

CAR2548FP series rectifier

Input: 90Vac to 264Vac; Output: 48Vdc @ 2500W; 3.3Vdc or 5 Vdc @ 1A



Applications

- 48Vdc distributed power architectures
- Cellular Base Stations
- Blade Servers
- Network/ATE Equipment
- Network Attached Storage
- Telecom Access Nodes
- Routers/Switches

Description

The CAR2548FP series of Front-End rectifiers provide highly efficient isolated power from worldwide input mains in a compact 1U industry standard form factor in an unprecedented power density of 27W/in³. These rectifiers complement the CAR2548DC converter, providing comprehensive solutions for systems connected either to commercial ac mains, 48/60Vdc power plants or telecom central offices. This plug and play approach offers significant advantages since systems can be reconfigured and repositioned readily by simply replacing the power supply. The high-density, front-to-back airflow is designed for minimal space utilization and is highly expandable for future growth. The industry standard PMBus compliant I²C communications buss offers a full range of control and monitoring capabilities. The SMBusAlert signal pin alerts customers automatically of any state change within the power supply.

Features

- Universal input with PFC
- Constant power characteristic
- 3 front panel LEDs: 1-input;2-output; 3 - fault
- Remote ON/OFF control of the 48Vdc output
- Remote sense on the 48Vdc output
- No minimum load requirements
- Redundant parallel operation
- Active load sharing (single wire)
- Hot Plug-ability
- Efficiency: typically 92% @ 50% load
- Standby orderable either as 3.3Vdc or 5Vdc
- Auto recoverable OC & OT protection
- Operating temperature: -10 - 70°C (de-rated above 50°C)
- Digital status & control: I²C and PMBus serial bus
- EN/IEC/UL60950-1 2nd edition; UL, CSA and VDE
- EMI: class B FCC docket 20780 part 15, EN55022
- Meets EN6100 immunity and transient standards
- Shock & vibration: NEBS GR-63-CORE, level 3

* UL is a registered trademark of Underwriters Laboratories, Inc.

† CSA is a registered trademark of Canadian Standards Association.

‡ VDE is a trademark of Verband Deutscher Elektrotechniker e.V.

§ Intended for integration into end-user equipment. All the required procedures for CE marking of end-user equipment should be followed. (The CE mark is placed on selected products.)

** ISO is a registered trademark of the International Organization of Standards.

+ PMBus name and logo are registered trademarks of the System Management Interface Forum (SMIF)

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Absolute Maximum Ratings

Stresses in excess of the absolute maximum ratings can cause permanent damage to the device. These are absolute stress ratings only, functional operation of the device is not implied at these or any other conditions in excess of those given in the operations sections of the data sheet. Exposure to absolute maximum ratings for extended periods can adversely affect the device reliability.

| Parameter | Symbol | Min | Max | Unit |
|---|------------------|-----|-----------------|-----------------|
| Input Voltage: Continuous | V _{IN} | 0 | 264 | V _{ac} |
| Operating Ambient Temperature | TA | -10 | 70 ¹ | °C |
| Storage Temperature | T _{stg} | -40 | 85 | °C |
| I/O Isolation voltage to Frame (100% factory Hi-Pot tested) | | | 1500 | V _{ac} |

Electrical Specifications

Unless otherwise indicated, specifications apply over all operating input voltage, load, and temperature conditions.

| INPUT | | | | | |
|--|-----------------|------|---------|-----|-------------------|
| Parameter | Symbol | Min | Typ | Max | Unit |
| Operational Range | V _{IN} | 90 | 110/230 | 264 | V _{ac} |
| Frequency Range | F _{IN} | 47 | 50/60 | 63 | Hz |
| Main Output Turn_OFF | V _{IN} | | | 80 | V _{ac} |
| Maximum Input Current, (V _{IN} = 180Vac, V _O = V _{O, set} , I _O =I _{O, max}) | I _{IN} | | | 16 | A _{ac} |
| Cold Start Inrush Current (Excluding x-caps, 25°C, <10ms, per ETSI 300-132) | I _{IN} | | | 50 | A _{peak} |
| Efficiency, (T _{amb} =25°C, V _{in} = 230Vac, V _{out} = 48Vdc, I _O =I _{O, max}) | η | | 92 | | % |
| Power Factor, (V _{in} =230Vac, I _O =I _{O, max}) | PF | | 0.99 | | |
| Holdup time, (V _{in} = 230Vac, V _{out} = 48Vdc, T _{amb} 25°C, I _O =I _{O, max}) | T | | 16.8 | | ms |
| Early warning prior to loss of DC output below regulation | | | 2 | | ms |
| Ride through | T | | 8.3 | | ms |
| Leakage Current, (V _{in} = 250Vac, F _{in} = 60Hz) | I _{IN} | | 3 | | mArms |
| Isolation Input/Output | | 3000 | | | V _{ac} |
| Input/Frame | | 1500 | | | V _{ac} |
| Output/Frame | | 100 | | | V _{dc} |

| 48V _{dc} MAIN OUTPUT | | | | | |
|---|------------------|-------|-------|-----------|-------------------|
| Parameter | Symbol | Min | Typ | Max | Unit |
| Output Power High Line Operation (180 – 264 Vac) | W | 0 | - | 2500 | W |
| Low Line Operation: 99Vac [Z03A/Z01A] | | 0 | - | 1300/1000 | W |
| 90 – 98 Vac [Z03A/Z01A] | | 0 | - | 1200/1000 | |
| Set point | V _{out} | 47.95 | 48.00 | 48.05 | V _{dc} |
| Overall regulation (load, temperature, aging) | | -3 | | +3 | % |
| Ripple and noise ² | | | | 540 | mV _{p-p} |
| Turn-ON overshoot | T | | | +3 | % |
| Turn-ON delay | | | | 2 | sec |
| Remote ON/OFF delay time | | | | 40 | ms |
| Turn-ON rise time (10 – 90% of V _{out}) | | | | 50 | ms |

¹ Derated above 50°C at 2.5%/°C

² Measured across a 10µf electrolytic and a 0.1µf ceramic capacitors in parallel. 20MHz bandwidth

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| 48V _{dc} MAIN OUTPUT (continued) | | | | | |
|---|------------------|----------------|-----|------|-------------------|
| Parameter | Symbol | Min | Typ | Max | Unit |
| Transient response 50% step [10%-60%, 50% - 100%] (di/dt – 1A/μs, recovery 300μs) | V _{out} | -5 | | +5 | %V _{out} |
| Programmable range (hardware & software) | | 43.2 | | 52.8 | V _{dc} |
| Oversvoltage protection, latched (recovery by cycling OFF/ON via hardware or software) | I _{out} | 58 | 59 | 60 | V _{dc} |
| Output current | | 1 ³ | | 52 | A _{dc} |
| Current limit, Hiccup (programmable level) | | 57.3 | | 67.7 | A _{dc} |
| Active current share | | -5 | | +5 | % of FL |

| STANDBY OUTPUT | | | | | |
|---|------------------|-----|-----------|-----|-----------------|
| Parameter | Symbol | Min | Typ | Max | Unit |
| Set point | V _{out} | | 3.3 / 5.0 | | V _{dc} |
| Overall regulation (load, temperature, aging) | V _{out} | -5 | | +5 | % |
| Ripple and noise | | | | 50 | mVp-p |
| Output current | I _{out} | 0 | | 1 | A _{dc} |
| Isolation Output/Frame | | 100 | | | V _{dc} |

