the other/itself BBUs from performing an SoH check

Important: the step-down (charger) and the step-up converter shall never be on at the same time.

10.3.2 SoH

- If SoH is low, the PSU shall check that all the criteria are met in [Section 9.2](#), if so the PSU shall use the BBU as the energy source until SoH signal goes back high. If any of the conditions in [Section 9.2](#) are not met the PSU shall recheck the conditions for example every x minutes as long as the SoH signal is low (vendor can feel free to implement a timing so that they do not overload any microcontroller by continuously checking. For example, if a PSU is failed in the shelf, it might not be replaced for 48 hours and therefore there is no point continuously checking).
- If at any time during the battery test, when the SoH signal is low, the BBU gives the 'stop_discharge' or 'fail' signal the PSU shall stop using the BBU as a source of power.

10.3.3 Stop_Discharge

- If Stop_Discharge is asserted low the PSU shall stop discharging the BBU.
- If one of the Stop_Discharge signals is low for any of the three BBUs then it should block the other/itself BBUs from performing an SoH check

10.3.4 Sleep

- If the BBU has the sleep signal high that means the BBU has gone into sleep mode. The PSU shall not use that BBU during an AC outage, charge the BBU or allow another PSU in the shelf to perform a self-test (SoH).

10.3.5 EoL

- If one of the EoL signals is low for any of the three BBUs then it should block the other/itself BBUs from performing an SoH check.
- Otherwise the EoL signal being low shall not affect the definition or behavior of the PSU as defined earlier.

10.3.6 Fail

- If the BBU has the fail signal low that means the BBU has failed. The PSU shall not use that BBU during an AC outage/self-test.
- If one of the fail signals is low for any of the three BBUs then it should block the other/itself BBUs from performing an SoH check.

10.3.7 Protection

- This signal is ORed together with the PSU analog sense $2.154V_{DC}$ ($28V_{DC}$) voltage reading and will turn off the driver to the step-up converter MOSFETs.
- If one of the protection signals is low for any of the three BBUs then it should block the other/itself BBUs from performing an SoH check.
- Persistence delay reduced 100mS instead of 1 second for the other signal.

10.3.8 S_RTN / Insert BBU

- Signal is low when the BBU is physically installed in the shelf.
- This signal is used by the BBU to identify if it is inserted into the shelf and is tied to S_RTN inside the BBU.
- This signal can have a shorter persistence delay.

All signals above shall be pulled up to 3.3V with 10K Ω pull up resistor.

10.4 Current_Share

The current share is an analog share bus for the main $12.6V_{DC}$ output. The three PSUs shall share equally. The share bus voltage is 8V @265A. The slave PSU with the lower current will increase the output voltage by 10mV per 1A current difference, up to 200mV max.

10.5 CANBus

The three power modules are digitally interconnected with a separate internal digital bus (it does not go out from the shelf) for data exchange between the units, such as battery test priority (SoH), and randomization of the AC restart at shelf level. If a PSU's internal, CANbus communication fails and cannot receive message from any of the other PSUs then its fail LED should turn red, but still allow the main $12.6V_{DC}$ to provide power.

Note: the shelf shall still be able to start up if not all PSUs and BBUs are installed. A failed PSU may block the initial turn on off the shelf (please see CANbus definition).

10.6 SMBus

Communication between the PSU and BBU. Refer to Section 4 in the V2 Communication specifications document. The SMBus signal integrity should meet the latest standard, both voltage and timing requirements.

10.7 Modbus

A Modbus protocol using a an RS485 isolated digital bus is generated by each PSU, paralleled inside the shelf, and connected to the RJ45 socket in the shelf's rear panel). The S_RTN is not used for the RS485 GND. RS485 GND does not come out of the PSU.

This digital bus is solely used for data reporting, basically power module failure, output / input power, and for the boot-loader function: it is possible to update the firmware of all the DSPs and/or microprocessors used inside the power module through boot-loader through the shelf's RJ45 socket. Please refer to the V2 Communication Specification Document. The PSU shall blink green at 2Hz when the PSU is being updated via the boot-loader function.

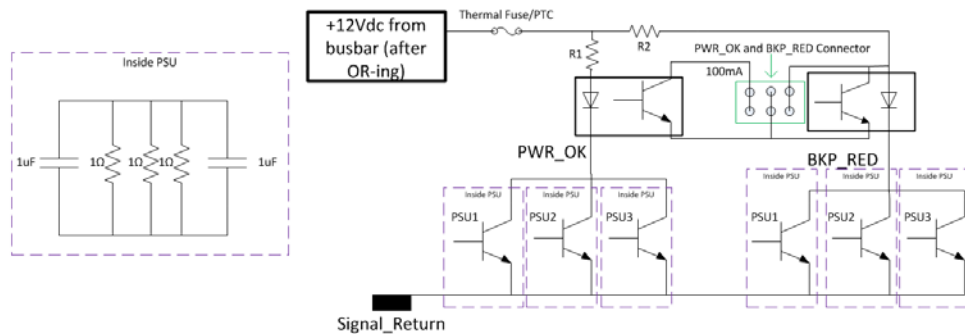
All power supplies must have high signals (or 1) for 'Shelf Position' and 'Rack Position' addresses. These high signals are brought to ground inside the Open Rack DC PDU for Shelf position and inside the Rack monitor for Rack position.

