Battery Charger Series

Linear Charger for Low Voltage Battery BD71631QWZ EVK

BD71631QWZ-EVK-001 (5V→4.2V, 0.1A)

Introduction

This user’s guide provides the necessary steps to operate the EVK of ROHM’s BD71631QWZ linear charger for low charge voltage battery. This include the external parts, operating procedures, and application data.

Description

This EVK is for evaluating the linear charging IC BD71631QWZ, and charges 4.2V from the 5V input voltage. BD71631QWZ accepts a power supply input range of 2.9V to 5.5V and generates a charging battery voltage ranging from 2.0V to 4.7V using external resistors. If the charging current is VIN ≥ 4 V, it can be used up to 300 mA under the condition of VIN-VOUT ≥ 1 V and up to 100 mA under the condition of VIN-VOUT ≥ 0.3 V. If 2.9 V ≤ VIN ≤ 5.5 V, it can be used up to 30 mA under the condition of VIN-VOUT ≥ 0.3 V. The charging current can be set with an external resistor. The termination current can be set from 50 µA to 10 mA using external resistors. Additional protection functions include a built-in Fixed 10-hour Safety Timer, UVLO (Under Voltage Lock Out), TSD (Thermal Shutdown Detection), and Battery Over Voltage Protection.

Application

Low Voltage Battery Products
Li-ion 1Cell Battery Products

Operating Limits

Table 1. Operating Limits

Parameter	Symbol	Min	Typ	Max	Units	Conditions
Input Voltage	VIN	4.5	5.0	5.5	V	
Charge Voltage	V_{CHG}		4.2		V	RVFB1=180kΩ, RVFB2=30kΩ
Pre Charge Voltage	V_{PRE}		0.7		V	
Re Charge Voltage	V_{RECHG}		3.0		V	RVFBRE1=120kΩ, RVFBRE2=30kΩ
Charge Current	I_{CHG}		98		mA	RICHG1=5.1kΩ
Termination Current	I_{TERM}		0.98		mA	RITERM=51kΩ
VOUT Leak Current	I_{BAT}		0	1	µA	VIN=Open

EVK

Figure 1. BD71631QWZ-EVK-001(Top View)

