

**■ Information**

This product is a step down DC-DC converter that makes it possible to change settings during operation by serial communication (PMBus). It also allows changing settings while keeping the outputs such as the output voltage, start-up and shut down sequences. Furthermore, high-speed load response has been achieved by adopting digital control.

**■ Features**

- Serial Communication (PMBus) that enables it to change settings during operation.
- Allows start-up and shut down sequence settings
- Very thin type
- High-speed load response
- Over voltage protection
- Non-isolated type converter
- Under voltage lock out
- ON/OFF control
- SMD package
- Operating temp -40°C to +85°C (Temp derating required)
- RoHS compliance

**■ Model/Rating**

Figure 1

Models BDA Series	Input V Vdc	Output V Vdc	Output I A	Line Reg. % (typ.)	Load Reg. % (typ.)	Noise MVpp (typ.)	Efficiency % (typ.)
BDA-2.5S12R0	4.5 – 5.5	0.8 – 2.5	0 – 12	0.5	0.5	50	91

Note 1: Output voltage may not be adjusted by an external resistor.

Output voltage may only be adjusted by serial communications.

Note 2: Ripple noise and efficiency are when the input voltage is 5V, the output voltage is 2.5V and the output current is 12A.

Note 3: Ripple noise is measured by 20MHz bandwidth, with a multi-layered ceramic capacitor with 220μF (SP-CAP)x2+47Mf.

Note 4: Depending on ambient temp conditions, cooling air flow may be required.

**■ Specifications**

Figure 2

Input voltage change	Refer to Figure 1
Rated input voltage	5.0V
Rated output voltage	2.5V
Adjustable output voltage	0.8 to 2.5V
Line Regulation	Refer to Figure 1 (Rated output, input voltage varying from 4.5 to 5.5V)
Load Regulation	Refer to Figure 1 (Rated input/output voltage, load varying from 0 to 100%)
Temp Regulation	0.01%/°C (Rated input/output, operating temp varying from -40°C to +85°C)
Ripple noise	Refer to Figure 1 (Rated input/output, common temp, measurement frequency bandwidth 20MHz)
Efficiency	91% typ. (Rated input/output, common temp, refer to Figure 1)
Over voltage protection	Operates at 105%+ of rated load current, Auto recovery type
Under Voltage Lock Out	Yes
Over input current protection	None
Remote ON/OFF control	Between 13 pin (ON/OFF) and 11 pin (S.GND) : Output switches on when open, output switches off when short. *Refer to Page 12
Standby current	50mA typ.
P-Good signal	Open (When output voltage is within the adjustable range), Low (When output voltage is outside the adjustable range, except when P-Good signal is Low by over current protection)
Remote sensing	Yes
Operating temp range	Operating temp :-40°C to +85°C (Refer to the temp derating section)
Storage temp range	Storage temp : -40°C to +85°C
Humidity range	20 to 95%R.H. (While the max bulb temp is 35°C, there is no dewing)
Storage conditions	Store the product at 30°C/60% R.H. or lower before mounting.
Cooling conditions	Refer to the temp derating section
Vibrations	5-10Hz, all amplitude 10mm, 10-55Hz acceleration 2G (1 hour in each of 3 orthogonal axes)
Shock	Acceleration 20G (3 directions, 3 times each), Shocking time 11±5ms
Weight	3.2g typ.
Dimensions	W=23.0 L=27.0 H=4.2 typ. (mm) *For more details, refer to the outline section

\*The above specifications are provided with rating value, unless otherwise specified.

## Specifications

## 1. Applicable range

The specifications are applied to the direct current input and non-isolated type DC/DC converter, BDA-2.5S12R0.

## 2. Model/Rating

Model	Rating Input Voltage	Rating Output	Package type	Note
BDA-2.5S12R0	DC5.0V	2.5V, 12.0A	SMD	

\*The input/output is rated and the ambient temperature is  $25^{\circ}\text{C} \pm 5^{\circ}\text{C}$ , unless otherwise mentioned in the specifications.

## 3. Environmental Condition

## 3-1. Temperature range

When operating  $-40^{\circ}\text{C}$  to  $+85^{\circ}\text{C}$  (Derating required)

When storing  $-40^{\circ}\text{C}$  to  $+85^{\circ}\text{C}$

## 3-2. Humidity range

When operating 20 to 95% R.H. (Max web bulb temp is  $35^{\circ}\text{C}$  and no dew condensation allowed)

When storing 20 to 95% R.H. (Max web bulb temp is  $35^{\circ}\text{C}$  and no dew condensation allowed)

Note) Before mounting, store the product at  $30^{\circ}\text{C}/60\%\text{R.H.}$  or lower.

## 4. Specifications and Standards

This product complies with RoHS.

## 4-1. Input characteristics

Article	Specifications and Standards	Terms
Input voltage	+4.5 to 5.5V (Rating 5.0V)	
Input Current	6.6A typ.	When input/output is rated

## 4-2. Output characteristics and attached functions

Article	Specifications/Standards	Terms
Rated output voltage	2.5V	
Output voltage at default setting (Note 3)	0.8V	
Output voltage setting deviation	±2%	$2.5 \geq V_{out} \geq 1.6$
	±3%	$1.6 > V_{out} \geq 0.8V$
Adjustable output voltage	0.8 to 2.5V	Using serial communications
Output current	0 to 12A	Derating required
Line regulation	0.5% typ., 1.0% max.	Input varying from 4.5 to 5.5V
Load regulation	0.5% typ., 1.0% max.	Load varying from 0 to 12A
Temp regulation	±0.01%/°C typ.	Temp varying from -40 to +85°C
Ripple noise	50mVp-p typ., 100mVp-p max.	BW = 20MHz
Efficiency	91% typ.	
Over current protection	Operates at 105%+, Auto Recovery	
Under voltage lockout	Yes Start up voltage : 4.0V typ. Shut down voltage : 3.5V typ.	
ON/OFF control	Between ON/OFF pin and S.GND pin, OPEN -> Output ON SHORT or LOW -> Output OFF	Control logic may be changed by serial communications. The ON/OFF switch may be controlled by serial communications
P-Good output (Note 4)	Open (When output voltage is within the adjustable range) Low (When output voltage is outside the adjustable range)	
Over voltage protection	Yes	At shutdown
Under voltage protection	Yes	At shutdown
Overheat protection	Yes	At shutdown
Communications	Yes	PMBus Rev.1.1 compliance
Sequence settings	Yes	By serial communications
Monitoring functions	Yes	By serial communications

Note 1 : In regards to the measurement circuit of 4-4

Note 2 : Measured by the following conditions unless otherwise specified,

Input voltage 5.0V, Output voltage 2.5V, Output current 12A and the ambient temperature  $25^{\circ}\text{C} \pm 5^{\circ}\text{C}$

Note 3 : Output voltage default setting is 0.8V. In order to change the output voltage, serial communications are required.

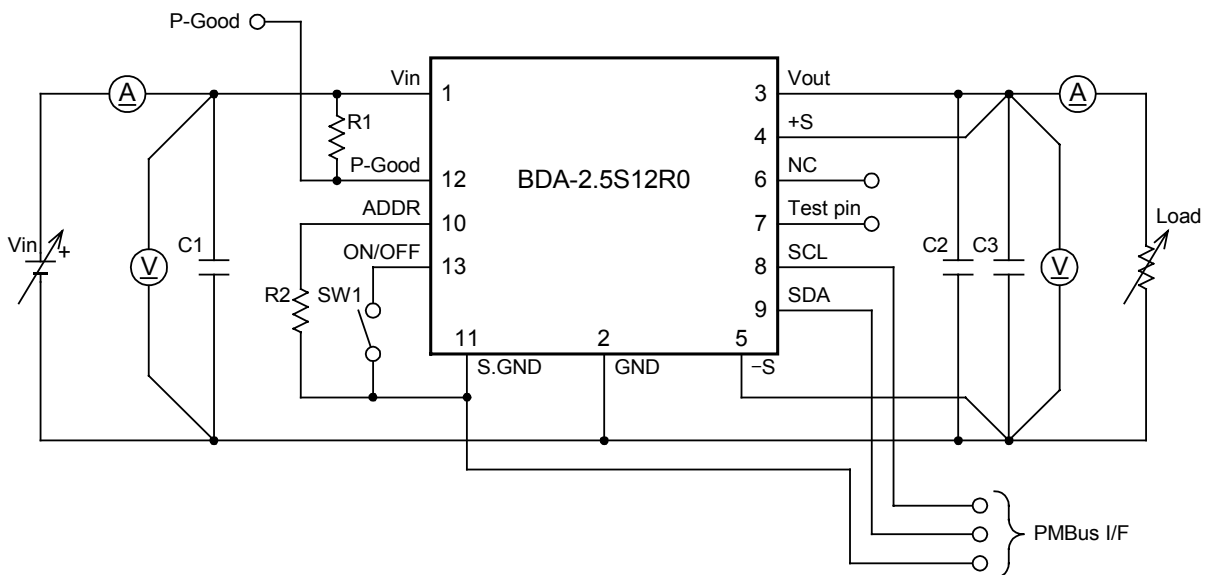
Note 4 : P-Good output is open when output voltage is outside the adjustable range due to over current protection.

