

# PL93061 High Efficiency, Synchronous bi-directional Buck-Boost Charger with integrated fast charge protocols

## 1 Features

- Bi-directional buck-boost charging and discharging with PD3.0, QC3.0, AFC, SCP, FCP, BC1.2 protocols integrated
- Support source role, sink role and DRP role for PD3.0
- Charging management, including trickle charging, CC charging, CV charging and charging termination functions
- Wide VBUS and VBAT voltage operation range up to 24V
- Integrated 8mR H-bridge MOSFET
- Support two C port
- Support over current, over voltage protection for each port.
- 1 Cell to 4 Cells battery charge management
- Support both 4.2V and 3.5V battery charging
- Programmable switching frequency 150Khz and 300Khz
- Programmable VINREG voltage to prevent overloading adaptor.
- 12-bit DAC converter to guarantee programmable current limit with 10mA/step
- 12-bit DAC converter to guarantee programmable output voltage with 5mV/step
- Programmable cable drop compensation
- Integrate N-Gate drivers for USB ports
- Battery voltage, BUS voltage and all ports voltage sensing on VMON pin
- Battery current, BUS current and all ports current sensing on VMON pin
- Comprehensive protection features in on-chip buck-boost controller
- Supports pass-through operation when VBUS is close to VBAT
- I<sup>2</sup>C interface is available to communicate with MCU
- On-chip LDO to provide power for MCU
- QFN6x6-42 package

## 2 Applications

- Power Bank
- Battery packs
- Li-ion Battery Charger
- Portable equipments
- General fast Charging
- Smart USB Sockets

## 3 Description

PL93061 is a high efficiency, synchronous bi-directional buck-boost charger with integrated fast charge protocols. It is a comprehensive and flexible buck-boost charger platform designed for most of fast charging applications with type-C port and PD protocol. It can be programmed to buck charging, boost charging or buck-boost charging. PL93061 provides I<sup>2</sup>C interface to communicate with MCU, provides high voltage sensing for battery and BUS terminals, accurate rail-rail current sensing for battery current, BUS current and USB ports currents. It also provides high voltage blocking for CC1, CC2, DP, DM communication signals for all of the USB ports. PL93061 can work with a general MCU to provide a complete, powerful and flexible buck-boost charging system for all kinds of fast charge application such as power bank, battery packs, or portable energy cubic etc.

In charging mode, it steps up or down the input voltage to effectively charge the batteries. PL93061 supports trickle charging, constant current (CC) charging and constant voltage (CV) charging management. The charging current and charging voltage can be programmed by two 12-bit DAC converters.

The PL93061 features I<sup>2</sup>C interface, so the user can easily control the charging/discharging mode, and program charging current, charging voltage, output voltage, and output current limits through I<sup>2</sup>C. It also monitors the status of USB ports and provides two NMOS gate drivers to control the power path independently. User can also use I<sup>2</sup>C to monitor the status of DC-DC, even the whole system.

PL93061 also provides VMON pin, through which the MCU can monitor VBUS, VBAT voltage, IBUS, IBAT current and the current of each port in real time. All these features simplify the system design and reduce BOM cost for any charging system.

The PL93061 supports under voltage protection, over voltage protection, over current protection, short circuit protection and over temperature protections to ensure system safety under different abnormal conditions.