General Specifications

| Parameter | Min | Typ | Max | Units | Notes |
|--------------|-----|---------------|-----|--------------|---|
| Reliability | | 100,000 | | Hrs | Full load, 50°C ; MTBF per SR232 Reliability protection for electronic equipment, method I, case III, |
| Service Life | | 10 | | Yrs | Full load, excluding fans |
| Weight | | 2.2 (4.85) | | Kgs (Lbs) | |

Feature Specifications

Unless otherwise indicated, specifications apply over all operating input voltage, resistive load, and temperature conditions. See Feature Descriptions for additional information.

| Parameter | Symbol | Min | Typ | Max | Unit |
|--|-----------------|--------------------|-----|-----|-----------------|
| Remote ON/OFF (Needs to be pulled HI via an external resistor) | | | | | |
| Logic High (Module ON) | I _{IH} | | — | 20 | μA |
| | V _{IH} | 0.7V _{DD} | — | 12 | V _{DC} |
| Logic Low (Module OFF) | I _{IL} | — | — | 1 | mA |
| | V _{IL} | 0 | — | 0.8 | V _{DC} |

³ Minimum load is required only when units are being paralleled in the application

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Feature Specifications (continued)

| Parameter | Symbol | Min | Typ | Max | Unit |
|--|--------------------|--------------------|-----|------|------------------|
| Output Voltage programming (Vprog) Equation: $V_{out} = 10.8 + (V_{prog} * 0.96)$ | | | | | |
| Vprog range | V _{prog} | 0 | — | 2.5 | V _{DC} |
| Programmed output voltage range | V _o | 10.8 | — | 13.2 | V _{DC} |
| Voltage adjustment resolution (8-bit A/D) | V _o | — | 10 | — | mV _{DC} |
| Output configured to 13.2Vdc | V _{prog} | 2.5 | — | 3.0 | V _{DC} |
| Output configured to the 12Vdc set-point | V _{prog} | 3.0 | — | — | V _{DC} |
| Enable [short pin controlling presence of the 12V _{DC} output] | | | | | |
| 12V output OFF | V _I | 0.7V _{DD} | — | 12 | V _{DC} |
| 12V output ON | V _I | 0 | — | 0.8 | V _{DC} |
| Write protect (Wp) | | | | | |
| Write protect enabled | V _I | 0.7V _{DD} | — | 12 | V _{DC} |
| Write protect disabled | V _I | 0 | — | 0.8 | V _{DC} |
| INPUT(AC)-OK (Needs to be pulled HI via an external resistor) | | | | | |
| Logic High (Input within normal range; V _{IN} ≥ 80V _{AC}) | I _{OH} | — | — | 20 | μA |
| | V _{OH} | 0.7V _{DD} | — | 12 | V _{DC} |
| Logic Low (Input out of range; V _{IN} ≤ 75V _{AC}) | I _{OL} | — | — | 20 | mA |
| | V _{OL} | 0 | — | 0.4 | V _{DC} |
| DC-OK (Internally connected to 3.3V via a 10kΩ resistor) | | | | | |
| Logic High (Output voltage is present; V _{OUT} ≥ 10.7Vdc) | I _{OH} | — | — | 20 | μA |
| | V _{OH} | 0.7V _{DD} | — | 12 | V _{DC} |
| Logic Low (Output voltage is not present; V _{OUT} ≤ 10.2V _{DC}) | I _{OL} | — | — | 20 | mA |
| | V _{OL} | 0 | — | 0.4 | V _{DC} |
| Over Temperature Warning (Needs to be pulled HI via an external resistor) | | | | | |
| Logic High (temperature within normal range) | I _{OH} | — | — | 20 | μA |
| | V _{OH} | 0.7V _{DD} | — | 12 | V _{DC} |
| Logic Low (temperature is too high) | I _{OL} | — | — | 20 | mA |
| | V _{OL} | 0 | — | 0.4 | V _{DC} |
| Delayed shutdown after Logic Low transition | T _{delay} | 10 | — | — | sec |
| Fault (Needs to be pulled HI via an external resistor) | | | | | |
| Logic High (No fault is present) | I _{OH} | — | — | 20 | μA |
| | V _{OH} | 0.7V _{DD} | — | 12 | V _{DC} |
| Logic Low (Fault is present) | I _{OL} | — | — | 20 | mA |
| | V _{OL} | 0 | — | 0.4 | V _{DC} |
| PS Present (Needs to be pulled HI via an external resistor) | | | | | |
| Logic High (Power supply is not plugged in) | | | | | |
| Logic Low (Power supply is present) | V _{IL} | 0 | — | 0.1 | V _{DC} |

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Feature Specifications (continued)

| Parameter | Symbol | Min | Typ | Max | Unit |
|--|------------------|--------------------|-----|-----|------------------|
| SMBAlert# (Interrupt) (Needs to be pulled HI via an external Logic High (No Alert - normal) Logic Low (Alert is set)) | I _{OH} | | — | 20 | μA |
| | V _{OH} | 0.7V _{DD} | — | 12 | V _{DC} |
| | I _{OL} | — | — | 20 | mA |
| | V _{OL} | 0 | — | 0.4 | V _{DC} |
| Output current monitor (I _{mon}) | | | | | |
| Resolution | | | 15 | | mV/A |
| Measurement range | I _o | 0 | | 208 | A _{DC} |
| Measurement accuracy, load > 25% of FL | | -10 | | +10 | % |
| Analog output range | V _{mon} | 0 | | 3.3 | V _{DC} |
| Sourced output current | I _o | | | 5 | mA _{DC} |

