

Application Circuits of eFuse IC TCKE805 Series

Design guide

RD164-DGUIDE-01

Overview

This document explains the application circuit of Toshiba's eFuse IC TCKE805 series. This section explains the basic usage of the TCKE805 Series, various protective functions, and settings. Toshiba hopes that this document will help you to realize your application with TCKE805 Series.

TOSHIBA ELECTRONIC DEVICES & STORAGE CORPORATION

Table of Contents

1. Introduction	3
2. Circuit design	4
2.1. Specifications for TCKE805 Series application circuit	4
2.2. Application circuit	4
2.3. Auto-retry type and latch type (overheat protection function).....	5
2.4. Calculation of overcurrent protection limit current	8
2.5. Short-circuit protection current.....	8
2.6. Setting of inrush current suppression function (slew rate control).....	9
2.7. Design of reverse current protection circuit.....	10
2.8. Other functions of TCKE805 Series	11
3. PCB Design	12
3.1. Example of component arrangement.....	12
3.2. Design of PCB patterns.....	12
4. Precautions for Design.....	13
5. Product Overview	14
5.1. Features.....	14
5.2. Appearance and Pin Arrangement	14
5.3. Internal circuit block diagram	15
5.4. Pin Description.....	15

1. Introduction

Currently, glass tube fuses, chip current fuses, and poly-switches (resettable fuses, poly-fuses), which utilize Joule heat generated by the flow of a current exceeding the rated value, are widely used as parts for preventing overheating and ignition in various electronic devices. These devices protect the circuit and prevent equipment from being damaged by interrupting or restricting the current supply by fusing the built-in metal parts (glass tube fuses, chip current fuses) or by rapidly increasing the resistance value (poly-switch) due to thermal expansion of the conductive polymer. However, these parts have disadvantages such as low accuracy of the current to operate, uncertainty of the interrupting current, and time required from the start of the overcurrent flow to the start of protection due to the use of Joule heat. Another disadvantage is that a fuse like metal blown type requires replacement of the fuse itself because it irreversibly breaks once it is operated.

eFuse IC (electronic fuses) overcomes these disadvantages by shutting off the current through MOSFET switches. It can be used in the same way as a conventional fuse, and it is possible to incorporate various protection functions other than overcurrent.

Toshiba develops and introduces the eFuse IC TCKE805 Series. TCKE805 Series have overcurrent protection, short-circuit protection, overvoltage protection, overheat protection, rush current suppression (slew rate control) and reverse current protection. The TCKE805 series is compatible with 5 V power supply circuits with a clamping voltage of 6.04 V when overvoltage is protected. This product lineup includes an auto-retry type (TCKE805NA) that automatically attempts to return to normal operation after being shut off for a certain period of time from the beginning of each protective operation, and a latch type (TCKE805NL) that allows external signals to return to normal operation. Select one of the types according to the application and specifications of the device.

Table 1.1 Lineup of TCKE805 Series

Part number	Over-voltage clamp voltage	Return operation
TCKE805NA	6.04 V	Auto-retry type
TCKE805NL	6.04 V	Latch type

This guide explains the application circuit of the TCK805 series. Refer to the following link for detailed characteristics.

For data sheets of TCKE805 Series →

[Click Here](#)

For details on the basic usage of these eFuse ICs and the built-in functions, please also refer to the application note.

For eFuse IC application note →

[Click Here](#)

2. Circuit design

2.1. Specifications for TCKE805 Series application circuit

Specifications of the application circuit of the TCKE805 series described in this guide are shown as Table 2.1.

Table 2.1 Specifications of application circuit for TCKE805 Series

Item	Specifications
Overvoltage protection clamp voltage	6.04 V
Overcurrent protection current limit	2.96 A
Inrush current limit ($V_{IN}=5V$)	0.6 ms
eFuse IC	Toshiba Devices & Storage Corporation TCKE805NA/TCKE805NL
Reverse current protection external N-ch MOSFET (If used)	Toshiba Devices & Storage Corporation SSM6K513NU

2.2. Application circuit

The eFuse IC is a type of load switch, and is inserted into the power supply line and used in the same manner as conventional fuses and poly switches. Fig. 2.1 shows typical application of the TCKE805 series.

