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DS04-71104-1Ea

ASSP for Power Supply Applications

Evaluation Board

MB3887

■ DESCRIPTIONS

The MB3887 evaluation board is a surface mounted circuit board of a down-conversion circuit for Li-ion battery charge controller. This board is possible to be set from 1 cell to 4 cells, and controls charging voltage and charging current by supply voltage of AC adapter or etc. The board is a battery charger having high accuracy and efficiency to supply the maximum 3 A current. MB3887 detects a voltage drop for AC adapters and has an ability of dynamically-controlled charging to keep it power constant.

Also it is possible to change to dead battery mode (charging current: 260 mA) by switching depending on the state of batteries.

■ EVALUATION BOARD SPECIFICATIONS

		Min	Typ	Max	Unit
Input voltage	3 cells	13.93	—	25	V
	4 cells*1	17.65	—	25	V
Oscillation frequency		190	290	390	kHz
Output voltage	3 cells	12.41	12.6	12.78	V
	4 cells*1	16.54	16.8	17.06	V
Charge current	CC mode	2.8	3	3.3	A
	Dead Battery mode	182	260	429	mA
AC adapter detection voltage*2		17.2	17.65	18.1	V
Soft-start		5.9	9.2	17.0	ms
Output ripple voltag	3 cells	—	—	252	mV
	4 cells	—	—	336	

*1: Initial setting value is for 4 cells.

*2: AC adapter detection voltage is set 17.65 V for “Constant power control”.
In normal operating, VIN terminal should be appended over 17.65 V.
Without above condition, see “Resistor value at VIN = 15 V, 16 V or 19 V” in “■ PART LIST”.

■ TERMINAL DESCRIPTION

Symbol	Function
VIN	DC power supply, AC adapter input terminal
BATT	DC/DC converter output terminal
CTL	Power supply control terminal (at SW1 (switch1) = OFF) VCTL = 0 V to 0.8 V: Standby mode VCTL = 2.0 V to VIN: Operation mode
VREF	Reference voltage output terminal
MODE SW	Mode control terminal (at SW2 (switch1) = OFF) VMODE SW = 0 V to 1.0 V: Dead battery mode*1 VMODE SW = High-Z (or 2.5 V to VIN) : DCC mode*2
GND	Battery charge system GND
SGND	IC control side GND

*1: This mode is for chekking regular / irregular battery.
On dead battery mode, charge current is set 260 mA (Typ) .

*2: This mode is charged in the dynamically-controlled charging (DCC) mode.
On DCC mode, charge current is set 3 A (Typ).

■ SWITCH DESCRIPTION

SW	Name	Function	ON	OFF
1	CTL	Power supply control	Operating	Stand-by
2	Mode SW	Charge current mode control	DCC Mode*	Dead Battery Mode*

*: for Note book PC

■ SETUP AND CHECKUP

(1) Setup

- Connect the power-supply terminal side to VIN and GND. Connect BATT to the required loading device or measuring instrument.
- Please turn off all SW.

(2) Checkup

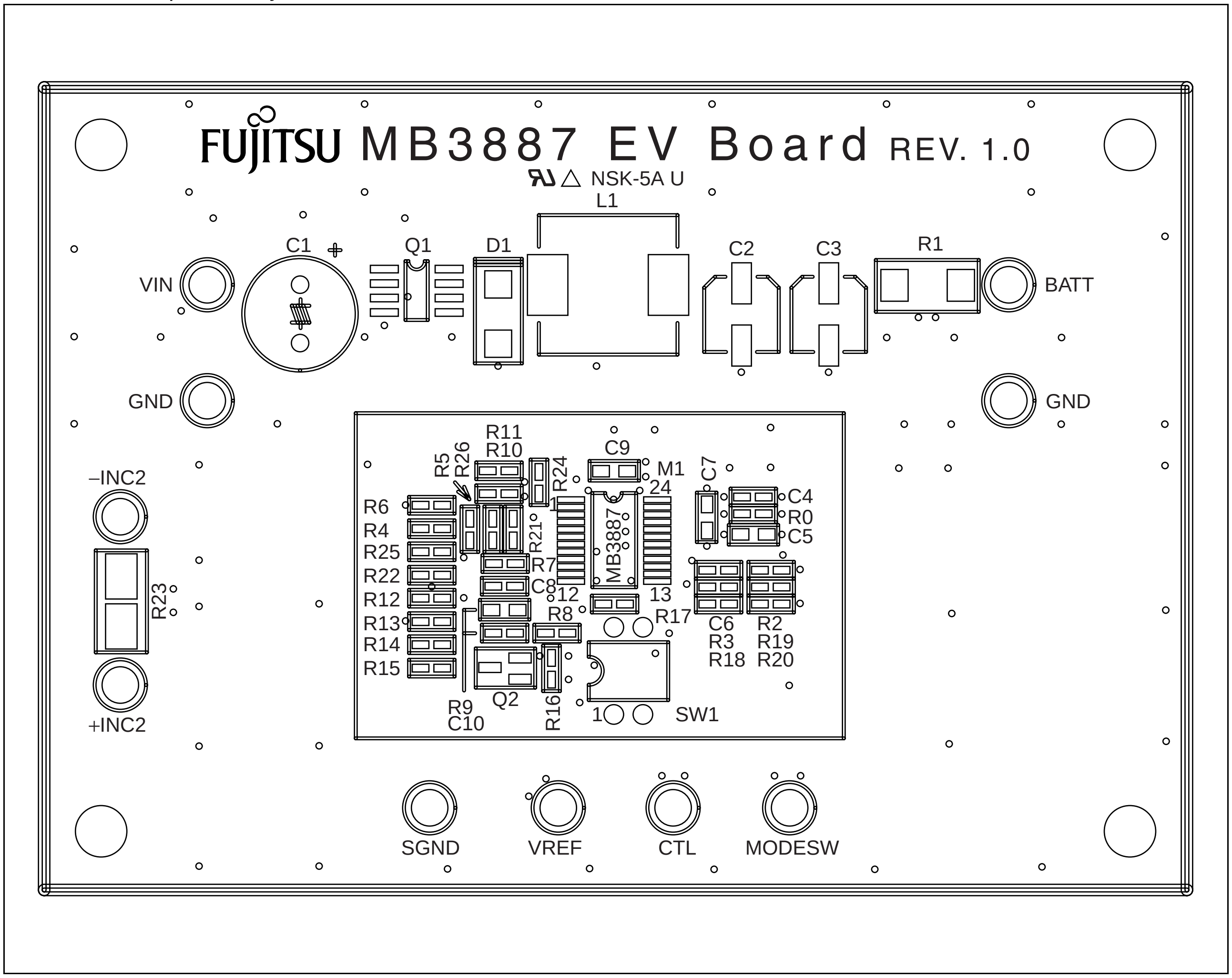
- Turn on SW1 and turn on the power to VIN (power supply) while turned on. When the output voltage at BATT is 16.8 V(Typ) the IC is operating normally.