The Modbus communication shall be able to achieve a maximum of 115200 baud rate. But shall be set to 19200 baud rate as defined in the V2 Communication spec.

10.8 S_GND

All signals return should be decoupled from the power return using three 1Ω high pulse current resistors in parallel (SMT1206) and a $1\mu\text{F}$ capacitors on either side or the resistors between the negative return plane of the logic board and the negative return of the main 3300W DC/DC converter.

The figure below shows the signal ground decoupling in the BBU (left) connected to the DSP of the PSU (right).



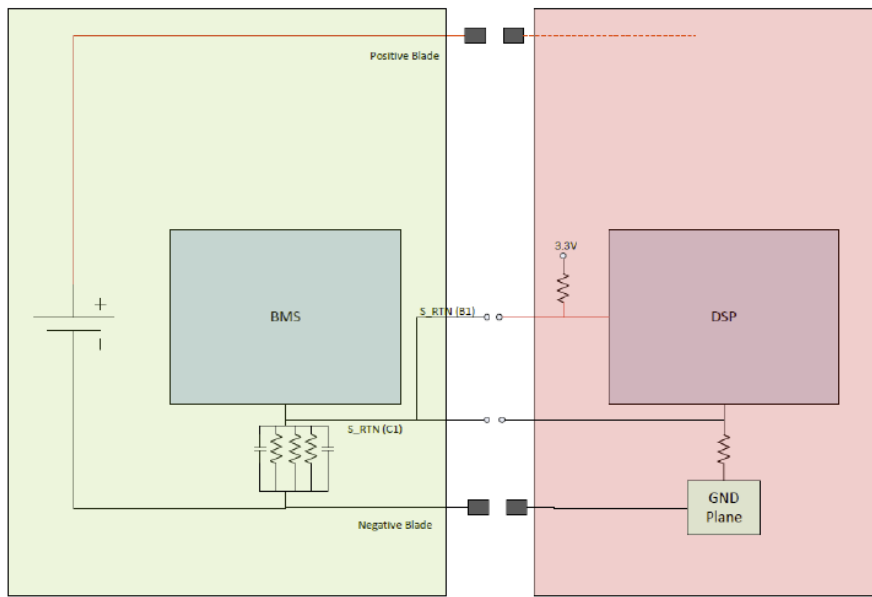


Figure 8: Signal ground decoupling

Please refer to V2 BBU, Battery Backup Module 3600W, Specification for the BBU signal and operation information.

10.9 LED

This section below will describe the operation of the LEDs on the front face of the PSUs:

10.9.1 PWR OK / BKP LED

- Yellow solid when a valid AC input is applied, 12.6V_{DC} output is in regulation, and there is not a valid backup power source.
 - Invalid DC backup source can be the following: BBU is not installed, BBU under 31.85V_{DC}, has the Fail/Protection/Stop_Discharge signals low or Sleep/Insert signal is high.
- Green solid when a valid AC input is applied, 12.6V_{DC} output is in regulation, and there is a valid DC backup source (a valid BBU voltage should be 31.85V_{DC} or greater).
- Note, the BBU voltage should be measured at the DC input to the PSU via BBU sense lines for accurate voltage and from the discharge path (3 + 3 blades) >20V_{DC} from the BBU, in case of a blown fuse inside the BBU.
- Yellow blinking at 1Hz during backup phase, AC outage (90 second timeout). Note that during backup phase, the time counter of each of the individual power modules shall be 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, or with equivalent means.

10.9.2 FAIL LED

- Red LED for general power module failure (fan failure is included). It follows the same rules as for the red LED in the 'Power Module'. Off otherwise.
- If the main 12.6V_{DC} output fails, all other secondary converters shall be latched off (the battery charger converters should also shut down).

- If the BBU step-up or the step-down battery charger converter fails or the CANbus internal communication fails, the red fail LED should turn on and the fail signal should be latched but the other converters should still provide 12.6V_{DC} to the busbars.
 - If the BBU step-up converter fails do not allow an AC reset to clear the Fail LED.

Note: The green/yellow PWR OK LED and FAIL LED cannot be lighted on at the same time. Also the fail LED should not clear while the PSU enters a back-up condition. The FAIL LED should be latched permanently when a failure in the step-up converters occurs.

