1~4 series lithium battery/lithium ion battery step-down charging IC

1 .feature

- Built-in power MOS
- Working input voltage range: 5V to 26V
- Support 1-4 series lithium-ion battery charging
- 3A maximum charging current
- 250kHz switching frequency
- Support external resistor to adjust the charging current (input terminal and battery terminal)
- Support charging NTC temperature protection
- Support external resistor to adjust input under voltage protection voltage
- Support LED charging status indication
- Output over current, short circuit protection
- Input overvoltage and undervoltage protection
- Over-temperature protection
- ESD 4kV

2 application

- Lithium battery/lithium ion battery charging
- Lithium iron phosphate battery charging (customization required))

3 Introduction

IP2365 is a step-down converter with integrated synchronous switch, supporting 1~4 series lithium battery/lithium ion battery step-down charging management IC.

IP2365 built-in power MOS, adopts synchronous switch architecture, switching frequency 250kHz, conversion efficiency up to 95%.

The working input voltage range of IP2365 is 4.5V to 26V, and the input can intelligently adjust the charging current to prevent the adapter from being pulled. Supports external resistance to adjust the input under-voltage protection voltage.

IP2365 supports an external resistor to adjust the charging current, and supports a maximum battery terminal charging current of 3A.

IP2365 supports external resistance to set the full charge voltage, and supports 1~4 string lithium battery charging

IP2365 supports NTC function, which can realize charging NTC temperature protection through external NTC resistor.

IP2365 has a soft start function, which can prevent the inrush current at start from affecting the stability of the input power supply。

IP2365 has multiple protection functions, including input over-voltage and under-voltage protection, output over-current, short-circuit protection, etc.

QFN24 package。

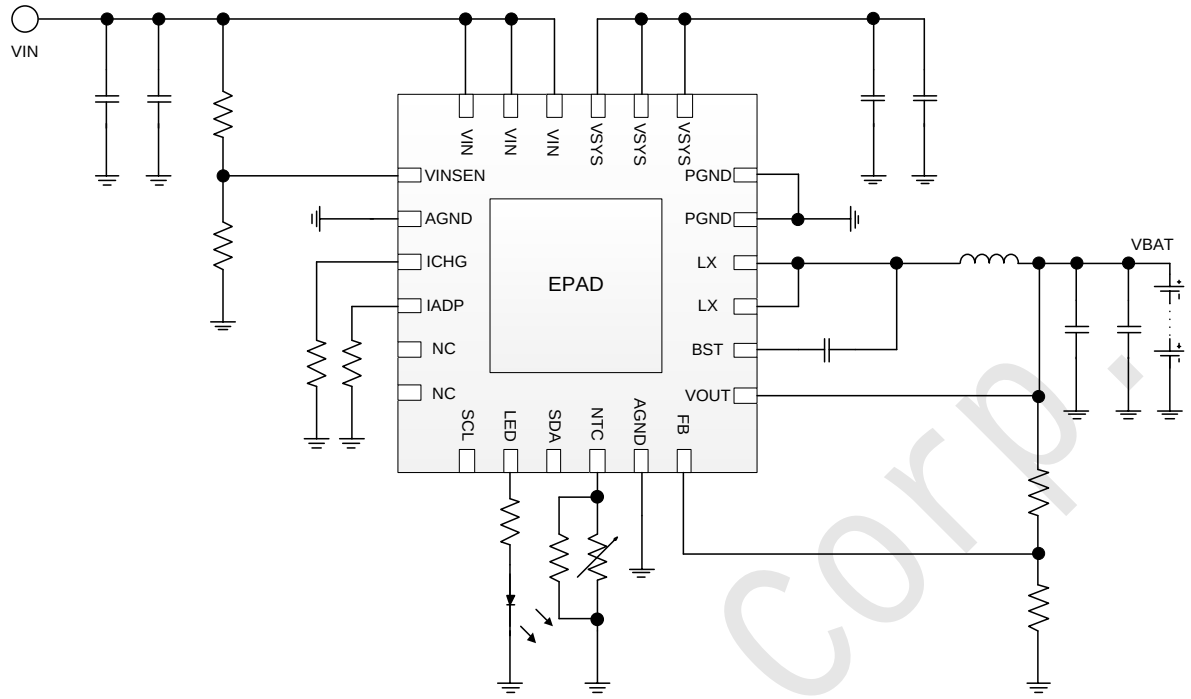


Figure 1 IP2365 simplified application schematic diagram

4 pin definition

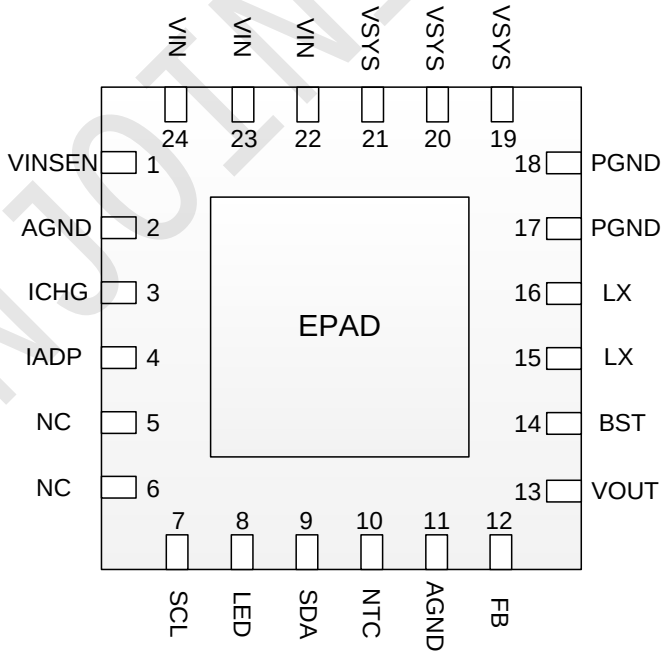


Figure 2 IP2365 pin diagram

PIN		description
PIN NUM	PIN NAME	
1	VINSEN	Input voltage detection pin
2、11	AGND	Analog ground
3	ICHG	Charging current setting pin, connect an external resistor to GND to adjust the charging current
4	IADP	Input current limit setting pin, connect an external resistor to GND to adjust the input current limit
5、6	NC	NC
7	SCL	I2C SCL
8	LED	Charge status indicator output pin
9	SDA	I2C SDA
10	NTC	NTC temperature protection, connect NTC resistance
12	FB	Output voltage feedback pin
13	VOUT	Output voltage sampling pin
14	BST	Bootstrap circuit pins, close to the chip BST pin and SW pin to place a bootstrap capacitor to provide voltage for the gate drive of the upper tube
15、16	LX	DCDC switch node, connected to the inductor
17、18	PGND	Power GND
19、20、21	VSYS	System voltage pin
22、23、24	VIN	Input voltage pin, close to IC need to place filter capacitor
EPAD	GND	Power ground and heat dissipation ground, need to keep good contact with GND