4-3. Absolute maximum rating

Absolute maximum rating is a transient rating. Excessive use of the product over a long duration at absolute maximum rating could cause permanent damage. Eventually.

Pin	Name	Absolute Maximum Rating (V)	
		Min.	Max.
1	Vin	-0.3	6.0
3	Vout	-0.3	Vin
4	+S	-0.3	Vin
5	-S	-0.3	3.0
8	SCL	-0.3	6.0
9	SDA	-0.3	6.0
10	ADDR	-0.3	4.25
12	P-Good	-0.3	6.0
13	ON/OFF	-0.3	6.0

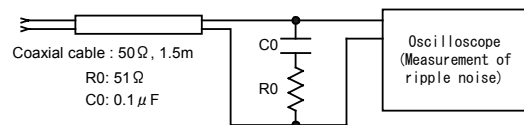
4-4. Measurement Circuit



- C1: 220 $\mu$ F, ESR 15m $\Omega$  (SP-Cap) EEFU0J221R (Panasonic)
- C2: 220 $\mu$ F, ESR 15m $\Omega$   $\times$ 2 (SP-Cap) EEFU0J221R (Panasonic)
- C3: 47 $\mu$ F (Multi layered ceramic capacitor)

- R1: 4.7k  $\Omega$
- R2: 10k  $\Omega$

- SW1: Open = Output ON  
Short = Output OFF



## 5. Temperature Derating

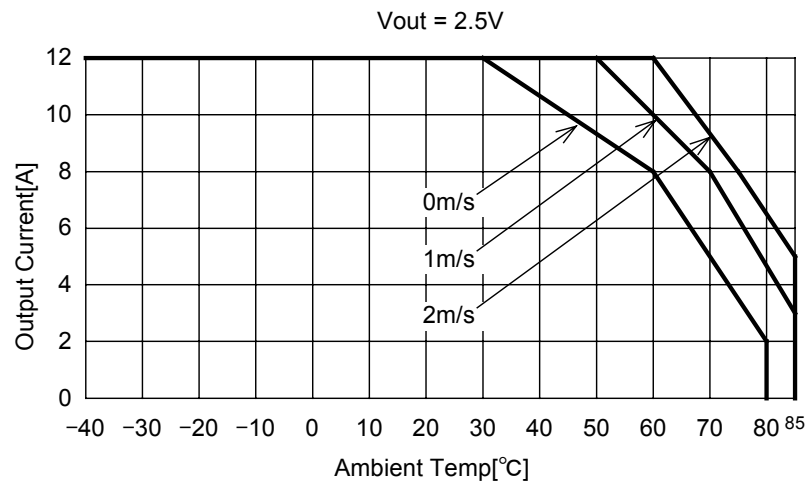
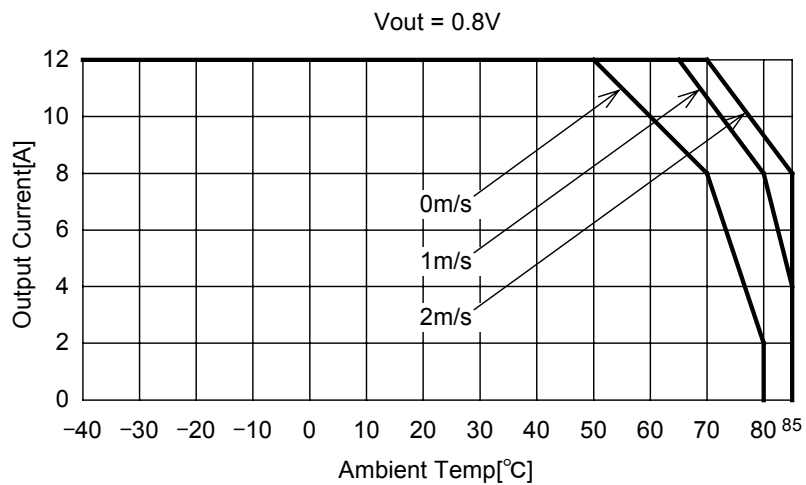
Place this product in a position with good airflow. The product must be mounted on a board during use. This product has been designed to radiate heat utilizing the mounted board. Use as much space as possible for the line and design the board to make sure that the heat escapes.

The derating curve below shows the product data when mounted on a double-sided board of copper foil (thickness  $35\mu\text{m}$ ), copper foil area ( $100\times 100\text{mm}$ ) and thickness of the board ( $1.6\text{mm}$ ). Since the heat radiation characteristics will vary depending on the wiring, please use the data as a reference.

The thermal characteristics of this converter will be largely influenced by the mounted board and the ambient condition.

For this reason, ultimately mount the converter inside the device and operate at the max ambient temperature of the device.

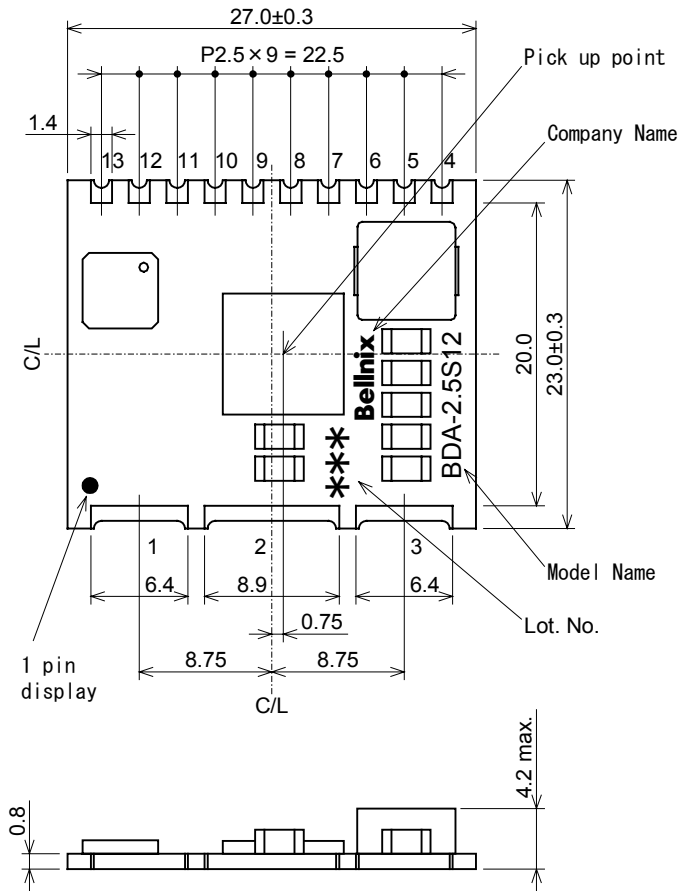
Make sure that the surface temperature of the board does not exceed  $100^{\circ}\text{C}$ .



The derating curve shows the product data when mounted on a double-sided board of copper foil  $100\times 100\text{mm}$

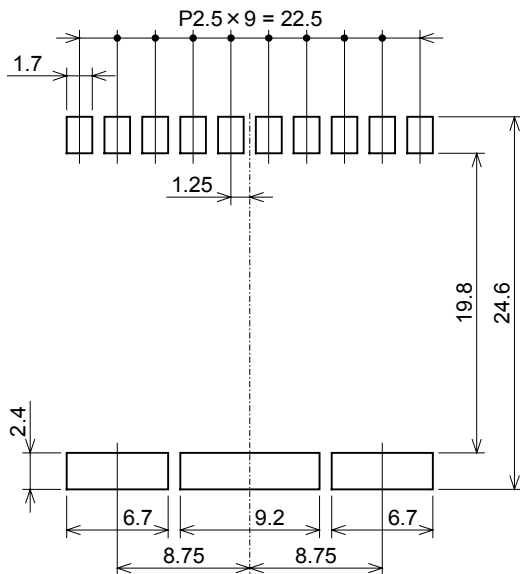
6. Outer dimensions and pin informations

