Shaoxing Yuli Semiconductor CO.,LTD
绍 兴 宇 力 半 导 体 有 限 公 司

U3502C Data Sheet

V 1.4

100V Input, Switching Current Limit Step-Down Converter

General Description

The U3502C is a high voltage, step-down, switching regulator built-in MOSFET. It integrates a high-side, high-voltage, power MOSFET with a current limit of 3A(IPK) typically. The input ranges accommodates a variety of step-down applications, making it ideal for automotive, industry, and lighting applications. Hysteretic voltage-mode control is employed for very fast response. UNIU's proprietary feedback control scheme minimizes the number of required external components.

The switching frequency is 150KHz, allowing for small component size. Thermal shutdown and short-circuit protection (SCP) provide reliable and fault-tolerant operations. Low quiescent current allows the U3502C to be used in battery-powered applications.

The U3502C is available in a ESOP-8 package with an exposed pad.

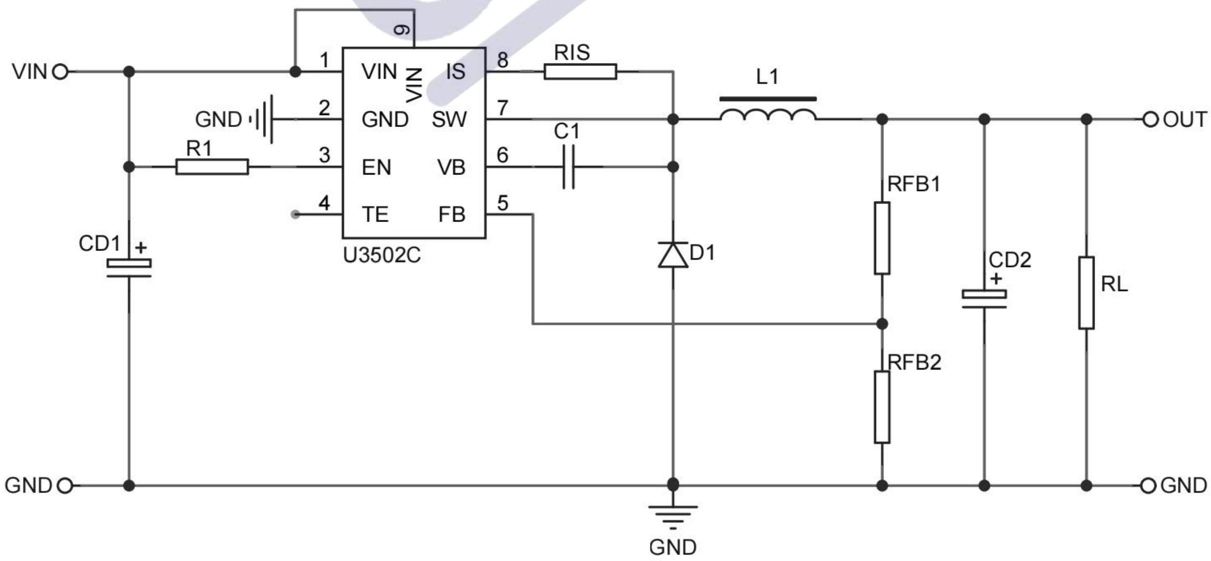
Key Features

- Integrated high voltage start circuit
- Integrated 5.3V reference
- Built-In 100V/135 mΩ MOSFET
- Built-in bootstrap diode
- Hysteretic control: No compensation
- 150 KHz switching frequency
- PWM dimming control input for step-down application
- Short-circuit protection (SCP) with integrated High-side MOSFET
- Low quiescent current
- Thermal shutdown
- Available in a ESOP-8 package with an exposed pad

Applications

- Scooters, E-Bike control power supplies
- Solar energy systems
- Automotive system power
- Industrial power supplies
- High-power LED drivers
- USB

Simplified Application



Operation

Hysteresis voltage control with adaptive threshold adjustment

The U3502C operates in a hysteretic voltage-control mode to regulate the output voltage. FB is connected to the tap of a resistor divider, which determines the output voltage. The power MOSFET is turned on when the FB voltage (V_{FB}) rises to FBon and remains on until V_{FB} rises to FBoff. The power MOSFET is turned off when V_{FB} drops to FBoff and remains off until VFB falls to FBon. The two thresholds of FBon and FBoff are adjusted adaptively to compensate for all the circuit delays, so the output voltage is regulated with an average 1.275V value at FB.