6 limit parameters

parameters	symbol	Value	unit
VIN/VSYS/VINSEN voltage range	V_{IN}、V_{SYS}、V_{VINSEN}	-0.3 ~ 28	**V**
VOUT/VFB voltage range	V_{OUT}、V_{FB}	-0.3 ~ 24	**V**
LX voltage range	V_{LX}	-0.3 ~ 32	**V**
BST voltage range	V_{BST}	-0.3 ~ V_{LX}+8	**V**
LED/NTC/ICHG voltage range	$V_{LED/NTC/ICHG}$	-0.3 ~ 6	**V**
Junction Temperature Range	T_J	-40 ~ 150	℃
Storage Temperature Range	Tstg	-60 ~ 150	℃
Junction Temperature(junction to ambient)	θ_{JA}	50	**℃/W**
Human Body Model(HBM)	ESD	4	**kV**

* Stress higher than the values listed in the Absolute Maximum Ratings section may cause permanent damage to the device. Excessive exposure under any absolute maximum rating conditions may affect the reliability and service life of the device

7 Recommended working conditions

parameter	symbol	Min	Typical value	Max	unit
Input voltage	V_{IN}	V_{BAT_END}+0.8	12	24	V

* Beyond these operating conditions, device operating characteristics cannot be guaranteed.

8 Electrical characteristics

Unless otherwise specified，TA=25℃，L=10uH，VIN=12V，VBAT=3.7V

Parameter	Symbol	Test Conditions	Min	Typical value	Max	Unit
Input voltage	V_{IN}		V_{BAT_END}+0.8	12	24	V
Input overvoltage threshold	V_{IN-OV}	Trigger voltage	26	27	28	V
		Release voltage	24	25	26	V
Input quiescent current	I_{VIN_Q}	VIN=12V，IBAT=0A		10	20	mA
stand-by current	$I_{BAT\_standby}$	VIN=0V，VBAT=8.4V		20	30	uA
		VIN=12V，VBAT=8.4V，Full stop		40	50	uA
		VIN=12V，VBAT=8.4V，VINSEN=0V		40	50	uA
Charging target voltage	V_{TRGT}	The voltage of FB after full stop	2.085	2.1	2.115	V
recharging current	I_{CHRG}	1 lithium battery，VIN=12V，R_{ICHG}=25K, R_{IADP}=0R	2.7	3	3.3	A
		2 lithium batteries，VIN=12V R_{ICHG}=25K, R_{IADP}=0R	2.7	3	3.3	A
		3 lithium batteries，VIN=24V R_{ICHG}=37.5K, R_{IADP}=0R	1.8	2	2.2	A
		4 lithium batteries，VIN=24V R_{ICHG}=50K, R_{IADP}=0R	1.35	1.5	1.65	A
Trickle cut-off voltage	V_{TRKL}	Detect FB pin voltage	1.49	1.5	1.51	V
Trickle charge current	I_{TRKL}		50	100	150	mA
Recharge	V_{RCH}	Detect FB pin voltage	2.02	2.05	2.08	V

threshold						
Input undervoltage protection	V_{UVLO}	Detect VINSEN pin voltage	1.25	1.3	1.35	V
NMOS on resistance	$R_{DS(ON)}$	Upper NMOS	40	50	60	mΩ
NMOS on resistance	$R_{DS(ON)}$	Lower NMOS	30	40	50	mΩ
LED output current	I_{LED}			5	10	mA
operating frequency	F_S		200	250	300	KHz
Thermal Shutdown Temperature	T_{OTP}		120	140	160	℃
Thermal Shutdown Temperature Hysteresis	ΔT_{OTP}		30	40	50	℃

9 Type Description

Type name	Function
IP2365	Standard product, support 1/2/3/4 series charging, charging voltage and charging current pin resistance can be set
IP2365_DA	Base on IP2365 standard, modify the light display: the LED is on during charging, and the LED is off when it is full
IP2365_LFP	Support customized models of LiFePO4 batteries: full FB voltage 1.8V, trickle current constant current FB voltage 1.35V
IP2365_OVS	Base on IP2365 standard, modify the input overvoltage protection to look at the voltage of the VINSEN pin. If VINSEN is greater than 2.6V, it will enter the overvoltage protection.

