6V/1.4A Synchronous Step-Down Converter

1 Description

The CN2501TCR is a monolitic buck switching regulator based on constant on-time (COT) control for fast transient response. Operating with an input range of 2.6V-6.0V makes the CN2501TCR ideally suited for single Li-Ion battery powered applications. The CN2501TCR delivers 1.4A of continuous output current with integrated P-Channel and N-Channel MOSFETs. The internal synchronous power switches provide high efficiency. At light loads, the regulator operate in low frequency to maintain high efficiency and low output ripples. The CN2501TCR guarantees robustness with hiccup output short-circuit protection, FB short-circuit protection, start-up current run-away protection, input under voltage lockout and Input over voltage protection, and thermal protection. The CN2501TCR is available in 5-pin SOT23-5 package, which provides a compact solution with minimal external components.

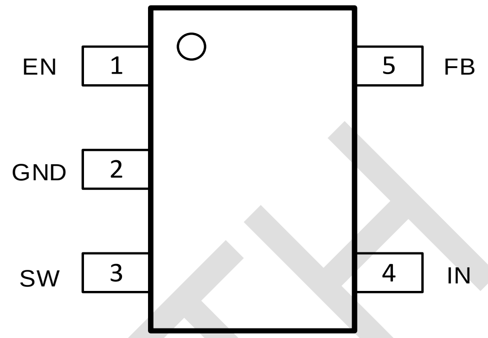
2 Features

- 2.6V to 6.0V operating input range
- Up to 1.4A output current
- Up to 97% peak efficiency
- Internal soft-start
- 1.5MHz switching frequency
- Input under voltage lockout
- Input over voltage protection
- Short circuit protection
- Thermal protection
- Available in SOT23-5

3 Applications

- Set Top Boxes
- Telecom/Networking Systems
- Storage Equipment
- GPU/DDR Power Supply

4 Pinout



SOT23-5

5 Ordering information

Product Number	Package	Quantity/Tape
CN2501TCR	SOT23-5	3000/Tape

6 Marking

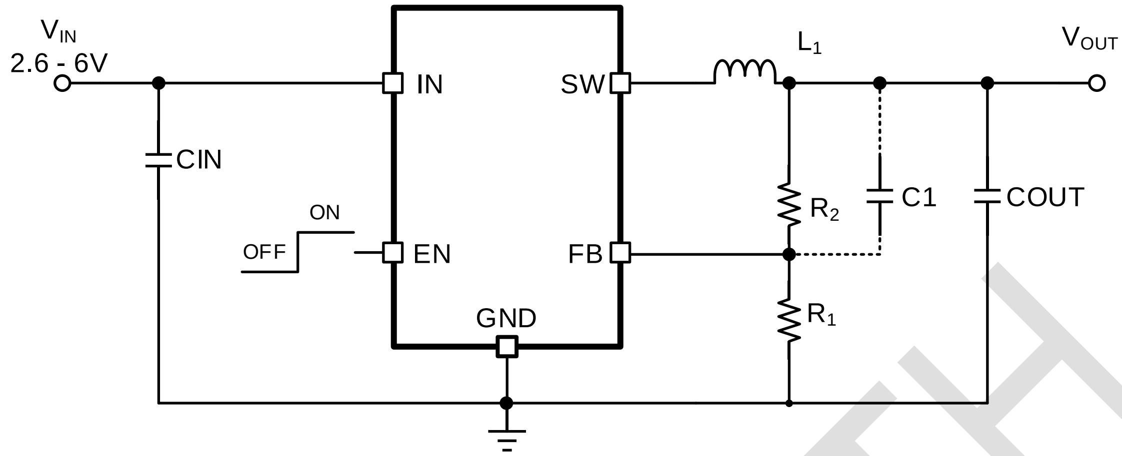
Product Number	Marking
CN2501TCR	CN2501 YYWW

Note: YY=Year WW=Week.

Green (RoHS & HF): CHIPNORTH defines "Green" to mean Pb-Free (RoHS compatible) and free of halogen substances. If you have additional comments or questions, please contact your CHIPNORTH representative directly.