## 4 Typical Application Schematic

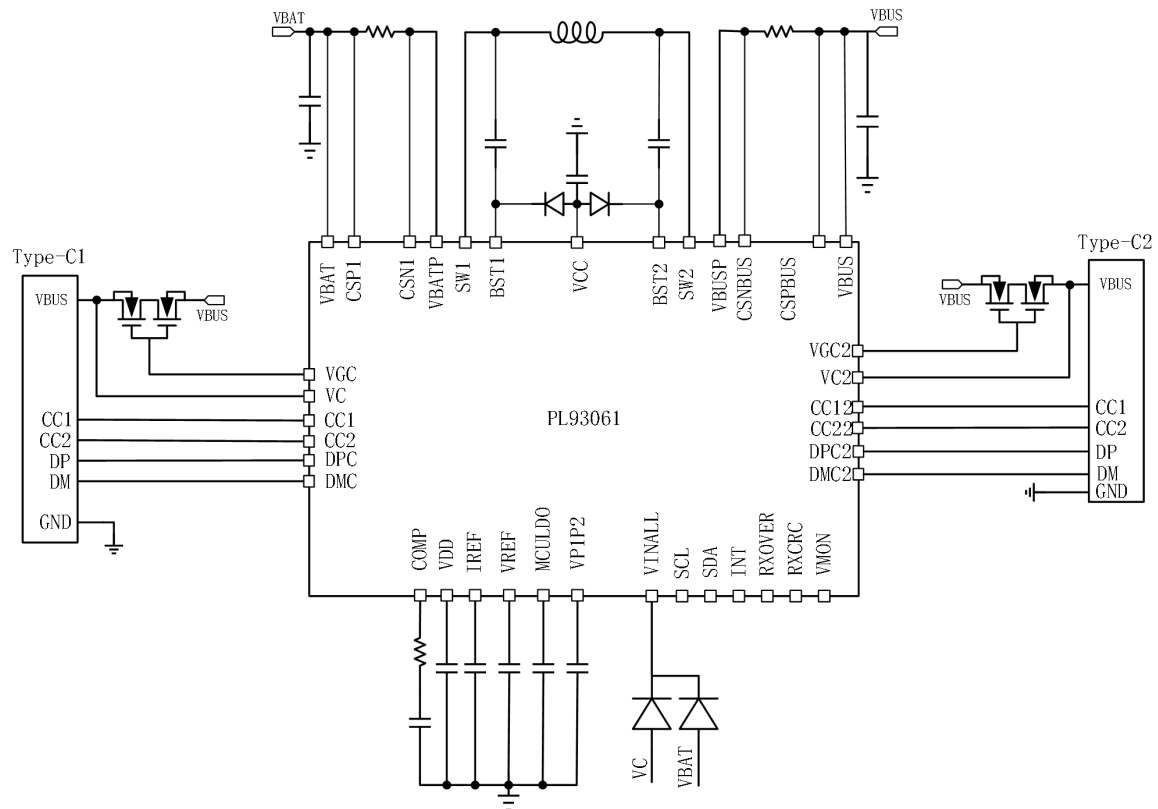


Fig. 4-1 Typical Application Schematic

## 5 Pin Configuration and Functions

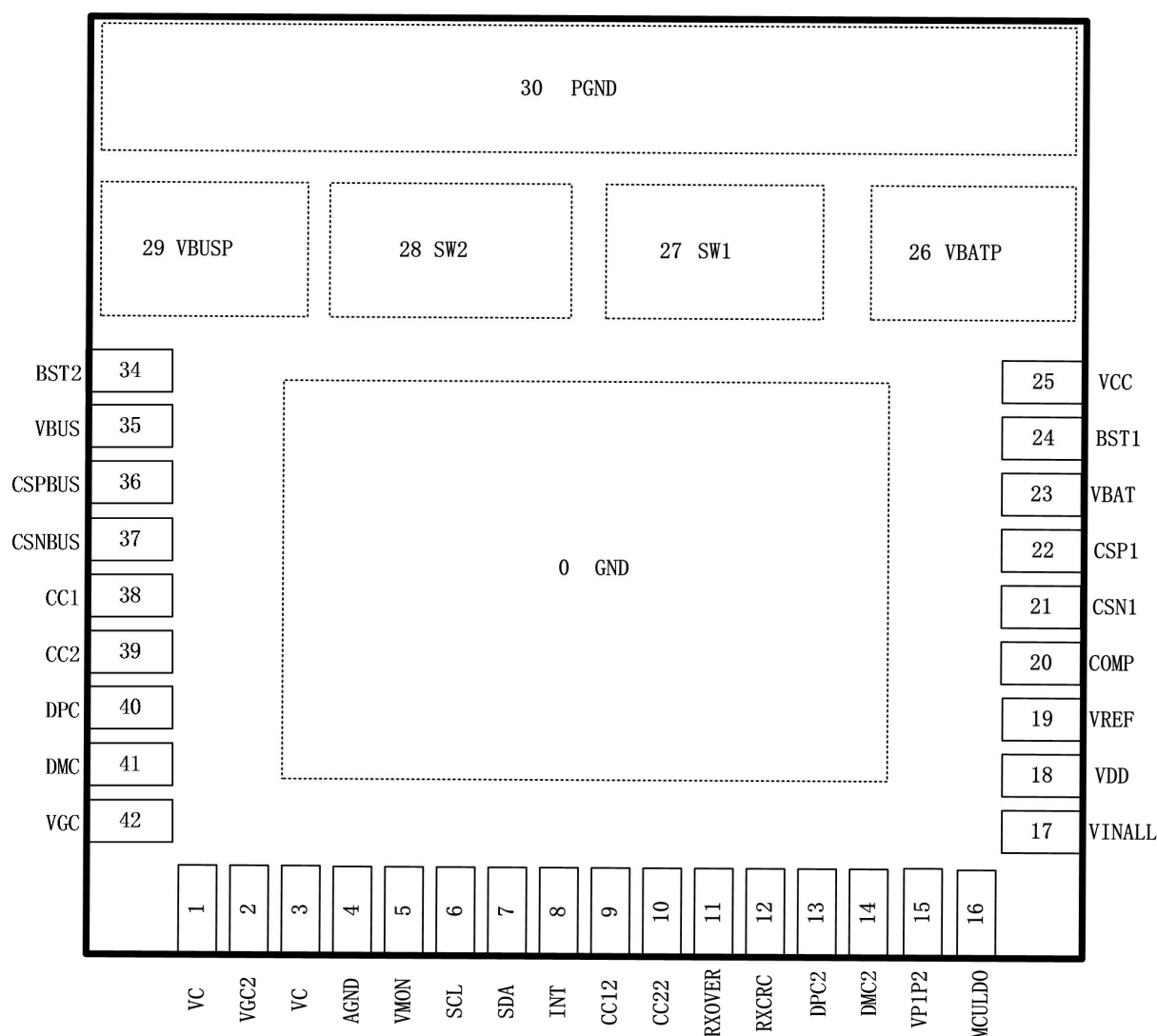


Fig. 5-1 Top view

Tab.5-1 PL93061 Pin-Functions (QFN6x6-42 Package)

Pin		Description
Number	Name	
1	VC	Used to sense the voltage of C port.
2	VGC2	NMOS gate driver to control the external NMOS of C2 port
3	VC2	Used to sense the voltage of C2 port.
0,4	AGND	Analog ground. User shall connect PGND and AGND together on PCB.
5	VMON	Used to detect VBUS/VBAT voltage, IBUS/IBAT current, and the voltage drop of cut-off MOS for A/C ports. Connect this pin to MCU with a RC filter.
6	SCL	I <sup>2</sup> C clock line. Connect with a pull up resistor (typical 10kΩ). Connect to MCU
7	SDA	I <sup>2</sup> C data line. Connect with a pull up resistor (typical 10kΩ). Connect to MCU
8	INT	Open drain output for interrupt signal. Connect to MCU
9	CC12	Configuration Channel 1 for C2 port
10	CC22	Configuration Channel 2 for C2 port
11	RXOVER	Connect this pin to MCU
12	RXCRC	Connect this pin to MCU
13	DPC2	D+ signal for C2 port

14	DMC2	D- signal for C2 port
15	VP1P2	1.2V power supply.
16	MCULDO	3.3V voltage output for MCU
17	VINALL	Power supply to the IC. Connect to power rails with low voltage schottky diodes. Place a 1 $\mu$ F capacitor from this pin to GND as close to the IC as possible.
18	VDD	Output of internal 5V linear regulator. Connect a 1 $\mu$ F capacitor from VDD pin to GND as close to the IC as possible.
19	VREF	Reference voltage for voltage control loop
20	COMP	Error amplifier output and input to the PWM comparator. Connect frequency compensation components to this pin.
21	CSN1	Negative input of a current sense amplifier. Connect to one terminal of the current sense resistor in the VBAT side.
22	CSP1	Positive input of a current sense amplifier. Connect to one terminal of the current sense resistor in the VBAT side.
23	VBAT	Battery voltage or Input voltage. Place a 1 $\mu$ F capacitor from this pin to GND as close to the IC as possible.
24	BST1	Boot-Strap pin Connect a 0.1 $\mu$ F or greater capacitor between SW and BST to power the high side gate driver.
25	VCC	Power supply for high side and low side driver
26	VBATP	The power output node of the converter in charging mode, and the power input node of the converter in discharging mode. Connect these pins to the positive node of battery cells.
27	SW1	Power Switching pin. Connect this pin to the switching node of inductor.
28	SW2	Power Switching pin. Connect this pin to the switching node of inductor.
29	VBUSP	The power input node of the converter in charging mode, and the power output node of the converter in discharging mode.
30	PGND	Power ground. User shall connect PGND and AGND together on PCB.
34	BST2	Boot-Strap pin Connect a 0.1 $\mu$ F or greater capacitor between SW and BST to power the high side gate driver.
35	VBUS	Power node of the charger.
36	CSPBUS	Positive input of a current sense amplifier. Connect to one terminal of the current sense resistor.
37	CSNBUS	Negative input of a current sense amplifier. Connect to one terminal of the current sense resistor.
38	CC1	Configuration Channel 1 for C port
39	CC2	Configuration Channel 2 for C port
40	DPC	D+ signal for C port
41	DMC	D- signal for C port
42	VGC	NMOS gate driver to control the external NMOS of C port

## 6 Device Marking Information

Tab. 6-1 Device Marking Information

Part Number	Order Information	Package	Package Qty	Top Marking
PL93061	PL93061IQN42	QFN6x6-42	2500	93061 RAAYMD

**PL93061:** Part Number

**RAAYMD:** RAA: LOT NO.; YMD: Package Date

## 7 Specifications

### 7.1 Absolute Maximum Ratings <sup>(Note1)</sup>

Over operating free-air temperature range (unless otherwise noted).

**Tab. 7-1-1 Absolute Maximum Ratings**

		MIN	MAX	Unit
Voltage range at terminals <sup>(Note2)</sup>	VC, VC2, VBUS, VBAT, VINALL, CSP1, CSN1, CSPBUS, CSNBUS, SW1, SW2	-0.3	30	V
	VGC-VC, VGC2-VC2	-0.3	15	
	VGC2-VBUS, VGC-VBUS	-0.3	15	
	BST1 to SW1, BST2 to SW2	-0.3	7	
	HG1 to SW1, HG2 to SW2	-0.3	7	
	CC1, CC2, DPC, DMC, DPC2, DMC2	-0.3	22	
	COMP, VMON, SCL, SDA, INT, RXOVER, RXCRC, IREF, VP1P2, MCULDO, VDD, VREF, LG1, LG2	-0.3	6.5	
	Others	-0.3	6.5	

### 7.2 Handling Ratings

**Tab. 7-2-1 Handling Ratings**

PARAMETER	DEFINITION	MIN	MAX	UNIT
T <sub>ST</sub>	Storage Temperature Range	-65	150	°C
T <sub>J</sub>	Junction Temperature		+160	°C
T <sub>L</sub>	Lead Temperature		+260	°C
V <sub>ESD</sub>	HBM Human body model	2	4	kV

## 7.3 Recommended Operating Conditions (Note 3)

Tab. 7-3-1 Recommended Operating Conditions

		MIN	MAX	Unit
Voltage range at terminals <sup>(Note2)</sup>	VC2, VC, VBUS, VBAT, CSP1, CSN1, CSPBUS, CSNBUS, SW1, SW2, VINALL	-0.3	24	V
	VGC2-VC2, VGC-VC	-0.3	12	
	VGC2-VBUS, VGC-VBUS	-0.3	12	
	BST1 to SW1, BST2 to SW2	-0.3	6.5	
	HG1 to SW1, HG2 to SW2	-0.3	6.5	
	CC1, CC2, DPC, DMC, DPC2, DMC2	-0.3	20	
	COMP, VMON, SCL, SDA, INT, RXOVER, RXCRC, IREF, VP1P2, MCULDO, VDD, VREF, LG1, LG2	-0.3	6.5	
	Others	-0.3	6.5	

## 7.4 Thermal Information(Note 4)

Tab. 7-4-1 Thermal Information

Symbol	Description	QFN6x6-42	Unit
$\theta_{JA}$	Junction to ambient thermal resistance	30	°C/W
$\theta_{JC}$	Junction to case thermal resistance	8	

### Notes:

- 1) Exceeding these ratings may damage the device.
- 2) All voltage VC2lues are with respect to network ground terminal.
- 3) The device function is not guaranteed outside of the recommended operating conditions.
- 4) Measured on approximately 1" square of 1 oz copper.

## 7.5 Electrical Characteristics

(Typical at VBUS = 12V, VBAT = 3.6V, T<sub>J</sub>=25°C, unless otherwise noted.)