Digital Interface Specifications

| Parameter | Conditions | Symbol | Min | Typ | Max | Unit |
|--|-------------------------|-----------------------|-----|-----|------|-----------------|
| PMBus Signal Interface Characteristics | | | | | | |
| Input Logic High Voltage (CLK, DATA) | | V _{IH} | 2.1 | | 3.6 | V _{DC} |
| Input Logic Low Voltage (CLK, DATA) | | V _{IL} | 0 | | 0.8 | V _{DC} |
| Input high sourced current (CLK, DATA) | | I _{IH} | 0 | | 10 | μA |
| Output Low sink Voltage (CLK, DATA, SMBALERT#) | I _{OUT} =3.5mA | V _{OL} | | | 0.4 | V _{DC} |
| Output Low sink current (CLK, DATA, SMBALERT#) | | I _{OL} | 3.5 | | | mA |
| Output High open drain leakage current (CLK, DATA, SMBALERT#) | V _{OUT} =3.6V | I _{OH} | 0 | | 10 | μA |
| PMBus Operating frequency range | Slave Mode | F _{PMB} | 10 | | 400 | kHz |
| Measurement System Characteristics (all measurement tolerances are typical estimations under normal operating conditions) | | | | | | |
| Clock stretching | | t _{STRETCH} | | | 25 | ms |
| I _{OUT} measurement range | Linear | I _{RNG} | 0 | | 208 | A _{DC} |
| I _{OUT} measurement accuracy 25°C | | I _{ACC} | -3 | | +3 | % of FL |
| V _{OUT} measurement range | Linear | V _{OUT(rng)} | 0 | | 14 | V _{DC} |
| V _{OUT} measurement accuracy | | V _{OUT(acc)} | -3 | | +3 | % |
| Temp measurement range | Linear | Temp _(rng) | 0 | | 120 | °C |
| Temp measurement accuracy ⁴ | | Temp _(acc) | -5 | | +5 | °C |
| I _{IN} measurement range | Linear | I _{IN(rng)} | 0 | | 40 | A _{AC} |
| I _{IN} measurement accuracy | | I _{IN(acc)} | -5 | | +5 | % |
| V _{IN} measurement range | Linear | V _{IN(rng)} | 0 | | 264 | V _{AC} |
| V _{IN} measurement accuracy | | V _{IN(acc)} | -3 | | +3 | % |
| P _{IN} measurement range | Linear | P _{IN(rng)} | 0 | | 3000 | W |
| P _{IN} measurement accuracy | | P _{IN(acc)} | -5 | | +5 | % |
| Fan Speed measurement range | Linear | | 0 | | 30k | RPM |
| Fan Speed measurement accuracy | | | -5 | | 5 | % |
| Fan speed control range | -direct- | | 0 | | 100 | % |

⁴ Temperature accuracy reduces non-linearly with decreasing temperature

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Environmental Specifications

| Parameter | Min | Typ | Max | Units | Notes |
|----------------------------------|------------------|--------|-----------|------------------------|--|
| Ambient Temperature | -10 ⁵ | | 70 | °C | Derated above 50°C |
| Storage Temperature | -40 | | 85 | °C | |
| Operating Altitude | | | 2250/7382 | m/ft | |
| Non-operating Altitude | | | 8200/30k | m / ft | |
| Power Derating with Temperature | | | 2.5 | %/°C | 50°C to 70°C |
| Power Derating with Altitude | | | 2.0 | °C/301 m °C/1000 ft | Above 2250 m/7382 ft |
| Acoustic noise | | | 55 | dba | Full load |
| Over Temperature Protection | | 110/95 | | °C | Shutdown / restart |
| Humidity Operating Storage | 30 10 | | 95 95 | % | Relative humidity, non-condensing |
| Shock and Vibration acceleration | | | 6 | Grms | NEBS GR-63-CORE, Level 3, 20 - 2000Hz, min 30 minutes |
| Earthquake Rating | 4 | | | Zone | NEBS GR-63-CORE, all floors, Seismic Zone 4 Designed and tested to meet NEBS specifications. |

EMC Compliance

| Parameter | Criteria | Standard | Level | Test |
|--------------------|---------------------|---|----------------------------------|-----------------------------|
| AC input | Conducted emissions | EN55022, FCC Docket 20780 part 15, subpart J EN61000-3-2 | A | 0.15 – 30MHz 0 – 2 KHz |
| | Radiated emissions | EN55022 | A | 30 – 10000MHz |
| AC input immunity | Voltage dips | EN61000-4-11 | A | -30%, 10ms |
| | | | B | -60%, 100ms |
| | | | B | -100%, 5sec |
| | Voltage surge | EN61000-4-5 | A | 4kV, 1.2/50µs, common mode |
| Fast transients | EN61000-4-4 | A | 2kV, 1.2/50µs, differential mode | |
| | | B | 5/50ns, 2kV (common mode) | |
| Enclosure immunity | Conducted RF fields | EN61000-4-6 | A | 130dBµV, 0.15-80MHz, 80% AM |
| | Radiated RF fields | EN61000-4-3 | A | 10V/m, 80-1000MHz, 80% AM |
| | | ENV 50140 | A | |
| | ESD | EN61000-4-2 | B | 4kV contact, 8kV air |

⁵ Designed to start at an ambient down to -40°C; meet spec after ≈ 30 min warm up period, may not meet operational limits below -10°C.

Control and Status

Control hierarchy: Some features, such as output voltage, can be controlled both through hardware and firmware. For example, the output voltage is controlled both by the signal pin (Vprog) and the PMBus command, (Vout_command).

Using output voltage as an example; the Vprog signal pin has ultimate control of the output voltage until the Vprog is either > 3Vdc or a no connect. When the programming signal via Vprog is either a no connect or > 3Vdc, it is ignored, the output voltage is set at its nominal 12Vdc and the unit output voltage can be controlled via the PMBus command, (Vout_command).

Analog controls: Details of analog controls are provided in this data sheet under Signal Definitions.

Common ground: All signals and outputs are referenced to Output return. These include 'Vstb return' and 'Signal return'.

Control Signals

Voltage programming (V_{prog}): An analog voltage on this signal can vary the output voltage ± 10% from 43.2Vdc to 52.8Vdc. The equation of this signal is:

$$V_{out} = 43.2 + 3.3 (V_{prog} - 0.09) \quad 0.09 < V_{prog} < 3$$

If Vprog is > 3V or left open the programming signal is ignored and the unit output is set at the setpoint of 48Vdc.

Load share (Ishare): This is a single wire analog signal that is generated and acted upon automatically by power supplies connected in parallel. The Ishare pins should be tied together for power supplies if active current share among the power supplies is desired. No resistors or capacitors should get connected to this pin.

Remote_ON/OFF: Controls presence of the 12Vdc output voltage. This is an open collector, TTL level control signal that needs to be pulled HI externally through a resistor.

A turn OFF command either through this signal (Remote ON/OFF) or firmware commanded would turn OFF the 12V output.

Enable: This is a short signal pin that controls the presence of the 12Vdc main output. This pin should be connected to 'output return' on the system side of the output connector. The purpose of this pin is to ensure that the output turns ON after engagement of the power blades and turns OFF prior to disengagement of the power blades.

Write protect (WP): This signal protects the contents of the EEPROM from accidental over writing. When left open the EEPROM is write protected. A LO (TTL compatible) permits writing to the EEPROM. This signal is pulled HI internally by the power supply.

Status signals

Output current monitor (I_{mon}): A voltage level proportional to the delivered output current is present on this pin. The signal level is 0.1V per amp ± 0.25V.