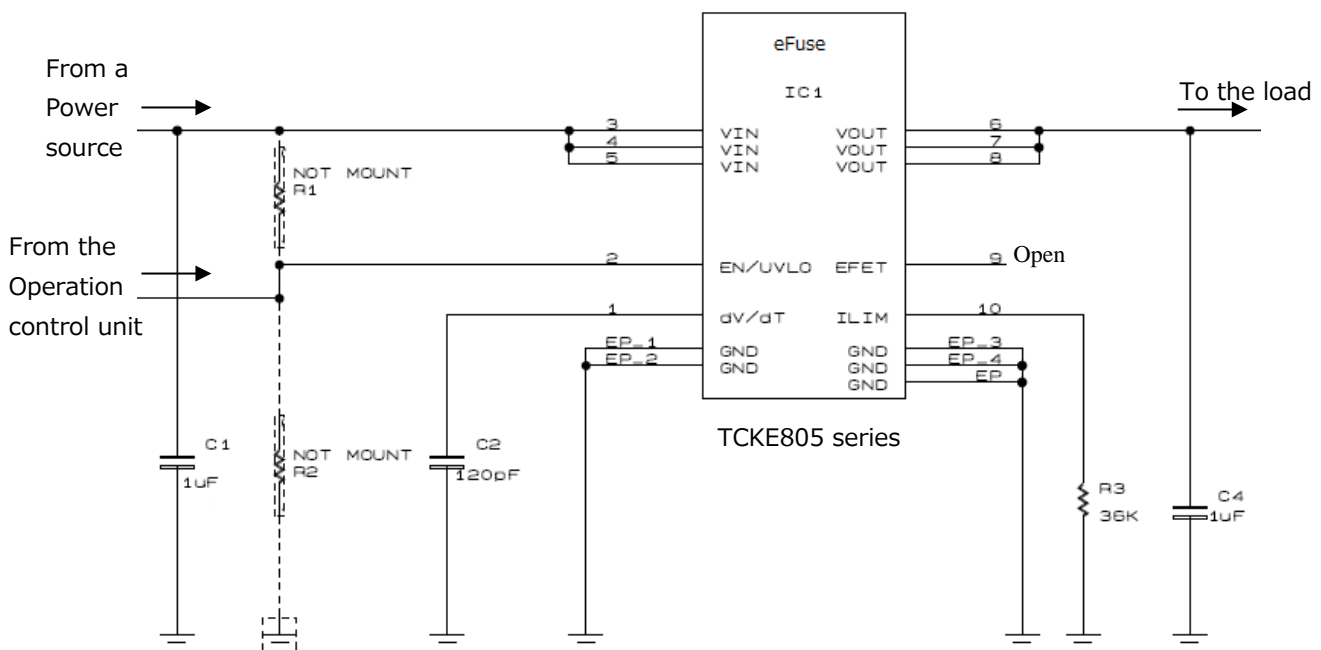


Fig. 2.1 Application circuit of eFuse IC

Connect the power supply to the VIN pin. During normal operation, the voltage is output from the VOUT pin through the MOSFET built in the eFuse IC. However, since the built-in MOSFET has a low on-resistance, almost the same voltage between power source output and the VOUT pin to the loads.

VIN and VOUT pins may be damaged or damaged due to high-spike voltages caused by back electromotive force generated by package inductance when the current suddenly decreases, for example, when short-circuiting or overcurrent is protected. External capacitors between the VIN and VOUT pins and GND are available to reduce the spike voltage. Generally, capacitors of 0.1 μF or more are used. In this application circuit, the capacitor C1 on the VIN side and the capacitor C4 on the VOUT side are both set to 1 μF including some margin.

Connect a resistor to the ILIM pin to determine the ILIM of current limit for overcurrent protection. In Fig. 2.1, the limit current is set to 3 A.

Connect a capacitor to the dV/dT pin for slew rate control to suppress inrush current. This feature is described in Section 2.6.

The EFET pin is a gate-driving pin of an external reverse current protection N-ch MOSFET. Fig. 2.1 shows an example of an application circuit when the reverse current protection function is not used. This pin outputs internally boosted voltage ($V_{\text{IN}}+4.9\text{ V}$ (Typ.)) as a voltage for driving the gates of the external devices during normal operation. Therefore, open the pin if the reverse current protection function is not used. Use of the reverse current protection function is described in Section 2.7.

The EN/UVLO pin is a pin for controlling the on/off of ICs by input external signals. When the input is High, the IC is enabled. This feature is described in Section 2.8.

2.3. Auto-retry type and latch type (overheat protection function)

As described, the TCKE805 series has two types: auto-retry type for automatic recovery and latch type for external recovery, depending on how to recover from overcurrent, short-circuit, and overvoltage protection to normal operation. The application circuit is exactly the same for both types, since the return operation is only different.

Overcurrent, short-circuit, and overvoltage protection functions ultimately utilize the overheat protection function (TSD = Thermal Shut Down). The overheat protection function determines that the IC is overheated when the junction temperature rises to 160 $^{\circ}\text{C}$ (Typ.) and stops and protects the operation. However, if this protection function differs in that the auto-retry type does not latch, then the latch type latches.

If the overcurrent or overvoltage clamp operation continues, or if the short circuit is not resolved and a large current flows during the automatic restoration attempt of short circuit protection (see Section 2.5), the overheat protection function will operate due to the increase in junction temperature. However, the current will not flow thereafter, and the temperature will start to decrease.

