

TET4000-48-069RA

4000 W AC-DC Front-End Power Supply

Bel Power Solutions **TET4000-48-069RA** is a 4000 Watt AC-DC power-factor-corrected (PFC) and DC-DC power supply that converts standard AC mains power or high voltage DC bus voltages into a main output of 54.5 VDC (42 – 58 VDC) for supplying 48 VDC power distribution in high performance and reliability data center equipment, servers, routers, and network switches.

The TET4000-48-069RA meets international safety standards and displays the CE-Mark for the European Low Voltage Directive (LVD).



Key Features & Benefits

- Best-in-class efficiency of up to 97%
- Wide input voltage range: Full power available at 200-250 VAC, reduced output power at 100-200 VAC
- AC input with power factor correction
- 4000 W main output with programmable voltage set-point of 42-58 VDC
- Optional Standby output 12 VDC / 60 W
- One single rear side connector for input and output power and signaling
- Parallel operation with active digital current sharing through CAN bus
- Hot-plug capable
- High density design: 44 W/in³
- Small form factor: 69 x 40.6 x 528 mm (2.72 x 1.60 x 20.79 in)
- Full digital controls for improved performance
- CAN communication interface for monitoring, control, and firmware update via bootloader, optional I²C communication instead of CAN bus foreseen
- Overtemperature, output overvoltage and overcurrent protection
- 2 Status LEDs: AC OK and DC OK with fault signaling
- Safety-approved to UL/CSA 62368-1 and IEC 62368-1
- RoHS Compliant
- US Patent Pending

Applications

- Data Center
- High Performance Servers
- Routers
- Switches



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1. ORDERING INFORMATION

| TET | 4000 | - | 48 | - | 069 | R | A | Option Code |
|----------------|-------------|------|-----------|------|-------|--------------------------|-------|----------------|
| Product Family | Power Level | Dash | V1 Output | Dash | Width | Airflow | Input | Blank |
| TET Front-Ends | 4000 W | | 48 V | | 69 mm | R: Reversed ¹ | A: AC | Standard model |

2. OVERVIEW

The TET4000-48-069RA is a fully DSP controlled, highly efficient front-end power supply. It incorporates resonant-soft-switching technology and highly integrated conversion stages to reduce component stresses, providing increased system reliability, very high efficiency and high power density. With a wide input operating voltage range and minimal linear derating of output power with respect to ambient temperature, the TET4000-48-069RA maximizes power availability in demanding server, switch, and router applications. The power supply is fan cooled and ideally suited for server integration with a matching airflow path.

The PFC stage is digitally controlled using a state-of-the-art digital signal processing algorithm to guarantee best efficiency and unity power factor over a wide operating range.

The DC-DC stage uses soft switching resonant techniques in conjunction with synchronous rectification. An active OR-ing device on the output ensures no reverse load current and renders the supply ideally suited for operation in redundant power systems.

The optional always-on +12V standby output provides power to external power distribution and management controllers. Its protection with an active OR-ing device provides for maximum reliability.

Status information is provided with front-panel LEDs. In addition, the power supply can be monitored and controlled (i.e. fan speed setpoint) via CAN communication interface. It allows full monitoring of the supply, including input and output voltage, current, power, and inside temperatures. The same CAN bus supports the bootloader to allow field update of the firmware in the DSP controllers.

Cooling is managed by a fan, controlled by the DSP controller. The fan speed is adjusted automatically depending on the actual power demand and supply temperature and can be overridden through the CAN bus. Availability of an optional I2C bus instead of CAN bus is foreseen.

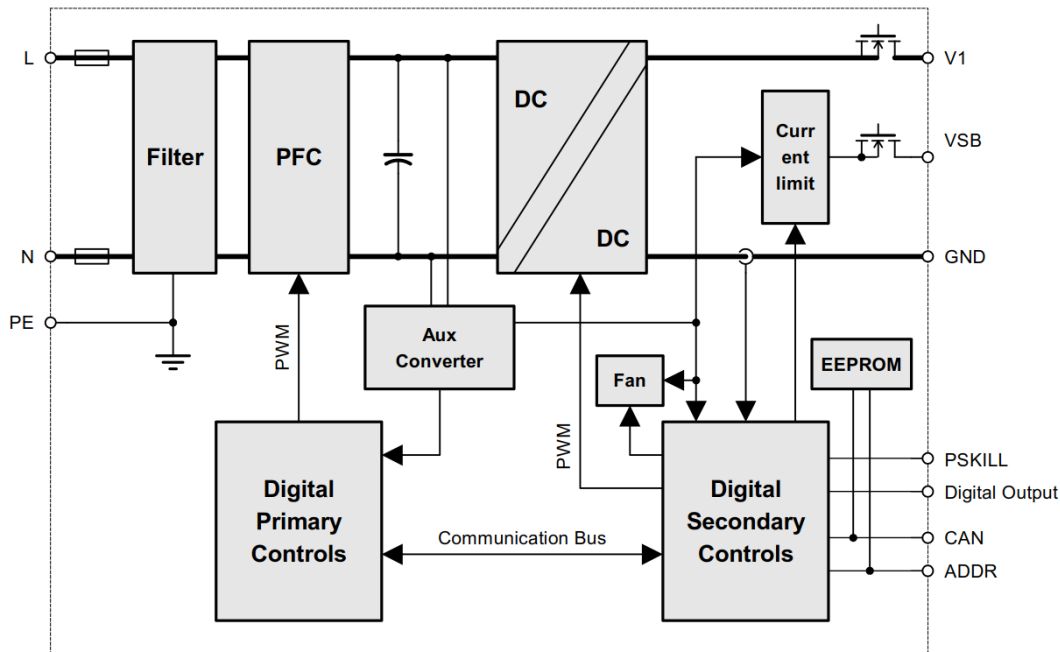


Figure 1. TET4000-48-069RA Block Diagram

¹ Front to Rear

3. ABSOLUTE MAXIMUM RATINGS

Stresses in excess of the absolute maximum ratings may cause performance degradation, adversely affect long-term reliability, and cause permanent damage to the power supply.

| PARAMETER | CONDITIONS / DESCRIPTION | MIN | MAX | UNITS |
|---------------|--------------------------|-----|-----|-------|
| $V_{i\ maxc}$ | Maximum Input | | 300 | VAC |

4. INPUT

General Condition: $T_A = 0...45\ ^\circ\text{C}$ unless otherwise specified.