EVK Schematic

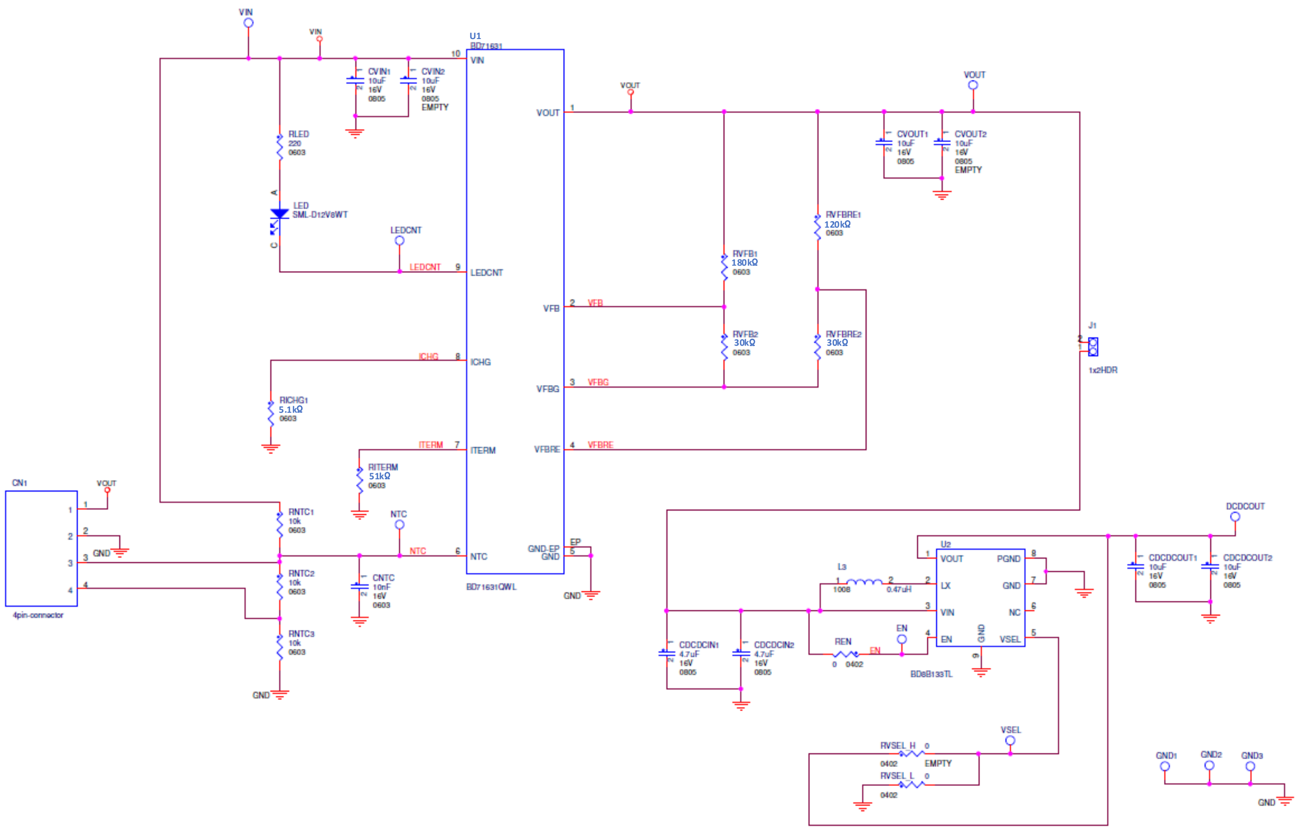


Figure 2. BD71631QWZ-EVK-001 Circuit Diagram

Operating Procedure

1. Turn off the DC power supply and connect the GND terminal of the power supply to the GND1 terminal of the EVK.
2. Connect the positive terminal of the DC power supply to the VIN pin of the EVK.
3. Connect the positive terminal of the DC power supply that can sink to the VOUT pin of the EVK.
4. Connect a current meter between the VOUT terminal of the EVK and the positive terminal of DC power supply of VOUT.
5. Connect a voltmeter between the VOUT terminal and GND terminal of EVK.
6. Turn on the DC power supply of VOUT.
7. Turn on the DC power supply of VIN. The power supply on the VOUT side is set to 4.2V or lower, charging will start and current will flow through the ammeter.

(Caution) This EVK does not support hot plug. Do not perform hot plug test.

Charging State

Below is a charging state of BD71631QWZ.

