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AP2200

Step-up DC/DC converter IC supporting 1 or 2 solar cells

OVERVIEW

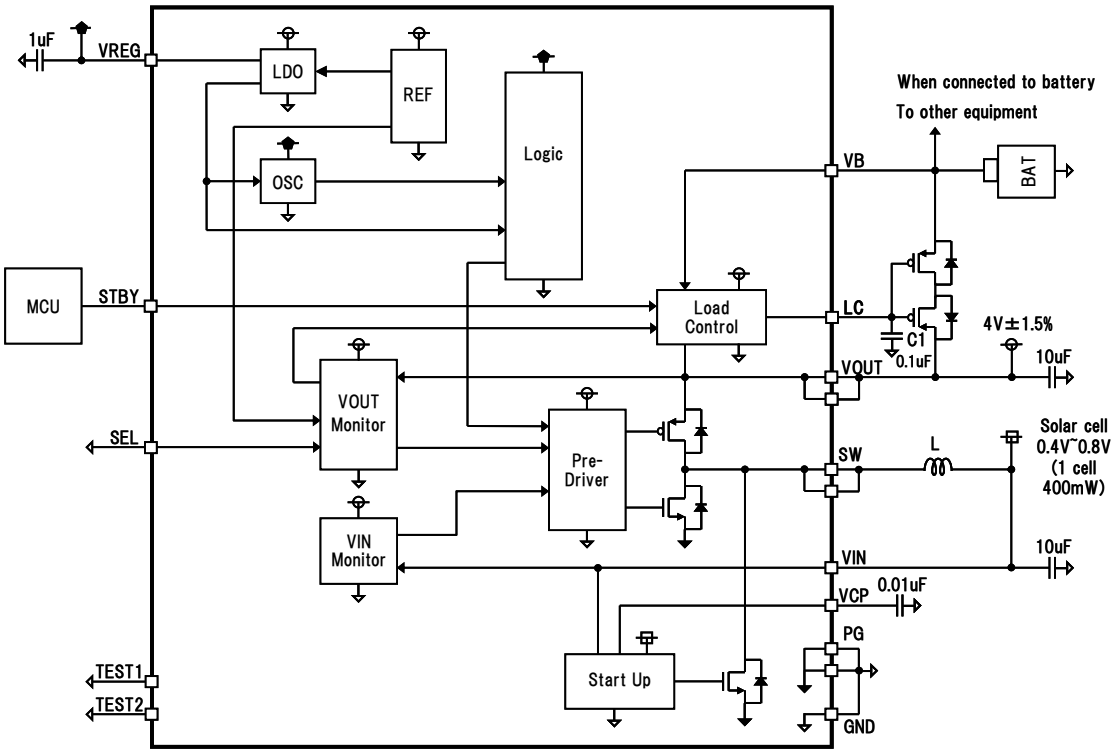
The AP2200 is a voltage step-up DC/DC converter using the synchronous rectification method to be activated with 1 or 2 solar cells and is ideal for charging lithium-ion batteries or outputting USB VBUS voltage. Also, the MPPT (Max Power Point Tracking) function is embedded in order to maximize the output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

FEATURES

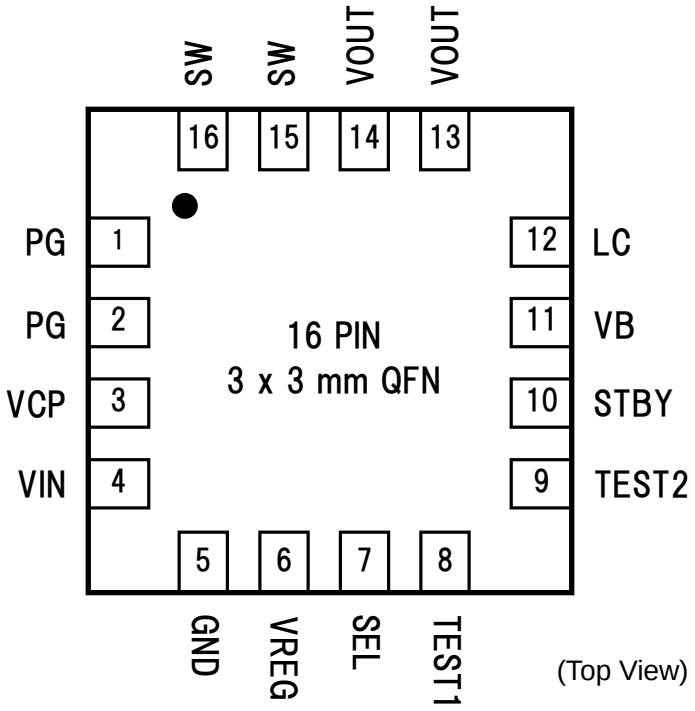
■ Input voltage range	0.4 V to 1.6 V
■ Operating temperature range	-30 to 85°C
■ Input power	Up to 400 mW per 1 cell Up to 800 mW per 2 cells
■ Output voltage	4.0 V (±2%) per 1 cell 5.0 V (±5.0%) per 2 cells
■ Control method	Comparator control method
■ Rectification method	Synchronous rectification method
■ 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