The overheat protection operation temperature has a hysteresis of 20 $^{\circ}\text{C}$ (Typ.) width. If the temperature drops to this point, the auto-retry type will return to normal operation. If the overcurrent, overvoltage, or short circuit continues at this time, the overheat protection will operate again. Thereafter, the overheat protection operation and release will be repeated until the

overcurrent, overvoltage, or short circuit is resolved. The auto-retry type attempts to automatically recover using this operation.

On the other hand, the latch type latches the overheat protection operation. Therefore, it does not return to normal operation even if the temperature drops. Latch type recovery requires external input-voltage and EN/UVLO pin control signals to be turned on again.

The timing chart for each protection operation of the auto-retry type and the latch type is shown as Fig. 2.2 and Fig. 2.3.

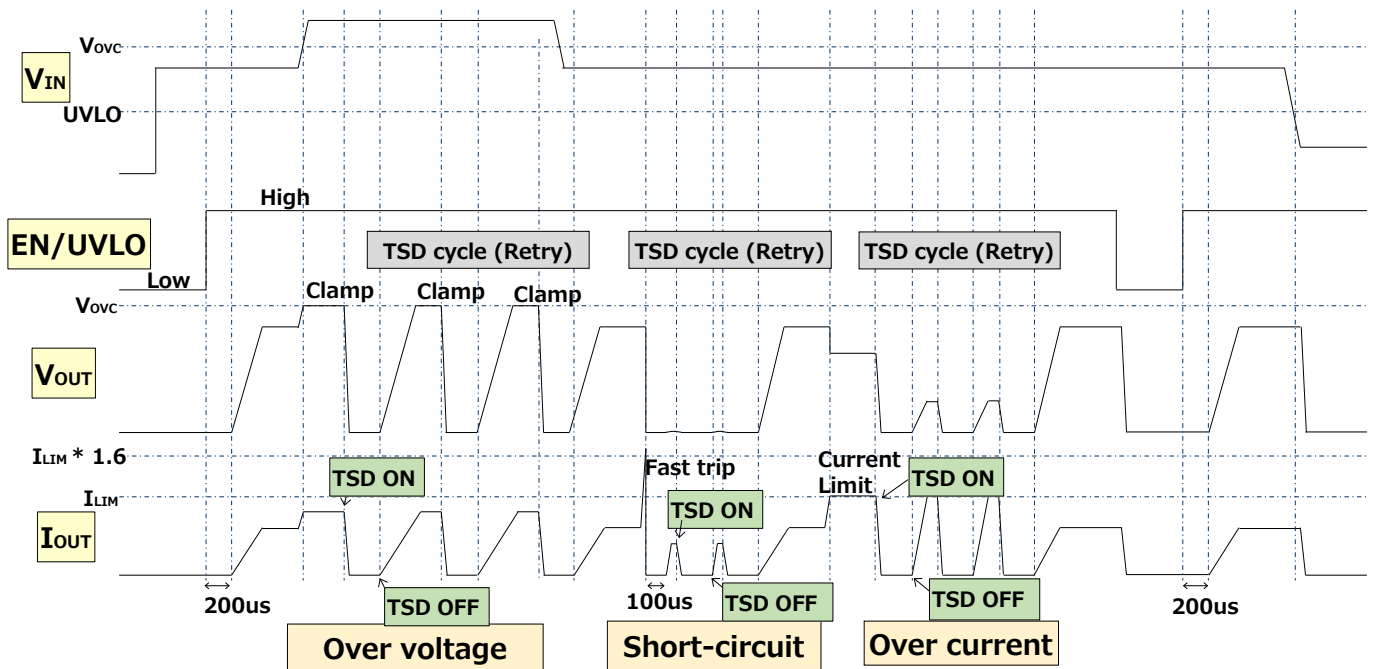


Fig. 2.2 Timing chart of various protection operations (auto-retry type)

