IP2501

Ultra low I_Q 400mA High Efficiency Synchronous Step-up Converter

1. Features

- **Ultra low I_Q, Typical Quiescent Current 1.5μA**
- **Ultra low Operating Input Voltage 0.9V, Wide Input Voltage Range 0.7V-5.5V**
- **Wide Adjustable Output Voltage Range up to 5.5V**
- **Up to 96% Efficiency**
- **Output Voltage Accuracy ±2%**
- **Maximum 400mA Output Current**
- **Internal Synchronous Rectifier**
- **True Shutdown Mode**
- **Thermal Shutdown**
- **Short Circuit Protection**
- **SOT23-6 Package**

2. Applications

- All One-Cell, Two-Cell, and Three-Cell Alkaline, NiCd or NiMH
- Single-Cell Li
- TWS Charging Box
- Wearable Device, MID

3. Description

The IP2501 is a fixed PWM frequency, high efficiency synchronous step-up converter, it provide a power supply solution for products powered by either a one-cell, two-cell, or three-cell alkaline, NiCd or NiMH, or one-cell Li-ion or Li-polymer battery. At low load currents, the IP2501 exits the fixed switching frequency mode and enter the power-down mode to maintain a high efficiency over a wide load current range. The IP2501 provide a wide output voltage range by adjusting the feedback resistor divider. During shutdown, the load is completely disconnected from the battery, and the quiescent current is less than 1.5μA to ensure the battery capacity.

The IP2501 is packaged in a 6-pin thin SOT23 package.

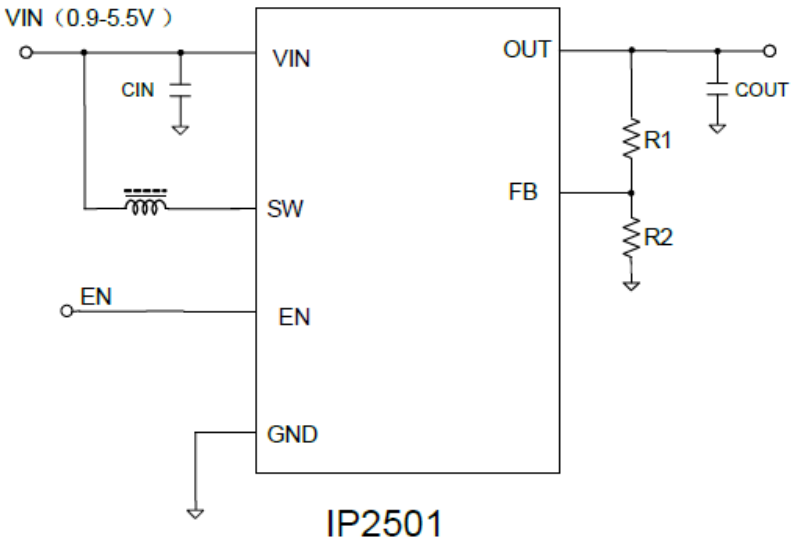


Figure1 Simplified Application Circuit

4. Pin Definition

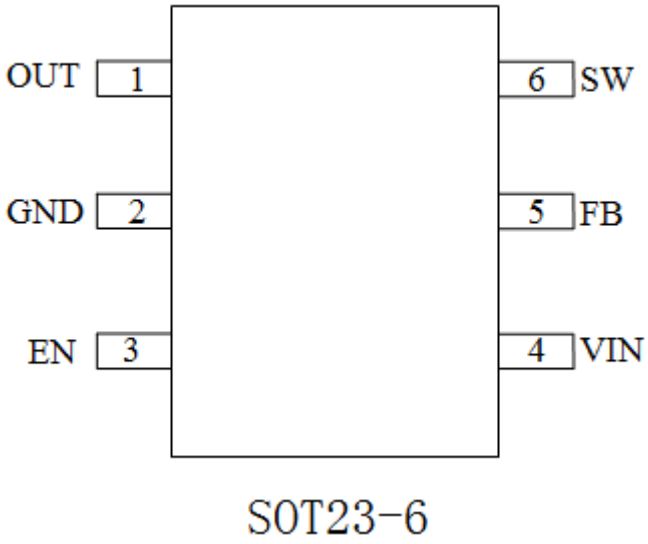


Figure1 IP2501 Pin Assignments

Pin Num	Pin Name	Type	Description
1	OUT	PWR	Boost converter output.
2	GND	GND	Power and logic ground.
3	EN	DI	Boost converter enable pin. Input high: enable; low: disable.
4	VIN	PWR	Input supply voltage.
5	FB	AI	Voltage feedback for programming the output voltage.
6	SW	PWR	Boost and rectifying switch input, connect to inductor.