| PARAMETER | DESCRIPTION / CONDITION | MIN | NOM | MAX | UNIT | | | |
|---------------------------|--|--|-------|-----|------|-----------|----|-----|
| $V_{i\ AC\ nom}$ | Rated AC Input Voltage | 100 | 230 | 250 | VAC | | | |
| $V_{i\ AC\ operating}$ | AC Input Voltage Range | Operating AC Input Voltage ($V_{i\ AC\ min}$ to $V_{i\ AC\ max}$) | | | VAC | | | |
| $V_{i\ AC\ HL}$ | High line AC Input Voltage | 180 | | 275 | VAC | | | |
| $V_{i\ AC\ Red}$ | Derated AC Input Voltage | 90 | | 180 | VAC | | | |
| $I_{i\ max}$ | Max Input Current | $V_{i\ AC} > 200\ \text{VAC}$ | | | 23 | A_{rms} | | |
| $I_{i\ p}$ | Inrush Current Limitation | $V_{i\ AC\ min}$ to $V_{i\ AC\ max}$ | | | 50 | A_p | | |
| F_i | Input Frequency | 47 | 50/60 | 63 | Hz | | | |
| PF | Power Factor | $V_{i\ AC\ nom}$, 50Hz, $I_1 > 0.3\ I_{1\ nom}$ | | | | W/VA | | |
| THD | Total Harmonic Distortion on Input Current | $V_{i\ AC\ HL}$, $> 50\ \% P_1\ nom$ | | | 3 | 5 | % | |
| $V_{i\ AC\ on}$ | Turn-on AC Input Voltage ² | Ramping up | | | 86 | 88 | 90 | VAC |
| $V_{i\ AC\ off}$ | Turn-off AC Input Voltage | Ramping down | | | 80 | 83 | 86 | VAC |
| η | Efficiency ³ | $V_i = 277\ \text{VAC}$, $0.1 \cdot I_{1\ nom}$, $I_{SB} = 0A$, $V_x\ nom$, $T_A = 25^\circ\text{C}$ | | | 93.0 | | | |
| | | $V_i = 277\ \text{VAC}$, $0.2 \cdot I_{1\ nom}$, $I_{SB} = 0A$, $V_x\ nom$, $T_A = 25^\circ\text{C}$ | | | 95.7 | | | |
| | | $V_i = 277\ \text{VAC}$, $0.5 \cdot I_{1\ nom}$, $I_{SB} = 0A$, $V_x\ nom$, $T_A = 25^\circ\text{C}$ | | | 96.5 | | % | |
| | | $V_i = 277\ \text{VAC}$, $I_{1\ nom}$, $I_{SB} = 0A$, $V_x\ nom$, $T_A = 25^\circ\text{C}$ | | | 95.5 | | | |
| T_{hold} | Hold-up Time | After last AC zero crossing, $V_1 > 41\ \text{V}$, $V_{i\ AC\ nom}$, $P_1\ nom$ | | | 15 | | ms | |
| $T_{hold-up, vsb-to-vo1}$ | Time from Vo1 to Vsb Leaving Regulation | All hold-up conditions | | | 40 | | ms | |

4.1. INPUT FUSE

Fast-acting 30 A input fuses (6.3 × 32 mm) in series with both the L- and N-line inside the power supply protect against severe defects. The fuses are not accessible from the outside and are therefore not serviceable parts.

4.2. INRUSH CURRENT

The AC-DC power supply exhibits an X capacitance of 5.8 μF , resulting in a low and short peak current, when the supply is connected to the mains. The internal bulk capacitors will be charged through NTC resistors which will limit the inrush current.

NOTE:

Do not repeat plug-in / out operations below 30 sec interval time, or else the internal in-rush current limiting device (NTC) may not sufficiently cool down and excessive inrush current may result.

² The Front-End is provided with a minimum hysteresis of 3 V during turn-on and turn-off within the ranges

³ Efficiency measured with fan loss included in PSU losses

4.3. INPUT UNDER-VOLTAGE

If the input voltage is reduced below the input under-voltage lockout threshold $V_{iAC\ off}$, the supply will be inhibited. Once the input voltage rises above $V_{iAC\ on}$, the supply will return to normal operation again.

4.4. POWER FACTOR CORRECTION

Power factor correction (PFC) is achieved by controlling the input current waveform synchronously with the input voltage. A fully digital controller is implemented giving outstanding PFC results over a wide input voltage and load range. The input current will follow the shape of the input voltage. If, for instance, the input voltage has a trapezoidal waveform, then the current will also show a trapezoidal waveform.

4.5. EFFICIENCY

The high efficiency is achieved by using state-of-the-art silicon power devices in conjunction with soft-transition topologies minimizing switching losses and a full digital control scheme. Synchronous rectifiers on the output reduce the losses in the high current output path. The rpm of the fan is digitally controlled to keep all components at an optimal operating temperature regardless of the ambient temperature and load conditions. *Figure 2* shows the measured efficiency with AC input voltage applied, with standby output at zero load.

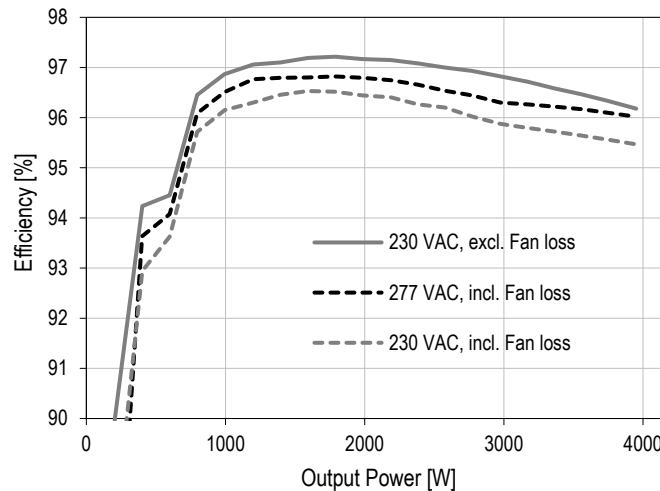


Figure 2. Typical Efficiency vs. Load Current

5. OUTPUT

General Condition: $T_A = 0 \dots 45^\circ\text{C}$ unless otherwise noted.