Tab. 7-5-1 Electrical Characteristics

SYMBOL	PARAMETER	CONDITION	MIN	TYP	MAX	UNIT
<b>Power supplies</b>						
VBUS	Input voltage on VBUS		3.5		24	V
VBAT	Input voltage on VBAT		3.2		24	V
VINALL	Input voltage on VINALL		3.2		24	V
V <sub>UVLO_VBUS</sub>	VBUS under-voltage lockout threshold	Charging mode, rising edge		3.5		V
		Hysteresis		180		mV
V <sub>UVLO_VBAT</sub>	VBAT under-voltage lockout threshold	Discharging mode, Rising edge		3.2	3.3	V
		Hysteresis		220		mV
V <sub>UVLO_VINALL</sub>	VINALL under-voltage lockout threshold			1.2		V
I <sub>Q_shutdown</sub>	shutdown current	VBAT= 8.4V, EN = 0		0	1	μA
I <sub>Q_stdby</sub>	Standby current	VBAT= 8.4V, GOACTIVE = 0		60	80	μA
I <sub>Q_noclk</sub>	Quiescent current with digital CLK disabled	VBAT= 8.4V, GOACTIVE = high, DISCLK = high, ENDCDC=low		2		mA
I <sub>Q_nodcdc</sub>	Quiescent current with DC-DC disabled	VBAT= 8.4V, GOACTIVE = high, DISCLK = low,		12		mA

		ENDCDC=low			
V <sub>DD</sub>	VDD regulation voltage	VINALL = 12V, I <sub>VDD</sub> = 1~70mA	4.9	5.1	5.35
I <sub>VDD_LIM</sub>	VDD regulator current limit	VINALL = 12V, VDD = 4V	40	80	120
V <sub>MCULDO</sub>	LDO regulation voltage	LDO set to 3.3V, ILDO = 1~50mA	3.23	3.30	3.37
V <sub>VP1P2</sub>	1.2V power supply for BMC voltage	VINALL = 12V, connect 1uF from VP1P2 pin to GND.		1.2	
V <sub>VCC</sub>	Power supply for buck-boost drivers	VBAT = 12V, connect 1uF from VCC pin to GND.		6.6	
V <sub>cp</sub>	Charge pump voltage	VBAT = 8.4V, VBUS=0V		7	
<b>Oscillators</b>					
F <sub>SW</sub>	Switching frequency	FSW_SET = 00		150	kHz
		FSW_SET = 01		300	kHz
F <sub>CLK_1ms</sub>	1ms CLK for CC scan and timer			1	kHz
F <sub>CLK_Dig</sub>	CLK for digital core			8000	kHz
<b>Battery Charging</b>					
V <sub>BAT_chg</sub>	Battery full-charge voltage	1 cell		4.2	V
		2 cell		2*4.2	V
		3 cell		3*4.2	V
		4 cell		4*4.2	V
V <sub>BAT_chg3p5</sub>	Battery full-charge voltage for 3.5V battery cell	1 cell		3.5	V
		2 cell		2*3.5	V
		3 cell		3*3.5	V
		4 cell		4*3.5	V
V <sub>INREG</sub>	VINREG voltage regulation	VREG_SET = 00	4.4	4.5	4.6
		VREG_SET = 01	8	8.1	8.2
		VREG_SET = 10	10.7	10.8	10.9
		VREG_SET = 11	17.9	18	18.1
V <sub>EOC</sub>	End of charge voltage threshold		98%	99%	100%
V <sub>RECHG</sub>	Recharge threshold		96.0%	97.6%	98.8%
V <sub>CHG_OV</sub>	Battery over charge voltage			105%	
<b>Discharging mode</b>					
V <sub>VREF</sub>	Reference voltage for voltage loop			2.0	V
V <sub>IREF</sub>	Reference voltage for current loop			2.0	V
I <sub>SINK_COMP</sub>	COMP sink current	VFB=VREF+100mV		15	uA
I <sub>SOUR_COMP</sub>	COMP source current	VFB=VREF-100mV		20	uA
<b>Port detection</b>					
V <sub>C_RDY</sub>	Plug-in detection threshold for port C used as charging port		4.3	4.4	4.5
V <sub>C2_DET</sub>	Plug-in detection threshold for port A used as discharging port		1.9	2	2.1
I <sub>COM</sub>	Small current detection threshold for I <sub>BUS</sub>	Falling edge	10	50	80
V <sub>Ref_bg</sub>	Band gap voltage	VBAT = 8.4V, GOACTIVE = high, ENDCDC=high		1.192	V
<b>PD protocol</b>					
I <sub>PU_CC13A</sub>	Pull up current for CC1 in 3A mode			330	uA
I <sub>PU_CC11p5A</sub>	Pull up current for CC1 in 1.5A mode			180	uA
I <sub>PU_CC1USB</sub>	Pull up current for CC1 in default USB mode			80	uA
I <sub>PU_CC23A</sub>	Pull up current for CC2 in 3A mode			330	uA
I <sub>PU_CC21p5A</sub>	Pull up current for CC2 in 1.5A mode			180	uA
I <sub>PU_CC2USB</sub>	Pull up current for CC2 in default			80	uA



	USB mode			
R <sub>d_cc1</sub>	R <sub>d</sub> pull down resistor on CC1		5.6	kΩ
R <sub>d_cc2</sub>	R <sub>d</sub> pull down resistor on CC2		5.6	kΩ
<b>Cut-off switch control</b>				
I <sub>TURNONC</sub>	C port cut-off switch turn on current		1	uA
I <sub>TURNONA</sub>	A port cut-off switch turn on current		1	uA
<b>I<sup>2</sup>C</b>				
V <sub>IL</sub>	SCL, SDA input low voltage		0.4	V
V <sub>IH</sub>	SCL, SDA input high voltage		1.2	V
<b>THERMAL SHUTDOWN</b>				
T <sub>SD</sub>	Thermal shutdown temperature	Rising	165	°C
		Hysteresis	15	°C

**Note:**

- 1) Guaranteed by design

## 8 Typical Characteristics

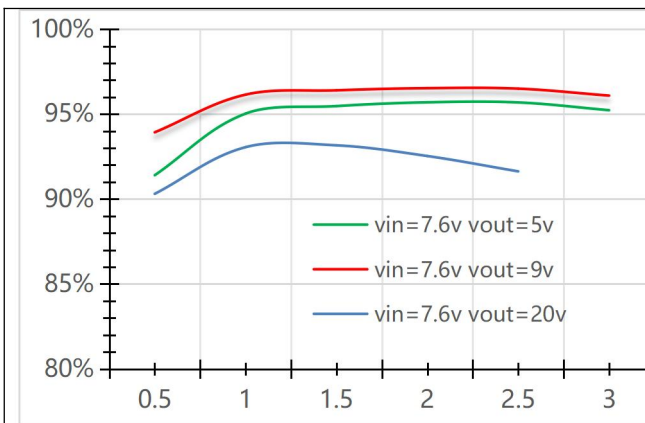


Fig. 8-1 Efficiency

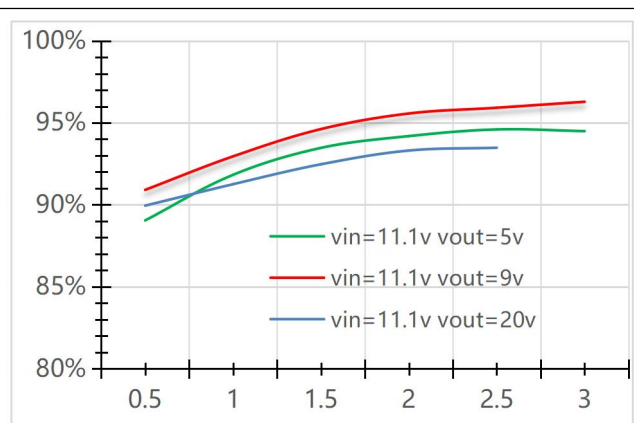
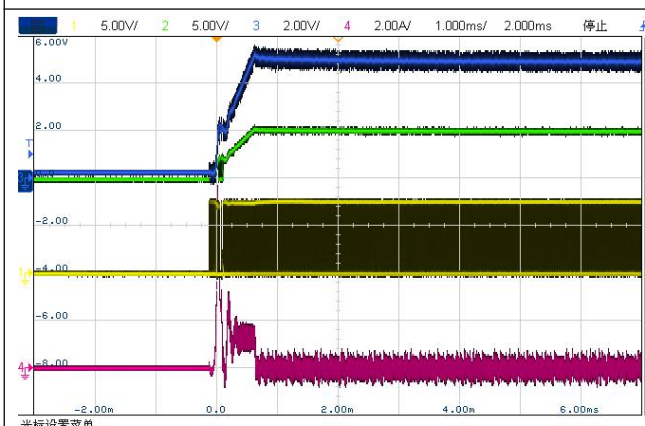
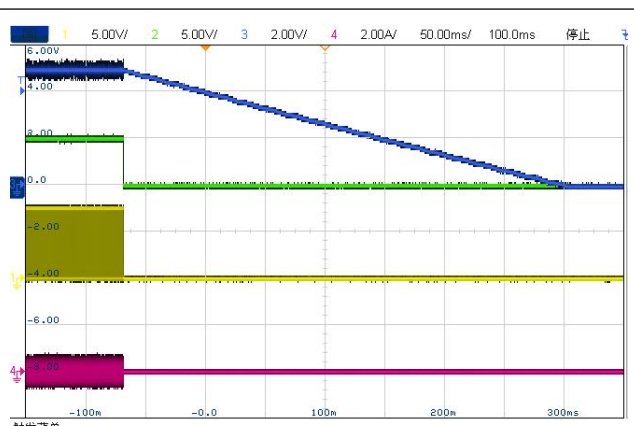