10 Function description

Internal block diagram

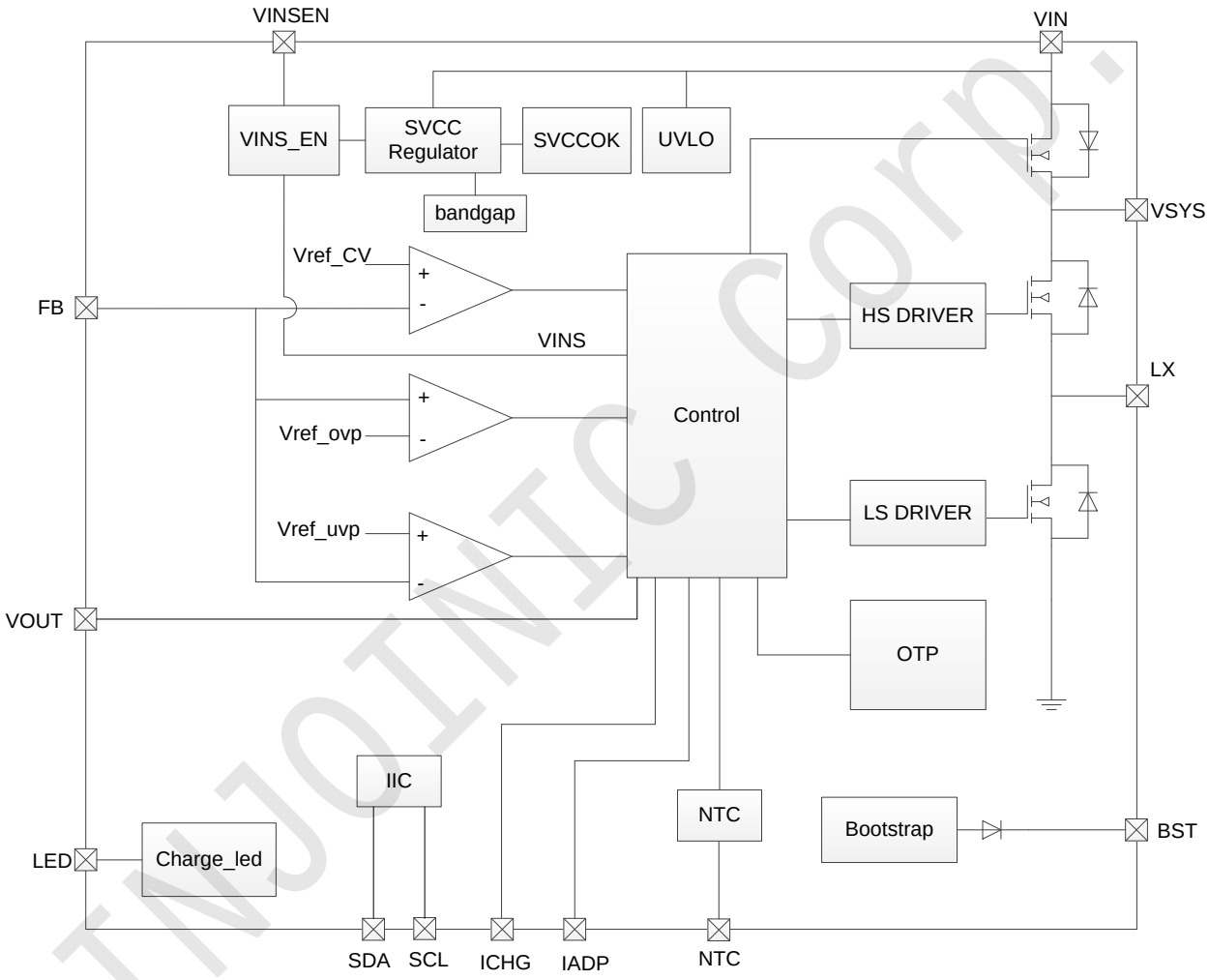


Figure 3 IP2365 internal block diagram

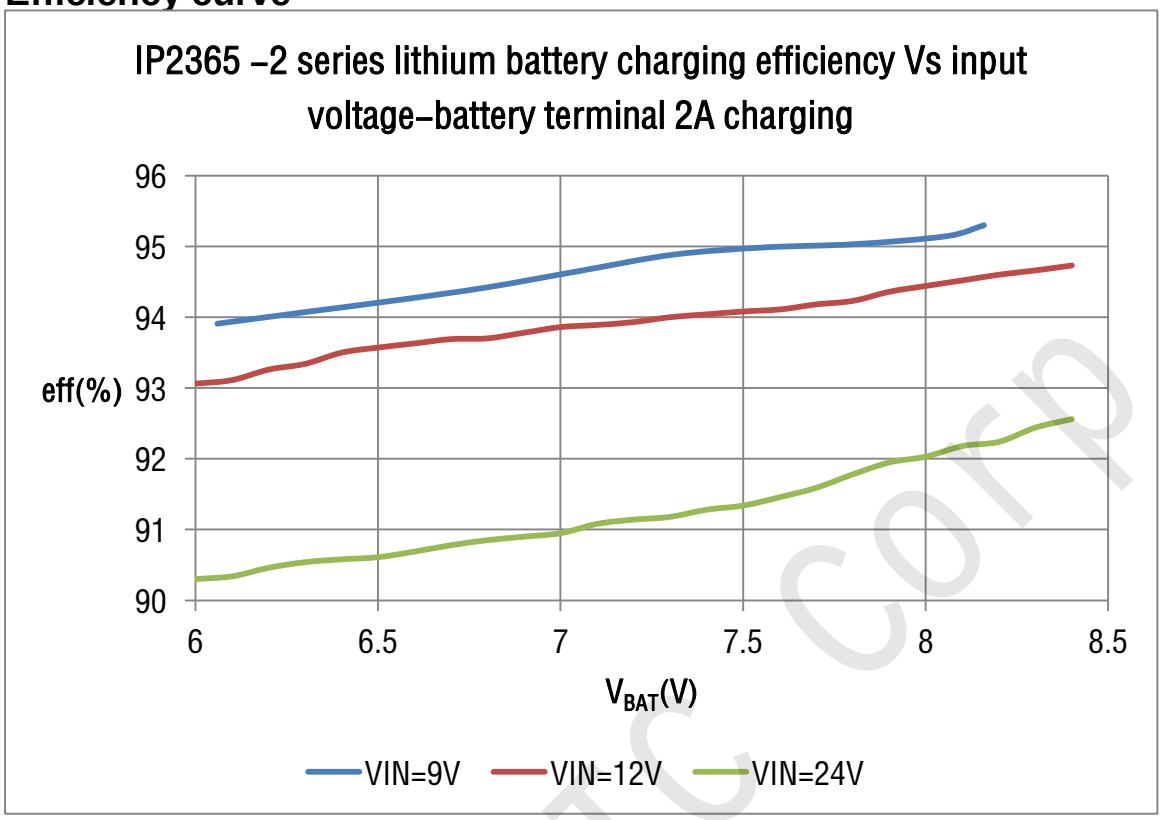
Synchronous switching buck converter

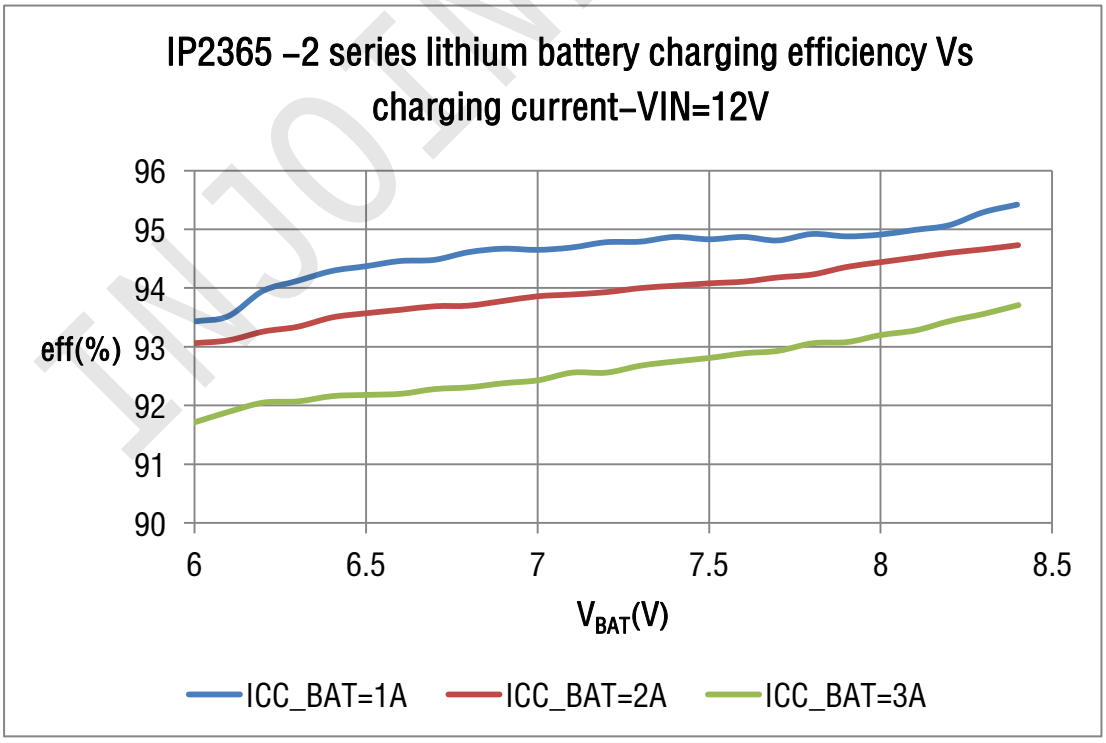
IP2365 integrates a synchronous switch buck converter. The input voltage range is 5V~26V, and the maximum charging current is 3 A. IP2365 has a built-in power switch tube, and the

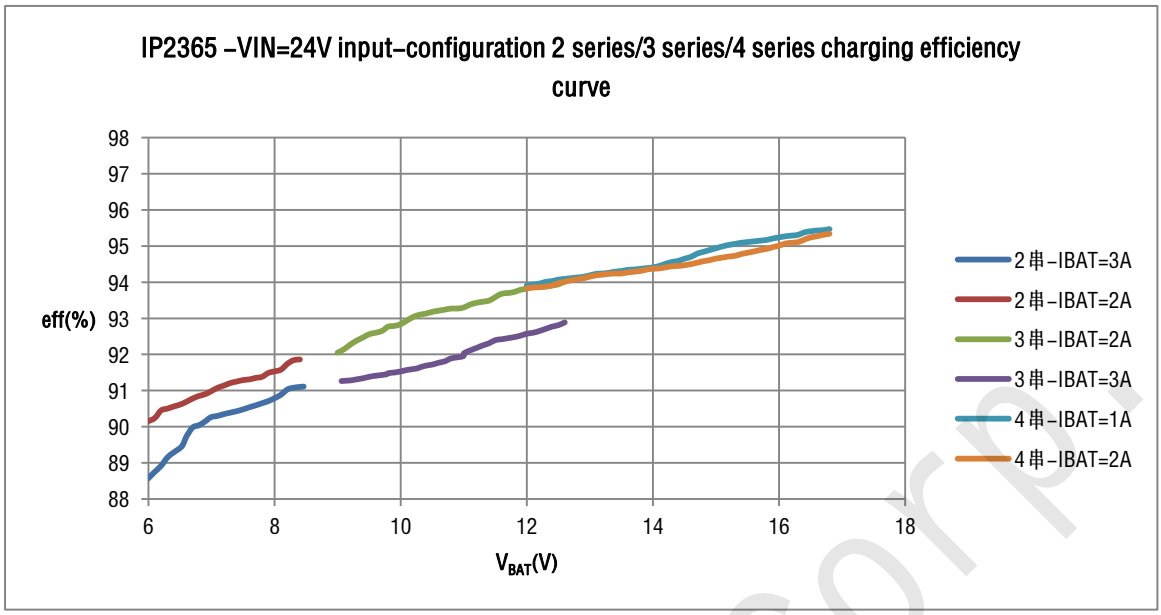
switching frequency during operation is 250kHz. When VIN=12V, VBAT=8.0V@3 A, the conversion efficiency is 93%。

IP2365 is a step-down charging method, so the input voltage is required to be at least 0.8V higher than the maximum output voltage.

Efficiency curve







Charging process

IP2365 determines the charging status by detecting the voltage of the FB pin:

If the FB voltage VFB<1.5V, enter the pre-charge state, and trickle charge the battery with a current of about 100mA;;