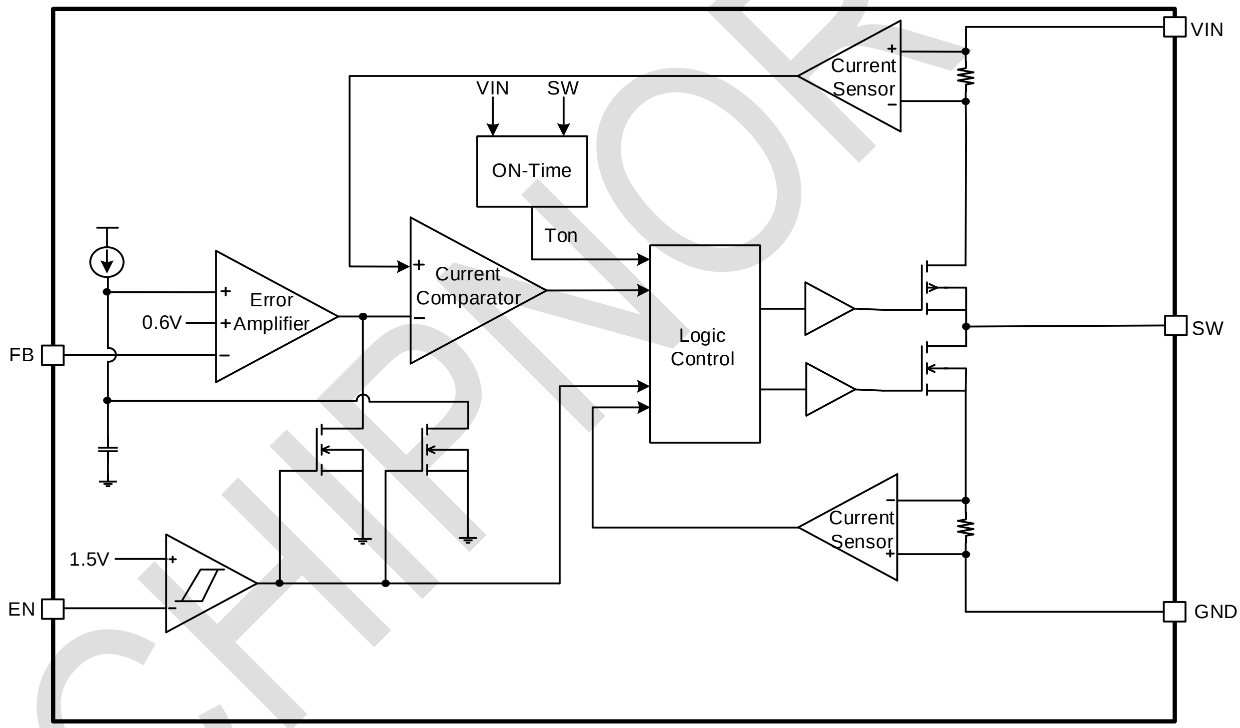
Moisture sensitivity level(MSL):3

7 Typical Application



Note: Output voltages are set by external resistors: $R_2 = R_1 \times [(V_{OUT} / 0.6) - 1]$.

8 Block Diagram



9 Pin Descriptions

Pin No.	Pin Name	Descriptions
1	EN	Enable pin for the IC. Drive this pin to high to enable the part, low to disable.
2	GND	Ground
3	SW	Inductor Connection. Connect an inductor Between SW and the regulator output
4	IN	Supply Voltage. Bypass with a 10μF ceramic capacitor to GND
5	FB	Feedback Input. Connect an external resistor divider from the output to FB and GND to set the output to a voltage between 0.6V and V_{IN}

10 Specifications

10.1 Absolute Maximum Ratings

Parameter	Symbol	Value	Units
Input Voltage	V_{IN}	-0.3 ~ 7	V
SW and EN Operating Voltage	V_{SW}, V_{EN}	-0.3 ~ 7	V
FB pin voltage	V_{FB}	-0.3 ~ 7	V
Operating Junction Temperature Range	T_J	-40 ~ 160	°C
Operating Ambient Temperature Range	T_A	-40 ~ 85	°C
Soldering Temperature	T_{LEAD}	260（soldering,10s）	°C
Storage Temperature Range	T_{STG}	-65 ~ 150	°C

Note: Operation beyond the absolute maximum ratings may cause damage to the device. Absolute maximum ratings do not indicate that the device will operate properly under these conditions or any other conditions other than the recommended operating conditions. If used outside of the recommended operating conditions but within the absolute maximum ratings, the device may not operate at full functionality, which may affect reliability, functionality, and performance and shorten device life.

10.2 ESD Ratings

Discharge mode	Value	Units
HBM	±4000	V
CDM	±2000	V
Latch up	±800	mA

10.3 Recommended Operating Range

Parameter	Symbol	Min.	Max.	Units
Input Voltage Range	V_{IN}	2.6	6	V
Input Capacitance Range	C_{IN}	10		μF
Output Capacitance Range	C_{OUT}	10		μF
Inductance range	L	2.2		μH

10.4 Thermal Information

Parameter	Descriptions	Value	Unit
Junction to Ambient Thermal Resistance	$R\theta_{JA}$	208.3	°C/W
Thermal Resistance to Enclosure (Top)	$R\theta_{JC(top)}$	73.5	°C/W
Thermal Resistance to Circuit Board	$R\theta_{JB}$	36.1	°C/W

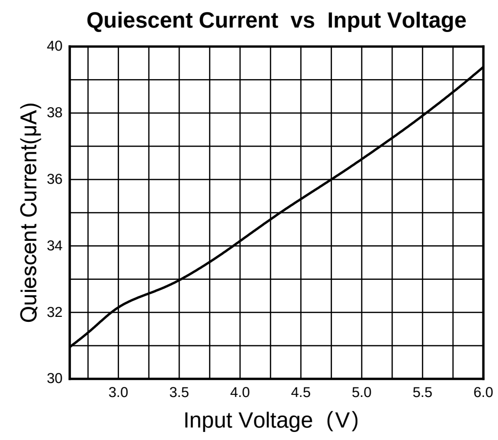
10.5 Electrical Characteristics

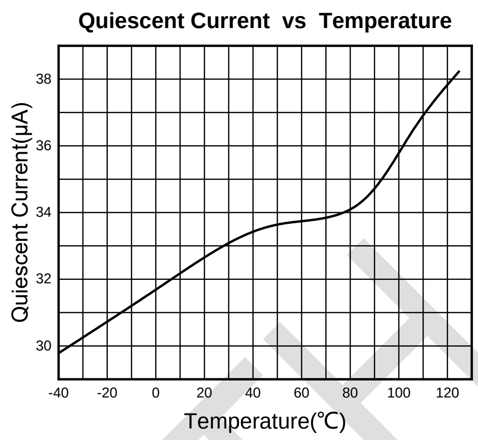
Test: V_{IN}=3.6V, T_A=25°C, unless otherwise specified.