BLOCK DIAGRAM

Set output voltage to 4 V



PIN LAYOUT



(Top View)

I/O PINS & FUNCTIONS

Table 1 Pin functions

Pin No	Pin name	Type (Note1)	I/O (Note2)	Description	Remarks
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: 4 V / H: 5 V
8	TEST1	-	-	Test pin	(Note3)
9	TEST2	-	-	Test pin	(Note3)
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	(Note4)

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: The test pin should be connected to GND.

Note 4: The tab pin may be connected to GND or left open.

ABSOLUTE MAXIMUM RATINGS

Table 2 Absolute maximum ratings

T_A = 25ºC except as otherwise noted

Item	Symbol	Min	Max	Unit	Remarks
Pin voltage Range (Note1)	V_{IN1}	-0.3	1.98	V	Note3
	V_{IN2}	-0.3	5.5	V	Note4
Input power	P_{IN}		0.8	W	
Operational temperature Range	T_A	-30	85	°C	
Storage temperature Range	T_{STG}	-40	150	°C	
Junction temperature	T_J		150	°C	
Power dissipation	P_D		0.8	W	

Note 1: The voltage is based on ground pin voltage.

Note 2: If the absolute maximum rating is exceeded, the device may be damaged.
Also, normal behavior cannot be guaranteed.

Note 3: VIN pin and VREG pin

Note 4: VCP pin, SEL pin, STBY pin, VB pin, LC pin, VOUT pin and SW pin

OPERATING CONDITIONS

Table 3 Operating conditions

Item	Symbol	Condition	Min	Typ	Max	Unit
Supply voltage range	V_{IN}		0.4		1.6	V
Supply voltage on startup	V_{INSTUP}	-30°C < T_A <-10°C -10°C < T_A <85°C	0.5 0.4	-	1.6	V
Operational temperature	T_A		-30	-	85	°C

Note 1: The voltage is based on the ground pin.

ELECTRIC CHARACTERISTICS

Table 4 Electric characteristics

T_A = 25ºC except as otherwise noted

Item	Symbol	Condition	Min	Typ	Max	Unit
DC/DC converter						
V_{OUT} voltage (Note3)	V_{TGT}	T_A = 25 ºC, SEL=0	3.96	4.0	4.04	V
		T_A = -30 to 85ºC , SEL=0	3.92	4.0	4.08	
		T_A = -30 to 85ºC , SEL=1	4.75	5.0	5.25	
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 (Note 2)	I_{LIM}		0.9	1.2	1.5	A
MPPT circuit						
VPM open circuit voltage ratio	MPP	MPP=V_{PM}/V_{OC}	78	80	82	%
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}	I=-1uA	-	-	GND+0.1	V
	V_{OHLC}	I=1uA $V_{OUT}>V_B$ $V_{OUT}<V_B$	 V_{OUT}-0.45 V_B-0.45	-	-	
Standby input voltage	V_{ILSTB}		-	-	0.3	V
	V_{IHSTB}		1.0	-	-	
Output voltage switching input voltage (Note 4)	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}	During normal operation: VIN<1.2V@ T_A >25°C VIN<1.6V@ T_A <25°C	-	-	50	μA
VB pin current	I_{VB}	LC=H/L	-	10	20	μA
Internal pull-down resistance						
STBY pin	R_{PDSTBY}		0.5	-	1.5	MΩ
SEL pin	R_{PDSEL}		0.5	-	1.5	MΩ

Note 1: The voltage is based on the ground pin.

Note 2: Not tested in mass production.

Note 3: Only tested at T_A = 25ºC in mass production.

Note 4: Connect the SEL pin to the VOUT or the GND pin.

OPERATION DETAILS

1. Operation overview

When the output voltage is entered into V_{IN} 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:

- 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}) by applying voltage, the external load switch is turned OFF to stop the power supply. The step-up converter is still running even in a standby state. When the STBY pin is set to a low level (V_{ILSTB}) by applying voltage, the standby mode is released to start the power supply.