SW2 = ON: DCC mode

SW2 = OFF: Dead battery mode

■ COMPONENT LAYOUT

• On-board Component Layout



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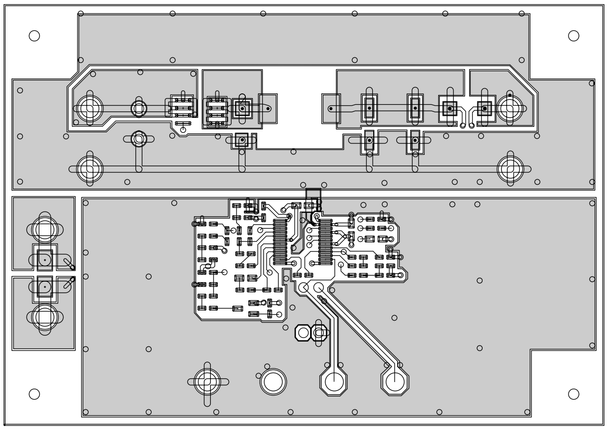
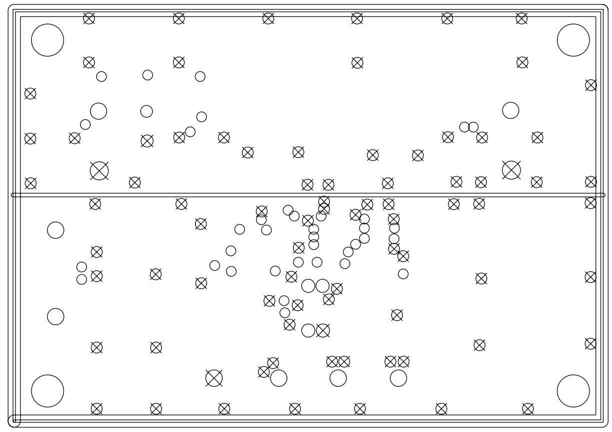
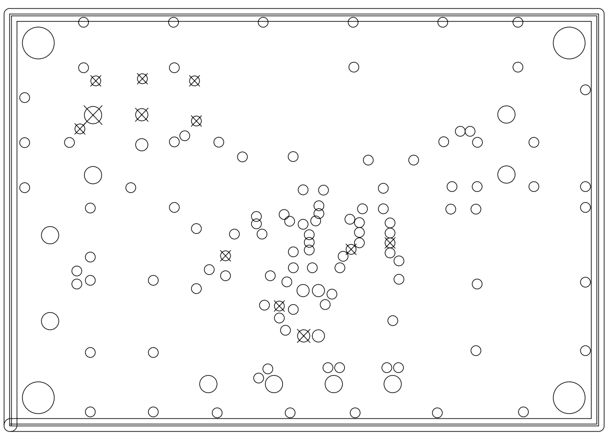


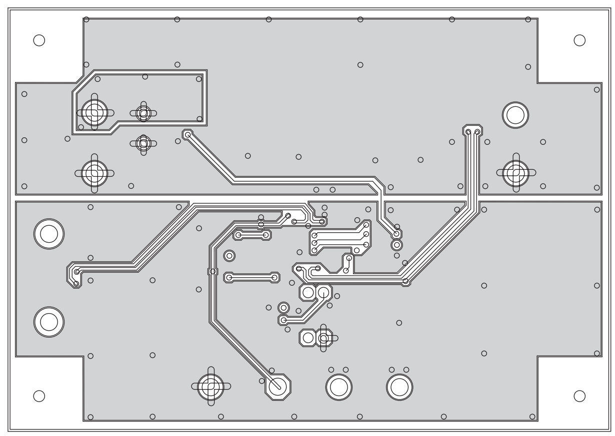
Top Side



Inside GND (LAYER2)

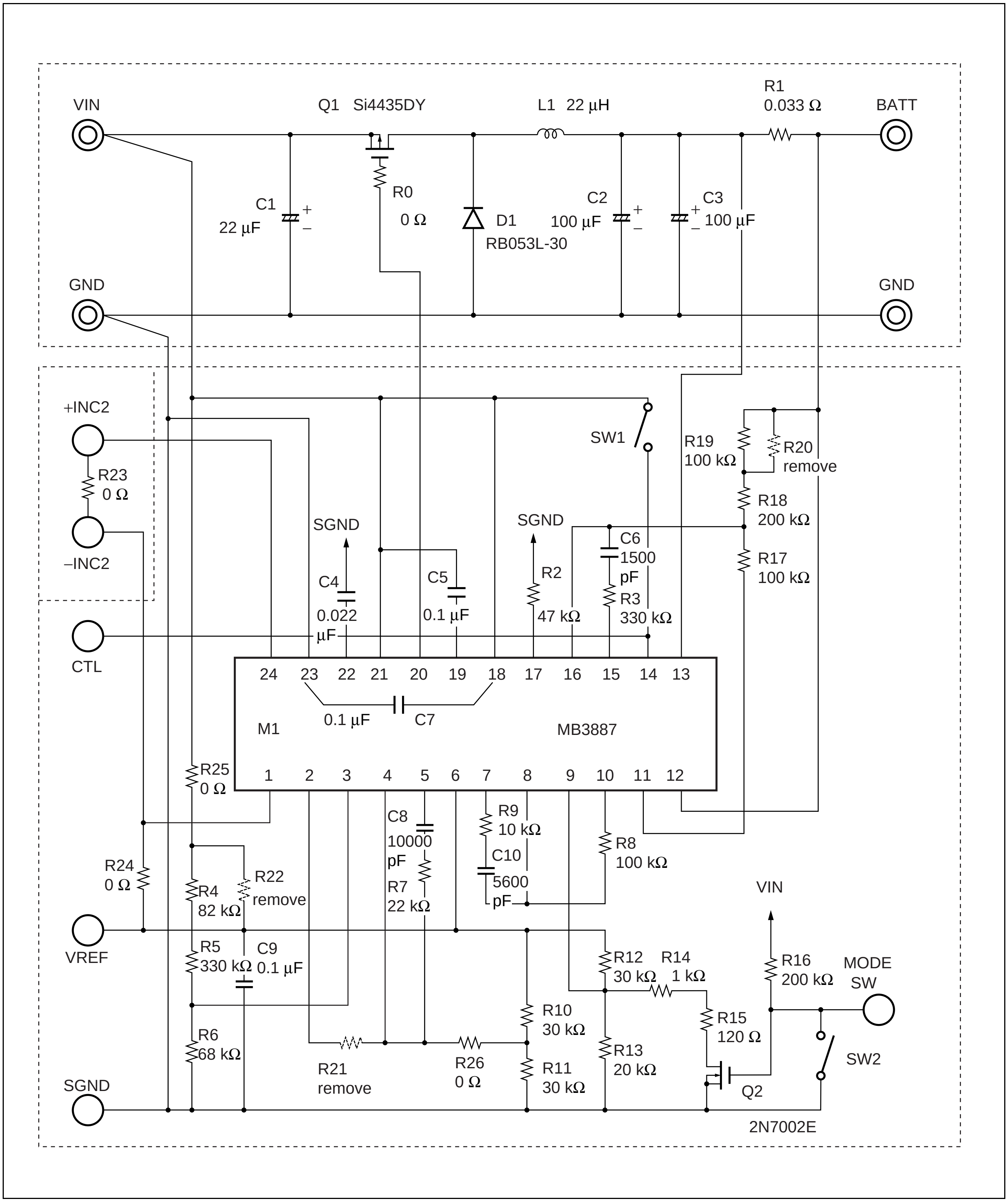


Inside VIN (LAYER3)



Bottom Side

■ CONNECTION DIAGRAM



■ PARTS LIST

Symbol	Part name	Model name	Specification	Package	Manufacturer	Note
M1	IC	MB3887	MB3887	FPT-24P-M03	Fujitsu	
Q1	P-ch FET	Si4435DY	VDS = − 30 V, ID = ± 8 A (Max)	SO-8	Siliconix	
Q2	N-ch FET	2N7002E	VDS = 60 V, ID = 0.115 A (Max)	TO-236	Siliconix	
D1	Diode	RB053L-30	VF = 0.42 V (Max) at IF = 3 A	PMDS	Rohm	
L1	Inductor	SLF12565T-220M3R5	22 µH 3.5 A, 31.6 mΩ	SMD	TDK	
C1	OS CON™	25SL22M	22 µF (25 V)	—	SANYO	
C2, C3	Electrolytic condenser	25CV100AX	100 µF (25 V)	—	SANYO	Double pallarel
C4	Ceramic condenser	C1608JB1H223K	0.022 µF (50 V)	1608 type	TDK	
C5	Ceramic condenser	CM21W5R104K16	0.1 µF (16 V)	2012 type	KYOCERA	
C6	Ceramic condenser	GRM39B152K10	1500 pF (10 V)	1608 type	MURATA	
C7	Ceramic condenser	GRM39F104Z25	0.1 µF (25 V)	1608 type	MURATA	
C8	Ceramic condenser	GRM39B103K10	10000 pF (10 V)	1608 type	MURATA	
C9	Ceramic condenser	CM21W5R104K16	0.1 µF (16 V)	2012 type	KYOCERA	
C10	Ceramic condenser	GRM39B562K10	5600 pF (10 V)	1608 type	MURATA	
R0	Jumper	RK73Z1J-0D	0 Ω	1608 type	KOA	
R1	Resistor	SRS1R033F	33 mΩ (1%)	6.3 × 3.2 mm	SEIDEN TECHNO	
R2	Resistor	RK73G1J-473D	47 kΩ (0.5%)	1608 type	KOA	
R3	Resistor	RK73G1J-334D	330 kΩ (0.5%)	1608 type	KOA	
R4	Resistor	RK73G1J-823D	82 kΩ (0.5%)	1608 type	KOA	
R5	Resistor	RK73G1J-334D	330 kΩ (0.5%)	1608 type	KOA	
R6	Resistor	RK73G1J-683D	68 kΩ (0.5%)	1608 type	KOA	
R7	Resistor	RK73G1J-223D	22 kΩ (0.5%)	1608 type	KOA	
R8	Resistor	RK73G1J-104D	100 kΩ (0.5%)	1608 type	KOA	
R9	Resistor	CR21-103-F	10 kΩ (1%)	1608 type	KYOCERA	
R10 to R12	Resistor	RK73G1J-303D	30 kΩ (0.5%)	1608 type	KOA	
R13	Resistor	RK73G1J-203D	20 kΩ (0.5%)	1608 type	KOA	
R14	Resistor	RK73G1J-102D	1 kΩ (0.5%)	1608 type	KOA	
R15	Resistor	RR0816P-121-D	120 Ω (0.5%)	1608 type	ssm	
R16, R18	Resistor	RK73G1J-204D	200 kΩ (0.5%)	1608 type	KOA	