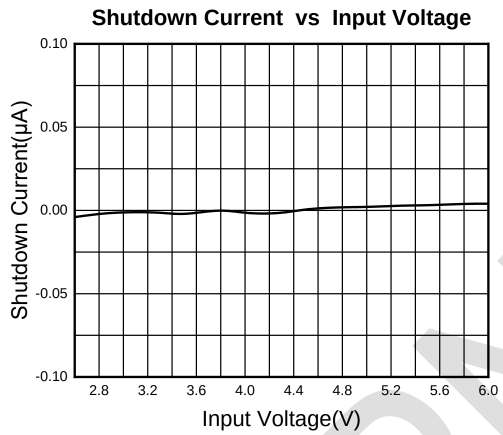
Parameter	Symbol	Conditions	Min	Typ	Max	Unit
V_{IN} Under Voltage Lockout Threshold	V_{IN_UVLO}	V_{IN} rising		2.4		V
V_{IN} Under Voltage Lockout Hysteresis	$V_{IN\_UVLO\_HYST}$	V_{IN} falling		100		mV
V_{IN} Over Voltage Protection	V_{IN_OVP}	V_{IN} rising		6.4		V
V_{IN} Over Voltage Protection Hysteresis	$V_{IN\_OVP\_HYST}$	V_{IN} falling		400		mV
Shutdown Current	I_{SHDN}	V_{IN}=6.0V, V_{EN}=0V		0.1	1	μA
Quiescent Current	I_Q	V_{EN}=5V, I_{OUT}=0A, V_{FB}=V_{REF}*105%		32		μA
Regulated Feedback Voltage	V_{FB}	2.6V<V_{IN}<6.0V	0.588	0.6	0.612	V
PFET On Resistance	R_{DSON_P}	VIN=5V		280		mΩ
NFET On Resistance	R_{DSON_N}	VIN=5V		150		mΩ
PFET Leakage Current	I_{LEAK_P}				1	μA
NFET Leakage Current	I_{LEAK_N}				1	μA
PFET Current Limit	I_{LIM_TOP}			2.4		A
NFET Current Limit	I_{LIM_BOT}			1.7		A
Switch Frequency	F_{SW}	I_{OUT}=1.2A		1.5		MHZ
Minimum On Time	T_{ON_MIN}			100		ns
Maximum Duty Cycle	D_{MAX}			100		%
EN Threshold Voltage	V_{EN_H}	V_{EN} rising, FB=0.3V	1.5			V
EN Falling Threshold	V_{EN_L}	V_{EN} falling, FB=0.3V			0.4	V
Thermal Shutdown Threshold	T_{SHDN}			160		°C
Thermal Shutdown Hysteresis	T_{HYST}			30		°C

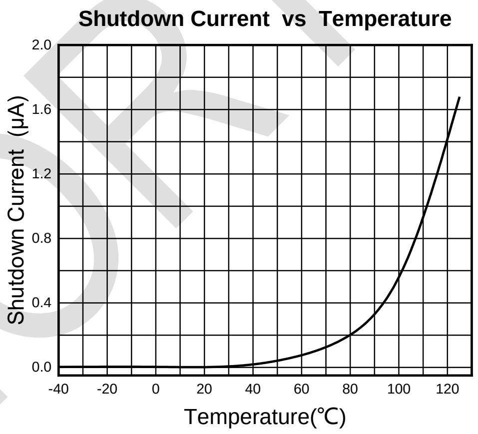
10.6 Characteristics Curve

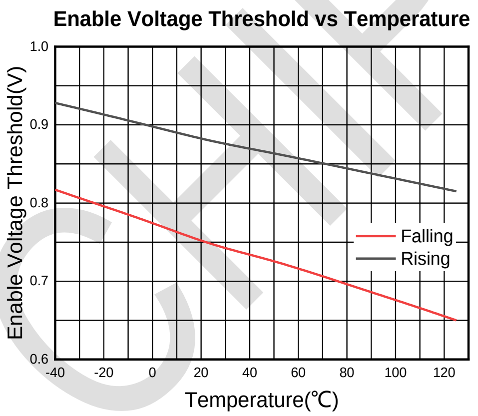
Test: V_{IN}=3.6V, T_A=25°C, unless otherwise specified.

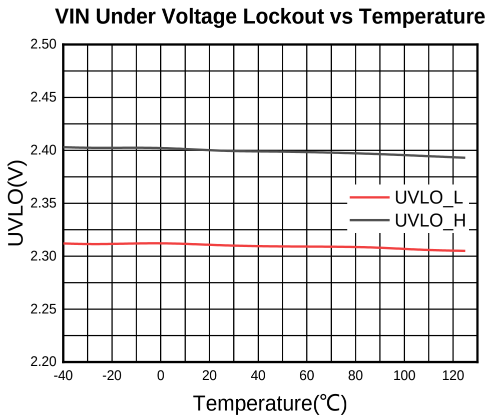




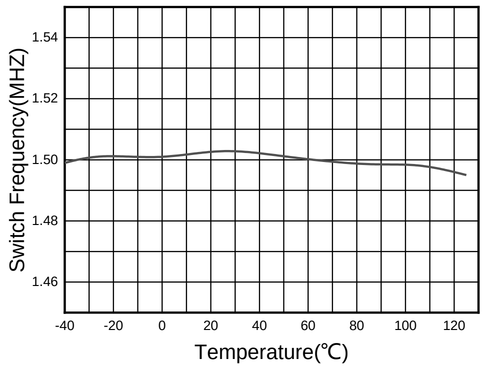




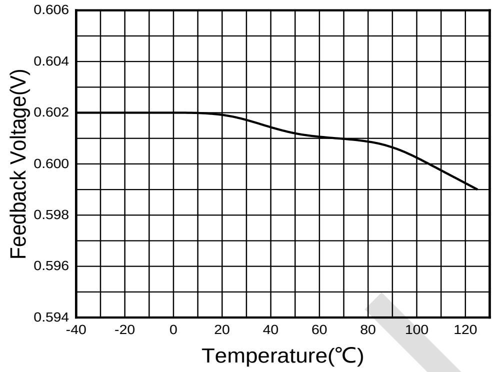




Switch Frequency vs Temperature



Feedback Voltage vs Temperature



11 Functional Description

11.1 Overview

The CN2501TCR is a constant on-time control, synchronous, step-down regulator. It regulates input voltages from 2.6V~6.0V down to an output voltage as low as 0.6V, and is capable of supplying up to 1.4 A of load current.