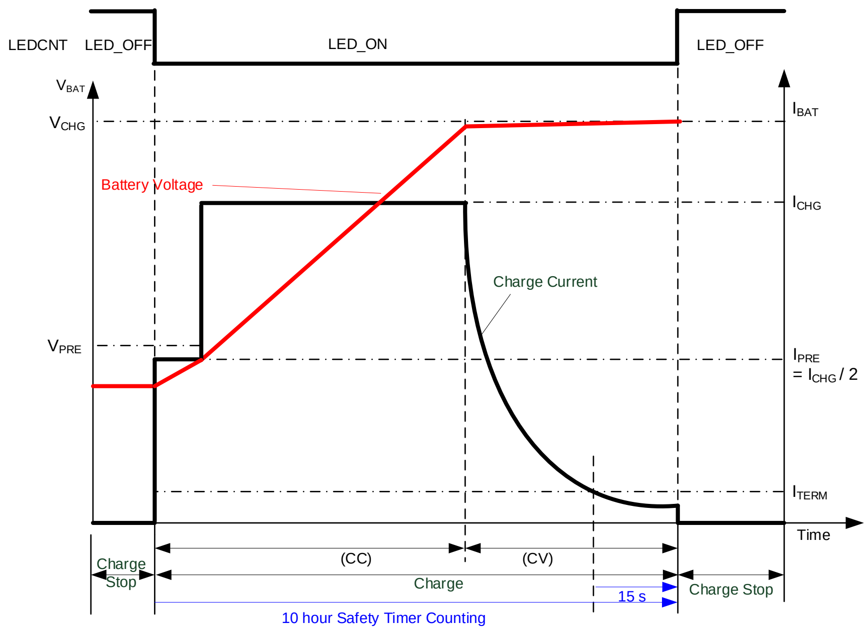


Figure 3. Charging profile

Charging stop section on the left in Figure 3 is in the state of SUSPEND in Figure 4, and charging is stopped.
In the Charge section, charging starts and the charging current I_{PRE} or I_{CHG} flows.
The Pre-charge current I_{PRE} flows until the battery voltage reaches the Pre-charge voltage V_{PRE}. I_{PRE} is I_{CHG} / 2 that is charged at Constant Current (CC) and the charging current I_{PRE} flows.
When the battery voltage reaches the Pre-Charge voltage V_{PRE}, it is charged at Constant Current (CC) and the charging current I_{CHG} flows.
When the battery voltage reaches the V_{CHG} voltage, it is charged at Constant Voltage (CV) and the charging current decreases.
When the charging current reaches the Termination current I_{TERM}, it will be in the TOP-OFF state, and after 15 seconds have passed, it will be in the DONE state.

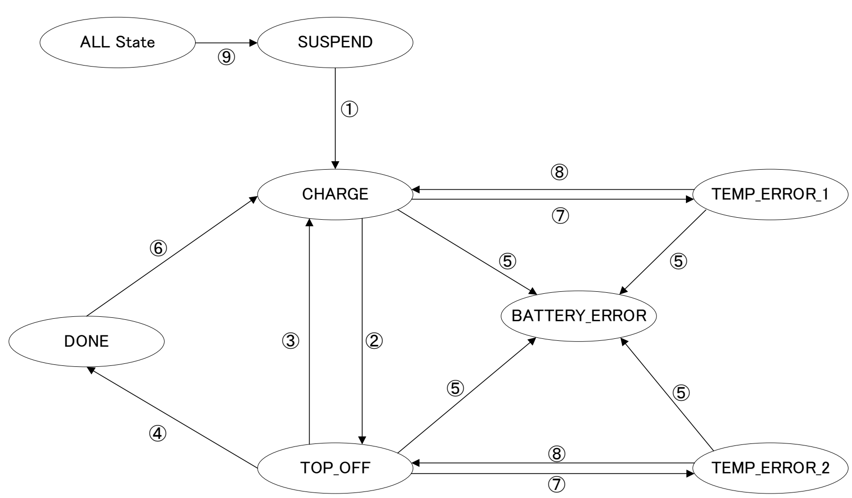


Figure 4. Charging state

Table 2. Charging state transition condition

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 3. Safety timer and Internal control settings for each state of LEDCNT

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

Peripheral Components Setting

1. Charging voltage (V_{CHG}), Recharge voltage (V_{RECHG}) setting

The resistance values of the charging voltage V_{CHG} and re-charge voltage V_{RECHG} can be set by the following formula.

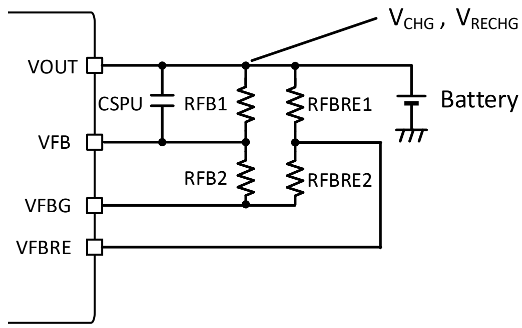


Figure 5. Resistor setting of V_{CHG} and V_{RECHG}

The charge voltage is determined as follows :

$$V_{CHG} = (RFB1 + RFB2)/RFB2 \times 0.6\ [V]$$

The re-charge voltage is determined as follows :

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

About total feedback resistance, the following is a reference example of operation settings. .

