

JEDEC STANDARD

Backup Energy Module Standard for NVDIMM Memory Devices (BEM)

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BACKUP ENERGY MODULE STANDARD FOR NVDIMM MEMORY DEVICES (BEM)

(From JEDEC Board Ballot JCB-21-48, formulated under the cognizance of the JC-45 Committee on DRAM Modules, item 2279.03.)

1 Scope

This standard defines the functional requirements of Backup Energy Module (BEM), henceforth referred to as BEM in this standard. This module shall be used to provide backup power to the Industry Defined Storage Array Controller Cards and NVDIMM-n as applicable. All standards are applicable under all operating conditions unless otherwise stated.

2 Reference Documents

2.1 Applicable Documents

The following documents form a part of this standards reference to the extent specified herein. Unless otherwise indicated, the content of this standard applies. Undated references refer to the latest revision of the standard that is in effect at the time the product is intended to be released.

Table 1 — Reference documents

Reference	Description
PMBus_Specification_Part_I_Rev_1_3_1_20150313	PMBus™ Power System Management Protocol Specification Part I – General Requirements, Transport And Electrical Interface
PMBus_Specification_Part_II_Rev_1_3_1_20150313	“PMBus™ Power System Management Protocol Specification Part II – Command Language
Smart Battery Data Specification	Smart Battery Data Specification Revision 1.1 December 11, 1998
JESD245C	JEDEC STANDARD, Byte Addressable Energy Backed Interface
ANSI C63.4	“American National Standard for Methods of Measurement of Radio- Noise Emissions from Low-Voltage Electrical and Electronic Equipment in the Range of 9 kHz to 40 GHz.” American National Standards Institute (ANSI), 2014.
Australian Communications & Media Authority	Electromagnetic Compatibility Framework - Information for Suppliers – Residential, Commercial and Light Industry”(and amendments) URL: http://www.acma.gov.au
C.I.S.P.R. Pub. 32	"Limits and methods of measurement of radio interference characteristics of information technology equipment.” International Special Committee on Radio Interference (C.I.S.P.R.), 2008.
CCC EMC	"Regulations for Compulsory Product Certification,” China Certification Center, URL: http://www.cemc.org.cn .

Table 1 — Reference documents (cont'd)

Reference	Description
CFR 47, Part 15	"Unintentional Radiators". Title 47 of the Code of Federal Regulations, Part 15, FCC Rules, Radio Frequency Devices, Subpart B.
CNS14336-1: 2010	"Information technology equipment – Safety – General requirements", Bureau of Standard, Metrology and Inspection
CNS13438	"Limits and Methods of Measurement of Radio Interference Characteristics of Information Technology Equipment", Bureau of Standard, Metrology and Inspection
EN 55022	"Limits and methods of measurement of radio interference characteristics of information technology equipment." European Committee for Electro technical Standardization (CENELEC), 2010.
EN 55024	"Information technology equipment - Immunity characteristics - Limits and Methods of measurement." European Committee for Electro technical Standardization (CENELEC) 2010.
EN 55032	"Electromagnetic compatibility of multimedia equipment - Emission requirements." European Committee for Electro technical Standardization (CENELEC), 2012.
EN 60320-1	"Appliance Couplers for Household and Similar General Purposes – Part: General Requirements" European Committee for Electro technical Standardization (CENELEC).
EN 60950-1:2006 A11: 2008 A1: 2010 A12: 2011 A2: 2013	"Safety of Information Technology Equipment - Safety - Part 1: General requirements", Second Edition European Committee for Electro technical Standardization (CENELEC), 2006, including A11:2008, A1:2010, A12:2011 and A2:2013.
EN 62368-1	"Audio/video, information and communication technology equipment – Part 1: Safety requirements", European Committee for Electro technical Standardization (CENELEC), 2014
EN 61000-3-2	"Electromagnetic Compatibility (EMC) Part 3-2 Limits - Limits for Harmonics Current Emissions (Equipment input current ≤16A per phase)." International Electrotechnical Commission, 2014
EN61000-3-3	"Electromagnetic compatibility (EMC) - Part 3-3 Limits - Limitation of voltage fluctuations and flicker in low-voltage supply systems for equipment with rated current ≤ 16 A" European Committee for Electrotechnical Standardization (CENELEC), 2013.
EU address on Product	These extended versions of the CE marking are explained at: http://intranet.hp.com/Sites/WTR-EU/Home/Pages/CE_Marking.aspx
GB4943.1	"Safety of Information technology equipment", Standardization Administration of China. 2011
GB17625.1	Electromagnetic compatibility- Limits for harmonic current emissions (equipment input current ≤ 16 A per phase)', Standardization Administration of China, 2012.
GB9254	"Limits and methods of measurement of radio interference characteristics of information technology equipment." SAC, 2008.

Table 1 — Reference documents (cont'd)

Reference	Description
IEC 60950-1: 2005 A1: 2009 A2: 2013	“Safety of Information Technology Equipment - Safety - Part 1: General requirements”, Second Edition, International Electrotechnical Commission, 2005, including A1:2009 and A2:2013.
IEC 62368-1	“Audio/video, information and communication technology equipment – Part 1: Safety requirements”, International Electrotechnical Commission, 2014.
IEC 61000-4 Sections 2 – 6, 11	“Electromagnetic Compatibility (EMC) – Part 4: Testing and measurement techniques.” International Electro technical Commission (IEC).
IEC 62391-1:2015 (JIS C 5160-1)	Fixed electric double-layer capacitors for use in electric and electronic equipment - Part 1: Generic specification
Korea KCC (MSIP) Approval	EMC Registration Regulation, URL: http://www.rra.go.kr/
Taiwan EMC Law	“Commodity EMC Regulation” (Taiwan EMC Law), Bureau of Standards, Metrology, and Inspection under auspices of the Ministry of Economic Affairs, http://www.bsmi.gov.tw
UL 60950-1, 2nd Ed, CSA C22.2 No. 60950-1-07, 2nd Ed + A1:2011	"Safety of Information Technology Equipment including Electrical Business Equipment- Safety – Part 1: General Requirements, First Second Edition." Underwriters Laboratories, Inc., 2007, Canadian Standards Association, 2007, including Amendment 1:2011.
UL 62368-1, 2nd Ed, CSA C22.2 No. 62368-1-14	Standard for Safety “Audio/video, information and communication technology equipment – Part 1: General Requirements, Second Edition.” Underwriters Laboratories, Inc., 2014, Canadian Standards Association, 2014
UL 1642, 5th edit	“Standard for Lithium Batteries” Underwriters Laboratories, Inc., 2012.
UN 38.3	Subsection 38.3 of the UN Manual of Tests and Criteria, Part III
UN3508	The transport of Lithium Ion Capacitors is regulated by UN3508 “Capacitor, asymmetric (with an energy storage capacity greater than 0.3Wh)”. For air freight Special Provision A196 is applicable as described in the IATA “Dangerous Goods Regulations” handbook.

2.2 Order of Precedence

In the event of a conflict between this standard and references cited herein, this standard shall take precedence.

2.3 Definitions

1. In this standard, “product” refers to Energy Backup Module as BEM.
2. IC= Integrated circuit controller
3. LIC = Lithium-Ion Capacitor
4. EDLC = Electrical Double Layer Capacitor
5. Li-Ion = Lithium Ion Battery
6. PSU= Power Supply Unit
7. SOC= State of Charge
8. CC= Constant Current
9. CV= Constant Voltage
10. LOAD = Smart Array Controller Card or NVDIMM-n module

3 Backup Energy Module Overview

BEM may be designed using one of the many available energy source components, e.g., EDLC Capacitor/s, Li-Ion Capacitor/s, Li-Ion Batteries, etc. Each BEM may contain one or more series or parallel connected energy source components as applicable to fulfill published product specifications. Mechanical example of BEM supporting 1 load is illustrated in Figure 2.

Figure 1 illustrates general connection interface between system load and module for clarity of terms used in this standard. All specifications herein are based on two separate arrangements of the same electrical block diagram. First illustration shows BEM with charge/discharge and monitoring controls contained in the module.