11.2 Constant On-time Control

The CN2501TCR utilizes constant on-time control to regulate the output voltage. The output voltage is measured at the FB pin through a resistive voltage divider and the error is amplified by the internal transconductance error amplifier. Output of the internal error amplifier is compared with the switch current measured internally to control the output current limit.

11.3 PFM Mode

The CN2501TCR operates in PFM mode at light load. In PFM mode, switch frequency is continuously controlled in proportion to the load current, i.e. switch frequency decreases when load current drops to boost power efficiency at light load by reducing switch-loss, while switch frequency increases when load current rises, minimizing output voltage ripples.

11.4 Shut-Down Mode

The CN2501TCR operates in shut-down mode when voltage at EN pin is driven below 0.4V. In shut-down mode, the entire regulator is off and the supply current consumed by the CN2501TCR drops below 1μA.

11.5 Under-Voltage Lockout (UVLO)

Under-voltage lockout (UVLO) protects the chip from operating at an insufficient supply voltage. UVLO protection monitors the internal regulator voltage. When the voltage is lower than UVLO threshold voltage, the device is shut off. When the voltage is higher than UVLO threshold voltage, the device is enabled again.

11.6 Short Circuit Protection

When output is shorted to ground, the switching frequency is reduced to prevent the inductor current from increasing beyond PFET current limit. If short circuit condition holds for more than 1024 cycles, both PFET and NFET are forced off and can be enabled again after 8ms. This procedure is repeated as long as short circuit condition is not removed.

11.7 FB Short Circuit Protection

When FB is shorted to ground and holds for more 16 cycles, NFET will be turned off after inductor current drops to zero, and then both PFET and NFET are latched off. When short circuit condition is removed, it can be recovery.

11.8 Input Overvoltage Protection

When input voltage is greater than hot plug-in protection threshold, typical 6.4V, it will disable CN2501TCR. When input voltage decrease below 6 V, it will be enabled again.

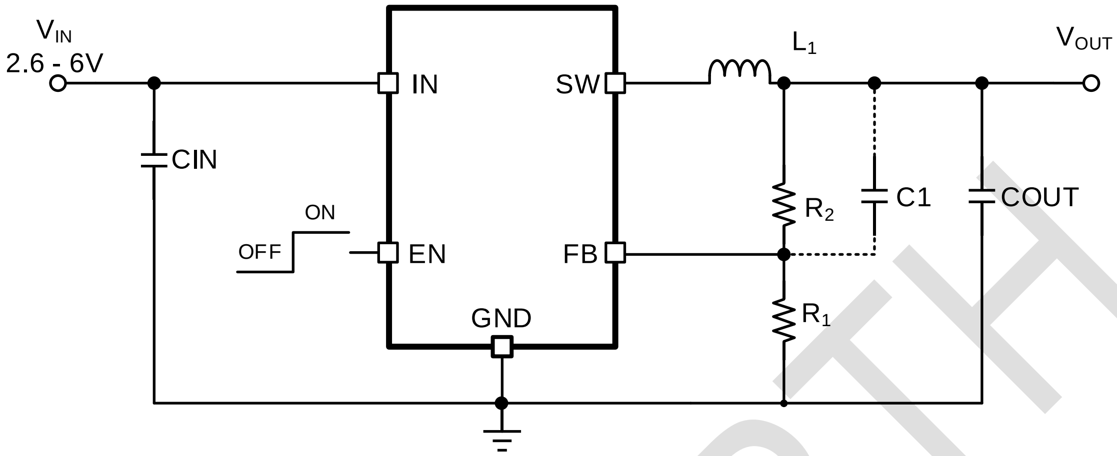
11.9 Thermal Protection

When the temperature of the CN2501TCR rises above 160°C, it is forced into thermal shut-down. Only when core temperature drops below 130°C can the regulator becomes active again.

12 Application Information

12.1 Typical Application

The following figure shows a typical application schematic for a circuit that can be used to evaluate the performance of the CN2501TCR.



12.2 External Component Selection

12.2.1 External Output Voltage Setting

In external Output Voltage Setting Version selected, the CN2501TCR regulator is programmed using an external resistor divider. The output voltage is calculated using below equation.

$$V_{OUT} = V_{FB} \times \left(1 + \frac{R_2}{R_1}\right)$$

Where: V_{FB} =0.6V typically (the internal reference voltage).

12.2.2 Selecting the Inductor

A DC current rating of at least 20% percent higher than the maximum load current is recommended for most applications. Inductance value is related to inductor ripple current value, input voltage, output voltage setting and switching frequency. The inductor value can be derived from the following equation:

$$L = \frac{V_{OUT} \times (V_{IN} - V_{OUT})}{V_{IN} \times \Delta I_L \times f_{osc}}$$

Where ΔI_L is inductor ripple current. Large value inductors result in lower ripple current and small value inductors result in high ripple current, so inductor value has effect on output voltage ripple value. DC resistance of inductor which has impact on efficiency of DC/DC converter should be taken into account when selecting the inductor. The maximum inductor peak current is:

$$I_{L(MAX)} = I_{LOAD} + \frac{\Delta I_L}{2}$$

Under light load conditions, larger inductance is recommended for improved light load efficiency.

12.2.3 Selecting the Intput Capacitor

The input capacitor is used to supply the AC input current to the step-down converter and maintaining the DC input voltage. The ripple current through the input capacitor can be calculated by:

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

where I_{LOAD} is the load current, V_{OUT} is the output voltage, V_{IN} is the input voltage.