5. Absolute Maximum Ratings

Parameter	Symbol	Value	Unit
Input Voltage Range	VIN	-0.3 ~ 6.5	**V**
Junction Temperature Range	T_J	-40 ~ 125	℃
Storage Temperature Range	Tstg	-60 ~ 150	℃
Thermal Resistance (Junction to Ambient)	θ_{JA}	120	**℃/W**
ESD (Human Body Model)	ESD	2	**KV**

*Stresses beyond these listed parameter may cause permanent damage to the device.

Exposure to Absolute Maximum Rated conditions for extended periods may affect device reliability.

6 Recommended Operating Conditions

Parameter	Symbol	Min.	Typ.	Max.	Unit
Input Voltage	VIN	0.9	--	5.5	V
Operating Temperature	T_A	-40	--	85	℃

*Device performance cannot be guaranteed when working beyond these Recommended Operating Conditions.

7 Electrical Characteristics

Unless otherwise specified, TA=25℃, L=2.2uH, VIN=3.6V, C_{OUT}=10uF

Parameter	Symbol	Test Conditions	Min.	Typ.	Max.	Unit
Input VIN/ Output Voltage						
Input voltage range	VIN	After start	0.7	-	5.5	V
UVLO threshold	VIN_{UVLO}	VIN rising, no load	0.8	0.9	1.1	V
Quiescent current	I_{OUT_Q}	EN=1, no load	-	1.5	3	uA
Shutdown current	I_{OUT_S}	EN=0	-	0.5	0.7	uA
Start-up current limit	I_L	VIN>2.4V	-	1	1.2	A
Output voltage Accuracy	VOUT	T_A = +25°C, VOUT=5.0V，PWM mode	4.9	5	5.1	V
		T_A = +25°C, VOUT=3.3V，PWM mode	3.2	3.3	3.4	
Output voltage range	VOUT	EN=1	2.5	-	5.5	V
Load regulation	VOUT	PWM mode, IN=3.6V, VOUT=5V	-	0.4	2	%
Line regulation	VOUT	PWM mode, VOUT=5V, VIN:0.8V-5.5V	-	0.2	2	%
Short circuit hiccup time	-	ON		2.2		ms
		OFF		60		

Start up time	VOUT	VOUT=5V,VIN=3.6V, EN from low to high	0.2	0.5	0.8	ms
Turn on resistance(switch MOS)						
Boost switch-on resistance	$R_{DS(ON)}$	VOUT=5V		180		mΩ
Rectifying switch-on resistance	$R_{DS(ON)}$	VOUT=5V		180		mΩ
LOGIC SIGNALS (EN), FB， SW						
High-level input voltage (EN)	V_{EN-H}	VIN=1.2V to 5.5V	1.2	-	-	V
Low-level input voltage (EN)	V_{EN_L}	VIN=0.9V to 5.5V	-	-	0.4	V
EN pin current (EN)	I_{EN}	EN=3.3V	-	0	0.1	uA
Feedback Voltage	V_{FB}	VIN=0.9V to 5.5V	1.164	1.215	1.236	V
Switch Frequency	F_{SW}		0.7	1	1.3	MHz
Normal Switch current limit	I_{SW}			1		A
Thermal Regulation and Thermal Shutdown						
OTP	T_{OTP}			150		℃
OTP hysteresis	ΔT_{OTP}			25		℃