| PARAMETER | DESCRIPTION / CONDITION | MIN | NOM | MAX | UNIT | |
|-----------------------|--|---|-----|-----------------------------------|----------------|----------------------|
| Main Output V1 | | | | | | |
| $V_{1\text{ nom}}$ | Nominal Output Voltage | $0.5 \cdot I_{1\text{ nom}}, T_A \leq 45^\circ\text{C}$ | | 54.5 | VDC | |
| $V_{1\text{ prg}}$ | Programmable Output Voltage Range | $0.5 \cdot I_{1\text{ nom}}, T_A \leq 45^\circ\text{C}$ | | 42 | 58 | VDC |
| $V_{1\text{ set}}$ | Output Setpoint Accuracy | $0.5 \cdot I_{1\text{ nom}}, T_A \leq 45^\circ\text{C}$ | | -0.5 | +0.5 | % $V_{1\text{ nom}}$ |
| $dV_{1\text{ tot}}$ | Total Regulation | $V_{i\text{ min}}$ to $V_{i\text{ max}}$, 0 to 100% $I_{1\text{ nom}}, T_{a\text{ min}}$ to $T_{a\text{ max}}$ | | -2 | +2 | % $V_{1\text{ nom}}$ |
| $P_{1\text{ nom}}$ | Nominal Output Power | $V_{i\text{ AC HL}}, T_A \leq 45^\circ\text{C}, V_1 \geq 48.0\text{ V}$ | | 4000 | W | |
| | | $V_{i\text{ AC HL}}, T_A = 55^\circ\text{C}, V_1 \geq 48.0\text{ V}$ | | 3000 | W | |
| $I_{1\text{ nom}}$ | Nominal Output Current | $V_{i\text{ AC HL}}, T_A \leq 45^\circ\text{C}, V_1 = 54.5\text{ V}$ | | 73 | ADC | |
| | | $V_{i\text{ AC HL}}, T_A = 55^\circ\text{C}, V_1 = 54.5\text{ V}$ | | 55 | ADC | |
| | | $V_{i\text{ AC HL}}, T_A \leq 45^\circ\text{C}, V_1 = 48.0\text{ V}$ | | 83 | ADC | |
| | | $V_{i\text{ AC HL}}, T_A \leq 45^\circ\text{C}, V_1 = 58.0\text{ V}$ | | 69 | ADC | |
| $P_{1\text{ red}}$ | Available Output Power at $V_{in} < 180\text{ V}$ | $V_{i\text{ AC Red}}, T_A \leq 45^\circ\text{C}, V_1 \geq 48.0\text{ V}$ | | 22Arms*Vin - 400W ⁴ | | |
| $P_{1\text{ red}}$ | Low Line Output Power | $V_i = 120\text{ VAC}, T_A \leq 45^\circ\text{C}, V_1 \geq 48.0\text{ V}$ | | 2240 | W | |
| $I_{1\text{ ol}}$ | Short Time Over Load Current, Maximum duration 10 ms | $V_{i\text{ AC Red}}, V_{i\text{ AC HL}}$, relative to static output current available | | | 110 | % |
| $V_{1\text{ pp}}$ | Output Ripple Voltage | 20 MHz BW | | | 1000 | mVpp |
| $dV_{1\text{ Load}}$ | Load Regulation | $V_i = V_{1\text{ nom}}, 0 - 100\% I_{1\text{ nom}}$ | | -10 | mV/A | |
| $dV_{1\text{ Line}}$ | Line Regulation | $V_i = V_{i\text{ AC min}} \dots V_{i\text{ AC max}}$ | | 0 | mV | |
| dI_{share} | Current Sharing | Deviation from $I_{1\text{ tot}} / N, I_1 > 25\% I_{1\text{ nom}}$ | | -2.5 | +2.5 | ADC |
| dV_{dyn} | Dynamic Load Regulation | $\Delta I_1 = 50\% I_{1\text{ nom}}, I_1 = 10 \dots 100\% I_{1\text{ nom}}, dI_1/dt = 1\text{A}/\mu\text{s}, f = 2 \dots 50\text{ Hz}, \text{Duty cycle} = 20 \dots 80\%$ | | -2 | 2 | V |
| T_{rec} | Recovery Time | Within 1% of V_1 final steady state $I_1 = 10 \dots 100\% I_{1\text{ nom}}$ | | | 2 | ms |
| $t_{\text{AC } V_1}$ | Start-up Time from AC | Time from V_i in range to V_1 in regulation, $T_A > 10^\circ\text{C}$ | | | 4 ⁵ | sec |
| $t_{V_1\text{ rise}}$ | Rise Time | $V_1 = 10 \dots 90\% V_{1\text{ nom}}$ | | 12 | ms | |
| C_{V_1} | Maximum Capacitive Load | | | | 15000 | μF |

⁴ Example: At nominal grid 120 VAC the max. output power is 2240 W, will be provided also with grid fluctuation -10 % down to 108 VAC.

⁵ At low ambient temperature $T_A < 10^\circ\text{C}$ this time can rise to max 10 s

5.1. STANDBY OUTPUT

An optional standby output is available, delivering 12 V with up to 5 A, to provide power to system management controls.

The output is always enabled if the input voltage is within operating range, and provides over current, over voltage and over temperature protections. Current share on standby output is provided by passive droop sharing.

General Condition: $T_A = 0 \dots 45 \text{ }^\circ\text{C}$ unless otherwise noted.

| PARAMETER | DESCRIPTION / CONDITION | MIN | NOM | MAX | UNIT |
|--------------------------------------|--------------------------|--|------|----------------|-----------------------|
| <i>Standby output V_{SB}</i> | | | | | |
| V _{SB nom} | Nominal Output Voltage | I _{SB} = 0 A, T _A = 25 °C | 12 | | VDC |
| V _{SB set} | Output Setpoint Accuracy | I _{SB} = 0 A, T _A = 25 °C | -2 | +2 | % V _{SB nom} |
| dV _{SB tot} | Total Regulation | V _{i min} to V _{i max} , 0 to 100 % I _{SB nom} , T _{A min} to T _{A max} | -5 | +3 | % V _{SB nom} |
| P _{SB nom} | Nominal Output Power | | 60 | | W |
| I _{SB nom} | Nominal Output Current | | 5 | | ADC |
| V _{SB pp} | Output Ripple Voltage | 20 MHz BW | | 300 | mVpp |
| dV _{SB Load} | Load Regulation | 0 - 100 % I _{SB nom} | -72 | | mV/A |
| dV _{SB Line} | Line Regulation | V _i = V _{i AC min} ... V _{i AC max} | 0 | | mV |
| d _{share} | Current Sharing | Deviation from I _{SB tot} / N | | 2 | ADC |
| dV _{dyn} | Dynamic Load Regulation | $\Delta I_{SB} = 50\% I_{SB nom}$, I _{SB} = 10 ... 100% I _{SB nom} , dI _{SB} /dt = 0.1A/μs, f = 2 ... 50 Hz, Duty cycle = 20 ... 80% | -600 | 600 | mV |
| T _{rec} | Recovery Time | Within 1% of V _{SB} final steady state | | 2 | ms |
| t _{AC VSB} | Start-up Time from AC | Time from V _i in range to V _{SB} in regulation, T _A > 10°C | | 3 ⁶ | sec |
| t _{VSB rise} | Rise Time | V _{SB} = 10 ... 90% V _{SB nom} | 15 | | ms |
| C _{VSB} | Maximum Capacitive Load | | | 3000 | μF |

5.2. OUTPUT VOLTAGE RIPPLE

The internal output capacitance at the power supply output (behind OR-ing element) is minimized to prevent disturbances during hot plug. To provide low ripple voltage at the application, external capacitors should be added at the input of the connected load circuits.