Thus the input capacitor can be calculated by the following equation when the input ripple voltage is determined.

$$C_{IN} = \frac{I_{LOAD}}{f_s \times \Delta V_{IN}} \times \frac{V_{OUT}}{V_{IN}} \times (1 - \frac{V_{OUT}}{V_{IN}})$$

where C_{IN} is the input capacitance value, fs is the switching frequency, ΔV_{IN} is the input ripple current. The input capacitor can be electrolytic, tantalum or ceramic. To minimizing the potential noise, a small X5R or X7R ceramic capacitor, i.e. 0.1μF, should be placed closer than 3mm to the IC as possible when using electrolytic capacitors.

12.2.4 Selecting the Output Capacitor

An output capacitor is required to maintain the DC output voltage. The output voltage ripple can be estimated with equation:

$$\Delta V_{OUT} = \frac{V_{OUT}}{f_s \times L} \times (1 - \frac{V_{OUT}}{V_{IN}}) \times (R_{ESR} + \frac{1}{8 \times f_s \times C_{OUT}})$$

Where L is the inductor value and R_{ESR} is the equivalent series resistance (ESR) value of the output capacitor. The output capacitor can be low ESR electrolytic, tantalum or ceramic, which lower ESR capacitors get lower output ripple voltage. The output capacitors also affect the system stability and transient response.

12.2.5 Bom list

The BOM table for V_{IN}=3.6V，V_{OUT}=1.8V is as follows

Symbol	Description	Manufacturers	Part Number	Qty
C_{IN}	10μF，10V，X5R，±10%，0805	MURATA	GRM21BR61A106KE19L	1
C_{OUT}	10μF，10V，X5R，±10%，0805	MURATA	GRM21BR61A106KE19L	1
C_1（option）	47pF，25V，NP0，±5%，0603	YAGEO	CC0603JRNPO8BN470	1
R_1	10K,±1%，0805	UNI-ROYAL(厚声)	0805W8F1002T5E	1
R_2	20K,±1%，0805	UNI-ROYAL(厚声)	0805W8F2002T5E	1
L_1	2.2μH±20%，Irms=2.7A，Isat=2.8A，DCR=72mΩ	Sunlord	WPN4012H2R2MT	1

The BOM table for V_{IN}=5V，V_{OUT}=3.3V is as follows

Symbol	Description	Manufacturers	Part Number	Qty
C_{IN}	10μF，10V，X5R，±10%，0805	MURATA	GRM21BR61A106KE19L	1
C_{OUT}	10μF，10V，X5R，±10%，0805	MURATA	GRM21BR61A106KE19L	1
C_1（option）	22pF，25V，NP0，±5%，0603	YAGEO	CC0603JRNPO8BN220	1
R_1	10K,±1%，0805	UNI-ROYAL(厚声)	0805W8F1002T5E	1
R_2	45K,±1%，0805	Meritek	CR104502F	1
L_1	2.2μH±20%，Irms=2.7A，Isat=2.8A，DCR=72mΩ	Sunlord	WPN4012H2R2MT	1

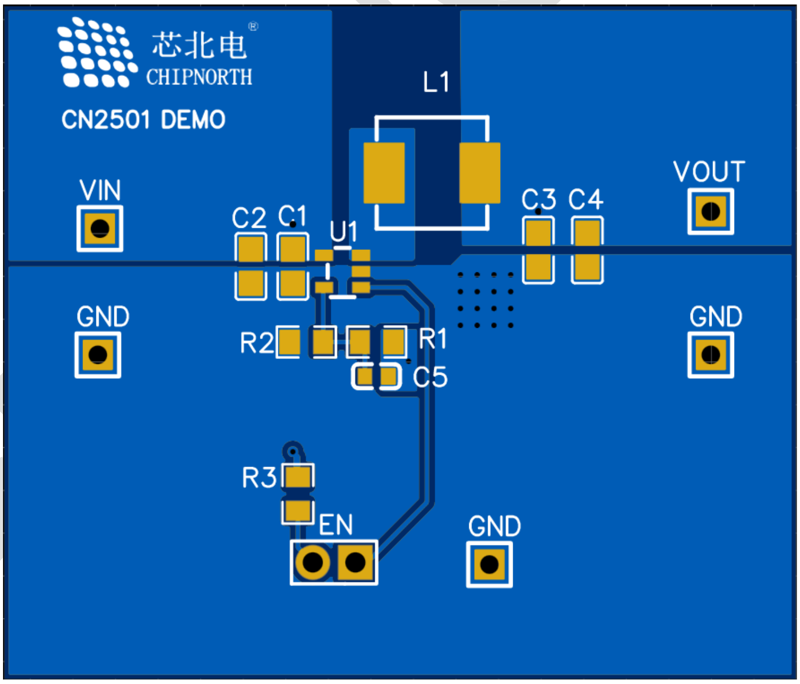
Note：C_1 optional, is the feed-forward capacitance, for the output of 1.8V, the use of 47pF capacitance so that the feed-forward zero point in the 160kHZ or so, can be a small reduction in the amplitude of the output voltage ripple. For the output of 3.3V, the use of 22pF capacitance so that the feed-forward zero point in the 160kHZ or so. The capacitor can be added for applications requiring low ripple amplitude.

12.3 PCB Layout Guides

Layout is an important step for all switching power supplies, especially in the case of high peak currents with high frequencies, and a less careful layout may have an effect on the stability of the converter as well as electromagnetic interference. The following are some suggestions for layout and wiring:

- The upper tube conduction loop, the lower tube conduction loop should be as small as possible, especially the upper tube and the lower tube parasitic diode common loop should be small, the specific approach is the input capacitance, especially small capacitance (100nF) to be close to the chip's V_{IN} and GND, the output capacitance should be close to the inductance and the chip's GND.
- Inductor should be placed close to SW.
- Keep the VOUT feedback line away from interference sources such as inductor and SW, and place ground shielding and filtering on both sides of the line.
- The signal part and power part should be separated to avoid interference by electromagnetic coupling of the power circuit, refer to the datasheet which is separated from the top and bottom. The signal part is at the bottom and the power part is at the top.
- Ground floor plan to be finished as much as possible with less cutting.
- The positive and negative terminals of the input and output should be placed close to the input and output capacitors respectively, especially the GND terminal, which should not be placed arbitrarily and will affect the actual path of current return. This will affect the actual path of current return and affect the layout effect.