10.10 Led Behavior

Alarm in AC mode	PWR OK	Fail Behavior		How to clear the Alarm?
	LED	LED	12.6V _{DC} Output	Physical plug out/AC recycle
AC input without BBU connected	Yellow	Off	On	
AC input with BBU <31.85V _{DC} @ sense lines OR <20V _{DC} at BBU blades				
AC input with BBU Fail, Protection, or Stop_Discharge signals low OR Sleep signal high				
AC input with BBU connected (BBU >31.85V _{DC} @ sense lines AND >20V _{DC} at BBU blades.	Green	Off	On	
Back-up mode (AC outage only)	Blinking Yellow (1Hz). All PSUs in PowerShelf synchronized.	Off	On	
SoH battery test (only during discharge)	Blinking Yellow (1 Hz)	Off	On	
Boot-loading Mode	Blinking Green (2Hz)	-	Off	
Fan Failure, any 12V failures due to 12V OCP, 12V OVP, Any general failures which cause 12V out of regulation	Off	On	Off	If PSU is physically removed from the shelf or sees an AC outage/recycle and if the failure is now cleared the red fail LED is remove.
Component out of temperature range	Off	On	Off	Latched failure.
If inlet temperature out of spec.	Off	On	Off	Able to auto recover when temperature goes back within acceptable range.
PSU not outputting 12V during AC outage (ex. Failed BBU, etc.)	Off	On	Off	Fail LED remains on when AC power returns.

BBU Step-up converter fail	Off	On	On	Fail LED remains on when AC power returns and 12.6V _{DC} available. (write to EEPROM, for HW failures, LED can be cleared with a command)
BBU Charger Fail	Off	On	On	If PSU is physically removed from the shelf or sees an AC outage/recycle and if the failure is now cleared the red fail LED is remove.
CAN bus internal communication failure	Off	On	On	Allow Restart (If PSU is physically removed or sees an AC outage/recycle and if the failure is now cleared the red fail LED is removed)
If one PSU is failed in the shelf during startup. The one that is fail will:	Blinking Green (1 Hz)		Off	
If input AC <180V _{AC} and out of turn on frequency range. If AC >330V _{AC} (after PSU turns off)	Off	On	Off	When Vin goes above 180Vac and PSU turns on LED will clear.

Latching-OFF conditions (power module also latches-OFF):

- General power supply failure
- The output 12.6V_{DC} before the ORing MOSFET goes out of regulation
- Fan failure or fan low speeds (5 seconds delay on persistency)
- Over current protection (2 seconds delay on persistency)
- Over voltage protection

As long as there is 12.6V_{DC} on the common output bus, then the fail LED shall remain on, no matter if there is an outage, no BBU, failed BBU etc. Basically the only way to reset the FAIL LED is to not see 12.6V_{DC} on the common bus (either the entire shelf turns off or an individual PSU is removed from the shelf and reinsert it). The above shall not clear any of the fail conditions when the fail status has been written to the EEPROM for the step-up converter.

These are the three main testing conditions:

- If 12V present on the PSU, but FAIL LED ON, prior to the AC outage and then when AC outage happens, continue working with the fail LED on, do not clear the failure when AC returns.
- If 12V present on the PSU before the outage and AC outage happens, but no BBU or failed/sleep/S_D BBU asserted, but 12V present on common bus from the other PSUs, keep red LED, and do not clear when AC returns (uses back bias voltage to keep the LED ON).

- If 12V not present on the PSU, an AC outage happens (regardless of BBU good or not) and 12V on common bus is present, do not reset the LED. The technician will come and physically remove it and try to reinsert it again.

10.11 Metering Accuracy

Accurate reporting of input power (input current and voltage) and output power (output current and voltage) readings shall be reported via RS485 communication system at all rated voltage.

Input power accuracy (voltage x current readings) should be less than 5% error, when the PSU load is between 5-20% loading. When the PSU is between 20-100% loading the accuracy shall be within 3%. AC input power includes all PSU outputs (main converter, housekeeping, charger).

Output power accuracy (voltage x current readings) should be less than 5% error, when the PSU load is between 5-20% loading. When the PSU is between 20-100% loading, the accuracy shall be within 2%.

Input Voltage	Output	Load	Accuracy
Rated Voltage (200-277V _{AC})	AC input power	<5%	±25W
		5-20%	< 5%
		20-100%	< 3%
	12.6V _{DC} output power	<5%	±25W
		5-20%	<3%
		20-100%	<2%

10.12 Blackbox Function

For the following section please refer to the latest Communication Interface Specification for detailed information.

The black box function shall store key important data to be used when a fault occurs.