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Symbol	Part name	Model name	Specification	Package	Manufacturer	Note
R17, R19	Resistor	RK73G1J-104D	100 kΩ (0.5%)	1608 type	KOA	
R20	Jumper	RK73Z1J-0D	0 Ω	1608 type	KOA	Not mounted
R21	—	—	—	—	—	Not mounted
R22	—	—	—	—	—	Not mounted
R23 to R26	Jumper	RK73Z1J-0D	0 Ω	1608 type	KOA	
SW1, SW2	DIP SW	DAS-2H	2 poles	—	MATSUKYU	
—	Terminal pins	WT-2-1	—	—	MacEight	

Note: OS-CON is trademark of SANYO Electric Co., Ltd.

Siliconix	VISHAY Intertechnology, Inc
ROHM	Rohm Co., Ltd.
SANYO	SANYO Electric Co., Ltd.
TDK	TDK Corporation
MURATA	Murata Manufacturing Co., Ltd.
KYOCERA	Kyocera Corporation.
SEIDEN TECHNO	SEIDEN TECHNO Co., Ltd.
KOA	KOA Corporation.
MATSUKYU	MATSUKYU CO.,LTD.
Maceight	MacEight

Resistor value at VIN = 15 or 16 or 19 V

VIN	15 V	16 V	19 V
R4 (Ω)	91 k	0	82 k
R5 (Ω)	220 k	330 k	330 k
AC Adapter detection voltage (V)	13.93	14.63	17.65

Resistor value at 3 cell or 4 cell

Battery	3 cell	4 cell
R20 (Ω)	0	Remove
VBATT (V)	12.6	16.8

■ INITIAL SETTINGS

(1) Output voltage

$$VBATT\ (V) = (R17 + R18 + R19) / R17 \times 4.2\ (V) \fallingdotseq 16.8\ (V)$$

Notes: • For R17 and R19, resistor value should be use to be ignored by internal FET ON resistor (35 Ω, at 1mA) that is connected to OUT terminal (pin 11).

• As using 3 cells, jumper should be put on R20.

(2) AC adapter detection voltage

$$Vth = \frac{R11}{R10 + R11} \times VREF \times \frac{R4 + R5 + R6}{R6} \fallingdotseq 17.65\ (V)$$

(3) Max charge current (DCC mode)

$$IBATT\ (Max) = \frac{R13}{R12 + R13} \times VREF \times \frac{1}{R1 \times 20} \fallingdotseq 3\ (A)$$

(4) Dead Battery mode charge current

$$IDEAD = \frac{R13 // (R14 + R15)}{R12 + R13 // (R14 + R15)} \times VREF \times \frac{1}{R1 \times 20} \fallingdotseq 260\ (mA)$$

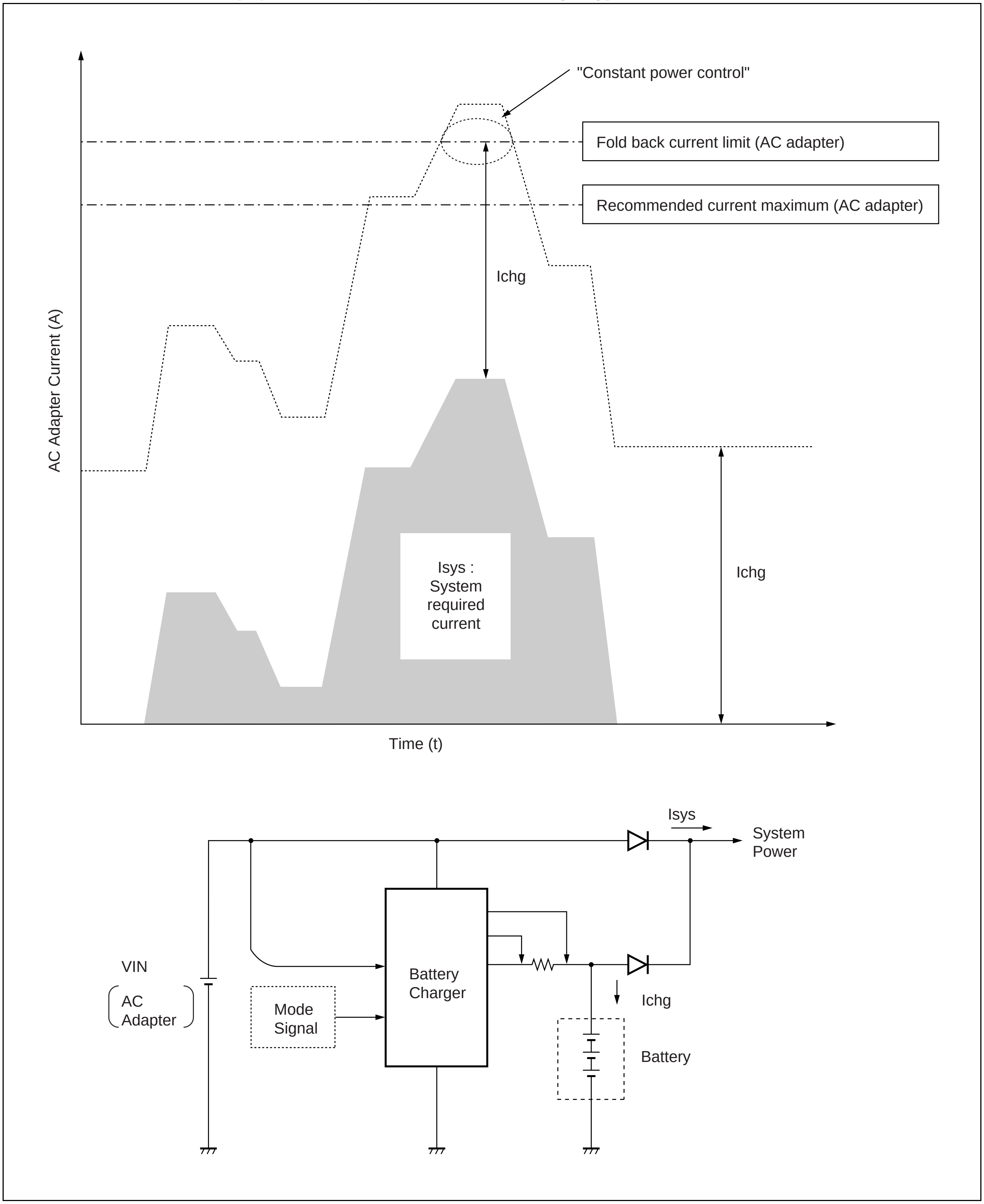
(5) Soft-start time

$$ts\ (s) = 0.42 \times C_S\ (\mu F) \fallingdotseq 9.2\ (ms)$$

(6) Oscillation frequency

$$f_{OSC}\ (kHz) = 13630 / R_T\ (k\Omega) \fallingdotseq 290\ (kHz)$$

■ CHARGING TYPE (Dynamically-controlled charging)