Floating driver and bootstrap charging

The floating power MOSFET driver is powered by an external bootstrap capacitor.
The bootstrap capacitor is charged and regulated to about 12V by the dedicated internal bootstrap regulator.
If the internal circuit does not have sufficient voltage, and the bootstrap capacitor is not sufficiently charged, extra external circuitry can be used to ensure that the bootstrap voltage is in the normal operating region. Refer to the External Bootstrap Diode section for more details.

Fast charging function for USB applications

Because the FB reference of the U3502C is very flexible, it is recommended to use the U3502C for USB fast charging applications by connecting the current sense resistor between FB and GND.

Thermal shutdown

Thermal shutdown is implemented to prevent the chip from operating at exceedingly high temperatures. When the silicon die temperature is higher than its upper threshold, the entire chip shuts down. When the temperature is lower than its lower threshold, the chip is enabled again.

Output short protection

The output voltage is well-regulated when V_{FB} is around 1.275V. If the output is pulled low in over-current protection (OCP) or is shorted to GND directly, V_{FB} is low, even though the power MOSFET is turned on. The U3502C regards the low V_{FB} as a failure. The power MOSFET shuts off if the failure time is longer than 10μs. The U3502C attempts operation again after a delay of about 300μs.
The power MOSFET current is also accurately sensed via a current sense MOSFET. If the current is over the current limit, the IC is shut down. This offers extra protection under output-short conditions.

Application Information

Setting the output voltage

The output voltage (V_{OUT}) is set by a resistor divider (R1 and R2) (see the Typical Application on page 1). To achieve good noise immunity and low power loss, R2 is recommended to be in the range of 1kΩ to 50kΩ. R1 can then be determined with equation (1):

$$R1 = \frac{V_{OUT} - V_{FB}}{V_{FB}} \times R2 \quad (1)$$

Where V_{FB} is 1.275V, typically.
FB has 50K resistance inside, and the calculation is in parallel with R2.

Output capacitor and frequency setting

The output capacitor (C_{OUT}) is necessary for achieving a smooth output voltage. The ESR of the capacitor should be sufficiently large compared to the capacitance; otherwise, the system may behave in an unexpected way, and the current ripple may be very high. When the power MOSFET is turned on, V_{FB} becomes 1.275V. To charge the capacitor and generate 1.275V at FB, the system needs ESR and some inductor current. For example, for a 5V V_{OUT}, if the forward capacitor is 0.1μF, the suggested ESR range of the output capacitor is 100mΩ to 250mΩ. Tantalum or aluminum electrolytic capacitors with a small ceramic capacitor are recommended.
A forward capacitor across R1 is recommended when the output capacitor is tantalum or aluminum electrolytic, which can set the desired frequency if the output capacitor and ESR cannot be changed. The forward capacitor can reduce the output voltage ripple.
In some application, simply a forward capacitor may not get proper frequency, then we can add a forward resistor in series with the forward capacitor or even more add a ceramic on the output.

Selecting the inductor

The inductor (L) is required to convert the switching voltage to a smooth current to the load. Although the output current is low, it is recommended that the inductor current be continuous in each switching period to prevent reaching the current limit. Calculate the inductor value with equation (2):

$$L = \frac{(V_{IN} - V_{OUT}) \times V_{OUT}}{F_{SW} \times I_{OUT} \times V_{IN} \times K} \quad (2)$$

Where K is a coefficient of about 0. 15 ~ 0.85.

Output rectifier diode

The output rectifier diode supplies current to the inductor when the high-side switch is off. To reduce losses due to the diode forward voltage and recovery times, use a Schottky diode. The average current through the diode can be approximated with equation (3):

$$I_D = I_{OUT} \times (1 - \frac{V_{OUT}}{V_{IN}}) \quad (3)$$

Choose a diode with a maximum reverse voltage rating greater than the maximum input voltage and a current rating is greater than the average diode current.

Peak current regulation

Current estimation formula(4)

$$I_{PK} = \frac{V_{IPK}}{R_{CS}} = \frac{0.23V}{Rcs} \quad (4)$$

Note: The voltage calculation will be affected by the freewheeling diode, and the actual debugging shall prevail.