6-1. Configurations/Dimensions



- Units : mm
- Tolerances unless otherwise specified :  $\pm 0.5$

6-2. Recommended Pad Layout



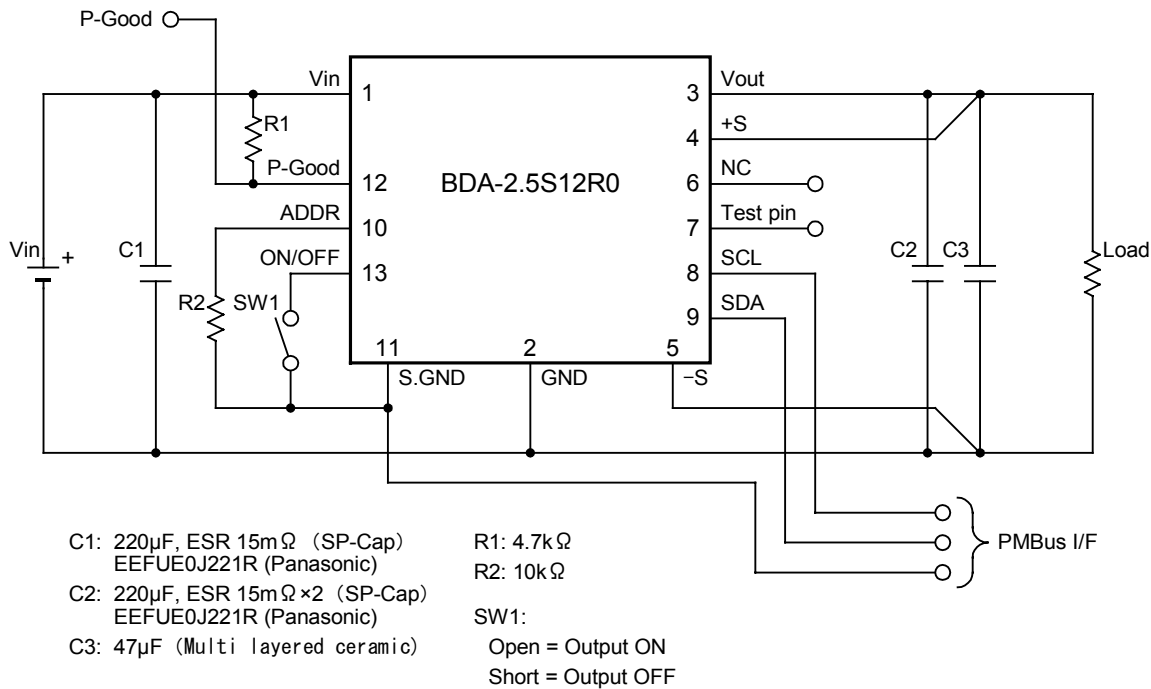
- Units : mm

Note) Do not wire a pattern below the converter (The first layer). The converter adopts an ordinary through hole board. If there is a pin hole on the resist film, it could be a problem.

## 6-3. Pin descriptions

Pin	Name	Function
1	Vin	Input Power Supply
2	GND	Power Ground
3	Vout	Converter Output
4	+S	Remote Sensing on + side
5	-S	Remote Sensing on - side
6	NC	No Connect. These pins should not be electrically connected to each other or to any external signal, voltage, or ground.
7	Test pin	Test pin for shipping
8	SCL	Serial Communication Clock Input pin
9	SDA	Serial Communication Data Input/Output pin
10	ADDR	Device Address Setting
11	S.GND	Signal Ground. This pin is internally connected to GND pin.
12	P-Good	P-Good Output
13	ON/OFF	Remote ON/OFF Control Input

## 7. Standard Connection Circuit



Note 1 : Make sure to connect +S pin and -S pin.

Note 2 : It is a prerequisite for this product to be mounted onto a board, thereby heat release is done.

Use as much space as possible for the pattern and design the board to make radiation easy.

Note 3 : Do not wire a pattern under the converter (first layer). For other layers wiring a pattern will be no problem.

Note 4 : R2 is a resistor to set device addresses for serial communication. Connect the resistor with applicable addresses.

#### External Capacitor

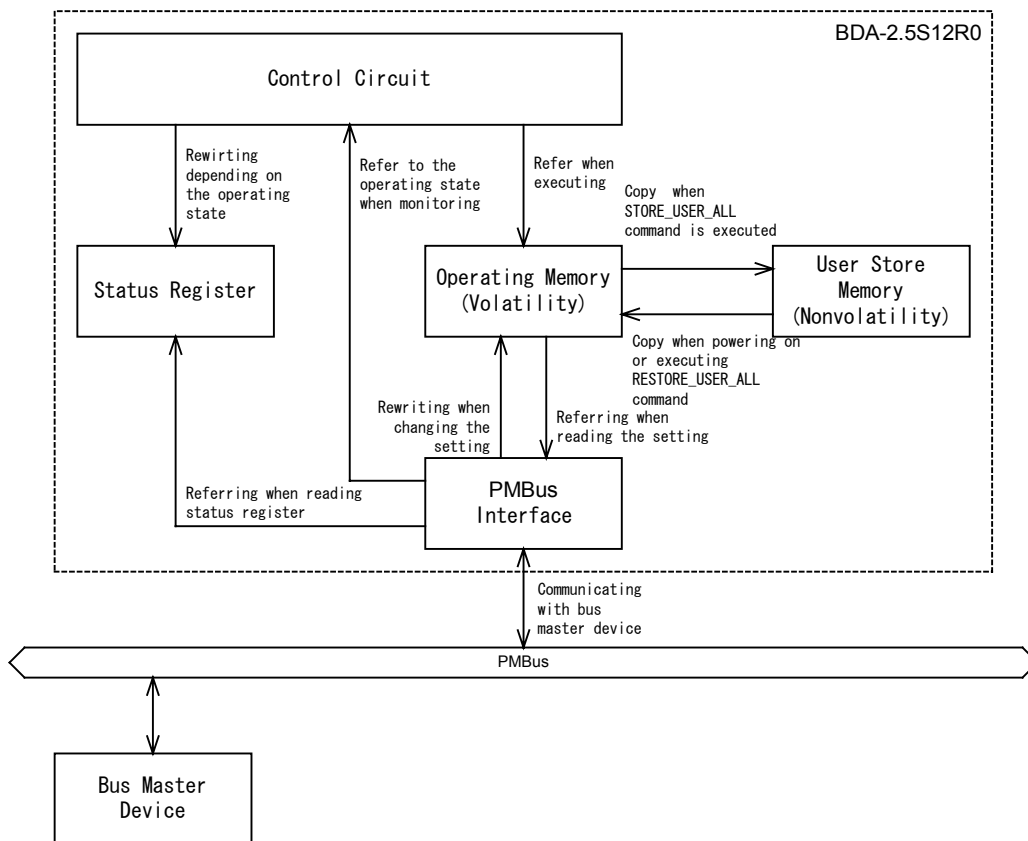
Please connect with 440 $\mu$ F or above (capacitance), ESR7.5m $\Omega$  or below (functional polymer) and 47 $\mu$ F or above (multi layered ceramic capacitor) on the output side. These capacitors are required to satisfy the characteristics.

8. Various Features

8-1. Digital Control

This product can change various settings such as output voltage and sequences by communicating through a PMBus interface (serial communication). It also allows you to get information such as input voltage and output current, etc.

Control target value may be set by serial communication and the set value and the actual operating value may slightly vary depending on the product.



Schematic diagram for digital control

**8-1-1. Embedded Memory**

This product has volatile operating memory and non-volatile user store memory built in. User Store Memory stores setting value for the converter and the contents of User Store Memory are copied onto the operating memory at power-on.

The control circuit of the product operates with a reference of the contents of the operating memory. When changing the setting value by serial communication, the contents of the operating memory will be rewritten. Since the operating memory is volatile, the changed set value will be lost when input power is switched off.

When changing the set value at power-on, after rewriting the operating memory, the set value is required to be stored in non-volatile User Store Memory by the STORE\_USER\_ALL command. Furthermore, the RESTORE\_USER\_ALL command allows the contents of the operating memory to be restored back to the setting just before the STORE\_USER\_ALL command has been executed.

Setting Item	PMBus Command
Storing the set value	STORE_USER_ALL
Restoring the set value	RESTORE_USER_ALL

**8-1-2. Write Protect**

This product bans writing onto the operating memory and the User Store Memory until the write-protect is inactive in order to prevent the setting changed unexpectedly. The write-protect is required to be switched off by serial communication to allow writing.

Since the setting of the write-protect is separate from the operating memory and the User Store Memory, the setting of the write-protect may be changed even if the write-protect of the operating memory is active.

Setting Item	PMBus Command	Default Setting
Operating memory write-protection	OPERATE_MEMORY_PROTECT	Write-protect on
User Store Memory write-protection	USER_MEMORY_PROTECT	Write-protect on

**8-2. Setting method for output voltage**

This product allows you to adjust output voltage between 0.8 to 2.5V by serial communication.

The output voltage can not be changed by an external pin.

Setting Items	PMBus Command	Setting Range	Resolution Capability	Default Setting
Set value for output voltage	VOUT_COMMAND	0.8-2.5V	25mV	0.8V

### 8-3. Changing Margin State

Output voltage setting feature of this product has a concept called Margin State that has three states, Margin Off, Margin High, Margin Low. Each Margin State has a different output voltage set. Also the output voltage of each Margin State can be set at an individual value between 0.8 and 2.5V by serial communication.

Setting Item	PMBus Command	Set Value	Resolution Capability	Default Setting
Output Voltage Set Value (Margin Off)	VOUT_COMMAND	0.8-2.5V	25mV	0.8V
Output Voltage Set Value (Margin High)	VOUT_MARGIN_HIGH	0.8-2.5V	25mV	0.8V
Output Voltage Set Value (Margin Low)	VOUT_MARGIN_LOW	0.8-2.5V	25mV	0.8V

The default Margin State is Off. When output voltage is temporarily adjusted, Margin State should be High or Low. Margin State is switched on and off by serial communication.

Setting Item	PMBus Command	Default Setting
Switching Margin State	OPERATION	Margin OFF

### 8-4. Output Voltage Cropping Feature

Output voltage may be adjusted with higher resolution capability than output voltage setting feature of section 8-2 by using output voltage cropping feature.

The set value of output voltage cropping feature may be adjusted by serial communication.

Setting Item	PMBus Command	Setting Range	Resolution Capability	Default Setting
Output voltage cropping set value	VOUT_TRIM	-100 – 96.875mV	3.125mV	0mV

### 8-5. Remote Sensing Feature

Good load change characteristics may be obtained on load side by using the remote sensing feature. The sensing line is a part of a feedback loop and since it is very sensitive, wiring should be done appropriately with sufficient attention. +S pin and –S pin should be wired close to each other and connected to the load.