- The VB pin voltage is less than or equal to V_{BLOW}:

  The AP2200 has a battery monitoring function. When the VB pin voltage deceases to V_{BLOW} or lower, a battery is assumed to be removed and the external load switch is turned OFF to stop the power supply. When the VB pin voltage increases to V_{BLOW} or higher, a battery is assumed to be reinserted and the external load switch in turned ON to start the power supply.
  To disable this function, connect the VB pin to the VOUT pin.

- 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 the power supply. The step-up converter is still running. When V_{OUT} reaches V_{TGT} again, the power supply is restarted.

- 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.

2. Output voltage setting

The output voltage (V_{TGT}) is selectable based on the SEL pin. (Table 5)

Table 5 Output voltage setting

SEL pin level	Output voltage (V_{TGT}) setting
0	4 V
1	5 V

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.

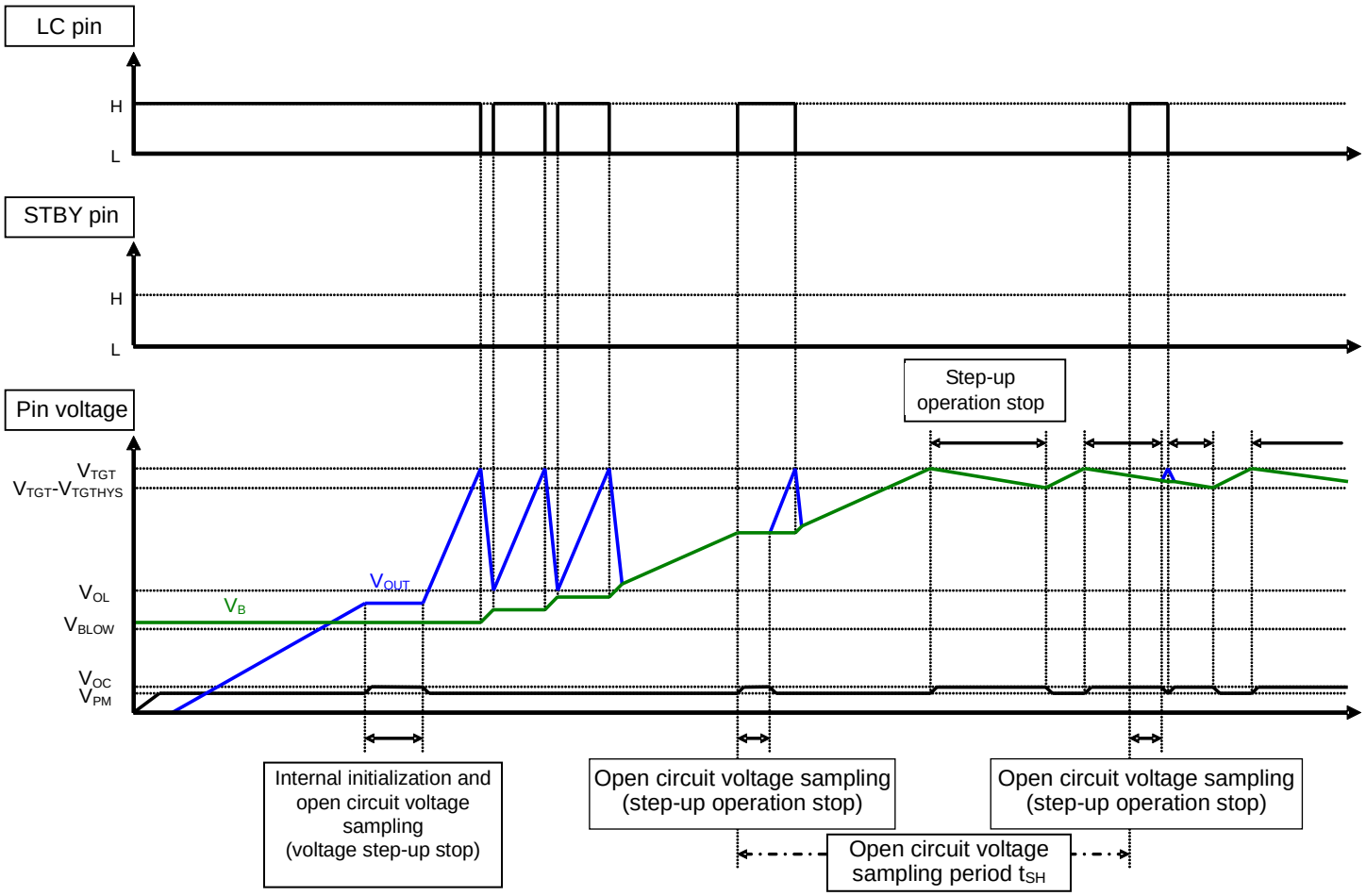
4. Output voltage control

The step-up converter always monitors V_{OUT}. As soon as VOUT 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 form V_{TGT}, the step-up operation is restarted.

