

**AP2200****Step-up DC-DC Converter IC Supporting 1 or 2 Solar Cells**

### 1. General Description

The AP2200 is a voltage step-up DC-DC converter using the synchronous rectification method to be activated with 1 or 2 solar cells and is ideal for charging lithium-ion batteries or outputting USB VBUS voltage. Also, the MPPT (Max Power Point Tracking) function is embedded in order to maximize the output power from the solar cells.

### 2. Features

- Input voltage range 0.4 V to 1.6 V
- Operating temperature range -30 to 85°C
- Input power Up to 400 mW per 1 cell  
Up to 800 mW per 2 cells
- Output voltage 4.0 V ( $\pm 2\%$ ) per 1 cell  
5.0 V ( $\pm 5.0\%$ ) per 2 cells
- Control method Comparator control method
- Rectification method Synchronous rectification method
- Standby function When the STBY pin is H, the LC pin is fixed to H
- No battery detect function When the VB pin voltage decreases, the LC pin is fixed to H
- Efficiency 70% (1 cell input, 4.0 V, 50 mA output),  
80% (2 cells input, 5.0 V, 80 mA output)
- Package QFN 16-pin
- Application For charging a lithium-ion battery and USB VBUS source  
with 1 or 2 solar cells

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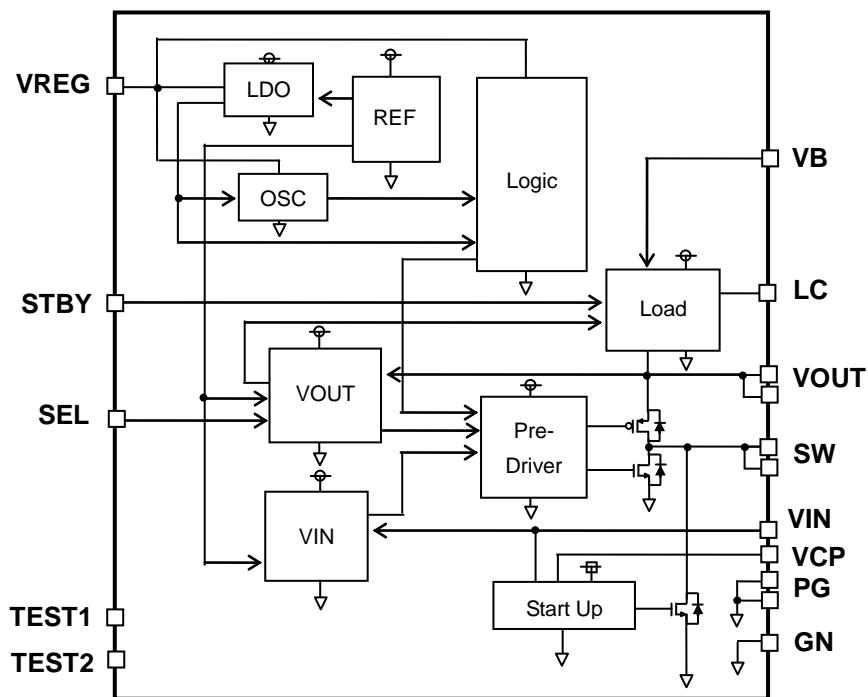
**4. Block Diagram****■ When set output voltage to 4 V**

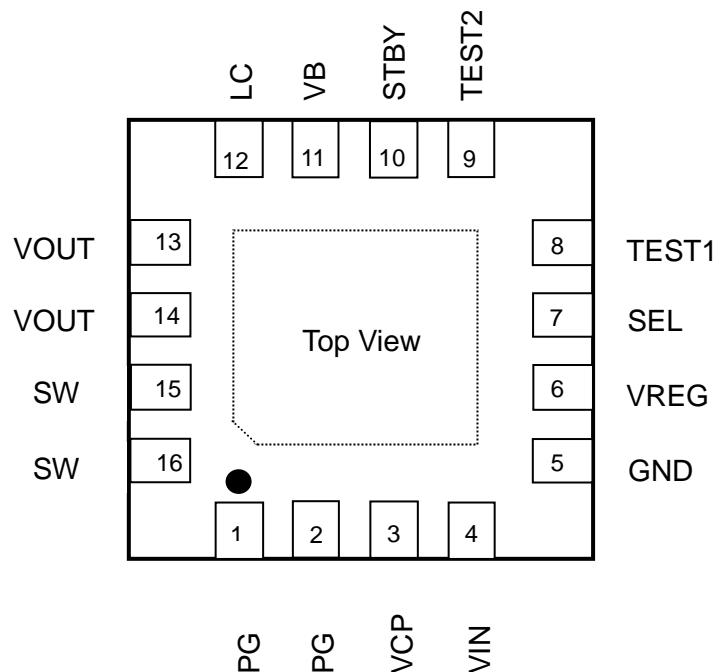
Figure 1. AP2200 Block Diagram

**5. Ordering Information**

AP2200 -30 ~ 85°C 16-pin QFN

## 6. Pin Configurations and Functions

### ■ Pin Configurations



Please connect exposed pad to GND or leave OPEN.