5.3. OVERSUBSCRIPTION

The main output has the capability to allow a load current of up to 10 A above the nominal output current rating for a maximum duration of 5 ms. This allows the system to consume extended power for short time dynamic processes. Oversubscription can be used with maximum 10% duty cycle. If the output current is less than 10 A above nominal output current, then the oversubscription time can be longer.

5.4. OUTPUT ISOLATION

Main and standby output (if available) and all signals are isolated from the chassis and protective earth connection, although the applied voltage must not exceed 100 V_{peak} to prevent any damage to the power supply.

The main output return path serves as main and standby power return and reference for the two address signals ADDR0 and ADDR1. Care needs to be taken to reference these address signals as close as possible to the PSU's GND pins.

The CAN bus lines CAN_H and CAN_L, the output signal ACOK_L and the input signal PSKILL are referenced to signal ground SGND. These signals and SGND are isolated from main output and chassis allowing a maximum voltage of 50 V_{peak} between signals/SGND and main return GND. Signal ground SGND may be connected to power ground GND within the application, shown as dotted lines in *Figure 3*, allowing powering of system communication and logic from VSB output.

⁶ At low ambient temperature T_A < 10 °C this time can rise to max 10s

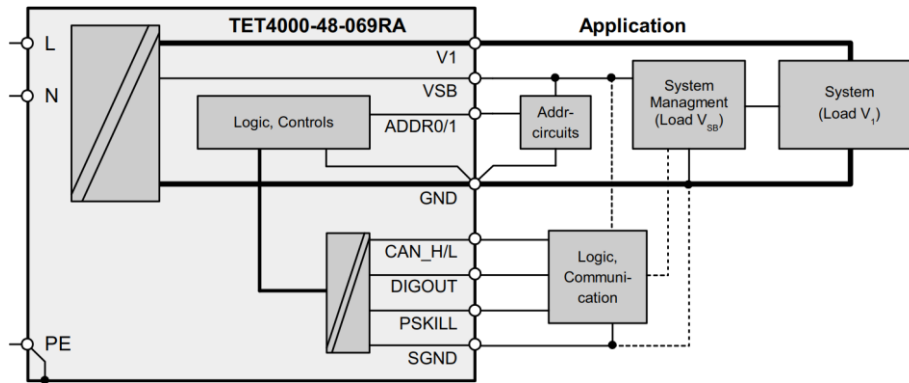


Figure 3. Output connection

6. PROTECTION

| PARAMETER | DESCRIPTION / CONDITION | MIN | NOM | MAX | UNIT |
|-----------------------|---|--|------|------|--------|
| F | Input Fuses (L+N) | Not user accessible, fast-acting (F) | | | A |
| $V_{1\text{ ov}}$ | OV Threshold V_1 | 64 | 66 | 68 | VDC |
| $t_{V1\text{ ov}}$ | OV Latch Off Time V_1 | 1 | | | ms |
| $P_{1\text{ lim}}$ | Nominal Power Limitation | $V_{1\text{ AC HL}}, T_a \leq 45^\circ\text{C}, V_1 \geq 48\text{ V}$ | 4000 | 4100 | W |
| | | $V_{1\text{ AC HL}}, T_a = 55^\circ\text{C}, V_1 \geq 48\text{ V}$ | 3000 | 3100 | W |
| $I_{1\text{ lim}}$ | Nominal Current Limitation | $V_{1\text{ AC HL}}, T_a \leq 45^\circ\text{C}, V_1 = 54.5\text{ V}$ | 73 | 76 | ADC |
| | | $V_{1\text{ AC HL}}, T_a \leq 45^\circ\text{C}, V_1 = 42 \dots 48\text{ V}$ | 83 | 86 | ADC |
| | | $V_{1\text{ AC HL}}, T_a = 55^\circ\text{C}, V_1 = 54.5\text{ V}$ | 55 | 57 | ADC |
| $t_{1\text{ lim}}$ | Power Limit Blanking Time | Time until power limit is reduced to nominal value | | | ms |
| $P_{1\text{ ol lim}}$ | Power Limit during Short Time Over Load V_1 | $V_{1\text{ AC HL}}, T_a \leq 45^\circ\text{C}, V_1 \geq 48\text{ V}$, Maximum duration 10 ms | | | W |
| $I_{1\text{ ol lim}}$ | Current Limit during Short Time Over Load V_1 | $V_{1\text{ AC HL}}, T_a \leq 45^\circ\text{C}, V_1 = 54.5\text{ V}$, Maximum duration 5 ms | | | A |
| $I_{1\text{ SC}}$ | Max Short Circuit Current V_1 | $V_1 < 10\text{ VDC}$, excluding output capacitor discharging current | | | 83 ADC |
| $t_{1\text{ SC off}}$ | Short Circuit Latch off time | Time to latch off when in short circuit or output under voltage ($V_1 < V_{1\text{ UV}}$) | | | 100 ms |
| $V_{1\text{ UV}}$ | Output Under Voltage Protection | 39 | 40 | 41 | VDC |
| $t_{1\text{ UV}}$ | Output Under Voltage Protection Delay time | $V_1 < V_{1\text{ UV}}$ | | | 250 ms |
| T_{SD} | Over Temperature on critical points | Inlet Ambient Temperature | 60 | | °C |
| | | PFC Primary Heatsink Temperature | 90 | | |
| | | DC/DC Primary Heatsink Temperature | 90 | | |
| | | Secondary Sync Mosfet Temperature | 100 | | |
| $V_{\text{SB UV}}$ | Output Under Voltage Protection Standby | 11.1 | 11.2 | 11.3 | VDC |
| $I_{\text{SB Lim}}$ | Standby Over Current Limit | 5.0 | 5.5 | ADC | |

6.1. LATCH OFF

For all fault conditions except over current on standby output and over temperature, the output will shut down and latch off. The latch can be cleared by recycling the input voltage or the PSKILL input. A failure on the main output will only shut down the main output, while the optional standby output continues to operate. A failure on the standby output will only shut down the standby output.

Overtemperature protection has a hysteretic behavior. Once the power supply has cooled down below the warning thresholds the PSU will restart.

6.2. OVER VOLTAGE PROTECTION

The TET front-ends provide a variable threshold, tracking programmed output voltage set-point, implemented in FW plus a fixed threshold over voltage (OV) protection implemented with a HW comparator. Once an OV condition has been triggered, the supply will shut down and latch off as described under 6.1.

6.3. UNDER VOLTAGE DETECTION

Both main and optional standby outputs are monitored. LED and PWOK_L pin signal if the output voltage exceeds $\pm 7\%$ of its nominal voltage.

Output under voltage protection is provided on both outputs. When the main output falls below V_{1UV} or the standby output falls below V_{SBUV} , the output is inhibited and latches off as described under 6.1.

6.4. CURRENT LIMITATION MAIN OUTPUT

Two different over current protection features are implemented on the main output.