All electrical specifications defined in this standard are specific to BEM supporting one load. All electrical specifications refer to block illustration in Figure 1, e.g., Input means input to the charger; Output means output of the backup converter, etc.

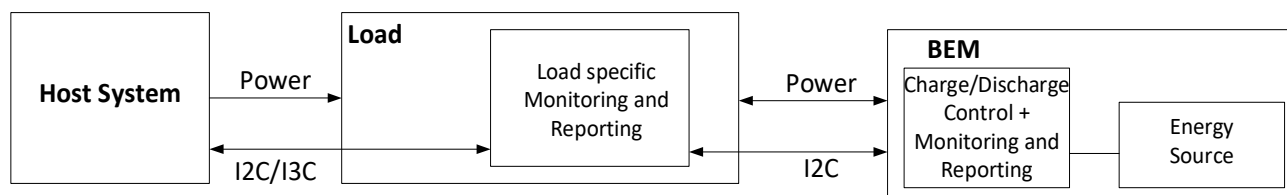
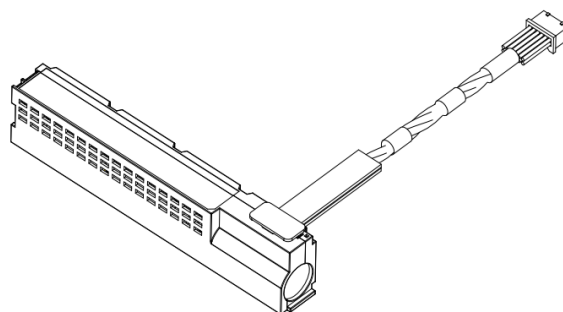


Figure 1 — BEM definition diagram

4 Mechanical Overview

BEM Mechanical definition shall follow JEDEC module drawing item # MO-334.



NOTE Mechanical illustration for reference only, not to scale.

Figure 2 — Mechanical outline

5 Functional Block Diagram

Figure 3 defines recommended functional diagram for guidance. This diagram guides BEM electrical specifications in this standard. The functional operation is based on buck converter for charging energy source and boost converter for backup from the energy source.

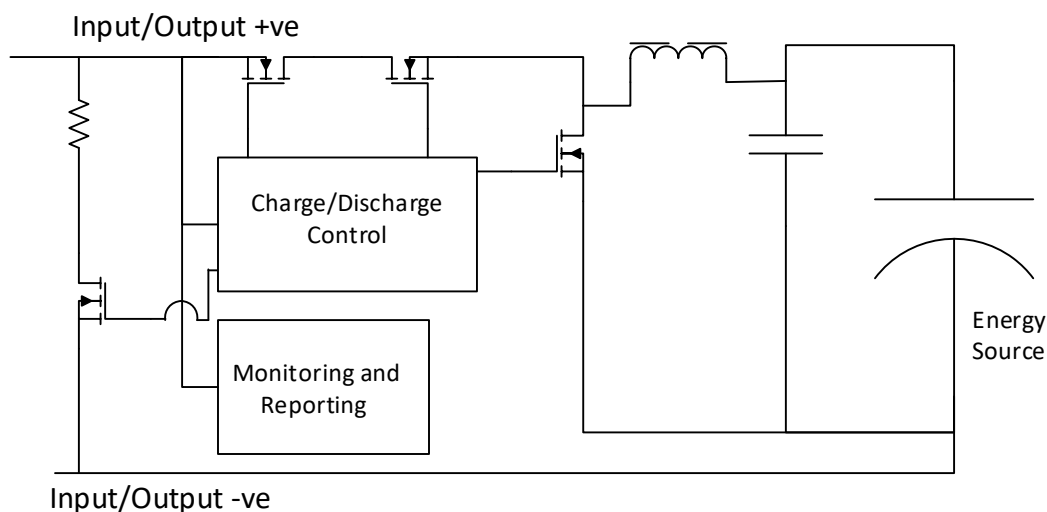


Figure 3 — Functional block diagram

6 Electrical Requirements

6.1 Pin Definition, Cable, and Connector

The output shall be a plug and cable assembly extended from the PCB board internal to the module and shall blind mate with a 6 pin receptacle on the load side.

Table 2 — Connector Pin Outs

Pin #	In/Out	Function	Description	Color	AWG
1	PWR +	Input/Output +ve	Power Input/Output (+ve terminal)	Red	24
2	Alert #	SM Alert#	Interrupt function as defined in SM Bus/ PM Bus standard	White	28
3	BAT_OK/ BUP_STOP	Battery OK/ Stop Backup	Cell Health & Backup Control	Blue	28
4	SCL	SCL	I2C Clock	Green	28
5	SDA	SDA	I2C Data	Yellow	28
6	PWR -	Input/Output -ve	Power Return (-ve terminal)	Black	24

6.2 Input Output Pins and Signal Definitions

6.2.1 PWR+

Bi-directional power supply positive wire used for charging BEM using load power. Also to be used as power supply positive wire for supplying backup power from BEM during load power loss.

6.2.2 PWR-

Bi-directional power supply negative wire used for charging BEM using load power. Also to be used as power supply negative wire for supplying backup power from BEM during load power loss.

6.2.3 SCL

I2C serial communication CLOCK signal wire. Pull up to $3.3\text{ V} \pm 10\%$ supply voltage in the load.

6.2.4 SDA

I2C serial communication DATA signal wire. Pull up to $3.3\text{ V} \pm 10\%$ supply voltage in the load.

6.2.5 Alert#

SMBus, PMBus protocol defined Alert# signal wire. Pull up to $3.3\text{ V} \pm 10\%$ supply voltage in the load.

6.2.6 BAT_OK/BUP_STOP

Bi-directional status signal for indicating BEM status to provide backup and load status to accept backup. Pull up to $3.3\text{ V} \pm 10\%$ supply voltage in the load.

As illustrated in Figure 4, BEM and target load shall implement logic circuit blocks to implement this signal functionality.

As illustrated in Figure 5, target load shall implement BEM detection logic to address unconnected BEM issue. Detection circuit shall measure voltage difference across the resistor to confirm BEM presence when load supply voltage is $12\text{ V} \pm 10\%$. The circuit logic shall control parallel FET turn on below 10.80 V and turn off the parallel bypass FET above 11.00 V for detection purpose and for optimal voltage drop during charging and backup operations.

6.2.6.1 Bat_OK

This is BEM generated signal which indicates three states as follows:

Bat_OK Signal State	BEM Operating State
High	Charged or Charging and Ready to Provide Backup
50% Duty Cycle Square Wave	Charging and NOT Ready to Provide Backup
Low	Fault

When Bat_OK signal is in LOW state, BEM shall register the fault in STATUS_WORD COMMAND high byte register by changing bit# 3 to 1 from 0.

6.2.6.2 BUP_STOP

This is load generated signal which indicates two states as follows:

BUP_STOP Signal State	Load Operating State
High	Ready for backup
Low	Stop backup

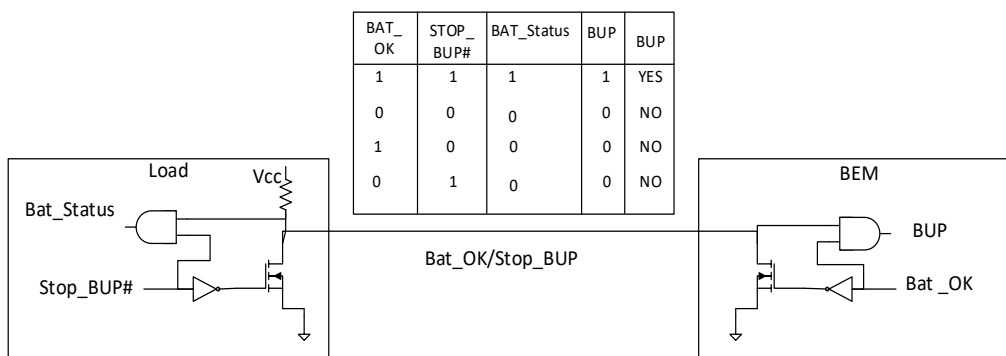


Figure 4 — BEM and Load side Battery OK/Stop Backup# dual function signal implementation