### ■ Pin Functions

Pin No	Pin name	Type (Note 1)	I/O (Note 2)	Function	Description
1	PG	GND	-	DC-DC ground pin	
2	PG	GND	-	DC-DC ground pin	
3	VCP	A	IO	Charge pump pin	
4	VIN	PWR	-	Power input pin	
5	GND	GND	-	Ground pin	
6	VREG	A	IO	Internal regulator output pin	
7	SEL	D	I	Output voltage switch input pin	“L” = 4V, “H” = 5V
8	TEST1	-	-	Test pin	(Note 3)
9	TEST2	-	-	Test pin	(Note 3)
10	STBY	D	I	Standby input pin	“H” : standby
11	VB	A	I	Battery monitoring input pin	
12	LC	D	O	External switch control pin	
13	VOUT	A	IO	DC-DC output pin	
14	VOUT	A	IO	DC-DC output pin	
15	SW	A	IO	Inductor connect pin	
16	SW	A	IO	Inductor connect pin	
EP	GND	GND	-	Tab pin	

Note 1. A: analog pin, D: digital pin, GND: ground pin, PWR: power pin.

Note 2. I: input pin, O: output pin, IO: input and output pin.

Note 3. Test pins should be connected to GND.

## 7. Absolute Maximum Ratings

Parameter	Symbol	min	max	Unit	Conditions
Pin voltage Range (Note 4)	V <sub>VIN1</sub>	-0.3	1.98	V	(Note 5)
	V <sub>VIN2</sub>	-0.3	5.5	V	(Note 6)
Input power	P <sub>IN</sub>		0.8	W	
Storage temperature Range	T <sub>STG</sub>	-40	150	°C	
Junction temperature	T <sub>J</sub>	-30	150	°C	
Power dissipation	P <sub>D</sub>		0.8	W	

Note 4. All voltages with respect to ground.

Note 5. VIN pin and VREG pin

Note 6. VCP pin, SEL pin, STBY pin, VB pin, LC pin, VOUT pin and SW pin

**WARNING:** Operation at or beyond these limits may result in permanent damage to the device. Normal operation is not guaranteed at these extremes.

## 8. Recommended Operating Conditions

Parameter	Symbol	min	typ	max	Unit	Conditions
Supply voltage range	V <sub>VIN</sub>	0.4		1.6	V	(Note7)
Operational temperature	T <sub>A</sub>	-30		85	°C	

Note 7. All voltages with respect to ground.

## 9. Electrical Characteristics

(Ta = 25 °C, except as otherwise noted)

Item	Symbol	Min	Typ	Max	Unit	Condition
Startup circuit						
Supply voltage on startup	V <sub>VINSTUP</sub>		-	0.5	V	-30°C < Ta < -10°C
			0.3	0.4	V	-10°C < Ta < 85°C
DC-DC converter						
V <sub>OUT</sub> voltage	V <sub>TGT</sub>	3.96	4.0	4.04	V	T <sub>A</sub> = 25 °C, SEL="L"
		3.92	4.0	4.08		T <sub>A</sub> = -30 to 85°C , SEL="L"
		4.75	5.0	5.25		T <sub>A</sub> = -30 to 85°C , SEL="H"
V <sub>OUT</sub> hysteresis	V <sub>TGTHYS</sub>	0.16	0.38	0.60	%	
High-side on resistance	R <sub>ONTOP</sub>		0.2		Ω	
Low-side on resistance	R <sub>ONBOT</sub>		0.1			
Switching frequency	f <sub>OSC</sub>	450	500	550	kHz	
Low-side current limit	I <sub>LIM</sub>	0.9	1.2	1.5	A	
MPPT circuit						
VPM open circuit voltage ratio	MPP	78	80	82	%	MPP=V <sub>PM</sub> /V <sub>OC</sub>
Open circuit voltage sampling period	t <sub>SH</sub>	90	100	110	ms	
Monitoring circuit						
No battery detect voltage	V <sub>BLOW</sub>	1.0	-	2.5	V	
Low V <sub>OUT</sub> detect voltage	V <sub>OL</sub>	2.35	2.65	2.90	V	
Logic I/O						
External switch driving voltage	V <sub>OLLC</sub>	-	-	GND+0.1	V	I <sub>LC</sub> =-1uA
	V <sub>OHLC</sub>	V <sub>OUT</sub> -0.45 V <sub>B</sub> -0.45	-	-		I <sub>LC</sub> =1uA V <sub>OUT</sub> >V <sub>B</sub> V <sub>OUT</sub> <V <sub>B</sub>
Standby input voltage	V <sub>ILSTB</sub>	-	-	0.3	V	
	V <sub>IHSTB</sub>	1.0	-	-		
Output voltage switching input voltage <b>(Note 9)</b>	V <sub>ILSEL</sub>	-	-	V <sub>OUT</sub> *0.3	V	
	V <sub>IHSEL</sub>	V <sub>OUT</sub> *0.7	-	-		
Control part						
Internal regulator voltage	V <sub>REG</sub>	1.62	1.8	1.98	V	
Operating frequency	f <sub>CK</sub>	0.9	1.0	1.1	MHz	
Pin current						
VIN pin current	I <sub>VIN</sub>	-	-	50	µA	During DC-DC operation: VIN<1.2V@ T <sub>A</sub> >25°C VIN<1.6V@ T <sub>A</sub> <25°C
VB pin current	I <sub>VB</sub>	-	10	20	µA	LC=H/L
Internal pull-down resistance						
STBY pin	R <sub>PDSTBY</sub>	0.5	-	1.5	MΩ	
SEL pin	R <sub>PDSEL</sub>	0.5	-	1.5	MΩ	