If the output current exceeds I_{1lim} for more than 10 ms the output will reduce its voltage, to reduce output current to I_{1lim} . In case the output voltage will be reduced below the under-voltage level V_{1UV} the output will turn off after 250 ms, signaling an under-voltage fault.

The 2nd protection is a substantially rectangular output characteristic controlled by a software feedback loop. This protects the power supply and system during the 10 ms blanking time of the short time over load mode. If the output current is rising fast and reaches I_{1ollim} , the supply will immediately reduce its output voltage to prevent the output current from exceeding I_{1ollim} . When the output current is reduced below I_{1ollim} , the output voltage will return to its nominal value.

The main output current limitation level I_{1lim} and I_{1ollim} are decreased if the ambient (inlet) temperature increases beyond 45°C. The current limit depends on programmed output voltage, to keep output power constant at about 4000 W. See also *Figure 4* for output characteristic and current limitation at different output voltage settings.

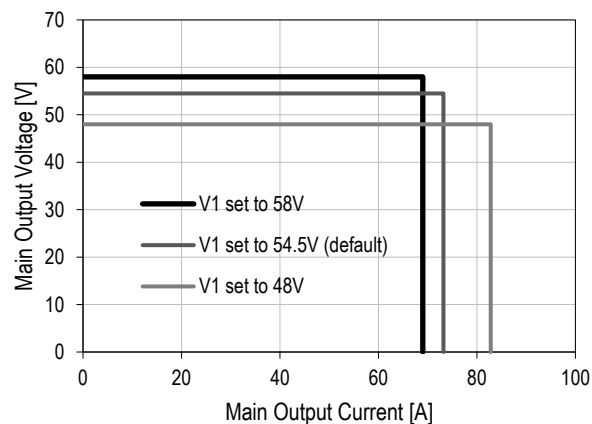


Figure 4. Output characteristics V_1

6.5. CURRENT LIMITATION STANDBY OUTPUT

The standby output has a hiccup current limitation implemented. If the standby current exceeds I_{SBLim} the standby converter switches off and retries automatically after 1 second off time.

7. MONITORING

The power supply provides information about operating conditions through its CAN bus interface. Details can be found in the CAN Communication Manual BCA.00231.0. Accuracy of sensors within PSU is given in following table.

| PARAMETER | DESCRIPTION / CONDITION | MIN | NOM | MAX | UNIT |
|---------------|---|------------|-----|------------|------------|
| $V_{i\ mon}$ | Input RMS Voltage $V_{i\ min} \leq V_i \leq V_{i\ max}$ | -3 | | +3 | V_{rms} |
| $I_{i\ mon}$ | Input RMS Current | -1.25 | | +1.25 | A_{rms} |
| $P_{i\ mon}$ | True Input Power | -200 | | +200 | W |
| $V_{1\ mon}$ | V_1 Voltage $V_1 > 40\ VDC$ | -1 | | +1 | % |
| $I_{1\ mon}$ | V_1 Current $I_1 > 25\ A$ $I_1 \leq 25\ A$ | -2 -0.5 | | +2 +0.5 | % A |
| $V_{SB\ mon}$ | V_{SB} Voltage $I_{SB} = 0 \dots 5A$ | -0.25 | | +0.25 | V |
| $I_{SB\ mon}$ | V_{SB} Current $I_{SB} = 0 \dots 5A$ | -0.25 | | +0.25 | A |
| $P_{1\ mon}$ | P_1 Output Power $P_1 > 1000\ W$ $P_1 \leq 1000\ W$ | -3 -30 | | +3 +30 | % W |
| $P_{SB\ mon}$ | P_{SB} Output Power $P_{SB} = 0 \dots 60W$ | -4 | | +4 | W |
| $T_{a\ mon}$ | Inlet air temperature $T_a = 0 \dots 45^\circ C$ | -5 | | +5 | $^\circ C$ |

8. SIGNALING AND CONTROL

8.1. ELECTRICAL CHARACTERISTICS

| PARAMETER | DESCRIPTION / CONDITION | MIN | NOM | MAX | UNIT |
|-------------------|--|------|------|-----|------------|
| PSKILL | | | | | |
| V_{iL} | Input low level voltage (Main output enabled) | -0.2 | | 0.8 | V |
| V_{iH} | Input high level voltage (Main output disabled) | 2.0 | | 3.5 | V |
| $I_{iL, H}$ | Maximum input sink or source current | 0 | | 1 | mA |
| $R_{puPSKILL}$ | Internal pull up resistor on PSKILL to internal 3.3V | | 4.75 | | k Ω |
| ACOK_L | | | | | |
| V_{oL} | Output low level voltage $I_{sink} < 4\ mA$ | -0.2 | | 0.4 | V |
| V_{puACOK_L} | External pull up voltage | 0 | | 13 | V |
| R_{puACOK_L} | Recommended external pull up resistor on ACOK_L at $V_{puACOK_L} = 3.3\ V$ | | 10 | | k Ω |
| Low level output | Input voltage within operating range | | | | |
| High level output | No input voltage, or low input voltage | | | | |

8.2. PSKILL INPUT

The PSKILL input is an active-high and trailing pin in the connector and is used to switch off the main output as soon as the power supply is being plugged out.

This input can be connected to SGND, enabling main output as soon as power supply is plugged-in into system with input voltage present. Alternatively, this input can be driven by a logical signal (preferably an open collector signal) from the application, allowing remote control of the main output.

The standby output will remain on regardless of the PSKILL input state.

This pin is isolated and referred to SGND. A 4.75 kOhm pullup resistor to 3.3 V is present within the power supply.

8.3. ACOK_L OUTPUT

The ACOK_L is an isolated open collector output referred to SGND. It requires an external pull-up resistor. A low voltage on this pin reflects input voltage to be within operating range.

8.4. CAN BUS INTERFACE

The CAN bus interface serves for information exchange between paralleled power supplies (e.g. for current share) and for communication with a system controller (e.g. voltage setting, monitoring). The CAN bus operates at 1000 kbit/s with a Bel defined protocol. System wiring requires only interconnection of CAN_H and CAN_L lines, in addition a 120 Ohm termination resistor is required at each end of the CAN bus to prevent signal reflections.

NOTE: To enable active current share between paralleled power supplies, their CAN bus interface must be interconnected.