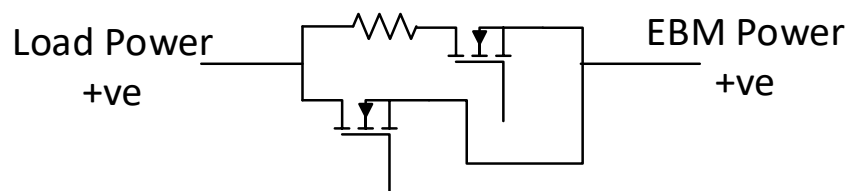
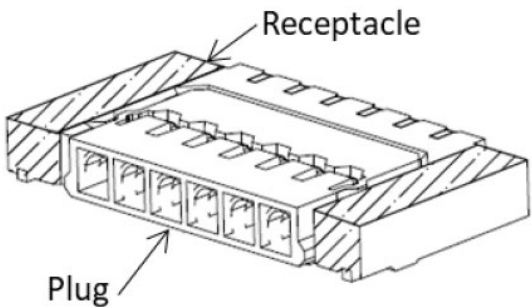


Figure 5 — Load side BEM detection and BEM reset circuit implementation

Table 3 — Cable length and connector type

Cable Length	Connector Type
300 mm (± 5 mm) max.	1 x 6 pins plug housing

Table 4 — Mating connector (for system side reference)

Part Number	Connector Type
TBA	1 x 6 pins Header
<p>NOTE Cable plug housing and receptacle mechanical and electrical specifications as per drawing # SO-026, SO-027, and SO-028.</p> 	

6.3 Input and Charge Operation

6.3.1 Input Voltage

The input of BEM is connected to the main output of system power supply through connector located on the load. The input to BEM shall be 10.20 V to 13.80 V. Minimum Input rise time of 10 V/msec shall be met when BEM cable is plugged into the load and then load power is ON.

6.3.2 Input Ripple and Noise

Input DC voltage from the system power supply to the BEM can contain 120 mV peak to peak ripple and noise component. BEM shall be designed to accept AC input ripple and noise with appropriate input filtering.

6.3.3 Charger

BEM shall contain a charger to charge the energy source. The charger shall be functional with the input voltage ≥ 10.2 V and stop charging with the input voltage < 9.8 V. The charger shall have following modes to charge the energy source. The charger circuit shall monitor charge voltage and current to determine the charge mode.

6.3.3.1 Trickle Charge Mode

The charger may provide trickle charge mode to maintain charge on the energy source. In trickle charge mode, the charge current shall be limited to < 10 mA.

6.3.3.2 Normal Charge Mode

The charger shall provide constant current (CC) and constant voltage (CV) charge in the normal charge mode. Charger output current ≥ 0.9 A (CC charge).

6.3.4 Charger Output Voltage

The charger output voltage is dependent on the energy source voltage. The charger shall be capable of providing charge to energy source at 0 V to 9.0 V charge level.

6.3.5 Charger Efficiency

This clause is to define the minimum efficiency requirement of the charger with different output voltage in CC charge mode.

Table 5 — Minimum efficiency of charger

Input [V]	Output Load of Charger [A]	Charger Output Voltage [V]	Minimum Efficiency [%]
12VDC	1	2.0	90

6.3.6 Feedback Loop Stability of Charger

The charger converter control loop shall be unconditionally stable.

6.4 Output and Discharge Operation

6.4.1 Output Voltage

The output voltage of the BEM is defined as the voltage measured on the output connector. The output voltage shall be set to regulate to 8 V during backup as default. The BEM design shall be capable of setting the output to 4.5 V min. and 9.0 V max. using PMBus VOUT_COMMAND. A load needing backup voltage level other than 8.0 V nominal shall write target set value upon valid input is applied to BEM. BEM shall maintain set output voltage threshold till an input power cycle (Off then On) is performed. At that instance load shall write the desired output set point again. All output voltage related protection parameters shall change proportionally to the new set value by a factor of (Vset)/(8.0).

The minimum output voltage shall be guaranteed with the conditions per Table 6.

Table 6 — Output power, output voltage, and backup time

Minimum Output Backup Load (Watt)	Minimum Backup Time at initial state (s)	Minimum Energy at initial state (Joule)	Vout Set point BACKUP MODE (V)
10	30	300	8.0 \pm 0.4

6.4.2 Output Current

BEM shall source continuous output rated load current proportional to output voltage setting. BEM shall source 2x rated max. current for ≤ 1 millisecond to support transient current demand from the load. For output voltage setting other than 8.0 V, all output current related protection parameters shall change proportionally to the new set value by a factor of $(8.0 \text{ V})/(V_{\text{set}})$.

Table 7 — Output power, output voltage, and output current

Minimum Output Backup Load (Watt)	Minimum Backup Time at initial state (s)	Minimum Energy at initial state (Joule)	Vout Set point BACKUP MODE (V)	Minimum Iout BACKUP MODE (A)
10	30	300	8.0 ± 0.4	1.40
10	30	300	4.5 ± 0.25	2.40

6.4.3 Output Ripple and Noise

Ripple and noise shall be measured at the output connector over a bandwidth of 0Hz to 20MHz. Ripple and Noise shall be measured in discharge mode at minimum output load (0A) and Maximum Output load. Energy Source voltage shall be monitored for this test such that Ripple and Noise measurements are taken at minimum and maximum energy source voltage levels. Output Ripple and Noise shall not exceed the limits in Table 8. For this measurement, the minimum capacitive load shall be in parallel with a 10 °F tantalum capacitor (minimum 100 mΩ ESR) and with a 0.47 °F ceramic capacitor placed at the point of measurement.

Table 8 — Ripple and noise Limits

MAX RIPPLE [mV pk-pk]
100

6.4.4 Backup Converter Efficiency

This clause defines minimum efficiency requirement of boost converter during backup mode. The measuring point of input voltage shall be energy source voltage, the output voltage shall be measured at the output connector.

Table 9 — Minimum efficiency of discharger

Output Load [W]	Energy Source String Voltage [V]	Minimum Efficiency [%]
10	2.0 to 7.6	90

6.4.5 Feedback Loop Stability – Backup Converter

Backup converter control loop shall be unconditionally stable under all output load and input voltage conditions.

6.5 Fault Protections

BEM shall meet operating fault protections for host system, load and energy backup source functional and structural protections.

Protection circuits shall be installed in the BEM. BEM shall include circuits to monitor and maintain energy backup cell balance in case of multiple cells used in series or parallel for backup. BEM shall include over temperature, over voltage and over current warning to host system.

6.5.1 Voltage Protection

BEM design shall include over and under voltage protection including input and output voltage, the BEM shall be capable of protecting the energy cells from over charge damage.

6.5.2 Current Protection

BEM design shall include Input and Output current protection including input and output current, the BEM shall be capable to protect the energy cells from over discharge damage.

6.5.3 Temperature Protection

BEM design shall include high and low temperature protection. BEM shall include cell charge and discharge protection by sensing the surface temperature of the energy cells. Different type of the energy cell determines the range of the operation temperature of the BEM.

6.5.4 Cell Voltage Balancing

When the energy cells are connected in series, cell voltage imbalance may occur, resulting in energy cell over charge or over discharge. When energy cells are connected in parallel, cell charge/discharge current imbalance may occur. BEM shall include appropriate monitoring and balancing circuits to manage cell balance in series or parallel connected configurations.

6.5.5 Charge/Discharge Mode Protection and Operation Table

BEM shall provide protection against damaging internal circuits or intended load or host system circuits by implementing Input/Output directional current flow monitoring and management in and out of the BEM as per operating conditions. Table 10 describes possible operating/fault conditions. These signal states related to operating conditions in conjunction with fault reporting status over I²C shall be used by host load to determine specific fault. Example thresholds are for 8 V nominal output in backup mode. Different output voltage set point will change voltage and current levels in rows marked with asterisk.