Note 8. All voltages with respect to ground.

Note 9. Connect the SEL pin to the VOUT or the GND pin.

## 10. Functional Descriptions

### 10.1 Overview

When the output voltage is entered into VIN from the solar cell(s), the low voltage startup circuit starts to step up the output voltage ( $V_{OUT}$ ). When  $V_{OUT}$  reaches the voltage required for operation of the step-up converter, the low voltage startup circuit stops and the step-up converter starts. After that, the step-up converter increases  $V_{OUT}$  to the target voltage ( $V_{TGT}$ ) and controls  $V_{OUT}$  so that it will be stabilized at  $V_{TGT}$ . Also, when  $V_{OUT}$  reaches  $V_{TGT}$ , the step-up converter decreases the LC pin to a low level. For the application where an external PMOS load switch is connected to the LC pin, when the LC pin becomes a low level, the external switch is turned ON to start the power supply to the equipment. However, if one of the conditions below is met, the external load switch is turned OFF to stop the power supply:

Table 1. stop power supply

1	The STBY pin is set to a high level:	The AP2200 has a standby function. When the STBY pin is set to a high level ( $V_{IHSTB}$ ), the external load switch is turned OFF to stop power supply. In this case, the step-up converter is still running even in a standby state. When the STBY pin is set to a low level ( $V_{ILSTB}$ ), the standby mode is released and the power supply is resumed.
2	The VB pin voltage is less than or equal to $V_{BLOW}$ :	The AP2200 has a battery monitoring function. When the VB pin voltage decrease to $V_{BLOW}$ or lower, it is assumed that the battery is removed, and the external load switch is turned OFF to stop power supply. When the VB pin voltage increases to $V_{BLOW}$ or higher, it is assumed that the battery is reinserted, and the external load switch is turned ON to start power supply. To disable this function, connect the VB pin to the $V_{OUT}$ pin.
3	The $V_{OUT}$ pin voltage is less than or equal to $V_{OL}$ :	When the $V_{OUT}$ pin voltage decreases to $V_{OL}$ and lower, the external load switch is turned OFF to stop power supply. In this case, the step-up converter is still running. When $V_{OUT}$ reaches $V_{TGT}$ again, the power supply is resumed.
4	When sampling the open circuit voltage ( $V_{OC}$ ) of the solar cell(s) per the cycle $t_{SH}$ ,	The AP2200 turns OFF the external load switch as well as pausing the voltage step-up operation. When the sampling of the open circuit voltage comes to an end, the voltage step-up operation resumes. Unless $V_{OUT}$ reaches $V_{TGT}$ again, the external load switch is not turned ON. This prevents back flow from the battery to $V_{OUT}$ to minimize the battery consumption when the power supply from the solar cell(s) decreases, and the step-up converter cannot increase the voltage sufficiently.

## 10.2 Target voltage setting

The target voltage ( $V_{TGT}$ ) is selectable based on the SEL pin.

Table 2. Target voltage setting

SEL pin level	Target voltage ( $V_{TGT}$ ) setting
L	4 V
H	5 V

## 10.3 MPPT control

The voltage step-up operation is paused per the cycle  $t_{SH}$  and the open circuit voltage ( $V_{OC}$ ) of the solar cell(s) is sampled. This PWM function first calculates the voltage ( $V_{PM}$ ) from  $V_{OC}$  where the maximum output can be obtained based on the solar cell properties and then controls the step-up converter to obtain the voltage( $V_{PM}$ ).