If FB voltage 1.5V<VFB<2.075V, enter the constant current charging state, and charge with the set constant current charging current;

If FB voltage VFB> 2.075V, enter the constant voltage charging state, IP2365 will stop charging every 30 seconds (charging current drops to 0), and then detect the FB voltage, if VFB> 2.075V, the battery is considered to be fully charged and the charging ends . Otherwise, continue charging

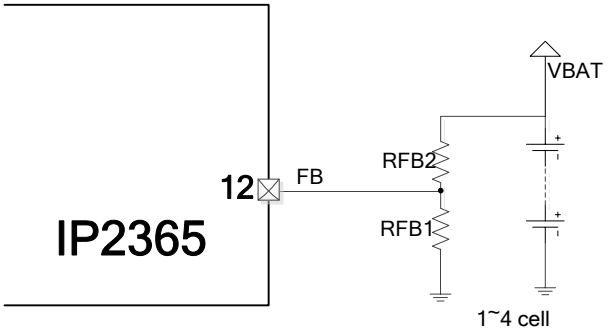
If the battery is fully charged, the FB voltage VFB <2.05V is detected, and the battery will be charged again

Battery type and full voltage setting

IP2365 selects the battery type and sets the charging voltage through the FB pin. After the battery voltage is divided by the voltage divider resistor, it is connected to FB, and different battery types and charging voltages can be selected. The relationship is as follows.