8 Function Description

System Diagram

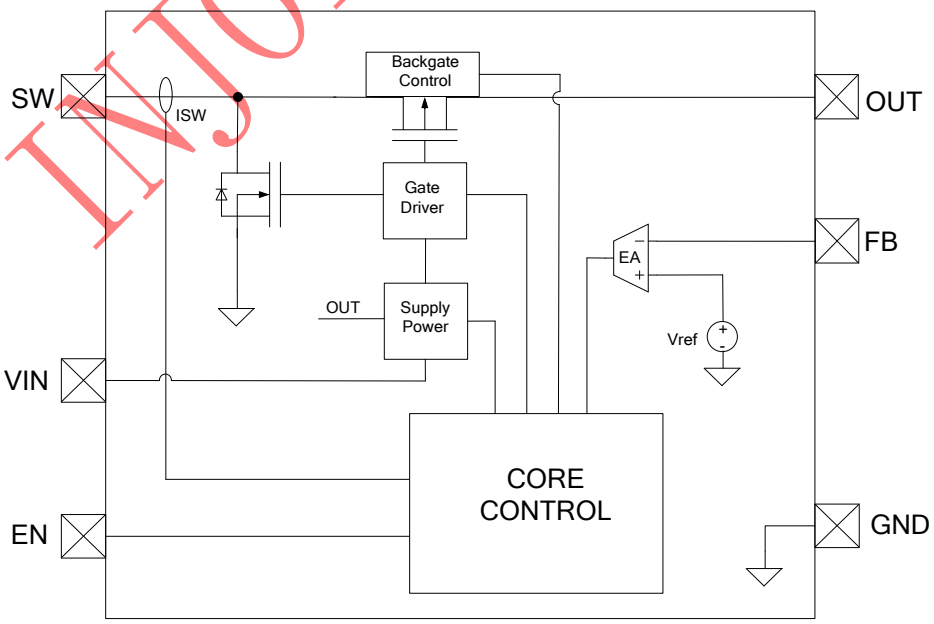


Figure3 IP2501 Internal System Diagram

Overview

IP2501 high efficiency synchronous boost converter integrates low Rdson switching NMOSFET and rectifying PMOSFET with ultra-low quiescent current down to 1.5uA.IP2501 features fixed-frequency peak current mode pulse-width modulation(PWM) for excellent line and load regulation, regulates targeted output voltage by comparing feedback voltage with internal 1.215V reference voltage, also senses low side NMOSFET peak current or inductor peak current and limits it to internal setting reference threshold. Over temperature protection is employed to prevent overheated.

Synchronous Rectifier and Shutdown

IP2501 integrates a P-channel MOSFET as synchronous rectifier. The power conversion efficiency is above 90%, because of using the low R_{DSON} PMOS instead of commonly discrete Schottky rectifier. When the converter is not enabled (EN=0) or in protection cases, a propriety substrate selection circuit can completely disconnect the output from input without additional components in the design to make sure that the battery is not depleted during shutdown of the converter.

Ultra Low Current Consumption Operation Mode（Burst Mode）

IP2501 employs burst mode to provide high light load efficiency and ultra-low operational current (1.5uA) without load. IP2501 automatically switches to burst mode from PWM mode when load current is smaller than 1/2 inductor current ripple (inductor current DCM mode) by internal propriety control mechanism; Conversely IP2501 works in PWM mode when inductor currents enters CCM mode. In the burst mode, the converter only operate when the output voltage trips below a set threshold voltage, it ramps the output voltage with one or several pulses.

Output Voltage Setting

The output voltage options are as follows in factory trimming:

Vout=5V	Option1:Internal feedback
Vout=3.3V	Option2:Internal feedback
FB resistor setting	Option3: external feedback

If users need another output voltage expect 5V and 3.3V, option3 is selected. The output voltage of the IP2501 converter can be adjusted with external resistor divider. The maximum recommended output voltage is 5.5V, the value for the R2 recommended to be 150K or less. When R1 and R2 are used to set output voltage, the overall consumption will be increased. The output voltage is set as following equation:

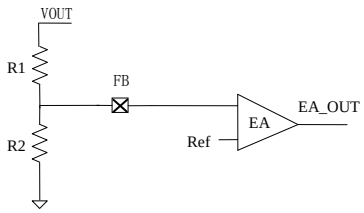


Figure 4 Output voltage setting circuit

$$V_{OUT} = \frac{R1 + R2}{R2} \times V_{Ref}\ (V)$$

Here, V_{Ref} = 1.215V. If the input voltage is higher than the set output voltage, the output voltage will follow the input voltage and maintain a 200mV deviation.

Start-up & Shut-down Sequencing

When the IP2501 enables, the internal start-up cycle starts with the pre-charge (LDO) phase. During pre-charge phase, the rectifying switch is turn on until the output capacitor is charged to the voltage of the input. The rectifying switching current is limited to 1A during this phase. Then, the converter starts boost switching to charge the output capacitor to the setting value. In switching start up stage, inductor peak current is limit 1A if there are big load during start up. Here, Figure5、Figure6 shows the start-up timing(TA<100us). The EN pin is internal weak pulled up, and the device is also enabled if the EN pin is floating.

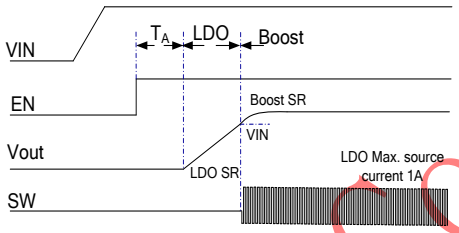


Figure 5 EN Start-up sequencing

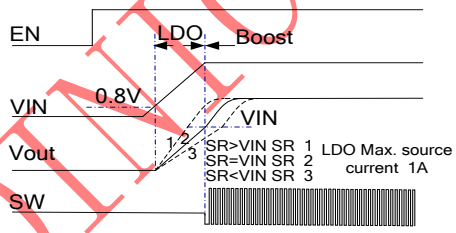


Figure 6 VIN Start-up sequencing

IP2501 integrates output voltage discharge circuit: when EN is low, internal resistance of about 100Ω will connected between the VOUT node and GND to quickly discharge the output voltage (Figure7). If the device is turned off due to the VIN under-voltage protection, and the EN pin is still high, the internal discharge circuit will not work (Figure8).

