



## BMR350

### 860-1200 W digital quarter brick DC/DC IBC

The BMR350 is the next generation of high-power digital DC/DC converter. The impressive performance of this converter includes an efficiency of 97.8% at 54V<sub>in</sub> and half load.

The BMR350 is a non-isolated quarter brick, and has a low building height of only 12 mm. The converter delivers a fully regulated 12 V. The BMR350 delivers a continuous power level of 860 W and has a peak power capability of up to 1200 W for less than 1 second.

This converter is designed for through-hole mounting using wave solder or pin-in-paste production, and incorporates a novel design of baseplate, which optimizes thermal performance while minimizing height.



### Key features

- High efficiency with 97.8%
- Non-isolated
- 12 V fully regulated
- Event data recorder (black-box)
- Active current sharing
- Screwed baseplate
- Monotonic start-up
- Output over voltage protection
- Over temperature protection
- Output short-circuit protection
- Remote control
- PMBus configuration

### Soldering methods

- Reflow soldering Pin-in-paste
- Wave soldering
- Manual soldering

### Key electrical information

| Parameter      | Values  |
|----------------|---------|
| Input range    | 40-60 V |
| Output voltage | 12 V    |
| Output current | 100 A   |
| Output power   | 860 W   |
| Peak power     | 1200 W  |

### Mechanical

58.4 x 36.8 x 12 mm / 2.30 x 1.45 x 0.47 in

### Application areas

- Datacom applications

## Product options

The table below describes the different product options.

| Example: BMR350 2 1 00 /031   |        |   |   |    |      | H | Definitions   |
|-------------------------------|--------|---|---|----|------|---|---|
| <b>Product family</b>         | BMR350 |   |   |    |      |   |   |
| <b>Pin length options</b>     |        | 2 |   |    |      |   | 0 = 5.33 mm / 0.21 in<br>2 = 3.69 mm / 0.15 in<br>3 = 4.57 mm / 0.18 in<br>4 = 2.79 mm / 0.11 in  |
| <b>Baseplate / HS option</b>  |        |   | 1 |    |      |   | 1 = base plate  |
| <b>Other hardware options</b> |        |   |   | 00 |      |   | 00 = 7-pin digital header   |
| <b>Configuration code</b>     |        |   |   |    | /031 |   | /031=12 V <sub>out</sub> Current share config. for 40-60 V <sub>in</sub>  |
| <b>Packaging options</b>      |        |   |   |    |      | H | E = soft tray, dry pack (PIP reflow soldering)<br>H = hard tray, dry pack (PIP reflow soldering)<br>blank = foam tray (no dry pack, wave soldering) |

For more information, please refer to Part 3 [Mechanical information](#).

If you do not find the variant you are looking for, please contact us at [Flex Power Modules](#).

## Order number examples

| Part number     | V <sub>in</sub> | Outputs          | Configuration  |
|-----------------|-----------------|------------------|--|
| BMR3502100/031H | 40-60 V         | 12V / 72A/ 860 W | 3.69 mm pins / 7-pin digital header / base plate / current share / dry pack, hard tray |

## Part 1: Electrical specifications

### Absolute maximum ratings

Stress in excess of our defined *absolute maximum ratings* may cause permanent damage to the converter. Absolute maximum ratings, also referred to as *non-destructive limits*, are normally tested with one parameter at a time exceeding the limits in the electrical specification.

| Characteristics                          | min  | typ | max  | Unit |
|--|------|-----|------|------|
| Operating temperature (T <sub>P1</sub> ) | -40  |     | +125 | °C   |
| Storage temperature                      | -55  |     | +125 | °C   |
| Input voltage (V <sub>in</sub> )         | -0.5 |     | +65  | V    |
| Input voltage transient (100 ms)         |      |     | +80  | V    |
| Isolation voltage (input to output)      |      |     | 0    | V    |
| Isolation voltage (baseplate to output)  |      |     | 0    | V    |
| Remote control pin voltage               | -0.3 |     | 5    | V    |

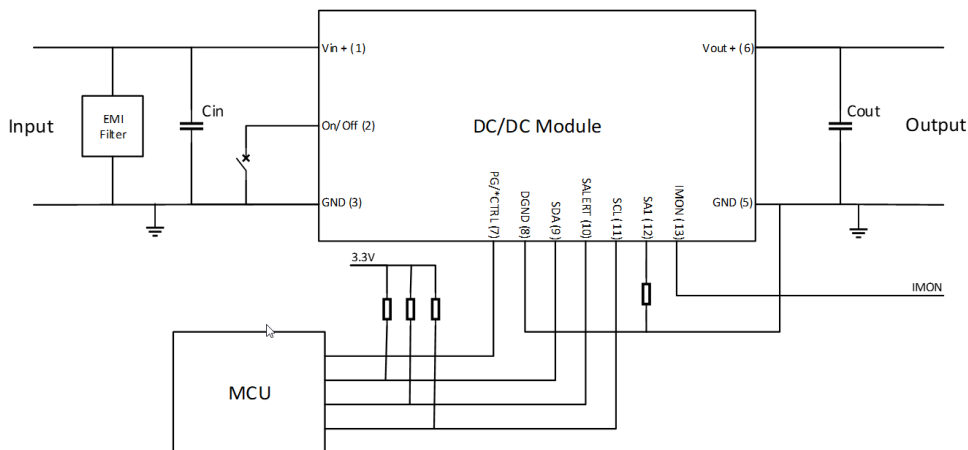
### Reliability

Failure rate ( $\lambda$ ) and mean time between failures (MTBF= 1/  $\lambda$ ) are calculated based on *Telcordia SR-332 Issue 4: Method 1, Case 3, (80% of I<sub>out\_TDP</sub>, T<sub>P1</sub>=40°C, Airflow=200 LFM)*.

|   | Mean | 90% confidence level | Unit        |
|---|------|----------------------|-------------|
| Steady-state failure rate ( $\lambda$ ) | 132  | 161                  | nfailures/h |
| Standard deviation ( $\sigma$ )         | 22,4 |                      | nfailures/h |
| MTBF                                    | 7,57 | 6,22                 | MHr         |

### Typical application diagram

Capacitor values are defined in the Electrical Specification tables. The EMI filter is defined in the [EMC Part 2](#).



## Part 1: Electrical specifications

**Electrical specifications for BMR350X100/031****12.24V, 72A (100A) ≤ 860W (1200W)**

Min and Max values are valid for:  $T_{P1} = -30$  to  $+90^{\circ}\text{C}$ ,  $V_{in} = 40\text{V}$  to  $60\text{V}$ , unless otherwise specified under conditions. Typical values given at:  $T_{P1} = +25^{\circ}\text{C}$ ,  $V_{in} = 54\text{V}$ , max  $P_{out\_TDP}$ , unless otherwise specified under conditions, see Note 1.

Additional external  $C_{in} = 470\ \mu\text{F}$ ,  $C_{out} = 1\ \text{mF}$

| Characteristic                                   | conditions  | minimum | typical | maximum | unit          |
|--|---|---------|---------|---------|---------------|
| <b>Key features</b>                              |   |         |         |         |               |
| Efficiency ( $\eta$ )                            | 50% of $P_{out\_TDP}$                             |         | 97.8    |         | %             |
|  | 100% of $P_{out\_TDP}$                            |         | 97.6    |         | %             |
|  | 50% of $P_{out\_TDP}$<br>$V_{in} = 48\ \text{V}$  |         | 98.1    |         | %             |
|  | 100% of $P_{out\_TDP}$<br>$V_{in} = 48\ \text{V}$ |         | 97.8    |         | %             |
| $P_{out\_TDP}$ thermal design power (TDP)        | See Note 1  |         |         | 860     | W             |
| $P_{out\_MAX}$ peak power ( $t \leq 1\text{s}$ ) | See Note 1  |         |         | 1200    | W             |
| Power dissipation                                | 100% of $P_{out\_TDP}$                            |         | 21.5    | 29      | W             |
| Switching frequency ( $f_s$ )                    | 0-100 % of $P_{out\_TDP}$                         |         | 150     |         | kHz           |
| Recommend capacitive load                        |   | 1000    |         | 20000   | $\mu\text{F}$ |
| <b>Input characteristics</b>                     |   |         |         |         |               |
| Input voltage range ( $V_{in}$ )                 |   | 40      |         | 60      | V             |
| Input idling power                               | $P_{out} = 0\ \text{W}$                           |         | 5.3     |         | W             |
| Input standby power                              | (turned off with RC)                              |         | 650     |         | mW            |
| Input OVP  |   |         | 85      |         | V             |
| Internal input capacitance                       |   |         | 90      |         | $\mu\text{F}$ |
| Recommended external input capacitance           |   | 220     |         |         | $\mu\text{F}$ |

Note 1: Max. output current is rated at 100 A. Max power is  $\leq 1200\ \text{W}$  and continuous power (thermal design power (TDP)) is  $\leq 860\ \text{W}$  depending on thermal conditions.

## Part 1: Electrical specifications

**Electrical specifications for BMR350X100/031****12.24V, 72A (100A) ≤ 860W (1200W)**

Min and Max values are valid for:  $T_{P1} = -30$  to  $+90^{\circ}\text{C}$ ,  $V_{in} = 40\text{V}$  to  $60\text{V}$ , unless otherwise specified under conditions. Typical values given at:  $T_{P1} = +25^{\circ}\text{C}$ ,  $V_{in} = 54\text{V}$ , max  $P_{out\_TDP}$ , unless otherwise specified under conditions, see Note 1.

Additional external  $C_{in} = 470\ \mu\text{F}$ ,  $C_{out} = 1\ \text{mF}$

| Characteristic                              | conditions   | minimum | typical   | maximum   | unit              |
|---|--|---------|-----------|-----------|-------------------|
| <b>Output characteristics</b>               |  |         |           |           |                   |
| Output voltage initial setting and accuracy | $P_{out} = 0\ \text{W}$  | 12.18   | 12.24     | 12.3      | V                 |
| Output voltage tolerance band               | 0 – 100% of max $P_{out\_TDP}$<br>$V_{in} = 40\text{-}60\ \text{V}$                            | 11.7    |           | 12.4      | V                 |
| Output adjust range                         | 0-100% of max $P_{out\_TDP}$   | 8       |           | 13.2      | V                 |
| Idling voltage                              | $P_{out} = 0\ \text{W}$ , 48 V   | 12.1    |           | 12.4      | V                 |
| Line regulation                             | $V_{in} = 40 - 60\ \text{V}$<br>0 – 100% of max $P_{out\_TDP}$                                 |         | 3         | 12        | mV                |
| Load regulation                             | 0 - 100% of max $P_{out\_TDP}$   |         | 94        | 145       | mV                |
| Output current ( $I_{out}$ )                | $V_{in} = 40 - 60\ \text{V}$   | 0       |           | 100       | A                 |
| Load transient voltage deviation            | Load step 25-75-25% of max $P_{out\_TDP}$<br>$di/dt = 1\ \text{A}/\mu\text{s}$ .<br>See Note 2 |         | $\pm 100$ | $\pm 300$ | mV                |
| Load transient recovery time                |  |         | 50        | 100       | $\mu\text{s}$     |
| Output ripple & noise                       | max $P_{out\_TDP}$<br>See Note 3   |         | 50        | 78        | mV <sub>p-p</sub> |

Note 1: Max. output current is rated at 100 A. Max power is  $\leq 1200\ \text{W}$  and continuous power (thermal design power (TDP) is  $\leq 860\ \text{W}$  depending on thermal conditions.

Note 2:  $C_{out}$  is 2x2.2mF

Note 3: See Technical Reference doc: Design considerations

## Part 1: Electrical specifications

**Electrical specifications for BMR350X100/031****12.24V, 72A (100A) ≤ 860W (1200W)**

| Characteristic  | conditions                   | minimum | typical | maximum | unit    |
|---|------------------------------|---------|---------|---------|---------|
| <b>On/off control</b>   |                              |         |         |         |         |
| Turn-off input voltage  | Decreasing input voltage     | 34      | 35      | 36      | V       |
| Turn-on input voltage   | Increasing input voltage     | 36      | 37      | 38      | V       |
| Ramp-up time<br>(from 0–100% of $V_{out}$ )                   |                              | 7       | 10      | 13      | ms      |
| Start-up time (from $V_{in}$ connection to 90% of $V_{out}$ ) |                              |         | 40      |         | ms      |
| RC start-up time  |                              |         | 26      |         | ms      |
| Logic high: trigger level                                     |                              |         | 1.4     |         | V       |
| Logic low: trigger level                                      |                              |         | 1.3     |         | V       |
| Logic low: response time                                      |                              | 0.1     | 0.2     | 0.3     | ms      |
| Sink current  |                              | 0.4     |         |         | mA      |
| <b>Protection features</b>                                    |                              |         |         |         |         |
| Current limit threshold (OCP)                                 | $T_{P1} < \max T_{P1}$       | 102     | 110     | 125     | A       |
| Output current limit (OCP) response time and type             | hiccup                       |         | 25      |         | $\mu$ s |
| Output overvoltage protection (OVP)                           |                              |         | 15.6    |         | V       |
| Output overvoltage protection (OVP) response time and type    | Disabled until fault cleared |         | 70      |         | $\mu$ s |
| Over temperature protection (OTP)                             | See note 1                   |         | 120     |         | °C      |
| Over temperature protection (OTP) type                        | Disabled, Resume when OK     |         |         |         | ms      |

Note 1: Please attach thermocouple on NTC resistor to test OTP function, the hot spot (P1) temperature is just for reference.

**Electrical specifications for BMR350X100/031****12.24V, 72A (100A) ≤ 860W (1200W)**

In the table below all PMBus are written in capital letters.

$T_{P1} = -30$  to  $+90^{\circ}\text{C}$ ,  $V_{in} = 40\text{V}$  to  $60\text{V}$ , unless otherwise specified under conditions.

Typical values given at:  $T_{P1} = +25^{\circ}\text{C}$ ,  $V_{in} = 54\text{V}$ , max  $P_{out\_TDP}$ , unless otherwise specified under conditions

| Command                           | Conditions   | minimum | typical | maximum | Unit               |
|-----------------------------------|--|---------|---------|---------|--------------------|
| <b>Monitoring accuracy</b>        |  |         |         |         |                    |
| Input voltage<br>READ_VIN         |  |         | ±125    |         | mV                 |
| Output voltage<br>READ_VOUT       |  |         | ±40     |         | mV                 |
| Output current<br>READ_IOUT       | $T_{P1} = 25^{\circ}\text{C}$ , $V_O = 12\text{V}$                     |         | ±0.5    |         | A                  |
|                                   | $T_{P1} = -20-120^{\circ}\text{C}$ , $V_O = 12\text{V}$                |         | ±2.5    |         | A                  |
| Duty cycle<br>READ_DUTY_CYCLE     | No tolerance, Read value is the actual value applied by PWM controller |         |         |         |                    |
| Temperature<br>READ_TEMPERATURE_1 | Temperature sensor, $-20-120^{\circ}\text{C}$                          |         | ±5      |         | $^{\circ}\text{C}$ |

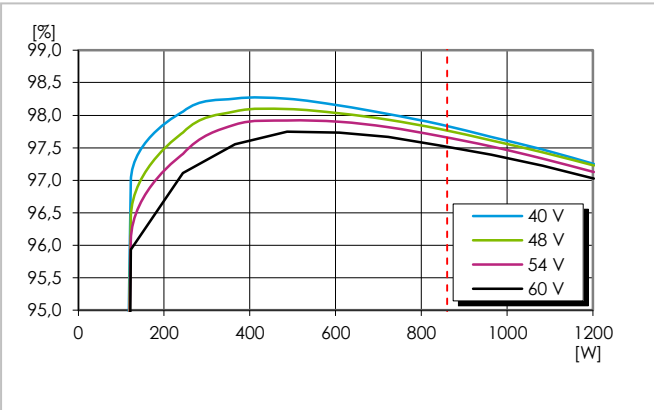
For more detailed information please refer to Technical Reference Document: PMBus commands.

This product is supported by the [Flex Power Designer tool](#).

**Electrical graphs for BMR350X100/031**

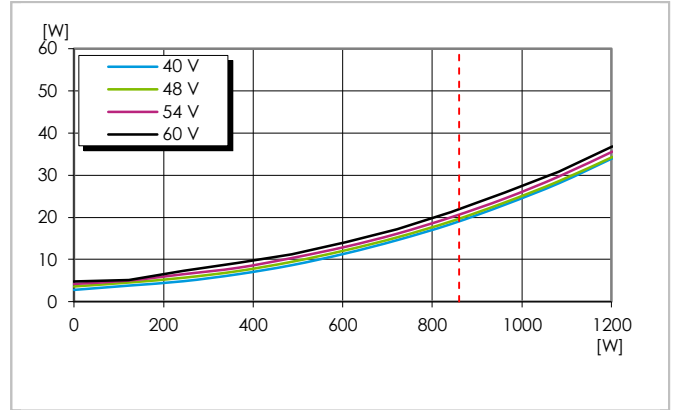
**12V, 72A (100A) ≤860W (1200W)**

**Efficiency**



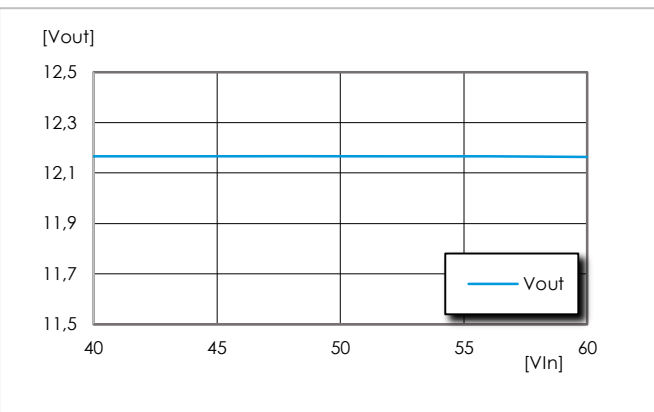
Efficiency vs. output power and input voltage at  $T_{PI} = +25^{\circ}C$   
Above 860W only peak  $t \leq 1s$

**Power dissipation**



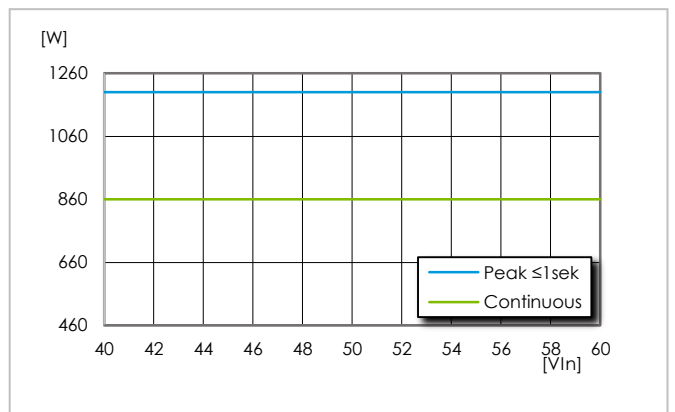
Dissipated power vs. load power at  $T_{PI} = +25^{\circ}C$   
Above 860W only peak  $t \leq 1s$

**Line regulation**



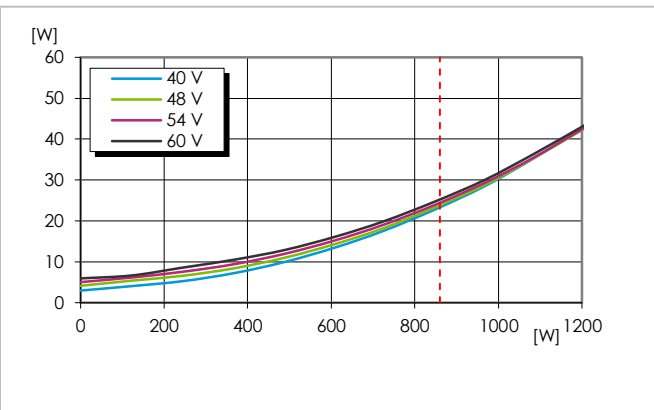
Output voltage vs. input voltage at  $T_{PI} = +90^{\circ}C$ , 100% of max  $P_{out\_TDP}$

**Available power**



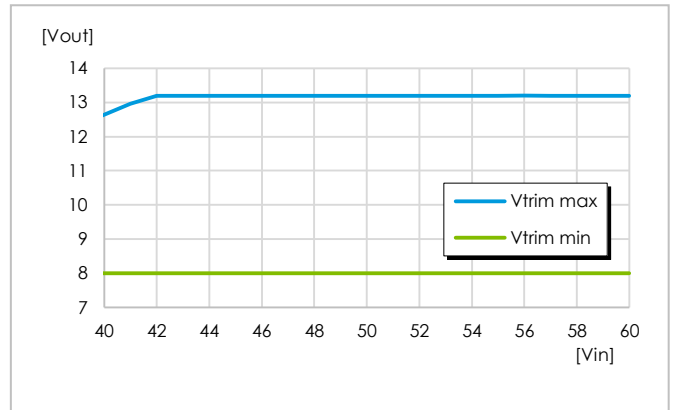
Available output power vs. input voltage,  $T_{PI} = +90^{\circ}C$

**Power loss at max temperature**



Dissipated power vs. output power and input voltage at  $T_{PI} = +90^{\circ}C$   
Above 860W only peak  $t \leq 1s$

**Output voltage adjust range**



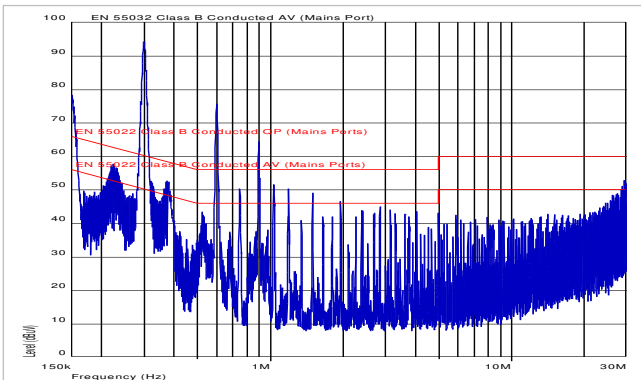
Max and min  $V_{out}$  trim vs  $V_{in}$



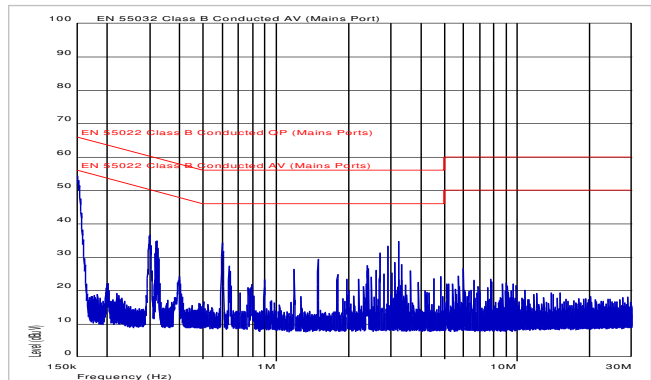
## Part 2: EMC

### EMC specifications

Conducted EMI measured according to EN55022 / EN55032, CISPR 22 / CISPR 32 and FCC part 15J (see test set-up below). The fundamental switching frequency is 150kHz for BMR350. The EMI characteristics below is measured at  $V_{in} = 54\text{ V}$  and max  $I_{out}$ .



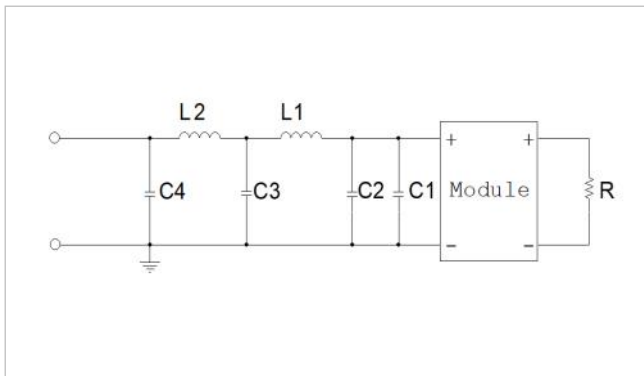
EMI without filter. EN55032 test method and limits are the same as EN55022. 220  $\mu\text{F}$  100V input capacitor and 1000  $\mu\text{F}$  16 V OS-CON output capacitor used



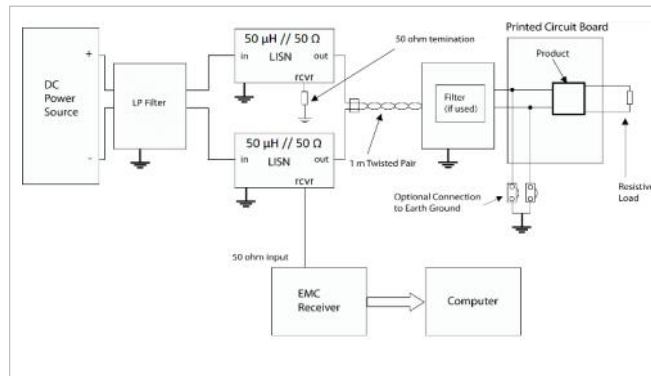
EMI with filter, EN55032 test methods and limits are the same as EN55022.

### Optional external filter for Class B

Suggested external input filter in order to meet Class B in EN 55022 / EN 55032, CISPR 22 / CISPR 32 and FCC part 15J.



