Shaoxing Yuli Semiconductor CO.,LTD

绍 兴 宇 力 半 导 体 有 限 公 司

# U3504D Data Sheet

V 1.4

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# 150V Input, Switching Current Limit Step-Down Converter

## ■ General Description

The U3504D 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 7A(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 U3504D to be used in battery-powered applications.

The U3504D is available in a ESOP-8 package with an exposed pad.

## ■ Key Features

- Integrated high voltage start circuit
- Default 5V output（Type）
- Built-in 150V/288mΩ MOSFET
- Built-in bootstrap diode
- Hysteretic control: No compensation
- 150KHz 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
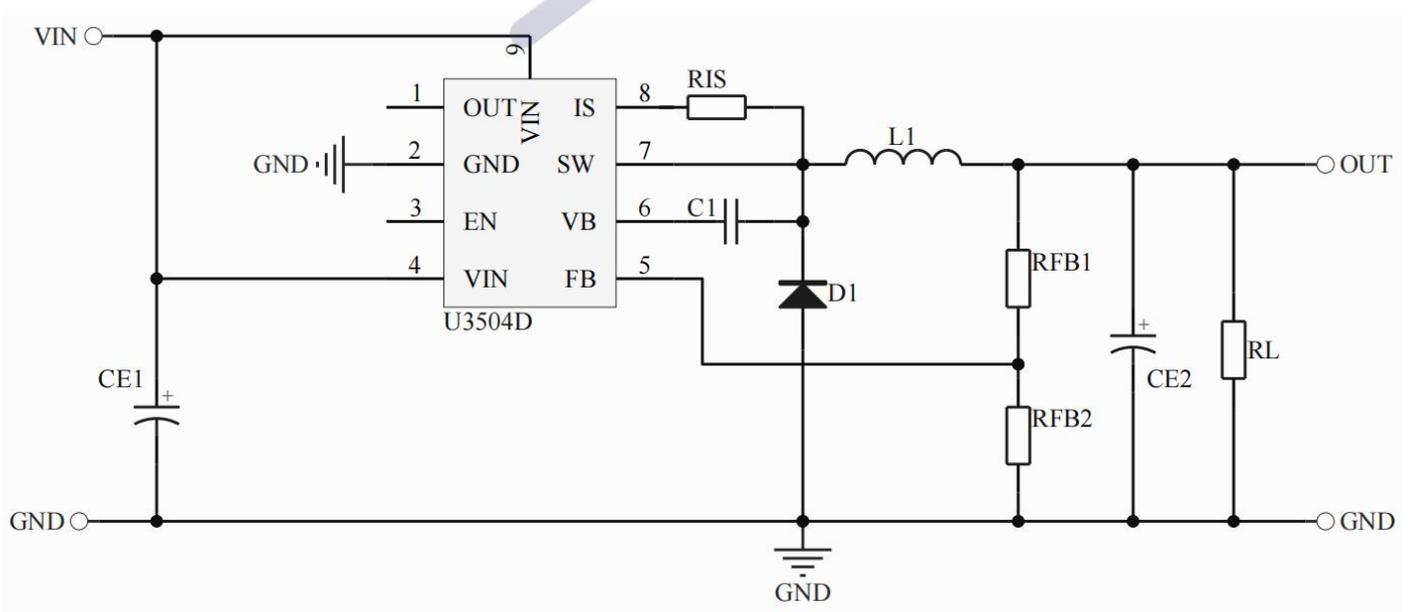
## ■ Operation

**Hysteresis current control with adaptive threshold adjustment**

The U3504D 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 $V_{FB}$ 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 1.30V 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 U3504D is very flexible, it is recommended to use the U3504D 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 1.30V. 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 U3504D regards the low VFB as a failure. The power MOSFET shuts off if the failure time is longer than 10μs. The U3504D 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):

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

Where $V_{FB}$ is 1.30V 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. $V_{FB}$ changes from 1.25V to 1.35V when the power MOSFET switches on. To charge the capacitor and generate 1.35V 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):

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

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):

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

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)

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

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):

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

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

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

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.
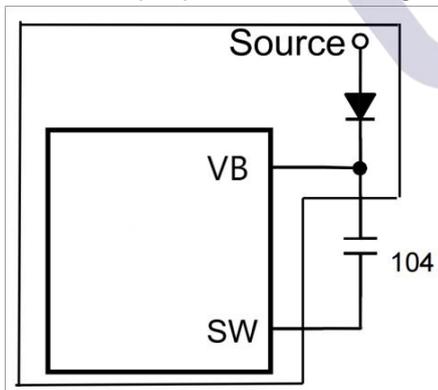