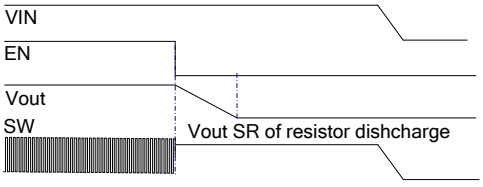


Figure 7 EN turned off， FB floating

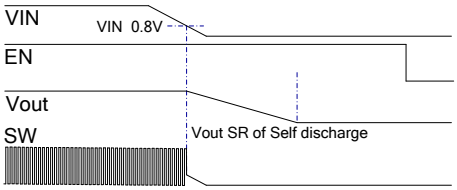


Figure 8 VIN UVLO, FB floating

Protection Mechanisms

IP2501 integrates input under-voltage protection, LDO current limiting, inductor peak current limiting, output short-circuit protection and over-temperature protection to ensure that the device will not be damaged in abnormal applications.

VIN UVLO

If the VIN voltage is higher than 0.9V typically, the converter will start up automatically. If VIN voltage is lower than 0.7V typically, the IP2501 will shutdown.

Over-current & short-circuit Protection

When inductor peak current reaches limit threshold 1A typically, converter enters peak current limit mode. In the stage, VOUT will drop with load increasing. When VOUT is lower than VIN, low side NMOSFET turns off and IP2501 enter linear mode with 1A limit with hiccup mode operation.
When output shorts, IP2501 works in hiccup mode: start up 2.2ms and shut down 60ms typically.

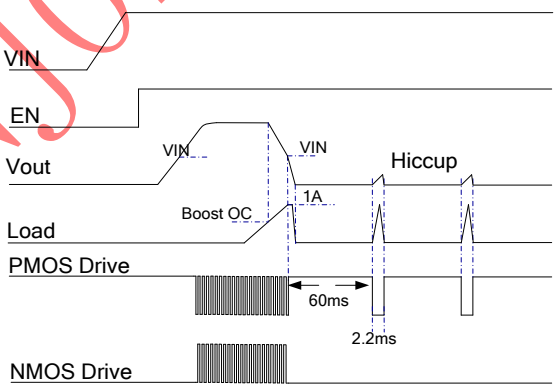


Figure 9 over-current & short-circuit protection

OTP

When the junction temperature rises above 150°C, the boost switch and the rectifier will turn off, when the junction temperature is lower than 125°C, the device will restart automatically.

9. Application Performance Characteristics

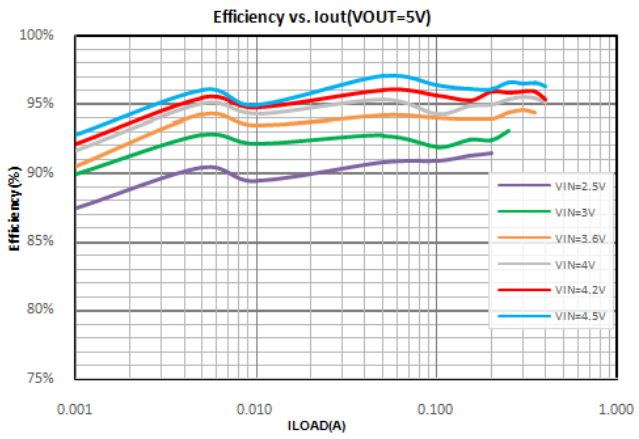


Chart1 Efficiency vs. IOUT(VOUT=5V)

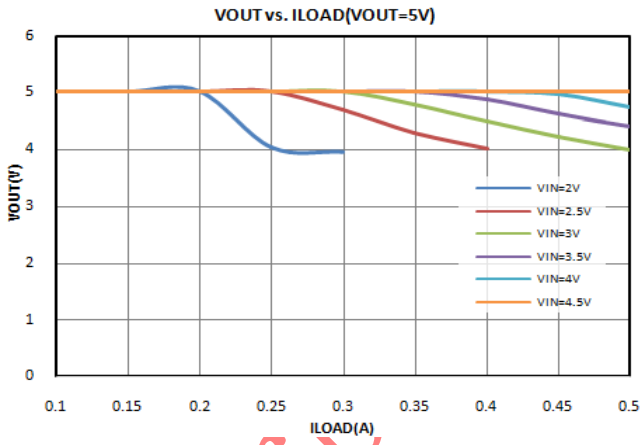


Chart 2 VOUT vs. ILOAD(VOUT=5V)