The standard product only supports lithium battery charging, FB pin voltage is 2.1V;

Through customization, it can support lithium iron phosphate battery charging (after customizing as a lithium iron phosphate battery, the FB pin voltage is 1.8V)



RFB1, RFB2 select battery type and set full voltage V(BAT_END)=2.1V

RFB1、RFB2 = X(1+RFB2/RFB1) V_BAT_END

100K	100K	4.2V 1cell
100K	300K	8.4V 2 cells
100K	500K	12.6V 3 cells
100K	700K	16.8V 4 cells

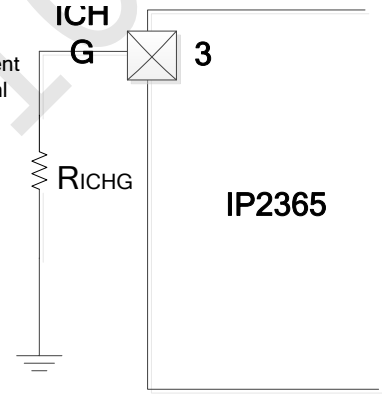
In order to ensure the accuracy of the full voltage, R1 and R2 should use 0.1% precision resistors。

Charging current

IP2365 can adjust the charging current during constant current charging through an external resistor;;

IP2365 can set the charging current of the battery terminal or the input terminal through an external resistor;

IP2365 can set the constant current rechargeable battery terminal current ICC_BAT (accuracy ±10%) by connecting the ICHG pin (pin 3) to the resistor RICHG of different resistance, the relationship is as follows:

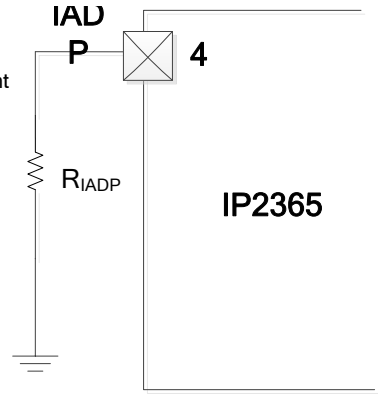


RICHG sets constant current charging battery terminal current

I_{CC_BAT}=75K / R_{ICHG}

R_{ICHG}	I_{CC_BAT}
25K	3.0A
37.5K	2.0A
50K	1.5A
75K	1.0A

IP2365 can set the constant current charging input current ICC_ADP (accuracy ±10%) by connecting a resistor RIADP of different resistance to the IADP pin (pin 4), the relationship is as follows:



RIADP set constant current charging input current

I_{CC_ADP}=75K / R_{IADP}

R_{IADP}	I_{CC_ADP}
37.5K	2.0A
50K	1.5A
75K	1.0A

The charging current setting pin cannot be left floating, there will be no charging current after floating;
The actual constant current charging current will be the smaller value between the battery charging

setting current and the input charging setting current；

For example: set the battery terminal constant current charging current is 2A (RICHG=50K), the input terminal constant current charging current is 1.2A (RIADP=62.5K), VIN=12V, set the 2 string charging, input and output conversion efficiency 95 %, when the battery voltage is below 6.84V and the battery terminal current is 2A, the input terminal current is less than 1.2A, and the charging current is charged with the set battery terminal charging current 2A (RICHG=50K). As the battery voltage rises, the battery The terminal charging current remains the set 2A unchanged, and the input terminal charging current gradually increases to 1.2A; after the battery voltage is greater than 6.84V, if the battery terminal charging current is still equal to 2A, the input terminal current will exceed the set 1.2A , So it will actually be charged with the set input charging current of 1.2A (RIADP=62.5K). As the battery voltage rises, the input battery current remains unchanged at the set 1.2A, and the battery charging current starts from 2A Gradually decrease；

If you only need a constant battery terminal charging current, you can set the input terminal charging current to infinity (RIADP=0R)；；

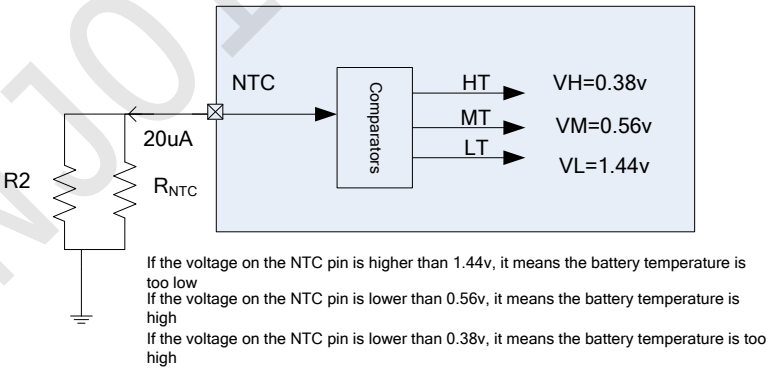
If you only need a constant input terminal charging current, you can set the battery terminal charging current to infinity (RICHG=0R)；

Note that you cannot set both the battery charging current and the input charging current to infinity (both RIADP and RICHG are 0R), so the charging current will reach more than 5A, which exceeds the maximum value of the chip design, and the chip will be damaged after long time operation risk；

It is recommended to set the maximum battery terminal charging current not to exceed 3A; if the input voltage is high and is more than 10V higher than the maximum full battery voltage, the charging efficiency will be reduced, and the charging current setting needs to be appropriately reduced;

Charging NTC

IP2365 supports NTC protection function. It detects the battery temperature through the NTC pin, and stops charging when the detected temperature exceeds the set temperature.



When NTC detects that the temperature is within the range of -10 to 45 degrees, it is charged normally. When the temperature is higher than 45 degrees, the charging current is reduced by half; when the temperature is higher than 60 degrees, the charging is stopped.

If the NTC function is not needed, connect the NTC pin to the ground with a 51K resistor and cannot be left floating。

Discharge 20uA current from NTC, connect a resistor to GND on NTC, the voltage drop generated by this current on the resistor to judge the temperature range。

For example: RNTC=100K@25℃, NTC resistance of B=4100, R2=82K, corresponding temperature

and NTC voltage: VNTC=20uA* RNTC *R2 / (RNTC +R2)

