Battery Management System Reference Design

EnerCera® Pouch + Nano Energy™ Collaboration Board

REFLVBMS001-EVK-001

Introduction

This User's Guide provides the information and necessary procedures to operate and evaluate the EnerCera® Pouch + Nano Energy™ Collaboration Board. It includes the board schematic, peripheral parts list, operating instructions, and application data. Please note that this board has been prepared for the purpose of simple evaluation of EnerCera and Nano Energy characteristics, and we cannot guarantee its quality. In addition, this evaluation board is intended to be used by professionals for research and development purposes. This board is not intended to be used in mass-produced products or any part thereof.

Note: EnerCera® is a registered trademark of NGK INSULATORS, LTD.

Note: Nano Energy™ is a trademark or registered trademark of ROHM Co., Ltd.

Description

This collaboration board charges the EnerCera Pouch rechargeable battery manufactured by NGK, and outputs the power stored in the EnerCera by stepping down and stabilizing it. The Power Supply and RESET ICs with Nano Energy technology maximizes the battery life.

The datasheets of the linear charger, RESET IC, and step-down DC/DC converter ICs that are used in this solution are available ROHM's website and the datasheet of EnerCera Pouch is available at NGK's website.

NGK INSULATORS, LTD. (https://www.ngk.co.jp/) EnerCera's dedicated website (https://enercera.ngk-insulators.com/)	
Battery	EnerCera EC382704P-C
ROHM Co., Ltd. (https://www.rohm.co.jp/)	
Linear Charger	BD71631QWZ
Step-down DC/DC converter	BD70522GUL
RESET	BD5230NVX

Storage Precautions

The board is equipped with a battery.

When storing the board, keep it in a bag to prevent short-circuit between the positive and negative terminals of the battery.

Set the EN jumper at the board to "L" to turn off the DC/DC converter.

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Operating conditions

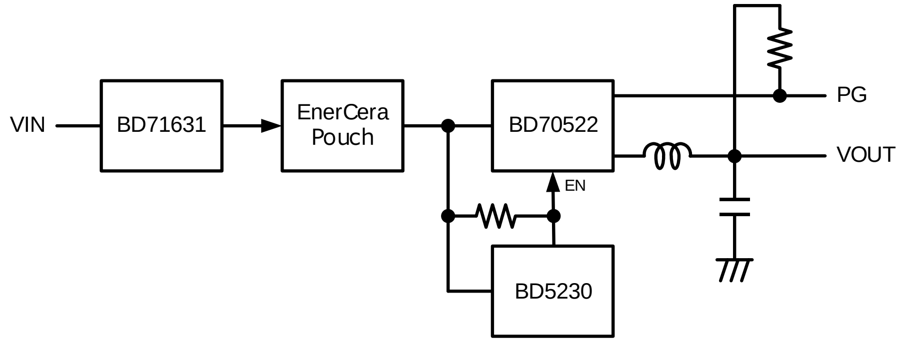


Figure 1. Block Diagram of EnerCera and each IC

Figure 1 shows the block diagram of the collaboration board. The charger IC (BD71631) starts charging the EnerCera by applying voltage to the VIN pin. If charging is not required, leave the VIN pin open. The RESET IC (BD5230) constantly monitors the EnerCera pin voltage and forcibly stops the operation of the DC/DC converter when the EnerCera voltage falls below 3.0V. The DC/DC converter (BD70522) converts the power stored in the EnerCera with high efficiency and can output up to 500mA. The discharge time is determined by the stored power of the EnerCera. The PG pin monitors the status of the DC/DC converter output voltage and is High (≈VOUT) during normal operation.

Below are the recommended operating conditions for the EnerCera Pouch + Nano Energy collaboration board:

Item	Symbol	Min	Typ	Max	Unit	Conditions
Charge Input Voltage	V_{IN}	4.5	-	5.5	V	Charge current≤100mA, CV+0.3V
Output Current	I_{OUT}	-	-	0.5	A	
PG Pin Sink Current	I_{PG}	-	-	10	mA	
Operating Ambient Temperature (Charging)	$T_{a,chg}$	0	-	45	°C	As per EnerCera Pouch regulations.
Operating Ambient Temperature (Discharge)	$T_{a,dischg}$	-20	-	+45	°C	As per EnerCera Pouch regulations.

Table 1. Recommended Operating Conditions

Typical characteristics are shown below. For detailed characteristics, please refer to the datasheet of each IC.

Item	Symbol	Min	Typ	Max	Unit	Conditions
Battery-monitoring Detection Voltage	V_{DETECT}	2.925	3.000	3.075	V	DC/DC converter OFF voltage
Battery-monitoring Release Voltage	$V_{RELEASE}$	3.105	3.150	3.195	V	DC/DC converter ON voltage
Output Voltage Setting Range	V_{OUTSEL}	1.2	-	3.3	V	9 Selectable Output Voltages
Output Voltage Accuracy	V_{TOL}	-2.0	0.0	+2.0	%	I_{OUT} = 10mA
VOUT-monitoring Detection Voltage	V_{PGdet}	-	95% of VOUT	-	V	VOUT sweep up
VOUT-monitoring Release Voltage	V_{PGrel}	-	90% of VOUT	-	V	VOUT sweep down
PG Output Leakage Current	I_{PGleak}	-	0.0	1.0	μA	
PG Output Low Level Voltage	V_{PGlow}	-	0.0	0.3	V	I_{SINK}=1mA
Charging Voltage	V_{CHG}	-	4.143	-	V	R4=620kΩ,R5=105kΩ, 1mA~300mA adjustable
Charging Current	I_{CHG}	-	13	-	mA	R2=39kΩ, 1mA~300mA adjustable
Termination Current	I_{TERM}	-	1.28	-	mA	R3=39kΩ, 50μA~10mA adjustable

Table 2. Typical Specification Values for ICs (Excerpt)

Board Overview

This board achieves low profile and small area mounting with the ultra-thin EnerCera Pouch and Nano Energy IC which uses ultra-small packages. Since it has a charge and discharge functions to manage the battery on the same board, the total characteristics of the "battery + power supply" can be evaluated.

In addition, various types of EnerCera Pouch are lined up, it is possible to evaluate other EnerCera Pouch by simply replacing these batteries since they have the same terminal shape. (It is necessary to change the charge current setting resistance value of the charging IC to match the EnerCera Pouch to be used.)

Figure 2. Products Mounted on Collaboration Board

[Information] Board Configuration that Utilizes EnerCera's thin package

By mounting the EnerCera Pouch on the back, the mounting area of the battery is virtually zero, contributing to the miniaturization and thinness of IoT devices.