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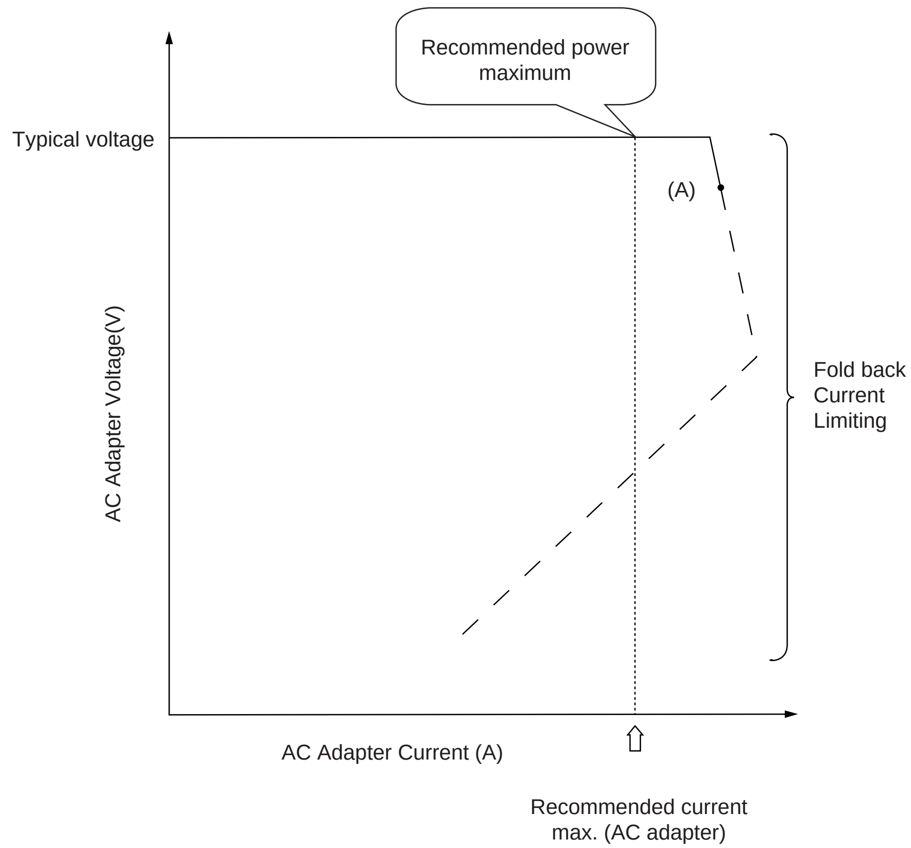


- **Limitations of AC adapter current**

  Normally, AC adapter has built-in protecting function called hold back current limit in order to avoid getting damage to internal element. So, even if output is in the situation of short circuit, AC adapter is not destroyed.

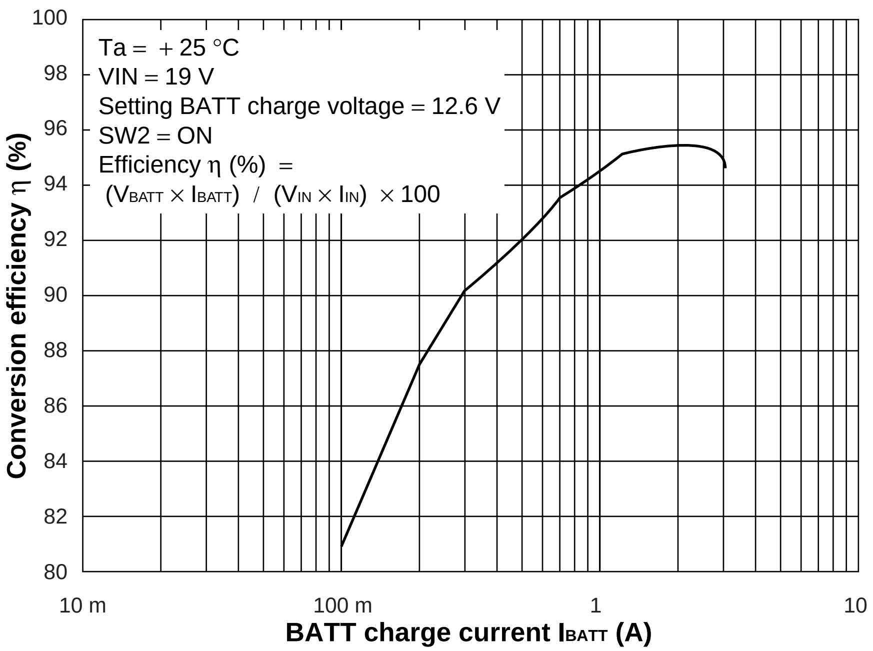
- **Dynamically-controlled charging**

  Dynamically-controlled charging is constant power controlling type. The charging is detecting voltage at (A), and controls charge current to keep constant power of AC adapter.

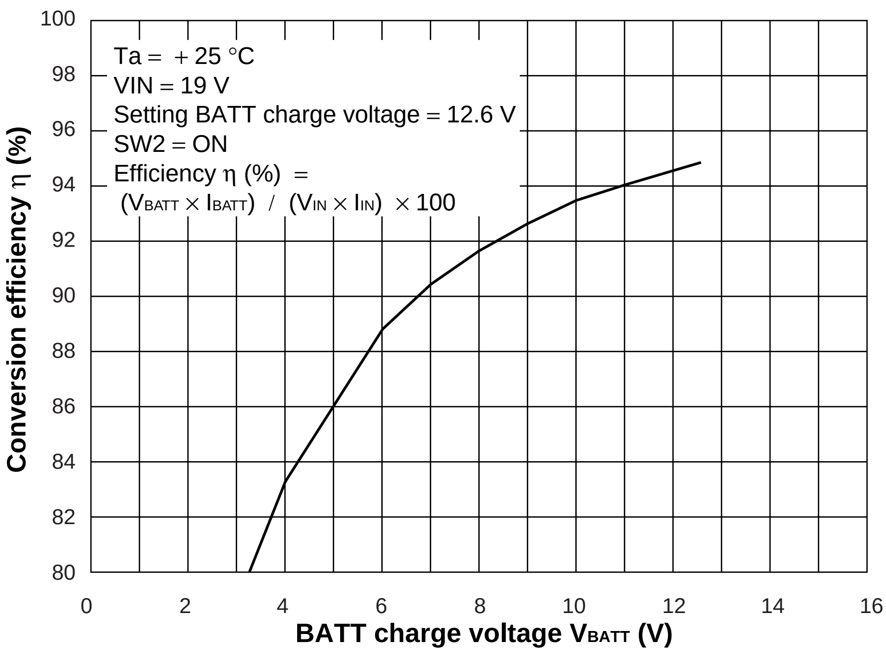
■ REFERENCE DATA

• **Conversion efficiency**

Conversion efficiency vs. Charge current (Constant voltage mode)



Conversion efficiency vs. Charge voltage (Constant current mode)