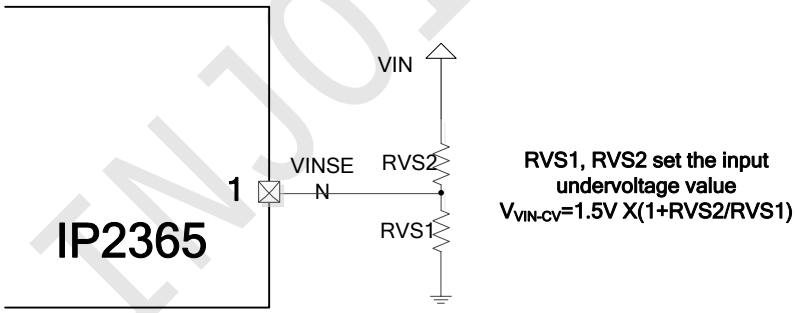
Temperature	100K@25℃，B=4100 的 NTC temperature resistance value （KΩ）	R2//RNTCresistance （KΩ）	NTC pin voltage (V) The voltage generated by 20uA current on R2//RNTC
-20	1105	76	1.52
-15	814	74.5	1.49
-10	606	72	1.44
0	347	66	1.32
45	42.1	27.8	0.56
50	34.8	24.5	0.49
55	28.5	21.2	0.43
60	23.5	18.3	0.38

Through customized parameters, the NTC protection temperature can be fine-tuned;

VINSEN sets input undervoltage

IP2365 will detect the VINSEN voltage. If the VINSEN voltage is lower than 1.5V, the charging current will be reduced to stabilize the VINSEN voltage at 1.5V to ensure that the adapter is not pulled dead. When IP2365 detects that VINSEN is lower than 1.3V, it will stop charging and enter standby.

The VINSEN pin can be used as an enable pin to connect to a signal greater than 1.5V and work normally; for a signal less than 1.3V, stop charging and enter standby；



Protective function

IP2365 has an input overvoltage protection function: when VIN rises above 27V, IP2365 detects input overvoltage and stops charging; when VIN drops to 25V again, IP2365 considers the input normal and restarts charging.

Through customization, the input overvoltage protection function can also be set with VINSEN. The overvoltage threshold of VINSEN has four gears of 2.2V, 2.6V, 2.8V and 3.0V.

VINSEN setting input overvoltage must use a customized model;

IP2365 has an over-temperature protection function: when IP2365 detects that the chip temperature reaches 140℃, it will stop charging; when the temperature drops to 100℃, IP2365 will consider the temperature to return to normal and restart charging;

Charging instructions

IP2365 supports battery charging LED indicator. The default configuration is: the LED light flashes at 0.5 Hz during charging, and it stays on when fully charged.

Can also be customized:

1、It is always on during the charging process and turns off after being fully charged.

2、The light will be off during charging, and it will be on after being fully charged

I2C

IP2365 supports I2C function by default, the connection method is as follows:

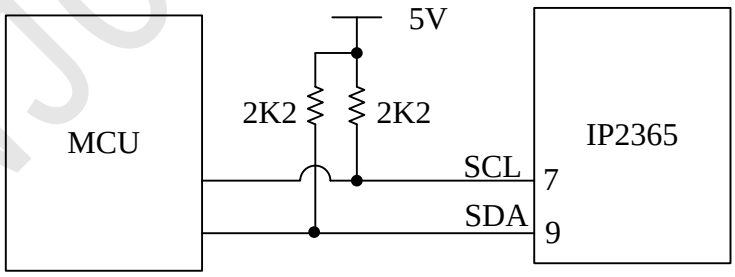
note:

1. When IP2365 is powered on or VINSEN changes from low to high, ensure that both SCL (pin 7) and SDA (pin 9) are high before entering I2C mode; if IP2365 is powered on, SCL and SDA As long as any one of SDA is low, IP2365 cannot enter I2C mode;

2、IP2365 I2C high level is 5V, if MCU IO high level is 3.3V, level conversion is required;

3、After the chip is in standby (VINSEN is lower than 1.3V), I2C will not be able to communicate;

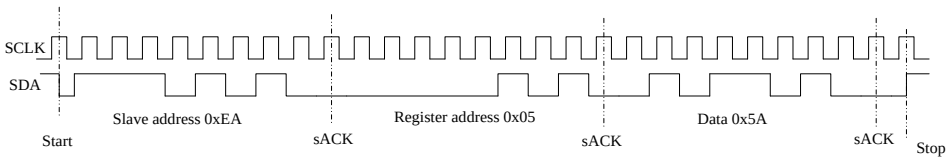
4、After standby or VIN power failure, when restarting, the value of the register will be restored to the factory default setting;



I2C mode supports up to 400Kbps (recommended to be set to about 100K), 8bit register address, 8bit register data, both sending and receiving are MSB, I2C device address: write 0xEA, read 0xEB。

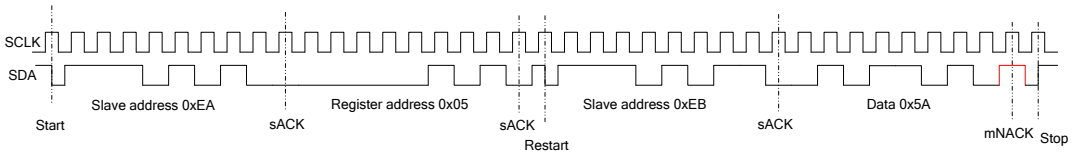
E.g:

Write data 0x5A to register 0x05



I2C WRITE

Read back data from 0x05 register



I2C Read

Special note: At the end of the I2C read data, when the last BYTE is read, the NACK signal must be given, otherwise the IP2365 will think that the MCU needs to continue to read the data, and the next SCLK will output the next data, which is not normal Receiving the STOP signal may cause the I2C bus to be pulled dead。

* The reserved register cannot write data at will, and cannot change the original value, otherwise, unexpected results will occur. The operation of the register must be carried out in accordance with read-modify-write. Only the used bits are modified, and the values of other unused bits cannot be modified.

SYS_CTL1

Register address = 0x00

Bit(s)	Name	Description	R/W
7:1		Reserved	
0		Charger Enable 0:disable，Stop charging 1:enable	R/W

VINOV_SET

Register address = 0x04

Bit(s)	Name	Description	R/W
7:5		Reserved	
4:3		VINSEN over voltage setting： 00：3.0V 01：2.8V 10：2.6V 11：2.2V	R/W
2		Reserved	

1		Over voltage choose： 0：choose VINSEN to set overvltage（Reg0x04[4:3]） 1：Do not use VINSEN pin to set overvoltage, overvoltage directly detect VIN voltage, VIN greater than 27V enters overvoltage protection	
0		Reserved	

NTC_CTL

Register address = 0x05

Bit(s)	Name	Description	R/W
7		Reserved	
6:5		NTC high temperature judgment voltage： 00：0.56V 01：0.49V 10：0.43V 11：0.38V	R/W
4:3		NTC Intermediate temperature judgment voltage： 00：0.6V 01：0.58V 10：0.56V 11：0.54V	R/W
2:1		NTC Low temperature judgment voltage： 00：1.52V 01：1.49V 10：1.44V 11：1.32V	R/W
0		NTC Function enable 0:disable，Turn off NTC detection function 1:enable	R/W