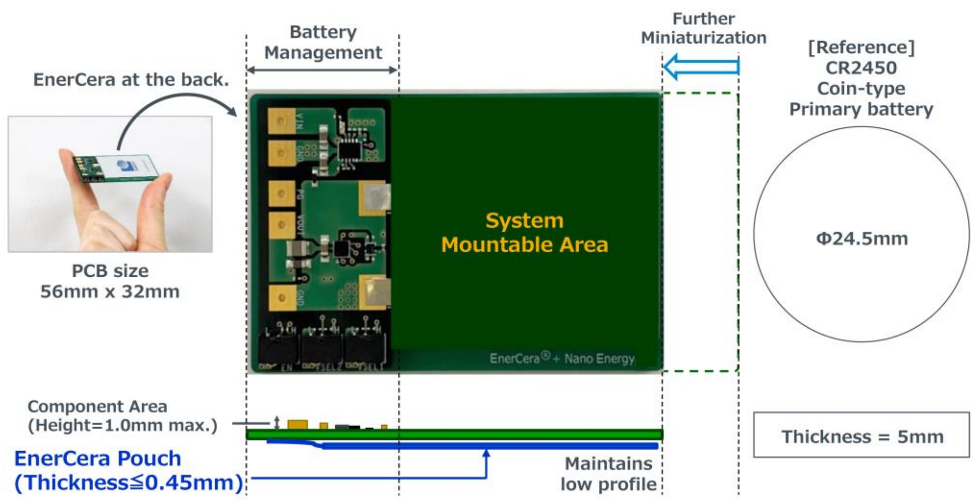


Figure 3. Mounting Example of EnerCera Pouch Utilizing its Thinness

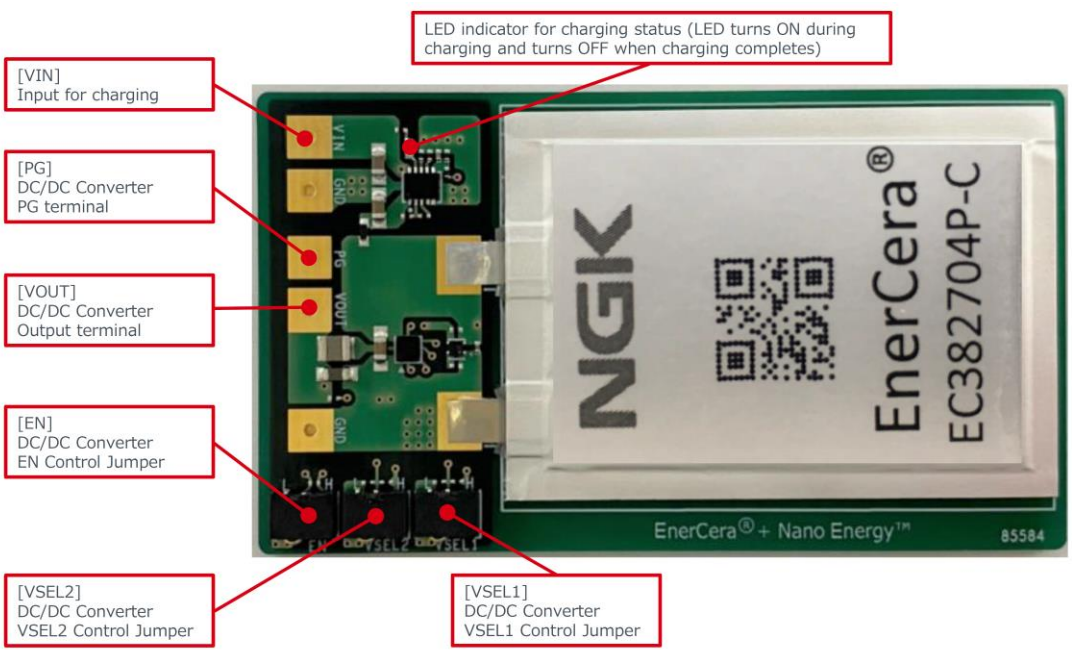
Board photo

Top View

Bottom View

Figure 4. Collaboration Board Photo

Board Description



The factory default pin settings are EN=L, VSEL1=L, and VSEL2=L.

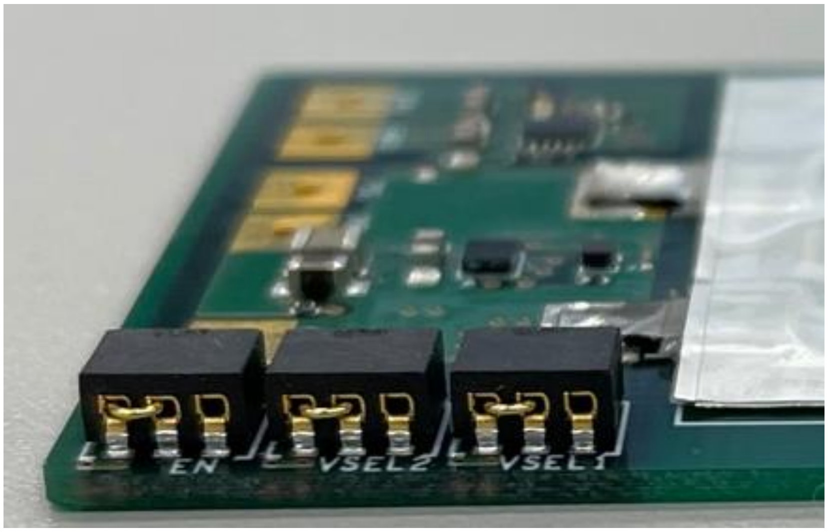
Figure 5. Collaboration Board Pin and Jumper Description

About Jumper Settings

The board used HHP-3 jumpers manufactured by MAC EIGHT CO., LTD..

To set the state of the jumpers, short the center terminal of the HHP-3 to the H side terminal or L side terminal as specified on the silk.

When the EN jumper is removed, the EN of the DC/DC converter can be controlled directly from the center terminal. The RESET output that monitors the EnerCera output voltage can be measured from the H terminal.