Filter components:  
 C1 = 220  $\mu\text{F}$  (e-lyt)  
 C2 = 2 x 2.2  $\mu\text{F}$   
 C3, C4 = 10  $\mu\text{F}$   
 L1, L2 = 4.7  $\mu\text{H}$



Test set-up

### Layout recommendations

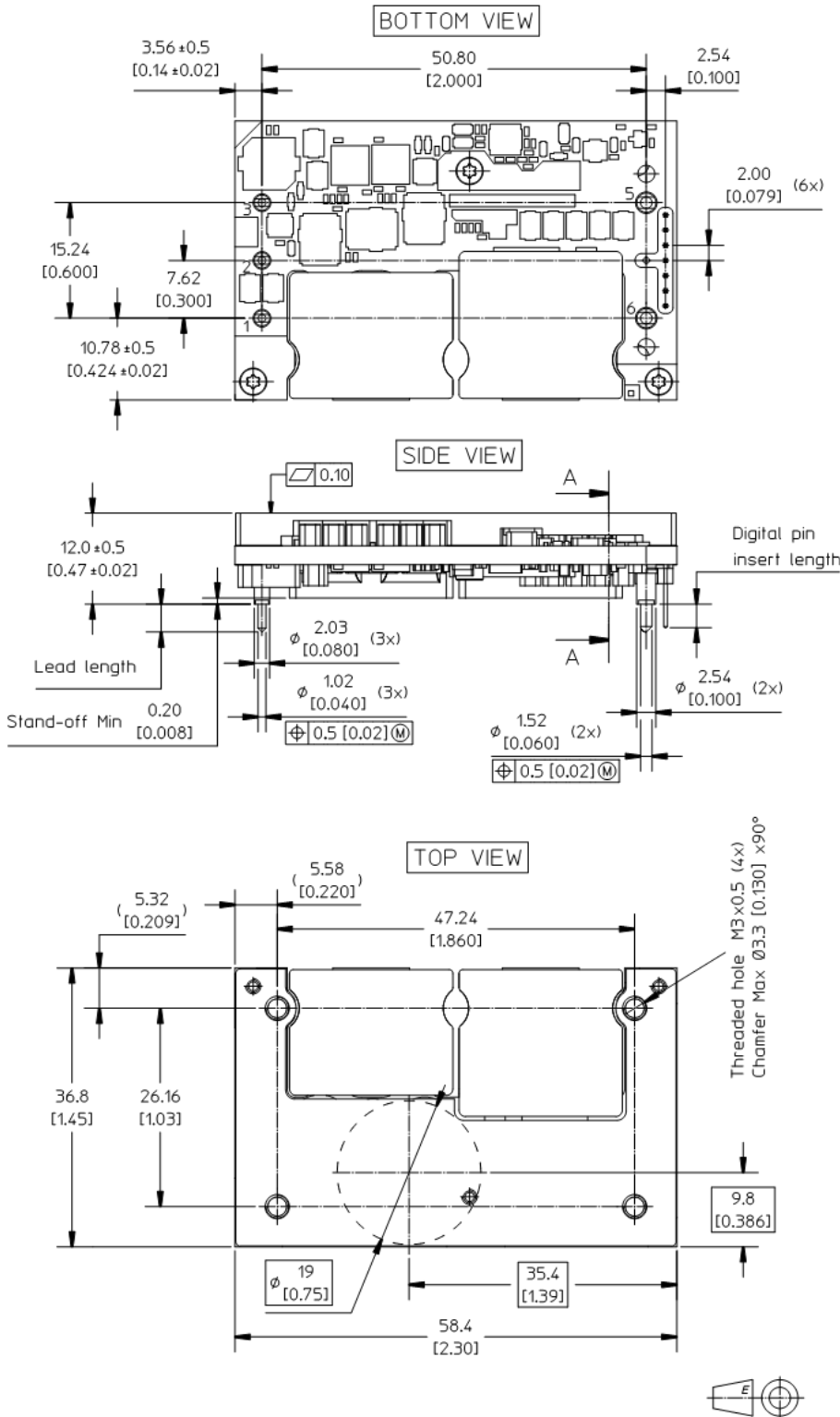
The radiated EMI performance of the product will depend on the PWB layout and ground layer design. It is also important to consider the stand-off of the product. If a ground layer is used, it should be connected to the output of the product and the equipment ground or chassis.

A ground layer will increase the stray capacitance in the PWB and improve the high frequency EMC performance.

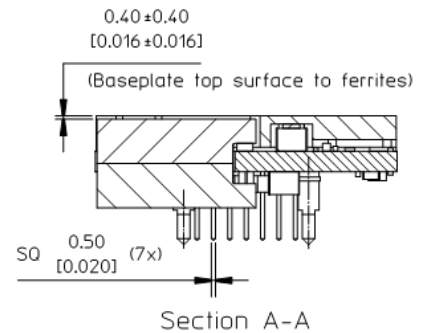
### Part 3: Mechanical information

#### BMR350X1XX/XXX: hole mounted, baseplate version

The mechanical information is based on a module which is hole mounted and has a baseplate.



|          | Lead length  | Digital pin insert length |
|----------|--------------|---------------------------|
| Standard | 5.33 [0.210] | 4.10 [0.161]              |
| LA       | 3.69 [0.145] | 3.10 [0.122]              |
| LB       | 4.57 [0.180] | 4.10 [0.161]              |
| LC       | 2.79 [0.110] | 2.10 [0.083]              |



**NOTES:**

**BASEPLATE INTERFACE**  
Material: Aluminium  
For screw attachment apply mounting torque of max 0.48 Nm [4.3 lbf in.]. M3 screw must not protrude more than 3.0 mm [0.118 in.] into the baseplate.

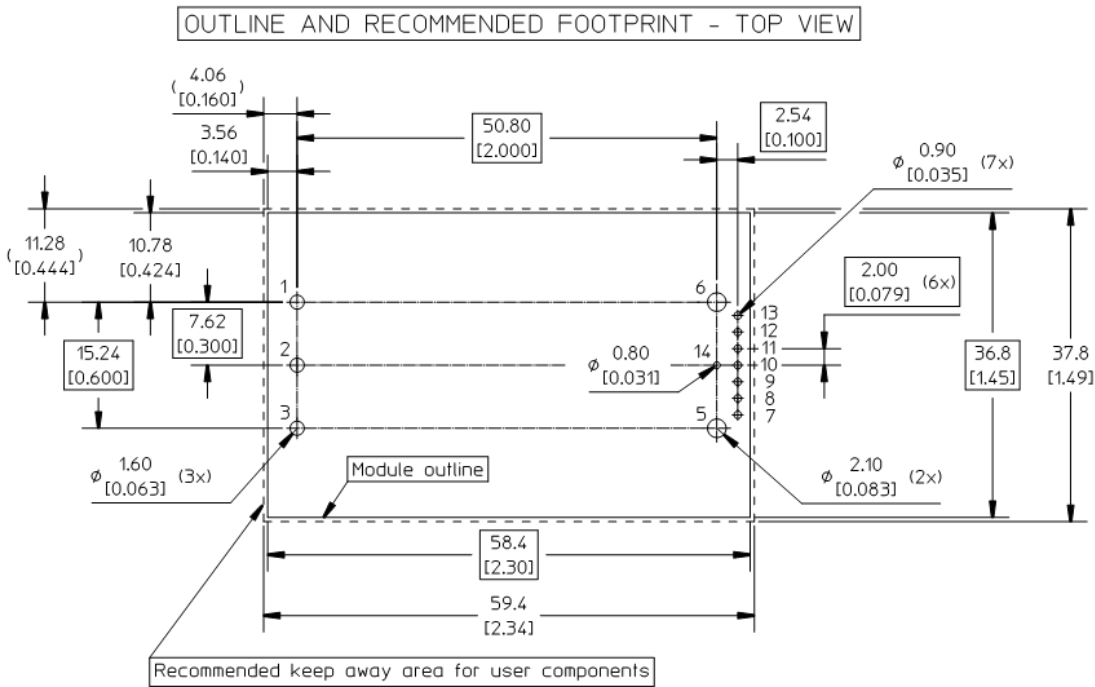
**WEIGHT**  
Typical: 83 g

All dimensions are in mm and [inch].  
Tolerances unless specified:  
x.x mm ±0.50 mm, [x.xx in. ±0.02 in.]  
x.xx mm ±0.25 mm, [x.xxx in. ±0.010 in.]

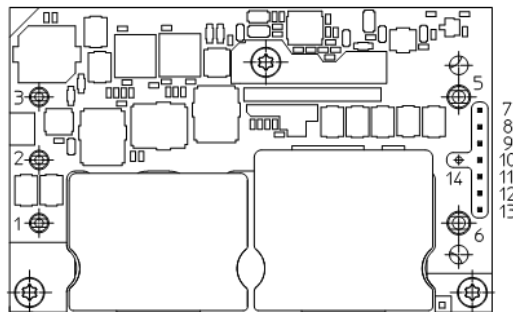
**3D MODELS**  
3D .stp models are available on request.

All component placements, whether shown as physical components or symbolical outline, are for reference only and are subject to change throughout the product's life cycle unless explicitly described and dimensioned in this drawing.

Footprint and pin positions



CONNECTIONS - BOTTOM VIEW



**PIN SPECIFICATIONS:**

Pin 1-3, 5-6 Material: Copper alloy  
Plating: Min Au 0.1 µm over Ni 1-3 µm

Pin 7-13 Material: Brass  
Plating: Min Au 0.1 µm over Ni 1-3 µm

Pin 14 Not mounted (Option)

| Pin | Designation | Function 7 pin  |
|-----|-------------|-----------------|
| 1   | +In         | Positive Input  |
| 2   | RC          | Remote Control  |
| 3   | -In         | Negative Input  |
| 5   | -Out        | Negative Output |
| 6   | +Out        | Positive Output |

| Pin | Designation | Function 7 pin     |
|-----|-------------|--------------------|
| 7   | PG          | Power Good         |
| 8   | DGND        | PMBus ground       |
| 9   | SDA         | PMBus Data         |
| 10  | SALERT      | PMBus alert signal |
| 11  | SCL         | PMBus Clock        |
| 12  | SA1         | PMBus Address 1    |
| 13  | IMON        | Current Share      |

## Part 4: Thermal considerations

### Thermal considerations

The products are designed to operate in different thermal environments and sufficient cooling must be provided to ensure reliable operation.

#### General

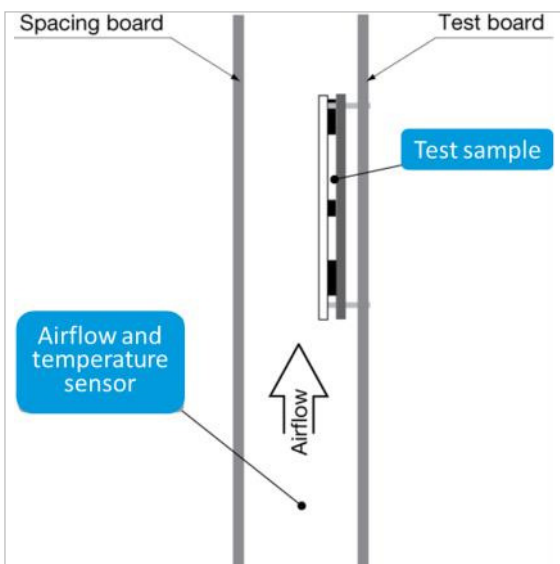
For products mounted on a PWB without a heatsink attached, cooling is achieved mainly by conduction, from the pins to the host board, and convection, which is dependent on the airflow across the product. Increased airflow enhances the cooling of the product. The wind speed and temperature are measured in a point upstream the device. The *output current derating graphs* found later in this section for each model provide the available output current vs. ambient air temperature and air velocity at  $V_{in} = 54\text{ V}$ .

For products using any form of heatsink structure a top spacing board and side airflow guides are used to ensure airflow hitting the module and not diverted away.

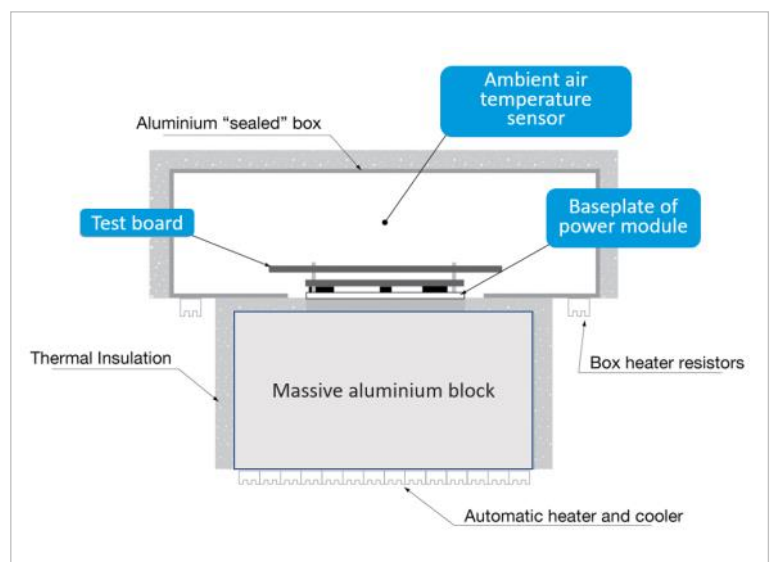
Distance between the tested device and the top space board and the side airflow guides are  $6.35\text{ mm} \pm 1\text{ mm}$ .

The product is tested on a  $185 \times 185\text{ mm}$ ,  $105\text{ }\mu\text{m}$  (3 oz), 6-layer test board mounted vertically in a wind tunnel.

For products with baseplate used in a sealed box/cold wall application, cooling is achieved mainly by conduction through the cold wall. The product is tested in a sealed box test set up with ambient temperatures  $85^\circ\text{C}$ . See [Design Note 028](#) for further details.



Picture: general test set-up



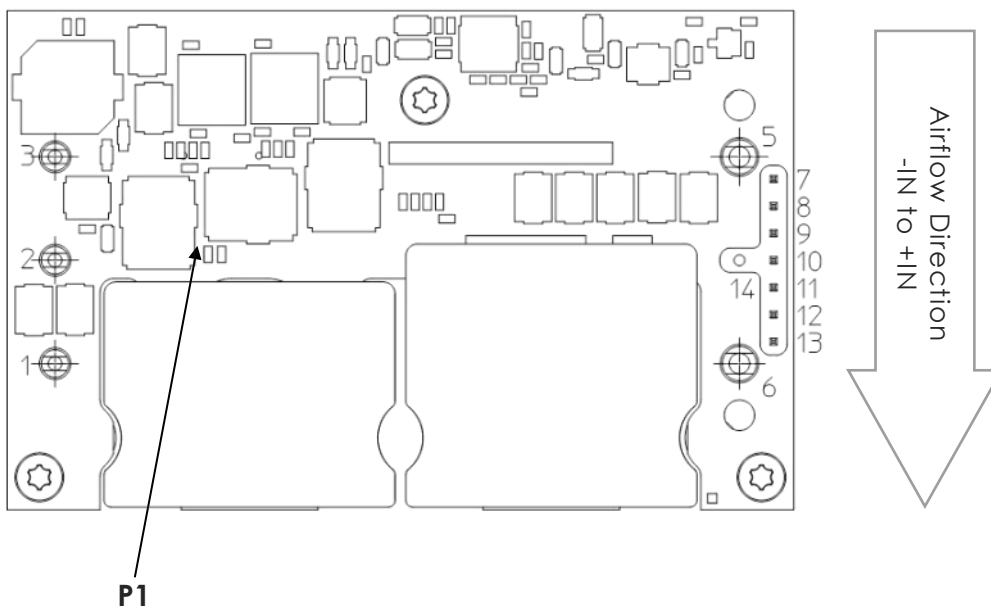
Picture: cold wall test set-up

## Part 4: Thermal considerations

**Definition of product operating temperature**

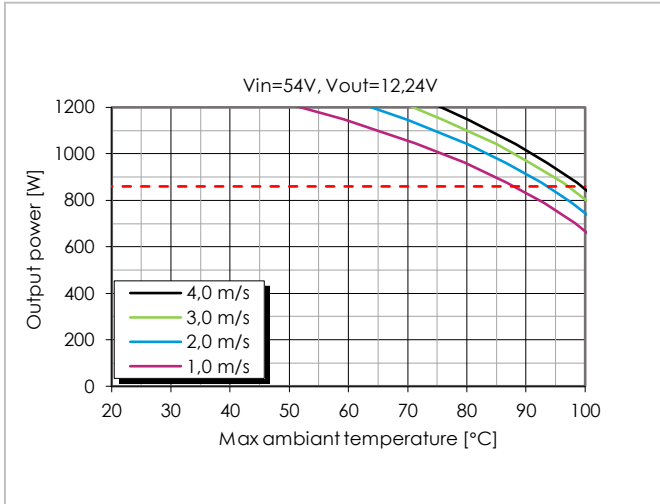
Proper thermal conditions can be verified by measuring the temperature at position P1 as shown below. The temperature at this position ( $T_{P1}$ ) should not exceed the maximum temperatures in the table below. The number of measurement points may vary with different thermal design and topology. Temperatures above maximum  $T_{P1}$ , measured at the reference point P1 are not allowed and may cause permanent damage.

| Position | Description         | Max. Temp.                     |
|----------|---------------------|--------------------------------|
| P1       | PWB reference point | $T_{P1} = 125^{\circ}\text{C}$ |

**Bottom view**

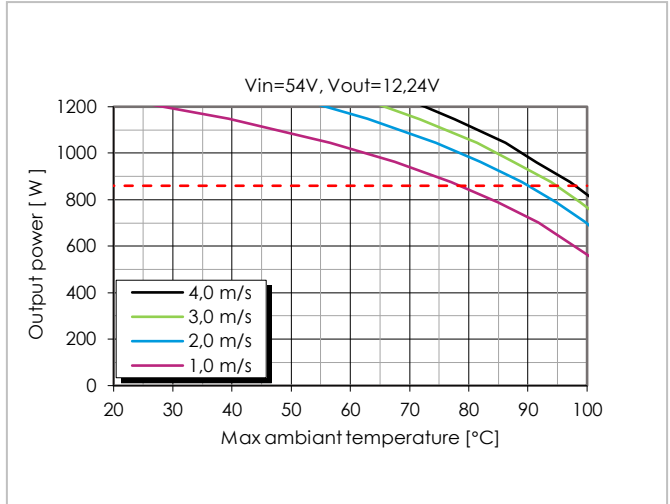
Thermal graphs

Output power derating - 1.0 inch heatsink



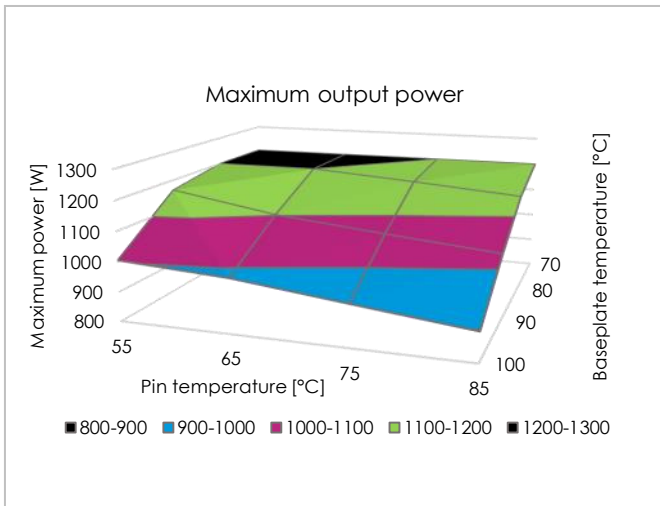
Available output power vs. ambient air temperature and airflow. Above 860W only peak  $t \leq 1s$ . Airflow Direction -IN to +IN.

Output power derating - 0.5 inch heatsink



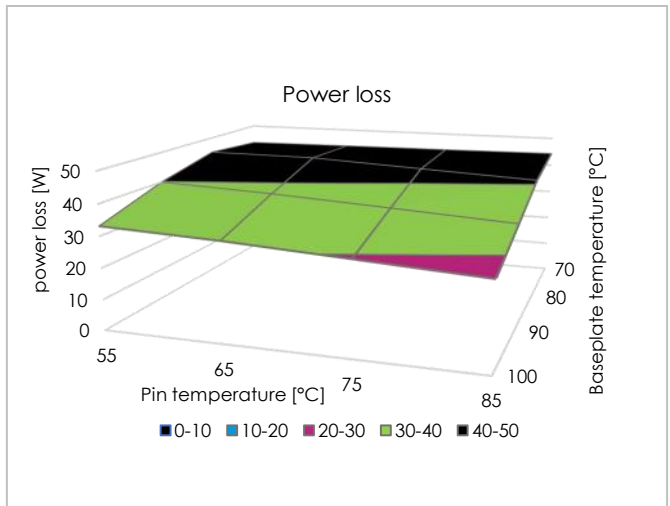
Available output power vs. ambient air temperature and airflow. Above 860W only peak  $t \leq 1s$ . Airflow Direction -IN to +IN.

Maximum Output Power



Maximum allowed thermal power (restriction by POMAX might occur). Above 860W only peak  $t \leq 1s$ .

Maximum Allowed Power Loss



Available output power vs. pin and baseplate temperature See Thermal Consideration section. Above 860W only peak  $t \leq 1s$ .

For more information, please refer to our [thermal models](#) on the website.

## Part 5: Packaging

### Packaging information

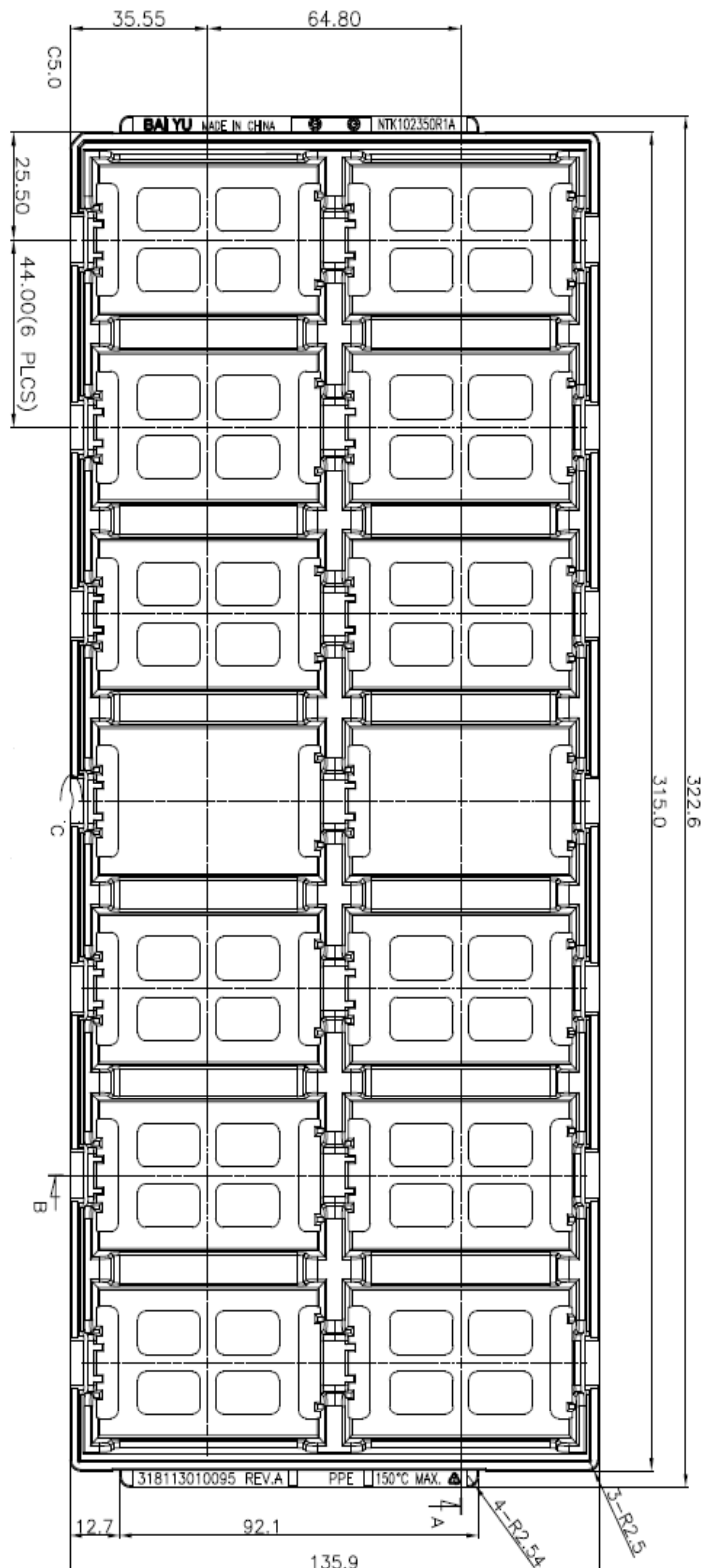
|   |  |
|---|--|
| <b>H option:</b> Select for PIP reflow solder and pick & place - dry packed |  |
| <b>Material</b>   | Antistatic Polyphenylene Ester (PPE)   |
| <b>Surface resistance</b>   | $\geq 1 \times 10^4$ to $< 1 \times 10^{11}$ ohms                                    |
| <b>Bakability</b>   | Tray can be baked at max. 125 °C for 24 h. Please remove the fitments before baking. |
| <b>Tray capacity</b>  | 14 converters/tray   |
| <b>Box capacity</b>   | 42 products (3 full trays/box)   |
| <b>Tray weight</b>  | 156 g empty tray, 1318 g full tray open deck baseplate.                              |

JEDEC standard tray.  
All dimensions in mm

Tolerances: X.x  $\pm 0.26$  [0.01], X.xx  $\pm 0.13$  [0.005]

**Note:** Pick up positions refer to center of pocket.

See [mechanical drawing](#) for exact location on product.

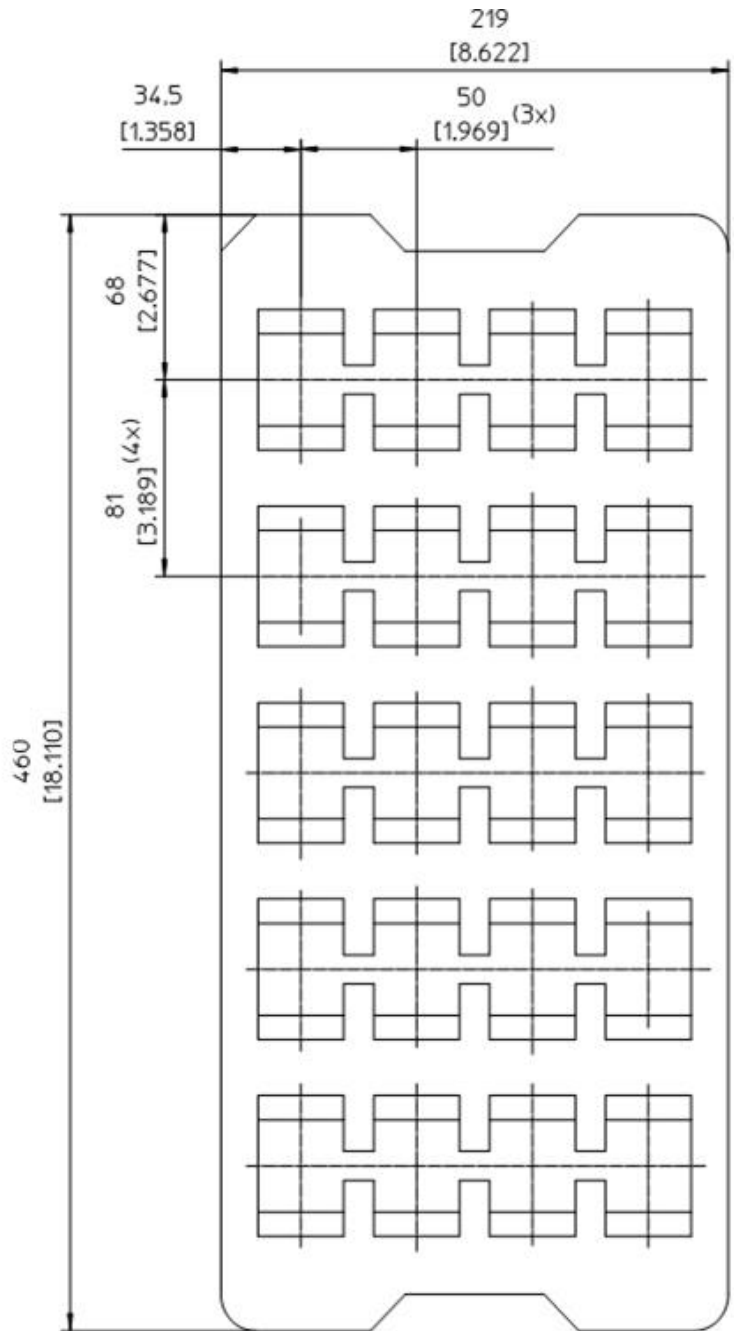


Example hard tray (14 pcs)

**Packaging information**

**Blank option:** Select for wave or hand soldering, NOT dry packed

|                           |   |
|---------------------------|---|
| <b>Material</b>           | Antistatic Polyethylene (PE) foam                 |
| <b>Surface resistance</b> | $\geq 1 \times 10^4$ to $< 1 \times 10^{11}$ ohms |
| <b>Bakability</b>         | Tray cannot be baked                              |
| <b>Tray capacity</b>      | 20 converters / tray                              |
| <b>Box capacity</b>       | 60 products (3 full trays/ box)                   |
| <b>Weight</b>             | 48 g empty tray, 1708 g full tray.                |



Example PE foam tray



## Part 6: Revision history

### Revision table

| Revision number | revision change   | date           | revisor       |
|-----------------|---|----------------|---------------|
| Rev. A          | New document  | Mar 1st, 2022  | Marshall Wang |
| Rev. B          | Add baseplate flatness 0.1mm;<br>Update EMI filter graph; | July 8th, 2022 | Marshall Wang |
| Rev. E          | Update product drawing in page 13                         | Feb 14th, 2023 | Frank Wu      |
| Rev. F          | Remove space inside P/Ns                                  | May 15th, 2023 | Marshall Wang |

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The information and specifications in this technical specification is believed to be correct at the time of publication. However, no liability is accepted for inaccuracies, printing errors or for any consequences thereof. Flex reserves the right to change the contents of this technical specification at any time without prior notice.