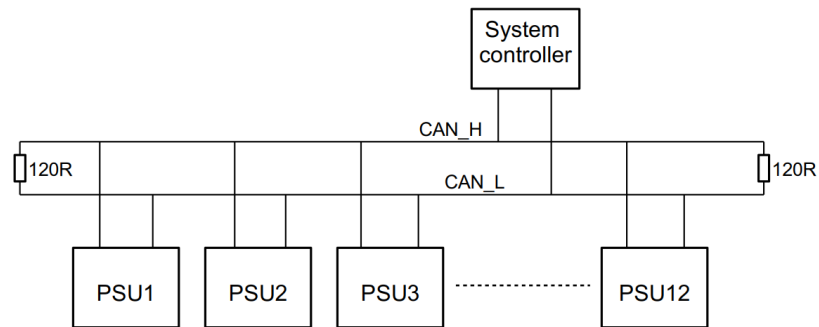


Figure 5. CAN bus wiring

8.5. CAN ADDRESSING

The CAN address (Node-ID) of each PSU is a combination of Shelf Number and PSU position within the shelf.

The Shelf-Number is given by a precision voltage source to be applied to the ADDR1 pin (versus power GND). The output impedance of this voltage source should not exceed 100 Ohm and the voltage range is between 0.0 V and 3.0 V. Accuracy is required to be ± 30 mV or better.

A resistor needs to be connected from the ADDR0 pin to power GND to define the position of the PSU slot within the shelf. The resistor tolerance needs to be $\pm 1\%$ or lower.

The resulting Node-ID is given by following formula: $\text{Node-ID} = (\text{Shelf-Nr} - 1) * 16 + \text{Slot-Nr}$.

If the PSU is not running, the ADDR0 pin is pulled low and the ADDR1 pin is switched to a high impedance input. Thus, the ADDR1 signal may be shared between PSUs while ADDR0 needs to be separated. Refer to the CAN manual for further information.

If either ADDR0 or ADDR1 pins are left open or shorted to GND or 3.0 V the PSU will detect an invalid Node-Id (reflected by corresponding LED state) and will not respond to a CAN request.

| Shelf-Nr | Voltage on ADDR1 [V] | Slot-Nr | Resistor on ADDR0 [Ohm] | Resulting Voltage on ADDR0 [V] |
|----------|----------------------|---------|-------------------------|--------------------------------|
| 1 | 0.332 | 1 | 150 | 0.130 |
| 2 | 0.664 | 2 | 470 | 0.374 |
| 3 | 0.998 | 3 | 866 | 0.624 |
| 4 | 1.330 | 4 | 1330 | 0.862 |
| 5 | 1.666 | 5 | 1960 | 1.118 |
| 6 | 1.998 | 6 | 2740 | 1.361 |
| 7 | 2.332 | 7 | 3900 | 1.625 |
| 8 | 2.664 | 8 | 5620 | 1.890 |
| | | 9 | 8060 | 2.129 |
| | | 10 | 12700 | 2.381 |
| | | 11 | 22600 | 2.618 |
| | | 12 | 75000 | 2.874 |

Table 1. Address pin voltage and resistor requirements

8.6. FRONT LEDs

The front-end has 2 front LEDs showing the status of the supply. LED number one is green and indicates AC power is on or off, while LED number two is bi-colored: green and yellow, and indicates DC power presence or fault situations. If the PSU is bootloaded both LEDs are alternating green blinking. All other conditions are specified in the *Table 2*. The order of the criteria in the table corresponds to the testing precedence in the controller. LEDs are only available if sufficient input voltage is applied for operation of the internal supply circuits.

| OPERATING CONDITION | LED SIGNALING |
|---|---------------------------|
| Bootloading | LEDs alternately blinking |
| AC LED | |
| AC Line within range | Solid Green |
| AC Line out of range | Off |
| DC LED | |
| V_I or V_{SB} out of regulation | |
| Over temperature shutdown | |
| Output over voltage shutdown (V_I or V_{SB}) | Solid Yellow |
| Output under voltage shutdown (V_I or V_{SB}) | |
| Output over current shutdown (V_I or V_{SB}) | |
| Invalid Node-Id | Blinking Yellow |
| Main output disabled by application | Blinking Green |
| Normal Operation | Solid Green |
| PSU backsupplied and input voltage present but out of range | Blinking Yellow |
| Otherwise | All LEDs off |

Table 2. LED Status

8.7. CURRENT SHARE

The front-end has an active current share scheme implemented for V1. CAN bus interface of the paralleled power supplies need to be interconnected to activate the sharing function.

The controller implements a Master/Slave current share function. The power supply providing the largest current among the group is automatically the Master. The other supplies will operate as Slaves and increase their output current to a value close to the Master by slightly increasing their output voltage. The voltage increase is limited to +1 V.

The standby output uses a passive current share method (droop output voltage characteristic).

Due to non-ideal current share the maximum total output power of paralleled power supplies is less than the theoretical maximum and is defined in *Table 3*.

| No of paralleled PSUs | Maximum available power on main output V | | Maximum available power on standby output (optional) | |
|-----------------------|--|----------------|--|----------------|
| | without redundancy | n+1 redundancy | without redundancy | n+1 redundancy |
| 1 | 4000 W | - | 60 W | - |
| 2 | 7800 W | 4000 W | 95 W | 60 W |
| 3 | 11600 W | 7800 W | 131 W | 95 W |
| 4 | 15400 W | 11600 W | 166 W | 131 W |
| 5 | 19200 W | 15400 W | 202 W | 166 W |
| 6 | 23000 W | 19200 W | 238 W | 202 W |

Table 3. Power available when PSU in redundant operation

9. TEMPERATURE AND FAN CONTROL

To achieve best cooling results sufficient airflow through the supply must be ensured. Do not block or obstruct the airflow at the rear of the supply by placing large objects directly at the output connector. The TET4000-48-069RA is provided with a reverse airflow, which means the air enters through the front of the supply and leaves at the rear.

9.1. FAN CONTROL

The average speed of the two individual fans within the dual-axis-fan is controlled to meet the reference. The reference is given by the maximum of following 3 items:

- Load depending Fan Speed curve, see *Figure 6*. This curve is in use at nominal conditions.
- Component depending Fan Speed curve according to *Figure 7*.
- System commanded Fan Speed through CAN bus.

