Excellent Integrated System Limited

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 (±2%) per 1 cell 5.0 V (±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

3. Table of Contents

4. Block Diagram

■ **When set output voltage to 4 V**

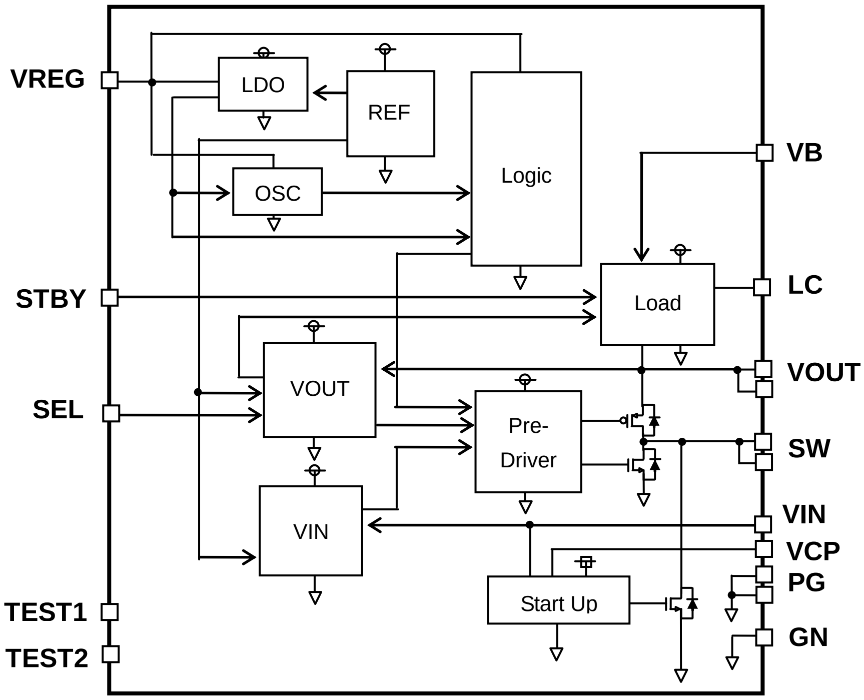


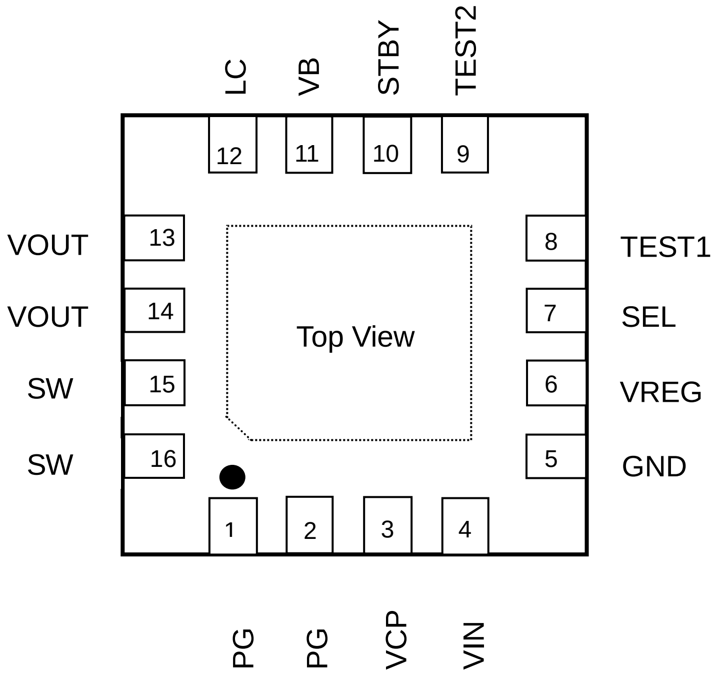
Figure 1. AP2200 Block Diagram

5. Ordering Information

AP2200 -30 ～ 85℃ 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_{VIN1}	-0.3	1.98	V	(Note 5)
	V_{VIN2}	-0.3	5.5	V	(Note 6)
Input power	P_{IN}		0.8	W	
Storage temperature Range	Tstg	-40	150	°C	
Junction temperature	Tj	-30	150	°C	
Power dissipation	Pd		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_{VIN}	0.4		1.6	V	(Note7)
Operational temperature	T_A	-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	$V_{VINSTUP}$		-	0.5	V	-30°C < Ta < -10°C
			0.3	0.4	V	-10°C < Ta < 85°C
DC-DC converter						
V_{OUT} voltage	V_{TGT}	3.96	4.0	4.04	V	T_A = 25 °C, SEL="L"
		3.92	4.0	4.08		T_A = -30 to 85°C , SEL="L"
		4.75	5.0	5.25		T_A = -30 to 85°C , SEL="H"
V_{OUT} hysteresis	V_{TGTHYS}	0.16	0.38	0.60	%	
High-side on resistance	R_{ONTOP}		0.2		Ω	
Low-side on resistance	R_{ONBOT}		0.1			
Switching frequency	f_{OSC}	450	500	550	kHz	
Low-side current limit	I_{LIM}	0.9	1.2	1.5	A	
MPPT circuit						
VPM open circuit voltage ratio	MPP	78	80	82	%	MPP=V_{PM}/V_{OC}
Open circuit voltage sampling period	t_{SH}	90	100	110	ms	