Fig. 8-2 Efficiency



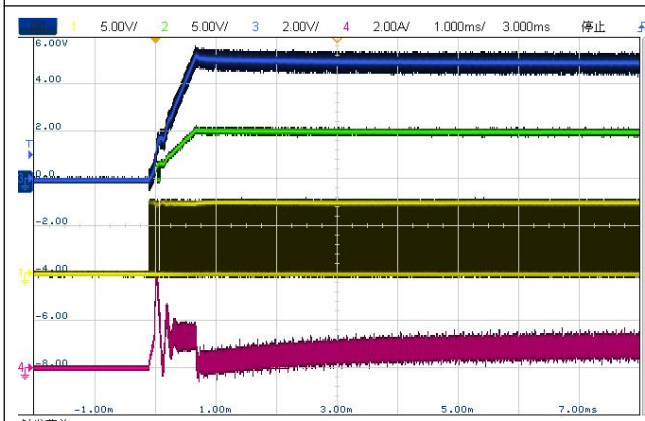
Vin=7.6V Vout=5V

Fig.8-3 Start up waveform, Iout=0A



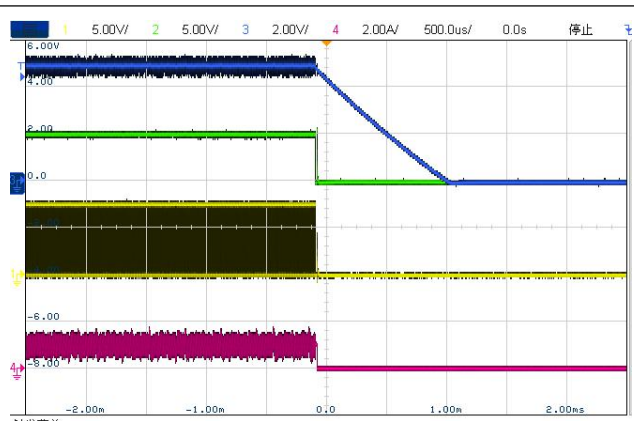
Vin=7.6V Vout=5V

Fig.8-4 Shut down waveform, Iout=0A



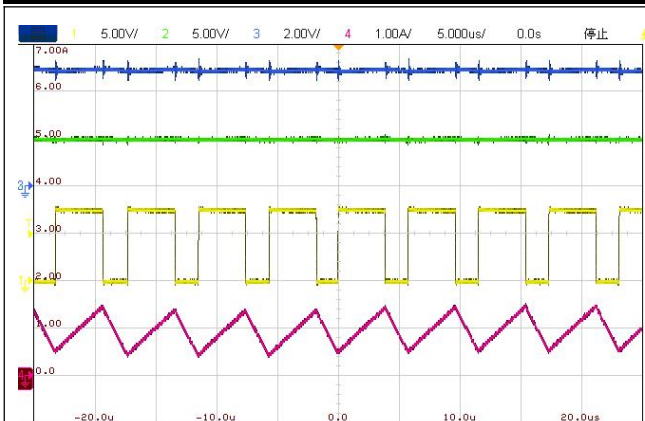
Vin=7.6V Vout=5V

Fig.8-5 Start up waveform, Iout=1A



Vin=7.6V Vout=5V

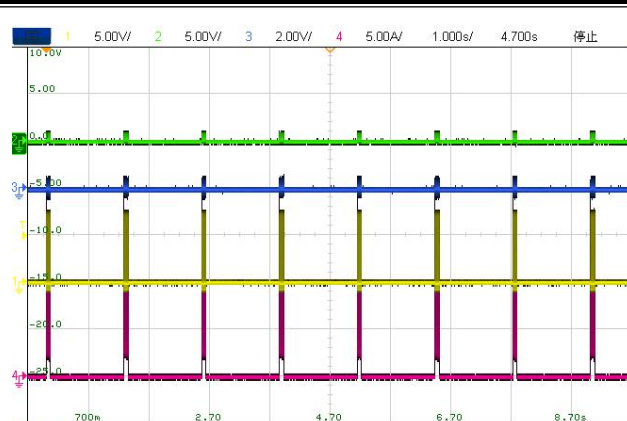
Fig.8-6 Shut down waveform, Iout=1A



CH1: SW1 CH2:SW2 CH3:Vout CH4:IL

Vin=7.6V Vout=5V

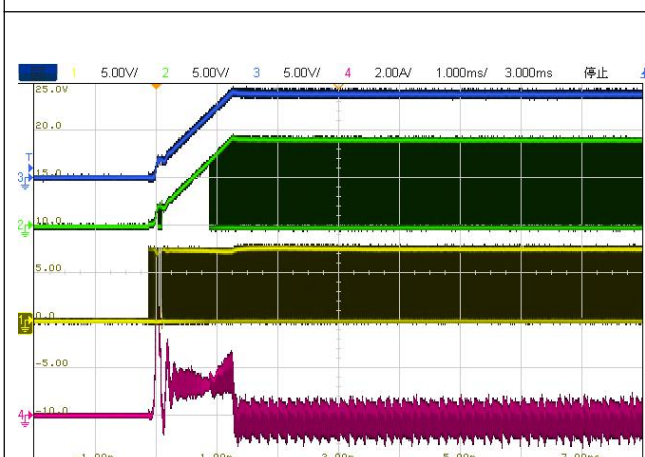
Fig.8-7 Steady State waveform, Iout =1A



CH1: SW1 CH2:SW2 CH3:Vout CH4:IL

Vin=7.6V Vout=5V

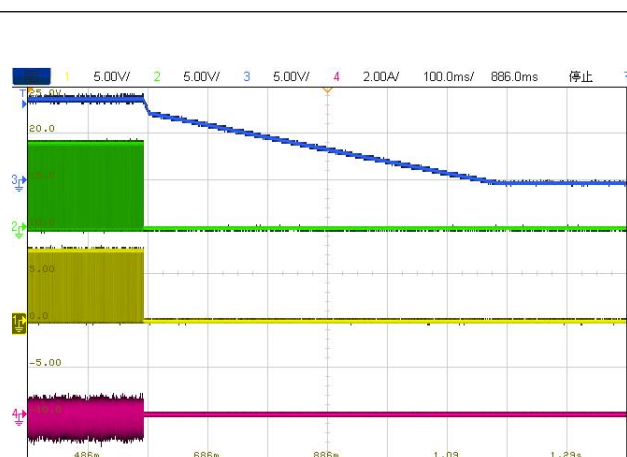
Fig.8-8 Short Circuit waveform



CH1:SW1 CH2:SW2 CH3:Vout CH4:IL

Vin=7.6V Vout=9V

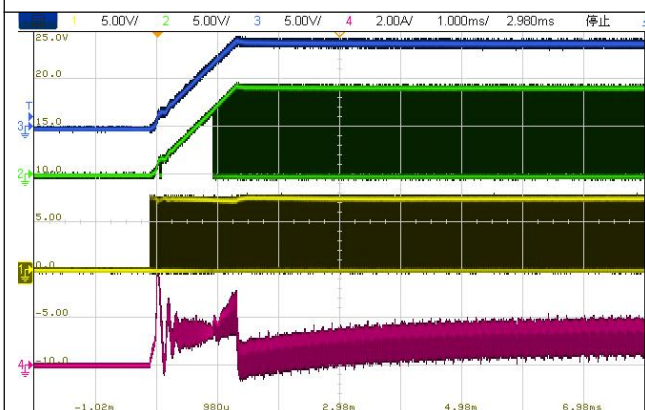
Fig.8-9 Start up waveform, Iout =0A



CH1: SW1 CH2:SW2 CH3:Vout CH4:IL

Vin=7.6V Vout=9V

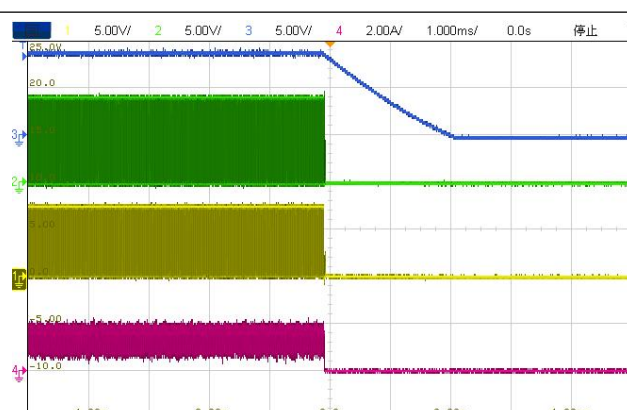
Fig.8-10 Shut down waveform, Iout =0A



CH1: SW1 CH2:SW2 CH3:Vout CH4:IL

Vin=7.6V Vout=9V

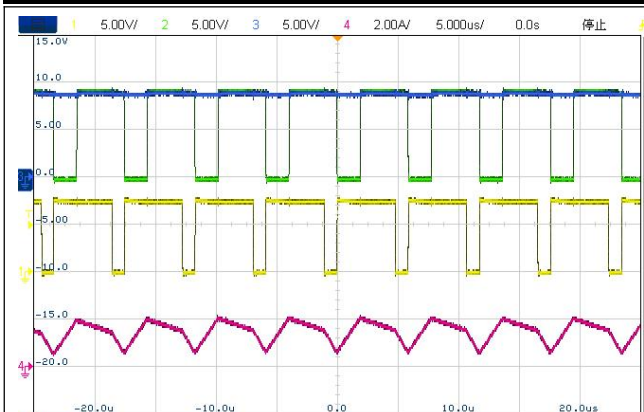
Fig.8-11 Start up waveform, Iout =1A



CH1: SW1 CH2:Vout CH3:SW CH4:IL

Vin=7.6V Vout=9V

Fig.8-12 Shut down waveform, Iout =1A



CH1: SW1 CH2:SW2 CH3:Vout CH4:IL

Vin=7.6V Vout=9V

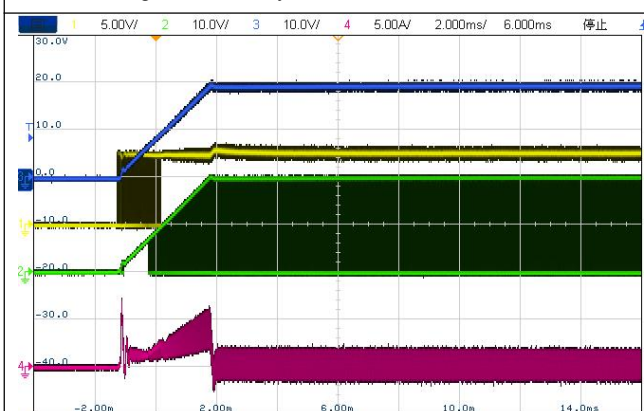
Fig.8-13 Steady State waveform, Iout =1A



CH1: SW1 CH2:SW2 CH3:Vout CH4:IL

Vin=7.6V Vout=9V

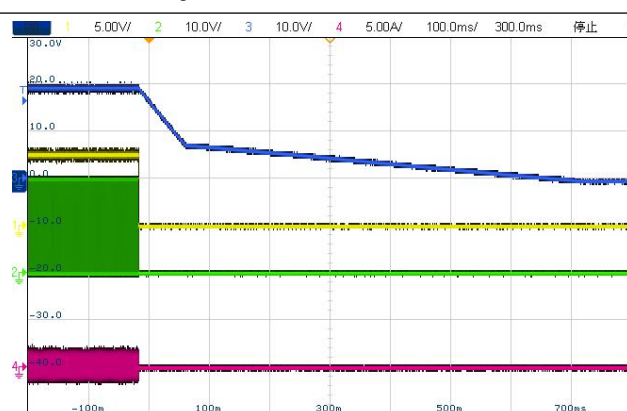
Fig.8-14 Short Circuit waveform



CH1: SW1 CH2:SW2 CH3:Vout CH4:IL

Vin=7.6V Vout=20V

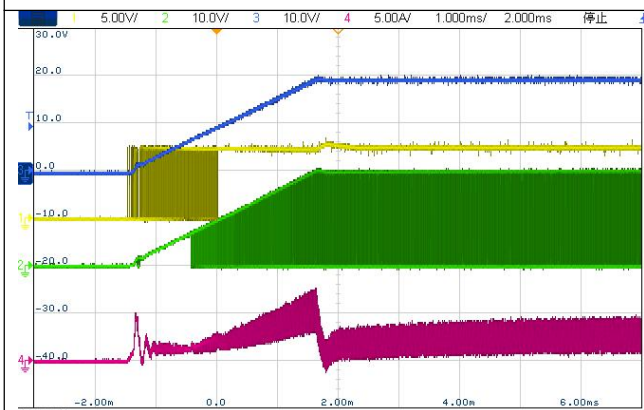