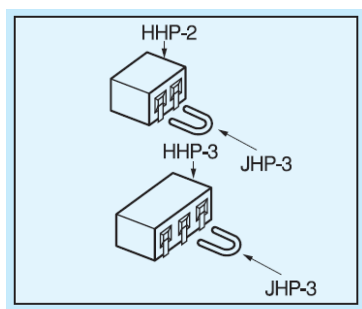
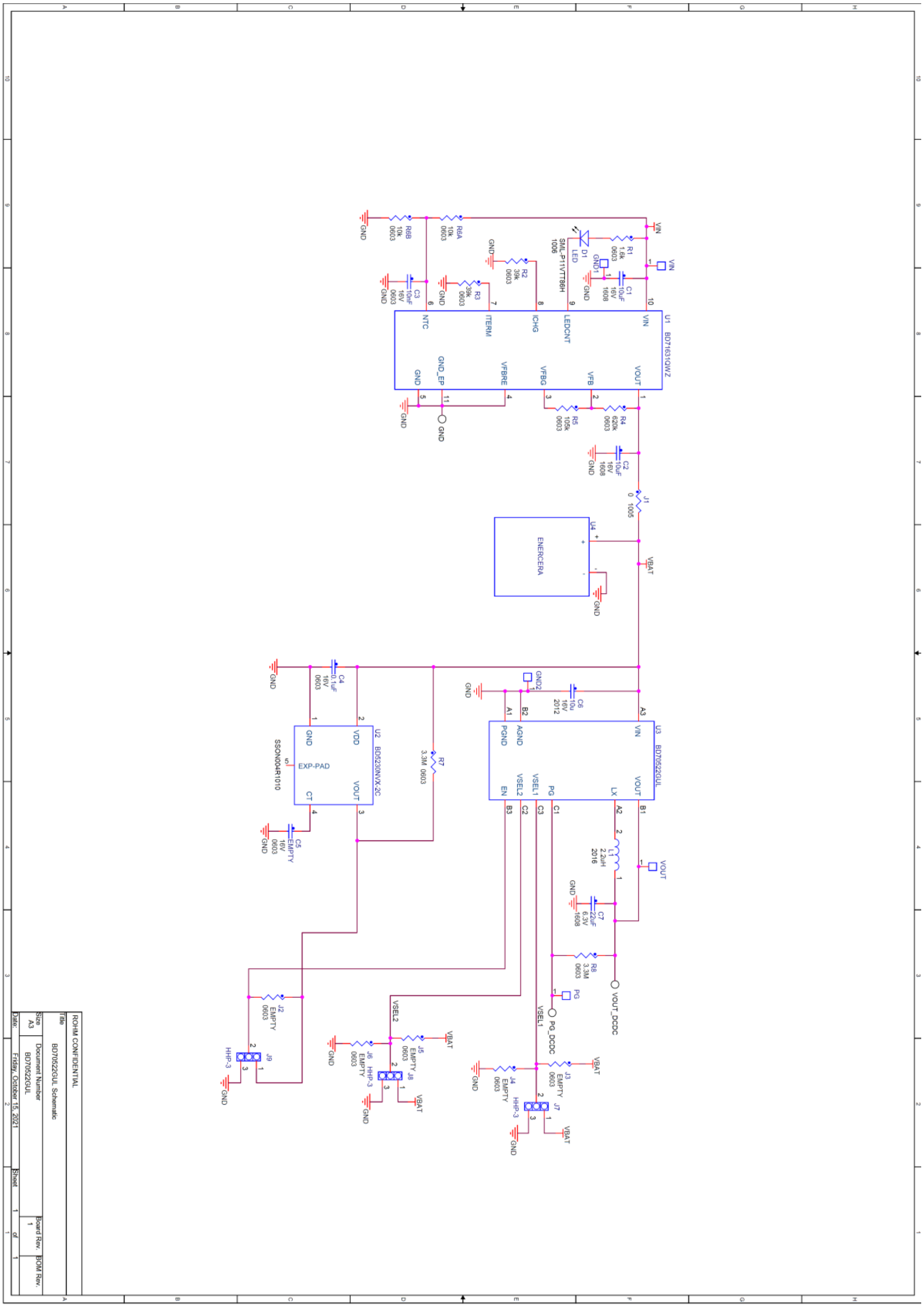


Figure 6. Terminal Jumper Description

Board Schematic



Note: Refer to the parts list on the next page for the fixed value of parts.

Figure 7. Board Schematic

Parts List

Unit	Part	Value	Description		
Charger	U1	-	IC	ROHM	BD71631QWZ
	R1	1.6kΩ	Resistor	ROHM	MCR006PLPZF1601
	R2	39kΩ	Resistor	ROHM	MCR006PLPZF3902
	R3	39kΩ	Resistor	ROHM	MCR006PLPZF3902
	R4	620kΩ	Resistor	ROHM	MCR006PLPZF6203
	R5	105kΩ	Resistor	ROHM	MCR006PLPZF1053
	R6A	10kΩ	Resistor	ROHM	MCR006PLPZF1002
	R6B	10kΩ	Resistor	ROHM	MCR006PLPZF1002
	C1	10μF	Capacitor	TDK	C1608X5R1A106K
	C2	10μF	Capacitor	TDK	C1608X5R1A106K
	C3	10nF	Capacitor	TDK	C0603X7R1A103K
	D1	-	LED	ROHM	SML-P11VTT86RH
RESET	U2	-	IC	ROHM	BD5230NVX
	R7	3.3MΩ	Resistor	ROHM	MCR006PLPF3304
	C4	0.1μF	Capacitor	TDK	C0603X5R1A104K
	C5	EMPTY	Capacitor		
DC/DC	U3	-	IC	ROHM	BD70522GUL
	R8	3.3MΩ	Resistor	ROHM	MCR006PLPF3304
	C6	10μF	Capacitor	TDK	C1608X5R1A106K
	C7	22μF	Capacitor	TDK	C1608X5R0J226M
	L1	2.2μH	Inductor	TDK	TFM201610ALM-2R2MTAA
Battery	U4	-	EnerCera	NGK	EnerCera EC382704P-C
Other	J1	0Ω	Jumper	ROHM	PMR01ZZPJ000
	J2	EMPTY	Jumper		
	J3	EMPTY	Jumper		
	J4	EMPTY	Jumper		
	J5	EMPTY	Jumper		
	J6	EMPTY	Jumper		
	J7	-	Jumper	MAC EIGHT	HHP-3
	J8	-	Jumper	MAC EIGHT	HHP-3
	J9	-	Jumper	MAC EIGHT	HHP-3

Table 3. Parts List of Collaboration Board

Board Operating Procedure

■ Charging Procedure for EnerCera

Apply a DC voltage input from 4.5V to 5.5V (current capability of 20mA or more) between VIN and GND.
The LED lights up while charging the EnerCera and turns OFF when charging is complete.
Note: When the EN jumper is set to "H", the DC/DC converter operates during charging and PG=H.

■ DC/DC Output Procedure

To operate the DC/DC converter, set EN=H.
When start-up is complete, the PG pin changes from 0V to VOUT.

■ DC/DC Output Voltage Setting Procedure

(1) Set EN = L to turn OFF the DC/DC converter.
(2) Set the jumper status of VSEL1 and VSEL2 to the desired output voltage setting (see table below).
(3) Set EN = H to turn ON the DC/DC converter. VOUT will be equal to the configured voltage output.

VOUT	VSEL1	VSEL2
1.2V	L	OPEN
1.5V	OPEN	L
1.8V	L	L
2.0V	H	L
2.5V	OPEN	H
2.8V	H	OPEN
3.0V	OPEN	OPEN
3.2V	L	H
3.3V	H	H

Table 4. DC/DC Converter Output Voltage Setting by VSEL Jumper

Operation of the Charger IC (BD71631QWZ)

The charging IC (BD71631QWZ) can be configured for various parameters with external resistors. The board has default component setting. Refer to the following when adjusting the characteristics.

Figure 8 shows the charging state of BD71631QWZ.