R_ISET

Register address = 0x0F

Bit(s)	Name	Description	R/W
7:4		Reserved	
3		Set the charge current function enable by ICHG pin resistance 0：disable ，Regardless of the resistance value of ICHG pin RICHG, the charging current set by reg0x1F[5:0] is fixed 1：enable, ICC_BAT=ISET_BAT*75K/RICHG, where ISET_BAT corresponds to the charging current set by reg0x1F[5:0]	
2		Set the charge current function enable through the IADP pin resistance 0：disable，Regardless of the resistance value of the IADP pin RIADP, the charging current set by reg0x19[5:0] is fixed 1：enable ，ICC_VIN=ISET_VIN*75K/RIADP, where ISET_VIN corresponds to the charging current set by reg0x19[5:0]	R/W
1:0		Reserved	

VIN_ISET

Register address = 0x19

Bit(s)	Name	Description	R/W
7:6		Reserved	
5:0		Set the input charging current $I_{SET\_VIN}=I_{SET}*0.1A+0.05A$	R/W

BAT _ISET

Register address = 0x1F

Bit(s)	Name	Description	R/W
7:6		Reserved	
5:0		Set the battery charging current	R/W

		$I_{SET\_BAT}=I_{SET}*0.1A+0.05A$	

LED_REG

Register address = 0x1A

Bit(s)	Name	Description	R/W
7:6		Reserved	
5:4		LED indication status during charging: 00 or 01：off 10：blink 11：on	R/W
3:2		Reserved	
1		LED indicates status after full 0：off 1：on	
0		Reserved	

CHG_FULL

Register address = 0x2B

Bit(s)	Name	Description	R/W
7:6		Reserved	
5		Charge full flag 0：Charging 1：Full	R
4:3		Reserved	
2:0		Charging state flag： 000：Trickle charging 001：Constant current charging 011：Constant voltage charging	R

NTC_STAT

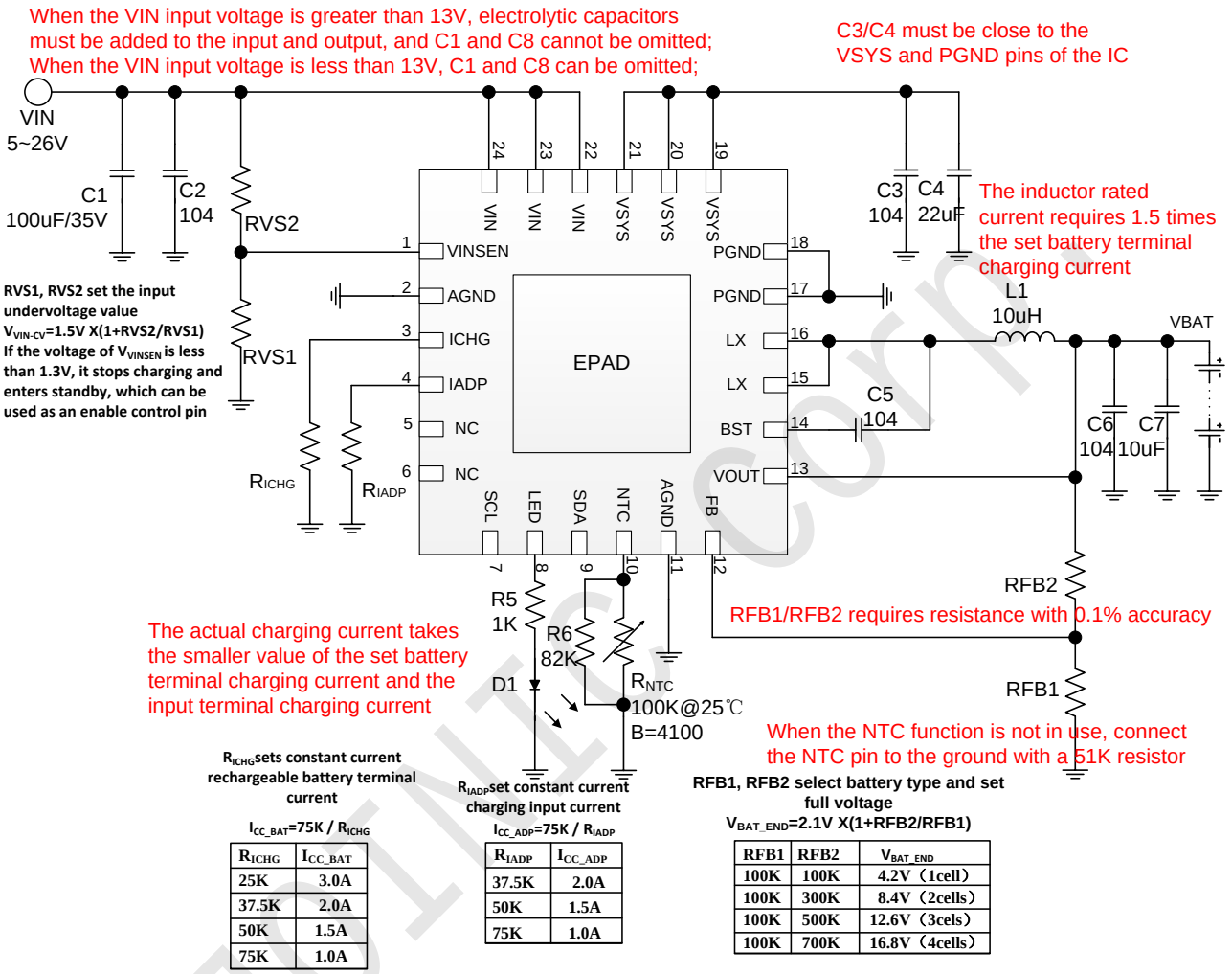
Register address = 0x22

Bit(s)	Name	Description	R/W
7		Reserved	
6:4		NTC status indication： 000：NTC detects high temperature 100：NTC detects moderate temperature 110：NTC detects that the temperature is normal 111：NTC detects low temperature	R
2:1		Reserved	
0		VIN overvoltage status indicator 0：VIN input has no overvoltage 1：VIN input is in an overvoltage state VIN input is in an overvoltage state .	R