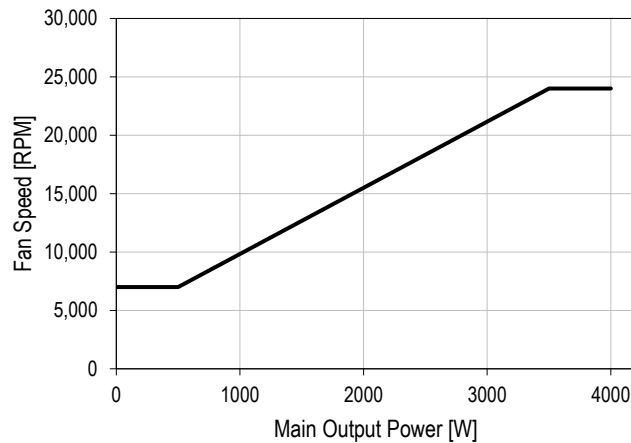


Figure 6. Fan speed versus main output power

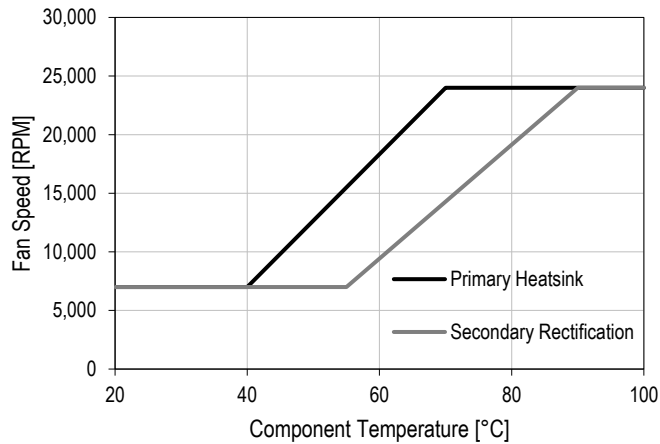


Figure 7. Fan speed versus power stage temperatures

10. ELECTROMAGNETIC COMPATIBILITY

10.1. IMMUNITY

NOTE: Most of the immunity requirements are derived from EN 55024:1998/A2:2003.

| PARAMETER | DESCRIPTION / CONDITION | CRITERION |
|--------------------------------|---|-------------------------|
| ESD Contact Discharge | IEC / EN 61000-4-2, ±8 kV, 25+25 discharges per test point (metallic case, LEDs, connector body) | A |
| ESD Air Discharge | IEC / EN 61000-4-2, ±15 kV, 25+25 discharges per test point (non-metallic user accessible surfaces) | A |
| Radiated Electromagnetic Field | IEC / EN 61000-4-3, 10 V/m, 1 kHz/80% Amplitude Modulation, 1 µs Pulse Modulation, 10 kHz...2 GHz | A |
| Burst | IEC / EN 61000-4-4, level 3 AC port ±2 kV, 1 minute | A |
| Surge | IEC / EN 61000-4-5, level 3 Line to earth: ±2 kV Line to line: ±2 kV @ | A |
| RF Conducted Immunity | IEC/EN 61000-4-6, Level 3, 10 Vrms, CW, 0.1 ... 80 MHz | A |
| Voltage Dips and Interruptions | IEC/EN 61000-4-11 1: Vi 230 Volts, 100% Load, Dip 100%, Duration 12 ms 2: Vi 230 Volts, 100% Load, Dip 100%, Duration < 150 ms 3: Vi 230 Volts, 100% Load, Dip 100%, Duration > 150 ms | A V1: B, VSB: A B |

10.2. EMISSION

| PARAMETER | DESCRIPTION / CONDITION | CRITERION |
|--------------------|--|----------------------|
| Conducted Emission | EN55022 / CISPR 22: 0.15 ... 30 MHz, QP and AVG | Class A + 6dB margin |
| Radiated Emission | EN55022 / CISPR 22: 30 MHz ... 1 GHz, QP | Class A + 6dB margin |
| Harmonic Emissions | IEC61000-3-12, Vin = 230 VAC, 50 Hz, 100% Load | Class A |
| Audible Noise LpA | V _{nom} , 50% I _{nom} , T _A = 25°C, at the bystander position | 60 dBA |
| AC Flicker | IEC / EN 61000-3-3, d _{max} < 3.3% | PASS |

11. SAFETY / APPROVALS

Maximum electric strength testing is performed in the factory according to UL/CSA 62368-1, IEC 62368-1. Input-to-output electric strength tests should not be repeated in the field. Bel Power Solutions will not honor any warranty claims resulting from electric strength field tests.

| PARAMETER | DESCRIPTION / CONDITION | MIN | NOM | MAX | UNIT |
|--------------------------|---|--------------|---|-----|------|
| Agency Approvals | Approved to the latest edition of the following standards: UL/CSA 62368-1, IEC 62368-1 | | | | |
| Isolation Strength | Input (L/N) to case (PE) Input (L/N) to output Output to case (PE) | | Basic Reinforced Functional | | |
| dc Creepage / Clearance | Primary (L/N) to protective earth (PE) Primary to secondary | | According to UL/CSA 62368-1, IEC 62368-1 | | |
| Electrical Strength Test | Input to case Input to output (tested by manufacturer only) | 2121 4242 | | | VDC |

12. ENVIRONMENTAL

| PARAMETER | DESCRIPTION / CONDITION | MIN | NOM | MAX | UNIT |
|-------------------|-------------------------|---|-----|------|---------------------|
| T _A | Ambient Temperature | V _{min} to V _{max} , I _{nom} , I _{SB nom} at 4000 m | | +35 | °C |
| | | V _{min} to V _{max} , I _{nom} , I _{SB nom} at 1800 m | | +45 | °C |
| T _{Aext} | Extended Temp. Range | Derated output | | +55 | °C |
| T _S | Storage Temperature | Non-operational | | +70 | °C |
| | Altitude | Operational, above Sea Level (see derating) | | 4000 | m |
| | Cooling | System Back Pressure | | 0.5 | in-H ₂ O |



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13. MECHANICAL

| PARAMETER | DESCRIPTION / CONDITION | MIN | NOM | MAX | UNIT |
|-----------------|-------------------------|-----|-------|-----|------|
| Dimensions | Width | | 69 | | mm |
| | Height | | 40.6 | | mm |
| | Depth | | 528.4 | | mm |
| <i>m</i> Weight | | | 2.7 | | kg |

NOTE: A 3D step file of the power supply casing is available on request.