This feature guarantees up to 100mV of output voltage.

When not using this feature, make sure to connect Vout pin with +S pin and GND pin with –S pin.

**8-6. ON/OFF Control feature**

Output voltage can be switched on and off, without physically powering-on and powering-off, by using the On/Off control feature. This product allows you to control the ON/OFF control feature by two ways, one is by using the On/off pin (13 pin) and the other is by serial communication.

Each way can be set either active or inactive through serial communication. The default setting for both ON/OFF control feature is active.

Since the ON/OFF control command has the OFF state higher in priority, both controls should be active in order to switch on output.

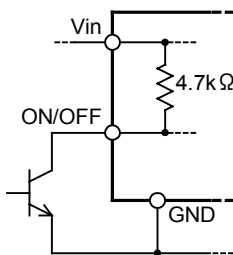
**8-6-1. ON/OFF control by the ON/OFF pin**

Output is On when open and output is off when short between ON/OFF pin (13 pin) and S.GND pin (11 pin). The ON/OFF control is internally connected to Vin pin with 4.7kΩ resistance.

Control logic of the ON/OFF pin may be set to either positive logic (When on, output switches on) or negative logic (When off, output switches off). This is done by serial communication. The default setting is positive logic.

When output is switched off, by the ON/OFF pin, you can either switch off the output immediately or by applying a sequence. These options are set by serial communication. The default setting is to switch off immediately.

Between ON/OFF pin (13 pin) and S.GND pin (11 pin)	Positive Logic	Negative Logic
OPEN (0.8V and over)	Output ON	Output OFF
SHORT (0 to 0.4V, 2mA max.)	Output OFF	Output On



Note : Make sure that the ON/OFF pin does not have chattering. The internal circuit may malfunction if chattering occurs.

8-6-2. ON/OFF control by serial communication

Output voltage can be switched on and off by serial communication.

When switching off the output by serial communication, immediately switch it off or switch off by Turn-off sequence.

Article	PMBus Command	Default Setting
ON/OFF control by serial communication	OPERATION	Output On
Operating setting of ON/OFF control	ON_OFF_CONFIG	-Activated by ON/OFF pin -Activated by serial communication -Positive logic of the ON/OFF pin -Turn-off sequence is not applied when switching off by ON/OFF pin

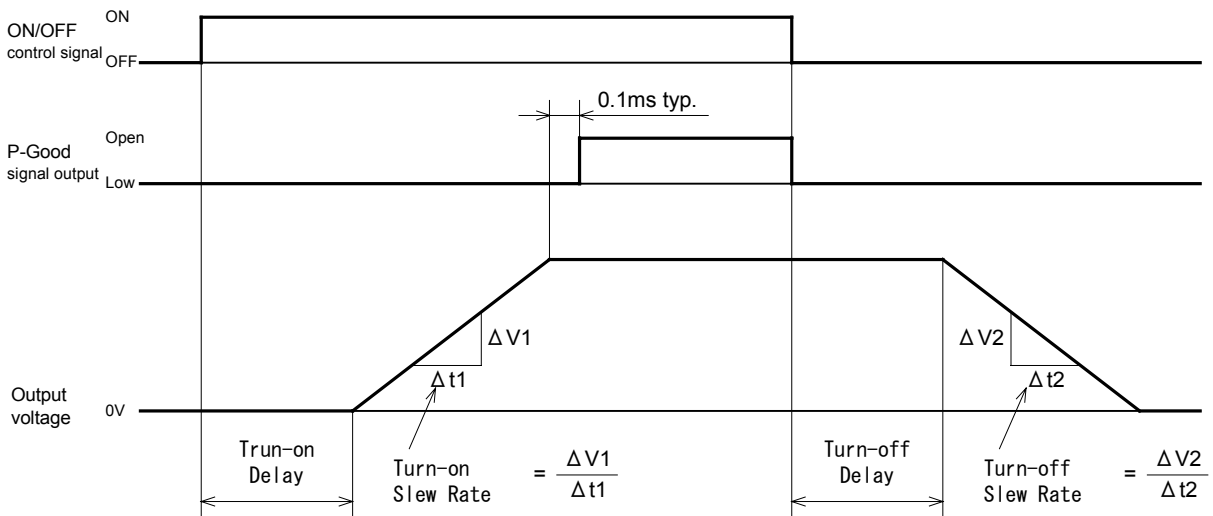
8-7. Sequence setting feature

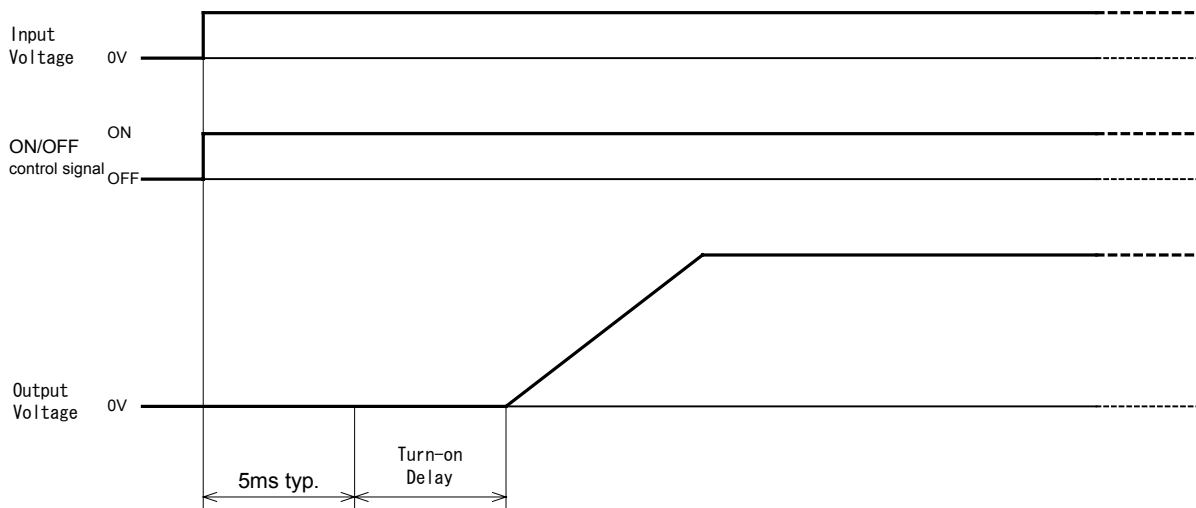
The following items may be set by using sequence setting feature.

- Turn-on Delay
- Turn-on Slew Rate
- Turn-off Delay
- Turn-off Slew Rate

Turn-on Delay is the time from when the ON order is given by the ON/OFF control (ON/OFF pin or serial communication) to when the output voltage starts to increase (Refer to the below diagram).

Turn-off Delay is the time from when the OFF order is given by the ON/OFF control (ON/OFF pin or serial communication) to when the output voltage starts to decrease (Refer to the below diagram).





It takes 5ms typ. until Turn-on sequence starts after power-on (Refer to the above diagram).

The sequence feature option may be set by serial communication.

However, Turn-on Slew Rate and Turn-off Slew Rate may not be the Slew Rate as planned, depending on the load capacitance.

Setting Item	PMBus Command	Setting Range	Resolution Capability	Default Setting
Turn-on Delay	TON_DELAY	2-102ms	0.4ms	2ms
Turn-on Slew Rate	TON_TOFF_RATE	11.97-3052V/s	*1	762.9V/s
Turn-off Delay	TOFF_DELAY	0-102ms	0.4ms	0ms
Turn-off Slew Rate	TON_TOFF_RATE	11.97-3052V/s	*1	762.9V/s

\*1 Refer to section 9-6-18 TON\_TOFF\_RATE command

Turn-off Delay and Turn-off Slew Rate do not apply to the followings.

-Choosing Turn-off sequence when the product is switched off by serial communication.

-Switching off the product by the ON/OFF pin without applying a sequence.

-Suspending the product by various protection features (Under Voltage Protection, Over Voltage Protection, Under Voltage Protection, Overheat Protection).

#### 8-8. P-Good signal output

Output state of DC-DC converter may be acquired by using the P-Good pin (12 pin). This pin is an open drain output.

OPEN (High impedance) : | Actual output voltage – the set value of output voltage |  $\leq 80\text{mV}$  typ.

LOW (0.4V max.) : Other than the above

P-Good pin keeps the OPEN state when output voltage decreases by over current protection.

When applying voltages to the P-Good pin, the max value is up to 5.5V.

Sink current of the P-Good pin should be 5mA and below.

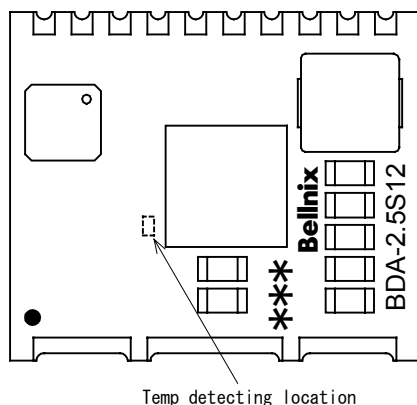
## 8-9. Monitoring feature of operating state

Input voltage, output voltage, output current and converter temp may be obtained by serial communication.