- Must store data in memory and be able to withstand several read/write cycles
- PSU must be able to store failure data before the PSU turns off/fails even in catastrophic failure events both on primary and secondary side. Hold up time of the blackbox microcontroller must be able to store all the information and then shutdown.
- Data stored in PSU memory needs to be accessible via RS485
- Last 4 events stored in memory.
- AC input current, AC input voltage, Input Power, DC 12V output voltage, DC 12V output current,
- Temperature readings, fan Speed, input voltage, output voltage, bulk voltage, various error codes from all the different converters (OTP, OVP, OCP, UVP), and warnings.
- BBU signals at time of failure (fail, charge_enable, BBU voltage, etc)
- Total run time of PSU
- Run time since last turn on
- Number of AC power cycles
- Number of AC outages (can be determined by going into backup without counting the battery test conditions)

10.11.1 Fault Log History

The FAULT_LOG_HISTORY is used to read the 244 byte event data of the unit. The fault log history data stores up to 4 event data sets. If the event data sets exceed 4, the oldest data set shall be removed to give way for the latest data set (first in, first out). Unused history data sets shall have a value of zero for all registers.

This command is using MODBUS Function Read File Record. Each data set is a file record containing up to 244 bytes.

Here is a sample table of the power supply event data which contains up to 244 bytes of data:

Registers	Size in Byte
PSU Status Register	2
Battery Status Register	2
General Alarm Status Register	2
PFC Alarm Status Register	2
Secondary Alarm Status Register	2
Discharger Alarm Status Register	2
Aux Alarm Status Register	2
Battery Charger Alarm Status Register	2
Temperature Alarm Status Register	2
Fan Alarm Status Register	2
Communication Alarm Status Register	2
PSU_Input Voltage AC	2
PSU_Input Current AC	2
PSU_Output Voltage (main converter)	2
PSU_Output Current (main converter)	2
BBU_SIGNALS	1
AC Line Frequency	1
TOTAL_TIME	4
TIME_SINCE_LAST_ON	4
AC Power Cycles (# of times of cold start)	2
AC Outages (# of times step-up converter turns on due to AC input out of range, not including SoH test)	2
AC Input Voltage (20 samples @ 1ms)	40
AC Input Current (20 samples @ 1ms)	40
Main Output Voltage (20 samples @ 1ms)	40
Main Output Current (20 samples @ 1ms)	40
Temp0 – Inlet (5 samples @ 5 sec)	10
Temp1 – Outlet (5 samples @ 5 sec)	10
RPM Fan 0 (5 samples @ 5 sec)	10
RPM Fan 1 (5 samples @ 5 sec)	10
<i>Total</i>	244

10.13 Firmware

The firmware of the microprocessor and/or DSP must be upgradeable anytime during the life of the power supply and so the design (and the Vendor) is expected to support the following:

- The Vendor will supply the programmer, interconnection cables, functional software, and the set of instructions needed for the firmware upgrade at the remote sites.
- The Vendor will provide a reasonable amount of connectors, wire harness, and other items needed for Facebook to qualify and use in their testing set up, free of charge.
- The Vendor will be able to provide quick new releases of the firmware code during the development in order to speed-up fixes of any PSU issues, phase in improvements, system level bug fixes; including late findings or fine tuning.
- The Vendor's R&D team is expected to be proactive and quick in providing resolution of any hardware or firmware issues that could arise during the development, including potential technical malfunctions at system level, should any system integration issues arise. A strict technical collaboration, as well as fast responses and responsiveness, are mandatory for a swift custom development with a challenging timeline.
- The Vendor's R&D team shall be able to support Facebook locally should any issues arise that potentially jeopardize the development timelines; and whenever requested by Facebook.

11 Environmental Requirements

- Gaseous Contamination: Severity Level G1 per ANSI/ISA 71.04-1985
- Ambient operating temperature range: -5°C to +45°C
- PSU is able to 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 +70°C (short-term storage)
- Operating altitude with no de-ratings: 3000m (10 000 feet)
- System level ambient temperature: target is < 27°C (for information only)

11.1 Vibration and Shock

The PSU shall meet vibration and shock test per EN 60068-2-6 and 60068-2-27, respectively, for both non-operating and operating condition, with the specifications listed below. During operating vibration and shock tests, the PSU shall exhibit full compliance to the specification without any electrical discontinuities.

During the non-operating tests, no damages of any kinds (included physical damages) should occur and they should not corrupt the functionalities of the PSU per the specifications.

11.1.1 Vibration Non-Operating

Excitation Mode:	Sinusoidal
Test Frequency:	5Hz to 500Hz (5.0-9.0Hz) 6mm peak to peak (9.0-500.0Hz) 1g
Amplitude:	1g
Frequency Change Rate:	1 octave / min
Test Directions:	3 directions in space (x,y,z)
Duration:	10 sweep cycles for each direction (2hours 13 minutes)
Test Temperature:	Room temperature
Electrical Work:	none

11.1.2 Shock Non-Operating

Shock Pulse:	half sinus
Shock duration:	11ms
Shock Amplitude:	12g
Test Directions:	6 directions
Number of Shocks:	60 (10 per each direction)
Test Temperature:	Room temperature
Electrical Work:	None

11.1.3 Vibration Operating

Excitation Mode:	Sinusoidal
Test Frequency:	5Hz to 500Hz (5.0-9.0Hz) 6mm peak to peak (9.0-500.0Hz) 1g
Amplitude:	0.5g
Frequency Change Rate:	1 octave / min

Test Directions:	3 directions in space (x,y,z)
Duration:	10 sweep cycles for each direction (2hours 13 minutes)
Test Temperature:	Room temperature
Electrical Work:	Power supply in operation

11.1.4 Shock Operating

Shock Pulse:	half sinus
Shock duration:	11ms
Shock Amplitude:	6g
Test Directions:	6 directions
Number of Shocks:	30 (5 per each direction)
Test Temperature:	Room temperature
Electrical Work:	Power supply in operation

12 Production Line Testing

Testing shall be completed in several stages on 100% of the power supplies to ensure it meets high quality production standards.