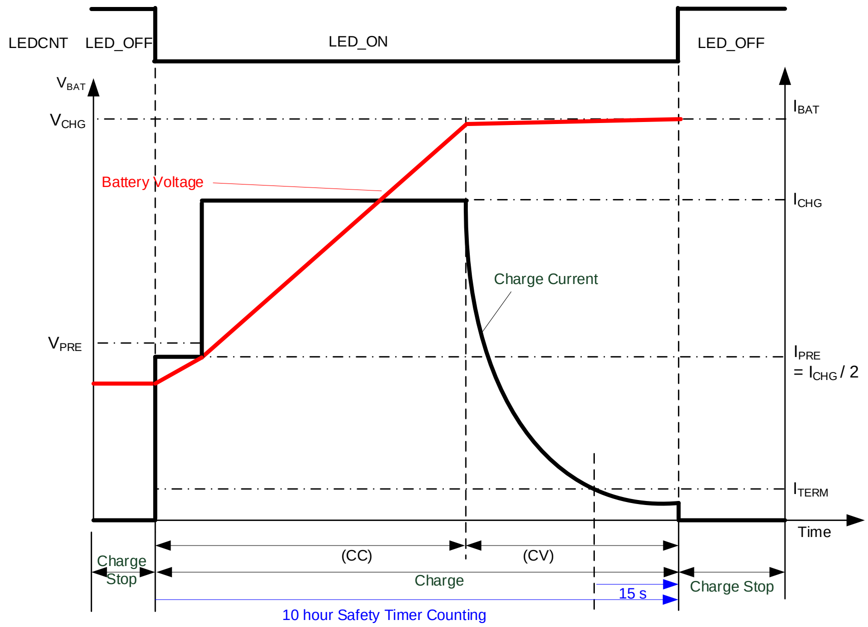


Figure 8. Charging Profile

Stop section located on the left of Figure 8 is the SUSPEND state in Figure 9 where charging is stopped.

In the CHARGE section, charging starts and the charging current IPRE or ICHG flows.

The Pre-charge current (IPRE) flows until the battery voltage reaches the Pre-charge voltage (VPRE). IPRE is flows at Constant Current (CC) that has a value of ICHG / 2 and the charging current ICHG flows after pre-charge.

When the battery voltage reaches the Pre-Charge voltage VPRE, it is charged at Constant Current (CC) with charging current (ICHG). When the battery voltage reaches VCHG voltage, it is charged at Constant Voltage (CV) and the charging current decreases. When the charging current reaches the Termination current (ITERM), it will be in the TOP-OFF state, and after 15 seconds, it will be in the DONE state.

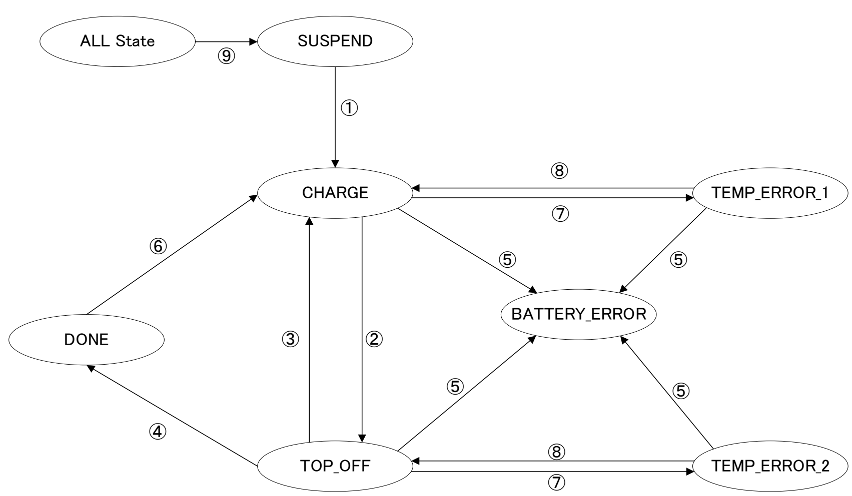


Figure 9. Charging State

Operation of the Charger IC (BD71631QWZ) – continued

No.	State Transition	Condition
①	SUSPEND -> CHARGE	UVLO, TSD not detect and VIN > V_{BAT}+0.3 V and V_{BAT} OVP not detect and Temp Error not detect Continue to satisfy the condition for 25 ms
②	CHARGE -> TOP_OFF	Charge current < I_{TERM} Continue to satisfy the condition for 25 ms
③	TOP_OFF -> CHARGE	Charge current > I_{TERM} Continue to satisfy the condition for 25 ms
④	TOP_OFF -> DONE	Continue to satisfy the ③ condition for 15 s
⑤	CHARGE or TOP_OFF or TEMP_ERROR_1 or TEMP_ERROR_2 -> BATTERY ERROR	V_{BAT} OVP detect or 10 hours safety timer expired
⑥	DONE -> CHARGE	V_{BAT} < Re-charge voltage Continue to satisfy the condition for 25 ms
⑦	CHARGE -> TEMP_ERROR_1 or TOP_OFF -> TEMP_ERROR_2	Temp Error detect Continue to satisfy the condition for 25 ms
⑧	TEMP_ERROR_1 -> CHARGE or TEMP_ERROR_2 -> TOP_OFF	Temp Error not detect Continue to satisfy the condition for 25 ms
⑨	ALL State -> SUSPEND	UVLO, TSD detect or VIN < V_{BAT}+0.3 V

Table 5. Charging State Transition Condition

State	Battery charge	10 hours safety timer	LEDCNT
SUSPEND	Stop	Stop and reset	Hi-Z
CHARGE	Charge	Count	Low
TOP_OFF	Charge	Count	Low
DONE	Stop	Stop and reset	Hi-Z
BATTERY_ERROR	Stop	Stop and reset	Hi-Z
TEMP_ERROR_1	Stop	Count	Hi-Z
TEMP_ERROR_2	Stop	Count	Hi-Z

Table 6. Safety Timer and Internal Control Settings for each State of LEDCNT

Charging IC (BD71631QWZ) Parts Configuration

1. Charging Voltage (V_{CHG}), Recharge Voltage (V_{RECHG}) Setting

The charging voltage (V_{CHG}) can be set by the following formula.

$$V_{CHG} = (R4 + R5)/R5 \times 0.6\ [V]$$

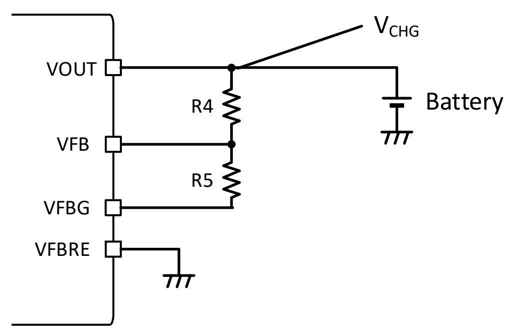


Figure 10. Resistor Setting of V_{CHG}

The re-charge voltage is determined as follows by adding resistors RFBRE1 and RFBRE2 to the VREBRE pin.

$$V_{RECHG} = (RFBRE1 + RFBRE2)/RFBRE2 \times 0.6\ [V]$$

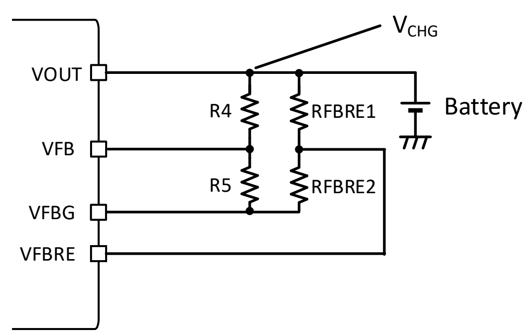


Figure 11. Resistor Setting of VRECHG

The following are reference examples of feedback resistor settings for different operating conditions.