Table 10 — Input/output fault protections and operation conditions

INPUT VOLTAGE	INPUT CURRENT	STOP_BUP	Battery OK	OUTPUT VOLTAGE	OUTPUT CURRENT	COMMENT
10.8 V – 13.2 V	≤ 1 A	High	Pulsed	N/A	N/A	Power On BEM Charging
10.8 V – 13.2 V	≤ 0.1 A	High	Low	N/A	N/A	Charger Fault
< 7 V	N/A	High	High	8 V*	≤ 1.3 A*	Backup On
5 V – 13.2 V	≤ 1 A	Low	High	N/A	N/A	Load initiated Backup stopped
5 V – 13.2 V	≤ 1 A	High	Pulsed	N/A	N/A	BEM Initiated Backup stopped
< 10 V	N/A	N/A	Low	N/A	N/A	Input Under Voltage Fault
> 14 V	N/A	N/A	Low	N/A	N/A	Input Over Voltage Fault
NA	N/A	N/A	Low	< 6 V*	N/A	Output Under Voltage Fault
NA	N/A	N/A	Low	> 14 V*	N/A	Output Over Voltage Fault
10.8 V - 13.2 V	≥ 2 A	N/A	Low	N/A	N/A	Input Over Current Fault
10.8 V - 13.2 V	N/A	N/A	Low	N/A	≥ 2.6 A*	Output Over Current Fault
10.8 V - 13.2 V	≤ 1 A	N/A	Low	NA	NA	Over Temperature Fault
NA	NA	N/A	Low	8 V*	≤ 1.3 A*	Over Temperature Fault

7 Environmental Requirements

7.1 Operating Environment

BEM shall be capable of normal functional operation from 10 °C to 60 °C ambient. Applicable airflow and cell temperature controls shall be provided to satisfy energy backup cell operating life requirements.

7.2 Storage Environment

BEM shall be used within a short period after charging because long-term storage may cause loss of capacity by self-discharging. If long-term storage is necessary, the BEM shall be stored at lower voltage within a range specified in the energy cell specification, because storage with higher voltage may cause more loss of performance characteristics. Storage and re-charge requirements shall be clearly defined by the BEM product manufacturer.

7.3 Environmental Responsiveness

BEM shall not contain environmentally hazardous substances: 1. Lead 2. Mercury 3. Cadmium 4. Hexavalent Chromium 5. Polybrominated Biphenyls (PBB), and 6. Polybrominated Diphenyl ethers (PBDE).

7.4 Disposal

BEM shall be disposed according to the local regulations when it is disposed. The BEM shall be disposed in a discharged state to avoid heat generation by an inadvertent short-circuit.

7.5 Temperature

7.5.1 Operating Environment

10 °C to 60 °C.

7.5.2 Storage

BEM shall be designed for storage at room ambient of 10 °C to 35 °C and less than 65% relative humidity is recommended.

7.6 Humidity

65% RH or less (non-condensing) for storage.

7.7 Altitude

7.7.1 Operating

Maximum operating ambient temperature of BEM shall have an altitude derating from sea level of 1.0 °C per every 304.8 m. (1.8 °F per every 1000 ft.) above sea level to a maximum of 3048 m (10,000 ft.).

7.7.2 Non-operating

15,240 m. (50,000 ft.) above sea level.

7.8 Mechanical shock

7.8.1 Fixturing

Equipment Under Test subassembly shall be rigidly clamped directly to the shock equipment surface.

7.8.2 Operating

Half sine wave shock - 5 G, 11 ms duration, half sine wave shock in each direction of three mutually perpendicular axes. There shall be one shock input in each direction of three mutually perpendicular axes for a total of six shock inputs.

7.8.3 Non-operating

Half sine wave shock - 140 G, 2 ms duration, half sine wave shock in each direction of three mutually perpendicular axes. There shall be one shock input in each direction of three mutually perpendicular axes for a total of six shock inputs.

Square wave shock - 40 G, 166 inch/sec velocity change, square wave shock in each direction of three mutually perpendicular axes. There shall be one shock input in each direction of three mutually perpendicular axes for a total of six shock inputs.

7.9 Vibration

7.9.1 Fixturing

Equipment Under Test subassembly shall be rigidly clamped directly to the vibration equipment surface.

7.9.2 Operating

Sinusoidal Vibration - 0.25 G zero-to-peak, 10 to 500 Hz, 0.25 oct/min in each of three mutually perpendicular axes. The test duration shall be one sweep from 10 to 500 to 10 Hz in each of three mutually perpendicular axes.

Random Vibration - $0.002 \text{ G}^2/\text{Hz}$, 10 to 500 Hz, nominal 1.0 Grams in each of three mutually perpendicular axes. The test duration shall be one hour/axis for a total test duration of three hours.

7.9.3 Non-Operating

Sinusoidal Vibration - 0.75 G zero-to-peak, 10 to 500 Hz, 0.5 oct/min. The test duration shall be one sweep from 10 to 500 to 10 Hz in each of three mutually perpendicular axes.

Random Vibration - $0.008 \text{ G}^2/\text{Hz}$, 10 to 500 Hz, nominal 2.0 Grams in each of three mutually perpendicular axes. The test duration shall be one hour/axis for a total test duration of three hours.

7.10 Electrostatic Discharge (ESD)

Module shall meet ESD test criterion as per EN 55024.

8 Communication Bus Descriptions

This clause describes the communication interface that a module compliant with this publication shall support.

8.1 I²C Bus Signal

BEM shall support enhanced monitoring and control functions implemented via I²C bus. The I²C functionality (PMBus™ and FRU data) shall be accessed via output connector control signals. The communication bus is powered either by the internal 3.3 V supply or from an external 3.3 V power source.

BEM shall support programming through configuration file, undesired access protection of factory programmed and other registers deemed user inaccessible.

When load receives all zeros in response to any transaction initiation, it shall wait for the BEM to get ready for communicating with it. BEM shall allow communication with the load multiple times per second. This provision is provided for possible implementations of supporting multiple loads with single BEM.

8.2 PMBus™ Interface Support

BEM shall be compliant with industry standard PMBus™ protocol for monitoring and control functions between BEM and load via the I²C interface port. In the following clauses, required commands shall be supported at the minimum. Manufacturer shall clearly specify all supported commands for user information.

8.3 Packet Error Checking (PEC)

Recommend using PEC when you implement PMBus™ communication. PEC (Packet Error Checking) functionality shall be implemented within BEM in accordance with PMBus™ protocol standard. Use of PEC for communication between host and BEM is recommended but shall not be required in system implementation.

8.4 Device Address

BEM shall support default I2C device address C0h for the host load to communicate. BEM shall be designed to respond as a slave device on the communication bus.

8.5 Command Codes

PMBus™ commands are expressed in single byte command codes. A listing of PMBus™ commands and their hexadecimal command codes are listed in APPENDIX I in Table 31 in “PMBus_Specification_Part_II_Rev_1_3_1_20150313”. Command codes are not register addresses in PMBus™ devices. The mapping of PMBus™ command codes to memory locations in the device shall be defined by BEM manufacturer.

8.6 Numeric Data Format

The module shall support numeric data format per Table 11.

8.7 Paging

All modules supporting this standard shall support a paging mechanism. The page command provides the ability to configure, control and monitor through only one physical address either:

- Multiple outputs on one unit (Page 0 to page 20 are reserved for multiple outputs, page 0 is mandatory)
- Debug command (optional)
- Upgrade command (optional)
- Calibration command (optional)
- Other Manufacturer specific command (optional)

Each PAGE contains the Operating Memory (and at the option of the device manufacturer, User Store and Default Store) for each output.

8.8 Command Summary

Table 11 shows the list of PMBus™ commands. BEM supported commands shall be a list of commands marked as Yes in the Required column of the table at the minimum. BEM manufacturer shall clearly document Command List, Data Format and Function for user.

All Read operations refer to host load read from BEM memory area. All Write operations refer to host load Write into BEM memory area. All Send operations refer to Send instruction from host load to BEM.

Upon Alert# assertion from BEM, host load shall execute series of commands at the minimum as commented in Table 11. Command 03h “Clear Faults” shall be executed at the end of communication sequence. The mandatory command execution list enables single BEM supporting multiple loads.