Fig.8-15 Start up waveform, Iout =0A



CH1: SW1 CH2:SW2 CH3:Vout CH4:IL

Vin=7.6V Vout=20V

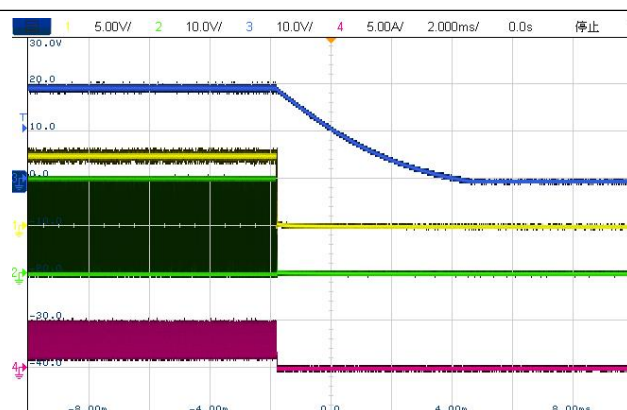
Fig.8-16 Shut down waveform, Iout =0A



CH1: SW1 CH2:SW2 CH3:Vout CH4:IL

Vin=7.6V Vout=20V

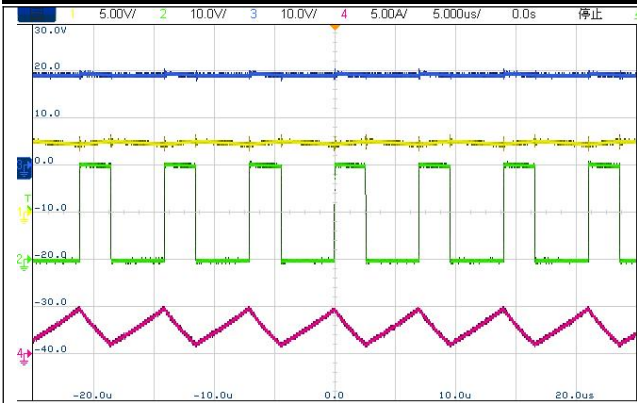
Fig.8-17 Start up waveform, Iout =1A



CH1: SW1 CH2:SW2 CH3:Vout CH4:IL

Vin=7.6V Vout=20V

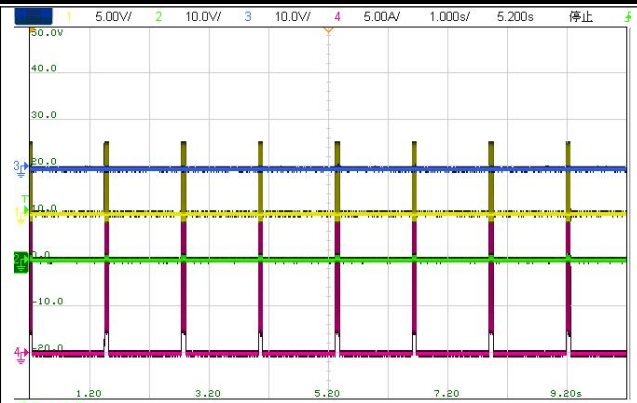
Fig.8-18 Shut down waveform, Iout =1A



CH1: SW1 CH2:SW2 CH3:Vout CH4:IL

Vin=7.6V Vout=20V

Fig.8-19 Steady State, Iout =1A



CH1: SW1 CH2:SW2 CH3:Vout CH4:IL

Vin=7.6V Vout=20V

Fig.8-20 Short Circuit waveform



## 9 Detailed Description

### 9.1 Overview

PL93061 is a high efficiency, synchronous bi-directional buck-boost charger with integrated fast charge protocols. It is a comprehensive and flexible buck-boost charger platform designed for most of fast charging application with type-C port and PD protocol. It can be programmed to buck charging, boost charging or buck-boost charging. PL93061 provides I<sup>2</sup>C interface to communicate with MCU, provides high voltage sensing for battery and BUS terminals, accurate rail-rail current sensing for battery current, BUS current and USB ports current. It also provides high voltage blocking for CC1, CC2, DP, DM communication signals for all of the USB ports. PL93061 can work with a general MCU to provide a complete, powerful and flexible buck-boost charging system for all kinds of fast charge application such as power bank, battery packs, or portable energy cubic etc.