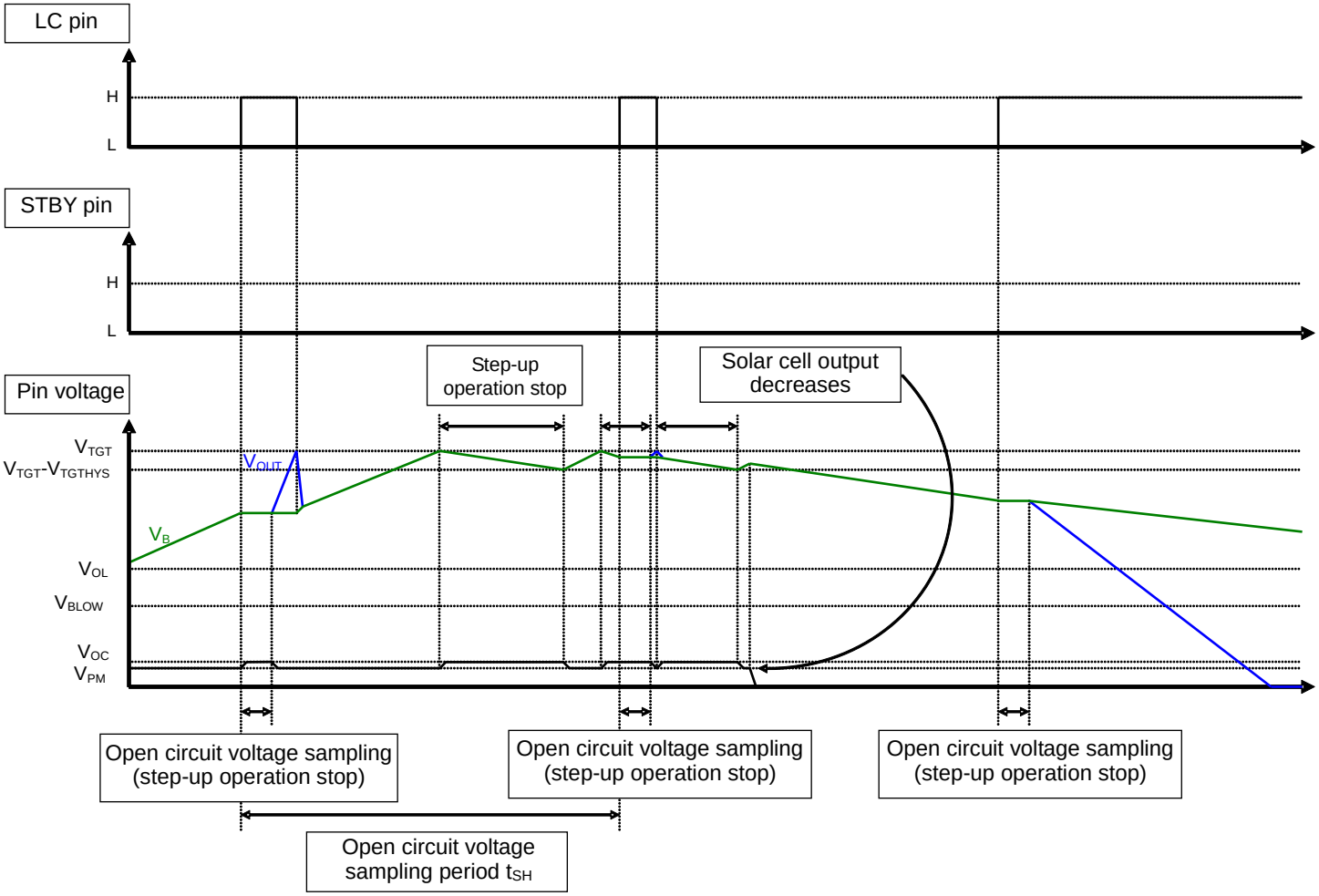
5. Timing chart

Note: A timing chart only shows an operation overview and the scale of time and voltage is not accurate.