Charge Condition	V_{CHG} = 4.143 V V_{RECHG} = Disenable	V_{CHG} = 2.2 V V_{RECHG} = Disenable	V_{CHG} = 4.2 V V_{RECHG} = 3.9 V
Resistor value [Ω]			
R4	620 k	200 k	600 k
R5	105 k	75 k	100 k
RFBRE1	-(Note)	-(Note)	1.1 M
RFBRE2	-(Note)	-(Note)	200 k

(Note) VFBRE pin connect to GND.

Table 7. Resistor Reference Value

Charging IC (BD71631QWZ) Parts Configuration – continued

About the current of the external resistor that generated by the FB terminal and FBRE terminal

An Nch FET is built between VFBG and GND terminals.
When the VIN terminal is connected, the Nch FET turns ON and current flows from the battery to the external resistor.
When the VIN terminal is disconnected, the Nch FET turns OFF and no current flows from the battery to the external resistor.
If the VFBRE terminal is connected to GND and recharging is disabled, the internal Nch FET will be turned OFF when charging is complete even if VIN is connected.

2. Charge Current, Termination Current Setting

The charging current (I_{CHG}) can be set by the following formula using an external resistor (R2).

$$I_{CHG} = (500000\ /R2\ [\Omega])[\text{mA}]$$

The charging current can be set up to 300 mA (V_{IN} ≥ 4 V, V_{IN}-V_{OUT} ≥ 1 V), 100 mA (V_{IN} ≥ 4 V, V_{IN}-V_{OUT} ≥ 0.3 V), and 30 mA (2.9 V ≤ V_{IN} ≤ 5.5 V, V_{IN}-V_{OUT} ≥ 0.3V). There is a limit to the voltage between VIN and VOUT in the operating range of the charging current.
The termination current (I_{TERM}) can be set from 50μA to 10mA an external resistor R3.

$$I_{TERM} = (50000\ /R3\ [\Omega])[\text{mA}]$$

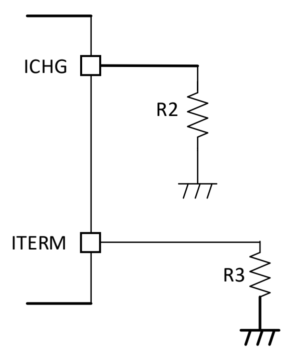


Figure 12. Resistor Setting of I_{CHG} and I_{TERM}

Charging IC (BD71631QWZ) Parts Configuration – continued

3. Charge Current vs Battery Temperature

It is possible to monitor the temperature of the battery using NTC thermistor.

The charging current is controlled by the battery temperature as shown in the temperature profile in Figure 13.

It is set by the NTC thermistor and pull-up resistor in Figure14.

The component values can be set according to the voltage of the NTC terminal at each temperature.

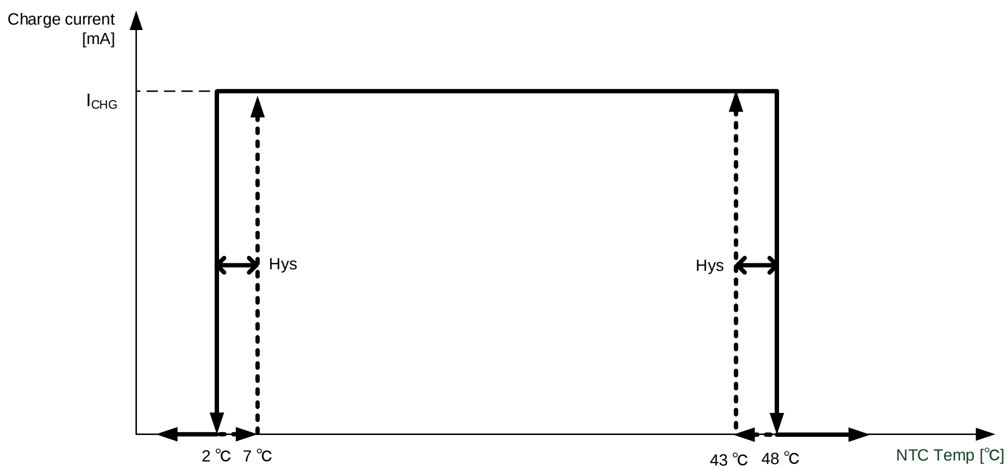
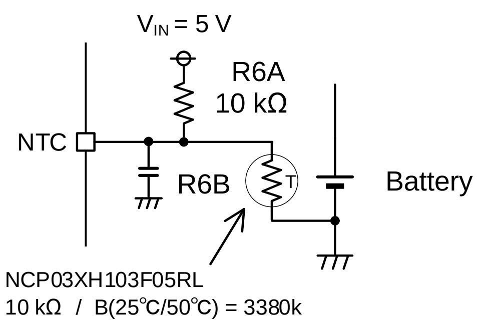


Figure 13. Charge Current vs Battery Temperature



NTC terminal voltage (V_{NTC_Cold}、V_{NTC_Hot})

2 °C: 3.605 V

7 °C: 3.375 V

43 °C: 1.720 V

48 °C: 1.535 V

Figure 14. Resistor Setting of NTC Terminal

Charging IC (BD71631QWZ) Parts Configuration – continued

Charge Current vs Battery Temperature – continued

The procedure to compute for the external resistance of the NTC terminal and the NTC constant are as follows:
When calculating R6A and R6B, use the NTC thermistor temperature profile in Figure 13 to calculate the resistances for the voltage dividers V_{Hot} and V_{Cold} at the point where charging stops. The error of the $\%V_{Cold}$ and $\%V_{Hot}$ thresholds will depend on temperature coefficient B of the chosen NTC thermistor resistor.
By simulated calculation, the resistance value is calculated so that the error of the NTC terminal voltage at each temperature is reduced.

$$V_{Cold} = \left(\frac{RNTC\_cold}{RNTC1 + RNTC\_cold}\right) \times VIN\ [V]$$

$$V_{Hot} = \left(\frac{RNTC\_Hot}{RNTC1 + RNTC\_Hot}\right) \times VIN\ [V]$$

$$\%V_{Cold} = \frac{V_{Cold}}{V_{NTC\_Cold}}$$

$$\%V_{Hot} = \frac{V_{Hot}}{V_{NTC\_Hot}}$$

Where the NTC thermistor resistance at the T_Cold and T_Hot temperatures are as follows:

$$R_{NTC\_Cold} = Ro \times e^{B\left({}^{1}/_{T\_Cold} - {}^{1}/_{To}\right)}$$
$$R_{NTC\_Hot} = Ro \times e^{B\left({}^{1}/_{T\_Hot} - {}^{1}/_{To}\right)}$$

Where:
V_{Cold} is the value of the voltage divided by the resistance at low temperatures
V_{Hot} is the value of the voltage divided by the resistance at hot temperatures
V_{NTC_Cold} is the Detection voltage of NTC terminal at low temperatures. 3.605 V at Ta=2 °C
V_{NTC_Hot} is the Detection voltage of NTC terminal at high temperatures. 1.535 V at Ta=48 °C
R_{NTC_Cold} is the NTC thermistor resistance at cold temperatures
R_{NTC_Hot} is the NTC thermistor resistance at hot temperatures
Ro is the NTC thermistor resistance at Ta 25°C
B is the B constant of NTC thermistor
T_Cold is the Low temperature
T_Hot is the High temperature
To is 25°C