Table 11 — BEM supported commands and settings

Code	Command Name	Access Type	Data Bytes	Required (Yes/No)	Data Format	Comments
00h	PAGE	R/W	1	Y		
01h	OPERATION	R/W	1	N		
02h	ON_OFF_CONFIG	R/W	1	Y		
03h	CLEAR_FAULTS	Send	0	Y		Execute on Alert# assertion
10h	WRITE_PROTECT	R/W	1	Y		Execute on Alert# assertion
11h	STORE_DEFAULT_ALL	Send	0	Y		
12h	RESTORE_DEFAULT_ALL	Send	0	Y		
13h	STORE_DEFAULT_CODE	W	1	Y		
14h	RESTORE_DEFAULT_CODE	W	1	Y		
15h	STORE_USER_ALL	Send	0	Y		
16h	RESTORE_USER_ALL	Send	0	Y		

Table 11 — BEM supported commands and settings (cont'd)

Code	Command Name	Access Type	Data Bytes	Required (Yes/No)	Data Format	Comments
17h	STORE_USER_CODE	W	1	Y		
18h	RESTORE_USER_CODE	W	1	Y		
19h	CAPABILITY	R	1	Y		
1Ah	QUERY	R/W	1	Y		
1Bh	SMBALERT_MASK_INPUT	R/W	2	Y		
20h	VOUT_MODE	R	2	Y		
21h	VOUT_COMMAND (V)	R/W	WORD, 2 Data Bytes	Y	DIRECT	
22h	VOUT_TRIM	R/W	WORD, 2 Data Bytes	N		
23h	VOUT_CAL_OFFSET	R/W	WORD, 2 Data Bytes	N		
24h	VOUT_MAX	R/W	WORD, 2 Data Bytes	Y	DIRECT	
25h	VOUT_MARGIN_HIGH	R/W	WORD, 2 Data Bytes	N		
26h	VOUT_MARGIN_LOW	R/W	WORD, 2 Data Bytes	N		
27h	VOUT_TRANSITION_RATE	R/W	WORD, 2 Data Bytes	N		
28h	VOUT_DROOP	R/W	WORD, 2 Data Bytes	N		
29h	VOUT_SCALE_LOOP	R/W	WORD, 2 Data Bytes	N		
2Ah	VOUT_SCALE_MONITOR	R/W	WORD, 2 Data Bytes	N		
2Bh	VOUT_MIN	R/W	WORD, 2 Data Bytes	Y	DIRECT	
30h	COEFFICIENTS	R/W	BLOCK, 5 Data Bytes	Y		
31h	POUT_MAX (Watts)	R/W	2	Y	LINEAR11	BEM designs not supporting this feature shall return pre-programmed fixed value. BEM may store the modified value by host in separate register
32h	MAX_DUTY	R/W	2	N		
33h	FREQUENCY_SWITCH	R/W	2	N		
34h	POWER_MODE	R/W	1	N		
35h	VIN_ON	R/W	2	N		
36h	VIN_OFF	R/W	2	N		

Table 11 — BEM supported commands and settings (cont'd)

Code	Command Name	Access Type	Data Bytes	Required (Yes/No)	Data Format	Comments
37h	INTERLEAVE	R/W	2	N		
38h	IOUT_CAL_GAIN	R/W	2	N		
39h	IOUT_CAL_OFFSET	R/W	2	N		
3Ah	FAN_CONFIG_1_2	R/W	1	N		
3Bh	FAN_COMMAND_1	R/W	2	N		
3Ch	FAN_COMMAND_2	R/W	2	N		
3Dh	FAN_CONFIG_3_4	R/W	1	N		
3Eh	FAN_COMMAND_3	R/W	2	N		
3Fh	FAN_COMMAND_4	R/W	2	N		
40h	VOUT_OV_FAULT_LIMIT (V)	R/W	2	Y	DIRECT	
41h	VOUT_OV_FAULT_RESPONSE	R/W	1	Y		
42h	VOUT_OV_WARN_LIMIT (V)	R/W	2	Y	DIRECT	
43h	VOUT_UV_WARN_LIMIT (V)	R/W	2	Y	DIRECT	
44h	VOUT_UV_FAULT_LIMIT (V)	R/W	2	Y	DIRECT	
45h	VOUT_UV_FAULT_RESPONSE	R/W	1	Y		
46h	IOUT_OC_FAULT_LIMIT (A)	R/W	2	Y	LINEAR11	
47h	IOUT_OC_FAULT_RESPONSE	R/W	1	Y		
48h	IOUT_OC_LV_FAULT_LIMIT	R/W	2	N		
49h	IOUT_OC_LV_FAULT_RESPONSE	R/W	1	N		
4Ah	IOUT_OC_WARN_LIMIT (A)	R/W	2	Y	LINEAR11	
4Bh	IOUT_UC_FAULT_LIMIT	R/W	2	N		
4Ch	IOUT_UC_FAULT_RESPONSE	R/W	1	N		
4Fh	OT_FAULT_LIMIT (°C)	R/W	2	Y	LINEAR11	
50h	OT_FAULT_RESPONSE	R/W	1	Y		
51h	OT_WARN_LIMIT (°C)	R/W	2	Y	LINEAR11	
52h	UT_WARN_LIMIT (°C)	R/W	2	Y	LINEAR11	
53h	UT_FAULT_LIMIT (°C)	R/W	2	Y	LINEAR11	
54h	UT_FAULT_RESPONSE	R/W	1	Y		
55h	VIN_OV_FAULT_LIMIT (V)	R/W	2	Y	LINEAR11	
56h	VIN_OV_FAULT_RESPONSE (V)	R/W	1	Y	LINEAR11	
57h	VIN_OV_WARN_LIMIT (V)	R/W	2	Y	LINEAR11	
58h	VIN_UV_WARN_LIMIT (V)	R/W	2	Y	LINEAR11	
59h	VIN_UV_FAULT_LIMIT (V)	R/W	2	Y	LINEAR11	
5Ah	VIN_UV_FAULT_RESPONSE	R/W	1	Y		

Table 11 — BEM supported commands and settings (cont'd)

Code	Command Name	Access Type	Data Bytes	Required (Yes/No)	Data Format	Comments
5Bh	IIN_OC_FAULT_LIMIT (A)	R/W	2	Y	LINEAR11	
5Ch	IIN_OC_FAULT_RESPONSE	R/W	1	Y		
5Dh	IIN_OC_WARN_LIMIT (A)	R/W	2	Y	LINEAR11	
5Eh	POWER_GOOD_ON (V)	R/W	2	N		
5Fh	POWER_GOOD_OFF (V)	R/W	2	N		
60h	TON_DELAY	R/W	2	N		
61h	TON_RISE	R/W	2	N		
62h	TON_MAX_FAULT_LIMIT	R/W	2	N		
63h	TON_MAX_FAULT_RESPONSE	R/W	1	N		
64h	TOFF_DELAY	R/W	2	N		
65h	TOFF_FALL	R/W	2	N		
66h	TOFF_MAX_WARN_LIMIT	R/W	2	N		
68h	POUT_OP_FAULT_LIMIT	R/W	2	N		
69h	POUT_OP_FAULT_RESPONSE	R/W	1	N		
6Ah	POUT_OP_WARN_LIMIT	R/W	2	N		
6Bh	PIN_OP_WARN_LIMIT	R/W	2	N		
78h	STATUS_BYTE	R	1	Y		Execute on Alert# assertion
79h	STATUS_WORD	R	2	Y		Execute on Alert# assertion
7Ah	STATUS_VOUT	R	1	Y		Execute on Alert# assertion
7Bh	STATUS_IOUT	R	1	Y		Execute on Alert# assertion
7Ch	STATUS_INPUT	R	1	Y		Execute on Alert# assertion
7Dh	STATUS_TEMPERATURE	R	1	Y		Execute on Alert# assertion
7Eh	STATUS_CML	R	1	Y		Execute on Alert# assertion
7Fh	STATUS_OTHER	R	1	Y		Execute on Alert# assertion
80h	STATUS_MFR_SPECIFIC	R	1	Y		Execute on Alert# assertion
81h	STATUS_FAN_1_2	R/W	1	N		
82h	STATUS_FAN_3_4	R/W	1	N		
83h	READ_KWH_IN	R	4	N		
84h	READ_KWH_OUT	R	4	N		
85h	READ_KWH_CONFIG	R/W	1	N		
86h	READ_EIN	R	5	N		
87h	READ_EOUT (J)	R	5	Y	LINEAR11	Execute on Alert# assertion
88h	READ_VIN (V)	R	2	Y	LINEAR11	Execute on Alert# assertion
89h	READ_IIN (A)	R	2	Y	LINEAR11	Execute on Alert# assertion