Table 4. Resister reference value

Charge Condition	V_{CHG} = 4.2 V V_{RECHG} = 3.0V	V_{CHG} = 2.2 V V_{RECHG} = Disenable	V_{CHG} = 4.2 V V_{RECHG} = 3.9 V
Resistor value [Ω]			
RFB1	180 k	200 k	600 k
RFB2	30 k	75 k	100 k
RFBRE1	120 k	-*	1.1 M
RFBRE2	30 k	-*	200 k

*VFBRE pin connect to GND

A capacity of 10µF or more is required between the VOUT terminal and GND terminal of BD71631QWZ. Connect C_{SPU} for stable operation when the battery capacity is too small.
The capacitance of C_{SPU} is determined as follows :

$$C_{SPU} = 1/(2\pi \times 300 \times RFB1)\ [F]$$

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

Nch FET is built in between the VFBG terminal and the GND terminal.
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 completed even if VIN is connected.

2. Charge current, Termination current setting

The charging current I_{CHG} can be set by the following formula using the external resistor RICHG1.

$$I_{CHG} = (500000\ /\mathrm{RICHG1}\ [\Omega])[\mathrm{mA}]$$

The charging current can be set up to 300 mA (VIN ≥ 4 V, VIN-VOUT ≥ 1 V), 100 mA (VIN ≥ 4 V, VIN-VOUT ≥ 0.3 V), and 30 mA (2.9 V ≤ VIN ≤ 5.5 V, VIN-VOUT ≥ 0.3V). There is a limit to the voltage between VIN and VOUT in the usage range of the charging current.

The termination current I_{TERM} can be set by the following equation using the external resistor RITERM.
The termination current can be set from 50 µA to 10 mA.

$$I_{TERM} = (50000\ /\mathrm{RITERM}\ [\Omega])[\mathrm{mA}]$$

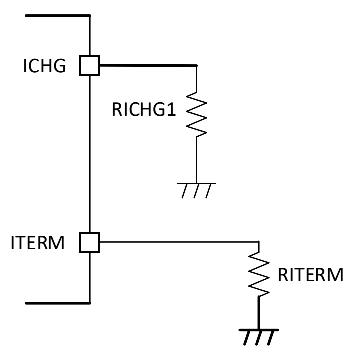


Figure 6. Resistor setting of I_{CHG} and I_{TERM}

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 7.
It is set by the NTC thermistor and pull-up resistor in Figure 8.
The component constants can be set according to the voltage of the NTC terminal at each temperature.

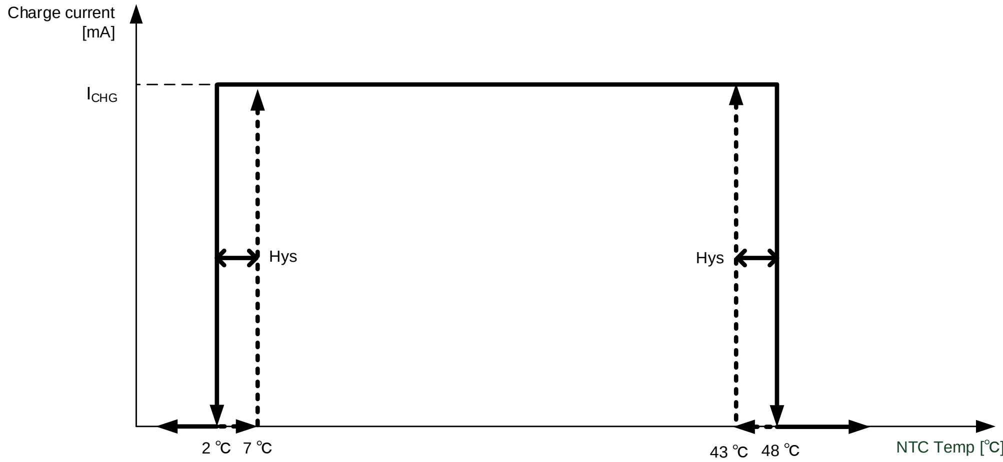
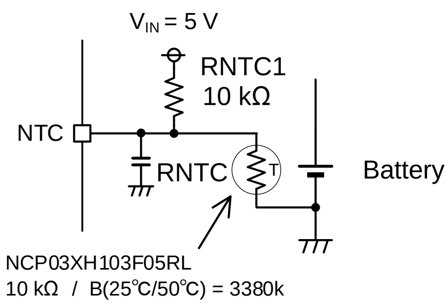