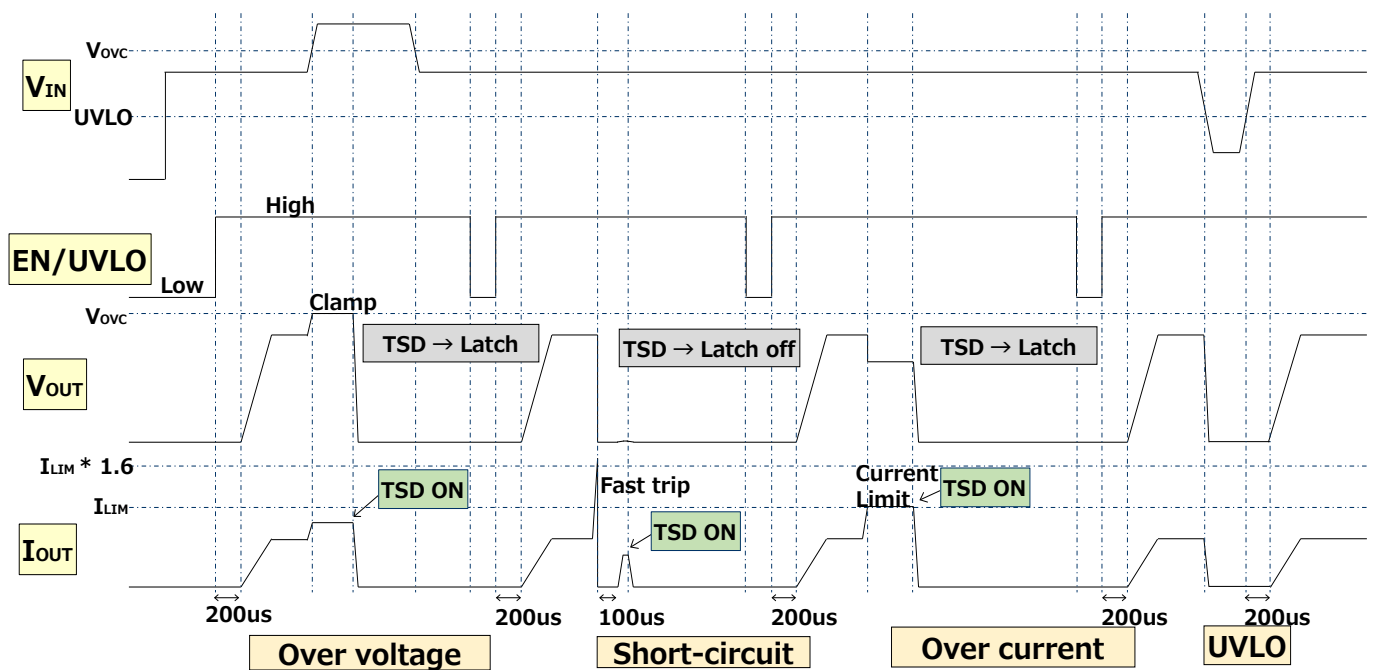


Fig. 2.3 Timing chart of various protection operations (latch type)

If the overvoltage or overcurrent is removed before the overheat protection operation is started, the normal operation is restored at that time.

2.4. Calculation of overcurrent protection limit current

Resistor R3 sets the overcurrent protection limit current I_{LIM} of TCKE805 series. The I_{LIM} is calculated by the following equation, and the limit current is 2.96 A because $R3=36\text{ k}\Omega$ in the application circuit of this guide. The difference between the calculated value and the measured value may become large. Be sure to check the actual resistance value when selecting it.

$$I_{LIM} = 0.13 + \frac{101.8}{R3} = 0.13 + \frac{101.8}{36} \cong 2.96 \text{ (A)}$$

R3: ILIM pin external resistor (kΩ)

For reference, Fig. 2.4 shows the graphs of R3 and the limiting current I_{LIM} according to the above equation.

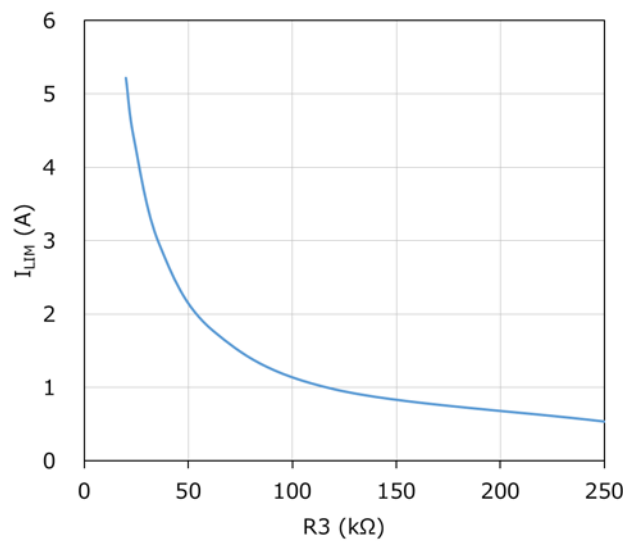


Fig. 2.4 Relationship between R3 and limited current

2.5. Short-circuit protection current

The short-circuit protecting function is that determines a short-circuit when the current reaches 1.6 times the limit current (I_{LIM}) earlier than the overcurrent limit function when the power supply lines and loads are short-circuited due to some malfunction, and turns off the MOSFET to protect the ICs and other devices. The short-circuit detection current is interlocked with the limit current and is always set to 1.6 times the limit current set in R3.

The TCKE805 Series has a high-speed short-circuit protecting circuit (Fast trip function), and 150 ns (designed value, Typ) from the occurrence of a short circuit to the current cut off by the operation.