PSU BOM and manufacturing information shall be traceable, and all information shall be easily retrieved as requested by Facebook.

12.1 Hi-Pot

- The PSU shall be tested 100% in production for both Hi-Pot (with the applicable limits for the AC leakage current) and ground continuity (per the applicable standard). Stamps shall be applied to the chassis proving that both tests passed in productions.

12.2 Ground Continuity

- The ground bond test is to be verified at design stage, and it must comply with applicable IEC standards.

Tech tips:

- Ground continuity test is performed on the GND pin of a line cord-terminated product (normally center pin of an IEC320 socket). This test verifies that the safety ground is present in the system, but it does not test the ability of the safety ground to withstand any faulty current.
- The ground bond test is performed in a similar fashion and it verifies that a products safety ground can adequately handle any fault currents due to an insulation failure. The test duration may vary (it can be as high as 120 seconds).

13 Compliance Requirements

The power supply shall comply with the following standards as a stand-alone unit, and it shall be Certified and labeled accordingly.

13.1 Safety Certifications, Applicable Documents

- UL60950-1 (and CAN/CSA-C22.2 No. 60950-1 plus all revisions)
- Latest version of IEC/EN60950-1 plus all country deviations
- Latest version of UL 62368-1
- NRTL report and certifications (cUL, CSA/UL)
- CE Declaration of Conformity, accompanying by CB Report and Certificate
- Official Journal of the European Union 2014/35/EC Low Voltage Directive
- BIS IS13252:India BIS Safety standard for ITE products
- Taiwan CNS 14336: Chinese National Standard (Power Supply Safety)

13.2 Emissions Standards Compliance

The power supply shall comply with the following applicable emission and immunity requirements.

- Official Journal of the European Union 2014/30/EC EMC Directive
- EN61000 / IEC61000 applicable standards for Emissions and Immunity Requirements
- EN55024 (Generic standard)
- EN61000-3-2 (Harmonics) [test with 15A]
- EN61000-3-3 (Voltage Flicker) [test with 15A]
- EN61000-4-2, Level 4 (ESD)
- EN61000-4-3 (Radiated Immunity, 3V/m)
- EN61000-4-4, Level 4 (EFT/Burst)
- EN61000-4-5 (AC Mains Surge Immunity, 2kV DM and 4kV CM)
- EN61000-4-6 (Conducted Radio Frequency Immunity, 3V/m)
- EN61000-4-11 (AC Mains Voltage Dips & Sags, Fluctuations)
- EN/CISPR 55024 (Latest Version) – Information Technology Equipment
- Power supply shall always resume operations after any fatal PLD
- Output Voltage shall never dip if backup voltage is applied to the PSU
- Backup functionality is not affected by substantial repetitive dips & sags
 - GR-1089-CORE, Issue 4 (Power Line Disturbances)

Note: When the PSU is installed at System level, the equipment under test powered by the PSU shall continue to operate without interruptions and/or reset occurrences during the above tests under EN61000-4-(*).

13.2.1 Input Surge

The power supply shall be tested in accordance of the EN61000-4-5 and up to the following limits below:

- 2kV DM (Differential Mode is Line to Neutral)
- 4kV CM (Common Mode is Line/Neutral to ground)

The power supply shall be protected against surge events and it will not be damaged in such occurrences. The PSU shall continue to operate without functional failures or hiccups during surge tests per the above limits. The output voltage shall also not be affected by the surge pulses under any conditions. Surge events shall not be able to reset the system when the PSU is used in the final application at system level (at system level this mean the 12.6V_{DC} doesn't go out of range.). At system level, the PSU is powered by a custom AC PDU, which is directly connected to the tap box without any other protection or surge circuitry. Under these conditions, the PSU is expected to pass 2kV DM and 4kV CM (to be tested and verified), stand alone and at shelf level with (one, two or three) power modules installed in the shelf.