Figure 7. Charge Current vs Battery Temperature



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 8. Resistor setting of NTC terminal

How to find the external resistance of the NTC terminal and the NCT constant is as follows.
When calculating RNTC and RNTCR1, firstly calculate the resistance voltage dividers V_{Hot} and V_{Cold} when charging stops with the NTC thermistor temperature profile in Figure 7. 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 becomes small.

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

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

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

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

Where the NTC thermistor resistance at the $T_{\_Cold}$ and $T_{\_Hot}$ temperatures must be resolved as follows:

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

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

V_{Cold}: The value of the voltage divided by the resistance at low temperature
V_{Hot}: The value of the voltage divided by the resistance at hot temperature
V_{NTC_Cold}: Detection voltage of NTC terminal at low temperature . 3.605 V at Ta=2 °C
V_{NTC_Hot}: Detection voltage of NTC terminal at high temperature. 1.535 V at Ta=48 °C
R_{NTC_Cold}: NTC thermistor resistance at cold temperature
R_{NTC_Hot}: NTC thermistor resistance at hot temperature
Ro: NTC thermistor resistance at Ta 25°C
B: B constant of NTC thermistor
$T_{\_Cold}$: Low temperature
$T_{\_Hot}$: High temperature
To: 25°C

Parts list

Table 5. Parts list

Count	Parts No.	Type	Value	Description	Manufacturer Part Number	Manufacturer	Size [Unit: mm(inch)]
IC							
1	U1	Charger	-	Linear Charger	BD71631QWZ-E2	ROHM	1.8 x 2.4 (0.071x0.094)
Capacitor							
1	CVIN1	MLCC	4.7µF	16V, X5R, ±10%	GRM188R61C475KAAJD	MURATA	1608(0603)
1	CVOUT1	MLCC	1µF	25V, X5R, ±10%	GRM155R61E105KA12D	MURATA	1005(0402)
1	CNTC	MLCC	0.01µF	16V, B, ±10 %	GRM155B11C103KA01	MURATA	1005(0402)
2	CVIN2, CVOUT2	MLCC	OPEN	-	-	-	-
Resistor							
3	RLED, RNTC1, RNTC2	Resistor	10kΩ	1/10W, 50V, ±0.5%	MCR03EZPD1002	ROHM	1608(0603)
1	RICHG1	Resistor	5.1kΩ	1/10W, 50V, ±0.5%	MCR03EZPD5101	ROHM	1608(0603)
1	RITERM	Resistor	51kΩ	1/10W, 50V, ±0.5%	MCR03EZPD5102	ROHM	1608(0603)
1	RVFB1	Resistor	180kΩ	1/10W, 50V, ±0.5%	MCR03EZPD1803	ROHM	1608(0603)
1	RVFBRE1	Resistor	120kΩ	1/10W, 50V, ±0.5%	MCR03EZPD1203	ROHM	1608(0603)
2	RVFB2, RVFBRE2	Resistor	30kΩ	1/10W, 50V, ±0.5%	MCR03EZPD3002	ROHM	1608(0603)
1	RNTC3	-	SHORT	-	-	-	-
LED							
1	LED	-	LED	White, Clear	SML312WBCW1	ROHM	1608(0603)
Connector							
1	J1	-	OPEN	-	-	-	-
1	CN1	Connector	4terminals	3.81mm pitch	MKDS 1/ 4-3,81	Phoenix contact	15.23x 7.3 (0.6x0.29)
Optional parts (Boost converter)							
1	U2	-	OPEN	-	-	-	-
1	L3	-	OPEN	-	-	-	-
2	CDCDCIN1, CDCDCIN2	-	OPEN	-	-	-	-
2	CDCDCOUT1, CDCDCOUT2	-	OPEN	-	-	-	-
3	REN, RVSEL_H, RVSEL_L	-	OPEN	-	-	-	-

The product and manufacturer names listed in the parts list are current at the time this user’s guide was prepared, and some parts may not be available. Please select the equivalent product based on the characteristics listed in the table. Select a ceramic capacitor with the same actual capacitance in consideration of the DC bias characteristics.