Input capacitor (C_{IN})

The input current to the step-down converter is discontinuous and therefore requires a capacitor to supply AC current to the step-down converter while maintaining the DC input voltage. Use low ESR capacitors for the best performance, especially under high switching frequency applications.

The RMS current through the input capacitor can be calculated with equation (5):

$$I_{IN\_AC} = I_{OUT} \times \sqrt{\frac{V_{OUT}}{V_{IN}} \times (1 - \frac{V_{OUT}}{V_{IN}})} \qquad (5)$$

With low ESR capacitors, the input voltage ripple can be estimated with equation (6):

$$\Delta V_{IN} = \frac{I_{OUT} \times V_{OUT}}{F_{SW} \times C_{IN} \times V_{IN}} \times (1 - \frac{V_{OUT}}{V_{IN}}) \qquad (6)$$

Choose an input capacitor with enough RMS current rating and enough capacitance for small input voltage ripples.

When electrolytic or tantalum capacitors are applied, a small, high-quality ceramic capacitor (i.e.: 0.1μF) should be placed as close to the IC as possible.

External bootstrap diode

An external bootstrap diode may enhance the efficiency of the converter (see Figure 2).

The bootstrap diode can be a low-cost one, optimize circuit structure, save cost, and reduce error rate for peripheral circuit configuration.

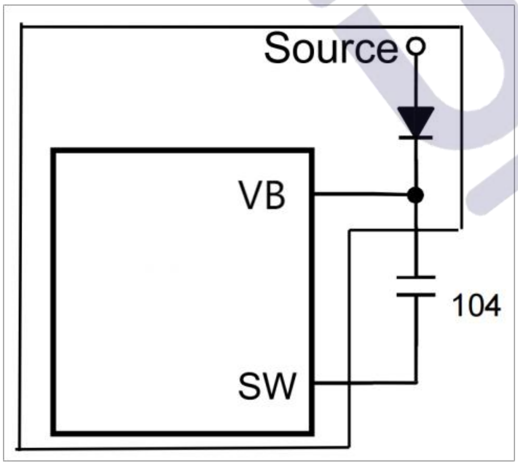


Figure 2: External Bootstrap Diode

PCB Layout guidelines

Efficient PCB layout is critical for stable operation. For best results, follow the guidelines below.

1.Place the input decoupling capacitor, catch diode, and the U3502C (VIN, SW, and PGND) as close to each other as possible.

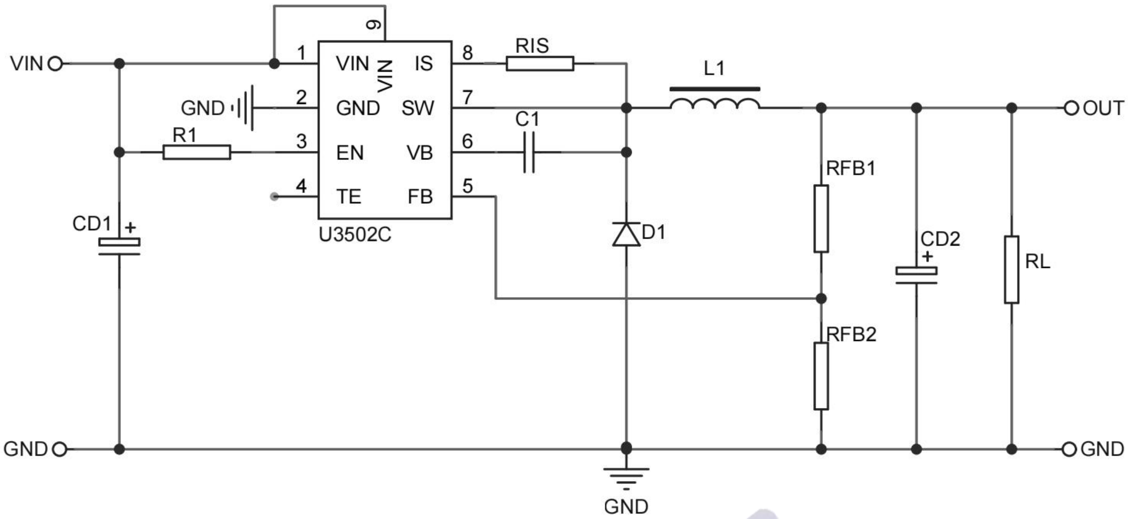
2.Keep the power traces very short and fairly wide, especially for the SW node. This can help greatly reduce voltage spikes on the SW node and lower the EMI noise level.