# flex<sup>®</sup>

Flex Power Modules, a business line of Flex, is a leading manufacturer and solution provider of scalable DC/DC converter primarily serving the data processing, communications, industrial and transportation markets. Offering a wide range of both isolated and non-isolated solutions, its digitally-enabled DC/DC converters include PMBus compatibility supported by the powerful Flex Power Designer.



## TECHNICAL REFERENCE DOCUMENT: GENERAL INFORMATION

### Compatibility with RoHS requirements

The products are compatible with the relevant clauses and requirements of the *RoHS directive 2011/65/EU* and *2015/863* have a maximum concentration value of 0.1% by weight in homogeneous materials for lead, mercury, hexavalent chromium, PBB, PBDE, DEHP, BBP, DBP, DIBP and of 0.01% by weight in homogeneous materials for cadmium.

Exemptions in the RoHS directive utilized in Flex Power Modules products are found in the Statement of Compliance document.

Flex Power Modules fulfills and will continuously fulfill all its obligations under regulation (EC) No 1907/2006 concerning the registration, evaluation, authorization and restriction of chemicals (REACH) as they enter into force and is through product materials declarations preparing for the obligations to communicate information on substances in the products.

### Quality statement

The products are designed and manufactured in an industrial environment where quality systems and methods like *ISO 9000*, *Six Sigma*, and *SPC* are intensively in use to boost the continuous improvements strategy. Infant mortality or early failures in the products are screened out and they are subjected to an ATE-based final test. Conservative design rules, design reviews and product qualifications, plus the high competence of an engaged workforce, contribute to the high quality of the products.

### Warranty

Warranty period and conditions are defined in *Flex Power Modules' General Terms and Conditions of Sales*.

### Limitation of Liability

Flex Power Modules does not make any other warranties, expressed or implied including any warranty of merchantability or fitness for a particular purpose (including, but not limited to, use in life support applications, where malfunctions of product can cause injury to a person's health or life).

## Product qualification specifications

| Characteristics                                 |  |  |   |
|---|--|--|---|
| External visual inspection                      | IPC-A-610  |  |   |
| Temperature shock test<br>(Temperature cycling) | IEC 60068-2-14 Na  | Temperature range<br>Number of cycles<br>Dwell/transfer time | -40 to 125°C<br>700<br>15 min/0-1 min                               |
| Cold (in operation)                             | IEC 60068-2-1 Ad   | Temperature T <sub>A</sub><br>Duration                       | -45°C<br>72 h   |
| Damp heat                                       | IEC 60068-2-67 Cy  | Temperature<br>Humidity<br>Duration                          | 85°C<br>85% RH<br>1000 hours  |
| Dry heat  | IEC 60068-2-2 Bd   | Temperature<br>Duration                                      | 125°C<br>1000 h   |
| Electrostatic discharge<br>susceptibility       | IEC 61340-3-1, JESD 22-A114<br>IEC 61340-3-2, JESD 22-A115 | Human body model (HBM)<br>Machine Model (MM)                 | Class 2, 2000 V<br>Class 3, 200 V                                   |
| Immersion in cleaning solvents                  | IEC 60068-2-45 XA, method 2                                | Water  | 55°C  |
| Mechanical shock                                | IEC 60068-2-27 Ea  | Peak acceleration<br>Duration                                | 100 g<br>6 ms   |
| Moisture reflow sensitivity <sup>1</sup>        | J-STD-020E   | Level 1 (SnPb-eutectic)<br>Level 3 (Pb Free)                 | 225°C<br>245°C  |
| Operational Life test Rapid Temp.               | MIL-STD-202G, method 108A                                  | Duration   | 1000 h  |
| Resistance to soldering heat <sup>2</sup>       | IEC 60068-2-20 Tb, method 1A                               | Solder temperature<br>Duration                               | 270°C<br>10-13 s  |
| Robustness of terminations                      | IEC 60068-2-21 Test Ua1<br>IEC 60068-2-21 Test Ue1         | Through hole mount products<br>Surface mount products        | All leads<br>All leads  |
| Solderability                                   | IEC 60068-2-20 test Ta                                     | Preconditioning<br>Temperature, Pb-free                      | Steam ageing<br>245°C   |
| Vibration, broad band random                    | IEC 60068-2-64 Fh, method 1                                | Frequency<br>Spectral density<br>Duration                    | 10 to 500 Hz<br>0.07 g <sup>2</sup> /Hz<br>10 min in each direction |

Note 1: only for products intended for reflow soldering (surface mount products & pin-in paste products)

Note 2: only for products intended for wave soldering (plated through hole products)

## TECHNICAL REFERENCE DOCUMENT: DESIGN & APPLICATION GUIDELINES

### OPERATING INFORMATION: COMMON FEATURES

The features listed in the following pages are common to DC/DC converters.

#### Turn on and off input voltage

The product monitors the input voltage and will turn on and turn off at configured thresholds (see *Technical Specification: part 1 - Electrical Specification*). The turn-on input voltage threshold is set higher than the corresponding turn-off threshold. Hence, there is a hysteresis between turn-on and turn-off input voltage levels.

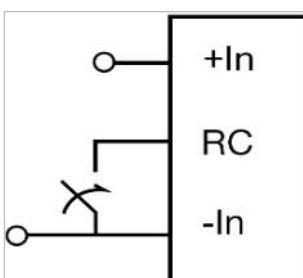
#### Input voltage transient

The end-user must secure that the transient voltage will not exceed the value stated in the Technical Specification under Absolute maximum ratings of each product. ETSI TR 100 283 examines the parameters of DC distribution networks and provides guidelines for controlling the transient and reduce its harmful effect.

#### Remote control (RC)

The products are fitted with a remote control function referenced to the primary negative input connection (-In), with negative logic options available. The RC function allows the product to be turned on/off by an external device like a semiconductor or mechanical switch. The RC pin has an internal pull up resistor.

The external device must provide a minimum required sink current  $>0.5$  mA to guarantee a voltage not higher than maximum voltage on the RC pin (see Electrical characteristics table). To turn off the product the RC pin should be left open for a minimum time of  $150 \mu\text{s}$ , the same time requirement applies when the product shall turn on. When the RC pin is left open, the voltage generated on the RC pin is max 5 V. The standard product is provided with "negative logic" RC and will be off until the RC pin is connected to the -In. To turn off the product the RC pin should be left open. In situations where it is desired to have the product to power up automatically without the need for control signals or a switch, the RC pin shall be wired directly to -In.



Remote control

## Input and output impedance

The impedance of both the input source and the load will interact with the impedance of the product. It is important that the input source has low characteristic impedance. Minimum recommended external input capacitance is given in the *Technical Specification*. Electrolytic capacitors will be degraded in low temperature. The needed input capacitance in low temperature should be equivalent to the value stated in the Technical Specification at 25°C. The performance in some applications can be enhanced by addition of external capacitance as described under External decoupling capacitors (next paragraph). If the input voltage source contains significant inductance, the addition of a low ESR ceramic capacitor of 22 – 100 µF capacitor across the input of the product will ensure stable operation. The minimum required capacitance value depends on the output power and the input voltage. The higher output power the higher input capacitance is needed.

## External decoupling capacitors

When powering loads with significant dynamic current requirements, the voltage regulation at the point of load can be improved by addition of decoupling capacitors at the load.

The most effective technique is to locate low ESR ceramic and electrolytic capacitors as close to the load as possible, using several parallel capacitors to lower the effective ESR. The ceramic capacitors will handle high-frequency dynamic load changes while the electrolytic capacitors are used to handle low frequency dynamic load changes. It is equally important to use low resistance and low inductance PWB layouts and cabling.

External decoupling capacitors will become part of the product's control loop. The control loop is optimized for a wide range of external capacitance and the maximum recommended value that could be used without any additional analysis is found in the Technical Specification under Electrical specifications. Output filter can be configured and simulated based on the needed control loop and transient response.

For further information please contact your local Flex Power Modules' representative or email us at [pm.info@flex.com](mailto:pm.info@flex.com).

## Output voltage adjust using PMBus

The output voltage of the product can be reconfigured via PMBus command VOUT\_COMMAND (0x21) or VOUT\_TRIM (0x22). This can be used when adjusting the output voltage above or below output voltage initial setting up to a certain level, see Electrical specification for adjustment range.

When changing the output voltage, the voltage at the output pins must be kept within Vtrim max and Vtrim min. Output voltage setting must be kept below the threshold of the over voltage protection (OVP) to prevent the product from shutting down. At increased output voltages the maximum power rating of the product remains the same, and the max output current must be decreased correspondingly.

## Margin up and down control

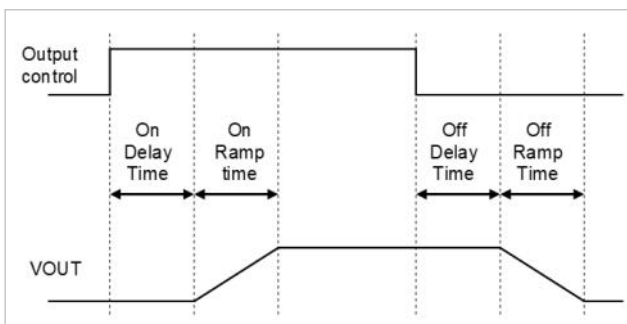
These controls allow the output voltage to be momentarily adjusted, either up or down, by a nominal 10%. The margin high and margin low shall be limited to max and min output voltage, if the nominal output voltage is changed. This provides a convenient method for dynamically testing the operation of the load circuit over its supply margin or range. It can also be used to verify the function of supply voltage supervisors.

The margin up and down levels of the product can easily be re-configured using [Flex Power Designer software](#).

## Soft start power up and soft stop

The default rise time for a single product is 10 ms. When starting by applying input voltage the control circuit boot-up time adds approximately an additional 15 ms delay. The soft-start and soft-stop control functionality allows the output voltage to ramp-up and ramp-down with defined timing with respect to the control of the output. This can be used to control inrush current and manage supply sequencing of multiple controllers.

The rise time is the time taken for the output to ramp to its target voltage, while the fall time is the time taken for the output to ramp down from its regulation voltage to 0 V. The TON\_DELAY (0x60) time sets a delay from when the output is enabled until the output voltage starts to ramp up. The TOFF\_DELAY (0x64) delay time sets a delay from when the output is disabled until the output voltage starts to ramp down. By default, soft-stop is disabled, and the regulation of output voltage stops immediately when the output is disabled. Soft-stop can be enabled through the PMBus command ON\_OFF\_CONFIG (0x02). The delay and ramp times can be reconfigured using the PMBus commands TON\_DELAY (0x60), TON\_RISE (0x61), TOFF\_DELAY (0x64) and TOFF\_FALL (0x65).



Soft start power up

## Pre-bias start-up

The product has a pre-bias start up functionality and will not sink current during start up if a pre-bias source is present at the output terminals. If the pre-bias voltage is lower than the target value set in VOUT\_COMMAND (0x21), the product will ramp up to the target value. If the pre-bias voltage is higher than the target value set in VOUT\_COMMAND (0x21), the product will ramp down to the target value and in this case sink current for a time interval set by the command TOFF\_MAX\_WARN\_LIMIT (0x66).

## Over/under temperature protection (OTP/UTP)

The products are protected from thermal overload by an internal over temperature sensor. The product will make continuous attempts to start up (non-latching mode) and resume normal operation automatically when the temperature has dropped below the temperature threshold set in command OT\_WARN\_LIMIT (0x51). The OTP and hysteresis of the product can be re-configured using the PMBus interface. The product also has an under-temperature protection. The OTP and UTP fault limit and fault response can be configured via the PMBus.

Note: using the fault response "continue without interruption" may cause permanent damage to the product.

## Input over/under voltage protection

The product can be protected from high input voltage and low input voltage by a pre-configured value with a response time of 70µs. The over/under-voltage fault level and fault response is easily configured using Flex Power Designer software.

For more information, see *Technical Reference Document: PMBus*.

## Output Over Voltage Protection (OVP)

The product includes over voltage limiting circuitry for protection of the load. The default OVP limit is 30% above the nominal output voltage. If the output voltage exceeds the OVP limit, the product can respond in different ways.

The default response from an over voltage fault is to immediately shut down, with a response time of ~70µs. The device will continuously check for the presence of the fault condition, and when the fault condition no longer exists the device will be re-enabled.

The OVP fault level and fault response can be configured via the PMBus interface

For more information, see *Technical Reference Document: PMBus*.

## Over current protection (OCP)

The products include current limiting circuitry for protection at continuous overload. For standard configuration the output voltage will shutdown and automatic restart (hiccup mode) for output currents in excess of max output current (max I<sub>O</sub>). The product will retry 3 times with 1s delay time between each retry attempt. The load distribution should be designed for the maximum output short circuit current specified.

The over current protection of the product can be configured via the PMBus interface

For more information, see *Technical Reference Document: PMBus*.



## Switching frequency

The product is optimized at the frequency given in the Technical Specification under part 1- Electrical Specification, but can run at lower and higher frequencies through PMBus configuration. The electrical performance can be affected at different frequencies. Please contact your local Flex Power Modules FAE for more details.

## Multi pin configurations

The MFR\_MULTI\_PIN\_CONFIG (0xF9) command can be re-configured using the PMBus interface to enable or disable different functions and set the pin configuration of the digital header.

The MULTI\_PIN\_CONFIG is easily configured using [Flex Power Designer](#).

For more information, see *Technical Reference Document: PMBus*.

## Address offset

The command FW\_CONFIG\_PMBUS (0xC9) can be configured to utilize different address offset option. There are 3 different address setting option.

1. The bit 16 in command 0xC9 must be set to 1 to enable PMBus address offset via resistors.
2. The resistor address offset in combination with a value set by PMBus base address offset, [31:24] in command FW\_CONFIG\_PMBUS (0xC9). This can be chosen when 1 address resistor is used.
3. A pre-configured PMBus address, [23:17] in FW\_CONFIG\_PMBUS (0xC9). The bit 16 in command 0xC9 must be set to 0 to enable digital PMBus address offset. The digital PMBus address offset in combination with a digital PMBus base address offset, [31:24] in command FW\_CONFIG\_PMBUS (0xC9) adds a larger range of address possibilities. This combination can be chosen if no address resistors are used.

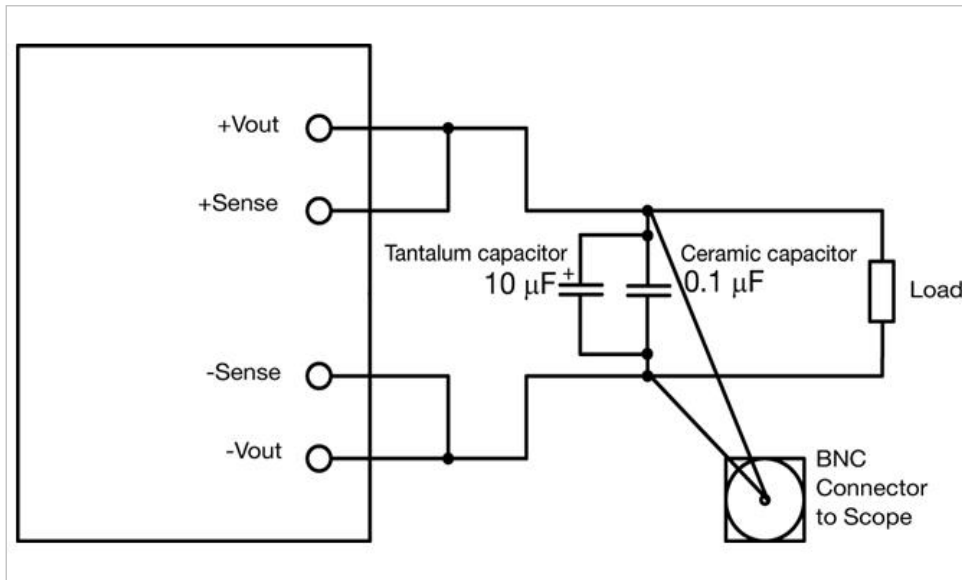
The PMBus-address offset's with resistor value increments the address value following the formula in the PMBus Addressing section of documentation. This increases flexibility when the part is used in single-pin and no-pin addressing scenarios.

## Feed Forward Capability

The BMR350 products have a Feed Forward function implemented that can handle sudden input voltage changes. The output voltage will be regulated during an input transient and will typically stay within 10% when an input transient is applied. The Feed Forward acts on both positive and negative input voltage transients

## Output ripple and noise

Output ripple and noise measured according to figure below.  
See [Design Note 022](#) for detailed information



Output ripple and noise test set-up

## Non-Volatile Memory (NVM)

The product incorporates two Non-Volatile Memory areas for storage of the PMBus command values; the Default NVM and the User NVM. The Default NVM is pre-loaded with Flex factory default values. The Default NVM is write-protected and can be used to restore the Flex factory default values through the command RESTORE\_DEFAULT\_ALL (0x12).

The User NVM is pre-loaded with Flex factory default values. The User NVM is writable and open for customization. The values in NVM are loaded during initialization according to section Initialization Procedure, where after commands can be changed through the PMBus Interface.

The module contains a one-time programmable memory (OTP) used to store configuration settings, which will not be programmed into the device OTP automatically. The STORE\_USER\_ALL(0x15) commands must be used to commit the current settings are transferred from RAM to OTP as device defaults.

Note: The one-time programmable memory (OTP) has limited storing times, frequent use of STORE\_USER\_ALL command can lead to memory space exhaustion. Remaining available memory is displayed in Flex Power Designer. To retrieve OTP memory MFR\_FLEX\_FIRMWARE\_CMD (0xE0) can be used, see section OTP Memory Check.

## OPERATING INFORMATION: PRODUCT SPECIFIC FEATURES

### OTP Memory Check

This command, MFR\_FLEX\_FIRMWARE\_CMD (0xE0), can be used to retrieve information about OTP memory. The command works by first writing an 8 byte large block containing instructions for what information to retrieve and then that information is accessed by performing a block read operation. The first 8 bits in the request block contains a sub-command code. The usable codes are described in the following examples:

Read OTP partition size (cmd=0). Retrieves the memory size of a specific partition. This is the size that was set during the OTP partition trim process.

Request:

|        |   |   |   |   |   |   |   |   |               |    |        |
|--------|---|---|---|---|---|---|---|---|---------------|----|--------|
| 0      | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 15            | 16 | 31     |
| 0      | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | OTP partition |    | Unused |
| Unused |   |   |   |   |   |   |   |   |               |    |        |

Response:

|                         |    |
|-------------------------|----|
| 0                       | 31 |
| Partition size in bytes |    |
| Unused                  |    |

Read remaining memory size of OTP partition (cmd=1). Retrieves the remaining memory size of a specific partition. This is the size that is still available for writing patches, which depending on the partition can be firmware patches, PMBus configuration patches or snapshot events.

Request:

|        |   |   |   |   |   |   |   |   |               |    |        |
|--------|---|---|---|---|---|---|---|---|---------------|----|--------|
| 0      | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 15            | 16 | 31     |
| 1      | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | OTP partition |    | Unused |
| Unused |   |   |   |   |   |   |   |   |               |    |        |

Response:

|                         |    |
|-------------------------|----|
| 0                       | 31 |
| Remaining size in bytes |    |
| Unused                  |    |

Read size of STORE\_X\_ALL memory usage (cmd=2). Retrieves the memory used when storing a full PMBus configuration through STORE\_DEFAULT\_ALL or STORE\_USER\_ALL. This includes padding bytes for alignment, the OTP frame size and checksum.

Request:

|        |   |   |   |   |   |   |   |   |               |    |        |
|--------|---|---|---|---|---|---|---|---|---------------|----|--------|
| 0      | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 15            | 16 | 31     |
| 0      | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | OTP partition |    | Unused |
| Unused |   |   |   |   |   |   |   |   |               |    |        |

Response:

|                     |    |
|---------------------|----|
| 0                   | 31 |
| Block size in bytes |    |
| Unused              |    |

## Power good

The power good pin (PG) indicates when the product is ready to provide regulated output voltage to the load. During ramp-up and during a fault condition, PG is held low. By default, PG is asserted low after the output has ramped to setting according to POWER\_GOOD\_ON (0x5E), and de-asserted if the output voltage falls below the setting according to POWER\_GOOD\_OFF (0x5F). These thresholds may be changed using the PMBus commands POWER\_GOOD\_ON (0x5E) and POWER\_GOOD\_OFF (0x5F).

By default, the PG pin is configured as open drain output, but it is also possible to set the output in push/pull mode by the command MFR\_MULTI\_PIN\_CONFIG (0xF9).

The polarity is by default configured to active high, the polarity of PG can be set to active low using bit [39] in the command FW\_CONFIG\_PMBUS (0xC9) :

bit[39] = 0 (active low)

bit[39] = 1 (active high)

The product provides a Power Good flag in the Status Word register that indicates the output voltage is within a specified tolerance of its target level and no-fault condition exists. It is not recommended to use push-pull when paralleling PG- pins.

For more information, see *Technical Reference Document: PMBus*.

## Remote Control (secondary side)

The CTRL pin (Pin 7) can be configured as remote control in combination with hardware and PMBus configuration. With hardware option, Pin 7 used for secondary remote control, Power Good is disabled. The secondary remote control uses an internal pull-up resistor. The logic options for the secondary remote control can be positive or negative logic. The logic option for the secondary remote control is easily configured via ON\_OFF\_CONFIG (0x02) using Flex Power Designer software command.

## Peak power considerations

The DC/DC converter has a peak power capability ( $t \leq 1$  s) in order to handle higher power than the thermal design power (TDP) for the converter. In the peak power area the power loss increases. Extended use of peak power capability will cause increased heating of the converter. A typical guideline is that the average power loss of the converter during a 10 s period does not exceed the maximum TDP power loss. The overload protections do not monitor the average power and will not actively limit the power over time.

For further assistance, contact your local Flex Power Modules' representative or email us to

[pm.info@flex.com](mailto:pm.info@flex.com)

## Parallel operation Active Current Sharing (ACS)

Two or more products may be paralleled for redundancy if the total power is equal or less than  $P_{O\ max}$ . The products provide output voltage droop corresponding to pre-configured artificial resistance in the output circuit to enable direct paralleling. The stated output voltage set point is at no load. The output voltage will decrease when the load current is increased. This feature allows the products to be connected in parallel and share the current. To prevent unnecessary current stress, changes of the output voltage must be done with the output disabled. This must be considered for all commands that affect the output voltage.

Each module in the bus will trim its regulated output up and down continuously to be able to output the same current seen from the current share bus. This feature will cancel out the current share error caused by the modules output voltage deviation, temperature deviation and layout asymmetry. The max load of the paralleled modules equals to  $(\text{max load of single module} - 2.5A) \times \text{number of paralleled modules}$ . The 2.5A is the maximum error of the output current monitor and current accuracy between products in a current sharing group is  $2 \times 2.5A$ . The modules are adjusting their output continuously according to the ACS algorithm, the output voltage at idle will vary maximum  $\pm 100mV$  due to limitations in idle current measurements. The maximum load during ramp up will be limited to  $\text{number of modules} \times \text{nom load of single module} \times 90\%$  ( $n_{\text{modules}} \times I_{\text{outnom}} \times 0.9$ ).

How to setup the ACS: All the IMON (Pin 13) pins of the paralleled modules need to be tied together and close to each module.

## POWER MANAGEMENT

### PMBUS overview

This product is equipped with a PMBus interface. The product incorporates a wide range of readable and configurable power management features that are simple to implement with a minimum of external components. Additionally, the product includes protection features that continuously safeguard the load from damage due to unexpected system faults. A fault is also shown as an alert on the SALERT pin. The following product parameters can continuously be monitored by a host: Input voltage, output voltage/current, duty cycle and internal temperature.

The product is delivered with a default configuration suitable for a wide range operation in terms of input voltage, output voltage, and load. The configuration is stored in an internal Non-Volatile Memory (NVM). All power management functions can be reconfigured using the PMBus interface.

Throughout this document, different PMBus commands are referenced. The Flex Power Designer software suite can be used to configure and monitor this product via the PMBus interface. More information is found on [our website](#).

### SMBus interface

This product provides a PMBus digital interface that enables the user to configure many aspects of the device operation as well as to monitor the input and output voltages, output current and device temperature. The product can be used with any standard two-wire I<sup>2</sup>C (master must allow for clock stretching) or SMBus host device. In addition, the product is compatible with PMBus version 1.3 and includes an SALERT line to help mitigate bandwidth limitations related to continuous fault monitoring. The product supports 100 kHz and 400 kHz bus clock frequency only. The PMBus signals, SCL, SDA and SALERT require passive pull-up resistors as stated in the SMBus Specification. Pull-up resistors are required to guarantee the rise time as follows:

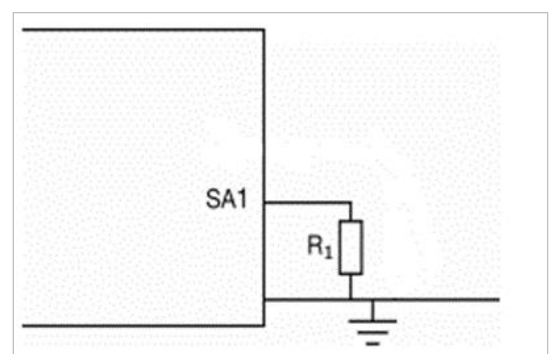
$$\tau = R_p C_p \leq 1\mu s \quad \text{Eq. 7}$$

where  $R_p$  is the pull-up resistor value and  $C_p$  is the bus load. The maximum allowed bus load is 400 pF. The pull-up resistor should be tied to an external supply between 2.7 to 3.8 V, which should be present prior to or during power-up. If the proper power supply is not available, voltage dividers may be applied. Note that in this case, the resistance in the equation above corresponds to parallel connection of the resistors forming the voltage divider.