Detection resolution of the input voltage monitor and detection accuracy are 0.125V and  $\pm 0.375V$  typ. respectively.

Detection resolution of the output current monitor and detection accuracy are 0.125A and  $\pm 1A$  typ. respectively.

Temp of the converter is detected as pinpointed in the below diagram.



The product has 6 status registers, STATUS\_BYTE, STATUS\_WORD, STATUS\_VOUT, STATUS\_IOUT, STATUS\_INPUT, STATUS\_TEMPERATURE. The errors of the product can be obtained by checking the contents of the status registers.

The status registers may be set when protection feature is activated. The contents of the status registers may be stored in memory. The registers may be cleared under the following conditions.

- Executing CLEAR\_FAULTS command
- Power-on the product
- Switching off the product by the ON/OFF control (ON/OFF pin or Serial communication)

Each register may be read by serial communication. Refer to the command section for each register's details.

Article	PMBus Command
Input Voltage Monitor	READ_VIN
Output Voltage Monitor	READ_VOUT
Output Current Monitor	READ_IOUT
Converter Temp Monitor	READ_TEMPERATURE_2
STATUS_BYTE Register	STATUS_BYTE
STATUS_WORD Register	STATUS_WORD
STATUS_VOUT Register	STATUS_VOUT
STATUS_IOUT Register	STATUS_IOUT
STATUS_INPUT Register	STATUS_INPUT
STATUS_TEMPERATURE Register	STATUS_TEMPERATURE

**8-10. Under Voltage Lockout**

This product provides UVLO to prevent malfunction when input voltage decreases. When input voltage increases to operating onset voltage (4.0V typ.), the product allows itself to start the switching operation. When input voltage decreases to operating stopping voltage (3.5V typ.), the product stops the switching operation.

**8-11. Over Voltage Protection**

Output voltage (between +S pin and –S pin) goes over the operating threshold of over voltage protection, the product suspends the switching operation. However, if over voltage occurs due to the product's breakage, this feature does not function.

Since the feature is latch-operated, the product does not recover itself. To release the latched state, switch it on or off via the ON/OFF control (ON/OFF pin or serial communication).

The operating threshold of over voltage protection may be set by serial communication.

Setting Items	PMBus Command	Setting Range	Resolution Capability	Default Setting
Over Voltage Protection Threshold	VOUT_OV_FAULT_LIMIT	0 – 3.975V	25mV	3.975V

**8-12. Under Voltage Protection**

When the output voltage (between +S pin and –S pin) goes below the operating threshold, the product suspends the switching operation.

Since the feature is latch-operated, the product does not recover itself. To release the latched state, switch it on or off (by or via) the ON/OFF control (ON/OFF pin or serial communication).

The operating threshold of under voltage protection may be set by serial communication.

Setting Items	PMBus Command	Setting Range	Resolution Capability	Default Setting
Under Voltage Protection Threshold	VOUT_UV_FAULT_LIMIT	0-3.975V	25mV	0V

**8-13. Over Current Protection**

When over current protection starts operating, output current is limited to decrease the output voltage.

Once releasing the over current state, output voltage will recover automatically.

**8-14. Overheat Detection Feature**

When the product's detection temp goes above the operating threshold, the bit, which falls under the status registers, is set, notifying that overheat detection feature is activated. Since the feature only gives out the notification, switching operation does not stop.

The operating threshold of the overheat detection feature may be set by serial communication.

Refer to section 8-9 for temp detecting location of the product.

Setting Items	PMBus Command	Setting Range	Resolution Capability	Default Setting
Operating threshold of overheat detection feature	OT_WARN_LIMIT	0-125°C	1°C	110°C

## 8-15. Over heat protection

- If temp. of this product exceeds 125°C, it will stop the switching operation.
- This product is a latched type, it does not auto-restart.
- In order to release the latched state, either re-input or switch off with the ON/OFF control.
- Please refer to section 8-9 about set point temp.

## 9. Serial Interface

## 9-1) Symbol/Term

Please refer the definition for section 9 as below:

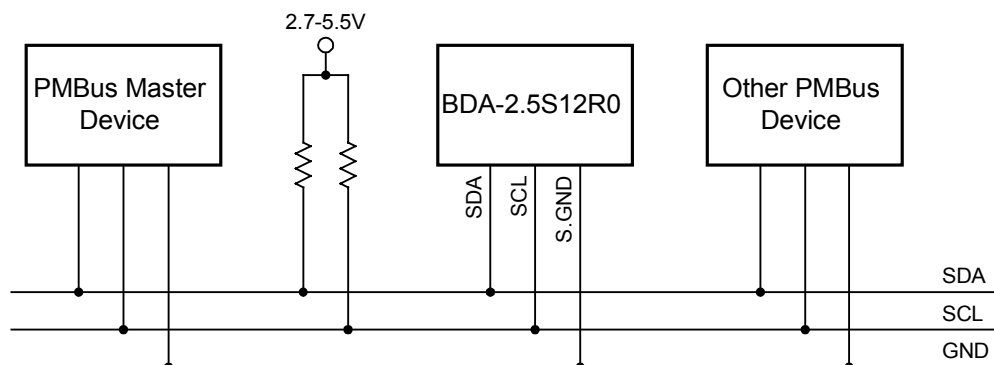
Code/Term	Definition
Byte	8bit
Word	16bit (2 byte)
Set	Bit is the value of logic“1”.
Clear	Bit is the value of logic“0”.
nbn	Number "nn" represented as a binary number
nnh	Number "nn" represented as a hex

## 9-2) Communication method

- The Serial Interface comply to the PMBus Specification Revision 1.1.
- Please refer the PMBus specification for the transmission method of command and the details for the data format.

## 9-3) Communication terminal

Please connect the PMBus communication terminal(SDA,SCL) to the power supply of 2.7 to 5.5V by pull up resistance or related method. Leave PMBus communication terminal open when serial communication is not under procedure.



## 9-3-1) SDA terminal

SDA terminal (9Pin) is a data Input/Output terminal for serial communication.

When output, SDA terminal is in open drain output.

- Input Low Level : 0 to 0.8V
- Input High Level : 2.4V min.
- Output Low Level : 0.4V max. (Sink current 5mA max.)

## 9-3-2) SCL terminal

SCL terminal (8Pin) is a clock input terminal of serial communication.

SCL terminal will not operate from this unit.

SCL terminal will operate by the Bus Master Device.

- Input Low Level: 0 to 0.8V
- Input High Level: 2.4Vmin.

## 9-4) Device/ Address Setting

- At the PMBus, many devices will share one data bus. The user set the device address to each device for identification.
- Device address needs to be set upon the same data bus with no duplication.
- The device address may be set by connecting the resistor between ADDR pin (10Pin) and GND pin (11Pin)
- Please refer to the below data for the relation of the device address and the resistor Raddr for the address setting. Please use the resistor with permissible difference of 1%.
- The device address will be set by the resistance value between the ADDR pin and GND pin when power on.
- The device address will not remain even if the resistance value between the ADDR pin and S.GND pin is adjusted after power on.
- ADDR pin may left open when communication function is not functioning.

Device address	Resistance of ADDR Pin – S.GND Pin[kΩ]
1011 110	10.0
1011 101	9.31
1011 100	8.66
1011 011	7.87
1011 010	7.15
1011 001	6.49
1011 000	5.90
1010 111	5.11
1010 110	4.42
1010 101	3.74
1010 100	3.09
1010 011	2.43
1010 010	1.74
1010 001	1.02
1010 000	≤ 0.34

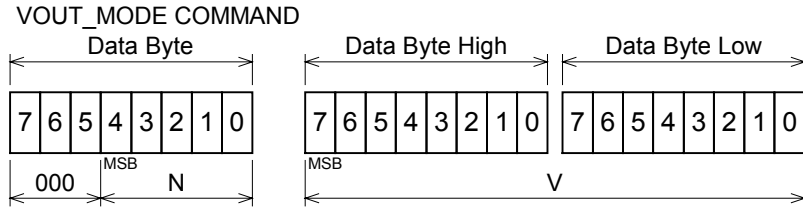
9-5) Data type

9-5-1. 16 bit Linear Format

The data type is used to show the output voltage related value. It comprise of the below elements.

- Exponent part (Exponent) of 5 bit, N (two's complement signed integer)
- Significant of 16bit (mantissa), V (no signed integer or two's complement signed integer)

The exponent part N of 5 bit is set by VOUT\_MODE command.



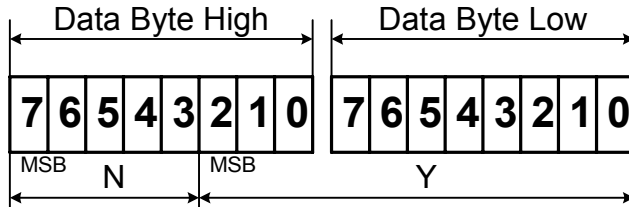
The formula of value voltage value described by Linear Format and Exponent N and Mantissa Y is as follows:

$$Voltage = V \times 2^N$$

9-5-2. 11bit Linear Data Format

The data type is used to show the value other than the output voltage, 2 byte comprise of the below elements.

- Exponent part of 5 bit (Exponent) N (integral number with code of complement representation of 2)
- Mantissa part of 11 bit (Mantissa) Y (integral number with code of complement representation of 2)



The formula of value X described by Linear Data Format and Exponent N and Mantissa Y is as follows:

$$X = Y \times 2^N$$

## 9-6) PMBus

## 9-6-1. PMBus command list

BDA series may use the below commands.