3.Run the feedback trace as far from the inductor and noisy power traces (like the SW node) as possible.

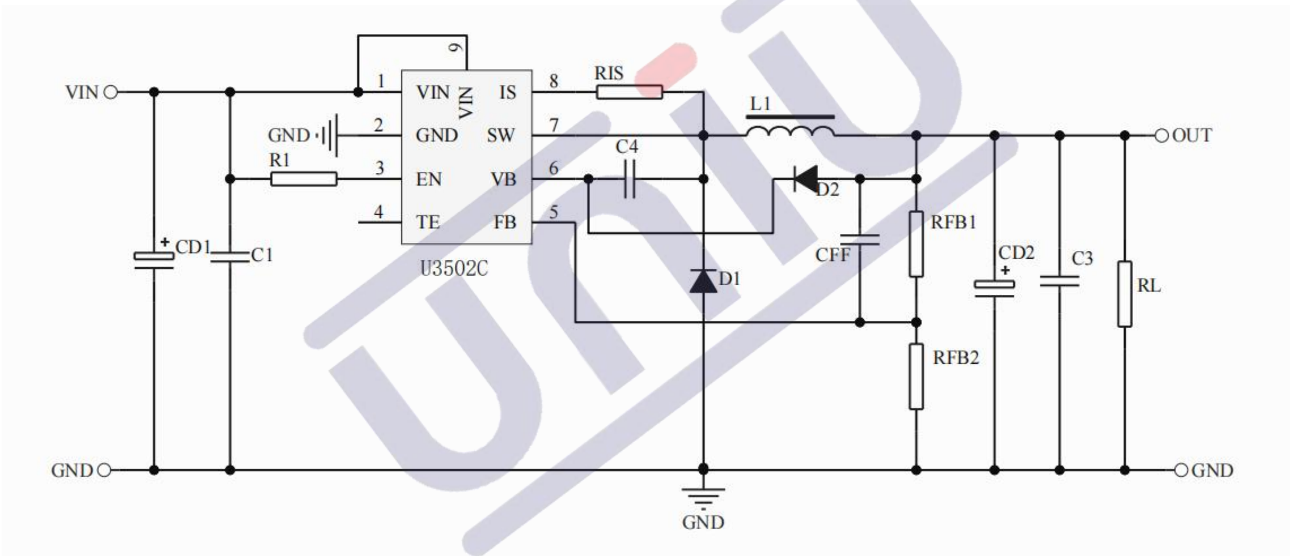
4.Place thermal vias with 15mil barrel diameter and 40mil pitch (distance between the centers) under the exposed pad to improve thermal conduction.