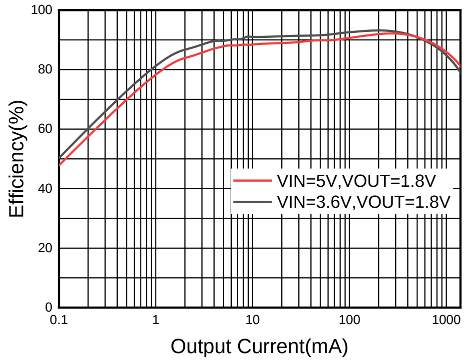
In addition, the need to add power or signal points to be measured, it is best to lead out and connect to the terminals to facilitate the test, pay attention to these wires are also Do not arbitrarily route, also refer to the above principles to avoid interference and be interfered with.



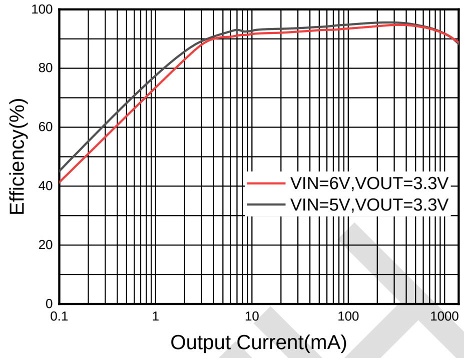
12.4 Basic performance

Test: V_{IN}=3.6V, T_A=25°C, unless otherwise specified.