11 Design considerations

1. When the VIN input voltage is greater than 13V, electrolytic capacitors must be used on the VIN input and VOUT output and cannot be omitted; when the VIN input voltage is less than 13V, the electrolytic capacitors on VIN and VOUT can be omitted;
2. A 22uF ceramic capacitor must be added to the VSYS pin. It cannot be omitted or replaced with an electrolytic capacitor. The 22uF capacitor should be close to the VSYS pin (1 PIN) and EPAD pin (GND pin under the chip);

12 Typical application schematic



R_{ICHG}sets constant current rechargeable battery terminal current

I_{CC_BAT}=75K / R_{ICHG}

R_{ICHG}	I_{CC_BAT}
25K	3.0A
37.5K	2.0A
50K	1.5A
75K	1.0A

R_{IADP}set constant current charging input current

I_{CC_ADP}=75K / R_{IADP}

R_{IADP}	I_{CC_ADP}
37.5K	2.0A
50K	1.5A
75K	1.0A

RFB1, RFB2 select battery type and set full voltage

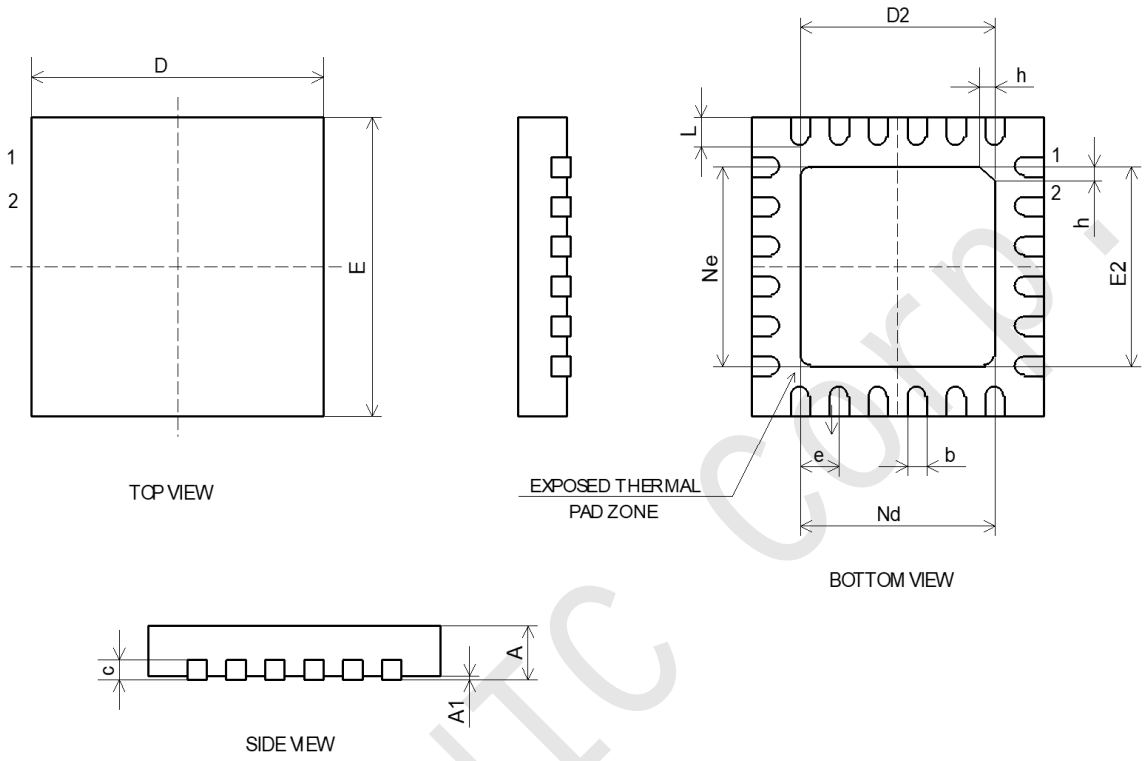
V_{BAT_END}=2.1V X(1+RFB2/RFB1)

RFB1	RFB2	V_{BAT_END}
100K	100K	4.2V（1cell）
100K	300K	8.4V（2cells）
100K	500K	12.6V（3cels）
100K	700K	16.8V（4cells）

13 BOM

Num	Component name	Model & Specification	Unit	用量	position	Note
1	IC	IP2365	PCS	1	U1	
2	SMD resistance	0603 1K 1%	PCS	1	R5	R5 adjusts the brightness of the indicator light
3	SMD resistance	0603 82K 1%	PCS	1	R6	When NTC function is not used, use 51K resistor
4	NTC resistance	100K@25℃, B=4100	PCS	1	R_{NTC}	NTC resistance
5	SMD resistance	0603 ？ 1%	PCS	1	R_{ICHG}	RICHG sets the battery charging current
6	SMD resistance	0603 ？ 1%	PCS	1	R_{IADP}	RIADP sets the input charging current
7	SMD resistance	0603 ？ 1%	PCS	1	RVS1、RVS2	RVS1, RVS2 set the input undervoltage threshold
8	SMD resistance	0603 ？ 1%	PCS	1	RFB1、RFB2	RFB1, RFB2 set the number of battery cells and full voltage
9	inductance	10uH	PCS	1	L1	The rated current is required to be greater than 1.5 times the battery terminal charging current
10	SMD LED	0603	PCS	1	D1	SMD LED indicator
11	SMD capacitors	0603 104 50V 10%	PCS	4	C2、C3、C5、C6	
12	SMD capacitors	0805 10uF 25V 10%	PCS	1	C7	
13	SMD capacitors	0805 22uF 25V 10%	PCS	1	C4	
14	SMD capacitors	100uF/35V	PCS	1	C1	When the VIN input voltage is greater than 13V, electrolytic capacitors must be added to the input and output, and C1 and C8 cannot be omitted; When the VIN input voltage is less than 13V, C1 and C8 can be omitted;

14 Package information



SYMBOL	MILLIMETER		
	MIN	NOM	MAX
A	0.70	0.75	0.80
A1	-	0.02	0.05
b	0.18	0.25	0.30
c	0.18	0.20	0.25
D	3.90	4.00	4.10
D2	2.40	2.50	2.60
e	0.50BSC		
Ne	2.50BSC		
Nd	2.50BSC		
E	3.90	4.00	4.10
E2	2.40	2.50	2.60
L	0.35	0.40	0.45
h	0.30	0.35	0.40

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