## 10.4 Output voltage control

The step-up converter always monitors  $V_{OUT}$ . As soon as  $V_{OUT}$  reaches the setting voltage ( $V_{TGT}$ ), the converter stops the voltage step-up. When the voltage step-up operation is stopped,  $V_{OUT}$  decreases due to load consumption. When  $V_{OUT}$  drops by  $V_{TGTHYS}$  or more from  $V_{TGT}$ , the step-up operation is restarted.

### 10.5 Timing chart

- Normal operation (the voltage increases to VOUT after startup)

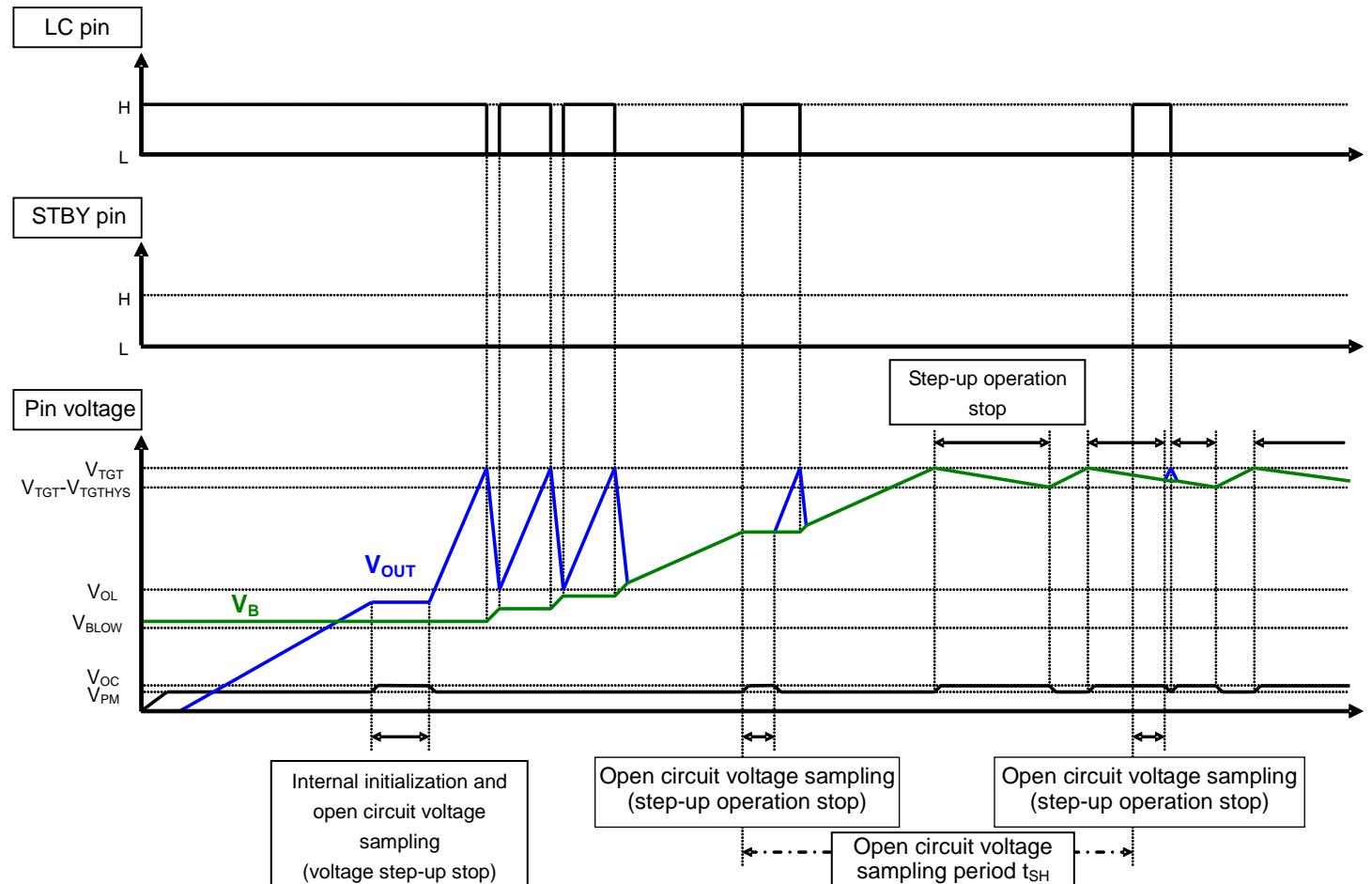


Figure 2. Normal operation

- Behavior of when solar cell output decreases