**Figure 2: External Bootstrap Diode**

## 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 U3504D (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.
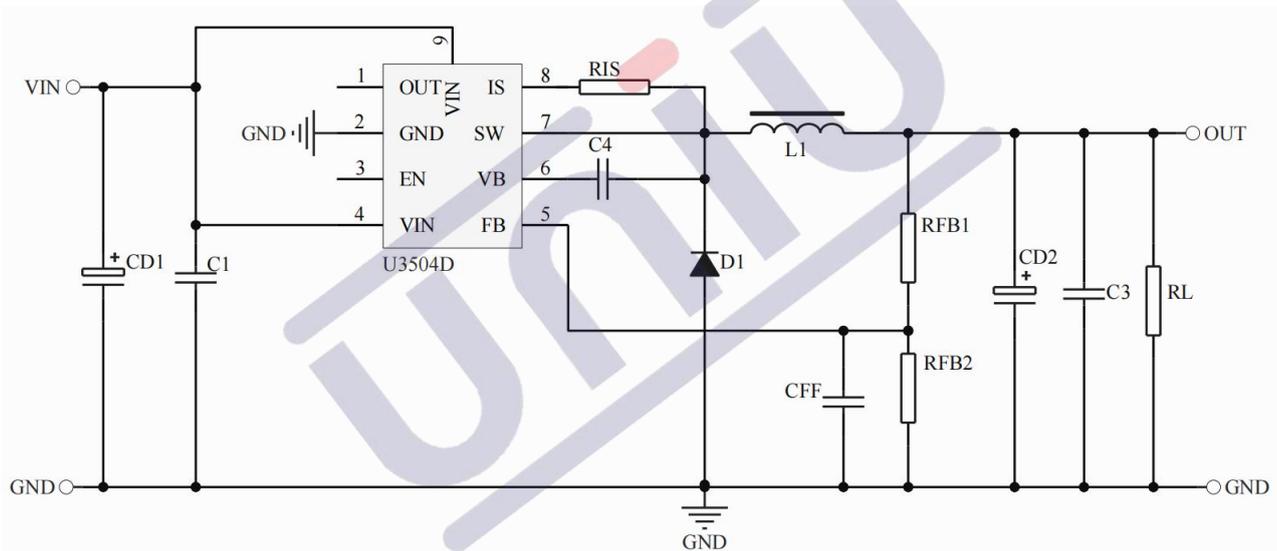
4. Place thermal vias with 15mil barrel diameter and 40mil pitch (distance between the centers) under the exposed pad.
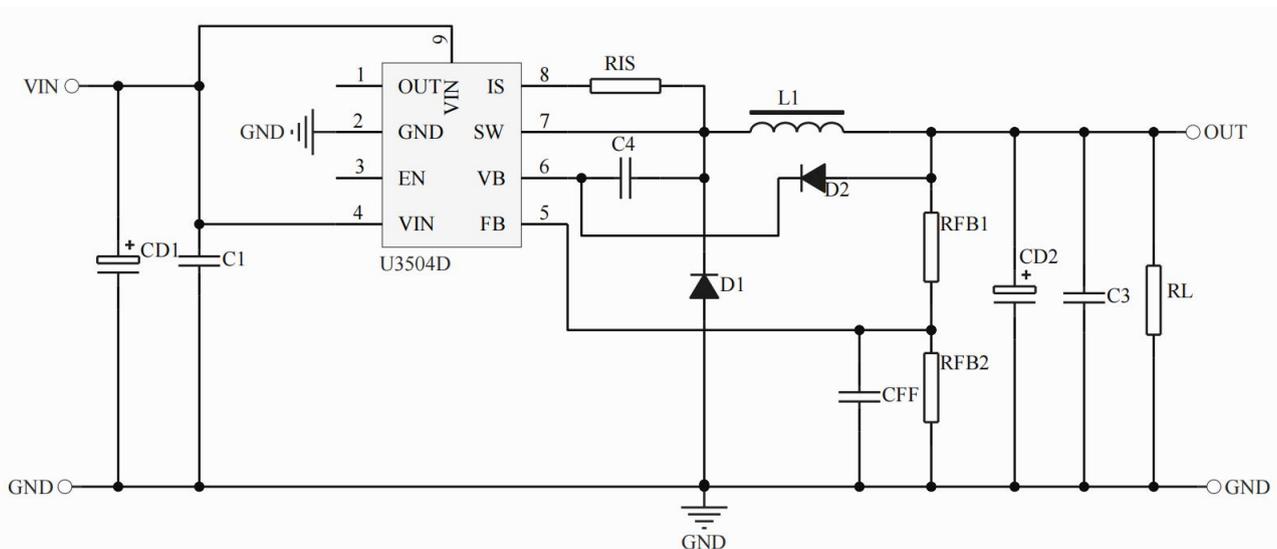
## ■ Typical Application Circuit(Note3)
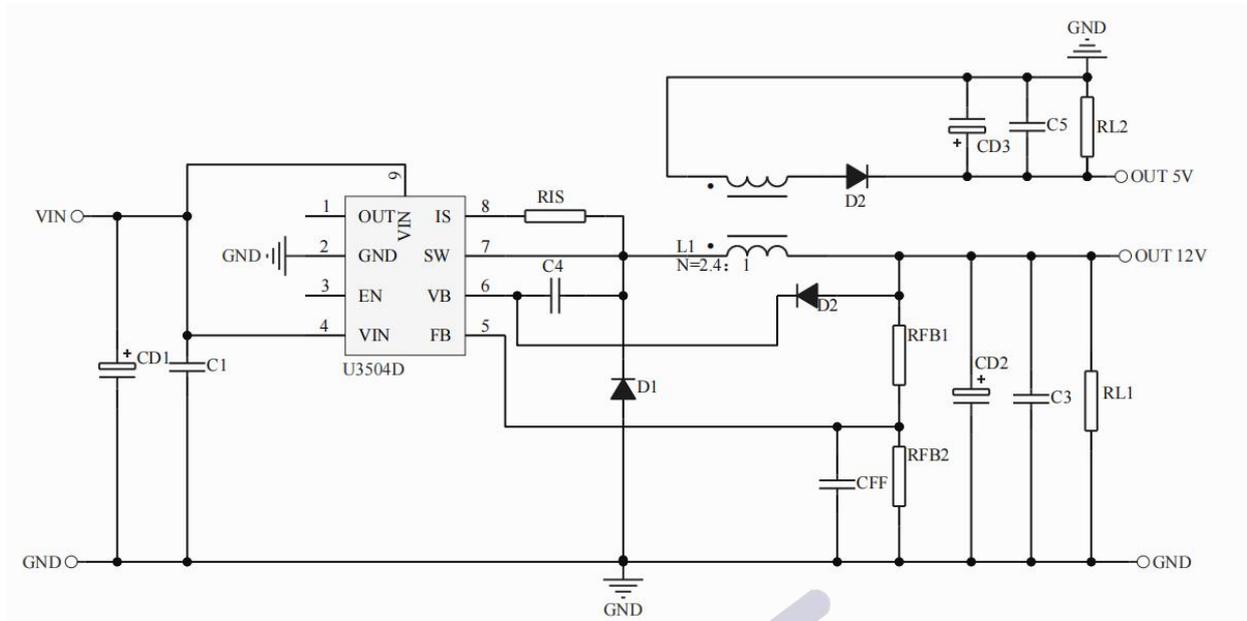