13.3 Further Applicable Immunity Standards

- EN61000 standards for Industrial Immunity
 - EN61000-6-1 (Immunity / Light Industry)
 - EN61000-6-2 (Immunity / Industry)

This section of BS EN 61000 applies to electrical and electronic apparatus intended for use in industrial environments. This standard applies to an apparatus intended to be connected to a power network supplied from a high or medium voltage transformer dedicated to the supply of an installation feeding industrial plants, and intended to operate in (or in proximity to) industrial locations. This standard applies also to apparatus that is battery operated and intended to be used in industrial locations. The environments encompassed by this standard are industrial, both indoor and outdoor, and where heavy inductive or capacitive loads are frequently switched, and/or with presence of high currents and associated magnetic fields.

13.4 EMI Compliance & Limits

The AC mains tests are conducted as stand-alone unit, at 200Vac and 277V_{AC}, full load (3300W + 270W charger) with the following requirement to comply:

- FCC Part 15, EN55032, CISPR 32: Conducted Emission, Class B
- FCC Part 15, EN55032, CISPR 32: Radiated Emission, Class B
- The power shelf with fully populated, with power supply units and batteries shall comply with Class A limits of above standards for both conducted and radiated emissions, with at least 6dB margin for AC input only.
 - Quick scan with peak mode detection should be done with DC input, and results submitted to Facebook.
- Taiwan CNS13438, Class B

13.5 Environmental Engineering Standards

- ETS 300 019-2-3, Class 3.2 (Operation)
- ETS 300 019-2-1, Class 1.2 (Storage)

13.6 Environmental Engineering Standards

- ETS 300 019-2-3, Class 3.2 (Operation)
- ETS 300 019-2-1, Class 1.2 (Storage)

13.7 RoHS/Environmental Compliance

The power supply shall be compliant to the following RoHS and environment regulations (BOM & Manufacturing Process)

- RoHS 2 Directive (2011/65/EU); aims to reduce the environmental impact of EEE by restricting the use of certain substances during manufacture.
- China RoHS.
- Taiwan RoHS.
- REACH Regulation (EC) No 1907/2006; registration with the European Chemicals Agency (ECHA), evaluation, authorization and restriction of chemicals.
- Halogen Free: IEC 61249-2-21, Definition of halogen free: 900ppm for Br or Cl, or 1500ppm combined.
- US Conflict Minerals law: section 1502 of the Dodd-Frank Act which requires companies using tin, tantalum, tungsten, and gold (“3TG”) in their products to verify and disclose the mineral source.
- The Persistent Organic Pollutants Regulation (EC) No. 850/2004, which bans production, placing on the market and use of certain persistent organic pollutants.
- The California Safe Drinking Water and Toxic Enforcement Act of 1986 (“Prop 65”), which sets forth a list of regulated chemicals that require warnings in the State of California
- Packaging and Packaging Waste Directive 94/62/EC.
- Phthalates (DEHP, DBP, DiBP, BBP): 1000 ppm (or 0.1% by weight).
- Arsenic: 1000 ppm (or 0.1% by weight).

14 Safety Label

The power supply will be shipped with the safety label applied to the cover, location is free and up to the Vendor to propose a location. Label is to be UL approved material, ORANGE color “Pantone 715” (or similar agreed upon) with matte finish, no “glossy”. The fonts shall be black color, Arial bold with ~ 2.5mm of font size. Barcodes shall follow the “CODE 128-AUTO” standard. The label location and orientation on the chassis cover is indicated in the mechanical drawing; the sheet-metal shall be recessed 1mm to avoid scratch of the label at power supply installation in the system (see mechanical drawing). Label material shall be scratch resistant as well. The label shall include at least the following information and identification marks. Note, small details can be changed with approval from Facebook. Sample of the label will be submitted to Facebook for review and approval. The barcodes shall be scan able.

- Vendor Name, Country of Origin, Vendor Address
- Model: 700-014671-0000
- Type: “Vendor P/N” (shall also have a barcode)
 - ACDC-ORv2-3600W
- Facebook Part Number: “FB P/N: 03-000661” (shall also have a barcode)
- The output format should be as follows; Voltage (at No Load), Output (max), Current (max). The maximum accuracy of the values should be to one decimal place. Note, in this case the voltage and current does not match the rated power capability. The Vendor is free to suggest any other format based on Facebook’s approval.
 - Input 1: 200-277V_{AC} ~ 50/60Hz - 22A
 - Input 2: 33.8-52.5V_{DC} - 120A
 - Output 1: 12.6V == 265A
 - Output 2: 52.5V == 5A
- Date Code, S/N, and HW REV (shall also have a barcode)
 - Date Code: WW/YYYY
 - S/N: SSSSS
 - HW REV: XX
- FW REV:PP.SS.DD.LL (primary, secondary, discharger, logic)
- All applicable safety markings (BSMI logo, etc.)
- RoHS-6 symbol of compliance shall be added to the label
- WEEE symbol: the PSU label will have the crossed out wheeled bin symbol to indicate that it will be taken back by the Manufacturer for recycle at the end of its useful life. This is defined in the European Union Directive 2002/96/EC of January 27, 2003 on Waste Electrical and Electronic Equipment (WEEE) and any subsequent amendments.