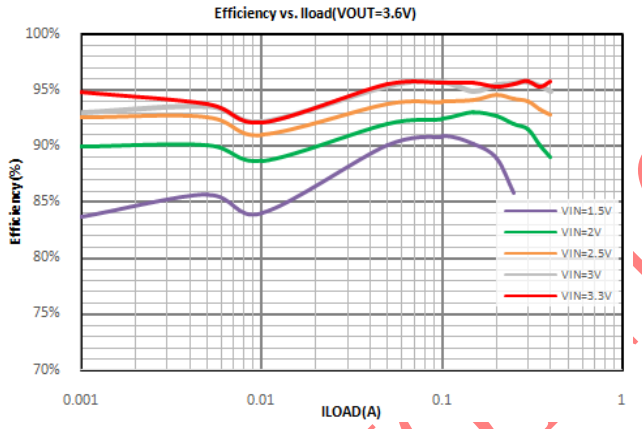


Chart3 Efficiency vs. IOUT(VOUT=3.6V and external feedback)

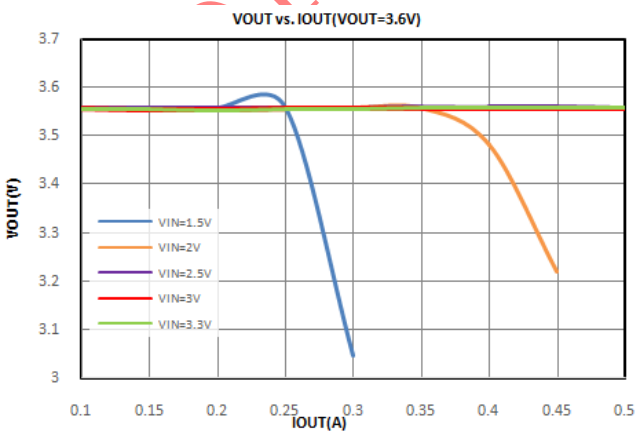


Chart 4 VOUT vs. ILOAD(VOUT=3.6V and external feedback)

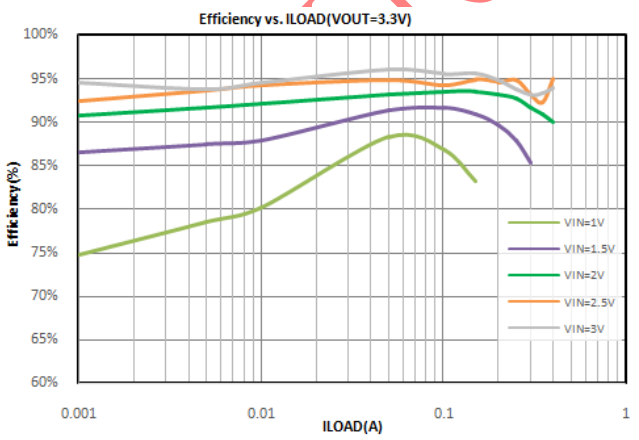


Chart 5 Efficiency vs. IOUT(VOUT=3.3V)

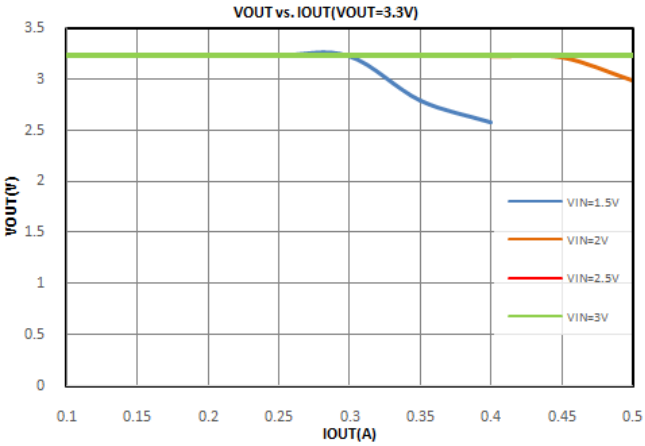


Chart 6 VOUT vs. ILOAD(VOUT=3.3V)