Typical Application Circuit

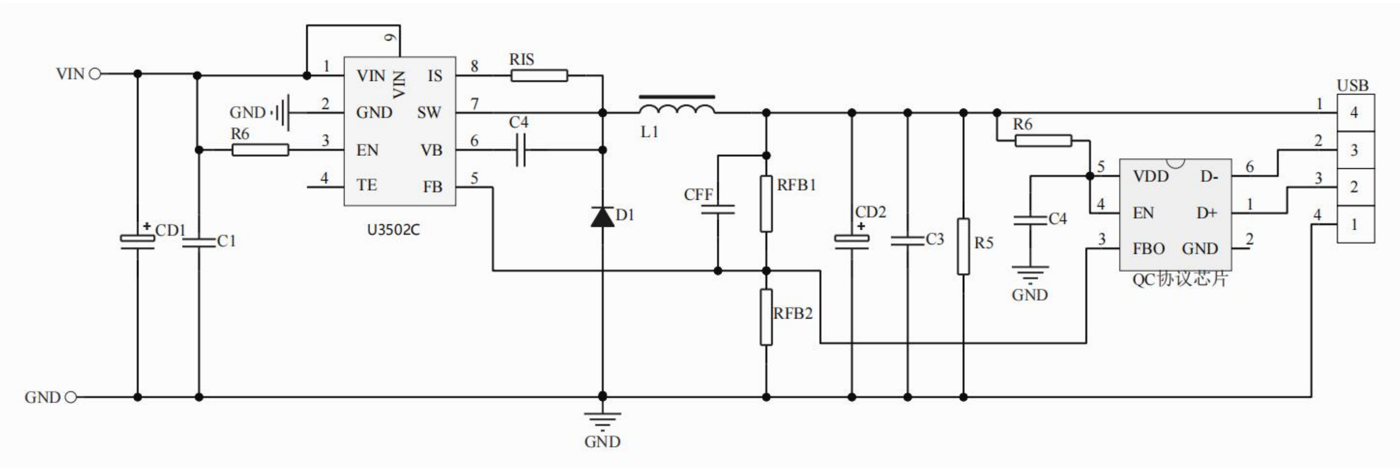
APP1: V_{OUT} <10V



APP2:V_{OUT}=10~15V



APP3: QC2.0/QC3.0



Note:Typical application circuit and parameters for reference, the actual application circuit parameters please set on the basis of measurement, mass production please communicate with the original factory, other unknown please contact our engineers.

1、Version Record

Date	Rev.	Description
2023/2/25	1.0	First release
2023/7/12	1.1	Optimization parameter
2024/5/16	1.2	Application diagram change
2024/6/13	1.3	Add IPK calculation formula
2024/8/12	1.4	Add a functional comparison table and modify the description of pin 4

2、Contact

Shaoxing Yuli Semiconductor CO.,LTD

Shaoxing Address：4th & 5th Floors, Building 45, CECEP Science and Technology Innovation Park, No. 25 Paodu Road, Doumen Subdistrict, Yuecheng District, Shaoxing City, Zhejiang Province, China

Telephone：0575-85087896（R&D Department）

Fax：0575-88125157

E-mail：htw@uni-semic.com

Wuxi Address：Room 503, Building 1# (Comprehensive Building), China Electronics (Wuxi) Digital Chip City, No. 6 Xianfeng Middle Road, Xishan District, Wuxi City, Jiangsu Province, China

Telephone：0510-85297939

E-mail：zh@uni-semic.com

Shenzhen Address：Room 410, Yonghui International Business Building, Baoyuan Road, Nanchang Community, Xixiang Subdistrict, Bao'an District, Shenzhen, Guangdong Province, China

Telephone：0755-84510976

E-mail：htw@uni-semic.com

Disclaimers:

1.Shaoxing Yuli Semiconductor Co.,LTD., (referred to as "Yuli"), reserves the right to modify user manuals, application guidelines, etc., without prior notice. When purchasing, customers should obtain the latest version of our company's materials and verify whether the relevant information is up-to-date and complete. Before using the products,please carefully read the user manuals, application guides, and other relevant materials along with all precautions contained therein.

2.This product is intended for consumer electronics use and Yuli makes no guarantees as to the suitability of Yuli products for any particular purposes. The products must not be applied in any equipment or system whose manufacture, use, or sale is prohibited by applicable laws or regulations. If Yuli's products are utilized in such prohibited devices or systems, all risks associated with such applications shall be solely borne by the customer, and Yuli shall not be held liable for any consequences arising therefrom.

3.The applications of the products described in this document and related materials such as application guides are provided for illustrative reference only. The parameters provided in this document may and do vary in different applications, and the actual performance may change accordingly. Further evaluation, testing, and validation are required during use. Yuli disclaims all responsibility for any assistance provided in the application of its products or the design of customer products.

4.Customers must utilize the products within their valid storage period. If customers have any questions regarding the valid storage period of Yuli's products, please contact Yuli's sales personnel or customer service support immediately. Yuli shall not assume any responsibility for the use of products beyond their storage period.

5.Without the prior written consent of Yuli, the files and products shall not be disassembled, altered, modified, or copied.

6.When purchasing products, please verify the Yuli trademark and product specifications. For any inquiries, please contact Yuli for clarification. Third-party purchasers are advised to confirm whether the seller holds authorized credentials from Yuli and must contact our company prior to procurement to ensure the products are genuine Yuli-manufactured items.

7.When using or applying the products, customers must comply with all applicable laws and regulations, including but not limited to trade control regulations, etc. This product is designated for civilian electronic purposes. It must not be used in non-civilian fields.

8.Product improvement is an endless journey. Our company remains fully committed to delivering superior products to our customers!