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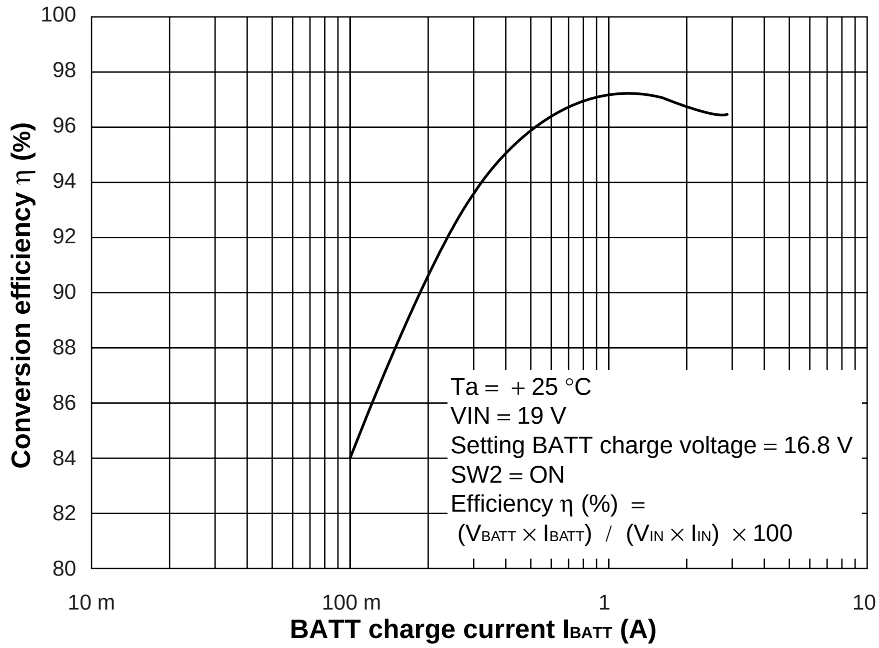
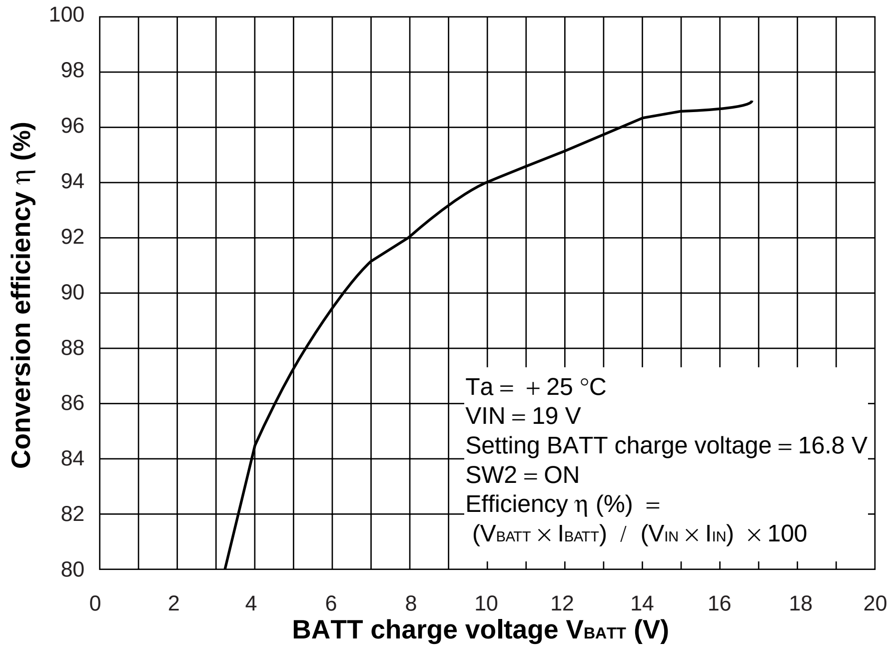
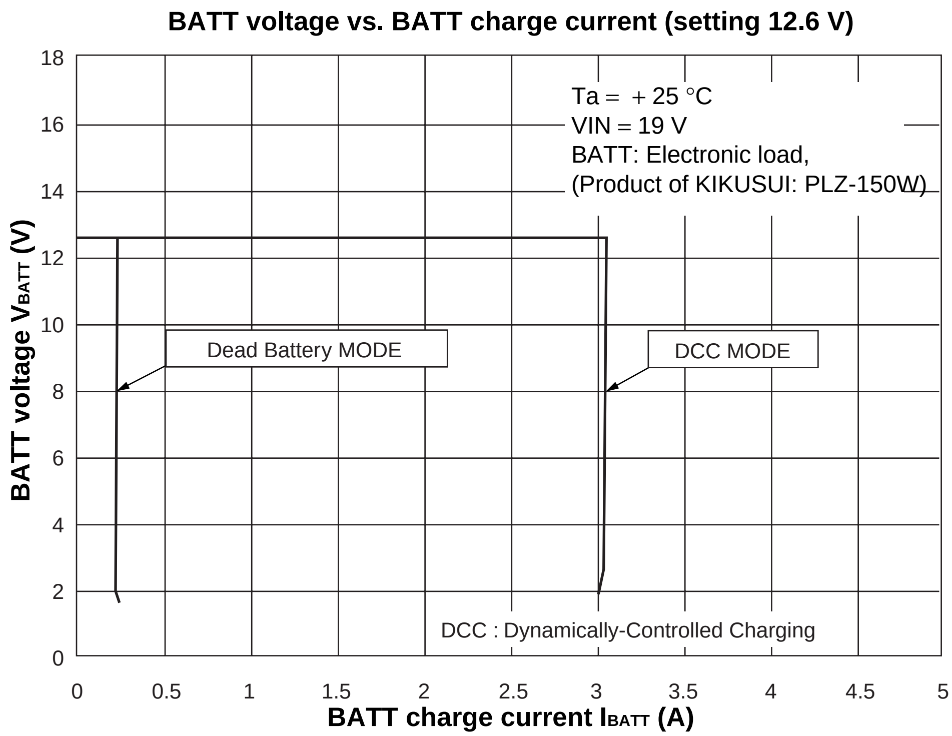
Conversion efficiency vs. Charge current (Constant voltage mode)

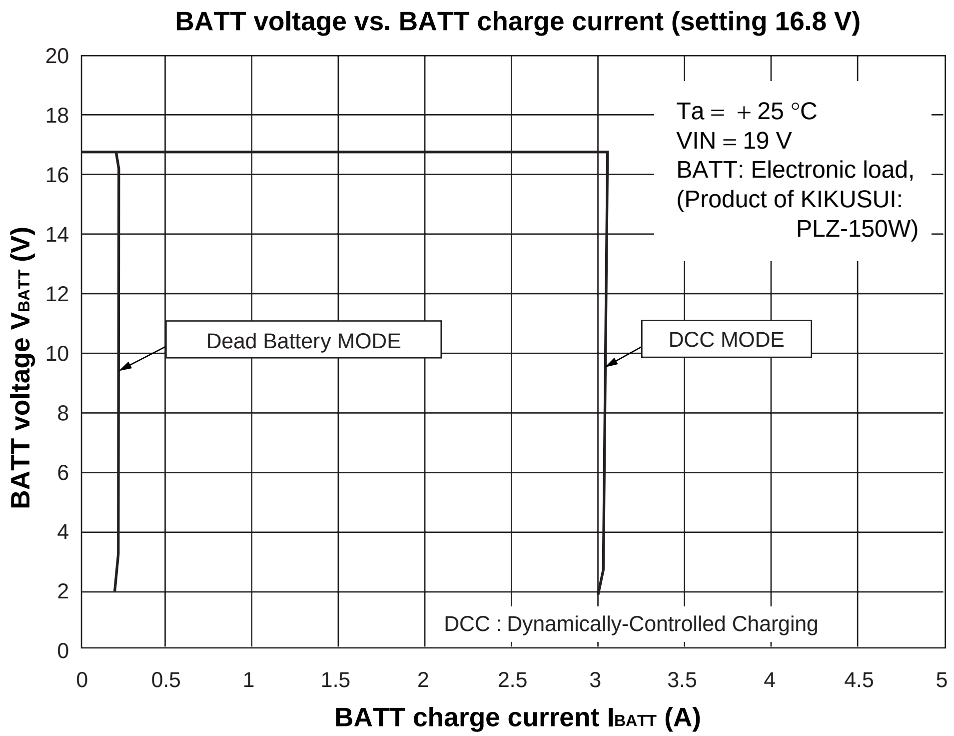


Conversion efficiency vs. Charge voltage (Constant current mode)