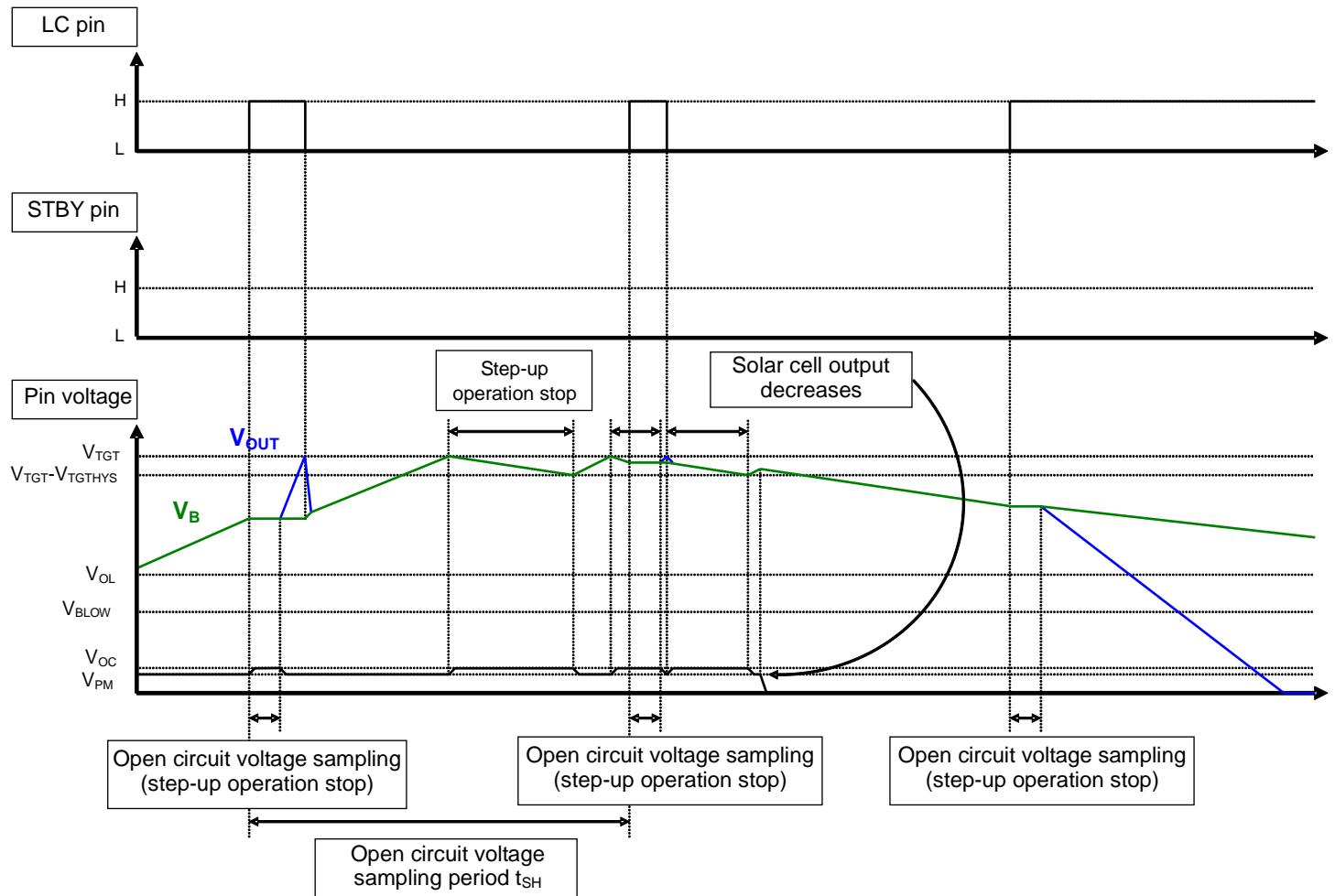


Figure 3. Behavior of when solar cell output decreases

- Behavior when the STBY pin is asserted

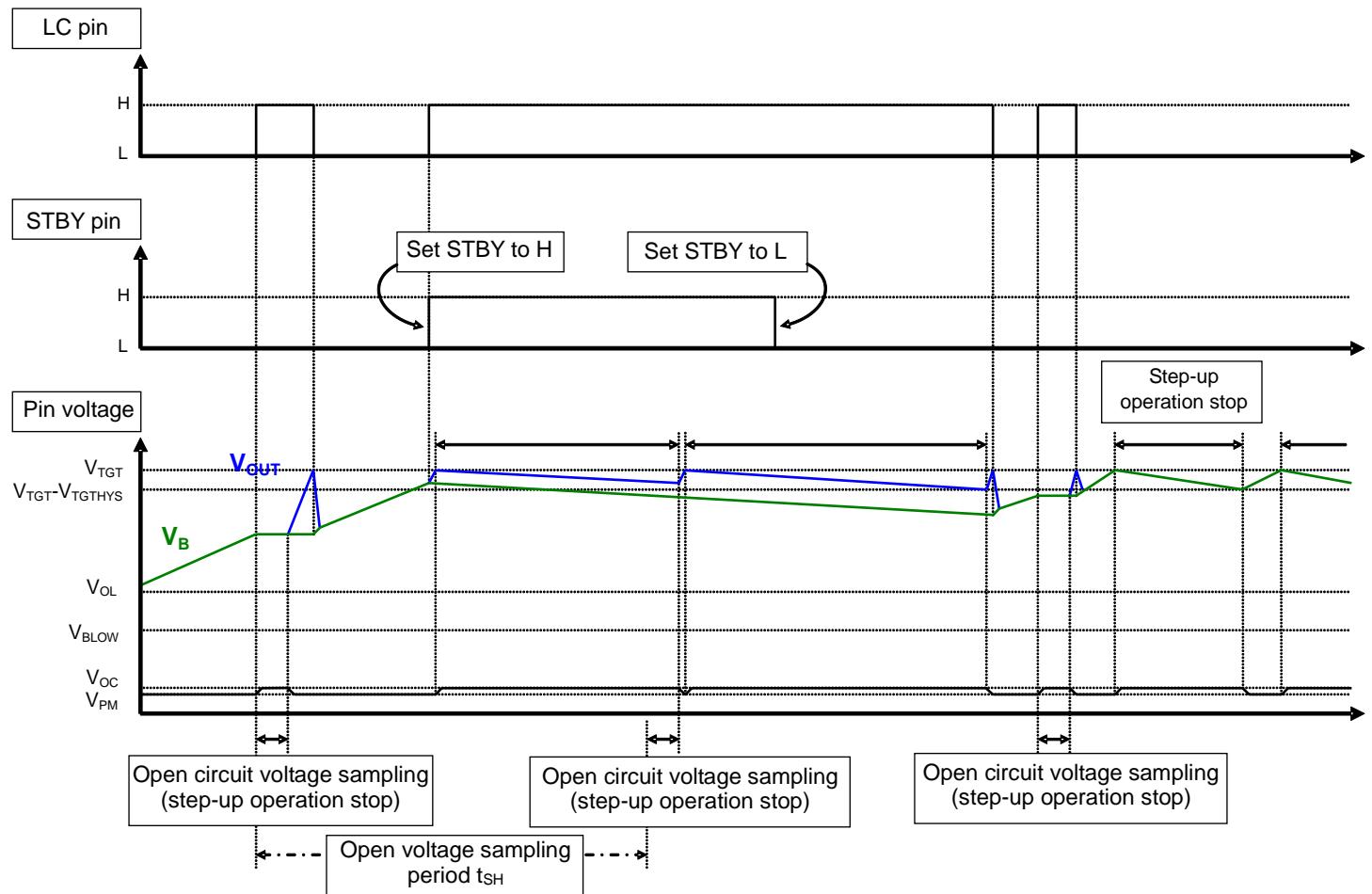


Figure 4. Behavior when the STBY pin is asserted

- Behavior when no battery is connected.