PMBus Command	Command code	Transaction type	Data Length (Byte)	Data type	Setting at shipping
OPERATION	01h	R/W Byte	1	—	80h
ON_OFF_CONFIG	02h	R/W Byte	1	—	1Fh
CLEAR_FAULTS	03h	Send Byte	0	—	—
STORE_USER_ALL	15h	Send Byte	0	—	—
RESTORE_USER_ALL	16h	Send Byte	0	—	—
VOUT_MODE	20h	R/W Byte	1	—	14h (-12)
VOUT_COMMAND	21h	R/W Word	2	Linear (16bit)	0CCCCh (0.8V)
VOUT_TRIM	22h	R/W Word	2	Linear (16bit)	0000h (0mV)
VOUT_MAX	24h	R/W Word	2	Linear (16bit)	27FEh (2.5V)
VOUT_MARGIN_HIGH	25h	R/W Word	2	Linear (16bit)	0CCCCh (0.8V)
VOUT_MARGIN_LOW	26h	R/W Word	2	Linear (16bit)	0CCCCh (0.8V)
VOUT_OV_FAULT_LIMIT	40h	R/W Word	2	Linear (16bit)	3F96h (3.974V)
VOUT_UV_FAULT_LIMIT	44h	R/W Word	2	Linear (16bit)	0000h (0V)
OT_WARN_LIMIT	51h	R/W Word	2	Linear (16bit)	006Eh (110°C)
TON_DELAY	60h	R/W Word	2	Linear (11bit)	E810h (2ms)
TOFF_DELAY	64h	R/W Word	2	Linear (11bit)	E800h (0ms)
TON_TOFF_RATE	FE28h* <sup>1</sup>	Ex. R/W Word	2	—	0404h (762.9V/s)
STATUS_BYTE	78h	Read Byte	1	—	—
STATUS_WORD	79h	Read Word	2	—	—
STATUS_VOUT	7Ah	Read Byte	1	—	—
STATUS_IOUT	7Bh	Read Byte	1	—	—
STATUS_INPUT	7Ch	Read Byte	1	—	—
STATUS_TEMPERATURE	7Dh	Read Byte	1	—	—
READ_VIN	88h	Read Word	2	Linear (11bit)	—
READ_VOUT	8Bh	Read Word	2	Linear (16bit)	—
READ_IOUT	8Ch	Read Word	2	Linear (11bit)	—
READ_TEMPERATURE_2	8Eh	Read Word	2	Linear (11bit)	—
USER_MEMORY_PROTECT	D0h	R/W Byte	1	—	00h
OPERATE_MEMORY_PROTECT	D1h	R/W Byte	1	—	00h

\*1 Command Extension Code: FEh, Command Code: 28h

The meaning of Transaction type from the previous list is as follows:

Transaction type	Communication Protocol
Send Byte	Send Byte Protocol compatible
Read Byte	Read Byte Protocol compatible
Read Word	Read Word Protocol compatible
R/W Byte	Compatible with Read Byte Protocol & Write Byte Protocol
R/W Word	Compatible with Read Word Protocol & Write Word Protocol
Ex. R/W Word	Compatible with Extended Command Read Word Protocol & Extended Command Write Word Protocol

### 9-6-2. OPERATION Command (01h)

This command uses for switching of the ON/OFF control and margin State.

The data byte is 1byte. Please refer the below list for the meaning of each bit.

Bit				Output ON/OFF	Margin State	Reference	Setting at Shipping
7-6	5-4	3-2	1-0				
00	XX	XX	XX	OFF	Margin OFF	No decay sequence Switching stop operates immediately	
01	XX	XX	XX	OFF	Margin OFF	Decay sequence available Apply the sequence which is set by TOFF_DELAY or TON_TOFF_RATE Command and stop.	
10	00	XX	XX	ON	Margin OFF	—	●
10	01	01	XX	ON	Margin Low	Invalid the over voltage protection or under voltage protection	
10	01	10	XX	ON	Margin Low	—	
10	10	01	XX	ON	Margin High	Invalid the over voltage protection or under voltage protection	
10	10	10	XX	ON	Margin High	—	

The Bit which indicates X may use 0 or 1 and either one will not affect the operation.

In case of setting combination values which is not listed above, the operation is undefined.

When the ON/OFF control with the serial communication is disabled by the ON\_OFF\_CONFIG command (Bit 4 is clear or Bit 3 is clear), the ON/OFF control may not be used. Changing the Margin State is possible.

## 9-6-3. ON\_OFF\_CONFIG Command (02h)

-This command is for setting the operation of the ON/OFF control.

- Data byte is 1 byte. The meaning of each bit is as follows.

Bit	Purpose	Value	Meaning	Set status at shipping
7-5	Backup	disvalue	Invalid	
4	Choose the valid and invalid of ON/OFF control	0	<b>Invalid</b> the ON/OFF control of ON/OFF terminal or serial communication.	
		1	<b>Valid</b> the ON/OFF control of ON/OFF terminal or serial communication.	●
3	Valid and Invalid of ON/OFF control of serial communication.	0	<b>Invalid</b> the ON/OFF control of serial communication.	
		1	<b>Valid</b> the ON/OFF control of serial communication.	●
2	Valid and Invalid of ON/OFF control of ON/OFF terminal.	0	<b>Invalid</b> the ON/OFF control of ON/OFF terminal	
		1	<b>Valid</b> the ON/OFF control of ON/OFF terminal.	●
1	Control logic of ON/OFF terminal	0	Negative logic (ON at Low status)	
		1	Positive logic (ON at Open status)	●
0	Option of valid or invalid of decay sequence when off by ON/OFF terminal	0	Apply the sequence which specified by TOFF_DELAY command and TON_TOFF_RATE command and stop.	
		1	Stop the switching immediately.	●

When the ON/OFF control with the ON/OFF pin and the ON/OFF control with the serial communication are both enabled (Bit 4-2 are all set), unless both the ON/OFF commands are ON, the output will not be ON.

## 9-6-4. CLEAR\_FAULTS Command (03h)

This command clears all the bits of the status register

This command only clears the status register. Even if this command is executed without removing the cause which the status register is set, the status register will be reset.

**9-6-5. STORE\_USER\_ALL Command (15h)**

This command is to save the contents of the operating memory into the nonvolatile user store memory. The setting of write protect will not be saved.

Attention: Please hold the input voltage for 1 sec after the command is executed.

Do not perform communication for 1sec after the command is executed.

The user store memory may be destroyed and may not be restored.

**9-6-6. RESTORE\_USER\_ALL Command (16h)**

This command is to change the contents of the operating memory into the contents which is saved in the nonvolatile user store memory.

**9-6-7. VOUT\_MODE Command (20h)**

This command reads and changes the setting of Linear Data Format exponent part.

The data byte is 1byte and lower 5 byte shall use 5 byte signed integer form.

High 3 bit shall be all 0.

Setting is 14h(Linear Mode, ExponentN=-12) at shipping.

**9-6-8. VOUT\_COMMAND Command (21h)**

This command is to readout and change the setting value of the Margin OFF output voltage.

The data byte is 2byte and it is 16 bit Linear Data Format (unit : V)

**9-6-9. VOUT\_MARGIN\_HIGH Command (25h)**

This command is to read and change the setting value of the Margin High output voltage.

The data byte is 2byte and is 16 bit Linear Data Format (unit : V)

**9-6-10. VOUT\_MARGIN\_LOW Command (26h)**

This command is to read and change the setting value of the Margin Low output voltage.

The data byte is 2byte and is 16 bit Linear Data Format (unit : V)

**9-6-11. VOUT\_TRIM Command (22h)**

This command is to readout and change the setting value of the output voltage fine adjustment.

The data byte is 2byte and is 16 bit Linear Data Format (unit : V)

**9-6-12. VOUT\_MAX Command (24h)**

This command is to readout and change the maximum setting value of VOUT\_COMMAND, VOUT\_MARGIN\_HIGH, and VOUT\_MARGIN\_LOW

The data byte is 2byte and is 16 bit Linear Data Format (unit : V) . This command prevents it from setting voltage excessively. Since controlling the setting maximum value, it does not have the over voltage protection feature.

## 9-6-13. VOUT\_OV\_FAULT\_LIMIT Command (40h)

This command is to readout and change the set point of the output over voltage detection.

The data byte is 2byte and is 16 bit Linear Data Format (unit : V)

## 9-6-14. VOUT\_UV\_FAULT\_LIMIT Command (44h)

This command is to readout and change the set point of the output low voltage detection.

The data byte is 2byte and is 16 bit Linear Data Format (unit : V)

## 9-6-15. OT\_WARN\_LIMIT Command (51h)

This command is to readout and change the set point for the overheat alert.

The data byte is 2byte and is 11 bit Linear Data Format (unit : ° C)

## 9-6-16. TON\_DELAY Command (60h)

This command is to readout and change the setting value of the Turn-On Delay.

The data byte is 2byte and is 11 bit Linear Data Format (unit : ms)

## 9-6-17. TOFF\_DELAY Command (64h)

This command is to readout and change the setting value of the Turn-Off Delay.