Board Layout

EVK PCB information

Number of Layers	Material	Board Size	Copper Thickness
4	FR-4	46mm x 36mm x 1.6mm	1oz (35μm)

The layout of BD71631QWZ-EVK-001 is shown below.

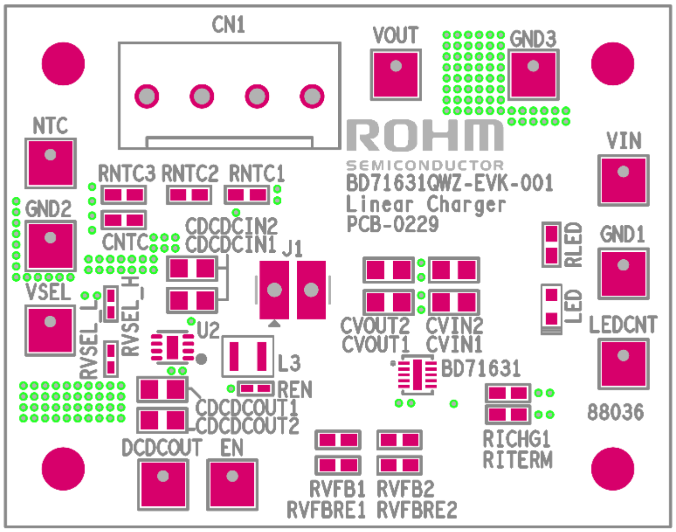


Figure 9. Top Silkscreen Layout
(Top View)

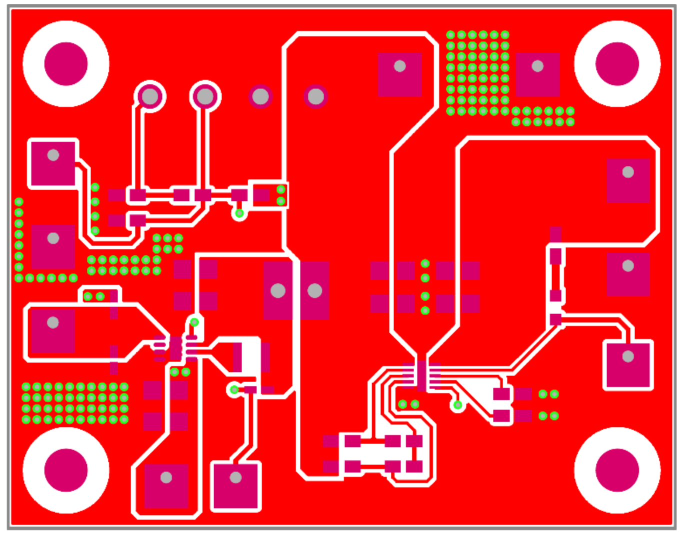


Figure 10. Top Layer Layout
(Top View)