It is recommended to always use PEC (Packet Error Check) when communicating via PMBus. There is an optional setting that makes PEC required which further increase communication robustness. This can be configured by setting bit 7 in command MFR\_SPECIAL\_OPTIONS (0xE0).

### PMBus addressing

The following figure and table show recommended resistor values with min and max voltage range for hard-wiring PMBus addresses (series E96, 1% tolerance resistors suggested):



Schematic of connection address resistors

| SA1 index | R <sub>SA1</sub> [kΩ] | Resulting address with MFR_OFFSET_ADDRESS = 0x60 |
|-----------|-----------------------|--|
| 0         | 10                    | 96d (0x60)                                       |
| 1         | 15                    | 97d (0x61)                                       |
| 2         | 21                    | 98d (0x62)                                       |
| 3         | 28                    | 99d (0x63)                                       |
| 4         | 35.7                  | 100d (0x64)                                      |
| 5         | 45.3                  | 101d (0x65)                                      |
| 6         | 56.2                  | 102d (0x66)                                      |

| SA1 index | R <sub>SA1</sub> [kΩ] | Resulting address with MFR_OFFSET_ADDRESS = 0x60 |
|-----------|-----------------------|--|
| 7         | 69.8                  | 103d (0x67)                                      |
| 8         | 88.7                  | 104d (0x68)                                      |
| 9         | 107                   | 105d (0x69)                                      |
|           |                       |  |
|           |                       |  |
|           |                       |  |
|           |                       |  |

PMBus base address offset value is configured via PMBus command 0xC9. Specific variants may already have a default non-zero value set for PMBus base address offset.

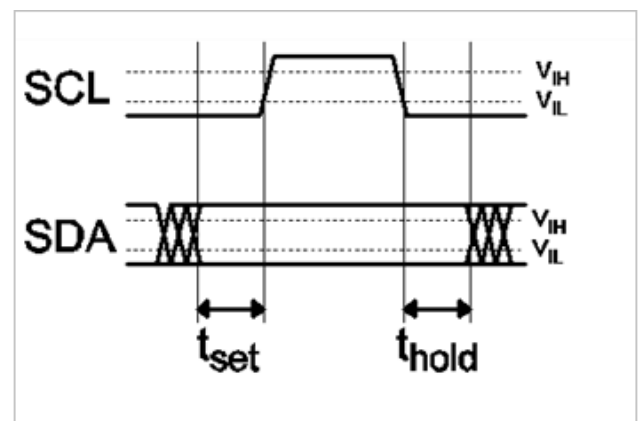
Configuring the address setup by command FW\_CONFIG\_PMBUS (0xC9), see section Offset Address.

The allowed range of the PMBus address is: 1-126 excluding 12 and 16. When the calculated PMBus address falls outside the allowed range address 126 is assigned instead. It is not recommended to keep the SA1 pins left open.

## I2C/SMBus timing

The setup time,  $t_{set}$ , is the time data, SDA, must be stable before the rising edge of the clock signal, SCL. The hold time  $t_{hold}$ , is the time data, SDA, must be stable after the rising edge of the clock signal, SCL. If these times are violated incorrect data may be captured or meta-stability may occur and the bus communication may fail. All standard SMBus protocols must be followed, including clock stretching. This product supports the BUSY flag in the status commands to indicate product being too busy for SMBus response. A bus-free time delay between every SMBus transmission (between every stop & start condition) must occur. Refer to the SMBus specification, for SMBus electrical and timing requirements.

Note that an additional delay of 5 ms has to be inserted in case of storing the RAM content into the internal non-volatile memory.



Set-up and hold timing diagramm

## Monitoring via PMBus

It is possible to continuously monitor a wide variety of parameters through the PMBus interface. These include, but are not limited to, the parameters listed in the table below.

| Parameter           | PMBus command      |
|---------------------|--------------------|
| Input voltage       | READ_VIN           |
| Output voltage      | READ_VOUT          |
| Output current      | READ_IOUT          |
| Temperature*        | READ_TEMPERATURE_1 |
| Switching frequency | READ_FREQUENCY     |
| Duty cycle          | READ_DUTY_CYCLE    |

\* reports the temperature from temperature sensor set in command 0xDC, internal (controller IC)/external (temp. sensor)

## Monitoring faults

Fault conditions can be detected using the SALERT pin, which will be asserted low when any number of pre-configured fault or warning conditions occurs. The SALERT pin will be held low until faults and/or warnings are cleared by the CLEAR\_FAULTS command, or until the output voltage has been re-enabled. It is possible to mask which fault conditions should not assert the SALERT pin by the command SMBALERT\_MASK. In response to the SALERT signal, the user may read a number of status commands to find out what fault or warning condition occurred, see table below.

| Fault and warning    | PMBus command              |
|----------------------|----------------------------|
| Overview, Power Good | STATUS_BYTE<br>STATUS_WORD |
| Output voltage level | STATUS_VOUT                |
| Output current level | STATUS_IOUT                |
| Input voltage level  | STATUS_INPUT               |
| Temperature level    | STATUS_TEMPERATURE         |
| PMBus communication  | STATUS_CML                 |
| Miscellaneous        | STATUS_MFR_SPECIFIC        |



## General PMBus comand summary

PMBus signal interfaces characteristics

| Characteristic                                      | conditions   | minimum | typical                                | maximum | unit |
|---|--|---------|--|---------|------|
| <b>PMBus signal interface characteristics</b>       |  |         |  |         |      |
| Input clock frequency drift tolerance               | External sync.   | -4      |  | 4       | %    |
| Initialization time                                 | From VI > 27 V to ready to be enabled                      |         | 15                                     |         | ms   |
| Output voltage total on delay time                  | Enable by input voltage                                    |         | T <sub>INIT</sub> + T <sub>ONdel</sub> |         |      |
|   | Enable by RC or CTRL pin                                   |         | T <sub>ONdel</sub>                     |         |      |
| Logic output low signal level                       | SCL, DA, SYNC, GCB, SALERT, PG, sink/source current = 5 mA |         |  | 0.4     | V    |
| Logic output high signal level                      |  | 2.6     |  |         | V    |
| Logic output low sink current                       |  |         |  | 5       | mA   |
| Logic output high source current                    |  |         |  | 5       | mA   |
| Logic input low threshold                           | SCL, SDA, CTRL, SYNC                                       |         |  | 1.0     | V    |
| Logic input high threshold                          |  | 2.1     |  |         | V    |
| Logic pin input capacitance                         | SCL, SDA, CTRL, SYNC                                       |         | 1.5                                    |         | pF   |
| Supported SMBus operating frequency                 |  | 100     |  | 400     | kHz  |
| SMBus bus free time                                 | STOP bit to START bit                                      |         | 1.3                                    |         | μs   |
| SMBus SDA setup time from SCL                       |  |         | 100                                    |         | μs   |
| SMBus SDA hold time from SCL                        |  |         | 0                                      |         | ns   |
| SMBus START/STOP condition setup/hold time from SCL |  |         | 600                                    |         | ns   |
| SCL low period                                      |  | 1.3     |  |         | μs   |
| SCL high period                                     |  |         | 0.6                                    | 50      | μs   |

## BLACK BOX/EVENT READER

### Overview

A black box, or history event recorder, is provided to capture brick data at the time of fault occurrence. The intent is to assist in fault diagnosis.

Black box will respond to following faults: OVF, OCF, OTF. For each fault a block of data will be stored into a dedicated black box memory partition. This partition consists of 4KiB non-volatile memory and can store a total of 102 events. When the memory section for event recording is filled up, no more black box data can be stored.

When a fault occurs, the following data will be stored:

- Telemetry for Vin, Vout, Iout, temperature and duty
- All PMBus status registers
- Regulation state of module, current and prior to fault.
- Time stamp

If several subsequent faults of the same type occur only the first fault of same type will be recorded. Though, if fault is cleared e.g. with RC or PMBus a new fault of same type will activate a new recording.

All telemetry values are two's complement numbers:

| Telemetry      | #bits | LSB               |
|----------------|-------|-------------------|
| Input voltage  | 16    | 250 mV            |
| Output voltage | 16    | 488.28125 $\mu$ V |
| Output current | 16    | 500 mA            |
| Temperature    | 16    | 1°C               |
| Duty           | 16    | 1%                |

The PMBus status registers have the same form as their corresponding PMBus registers. See section 17 of PMBus specification part II rev 1.3 for details.

Regulation states upper 4 bits represent state prior to fault. Lower 4 bits represent current state.

| No. | State:     |
|-----|------------|
| 0   | IDLE       |
| 1   | TON_DELAY  |
| 2   | RAMP UP    |
| 3   | REGULATING |
| 4   | TOFF_DELAY |
| 5   | RAMP DOWN  |
| 6   | FAULT      |

## Black box/event reader

Time stamp:

| Name     | #bits | LSB             |
|----------|-------|-----------------|
| ticks_hi | 8     | ~1563.75 h      |
| ticks    | 32    | 1310.72 $\mu$ s |

Max: ~45years. Note, due to Non-Volatile memory, ticks counter will restart at 0 each time power is cycled.

### Method of retrieving event data

1. Read the number of total events by performing a **Read Word** on 0xDB (MFR\_EVENT\_INDEX). The index of the first event is 0 and the index of the last event is *number of total events - 1*.
2. Set the current index by performing a **Write Word** on 0xDB (MFR\_EVENT\_INDEX).
3. Read the event data by performing a **Block Read** on 0xD7 (READ\_EVENT). The format of the response data can be seen in the table below.
4. Unless done, choose a new index and continue from **2**.

READ\_EVENT response (Block Read 0xD7, 26 bytes):

| 0                | 7         | 8                  | 15           | 16               | 23           | 24          | 31           |
|------------------|-----------|--------------------|--------------|------------------|--------------|-------------|--------------|
| Index            |           |                    |              | V <sub>in</sub>  |              |             |              |
| V <sub>out</sub> |           |                    |              | I <sub>out</sub> |              |             |              |
| Temperature      |           |                    |              | Duty             |              |             |              |
| STATUS_WORD      |           |                    |              | STATUS_VOUT      |              | STATUS_IOUT |              |
| STATUS_INPUT     |           | STATUS_TEMPERATURE |              | STATUS_CML       |              | STATUS_MFR  |              |
| Error state      | Old state |                    | Ticks byte 4 |                  | Ticks byte 0 |             | Ticks byte 1 |
| Ticks byte 2     |           | Ticks byte 3       |              |                  |              |             |              |

## TECHNICAL REFERENCE DOCUMENT: SOLDERING

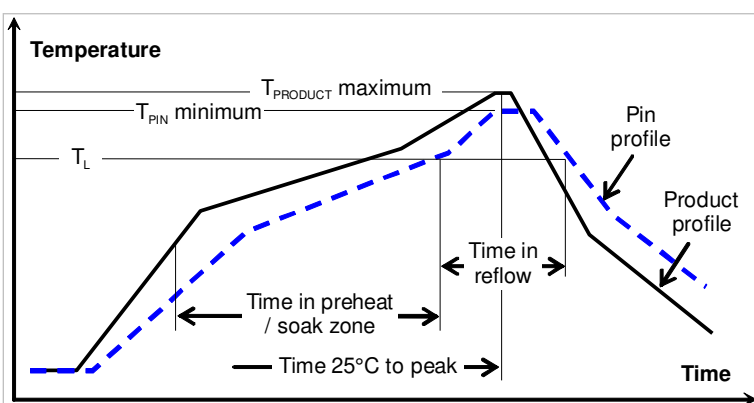
### Soldering information—hole mounted through pin-in-paste assembly

The pin-in-paste mount product is intended for forced convection or vapor phase reflow soldering in SnPb and Pb-free process.

Reflow soldering is not preferred for through-hole mounted power modules due to challenges resulting in reduced reliability. High temperature reflow soldering causing IMC layer thickness increase results in shorten solder joint lifetime. To avoid component or solder failure a module peak temperature higher than 245 degrees and above 217 degrees more than 90 seconds is not recommended. To prevent re-melt of module internal solder joints shielding cap is required during reflow process.

A no-clean flux is recommended to avoid entrapment of cleaning fluids in cavities inside the product or between the product and the host board, since cleaning residues may affect long time reliability and isolation voltage.

| General reflow process specification         |                      | SnPb eutectic | Pb-free    |
|--|----------------------|---------------|------------|
| Average temperature ( $T_{\text{product}}$ ) |                      | 3 °C/s max    | 3 °C/s max |
| Typical solder melting temp.                 | $T_L$                | 183 °C        | 221 °C     |
| Min. Reflow time above $T_L$                 | $T_{\text{pin}}$     | 60 s          | 60 s       |
| Min. pin temp.                               | $T_{\text{pin}}$     | 210 °C        | 235 °C     |
| Peak product temp.                           | $T_{\text{product}}$ | 225 °C        | 245 °C     |
| Average ramp-down ( $T_{\text{product}}$ )   |                      | 6°C/s max     | 6°C/s max  |
| Max. time 25° C to peak                      |                      | 6 minutes     | 8 minutes  |



Typical soldering profile

### Thermocoupler attachment

$T_{\text{PRODUCT}}$  IS MEASURED ON THE BASEPLATE TOP SIDE SINCE THIS WILL LIKELY BE THE WARMEST PART OF THE PRODUCT DURING THE REFLOW PROCESS.

$T_{\text{PIN}}$  TEMPERATURE IS MEASURED ON THE POWER MODULE OUTPUT POWER PINS SOLDER JOINTS AT THE CUSTOMER BOARD.

## Soldering information - hole mounting

The hole mounted product is intended for plated through hole mounting by wave or manual soldering. The pin temperature is specified to maximum to 270°C for maximum 10 seconds.

A maximum preheat rate of 4°C/s and maximum preheat temperature of 150°C is suggested. When soldering by hand, be careful to avoid direct contact between the hot soldering iron tip and the pins for more than a few seconds in order to prevent overheating.

A no-clean flux is recommended to avoid entrapment of cleaning fluids in cavities inside the product or between the product and the host board. The cleaning residues may affect long time reliability and isolation voltage.

## Product reflow classification

The product has been tested for the following:

### Pb-free solder classification

For Pb-free solder processes, the product is qualified for MSL 3 according to IPC/JEDEC standard J-STD-020C.

## Product reflow processes

### Lead-free (Pb-free) solder processes

For Pb-free solder processes, a pin temperature ( $T_{PIN}$ ) in excess of the solder melting temperature ( $T_L$ , 217 to 221°C for SnAgCu solder alloys) for more than 60 seconds and a peak temperature of 245°C on all solder joints is recommended to ensure a reliable solder joint

## Dry pack information

Products intended for Pb-free reflow soldering processes are delivered in standard moisture barrier bags according to IPC/JEDEC standard J-STD-033 (handling, packing, shipping and use of moisture/reflow sensitivity surface mount devices).

Using products in high temperature Pb-free soldering processes requires dry pack storage and handling. In case the products have been stored in an uncontrolled environment and no longer can be considered dry, floor life according to MSL 3, the modules must be baked according to J-STD-033.

## TECHNICAL REFERENCE DOCUMENT: SAFETY

### Safety specifications

Flex Power Modules' DC/DC converters and DC/DC regulators are designed in accordance with the safety standards *IEC 62368-1*, *EN 62368-1* and *UL 62368-1 Audio/video, information and communication technology equipment - Part 1: Safety requirements*

IEC/EN/UL 62368-1 contains requirements to prevent injury or damage due to the following hazards:

- Electrical shock
- Electrically-caused fire
- Injury caused by hazardous substances
- Mechanically-caused injury
- Skin burn
- Radiation-caused injury

On-board DC/DC converters, Power Interface Modules and DC/DC regulators are defined as component power supplies. As components they cannot fully comply with the provisions of any safety requirements without "conditions of acceptability". Clearance between conductors and between conductive parts of the component power supply and conductors on the board in the final product must meet the applicable safety requirements. Certain conditions of acceptability apply for component power supplies with limited stand-off (please refer to *Technical Specification under Mechanical Information* for further information). It is the responsibility of the installer to ensure that the final product housing these components complies with the requirements of all applicable safety standards and regulations for the final product.

Component power supplies for general use shall comply with the requirements in *IEC/EN/UL 62368-1*. Product related standards, e.g. *IEEE 802.3af Power over Ethernet*, and *ETS-300132-2 Power interface at the input to telecom equipment, operated by direct current (dc)* are based on *IEC/EN/UL 62368 -1* with regards to safety.

All Flex Power Modules' DC/DC converters, Power Interface Modules and DC/DC regulators are UL 62368-1 recognized and certified in accordance with *EN 62368-1*. The flammability rating for all construction parts of the products meet requirements for V-0 class material according to *IEC 62368 -11-10*, Fire hazard testing, test flames – 50 W horizontal and vertical flame test methods.

## Isolated DC/DC converters

The product may provide basic or functional insulation between input and output according to IEC/EN/UL 62368-1 different conditions shall be met if the output of a basic or a functional insulated product shall be considered as safety extra low voltage (SELV).

For basic insulated products the output is considered as safety extra low voltage (SELV) if one of the following condition is met:

- The input source provides supplementary or double or reinforced insulation from the AC mains according to IEC/EN/UL 62368-1.
- The input source provides functional or basic insulation from the AC mains and the product's output is reliably connected to protective earth according to IEC/EN/UL 62368-1.

For functional insulated products the output is considered as safety extra low voltage (SELV) if one of the following conditions is met:

- The input source provides double or reinforced insulation from the AC mains according to IEC/EN/UL 62368-1.
- The input source provides basic or supplementary insulation from the AC mains and the product's output is reliably connected to protective earth according to IEC/EN/UL 62368 -1.
- The input source is reliably connected to protective earth and provides basic or supplementary insulation according to IEC/EN/UL 62368 -1 and the maximum input source voltage is 60 Vdc.

Galvanic isolation between input and output is verified in an electric strength test and the isolation (VISO) meets the voltage strength requirements for basic insulation according to IEC/EN/UL 62368-1.

It is recommended to use slow blow fuses at the input of each DC/DC converter. If an input filter is used in the circuit the fuse should be placed in front of the input filter. In the rare event of a component problem that imposes a short circuit on the input source, this fuse will provide the following functions:

- Isolate the fault from the input power source so as not to affect the operation of other parts of the system
- Protect the distribution wiring from excessive current and power loss thus preventing hazardous overheating

## Technical Reference PMBus BMR 350 2100/031

This appendix contains a detailed reference of the PMBus commands supported by the product.

### Data Formats

The products make use of a few standardized numerical formats, along with custom data formats. A detailed walkthrough of the above formats is provided in AN304, as well as in sections 7 and 8 of the PMBus Specification Part II. The custom data formats vary depending on the command, and are detailed in the command description.

### Standard Commands

The functionality of commands with code 0x00 to 0xCF is usually based on the corresponding command specification provided in the PMBus Standard Specification Part II (see Power System Management Bus Protocol Documents below). However there might be different interpretations of the PMBus Standard Specification or only parts of the Standard Specification applied, thus the detailed command description below should always be consulted.

### Forum Websites

The System Management Interface Forum (SMIF)

<http://www.powersig.org/>

The System Management Interface Forum (SMIF) supports the rapid advancement of an efficient and compatible technology base that promotes power management and systems technology implementations. The SMIF provides a membership path for any company or individual to be active participants in any or all of the various working groups established by the implementer forums.

Power Management Bus Implementers Forum  
(PMBUS-IF)

<http://pmbus.org/>

The PMBus-IF supports the advancement and early adoption of the PMBus protocol for power management. This website offers recent PMBus specification documents, PMBus articles, as well as upcoming PMBus presentations and seminars, PMBus Document Review Board (DRB) meeting notes, and other PMBus related news.

### PMBus – Power System Management Bus Protocol Documents

These specification documents may be obtained from the PMBus-IF website described above. These are required reading for complete understanding of the PMBus implementation. This appendix will not re-address all of the details contained within the two PMBus Specification documents.

Specification Part I – General Requirements Transport And Electrical Interface

Includes the general requirements, defines the transport and electrical interface and timing requirements of hard wired signals.

Specification Part II – Command Language

Describes the operation of commands, data formats, fault management and defines the command language used with the PMBus.

### SMBus – System Management Bus Documents

System Management Bus Specification, Version 2.0, August 3, 2000

This specification specifies the version of the SMBus on which Revision 1.2 of the PMBus Specification is based. This specification is freely available from the System Management Interface Forum Web site at:

<http://www.smbus.org/specs/>



## PMBus Command Summary and Factory Default Values of Standard Configuration

The factory default values provided in the table below are valid for the Standard configuration. Factory default values for other configurations can be found using the Flex Power Designer tool.

| Code | Name   | Data Format      | Factory Default Value<br>Standard<br>Configuration<br>BMR350XX00/031 R1 | Min Set<br>Value | Max Set<br>Value | Unit       |
|------|--|------------------|---|------------------|------------------|------------|
| 0x01 | OPERATION  | R/W Byte         | 0x80  |                  |                  |            |
| 0x02 | ON_OFF_CONFIG  | R/W Byte         | 0x1F  |                  |                  |            |
| 0x03 | CLEAR_FAULTS   | Send Byte        |   |                  |                  |            |
| 0x12 | RESTORE_DEFAULT_ALL                                  | Send Byte        |   |                  |                  |            |
| 0x15 | STORE_USER_ALL                                       | Send Byte        |   |                  |                  |            |
| 0x16 | RESTORE_USER_ALL                                     | Send Byte        |   |                  |                  |            |
| 0x19 | CAPABILITY   | Read Byte        |   |                  |                  |            |
| 0x1B | SMBALERT_MASK_VOUT<br>(STATUS_VOUT)                  | SMBAlert<br>Mask | 0x00  |                  |                  |            |
| 0x1B | SMBALERT_MASK_IOUT<br>(STATUS_IOUT)                  | SMBAlert<br>Mask | 0x00  |                  |                  |            |
| 0x1B | SMBALERT_MASK_INPUT<br>(STATUS_INPUT)                | SMBAlert<br>Mask | 0x00  |                  |                  |            |
| 0x1B | SMBALERT_MASK_TEMPERATU<br>RE (STATUS_TEMPERATURE)   | SMBAlert<br>Mask | 0x00  |                  |                  |            |
| 0x1B | SMBALERT_MASK_CML<br>(STATUS_CML)                    | SMBAlert<br>Mask | 0x00  |                  |                  |            |
| 0x1B | SMBALERT_MASK_OTHER<br>(STATUS_OTHER)                | SMBAlert<br>Mask | 0x00  |                  |                  |            |
| 0x1B | SMBALERT_MASK_MFR_SPECIFI<br>C (STATUS_MFR_SPECIFIC) | SMBAlert<br>Mask | 0x00  |                  |                  |            |
| 0x20 | VOUT_MODE  | Read Byte        | 0x15  |                  |                  |            |
| 0x21 | VOUT_COMMAND   | R/W Word         | 0x61EC  | 12.24            | 8                | 13.2<br>V  |
| 0x22 | VOUT_TRIM  | R/W Word         | 0x0000  | 0.00             |                  | V          |
| 0x23 | VOUT_CAL_OFFSET                                      | R/W Word         | Unit Specific   |                  |                  |            |
| 0x24 | VOUT_MAX   | R/W Word         | 0x7333  | 14.40            | 0                | 16<br>V    |
| 0x25 | VOUT_MARGIN_HIGH                                     | R/W Word         | 0x699A  | 13.20            | 0                | 16<br>V    |
| 0x26 | VOUT_MARGIN_LOW                                      | R/W Word         | 0x5666  | 10.80            | 0                | 16<br>V    |
| 0x27 | VOUT_TRANSITION_RATE                                 | R/W Word         | 0xE810  | 2.00             |                  | V/ms       |
| 0x28 | VOUT_DROOP   | R/W Word         | 0xE015  | 1.31             |                  | mV/<br>A   |
| 0x2B | VOUT_MIN   | R/W Word         | 0x0000  | 0.00             |                  | V          |
| 0x32 | MAX_DUTY   | R/W Word         | 0xF186  | 97.50            | 0                | 100<br>%   |
| 0x33 | FREQUENCY_SWITCH                                     | R/W Word         | 0x084B  | 150.00           | 135              | 165<br>kHz |
| 0x35 | VIN_ON   | R/W Word         | 0x0025  | 37.00            | 30               | 60<br>V    |
| 0x36 | VIN_OFF  | R/W Word         | 0x0020  | 32.00            | 30               | 60<br>V    |
| 0x37 | INTERLEAVE   | R/W Word         | 0x0000  |                  |                  |            |
| 0x39 | IOUT_CAL_OFFSET                                      | Read Word        | Unit Specific   |                  |                  |            |
| 0x40 | VOUT_OV_FAULT_LIMIT                                  | R/W Word         | 0x7CCD  | 15.60            | 0                | 16<br>V    |
| 0x41 | VOUT_OV_FAULT_RESPONSE                               | R/W Byte         | 0xB8  |                  |                  |            |
| 0x42 | VOUT_OV_WARN_LIMIT                                   | R/W Word         | 0x7800  | 15.00            | 0                | 16<br>V    |
| 0x43 | VOUT_UV_WARN_LIMIT                                   | R/W Word         | 0x0001  | 0.00             | 0                | 16<br>V    |
| 0x44 | VOUT_UV_FAULT_LIMIT                                  | R/W Word         | 0x0000  | 0.00             | 0                | 16<br>V    |
| 0x45 | VOUT_UV_FAULT_RESPONSE                               | R/W Byte         | 0x00  |                  |                  |            |
| 0x46 | IOUT_OC_FAULT_LIMIT                                  | R/W Word         | 0x006E  | 110.00           | 0                | 255<br>A   |
| 0x47 | IOUT_OC_FAULT_RESPONSE                               | R/W Byte         | 0xDE  |                  |                  |            |