AC OK: A TTL compatible status signal representing whether the input voltage is within the anticipated range. This signal is internally pulled HI to 3.3V via a 10kΩ resistor. A (HI) on this signal indicates that the input voltage is applied within the specified input range.

DC OK: A TTL compatible status signal representing whether the output voltage is present. This signal is internally pulled HI to 3.3V via a 10kΩ resistor. A (HI) on this signal indicates that the output voltage is present.

Over temp warning: A TTL compatible status signal representing whether an over temperature exists. This signal needs to be pulled HI externally through a resistor. Open collector (HI) on this signal indicates that temperatures are normal.

If an over temperature should occur, this signal would pull LO for approximately 10 seconds prior to shutting down the power supply. The unit would restart if internal temperatures recover within normal operational levels. At that time the signal reverts back to its open collector (HI) state.

Fault: A TTL compatible status signal representing whether a Fault occurred. This signal needs to be pulled HI externally through a resistor. Open collector (HI) on this signal indicates that no Fault is present.

This signal activates for OTP, OVP, OCP, AC fault or No output.

PS Present: This pin is connected to 'output return' within the power supply. Its intent is to indicate to the system that a power supply is present. This signal may need to be pulled HI externally through a resistor.

Interrupt (SMBAlert#): A TTL compatible status signal, representing the SMBAlert# feature of the PMBus compatible I²C protocol in the power supply. This signal needs to be pulled HI externally through a resistor.

Serial Bus Communications

The I²C interface facilitates the monitoring and control of various operating parameters within the unit and transmits these on demand over an industry standard I²C Serial bus.

All signals are referenced to 'Signal Return'.

Device addressing: The microcontroller (MCU) and the EEPROM have the following addresses:

| Device | Address | Address Bit Assignments (Most to Least Significant) | | | | | | | |
|-----------|---------|---|---|---|---|----|----|----|-----|
| MCU | 0xBx | 1 | 0 | 1 | 1 | A2 | A1 | A0 | R/W |
| Broadcast | 0x00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| EEPROM | 0xAx | 1 | 0 | 1 | 0 | A2 | A1 | A0 | R/W |

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The **Global Broadcast** instruction executes a simultaneous **write** instruction to all power supplies. A **read** instruction cannot be accessed globally. The three programmable address bits are the same for all I²C accessible devices within the power supply.

Address lines (A2, A1, A0): These signal pins allow up to eight (8) modules to be addressed on a single I²C bus. The pins are pulled HI internal to the power supply. For a logic LO these pins should be connected to 'Output Return'

Serial Clock (SCL): The clock pulses on this line are generated by the host that initiates communications across the I²C Serial bus. This signal is pulled up internally to 3.3V by a 10kΩ resistor. The end user should add additional pull up resistance as necessary to ensure that rise and fall time timing and the maximum sink current is in compliance to the I²C specifications.

Serial Data (SDA): This line is a bi-directional data line. This signal is pulled up internally to 3.3V by a 10kΩ resistor. The end user should add additional pull up resistance as necessary to ensure that rise and fall time timing and the maximum sink current is in compliance to the I²C specifications.

Digital Feature Descriptions

PMBus™ compliance: The power supply is fully compliant to the Power Management Bus (PMBus™) rev1.2 requirements. Manufacturer specific commands located between addresses 0xD0 to 0xEF provide instructions that either do not exist in the general PMBus specification or make the communication interface simpler and more efficient.

Master/Slave: The 'host controller' is always the MASTER. Power supplies are always SLAVES. SLAVES cannot initiate communications or toggle the Clock. SLAVES also must respond expeditiously at the command of the MASTER as required by the clock pulses generated by the MASTER.

Clock stretching: The 'slave' μController inside the power supply may initiate clock stretching if it is busy and it desires to delay the initiation of any further communications. During the clock stretch the 'slave' may keep the clock LO until it is ready to receive further instructions from the host controller. The maximum clock stretch interval is 25ms.

The host controller needs to recognize this clock stretching, and refrain from issuing the next clock signal, until the clock line is released, or it needs to delay the next clock pulse beyond the clock stretch interval of the power supply.

Note that clock stretching can only be performed after completion of transmission of the 9th ACK bit, the exception being the START command.

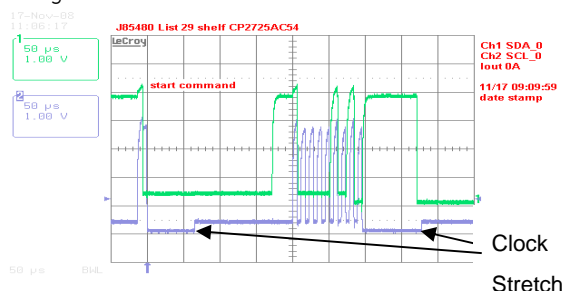


Figure 1. Example waveforms showing clock stretching.

I²C Bus Lock-Up detection: The device will abort any transaction and drop off the bus if it detects the bus being held low for more than 35ms.

Communications speed: Both 100kHz and 400kHz clock rates are supported. The power supplies default to the 100kHz clock rate. The minimum clock speed specified by SMBus is 10 kHz.

Packet Error Checking (PEC): Although the power supply will respond to commands with or without the trailing PEC, it is highly recommended that PEC be used in all communications. The integrity of communications is compromised if packet error correction is not employed. There are many functional features, including turning OFF the main output, that should require validation to ensure that the correct command is executed.

PEC is a CRC-8 error-checking byte, based on the polynomial $C(x) = x^8 + x^2 + x + 1$, in compliance with PMBus™ requirements. The calculation is based in all message bytes, including the originating write address and command bytes preceding read instructions. The PEC is appended to the message by the device that supplied the last byte.

SMBAlert#: The μC driven SMBAlert# signal informs the 'master/host' controller that either a STATE or ALARM change has occurred. Normally this signal is HI. The signal will change to its LO level if the power supply has changed states and the signal will be latched LO until the power supply either receives a 'clear' instruction as outlined below or executes a READ STATUS_WORD. If the alarm state is still present after the STATUS registers were reset, then the signal will revert back into its LO state again and will latch until a subsequent reset signal is received from the host controller.

The signal will be triggered for any state change, including the following conditions;

- VIN under or over voltage
- Vout under or over voltage
- IOU over current
- Over Temperature warning or fault
- Fan Failure
- Communication error
- PEC error
- Invalid command
- Detected internal faults

The power supply will clear the SMBAlert# signal (release the signal to its HI state) upon the following events:

- Receiving a CLEAR_FAULTS command
- The main output recycled (turned OFF and then ON) via the ENABLE signal pin
- The main output recycled (turned OFF and then ON) by the OPERATION command
- Execution of a READ of the STATUS_WORD register

Global broadcast: This is a powerful command because it can instruct all power supplies to respond simultaneously in one command. But it does have a serious disadvantage. Only a single power supply needs to pull down the ninth *acknowledge* bit. To be certain that each power supply responded to the global instruction, a READ instruction should

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be executed to each power supply to verify that the command properly executed. The GLOBAL BROADCAST command should only be executed for write instructions to slave devices.