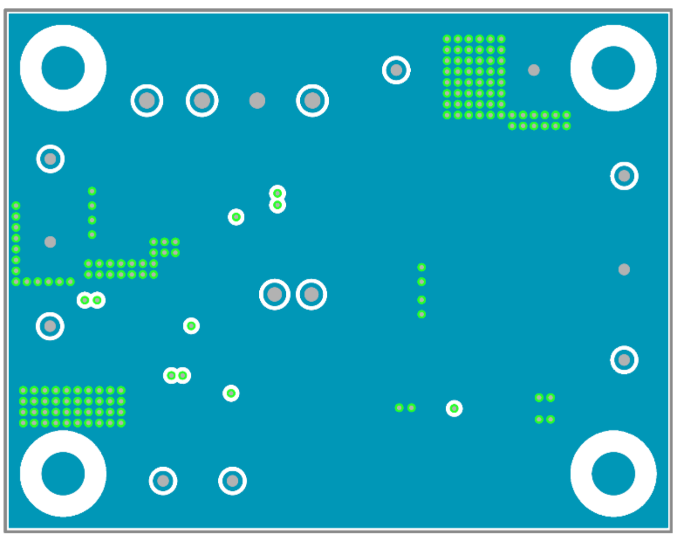


Figure 11. Middle1 Layer Layout
(Top View)

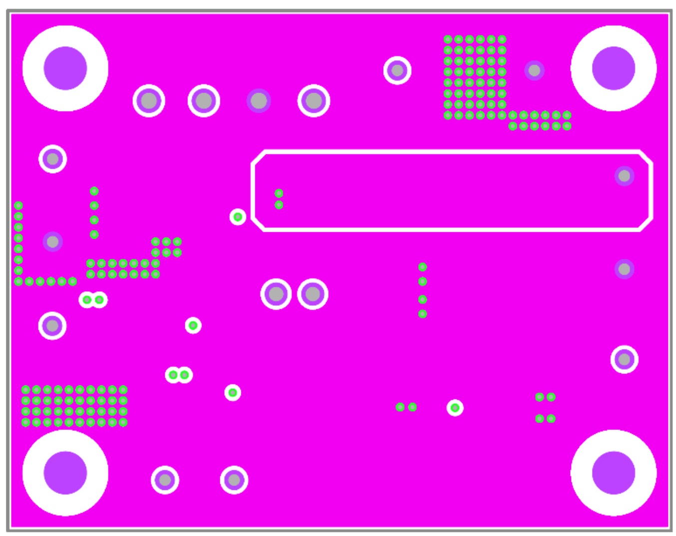


Figure 12. Middle2 Layer Layout
(Top View)

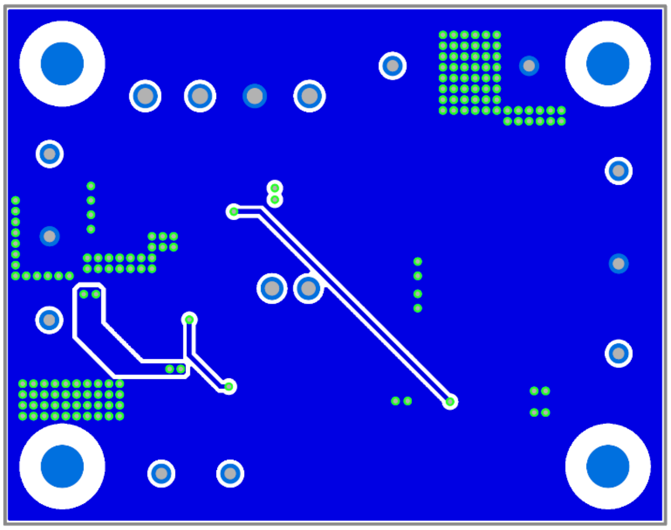


Figure 13. Bottom Layer Layout
(Top View)