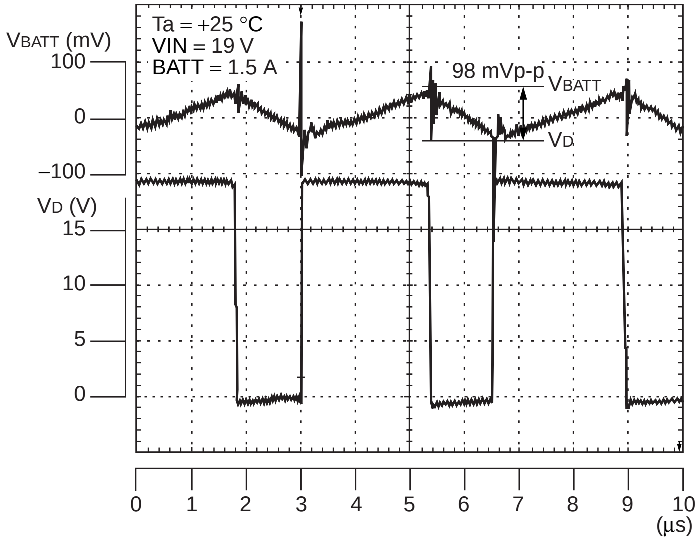
• **Dropping characteristic**



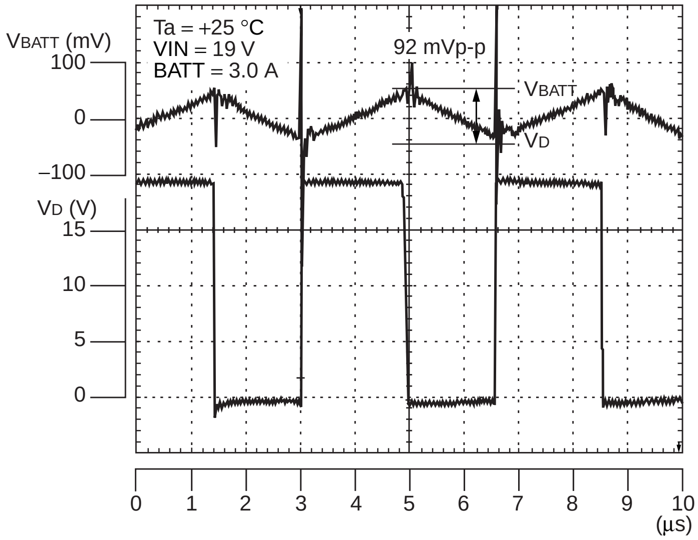


• **Switching waveform**

Switching wave form of constant voltage mode (setting 12.6 V)



Switching wave form of constant current mode (setting 12.6 V at 10 V)



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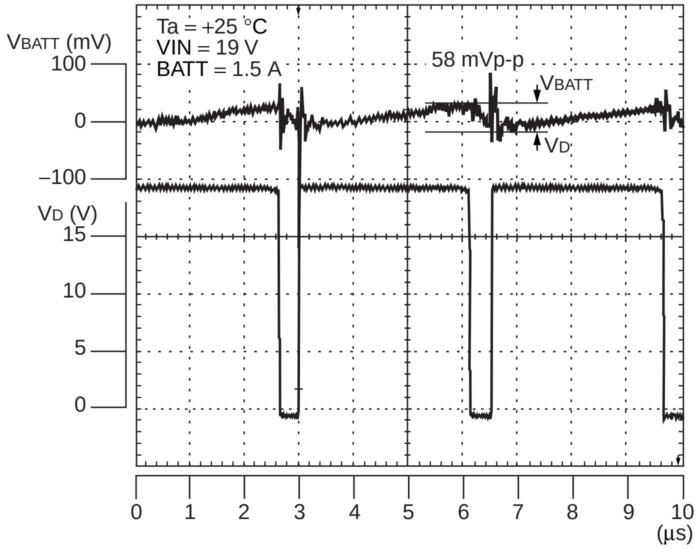
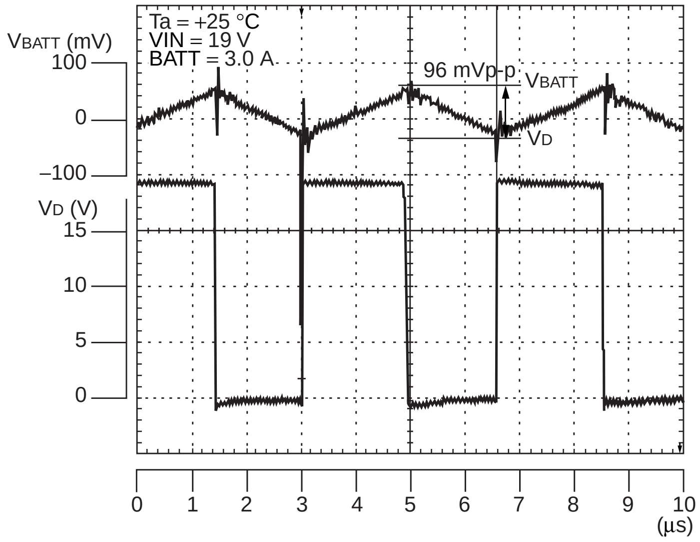
Switching wave form of constant voltage mode (setting 16.8 V)

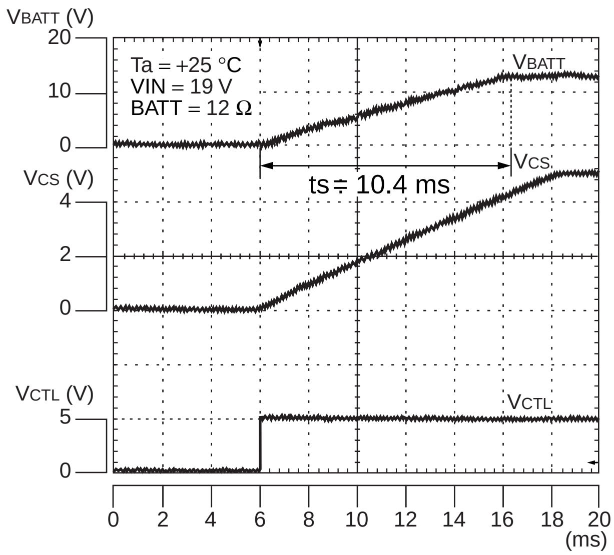


Switching wave form of constant current mode (setting 16.8 V at 10 V)

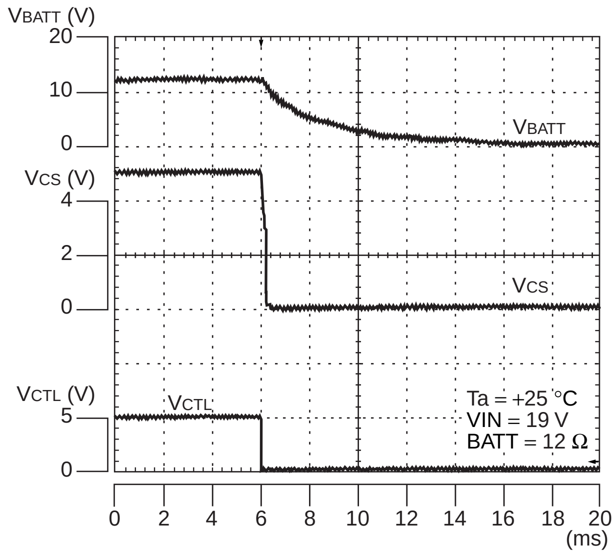


• **Soft-start/Discharge operating waveforms**

Soft-start operating waveforms constant voltage mode (setting 12.6 V)



Discharge operating waveforms constant voltage mode (setting 12.6 V)