The TCKE805 Series automatically attempts to recover from the Fast trip operation after 100 μs. If the short circuit is not resolved, heat is generated by the large current flowing at that time, and the operation starts overheat protection. The subsequent operation is as described in Section 2.3.

2.6. Setting of inrush current suppression function (slew rate control)

When the output is turned on after starting operation, an inrush current flows to charge the capacitor connected to the load side. If this current exceeds the limit current for overcurrent protection, the protection circuit may operate, which may cause an overshoot of the output or an inability to start up. This function limits the inrush current and controls the slew rate at the rise of the output voltage to prevent these phenomena.

In the TCKE805 series, the external capacitor C2 of the dV/dT pin can appropriately set the rise time ($t_{dV/dT}$) of the output voltage. The external capacitor of 120 pF is used in the application circuit of this guide. The rise time at this setting is calculated as shown in the following equation.

$$\begin{aligned}
 t_{dV/dT} (s) &= 0.36 \times 10^6 \times V_{IN} \times (C2 + 50 \times 10^{-12}) + 3 \times 10^{-4} \\
 &= 0.36 \times 10^6 \times 5 \times (120 + 50 \times 10^{-12}) + 3 \times 10^{-4} \\
 &\cong 0.0006 (s) = 0.6 (ms)
 \end{aligned}$$

V_{IN} : Input voltage=5 V, C2: External capacitance of dV/dT pin (nF)

Fig. 2.5 shows the relationship between C2 and rise time.

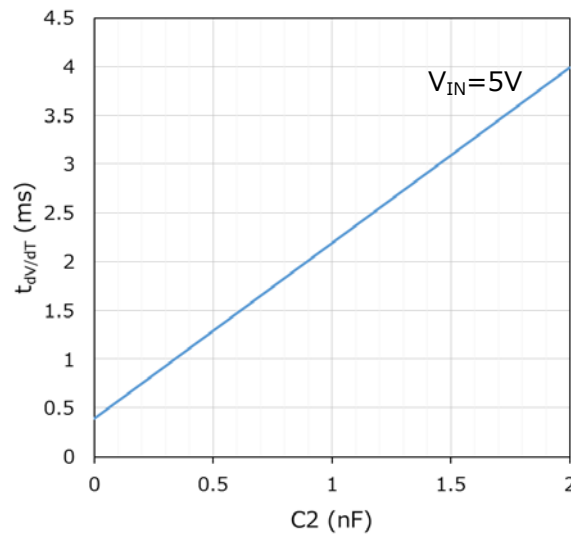


Fig. 2.5 Relationship between C2 and rise time

2.7. Design of reverse current protection circuit

You can also use the TCKE805 Series' reverse current protection feature. This function prevents current from flowing back from the output side to the input side through the body diodes of the MOSFET built in the eFuse IC when the eFuse IC stops operating due to a drop in the power supply voltage connected to the VIN or the power supply voltage is turned off. The application circuit using this function is shown in Fig.2.6.