|      |                        |             |  |         |     |      |    |
|------|------------------------|-------------|--|---------|-----|------|----|
| 0x48 | IOUT_OC_LV_FAULT_LIMIT | R/W Word    | 0x1800   | 3.00    |     |      | V  |
| 0x4A | IOUT_OC_WARN_LIMIT     | R/W Word    | 0x0069   | 105.00  | 0   | 255  | A  |
| 0x4B | IOUT_UC_FAULT_LIMIT    | R/W Word    | 0x07DD   | -35.00  |     |      | A  |
| 0x4C | IOUT_UC_FAULT_RESPONSE | R/W Byte    | 0xB8   |         |     |      |    |
| 0x4F | OT_FAULT_LIMIT         | R/W Word    | 0x0082   | 130.00  | -50 | 150  | °C |
| 0x50 | OT_FAULT_RESPONSE      | R/W Byte    | 0xC0   |         |     |      |    |
| 0x51 | OT_WARN_LIMIT          | R/W Word    | 0x005A   | 90.00   | -50 | 150  | °C |
| 0x52 | UT_WARN_LIMIT          | R/W Word    | 0x0FEC   | -40.00  | -50 | 150  | °C |
| 0x53 | UT_FAULT_LIMIT         | R/W Word    | 0x0FE7   | -50.00  | -50 | 150  | °C |
| 0x54 | UT_FAULT_RESPONSE      | R/W Byte    | 0x00   |         |     |      |    |
| 0x55 | VIN_OV_FAULT_LIMIT     | R/W Word    | 0xF154   | 85.00   | 0   | 128  | V  |
| 0x56 | VIN_OV_FAULT_RESPONSE  | R/W Byte    | 0xB8   |         |     |      |    |
| 0x57 | VIN_OV_WARN_LIMIT      | R/W Word    | 0xF104   | 65.00   | 0   | 128  | V  |
| 0x58 | VIN_UV_WARN_LIMIT      | R/W Word    | 0x0025   | 37.00   | 0   | 128  | V  |
| 0x59 | VIN_UV_FAULT_LIMIT     | R/W Word    | 0x0023   | 35.00   | 0   | 128  | V  |
| 0x5A | VIN_UV_FAULT_RESPONSE  | R/W Byte    | 0xBC   |         |     |      |    |
| 0x5E | POWER_GOOD_ON          | R/W Word    | 0x5C00   | 11.50   | 0   | 16   | V  |
| 0x5F | POWER_GOOD_OFF         | R/W Word    | 0x5666   | 10.80   | 0   | 16   | V  |
| 0x60 | TON_DELAY              | R/W Word    | 0x000F   | 15.00   | 0   | 1023 | ms |
| 0x61 | TON_RISE               | R/W Word    | 0xF028   | 10.00   | 0   | 1023 | ms |
| 0x62 | TON_MAX_FAULT_LIMIT    | R/W Word    | 0xF3FC   | 255.00  |     |      | ms |
| 0x63 | TON_MAX_FAULT_RESPONSE | R/W Byte    | 0x00   |         |     |      |    |
| 0x64 | TOFF_DELAY             | R/W Word    | 0x0000   | 0.00    | 0   | 1023 | ms |
| 0x65 | TOFF_FALL              | R/W Word    | 0xF028   | 10.00   | 0   | 1023 | ms |
| 0x66 | TOFF_MAX_WARN_LIMIT    | R/W Word    | 0xF0FF   | 63.75   |     |      | ms |
| 0x6A | POUT_OP_WARN_LIMIT     | R/W Word    | 0x13FF   | 4092.00 |     |      | W  |
| 0x6B | PIN_OP_WARN_LIMIT      | R/W Word    | 0x13FF   | 4092.00 |     |      | W  |
| 0x78 | STATUS_BYTE            | Read Byte   |  |         |     |      |    |
| 0x79 | STATUS_WORD            | Read Word   |  |         |     |      |    |
| 0x7A | STATUS_VOUT            | Read Byte   |  |         |     |      |    |
| 0x7B | STATUS_IOUT            | Read Byte   |  |         |     |      |    |
| 0x7C | STATUS_INPUT           | Read Byte   |  |         |     |      |    |
| 0x7D | STATUS_TEMPERATURE     | Read Byte   |  |         |     |      |    |
| 0x7E | STATUS_CML             | Read Byte   |  |         |     |      |    |
| 0x7F | STATUS_OTHER           | Read Byte   |  |         |     |      |    |
| 0x80 | STATUS_MFR_SPECIFIC    | Read Byte   |  |         |     |      |    |
| 0x88 | READ_VIN               | Read Word   |  |         |     |      |    |
| 0x8B | READ_VOUT              | Read Word   |  |         |     |      |    |
| 0x8C | READ_IOUT              | Read Word   |  |         |     |      |    |
| 0x8D | READ_TEMPERATURE_1     | Read Word   |  |         |     |      |    |
| 0x94 | READ_DUTY_CYCLE        | Read Word   |  |         |     |      |    |
| 0x95 | READ_FREQUENCY         | Read Word   |  |         |     |      |    |
| 0x98 | PMBUS_REVISION         | Read Byte   |  |         |     |      |    |
| 0x99 | MFR_ID                 | R/W Block12 | Unit Specific  |         |     |      |    |
| 0x9A | MFR_MODEL              | R/W Block20 | Unit Specific  |         |     |      |    |
| 0x9B | MFR_REVISION           | R/W Block12 | Unit Specific  |         |     |      |    |
| 0x9C | MFR_LOCATION           | R/W Block12 | Unit Specific  |         |     |      |    |
| 0x9D | MFR_DATE               | R/W Block12 | Unit Specific  |         |     |      |    |
| 0x9E | MFR_SERIAL             | R/W Block20 | Unit Specific  |         |     |      |    |
| 0xB0 | USER_DATA_00           | R/W Block16 | Unit Specific  |         |     |      |    |
| 0xC8 | FW_CONFIG_FAULTS       | R/W Block25 | 0x000000000000000000<br>00000000200000000000<br>000000000008 |         |     |      |    |
| 0xC9 | FW_CONFIG_PMBUS        | R/W Block11 | 0x00000000B800806001<br>1000                                 |         |     |      |    |

|      |                                 |             |               |      |  |  |          |
|------|---------------------------------|-------------|---------------|------|--|--|----------|
| 0xCA | MFR_IOUT_OC_FAST_FAULT_RESPONSE | R/W Byte    | 0xDE          |      |  |  |          |
| 0xD1 | MFR_IOUT_OC_FAST_FAULT_LIMIT    | R/W Word    | 0x0079        | 121  |  |  | A        |
| 0xD7 | MFR_READ_EVENT                  | R/W Block26 |               |      |  |  |          |
| 0xDA | MFR_ISHARE_THRESHOLD            | R/W Word    | 0xF801        | 0.50 |  |  | A        |
| 0xDB | MFR_EVENT_INDEX                 | R/W Word    |               |      |  |  |          |
| 0xDC | MFR_SELECT_TEMPERATURE_SENSOR   | R/W Byte    | 0x01          |      |  |  |          |
| 0xE0 | MFR_FLEX_FIRMWARE_CMD           | R/W Block8  |               |      |  |  |          |
| 0xE8 | MFR_FILTER_COEFF                | R/W Block4  | 0x3C532A28    |      |  |  |          |
| 0xEA | MFR_IOUT_APC                    | Read Word   | Unit Specific |      |  |  |          |
| 0xF9 | MFR_MULTI_PIN_CONFIG            | R/W Word    | 0x0206        |      |  |  |          |
| 0xFC | MFR_ADDED_DROOP_DURING_RAMP     | R/W Word    | 0x0002        | 2.00 |  |  | mV/<br>A |

**PMBus Command Details****OPERATION (0x01)**

Description: Sets the desired PMBus enable and margin operations.

| Bit | Function     | Description  | Value | Function      | Description   |
|-----|--------------|--|-------|---------------|---|
| 7:6 | Enable       | Make the device enable or disable.                       | 00    | Immediate Off | Disable Immediately without sequencing.   |
|     |              |  | 01    | Soft Off      | Disable "Softly" with sequencing.   |
|     |              |  | 10    | Enable        | Enable device to the desired margin state.  |
| 5:4 | Margin       | Select between margin high/low states or nominal output. | 00    | Nominal       | Operate at nominal output voltage.  |
|     |              |  | 01    | Margin Low    | Operate at margin low voltage set in VOUT_MARGIN_LOW.   |
|     |              |  | 10    | Margin High   | Operate at margin high voltage set in VOUT_MARGIN_HIGH.   |
| 3:2 | Act on Fault | Set 10b to act on fault or set to 01b to ignore fault.   | 01    | Ignore Faults | Ignore Faults when in a margined state. The overvoltage/undervoltage warnings and faults are ignored.   |
|     |              |  | 10    | Act on Faults | Act on Faults when in a margined state. The device will handle appropriate overvoltage/undervoltage warnings and faults and respond as programmed by the warning limit or fault response command. |

**ON\_OFF\_CONFIG (0x02)**

Description: Configures how the device is controlled by the CONTROL pin and the PMBus.

| Bit | Function          | Description   | Value | Function            | Description  |
|-----|-------------------|---|-------|---------------------|--|
| 4   | Powerup Operation | Sets the default to either operate any time power is present or for the on/off to be controlled by CONTROL pin and serial bus commands. | 0     | Enable Always       | Unit powers up any time power is present regardless of state of the CONTROL pin, taking the RC configuration into account, see command 0xE3. |
|     |                   |   | 1     | Enable pin or PMBus | Unit does not power up until commanded by the CONTROL pin and OPERATION command.   |
| 3   | PMBus Enable Mode | Controls how the unit responds to commands received via the serial bus.   | 0     | Ignore PMBus        | Unit ignores the on/off portion of the OPERATION command from serial bus.  |
|     |                   |   | 1     | Use PMBus           | To start, the unit requires that the on/off portion of the OPERATION command is instructing the unit to run.                                 |

|   |                     |  |   |             |   |
|---|---------------------|--|---|-------------|---|
| 2 | Enable Pin Mode     | Controls how the unit responds to the CONTROL pin.       | 0 | Ignore pin  | Unit ignores the CONTROL/Enable pin.  |
|   |                     |  | 1 | Use pin     | Unit requires the CONTROL pin to be asserted to start the unit.   |
| 1 | Enable Pin Polarity | Polarity of the CONTROL pin.                             | 0 | Active High | Enable pin will cause device to enable when driven high.  |
|   |                     |  | 1 | Active Low  | Enable pin will cause device to enable when driven low.   |
| 0 | Disable Action      | CONTROL pin action when commanding the unit to turn off. | 0 | Soft Off    | Use the programmed turn off delay and fall time.  |
|   |                     |  | 1 | Imm. Off    | Turn off the output and stop transferring energy to the output as fast as possible. The device's product literature shall specify whether or not the device sinks current to decrease the output voltage fall time. |

**CLEAR\_FAULTS (0x03)**

Description: Clears all fault status bits

**RESTORE\_DEFAULT\_ALL (0x12)**

Description: Commands the device to restore its configuration from the Default Store.

**STORE\_USER\_ALL (0x15)**

Description: Stores, at the USER level, all PMBus values that were changed since the last restore command.

**RESTORE\_USER\_ALL (0x16)**

Description: Restores PMBus settings that were stored using STORE\_USER\_ALL. This command is automatically performed at power up.

**CAPABILITY (0x19)**

Description: This command provides a way for a host system to determine some key capabilities of a PMBus device.

| Bit | Function              | Description            | Value | Function      | Description  |
|-----|-----------------------|------------------------|-------|---------------|--|
| 7   | Packet Error Checking | Packet error checking. | 00    | Not Supported | Packet Error Checking not supported.   |
|     |                       |                        | 01    | Supported     | Packet Error Checking is supported.  |
| 6:5 | Maximum Bus Speed     | Maximum bus speed.     | 00    | 100kHz        | Maximum supported bus speed is 100 kHz.  |
|     |                       |                        | 01    | 400kHz        | Maximum supported bus speed is 400 kHz.  |
|     |                       |                        | 10    | 1MHz          | Maximum supported bus speed is 1 MHz.  |
| 4   | Smbalert              | SMBALERT               | 00    | No Smbalert   | The device does not have a SMBALERT# pin and does not support the SMBus Alert Response protocol. |
|     |                       |                        | 01    | Have Smbalert | The device does have a SMBALERT# pin and does support the SMBus Alert Response protocol.         |

|   |                |                 |   |   |   |
|---|----------------|-----------------|---|---|---|
| 3 | Numeric Format | Numeric format. | 0 | LINEAR or DIRECT Format                   | Numeric data is in LINEAR or DIRECT format.                   |
|   |                |                 | 1 | IEEE Half Precision Floating Point Format | Numeric data is in IEEE half precision floating point format. |
| 2 | AVSBus Support | AVSBus support. | 0 | AVSBus Not Supported                      | AVSBus not supported.   |
|   |                |                 | 1 | AVSBus Supported                          | AVSBus supported.   |

**SMBALERT\_MASK\_VOUT (0x1B)**

Status Registers: STATUS\_VOUT (0x7A)

Description: SMBALERT\_MASK bits for the STATUS\_VOUT command. The SMBALERT\_MASK command may be used to prevent a warning or fault condition from asserting the SALERT output signal.

| Bit | Function                  | Description | Value | Function    | Description |
|-----|---------------------------|-------------|-------|-------------|-------------|
| 7   | Vout Overvoltage Fault    |             | 0     | Pull SALERT |             |
|     |                           |             | 1     | Ignore      |             |
| 6   | Vout Overvoltage Warning  |             | 0     | Pull SALERT |             |
|     |                           |             | 1     | Ignore      |             |
| 5   | Vout Undervoltage Warning |             | 0     | Pull SALERT |             |
|     |                           |             | 1     | Ignore      |             |
| 4   | Vout Undervoltage Fault   |             | 0     | Pull SALERT |             |
|     |                           |             | 1     | Ignore      |             |
| 3   | Vout Max Warning          |             | 0     | Pull SALERT |             |
|     |                           |             | 1     | Ignore      |             |
| 2   | Ton Max Fault             |             | 0     | Pull SALERT |             |
|     |                           |             | 1     | Ignore      |             |
| 1   | Toff Max Warning          |             | 0     | Pull SALERT |             |
|     |                           |             | 1     | Ignore      |             |

**SMBALERT\_MASK\_IOUT (0x1B)**

Status Registers: STATUS\_IOUT (0x7B)

Description: SMBALERT\_MASK bits for the STATUS\_IOUT command. The SMBALERT\_MASK command may be used to prevent a warning or fault condition from asserting the SALERT output signal.

| Bit | Function                               | Description | Value | Function    | Description |
|-----|--|-------------|-------|-------------|-------------|
| 7   | Iout Overcurrent Fault                 |             | 0     | Pull SALERT |             |
|     |  |             | 1     | Ignore      |             |
| 6   | Iout Overcurrent And Low Voltage Fault |             | 0     | Pull SALERT |             |
|     |  |             | 1     | Ignore      |             |
| 5   | Iout Over Current Warning              |             | 0     | Pull SALERT |             |
|     |  |             | 1     | Ignore      |             |
| 4   | Iout Undercurrent Fault                |             | 0     | Pull SALERT |             |
|     |  |             | 1     | Ignore      |             |

**SMBALERT\_MASK\_INPUT (0x1B)**

Status Registers: STATUS\_INPUT (0x7C)

Description: SMBALERT\_MASK bits for the STATUS\_INPUT command. The SMBALERT\_MASK command may be used to prevent a warning or fault condition from asserting the SALERT output signal.

| Bit | Function                       | Description | Value | Function    | Description |
|-----|--------------------------------|-------------|-------|-------------|-------------|
| 7   | Vin<br>Overvoltage<br>Fault    |             | 0     | Pull SALERT |             |
|     |                                |             | 1     | Ignore      |             |
| 6   | Vin<br>Overvoltage<br>Warning  |             | 0     | Pull SALERT |             |
|     |                                |             | 1     | Ignore      |             |
| 5   | Vin<br>Undervoltage<br>Warning |             | 0     | Pull SALERT |             |
|     |                                |             | 1     | Ignore      |             |
| 4   | Vin<br>Undervoltage<br>Fault   |             | 0     | Pull SALERT |             |
|     |                                |             | 1     | Ignore      |             |
| 3   | Insufficient<br>Vin            |             | 0     | Pull SALERT |             |
|     |                                |             | 1     | Ignore      |             |

**SMBALERT\_MASK\_TEMPERATURE (0x1B)**

Status Registers: STATUS\_TEMPERATURE (0x7D)

Description: SMBALERT\_MASK bits for the STATUS\_TEMPERATURE command. The SMBALERT\_MASK command may be used to prevent a warning or fault condition from asserting the SALERT output signal.

| Bit | Function                        | Description | Value | Function    | Description |
|-----|---------------------------------|-------------|-------|-------------|-------------|
| 7   | Overtempera<br>ture Fault       |             | 0     | Pull SALERT |             |
|     |                                 |             | 1     | Ignore      |             |
| 6   | Overtempera<br>ture Warning     |             | 0     | Pull SALERT |             |
|     |                                 |             | 1     | Ignore      |             |
| 5   | Undertemper<br>ature<br>Warning |             | 0     | Pull SALERT |             |
|     |                                 |             | 1     | Ignore      |             |
| 4   | Undertemper<br>ature Fault      |             | 0     | Pull SALERT |             |
|     |                                 |             | 1     | Ignore      |             |

**SMBALERT\_MASK\_CML (0x1B)**

Status Registers: STATUS\_CML (0x7E)

Description: SMBALERT\_MASK bits for the STATUS\_CML command. The SMBALERT\_MASK command may be used to prevent a warning or fault condition from asserting the SALERT output signal.

| Bit | Function   | Description | Value | Function    | Description |
|-----|--|-------------|-------|-------------|-------------|
| 7   | Invalid Or<br>Unsupported<br>Command<br>Received |             | 0     | Pull SALERT |             |
|     |  |             | 1     | Ignore      |             |
| 6   | Invalid Or<br>Unsupported<br>Data<br>Received    |             | 0     | Pull SALERT |             |
|     |  |             | 1     | Ignore      |             |
| 5   | Packet Error<br>Check Failed                     |             | 0     | Pull SALERT |             |
|     |  |             | 1     | Ignore      |             |
| 4   | Memory Fault<br>Detected                         |             | 0     | Pull SALERT |             |
|     |  |             | 1     | Ignore      |             |

|   |                           |  |   |             |  |
|---|---------------------------|--|---|-------------|--|
| 3 | Processor Fault Detected  |  | 0 | Pull SALERT |  |
|   |                           |  | 1 | Ignore      |  |
| 1 | Other Communication Fault |  | 0 | Pull SALERT |  |
|   |                           |  | 1 | Ignore      |  |
| 0 | Memory Or Logic Fault     |  | 0 | Pull SALERT |  |
|   |                           |  | 1 | Ignore      |  |

**SMBALERT\_MASK\_OTHER (0x1B)**

Status Registers: STATUS\_OTHER (0x7F)

Description: SMBALERT\_MASK bits for the STATUS\_OTHER command. The SMBALERT\_MASK command may be used to prevent a warning or fault condition from asserting the SALERT output signal.

| Bit | Description | Value | Function    | Description |
|-----|-------------|-------|-------------|-------------|
| 0   |             | 0     | Pull SALERT |             |
|     |             | 1     | Ignore      |             |

**SMBALERT\_MASK\_MFR\_SPECIFIC (0x1B)**

Status Registers: STATUS\_MFR\_SPECIFIC (0x80)

Description: SMBALERT\_MASK bits for the STATUS\_MFR\_SPECIFIC command. The SMBALERT\_MASK command may be used to prevent a warning or fault condition from asserting the SALERT output signal.

| Bit | Function                       | Description | Value | Function    | Description |
|-----|--------------------------------|-------------|-------|-------------|-------------|
| 7   | Sync Fault                     |             | 0     | Pull SALERT |             |
|     |                                |             | 1     | Ignore      |             |
| 6   | Iout Average Overcurrent Fault |             | 0     | Pull SALERT |             |
|     |                                |             | 1     | Ignore      |             |
| 5   | Iout Fast Overcurrent Fault    |             | 0     | Pull SALERT |             |
|     |                                |             | 1     | Ignore      |             |
| 4   | Short Circuit Protection Fault |             | 0     | Pull SALERT |             |
|     |                                |             | 1     | Ignore      |             |

**VOUT\_MODE (0x20)**

Description: Controls how future VOUT-related commands parameters will be interpreted.

| Bit | Function | Description  | Format         |
|-----|----------|--|----------------|
| 4:0 |          | Five bit two's complement EXPONENT for the MANTISSA delivered as the data bytes for VOUT_COMMAND in VOUT_LINEAR Mode, five bit VID code identifier per in VID Mode or always set to 00000b in Direct Mode. | Integer Signed |

| Bit | Function | Description  | Value | Function | Description         |
|-----|----------|--|-------|----------|---------------------|
| 7:5 |          | Set to 000b to select VOUT_LINEAR Mode (Five bit two's complement exponent for the MANTISSA delivered as the data bytes for an output voltage related command), set to 001b to select VID Mode (Five bit VID code identifier per) or set to 010b to select Direct Mode (Always set to 00000b). | 000   | Linear   | Linear Mode Format. |
|     |          |  | 001   | VID      | VID Mode.           |
|     |          |  | 010   | Direct   | Direct Mode.        |



**VOUT\_COMMAND (0x21)**

Description: Commands the device to transition to a new output voltage.

| Bit  | Description                                   | Format                         | Unit |
|------|---|--------------------------------|------|
| 15:0 | Sets the nominal value of the output voltage. | Vout Mode Unsigned (Exp = -11) | V    |

**VOUT\_TRIM (0x22)**

Description: Configures a fixed offset to be applied to the output voltage when enabled.

| Bit  | Description  | Format                       | Unit |
|------|--|------------------------------|------|
| 15:0 | Sets VOUT trim value. The two bytes are formatted as a two's complement binary mantissa, used in conjunction with the exponent set in VOUT_MODE. | Vout Mode Signed (Exp = -11) | V    |

**VOUT\_CAL\_OFFSET (0x23)**

Description: Vout calibration value. It is a signed number in Vout linear mode. The setting will be applied output voltage.

| Bit  | Description  | Format                       | Unit |
|------|--|------------------------------|------|
| 15:0 | Vout calibration value. It is a signed number in Vout linear mode. The setting will be applied output voltage. | Vout Mode Signed (Exp = -11) | V    |

**VOUT\_MAX (0x24)**

Description: Configures the maximum allowed output voltage.

| Bit  | Description   | Format                         | Unit |
|------|---|--------------------------------|------|
| 15:0 | Sets the maximum possible value setting of VOUT. The maximum VOUT_MAX setting is 110% of the pin-strap setting. | Vout Mode Unsigned (Exp = -11) | V    |

**VOUT\_MARGIN\_HIGH (0x25)**

Description: Configures the target for margin-up commands.

| Bit  | Description                                      | Format                         | Unit |
|------|--|--------------------------------|------|
| 15:0 | Sets the value of the VOUT during a margin high. | Vout Mode Unsigned (Exp = -11) | V    |

**VOUT\_MARGIN\_LOW (0x26)**

Description: Configures the target for margin-down commands.

| Bit  | Description                                     | Format                         | Unit |
|------|---|--------------------------------|------|
| 15:0 | Sets the value of the VOUT during a margin low. | Vout Mode Unsigned (Exp = -11) | V    |

**VOUT\_TRANSITION\_RATE (0x27)**

Description: Configures the transition time for margins and VCOMMAND output changes.

| Bit  | Description   | Format | Unit |
|------|---|--------|------|
| 15:0 | Sets the transition rate during margin or other change of VOUT. | Linear | V/ms |

**VOUT\_DROOP (0x28)**

Description: Configures the Isense voltage to load current ratio.

| Bit  | Description  | Format | Unit |
|------|--|--------|------|
| 15:0 | Sets the effective load line (V/I slope) for the device. | Linear | mV/A |

**VOUT\_MIN (0x2B)**

Description: This command is used to limit the minimum output voltage, irrespective of whatever voltage is commanded by a combination of VOUT\_COMMAND (or VOUT\_MARGIN\_HIGH or VOUT\_MARGIN\_LOW) and VOUT\_TRIM. The intent of this command is to provide a safeguard against a user accidentally setting the output voltage to a possibly destructive level rather than to be the primary output overprotection. The exponent is set by VOUT\_MODE. If an attempt is made to program the output voltage lower than the limit set by this command, this will flag a WARNING condition, but NOT a fault.

| Bit  | Description  | Format                                  | Unit |
|------|--|---|------|
| 15:0 | This command is used to limit the minimum output voltage | Vout<br>Mode<br>Unsigned<br>(Exp = -11) | V    |

**MAX\_DUTY (0x32)**

Description: Configures the maximum allowed duty-cycle.

| Bit  | Description   | Format | Unit |
|------|---|--------|------|
| 15:0 | Sets the maximum allowable duty cycle of the switching frequency. | Linear | %    |

**FREQUENCY\_SWITCH (0x33)**

Description: Controls the switching frequency in 1kHz steps.

| Bit  | Description                   | Format | Unit |
|------|-------------------------------|--------|------|
| 15:0 | Sets the switching frequency. | Linear | kHz  |

**VIN\_ON (0x35)**

Description: The VIN\_ON command sets the value of the input voltage, in volts, at which the unit should start power conversion.

| Bit  | Description                | Format | Unit |
|------|----------------------------|--------|------|
| 15:0 | Sets the VIN ON threshold. | Linear | V    |

**VIN\_OFF (0x36)**

Description: The VIN\_OFF command sets the value of the input voltage, in volts, at which the unit, once operation has started, should stop power conversion.

| Bit  | Description                 | Format | Unit |
|------|-----------------------------|--------|------|
| 15:0 | Sets the VIN OFF threshold. | Linear | V    |

**INTERLEAVE (0x37)**

Description: Configures the phase offset with respect to a common SYNC clock. When multiple products share a common DC input supply, spreading of the switching phases between the products can be utilized. This reduces the input capacitance requirements and efficiency losses, since the peak current drawn from the input supply is effectively spread out over the whole switch period. If two or more units have their outputs connected in parallel, interleaving will reduce ripple currents. This requires that the products are synchronized using the SYNC pin.

| Bit  | Function        | Description   | Format           |
|------|-----------------|---|------------------|
| 11:8 | Group ID Number | Value 0-15. Sets an ID number to a group of interleaved rails.  | Integer Unsigned |
| 7:4  | Number of Rails | Value 0-15. Sets the number of units in the group, including the SYNC OUT product.                                    | Integer Unsigned |
| 3:0  | Rail Position   | Value 0-15. Sets the interleave order for this unit. The product configured to SYNC OUT shall be assigned to number 0 | Integer Unsigned |

**IOUT\_CAL\_OFFSET (0x39)**

Description: Sets the current-sense offset.

| Bit  | Description  | Format | Unit |
|------|--|--------|------|
| 15:0 | Sets an offset to IOUT readings. Use to compensate for delayed measurements of current ramp. | Linear | A    |

**VOUT\_OV\_FAULT\_LIMIT (0x40)**

Description: Output over voltage fault limit.

| Bit  | Description                      | Format                         | Unit |
|------|----------------------------------|--------------------------------|------|
| 15:0 | Output over voltage fault limit. | Vout Mode Unsigned (Exp = -11) | V    |

**VOUT\_OV\_FAULT\_RESPONSE (0x41)**

Description: Output over voltage fault response.