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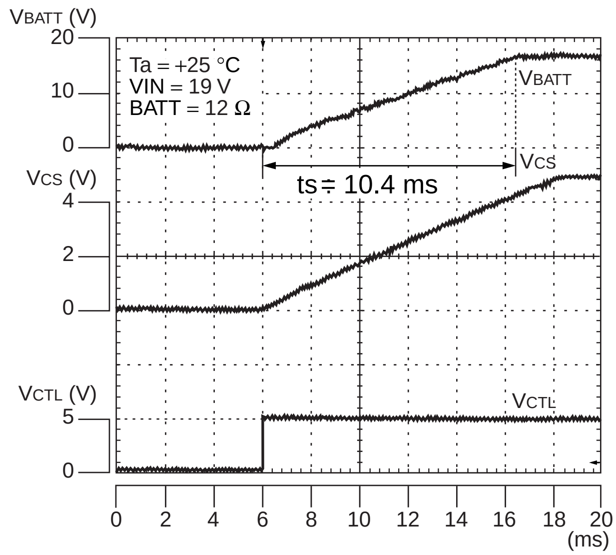
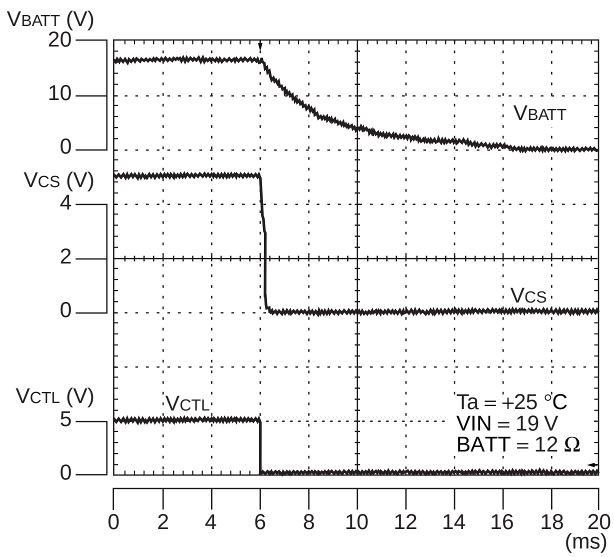
Soft-start operating waveforms constant voltage mode (setting 16.8 V)

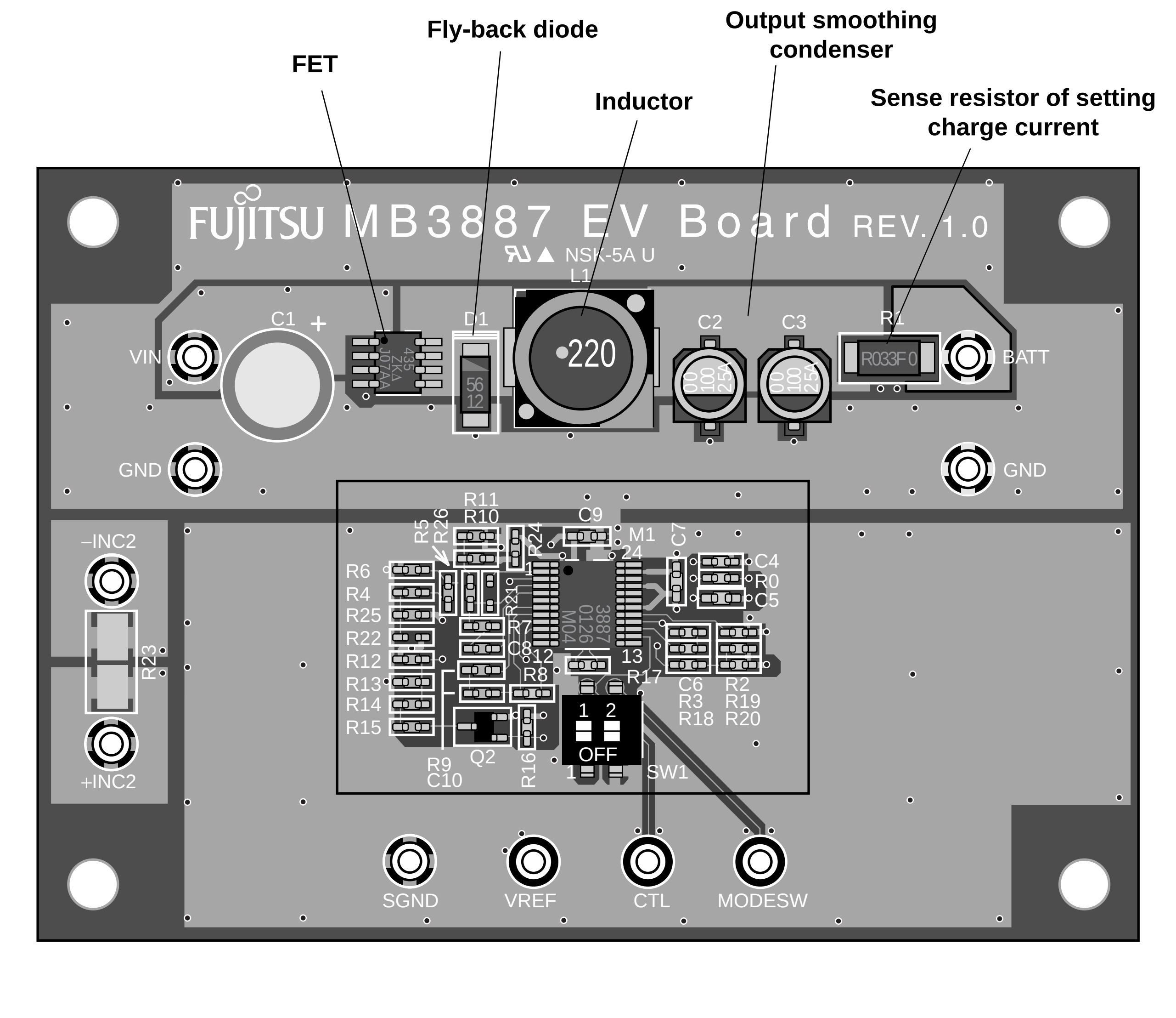


Discharge operating waveforms constant voltage mode (setting 16.8 V)



■ COMPONENT SELECTION METHODS

• Board View



The following subsections show the component selection methods with the following common parametric values.

1. At Output 16.8 V

V_{IN} = 25 V (Max) , Vo = 16.8 V, Io = 3 A, f_{OSC} = 290 kHz

(1) P-ch MOS FET (Si4435DY (VISHAY SILICONIX product))

V_{DS} = – 30 V, V_{GS} = ± 20 V, I_D = 8 A, R_{DS} (on) = 15 mΩ (Typ) , Qg = 47 nC (Typ)

• Drain current: Peak value

The peak drain current of this FET must be within its rated current.

If the FET's peak drain current is I_D, it is obtained by the following formula.

$$I_D \geq I_O + \frac{V_{IN} - Vo}{2L} ton$$

$$\geq 3 + \frac{25 - 16.8}{2 \times 22 \times 10^{-6}} \times \frac{1}{290 \times 10^3} \times 0.672$$

$$\geq \underline{3.43 \text{ A}}$$

(2) Inductor (SLF12565T-220M3R5: TDK product)

22 µH (tolerance ± 20%) , rated current = 3.5 A

L value at full load current condition: Peak-to-peak value of ripple current should be set under harf load-current.

$$L \geq \frac{2 (V_{IN} - Vo)}{I_O} ton$$

$$\geq \frac{2 \times (25 - 16.8)}{3} \times \frac{1}{290 \times 10^3} \times 0.672$$

$$\geq \underline{12.7 \ \mu\text{H}}$$

The load current satisfying the continuous current condition is obtained by the following formula.

$$I_O \geq \frac{Vo}{2L} toff$$

$$\geq \frac{16.8}{2 \times 22 \times 10^{-6}} \times \frac{1}{290 \times 10^3} \times (1 - 0.672)$$

$$\geq \underline{431.8 \text{ mA}}$$

• Ripple current: Peak value

The peak ripple current must be within the rated current of the inductor.

If the inductor's peak ripple current is I_L , it is obtained by the following formula.

$$I_L \geq I_O + \frac{V_{IN} - V_O}{2L} ton$$

$$\geq 3 + \frac{25 - 16.8}{2 \times 22 \times 10^{-6}} \times \frac{1}{290 \times 10^3} \times 0.672$$

$$\geq \underline{3.43\ A}$$

• Ripple current: Peak-to-peak value

If the peak-to-peak ripple current is ΔI_L , it is obtained by the following formula.

$$\Delta I_L = \frac{V_{IN} - V_O}{L} ton$$

$$= \frac{25 - 16.8}{22 \times 10^{-6}} \times \frac{1}{290 \times 10^3} \times 0.672$$

$$\fallingdotseq \underline{0.864\ A}$$

(3) Output smoothing condenser (25CV100AX: SANYO product)

100 µF, rated voltage = 25 V, ESR = 340 mΩ, maximum allowable ripple current = 280 mArms

The output ripple voltage (output voltage 2%), output smoothing condenser, ripple current, and series resistance are assumed to be ΔV_O , C_L , I_{CLrms} , and ESR, respectively. As using double pallarel the condenser, capacity is equal to 200 µF. So, ESR, C_L , and I_{CLrms} are obtained by the following formula.