### 9.2 Charging Mode

Two registers are used for charge setting: CHG\_CTR1 (0X04H) and CHG\_CTR2 (0X05H). In order to charge a battery, the following setting are needed to be set up correctly:

1. Use BAT\_CELL<2:0> to set up the number of cells in series for battery pack
2. It is optional to use register 0X2EH register to adjust the full battery voltage
3. Set register 0X1BH for a correct adaptive charging VREG point
4. Set bits 0X20H<7:6> to 11 to set IBUS sense gain to 200
5. Set bit 0X2DH<4> high to enable BUS constant current (CC) loop
6. Set correct VC2lue for 0X08H register to set up a needed charge current VC2lue. When battery voltage is low, set a small VC2lue for 0X08H register for trickle charge stage.
7. Set correct VC2lue in 0X1CH to turn on the cut-off switch for the corresponding charge port
8. Make sure that the VC2lue of battery type bit BATTYPE 0X04H<7> is correct
9. Make sure that OTG bit is 0 for battery charging

After all of the registers are set up correctly, set EN\_DCDC bit high to turn on DC-DC and start up to charge battery. During charging, MCU can keep monitoring the status of the whole system by checking status registers and VMON signal.

The default VC2lue of FDCM bit is high, which will force DC-DC to work in forced DCM mode. It is a good choice to start up the system for battery charging in forced DCM mode and set IBUS current limit to a low VC2lue. Once the battery voltage ramps above the trickle charge threshold, slowly ramp up IBUS current limit to a higher VC2lue (a good choice for IBUS current is 0.5A), then set FDCM bit low to allow the system to work in CCM mode. Sometimes, it may be helpful to make the system transit smoothly from DCM mode to CCM mode by setting VDCMSET<1:0> to 00 to lower down DCM-CCM transition point.

When the battery voltage is very close to full-charge voltage point, it will be better to lower down IREF VC2lue slowly by setting 0X08H at lower VC2lue. When the inductor current is lower down to be close to be around 0.3A, it is better to set FDCM bit high to force the system working in DCM mode again. When the cell voltage reaches the VBAT target, it enters into Constant Voltage charge phase, and charges the cells with gradually decreased current. Once termination voltage and termination current conditions are satisfied, the IC enters into End of Charge phase if ENEOC bit is high. In this phase the IC will terminate the charging.

User can set ENEOC bit to 0, system will not turn off DC-DC and charge the battery to the setting point. MCU can check battery voltage to determine when to terminate the charge. This mode is especially suitable for small current battery charging such as TWS.

After the battery is fully charged, it is better to disable DC-DC by setting ENDCDC bit low. Sometimes, it may be helpful to set 0X2EH<7> high to force the system go into standby mode to lower down quiescent current to be around 60uA.

If the IC terminates charging after EOC, the battery voltage may drop due to leakage or operation current from battery cells. Once the VBAT voltage drops below VRECH threshold, the IC enters into CC charge phase to recharge the battery. User can also use MCU to monitor battery voltage. Once the battery voltage reaches recharge threshold, MCU can enable the charge again.

During charging, if the IBUS charging current is higher than adapter's current capability, the adapter will be overloaded and VBUS voltage will be pulled lower. PL93061 supports dynamic power management; the allowed minimum VBUS operation voltage for charging is set by VINREG\_SET [2:0]. Once VBUS voltage drops to V<sub>INREG</sub> threshold, the IC reduces the charging current automatically and regulates the VBUS at V<sub>INREG</sub> threshold. If the VBUS voltage drops below VINREG threshold, the IC reduces the charging current to 0.

### 9.3 Discharging Mode

When OTG bit is set to 1, the IC is set to discharging mode. If FB\_SEL is set to 0, internal feedback resistors are used, and the VBUS output is set by 0X06H and 0X07H registers. The default VBUS output voltage is 5V, and can be adjusted from 0V to 20V with 0.5mV per step as below:

$$VBUS(V) = 2.15mV \times (VBUS\_SET[11] \times 2^{11} + VBUS\_SET[10] \times 2^{10} + \dots + VBUS\_SET[0] \times 2^0)$$

User shall write LDVREF bit to 1 to load the VBUS setting, otherwise the change will not take effect. If constant current loop is needed, user need to set bit 0X2DH<4> high to enable BUS constant current (CC) loop.

### 9.2.1 PFM Operation

To reduce the switching loss, the IC features Pulse-Frequency Modulation (PFM) operation under light load condition for discharging mode. The IC decreases the frequency automatically to reduce the switching loss so the efficiency can be improved under light load condition. User can also set 0X00H<3> to 1 to force the system to working in CCM mode. FDCM bit has higher priority than MODE bit, which means that system will work in DCM mode even if MODE is high with FDCM = 1.

### 9.2.2 Current Limit in Discharging Mode

When OTG is set to 1, the IC monitors the discharging current through the voltage drop from CSNBUS pin to CSPBUS pin (opposite direction of charging mode). User need to set bit 0X2DH<4> high to enable BUS constant current (CC) loop.

## 9.3 Port control

PL93061 integrates the port detection and control circuit for two C port. it is normally used for DRP TYPE-C port depending CCMOD<1:0> bits setting in 0X28H register.

## 9.4 Power Path Management

The IC provides two NMOS gate drivers for two C ports respectively.

The NGATE driver must be combined with corresponding port, that is, VC2G can only be used for VC2 and VCG only for VC.

Either a single NMOS or back-to-back NMOS can be used for each port as shown in typical application circuit. The VGS rating of the NMOS must be considered for the safe operation.

The NGATE driver is controlled by register 0X1CH.

For each port, a full protection system is designed such as over voltage, over current and short-circuits protection.

## 9.5 Adapter Detection

For the charging port (VC, VC2), the IC can detect the attachment / detachment of the adapter, and indicate the status through VCRDY bit in register 0X36H.

## 9.6 Small Current Indication

The IC monitors its output port current in discharging mode. Once the port current is lower than 50mA typically, it reports the status to MCU through INT bit.

## 9.7 Current and Voltage Monitor Function

A specific pin VMON is used to monitor the system currents and voltages. To turn on VMON function, set bit 0X1CH<2> high and use register bits 0X2DH<3:0> to select different signals to be sent to VMON pin. MCU can use ADC to monitor the system status.

## 9.8 Operation Modes

There are totally 4 operation modes in PL93061: shutdown mode, standby mode, no digital clock mode, no DC-DC mode and normal mode.

1. Shutdown mode: when EN pin is pulled low, the whole system will be off and  $I_q$  will be close to be 0 uA.
2. Standby mode: if no equipment is attached to PL93061 or 0X2EH<7> is set high, GOACTIVE bit will be low and PL93061 will be in standby mode.  $I_q$  will be around 60uA in this mode. Only port detection circuit and MCU LDO are alive in this mode.
3. No digital clock mode: if GOACTIVE is high and DISCLK in register 0X27H is set high, the digital clock will be disabled. All of the power supplies such as VDD, VCC, MCULDO etc. are all alive in this mode. Digital core will be disabled in this mode.
4. No DC-DC mode: if GOACTIVE is high and DISCLK is low, ENDCDC=low, all other circuits are all alive except that DC-DC is disabled.
5. Normal mode: if GOACTIVE is high, DISCLK is low and ENDCDC is high, PL93061 enters normal mode for charging or discharging.

## 10 Application and Implementation

### 10.1 Inductor Selection

The operating frequency and inductor selection are interrelated in that higher operating frequencies allow the use of smaller inductor and capacitor values. The inductor value has a direct effect on ripple current. The inductor current ripple  $\Delta I_L$  is typically set to 20% to 40% of the maximum inductor current in the boost region at  $V_{IN(MIN)}$ .

For a given ripple the inductance terms in continuous mode are as follows:

$$L_{BOOST} > \frac{V_{IN(MIN)}^2 * (V_{OUT} - V_{IN(MIN)}) * 1000}{f * I_{OUT\_MAX} * 40\% * V_{OUT}^2} \text{ H}$$

$$L_{BUCK} > \frac{V_{OUT} * (V_{IN(MAX)} - V_{OUT}) * 1000}{f * \Delta I_L * V_{IN(MAX)}} \text{ H}$$

where:  $f$  is operating frequency, kHz

$V_{IN(MIN)}$  is minimum input voltage, V

$V_{IN(MAX)}$  is maximum input voltage, V

$V_{OUT}$  is output voltage, V

$\Delta I_L$  is maximum inductor ripple current, A, usually select 20~40% maximum output current.

For high efficiency, choose an inductor with low core loss, such as ferrite. Also, the inductor should have low DC resistance to reduce the  $I^2R$  losses, and must be able to handle the peak inductor current without saturating. To minimize radiated noise, use a toroid, pot core or shielded bobbin inductor.

### 10.2 $C_{IN}$ and $C_{OUT}$ Selection

In boost region, input current is continuous. In buck region, input current is discontinuous. In buck region, the selection of input capacitor  $C_{IN}$  is driven by the need to filter the input square wave current. Use a low ESR capacitor sized to handle the maximum RMS current. For buck operation, the input RMS current is given by:

$$I_{CIN} = I_{OUT(MAX)} * \sqrt{\frac{V_{OUT}}{V_{IN}} * \left(1 - \frac{V_{OUT}}{V_{IN}}\right)}$$

This input current has a maximum at  $V_{IN} = 2V_{OUT}$ ,  $I_{CIN(MAX)} = I_{OUT(MAX)}/2$ .