Table 11 — BEM supported commands and settings (cont'd)

Code	Command Name	Access Type	Data Bytes	Required (Yes/No)	Data Format	Comments
8Ah	READ_VCAP (V)	R	2	Y	LINEAR11	Execute on Alert# assertion
8Bh	READ_VOUT (V)	R	2	Y	LINEAR11	Execute on Alert# assertion
8Ch	READ_IOUT (A)	R	2	Y	LINEAR11	Execute on Alert# assertion
8Dh	READ_TEMPERATURE_1 (°C)	R	2	Y	LINEAR11	Execute on Alert# assertion
8Eh	READ_TEMPERATURE_2 (°C)	R	2	N		
8Fh	READ_TEMPERATURE_3 (°C)	R	2	N		
90h	READ_FAN_SPEED_1	R	2	N		
91h	READ_FAN_SPEED_2	R	2	N		
92h	READ_FAN_SPEED_3	R	2	N		
93h	READ_FAN_SPEED_4	R	2	N		
94h	READ_DUTY_CYCLE	R	2	N		
95h	READ_FREQUENCY	R	2	N		
96h	READ_POUT (W)	R	2	Y	LINEAR11	Execute on Alert# assertion
97h	READ_PIN (W)	R	2	Y	LINEAR11	Execute on Alert# assertion
98h	PMBUS_REVISION	R	1	Y		Execute on Alert# assertion
99h	MFR_ID	R	Variable	Y		Execute on Alert# assertion
9Ah	MFR_MODEL	R	Variable	Y		Execute on Alert# assertion
9Bh	MFR_REVISION	R	Variable	Y		Execute on Alert# assertion
9Ch	MFR_LOCATION	R	Variable	N		Execute on Alert# assertion
9Dh	MFR_DATE	R	Variable	Y		Execute on Alert# assertion
9Eh	MFR_SERIAL	R	Variable	Y		Execute on Alert# assertion
9Fh	APP_PROFILE_SUPPORT	R	Variable	N		
A0h	MFR_VIN_MIN	R	2	N		
A1h	MFR_VIN_MAX	R	2	N		
A2h	MFR_IIN_MAX	R	2	N		
A3h	MFR_PIN_MAX	R	2	N		
A4h	MFR_VOUT_MIN	R	2	N		
A5h	MFR_VOUT_MAX	R	2	N		
A6h	MFR_IOUT_MAX	R	2	N		
A7h	MFR_POUT_MAX	R	2	N		
A8h	MFR_TAMBIENT_MAX	R	2	N		
A9h	MFR_TAMBIENT_MIN	R	2	N		
AAh	MFR_EFFICIENCY_LL	R	14	N		
ABh	MFR_EFFICIENCY_HL	R	14	N		
ACH	MFR_PIN_ACCURACY	R	1	N		

Table 11 — BEM supported commands and settings (cont'd)

Code	Command Name	Access Type	Data Bytes	Required (Yes/No)	Data Format	Comments
ADh	IC_DEVICE_ID	R	Variable	N		
A Eh	IC_DEVICE_REV	R	Variable	N		
B0h	USER_DATA_00	R/W	Variable	N		
B1h	USER_DATA_01	R/W	Variable	N		
B2h	USER_DATA_02	R/W	Variable	N		
B3h	USER_DATA_03	R/W	Variable	N		
B4h	USER_DATA_04	R/W	Variable	N		
B5h	USER_DATA_05	R/W	Variable	N		
B6h	USER_DATA_06	R/W	Variable	N		
B7h	USER_DATA_07	R/W	Variable	N		
B8h	USER_DATA_08	R/W	Variable	N		
B9h	USER_DATA_09	R/W	Variable	N		
BAh	USER_DATA_10	R/W	Variable	N		
BBh	USER_DATA_11	R/W	Variable	N		
BCh	USER_DATA_12	R/W	Variable	N		
BDh	USER_DATA_13	R/W	Variable	N		
BEh	USER_DATA_14	R/W	Variable	N		
BFh	USER_DATA_15	R/W	Variable	N		
C0h	MFR_MAX_TEMP_1	R/W	2	N		
C1h	MFR_MAX_TEMP_2	R/W	2	N		
C2h	MFR_MAX_TEMP_3	R/W	2	N		
C4h	ES_TECH	R	1	Y		Execute on Alert# assertion
C5h	STATE_OF_CHARGE (%)	R	2	Y	LINEAR11	Execute on Alert# assertion
C6h	FULL_CHARGE_ENERGY_CHECK (%)	R	2	N	LINEAR11	Execute on Alert# assertion
C7h	MAX_POWER_CAPABLE (W)	R	2	Y	LINEAR11	Execute on Alert# assertion
C8h	MAX_POWER_REQUIRED (W)	W	2	Y	LINEAR11	Execute on Alert# assertion
C9h	MAX_ENERGY_CAPABLE (J)	R	2	Y	LINEAR11	Execute on Alert# assertion
CAh	MAX_ENERGY_REQUIRED (J)	W	2	Y	LINEAR11	Execute on Alert# assertion
CBh	MAX_RUNTIME_CAPABLE (Sec)	R	2	Y	Unsigned Binary	Execute on Alert# assertion
CCh	MAX_RUNTIME_REQUIRED (Sec)	W	2	Y	Unsigned Binary	Execute on Alert# assertion
CDh	REMAINING_BACKUP_TIME (Sec)	R	2	Y	Unsigned Binary	Execute on Alert# assertion
CEh	CHARGE_TIME_TO_FULL (Sec)	R	2	Y	Unsigned Binary	Execute on Alert# assertion

Table 11 — BEM supported commands and settings (cont'd)

Code	Command Name	Access Type	Data Bytes	Required (Yes/No)	Data Format	Comments
CFh	POWER_CYCLE_COUNT	R	2	Y	Unsigned Binary	Execute on Alert# assertion
D0h	CHARGE_DISCHARGE_CYCLE_COUNT	R	2	Y	Unsigned Binary	Execute on Alert# assertion
D1h	LAST_BACKUP_TIME (Sec)	R	2	Y	Unsigned Binary	Execute on Alert# assertion
D2h	TOTAL_OPERATION_TIME (Hours)	R	2	Y	Unsigned Binary	Execute on Alert# assertion
D3h	TOTAL_OPERATION_TIME_SUPPORTED (Hours)	R	2	Y	Unsigned Binary	Execute on Alert# assertion
D4h	TOTAL_LOADS_DETECTED	R	1	Y	Unsigned Binary	Execute on Alert# assertion
D5h	MFR_SPECIFIC					
D6h	MFR_SPECIFIC					
D7h	MFR_SPECIFIC					
D8h	MFR_SPECIFIC					
D9h	MFR_SPECIFIC					
DAh	MFR_SPECIFIC					
DBh	MFR_SPECIFIC					
DCh	MFR_SPECIFIC					
DDh	MFR_SPECIFIC					
DEh	MFR_SPECIFIC					
DFh	MFR_SPECIFIC					
E0h	MFR_SPECIFIC					
E1h	MFR_SPECIFIC					
E2h	MFR_SPECIFIC					
E3h	MFR_SPECIFIC					
E4h	MFR_SPECIFIC					
E5h	MFR_SPECIFIC					
E6h	MFR_SPECIFIC					
E7h	MFR_SPECIFIC					
E2h	MFR_SPECIFIC					
E3h	MFR_SPECIFIC					
E4h	MFR_SPECIFIC					
E5h	MFR_SPECIFIC					
E6h	MFR_SPECIFIC					
E7h	MFR_SPECIFIC					
E8h	MFR_SPECIFIC					
E9h	MFR_SPECIFIC					