| Bit | Function | Description | Value | Function                        | Description   |
|-----|----------|-------------|-------|---------------------------------|---|
| 7:6 | Response |             | 00    | Ignore Fault                    | The PMBus device continues operation without interruption.  |
|     |          |             | 01    | Perform Retries while Operating | The PMBus device continues operation for the delay time specified by bits [2:0] and the delay time unit specified for that particular fault. If the fault condition is still present at the end of the delay time, the unit responds as programmed in the Retry Setting (bits [5:3]). |
|     |          |             | 10    | Disable and retry               | The device shuts down (disables the output) and responds according to the retry setting in bits [5:3].  |

|     |         |   |     |                             |   |
|-----|---------|---|-----|-----------------------------|---|
|     |         | Describes the device interruption operation. 00b - The PMBus device continues operation without interruption. 01b - The PMBus device continues operation for the delay time specified by bits [2:0] and the delay time unit specified for that particular fault. If the fault condition is still present at the end of the delay time, the unit responds as programmed in the Retry Setting (bits [5:3]). 10b - The device shuts down (disables the output) and responds according to the Retry Setting in bits [5:3]. 11b - The device's output is disabled while the fault is present. Operation resumes and the output is enabled when the fault condition no longer exists. | 11  | Disable until Fault Cleared | A fault can be cleared in several ways: The bit is individually cleared, The device receives a CLEAR_FAULTS command, a RESET signal (if one exists) is asserted, the output is commanded through the CTRL pin, the OPERATION command, or the combined action of the CTRL pin and OPERATION command, to turn off and then to turn back on, or Bias power is removed from the PMBus device. |
| 5:3 | Retries | The device attempts to restart the number of times set by these bits. 000b means the device does not attempt a restart. 111b means the device attempts restarting continuously.   | 000 | Do Not Retry                | A zero value for the Retry Setting means that the unit does not attempt to restart. The output remains disabled until the fault is cleared (Section 10.7).  |
|     |         |   | 001 | Retry Once                  | The PMBus device attempts to restart 1 time. If the device fails to restart, it disables the output and remains off until the fault is cleared as described in Section 10.7. The time between the start of each attempt to restart is set by the value in bits [2:] along with the delay time unit specified for that particular fault.   |
|     |         |   | 010 | Retry Twice                 | The PMBus device attempts to restart 2 times. If the device fails to restart, it disables the output and remains off until the fault is cleared as described in Section 10.7. The time between the start of each attempt to restart is set by the value in bits [2:] along with the delay time unit specified for that particular fault.  |

|  |  |  |     |                    |  |
|--|--|--|-----|--------------------|--|
|  |  |  | 011 | Retry 3 times      | The PMBus device attempts to restart 3 times. If the device fails to restart, it disables the output and remains off until the fault is cleared as described in Section 10.7. The time between the start of each attempt to restart is set by the value in bits [2:] along with the delay time unit specified for that particular fault. |
|  |  |  | 100 | Retry 4 times      | The PMBus device attempts to restart 4 times. If the device fails to restart, it disables the output and remains off until the fault is cleared as described in Section 10.7. The time between the start of each attempt to restart is set by the value in bits [2:] along with the delay time unit specified for that particular fault. |
|  |  |  | 101 | Retry 5 times      | The PMBus device attempts to restart 5 times. If the device fails to restart, it disables the output and remains off until the fault is cleared as described in Section 10.7. The time between the start of each attempt to restart is set by the value in bits [2:] along with the delay time unit specified for that particular fault. |
|  |  |  | 110 | Retry 6 times      | The PMBus device attempts to restart 6 times. If the device fails to restart, it disables the output and remains off until the fault is cleared as described in Section 10.7. The time between the start of each attempt to restart is set by the value in bits [2:] along with the delay time unit specified for that particular fault. |
|  |  |  | 111 | Retry Continuously | The PMBus device attempts to restart continuously, without limitation, until it is commanded OFF (by the CONTROL pin or OPERATION command or both), bias power is removed, or another fault condition causes the unit to shut down.  |

|     |                           |  |   |     |  |
|-----|---------------------------|--|---|-----|--|
| 2:0 | Retry Time and Delay Time | Number of delay time units. Used for either the amount of time the device is to continue operating after a fault is detected or for the amount of time between attempts to restart. The time unit is set in register 0xC8. | 0 | 1   |  |
|     |                           |  | 1 | 2   |  |
|     |                           |  | 2 | 4   |  |
|     |                           |  | 3 | 8   |  |
|     |                           |  | 4 | 16  |  |
|     |                           |  | 5 | 32  |  |
|     |                           |  | 6 | 64  |  |
|     |                           |  | 7 | 128 |  |

**VOUT\_OV\_WARN\_LIMIT (0x42)**

Description: Output over voltage warning limit.

| Bit  | Description                        | Format                         | Unit |
|------|------------------------------------|--------------------------------|------|
| 15:0 | Output over voltage warning limit. | Vout Mode Unsigned (Exp = -11) | V    |

**VOUT\_UV\_WARN\_LIMIT (0x43)**

Description: Output under voltage warning limit.

| Bit  | Description                         | Format                         | Unit |
|------|-------------------------------------|--------------------------------|------|
| 15:0 | Output under voltage warning limit. | Vout Mode Unsigned (Exp = -11) | V    |

**VOUT\_UV\_FAULT\_LIMIT (0x44)**

Description: Output under voltage fault limit.

| Bit  | Description                       | Format                         | Unit |
|------|-----------------------------------|--------------------------------|------|
| 15:0 | Output under voltage fault limit. | Vout Mode Unsigned (Exp = -11) | V    |

**VOUT\_UV\_FAULT\_RESPONSE (0x45)**

Description: Output under voltage fault response.

| Bit | Function | Description | Value | Function                        | Description   |
|-----|----------|-------------|-------|---------------------------------|---|
| 7:6 | Response |             | 00    | Ignore Fault                    | The PMBus device continues operation without interruption.  |
|     |          |             | 01    | Perform Retries while Operating | The PMBus device continues operation for the delay time specified by bits [2:0] and the delay time unit specified for that particular fault. If the fault condition is still present at the end of the delay time, the unit responds as programmed in the Retry Setting (bits [5:3]). |

|     |         |   |     |                             |   |
|-----|---------|---|-----|-----------------------------|---|
|     |         | Describes the device interruption operation. 00b - The PMBus device continues operation without interruption. 01b - The PMBus device continues operation for the delay time specified by bits [2:0] and the delay time unit specified for that particular fault. If the fault condition is still present at the end of the delay time, the unit responds as programmed in the Retry Setting (bits [5:3]). 10b - The device shuts down (disables the output) and responds according to the Retry Setting in bits [5:3]. 11b - The device's output is disabled while the fault is present. Operation resumes and the output is enabled when the fault condition no longer exists. | 10  | Disable and retry           | The device shuts down (disables the output) and responds according to the retry setting in bits [5:3].  |
|     |         |   | 11  | Disable until Fault Cleared | A fault can be cleared in several ways: The bit is individually cleared, The device receives a CLEAR_FAULTS command, a RESET signal (if one exists) is asserted, the output is commanded through the CTRL pin, the OPERATION command, or the combined action of the CTRL pin and OPERATION command, to turn off and then to turn back on, or Bias power is removed from the PMBus device. |
| 5:3 | Retries | The device attempts to restart the number of times set by these bits. 000b means the device does not attempt a restart. 111b means the device attempts restarting continuously.   | 000 | Do Not Retry                | A zero value for the Retry Setting means that the unit does not attempt to restart. The output remains disabled until the fault is cleared (Section 10.7).  |
|     |         |   | 001 | Retry Once                  | The PMBus device attempts to restart 1 time. If the device fails to restart, it disables the output and remains off until the fault is cleared as described in Section 10.7. The time between the start of each attempt to restart is set by the value in bits [2:] along with the delay time unit specified for that particular fault.   |
|     |         |   | 010 | Retry Twice                 | The PMBus device attempts to restart 2 times. If the device fails to restart, it disables the output and remains off until the fault is cleared as described in Section 10.7. The time between the start of each attempt to restart is set by the value in bits [2:] along with the delay time unit specified for that particular fault.  |

|  |  |  |     |                    |  |
|--|--|--|-----|--------------------|--|
|  |  |  | 011 | Retry 3 times      | The PMBus device attempts to restart 3 times. If the device fails to restart, it disables the output and remains off until the fault is cleared as described in Section 10.7. The time between the start of each attempt to restart is set by the value in bits [2:] along with the delay time unit specified for that particular fault. |
|  |  |  | 100 | Retry 4 times      | The PMBus device attempts to restart 4 times. If the device fails to restart, it disables the output and remains off until the fault is cleared as described in Section 10.7. The time between the start of each attempt to restart is set by the value in bits [2:] along with the delay time unit specified for that particular fault. |
|  |  |  | 101 | Retry 5 times      | The PMBus device attempts to restart 5 times. If the device fails to restart, it disables the output and remains off until the fault is cleared as described in Section 10.7. The time between the start of each attempt to restart is set by the value in bits [2:] along with the delay time unit specified for that particular fault. |
|  |  |  | 110 | Retry 6 times      | The PMBus device attempts to restart 6 times. If the device fails to restart, it disables the output and remains off until the fault is cleared as described in Section 10.7. The time between the start of each attempt to restart is set by the value in bits [2:] along with the delay time unit specified for that particular fault. |
|  |  |  | 111 | Retry Continuously | The PMBus device attempts to restart continuously, without limitation, until it is commanded OFF (by the CONTROL pin or OPERATION command or both), bias power is removed, or another fault condition causes the unit to shut down.  |



|     |                           |  |   |     |  |
|-----|---------------------------|--|---|-----|--|
| 2:0 | Retry Time and Delay Time | Number of delay time units. Used for either the amount of time the device is to continue operating after a fault is detected or for the amount of time between attempts to restart. The time unit is set in register 0xC8. | 0 | 1   |  |
|     |                           |  | 1 | 2   |  |
|     |                           |  | 2 | 4   |  |
|     |                           |  | 3 | 8   |  |
|     |                           |  | 4 | 16  |  |
|     |                           |  | 5 | 32  |  |
|     |                           |  | 6 | 64  |  |
|     |                           |  | 7 | 128 |  |

**IOUT\_OC\_FAULT\_LIMIT (0x46)**

Description: Output over current limit.

| Bit  | Description                      | Format | Unit |
|------|----------------------------------|--------|------|
| 15:0 | Output over current fault limit. | Linear | A    |

**IOUT\_OC\_FAULT\_RESPONSE (0x47)**

Description: Output over current fault response.

| Bit | Function | Description   | Value | Function                        | Description   |
|-----|----------|---|-------|---------------------------------|---|
| 7:6 | Response | For all values of bits [7:6], the device: Sets the corresponding fault bit in the status registers and If the device supports notifying the host, it does so. | 00    | Ignore Fault                    | The PMBus device continues to operate indefinitely while maintaining the output current at the value set by IOUT_OC_FAULT_LIMIT without regard to the output voltage (known as constant-current or brickwall limiting).   |
|     |          |   | 01    | Conditioned constant current    | The PMBus device continues to operate indefinitely while maintaining the output current at the value set by IOUT_OC_FAULT_LIMIT as long as the output voltage remains above the minimum value specified by IOUT_OC_LV_FAULT_LIMIT. If the output voltage is pulled down to less than that value, then the PMBus device shuts down and responds according to the Retry setting in bits [5:3].                            |
|     |          |   | 10    | Delay w/ Const. Current & Retry | The PMBus device continues to operate, maintaining the output current at the value set by IOUT_OC_FAULT_LIMIT without regard to the output voltage, for the delay time set by bits [2:0] and the delay time units for specified in the IOUT_OC_FAULT_RESPONSE. If the device is still operating in current limiting at the end of the delay time, the device responds as programmed by the Retry Setting in bits [5:3]. |

|     |         |   |     |                   |  |
|-----|---------|---|-----|-------------------|--|
|     |         |   | 11  | Disable and Retry | The PMBus device shuts down and responds as programmed by the Retry Setting in bits [5:3].   |
| 5:3 | Retries | The device attempts to restart the number of times set by these bits. 000b means the device does not attempt a restart. 111b means the device attempts restarting continuously. | 000 | Do Not Retry      | A zero value for the Retry Setting means that the unit does not attempt to restart. The output remains disabled until the fault is cleared (Section 10.7).   |
|     |         |   | 001 | Retry Once        | The PMBus device attempts to restart 1 time. If the device fails to restart, it disables the output and remains off until the fault is cleared as described in Section 10.7. The time between the start of each attempt to restart is set by the value in bits [2:] along with the delay time unit specified for that particular fault.  |
|     |         |   | 010 | Retry Twice       | The PMBus device attempts to restart 2 times. If the device fails to restart, it disables the output and remains off until the fault is cleared as described in Section 10.7. The time between the start of each attempt to restart is set by the value in bits [2:] along with the delay time unit specified for that particular fault. |
|     |         |   | 011 | Retry 3 times     | The PMBus device attempts to restart 3 times. If the device fails to restart, it disables the output and remains off until the fault is cleared as described in Section 10.7. The time between the start of each attempt to restart is set by the value in bits [2:] along with the delay time unit specified for that particular fault. |

|     |                           |  |     |                    |  |
|-----|---------------------------|--|-----|--------------------|--|
|     |                           |  | 100 | Retry 4 times      | The PMBus device attempts to restart 4 times. If the device fails to restart, it disables the output and remains off until the fault is cleared as described in Section 10.7. The time between the start of each attempt to restart is set by the value in bits [2:] along with the delay time unit specified for that particular fault. |
|     |                           |  | 101 | Retry 5 times      | The PMBus device attempts to restart 5 times. If the device fails to restart, it disables the output and remains off until the fault is cleared as described in Section 10.7. The time between the start of each attempt to restart is set by the value in bits [2:] along with the delay time unit specified for that particular fault. |
|     |                           |  | 110 | Retry 6 times      | The PMBus device attempts to restart 6 times. If the device fails to restart, it disables the output and remains off until the fault is cleared as described in Section 10.7. The time between the start of each attempt to restart is set by the value in bits [2:] along with the delay time unit specified for that particular fault. |
|     |                           |  | 111 | Retry Continuously | The PMBus device attempts to restart continuously, without limitation, until it is commanded OFF (by the CONTROL pin or OPERATION command or both), bias power is removed, or another fault condition causes the unit to shut down.  |
| 2:0 | Retry Time and Delay Time | Number of delay time units. Used for either the amount of time the device is to continue operating after a fault is detected or for the amount of time between attempts to restart. The time unit is set in register 0xC8. | 0   | 1                  |  |
|     |                           |  | 1   | 2                  |  |
|     |                           |  | 2   | 4                  |  |
|     |                           |  | 3   | 8                  |  |
|     |                           |  | 4   | 16                 |  |
|     |                           |  | 5   | 32                 |  |
|     |                           |  | 6   | 64                 |  |
|     |                           |  | 7   | 128                |  |

**IOUT\_OC\_LV\_FAULT\_LIMIT (0x48)**

Description: Set the output over-current low-voltage fault threshold.

| Bit  | Description  | Format                                  | Unit |
|------|--|---|------|
| 15:0 | Set the output over-current low-voltage fault threshold. | Vout<br>Mode<br>Unsigned<br>(Exp = -11) | V    |

**IOUT\_OC\_WARN\_LIMIT (0x4A)**

Description: Output over current warning limit.

| Bit  | Description                        | Format | Unit |
|------|------------------------------------|--------|------|
| 15:0 | Output over current warning limit. | Linear | A    |

**IOUT\_UC\_FAULT\_LIMIT (0x4B)**

Description: Sets the output under-current peak limit.

| Bit  | Description                                       | Format | Unit |
|------|---|--------|------|
| 15:0 | Sets the IOUT under-current peak fault threshold. | Linear | A    |

**IOUT\_UC\_FAULT\_RESPONSE (0x4C)**

Description: Configures the output undercurrent fault response. The command format is the same as the PMBus standard responses for voltage and temperature faults except that it sets the undercurrent status bit.

| Bit | Function      | Description   | Value | Function                        | Description   |
|-----|---------------|---|-------|---------------------------------|---|
| 7:6 | Response      | Describes the device interruption operation. For all modes set by bits [7:6], the device pulls SALERT low and sets the related fault bit in the status registers. | 00    | Ignore Fault                    | The PMBus device continues operation without interruption.  |
|     |               |   | 01    | Perform Retries while Operating | The PMBus device continues operation for the delay time specified by bits [2:0] and the delay time unit specified for that particular fault. If the fault condition is still present at the end of the delay time, the unit responds as programmed in the Retry Setting (bits [5:3]). |
|     |               |   | 10    | Disable and Retry               | The device shuts down (disables the output) and responds according to the retry setting in bits [5:3].  |
|     |               |   | 11    | Disable until clear             | The device's output is disabled while the fault is present. Operation resumes and the output is enabled when the fault condition no longer exists.  |
| 5:3 | Retry Setting | The device attempts to restart the number of times set by these bits.   | 000   | Do Not Retry                    | A zero value for the Retry Setting means that the unit does not attempt to restart. The output remains disabled until the fault is cleared.   |

|     |                           |  |     |                    |   |
|-----|---------------------------|--|-----|--------------------|---|
|     |                           |  | 001 | Retry Once         | The PMBus device attempts to restart 1 time. If the device fails to restart, it disables the output and remains off until the fault is cleared. The time between the start of each attempt to restart is set by the value in bits [2:0] along with the delay time unit specified for that particular fault. |
|     |                           |  | 010 | Retry Twice        | The PMBus device attempts to restart 2 times.   |
|     |                           |  | 011 | Retry 3 times      | The PMBus device attempts to restart 3 times.   |
|     |                           |  | 100 | Retry 4 times      | The PMBus device attempts to restart 4 times.   |
|     |                           |  | 101 | Retry 5 times      | The PMBus device attempts to restart 5 times.   |
|     |                           |  | 110 | Retry 6 times      | The PMBus device attempts to restart 6 times.   |
|     |                           |  | 111 | Retry Continuously | The PMBus device attempts to restart continuously, without limitation, until output is DISABLED, bias power is removed, or another fault condition causes the output to shut down.  |
| 2:0 | Retry Time and Delay Time | Number of delay time units. Used for either the amount of time the device (10 ms/unit) is to continue operating after a fault is detected or for the amount of time (8.2 ms/unit) between attempts to restart. | 0   | 0                  |   |
|     |                           |  | 1   | 1                  |   |
|     |                           |  | 2   | 2                  |   |
|     |                           |  | 3   | 3                  |   |
|     |                           |  | 4   | 4                  |   |
|     |                           |  | 5   | 5                  |   |
|     |                           |  | 6   | 6                  |   |
|     |                           |  | 7   | 7                  |   |

**OT\_FAULT\_LIMIT (0x4F)**

Description: Over temperature fault limit.

| Bit  | Description                   | Format | Unit |
|------|-------------------------------|--------|------|
| 15:0 | Over temperature fault limit. | Linear | °C   |

**OT\_FAULT\_RESPONSE (0x50)**

Description: Over temperature fault response.

| Bit | Function | Description | Value | Function     | Description  |
|-----|----------|-------------|-------|--------------|--|
| 7:6 | Response |             | 00    | Ignore Fault | The PMBus device continues operation without interruption. |

|     |         |  |     |                                 |   |
|-----|---------|--|-----|---------------------------------|---|
|     |         |  | 01  | Perform Retries while Operating | The PMBus device continues operation for the delay time specified by bits [2:0] and the delay time unit specified for that particular fault. If the fault condition is still present at the end of the delay time, the unit responds as programmed in the Retry Setting (bits [5:3]).   |
|     |         |  | 10  | Disable and retry               | The device shuts down (disables the output) and responds according to the retry setting in bits [5:3].  |
|     |         |  | 11  | Disable until Fault Cleared     | A fault can be cleared in several ways: The bit is individually cleared, The device receives a CLEAR_FAULTS command, a RESET signal (if one exists) is asserted, the output is commanded through the CTRL pin, the OPERATION command, or the combined action of the CTRL pin and OPERATION command, to turn off and then to turn back on, or Bias power is removed from the PMBus device. |
| 5:3 | Retries |  | 000 | Do Not Retry                    | A zero value for the Retry Setting means that the unit does not attempt to restart. The output remains disabled until the fault is cleared (Section 10.7).  |
|     |         |  | 001 | Retry Once                      | The PMBus device attempts to restart 1 time. If the device fails to restart, it disables the output and remains off until the fault is cleared as described in Section 10.7. The time between the start of each attempt to restart is set by the value in bits [2:] along with the delay time unit specified for that particular fault.   |

|  |  |  |     |               |  |
|--|--|--|-----|---------------|--|
|  |  |  | 010 | Retry Twice   | The PMBus device attempts to restart 2 times. If the device fails to restart, it disables the output and remains off until the fault is cleared as described in Section 10.7. The time between the start of each attempt to restart is set by the value in bits [2:] along with the delay time unit specified for that particular fault. |
|  |  |  | 011 | Retry 3 times | The PMBus device attempts to restart 3 times. If the device fails to restart, it disables the output and remains off until the fault is cleared as described in Section 10.7. The time between the start of each attempt to restart is set by the value in bits [2:] along with the delay time unit specified for that particular fault. |
|  |  |  | 100 | Retry 4 times | The PMBus device attempts to restart 4 times. If the device fails to restart, it disables the output and remains off until the fault is cleared as described in Section 10.7. The time between the start of each attempt to restart is set by the value in bits [2:] along with the delay time unit specified for that particular fault. |
|  |  |  | 101 | Retry 5 times | The PMBus device attempts to restart 5 times. If the device fails to restart, it disables the output and remains off until the fault is cleared as described in Section 10.7. The time between the start of each attempt to restart is set by the value in bits [2:] along with the delay time unit specified for that particular fault. |

|     |                           |  |     |                    |  |
|-----|---------------------------|--|-----|--------------------|--|
|     |                           |  | 110 | Retry 6 times      | The PMBus device attempts to restart 6 times. If the device fails to restart, it disables the output and remains off until the fault is cleared as described in Section 10.7. The time between the start of each attempt to restart is set by the value in bits [2:] along with the delay time unit specified for that particular fault. |
|     |                           |  | 111 | Retry Continuously | The PMBus device attempts to restart continuously, without limitation, until it is commanded OFF (by the CONTROL pin or OPERATION command or both), bias power is removed, or another fault condition causes the unit to shut down.  |
| 2:0 | Retry Time and Delay Time | Number of delay time units. Used for either the amount of time the device is to continue operating after a fault is detected or for the amount of time between attempts to restart. The time unit is set in register 0xC8. | 0   | 1                  |  |
|     |                           |  | 1   | 2                  |  |
|     |                           |  | 2   | 4                  |  |
|     |                           |  | 3   | 8                  |  |
|     |                           |  | 4   | 16                 |  |
|     |                           |  | 5   | 32                 |  |
|     |                           |  | 6   | 64                 |  |
|     |                           |  | 7   | 128                |  |

**OT\_WARN\_LIMIT (0x51)**

Description: Over temperature warning limit.

| Bit  | Description                     | Format | Unit |
|------|---------------------------------|--------|------|
| 15:0 | Over temperature warning limit. | Linear | °C   |

**UT\_WARN\_LIMIT (0x52)**

Description: Under temperature warning limit.

| Bit  | Description                      | Format | Unit |
|------|----------------------------------|--------|------|
| 15:0 | Under temperature warning limit. | Linear | °C   |

**UT\_FAULT\_LIMIT (0x53)**

Description: Under temperature fault limit.

| Bit  | Description                    | Format | Unit |
|------|--------------------------------|--------|------|
| 15:0 | Under temperature fault limit. | Linear | °C   |

**UT\_FAULT\_RESPONSE (0x54)**

Description: Under temperature fault response.

| Bit | Function | Description | Value | Function     | Description  |
|-----|----------|-------------|-------|--------------|--|
| 7:6 | Response |             | 00    | Ignore Fault | The PMBus device continues operation without interruption. |



|     |         |  |     |                                 |   |
|-----|---------|--|-----|---------------------------------|---|
|     |         |  | 01  | Perform Retries while Operating | The PMBus device continues operation for the delay time specified by bits [2:0] and the delay time unit specified for that particular fault. If the fault condition is still present at the end of the delay time, the unit responds as programmed in the Retry Setting (bits [5:3]).   |
|     |         |  | 10  | Disable and retry               | The device shuts down (disables the output) and responds according to the retry setting in bits [5:3].  |
|     |         |  | 11  | Disable until Fault Cleared     | A fault can be cleared in several ways: The bit is individually cleared, The device receives a CLEAR_FAULTS command, a RESET signal (if one exists) is asserted, the output is commanded through the CTRL pin, the OPERATION command, or the combined action of the CTRL pin and OPERATION command, to turn off and then to turn back on, or Bias power is removed from the PMBus device. |
| 5:3 | Retries |  | 000 | Do Not Retry                    | A zero value for the Retry Setting means that the unit does not attempt to restart. The output remains disabled until the fault is cleared (Section 10.7).  |
|     |         |  | 001 | Retry Once                      | The PMBus device attempts to restart 1 time. If the device fails to restart, it disables the output and remains off until the fault is cleared as described in Section 10.7. The time between the start of each attempt to restart is set by the value in bits [2:] along with the delay time unit specified for that particular fault.   |

|  |  |  |     |               |  |
|--|--|--|-----|---------------|--|
|  |  |  | 010 | Retry Twice   | The PMBus device attempts to restart 2 times. If the device fails to restart, it disables the output and remains off until the fault is cleared as described in Section 10.7. The time between the start of each attempt to restart is set by the value in bits [2:] along with the delay time unit specified for that particular fault. |
|  |  |  | 011 | Retry 3 times | The PMBus device attempts to restart 3 times. If the device fails to restart, it disables the output and remains off until the fault is cleared as described in Section 10.7. The time between the start of each attempt to restart is set by the value in bits [2:] along with the delay time unit specified for that particular fault. |
|  |  |  | 100 | Retry 4 times | The PMBus device attempts to restart 4 times. If the device fails to restart, it disables the output and remains off until the fault is cleared as described in Section 10.7. The time between the start of each attempt to restart is set by the value in bits [2:] along with the delay time unit specified for that particular fault. |
|  |  |  | 101 | Retry 5 times | The PMBus device attempts to restart 5 times. If the device fails to restart, it disables the output and remains off until the fault is cleared as described in Section 10.7. The time between the start of each attempt to restart is set by the value in bits [2:] along with the delay time unit specified for that particular fault. |

|     |                           |  |     |                    |  |
|-----|---------------------------|--|-----|--------------------|--|
|     |                           |  | 110 | Retry 6 times      | The PMBus device attempts to restart 6 times. If the device fails to restart, it disables the output and remains off until the fault is cleared as described in Section 10.7. The time between the start of each attempt to restart is set by the value in bits [2:] along with the delay time unit specified for that particular fault. |
|     |                           |  | 111 | Retry Continuously | The PMBus device attempts to restart continuously, without limitation, until it is commanded OFF (by the CONTROL pin or OPERATION command or both), bias power is removed, or another fault condition causes the unit to shut down.  |
| 2:0 | Retry Time and Delay Time | Number of delay time units. Used for either the amount of time the device is to continue operating after a fault is detected or for the amount of time between attempts to restart. The time unit is set in register 0xC8. | 0   | 1                  |  |
|     |                           |  | 1   | 2                  |  |
|     |                           |  | 2   | 4                  |  |
|     |                           |  | 3   | 8                  |  |
|     |                           |  | 4   | 16                 |  |
|     |                           |  | 5   | 32                 |  |
|     |                           |  | 6   | 64                 |  |
|     |                           |  | 7   | 128                |  |