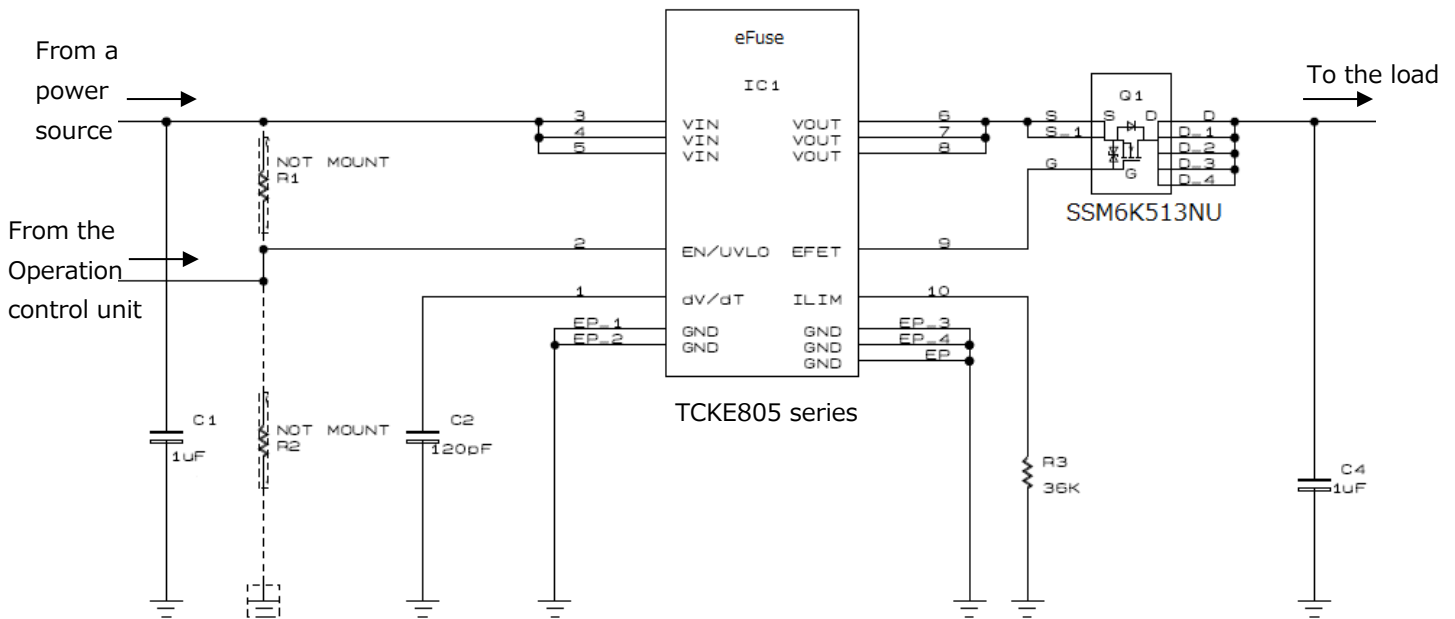


Fig. 2.6 Application circuit using reverse current protection function

Connect the source pin of the external MOSFET gated by the EFET pin to the VOUT pin of the eFuse IC, and interlock this device with the eFuse IC to prevent current flowing back from the output pin to the input pin by the body diode of the external MOSFET when operation stops. When using this function, connect the output capacitor to the drain of the external MOSFET as shown in Fig. 2.6.

Our SSM6K513NU is recommended for external MOSFET to prevent backflow. For more information on SSM6K513NU data sheets, please refer to the links shown below.

For more information on the SSM6K513NU, see here.

[Click Here](#)

The EFET pin outputs the internally boosted voltage $V_{IN}+4.9V$ (Typ.). If this function is not used, open the pin.

2.8. Other functions of TCKE805 Series

This section explains the other functions of the TCKE805 Series. For more information on these functions, refer to the application note.

For eFuse IC application note →

[Click Here](#)

- Low-voltage malfunction prevention function (UVLO = Under Voltage Lock-Out)

This function stops IC operation when the input voltage drops and prevents malfunction of the load. The TCKE805 series is designed to start operation at 4.15 V (Typ.) when the input voltage rises. However, the input voltage stops at 5% hysteresis (Typ.) when the input voltage rises. The input voltage stops operation at approximately 3.95 V, which is lower than 4.15 V.
- EN/UVLO pin

The IC can be controlled on/off by input a signal to this pin from outside. The IC operates with the High input, but the threshold voltage has hysteresis, and it becomes High at 1.1 V (Typ.) or more and Low at 0.96 V (Typ.) or less.

This pin can be used as a UVLO function by input a voltage dividing the input voltage with an external resistor, but cannot be set to a value lower than the internal UVLO operating voltage described above. See application note for examples and details of these applications.
- Over-voltage clamp function

The overvoltage clamp function is to prevent overvoltage from being applied to the load by clamping the output with a limited voltage so that no further voltage is output. The limit voltage is set to 6.04 V (Typ.).

If the clamp operation using the limited voltage continues, the operation stops due to the overheat protection function. However, the operation thereafter differs between the auto-retry type and the latch type, as described in Section 2.3.

3. PCB Design

3.1. Example of component arrangement

Fig. 3.1 shows an example of the layout of components.

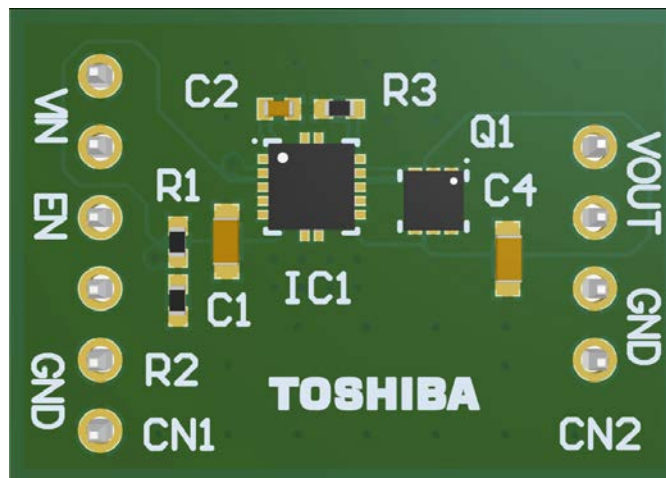


Fig. 3.1 Example of component arrangement

3.2. Design of PCB patterns

Fig. 3.2 shows an example of PCB pattern.