The data byte is 2byte and it is 11 bit Linear Data Format (unit : ms)

## 9-6-18. TON\_TOFF\_RATE Command (FE28h)

This command is to readout and change the setting value of Turn-On Slew Rate and Turn-Off Slew Rate.

The data byte is 2byte and lower 8 bit is Turn-On Slew Rate, upper 8 bit is Turn-Off Slew Rate.

The formula of value B of Data byte and Slew Rate SR is as follows:

$$SR = \frac{10^8}{32768 \times B} [V/s]$$

Example) Turn-On Slew Rate will be as follows when specified lower data byte is 04h.

$$SR = \frac{10^8}{32768 \times 4} = 762.9V/s$$

Data Byte	Slew Rate
01h	3052V/s
02h	1526V/s
03h	1017V/s
04h	762.9V/s
⋮	⋮
10h	190.7V/s
⋮	⋮
40h	47.68V/s
⋮	⋮
FEh	12.01V/s
FFh	11.97V/s

## 9-6-19. STATUS\_BYTE Command (78h)

This command is to readout the STATUS\_BYTE register.

The STATUS\_BYTE register is 1byte register and the meaning of each bit is in the below chart.

Bit number	Bit name	Meaning
7	Reserved	Constantly 0
6	OFF	Output OFF (Not only for shutoff by the protection function but also the function shutoff by ON/OFF control.)
5	VOUT_OV	Operates the output over voltage protect function.
4	IOUT_OC	Operates the output over current protect function
3	VIN_UV	Operates the low input voltage protect function
2	TEMPERATURE	STATUS_TEMPERATURE One of the registers is set.
1	—	Nondisclosure
0	—	Nondisclosure

## 9-6-20. STATUS\_WORD Command (79h)

This command is to readout the STATUS\_WORD register.

The STATUS\_WORD register is 2byte and the meaning of each bit is in the below chart.

	Bit number	Bit name	Meaning
Lower	7	Reserved	Constantly 0
	6	OFF	Output OFF (Not only for shutoff by the protection feature but also the feature shutoff by ON/OFF control.)
	5	VOUT_OV	Operates the output over voltage protect feature.
	4	IOUT_OC	Operates the output over current protect feature
	3	VIN_UV	Operates the low input voltage protect feature
	2	TEMPERATURE	STATUS_TEMPERATURE One bit of the registers is set.
	1	—	Nondisclosure
	0	—	Nondisclosure
Upper	7	VOUT	Operates the output over voltage protect feature or output under voltage protect feature.
	6	IOUT	STATUS_IOUT One bit of the registers is set.
	5	INPUT	STATUS_INPUT One bit of the registers is set.
	4		Nondisclosure
	3	POWER_GOOD#	P-Good signal of negative logic. Set when the P-Good terminal is in Low condition.
	2	Reserved	Constantly 0
	1	Reserved	Constantly 0
	0	Reserved	Constantly 0

## 9-6-21. STATUS\_VOUT Command (7Ah)

This command is to readout the STATUS\_VOUT register.

The STATUS\_VOUT register is 1byte and the meaning of each bit is as follows.

Bit number	Meaning
7	Operates the output over voltage protect feature.
6	Constantly 0
5	Constantly 0
4	Operates the output low voltage protect feature.
3	When the voltage is set higher than the VOUT_MAX command.
2	Constantly 0
1	Constantly 0
0	Constantly 0

## 9-6-22. STATUS\_IOUT Command (7Bh)

This command is to readout the STATUS\_IOUT register.

The STATUS\_IOUT register is 1byte and the meaning of each bit is as follows.

Bit number	Meaning
7	Activate the output over current protect feature.
6	Constantly 0
5	Constantly 0
4	Constantly 0
3	Constantly 0
2	Constantly 0
1	Constantly 0
0	Constantly 0

## 9-6-23. STATUS\_INPUT Command (7Ch)

This command is to readout the STATUS\_INPUT register.

The STATUS\_INPUT register is 1byte and the meaning of each bit is follows.

Bit number	Meaning
7	Constantly 0
6	Constantly 0
5	Constantly 0
4	Activate the low input voltage protect feature.
3	Constantly 0
2	Constantly 0
1	Constantly 0
0	Constantly 0

## 9-6-24. STATUS\_TEMPERATURE Command (7Dh)

This command is to readout the STATUS\_TEMPERATURE register.

The STATUS\_TEMPERATURE register is 1byte and the meaning of each bit is as follows.

Bit number	Meaning
7	Emerge the overheat alert.
6	Activate the over heat protect feature.
5	Constantly 0
4	Constantly 0
3	Constantly 0
2	Constantly 0
1	Constantly 0
0	Constantly 0

## 9-6-25. READ\_VIN Command (88h)

This command is to readout the input voltage of DC-DC converter.

The data byte is 2byte and is 11 bit Linear Data Format (unit: V)

## 9-6-26. READ\_VOUT Command (8Bh)

This command is to readout the output voltage of DC-DC converter.

The data byte is 2byte and is 16 bit Linear Data Format (unit: V) .

## 9-6-27. READ\_IOUT Command (8Ch)

This command is to readout the output current of DC-DC converter.

The data byte is 2byte and is 11 bit Linear Data Format (unit: A) .

## 9-6-28. READ\_TEMPERATURE\_2 Command (8Eh)

This command is to readout the temperature of DC-DC converter.

The data byte is 2byte and is 11 bit Linear Data Format (unit: °C) .

## 9-6-29. USER\_MEMORY\_PROTECT Command (D0h)

This command is to control the write protect of User store memory.

The data byte is 1 byte. USER\_MEMORY\_PROTECT will become able to write in when setting at 33h otherwise prohibited.

## 9-6-30. OPERATE\_MEMORY\_PROTECT Command (D1h)

This command is to control write protect of operating memory.

The data byte is 1 byte. OPERATE\_MEMORY\_PROTECT will be able to write in when setting at 55h otherwise prohibited.

## 10. Example of Communication

## 10-1) Setting the Output voltage

Set the output voltage at 2.5V and store the setting to USER\_STORE\_MEMORY.

1) Release Write Protect of Operating memory.

Write-in 55h by OPERATE\_MEMORY\_PROTECT order.

2) Release Write Protect of USER\_STORE\_MEMORY

Write-in 33h by USER\_MEMORY\_PROTECT

3) Change Output voltage setting value.

Write-in 2800h by VOUT\_COMMAND order(21h).

4) Store setting value to USER\_STORE\_MEMORY

Practice STORE\_USER\_ALL order(15h). Do not switch off or communicate within a second after practicing STORE\_USER\_ALL order.

## Calculating data byte of VOUT\_COMMAND

The data byte of VOUT\_COMMAND order is 16 bit Linear Format (Refer to 9-6-8). In 16 bit Linear Format, The formula of output voltage VOLTAGE and Exponent part N and Mantissa V is as follows (Refer to 9-5-1):

$$\text{Voltage} = V \times 2^N$$

As we specify Mantissa V in VOUT\_COMMAND order, Mantissa V is calculated as follows:

$$V = \frac{\text{Voltage}}{2^N}$$

As described in 9-6-7, setting at shipping is exponent N=-12 therefore mantissa V when Output voltage Voltage=2.5V is calculated as follows:

$$V = \frac{\text{Voltage}}{2^N} = \frac{2.5}{2^{-12}} = 10240 \text{ (2800h)}$$

When setting output voltage to 2.5 v, Data byte of VOUT\_COMMAND order will be 2800h.

## 10-2. Setting rise time and fall time

Setting set output voltage 1.8V, rise time 10ms, fall time 25ms (Do not store to USER\_STORE\_MEMORY).

1) Release Write Protect Operating Memory.

Write in 55h by OPERATE\_MEMORY\_PROTECT order(D1h)

2) Change Output voltage set value

Write in 1CCCh by VOUT\_COMMAND order. (Refer to the previous page for calculating Data byte)

3) Set rise and fall through rate

Write in 2A11h by TON\_TOFF\_RATE order(FE28h).

Calculating Data byte of TON\_TOFF\_RATE order.

Formula of Output voltage  $V_{out}$ , Rise (or fall) time  $t$ , Rise (or fall) slew rate  $SR$  is as follows:

$$SR = \frac{V_{out}}{t} [\text{V/s}]$$

To make output voltage  $V_{out}=1.8\text{V}$ , rise time  $t=10\text{ms}$ , set rise slew rate  $SR$  as follows:

$$SR = \frac{V_{out}}{t} = \frac{1.8}{10 \times 10^{-3}} = 180 [\text{V/s}]$$

As shown in 9-6-18, the formula of slew rate  $SR$  and Data byte  $B$  of TON\_TOFF\_RATE order is as follows:

$$SR = \frac{10^8}{32768 \times B}$$

To calculate Data byte  $B$  of TON\_TOFF\_RATE command when setting rise slew rate  $SR$  180V/s is as follows:

$$B = \frac{10^8}{32768 \times SR} = \frac{10^8}{32768 \times 180} = 17 \text{ (11h)}$$

Likewise, Data byte  $B$  of TON\_TOFF\_RATE command to make fall time 25ms will be 2Ah.

In TON\_TOFF\_RATE command, set stand slew rate lower 8 bit, fall slew rate higher 8 bit. Therefore, data byte of TON\_TOFF\_RATE command when output voltage 1.8V, rise time 10ms, fall time 25ms will be 2A11h.