Table 11 — BEM supported commands and settings (cont'd)

Code	Command Name	Access Type	Data Bytes	Required (Yes/No)	Data Format	Comments
EAh	MFR_SPECIFIC					
EBh	MFR_SPECIFIC					
ECh	MFR_SPECIFIC					
EDh	MFR_SPECIFIC					
EEh	MFR_SPECIFIC					
EFh	MFR_SPECIFIC					
F0h	MFR_SPECIFIC					
F1h	MFR_SPECIFIC					
F2h	MFR_SPECIFIC					
F3h	MFR_SPECIFIC					
F4h	MFR_SPECIFIC					
F5h	MFR_SPECIFIC					
F6h	MFR_SPECIFIC					
F7h	MFR_SPECIFIC					
F8h	MFR_SPECIFIC					
F9h	MFR_SPECIFIC					
FAh	MFR_SPECIFIC					
FBh	MFR_SPECIFIC					
FCh	MFR_SPECIFIC					
FDh	MFR_SPECIFIC					
FEh	MFR_SPECIFIC					
FFh	MFR_SPECIFIC					

8.8.1 Page (00h)

To access beyond 256 commands, a paging mechanism is needed. All modules supporting this standard shall support a paging mechanism. The module shall support at least 1 page and may support up to a maximum of 256 pages.

8.8.2 WRITE_PROTECT (10h)

This command is used to control writing to the BEM. Normally the host load is expected to READ most of the BEM parameter values and settings. It may perform WRITE Operation to WRITE_PROTECT, OPERATION, PAGE, ON_OFF_CONFIG, VOUT_COMMAND, PAGE, MAX_POWER_REQUIRED, MAX_ENERGY_REQUIRED and MAX_RUNTIME_REQUIRED commands. In rear events it may write to other commands. Host load shall complete any write transaction with writing data byte value 1000 0000 to WRITE_PROTECT command as the last step.

8.8.2 WRITE_PROTECT (10h) (cont'd)

BEM shall support manufacturer specified data byte value of 0000 0011 in addition to the PMBus defined data byte values as described in Table 12. Default data byte values of this command shall be programmed to 1000 0000. If the host load writes 0000 0000 to this command then BEM shall assert bit 0 of high byte in STATUS_WORD command register to notify of such event.

Table 12 — WRITE_PROTECT command data byte format

Data Byte Value	Meaning
1000 0000	Disable all writes except to the WRITE_PROTECT command
0100 0000	Disable all writes except to the WRITE_PROTECT and PAGE commands
0010 0000	Disable all writes except to the WRITE_PROTECT, OPERATION,PAGE, ON_OFF_CONFIG and VOUT_COMMAND commands
0000 0011	Disable all writes except to the WRITE_PROTECT, OPERATION,PAGE, ON_OFF_CONFIG, VOUT_COMMAND, PMAX, MAX_POWER_REQUIRED, MAX_ENERGY_REQUIRED and MAX_RUNTIME_REQUIRED commands
0010 0000	Manufacturer specified
0010 0000	Manufacturer specified
0000 0000	Enable writes to all commands

8.8.3 Capability (19h)

This command provides a way for a host system to determine some key capabilities of the module. There is one data byte formatted. This command is read only.

Table 13 — Capability command data byte format

Bits	Description	Value	Meaning
7	Packet Error Checking	0	Packet Error Checking not supported
		1	Packet Error Checking is supported
6:5	Maximum Bus Speed	00	Maximum supported bus speed is 100 kHz
		01	Maximum supported bus speed is 400 kHz
		10	Maximum supported bus speed is 1 MHz
		11	Reserved
4	SMBALERT#	0	The device does not have a SMBALERT# pin and does not support the SMBus Alert Response protocol
		1	The device does have a SMBALERT# pin and does support the SMBus Alert Response protocol
3	Numeric Format	0	Numeric data is in LINEAR11,ULINEAR16, SLINEAR16, or DIRECT format
		1	Numeric data is in IEEE Half Precision Floating Point Format
2	AVSBus Support	0	AVSBus Not Supported
		1	AVSBus Supported
1:0	Reserved	X	Reserved

8.8.4 VOUT_COMMAND (21h)

BEM shall use PMBUS defined VOUT_COMMAND to return preset Vout value and support programming new set value. It shall support host writing desired Vout value. The host shall limit $V_{out\ MIN} < V_{out\ value} < V_{out\ MAX}$. Vout MIN and Vout MAX Values are fixed by BEM design. All other supported Vout related read and write commands shall follow same data format as VOUT_COMMAND.

8.8.5 Coefficients (30h)

Module shall communicate computing coefficients m,R,b using PMBus Command 30h for load firmware to convert data into real value. Refer to PMBus specifications for DIRECT data format equations and coefficient definition. Similarly load shall provide coefficient values to the module firmware when sending data using DIRECT format.

8.8.6 STATUS_WORD (79h)

PG_STATUS# (bit 3 of high byte):

The module shall use this bit to indicate if output voltage of the module is valid (BAT_OK asserted) or not (BAT_OK negated). The PG_STATUS# bit reflects the status of the BAT_OK signal. If the BAT_OK signal is present and is negated (output voltage is not valid), then the PG_STATUS# bit is set. PG_STATUS# set is interpreted as “the status of the BAT_OK signal is negated”. If the BAT_OK signal is present and is asserted (output voltage is valid) then the PG_STATUS# bit is cleared. This is interpreted as “the status of the BAT_OK signal is ‘not negated’”, or in other words, the status of the BAT_OK signal is indicating that the output voltage is valid.

If the PG_STATUS# bit is set, this indicates that the BAT_OK signal, if present, is signaling that the output power is not good.

For the description about other bits of low and high byte, please refer to the PMBus™ specification, section 17.2 STATUS_WORD.

8.8.7 STATUS_MFR_SPECIFIC (80h)

Single Byte Status Summary for Energy Module Protocol. While the standard PMBus protocol creates a good foundation for the protocol for the Energy Module (EM) standard, there is still a need for additional command extensions for the uniqueness of energy storage type designs. One command deemed especially necessary is a command with a single byte response, that provides a clear and unambiguous assessment of the energy modules readiness to perform a backup operation when needed. The rationale for this single status byte is derived from the host system’s perspective of “minimum effort” to manage the readiness and availability of the energy module during operation. The system design goal is to put the burden of this assessment in the energy module’s firmware, freeing up the host system’s resources for other higher-level supervisory activities.

8.8.7 STATUS_MFR_SPECIFIC (80h) (cont'd)

The STATUS_MFR_SPECIFIC command returns one data byte with contents as follows in Table 14.

Table 14 — STATUS_MFR_SPECIFIC command data byte format

Bit	Name	Meaning
7	CONF_INCOMPLETE	Required power ,energy or backup time exceeds capability Either one condition below is true will set this bit <ul style="list-style-type: none"> • MAX_POWER_REQUIRED > MAX_POWER_CAPABLE • MAX_ENERGY_REQUIRED > MAX_ENERGY_CAPABLE All of the conditions above are false will clear this bit. <i>*The commands MAX_POWER_REQUIRED, MAX_POWER_CAPABLE, MAX_ENERGY_REQUIRED, MAX_ENERGY_CAPABLE, MAX_RUNTIME_REQUIRED and MAX_POWER_CAPABLE are defined in following clauses of the standard.</i>
6	CHG_FAULT	Charge fault, any kind of charge related fault occurs will set this bit. The bit shall be cleared if the charge fault is cleared.
5	WARN_SCN	BEM Warning Register State Change Notification
4	FAULT_SCN	BEM Fault Register State Change Notification
2-3	CHARGE_STATE	Charging State, defined as follows (Bit 2, Bit 1): (1, 1) – Charger Disabled for Fault Condition(s) (1, 0) – Charger Disabled for Warning Condition(s) (0, 1) – Charger Enabled and in Charging State (0, 0) – Charger Enabled and in Idle State
1	NOT_READY	The module is not capable of performing a backup discharge.
0	OPERATION TIME	This bit is set to 1 if the TOTAL OPERATION TIME exceeds TOTAL OPERATION TIME SUPPORTED else set to 0.