Monitoring circuit						
No battery detect voltage	V_{BLOW}	1.0	-	2.5	V	
Low V_{OUT} detect voltage	V_{OL}	2.35	2.65	2.90	V	
Logic I/O						
External switch driving voltage	V_{OLLC}	-	-	GND+0.1	V	I_{LC}=-1uA
	V_{OHLC}	V_{OUT}-0.45 V_B-0.45	-	-		I_{LC}=1uA $V_{OUT}>V_B$ $V_{OUT}<V_B$
Standby input voltage	V_{ILSTB}	-	-	0.3	V	
	V_{IHSTB}	1.0	-	-		
Output voltage switching input voltage (Note 9)	V_{ILSEL}	-	-	V_{OUT}*0.3	V	
	V_{IHSEL}	V_{OUT}*0.7	-	-		
Control part						
Internal regulator voltage	V_{REG}	1.62	1.8	1.98	V	
Operating frequency	f_{CK}	0.9	1.0	1.1	MHz	
Pin current						
VIN pin current	I_{VIN}	-	-	50	µA	During DC-DC operation: VIN<1.2V@ T_A >25°C VIN<1.6V@ T_A <25°C
VB pin current	I_{VB}	-	10	20	µA	LC=H/L
Internal pull-down resistance						
STBY pin	R_{PDSTBY}	0.5	-	1.5	MΩ	
SEL pin	R_{PDSEL}	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 VBLOW 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 VBLOW 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 VOUT pin.
3	The VOUT pin voltage is less than or equal to V_{OL}:	When the VOUT 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_{VOUT} 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 VOUT reaches VTGT again, the external load switch is not turned ON. This prevents back flow from the battery to VOUT 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 VOC 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)