Series resistance

$$ESR \leq \frac{\Delta V_O}{\Delta I_L} - \frac{1}{2\pi f C_L}$$

$$\leq \frac{0.336}{0.864} - \frac{1}{2\pi \times 290 \times 10^3 \times 200 \times 10^{-6}}$$

$$\leq \underline{386.1\ m\Omega}$$

When the above two condensers are used in parallel, the series resistance is <u>170 mΩ</u> and acceptable.

Condenser

$$C_L \geq \frac{\Delta I_L}{2\pi f (\Delta V_O - \Delta I_L \times ESR)}$$

$$\geq \frac{0.864}{2\pi \times 290 \times 10^3 \times (0.336 - 0.864 \times 0.17)}$$

$$\geq \underline{2.5\ \mu F}$$

When the above two condensers are used in parallel, the capacitance is <u>200 µF (Typ)</u> and acceptable.

Ripple current

$$I_{CL}rms \geq \frac{(V_{IN} - Vo)\ ton}{2\sqrt{3}L}$$

$$\geq \frac{(25 - 16.8) \times 0.672}{2\sqrt{3} \times 22 \times 10^{-6} \times 290 \times 10^{3}}$$

$$\geq \underline{249.3\ mArms}$$

When the above two condensers are used in parallel, the ripple current is 560 mArms and acceptable.

(4) Fly-back diode (RB053L-30: ROHM product)

VR (reverse DC voltage) = 30 V, Average output current = 3.0 A, Peak current = 70 A

V_R: Value enough to satisfy the input voltage→30 V

On time of the diode is assumed to be t_D (Max), the diode mean current I_{Di} is obtained by the following formula.

$$I_{Di} \geq I_O \times \left(1 - \frac{Vo}{V_{IN}}\right) = 3 \times (1 - 0.672) \fallingdotseq \underline{984\ mA}$$

On time of the diode is assumed to be t_D (Max), the diode peak current I_{Dip} is obtained by the following formula.

$$I_{Dip} \geq \left(I_O + \frac{Vo}{2L} toff\right) \fallingdotseq \underline{3.43\ A}$$

(5) Sense resistor of setting charge current (SRS1R033F: SEIDEN TECHNO product)

33 mΩ

Use the following formula to get R1 value when +INE terminal voltage 2 V makes charging current to be 3 A.

$$R1 = \frac{+INE1}{20 \times I1}$$

$$= \frac{2}{20 \times 3}$$

$$\fallingdotseq \underline{33.3\ (m\Omega)}$$

2. At Output 12.6 V

V_{IN} = 25 V (Max) , Vo = 12.6 V, Io = 3 A, f_{OSC} = 290 kHz

(1) P-ch MOS FET (Si4435DY (VISHAY SILICONIX product))

V_{DS} = – 30 V, V_{GS} = ± 20 V, I_D = 8 A, R_{DS} (on) = 15 mΩ (Typ) , Qg = 47 nC (Typ)

• Drain current: Peak value

The peak drain current of this FET must be within its rated current.

If the FET's peak drain current is I_D, it is obtained by the following formula.

$$I_D \geq I_O + \frac{V_{IN} - V_O}{2L} t_{on}$$

$$\geq 3 + \frac{25 - 12.6}{2 \times 22 \times 10^{-6}} \times \frac{1}{290 \times 10^{3}} \times 0.504$$

$$\geq \underline{3.49\ \text{A}}$$

(2) Inductor (SLF12565T-220M3R5: TDK product)

22 µH (tolerance ± 20%) , rated current = 3.5 A

L value at full load current condition: Peak-to-peak value of ripple current should be set under harf load-current.

$$L \geq \frac{2 (V_{IN} - V_O)}{I_O} t_{on}$$

$$\geq \frac{2 \times (25 - 12.6)}{3} \times \frac{1}{290 \times 10^{3}} \times 0.504$$

$$\geq \underline{14.4\ \mu\text{H}}$$

The load current satisfying the continuous current condition is obtained by the following formula.

$$I_O \geq \frac{V_O}{2L} t_{off}$$

$$\geq \frac{12.6}{2 \times 22 \times 10^{-6}} \times \frac{1}{290 \times 10^{3}} \times (1 - 0.504)$$

$$\geq \underline{489.8\ \text{mA}}$$

- **Ripple current: Peak value**

The peak ripple current must be within the rated current of the inductor.

If the inductor's peak ripple current is I_L , it is obtained by the following formula.

$$I_L \geq I_O + \frac{V_{IN} - V_O}{2L} ton$$

$$\geq 3 + \frac{25 - 12.6}{2 \times 22 \times 10^{-6}} \times \frac{1}{290 \times 10^3} \times 0.504$$

$$\geq \underline{3.49 \text{ A}}$$

- **Ripple current: Peak-to-peak value**

If the peak-to-peak ripple current is ΔI_L , it is obtained by the following formula.

$$\Delta I_L = \frac{V_{IN} - V_O}{L} ton$$

$$= \frac{25 - 12.6}{22 \times 10^{-6}} \times \frac{1}{290 \times 10^3} \times 0.504$$

$$\fallingdotseq \underline{0.980 \text{ A}}$$

(3) Output smoothing condenser (25CV100AX: SANYO product)

100 µF, rated voltage = 25 V, ESR = 340 mΩ, maximum allowable ripple current = 280 mArms

The output ripple voltage (output voltage 2%), output smoothing condenser, ripple current, and series resistance are assumed to be ΔV_O , C_L , I_{CLrms} , and ESR, respectively. As using double pallarel the condenser, capacity is equal to 200 µF. So, ESR, C_L , and I_{CLrms} are obtained by the following formula.

Series resistance

$$ESR \leq \frac{\Delta V_O}{\Delta I_L} - \frac{1}{2\pi f C_L}$$

$$\leq \frac{0.252}{0.980} - \frac{1}{2\pi \times 290 \times 10^3 \times 200 \times 10^{-6}}$$

$$\leq \underline{254.4 \text{ m}\Omega}$$

When the above two condensers are used in parallel, the series resistance is <u>170 mΩ</u> and acceptable.

Condenser

$$C_L \geq \frac{\Delta I_L}{2\pi f (\Delta V_O - \Delta I_L \times ESR)}$$

$$\geq \frac{0.980}{2\pi \times 290 \times 10^3 \times (0.252 - 0.980 \times 0.17)}$$

$$\geq \underline{6.3 \text{ µF}}$$

When the above two condensers are used in parallel, the capacitance is <u>200 µF (Typ)</u> and acceptable.

Ripple current

$$I_{CL}rms \geq \frac{(V_{IN} - Vo)\ ton}{2\sqrt{3}L}$$

$$= \frac{(25 - 12.6) \times 0.504}{2\sqrt{3} \times 22 \times 10^{-6} \times 290 \times 10^{3}}$$

$$\fallingdotseq \underline{282.8\ mArms}$$

When the above two condensers are used in parallel, the ripple current is 560 mArms and acceptable.

(4) Fly-back diode (RB053L-30: ROHM product)

VR (reverse DC voltage) = 30 V, Average output current = 3.0 A, Peak current = 70 A

V_R: Value enough to satisfy the input voltage→30 V

On time of the diode is assumed to be t_D (Max), the diode mean current $I_{D}i$ is obtained by the following formula.

$$I_{D}i \geq I_O \times \left(1 - \frac{Vo}{V_{IN}}\right) = 3 \times (1 - 0.504) \fallingdotseq \underline{1.49\ A}$$

On time of the diode is assumed to be t_D (Max), the diode peak current $I_{D}ip$ is obtained by the following formula.

$$I_{D}ip \geq \left(I_O + \frac{Vo}{2L}\ toff\right) \fallingdotseq \underline{3.49\ A}$$

■ ORDERING INFORMATION

EV board part No.	EVboard version No.	Note
MB3887EVB	MB3887EV Board Rev.1.0	

MEMO

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