In the boost region,  $C_{OUT}$  must be capable of reducing the output voltage ripple because of the discontinuous output current. The effects of ESR (equivalent series resistance) and the bulk capacitance must be considered when choosing the right capacitor for a given output ripple voltage. The steady ripple due to charging and discharging the bulk capacitance is given by:

$$\Delta V_{(BOOST, Cap)} = \frac{I_{OUT(MAX)} * (V_{OUT} - V_{IN(MIN)})}{C_{OUT} * V_{OUT} * f} \text{ V}$$

Where  $C_{OUT}$  is the output filter capacitor.

The steady ripple due to the voltage drop across the ESR is given by:

$$\Delta V_{(BOOST, ESR)} = I_{OUT(MAX, BOOST)} * ESR$$

In buck mode,  $V_{OUT}$  ripple is given by:

$$\Delta V_{OUT} \leq \Delta I_L * \left(ESR + \frac{1}{8 * f * C_{OUT}}\right)$$

Multiple capacitors placed in parallel may be needed to meet the ESR and RMS current handling requirements.

### 10.3 Current Sense Resistor

A power resistor with 5mΩ or less should be used to sense IBUS current and IBAT current. Resistor of 1% or higher accuracy and low temperature coefficient is recommended.



The resistor power rating and temperature coefficient should be considered. The power dissipation can be roughly calculated as  $P=I^2R$ , and  $I$  is the RMS current flowing through the resistor. The resistor power rating should be higher than the calculated  $VC2lue$ .

Normally the resistor  $VC2lue$  is  $VC2ried$  if the temperature increased and the  $VC2riation$  is decided by temperature coefficient. If high accuracy of current limit is required, select lower temperature coefficient resistor.

#### 10.4 Isolation MOSFET Selection

For each port, N-channel MOSFET can be used as isolation switch. When selecting the MOSFET, user shall consider the VGS rating, VDS rating and  $R_{dson}$  parameters. When the gate driver is turned on, the IC outputs high voltage based on the lower voltage of VBUS and port voltage. A clamping circuit is designed to guarantee that the VGS voltage will not exceed 8V.

#### 10.5 Diode Selection

PL93061 use VINALL pin to power the internal driver circuits and the LDOs; if a back-to-back isolation is used on a charging port, the port voltage shall also be connected to VINALL pin through a schottky diode. Schottky diodes with small voltage drop such as SS14 are recommended for applications with low battery voltage.

## 11 PCB Layout

### 11.1 Guideline

Layout is a critical portion of good power supply design. The following guidelines will help users design a PCB with the best power conversion performance, thermal performance, and minimized generation of unwanted EMI.

1. VBUS sensing path should stay away from noisy nodes and preferably through a layer on the other side of shielding layer.
2. The input bypass capacitor must be placed as close as possible to the VBUS pin and ground pin to decouple input noise.
3. The output bypass capacitor must be placed as close as possible to the VBAT pin and ground to decouple output noise.
4. Grounding for both the input and output capacitors should consist of localized top side planes that connect to the GND pin and PAD.
5. The inductor L should be placed close to the SW pin to reduce magnetic and electrostatic noise.
6. CSP1, CSN1, CSPBUS, CSNBUS should directly connected to sensing resistor terminals, and symmetrically route to IC with a kelvin connection style.
7. It is better to separate inductor, power MOSFETs, input bulk capacitor, output bulk capacitor to make a good thermal balance.
8. Put IC away from inductor, power MOSFETs. It is better to use a ground plane.