Read back delay: The power supply issues the SMBAlert # notification as soon as the first state change occurred. During an event a number of different states can be transitioned to before the final event occurs. If a read back is implemented rapidly by the host a successive SMBAlert# could be triggered by the transitioning state of the power supply. In order to avoid successive SMBAlert# s and read back and also to avoid reading a transitioning state, it is prudent to wait more than 2 seconds after the receipt of an SMBAlert# before executing a read back. This delay will ensure that only the final state of the power supply is captured.

Successive read backs: Successive read backs to the power supply should not be attempted at intervals faster than every one second. This time interval is sufficient for the internal processors to update their data base so that successive reads provide fresh data.

PMBus™ Commands

Standard instruction: Up to two bytes of data may follow an instruction depending on the required data content. Analog data is always transmitted as LSB followed by MSB. PEC is optional and includes the address and data fields.

| | | | | |
|---|---------------|----|--------------|---|
| 1 | 8 | 1 | 8 | 1 |
| S | Slave address | Wr | Command Code | A |

| | | | | | | |
|---------------|---|----------------|---|-----|---|---|
| 8 | 1 | 8 | 1 | 8 | 1 | 1 |
| Low data byte | A | High data byte | A | PEC | A | P |

Master to Slave Slave to Master
 SMBUS annotations; S – Start, Wr – Write, Sr – re-Start, Rd – Read, A – Acknowledge, NA – not-acknowledged, P – Stop

Standard READ: Up to two bytes of data may follow a READ request depending on the required data content. Analog data is always transmitted as LSB followed by MSB. PEC is mandatory and includes the address and data fields. PEC is optional and includes the address and data fields.

| | | | | | |
|---|---------------|----|---|--------------|---|
| 1 | 7 | 1 | 1 | 8 | 1 |
| S | Slave address | Wr | A | Command Code | A |

| | | | | | |
|----|---------------|----|---|-----|---|
| 1 | 7 | 1 | 1 | 8 | 1 |
| Sr | Slave Address | Rd | A | LSB | A |

| | | | | |
|-----|---|-----|--------|---|
| 8 | 1 | 8 | 1 | 1 |
| MSB | A | PEC | No-ack | P |

Block communications: When writing or reading more than two bytes of data at a time BLOCK instructions for WRITE and READ commands must be used instead of the Standard Instructions **Error! Reference source not found.** write any number of bytes greater than two.

Block write format:

| | | | | | |
|---|---------------|----|---|--------------|---|
| 1 | 7 | 1 | 1 | 8 | 1 |
| S | Slave address | Wr | A | Command Code | A |

| | | | | | |
|---|---|---|---|---|---|
| 8 | 1 | 8 | 1 | 8 | 1 |
|---|---|---|---|---|---|

| | | | | | |
|----------------|---|--------|---|--------|---|
| Byte count = N | A | Data 1 | A | Data 2 | A |
|----------------|---|--------|---|--------|---|

| | | | | | | |
|-------|---|---------|---|-----|---|---|
| 8 | 1 | 8 | 1 | 8 | 1 | 1 |
| | A | Data 48 | A | PEC | A | P |

CAR2548FP series rectifier

Input: 90Vac to 264Vac; Output: 48Vdc @ 2500W; 3.3Vdc or 5 Vdc @ 1A

Block read format:

| | | | | | |
|---|---------------|----|---|--------------|---|
| 1 | 7 | 1 | 1 | 8 | 1 |
| S | Slave address | Wr | A | Command Code | A |

| | | | |
|----|---------------|----|---|
| 1 | 7 | 1 | 1 |
| Sr | Slave Address | Rd | A |

| | | | | | |
|----------------|---|--------|---|--------|---|
| 8 | 1 | 8 | 1 | 8 | 1 |
| Byte count = N | A | Data 1 | A | Data 2 | A |

| | | | | | | |
|-------|---|---------|---|-----|-------|---|
| 8 | 1 | 8 | 1 | 8 | 1 | 1 |
| | A | Data 48 | A | PEC | NoAck | P |

Linear Data Format The definition is identical to Part II of the PMBus Specification. All standard PMBus values, with the exception of output voltage related functions, are represented by the linear format described below. Output voltage functions are represented by a 16 bit mantissa. Output voltage has a E=9 constant exponent.

The Linear Data Format is a two byte value with an 11-bit, two's complement mantissa and a 5-bit, two's complement exponent or scaling factor, its format is shown below.

| Data Byte High | | | | | Data Byte Low | | | | | | | | | | | |
|----------------|--------------|---|---|---|---------------|--------------|---|---|---|---|---|---|---|---|---|---|
| Bit | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| | Exponent (E) | | | | | Mantissa (M) | | | | | | | | | | |

The relationship between the Mantissa, Exponent, and Actual Value (V) is given by the following equation:

$$V = M * 2^E$$

Where: V is the value, M is the 11-bit, two's complement mantissa, E is the 5-bit, two's complement exponent

PMBus™ Command set:

| Command | Hex Code | Data Byte | Function |
|------------------------|----------|-----------|-----------------------|
| Operation | 01 | 1 | Output ON/OFF |
| ON_OFF_config | 02 | 1 | 09, output ON default |
| Clear_faults | 03 | 0 | Clear Status |
| Write_protect | 10 | 1 | Write control |
| Store_default_all | 11 | 0 | Store permanently |
| Restore_default_all | 12 | 0 | Reset defaults |
| Capability | 19 | 1 | 30h, 400kHz, SMBAlert |
| Vout_mode | 20 | 1 | Vout constants |
| Vout_command | 21 | 2 | Set Vout |
| Fan_command_1 | 3B | 2 | Set fan speed in RPM |
| Vout_OV_fault_limit | 40 | 2 | Set OV fault limit |
| Vout_OV_fault_response | 41 | 1 | |
| Vout_OV_warn_limit | 42 | 2 | Set OV warn limit |
| Vout_UV_warn_limit | 43 | 2 | Set UV warn limit |
| Vout_UV_fault_limit | 44 | 2 | |
| Vout_UV_fault_response | 45 | 1 | |
| Iout_OC_fault_limit | 46 | 2 | |
| Iout_OC_fault_response | 47 | 1 | Latch or hiccup |
| Iout_OC_warn_limit | 4A | 2 | Set OC warn limit |
| OT_fault_limit | 4F | 2 | |
| OT_fault_response | 50 | 1 | Latch or hiccup |
| OT_warn_limit | 51 | 2 | Set OT warn limit |
| UT_warn_limit | 52 | 2 | |