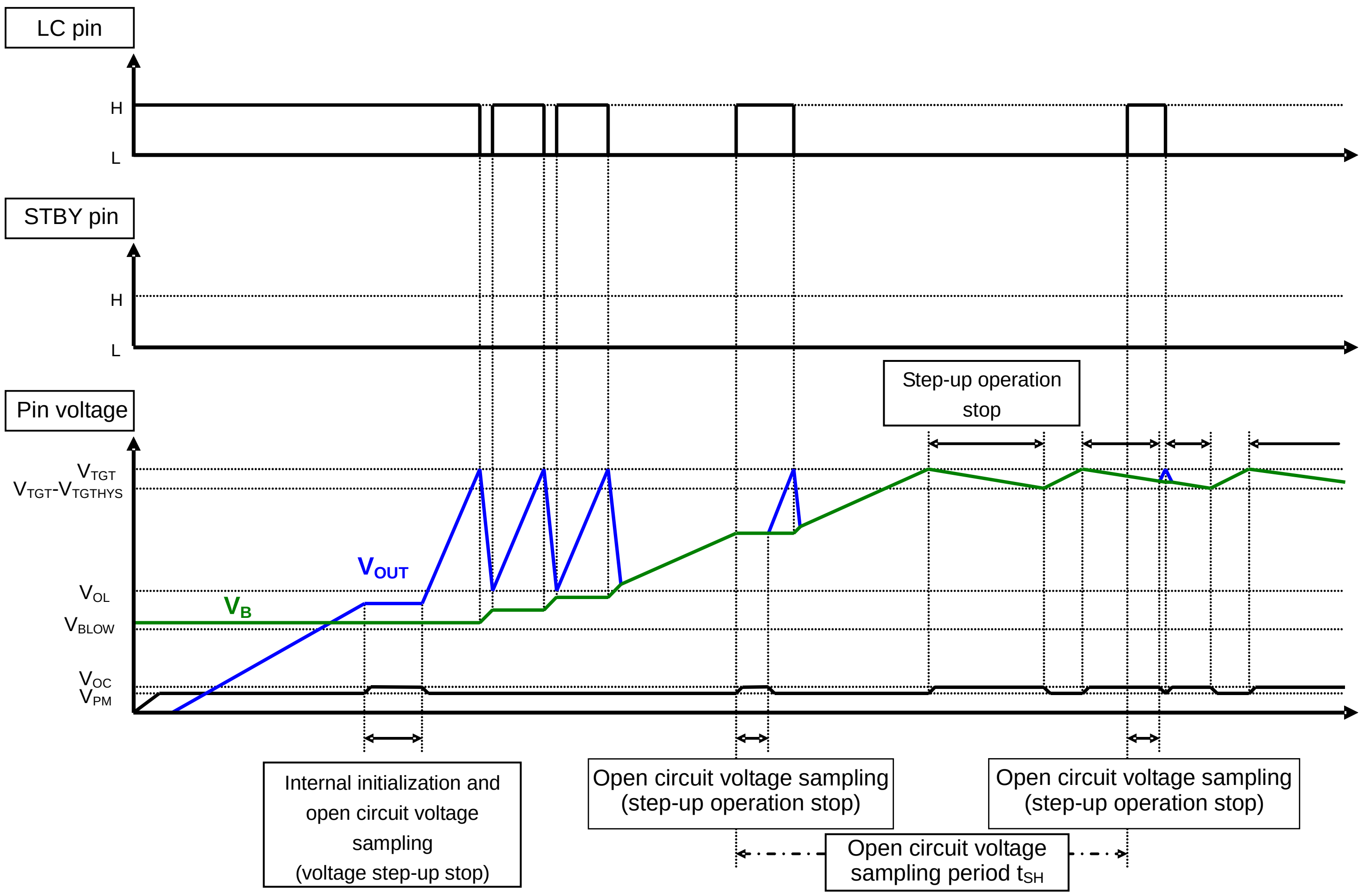


Figure 2. Normal operation

- Behavior of when solar cell output decreases