Board PCB Layout

■ **PCB information**

Layers	Material	Board dimension	Copper thickness
4	FR-4	56mm x 32mm x 1.0mmt	1oz (35μm)

Table 8. PCB Information

■ **Board Layout**

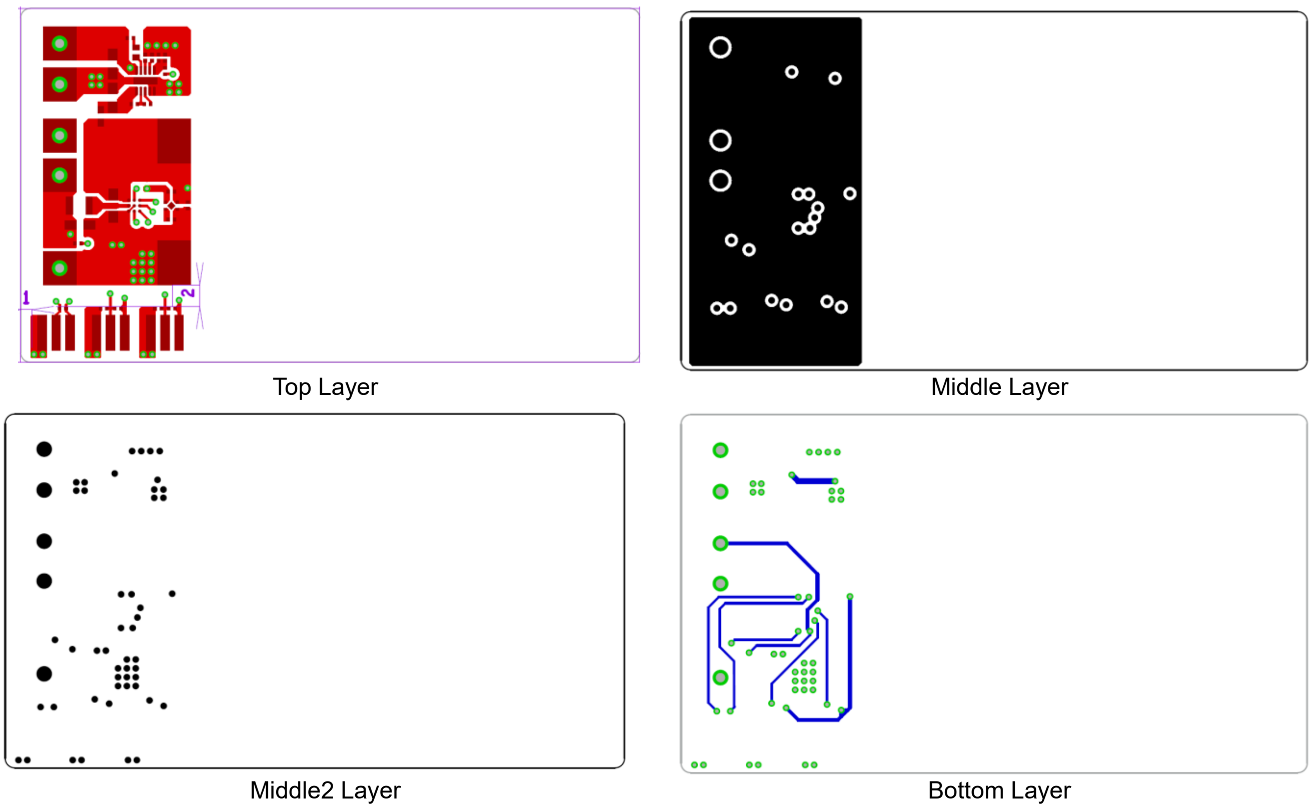
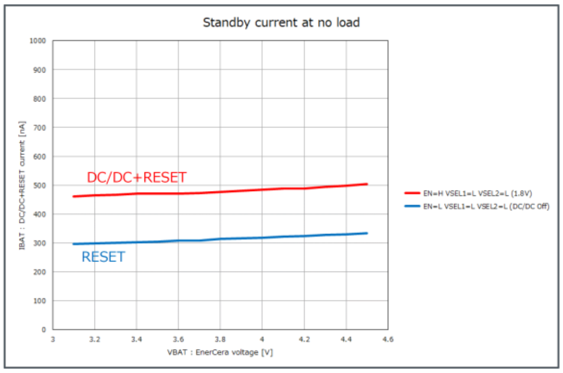
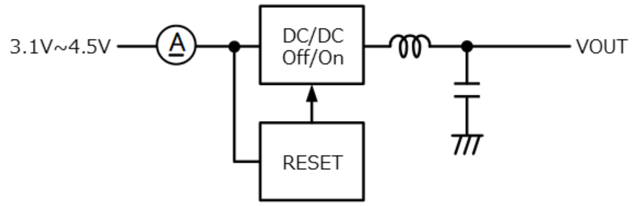