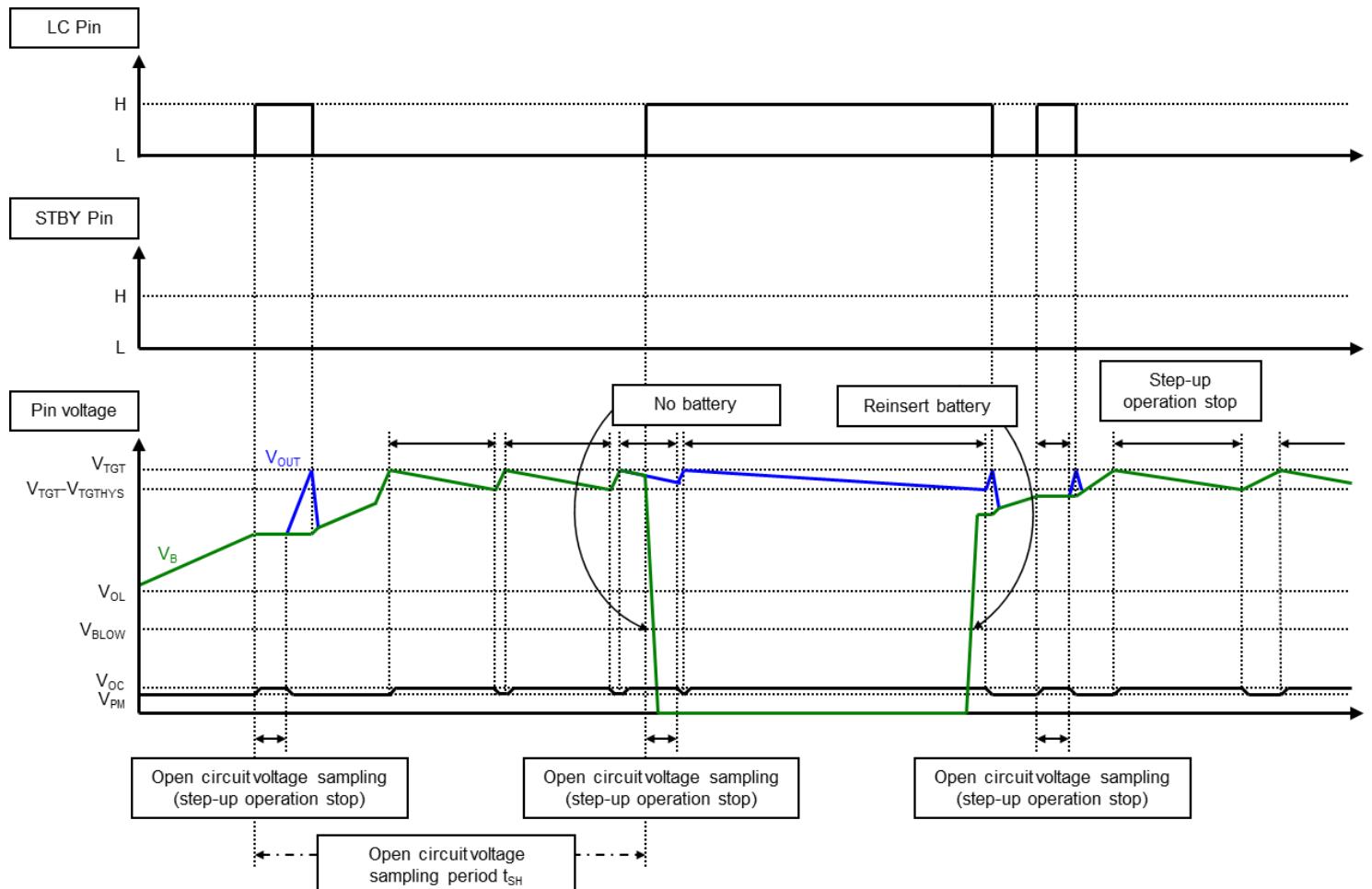


Figure 5. Behavior of when no battery is connected.