### 10-3. Obtaining Output current value.

#### 1) Obtaining output current value

Read out data byte by READ\_IOUT command (8Ch)

Example) When data byte which read out by READ\_IOUT command is E85Ch

Data byte of READ\_IOUT command is 11bit Linear Data Format (Refer to 9-6-27). In 11bit Linear Data Format, The formula of real number  $X$  and Exponent  $N$  and Mantissa  $Y$  is as follows (Refer to 9-5-2):

$$X = Y \times 2^N$$

The binary system of Data byte E85Ch of READ\_IOUT command is 1110100001011100b. Higher 5bit is Exponent  $N$ , Lower 11 bit is Mantissa  $Y$  therefore Exponent  $N$  is 11101b, Mantissa  $Y$  is 00001011100b.

By decimal system, Exponent  $N$  (signed integer) will be  $-3$ , Mantissa  $Y$  will be 92.

Therefore, Current value  $X$  of real number will be as follows:

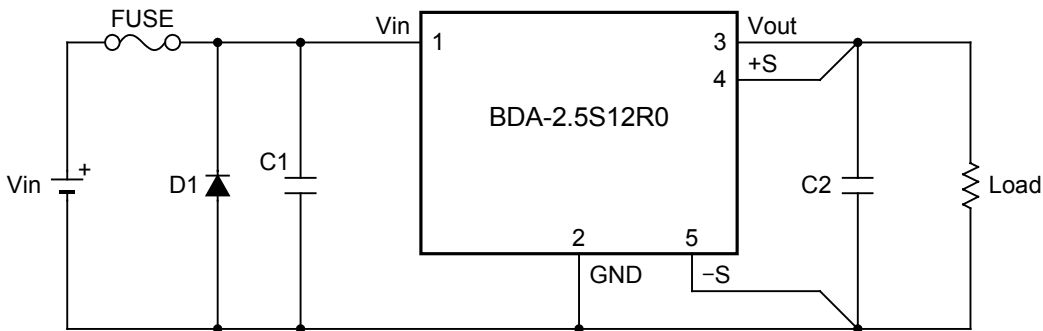
$$X = Y \times 2^N = 92 \times 2^{-3} = 11.5 (\text{A})$$

11. Prevention of inverse input power connections (Example)

This product may break if the polarities are connected reversed.

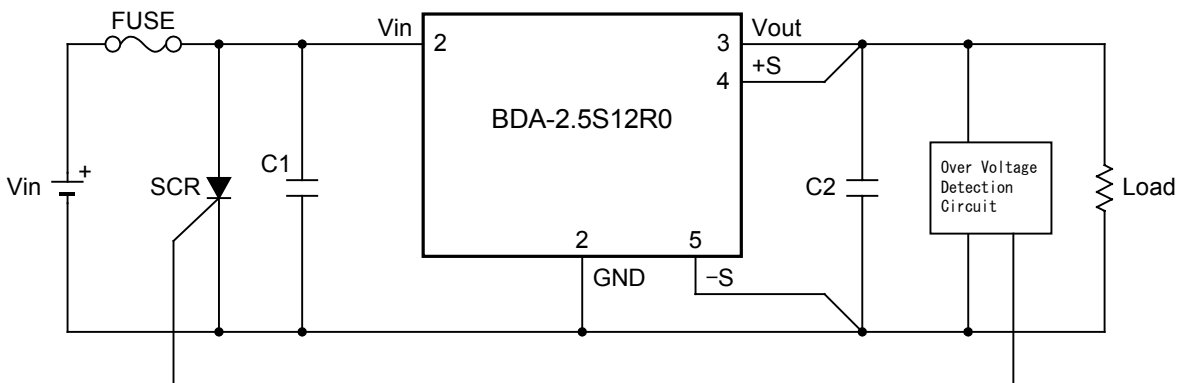
If there is a possibility of the reverse connection, add the protection circuit as in the below diagram.

The below example is using fuse and diode.



12. Over voltage protect circuit (Example)

This product has a built-in over voltage protect circuit. If the switch element inside the product breaks by short mode, the DC input voltage will directly show to the output. In case of the break by the over voltage mode, add the input shutdown circuit as in the below diagram.



Attention1. The ON/OFF control will not operate when it breaks by the over voltage mode.

Attention2. If the ON/OFF feature is the power supply side, it may be used.

Attention3. Hold the capacity for fusing on the DC power supply side.

## 13. Mounting condition

Use the below conditions for soldering temperature and time, storage before mounting.

## 13-1. Reflow

Pre-heat temperature: 150-180°C 60s max. (Refer to the below diagram)

Peak Temperature: 250°C max.

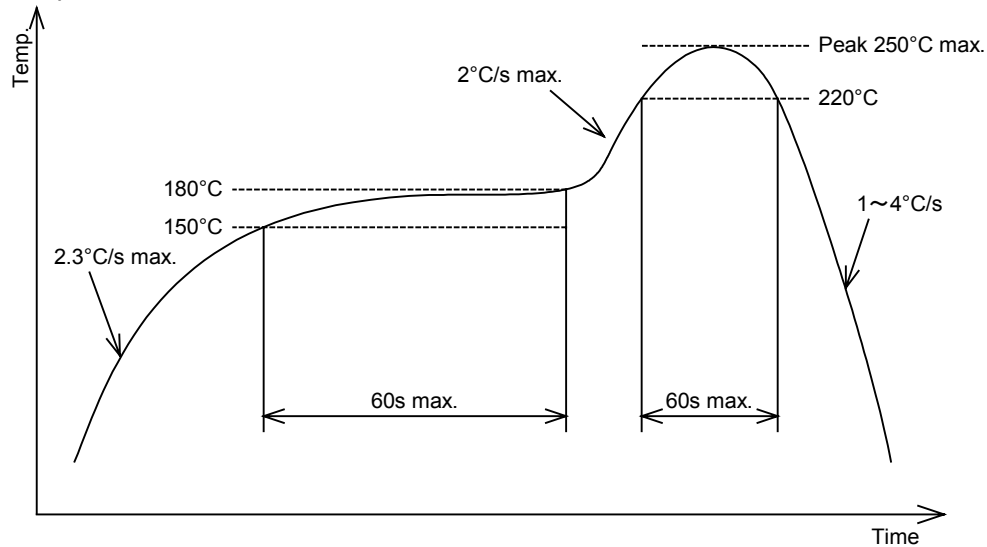
Over 220°C 60s max.

Re-flow : 2 times

Please do not vibrate at reflow. The components which compose the converter may move.

After mounting the converter to the base, do not re-reflow by turning inside out.

This product can not be mounted at flow.



## 13-2. Storage before mounting

The humidity is managed at MSL3 level. Please store at 30°C/60%RH after opening the dry pack.

-Pre-baking (125±5°C, 12H) is needed before soldering by reflow for the following conditions.

-Kept in a dry pack condition for one year.

-Kept in a condition where exceeds 168H at 30°C/60%RH after opening the dry pack.

## 14. Vibration / Shock

Vibration: 5 to 10Hz All Amplitude 10mm (1 hour each for 3 orthogonal axes)

10 to 55Hz Acceleration 2G (1 hour each for 3 orthogonal axes)

Shock: Acceleration 20G (3 times each for 3 orthogonal axes)

Shock time 11±5ms

Duration 11±5ms

**15. Cleaning Condition**

This product can not be washed as a whole. The no clean solder paste is recommended for this product.

**16. For the safety of our customer, please follow all warnings and specifications which are stated below.**

- This product is intended for use in general electronic appliances (office work machines, telecommunication equipment, and measurement equipments). Do not use for medical equipments, nuclear power equipments, and trains, etc. where the malfunction and damage of this product may directly cause harm to human life and or property. Please confirm when using except in general electronic equipment.
- For this product, series and parallel operation are not possible.
- For mounting this product, please do not use connectors or sockets. The performance may not be fulfilled by the effect of contacting resistors. Mount onto the PCB by soldering only.
- This product has a built-in over-current, short circuit protection, however long time usage in short circuit should be avoided since this may cause failure to the product.
- This product may be damaged if used under nonstandard electric and environmental conditions such as the temperature. Please be sure to always use within the standard conditions.
- Do not store this product where corrodible gases and dusts may generate.
- There is a possibility that the product may be damaged from static electricity. The workers should discharge all static electricity before handling the product, and the work atmosphere should also have a static countermeasure.
- This product does not have a fuse built in. When abnormal, please connect a fuse into + input line as a protection of over current. The electrical supply source should have enough capacity to be able to shut down a fuse.
- This product does not have an over voltage protection circuit built in. When large amount of voltage occur inside the module, there is a mode in which input voltage will directly released from the output, and may cause smoke or fire. Therefore, an over voltage protection circuit should always be connected.
- This product does not have an over voltage protection.
- No test certificate is attached to this product.

**17. Gurantee**

This product shall be guaranteed for year. During this period, if there should be any failure definitely due to our designing or manufacturing, we will repair or replace it with a new one at our expense. However, in any case that the product is modified and/or has made any internal remodeling by the buyer, the product can no longer be guaranteed. This guarantee shall cover only the BDA series.

If you have any further technical questions for this product, please contact to us.

E-mail: [info@bellnix.com](mailto:info@bellnix.com)

<http://www.bellnix.com>