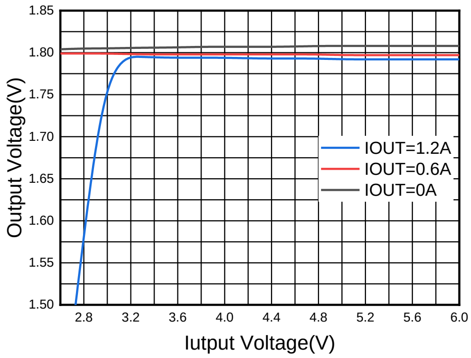
Efficiency vs Output Current



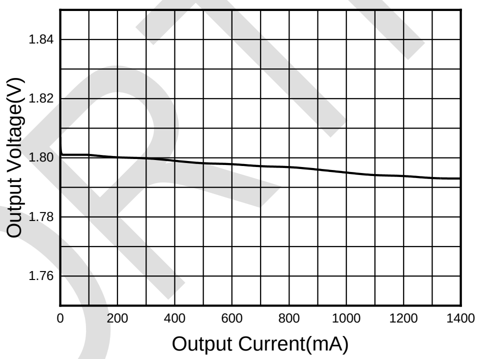
Efficiency vs Output Current

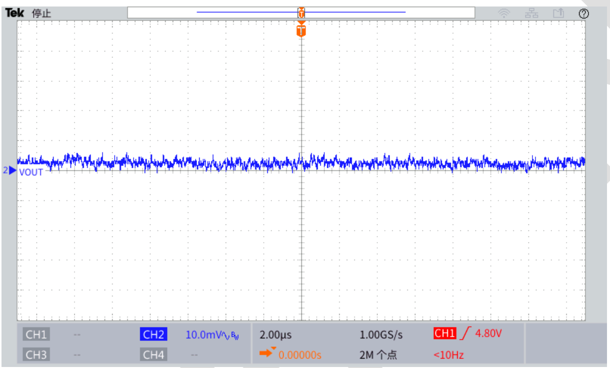


Line Regulation

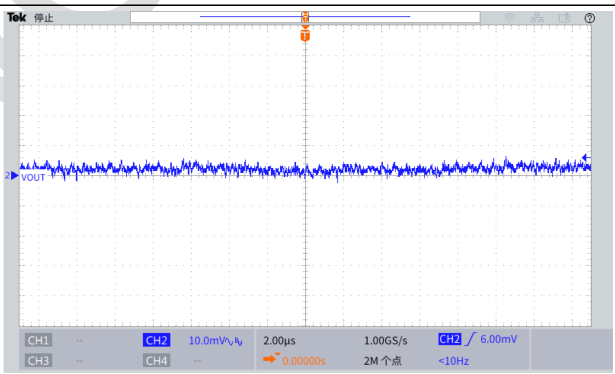


Load Regulation

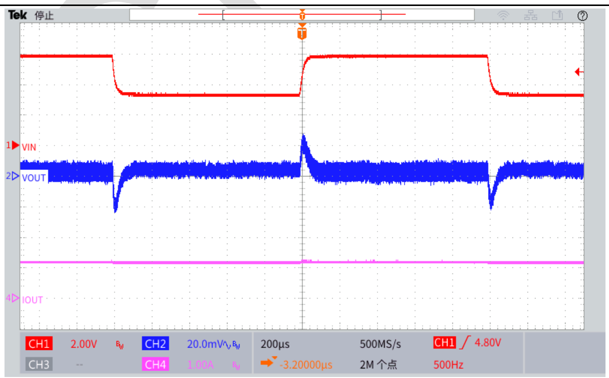




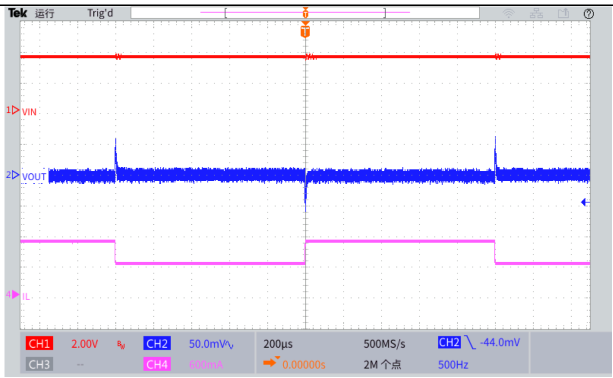
Ripple, I_{OUT}=0.6A



Ripple, I_{OUT}=1.2A



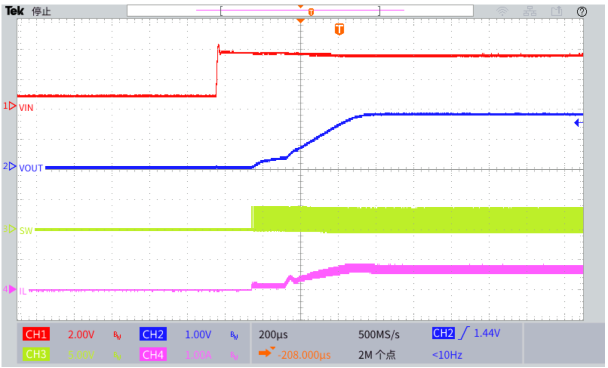
Line Transient, V_{IN}=3.6-6V, 0.1V/µs, I_{OUT}=1.2A



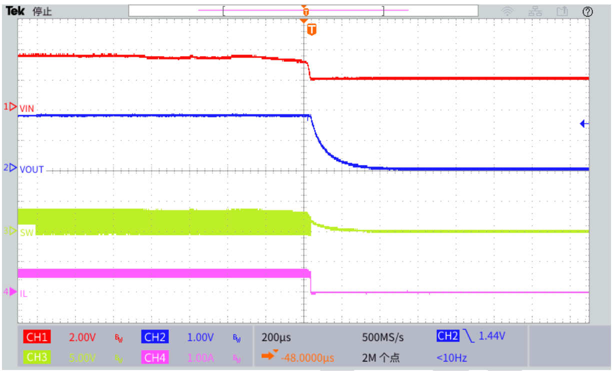
Load Transient, I_{OUT}=0.6-1.2A, 0.4A/µs

12.5 Working Waveform

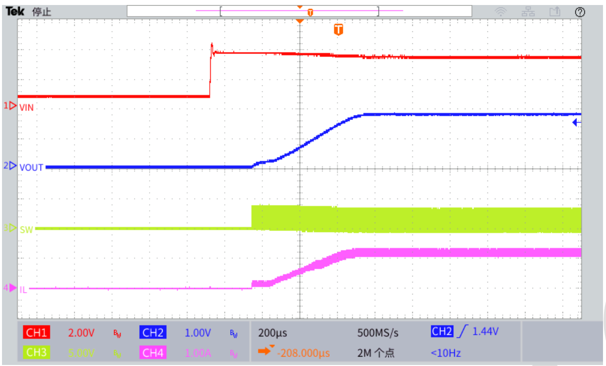
Test: V_{IN}=3.6V,T_A=25°C, unless otherwise specified.