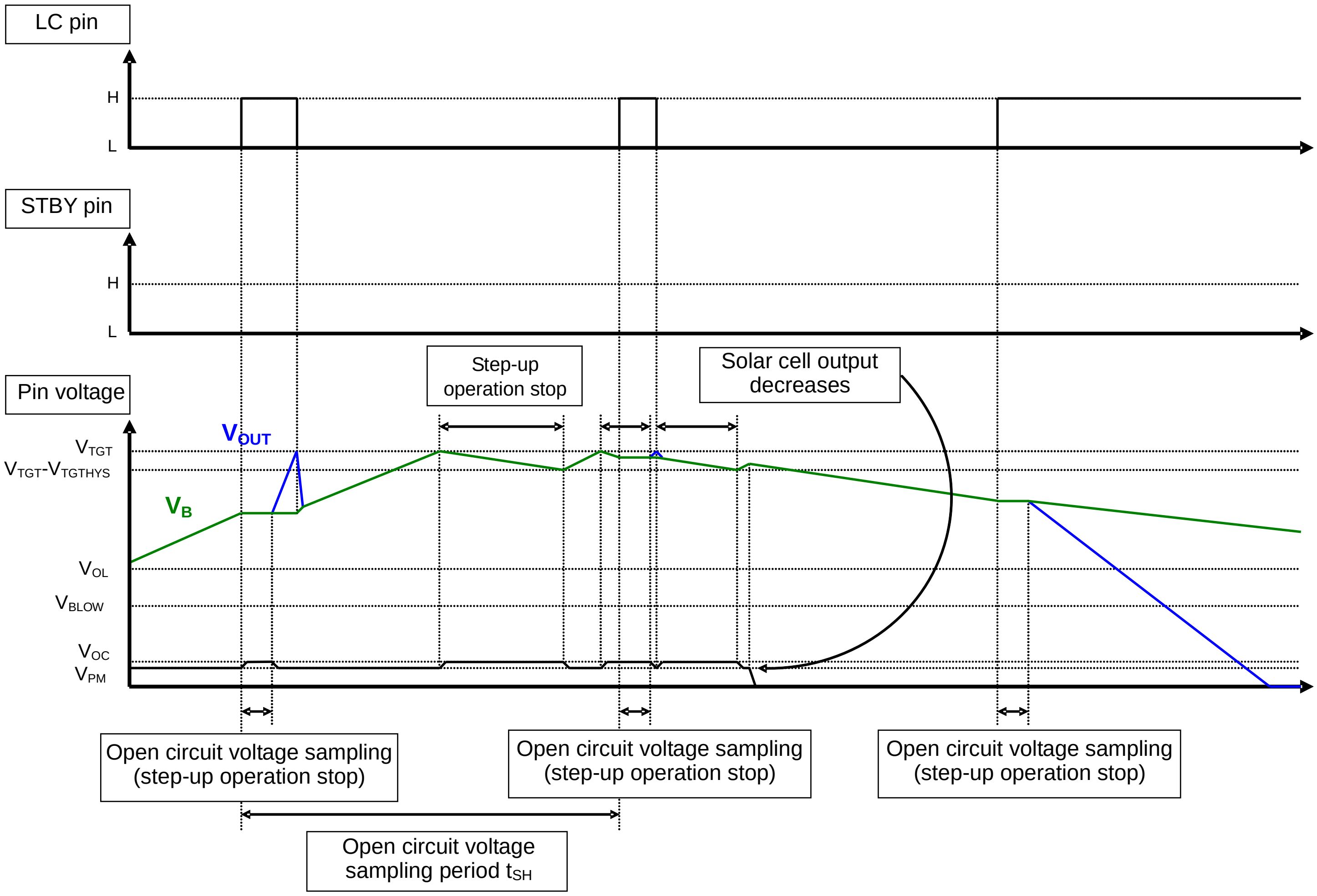


Figure 3. Behavior of when solar cell output decreases

- Behavior when the STBY pin is asserted