Figure 15. Collaboration Board Layout

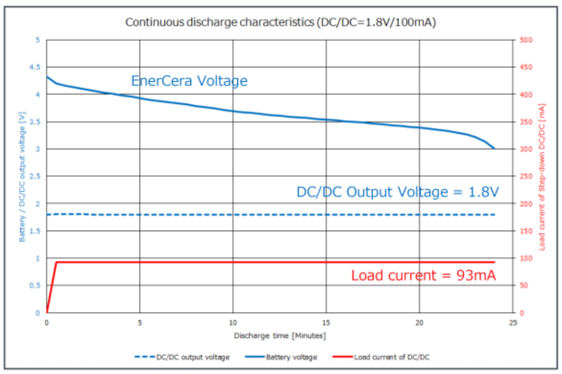
Application data

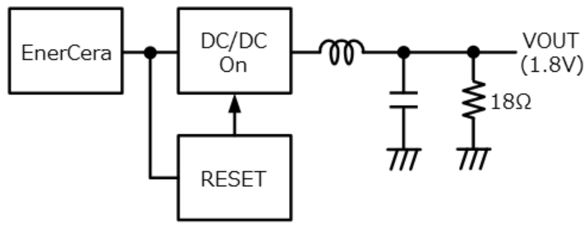
■ Standby Current at No Load



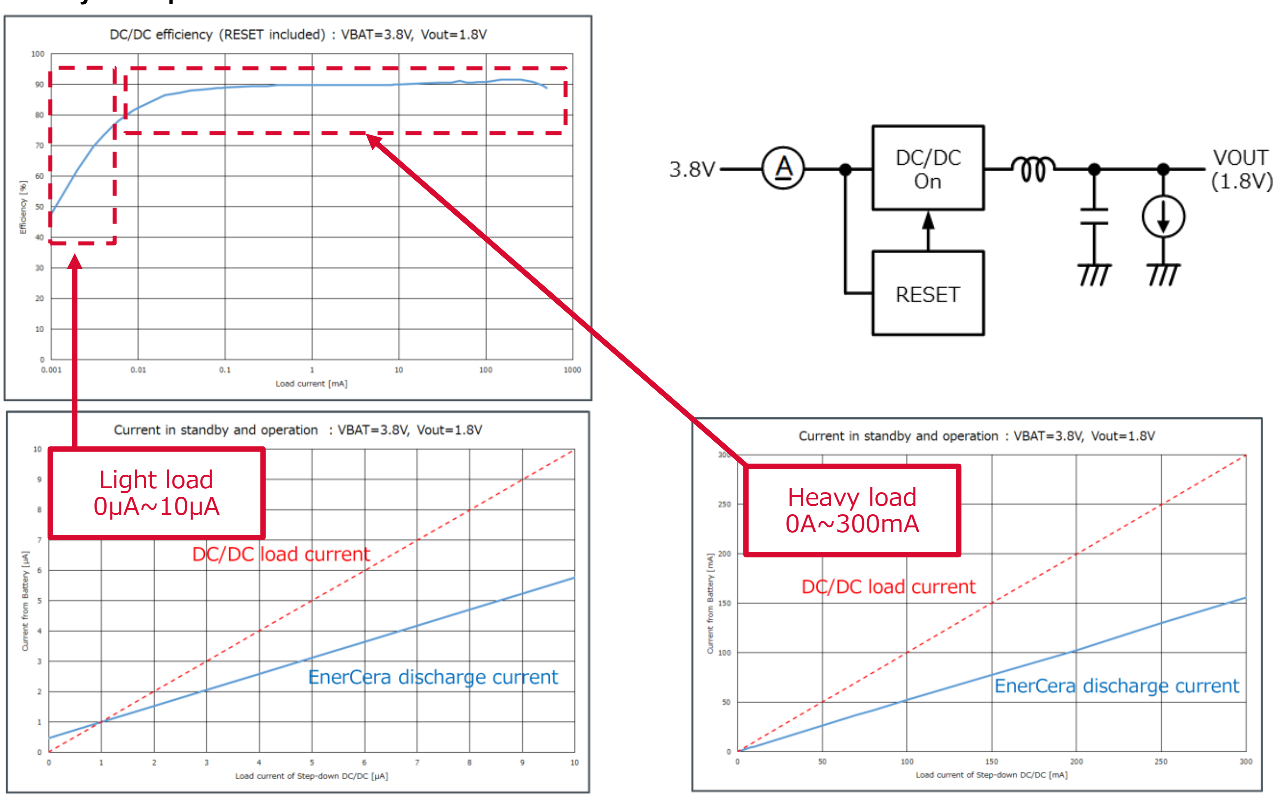


■ Continuous Discharge Characteristics (100mA Equivalent Resistive Load)