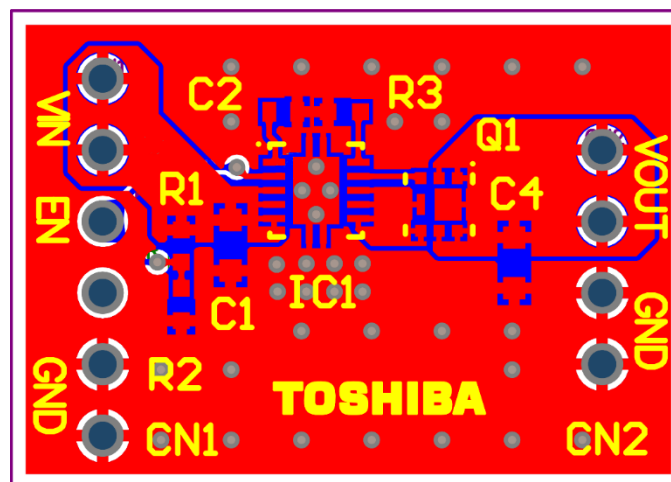


Figure 3.2 Example of PCB pattern

4. Precautions for Design

- About the EN/UVLO Pin

If the EN/UVLO pin is open (indefinite), the ICs may not operate properly. Be careful not to open this pin if the input signal level is either High or Low.

- About the EFET Pin

When the IC is operating normally, the EFET pin outputs the internally boosted voltage $V_{IN}+4.9V$ (Typ.) for driving the gates of the external MOSFET for preventing reverse current. If the reverse current protection function is not used, open the pin.

- Measures for spike voltage of input/output pins

Connect the TVS diode (ESD protection diode) between the input pin and GND if the spike voltage generated at the VIN pin exceeds the maximum rating when the current suddenly decreases, as described in Section 2.1.

Connect the SBD (Schottky Barrier Diode) between the output pin and the GND and the GND for negative spike voltages generated at the VOUT pin.

DF2S23P2CTC and CUS10F30 are recommended as TVS diodes and SBDs, respectively. For details of these products, please refer to the following link destinations.

For more information on the DF2S23P2CTC of TVS diodes →

[Click Here](#)

For more information on the Schottky barrier diode CUS10F30 →

[Click Here](#)

- Measures for spike voltage of input/output pins in PCB patterns

In order to reduce the inductance of the PCB pattern design with respect to the spike voltage described above, the line length on the input and output sides should be as short as possible and the line width should be as wide as possible. When using the reverse current protection function, be careful of the lines between the output pin of the IC and the source of the external MOSFET and tie from the drain to the load side.

In order to lower the impedance of the GND, make the GND wiring area as wide as possible.

- Using the reverse current protection function

When arranging components on the board, arrange the IC body and the external MOSFET for reverse current protection as close as possible, and arrange them in such an orientation that the wiring length of the output becomes the minimum. Place the input capacitance close to the input pin and the output capacitance close to the drain of the external MOSFET.

5. Product Overview

5.1. Features

The TCKE805 series is a one-input-one-output eFuse IC that can input 18V. It can be used as a repeatable fuse. In addition, it is equipped with adjustable overcurrent protection by external resistors, short-circuit protection, overvoltage clamping function, slew-rate adjustment by external capacitors, low-voltage malfunction protection, overheat protection, backflow protection by external MOSFET, and many other protection functions.

The on-resistance is as low as 28 mΩ (Typ.), the output current is as high as 5 A and has a wide range of operating input voltages, and is suitable for power management such as hard disk drives and battery charging applications.

The package is a compact 0.4 mm-pitch WSON10B (3.0 mm x 3.0 mm, t: 0.7 mm (Typ.)) that is best suited for applications requiring high-density packaging, such as mobile devices.

- High input voltage: $V_{IN} \text{ (Max)} = 18 \text{ V}$
- High output current: $I_{OUT} \text{ (DC)} = 5.0 \text{ A}$
- Low on resistance: $R_{ON} = 28 \text{ m}\Omega \text{ (Typ.)}$
- Adjustable overcurrent limit: 5.0 A (Max)
- Fixed over voltage clamp, 5 V For power supply lines: $V_{OVC} = 6.04 \text{ V (Typ.)}$
- Programmable slew rate control by external capacitance for inrush current reduction
- Programmable under voltage lockout by external resistor
- Adjustable under voltage lockout (UVLO) by external resistor
- Thermal shutdown
- Auto-discharge
- Small package: WSON10B (3.0 mm x 3.0 mm, t: 0.7 mm (Typ.))