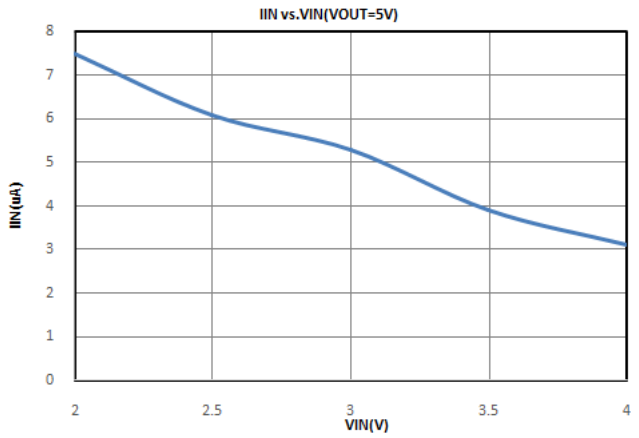


Chart 7 Input current with VIN voltage

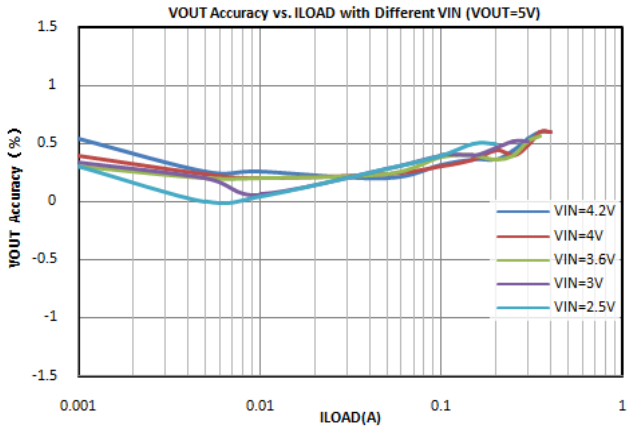


Chart 8 VOUT accuracy with load current

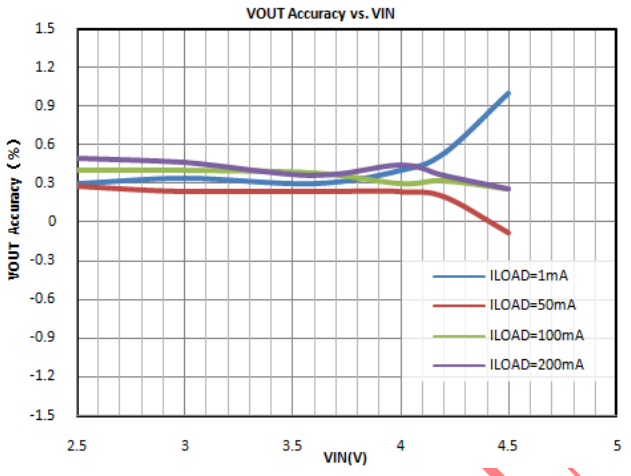


Chart 9 VOUT accuracy with input voltage

10. Application Examples

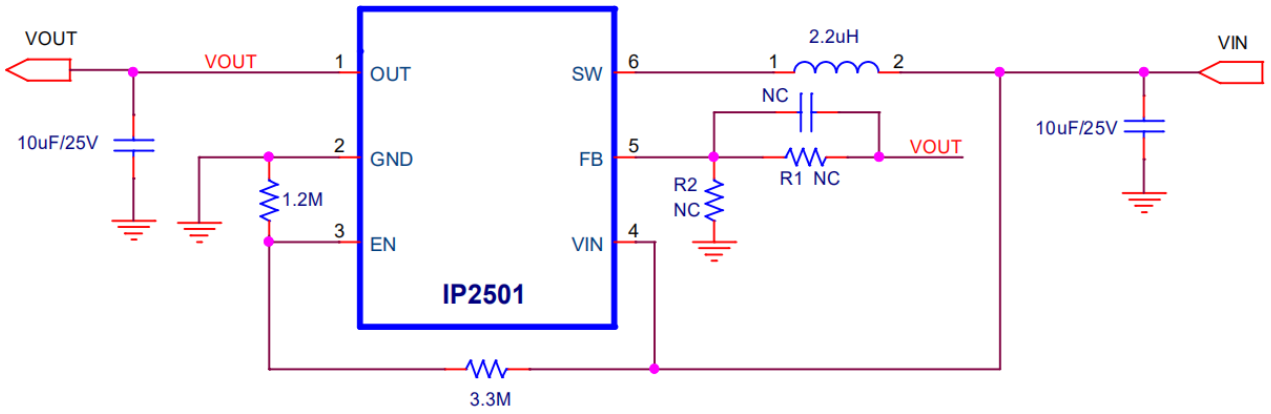


Figure 10 IP2501 Typical Application1 (Vout=5V without MCU)