| Command | Hex Code | Data Field | Function |
|---------------------|----------|------------|------------------------|
| UT_fault_limit | 53 | 2 | |
| UT_fault_response | 54 | 1 | |
| Vin_OV_fault_limit | 55 | 2 | |
| Vin_OV_warn_limit | 57 | 2 | Set OV warn limit |
| Vin_UV_warn_limit | 58 | 2 | Set UV warn limit |
| Vin_UV_fault_limit | 59 | 2 | Set UV shutdown |
| Status_byte | 78 | 1 | |
| Status_word | 79 | 2 | |
| Status_Vout | 7A | 1 | |
| Status_Iout | 7B | 1 | |
| Status_input | 7C | 1 | |
| Status_temperature | 7D | 1 | |
| Status_CML | 7E | 1 | |
| Status_other | 7F | 1 | |
| Status_mfr_specific | 80 | 1 | |
| Read_Vout | 8B | 2 | Read output voltage |
| Read_Iout | 8C | 2 | Read output current |
| Read_temperature | 8D | 2 | Read Temperature |
| Read_Pout | 96 | 2 | |
| PMBus revision | 98 | 1 | |
| Mfr_ID | 99 | 5 | FRU_ID |
| Mfr_model | 9A | 15 | |
| Mfr_revision | 9B | 4 | |
| Mfr_location | 9C | 4 | |
| Mfr_date | 9D | 6 | |
| Mfr_serial | 9E | 15 | |
| Mfr_Vin_min | A0 | 2 | |
| Mfr_Vin_max | A1 | 2 | |
| Mfr_Iin_max | A2 | 2 | |
| Mfr_Pin_max | A3 | 2 | |
| Mfr_Vout_min | A4 | 2 | |
| Mfr_Vout_max | A5 | 2 | |
| Mfr_Iout_max | A6 | 2 | |
| Mfr_Pout_max | A7 | 2 | |
| Mfr_Tambient_max | A8 | 2 | |
| Mfr_Tambient_min | A9 | 2 | |
| User_data_00 | B0 | 48 | User memory space |
| User_data_01 | B1 | 48 | User memory space |
| FRW_revision | D0 | 1 | |
| Ilimit_control_I²C | D3 | 2 | Ilimit set (1/100A) |
| Vout_control_I²C | D4 | 2 | Vout set (1/512V) |
| Fan_duty_cycle | D6 | 1 | Duty_cycle in % |
| Fan_speed | D7 | 1 | Control in duty cycle |
| Vprog_ext | D8 | 2 | |
| Read_Vout_I²C | E0 | 2 | 1/512V |
| Read_Iout_I²C | E1 | 2 | 1/100A |
| Read_TS_I²C | E2 | 2 | Heat sink temp °C |
| CMD_OFF_I²C | E3 | 2 | 01-OFF, 00-ON |
| OTF_limit_I²C | E4 | 2 | OT fault limit °C |
| OTF_recovery_I²C | E5 | 2 | OT fault recovery °C |
| DCOKHI_I²C | E6 | 2 | High OV fault (1/512V) |
| DCOKLO_I²C | E7 | 2 | Low OV fault (1/512V) |

CAR2548FP series rectifier

Input: 90Vac to 264Vac; Output: 48Vdc @ 2500W; 3.3Vdc or 5 Vdc @ 1A

Status Register Bit Allocation:

| Register | Code | Bit | Function |
|---------------------------------------|------|-----|---------------------------------------|
| Status_Byte | 78 | 7 | Busy |
| | | 6 | DC_OFF |
| | | 5 | Output OV Fault detected |
| | | 4 | Output OC Fault detected |
| | | 3 | Input UV Fault detected |
| | | 2 | Temperature Fault/warning detected |
| | | 1 | CML (communication fault) detected |
| | | 0 | None of Below |
| Status_word (includes Status_byte) | 79 | 7 | OV Fault/Warning detected |
| | | 6 | OC Fault/Warning detected |
| | | 5 | Input Fault/Warning detected |
| | | 4 | Mfr_specific register change detected |
| | | 3 | DC_OFF |
| | | 2 | Fan Fault or Warning detected |
| | | 1 | Other fault |
| | | 0 | Unknown |
| Status_Vout | 7A | 7 | Vout UV Fault |
| | | 6 | Vout UV Warning |
| | | 5 | Vout OV Warning |
| | | 4 | Vout OV Fault |
| | | 3 | N/A |
| | | 2 | N/A |
| | | 1 | N/A |
| | | 0 | N/A |
| Status_Iout | 7B | 7 | IOUT OC Fault |
| | | 6 | N/A |
| | | 5 | IOUT OC Warning |
| | | 4 | N/A |
| | | 3 | N/A |
| | | 2 | N/A |
| | | 1 | N/A |
| | | 0 | N/A |
| Status_input | 7C | 7 | Vin OV Fault |
| | | 6 | Vin OV Warning |
| | | 5 | Vin UV Warning |
| | | 4 | Vin UV Fault |
| | | 3 | N/A |
| | | 2 | N/A |
| | | 1 | N/A |
| | | 0 | N/A |
| Status_temperature | 7D | 7 | OT Fault |
| | | 6 | OT Warning |
| | | 5 | N/A |
| | | 4 | N/A |
| | | 3 | N/A |
| | | 2 | N/A |
| | | 1 | N/A |
| | | 0 | N/A |

| Register | Code | Bit | Function |
|---------------------|------|-----|-------------------------------|
| Status_cml | 7E | 7 | Invalid/Unsupported Command |
| | | 6 | Invalid/Unsupported Data |
| | | 5 | Packet Error Check Failed |
| | | 4 | Memory Fault Detected |
| | | 3 | Processor Fault Detected |
| | | 2 | Reserved |
| | | 1 | Other Communications Fault |
| | | 0 | Other Memory or Logic Fault |
| Status_mfr_specific | 80 | 7 | 3.3V_fault |
| | | 6 | N/A |
| | | 5 | Interrupt |
| | | 4 | Fault detected |
| | | 3 | PS_remote_OFF |
| | | 2 | DC_fault |
| | | 1 | INPUT_fault |
| | | 0 | AC: 0 -high line, 1 -low line |

Command Descriptions

Operation (01) : By default the Power supply is turned **ON** at power up as long as *Power ON/OFF* signal pin is active HI. The Operation command is used to turn the Power Supply ON or OFF via the PMBus. The data byte below follows the OPERATION command.

| FUNCTION | DATA BYTE |
|----------|-----------|
| Unit ON | 80 |
| Unit OFF | 00 |

To **RESET** the power supply cycle the power supply OFF, wait at least 2 seconds, and then turn back ON. All alarms and shutdowns are cleared during a restart.

Clear_faults (03): This command clears all STATUS and FAULT registers and resets the SMBAlert# line.

If a fault still persists after the issuance of the clear_faults command the specific registers indicating the fault are reset and the SMBAlert# line is activated again.