15 Reliability, Quality, Miscellaneous

15.1 Spec Compliance, Quality FA, Warranty

- The Vendor is responsible for the PSU to meet the specifications as stand-alone unit as well as at system level, and for assuring that the power supplies shipped in production will conform to the specifications with no deviations.
- A specification compliance matrix and test report shall be submitted to Facebook for each PSU revision: EVT(P1), DVT(P2), and PVT (Pilot).
- The Vendor is responsible to exceed production quality standards achieved on the pilot run built without fluctuations.
- All failures from EVT, DVT, PVT are required to complete failure and root cause analysis and report corrective action prior to entering mass production.
- Failure analysis on defective RMA units shall be provided to Facebook with corrective action plan, within two weeks from when the units are received at the Vendor's facility.
- The Vendor shall warrant the power supply for defects and workmanship for a period of three years from the date of shipment when the device is operated within specifications. The warranty is fully transferable to any end user. A standard "VOID" warranty sticker may be applied.

15.2 Mass Production First Article Samples

Prior to final project release and mass production, the Vendor will submit to Facebook a good quantity (70) of PVT production pilot run verification samples, including the following documentation:

- All the pertinent development docs, production docs, and reports necessary to Facebook to release the product for mass production.
- The pilot samples shall be built in the allocated facility for mass production and use hard-tooled chassis and parts (where applicable).
- Full spec compliance matrix, full test report, production line final test 'pass' tickets.
- Samples passed the burn in process planned for production.
- Samples are shipped using the approved for production shipping box.
- The units are certified and safety label is applied ("Pending Certification" sticker may be allowed until the certification process is complete).

15.3 MTBF Requirements

- The PSU shall meet the MTBF calculation, which is proposed by the Vendor and agreed upon by Facebook. The MTBF calculation should be at 90% confidence level, 45°C of ambient temperature, 277Vac of input voltage, and full load (per Telcordia SR-332 latest version, alternatively per MIL-HDBK-217). The fan is not included (MTBF of the fan will be provided separately).
- The PSU shall meet a demonstrated MTBF of minimum 500K hours at 90% confidence level prior to first customer shipment (Pilots samples, Mass Production units).
- MTBF goal: the Vendor shall provide to Facebook the best MTBF numbers that the PSU will be able to meet, no matter the minimum requested. Facebook will use this information for an overall reliability study of the whole system.
- The PSU shall have a minimum service life of 5 years (24 hours/day, Full load, 277Vac, 45°C of ambient temperature).

- The fan L10 life shall be at least 5 years at 45°C inlet air temp and full speed (to be verified with the fan vendor)

15.4 Design Rating Guidelines, DFT, DFM

- For all the boards used in the PSU design: the in-circuit test coverage and test point access shall be > 95% or higher.
- The Vendor will provide the standard de-rating guidelines normally used for the design of the industrial custom power products for Facebook audit.
- The Vendor shall provide DFT and DFM reports at EVT phase.

15.5 Catastrophic Failure

The PSU shall not smoke or catch on fire during catastrophic failure.

15.6 Disallowed Components

Facebook reserves the right to select some preferred/mandatory parts, during the development phase (selection of an approved vendor list (AVL) subset). The Vendor will work with Facebook to solve system integration problems, should any issues arise.

- Trimmers and/or potentiometers.
- Tantalum capacitors.
- Dip switches.
- High side driver ICs
- Paralleled power MOS are allowed provided that the design prevents parasitic oscillations
- SMT ceramic capacitors are allowed with the case size < 1206. The size 1206 can still be used when SMT capacitors are placed far from the PCBs edge, and with a correct orientation that minimizes risks of cracks [any size > 1206 must be highlighted to Facebook during DFM review].
- Allowed ceramics materials for SMT capacitors are: X7R or better material. The COG or NPO types should be used in critical portions of the design, such as feedback loop, PWM clock settings, etc. [any changes shall be highlighted and brought up during DFM review].
- Relays: the use of any electro-mechanical relays, and type shall be discussed up front before any approval is given include them in the design.
- Resistors by Royal Ohm are not to be used.
- Facebook will approve all control ICs.

15.6.1 Capacitors

- All the electrolytic capacitors shall be rated at 105°C and shall be selected from Japanese and US manufactures only.
- All capacitors shall have a predicted life of at least 5 years at 45°C inlet air temperature under worst conditions.

15.7 Quality Control Process, Burn-in

- All assembly inspection dimensions and tolerances in the drawings provided must be met.
- Incoming Quality: <0.1% rejections.
- CPK values should equal or exceed 1.33 (Pilot Build and Production) using a sample size equal to 32 for CPK measurement.