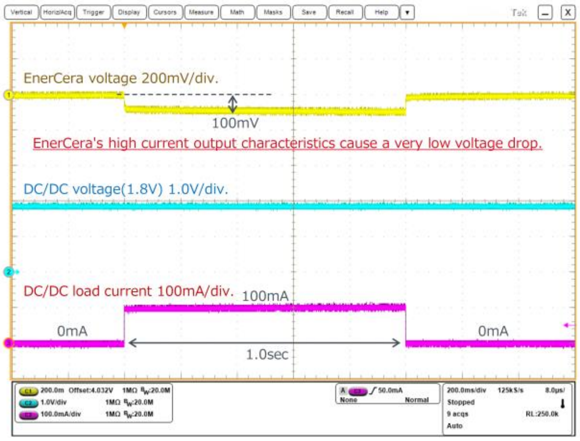


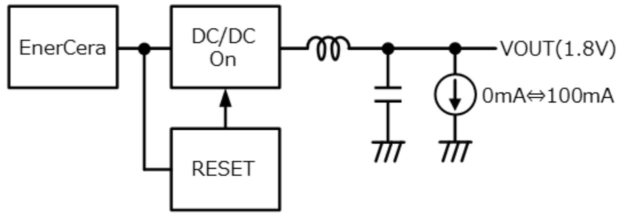
■ Standby and Operation Current



Application Data - continued

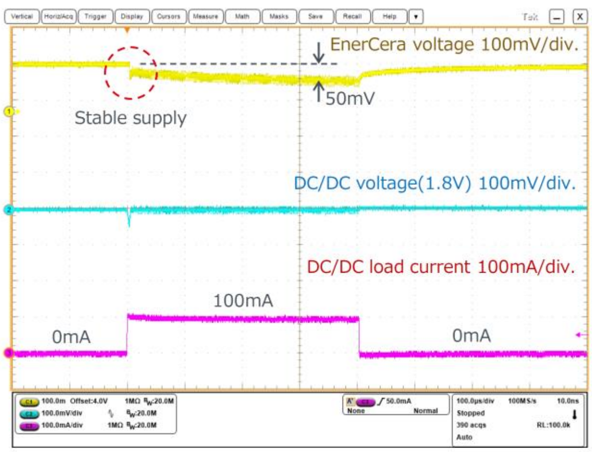
■ Discharge Waveform

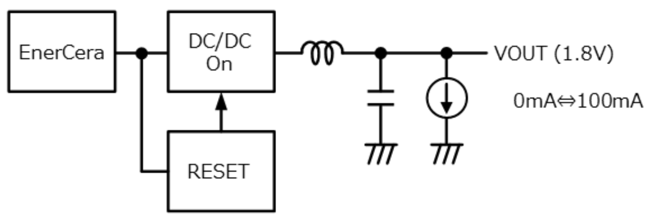




■ Load Transient Waveform（1/2）

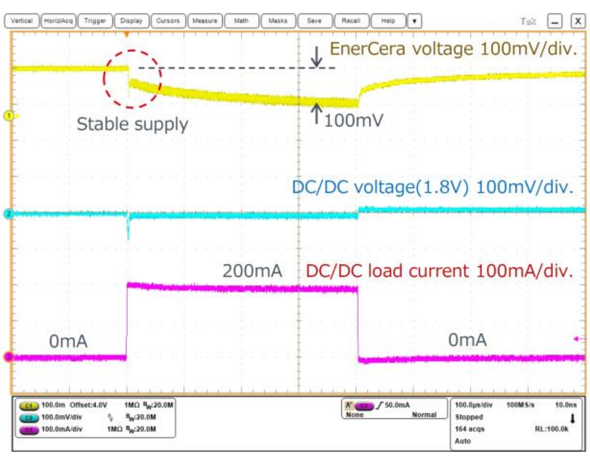
0mA⇔100mA Load Transient

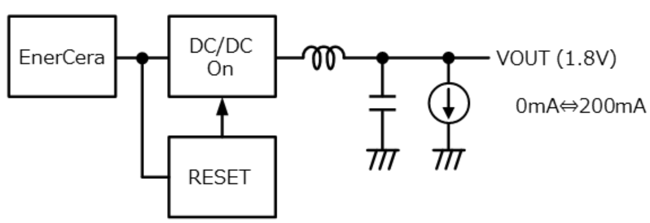




*Slew rate : tr=tf=1μsec

0mA⇔200mA Load Transient



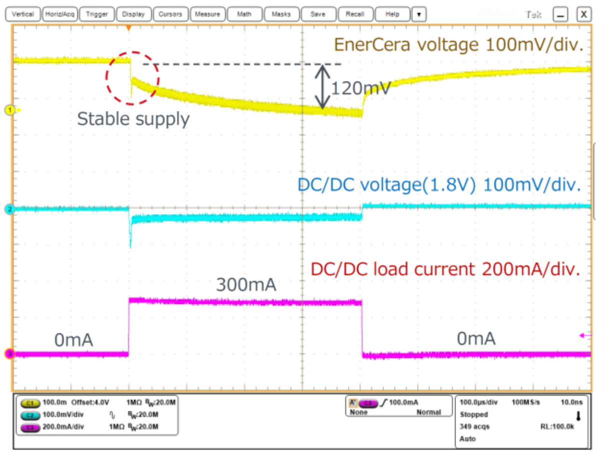


*Slew rate : tr=tf=1μsec

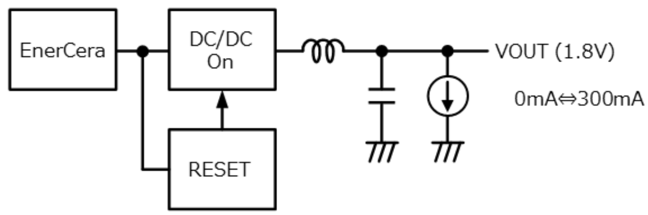
Application Data - continued

■ Load Transient Waveform（2/2）

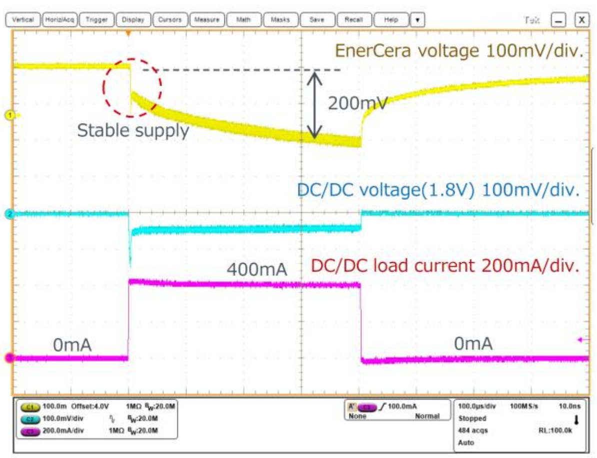
0mA⇔300mA Load Transient



*Slew rate : tr=tf=1μsec



0mA⇔400mA Load Transient



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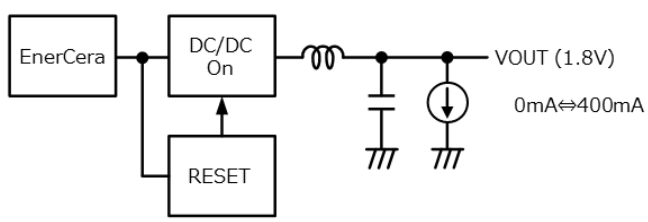
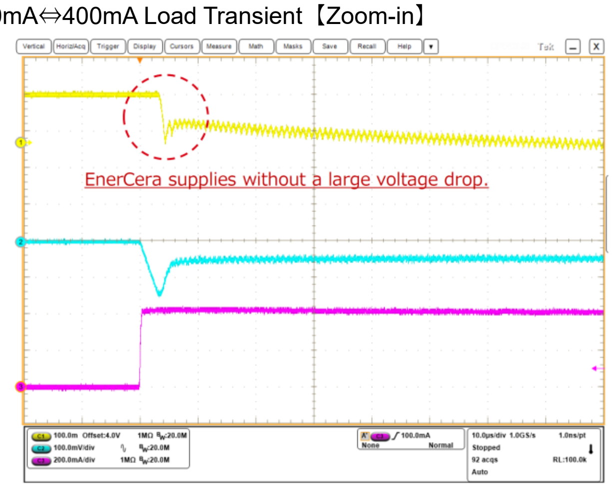


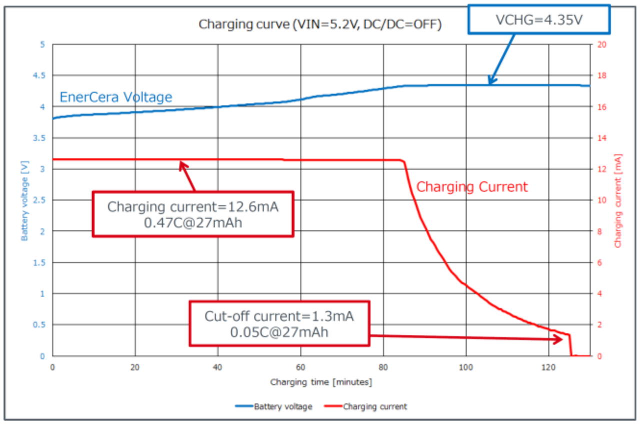
0mA⇔400mA Load Transient【Zoom-in】

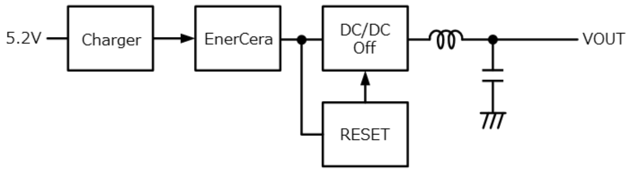


*Slew rate : tr=tf=1μsec

Application Data - continued

■ Charging Waveform





The charging time should be used as a guide. (It is not charging from a full discharged state.)

Notes

1) The information contained herein is subject to change without notice.

2) Before you use our Products, please contact our sales representative and verify the latest specifications :

3) Although ROHM is continuously working to improve product reliability and quality, semiconductors can break down and malfunction due to various factors.
Therefore, in order to prevent personal injury or fire arising from failure, please take safety measures such as complying with the derating characteristics, implementing redundant and fire prevention designs, and utilizing backups and fail-safe procedures. ROHM shall have no responsibility for any damages arising out of the use of our Poducts beyond the rating specified by ROHM.

4) Examples of application circuits, circuit constants and any other information contained herein are provided only to illustrate the standard usage and operations of the Products. The peripheral conditions must be taken into account when designing circuits for mass production.

5) The technical information specified herein is intended only to show the typical functions of and examples of application circuits for the Products. ROHM does not grant you, explicitly or implicitly, any license to use or exercise intellectual property or other rights held by ROHM or any other parties. ROHM shall have no responsibility whatsoever for any dispute arising out of the use of such technical information.

6) The Products specified in this document are not designed to be radiation tolerant.

7) For use of our Products in applications requiring a high degree of reliability (as exemplified below), please contact and consult with a ROHM representative : transportation equipment (i.e. cars, ships, trains), primary communication equipment, traffic lights, fire/crime prevention, safety equipment, medical systems, servers, solar cells, and power transmission systems.

8) Do not use our Products in applications requiring extremely high reliability, such as aerospace equipment, nuclear power control systems, and submarine repeaters.

9) ROHM shall have no responsibility for any damages or injury arising from non-compliance with the recommended usage conditions and specifications contained herein.

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