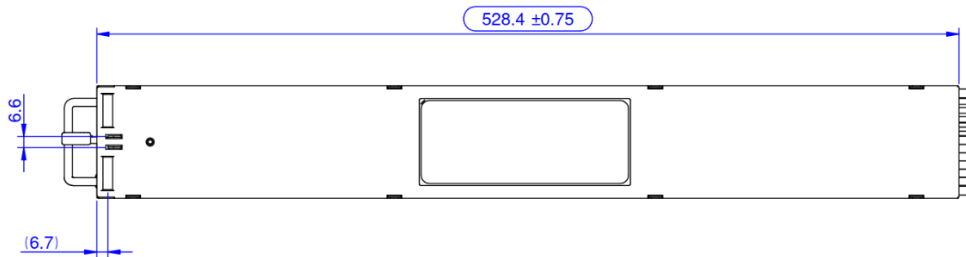


Figure 8. Top view

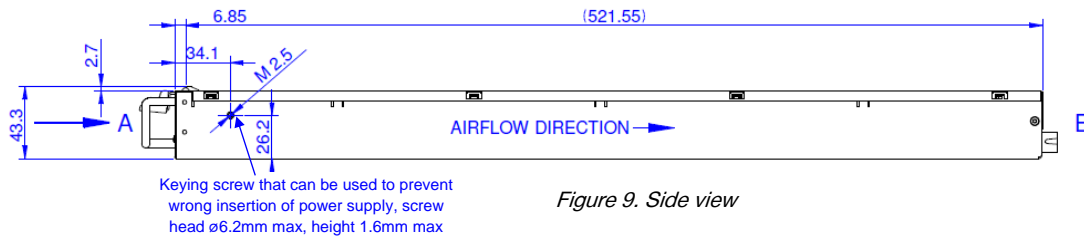


Figure 9. Side view

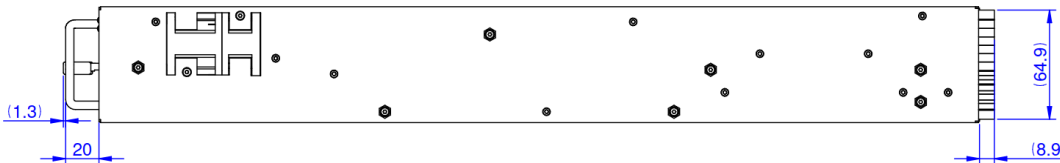


Figure 10. Bottom view

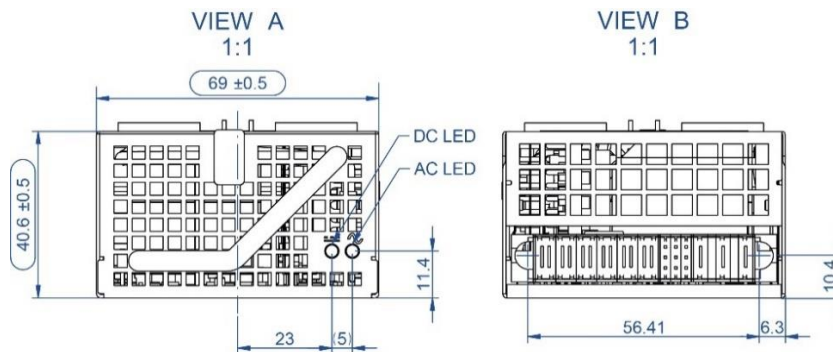


Figure 11. Front and Rear view

14. CONNECTOR

Rear side PSU connector serves as interface for input power, output power and signals. To guarantee proper mating sequence, the below noted connector P/N is required to be used.

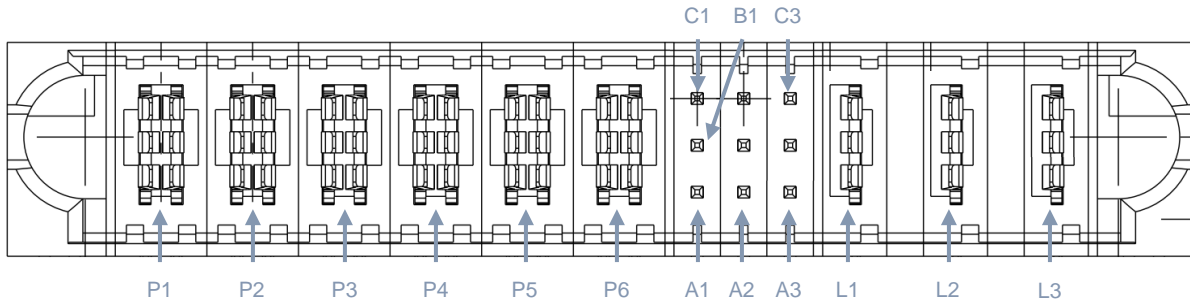


Figure 12. PSU rear side connector, view from mating side

| VERSION | TYPE | MANUFACTURER | BEL P/N | MANUFACTURER P/N |
|------------------|-----------------|--------------|------------------------|---|
| PSU Connector | PWRBLADE ULTRA® | Amphenol FCI | - | 10127397-07H1420LF |
| System Connector | PWRBLADE ULTRA® | Amphenol FCI | ZES.01164 ZES.01224 | 10127401-08H1420LF (Solder version) 10127400-01H1420LF (Press-Fit version) |

| PIN | SIGNAL NAME | DESCRIPTION | MATING SEQUENCE |
|------------|-------------|---|-----------------|
| L1 | PE | Protective Earth | 1 |
| L2 | N | AC input line (Neutral) | 2 |
| L3 | L | AC input line (Line) | 2 |
| P1, P2, P3 | GND | Power and ADDR0, ADDR1 return | 1 |
| P4, P5, P6 | V1 | +54.5 V main output | 2 |
| A1 | PSKILL | Power supply kill input (lagging pin); active-high | 3 |
| B1 | ACOK_L | Output signaling input voltage within operating range; active-low | 2 |
| C1 | SGND | Isolated GND. CAN, PSKILL and ACOK_L are referred to it. | 2 |
| A2 | ADDR0 | Analog input for PSU address setting | 2 |
| B2 | CAN_H | CAN-Interface, High ⁷ | 2 |
| C2 | CAN_L | CAN-Interface, Low ⁸ | 2 |
| A3 | ADDR1 | Analog input for Shelf address setting ⁹ | 2 |
| B3, C3 | VSB | +12 V Standby output | 2 |



Table 4. Pin assignment

⁷ With future I2C implementation will be optionally SDA

⁸ With future I2C implementation will be optionally SCL

⁹ With future I2C implementation will be optionally used as digital bidirectional share bus

15. ACCESSORIES

| ITEM | DESCRIPTION | ORDERING PN | SOURCE |
|---|---|-------------|--|
|  | Interface Utility Windows compatible GUI to program, control and monitor Bel products | N/A | belfuse.com/power-solutions |
|  | Evaluation Board Evaluation board to operate 2Pcs TET4000-48-069RA | YTM.U1900.0 | Bel Power Solutions |

16. REVISION HISTORY

| REV | DESCRIPTION | PSU PRODUCT VERSION | DATE | AUTHOR |
|-----|---|---------------------|-------------|--------|
| 001 | Initial Draft. | V001 | 04-Jan-2017 | WU |
| 002 | 13. Corrected PSU height | | | |
| 003 | Adjust Specifications to align with PSU electrical design | V002 | 23-Oct-2017 | RB |
| 004 | Formatting Changes | V003 | 07-Nov-2017 | VS |
| 005 | Add CAN address section <i>0</i> , add fan control <i>9.1</i> , add mechanical outline and weight <i>13</i> , add optional I2C interface <i>14</i> , add P/N for mating connector <i>14</i> , add adapter board P/N <i>15</i> | V003 | 16-Jan-2018 | RB/WU |
| 006 | Add DC input operating range | V005 | 29-Jun-2018 | RB |
| 007 | Removed HVDC input operation | V006 | 03-Sep-2018 | WU |
| A | Various minor updates | V006 | 11-Nov-2019 | WU |

For more information on these products consult: tech.support@psbel.com

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