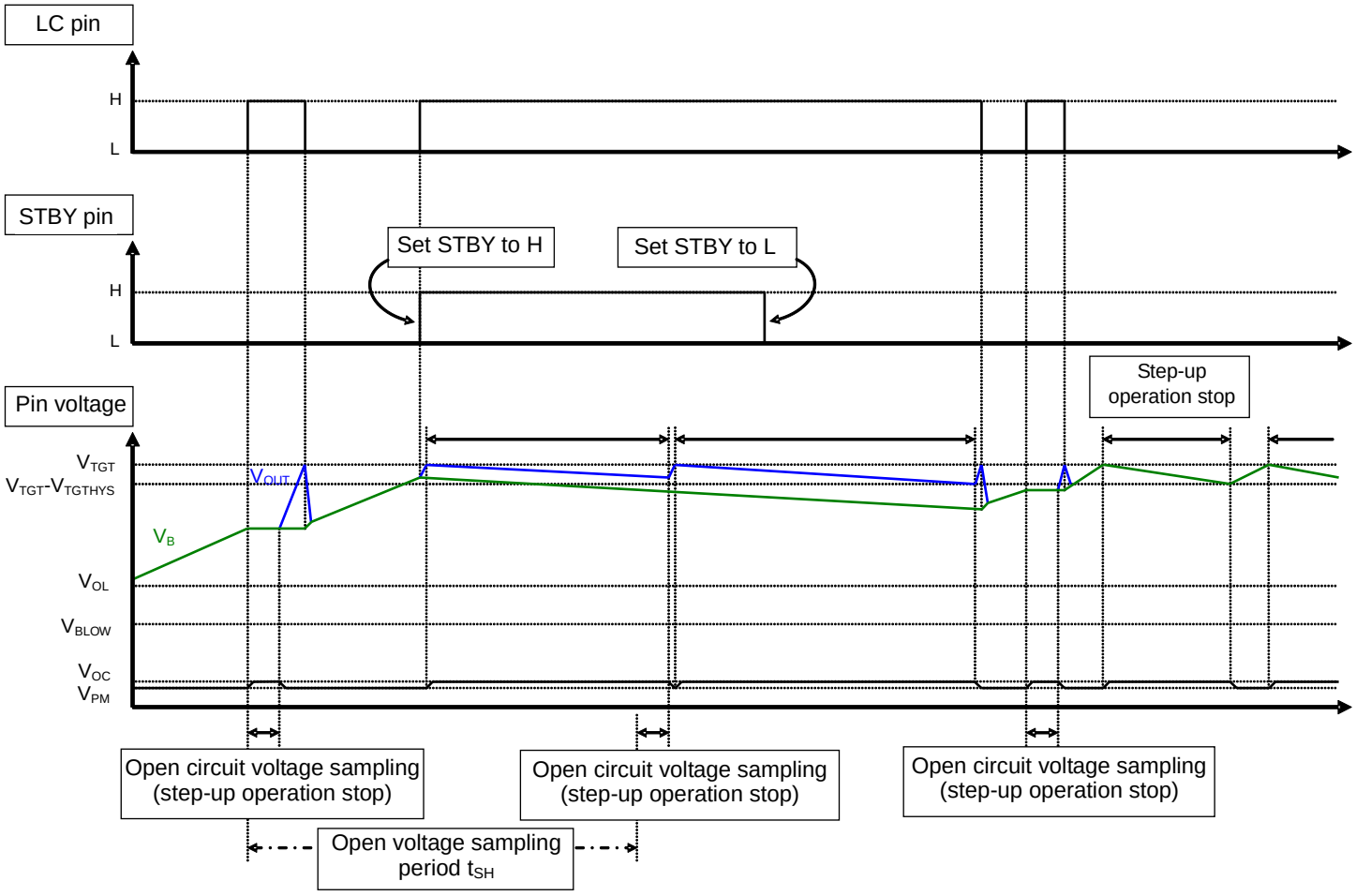
5.1. Normal operation (the voltage increases to V_{OUT} after startup)