## 11. Recommended External Circuits

## ■ When setting the output voltage to 5V or 4V

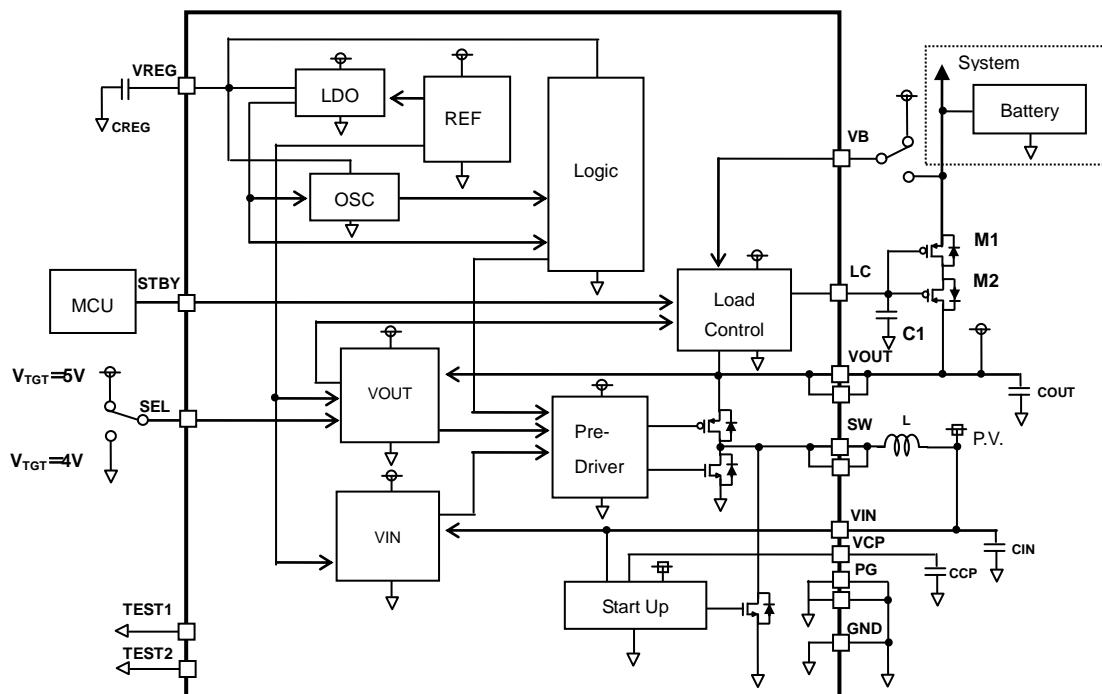


Figure 6. External Circuits

Note 10.  $\oplus$  : Power supply of the startup circuit. The supply source is P.V.

↑: Power supply of the Internal circuits, VB pin and SEL pin for pull up.

Note 11. Select the C1 value to prevent the LC pin voltage from exceeding the absolute maximum rating due to the current through parasitic capacitance of the external load switch.

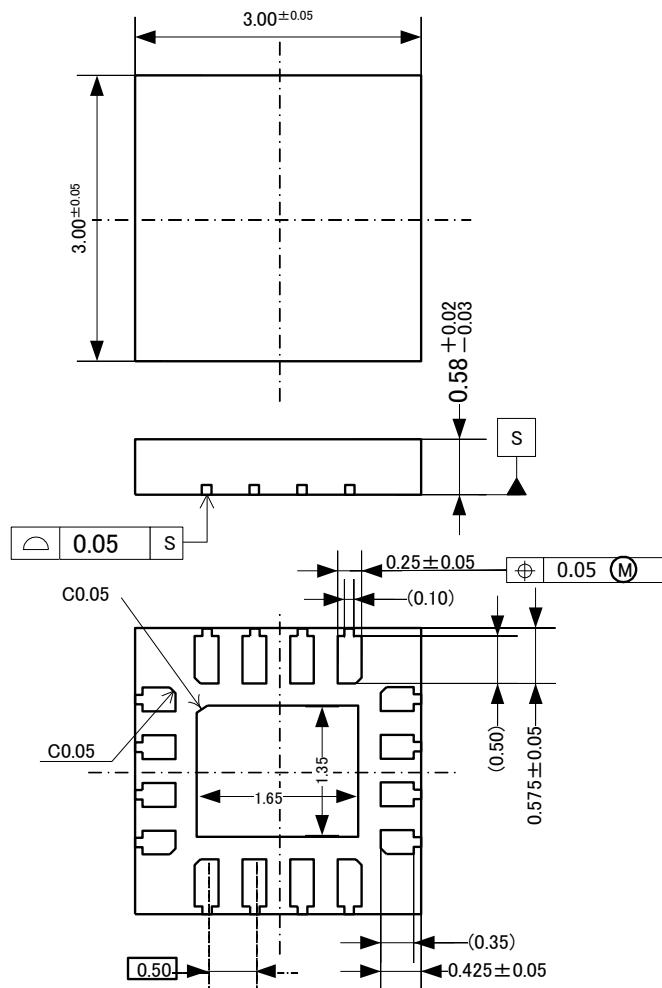
## ■ Recommended Parts

Table 3. Reference design list of materials

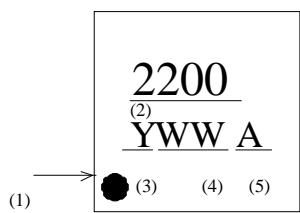
Item	Symbol	Value	Part number	Manufacturer
Ceramic Capacitors	CIN	10 $\mu$ F	-	-
	COUT	10 $\mu$ F	-	-
	CREG	1 $\mu$ F	-	-
	CCP	0.01 $\mu$ F	-	-
	C1	0.1 $\mu$ F	-	-
Inductors	L1(with 1cell)	4.7 $\mu$ H	SLF6045T-4R7N2R4-3PF	TDK
	L2(with 2cell)	6.8 $\mu$ H	SLF6045T-6R8N2R0-3PF	TDK
Load switches	M1, M2	-	NTS2101P	On Semiconductor

## 12. Package

### ■ Outline Dimensions



### ■ Marking



- (1) Pin 1 Mark
- (2) Part No. : 2200
- (3) Year Code (last 1 digit)
- (4) Week Code
- (5) Management Code.

**13. Revise History**

Date (YY/MM/DD)	Revision	Page	Contents
2012/11/19	00		First edition
2014/04/28	01	14	Replace "Outline dimensions"

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