WRITE_PROTECT register (10): Used to control writing to the PMBus device. The intent of this command is to provide protection against accidental changes. All supported command parameters may have their parameters read, regardless of the write_protect settings. The contents of this register can be stored to non-volatile memory using the Store_default_code command. The default setting of this register is disable_all_writes except write_protect 0x80h.

| FUNCTION | DATA BYTE |
|---|-----------|
| Enable all writes | 00 |
| Disable all writes except write_protect | 80 |
| Disable all writes except write_protect and OPERATION | 40 |

Vout_Command (21) : This command is used to change the output voltage of the power supply. Changing the output voltage should be performed simultaneously to all power supplies operating in parallel using the Global Address (Broadcast) feature. If only a single power supply is instructed to change its output, it may attempt to source all the required power which can cause either a power limit or shutdown condition.

Software programming of output voltage permanently overrides the set point voltage configured by the **Vprog** signal pin. The program no longer looks at the **Vprog** pin and will not respond to any hardware voltage settings. If power is removed from the μ Controller it will reset itself into its default configuration looking at the **Vprog** signal for output voltage control. In many applications, the **Vprog** pin is used for setting initial conditions, if different than the factory setting. Software programming then takes over once I²C communications are established.

To properly hot-plug a power supply into a live backplane, the system generated voltage should get re-configured into either the factory adjusted firmware level or the voltage level reconfigured by the margin pin. Otherwise, the voltage state of the plugged in power supply could be significantly different than the powered system.

Vout_OV_warn_limit (42): OV_warning is extremely useful because it gives the system controller a heads up that the output voltage is drifting out of regulation and the power supply is close to shutting down. Pre-emptive action may be taken before the power supply would shut down and potentially disable the system.

OC and OT_fault_response (47, 50): The default response for both OC and OT is auto_restart (hiccup). Each register, individually, can be reconfigured into a latched state. Latched and hiccup are the only supported states.

Restart after a latch off: Either of four restart possibilities are available. The hardware pin **Remote ON/OFF** may be turned OFF and then ON. The unit may be commanded to restart via i2c through the *Operation* command by first turning OFF then turning ON. The third way to restart is to remove and reinsert the unit. The fourth way is to turn OFF and then turn ON ac power to the unit. The fifth way is by changing firmware from **latch off to restart**. Each of these commands must keep the power supply in the OFF state for at least 2 seconds, with the exception of changing to **restart**.

A power system that is comprised of a number of power supplies could have difficulty restarting after a shutdown event because of the non-synchronized behavior of the individual power supplies. Implementing the latch-off mechanism permits a synchronized restart that guarantees the simultaneous restart of the entire system.

A synchronous restart can be implemented by;

1. Issuing a GLOBAL OFF and then ON command to all power supplies,
2. Toggling Off and then ON the **Remote ON/OFF** signal
3. Removing and reapplying input commercial power to the entire system.

The power supplies should be turned OFF for at least 20 – 30 seconds in order to discharge all internal bias supplies and reset the soft start circuitry of the individual power supplies.

Auto_restart: Auto-restart is the default configuration for recovering from over-current and over-temperature shutdowns.

An overvoltage shutdown is followed by three attempted restarts, each restart delayed 1 second, within a 1 minute window. If within the 1 minute window three attempted restarts failed, the unit will latch OFF. If less than 3 shutdowns occur within the 1 minute window then the count

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Input: 90Vac to 264Vac; Output: 48Vdc @ 2500W; 3.3Vdc or 5 Vdc @ 1A

for latch OFF resets and the 1 minute window starts all over again.

Vin_UV_warn_limit (58): This is another warning flag indicating that the input voltage is decreasing dangerously close to the low input voltage shutdown level.

Status_word (79): returns two bytes of information. The upper byte bit functionality is tabulated in the Status_word section. The lower byte bit functionality is identical to Status_byte.

Fan_speed (D7): This register can be used to 'read' the fan speed in adjustment percent (0 – 100%) or set the fan speed in adjustment percent (0 – 100%). The speed of the fan cannot be reduced below what the power supply requires for its operation. The register value is the percent number, it is not in linear format.

Invalid commands or data: The power supply notifies the MASTER if a non-supported command has been sent or invalid data has been received. Notification is implemented by setting the appropriate STATUS and ALARM registers and setting the SMBAlert# flag.

If a non-supported read is requested the power supply will return all 0x00h.

Restart after a lachoff: To restart after a latch_off either of four restart mechanisms are available. The hardware pin **Remote ON/OFF** may be turned OFF and then ON. The unit may be commanded to restart via i2c through the *Operation* command by first turning OFF then turning ON. The third way to restart is to remove and reinsert the unit. The fourth way is to turn OFF and then turn ON ac power to the unit. The fifth way is by changing firmware from **latch off** to **restart**. Each of these commands must keep the power supply in the OFF state for at least 2 seconds, with the exception of changing to **restart**.

A successful restart shall clear all alarm registers.

A power system that is comprised of a number of power supplies could have difficulty restarting after a shutdown event because of the non-synchronized behavior of the individual power supplies. Implementing the latch-off mechanism permits a synchronized restart that guarantees the simultaneous restart of the entire system.

A synchronous restart can be implemented by;

1. Issuing a GLOBAL OFF and then ON command to all power supplies,
2. Toggling Off and then ON the **Remote ON/OFF** signal
3. Removing and reapplying input commercial power to the entire system.

It is good practice to turn OFF the power supplies for about 20 – 30 seconds in order to discharge all internal bias supplies and reset the soft start circuitry of the individual power supplies.

Control and Read accuracy:

The estimates below are believed to be reasonable under most operating conditions. However, these are typical numbers and not hard bound values that cannot be exceeded. In most nominal operating conditions the returned values are significantly better than these estimates.

| FUNCTION | ACCURACY |
|---------------------|------------|
| Vout_command | ± 2% |
| Vout_OV_fault_limit | ± 3% |
| Iout_OC_warn_limit | ± 4% of FL |
| OT_warn_limit | ± 5°C |
| Vin_UV_warn_limit | ± 3% |
| Vin_UV_fault_limit | ± 3% |
| Read_Vout | ± 2% |
| Read_Iout | ± 4% of FL |
| Read_temperature | ± 5°C |
| Read_Pout | ±5% |

EEPROM

The microcontroller has 96 bytes of EEPROM memory available for the system host.

Another separate EEPROM IC will provide another 128 bytes of memory with write protect feature. Minimum information to be included in this separate EEPROM: model number, revision, date code, serial number etc.

LEDs

Three LEDs are located on the front faceplate. The AC_OK LED provides visual indication of the INPUT signal function. When the LED is ON GREEN the power supply input is within normal design limits.

When the DC_OK LED is GREEN the DC output is present.