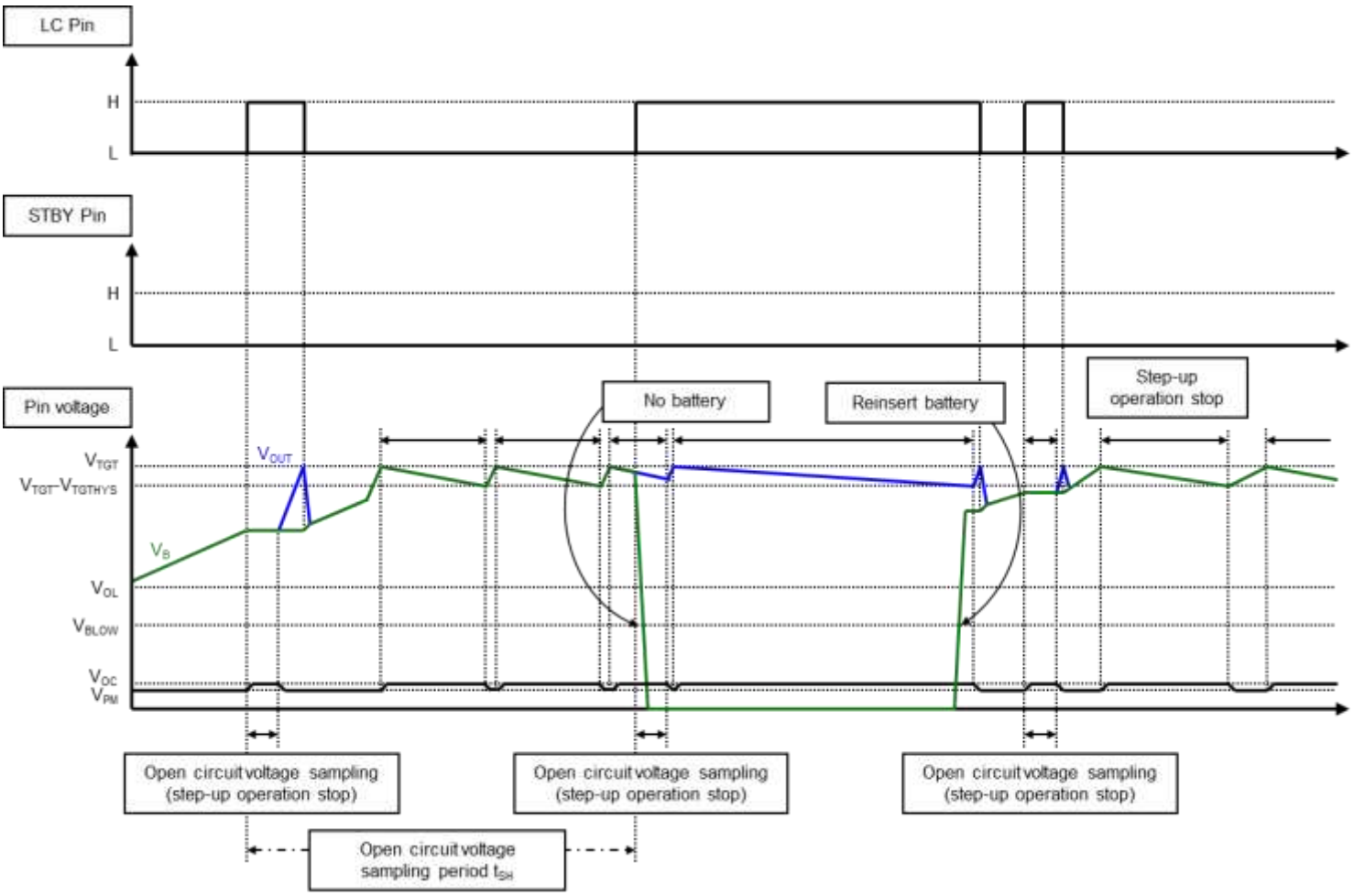
5.2. Behavior when solar cell output decreases



5.3. Behavior when the STBY pin is asserted



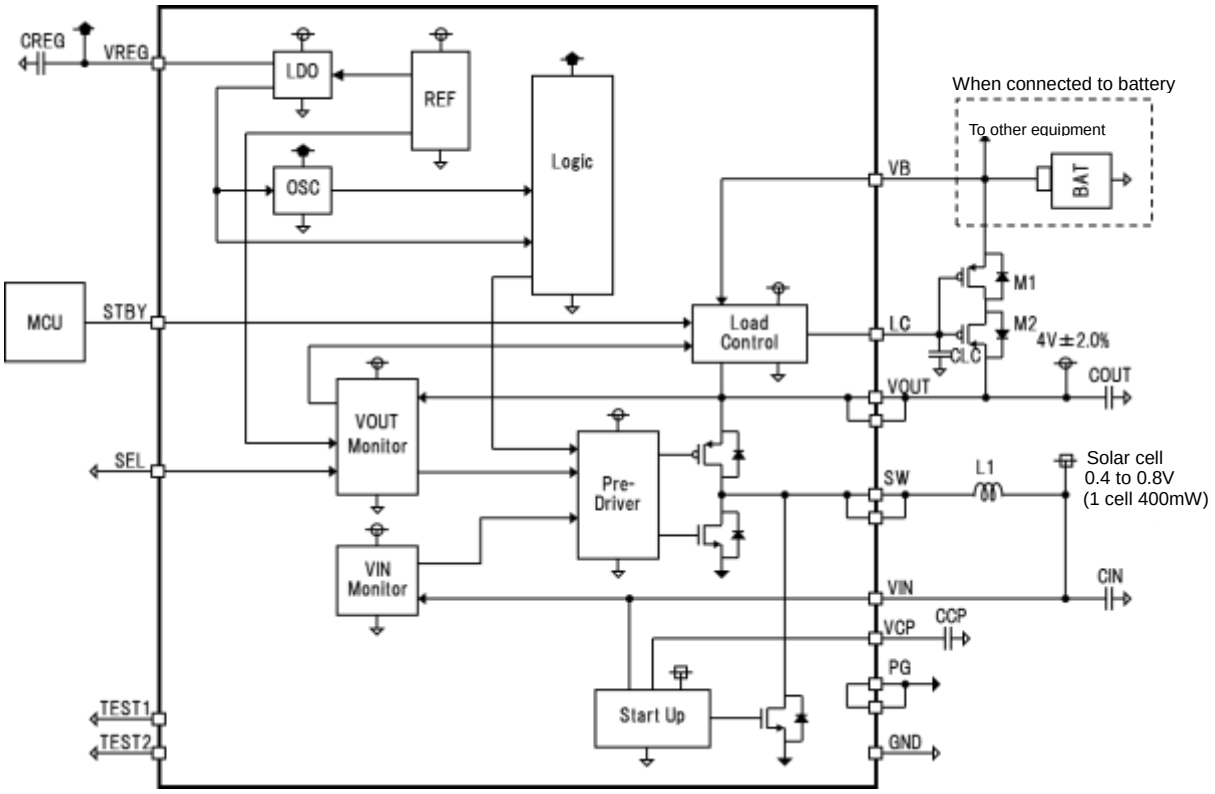
5.4. Behavior when no battery is connected.