- CPK measurement should be performed on every batch/lot build of pilot and mass production. During production, weekly CPK reports must be sent to Facebook engineering team.
- The Vendor will implement a further quality control procedure during production, by sampling power supplies randomly from the production line and running full test to prove ongoing compliance to the requirements (it may include EMI production). Process shall be documented and submitted to Facebook prior to production. The relative reports will be ongoing submitted to Facebook.
- The vendor will propose to Facebook, for audit and approval, ongoing burn-in procedure to be used in production, that will not start without an agreement on some sort of burn-in procedure
- PCB boards are UL recognized components rated 94 V-0 and rated 130°C MOT.
- Multi-layers (> 2 layers) PCB boards are welcome for a better layout and simplification of the manufacturing process, however if they make sense for cost.

15.8 Packaging

The PSU shall be shipped using a custom package containing multiple units. Quality of the packing assembly will be such that the PSU will not get damaged during transportation: units will arrive in optimum conditions and so suitable for immediate use. The shipping box 'shock test' shall be proposed by the Vendor and submitted to Facebook for audit and approval. The Vendor is required to provide a test report for shock and vibe and packaging drop test.

15.9 Documentation

The Vendor shall provide Facebook the following documentation (prototypes may not include Portion of these documents):

- Theory of Operation
- Block Diagram
- FW state machine
- Schematics, Component Placement, Board Layout (Design files and searchable PDF)
- BOM ordered per Reference Designators
- BOM ordered per Components (including AVL)
- Mechanical Drawings (PDF format. Native files and/or DXFs will be provided to perform collaborative work on the design, for a seamless PS integration at System level chassis)
- Functional Test Report (DVT Report)
- De-ratings Report (worst conditions)
- Temperature Test Report (with indication of critical de-ratings, if any)
- EMI plots for Conducted and Radiated emission
- MTBF data and Report, including calculation
- Production Line Automatic Final Test procedure

NOTE: The Vendor shall propose to Facebook a 'Qualification Test Plan' & 'Reliability Test Plan'. EDVT test procedure in thermal chamber, with four corners thermal shocks, expected to be included.

15.10 Change Authorization/Revision Control

Once the Project is released to mass production, no design changes, AVL changes, Manufacturing Process or materials changes are allowed without prior written authorization from Facebook.

AVL is 'Approved Vendor List' of all the components listed in the BOM (the 'Bill Of Materials'). Any request of changes must be submitted to Facebook with proper documentation showing the details of the changes, and reason for the changes, including changes affecting form, fit, function, safety, or serviceability of the product. Major changes in the product (or in the manufacturing process) will require re-qualification and/or re-certification to the Product. Hence a new set of First Article Samples may be required to complete the ECO process. Any modifications after approval would "phase-in" during production without causing any delays or shift of the current Production Schedule: enough ECO advance notice shall be given to Facebook (and to all appropriate entities in the Supply Chain) in such as occurrences. All changes must go through a formal ECO process, starting from the Pilot Run and onward, and the revision (shown in the Safety Label) will increment accordingly. Revision Control: copies of all ECOs affecting the product will be provided to Facebook for sign off.

15.11 Sheet Metal Material and Zinc Whisker Implications

- Sheet Metal Chassis Material is hot-dip Zinc coated, JIS G3302 SGCC (Z20 to Z22), with 1mm of thickness. The 'Z' parameter defines the metal coating thickness: Z20 is for 40µm of thickness, and Z22 is for 43µm.
- The Japanese standard is 'JIS G3302', while the US standard is 'ASTM A653'.
- Mechanical design shall prevent sharp edges and possible metal oxidation in the critical points of the sheet metal (e.g. in the cut & bends portions, etc.).
- Both chassis design and metal base material will not promote the growth and propagation of zinc and tin whiskers.
- Metal base materials with electro-zinc plating, or poor conductivity plating, are not allowed.
- Alloy materials are a possible option, while stainless steel is another possibility provided that it makes cost sense (both options are subject to Facebook approval)
- Aluminum material is not allowed for the enclosures.
- The chassis enclosure, as well as the whole electronics, shall meet certain contamination requirements (see ANSI spec at § 14)
- The modules are not classified as "Fire Enclosure"

15.12 Conformal Coating and Protection

The gate terminals of all high-voltage MOSFETs as well as the most sensitive areas of the electronic circuitry in the boards must be protected against potential resistive contacts with other voltage potentials (e.g. MOS Drain leads, etc.) due to whiskers, pollutant particles, dust, moisture (for example contaminant substances can become conductive in presence of moisture), and up to some local wet condensation occurrences.

Local automated, conformal coating shall be applied to critical areas of the boards to protect sensitive circuitries, using an atomized spray process (no dipping process is considered here). The thickness of the coating shall be ~50µm to ~150µm. The Vendor (mainly the ultimate Manufacturing Facility) shall demonstrate to possess good skills, experience, and long years of experience on automated conformal coating application and process. The power modules main board shall be partially conformal coated (top & bottom); critical board areas shall be agreed upon, typically the ac high-voltage input section at shelf level, like the AC input, board-mount connector area.

16 Mechanical 2D drawing