### 11.2 Application Examples

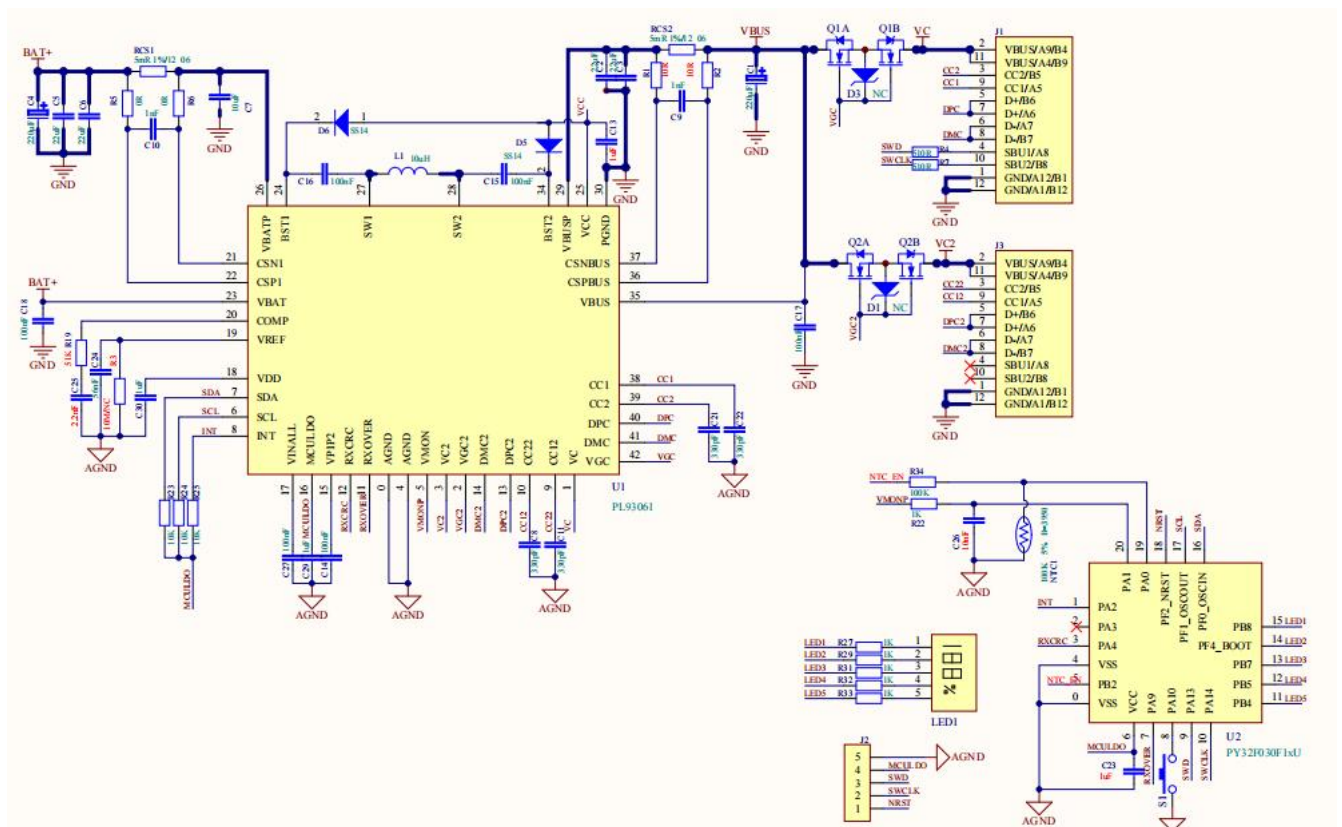


Fig. 11-2-1 Schematic

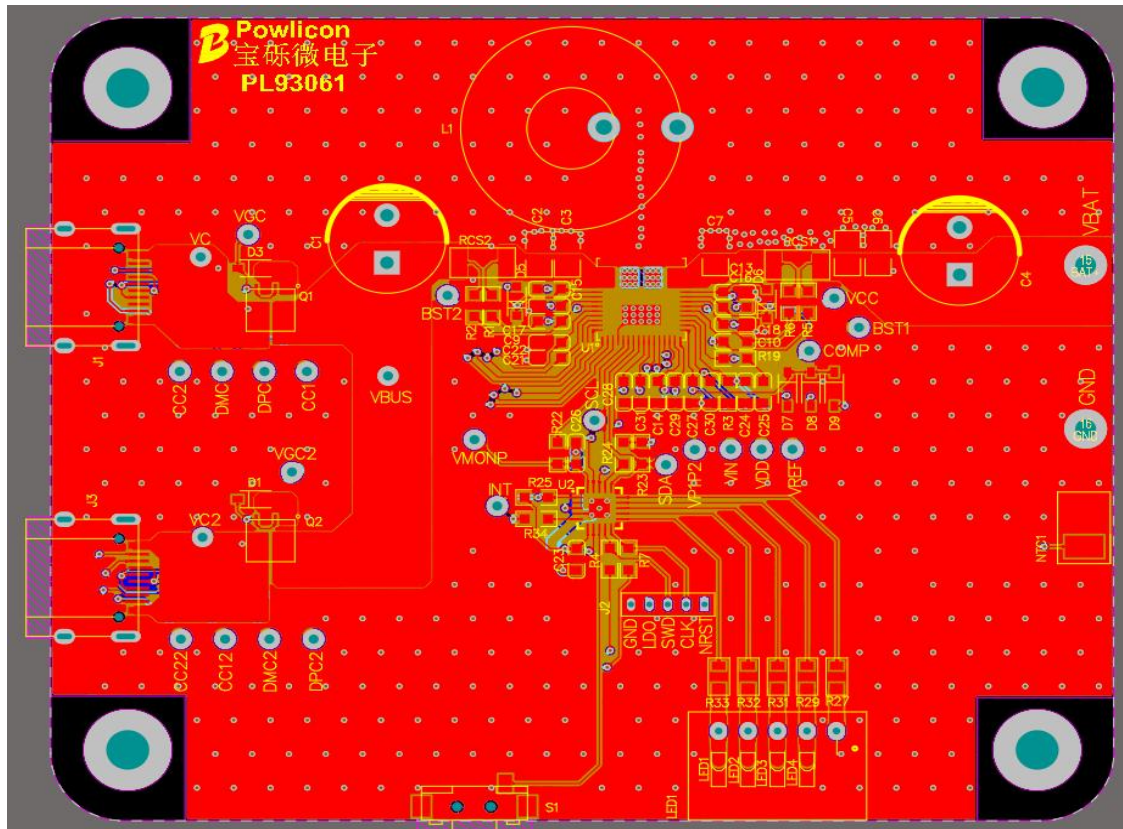


Fig. 11-2-2 Top Layer

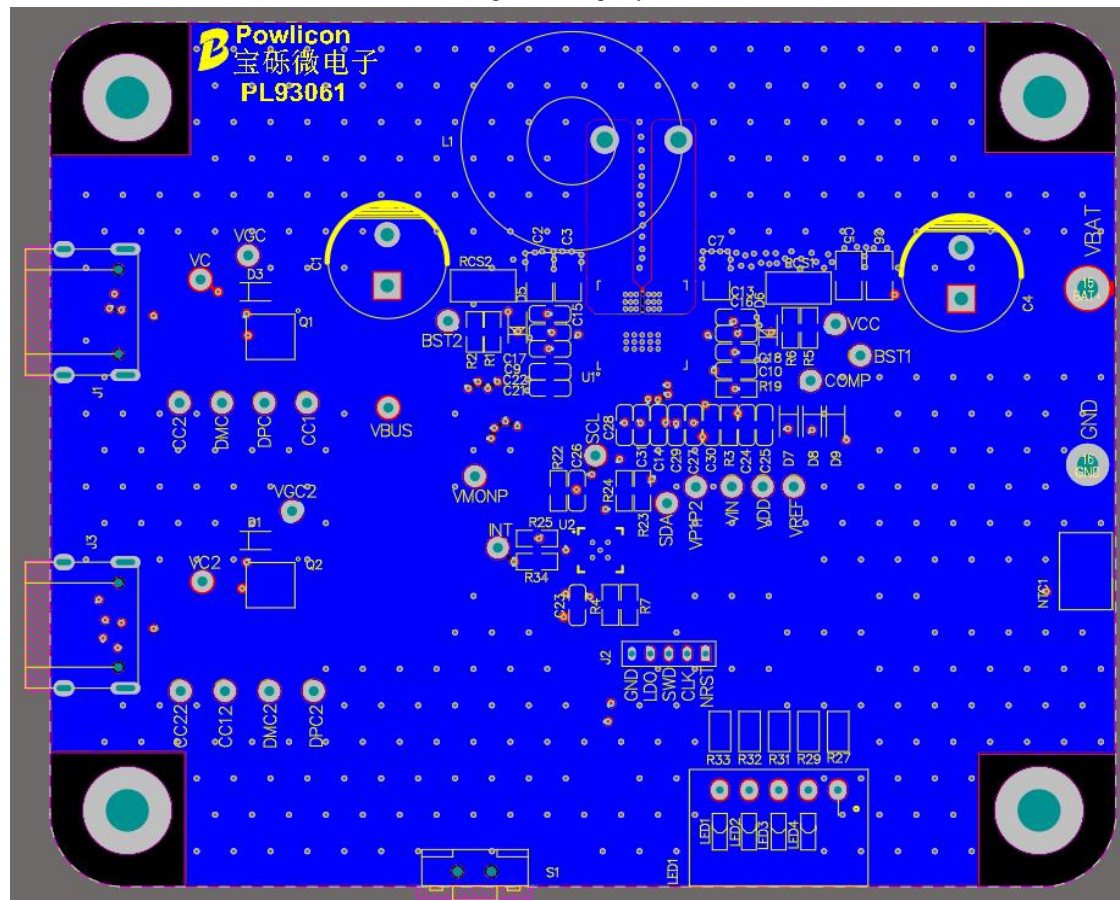
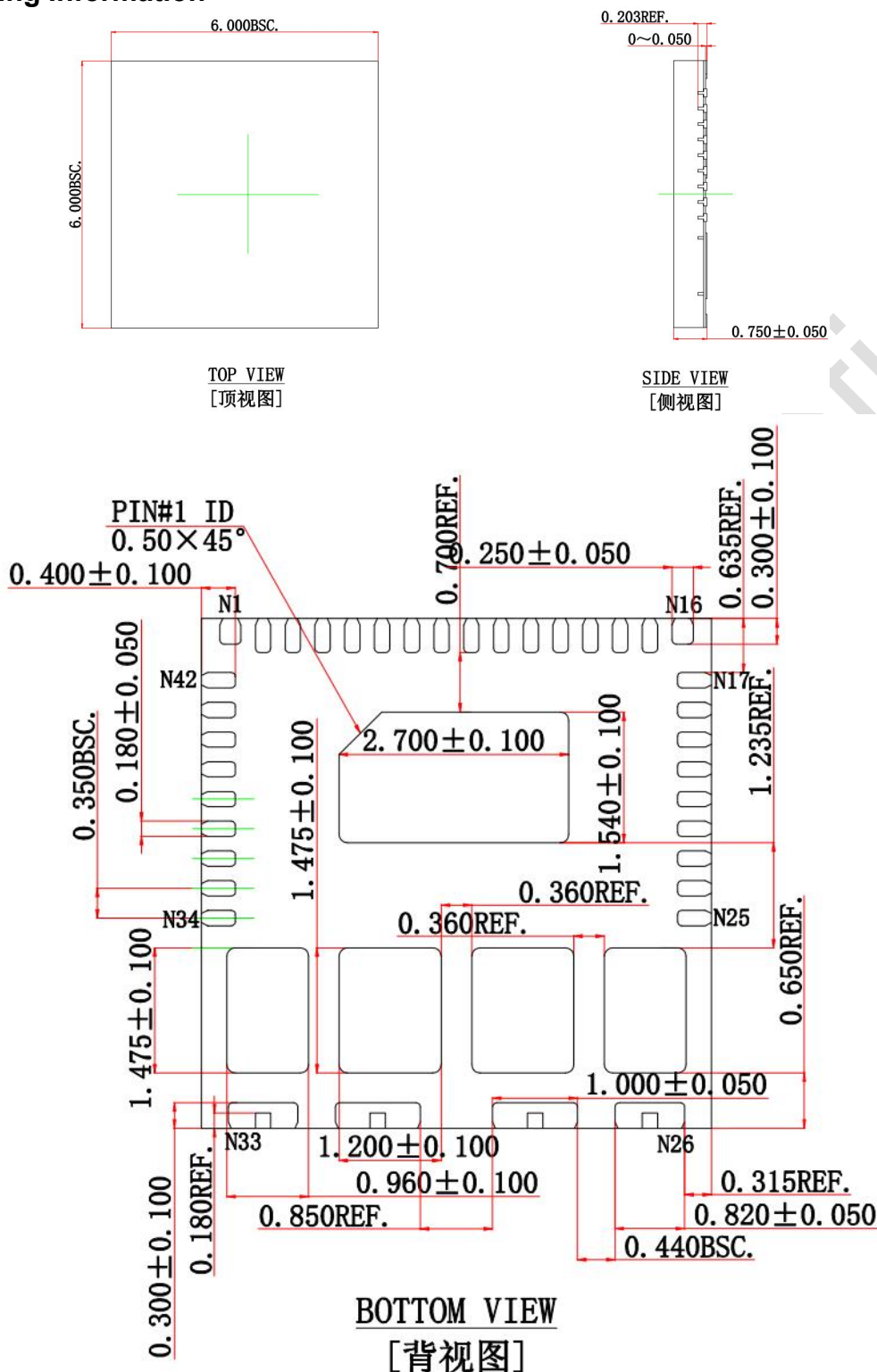


Fig. 11-2-3 Bottom Layer

## 8 Packaging Information



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