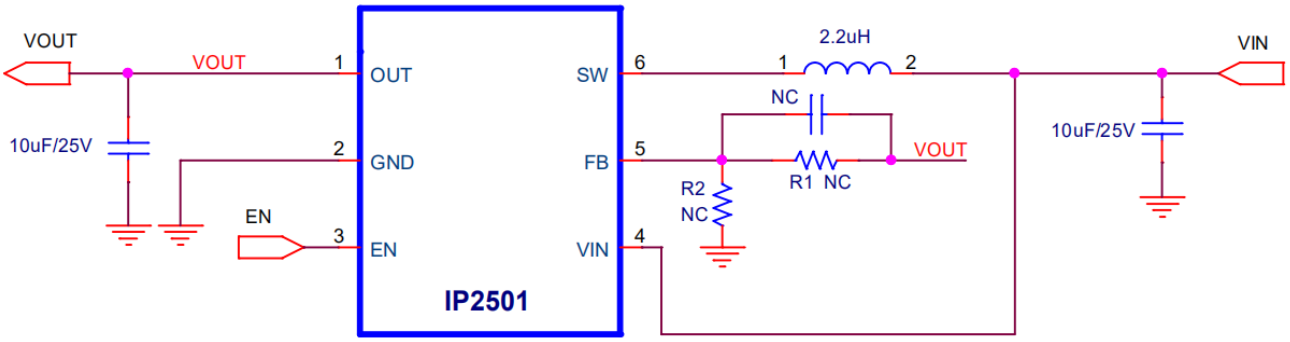


Figure 11 IP2501 Typical Application2 (Vout = 5V with EN be controlled by MCU)

11. Layout Example

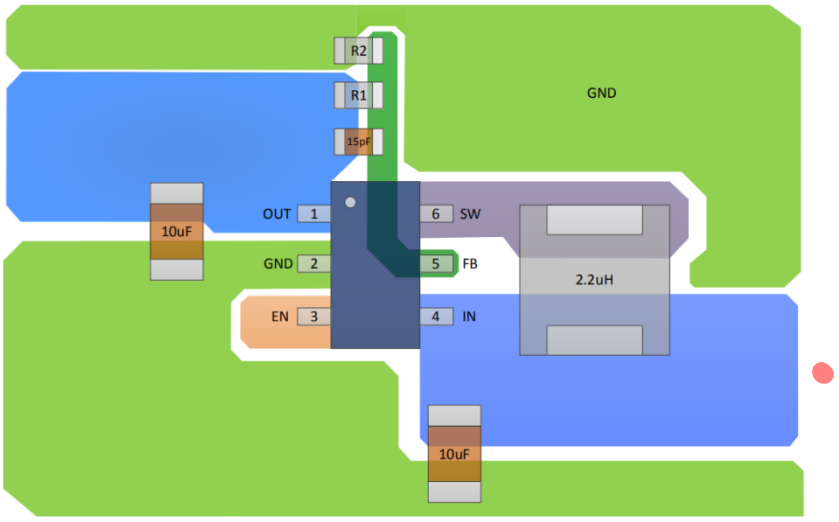
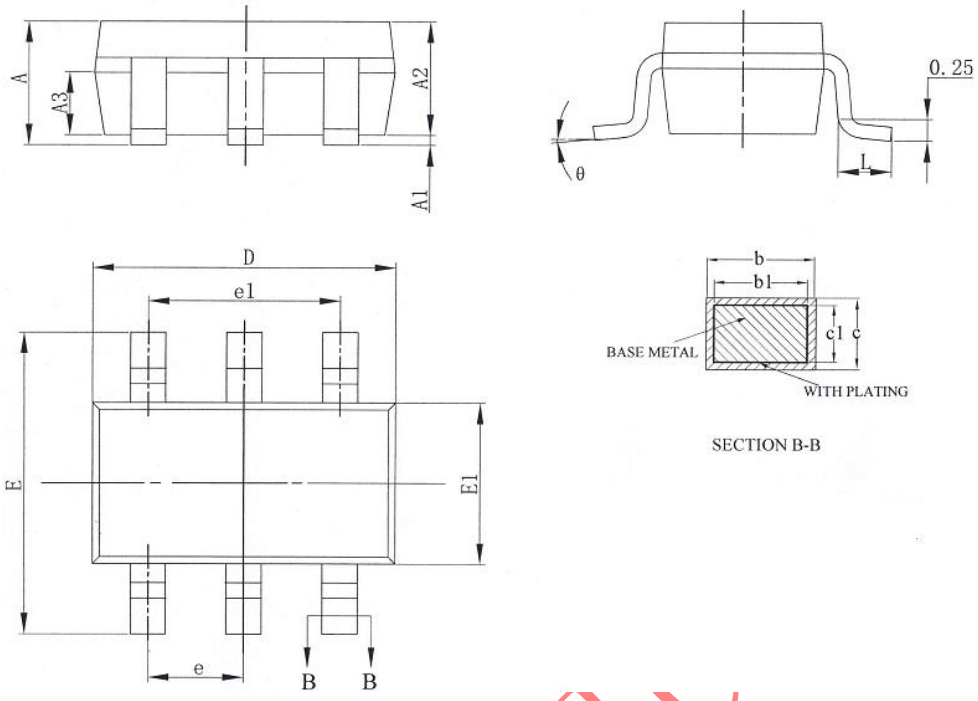