Reference Application Data

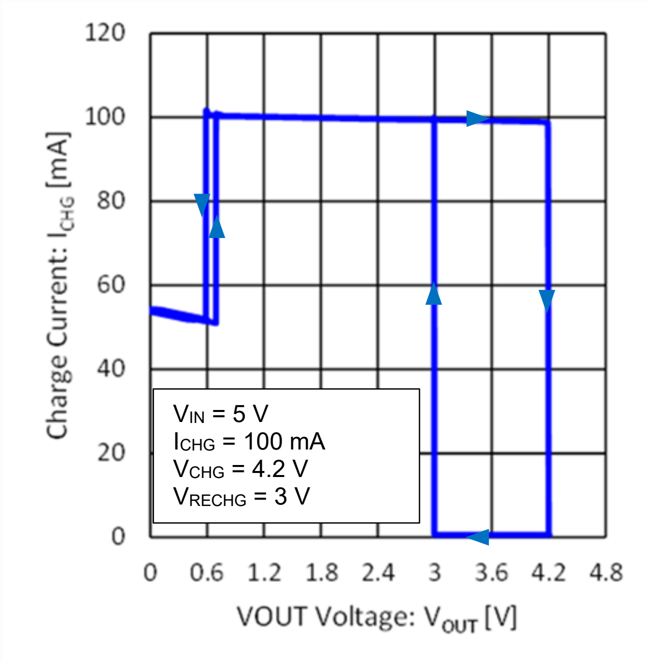


Figure 14. Charge Current vs VOUT Voltage

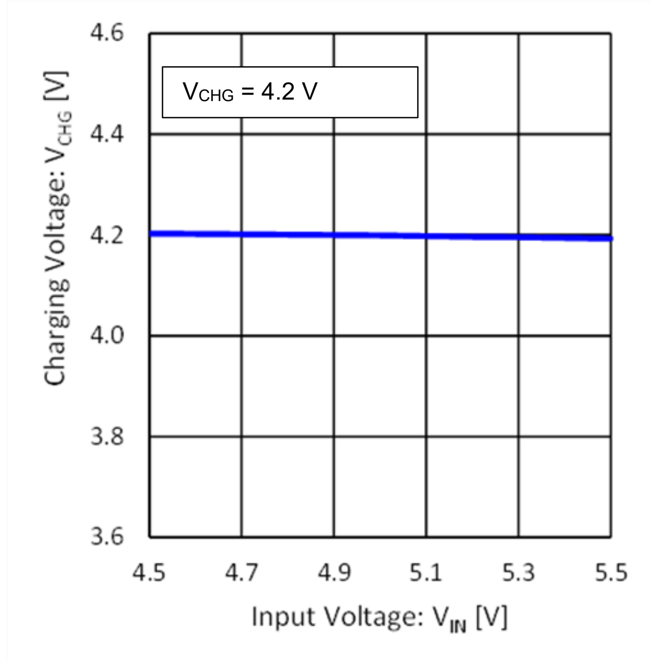


Figure 15. Charge Voltage vs Input Voltage

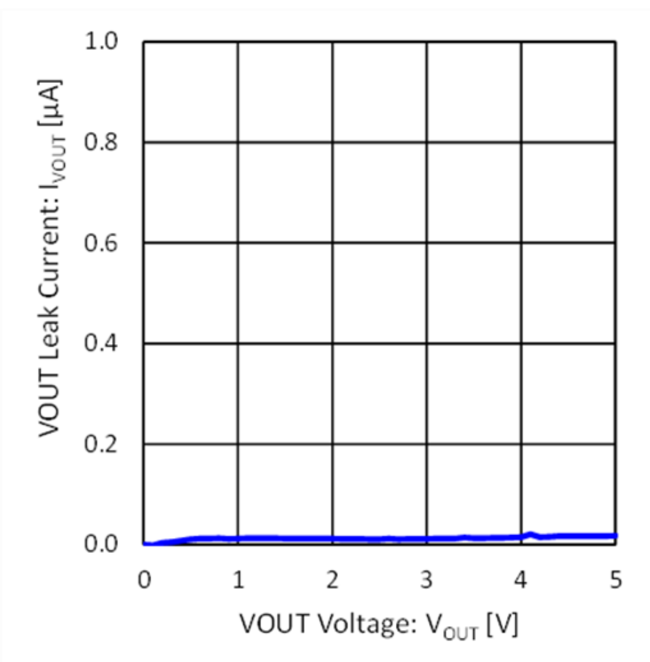


Figure 16. VOUT Leak Current vs VOUT Voltage
(VIN = Open)

Revision History

Date	Revision Number	Description
24. May. 2021	001	Initial release

Notes

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3) Although ROHM is continuously working to improve product reliability and quality, semiconductors can break down and malfunction due to various factors.
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ROHM SEMICONDUCTOR

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