8.8.8 READ_VCAP (8Ah)

In the PMBus™ specification, the READ_VCAP command returns voltage on the energy storage (hold-up or ride-through) capacitor in Volts. In this spec, as we may use different technologies of the energy storage cell (Li-ion battery or Li-ion hybrid caps, etc.), this commands shall be used for returning voltage of cell string. The value of the READ_VCAP shall return the voltage between the positive pole of high side cell and the negative pole of low side cell.

8.9 Manufacturer Specific Command List for BEM

Clauses 8.9.1 through 8.9.17 summarize the backup energy module commands using the MFR command code C4h~FDh. For a backup energy module to be recognized as a JEDEC backup energy module, it must support all the mandatory functions described by this standard.

8.9.1 ES_Tech (C4h)

The ES_Tech command provides the technology used in the backup module. A set bit indicates that the corresponding technology is used in the module. One or more bits may be set.

If Bit 0, Undefined, is set, this indicates that the technology used in the backup module is not defined in this spec.

If Bit 1, EDLC capacitor aka Supercapacitor, is set, this indicates that the backup module uses supercapacitor.

If Bit 2, Battery, is set, this indicates that the backup module uses Lithium Ion or other type battery.

If Bit 3, Hybrid capacitor aka Lithium Capacitor, is set, this indicates that the backup module uses hybrid capacitor.

Bit 4-F, reserved

8.9.2 State_Of_Charge (C5h)

Returns the predicted remaining capacity expressed as a percentage of FULL_CHARGE_CAPACITY.

When BEM is either charging or not discharging and input voltage is connected to it, this register value shall indicate available capacity in percentage with respect cell charge state and Backup Power Required Values.

State Of Charge = $(\text{Cell Voltage} / \text{Max. Cell Voltage}) * (\text{Max. Power Capable} / \text{Backup Power Required}) * 100$

When BEM is discharging, this register value shall indicate available capacity in percentage with respect to cell charge state and measured average backup power demand.

State Of Charge = $(\text{Cell Voltage} / \text{Max. Cell Voltage}) * (\text{Max. Power Capable} / \text{Backup Power Required}) * 100$.

Units: %

Data format: LINEAR11

8.9.3 FULL_CHARGE_ENERGY_CHECK (C6h)

Returns the predicted Energy Capability of the BEM as percentage of Max. Energy Capacity Value at Full Charge. This updated value may provide early indication of abnormal cell deterioration in the module.

Units: %

Data format: LINEAR11

8.9.4 MAX_POWER_CAPABLE (C7h)

The command reads the maximum discharge power supported in backup mode.

Units: Watts
Data format: LINEAR11

8.9.5 MAX_POWER_REQUIRED (C8h)

The command sets the maximum required backup power from the module.

Setting the values higher than the MAX_POWER_CAPABLE will set the EXCEEDS_CAPABILITY bit in STATUS_MFR_SPECIFIC

Units: Watts
Data format: LINEAR11

8.9.6 MAX_ENERGY_CAPABLE (C9h)

The command reads maximum energy supported backup mode

Units: Joules
Data format: LINEAR11

8.9.7 MAX_ENERGY_REQUIRED (CAh)

The command sets the maximum required energy from the module. The value is the sum of the loads calculating by the system host or load itself. This is two bytes, write-able, unsigned Integer, the default value is zero, rebooting the module will restore the value to default.

Setting the values higher than the MAX_POWER_CAPABLE will set the EXCEEDS_CAPABILITY bit in STATUS_MFR_SPECIFIC.

Units: Joules
Data format: LINEAR11

8.9.8 MAX_RUNTIME_CAPABLE (CBh)

The command reads or sets the maximum supporting backup time threshold of backup mode. This is two bytes, write-able, unsigned Integer, the default value is decided by the manufacture, rebooting the module will restore the value to default.

Units: Seconds
Data format: 16 Digit Unsigned Binary

8.9.9 MAX_RUNTIME_REQUIRED (CCh)

The command sets the maximum required backup time from the module. The value is the sum of the loads calculating by the system host or load itself. This is two bytes, write-able, unsigned Integer, the default value is zero, rebooting the module will restore the value to default.

Setting the values higher than the MAX_POWER_CAPABLE will set the EXCEEDS_ABILITY bit in STATUS_MFR_SPECIFIC

Units: Seconds

Data format: 16 Digit Unsigned Binary

8.9.10 REMAINING_BACKUP_TIME (Cdh)

Remaining backup time shall be calculated as follows –

$$\text{REMAINING_BACKUP_TIME} = (\text{FULL_CHARGE_ENERGY_CHECK}/100) * (\text{STATE_OF_CHARGE}/100) * (\text{MAX_BACKUP_TIME_SUPPORTED}).$$

With the rolling average of consuming capacity, the value is calculated based on output power and remaining energy.

Units: Seconds

Data format: 16 Digit Unsigned Binary

8.9.11 CHARGE_TIME_TO_FULL (Ceh)

Returns a value calculated based on charge current or power. The CHARGE_TIME_TO_FULL displays state-of-charge information in a time domain, the CHARGE_TIME_TO_FULL indicates the predicted charging time from present state-of-charge to full charged.

Units: Seconds

Data format: 16 Digit Unsigned Binary

8.9.12 POWER_CYCLE_COUNT (CFh)

Returns a value of power cycle counter. Once the module is powered up (input voltage is within regulation) then the input voltage is removed (out of regulation), the value of POWER_CYCLE_COUNT will be increased one.

Data format: 16 Digit Unsigned Binary

8.9.13 CHARGE_DISCHARGE_CYCLE_COUNT (D0h)

CHARGE_DISCHARGE_CYCLE_COUNT provides the number of lifetime charge and discharge cycle count the module has experienced. A cycle is defined as the amount of charge approximately equal to the 90% value of design capacity. The number shall be reported as an unsigned 16-bit binary number. Minimum reported value shall be 0 (0x0000) and maximum shall be 65535 (0xFFFF). The value needs to be saved to nonvolatile area and it can be retrieved back when module reboots. The CHARGE_DISCHARGE_CYCLE_COUNT shall include the partial charge, the module shall use the accumulated charge capacity to calculate the CHARGE_DISCHARGE_CYCLE_COUNT. Once the value reaches 65535, the value shall be kept at 65535.

Data format: 16 Digit Unsigned Binary

8.9.14 LAST_BACKUP_TIME (D1h)

LAST_BACKUP_TIME provides the recorded runtime of last backup in seconds. Minimum reported value shall be 0 (0x0000) and maximum shall be 65535 (0xFFFF). The value needs to be saved to nonvolatile area and it can be retrieved back when module reboots. The

Units: Seconds

Data format: 16 Digit Unsigned Binary

8.9.15 TOTAL_OPERATION_TIME (D2h)

TOTAL_OPERATION_TIME provides the total operating time experienced. When input voltage of the module is within regulation, the module shall start the counter until the output voltage drops out of regulation and if turned off. This counter shall be cumulative to indicate total runtime of the module.

Units: Hours

Data format: 16 Digit Unsigned Binary

8.9.16 MAX_OPERATION_TIME_SUPPORTED (D3h)

Specifies max. operation time the BEM can support at specified Power, Energy and Run Time.

If the Total Operation Time per (D5h) > Max. Operation Time Supported, then the bit 6 of STATUS_MFR_SPECIFIC (80h) shall be set

Units: Hours

Data format: 16 Digit Unsigned Binary

8.9.17 TOTAL_LOADS_DETECTED (D4h)

BEM shall return no. of loads connected to it with this command. Default value is 1. In case of one BEM supporting multiple loads that value can be >1.

Data format: 8 Digit Unsigned Binary



Standard Improvement Form

JEDEC Standard JESD315

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