Figure 12 Layout example

Notes: the power inductor and filter capacitor should be close to the chip pin as far as possible, the power pin should ensure enough copper area; if external feedback is used, the feedback wiring should be short and avoid SW noise area.

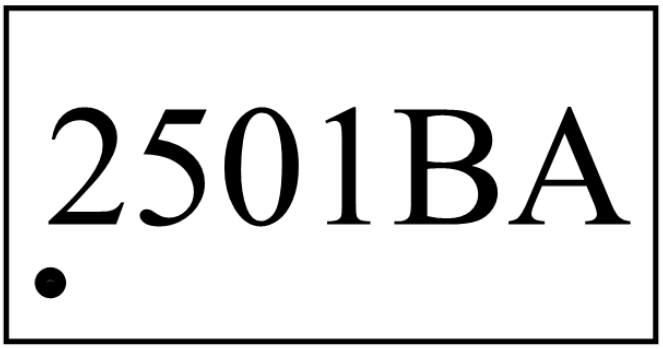
12 Package Information: SOT23-6



SYMBOL	MILLIMETER		
	MIN	NOM	MAX
A	—	—	1.25
A1	0.04	—	0.10
A2	1.00	1.10	1.20
A3	0.55	0.65	0.75
b	0.38	—	0.48
b1	0.37	0.40	0.43
c	0.11	—	0.21
c1	0.10	0.13	0.16
D	2.72	2.92	3.12
E	2.60	2.80	3.00
E1	1.40	1.60	1.80
e	0.95BSC		
e1	1.90BSC		
L	0.30	—	0.60
θ	0	—	8°

Figure 13 IP2501 SOT23-6

13. Mark Description



Note：
1、2501BA --Part number and Version
2、 ● --Pin1 location

IMPORTANT NOTICE

INJOINIC TECHNOLOGY and its subsidiaries reserve the right to make corrections, enhancements, improvements and other changes to its semiconductor products and services. Buyers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All semiconductor products (also referred to herein as “components”) are sold subject to INJOINIC TECHNOLOGY's terms and conditions of sale supplied at the time of order acknowledgment.

INJOINIC TECHNOLOGY assumes no liability for applications assistance or the design of Buyers' products. Buyers are responsible for their products and applications using INJOINIC TECHNOLOGY's components. To minimize the risks associated with Buyers' products and applications, Buyers should provide adequate design and operating safeguards.

Buyer acknowledges and agrees that it is solely responsible for compliance with all legal, regulatory and safety-related requirements concerning its products, and any use of INJOINIC TECHNOLOGY's components in its applications, notwithstanding any applications-related information or support that may be provided by INJOINIC TECHNOLOGY. Buyer represents and agrees that it has all the necessary expertise to create and implement safeguards which anticipate dangerous consequences of failures, monitor failures and their consequences, lessen the likelihood of failures that might cause harm and take appropriate remedial actions. Buyer will fully indemnify INJOINIC TECHNOLOGY and its representatives against any damages arising out of the use of any INJOINIC TECHNOLOGY's components in safety-critical applications.

Reproduction of significant portions of INJOINIC TECHNOLOGY's information in INJOINIC TECHNOLOGY's data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. INJOINIC TECHNOLOGY is not responsible or liable for such altered documentation. Information of third parties may be subject to additional restrictions.

INJOINIC TECHNOLOGY will update this document from time to time. The actual parameters of the product may vary due to different models or other items. This document voids all express and any implied warranties.

Resale of INJOINIC TECHNOLOGY's components or services with statements different from or beyond the parameters stated by INJOINIC TECHNOLOGY for that component or service voids all express and any implied warranties for the associated INJOINIC TECHNOLOGY's component or service and is an unfair and deceptive business practice. INJOINIC TECHNOLOGY is not responsible or liable for any such statements.