**VIN\_OV\_FAULT\_LIMIT (0x55)**

Description: Input over voltage fault limit.

| Bit  | Description                     | Format | Unit |
|------|---------------------------------|--------|------|
| 15:0 | Input over voltage fault limit. | Linear | V    |

**VIN\_OV\_FAULT\_RESPONSE (0x56)**

Description: Input over voltage fault response.

| Bit | Function | Description | Value | Function                        | Description   |
|-----|----------|-------------|-------|---------------------------------|---|
| 7:6 | Response |             | 00    | Ignore Fault                    | The PMBus device continues operation without interruption.  |
|     |          |             | 01    | Perform Retries while Operating | The PMBus device continues operation for the delay time specified by bits [2:0] and the delay time unit specified for that particular fault. If the fault condition is still present at the end of the delay time, the unit responds as programmed in the Retry Setting (bits [5:3]). |

|     |         |  |     |                             |   |
|-----|---------|--|-----|-----------------------------|---|
|     |         |  | 10  | Disable and retry           | The device shuts down (disables the output) and responds according to the retry setting in bits [5:3].  |
|     |         |  | 11  | Disable until Fault Cleared | A fault can be cleared in several ways: The bit is individually cleared, The device receives a CLEAR_FAULTS command, a RESET signal (if one exists) is asserted, the output is commanded through the CTRL pin, the OPERATION command, or the combined action of the CTRL pin and OPERATION command, to turn off and then to turn back on, or Bias power is removed from the PMBus device. |
| 5:3 | Retries |  | 000 | Do Not Retry                | A zero value for the Retry Setting means that the unit does not attempt to restart. The output remains disabled until the fault is cleared (Section 10.7).  |
|     |         |  | 001 | Retry Once                  | The PMBus device attempts to restart 1 time. If the device fails to restart, it disables the output and remains off until the fault is cleared as described in Section 10.7. The time between the start of each attempt to restart is set by the value in bits [2:] along with the delay time unit specified for that particular fault.   |
|     |         |  | 010 | Retry Twice                 | The PMBus device attempts to restart 2 times. If the device fails to restart, it disables the output and remains off until the fault is cleared as described in Section 10.7. The time between the start of each attempt to restart is set by the value in bits [2:] along with the delay time unit specified for that particular fault.  |

|  |  |  |     |                    |  |
|--|--|--|-----|--------------------|--|
|  |  |  | 011 | Retry 3 times      | The PMBus device attempts to restart 3 times. If the device fails to restart, it disables the output and remains off until the fault is cleared as described in Section 10.7. The time between the start of each attempt to restart is set by the value in bits [2:] along with the delay time unit specified for that particular fault. |
|  |  |  | 100 | Retry 4 times      | The PMBus device attempts to restart 4 times. If the device fails to restart, it disables the output and remains off until the fault is cleared as described in Section 10.7. The time between the start of each attempt to restart is set by the value in bits [2:] along with the delay time unit specified for that particular fault. |
|  |  |  | 101 | Retry 5 times      | The PMBus device attempts to restart 5 times. If the device fails to restart, it disables the output and remains off until the fault is cleared as described in Section 10.7. The time between the start of each attempt to restart is set by the value in bits [2:] along with the delay time unit specified for that particular fault. |
|  |  |  | 110 | Retry 6 times      | The PMBus device attempts to restart 6 times. If the device fails to restart, it disables the output and remains off until the fault is cleared as described in Section 10.7. The time between the start of each attempt to restart is set by the value in bits [2:] along with the delay time unit specified for that particular fault. |
|  |  |  | 111 | Retry Continuously | The PMBus device attempts to restart continuously, without limitation, until it is commanded OFF (by the CONTROL pin or OPERATION command or both), bias power is removed, or another fault condition causes the unit to shut down.  |

|     |                           |  |   |     |  |
|-----|---------------------------|--|---|-----|--|
| 2:0 | Retry Time and Delay Time | Number of delay time units. Used for either the amount of time the device is to continue operating after a fault is detected or for the amount of time between attempts to restart. The time unit is set in register 0xC8. | 0 | 1   |  |
|     |                           |  | 1 | 2   |  |
|     |                           |  | 2 | 4   |  |
|     |                           |  | 3 | 8   |  |
|     |                           |  | 4 | 16  |  |
|     |                           |  | 5 | 32  |  |
|     |                           |  | 6 | 64  |  |
|     |                           |  | 7 | 128 |  |

**VIN\_OV\_WARN\_LIMIT (0x57)**

Description: Input over voltage warning limit.

| Bit  | Description                       | Format | Unit |
|------|-----------------------------------|--------|------|
| 15:0 | Input over voltage warning limit. | Linear | V    |

**VIN\_UV\_WARN\_LIMIT (0x58)**

Description: Input under voltage warning limit. This command set also the input voltage threshold for the HRR function (Hybrid Ratio Regulation). The HRR function is enabled with command MFR\_SPECIAL\_OPTIONS (0xE0).

| Bit  | Description   | Format | Unit |
|------|---|--------|------|
| 15:0 | Input under voltage warning limit and/or HRR threshold. | Linear | V    |

**VIN\_UV\_FAULT\_LIMIT (0x59)**

Description: Input under voltage fault limit.

| Bit  | Description                      | Format | Unit |
|------|----------------------------------|--------|------|
| 15:0 | Input under voltage fault limit. | Linear | V    |

**VIN\_UV\_FAULT\_RESPONSE (0x5A)**

Description: Input under voltage fault response.

| Bit | Function | Description | Value | Function                        | Description   |
|-----|----------|-------------|-------|---------------------------------|---|
| 7:6 | Response |             | 00    | Ignore Fault                    | The PMBus device continues operation without interruption.  |
|     |          |             | 01    | Perform Retries while Operating | The PMBus device continues operation for the delay time specified by bits [2:0] and the delay time unit specified for that particular fault. If the fault condition is still present at the end of the delay time, the unit responds as programmed in the Retry Setting (bits [5:3]). |
|     |          |             | 10    | Disable and retry               | The device shuts down (disables the output) and responds according to the retry setting in bits [5:3].  |

|     |         |  |     |                             |   |
|-----|---------|--|-----|-----------------------------|---|
|     |         |  | 11  | Disable until Fault Cleared | A fault can be cleared in several ways: The bit is individually cleared, The device receives a CLEAR_FAULTS command, a RESET signal (if one exists) is asserted, the output is commanded through the CTRL pin, the OPERATION command, or the combined action of the CTRL pin and OPERATION command, to turn off and then to turn back on, or Bias power is removed from the PMBus device. |
| 5:3 | Retries |  | 000 | Do Not Retry                | A zero value for the Retry Setting means that the unit does not attempt to restart. The output remains disabled until the fault is cleared (Section 10.7).  |
|     |         |  | 001 | Retry Once                  | The PMBus device attempts to restart 1 time. If the device fails to restart, it disables the output and remains off until the fault is cleared as described in Section 10.7. The time between the start of each attempt to restart is set by the value in bits [2:] along with the delay time unit specified for that particular fault.   |
|     |         |  | 010 | Retry Twice                 | The PMBus device attempts to restart 2 times. If the device fails to restart, it disables the output and remains off until the fault is cleared as described in Section 10.7. The time between the start of each attempt to restart is set by the value in bits [2:] along with the delay time unit specified for that particular fault.  |
|     |         |  | 011 | Retry 3 times               | The PMBus device attempts to restart 3 times. If the device fails to restart, it disables the output and remains off until the fault is cleared as described in Section 10.7. The time between the start of each attempt to restart is set by the value in bits [2:] along with the delay time unit specified for that particular fault.  |

|     |                           |  |     |                    |  |
|-----|---------------------------|--|-----|--------------------|--|
|     |                           |  | 100 | Retry 4 times      | The PMBus device attempts to restart 4 times. If the device fails to restart, it disables the output and remains off until the fault is cleared as described in Section 10.7. The time between the start of each attempt to restart is set by the value in bits [2:] along with the delay time unit specified for that particular fault. |
|     |                           |  | 101 | Retry 5 times      | The PMBus device attempts to restart 5 times. If the device fails to restart, it disables the output and remains off until the fault is cleared as described in Section 10.7. The time between the start of each attempt to restart is set by the value in bits [2:] along with the delay time unit specified for that particular fault. |
|     |                           |  | 110 | Retry 6 times      | The PMBus device attempts to restart 6 times. If the device fails to restart, it disables the output and remains off until the fault is cleared as described in Section 10.7. The time between the start of each attempt to restart is set by the value in bits [2:] along with the delay time unit specified for that particular fault. |
|     |                           |  | 111 | Retry Continuously | The PMBus device attempts to restart continuously, without limitation, until it is commanded OFF (by the CONTROL pin or OPERATION command or both), bias power is removed, or another fault condition causes the unit to shut down.  |
| 2:0 | Retry Time and Delay Time | Number of delay time units. Used for either the amount of time the device is to continue operating after a fault is detected or for the amount of time between attempts to restart. The time unit is set in register 0xC8. | 0   | 1                  |  |
|     |                           |  | 1   | 2                  |  |
|     |                           |  | 2   | 4                  |  |
|     |                           |  | 3   | 8                  |  |
|     |                           |  | 4   | 16                 |  |
|     |                           |  | 5   | 32                 |  |
|     |                           |  | 6   | 64                 |  |
|     |                           |  | 7   | 128                |  |

**POWER\_GOOD\_ON (0x5E)**

Description: Sets the output voltage threshold for asserting PG (Power Good).



| Bit  | Description  | Format                                  | Unit |
|------|--|---|------|
| 15:0 | The POWER_GOOD_ON command sets the output voltage at which an optional POWER_GOOD signal should be asserted. | Vout<br>Mode<br>Unsigned<br>(Exp = -11) | V    |

**POWER\_GOOD\_OFF (0x5F)**

Description: Sets the output voltage threshold for deasserting PG (Power Good).

| Bit  | Description   | Format                                  | Unit |
|------|---|---|------|
| 15:0 | The POWER_GOOD_OFF command sets the output voltage at which an optional POWER_GOOD signal should be deasserted. | Vout<br>Mode<br>Unsigned<br>(Exp = -11) | V    |

**TON\_DELAY (0x60)**

Description: Sets the turn-on delay time

| Bit  | Description  | Format | Unit |
|------|--|--------|------|
| 15:0 | Sets the delay time from ENABLE to start of VOUT rise. | Linear | ms   |

**TON\_RISE (0x61)**

Description: Sets the turn-on transition time.

| Bit  | Description  | Format | Unit |
|------|--|--------|------|
| 15:0 | Sets the rise time of VOUT after ENABLE and TON_DELAY. | Linear | ms   |

**TON\_MAX\_FAULT\_LIMIT (0x62)**

Description: Sets an upper limit, in milliseconds, on how long the unit can attempt to power up the output without reaching the output undervoltage fault limit.

| Bit  | Description   | Format | Unit |
|------|---|--------|------|
| 15:0 | A value of 0 milliseconds means that there is no limit and that the unit can attempt to bring up the output voltage indefinitely. | Linear | ms   |

**TON\_MAX\_FAULT\_RESPONSE (0x63)**

Description: Only some of the response types are supported.

| Bit | Function | Description | Value | Function                        | Description   |
|-----|----------|-------------|-------|---------------------------------|---|
| 7:6 | Response |             | 00    | Ignore Fault                    | The PMBus device continues operation without interruption.  |
|     |          |             | 01    | Perform Retries while Operating | The PMBus device continues operation for the delay time specified by bits [2:0] and the delay time unit specified for that particular fault. If the fault condition is still present at the end of the delay time, the unit responds as programmed in the Retry Setting (bits [5:3]). |

|     |         |  |     |                             |   |
|-----|---------|--|-----|-----------------------------|---|
|     |         |  | 10  | Disable and retry           | The device shuts down (disables the output) and responds according to the retry setting in bits [5:3].  |
|     |         |  | 11  | Disable until Fault Cleared | A fault can be cleared in several ways: The bit is individually cleared, The device receives a CLEAR_FAULTS command, a RESET signal (if one exists) is asserted, the output is commanded through the CTRL pin, the OPERATION command, or the combined action of the CTRL pin and OPERATION command, to turn off and then to turn back on, or Bias power is removed from the PMBus device. |
| 5:3 | Retries |  | 000 | Do Not Retry                | A zero value for the Retry Setting means that the unit does not attempt to restart. The output remains disabled until the fault is cleared (Section 10.7).  |
|     |         |  | 001 | Retry Once                  | The PMBus device attempts to restart 1 time. If the device fails to restart, it disables the output and remains off until the fault is cleared as described in Section 10.7. The time between the start of each attempt to restart is set by the value in bits [2:] along with the delay time unit specified for that particular fault.   |
|     |         |  | 010 | Retry Twice                 | The PMBus device attempts to restart 2 times. If the device fails to restart, it disables the output and remains off until the fault is cleared as described in Section 10.7. The time between the start of each attempt to restart is set by the value in bits [2:] along with the delay time unit specified for that particular fault.  |

|  |  |  |     |                    |  |
|--|--|--|-----|--------------------|--|
|  |  |  | 011 | Retry 3 times      | The PMBus device attempts to restart 3 times. If the device fails to restart, it disables the output and remains off until the fault is cleared as described in Section 10.7. The time between the start of each attempt to restart is set by the value in bits [2:] along with the delay time unit specified for that particular fault. |
|  |  |  | 100 | Retry 4 times      | The PMBus device attempts to restart 4 times. If the device fails to restart, it disables the output and remains off until the fault is cleared as described in Section 10.7. The time between the start of each attempt to restart is set by the value in bits [2:] along with the delay time unit specified for that particular fault. |
|  |  |  | 101 | Retry 5 times      | The PMBus device attempts to restart 5 times. If the device fails to restart, it disables the output and remains off until the fault is cleared as described in Section 10.7. The time between the start of each attempt to restart is set by the value in bits [2:] along with the delay time unit specified for that particular fault. |
|  |  |  | 110 | Retry 6 times      | The PMBus device attempts to restart 6 times. If the device fails to restart, it disables the output and remains off until the fault is cleared as described in Section 10.7. The time between the start of each attempt to restart is set by the value in bits [2:] along with the delay time unit specified for that particular fault. |
|  |  |  | 111 | Retry Continuously | The PMBus device attempts to restart continuously, without limitation, until it is commanded OFF (by the CONTROL pin or OPERATION command or both), bias power is removed, or another fault condition causes the unit to shut down.  |

|     |                           |  |   |     |  |
|-----|---------------------------|--|---|-----|--|
| 2:0 | Retry Time and Delay Time | Number of delay time units. Used for either the amount of time the device is to continue operating after a fault is detected or for the amount of time between attempts to restart. The time unit is set in register 0xC8. TON_MAX_FAULT_RESPONSE time unit is referenced to VOUT FAULT time unit. | 0 | 1   |  |
|     |                           |  | 1 | 2   |  |
|     |                           |  | 2 | 4   |  |
|     |                           |  | 3 | 8   |  |
|     |                           |  | 4 | 16  |  |
|     |                           |  | 5 | 32  |  |
|     |                           |  | 6 | 64  |  |
|     |                           |  | 7 | 128 |  |

**TOFF\_DELAY (0x64)**

Description: Sets the turn-off delay.

| Bit  | Description   | Format | Unit |
|------|---|--------|------|
| 15:0 | Sets the delay time from DISABLE to start of VOUT fall. | Linear | ms   |

**TOFF\_FALL (0x65)**

Description: Sets the turn-off transition time.

| Bit  | Description   | Format | Unit |
|------|---|--------|------|
| 15:0 | Sets the fall time for VOUT after DISABLE and TOFF_DELAY. | Linear | ms   |

**TOFF\_MAX\_WARN\_LIMIT (0x66)**

Description: Sets an upper limit, in milliseconds, on how long the unit can attempt to power down the output without reaching 12.5% of the output voltage programmed at the time the unit is turned off.

| Bit  | Description | Format | Unit |
|------|-------------|--------|------|
| 15:0 |             | Linear | ms   |

**POUT\_OP\_WARN\_LIMIT (0x6A)**

Description: Sets the output over-power warning limit.

| Bit  | Description                                   | Format | Unit |
|------|---|--------|------|
| 15:0 | Sets the output over-power warning threshold. | Linear | W    |

**PIN\_OP\_WARN\_LIMIT (0x6B)**

Description: Sets the input over-power warning limit.

| Bit  | Description                                  | Format | Unit |
|------|--|--------|------|
| 15:0 | Sets the input over-power warning threshold. | Linear | W    |

**STATUS\_BYTE (0x78)**

Description: Returns a brief fault/warning status byte.

| Bit | Function               | Description  | Value | Description |
|-----|------------------------|--|-------|-------------|
| 6   | Off                    | This bit is asserted if the unit is not providing power to the output, regardless of the reason, including simply not being enabled. | 0     | No fault    |
|     |                        |  | 1     | Fault       |
| 5   | Vout Overvoltage Fault | An output overvoltage fault has occurred.  | 0     | No fault    |
|     |                        |  | 1     | Fault       |
| 4   | Iout Overcurrent Fault | An output overcurrent fault has occurred.  | 0     | No fault    |
|     |                        |  | 1     | Fault       |
| 3   |                        | An input undervoltage fault has occurred.  | 0     | No fault    |

|   |                        |   |   |          |
|---|------------------------|---|---|----------|
|   | Vin Undervoltage Fault |   | 1 | Fault    |
| 2 | Temperature            | A temperature fault or warning has occurred.              | 0 | No fault |
|   |                        |   | 1 | Fault    |
| 1 | Communication/Logic    | A communications, memory or logic fault has occurred.     | 0 | No fault |
|   |                        |   | 1 | Fault    |
| 0 | None of the Above      | A fault or warning not listed in bits [7:1] has occurred. | 0 | No fault |
|   |                        |   | 1 | Fault    |

**STATUS\_WORD (0x79)**

Description: Returns an extended fault/warning status byte.

| Bit | Function               | Description  | Value | Description |
|-----|------------------------|--|-------|-------------|
| 15  | Vout                   | An output voltage fault or warning has occurred.   | 0     | No fault    |
|     |                        |  | 1     | Fault       |
| 14  | Iout/Pout              | An output current or output power fault or warning has occurred.   | 0     | No Fault.   |
|     |                        |  | 1     | Fault.      |
| 13  | Input                  | An input voltage, input current, or input power fault or warning has occurred.   | 0     | No Fault.   |
|     |                        |  | 1     | Fault.      |
| 12  | Mfr Specific           | A manufacturer specific fault or warning has occurred.   | 0     | No fault.   |
|     |                        |  | 1     | Fault.      |
| 11  | Power-Good             | The Power-Good signal, if present, is negated.   | 0     | No Fault.   |
|     |                        |  | 1     | Fault.      |
| 9   | Other                  | A bit in Status-Other is set.  | 0     | No fault    |
|     |                        |  | 1     | Fault       |
| 6   | Off                    | This bit is asserted if the unit is not providing power to the output, regardless of the reason, including simply not being enabled. | 0     | No fault    |
|     |                        |  | 1     | Fault       |
| 5   | Vout Overvoltage Fault | An output overvoltage fault has occurred.  | 0     | No Fault.   |
|     |                        |  | 1     | Fault.      |
| 4   | Iout Overcurrent Fault | An output overcurrent fault has occurred.  | 0     | No Fault.   |
|     |                        |  | 1     | Fault.      |
| 3   | Vin Undervoltage Fault | An input undervoltage fault has occurred.  | 0     | No Fault.   |
|     |                        |  | 1     | Fault.      |
| 2   | Temperature            | A temperature fault or warning has occurred.   | 0     | No Fault.   |
|     |                        |  | 1     | Fault.      |
| 1   | Communication/Logic    | A communications, memory or logic fault has occurred.  | 0     | No fault.   |
|     |                        |  | 1     | Fault.      |
| 0   | None of the Above      | A fault or warning not listed in bits [7:1] has occurred.  | 0     | No fault.   |
|     |                        |  | 1     | Fault.      |

**STATUS\_VOUT (0x7A)**

Description: Returns Vout-related fault/warning status bits.

| Bit | Function                  | Description                | Value | Description |
|-----|---------------------------|----------------------------|-------|-------------|
| 7   | Vout Overvoltage Fault    | Vout Overvoltage Fault.    | 0     | No Fault.   |
|     |                           |                            | 1     | Fault.      |
| 6   | Vout Overvoltage Warning  | Vout Overvoltage Warning.  | 0     | No Warning. |
|     |                           |                            | 1     | Warning.    |
| 5   | Vout Undervoltage Warning | Vout Undervoltage Warning. | 0     | No Warning. |
|     |                           |                            | 1     | Warning.    |
| 4   | Vout Undervoltage Fault   | Vout Undervoltage Fault.   | 0     | No Fault.   |
|     |                           |                            | 1     | Fault.      |
| 3   | Vout Max Warning          |                            | 0     | No Warning. |

|   |                  |  |   |             |
|---|------------------|--|---|-------------|
|   |                  | Vout Max Warning (An attempt has been made to set the output voltage to value higher than allowed by the Vout Max command (Section 13.5)). | 1 | Warning.    |
| 2 | Ton Max Fault    | Ton-Max Fault.   | 0 | No Fault    |
|   |                  |  | 1 | Fault.      |
| 1 | Toff Max Warning | Toff Max Warning.  | 0 | No Warning. |
|   |                  |  | 1 | Warning.    |

**STATUS\_IOUT (0x7B)**

Description: Returns Iout-related fault/warning status bits.

| Bit | Function                               | Description                             | Value | Description |
|-----|--|---|-------|-------------|
| 7   | Iout Overcurrent Fault                 | Iout Overcurrent Fault.                 | 0     | No Fault.   |
|     |  |   | 1     | Fault.      |
| 6   | Iout Overcurrent And Low Voltage Fault | Iout Overcurrent and low voltage fault. | 0     | No Fault.   |
|     |  |   | 1     | Fault.      |
| 5   | Iout Over Current Warning              | Iout Overcurrent Warning.               | 0     | No Warning. |
|     |  |   | 1     | Warning.    |
| 4   | Iout Undercurrent Fault                | Iout Undercurrent Fault.                | 0     | No Fault.   |
|     |  |   | 1     | Fault.      |

**STATUS\_INPUT (0x7C)**

Description: Returns VIN/IIN-related fault/warning status bits.

| Bit | Function                 | Description   | Value | Description                          |
|-----|--------------------------|---|-------|--------------------------------------|
| 7   | Vin Overvoltage Fault    | Vin Overvoltage Fault.  | 0     | No Fault.                            |
|     |                          |   | 1     | Fault.                               |
| 6   | Vin Overvoltage Warning  | VIN Overvoltage Warning.  | 0     | No Warning.                          |
|     |                          |   | 1     | Warning.                             |
| 5   | Vin Undervoltage Warning | Vin Undervoltage Warning.   | 0     | No Warning.                          |
|     |                          |   | 1     | Warning.                             |
| 4   | Vin Undervoltage Fault   | Vin Undervoltage Fault.   | 0     | No Fault.                            |
|     |                          |   | 1     | Fault.                               |
| 3   | Insufficient Vin         | Asserted when either the input voltage has never exceeded the input turn-on threshold Vin-On, or if the unit did start, the input voltage decreased below the turn-off threshold. | 0     | No Insufficient VIN encountered yet. |
|     |                          |   | 1     | Insufficient Unit is off.            |

**STATUS\_TEMPERATURE (0x7D)**

Description: Returns the temperature-related fault/warning status bits

| Bit | Function                 | Description               | Value | Description |
|-----|--------------------------|---------------------------|-------|-------------|
| 7   | Overtemperature Fault    | Overtemperature Fault.    | 0     | No Fault.   |
|     |                          |                           | 1     | Fault.      |
| 6   | Overtemperature Warning  | Overtemperature Warning.  | 0     | No Warning. |
|     |                          |                           | 1     | Warning.    |
| 5   | Undertemperature Warning | Undertemperature Warning. | 0     | No Warning. |
|     |                          |                           | 1     | Warning.    |
| 4   | Undertemperature Fault   | Undertemperature Fault.   | 0     | No Fault.   |
|     |                          |                           | 1     | Fault.      |

**STATUS\_CML (0x7E)**

Description: Returns Communication/Logic/Memory-related fault/warning status bits.

| Bit | Function                                | Description  | Value | Description                  |
|-----|---|--|-------|------------------------------|
| 7   | Invalid Or Unsupported Command Received | Invalid Or Unsupported Command Received.                                     | 0     | No Invalid Command Received. |
|     |   |  | 1     | Invalid Command Received.    |
| 6   | Invalid Or Unsupported Data Received    | Invalid Or Unsupported Data Received.  | 0     | No Invalid Data Received.    |
|     |   |  | 1     | Invalid Data Received.       |
| 5   | Packet Error Check Failed               | Packet Error Check Failed.   | 0     | No Failure.                  |
|     |   |  | 1     | Failure.                     |
| 4   | Memory Fault Detected                   | Memory Fault Detected.   | 0     | No Fault.                    |
|     |   |  | 1     | Fault.                       |
| 3   | Processor Fault Detected                | Processor fault detected.  | 0     | No Fault.                    |
|     |   |  | 1     | Fault.                       |
| 1   | Other Communication Fault               | A communication fault other than the ones listed in this table has occurred. | 0     | No Fault.                    |
|     |   |  | 1     | Fault.                       |
| 0   | Memory Or Logic Fault                   | Other Memory Or Logic Fault has occurred.                                    | 0     | No Fault.                    |
|     |   |  | 1     | Fault.                       |

**STATUS\_OTHER (0x7F)**

Description: Returns a brief other fault/warning status bits.

| Bit | Description                                  | Value | Description |
|-----|--|-------|-------------|
| 0   | The device was the first to assert SMBALERT. |       |             |

**STATUS\_MFR\_SPECIFIC (0x80)**

Description: Returns manufacturer specific status information.

| Bit | Function                       | Description                     | Value | Description |
|-----|--------------------------------|---------------------------------|-------|-------------|
| 7   | Sync Fault                     | Sync fault.                     | 0     | No fault.   |
|     |                                |                                 | 1     | Fault.      |
| 6   | Iout Average Overcurrent Fault | Iout average overcurrent fault. | 0     | No fault.   |
|     |                                |                                 | 1     | Fault.      |
| 5   | Iout Fast Overcurrent Fault    | Iout fast overcurrent fault.    | 0     | No fault.   |
|     |                                |                                 | 1     | Fault.      |
| 4   | Short Circuit Protection Fault | Short circuit protection fault. | 0     | No fault.   |
|     |                                |                                 | 1     | Fault.      |

**READ\_VIN (0x88)**

Description: Returns the measured input voltage.

| Bit  | Description                        | Format | Unit |
|------|------------------------------------|--------|------|
| 15:0 | Returns the input voltage reading. | Linear | V    |

**READ\_VOUT (0x8B)**

Description: Returns the measured output voltage.

| Bit  | Description                          | Format                         | Unit |
|------|--------------------------------------|--------------------------------|------|
| 15:0 | Returns the measured output voltage. | Vout Mode Unsigned (Exp = -11) | V    |