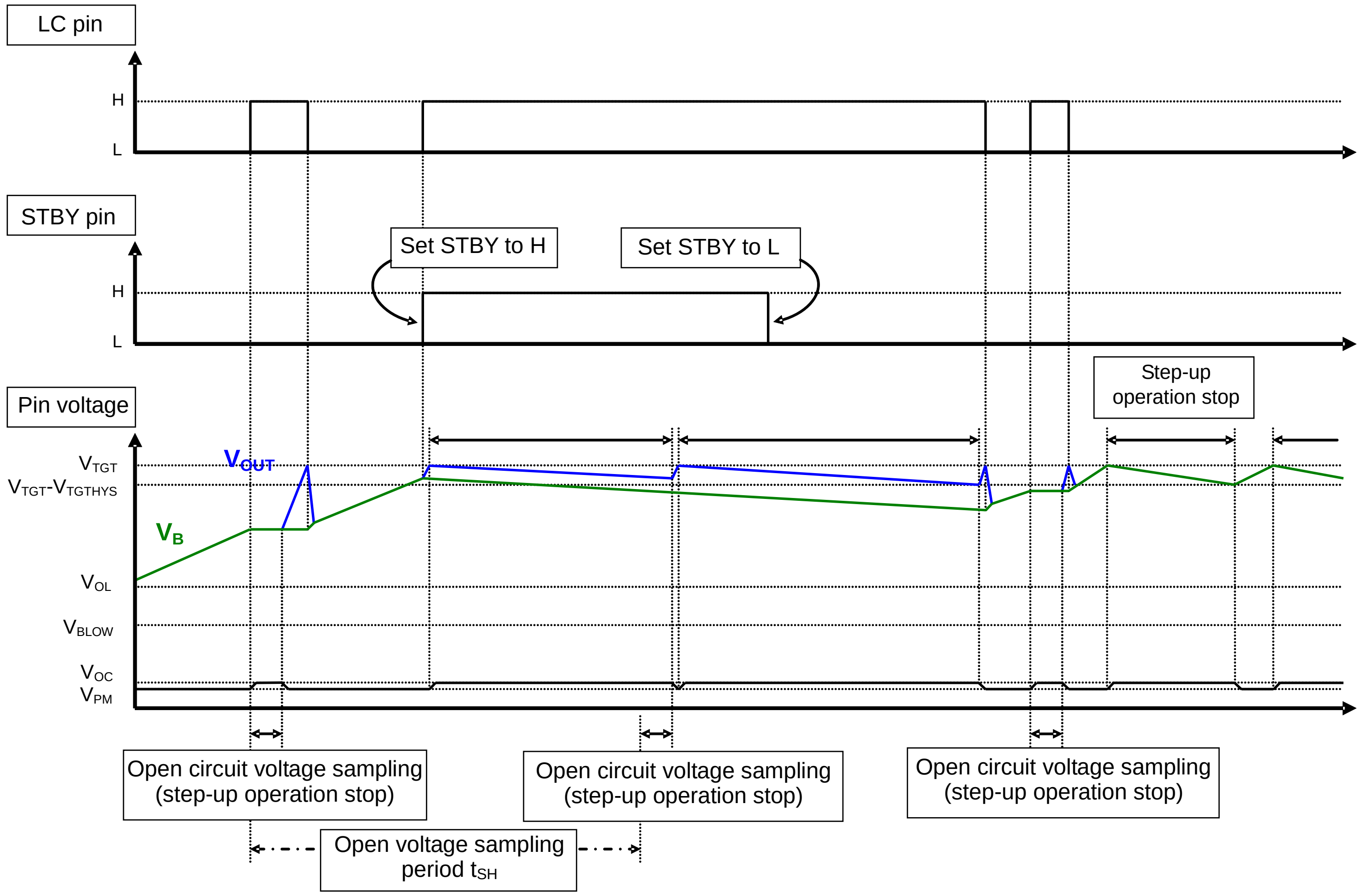


Figure 4. Behavior when the STBY pin is asserted

- Behavior when no battery is connected.