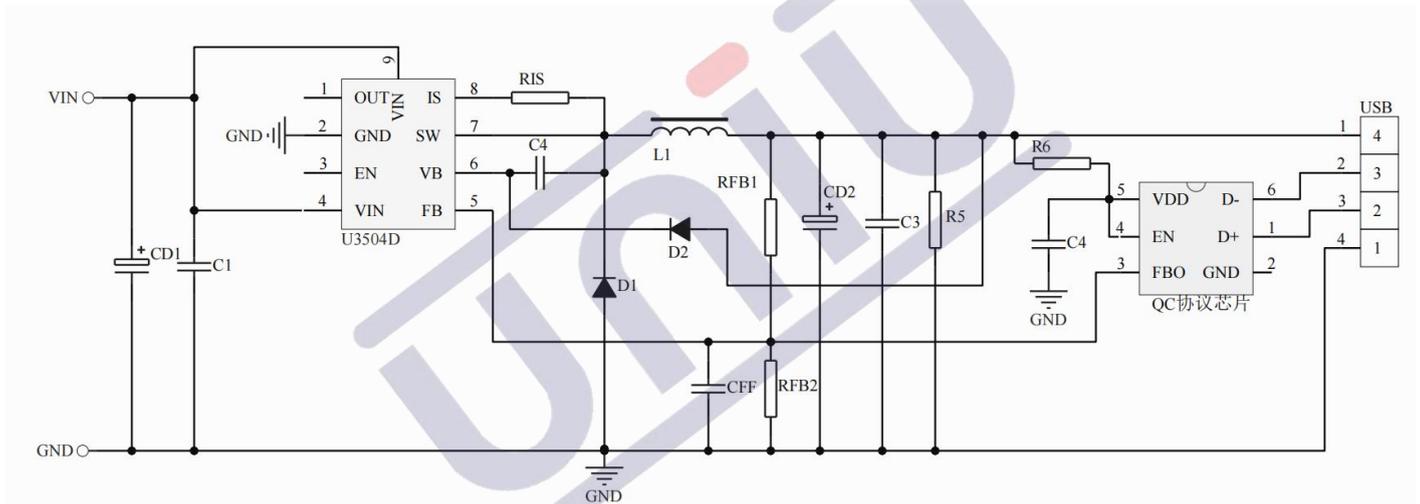### APP1: V<sub>OUT</sub> =5V
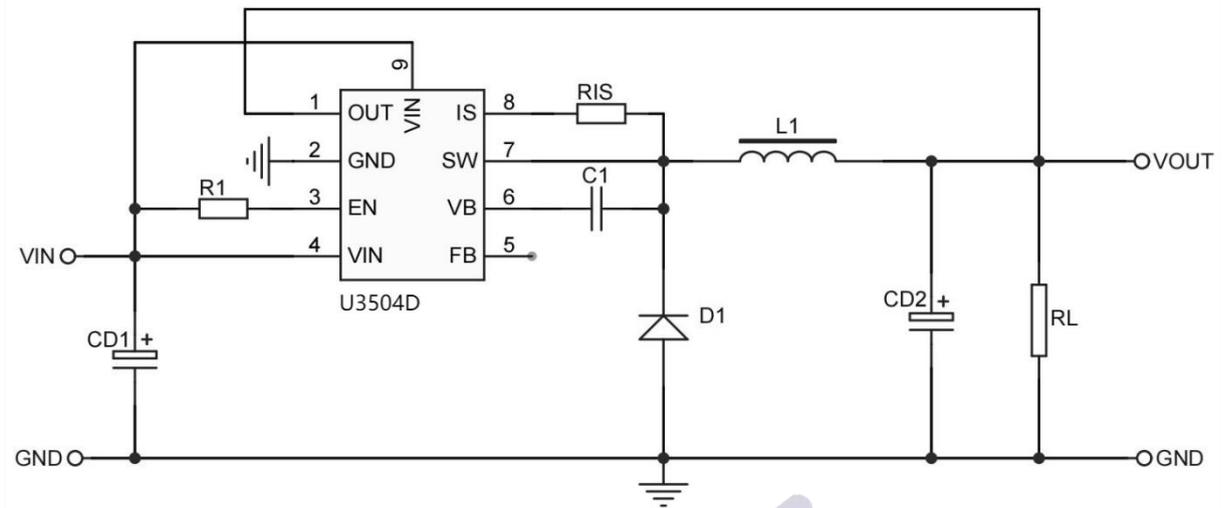


### APP2: V<sub>OUT</sub> <10V



### APP3:V<sub>OUT</sub>=10~15V

**APP4:V$_{OUT}$12V/V$_{OUT}$5V**



**APP5:QC2.0/QC3.0**



Note:1.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.
2.Input electrolytic capacitor (CE1) and continuous current diode (D1) according to the actual use of voltage, current to adjust.
3.Continuous current diode recommended to use Schottky.

## 1、Version Record

| Date | Rev. | Description |
|------|------|-------------|
| 2023/2/25 | 1.0 | First Release |
| 2023/7/12 | 1.1 | Optimize parameters |
| 2024/5/16 | 1.2 | Add 5V Fixed Output Application |
| 2024/6/20 | 1.3 | Add IPK Calculation Formula |
| 2024/9/20 | 1.4 | Add a Feature Comparison Table and Modify Some Parameters |
| | | |

## 2、Contact

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