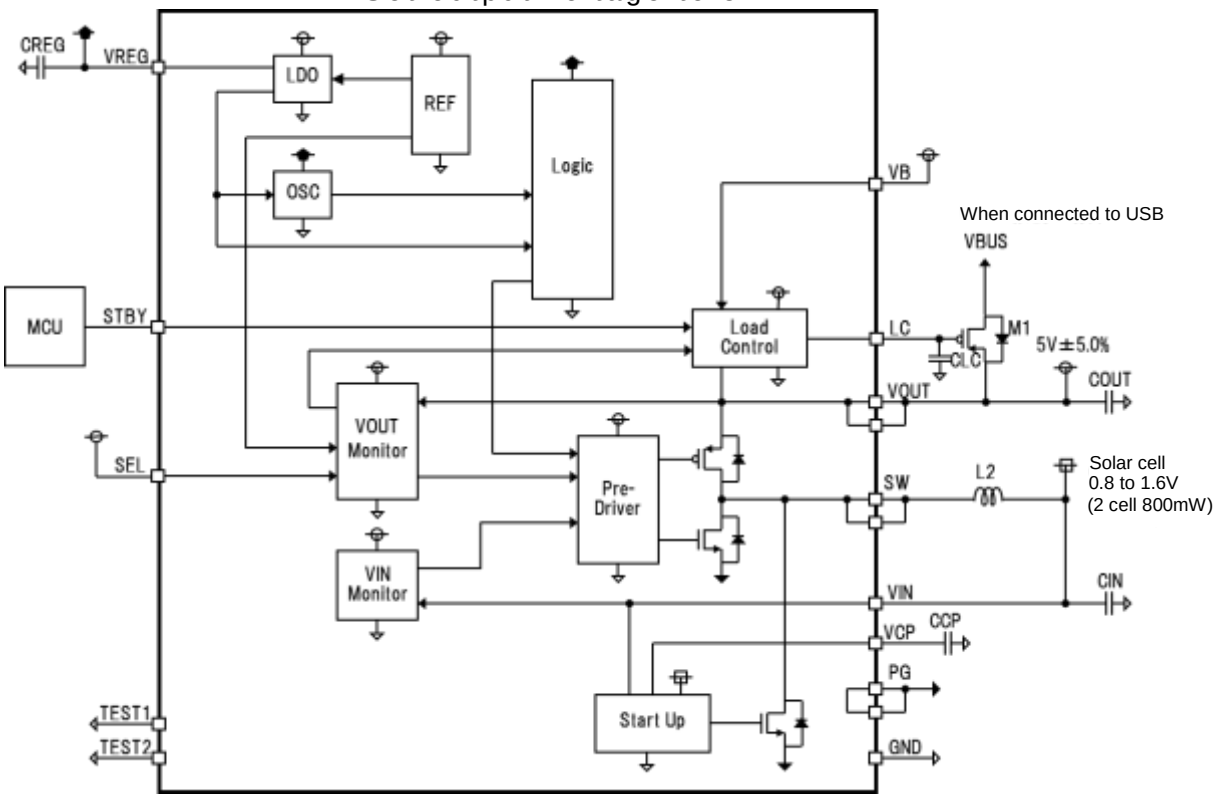
REFERENCE DESIGN

- Application schematics

Set output voltage to 4V



Set output voltage to 5V



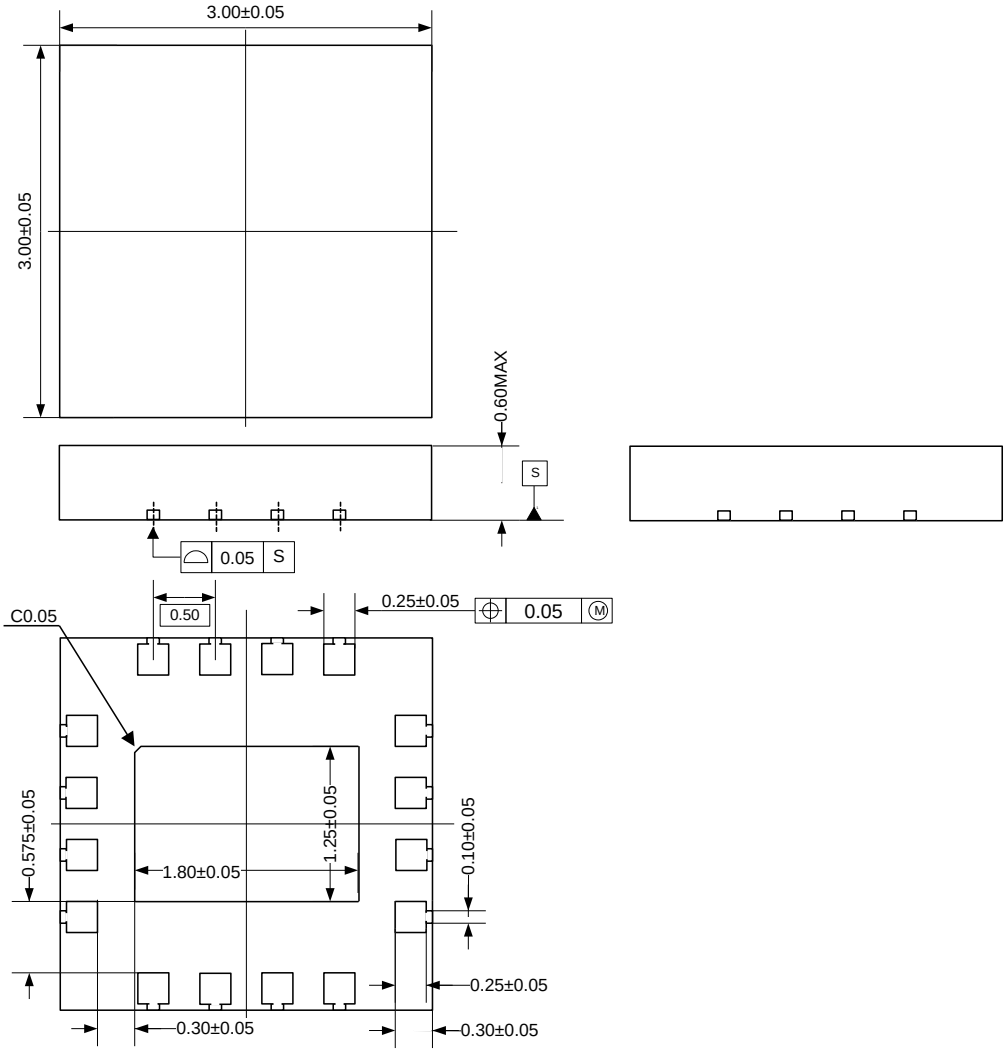
Note1: Select the C1 value to prevent the LC pin voltage from exceeding the absolute maximum rating due to the current through parasitic capacitance of the external load switch.

Note2: Please refer to table 6 for external components.

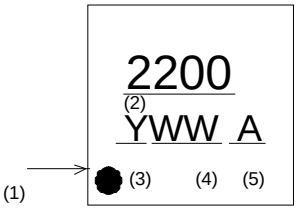
Table 6. Reference design list of materials

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

PACKAGE


3.00±0.05
3.00±0.05
0.60MAX
S
0.05 S
0.50
0.25±0.05
0.05 M
C0.05
0.575±0.05
1.25±0.05
1.80±0.05
0.10±0.05
0.25±0.05
0.30±0.05
0.30±0.05

MARKING



(1) Pin 1 Mark
(2) Part No. : 2200
(3) Year Code (last 1 digit, ex: “2” for year 2012)
(4) Week Code
(5) Management No.

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