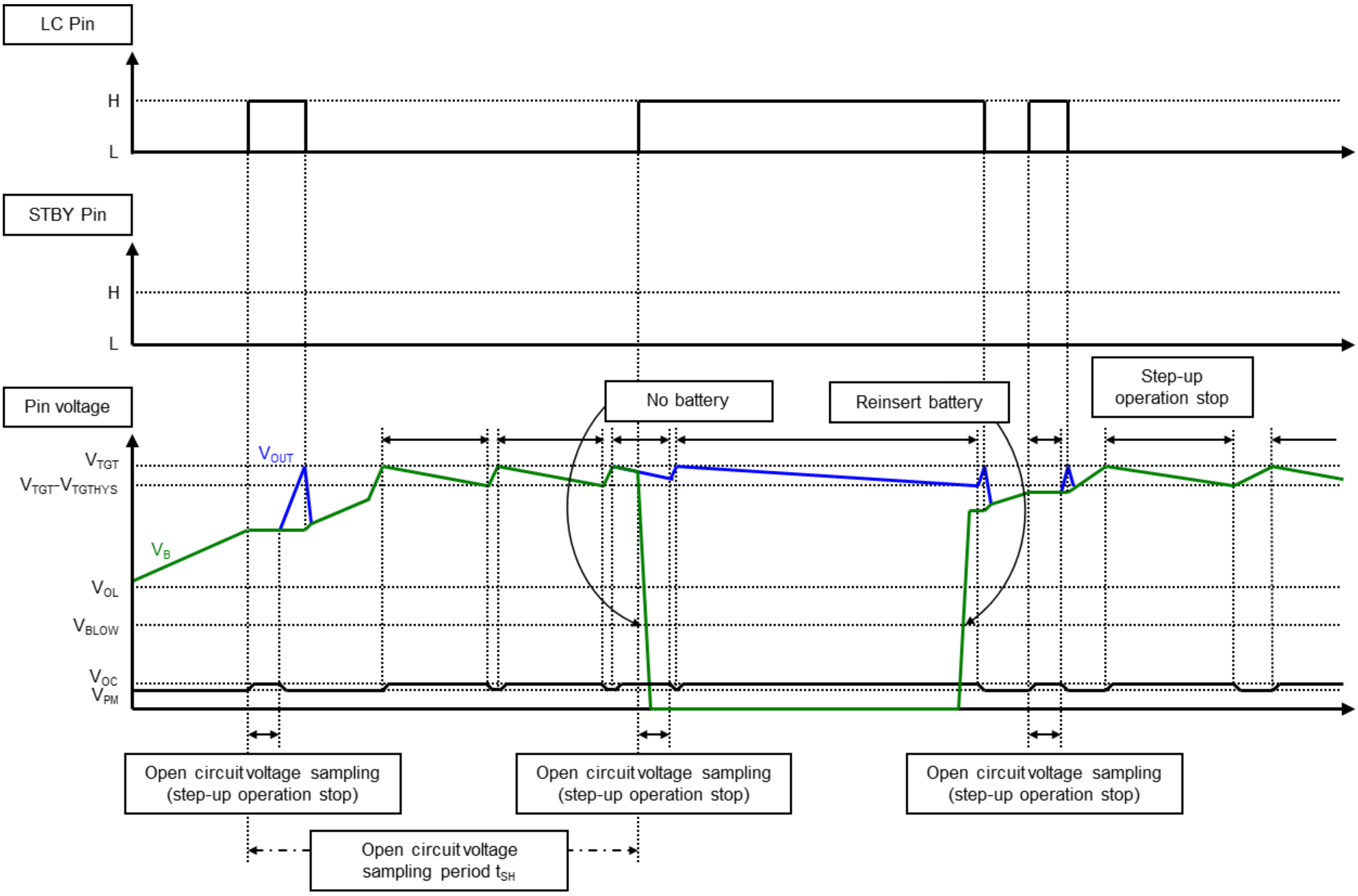


Figure 5. Behavior of when no battery is connected.