When the FAULT_LED is RED then a fault condition exists and the power supply may not provide output power. The table below further defines these states:

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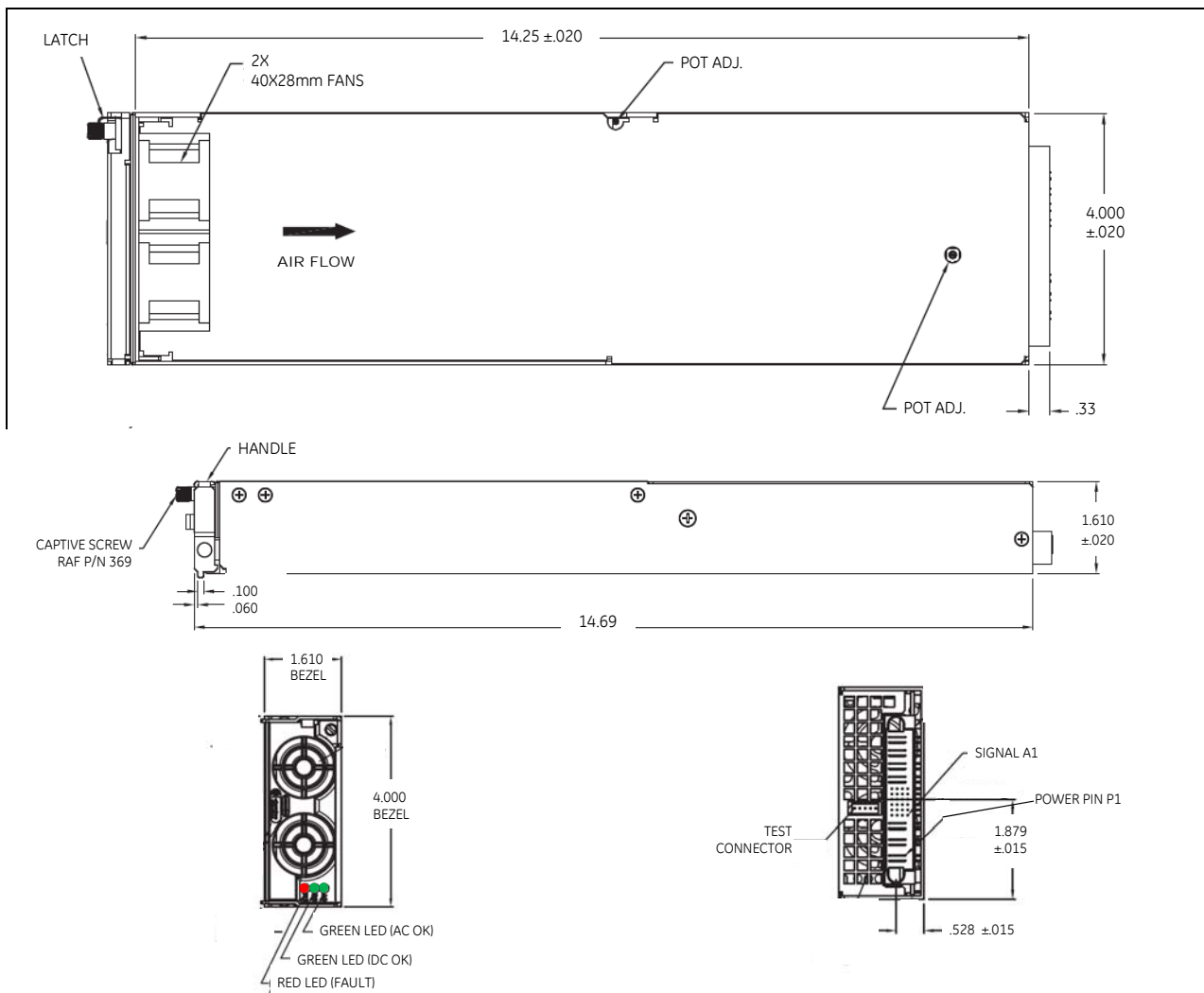
Input: 90Vac to 264Vac; Output: 48Vdc @ 2500W; 3.3Vdc or 5 Vdc @ 1A

Alarm Table

| Test Condition | | LED Indicator | | | Monitoring Signals | | | |
|----------------|------------------|---------------|-------|-------|--------------------|-------|-------|---------|
| | | AC OK | DC OK | FAULT | FAULT | DC OK | AC OK | TEMP OK |
| 1 | Normal Operation | Green | Green | OFF | High | High | High | High |
| 2 | Low or NO INPUT | OFF | OFF | Red | Low | Low | Low | High |
| 3 | OVP | Green | OFF | Red | Low | Low | High | High |
| 4 | Over Current | Green | OFF | Red | Low | Low | High | High |
| 5 | Over Temp Fault | Green | OFF | Red | Low | Low | High | Low |

Note: Test condition #2 has 2 modules working in parallel. One module is running and the other has no AC.

Outline Drawing

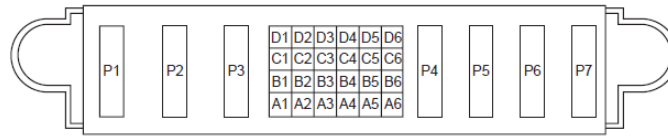


CAR2548FP series rectifier

Input: 90Vac to 264Vac; Output: 48Vdc @ 2500W; 3.3Vdc or 5 Vdc @ 1A

Connector Pin Assignments

Mating Connector: FCI Berg P/N: 51939-030LF or Molex 87663-9002
 Mating connector: 51915-051LF or Molex 87664-2004



| Pin | Function | Pin | Function | Pin | Function | Pin | Function |
|-----|--------------------|-----|----------------------------|-----|-------------------------------|-----|----------------|
| A1 | Vstb [3.3V] | B1 | Fault | C1 | ISHARE | D1 | VProg |
| A2 | Vstb [3.3V] Return | B2 | I Monitor (IMON) | C2 | N/C | D2 | OVP Test Point |
| A3 | Signal Return | B3 | PS Present | C3 | Over Temp Warning | D3 | Remote ON/OFF |
| A4 | Write Protect (WP) | B4 | Enable: "0" -ON "1" -OFF | C4 | I ² C Address (A0) | D4 | DC OK |
| A5 | Remote Sense (+) | B5 | SDA (I ² C bus) | C5 | I ² C Address (A1) | D5 | AC OK |
| A6 | Remote Sense (-) | B6 | SCL (I ² C bus) | C6 | I ² C Address (A2) | D6 | Interrupt |
| | | | | | | | |
| P1 | Line | P2 | Neutral | P3 | Chassis | | |
| P4 | +Vout | P5 | +Vout | P6 | Output Return | P7 | Output Return |



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CAR2548FP series rectifier

Input: 90Vac to 264Vac; Output: 48Vdc @ 2500W; 3.3Vdc or 5 Vdc @ 1A

Ordering Information

Please contact your GE Sales Representative for pricing, availability and optional features.

| PRODUCT | DESCRIPTION | PART NUMBER |
|-----------------|---|----------------|
| 2500W Front-End | +48Vout Front-End, 3.3Vaux, low line power capacity 1000W | CAR2548FP-Z01A |
| 10Kw Shelf | Shelf for CAR2548FP - hold 4 modules | ACE254RUW-1A |

PART NUMBER DEFINITION GUIDE EXAMPLE