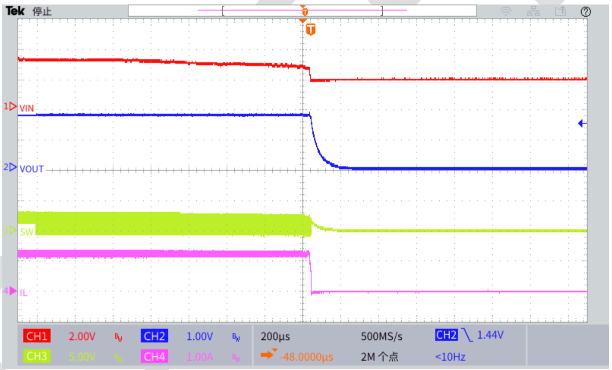
V_{IN} power-up, IOUT=0.6A



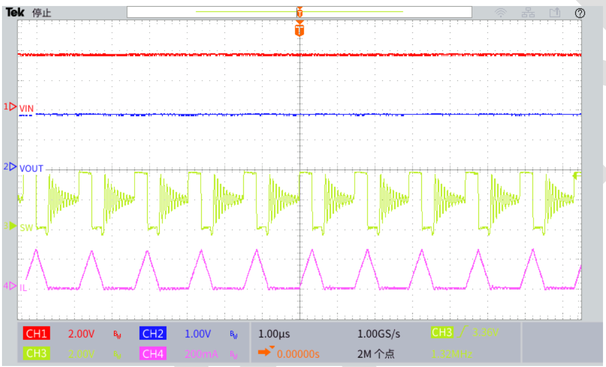
V_{IN} power-down, IOUT=0.6A



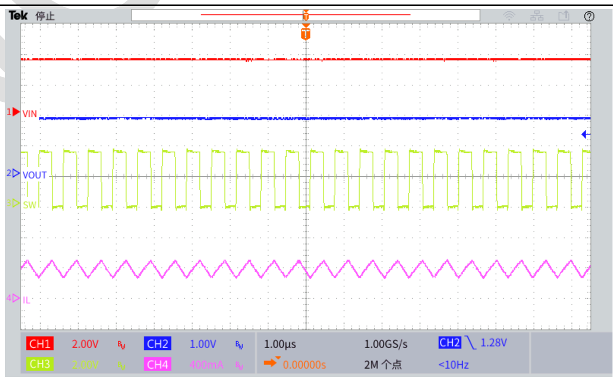
V_{IN} power-up, IOUT=1.2A



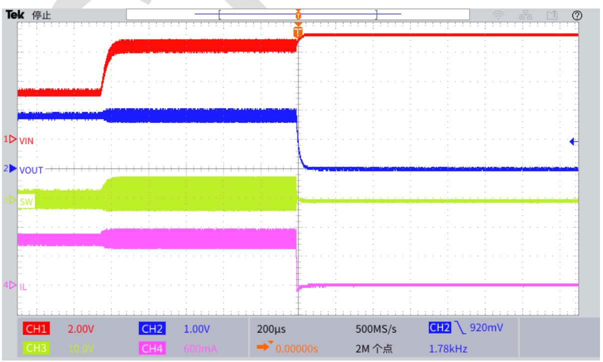
V_{IN} power-down, IOUT=1.2A



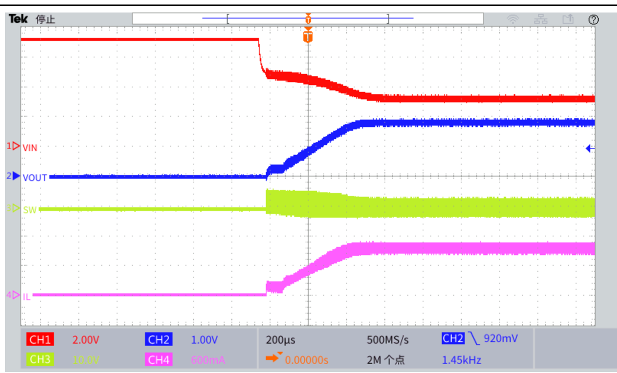
I_{OUT}= 60mA, PFM mode



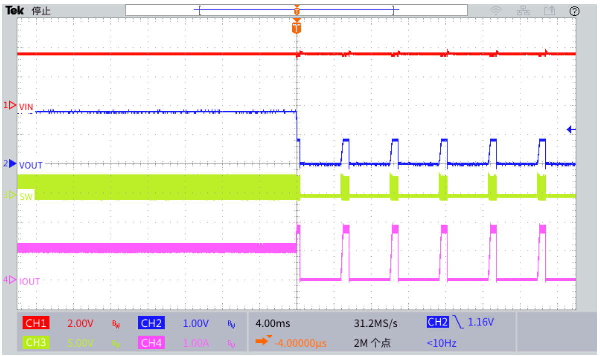
I_{OUT}=0.6A, PWM mode



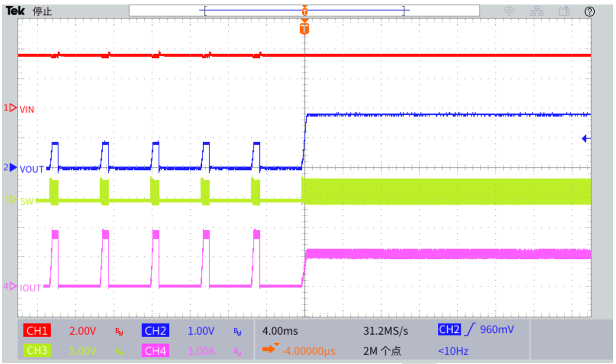
V_{IN} overvoltage protection



V_{IN} overvoltage protection recovery



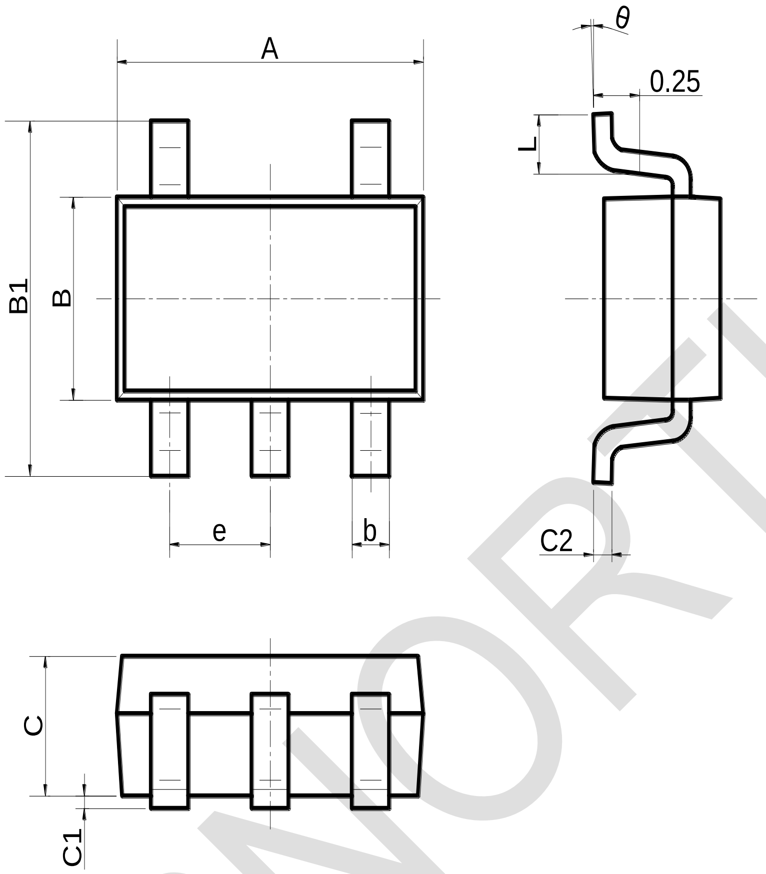
short circuit protection



short circuit protection recovery

13 Package Information

SOT23-5



Dimension / Symbol	Min (mm)	Nom (mm)	Max (mm)
A	2.82	2.92	3.02
B	1.50	1.62	1.70
B1	2.60	2.90	3.00
b	0.27	-	0.35
e	0.95（BSC）		
C	1.05	1.10	1.15
C1	0.03	0.08	0.15
C2	0.135	-	0.23
L	0.35	0.45	0.55
θ	0°	-	8°

14 Important Statement

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