11. Recommended External Circuits

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

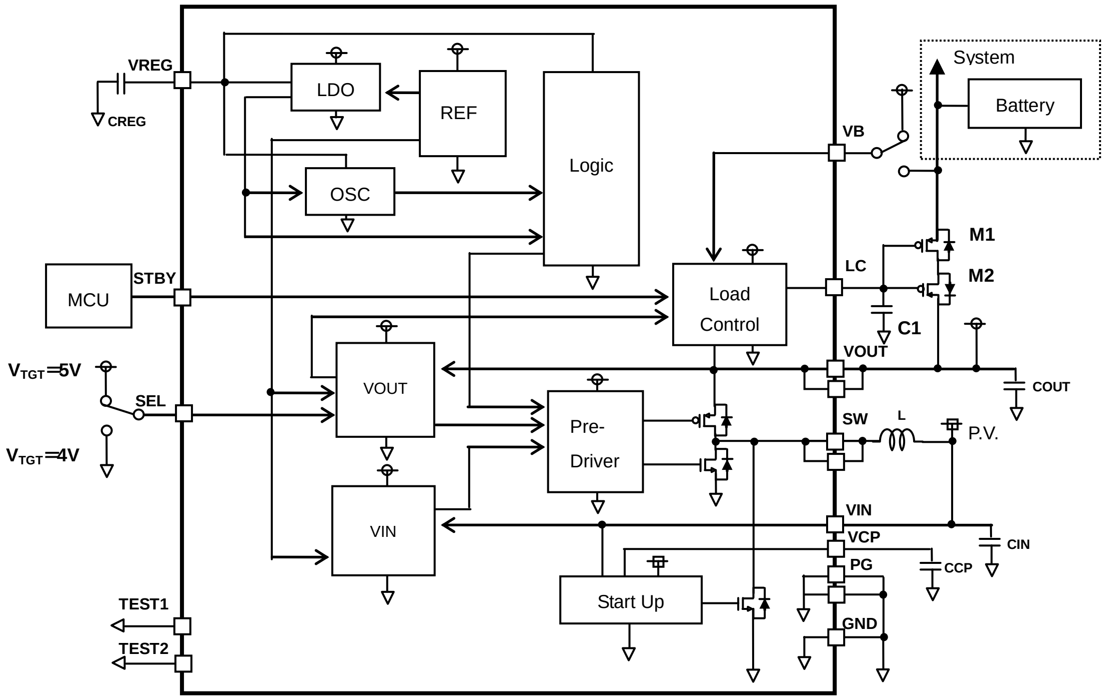


Figure 6. External Circuits

Note 10. : 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.

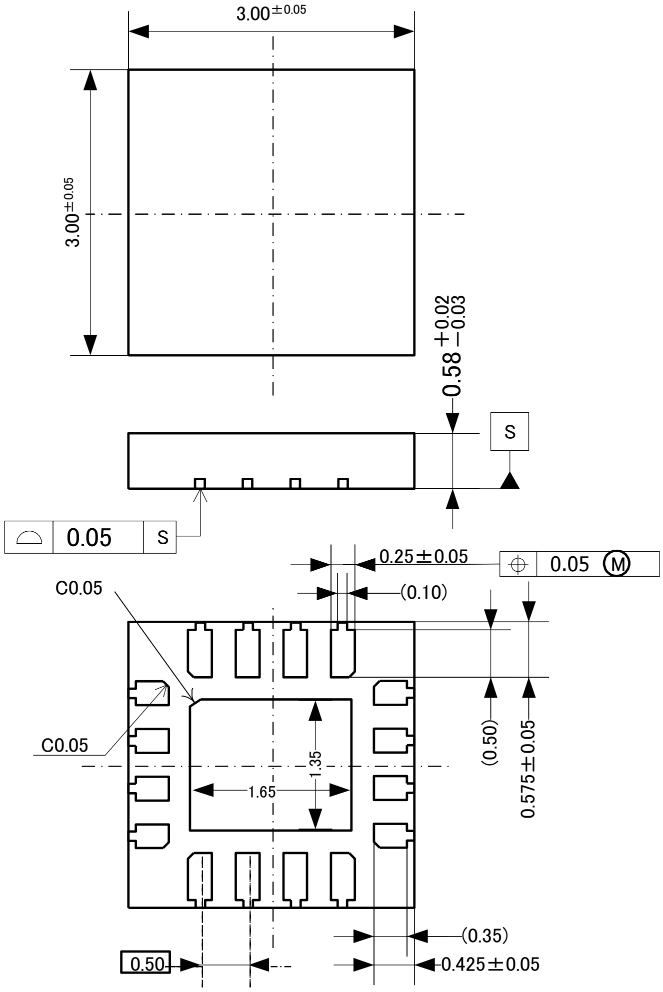
■ Recommended Parts

Table 3. Reference design list of materials

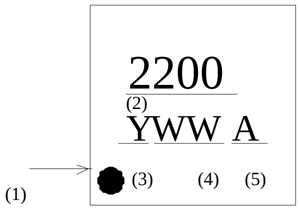
Item	Symbol	Value	Part number	Manufacturer
Ceramic Capacitors	CIN	10μF	-	-
	COUT	10μF	-	-
	CREG	1μF	-	-
	CCP	0.01μF	-	-
	C1	0.1μF	-	-
Inductors	L1(with 1cell)	4.7μH	SLF6045T-4R7N2R4-3PF	TDK
	L2(with 2cell)	6.8μH	SLF6045T-6R8N2R0-3PF	TDK
Load switches	M1, M2	-	NTS2101P	On Semiconductor

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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