5.2. Appearance and Pin Arrangement

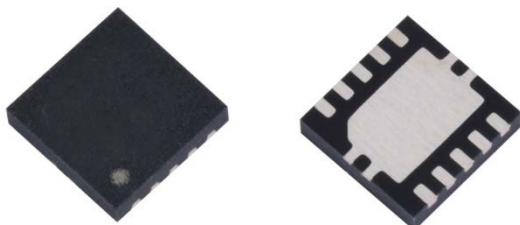


Fig. 5.1 External view of the TCKE805NA/NL

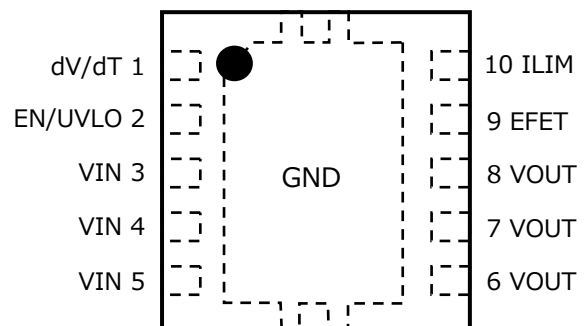


Fig. 5.2 Pin layout

5.3. Internal circuit block diagram

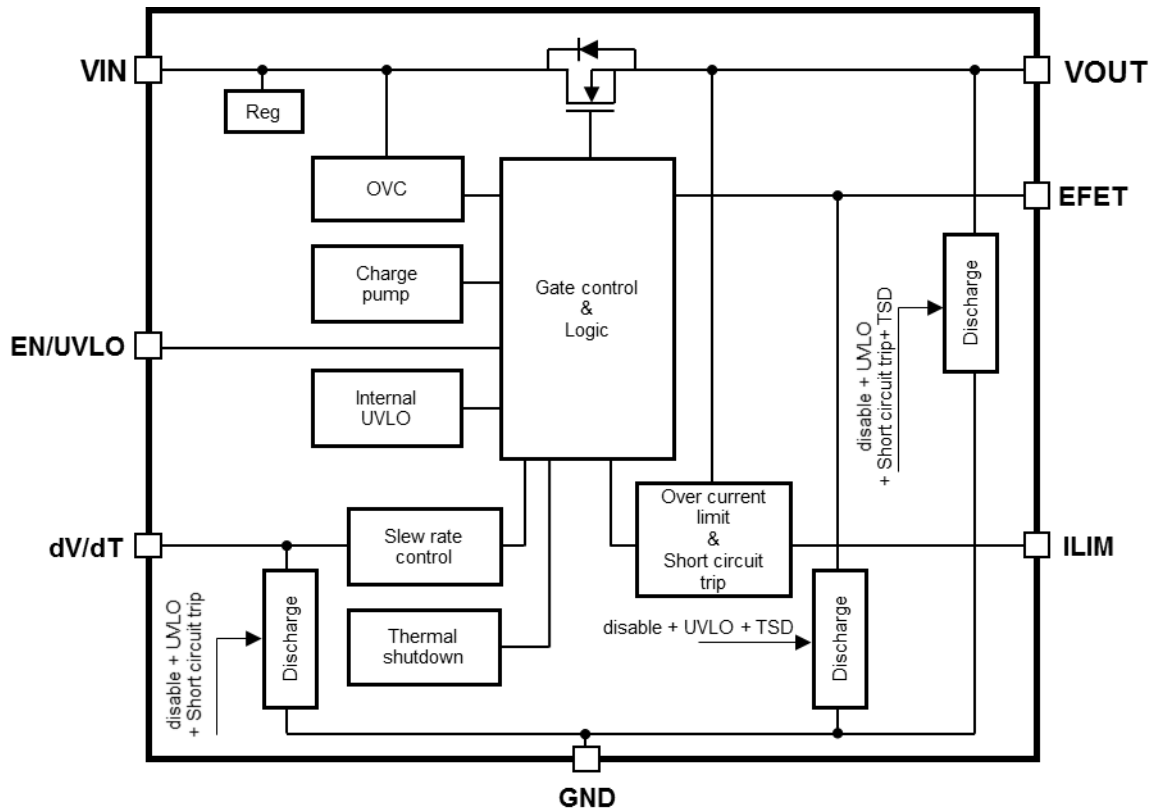


Figure 5.3 Internal circuit block diagram

5.4. Pin Description

Table 5.1 Pin Description

Pin number	Pin name	Description
1	dV/dT	Sets the VOUT start-up slew rate when the power is turned on using the external capacitance connected to the GND/GND.
2	EN/UVLO	Controls the output voltages of the built-in MOSFET and EFET pin. Enable when "H" is selected. Do not open the camera.
3, 4, 5	VIN	Power input pin
6, 7, 8	VOUT	Output pin
9	EFET	Drive the gates of the external MOSFET to prevent backflow. If the reverse current protection function is not used, open the product.
10	ILIM	Set the limit current value of the overcurrent protection circuit with an external resistor connected to GND.
GND	GND	Ground pin

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