**READ\_IOUT (0x8C)**

Description: Returns the measured output current.

| Bit  | Description                          | Format | Unit |
|------|--------------------------------------|--------|------|
| 15:0 | Returns the measured output current. | Linear | A    |

**READ\_TEMPERATURE\_1 (0x8D)**

Description: Reads temperature from the temperature sensor chosen in MFR\_SELECT\_TEMPERATURE\_SENSOR (0xDC) command.

| Bit  | Description | Format | Unit |
|------|-------------|--------|------|
| 15:0 |             | Linear | °C   |

**READ\_DUTY\_CYCLE (0x94)**

Description: Returns the actual duty cycle in percent.

| Bit  | Description                               | Format | Unit |
|------|---|--------|------|
| 15:0 | Returns the actual duty cycle in percent. | Direct | %    |

**READ\_FREQUENCY (0x95)**

Description: Returns the actual switching frequency.

| Bit  | Description                             | Format | Unit |
|------|---|--------|------|
| 15:0 | Returns the actual switching frequency. | Linear | kHz  |

**PMBUS\_REVISION (0x98)**

Description: Returns the PMBus revision number for this device.

| Bit | Function         | Description       | Value | Function | Description           |
|-----|------------------|-------------------|-------|----------|-----------------------|
| 7:4 | Part I Revision  | Part I Revision.  | 0x0   | 1.0      | Part I Revision 1.0.  |
|     |                  |                   | 0x1   | 1.1      | Part I Revision 1.1.  |
|     |                  |                   | 0x2   | 1.2      | Part I Revision 1.2.  |
|     |                  |                   | 0x3   | 1.3      | Part I Revision 1.3.  |
| 3:0 | Part II Revision | Part II Revision. | 0x0   | 1.0      | Part II Revision 1.0. |
|     |                  |                   | 0x1   | 1.1      | Part II Revision 1.1. |
|     |                  |                   | 0x2   | 1.2      | Part II Revision 1.2. |
|     |                  |                   | 0x3   | 1.3      | Part II Revision 1.3. |

**MFR\_ID (0x99)**

Description: Sets the Manufacturers ID

| Bit  | Description               | Format |
|------|---------------------------|--------|
| 95:0 | Maximum of 12 characters. | ASCII  |

**MFR\_MODEL (0x9A)**

Description: Sets the MFR MODEL string.

| Bit   | Description               | Format |
|-------|---------------------------|--------|
| 159:0 | Maximum of 20 characters. | ASCII  |

**MFR\_REVISION (0x9B)**

Description: Sets the MFR revision string.

| Bit  | Description               | Format |
|------|---------------------------|--------|
| 95:0 | Maximum of 12 characters. | ASCII  |



**MFR\_LOCATION (0x9C)**

Description: Sets the MFR location string.

| Bit  | Description               | Format |
|------|---------------------------|--------|
| 95:0 | Maximum of 12 characters. | ASCII  |

**MFR\_DATE (0x9D)**

Description: This command returns the date the regulator was manufactured.

| Bit  | Description               | Format |
|------|---------------------------|--------|
| 95:0 | Maximum of 12 characters. | ASCII  |

**MFR\_SERIAL (0x9E)**

Description: This command returns a string of 13 characters and numbers that provides a unique identification of the regulator.

| Bit   | Description               | Format |
|-------|---------------------------|--------|
| 159:0 | Maximum of 20 characters. | ASCII  |

**USER\_DATA\_00 (0xB0)**

Description: This command is available as generic read/write storage for customers.

| Bit   | Description            | Format     |
|-------|------------------------|------------|
| 127:0 | 16 bytes of user data. | Byte Array |

**FW\_CONFIG\_FAULTS (0xC8)**

Description: FW CONFIG FAULTS parameter

| Bit | Function        | Description   | Value | Function   | Description                                    |
|-----|-----------------|---|-------|------------|--|
| 7:6 | Vout Delay Unit | Vout_Delay_Unit Time unit for retry responses. 0: 1ms, 1: 4ms, 2: 16ms, 3: 256ms  | 00    | 1ms/unit   | Vout Delay Unit Time unit for retry responses  |
|     |                 |   | 01    | 4ms/unit   | Vout Delay Unit Time unit for retry responses  |
|     |                 |   | 10    | 16ms/unit  | Vout Delay Unit Time unit for retry responses  |
|     |                 |   | 11    | 256ms/unit | Vout Delay Unit Time unit for retry responses  |
| 5:4 | Vin Delay Unit  | Vin_Delay_Unit Time unit for retry responses. 0: 1ms, 1: 4ms, 2: 16ms, 3: 256ms   | 00    | 1ms/unit   | Vin Delay Unit Time unit for retry responses   |
|     |                 |   | 01    | 4ms/unit   | Vin Delay Unit Time unit for retry responses   |
|     |                 |   | 10    | 16ms/unit  | Vin Delay Unit Time unit for retry responses   |
|     |                 |   | 11    | 256ms/unit | Vin Delay Unit Time unit for retry responses   |
| 3:2 | Iout Delay Unit | IOOUT_Delay_Unit Time unit for retry responses. 0: 1ms, 1: 4ms, 2: 16ms, 3: 256ms | 00    | 1ms/unit   | IOOUT Delay Unit Time unit for retry responses |
|     |                 |   | 01    | 4ms/unit   | IOOUT Delay Unit Time unit for retry responses |
|     |                 |   | 10    | 16ms/unit  | IOOUT Delay Unit Time unit for retry responses |
|     |                 |   | 11    | 256ms/unit | IOOUT Delay Unit Time unit for retry responses |

|     |                        |   |    |            |  |
|-----|------------------------|---|----|------------|--|
| 1:0 | Temperature Delay Unit | Temperature_Delay_Unit Time unit for retry responses. 0: 1ms, 1: 4ms, 2: 16ms, 3: 256ms | 00 | 1ms/unit   | Temperature Delay Unit Time unit for retry responses |
|     |                        |   | 01 | 4ms/unit   | Temperature Delay Unit Time unit for retry responses |
|     |                        |   | 10 | 16ms/unit  | Temperature Delay Unit Time unit for retry responses |
|     |                        |   | 11 | 256ms/unit | Temperature Delay Unit Time unit for retry responses |

**FW\_CONFIG\_PMBUS (0xC9)**

Description: The GPIO selection for the fault select, Power good select, and enable select has to be unique, please choose different values for these configurations. The overall I2C address (Base + offset or XADDR1/XADDR2) and PMBus (Base + offset or XADDR1/XADDR2) can not be same, please configure different address either base or offset.

| Bit   | Function          | Description   | Format           |
|-------|-------------------|---|------------------|
| 31:24 | PMBus Base Addr   | Base Address for PMBus offset to start from           | Integer Unsigned |
| 23:17 | PMBus Addr Offset | PMBUS Address offset when resistor offset Not enabled | Integer Unsigned |

| Bit | Function                          | Description   | Value | Function    | Description |
|-----|-----------------------------------|---|-------|-------------|-------------|
| 39  | Power good polarity               | Power good polarity (1:active high; 0: active low).               | 0     | Active low  |             |
|     |                                   |   | 1     | Active high |             |
| 32  | Control pin polarity              | Control pin polarity (1:active high; 0: active low).              | 0     | Active low  |             |
|     |                                   |   | 1     | Active high |             |
| 16  | PMBus Addr Offset Resistor Enable | PMBus_addr_offset_enable Enable PMBUS Address Offset via resistor | 0     | Disabled    |             |
|     |                                   |   | 1     | Enabled     |             |

**MFR\_IOUT\_OC\_FAST\_FAULT\_RESPONSE (0xCA)**

Description: Output over current fault response.

| Bit | Function | Description  | Value | Function     | Description   |
|-----|----------|--|-------|--------------|---|
| 7:6 | Response | For all values of bits [7:6],the device: Sets the corresponding fault bit in the status registers and If the device supports notifying the host, it does so. | 00    | Ignore Fault | The PMBus device continues to operate indefinitely while maintaining the output current at the value set by IOUT_OC_FAULT_LIMIT without regard to the output voltage (known as constant-current or brickwall limiting). |

|     |         |   |     |                    |   |
|-----|---------|---|-----|--------------------|---|
|     |         |   | 11  | Shutdown and Retry | The PMBus device continues to operate, maintaining the output current at the value set by IOUT_OC_FAST_FAULT_LIMIT without regard to the output voltage, for the delay time set by bits [2:0] and the delay time units for specified in the IOUT_OC_FAST_FAULT_RESPONSE. If the device is still operating in current limiting at the end of the delay time, the device responds as programmed by the Retry Setting in bits [5:3]. |
| 5:3 | Retries | The device attempts to restart the number of times set by these bits. 000b means the device does not attempt a restart. 111b means the device attempts restarting continuously. | 000 | Do Not Retry       | A zero value for the Retry Setting means that the unit does not attempt to restart. The output remains disabled until the fault is cleared (Section 10.7).  |
|     |         |   | 001 | Retry Once         | The PMBus device attempts to restart 1 time. If the device fails to restart, it disables the output and remains off until the fault is cleared as described in Section 10.7. The time between the start of each attempt to restart is set by the value in bits [2:] along with the delay time unit specified for that particular fault.   |
|     |         |   | 010 | Retry Twice        | The PMBus device attempts to restart 2 times. If the device fails to restart, it disables the output and remains off until the fault is cleared as described in Section 10.7. The time between the start of each attempt to restart is set by the value in bits [2:] along with the delay time unit specified for that particular fault.  |

|  |  |  |     |                    |  |
|--|--|--|-----|--------------------|--|
|  |  |  | 011 | Retry 3 times      | The PMBus device attempts to restart 3 times. If the device fails to restart, it disables the output and remains off until the fault is cleared as described in Section 10.7. The time between the start of each attempt to restart is set by the value in bits [2:] along with the delay time unit specified for that particular fault. |
|  |  |  | 100 | Retry 4 times      | The PMBus device attempts to restart 4 times. If the device fails to restart, it disables the output and remains off until the fault is cleared as described in Section 10.7. The time between the start of each attempt to restart is set by the value in bits [2:] along with the delay time unit specified for that particular fault. |
|  |  |  | 101 | Retry 5 times      | The PMBus device attempts to restart 5 times. If the device fails to restart, it disables the output and remains off until the fault is cleared as described in Section 10.7. The time between the start of each attempt to restart is set by the value in bits [2:] along with the delay time unit specified for that particular fault. |
|  |  |  | 110 | Retry 6 times      | The PMBus device attempts to restart 6 times. If the device fails to restart, it disables the output and remains off until the fault is cleared as described in Section 10.7. The time between the start of each attempt to restart is set by the value in bits [2:] along with the delay time unit specified for that particular fault. |
|  |  |  | 111 | Retry Continuously | The PMBus device attempts to restart continuously, without limitation, until it is commanded OFF (by the CONTROL pin or OPERATION command or both), bias power is removed, or another fault condition causes the unit to shut down.  |

|     |                           |  |   |     |  |
|-----|---------------------------|--|---|-----|--|
| 2:0 | Retry Time and Delay Time | Number of delay time units. Used for either the amount of time the device is to continue operating after a fault is detected or for the amount of time between attempts to restart. The time unit is set in register 0xC8. | 0 | 1   |  |
|     |                           |  | 1 | 2   |  |
|     |                           |  | 2 | 4   |  |
|     |                           |  | 3 | 8   |  |
|     |                           |  | 4 | 16  |  |
|     |                           |  | 5 | 32  |  |
|     |                           |  | 6 | 64  |  |
|     |                           |  | 7 | 128 |  |

**MFR\_IOUT\_OC\_FAST\_FAULT\_LIMIT (0xD1)**

Description: The MFR\_IOUT\_OC\_FAST\_FAULT\_LIMIT command sets or retrieves lout fast overcurrent fault threshold, in Amperes.

| Bit  | Description                                  | Format           | Unit |
|------|--|------------------|------|
| 15:0 | Sets lout fast over-current fault threshold. | Integer Unsigned | A    |

**MFR\_READ\_EVENT (0xD7)**

Description: Retrieves historical information from the snapshot function stored in OTP memory. The MFR\_EVENT\_INDEX command is used to retrieve the number of available snapshots and to set which snapshot should be available to read through this command.

| Bit     | Function           | Description                               | Format               | Unit |
|---------|--------------------|---|----------------------|------|
| 207:176 | Ticks Low Bytes    | The Lowest bytes of the event ticks.      | Fixed Point Unsigned |      |
| 175:168 | Ticks High Byte    | The highest byte of the event ticks.      | Byte Array           |      |
| 95:80   | Read Duty Cycle    | Returns the actual duty cycle in percent. | Integer Unsigned     | %    |
| 79:64   | Read Temperature 1 |   | Integer Signed       | °C   |
| 63:48   | Read Iout          | Returns the measured output current.      | Fixed Point Signed   | A    |
| 47:32   | Read Vout          | Returns the measured output voltage.      | Fixed Point Signed   | V    |
| 31:16   | Read Vin           | Returns the input voltage reading.        | Fixed Point Signed   | V    |
| 15:0    | Event ID           | Event id < 2^16.                          | Integer Unsigned     |      |

| Bit     | Function    | Description   | Value | Function   | Description |
|---------|-------------|---|-------|------------|-------------|
| 167:164 | Old State   | The old state bit field contains the state of the module around 4ms before the error occurred. This is generally of higher interest than the error state. | 0000  | Idle       | Idle.       |
|         |             |   | 0001  | Ton Delay  | Ton Delay.  |
|         |             |   | 0010  | Ramp Up    | Ramp Up.    |
|         |             |   | 0011  | Regulating | Regulating. |
|         |             |   | 0100  | Toff Delay | Toff Delay. |
|         |             |   | 0101  | Ramp Down  | Ramp Down.  |
|         |             |   | 0110  | Fault      | Fault.      |
| 163:160 | Error State |   | 0000  | Idle       | Idle.       |
|         |             |   | 0001  | Ton Delay  | Ton Delay.  |

|     |   |   |      |            |                              |
|-----|---|---|------|------------|------------------------------|
|     |   | The error state bit field contains the state of the module when the error is detected, this will normally have the value FAULT unless a firmware fault occurs or the response setting is set to ignore fault. | 0010 | Ramp Up    | Ramp Up.                     |
|     |   |   | 0011 | Regulating | Regulating.                  |
|     |   |   | 0100 | Toff Delay | Toff Delay.                  |
|     |   |   | 0101 | Ramp Down  | Ramp Down.                   |
|     |   |   | 0110 | Fault      | Fault.                       |
| 159 | Sync Fault                              | Sync fault.   | 0    |            | No fault.                    |
|     |   |   | 1    |            | Fault.                       |
| 158 | Iout Average Overcurrent Fault          | Iout average overcurrent fault.   | 0    |            | No fault.                    |
|     |   |   | 1    |            | Fault.                       |
| 157 | Iout Fast Overcurrent Fault             | Iout fast overcurrent fault.  | 0    |            | No fault.                    |
|     |   |   | 1    |            | Fault.                       |
| 156 | Short Circuit Protection Fault          | Short circuit protection fault.   | 0    |            | No fault.                    |
|     |   |   | 1    |            | Fault.                       |
| 151 | Invalid Or Unsupported Command Received | Invalid Or Unsupported Command Received.  | 0    |            | No Invalid Command Received. |
|     |   |   | 1    |            | Invalid Command Received.    |
| 150 | Invalid Or Unsupported Data Received    | Invalid Or Unsupported Data Received.   | 0    |            | No Invalid Data Received.    |
|     |   |   | 1    |            | Invalid Data Received.       |
| 149 | Packet Error Check Failed               | Packet Error Check Failed.  | 0    |            | No Failure.                  |
|     |   |   | 1    |            | Failure.                     |
| 148 | Memory Fault Detected                   | Memory Fault Detected.  | 0    |            | No Fault.                    |
|     |   |   | 1    |            | Fault.                       |
| 145 | Other Communication Fault               | A communication fault other than the ones listed in this table has occurred.  | 0    |            | No Fault.                    |
|     |   |   | 1    |            | Fault.                       |
| 144 | Memory Or Logic Fault                   | Other Memory Or Logic Fault has occurred.   | 0    |            | No Fault.                    |
|     |   |   | 1    |            | Fault.                       |
| 143 | Overtemperature Fault                   | Overtemperature Fault.  | 0    |            | No Fault.                    |
|     |   |   | 1    |            | Fault.                       |
| 142 | Overtemperature Warning                 | Overtemperature Warning.  | 0    |            | No Warning.                  |
|     |   |   | 1    |            | Warning.                     |
| 141 | Undertemperature Warning                | Undertemperature Warning.   | 0    |            | No Warning.                  |
|     |   |   | 1    |            | Warning.                     |
| 140 | Undertemperature Fault                  | Undertemperature Fault.   | 0    |            | No Fault.                    |
|     |   |   | 1    |            | Fault.                       |
| 135 | Vin Overvoltage Fault                   | Vin Overvoltage Fault.  | 0    |            | No Fault.                    |
|     |   |   | 1    |            | Fault.                       |
| 134 | Vin Overvoltage Warning                 | VIN Overvoltage Warning.  | 0    |            | No Warning.                  |
|     |   |   | 1    |            | Warning.                     |
| 133 | Vin Undervoltage Warning                | Vin Undervoltage Warning.   | 0    |            | No Warning.                  |
|     |   |   | 1    |            | Warning.                     |
| 132 | Vin Undervoltage Fault                  | Vin Undervoltage Fault.   | 0    |            | No Fault.                    |
|     |   |   | 1    |            | Fault.                       |

|     |  |   |   |  |                                      |
|-----|--|---|---|--|--------------------------------------|
| 131 | Insufficient Vin                       | Asserted when either the input voltage has never exceeded the input turn-on threshold Vin-On, or if the unit did start, the input voltage decreased below the turn-off threshold. | 0 |  | No Insufficient VIN encountered yet. |
|     |  |   | 1 |  | Insufficient Unit is off.            |
| 127 | Iout Overcurrent Fault                 | Iout Overcurrent Fault.   | 0 |  | No Fault.                            |
|     |  |   | 1 |  | Fault.                               |
| 126 | Iout Overcurrent And Low Voltage Fault | Iout Overcurrent and low voltage fault.   | 0 |  | No Fault.                            |
|     |  |   | 1 |  | Fault.                               |
| 125 | Iout Over Current Warning              | Iout Overcurrent Warning.   | 0 |  | No Warning.                          |
|     |  |   | 1 |  | Warning.                             |
| 124 | Iout Undercurrent Fault                | Iout Undercurrent Fault.  | 0 |  | No Fault.                            |
|     |  |   | 1 |  | Fault.                               |
| 119 | Vout Overvoltage Fault                 | Vout Overvoltage Fault.   | 0 |  | No Fault.                            |
|     |  |   | 1 |  | Fault.                               |
| 118 | Vout Overvoltage Warning               | Vout Overvoltage Warning.   | 0 |  | No Warning.                          |
|     |  |   | 1 |  | Warning.                             |
| 117 | Vout Undervoltage Warning              | Vout Undervoltage Warning.  | 0 |  | No Warning.                          |
|     |  |   | 1 |  | Warning.                             |
| 116 | Vout Undervoltage Fault                | Vout Undervoltage Fault.  | 0 |  | No Fault.                            |
|     |  |   | 1 |  | Fault.                               |
| 115 | Vout Max Warning                       | Vout Max Warning (An attempt has been made to set the output voltage to value higher than allowed by the Vout Max command (Section 13.5).   | 0 |  | No Warning.                          |
|     |  |   | 1 |  | Warning.                             |
| 114 | Ton Max Fault                          | Ton-Max Fault.  | 0 |  | No Fault                             |
|     |  |   | 1 |  | Fault.                               |
| 113 | Toff Max Warning                       | Toff Max Warning.   | 0 |  | No Warning.                          |
|     |  |   | 1 |  | Warning.                             |
| 111 | Vout                                   | An output voltage fault or warning has occurred.  | 0 |  | No fault                             |
|     |  |   | 1 |  | Fault                                |
| 110 | Iout/Pout                              | An output current or output power fault or warning has occurred.  | 0 |  | No Fault.                            |
|     |  |   | 1 |  | Fault.                               |
| 109 | Input                                  | An input voltage, input current, or input power fault or warning has occurred.  | 0 |  | No Fault.                            |
|     |  |   | 1 |  | Fault.                               |
| 108 | Mfr Specific                           | A manufacturer specific fault or warning has occurred.  | 0 |  | No Fault.                            |
|     |  |   | 1 |  | Fault.                               |
| 107 | Power-Good                             | The Power-Good signal, if present, is negated.  | 0 |  | No Fault.                            |
|     |  |   | 1 |  | Fault.                               |
| 102 | Off                                    |   | 0 |  | No fault                             |

|     |                        |  |   |  |           |
|-----|------------------------|--|---|--|-----------|
|     |                        | This bit is asserted if the unit is not providing power to the output, regardless of the reason, including simply not being enabled. | 1 |  | Fault     |
| 101 | Vout Overvoltage Fault | An output overvoltage fault has occurred.  | 0 |  | No Fault. |
|     |                        |  | 1 |  | Fault.    |
| 100 | Iout Overcurrent Fault | An output overcurrent fault has occurred.  | 0 |  | No Fault. |
|     |                        |  | 1 |  | Fault.    |
| 99  | Vin Undervoltage Fault | An input undervoltage fault has occurred.  | 0 |  | No Fault. |
|     |                        |  | 1 |  | Fault.    |
| 98  | Temperature            | A temperature fault or warning has occurred.   | 0 |  | No Fault. |
|     |                        |  | 1 |  | Fault.    |
| 97  | Communication/Logic    | A communications, memory or logic fault has occurred.  | 0 |  | No fault. |
|     |                        |  | 1 |  | Fault.    |
| 96  | None of the Above      | A fault or warning not listed in bits [7:1] has occurred.  | 0 |  | No fault. |
|     |                        |  | 1 |  | Fault.    |

**MFR\_ISHARE\_THRESHOLD (0xDA)**

Description: MFR\_ISHARE\_THRESHOLD defines a current sharing deadzone.

| Bit  | Description  | Format | Unit |
|------|--|--------|------|
| 15:0 | MFR_ISHARE_THRESHOLD defines a current sharing deadzone, which ishare adjustment is zero out. This means that the current sharing error must be greater than the value specified in MFR_ISHARE_THRESHOLD. By setting this command to 0x0000, the active current share is disabled. | Linear | A    |

**MFR\_EVENT\_INDEX (0xDB)**

Description: When reading this command returns the number of events logged. When writing to this command it controls which event can be retrieved via the MFR\_READ\_EVENT command. Valid values when writing are the integers in the interval [0; count - 1].

| Bit  | Description       | Format           |
|------|-------------------|------------------|
| 15:0 | Mfr. event index. | Integer Unsigned |

**MFR\_SELECT\_TEMPERATURE\_SENSOR (0xDC)**

Description: Select which temperature sensor, internal one or external remote temperature sensor, is used.

| Bit | Function                         | Description   | Value | Function       | Description  |
|-----|----------------------------------|---|-------|----------------|--|
| 4:3 | Fault Source Select              | Select which temperature sensor, internal one or external remote temperature sensor, is used. | 00    | Temp A         | Temp A temperature sensor selected.  |
|     |                                  |   | 01    | Temp B         | Temp B temperature sensor selected.  |
|     |                                  |   | 10    | Temp I         | Temp I temperature sensor selected.  |
| 2:0 | READ_TEMPERATURE_1               | READ_TEMPERATURE_1<br>READ_TEMPERATURE_2 Source Select.                                       | 000   | TempA<br>TempB | TempA (External Temperature sensor A) TempB (External Temperature sensor B). |
|     | READ_TEMPERATURE_2 Source Select |   | 001   | TempA TempI    | TempA (External Temperature sensor A) TempI (Internal Temperature sensor).   |



|  |  |  |     |                |  |
|--|--|--|-----|----------------|--|
|  |  |  | 010 | TempB<br>TempA | TempB (External Temperature sensor B) TempA (External Temperature sensor A). |
|  |  |  | 011 | TempB<br>Templ | TempB (External Temperature sensor B) Templ (Internal Temperature sensor).   |
|  |  |  | 100 | Templ TempA    | Templ (Internal Temperature sensor) TempA (External Temperature sensor A).   |
|  |  |  | 101 | Templ TempB    | Templ (Internal Temperature sensor) TempB (External Temperature sensor B).   |

**MFR\_FLEX\_FIRMWARE\_CMD (0xE0)**

Description: Mfr. firmware command.

| Bit  | Description            | Format     |
|------|------------------------|------------|
| 63:0 | Mfr. firmware command. | Byte Array |

**MFR\_FILTER\_COEFF (0xE8)**

Description: Mfr. pid coefficients

| Bit   | Function         | Description                  | Format           |
|-------|------------------|------------------------------|------------------|
| 30:24 | PID KD           | PID derivative coefficient   | Integer Unsigned |
| 23:18 | PID KI           | PID integral coefficient     | Integer Unsigned |
| 17:12 | PID KP           | PID proportional coefficient | Integer Unsigned |
| 11:6  | PID pre-filter 2 | PID pre-filter 2 coefficient | Integer Unsigned |
| 5:0   | PID pre-filter 1 | Pid pre-filter 1 coefficient | Integer Unsigned |

**MFR\_IOUT\_APC (0xEA)**

Description: The iout apc gain.

| Bit  | Description   | Format | Unit |
|------|---|--------|------|
| 15:0 | SSet the iout apc gain. the format is Linear 11, Exponent is -9 or -8 (User selection possible). The LSB varies with isen_gain_mode - ISEN_LSB/Secondary current sense resistor (Rsense). | Linear | A    |

**MFR\_MULTI\_PIN\_CONFIG (0xF9)**

Description: The MFR\_MULTI\_PIN\_CONFIG command can be re-configured to enable or disable different functions and set the pin configuration.

| Bit | Function                | Description  | Value | Function   | Description                       |
|-----|-------------------------|--|-------|------------|-----------------------------------|
| 9   | Enable Snapshot Feature | Enables the snapshot feature. When enabled the snapshot function will run once every ms to collect telemetry data and regulator state into ring buffers and to check for OVF, OCF or OTF events. | 0     |            | Disabled                          |
|     |                         |  | 1     |            | Enabled                           |
| 2   | Power Good Pull-down    | This bit enables or disables Power Good pin pull-down.   | 0     | Disabled   |                                   |
|     |                         |  | 1     | Enabled    |                                   |
| 1   | Power Good Output       | Two output options are available for Power Good output, they are Push/Pull or Open Drain.  | 0     | Push/Pull  | Power Good configured Push/Pull.  |
|     |                         |  | 1     | Open Drain | Power Good configured Open Drain. |

**MFR\_ADDED\_DROOP\_DURING\_RAMP (0xFC)**

Description: Set an added droop during ramp.

| Bit  | Description   | Format | Unit     |
|------|---|--------|----------|
| 15:0 | Sets an added effective load line (V/I slope) for the rail in which the device is used, during ramp up. | Linear | mV/<br>A |